The inclusion of cloudy radiances in the NCEP GSI analysis system

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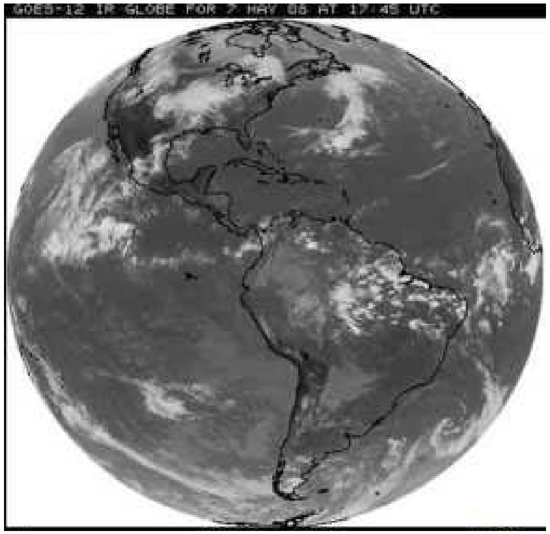
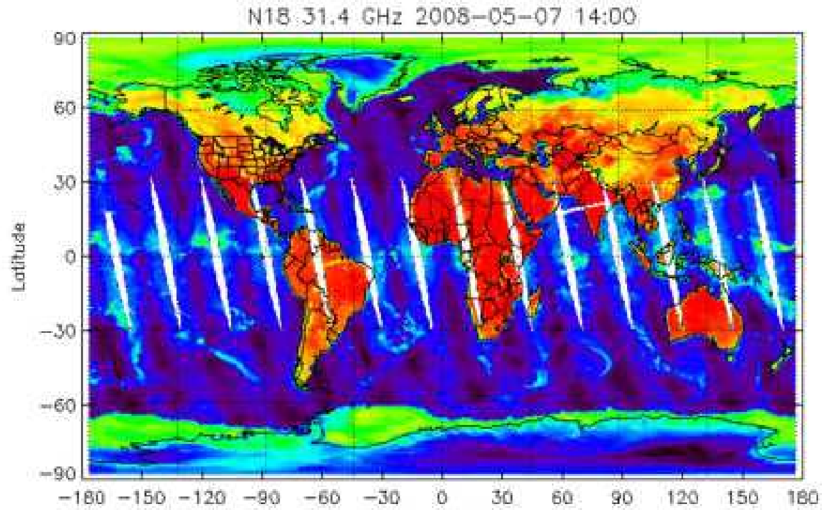
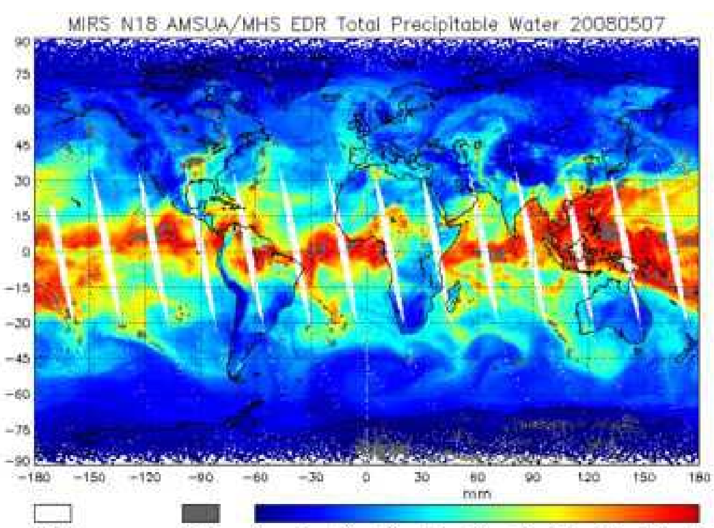
Outline

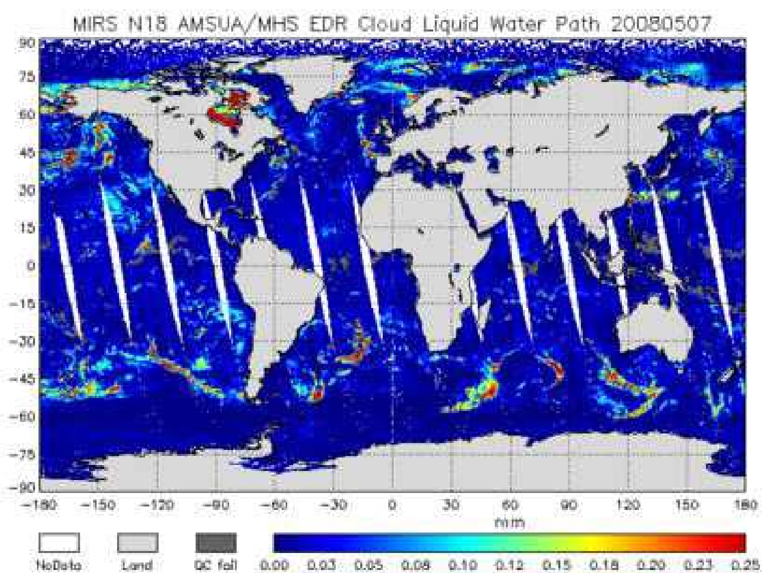
- Cloudy radiance assimilation: Importance and Challenges
- Overview of Global Data Assimilation System (GDAS) in NCEP
  - Gridpoint Statistical Interpolation (GSI) system
  - Global Forecast System (GFS) model
  - Community Radiative Transfer Model (CRTM)
- Inclusion of cloudy radiance assimilation components in GSI
- Preliminary results
- Discussions and future work

