Numerical Prediction Division,
Japan Meteorological Agency

Operational Use of AMSR-E Radiance Data in the JMA Global Analysis

JMA/NPD
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Numerical Prediction Division,
Japan Meteorological Agency

Outline

- JMA NWP Models
- MWR data utilization status
- OSE performed before the operation
- Current status
  - Precipitable water fields
  - Bias correction coefficients
  - Number of used data

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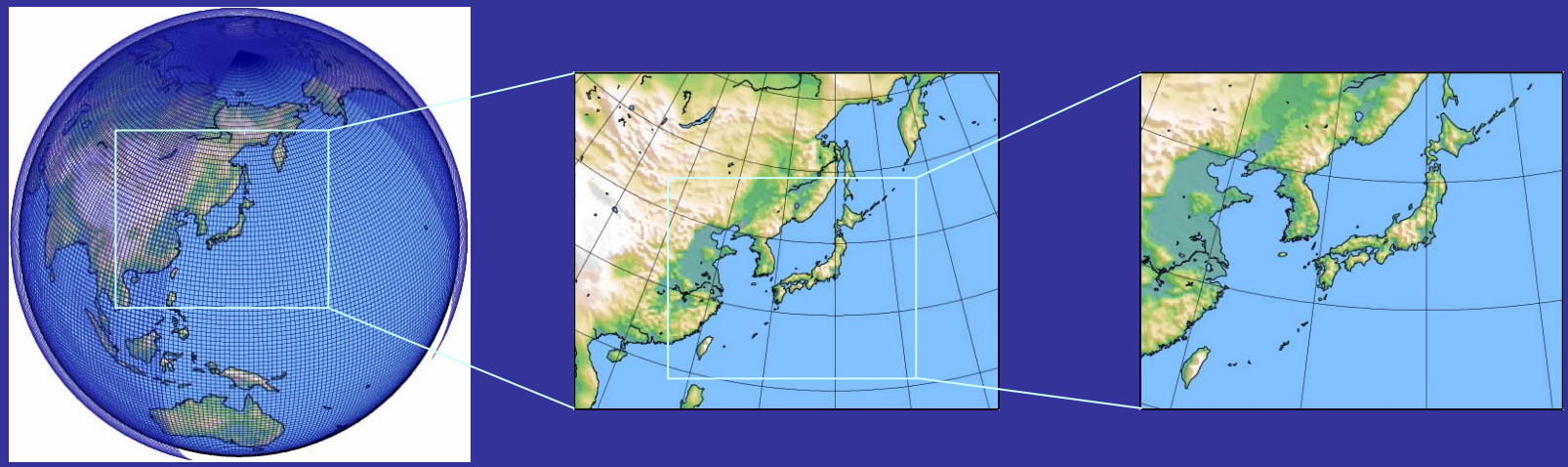
Introduction

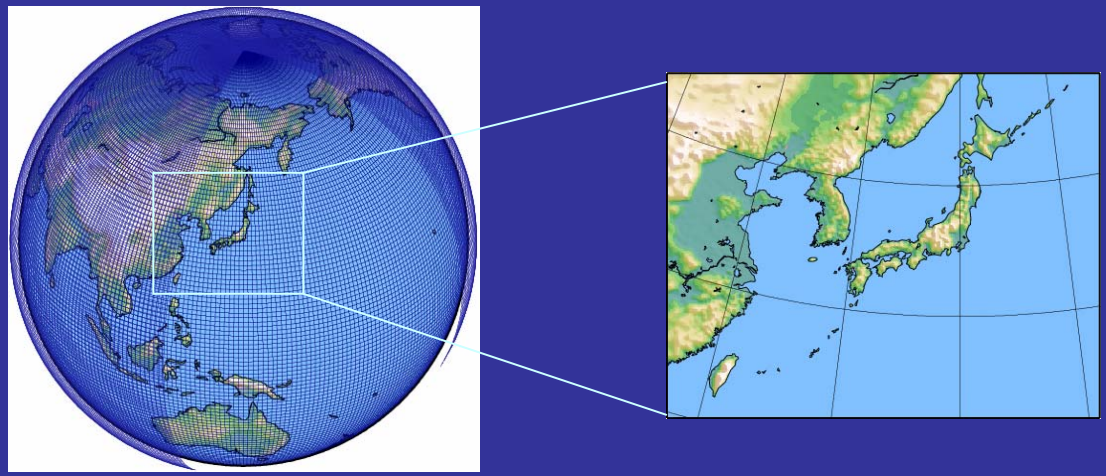
Current Operational Models in JMA



GSM	RSM	MSM
TL319 (60km) L40 (~0.4hPa)	dx=20km L40 (~10hPa)	dx=5km L50 (~22km) (Updated on Mar. 2006)
4 times/day 36, 90 and 216 hrs fcst	2 times/day 51 hrs fcst	8 times/day 15 hrs fcst
DA system 4DVAR (T106) (Updated on Mar. 2006)	DA system 4DVAR (40km)	DA system 4DVAR (20km)

Introduction

Next Operational Models in JMA



GSM	MSM
TL959 (20km)	dx=5km
L60 (~0.1hPa)	L50 (~22km)
4 times/day	8 times/day
36, 90 and 216 hrs fcst	15, 33 hrs fcst
DA system	DA system
4DVAR (T159)	4DVAR (20km)

MWR data utilization status

- For GSM
  - Assimilating SSM/I, TMI and AMSR-E radiance data from May 2006
  - MGDSST, which is analyzed SST using AVHRR, AMSR-E and in situ data, is planned to be used from the first half of 2007 for High-Resolution GSM
- For MSM
  - Assimilating SSM/I and TMI - TCPW and Rain data from Oct 2003
  - Assimilating AMSR-E - TCPW and Rain data from Nov 2004
  - MGDSST is used as boundary condition over the ocean from Mar 2006.

MWR radiance assimilation

- Configurations for GSM
  - DA system : T106(dx~120km)-4DVAR
  - Using vertical polarized channels only
    - SSM/I: 19V, 22V, 37V, 85V
    - TMI: 19V, 21V, 37V, 85V
    - AMSR-E: 18V, 23V, 36V, 89V

> Flow

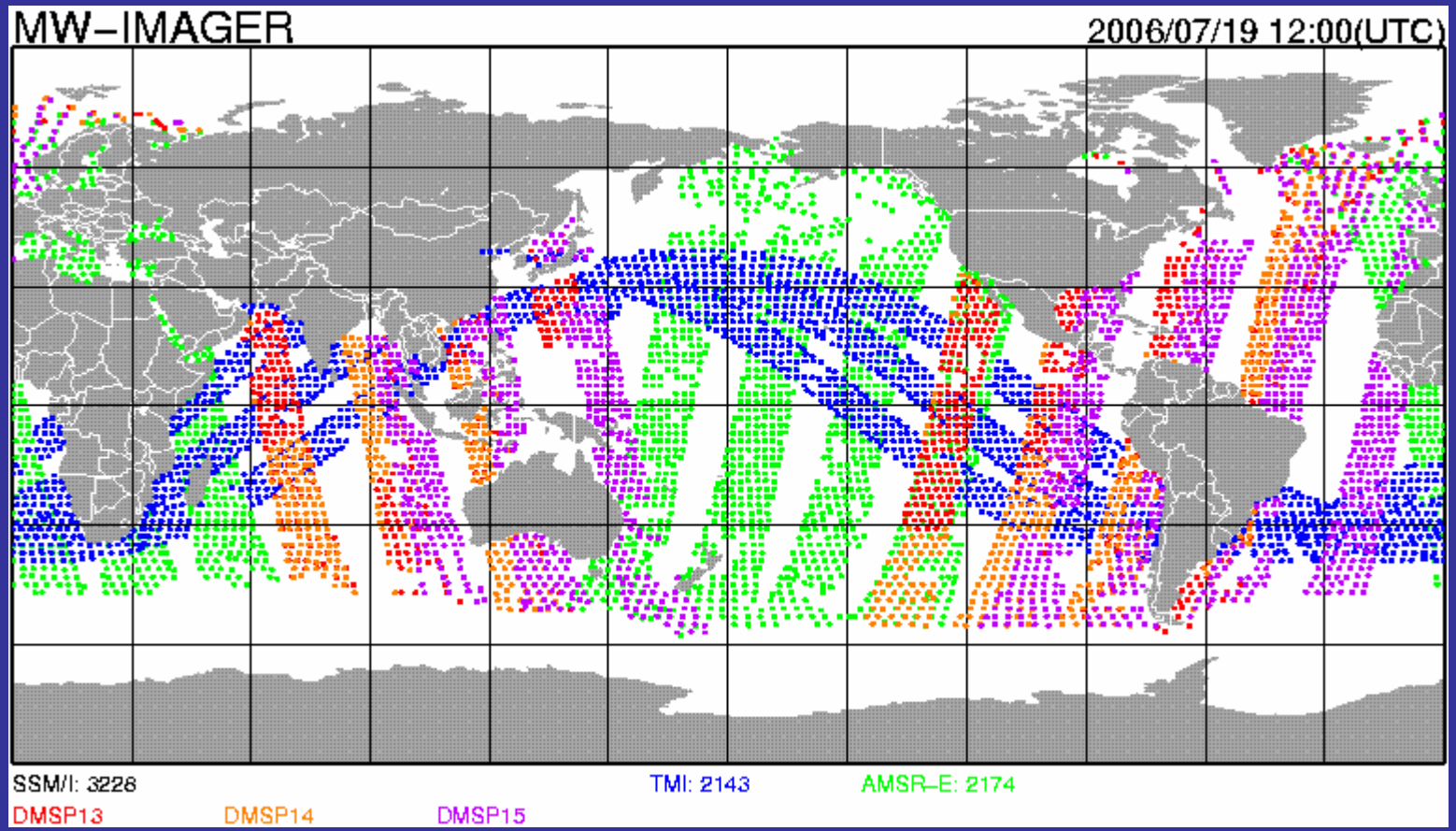
σ [K]	T19V	T22V	T37V	T85V
SSM/I	2.3	3.7	2.1	2.7
TMI	2.5	3.7	2.1	2.6
AMSR-E	2.0	3.4	2.0	2.7

  - Over clear sky ocean with SST > 5deg.C
  - Thinned by ~200km^2 box for every time slots

> Figure

  - Observation Error Settings: 4σ
  - Variational Bias Correction
    - Bias correction coefficients are updated in the each analysis
    - Predictors: TCPW, T_{SRF}, T_{SRF}^2, WS_{SRF}, $\cos(Z_{ang})$, Constant
  - With these settings, OSE was performed.

