The Assimilation of Satellite Radiances at NCEP

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Slide 1

Plan of the Presentation

- Currently Assimilated Satellite Radiances
- Upgrades for QY14 implementation:
  - Resolution Changes
  - Radiative Transfer (CRTM)
  - SSMIS
- Upgrades for QY15 Implementation
  - Near Sea Surface Temperature (NSST)
  - Cloudy Radiance

Slide 2

Satellite Radiances Assimilated in NCEP Global Model

- GOES-15 Sounder
  - Channels 1-15
- SEVIRI
  - Meteosat 10 Channels 5-6
- AMSU-A
  - NOAA-15 Ch.1-10,12-13,15
  - NOAA-18 Ch.1-8,10-13,15
  - NOAA-19 Ch.1-7,9-13,15
  - MetOp-A Ch.1-6,9-13,15
  - MetOp-B Ch.1-13,15
  - Aqua Ch.6,8-13
- ATMS
  - SNPP Ch. 1-14, 16-22
- SSMIS
  - F17 Ch. 1-3,5-7,24
  - F18 Ch. 1-7, 24
- MHS
  - NOAA-18 Ch 1-5
  - NOAA-19 Ch 1-5
  - MetOp-A Ch 1-5
  - MetOp-B Ch 1-5
- HIRS
  - MetOp-A Ch. 2-15
- AIRS
  - Aqua 120 Channels
- IASI
  - MetOp-A 165 Channels
  - MetOp-B 165 Channels
- CrIS
  - 84 Channels

Slide 3

In Fall 2014
Operational Upgrade

EnKF/DA-Resolution components in T1534 GFS Package

Resolution for Data Assimilation

Current operations

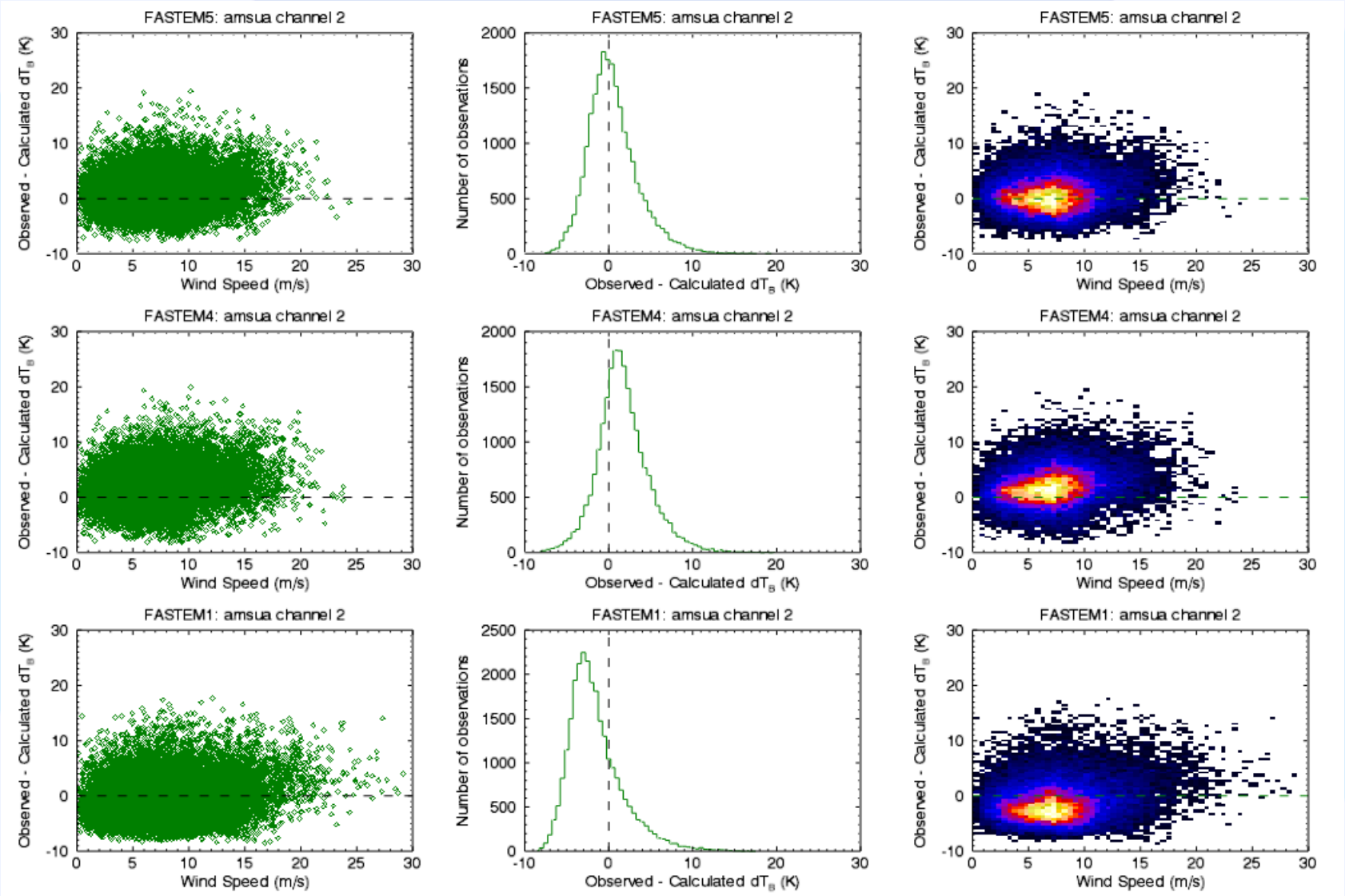
- Analysis done on linear grid that corresponds to the model truncation: T574 – 1152 x 576
- However, the 80 member ensemble that prescribes 75% of the solution is at T254 – 512 x 256.

Proposed configuration for T1534 SL (3072 x 1536) GFS

- Increase 80 member EnKF resolution to T574 (SL)
- Compute GSI-hybrid analysis increment at the ensemble resolution (T574 – 1152 x 576)
  - 75% of the solution is driven by information at this (or coarser) resolution already
- Increment is transformed to wave space and added to full resolution background

CRTM Upgrade

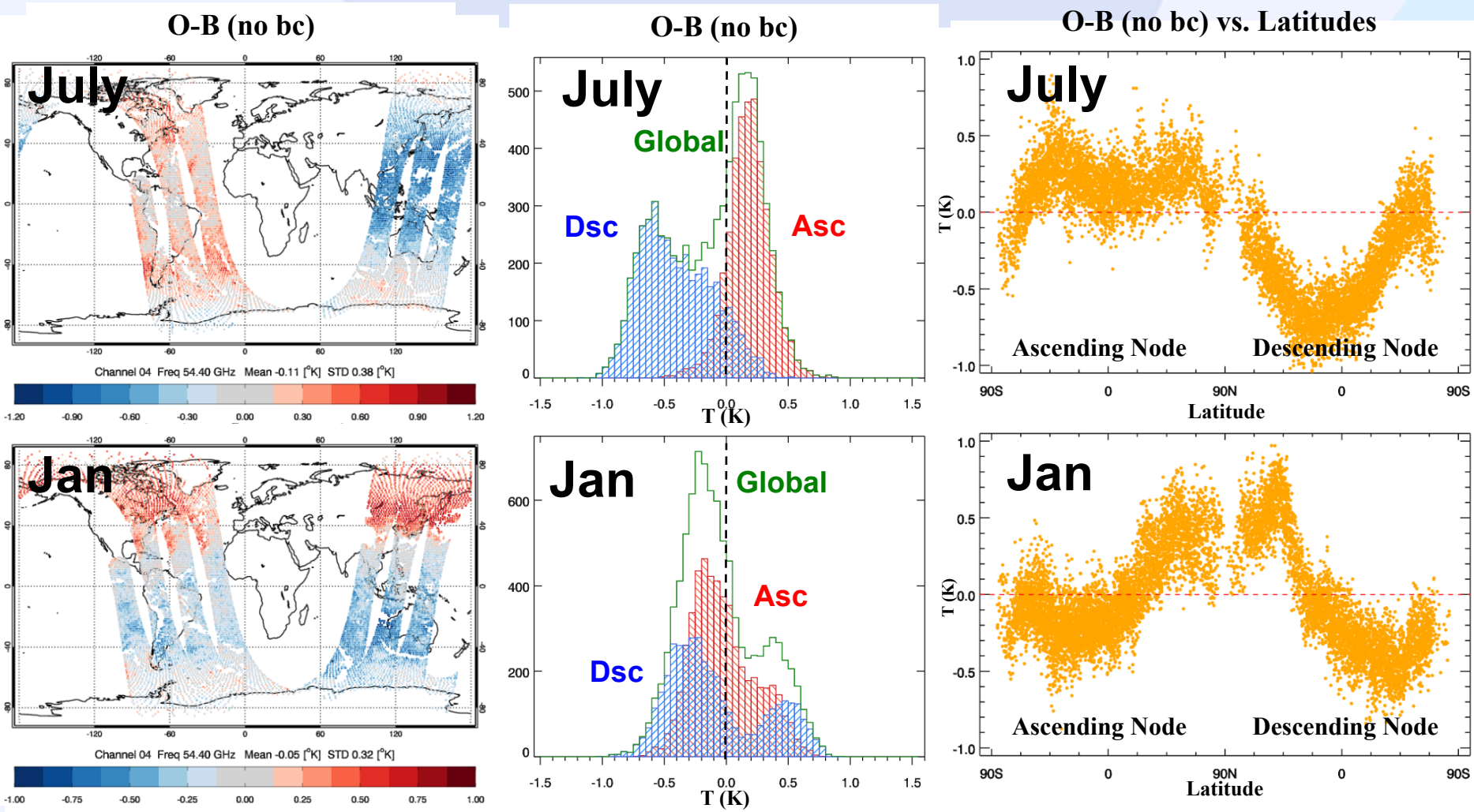
FASTEM-5


FASTEM5: amsua channel 2
Observed - Calculated dT_B (K)
Wind Speed (m/s)
Number of observations
Observed - Calculated dT_B (K)
FASTEM4: amsua channel 2
FASTEM1: amsua channel 2