Cloudy Radiance Assimilation: Importance and Challenges





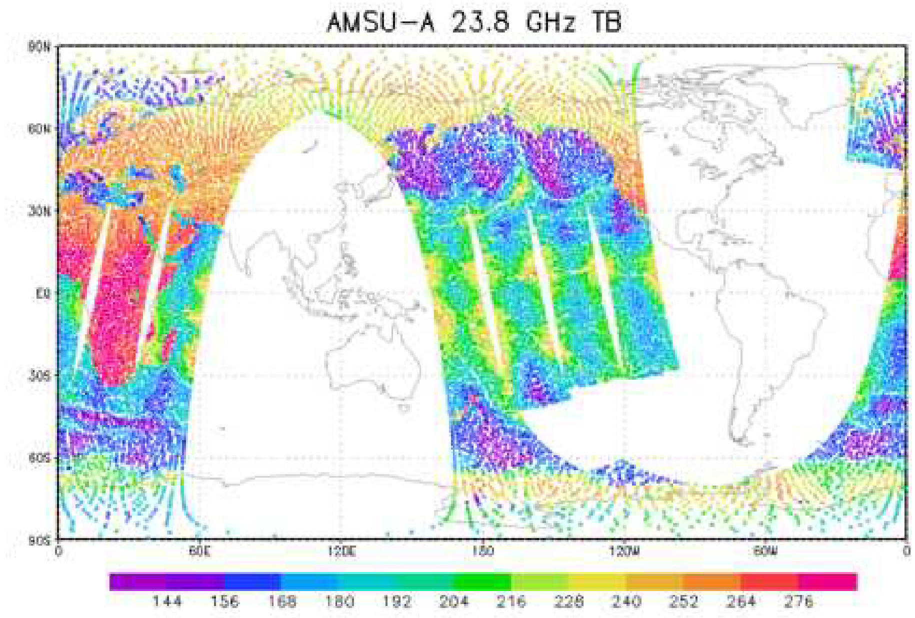




MIRS (http://www.osdpd.noaa.gov/PSB/mirs

Cloudy Radiance Assimilation:

Importance and Challenges



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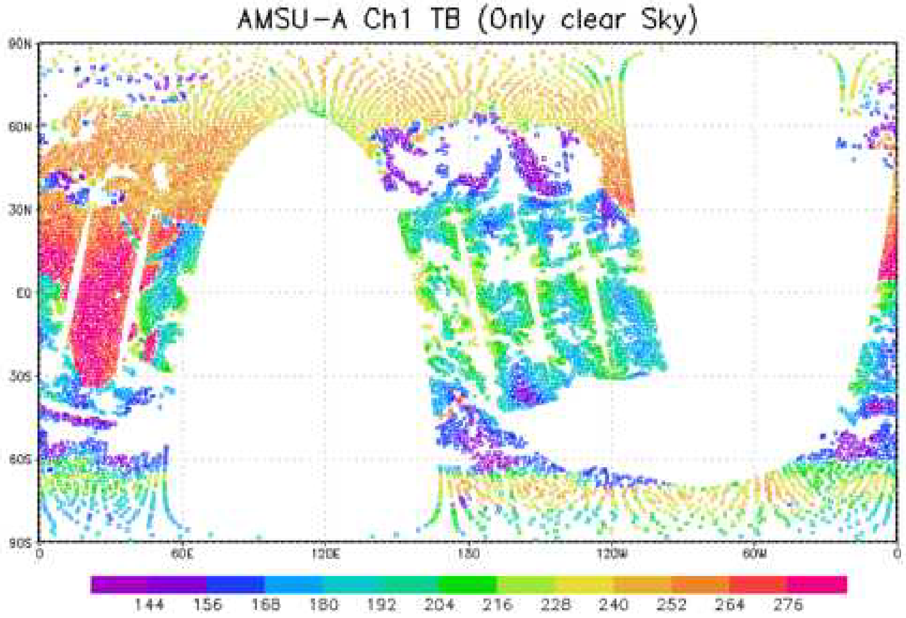
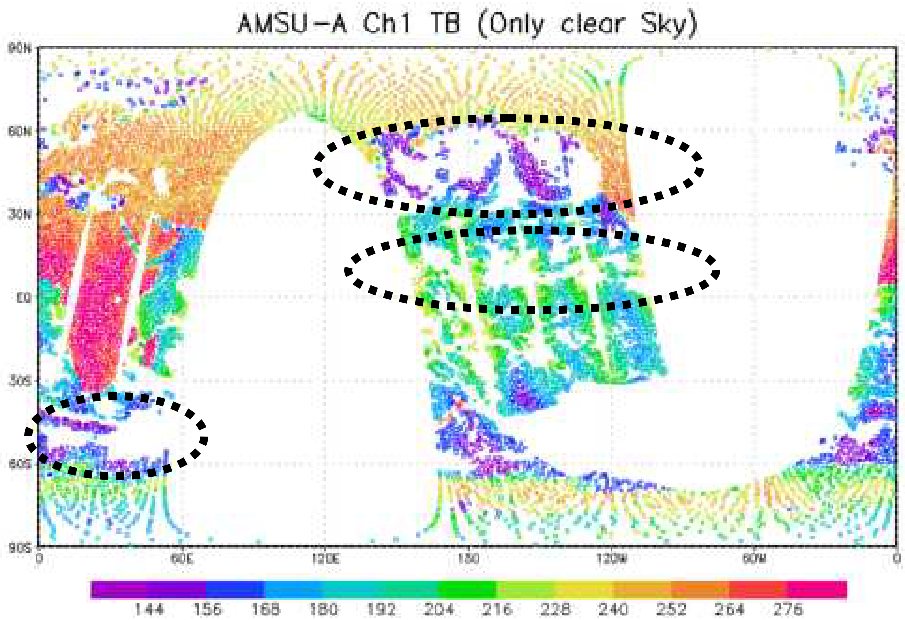
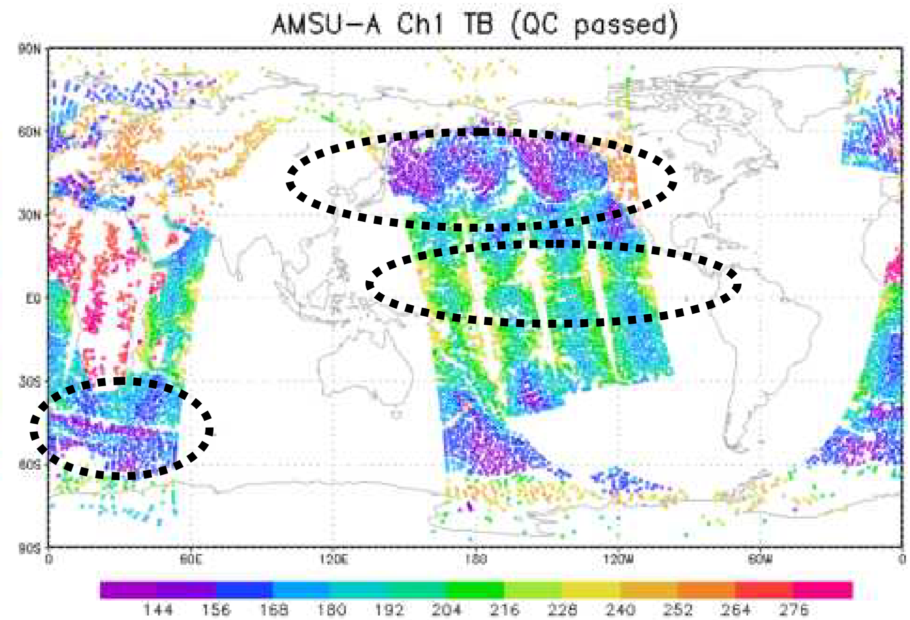