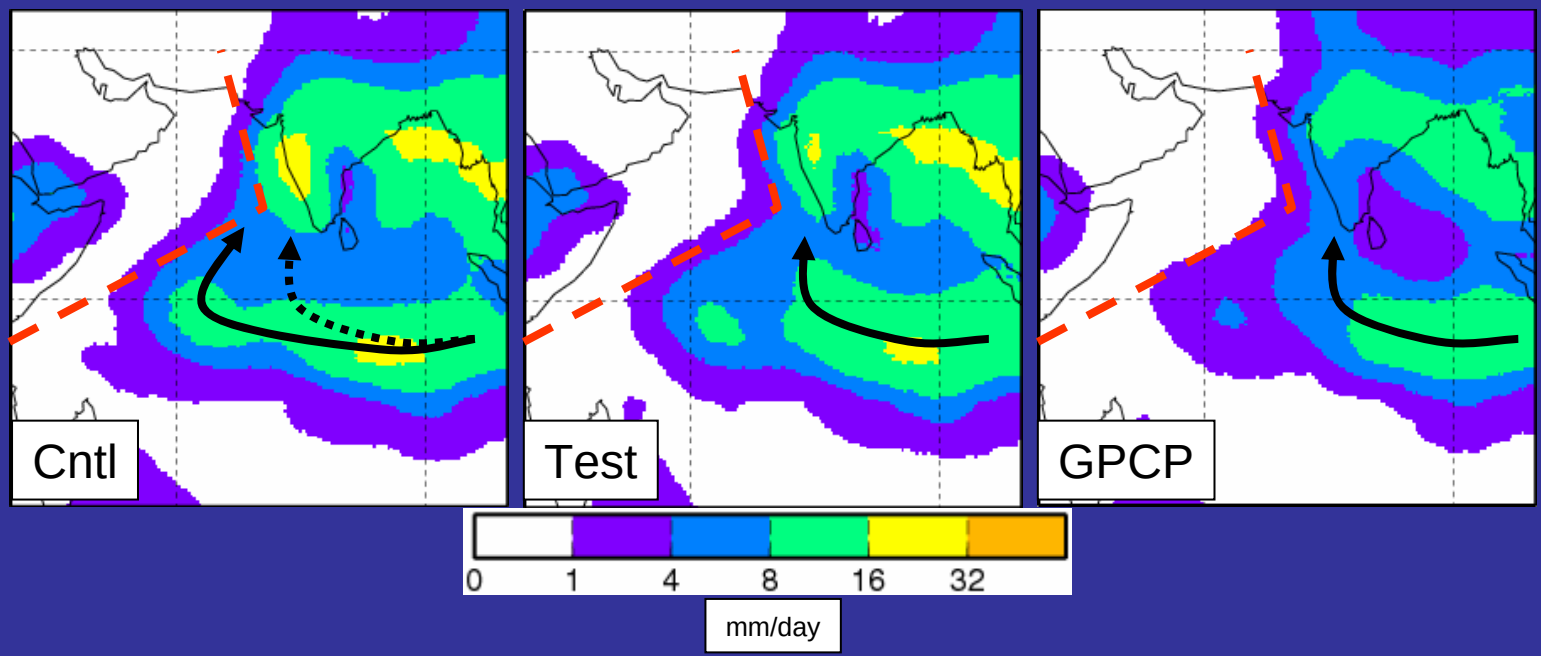
Sample of assimilated MWR data



DMSP13,14,15 ~ 40% TMI ~ 30% AMSR-E ~ 30%

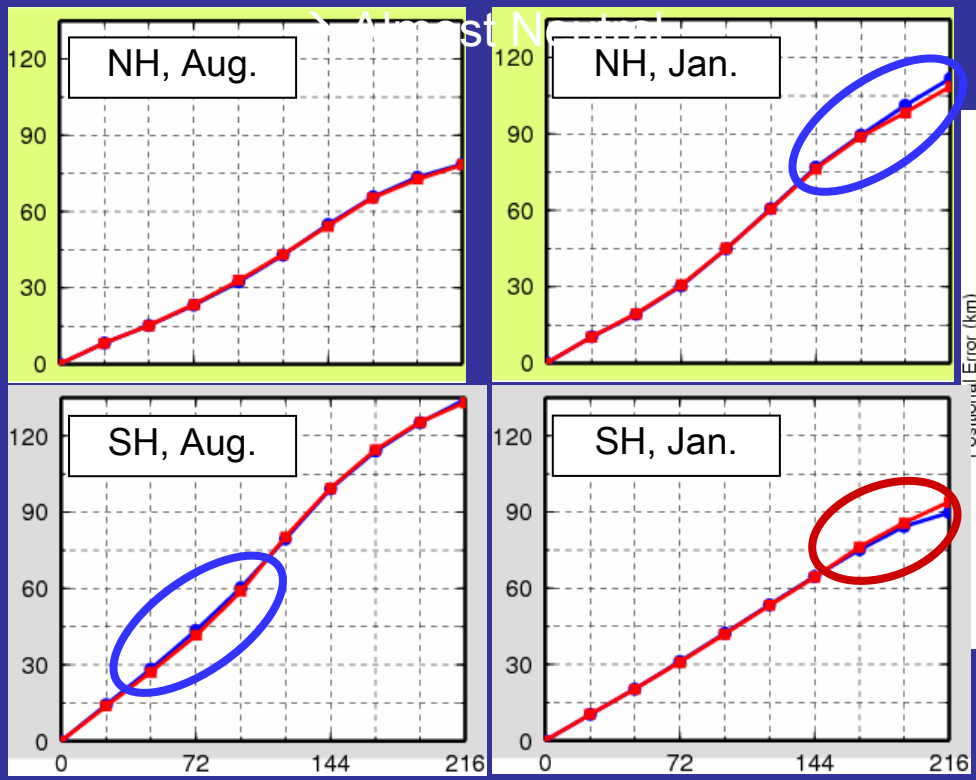
OSE results

- Monthly averaged daily rainfall amount
  - Correlations against GPCP:
    - Cntl:0.881 ➔ Test:0.891 (Aug)
    - Cntl:0.835 ➔ Test:0.841 (Jan)
    - The lower figures show the data on Aug 2004.