SSMIS

(Emily Liu)

SSMIS F18 Bias Characteristics



- Ascending and descending biases are significant (summer season is worse)
- Ascending pass is warmer than the descending pass

Variational Bias Correction Scheme

- Variational bias correction provides an automatic inter-calibration of the observing system in the context of the forecast model, producing bias corrections that improve the consistency of the information entering the analysis

- For instruments other than SSMIS the bias correction is calculated using five air-mass predictors and four scan angle predictors

- For SSMIS a variety of different additional predictors were tried based on experience at the Met Office, NRL and ECMWF

Bias correction predictors used are:

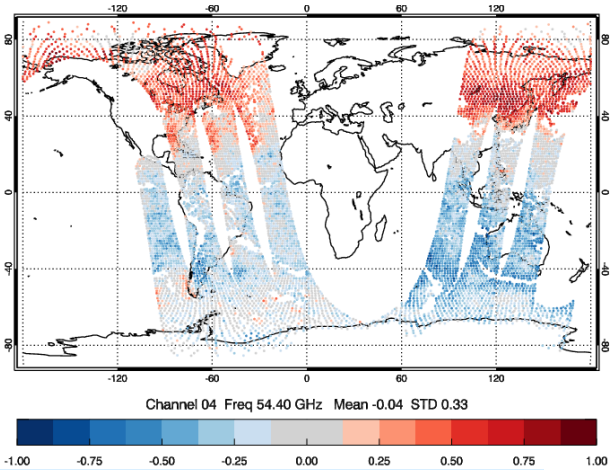
Air-mass					SSMIS specific		Scan angle (θ)			
const offset	zenith angle	cloud liquid water	lapse rate	lapse rate square	$node^{*} \times \cos(lat)$	$\sin(lat)$	θ^4	θ^3	θ^2	θ

*node is +1 if ascending, -1 if descending

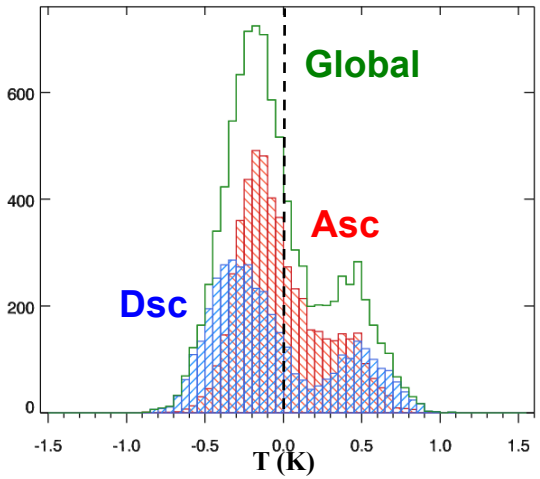
Application of NWP Bias Correction for SSMIS F18

