Variational LAPS

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Acknowledgment:
FAB team, domestic and international collaborators

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Outline

- Brief review variational analysis for LAPS;
- Improvement of variational LAPS since last workshop;
- Future plan

LAPS Achievements

- Observation oriented analysis;
- Efficient and fine resolution analysis;
- Portability and ease of use;

- Multiscale analysis;
- Hotstart analysis;
- Cloud analysis;
- Good performance in real time verification;
- Continuing improvement;
- ……

Why Variational LAPS

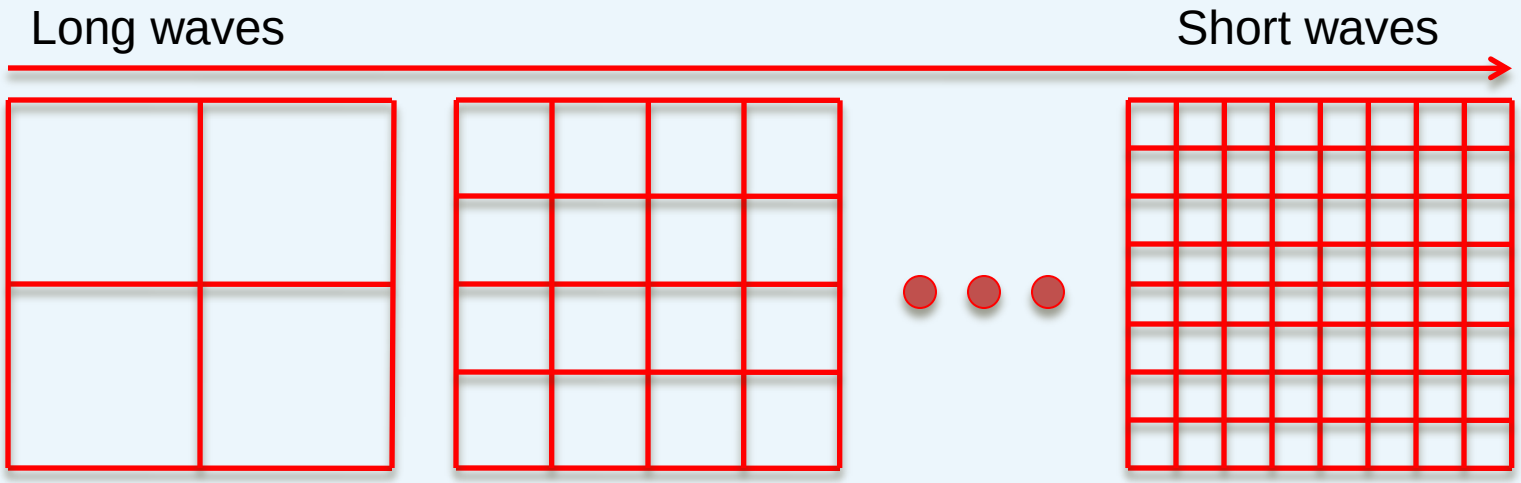
To make improvement of LAPS, some issues need to be addressed,

- *Balance and constraints cannot be applied simultaneously in the current LAPS objective analysis;*
- *Remotely sensed data may not be treated optimally;*
- *Cross variable covariance cannot be applied directly.*

A variational analysis can address all of these issues but it is required to possess the advantages of LAPS objective analysis. A multiscale variational analysis can meet these criteria (STMAS).

Current GSI has difficulty implementing the multiscale feature, for example.

A multiscale variational analysis system



Sequence of 3-4DVARs with proper balances

Similar to LAPS analysis with less requirement of covariance

Analysis and model initialization may end
at different multigrid levels

Standard 3-4DVAR
With a band covariance

Possible ensemble
Filter application

Xie et al. “A Space–Time Multiscale Analysis System:
A Sequential Variational Analysis Approach”, MWR 2011

Variational LAPS Analysis

- Matching up with LAPS objective analysis' real time forecast performance;
- Running on a single processor;
- Being integrated in LAPS, users have options to run either analysis;
- Gradually expending analysis data sets;
- Gradually merging LAPS processes into a unified variational system.

