Data Assimilation over Complex Terrain
with emphasis on DPG

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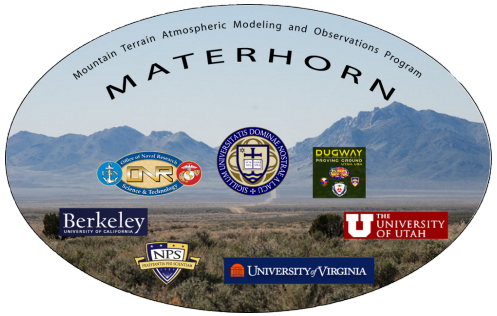


Materhorn Annual Review Meeting
August 17, 2012
Salt Lake City, Utah

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.

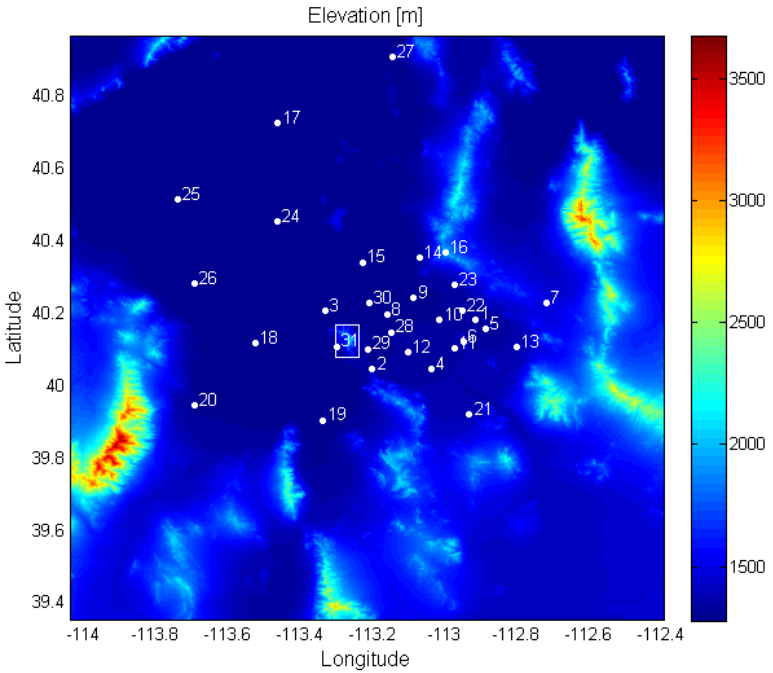
Objective

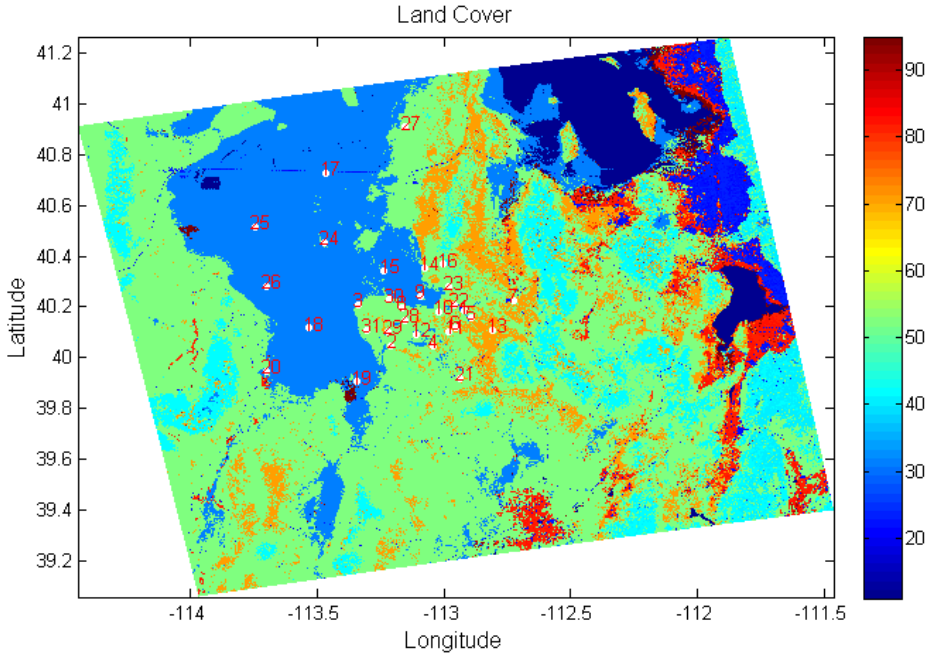
- **To what extent can data assimilation and ensemble forecasting reduce the uncertainties in near surface and boundary layer atmosphere over mountainous terrain?**

Model and Data Assimilation System

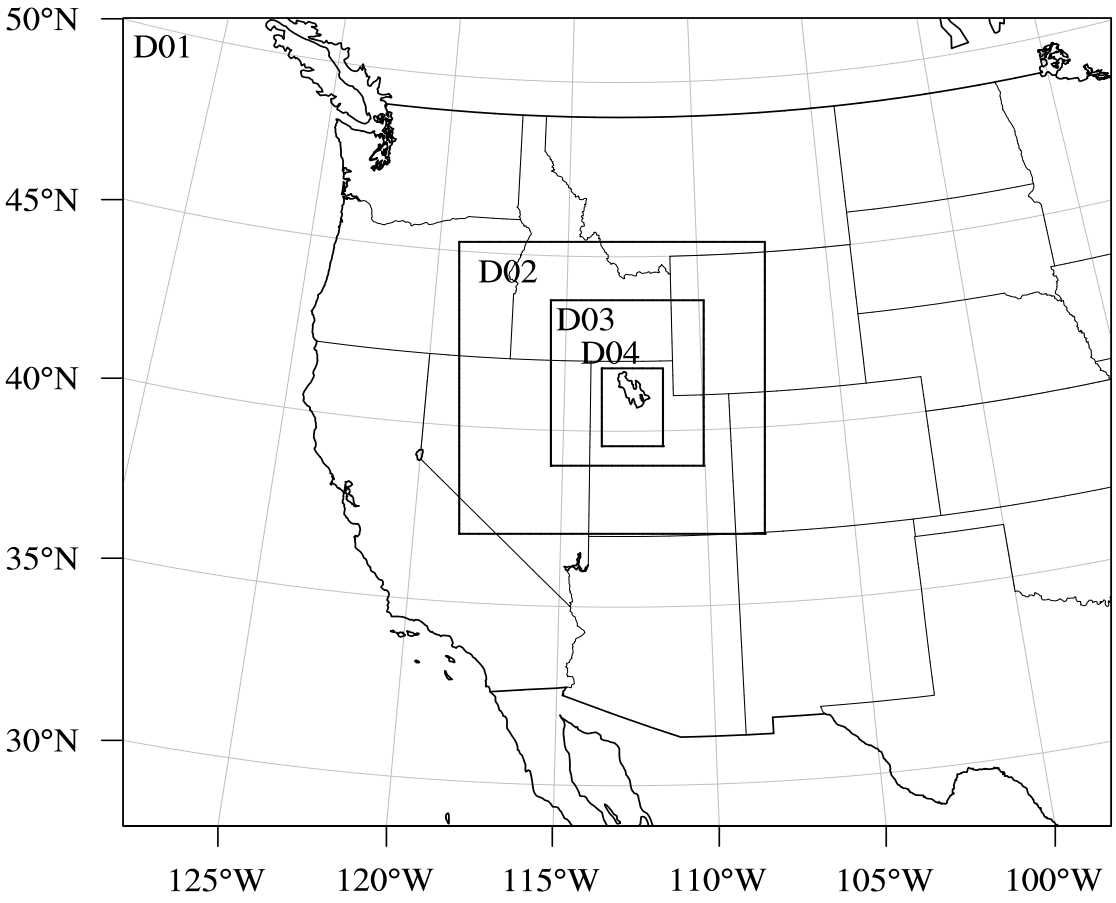
- An advanced research version of Weather Research and Forecasting (WRF) model
- 3-dimensional variational data assimilation (3DVAR) system
- An ensemble Kalman filter system developed by NCAR/DART for WRF model (DART/WRF)