Using Met Office SSMIS Bias Correction Predictors

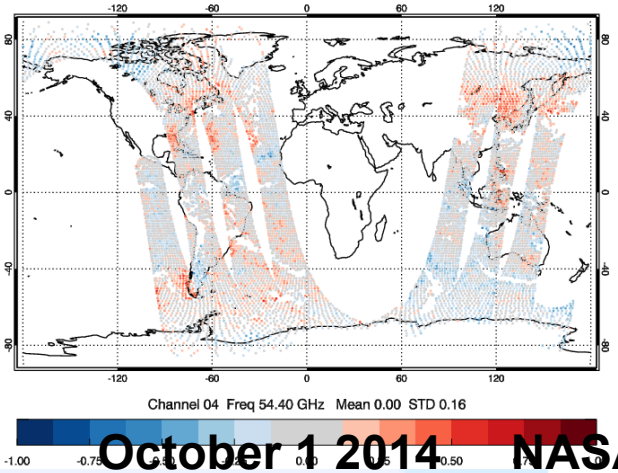
O-B Before Bias Correction



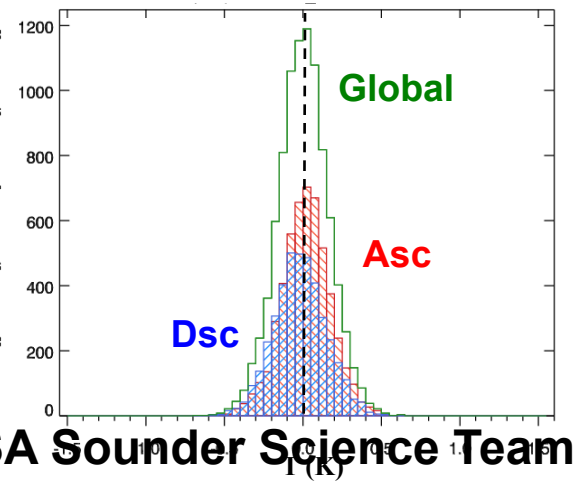
O-B Before Bias Correction



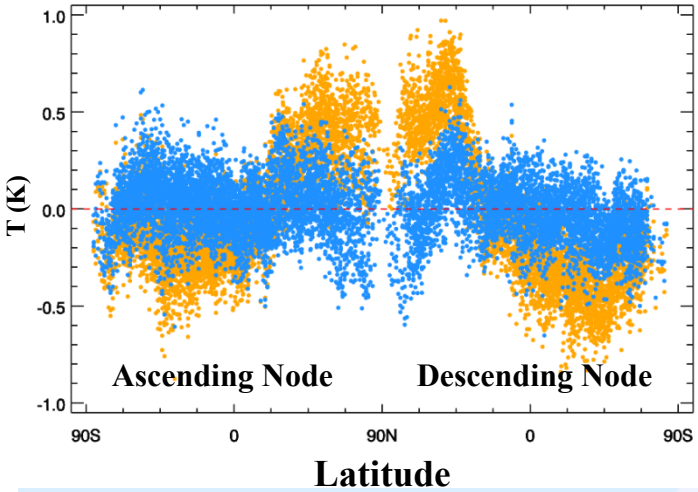
O-B After Bias Correction



O-B After Bias Correction

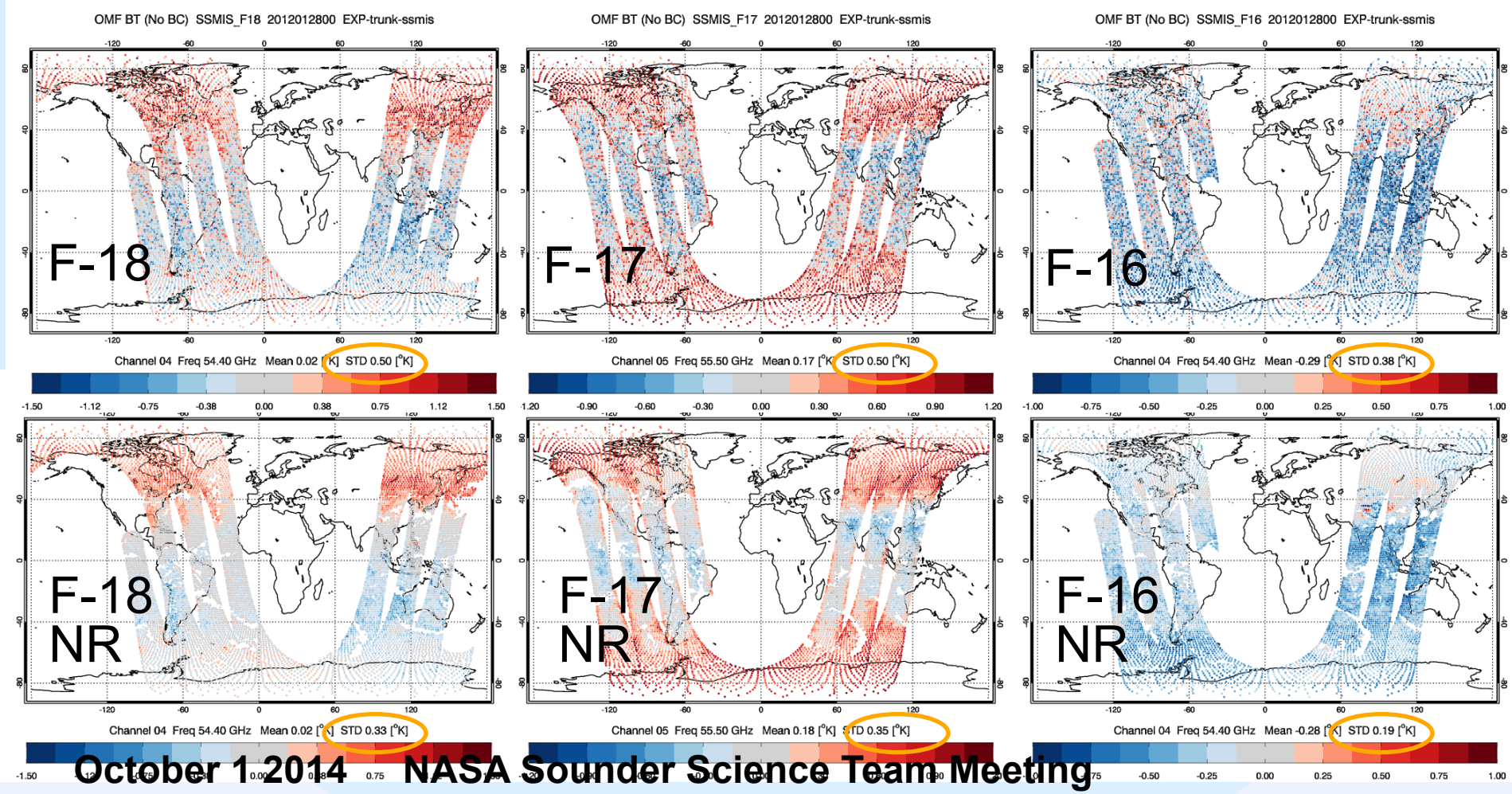


Unbias & Bias Corrected O-B



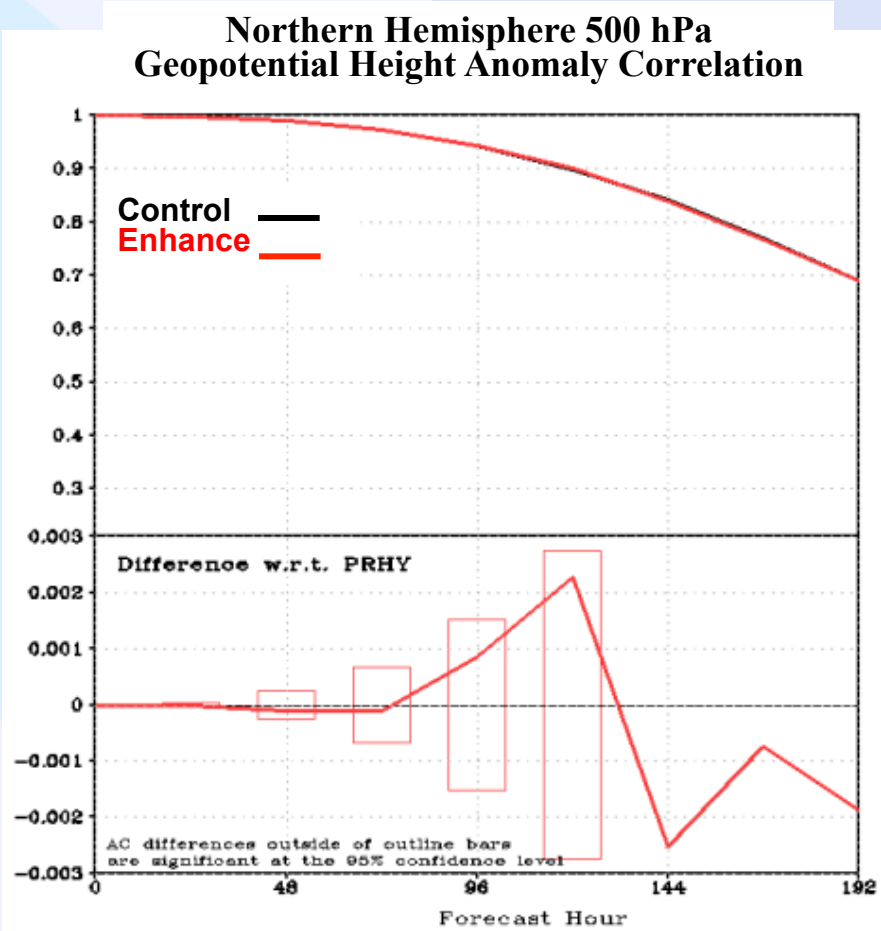
Application of NWP Noise Reduction for SSMIS

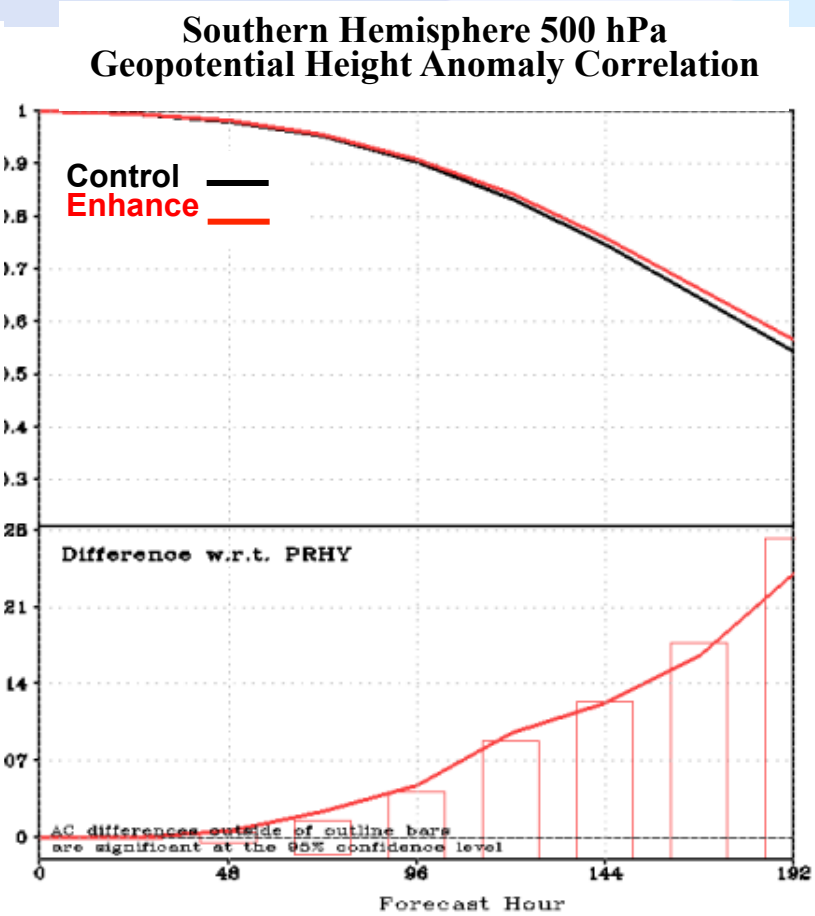
- By design SSMIS oversamples the brightness temperature field at relatively high noise
- Must apply spatial averaging before assimilating the data to reduce the noise
- A spatial averaging scheme was implemented inside of analysis(GSI) for SSMIS



Impact of Assimilating SSMIS into Current Operational System (1)

15 Jan to 30 Mar 2012 (00Z cycles only)



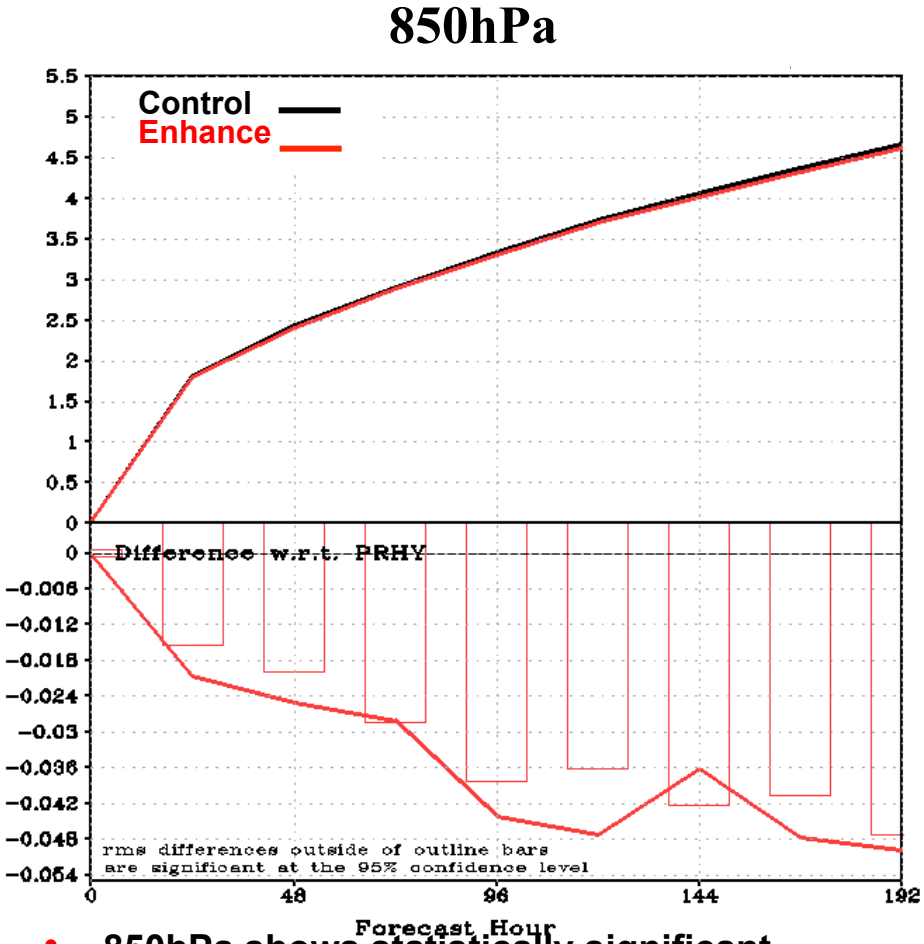


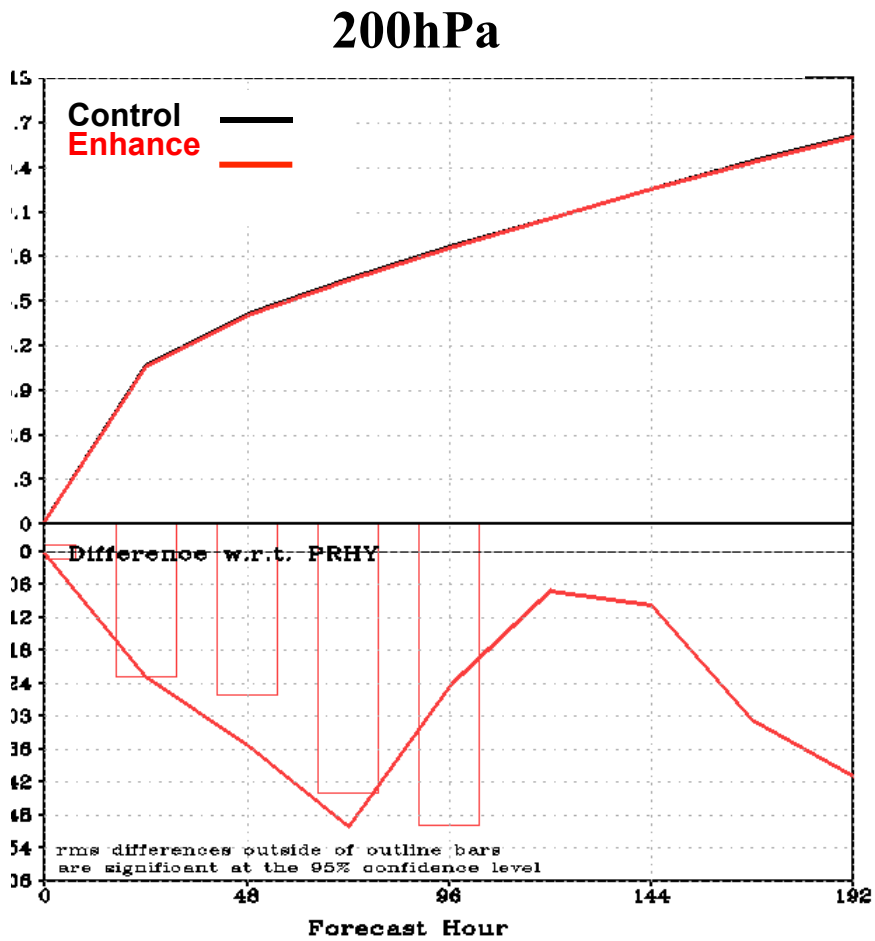
- Impact is not significant in northern hemisphere
- Marginally significant positive impact in southern hemisphere

