Meeting Home Page

FY2011 Interagency Weather Research Review and Coordination Meeting

November 30 – December 2, 2010
Boulder, Colorado

Introduction

The FY2011 Interagency Weather Research Review and Coordination Meeting was held 30 November through 2 December 2010 at the Millennium Harvest House, Boulder, CO. The objective of the meeting was to review and/or identify the science research being conducted or sponsored by FAA, NASA, NOAA and their partners, which will produce critical information that will ultimately reside in the Next Generation Air Transportation System (NextGen) 4-D data cube. Selected researchers from within and outside the aviation weather community were asked to share their research progress and plans with their colleagues in the audience so that a clear path to meet agency and user requirements could be identified. A copy of the detailed agenda of this meeting is included in Appendix 1 of this summary. Individual presentations in PDF format can be found at http://www.esrl.noaa.gov/gsd/research/events/nov2010/.

In addition to the wealth of shared knowledge covered in this meeting, many key points of information and discussions are especially noteworthy. Three deserve special attention. First, since convective weather is the greatest cause of delays and cancellations in the National Airspace System, the lack of a clear path to operations for an improved standard NextGen convective weather capability continues to be viewed with great concern. The inability for NOAA to operationally implement, in the near to mid-term, the high-resolution numerical weather prediction model required to underpin this is a primary stumbling block. Second, Session 10 – the panel discussion and audience feedback session at the end of this meeting – provided a number of new, unique and valuable insights into how to improve research coordination and transition to operations. It is strongly recommended that the summary of that session receive particular consideration, wide distribution and considerable discussion since many of the ideas and suggestions will be pursued. Third, the continued uncertainty concerning the future of NASA Applied Science Program weather research was also viewed with great concern. An increasingly high level of coordination has existed since 2003 between the FAA, NASA and NOAA in pursuit of national priorities such as enabling NextGen, in particular, and improving all weather forecasting capabilities in general. NASA's unique ability to provide satellite data applications is invaluable. If the NASA Applied Science Program is unable to continue participating in this partnership, significant setbacks in much-needed and anticipated convective weather, in-flight icing, turbulence, volcanic ash, space weather and other nationally-critical forecast and warning capabilities are expected.

The meeting was well attended with 110 online-registered participants; there were additional unregistered attendees which brought the total to over 150. The private sector constituted 28% of attendees, academia and research 27%, with the remainder a mix of federal research, operations, and DOD participants.

The next Interagency Weather Research Review and Coordination Meeting is tentatively planned for the week of 14 November 2011.

Executive Summary

Day 1 – November 30, 2010

After a brief welcome from the meeting organizers, opening remarks on Day 1 by John Haynes of the NASA Applied Sciences Program consisted of NASA perspectives presented to the audience. Days 2 and 3 were, respectively, opened with comments from FAA and NOAA management.

NASA Weather Applications Program Perspective. *John Haynes, Program Manager, NASA HQ; Washington, DC.* Under the NASA Applied Sciences Program, the Weather Applications Program focuses on Earth science applications to support weather-effected economic interests, particularly involving aviation and support for the Next Generation Air Transportation System (NextGen). To this end, the program has entered into multiple MOUs with partner agencies (NOAA, FAA) and is represented on a myriad of interagency working groups. Additionally, the weather research coordination plan mandated by Congress in section 306 of the NASA Authorization Act of 2008 (PL 110-422) was prepared and recently concurred upon by NOAA and NASA ESD. The plan formalizes joint interagency research activities which have become increasingly interdependent since the Applied Sciences Program Weather area was established. The focus of this area began with NASA coordination with NOAA and the FAA in the development of fine spatial, temporal, and spectral scale analysis and forecasting tools for aviation. These tools have become increasingly integral and ubiquitous throughout NOAA operations. NASA weather applications are also routinely employed in the most fundamental research conducted by the NOAA Office of Atmospheric Research which has documented their significant, positive forecast model impact. These applications are regularly transitioned to operations through close coordination with the National Weather Service, NOAA/NESDIS, the NOAA National Centers for Environmental Prediction, and other federal agency partners. This is facilitated publicly through joint annual interagency weather research and coordination meetings between NASA, NOAA, FAA, DOD services and programs, and a number of interagency offices such as Office of the Federal Coordinator for Meteorology (OFCM) and the Next Generation Air Transportation System Joint Planning and Development Office (JPDO). NASA weather applications are further implemented through coordination with our federal counterparts during the preparation of NASA ROSES weather research solicitations.

The Weather Applications Program has established strong relationships with federal partners to identify unique applications of NASA satellite observations and realize their operational use. These applications provide critical components for integration with their operational products to drive various forecasts and systems. This will continue to be the case with the launch of upcoming NASA satellite missions. NASA's participation in weather applications research and related transition to operations activities currently performed with NOAA, FAA, DOD, and others fills a significant void in national capabilities and is a critical component in current and future national weather programs and plans. More information can be obtained at the following links: http://appliedsciences.nasa.gov; http://science.larc.nasa.gov/asap.

Special Invited Presentation: NWS Aviation Weather Product Survey. *Thomas Schlatter, NOAA.* Dr. Schlatter summarized progress on a survey he is conducting for the National Weather Service. The survey will provide a snapshot of current aviation weather product capabilities relating to convection, turbulence, icing, and low ceiling and visibility. The survey includes not only the effects these hazards have on aircraft en route but also on ground operations, namely, airport delays and changes in the acceptance rate for aircraft. The NWS will use this survey to guide future development of aviation weather products. Dr. Schlatter is nearing the end of the information gathering phase of this project (he says the Tri-Agency meeting provided a "gold mine" of information), but still plans to visit Alaska in January to gain information on the special problems faced by pilots in that state. A draft of the report is due at the end of March 2011.

Session 1 – Issues in Numerical Weather Prediction

Introduction. *Steve Weygandt, NOAA ESRL/GSD*. Improved numerical weather prediction (NWP) for aviation depends on advancements in three core areas: data assimilation; model formulation; and model post-processing. Speakers in this session will cover various aspects of this topic, including user needs, current operational systems, model physics and data assimilation enhancements, and model post-processing. Key issues and challenges in NWP for NextGen include determining the key user guidance needs, crucial observations and best ways to assimilate them, optimal model, ensemble, and post-processing configurations, needed computer resources, and ways for increasing collaboration to build the best community weather prediction systems.

Current and Future needs of Numerical Weather Prediction Guidance at the NOAA Aviation Weather Center. *Jason Levit, NOAA AWC.* The Aviation Weather Center (AWC) currently utilizes numerical weather model data from global, regional, mesoscale, and stormscale deterministic and ensemble models to produce forecasts for the national airspace system. The AWC routinely issues products generated by operational forecasters, and automated guidance derived from algorithms. All of these products use numerical model data created at the Environmental Modeling Center and from research partners. In the future, the AWC will use guidance from planned model upgrades such as higher resolution, post-processed ensemble guidance, and enhanced boundary-layer physics and cloud microphysics. The Aviation Weather Testbed, located at the AWC, plans to test new model outputs during experimental evaluation periods, focusing on developing new tools for enhancing decision support for air traffic impact management.

Numerical Modeling at NCEP/EMC: Progress and Plans. *Geoff DiMego, NCEP/EMC.* NCEP's modeling activities span the full range of aviation. For the strategic time frames beyond 3.5 days NCEP produces deterministic forecast guidance with Global Forecast System (GFS) and probabilistic guidance from the Global Ensemble Forecasting System (GEFS) and for shorter time frames with the North American Mesoscale (NAM) model and the Short Range Ensemble Forecasting (SREF) systems. Tactical guidance comes from Rapid Update Cycle (RUC - soon to be replaced by Rapid Refresh) and a new Very Short Range Ensemble Forecast (VSREF) system. Plans call for a merger of NAM (with its nests) & RUC (RR & HRRR) into a powerful North American Rapid Refresh Ensemble with High Resolution Rapid Refresh Ensemble embedded in it which will serve NextGen's enroute and terminal needs. Progress along this path is endangered by the lack of sufficient computer power for implementation at NCEP. Increases in base funding must be obtained, and soon, because the current plans for increasing computer power are insufficient to support even a single HRRR run in NCEP operations anytime before 2015.

Update on RUC, Rapid Refresh, HRRR, and NCPF. *Stan Benjamin, NOAA ESRL/GSD*. This presentation entailed a summary on recent improvements on NOAA hourly-updated models (RUC, Rapid Refresh, HRRR). The RUC/RR/HRRR models are a backbone for US convection forecasting since they have demonstrated improved forecast skill with hourly updating of initial conditions with the latest observations. The radar-digital filter initialization technique developed for the RUC is now implemented in the RR, and via either the RUC or RR, allows effective initialization of ongoing convection of the HRRR.

NOAA/ESRL and NCEP have collaborated over many years to implement and update the RUC yearly, now running out to 18h each hour (March 2010 implementation). The Rapid Refresh is a new-generation replacement (also at 13-km resolution) of the hourly RUC based on community GSI and WRF components, each with RUC-unique enhancements (e.g., cloud/hydrometeor analysis, radar assimilation, digital filter initialization). The RR is now showing clear improvement over the RUC for wind, temperature, moisture, and ceiling forecasts, resulting from improvements to GSI and WRF even within the last few months. As of this writing, the Rapid Refresh implementation at NCEP is planned for July-August 2011. Experiments now in development with different levels of maturity with the RUC and Rapid Refresh include different latent heat design specifications for radar assimilation, assimilation of GOES-based cumulus-cloud-growth fields (e.g., SatCast), tropical cyclone proxy data, and wind tower/turbine observations.

The High-Resolution Rapid Refresh (HRRR), a 3-km resolution, hourly updated application of the WRF-ARW initialized by radar-enhanced RUC (or RR in near future), continues to be updated significantly each year. NOAA/ESRL and NCAR are performing many configuration experiments to address current shortcomings with the HRRR (e.g., 1-2h delay in onset of diurnal convection). These updates include both data assimilation variations (*e.g.,* last paragraph) and model variations (physics, diffusion, etc.). Experiments already performed show strength in using more effective initial conditions capturing the pre-convective environment from the RUC (vs. NAM or GFS) and exploration to improve forecasts of mesoscale convective systems (MCSs). Implementation of the HRRR is planned at NCEP, but expected computing resources at NCEP will not allow this to occur until ~2014. Until then, the HRRR run at NOAA/ESRL will likely continue as a demonstration system. A *HRRR Convective Probabilistic Forecast* (HCPF) product (based on time-lagged HRRR forecasts valid at the same time) has been developed at NOAA/ESRL over the past two to three years and continues to be optimized until computer resources allow a more traditional ensemble to be used for probabilistic convective guidance. The GSI and WRF applications of the Rapid Refresh and HRRR with their unique designs continue to be a strong point of coalescence for other model and assimilation experiments by multiple groups, including NCAR, NCEP, Univ. of Oklahoma, and other partners.

Model Physics. *Roy Rasmussen, NCAR/RAL***.** NCAR is working on improvements to microphysical parameterizations directed toward operational models (Rapid Update Cycle and the Weather and Research Forecast models) under funding from the FAA Model Development and Enhancement (MD&E) and In-Flight Icing (IFI) Product Development Teams. The goals of this work are to:

- improve prediction of water phase at surface and aloft to support aircraft icing forecasts;
- incorporate recent microphysical observations from field projects (WISP, AIRS, SLDRP, ICE-L, PLOWS, etc.); and
- transition improvements to operations.