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

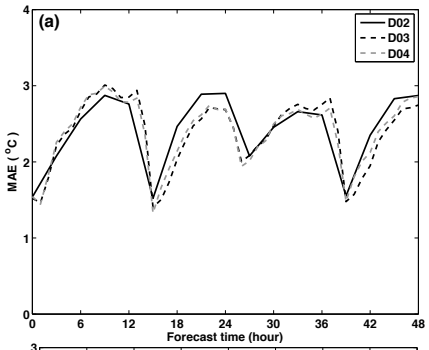
I. Control Run

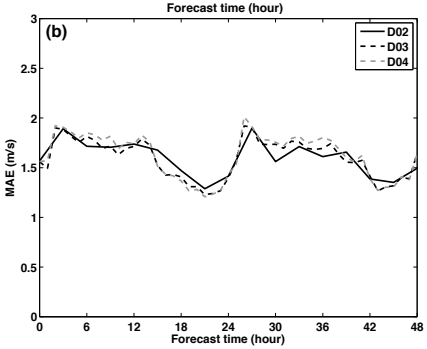
- Two-month simulations from 15 September to 15 November 2011
  - WRF V3.3
  - Four one-way nested domains
  - Model horizontal resolution 30km/10km/3.3km/1.1 km
  - 4 sets of 48-h forecasts per day from 00Z, 06Z, 12Z and 18Z.
  - **Cold start** -- Initial and boundary conditions derived from NCEP NAM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

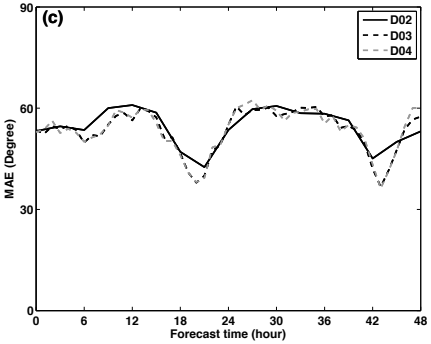
- Evaluation is performed for a month-long (15 September to 14 October 2011) period only, considering the originally planned MATERHORN field experiment at the time

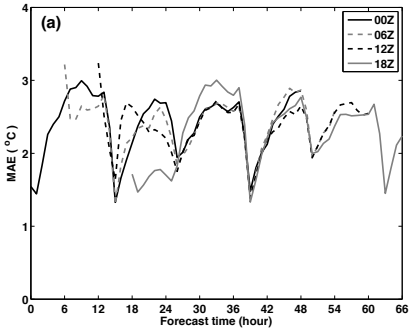
- Verification against surface mesonet (SAMS) observations: 2-m temperature and 10-m wind