OSE results

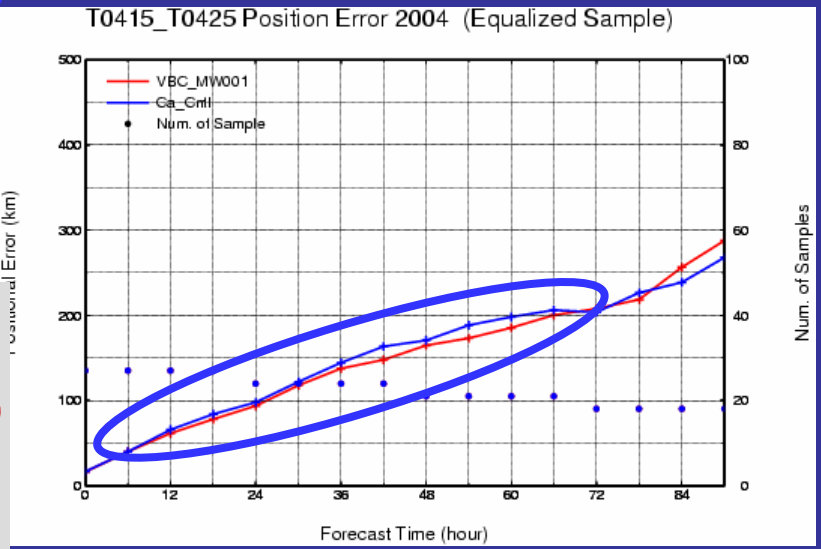
500hPa GPH forecast RMSE time sequence



Red: Test / Blue: Cntl

Typhoon position error time sequence

→ Improved

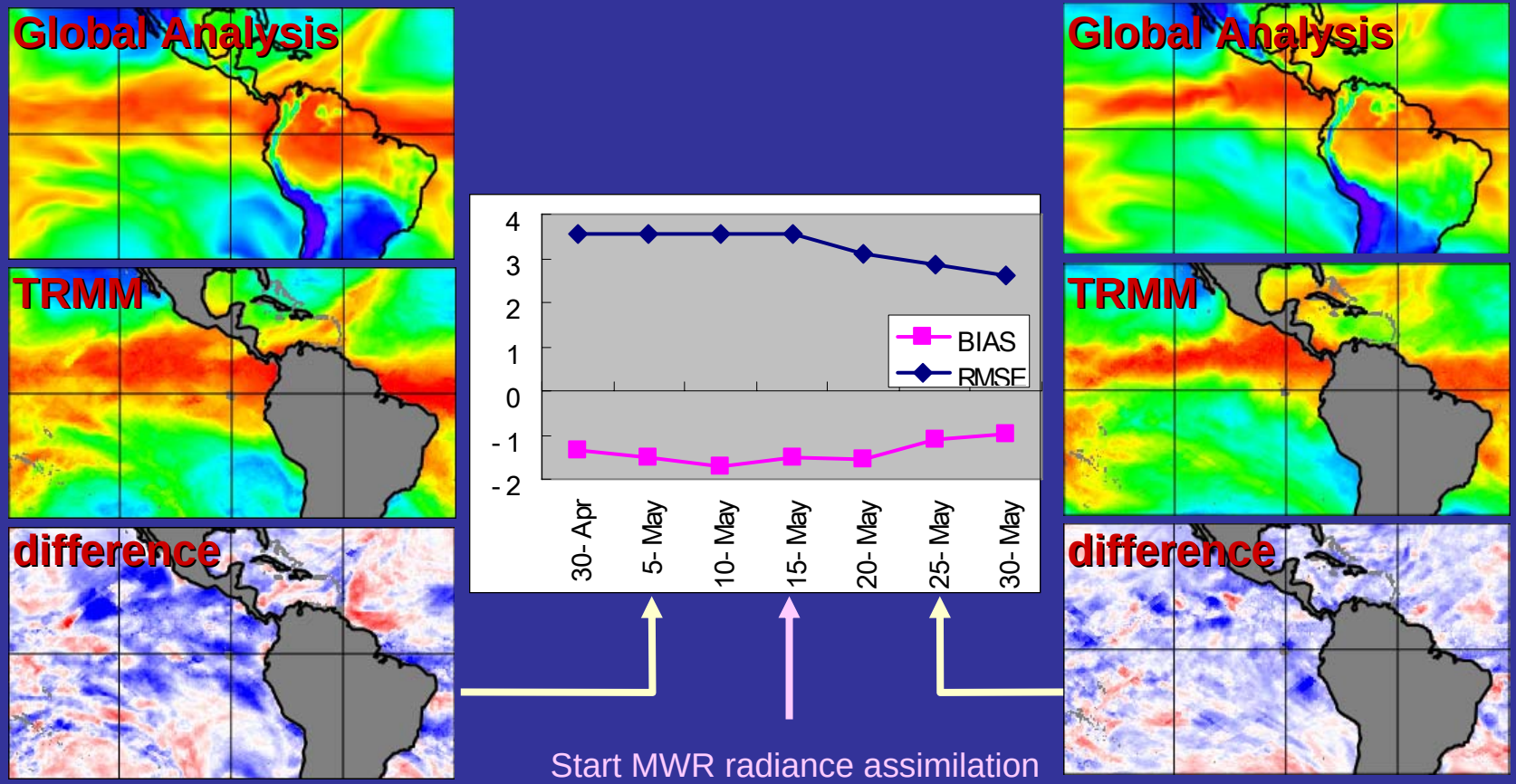


Red: Test / Blue: Cntl

With the results, JMA decided to use MWR radiances in the operational Global Analysis.

MWR Assimilation Status

- Compared with TRMM 3-day-averaged TCPW

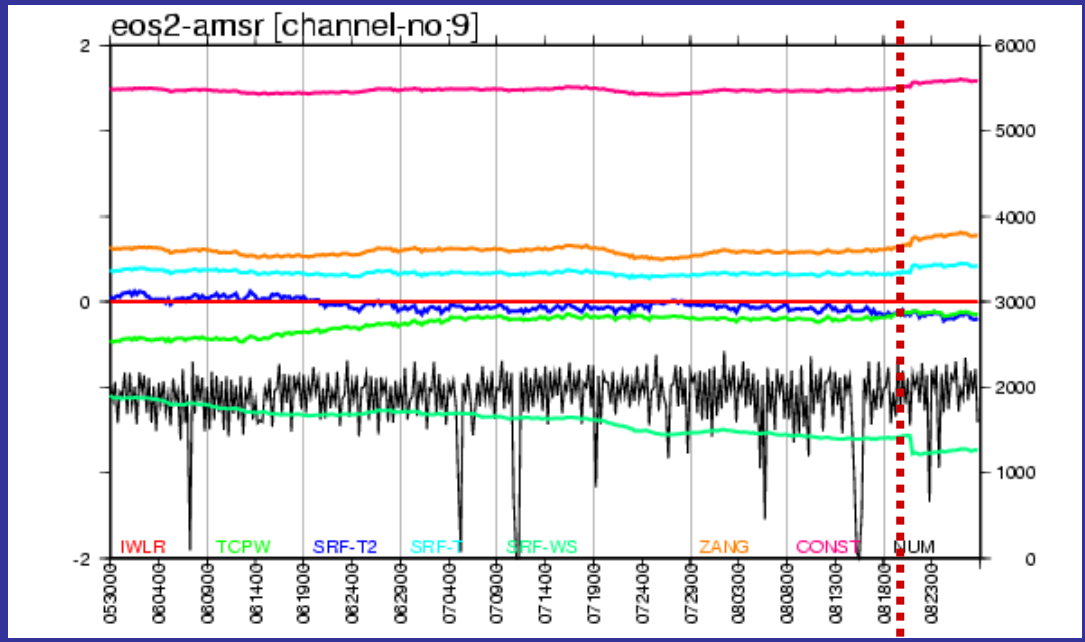


Variational Bias Correction

- Bias correction term is in the observation operator

Observation Operator: $y = \tilde{h}(\mathbf{z}) \equiv h(\mathbf{x}) + \sum \boldsymbol{\beta}\, p(\mathbf{x}_b (\cong \mathbf{x}))$

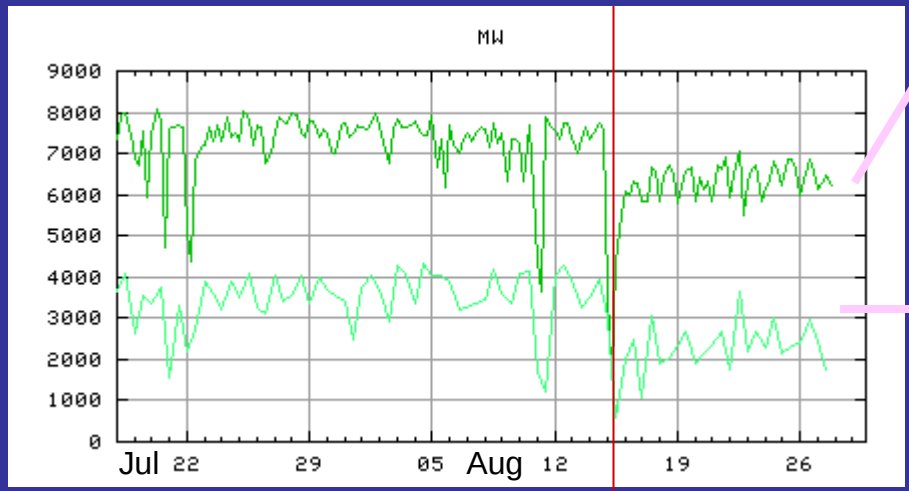
  - Coefficients: β
    - Calculated in the system automatically → Time developing data
    - It shows the relation between the instrument and model fields
  - Predictors: p
    - TCPW,
    - T_{SRF},
    - T_{SRF}^2,
    - WS_{SRF},
    - $1/\cos(Z_{ANG})$,
    - 1(Const)



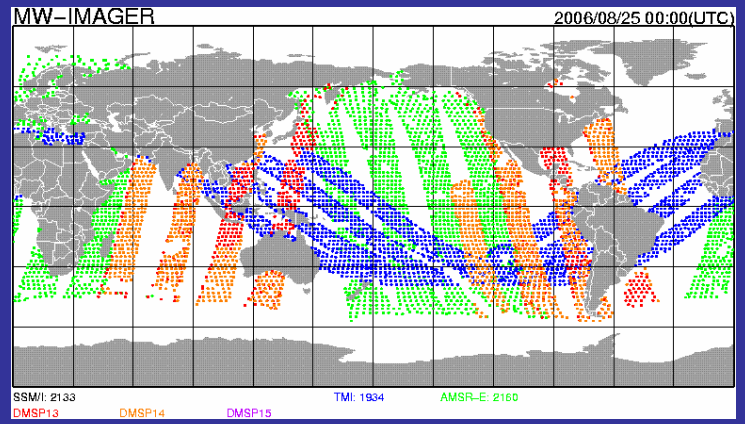
Red Line shows Analysis System Update. The discontinuity of the coefficients are come from it.

Used MWR Data Number

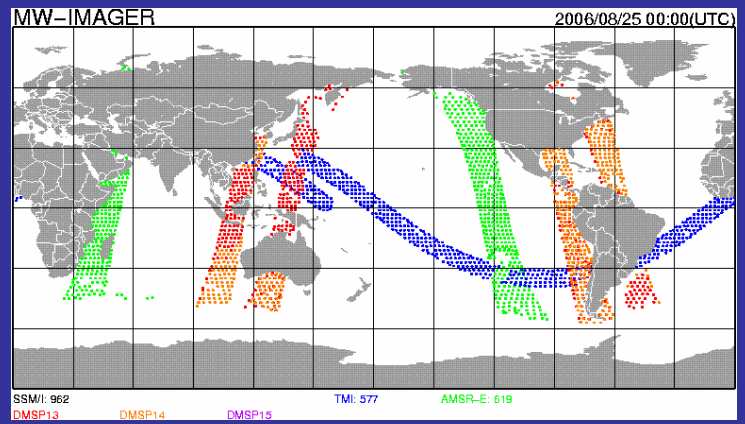
- 2 types of Global Analysis
  - Cycle Analysis
    - For Accurate Global Analysis
    - Dealing with Late Delivery Data
  - Early Analysis
    - For Weather Forecast
    - Cannot wait Late Delivery Data



