Satellite data assimilation for tropical weather prediction: Observing system design and observation impact

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Group meeting, Dec 11, 2015

Motivation

How to use satellite-based observations *optimally* to constrain model

- Temperature, moisture
- Wind
- Hydrometeors

Satellite-base observations:

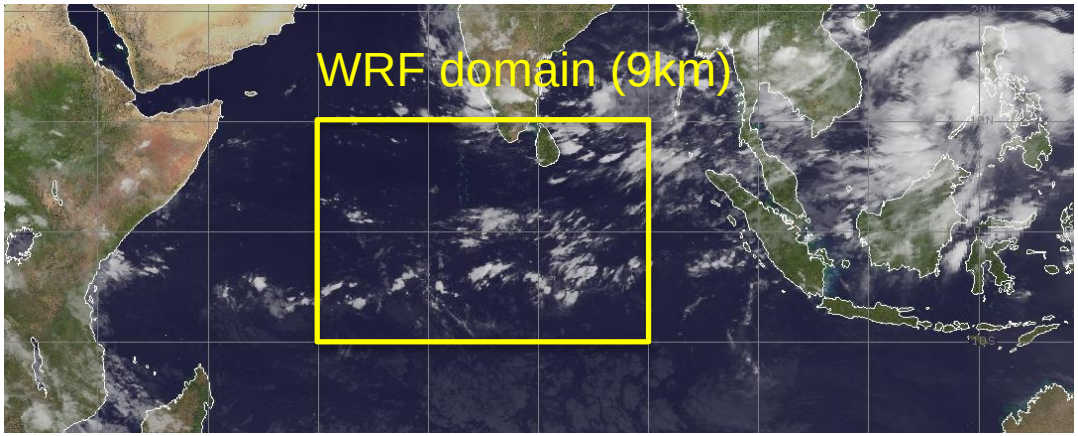
- Direct observations of brightness temperature
- Retrieved temperature moisture profiles
- Cloud-tracing wind
- Surface-roughness wind

Data assimilation should consider:

- Observation availability, density (localization)
- Error modeling (inflation)
- QC, bias correction
- Nonlinearity in forward model (CRTM)
- Non-Gaussian variables (hydrometeors)

➡ Observing system simulation experiment (OSSE)

Experimental design: EnKF OSSE



Truth: ERA-initialized WRF simulation

60-member EnKF
First-guess from GFS
Assimilate every 3 h

Advanced Baseline Imager (**ABI**)
Channel-8 Brightness Temperature
Horizontal resolution: every pixel

Advanced TIROS Operational Vertical Sounder (**ATOVS**): temperature, moisture profiles
Horizontal resolution: every 90 km

Atmospheric Motion Vectors (**AMV**)

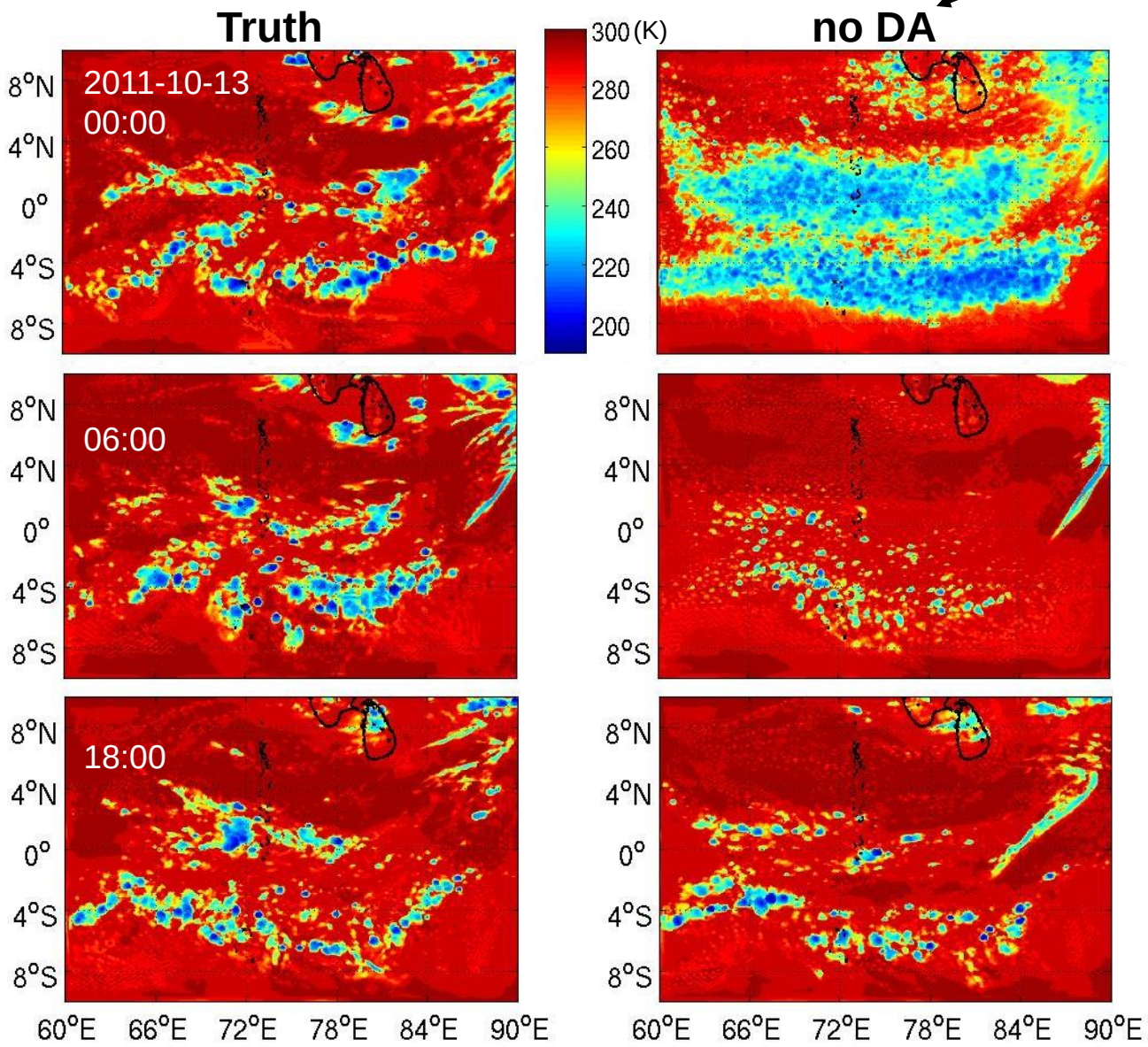
Localization (60 km for hydrometeors, 400 km for other variables)