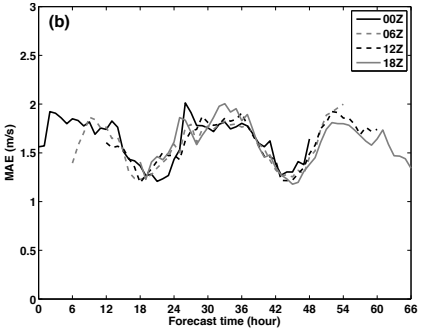
Mean Average Error

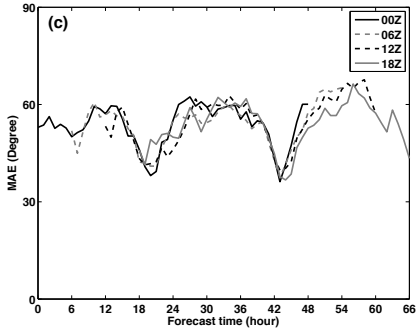




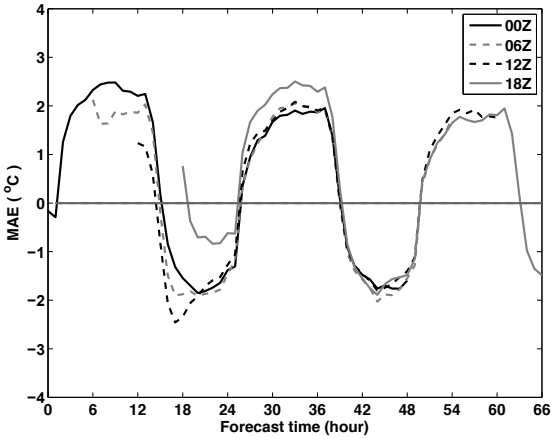








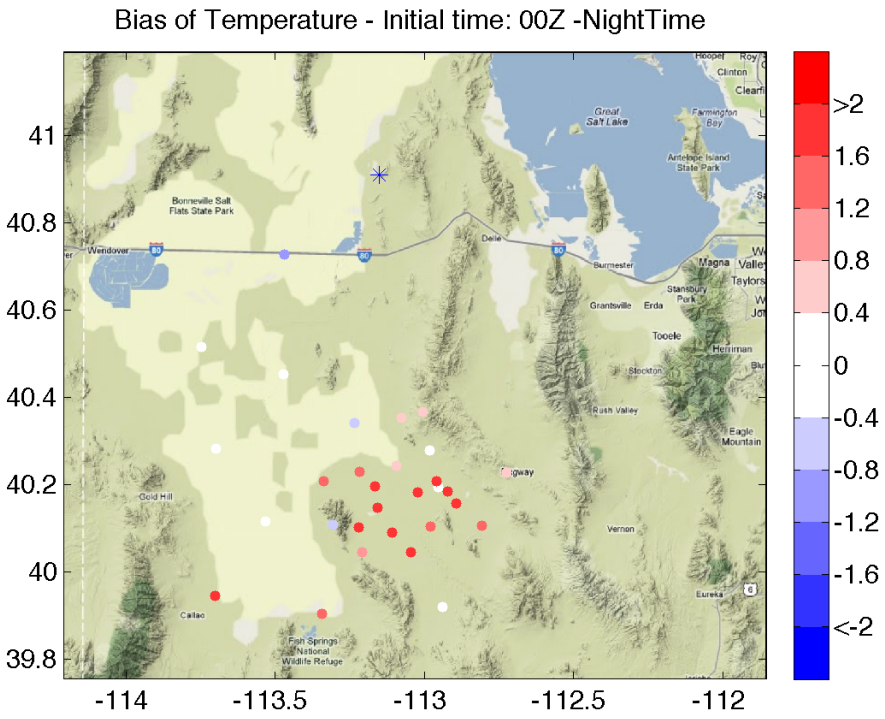
Bias Error

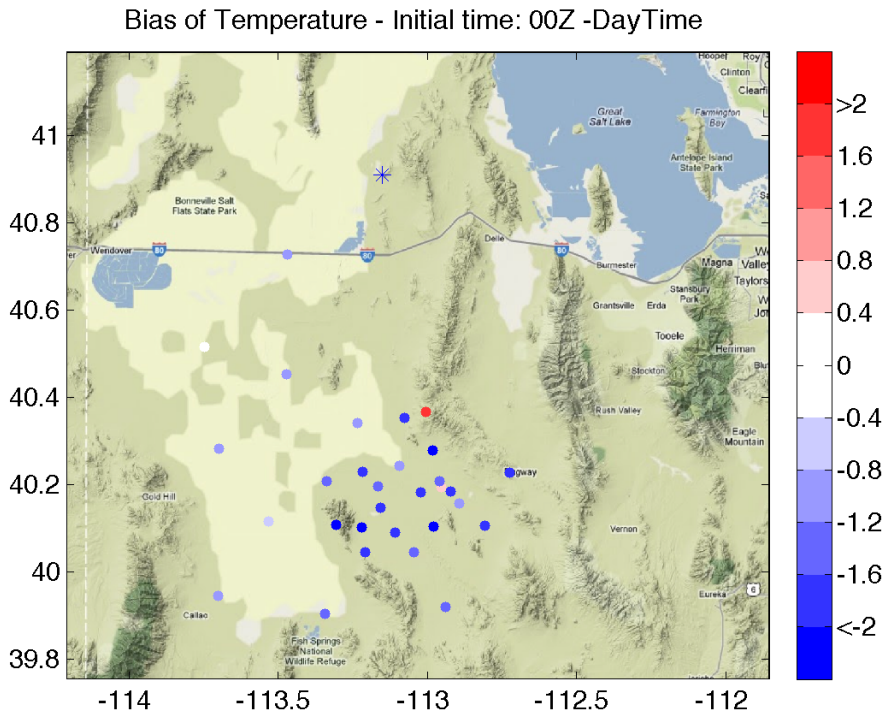


Biases at sations

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

Temperature

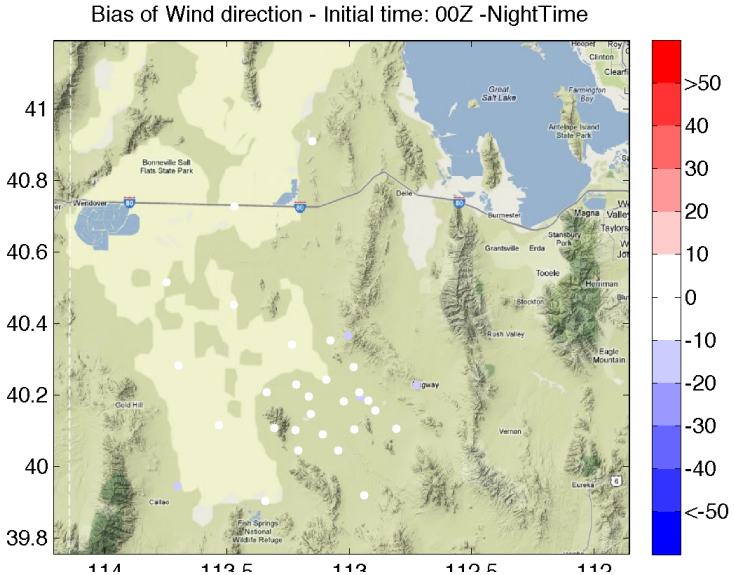


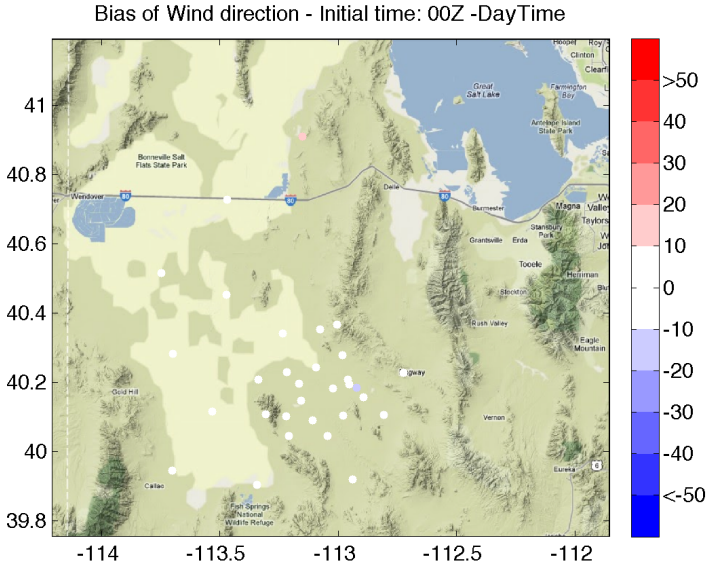


- Warm bias during nighttime
- Cold bias during daytime.

