Utilizing All-sky Satellite Radiance Data to Improve GEOS-5 Clouds, Precipitation, and Water Vapor Analyses and Forecasts

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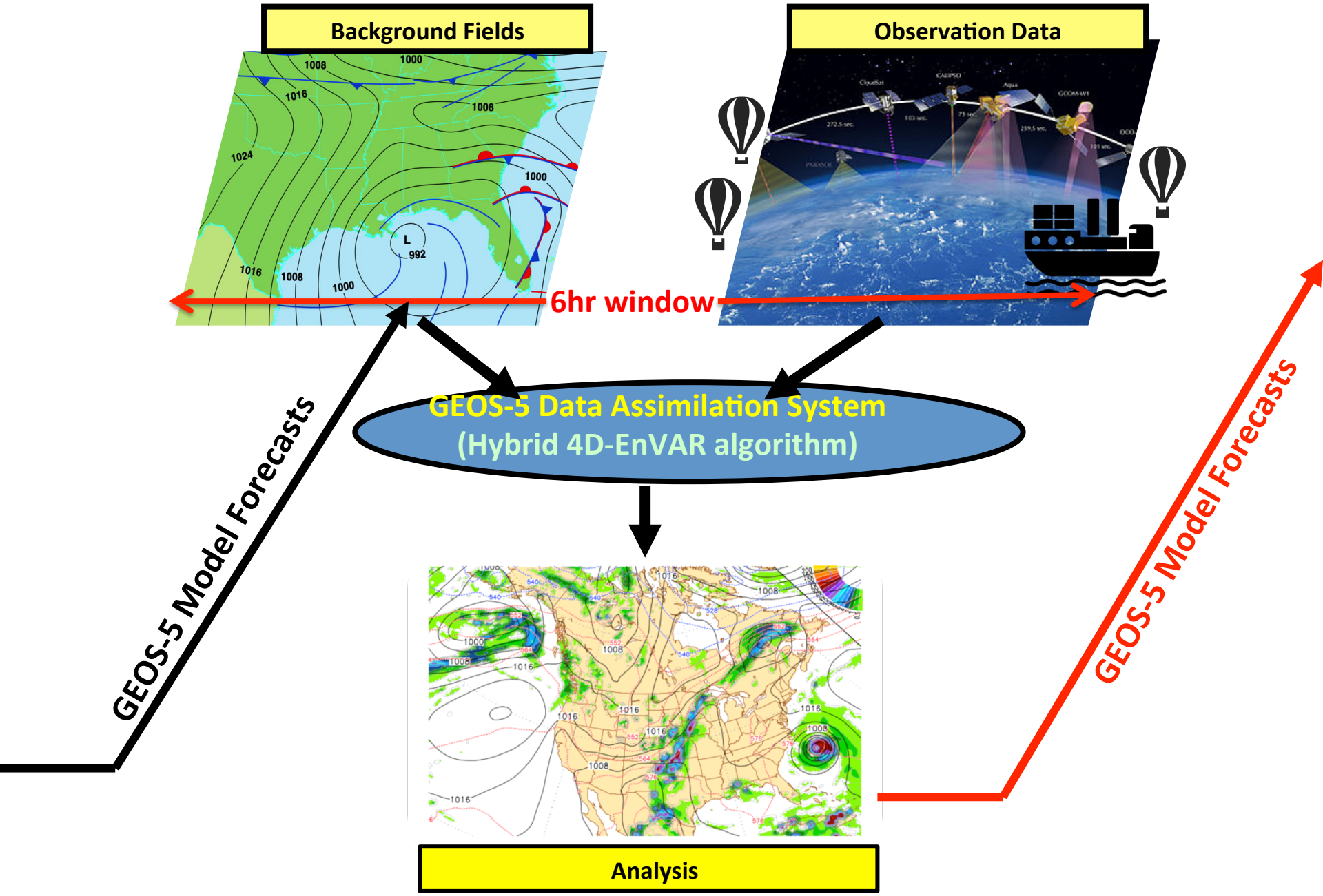
3. SSAI

GEOS-5 Modeled Clouds
(Courtesy of Bill Putman, NASA GMAO)

Outline

- Satellite data assimilation in GEOS-5 analysis system
- Why all-sky satellite radiance data?
- Challenges in developing all-sky data assimilation system
- Impacts of all-sky GPM Microwave Imager (GMI) data on GEOS-5 Clouds, Precipitation, and Water Vapor analyses and forecasts
- Future work

Atmospheric Data Assimilation



Data Currently Assimilated In GEOS-5 System

- AMSU-A (in NOAA 15, 18, 19, Aqua, METOP-A & B AMSU-A)
- MHS (in NOAA 18, METOP-A & B)
- ATMS (in Suomi NPP)
- SSMIS (in DMSP F17, F18)

Passive Microwave Radiometers

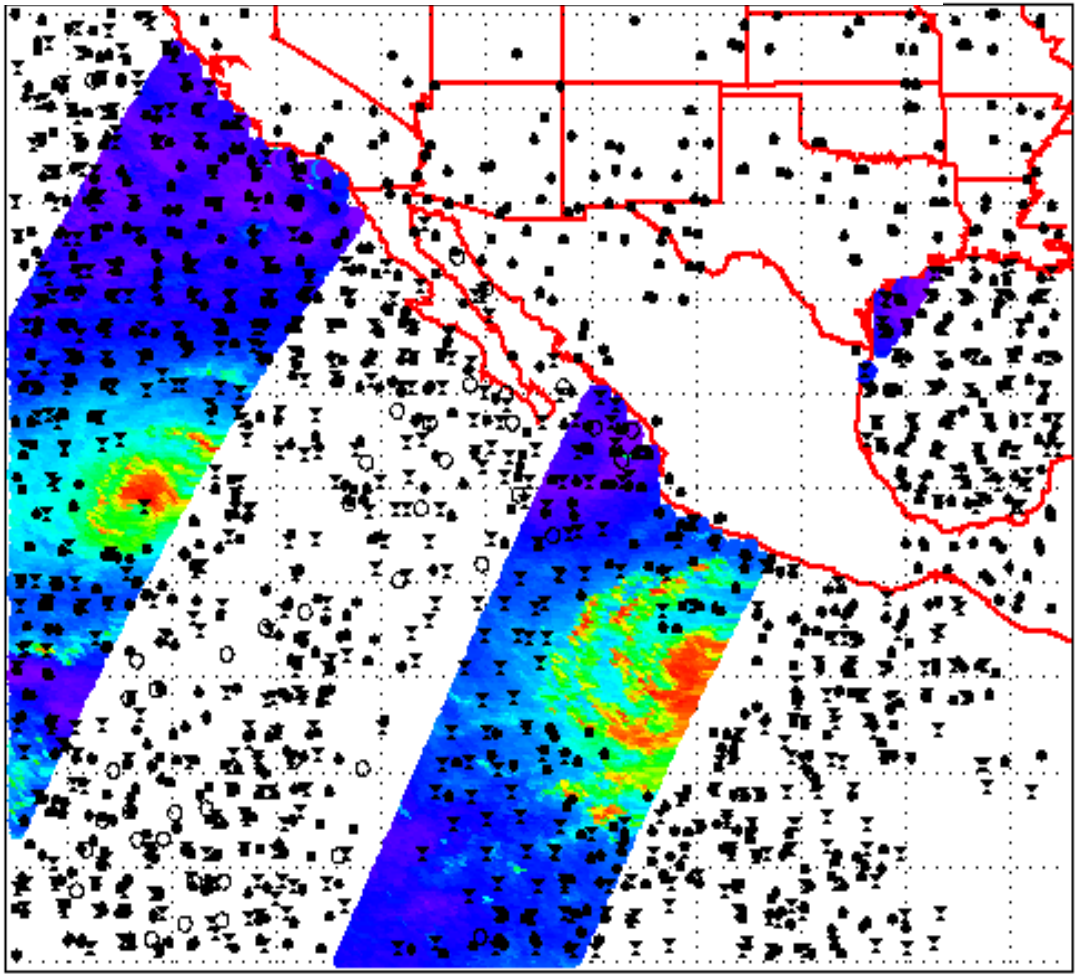
- AIRS (in Aqua)
- IASI (in METOP-A & B)
- HIRS (in METOP-A)
- CrIS (in Suomi NPP)

- SEVIRI (in METEOSAT-10)
- GOES13, GOES15
- GOES-13
- GOES-15

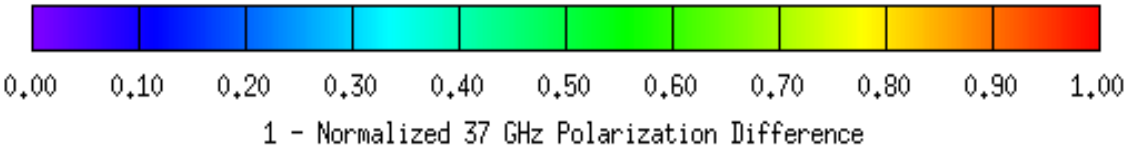
Passive Visible/Infrared Radiometers

- Conventional Data : Sonde, Buoy, Ship data, Aircraft data
- GPS Radio Occultation : refractivity
- SatWind retrieved wind vectors

