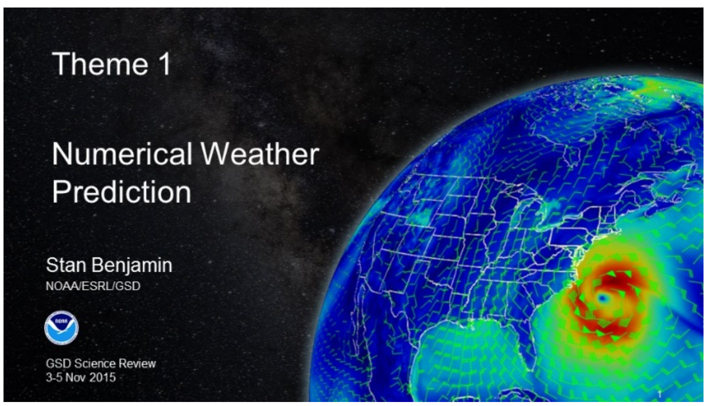
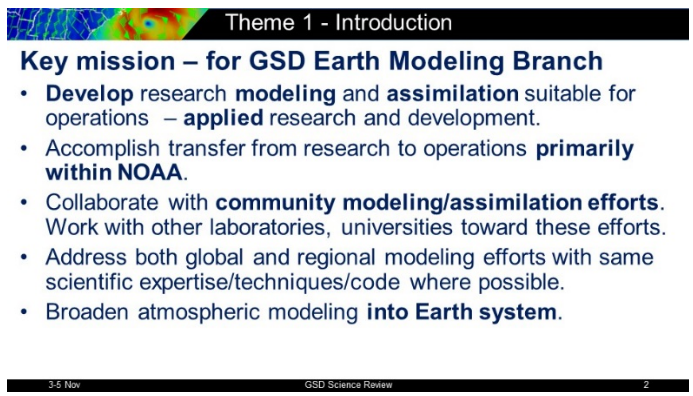
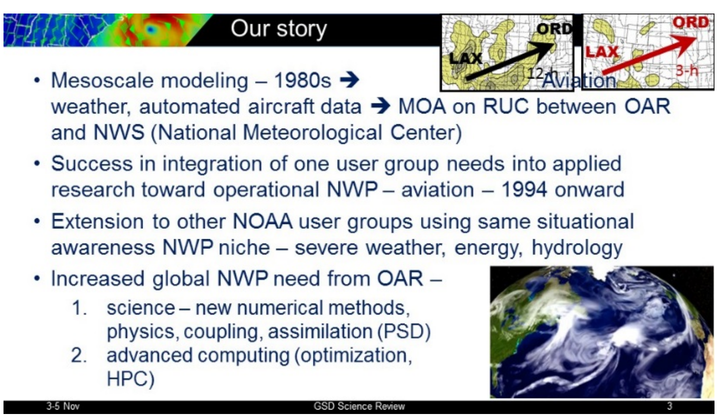
A. Presentations and Posters

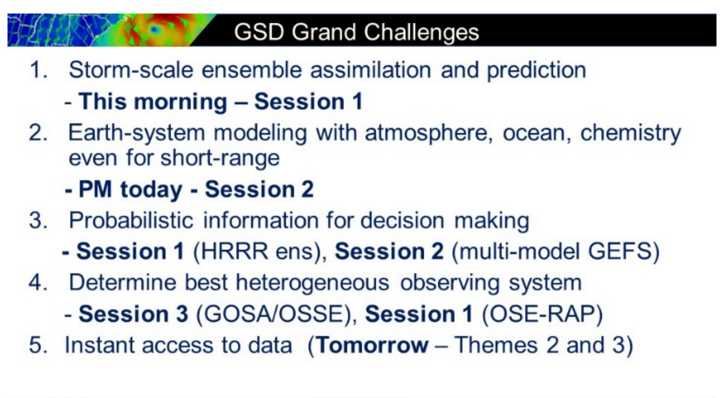
Session 1: Numerical Weather Prediction – Regional Models

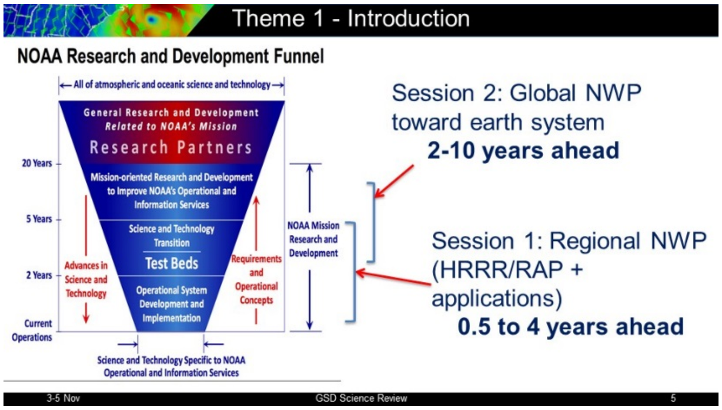
- Numerical Weather Prediction: Mission and Grand Challenges (Stan Benjamin)
- Modeling Challenge #1 - Toward Storm-scale Ensemble Data Assimilation and Prediction (Steve Weygandt)
- HRRR Overview – R2O to NWS and Application to Severe Weather (Curtis Alexander)
- Radar Assimilation for HRRR (David Dowell)
- Land-surface Cycling for Better Hydrometeorology (Tanya Smirnova)
- Energy Applications and Design for RAP/HRRR (Joe Olson)
- HRRR/RAP - Mitigating Aviation Hazards for Safety and Efficiency (Jaymes Kenyon)
- Probabilistic Forecasting at Regional Scales (Isidora Jankov)

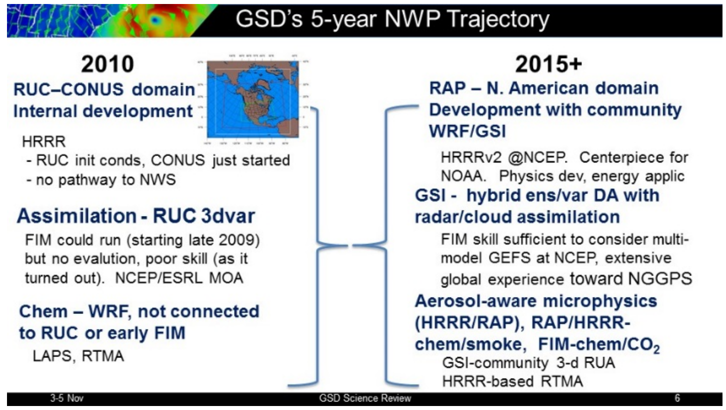


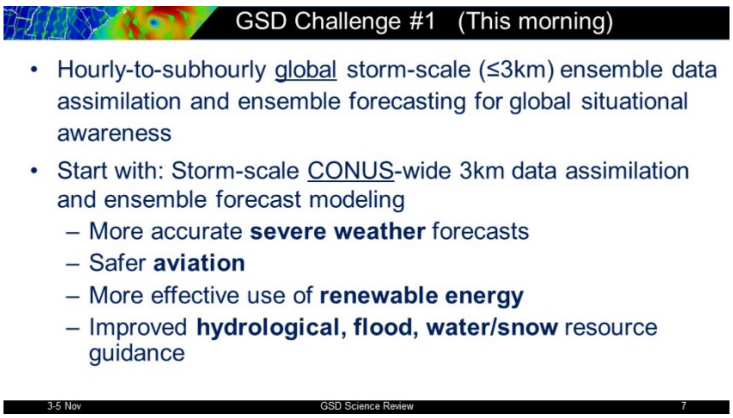


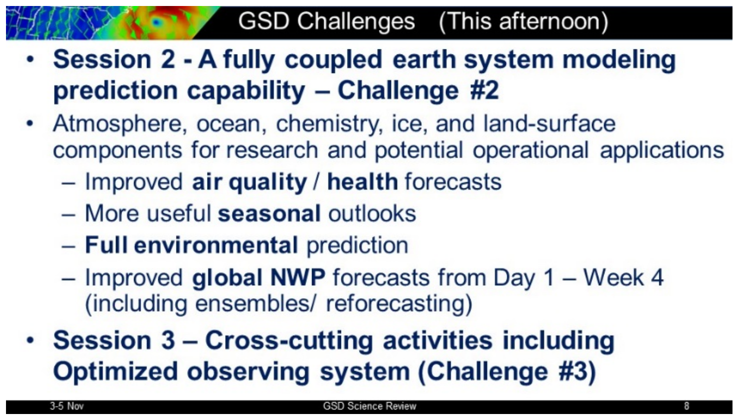


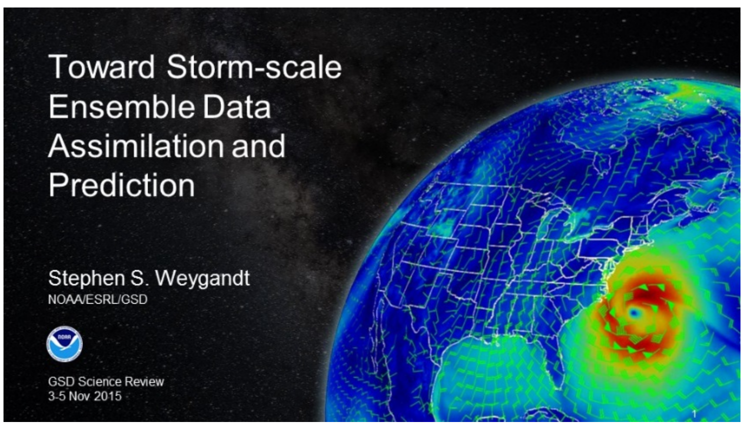



Theme 1 - Introduction
NOAA Research and Development Funnel
All of atmospheric and oceanic science and technology
General Research and Development Related to NOAA's Mission
Research Partners
Mission-oriented Research and Development to Improve NOAA's Operational and Information Services
Science and Technology Transition
Test Beds
Operational System Development and Implementation
20 Years
5 Years
2 Years
Current Operations
Advances in Science and Technology
Requirements and Operational Concepts
NOAA Mission Research and Development
Science and Technology Specific to NOAA Operational and Information Services
Session 2: Global NWP toward earth system
2-10 years ahead
Session 1: Regional NWP (HRRR/RAP + applications)
0.5 to 4 years ahead
3-5 Nov
GSD Science Review
5

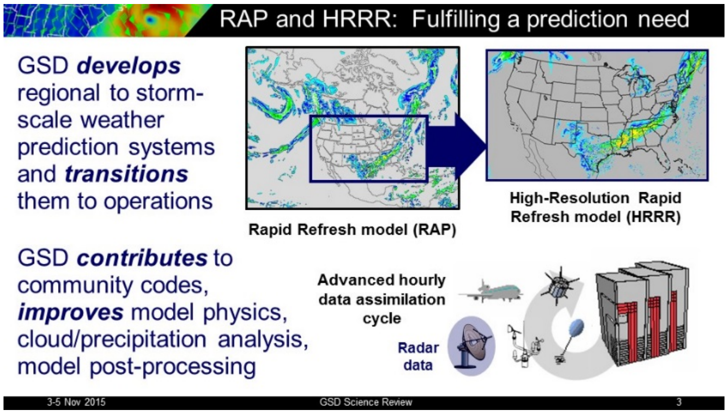

GSD's 5-year NWP Trajectory
2010
RUC–CONUS domain
Internal development
HRRR
- RUC init conds, CONUS just started
- no pathway to NWS
Assimilation - RUC 3dvar
FIM could run (starting late 2009) but no evalution, poor skill (as it turned out). NCEP/ESRL MOA
Chem – WRF, not connected to RUC or early FIM
LAPS, RTMA
2015+
RAP – N. American domain
Development with community WRF/GSI
HRRRv2 @NCEP. Centerpiece for NOAA. Physics dev, energy applic
GSI - hybrid ens/var DA with radar/cloud assimilation
FIM skill sufficient to consider multi-model GEFS at NCEP, extensive global experience toward NGGPS
Aerosol-aware microphysics (HRRR/RAP), RAP/HRRR-chem/smoke, FIM-chem/CO2
GSI-community 3-d RUA
HRRR-based RTMA
3-5 Nov
GSD Science Review
6

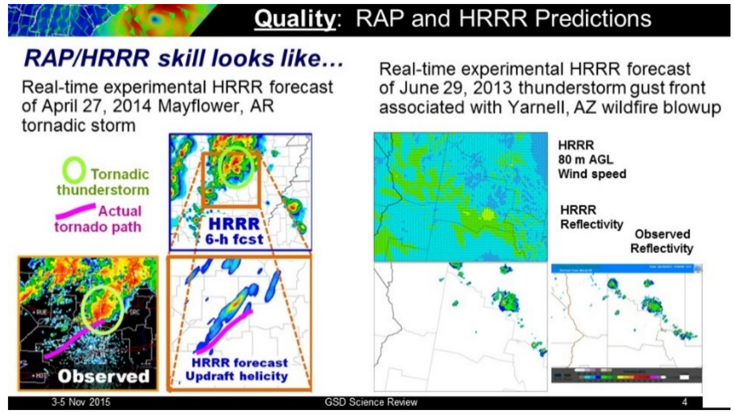

GSD Challenge #1 (This morning)
• Hourly-to-subhourly global storm-scale (≤3km) ensemble data assimilation and ensemble forecasting for global situational awareness
• Start with: Storm-scale CONUS-wide 3km data assimilation and ensemble forecast modeling
– More accurate severe weather forecasts
– Safer aviation
– More effective use of renewable energy
– Improved hydrological, flood, water/snow resource guidance
3-5 Nov
GSD Science Review
7


GSD Challenges (This afternoon)
• Session 2 - A fully coupled earth system modeling prediction capability – Challenge #2
• Atmosphere, ocean, chemistry, ice, and land-surface components for research and potential operational applications
– Improved air quality / health forecasts
– More useful seasonal outlooks
– Full environmental prediction
– Improved global NWP forecasts from Day 1 – Week 4 (including ensembles/ reforecasting)
• Session 3 – Cross-cutting activities including Optimized observing system (Challenge #3)
3-5 Nov
GSD Science Review
8

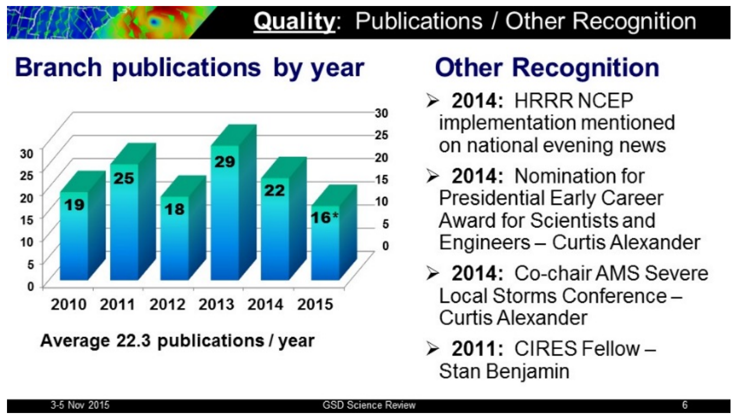

Toward Storm-scale Ensemble Data Assimilation and Prediction
Stephen S. Weygandt
NOAA/ESRL/GSD
GSD Science Review
3-5 Nov 2015
1

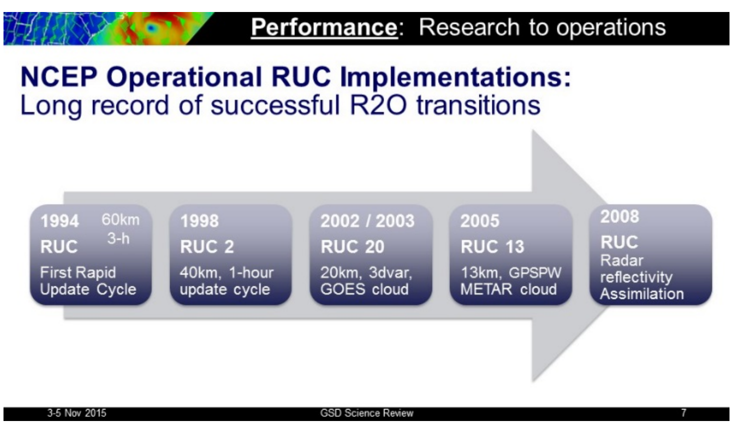

Need: Accurate Hazardous Weather Guidance
Mayflower Arkansas devastation: Deadly tornado destroys everything in its path
19 firefighters killed battling fast-moving Ariz. wildfire
3-5 Nov 2015
GSD Science Review
2

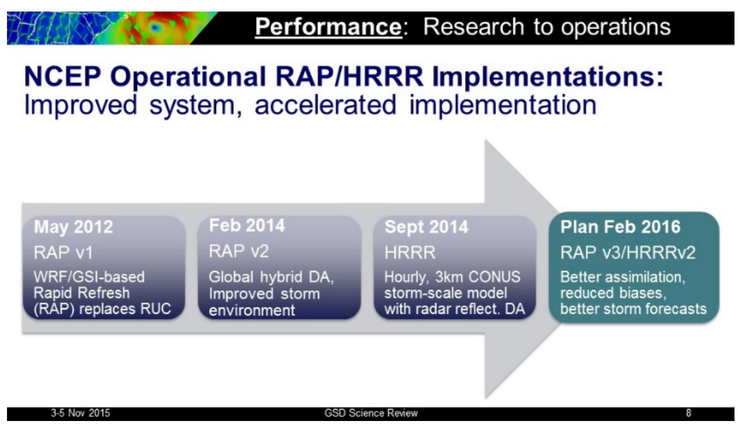

RAP and HRRR: Fulfilling a prediction need
GSD develops regional to storm-scale weather prediction systems and transitions them to operations
Rapid Refresh model (RAP)
High-Resolution Rapid Refresh model (HRRR)
GSD contributes to community codes, improves model physics, cloud/precipitation analysis, model post-processing
Advanced hourly data assimilation cycle
Radar data
3-5 Nov 2015
GSD Science Review
3

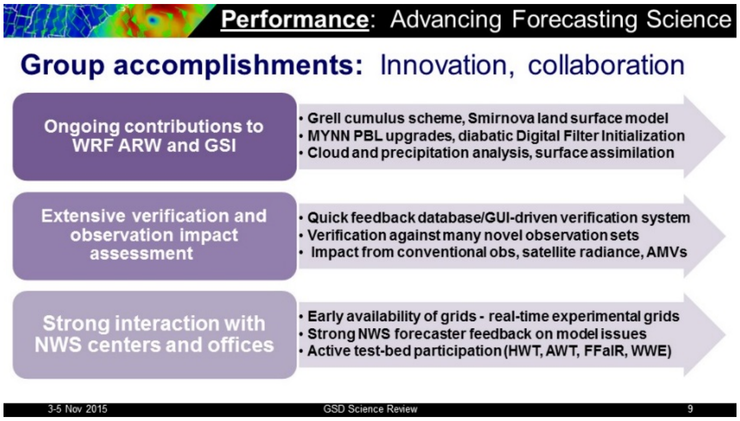

Quality: RAP and HRRR Predictions
RAP/HRRR skill looks like…
Real-time experimental HRRR forecast of April 27, 2014 Mayflower, AR tornadic storm
Tornadic thunderstorm
Actual tornado path
HRRR 6-h fcst
Observed
HRRR forecast Updraft helicity
Real-time experimental HRRR forecast of June 29, 2013 thunderstorm gust front associated with Yarnell, AZ wildfire blowup
HRRR 80 m AGL Wind speed
HRRR Reflectivity
Observed Reflectivity
3-5 Nov 2015
GSD Science Review
4


Quality: RAP / HRRR Recognition
Group and individual awards
2015: Department of Commerce Gold Medal
2015: Governor's Award for High-Impact Research
2015: CIRA Research and Service Initiative Award
2014: Commendation from NASA
2014: CIRES Outstanding Performance Award
2013: NOAA Research Employees of the Year (Team)
2012: CIRES Employees of the Year (Team)
2010: Department of Commerce Bronze Medal
GOVERNOR'S AWARD for HIGH-IMPACT RESEARCH
3-5 Nov 2015
GSD Science Review
5

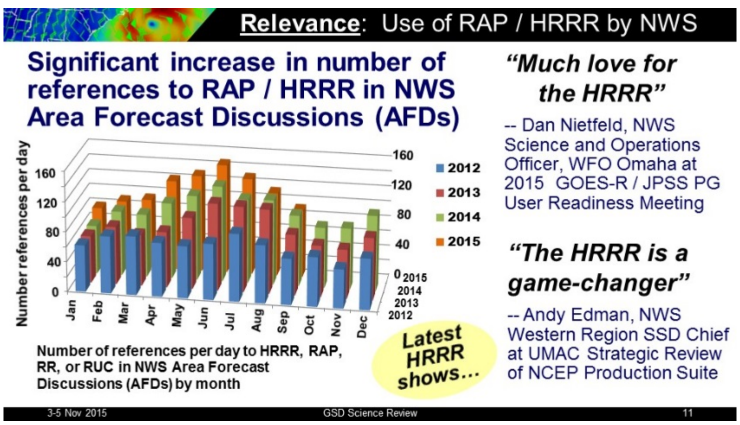

Quality: Publications / Other Recognition
Branch publications by year
19
25
18
29
22
16*
2010 2011 2012 2013 2014 2015
Average 22.3 publications / year
Other Recognition
2014: HRRR NCEP implementation mentioned on national evening news
2014: Nomination for Presidential Early Career Award for Scientists and Engineers – Curtis Alexander
2014: Co-chair AMS Severe Local Storms Conference – Curtis Alexander
2011: CIRES Fellow – Stan Benjamin
3-5 Nov 2015
GSD Science Review
6

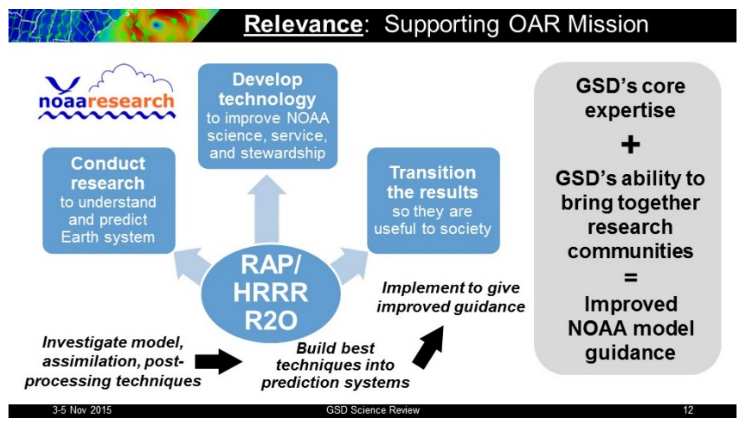

Performance: Research to operations
NCEP Operational RUC Implementations:
Long record of successful R2O transitions
1994 RUC 60km 3-h First Rapid Update Cycle
1998 RUC 2 40km, 1-hour update cycle
2002 / 2003 RUC 20 20km, 3dvar, GOES cloud
2005 RUC 13 13km, GPSPW METAR cloud
2008 RUC Radar reflectivity Assimilation
3-5 Nov 2015
GSD Science Review
7

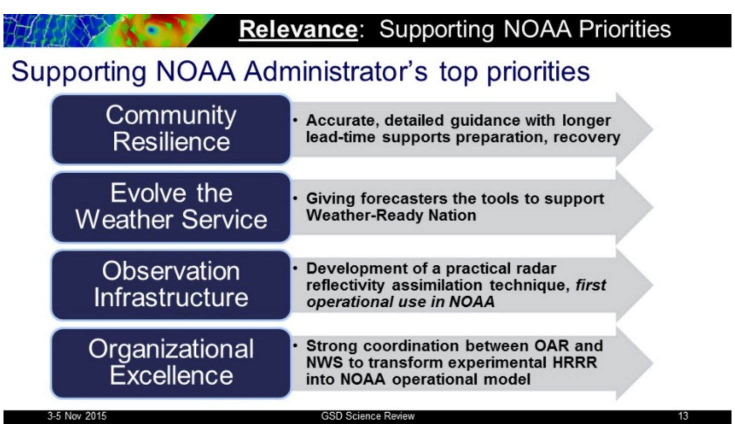

Performance: Research to operations
NCEP Operational RAP/HRRR Implementations:
Improved system, accelerated implementation
May 2012 RAP v1 WRF/GSI-based Rapid Refresh (RAP) replaces RUC
Feb 2014 RAP v2 Global hybrid DA, Improved storm environment
Sept 2014 HRRR Hourly, 3km CONUS storm-scale model with radar reflect. DA
Plan Feb 2016 RAP v3/HRRRv2 Better assimilation, reduced biases, better storm forecasts
3-5 Nov 2015
GSD Science Review
8

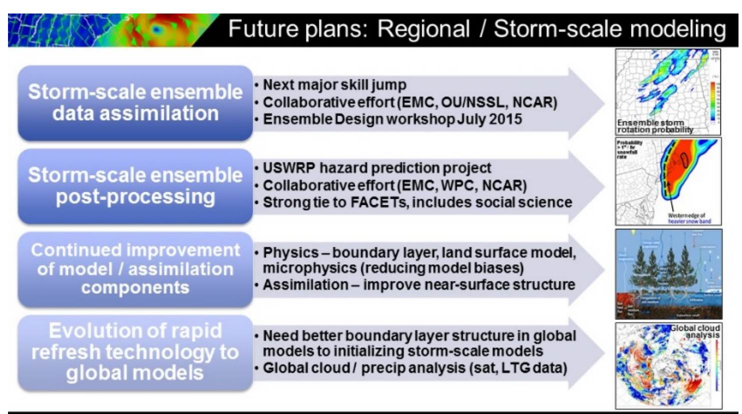

Performance: Advancing Forecasting Science
Group accomplishments: Innovation, collaboration
Ongoing contributions to WRF ARW and GSI
• Grell cumulus scheme, Smirnova land surface model
• MYNN PBL upgrades, diabatic Digital Filter Initialization
• Cloud and precipitation analysis, surface assimilation
Extensive verification and observation impact assessment
• Quick feedback database/GUI-driven verification system
• Verification against many novel observation sets
• Impact from conventional obs, satellite radiance, AMVs
Strong interaction with NWS centers and offices
• Early availability of grids - real-time experimental grids
• Strong NWS forecaster feedback on model issues
• Active test-bed participation (HWT, AWT, FFaIR, WWE)
3-5 Nov 2015
GSD Science Review
9


Performance: Extensive collaborations
We work with many groups
NCEP
Storm Prediction Center
AWC
WPC
NCAR
CAPS
HWT
NASA
GOES-R
NOAA • NESDIS JPSS Joint Polar Satellite System
FACETS
WARN on FORECAST
3-5 Nov 2015
GSD Science Review
10


Relevance: Use of RAP / HRRR by NWS
Significant increase in number of references to RAP / HRRR in NWS Area Forecast Discussions (AFDs)
Number references per day
2012
2013
2014
2015
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Number of references per day to HRRR, RAP, RR, or RUC in NWS Area Forecast Discussions (AFDs) by month
Latest HRRR shows…
"Much love for the HRRR"
-- Dan Nietfeld, NWS Science and Operations Officer, WFO Omaha at 2015 GOES-R / JPSS PG User Readiness Meeting
"The HRRR is a game-changer"
-- Andy Edman, NWS Western Region SSD Chief at UMAC Strategic Review of NCEP Production Suite
3-5 Nov 2015
GSD Science Review
11


Relevance: Supporting OAR Mission
noaaresearch
Develop technology to improve NOAA science, service, and stewardship
Conduct research to understand and predict Earth system
Transition the results so they are useful to society
RAP/ HRRR R2O
Investigate model, assimilation, post-processing techniques
Build best techniques into prediction systems
Implement to give improved guidance
GSD's core expertise
+
GSD's ability to bring together research communities
=
Improved NOAA model guidance
3-5 Nov 2015
GSD Science Review
12

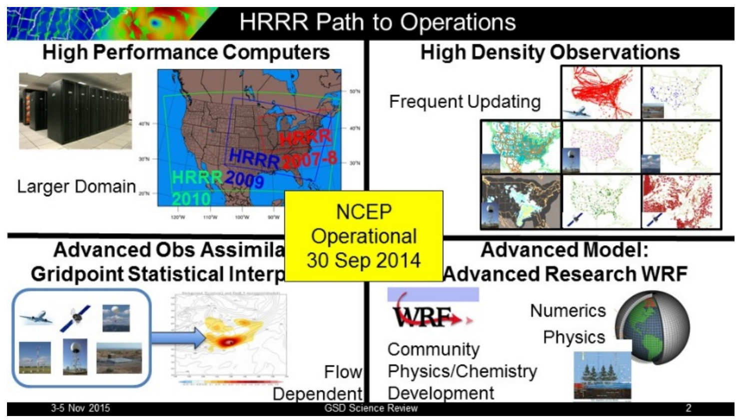

Relevance: Supporting NOAA Priorities
Supporting NOAA Administrator's top priorities
Community Resilience
• Accurate, detailed guidance with longer lead-time supports preparation, recovery
Evolve the Weather Service
• Giving forecasters the tools to support Weather-Ready Nation
Observation Infrastructure
• Development of a practical radar reflectivity assimilation technique, first operational use in NOAA
Organizational Excellence
• Strong coordination between OAR and NWS to transform experimental HRRR into NOAA operational model
3-5 Nov 2015
GSD Science Review
13

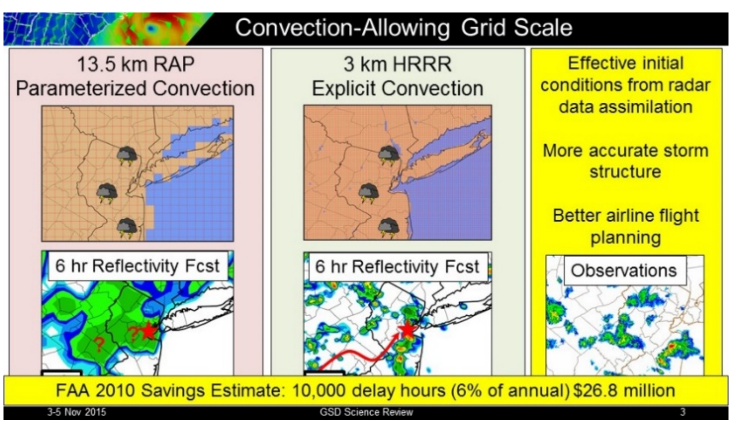

Future plans: Regional / Storm-scale modeling
Storm-scale ensemble data assimilation
• Next major skill jump
• Collaborative effort (EMC, OU/NSSL, NCAR)
• Ensemble Design workshop July 2015
Storm-scale ensemble post-processing
• USWRP hazard prediction project
• Collaborative effort (EMC, WPC, NCAR)
• Strong tie to FACETs, includes social science
Continued improvement of model / assimilation components
• Physics – boundary layer, land surface model, microphysics (reducing model biases)
• Assimilation – improve near-surface structure
Evolution of rapid refresh technology to global models
• Need better boundary layer structure in global models to initializing storm-scale models
• Global cloud / precip analysis (sat, LTG data)
Ensemble storm rotation probability
Global cloud analysis

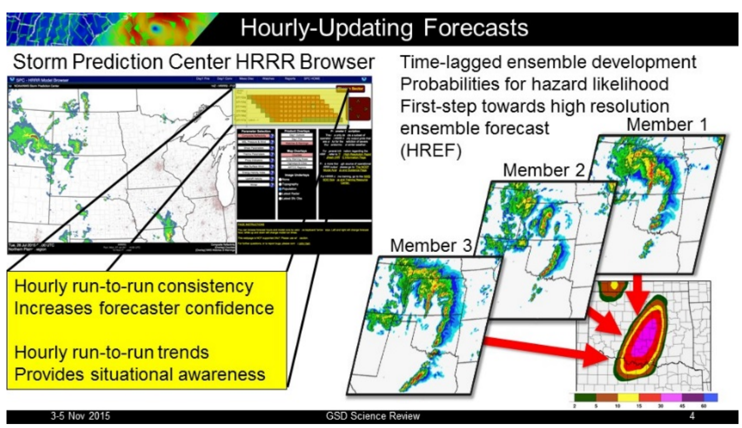
Electronic Posters with Science Highlights

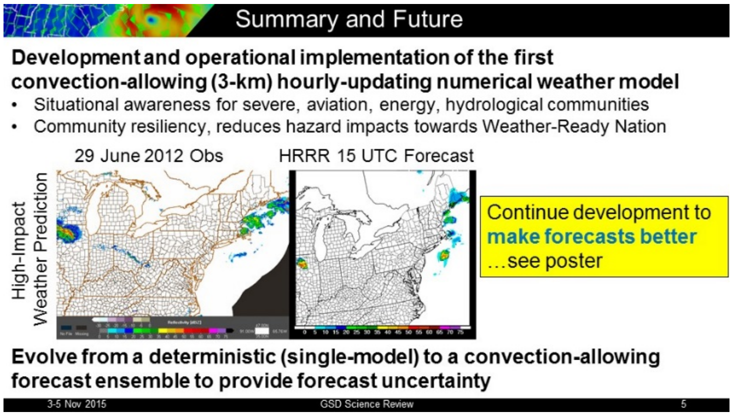
Presenter	Electronic Poster	Station
Curtis Alexander	HRRR science, NCEP implementation	1
David Dowell	Radar and storm-scale assimilation	2
Tanya Smirnova	Land-surface model and hydrology	3
Joe Olson	Boundary-layer and energy applications	4
Jaymes Kenyon	Post-processing, aviation applications	5
Isidora Jankov	Ensembles and probabilistic guidance	6

3-5 Nov 2015 GSD Science Review 15

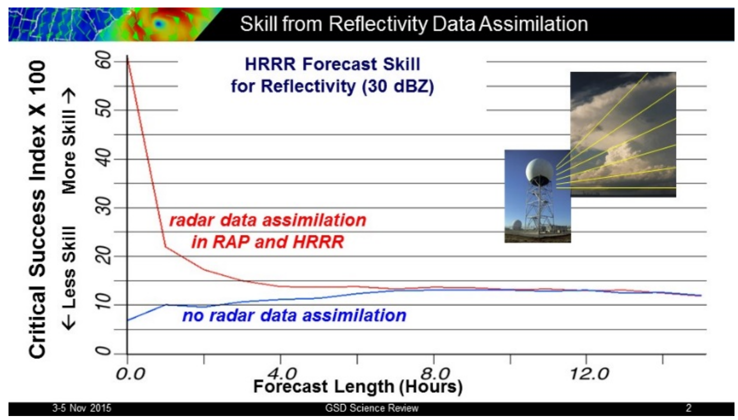


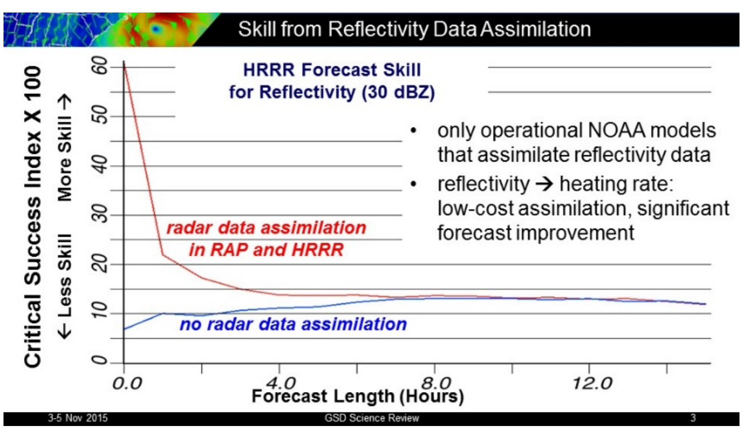


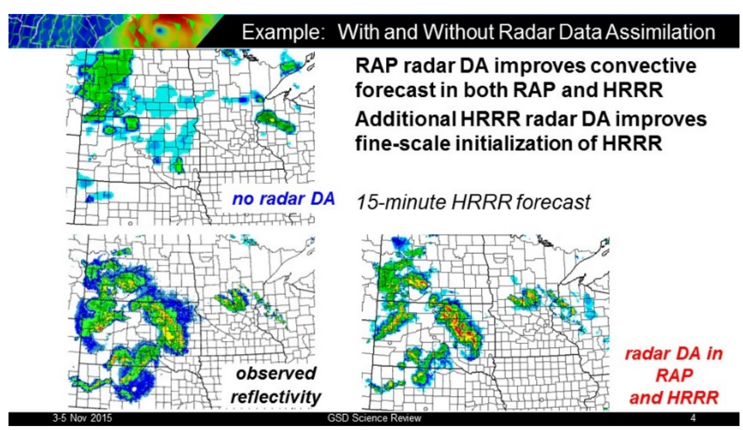


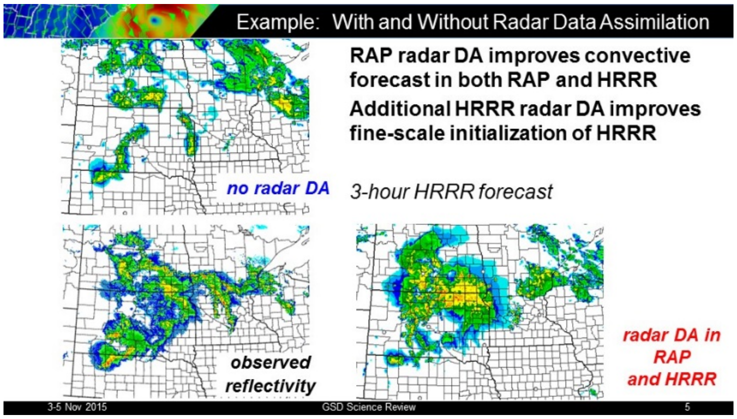

Summary and Future
Development and operational implementation of the first convection-allowing (3-km) hourly-updating numerical weather model
• Situational awareness for severe, aviation, energy, hydrological communities
• Community resiliency, reduces hazard impacts towards Weather-Ready Nation
High-Impact Weather Prediction
29 June 2012 Obs
HRRR 15 UTC Forecast
Continue development to make forecasts better …see poster
Evolve from a deterministic (single-model) to a convection-allowing forecast ensemble to provide forecast uncertainty
3-5 Nov 2015
GSD Science Review
5

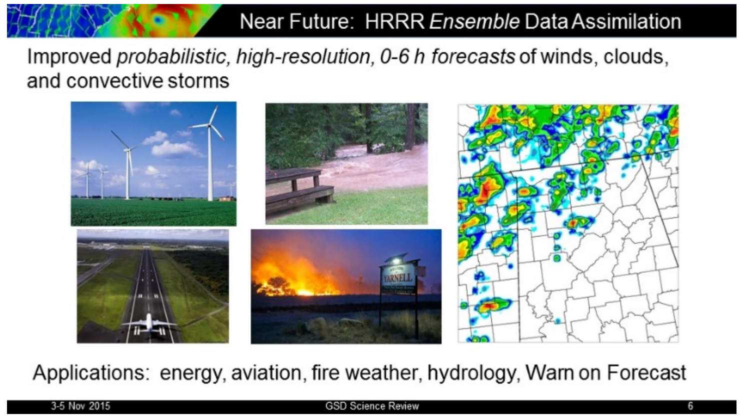

Radar Data Assimilation for RAP and HRRR
David Dowell
NOAA/ESRL/GSD
GSD Science Review
3-5 Nov 2015

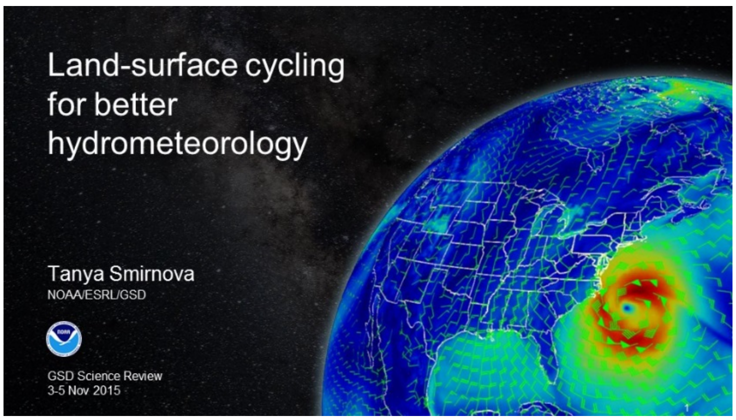

Skill from Reflectivity Data Assimilation
HRRR Forecast Skill for Reflectivity (30 dBZ)
Critical Success Index X 100
← Less Skill More Skill →
radar data assimilation in RAP and HRRR
no radar data assimilation
Forecast Length (Hours)
0.0
4.0
8.0
12.0
3-5 Nov 2015
GSD Science Review
2

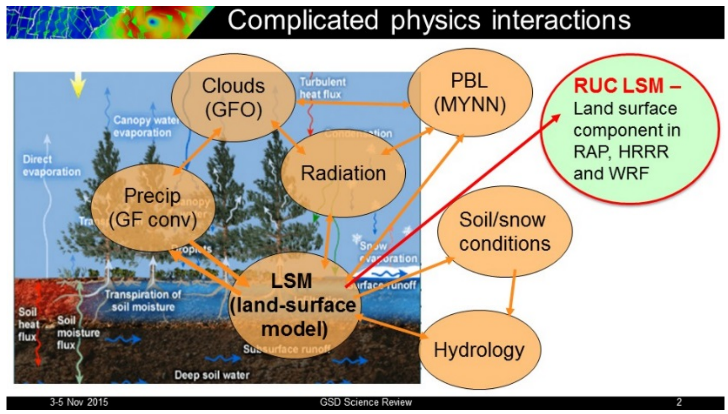

Skill from Reflectivity Data Assimilation
HRRR Forecast Skill for Reflectivity (30 dBZ)
• only operational NOAA models that assimilate reflectivity data
• reflectivity → heating rate: low-cost assimilation, significant forecast improvement
Critical Success Index X 100
← Less Skill More Skill →
radar data assimilation in RAP and HRRR
no radar data assimilation
Forecast Length (Hours)
0.0
4.0
8.0
12.0
3-5 Nov 2015
GSD Science Review
3

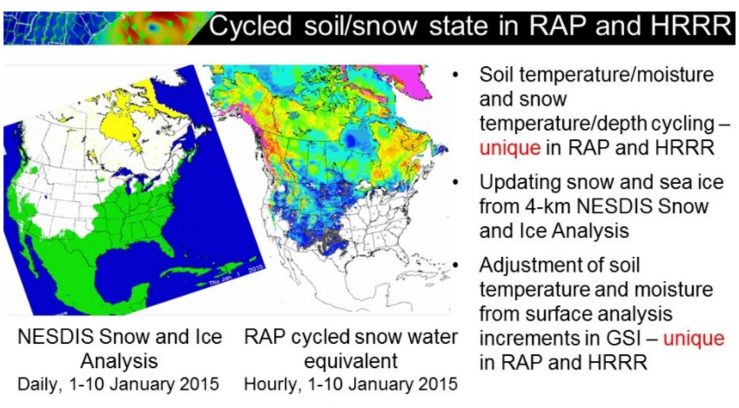

Example: With and Without Radar Data Assimilation
RAP radar DA improves convective forecast in both RAP and HRRR
Additional HRRR radar DA improves fine-scale initialization of HRRR
no radar DA
15-minute HRRR forecast
observed reflectivity
radar DA in RAP and HRRR
3-5 Nov 2015
GSD Science Review
4

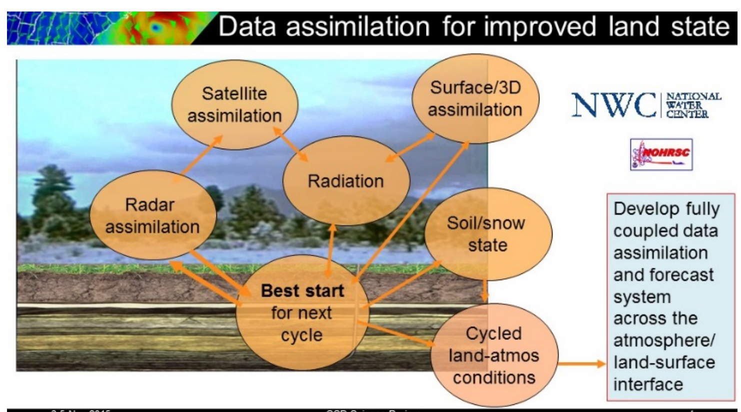

Example: With and Without Radar Data Assimilation
RAP radar DA improves convective forecast in both RAP and HRRR
Additional HRRR radar DA improves fine-scale initialization of HRRR
no radar DA
3-hour HRRR forecast
observed reflectivity
radar DA in RAP and HRRR
3-5 Nov 2015
GSD Science Review
5

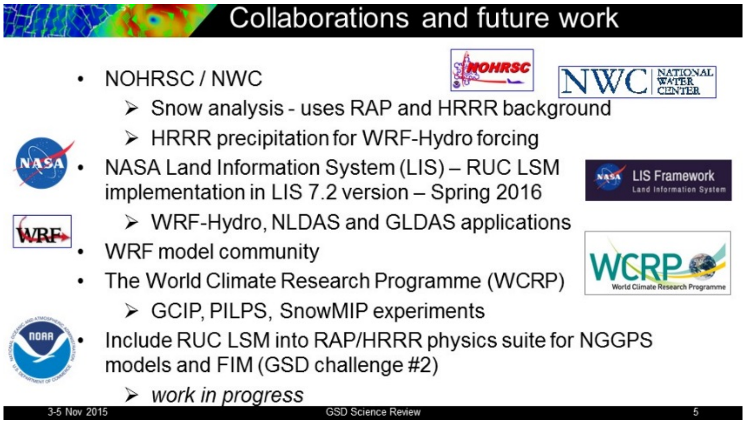

Near Future: HRRR Ensemble Data Assimilation
Improved probabilistic, high-resolution, 0-6 h forecasts of winds, clouds, and convective storms
Applications: energy, aviation, fire weather, hydrology, Warn on Forecast
3-5 Nov 2015
GSD Science Review
6


Land-surface cycling for better hydrometeorology
Tanya Smirnova
NOAA/ESRL/GSD
GSD Science Review
3-5 Nov 2015

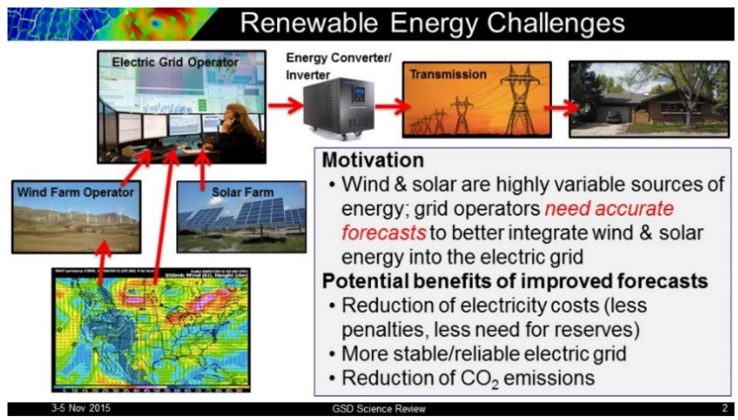

Complicated physics interactions
Clouds (GFO)
PBL (MYNN)
Radiation
Precip (GF conv)
Soil/snow conditions
LSM (land-surface model)
Hydrology
RUC LSM – Land surface component in RAP, HRRR and WRF
Turbulent heat flux
Canopy water evaporation
Direct evaporation
Transpiration of soil moisture
Soil heat flux
Soil moisture flux
Deep soil water
3-5 Nov 2015
GSD Science Review
2

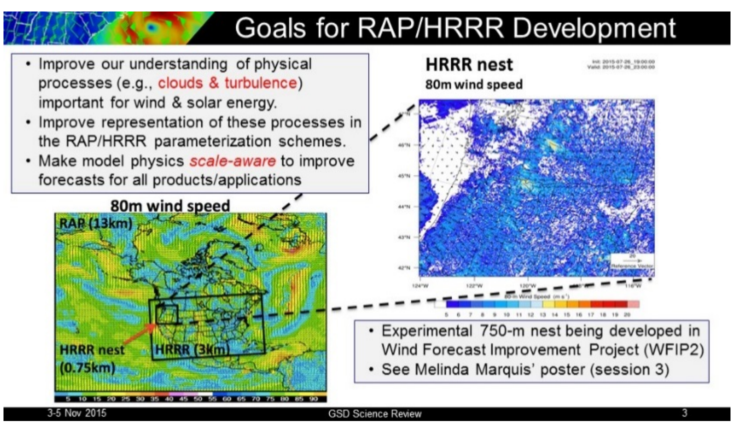

Cycled soil/snow state in RAP and HRRR
Soil temperature/moisture and snow temperature/depth cycling – unique in RAP and HRRR
Updating snow and sea ice from 4-km NESDIS Snow and Ice Analysis
Adjustment of soil temperature and moisture from surface analysis increments in GSI – unique in RAP and HRRR
NESDIS Snow and Ice Analysis
Daily, 1-10 January 2015
RAP cycled snow water equivalent
Hourly, 1-10 January 2015
3-5 Nov 2015
GSD Science Review
3

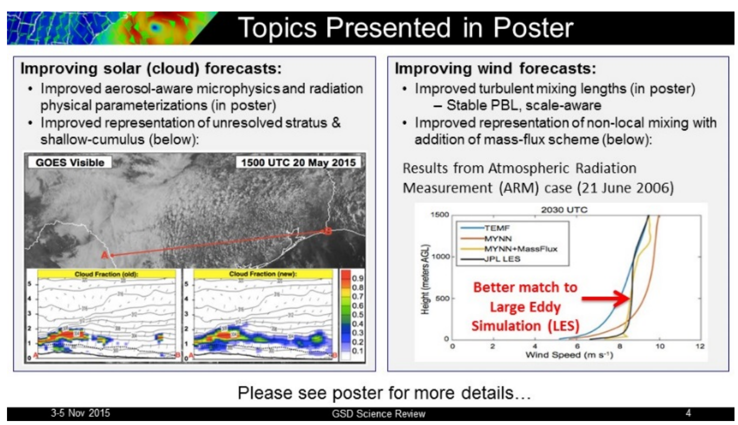

Data assimilation for improved land state
Satellite assimilation
Surface/3D assimilation
Radiation
Radar assimilation
Soil/snow state
Best start for next cycle
Cycled land-atmos conditions
NWC NATIONAL WATER CENTER
NOHRSC
Develop fully coupled data assimilation and forecast system across the atmosphere/ land-surface interface
3-5 Nov 2015
GSD Science Review
4


Collaborations and future work
NOHRSC / NWC
NOHRSC
NWC NATIONAL WATER CENTER
Snow analysis - uses RAP and HRRR background
HRRR precipitation for WRF-Hydro forcing
NASA Land Information System (LIS) – RUC LSM implementation in LIS 7.2 version – Spring 2016
LIS Framework
Land Information System
WRF-Hydro, NLDAS and GLDAS applications
WRF model community
The World Climate Research Programme (WCRP)
WCRP
World Climate Research Programme
GCIP, PILPS, SnowMIP experiments
Include RUC LSM into RAP/HRRR physics suite for NGGPS models and FIM (GSD challenge #2)
work in progress
3-5 Nov 2015
GSD Science Review
5

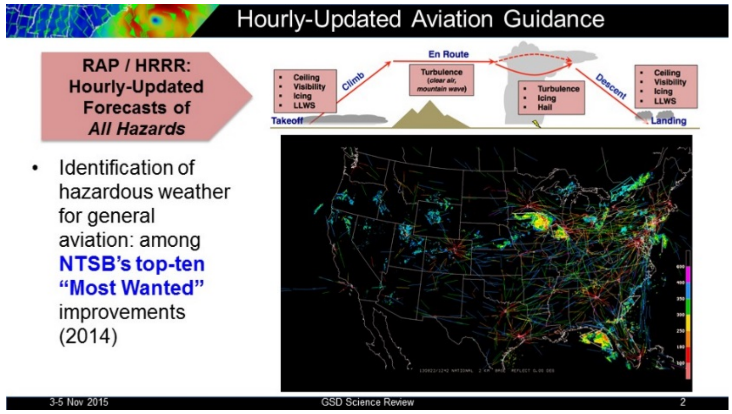

Renewable Energy Applications and Design for the RAP and HRRR
Joseph Olson
NOAA/ESRL/GSD
GSD Science Review
3-5 Nov 2015

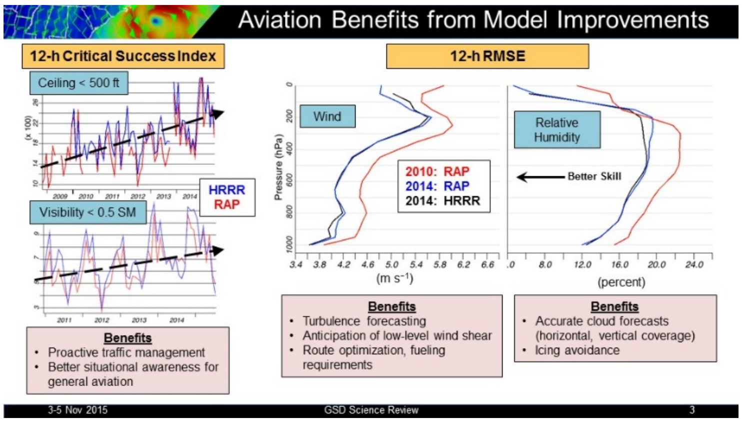

Renewable Energy Challenges
Electric Grid Operator
Energy Converter/ Inverter
Transmission
Wind Farm Operator
Solar Farm
Motivation
Wind & solar are highly variable sources of energy; grid operators need accurate forecasts to better integrate wind & solar energy into the electric grid
Potential benefits of improved forecasts
Reduction of electricity costs (less penalties, less need for reserves)
More stable/reliable electric grid
Reduction of CO2 emissions
3-5 Nov 2015
GSD Science Review
2