Cloudy Radiance Assimilation:

Importance and Challenges





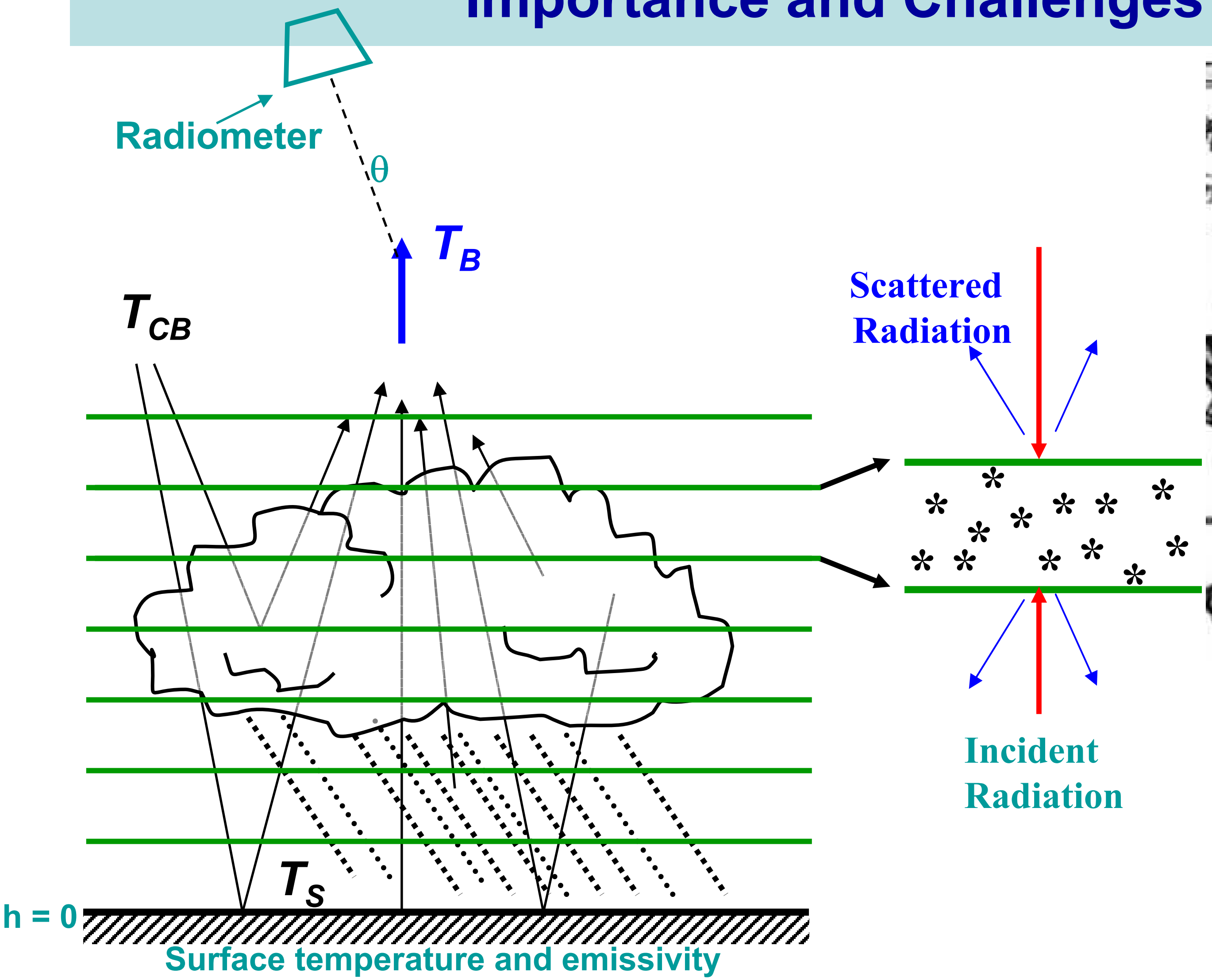
1.Thin cloudy area have been assimilated without including cloudy radiance computation.

