# Assimilation of Satellite Microwave Water Vapor Sounding Channel Data in NCEP Global Forecast System (GFS)

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# Outline

- Introduction

- Assimilation of MHS and (F16) SSMIS water vapor sounding channel data

- Preliminary assessment of F18 SSMIS data

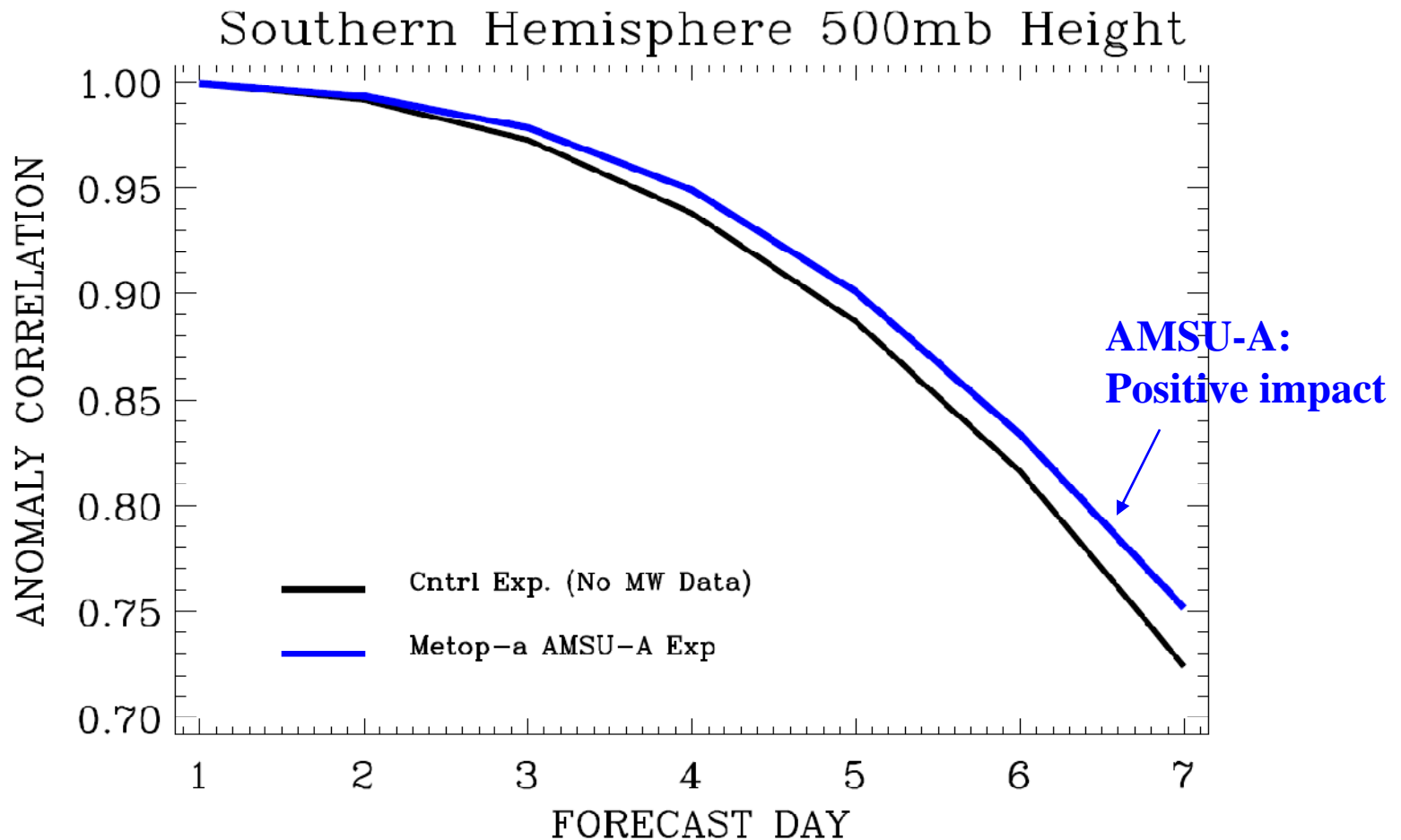- Summary

# Satellite Microwave Sounding Channels

- Two groups of microwave sounding channels: one is temperature sounding channels which are between 50 and 60 GHz; other one is water vapor sounding channels nearby 183 GHz provide rich sounding information of water vapor

- Those channel measurements are mostly available from NOAA, Metop, DMSP, and Fengyun-3 satellites