Current work areas are in aerosol physics and planetary boundary layer (PBL) parameterizations. Aerosols can have a significant effect on the composition of clouds; similarly, clouds process and change the nature of aerosol populations. Measurements are scarce to non-existent, so amounts, sizes, and geographic distributions of aerosol particles must be inferred from previous intensive field campaigns or derived from satellite-based sensors. A progression of sophistication in aerosol parameterization is planned for testing. PBL schemes affect the amounts and distribution of condensate in a modeled cloud or storm; becoming more noticeable as model resolution increases. Tests are being performed to determine which scheme works best for the desired parameters such as liquid water and ice crystal concentration and size. Field project data are available for comparison.

Advanced Methods for Mesoscale Data Assimilation. *David Dowell, NOAA ESRL/GSD*. Advanced methods for mesoscale data assimilation, including ensemble Kalman filter (EnKF), 4D variational (4DVar), and hybrid methods, are now being demonstrated for real cases -- real time and retrospective -- in fully complex models. During the last few years, EnKF and hybrid methods have received much attention. EnKF methods can be particularly useful when background-error covariances are anisotropic and/or difficult to characterize, observations are sparse, most fields are unobserved, and/or parallel computing is feasible. For mesoscale EnKF applications, background-error covariances are estimated from forecast ensembles with typically 30-100 members. Hybrid methods have the potential to utilize ensemble-based situation-dependent background-error covariances but with reduced computational cost relative to an EnKF. EnKF methods have been demonstrated in real time in mesoscale models (mid-latitudes and tropics) and retrospectively in high-resolution convection-allowing models into which radar data are assimilated. Ongoing research aimed at making advanced data-assimilation methods more practical for operational applications must include reducing model bias errors, improving ensemble design, and increasing computational efficiency.

Model Post-processing. *Zoltan Toth, NOAA ESRL/GSD*. In his presentation, Dr. Toth discussed some changes needed in numerical weather prediction as the National Weather Service moves from the paradigm of distributing products on a schedule to the new paradigm of flexible provision of services

needed by the aviation and other user communities. For efficient decision making, users must have access to information on the uncertainty in weather forecasts. Probabilistic forecasts, such as for exceedance probabilities at various thresholds for aviation impact variables, is one possible form for such information. Considering, however, that different users may be affected by various thresholds, and that in many instances it is a combination of AIV variables that affect operations, it is impractical to generate and distribute all uni- and multivariate probabilistic forecasts that may be needed by the multitude of users on any day. An alternative approach is to make the ensemble of numerical forecasts from which those probabilistic statements can be derived available to the user community, along with an intelligent interrogation tool. This interrogation toolset can respond to user requests for any weather related information. Users can either derive uni- or multivariate joint probabilistic information for any variables or combination of variables for user selected thresholds, or they can feed the ensemble weather scenarios for their variables and areas of interest directly into their decision making systems. The presentation discussed how this concept can be implemented into the 4D datacube in two phases. In Phase One, derived from an ensemble, the 10th and 90th percentile values of the forecast probability distribution can be added to the expected value (50th percentile) already planned for the 4D cube for each variable. In Phase Two, the data cube can contain an ensemble of 20-100 members. Development of user-friendly interrogation tools and statistical bias correction algorithms will be critical for taking full advantage of what numerical weather prediction can offer to the aviation community.

Localized Aviation MOS Program (LAMP) and Model Post-processing in MDL. *Judy Ghirardelli, NOAA MWS/MDL.* The National Weather Service's (NWS) Meteorological Development Laboratory (MDL) develops operational post-processed products to assist forecasters. MDL produces Model Output Statistics (MOS) guidance products from various Numerical Weather Prediction (NWP) models. In addition, MDL produces the Localized Aviation MOS Program (LAMP), which provides aviation guidance on an hourly basis out to 25 hours. MOS and LAMP use the statistical technique of multiple linear regression to produce objective guidance for sensible weather elements. MDL is currently developing Gridded LAMP to provide objective guidance on a 2.5-km grid for the aviation community. The Gridded LAMP guidance will run hourly and be available to the NWS community including NWS Weather Forecast Offices, and will also be available in the Next Generation Air Transportation System (NextGen). In this presentation, an overview of MDL's contribution to NOAA/NWS Products and Services was provided. Advantages and challenges associated with statistical model post-processing were discussed. An overview of the products making up the current MDL MOS guidance suite was given, and an introduction to LAMP was presented. An overview and status of the current experimental Gridded LAMP products for temperature, dewpoint, ceiling height, and visibility were presented, and future work was mentioned.

Day 2 – December 1, 2010

Day 2 began with an overview of FAA perspectives by Ray Moy of the FAA Aviation Weather Group. A summary of the presentation is not available. The presentation may be viewed at: http://www.esrl.noaa.gov/gsd/research/events/nov2010/agenda.html

Session 2 – Testbeds and Demos

Jason Levit of AWC led this session which began with his presentation on NOAA's Aviation Weather Testbed at the NOAA Aviation Weather Center. This was followed by presentations on Storm Prediction Center Activities by Steve Weiss of the NOAA Storm Prediction Center, Hydromet Prediction Center Activities by Dave Novak of the NOAA Hydrological Prediction Center and an Objective Evaluation of Aviation Related Variables during 2010 Hazardous Weather Testbed (HWT) Spring Experiment by Tara Jensen of the NCAR Research Applications Laboratory. Highlights follow.

Aviation Weather Testbed (Aviation Weather Center). *Jason Levit, NCEP AWC.* The Aviation Weather Testbed (AWT), located at the Aviation Weather Center in Kansas City, MO, is responsible for the

evaluation of new and emerging technologies and methodologies for aviation weather forecasting. Over the past several years, the AWT has overseen the research-to-operations process for transitioning developmental Aviation Weather Research Program algorithms into real-time operations. Future projects for the AWT include an experiment in the summer of 2011 investigating the use of high-resolution ensembles for aviation weather impacts, evaluation of new software for examining gridded weather data (AWIPS II, IC4D), and conducting an experiment on "operational bridging" for improved decision support to air traffic decision makers. The AWT participated in the 2010 Hazardous Weather Testbed spring experiment and organized its aviation weather component. Participants evaluated high-resolution models for use in improving forecasts of maximum height and intensity of convection, and issued experimental forecast fields for both variables. Forecasts were issued two times a day, for both short-term (day 1) impacts and next day (day 2) time periods. Initial results indicate that while high-resolution models provided useful and detailed information for aviation weather forecasts, better tools are needed for data interrogation and display to aid forecasters in creating more accurate products.

Summary of the Hazardous Weather Testbed and 2010 Spring Experiment. *Steve Weiss, NCEP SPC***.** The NOAA Hazardous Weather Testbed (HWT) conducts annual Spring Forecasting Experiments organized by the Storm Prediction Center (SPC) and National Severe Storms Laboratory (NSSL) to test and evaluate emerging scientific concepts and technologies for improved analysis and prediction of hazardous mesoscale weather. A primary goal is to accelerate the transfer of promising new tools from research to operations, through the use of intensive realtime experimental forecasting and evaluation activities conducted during the spring and early summer convective storm period. Much of the focus is on testing and evaluating an experimental, high-resolution convection-allowing NWP system for high impact thunderstorm prediction. High-resolution modeling systems running over three-fourths to full CONUS domains were contributed by numerous collaborators, including NSSL, the University of Oklahoma's Center for Analysis and Prediction of Storms (CAPS) working with the University of Tennessee National Institute for Computational Sciences, the NOAA/National Centers for Environmental Prediction Environmental Modeling Center (NCEP/EMC), NOAA/Earth System Research Laboratory Global Systems Division (ESRL/GSD), and the National Center for Atmospheric Research (NCAR). Automated thunderstorm guidance products were also provided by the NWS/Meteorological Development Laboratory (MDL) and MIT/Lincoln Lab. A cornerstone of the modeling systems was a 26-member, 4-km grid length Storm-Scale Ensemble Forecast system run by CAPS, which enabled the development of probabilistic, explicit convective-scale forecast guidance. The 2010 Spring Experiment ran from 17May through 18 June 2010, with more than seventy participants including operational forecasters, research scientists, academic faculty, graduate students, and administrators from numerous organizations across the US. While the experiment has primarily addressed convective scale prediction in the 12 to 36-h time frame, the scientific emphasis is aligned closely with the Warn-On-Forecast concept that uses high-resolution ensemble prediction systems as a foundation for short-term probabilistic forecasts of severe storms. This year, in addition to the traditional HWT focus on severe convective storms producing tornadoes, damaging wind gusts, and large hail, collaborations with other NCEP Centers were established within the HWT to help address a wider range of convective weather hazards. The Hydrometeorological Prediction Center (HPC) led an initial effort to explore high-resolution model forecasts of precipitation and excessive rainfall associated with warm-season convection, and the Aviation Weather Center (AWC) tested and evaluated new forecasting tools to improve thunderstorm forecasts for aviation. The three convective forecasting components operated simultaneously within the HWT with structured forecast and evaluation activities occurring each day. The weekly participants rotated through each component daily to broaden their understanding and gain unique perspectives on the different thunderstorm forecasting challenges. The experiment also provided an opportunity to strengthen collaborations between the severe weather, aviation, and Quantitative Precipitation Forecast (QPF) communities by identifying shared thunderstorm forecast challenges, and helped to enhance awareness of operational issues related to convective forecast consistency.

Hydrometeorological Weather Testbed (Hydromet Prediction Center). *Dave Novak, NWS HPC.* The Hydrometeorological Prediction Center (HPC) has a broad variety of forecast responsibilities ranging from short-range QPF to medium range sensible weather. HPC's forecasts are used as guidance among WFOs, CWSUs, and the AWC for aviation forecasts. The Hydrometeorological Testbed at the HPC

(HMT-HPC) led a QPF component of the annual HMT Spring Experiment. The QPF component explored the use of high resolution (1 to 4-km) convection allowing deterministic and ensemble model guidance for forecasting precipitation associated with warm-season convection. While not perfect, high-resolution convection-allowing models were found to be useful and can help improve QPF forecasts. In particular, the subjective evaluations showed that 65% of the forecasts from the Storm Scale Ensemble Forecast system (SSEF), a 4-km, 26-member ensemble, and 57% of the forecasts from the 4-km WRF-NSSL4 provided better forecast guidance than their operational counterparts (Short Range Ensemble Forecast System (SREF) and North American Mesoscale Model (NAM), respectively). Participating in this experiment allowed HPC forecasters to gain experience using high-resolution model guidance and to begin to determine how to best incorporate this guidance into their forecast process. Work is already underway to expand the QPF component of next year's Spring Experiment.

Evaluation of Aviation Weather Variables during the 2010 Hazardous Weather Testbed Spring Experiment. *Tara Jensen, NCAR.* The Developmental Testbed Center (DTC) objective evaluation for the 2010 Hazardous Weather Testbed (HWT) Spring Experiment included calculation of traditional skill scores and object-based scores and attributes using the DTC Model Evaluation Tools (MET). Models evaluated included the CAPS Storm Scale Ensemble Forecast (SSEF) system, the High Resolution Rapid Refresh (HRRR), the North American Mesoscale (NAM), and the Short Range Ensemble Forecast (SREF) system. In all, thirty models and four ensemble products were evaluated during HWT 2010. The forecast composite reflectivity field and 18 dBZ radar echo top fields (RETOP) were evaluated in support of the Aviation forecast desk. Most models had reflectivity as a variable but only three provided Radar Echo Top as a variable (HRRR, CAPS Ensemble, CAPS 1km). Preliminary results indicate all models tended to overpredict RETOP areal coverage by at least a factor of 2-5 based on frequency bias and a factor of 5-10 based on MET Method for Object-based Diagnostic Evaluation (MODE) area ratio of matched forecast and observed objects.

