Assimilation of SEVIRI Radiance in NAMRR System over Africa Region

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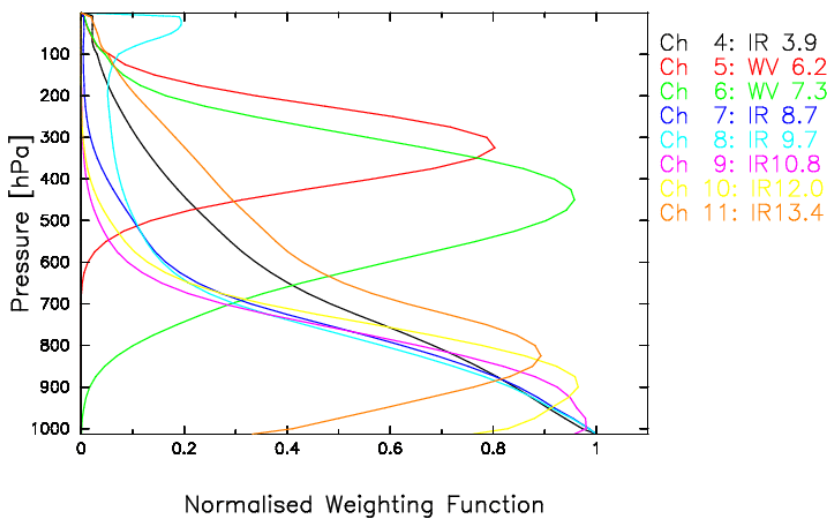
Motivation

- **Develop and test the ability to assimilate cloudy radiances from GOES-R to improve the prediction of high impact weather with NCEP NDAS and NMMB model**
- **Select EUMETSAT Meteosat Second Generation (MSG) Geostationary Satellite SEVIRI as the proxy data before GOES-R launch, since SEVIRI has the similar channels, resolutions as GOSE-R ABI**

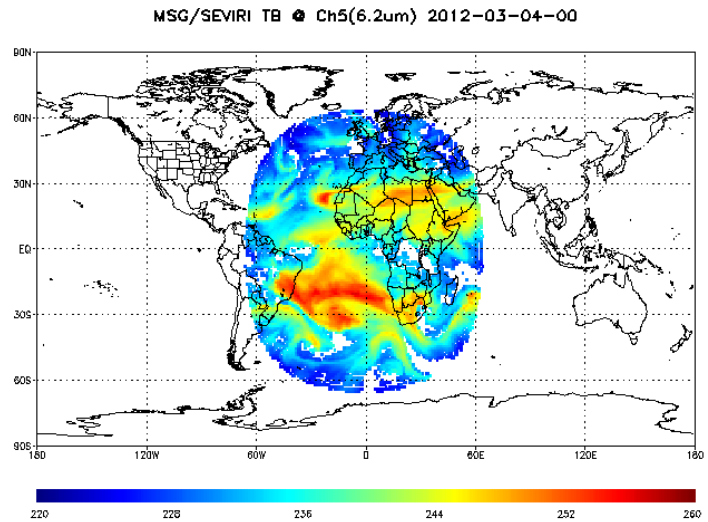
About SEVIRI

- **SEVIRI** (Spinning Enhanced Visible and Infrared Imager)launched on Metesoat satellite (geostationary meteorological satellites operated by EUMETSAT).
- 15 minutes temporal resolution and 3-km horizontal resolution
- Similar channels as GOES-R ABI

SEVIRI Weighting Function



SEVIRI full-disk coverage



SEVIRI in NCEP GDAS

SEVIRI clear-sky radiance from two water vapor channels are operationally assimilated in NCEP GDAS (global data assimilation system). Other IR channels (4,7-11) only being monitored.

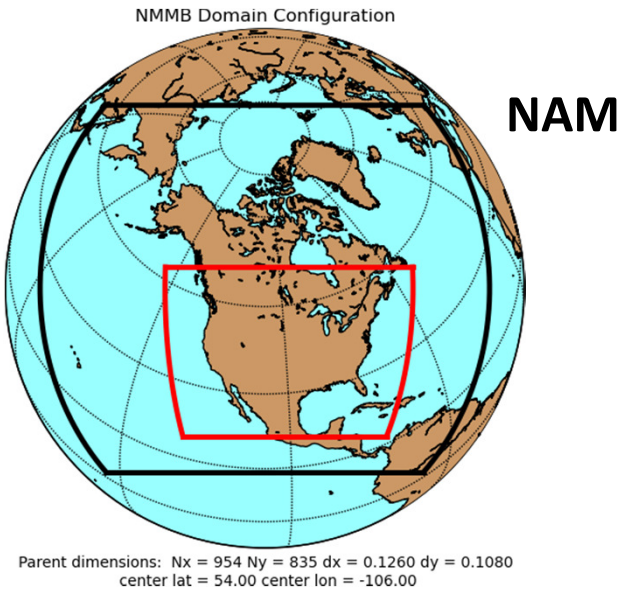
Extend SEVIRI to Hourly-Updated NAM Forecast System

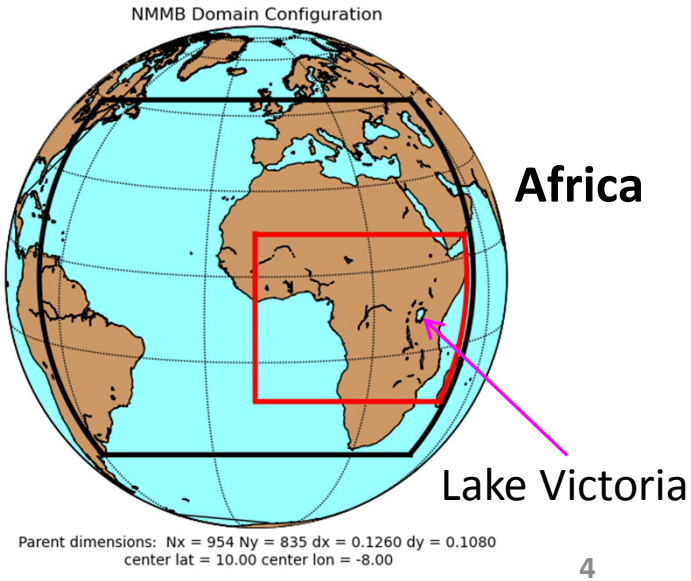
NAM – North American Mesoscale forecast system
- Runs 4x daily at 00, 06, 12, 18Z
- Short-range mesoscale NWP system for the U.S. which provides guidance to day 3.5

NAM*RR*: NAM Rapid Refresh
- *Hourly updates*
- Future North American Rapid Refresh Ensemble system (NARRE)
- NAMRR + RAP/HRRR Foundation

Development of *hourly* NAM cycling capabilities on NOAA R&D machine Zeus
- Part of DOE-funded wind energy projects
  - WFIP/POWER
- Cycling 12 km NAM *and* 4 (3) km CONUS nest
- Hybrid ensemble-3DVar via Global Data Assimilaion System's EnKF members
- Cloud analysis and diabatic digital filter initialization with radar-derived temperature tendencies

(from: Jacob Carley)