Impact of Assimilating SSMIS into Current Operational System (2)

Tropical (20°N-20°S) 0 to 5 Day Wind Forecast RMS Errors

15 Jan to 30 Mar 2012 (00Z cycles only)



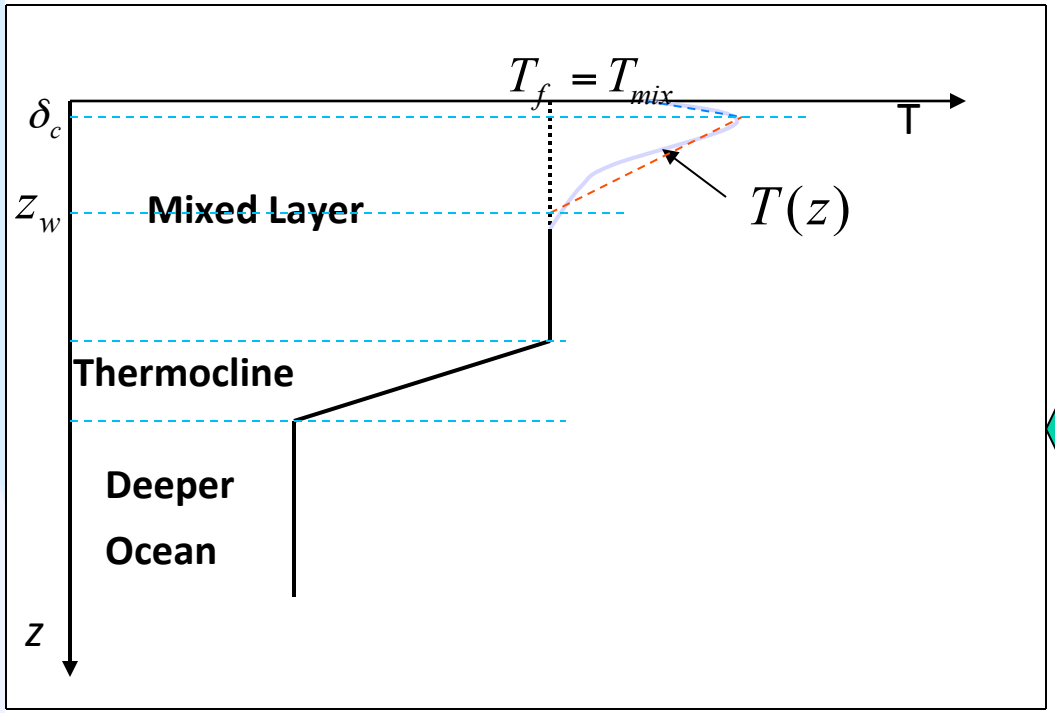


- 850hPa shows statistically significant positive impact in medium range
- Some small but significant positive impact in short range for 200hPa winds

Near Sea Surface Temperature (NSST)

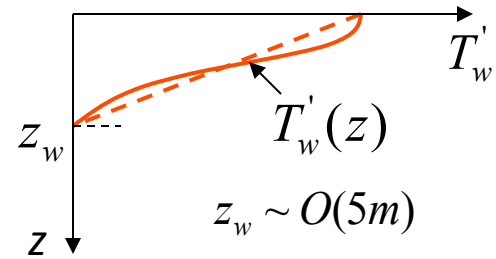
What is NSST (Near-Surface Sea Temperature)?

NSST is a **T-Profile** just below the sea surface.
Here, only the vertical thermal structure due to **diurnal thermocline layer warming** and **thermal skin layer cooling** is resolved



Diurnal Warming Profile

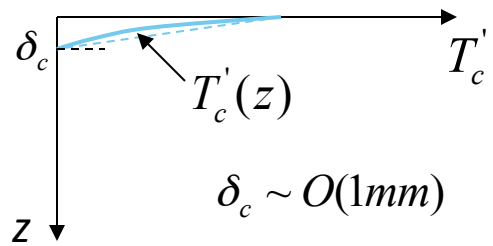
$$T_w^{'}(z) = (1 - z / z_w) T_w^{'}(0)$$



