Numerical Prediction Division,
Japan Meteorological Agency

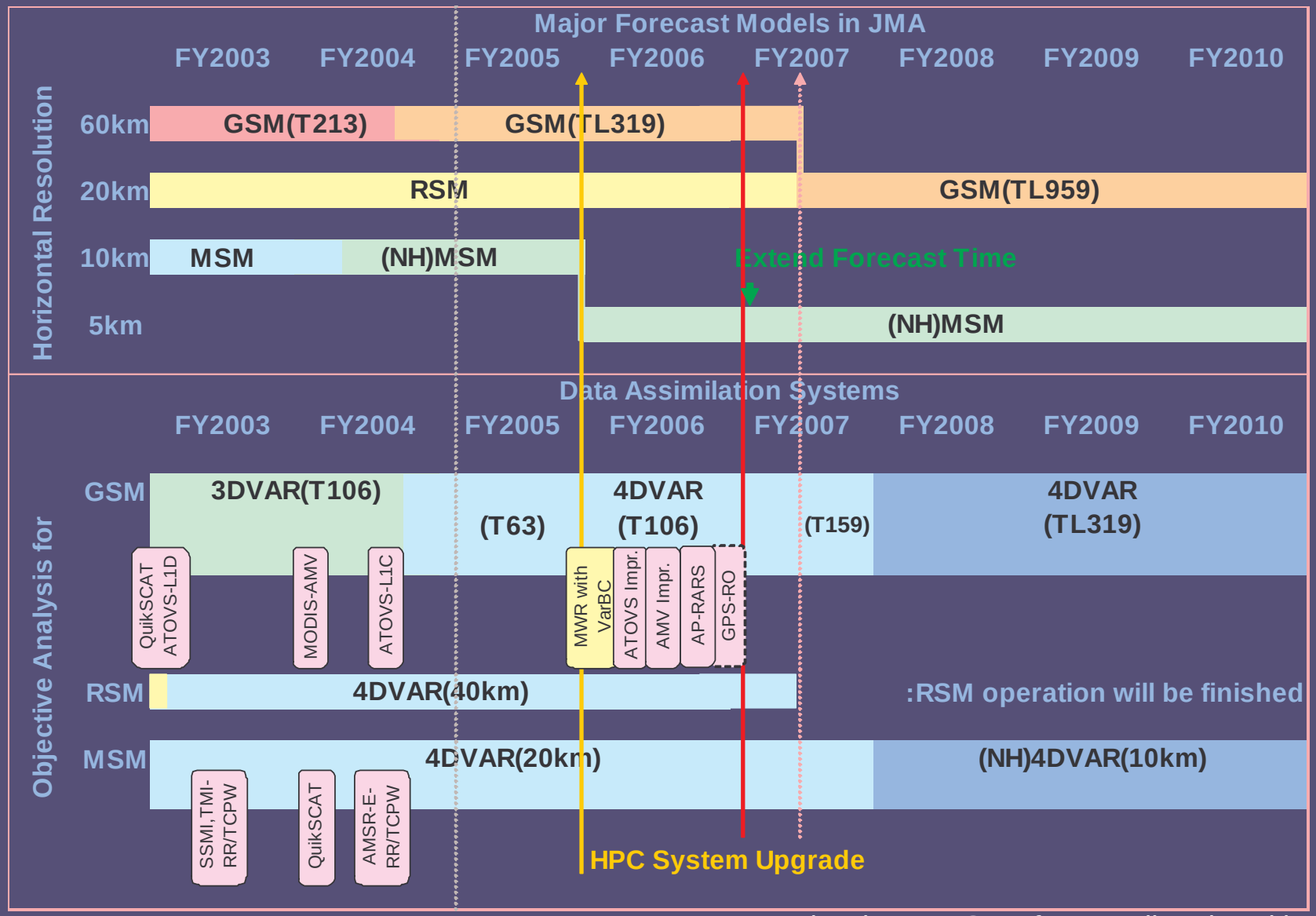
Recent Development of the JMA Global Data Assimilation System

Yoshiaki SATO (JMA/NPD, visiting NCEP/EMC)
<Yoshiaki.Sato@noaa.gov>
8 May 2007

Mt. Fuji from JMA/MSC (Meteorological Satellite Center)

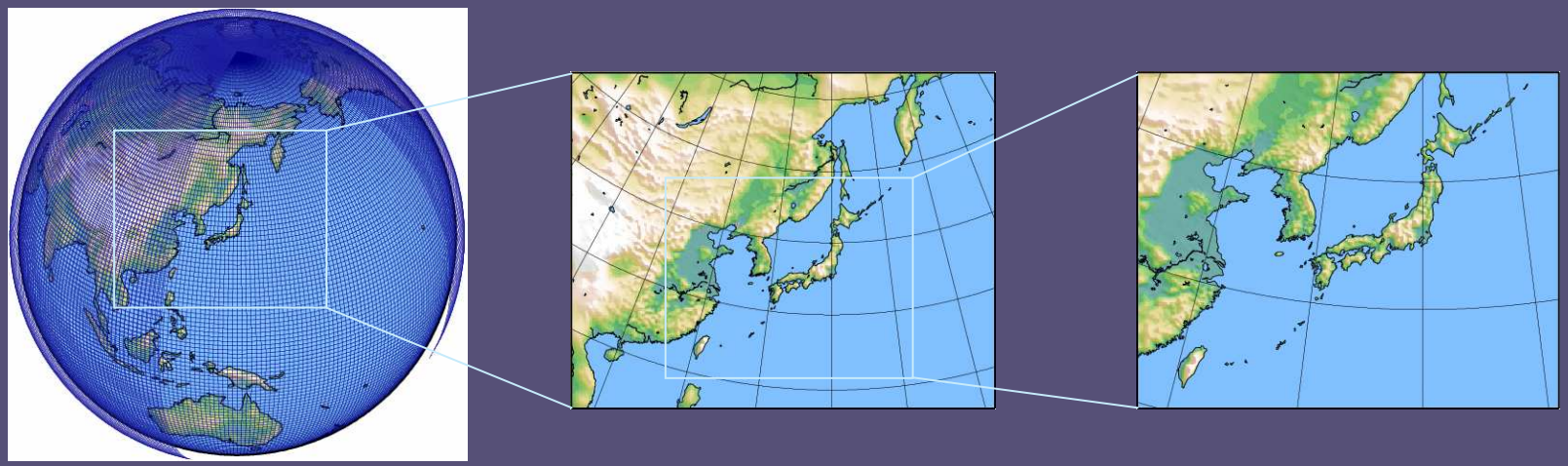
Numerical Prediction Division,
Japan Meteorological Agency

JMA/NWP – Update & Plan



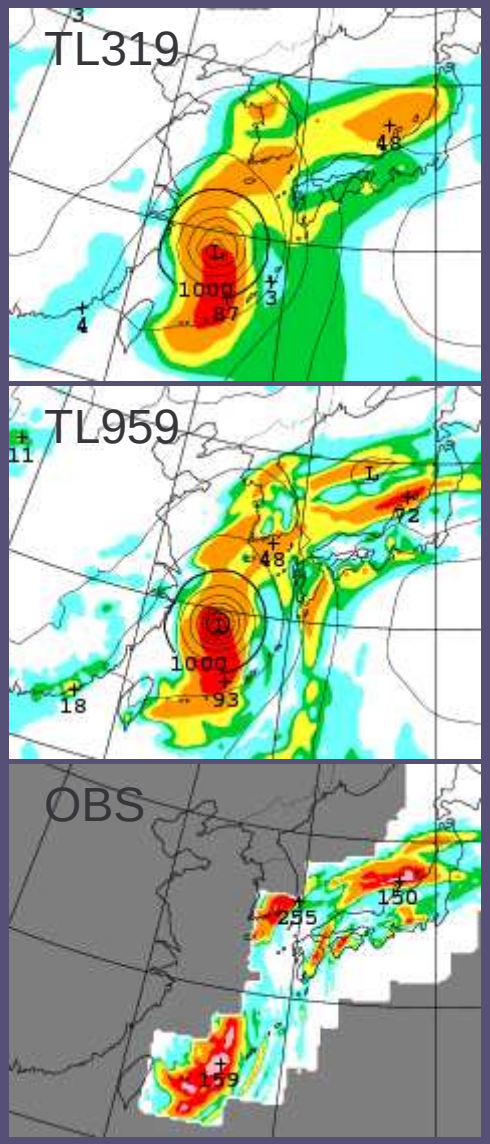
* Japanese Fiscal Year : Start from April and End in March