2. Thick cloudy area screened out. Can we extract useful information on cloud out of observations by cloudy radiance assimilation?

- 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.

Cloudy Radiance Assimilation:

Importance and Challenges



Cloudy Radiance Assimilation:

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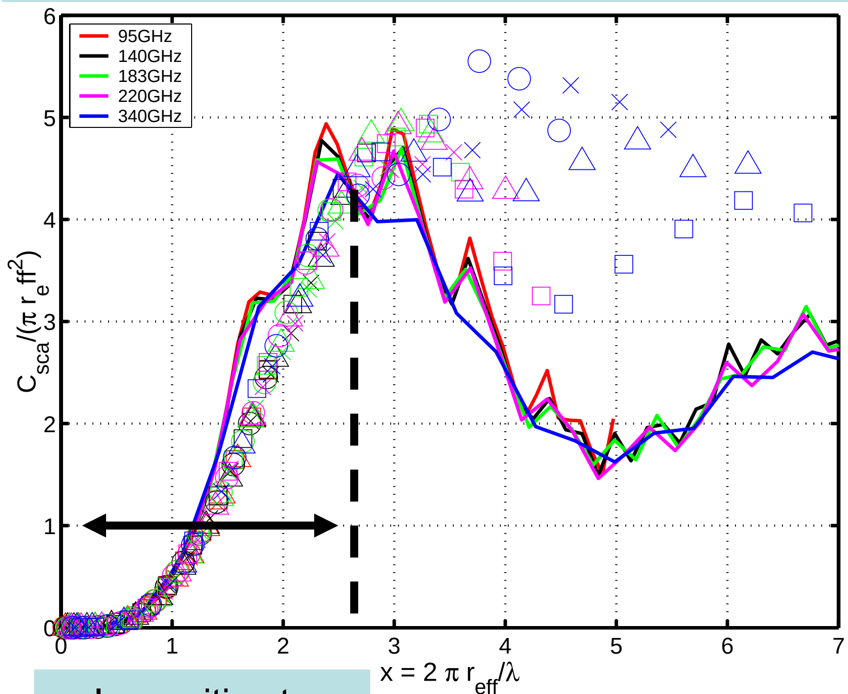
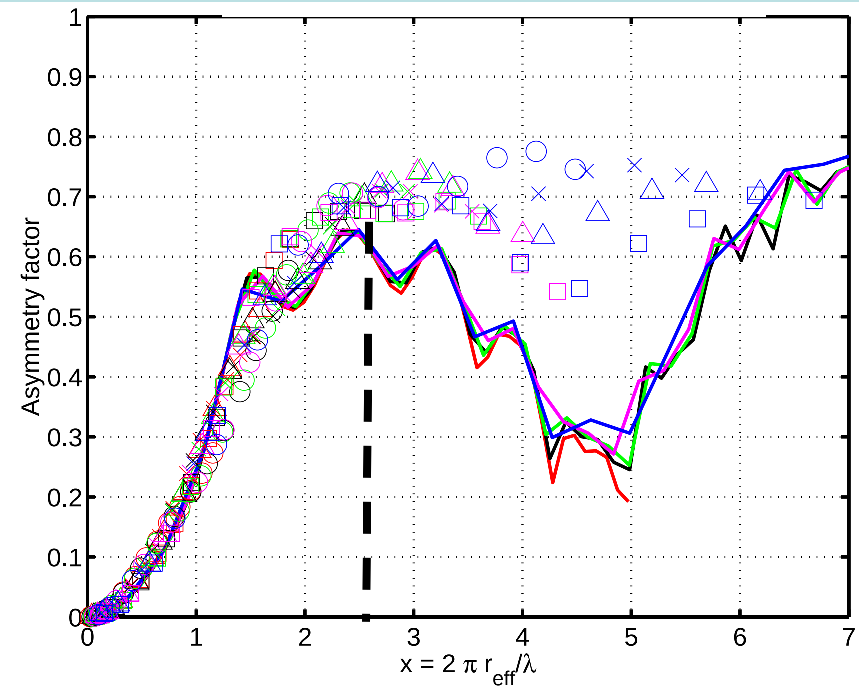
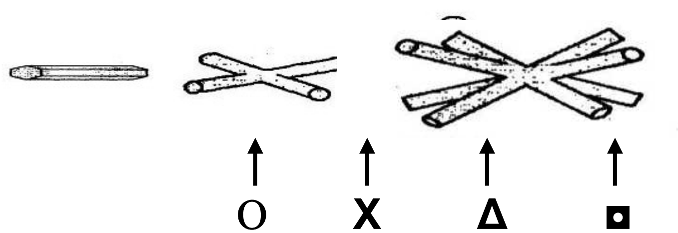




Insensitive to particle shapes.