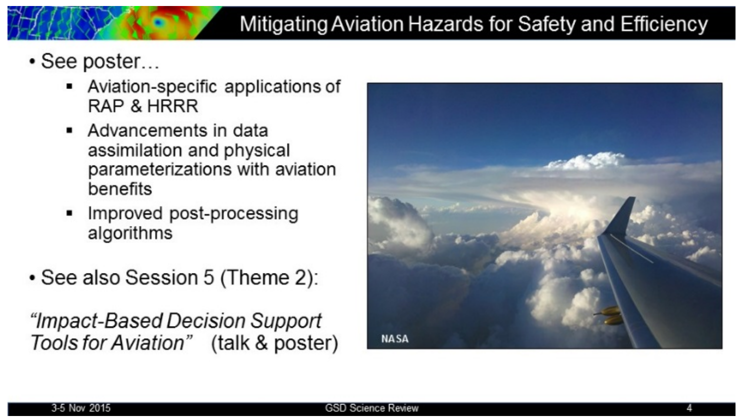

Goals for RAP/HRRR Development
Improve our understanding of physical processes (e.g., clouds & turbulence) important for wind & solar energy.
Improve representation of these processes in the RAP/HRRR parameterization schemes.
Make model physics scale-aware to improve forecasts for all products/applications
HRRR nest
80m wind speed
80m wind speed
RAP (13km)
HRRR nest (0.75km)
HRRR (3km)
Experimental 750-m nest being developed in Wind Forecast Improvement Project (WFIP2)
See Melinda Marquis' poster (session 3)
3-5 Nov 2015
GSD Science Review
3

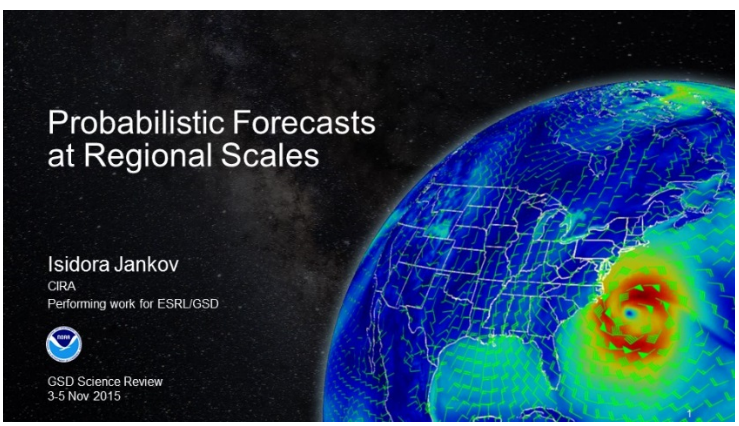

Topics Presented in Poster
Improving solar (cloud) forecasts:
Improved aerosol-aware microphysics and radiation physical parameterizations (in poster)
Improved representation of unresolved stratus & shallow-cumulus (below):
GOES Visible
1500 UTC 20 May 2015
Cloud Fraction (old):
Cloud Fraction (new):
Improving wind forecasts:
Improved turbulent mixing lengths (in poster)
– Stable PBL, scale-aware
Improved representation of non-local mixing with addition of mass-flux scheme (below):
Results from Atmospheric Radiation Measurement (ARM) case (21 June 2006)
2030 UTC
TEMF
MYNN
MYNN+MassFlux
JPL LES
Better match to Large Eddy Simulation (LES)
Height (meters AGL)
Wind Speed (m s-1)
Please see poster for more details…
3-5 Nov 2015
GSD Science Review
4

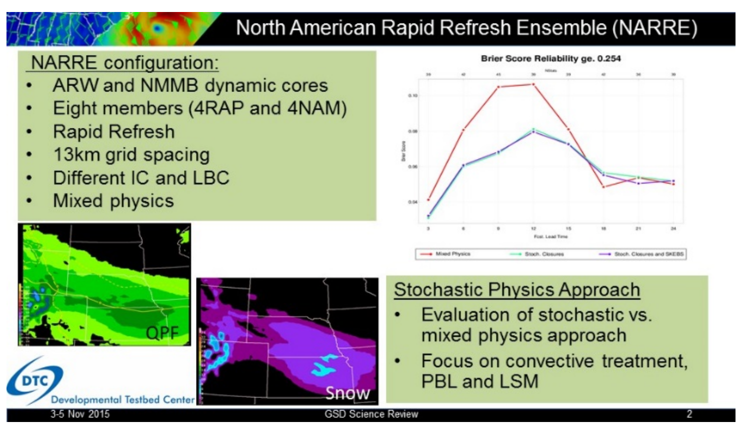

HRRR / RAP –
Mitigating Aviation Hazards for Safety and Efficiency
Jaymes Kenyon
CIRES
Performing Work for NOAA/ESRL/GSD
GSD Science Review
3-5 Nov 2015

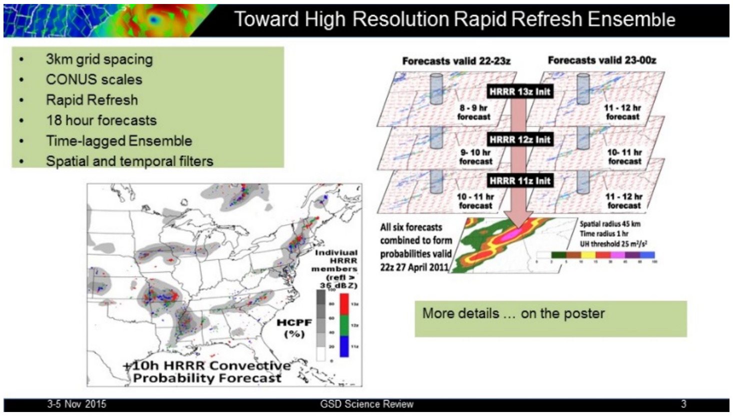

Hourly-Updated Aviation Guidance
RAP / HRRR: Hourly-Updated Forecasts of All Hazards
En Route
Climb
Descent
Takeoff
Landing
Ceiling
Visibility
Icing
LLWS
Turbulence (clear air, mountain wave)
Turbulence
Icing
Hail
• Identification of hazardous weather for general aviation: among NTSB's top-ten "Most Wanted" improvements (2014)
3-5 Nov 2015
GSD Science Review
2


Aviation Benefits from Model Improvements
12-h Critical Success Index
Ceiling < 500 ft
Visibility < 0.5 SM
HRRR
RAP
Benefits
• Proactive traffic management
• Better situational awareness for general aviation
12-h RMSE
Wind
Relative Humidity
Pressure (hPa)
(m s-1)
(percent)
2010: RAP
2014: RAP
2014: HRRR
Better Skill
Benefits
• Turbulence forecasting
• Anticipation of low-level wind shear
• Route optimization, fueling requirements
Benefits
• Accurate cloud forecasts (horizontal, vertical coverage)
• Icing avoidance
3-5 Nov 2015
GSD Science Review
3


Mitigating Aviation Hazards for Safety and Efficiency
• See poster…
▪ Aviation-specific applications of RAP & HRRR
▪ Advancements in data assimilation and physical parameterizations with aviation benefits
▪ Improved post-processing algorithms
• See also Session 5 (Theme 2):
"Impact-Based Decision Support Tools for Aviation" (talk & poster)
NASA
3-5 Nov 2015
GSD Science Review
4

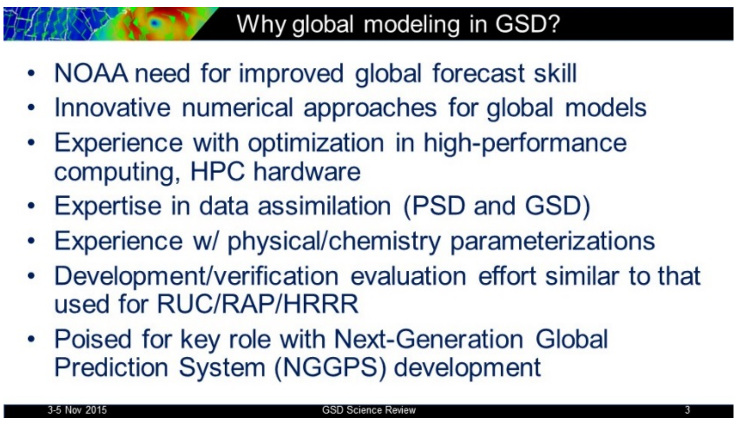

Probabilistic Forecasts at Regional Scales
Isidora Jankov
CIRA
Performing work for ESRL/GSD
GSD Science Review
3-5 Nov 2015

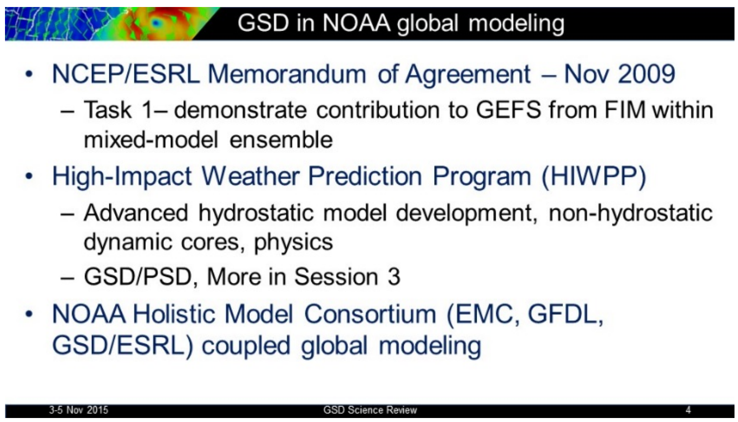

North American Rapid Refresh Ensemble (NARRE)
NARRE configuration:
• ARW and NMMB dynamic cores
• Eight members (4RAP and 4NAM)
• Rapid Refresh
• 13km grid spacing
• Different IC and LBC
• Mixed physics
Brier Score Reliability ge. 0.254
QPF
Snow
DTC Developmental Testbed Center
Stochastic Physics Approach
• Evaluation of stochastic vs. mixed physics approach
• Focus on convective treatment, PBL and LSM
3-5 Nov 2015
GSD Science Review
2


Toward High Resolution Rapid Refresh Ensemble
• 3km grid spacing
• CONUS scales
• Rapid Refresh
• 18 hour forecasts
• Time-lagged Ensemble
• Spatial and temporal filters
Forecasts valid 22-23z
Forecasts valid 23-00z
HRRR 13z Init
8 - 9 hr forecast
11 - 12 hr forecast
HRRR 12z Init
9- 10 hr forecast
10- 11 hr forecast
HRRR 11z Init
10 - 11 hr forecast
11 - 12 hr forecast
All six forecasts combined to form probabilities valid 22z 27 April 2011
Spatial radius 45 km
Time radius 1 hr
UH threshold 25 m²/s²
Indiviual HRRR members (refl > 35 dBZ)
HCPF (%)
+10h HRRR Convective Probability Forecast
More details … on the poster
3-5 Nov 2015
GSD Science Review
3

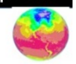
Session 2: Numerical Weather Prediction – Global Models

- Modeling Challenge #2 – Toward Earth System Modeling (Stan Benjamin)
- FIM Atmospheric Global Model for Medium-range Forecast Applications (Stan Benjamin)
- Impact of Composition and Chemistry on Weather Forecasting (Georg Grell)
- Coupled Atmospheric-Ocean Earth System Modeling for Sub-seasonal Prediction (Shan Sun)
- Development of Non-hydrostatic Global Models – NIM (Jin Lee)
- High-performance Software Engineering (Tom Henderson)
- Physics for Global Non-hydrostatic Applications (John Brown)





Quality – innovative global model development



- Accurate numerics (FIM, NIM)
- Extension to in-line chemistry – FIM-chem
- Coupling to ocean community model (HYCOM)
  - First/only NOAA global coupled model with HYCOM
- Development of non-hydrostatic icosahedral model (NIM)
- Real-data evaluation
  - Successful performance vs. GFS – deterministic (including hurricane) and mixed-model ens.
- Physical parameterizations
  - GFS physics suite within alternate dynamic core
  - Development of scale-independent and storm-scale physics suites, aerosol-chemistry

3-5 Nov 2015 GSD Science Review 5

ESRL Finite-volume Icosahedral Models

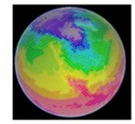
FIM: Hydrostatic

- Model candidate for NOAA global ensemble and subseasonal real-time applications.
- Backbone for ESRL Earth-System Analyzer (ESA – chem-global) research applications.

Target resolution ≥ 10 km

NIM: Nonhydrostatic

- Demonstration for actual 3km real-data global forecasting with advanced computing and numerics.



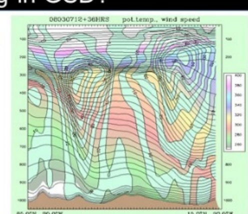
Target resolution: Down to O(1 km)

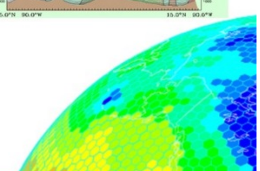
3-5 Nov 2015 GSD Science Review 6

Why global modeling in GSD?

Innovative numerical approaches for global models

- Icosahedral horizontal coordinate
- Isentropic-adaptive coordinate
- Application of finite-volume approach within icosahedral and isentropic framework





3-5 Nov 2015 GSD Science Review 7

Why global modeling in GSD?

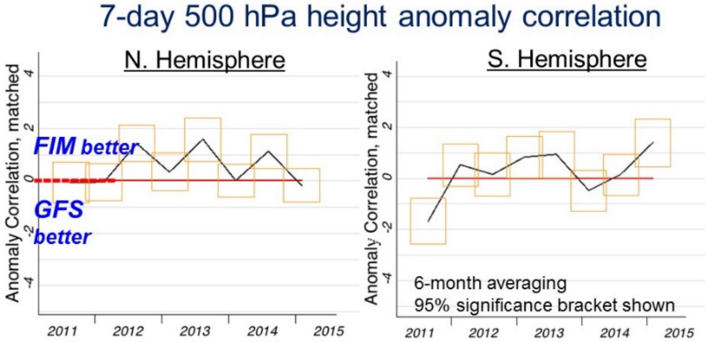
Experience with physical parameterizations

- Successful incorporation of GFS physics (2008, 2011, 2015 versions) into alternate dynamic core global models.
- Alternative scale-aware deep cumulus parameterization, sub-grid-scale cloud effects
- Development and demonstration of HRRR-RAP physics suite (main NOAA development for storm-scale physics suite)
- Aerosol-aware physics, aerosol chemistry (smoke, volcanic ash)
- Collaboration with WRF, WRF-Chem, Climate Processes Team, NGGPS Global Modeling Test Bed

3-5 Nov 2015 GSD Science Review 8

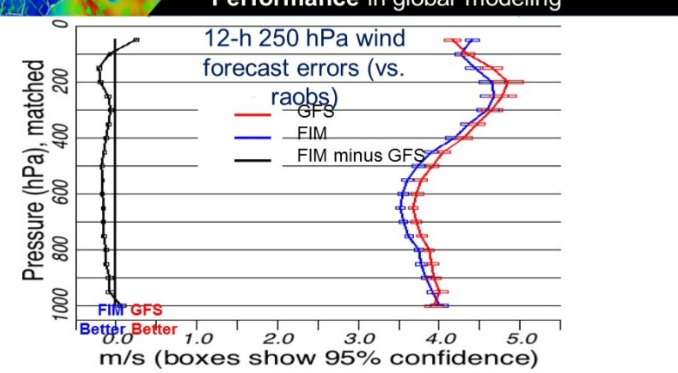
Performance in global modeling

7-day 500 hPa height anomaly correlation

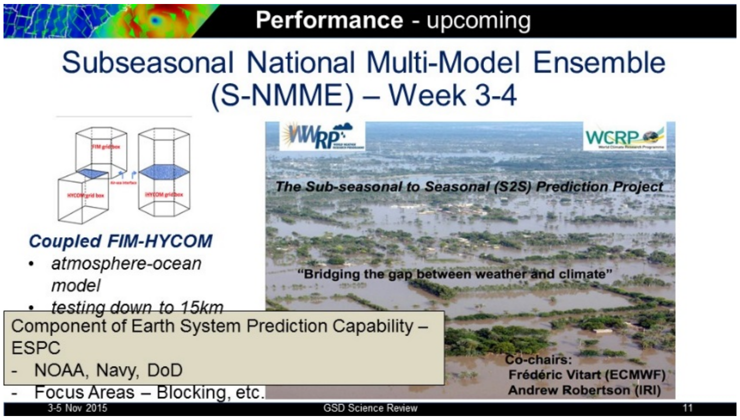


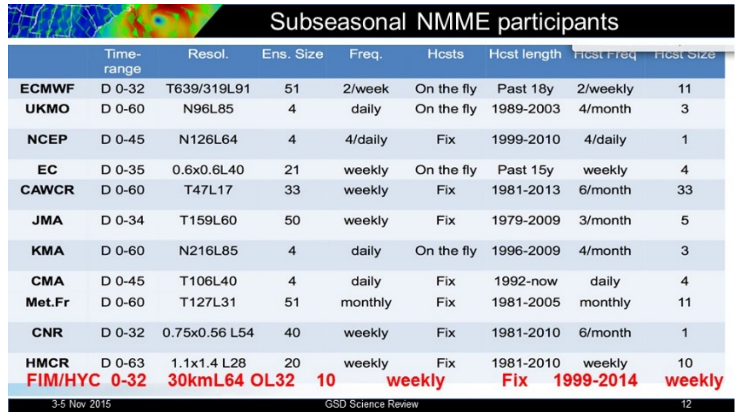
GSD Science Review November 3-5, 2015 9

Performance in global modeling

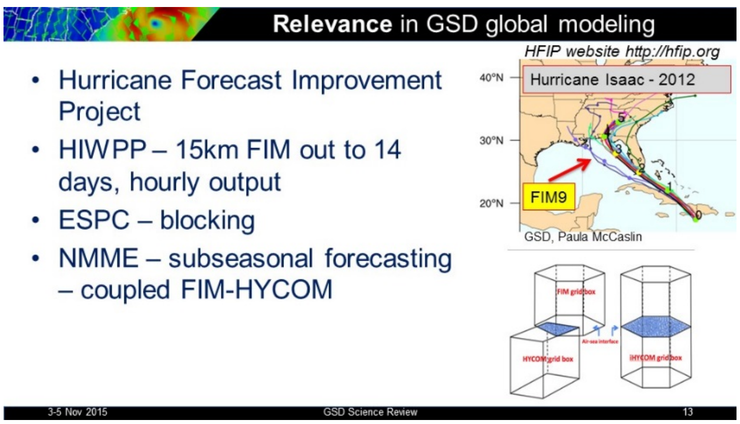


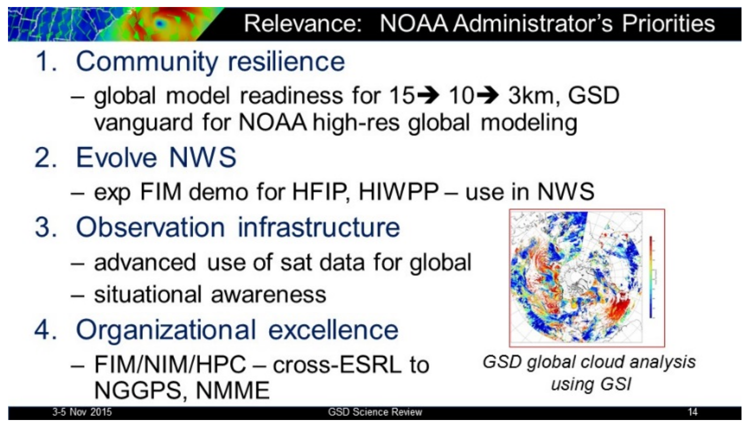
3-5 Nov 2015 GSD Science Review 10

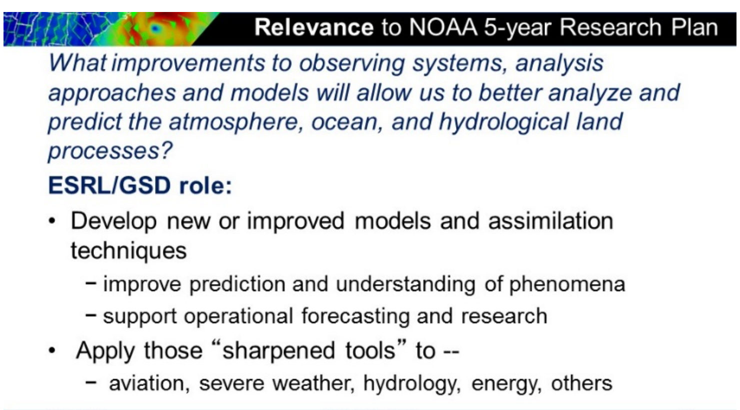


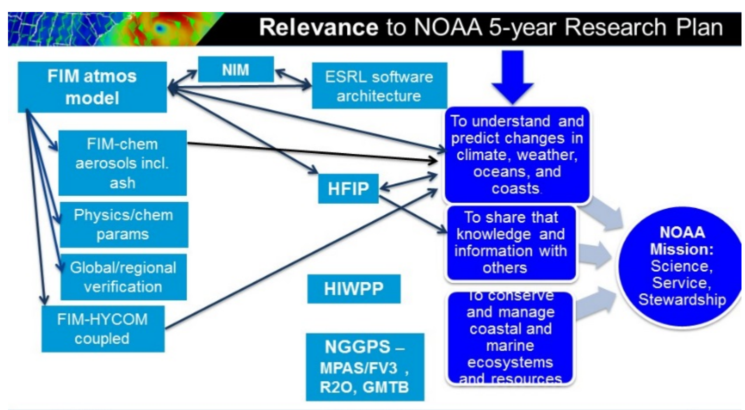


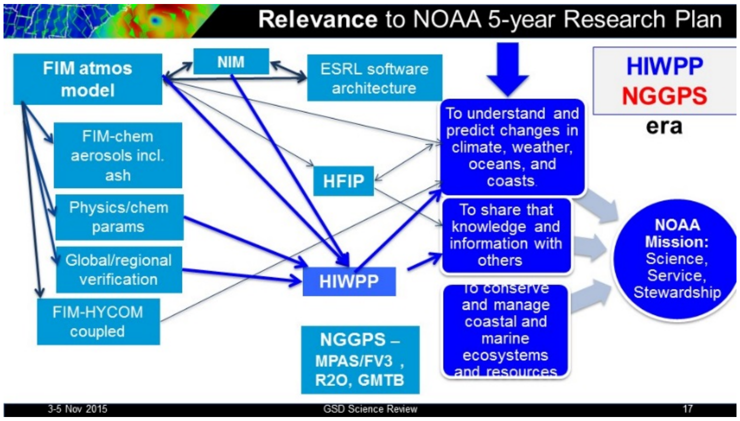
	Time-range	Resol.	Ens. Size	Freq.	Hcsts	Hcst length	Hcst Freq	Hcst Size
ECMWF	D 0-32	T639/319L91	51	2/week	On the fly	Past 18y	2/weekly	11
UKMO	D 0-60	N96L85	4	daily	On the fly	1989-2003	4/month	3
NCEP	D 0-45	N126L64	4	4/daily	Fix	1999-2010	4/daily	1
EC	D 0-35	0.6x0.6L40	21	weekly	On the fly	Past 15y	weekly	4
CAWCR	D 0-60	T47L17	33	weekly	Fix	1981-2013	6/month	33
JMA	D 0-34	T159L60	50	weekly	Fix	1979-2009	3/month	5
KMA	D 0-60	N216L85	4	daily	On the fly	1996-2009	4/month	3
CMA	D 0-45	T106L40	4	daily	Fix	1992-now	daily	4
Met.Fr	D 0-60	T127L31	51	monthly	Fix	1981-2005	monthly	11
CNR	D 0-32	0.75x0.56 L54	40	weekly	Fix	1981-2010	6/month	1
HMCR	D 0-63	1.1x1.4 L28	20	weekly	Fix	1981-2010	weekly	10
FIM/HYC	0-32	30kmL64 OL32	10	weekly	Fix	1999-2014	weekly	

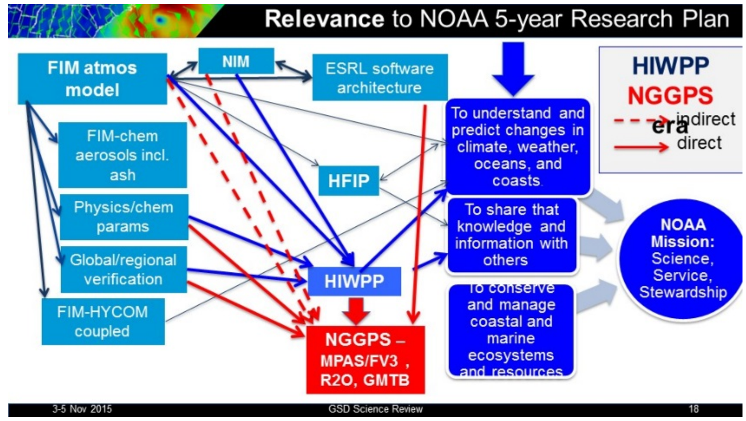








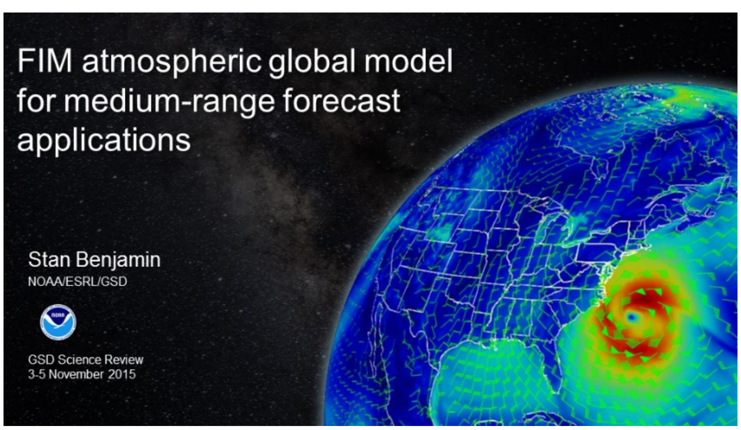


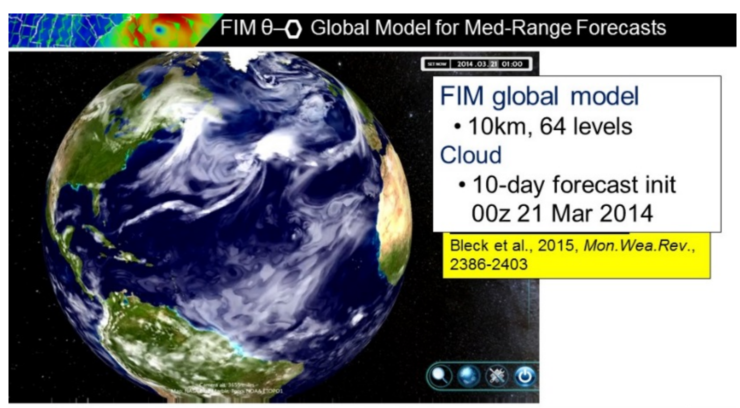


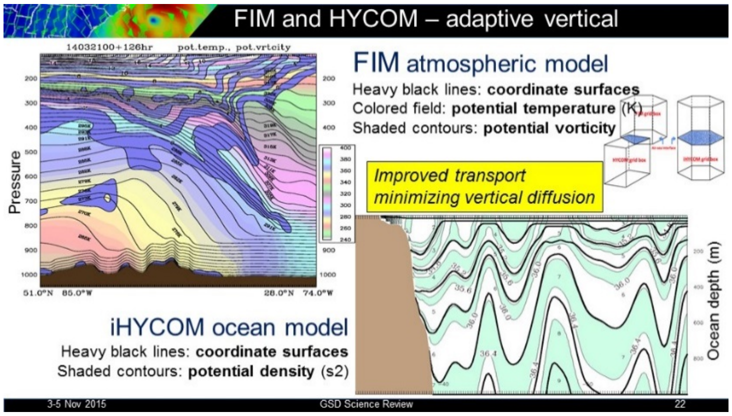
NWP Session 2 Posters – Science Highlights

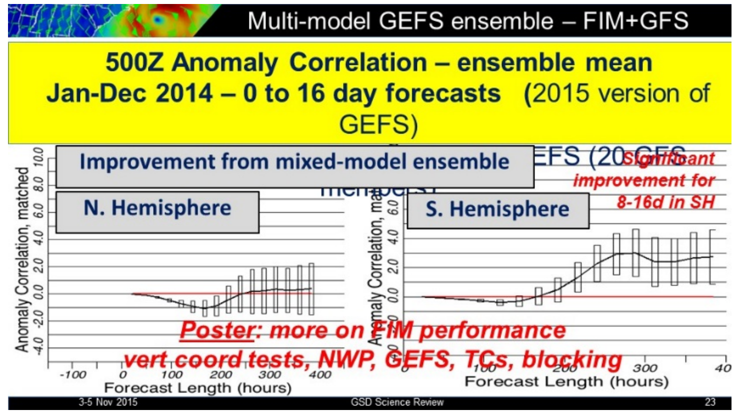
Presenter	Electronic Poster	Station
Stan Benjamin	FIM atmospheric global model for medium-range forecast applications	1
Georg Grell	Impact of composition and chemistry on weather forecasting	2
Shan Sun	Coupled atmospheric-ocean earth system modeling for sub-seasonal prediction	3
Jin Lee	Development of non-hydrostatic global modeling - NIM	4
Tom Henderson	High-performance software engineering	5
John Brown	Physics for global non-hydrostatic applications	6

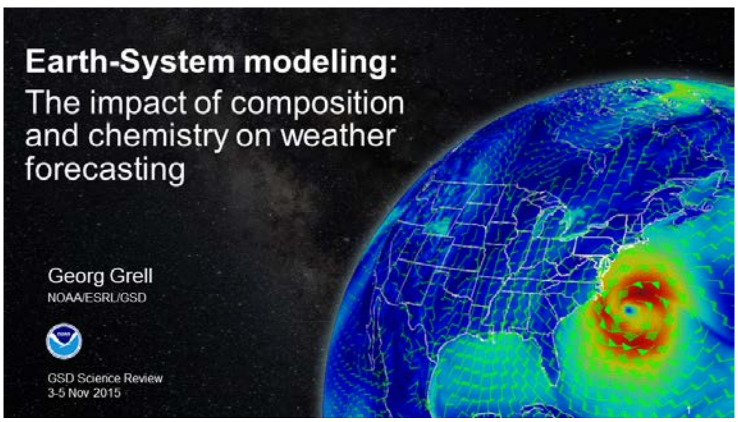
3-5 Nov 2015 GSD Science Review 19

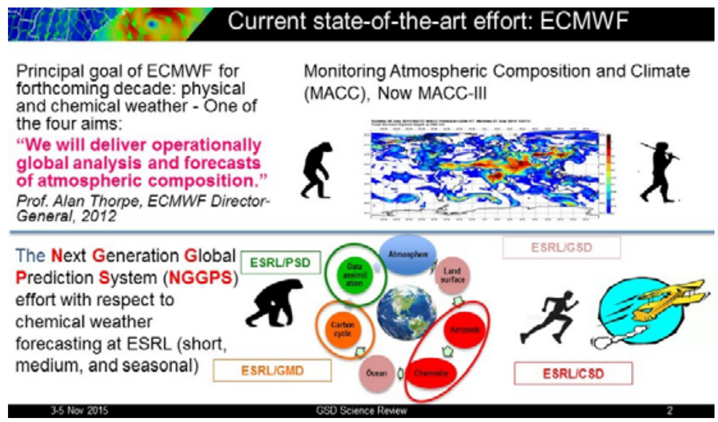


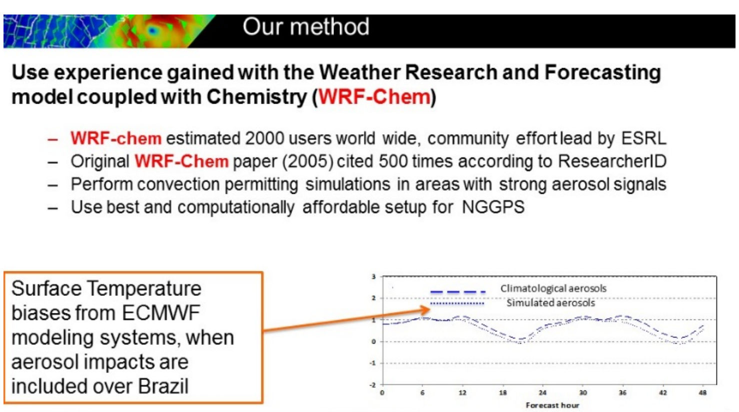


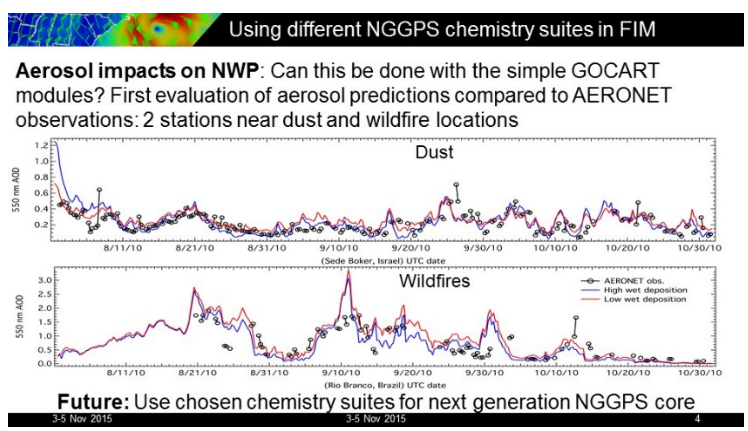

FIM and HYCOM – adaptive vertical
FIM atmospheric model
Heavy black lines: coordinate surfaces
Colored field: potential temperature (K)
Shaded contours: potential vorticity
Improved transport
minimizing vertical diffusion
Pressure
iHYCOM ocean model
Heavy black lines: coordinate surfaces
Shaded contours: potential density (s2)
Ocean depth (m)
3-5 Nov 2015
GSD Science Review
22

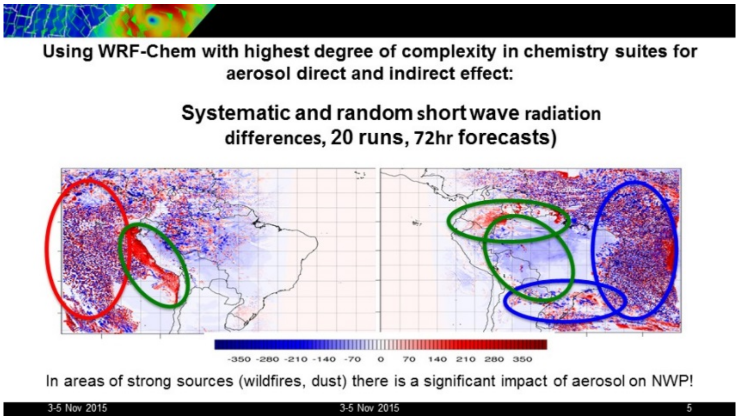

Multi-model GEFS ensemble – FIM+GFS
500Z Anomaly Correlation – ensemble mean
Jan-Dec 2014 – 0 to 16 day forecasts (2015 version of GEFS)
Improvement from mixed-model ensemble
N. Hemisphere
S. Hemisphere
Significant improvement for 8-16d in SH
Anomaly Correlation, matched
Poster: more on FIM performance
vert coord tests, NWP, GEFS, TCs, blocking
Forecast Length (hours)
Forecast Length (hours)
3-5 Nov 2015
GSD Science Review
23

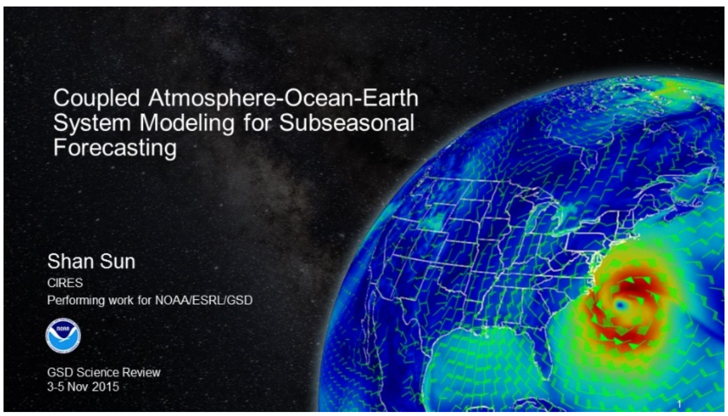

Earth-System modeling:
The impact of composition and chemistry on weather forecasting
Georg Grell
NOAA/ESRL/GSD
GSD Science Review
3-5 Nov 2015

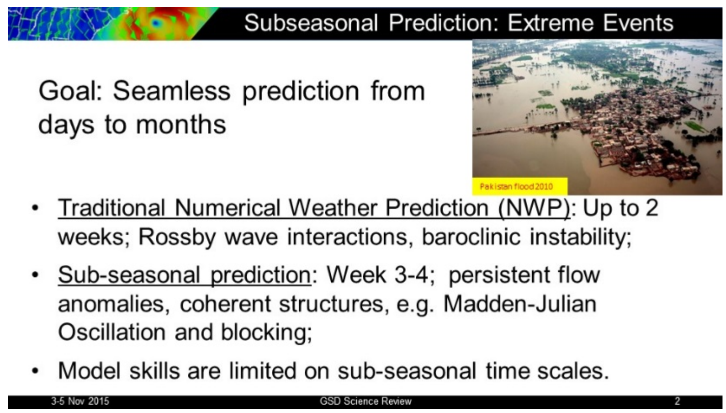

Current state-of-the-art effort: ECMWF
Principal goal of ECMWF for forthcoming decade: physical and chemical weather - One of the four aims:
"We will deliver operationally global analysis and forecasts of atmospheric composition."
Prof. Alan Thorpe, ECMWF Director-General, 2012
Monitoring Atmospheric Composition and Climate (MACC), Now MACC-III
The Next Generation Global Prediction System (NGGPS) effort with respect to chemical weather forecasting at ESRL (short, medium, and seasonal)
ESRL/PSD
ESRL/GSD
ESRL/GMD
ESRL/CSD
3-5 Nov 2015
GSD Science Review
2

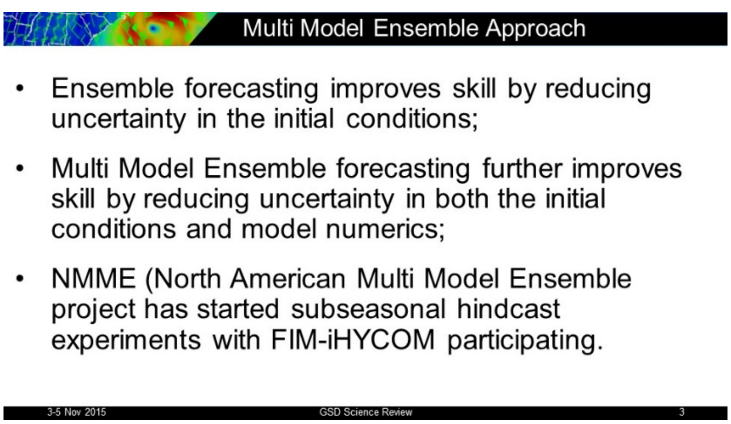

Our method
Use experience gained with the Weather Research and Forecasting model coupled with Chemistry (WRF-Chem)
– WRF-chem estimated 2000 users world wide, community effort lead by ESRL
– Original WRF-Chem paper (2005) cited 500 times according to ResearcherID
– Perform convection permitting simulations in areas with strong aerosol signals
– Use best and computationally affordable setup for NGGPS
Surface Temperature biases from ECMWF modeling systems, when aerosol impacts are included over Brazil
Climatological aerosols
Simulated aerosols
Forecast hour
3-5 Nov 2015
GSD Science Review

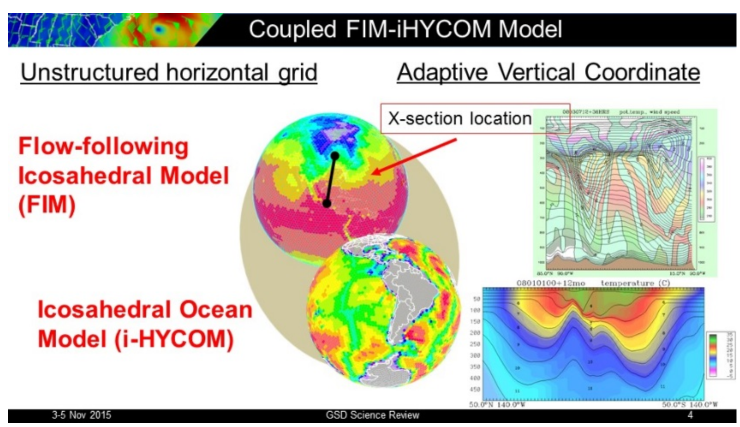

Using different NGGPS chemistry suites in FIM
Aerosol impacts on NWP: Can this be done with the simple GOCART modules? First evaluation of aerosol predictions compared to AERONET observations: 2 stations near dust and wildfire locations
Dust
(Sede Boker, Israel) UTC date
Wildfires
AERONET obs.
High wet deposition
Low wet deposition
(Rio Branco, Brazil) UTC date
Future: Use chosen chemistry suites for next generation NGGPS core
3-5 Nov 2015
4

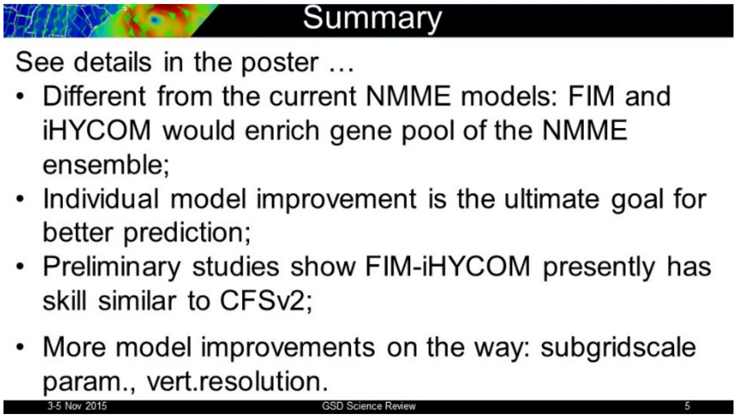

Using WRF-Chem with highest degree of complexity in chemistry suites for aerosol direct and indirect effect:
Systematic and random short wave radiation differences, 20 runs, 72hr forecasts)
-350 -280 -210 -140 -70 0 70 140 210 280 350
In areas of strong sources (wildfires, dust) there is a significant impact of aerosol on NWP!
3-5 Nov 2015
3-5 Nov 2015
5

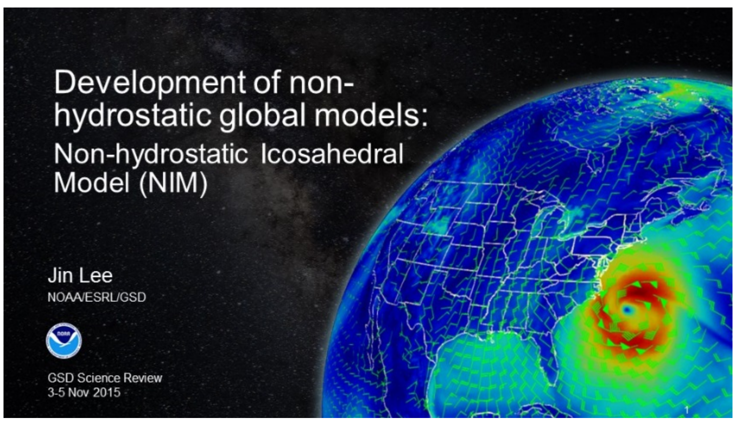

Coupled Atmosphere-Ocean-Earth System Modeling for Subseasonal Forecasting
Shan Sun
CIRES
Performing work for NOAA/ESRL/GSD
GSD Science Review
3-5 Nov 2015

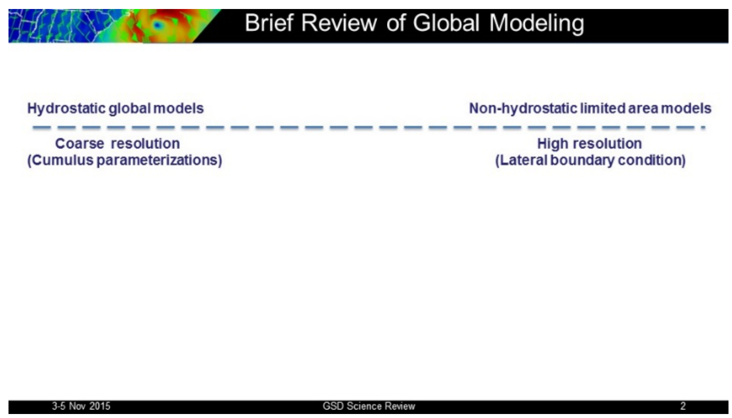

Subseasonal Prediction: Extreme Events
Goal: Seamless prediction from days to months
Pakistan flood 2010
• Traditional Numerical Weather Prediction (NWP): Up to 2 weeks; Rossby wave interactions, baroclinic instability;
• Sub-seasonal prediction: Week 3-4; persistent flow anomalies, coherent structures, e.g. Madden-Julian Oscillation and blocking;
• Model skills are limited on sub-seasonal time scales.
3-5 Nov 2015
GSD Science Review
2

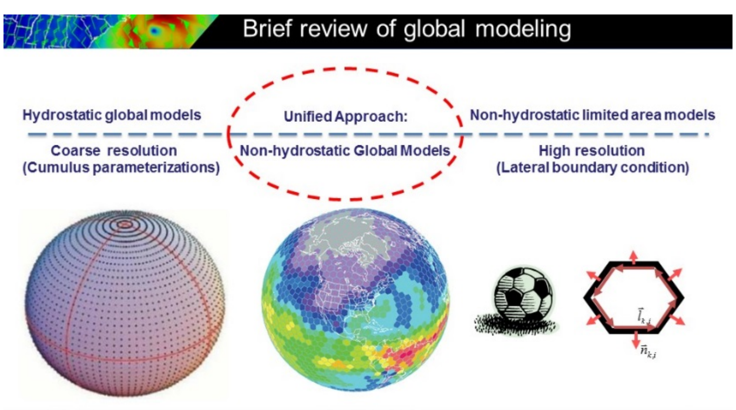

Multi Model Ensemble Approach
• Ensemble forecasting improves skill by reducing uncertainty in the initial conditions;
• Multi Model Ensemble forecasting further improves skill by reducing uncertainty in both the initial conditions and model numerics;
• NMME (North American Multi Model Ensemble project has started subseasonal hindcast experiments with FIM-iHYCOM participating.
3-5 Nov 2015
GSD Science Review
3

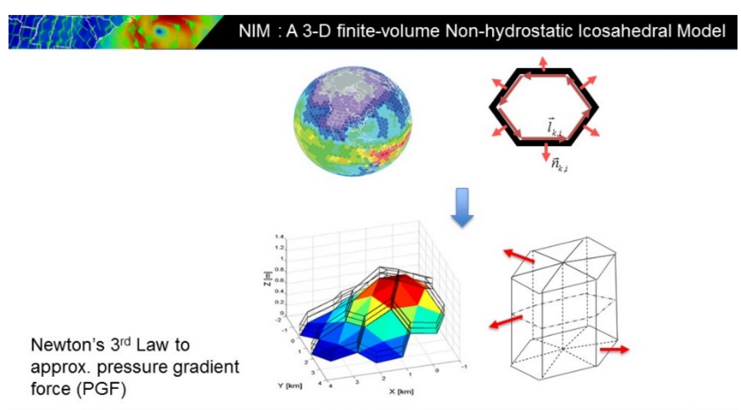

Coupled FIM-iHYCOM Model
Unstructured horizontal grid
Adaptive Vertical Coordinate
X-section location
Flow-following Icosahedral Model (FIM)
Icosahedral Ocean Model (i-HYCOM)
3-5 Nov 2015
GSD Science Review
4

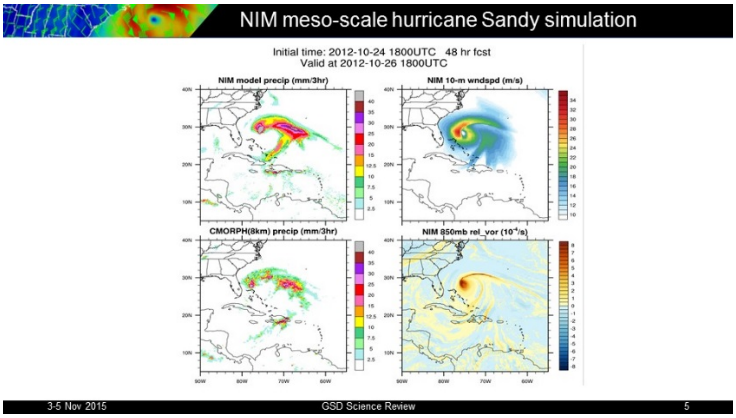

Summary
See details in the poster …
• Different from the current NMME models: FIM and iHYCOM would enrich gene pool of the NMME ensemble;
• Individual model improvement is the ultimate goal for better prediction;
• Preliminary studies show FIM-iHYCOM presently has skill similar to CFSv2;
• More model improvements on the way: subgridscale param., vert.resolution.
3-5 Nov 2015
GSD Science Review
5

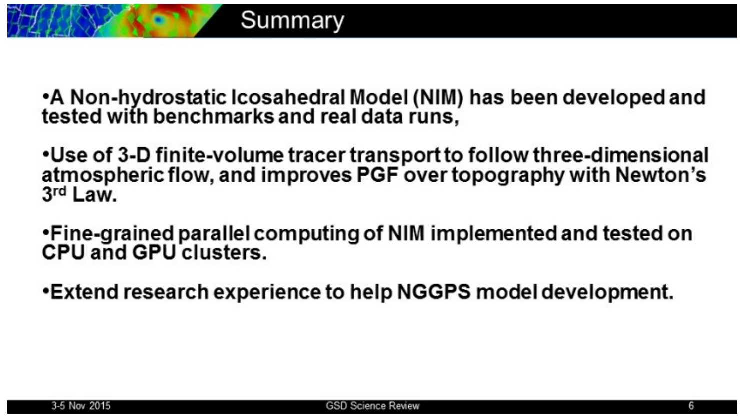

Development of non-hydrostatic global models:
Non-hydrostatic Icosahedral Model (NIM)
Jin Lee
NOAA/ESRL/GSD
GSD Science Review
3-5 Nov 2015


Brief Review of Global Modeling
Hydrostatic global models
Non-hydrostatic limited area models
Coarse resolution
(Cumulus parameterizations)
High resolution
(Lateral boundary condition)
3-5 Nov 2015
GSD Science Review
2

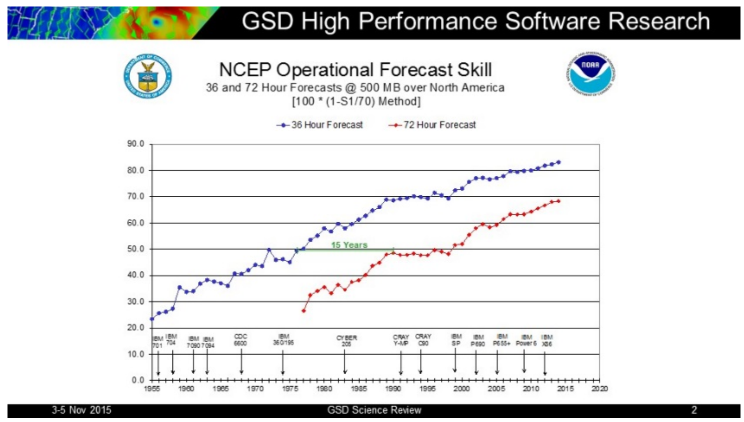

Brief review of global modeling
Hydrostatic global models
Unified Approach:
Non-hydrostatic limited area models
Coarse resolution
(Cumulus parameterizations)
Non-hydrostatic Global Models
High resolution
(Lateral boundary condition)
3-5 Nov 2015
GSD Science Review
3

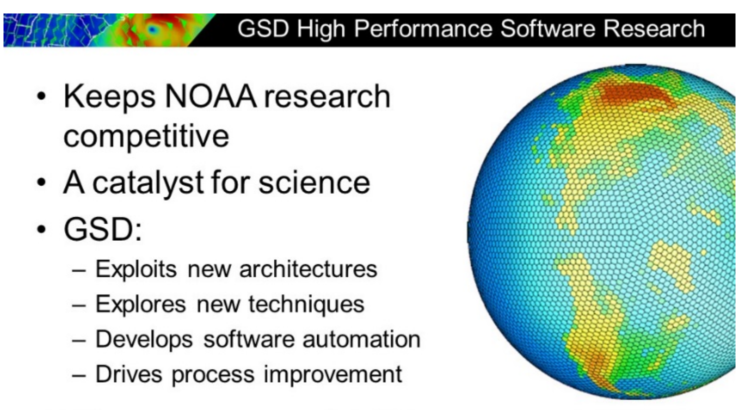

NIM : A 3-D finite-volume Non-hydrostatic Icosahedral Model
Newton's 3rd Law to approx. pressure gradient force (PGF)
Y [km]
X [km]
3-5 Nov 2015
GSD Science Review
4