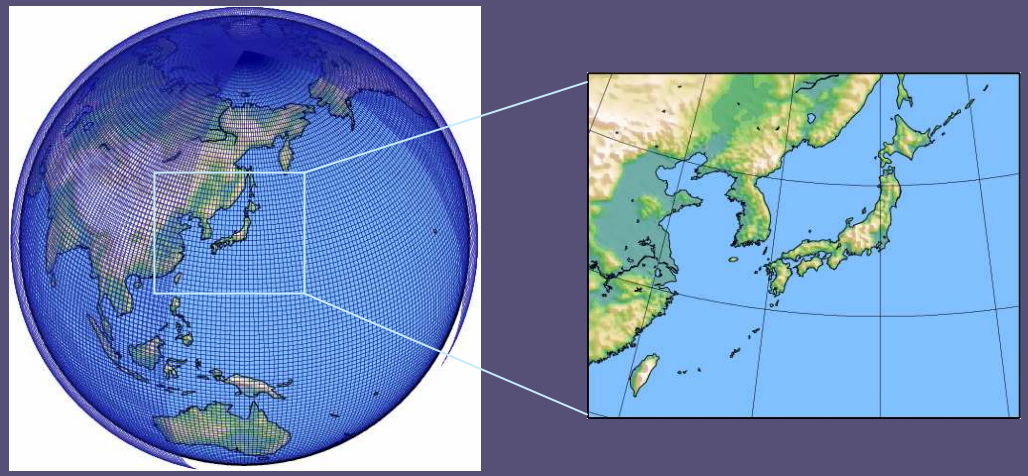
Current Operational Models in JMA



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

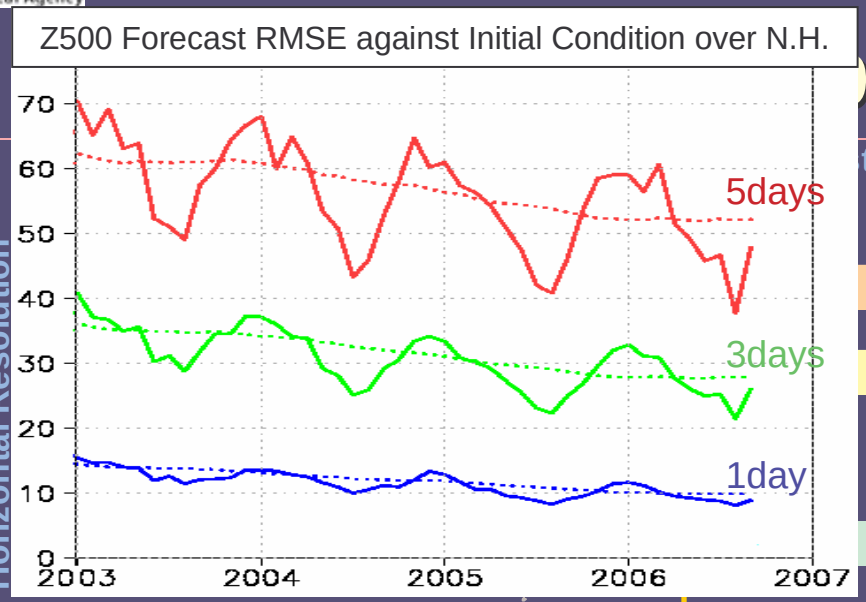
Next Operational Models in JMA

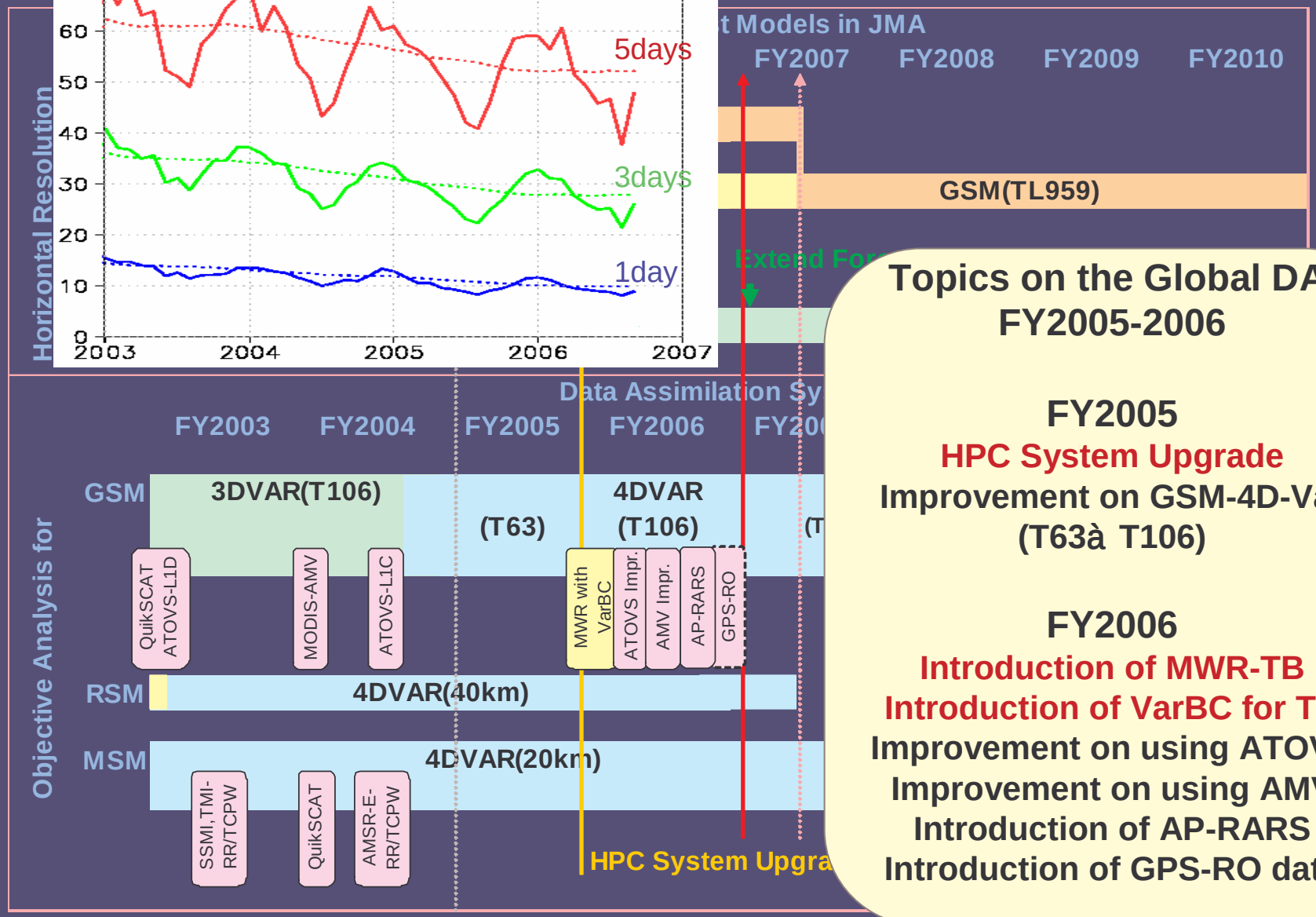




GSM	MSM
TL959 (20km)	dx=5km
L60 (~0.1hPa)	L50 (~22km)
4 times/day	8 times/day
36, 90 and 216 hrs fcst	15, 33 hrs fcst
DA system	DA system
4DVAR (T159)	4DVAR (20km)
Nov. 2007	May 2007

date & Plan





Topics on the Global DA FY2005-2006

FY2005

HPC System Upgrade

Improvement on GSM-4D-Var (T63à T106)

FY2006

Introduction of MWR-TB

Introduction of VarBC for TB

Improvement on using ATOVS

Improvement on using AMV

Introduction of AP-RARS

Introduction of GPS-RO data

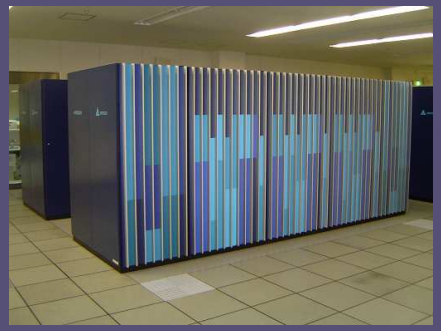
FY2005

- HPC System Upgrade (Mar 2006, all of us)
  - NAPS (Numerical Analysis and Prediction System): **7th à 8th**
  - Most of us were occupied in porting the systems for NAPS8
- Improvement on GSM-4D-Var (Mar 2006, Narui)
  - Horizontal resolution of the inner model : **T63 à T106**

JMA HPC SYSTEM

- Replaced on 1 Mar. 2006

	NAPS8	NAPS7
DATE	3/1/2006	3/1/2001
SYSTEM	HITACHI SR11000K1	HITACHI SR8000E1
CPU/NODE	16	8
NODE	80NODE x 2	80NODE
Performance	21.5 TFLOPS	768 GFLOPS
Memory	10.0TB	640GB



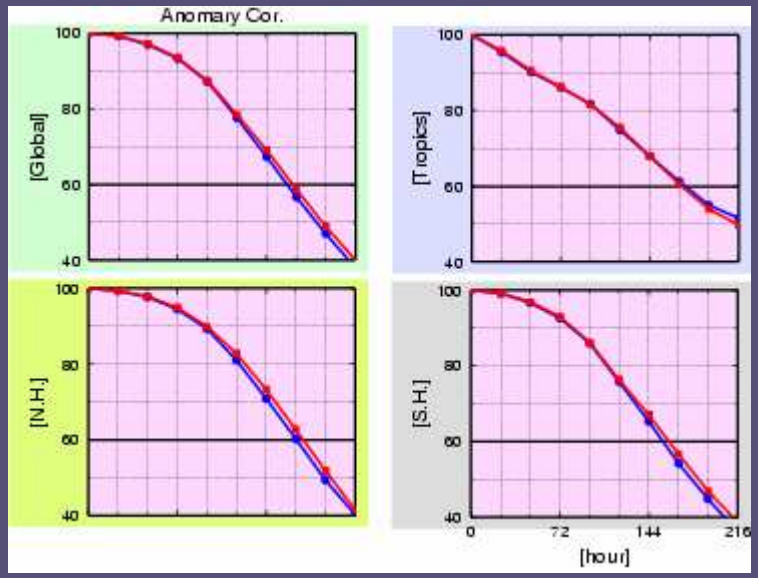
FY2005

- HPC System Upgrade (Mar 2006, all of us)
  - NAPS (Numerical Analysis and Prediction System): **7th à 8th**
  - Most of us were occupied in porting the systems for NAPS8
- Improvement on GSM-4D-Var (Mar 2006, Narui)
  - Horizontal resolution of the inner model : **T63 à T106**

Improvement on GSM-4D-Var

- GSM-4D-Var on NAPS7
  - Horizontal resolution of the inner model was T63
    - Because of the system resource Ł NAPS8 has the larger resource
  - Cycle experiments for increasing the resolution (T106)

    à Positive impacts on the most of forecast elements.

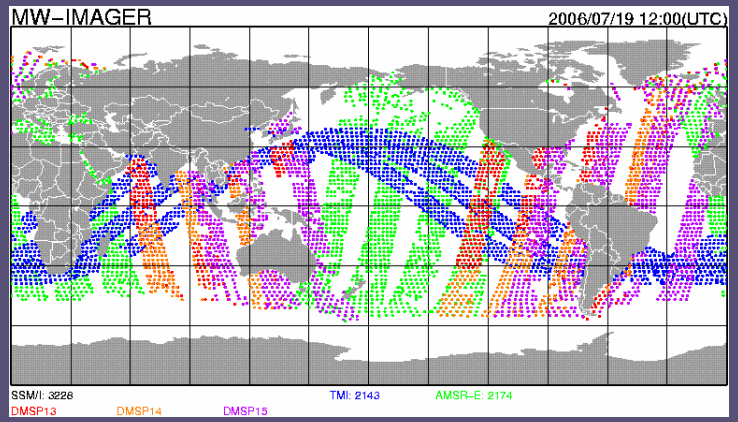


Anomaly Correlation on Z500

FY2006

- Introduction of MWR-TB (May 2006, Sato)
  - DMSP/SSM/I, TRMM/TMI, and Aqua/AMSR-E
- Introduction of VarBC for TB (May 2006, Sato)
  - For all radiance data (NOAA/AMSU, Aqua/AMSU-A and MWR)
- Improvement on using ATOVS (July 2006, Okamoto)
  - VarBC predictors, observation error, etc.
- Improvement on using AMV (Oct 2006, Yamashita)
  - Thinning method, introduction of hourly AMV from MTSAT-1R
- Introduction of AP-RARS (Feb 2007, Owada)
  - Direct receiving data
- Introduction of GPS-RO data (Mar 2007, Ozawa)
  - The Data from CHAMP

