PennState
College of Earth
and Mineral Sciences

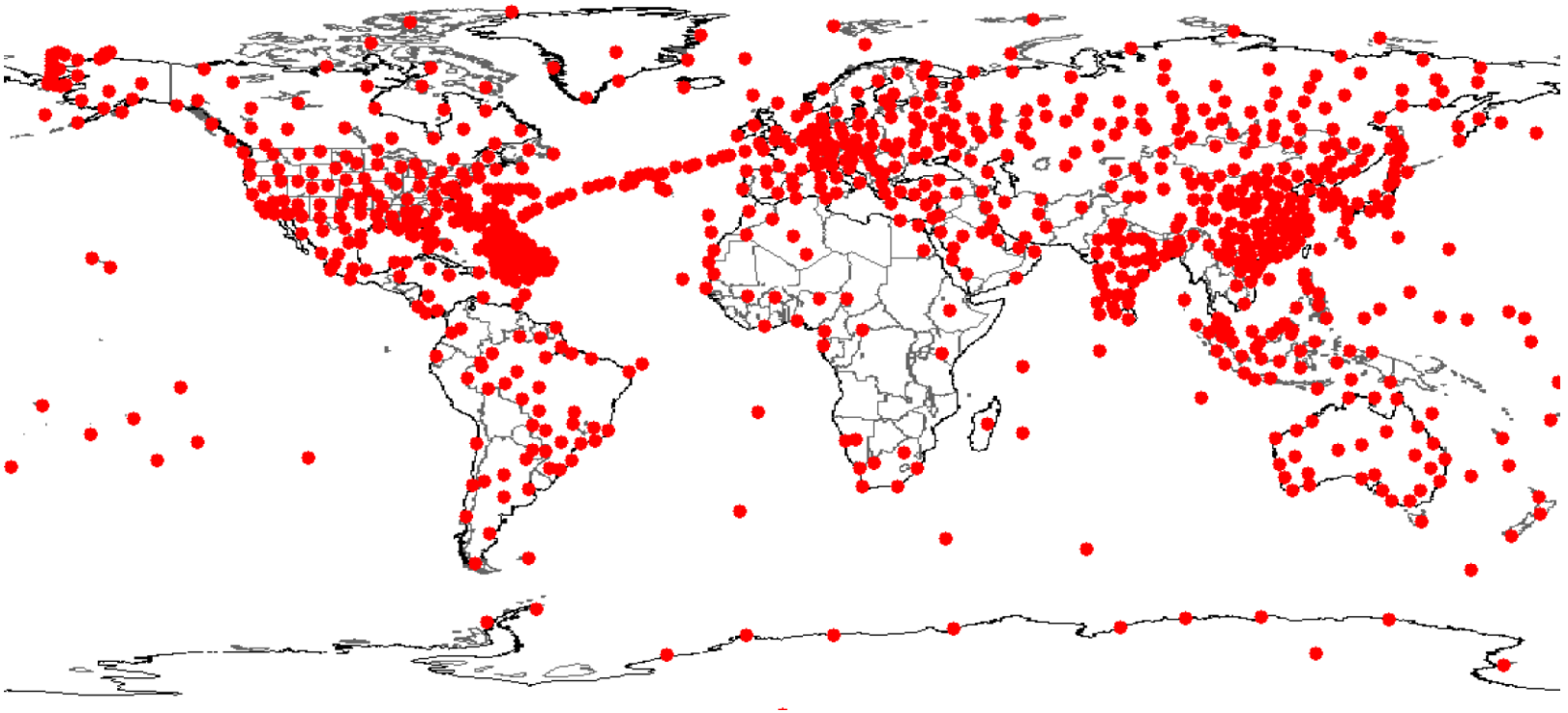
The impact of all-sky infrared satellite DA on moisture variables over the equatorial Indian Ocean

Man-Yau (“Joseph”) Chan

Advisor: Fuqing Zhang

Motivation

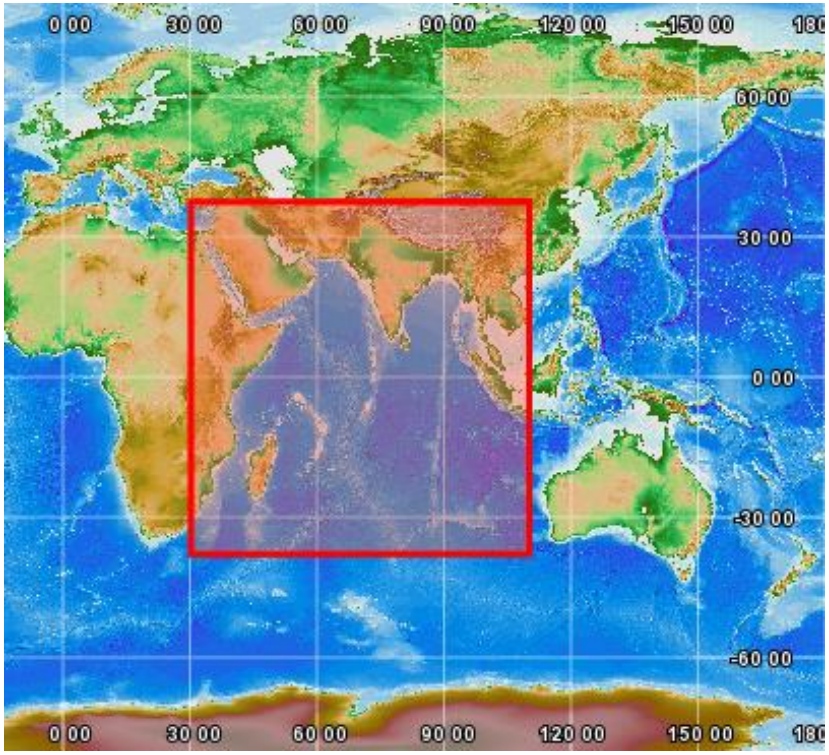
Sparse and infrequent direct observations over tropical oceans



