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Model error representation in mesoscale WRF-DART cycling

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Model uncertainties in the mesoscale EnKF system

- The Ensemble Kalman Filter (EnKF) estimates the flow-dependent background covariance from an ensemble forecast.

- Parameterized physics especially in the PBL and the land surface schemes are subject to large uncertainties.

- If the model uncertainties are not properly accounted for in the EnKF, ensemble spread will be insufficient, which can lead to poor analysis and forecast.

Techniques to represent model errors

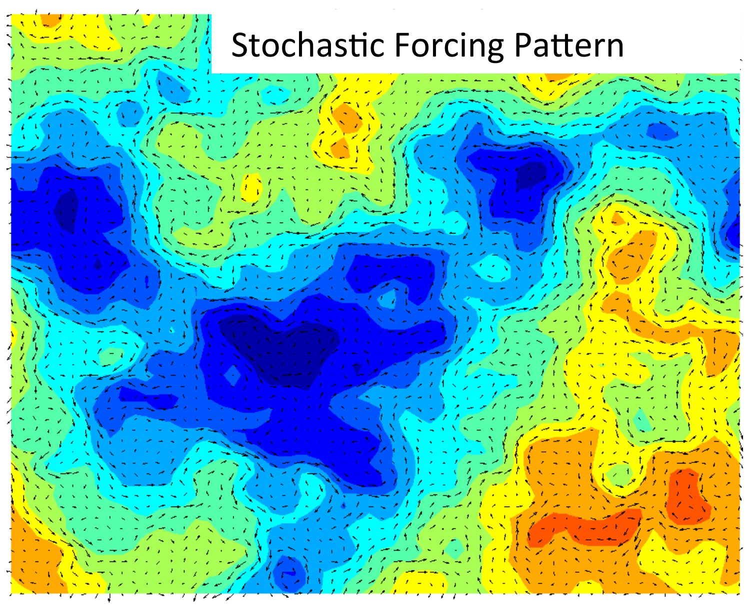
Baseline: “control-physics” (CP)

1. Stochastic kinetic-energy backscatter (SP)
2. Multi-physics (MP)

Model error technique: SP – stochastic backscatter

❖ Original rationale: A fraction of the subgrid-scale energy is scattered upscale and acts as random streamfunction and temperature forcing for the resolved-scale flow. Here: simply considered as additive noise

❖ Similar to ECMWF global ensemble system (Shutts 2005) but with constant dissipation rate and potential temperature perturbations (Berner et al. 2011).



Model error technique: MP – multiphysics

- Each ensemble member uses one of 10 suites of physics schemes.
- Each suite is employed 5 times in 50-member ensemble.
- Physics suite 5 is used for control-physics ensemble (in CP and SP).

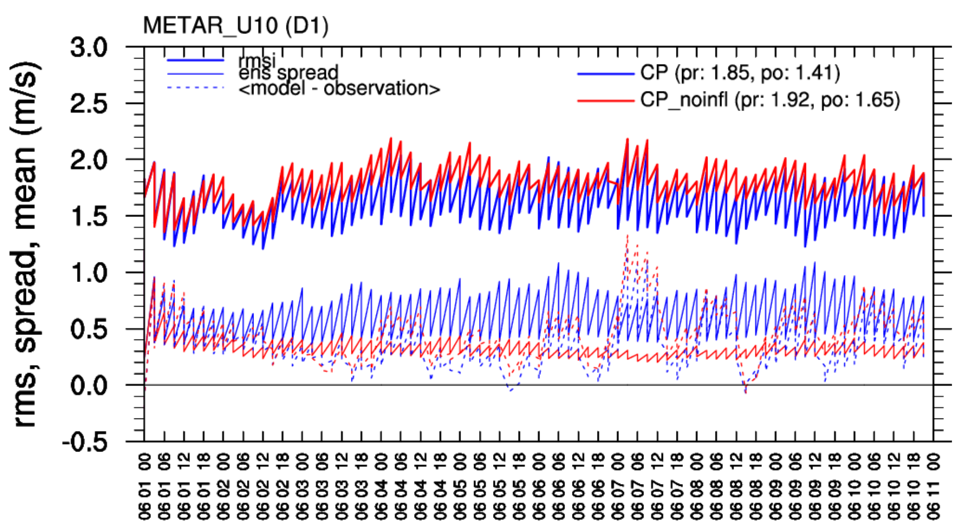
Physics suite	Physical parameterizations					
	Surface	Microphysics	PBL	Cumulus	LW_RA	SW_RA
1	Thermal	Kessler	YSU	KF	RRTM	Dudhia
2	Thermal	WSM6	MYJ	KF	RRTM	CAM
3	Noah	Kessler	MYJ	BM	CAM	Dudhia
4	Noah	Lin	MYJ	Grell	CAM	CAM
5	Noah	WSM5	YSU	KF	RRTM	Dudhia
6	Noah	WSM5	MYJ	Grell	RRTM	Dudhia
7	RUC	Lin	YSU	BM	CAM	Dudhia
8	RUC	Eta	MYJ	KF	RRTM	Dudhia
9	RUC	Eta	YSU	BM	RRTM	CAM
10	RUC	Thompson	MYJ	Grell	CAM	CAM