System validation

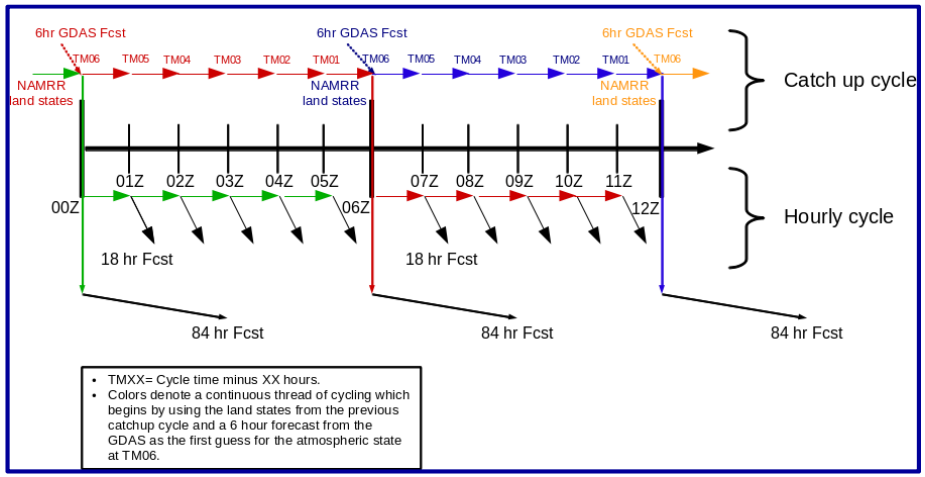
Two Experiments:

CTRL: Conventional data radiance observations

SEVIRI: + SEVIRI clear-sky radiance

- 30-day period: March 1-April 1 2012
- 12-km parents domain only
- Region: Europe and Africa
- Grid size: 954x835x 60
- Hourly update with NAMRR
- GSI 3D-Var & NMMB Model
- Verification against GDAS Analysis

Flow Chart



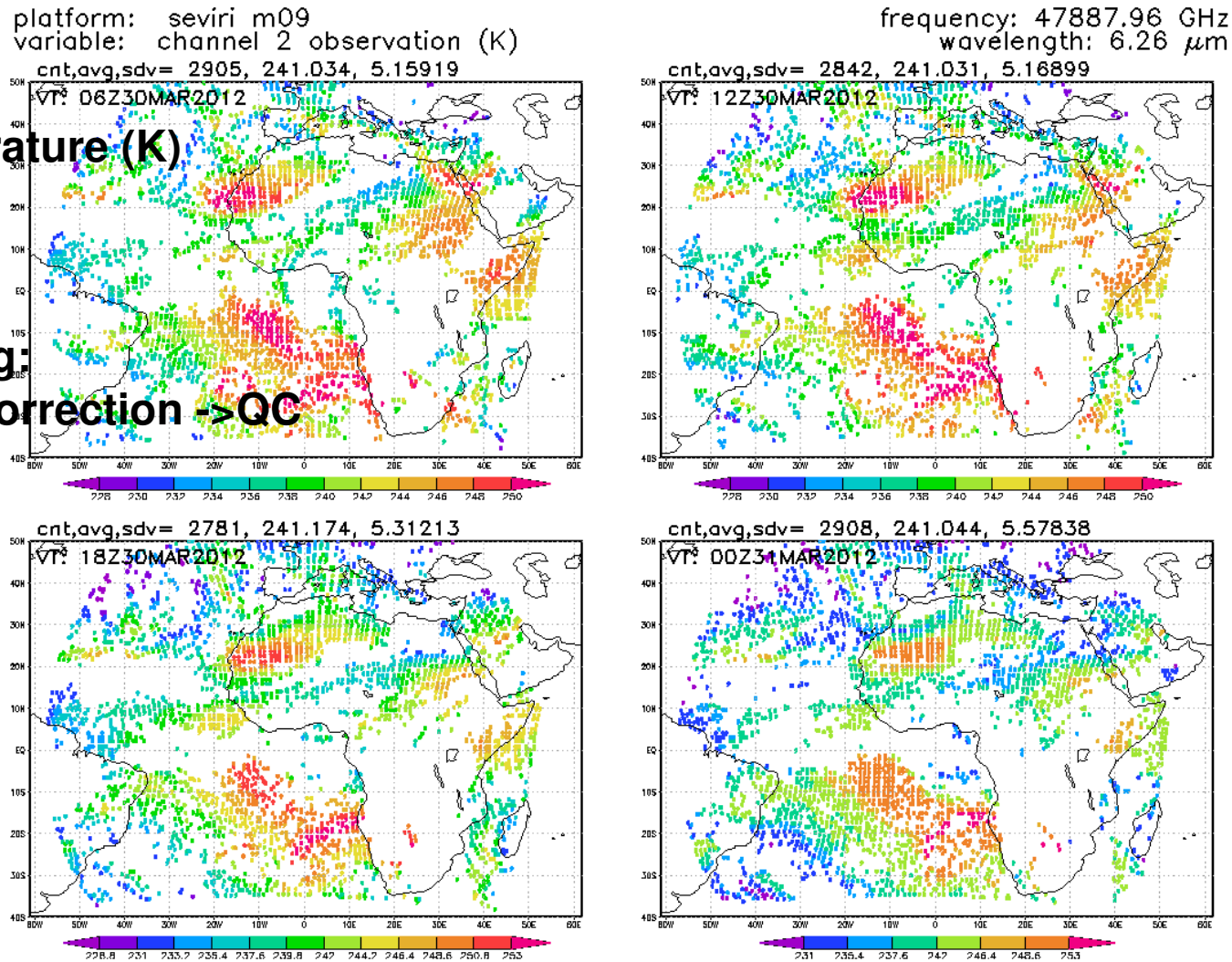
Satellite Radiance include:

- AMSUA (METOP-a; NOAA-15;NOAA-18;NOAA-19)
- AMSUB (NOAA-17)
- HIRS4 (METOP-a,NOAA-19)
- IASI (METOP-a); AIRS (AQUA)
- MHS (METOP-a; NOAA-19)
- Clear-sky SEVIRI (MSG-9)