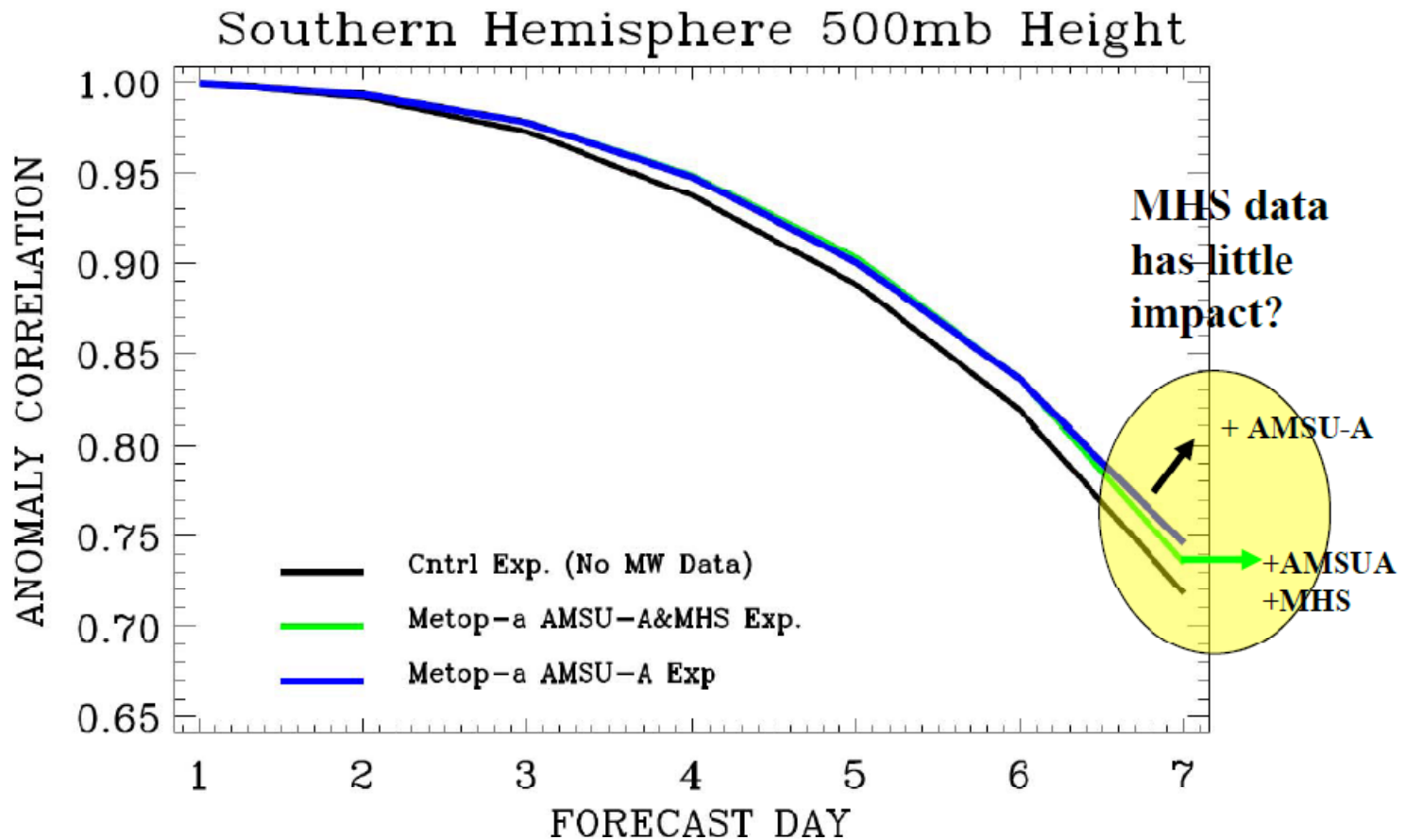**Temperature sounding channels (50 ~ 60 GHz) (e.g., AMSU-A, SSMIS LAS)**

**H$_2$O sounding channels (nearby 183 GHz) (e.g., MHS, SSMIS)**
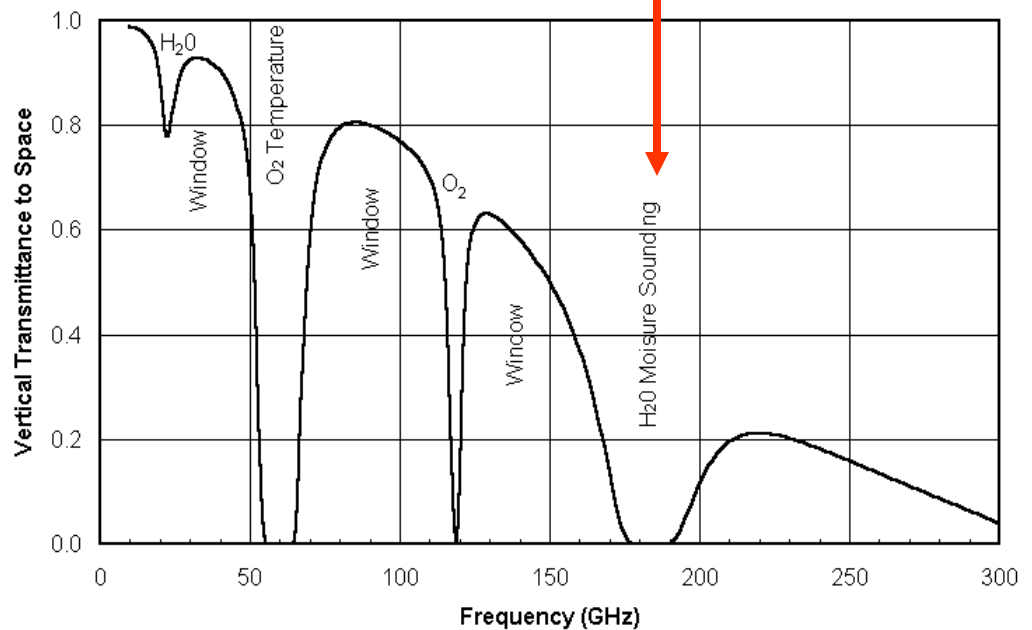
# Assimilation Impact
# of METOP-A AMSU-A Data



Southern Hemisphere 500mb Height

# Assimilation Impact of METOP-A MHS Data (Current Quality Control)



Southern Hemisphere 500mb Height

MHS data has little impact?