Control Physics (CP)

- ❖ A single physics configuration - all ensemble members have the same climatological distribution
- ❖ Ensemble prior spread is adaptively inflated right before the assimilation.

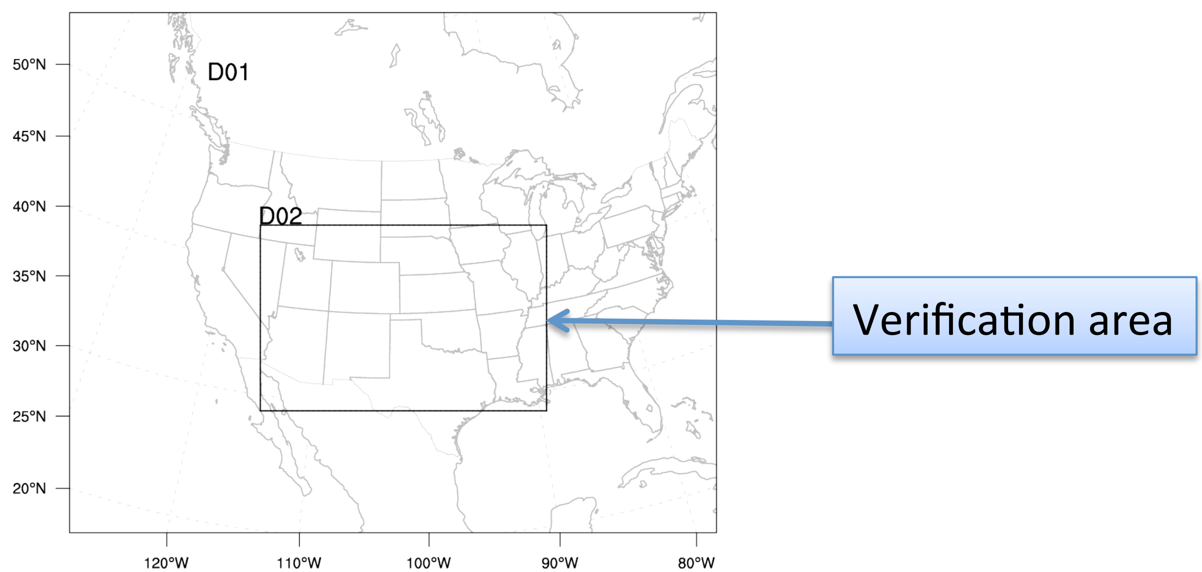
<u>Adaptive inflation (Anderson 2009)</u>

- Increases forecast variance by linearly inflating ensemble around mean.
- Spatially-varying state space inflation, time-evolving with slow damping
- Included in all three experiments in this study



Experiment design

- Domain: Two domains w/ 45- and 15-km grids in two-way nesting
- 50-member ensemble
- IC/LBCs from GFS data
- Filter with half-width localization radius: 300-km (H) and 4-km (V)
- Cycling period: June 1 – 30, 2008 (every 3 hr)



WRF/DART cycling

- Analysis step:

  EnKF data assimilation using Data Assimilation Research Testbed (DART) system

  http://www.image.ucar.edu/DAReS/DART/

- Forecast step:

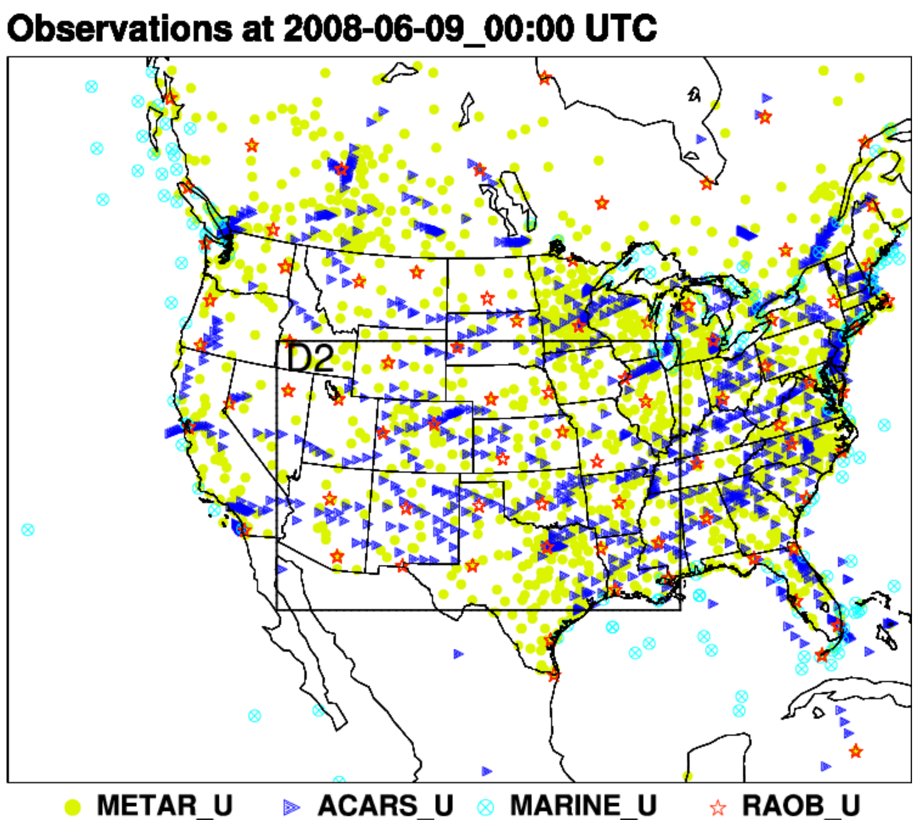
  Short-range ensemble forecast using the non-hydrostatic Advanced Research WRF model version V3.3

  http://www.mmm.ucar.edu/wrf/users/

- Continuous cycling (3-hourly)