MWR radiance assimilation

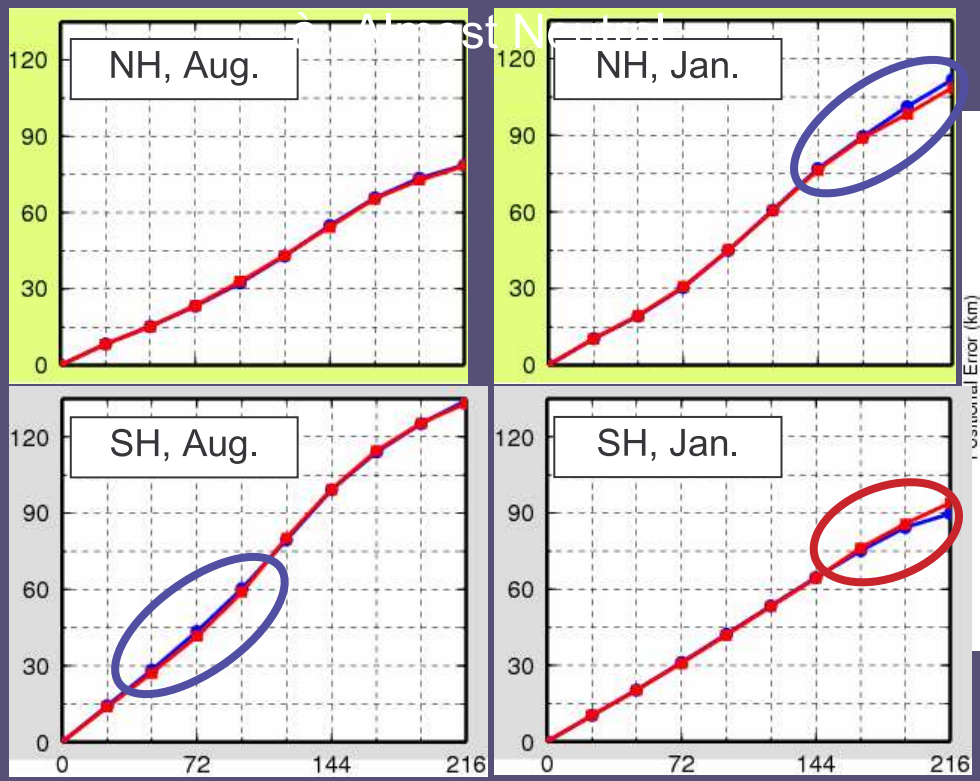


- Configurations
  - Using vertical polarized channels only
    - SSM/I: 19V, 22V, 37V, 85V
    - TMI: 19V, 21V, 37V, 85V
    - AMSR-E: 18V, 23V, 36V, 89V
  - Over clear sky ocean with SST > 5 deg. C
  - Thinned by 200x200 km grid box for every time slots
  - Observation Error Settings: 4σ
  - Variational 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, OSEs (Aug 2004 & Jan 2005) were performed.