ABI: Observation error inflation (use innovation as predictor)

The truth and no-DA case

Ch-14 Tb for verification

Deterministic forecast from prior ensemble mean



A “smoothed-out” prior mean (members all have different cloud cluster locations)

Smoothed clouds dissipated

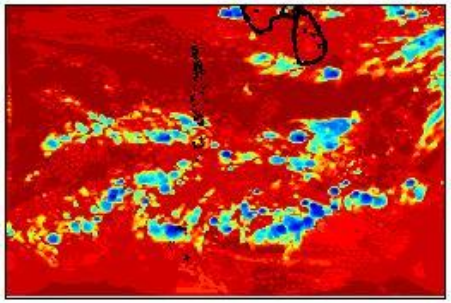
Correct LBC forces out some convective clouds

Assimilation of ABI (ch-8 Tb) vs. ATOVS (T, Qv)

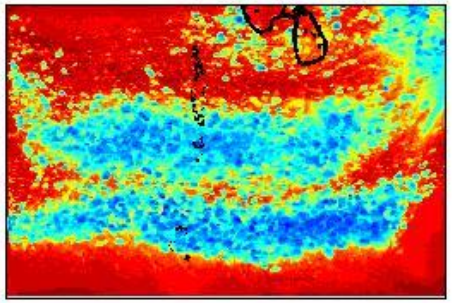
Ch-14 Tb for verification

2011-10-13 00:00

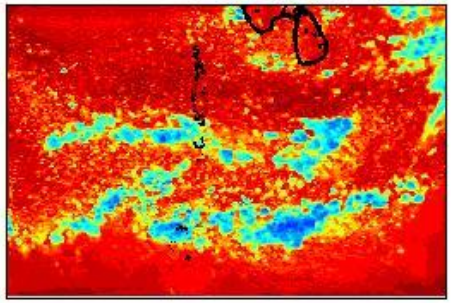
Truth

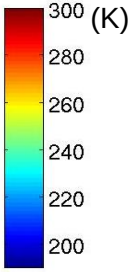


ABI (prior)



ABI (posterior)

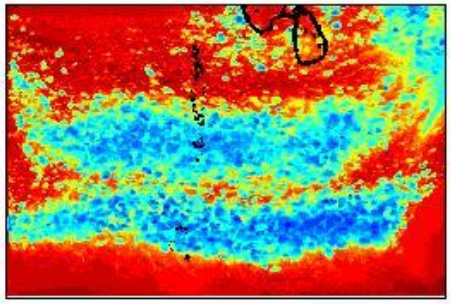




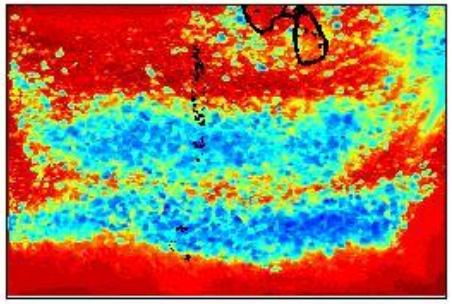
ABI observation recovers the spatial pattern of cloud clusters

ATOVS doesn't bring too much adjustment to the cloud field

ATOVS (prior)



ATOVS (posterior)

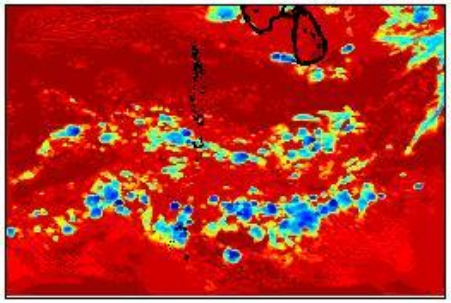


Assimilation of ABI (ch-8 Tb) vs. ATOVS (T, Qv)

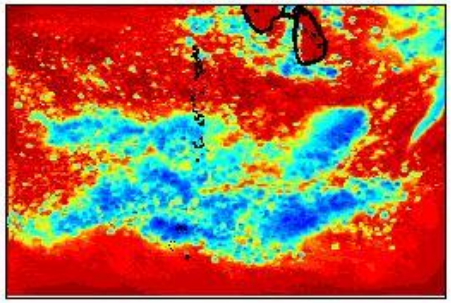
Ch-14 Tb for verification

2011-10-13 03:00

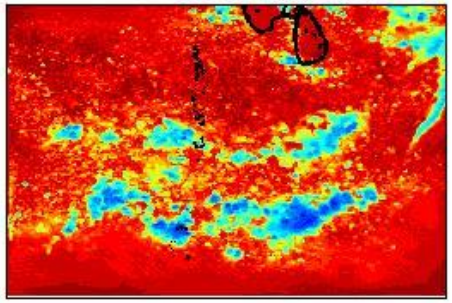
Truth

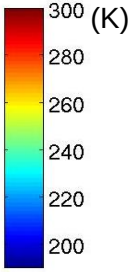


ABI (prior)



ABI (posterior)