Radiosonde and dropsonde locations from Sep 16, 2016 to Sep 23, 2016 recorded in NOAA Products Validation System (NPROVS)

Motivation

Dense and frequent remote observations from geostationary satellites are available



Meteosat-7 field-of-view

Meteorological Satellite 7

Infrared resolution: 5 km

Visible resolution: 2.5 km

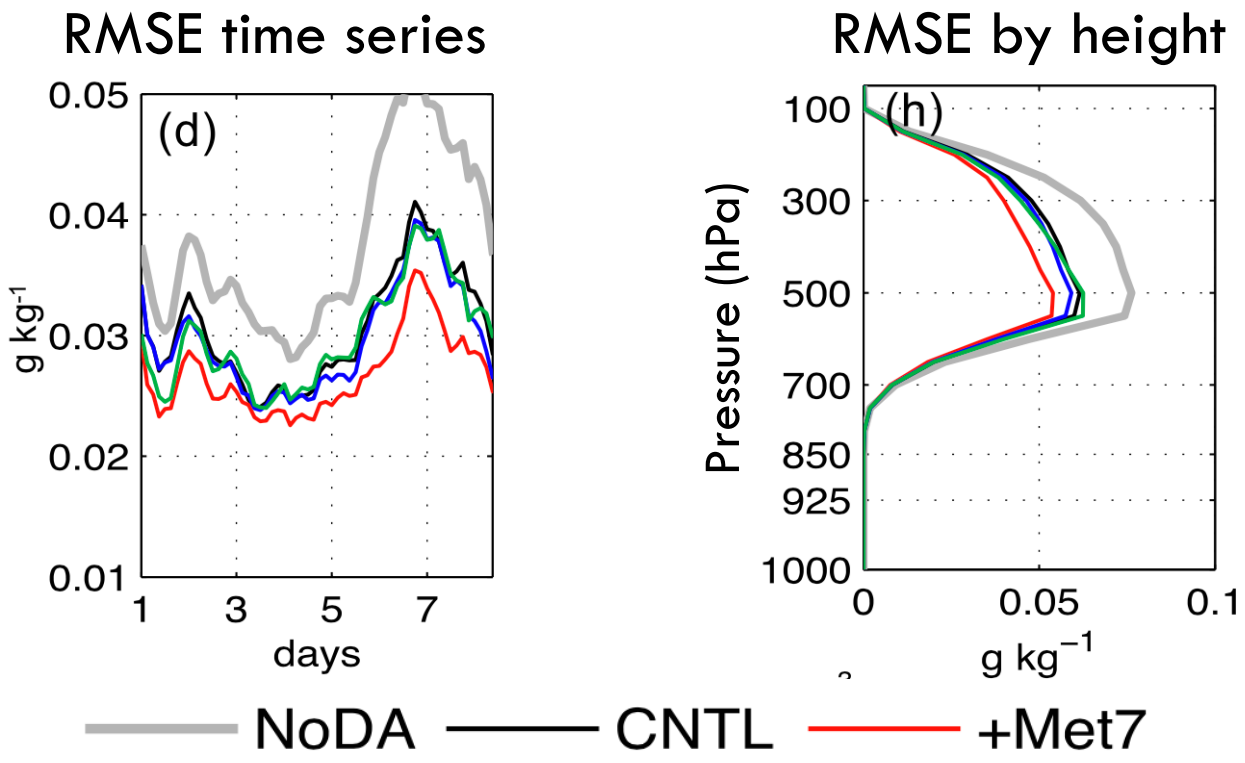
Scan cycle period: 30 min

Covered Indian Ocean from Dec 2006 to Feb 2017

Motivation

Ying and Zhang (2018)'s OSSE shows all-sky IR DA can improve frozen hydrometeors

Frozen hydrometeor mixing ratio RMSE

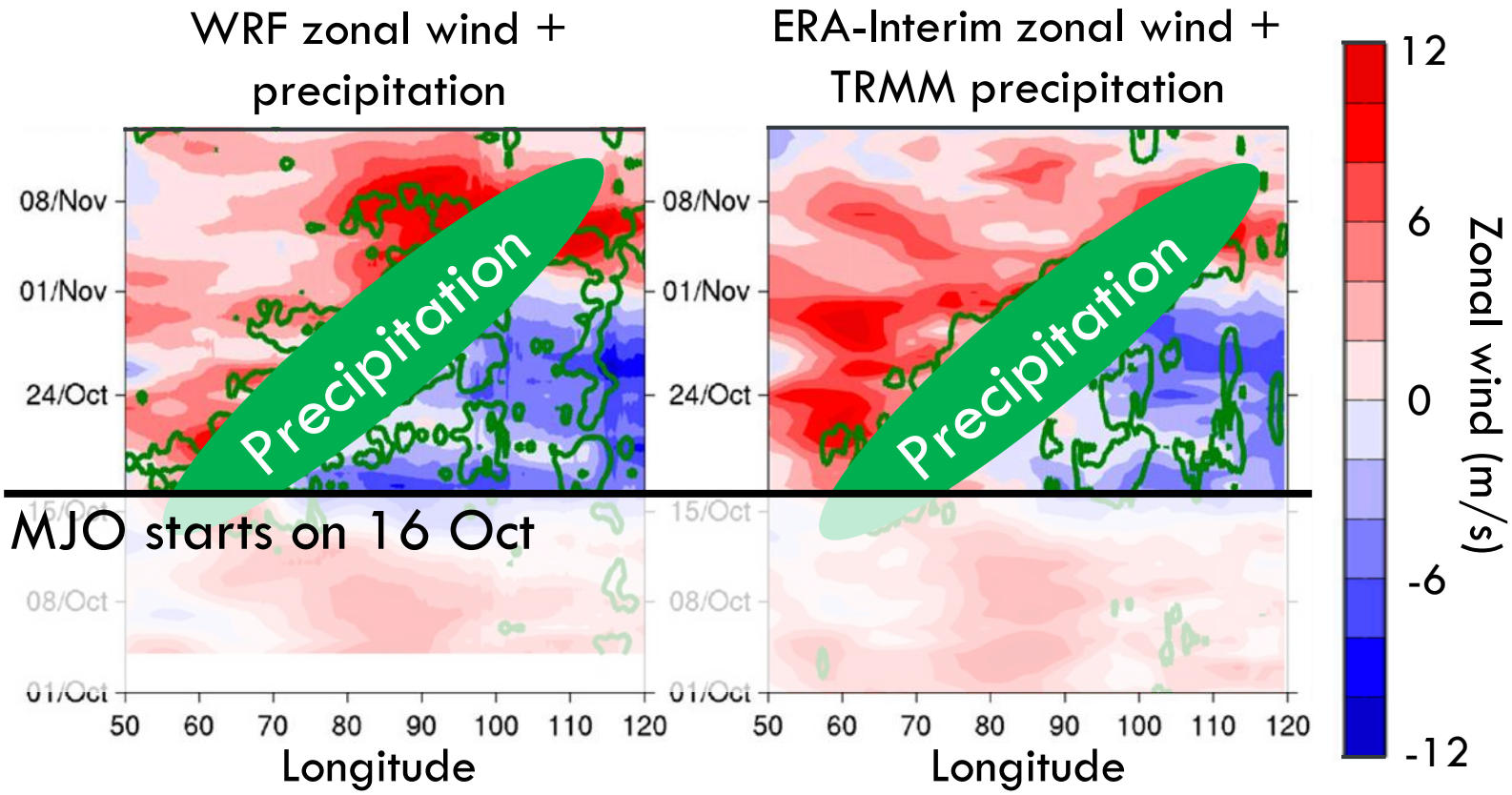


Research Question