+ AMSU-A

+AMSUA +MHS

Cntrl Exp. (No MW Data)
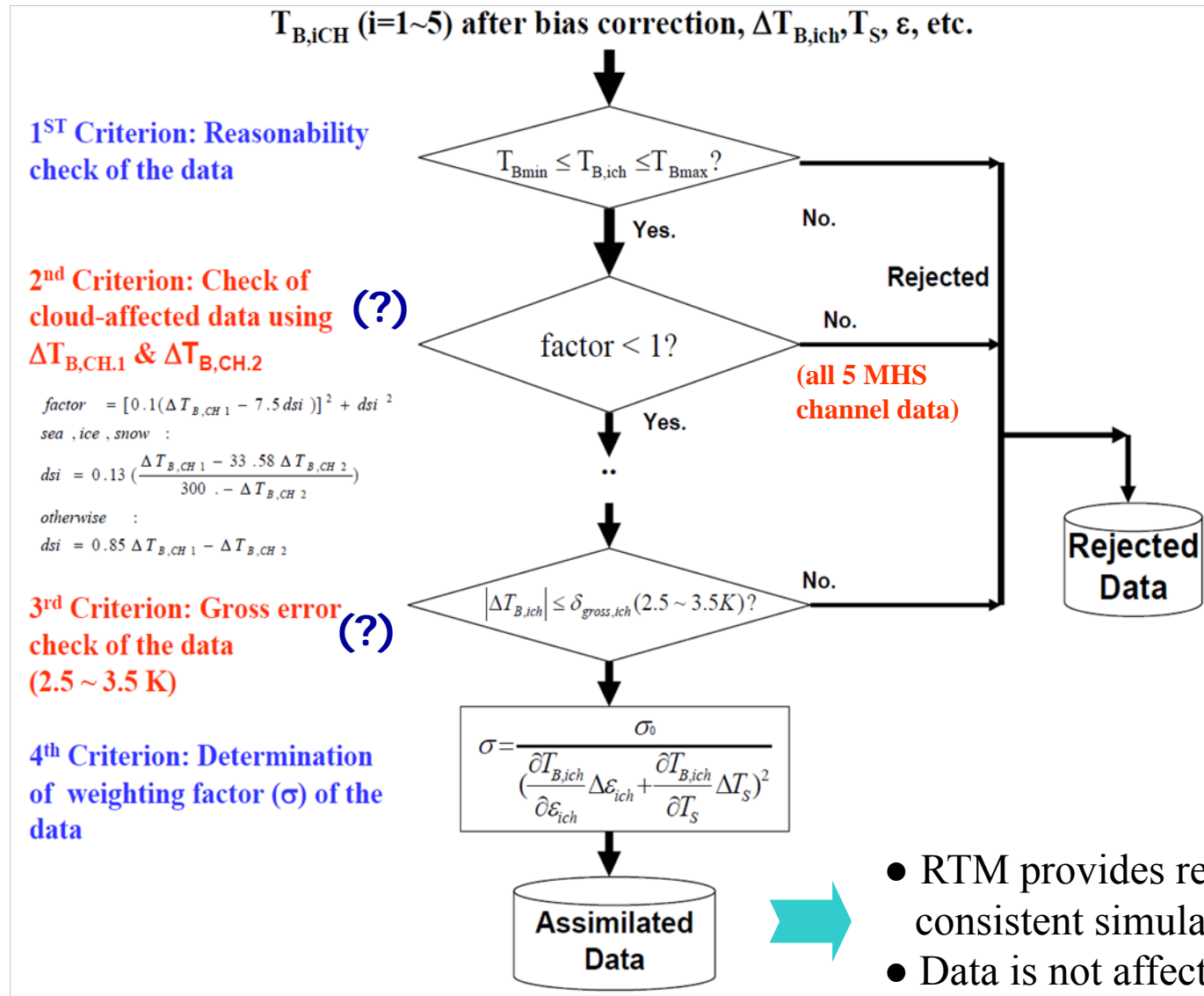
Metop-a AMSU-A&MHS Exp.

Metop-a AMSU-A Exp

- Little impacts in GFS are observed from assimilation of water vapor sounding channels

# Requirements in Satellite Data Assimilation

- Observations have no bias after better calibration and bias correction

- Radiative Transfer Model (RTM) associated with surface emissivity model is physically consistent with what data represents

- Data passing **quality control** is 1) not affected by clouds and 2) can also be well simulated by RTM

  (which are due to limited capabilities in RTM, Global Data Assimilation System, and GFS)

# Current Quality Control Scheme for Satellite Microwave Water Vapor Channels

$T_{B,iCH}$ (i=1~5) after bias correction, $\Delta T_{B,ich}$, $T_S$, $\varepsilon$, etc.

**1ST Criterion: Reasonability check of the data**

$T_{Bmin} \leq T_{B,ich} \leq T_{Bmax}$?

Yes. → No. → **Rejected**

**2nd Criterion: Check of cloud-affected data using** (?) $\Delta T_{B,CH.1}$ **&** $\Delta T_{B,CH.2}$

$factor = [0.1(\Delta T_{B,CH1} - 7.5\,dsi)]^2 + dsi^2$

$sea, ice, snow:$

$dsi = 0.13\left(\dfrac{\Delta T_{B,CH1} - 33.58\,\Delta T_{B,CH2}}{300. - \Delta T_{B,CH2}}\right)$

$otherwise:$

$dsi = 0.85\,\Delta T_{B,CH1} - \Delta T_{B,CH2}$

factor < 1?

No. **(all 5 MHS channel data)**

Yes.

**3rd Criterion: Gross error check of the data** (?)
**(2.5 ~ 3.5 K)**

$|\Delta T_{B,ich}| \leq \delta_{gross,ich}(2.5 \sim 3.5 K)$?