Motivation and Objectives



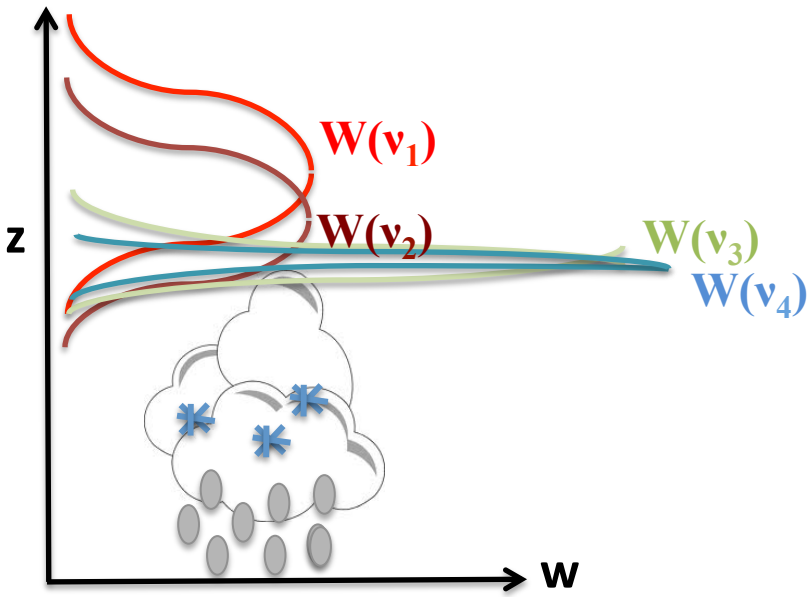
Hurricane Andres and Blanca (6/3/2015, 09Z-15Z)

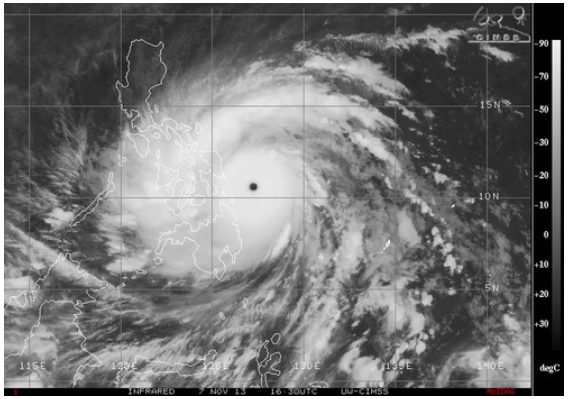


- **Color map: GPM Microwave Imager 37GHz brightness temperature observations**
- **Black symbols: Locations of lower/ middle troposphere observing satellite data from AMSU-A, MHS, and AIRS that are currently assimilated in the GEOS-5 FP system**
- **Large number of radiance data containing cloud and precipitation signal are currently discarded.**
- **We want to improve NWP initial conditions especially in cloudy and precipitating regions by assimilating satellite data in these regions.**

Satelle Radiance Observations in Cloudy/Precipitating Sky Condition

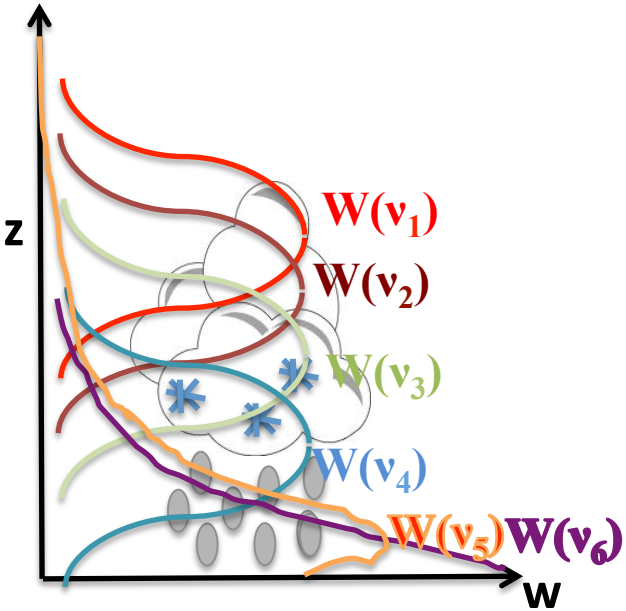
IR sensors

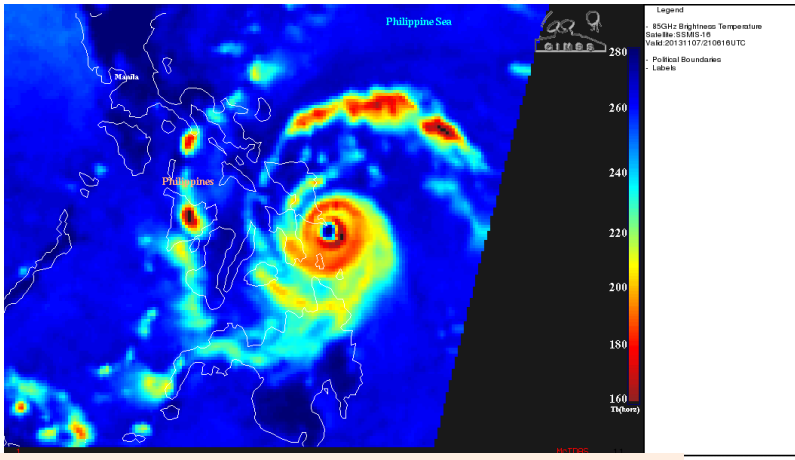




Indirect estimation of precipitation using information from the cloud top.

Microwave sensors





- Poor temporal and horizontal resolution
- Long wavelengths allow microwave signals directly interact with precipitating particles.

Challenges: Assimilation of Satellite Radiance Data

$$x_{analysis} = x_{bkg} + \mathbf{K}\,(y_{obs} - H(x_{bkg}))$$

"Observation operator"
(a radiative transfer model) converting *model space* into *observation space*

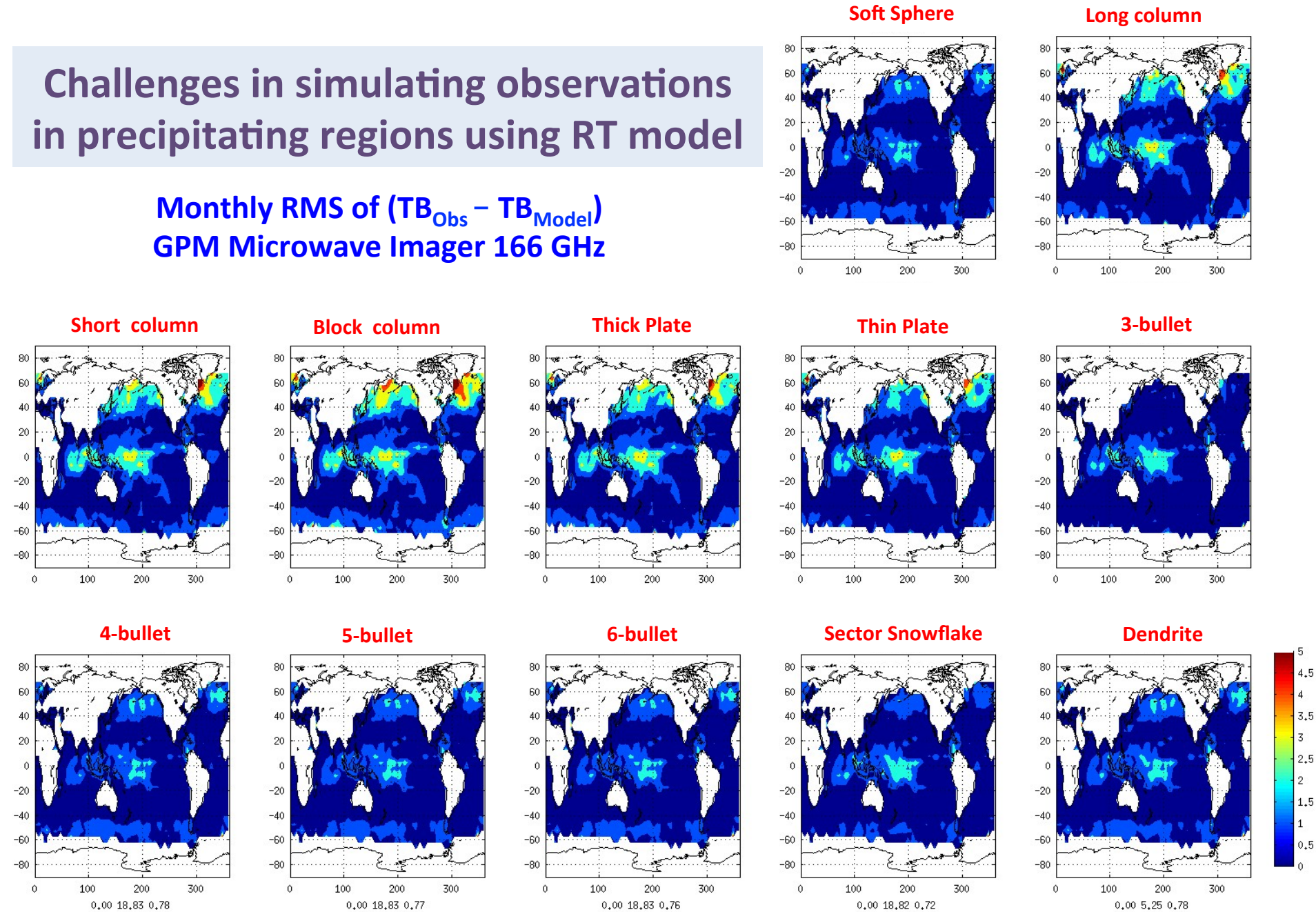
$$K = \frac{\sigma^2_{bkg}}{\sigma^2_{bkg} + \sigma^2_{obs}}$$