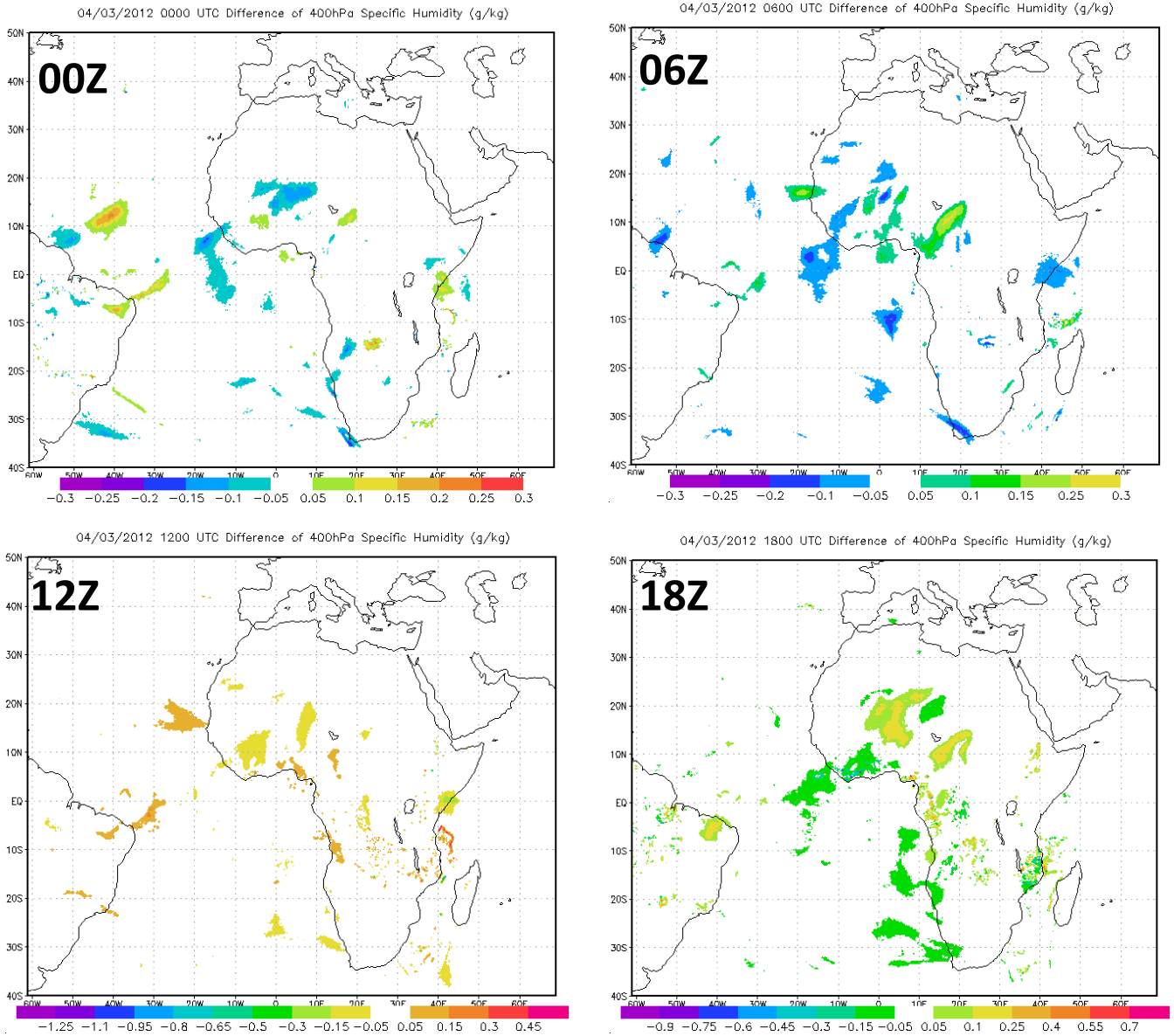
Assimilated clear-sky SEVIRI radiance

Brightness Temperature (K)

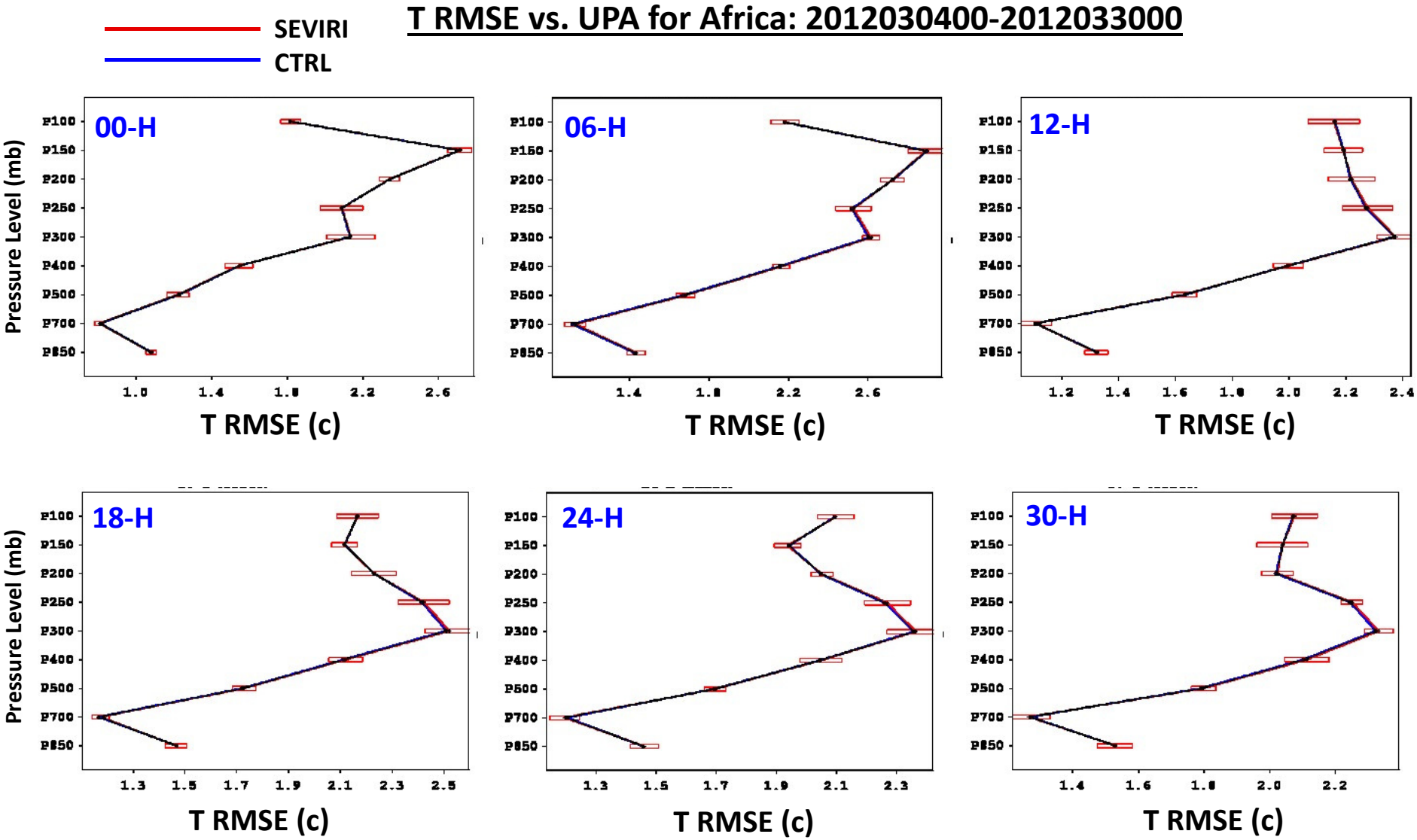
Before Assimilating:
Thinning -> Bias Correction ->QC