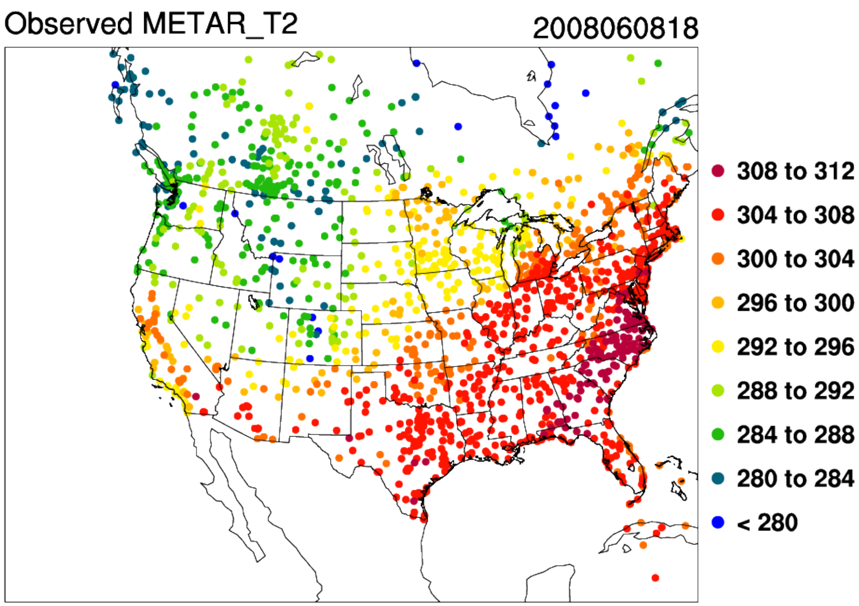
Observations for data assimilation

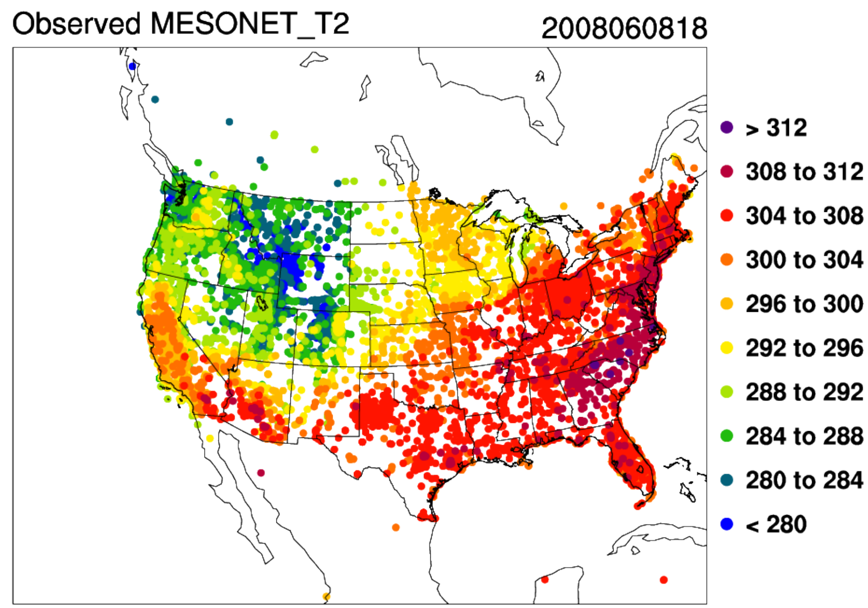
- Assimilated observations
  - RAOB - u, v, t, td, surface altimeter
  - METAR - u, v, t, td, surface altimeter
  - Marine - u, v, t, td, surface altimeter
  - ACARS - u, v, t, td