What are the impacts of assimilating actual all-sky infrared observations over the tropical Indian Ocean?

Testbed: Oct 2011 MJO event

Successfully reproduced in 9-km resolution WRF



Green contour indicates 15mm/day precipitation

Figure taken from Wang et al (2015).

Focus of this talk

- Assimilating all-sky Meteosat-7 WV channel observations improved horizontal cloud patterns.

- All-sky WV channel DA removed domain-averaged QVAPOR during update, creating a dry bias.

Setup of WRF ensemble
WRF domain and settings

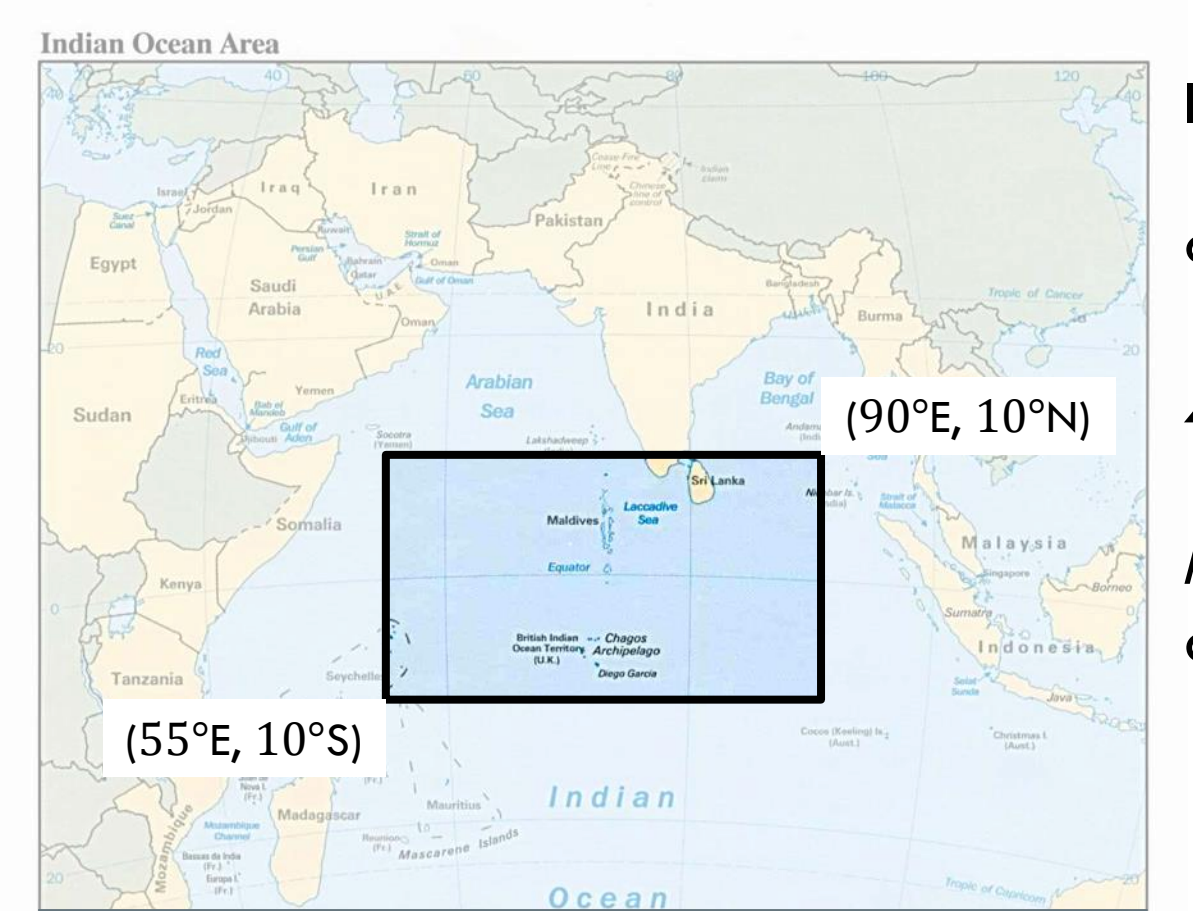


Figure adapted from
https://legacy.lib.utexas.edu/maps/islands_oceans_poles/indianoceanarea.jpg

