Center Report
- JMA 2014 -

Chiashi Muroi and colleagues at JMA

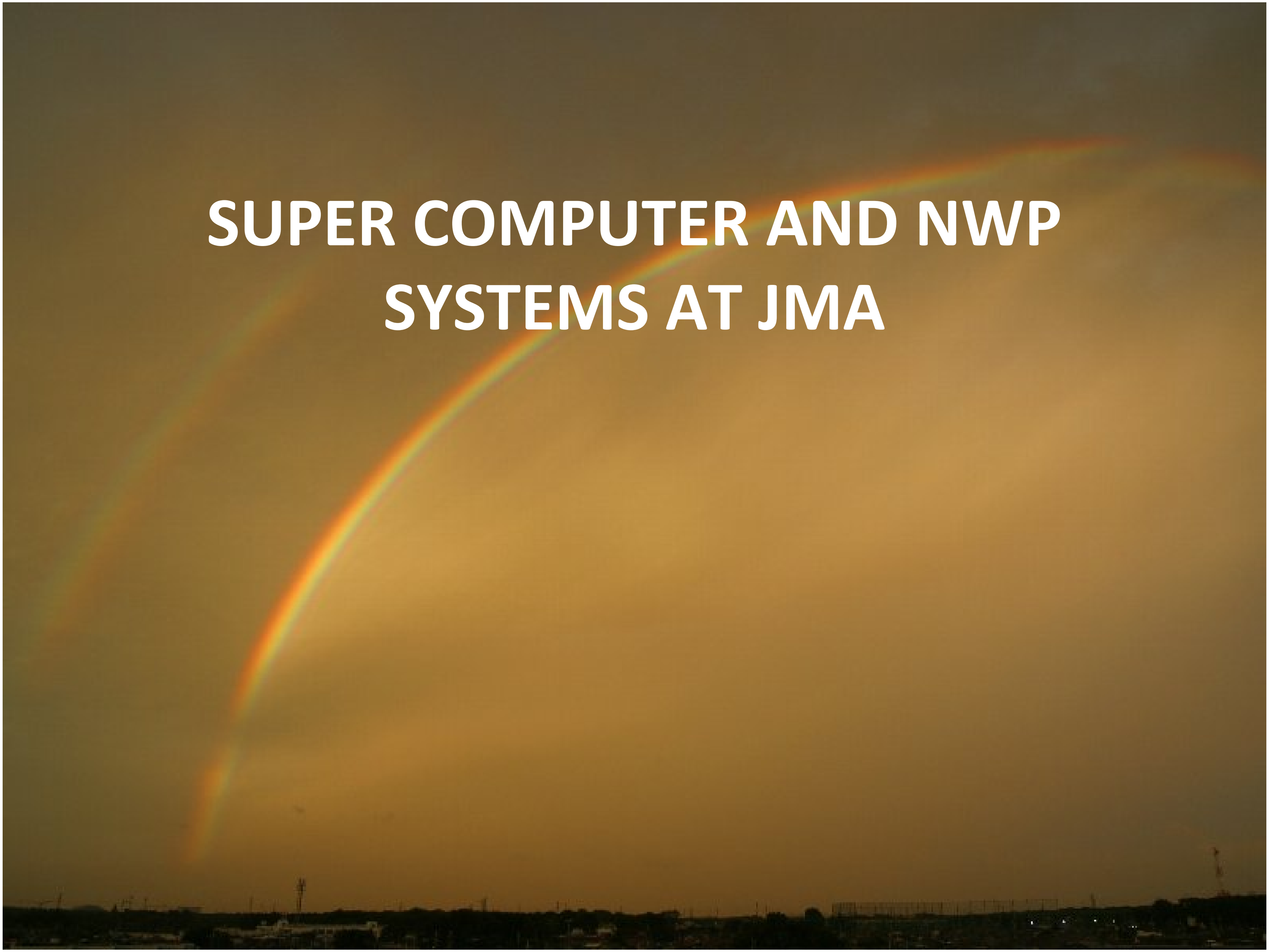
10-13 Mar. 2014, Melbourne

WGNE-29

気象庁 Japan Meteorological Agency

JMA

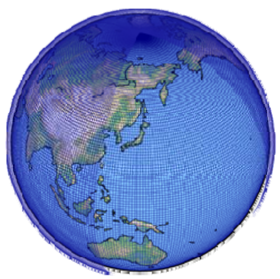
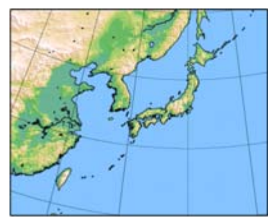
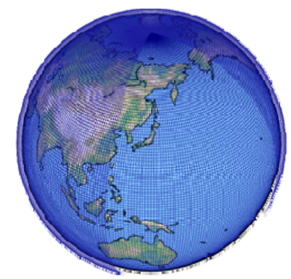
SUPER COMPUTER AND NWP SYSTEMS AT JMA