OSE results

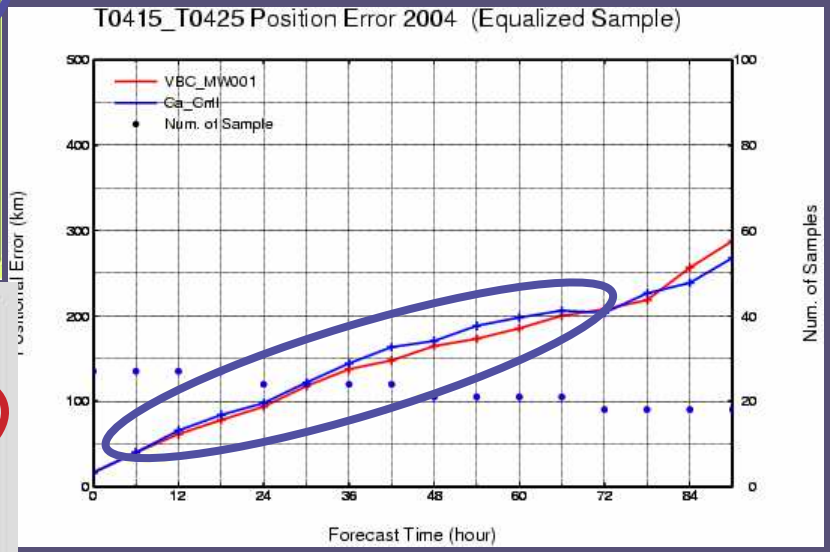
500hPa GPH forecast RMSE time sequence



Red: Test / Blue: Cntl

Typhoon position error time sequence

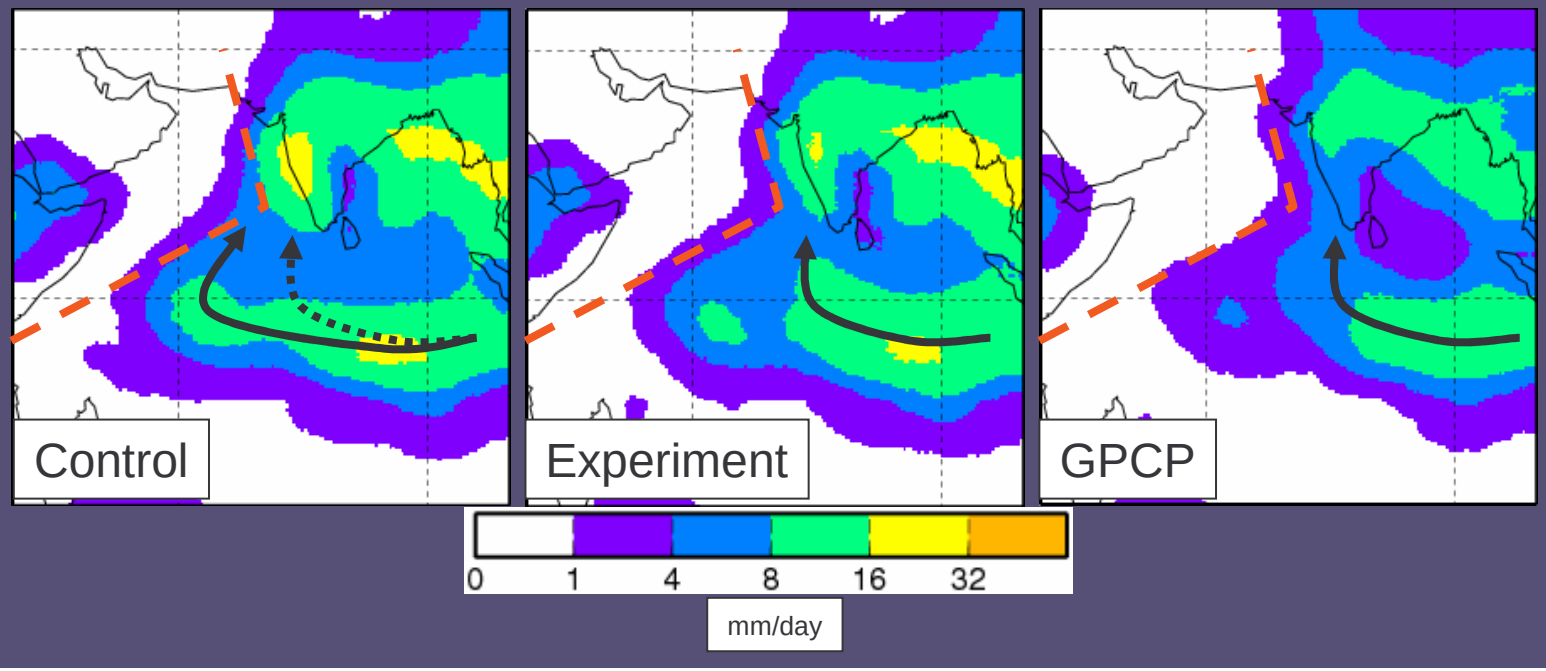
à Improved



Red: Test / Blue: Cntl

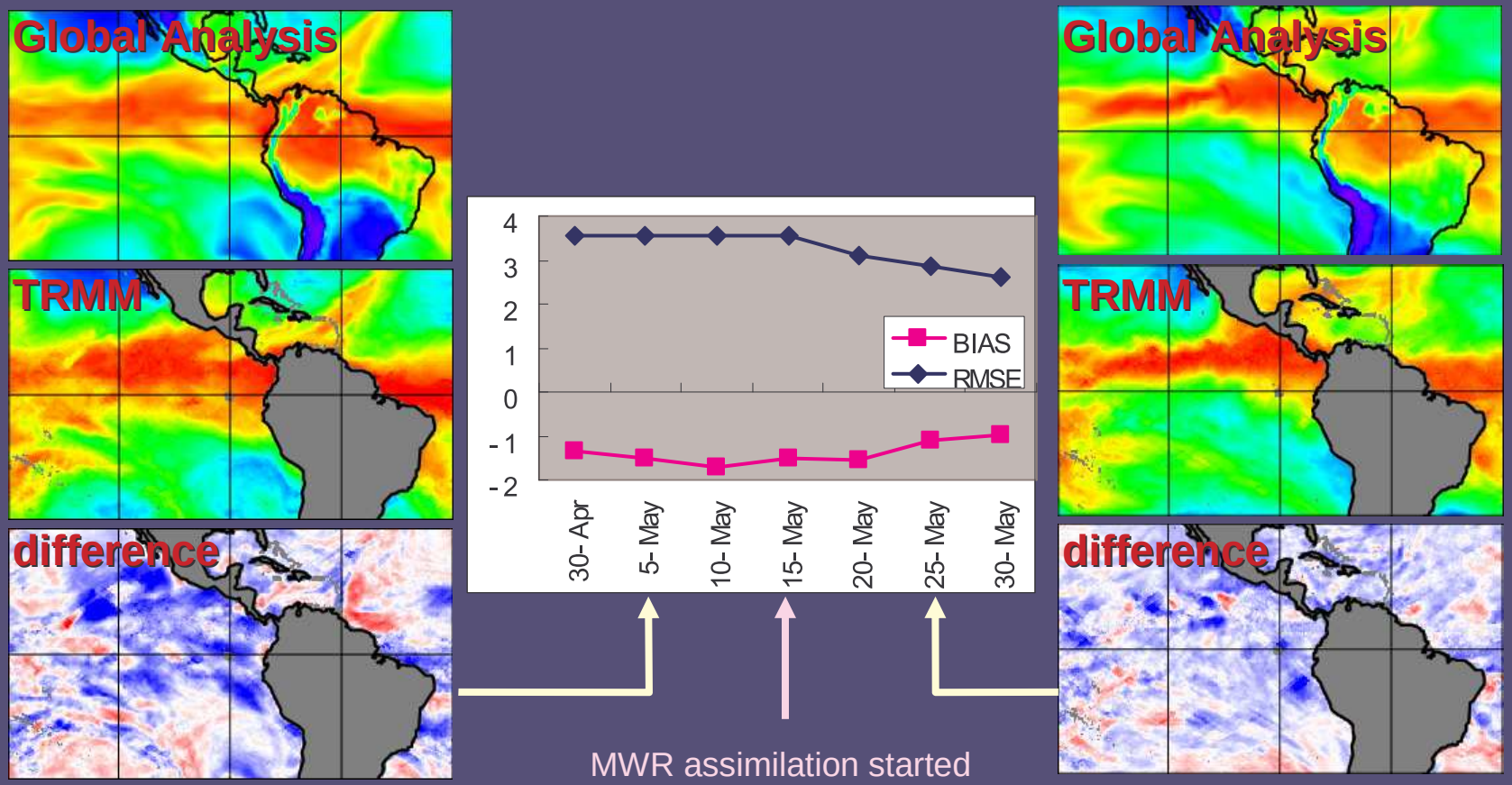
Cycle Experiment Results

- 24-h rainfall forecasts were evaluated using GPCP
  - Correlation Coefficients:
    - Control: 0.881 Ł with MWR: 0.891 (Aug)
    - Control: 0.835 Ł with MWR: 0.841 (Jan)
    - Lower figure shows Indian monsoon region in the experiment of Aug
      - The rainfall pattern showed better distribution.



Operation status for MWR

- Compared with TRMM product ß Not independent data



MWR assimilation started

5 May

25 May

Variational Bias Correction Settings

WILR: Weighted Integrated Lapse Rate ß For AMSU-A

TCPW: Total Column Precipitable Water ß 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

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

Obs ~ Bkg

N<N_{MIN} Ł Bkg > Obs

N=N_{MIN} Ł Bkg ~ Obs

N>N_{MIN} Ł Bkg < Obs

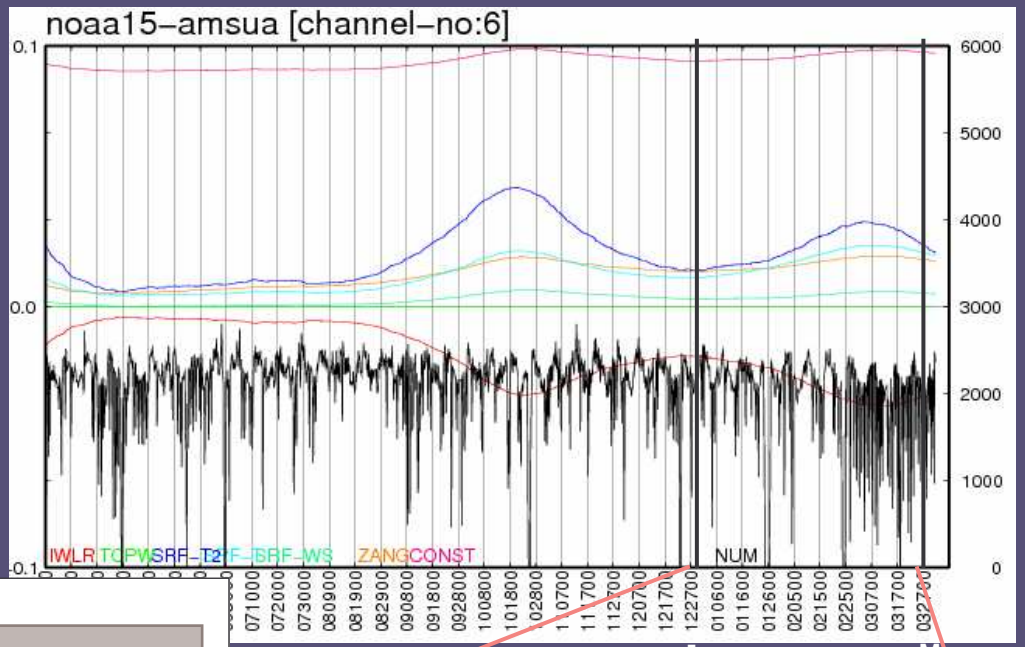
    - Our Settings

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

$$N_{MIN} = 400$$

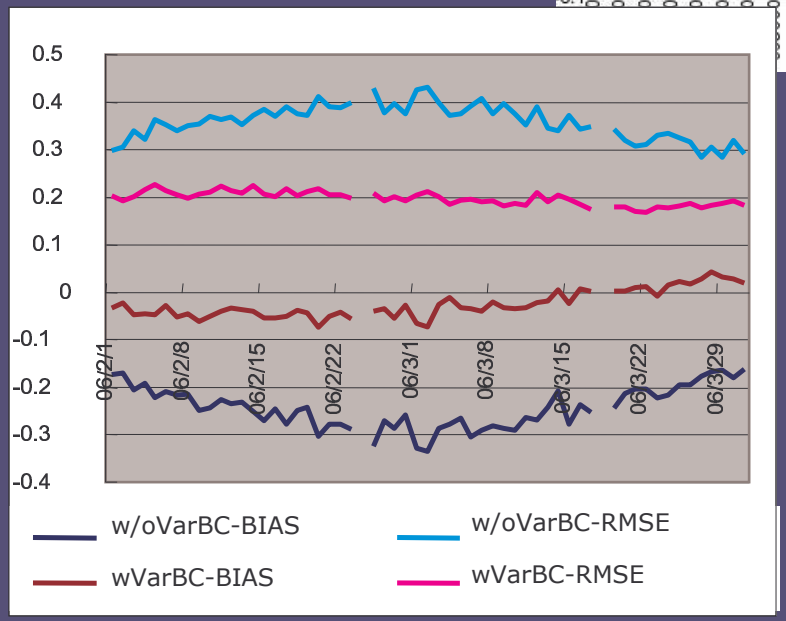
Behavior for the coefficients

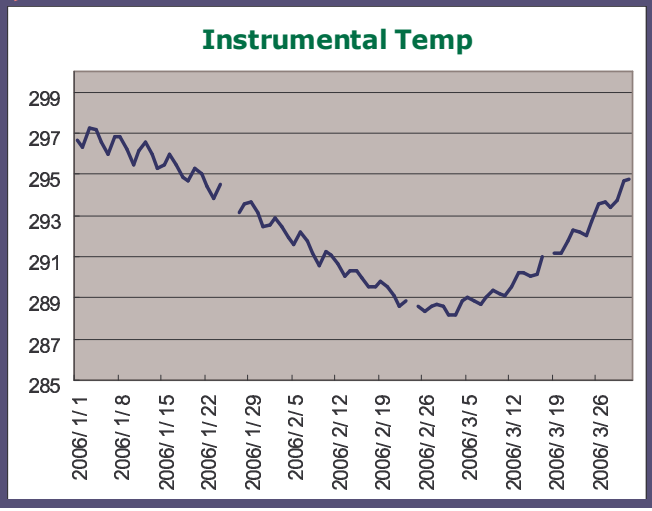
- ex. NOAA15 AMSU-A ch6
  - Fluctuation of VarBC coef well correspond to inst. temp. fall
- à It should be going well



Jan 2006

Mar 2006





FY2006

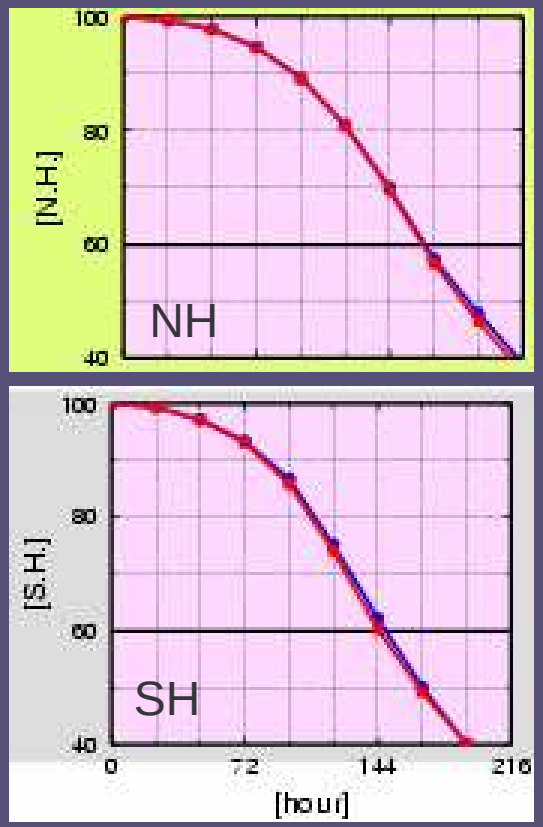
- Introduction of MWR-TB (May 2006, Sato)
  - DMSP/SSM/I, TRMM/TMI, and Aqua/AMSR-E
- Introduction of VarBC for TB (May 2006, Sato)
  - For all radiance data (ATOVS, Aqua/AMSU-A and MWR)
- Improvement on using ATOVS (July 2006, Okamoto)
  - VarBC predictors, observation error, etc.
- Improvement on using AMV (Oct 2006, Yamashita)
  - Thinning method, introduction of hourly AMV from MTSAT-1R
- Introduction of AP-RARS (Feb 2007, Owada)
  - Direct receiving data
- Introduction of GPS-RO data (Mar 2007, Ozawa)
  - The Data from CHAMP