Indian Ocean domain

9 km horizontal resolution

44 vertical model levels

Model physics follow Ying and Zhang (2018)

Setup of WRF ensemble

9 km grid spacing – gray zone resolution

Mesoscale convective complexes

Individual convective updrafts

Setup of WRF ensemble
Initial & boundary conditions

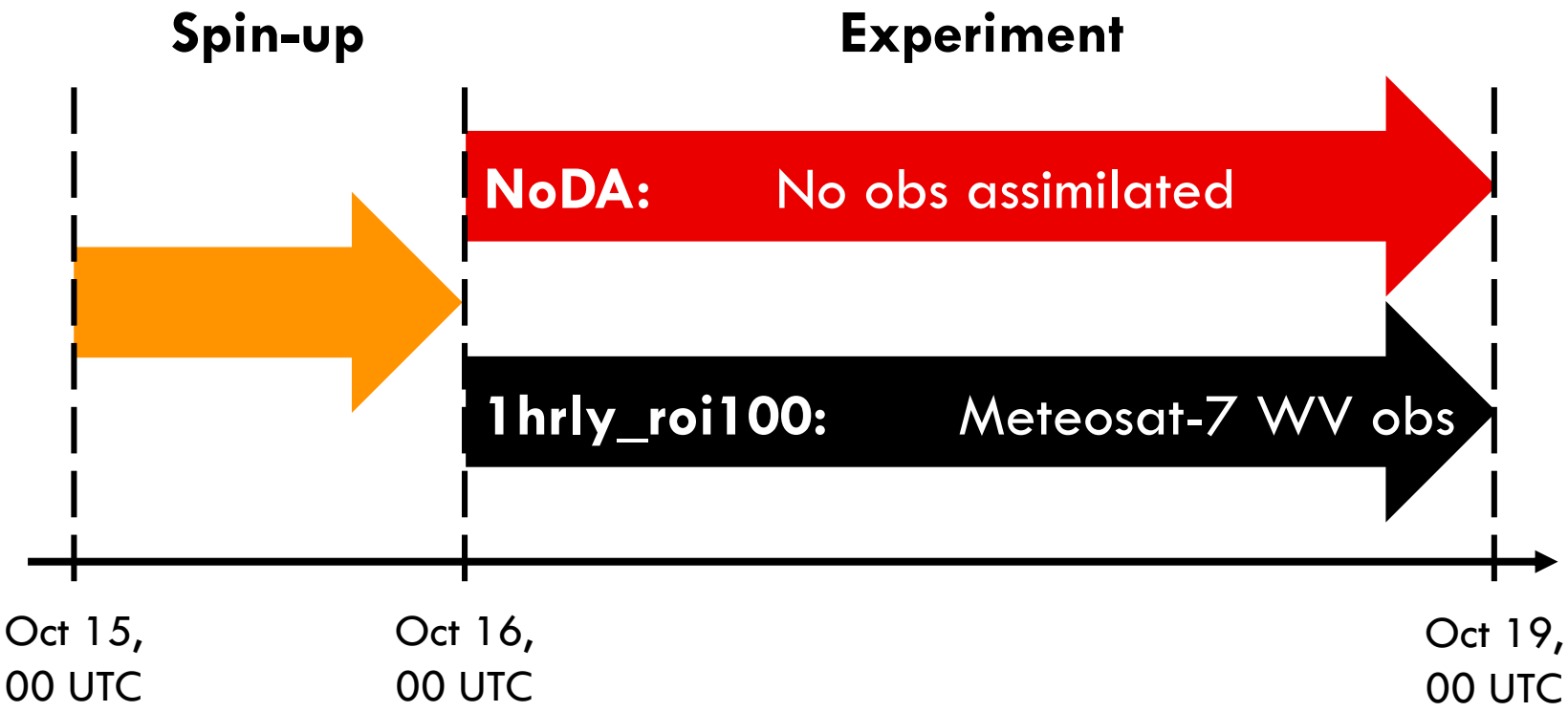
Initial & boundary conditions from ECMWF's 50-member perturbed forecast ensemble

Missing data filled in using ERA-Interim

- Some surface variables and data above 200 hPa

Initial conditions valid on Oct 15, 2011, at 00 UTC

Setup of experiments
Overview



Focus of this talk

- Assimilating all-sky Meteosat-7 WV channel observations improved horizontal cloud patterns.

- All-sky WV channel DA removed domain-averaged QVAPOR during update, creating a dry bias.