B: background error variance

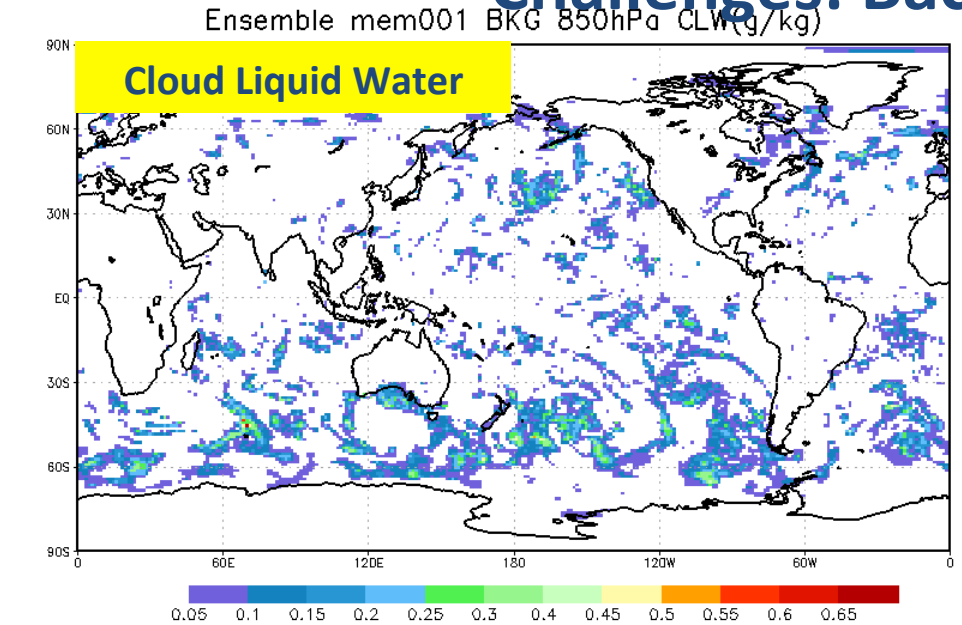
R: Observation error variance

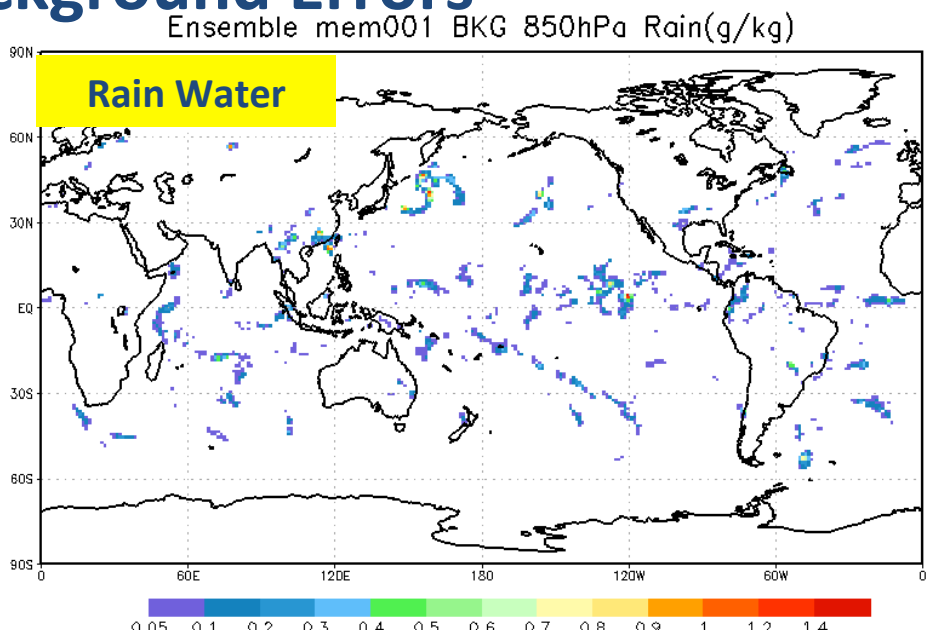
Challenges in simulating observations in precipitating regions using RT model