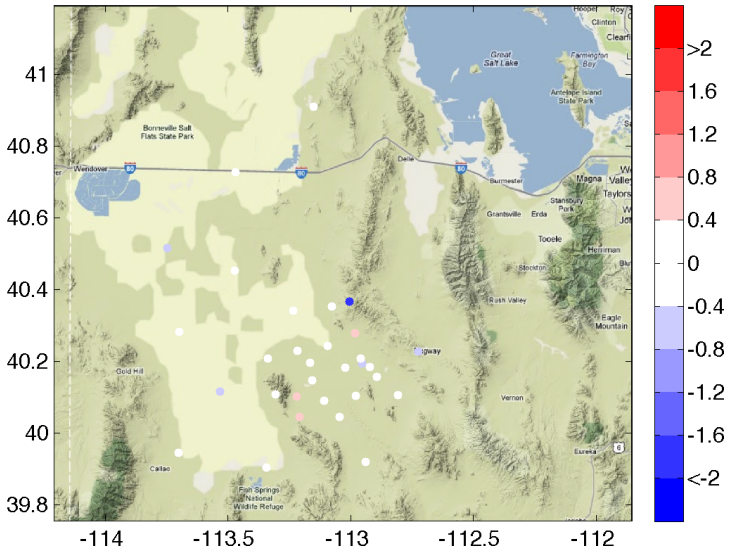
Bias at Stations

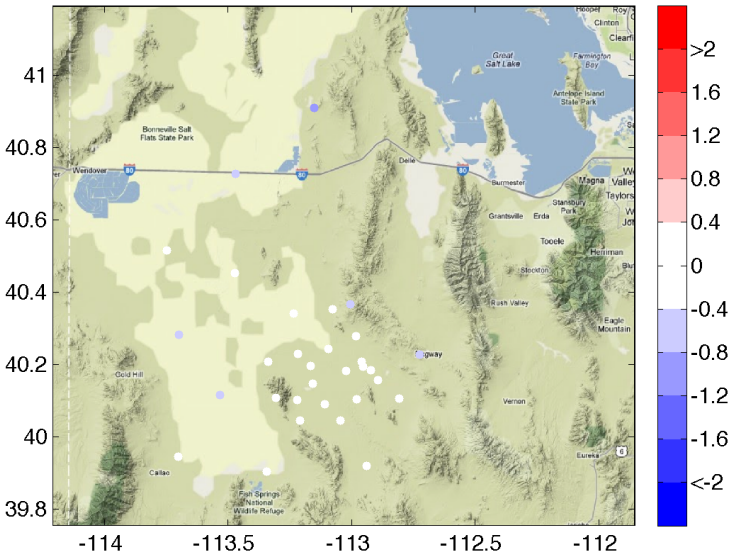
wind direction



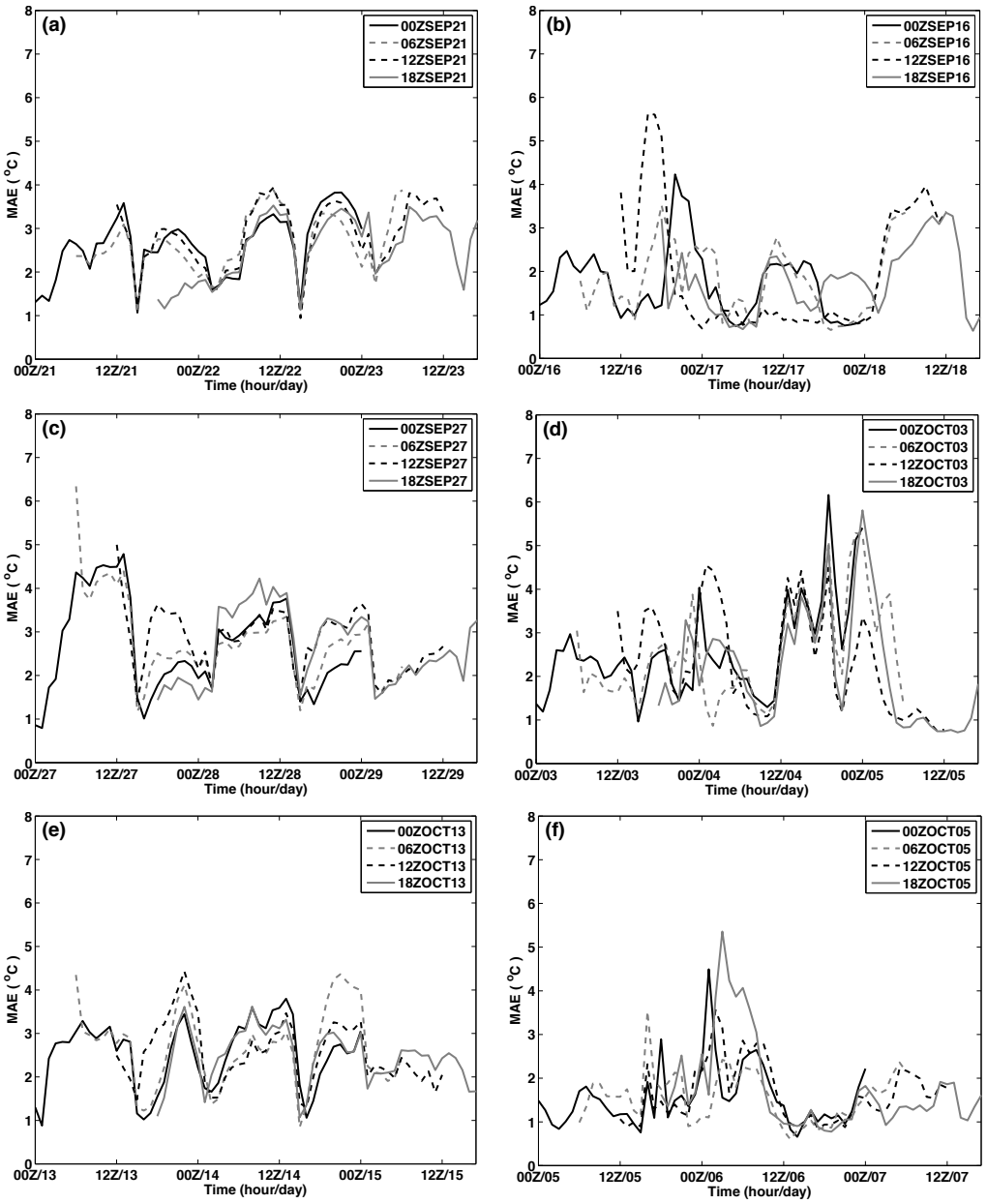


wind speed





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

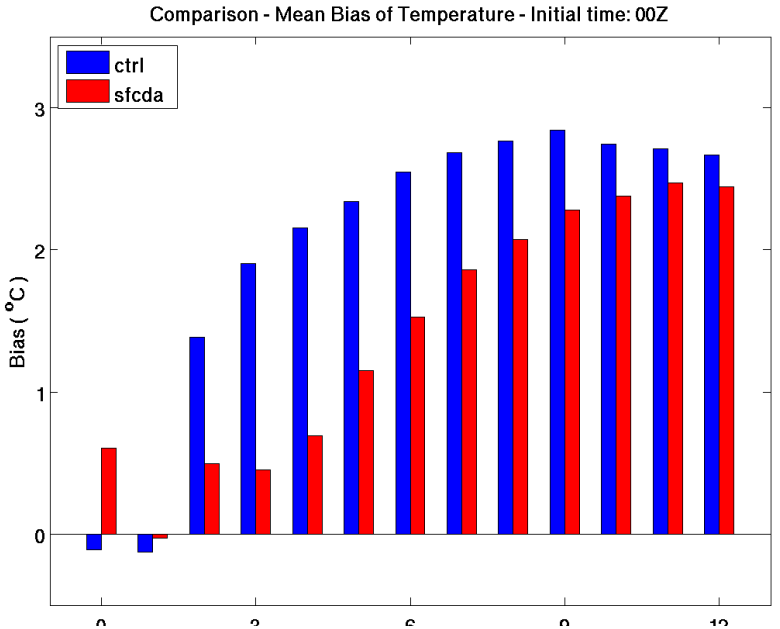
- Two-month WRF simulations from 15 September to 15 November 2011
  - Four one-way nested domains
  - Model horizontal resolution 30km/10km/3.3km/1.1 km
  - 4 sets of 48-h forecasts per day from 00Z, 06Z, 12Z and 18Z.