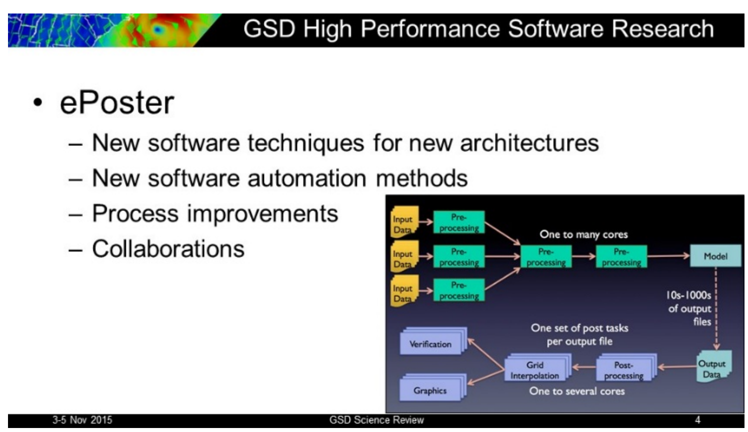

NIM meso-scale hurricane Sandy simulation
Initial time: 2012-10-24 1800UTC 48 hr fcst
Valid at 2012-10-26 1800UTC
NIM model precip (mm/3hr)
NIM 10-m wndspd (m/s)
CMORPH(8km) precip (mm/3hr)
3-5 Nov 2015
GSD Science Review
5

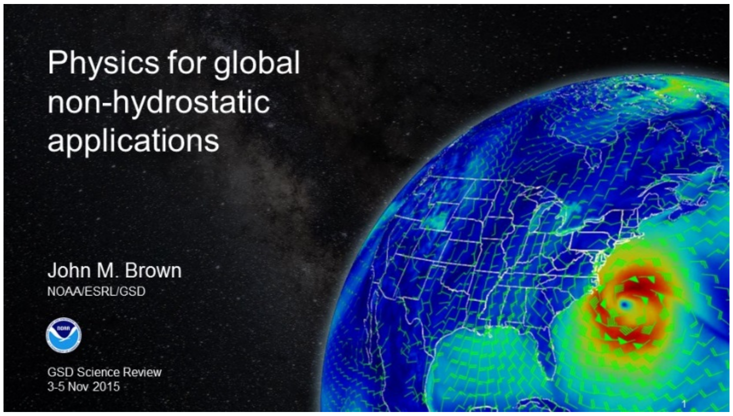

Summary
•A Non-hydrostatic Icosahedral Model (NIM) has been developed and tested with benchmarks and real data runs,
•Use of 3-D finite-volume tracer transport to follow three-dimensional atmospheric flow, and improves PGF over topography with Newton's 3rd Law.
•Fine-grained parallel computing of NIM implemented and tested on CPU and GPU clusters.
•Extend research experience to help NGGPS model development.
3-5 Nov 2015
GSD Science Review
6

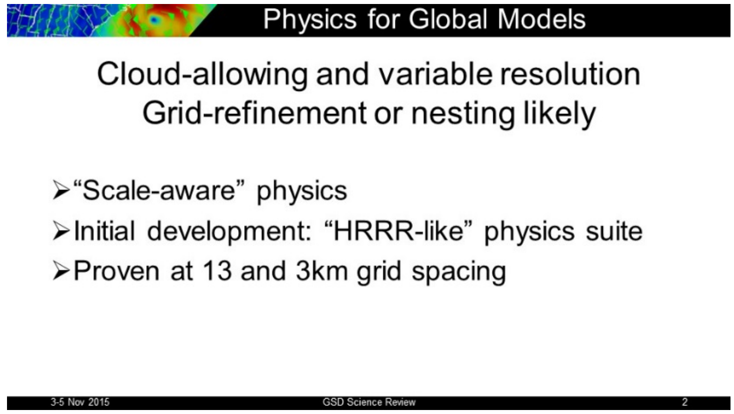

High Performance
Software Engineering
Tom Henderson
CIRA
Performing work for NOAA/ESRL/GSD
GSD Science Review
3-5 Nov 2015

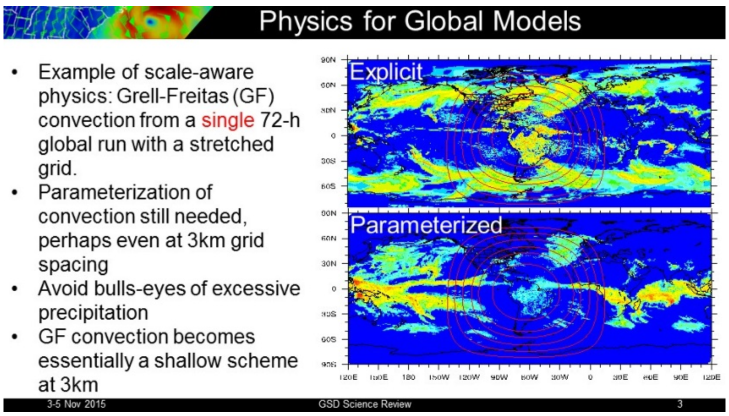

GSD High Performance Software Research
NCEP Operational Forecast Skill
36 and 72 Hour Forecasts @ 500 MB over North America
[100 * (1-S1/70) Method]
36 Hour Forecast
72 Hour Forecast
15 Years
3-5 Nov 2015
GSD Science Review
2

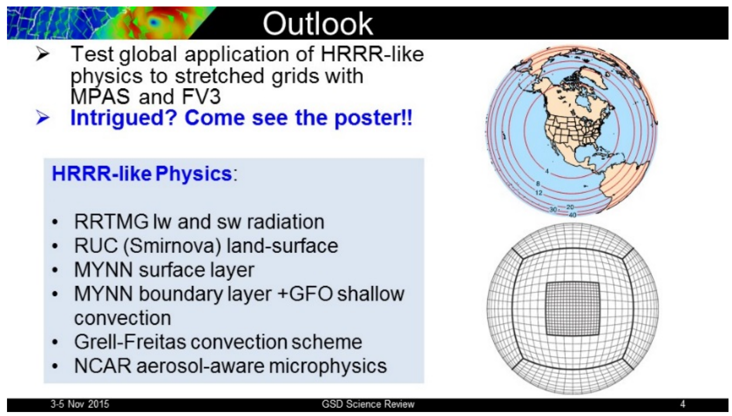

GSD High Performance Software Research
• Keeps NOAA research competitive
• A catalyst for science
• GSD:
– Exploits new architectures
– Explores new techniques
– Develops software automation
– Drives process improvement
3-5 Nov 2015
GSD Science Review
3


GSD High Performance Software Research
• ePoster
– New software techniques for new architectures
– New software automation methods
– Process improvements
– Collaborations
Input Data
Pre-processing
One to many cores
Model
10s-1000s of output files
One set of post tasks per output file
Verification
Graphics
Grid Interpolation
Post-processing
Output Data
One to several cores
3-5 Nov 2015
GSD Science Review
4


Physics for global non-hydrostatic applications
John M. Brown
NOAA/ESRL/GSD
GSD Science Review
3-5 Nov 2015

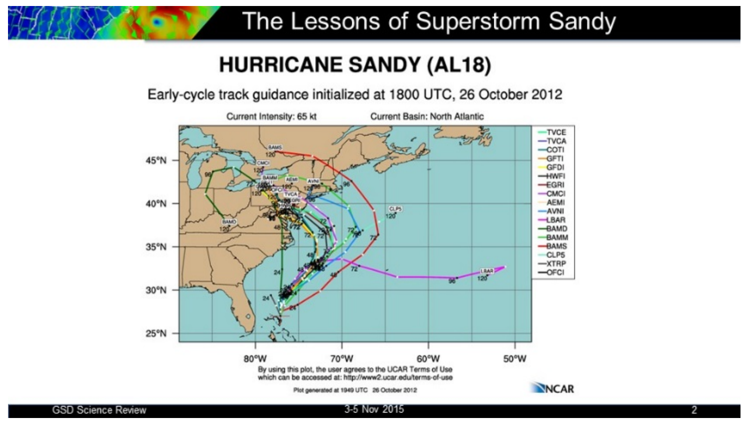

Physics for Global Models
Cloud-allowing and variable resolution
Grid-refinement or nesting likely
➢"Scale-aware" physics
➢Initial development: "HRRR-like" physics suite
➢Proven at 13 and 3km grid spacing
3-5 Nov 2015
GSD Science Review
2

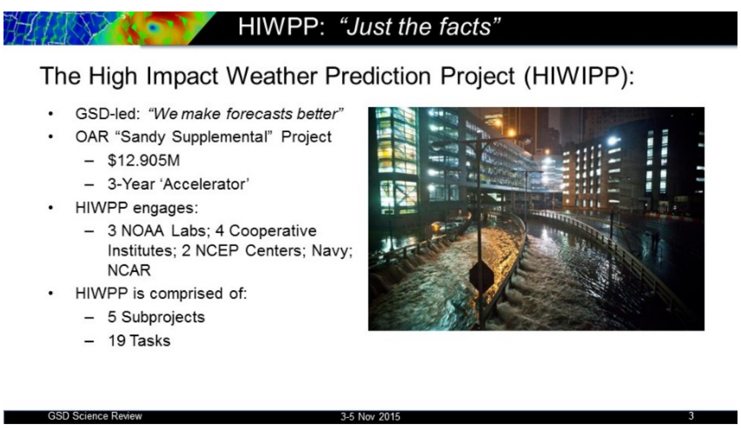

Physics for Global Models
• Example of scale-aware physics: Grell-Freitas (GF) convection from a single 72-h global run with a stretched grid.
• Parameterization of convection still needed, perhaps even at 3km grid spacing
• Avoid bulls-eyes of excessive precipitation
• GF convection becomes essentially a shallow scheme at 3km
Explicit
Parameterized
3-5 Nov 2015
GSD Science Review
3

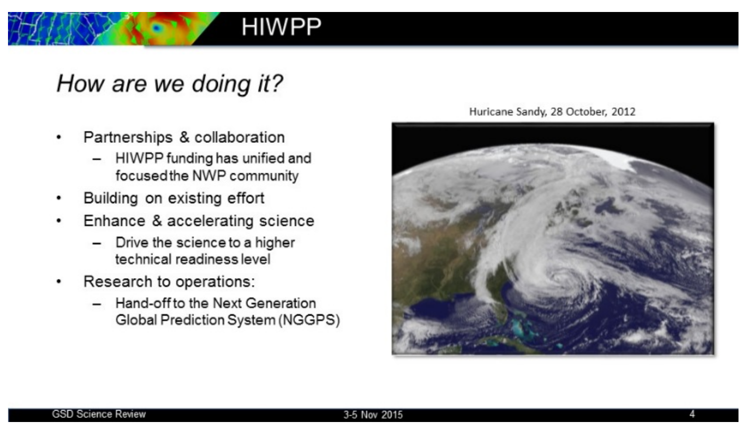

Outlook
➢ Test global application of HRRR-like physics to stretched grids with MPAS and FV3
➢ Intrigued? Come see the poster!!
HRRR-like Physics:
• RRTMG lw and sw radiation
• RUC (Smirnova) land-surface
• MYNN surface layer
• MYNN boundary layer +GFO shallow convection
• Grell-Freitas convection scheme
• NCAR aerosol-aware microphysics
3-5 Nov 2015
GSD Science Review
4

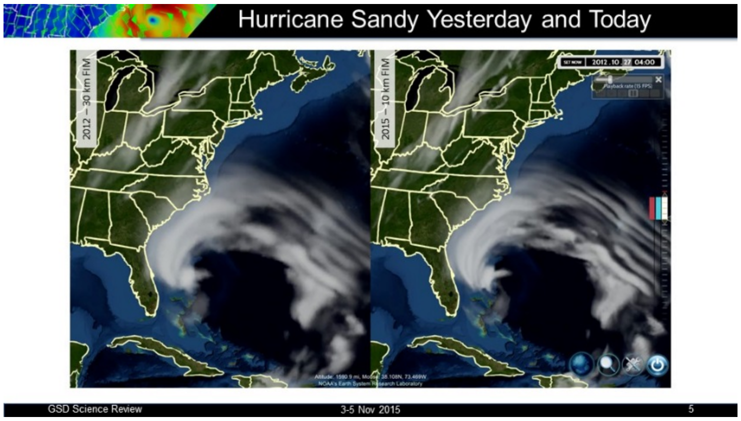
Session 3: Numerical Weather Prediction – Cross-Cutting Activities

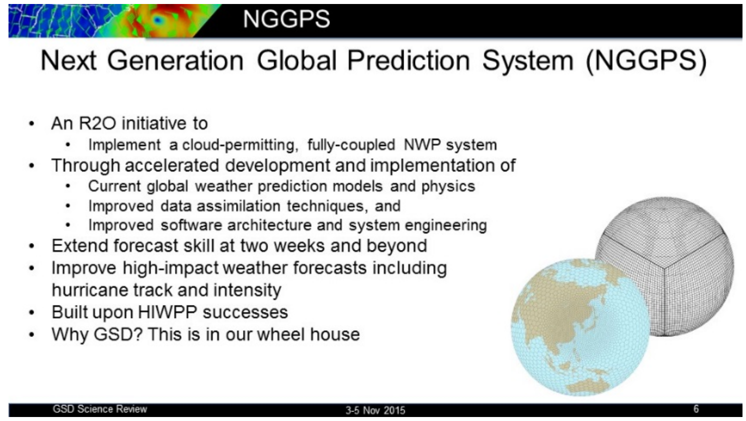
- NWP: GSD's Path Forward (Tim Schneider)
- Global Developmental Testbed Center (DTC) (Ligia Bernardet)
- Global Observing Systems Analysis (Lidia Cucurull)
- Improving Winter Storm Forecasts with Dropsonde Data (Jason English)
- Renewable Energy Program (Melinda Marquis)

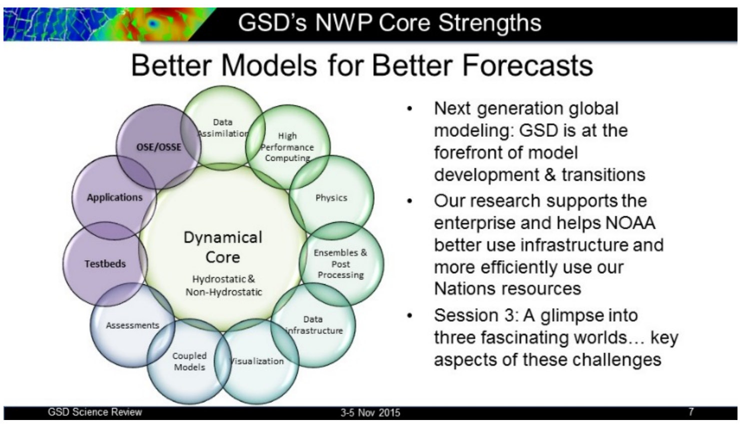


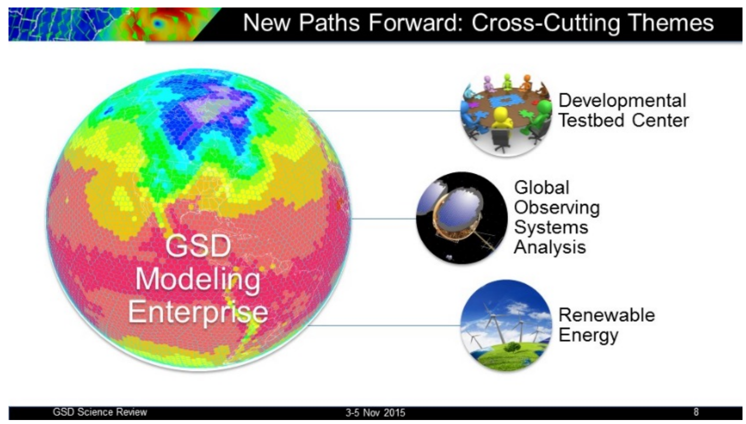


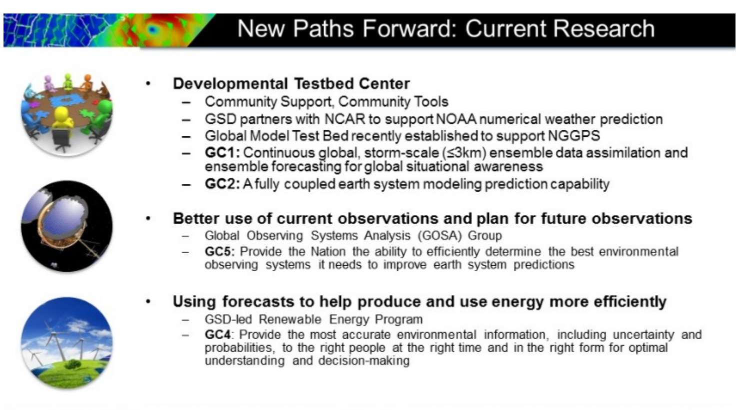


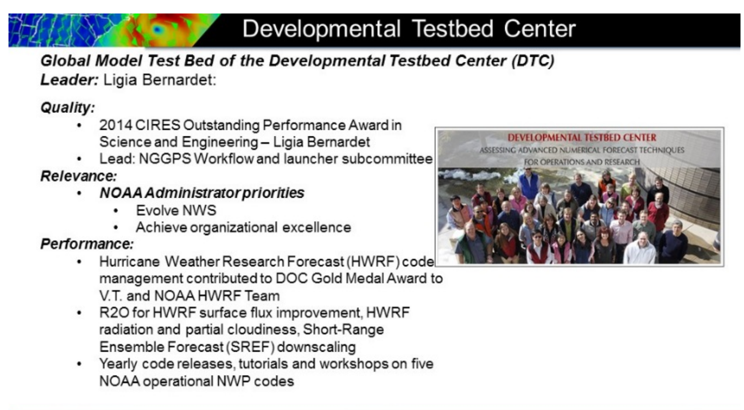

Hurricane Sandy Yesterday and Today
2012 – 30 km FIM
2015 – 10 km FIM
GSD Science Review
3-5 Nov 2015
5


NGGPS
Next Generation Global Prediction System (NGGPS)
• An R2O initiative to
• Implement a cloud-permitting, fully-coupled NWP system
• Through accelerated development and implementation of
• Current global weather prediction models and physics
• Improved data assimilation techniques, and
• Improved software architecture and system engineering
• Extend forecast skill at two weeks and beyond
• Improve high-impact weather forecasts including hurricane track and intensity
• Built upon HIWPP successes
• Why GSD? This is in our wheel house
GSD Science Review
3-5 Nov 2015
6


GSD's NWP Core Strengths
Better Models for Better Forecasts
Data Assimilation
High Performance Computing
Physics
Ensembles & Post Processing
Data Infrastructure
Visualization
Coupled Models
Assessments
Testbeds
Applications
OSE/OSSE
Dynamical Core
Hydrostatic & Non-Hydrostatic
• Next generation global modeling: GSD is at the forefront of model development & transitions
• Our research supports the enterprise and helps NOAA better use infrastructure and more efficiently use our Nations resources
• Session 3: A glimpse into three fascinating worlds… key aspects of these challenges
GSD Science Review
3-5 Nov 2015
7


New Paths Forward: Cross-Cutting Themes
GSD Modeling Enterprise
Developmental Testbed Center
Global Observing Systems Analysis
Renewable Energy
GSD Science Review
3-5 Nov 2015
8


New Paths Forward: Current Research
• Developmental Testbed Center
– Community Support, Community Tools
– GSD partners with NCAR to support NOAA numerical weather prediction
– Global Model Test Bed recently established to support NGGPS
– GC1: Continuous global, storm-scale (≤3km) ensemble data assimilation and ensemble forecasting for global situational awareness
– GC2: A fully coupled earth system modeling prediction capability
• Better use of current observations and plan for future observations
– Global Observing Systems Analysis (GOSA) Group
– GC5: Provide the Nation the ability to efficiently determine the best environmental observing systems it needs to improve earth system predictions
• Using forecasts to help produce and use energy more efficiently
– GSD-led Renewable Energy Program
– GC4: Provide the most accurate environmental information, including uncertainty and probabilities, to the right people at the right time and in the right form for optimal understanding and decision-making
GSD Science Review
3-5 Nov 2015
9


Developmental Testbed Center
Global Model Test Bed of the Developmental Testbed Center (DTC)
Leader: Ligia Bernardet:
Quality:
• 2014 CIRES Outstanding Performance Award in Science and Engineering – Ligia Bernardet
• Lead: NGGPS Workflow and launcher subcommittee
Relevance:
• NOAA Administrator priorities
• Evolve NWS
• Achieve organizational excellence
Performance:
• Hurricane Weather Research Forecast (HWRF) code management contributed to DOC Gold Medal Award to V.T. and NOAA HWRF Team
• R2O for HWRF surface flux improvement, HWRF radiation and partial cloudiness, Short-Range Ensemble Forecast (SREF) downscaling
• Yearly code releases, tutorials and workshops on five NOAA operational NWP codes
DEVELOPMENTAL TESTBED CENTER
ASSESSING ADVANCED NUMERICAL FORECAST TECHNIQUES FOR OPERATIONS AND RESEARCH
GSD Science Review
3-5 Nov 2015
10

Global Observing Systems Analysis

Global Observing Systems Analysis (GOSA) Group
Chief: *Lidia Cucurull*

Quality:
Cucurull
- AMS Fellow
- 2011 NOAA David Johnson Award
- NOAA COSMIC-2 Program Scientist
- Chair, Expert Team on New Remote-Sensing Technologies of WMO
- NOAA OAR Technical Liaison for the JCSDA
- Quantitative Observing System Assessment Program (QOSAP) OAR Representative

Relevance: NOAA Priorities
- Evolve the NWS, invest in observational infrastructure, Achieve organizational excellence

Performance:
- MOU with NESDIS/NWS to lead R&D and R2O for Radio Occultation technology
- Global OSE/OSSEs for NOAA UAS Program and Radio Occultation observations
- GPS-Met

Team:
Jason English
Tanya Peevey
Hongli Wang
Kirk Holub
Andrew Kren
Ruifang Li
Guoqing Ge

GSD Science Review 3-5 Nov 2015 11

Renewable Energy Program

Renewable Energy Program
Program Manager: Melinda Marquis
Quality:
- **Utility Variable-Generation Integration Group Annual Achievement Award**
  - **2014 –** Melinda Marquis for leadership at NOAA for wind energy forecasting
  - **2015 –** Group award for WFIP-1
- **2015 Department of Commerce Gold Medal** "For the success of HRRR, the first storm-scale model to give forecasters and decision-makers fast, local weather guidance"
- **2015 Colorado Governor's Award for High Impact Research:** Sustainability

Relevance: NOAA Priorities
- NOAA Next Generation Strategic Plan (NGSP) – "Production gains in renewable energy through better information"
- Support NGSP goal about climate adaptation and mitigation
- Evolve the weather service

Performance
- Improved wind forecast skill at turbine height
- Leveraged RAP and HRRR (developed for aviation and severe weath
- SFIP results transitioned to NCEP early 2016 HRRR and RAP
- WFIP-1 improvements were transitioned to NCEP Feb 2014
- WFIP-2 (Oct 2015-March 2017)

GSD Science Review 3-5 Nov 2015 12

Session Presentations & Posters

Ligia Bernardet
- *Developmental Testbed Center (including Global Model Test Bed)*

Lidia Cucurull
- *Global Observing Systems Analysis (GOSA) Group*

Jason English
- *GOSA project: Improving Winter Storm Forecasts with Dropsonde Data*

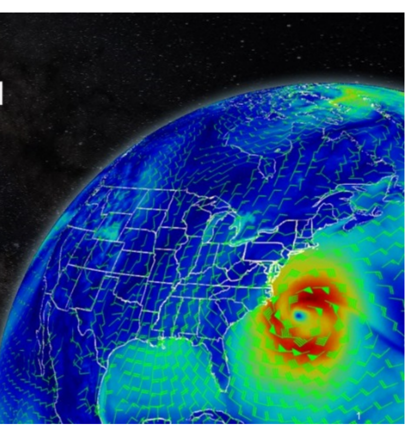
Melinda Marquis
- *NOAA Renewable Energy Program*

GSD Science Review 3-5 Nov 2015 13

The Developmental Testbed Center (DTC)

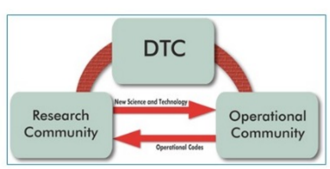
Ligia Bernardet
CIRES
Performing work for NOAA/ESRL/GSD

GSD Science Review
3-5 Nov 2015



Bridging Research and Operations

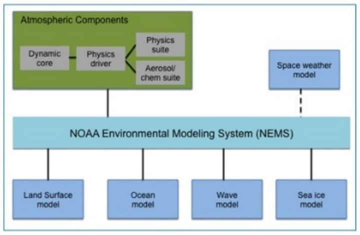
DTC improves operational models by transitioning innovations from the research community



By supporting operational codes to the community, development can be implemented and tested directly in the operational model, which reduces transition costs

3-5 Nov 2015 GSD Science Review 2

Global Model Test Bed



A new effort within DTC toward increased transfer of research to operations for NOAA's next generation global prediction system

GMTB builds on the experiences of the DTC and High-Impact Weather Prediction Project to evaluate models for operations

Initial focus is on community involvement in the development of atmospheric physics

3-5 Nov 2015 GSD Science Review 3

Summary

- DTC connects operational models and the research community outside of NOAA
- DTC is a collaboration between GSD and the National Center for Atmospheric Research and has staff at both institutions

Come see the poster!

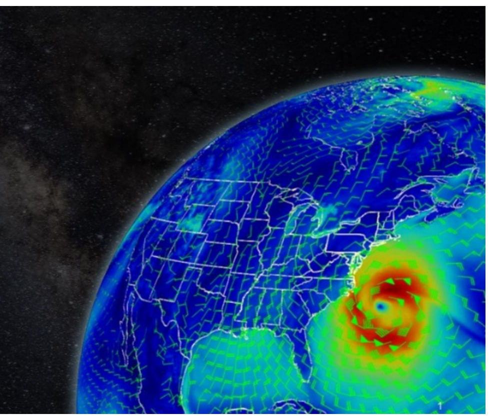
- Evaluation of innovations in clouds and radiation for two operational models
- Details on the Global Test Bed

3-5 Nov 2015 GSD Science Review 4

Global Observing Systems Analysis

Lidia Cucurull
NOAA/ESRL/GSD

GSD Science Review
3-5 Nov 2015



Observing System (Simulation) Experiments

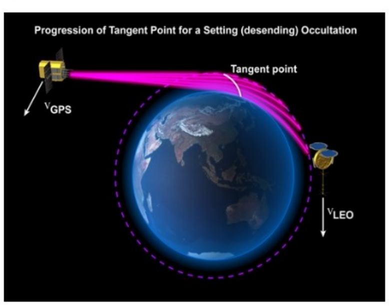
- Necessary to quantitatively evaluate benefits of current and new obs in weather forecasting
- Helps NOAA management prioritize mission designs in a cost-effective way
- Saves taxpayer and NOAA $$

3-5 Nov 2015 GSD Science Review 2

Radio Occultation (RO)

One of the top contributors to improve global weather forecast skill

- Provides very accurate weather observations under all-weather conditions
- Improve the use of current obs in operational weather models
- Evaluate the impact of future constellations

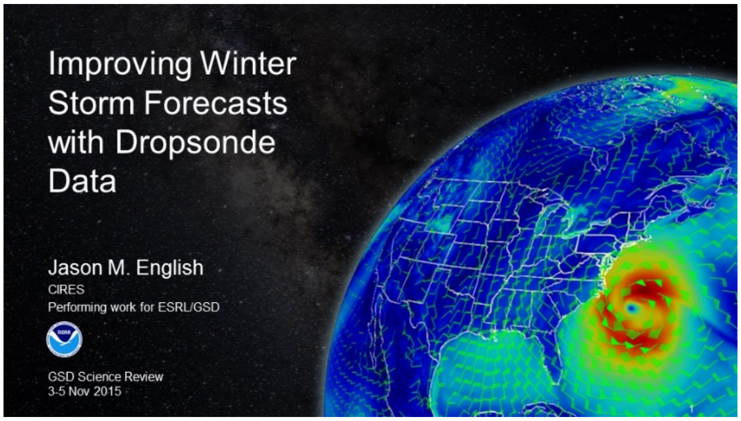


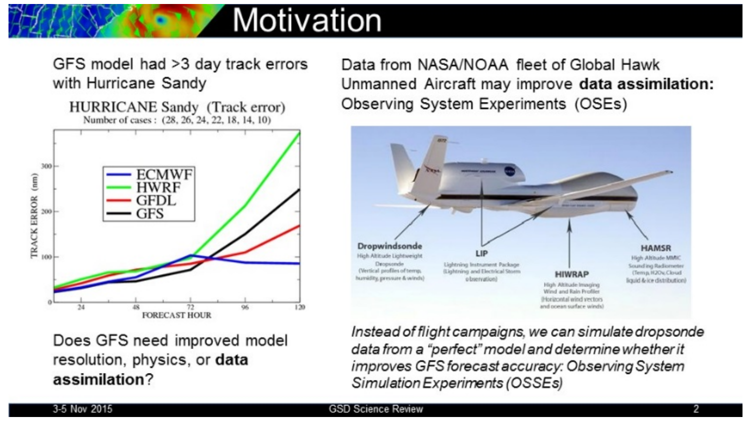
3-5 Nov 2015 GSD Science Review 3

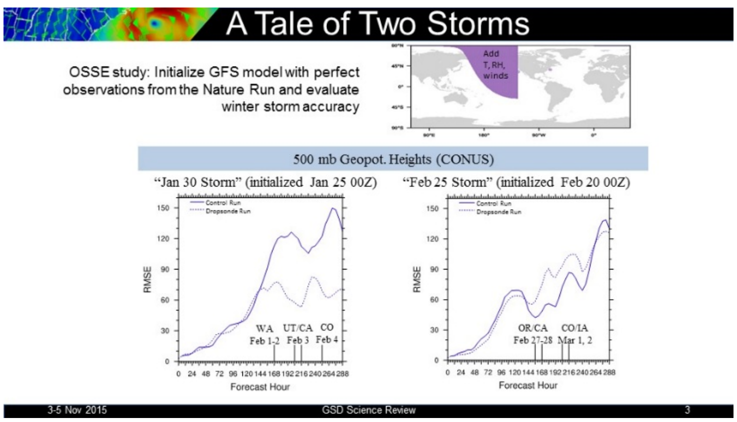
Summary

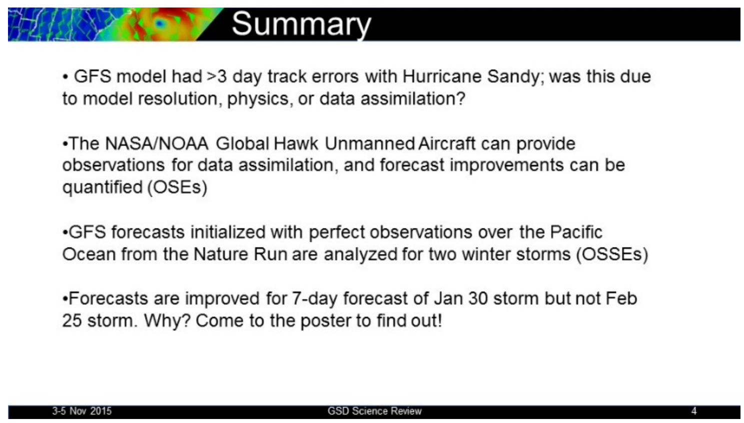
- Increasing demand for tradeoff studies
- Need to quickly and efficiently assess the value and capabilities of existing and proposed observing systems
- Strengthen collaboration with AOML, NWS/EMC, JCSDA, NESDIS, UCAR, and the private sector
- More details at my poster
- Poster BONUS: GSD's Global Positioning System (GPS) precipitable water network!

3-5 Nov 2015 GSD Science Review 4

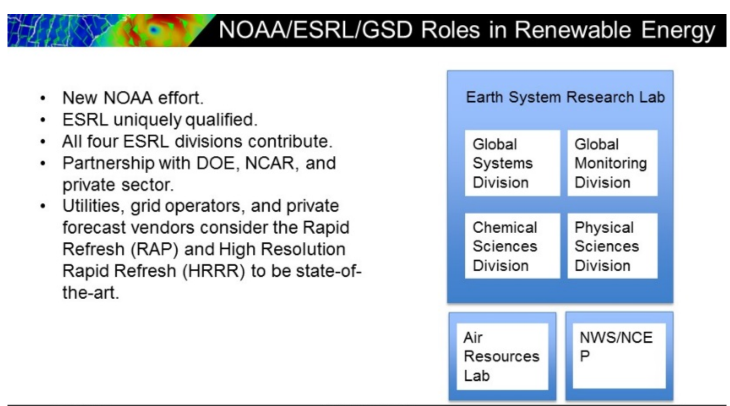

Improving Winter Storm Forecasts with Dropsonde Data
Jason M. English
CIRES
Performing work for ESRL/GSD
GSD Science Review
3-5 Nov 2015


Motivation
GFS model had >3 day track errors with Hurricane Sandy
HURRICANE Sandy (Track error)
Number of cases : (28, 26, 24, 22, 18, 14, 10)
ECMWF
HWRF
GFDL
GFS
TRACK ERROR (nm)
FORECAST HOUR
Does GFS need improved model resolution, physics, or data assimilation?
Data from NASA/NOAA fleet of Global Hawk Unmanned Aircraft may improve data assimilation: Observing System Experiments (OSEs)
Dropwindsonde
LIP
HIWRAP
HAMSR
Instead of flight campaigns, we can simulate dropsonde data from a "perfect" model and determine whether it improves GFS forecast accuracy: Observing System Simulation Experiments (OSSEs)
3-5 Nov 2015
GSD Science Review
2


A Tale of Two Storms
OSSE study: Initialize GFS model with perfect observations from the Nature Run and evaluate winter storm accuracy
Add T, RH, winds
500 mb Geopot. Heights (CONUS)
"Jan 30 Storm" (initialized Jan 25 00Z)
"Feb 25 Storm" (initialized Feb 20 00Z)
Control Run
Dropsonde Run
RMSE
WA Feb 1-2
UT/CA Feb 3
CO Feb 4
OR/CA Feb 27-28
CO/IA Mar 1, 2
Forecast Hour
3-5 Nov 2015
GSD Science Review
3


Summary
• GFS model had >3 day track errors with Hurricane Sandy; was this due to model resolution, physics, or data assimilation?
•The NASA/NOAA Global Hawk Unmanned Aircraft can provide observations for data assimilation, and forecast improvements can be quantified (OSEs)
•GFS forecasts initialized with perfect observations over the Pacific Ocean from the Nature Run are analyzed for two winter storms (OSSEs)
•Forecasts are improved for 7-day forecast of Jan 30 storm but not Feb 25 storm. Why? Come to the poster to find out!
3-5 Nov 2015
GSD Science Review
4


Research for Weather-Dependent Renewable Energy
Melinda Marquis
NOAA/ESRL/GSD
GSD Science Review
3-5 Nov 2015


NOAA/ESRL/GSD Roles in Renewable Energy
• New NOAA effort.
• ESRL uniquely qualified.
• All four ESRL divisions contribute.
• Partnership with DOE, NCAR, and private sector.
• Utilities, grid operators, and private forecast vendors consider the Rapid Refresh (RAP) and High Resolution Rapid Refresh (HRRR) to be state-of-the-art.
Earth System Research Lab
Global Systems Division
Global Monitoring Division
Chemical Sciences Division
Physical Sciences Division
Air Resources Lab
NWS/NCEP
3-5 Nov 2015
GSD Science Review
2

Research Topics

- Physical processes that affect irradiance and turbine-height winds
- Model physics and data assimilation
- Optimal suite of sensors to support renewable energy
- Balance of power supply and demand
- Design optimized energy systems using high resolution weather data.

Photo courtesy of Iberdrola Renewables

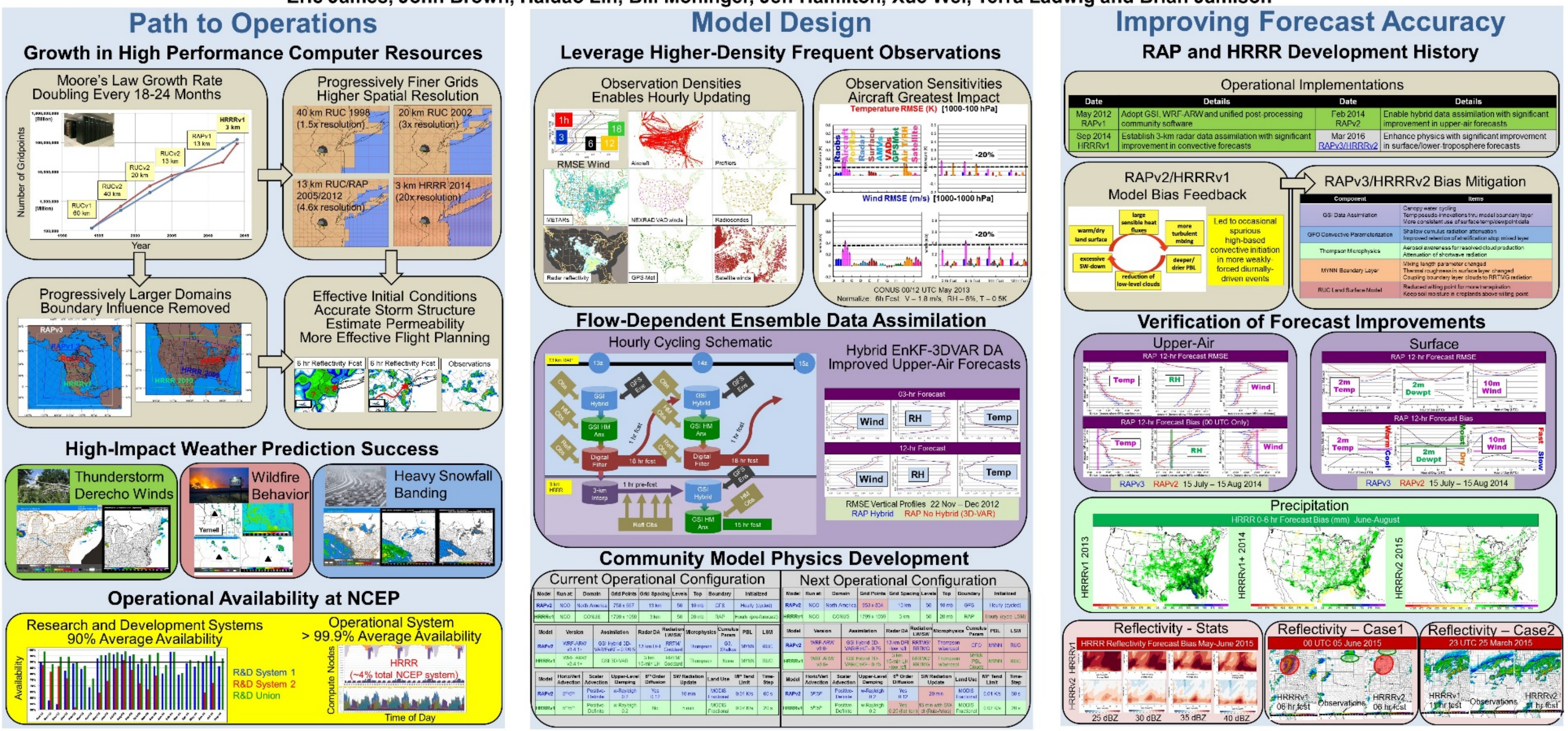
Projects

- Wind Forecast Improvement Projects
- Solar Forecast Improvement Project
- National Energy Weather System

Photo courtesy of Will von Dauster

High-Resolution Rapid Refresh: From Research to Operations

Curtis Alexander, Steve Weygandt, Stan Benjamin, David Dowell, Ming Hu, Tanya Smirnova, Joe Olson, Jaymes Kenyon, Georg Grell, Eric James, John Brown, Haidao Lin, Bill Moninger, Jeff Hamilton, Xue Wei, Terra Ladwig and Brian Jamison



Radar Data Assimilation for RAP and HRRR

David Dowell, Curtis Alexander, Stan Benjamin, John Brown, Ming Hu, Eric James, Terra Ladwig, Tanya Smirnova, Steve Weygandt

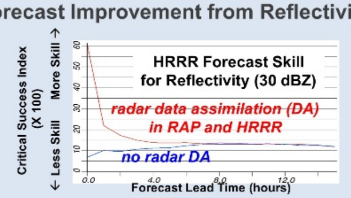
Current Use of Radar Data

Motivation

Accurate convective forecasts needed for severe weather forecasting and aircraft routing

Opportunity provided by national radar network (WSR-88D) and quality-controlled reflectivity composite from Multi-Radar Multi-Sensor (MRMS) system

Forecast Improvement from Reflectivity Assimilation



no radar DA | observed reflectivity | *radar DA in RAP and HRRR*

HRRR forecast improved by both coarser RAP reflectivity assimilation and finer HRRR reflectivity assimilation

A Closer Look

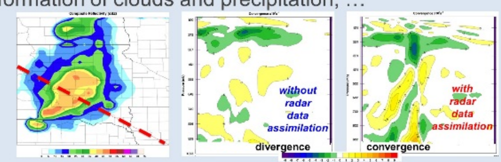
Reflectivity Assimilation Method

Temperature tendency from precipitation microphysics scheme replaced by reflectivity-based heating during WRF model integration

$$LH(i,j,k) = \left(\frac{1000}{p}\right)^{R_d/c_p} \frac{(L_v + L_f)(f[Z_e])}{t * c_p}$$

LH = latent heating rate
f[Ze] = reflectivity factor converted to rain/snow
t = time period of condensate formation (300 s)

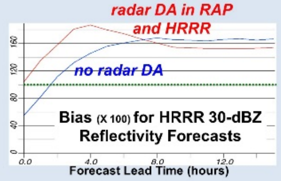
Model response to heating: development of updrafts, formation of clouds and precipitation, …

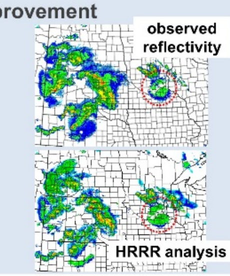


Combined Use of Radar, Satellite, and Surface Data

Cloud and precipitating hydrometeors added (removed) in GSI where radar, satellite, and surface observations indicate hydrometeors (no hydrometeors)

Opportunities for Further improvement





Ensemble Data Assimilation

Why Ensembles?

Situation-dependent background-error covariances representative of convective systems, which are localized, non-geostrophic, and non-hydrostatic

Better radar-data quality control (Doppler-velocity unfolding, identification of non-hydrometeor reflectivity observations)

Applications

0-6 hour probabilistic predictions of clouds, storms, and other local phenomena (e.g., wind shifts)

Research and Development

Proof of concept demonstrated through collaboration with NOAA's Warn-on-Forecast project

reflectivity analysis and forecast at 2-minute intervals

27 April 2011
Southeast US Tornado Outbreak

HRRR ensemble radar-data assimilation development underway, real-time testing planned in 2016

Land-surface cycling for better hydrometeorology

Tatiana Smirnova, Eric James, Stan Benjamin, John Brown

GOAL: Accurate initial land surface state – important for both regional and global predictions

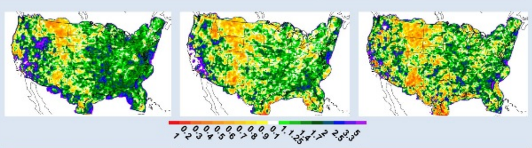
- Sufficient skill of physics parameterizations
- Use of observations to prevent from model drift
  - radar, satellite, surface observations, etc.
- Cycling of soil/snow fields
  - soil temperature/moisture adjustments in GSI
  - NESDIS snow/sea-ice analysis
- Coupling to sub-surface hydrology, water drainage, large-scale river routing

Precipitation verification in 13-km RAP and storm-scale HRRR;

- 1-h RAP minus Stage IV (precipitation total)

01 Jun – 31Aug 2013 | 01 Jun – 31 Aug 2014 | RAP/HRRR QPF bias

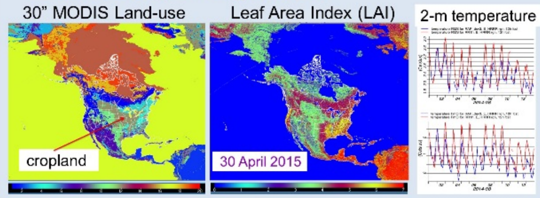
- Ratio 1-h HRRR QPF/QPE (Stage IV)



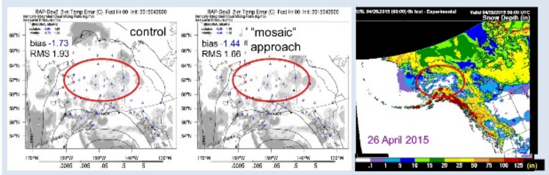
01 Jun – 31Aug 2013 | 01 Jun – 31 Aug 2014 | 01 Jun – 31 Aug 2015

Recent improvements to RUC LSM - WRF v3.7 and NASA Land Information System

- Simple treatment of cropland irrigation during the growing season

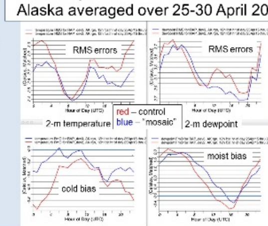


- Mosaic approach to snow-covered and snow-free portions of the grid cell;



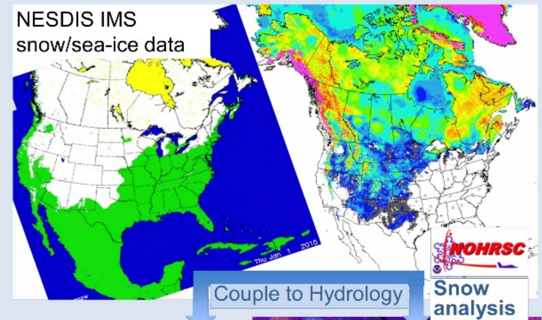
- ➢ Separate treatment of energy and moisture budgets for snow-covered and snow-free portions of the grid cell
- ➢ Aggregate solutions at the end of time step

Diurnal cycle of 12-h forecast errors for Alaska averaged over 25-30 April 2015



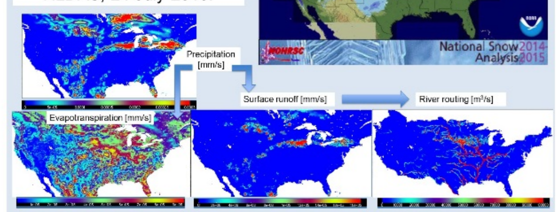
Cycled RAP snow water equivalent

1-10 January 2015



Add RUC LSM to LIS:

- 1-d testing is finished
- 2-d testing is underway NLDAS, 24 July 2010:



Collaborations:

WRF · LIS Framework Land Information System · NOHRSC · NWC National Water Center · WCRP

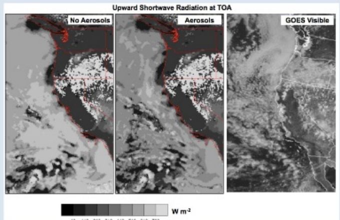
Renewable Energy Applications and Design for the RAP and HRRR

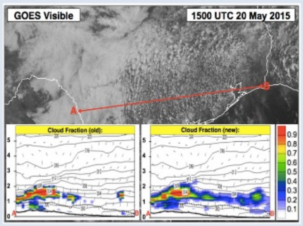
Joseph Olson, Jaymes Kenyon, John Brown, Stan Benjamin, Eric James, Terra Ladwig, Curtis Alexander, Tanya Smirnova

Improving Solar Forecasts

Aerosol-Aware Microphysics and Radiation

- Improved cloud cover over land and water
- Improved downward SW in clear-skies



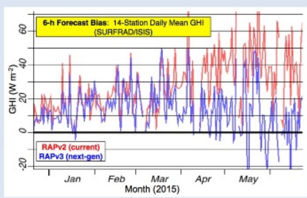


Improved Subgrid-Scale Clouds

- Addition of cloud probability distribution functions coupled to radiation scheme
- Improved shallow-cumulus scheme

Improved Downward Shortwave Radiation Forecasts:

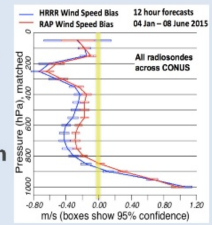
- Daily averaged GHI comparisons show large improvements in warm season due to better shallow-cumulus treatment.
- Improved treatment of stratus is necessary for remaining errors.



Improving Wind Forecasts

RAP/HRRR Wind Speed Bias

The current RAP/HRRR has a distinct high wind speed bias in the boundary layer. This bias is robust in all observational platforms.

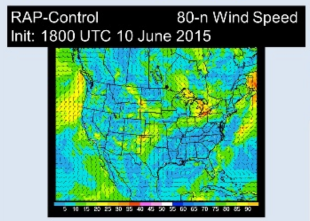


Reducing the High-Wind Speed Bias: Mixing Length (l_m) Revision

Important for controlling diffusivity:

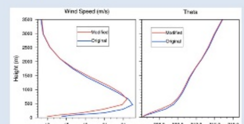
$$K_{H,M} = l_m S_{H,M} (2*TKE)^{1/2}$$

- Problems with mixing lengths
- Revised mixing lengths



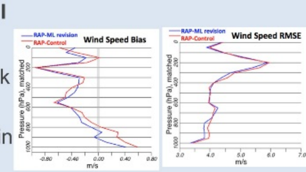
Example of Impact on Strong Low-Level Jet

Mean profiles over Kansas 06-08 UTC 11 June 2015.



Improved Forecast Skill

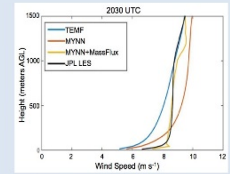
RAP forecasts validated against a variety of platforms during the week of the strong LLJ event (08-15 June 2015) show consistent improvement in wind speed forecast.



Current/Future Work

Improved Non-Local Mixing

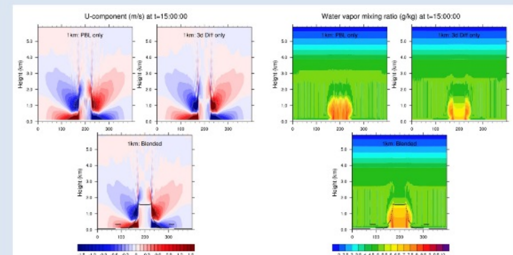
- Mass-flux scheme
- Momentum transport
- TKE transport
- Scale-aware adapting to grid spacing



Fully Scale-Aware Turbulence Scheme

- Blended diffusivity
- Transforms from 1D to 3D

$$K_{blended} = W K_{PBL} + (1 - W) K_{3d}$$



Summary

Substantial Improvements for Future RAP/HRRR

Major improvements to subgrid-scale clouds, inclusion of aerosols, and turbulent mixing.

Ongoing collaborations:

- Wind Forecast Improvement Project II (DOE & Vaisala)
- Solar Forecast Improvement Project (DOE, NCAR, IBM)
- ESRL Renewable Energy Team (GSD, CSD, PSD, GMD)

HRRR / RAP: Mitigating Aviation Hazards for Safety and Efficiency

Jaymes Kenyon, Joe Olson, Curtis Alexander, John Brown, Stan Benjamin, Tanya Smirnova, Steve Weygandt, Eric James, Ming Hu, Terra Ladwig, David Dowell, Georg Grell, Isidora Jankov, Steven Peckham, and Bill Moninger

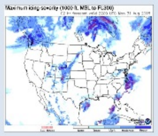
Providing Hazard Guidance for Routing and Traffic-Management Decisions

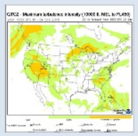
Frequently cycled models are adept at leveraging available observations to “keep up” with rapidly evolving weather within U.S. airspace.