ABI observation recovers the spatial pattern of cloud clusters

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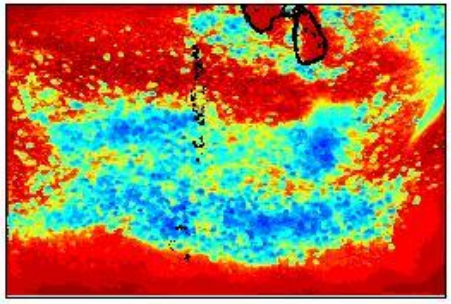
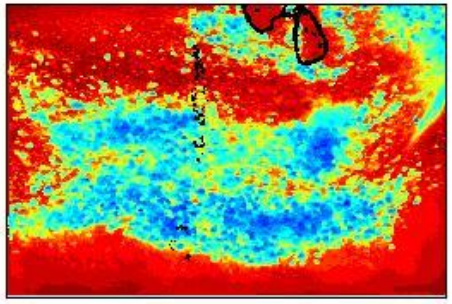
ATOVS (prior)



ATOVS (posterior)

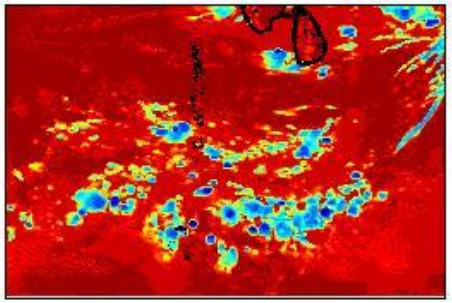


Assimilation of ABI (ch-8 Tb) vs. ATOVS (T, Qv)

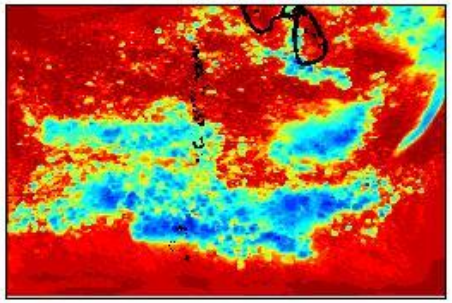
Ch-14 Tb for verification

2011-10-13 06:00

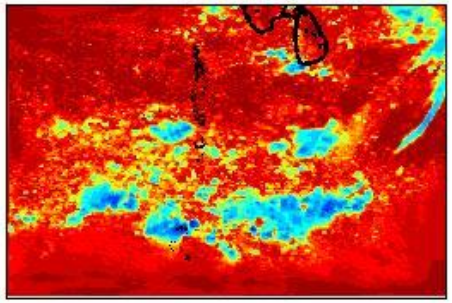
Truth

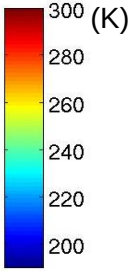


ABI (prior)

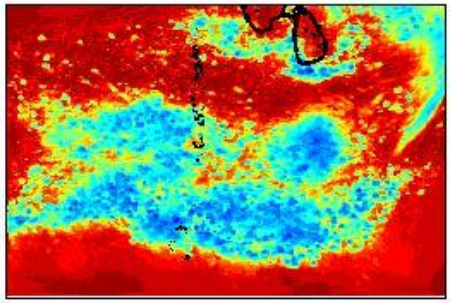


ABI (posterior)

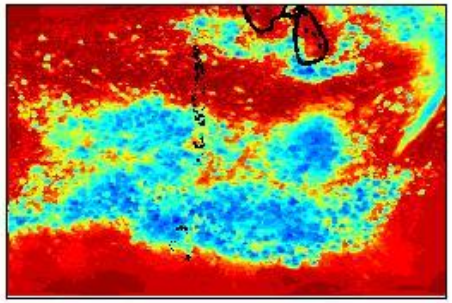




ATOVS (prior)



ATOVS (posterior)



ABI observation recovers the spatial pattern of cloud clusters

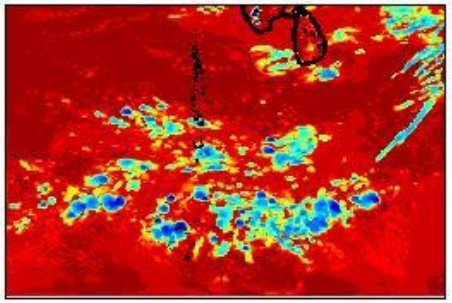
ATOVS doesn't bring too much adjustment to the cloud field

Assimilation of ABI (ch-8 Tb) vs. ATOVS (T, Qv)

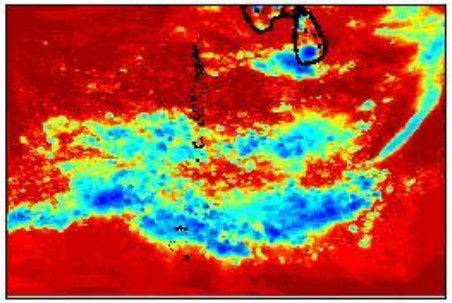
Ch-14 Tb for verification

2011-10-13 09:00

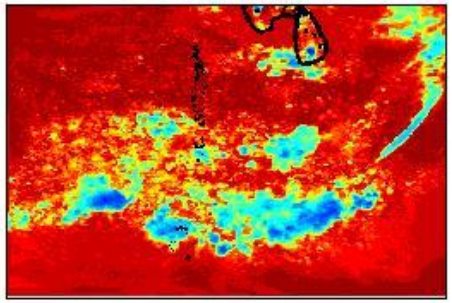
Truth

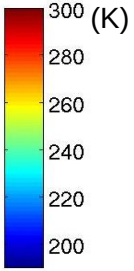


ABI (prior)

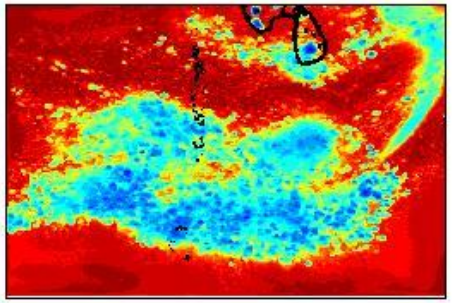


ABI (posterior)