Stopped using DMSP-F15 SSM/I Data



Cycle Analysis,CutOff:6:00,~4orbit

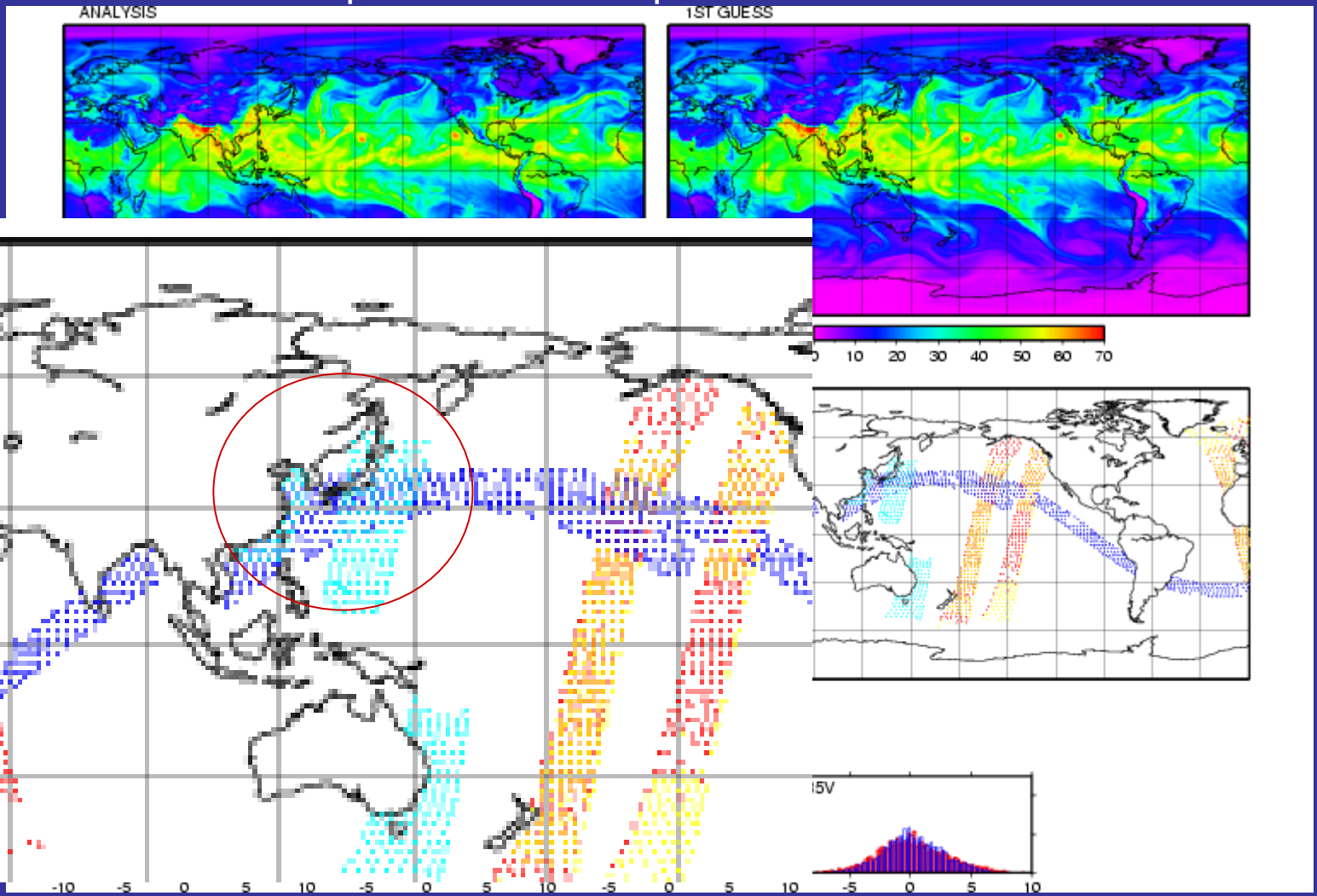


Early Analysis,CutOff:2:20,~1-1.5orbit

> Difference

Direct Receiving Data

Impact on the Precipitable Water Fields



Summary

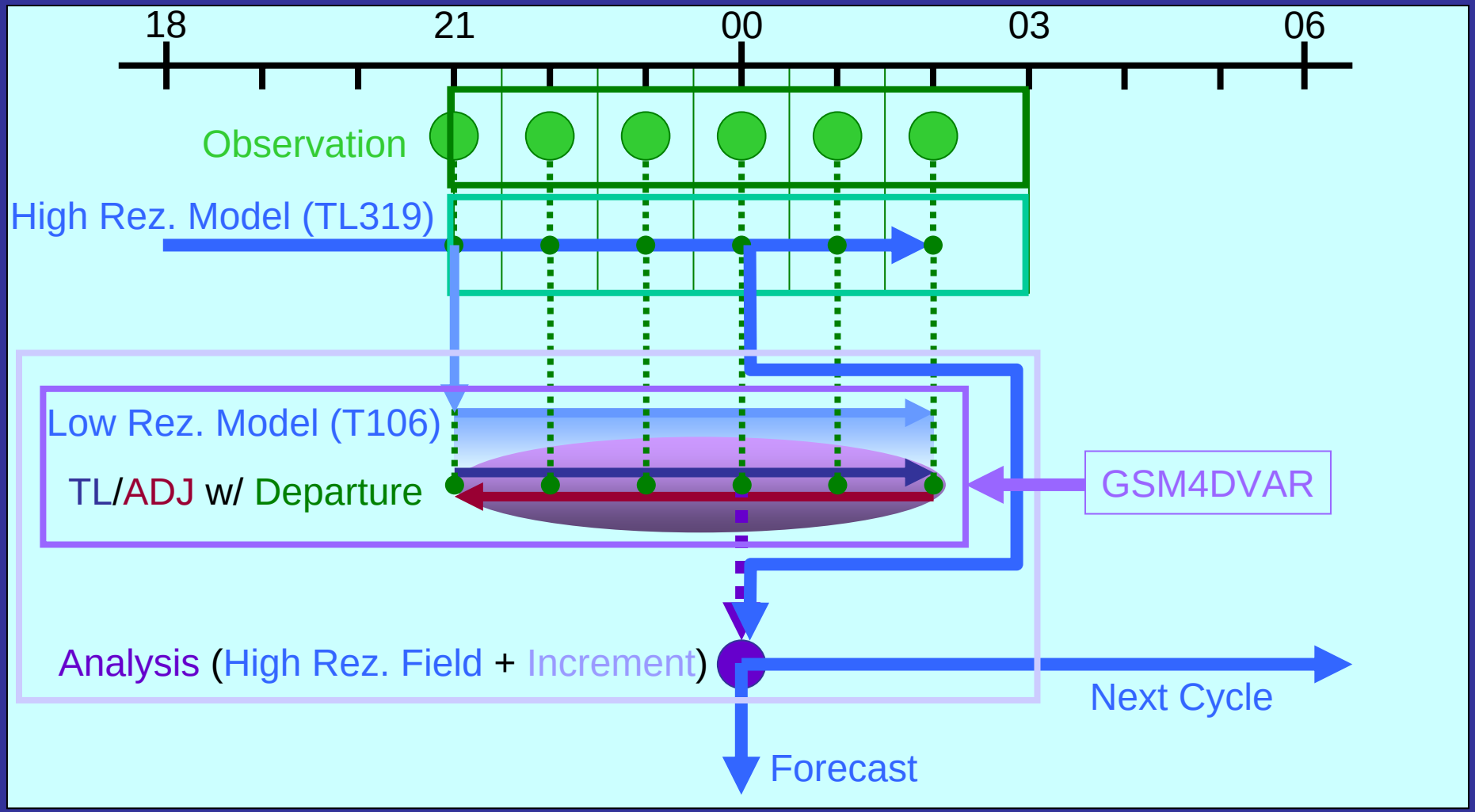
- AMSR-E data has been used in the JMA operational NWP
  - Global Spectral Model as a form of radiance
  - Meso-Scale Model as forms of Precipitable Water and Rain Rate
  - The PM orbit is important to complement SSM/I coverage.

- OSE for GSM was performed before the operation:
  - MWR assimilation had good impact on the typhoon track forecast and rainfall forecast
  - With the results, JMA decided to use MWR in the operation

- In the operation:
  - AMSR-E data is very stable in the view from bias correction coefficients sequence.
  - Earlier delivery is highly appreciated.
    - About 1~1.5 orbit data is delivered in time for the early analysis.