$$z_w \sim O(5m)$$

Skin Layer Cooling Profile

$$T_c^{'}(z) = (1 - z / \delta_c) T_c^{'}(0)$$

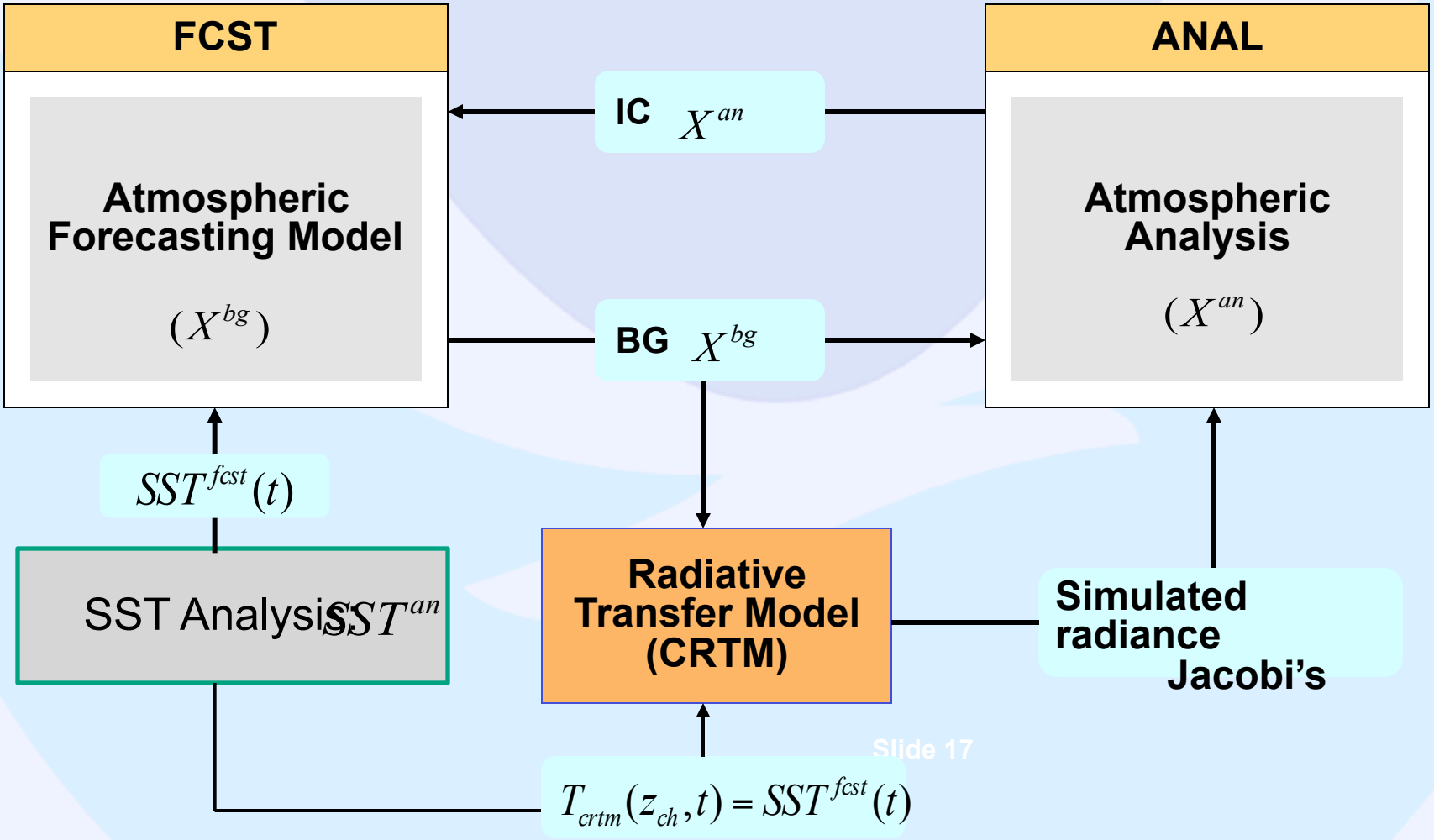


$$\delta_c \sim O(1mm)$$

$$T(z,t) = T_f(z_w, t) + T_w^{'}(z,t) - T_c^{'}(z,t)$$

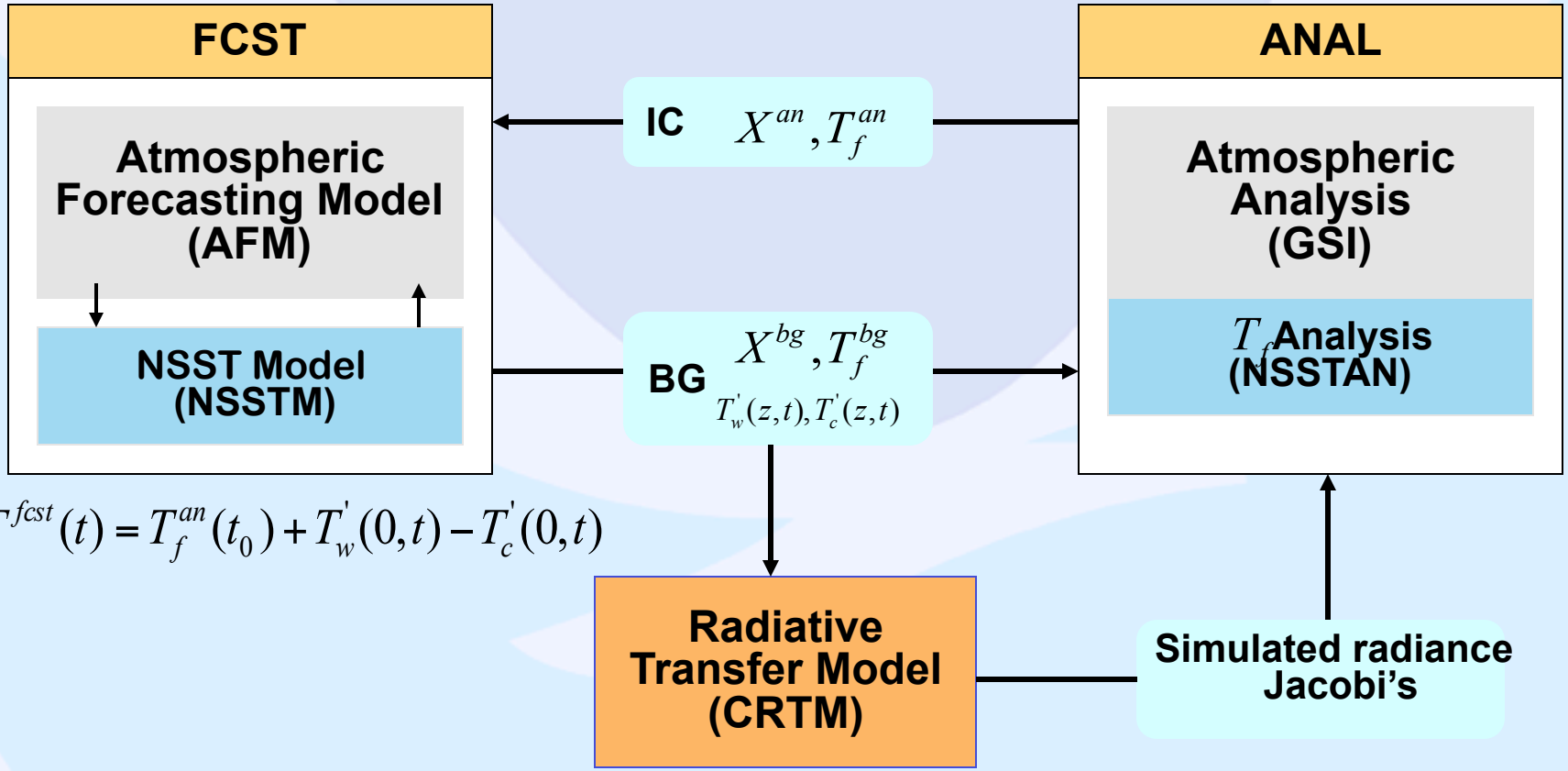
$$z \in [0, z_w]$$

Current oceanic component (SST) in the NCEP GFS



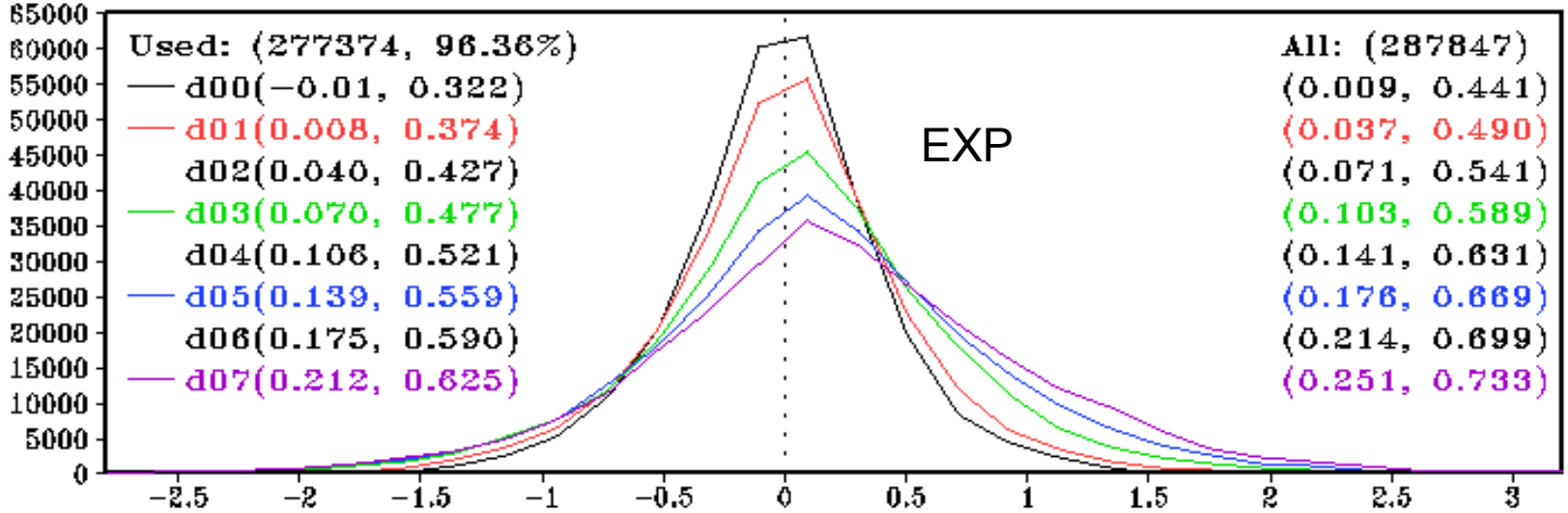
$$SST^{fcst}(t) = [SST^{an}(t_0) - SST^{clim}(t_0)]e^{-(t-t_0)/T_{90d}} + SST^{clim}(t)$$