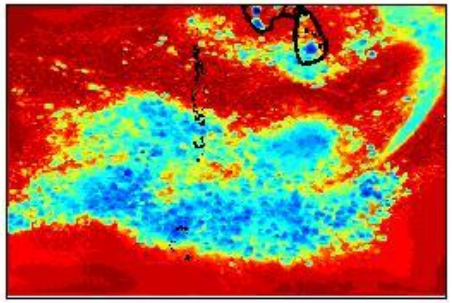




ATOVS (prior)



ATOVS (posterior)



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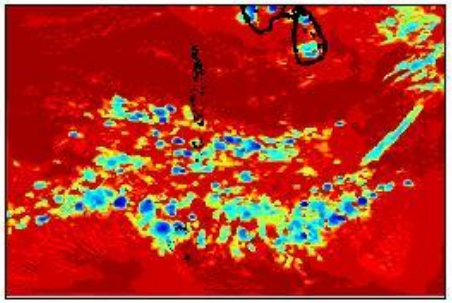
Assimilation of ABI (ch-8 Tb) vs. ATOVS (T, Qv)

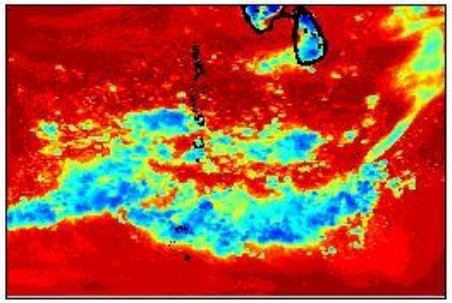
Ch-14 Tb for verification

2011-10-13 12:00

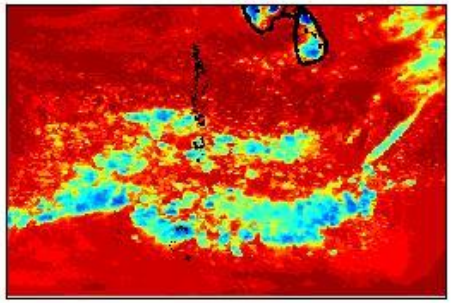
Truth

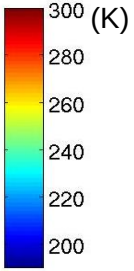


ABI (prior)



ABI (posterior)





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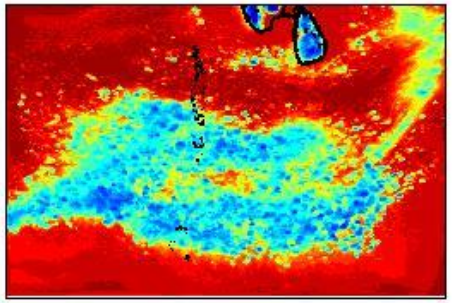
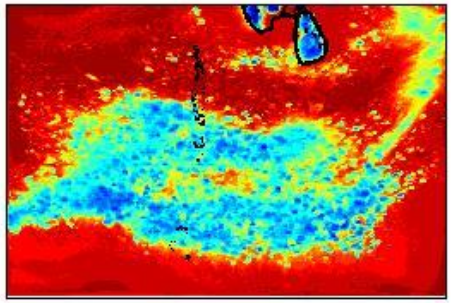
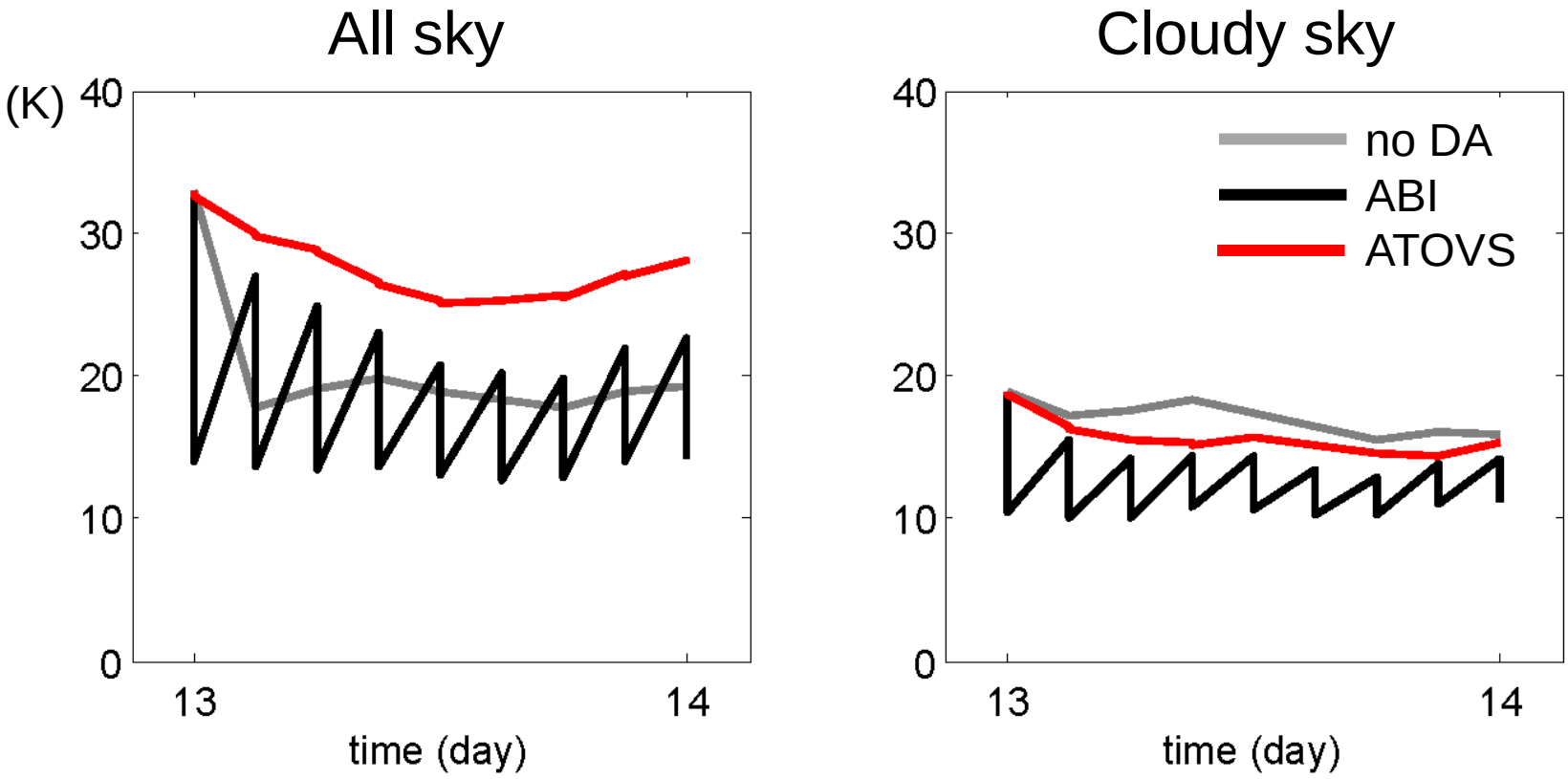


