Status on Cloudy Radiance Data Assimilation in NCEP GSI

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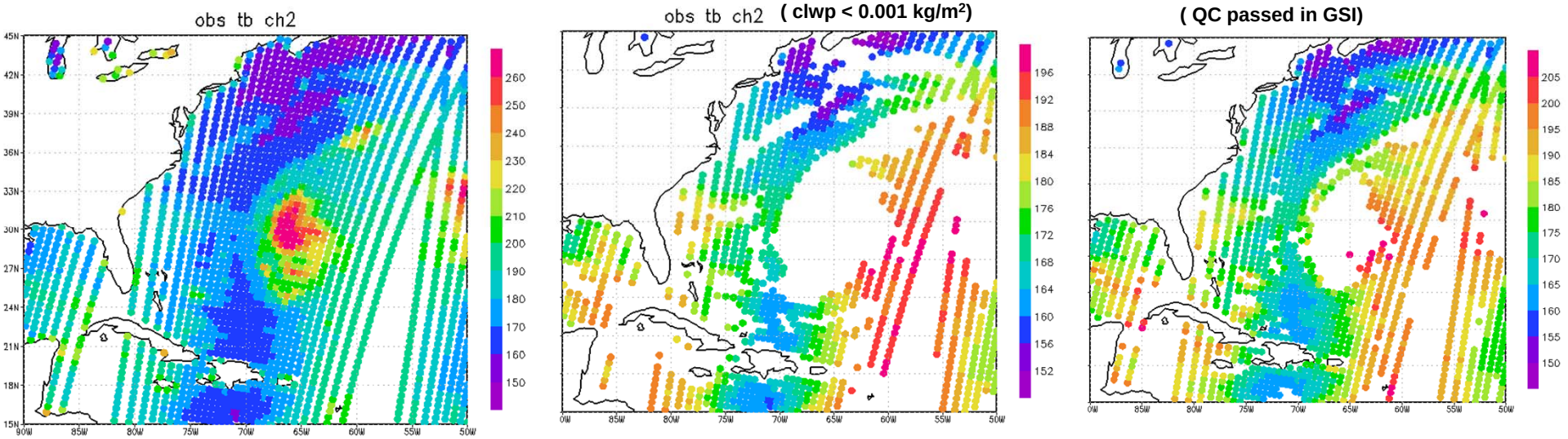
Outline

1. Motivation
2. Progress made to date
3. Assessments from preliminary results
4. Current Issues
5. Summary
6. Future Work

Motivation & Objective

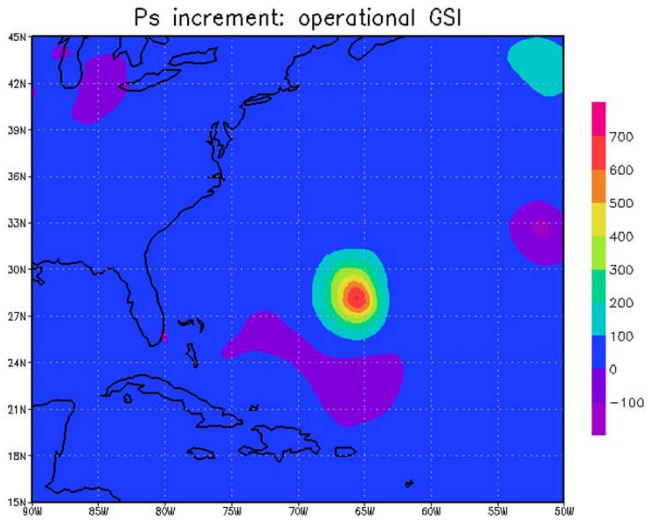


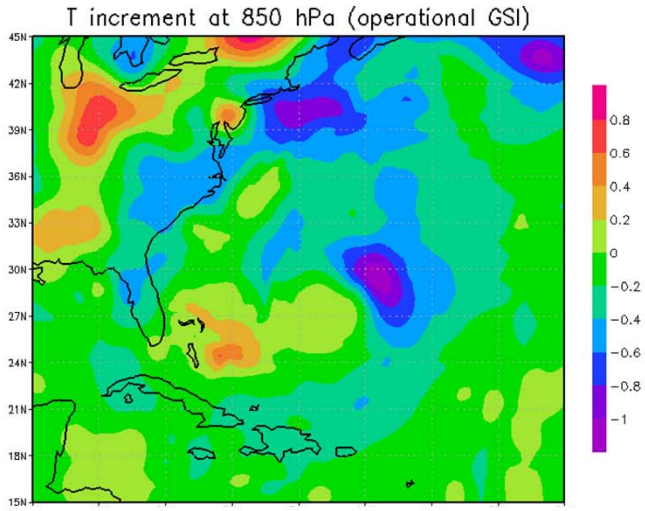
Hurricane Igor (09/19/2010)

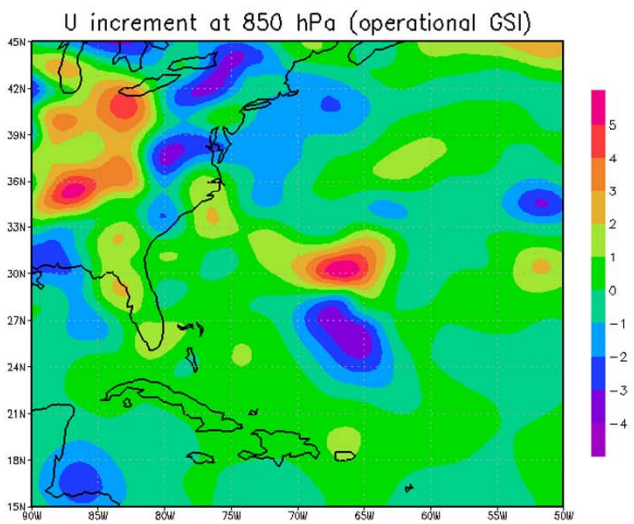
Cloud or precipitation indicates that some dynamically important weather is occurring. Subsequent forecasts are often sensitive to initial conditions in regions with cloud and precipitation occurrence.

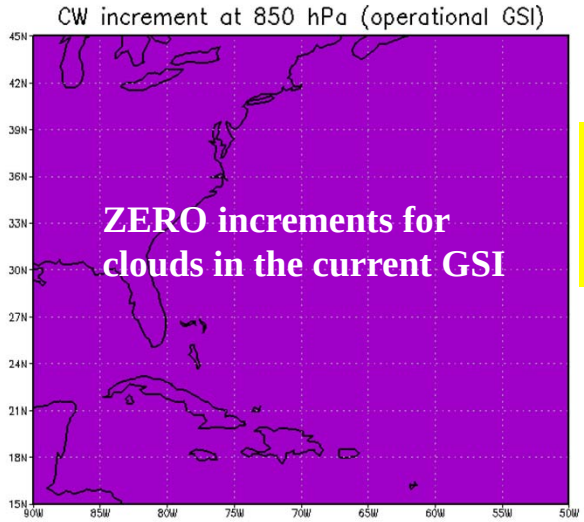
Motivation & Objective

Analysis increments from current operational GSI









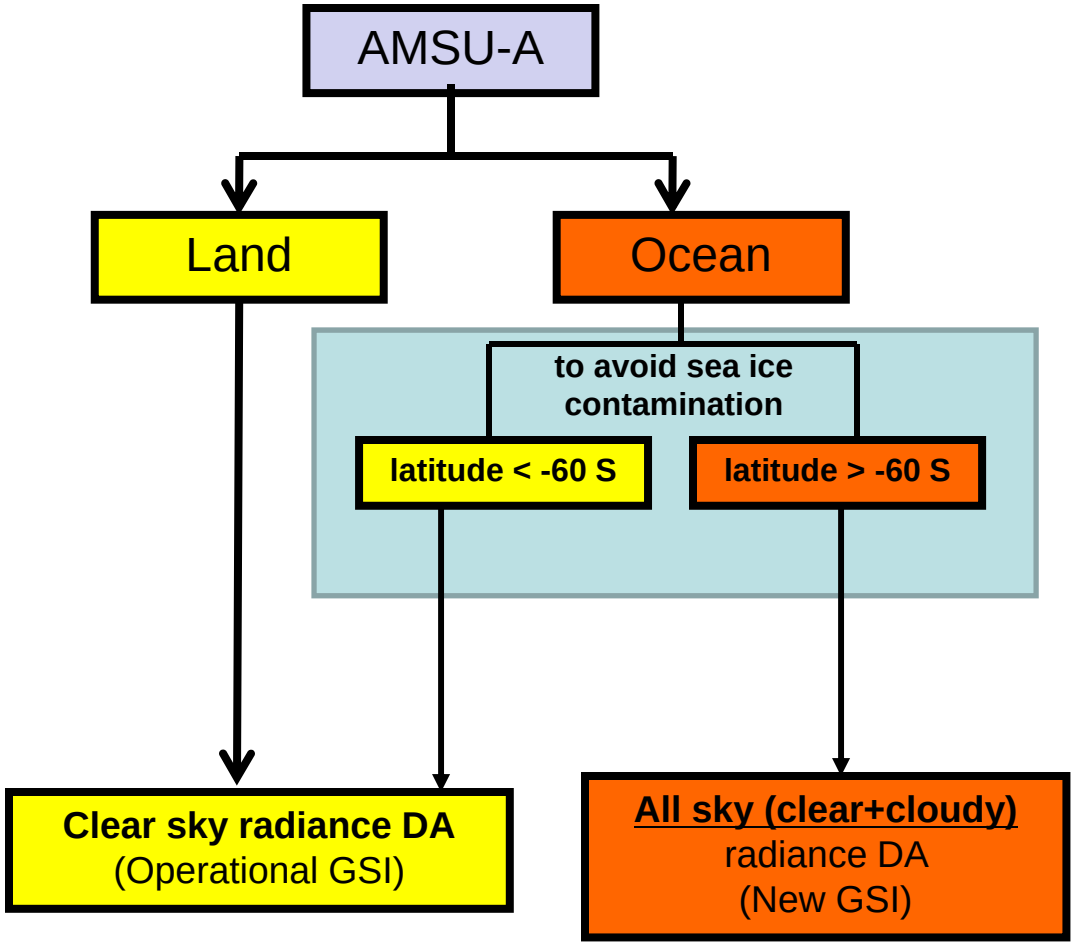
We might be able to improve cloud analysis by assimilating cloudy radiance data.

