Skill of Nowcasting of Precipitation by NWP and by Lagrangian Persistence

(where we chronicle a bridging of the gap)

There were various attempts at improving precipitation nowcasting through addition of NWP:

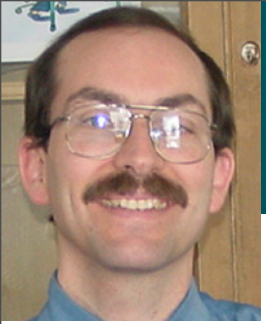
Skill-weighted average of Lagrangian Persistence (LP) and NWP

Correction of positional errors (and more) of NWP

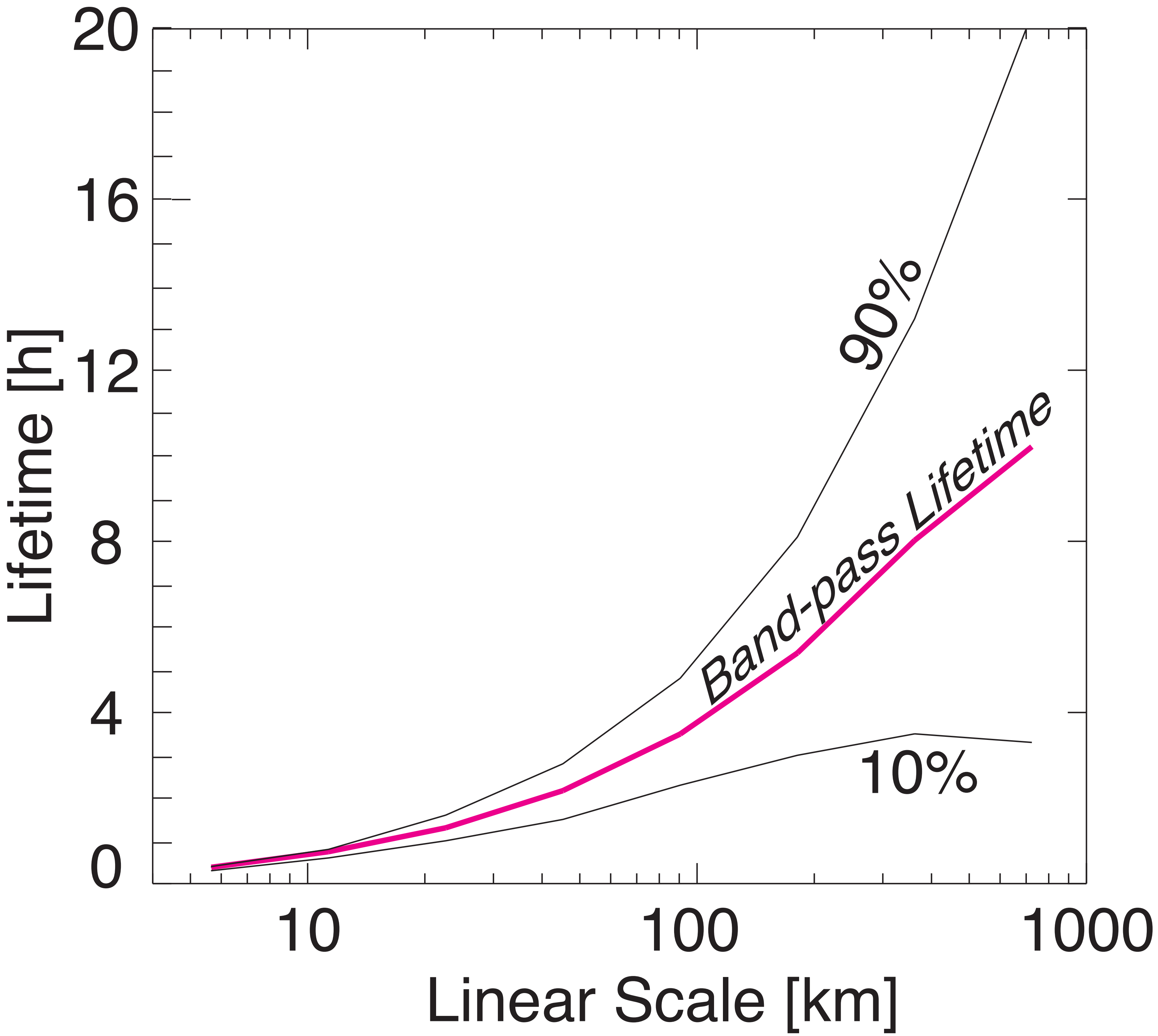
Selectively adding NWP-predicted growth and decay to LP

Correction of phase errors of NWP

(As a standalone or in combination with LP,
with or without data assimilation; deterministic or ensemble NWP)



Basic fact of life: short scales are ephemeral



Basic fact of life: Precipitation patterns have characteristics of pink noise

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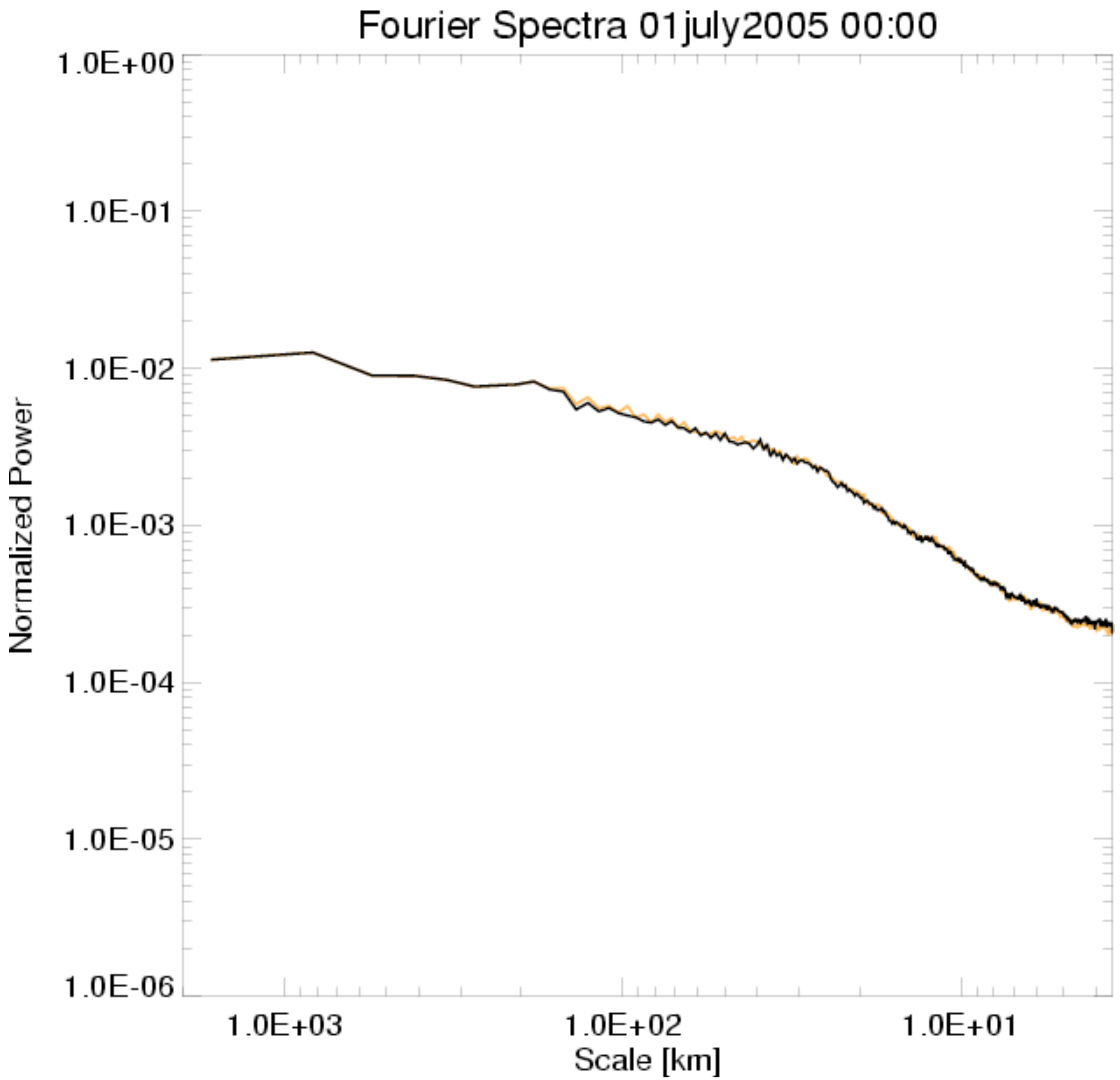


Nowcasting Skill of Model and of Lagrangian Persistence

The nowcast is improved when NWP nowcast and Lagrangian persistence nowcast are merged by a skill-weighted average.

However, there is no advantage in doing this adaptively: climatological skill is as good as the skill determined in a particular situation just prior to the nowcast.

Question: Why?

Possible answers:

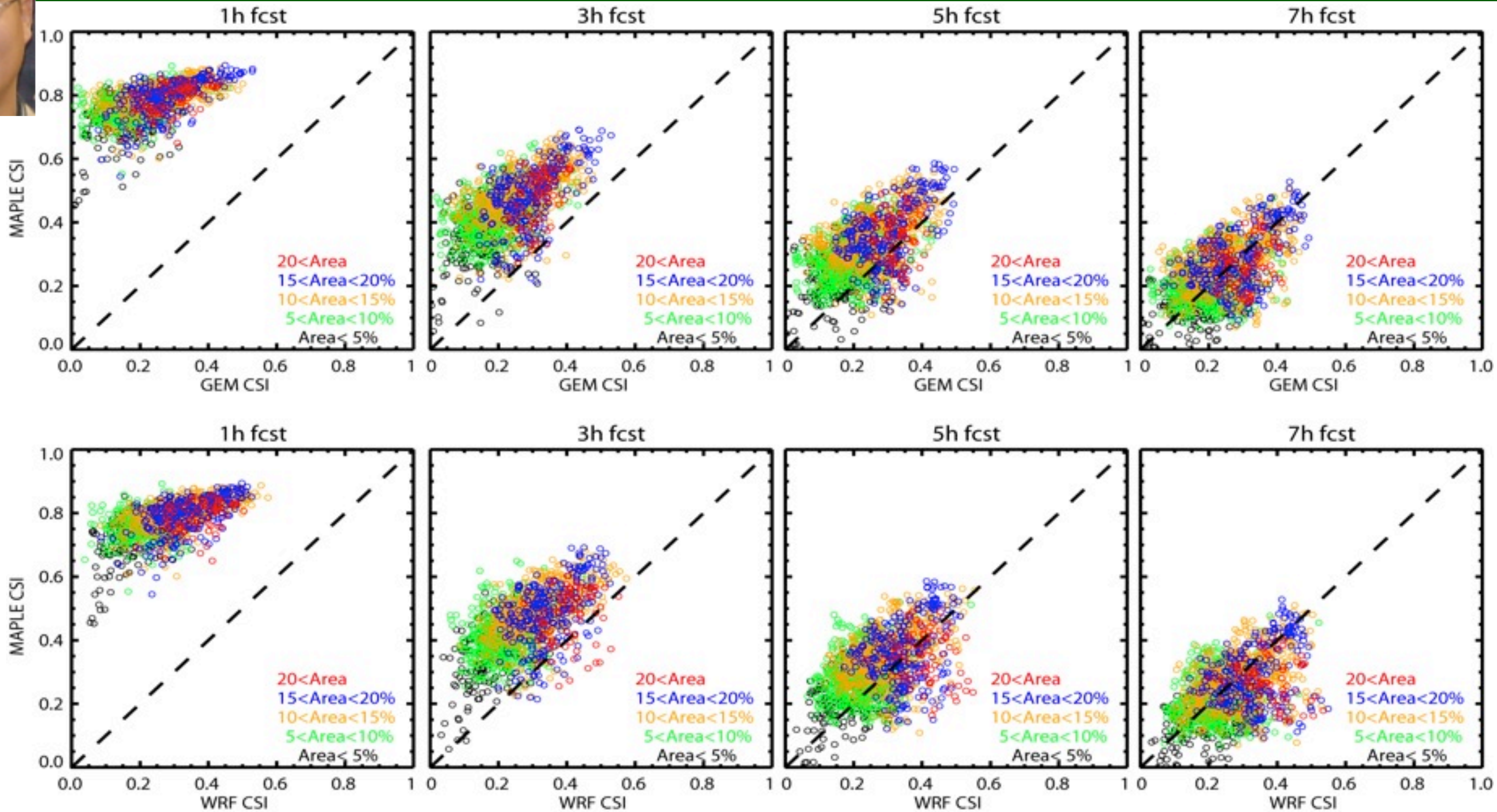
Either model skill is not sufficiently persistent in time
(ex: effect of diurnal cycle)

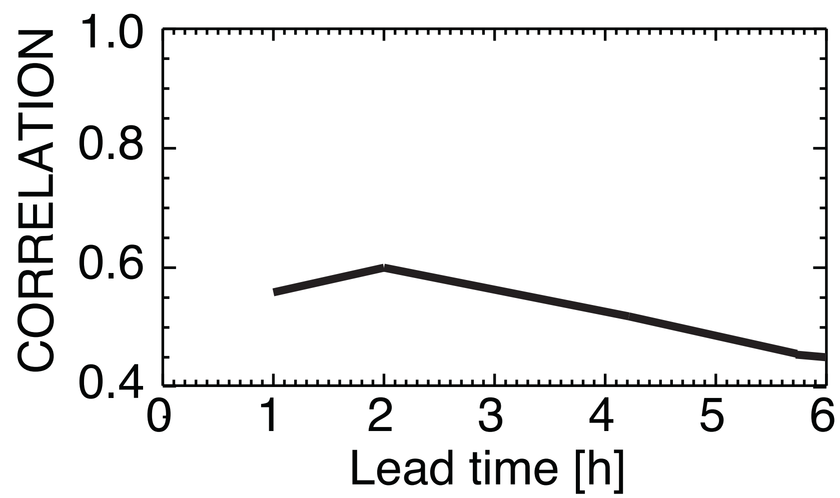
or

the skill of model and of LP are correlated

Scatterplots of CSI

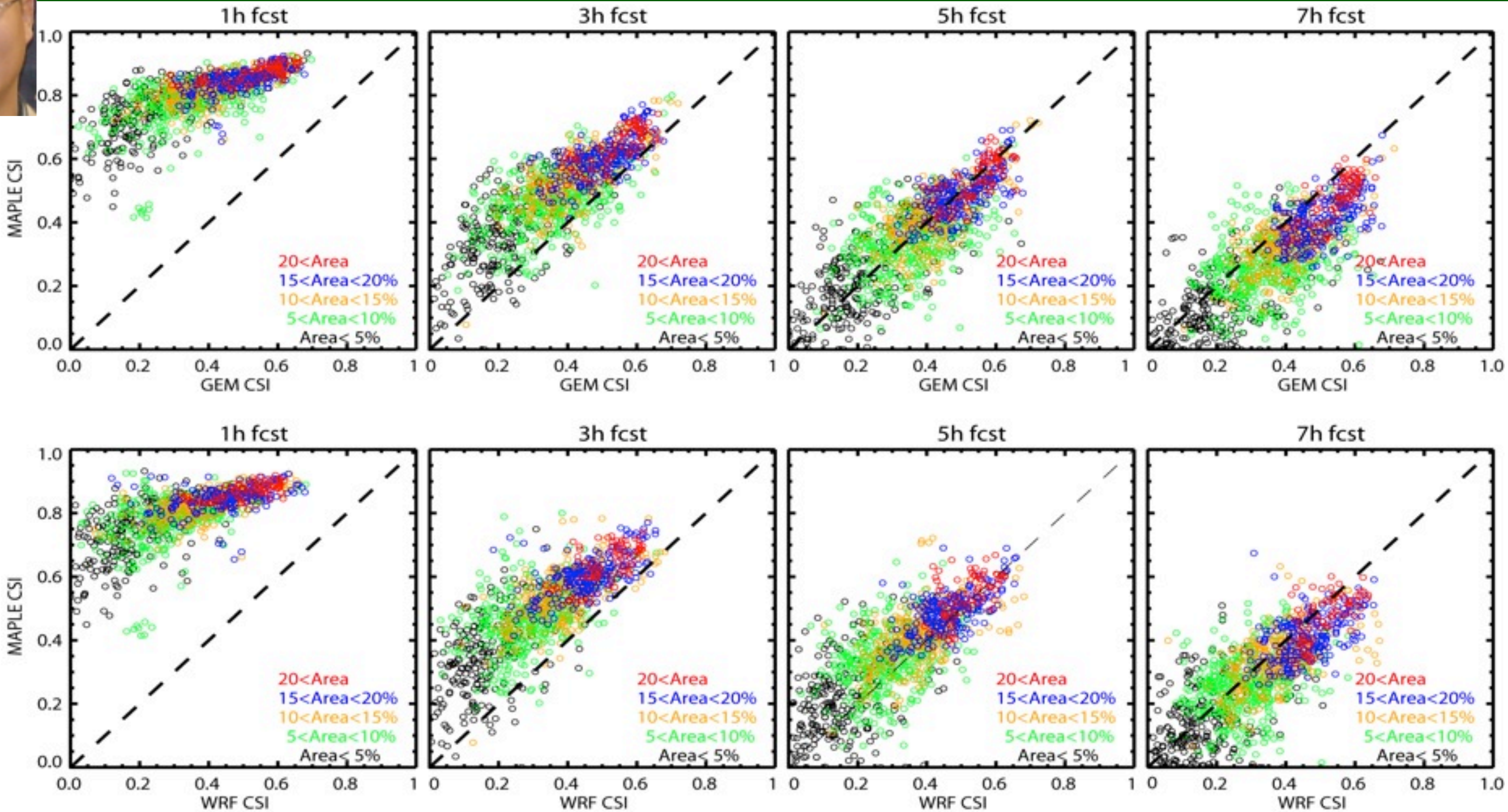
June to August 2005

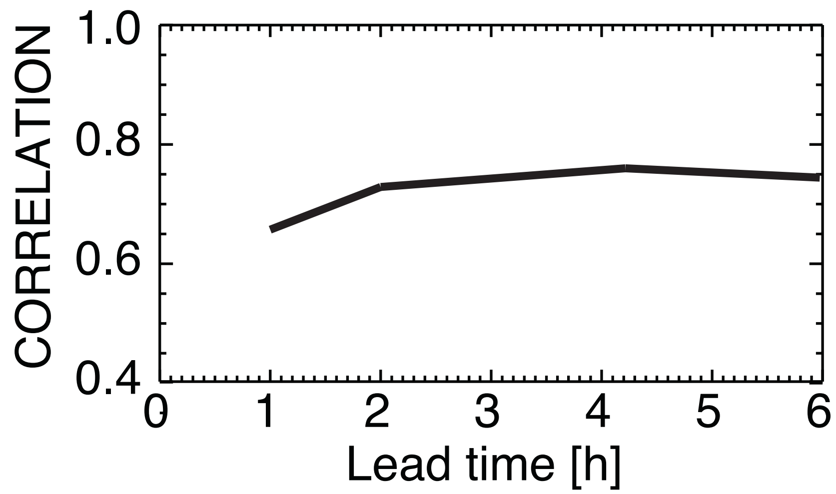




Scatterplots of CSI

Jan. to March 2005





Monday, 12 August, 13

Scatterplots of CSI

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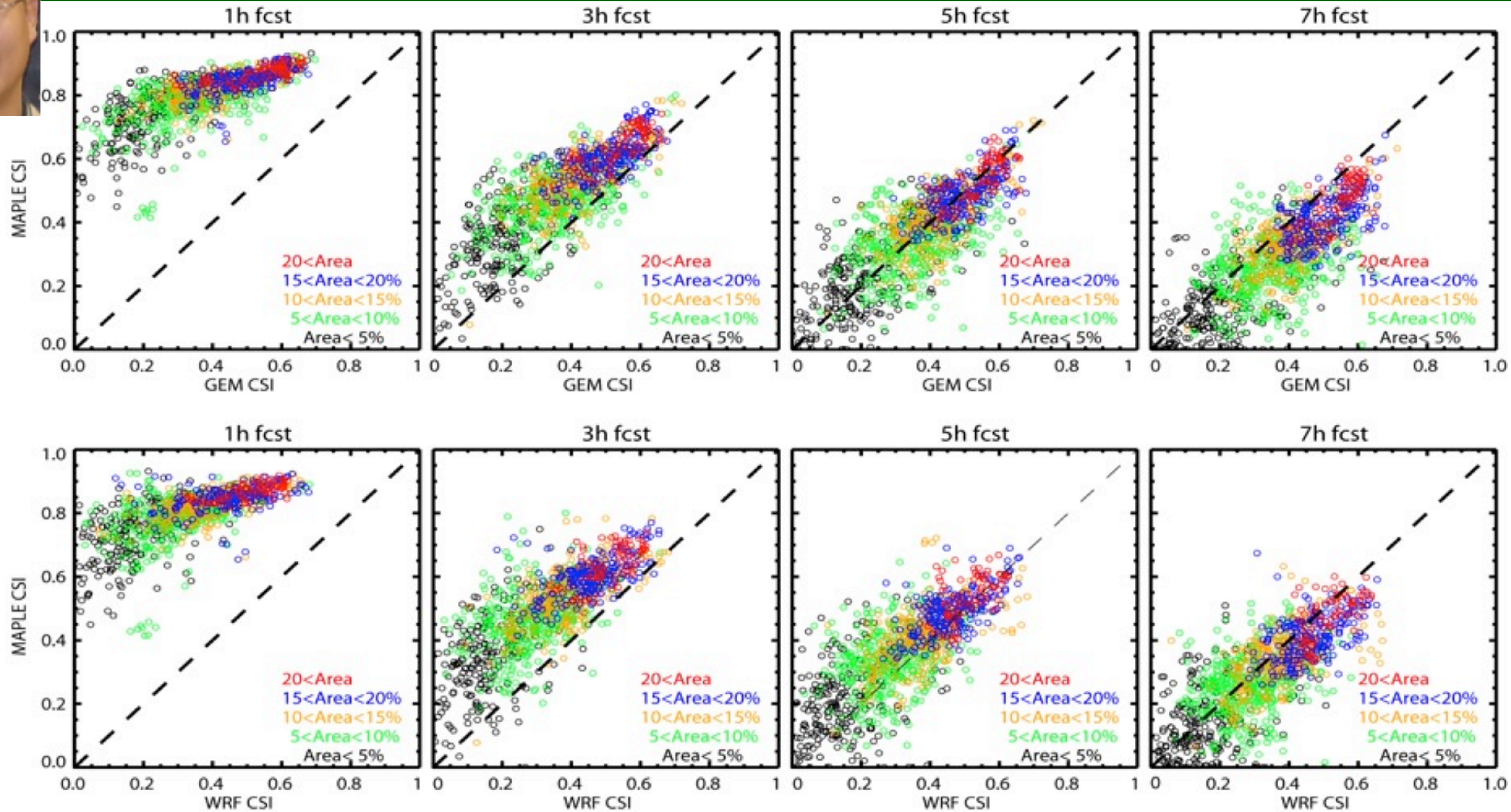