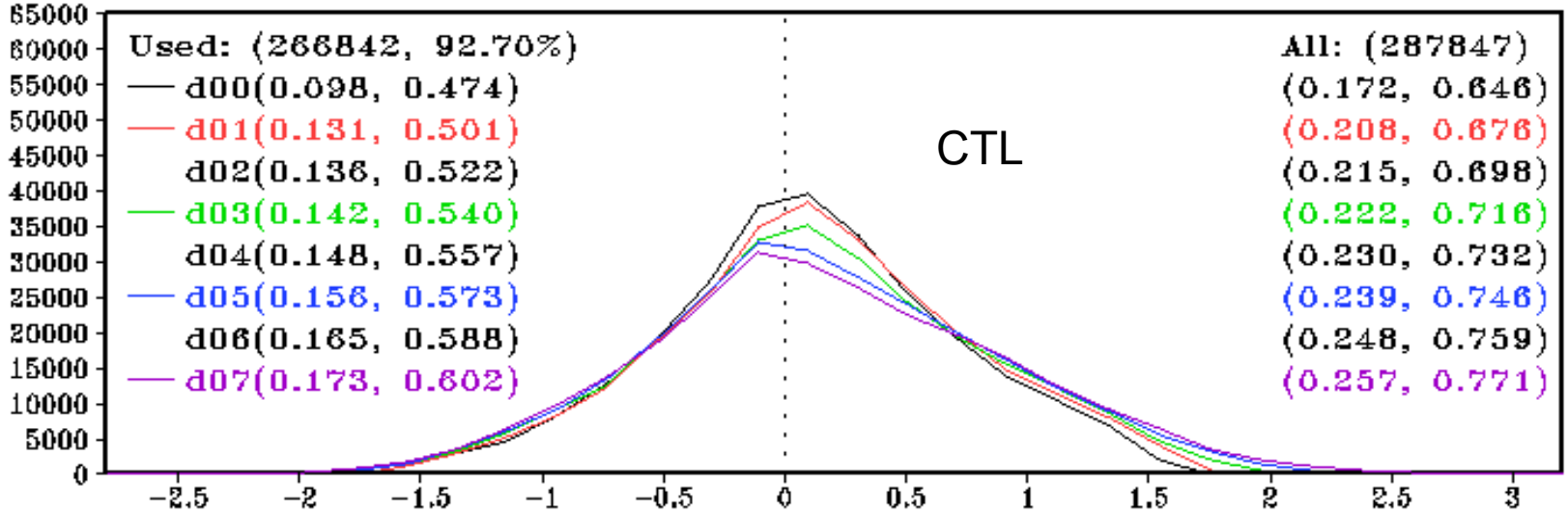
The NSST within the NCEP GFS



$$SST^{fcst}(t) = T_f^{an}(t_0) + T_w^{'}(0,t) - T_c^{'}(0,t)$$

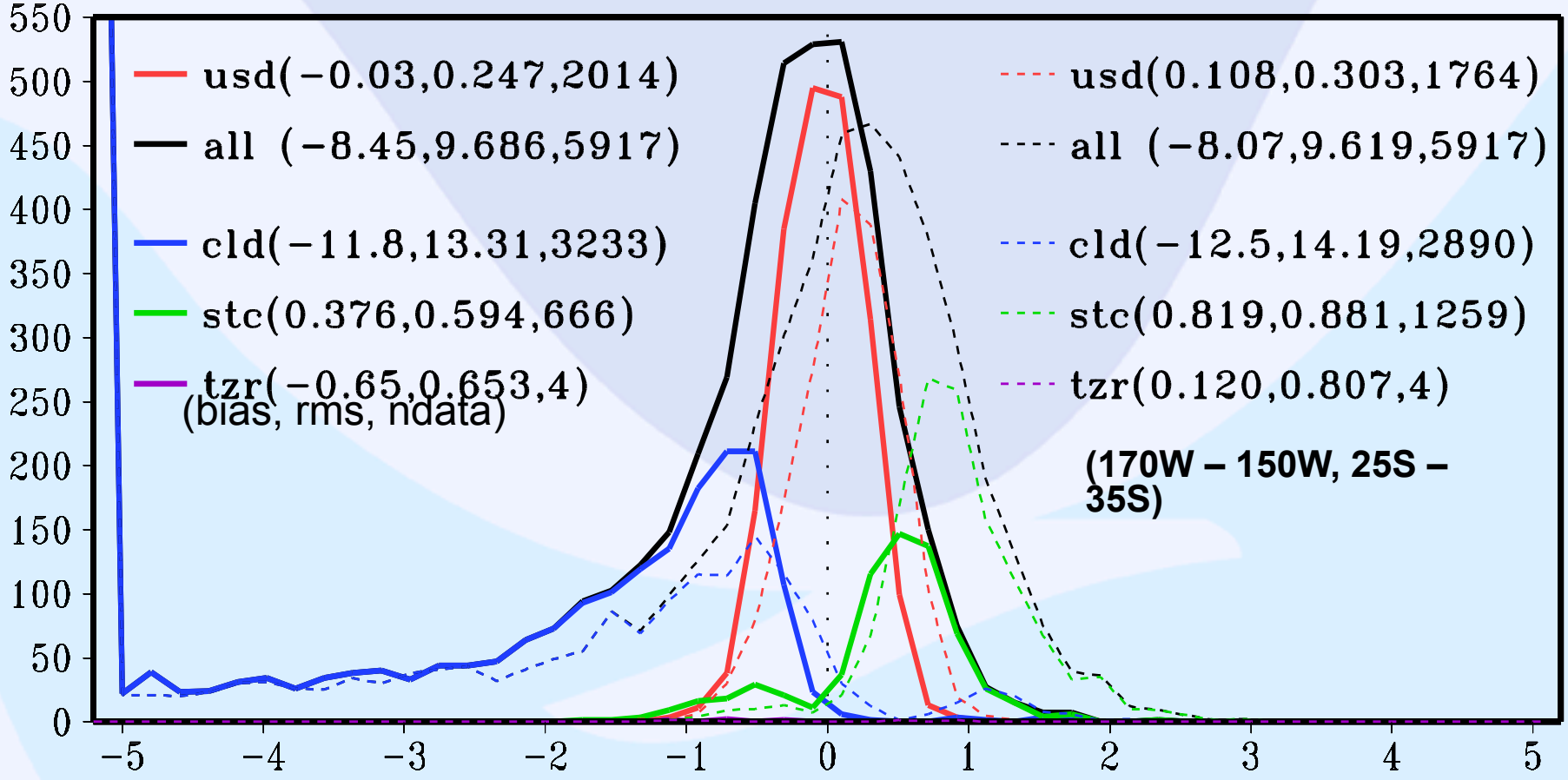
$$T_{crtm}(z_{ch},t) = T_f(t_0) + T_w^{'}(z_{ch},t) - T_c^{'}(z_{ch},t)$$





Histogram of (O – B) for SST verified vs buoys, S.Mid (20S – 50S). Jan. 2011

Hitogram of (O- B) for IASI satellite radiance. CH-211, Jan. 2011. S.Mid.Pac

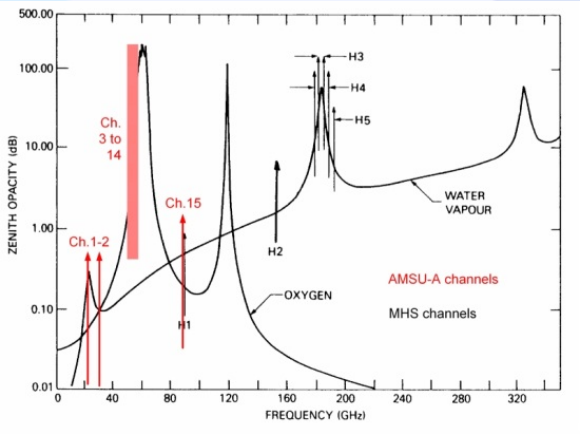


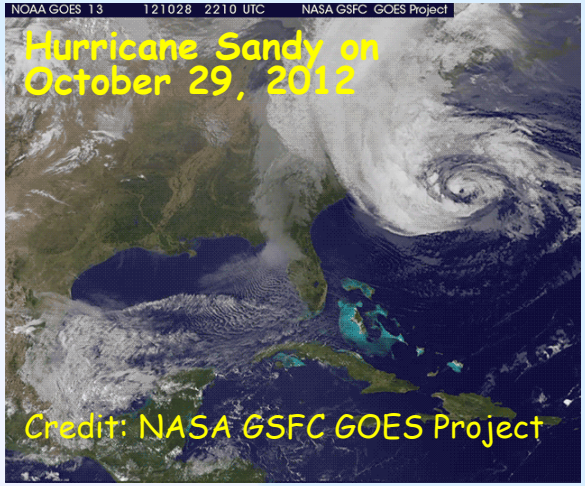
The impact of SST on Quality Controls in the use of satellite radiance

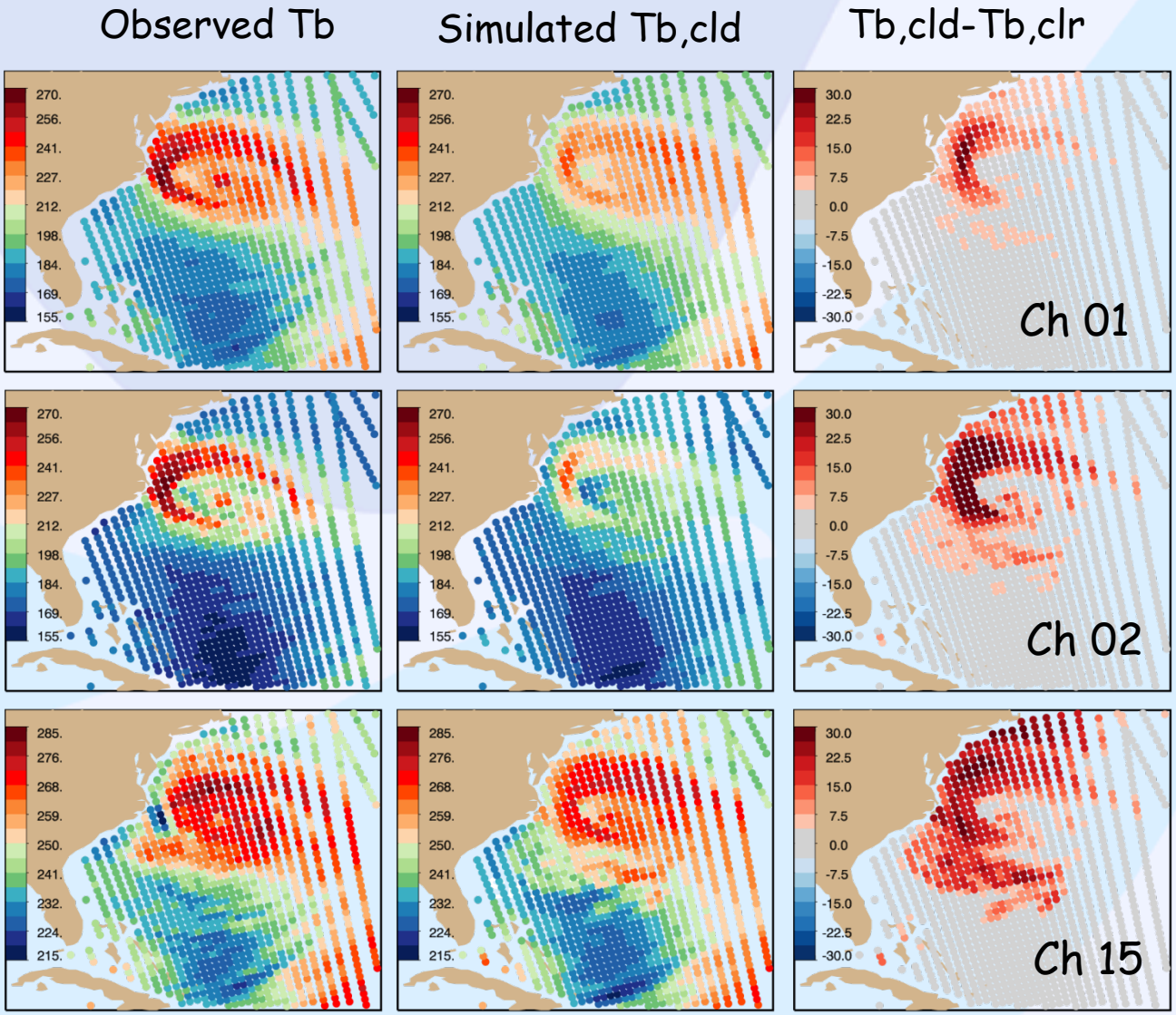
Solid: EXP; Dashed: CTL
cld: Cloud detection test
stc: Surface temperature test
tzr: Tz physical retrieval based test