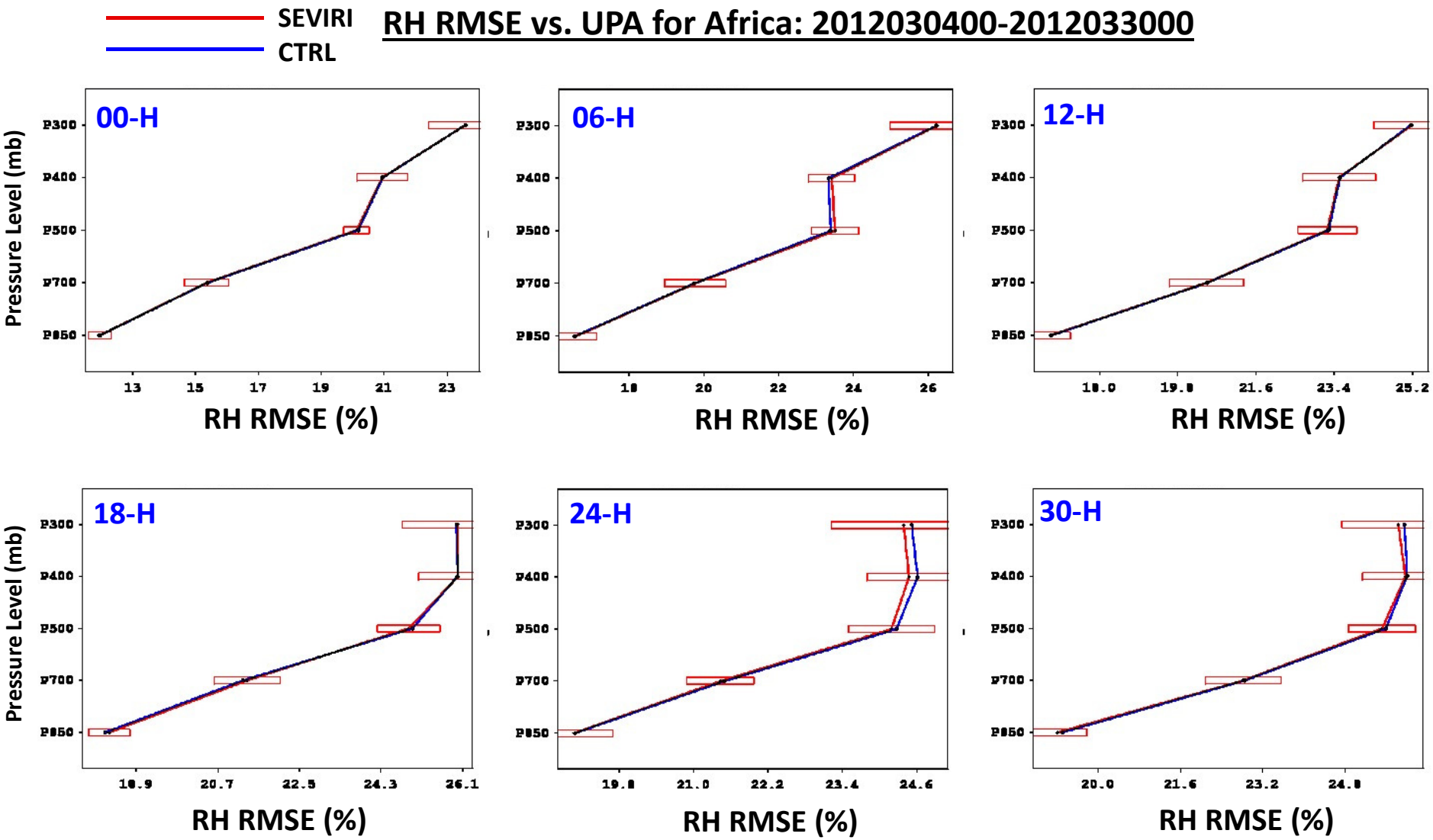
400hPa Specific Humidity Analysis Differences (w/n) SEVIRI



Time Averaged Forecast RMSE for Temperature

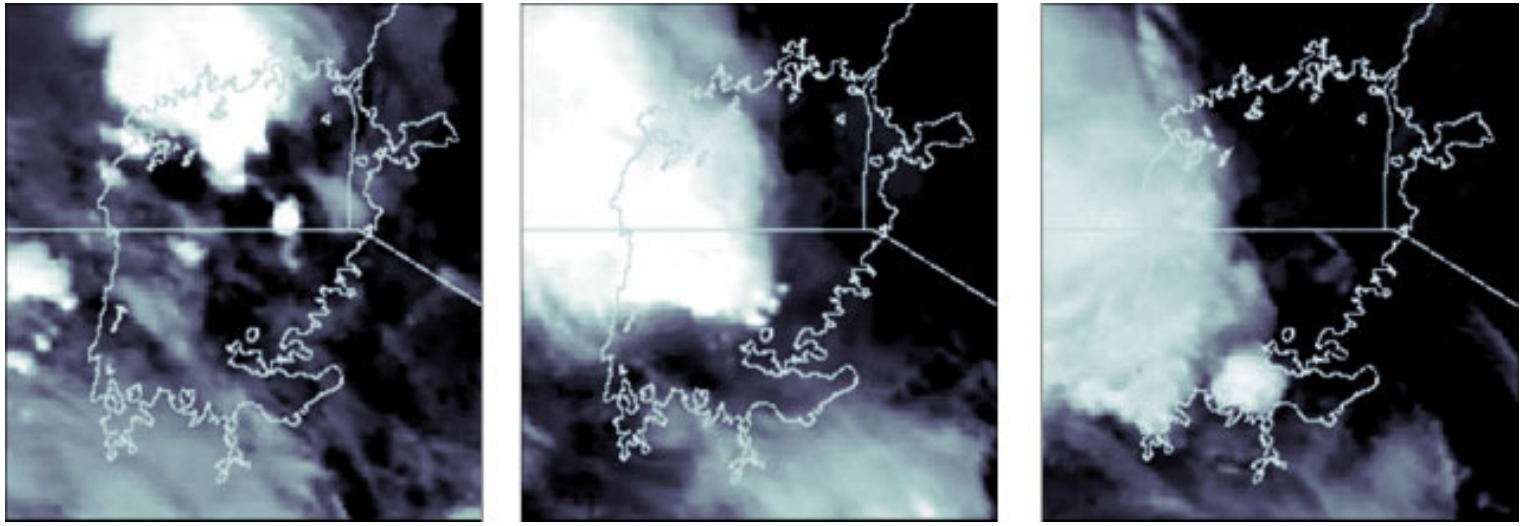


Time Averaged Forecast RMSE for RH



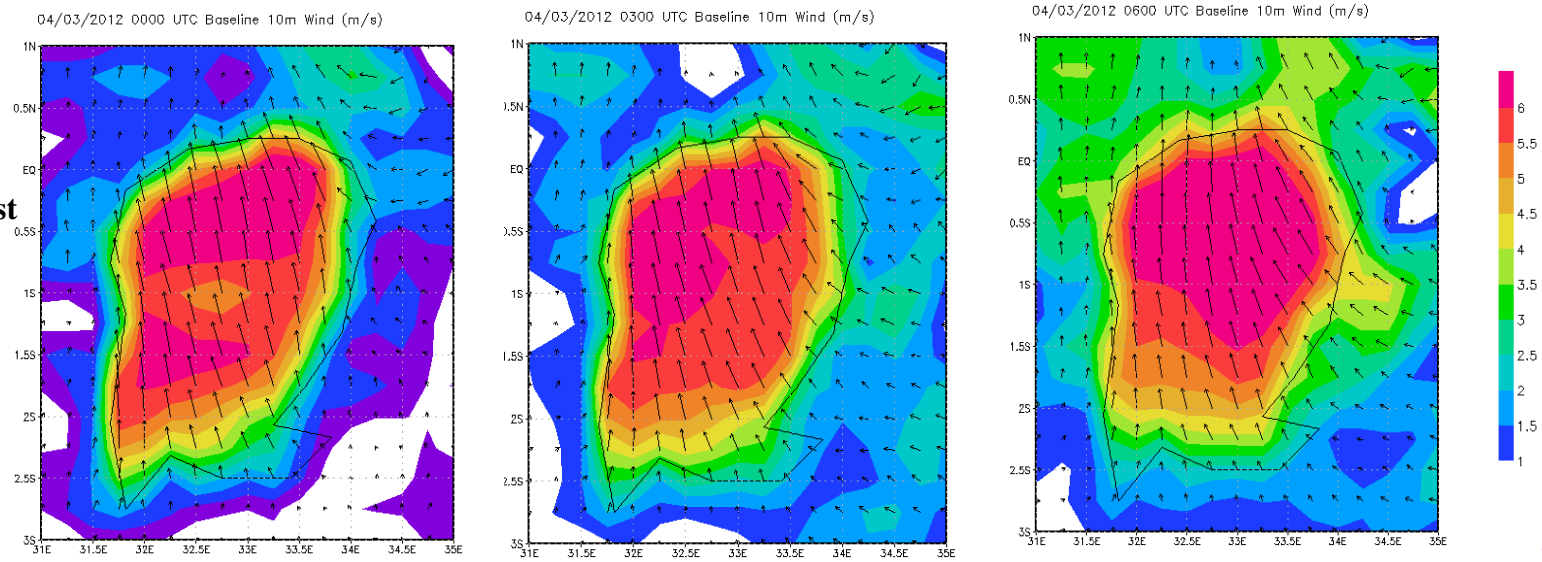
Storm Case

IR 04/03/2012 0000 UTC **IR 04/03/2012 0300 UTC** **IR 04/03/2012 0600 UTC**



Evolution of the storm on 4 March 2012. 10.8 µm infrared images taken by Meteosat (**J.M. Chamberlain et. al. , 2013**)