Monthly RMS of ($TB_{Obs} - TB_{Model}$)
GPM Microwave Imager 166 GHz

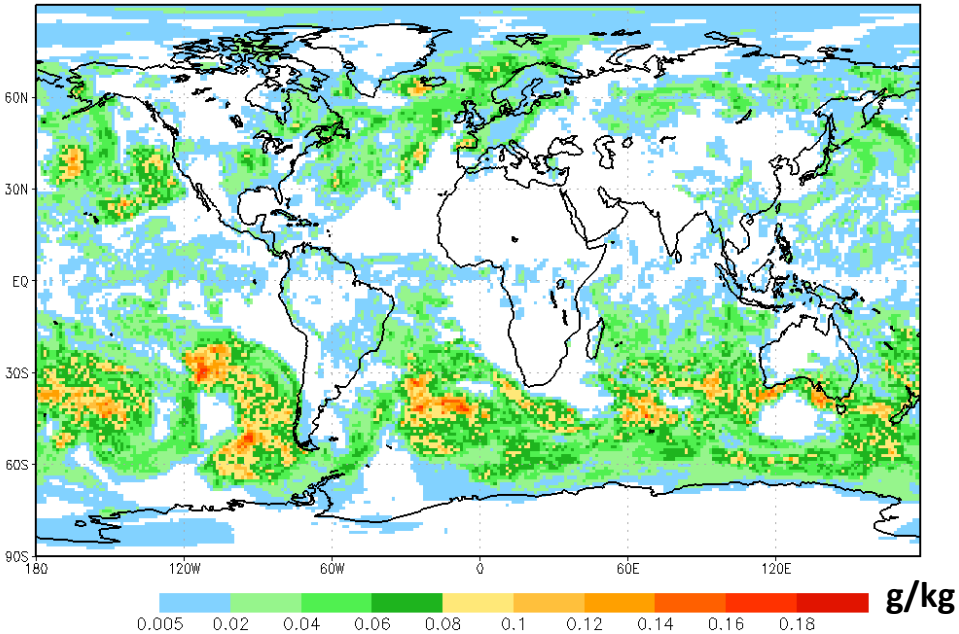


Challenges: Background Errors

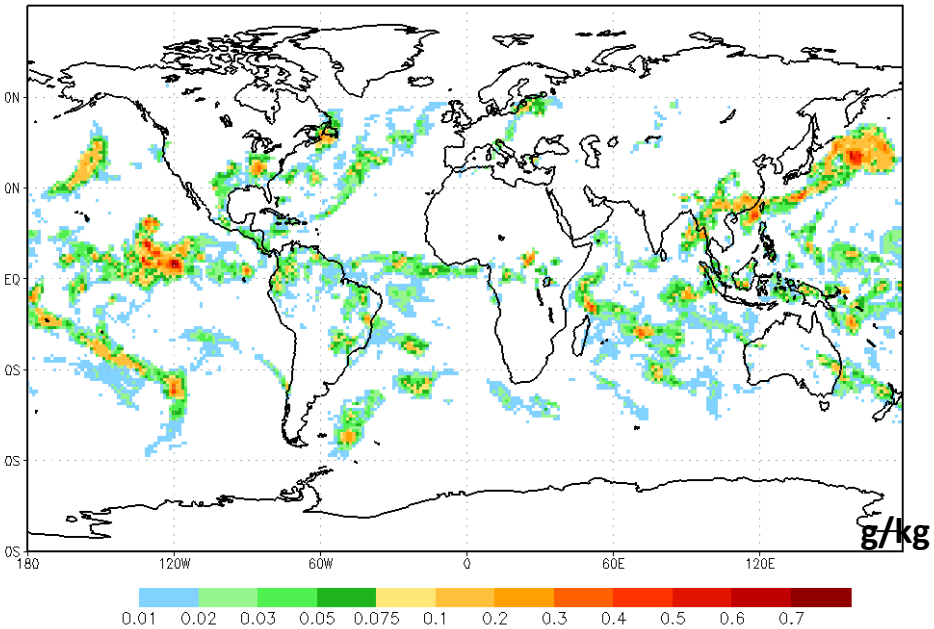




STD of Cloud Liquid at 850 hPa

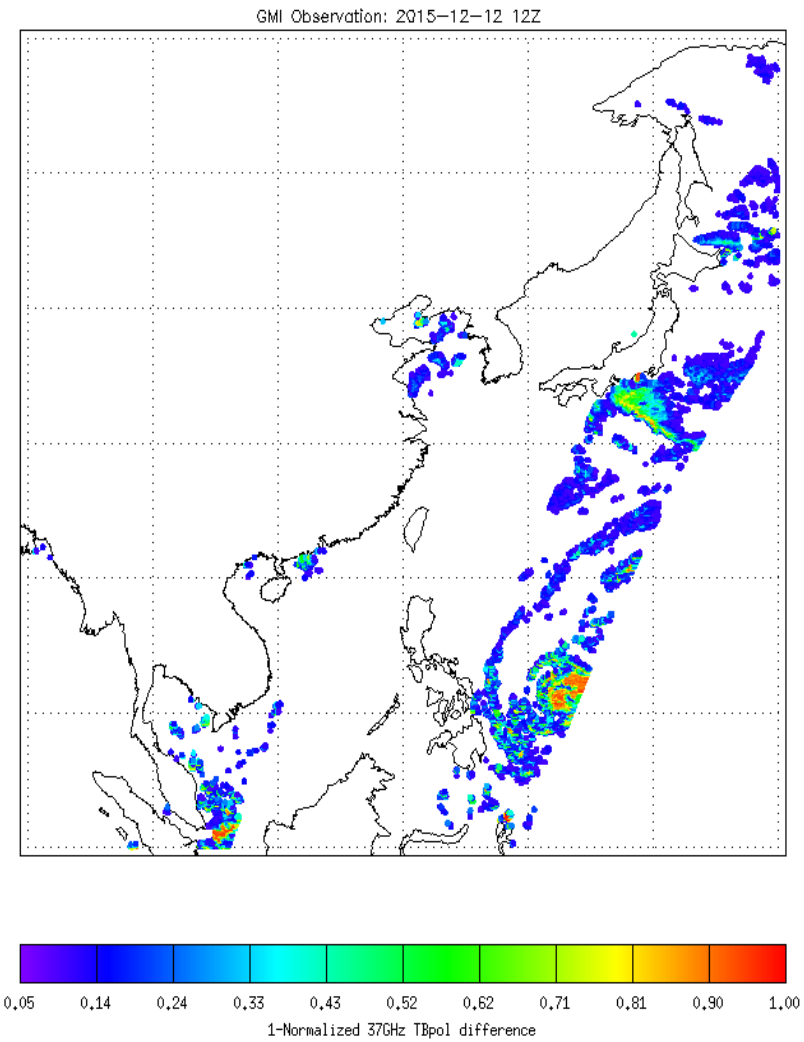


STD of Rain Water at 850 hPa

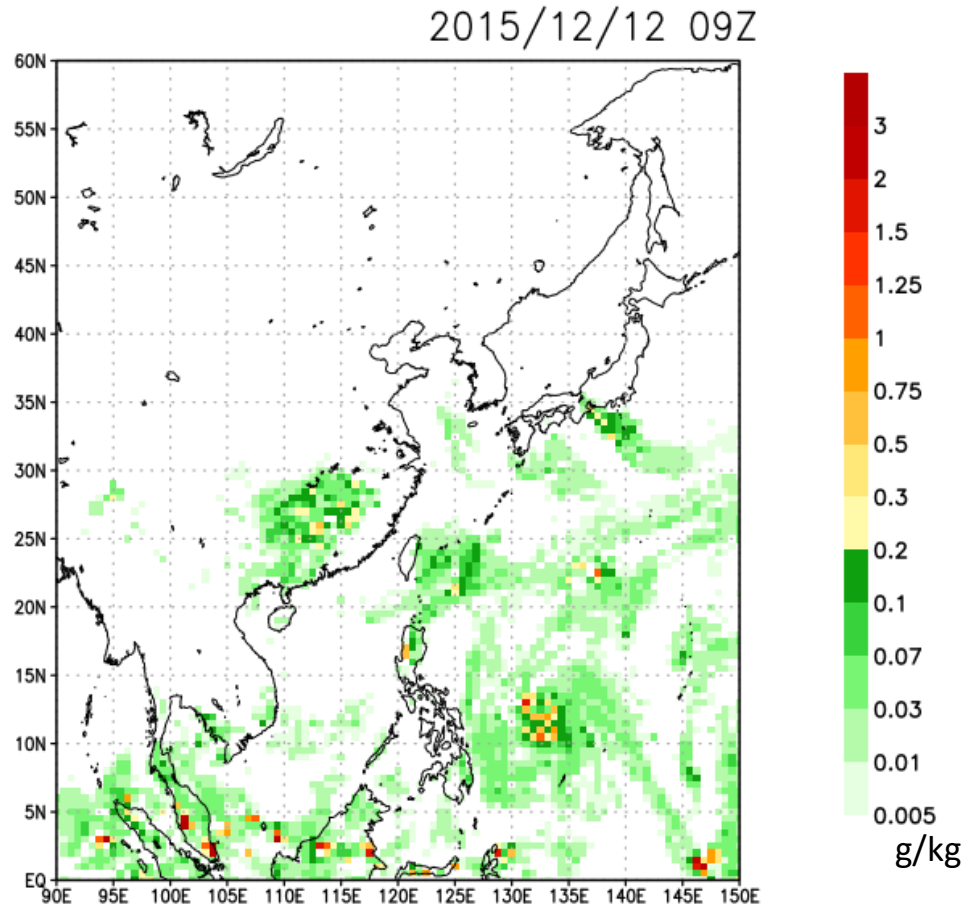


Case Study: Hurricane Melor (Dec 2015)