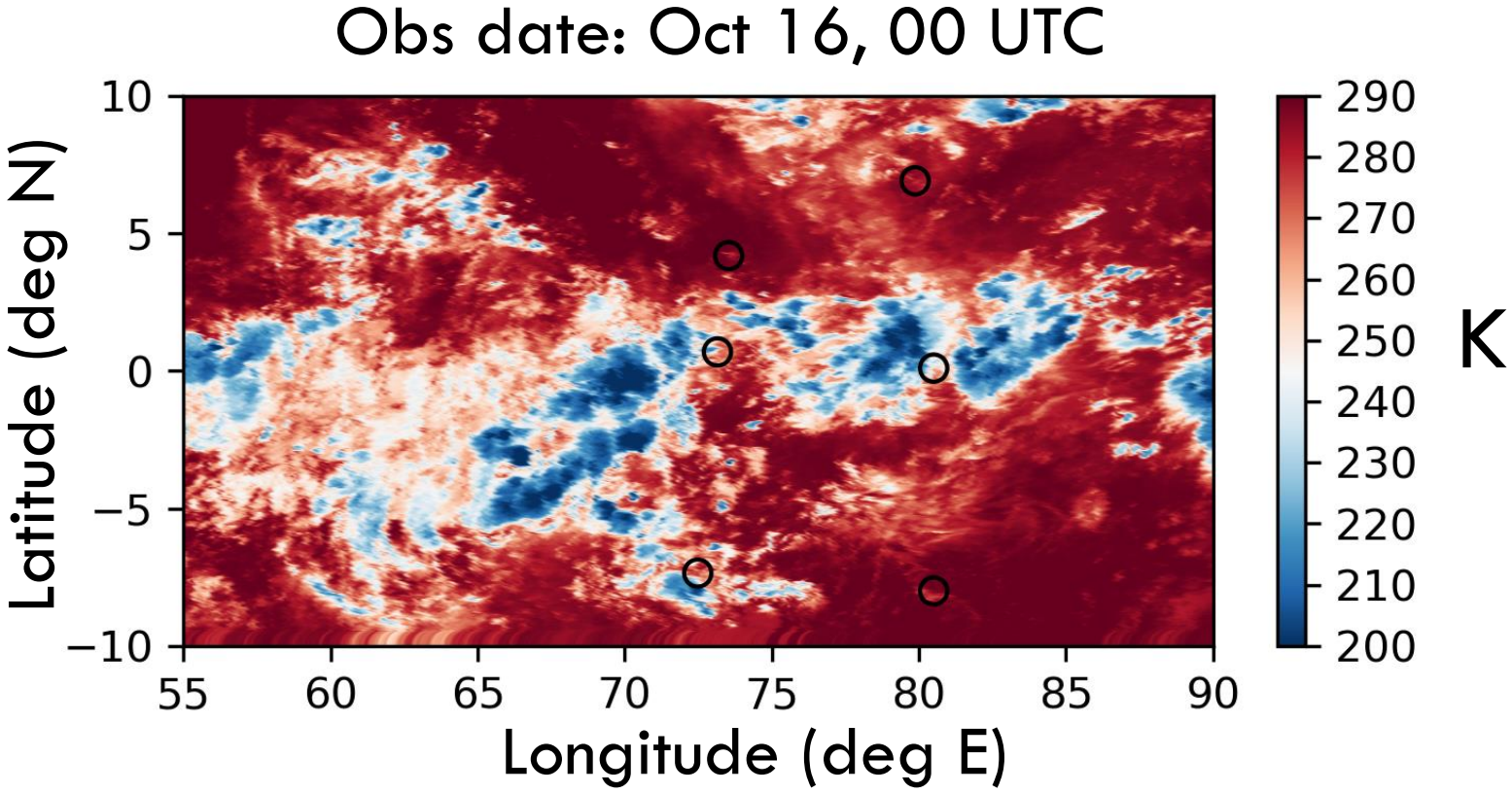
Focus of this talk

- Assimilating all-sky Meteosat-7 WV channel observations improved horizontal cloud patterns.

- All-sky WV channel DA removed domain-averaged QVAPOR during update, creating a dry bias.