NAMRR Forecast 10m Wind



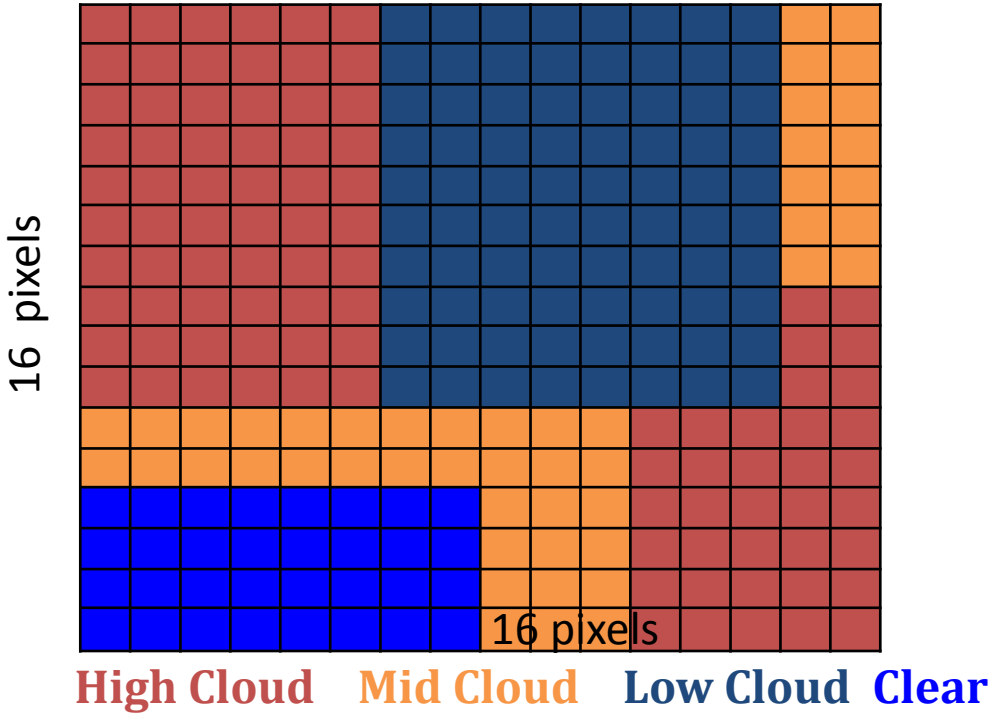
Assimilation of cloudy SEVIRI radiance

- Clear-sky SEVIRI radiance has neutral impact over the Africa 12-km resolution domain.
- To further improve the impact of SEVIRI on regional forecast and the severe storm forecast, the next step is to include cloud information in the analysis.
- Keep using the hourly update system-NAMRR
- Switch SEVIRI clear-sky (CSR) data product to all-sky (ASR) in GSI.
- ASR include total, clear, cloud, low cloud, middle cloud, and high cloud radiance.

Demonstration of EUMETSAT ASR data

ASR is mean BT in a 48km by 48 km square box (16 X 16 pixels);
Bufr files contain average BT for all pixels from WV and IR channels;
Percentage of pixels flagged as clear and cloudy (high, middle, low)

One sample of averaged box



Methodology

- Extend the scheme assimilating cloud-affected AIRS IR radiance developed by NASA/GMAO in GSI to assimilate SEVIRI cloudy radiance.
- Add observation-centered cloud top height as the control variables.

  Consider a control variable at a footprint location over all channels measured at that point
- In addition to modified $\partial T_B/\partial T(p)$, $\partial T_B/\partial q_v(p)$, etc., the minimization now incorporates the CTP Jacobian, $\partial T_B/\partial p_{cld}$.
- Under the greybody assumption, the partially cloudy observation can then be considered for a single, fractional cloud as:

$$I_{cld} = N I_{overcast} + (1-N)\, I_{clear}$$

- GSI IR cloud detection solved the cloud top height and cloud fraction.
- Similar method is already operationally used in ECMWF to assimilate cloud-affected IR radiance from hyperspectral sounders (*i.e.*, AIRS and IASI) and geostationary orbits (*i.e.,* SEVIRI).

Processing of cloudy radiance

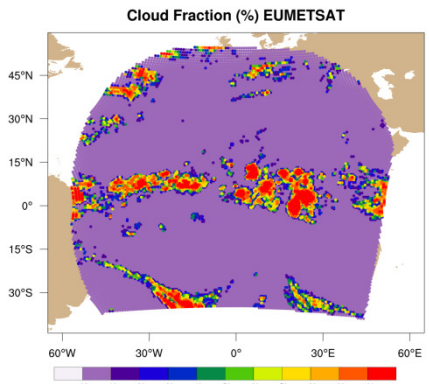
- Only overcast cloud (cloud fraction > 90%) scenes are selected
- Bias correction is consistent between cloudy and clear-sky
- Observation error for SEVIRI cloud is 2.5K consistent with clear-sky
- Quality control for cloud affected SEVIRI is completed at qc_irsnd

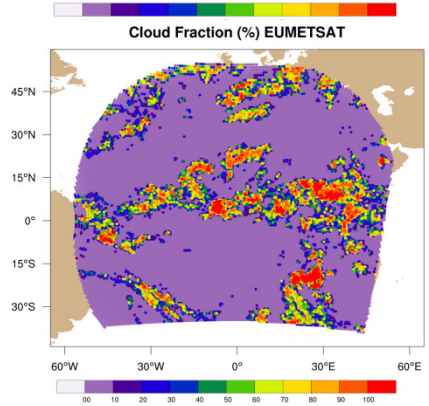
Channel Selections

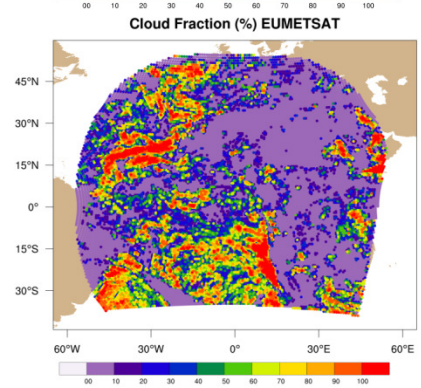
SEVIRI chn #	Wave length (µm)	Assimilated ?	Used in cloud detection
1	IR3.9		
2	WV6.2	**YES**	**YES**
3	WV7.4	**YES**	**YES**
4	IR8.7		**YES**
5	IR9.7		
6	IR10.8		**YES**
7	IR12.0		**YES**
8	IR13.34		**YES**