GMI Observations



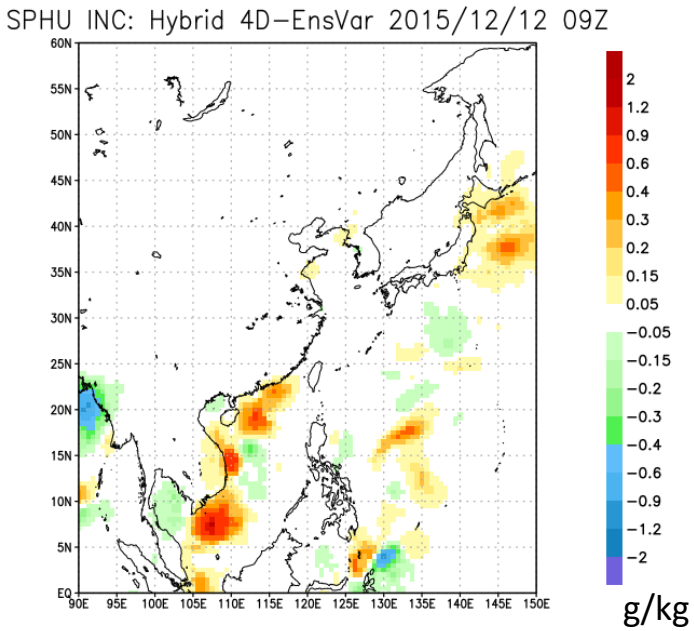
GEOS-5 forecast: 850hPa Rainwater

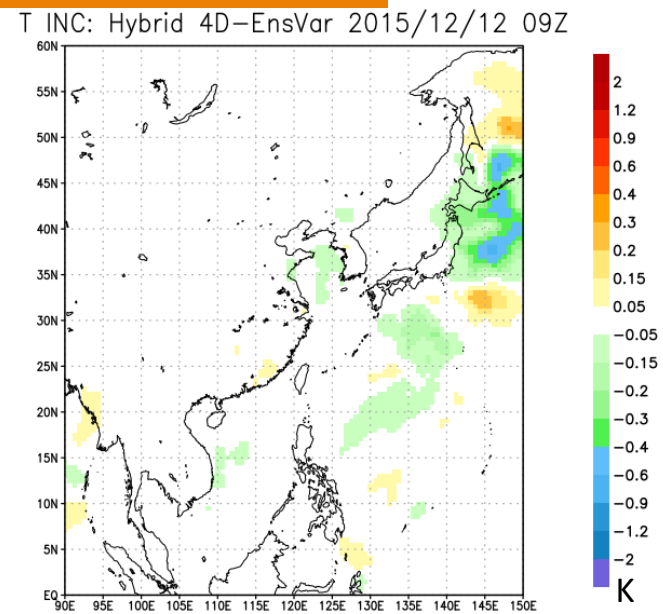


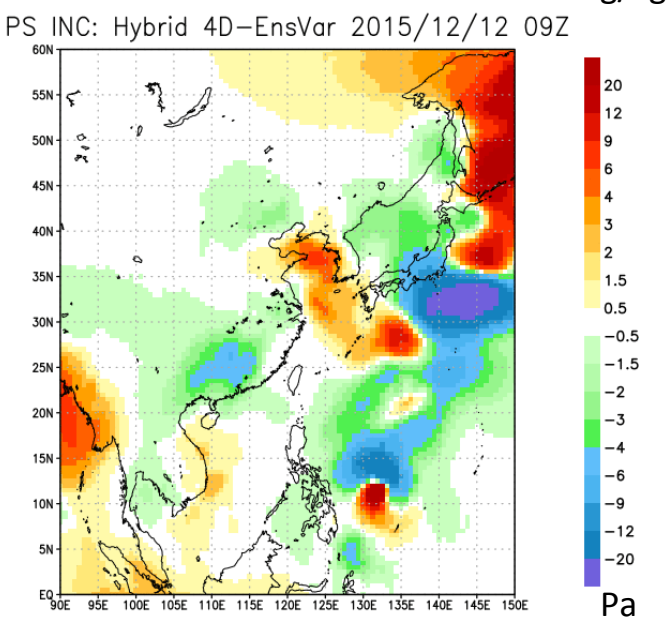
2015-12-12: 09Z~15Z

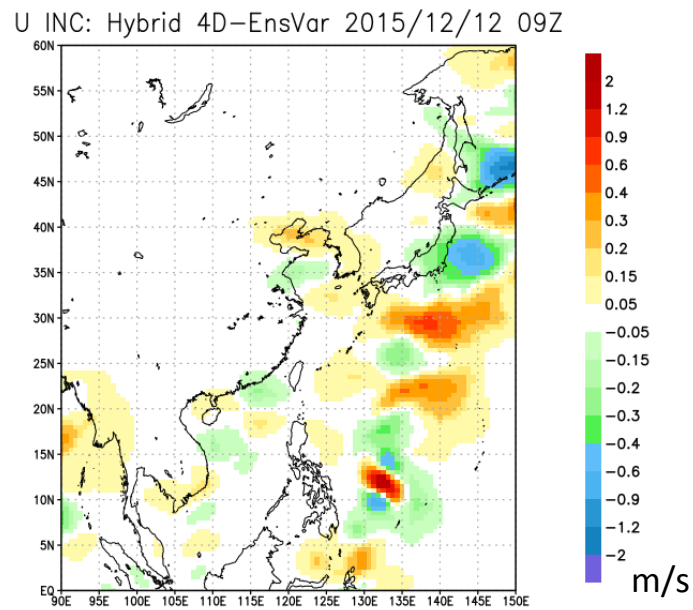
Case Study: Hurricane Melor (Dec 2015)

Analysis - Background



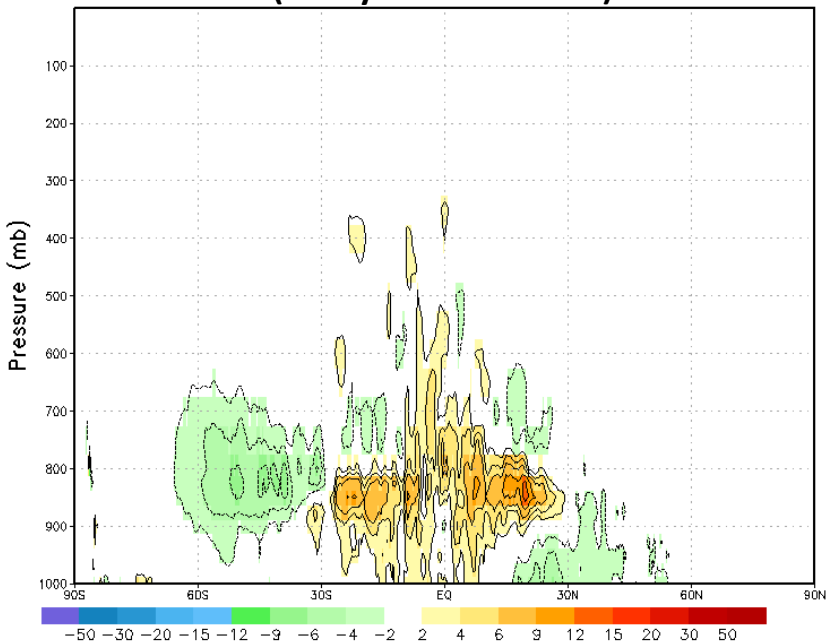




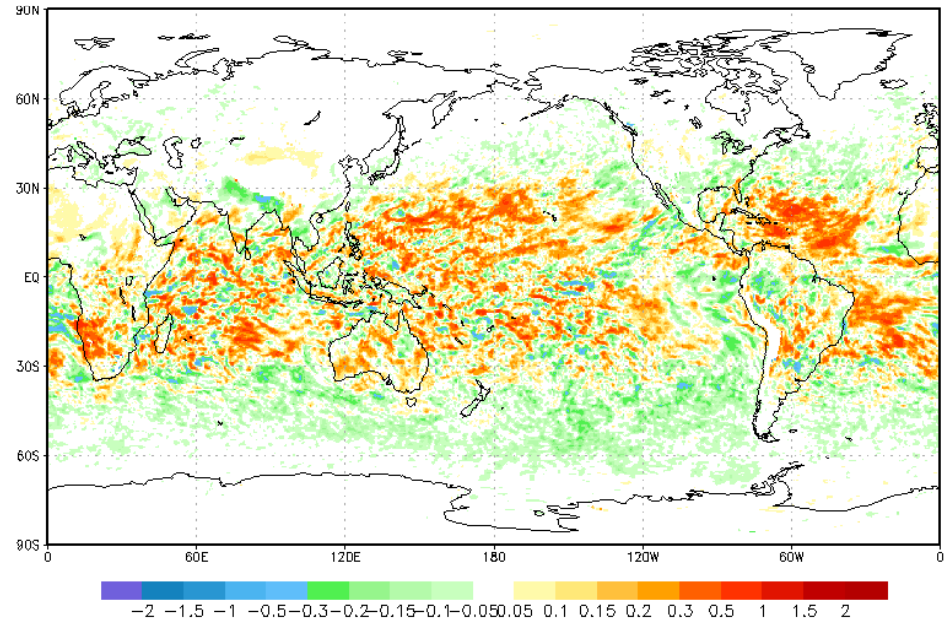


Comparisons of Water Vapor Analyses

Difference of Monthly Zonal Mean Specific Humidity (Allsky GMI – NoGMI)

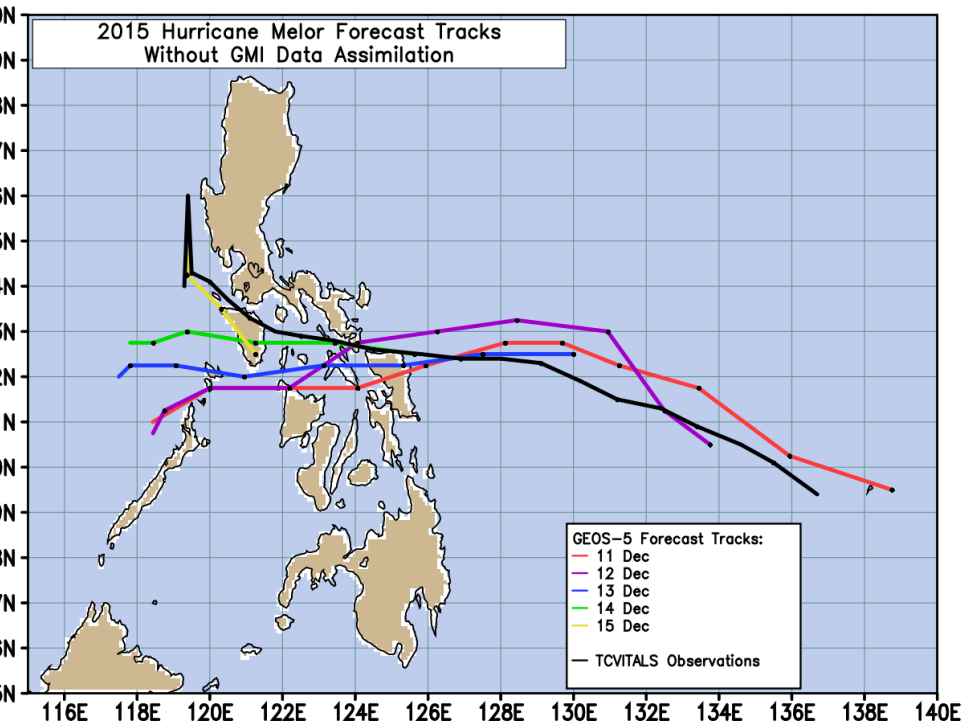


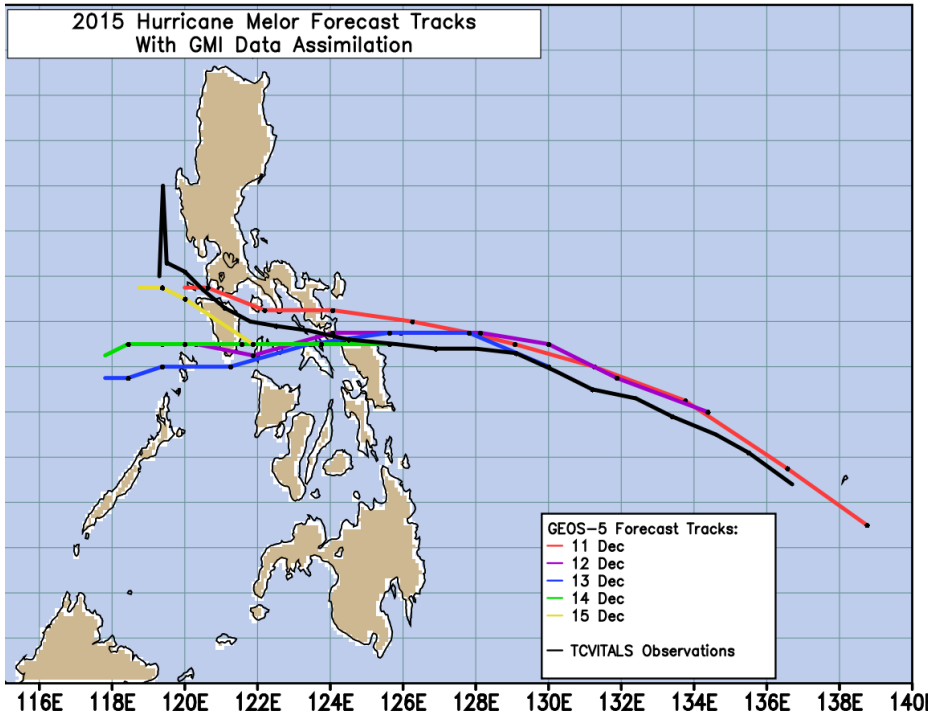
Difference of Monthly Mean 850hPa Specific Humidity (AllskyGMI – NoGMI)