Framework

• **Which Instruments ?** **AMSU-A** cloudy radiance data are being tested. Microwave imagers such as AMSR-E and TMI will be tested afterwards.

• **Cloud type?** Cloudy radiance data in the region with **non-precipitating clouds over the ocean** are currently included in addition to the data already assimilated in the operational GSI system.

• **Global analysis or regional analysis?** Cloudy radiance data assimilation are being tested **only for global GSI analysis for now**. Similar methodologies will be tested in NCEP WRF NMM and HWRF cloud analyses in the future.



Quick View of the Progress to Date

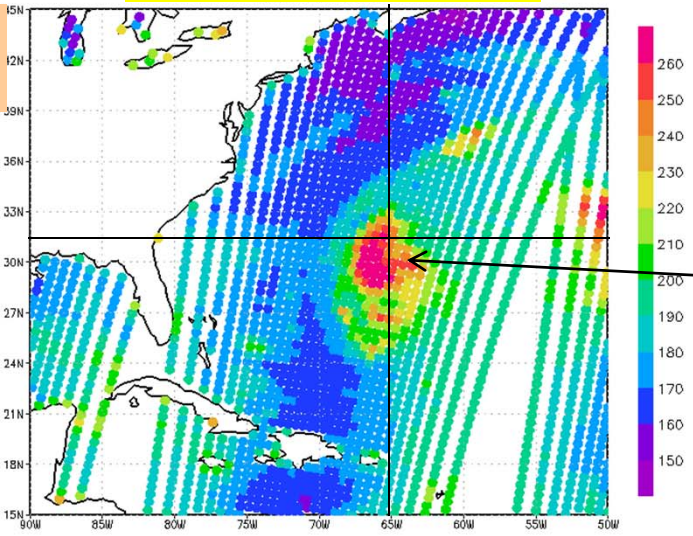
	Operational GSI (Clear Sky radiance DA)	New GSI (All-sky radiance DA)
(1) Forward operator & First guess fields	Do not include cloud	Include clouds for Tb and jacobians
(2) AMSU-A radiance Observations	Clear sky over land and ocean	Clear sky over land and ocean + Cloudy sky over the ocean
(3) Observation error	Statistics based in clear sky conditions	Statistics based in clear and cloudy sky conditions
(4) Control variable	T, q, ozone profiles, sfc P, u, v Not including cloud water	T, q, ozone profiles, sfc P, u, v + Cloud water profile
(5) Background error covariance	T, q, ozone profiles, sfc P, u, v Using NMC method	T, q, ozone profiles, sfc P, u, v + cloud water Using NMC method
(6) Quality control	• Screen out cloudy data • Gross check: $\frac{\lvert Tb_{obs} - Tb_{FG} \rvert}{\sigma_{clear\ sky}} > 3$	• Keep cloudy data unless cloud liquid water path > 0.5kg/m^2 • Gross check: $\frac{\lvert Tb_{obs} - Tb_{FG} \rvert}{\sigma_{all\ sky}} > 3$