• Kim (2006): Comparisons of single scattering parameters of nonspherical snow particles at microwave frequencies, *J. Geophy. Res.*

Overview of NCEP GSI

• The **Gridpoint Statistical Interpolation (GSI)** system was initially developed as the next generation global analysis system.

• It is based on the Spectral-Statistical Interpolation (SSI) analysis system and replaced spectral definition for background errors with grid point version based on recursive filters.

• After initial development, GSI analysis system was modified for applications of single global/regional analysis system. **Became operational in June 2006(regional analysis) and in May 2007 (global analysis**).

• **First guess fields**: 06hr GFS fcst (global), 03hr NMM fcst (regional)

• **Background errors**: NMC method(global), ensemble method(regional)

• **Currently assimilated observations**: conventional data, GPS, SSMI-rain, TMI-rain, sbuv, goes-snd, AMSU-A and B, HIRS2,3, and 4, MHS, MSU, and AIRS data. New instruments like SSMIS, OMI, and IASI are being tested.

Overview of NCEP GDAS

$$J = (x-x_b)TB^{-1}(x-x_b) + (H(x)-y_0)^T(E+F)^{-1}(H(x)-y_0) + J_C$$

x= Analysis, x_b= Background, B= Background error covariance , H= Forward model,
y_0= Observations E+F= R = Instrument error + Representativeness error, J_C = Constraint term

- Community Radiative Transfer Model (CRTM) was developed and maintained by JCSDA. The CRTM calculates radiances and jacobians in GDAS.
- The current analysis variables are unbalanced temperature, specific humidity, ozone, cloud liquid water, velocity potential, surface pressure, and stream functions.
- Cloud liquid water is only being modified slightly.

Current MW radiance assimilation in GDAS

Clear radiance asssimilation

Data thinning = 145 km for AMSU-A

User input & initializations → **Read in & distribute Observations, guess fields background error** → **Additional initializations**

GFS 6hr fcst

T, q, sfc P, u, v, ozone

Outer loop

a) Calculate radiances and jacobians with CRTM,
b) Applying bias corrections
c) Screening observation with QC processes
d) Set up right hand side of analysis equation
e) Call inner loop

i. Compute gradient information
ii. Apply background error
iii. Compute search direction
iv. Compute step size
v. Update analysis increment

Clear radiances computed

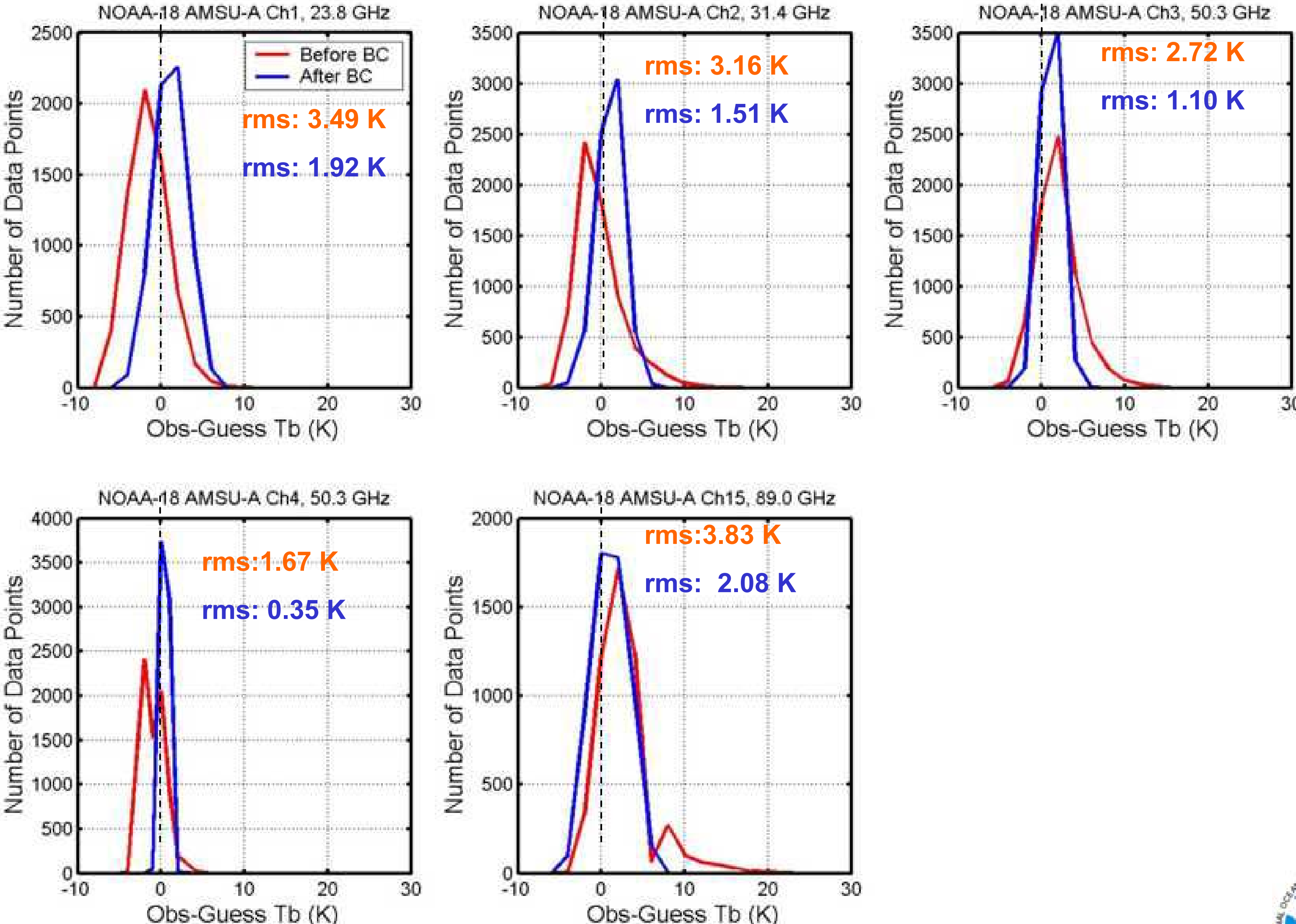
bias corrections

$$\mathrm{TB}^{i}_{bc} = \mathrm{TB}^{i} + \sum(\beta^{i} \times \mathrm{clw}) + \mathrm{others..}$$