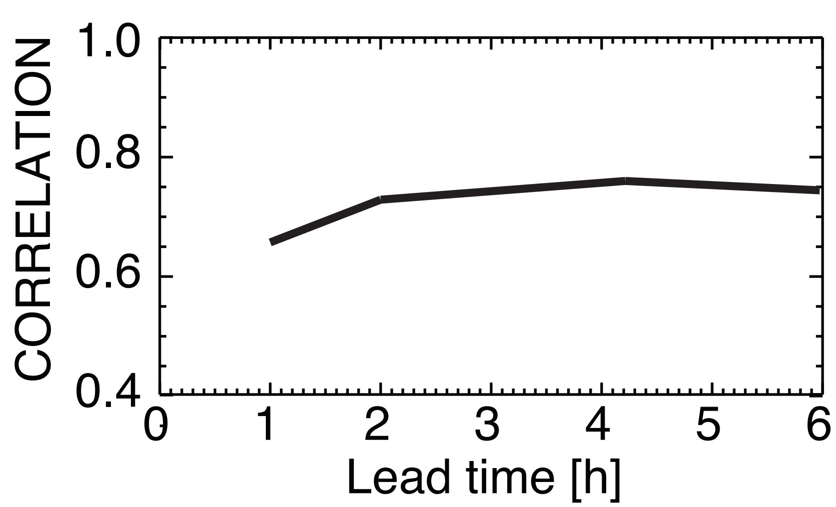

Should we be asking why so much scatter?

We acquired outputs of ensemble runs (OU, Ming Xue) to further experiment with NWP contributions to nowcasting. The ensemble is generated by varying initial conditions and model physics.

Radar data are assimilated in all members except **c0** ; **cn** is identical to **c0** except that radar data were assimilated

Ensemble mean is re-calibrated by probability matching, PM (making the pdf of intensity equal to the average pdf of members)

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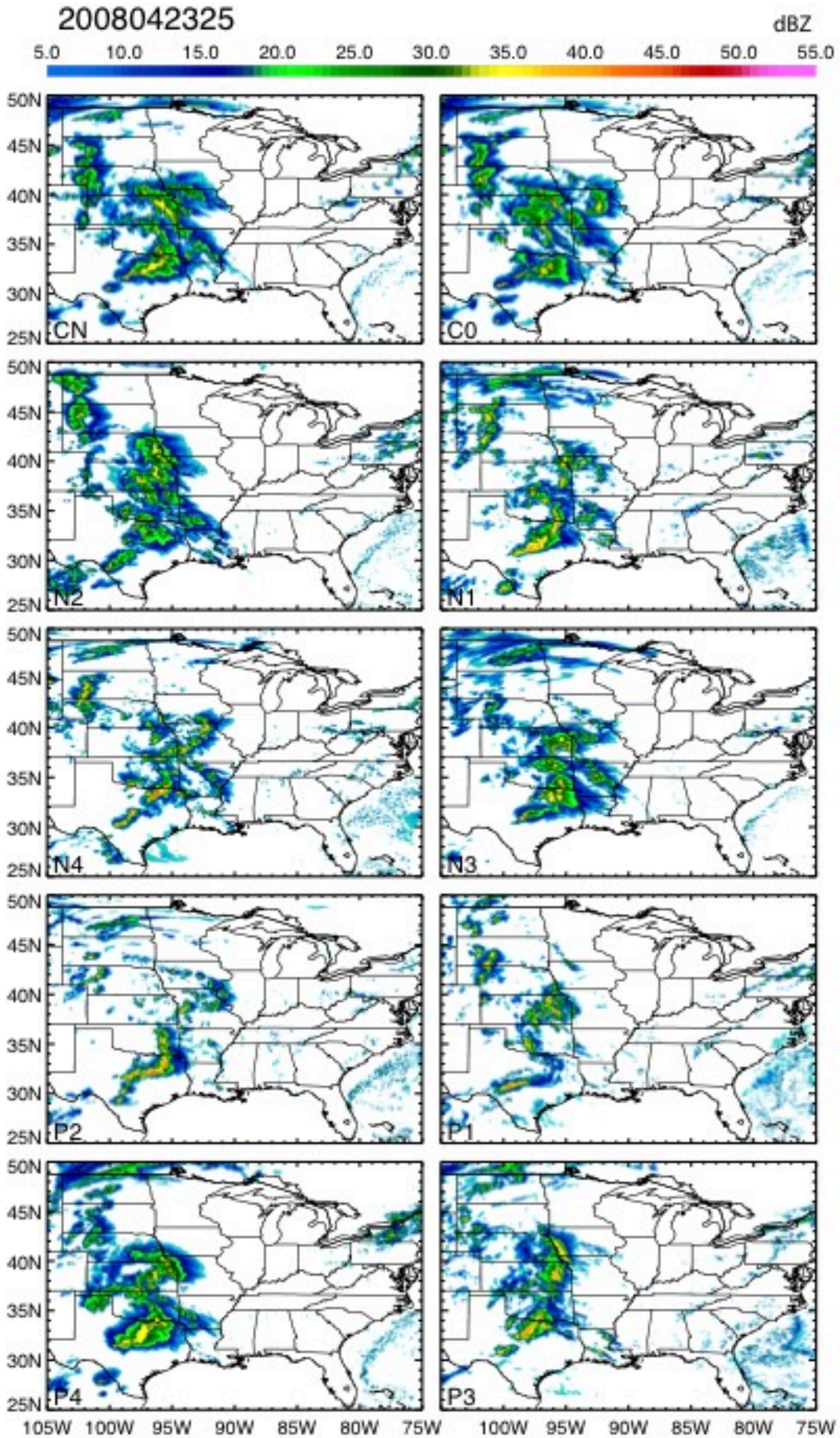
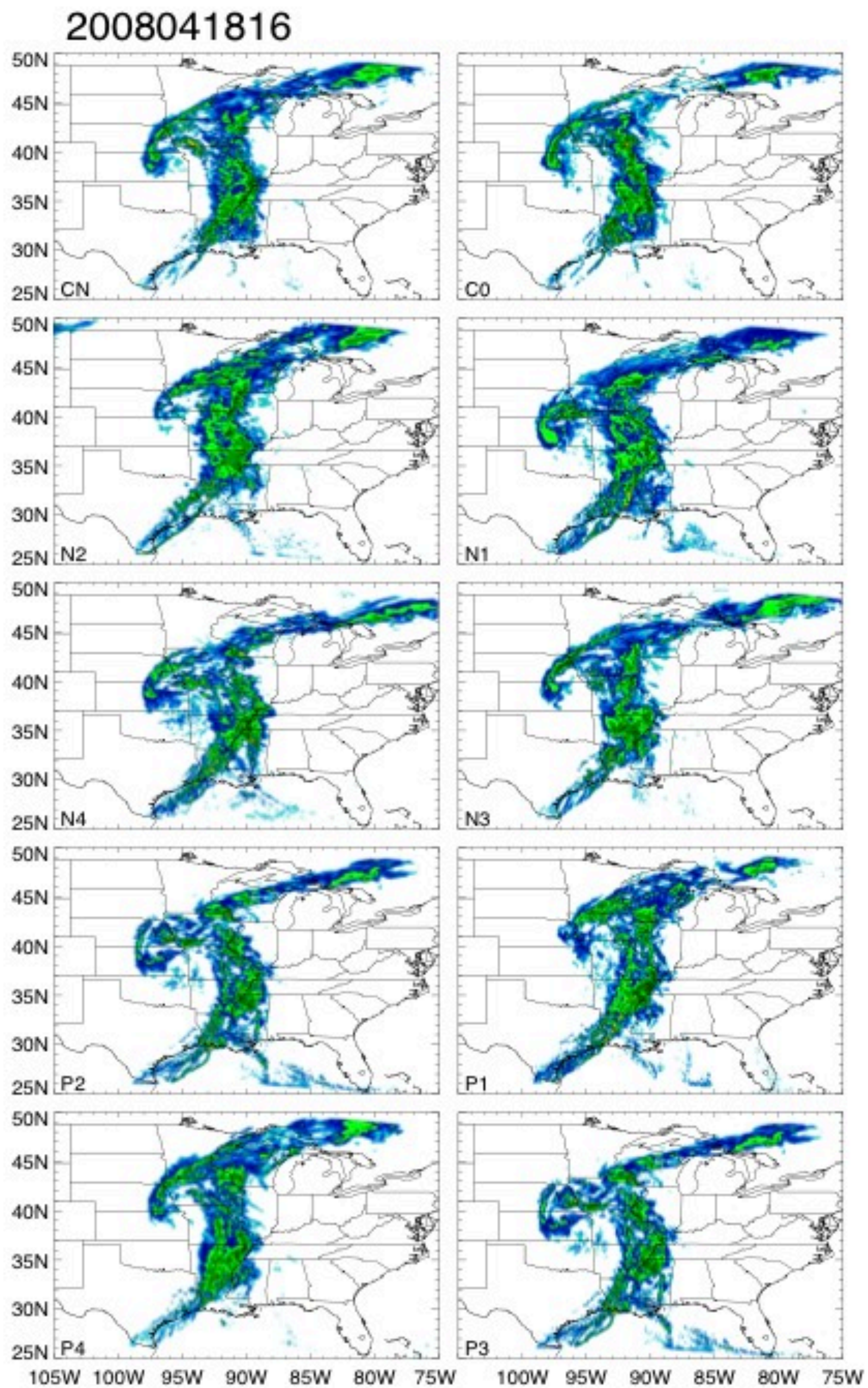
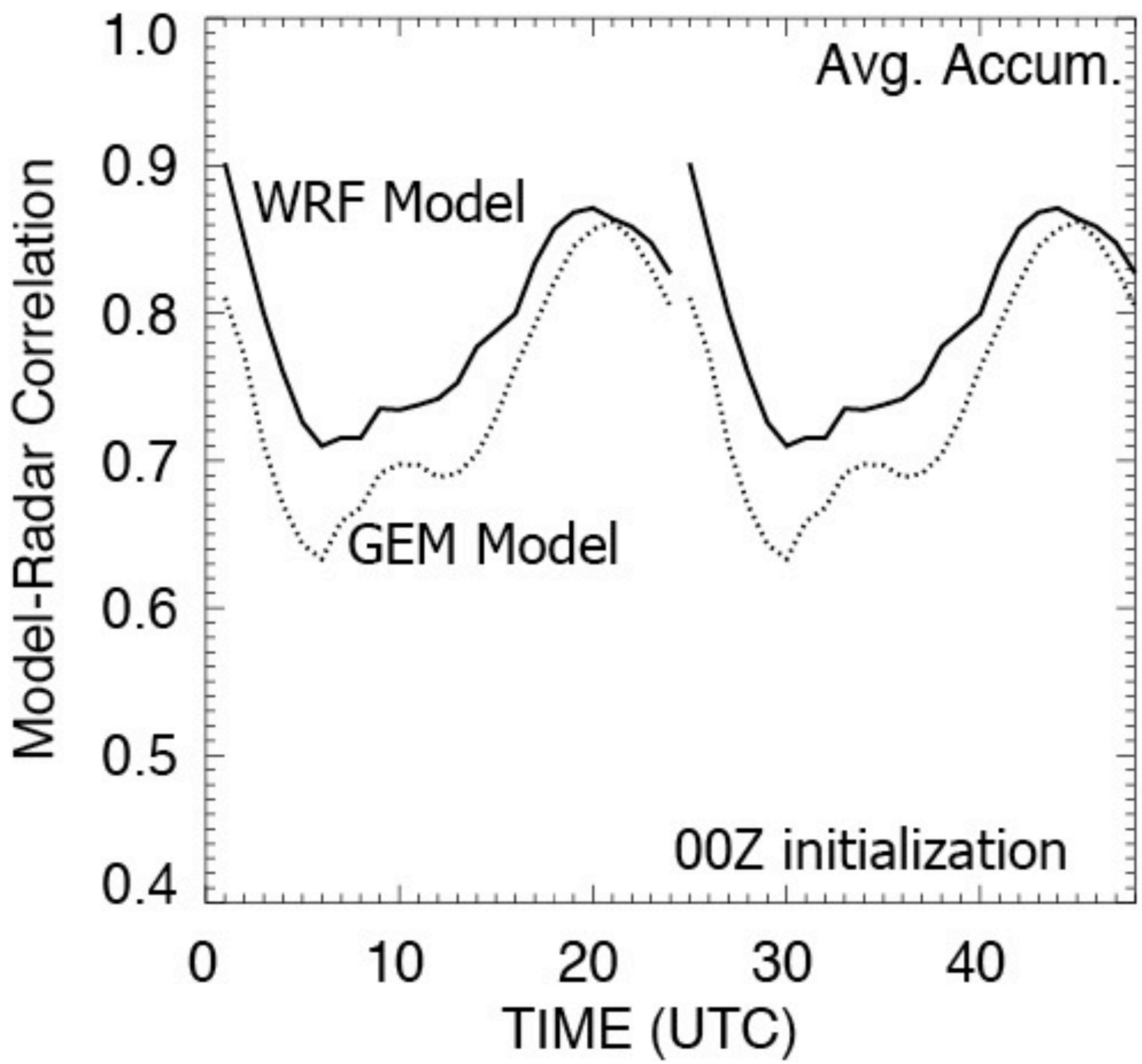
Note: the POD of the ensemble mean (before PM) is smaller than one, indicating that the ensemble does not cover all observed precipitation)

NWP Ensembles (poor and best predictability cases)