Progress (1) : Set-up Observation Operator

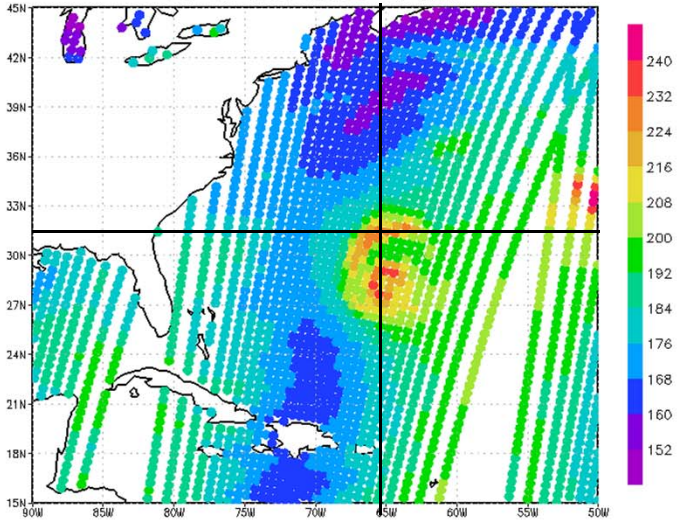
AMSU-A Observed Tb

First-Guess Tb

CH 2
31.4 GHz

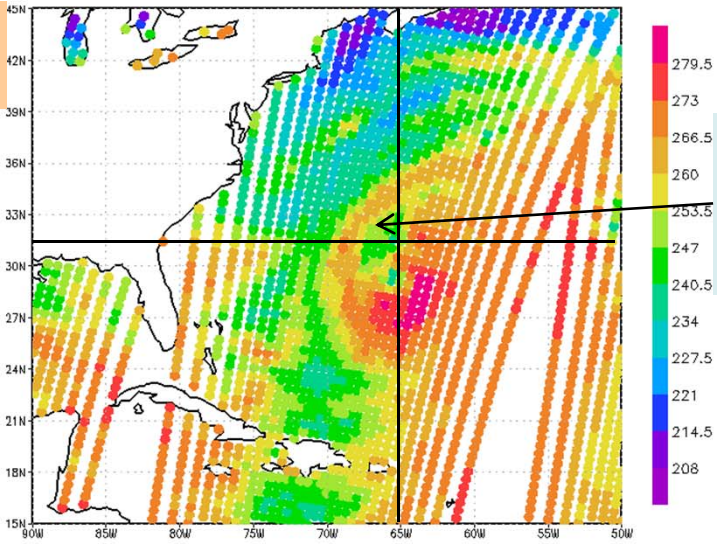


Much warmer than FG

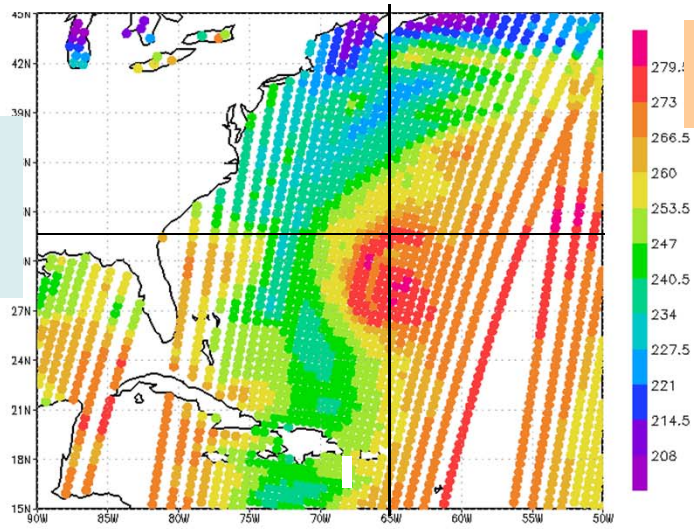


CH 2
31.4 GHz

CH 15
89.0 GHz



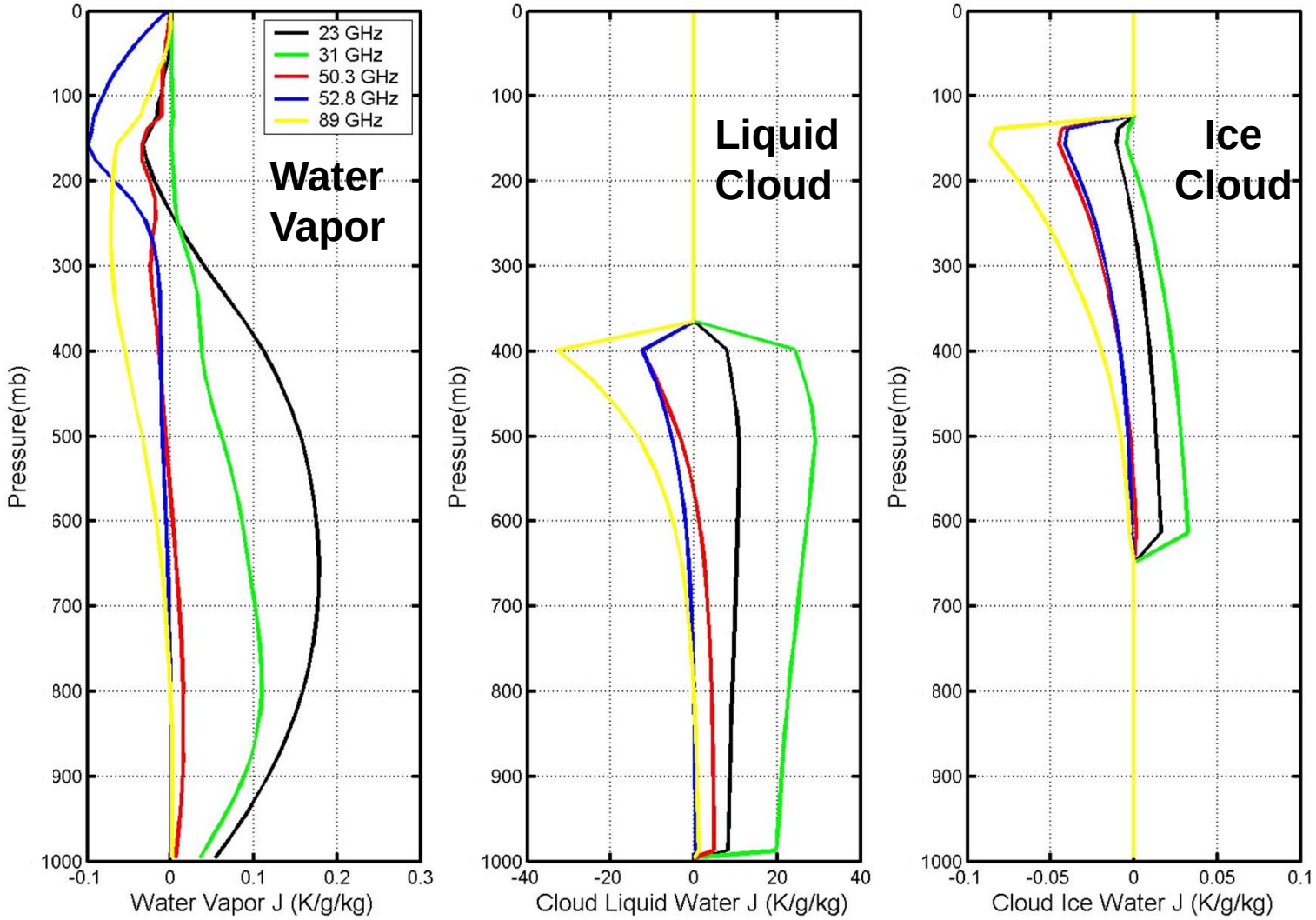
Scattering signal in observations.
➔Precipitation + ice clouds



CH 15
89.0 GHz

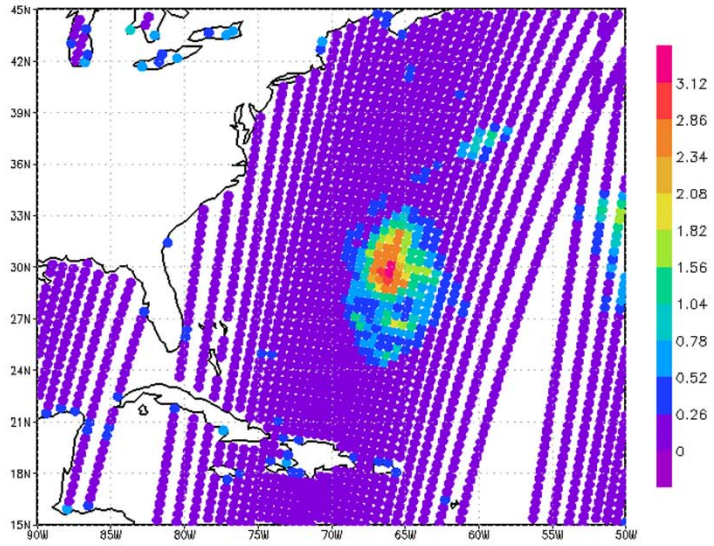
Progress (2) : Including Tb Sensitivity to CW

CRTM Computed Jacobians

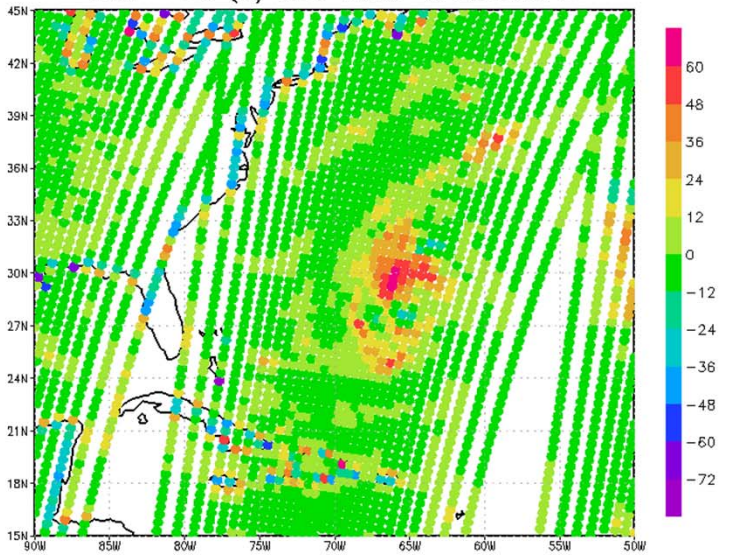


Progress (3): Understanding O-F behaviors in cloudy conditions

Retrieved Cloud Liquid Water Path (CLWP)



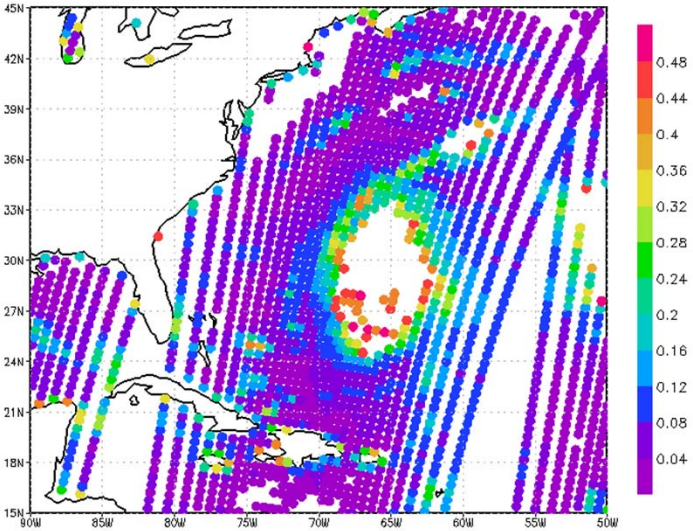
Obs – FG (K) N19 AMSU-A Channel 2



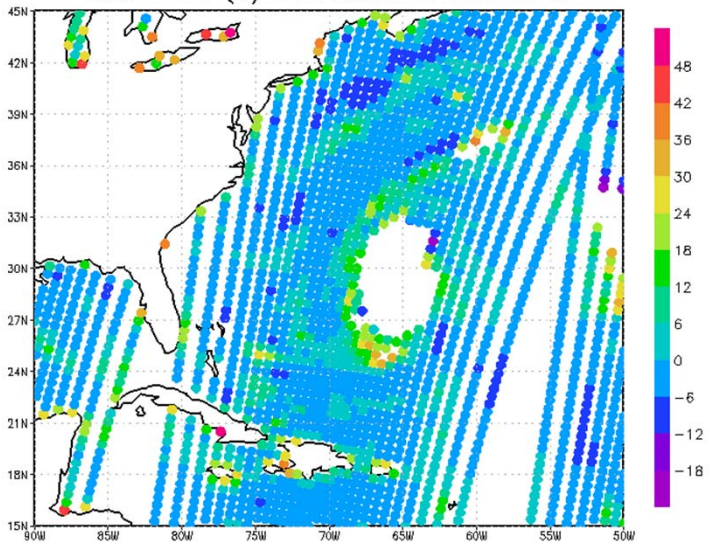
Non-Precipitating Cloudy Conditions

Obs Tbs with CLWP > 0.5kg/m2 screened out

Retrieved Cloud Liquid Water Path (CLWP)