Cloud fraction validatation

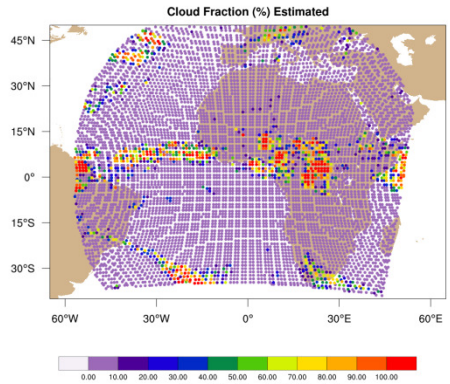
Obs. Cloud Fraction

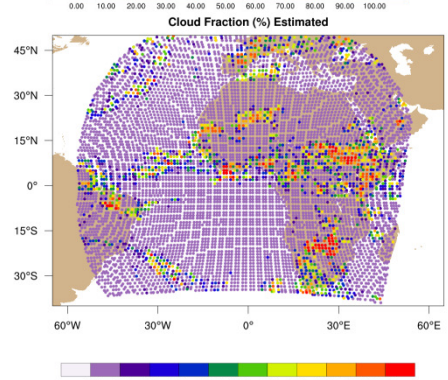


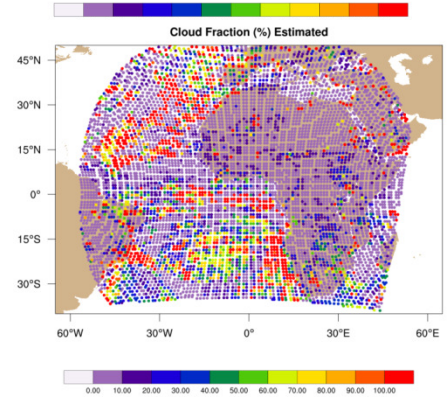




GSI Cloud Fraction







High cloud (above 300hPa)

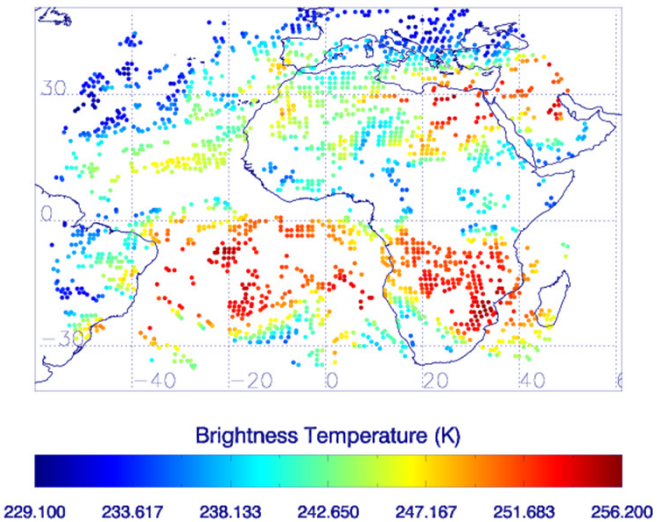
Middle cloud (600-300hPa)

Low cloud (900-600hPa)

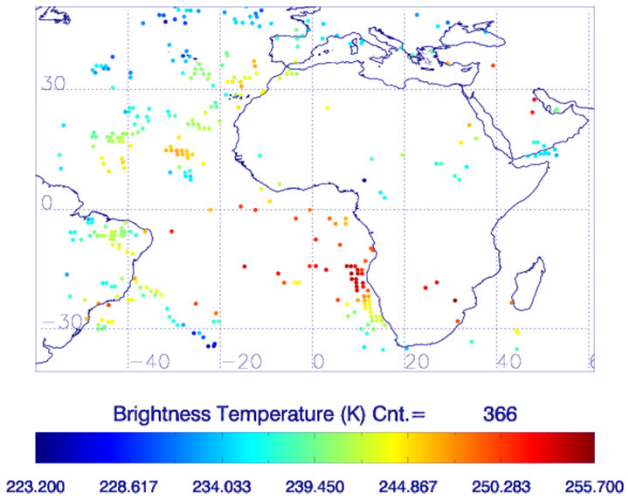
Final selected cloud with the criteria of cloud fraction > 90%

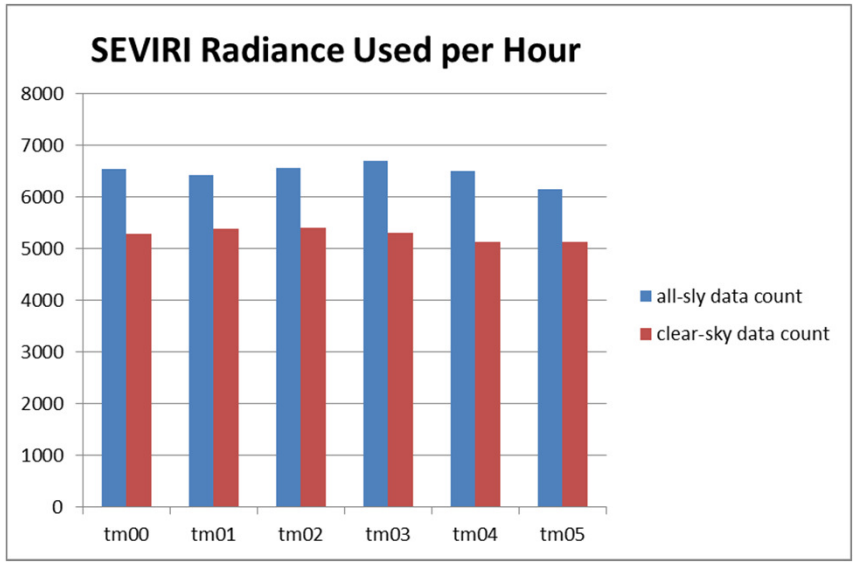
Assimilated SEVIRI clear-sky & cloudy radiance