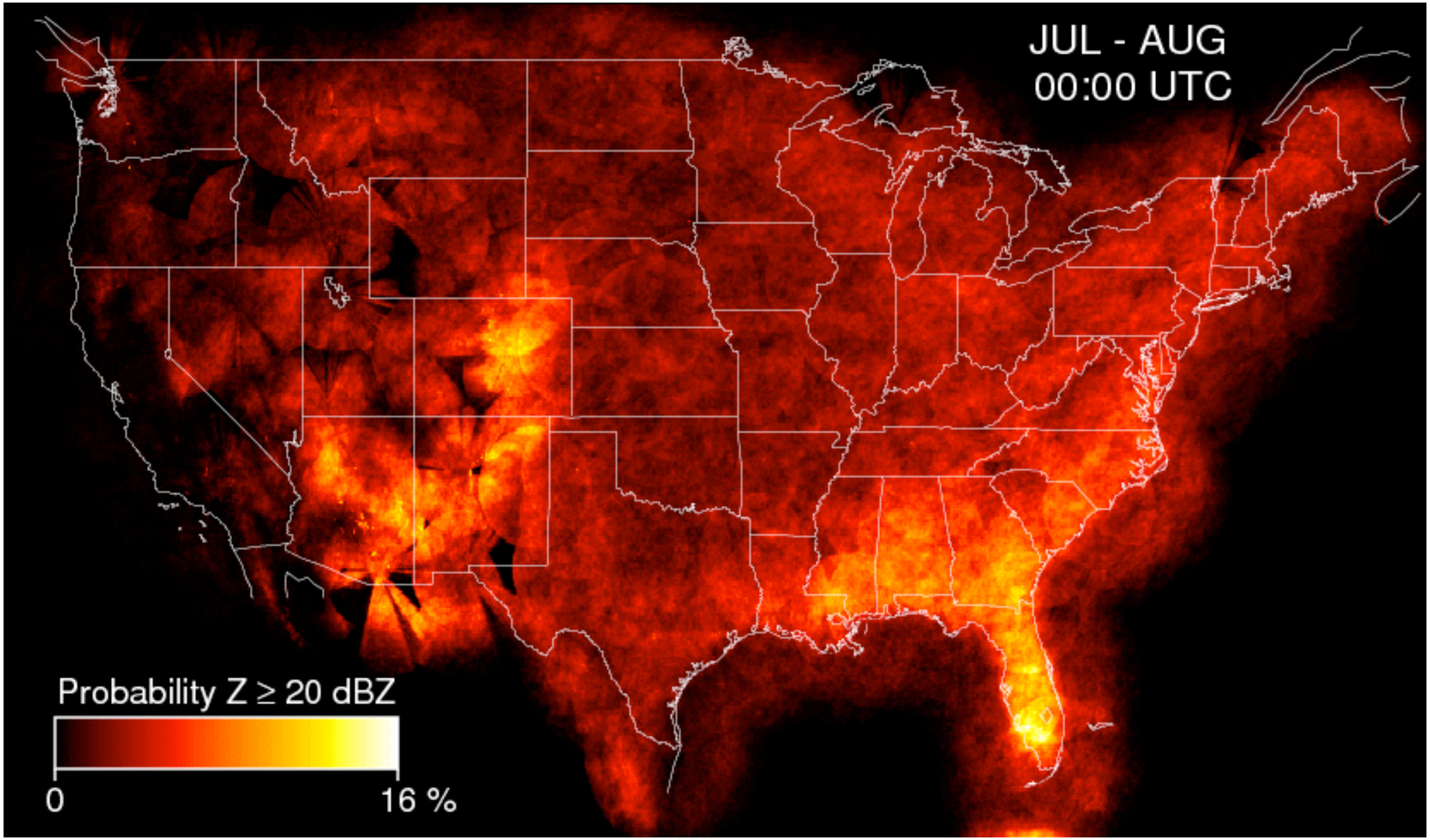




Diurnal cycle in NWP of rain

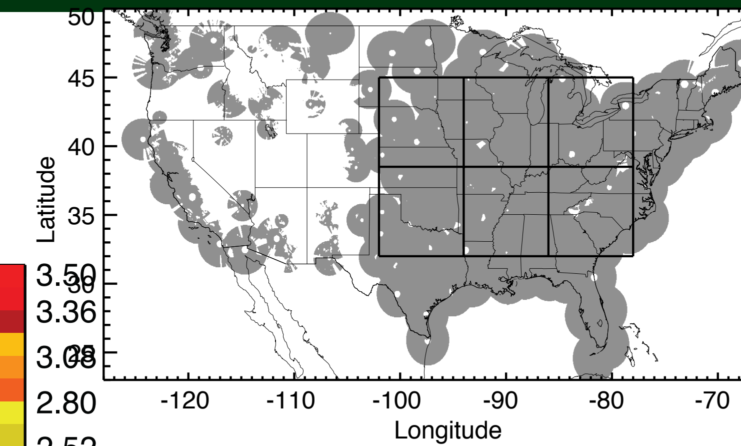


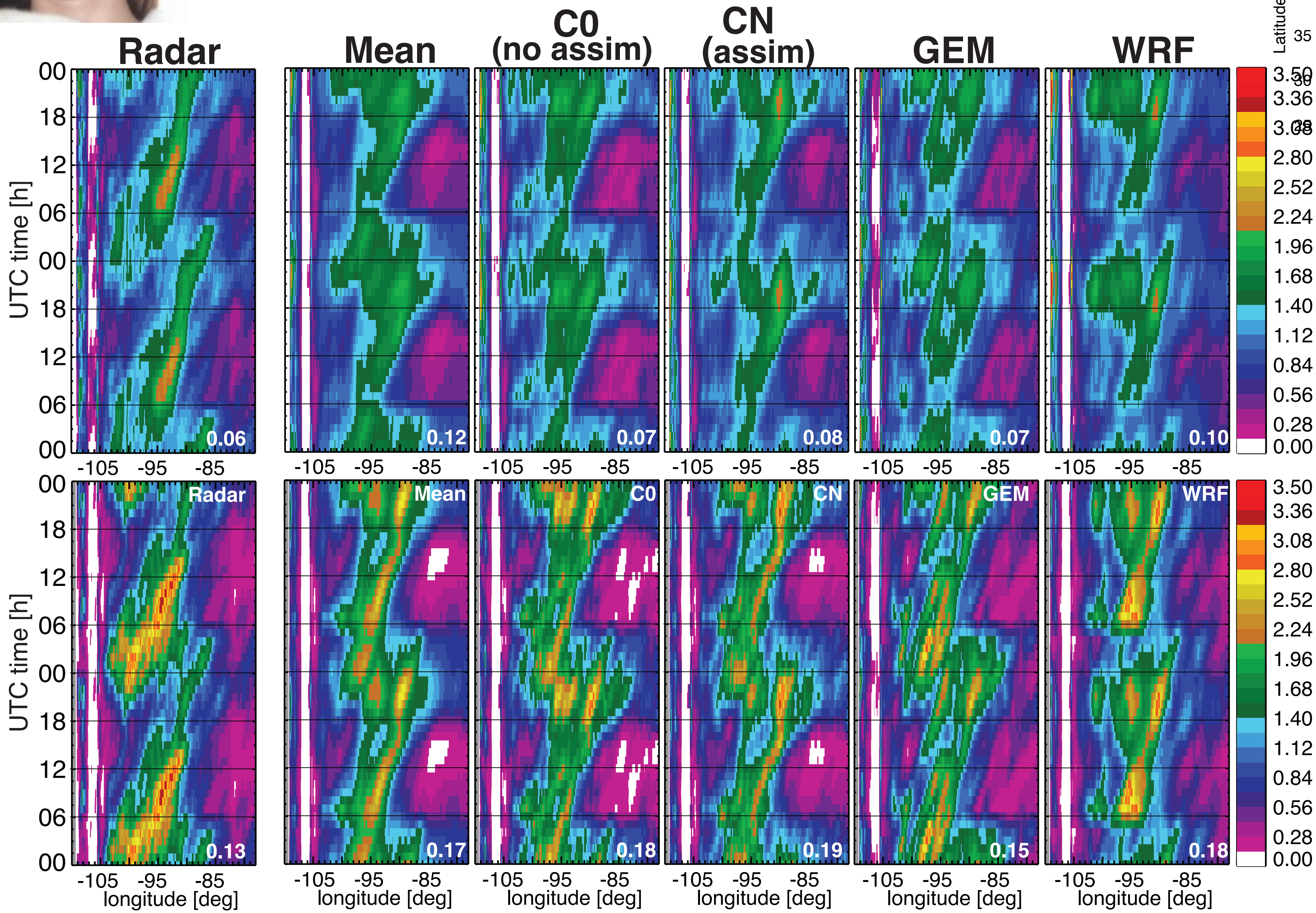
Diurnal cycle in pdf of rain



Models fail to correctly reproduce the diurnal cycle

Summer precipitation over this domain:



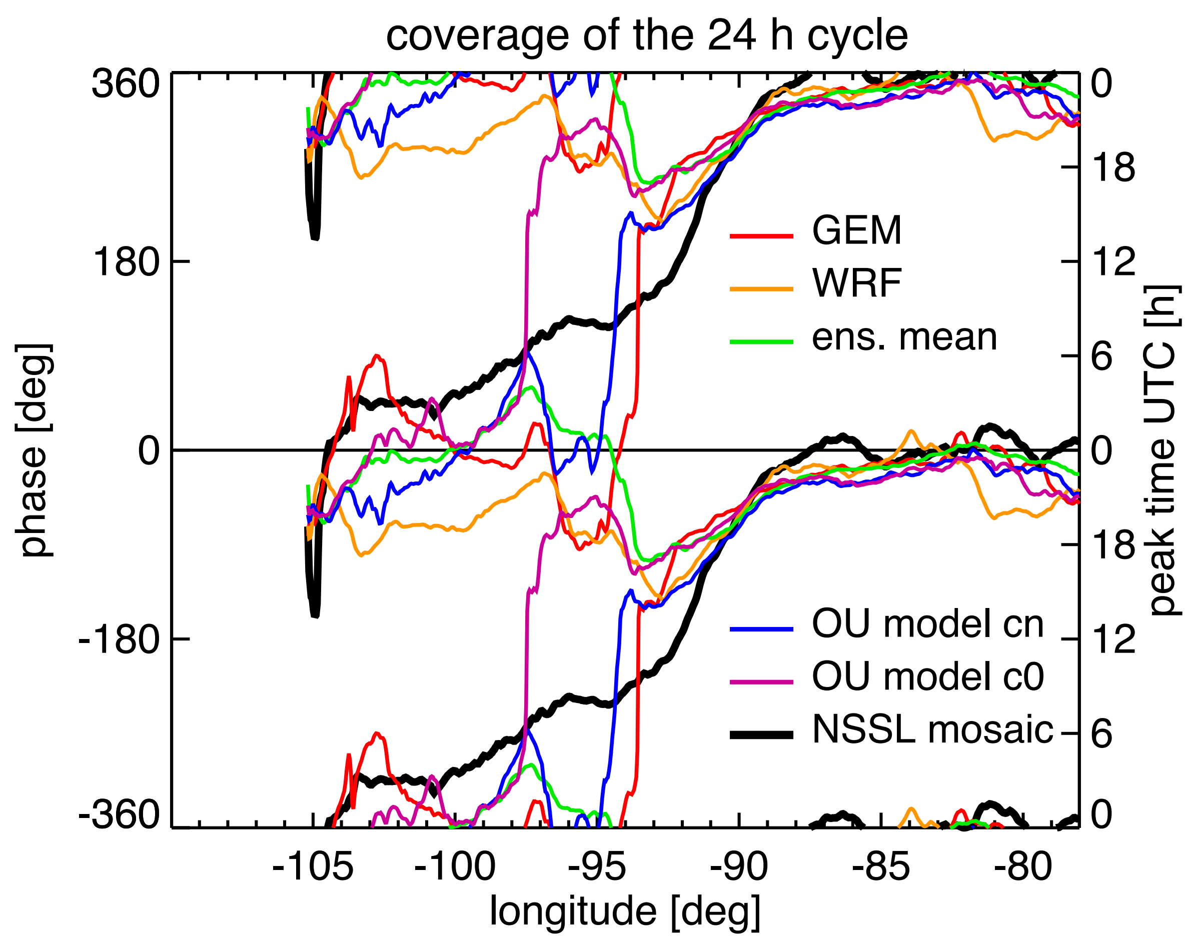


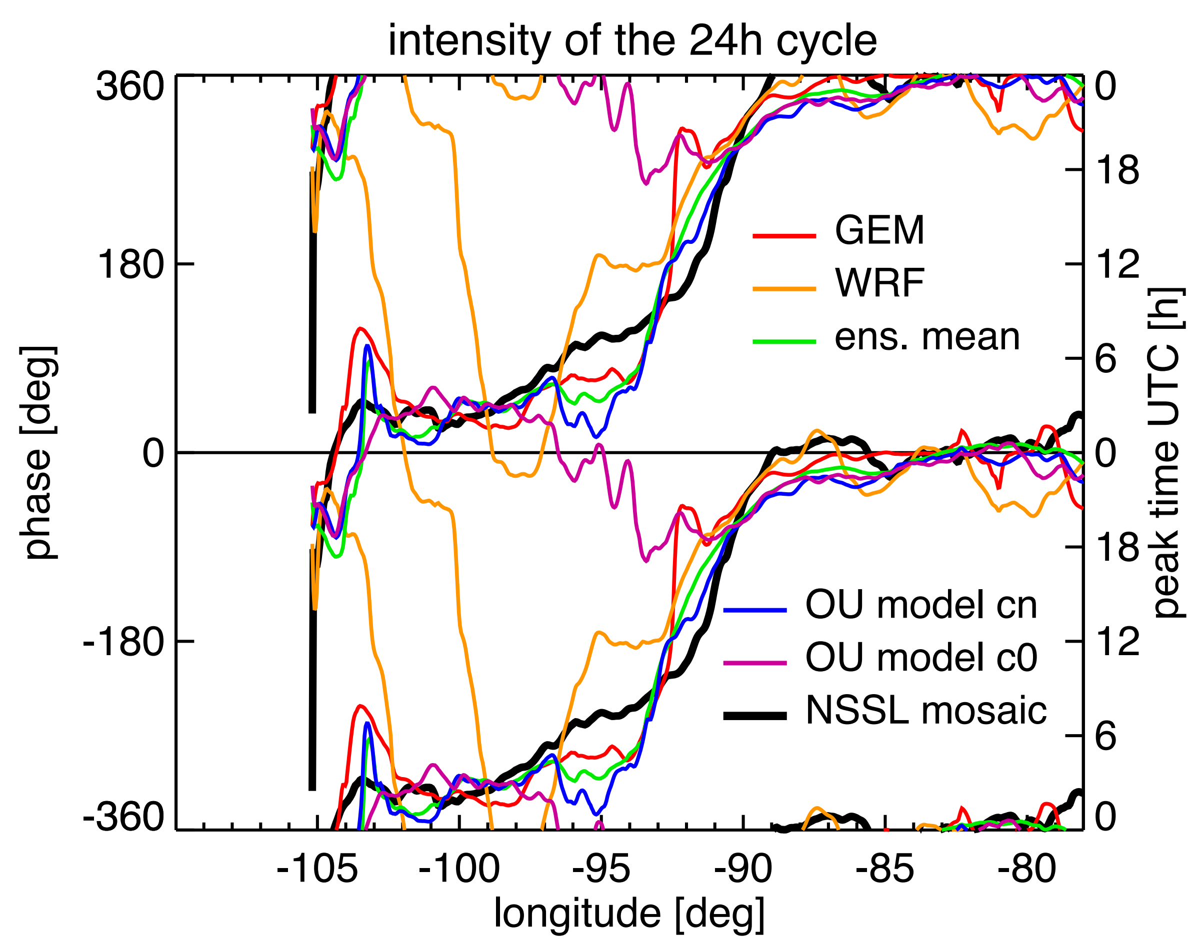
Coverage

Intensity

Note the more consistent diurnal cycle in observations

Models fail to correctly reproduce the diurnal cycle





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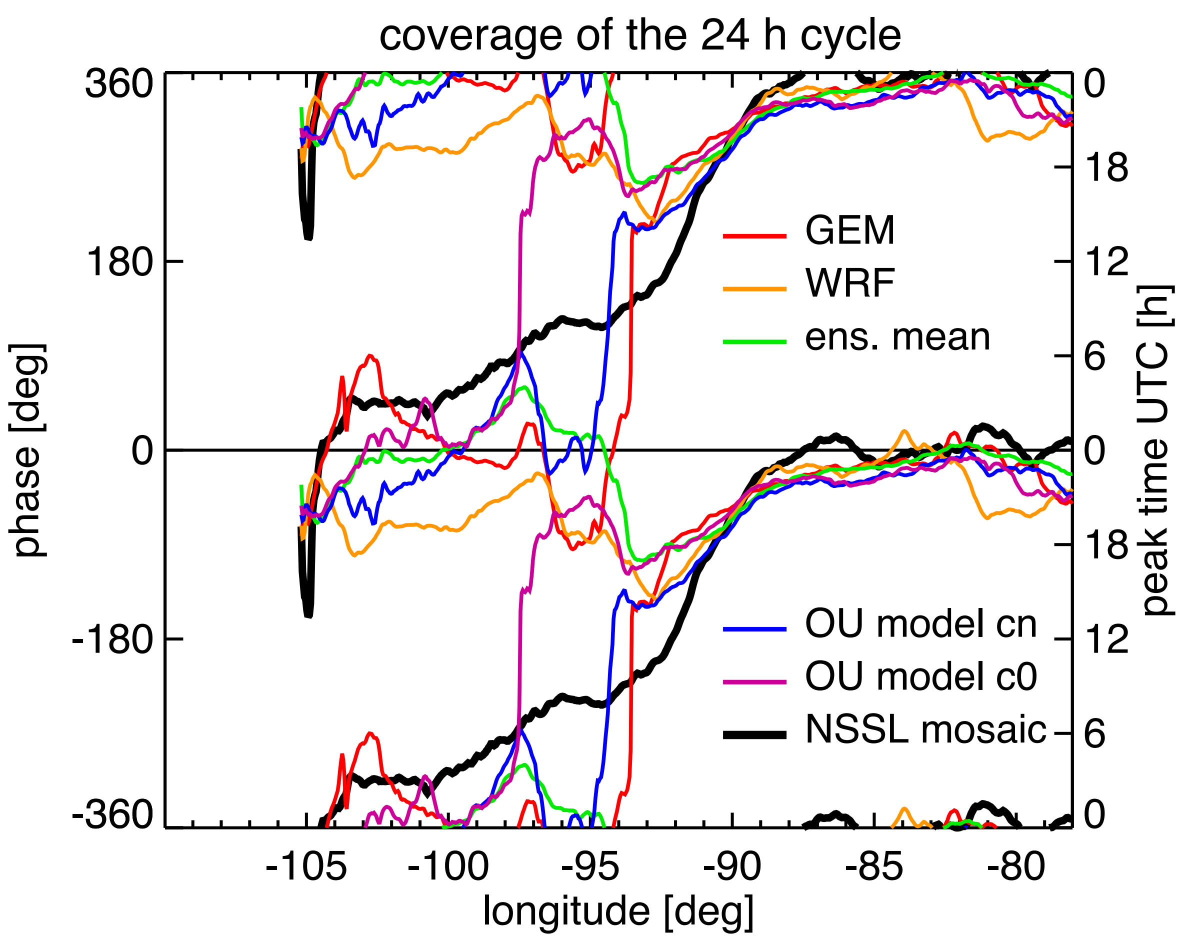
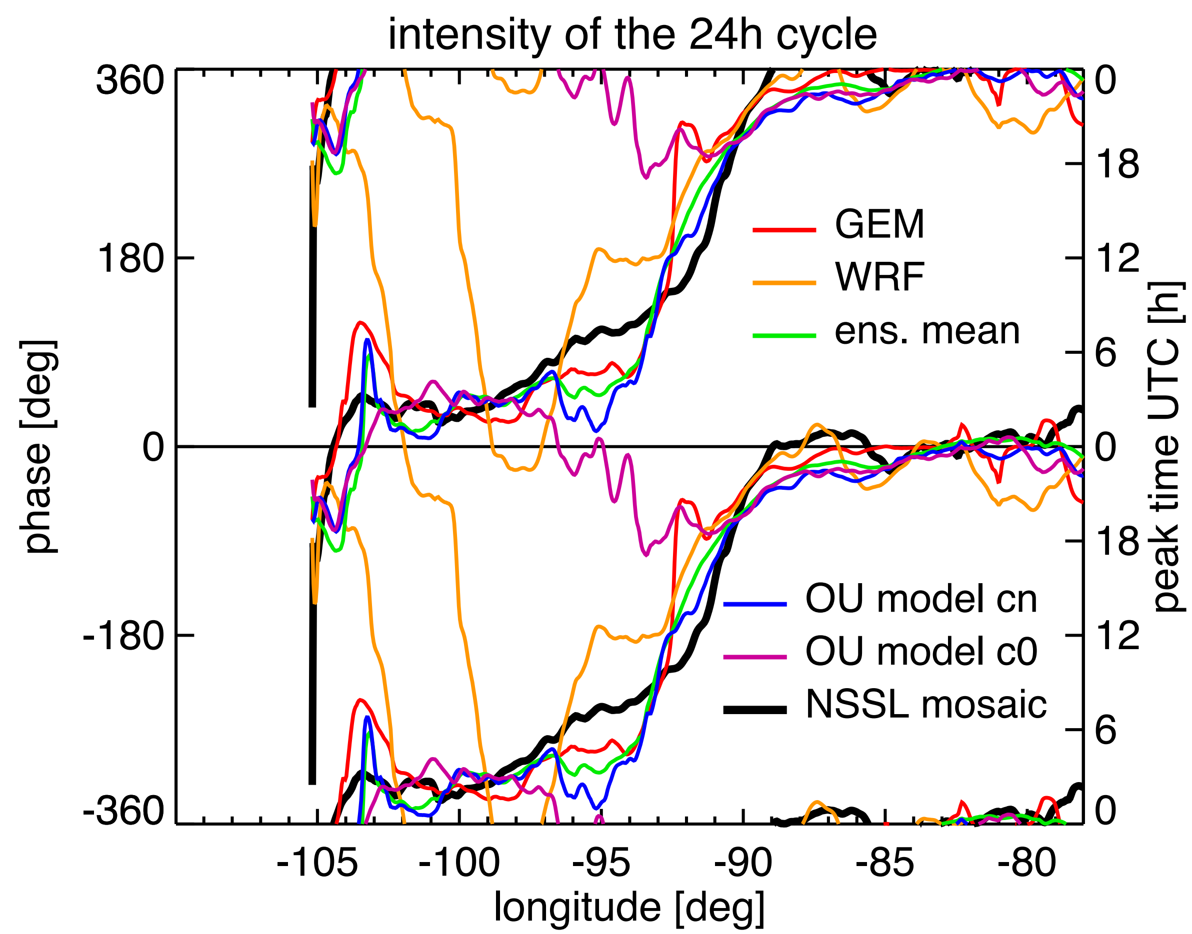
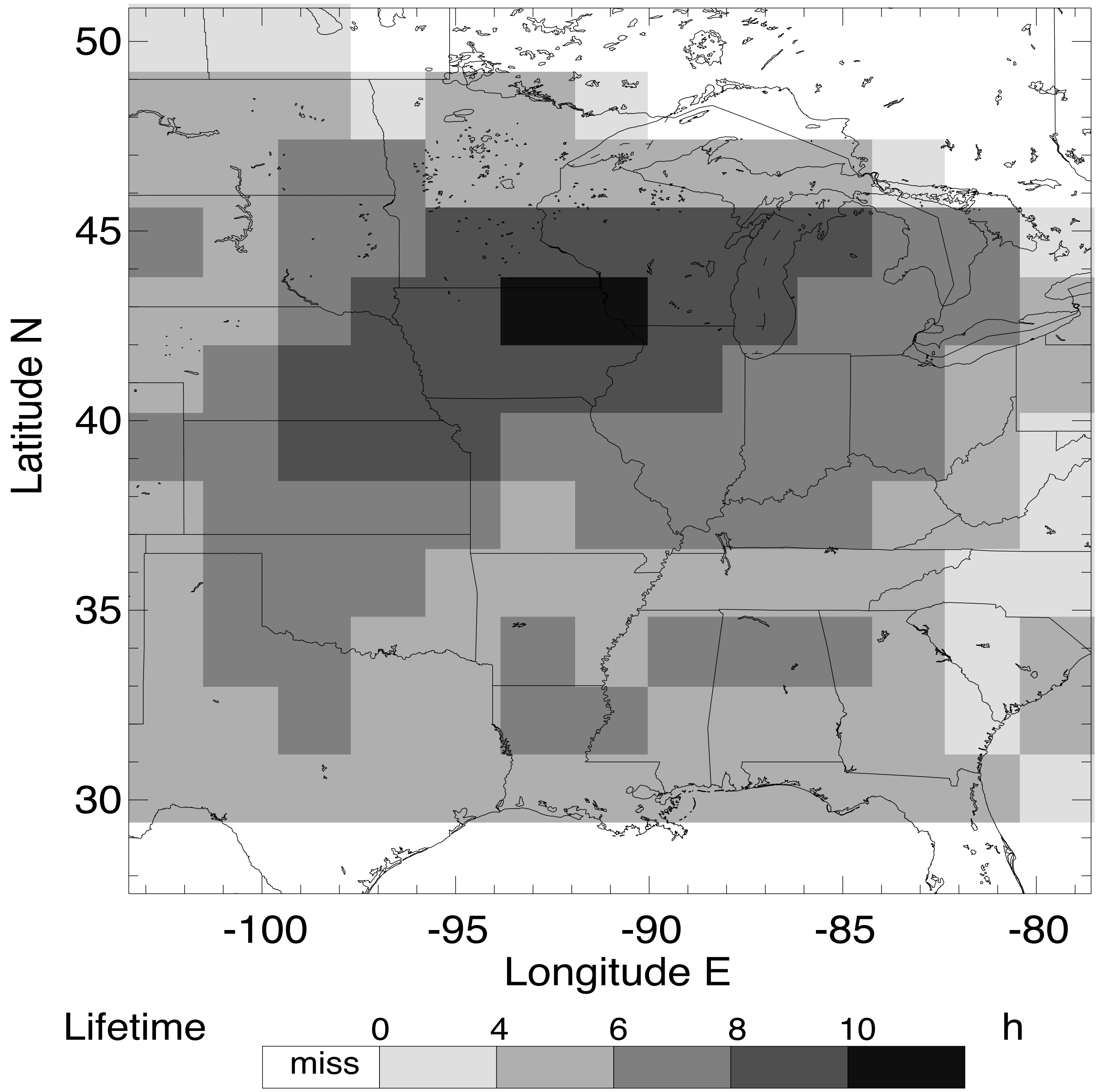




Region of transport of diurnal cycle

The larger forecast errors of diurnal cycle happens where LP is longer !!