No. → **Rejected Data**

**4th Criterion: Determination of weighting factor (σ) of the data**

$\sigma = \dfrac{\sigma_0}{\left(\dfrac{\partial T_{B,ich}}{\partial \varepsilon_{ich}}\Delta\varepsilon_{ich} + \dfrac{\partial T_{B,ich}}{\partial T_S}\Delta T_S\right)^2}$

**Assimilated Data**

- RTM provides relatively consistent simulation for data
- Data is not affected by clouds

# Major Problems in Current Quality Control Scheme for MHS (AMSU-B) Water Vapor Channels
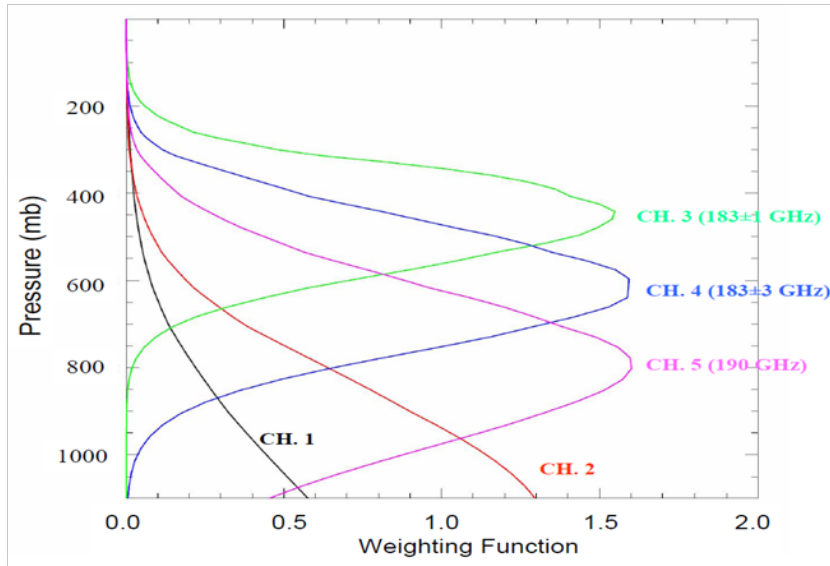


e.g., when $\Delta\varepsilon = 0.04$,
  $\Delta T_B$: around 8 K
      (89 and 157 GHz)
  $\Delta T_B$: around 6 K  (183±7 GHz)
  $\Delta T_B$: around 3 K  (183±3 GHz)
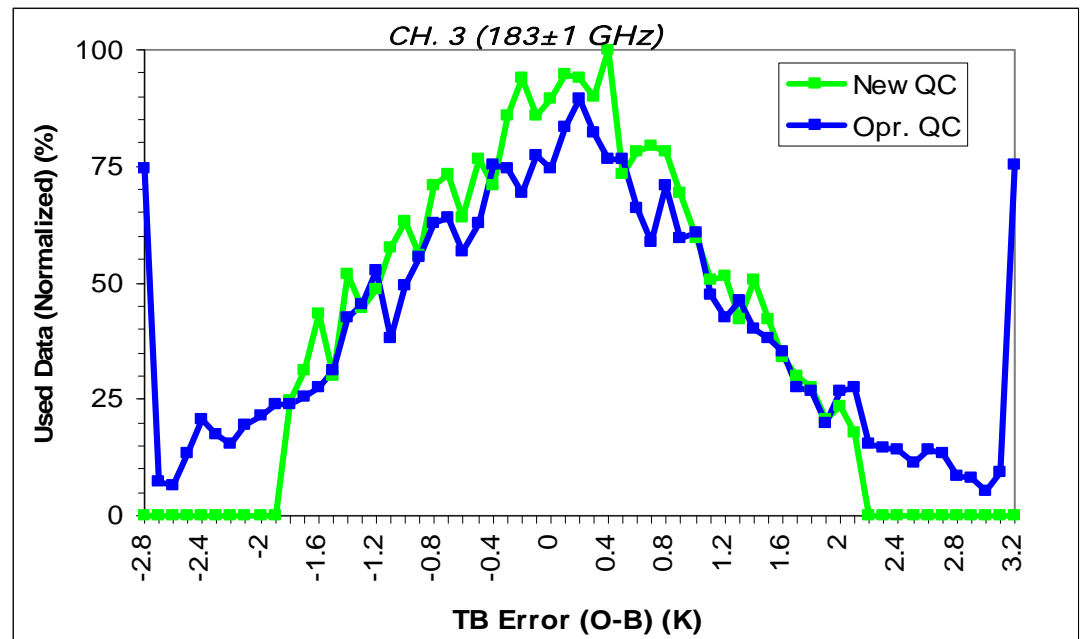  $\Delta T_B$: around 1 K  (183±1 GHz)
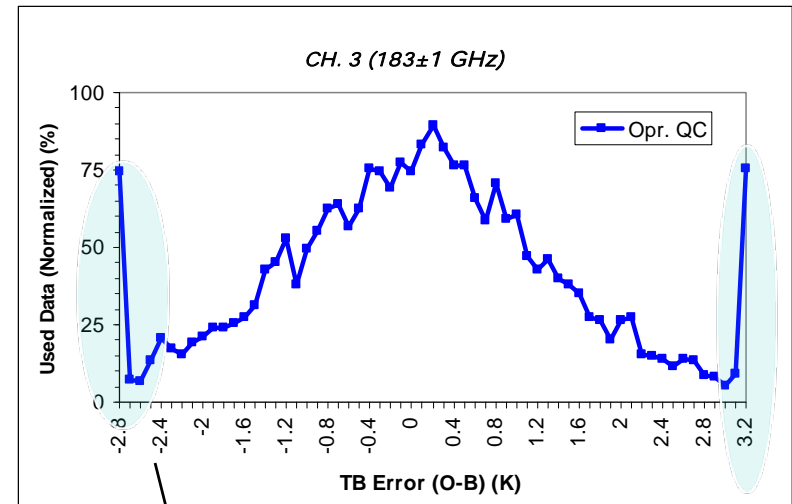