Observations for verification

❖ <u>Independent</u> observations for evaluation - Integrated mesonet

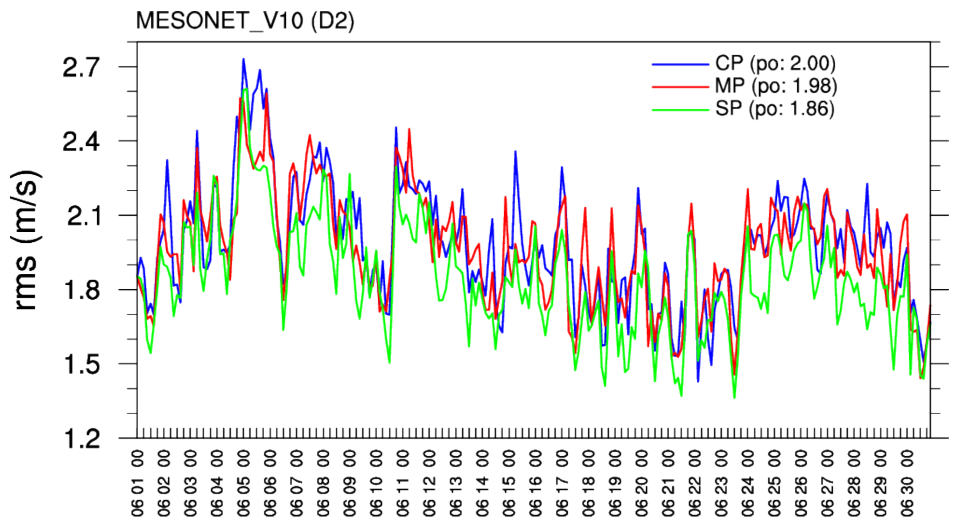




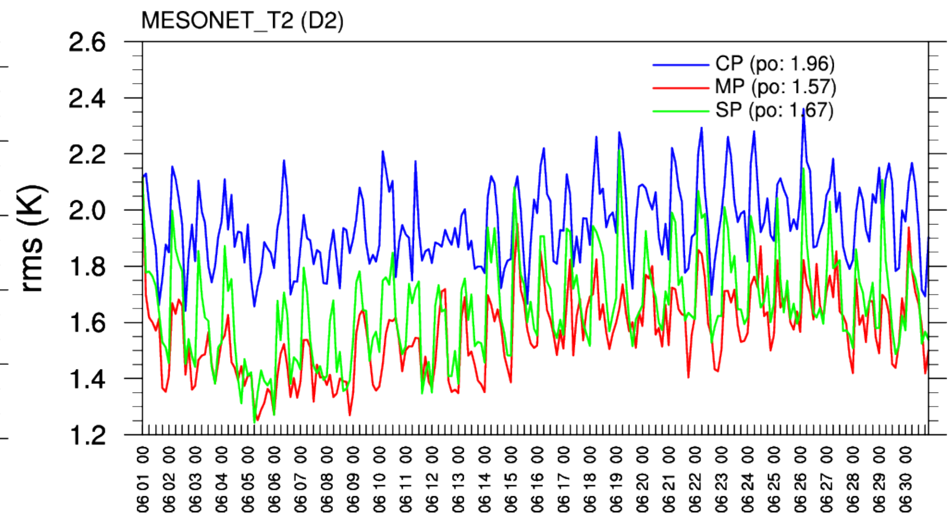
➢ Mesonet data is generally in a lower quality but shows similar temperature distribution with more surface stations.