Write analysis & related output

Observation – Guess

clear sky radiance assimilation



Observation – Guess

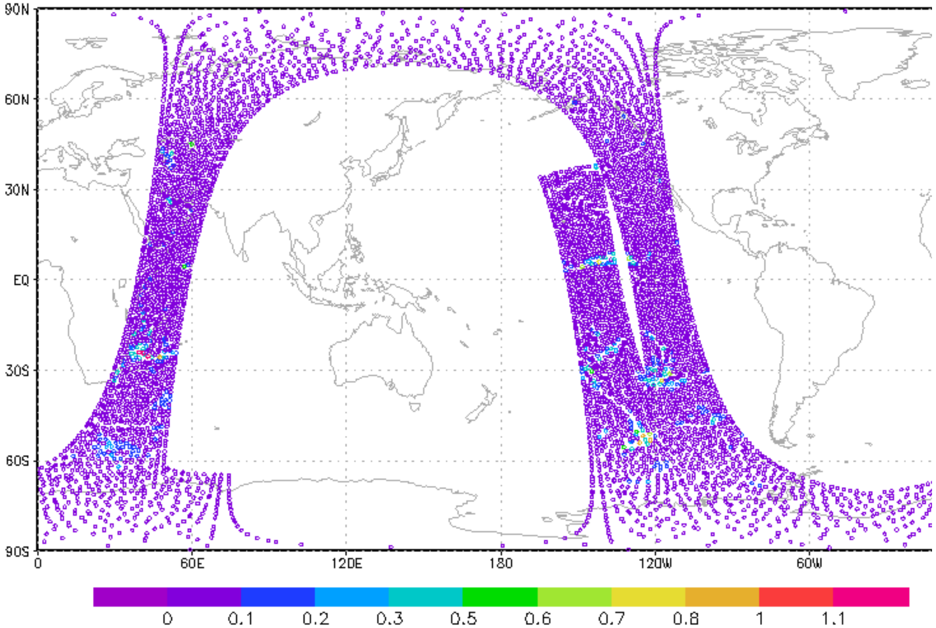
clear sky radiance assimilation

Ocean only

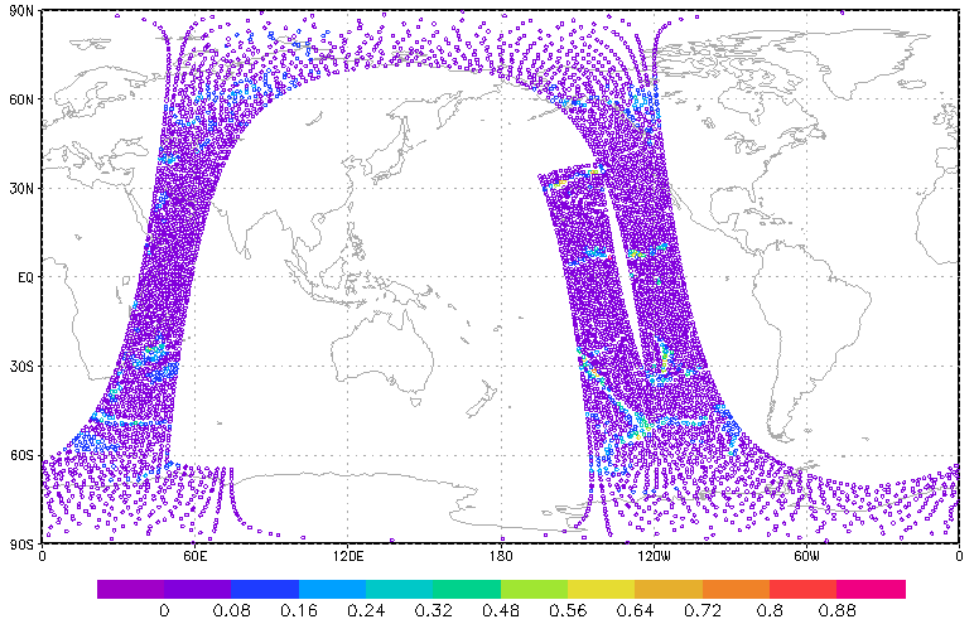
	Clear Sky (QC passed) Mean (STD) [K]		Cloudy Sky (QC passed) Mean (STD) [K]	
AMSU-A	No BC	BC	No BC	BC
Channel 1	-3.41(1.93)	-0.17 (1.91)	0.47(2.42)	0.60 (1.94)
Channel 2	-2.87 (1.34)	-0.275(1.41)	4.49 (2.70)	0.25(2.15)
Channel 3	-0.167 (1.67)	-0.06(1.02)	4.23 (3.17)	-0.16(1.33)
Channel 15	0.69 (2.02)	-0.12 (1.98)	7.84 (4.52)	-0.12 (2.47)

Cloud Observation vs. First guess

AMSU-A Retrieved CLW path (mm)