Obs – FG (K) N19 AMSU-A Channel 2

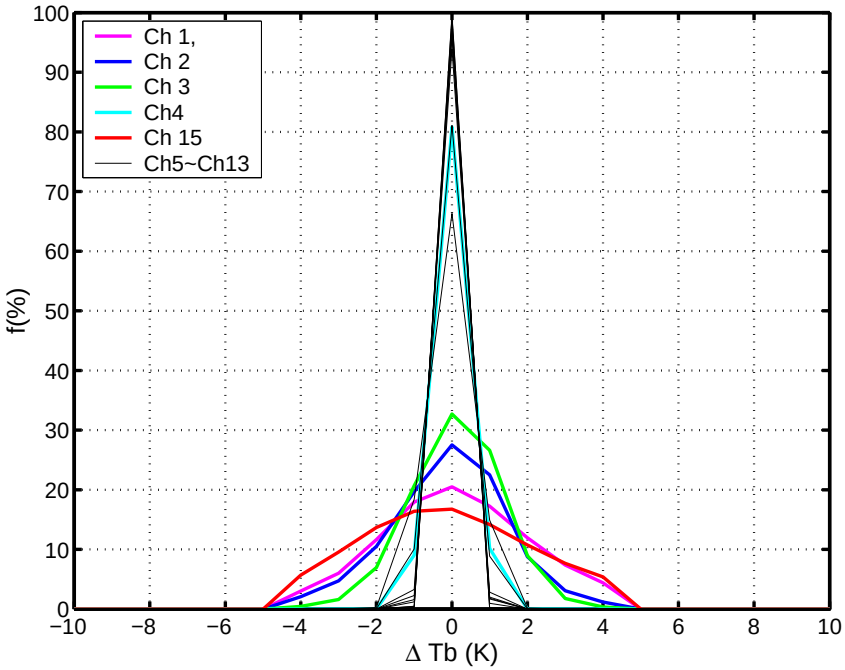


Progress (3): Understanding O-F behaviors in cloudy conditions

Histogram: Observed Tbs - First guess Tbs

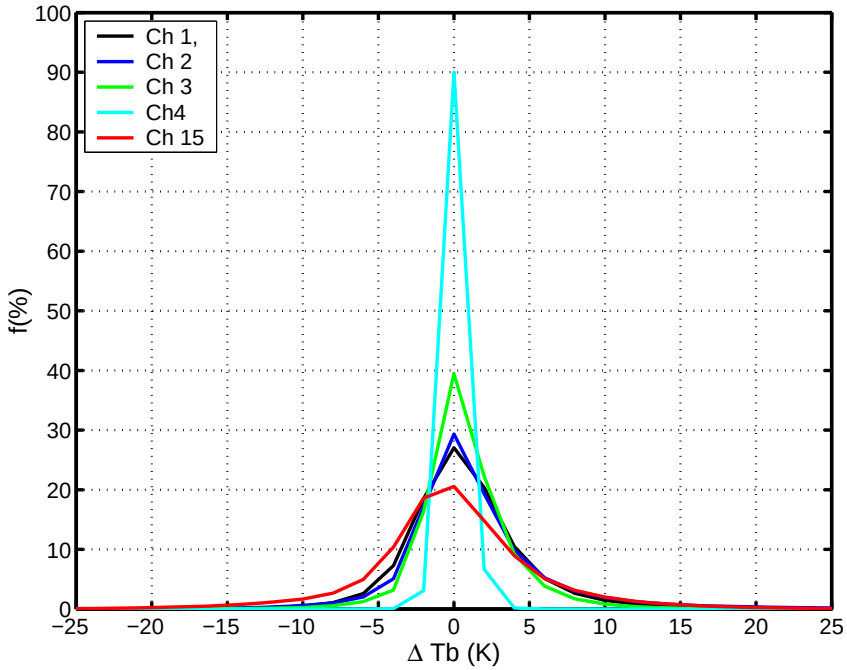
Original GSI

clear sky over the ocean



All-Sky GSI

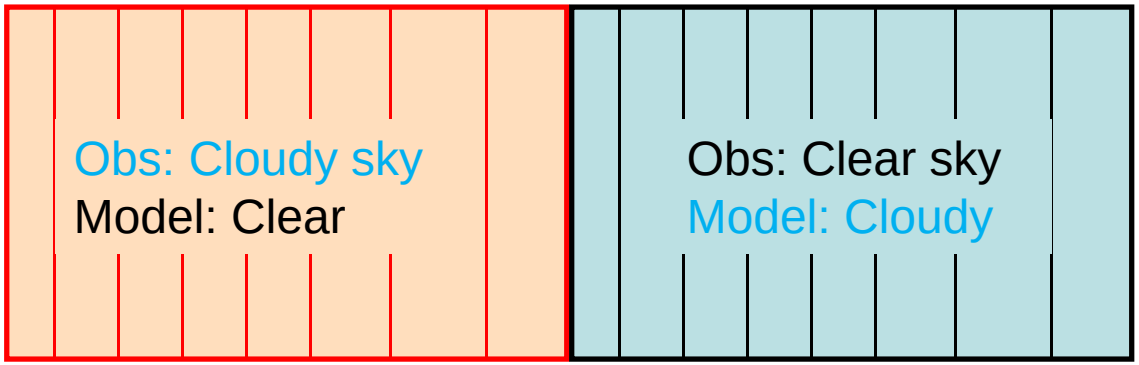
clear sky for all surface + nonprecipitating cloudy sky over the ocean



Progress (4) : New Observation Errors

function of observed cloud or model cloud ?

Method learned from Geer et al. (2010) @ ECMWF



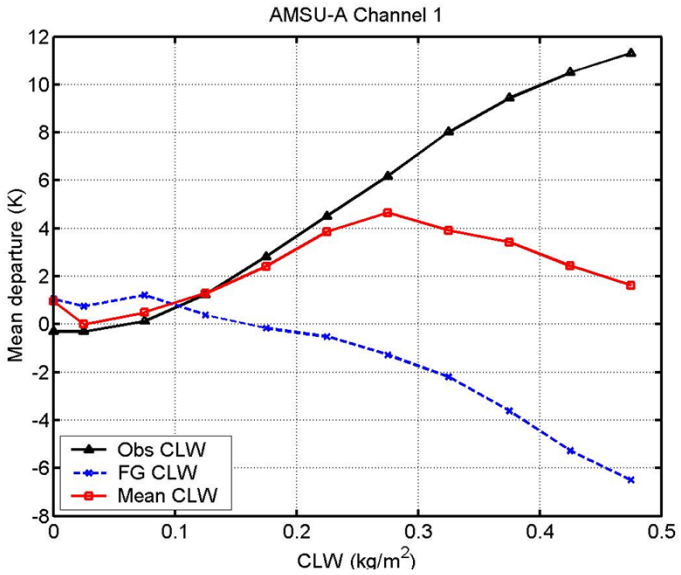
Obs error function of Obs cloud → Large obs error (Small weight) → Small obs error (Large weight) → Dry model atmosphere

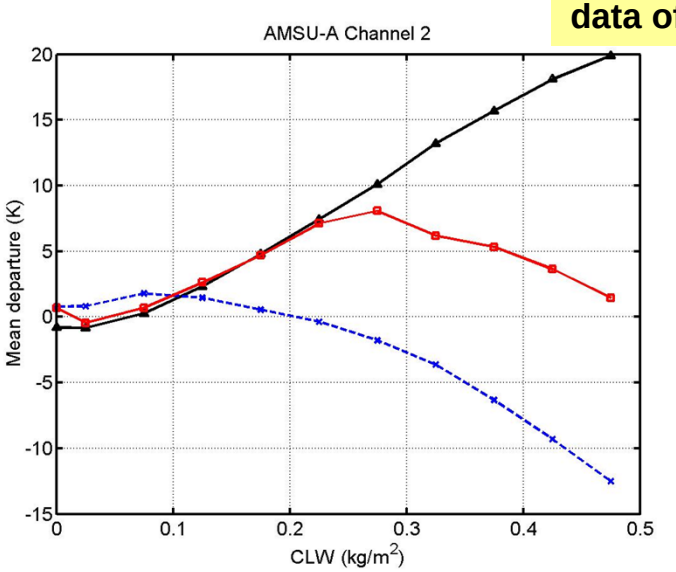
Obs error function of Model cloud → Small obs error (Large weight) → Large obs error (Small weight) → Moisten model atmosphere