Analysis verification against mesonet

V-10m



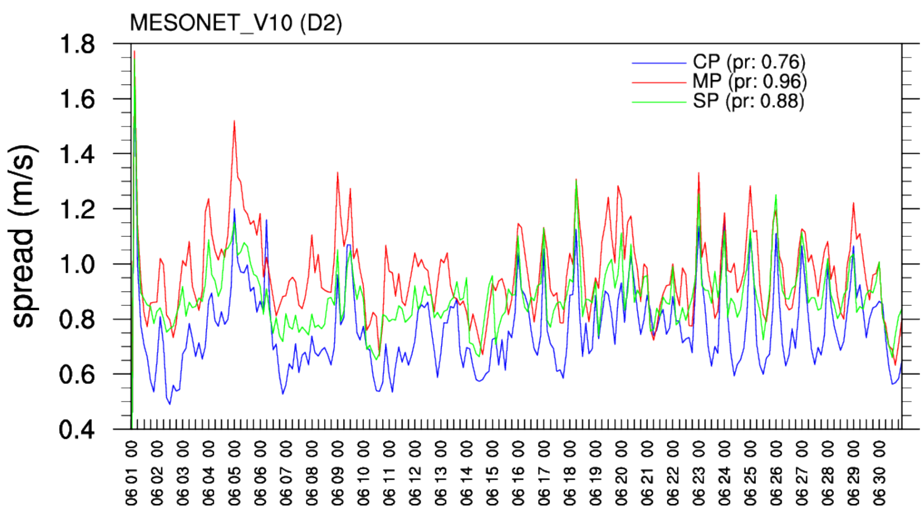
T-2m



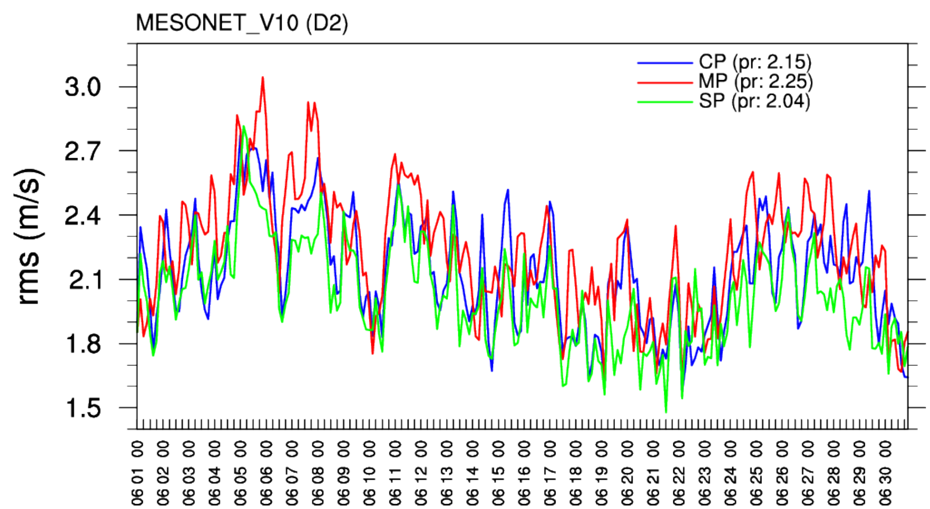
- SP (green) shows the smallest rms error in the surface wind analysis.
- MP (red) performs best in terms of surface temperature.

3-hr forecast verification against mesonet: V-10m

Spread

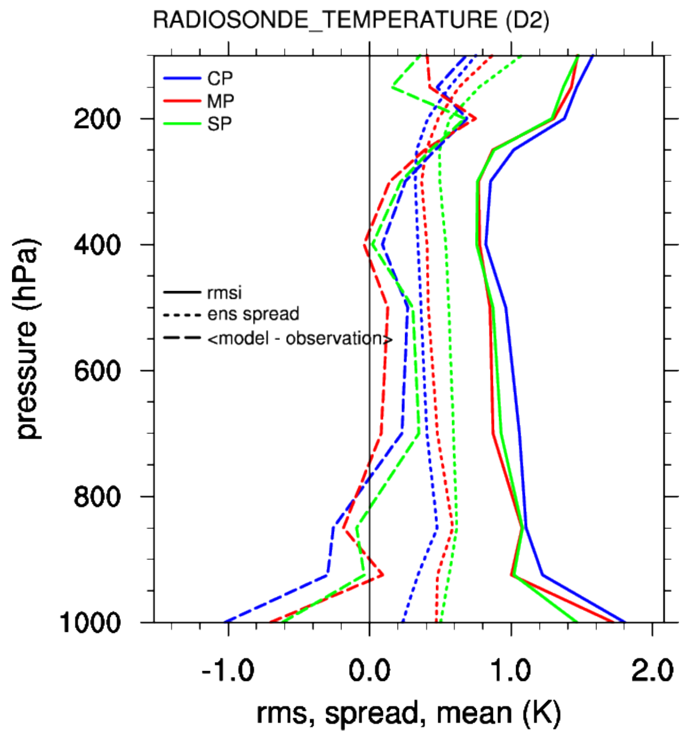


RMSE



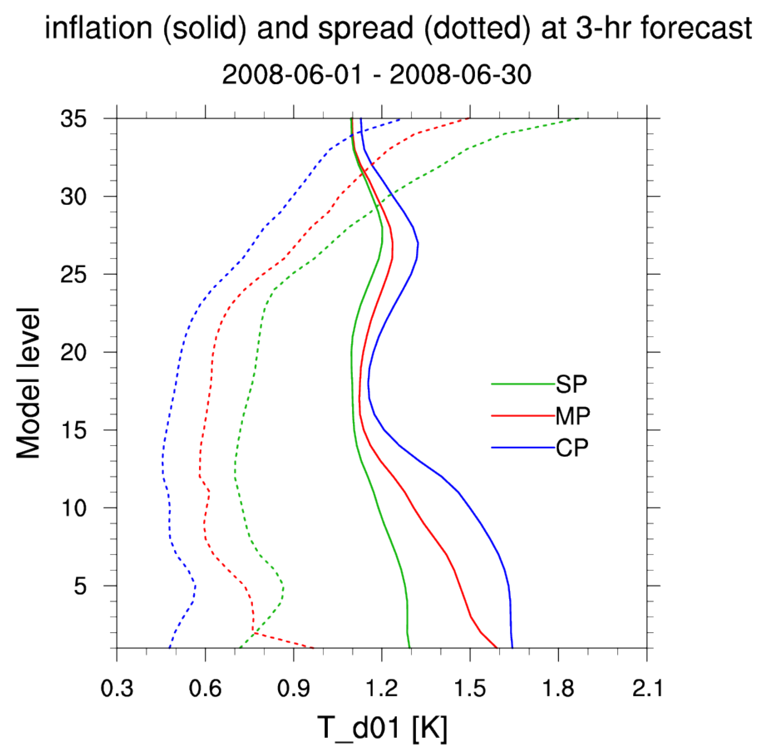
- MP has largest spread and largest rms error, despite of the smallest errors in the analysis.
- SP increased spread and reduced rms error.
- Same performance order in U-10m and T-2m.