Back Up Slides

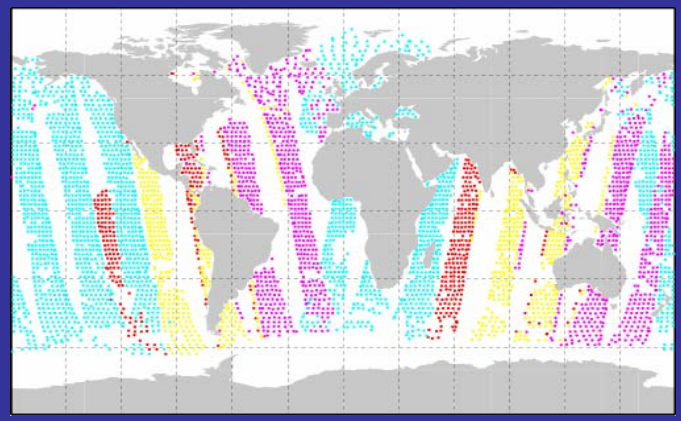
JMA Global Analysis Flow



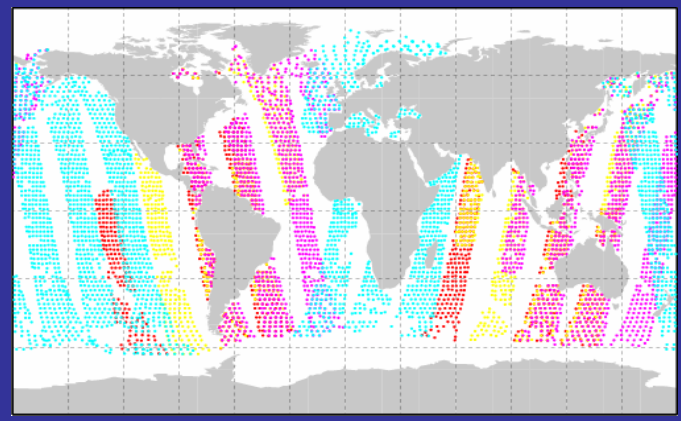
> Return

Thinning

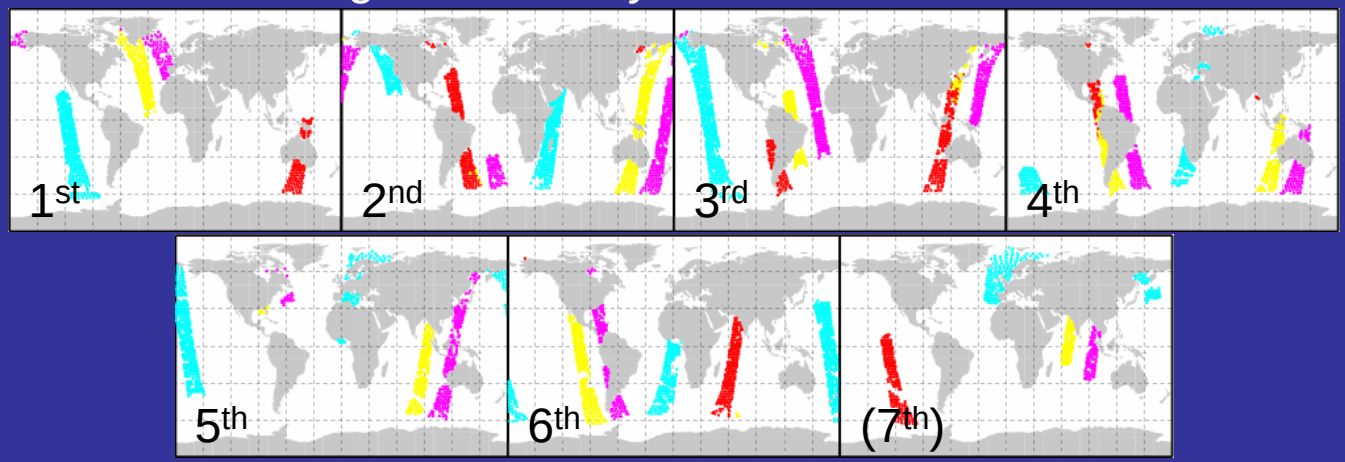
Previous Thinning (N=4337)
(Only Considering Spatial Distribution)



New Thinning (N=6396)
(Considering Assimilation Time Slot)



Dividing to the hourly assimilation time slots.

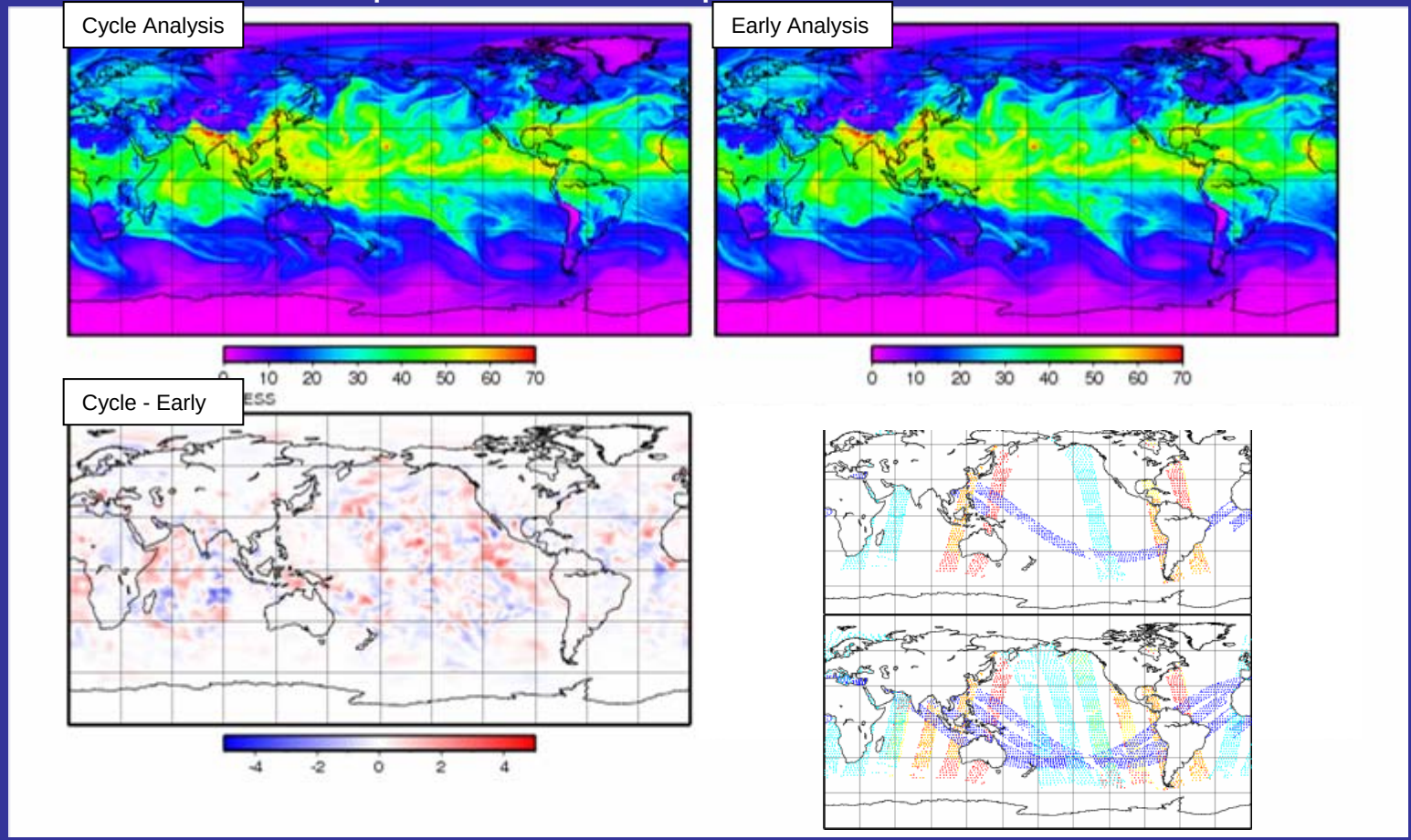


SSM/I(13,14,15), AMSR-E

> Return

Difference between the Analyses

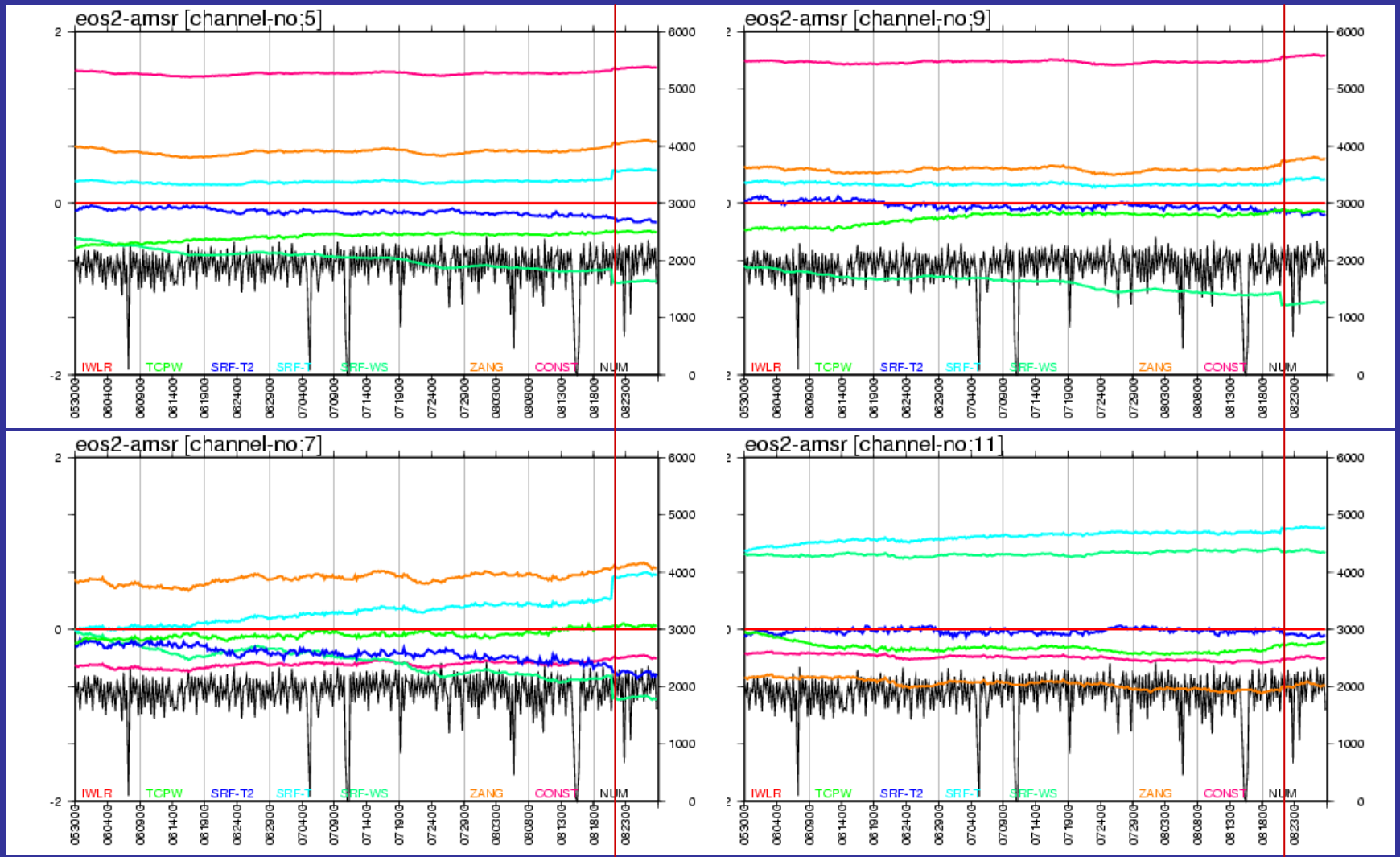
Impact on the Precipitable Water Fields



The difference shows late delivery data impact.
The impact of the MWR on the PW fields was very Large.