Based on some traditional and object-oriented metrics, the HRRR appeared to have a slight edge over CAPS simulations for RETOP during the 2010 Spring Experiment but the differences were not statistically significant. The 1km simulation did not provide improved skill scores or object attributes. From the ensemble perspective, the probability-matching ensemble post-processing technique (Ebert, 2001) seems to inflate the over-prediction of areal extent of cloud shield to a non-useful level. The objective assessment of the probability-matching technique for RETOP agreed with the subjective assessment made by the forecasters during the experiment.

Reference: Ebert, E.E., 2001. Ability of a Poor Man's Ensemble to Predict the Probability and Distribution of Precipitation. *Mon. Wea. Rev*. **129**: 2461-2480.

Session 3 – Observational Needs

Observational Needs Pt I. Roger Pierce (NOAA) chaired this session. A summary of the presentations follows.

Phased Array Radar. *Pam Heinselman (NOAA NSSL).* This presentation was taken from an article by the author in *Monthly Weather Review*. The unique electronic scanning capabilities of the National Weather Radar Testbed phased-array radar (NWRT PAR) are advancing rapid-scanning techniques that improve the depiction of storm evolution and improve understanding of hazardous weather. Electronic rapid scanning techniques developed through 2010 include beam multiplexing, which improves update time by about a factor of two, and adaptive scanning, which improves efficiency by scanning only regions with weather signal. Rapid update data (~1 min) collected using these and other sampling techniques show improved depiction of significant storm evolution currently unobserved by operational radars. This improvement was shown for a variety of storm types, including a reintensifying supercell, tornadic supercell, microburst, and hail-producing storm. Such rapid update data, combined with other sensors, have been analyzed to better understand both the evolution of circulations prior to tornadogenesis on 14

May 2009 (via dual-Doppler analysis) and the evolution of lightning relative within a hail-producing storm. Potential impacts of rapid update phased-array radar data on NWS warning decision making are also being explored through the 2010 Phased-array Innovative Sensing Experiment. Impacts on data assimilation are also in progress.

Polarimetric Radar Capabilities. *Kimberly Elmore (NSSL/CIMMS*). The WSR-88D radar network is scheduled to undergo a dual-pol upgrade in 2011. This upgrade will provide additional radar moments to the current data stream, including differential reflectivity (Zdr), differential propagation phase shift (or simply differential phase, PHIdp), specific differential phase (Kdp, the derivative with range of PHIdp), and the cross correlation coefficient, (RHOhv). Currently, the existing hydrometeor classification algorithm (HCA) show considerable skill at discriminating between rain and rain containing hail (larger than about 1 cm) along with potentially better quantitative precipitation estimation. However, this same HCA does not perform well for precipitation classification near the surface in winter precipitation. These problems are related to the fact the HCA can indentify only one melting level and, once identified, disallows any form of frozen precipitation below it. In addition, the current HCA does not make use of any environmental data or information, relying only upon the radar variables for hydrometeor classification. This limits the utility of the HCA in winter weather.

However, as shown in a paper that appears in Monthly Weather Review (Discrimination of Mixed- versus Ice-Phase Clouds Using Dual-Polarization Radar with Application to Detection of Aircraft Icing Regions, by D. M. Plummer, S. Goke, R. M. Rauber and L. Di Girolama, Monthly Weather Review, May 2010) it is possible to discriminate between mixed phase clouds and all-ice clouds using dual-pol radar variables that will be available in the upgraded WSR-88D radars. This work shows that in reflectivity (Z), Zdr and Kdp, there is a signal useful for discrimination between mixed phase and ice-only clouds. This result is vitally important because mixed phase clouds are those that contain potential for icing, while ice-only clouds do not. With this information in hand, an outline of how to proceed was presented. In this outline, polarimetric radar data are analyzed to a 3D grid over the CONUS, merged with environmental information from a numerical model, such as the RUC. Icing PIREPs are actively solicited during two full winter periods when clouds are present and, using these data, an algorithm for icing detection using dual-pol radar is developed. The resulting algorithm output, containing binary yes/no icing probabilities, would be placed on a 3D grid. No icing intensity information would be available initially, but would be added later.

Observational Needs Pt 2. Wayne Feltz and Ralph Petersen (UW SSEC) co-chaired this session. A summary of the presentations follows.

FAA Right-sizing. *Victor Passetti (FAA)*. The RightSizing Project is a FAA NextGen portfolio element aimed to ensure NextGen weather observing capabilities utilize a broad range of weather improvements and technologies to mitigate the effects of weather in future NAS operations. Improvements of the weather observation network support improvements of weather forecasts. The RightSizing Project will conduct planning, prototyping, demonstrations, engineering evaluations, and investment readiness activities leading to implementation of operational capabilities throughout NextGen near, mid and far terms.

The RightSizing Project will focus on evaluating the current observation capability against that needed to support NextGen. A consistent and effective weather observation sensor network will be a cornerstone to improved NextGen weather capabilities. This evaluation will determine the optimal quantity and quality of ground, air and space based sensors needed for NextGen support and will include a gap analysis. The gap analysis will help determine how cost effective sensor densities and performance, redundancies, or inconsistencies impact aviation operations.

The RightSizing Project is tied to a set of NextGen operational improvements that define weather-related enhancements needed to realize the goals of the NextGen Implementation Plan. Improvements of the observational network will benefit other NextGen solution sets, including trajectory based operations, collaborative air traffic management, and high density operations. The RightSizing Project will:

- *Optimize observing platforms to include legacy and future systems.* Determine the right sensors and the right sensor mix among ground, airborne, and other sensing sources to provide a more complete, consistent, and cost effective measurement of the atmosphere
- *Provide observational data of requisite space and time resolution for NextGen*. Focuses on an aviation weather sensor network that provides the spatial and temporal resolution needed to improve the quality of current and forecast weather impact information for all operational decision makers and satisfy NextGen aviation requirements
- *Develop adaptive sensing technologies and strategies*
- *Develop an observational strategy to guide acquisition of emerging sensing technologies*

For risk reduction and ease of transition these technologies will be evaluated for scientific correctness, safety, and operational suitability. Working with appropriate scientific, modeling, and user communities, current sensor information and dissemination short falls will be identified and evaluated. There will be efforts toward investigating technologies for optimizing, and improving aircraft weather sensing reporting. There will be evaluations for increased and improved use of satellite weather information. A subset of these candidate observation technologies will be targeted for early implementation and demonstrations of the viability of these technologies will be conducted.

AMDAR/WVSSI/OSSE. Ralph Petersen (SSEC) provided a summary of two recent studies on these topics. The abstracts follow.

Aircraft Moisture Observations: Assessment of WVSS-II vs. Rawinsonde Observations during 2009-2010 at Rockford, IL. Ralph Petersen[1], Lee Cronce[1], Erik Olson[1], Wayne Feltz[1], David Helms[2] and Randy Baker[3]
[1] Cooperative Institute for Meteorological Satellite Studies (CIMSS), University of Wisconsin – Madison
[2] NOAA, National Weather Service, Office of Science and Technology, Silver Spring, Maryland
[3] United Parcel Service, Louisville, Kentucky

The Cooperative Institute for Meteorological Satellite Studies (CIMSS) University of Wisconsin-Madison (UW) has performed inter-comparison analyses of the co-located evening rawinsonde and WVSS-II data during fall 2009, spring 2010 and summer 2010 at Rockford IL (RFD) to assess the general performance of the systems and to provide statistical evidence of the accuracy of the re-engineered WVSS-II system. As in previous inter-comparison tests conducted by CIMSS, the rawinsonde observations were taken using Vaisala model RS-92 instruments with new humidity sensors. The rawinsonde observations were made at approximately 3-h intervals, immediately before periods when UPS-757 aircraft equipped with the WVSS-II instruments landed, immediately after aircraft departed, and during the break between landings and departures. The analysis shown here was done using all available data from all aircraft, excluding those with known engineering failures.

Overall, the re-engineered WVSS-II systems appear to meet WMO observing requirements across all data ranges and in both ascent and descent. When the large match-up differences that are probably due to small-scale natural variability are excluded, the WVSS-II fundamental Specific Humidity (SH) observations match the rawinsonde data very closely, with random differences ranging primarily from 0.2 to 0.7 g/kg, well within WMO recommendations. The slight moist Bias (ranging from 0.1 to 0.3 g/kg) should be correctable in ground-processing if the data. When viewed in terms of Relative Humidity (RH) with aircraft temperature biases removed, the RH statistics show Biases that range from negligible near the surface to exceed ±5% at several higher levels and Standard Deviations generally between 5-10%. Inter-comparisons between aircraft measurements within the WVSS-II data set itself further validate these results. WVSS-II observations made within 15 min time, 60 km distance and 55 m altitude showing variability of less than 0.2 g/kg. This agreement between independent observations of moisture exceeds that of most, if not all, other operational data sets.

A Nationwide "Network of Networks": Investigating the Impacts of a Potential Ground-based Profiling System using an Observing System Simulation Experiment. Dave Turner[1], Dan Hartung[2], Jason Otkin[2], Wayne Feltz[2], Ralph Petersen[2], Erik Janzon[2]
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In a 2009 report, the National Research Council (NRC) called for a more comprehensive and adaptive national strategy for ground-based observations, with an emphasis on the planetary boundary layer (PBL) where existing observation capabilities were found to be particularly inadequate. This report takes a first step toward addressing this need by conducting an Observation System Simulation Experiment (OSSE) of a single case study for a 06-08 January 2008 synoptic-scale extratropical cyclone using the Weather Research and Forecasting (WRF) model and the Data Assimilation Research Testbed (DART) assimilation system. Commercially viable sensors that measure vertical profiles from the surface to at least 3 km AGL, have vertical resolution of the order of 100 m, temporal resolution of at least one sounding every 2 h, and parameter accuracy meeting WMO minimum requirements with at least 90% data availability. Synthetic observations were generated to emulate the Doppler wind lidar (DWL), microwave radiometer (MWR), Atmospheric Emitted Radiance Interferometer (AERI), and Raman lidar (RAM) as a research-grade reference. For these tests, the synthetic observations were placed at each of the 140 existing Weather Surveillance Radar (WSR-88D) sites to reduce infrastructure costs.

Overall, the results demonstrate that the assimilation of high-quality observations from an array of surface-based profiling systems has the potential to greatly improve the accuracy of atmospheric analyses used by numerical weather prediction models. The best assimilation results were achieved when DWL wind observations were assimilated simultaneously with AERI, or MWR temperature and moisture data. The results met the improvement noted when using DWL with the more expensive RAM system. The forecast results indicate that the improved wind and moisture analyses that result from joint assimilation of high spatial and temporal resolution thermodynamic and wind observations are carried through into the initial 12-h forecast, corresponding to improved intensity and location forecasts of accumulated precipitation (ACPC) and moisture flux convergence. The largest ACPC forecast improvements in both location and intensity were made when thermodynamic and DWL wind observations were assimilated simultaneously with conventional observations.

GOES-R/JPSS. *Wayne Feltz (UW-CIMSS).* The GOES-R Aviation Algorithm Working Group was formed in November 2006 to assess meeting aviation related requirements as defined in the GOES-R Mission Requirements Document. A suite of experimental products are in development and are being evaluated to assess meteorological hazards to aircraft in flight derived from the current generation of Geostationary Operational Environmental Satellite (GOES) and European SEVIRI imager data. The specific GOES-R Advanced Baseline Imager (ABI) measurement requirements relating to satellite-based aviation hazard derived products are fog, aircraft icing, visibility, turbulence, SO_2, volcanic ash, convective initiation, and enhanced-v/overshooting top detection. The GOES-R Aviation AWG is tasked to adapt the current suite of experimental and operational aviation product algorithms, with modifications and enhancements, for the GOES-R Advanced Baseline Imager (ABI). The main purpose of this presentation was to make tri-agency participants aware of these upcoming capabilities and to promote solutions for connectivity to NextGen related satellite-based needs in the future.