- All-sky GPM Microwave Imager (GMI) data increase lower tropospheric humidity in the GEOS analyses.
- The data generally have a significant impact on the lower tropospheric humidity and temperature analyses, especially in the tropics, which leads to improved forecasts of these quantities

Impact on Hurricane Track (Merlor, Dec 2015)





- In addition, a noticeable positive impact of all-sky GPM Microwave Imager (GMI) assimilation on hurricane track forecasts was identified for Hurricane Melor, which occurred in the western Pacific during Dec. 2015.

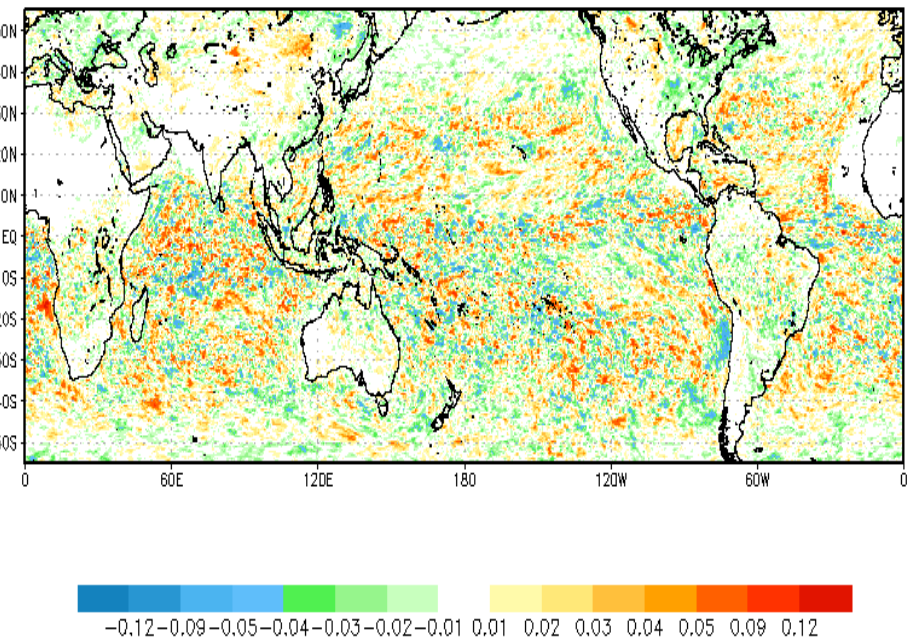
- More hurricane case studies to understand the impacts of all-sky radiance data are underway.

Comparisons of GEOS-5 Cloud Analyses

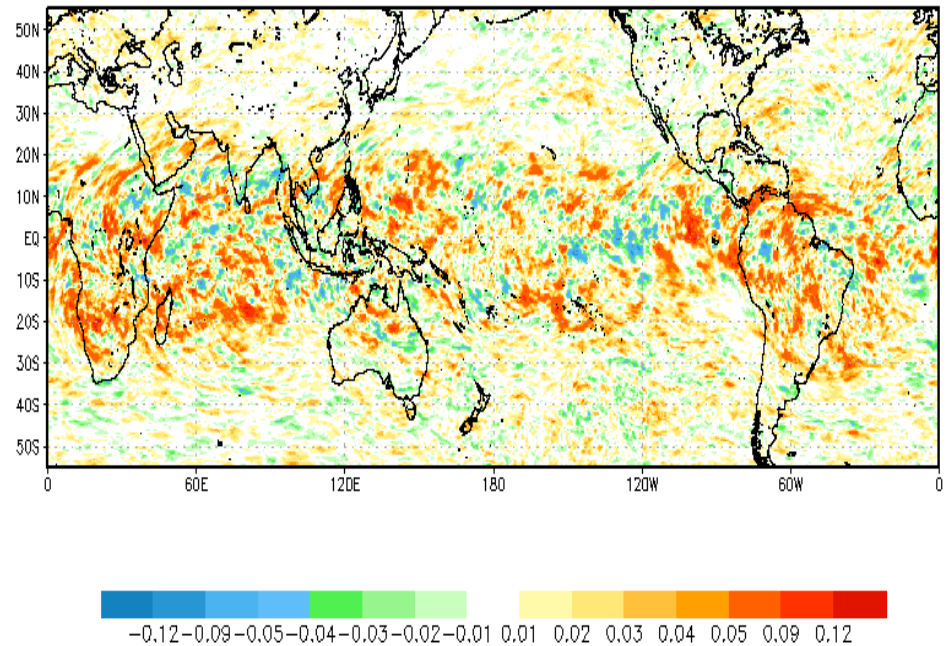
Monthly Mean Cloud Fraction Difference

$CloudFrac_{AllskyGMI} - CloudFrac_{NoGMI}$

Low Cloud



High Cloud



December 2015

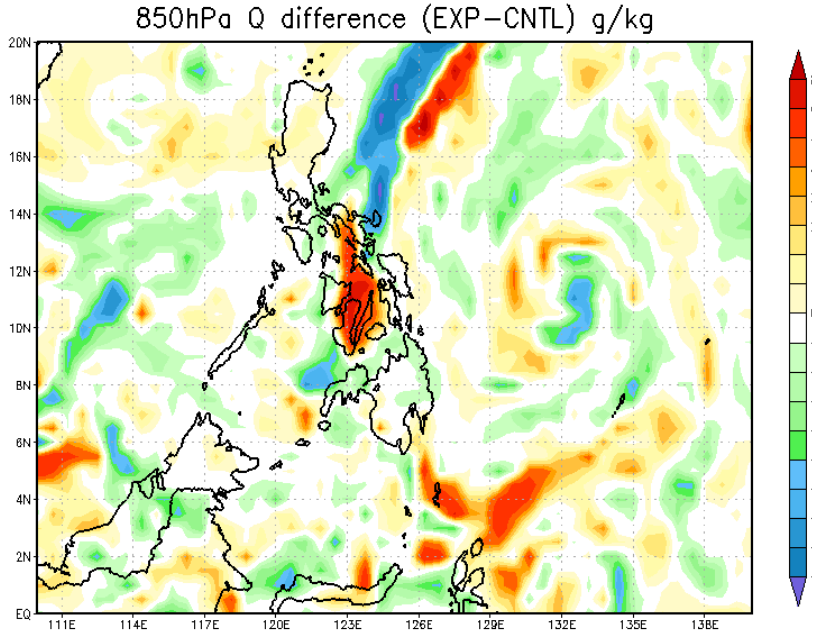
Noticeable impact of all-sky GPM Microwave Imager (GMI) assimilation on cloud fraction especially for middle and high cloud during Dec. 2015.