> Return

Bias Coefficients for AMSR-E



Red Line shows Analysis System Update. The discontinuity of the coefficients are come from it.

VarBC (Variational Bias Correction)

- Basic Idea (Dee, 2004)
  - Observation Operator includes Bias Correction Term
  - Control Variable includes Bias Correction Coefficients
    - Normal (x: model variables, h(x): observation operator)

$$y = \mathrm{h}(\mathbf{x}) \equiv RTM\left[RTTOV7\right]\cdots \mathrm{For MWR-TB}$$

$$J = (\mathbf{x_b} - \mathbf{x})^{\mathrm{T}} \mathbf{B}^{-1} (\mathbf{x_b} - \mathbf{x}) + (\mathbf{y} - \mathrm{h}(\mathbf{x}))^{\mathrm{T}} \mathbf{R}^{-1} (\mathbf{y} - \mathrm{h}(\mathbf{x}))$$

    - Variational Bias Correction (β: Coefficients, $\mathrm{p}(\mathbf{x})$: Predictors)

$$y = \tilde{\mathrm{h}}(\mathbf{z}) \equiv \mathrm{h}(\mathbf{x}) + \sum \boldsymbol{\beta}\, \mathrm{p}(\mathbf{x_b}(\cong \mathbf{x})), \quad \mathbf{z} \equiv [\mathbf{x}, \boldsymbol{\beta}]$$

$$J = (\mathbf{z_b} - \mathbf{z})^{\mathrm{T}} \mathbf{B_z}^{-1} (\mathbf{z_b} - \mathbf{z}) + \left(\mathbf{y} - \tilde{\mathrm{h}}(\mathbf{x})\right)^{\mathrm{T}} \mathbf{R}^{-1} \left(\mathbf{y} - \tilde{\mathrm{h}}(\mathbf{x})\right)$$

$$= (\mathbf{x_b} - \mathbf{x})^{\mathrm{T}} \mathbf{B}^{-1} (\mathbf{x_b} - \mathbf{x}) + \left(\mathbf{y} - \tilde{\mathrm{h}}(\mathbf{x})\right)^{\mathrm{T}} \mathbf{R}^{-1} \left(\mathbf{y} - \tilde{\mathrm{h}}(\mathbf{x})\right)$$

$$+ (\boldsymbol{\beta_b} - \boldsymbol{\beta})^{\mathrm{T}} \mathbf{B}_{\boldsymbol{\beta}}^{-1} (\boldsymbol{\beta_b} - \boldsymbol{\beta})$$

VarBC Settings

WILR: Weighted Integrated Lapse Rate ← For AMSU-A

TCPW: Total Column Precipitable Water ← For AMSU-B, MWRT

- Predictors (p)
  - WILR/TCPW, T_{SRF}, T_{SRF}^2, WS_{SRF}, $1/\cos(Z_{ANG})$, 1(Const)
- Back Ground Term (β_b)
  - The Last β
- Back Ground Error (B_β (σ_β))
  - Do Not Considering the Correlations among Predictors
  - N: Observation Data Number
    - Original

Obs ~ Bkg

$$\sigma_\beta = \sigma_{obs} / N$$

    - Our Settings

$$\sigma_\beta = \begin{cases} \sigma_{obs} / N_{MIN} & N < N_{MIN} \\ \sigma_{obs} / \left(N \left(\log_{10} \left(\mathrm{N} / \mathrm{N}_{\mathrm{MIN}} \right) + 1 \right) \right) & N \geq N_{MIN} \end{cases}$$