  - Surface mesonet data are assimilated at a hourly cycle in first 3-h

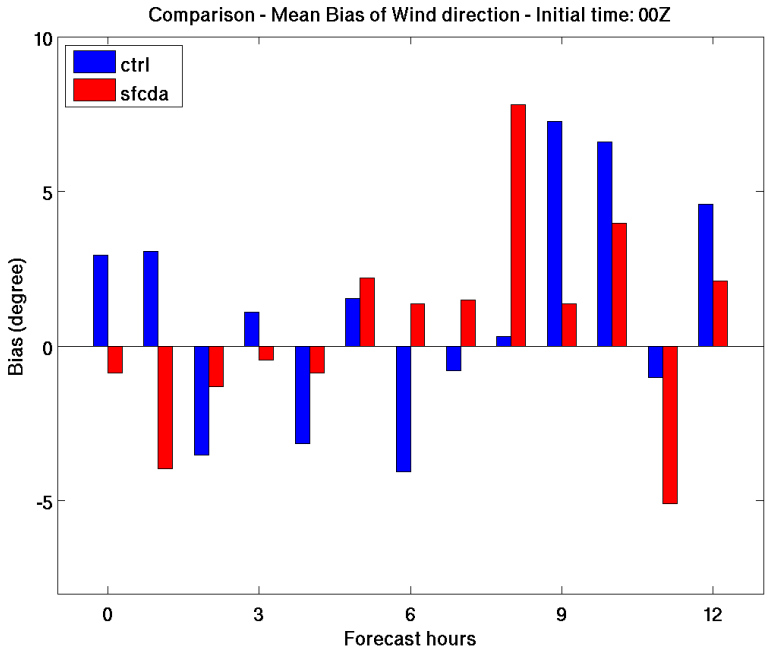
- Evaluation is performed for a month-long (15 September to 14 October 2011) period only, considering the origionally planned MATERHORN field experiment at the time

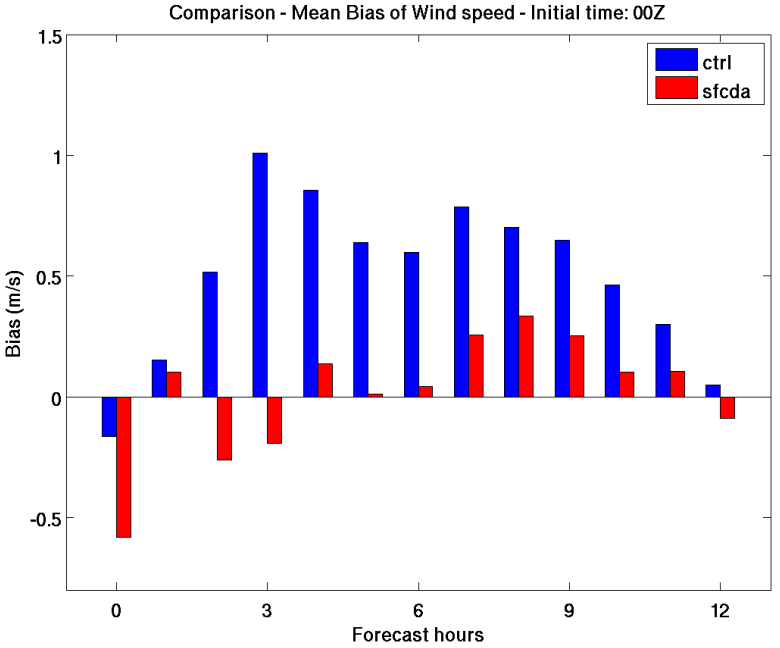
- Verification against surface mesonet (SAMS) observations: 2-m temperature and 10-m wind

Biases

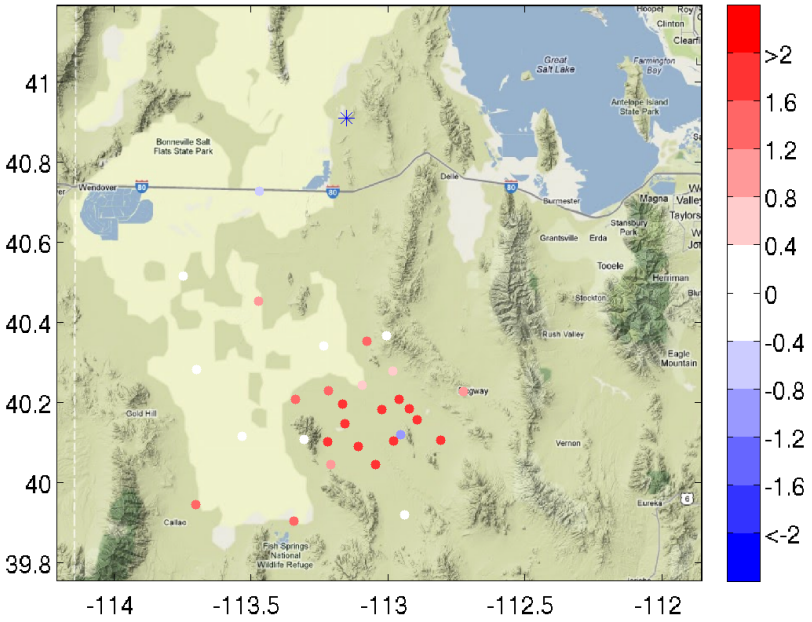
Significant reduction of biases in short-rang forecasts!