Mulit-Radar Mosaic System (MRMS). *Kenneth Howard (NOAA NSSL).* The Multi Radar Multi Sensor (MRMS) capability provides high-resolution 3-D radar grids for advanced weather detection and forecast applications. The flexible and efficient MRMS software computing architecture accommodates rapid changes or additions to the NextGen objectives/requirements while providing a straightforward research-to-operations (RTO) integration platform for radar dependent, turbulence and icing solution portfolios without system dependencies or delays in implementation within the WSR-88D system. The turbulence and icing solution portfolios can be implemented and configured to allow the creators to modify and improve solutions quickly in addition to expanding the capability to utilize gap filling and international radars/networks. In November 2011, the MRMS capability was successfully installed in the FAA WJHTC NWEC environment. This activity allows for a significant return on FAA investment as MRMS will

facilitate the prototyping, testing and evaluation of advanced weather surveillance applications across the entire weather portfolio of NextGen Segment 2 (MOC) requirements while demonstrating a real time robust implementation of segment 1 (IOC) requirements across scalable time and space resolutions. The initial MRMS system implementation at the WJHTC is at a 1km CONUS resolution with a 2-min update cycle that will be reduced to 30 s as the capability matures and computational resources are made available.

Wind Profiler Upgrades. *Doug Van de Kamp (NOAA).* The existing twenty-year old network consists of 35 profiler sites, located generally in the central U.S. and Alaska. Each site currently transmits on a frequency of either 404 or 449 MHz, and typically provides hourly wind profiles throughout the troposphere. Data are routinely used in many aspects of operational NWS weather forecasting applications and are assimilated into numerical weather prediction models. To resolve an interference issue, all profiler transmissions at 404 MHz must be terminated, and transitioned to 449 MHz. As the old hardware is replaced in the years to come, improved meteorological data products are expected. Advancements in signal and data processing have led to improved rejection of ground clutter, migrating birds, and radio frequency interference, while reducing the minimum measurement height to 200 m AGL. above ground.

Session 4 – Convective Weather

Steve Abelman (formerly NOAA NextGen Content Lead, moving to FAA Weather Office in January 2011) and Jenny Colavito (FAA Weather Office) lead this session. Summary of presentations follow.

Convective Hazard Volume. *Jack May (AvMet).* The purpose of the presentation was two-fold: To inform the aviation weather research community of particular characteristics of the draft Full Operating Capability (FOC) weather requirements resulting from convection and to describe the *construction* of the 3-D object which contains the amalgamation of aviation weather hazards within a convective cell called the *Convective Hazard Volume* or CHV. The team responsible for providing the initial draft of functional and performance requirements for the 4-D SAS made several assumptions. The requirements are based on NextGen Concept of Operations and the NextGen Weather Concept of Operations, they are NAS-level requirements unallocated to any solution system or specific products, they are at a primitive level (that is, complicated 3-D structures such as freezing level and gust front will be *constructed* outside the SAS using SAS information, and it is acknowledged that some functional and performance requirements may not be met by FOC. It was also assumed that the fine spatial and temporal resolution required for NextGen operations required description of each aviation impact variable rather than aggregated into terms commonly used today such as “convection” or “thunderstorm”. This is due to the finding that the presence and magnitude of aviation impact variables within thunderstorm cells are not evenly distributed. The FOC functional and performance requirements team has recommended that any 3-D construction made to represent the 3-D hazards associated with convection be referred to as the Convective Hazard Volume (CHV).

Science Enhancements with CoSPA. *Haig Iskendarian (MIT-LL).* CoSPA produces 0 to 8-h deterministic forecasts of VIL and echo tops using a blending module (developed at NCAR) to seamlessly merge the Corridor Integrated Weather System extrapolation forecast (developed at MIT/LL) with the High Resolution Rapid Refresh (HRRR) numerical weather prediction model (developed at NOAA/ESRL). The team has been working on using wavelets to improve the radar track vectors used for the extrapolation portion of the forecast. Five new capabilities have been implemented on the CoSPA “shadow” system for real-time evaluation and testing: 1) Improvements to echo top decay using better echo top trend routines and trends in cloud-to-ground lightning; 2) algorithms that use output from the NASA SATCAST system to improve the forecast of convective initiation; 3) a probabilistic forecast capability that uses a 3-member time-lagged ensemble approach; 4) a capability to identify and track surface wind shifts and convergence zones; and 5) a capability to forecast precipitation phase (rain, snow, mixed) out to 8 h. The blending module has also received numerous upgrades. Dynamic calibration of the HRRR VIL has replaced the original static calibration, Lagrangian phase correction of

the HRRR forecast has replace the original Eulerian phase correction, and better handling of storm initiation in the blending weights have all led to improvement in CoSPA's forecast skill.

Objective Satellite-Based Detection of Hazardous Convective Storm Signatures. *Kristopher Bedka (NASA Langley Research Center).* Signatures in multispectral satellite imagery often indicate the regions within convective storms that are producing turbulence, frequent lightning, and severe weather such as tornadoes, large hail, and damaging winds. Research supported by prior NASA Decision Support CAN funding showed that rapid lateral anvil expansion, the presence of transverse cirrus cloud bands, rapid vertical cloud growth, and overshooting convective cloud tops were frequently present in high-impact turbulence events. An objective overshooting top (OT) detection algorithm has recently been developed at NASA LaRC and UW-CIMSS via the GOES-R Advanced Baseline Imager Program. The algorithm detects clusters of anomalously cold pixels within a region of anvil cloud with a uniformly warmer temperature. Validation of the algorithm relative to OT observations by NASA CloudSat and NEXRAD Echo Top indicate a false detection rate between 10 and 15%. Statistical comparisons of objective OT detections from current GOES with multiple years of NLDN lightning and objective United Airlines Eddy Dissipation Rate turbulence inferences show that these hazards are concentrated near the OT region The product also shows a strong relationship with severe weather, where OTs were found near 55% of severe weather reports over CONUS during the 2004-2009 warm seasons. This product operates on any current and future imaging sensor in real-time and it will be produced operationally in the GOES-R era. Current NASA ROSES funding is supporting integration of the objective overshooting top detection product into the Graphical Turbulence Guidance-Nowcast product that is currently being developed at NCAR.

Convective Initiation and Lightning. *John Mecikalski (University of Alabama at Huntsville).* Convective initiation nowcasting research, largely supported by NASA Applied Science, has progressed considerably since 2005. The presentation highlighted the current ability to use GOES infrared data, which has progressed to supplying 0 to1-h convective initiation information to the Corridor Integrated Weather System (CIWS), the 0-2 h component of CoSPA. The GOES-based information is used to develop vertically-integrated liquid (VIL) fields that mimic radar echoes, within CIWS, which then are tracked and grown in time. The result is that the precursor information to new thunderstorm development enters CIWS, which has been quantified as substantially improving convective weather forecasts. The use of GOES fields has recently expanded to the Meteosat Second Generation (MSG) fields, infrared and visible, toward improving 0 to 1-h convective initiation nowcasting ahead of the GOES-R launch in ~2015. Recent work also has emphasized the use of GOES 3.9 μm reflectance fields and tuning the thresholds for new thunderstorm formation, to help identify convective storms likely to produce first lightning ("lightning initiation"). Lightning Mapping Array (LMA) datasets over four LMA networks are were used to train GOES's detection of lightning (total lighting -- cloud-to-cloud, cloud-to-air, cloud-to-ground, intra-cloud). Presently via a NASA Applied Science effort, the lightning initiation capabilities are being evaluated within CIWS as well. Present emphasis is on improving the use of GOES infrared and visible fields to account for regional variability in atmospheric conditions, which cause "critical" threshold values to vary from location-to-location on meso-scales (~100-250 km), as a function of environmental moisture and stability. New research constitutes understanding how derived cloud-top properties such as optical thickness, particle effective radius, cloud phase and cloud top pressure may be used to enhance the ability to understand in-cloud processes, ultimately helping to enhance predictability of new thunderstorm development. UAHuntsville is also testing new approaches to assess convective storm intensity from satellite, and eventually space-based lightning observations, to enhance the diagnosis and prediction of convective storms over oceanic and other remote locations. Present collaboration involves scientists at EUMETSAT, NCAR, MIT-Lincoln Laboratory, NASA Langley, NASA Marshall Space Flight Center, and the University of Wisconsin-CIMSS.

Autonowcaster. *Rita Roberts (NCAR).* The AutoNowCaster System, which provides short-term 60-min nowcasts of storm initiation, growth and decay, was run this year in Florida at the Melbourne WFO (MLB). In collaboration with the MLB forecasters research and testing were conducted on weather regimes relevant to the Florida area. The primary focus has been the development of warm-season weather

regimes. Evaluation and testing of the performance of short-term thunderstorm nowcasts has taken place including the following new predictor fields: the Florida 7-y lightning climatology, prevailing wind direction, precipitable water and additional instability fields (K-index and others). Sensitivity studies have also been performed on optimal resolutions for producing VDRAS (variational Doppler radar assimilation system) wind fields over Florida, which are incorporated into the AutoNowcaster system. A comparison of the ANC performance using RUC versus Rapid Refresh NWP models has been ongoing for the Dallas/Ft. Worth WFO (FWD) area. SPC mesoanalysis fields are being tested as new predictor fields for the FWD area as well. An intensive demonstration of the ANC system was run at the Dallas/Ft. Worth WFO and a variety of validation studies are being conducted both by NOAA/GSD and NCAR on the ANC performance with and without a forecaster in the loop.

Oceanic Convection. *Cathy Kessinger (NCAR).* Four NASA ROSES grants were discussed. First, the Oceanic Convection Diagnosis and Nowcasting system identifies deep convection through a data fusion of three geostationary satellite methodologies over regional domains. For the global domain, two of the component algorithms identify convection. The system nowcasts the future location of deep convection at 1-8 h by merging storm vectors from an object-tracking methodology with the model wind field. The diagnosis algorithm has undergone extensive testing and validation using the Tropical Rainfall Measuring Mission (TRMM) observatory. Likewise, the extrapolation methodology has been validated. Second, output from the diagnosis and nowcasting systems are being input into the Global Atmospheric Turbulence Decision Support System (DSS) for Aviation as an indicator for convectively-induced turbulence (CIT). Third, relationships between cloud-to-ground lightning production, reflectivity and CIT are being examined in preparation for the Geostationary Lightning Mapper (GLM). Use of the GLM observations in remote, oceanic regions should better define regions of convective hazards for aviation. Fourth, work to blend the Oceanic Convection extrapolation forecasts with model forecasts over the Gulf of Mexico domain is underway.

Warn on Forecast and Convective Initiation. *Kurt Hondl (NSSL).* Convection is one of the major problems impacting aviation. The problem is compounded by the fact that the FAA requires advance notification of the location, strength, and coverage on convection with greater and greater lead times (as much as 6-8 h advance notice). There are many questions when it comes to convection.

* Where will the convection initiate?
* What convective mode (isolated cells, multi-cellular clusters, lines, etc) will form?
* What are the hazards associated with the convection?

At the longer time-scales, we have to rely on numerical weather prediction models which are just beginning to be run operationally (or routinely within research organizations) with sufficient spatial resolution to resolve convective elements. An even higher spatial resolution would be required to typify the hazards (hail, tornadoes, microbursts) associated with the convective cells. An ensemble of models would be required to sufficiently describe some probability of convective activity (location, mode, and intensity of associated hazards). There is plenty of research to do on improving models (*e.g.*, data assimilation techniques, microphysical processes, etc.) before the necessary computational power available to run the models in real time.