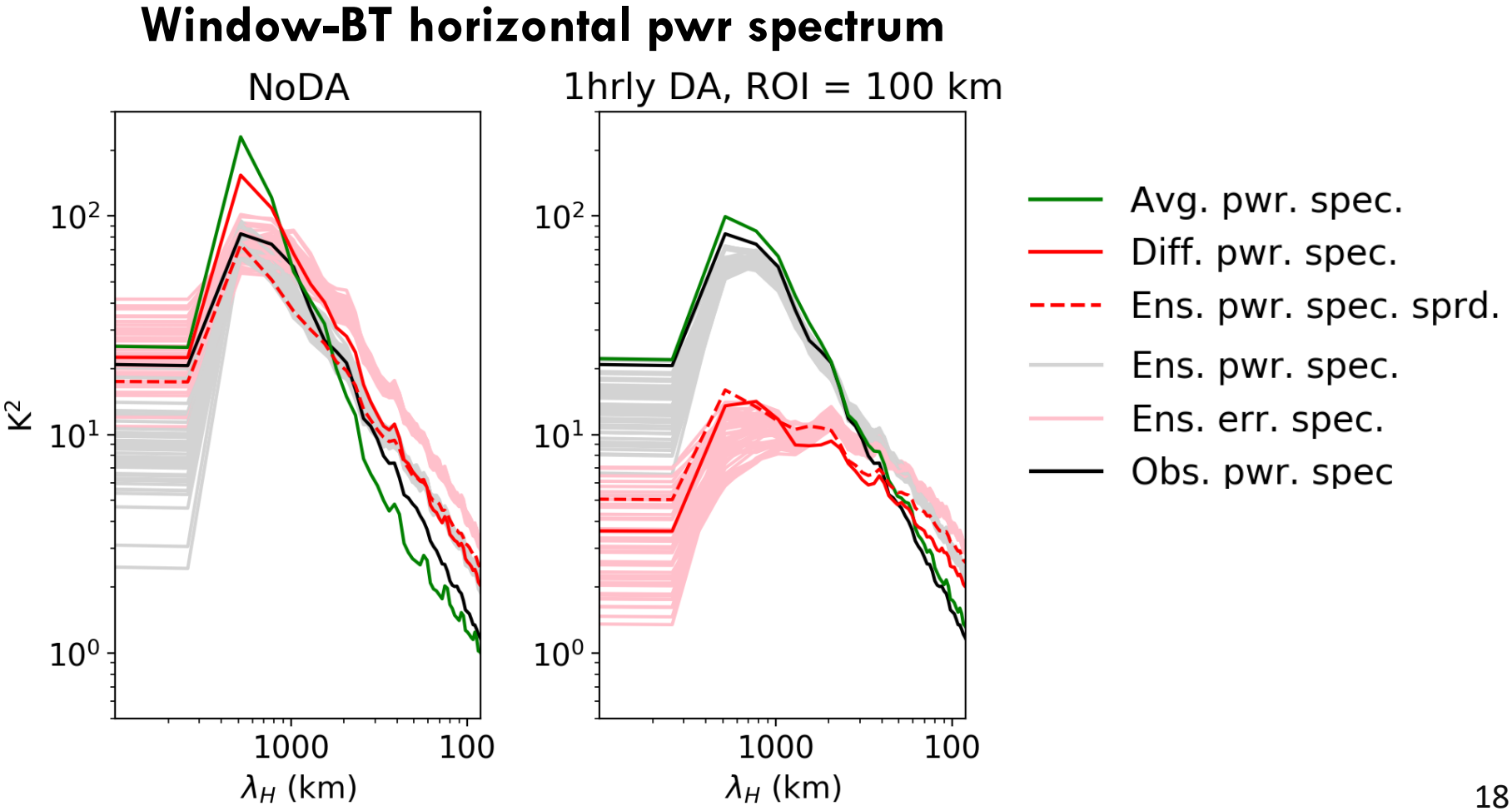
Ensemble validation

Meteosat-7 infrared window channel brightness temperatures (Window-BT, 11.5 micron)



Impact on cloud field

Improved ens mean power spectrum, reduced errors in both members and mean.



Focus of this talk

- Assimilating all-sky Meteosat-7 WV channel observations improved horizontal cloud patterns.