3-hr forecast verification against sounding: Temperature



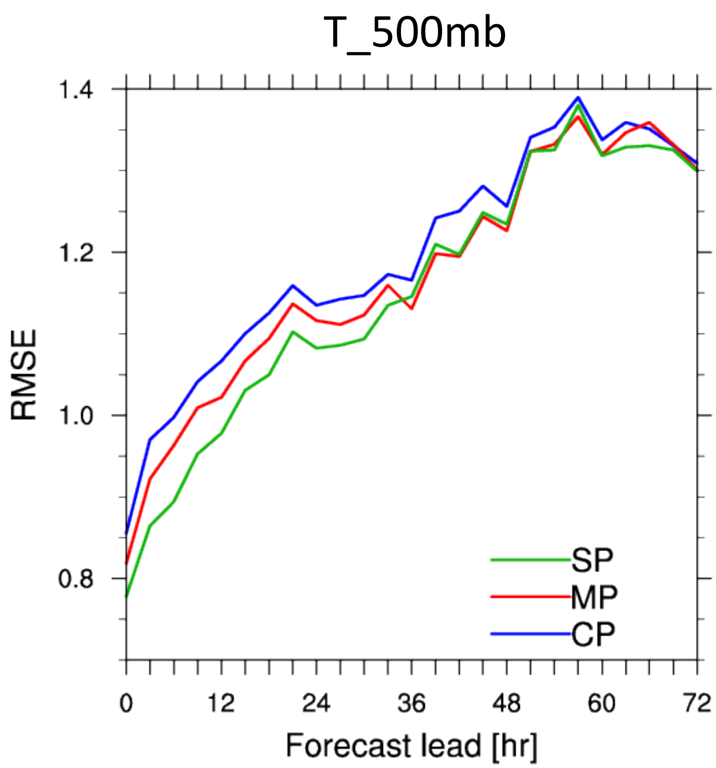
- Bias error (long dash): MP < SP ≤ CP
- RMS error (solid): SP < MP < CP
- Ensemble spread (dotted): SP > MP > CP
- Similar in other fields

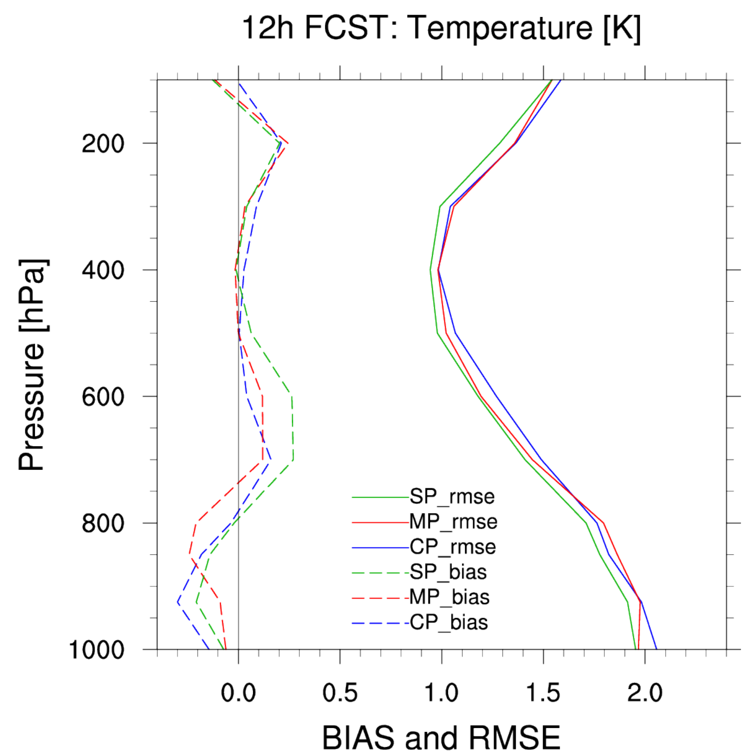
State-space: Prior inflation and ensemble spread: T



- ➢ Smallest spread in CP needs largest inflation in all variables for entire atmosphere.
- ➢ SP shows largest spread (except at the lowest level), smallest inflation.