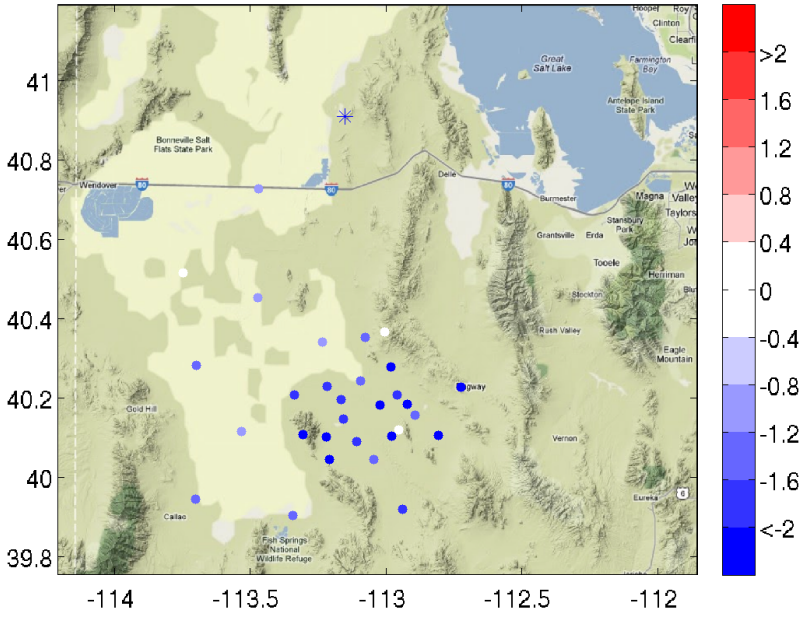




Bias of Temperature - Initial time: 00Z -NightTime

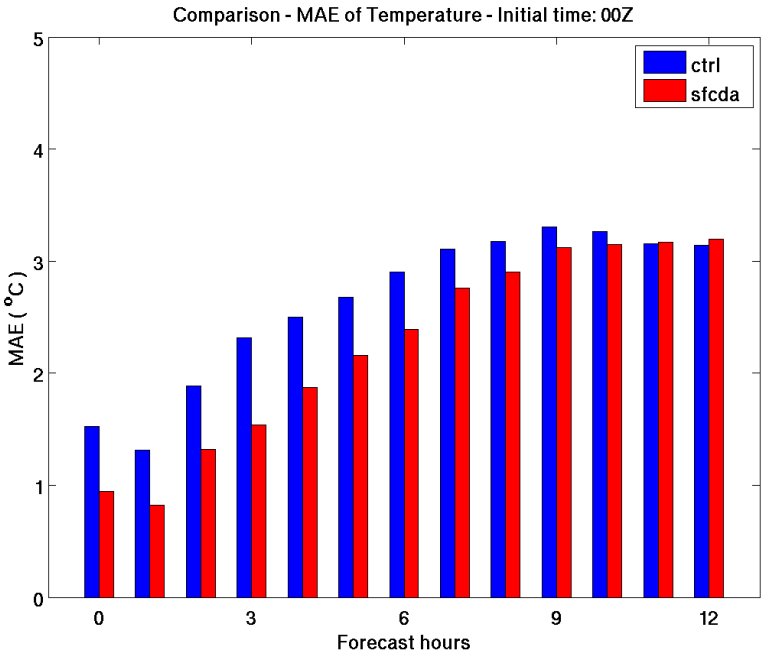


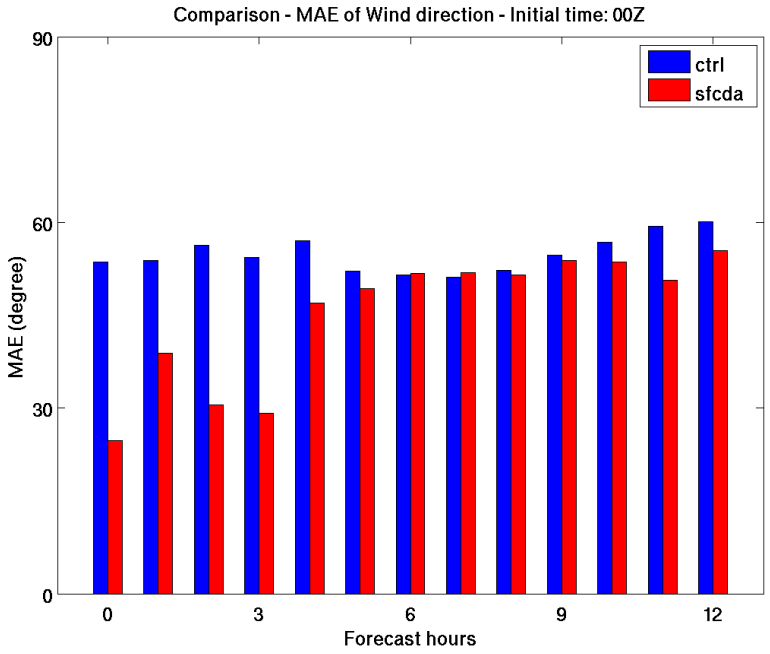
Bias of Temperature - Initial time: 00Z -DayTime