First guess CLW path (GFS 06hr fcst)



Inclusion of Cloudy Radiances in GSI

Cloud profiles in first guess fields

Hou, Moorthi, and Campana (2002)

F = (0°C – T)/20, 0 $\leq$ F $\leq$ 1 : fraction of ice cloud

Liquid cloud = Cloud Water *(1-F)

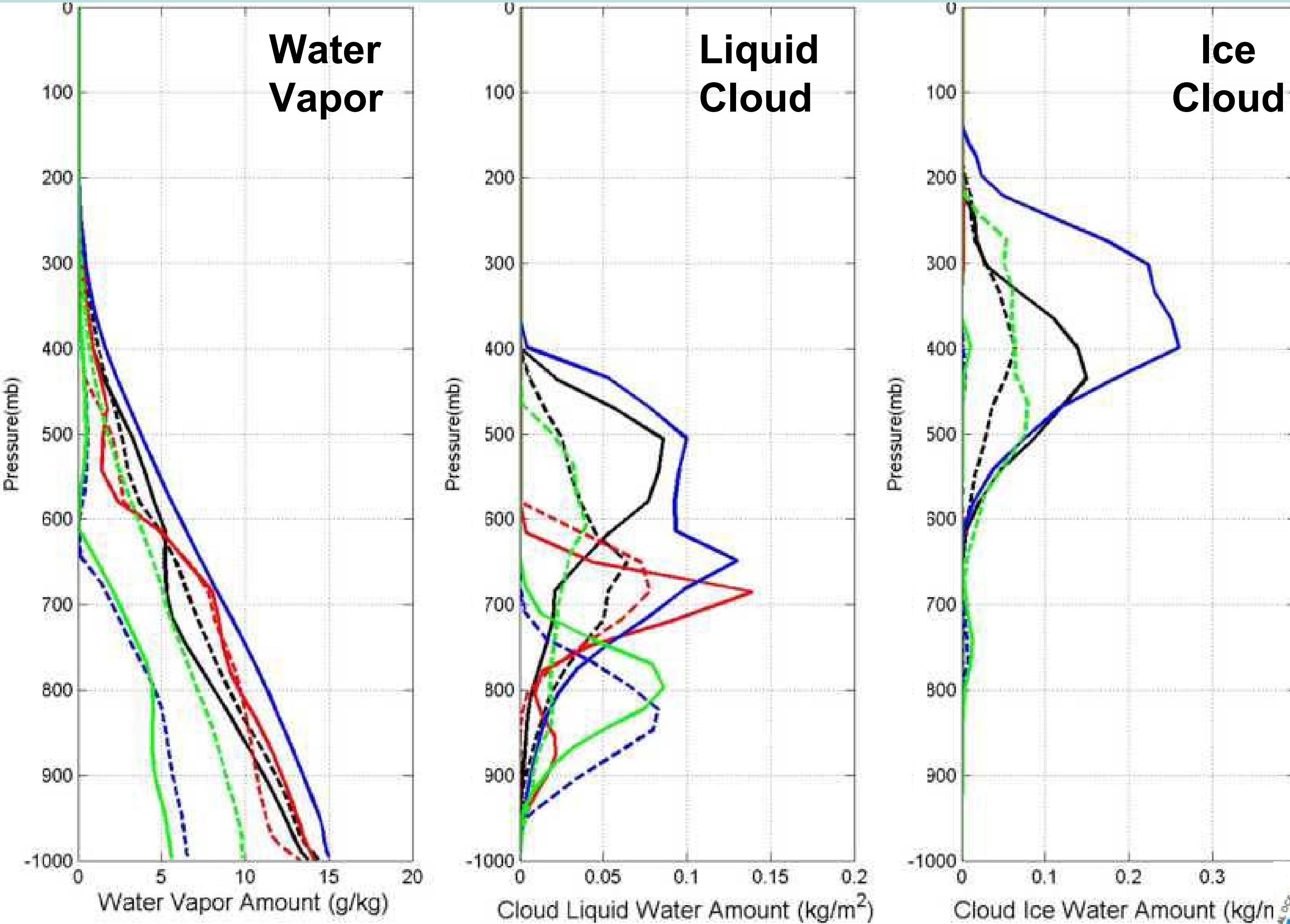
Ice cloud = Cloud water* F

Reff_ice, Reff_liquid = f(T,P,q)