Super Computing System

	New
Machine	Hitachi SR16000/M1
CPU	Power 7 (3.83GHz, 8core)
CPU/NODE	4 processors (total 32cores)
NODE	864 (432x2)
Peak Performance	847 (423.5x2) T Flops
Main Memory	108 T Byte
operation was started on	5 June 2012 -

Current NWP models of NPD/JMA

	Global Spectral Model **GSM**	Meso-Scale Model **MSM**	Local Forecast Model **LFM**	One-week Ensemble **WEPS**	Typhoon Ensemble **TEPS**
Objectives	Short- and Medium-range forecast	Disaster reduction Aviation forecast	Aviation forecast Disaster reduction	One-week forecast	Typhoon forecast
Forecast domain	Global 	Japan and its surroundings (4080km x 3300km) 	Japan and its surroundings (3160km x 2600km) 	Global 	
Horizontal resolution	TL959(0.1875 deg)	5km	2km	New! TL479(0.375 deg)	
Vertical levels / Top	60 → 100 0.1 → 0.01 hPa Coming soon!	50 21.8km	60 20.2km	60 0.1 hPa	
Forecast Hours (Initial time)	84 hours (00, 06, 18 UTC) 264 hours (12 UTC)	39 hours (00, 03, 06, 09, 12, 15, 18, 21 UTC)	9 hours (00-23 UTC hourly)	264 hours (00, 12 UTC) 27 members	132 hours (00, 06, 12, 18 UTC) 25 members
Initial Condition	Global Analysis (4D-Var)	Meso-scale Analysis (4D-Var)	Local Analysis (3D-Var)	Global Analysis with ensemble perturbations (SV)	

Data assimilation systems of NPD/JMA

	Global Analysis (GA)	Meso-scale Analysis (MA)	Local Analysis (LA)
Analysis scheme	4D-Var		3D-Var
Analysis time	00, 06, 12, 18 UTC	00, 03, 06, 09, 12, 15, 18, 21 UTC	hourly
Data cut-off time	2 hours 20 minutes [Early Analysis] 11 hours 50 minutes (00, 12 UTC) 7 hours 50 minutes (06, 18 UTC) [Cycle Analysis]	50 minutes	30 minutes
Horizontal resolution (inner-model resolution)	TL959 / 0.1875 deg (TL319 / 0.5625 deg)	5 km (15 km)	5km
Vertical levels	60 levels up to 0.1 hPa → 100 levels up to 0.01 hPa	50 levels up to 21.8km	50 levels up to 21.8km
Assimilation window	-3 hours to +3 hours of analysis time	-3 hours to analysis time	-

Coming soon!

Specifications of seasonal EPSs

	1-month EPS	4/7-month EPS
Model	AGCM	CGCM
Resolution	Horizontal: approx. 55 km (TL319) Vertical: 60 levels (~0.1 hPa)	* Atmospheric component Horizontal: approx. 180 km (TL95) Vertical: 40 levels (~0.4hPa) * Oceanic component Horizontal: 1.0º longitude, 0.3–1.0º latitude (75°S – 75°N) Vertical: 50 levels
Forecast range	Up to 34 days	7-months (for summer/winter forecast) 4 months (other initial month)
SST	Persisted anomaly	Prognostic variable of CGCM
Sea ice	Climatology	
Ensemble method	Combination of Breeding of Growing Modes (BGM) and Lagged Average Forecast (LAF)	
Ensemble size	50 (25 BGMs & 2 days with 1-day LAF)	51 (9 BGMs & 6 days with 5-day LAF)
Frequency of operation	Every Tuesday and Wednesday	Every 5 days
Frequency of model product creation	Once a week Every Thursday	Once a month Around the 20th (no later than the 22nd) of every month