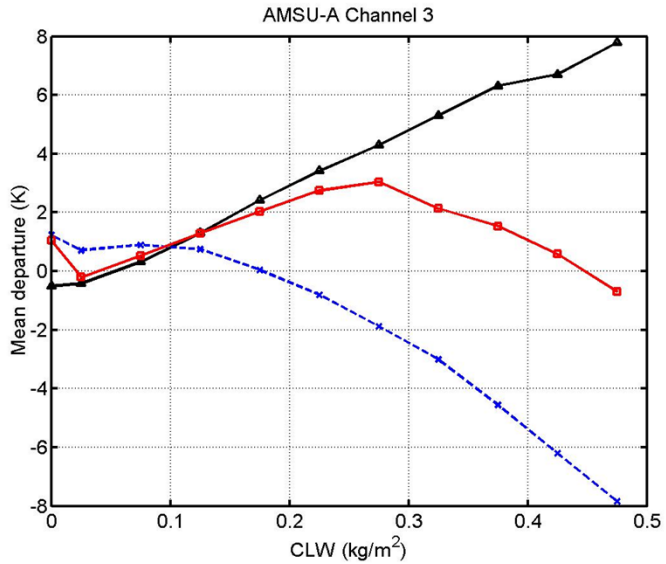
Progress (4) : New Observation Errors

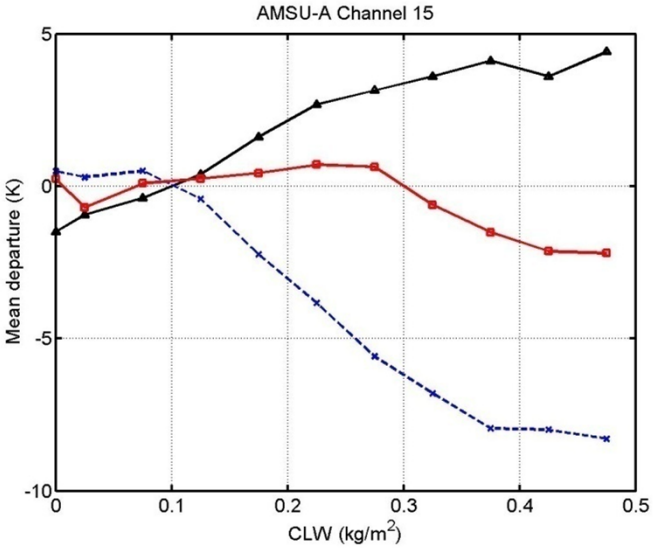
Mean of Tb Departure

All statistics from data of 7 days





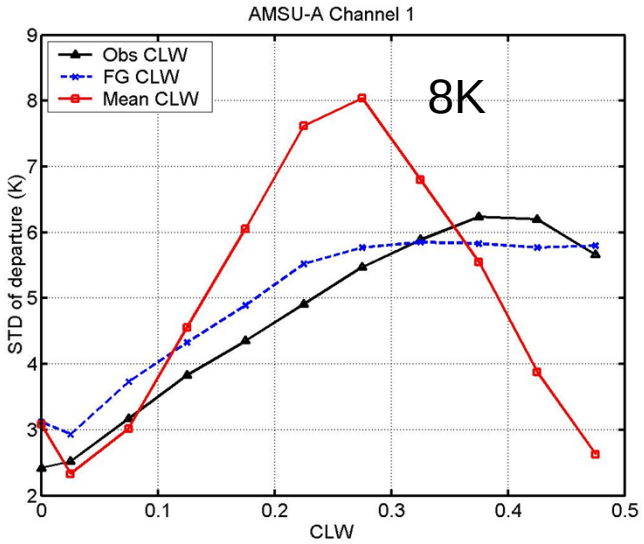


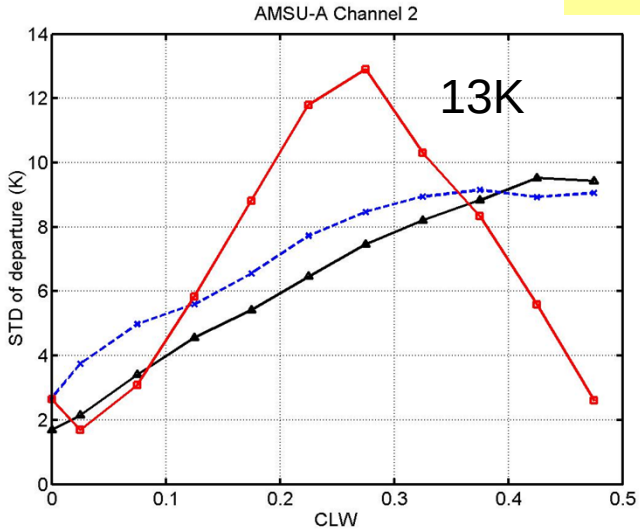


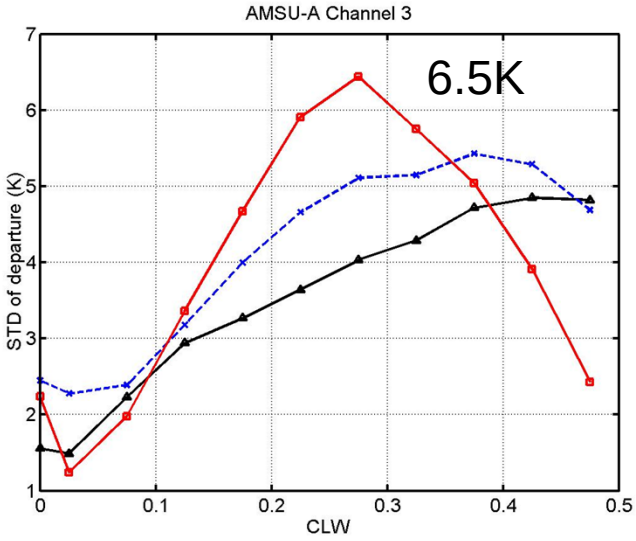
Progress (4) : New Observation Errors

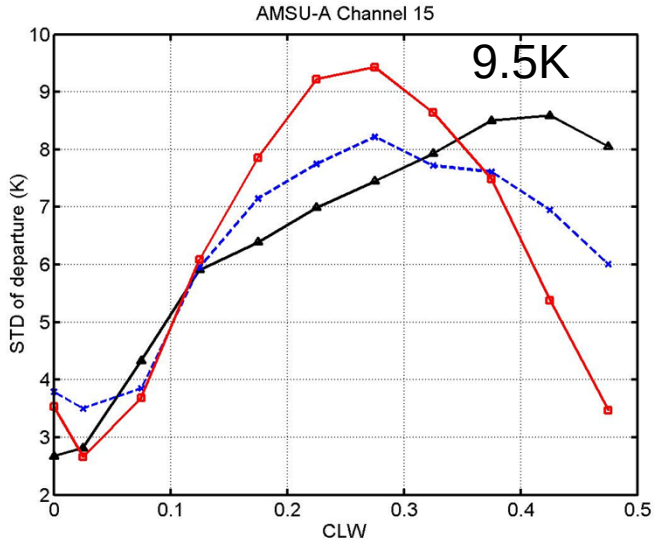
Standard Deviation of Tb Departure

All statistics from data of 7 days









Progress (4) : New Observation Errors

For clear and non-precipitating cloudy sky over the ocean

CLWP = 0.5*(obs clwp + model clwp)
A_i = clear sky obs error for each channel(i)
B_i = cloudy sky obs error for each channel(i)

If(CLWP .lt. 0.05) then
$Obs\_error_i = A_i$
else if (CLWP .ge. 0.05 .and. .lt. 0.25) then
$Obs\_error_i = A_i + (CLD-0.05)*(B_i-A_i)/(0.25-0.05)$
else if (CLWP .ge. 0.25 .and. lt. 0.5) then
$Obs\_error_i = A_i + (CLD-0.25)*(A_i - B_i)/(0.5-0.25)$
else
$Obs\_error_i = B_i$
endif

Progress (5): New Quality Control Methods

1. Screening cloud affected AMSU-A data
   Criteria:(1) scattering index (using ch1, 2, and 15 + ch6 Tb departure)
   (2) retrieved clwp + ch4 Tb departure

➔ New: Screening retrieved averaged CLWP > 0.5kg/m^2 over the ocean

2. Topography effect: for observations at Zsfc > 2km, observation errors get increased.

4. Transmittance at the top of the model less than 1 : inflating observation error

3. Too much sensitivity to sfc temperature/sfc emissivity: inflating observation error

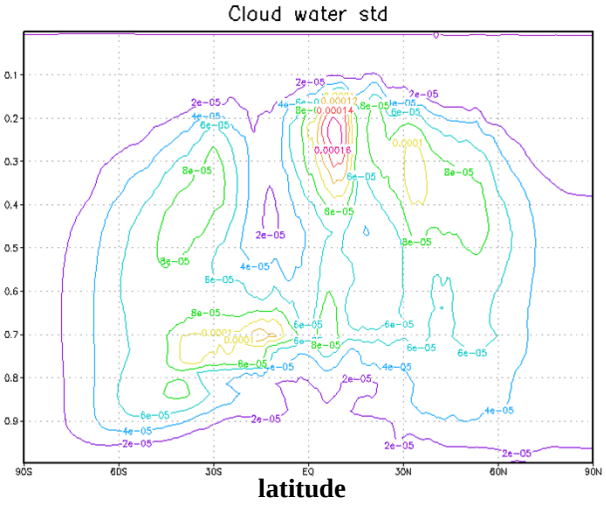
4. New gross check for all-sky(clear and cloudy) radiance data

$$\frac{|\Delta Tb_{ich}|}{\sigma_{ich}} > 3$$

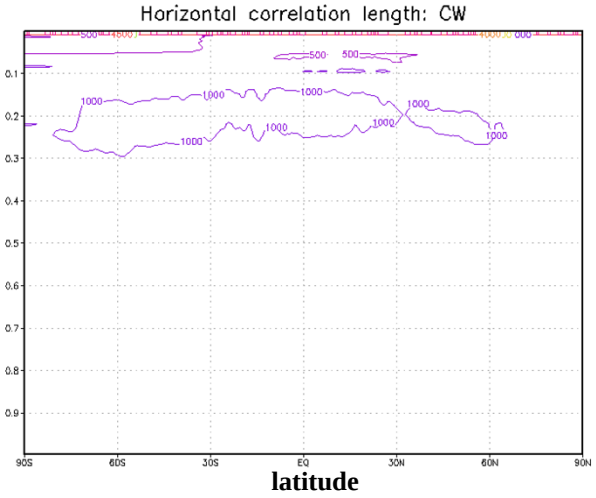
σ_{ich} : New observation error (I.e. function of averaged CLWP)

Progress (6): Adding Cloud Control Variable & Cloud Background Error Covariance for Radiance DA

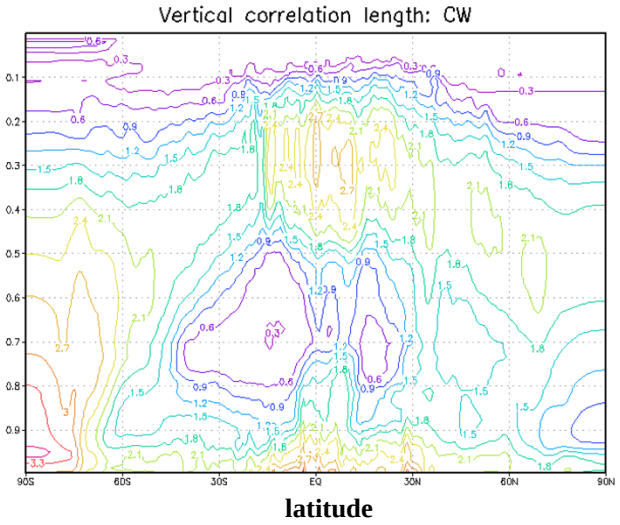
- Cloud water mixing ratio at each layer is additional control variable
- Background error covariance for clouds are from NMC method.