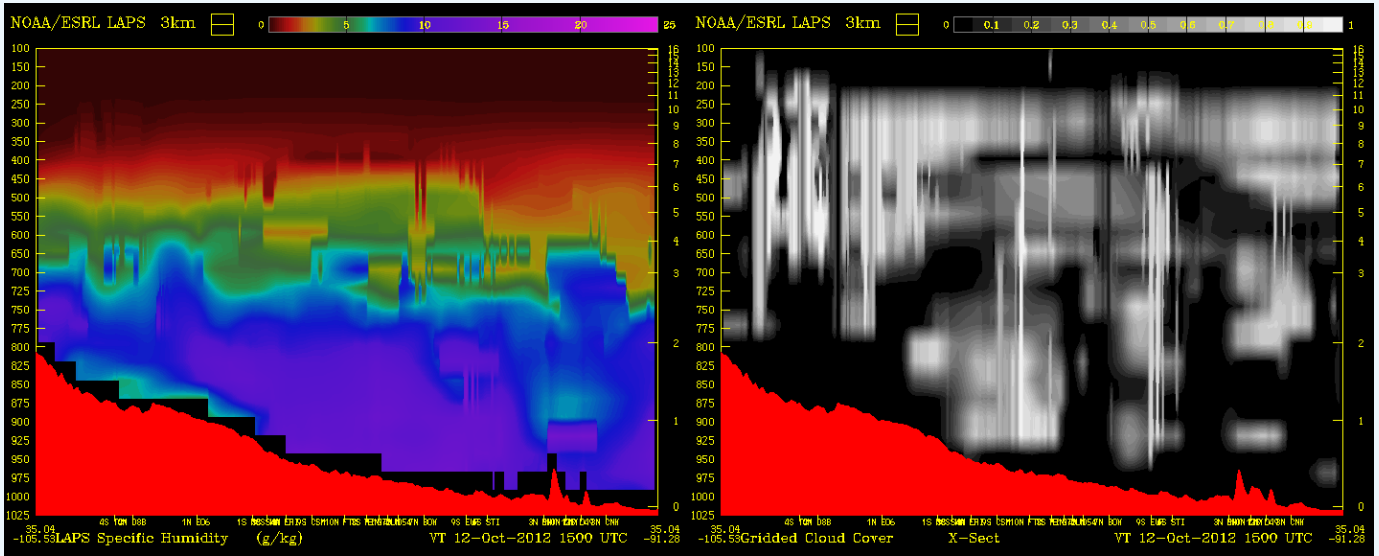
Variational Analysis Improvements

since last workshop

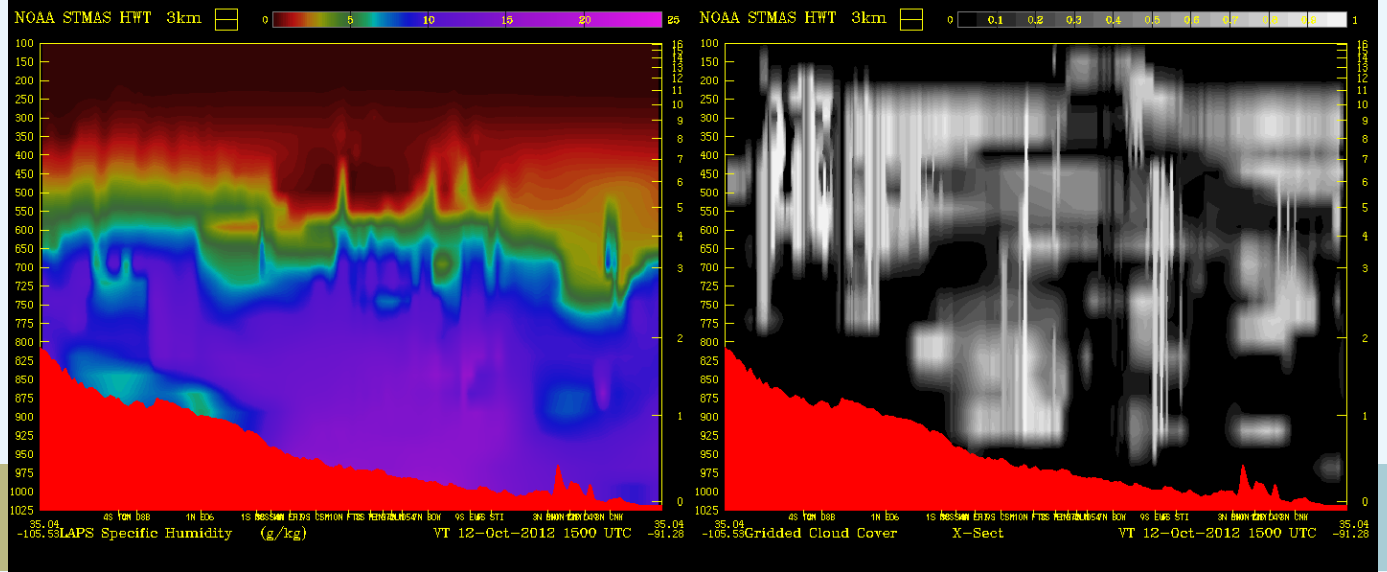
- Humidity analysis is integrated into the variational analysis system;
- CRTM (Community Radiative Transfer Model) is ported to the variational system and AMSU-A and B data can be assimilated in addition to the satellite data assimilated by LAPS;
- Efficiency improvement so it can run a CONUS analysis at 3km resolution;
- Terrain-following coordinate variational analysis is being tested;
- ……

Humidity Analysis

resolving discontinuity



LAPS



STMAS

Humidity (continue)

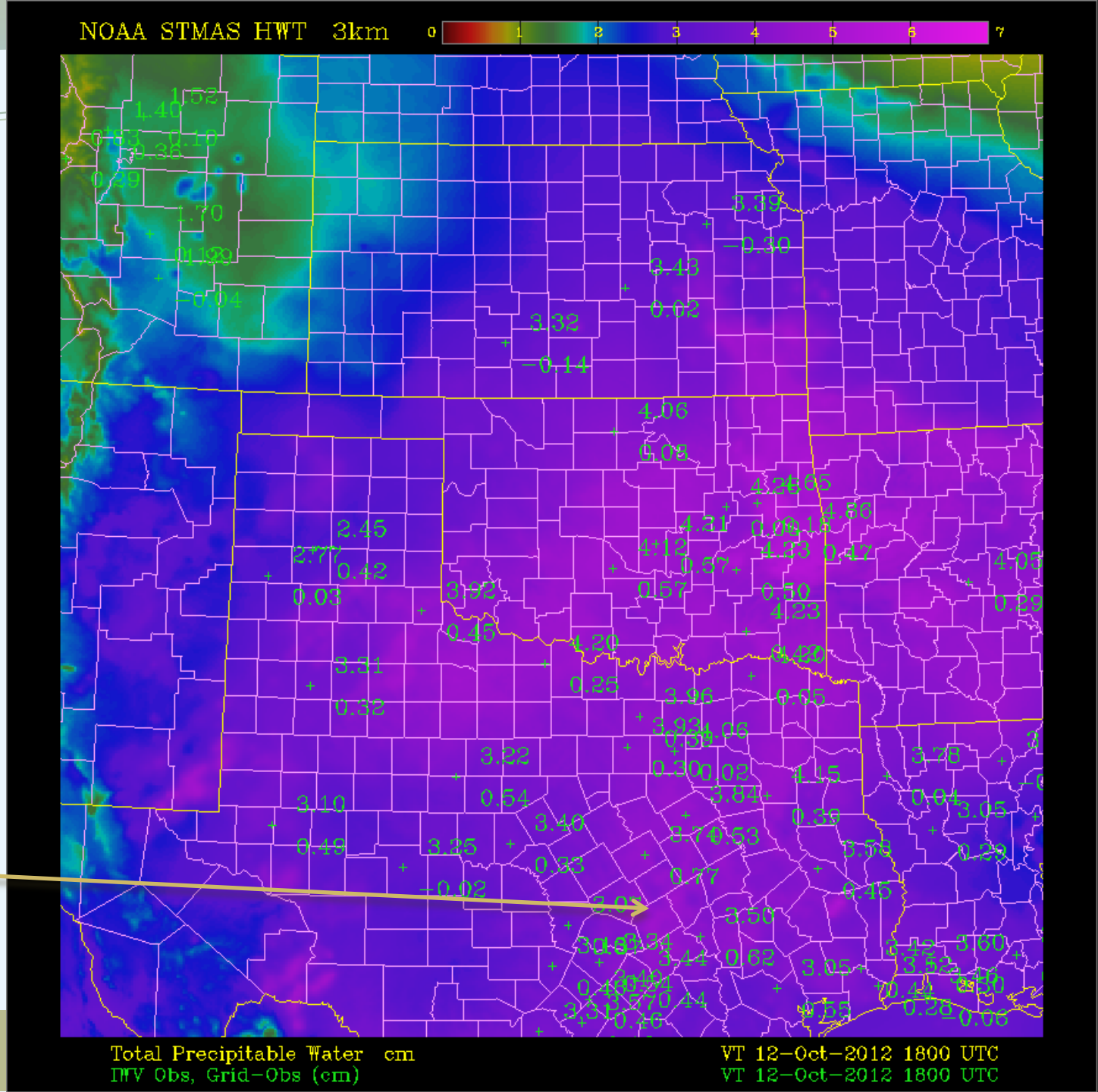
- Variational LAPS analysis provides smoother humidity analysis, which may be less shock to WRF;
- The smoothness can be adjusted by a namelist parameter;
- Both LAPS analyses (variational and objective) use reflectivity and LAPS cloud analysis to constrain the humidity analysis. Variational converts them into a low bound constraint;
- Other data source will be added to improve variational humidity analysis.