Acknowledgment: FAA Aviation Weather Research Program, NOAA

Icing and Turbulence

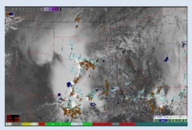
- RAP drives hourly-updated operational icing turbulence algorithms at AWC





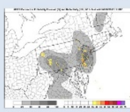
CoSPA

- Blends short-term extrapolation with longer-term HRRR dynamical guidance



HCPF & Gate Forecasts

- Time-lagged HRRR ensemble decision tools



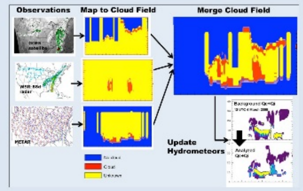
CCFPG

- Incorporates HRRR guidance to facilitate strategic decision making by FAA, industry

Towards Improved Ceiling, Visibility, and Icing Guidance

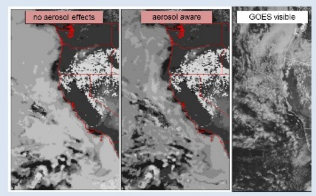
The GSD Hydrometeor Analysis

- Leverages METAR, radar, and satellite observations for better initial-state cloud field in RAP & HRRR



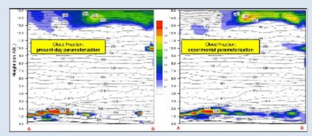
Aerosol-Aware Microphysics

- Accounts for essential role of aerosols in double-moment representation of ice, liquid clouds



Subgrid-Scale Cloud Parameterizations

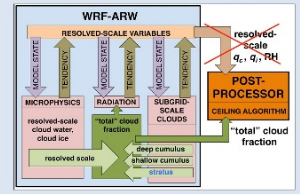
- Represent clouds of limited vertical and/or horizontal extent, not depicted by microphysics scheme

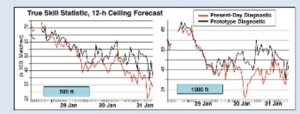


Future Directions

Improved Postprocessing Algorithms

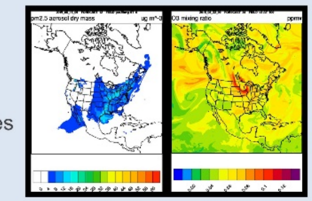
- Utilize both resolved-scale and subgrid-scale information for more accurate diagnostics



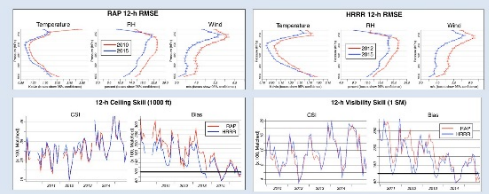


Model In-Line Chemistry

- Explicitly predict concentrations of operationally important particulates and trace gases



HRRR / RAP Aviation Skill Metrics



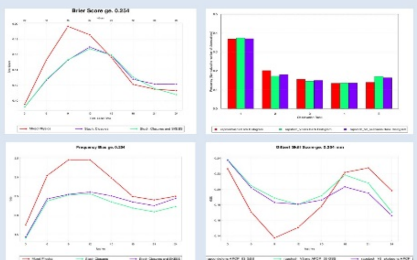
Probabilistic Forecasts at Regional Scales

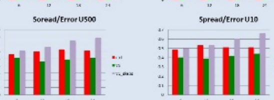
Isidora Jankov, Curtis Alexander, Jeff Beck, Trevor Alcott, Hongli Jiang, Scott Gregory, Joseph Olson, Jaymes Kenyon, Tatiana Smirnova, Georg Grell, John Brown and Stan Benjamin

North American Rapid Refresh Ensemble (NARRE)

- NARRE is planned for implementation into operations in 2017
- Collaborative work between GSD and EMC
  - 13km horizontal grid spacing
  - RAP members include variations in
  - PBL, sfc. layer, and convective treatment
  - IC/LBCs
  - NMMB members differ only in IC/LBCs

Testing of use of Stochastic Physics approach *



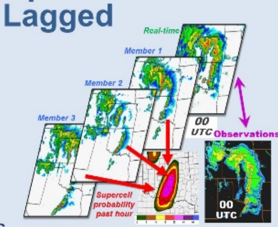


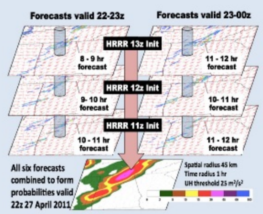
Comparable performance between stochastically perturbed parameterization ensemble and mixed-physics ensemble

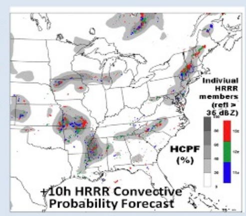
High Resolution Rapid Refresh Ensemble – Time Lagged

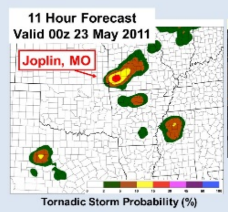
Time-Lagged Design

- 3km, 18 hour forecasts
- CONUS scales
- Rapid Refresh
- Time-lagged
- Spatial and temporal filters





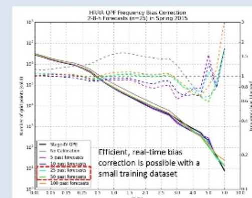


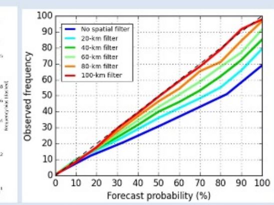


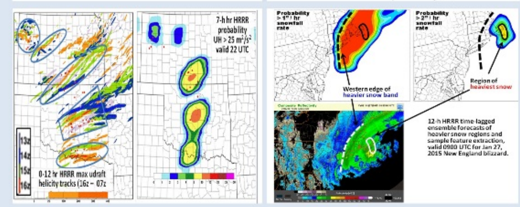
Next generation ensemble will consist of multiple ensemble members with stochastically perturbed physics parameterizations.

Probabilistic Hazard Prediction Tool

- The tool will facilitate process of issuing watches and warnings
- The product is planned for operation implementation in 2018
- The tool will be addressing wide spectra of hazards:
  - Intense rainfall
  - Heavy snowfall
  - Severe weather
  - Aviation hazards

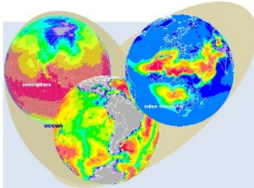






The FIM global model for medium-range forecast applications

Stan Benjamin, Shan Sun, Rainer Bleck, Haiqin Li, Georg Grell, Jian-Wen Bao, and John Brown

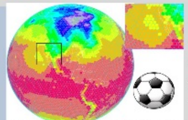


Development of Earth System Models for All Time-Scales

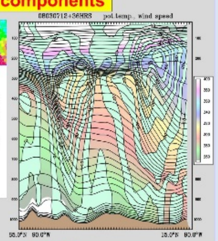
- Atmos-ocean-chem-bio
- NWP to seasonal to nowcasting
- Cloud/precipitation/AQ

FIM earth system model components

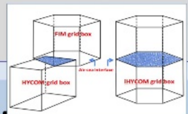
Atmosphere
The Flow-following finite-volume Icosahedral Model – FIM



Potential temperature at FIM lowest atmospheric level - 240km resolution – N.Hem. winter case



http//:fim.noaa.gov



Ocean
IHYCOM – *icosahedral* ocean model
US Navy/NOAA community Hybrid Community Ocean Model (HYCOM)
•Hybrid quasi-Lagrangian vertical coordinate (isopycnal/sigma), adaptive similar to FIM atmos.

Chemistry
FIM-chem options

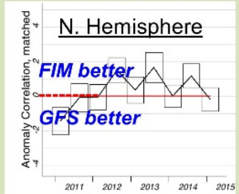
- Aerosol and simple sulfur chemistry modules from the Global Chemistry Aerosol Radiation and Transport (GOCART) model

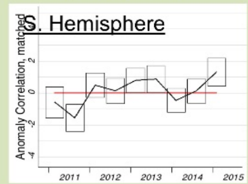
	Init conds	Resolution	Horiz.	Vertical coord	Physics
GFS	GFS	T574 to 8d, T382 to 16d (Next version to T1534)	Spectral	Sigma-pressure hybrid	GFS suite
FIM	GFS	60km/30km/15km/10km	Icosahedral grid point	Isentropic-sigma hybrid	GFS suite, 2011 version, 2015 (T1534 version) - Chem option, ocean/HyCOM option - Grell-Freitas cu option for seasonal, chem, NWP testing)

Results

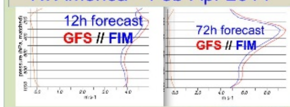
Numerical Weather Prediction

7-day 500 hPa height anomaly correlation

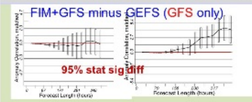


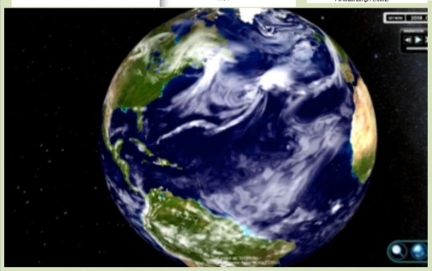


GFS // FIM - Wind RMS error
vs. rawinsondes -
N. America – Feb-Apr 2014



FIM+GFS vs. GEFS
500 hPa AC – out to 16-day fcsts
Effect of multi-model ensemble



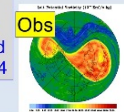


FIM global model – **10km,** 64 levels
Cloud - 10-day forecast init 00z 21 Mar 2014

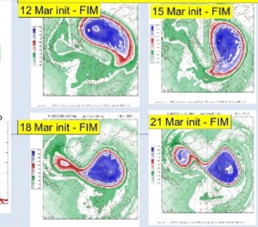
Tropical Cyclone Prediction Results

Advantages of Isentropic Coordinates

Stratospheric vortex breakdown
PV on 600K sfc valid 00 UTC 28 Mar 2014



FIM fcsts valid 00 UTC 28 Mar 2014

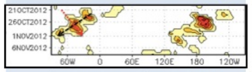


Current NWP activities and near future:

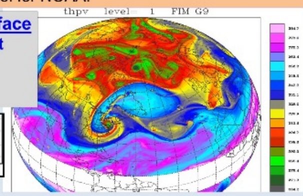
Next coupled model/seasonal directions:

Key aspects of FIM atm/ocean/chem model:
- Quasi-uniform horizontal unstructured grid – icosahedral, like NIM
- Quasi-lagrangian vertical structure
- Skill slightly exceeding that of GFS, benchmark for NGGPS skill
- Contributes to NOAA coupled model capability including component interoperability with CFS/NCEP and GFDL.
- Candidate for multi-model global ensemble.
- Likely use within subseasonal NMME ensemble
- Earth system research tool for NOAA.

Potential temp on PV=2 surface
15km FIM model - 72h forecast
Valid 12z 30 Oct 2012
12h after landfall of Hurricane/Superstorm Sandy



Obs blocking – Oct-Nov 2012



Outlook for FIM

Earth-System modeling: The impact of composition and chemistry on weather forecasting

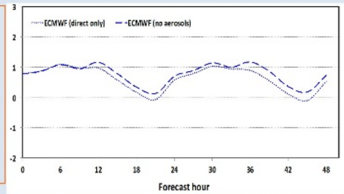
Georg Grell, Steven Peckham, Pallavi Marrapu, Li Zhang, Stuart McKeen

Principal goal of ECMWF for forthcoming decade: physical and chemical weather - One of the four aims:

"We will deliver operationally global analysis and forecasts of atmospheric composition."

Prof. Alan Thorpe, ECMWF Director-General, 2012

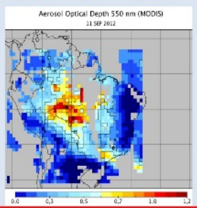
Surface Temperature biases from ECMWF modeling system, when aerosol impacts are included over Brazil during biomass burning season, September 2012, average over 10 day period



Working Group for Numerical Experimentation (WGNE) exercise: Impacts of aerosols on weather prediction

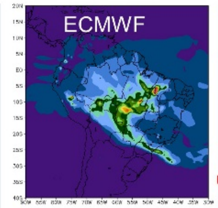
Case 3- Persistent Smoke in Brazil - SEP 2012

Forecast experiments:
- September 5-15, 2012
- Twice daily, 00 UTC and 12 UTC
- 10 day forecasts for global models
- 3 day forecasts for regional (WRF-Chem) model
- Input and boundary conditions from ECMWF
- Chemistry from MACC

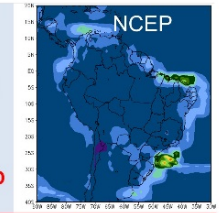


Using WRF-chem chemistry and physics suites:

- Estimated 2000 users world wide, community effort lead by ESRL, Original WRF-Chem paper (2005) cited 500 times
- **Outreach**: we teach national and international tutorials (last international ones in Nepal, Brazil, Malaysia, and Cabo Verde, funding from United Nations, World Meteorological Organization, or local Met services)



AOD during SAMBBA, Sep 10, 00UTC **Climatological aerosol provides a completely unrealistic AOD field.**



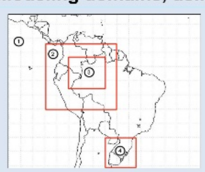
Aerosol impacts on NWP: can this be done with simple bulk aerosol modules?

Our Method: Use chemistry and aerosol packages with different levels of complexity to evaluate interaction of aerosols with radiation and microphysics, five experiments:

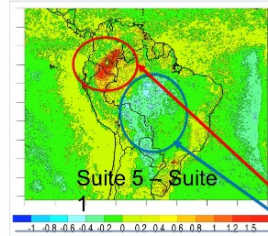
1. Only climatology for aerosols, no chemistry
2. A tracer transport package for decadal simulations of CO2, CH4, and SF6 (earth-analyzer experiments)
3. Very light package that uses GOCART modules only – ideal solution for NWP, only 17 additional variables
4. A medium package (similar to ECMWF), that includes gas-phase chemistry (around 80 additional variables)
5. A sophisticated package with even more complexity than what is used for air quality forecasting (150 additional variables)

The three chemistry suites [(3) – (5)] may later be included in any future NGGPS dynamic core

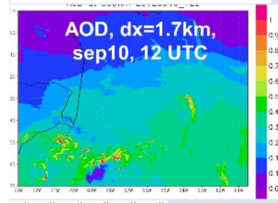
Modeling domains, using WRF-Chem and suites 1,3,4, and 5

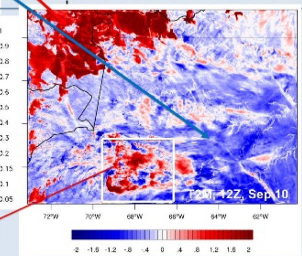


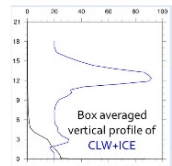
Domain	Resolution	Grid Size
1 (South America)	15km	590 * 420
2 (North Brazil)	5km	586 * 439
3 (North Brazil)	1.67km	847 * 595
4 (South Brazil)	5km	276 * 276



Near surface temperature differences (Temperature at 2m above surface) during mid-morning hours averaged *over twenty 12, 36, 60-hr forecasts*, using convection permitting simulations with a regional model and a sophisticated chemistry

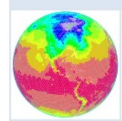


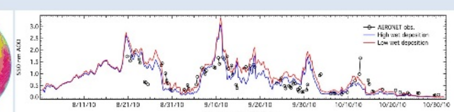




Using complex physics/chemistry, *significant differences* are found compared to meteorology only runs

FIM-Chem, Suite 3, comparison of AOD with Aeronet station near biomass burning sites



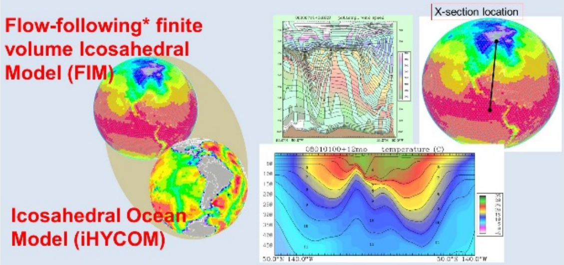


Coupled Atmospheric-Ocean Earth System Modeling for Subseasonal Forecasting

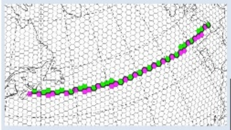
Shan Sun, Rainer Bleck, Haiqin Li, Stan Benjamin, Georg Grell and Ben Green

Introduction

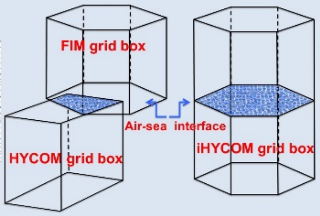
Unstructed Horizontal Grid **Adaptive Vertical Coordinate**



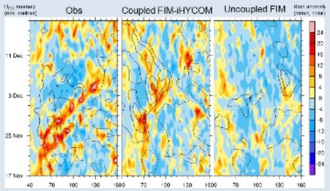
- A matched pair of numerical models for simulating the global atmospheric and oceanic circulation is under development at NOAA's Earth System Research Laboratory. Both models use an icosahedral horizontal grid and a hybrid-isentropic adaptive vertical coordinate.
- The atmospheric component FIM has already undergone extensive testing as a medium-range forecast model (http://fim.noaa.gov) [1,2] . Column physics in FIM is based on GFS & CFS.
- iHYCOM is an icosahedral-grid version of the ocean model HYCOM [3].
- Coupling strategy: Grid nesting is common in weather modeling, but grid discontinuities are usually kept away from the region of interest. To avoid joining disparate grids at the ocean-atmosphere interface, arguably the region of most interest in coupled modeling, the two models share the same horizontal grid.



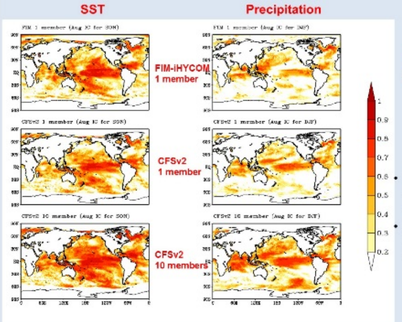
Sample transect for flux calculations on an icosahedral mesh.



No need for flux coupler



- Equatorial Hovmoller plots from 40E to 160E longitude
- Coupling with an ocean model yields much stronger anomalies in both precipitation and 850-mb zonal wind anomalies



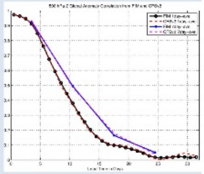
Anomaly correlation of 1 month lead prediction with Aug 1st Ics 1982-2010

- FIM-iHYCOM has comparable skills with CFSv2, when one member is used for evaluation
- CFSv2 10-member ensemble has high skills than 1-member of FIM-iHYCOM or CFSv2

NMME subseasonal forecast

➢ Multi-model ensembles improve the skill over that of each individual model;

➢ North American Multi-Model Ensemble (NMME) project by NOAA/CPC is aimed at improving forecast skill by blending predictions from different models and reducing uncertainties in the initial conditions as well as in the numerical models.



500 hPa geopotential height anomaly correlation from FIM and CFSv2, from 140 cases in January 1999-2009 . The 32-day forecasts are verified against CFSRR.

Summary

- Sub-seasonal predictability of extreme weather is of great interest to many sectors of the community. Finding potential sources of predictability is crucial on this time scale, including Madden Julian Oscillation (MJO), blocking, sudden stratospheric warming, etc.;
- The innovative FIM-iHYCOM uses unstructed horizontal grid and adaptive vertical grid;
- Preliminary evaluation of FIM-iHYCOM results suggests its monthly and seasonal predictions are credible;
- 16yr hindcast sub-seasonal experiments are under way with FIM-iHYCOM at 30km horizontal resolution (50% done);
- Given that both FIM and iHYCOM are very different from the current NMME models, they would add diversity to the NMME ensemble, and likely improve the overall skills;
- More model results are here: MJO[1], MJO[2], blocking.

References

[1] Lee, J.-L., and A. E. MacDonald, 2009: A finite-volume icosahedral shallow water model on local coordinate. *Mon. Wea. Rev.*, **137**, 1422-1437.
[2] Bleck, R. and 13 Coauthors, 2015: A vertically flow-following icosahedral grid model for medium-range and seasonal prediction. Part I: Model description. *Mon. Wea. Rev.*, **143**, 2386-2403.
[3] Bleck, R., 2002: An oceanic general circulation model framed in hybrid isopycnic-Cartesian coordinates. *Ocean Modelling*, **4**, 55-88.

Non-hydrostatic Icosahedral Model (NIM)

NIM team: Jin Lee, Man Zhang, Kayee Wong, Gerard Ketefian

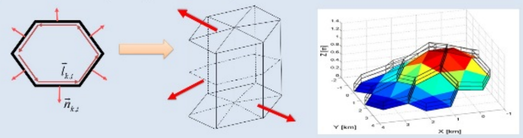
Introduction

The Earth System Research Laboratory (ESRL) is developing a new global 3-D finite-volume Non-hydrostatic Icosahedral Model, NIM, for ESRL Earth System Analyzer and weather and climate prediction. NIM is a multi-scale model can be used to improve tropical convective clouds and to extend weather forecasts into intra-seasonal predictions.

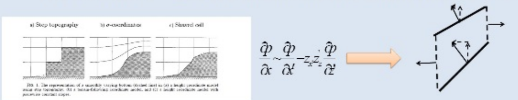
NIM model characteristics

NIM uses innovations in model formulations similar to those of FIM developed by ESRL. These innovations include:

- A finite-volume icosahedral shallow water model on local coordinate (Lee and MacDonald, MWR, 2009),
- A multistep flux-corrected transport scheme (Lee, Bleck and Macdonald, 2010 JCP),
- Efficient indirect addressing scheme on irregular grids (MacDonald, Middlecoff, Henderson, and Lee, 2010, IJHPC),
- Grid optimization for efficiency and accuracy (Ning and Lee, 2011, SIAM),
- Implementation of NIM Fine-grained parallel computing to run on CPU/GPU clusters.
- Use of the three-dimensional finite-volume for advection and pressure gradient force (PGF) over complex terrains



The Newton 3rd Law .vs. mathematical chain rule for PGF

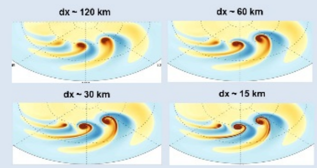


Idealized benchmarks

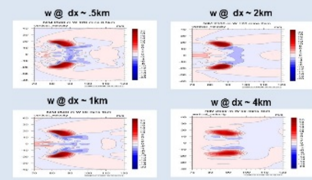
NIM has been tested with many idealized benchmarks as well as real data simulations. These idealized test cases include:

Warm bubble

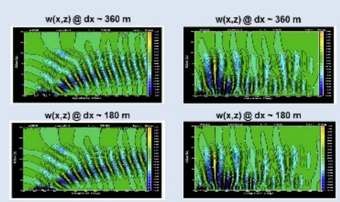
Baroclinic waves



Supercells

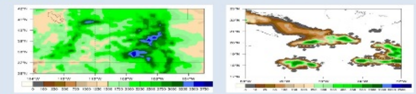


Mountain waves

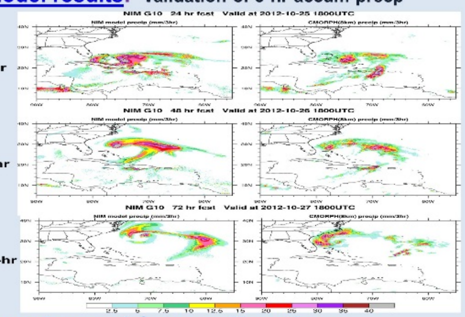


NIM 3-km hurricane Sandy (2012) simulation

- **Initial condition**: GSI/T1534 at 2012-10-24 1800 UTC
- **Topography**: GSI/T1534 surface geopotential height



- **Physics package**: GFS physics
- **Model results**: **Validation of 3-hr accum precp**



Remarks and future directions

- **A Nonhydrostatic Icosahedral Model (NIM) has been developed and tested with benchmarks and real data retro runs,**
- **Use of the three-dimensional control volume and the Newton 3rd Law to improve PGF over complex terrain,**
- **Incorporation of GFS physics into NIM modeling systems,**
- **Implement and test of Fine-grained parallel computing of NIM on CPU and GPU HPCs.**
- **NIM 3km simulation at 1% wall-clock time w/ O(100,000) cores,**
- **Extend research experience to help NGGPS development.**

High Performance Software Engineering: A Catalyst for NWP

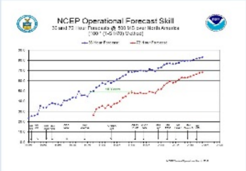
Tom Henderson, Mark Govett, Jacques Middlecoff, James Rosinski, Paul Madden, Chris Harrop, Craig Tierney

Software Techniques

Purpose

Enable research NWP models to run on operational schedules on the world's largest supercomputers

- **Improvements in Numerical Weather Prediction skill well correlated with improvements in computational power since 1956**
- **NOAA research must use all available resources to remain competitive**
  - 3km NGGPS forecast tests consumed half of "theia"!
- **CPU clock speeds have stalled**
  - Use traditional and emerging architectures to increase computing power
    - CPU, millions of cores
    - Graphics Processing Units
    - Many Integrated Core
  - Single source code required to avoid slowing NWP development
    - Solution: Directives



Target Architecture	Directive-Based Programming Model
CPU, MIC	Scalable Modeling System, OpenMP, Vendor Vectorization
GPU	OpenACC, F2C-ACC

- **Different directives must play well together**
  - Scalable Modeling System
    - Developed at GSD
  - OpenMP
  - OpenACC

```
!SMS$PARALLEL (ipn) BEGIN
!$OMP PARALLEL DO
do i=1,nip
!$ACC loop gang(16), vector(32)
  do k=1,nz
    x(k,i) = z(k,i) + y(k,i)
  end do
!$ACC end loop
end do
!$OMP END PARALLEL DO
!SMS$ PARALLEL END
```

Why is Software Engineering So Important?

- **NWP models require advanced software techniques to run efficiently on modern supercomputers**
- **Scientific Method depends upon strong software automation and processes**
  - Experimental "apparatus" must be controlled or experiments cannot be repeated!
  - *Software is the apparatus* for NWP
  - Use software engineering "best practices" to control our apparatus

Techniques: WSM6 Microphysics

Purpose

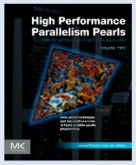
Use directive-based techniques to improve performance of popular microphysics package

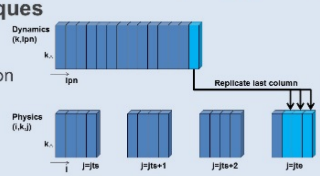
- **Strong Collaborations**
  - NCEP: John Michalakes
  - Intel: Hardware and compiler engineers
- **Improvements benefit all architectures**
  - CPU: Intel & AMD
  - MIC: Intel
  - GPU: NVIDIA

```
real :: y(ims:ime,kms:kme)
real :: x(kms:kme)
do k=kts,kte
  do i=its,ite
```

```
real :: y(1:8,1:32)
real :: x(1:32)
do k=1,32
  do i=1,8
```

- **Apply Proven Techniques**
  - Loop "chunking"
  - Compile-time constants
  - Threading & Vectorization





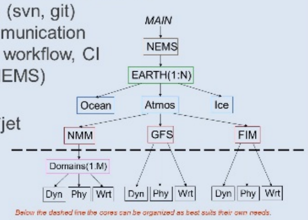
Device	Threads	Baseline Time	Time With Constants
MIC	240	12.5	8.7
CPU	48	4.4	3.4

Software Automation and Processes

Purpose

Reduce risk and increase pace of NWP software development

- **Use Best Practices**
  - Separate "science" and software engineering
  - Use software repositories (svn, git)
  - Formalize developer communication
  - Automate build, run, test, workflow, CI
  - Prepare for operations (NEMS)
- **Target All Resources**
  - NOAA Research: theia, *jet
  - ORNL: Titan (GPU)
  - TACC: Stampede (MIC)
- **Collaborate**
  - NCEP, SWPC, NASA

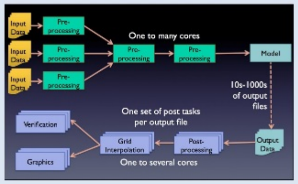


Automation: Rocoto

Purpose

Support deadline-driven NWP workflows involving tens of thousands of jobs on modern HPC systems

- **NWP workflows are extremely complex**
  - Many types of dependencies: [FIM9=2000, x10 if ensemble]
  - Many failure modes
  - Many recovery modes
- **Rocoto solutions**
  - Serverless
  - Flexible dependencies
  - Automatic fault tolerance
- **DDTS Users**
  - NOAA
    - NWS NCEP
    - GSD
  - NCAR
    - DTC



Physics for Global Non-Hydrostatic Applications

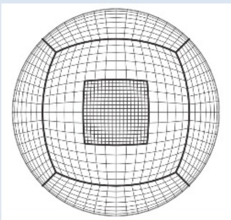
John M. Brown, Georg Grell, Tanya Smirnova, Joe Olson, Stan Benjamin, Jaymes Kenyon, Ligia Bernardet

Next Generation Global Prediction System (NGGPS)

Challenge: Physics schemes, particularly that for deep convection, must work well at a range of resolutions for which the hydrostatic approximation is valid down to where realistic deep convection can be forecast explicitly, i.e., horizontal cell spacings ranging from ~ 3-20km.

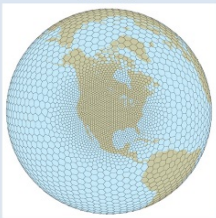
Semifinalists in NGGPS "competition"

FV3



Finite Volume dynamical core discretized on a cubedsphere grid (GFDL)

MPAS



Model for Prediction Across Scales (NCAR)

Envisioned physics development process

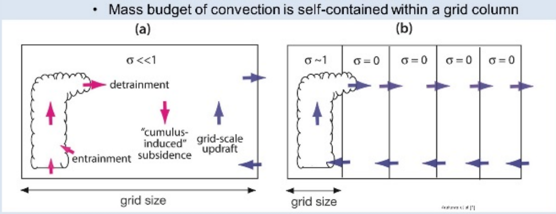
- Will concentrate on improvement / development of a few physics suites. Possibilities:
- Global Model Test Bed (DTC contribution)
- Will require extensive objective and subjective verification
- Viable data assimilation system will be required in advanced stages of testing
- Parallel real-time cycles and extensive retrospective testing will require large computational resources (far beyond what is currently available through the NESCC (NOAA Environmental Security Computing Center)

What does it mean to be "scale-aware"

Critical for "deep" (cumulonimbus) convection at planned NGGPS horizontal resolutions

Current mass-flux parameterizations assume [(a) below]

- Updrafts occupy small fractional area (σ) of grid cell
- Mass budget of convection is self-contained within a grid column

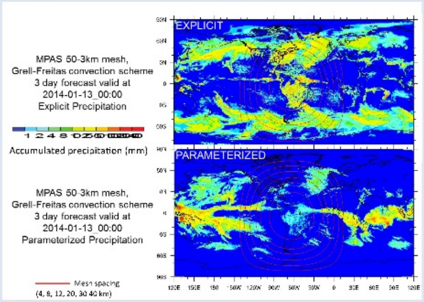


When grid cell sizes approach size of clouds, these assumptions break down (b)

Grell-Freitas (GF) parameterization relaxes both these assumptions by

- Reducing parameterized vertical fluxes by $(1 - \sigma)^2$
- Increasing updraft entrainment for small grid sizes
- Allowing "cumulus-induced" subsidence to occur in adjacent grid cells

Model Prediction for All Scales (MPAS) results: Global test at **50km with 3km zone** over South America runs using **Grell-Freitas convective parameterization**



RAP / HRRR physics suite

Processes intensively worked on over past several years by GSD

Land-surface – Smirnova
Surface layer
Boundary layer
Shallow boundary-layer-driven clouds (fair-weather cumulus, marine and post-frontal stratocumulus, etc.) } Olson, Kenyon, Grell, others
Deep convection – Grell, Freitas
Microphysics – Thompson (NCAR)
Coupling between schemes – all

Work is continuing on all these, with particular emphasis on how they contribute to the formation and dissipation of clouds.

Current components of RAP / HRRR physics suite

RRTMG long and short-wave radiation
Includes climatological aerosol, trace gases, clouds
RUC land-surface model (Smirnova et al [4])
Includes snow, snow on sea and lake ice
MYNNO Surface-layer, boundary-layer and boundary-layer clouds; includes forecast of fractional coverage by low-level clouds [2]
Grell-Freitas [3] scale-aware deep convection
Thompson-Eidhammer [5] aerosol-aware microphysics
Includes
- cloud water (2-moment)
- rain (2-moment)
- cloud ice (2-moment)
- snow
- graupel

References

1. Arakawa, A., J.-H. Jung, and C.-M. Wu, 2011: Toward unification of the multiscale modeling of the atmosphere *Atmos. Chem. Physics*, **11**, 3731-3742.
2. Benjamin, S. G., S. S. Weygandt, M. Hu, C. Alexander, T. G. Smirnova, J. B. Olson, J. M. Brown, E. James, D. C. Dowell, G. A. Grell, H. Lin, S. E. Peckham, T. L. Smith, and W. R. Moninger, 2015: A North American hourly assimilation and model forecast cycle: the Rapid Refresh. *Mon. Wea. Rev.*, accepted pending revision.
3. Grell, G. A., and S. R. Freitas, 2014: A scale and aerosol aware stochastic convective parameterization for weather and air quality modeling. *Atmos. Chem. Phys.*, 14, 5233-5250.
4. Smirnova, T., J. M. Brown, S. G. Benjamin, and J. Kenyon, 2015: Modifications to the Rapid Update Cycle Land-surface model (RUC-LSM) available in the Weather Research and Forecast (WRF) model. *Mon. Wea. Rev.*, accepted pending revision.
5. Thompson, G., and T. Eidhammer, 2014: A Study of aerosol Impacts on clouds and precipitation development in a large winter cyclone. *J. Atmos. Sci.*, 71, 3636-3658.

The Developmental Testbed Center

Ligia Bernardet, Kevin Kelleher, Stan Benjamin, Bill Kuo*, Louisa Nance* (* National Center for Atmospheric Research - NCAR)

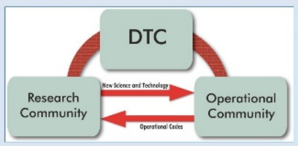
What is the DTC?

Purpose

Facilitate the interaction and transition of numerical weather prediction (NWP) technology between research and operations

- **O2R**: Support operational NWP systems to the community
- **R2O**: With developers, get innovations tested, incorporated into central code, and available for operational implementation
- **Interaction between R & O**: workshops, visitor program

DTC staff at GSD and at NCAR work together to address common objectives



Activities with operational NWP codes

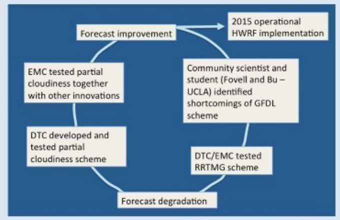
Data assimilation	• Gridpoint Statistical Interpolation (GSI) • Ensemble Kalman Filter (EnKF) • Regional ensemble data assimilation toward the N American Rapid Refresh Ensemble
Tropical Cyclone atmos-ocean	• Hurricane Weather Research and Forecast (Hurricane WRF)
Regional NWP	• Non-hydrostatic Multiscale Model on the B-grid (NMMB) • ARW (Advanced Research WRF) for the High-Resolution Rapid Refresh model

Sample of operational codes used at DTC. Activities vary and can include testing and/or community support (e.g., repository maintenance, extension to more computational platforms, tutorials, and documentation) This work complements WRF support provided by NCAR Microscale and Mesoscale Meteorology Laboratory

Regional Testing and Evaluation

Hurricane WRF

A successful collaboration with the NOAA Environmental Modeling Center and community scientists to improve the forcing in the operational HWRF.

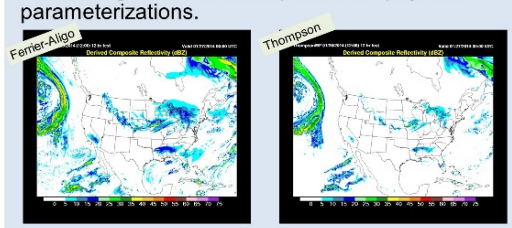


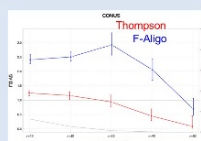
UCLA scientists acted as subject matter experts to assist in DTC's testing, evaluation, and improvement of HWRF.

Funding from the DTC Visitor Program was instrumental to facilitate this collaboration.

Non-Hydrostatic Multiscale Model in B-grid (NMMB)

DTC ran the operational NMMB model using the default Ferrier-Aligo and the Thompson microphysical parameterizations.





Results for a 94-case test over four seasons indicate that the Thompson microphysics alleviates the overprediction of composite reflectivity for light precipitation associated with winter storms

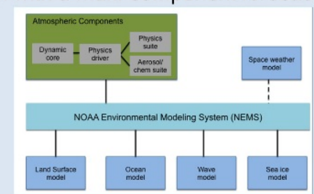
Global Numerical Weather Prediction

Global Model Test Bed (GMTB): a new area for DTC

The Next-Generation Global Prediction System (NGGPS) will replace the current Global Forecast System (GFS) and become operational in 2019.

This is a community system for non-hydrostatic NWP and seasonal prediction with a multi-component forecast application.

DTC is participating by fostering community involvement and creating mechanisms to evaluate innovations in physical parameterizations



DTC is consulting on the NWP Information Technology Environment (NITE) to facilitate the use of NCEP operational models by the general community

Availability of datasets, codes and scripts are some of the important elements to support the GMTB physics testbed

Contributions from DTC

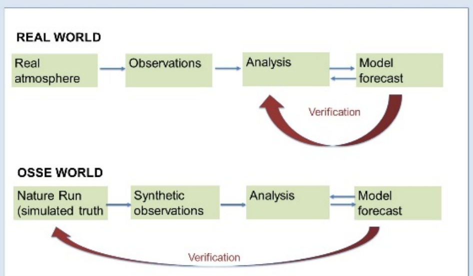
- Research and operational communities closely connected
- Relevant research and development using operational codes
- Mature testing infrastructure
- Transition of several developments to operational models

Global Observing Systems Analysis (GOSA) Group

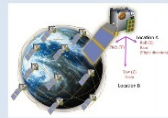
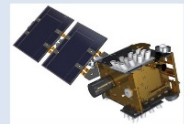
L. Cucurull (1), K. Holub (1), R. Li (2), G. Ge (2), H. Wang (3), J. English (2), T. Peevey (2), A. Kren (3)

OSSEs and OSEs

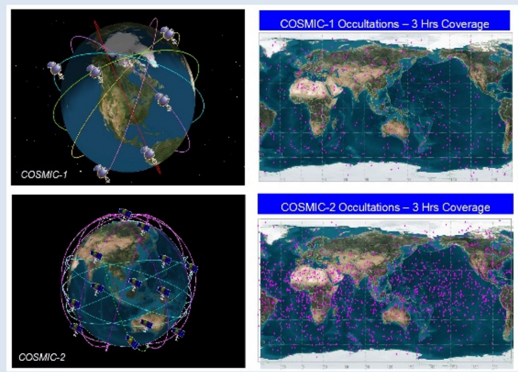
- Observing System Experiments (OSEs) allow the evaluation of the impact of **current** observations in weather forecasting
- Observing System Simulation Experiments (OSSEs) provide a rigorous, cost-effective approach to evaluate the potential impact of **new observing systems**, alternate configurations and deployments of existing systems, and to optimize observing strategies. They are also used to prepare for the utilization of new types of data and to optimize the utilization of existing data
- Both OSEs and OSSEs are necessary to **quantitatively** evaluate the benefits of observations in weather forecasting



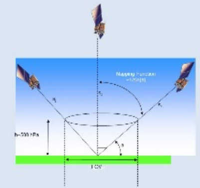
Radio Occultation Science

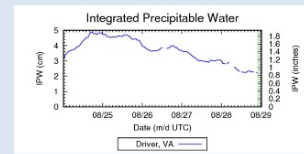



- Engaged in ongoing R&D to quantify impacts of additional GNSS Radio Occultation measurements on operational forecast models (e.g., what is the saturation point?)
- Leading GNSS science activities within NOAA
- Fully committed to Radio Occultation and the COSMIC-2 Program – formal agreement with NWS and NESDIS to support Radio Occultation research and associated R2O



GPS-Met Network



- NOAA/GSD GPS-Met network to be transitioned to the private sector
- Observations currently assimilated in NOAA's operational regional models
- Started work on the assimilation of less retrieved ground-based products with global coverage in NOAA's operationall global models

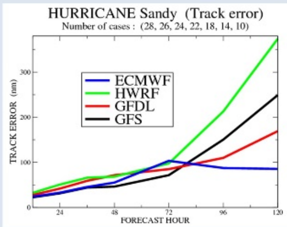
Improving Winter Storm Forecasts with Dropsonde Data

Jason M. English (CIRES/NOAA), Tanya R. Peevey (CIRES/NOAA), Hongli Wang (CIRA/NOAA), Lidia Cucurull (NOAA)

Motivation

Hurricane Sandy errors in GFS medium-range forecast

- The medium-range forecast track of Hurricane Sandy was accurately predicted by the ECWMF model but not GFS
- Does GFS need better model resolution, model physics, or **data assimilation**?

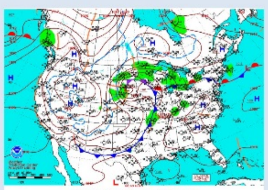


Global Hawk Aircraft may improve data assimilation

- Data from NASA/NOAA fleet of Global Hawk Unmanned Aircraft may improve **data assimilation**: Observing System Experiments (OSEs)

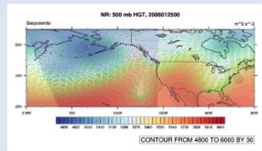
OSSEs: Compare GFS to the "Nature Run"

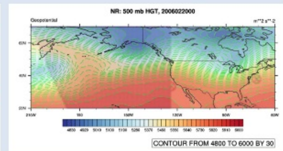
- Instead of flight campaigns, we can simulate dropsonde data from a "perfect" model and determine whether it improves GFS forecast accuracy: Observing System Simulation Experiments (OSSEs)



OSSE Studies: Two Winter Storms

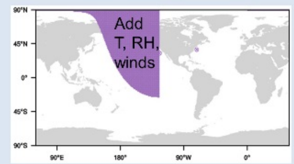
Jan 30 Storm **Feb 25 Storm**



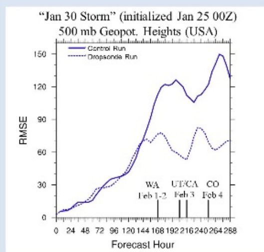


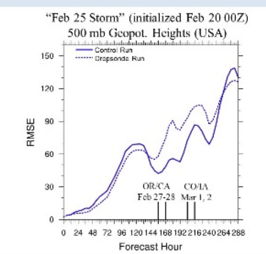
Initialize GFS with Nature Run "observations"

- Initialize GFS model with temperature, winds, and relative humidity from the Nature Run and compare forecast accuracy



Improved forecast for Jan 30 storm but not Feb 25!



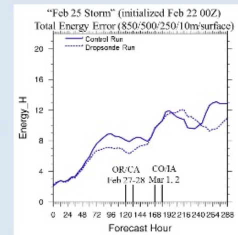


- Initializing the GFS with perfect observations from the Nature Run improves 7-day forecast accuracy for the Jan 30 Storm but not the Feb 25 Storm. Why?

Exploring Storm Differences

Why the poor forecast for the Feb 25 Storm?

- Important dynamical features outside of sampling region? *Storm enters sampling region Feb 22; Forecasts initialized after this date are improved*
- Other storm features beyond 500 mb Geopotential Heights are improved? *Total Energy Error is improved more than 500 mb Geopotential Heights*
- Model physics error?



Summary

- GFS had long-range track errors with Hurricane Sandy; due to model resolution, physics, or data assimilation?
- The NASA/NOAA Global Hawk can provide observations for data assimilation, and forecast improvements can be quantified (OSEs)
- GFS forecasts initialized with perfect observations over the Pacific Ocean from the Nature Run are analyzed for two winter storms (OSSEs)
- Adding perfect observations improves some forecast parameters, depending on when important features enter the sampling region.

Next Steps

- Run a series of GFS forecast runs on Theia with lead times 1-7 days for both Jan 30 and Feb 25 storms and evaluate forecast accuracy
- Using targeting techniques, reduce sampling area and quantify forecast accuracy; results can guide whether and where to fly Global Hawk aircraft for OSEs

ESRL Renewable Energy Research Program

Melinda Marquis[1], Joe Olson[2], Stan Benjamin[1], Eric James[2], Jaymes Kenyon[2], Terra Ladwig[2], Jim Wilczak[1], Laura Biano[2], Irina Djalalova[2], Katie McCaffrey[2], Yelena Pichugina[2], Bob Banta[1], Aditya Choukulkar[2], Alan Brewer[1], Kathy Lantz[2], Allison McComisky[1], Chuck Long[1], Chris Clack[1], Sandy MacDonald[1], Adam Dunbar[1], Yuanfu Xie[2], Anneliese Alexander[2]

1 NOAA
2 CIRES
3 CIRA

Wind Forecast Improvement Project-1

DOE-led Public Private Partnership

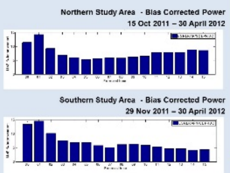
WFIP1 had four main goals:

1) To collect new meteorological observations from the public and private sector
2) To incorporate those observations into the RAP model
3) To determine whether using these additional observations led to better wind forecasts
4) To determine whether improved model forecasts also improved the economics of wind power generation.

Results

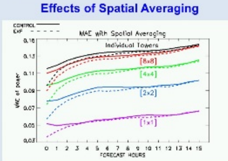
Model Evaluation Using Tall Tower Observations

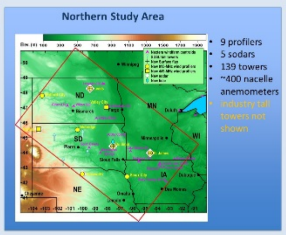
Old ops model (RUC) with no WFIP obs assimilated versus New research model (RAP) with WFIP obs assimilated

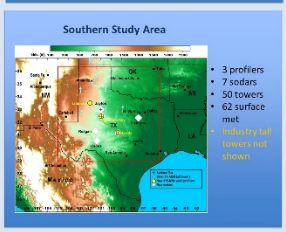


Combined effects of new model and assimilation of WFIP obs

Effects of Spatial Averaging







Solar Forecast Improvement Project

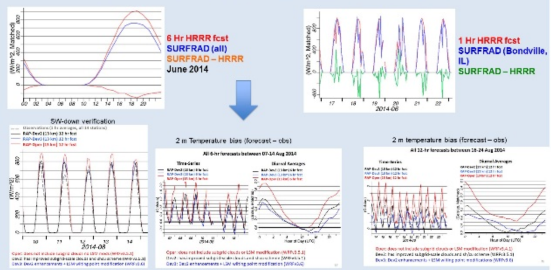
DOE-led Public Private Partnership

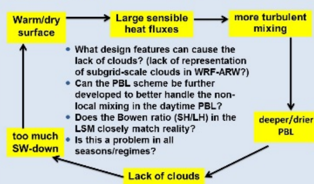
This project has three main goals:

1) Determination of a standardized set of metrics for quantifying forecast accuracy
2) Transformational improvements over the state of the art for solar irradiance forecasting
3) Incorporation of the improved solar irradiance and power forecasts into utility and ISO system operations, and their quantification of the resultant economic and reliability benefits.

This project marks NOAA's first focused efforts to provide forecasts of solar irradiance.

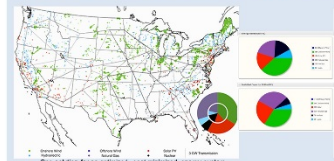
Validation of HRRR-GHI against ground measurements:
Left: diurnal variation of HRRR 6-h forecasts vs. SURFRAD/ISIS (June 2014)
Right: HRRR 1-h forecasts vs. SURFRAD at Bondville, IL (17-22 June 2014)





National Energy with Weather System

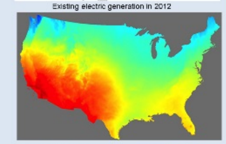
We have developed a tool that simulates the electric (and energy) sector to investigate what happens in the system as large amounts of variable generation (wind and solar PV) are integrated as power sources. The aim is to produce a simulator that can be leveraged for decision making on a variety of scales and incorporate a broad range of technologies. The NEWS simulator designs new systems based on the inputs provided, and the system is cost optimized. NEWS can find additional solutions that produce the least amount of carbon dioxide, waste the smallest percentage of the electric load, build the least amount of new generation, or even create the smallest amount of new transmission.



One solution for an optimized, cost-minimized energy system.

Existing electric generation in 2012

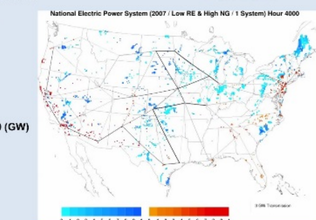
Average wind power at 80 m for 2012 modeled by the High-Resolution Rapid Refresh (HRRR) model, one of the inputs for NEWS. Purple is 55% and dark blue is 5%.



Average solar PV power for the three years 2006-2008 modeled by the Rapid Update Cycle (RUC). Dark red is 30% and dark blue is 15%.