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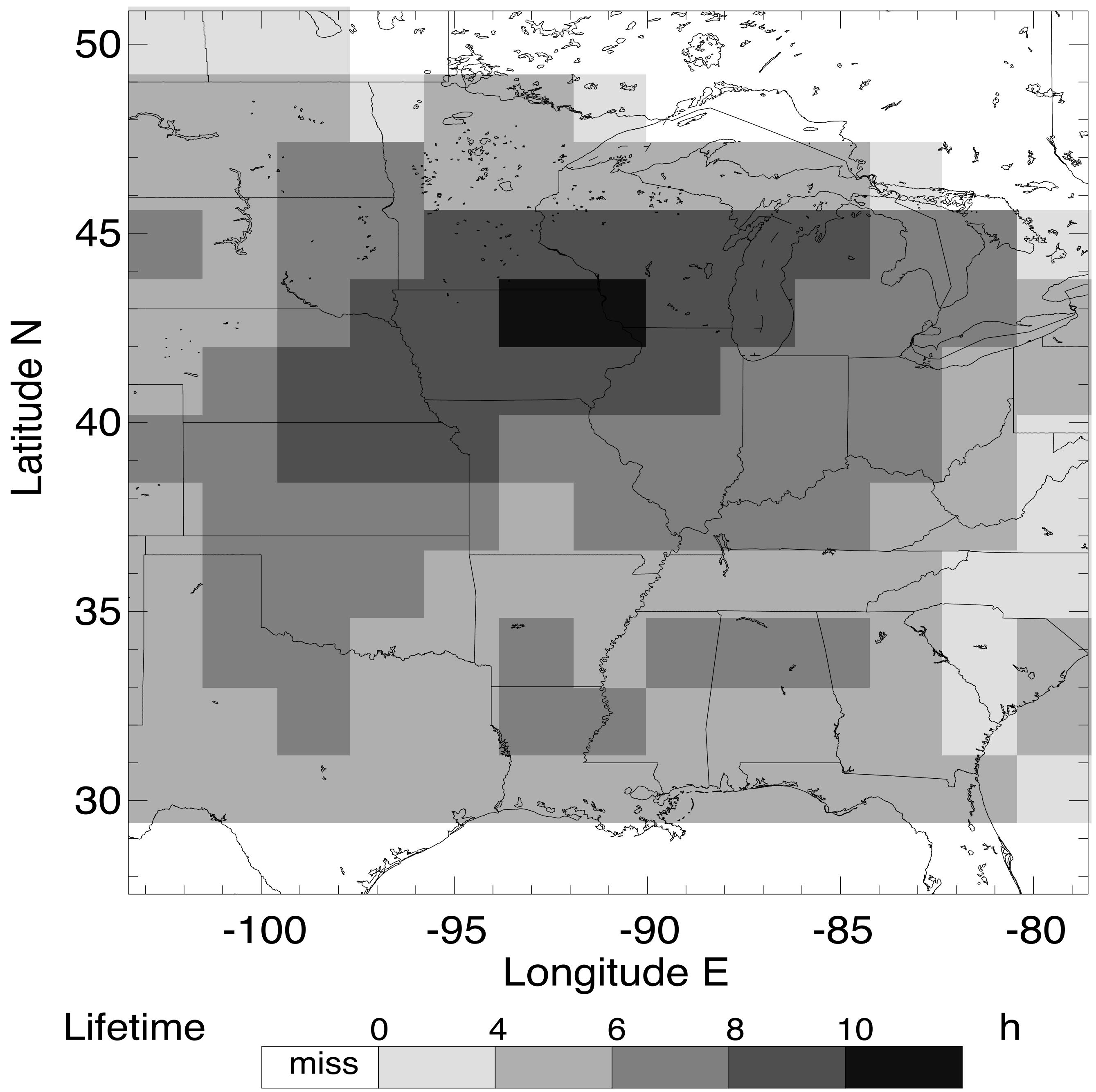
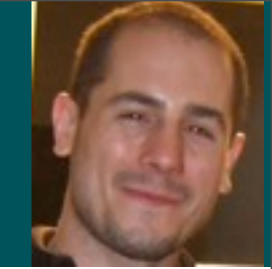
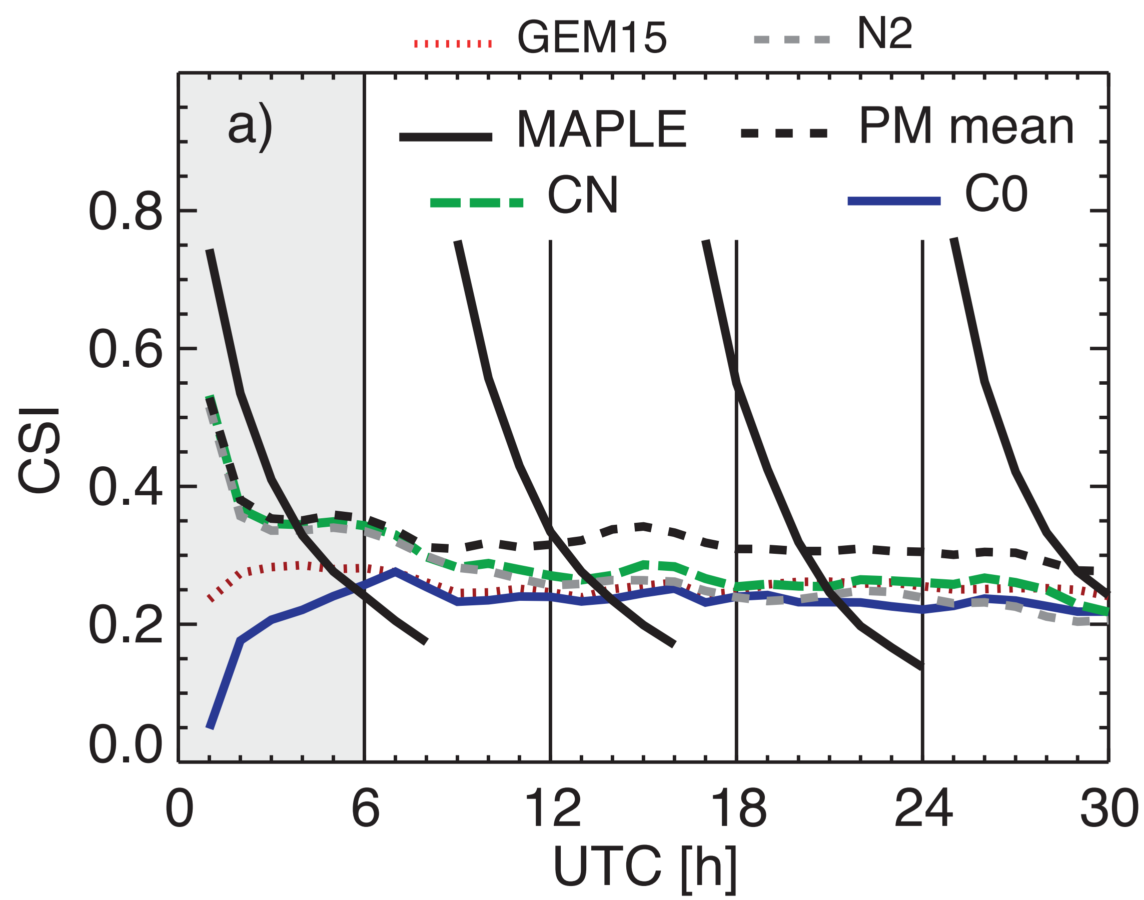


Is this one of the reasons why the predictability by LP and NWP is not better correlated?

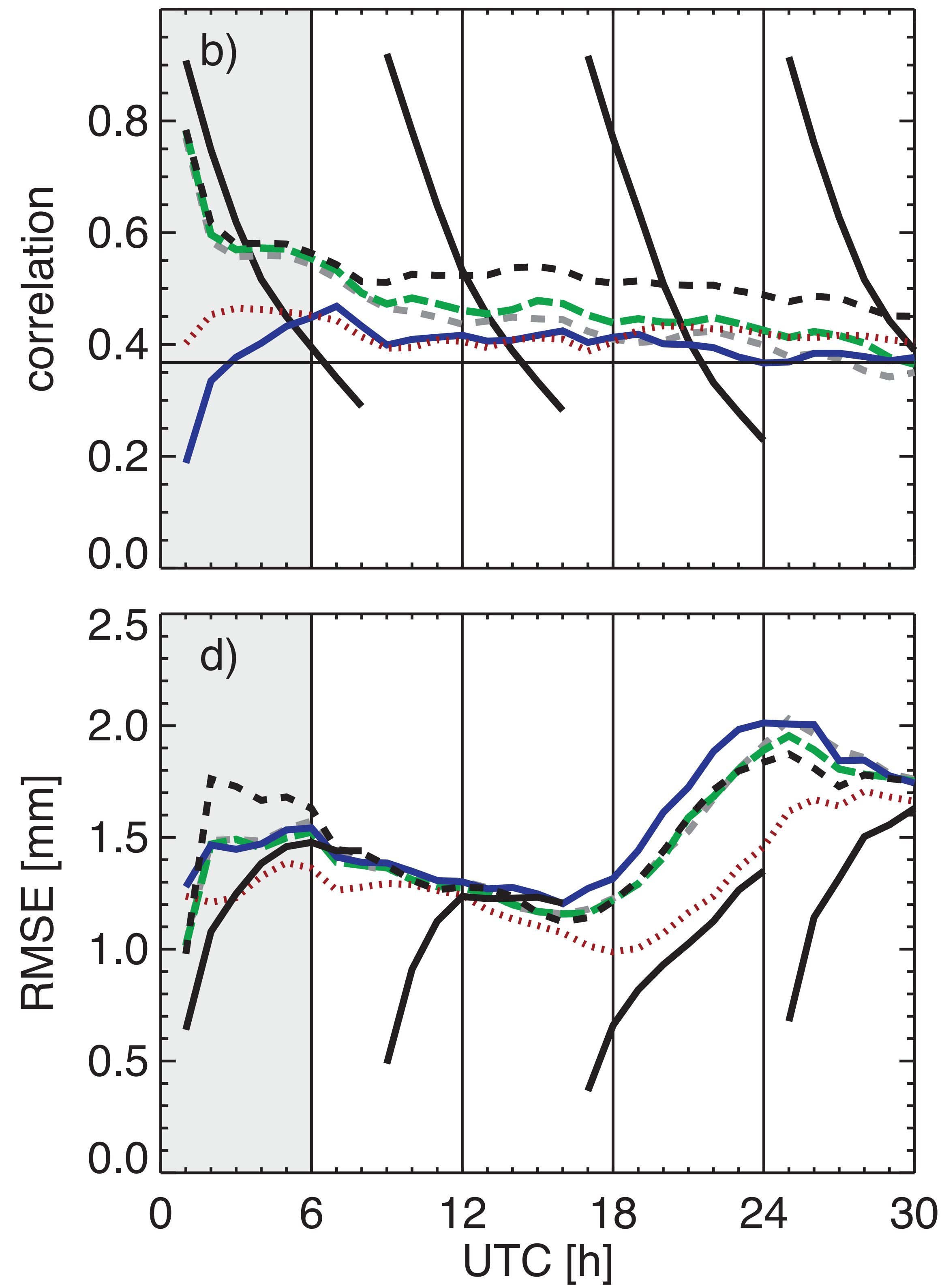
Summary: Model-LP comparison of precipitation nowcasting





EPS mean is re-calibrated by PM

Note the diurnal cycle in the RMS error



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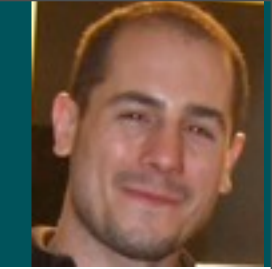
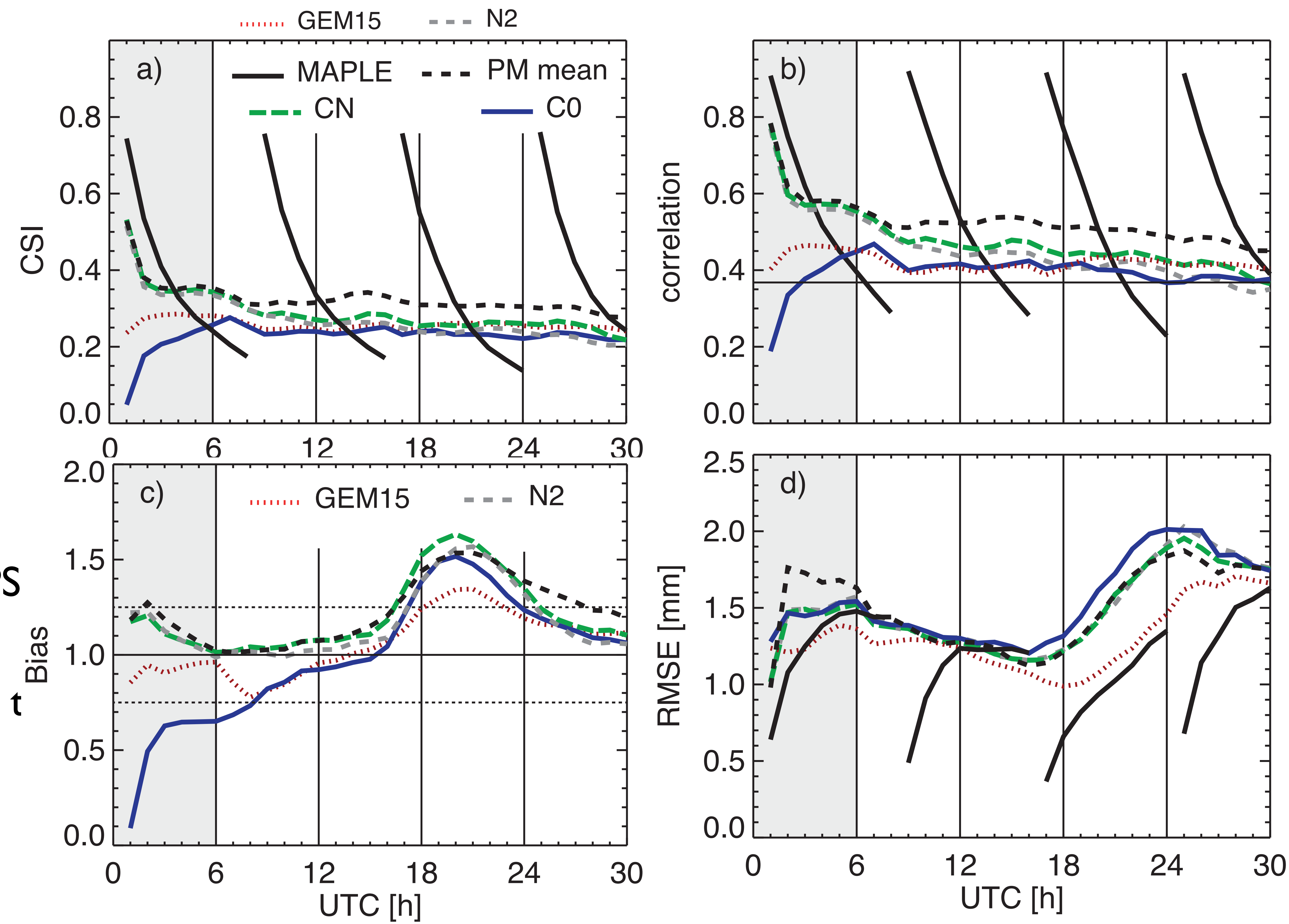
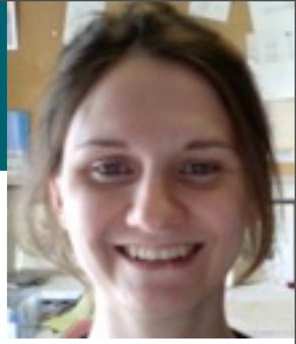




EPS

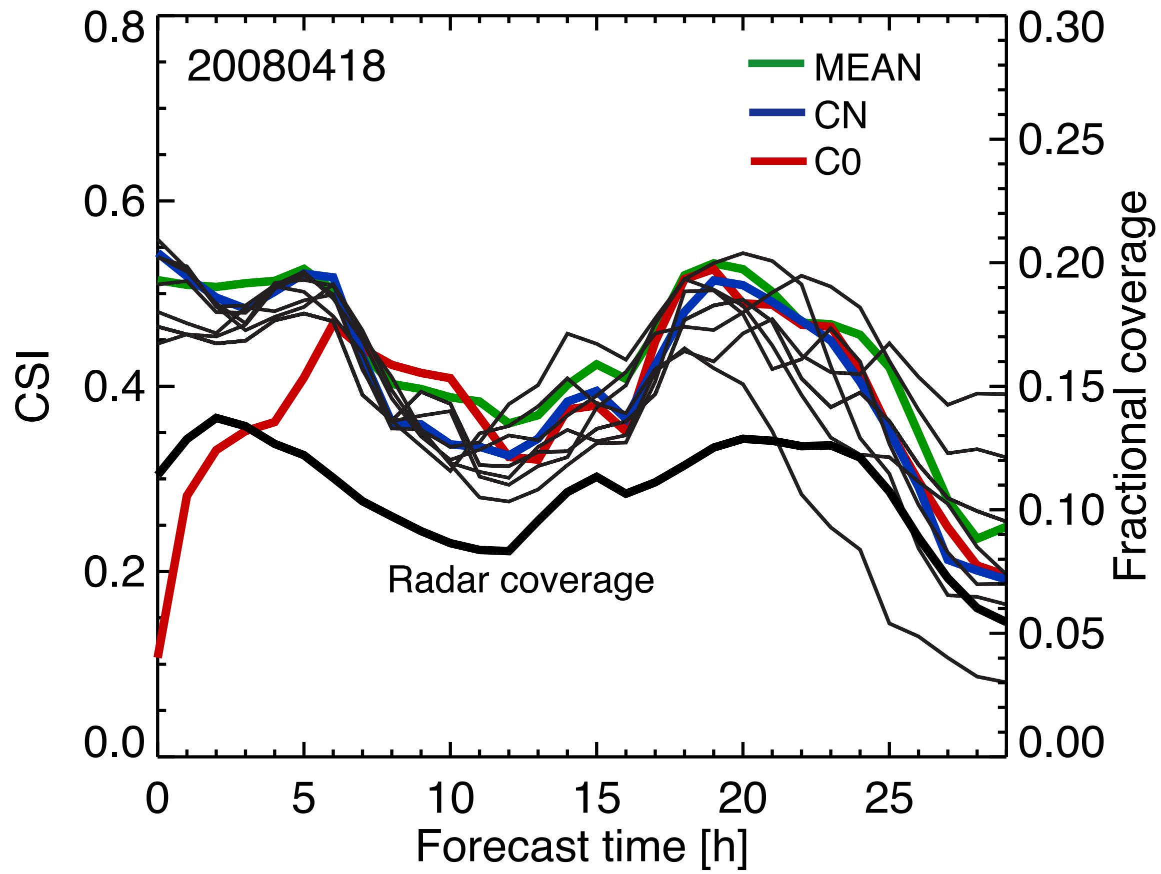
Note t

NWP Ensembles (the best case)