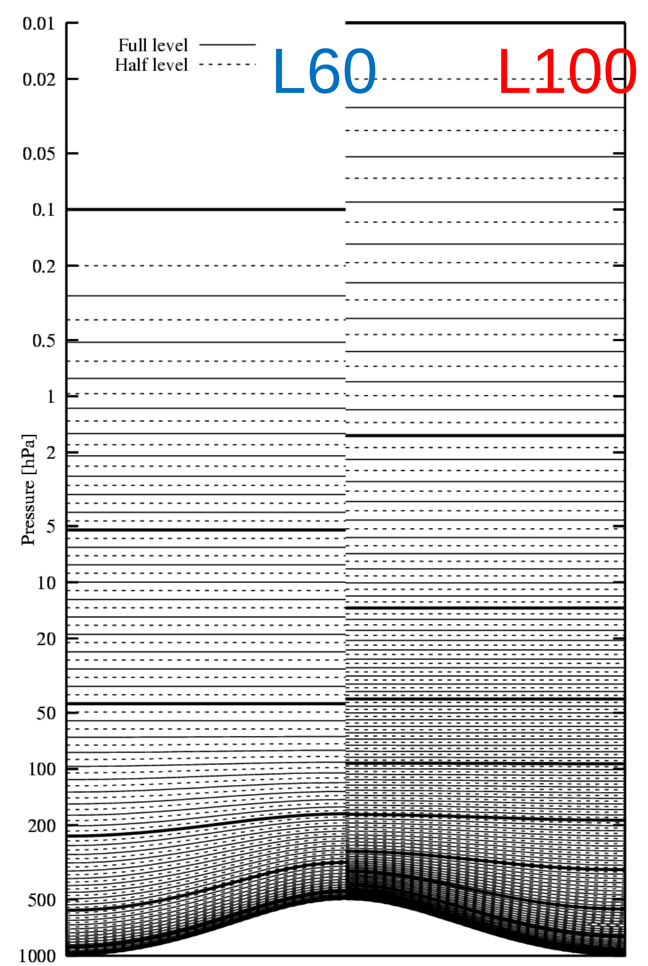

RECENT CHANGES AND
DEVELOPMENT

Development
– physics and dynamics-

- Recent changes
  - 28 Mar 2013: 11 days forecast (← 9 days) for both deterministic and ensemble system.
  - 25 Apr. 2013: Revise radiation scheme
    - Update aerosol optical depth climatology
    - Revise shortwave absorption by water vapor in radiation scheme （Collins et al. 2006）
  - ***17? Mar. 2014:***
    - ***Increasing the number of vertical levels (top:0.1→0.01 hPa)***
    - ***Revise physical processes***

Enhancement of GSM (Mar 2014)

- The number of vertical levels in GSM will be enhanced from 60 to 100
- the top level of the model will be raised from 0.1 hPa to 0.01 hPa.
- Time Step: 600s → 400s

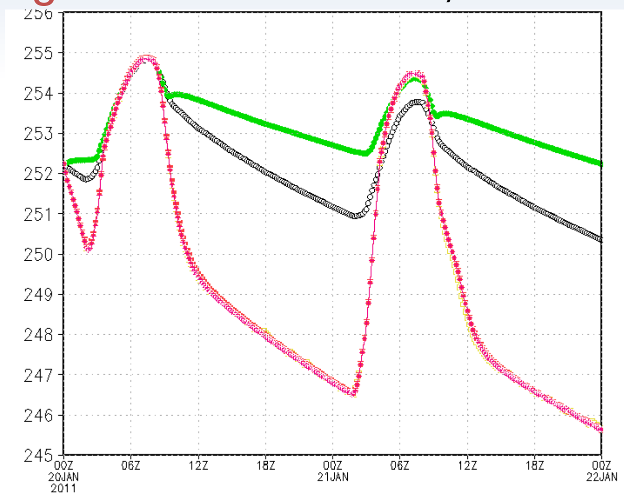


Update of physical processes

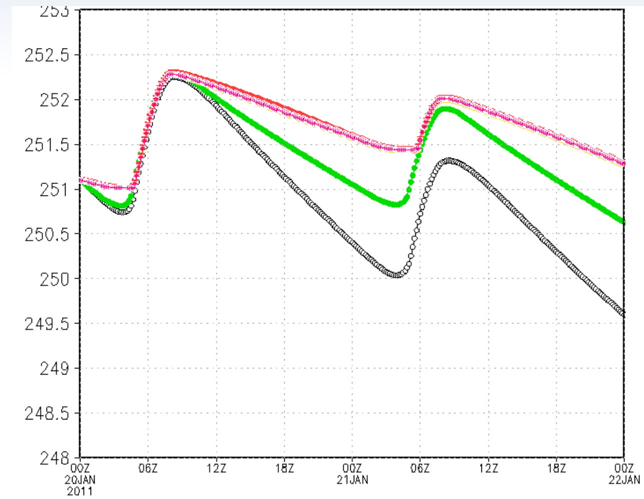
1. Revising a stable boundary layer scheme
   →Improving wind fields and diurnal temperature variation in stable conditions
2. Revising albedo parameters in the desert areas
   →Reducing clear sky radiation biases
3. Introducing two-stream approximation for long wave radiation scheme
   →Accelerating radiation code and improving the middle atmosphere temperature structure
4. Introducing a non-orographic gravity wave forcing scheme
   →Improving the middle atmosphere climate and representation of long-term oscillation in the tropical lower stratosphere such as QBO
5. Changing the application criteria of energy correction terms in convective parameterization
   →Improving general circulation and global precipitation distribution
6. Applying 2nd-order linear horizontal diffusion in the divergence equation and adjusting 4th-order linear diffusion as a sponge layer around the model top region
   →Improving the middle atmosphere forecast accuracy

1. Revised surface and PBL scheme in stable

Black: Old version,
Magenta: New version, Green: Old PBL Scheme + new surface scheme



T [K] in lowest model layer (∼10m).