ATOVS (posterior)



Analysis RMSE of ch-14 Tb

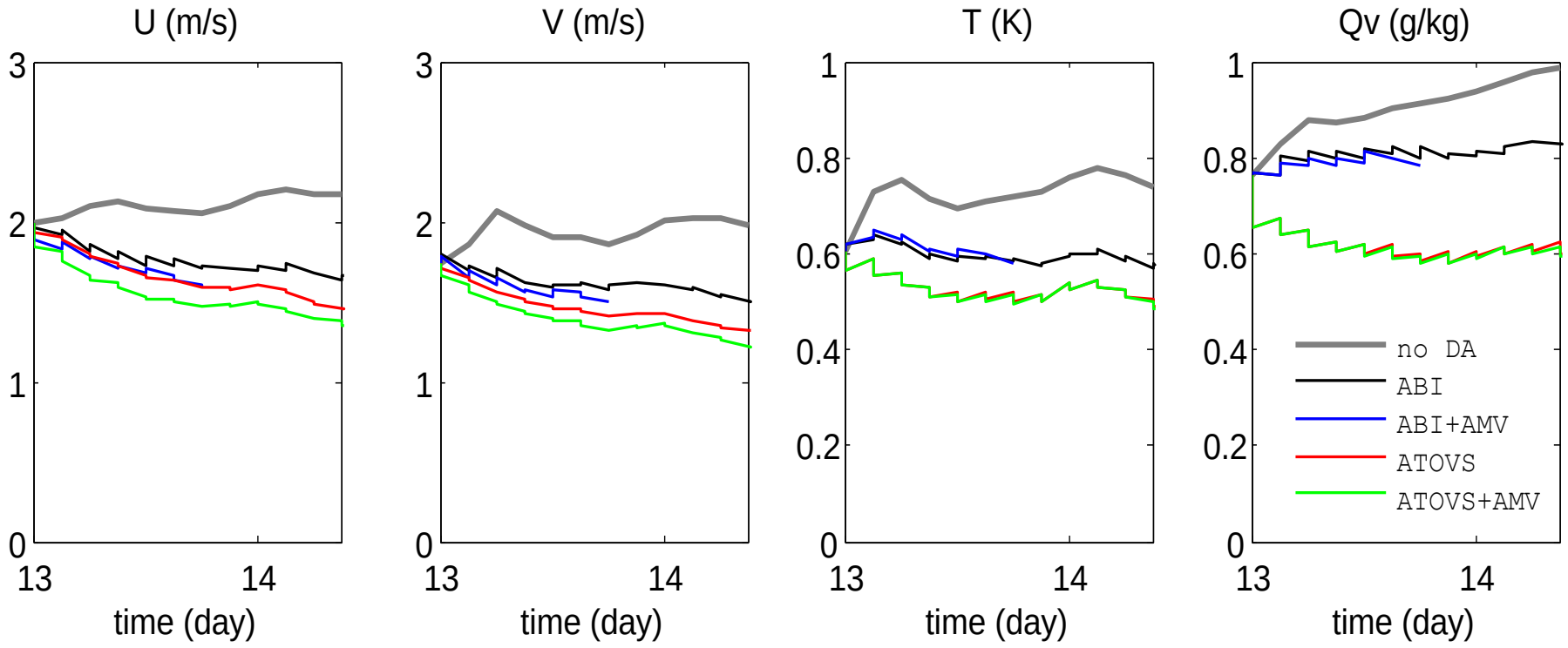


no-DA: doing a good job with clear region
ATOVS: “smoothed-out” cloud contaminates clear region

ABI: prior also has smoothed cloud, assimilating Tb gets rid of them in posterior.