OU & 4 km resolution

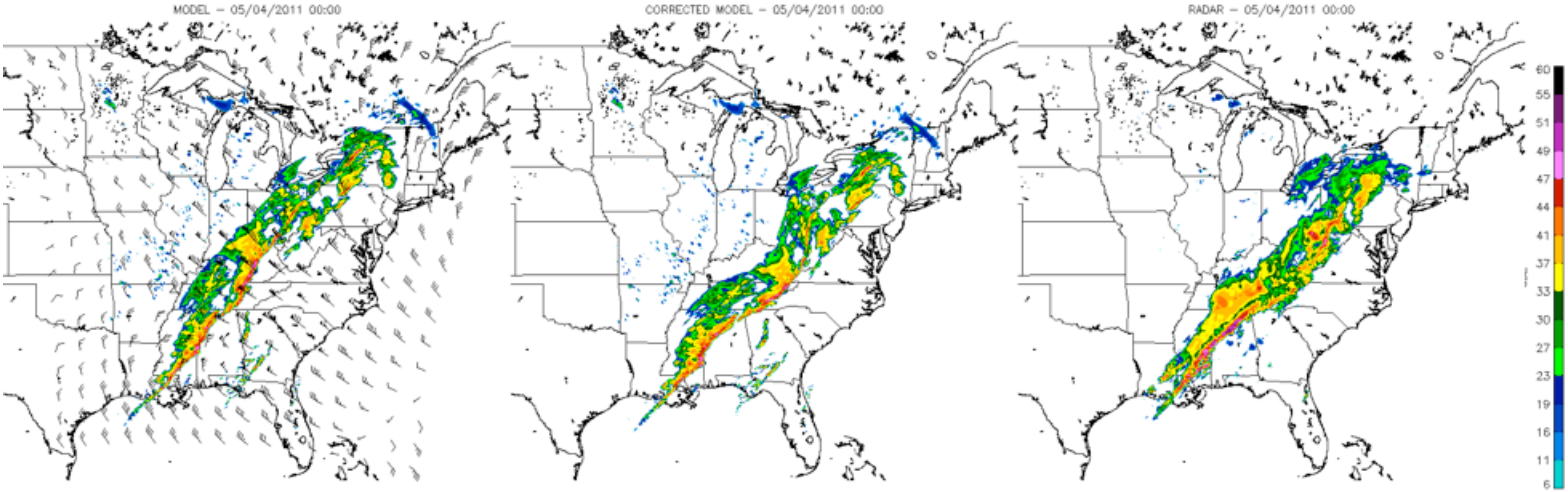
Scores at 15 dBZ threshold

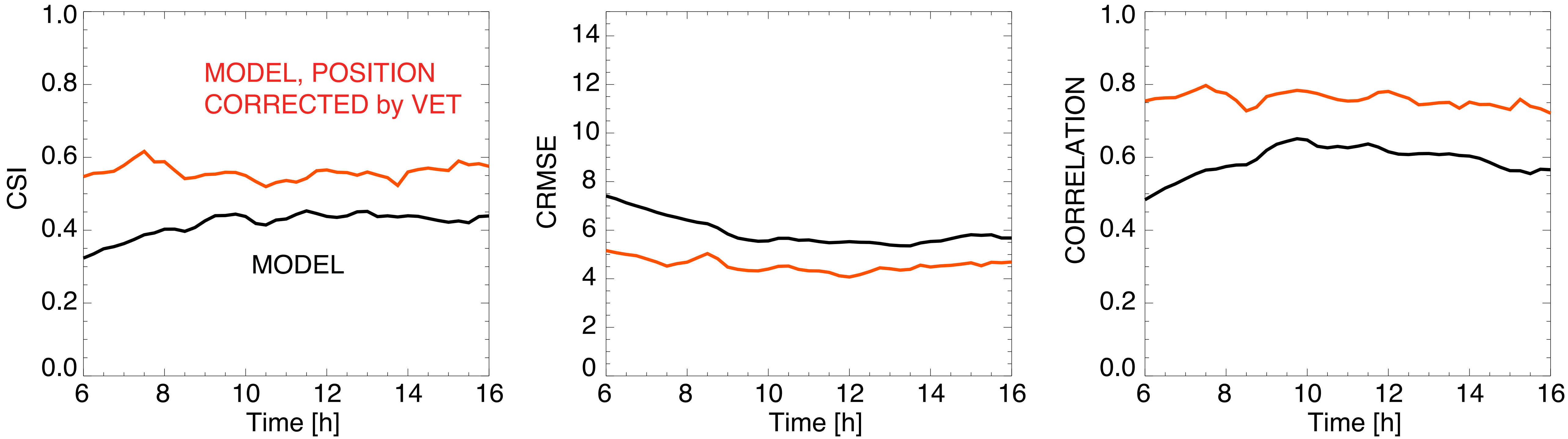


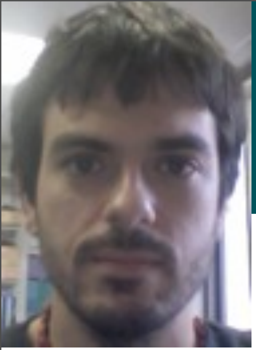
No single member is better
Effect of data assimilation is short-lived

Position distance between model and radar

WRF Model | Corrected model | Radar

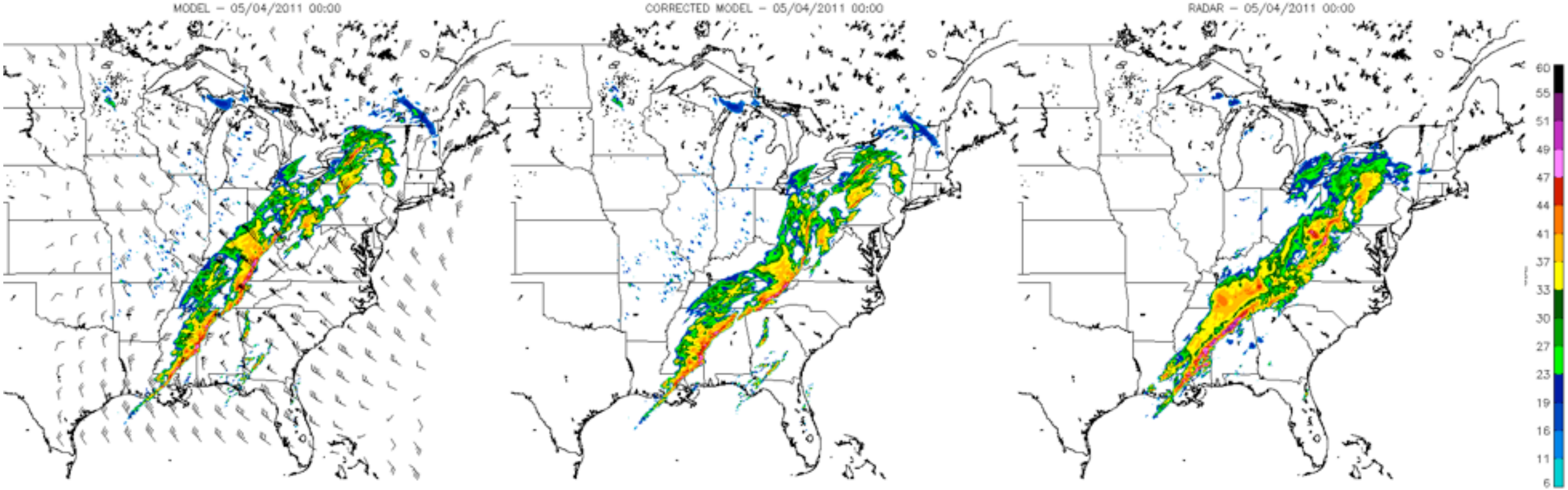


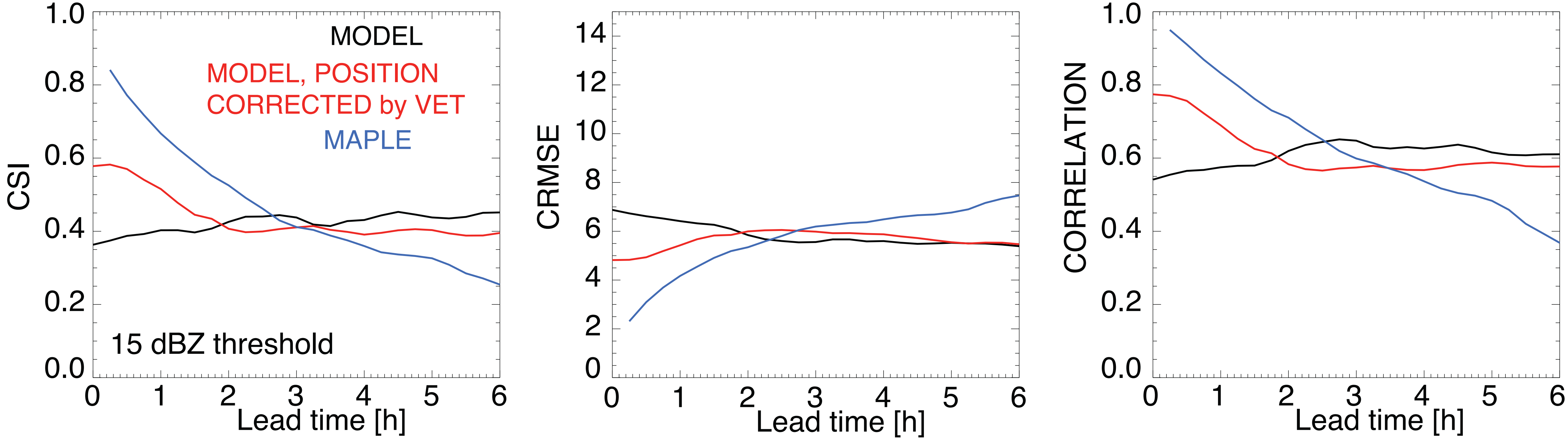


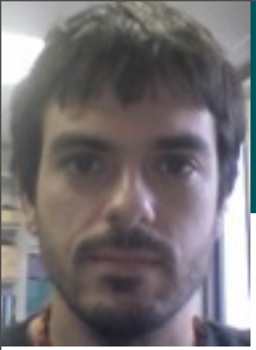


Nowcasting by correcting the model-radar distance

WRF Model | Corrected model | Radar







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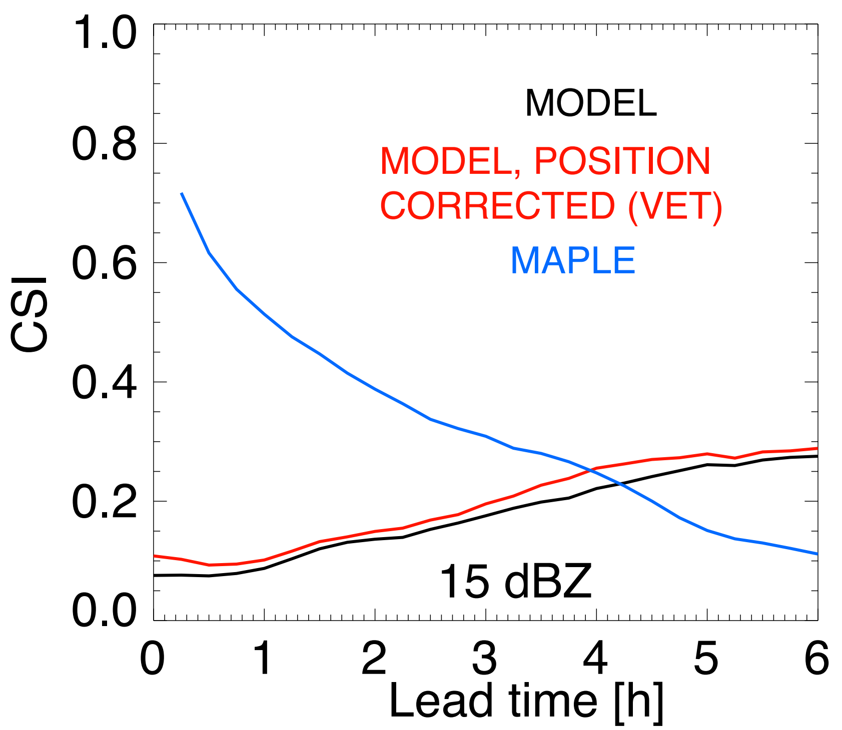
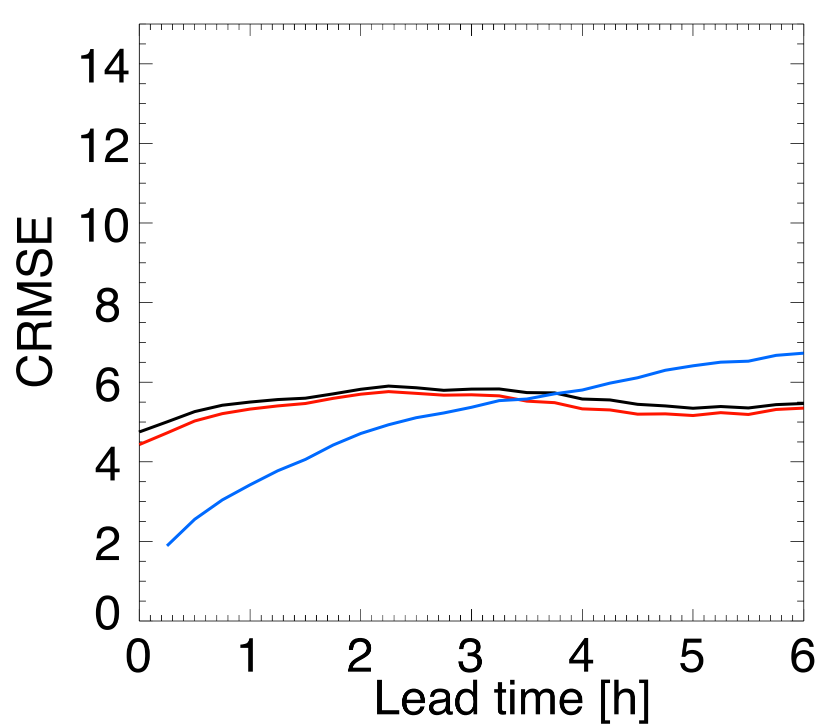
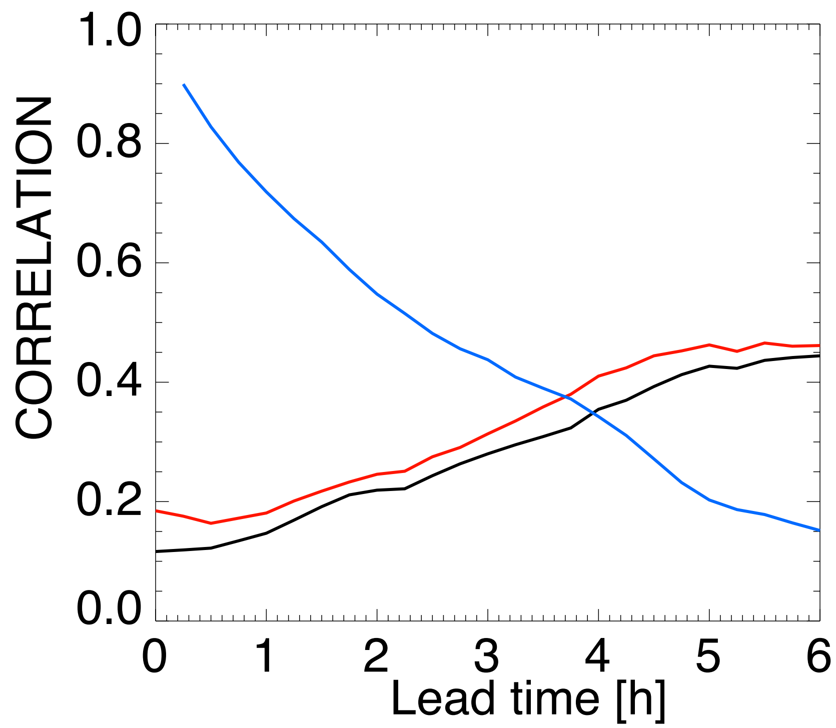
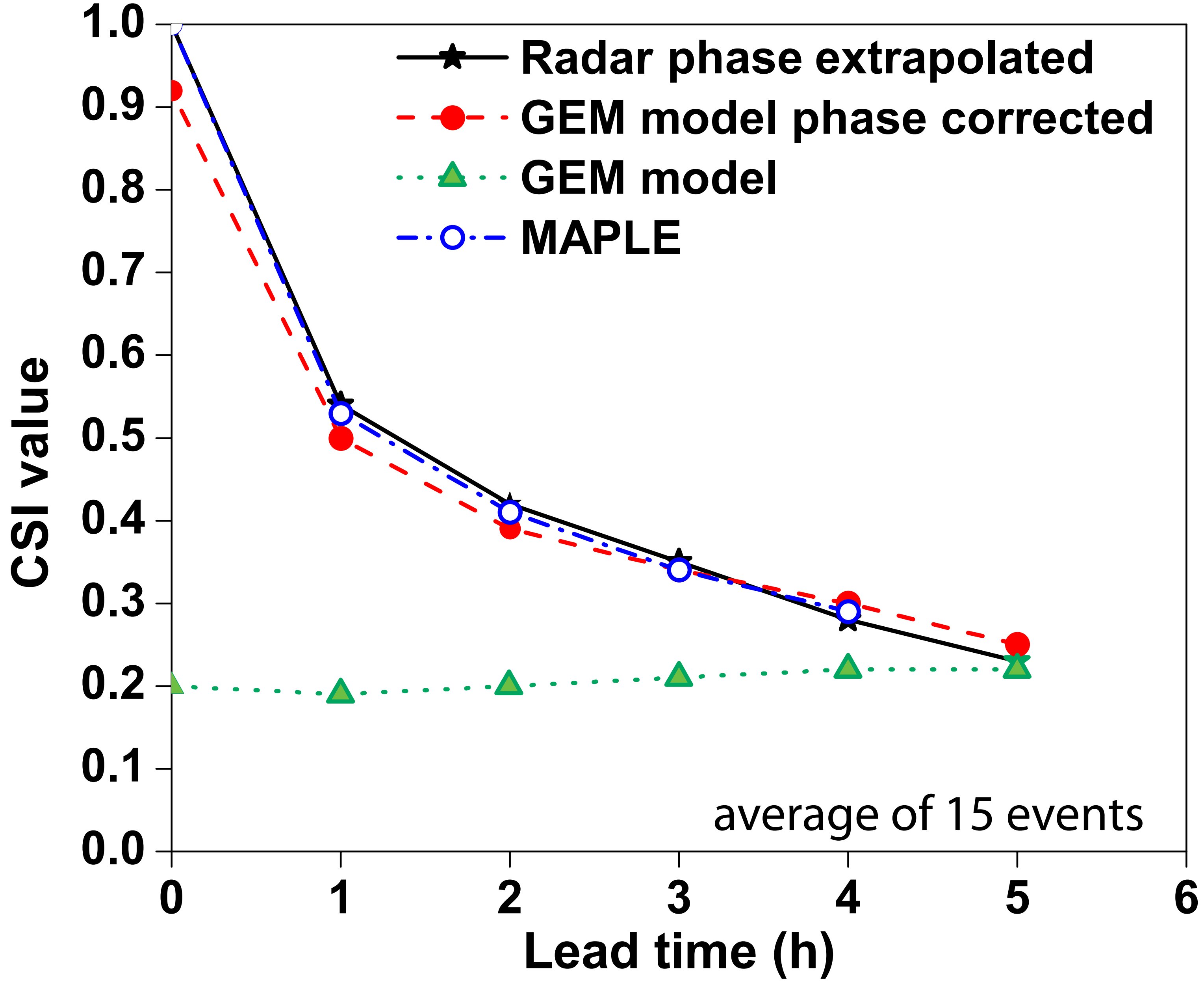