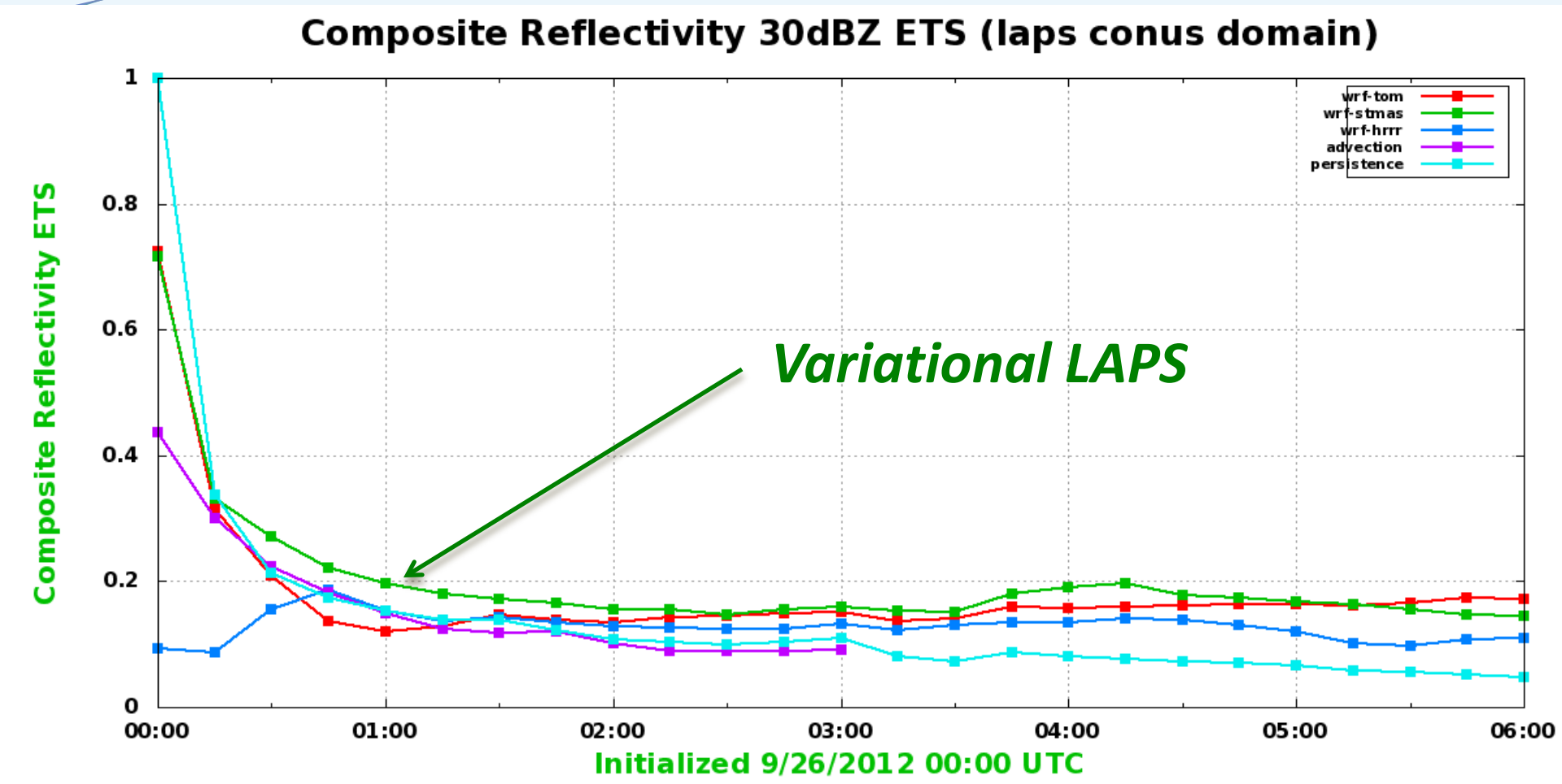
Data not being used yet: GPS, satellite (moisture channels), radiometers, lidar, and etc.

Additional data will help

Example: GPS TWP constraint could reduce variational humidity bias (See Seth's talk)