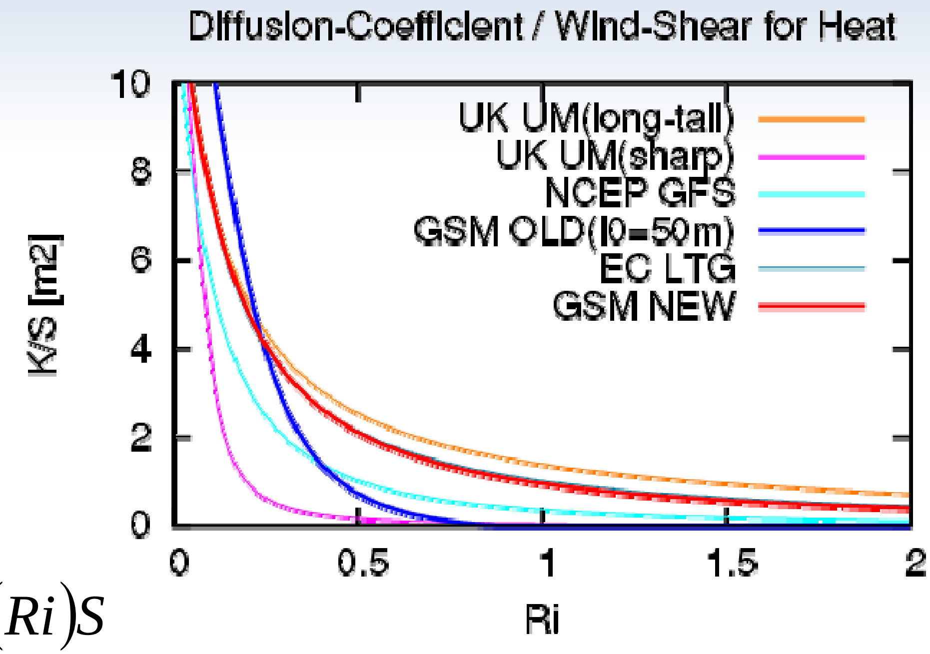
T [K] at 6th model layer(∼200m)

SCM(Physics only, no forcing)
lon 99.28° , lat 54.82°
2011/01/20 00UTC inital

The vertical diffusive coefficients in stable boundary layer and surface exchange coefficients were revised.

GSM had been introduced a lower limit of diffusion coefficient to avoid "air-land split-off" in strongly stable cases. But the too large limit value (2 m2/s) make a high temperature bias and a poorly nocturnal low level jet around high latitudes.

Local Diffusion Coefficients Comparison



$$K_{local} = \lambda^2 f(Ri)S$$

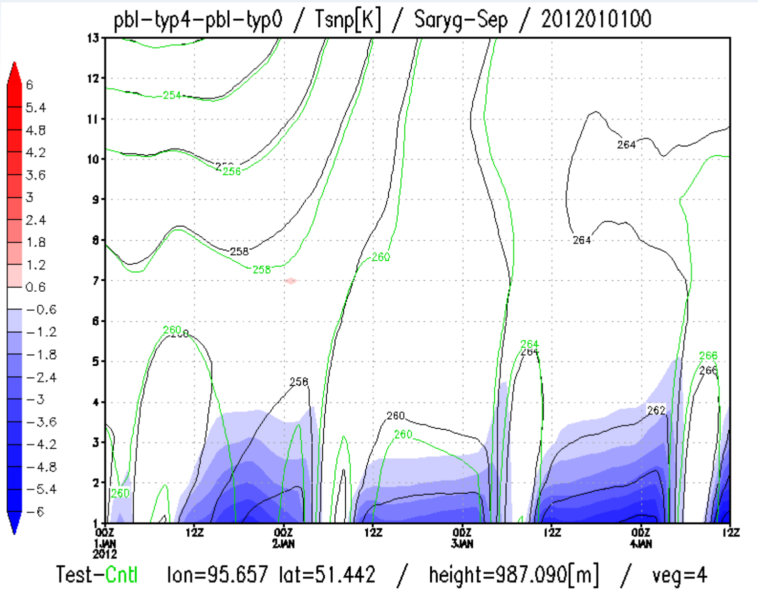
(S: wind shear)

$$f_H(Ri) = \frac{1}{(1+5Ri)^{1.5}}, \quad f_M(Ri) = \frac{1+2.1Ri}{(1+5Ri)^{1.5}}, \quad \frac{1}{\lambda} = \frac{1}{kz} + \frac{1}{\lambda_0}, (\lambda_0 = 50m)$$

We stop using the lower limit and introduce a local closer K scheme in stable state. Surface exchange coefficients (Beljaars and Holtslag, 1991) based on the Monin-Obukhov similarity theory were introduced on bulk exchange formulations instead of Louis scheme (Louis, 1982).