Clear-sky Brightness Temperature



Cloudy Brightness Temperature

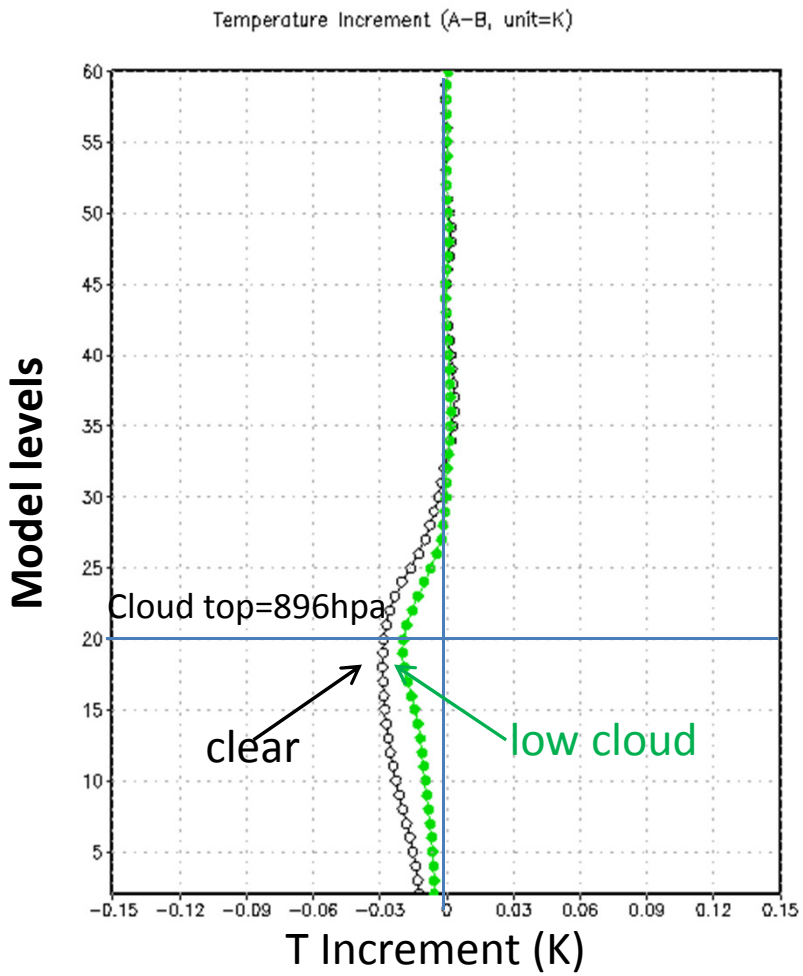




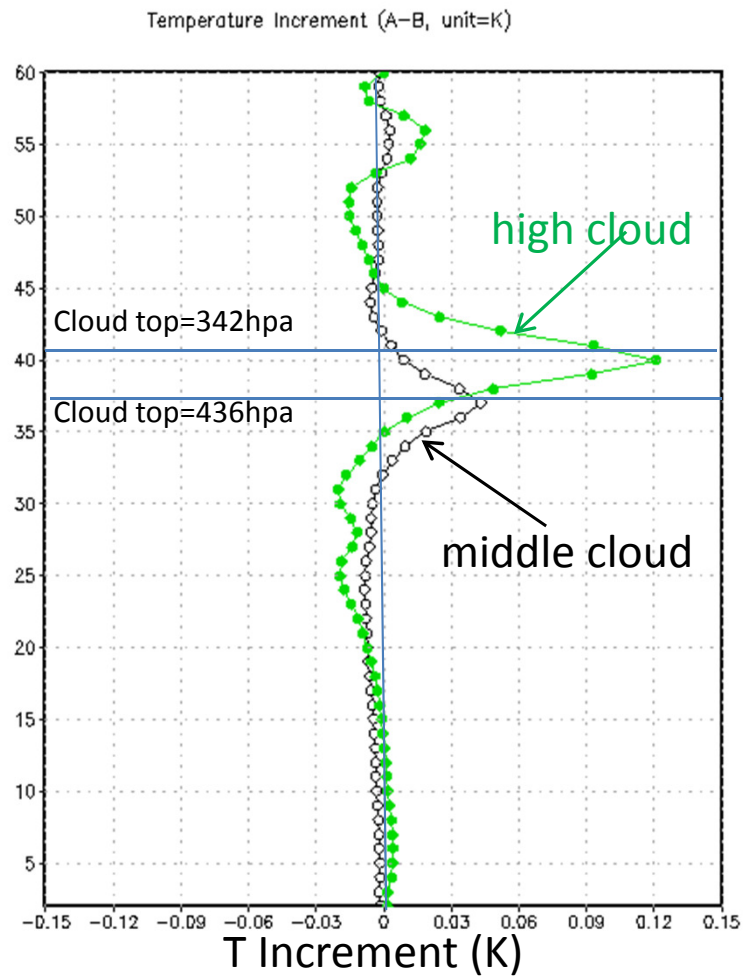
The small amount data increase due to only overcast radiance was selected.

Single Obs. Test-window channel (12.3μm)