Convective Modeling Enhancements. *Steve Weygandt. (NOAA GSD).* Improved numerical guidance for convective storms depends on advancements in three core areas of numerical weather prediction: data assimilation; model formulation; and model post-processing. Within the data assimilation area, accurate thunderstorm prediction depends on improvements in both mesoscale and storm-scale assimilation. Within the model formulation area, optimized model physics components -- especially cloud microphysics, boundary layer, and surface schemes -- are crucial. Finally, extraction of application-specific information from appropriately-constructed and bias-corrected ensembles enables the creation of statistically-reliable probabilistic convective guidance. An additional key constraint for frequently-updated convective model forecasts is the perishability of the model guidance and the associated need to streamline the model system configuration to reduce the latency to an absolute minimum. Many of these principles can be seen in the 3-km High-Resolution Rapid Refresh (HRRR) model running in real-time at NOAA ESRL/GSD. The HRRR currently runs as a one-way nest within the hourly updated RUC mesoscale analysis and prediction system (will be switched to running within the Rapid Refresh

mesoscale system early in 2011). Currently, the HRRR depends on the RUC/RR data assimilation cycle to provide hourly updates including both mesoscale assimilation (via 3DVAR using all convectional observations) and storm-scale assimilation (from a diabatic digital filter-based procedure for radar reflectivity/lightning data). Because the 3-km HRRR is run over a very large domain (covering all of the continental U.S.), use of 1-h old RUC forecasts for the lateral boundary conditions is acceptable (and significantly reduces HRRR forecast latency), but use of the latest RUC/RR initial fields (after the reflectivity / lightning assimilation procedure) is crucial to obtain the best short-range HRRR convection forecasts. The HRRR is a key component of CoSPA and was evaluated in real-time during the summer of 2010, leading to a better understanding of its strengths and also of areas for improvement. In particular, location and structure of HRRR forecast convective elements is quite good and scale-dependent verification indicates that the HRRR does well at predicting convective initiation within a 40-km distance (with minimal time lag). Areas for improvement include regionally-dependent bias issues, for which a number of possible causes have been identified. Retrospective tests to evaluate the effectiveness of possible solutions are planned, which should lead to further HRRR improvements for the 2012 convective season. As noted above, the HRRR will be switched from running as a nest within the RUC mesoscale model to running as a nest within the Rapid Refresh mesoscale model. Based on preliminary evaluation, it is expected that this will lead to improved HRRR forecasts. The formulation of the diabatic digital filter-based reflectivity assimilation will also likely be modified. Experiments are currently underway to evaluate potential positive impacts from reducing the strength of the heating currently being applied at 13-km within the RUC/RR. Additional work will focus on testing the application of this radar reflectivity assimilation procedure at 3-km within the HRRR.

Day 3 – December 2, 2010

NOAA Perspectives. *Mark Miller (NOAA).* After a brief overview of the NextGen initiative and the NOAA program itself, Miller briefed an overarching theme that the role for basic research in fulfilling NextGen requirements is understood, and that applied research in delivering capabilities required for NextGen is paramount. The balance of the two is key to success, wherein there is an operational requirements link to basic and applied research and vice versa. Also, he outlined challenges that exist: 1) the role of the NWS forecaster in a "NextGen era," *i.e*., high-resolution, rapidly updating weather information environment; 2) forecast consistency, *i.e*., the ability for NWS to move past artificial boundaries levied by policy and current ways of doing business in the future digital era; 3) implementing needed High-Performance Computing capabilities in a resource-constrained environment; 4) implementing common, understood definitions and processes for probabilistic information; and 5) harmonization of what we do in the U.S. with European and Pacific weather organizations, since air travel is international.

Session 5 – Volcanic Ash

The session on volcanic ash was chaired by Imani Jeffries of the FAA Aviation Weather Group. Summaries of the presentations follow.

Debrief of FAA Volcanic Ash Meeting. *Steve Albersheim (FAA Aviation Weather Group).* The FAA hosted a Volcanic Ash Public Meeting on 5 November 2010 at FAA Headquarters. Fifty-five attendees represented affiliations from US airlines, domestic and international flight planning companies, research and academia, domestic and international safety agencies, government providers and policy makers. The goal of this meeting was to provide stakeholders (*e.g*., aviation users) with the opportunity to hear about ongoing plans for volcanic ash information and to provide these users with the opportunity, via an open Public Meeting, to interact with representatives from the FAA and National Oceanic and Atmospheric Administration (NOAA) regarding their operational needs for volcanic ash information in their aviation decision making for strategic and tactical flight planning and operations. The objectives were to assist the FAA in defining the operational service requirements for the detection (observation) and forecast of the

volcanic ash hazards (*e.g.*, ash cloud) and to assist in validating the functional and performance requirements for volcanic ash for the Next Generation Air Traffic System (NextGen).

The morning session consisted of presentations from FAA and NOAA. Steve Albersheim, FAA, gave a general overview of today's volcanic ash issues including the ongoing work being done by the International Civil Aviation Organization's (ICAO) International Volcanic Ash Task Force (IVATF), which was formed following the eruption of Eyjafjallajökull in Iceland. Jeffrey Osiensky, NOAA, briefed the meeting on NOAA's role in volcanic ash detection and forecasting capabilities in the U.S. Barbara Stunder, NOAA, presented an informative briefing on Volcanic Ash Dispersion Modeling Capabilities, including discussions on the uncertainties on the model's output. Stewart Stepney, FAA gave a presentation on the FAA Concept of How to Formalize the NextGen Operational Requirements and Performance Metrics. Larry Burch, AvMet, finished the morning session with a presentation on Operational Concept and Service Needs Evaluation. The presentation on the Operational Concept was followed by a discussion on the issues of visible ash and the ash penetration zones. The operators desire more information on the location of the ash cloud including eruptions. Indexes or levels of ash concentration may be helpful, but operators want the choice to avoid specific areas. The operators also desire to have volcanic ash information sooner, even if there is less certainty to that information.

The afternoon session was devoted to an open discussion with the stakeholders to obtain their input on current products and what they would like to see in the future (both near term and NextGen). The first topic of discussion was the SIGMET. Most of the operators said they use SIGMETs as advisory and consider other information in addition to the SIGMET to make their operational decisions. Some of the operators provide an alternative product under their Enhanced Weather Information System (EWINS) certification. In further discussions, the operators agreed that a volcanic ash severity or intensity index, similar to the light/moderate/severe would be useful. The operators also commented on their lack of confidence in the SIGMET accuracy, thus the need to use other information before making operational decisions. SIGMET graphic versus text was discussed. Most of the audience was not aware of the ICAO requirements to limit the number of points in the SIGMET for describing the hazard. Thus, the graphical version of the SIGMET is a simple 4 or 5 sided polygon, while the actual cloud is complex in shape. All the operators agreed that it would be beneficial if the SIGMET graphic could provide more detail in the aerial depiction of the volcanic ash cloud, and that they would accept a difference between the simple text version of the SIGMET and a more detailed graphic version of that same SIGMET.

The operators stressed the importance of timely information when volcanic activity has started, including more frequent updates. Ideally, that information could be programmed into the airplane's Flight Management Computer (FMC) to show the volcanic ash with respect to the planned route of flight. More frequent updates of the SIGMET would allow the flight crew to know changes in the lateral and vertical limits more quickly. The operators discussed how anything available on the Internet will soon be accessible on the airplane, through iPads, cell phones; long before a new product could be developed by the government. They would like an Internet web page with all the available information pertaining to a volcanic eruption and the associated meteorological information. They want to have access to this in the near term, well before NextGen information is on airplanes.

The Volcanic Ash Advisory (VAA) was discussed. Users would like Volcanic Ash Advisory Center (VAAC) products to be more operationally specific with better vertical resolution of the altitudes of the volcanic ash cloud in the VAA. All the users stated that they desire better altitude resolution in the VAA but also desire standardized products between all VAACs. Some VAACs use predetermined altitude blocks for their VAA while other VAACs provide more specific detail in the vertical extent of the ash cloud. The topic of whether the base or top of the volcanic ash cloud was more important to the users was discussed with the stakeholders. In general, users are concerned with en route issues, thus the top of the ash cloud is the most important. They are also concerned about emergency aircraft cabin decompression profiles which might require the aircraft to descend and penetrate an ash cloud. All operators indicated that they would not fly under a cloud with a significant ash concentration. Overall, the airline operators want to be provided with the right information, and then they will make the operational decisions regarding ash avoidance, including flying over or under an ash cloud if necessary.

Regarding the possibility of operations in some levels of ash, the operators stated that they may consider operations in low level concentrations of volcanic ash for a limited period of time, but this would be contingent on an approved Safety Management System (SMS). The operators also stated that they would like a level of confidence on volcanic ash forecast information, but also that this confidence level must be understandable to be useable in their operational decisions.

The meeting concluded with suggestions to have a follow-on meeting next year, perhaps in conjunction with one of the established meeting sponsored by the VAACs.

NOAA/UW Satellite Based Volcanic Cloud Monitoring Supporting Operations. *Justin Sieglaff and Mike Pavolonis (SSEC).* A summary of the presentation is not available. The presentation may be viewed at: http://www.esrl.noaa.gov/gsd/research/events/nov2010/agenda.html.

Global Satellite Observations of Volcanic Plumes for Aviation Hazard Mitigation. *Kai Yang (GSFC/NASA and GEST/UMBC)*. New capabilities of measuring volcanic SO_2 plume height and enhanced volcanic ash detection with aerosol index using hyper-spectral UV measurements were described and illustrated with Aura/OMI measurements of recent eruptions. Examples of OMI observations of fresh volcanic plumes were also provided to demonstrate the capability of reliable early detection using both SO_2 and aerosol index. This presentation also emphasized the synergetic use of UV and IR satellite measurements for multiple looks of the same volcanic event globally during a day to provide timely information needed for aviation decision support. More accurate quantitative ash loading information is needed for better aviation hazard mitigation, and there are plans to conduct research in joint UV and IR retrievals to fully explore the information contained in these hyper-spectral measurements to meet this need.

HYSPLIT Volcanic Ash Dispersion Modeling in Support of the U.S. Volcanic Ash Advisory Centers. *Barbara Stunder (NOAA).* The NOAA OAR Air Resources Laboratory (ARL) performs work in collaboration within NOAA, among the Federal community, and through ICAO internationally. Dispersion model output is not required by ICAO, but the Advisory and SIGMET products are required. Following the volcanic eruption in Iceland in spring, 2010, NOAA decided to add capabilities to the HYSPLIT modeling system to better simulate such large eruptions, including a first order approximation to initializing the ash cloud based on observations. ARL research includes continued improvements to initializing with satellite observations, ensemble modeling and probabilistic output, and creating a volcanic ash dispersion modeling verification database.

Operational Experiences. *Jeff Osiensky (NOAA AAWU, remote).* A summary is not available. The presentation may be viewed at: http://www.esrl.noaa.gov/gsd/research/events/nov2010/agenda.html.

Session 6 - Verification Needs

The verification session was chaired by Cynthia Grzywinski, an engineering research psychologist from the FAA Air Traffic Organization's NextGen & Operations Planning, Aviation Weather Group, Operational Readiness & Impact Team (AJP-6830) at the Atlantic City International Airport. A summary of the session follows.