Analysis RMSE of wind, temperature and moisture

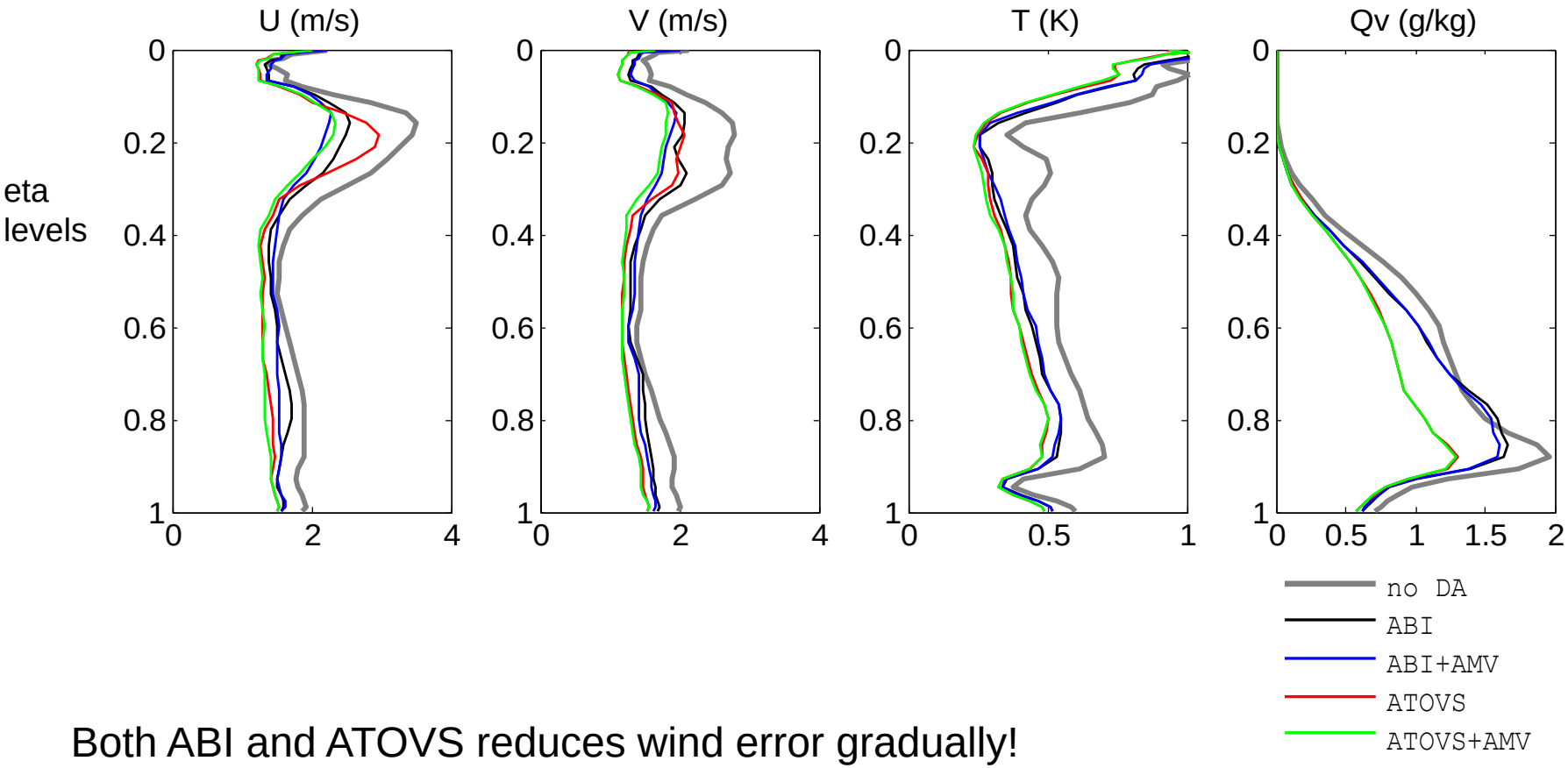
Time series



Both ABI and ATOVS reduces wind error gradually!
ATOVS reduces more temperature/moisture error (directly observed)
Adding AMV further reduces wind error

Analysis RMSE of wind, temperature and moisture

Vertical distribution



Both ABI and ATOVS reduces wind error gradually!
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Adding AMV further reduces wind error

Concluding remarks

- Proof-of-concept: Infrared brightness temperature observations are useful in constraining model cloud fields, and has positive impact on all other variables.

- Retrieved ATOVS profiles can improve T/Qv, but does not adjust cloud as much.

On going:

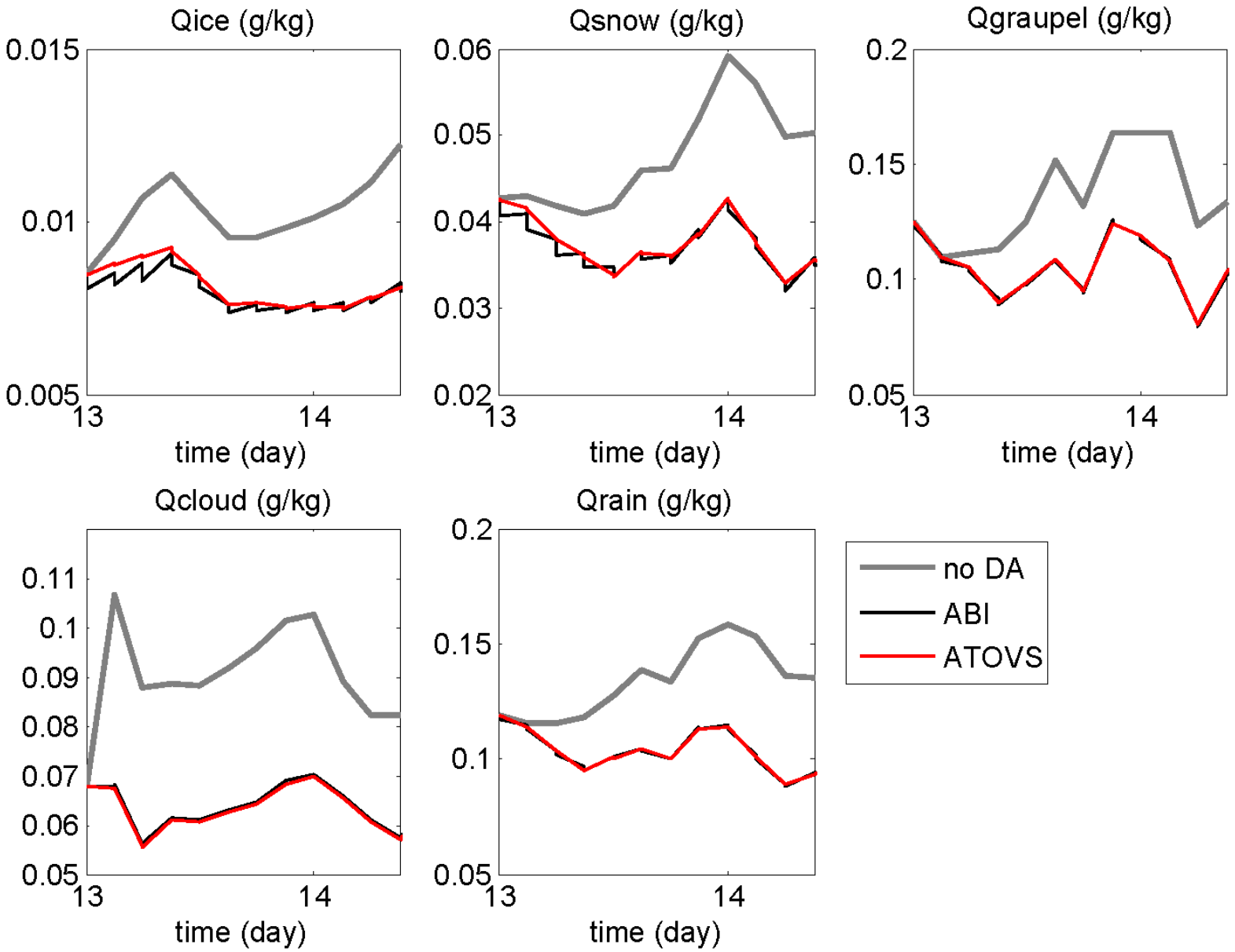
- The fast spreading ensemble cloud clusters suggest potential improvement when using higher frequency observations.