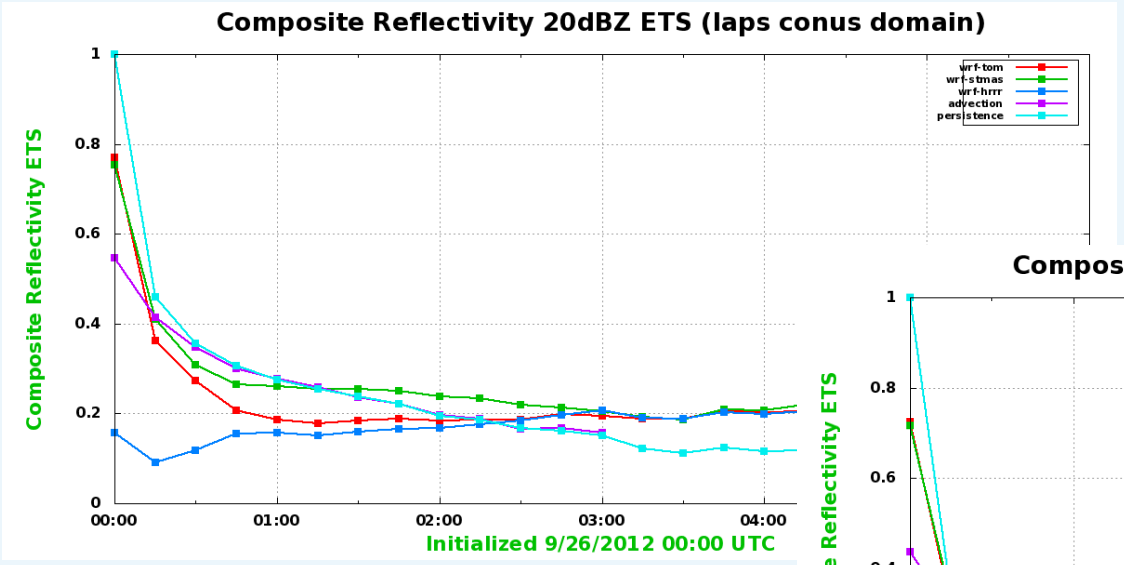
0.77 is too much bias humidification



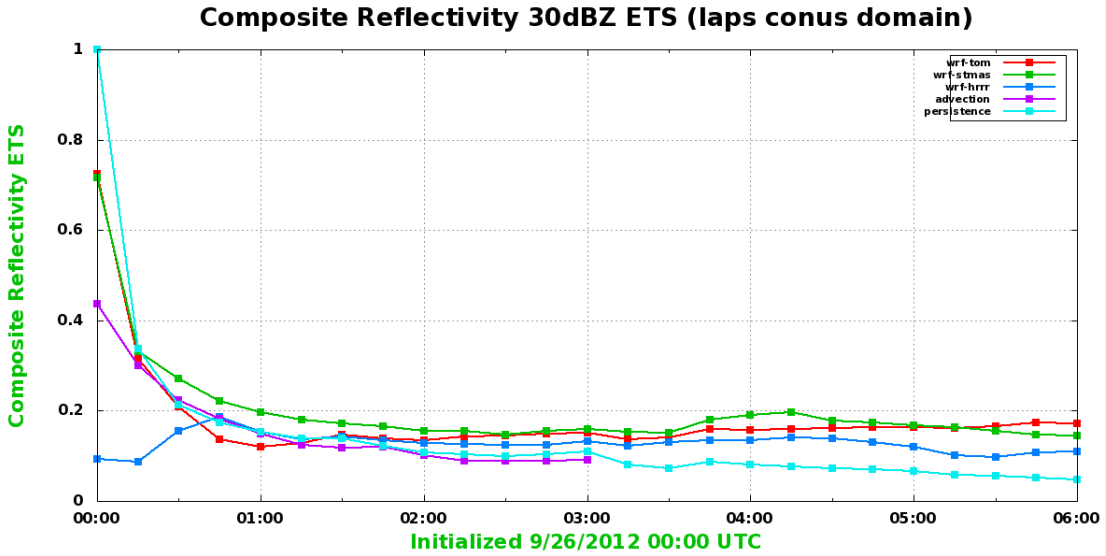


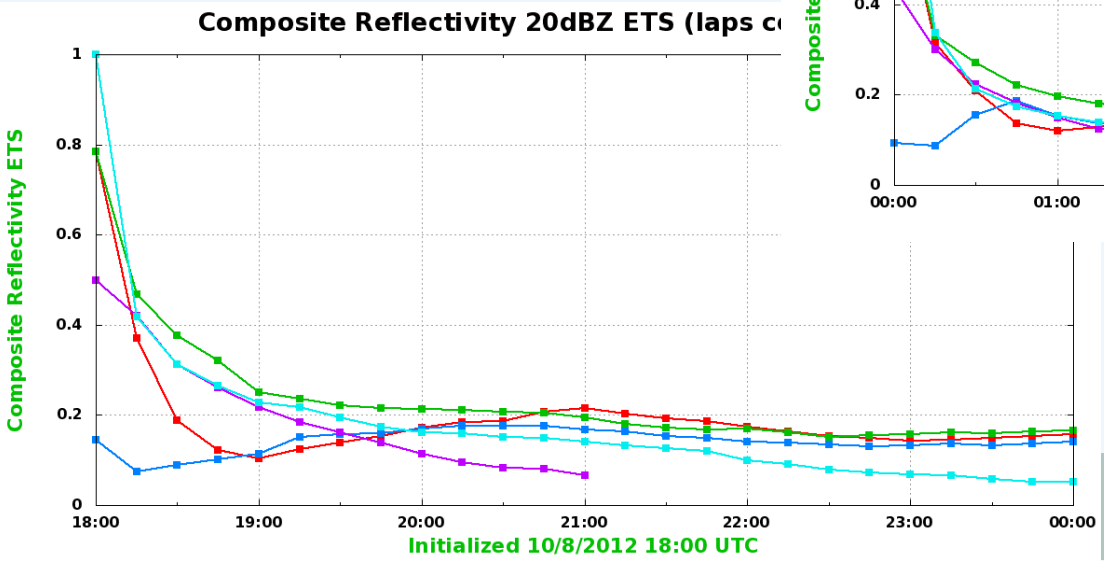
- On occasion, ***variational LAPS*** superior to ***advection*** and ***persistence***

Variational LAPS beats the persistence and advection in some cases



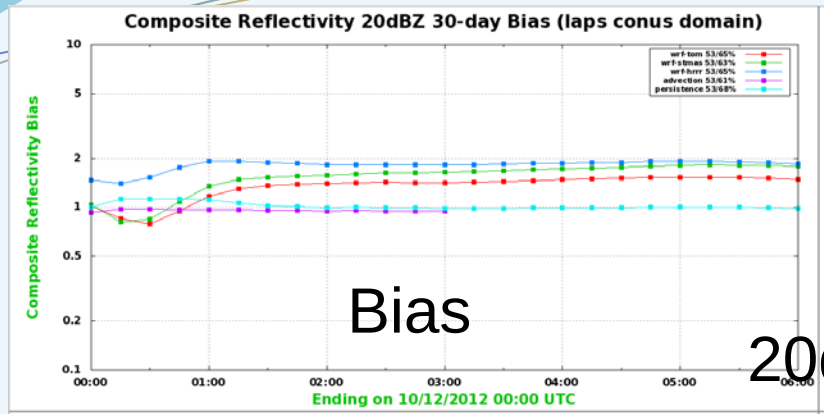
Persistence: Forecasts fixed at initial time



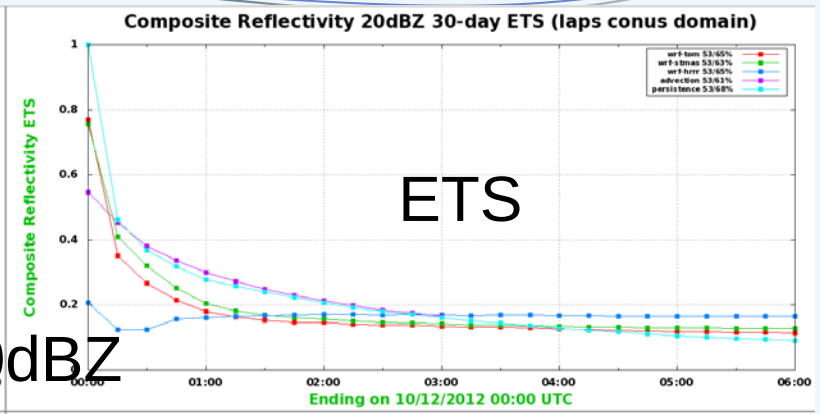


Advection: simply advects by wind.