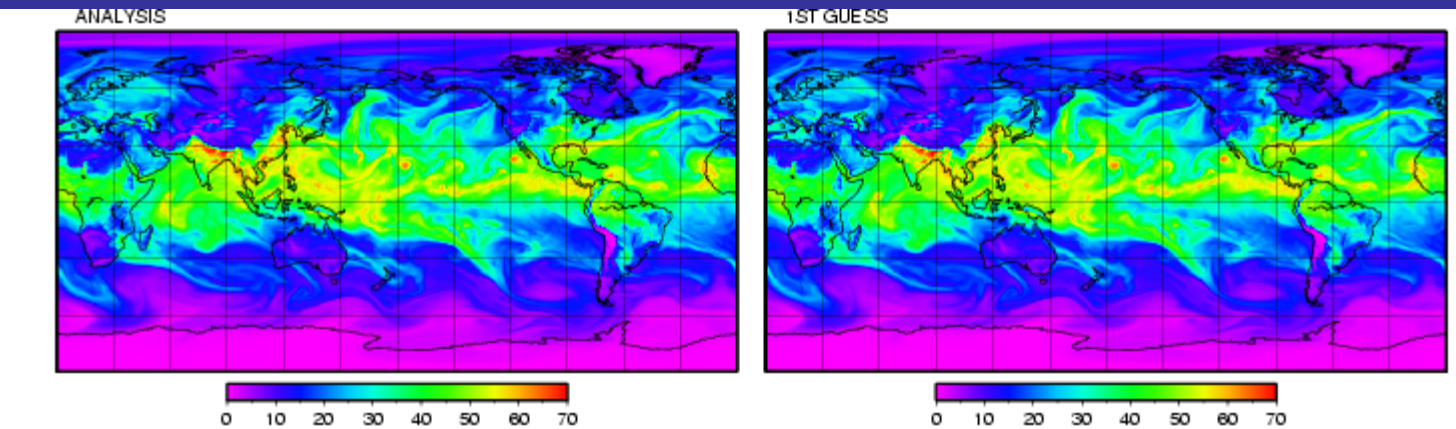
$$N_{MIN} = 400$$

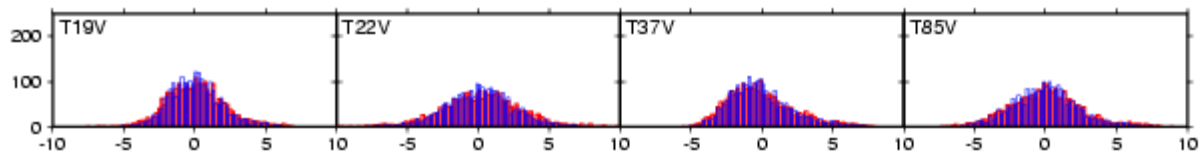
$N<N_{MIN}$ ➔ Bkg > Obs

$N=N_{MIN}$ ➔ Bkg ~ Obs

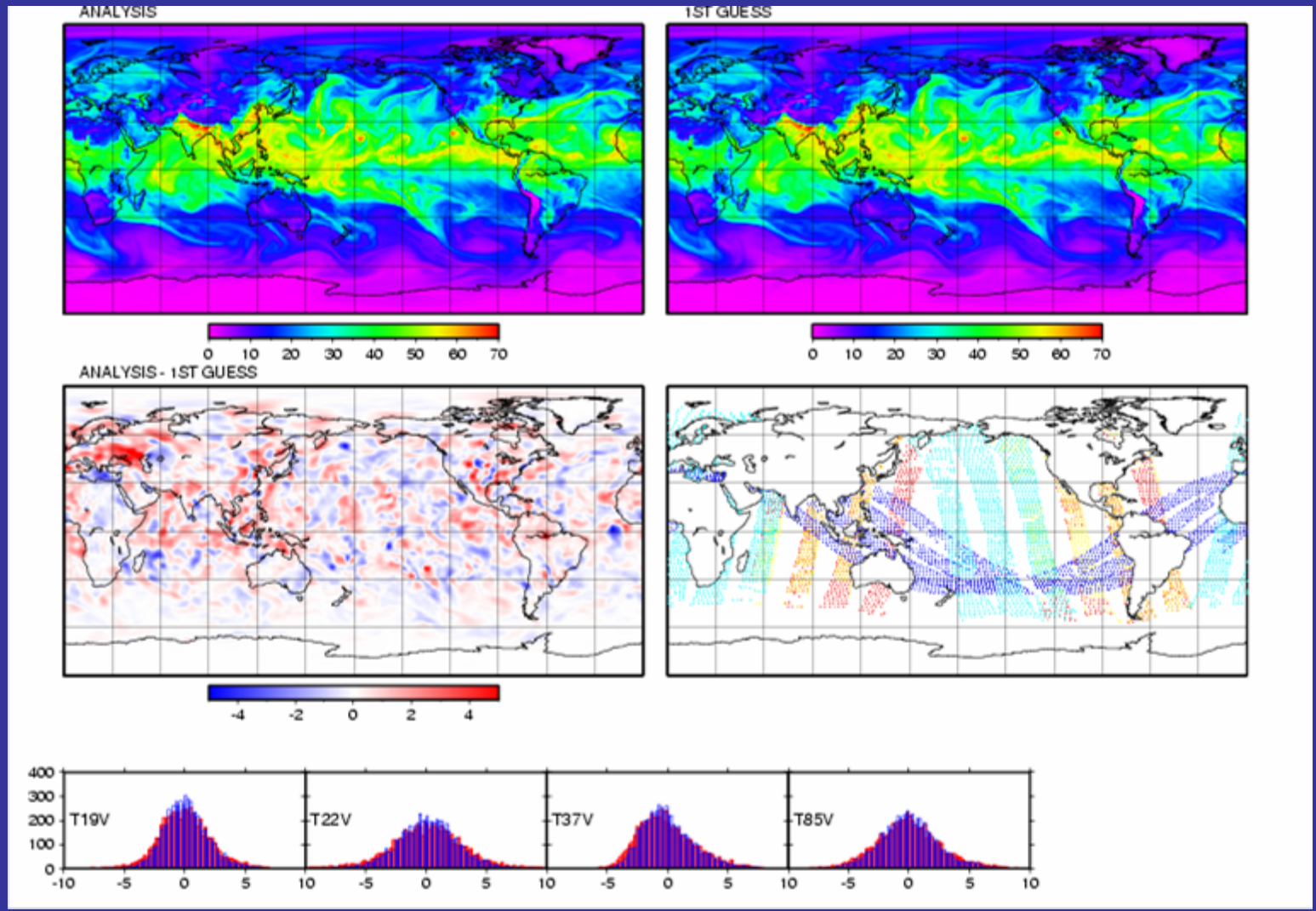
$N>N_{MIN}$ ➔ Bkg < Obs

Early Analysis





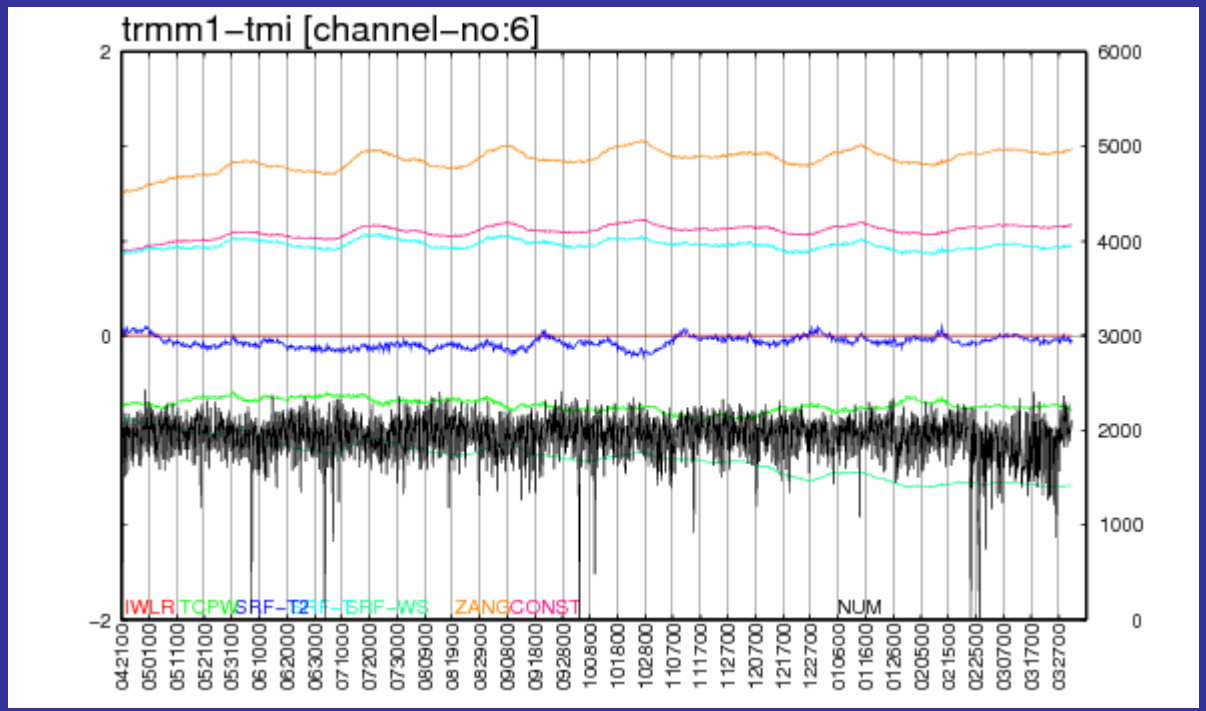
Cycle Analysis



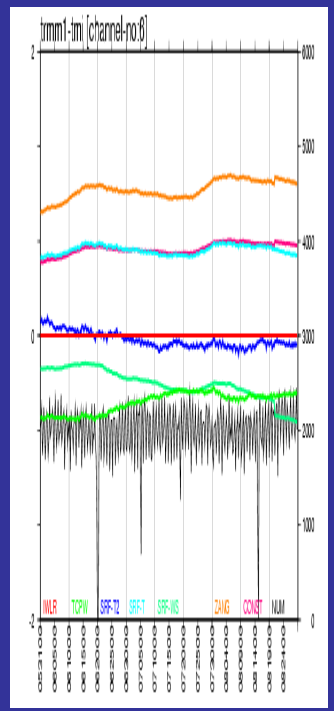
Bias Coefficients for TMI

- Periodic change is shown in the operation.
  - It was also shown in the long term assimilation experiment]
  - Because of the orbit ?

Long-Term Experiment

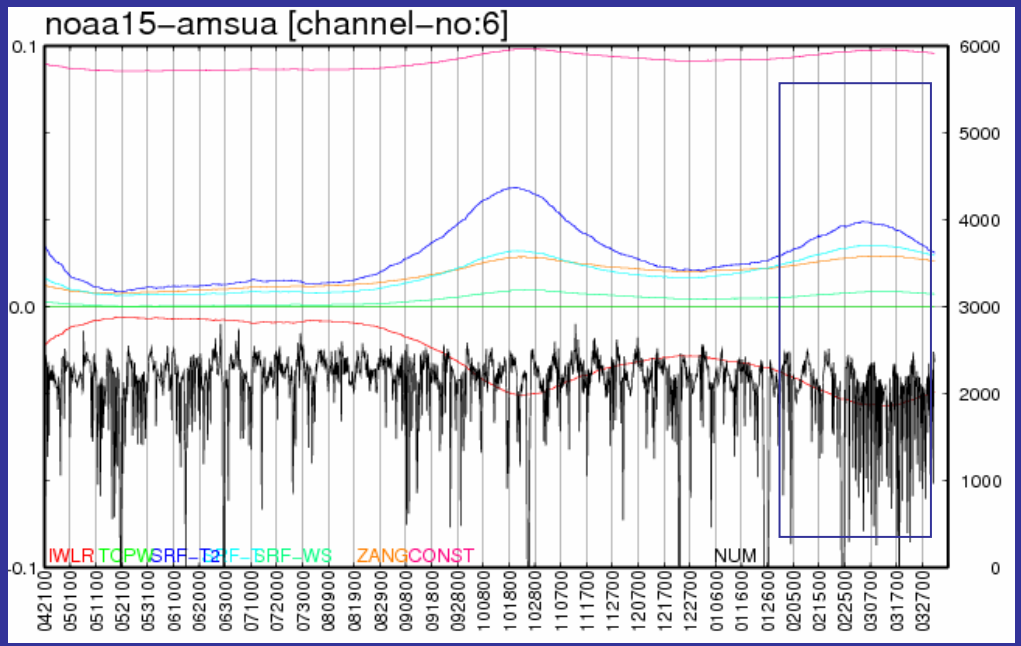


Operation

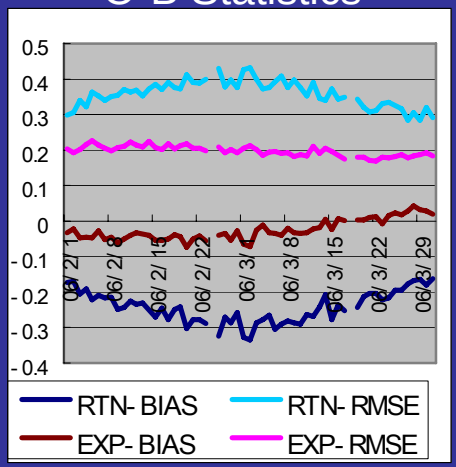


Bias correction coefficients

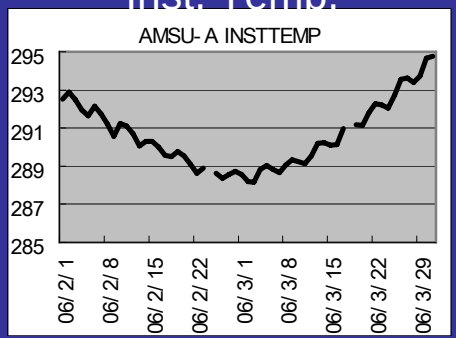
- May work as an instrument status monitor
  - Sample : AMSU-A ch.6 on NOAA15

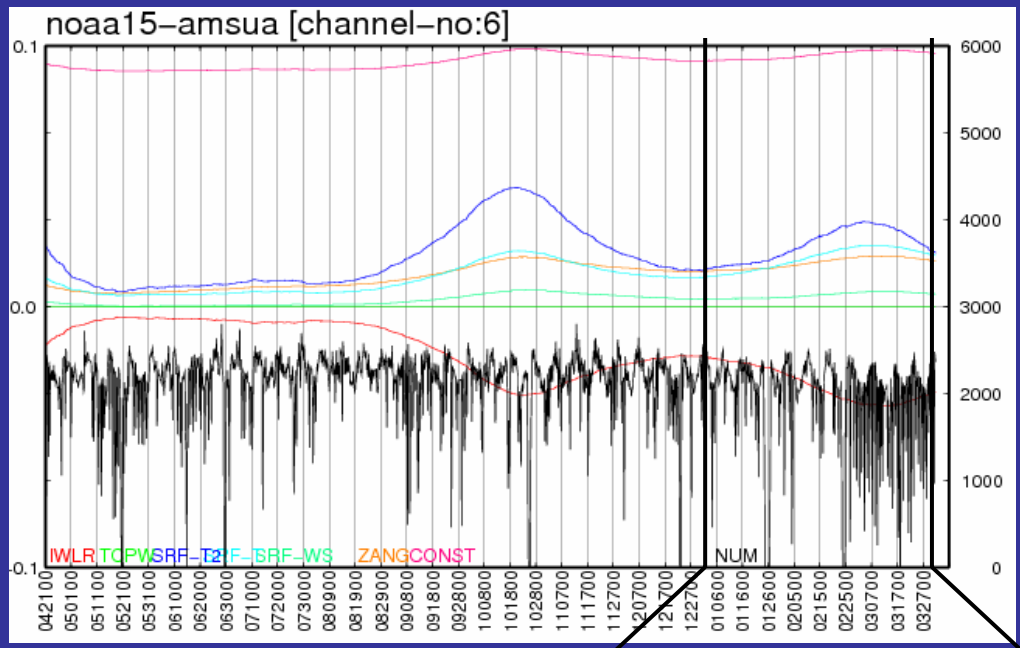


O-B Statistics



Inst. Temp.