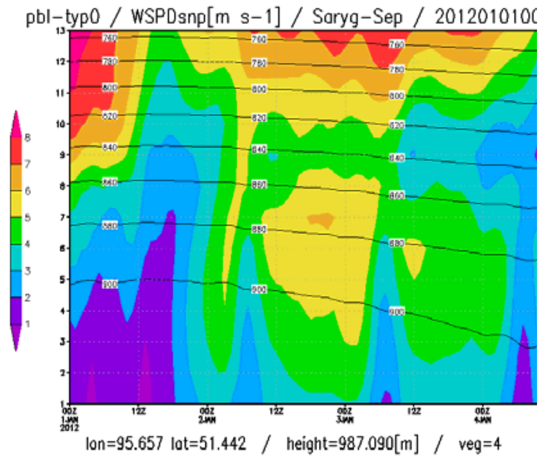
Improvement of Diurnal Cycles

T [K]　NEW—OLD

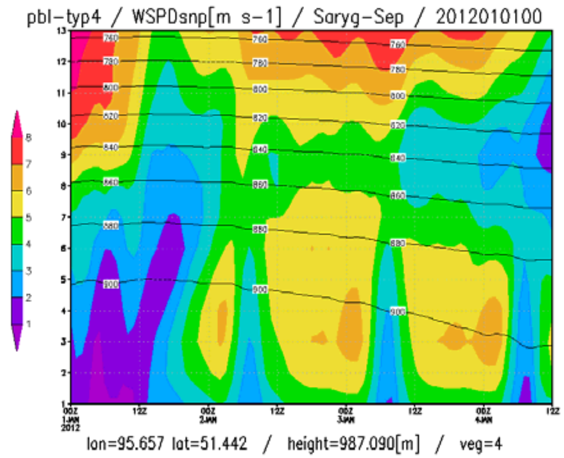


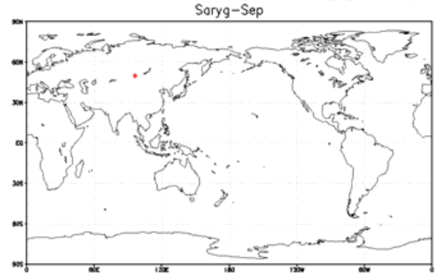
Wind Speed [m/s]

OLD



NEW





2011/01/01 00UTC init
3.5day forecast
Tl959L60
Lon=95.657, Lat=51.442

- Land surface cools well at night.
  - ➔ reduced the high temperature bias.
- Sharp representation of nocturnal low level jet.
  - ➔ improved the RMSE of winds.

2. Revising albedo parameters in the desert areas

- （previous） R_0 is constant

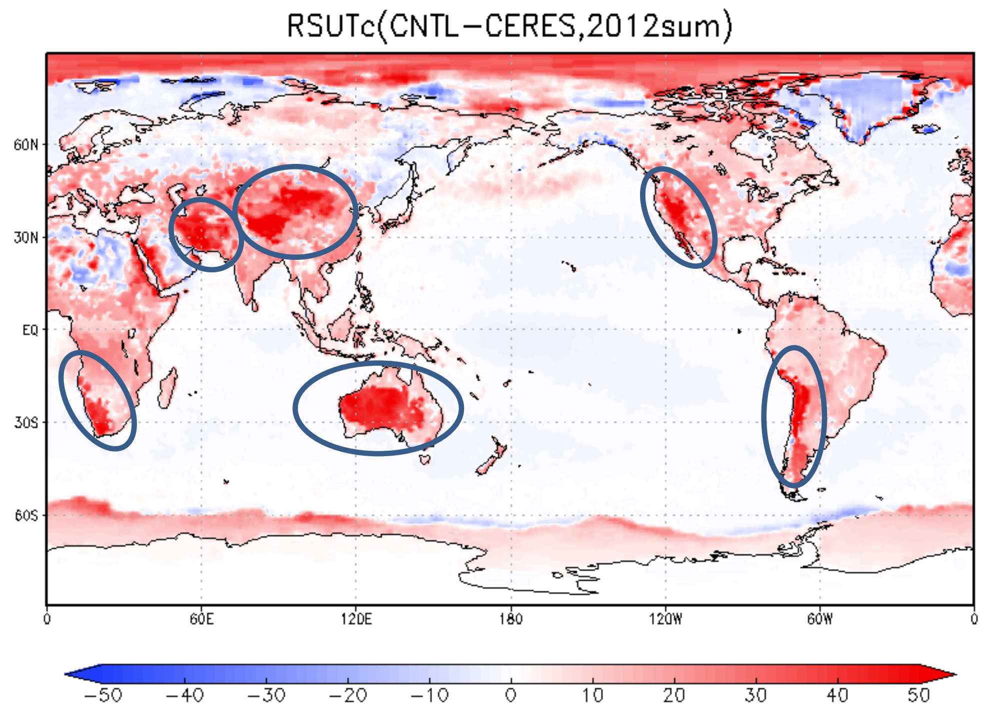
$$\alpha = R_0 \frac{1+d}{1+2d\cos\theta}$$