(gross error check threshold: about 3 K)

*Residual cloud contamination?*

**Problems: 1) High quality sounding channel data might be removed
          2) Some cloud-detected data might remain**

# Improved Cloud Detection for
# MHS (AMSU-B) Quality Control

- QC criteria from two window channels are not applied to three water vapor channels

- Gross error check threshold is set to 2 K

- More high quality is used and less cloud-contaminated data remain using new QC criteria

**TB departure histograms  (new/old QCs)**



CH. 3 (183±1 GHz)

# Impacts of METOP-A MHS Data (New/Old QCs)
## (Exp. Period: Sept. 1 – Oct. 30, 2009)



Southern Hemisphere 500mb Height

Legend:
- Cntrl Exp. (No MW Data)
- Metop-a AMSU-A Exp
- Metop-a AMSU-A&MHS Exp. (Old QC)
- Metop-a AMSU-A&MHS Exp. (New QC)

More positive impact!
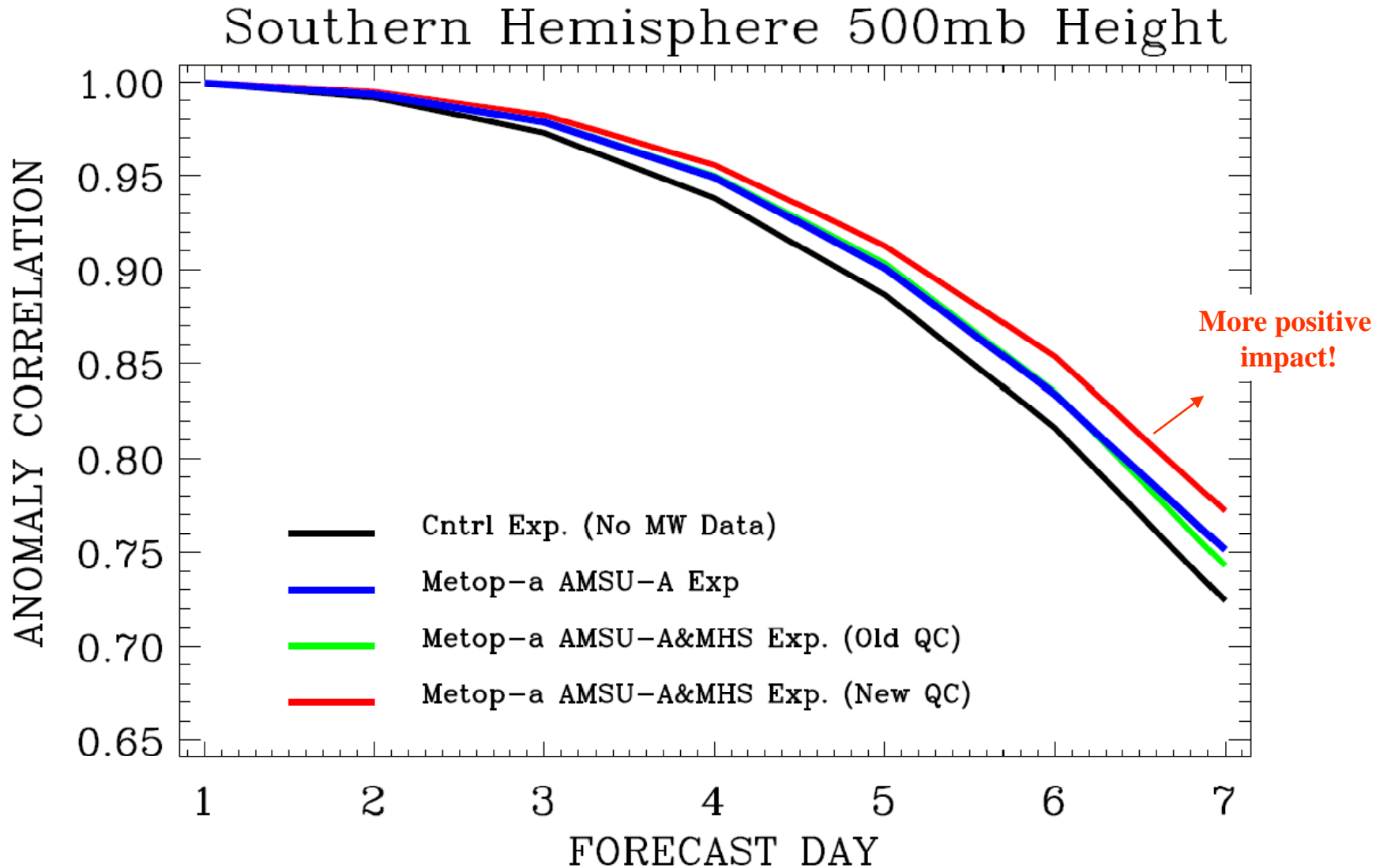
# Cloud Detection Algorithm
# for SSMIS Water Vapor Channel Data