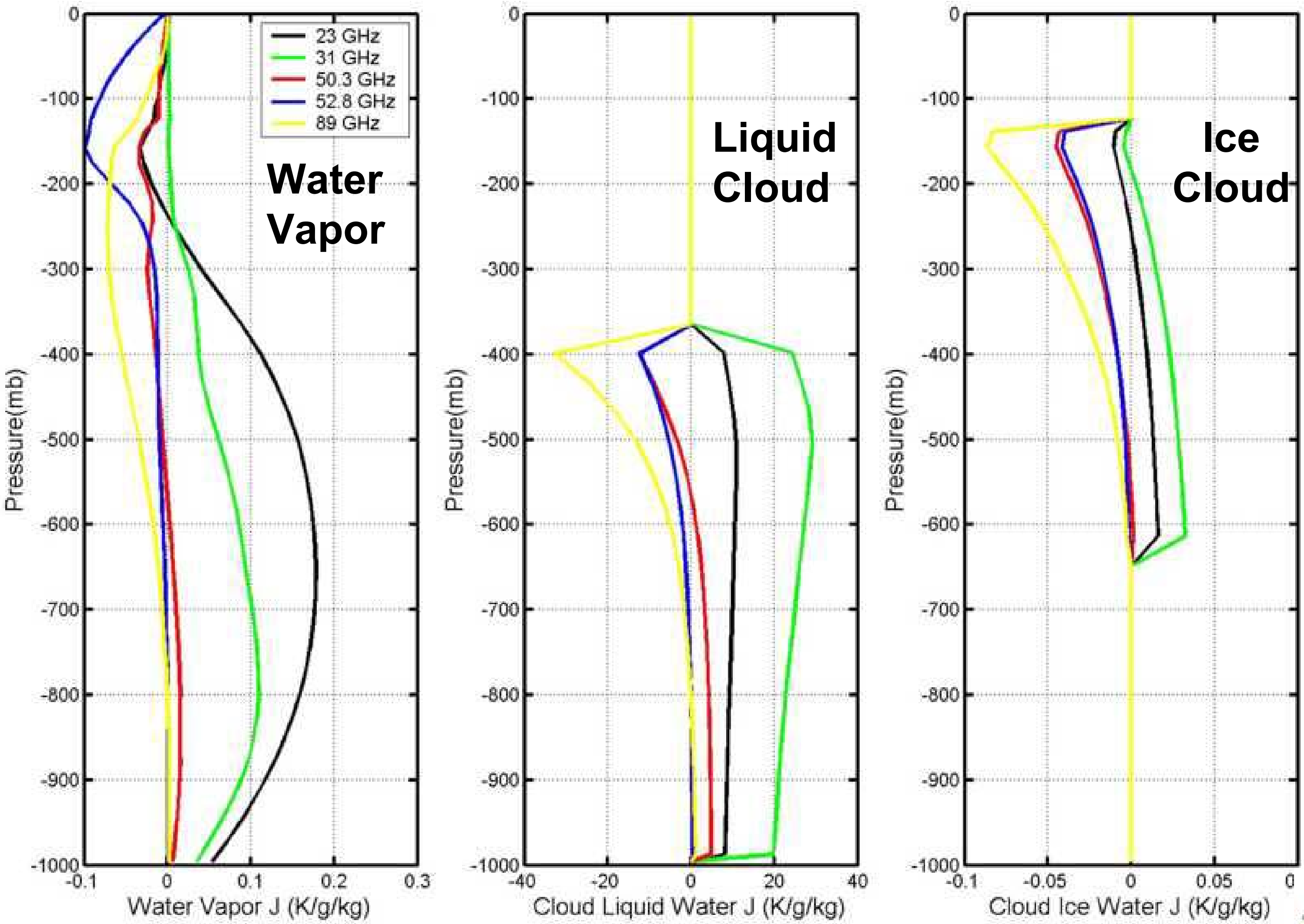
Hou, Y.-T., S. Moorthi, and K.A. Campana, 2002: Parameterization of solar radiation transfer in the NCEP models. NCEP Office Note 441.

Inclusion of Cloudy Radiances in GSI

Cloud profiles in first guess fields



CRTM computed WV and Cloud Jacobians



Observation – Guess

clear radiance vs. cloudy radiance

	Clear Sky, No BC Mean (STD) [K]		Cloudy Sky, No BC Mean (STD) [K]	
	Clear radiance DA	Cloudy radiance DA	Clear radiance DA	Cloudy radiance DA
Channel 1	-3.41(1.93)	-3.44 (2.00)	0.47(2.42)	-0.12(2.17)
Channel 2	-2.87 (1.34)	-3.03 (1.48)	4.49 (2.70)	3.18(2.67)
Channel 3	-0.167 (1.67)	-0.42 (1.78)	4.23 (3.17)	3.24(2.41)
Channel 15	0.69 (2.02)	0.39 (2.12)	7.84 (4.52)	6.53(3.94)

Inclusion of Cloudy Radiances in GSI

Tangent linear models

$$\frac{\partial T_B}{\partial T_v} = \frac{1}{1+\varepsilon q}\frac{\partial T_B}{\partial T}$$

$$\frac{\partial T_B}{\partial q} = \frac{-\varepsilon T}{1+\varepsilon q}\frac{\partial T_B}{\partial T} + \frac{1000}{(1-q)^2}\frac{\partial T_B}{\partial w}$$

$$\frac{\partial T_B}{\partial cwmr} = \frac{P_{mb}\times 100\times \Delta z_m}{R_d T_v}\cdot(1-F)\cdot\frac{\partial T_B}{\partial CL} + \frac{P_{mb}\times 100\times \Delta z_m}{R_d T_v}\cdot F\cdot\frac{\partial T_B}{\partial CI}$$

F: ice cloud fraction

Current Work

Inclusion of GFS model cloud and precipitation microphysics parameterizations (FW, TL, AD) in the GDAS analysis system.

Future Work

- Including cloud and precipitation microphysics parameterizations (FW, TL, AD) in the GDAS analysis system.

- Channel selection

- Bias correction and Quality control should be revisited.

- How to make a link to dynamic variables

- Impact studies

Bias Correction

Variational Bias Correction Method updates the bias inside the assimilation system by finding corrections that minimize the systematic radiance departures while simultaneously improving the fit to other observed data inside the analysis flow.

$$TB_{bc}^{i} = TB^{i} + \sum_{n=1}^{\#pred} (\beta_{n}^{i} p_{n})$$

p: predictor

b : bias correction coefficient

$$J = x^{T} B^{-1} x + (H(x) - y)^{T} R^{-1} (H(x) - y) + (\beta - \beta_{b})^{T} \beta^{-1} (\beta - \beta_{b})$$

Predictiors .. Constant, tlap, tlap^{2}, clw, scan angle dependent