noaa15–amsua [channel–no:6]
0.1
0.0
-0.1
6000
5000
4000
3000
2000
1000
0
IWLR TCPW SRF–T2 F–TBRF–WS ZANGCONST NUM
042100
050100
051100
052100
053100
061000
062000
063000
071000
072000
073000
080900
081900
082900
090800
091800
092800
100800
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110700
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020500
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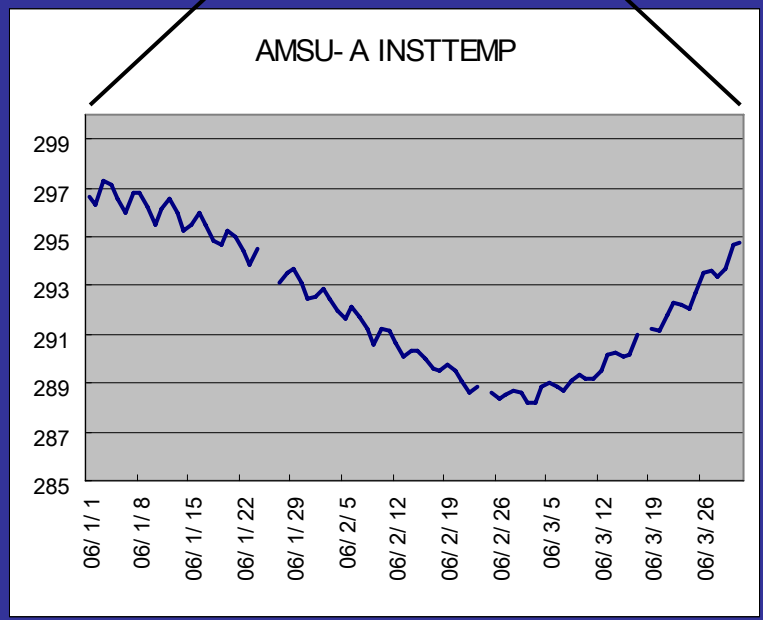
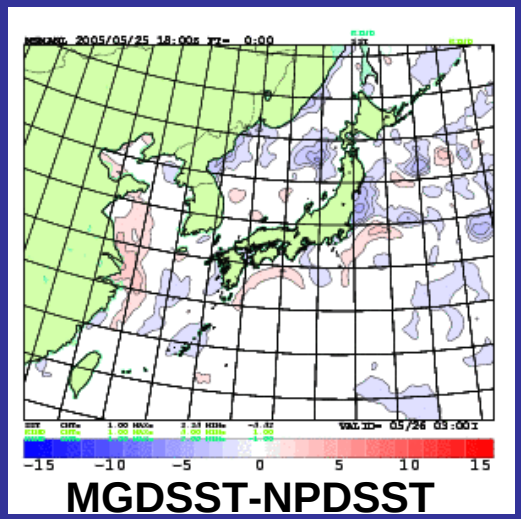
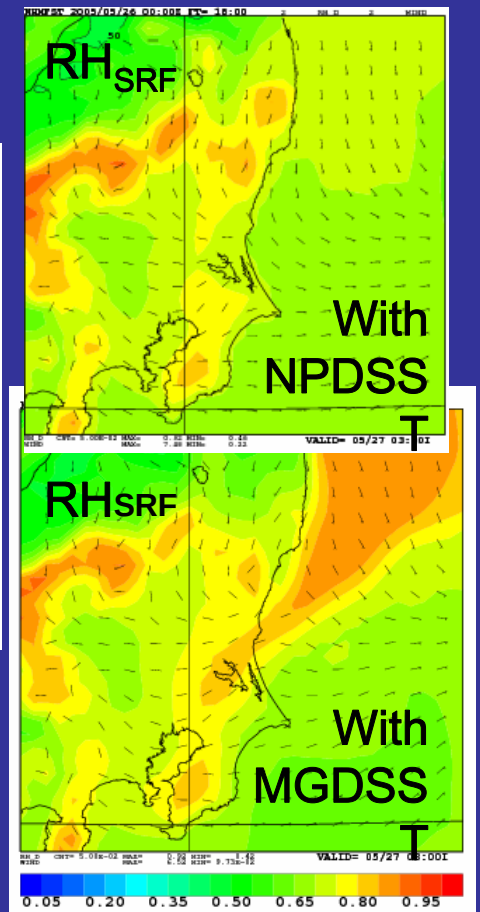
032700

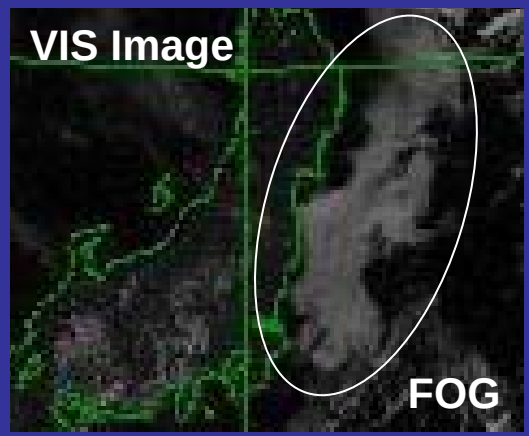

AMSU- A INSTTEMP
299
297
295
293
291
289
287
285
06/ 1/ 1
06/ 1/ 8
06/ 1/ 15
06/ 1/ 22
06/ 1/ 29
06/ 2/ 5
06/ 2/ 12
06/ 2/ 19
06/ 2/ 26
06/ 3/ 5
06/ 3/ 12
06/ 3/ 19
06/ 3/ 26

Impact of MGDSST

- NPDSST: 1deg, AVHRR & in situ
- MGDSST: 0.25deg, AVHRR, AMSR-E & in situ



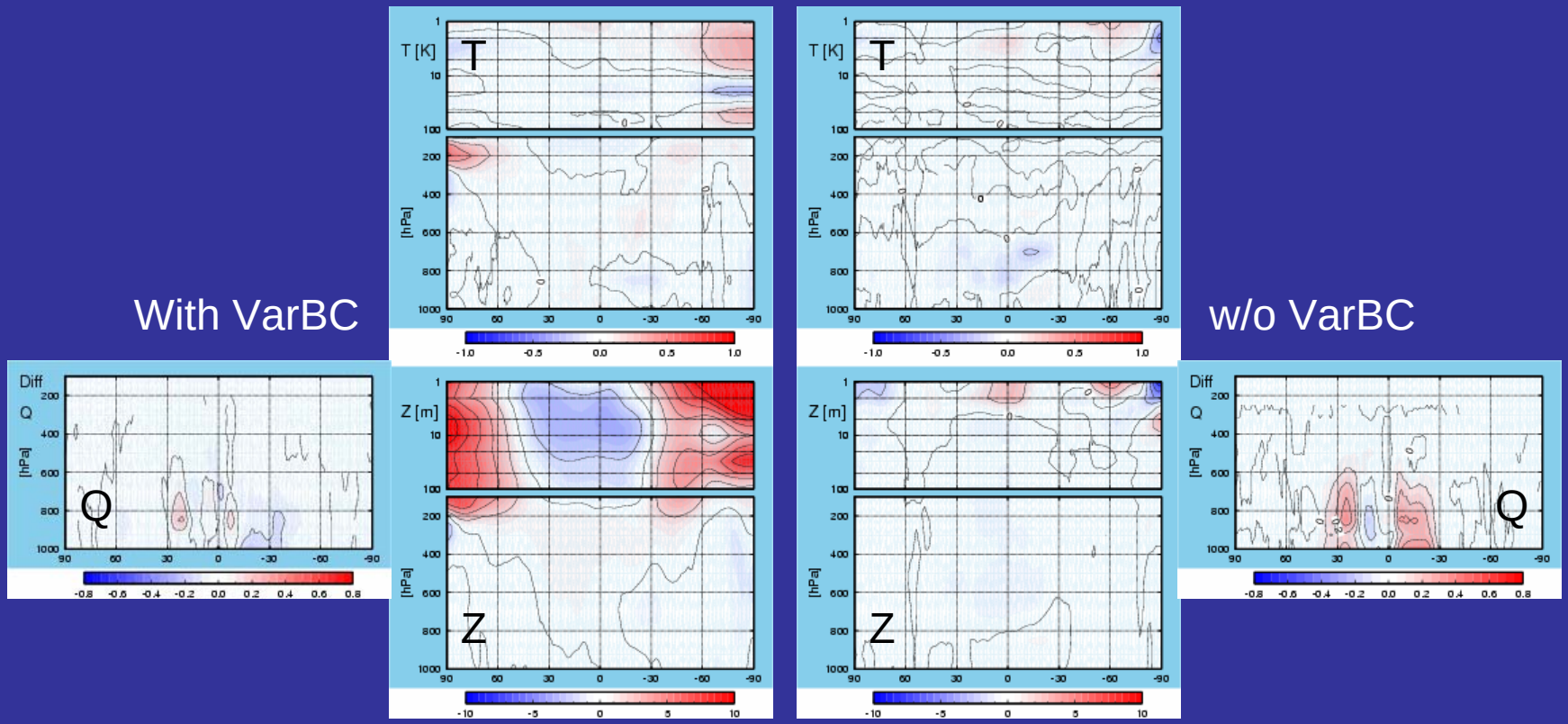




MWR impact

- Monthly averaged Zonal Mean Vertical Cross Section
  - Difference from their controls

With VarBC



w/o VarBC