- All-sky WV channel DA removed domain-averaged QVAPOR during update, creating a dry bias.

Focus of this talk

- Assimilating all-sky Meteosat-7 WV channel observations improved horizontal cloud patterns.

- All-sky WV channel DA removed domain-averaged QVAPOR during update, creating a dry bias.

Ensemble validation
DYNAMO Sounding Array

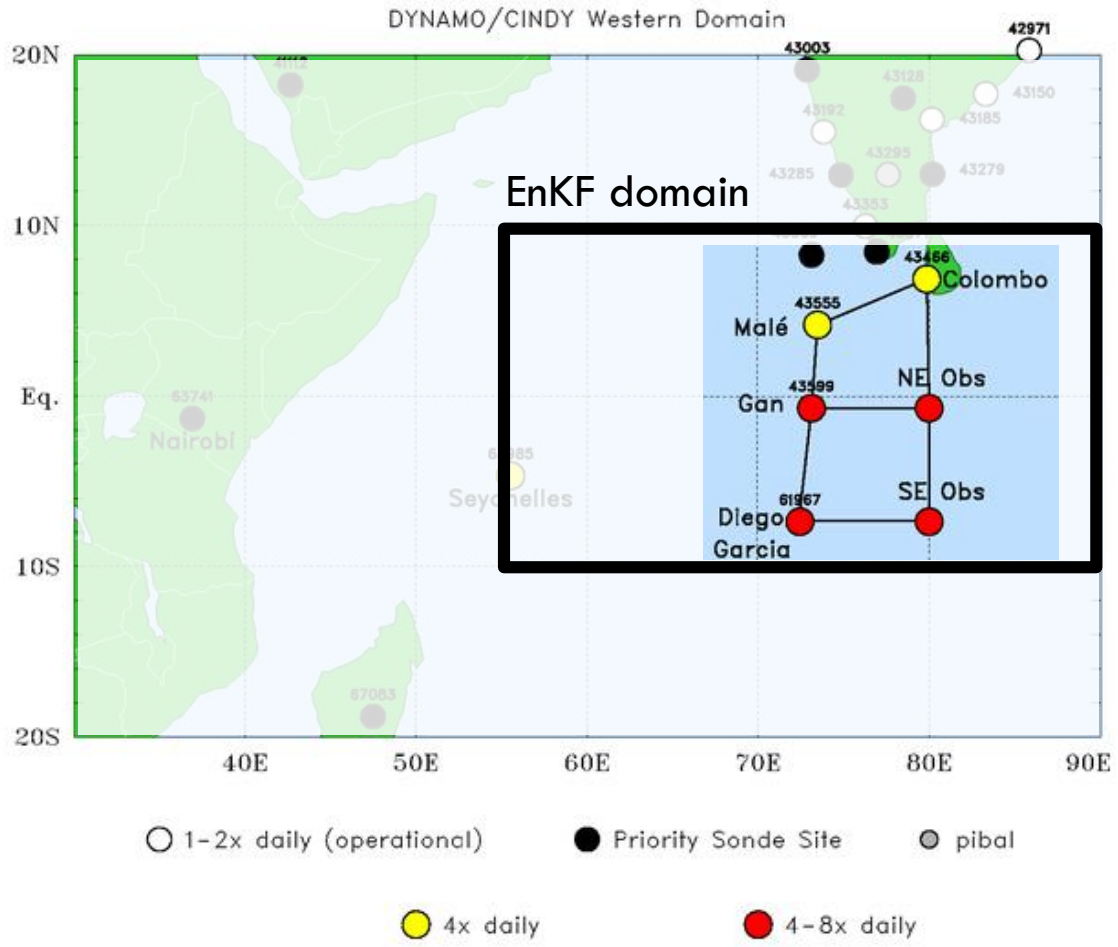
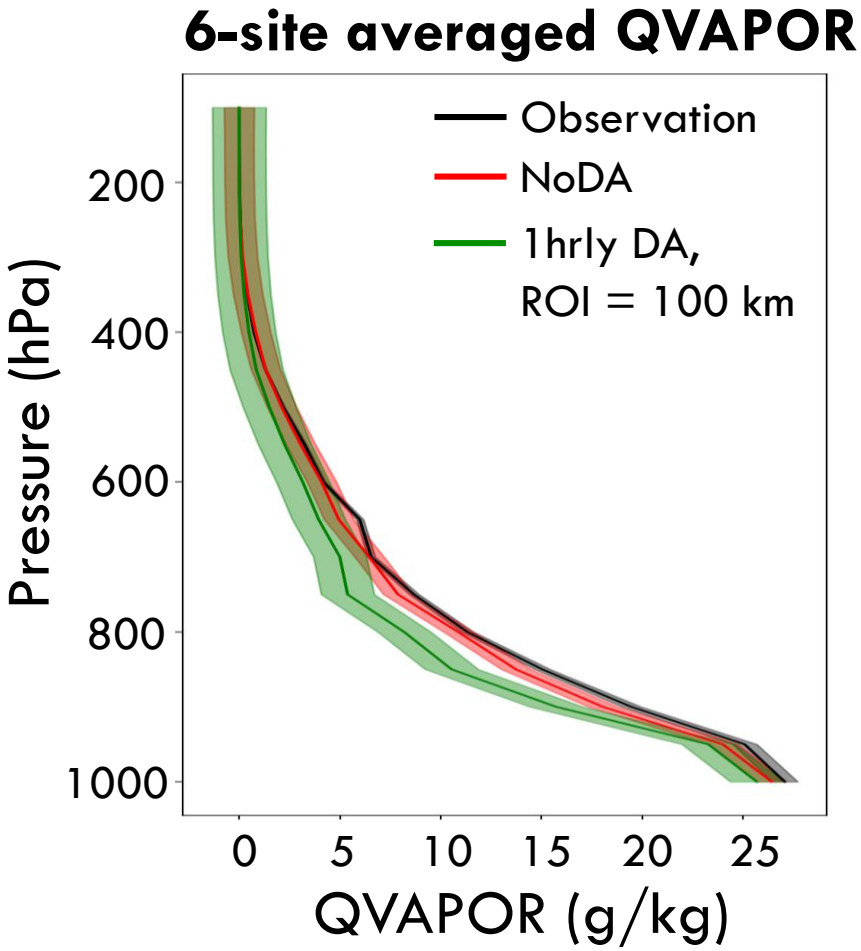


