Data Assimilation over Complex Terrain
with emphasis on DPG

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Personnel

- **Dr. Zhaoxia Pu** (University of Utah)
- **Graduate students** (Materhorn/ONR and NSF support)
  - Hailing Zhang (Ph.D. Student, UU Atmospheric Sciences)
  - Xuebo Zhang (M.S. student, UU Computational Engineering and Science)
- **Collaborators**
  - Dr. Jim Steenburgh, Jeff Massey (University of Utah)
  - Dr. Dragan Zajic, *Meteorology Division at Dugway Proving Ground*
  - Dr. Jason Knievel, NCAR
  - Dr. Joshua Hacker (Naval Postgraduate School)
  - Drs. David Whiteman, Sebastian Hoch, Eric Pardyjak (University of Utah)
  - *Many others in Materhorn*
Outline

• Research results from last year
  ➢ Compare 3DVAR and EnKF in assimilation of near surface observations over complex terrain: OSSEs
  ➢ Near real-time WRF high-resolution numerical simulations over DPG during September 15 to November 15, 2011
  ➢ Evaluation of analyses and forecasts of near-surface atmospheric conditions in a month-long WRF numerical simulation
    1) Cold start;  2) 3DVAR
  ➢ Sensitivity studies

• Recent research progress and plan to the support field program

• Plan for post-field studies
Four research areas for Materhorn-M

(1) Quantifying spatial and temporal scales of error growth internal to a mesoscale model, and relating them to Initial Condition (IC) uncertainty;

(2) Determining whether the errors can be reduced by improving ICs or whether we are already near the limits of predictability imposed by chaos;

(3) Proposing and testing observations and strategies that will reduce the important IC errors while bringing us closer to predictability limits;

(4) Quantifying and characterizing the importance of model inadequacy in maintaining prediction errors that are not reduced as much as expected.
Objective

- To what extent can data assimilation and ensemble forecasting reduce the uncertainties in near surface and boundary layer atmosphere over mountainous terrain?

Model and Data Assimilation System

- An advanced research version of Weather Research and Forecasting (WRF) model
- 3-dimensional variational data assimilation (3DVAR) system
- An ensemble Kalman filter system developed by NCAR/DART for WRF model (DART/WRF)
DPG SAMS locations and land cover
WRF model domains

Horizontal resolution: 30km/10km/3.33km/1.11km
Evaluation of analyses and forecasts of near-surface atmospheric Conditions in a month-long WRF numerical simulation

I. Control Run

• Two-month simulations from 15 September to 15 November 2011
  ➢ WRF V3.3
  ➢ Four one-way nested domains
  ➢ Model horizontal resolution 30km/10km/3.3km/1.1 km
  ➢ 4 sets of 48-h forecasts per day from 00Z, 06Z, 12Z and 18Z.
  ➢ Cold start -- Initial and boundary conditions derived from NCEP NAM analysis/forecast

• Evaluation is performed for a month-long (15 September to 14 October 2011) period only, considering the originally planned MATERHORN field experiment at the time

• Verification against surface mesonet (SAMS) observations: 2-m temperature and 10-m wind
Figure 21. Mean average error of simulated near surface variables for DPG area at different model domains: (a) 2-m temperature, (b) 10-m wind speed, (c) 10-m wind direction. D02, D03 and D04 represent results from model domains at different horizontal resolutions (10 km/3.33 km/1.11 km).

Figure 22. Mean average error of simulated near surface variables for various initialization times: (a) 2-m temperature, (b) 10-m wind speed, (c) 10-m wind direction. Various curves represent forecasts initialized with different time. The forecasting period for all forecasts is 48 h.

Figure 23. Bias error of simulated 2-m temperature with various initialization times. The forecasting period for all forecasts is 48 h.
Biases at stations

Daytime: 15Z - 00Z
Nighttime: 00Z - 15Z

Temperature

- Warm bias during nighttime
- Cold bias during daytime.
Bias at Stations

Wind direction

Wind speed
Weak vs. strong synoptic forcing cases
Evaluation of analyses and forecasts of near-surface atmospheric Conditions in a month-long WRF numerical simulation

II. Impact of surface data assimilation

- Two-month WRF simulations from 15 September to 15 November 2011
  - Four one-way nested domains
  - Model horizontal resolution 30km/10km/3.3km/1.1 km
  - 4 sets of 48-h forecasts per day from 00Z, 06Z, 12Z and 18Z.
  - Surface mesonet data are assimilated at a hourly cycle in first 3-h

- Evaluation is performed for a month-long (15 September to 14 October 2011) period only, considering the originally planned MATERHORN field experiment at the time

- Verification against surface mesonet (SAMS) observations: 2-m temperature and 10-m wind
Biases

Significant reduction of biases in short-rang forecasts!
MAEs
Significant reduction of errors in short-range forecasts!
Sensitivity to assimilation of different variables (Oct. 13, 2011)
Sensitivity to radiation schemes

Mean Absolute Error (MAE)

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Sensitivity to cumulus schemes

*Mean Absolute Error (MAE)*
Real-time forecasting during MATERHORN field program (9/25 – 10/25 2012)

UU Real-time WRF High-resolution Forecast

Model: WRF ARW; IC/BC: NCEP NAM

Contact: Prof. Zhaoxia Pu (Zhaoxia.Pu@utah.edu), Mr. Xuebo Zhang (Xuebo.Zhang@utah.edu)

Change Field: 10m-Wind(m/s)

Select Domain: d04

Select time: 2012082812

Weather Links

Mesowest
UU AS Weather Center

Disclaimer: These products are experiment/research forecasts - they're not official forecasts. The products posted on this website are for research purpose only. All rights are reserved.

http://www.inscc.utah.edu/~pu/dugway
Post-field research plan

• High-resolution analyses and forecast for major IOPs with data assimilation

• High-resolution ensemble forecasting with ensemble-based data assimilation

• Predictability studies
Concluding remarks

- A month-long high resolution simulations leads good understanding of the uncertainties in analyses and forecasts of near-surface atmospheric conditions over DPG

- Assimilation of surface observations results in positive impact on short-range forecasts

- A real time WRF high-resolution forecasting capability has been developed

- Testing of ensemble Kalman filter with real data is in progress

- Ready to assimilate observations during MATERHORN IOPs, retrospective runs are planned to be done with data assimilation and ensemble forecasting.

**MATERHORN-X provides a unique opportunity for evaluating data assimilation methods, validating ensemble forecasting, verifying numerical model and studying atmospheric processes over mountainous terrain.**