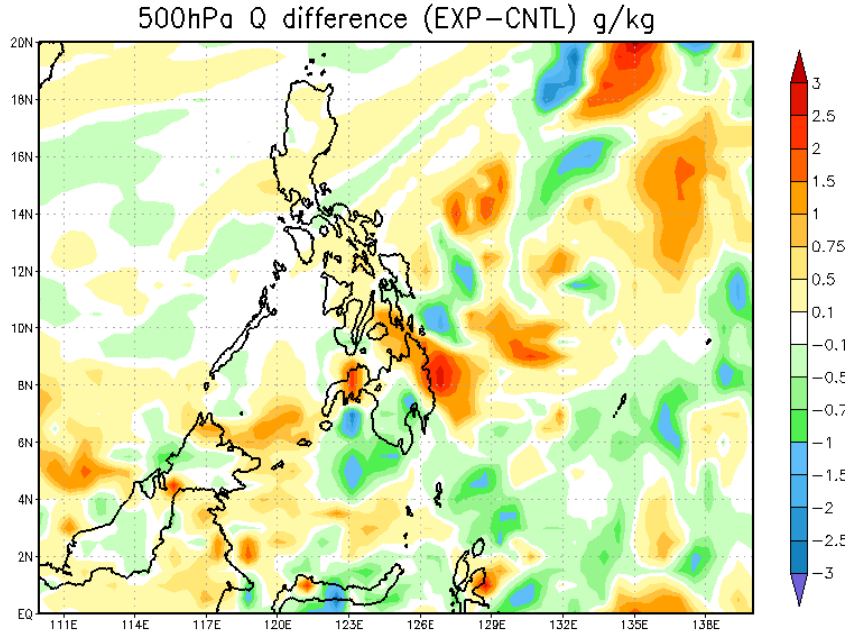
Work in Progress and Future Plans

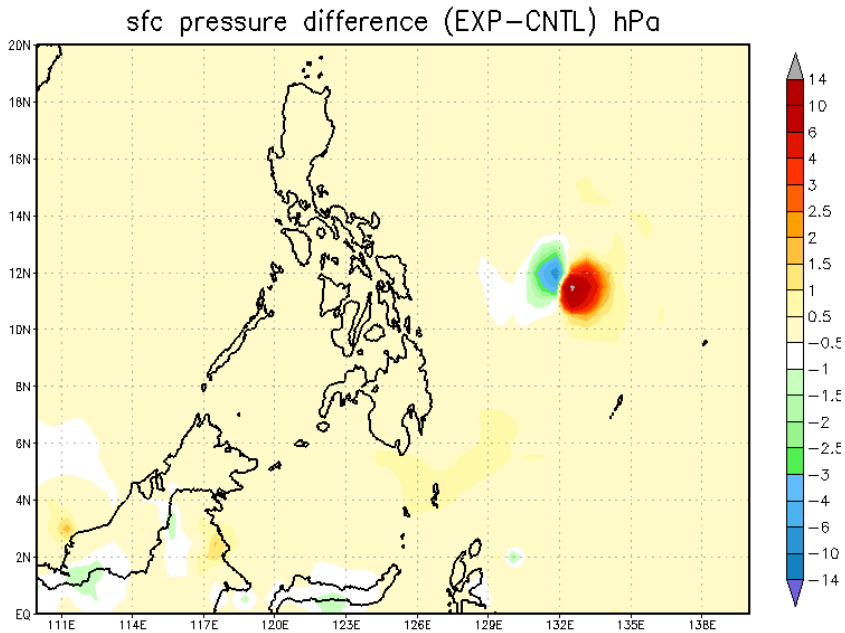
- Apply all-sky framework to all other microwave observations such as AMSR-2, MHS, AMSU-A, ATMS, …
- Extending to IR radiance data and active sensors' data such as reflectivity data from CloudSat and GPM Dual Frequency Rada (DPR).
- Incorporate updates of CRTM into All-sky data framework which will allow to utilize **Cloud Fraction from GEOS-5 Microphysics** in simulating satellite radiances
- And more …

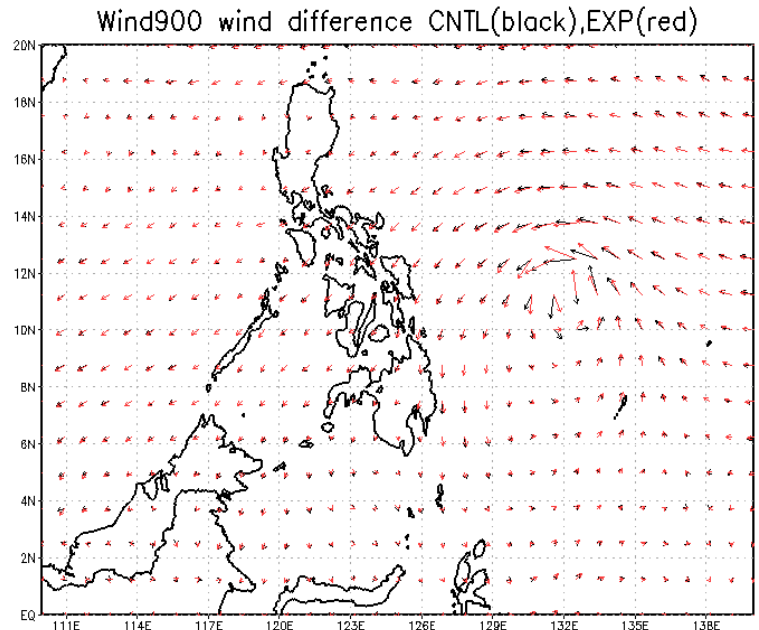
Back-up Slides

Difference of Analyses (Exp – Control) : 12 Dec 2015, 12UTC



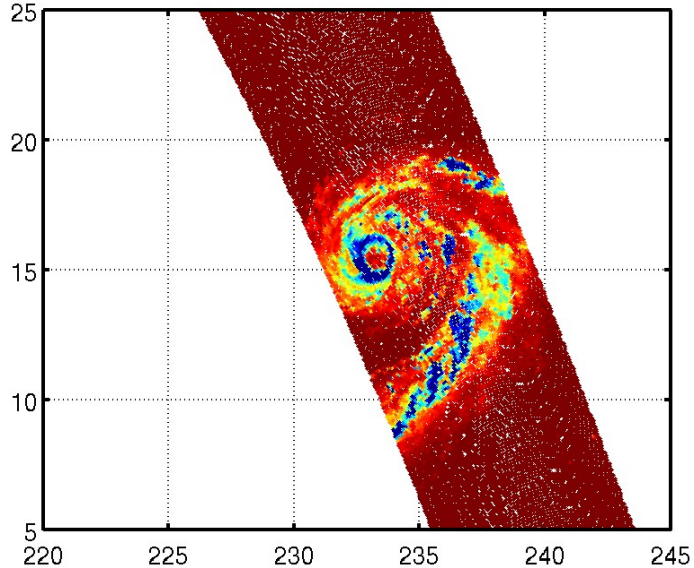




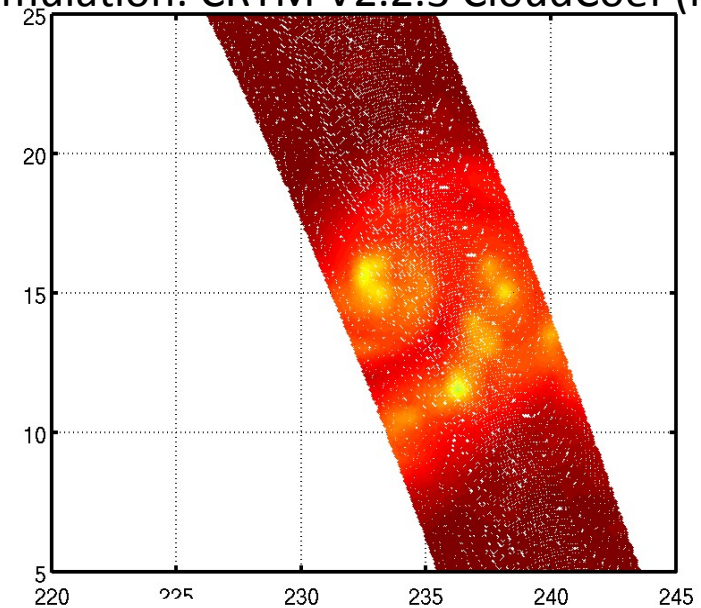


Comparisons of Simulated GMI TBs

Observation: GMI 166 GHzV TB

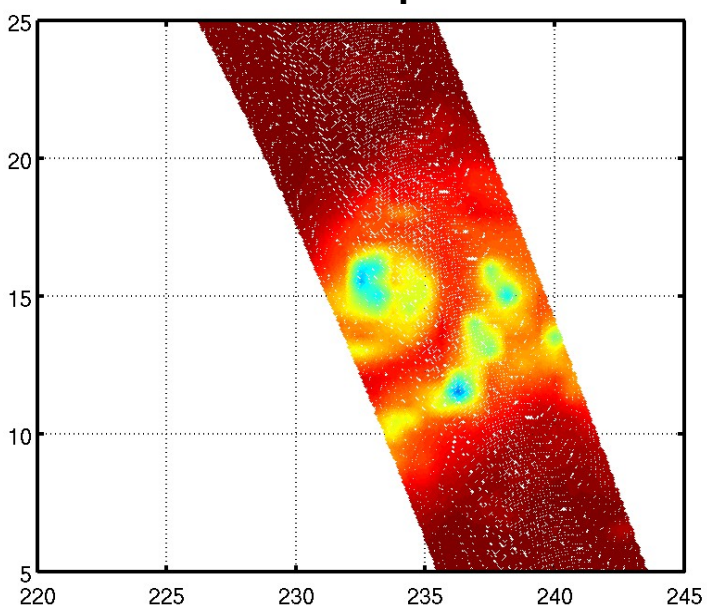


Simulation: CRTM V2.2.3 CloudCoef (Mie)



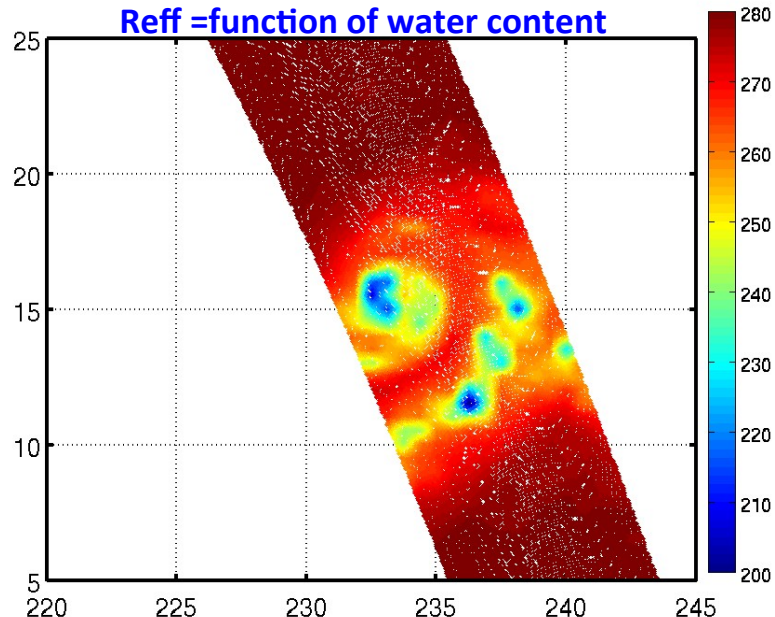
Simulation: CRTM V2.2.3 CloudCoef (DDA)