Using Weather Impact Traffic Index (WITI) for Airport Arrival Performance Analysis. *Sasha Klein (ATA, Inc.).* WITI is used to quantify the combined Terminal and En-route Convective Weather Impact on an airport. A WITI model trained on multiple years of historical performance of a major airport versus a variety of weather conditions is applied to estimating "actual" airport capacity based on diagnostic weather, as well as "forecast" airport capacity based on a rolling 4-h forecast. These capacity estimates are compared with scheduled and actual arrival rates, as well as with Ground Delay Program rates if any. The resulting comparison charts can be used for better understanding of the efficiency of air traffic management (ATM) and airport operators' response to weather impacts. This methodology can also be

applied in avoidable delay estimation and in decision support tools predicting airport delays given the weather and traffic demand forecast.

Network-Enabled Verification Service (NEVS).*Jennifer Mahoney (NOAA GSD).* The presentation introduced quality assessment for NextGen as the bridge between weather forecast information and the use of those forecasts for operational decisions. It was shown that this bridge relies on verification metrics that measure the quality of weather forecasts in the context of their operational use, and on technology to effectively deliver the information to users - this will be done through NEVS. It was also shown how NEVS can be used to synthesize weather forecast information and alert decision makers for changes to forecast information that is relevant to their planning processes. Ms. Mahoney also serves as lead of the FAA's Quality Assessment Product Development Team, responsible for formal forecast quality evaluations. Results from the evaluations are used as input to determine when forecast products meet sufficient quality requirements to be transitioned from research to NWS operations

Verification Studies of Model-Derived Cloud Fields in Support of Aviation Applications. *Tara Jensen and Paul Kucera (NCAR's DTC).* Paul Kucera presented a short summary of verification work within the NCAR Joint Numerical Testbed (JNT). Tara Jensen presented an overview of the HWT on Wednesday. Kucera highlighted that work but also focused on efforts to use NASA A-Train observations in their MET tool for verification of NWP cloud fields. Recent research activities have focused on ground validation studies in support of TRMM; polarimetric radar analysis of precipitating systems in Florida, Northern Plains, West Africa, and Panama; assessment of weather modification programs in Saudi Arabia and West Africa; and assessment of FAA products such as National Ceiling and Visibility and Forecast Icing Products.

Cloud and Radiation Properties for Assimilation and for Verification of Model Fields. *Patrick Minnis (NASA LaRC).* NASA Langley cloud products are currently derived in near-real time from geostationary satellites and in the near-term future, from polar-orbiting satellites. The data generated at LaRC have been used for model validation and assimilation. The NOAA Rapid Refresh model assimilates the results from the North American domain and the NASA GMAO is working on assimilating the products from the global geostationary satellite analyses. Various other forecasters and researchers around the country use the data for making their forecasts or verifying their model diagnoses and predictions. The North American data are available through NCEP and all of the data are available directly from Langley; examples were presented.

Space Weather Services for Aviation: Product Validation and Verification. *Rodney Viereck (NOAA/NWS/NCEP/SWPC).* This presentation focused on the validation and verification of one of the most important space weather products that are provided to the aviation community. Space weather impacts HF communication which is still the primary mode of communication with aircraft during the main phase of their travel. During solar flares and energetic particle events, the ionosphere is modified in a way that can completely eliminate the ground-to-air communication. NOAA SWPC provides a product called the D-Region Absorption Product (DRAP) that specifies the availability of communication channels and frequencies. A critical component of any product is the verification of that product's accuracy. Several studies have been undertaken and new observations are planned to address the verification of DRAP. This presentation stimulated a number of questions and comments from the audience and additional discussions after the talk. These questions and comments highlighted the numerous issues of validation that are common to both terrestrial and space weather.

The Severe Hazards Analysis and Verification Experiment (SHAVE). *Kurt Hondl (NSSL).* The availability of geospatial information with superimposed weather data have allowed researchers to collect high-resolution verification of severe weather occurrences (specifically hail, flash floods, and damaging winds thus far). The SHAVE verification data provides higher-resolution verification data than would otherwise be available through Storm Data reports. The SHAVE verification data can then be used to fine-tune automated algorithms and provide better algorithm products to the end user.

Session 7 – Ceiling & Visibility

Jim Hartman (FAA Aviation Weather Group) chaired this session. A summary of the presentations follows.

LAMP and Gridded LAMP for operational C&V forecasting. *Judy Ghirardelli (NOAA MDL)*. The National Weather Service's (NWS) Meteorological Development Laboratory (MDL) develops operational post-processed products to assist forecasters. MDL produces Model Output Statistics (MOS) guidance products from various Numerical Weather Prediction (NWP) models. In addition, MDL produces the Localized Aviation MOS Program (LAMP), which provides aviation guidance on an hourly basis out to 25 hours. MOS and LAMP use the statistical technique of multiple linear regression to produce objective guidance for sensible weather elements. MDL is currently developing Gridded LAMP to provide objective guidance on a 2.5-km grid for the aviation community. The Gridded LAMP guidance will run hourly and be available to the NWS community including NWS Weather Forecast Offices, and will also be available in the Next Generation Air Transportation System (NextGen). In this presentation, an introduction to LAMP was given. Details about the LAMP station guidance, including the types of predictors used in the system and the area over which the guidance is valid, were shared. Examples of the station-based LAMP guidance for ceiling height and visibility were displayed. An overview of the current experimental Gridded LAMP products for ceiling height and visibility was presented. Examples of Gridded LAMP observations and animated 1-25 hour forecasts of ceiling height and visibility were shown. The current status of the project was highlighted. Gridded LAMP guidance for ceiling height and visibility is being produced experimentally in NWS operations, and the methods by which the data can be accessed were discussed. Future work was discussed, including plans to add station input to the Gridded LAMP system, minimize inconsistencies on the grid, and develop gridded probabilistic guidance and new gridded guidance of additional elements. Examples of prototype gridded probabilistic guidance for ceiling height and visibility were also shown.

Using Observations and Rapid Refresh to Build on LAMP Skill. *Paul Herzegh (NCAR).* The National Ceiling and Visbility (NCV) Product Development Team of FAA's Aviation Weather Research Program is currently advancing two weather products:

1. The Ceiling and Visibility Analysis (CVA) – a continuously updating real-time analysis of current C&V conditions across the CONUS. As a tool to improve situational awareness, CVA targets the safety-of-operations needs of lower-end GA and HEMS pilots. CVA is currently assigned experimental status. With the completion of its January 2011 SRM evaluation, CVA is expected to become operational near FY11 year-end. CVA grids can be viewed on Experimental ADDS and via the HEMS viewer tool.
2. The Ceiling and Visibility Forecast (CVF) – a probabilistic 1-10 h forecast of C&V across the CONUS. CVF is in the development stage and is projected to support operational use by approximately Q4 of FY13. CVF blends LAMP probabilistic forecast data, statistical forecast data from an NCV algorithm, and time-lagged ensemble information from the Rapid Refresh to yield improved probabilistic forecasts that most often exceed the skill of any of these inputs individually. NOAA/ASB funding helps support forecast R&D and development coordination with NWS aviation forecasters, who are expected to be among the first users of CVF.

Emerging Changes in Forecast Methodology through NOAA C&V Research. *Cammye Sims (NOAA).* Several National Weather Service (NWS) Weather Forecast Offices (WFOs) are producing experimental digital forecasts of ceiling, visibility, and probability of thunder, from which Terminal Aerodrome Forecasts (TAFs) in support of the Next Generation Air Transportations System (NextGen) and to meet the evolving needs of the GA community. These enhanced digital aviation services will be expanded to more WFOs over the next few years, in order to produce a national mosaic of aviation forecast elements. In addition, NOAA's Aviation Weather Center (AWC) can utilize these same digital forecasts in the generation of Area Forecast and other aviation products. This will result in a seamless and completely consistent forecast suite from the local TAF to the national en-route aviation weather products.

Update on NOAA GSD Research. *Steve Albers (NOAA GSD).*The LAPS Ceiling and Visibility presentation was given which started with an introduction of LAPS, a high-resolution, rapid-update, local-to-global analysis and prediction system. Typical resolutions for aviation purposes are 1-km spatially and

15-min temporally. Since LAPS is typically run over small domains with efficient software, the gridded output fields can be produced faster than many other systems (e.g. RTMA). LAPS is also highly portable, having many collaborators and users world-wide. ESRL is highlighting the cloud analysis and model "hot-start" initialization that relates to C&V and icing AIVs. However the system is also very suitable for convection, wind, and turbulence forecasting. The cloud analysis uses remotely sensed and in-situ observations to analyze 3-D fields of cloud and precipitation. Corresponding divergence and vertical velocity fields help the model initial condition to start with active clouds and precipitation in a dynamically-consistent manner. There is good verification of squall line case studies with a side-by-side comparison of forecast radar reflectivity and the verifying observations. Skill scores of BIAS and ETS show good short-range forecasting ability, with some dependence on WRF model microphysical package. It was recommended to consider the use of LAPS techniques including higher resolution in time and space for cloud analysis and forecasting. Future modeling improvements should center on a variational formulation of the hot-start data assimilation, to be used in the STMAS implementation of LAPS, as well as the GSI (via the DTC). It was also suggested to add new data sources as they become available.

Session 8 – Turbulence

Tammy Farrar (FAA Aviation Weather Group) chaired this session. A summary of the presentations follows.

FAA-Sponsored Research Overview. *Robert Sharman (NCAR).* Fhe FAA Aviation Weather Research Program -sponsored turbulence nowcast/forecast products are fairly mature and are all intended to populate the NextGen 4D data cube for IOC. These include a deterministic turbulence forecast product (GTG3, Graphical Turbulence Guidance), based on the WRF-RR model that covers mid to upper levels and can be used for strategic guidance. There is also a nowcast product (GTGN) which provides 3D fields of eddy dissipation rate (EDR) updated every 15 min, which can be used for tactical avoidance. GTGN makes heavy use of new and improved observations developed under sponsorship by the FAA, including but not limited to *in situ* EDR reports and NEXRAD-based remotely sensed in-cloud turbulence (NTDA or Nexrad Turbulence Detection Algorithm). GTGN also includes a diagnostic tool to capture convectively-induced turbulence (CIT). Examples of CIT from high-resolution numerical simulations were provided which showed the importance of gravity wave production by the storm in the CIT generation process. Finally, future work areas were discussed that could make use of other agency sponsored (NASA, NOAA) turbulence research.

Satellite-based Inferences/Convection. Wayne *Feltz, UW-Madison/CIMSS.* NASA and NOAA-sponsored research into mountain wave, tropopause fold, and convectively-induced turbulence over the past ten years was shown along with how these various decision support products dovetail into FAA AWRP-sponsored turbulence “smart” algorithms such as the Graphical Turbulence Guidance system. Objective detection of convective overshooting tops (OT) has shown top location highly correlated with Eddy Dissipation Rate (EDR) detection of turbulence aboard United Boeing 757 aircraft (>40% chance of light or greater turbulence when within 10 km of OT). New satellite-based research to infer downslope wind events from water vapor imagery have shown high correlation with moderate to severe turbulence in regions prone to these winds. Satellite-detected tropopause fold regions show a 50% chance of moderate to severe turbulence when Boeing 757 aircraft fly through these regions. Future work areas such as transverse band, cloud top cooling, and rapid anvil detection methods were identified and paths need to be identified for seamless interface into NextGen weather data cube and decision support.