The Multigrid Variational LAPS Performance

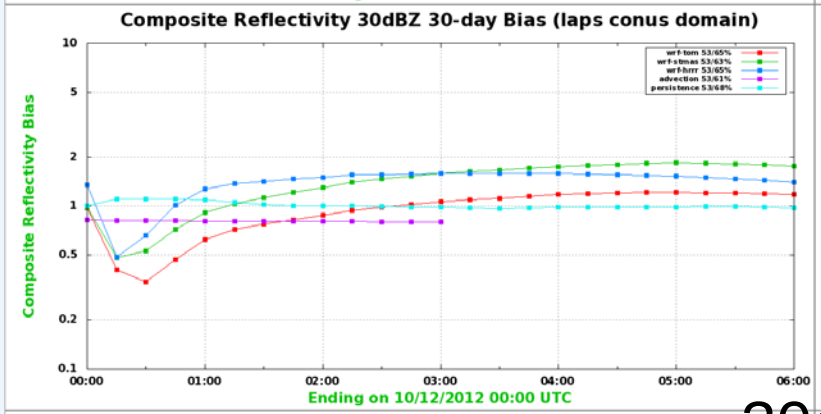


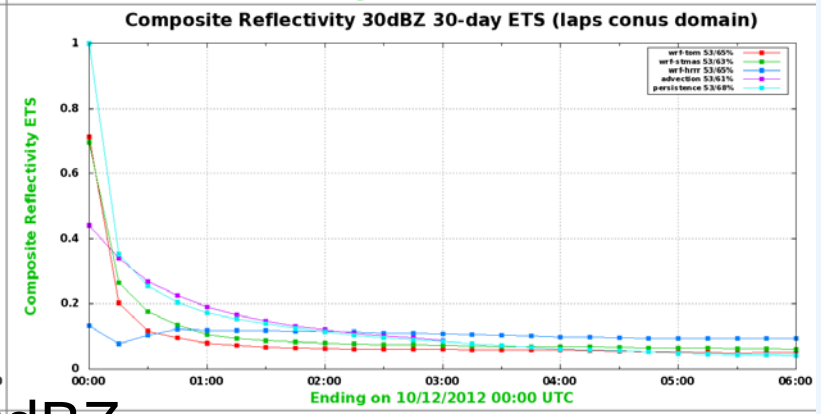
Bias



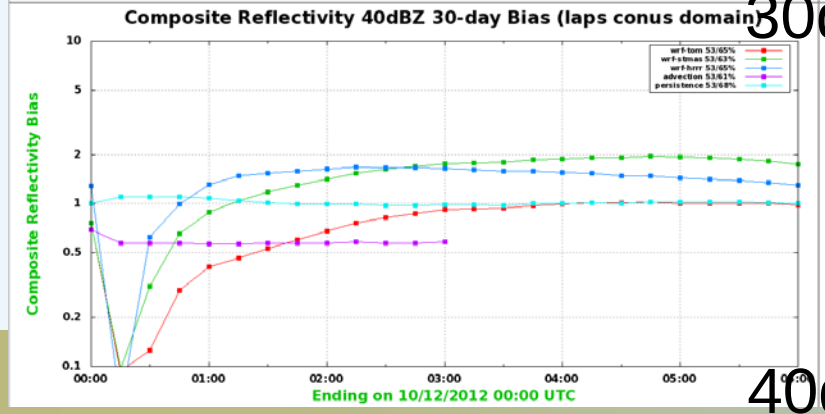
ETS

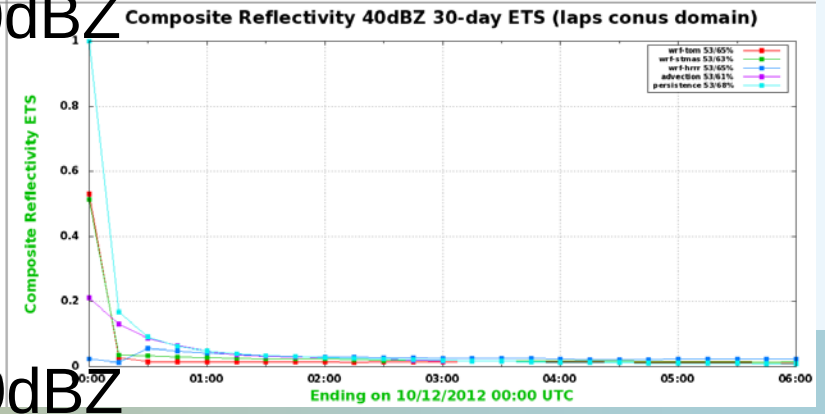
20dBZ





30dBZ





40dBZ

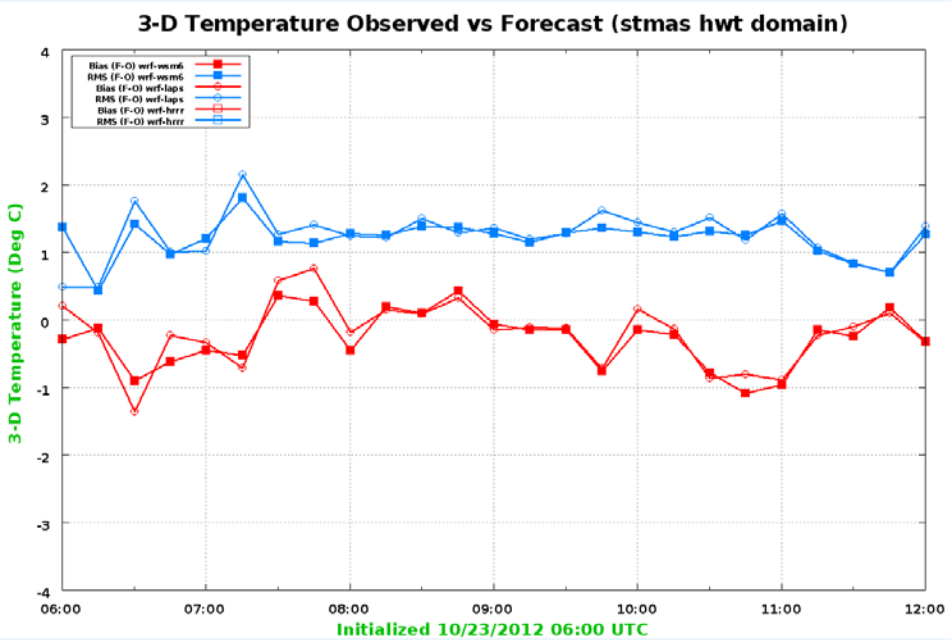
Red: LAPS

Green: STMAS

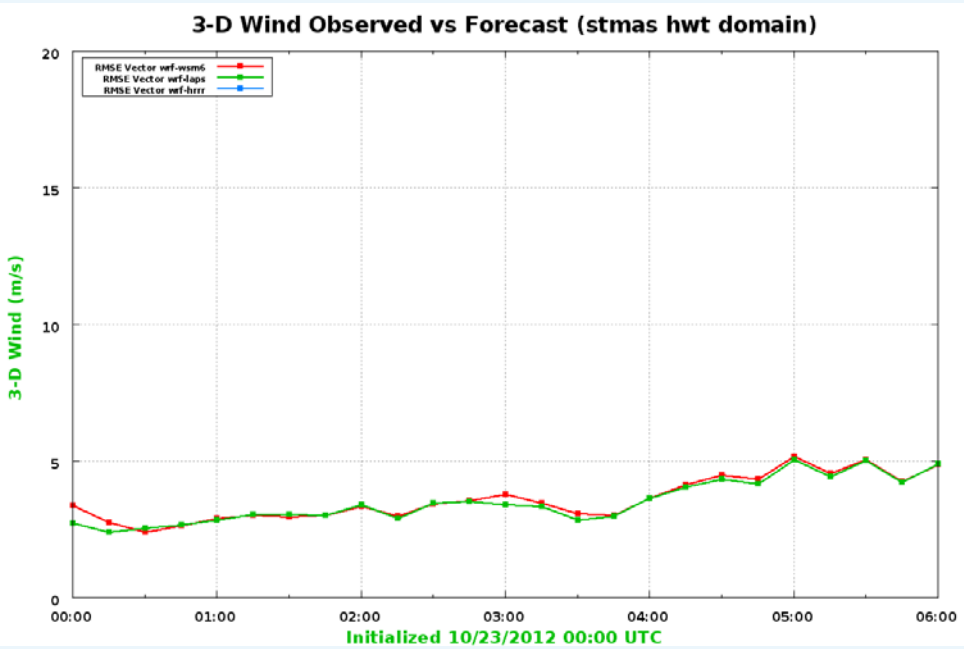
Blue: HRRR

Verification of other fields

Temperature (3D)



Wind (3D)



Steve Albers showed others, radiation and cloud.

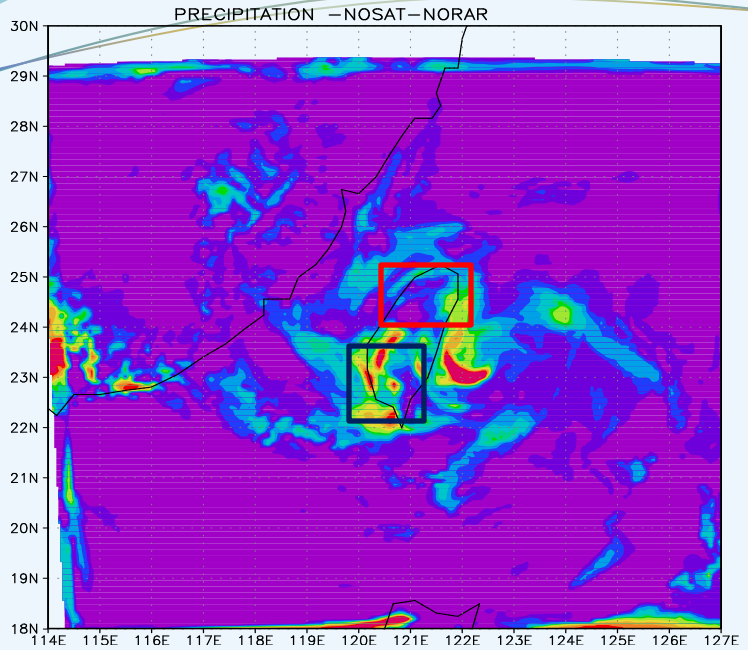
Satellite data assimilation

- CRTM has been built into variational analysis;
- AMSU-A and B are assimilated;
- More study needs to be done, particularly on those satellite moisture channels.