Nowcasting by phase correction



Morphing model into radar by phase correction (one wavelength at a time)

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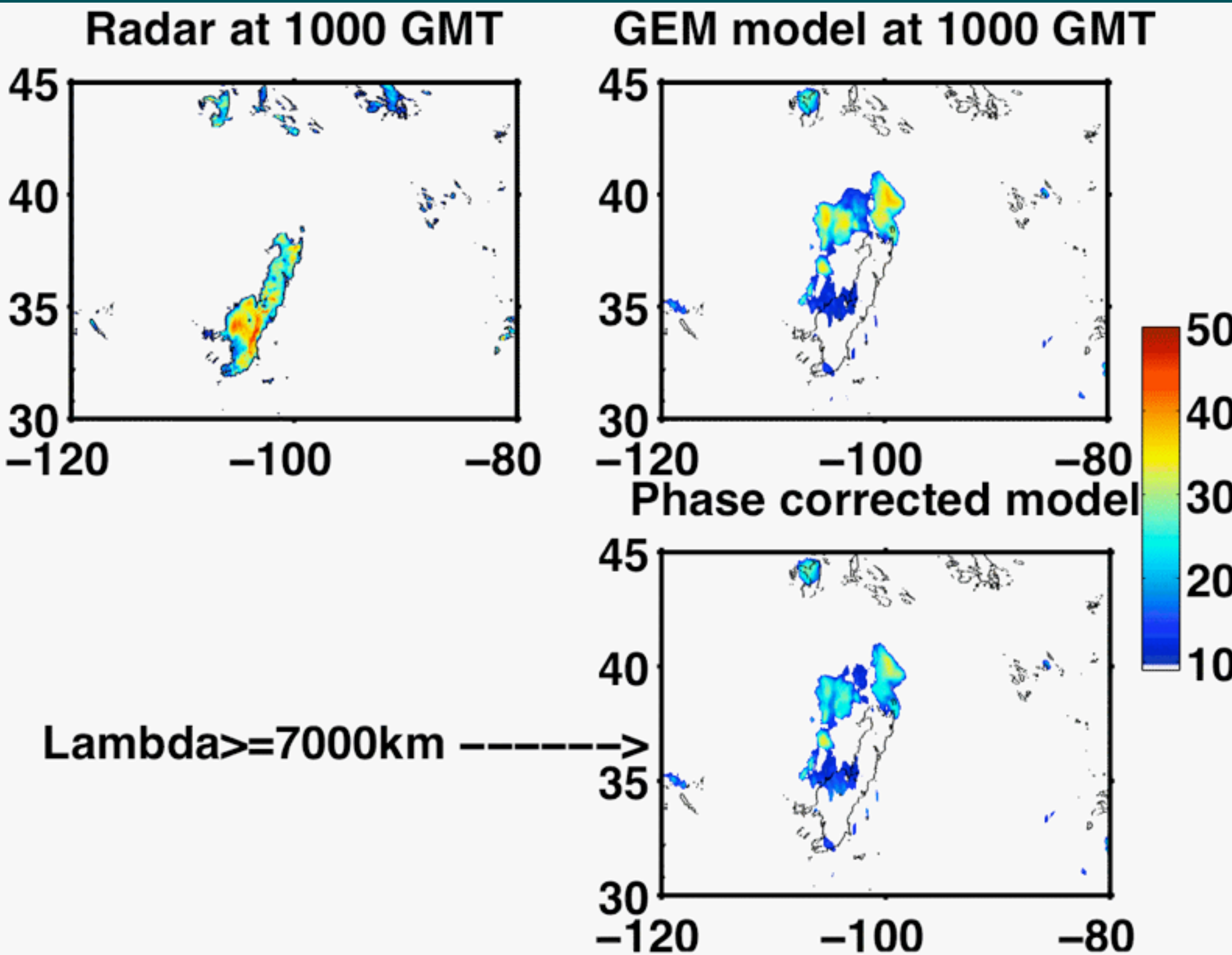
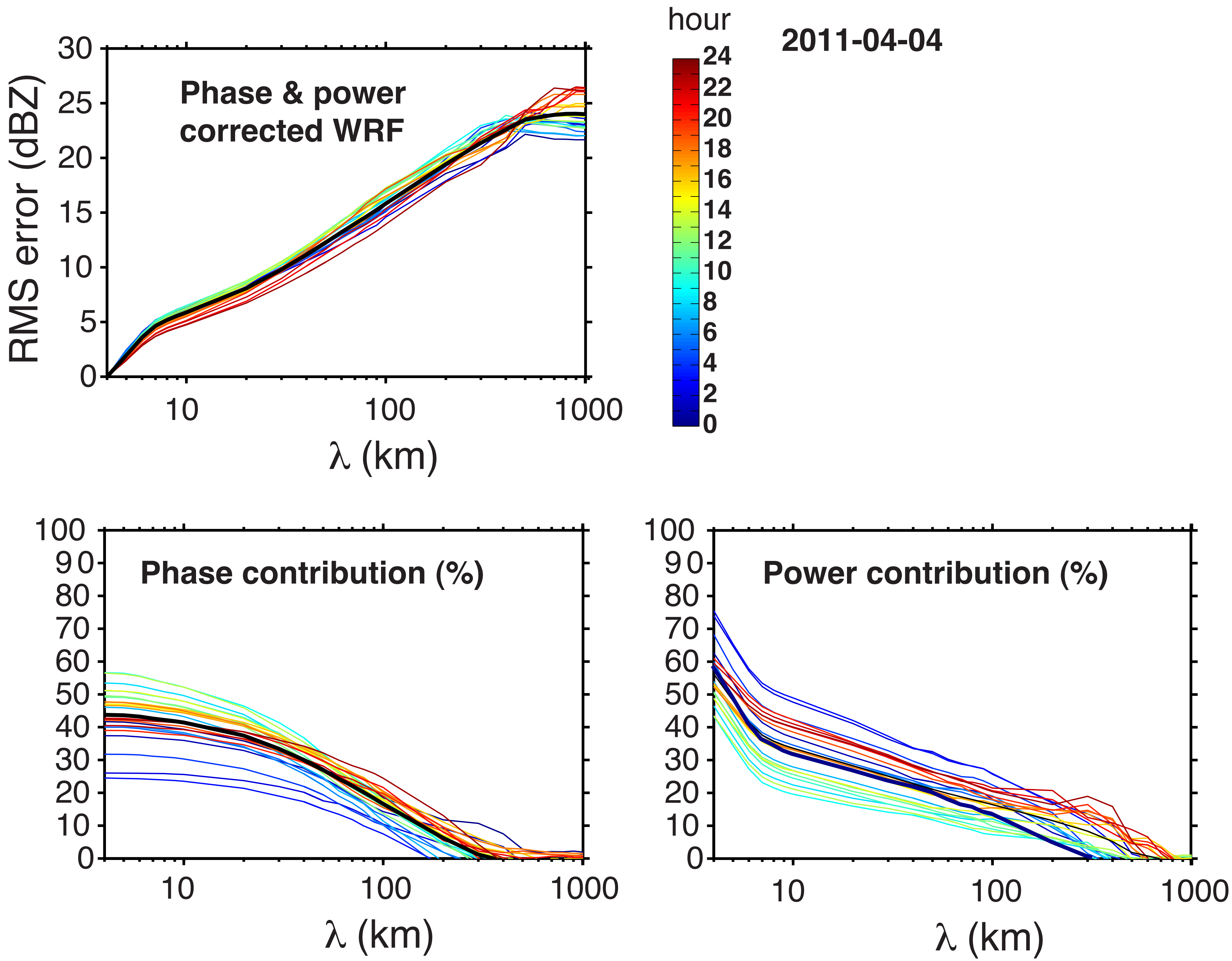


Phase distance between model and radar



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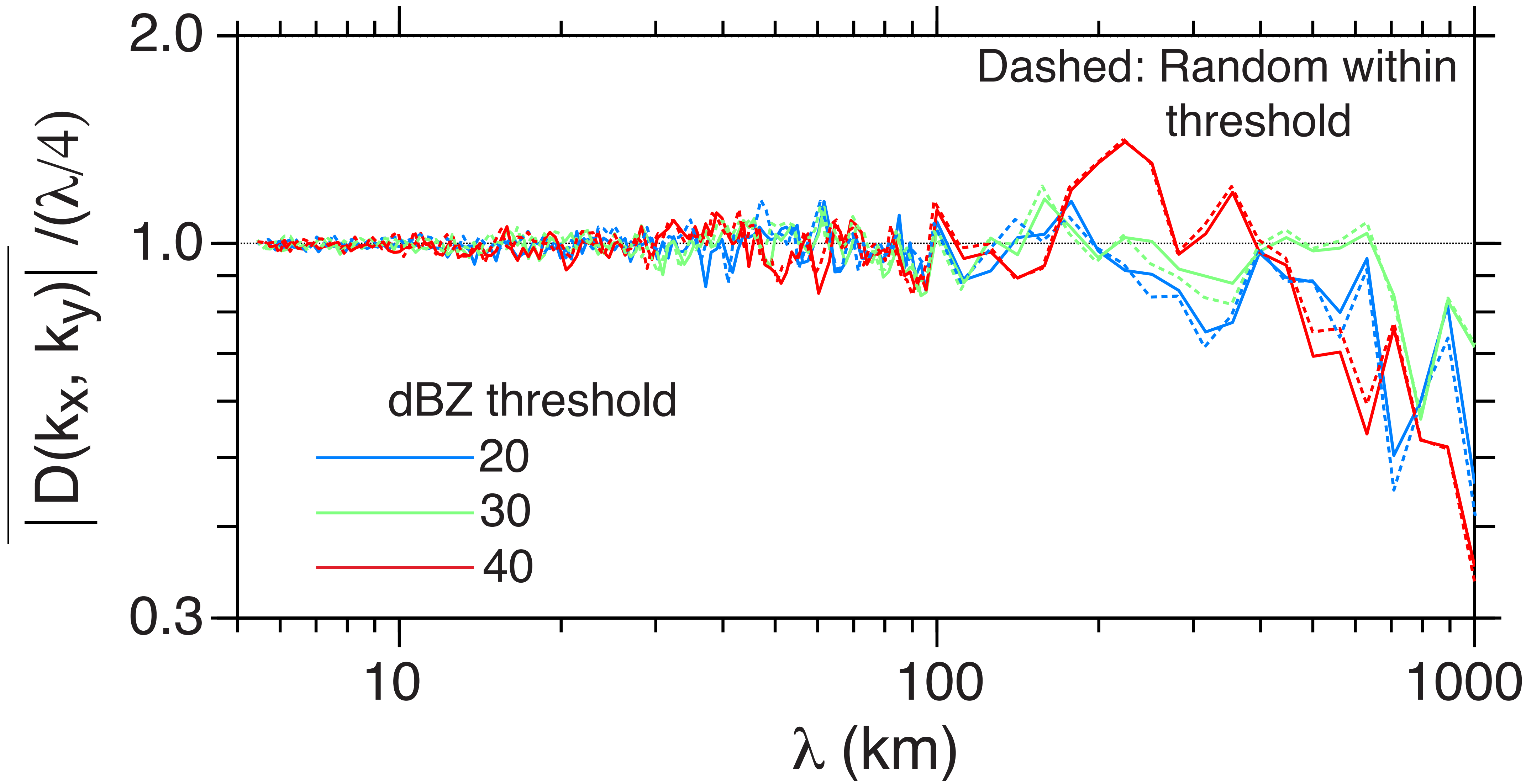
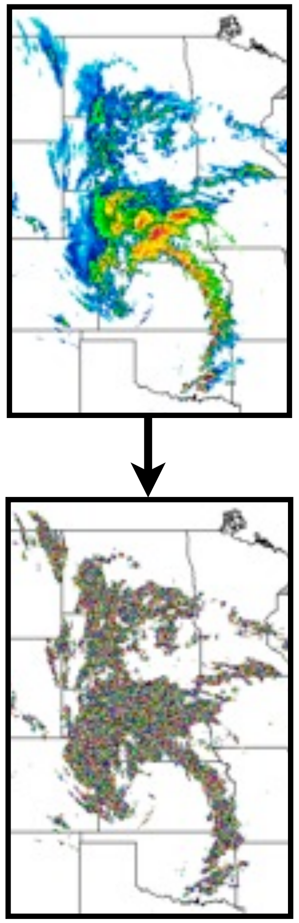
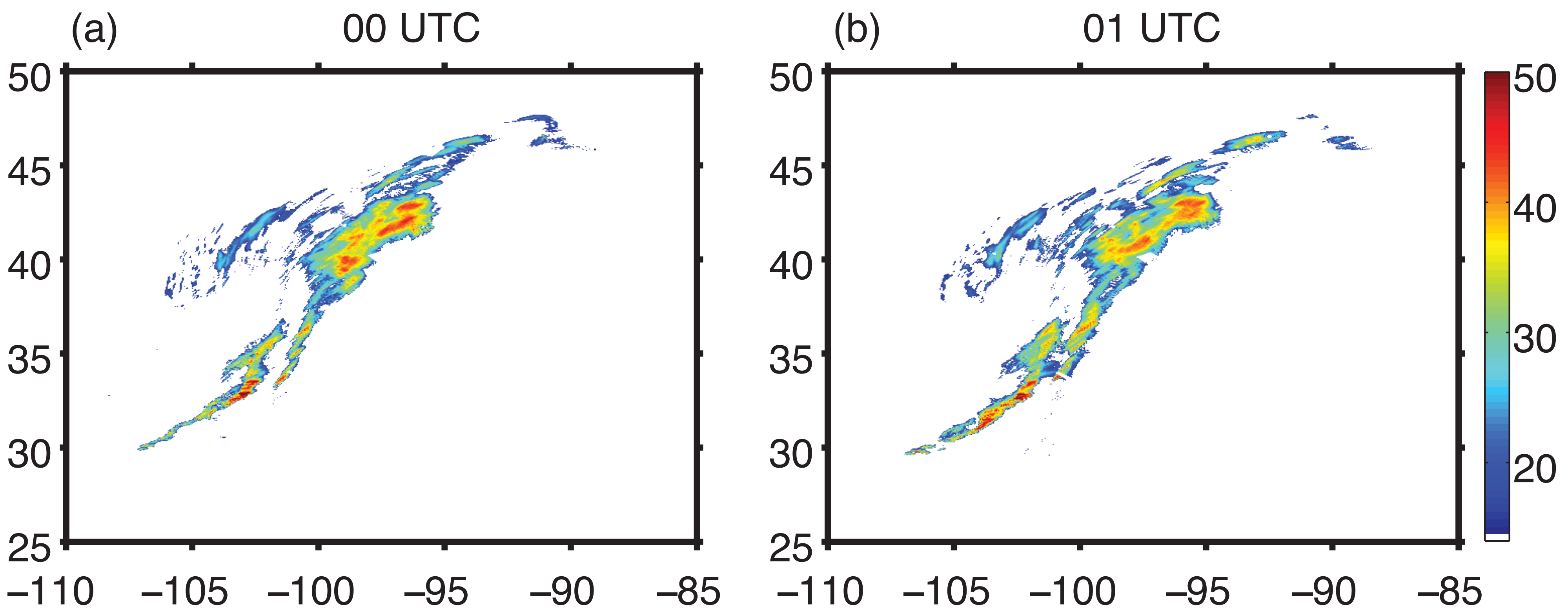
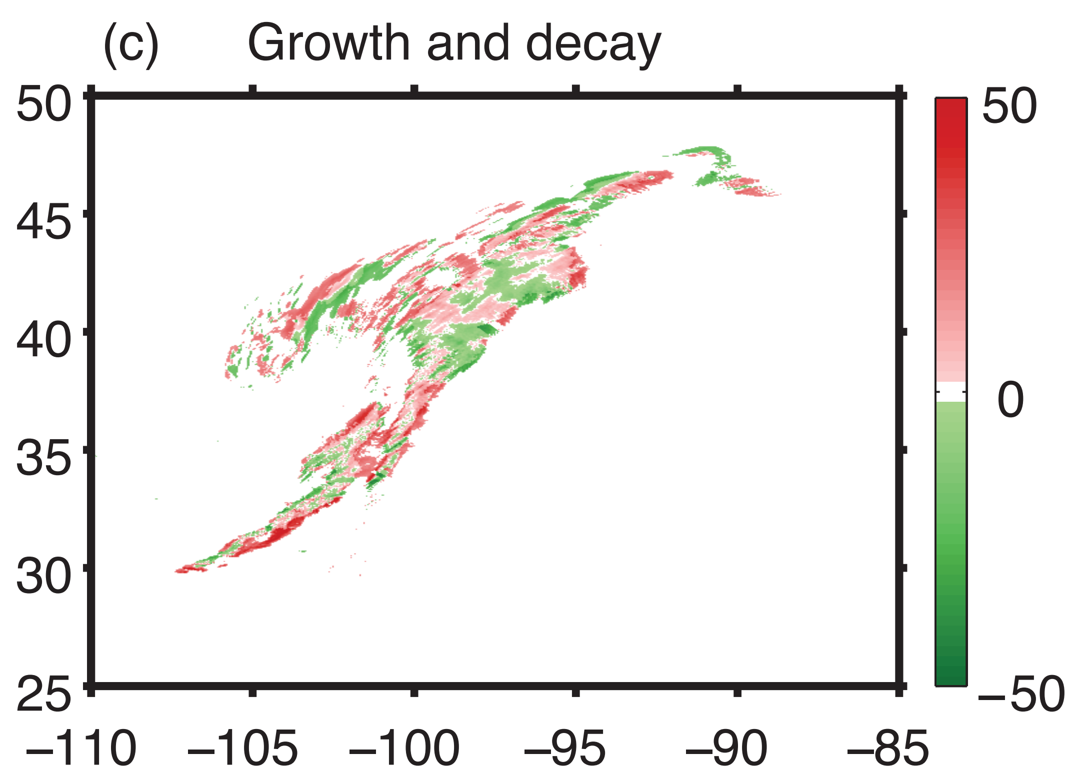




Defining growth and decay in radar



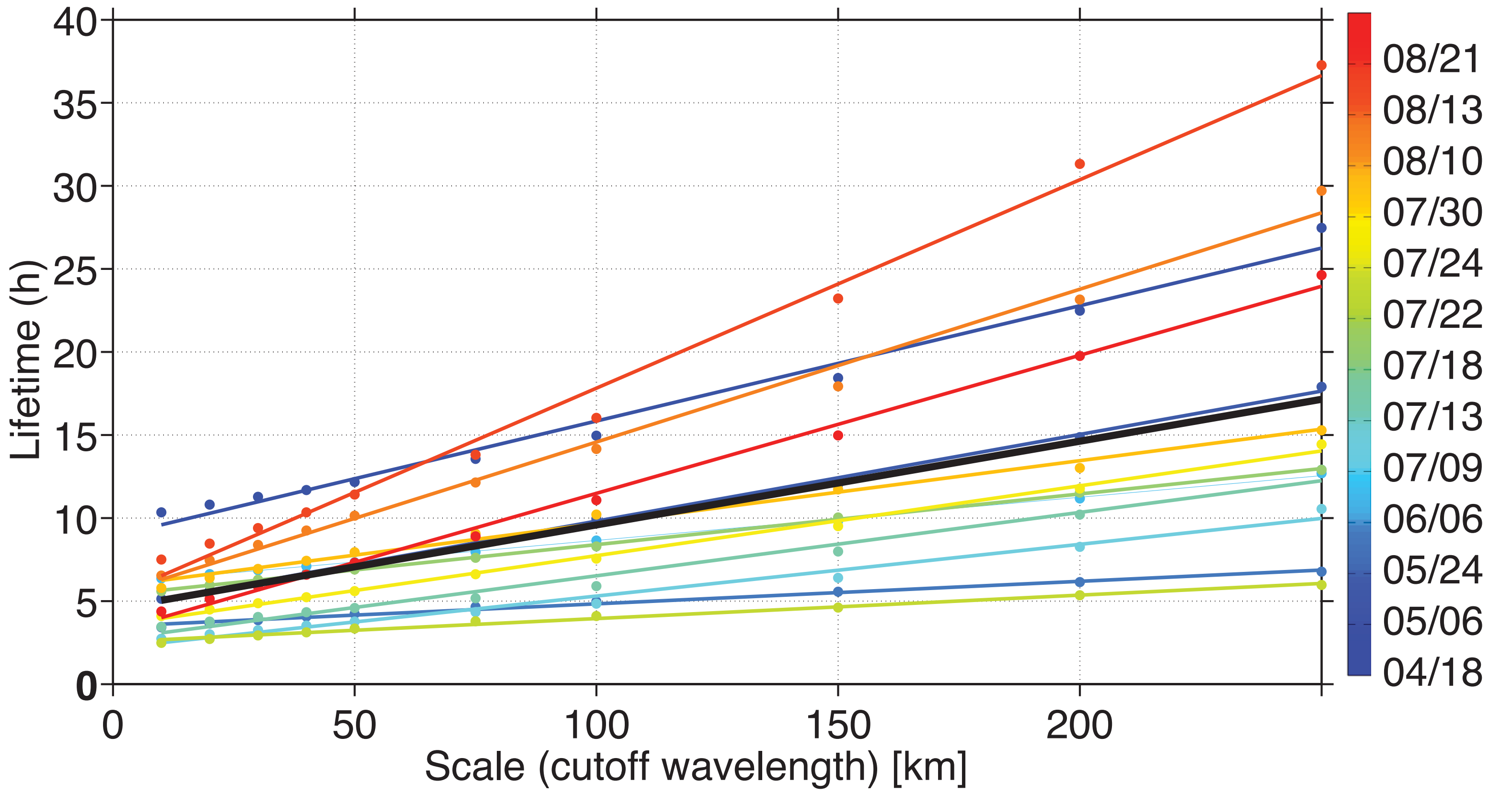


Maximize cross-correlation between (a) and (b) by a solid translation and rotation;