Figure from DYNAMO website by CSU Mesoscale Dynamic Group http://johnson.atmos.colostate.edu/dynamo/products/soundings/index.html

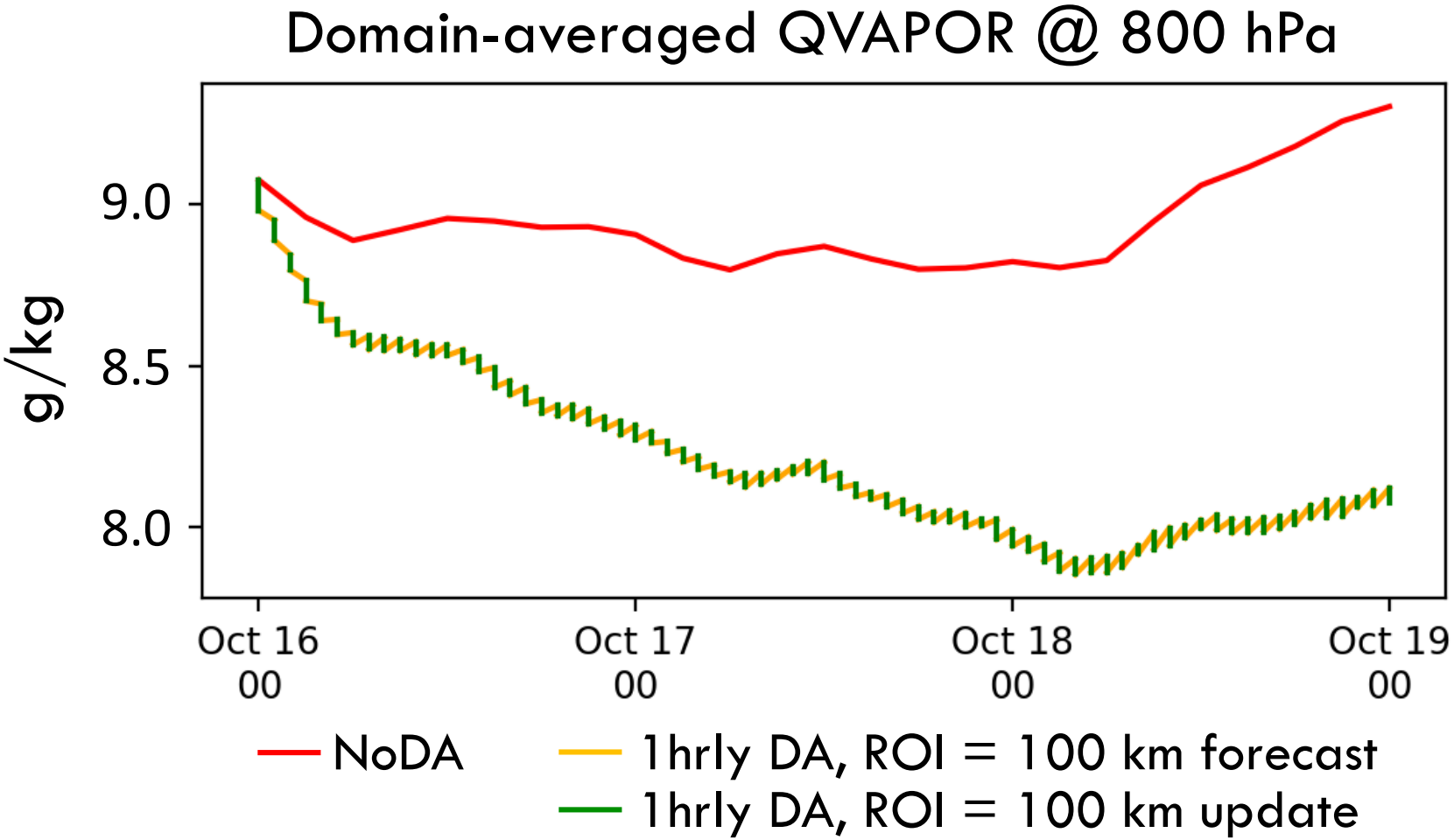
Impact on QVAPOR

Overall reduction in QVAPOR. Created dry bias.



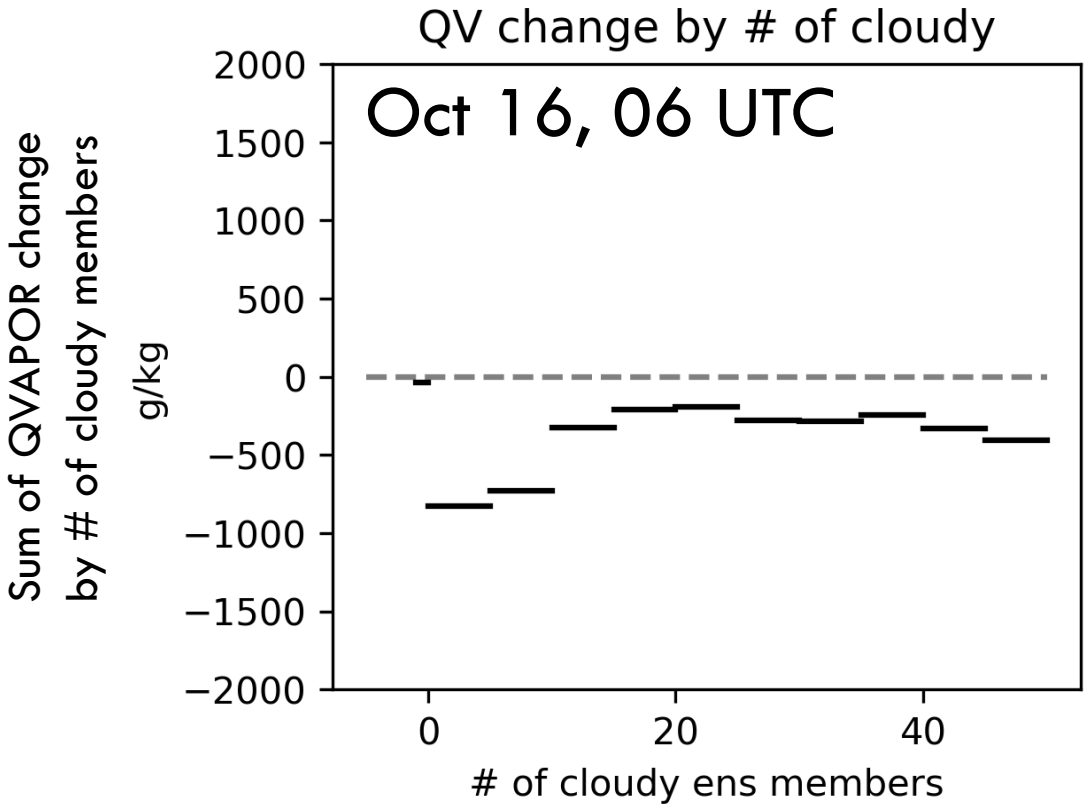
Impact on QVAPOR

Update step is responsible for dry bias creation



Dissecting QVAPOR removal

Much of removal comes from locations where # of cloudy members is between 1 and 20.



Possible origin of dry bias

CRTM sees top of the mean cloud

$$\overline{x^a} = \overline{x^f} + \frac{Cov\left(x^f, y\right)}{\sigma_f^2 + \sigma_o^2}\left\{y - h\left(\overline{x^f}\right)\right\}$$

If 0 members have clouds, $h\left(\overline{x^f}\right) \sim 250$ K

If 10 members have tall clouds, $h\left(\overline{x^f}\right) \sim 220$ K

If 50 members have tall clouds, $h\left(\overline{x^f}\right) \sim 215$ K

If covariance between QVAPOR and WV-BT is negative, and clear sky is observed (250 K), then removal of QVAPOR is very similar for both 10 member and 50 member case.

Future work

1. EnKF that sidesteps the need for ensemble average

2. Comparisons against radar observations and other observed sounding variables

3. Extend experiments beyond 3 days

Summary

Assimilation of WV-BT:

1. Improved horizontal cloud patterns above 500 km in both ens mean and ens average.

2. Created dry bias in update steps. Much of the bias comes from locations where only a few members have clouds. Likely tied to the nonlinear nature of radiative transfer.

Acknowledgements

Advisor: Dr. Fuqing Zhang

Department of Meteorology and Atmospheric Sciences

Center for Advanced Data Assimilation and Predictability Techniques (ADAPT)

National Science Foundation (Award #: 1712290)

Fin.

Summary

Assimilation of WV-BT:

1. Improved horizontal cloud patterns above 500 km in both ens mean and ens average.

2. Created dry bias in update steps. Much of the bias comes from locations where only a few members have clouds. Likely tied to the nonlinear nature of radiative transfer.