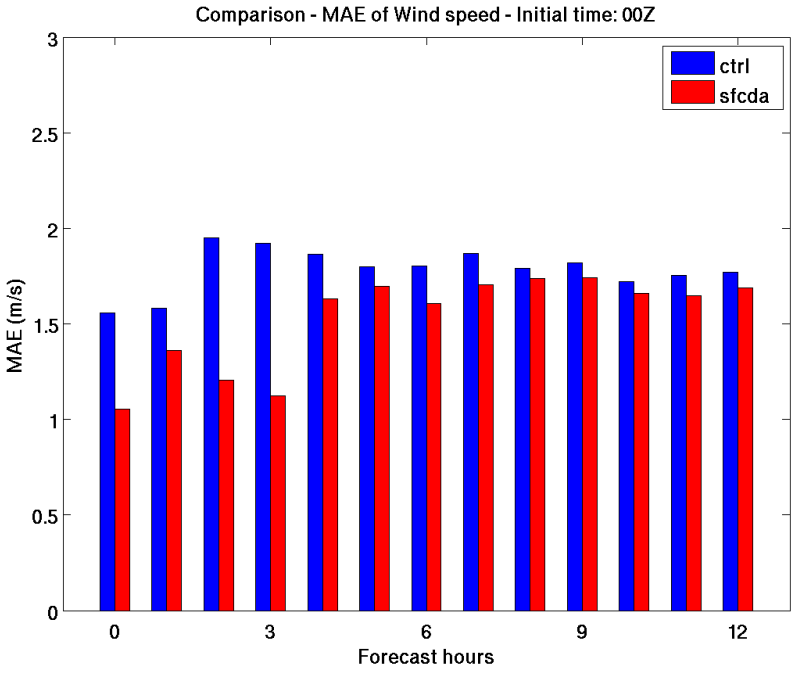


MAEs

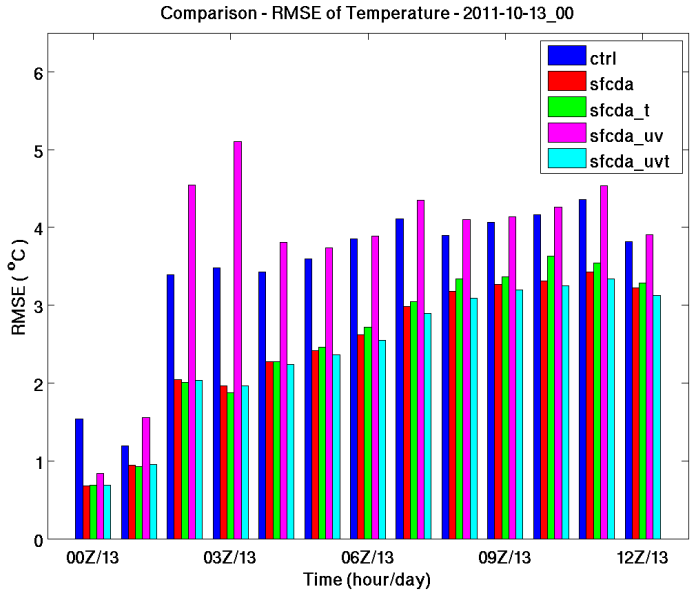
Significant reduction of errors in short-rang forecasts!

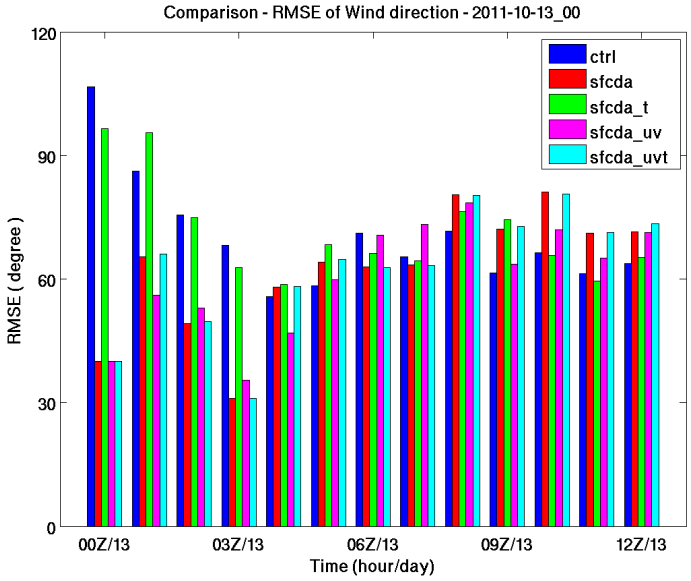


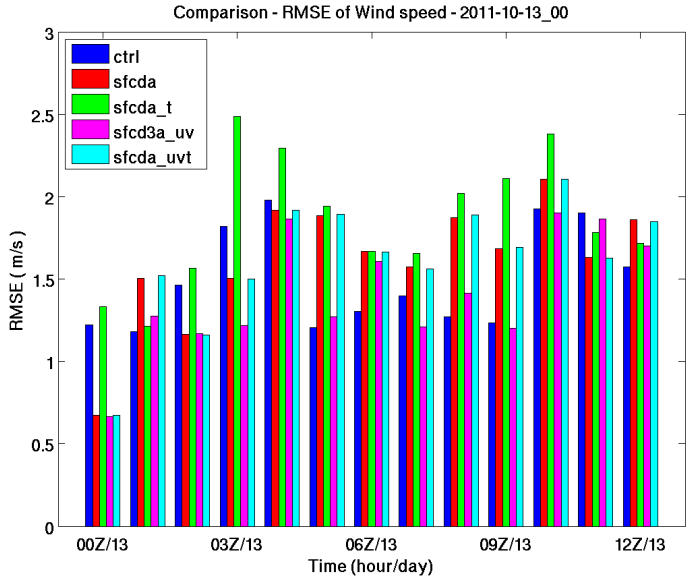




Sensitivity to assimilation of different variables (Oct. 13, 2011)