All-Sky Radiance Assimilation

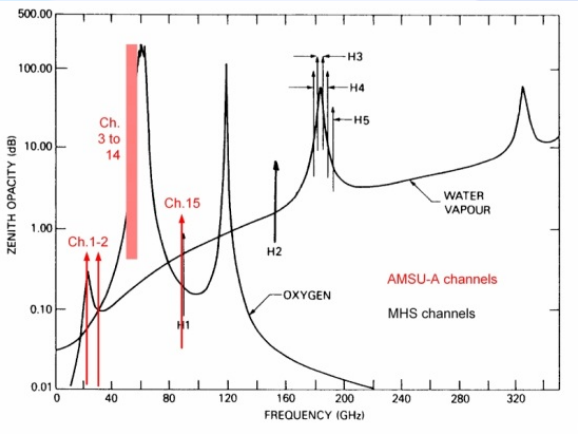
Information content of AMSU-A

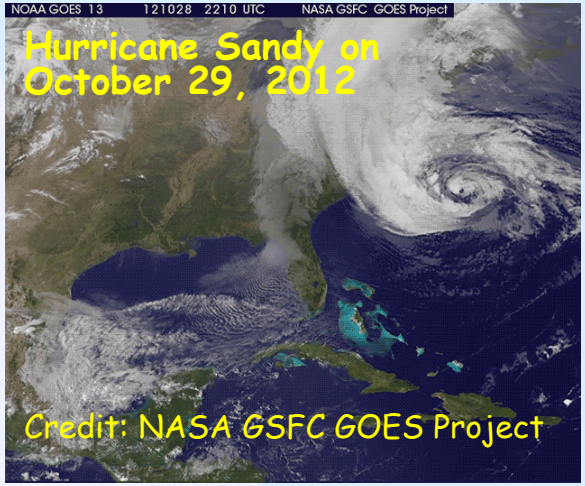


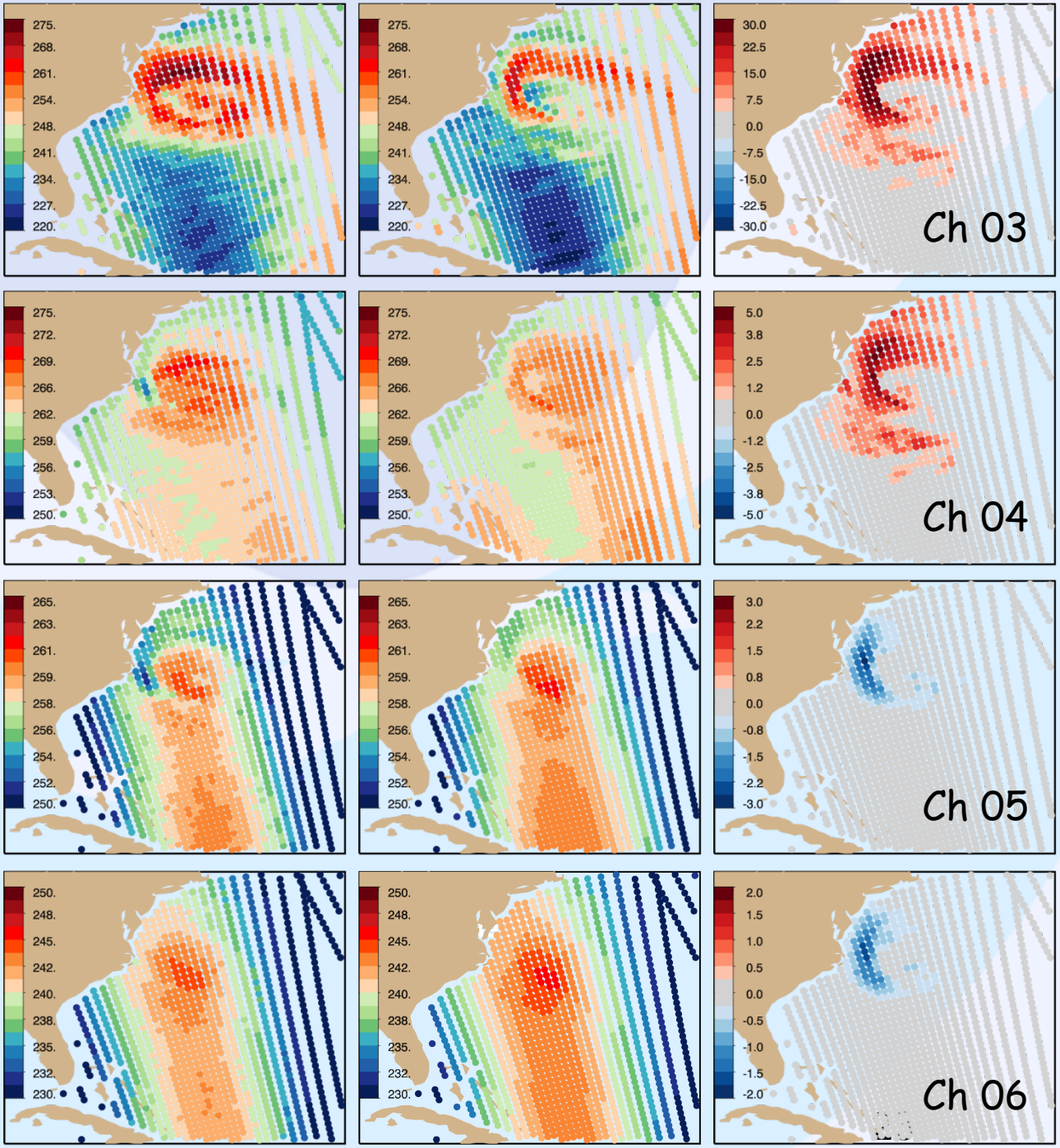




Hurricane Sandy captured by Metop-A AMSU-A

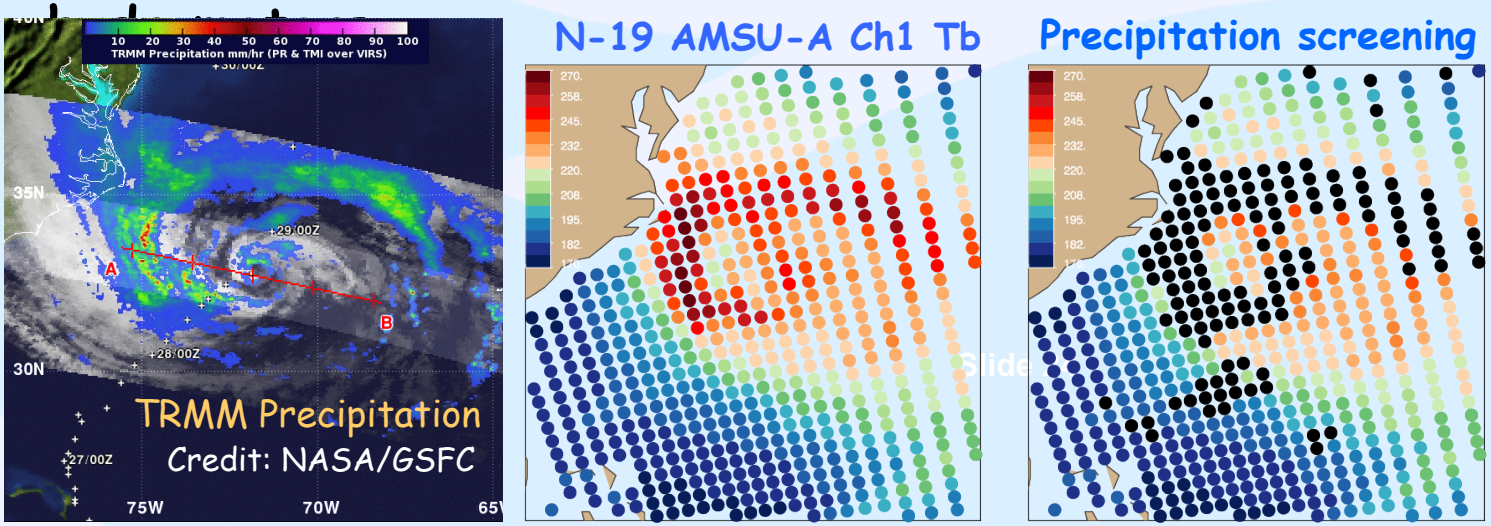

ZENITH OPACITY (dB)
FREQUENCY (GHz)
Ch. 3 to 14
Ch.15
Ch.1-2
H1
H2
H3
H4
H5
WATER VAPOUR
OXYGEN
AMSU-A channels
MHS channels


NOAA GOES 13 121028 2210 UTC NASA GSFC GOES Project
Hurricane Sandy on October 29, 2012
Credit: NASA GSFC GOES Project


Ch 03
Ch 04
Ch 05
Ch 06

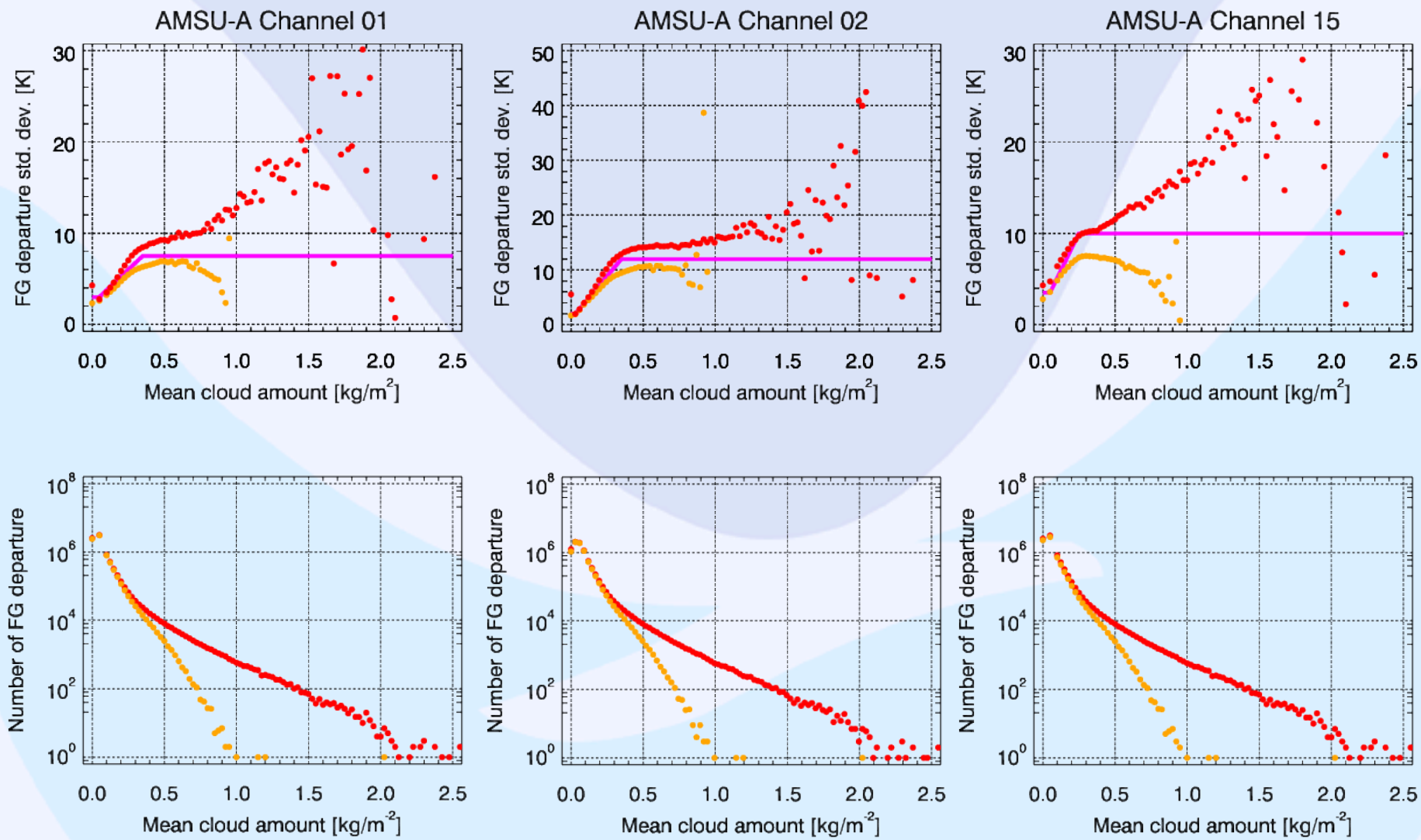
Quality control for all-sky condition

- To assimilate AMSU-A radiances with non-precipitating clouds, channel 4 cloud check was removed from QC
- Precipitation screening criteria (empirical)
  - Linearized form of the Grody scattering index (1999)
  - Channel 6 residual check for scattering effect from frozen