ATOVS assimilation changes in Aug2006

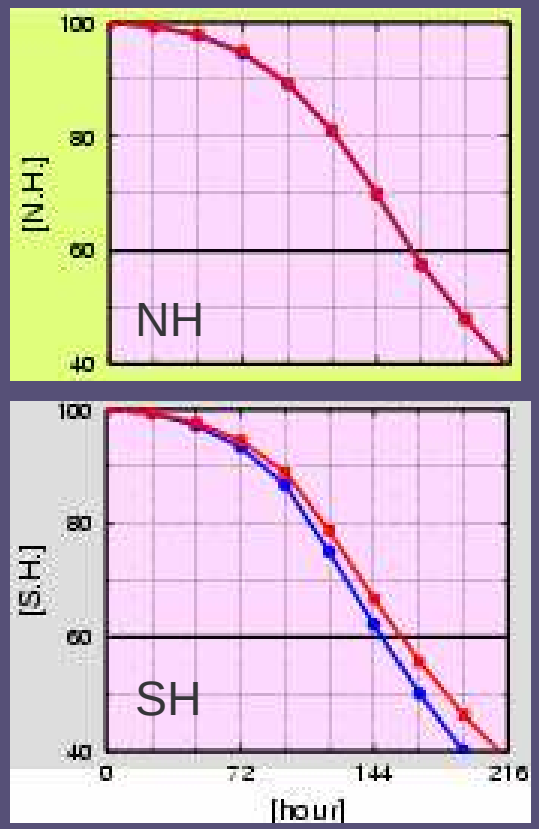
- improve QC
  - adopt MSPPS latest version for MW-cloud detection
  - stricter gross error QC, remove edge scans
- recalculate scanBC parameters
- change VarBC predictors
- modify obs errors of AMSU-A
  - reduce obs error inflation factor, 2.3 to 1.2
    - obs errors are inflated in 4DVar main analysis to complement neglecting horizontal error correlation and balance among contributions from other observations and guess.
  - O-B has been getting smaller due to using level-1C data, revising scanBC and including VarBC

The impact on the inflation factor

inflation factor = 2.3 500Z ANC



inflation factor = 1.0 500Z ANC

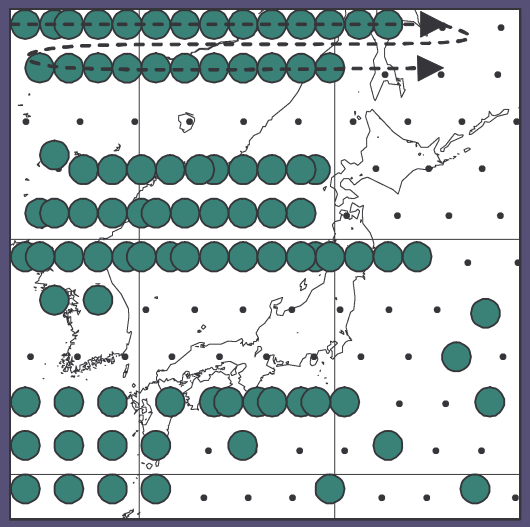


FY2006

- Introduction of MWR-TB (May 2006, Sato)
  - DMSP/SSM/I, TRMM/TMI, and Aqua/AMSR-E
- Introduction of VarBC for TB (May 2006, Sato)
  - For all radiance data (ATOVS, Aqua/AMSU-A and MWR)
- Improvement on using ATOVS (July 2006, Okamoto)
  - VarBC predictors, observation error, etc.
- Improvement on using AMV (Oct 2006, Yamashita)
  - Thinning method, introduction of hourly AMV from MTSAT-1R
- Introduction of AP-RARS (Feb 2007, Owada)
  - Direct receiving data
- Introduction of GPS-RO data (Mar 2007, Ozawa)
  - The Data from CHAMP

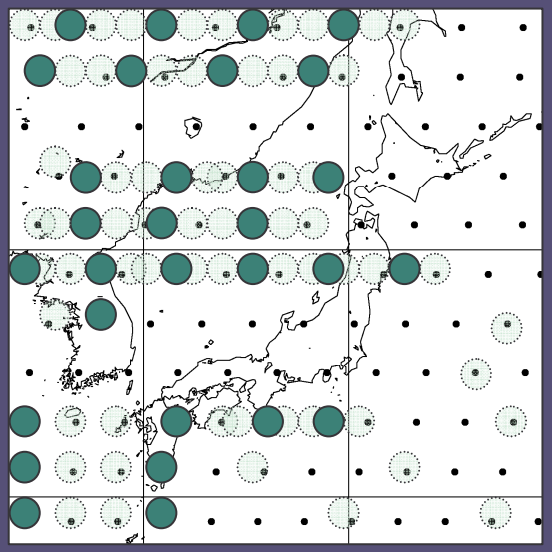
Improvement on using AMV

- Thinning method
  - By order à By Grid Box

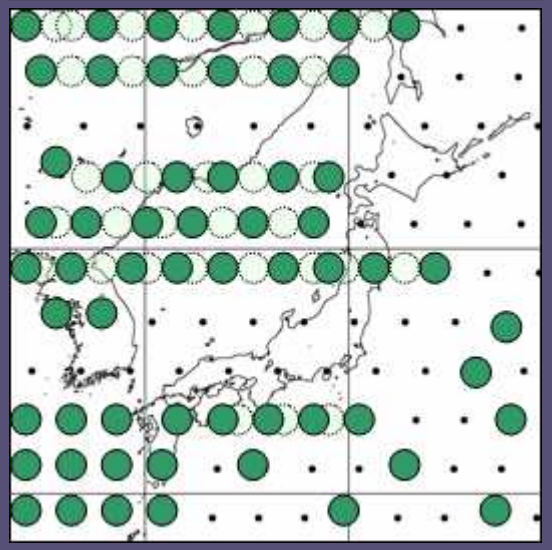


Reported Data

By Order →



By Grid Box →



- Hourly AMV data from MTSAT-1R

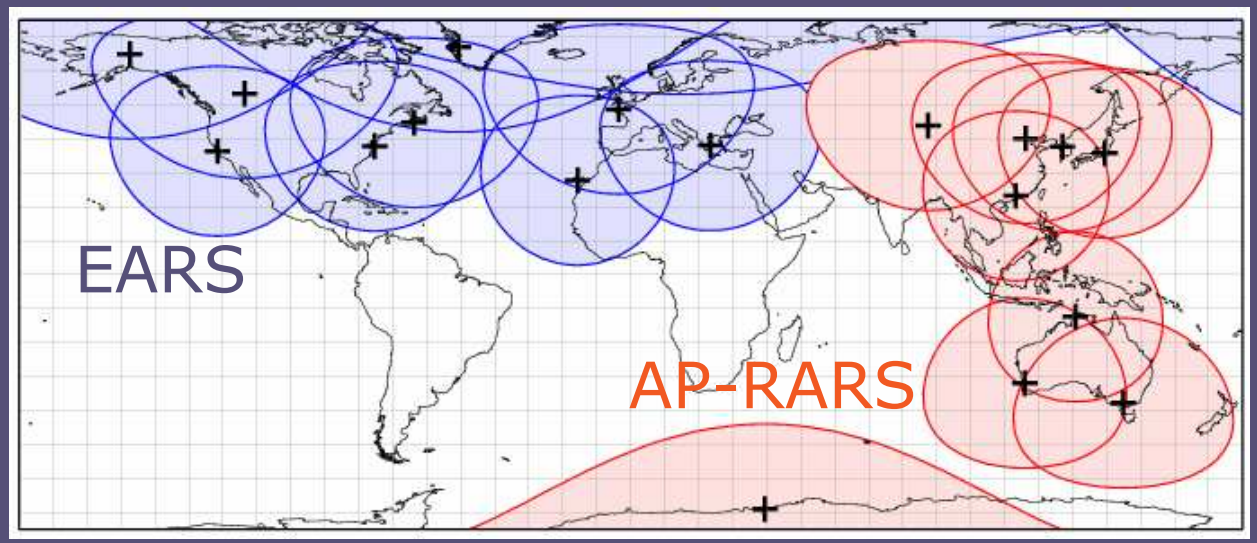
Ł Slight positive impact on the Z500 forecast

FY2006

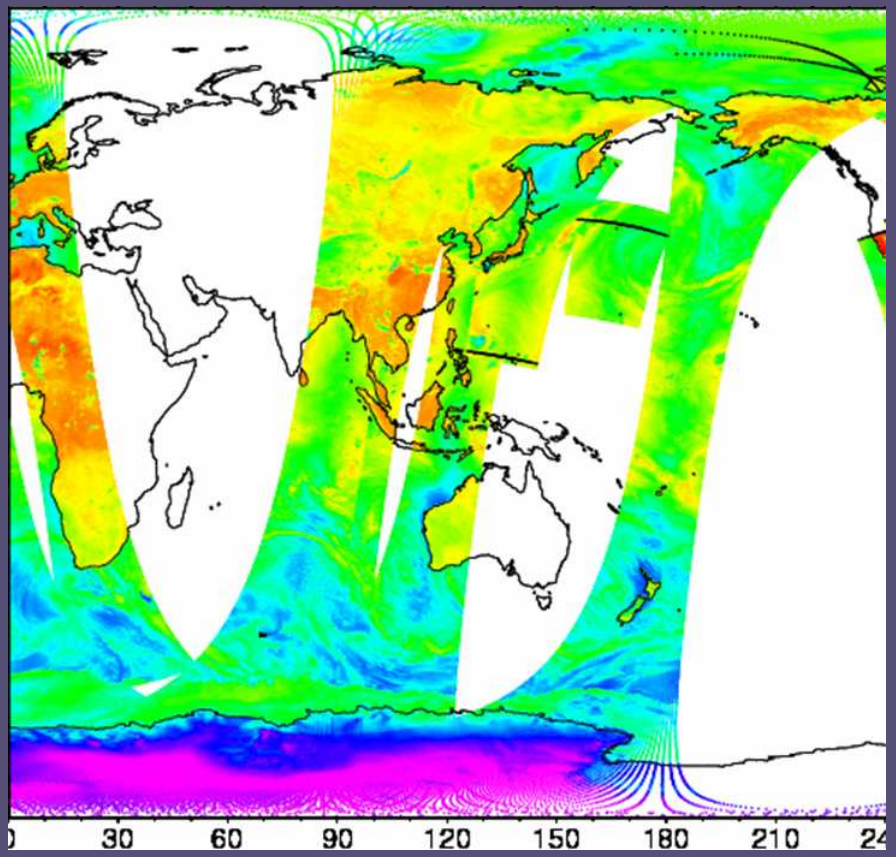
- Introduction of MWR-TB (May 2006, Sato)
  - DMSP/SSM/I, TRMM/TMI, and Aqua/AMSR-E
- Introduction of VarBC for TB (May 2006, Sato)
  - For all radiance data (ATOVS, Aqua/AMSU-A and MWR)
- Improvement on using ATOVS (July 2006, Okamoto)
  - VarBC predictors, observation error, etc.
- Improvement on using AMV (Oct 2006, Yamashita)
  - Thinning method, introduction of hourly AMV from MTSAT-1R
- Introduction of AP-RARS (Feb 2007, Owada)
  - Direct receiving data
- Introduction of GPS-RO data (Mar 2007, Ozawa)
  - Refractivity data from CHAMP