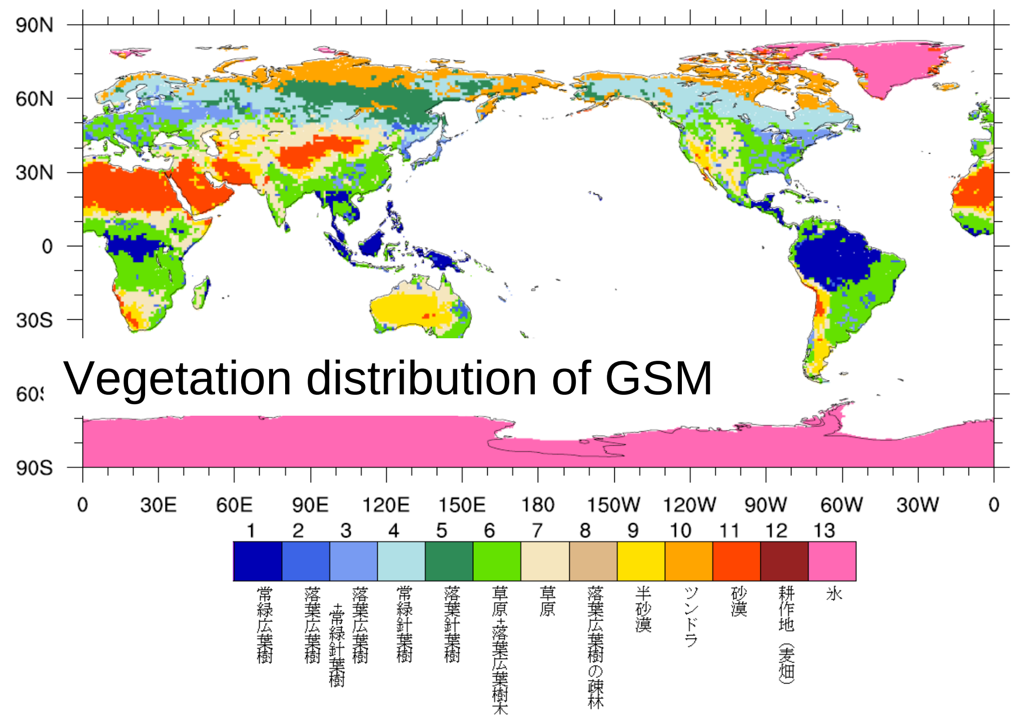
R_0：albedo at angle of solar zenithal 60 degree
θ： angle of solar zenithal
d：parameter（0.4 is set on desert）

- (new) 2-dim albedo climatology distribution based on MODIS observation is used on desert region

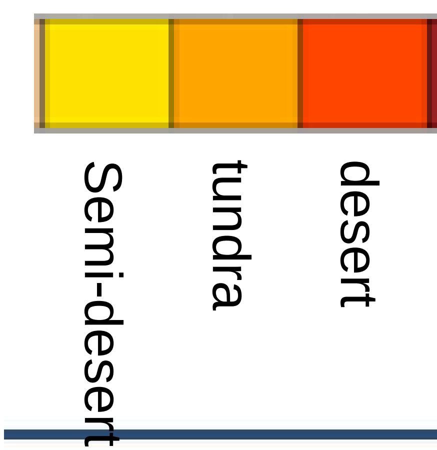
Bias of upward clear-sky shortwave radiation flux at top
(against CERES climatology, JJA 2012, FT-6)