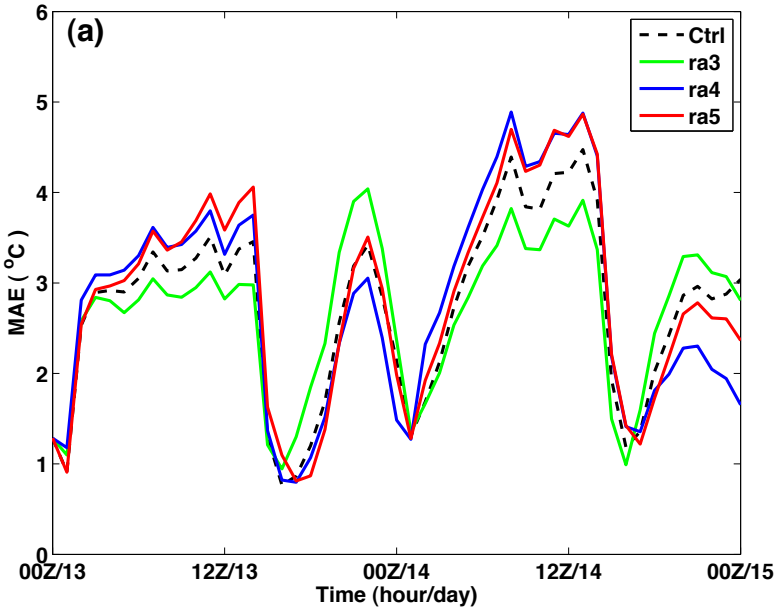




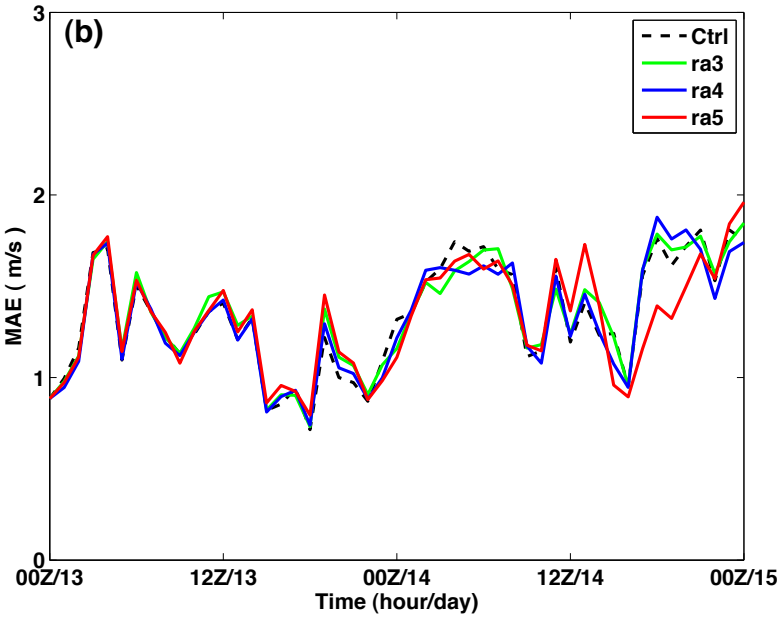


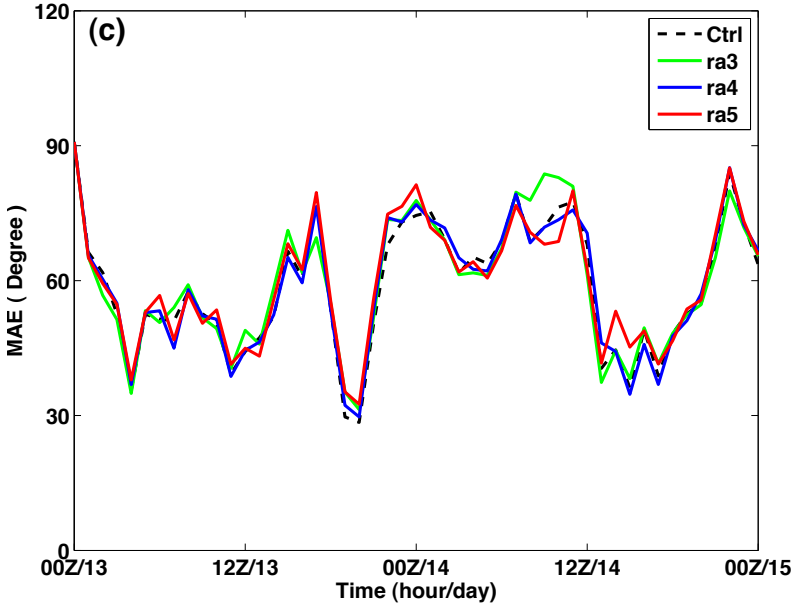
Sensitivity to radiation schemes

Mean Absolute Error (MAE)



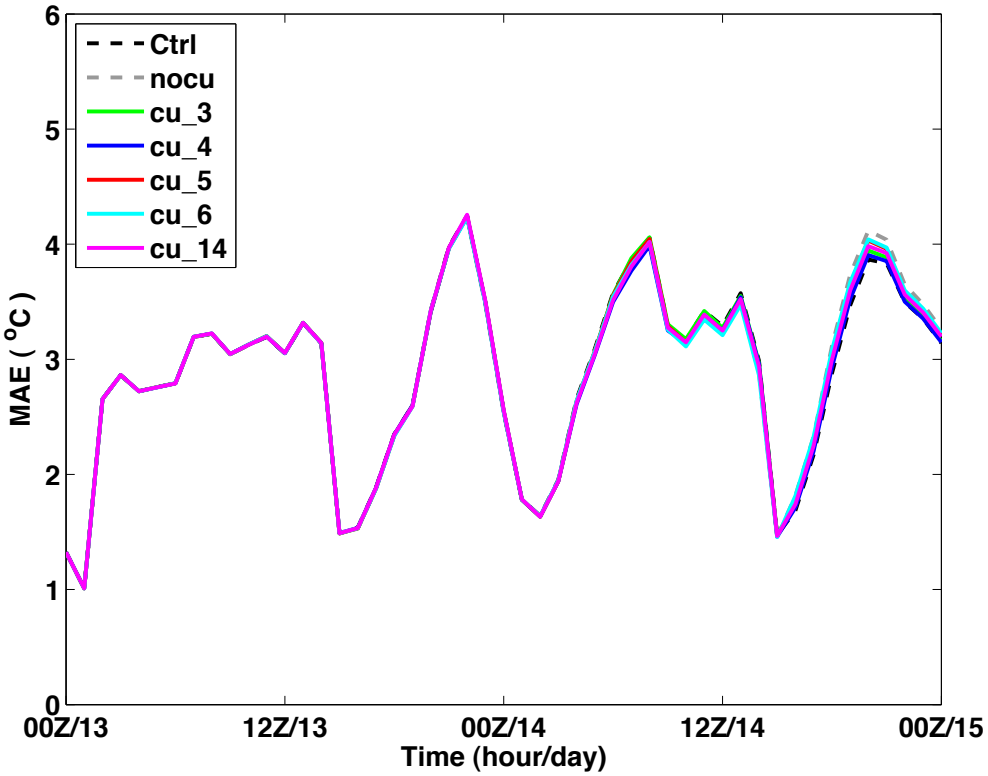
experiment	value	longwave scheme	shortwave scheme
ctrl	1	rrtm	Dudhia
ra3	3	CAM	CAM
ra4	4	rrtmg	rrtmg
ra5	5	Goddard	Goddard





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)

Loop Mode: Adjust Speed: Pic No: 19

Change Field:

10m-Wind(m/s)

Select Domain:

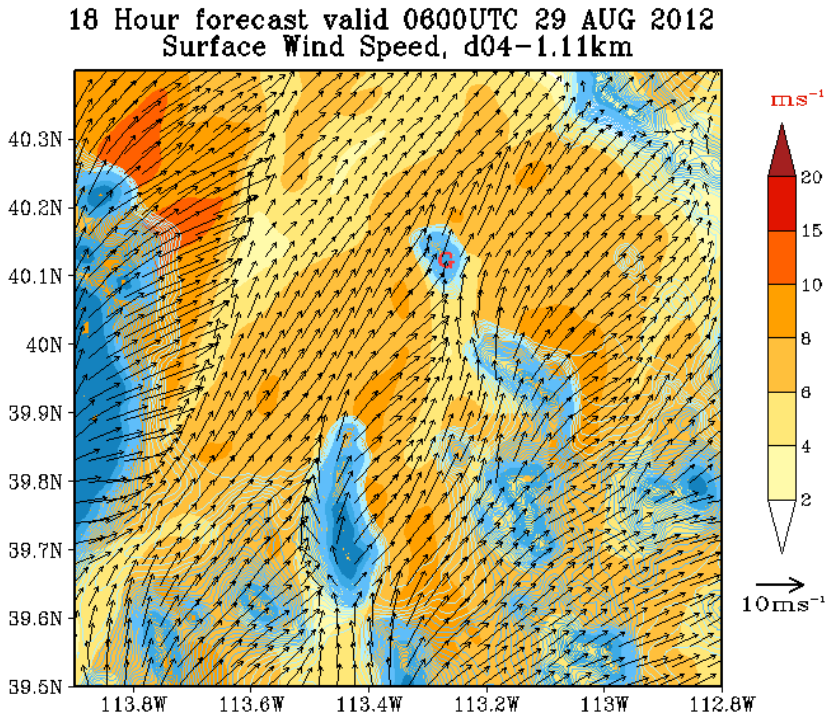
d04

Select time:

2012082812

Weather Links

Mesowest
UU AS Weather Center



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.