- Use Meteosat 7 (first generation) instead of ABI

- Consider using surface wind observations (CYGNSS, roughness-based wind speed) to further constrain wind field.

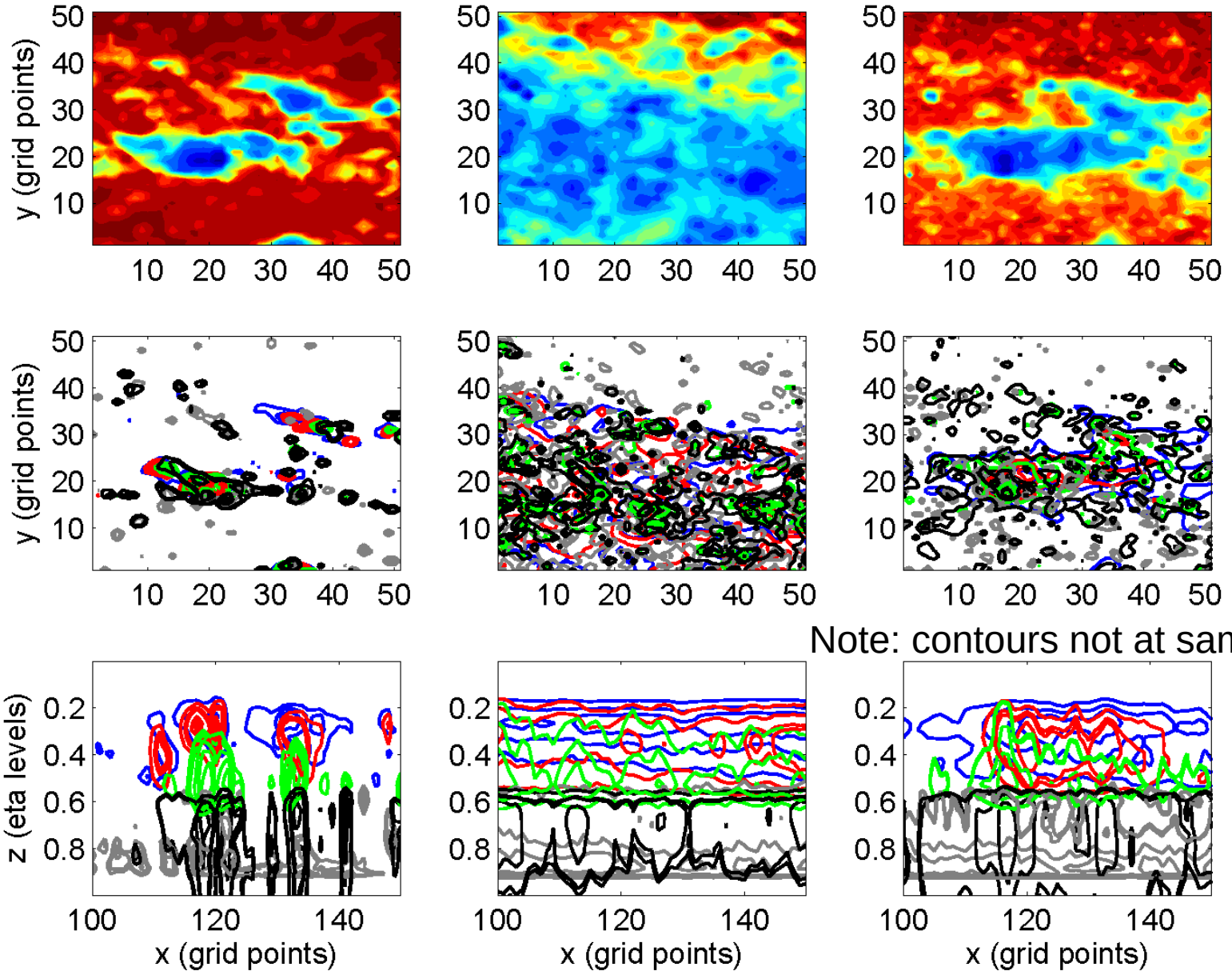
Supplementary slides

Analysis RMSE of Hydrometeors



Supplementary slides

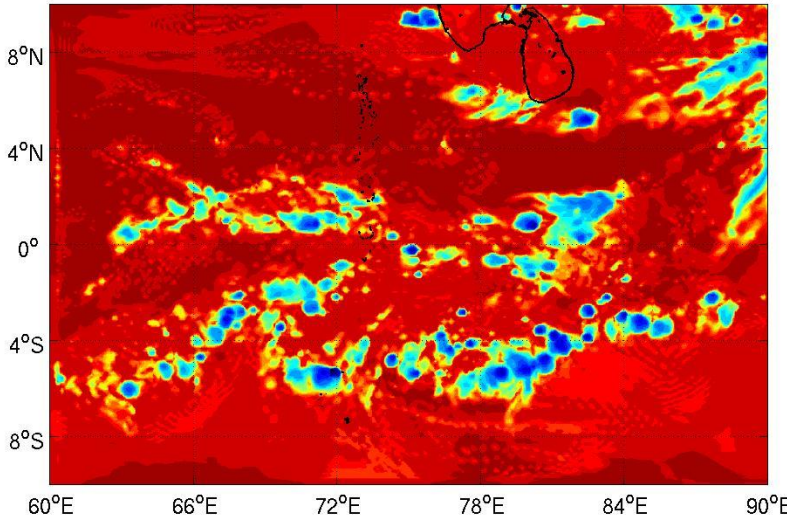
Updates to hydrometeors