Large standard deviations in the region of convections near tropics and midlatitude frontal systems



Not much horizontal correlation for cloud

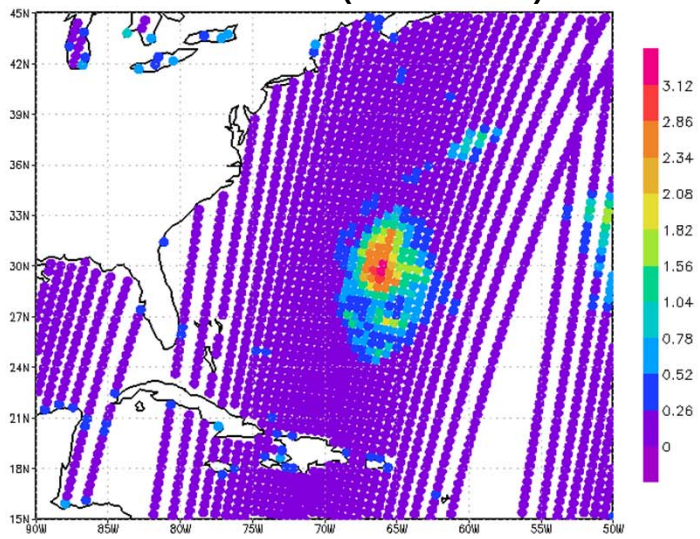


Larger correlation in vertical than in horizontal

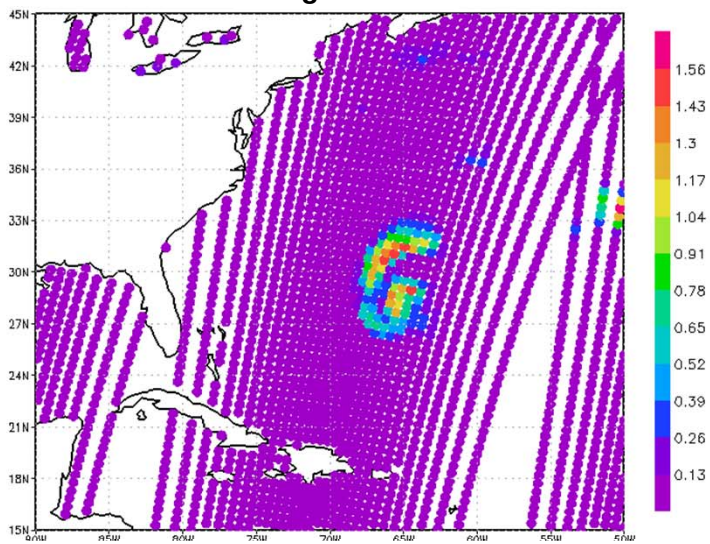
- **Daryl Kleist (EMC)** has set up for the current BK error covariance using NMC method.
- **Will McCarty (NASA/GMAO)** will improve BK error covariance for cloud related control variables.

Assessment: Cloud Analysis Increments

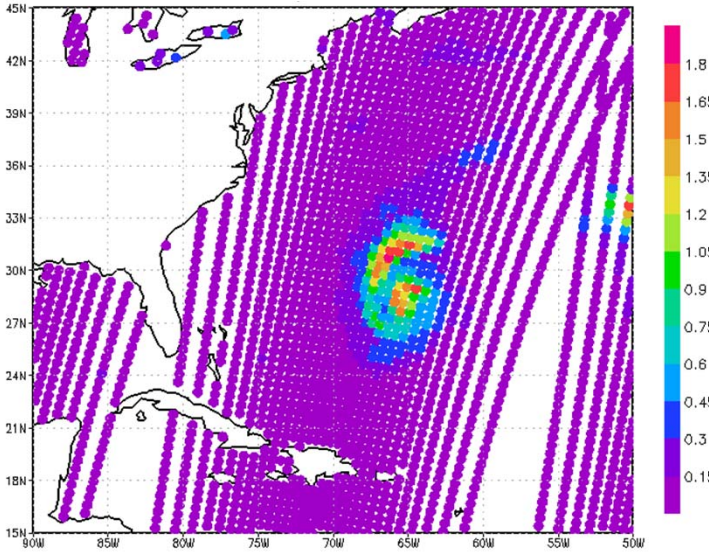
Retrieved CLWP (observations)