Reff= 1000µm



Simulation: 3-bullet (DDA)

Reff =function of water content



NASA GPM Microwave Imager (GMI): 13 Channels

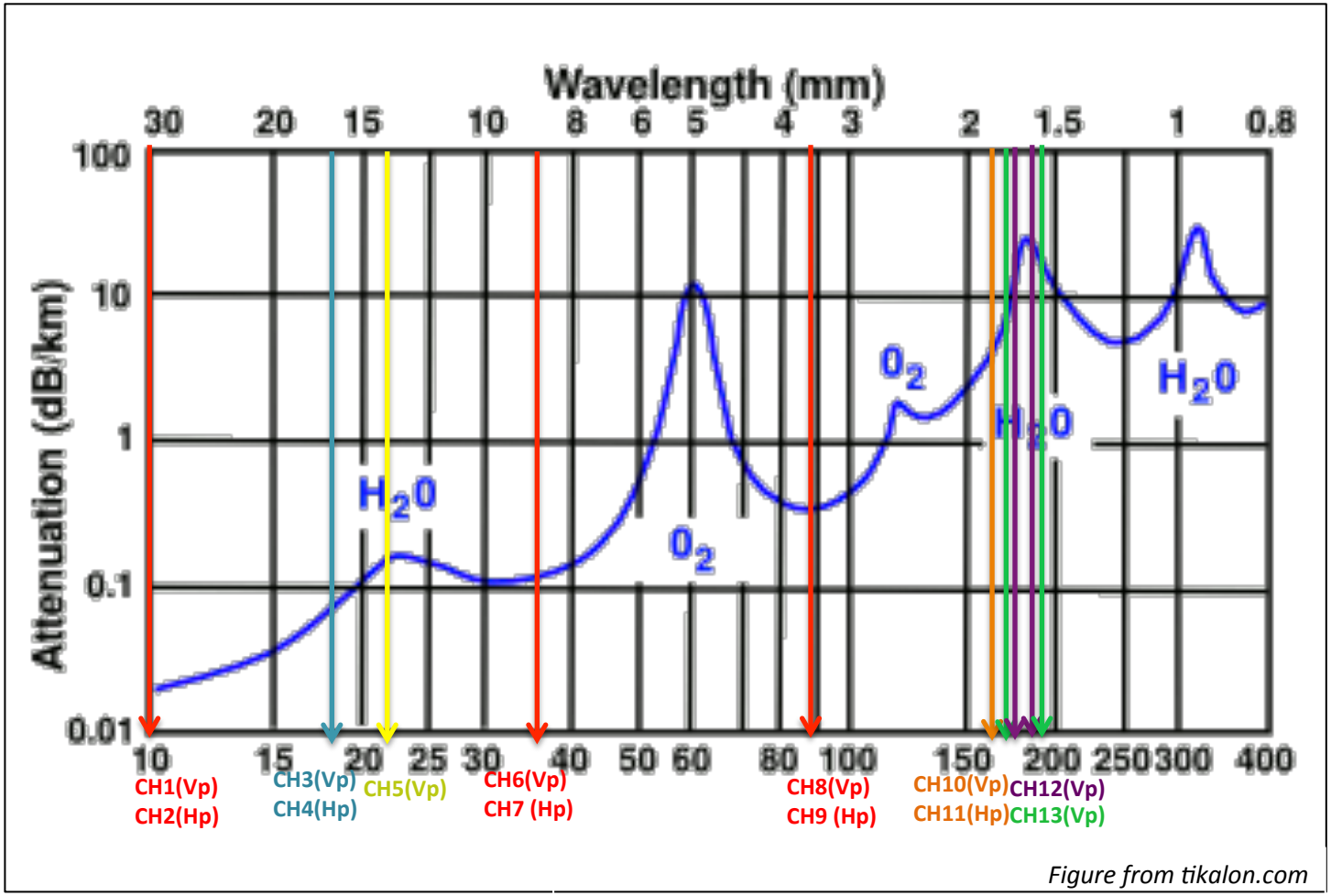


Figure from tikalon.com

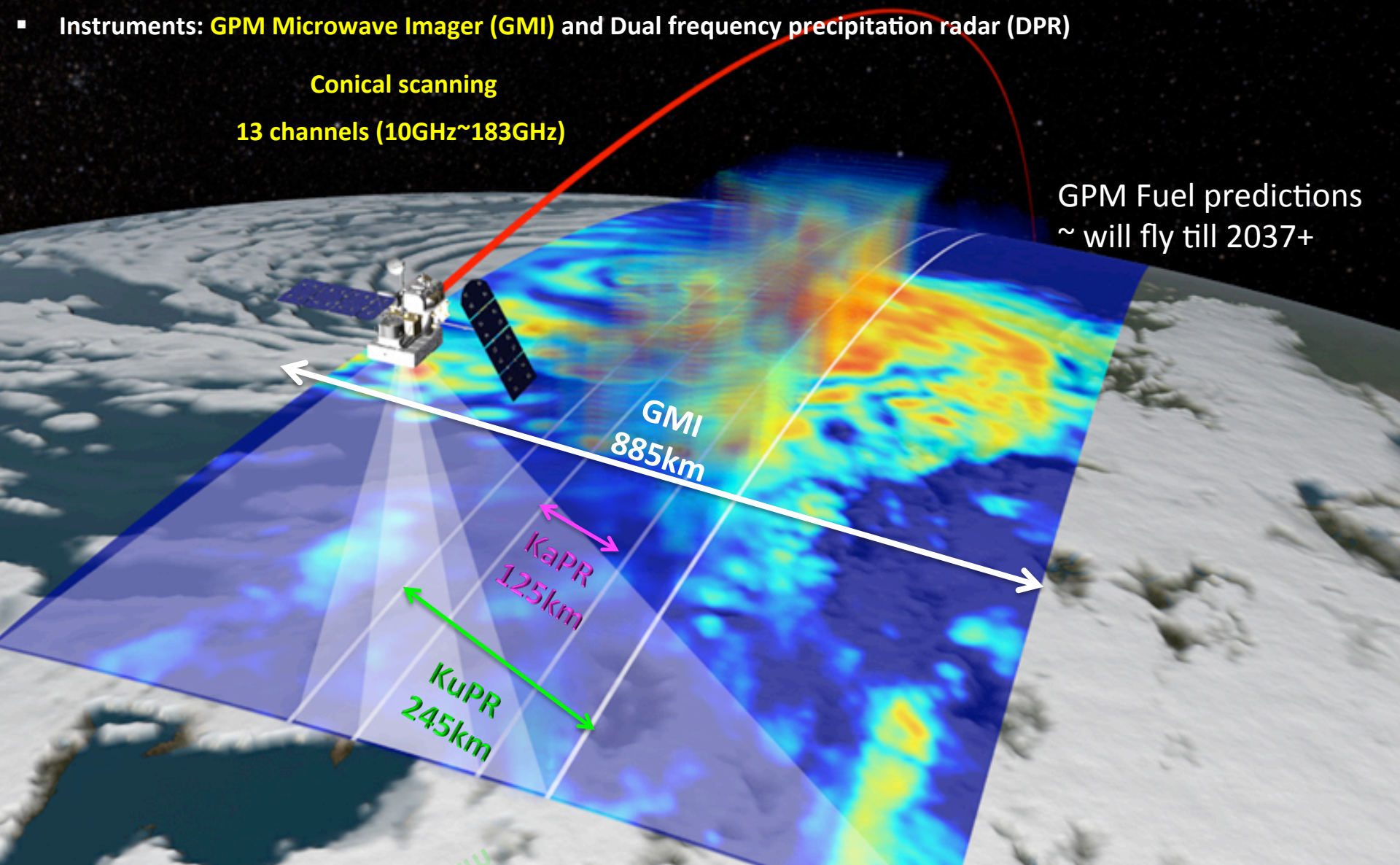
- **Blue line: Average atmospheric absorption of microwave at sea level (20°C 1013.24mb, water vapor density 7.5g/m³)**
- **GMI channels are indicated with colored arrows.**

Data: GPM Global Precipitation Measurement

- Launched February 27, 2014
- Orbit: non-sun synchronous, 65° inclination angle, 407km altitude,
- Instruments: GPM Microwave Imager (GMI) and Dual frequency precipitation radar (DPR)

Conical scanning

13 channels (10GHz~183GHz)



GPM Fuel predictions
~ will fly till 2037+