- Introduce a ratio (r) of two scattering parameters at 91.655 V-POL and 150 H-POL ($\Omega_{91}$, $\Omega_{150}$)
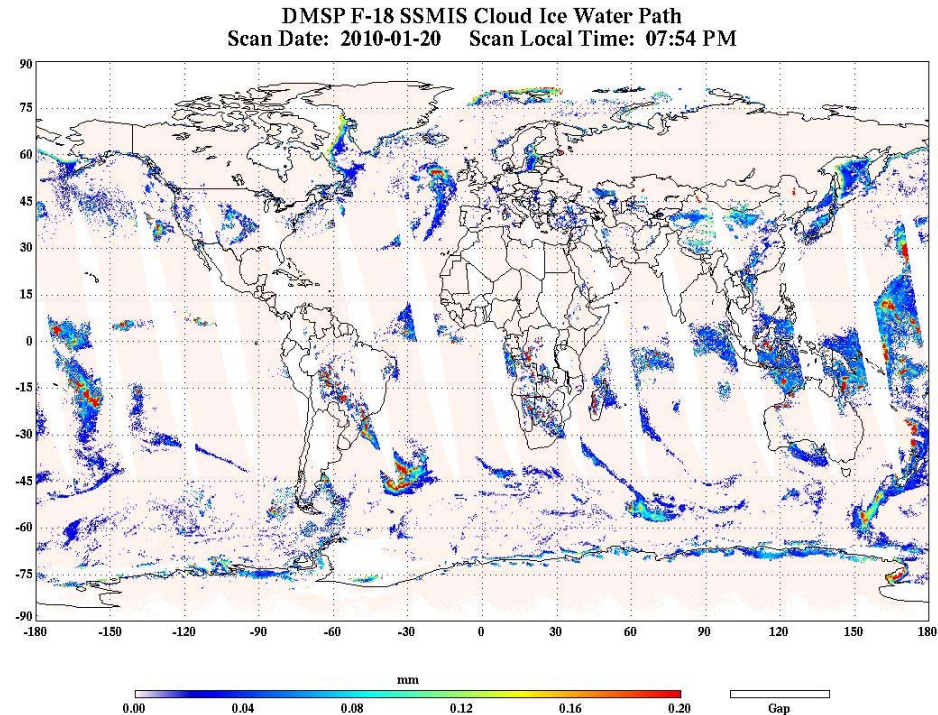
$$r = \frac{\Omega_{91}}{\Omega_{150}}$$

- Effective diameter of ice particles (De) is determined by r

$$D_e = \exp[a_0 + a_1 \ln(r) + a_2 \ln^2(r)]$$

- Ice water path (IWP) is determined by $\Omega_{91}$ and De)

$$IWP = \frac{\Omega_{91v} * De * COS(53.2^o) * \rho_{ice}}{\Omega_N}$$

$$\Omega_N = \exp[b_0 + b_1 \ln(D_e) + b_2 \ln^2(D_e)]$$

**DMSP F-18 SSMIS Cloud Ice Water Path**
**Scan Date: 2010-01-20     Scan Local Time: 07:54 PM**



**mm**

0.00   0.04   0.08   0.12   0.16   0.20        Gap

**(Reference:  Sun and Weng, JAMC, 2010)**

# Impacts of F16 SSMIS UPP Water Vapor Sounding Data

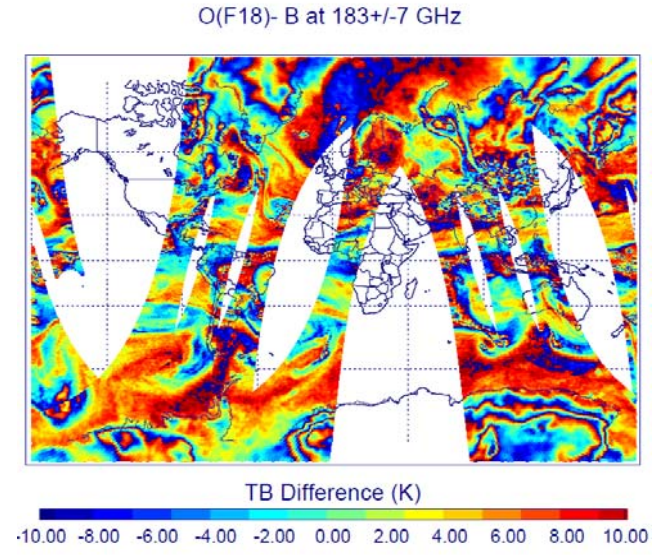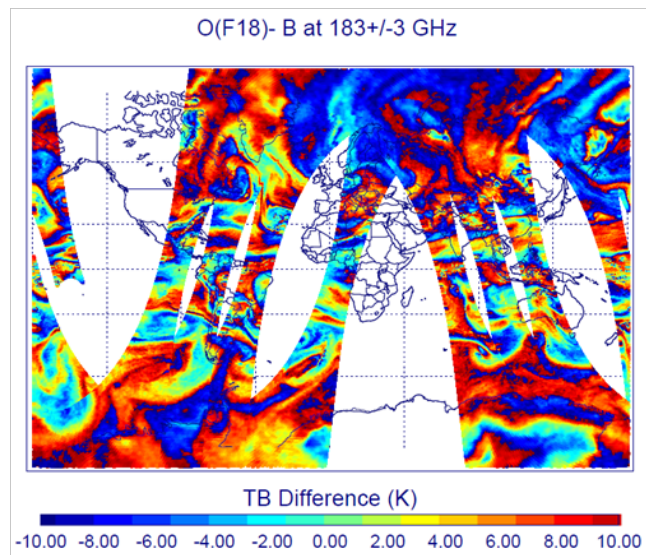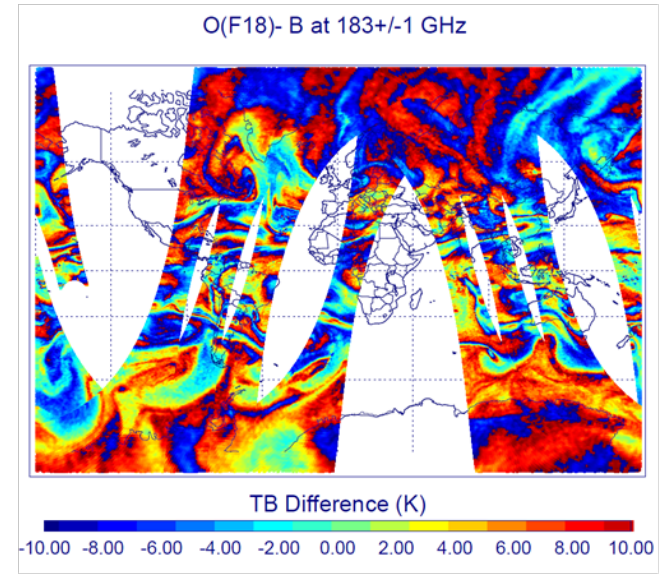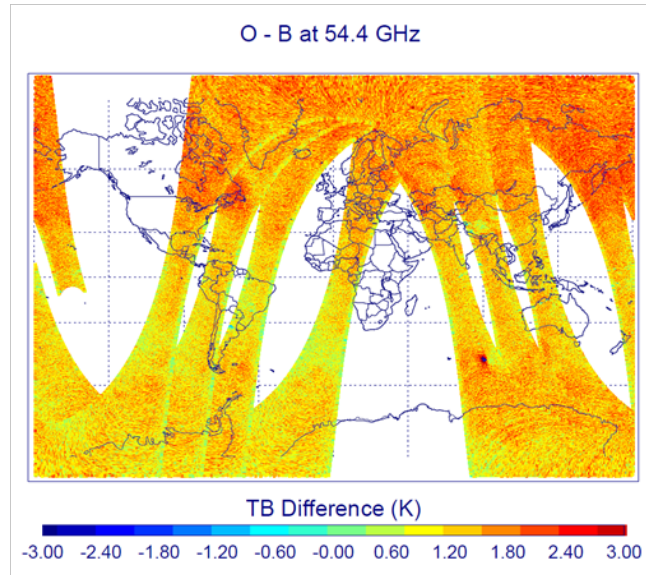- Positive impacts of F16 SSMIS UPP water vapor sounding data in NH (IWP-cloud detection of 0.1 mm)