Introduction of AP-RARS data

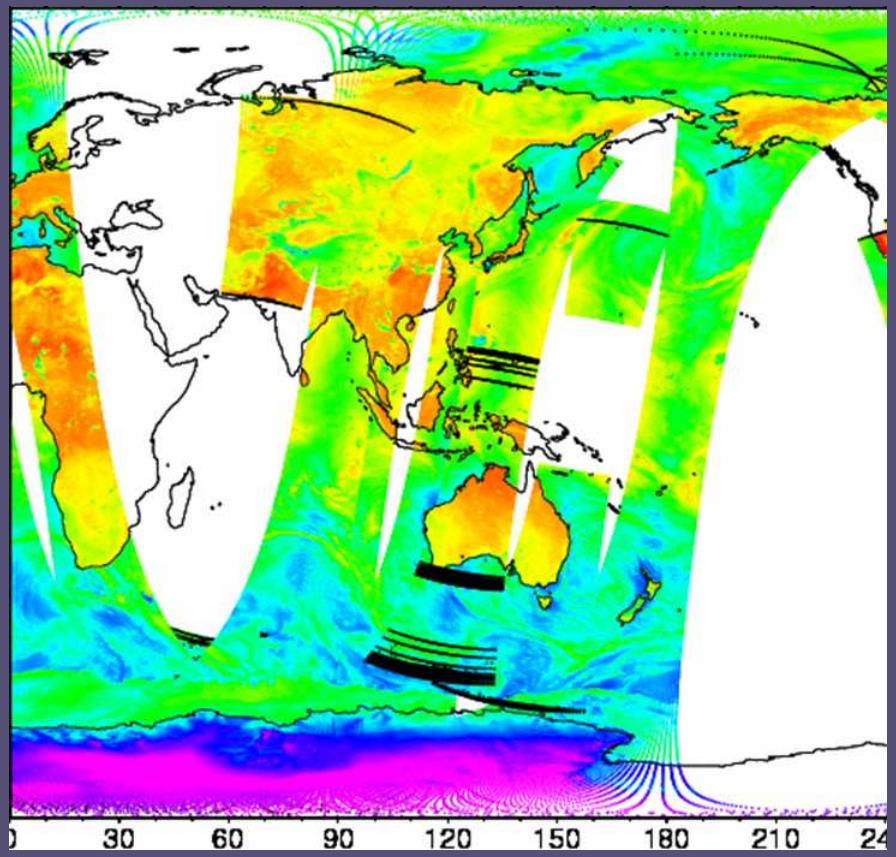
- Asia-Pacific Regional ATOVS Retransmission Service
  - The data has been used since Feb. 2007
  - Japan : Tokyo/Kiyose (JMA/MSC), Showa-Base (Antarctica) ;
    Korea : Seoul; China: Beijing, Guangzhou, Urumqi ;
    Australia : Melbourne, Perth, Darwin
    (Singapore: from Apr 2007 ?)



Data distribution sample



w/o AP-RARS



with AP-RARS

Data distribution sample on the Early Analysis at 22 July 2006 00UTC

FY2006

- Introduction of MWR-TB (May 2006, Sato)
  - DMSP/SSM/I, TRMM/TMI, and Aqua/AMSR-E
- Introduction of VarBC for TB (May 2006, Sato)
  - For all radiance data (ATOVS, Aqua/AMSU-A and MWR)
- Improvement on using ATOVS (July 2006, Okamoto)
  - VarBC predictors, observation error, etc.
- Improvement on using AMV (Oct 2006, Yamashita)
  - Thinning method, introduction of hourly AMV from MTSAT-1R
- Introduction of AP-RARS (Feb 2007, Owada)
  - Direct receiving data
- Introduction of GPS-RO data (Mar 2007, Ozawa)
  - The Data from GFZ-CHAMP

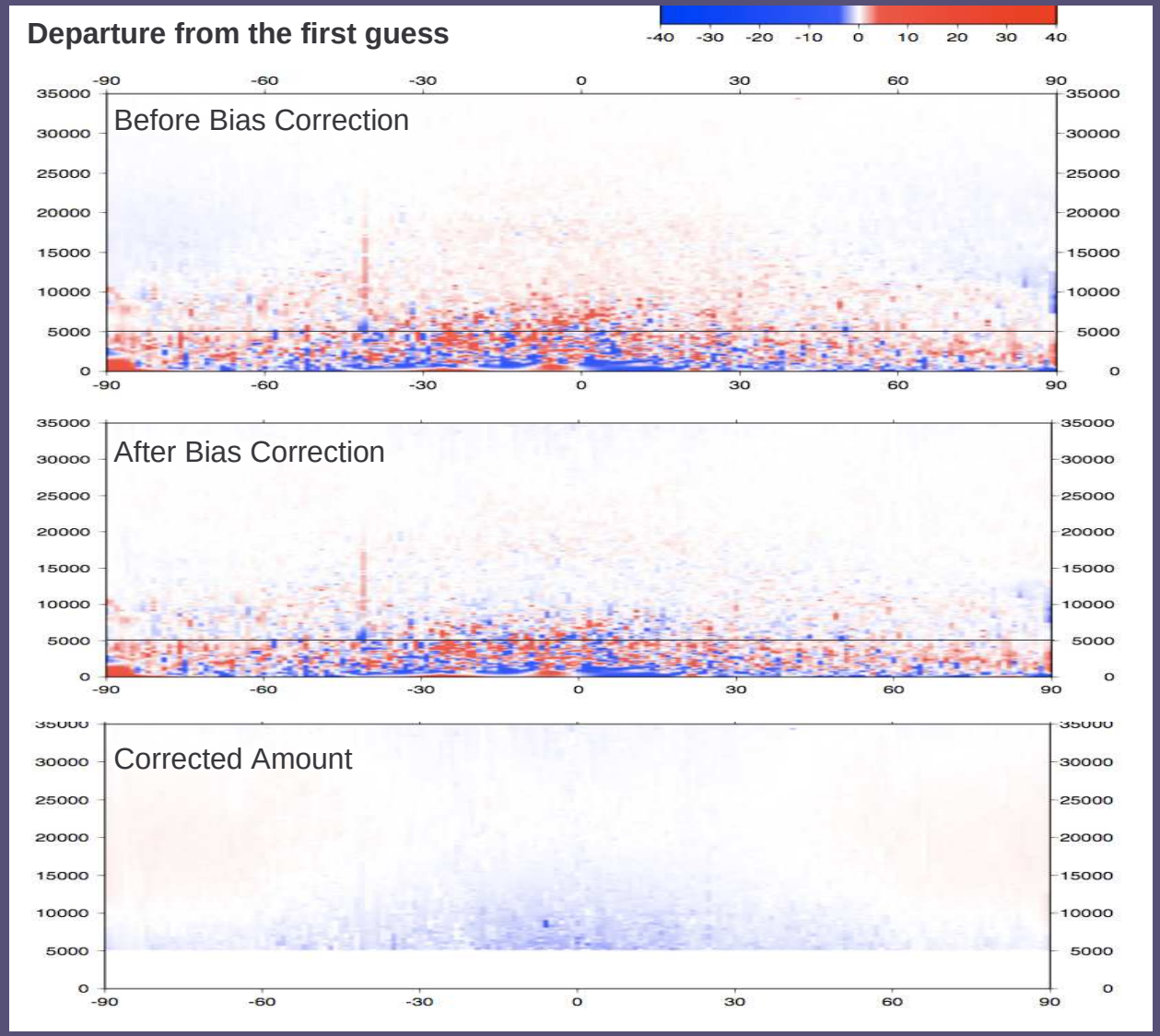
GPS Radio Occultation data

- Used data
  - Retrieved local refractive index data from CHAMP
  - Height : 5 – 35 km
  - Gross error : 2 σ
  - Thinning : by 2km for vertical (reported data interval : 200m)
  - Inflation factor for observation error
    - High Latitudes : 0%, Mid Latitudes : 10%, and Tropics : 20%
- Bias correction
  - Adaptive bias correction using Kalman Filtering
    - Predictors: Height index, Refractive index, and Latitude index
    - The coefficient sets are prepared for 5 areas
      - High Latitudes, Mid Latitudes, and Tropics

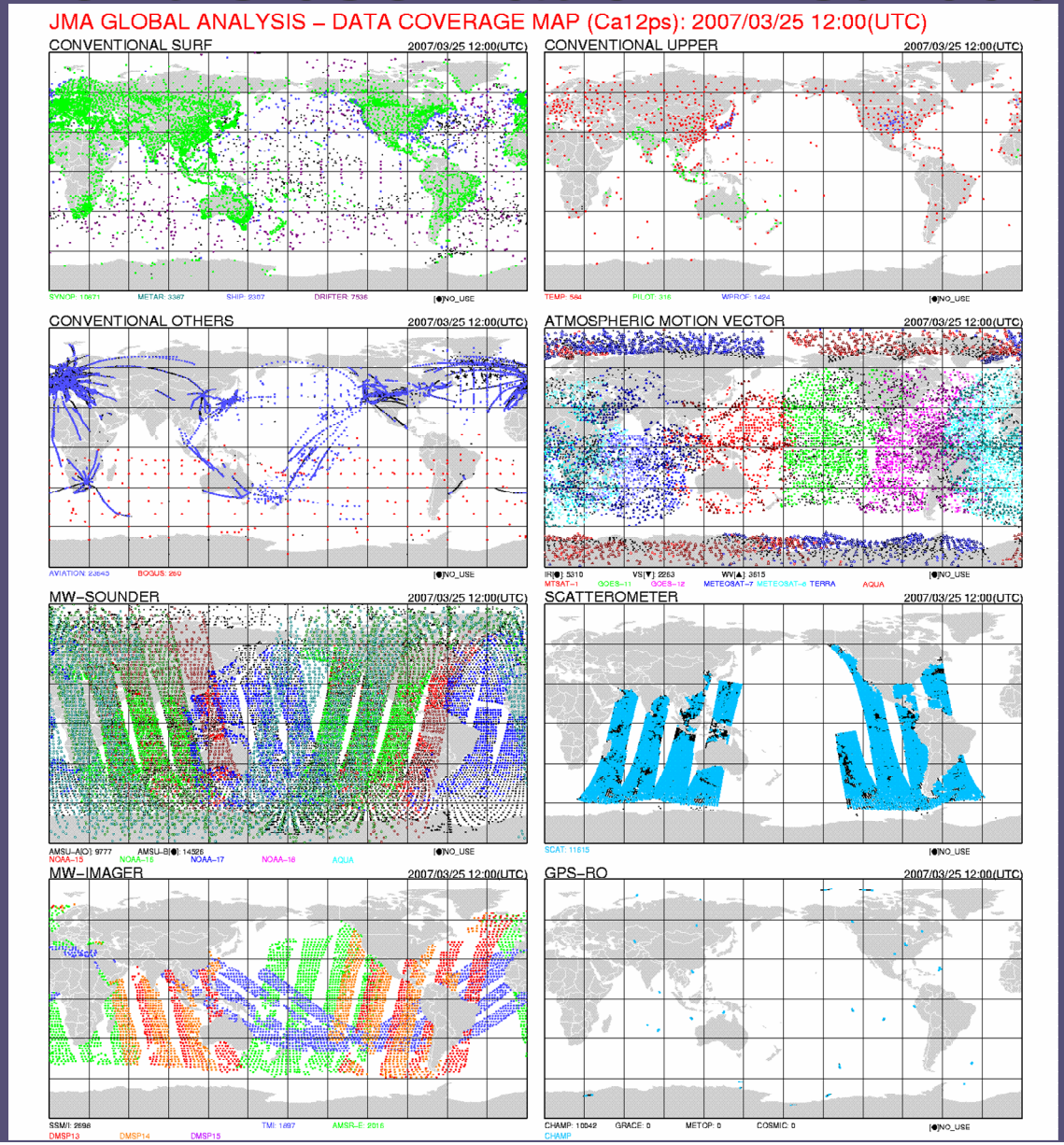
*Using the GSM 3D-Var, refractive index DA and bending angle DA were compared in advance. The result did not show the considerable effect. And it is tough work to implement the non-local operator for GSM 4D-Var.