Clear-sky and Low Cloud

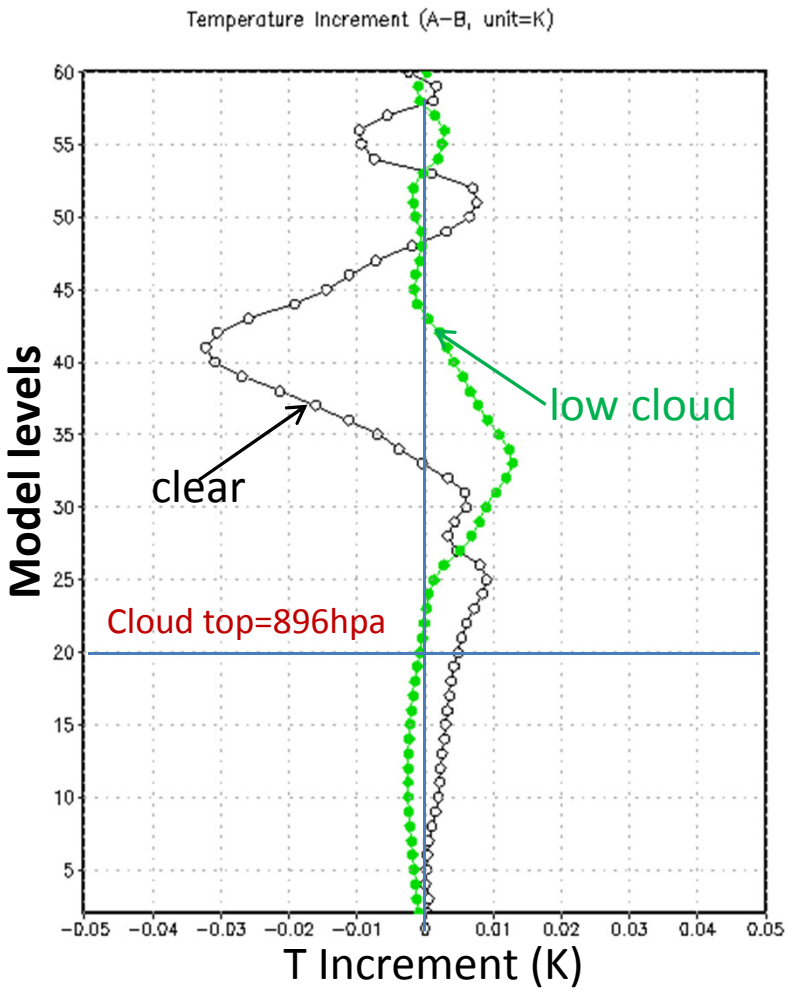


High and Mid cloud

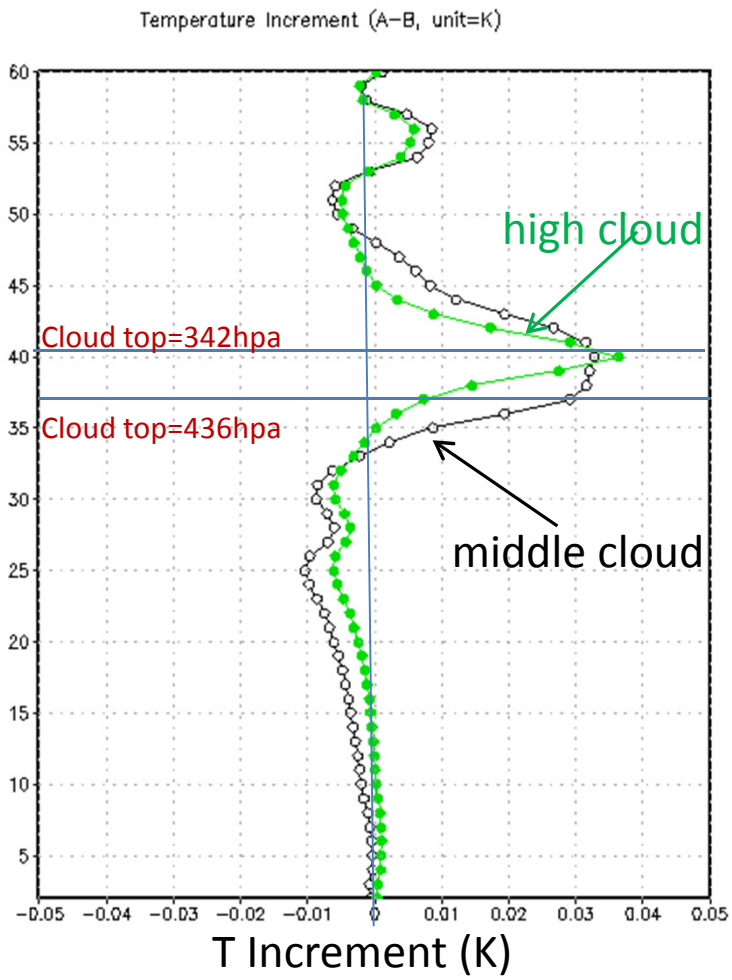


Single Obs. Test-WV channels (6.2 & 7.3 µm)

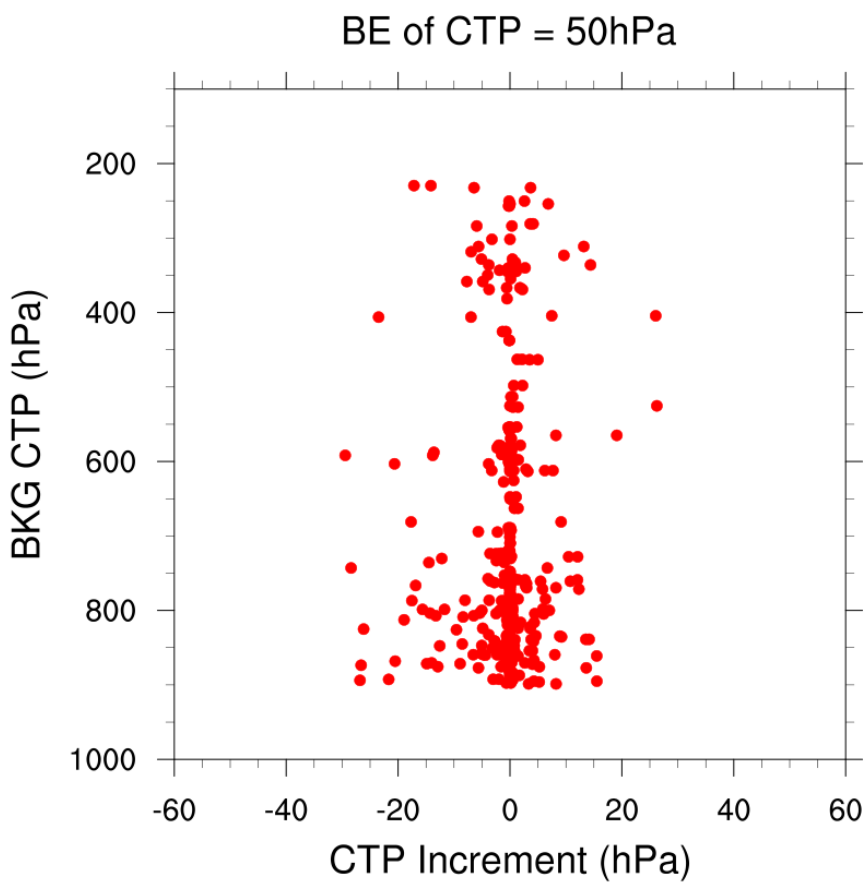
Clear-sky and Low Cloud

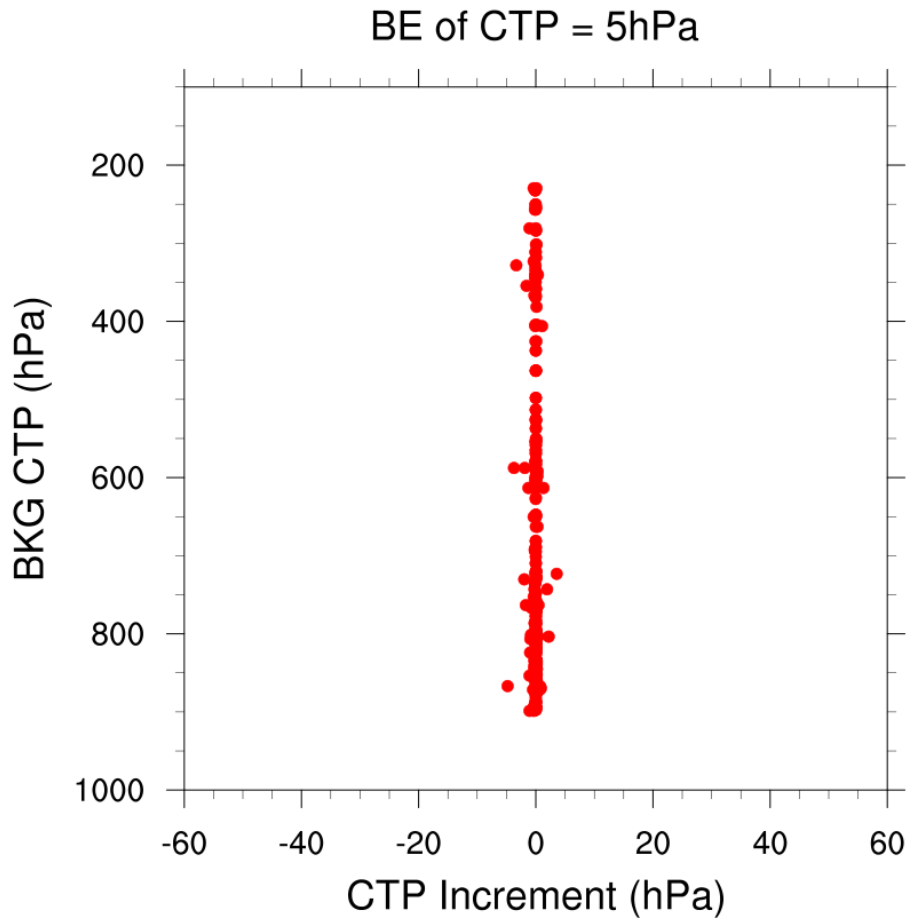


High and Mid cloud



Static BEs for cloud top height





More work will continue on the height dependent BEs.

Summary and Future Plan

- ✓ **Successfully moved NCEP NAMRR system to Africa, 30-day cycle experiment running stable;**
- ✓ **Implemented NCEP operational verification package for NAM to Africa domain;**
- ✓ **Impact of SEVIRI clear-sky radiance in this domain is neutral;**
- ✓ **Implemented cloud-affected SEVIRI radiance assimilation in GSI**

- ➢ **Need more single obs. tests to understand how to use EUMETSAT ASR data properly**
- ➢ **Will work on the height-dependent BEs for cloud top height**
- ➢ **Evaluate the impact of cloud-affected SEVIRI radiance over Africa domain comparing with clear-sky experiment**
- ➢ **Focus on improving the Lake Victoria severe storm case forecast with the assimilation of cloudy SEVIRI radiance, and with high resolution nested domain (i.e., 4/1.33km)**

THANKS !