NASA-Sponsored Research in Global Turbulence DSS. *John Williams (NCAR).* The NASA ROSES-sponsored Global Turbulence Decision Support System for Aviation, developed in collaboration between NCAR and UW-Madison/CIMSS, produces gridded global turbulence nowcasts and forecasts that incorporate model- and satellite-based turbulence diagnostics for clear-air, mountain-wave and convectively-induced turbulence. The 3 to 36- h Global Graphical Turbulence Guidance forecasts are intended to replace the current Ellrod-index turbulence grids used by the World Area Forecast System and facilitate creation of more accurate turbulence SIGMETs and SIGWX charts. The 0-3 h convection and turbulence nowcasts would support the WAFS in providing tactical turbulence information to users; a demonstration involving cockpit uplinks of this information is planned for next summer. The nowcast and forecast products also address NextGen MOC requirements for global weather. This project illustrates the importance of data fusion for drawing together disparate research outcomes, data sources and products, such as those from NOAA GOES-R and NASA-funded research, to create a decision-support product that directly addresses operational user needs. NASA ROSES has provided key support for cross-organization collaboration on end-to-end system development, but funding cuts may leave a significant gap in this approach transitioning from research to operations. Researchers would be assisted by better agency guidance on what data sources and products will be available in the future (and when), and on how new weather products can be officially evaluated, approved, and deployed to an operational environment serving user needs.

Session 9 – In-Flight Icing

Jim Riley (FAA Aircraft Icing Research Group) chaired this session. A summary of the presentations follows.

AWRP Icing Research Update. *Marcia Politovich (NCAR).* The FAA's Aviation Weather Research Program supports inflight icing research leading to improved diagnosis and forecast products. The take-home points of our research and development activities are:

1. The main conduits to users are the Current and Forecast Icing Products (CIP and FIP). CIP combines NWP model output with observations to create a three-dimensional field of icing probability, expected severity, and potential for supercooled large drops (SLD). FIP produces a similar product using only NWP model inputs, and provides forecasts to 12 h.
2. CIP and FIP do an excellent job with what they are currently asked to do: provide a medium-scale (now 20-km, 13-km for the IOC) depiction of the icing environment.
3. The InFlight Icing Product Development Team at NCAR works closely with other organizations to develop and implement concepts related to supercooled liquid water production and depletion to construct the best possible product. The organizations include NASA LaRC and GRC, NOAA GSD, NCEP MDL, AWC, AAWU, and several universities.
4. A broad-brush severity product is produced. The community has asked for an aircraft-specific severity product. To achieve this, collaboration with aerodynamicists to develop a means for assessing the effect of the icing environment on flight for any particular aircraft on any particular flight plan must occur. The meteorologists' must produce accurate predictions of liquid water content, drop size, and temperature. The aerodynamicists' job is to develop aircraft accretion and performance models to simulate flight in the virtual atmosphere and evaluate the effect on the airplane. This is a NextGen FOC goal and will require considerable research in the fields of NWP modeling improvements, interpretation of observations from radar and satellites, and verification of needed output fields.
5. At the same time, the icing team supports development of microphysical parameterizations for NWP models. Efforts are well integrated into the modeling community.

Satellite Diagnoses of Icing Conditions and HIWC for Aviation. *William Smith (NASA LaRC).* In the first part of the presentation, focused on airframe icing, a comparison of the NASA LaRC cloud products

with pilot reports found that PODs were good for unobscured low-level clouds during the daytime. Using a multilayer technique, icing conditions obscured by thin high-level clouds can be detected during the daytime with nearly the same skill. The multi-layer technique also improves the statistics at night which are not as good as the daytime statistics. The nighttime detection is expected to improve with future GOES satellites (i.e. GOES-R) which have additional spectral information. The LaRC satellite icing team is also estimating icing severity in two categories during the daytime, which has modest skill relative to PIREPS. Quantifying the accuracy and utility of a severity product with PIREPS is proving difficult. Other icing datasets being used for satellite validation include the NASA Icing Remote Sensing system (NIRSS) and TAMDAR. Future field campaigns with research aircraft could be useful if they are designed with a satellite validation component. Active remote sensing data from CloudSat and CALIPSO, as well as the ground-based NIRSS are being explored to demonstrate how improved knowledge of cloud vertical structure can be used to improve aircraft icing diagnoses from operational satellite data. The second part of the briefing focused on preliminary efforts to identify signals in satellite data to identify High Ice Water Content (HIWC) regions. A dual-satellite technique to estimate ice water content near the tops of clouds was developed and tested using GOES-E and GOES-W data during a HIWC event over Chicago on 26 July 2006. No distinct satellite signal was found for this particular case. Other cases, for which the exact location and timing of the HIWC events can be determined, will be examined in the near future.

High Ice Water Content (HIWC) Algorithm Concept. *Julie Haggerty (NCAR).* In response to reports of jet engine powerloss in the vicinity of convective systems, a working group has formed to investigate the meteorological conditions associated with these events. As part of this working group, NCAR/RAL has been tasked by the FAA to develop a nowcasting algorithm for warning purposes and investigate the utility of satellite products for detecting meteorological conditions associated with the hazard (NASA tasking).

Based on examination of meteorological conditions associated with prior engine powerloss events, it is currently thought that these events are caused when an aircraft encounters high mass concentrations of small ice particles. Although pilots were avoiding the most intense areas of convection, all of the known engine powerloss events have occurred in the vicinity of convection. Locations include tropical and midlatitude regions where oceanic and continental convective activity occur.

Early efforts to develop a nowcasting algorithm rely on analysis of prior engine events. In addition to convective conditions and the presence of ice phase hydrometeors, common attributes of these events include low radar reflectivity at flight level with moderate or heavy precipitation below the aircraft, absence of supercooled liquid, only light to moderate turbulence, cold cloud tops, anomalous total air temperature measurements, and others. The algorithm development process has begun by collecting model, satellite, METAR, lightning, and radar data products for detailed case studies of prior events. Results of these case studies are being used to better understand the conditions where engine performance may be affected, quantify hazardous levels of pertinent meteorological variables, and determine sources of data to be used in the HIWC Nowcasting Algorithm.

NASA Remote Icing Sensing System. *David Serke (NCAR).* NASA's Icing Remote Sensing System (NIRSS) is a prototype ground-based testbed, the purpose of which is the detection of in-flight icing hazards in the airport environment with existing, relatively inexpensive technologies. The system consists of a laser ceilometer, a multi-channel radiometer and a vertically-pointing Doppler K-band radar.

Over the last year, several improvements to the system have been incorporated. The project team has introduced and tested an algorithm to determine the mean radar-estimated size of any sensed liquid. Several cases of supercooled large drops detected by NIRSS were compared to nearby icing PIREPs and surface reports of drizzle. The NIRSS algorithm did well at classifying supercooled large and small drops with time resolution of less than a minute. Another study compared all of the severities of icing PIREPs reported within 40 km of NIRSS for a three-year period to NIRSS and CIP (Current Icing Product, an automated algorithm with 20-km/1000-ft resolution) icing severities. NIRSS did about as well as CIP at detecting positive PIREPs, and was somewhat better with null icing PIREPs. These results were achieved with much less airspace warned compared to CIP.

NCAR also provided a four-year archive of NIRSS raw data and processed icing hazard product to NASA Langley. The satellite icing development team at Langley used the NIRSS data along with PIREPs as their 'truth' datasets to help verify their satellite icing detection product.

A new 1° beamwidth multichannel scanning radiometer was commissioned by and delivered to NASA in late 2009. NCAR positioned the radiometer at Colorado State's polarized CHILL S-band radar site in Greeley, Colorado and tested it during in-flight icing cases. An integrated liquid water diagnosis algorithm was implemented for the radiometer, and the results were compared to CHILL's polarized moment data. NCAR worked with scientists at the University of Cologne, in Germany, to develop elevation angle-dependent coefficients to the integrated liquid water algorithm. In 2011 and 2012, this new algorithm will be tested to determine whether this new radiometer should be fully integrated into NIRSS to assist in volumetric, near-airport detection of icing.

NIRSS was moved to Platteville, Colorado for the winter of 2010/2011 as part of collaborative research with CSU and NCAR's Environmental Observation Laboratory. One advantage of the Platteville location is that it places NIRSS close to the flight paths of commercial aircraft on approach to Denver International Airport. This field campaign has three main goals:

1. Test and improve NIRSS's internal logic (supported by NASA, work performed by NCAR);
2. Support the development of an 'Icing Hazard Level' algorithm for the soon-to-be upgraded network of polarized NEXRAD radars (supported by the FAA NexRad Program Office through MIT-LL; work performed by NCAR); and
3. Support the development of a winter hydrometeor classifier algorithm (supported by FAA, work performed by NSSL and NCAR).

Freezing Drizzle Detection - Icing Hazard Level Development. *John Hubbert (NCAR).* The National Center for Atmospheric Research has been developing an Icing Hazard Level Algorithm for installation on the NexRad Open Radar Products Generator under funding from the FAA NexRad Program Office (through MIT-LL). The first year of this is completed and it is anticipated that at least one more year of initial development is required. In this first year, the results of two previous studies describing the radar signatures of two different types of icing conditions, namely supercooled large drops (SLD, drops with diameters >50 ☐m) and mixed phase, were utilized to examine the possibility of radar icing detection. The feature-fields described by Ikeda *et al.* (2009) to identify freezing drizzle were extended in order to test super-cooled drop detection above the ground. Also, dual polarization feature fields for detection of mixed phase were computed following Plummer *et al.* (2010). It was found that both feature-fields indicated an increased likelihood of icing at altitudes consistent with pilot reports near the time of the radar observations. Furthermore, the feature fields for super-cooled liquid and mixed phase were combined in separate, simple fuzzy logic identification algorithms and produced results that indicated icing in similar regions, both qualitatively consistent with pilot reports.

The initial results are encouraging and may indicate that dual-polarimetric radar measurements have value in detecting icing conditions. However, more case studies using data with icing verification are required to validate the radar signatures (feature-fields) and fuzzy logic algorithms. Analysis of known icing cases and known non-icing cases is required to estimate the performance of the feature fields and algorithms. Further analyses should be performed with the goal of optimizing the membership functions and weights. New feature fields also should be investigated that might lead to increased skill.

The combined resources of the CSU-CHILL and NCAR S-PolKa radars (known as the Front Range Observational Testbed, FRONT) provides an excellent opportunity for field measurements that would be invaluable to this study. It is planned to collect more data with S-PolKa and CHILL this upcoming fall and winter. There is a possibility of obtaining the NASA/GLEN NIRSS system to support S-PolKa and CSU-CHILL measurements.

References

Ikeda, K., R.M. Rasmussen, E. Brandes and F. McDonough, 2009: Freezing drizzle detection with WSR-88D radars. *J. Appl. Meteor. Clim*., **48**, 41 – 60.

Plummer, D.M., S. Goeke, R.M. Rauber and L.DiGirolamo, 2010: Discrimination of mixed-versus ice-phase clouds using dual-polarization radar with application to aircraft icing regions. *J. Appl. Meteor. Clim*., **49**, 920 – 936.

Session 10 – Panel Discussion and Audience Feedback

The objective of the meeting was restated: to present tri-agency (FAA, NASA, NOAA) sponsored research with a view toward collaboration in developing the critical aviation weather information that will ultimately reside in the NextGen 4D Weather Data Cube. The Program Committee thanked the presenters and audience for their excellent response to a somewhat quickly-convened meeting, and requested a single-paragraph abstract from each presenter to include as part of the final report. For the rest of the session, a panel was convened to gather feedback from the attendees concerning this meeting and suggestions for the next one. Notes from this session are summarized below. Next year's Program Committee will distill these notes into a more concise plan for the 2011 meeting which, by the way, will tentatively take place during the week of 14 November.

Some suggested that the next meeting should be more user and operations-focused while others felt that a user-focused meeting may suppress attendance from the science community. It was noted, however, that a meeting focusing solely on science may similarly suppress attendance from the user community. Certain users will not tolerate long meetings or detailed scientific review while others need the information, so balance is the key. A balance should be sought based on the overall objectives of the next meeting. It was felt that although this 2010 meeting was advertised as a science meeting, it included considerable information on end-products.