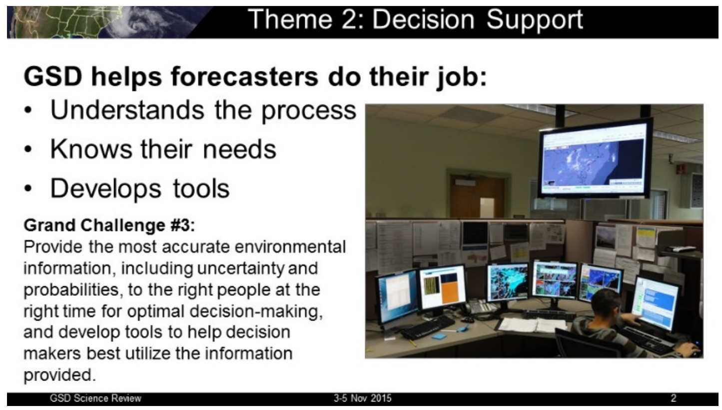
Energy generated (%)
0% Offshore wind
38% Onshore Wind
17% Solar PV
21% Natural Gas
16% Nuclear
8% Hydro

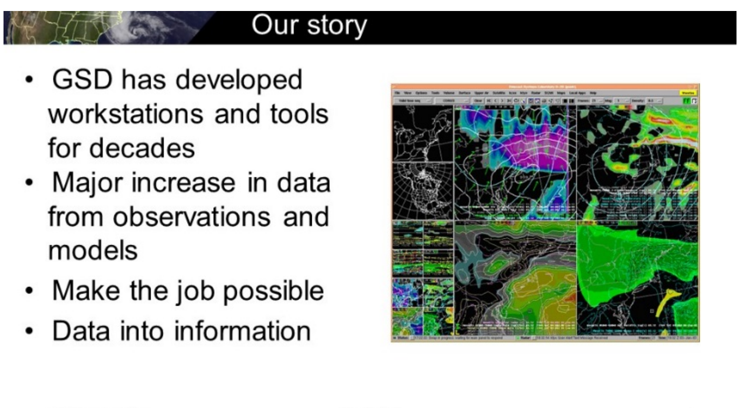
Installed Capacity 2030 (GW)
<1% Offshore wind
34% Onshore wind
24% Solar
30% Natural Gas
7% Nuclear
5% Hydro

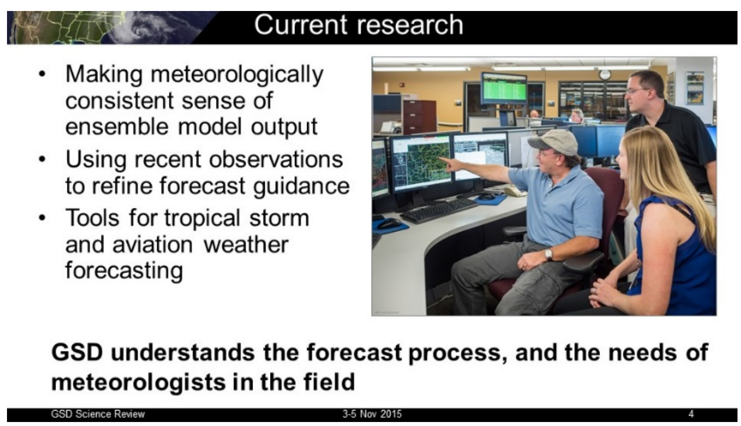


Session 4: Decision Support – A Busy Day at Forecast Offices

- A Busy Day at Forecast Offices (Mike Kraus)
- Ensemble Forecasts and Uncertainty (Paul Schultz)
- Forecast Monitoring and Short Term Updates (Kevin Manross)
- Tropical Hazards (Tom LeFebvre)
- Unified and Consistent Hazardous Weather Forecasts (Tracy Hansen)
- Sharing the Wealth: Forecaster Tools for Our Partners (Joe Wakefield)



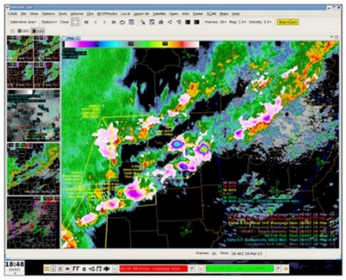




Quality

Tech Transfer – AWIPS Enhancements

- Prototype tools in the field
- Continual feedback
- Acceptance into operational software
- Primary operational tools for forecasters
- 7 Invited talks



GSD Science Review 3-5 Nov 2015 5

Performance

- In line with NWS field office and FAA requirements
- Development driven by sponsor needs
- Effectiveness gauged by:
  - sponsor satisfaction
  - operational implementation
  - continued support

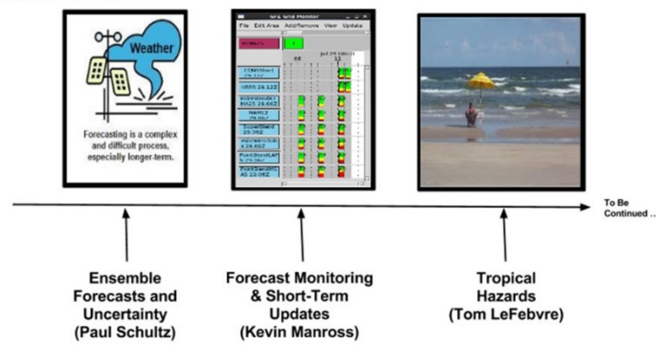
GSD Science Review 3-5 Nov 2015 6

Relevance

- **Co-author:** Weather-Ready Nation Roadmap *"Society is prepared for and responds to weather-related events"*
- **Objective:** Reduced loss of life, property, and disruption from high-impact events
- **Relationships**

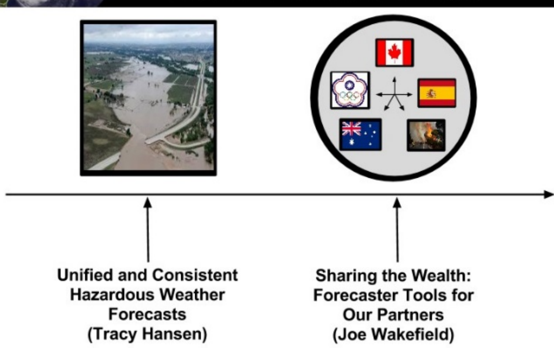
WRN

GSD Science Review 3-5 Nov 2015 7



GSD Science Review 3-5 Nov 2015 8

Theme 2 Session 4 Talks



GSD Science Review 3-5 Nov 2015 9

Decision support tools for WFOs

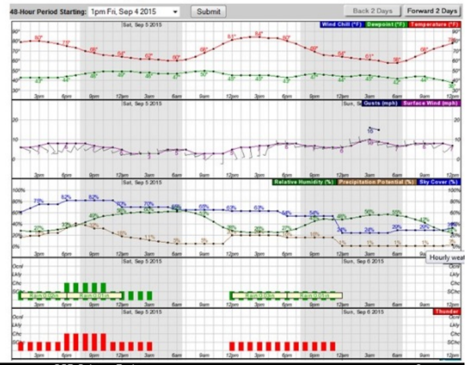
Paul Schultz
CIRES
Performing work for NOAA/ESRL/GSD

GSD Science Review
3-5 Nov 2015

1

Decision support

Decision support starts with a point forecast from an NWS Warning and Forecast Office



Forecasts that have no error bars are "deterministic"

3-5 Nov 2015 GSD Science Review 2

Evolving role of WFOs

- Increasingly sophisticated users are optimizing their weather-impacted decisions by considering:
  - Event probabilities
  - Alternate scenarios
- The *Ensemble Tool* in AWIPS II was developed to help forecasters communicate this information

3-5 Nov 2015 GSD Science Review 3

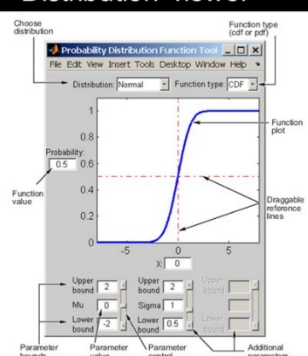
Primary source: Ensembles

- 10+ forecasts from computer models
  - Any one of them could be today's best
  - Each represents an *alternative scenario*
  - *Probabilities* are estimated from the frequency of an event in the ensemble:
    - *If 6 out of 10 of the forecast models indicate precipitation in excess of 1 cm, the probability of precipitation in excess of 1 cm is about 60%*

3-5 Nov 2015 GSD Science Review 4

Distribution viewer

This example comes from MATLAB

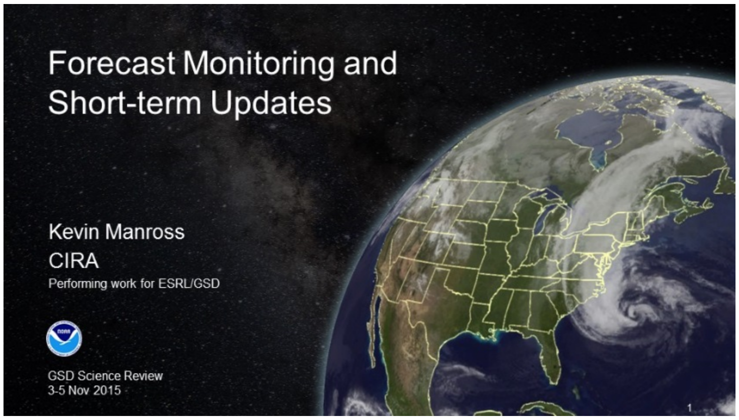


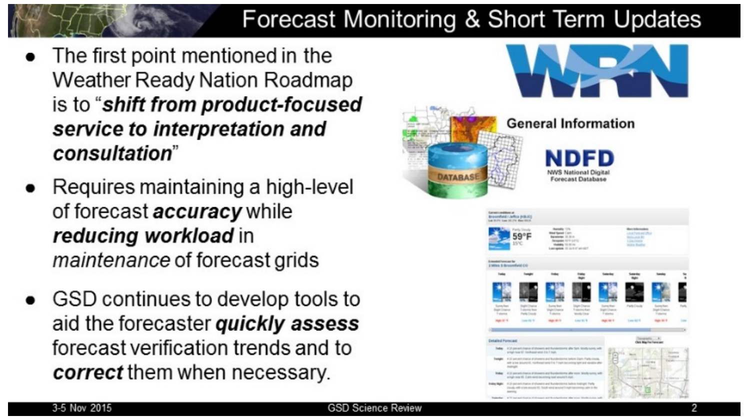
3-5 Nov 2015 GSD Science Review 5

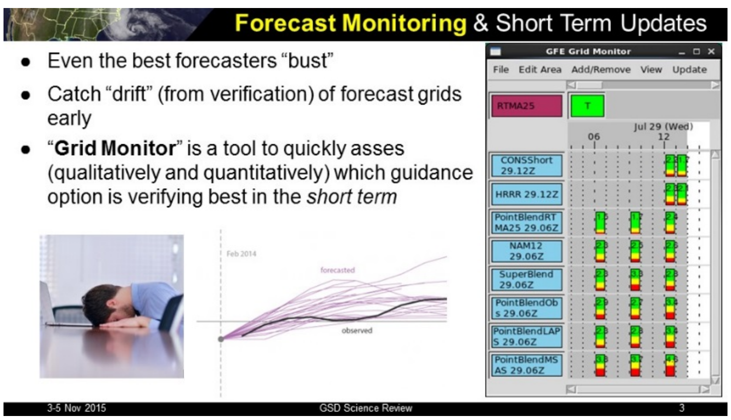
Summary

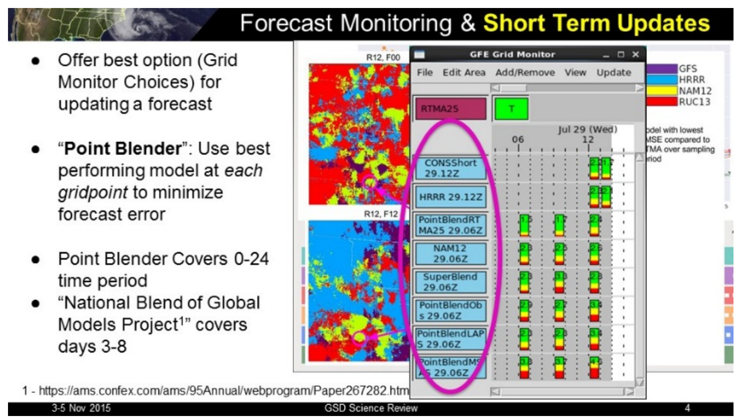
- *Weather Ready Nation* calls for better decision support by NWS forecasters
- Decision support = communicating forecasts *and their uncertainty*
- Uncertainty = probabilities and/or alternative scenarios
- Poster gives examples of how the Ensemble Tool enables this

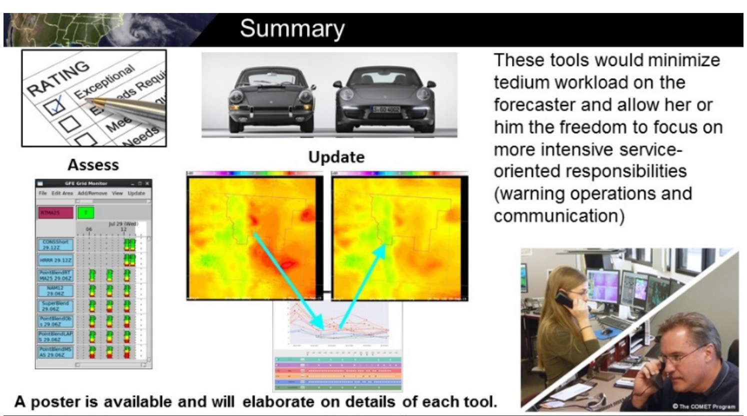
3-5 Nov 2015 GSD Science Review 6


Forecast Monitoring and
Short-term Updates
Kevin Manross
CIRA
Performing work for ESRL/GSD
GSD Science Review
3-5 Nov 2015
1

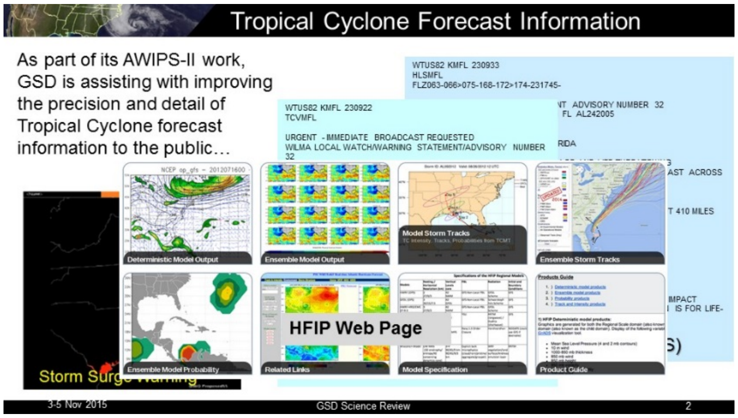

Forecast Monitoring & Short Term Updates
The first point mentioned in the Weather Ready Nation Roadmap is to "*shift from product-focused service to interpretation and consultation*"
Requires maintaining a high-level of forecast ***accuracy*** while ***reducing workload*** in *maintenance* of forecast grids
GSD continues to develop tools to aid the forecaster ***quickly assess*** forecast verification trends and to ***correct*** them when necessary.
WRN
General Information
DATABASE
NDFD
NWS National Digital Forecast Database
59°F
3-5 Nov 2015
GSD Science Review
2

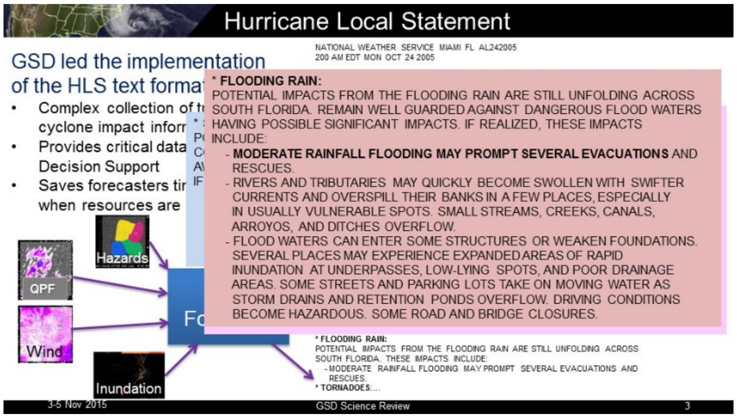

Forecast Monitoring & Short Term Updates
Even the best forecasters "bust"
Catch "drift" (from verification) of forecast grids early
"**Grid Monitor**" is a tool to quickly asses (qualitatively and quantitatively) which guidance option is verifying best in the *short term*
Feb 2014
forecasted
observed
GFE Grid Monitor
File Edit Area Add/Remove View Update
RTMA25
T
Jul 29 (Wed)
06
12
CONSShort 29.12Z
HRRR 29.12Z
PointBlendRTMA25 29.06Z
NAM12 29.06Z
SuperBlend 29.06Z
PointBlendObs 29.06Z
PointBlendLAPS 29.06Z
PointBlendMSAS 29.06Z
3-5 Nov 2015
GSD Science Review
3

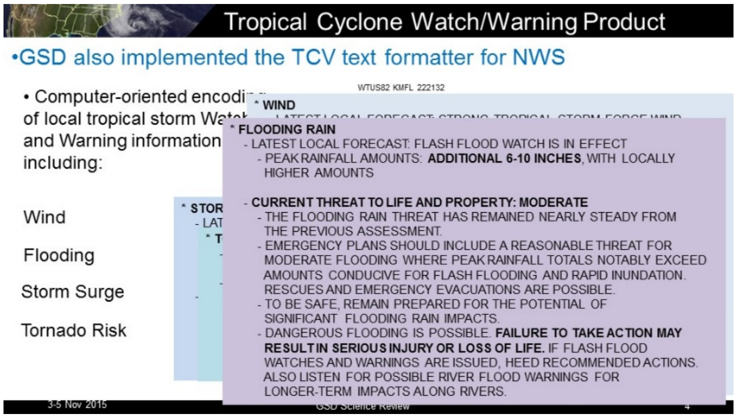

Forecast Monitoring & **Short Term Updates**
Offer best option (Grid Monitor Choices) for updating a forecast
"**Point Blender**": Use best performing model at *each gridpoint* to minimize forecast error
Point Blender Covers 0-24 time period
"National Blend of Global Models Project[1]" covers days 3-8
R12, F00
R12, F12
GFE Grid Monitor
File Edit Area Add/Remove View Update
RTMA25
T
Jul 29 (Wed)
06
12
CONSShort 29.12Z
HRRR 29.12Z
PointBlendRTMA25 29.06Z
NAM12 29.06Z
SuperBlend 29.06Z
PointBlendObs 29.06Z
PointBlendLAPS 29.06Z
PointBlendMSAS 29.06Z
GFS
HRRR
NAM12
RUC13
1 - https://ams.confex.com/ams/95Annual/webprogram/Paper267282.htm
3-5 Nov 2015
GSD Science Review
4

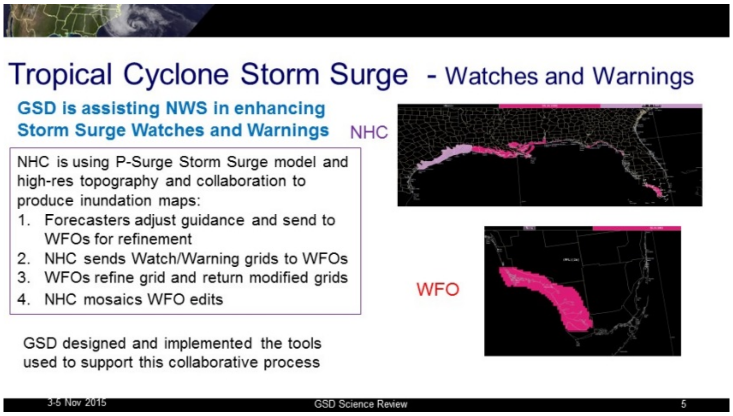

Summary
RATING
Exceptional
Assess
Update
These tools would minimize tedium workload on the forecaster and allow her or him the freedom to focus on more intensive service-oriented responsibilities (warning operations and communication)
A poster is available and will elaborate on details of each tool.
© The COMET Program
3-5 Nov 2015
GSD Science Review
5

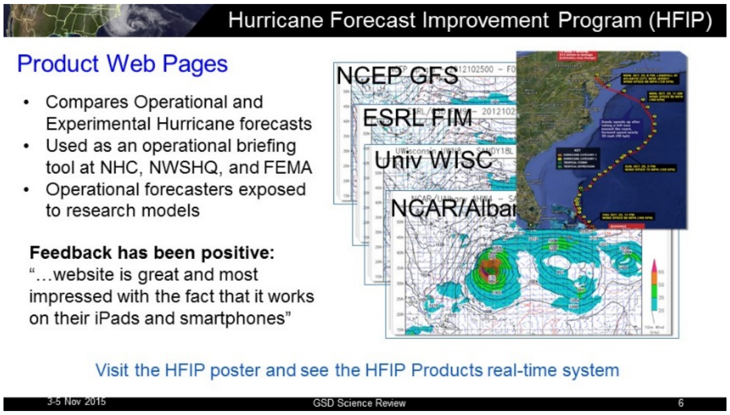

Tropical Hazards
Tom LeFebvre
NOAA/ESRL/GSD
GSD Science Review
3-5 Nov 2015


Tropical Cyclone Forecast Information
As part of its AWIPS-II work, GSD is assisting with improving the precision and detail of Tropical Cyclone forecast information to the public…
WTUS82 KMFL 230933
HLSMFL
WTUS82 KMFL 230922
TCVMFL
URGENT - IMMEDIATE BROADCAST REQUESTED
WILMA LOCAL WATCH/WARNING STATEMENT/ADVISORY NUMBER 32
Deterministic Model Output
Ensemble Model Output
Model Storm Tracks
Ensemble Storm Tracks
Ensemble Model Probability
HFIP Web Page
Related Links
Model Specification
Product Guide
Storm Surge Warning
3-5 Nov 2015
GSD Science Review
2


Hurricane Local Statement
GSD led the implementation of the HLS text format
Complex collection of tropical cyclone impact information
Provides critical data for Decision Support
Saves forecasters time when resources are
NATIONAL WEATHER SERVICE MIAMI FL AL242005
200 AM EDT MON OCT 24 2005
* FLOODING RAIN:
POTENTIAL IMPACTS FROM THE FLOODING RAIN ARE STILL UNFOLDING ACROSS SOUTH FLORIDA. REMAIN WELL GUARDED AGAINST DANGEROUS FLOOD WATERS HAVING POSSIBLE SIGNIFICANT IMPACTS. IF REALIZED, THESE IMPACTS INCLUDE:
- MODERATE RAINFALL FLOODING MAY PROMPT SEVERAL EVACUATIONS AND RESCUES.
- RIVERS AND TRIBUTARIES MAY QUICKLY BECOME SWOLLEN WITH SWIFTER CURRENTS AND OVERSPILL THEIR BANKS IN A FEW PLACES, ESPECIALLY IN USUALLY VULNERABLE SPOTS. SMALL STREAMS, CREEKS, CANALS, ARROYOS, AND DITCHES OVERFLOW.
- FLOOD WATERS CAN ENTER SOME STRUCTURES OR WEAKEN FOUNDATIONS. SEVERAL PLACES MAY EXPERIENCE EXPANDED AREAS OF RAPID INUNDATION AT UNDERPASSES, LOW-LYING SPOTS, AND POOR DRAINAGE AREAS. SOME STREETS AND PARKING LOTS TAKE ON MOVING WATER AS STORM DRAINS AND RETENTION PONDS OVERFLOW. DRIVING CONDITIONS BECOME HAZARDOUS. SOME ROAD AND BRIDGE CLOSURES.
Hazards
QPF
Wind
Inundation
* TORNADOES:...
3-5 Nov 2015
GSD Science Review
3


Tropical Cyclone Watch/Warning Product
•GSD also implemented the TCV text formatter for NWS
• Computer-oriented encoding of local tropical storm Watch and Warning information including:
Wind
Flooding
Storm Surge
Tornado Risk
WTUS82 KMFL 222132
* WIND
* FLOODING RAIN
- LATEST LOCAL FORECAST: FLASH FLOOD WATCH IS IN EFFECT
- PEAK RAINFALL AMOUNTS: ADDITIONAL 6-10 INCHES, WITH LOCALLY HIGHER AMOUNTS
- CURRENT THREAT TO LIFE AND PROPERTY: MODERATE
- THE FLOODING RAIN THREAT HAS REMAINED NEARLY STEADY FROM THE PREVIOUS ASSESSMENT.
- EMERGENCY PLANS SHOULD INCLUDE A REASONABLE THREAT FOR MODERATE FLOODING WHERE PEAK RAINFALL TOTALS NOTABLY EXCEED AMOUNTS CONDUCIVE FOR FLASH FLOODING AND RAPID INUNDATION. RESCUES AND EMERGENCY EVACUATIONS ARE POSSIBLE.
- TO BE SAFE, REMAIN PREPARED FOR THE POTENTIAL OF SIGNIFICANT FLOODING RAIN IMPACTS.
- DANGEROUS FLOODING IS POSSIBLE. FAILURE TO TAKE ACTION MAY RESULT IN SERIOUS INJURY OR LOSS OF LIFE. IF FLASH FLOOD WATCHES AND WARNINGS ARE ISSUED, HEED RECOMMENDED ACTIONS. ALSO LISTEN FOR POSSIBLE RIVER FLOOD WARNINGS FOR LONGER-TERM IMPACTS ALONG RIVERS.
3-5 Nov 2015
4


Tropical Cyclone Storm Surge - Watches and Warnings
GSD is assisting NWS in enhancing Storm Surge Watches and Warnings
NHC
NHC is using P-Surge Storm Surge model and high-res topography and collaboration to produce inundation maps:
1. Forecasters adjust guidance and send to WFOs for refinement
2. NHC sends Watch/Warning grids to WFOs
3. WFOs refine grid and return modified grids
4. NHC mosaics WFO edits
WFO
GSD designed and implemented the tools used to support this collaborative process
3-5 Nov 2015
GSD Science Review
5


Hurricane Forecast Improvement Program (HFIP)
Product Web Pages
• Compares Operational and Experimental Hurricane forecasts
• Used as an operational briefing tool at NHC, NWSHQ, and FEMA
• Operational forecasters exposed to research models
Feedback has been positive:
"…website is great and most impressed with the fact that it works on their iPads and smartphones"
NCEP GFS
ESRL FIM
Univ WISC
NCAR/Albany
Visit the HFIP poster and see the HFIP Products real-time system
3-5 Nov 2015
GSD Science Review
6

Summary

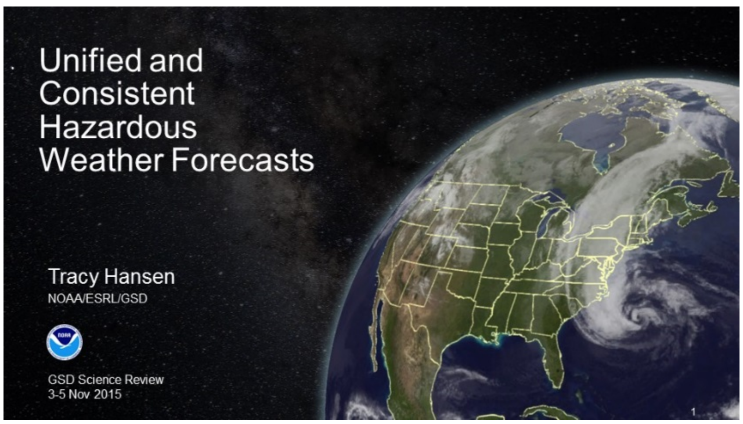
GSD developers continue to provide NWS with techniques to:

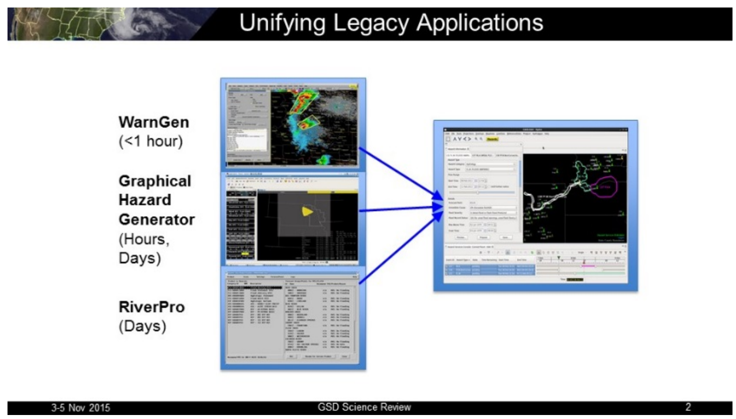
- Save forecasters valuable time, reduce effort
- Allow more time for Impact-based Decision Support Services
- Complete the transition from Research to Operations

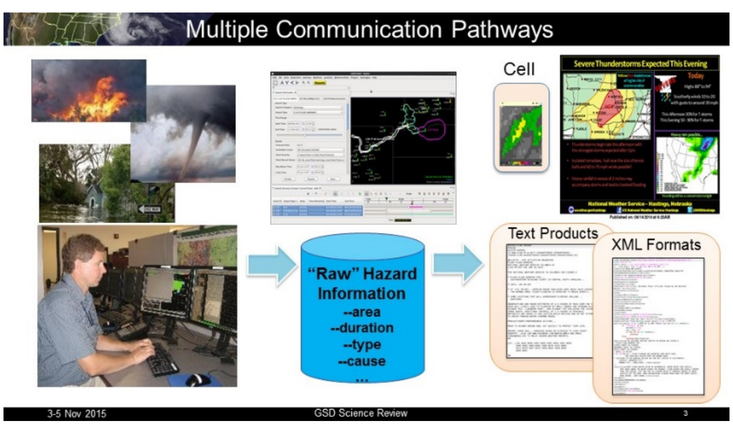
Future Work includes…

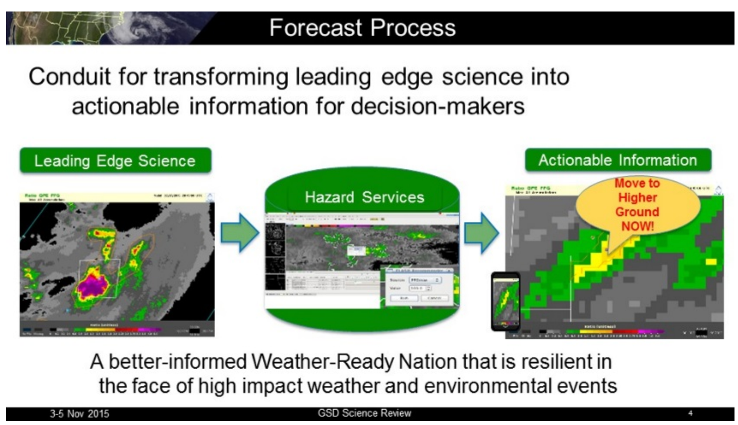
- Enhancements to existing techniques
- Extending Hazard collaboration to Wind, Inland Flooding
- New methods for defining tropical cyclone wind fields

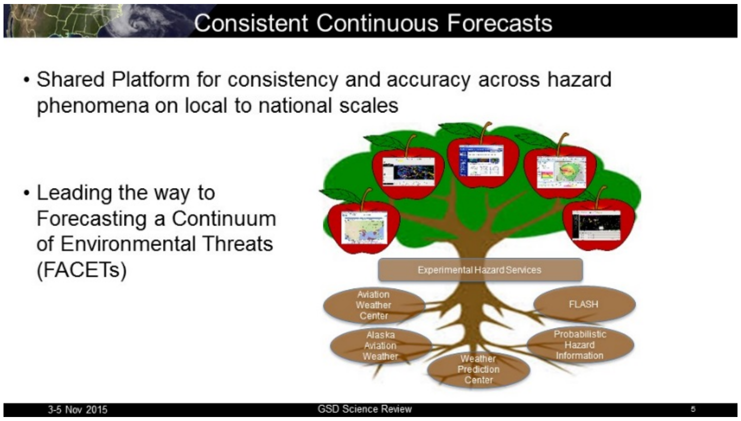
3-5 Nov 2015 GSD Science Review 7





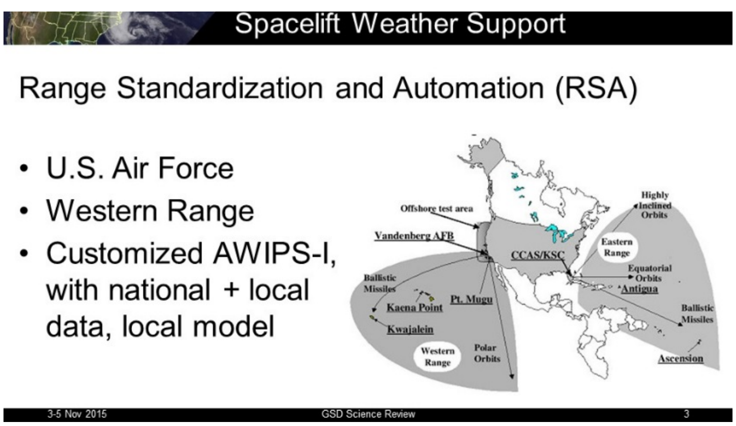


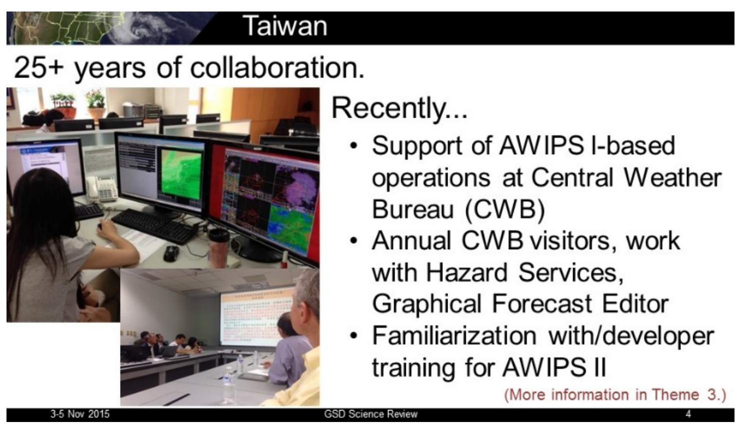



Consistent Continuous Forecasts
• Shared Platform for consistency and accuracy across hazard phenomena on local to national scales
• Leading the way to Forecasting a Continuum of Environmental Threats (FACETs)
Experimental Hazard Services
Aviation Weather Center
FLASH
Alaska Aviation Weather
Probabilistic Hazard Information
Weather Prediction Center
3-5 Nov 2015
GSD Science Review
5


Sharing the Wealth: Forecaster Tools for Our Partners
Joe Wakefield
NOAA/ESRL/GSD
GSD Science Review
3-5 Nov 2015
1


Wildfire Operations
Exploratory R&D of services and tools for fire weather decision support
Customers/funders
• National Interagency Fire Center (NIFC)
Field meteorologists, fire resource managers
• Wildland Fire Management Research, Development, and Application
Cloud-based software-as-a-service, AWIPS II virtual server
3-5 Nov 2015
GSD Science Review
2

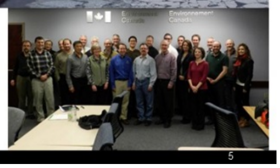

Spacelift Weather Support
Range Standardization and Automation (RSA)
• U.S. Air Force
• Western Range
• Customized AWIPS-I, with national + local data, local model
Offshore test area
Vandenberg AFB
CCAS/KSC
Highly Inclined Orbits
Eastern Range
Equatorial Orbits
Antigua
Ballistic Missiles
Pt. Mugu
Kaena Point
Kwajalein
Western Range
Polar Orbits
Ascension
Ballistic Missiles
3-5 Nov 2015
GSD Science Review
3


Taiwan
25+ years of collaboration.
Recently...
• Support of AWIPS I-based operations at Central Weather Bureau (CWB)
• Annual CWB visitors, work with Hazard Services, Graphical Forecast Editor
• Familiarization with/developer training for AWIPS II
(More information in Theme 3.)
3-5 Nov 2015
GSD Science Review
4

Canada

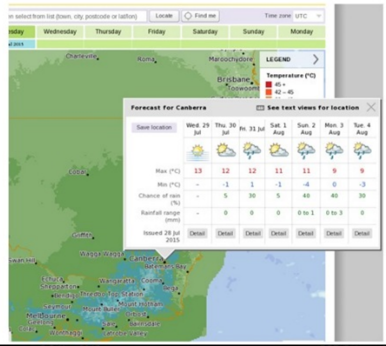
Environment Canada - NOAA Agreements

- Participation in Marine Forecast Systems focus
- Goal is improved and seamless forecasts provided to mariners - coastal, Great Lakes
- February 2014 Marine workshop, Halifax



3-5 Nov 2015 GSD Science Review 5

Adapt/customize Graphical Forecast Editor



Australia Bureau of Meteorology

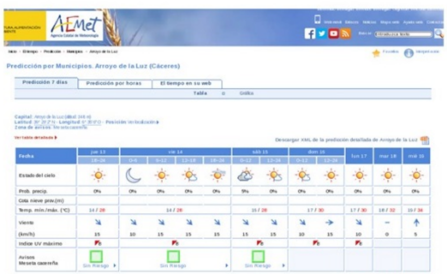
- work with NOAA began 2003
- completed nationwide implementation 2014
- numerous awards in-country, internationally

3-5 Nov 2015 GSD Science Review 6

Adapt/customize Graphical Forecast Editor

Spain - State Meteorological Agency (AEMET)

- collaborative work with NOAA since 2011
- initial operations 2014



3-5 Nov 2015 GSD Science Review 7

Looking ahead

Multi-year agreement being worked with NIFC

Ongoing RSA support

New five-year cycle starting with Taiwan CWB

Expecting continued interaction with Environment Canada under bi-lateral agreement

Exploring new work with Australia BoM

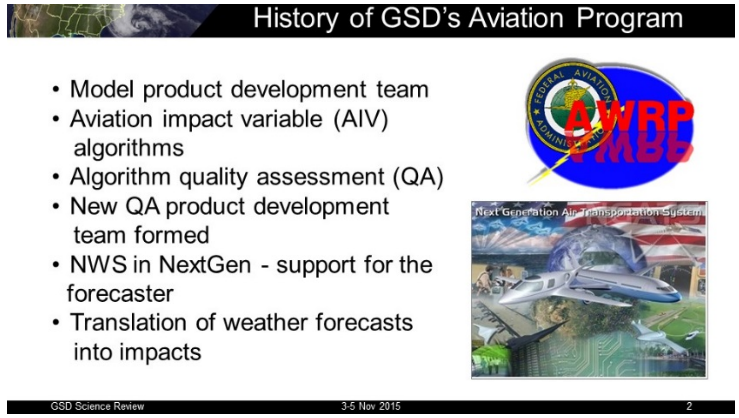
Anticipate new agreement with AEMET/Spain for continued development support

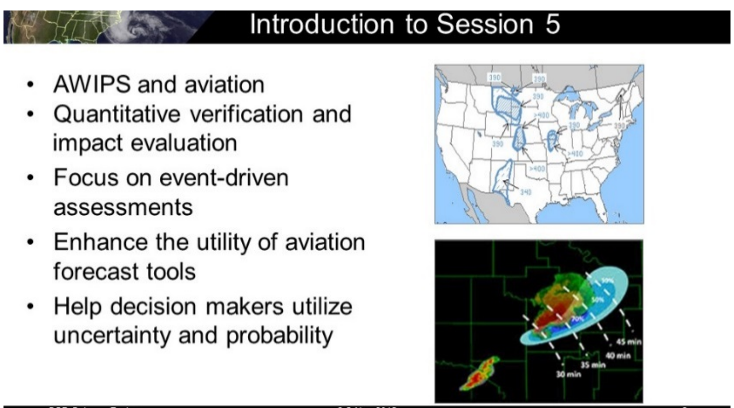
More detail and examples at the poster

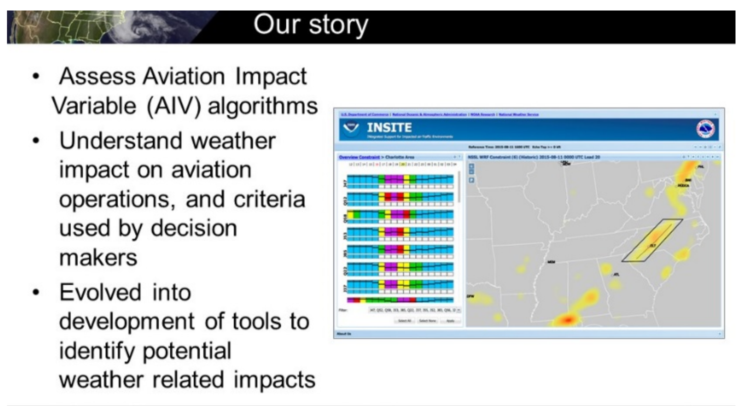
3-5 Nov 2015 GSD Science Review 8

Session 5: Decision Support – Aviation

- Decision Support and Evaluation for Aviation (Mike Kraus)
- Aviation Forecasting with AWIPS (Woody Roberts)
- Impact-based Decision Support for Aviation (Brian Etherton)
- Verification Tools for Aviation Weather (Missy Petty)
- Investigation of Truth Sets for Verification (Laura Paulik)
- Assessment of Aviation Algorithms and Forecast Technologies (Matt Wandishin)







Current QA Research

- Evaluation of AIV algorithms requires new methodologies
- Requires new ways to establish "truth"
- 25 years of experience

GSD Science Review 3-5 Nov 2015 5

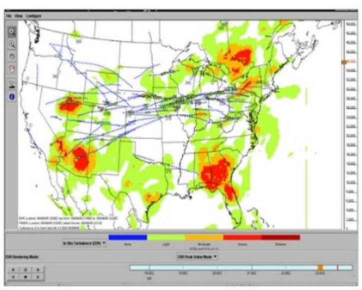
Quality

- **Publications** - 9 assessment reports
- **Methodology** is reviewed by stakeholders and developers
  - Invited presentations
- **Assessments** inform decisions on transition of algorithms to operations
- **Expertise** used to develop tools that translate forecasts into impact information

GSD Science Review 3-5 Nov 2015 6

Performance

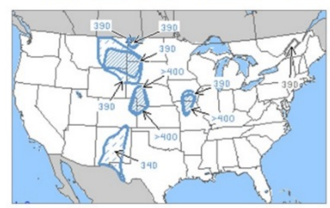
- Leadership role in conducting assessments - GSD is sought out
- Driven by sponsor needs and requirements
- Success gauged by:
  - Satisfaction
  - Effect on operational implementation
  - Continued support



GSD Science Review 3-5 Nov 2015 7

Relevance

- **Weather-Ready Nation:** Society is prepared for and responds to weather-related events
- **Objective:** Reduced loss of life, property, and disruption from high-impact events



GSD Science Review 3-5 Nov 2015 8

Decision support and evaluation for aviation



To Be Continued...

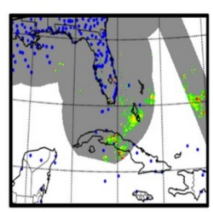
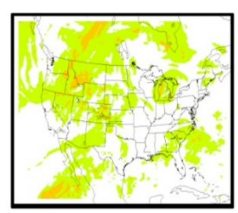
Aviation Forecasting with AWIPS (Woody Roberts)

Impact-based Decision Support for Aviation (Brian Etherton)

Verification Tools for Aviation Weather (Missy Petty)

GSD Science Review 3-5 Nov 2015 9

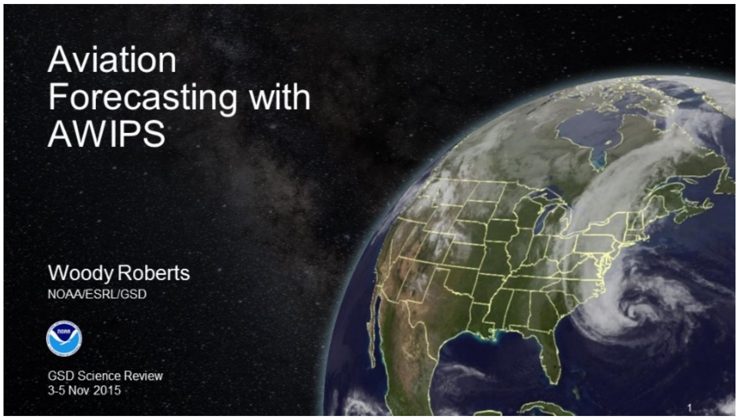
Decision support and evaluation for aviation

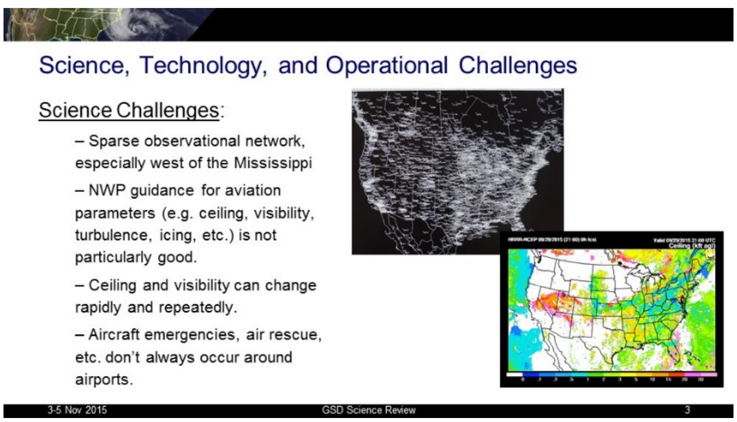
Investigation of Truth Sets for Verification (Laura Paulik)

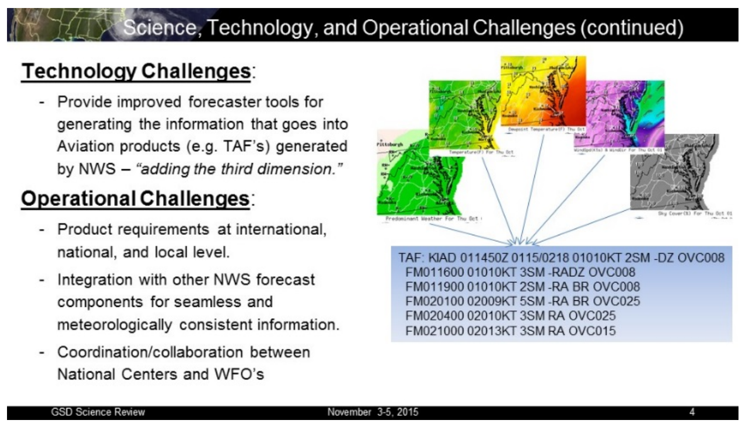
Assessment of Aviation Algorithms and Forecast Technologies (Matt Wandishin)

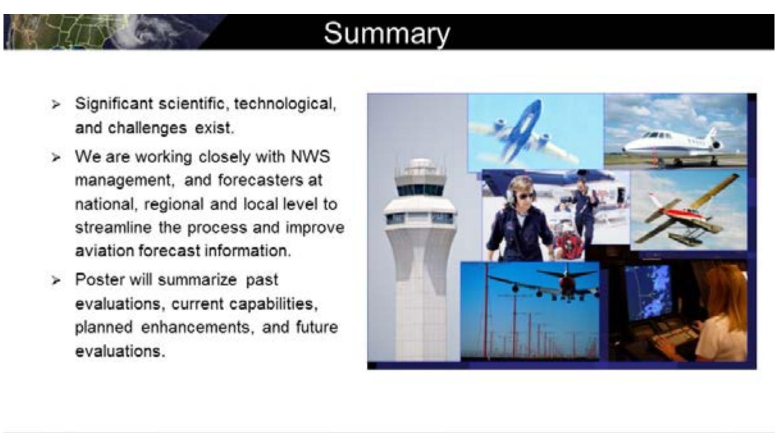
GSD Science Review 3-5 Nov 2015 10

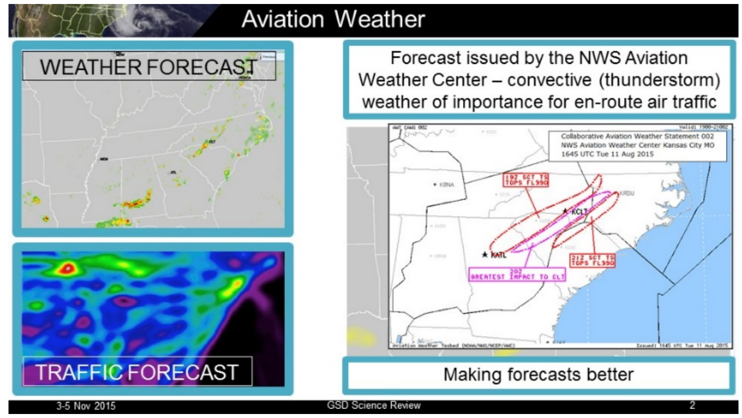

Aviation Forecasting with AWIPS
Woody Roberts
NOAA/ESRL/GSD
GSD Science Review
3-5 Nov 2015
1

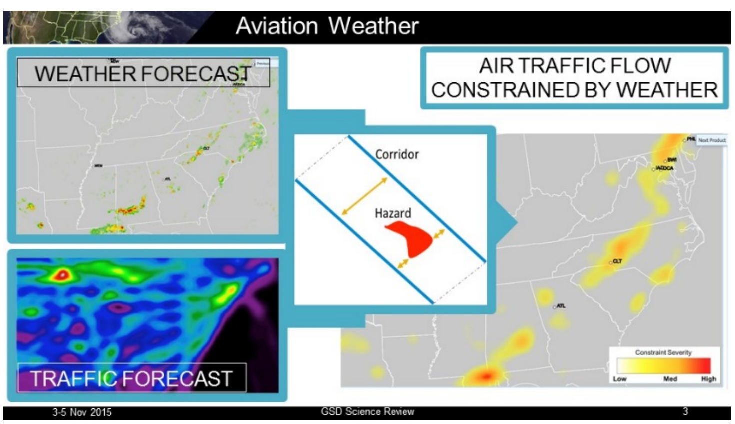

Mission Supports:
General Aviation,
Commercial Aviation,
USAF/Vandenberg Launch Facility
3-5 Nov 2015
GSD Science Review
2

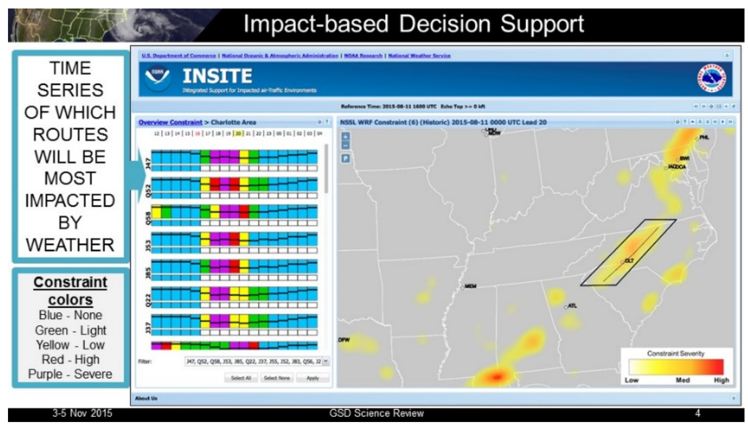

Science, Technology, and Operational Challenges
Science Challenges:
– Sparse observational network, especially west of the Mississippi
– NWP guidance for aviation parameters (e.g. ceiling, visibility, turbulence, icing, etc.) is not particularly good.
– Ceiling and visibility can change rapidly and repeatedly.
– Aircraft emergencies, air rescue, etc. don't always occur around airports.
3-5 Nov 2015
GSD Science Review
3


Science, Technology, and Operational Challenges (continued)
Technology Challenges:
- Provide improved forecaster tools for generating the information that goes into Aviation products (e.g. TAF's) generated by NWS – "adding the third dimension."
Operational Challenges:
- Product requirements at international, national, and local level.
- Integration with other NWS forecast components for seamless and meteorologically consistent information.
- Coordination/collaboration between National Centers and WFO's
TAF: KIAD 011450Z 0115/0218 01010KT 2SM -DZ OVC008
FM011600 01010KT 3SM -RADZ OVC008
FM011900 01010KT 2SM -RA BR OVC008
FM020100 02009KT 5SM -RA BR OVC025
FM020400 02010KT 3SM RA OVC025
FM021000 02013KT 3SM RA OVC015
GSD Science Review
November 3-5, 2015
4


Summary
Significant scientific, technological, and challenges exist.
We are working closely with NWS management, and forecasters at national, regional and local level to streamline the process and improve aviation forecast information.
Poster will summarize past evaluations, current capabilities, planned enhancements, and future evaluations.
GSD Science Review
November 3-5, 2015
5





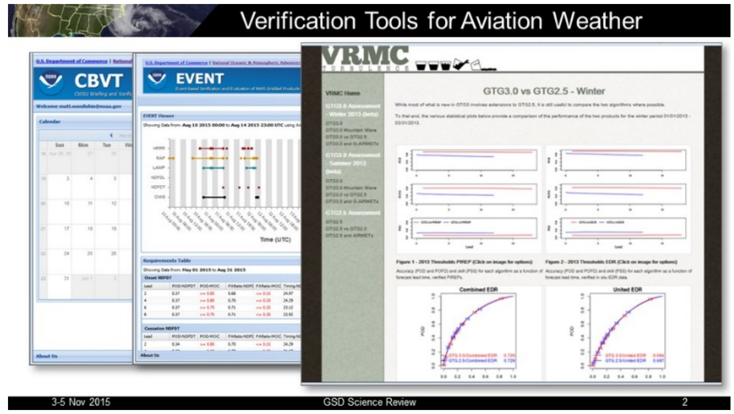


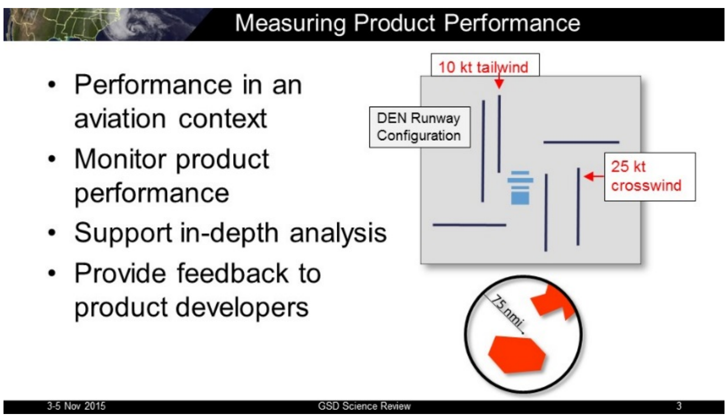
Impact-based Decision Support

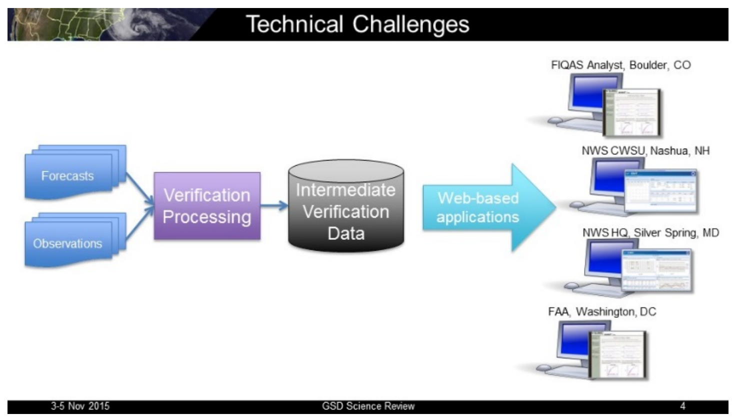
- Allow for better planning
  - Strategic, rather than tactical decisions
  - Fewer delays, diversions, and cancellations
  - Maintain safety, improve efficiency
- Operations
  - INSITE in transition to operations at the National Weather Service, expected in 2017
  - Transition via Integrated Dissemination Program (IDP)
- Future plans
  - Add in other weather (fog, snow, winds)
- Test INSITE
  - Incorporated into the electronic poster session

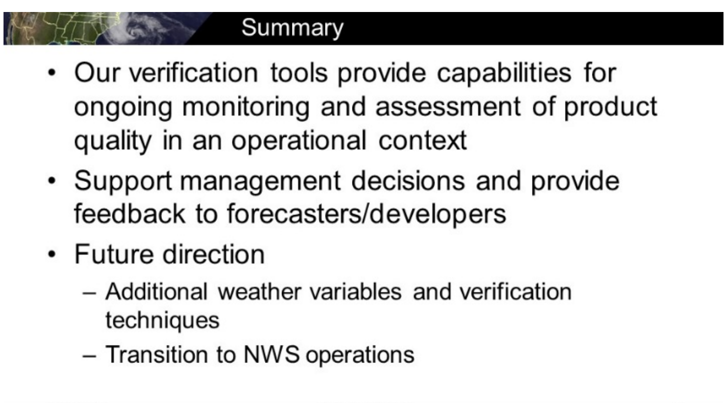
3-5 Nov 2015 GSD Science Review 5

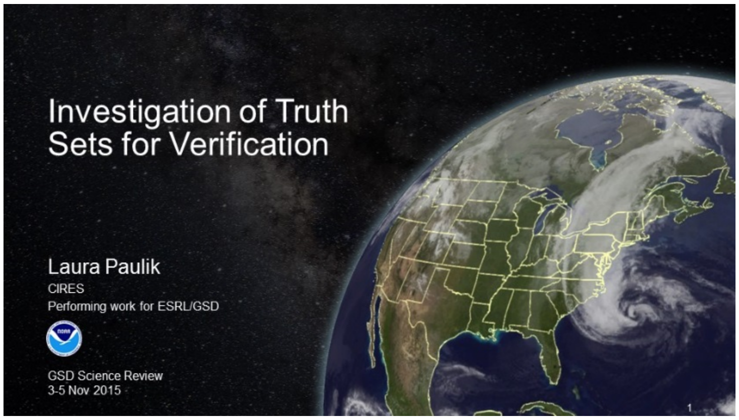

Verification Tools for
Aviation Weather
Missy Petty
CIRA
Performing work for ESRL/GSD
GSD Science Review
3-5 Nov 2015
1