Verification of extended mean forecast against RUC analysis

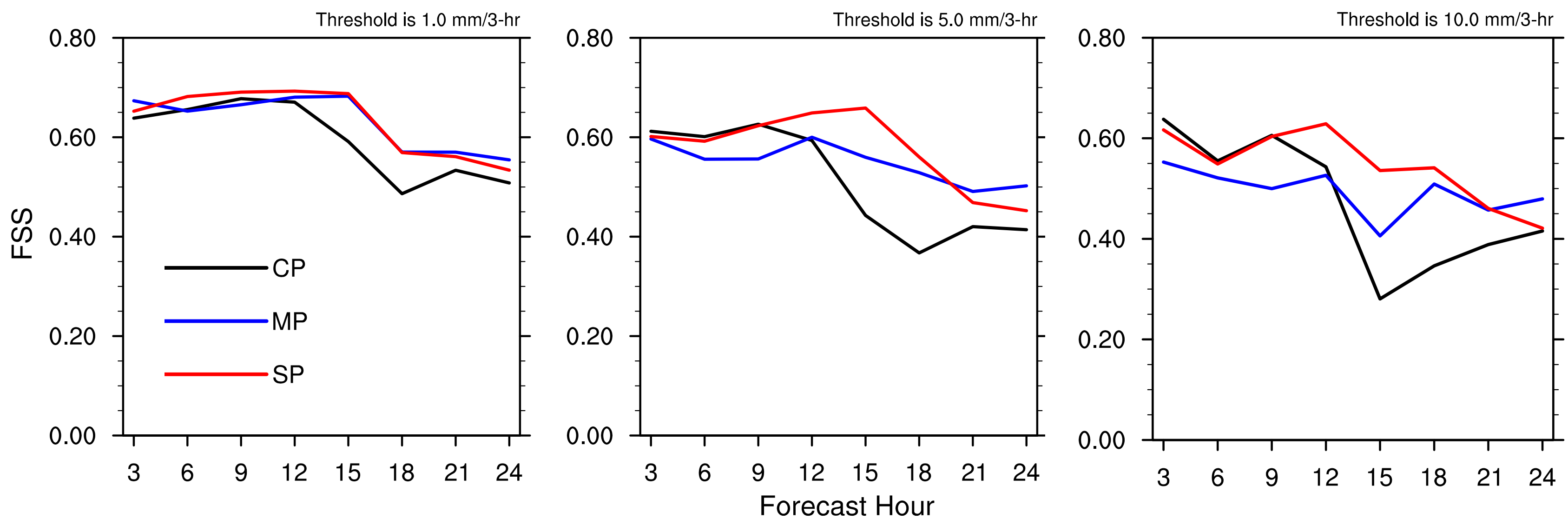




Precipitation verification in 3-hr forecast

<u>Fractional Skill Score (FSS)</u>:

- Roberts and Lean (2008) and Schwartz et al. (2009)
- The 3-hr accumulated precipitation in the ensemble mean forecast at 15-km grid was compared to the 3-hrly gridded NCEP stage IV precipitation analysis.



Courtesy of Craig Schwartz

Conclusion and the future work

- Different model error techniques were examined:

  Multi-physics (MP) and stochastic backscatter schemes (SP) compared to CP w/ adaptive inflation

- Model error techniques improved the analysis and the short-rage forecast in the mesoscale cycling run for a summer period of June 2008.

- All three approaches are broadly comparable, but stochastic backscatter performs consistently better than CP and MP

  (in the spread-error relationship and in the extended deterministic forecast).

- We plan to examine the model error representation in the ensemble forecast w/ probabilistic verification.