- Little impact of F16 water vapor sounding data in SH

- A remaining issue: F16 UPP water vapor sounding data has some residual calibration bias?
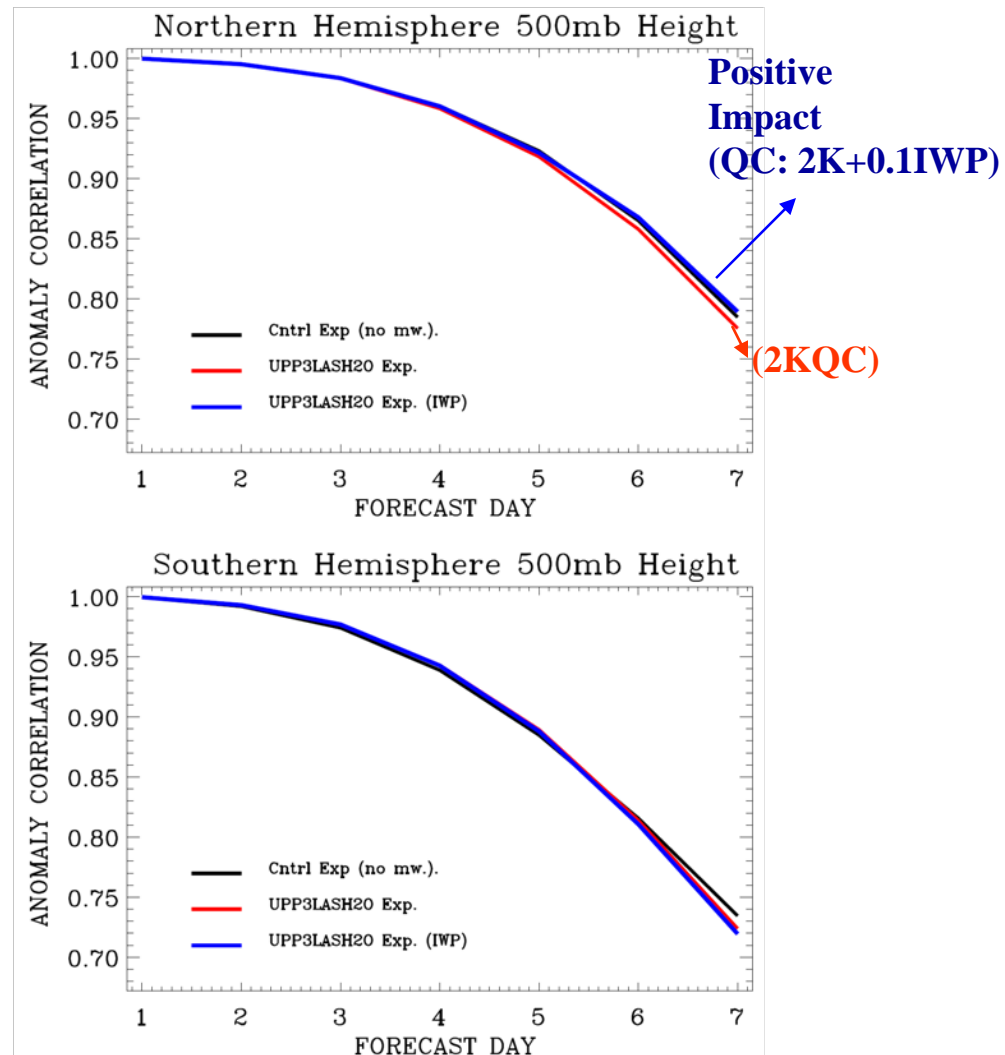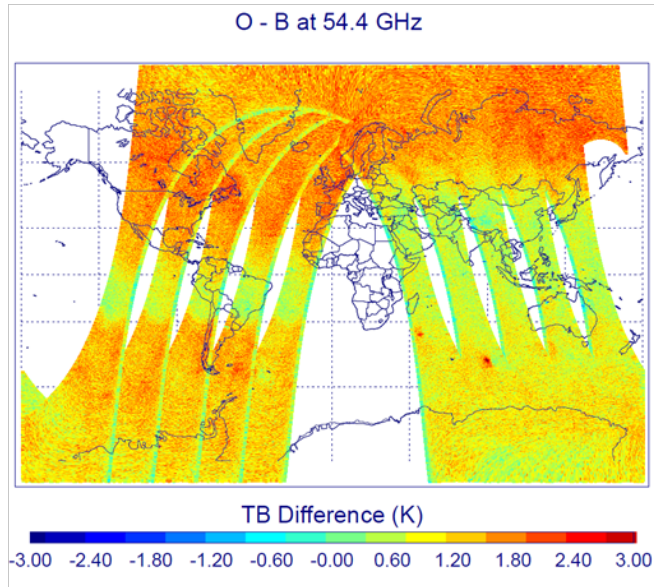
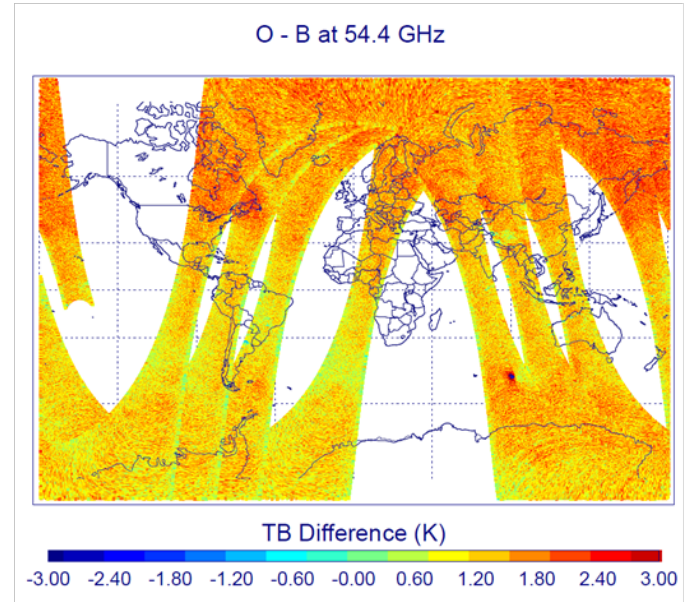# Preliminary Assessment of F18 SSMIS Data
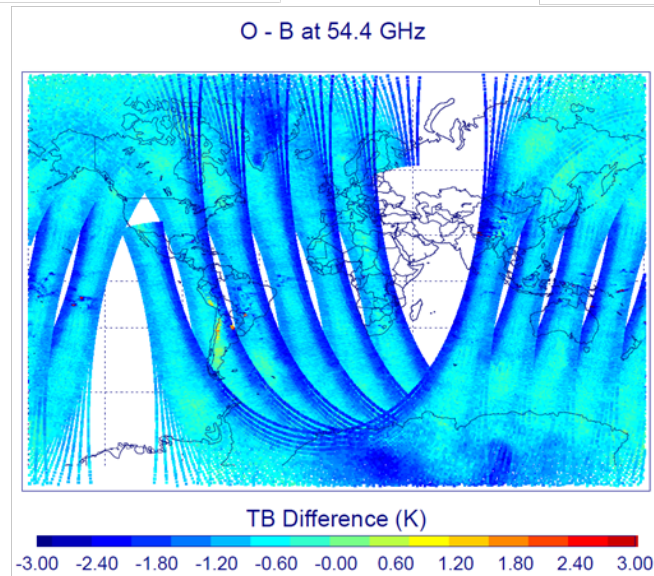
# O –B at 54.4 GHz
## (F16 and F18 SSMIS and N19 AMSU-A)

# Summary

- **Assimilation of MHS water vapor sounding channel data**
  - *An improved QC scheme is developed for MHS water vapor sounding channels*
  - *This improved QC results in more positive impacts of Metop-a MHS water vapor data in GFS*

- **Assimilation of SSMIS water vapor sounding channel data**
  - *An ice water path algorithm developed by Sun and Weng (2010) is applied to check (ice) cloud-contaminated data in F16 UPP*
  - *A positive impact is observed over NH from F16 SSMIS UPP water vapor data, but little impact over SH*

- **Preliminary assessment of F18 SSMIS data**
  - *Preliminary results show that F18 SSMIS data has an excellent performance compared to other SSMIS data*
  - *Assimilation impact of F18 is yet to be completed*

# F16 ~ F18 SSMIS TB Departures (O – B)



F16 SSMIS CH5 12Z01FEB2010
MAX=2.1709 MIN=−1.71978 MEAN=0.256969 SD=0.557057

F17 SSMIS CH5 12Z01FEB2010
MAX=1.80974 MIN=−1.56498 MEAN=0.0611884 SD=0.493974

F18 SSMIS CH5 12Z01FEB2010
MAX=3.69652 MIN=−2.27312 MEAN=0.893491 SD=0.567987