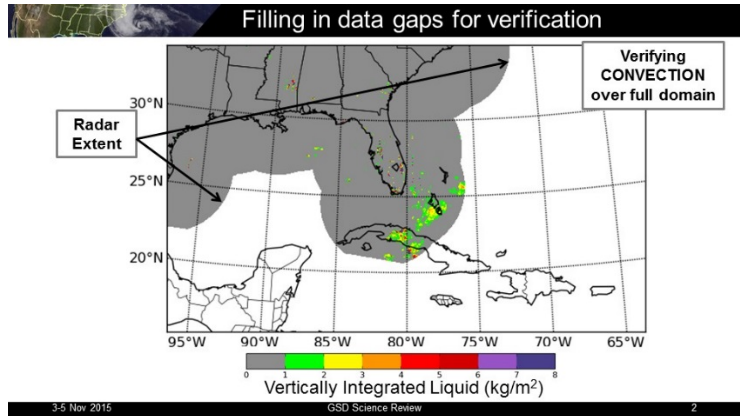

Verification Tools for Aviation Weather
CBVT
EVENT
VRMC
GTG3.0 vs GTG2.5 - Winter
3-5 Nov 2015
GSD Science Review
2

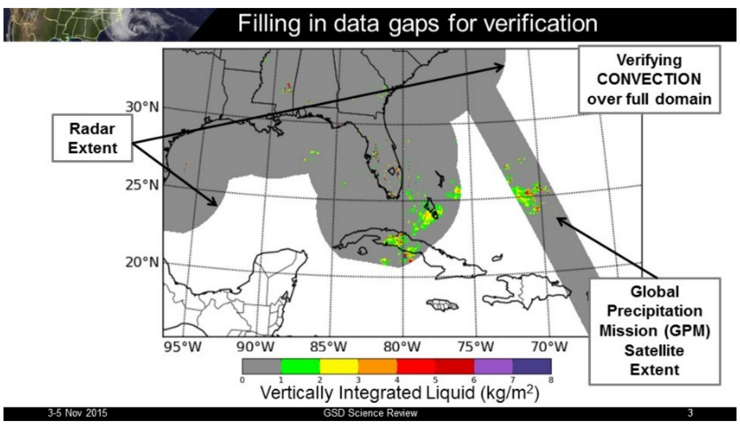

Measuring Product Performance
• Performance in an aviation context
• Monitor product performance
• Support in-depth analysis
• Provide feedback to product developers
10 kt tailwind
DEN Runway Configuration
25 kt crosswind
75 nmi
3-5 Nov 2015
GSD Science Review
3

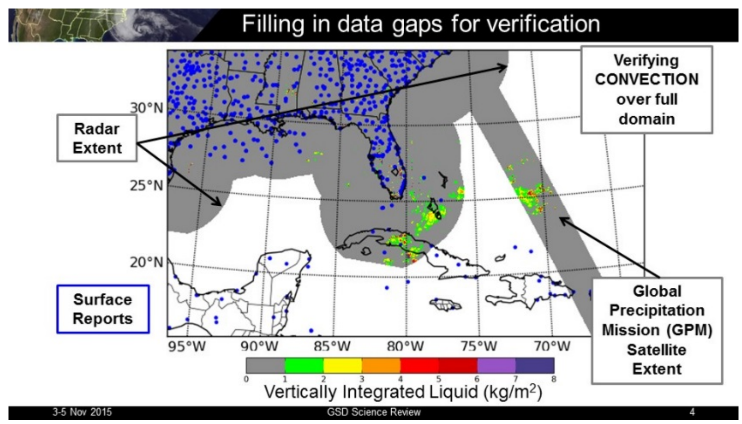

Technical Challenges
Forecasts
Observations
Verification Processing
Intermediate Verification Data
Web-based applications
FIQAS Analyst, Boulder, CO
NWS CWSU, Nashua, NH
NWS HQ, Silver Spring, MD
FAA, Washington, DC
3-5 Nov 2015
GSD Science Review
4

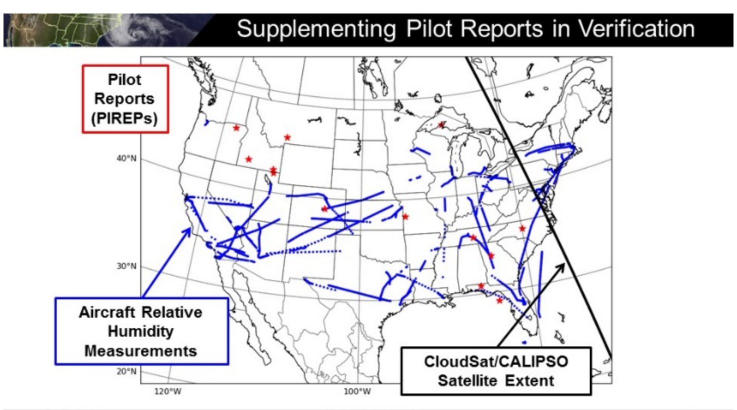

Summary
• Our verification tools provide capabilities for ongoing monitoring and assessment of product quality in an operational context
• Support management decisions and provide feedback to forecasters/developers
• Future direction
– Additional weather variables and verification techniques
– Transition to NWS operations
3-5 Nov 2015
GSD Science Review
5

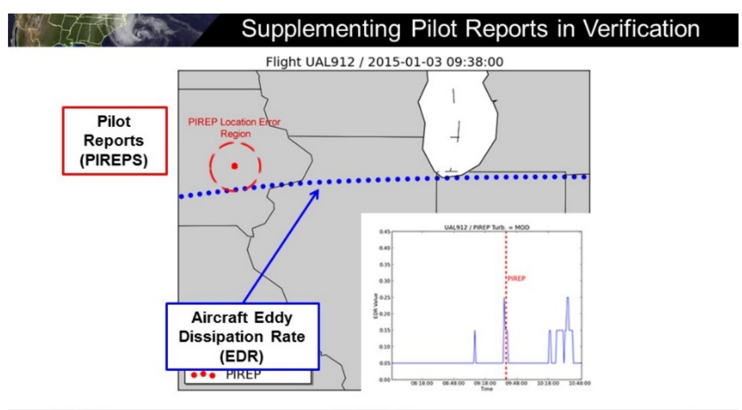

Investigation of Truth Sets for Verification
Laura Paulik
CIRES
Performing work for ESRL/GSD
GSD Science Review
3-5 Nov 2015
1


Filling in data gaps for verification
Verifying CONVECTION over full domain
Radar Extent
30°N
25°N
20°N
95°W 90°W 85°W 80°W 75°W 70°W 65°W
0 1 2 3 4 5 6 7 8
Vertically Integrated Liquid (kg/m2)
3-5 Nov 2015
GSD Science Review
2


Filling in data gaps for verification
Verifying CONVECTION over full domain
Radar Extent
30°N
25°N
20°N
Global Precipitation Mission (GPM) Satellite Extent
95°W 90°W 85°W 80°W 75°W 70°W
0 1 2 3 4 5 6 7 8
Vertically Integrated Liquid (kg/m2)
3-5 Nov 2015
GSD Science Review
3


Filling in data gaps for verification
Verifying CONVECTION over full domain
Radar Extent
30°N
25°N
20°N
Surface Reports
Global Precipitation Mission (GPM) Satellite Extent
95°W 90°W 85°W 80°W 75°W 70°W
0 1 2 3 4 5 6 7 8
Vertically Integrated Liquid (kg/m2)
3-5 Nov 2015
GSD Science Review
4

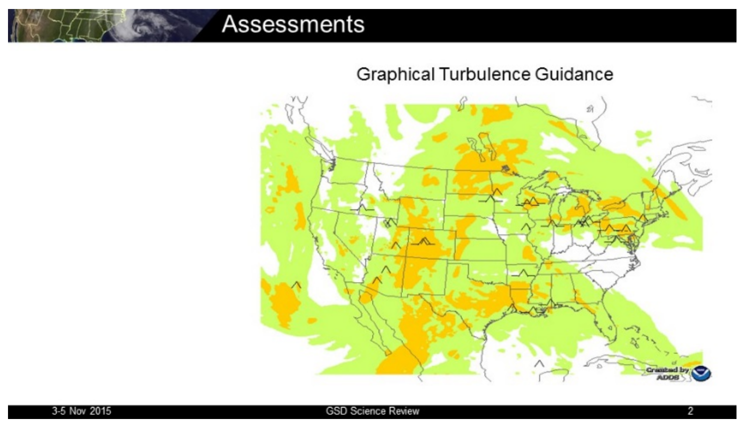

Supplementing Pilot Reports in Verification
Pilot Reports (PIREPs)
40°N
30°N
20°N
120°W
100°W
Aircraft Relative Humidity Measurements
CloudSat/CALIPSO Satellite Extent
3-5 Nov 2015
GSD Science Review
5

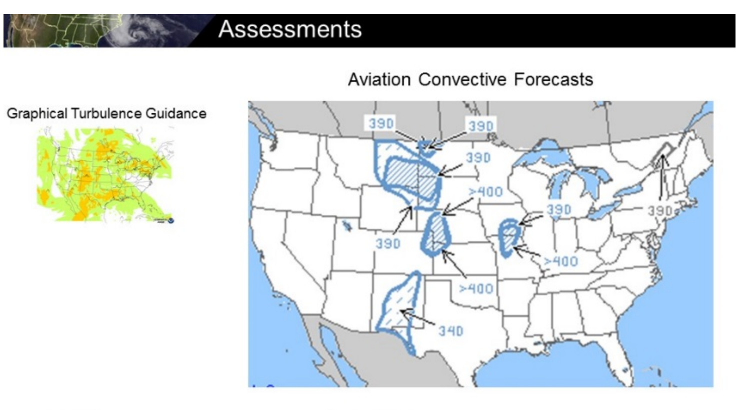

Supplementing Pilot Reports in Verification
Flight UAL912 / 2015-01-03 09:38:00
Pilot Reports (PIREPS)
PIREP Location Error Region
Aircraft Eddy Dissipation Rate (EDR)
PIREP
3-5 Nov 2015
GSD Science Review
6

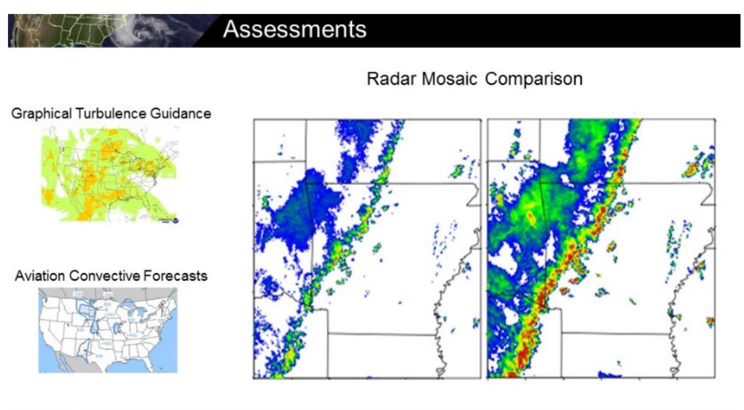
Summary

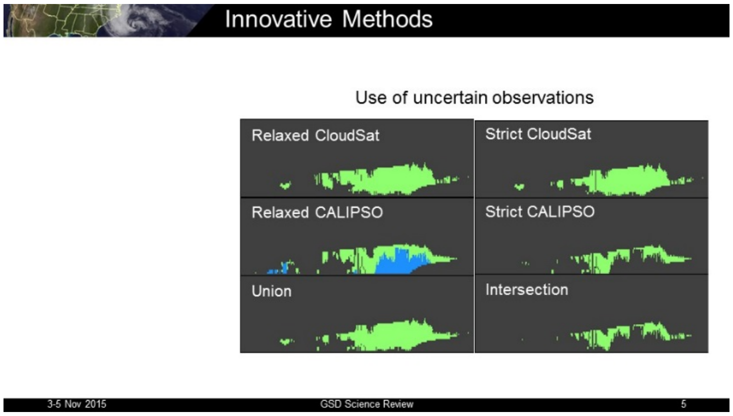
- We are investigating new truth sets and developing new verification techniques to support assessments and tools
- Future work
  - Global observations for turbulence and convection
  - Investigation of GOES-R for verification
  - Capturing forecast uncertainty through scenarios
- Please join me and co-author, Soner Yorgun, at our poster

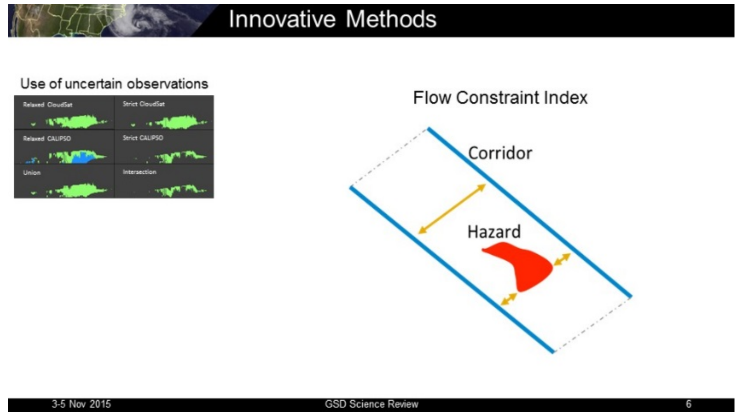
3-5 Nov 2015 GSD Science Review 7

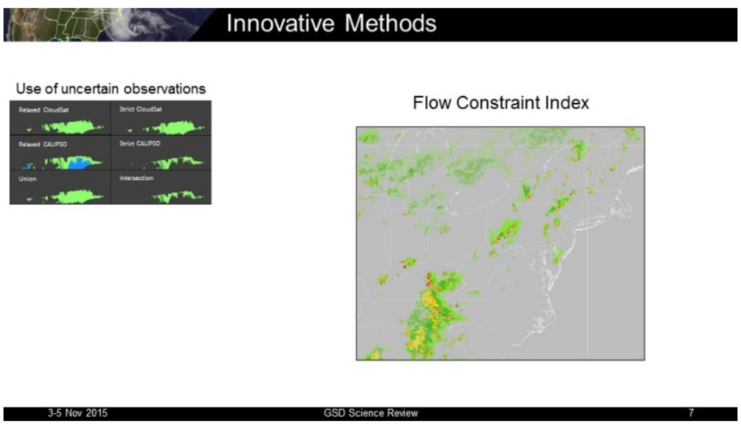


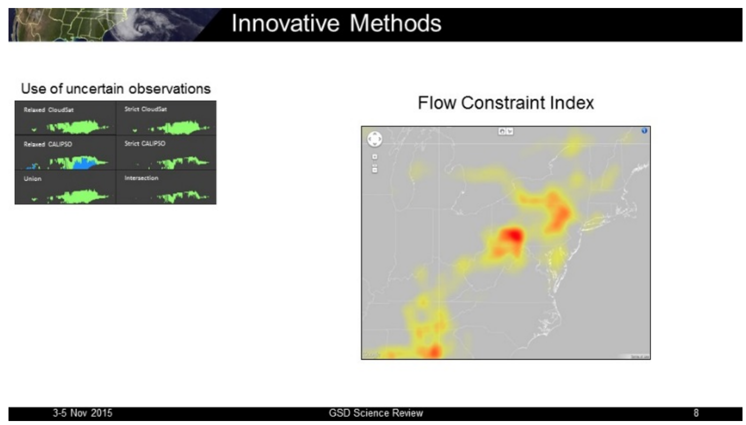


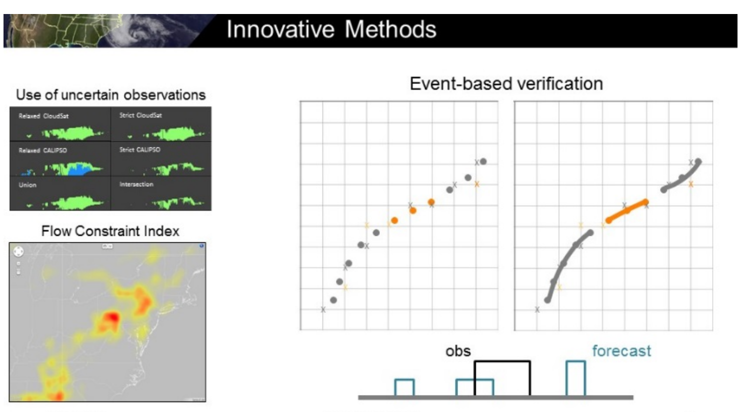


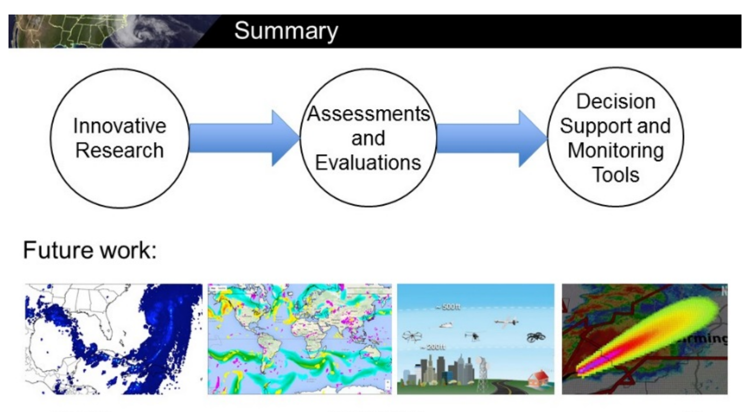

Innovative Methods
Use of uncertain observations
Relaxed CloudSat
Strict CloudSat
Relaxed CALIPSO
Strict CALIPSO
Union
Intersection
3-5 Nov 2015
GSD Science Review
5

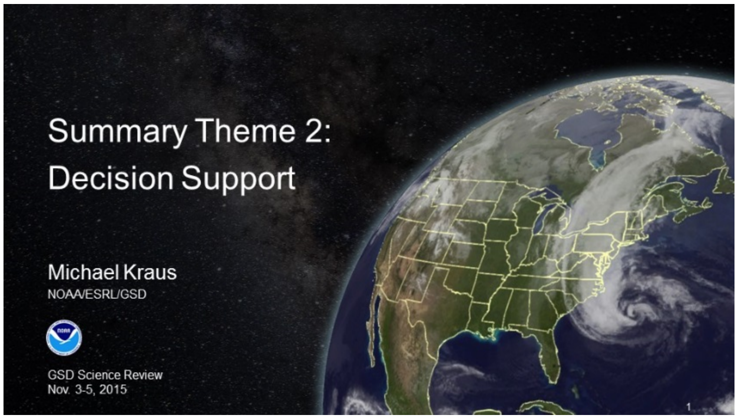

Innovative Methods
Use of uncertain observations
Flow Constraint Index
Corridor
Hazard
3-5 Nov 2015
GSD Science Review
6

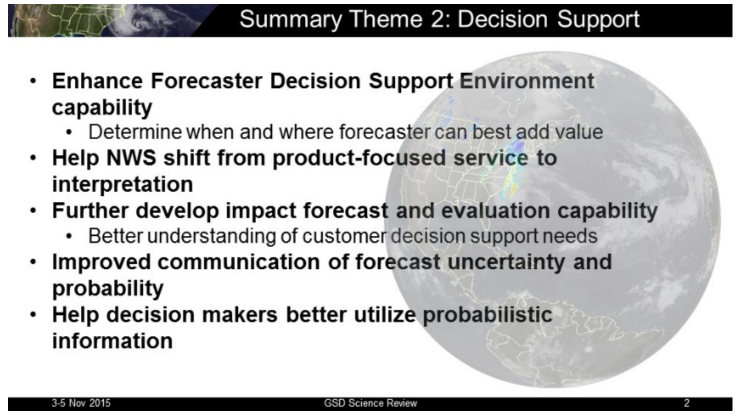

Innovative Methods
Use of uncertain observations
Flow Constraint Index
3-5 Nov 2015
GSD Science Review
7


Innovative Methods
Use of uncertain observations
Flow Constraint Index
3-5 Nov 2015
GSD Science Review
8


Innovative Methods
Use of uncertain observations
Flow Constraint Index
Event-based verification
obs
forecast
3-5 Nov 2015
GSD Science Review
9


Summary
Innovative Research
Assessments and Evaluations
Decision Support and Monitoring Tools
Future work:
3-5 Nov 2015
GSD Science Review
10


Summary Theme 2:
Decision Support
Michael Kraus
NOAA/ESRL/GSD
GSD Science Review
Nov. 3-5, 2015
1


Summary Theme 2: Decision Support
Enhance Forecaster Decision Support Environment capability
Determine when and where forecaster can best add value
Help NWS shift from product-focused service to interpretation
Further develop impact forecast and evaluation capability
Better understanding of customer decision support needs
Improved communication of forecast uncertainty and probability
Help decision makers better utilize probabilistic information
3-5 Nov 2015
GSD Science Review
2

Decision support tools for WFOs

Paul Schultz

Expanding role of WFOs

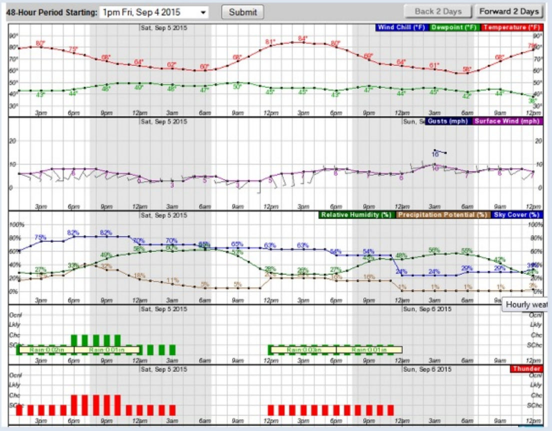
Users need more than the basic forecast

"How confident are you in your forecast?"

Uncertainty qualifiers:

- Event probabilities
- Alternative scenarios

A point forecast, the first basis for DS

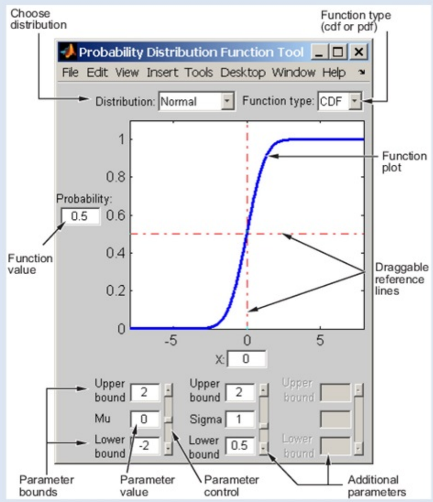


A "deterministic" forecast such as this is incomplete without additional information about the forecast's uncertainty.

Event probabilities

"What is the probability that the temperature will fall below 28F for three consecutive hours tonight?"

"What is the probability that the cross winds at I-25/Co7 will exceed 25 mph this afternoon?"



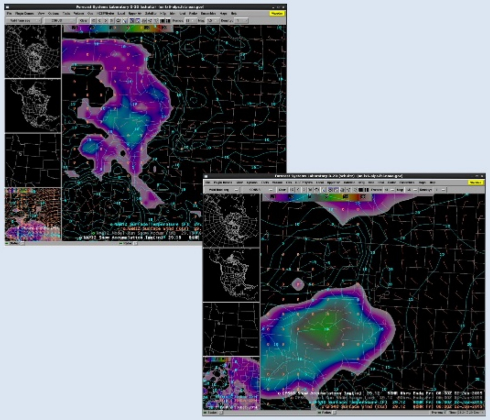
Distribution viewer example from MATLAB

Alternative scenarios

"What will the conditions be if the inversion doesn't break?"

"How cold will it get tonight if the clouds go away?"

"How much will the temperature drop if it rains?"

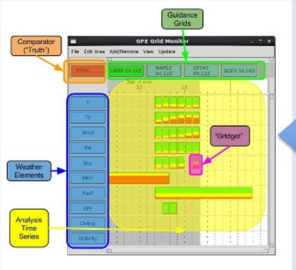


Forecast Monitoring and Short Term Updates

Kevin L. Manross, Thomas Lefebvre, I-Shan Tsai, Jeremy Kerr and Patrick Sobolewski

Forecast Monitoring

Graphical Forecast Editor Grid Monitor



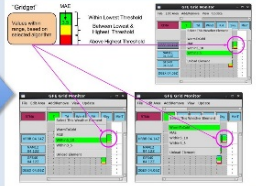
General layout of Graphical Forecast Editor "Grid Monitor"

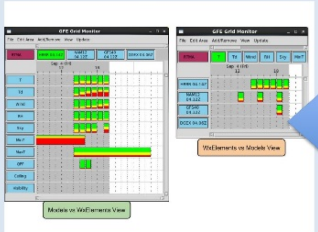
Highly configurable
- Model guidance selection
- Weather Element selection
- Spatial domain selection

"Gridget" Overview:

Used for quick assessment

Gridget display is configurable





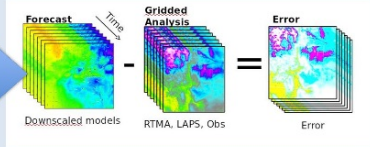
Forecasters can set preferred layout

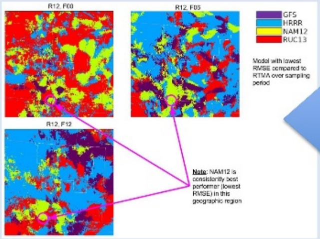
State (models, elements, layout) can be saved and recalled

Short Term Updates

Point Blender Framework

Create time-series of error grids





Determine best performing guidance (per MAE, RMSE, etc.) *at each gridpoint* and weight

Similar technique to NCEP-based "National Point Blender" project, but run at WFO to address 0-24 hour forecast period

Point Blender performance based on spatial mean MAE as compared to "Obs" verification grids.

Graphical User Interface developed to compare available guidance

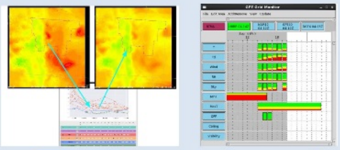
Archive:
- Separate, long-term HDF5 storage (time series of grids)
- Easily configurable

Efficient:
- Weights automatically update based on time window
- Bias-corrected grids calculated on the fly

Verification:
- User-selectable "Truth" dataset (RTMA, Obs, etc.)

Use Case

Combination of Tools Improves Efficiency



Setup → Assess → Update

Forecasters focus on support during incident/impact weather

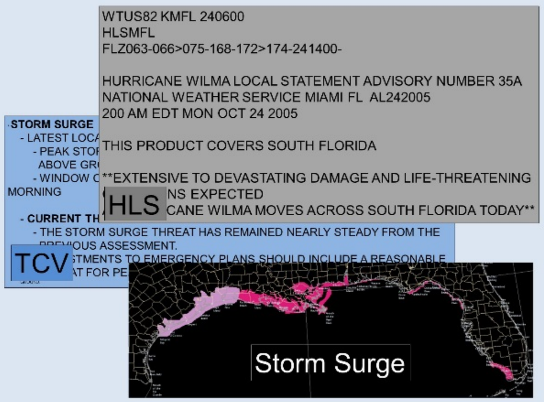
Tropical Hazards

Tom LeFebvre, Tracy Hansen, Paula McCaslin, and Sarah Pontius (CIRA)

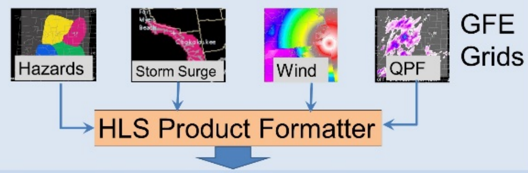
NWS improving the quality and precision of tropical forecasts

GSD is contributing to three separate efforts:

- Hurricane Local Statement (HLS) – text product formatter that provides detailed information such as watches, warnings, surge and tide,
- Tropical Cyclone Valid Time Event Code (TCV) – text product formatter that summarizes all watches and warnings by coastal breakpoint
- Digital Storm Surge – translates probabilistic storm surge forecasts into official Storm Surge Watches and Warnings

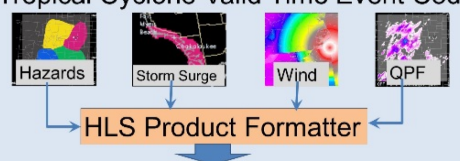


Hurricane Local Statement



**EXTENSIVE TO DEVASTATING DAMAGE AND LIFE-THREATENING CONDITIONS POSSIBLE AS HURRICANE WILMA MOVES NORTHEAST TOWARDS SOUTH FLORIDA
* STORM INFORMATION:
- ABOUT 530 MILES WEST-SOUTHWEST OF MIAMI...
- 21.4N 87.1W
- STORM INTENSITY 100 MPH
- MOVING NORTH OR 360 DEGREES AT 2 MPH
EXTREMELY DANGEROUS HURRICANE ...

Tropical Cyclone Valid Time Event Code

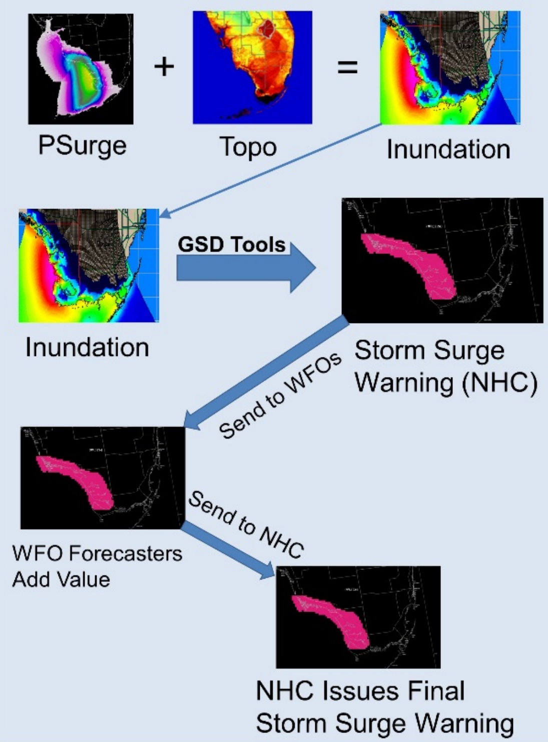


NATIONAL WEATHER SERVICE MIAMI FL AL242005
522 AM EDT SUN OCT 23 2005

FLZ173-231730-
/O.NEW.KMFL.HU.W.1024.051023T0922Z-000000T0000Z/
/O.UPG.KMFL.HU.A.1024.000000T0000Z-000000T0000Z/
\522 AM EDT SUN OCT 23 2005

...HURRICANE WARNING IN EFFECT...

Storm Surge Warning Generation



Unified and Consistent Hazardous Weather Forecasts

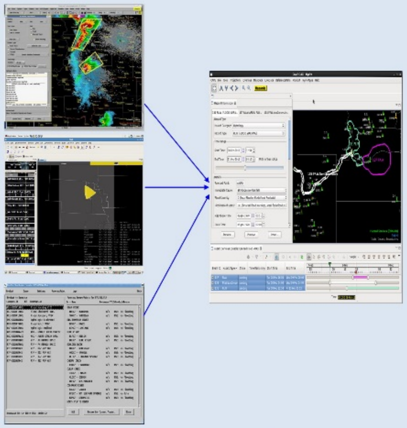
Tracy Hansen, Chris Golden, Kevin Manross, Jennifer Mahoney, Randy Pierce, Joe Wakefield, Susan Williams

Unifying Legacy Applications

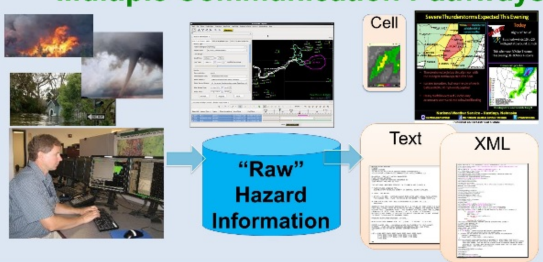
WarnGen (<1 hour)

Graphical Hazard Generator (Hours, Days)

RiverPro (Days)



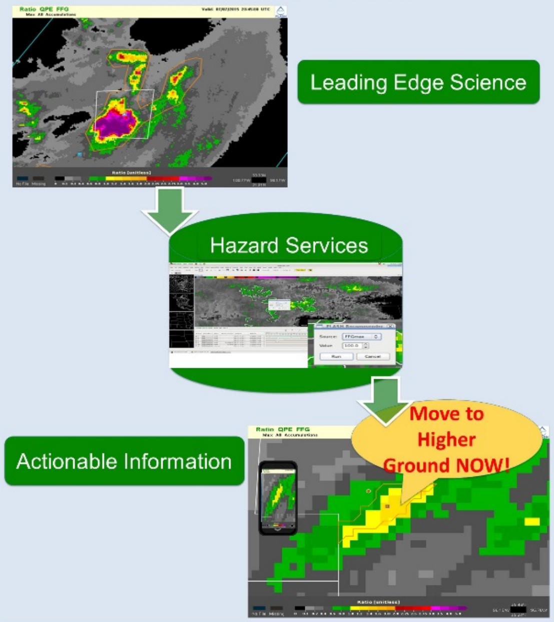
Multiple Communication Pathways



Forecast Process

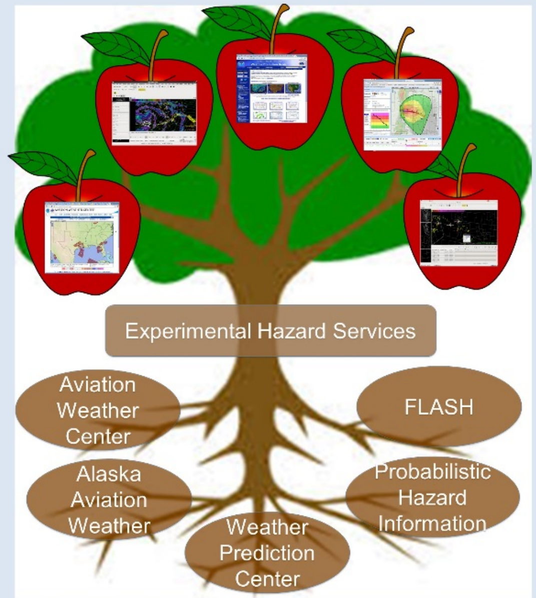
Conduit for Transforming Leading edge science into Actionable Information

A better-informed Weather-Ready Nation that is resilient in the face of high impact weather and environmental events



Consistent Continuous Forecasts

- **Consistency and accuracy across hazard phenomena on local to national scales**
- **Partnering to improve communicating probabilities and uncertainty – Forecasting a Continuum of Environmental Threats (FACETs)**



Sharing the Wealth: Forecaster Tools for Our Partners

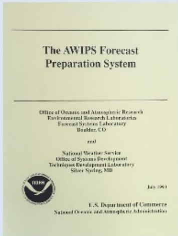
Joe Wakefield, Xiangbao Jing (CIRES), Tom LeFebvre, Tracy Hansen, Evan Polster (CIRA)

GFE: The Graphical Forecast Editor

Origins:

AFPS: AWIPS Forecast Preparation System

Early design work 1990-1993.



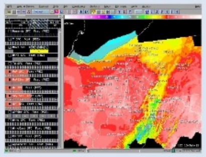
Development:

GFE

Prototypes 1993-1999

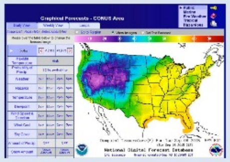
Rapid Prototyping 1999-2003

Operations: 2001-present



Forecasters manage a catalog of grids representing expected sensible weather conditions for the coming week.

Which become the source for forecasts, both locally and nationally. (Also used for long-fused hazards.)



Australia Bureau of Meteorology

Under a five-year agreement, NOAA helped BoM adapt the GFE for their use. Rolled out over several years, operational nation-wide in 2014.

Basic operation similar to NWS, but significantly modernized.

Agencia Estatal de Meteorología (AEMET) Spain

Seeing the success at BoM, AEMET approached GSD to help with a similar application of GFE to their local situation. Initial operations commenced 2014.

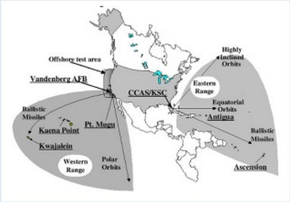
Wildfire Operations

Exploratory R&D of services and tools for fire weather decision support

- National Interagency Fire Center (NIFC) - Field meteorologists, fire resource managers
- Wildland Fire Management Research, Development, and Application
- Cloud-based software-as-a-service, AWIPS II virtual server

Spacelift Weather Support

Range Standardization and Automation (RSA)



- U.S. Air Force program, applied at the Western Range (Vandenberg)
- Customized AWIPS-I, with national + local data, local model

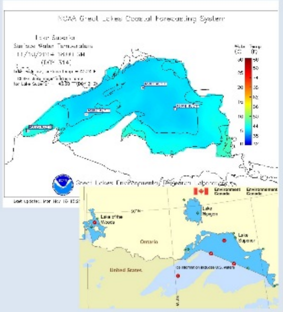
Taiwan Central Weather Bureau

Recent work with CWB has focused on transition from AWIPS I to AWIPS II; visitors learning about how to ingest and display local datasets.

CWB staff engaged in our development – GFE tools, Hazard Services, Decision Support tools – while supporting forecast operations.

Canada

GSD participates in bi-lateral planning to support collaboration between Environment Canada and NWS on common concerns such as Great Lakes shipping forecasts.



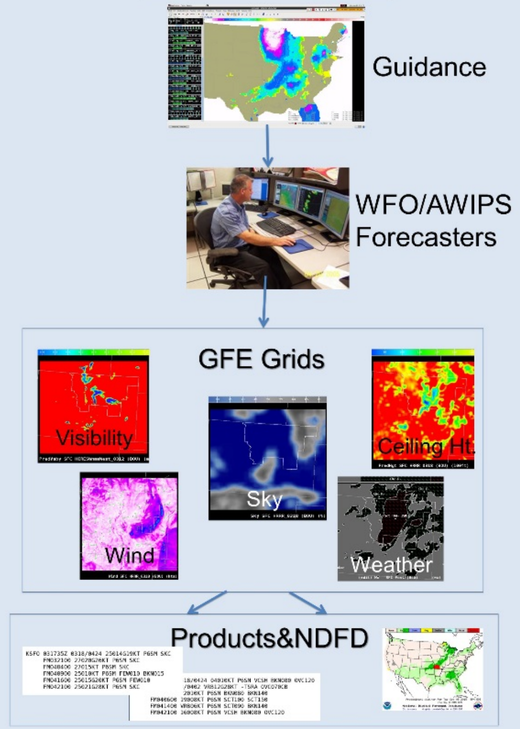
Aviation Forecasting with AWIPS

Woody Roberts, Tom LeFebvre, Tracy Hansen, Joe Wakefield, Kevin Manross, Sarah Pontius

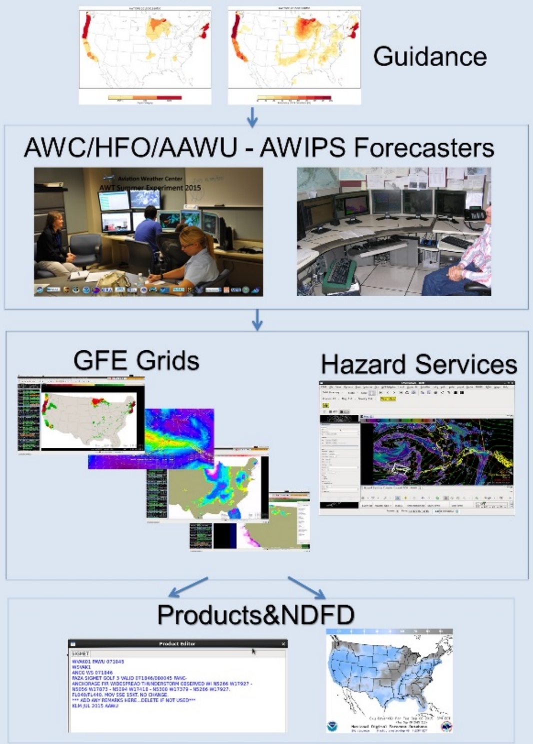
Aviation in AWIPS – A brief history

- Air Force Range Standardization and Automation (RSA)
  - Began in mid-1990s with transition to AWIPS system at Vandenberg
  - Became operational in mid 2000s
  - Includes specialized and customized features for enhanced range observations and LAPS analysis.
- Interactive Calibration in 4-Dimensions (IC4D)
  - Initially prototyped by NWS/MDL (starting with AWIPS/GFE) for evaluation by the Alaska Aviation Weather Unit (AAWU) ~2009.
  - Capability evaluated by GSD (Roberts, 2012)
  - Recommended capability transition to AWIPS-II baseline now under way.
- Terminal Aerodrome Forecasts (TAFs) using the AWIPS GFE for Ceiling and Visibility (C/V)
  - Capabilities initially developed by Eastern Region (ER) WFOs using AWIPS/GFE ~2009
  - Capabilities evaluated by GSD (Roberts, 2013) at 4 ER WFO's.
  - Recommended capability transition to AWIPS-II baseline now under way.
- In-flight Aviation product generation at the Aviation Weather Center (AWC) using GFE and Hazard Services
  - Initial demonstration/evaluation conducted at the Aviation Weather Testbed (AWT) in 2015.
  - Prototype tools under development at GSD
- Common technical challenges:
  - Content requirements
  - Formatting
  - Filtering out unnecessary information
  - Customization for specific range, areas, airports, and runway configurations
- Scientific challenges:
  - Aviation impact variables (ceiling, visibility, icing, turbulence, etc.) not well represented in NWS guidance.
  - Rapidly-changing conditions difficult to represent in analyses and NWP in a timely fashion.

Near Surface



In Flight



Impact-based Decision Support for Aviation

Brian Etherton, Forecast Impact and Quality Assessment Section

FCI

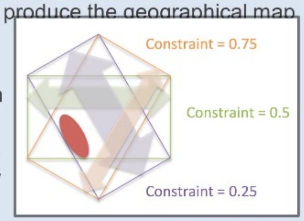
Flow Constraint Index

The Flow Constraint Index highlights potential constraints by combining raw weather information with air-traffic density, emphasizing constraint in areas of denser traffic

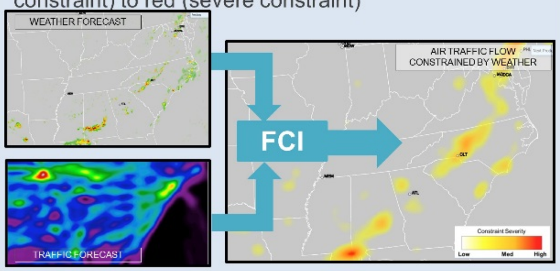
The area of interest (the CONUS) is broken into a set of hexagons. Traffic can flow in three different directions through each hexagon. Information for the individual hexagons is combined to produce the geographical map

FCI for each hexagon is computed as a normalized weighted sum

FCI = 0.75*(SW/NE)Flow
+ 0.5 *(W/E)Flow
+ 0.25*(NW/SE)Flow



The resulting summary is a 'heat map' representing constraint using a color spectrum from yellow (low constraint) to red (severe constraint)

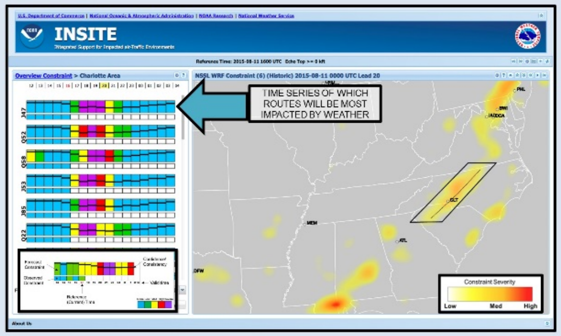


INSITE

Integrated Support for Impacted air-Traffic Environments

INSITE is a web-based tool designed to provide forecaster guidance by highlighting areas of potential impact and providing detailed information on the effects of convective weather on aviation operations.

- •Supporting a shift from product focus to product interpretation and consultation
- •Communicating on-demand forecast confidence information
- •Delivering information in a way that conveys potential impacts and supports good decision-making and planning



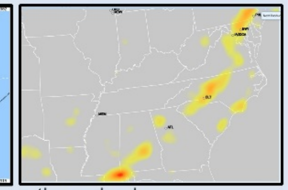
Time Summary

Summary constraint values are compuated for a specific time period and region using the hexagons contained within that region. Information is categorized and presented in a time series format for quick identification of event timing.

Transition/Expansion

Transition of INSITE to operations

The establishment of the Collaborative Aviation Weather Statement (CAWS) as a product produced by the NWS Aviation Weather Center (AWC) has proven the utility of the INSITE tool.



INSITE shall transition to operations via close collaboration with our partners. The platform for this transition if the Integrated Dissemination Program (IDP).

Expansion of INSITE

At present, INSITE is only configured to calculate the constraint to air traffic resulting from convection. There are a number of other weather types that can constrain air traffic, including: Winds, Ceiling and Visibility, and Winter Weather.

As INSITE is transitioned to operations, work will continue at GSD to incorporate these other types of weather into INSITE
http://esrl.noaa.gov/fiqas/tech/impact/insite/

Verification Tools for Aviation Weather

Missy Petty, Forecast Impact and Quality Assessment Section

Automated Tools

GSD has years of experience in the development of automated web-based verification tools for aviation weather that provide

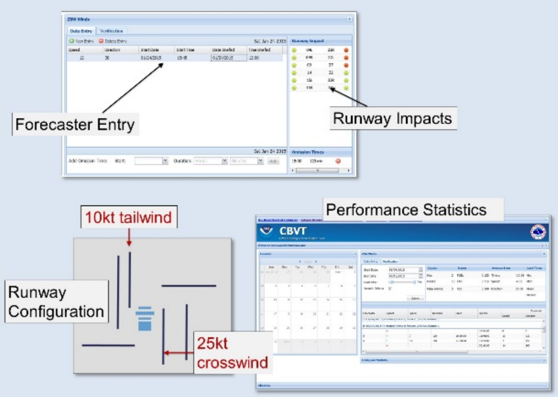
- Operationally relevant metrics – where weather matters
- Ongoing performance monitoring
- Feedback to Forecasters and Developers
- Support for in-depth analysis for assessments

CBVT

CWSU Briefing and Verification Tool

Capture CWSU briefings of wind shifts impacting current runway configuration

Challenge: Automated identification of wind events in ASOS observations

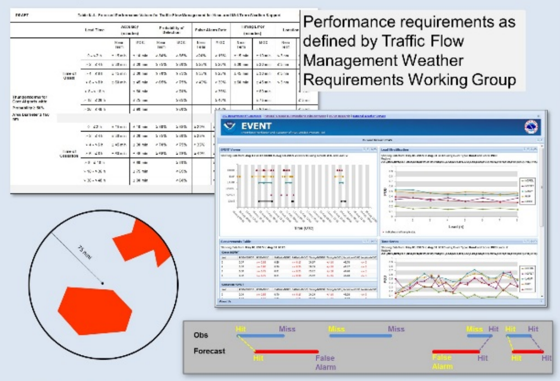


EVENT

Event-based Verification and Evaluation of NWS Gridded Products Tool

- Measure performance of NWS products in the context of thunderstorms at the terminal
- Requirements defined by TRWG
- Lead time to onset and cessation of events

Challenge: Defining event based verification techniques



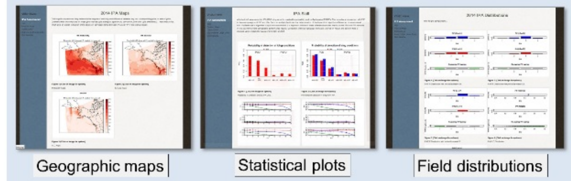
- Thunderstorm events within 75 nmi radius around terminal
- %coverage defines event
- Construct time series and merge into events with duration
- Matches occur within a certain time window
- Metrics for Onset and Cessation

VRMC

Verification Requirements and Monitoring Capability

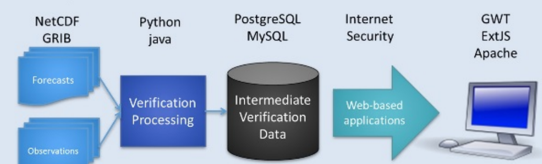
Supports assessment and monitoring of FAA AWRP products

Challenge: Flexibility for in-depth analysis



Technical Challenges

- Efficient storage and processing of raw data
- Timely computation
- Responsive user interface



Future Work

- CBVT: Extension to Ceiling &Visibility
- EVENT: Extension to other weather variables (winds, icing)
- VRMC: Capabilities for convection

Core Research: Datasets Investigation and Technique Development

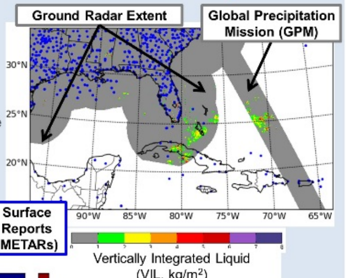
Laura Paulik[2], Soner Yorgun[2], and Forecast Impact and Quality Assessment Section

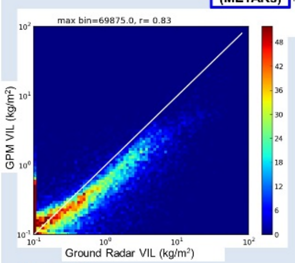
2 CIRES
CIRA

Verifying Offshore Precipitation with Satellite Data and Surface Reports

Filling the Data Gaps

Global Precipitation Mission (GPM) satellite data and surface reports (METARs) were investigated prior to the Offshore Precipitation Capability (OPC) Assessment, a product that provides radar-like variables over the Caribbean and western Atlantic.



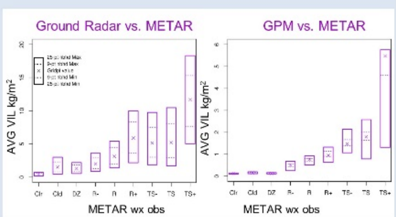


GPM Compared to Ground Radar

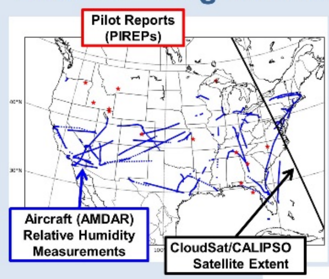
Vertically Integrated Liquid (VIL) derived from ground radar was compared to GPM satellite-derived VIL to better understand agreement where the products overlap and determine biases useful in assessing the OPC.

METAR Investigation

Ground and satellite radar signature associated with each present weather category were examined in order to evaluate the OPC product where surface reports stand alone.



Examining Aircraft and Satellite Data for Icing Verification

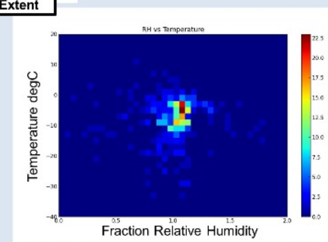


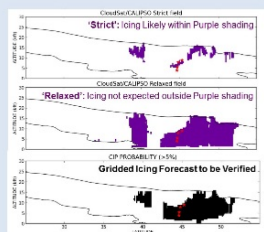
PIREPs: Background

PIREPs provide valuable in-situ observations of weather phenomena, such as icing and turbulence. However, they are inherently subjective. The location (horizontal and vertical), time and the intensity of the reported weather phenomenon are based on aircrew interpretation.

AMDAR Compared to PIREPs

Aircraft (AMDAR) observations of relative humidity were compared to icing PIREPs in order to identify the distributions of temperature and moisture associated with an icing event.





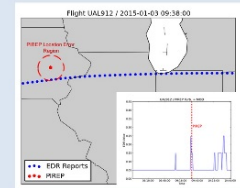
Satellite Datasets for Icing

CloudSat and CALIPSO cloud classification vertical cross-sections were used to implement icing verification given their usefulness in differentiating microphysical properties and determining icing potential.

PIREP Location Errors

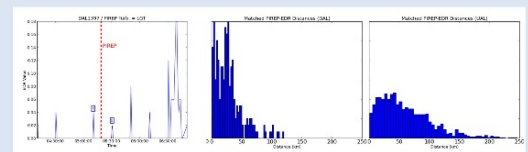
Eddy Dissipation Rate (EDR)

- Aircraft-independent measure of atmospheric turbulence.
- EDR measurements from Delta and United Airlines are compared to PIREPs.
- Jan 2013 – Jun 2015 period is analyzed.



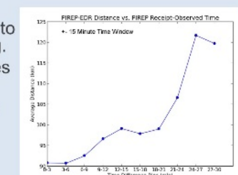
Matching PIREPs to EDRs

- PIREPs are matched to their corresponding set of EDRs from the same aircraft.
- Different time windows (around a PIREP) are used to match the maximum peak EDR value to the PIREP.



Summary of Results

- PIREP location errors show sensitivity to the choice of time window for matching.
- Location error statistics for ±7.5 minutes window agree with previous studies.
- There is a strong relationship between the PIREP report lag and the location errors.



- Further work is required to incorporate this new information into verification techniques

Assessment of Aviation Algorithms and Forecast Technologies

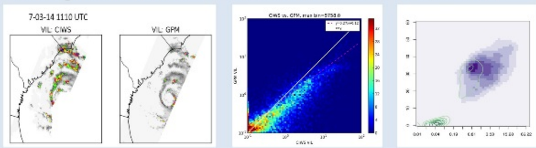
Matthew Wandishin, Forecast Impact and Quality Assessment Section

Introduction

Assessments are often just one step of a verification process in which core research informs assessments which then undergird ongoing monitoring efforts.

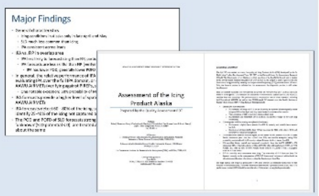
Core Research

Investigation of new data, new methods, new scores

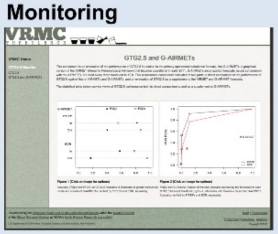


Assessments

Findings are presented along with a formal document of the results. This is used by FAA management for R2O decisions.