Hurricane Sandy on October 28 at 18Z

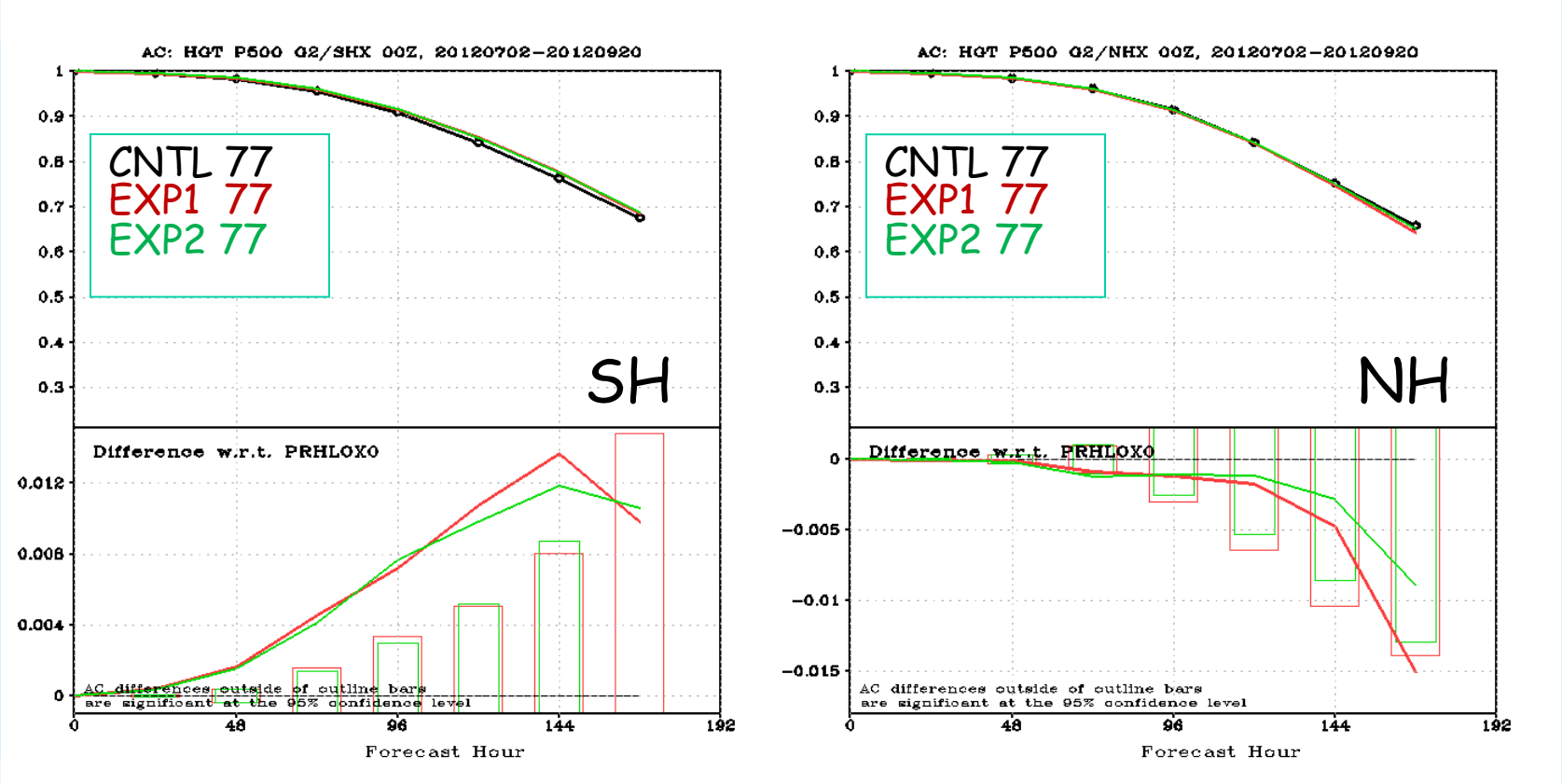
24



Tb departure samples calculated from first-guess profiles of the all-sky experiment using error model #1

(No QC, QC, Error Model#2)

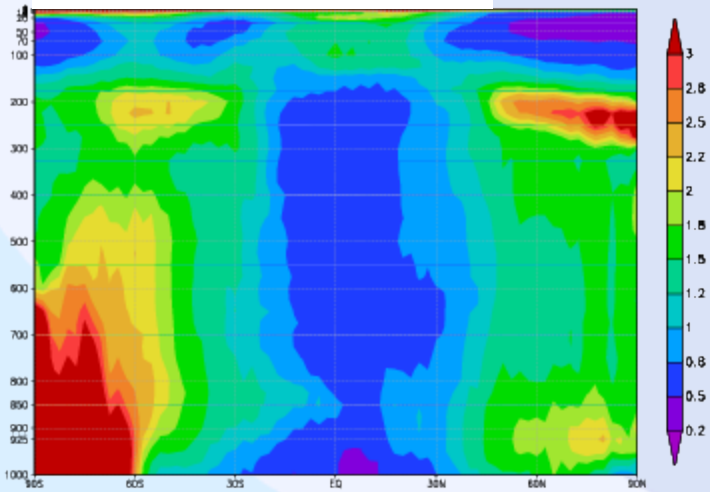
Impact of cloudy radiances on forecast



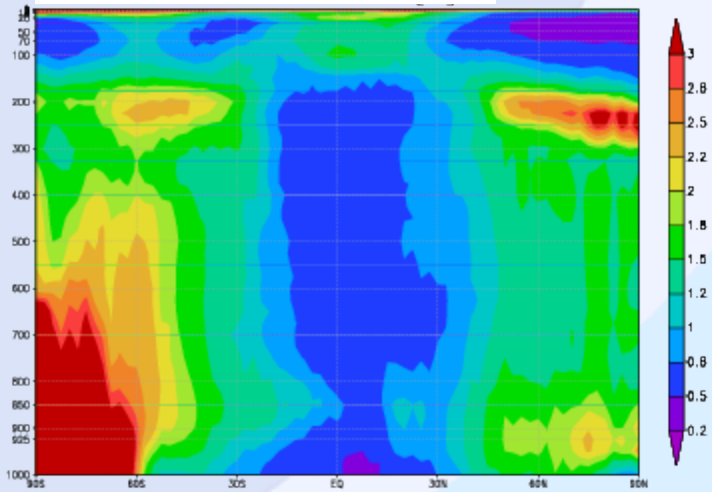
500 hPa anomaly correlation of geopotential height

26

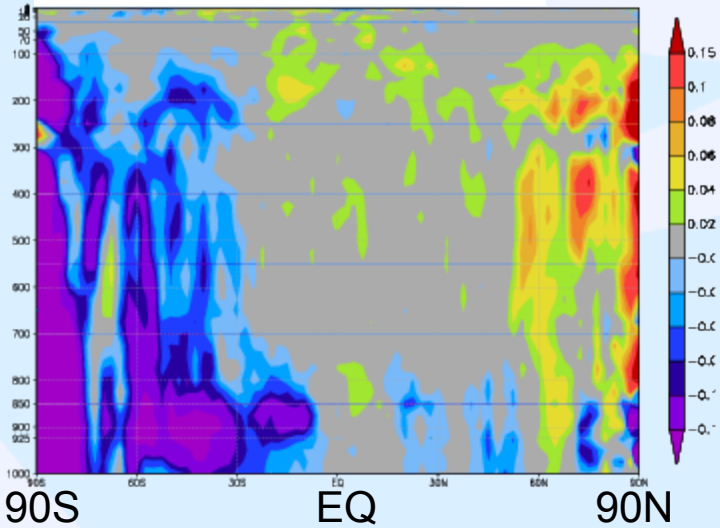
EXP2 (all-sky)



CNTL (clear-sky)



EXP2-CNTL



RMS

72-hr Forecast Error

Zonal Mean Temperature (K)

Aug 01 2012-Aug31 2012

Other Cloudy Radiance Projects

- Infrared All-Sky Radiances
  - Focussing on IASI water vapor band
- Cloud Cleared IR Radiances
  - CrIS radiances cloud-cleared inside the GSI data assimilation system
- Assimilation of IR radiances with cloud as sink variable
  - See Will McCarty's talk

Summary

- **The Global Forecast System upgrade in Fall 2014 will include**
  - **Model resolution upgrade to T1534 with T 574 analysis and EnKF ensemble**
  - **Assimilation of IASI MetOp-B & SSMIS**
  - **Improved CRTM and bias correction**
- **Ongoing Projects include**
  - **Sea Surface Temperature Analysis improvements**
  - **All Sky Radiance Assimilation**

Questions?