Ł Slight positive impact on the Z500 forecast

Sample of the bias correction



Current Observation Distribution



Other developments

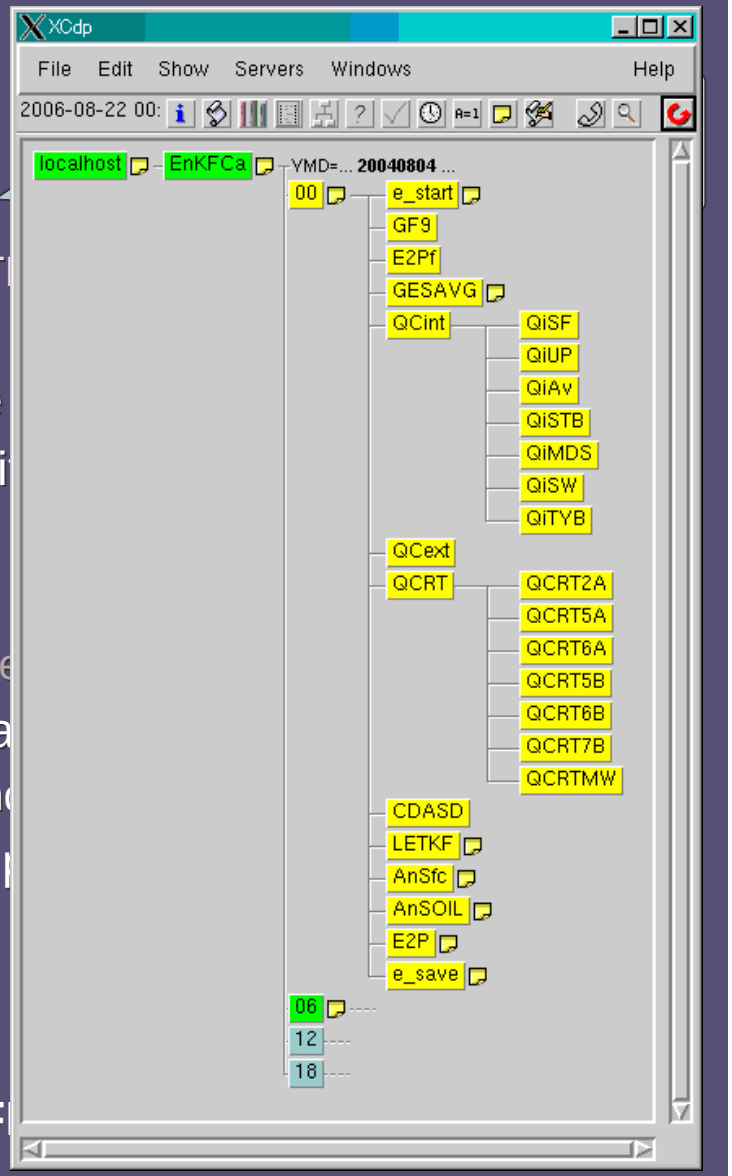
- At satellite data assimilation group
  - Radiance assimilation
    - Water vapor radiance from geo-synchronous satellite (Ishibashi)
    - AIRS (Okamoto)
    - SSMIS (Egawa (& Kazumori ?))
  - Other assimilation
    - Ambiguity winds from scatterometer (Tahara@MSC)
  - Others
    - GPS aboard Grace & CHAMP (Ozawa)
    - Improvement on the AMV accuracy (Imai@MSC)

MSC: Meteorological Satellite Center of JMA

Another Topic ~LETKF~

LETKF developments

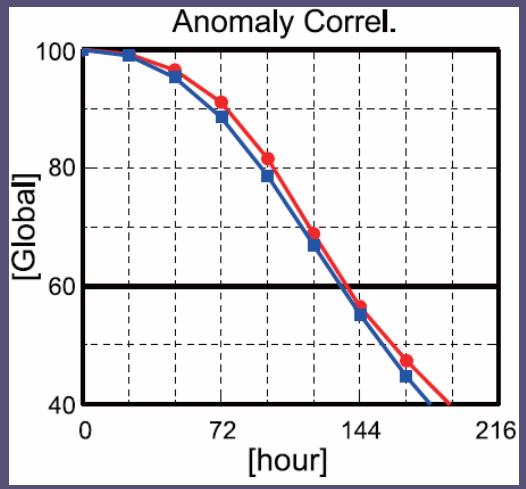
- GSM-LETKF (TL159L40)
  - The development was started in Jun 2006
    - LETKF core : Miyoshi (based on *AFES-LET
    - The surrounding systems : Sato
  - 1st exp: Jul 2006 – 20 member, w/o satellite
  - 2nd exp: Aug 2006 – 20 member, with satelli
    - Ref: Miyoshi and Sato (2007, SOLA)
  - 3rd exp: Sep 2006 – 50 member
    - Intermission: because of the routine system e
  - 4th exp: Dec 2006 – 50 member, no-local-pa
    - Miyoshi developed AFES version in Sep., an
  - 5th exp: Jan 2006 – 50 member, with tuned
  - 6th exp: Mar 2006 – 100 member

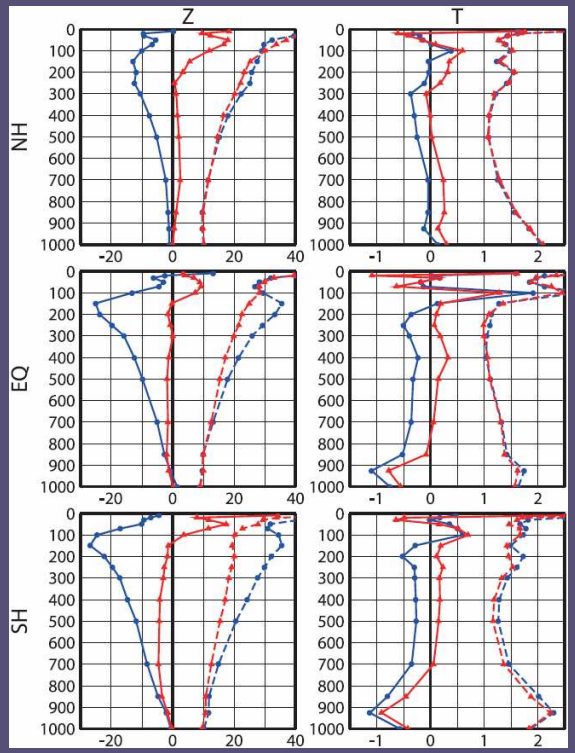


*AF

Radiance Assimilation

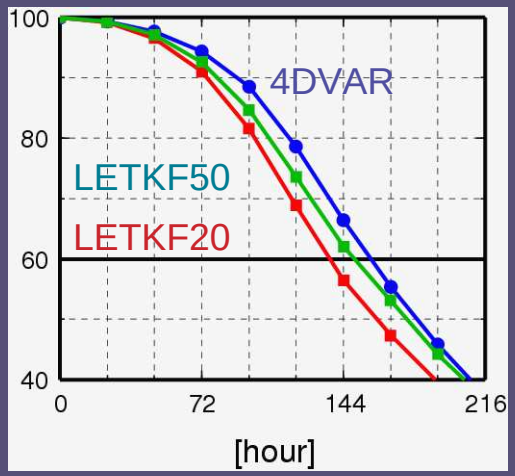
- Impact from radiance data
  - Because of the vertical localization problem, radiance data could not be assimilated with LETKF system easy.
  - à We applied weighting function shaped vertical localization.
    - It seems working well.





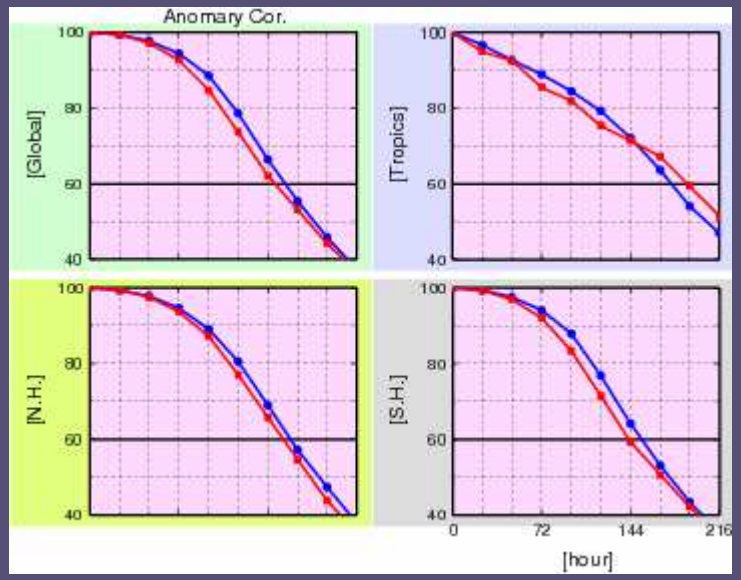
20 à 50 members

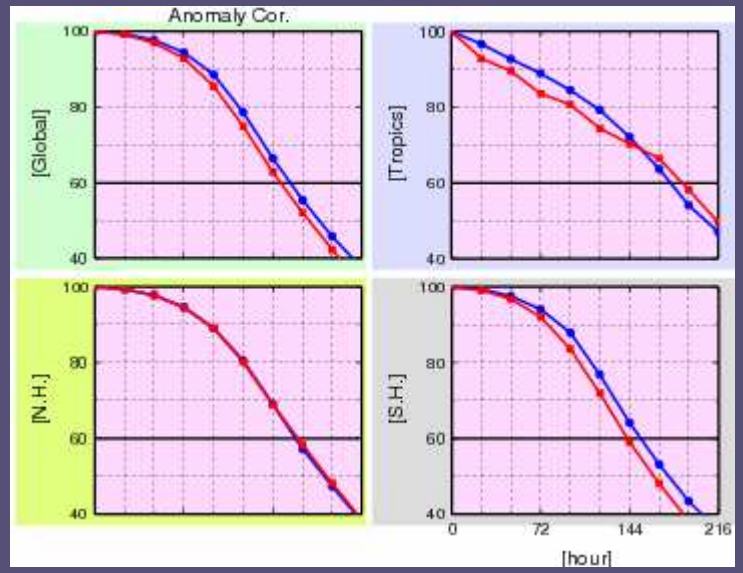
- Impact from increasing the ensemble size
  - We tried 20 member LETKF first, but 20 seemed too small to compare with 4D-Var.
  - à We performed 50 member LETKF.
    - It showed the better result as expected by the theory.
      - I had doubted it before trying it.