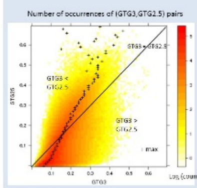
Monitoring



If the product moves into operations, the assessment infrastructure is leveraged to provide ongoing analysis via the Verification Requirements and Monitoring Capability (VRMC).

Examples:

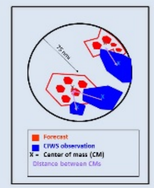
Graphical Turbulence Guidance



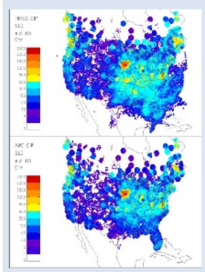
- The distribution of forecast values in GTG3 displayed a marked shift compared to the GTG2.5
- Product just recently moved to operations with a new approach to displaying the forecast information

EVENT Thunderstorm and Winds

- Thunderstorm: The remarkable gap between product skill and MOC requirements questions the practicality of those requirements
- Winds: Led to a consideration of the need for post-processing even for variables explicitly forecast by the models

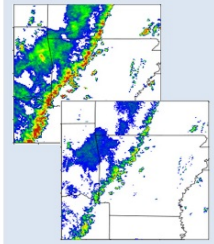


Current (Forecast) Icing Product



- Highlighted the differences between the prototype version developed at NCAR and the implemented version at AWC
- Also identified 'holes' in the CIP field that led to lower performance of the CIP than for the 1-h FIP forecast

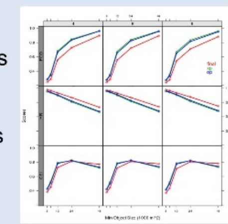
Radar Mosaic Comparison



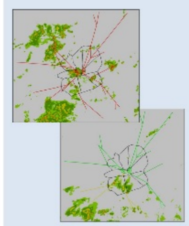
- The two radar mosaics present sharply dissimilar views of the intensity and coverage of the convection
- Led to the producer of the new product to create a new, aviation-targeted version of the VIL and ET fields

Auto-CCFP

- The auto-generated product has similar skill to the human-generated product, though with different forecast characteristics
- This helped alleviate concerns over the move away from the human-generated product



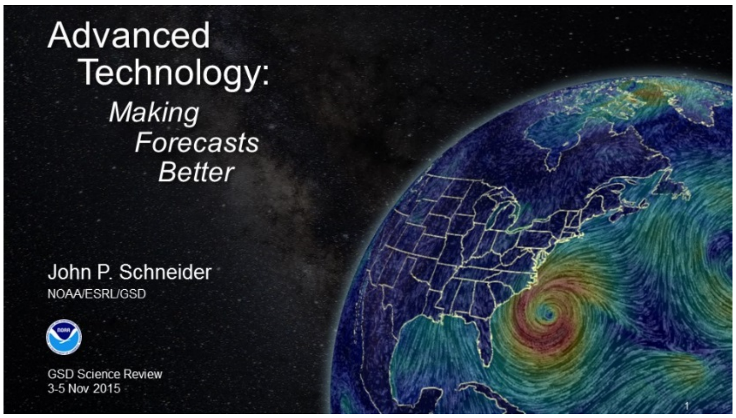
TRACON Gate Forecasts

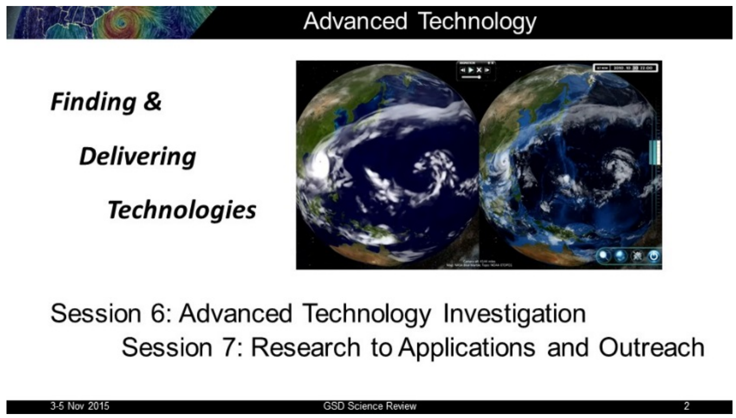


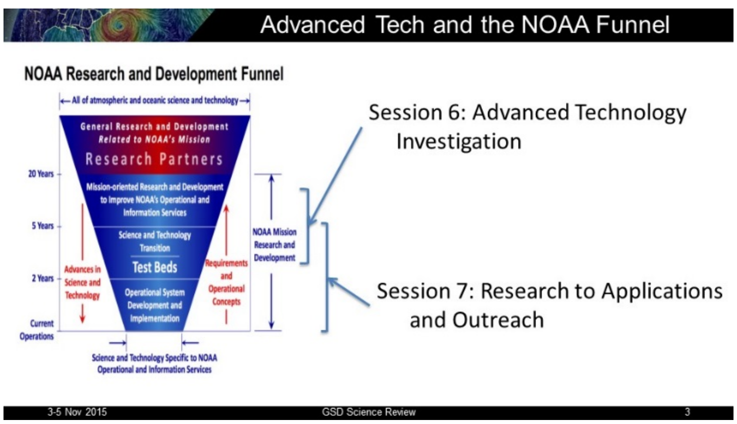
- Found substantially different results at CLT compared to ATL, where the forecast rules were developed
- This highlighted the fact that implementation of the forecast for other airports will likely not follow a simple plug-and-play model

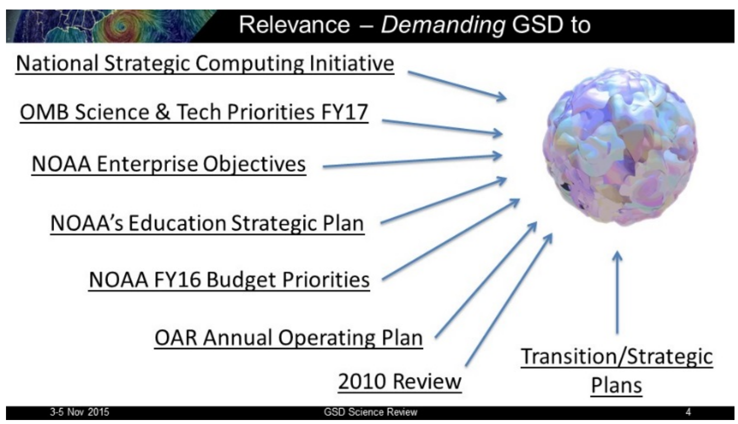
Session 6: Advanced Technologies

- Opening Talk: Advanced Technology (John Schneider)
- The NOAA Earth Information System (NEIS) Data Discovery, Collection, and Distribution (Jebb Stewart)
- Advanced Visualization Development using Gaming Technology (Eric Hackathorn)
- Massively Parallel Fine Grain (MPFG) Computing (Mark Govett)
- Specialized Information and Warning Systems (Greg Pratt)
- Science on a Sphere (SOS): Technical Innovation and Network Growth (Keith Searight and Shilpi Gupta)

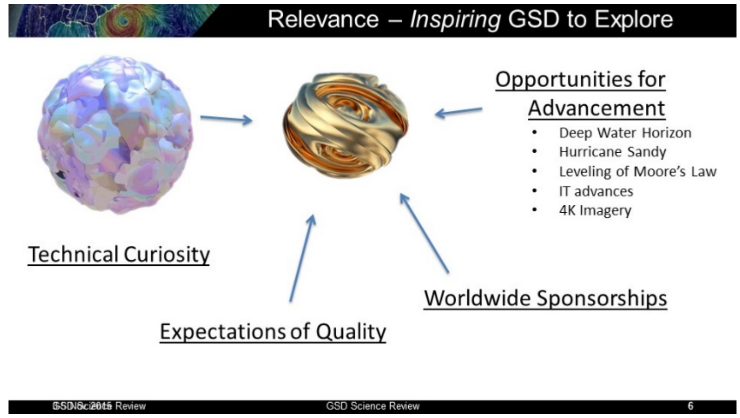


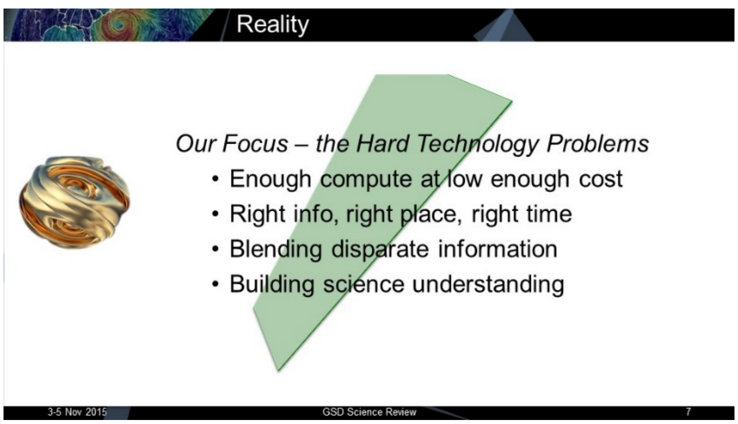


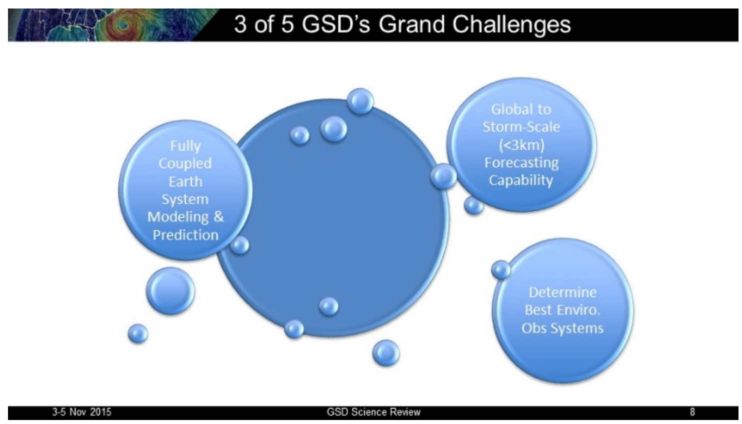


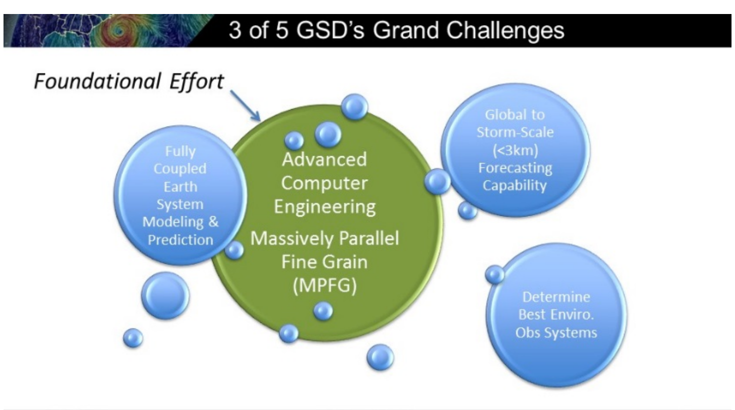


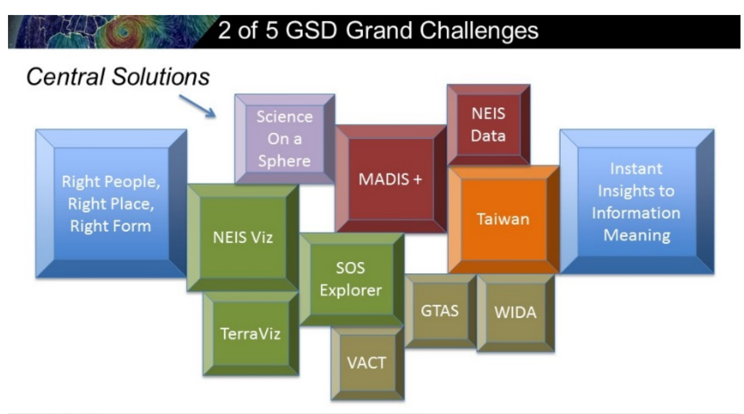

Relevance – *Inspiring* GSD to Explore
Opportunities for Advancement
• Deep Water Horizon
• Hurricane Sandy
• Leveling - Moore's Law
• IT advances
• 4K Imagery
Technical Curiosity
Worldwide Sponsorships
Expectations of Quality
3-5 Nov 2015
GSD Science Review
5

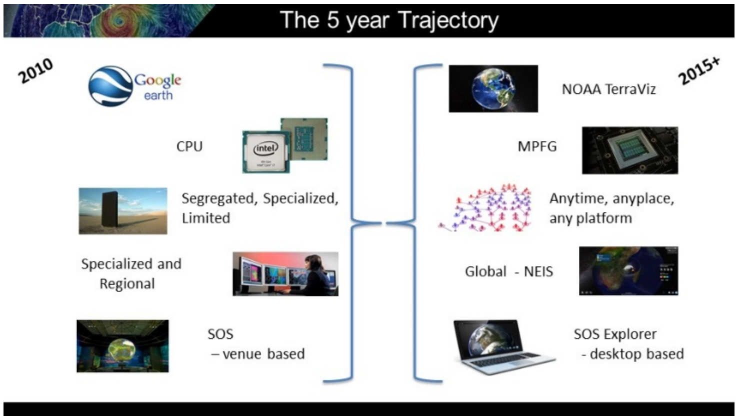

Relevance – *Inspiring* GSD to Explore
Opportunities for Advancement
• Deep Water Horizon
• Hurricane Sandy
• Leveling of Moore's Law
• IT advances
• 4K Imagery
Technical Curiosity
Worldwide Sponsorships
Expectations of Quality
GSD Science Review
6

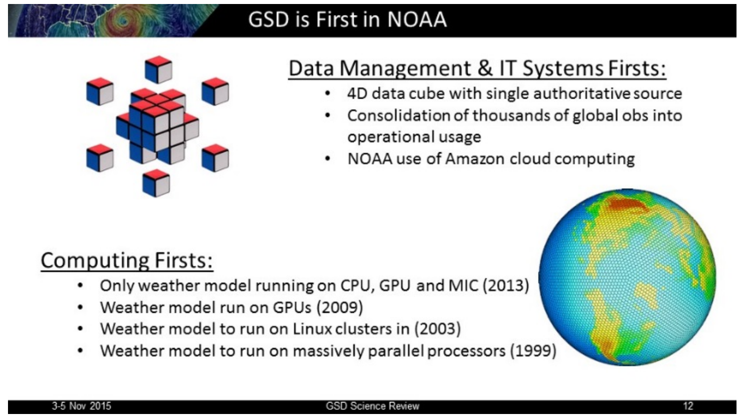

Reality
Our Focus – the Hard Technology Problems
• Enough compute at low enough cost
• Right info, right place, right time
• Blending disparate information
• Building science understanding
3-5 Nov 2015
GSD Science Review
7

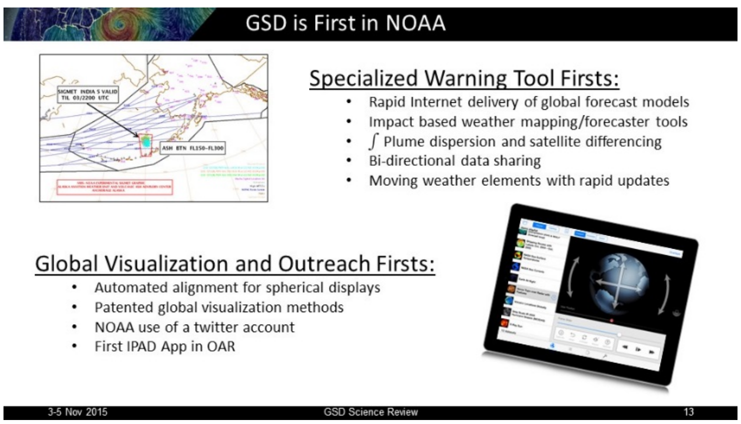

3 of 5 GSD's Grand Challenges
Fully Coupled Earth System Modeling & Prediction
Global to Storm-Scale (<3km) Forecasting Capability
Determine Best Enviro. Obs Systems
3-5 Nov 2015
GSD Science Review
8

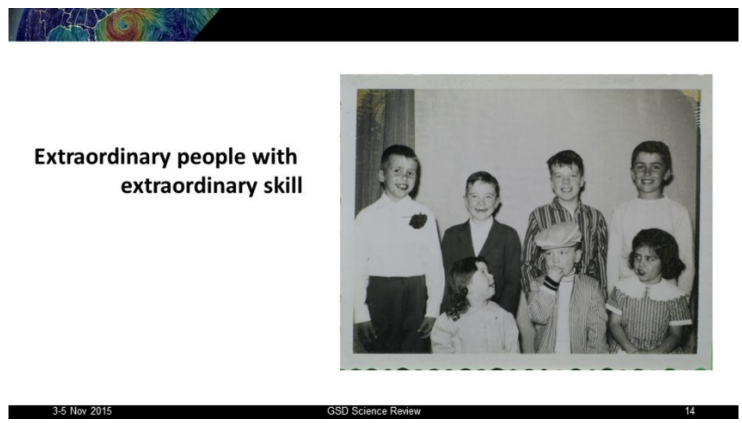

3 of 5 GSD's Grand Challenges
Foundational Effort
Fully Coupled Earth System Modeling & Prediction
Advanced Computer Engineering
Massively Parallel Fine Grain (MPFG)
Global to Storm-Scale (<3km) Forecasting Capability
Determine Best Enviro. Obs Systems
3-5 Nov 2015
GSD Science Review
9


2 of 5 GSD Grand Challenges
Central Solutions
Right People, Right Place, Right Form
Science On a Sphere
NEIS Data
MADIS +
NEIS Viz
Taiwan
Instant Insights to Information Meaning
SOS Explorer
GTAS
WIDA
TerraViz
VACT
3-5 Nov 2015
GSD Science Review
10

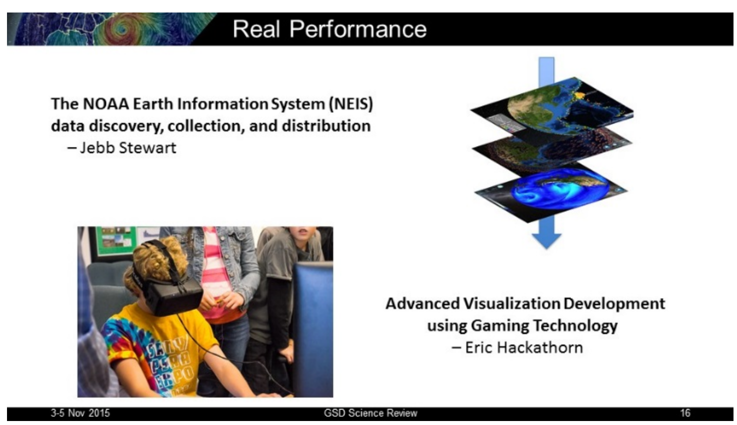

The 5 year Trajectory
2010
Google earth
CPU
Segregated, Specialized, Limited
Specialized and Regional
SOS
– venue based
2015+
NOAA TerraViz
MPFG
Anytime, anyplace, any platform
Global - NEIS
SOS Explorer
- desktop based

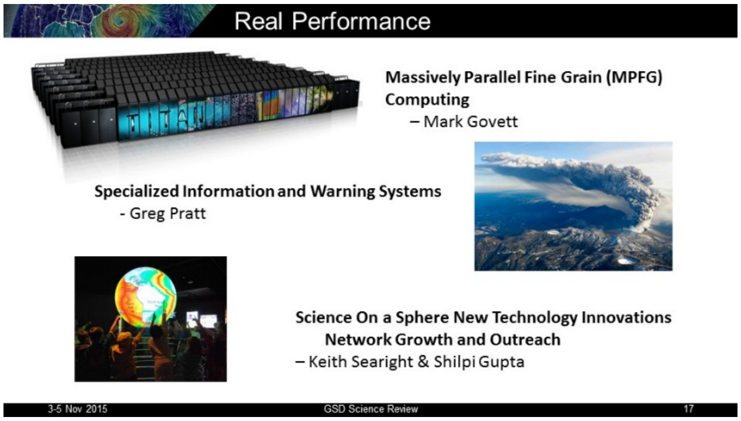

GSD is First in NOAA
Data Management & IT Systems Firsts:
• 4D data cube with single authoritative source
• Consolidation of thousands of global obs into operational usage
• NOAA use of Amazon cloud computing
Computing Firsts:
• Only weather model running on CPU, GPU and MIC (2013)
• Weather model run on GPUs (2009)
• Weather model to run on Linux clusters in (2003)
• Weather model to run on massively parallel processors (1999)
3-5 Nov 2015
GSD Science Review
12


GSD is First in NOAA
Specialized Warning Tool Firsts:
• Rapid Internet delivery of global forecast models
• Impact based weather mapping/forecaster tools
• ∫ Plume dispersion and satellite differencing
• Bi-directional data sharing
• Moving weather elements with rapid updates
Global Visualization and Outreach Firsts:
• Automated alignment for spherical displays
• Patented global visualization methods
• NOAA use of a twitter account
• First IPAD App in OAR
3-5 Nov 2015
GSD Science Review
13

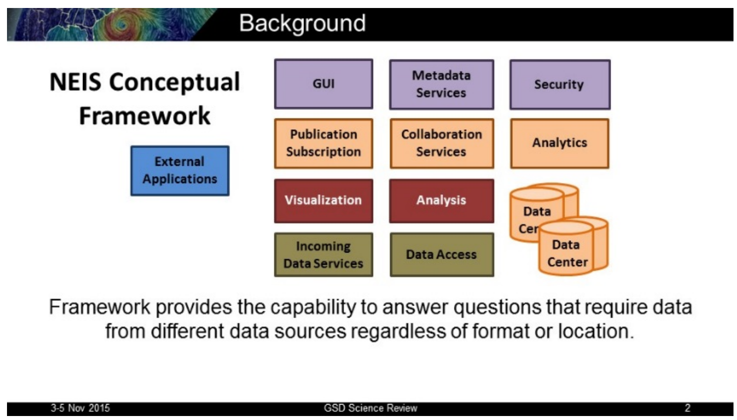

Extraordinary people with extraordinary skill
3-5 Nov 2015
GSD Science Review
14

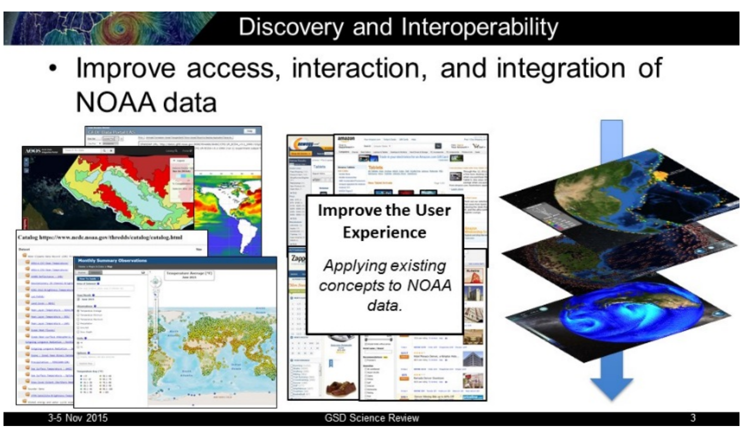

Session 6:
Advanced Technology Investigations
John P. Schneider
NOAA/ESRL/GSD
GSD Science Review
Nov. 3-5, 2015
15

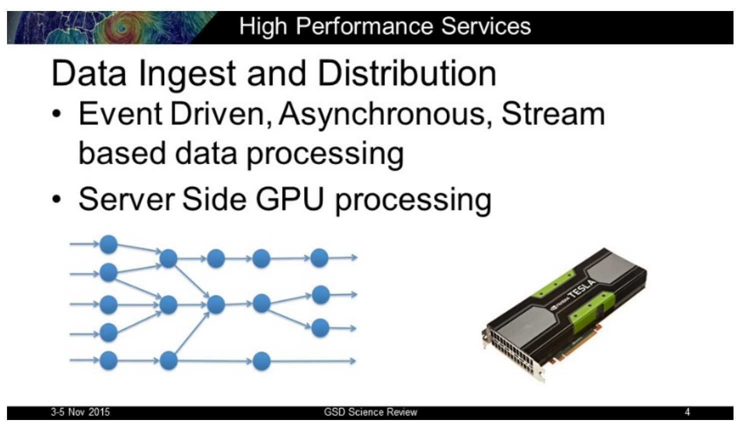

Real Performance
The NOAA Earth Information System (NEIS) data discovery, collection, and distribution
– Jebb Stewart
Advanced Visualization Development using Gaming Technology
– Eric Hackathorn
3-5 Nov 2015
GSD Science Review
16

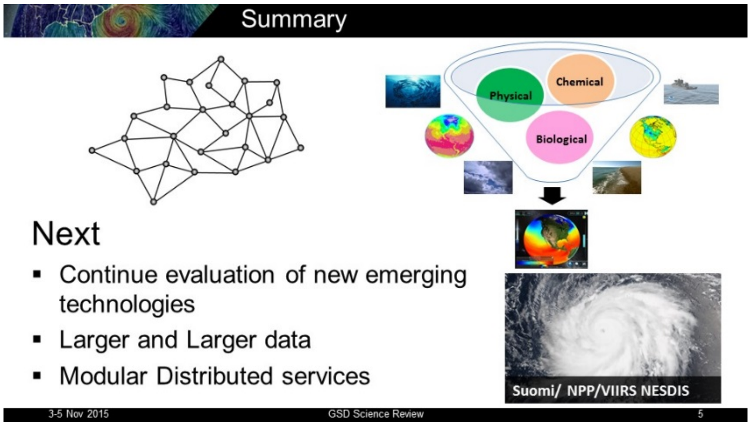

Real Performance
Massively Parallel Fine Grain (MPFG) Computing
– Mark Govett
Specialized Information and Warning Systems
- Greg Pratt
Science On a Sphere New Technology Innovations
Network Growth and Outreach
– Keith Searight & Shilpi Gupta
3-5 Nov 2015
GSD Science Review
17


The NOAA Earth Information System (NEIS)
Jebb Q Stewart
CIRA
Performing work for ESRL/GSD
GSD Science Review
3-5 Nov 2015
1


Background
NEIS Conceptual Framework
External Applications
GUI
Metadata Services
Security
Publication Subscription
Collaboration Services
Analytics
Visualization
Analysis
Data Center
Data Center
Incoming Data Services
Data Access
Framework provides the capability to answer questions that require data from different data sources regardless of format or location.
3-5 Nov 2015
GSD Science Review
2


Discovery and Interoperability
• Improve access, interaction, and integration of NOAA data
Improve the User Experience
Applying existing concepts to NOAA data.
3-5 Nov 2015
GSD Science Review
3


High Performance Services
Data Ingest and Distribution
• Event Driven, Asynchronous, Stream based data processing
• Server Side GPU processing
3-5 Nov 2015
GSD Science Review
4

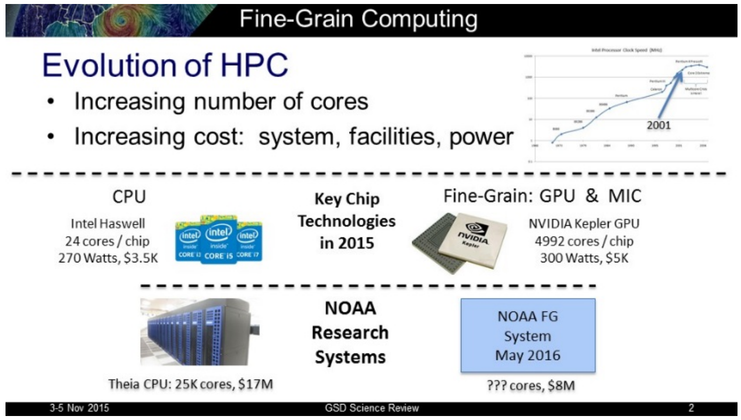

Summary
Physical
Chemical
Biological
Next
▪ Continue evaluation of new emerging technologies
▪ Larger and Larger data
▪ Modular Distributed services
Suomi/ NPP/VIIRS NESDIS
3-5 Nov 2015
GSD Science Review
5

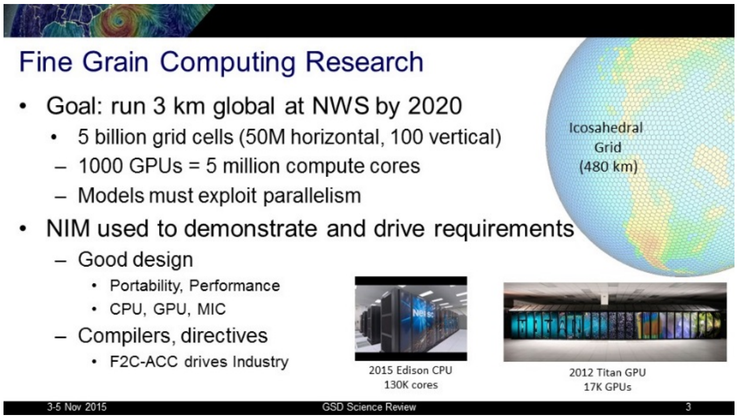

Advanced Visualization using Gaming Technology
Eric Hackathorn
NOAA/ESRL/GSD
GSD Science Review
3-5 Nov 2015
1

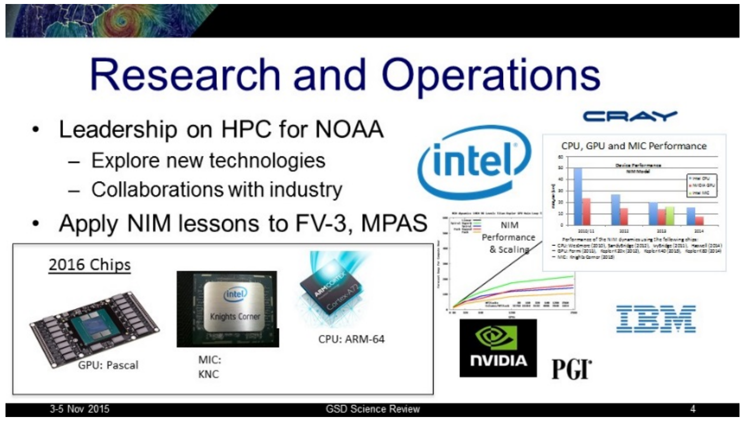

Gaming Technology
• What is your research
– Using game engines to drive the next generation of interactive data visualization and analysis
• Why is it important
– Gaming drives new technology as a research organization we need to keep up with industry trends
– Leveraging a multi-billion dollar industry in something with more value than pure entertainment
Photos by Will von Dauster
3-5 Nov 2015
GSD Science Review
2


Overview
GAMING TECHNOLOGIES
3-5 Nov 2015
GSD Science Review
3

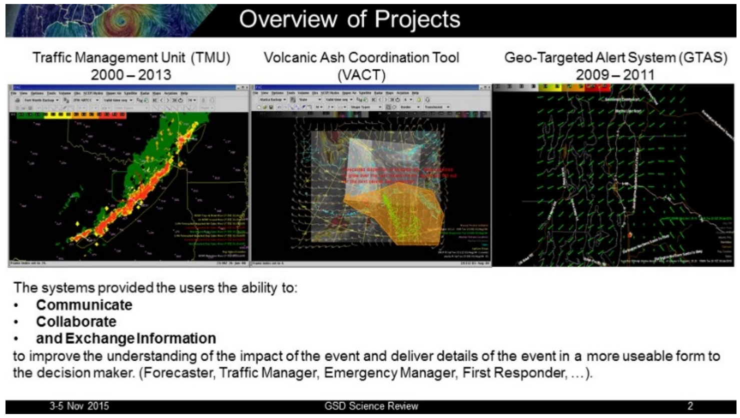

Fine-Grain Computing
Mark Govett
NOAA/ESRL/GSD
GSD Science Review
3-5 Nov 2015
1

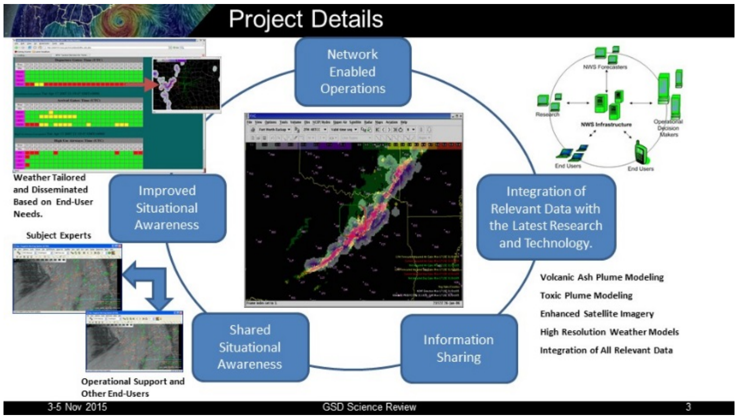

Fine-Grain Computing
Evolution of HPC
• Increasing number of cores
• Increasing cost: system, facilities, power
2001
CPU
Intel Haswell
24 cores / chip
270 Watts, $3.5K
Key Chip Technologies in 2015
Fine-Grain: GPU & MIC
NVIDIA Kepler GPU
4992 cores / chip
300 Watts, $5K
NOAA Research Systems
Theia CPU: 25K cores, $17M
NOAA FG System May 2016
??? cores, $8M
3-5 Nov 2015
GSD Science Review
2

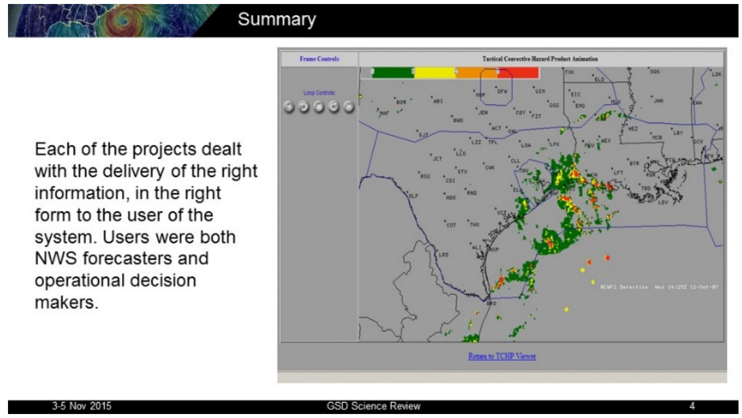

Fine Grain Computing Research
• Goal: run 3 km global at NWS by 2020
• 5 billion grid cells (50M horizontal, 100 vertical)
– 1000 GPUs = 5 million compute cores
– Models must exploit parallelism
• NIM used to demonstrate and drive requirements
– Good design
• Portability, Performance
• CPU, GPU, MIC
– Compilers, directives
• F2C-ACC drives Industry
Icosahedral Grid (480 km)
2015 Edison CPU
130K cores
2012 Titan GPU
17K GPUs
3-5 Nov 2015
GSD Science Review
3

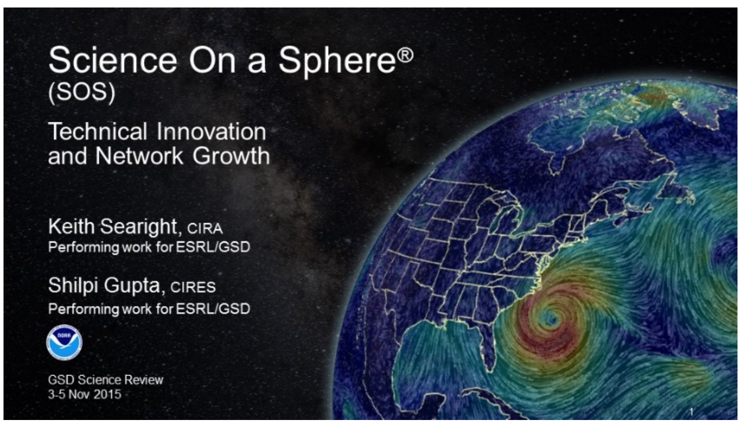

Research and Operations
• Leadership on HPC for NOAA
– Explore new technologies
– Collaborations with industry
• Apply NIM lessons to FV-3, MPAS
CRAY
intel
CPU, GPU and MIC Performance
NIM Performance & Scaling
2016 Chips
GPU: Pascal
MIC: KNC
Knights Corner
CPU: ARM-64
NVIDIA
PGI
IBM
3-5 Nov 2015
GSD Science Review
4


Specialized Information and Warning Systems
Greg Pratt
NOAA/ESRL/GSD
GSD Science Review
3-5 Nov 2015
1

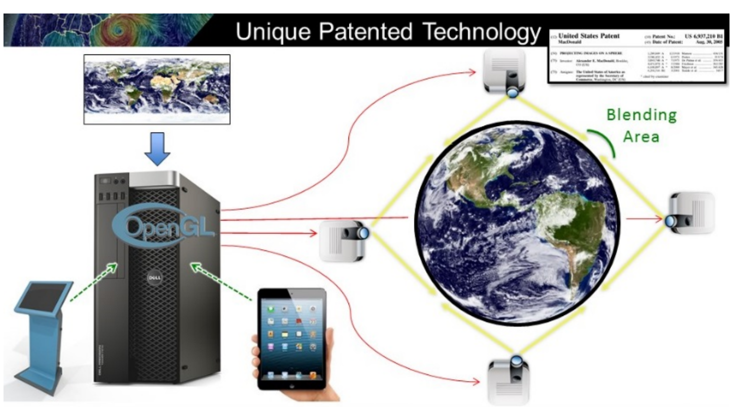

Overview of Projects
Traffic Management Unit (TMU)
2000 – 2013
Volcanic Ash Coordination Tool
(VACT)
Geo-Targeted Alert System (GTAS)
2009 – 2011
The systems provided the users the ability to:
• Communicate
• Collaborate
• and Exchange Information
to improve the understanding of the impact of the event and deliver details of the event in a more useable form to the decision maker. (Forecaster, Traffic Manager, Emergency Manager, First Responder, …).
3-5 Nov 2015
GSD Science Review
2

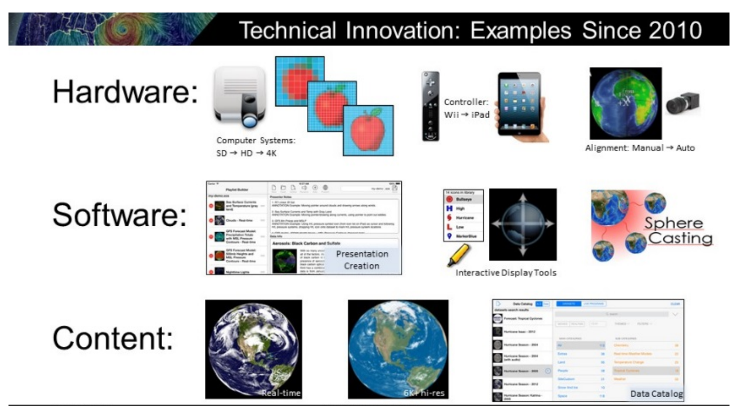

Project Details
Network Enabled Operations
Weather Tailored and Disseminated Based on End-User Needs.
Subject Experts
Improved Situational Awareness
Integration of Relevant Data with the Latest Research and Technology.
Volcanic Ash Plume Modeling
Toxic Plume Modeling
Enhanced Satellite Imagery
High Resolution Weather Models
Integration of All Relevant Data
Shared Situational Awareness
Information Sharing
Operational Support and Other End-Users
3-5 Nov 2015
GSD Science Review
3


Summary
Each of the projects dealt with the delivery of the right information, in the right form to the user of the system. Users were both NWS forecasters and operational decision makers.
Tactical Corrective Hazard Product Animation
Return to TCHP Viewer
3-5 Nov 2015
GSD Science Review
4


Science On a Sphere®
(SOS)
Technical Innovation and Network Growth
Keith Searight, CIRA
Performing work for ESRL/GSD
Shilpi Gupta, CIRES
Performing work for ESRL/GSD
GSD Science Review
3-5 Nov 2015
1


SOS Introduction
NOAA's most impactful outreach tool for public science education
128 Sites Installed
0.5 TB Data Distributed/Day
68" Sphere, 4 Projectors, 1 Linux Server, 1 iPad
2.6K Web Visits/Day
30K Likes
NOAA's #1 Award
$1.20 Stamp
100 Most Influential
3-5 Nov 2015
GSD Science Review
2


Unique Patented Technology
United States Patent
Blending Area
OpenGL
3-5 Nov 2015
GSD Science Review
3

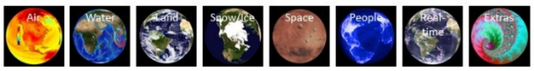

Technical Innovation: Examples Since 2010
Hardware:
Computer Systems: SD → HD → 4K
Controller: Wii → iPad
Alignment: Manual → Auto
Software:
Presentation Creation
Interactive Display Tools
Sphere Casting
Content:
Real-time
6K hi-res
Data Catalog
3-5 Nov 2015
GSD Science Review
4

SOS Growth And Reach

- 128 Science On a Sphere® (SOS) installations worldwide in:

Museums	Visitor Centers
Aquariums	Labs
Schools/Univ.	Zoos

  - 71 Domestic in 29 States
  - 57 International in 22 Countries
- 33 million viewers per year
- Technology transferred by 12 distributors worldwide
- SOS Data Catalog contains 500+ freely available datasets:



3-5 Nov 2015 November 3-5, 2015 5

The SOS Network

- **SOS Network:** institutions with SOS and partners creating and sharing content and educational programming for SOS
  - Build capacity of presenters
  - Provide guidelines for good SOS content
  - Evaluate the effectiveness of SOS
- SOS **Education Webinars** held quarterly
- SOS Users Collaborative **Network Workshops**

Live SphereCast of NOAA scientist on SOS to SOS workshop participants

3-5 Nov 2015 GSD Science Review 6

The Value of SOS

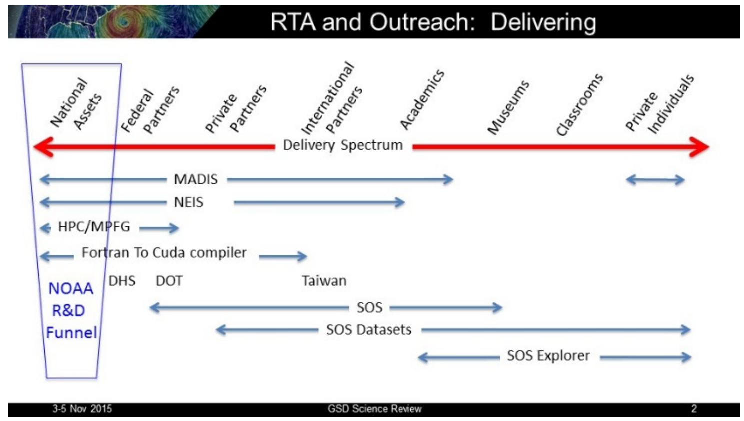
- Support NOAA's goal to enhance **environmental literacy**
  - Engage audiences of all ages
  - Build public understanding of diverse topics
  - Foster appreciation for the interconnectedness of the planet
- Excellent **collaboration and outreach** opportunities
- Discovering **innovative** ways to use SOS
- **Network surveys** *:
  - **82% of visitors** stated that seeing information on the sphere is more realistic and changed how they understood the information
  - **87% of visitors** who had a facilitated sphere experience reported learning something new

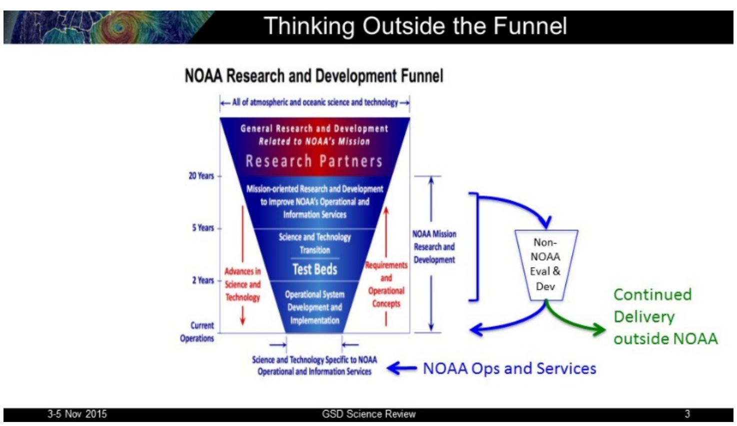
* Science On a Sphere®: Cross-Site Summative Evaluation, Sept. 2010

3-5 Nov 2015 GSD Science Review 7

Session 7: Advanced Technologies

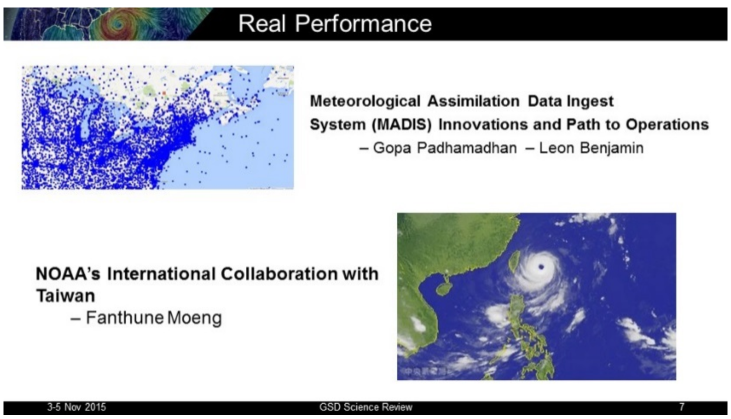
- Opening Talk: Outreach and Research to Operations (John Schneider)
- MADIS Innovations and the Path to Operations (Gopa Padmanabhan and Leon Benjamin)
- NOAA's International Collaboration with Taiwan (Fanthune Moeng)
- Global Visualization using NOAA's *TerraViz* (Beth Russell and Jeff Smith)



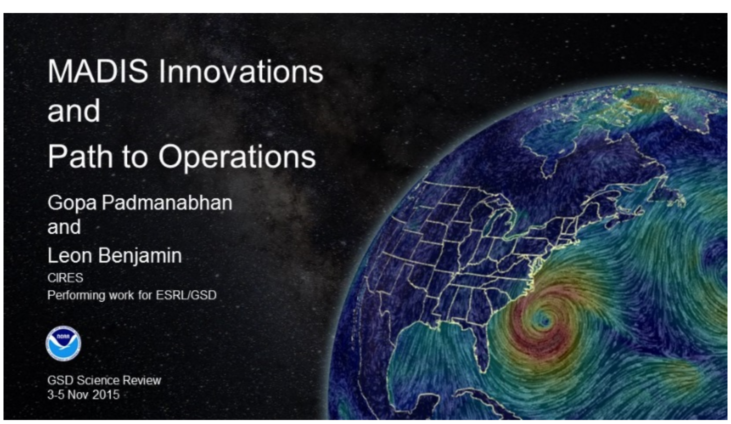


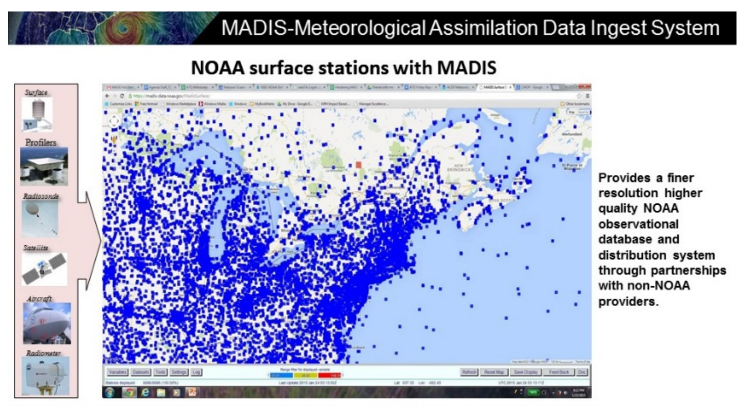

Relevance: Customers, Partners & Users
IBM
CRAY
intel
unity
NVIDIA
Airlines for America
USGS
NASA
Smithsonian Institution
U.S. Department of Transportation
OMSI
'IMILOA
visual climate center
McWane Science Center
3-5 Nov 2015
GSD Science Review
5


Quality: Recognition and Leadership
Patents
Terraviz™/NEIS – Pending
Science On a Sphere®
Auto alignment technique- soon
Leadership Positions
SOS Users Collaborative workshops 2015, 2014, 2012, 2010
Co-Organizer NCAR Multi-Core workshops 2011-2015
NOAA Representative - Federal Games Guild
Journal Editorships
OpenACC
BAMS
Bulletin of the American Meteorological Society (BAMS)
Parallel Computing
Workshop on Accelerated Programming using Directives (WACCPD)
Awards
NOAA Administrators Award – 2015 – MADIS
NOAA Bronze Medal – 2015 – SOS
NOAA Research Employee of the Year – David Himes – 2013
AMS Editors Award – 2015 – Mark Govett
Multiple awards – CIRES and CIRA
Invited presentations
Advanced Computing
Educational
Global visualization
Data management concepts
3-5 Nov 2015
GSD Science Review
6


Real Performance
Meteorological Assimilation Data Ingest System (MADIS) Innovations and Path to Operations
– Gopa Padhamadhan – Leon Benjamin
NOAA's International Collaboration with Taiwan
– Fanthune Moeng
3-5 Nov 2015
GSD Science Review
7


Real Performance
Global Visualization with NOAA's Terraviz
– Beth Russell
– Jeff Smith
3-5 Nov 2015
GSD Science Review
8


MADIS Innovations and Path to Operations
Gopa Padmanabhan and Leon Benjamin
CIRES
Performing work for ESRL/GSD
GSD Science Review
3-5 Nov 2015


MADIS-Meteorological Assimilation Data Ingest System
NOAA surface stations with MADIS
Surface
Profilers
Radiosonde
Satellite
Aircraft
Radiometer
Provides a finer resolution higher quality NOAA observational database and distribution system through partnerships with non-NOAA providers.
3-5 Nov 2015
GSD Science Review

MADIS 2010-2015

Collect/Integrate

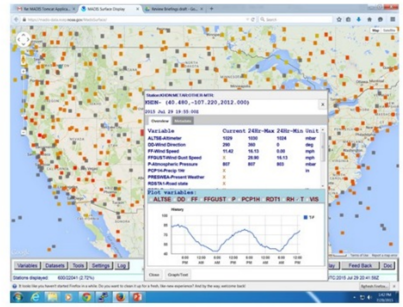
- Continue to handle disparate data sets.
- Improve Observational Knowledge.
- Adopt data standards where possible.
- Continue to fill holes.

3-5 Nov 2015 GSD Science Review

MADIS 2010-2015

Quality Control/Distribution

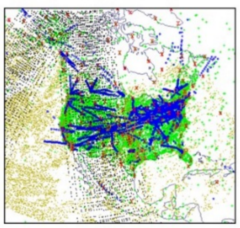
- MADIS data handling time cut from 15 minutes down to 5 minutes.
- Worked with NWS and the FAA on data delivery and discovery standards.
- Google maps and ESRI displays.



3-5 Nov 2015 GSD Science Review

MADIS Innovations Summary

+ - Surface
o - Aircraft
X - Radiosonde
P - Profiler
● - GOES Satellite
● - POES Satellite
R - Radiometer



- In order for MADIS to stay relevant, MADIS most continually be making improvements to:
  - Gap filling data from the ground up
  - Quality.
  - Data throughput.
  - Distribution services.

3-5 Nov 2015 GSD Science Review

Path to MADIS Operations

1	Pre 2005	General R&D on ingest, integration, Quality Control, and data delivery techniques.
2	2005 – 2008	Develop transition strategy. LOA between NWS and OAR signed
3	Sept 2010	MADIS accomplish Initial Operating Capability (IOC) at NWS
4	May 2012	Revised transition strategy from lessons learned with IOC system. New LOA between NWS, NESDIS, and OAR
5	Sept 2013	Funding and operational location for MADIS transition identified and agreed to
6	Oct 2013	MADIS Implementation Project charter signed
7	Dec 2014 – Jan 2015	MADIS enters final development and testing at NCEP and NESDIS
8	Jan 2015	Operational MADIS achieved

3-5 Nov 2015 GSD Science Review

Getting There Wasn't Easy!

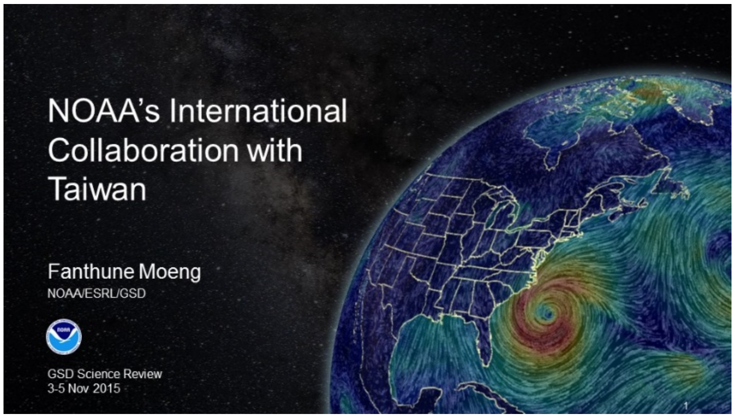
- Must be sustainable.
- Must have a common vision.
- The last mile is hardest, but most rewarding.