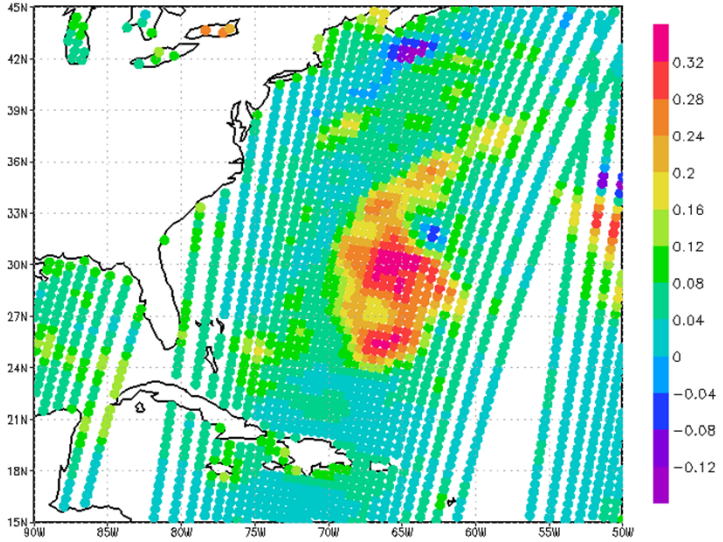
First-guess CLWP



Analysis CLWP



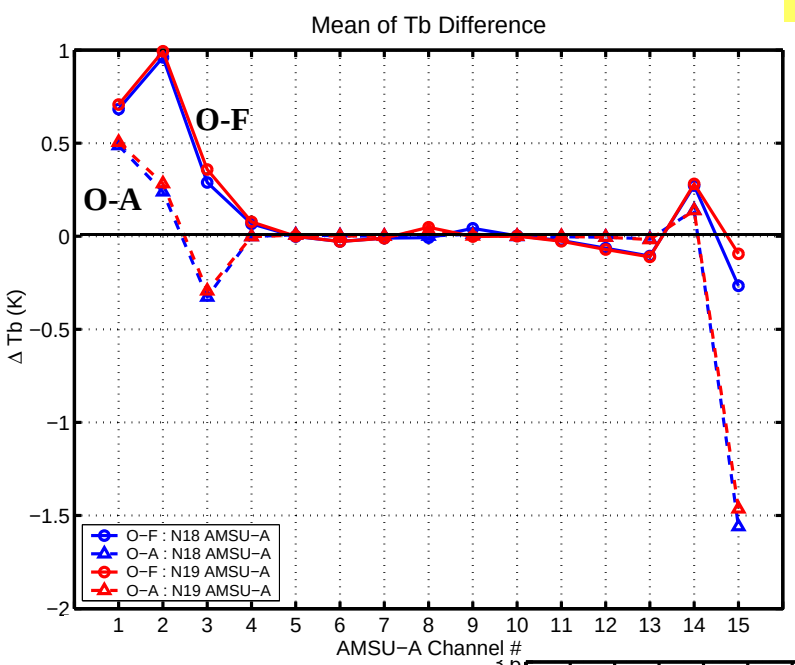
CLWP Analysis Increment

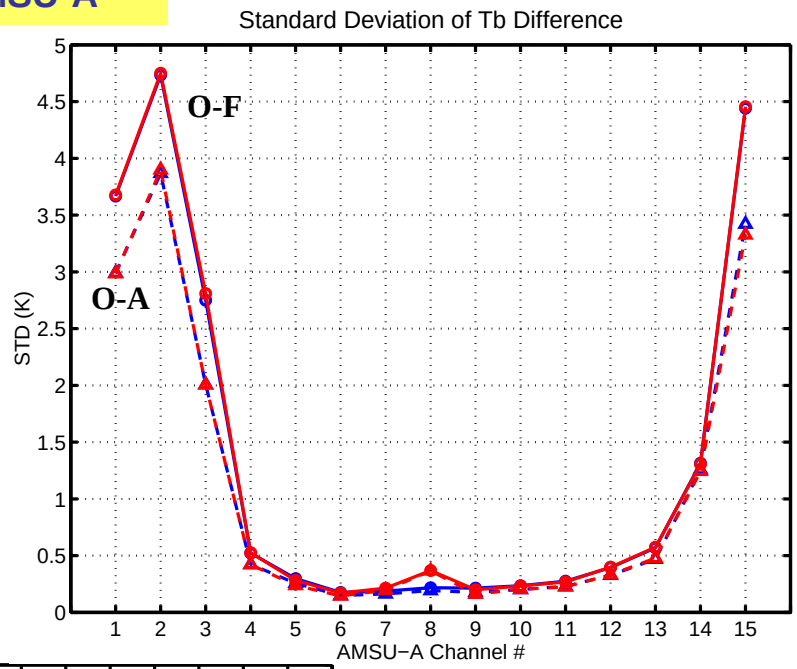


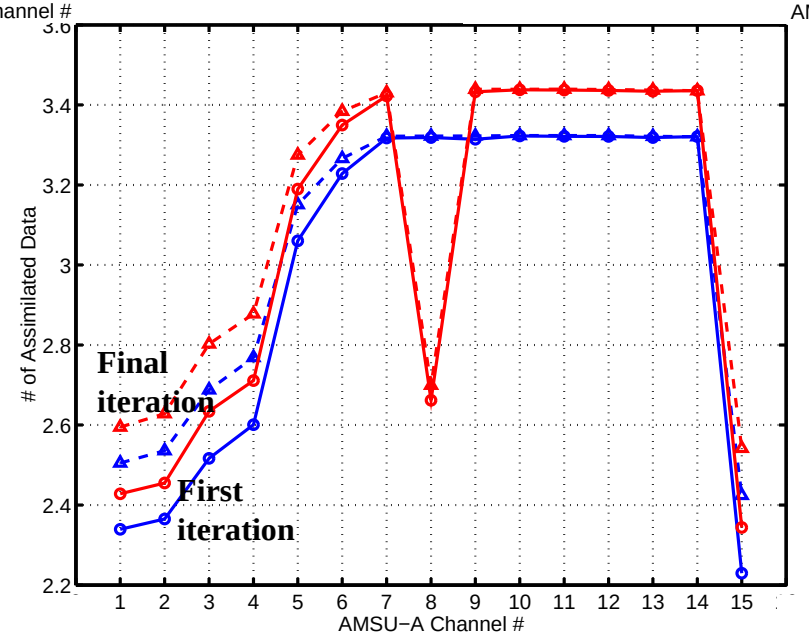
- **Clouds have been actively assimilated.**
- **Cloud analysis fields got improved and closer to the observations (retrieved clouds).**

Assessment : FG Tb departures vs. Analysis Tb departures

AMSU-A



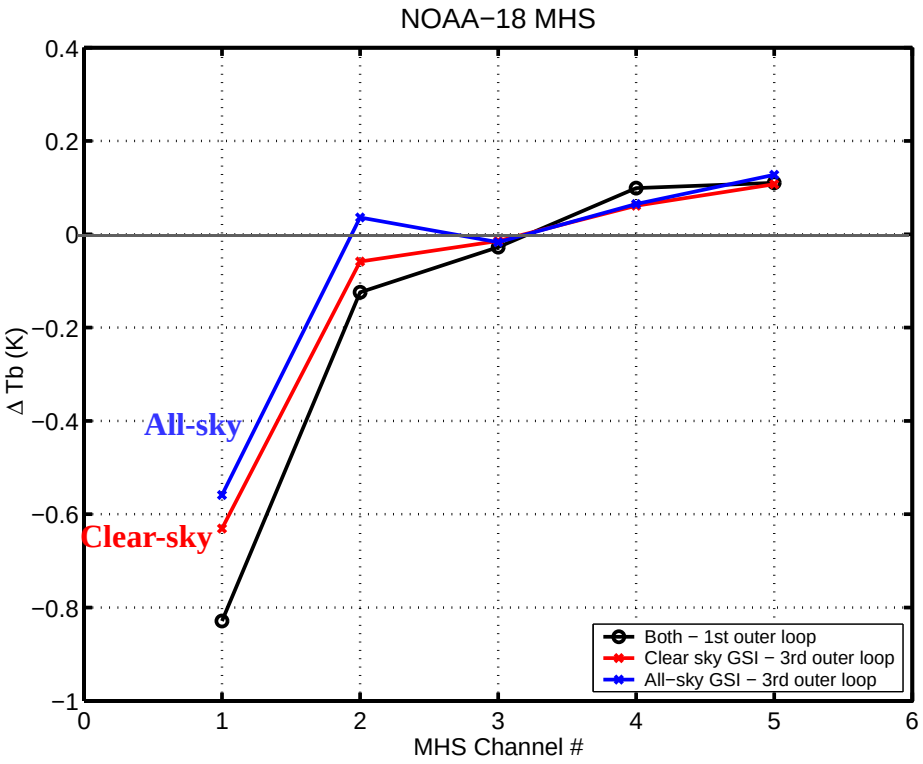


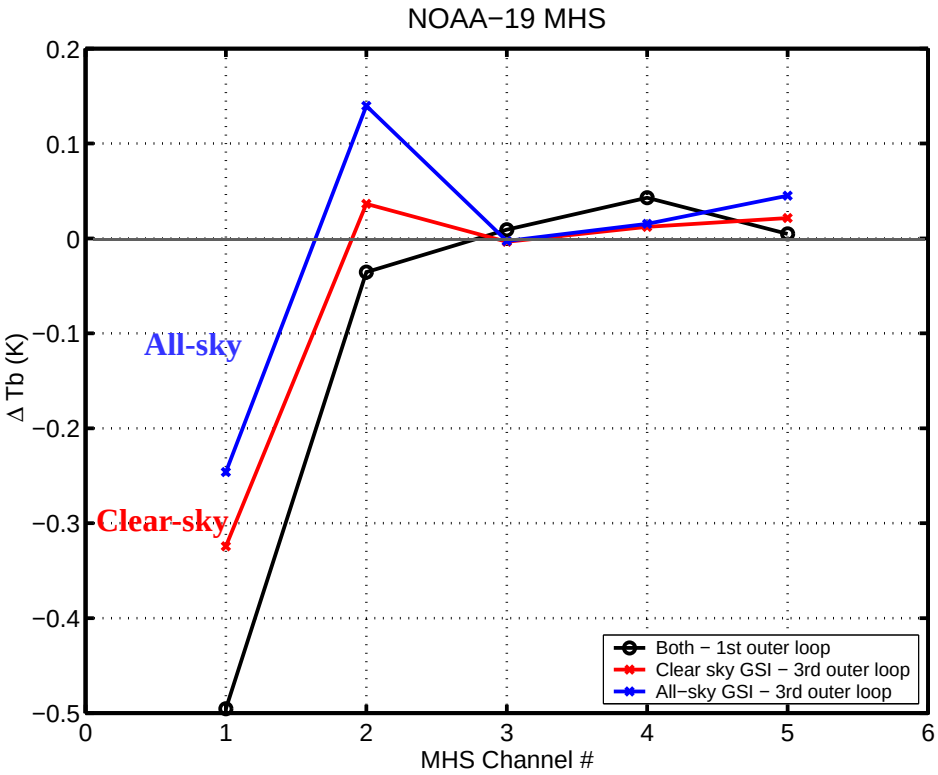


Something going on with channel 15 ..