Parameter sensitivity

- We did not tried the parameter tuning in the previous test.
- We change the inflation and localization parameters.
  - It showed the better result in the northern hemisphere.
  - It showed very impressive result in the typhoon track forecast
  - some system stability problems.

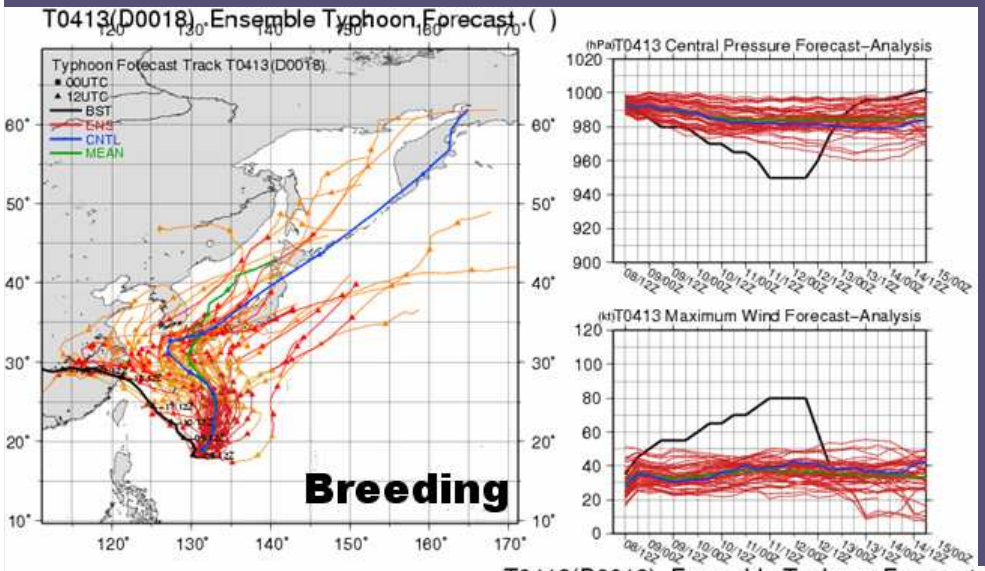




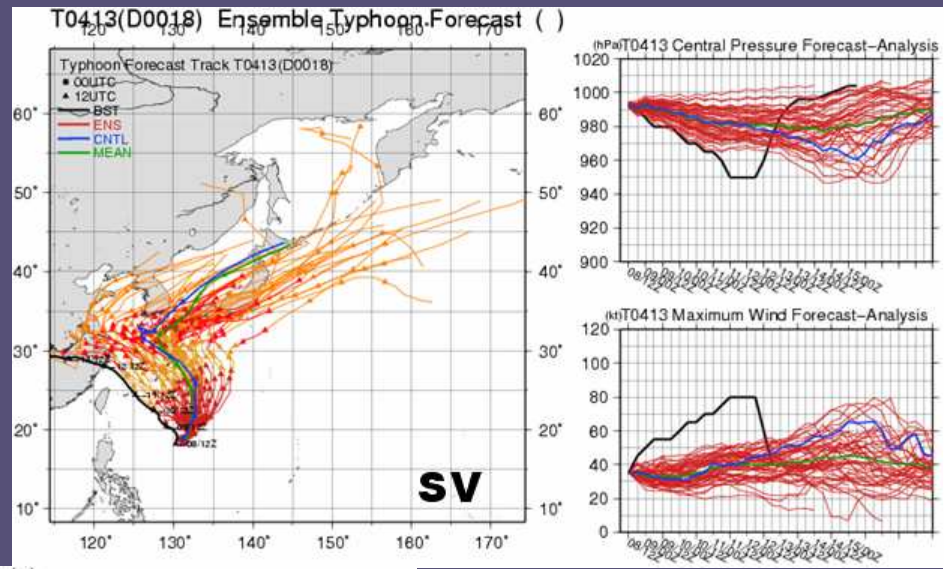
Compared with the latest 4DVAR

Best Case for typhoon track forecast

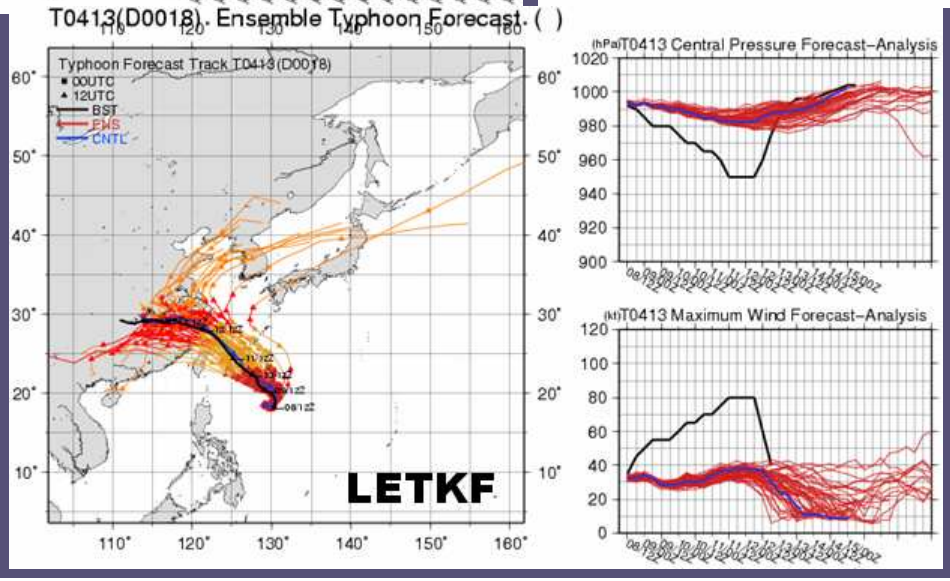
T0413 (RANANIM)



Op. 4D-Var with
Breeding method



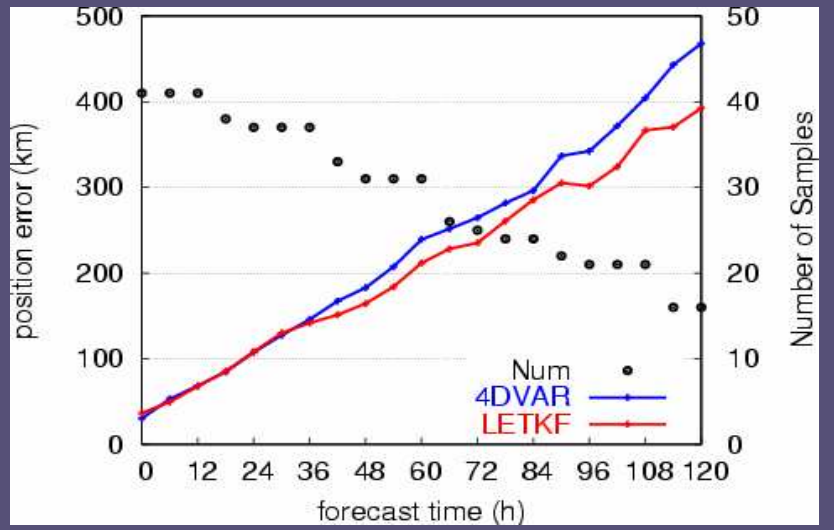
Next. 4D-Var with
Singular Vector method



Ongoing work

- The stability problems came up with the larger inflation.
  - We found large inflation greatly contributes better performance
  - Additive inflation indicates stable performance as suggested by Jeff Whitaker
- Plans:
  - Ensemble prediction experiments
    - LETKF is an ideal method for EPS
  - Further improvements
    - Retuning
    - Incremental LETKF
    - Radiance Bias Correction

The JMA has the LETKF DA system, which could be compared with the JMA op. 4D-Var under the same condition.



Summary

- The JMA updates the global data assimilation system several times in FY2005–6.
  - Improvement on the Inner model resolution,
  - Introduction of Variational bias correction,
  - Introduction of microwave imager radiance, AP-RARS, GPS-RO
  - Improvement of the usage of AMSU radiance, AMV
- The JMA plans the major upgrade of the global forecast system in this Autumn.

- The JMA continues GSM-LETKF developments, comparing with GSM-4D-Var under the same conditions.

References

- WGNE Blue Book 2006
  - Narui, A.: Changing the resolution of the inner loop of global 4D-Var at JMA.
- WGNE Blue Book 2007
  - Sato, Y.: Introduction of spaceborne microwave imager radiance data into the JMA global data assimilation system.
  - Sato, Y.: Introduction of variational bias correction technique into the JMA global data assimilation system.
  - Okamoto, K.: Improvement of ATOVS radiance assimilation.
  - Yamashita, K.: Revised usage of Atmospheric Motion Vectors (AMV) from all geostationary satellites in the operational global 4D-Var assimilation system.
  - Ozawa, E.: Assimilation of space based GPS occultation data for JMA GSM.
  - Miyoshi, T.: and Y. Sato, Applying a local ensemble transform Kalman filter to the JMA global model.
- Proceedings of ITSC-XV (2006)
  - Okamoto, K. H. Owada, Y. Sato, and T. Ishibashi: Use of satellite radiances in the global assimilation system at JMA.
- SOLA (peer-reviewed article)
  - Miyoshi, T and Y. Sato, 2007: Assimilating Satellite Radiances with a Local Ensemble Transform Kalman Filter (LETKF) Applied to the JMA Global Model (GSM). *SOLA*, **3**, 37-40.

Thanks for your attention