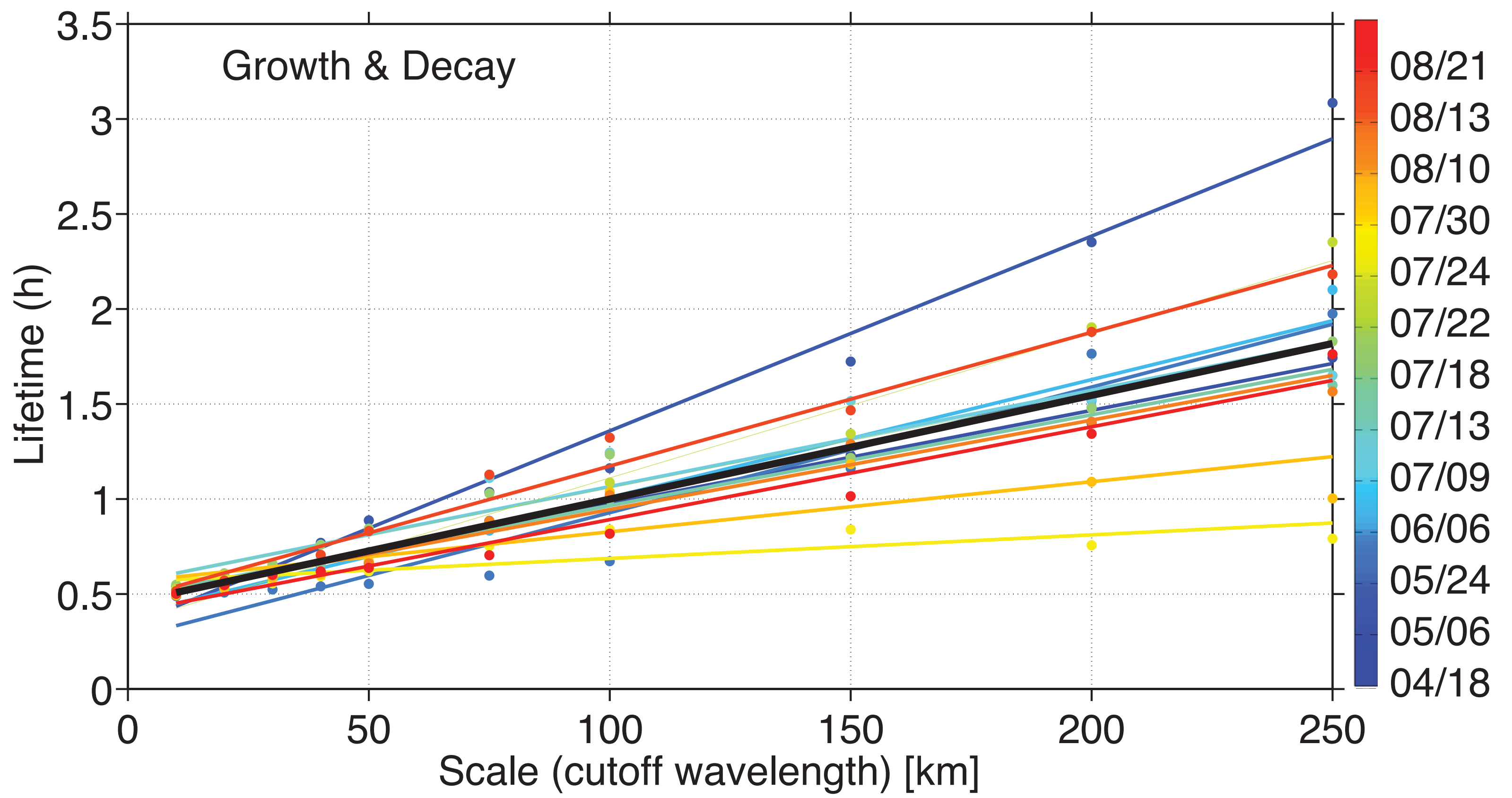
The difference defines growth and decay (c)

Lifetime of growth and decay

Precipitation lifetime

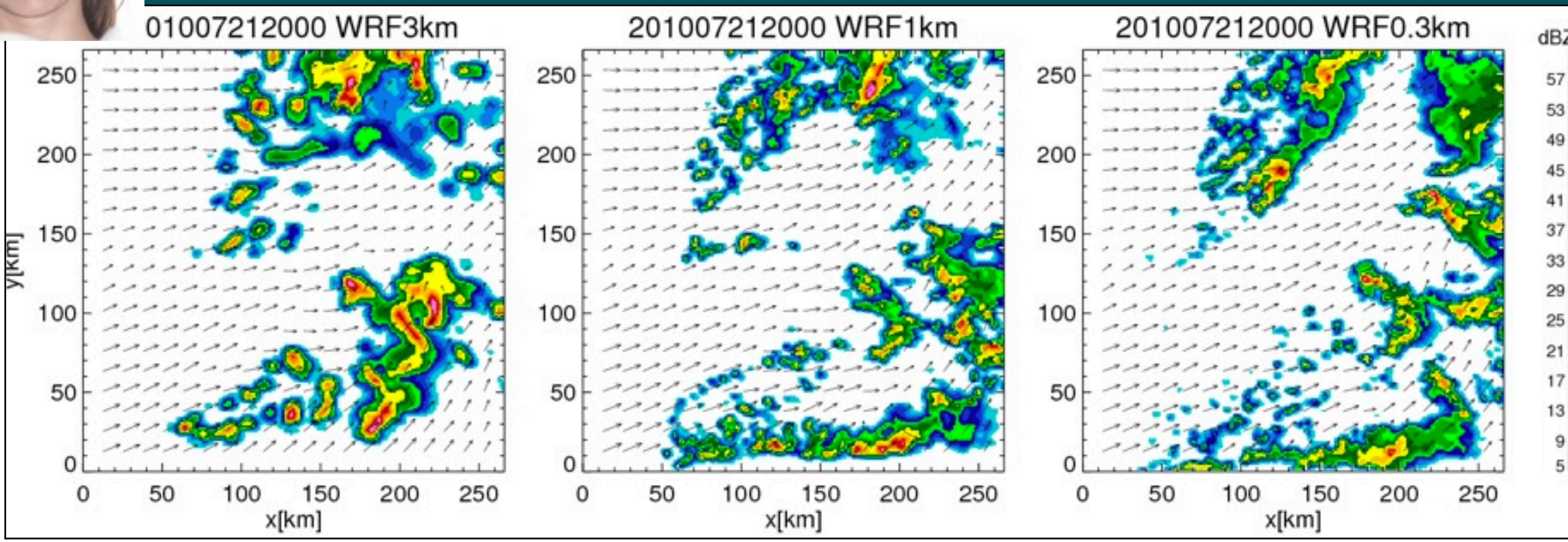


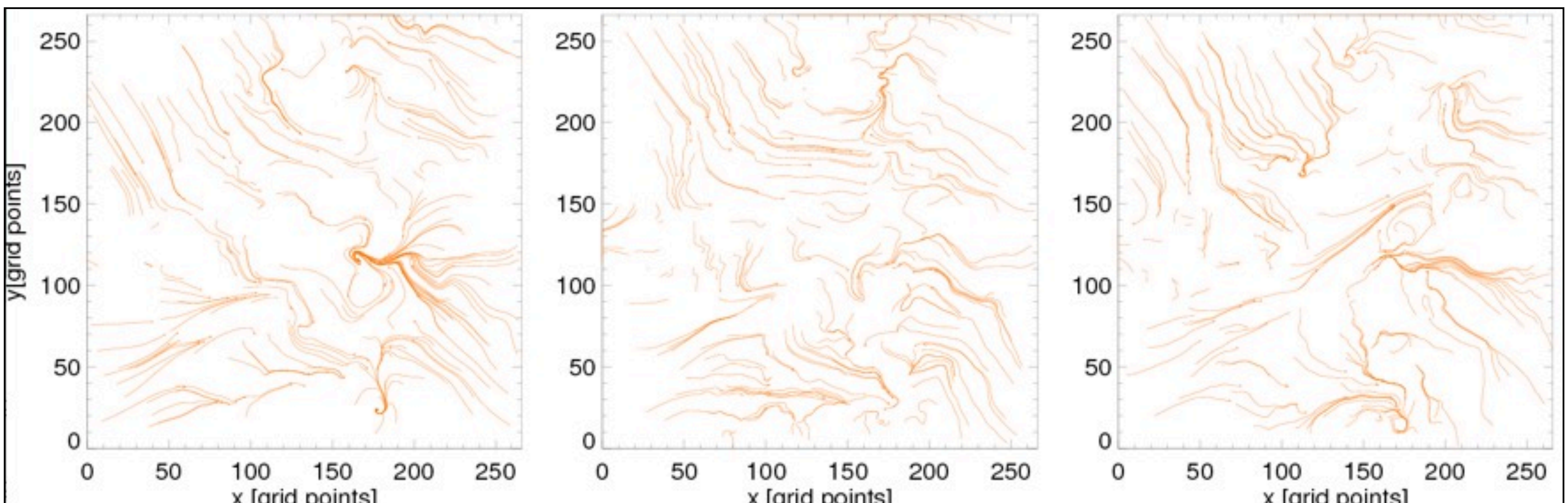
Growth & decay lifetime



Effect of model error due to resolution

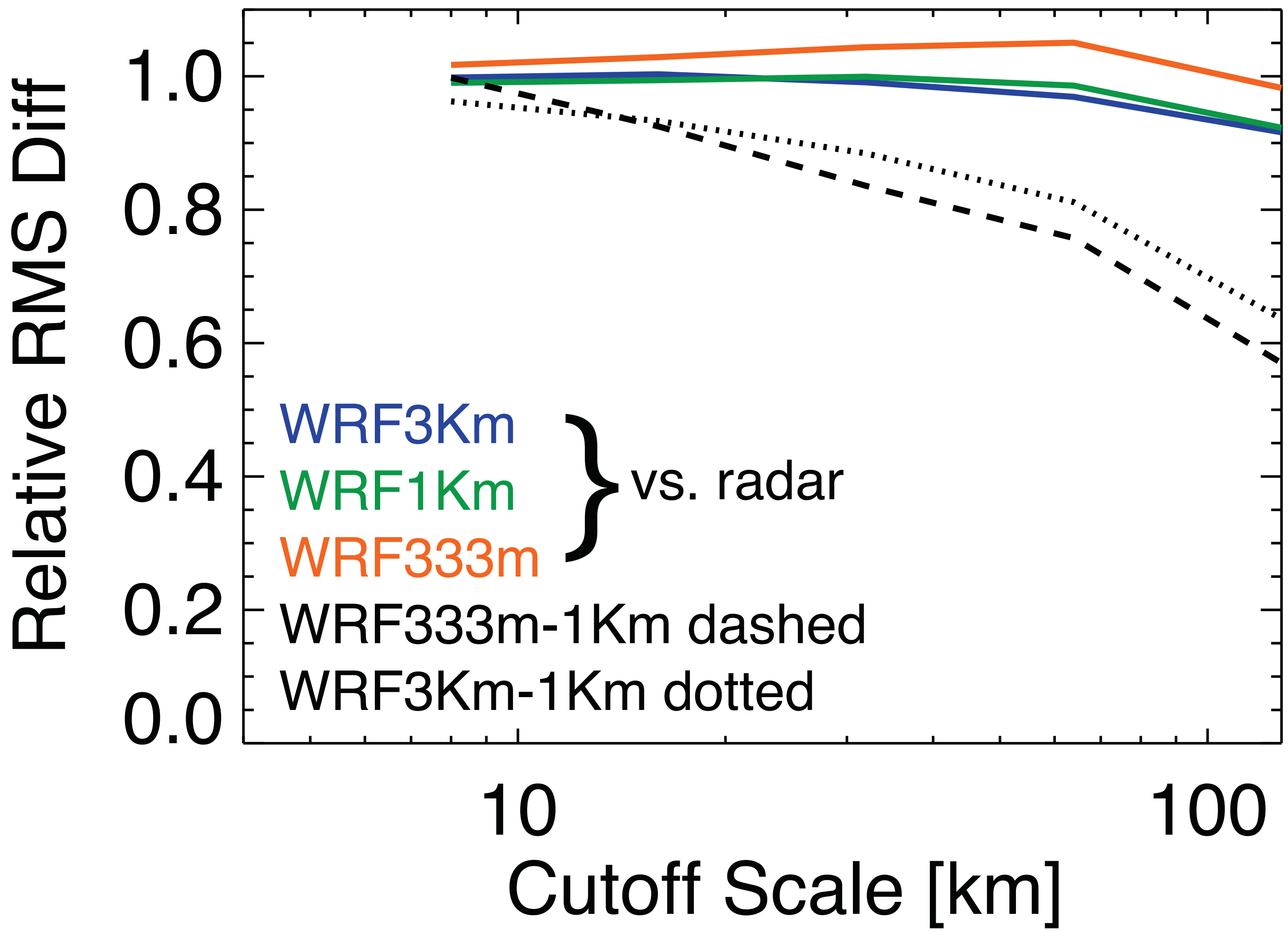
Reflectivity (top) and Streamlines (bottom)





Effect of model error due to resolution

$$\text{Rel}\,RMS\ \text{Diff} = \sqrt{\frac{\sum_i (X_i - Y_i)^2}{\sum_i (X_i + Y_i)^2}}$$



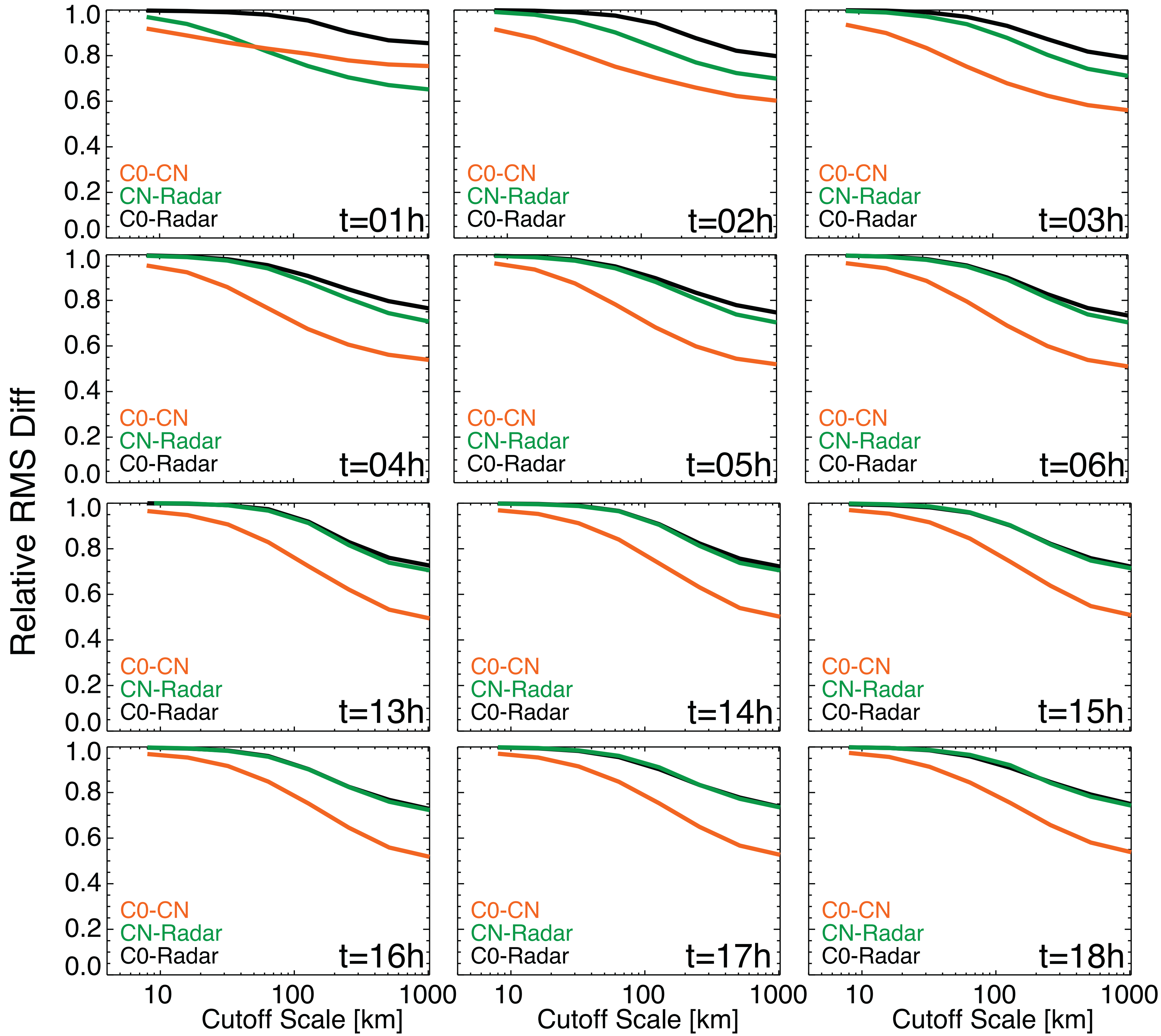
Effect of model error & data assimilation (average of 24 cases)