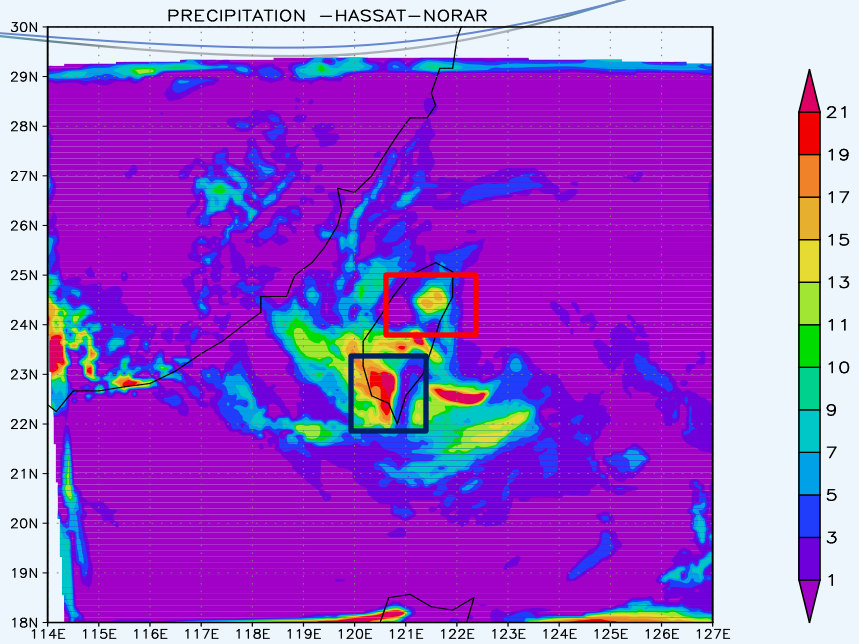
Note (more details in Dan Birkenheuer's talk)

CRTM is not a part of LAPS distribution package. Users have to download CRTM, compile and install by themselves. Then they can link to LAPS by manually modify the Makefile at this moment. The software will be improved later for ease of use CRTM.

Variational LAPS AMSU-A assimilation:

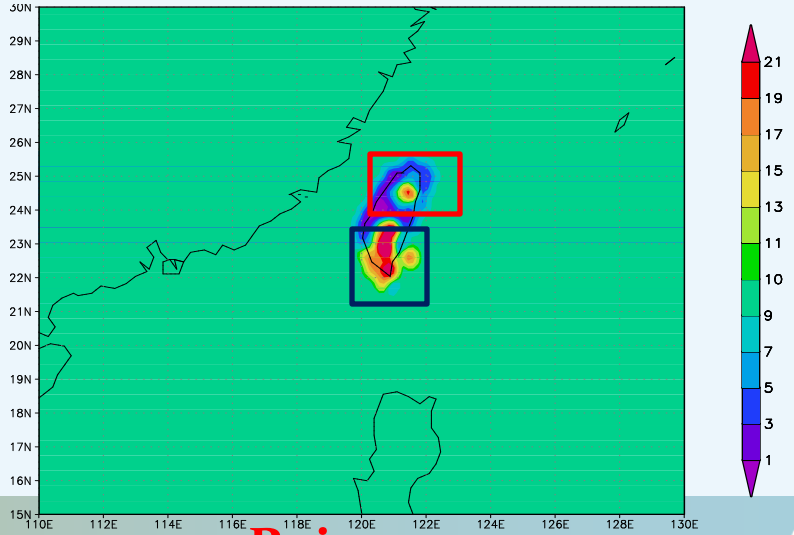


NO AMSU



AMSU

2 hr Precipitation
Forecast comparison



Rain-gauge

Dynamic downscaling (variational LAPS)

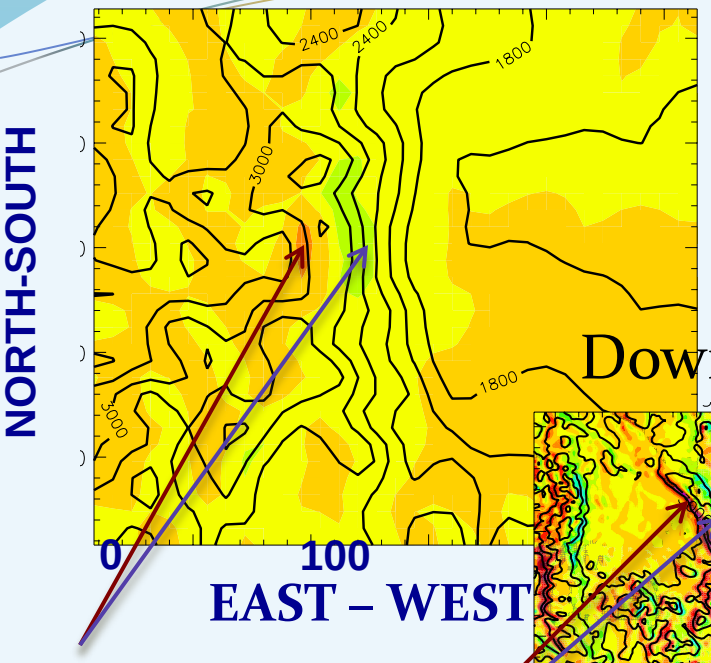
It is a part of variational LAPS analysis minimizing the temporal tendency based on a multigrid technique from coarser grid to fine grid gradually.

- Fire weather applications;
- Climate applications;
- Renewable energy applications (wind);
- ……