•Positive bias on desert can been seen





Vegetation distribution of GSM



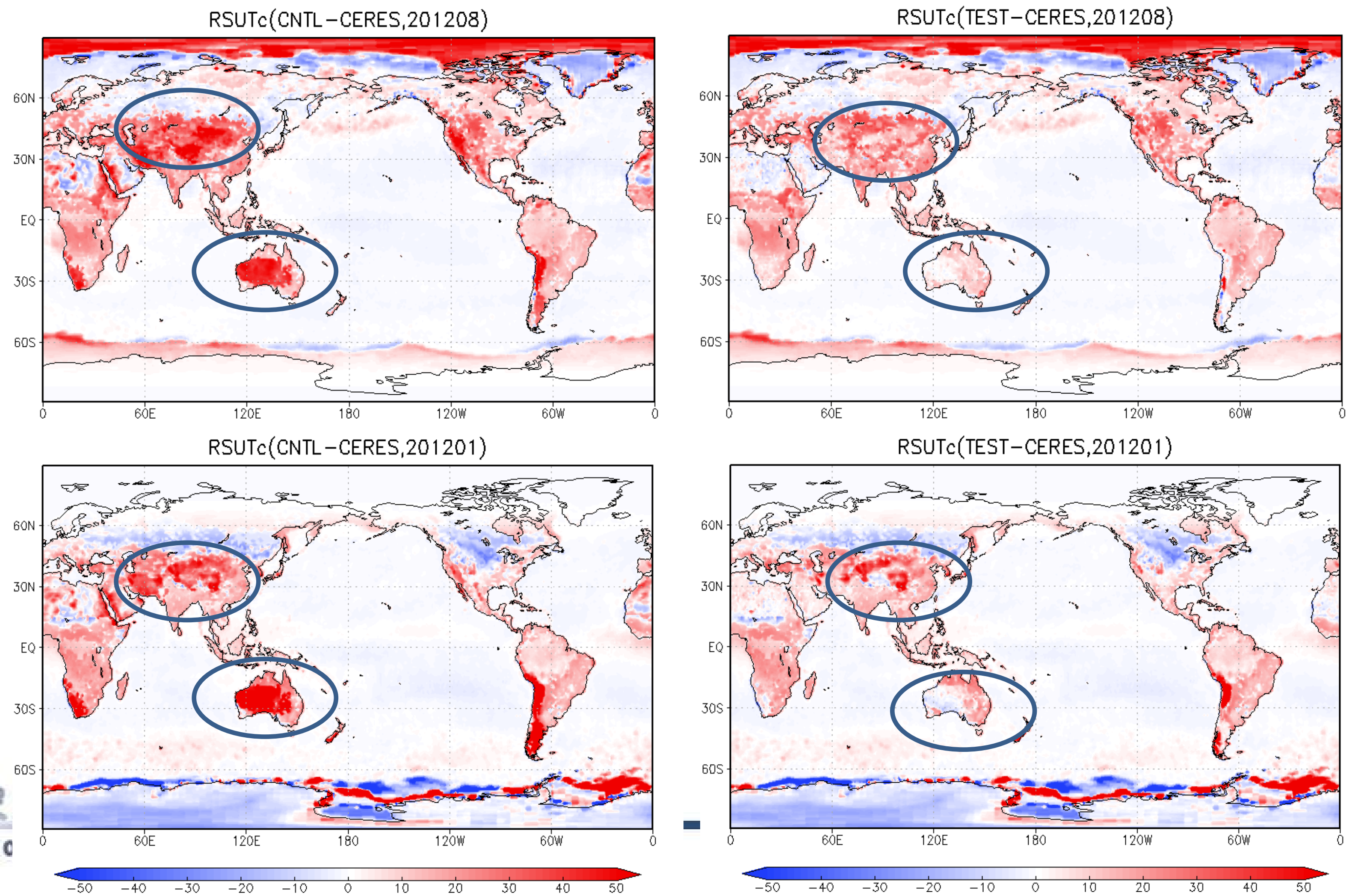
Reducing clear sky radiation biases

Bias of upward clear-sky shortwave radiation flux at top against CERES

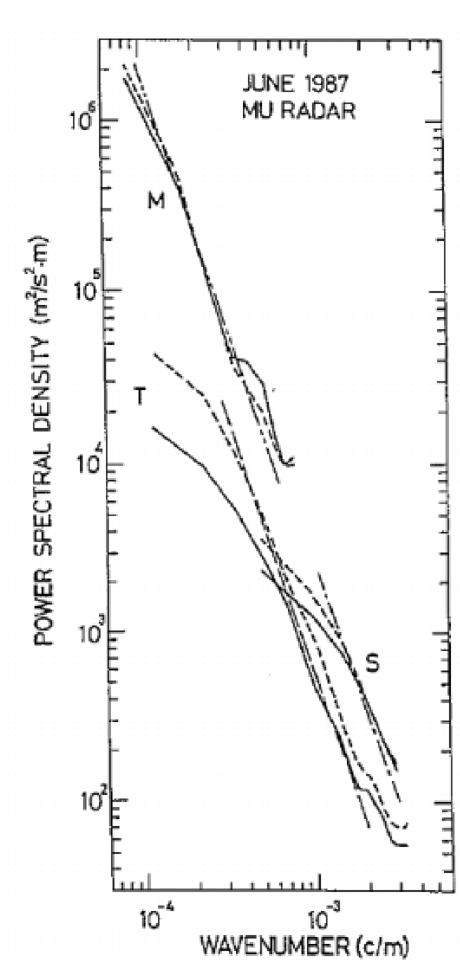
CNTL - CERES | TEST - CERES

JJA

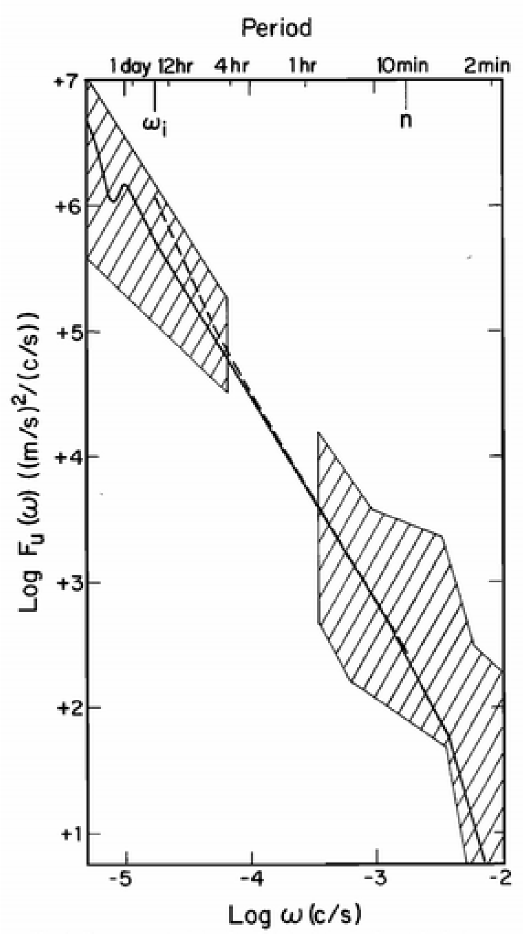
DJF



4. Scinocca(2003) non-orographic gravity wave forcing scheme