There was not enough topic discussion time during this meeting. A panel discussion concluding each session could consider the presentations and expand upon their ideas. On the other hand, this could increase the length of the meeting unacceptably. Narrowing focus while maintaining balance is key. Directing sessions toward issues and problems (rather than on meteorological topics) could be helpful.

Less focus on incremental improvements and more on larger questions and issues is needed.

The planning committee should give more guidance to speakers. It was also recommended providing speakers with a set of directed questions, *e.g.*, "what is the path to operations for this research?"

Another suggestion was to schedule workshops after presentations.

The importance of dialog between scientists and end-users cannot be understated. Collaborative decision making processes are being driven by NextGen requirements; translation of weather to information needed in decision support systems is the goal. If science isn't framed in terms of NextGen requirements, the science community won't receive agency senior level support. Historically it has been difficult for the science community to interact with the user community and this requires more deliberation. This may be a niche that future Interagency Meetings can fill.

Some felt that science-to-science interaction is available in AMS ARAM and other professional meetings. Science-to-user is generally the focus of the annual Friends and Partners of Aviation Weather meetings. It was noted that the latter is one of the few current forums for comprehensive review and coordination of the most salient science research needed for NextGen.

Some of the science presented will never make it into operations, so science groups seeking funding for aviation weather research need guidance from the users to focus efforts. More "bridge people" who are expert both as a scientist and as a user are needed. It was proposed to ask representatives from the ATCSCC to brief the tools they need and to prioritize them. It may also be useful to have use cases briefed to provide a context for future needs. Gaps in user needs should be identified.

EDR (eddy dissipation rate, an atmospheric measure of turbulence) guidance that users can readily understand is also needed.

Science operations demonstration briefings to explain guidance products should be presented. Some advanced weather products are easier to provide industry users than to provide to government users. Government users are very conservative and deliberate with respect to change.

Both the user and the science communities need more powerful computing resources to accommodate the science that is available today. If high performance computing capabilities are not available for another four years, what should the research focus be? An answer to this question is unavailable until after the next Congress meets.

The three agencies may be called upon to narrow their research scope to reduce overlaps in research programs and to help set priorities. Presentations that discuss how products get into the NAS are good for the community. Different products take different paths.

There is disagreement between the VAAC's on how to handle volcanic ash events. The main question that needs to be answered to enable harmonization of volcanic ash guidance is "How do we identify the best information to share?" Products should be digital, not more pictures to evaluate.

The challenge is to understand each agency's path to operations for new products. Disparate and/or disagreeing gridded databases are a problem. A common digital grid for NextGen is needed.

CoSPA is an integrated effort but CoSPA doesn't enter into TAF preparation. Different centers use different guidance resulting in disconnects between CoSPA used by CWSUs and TAFs used by WFOs. The path to consistent guidance is unclear. How will legacy products fare during transition to digital products without disrupting the NAS? ATM is the end-user of CoSPA, not NWS. How will products be targeted with user focus and at the same time maintain consistency? NWS has an idea of how to produce convection products to users but doesn't know how to achieve this through CoSPA. Science regarding ceiling and visibility analysis and forecasting is lagging behind the science regarding convection. A best-of-breed decision for convection tools is needed. "Consistency is more important than accuracy!"

Science becomes useful to the user community through translation of gridded digital information into user-specific products. The job of the scientists is to build the best information, not to build the best user interfaces -- that is left for the engineering community. But there still has to be a connection between the scientists and the users. This is an interdisciplinary problem. Weather translation tools should bridge air traffic managers and meteorologists, who require information presented in different formats.

Like the term "convection", the definition of "user" is unclear. To address NextGen needs, it may not be a good idea for scientists to meet directly with users. Instead, the meeting should be between scientists and weather translation tool engineers. These engineers should also be classified into a new group of users. On the ATM-Weather Integration Concept chart, the line connecting the research community to weather information providers should be put back in. This chart is a tool to bring the agencies together so it should be highlighted for the research community.

The research community needs to understand how each agency first sponsors and then transfers science to operations. Each agency's process must be explained so as a community it is understood how each community works -- that is a first step to collaboration on research efforts that can be effective operationally.

What do the scientists need to focus on in the next science review meeting so that the meeting is not overwhelmed with user requirements, but instead kept relevant to science program managers? Is it a good idea to bring in an example operational scenario as a backdrop for the science discussions in next year's meeting? The community needs to know what needs to be developed for the users. The FAA trusts NOAA to build the atmospheric state; weather translation for air traffic management is generally left to FAA. The ATM-Weather Integration Concept chart illustrates this division of labor. As was mentioned throughout the discussion, there is a huge need to address weather translation. Scientists need to participate in user meetings to better understand those needs. The air traffic management community

needs to tell the weather community what they want. Better-defined requirements between the communities are needed.

Next year's meeting needs to respond to clear expectations from sponsors, deliver on those expectations, and understand how the sponsors will use the results of the meeting. For next year's meeting, increased participation by the general aviation community may be useful.

Appendix 1 – Meeting Agenda

Tuesday, November 30, 2010

1. 1:00 pm Registration, Coffee
2. 2:00 pm Welcome *NOAA/NASA/FAA. Meeting Organizers*
3. 2:15 pm NASA Perspectives. *John Haynes (NASA)*
4. 2:30 pm Progress Report on Survey of Aviation Weather Products. *Tom Schlatter (NOAA)*
5. 3:00 pm Break
6. 3:30 pm Issues in Numerical Weather Prediction. *Steve Weygandt* (NOAA GSD)*
   User Needs for Model Guidance. *Jason Levit* (NOAA AWC)*
   GFS/NAM/HRW Update. *Geoff DiMego (NOAA EMC)*
   RUC/RR/HRRR/HCPF. *Stan Benjamin (NOAA GSD)*
   Model Physics. *Roy Rasmussen (NCAR)*
   Advanced Data Assimilation. *David Dowell (NOAA GSD)*
   Model Post Processing. *Zoltan Toth (NOAA GSD)*
   LAMP, Model Post Processing. *Judy Ghirardelli (NOAA MDL, remote)*
7. 5:30 pm End of Day 1

Wednesday, December 1, 2010

1. 8:00 am Continental Breakfast
2. 8:30 am FAA Perspectives. *Ray Moy (FAA)*
3. 9:00 am Testbeds and Demos. *Jason Levit* (NOAA)*
   NOAA's Aviation Weather. Testbed *Jason Levit* (NOAA)*
   Storm Prediction Center Activities. *Steve Weiss (NOAA SPC)*
   Hydromet Prediction Center Activities. *Dave Novak (NOAA HPC)*
   Objective Evaluation of Aviation Related Variables during 2010 Hazardous Weather Testbed (HWT) Spring Experiment. *Tara Jensen (NCAR/RAL)*
4. 10:00 am Break
5. 10:30 am Observational Needs, Pt I. *Roger Pierce* (NOAA)*
   Phased Array Radar. *Pam Heinselman (NOAA NSSL)*
   Polarimetric Radar Capabilities. *Kimberly Elmore (NSSL/CIMMS)*
6. 11:30 am Lunch
7. 1:00 pm Observational Needs, Pt II. *Wayne Feltz* (UW-CIMSS), Ralph Petersen* (SSEC)*
   FAA Right sizing. *Victor Passetti (FAA)*
   AMDAR/WVSSI/OSSE. *Ralph Petersen (SSEC)*
   GOES-R/JPSS. *Wayne Feltz (UW-CIMSS)*
   Mulit-Radar Mosaic System (MRMS). *Kenneth Howard (NOAA NSSL)*
   Wind Profiler Upgrades. *Doug Van de Kamp (NOAA)*
8. 3:00 pm Break
9. 3:30 pm Convection. *Steve Abelman (NOAA), Jenny Colavito* (FAA)*
   Convective Hazard Volume. *Jack May (AvMet)*
   Science Enhancements with CoSPA. *Haig Iskendarian (MIT-LL)*
   Objective Satellite-Based Detection of Hazardous Convective Storm Signatures. *Kristopher Bedka (MIT-LL)*
   Convective Initiationa and Lightning. *John Mecikalski (CIMSS)*
   AutoNowcaster. *Rita Roberts (NCAR)*
   Oceanic Convection. *Cathy Kessinger (NCAR)*
   Warn on Forecast and Convective Initiation. *Kurt Hondl (NSSL)*
   Convective Modeling Enhancements. *Steve Weygandt (NOAA GSD)*
10. 5:30 pm End of Day 2

Thursday, December 2, 2010

1. 8:00 am Coffee
2. 8:30 am NOAA Perspectives. *Mark Miller (NOAA)*
3. 9:00 am Volcanic Ash. *Imani Jeffries* (FAA)*
   Debrief of FAA Volcanic Ash Meeting. *Steve Albersheim (FAA)*
   NOAA/UW Satellite Based Volcanic Cloud Monitoring -- Supporting Operations. *Justin Sieglaff and Mike Pavolonis (SSEC)*
   Global Satellite Observations of Volcanic Plumes for Aviation Hazard Mitigation. *Kai Yang (GSFC/NASA and GEST/UMBC)*
   HYSPLIT Volcanic Ash Dispersion Modeling in Support of the U.S. Volcanic Ash Advisory Centers. *Babara Stunder (NOAA)*
   Operational Experiences. *Jeff Osiensky (NOAA AAWU, remote)*
4. 10:00 am Break
5. 10:30 am Verification Needs. *Cynthia Grzywinski* (FAA)*
   Weather Impact Traffic Index (WITI). *Sasha Klein (ATA, Inc.)*
   Network-Enabled Verification Service (NEVS). *Jennifer Mahoney (NOAA GSD)*
   Verification Studies of Model-Derived Cloud Fields in Support of Aviation Applications. *Tara Jensen and Paul Kucera (NCAR's DTC)*
   Cloud and Radiation Properties for Assimilation and for Verification of Model Fields. *Patrick Minnis (NASA LaRC)*
   Space Weather Services for Aviation: Product Validation and Verification. *Rodney Viereck (NOAA/NWS/NCEP/SWPC)*
   The Severe Hazards Analysis and Verification Experiment. *Kurt Hondl (NSSL)*
6. 11:30 am Ceiling & Visibility. *Jim Hartman* (FAA), Steve Abelman* (NOAA)*
   LAMP and Gridded LAMP for operational C&V forecasting. *Judy Ghirardelli (NOAA MDL)*
   Using Observations and Rapid Refresh to Build on LAMP skill. *Paul Herzegh (NCAR)*
   Emerging Changes in Forecast Methodology through NOAA C&V Research. *Cammye Sims (NOAA)*
   Update on NOAA GSD Research. *Steve Albers (NOAA GSD)*
7. 12:30 pm Lunch
8. 1:30 pm Turbulence. *Tammy Farrar* (FAA)*
   FAA-Sponsored Research Overview. *Robert Sharman (NCAR)*
   Satellite-based Inferences/Convection. *Tony Wimmers, Wayne Feltz (UW-CIMSS)*
   NASA-Sponsored Research in Global Turbulence DSS. *John Williams (NCAR)*
9. 2:30 pm In-Flight Icing. *Jim Riley (FAA)*
   AWRP Icing Research Update. *Marcia Politovich (NCAR)*
   Satellite Diagnoses of Icing Conditions and HIWC for Aviation *William Smith (NCAR LaRC)*
   High Ice Water Content (HIWC) Algorithm Concept. *Julie Haggerty (NCAR)*
   NASA Remote Icing Sensing System. *David Serke (NCAR)*
   Freezing Drizzle Detection - Icing Hazard Level Development. *John Hubbert (NCAR)*
10. 3:30 pm Break
11. 4:00 pm Panel discussion and wrap-up. Agency leads and all attendees.
12. 5:00 pm End of Meeting