c0 during spinup; clear effect of assimilation on cn

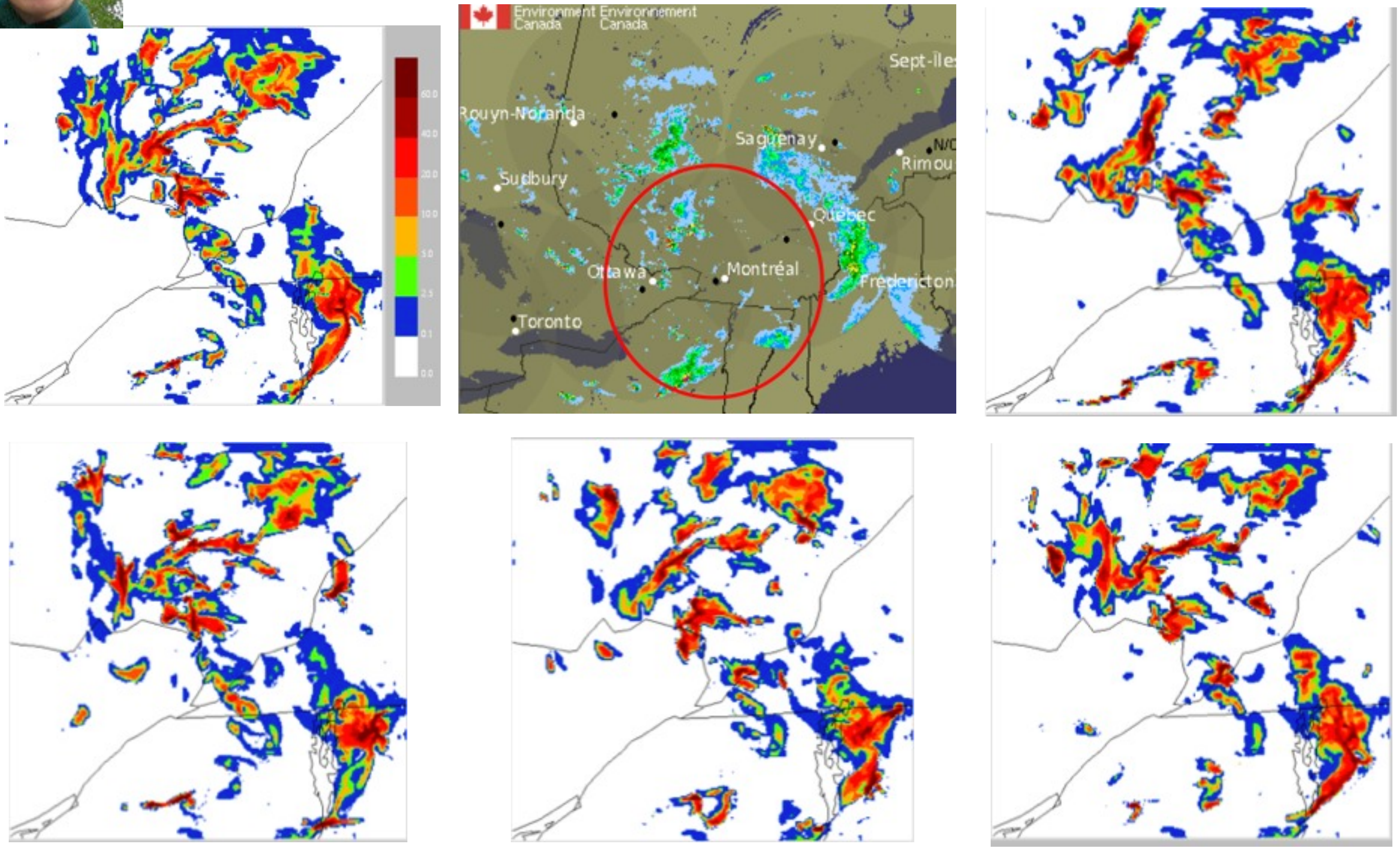
rapid loss of assimilation effect at the small scales

rapid loss of assimilation effect at the all scales

100% difference between c0 and cn at smal scales

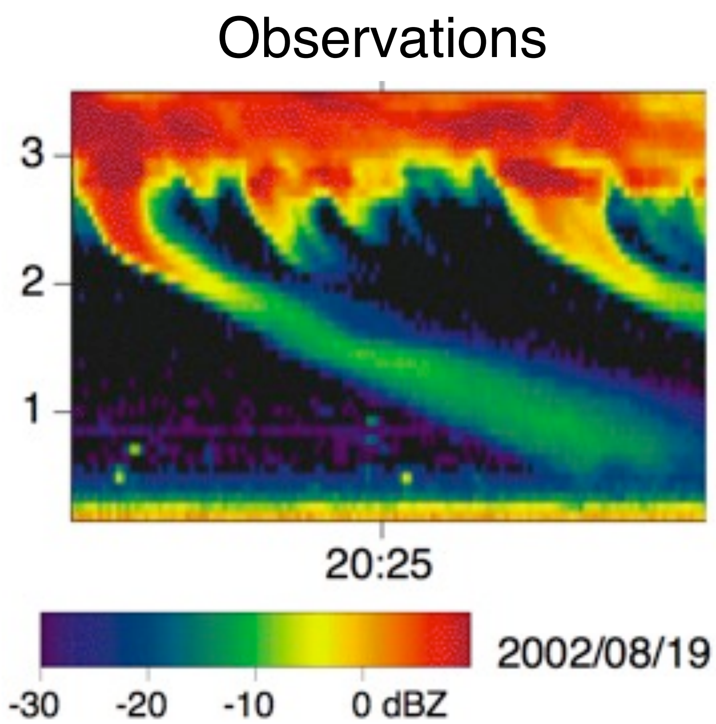


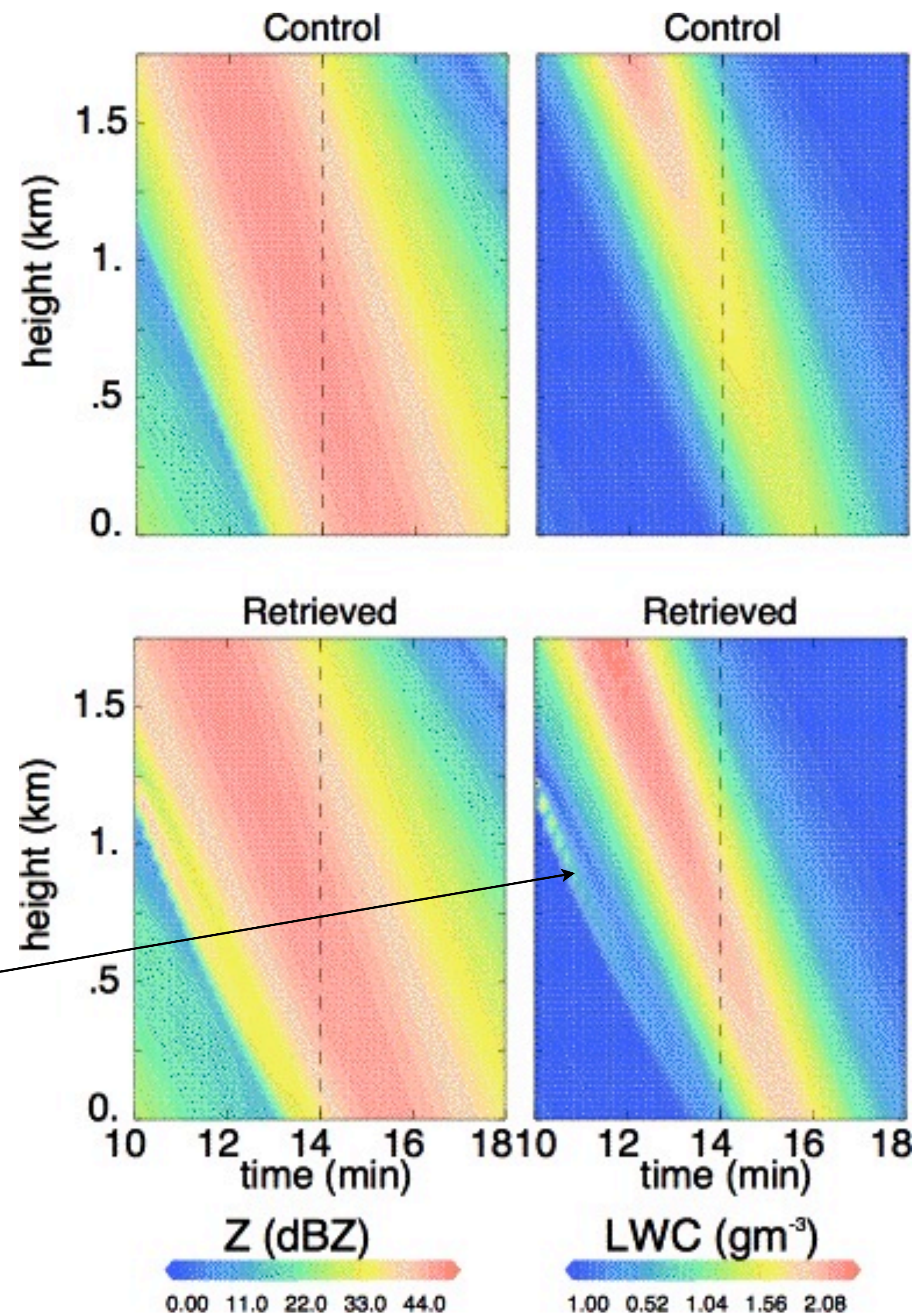
Ensembles (EnKF) to the rescue?



Effect of model errors on assimilation

Simulation using data assimilation (model as strong constraint) into a simple model of freely falling rain-shaft with a 2-parameter DSD representation. Note that 3 parameters are needed to correctly describe the DSDs of falling drops.





Note a second shaft due to model error

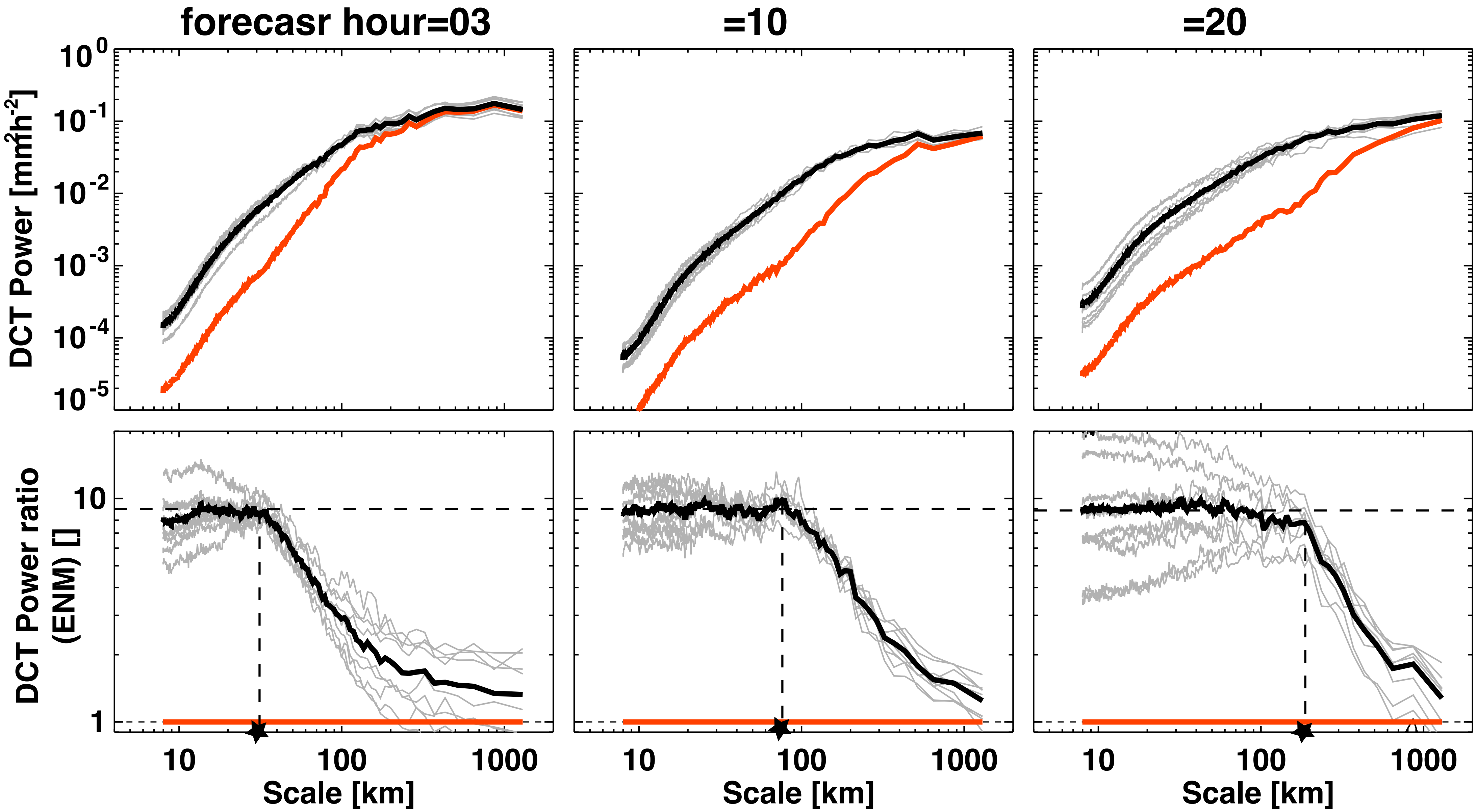
FROM:

Laroche, S., W. Szyrmer and I. Zawadzki, 2005: A microphysical bulk formulation based on scaling normalization. Part II: Data assimilation into physical processes. *J. Atmos. Sci.* **62**, 4222-4247.

The ensemble mean of precipitation forecasts

Grey lines: ensemble members; Black line: average for all members; Red line: ensemble mean

$$R_i(\lambda) = \frac{P_i(\lambda)}{P_{ENM}(\lambda)}$$



Total variance bias

For some scales, ratio is constant.

After a certain threshold, ratio decreases towards 1.

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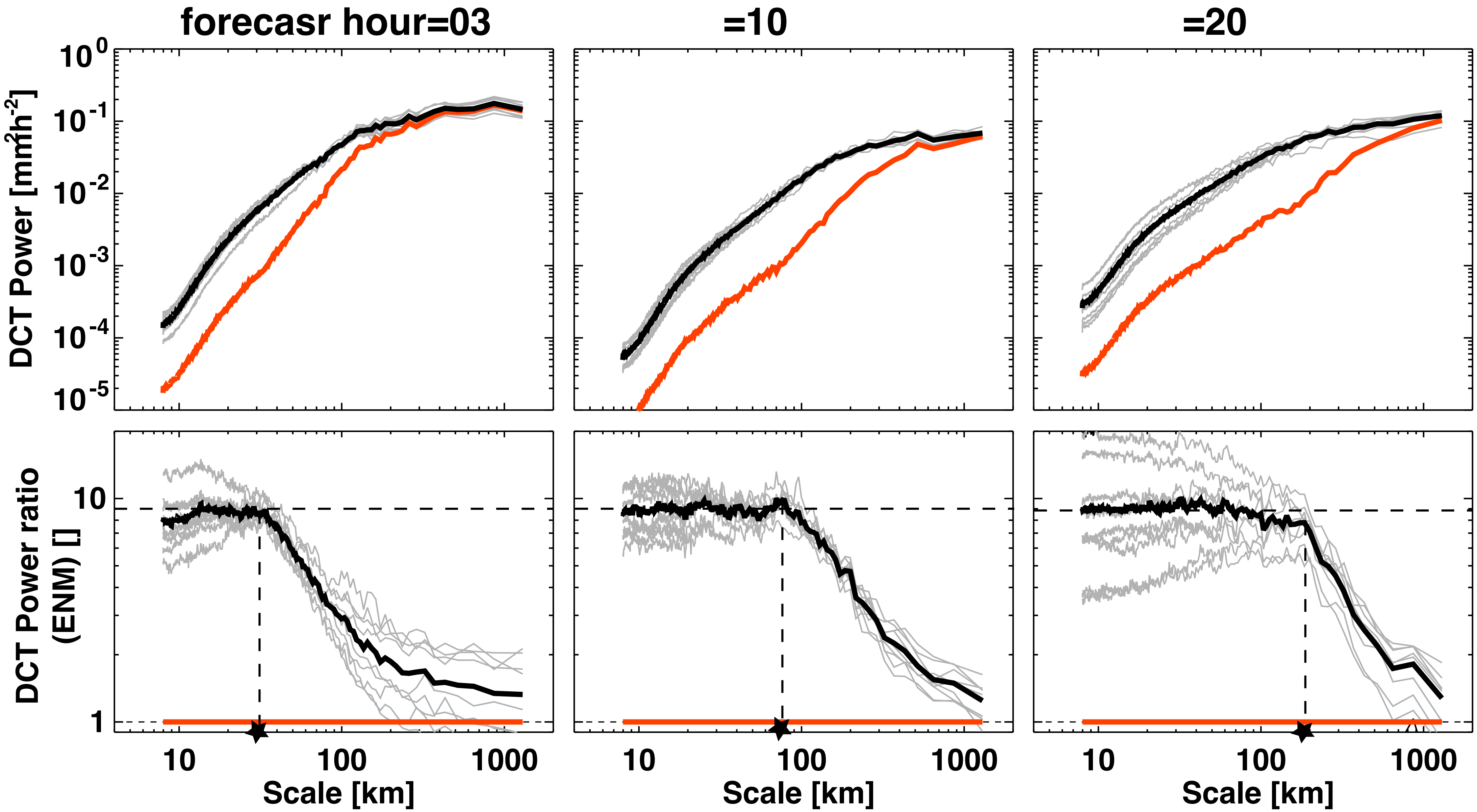

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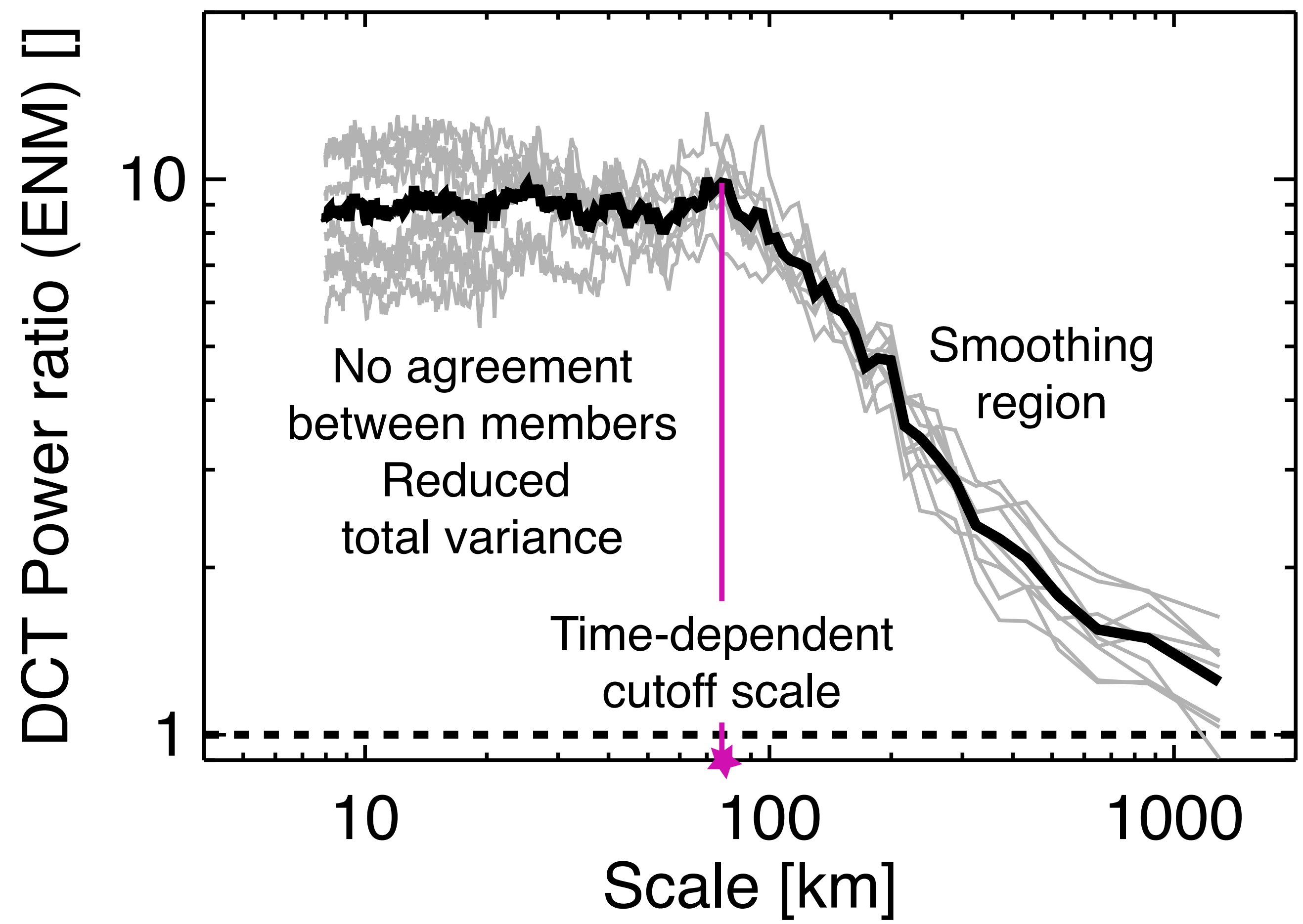
WHAT IS THE MEANING OF THIS SPECTRAL STRUCTURE?

The ensemble mean of precipitation forecasts and scale dependence of NWP predictability

The spectral structure of precipitation fields for the OU ensemble shows:

- no agreement between members at scales smaller than some S_0
- At scales larger than S_0, the ENM has the properties of a low-pass filter
- There is no perfect agreement between members at any scales, but the power ratio of members with respect to ENM approaches 1.
- The cutoff scale S_0 is lead-time-dependent.



Conclusions

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Let’s shutdown the supercomputers for a decade so there is time to study model errors and their origin