See more in Dr. Hongli Jiang presentation

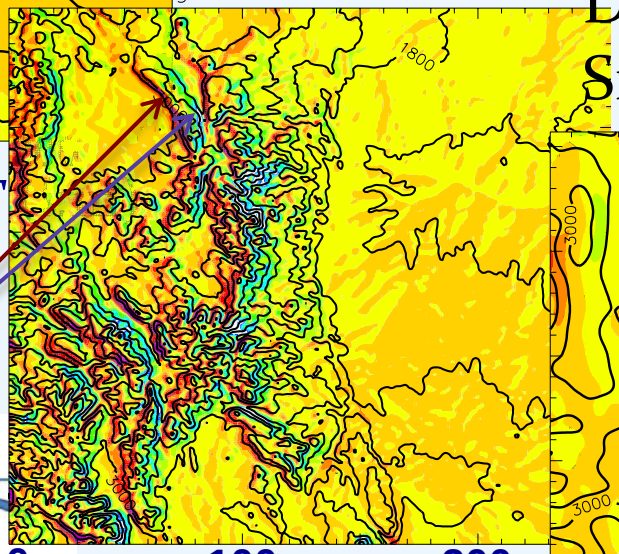
Terrain-following variational LAPS

Initial input at 8 km

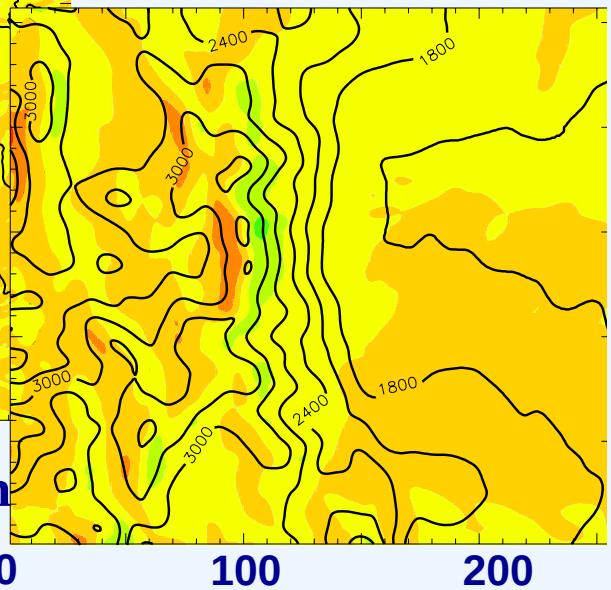


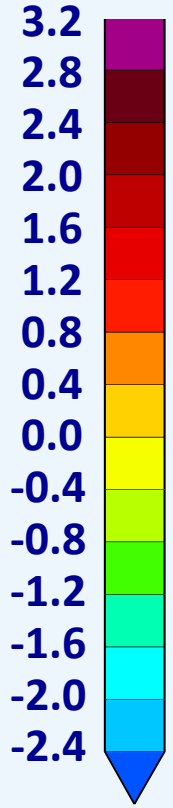
See Hongli Jiang's talk

Downscaled 1 km

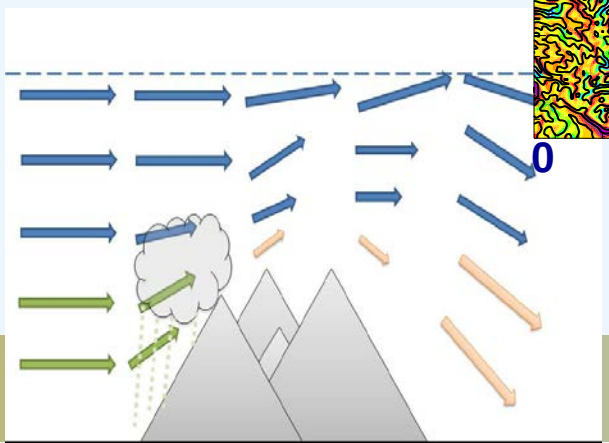


Downscaled and Smoothed Terrain

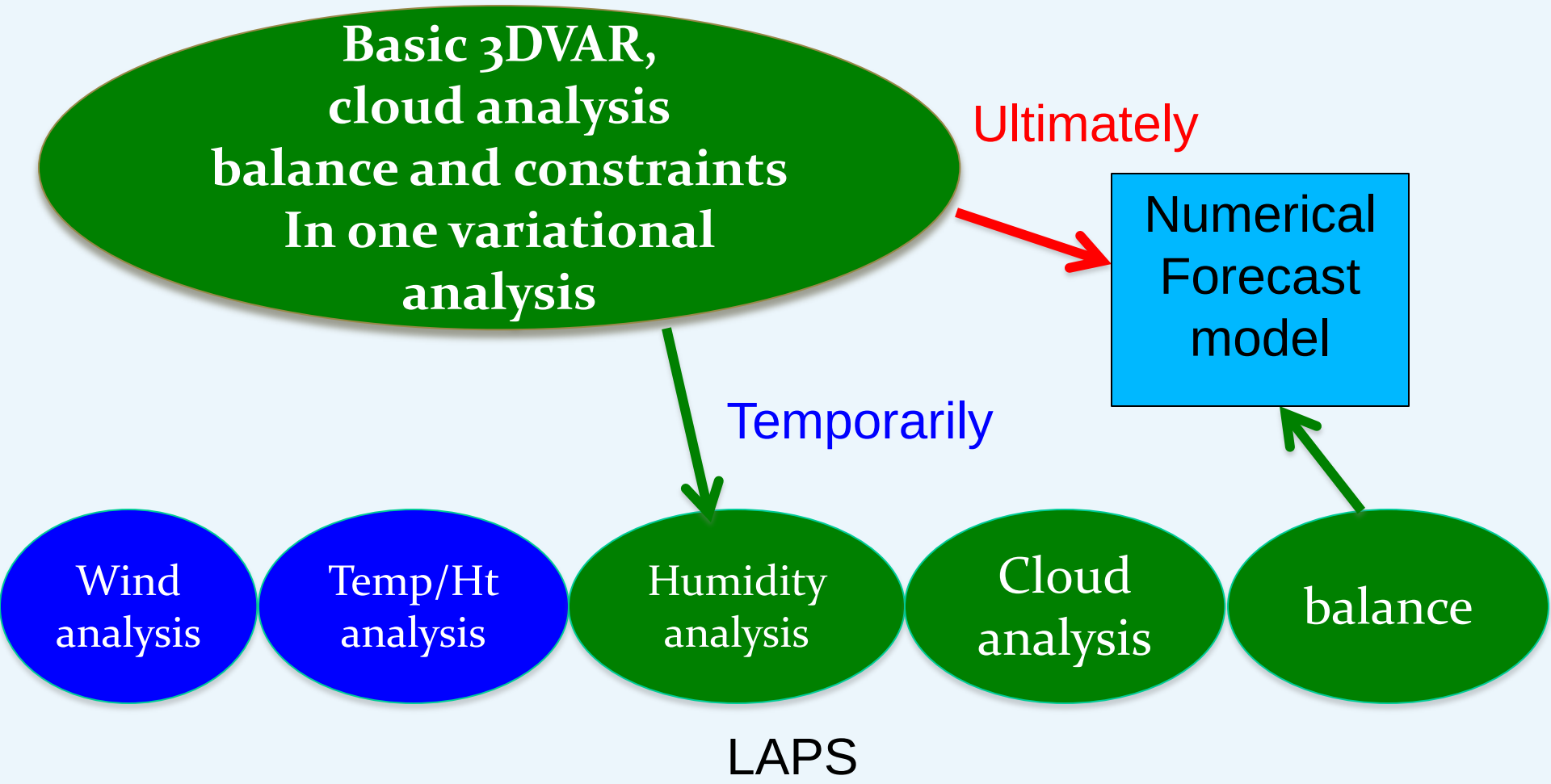




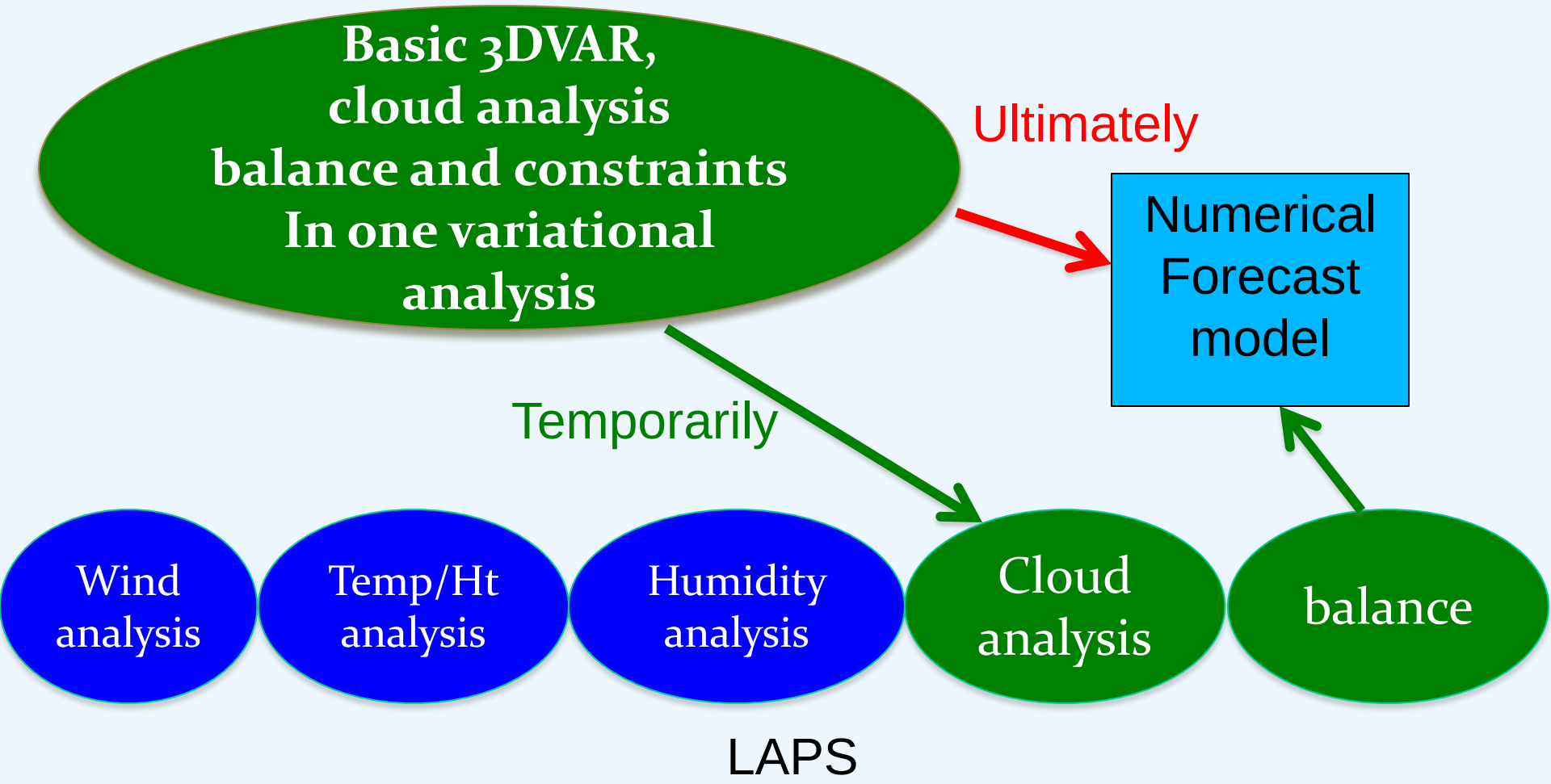
Flow over a Hill



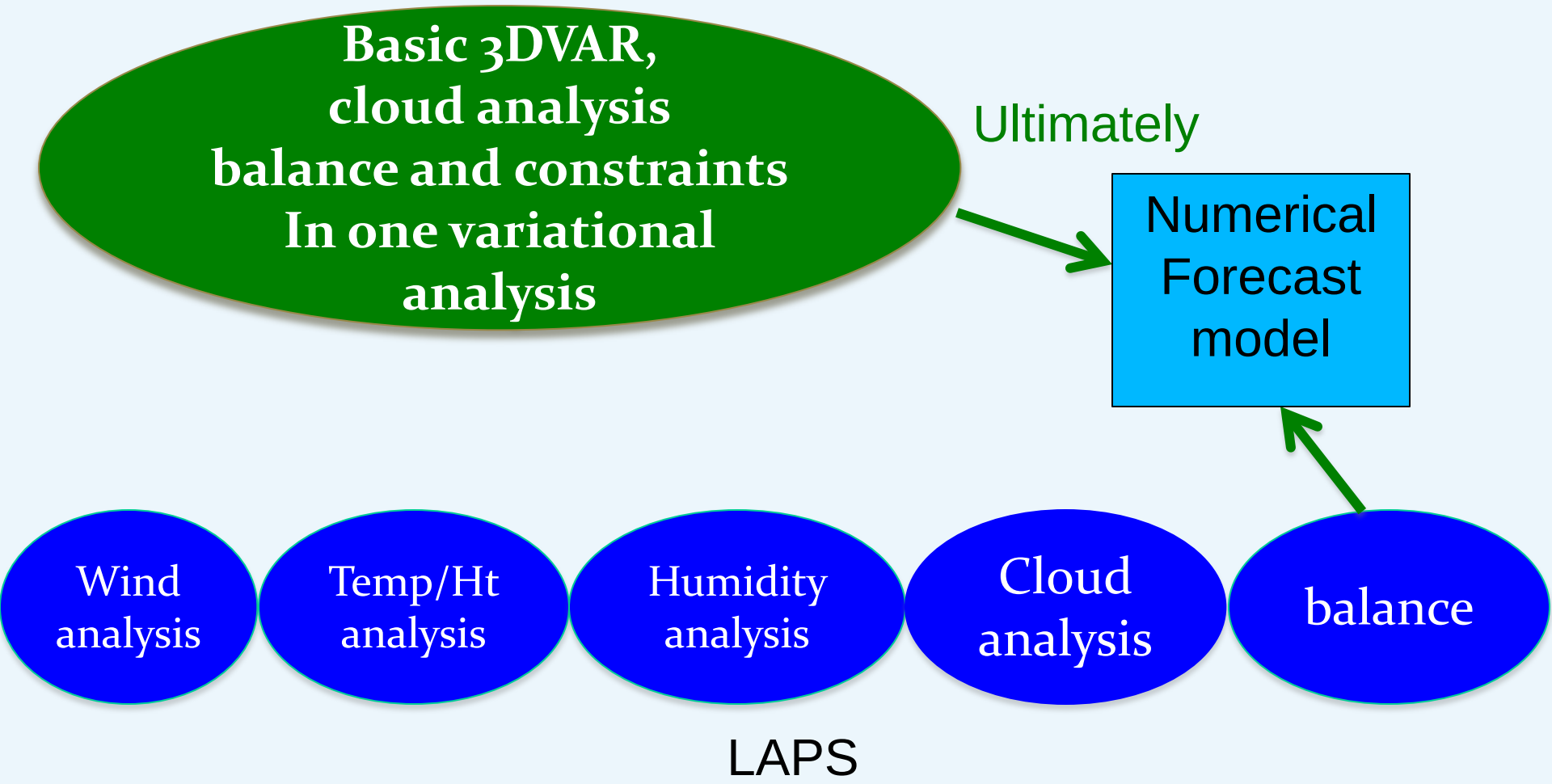
At last workshop variational LAPS



Current variational LAPS



Planning variational LAPS



LAPS vs. Variational LAPS

- Variational LAPS requires tuning for multigrid setup;
- Communication with LAPS development team is needed for setting up variational analysis;
- Possible tutorial material or lecture.

We are debating whether and when to switch to variational LAPS as default and for AWIPS.

Recommendations to LAPS users

- **Update your model boundary conditions so that they are consistent with LAPS analysis;**

- Update your LAPS to newer version to keep up with our improvements;
- Communicate with LAPS team for issues and problems;
- Use more vertical levels for fine scale analysis and forecasts;
- Collaborate with LAPS team for variational LAPS.

Future plan:
Higher ETC lower bias

- Parallelizing the minimization software (1 year);
- Developing variational cloud analysis (1.5 year);
- Using sophisticated covariance (0.5 year)
  - Terrain-following, flow-dependent variational analysis;
- Assimilating all available data, including GPS, other satellite data and lidar wind; (GPS: 0.5 year)
- Improving dynamic constraints for data assimilation consistency with forecast model (1.5-2 year)