Assessment : MHS FG departures vs. Analysis departures

Mean of Tb differences

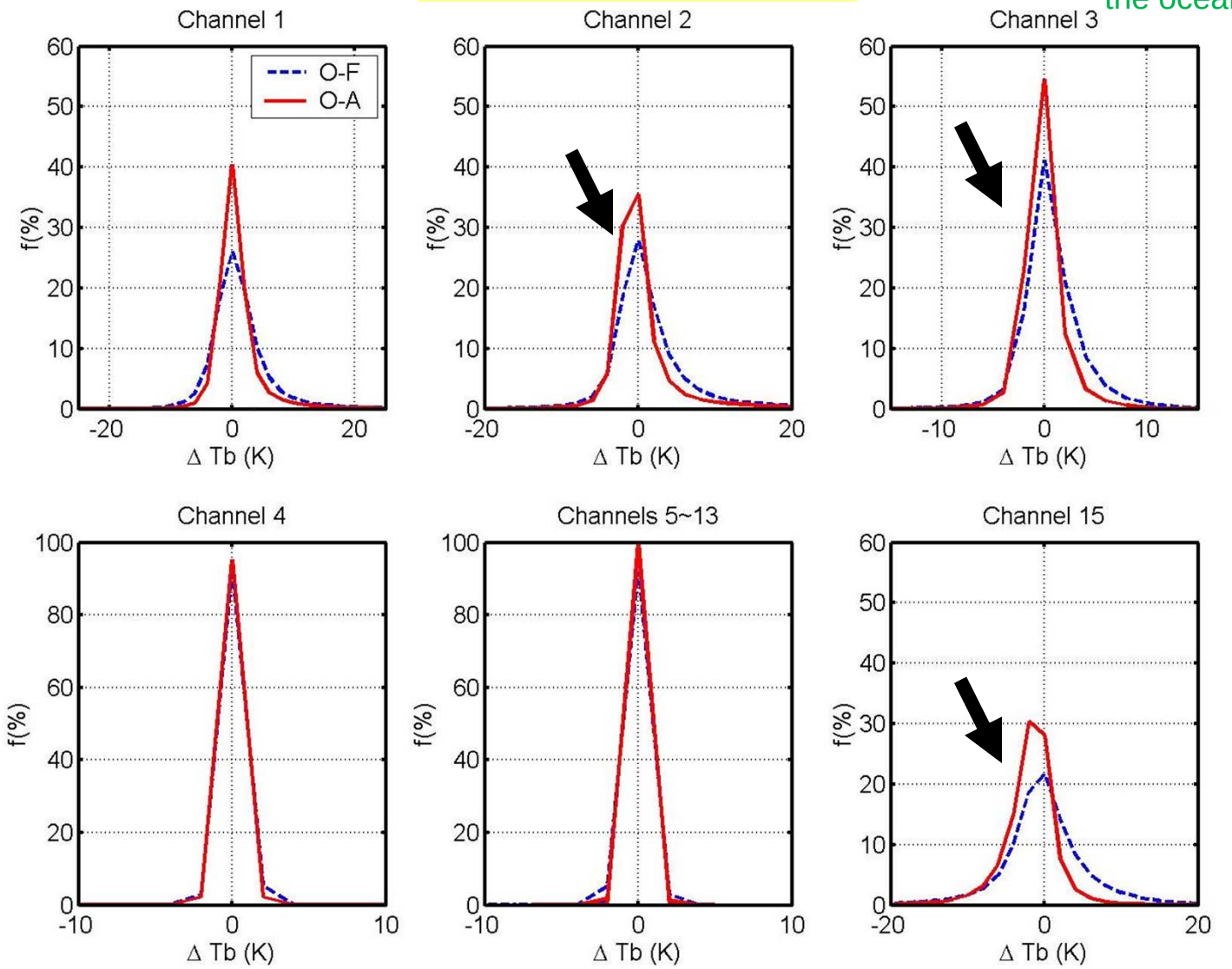




Current Issue (1) : Bias Correction

AMSU-A O-F vs. O-A

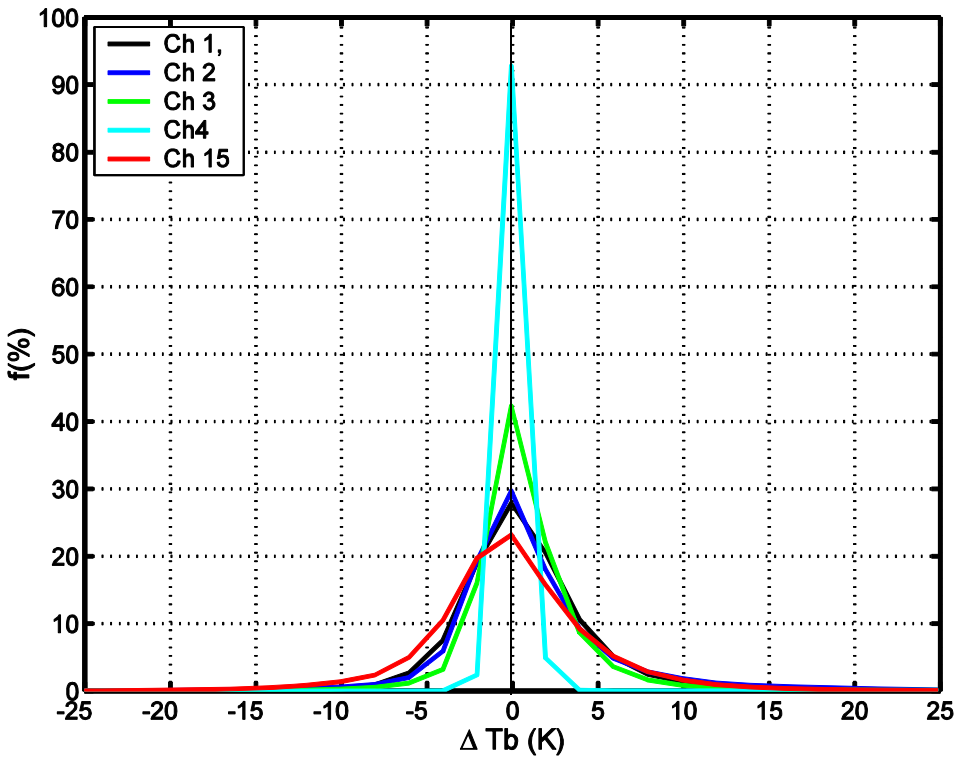
clear sky + nonprecipitating cloudy sky over the ocean

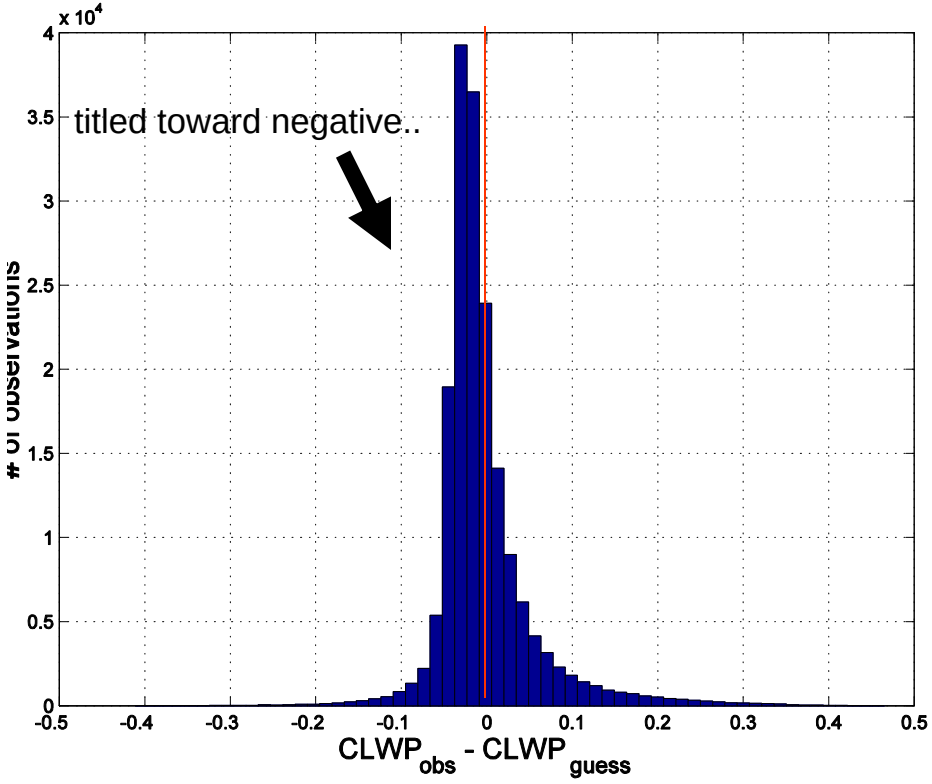


O-A Tb departure distribution : titled toward negative..

Current Issue (2) : Retrieval Algorithm for CLWP

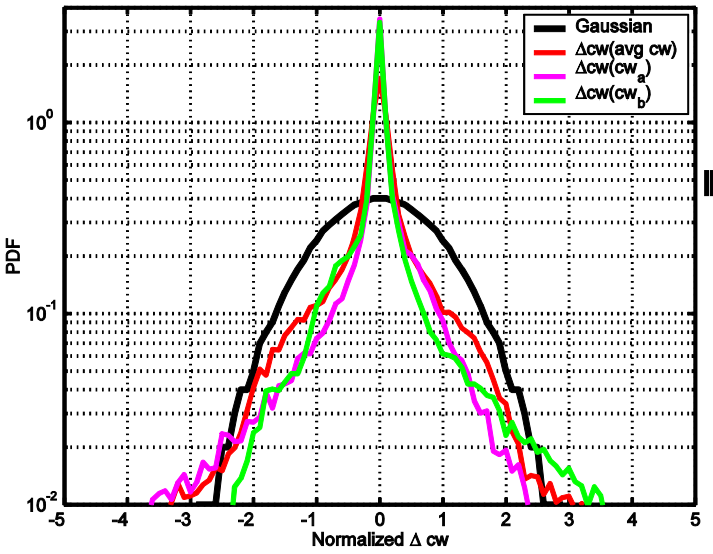
- Observation errors depend on retrieved cloud liquid water paths and no retrieval algorithms can be perfect.
- Separating precipitating clouds and non-precipitating clouds cannot be perfect.





Current Issue (3): Non-Gaussian BK Error Distribution

Cloud water error statistics show "**non-Gaussian**" distribution.



Approach I

- Single control variable: **total moisture, $q_{tot}(=q+q_c)$)**
- **UK Met Office** has been using q_{tot} as a single moisture control variable
- **Emily Liu has been working to set up with q_{tot} in GSI. (Next talk)**

Approach 2

- Keep **two separate control variables** for water vapor and clouds
- However, **develop a different form of cloud water related control variable** of which error distribution is more Gaussian than q_c
- **ECMWF**'s current efforts are toward this approach.
- This will be tested for comparisons with Approach 1.

Summary

1. There has been great progress in assimilating AMSU-A cloudy radiance data in NCEP Global Data Assimilation System (GDAS).

2. New observation errors and quality control methods, which are applicable for clear and cloudy sky conditions, have been developed.

3. For now, cloud water mixing ratio for each layer is used as a control variable and background error covariance from NMC method has been used.

4. Assessments based on statistics for AMSU-A and MHS sounders demonstrated that more data in cloud sensitive channels are being assimilated by including cloudy radiance data and brightness temperature departures got reduced for those channels.

5. Preliminary results from case studies show that cloud fields are now being actively assimilated and cloud analysis fields get much closer to the retrieved values. Assessments for other fields and forecast skill scores are in progress.

Ongoing Work & Future Plans

- **Improving bias corrections by testing different predictors.**
- **Adding observations in *precipitating* cloudy conditions to the current cloudy radiance data assimilation experiments**
- **Testing impacts on GFS model forecasts and HWRF model forecasts skill scores.**
- **Comparisons of static background error covariance with ensemble background error covariance**