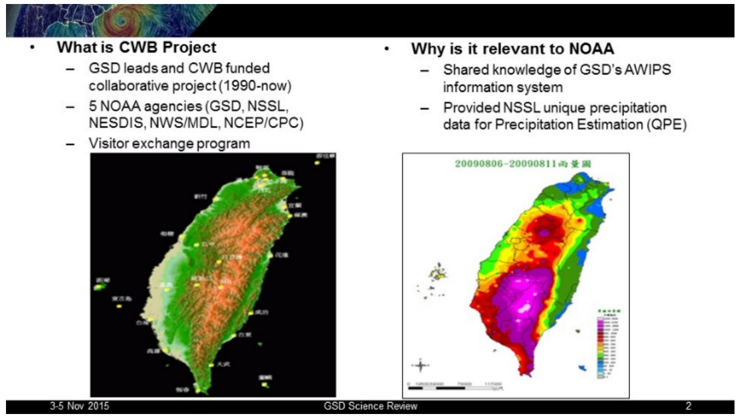
3-5 Nov 2015 GSD Science Review

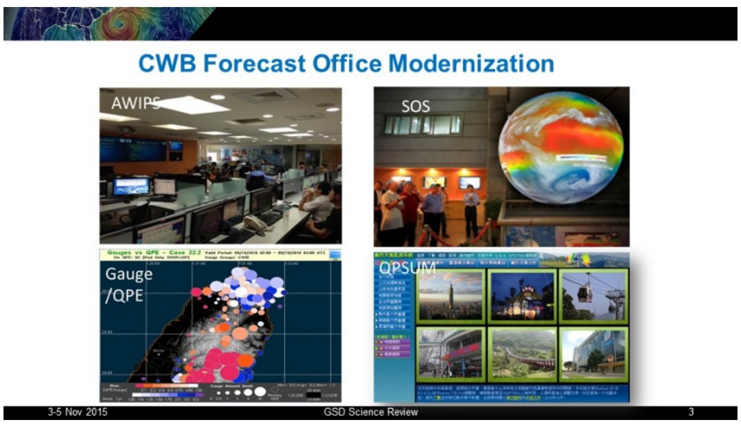
Path to Operations Summary

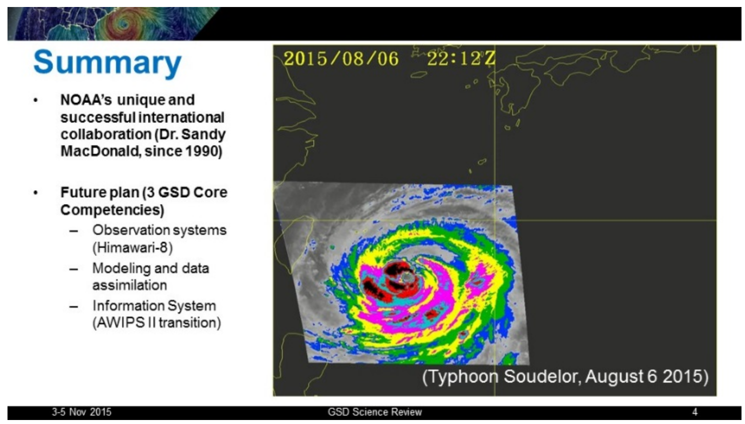
- It was a hard process to go through.
- MADIS now bridges the gap between research and operations.

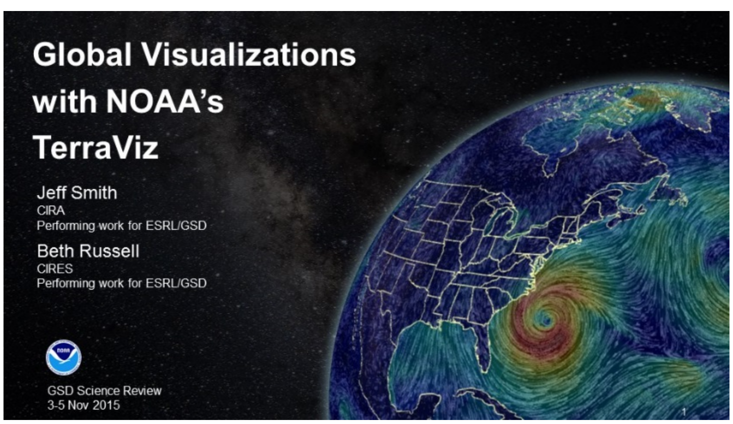
3-5 Nov 2015 GSD Science Review

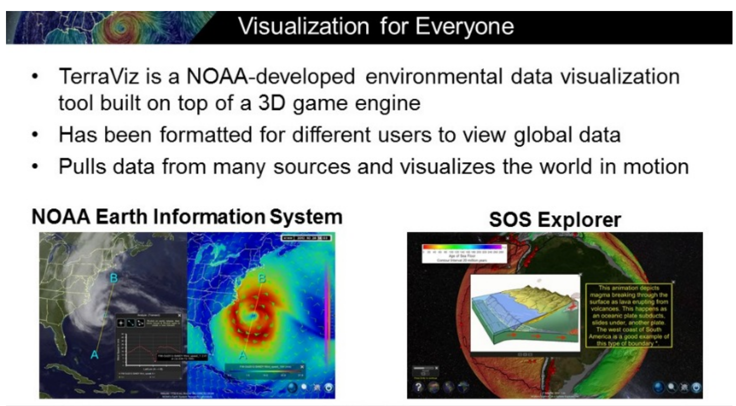

NOAA's International Collaboration with Taiwan
Fanthune Moeng
NOAA/ESRL/GSD
GSD Science Review
3-5 Nov 2015
1

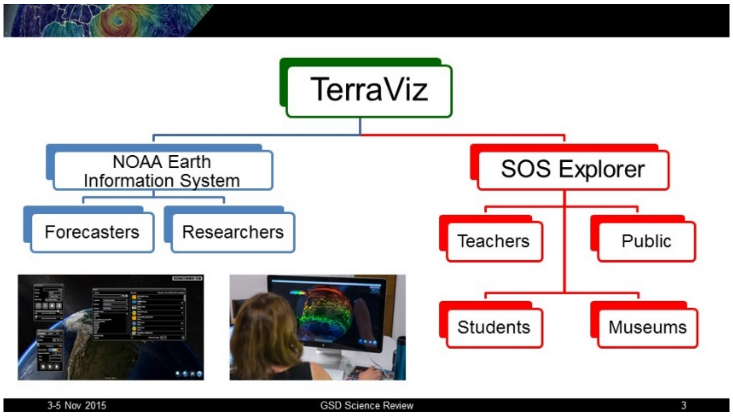

What is CWB Project
– GSD leads and CWB funded collaborative project (1990-now)
– 5 NOAA agencies (GSD, NSSL, NESDIS, NWS/MDL, NCEP/CPC)
– Visitor exchange program
Why is it relevant to NOAA
– Shared knowledge of GSD's AWIPS information system
– Provided NSSL unique precipitation data for Precipitation Estimation (QPE)
3-5 Nov 2015
GSD Science Review
2


CWB Forecast Office Modernization
AWIPS
SOS
Gauge /QPE
QPSUM
3-5 Nov 2015
GSD Science Review
3

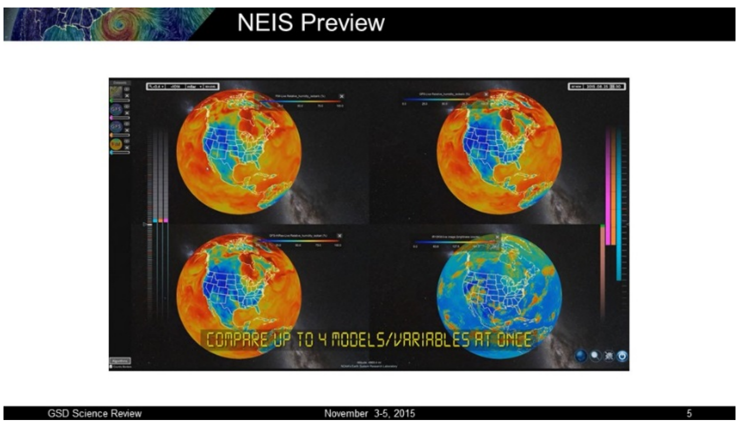

Summary
NOAA's unique and successful international collaboration (Dr. Sandy MacDonald, since 1990)
Future plan (3 GSD Core Competencies)
– Observation systems (Himawari-8)
– Modeling and data assimilation
– Information System (AWIPS II transition)
2015/08/06 22:12Z
(Typhoon Soudelor, August 6 2015)
3-5 Nov 2015
GSD Science Review
4

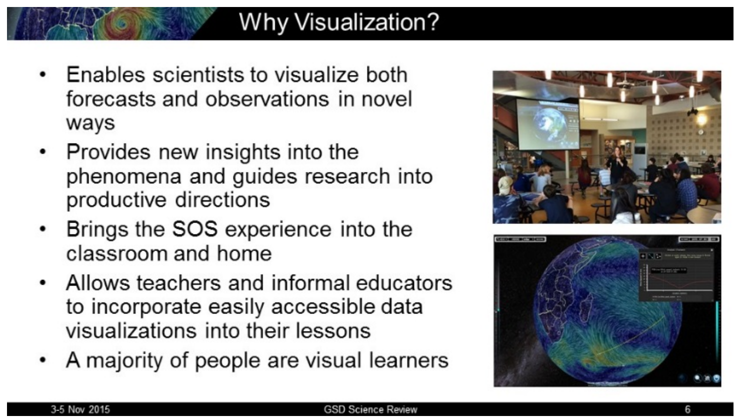

Global Visualizations with NOAA's TerraViz
Jeff Smith
CIRA
Performing work for ESRL/GSD
Beth Russell
CIRES
Performing work for ESRL/GSD
GSD Science Review
3-5 Nov 2015
1

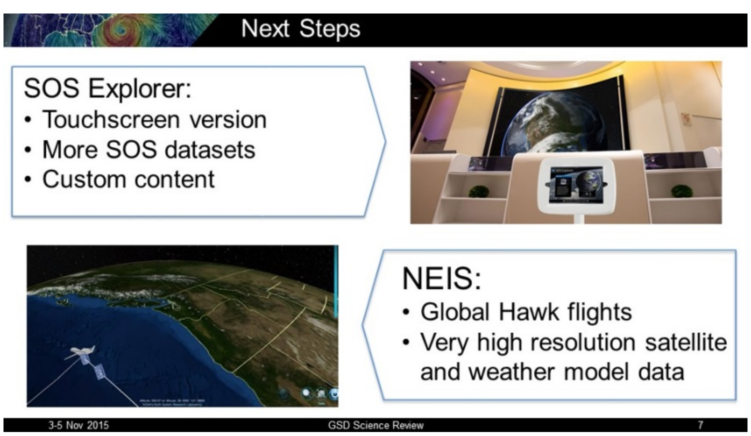

Visualization for Everyone
TerraViz is a NOAA-developed environmental data visualization tool built on top of a 3D game engine
Has been formatted for different users to view global data
Pulls data from many sources and visualizes the world in motion
NOAA Earth Information System
SOS Explorer
3-5 Nov 2015
GSD Science Review
2


TerraViz
NOAA Earth Information System
Forecasters
Researchers
SOS Explorer
Teachers
Public
Students
Museums
3-5 Nov 2015
GSD Science Review
3

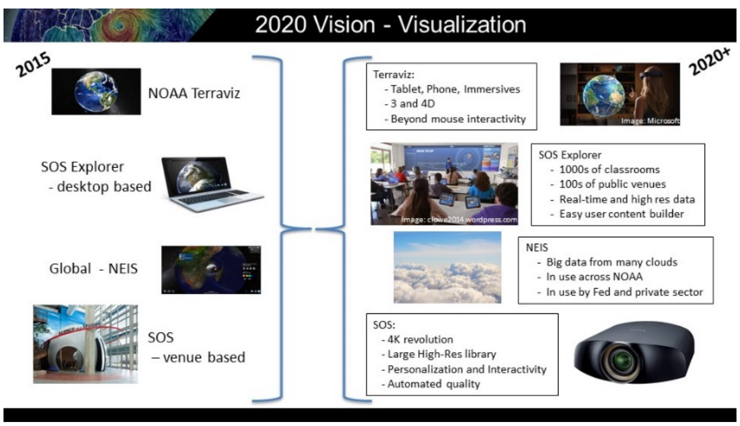

SOSx Preview
Welcome to SOS Explorer™!
Please take a minute to become familiar with the program
PRESS ENTER TO CONTINUE
Pressing the "X" will close the overview
GSD Science Review
November 3-5, 2015
4

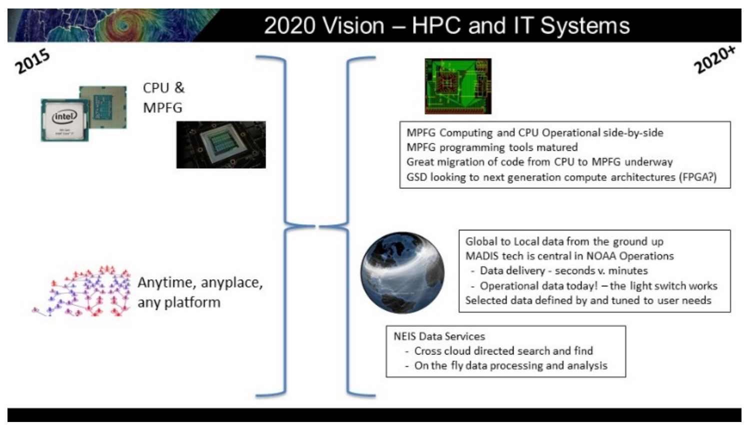

NEIS Preview
COMPARE UP TO 4 MODELS/VARIABLES AT ONCE
GSD Science Review
November 3-5, 2015
5


Why Visualization?
• Enables scientists to visualize both forecasts and observations in novel ways
• Provides new insights into the phenomena and guides research into productive directions
• Brings the SOS experience into the classroom and home
• Allows teachers and informal educators to incorporate easily accessible data visualizations into their lessons
• A majority of people are visual learners
3-5 Nov 2015
GSD Science Review
6


Next Steps
SOS Explorer:
• Touchscreen version
• More SOS datasets
• Custom content
NEIS:
• Global Hawk flights
• Very high resolution satellite and weather model data
3-5 Nov 2015
GSD Science Review
7


Advanced Technology:
The Way Forward
John P. Schneider
NOAA/ESRL/GSD
GSD Science Review
3-5 Nov 2015
3


2020 Vision - Visualization
2015
2020+
NOAA Terraviz
SOS Explorer
- desktop based
Global - NEIS
SOS
– venue based
Terraviz:
- Tablet, Phone, Immersives
- 3 and 4D
- Beyond mouse interactivity
Image: Microsoft
SOS Explorer
- 1000s of classrooms
- 100s of public venues
- Real-time and high res data
- Easy user content builder
Image: clowe2014.wordpress.com
NEIS
- Big data from many clouds
- In use across NOAA
- In use by Fed and private sector
SOS:
- 4K revolution
- Large High-Res library
- Personalization and Interactivity
- Automated quality


2020 Vision – HPC and IT Systems
2015
2020+
CPU &
MPFG
Anytime, anyplace,
any platform
MPFG Computing and CPU Operational side-by-side
MPFG programming tools matured
Great migration of code from CPU to MPFG underway
GSD looking to next generation compute architectures (FPGA?)
Global to Local data from the ground up
MADIS tech is central in NOAA Operations
- Data delivery - seconds v. minutes
- Operational data today! – the light switch works
Selected data defined by and tuned to user needs
NEIS Data Services
- Cross cloud directed search and find
- On the fly data processing and analysis

The NOAA Earth Information System (NEIS)

Jebb Q. Stewart[2], Jeff Smith[2], Jonathan Joyce[3], MarySue Schultz[2], Eric Hackathorn[1], Randy Pierce[2], Chris MacDermaid[2], Chris Golden[3]

Interoperability

What does it mean?

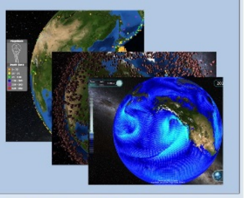
The ability to discover, access, view, interact, and integrate data regardless of format or physical location.

Components of an Interoperability System

- Format Agnostic
- Owner/Physical Location Agnostic
- Platform Agnostic
- Preview Capabilities
- Semantics/Ontology/Vocabulary
- Machine to Machine Communication

Benefits of Interoperability

- Improve accessibility
- Foster data exploration and use
- Decrease complexity
- Provide framework for new tools and applications
- Possibilities are endless



Support of Research: Physical, chemical, and biological data are all interrelated. The NEIS framework provides capabilities to quickly integrate and interact with data from all diverse sources through all time.

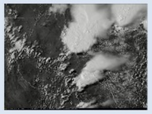
Interoperability through Standards

- Community developed allowing common language for interacting with services and exchanging information.
- Services allow user to get only the data they need (subset, format, time, station, etc…)
- Standards, like Open Geospatial Consortium (OGC), are widely adopted by vast user communities. Many applications already use these standards.
- Modular - Upgrade components without taking down entire framework.

High Performance Data Dissemination

New Data Require New Tools

GFDL FV3 Precipitation



Experimental NOAA/GOES-R

Suomi/NPP VIIRS True Color

- New real-time observation platforms
- Unmanned Aerial Systems (UAS), Micro Satellites

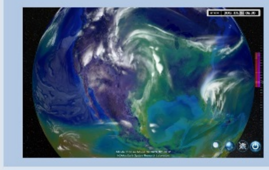
Our diverse and complex world requires new capabilities to understand complex relationships.

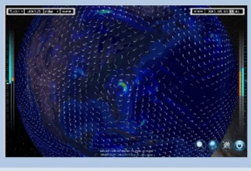
Understanding needs

- Terabytes to Petabytes of new data daily.
- Already have Petabytes of existing data.
- Tools needed to evaluate and compare data from different sources and different formats – remotely!
- Near real-time data access

What NEIS Provides

- High Performance Data Visualization through TerraViz
- High performance stream based data processing system.
- Ability to integrate data from a variety of sources
- Remote processing capability

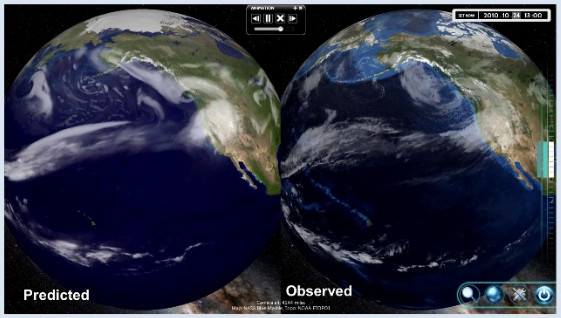




Impacts

Framework is built towards standards, not data.

- NOAA data ready for action. Services model facilitates agile response to events. Services can be combined or reused quickly, upgraded or modified independently.
- Any data available through framework can be operated on or combined with other data. Integrated standardized formats and access.
- New and existing systems have access to wide variety of NOAA data. Any new data added is easy incorporated with minimal to no changes required.



Benefits: A common picture in space and time for ecological, physical, and oceanic information, from the bottom of the ocean through the top of the atmosphere.

Ongoing Research

- Continue evaluation and development of new emerging technologies
- Modular Distributed services
- Larger and Larger data
- Better remote processing

Advanced Visualization using Gaming Technology

Eric Hackathorn[1], Jonathan Joyce[2], Jeff Smith[3]

Why Gaming Technology?

Cutting Edge Performance with Off-the-Shelf Pricing

While a game engine may seem a strange choice, it takes advantage of existing off-the-shelf technologies. Additionally, it can run on many platforms: desktops, browsers, consoles, and mobile devices.

Video games are a multi-billion dollar industry, and represent an ideal choice for providing a wealth of data to a user in real-time. The industry harnesses the power of graphical processing units (GPUs) available in commodity PCs to render and display information in efficient ways.

Our Mission

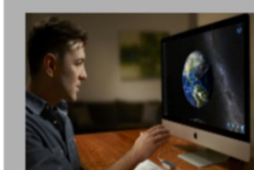
Our project leverages game mechanics and technology for a variety of projects and has unique expertise straddling science, education, and entertainment.

The goal is to ingest "big data" and prepare it for real-time analysis. Designed for a world where everything is in motion, game technologies allow fluid data integration and interaction across four dimensions and provide a tool for exploring vast collections of information. This demonstration is running on a standard desktop computer with an NVIDIA GPU.

Virtual Reality

Physical Presence in an Imaginary World

The Oculus Rift will be released in the first quarter of 2016, making it one of the first consumer-targeted virtual reality headsets. It has a resolution of 1080×1200 per eye, a 90 Hz refresh rate, and a 110 degree field of view. The final version have integrated headphones providing spatialised audio. The positional tracking is performed by a separate IR sensor, that is included with each Rift and normally sits on the user's desk. This system allows for using the Rift while sitting, standing, or walking around the same room.

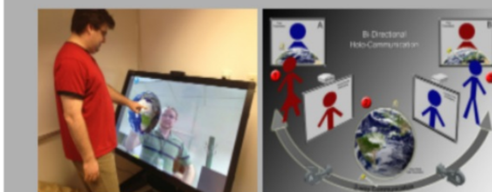


Leap Motion senses your hands and fingers and follows their every move. It lets them move in all that wide-open space between you and your computer. So you can do everything without touching anything.

zSpace is an immersive platform for users to interact in a true 3D holographic-like environment. By blending the physical world with a sensory rich virtual world where people can naturally and intuitively manipulate and navigate, zSpace revolutionizes the way people learn.

Collaboration

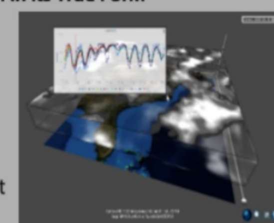
Augmented Reality for Visualization and Analysis



***1)** The first speaker is recorded by a web camera. Behind her is the second speaker as seen through viewport "A." **2)** A virtual world created from data that is added as a layer in front of the speakers. **3)** The second speaker is recorded by a web camera. Behind him is the first speaker as seen through viewport "B."*

Volumetric Visualization

Visualizating Information in its True Form



Slicing and dicing volumetric model data

The ability to look at weather and other Earth data in three dimensions gives researchers new insight into the nature of storm development, and that information can result in better forecasts. Historically it has been difficult to allow interactivity due to the amount of information being processed and the time it takes to render, but gaming technology can help.

Fine Grain Computing

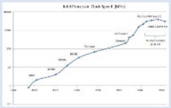
Mark Govett, Tom Henderson[1], Jacques Middlecoff[1], Jim Rosinski[1], Dan Connors[2], Antonio Duarte[2]

1 - CIRES
2 - CIRA

Background & Motivation

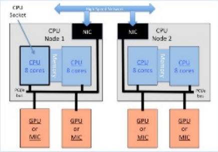
- GSD has been exploring new and emerging HPC technologies for NOAA since the early 1990s.

- With CPU clock speeds stalling manufacturers are increasing the number of CPUs or "cores" on a chip. CPU now have 24 or more cores / chip.



- In 2015, it is common for HPC systems to have more than 10,000 cores, with some systems containing over 100,000 cores. These systems often require specialized facilities to house them, with power bills exceeding $1M / year.
- There are two types of fine-grain computer chips: Graphics Processing Units (GPUs) from NVIDIA and AMD, and the Many Integrated Core (MIC) from Intel. These accelerator chips are currently attached to the CPU via the PCIe bus.

Intel MIC (Xeon-Phi) 61 vector cores

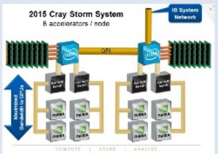


NVIDIA Kepler K80 4992 cores

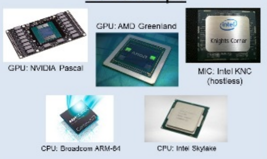
- By the end of the decade, CPU based systems could have more than 300,000 compute cores. Fine-grain systems will be sold containing millions of compute cores.

Fine-Grain Computing Chips

- Up to two accelerators can be directly attached to a CPU, with systems such as Cray Storm, that support 8 or more per compute node.



2016 Chips



Vendor Collaborations

- Collaborations with technical teams at Intel, Cray, PGI, IBM, and NVIDIA on the NIM model have led to significant hardware and software improvements.
- **F2C-ACC** is a GPU compiler developed at GSD in 2009 before commercial GPU compilers were available. It has been used to run the NIM, and evaluate performance of the commercial Fortran GPU compilers since 2011. In 2014, we showed the Cray and PGI compilers ran NIM 1.7 and 2.1 times slower than the F2C-ACC.
- GSD worked with PGI to improve their compiler, such that it's performance is now within 5% of F2C-ACC.

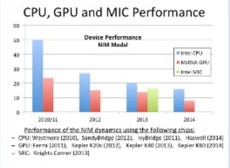
Vendors are telling us the NIM:

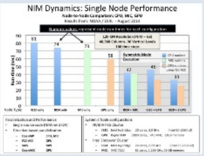
- *"has the best thread scaling on the MIC of any weather or climate application"*
- *"is the only weather or climate model where we can make comparisons between CPU, GPU and MIC architectures"*
- *"is the best weather model we've seen on the GPU"*

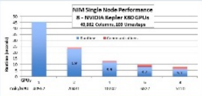
NIM Performance: CPU, GPU & MIC

Comparison between chips is essential. There are three general ways to compare performance.

Device Performance is the best way to compare chip technologies. We show performance of the NIM model thru four generations of CPUs, three generations of GPU, and one generation of the MIC.

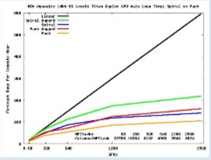






Node Performance considers both the host and attached GPU or MIC chips. Comparisons are also made when both the CPU and host are used (symmetric mode). We also make comparisons with nodes containing up to 8 GPUs.

Multi-Node Performance shows performance and scaling to thousands of GPUs. Efficient inter-process communications is key to getting good performance. Four optimizations are shown for the NIM



GPUs	Columns	Spiral HQ	Comms	Spiral	Comms	PackMp	Comms	PackCp	Comms
80	32768	50.4	30.2	59.6	10.6	60.6	12.9	80.3	32.7
160	16384	24.7	13.0	32.9	7.9	32.9	8.6	44.6	20.3
320	8192	13.6	9.0	18.3	5.5	17.4	4.9	24.5	12.0
640	4096	8.3	6.3	10.8	4.1	12.9	6.3	17.2	10.5
1280	2048	5.4	3.9	7.9	4.2	7.5	3.9	10.9	7.2
2560	1024	4.3	3.1	6.7	4.5	5.8	3.8	8.9	6.8

Specialized Information and Warning Systems

Greg Pratt[1], Jim Frimel[2], Herb Grote[2], Chris Golden[3], Leigh Cheatwood[2], Jim Ramer[2], and Xiangbao Jing[3]

Project Objectives

Traffic Management Unit (TMU)

• Improve and standardize the weather briefings given to FAA traffic managers.

Volcanic Ash Coordination Tool (VACT)

• Ensure warnings for ash are timely, accurate, and are fully consistent across domains of responsibility.

Geo-Targeted Alert System (GTAS)

• Ensure warnings for chemical spills and toxic plumes are timely, accurate, and share this and weather information with state and local emergency managers.

Initial State of Forecaster Systems and Delivery Process:

• Weather products may need interpretation.
• Weather products may be conflicting across areas of responsibility.
• NWS Center Weather Service Units (CWSU) not providing standardized weather briefings to FAA traffic managers.
• FAA traffic managers not supported 24X7.
• Inability to share products with other agencies and collaborators.
• Tools and products used to detect and forecast ash and chemical dispersion not available on NWS operational systems.

Products

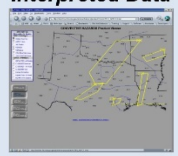

SUS32 KKCI 232103
SIGC
036MKCC WST 232103
CONVECTIVE SIGMET 5C
VALID UNTIL 2255Z
LA AR TX OK
FROM 10S FSM-30W LIT-30SSW EIC-50W GGG-10S FSM
DVLPG AREA EMBD TS MOV FROM 22030KT. TOPS TO FL350
...SPECIAL...
CONVECTIVE SIGMET 5C
VALID UNTIL 2255Z
TX
FROM 40WNW SPS-50SSW SPS-60WNW ABI-40SW CDS-40WNW SPS
DVLPG AREA TS MOV FROM 24030KT. TOPS TO FL300
OUTLOOK VALID 232255-240255
FROM SGF-MEM-ACT-CDS-SGF
WST ISSUANCES POSS. REFER TO THE MOST RECENT ACUS01 KWNS FROM THE
STORM PREDICTION CENTER FOR SYNOPSIS AND METEOROLOGICAL DETAILS
'000

Tools

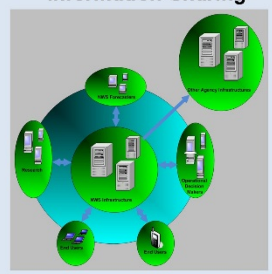
Delivery

Accomplishments

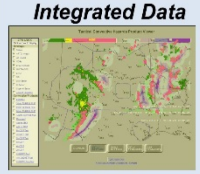
Interpreted Data



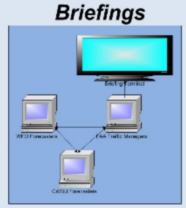
Information Sharing



Integrated Data



Briefings



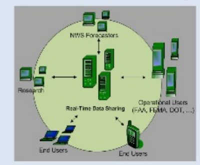
Tailored Delivery

Collaboration

Forecaster Tools

Concepts to Further Explore

Real-Time Information Sharing



GotoMeeting on Steroids

Tailored Delivery

Single Authoritative Source

Operational Achievements

- Aviation product ingest and display software implemented in AWIPS.
- The ability for the Hybrid Single Particle Lagrangian Integrated Dispersion (HySPLIT) model to handle chemicals.
- Interface requirements for NWS operations and collaborators to run HySPLIT.
- AWIPS collaboration capability.
- AWIPS drawing tool capability.

Testimonials

"ZFW TMU strongly supports the TMU-WIDA convective weather forecast tools used at ZFW. The CWSU, TMU team both have used the weather displays extensively. TMU-WIDA was a significant factor in making good tactical and strategic decisions during the significant thunderstorms that the airspace experienced during the Winter to Summer period of 2007. of the more than 90 days that the airspace experienced significant thunderstorm activity, TMU-WIDA was able to provide clear two hour thunderstorm predictions nearly 80 percent of the time, greatly increasing our effectiveness as an operational team."

Tom Amis, MIC, Ft Worth CWSU

"VACT enables more timely and accurate forecasts from a coordinated multi-agency response, allowing operational scientists in USGS and NWS to collaborate in real time with shared situational awareness. VACT was operationally tested during the 2006 eruptions of Augustine Volcano that caused ash to fall in several communities, many airline flights to be canceled, and military aircraft to be redeployed. AK Volcano Observatory (USGS) scientists repeatedly expressed gratitude for VACT because it facilitated coordination."

Laura Furgione, Director, NWS Alaska Region

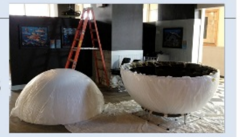
Science On a Sphere® – Technical Innovation

Keith Searight[1], Shilpi Gupta[2], Vincent Keller[2], Ian McGinnis[2], Beth Russell[2], Steve Albers[1], Stephen Kasica[2], Vivian LeFebvre[3], and Tony Liao[4]

([1]CIRA, [2]CIRES, [3]Federal, [4]Visitor)

Hardware

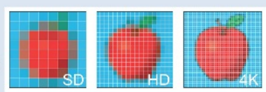
The Sphere
- Carbon fiber composition
- Custom manufactured for SOS in 68” and other sizes



Computer Systems
- Dell servers with Linux (5→1)
- Nvidia graphics cards (4→1)

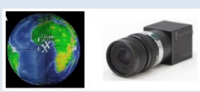
Projectors
- SD → HD → 4K
- Networked with server

Graphics Resolution
- SD → HD → 4K
- Limited by hardware specs



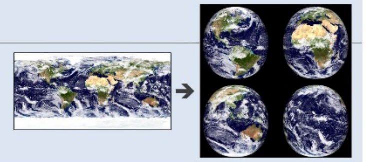
Controllers
- Wii gaming remote
- Apple iPad and iPhone

Alignment
- Manually set by controllers
- Automated using cameras



Software

Visualization
- On-the-fly Rendering
- Global “splitter”



Delivering Presentations
- Feature-rich iPad App
- Wi-Fi and Bluetooth support

Interactive Display Tools
- Annotations and Icons
- Animated pictures-in-pictures (PIPs)
- Adjustable zooming

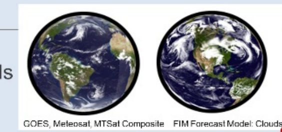
Creating Presentations
- Playlist Builder on iPad
- Playlist Editor on Desktop

Public Kiosk
- Touch screen interface
- Trackball-style sphere control

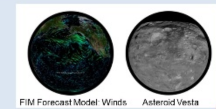
SphereCasting
- Remote SOS control
- Live video streaming

Content

Real-time Data
- Satellites & NOAA models
- 0.5 TB distributed daily



High Resolution Data
- 6K+ images and movies
- Crisp text and lines



Data Catalog
- Metadata management
- Powerful browse & search

SOS Website
- Extensive SOS information
- Interactive sphere
- Responsive design

Language Localization
- Multi-language interfaces
- Leverage dataset translations

Data Standards
- Google Earth KML
- Web Mapping Service

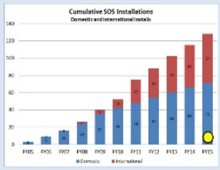
Science On a Sphere® (SOS) Network Growth and Reach

Shilpi Gupta[1], John Schneider[2], Beth Russell[1], Hilary Peddicord[1], Fanthune Moeng[2] ([1]CIRES, [2]NOAA)

SOS Reach and Growth

128 Installations worldwide
Museums, Science Centers, Visitor Centers, Aquariums, Labs, Schools, Universities, Zoos

Installation distribution
71 Domestic in 29 States,
57 International in 22 Countries



33 Million visitors per year
K-12, Families, University Students, Scientists, General Public, Policy Makers, Special Interest Groups, etc.

Technology transferred by 12 distributors worldwide
BWC Visual Technology, Climate Institute, Global Imagination, Huafeng Group, Korean Broadcast, System, Sigong Tech, Our Planet, Globocess, etc.

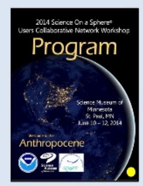
SOS Data Catalog of 500+ freely available datasets

The SOS Network

SOS Network
Institutions with SOS and partners creating content and educational programming for SOS

- Brings together people with different skills: technical, education, science, exhibits, film production, etc.
- Build capacity of presenters to interpret complex data visualizations and discuss Earth system science with public audiences
- Provide guidelines for creating easily understood, scientifically accurate content for spherical display systems
- Evaluate the effectiveness of SOS as a learning tool

SOS Users Collaborative Network Workshop
Held every 18 months at an SOS site



SOS Education Forum
Educators, docents, and content creators who meet quarterly via online webinar to discuss how to use SOS to effectively educate K-12 and beyond.

The Value of SOS

Support NOAA's goal to enhance environmental literacy and display Earth science data in a way that:

- Engages audiences of all ages
- Builds public understanding of scientific, technological, and environmental topics
- Fosters appreciation for the interconnectedness of the planet and its changing landscape

Collaboration opportunities amongst:
Scientists, Visualization Developers, Education/Outreach Specialists, Artists, Programmers, Film Producers, etc.

Outreach
SOS engages in many outreach activities with diverse audiences

Network Surveys and Feedback
Many evaluations have been conducted at SOS sites to evaluate its efficacy

Going beyond…
SOS is used in many innovative ways to engage the public

NOAA RESEARCH • EARTH SYSTEM RESEARCH LABORATORY • GLOBAL SYSTEMS DIVISION

Meteorological Assimilation Data Ingest System (MADIS) Innovations

Gopa Padmanabhan[3], Greg Pratt[1], Leon Benjamin[3], Tom Kent[2], Leigh Cheatwood-Harris[2], Michael Leon[2], Michael Vrencur[4], and Randy Collander[2]

MADIS

Providing Value-Added Observations to the Meteorological Community

NOAA Mission

"To understand and predict changes in climate, weather, oceans, and coasts; To share that information with others" increasingly demands advanced data management processes, including data integration, to achieve interoperable, accessible, and readily usable observational data.

MADIS Goal

A more usable, complete, accurate, timely, and higher density observational infrastructure for use in local weather warnings and products, numerical weather prediction, and use by the greater meteorological community.

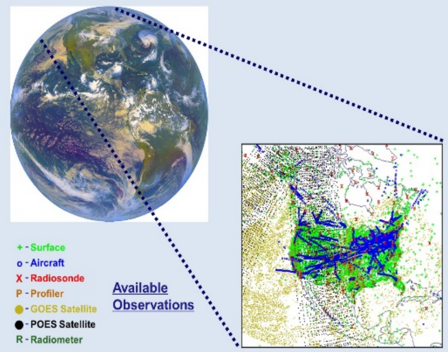
MADIS Provides

- Access to real-time and archived data sets
- Uniform data formats, observation units, and time stamps
- Observational Quality Control (QC)
- Network-enabled distribution with server-site sub-setting
- Authorization and authentication for proprietary data
- User documentation and help desk support

MADIS Data Scope

- 66,127 stations from over 160 surface networks producing nearly 13 million observations per day
- 113 Profiler sites (>200,000 observations per day)
- >700,000 aircraft observations per day
- Plus global radiosonde and satellite observations

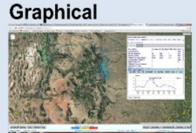
MADIS Data Sets



MADIS observations covering North America

MADIS Distribution Services

Graphical



Meteorological Surface

Aircraft Observations

CAP Profiler

Subsetting – Surface Dumps (Text, AML, CSV)

Meteorological

Hydrological

Application Interface

Future Plans

1. Gap filling data from the ground up.
   - National Mesonet program.
   - NWS Office of Observations.
   - 1 Minute ASOS data.
   - Non-Federal AWOS data.

2. Light Switch
   - Data and Metadata standards.
   - Standardized MADIS ingest interface.

3. Improved Quality Control
   - Extended metadata
   - Quality Control Sandbox
   - Faster throughput of data.

4. Distribution Services
   - Graphics – One display all data and metadata
   - Data queries – One dump utility for all data and metadata
   - Open Geospatial Consortium compliant
     - Formats - WXXM
     - Delivery – Web Feature Service
     - Data Discovery

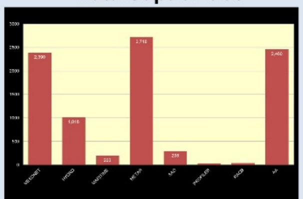
Meteorological Assimilation Data Ingest System (MADIS) Path to Operations

Leon Benjamin[3], Greg Pratt[1], Tom Kent[2], Gopa Padmanabhan[3], Leigh Cheatwood-Harris[2], Michael Leon[2], Michael Vrencur[4], and Randy Collander[2]

MADIS Time Line

2001 – Birth of MADIS.

Data Capabilities

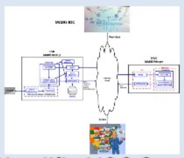


Average Reports Per Hour

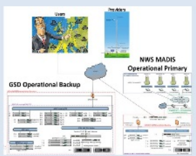
2005 – NWS sees value.

2008 – NWS and OAR sign Letter Of Agreement (LOA).

2010 - MADIS Initial Operating Capability.



Simplified IOC Systems



MADIS IOC Systems

2012 – NWS, OAR, and NESDIS sign new LOA.

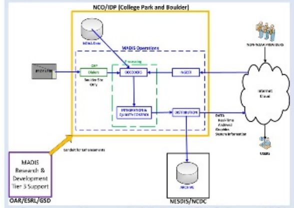
2012 – Centralized System at WOC.

2013 – Centralized System at NCO.

2013 – Centralized System at NCO/IDP.

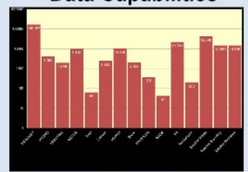
2015 – Operational MADIS Realized at NCO/IDP.

NCO/IDP MADIS



Operational MADIS Simplified

Data Capabilities



Average Reports Per Hour

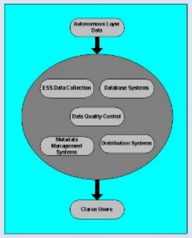
Operational Pulse

Hourly Station Counts

What Does the Bridge Provide?

Systems and Data in Transition

Clarus



1 Minute FAA ASOS

AMDAR.NOAA.GOV

HADS Hydrometeorological Automated Data System

SNOTEL

VOS

EDIS

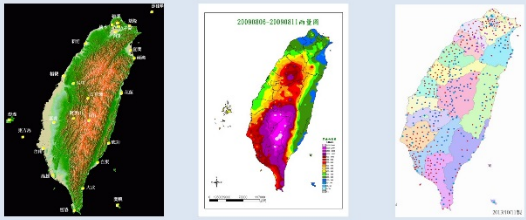
NOAA's International Collaboration with Taiwan

Fanthune Moeng[1], John Schneider[1], Joe Wakefield[1], Kenneth Howard[2], Jian Zhang[2], Fuzhong Weng[3], Ninghai Sun[3], Stephan Smith[4], Lingyan Xin[4], Shi-Keng Yang[5]
1. ESRL/GSD, 2. NSSL, 3. NESDIS, 4. NWS/MDL, 5. NWS/NCEP/CPC

Background

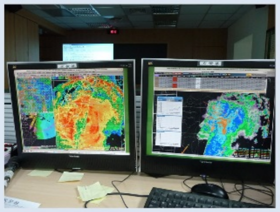
- Dr. Sandy MacDonald established the collaboration project with Taiwan Central Weather Bureau (CWB) in 1990
- Annual reimbursable budget ~ $1.2 M to $1.6 M (2010-2015)
- Five NOAA agencies involved currently

Taiwan complex terrain and heavy precipitation (and over 700 rain gauges)



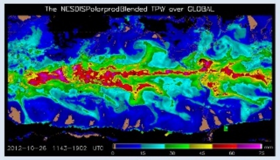
CWB AWIPS (GSD)

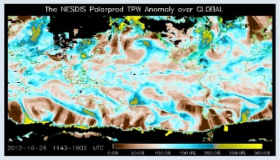
- CWB AWIPS (a.k.a. WINS- Weather Integration and Nowcasting System) is the essential component for their forecast operation



TPW data (NESDIS)

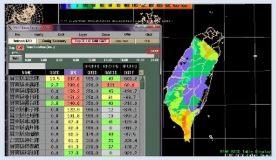
- Real-time blended and anomaly TPW (Total Precipitable Water) products to analysis heavy rain





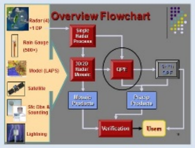
FFMP (MDL)

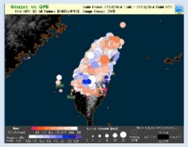
- FFMP (Flash Flood Monitoring and Prediction) localization, processing and display all data sources)

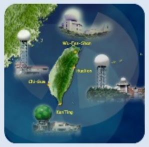


QPE (NSSL)

- QPE (Quantitative Precipitation Estimation) from 7 radars, over 700 rain gauges and lightning system







Taiwan-West Pacific Climate Forecast System (TWPCFC) Workshop (CPC)

- Annual TWPCFS Workshop since 2013 to plan for CWB Global Forecast System
- Training at NCEP's Monsoon Training Desk program

Research papers (GSD, NSSL, NESDIS since 2013)

Qin, Z., X. Zou, and F. Weng,, 2013: Evaluating added benefits of assimilating GOES imager radiance data in GSI for coastal QPFs. *Mon. Weather Rev*. 141, 75-92

Zou, X., F. Weng, B. Zhang, L. Lin, L., Z. Qin, and V. Tallapragada, 2013: Impacts of assimilation of ATMS data in HWRF on track and intensity forecasts of 2012 four landfall hurricanes. *J. Geo Res Atmos*, 118, 1-18.

Wang, Y., J. Zhang, P.-L. Chang, C. Langston, B. Kaney, and L. Tang, 2015: Operational C-band dual-polarization radar QPE for the sub-tropical complex terrain of Taiwan. *Advances in Meteorology*. submitted.

Wang, Y., J. Zhang, P.-L. Chang, and Q. Cao, 2015: Radar vertical profile of reflectivity correction with TRMM observations using a neural network approach. *J. Hydromet*. Doi: http://dx.doi.org/10.1175/JHM-D-14-0136.1.

Wang, Y., P. Zhang, A. Ryzhkov, J. Zhang, and P.-L. Chang, 2014: Utilization of specific attenuation for tropical rainfall estimation in complex terrain. *J. Hydromet*. 15, 2250-2266.

Wang, Y., J. Zhang, A. V. Ryzhkov, and L. Tang, 2013: C-Band Polarimetric Radar QPE Based on Specific Differential Propagation Phase for Extreme Typhoon Rainfall. *J. Atmos. Oceanic Tech*. 30, 1354-1370.

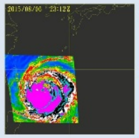
Wang, N., J.-W. Bao, J.-L. Lee, F. Moeng, and C. Matsumoto, 2015: Wavelet compression Technique for high resolution global model data on an icosahedral grid. *J. Atmos. Oceanic Technol. 32, 1650-1667.*

Wang, N., F. Moeng, C.-T. Terng, and Y. Xie, 2013: Wavelet data thinning and data compression in numerical modeling and data assimilation. Second China-U.S. Symposium on Meteorology, June, 2013, Qingdao, China.

Wang, N and F. Moeng, 2014: Wavelet data compression for global circulation models and Science On a Sphere® visualization. Invited presentation, Asia Oceania Geosciences Society 11th Annual Meeting Interdisciplinary Sciences Section, July 2014, Sapporo, Japan.

Future Plan

- New Japanese Himawari-8 Satellite
- New radars (4 new precipitation radars, and one wind profiler)
- Local-to-global models
- AWIPS II transition



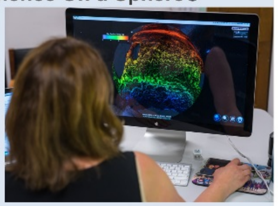
SOS Explorer for Education and the Public

Beth Russell[3], Eric Hackathorn[1], Jonathan Joyce[3], Hilary Peddicord[3], Jeff Smith[2]
1. NOAA, 2. Cooperative Institute for Research in the Atmosphere, 3. Cooperative Institute for Research in Environmental Science

What is SOS Explorer?

A flat screen version of Science On a Sphere®

- Provides teachers, students, and public their own personal Science On a Sphere (SOS)
- Uses the NOAA-developed Terraviz™ visualization engine to create an interactive Earth for a flat screen display



Sea Surface currents and temperature on SOS Explorer (SOSx)

Motivation for creating SOS Explorer

- High demand for the SOS experience in the classroom and home where SOS is not feasible
- Need from teachers and informal educators to incorporate data visualizations into their lessons

Sea Surface currents and temperature on Science On a Sphere (SOS)

Connection to TerraViz and NEIS

- TerraViz is a visualization engine developed by NOAA that uses gaming technology to generate high resolution displays
- SOSx is a simplified version of NEIS for teachers and the public

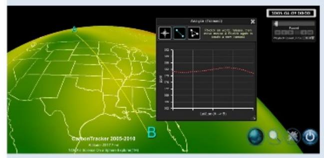
NEIS

SOSx

Why use SOS Explorer?

Visualization for the classroom and home

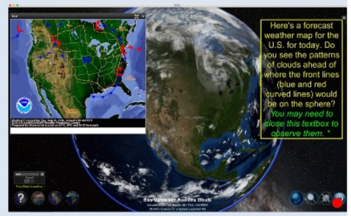
- Data visualization allows analysis and understanding of complex data relationships



- Data visualization helps bridge understanding of observations versus computer modeling
- Data visualization lets you see things that would otherwise go unnoticed - trends, behavior patterns.

Tours

Tours are scripted presentations with pop-up windows that walk a user through the datasets using a storyline and a learning goal.



School Materials

- Student worksheets and additional learning activities for each tour
- Direct hands-on learning activities provided for selected datasets as an example of what is possible
- Inquiry and scientific literacy lessons for selected datasets to give teachers an idea of how to encourage students to interact with the datasets

Where is SOS Explorer going?

One application, many venues

In it's current release, SOSx is designed for classrooms and homes, but future versions will allow for use in a broad range of settings

SOS Explorer

- **Version 1.0*** (pre-packaged 14 datasets and freely available)
- **Interactive Exhibit**
- **Tailored** (pre-packaged with specialized content)
- **Premium** (access to all features and SOS datasets)

*Released Sept. 2015

Interactive Exhibit

A touchscreen compatible version of SOSx on a kiosk in a public setting that will control a larger view projected on a wall or monitor. Museums will be able to choose which datasets and topics to use in their exhibit space.

Tailored

A prepackaged collection of datasets where a sponsoring group chooses which datasets and tours to include to tell their own story and support their own learning goals.

Premium

A version of SOSx that includes access to all the SOSx features and all the SOS datasets that are compatible with SOSx.

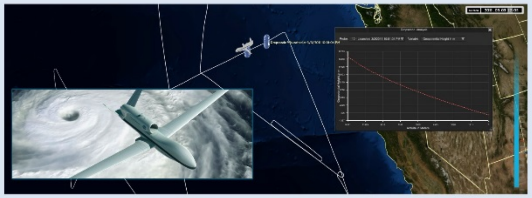
NOAA RESEARCH • EARTH SYSTEM RESEARCH LABORATORY • GLOBAL SYSTEMS DIVISION

NEIS Visualization for Professional Users

Jeff S Smith[1], Eric Hackathorn[2], Jonathan Joyce[3], Jebb Stewart[1], Chris Golden[3]

Flight Tracks / Dropsondes

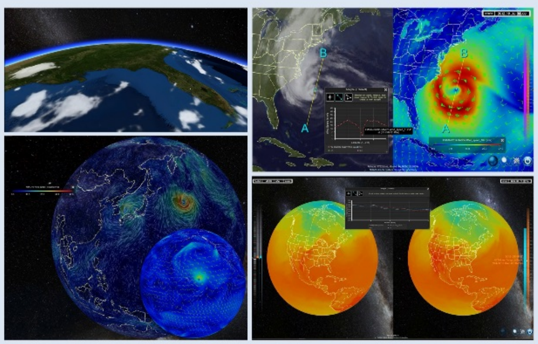
Visualizes the flight paths of UAVs such as Global Hawk aircraft, including charting the data captured from the 50-80 dropsondes typically dropped during a 24 hour mission.



Environmental Visualizations

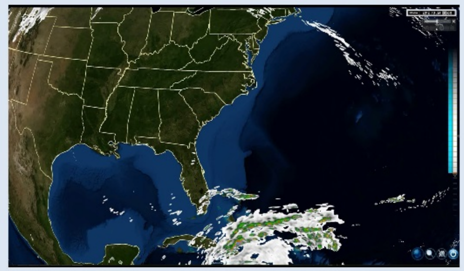
TerraViz can mash up multiple datasets at once, visualize clouds, wind as barbs, vectors, or trails of particles that flow over the globe, as well as KML (Google Earth) data.

Users can also animate data over time and graph transects.



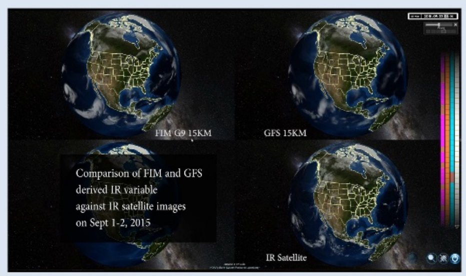
Supports Latest Hi-Res Global Models

Global 3 Km Models produce an enormous amount of data. For example, 72 time steps of the Hurricane Sandy animation depicted below consumes 8 GB on disk. TerraViz can not only display these 14400x7200 pixel images, it can animate them at 10 frames per second.



Compare Models To Observations

TerraViz can visualize up to 4 globes of data, enabling the comparison global models (each on its own globe) to the actual observations (e.g. satellite IR).

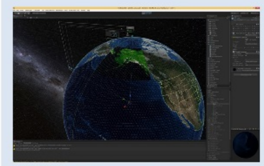


Built With Gaming Technology

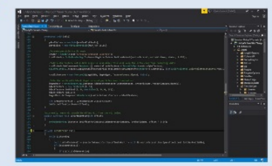
Games are basically data visualizations where the data might be soldiers on a "Call Of Duty" virtual battlefield. Billions of dollars have been invested by the gaming industry to optimize the rapid display of millions of polygons on modern graphics cards with graphical processing units (GPUs).

TerraViz leverages the advances in this industry to visualize environmental data such as storms moving across the ocean or the annual ebb and flow of sea ice in the Arctic. NOAA has filed a patent for TerraViz.

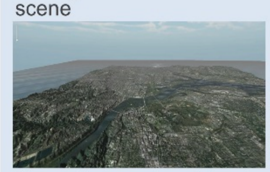
The development process is a combination of designing within the Unity 3D editor (similar to working in a CAD environment) and writing C# code (a language very similar to Java).



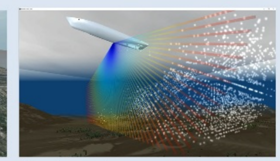
Editing TerraViz world scene



Editing C# source code



Simulated sea-level rise in Washington DC scene



Underwater sonar / fisheries scene