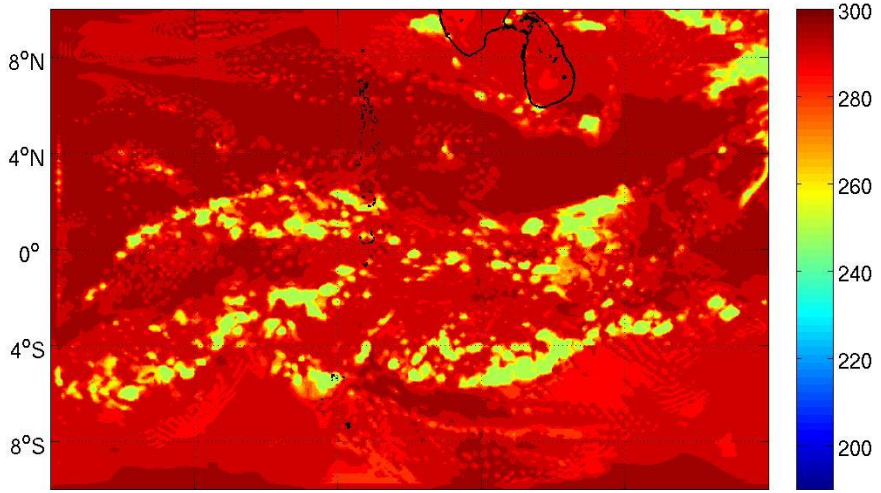
Supplementary slides

Sensitivity of CRTM to hydrometeors

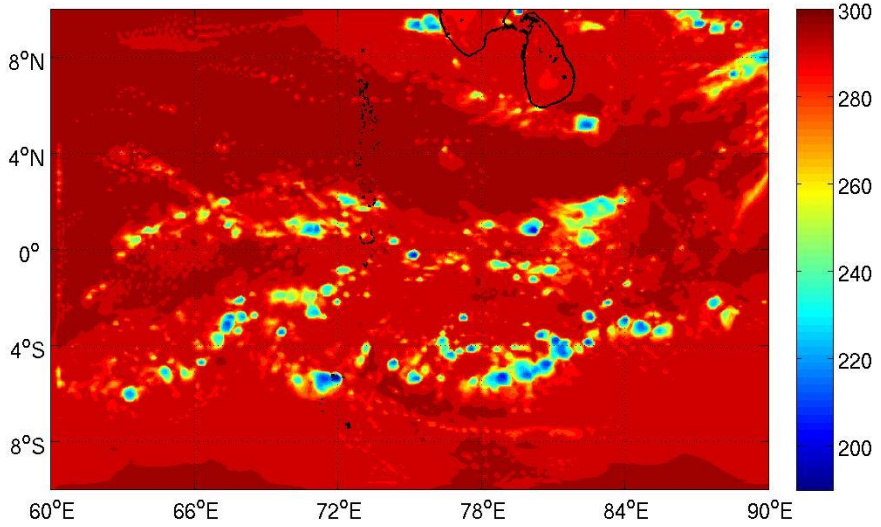
Control



No Q level25 up



1/10 all Q

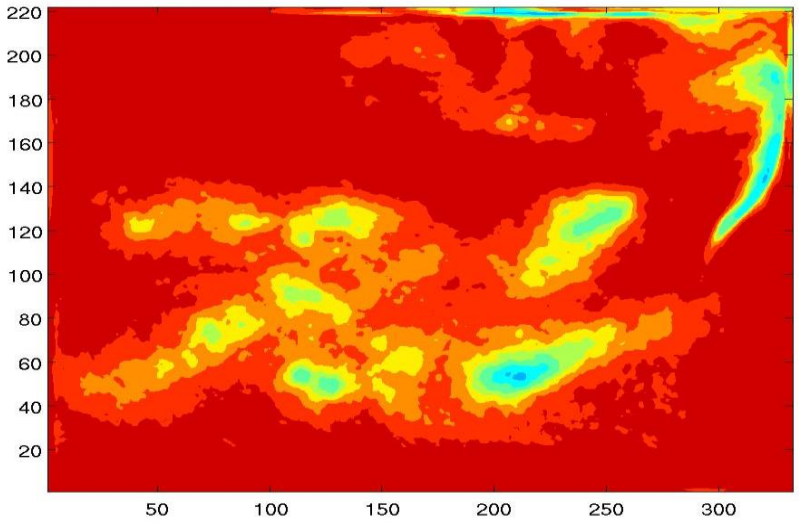


More sensitive to location of cloud than cloud amount?

Supplementary slides

Nonlinearity in forward operator (CRTM)

mean(Hx)



H(mean x)