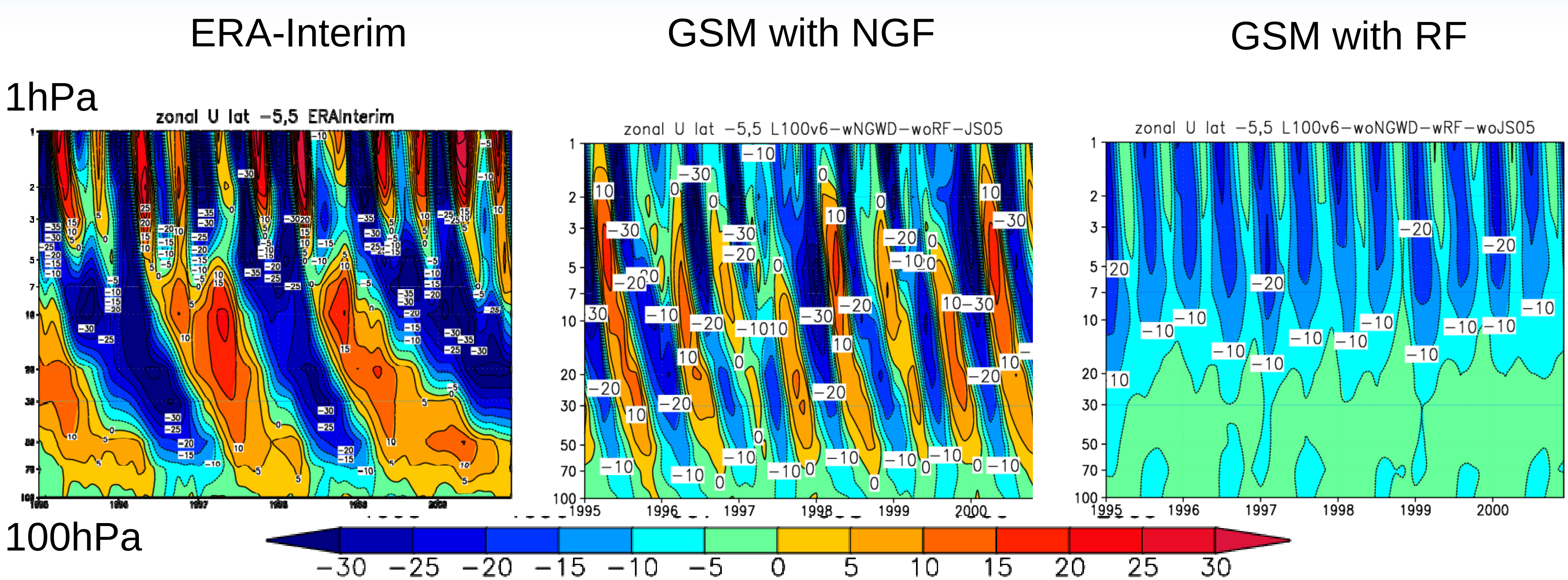
Power spectral density;
Solid: U; Dashed: V;
Straight lines: theoretical
(proportional to m^{-3}; smith1987)
Tsuda el al. (1989)



Power Spectrum of Horizontal Wind;
Solid line: Obs. ; Dashed line: Model
VanZandt. (1982)

- Scheme was developed based on observed power spectral
  - Tsuda et al. (1989)
  - VanZandt (1982)

zonally averaged zonal wind averaged over 5S-5N

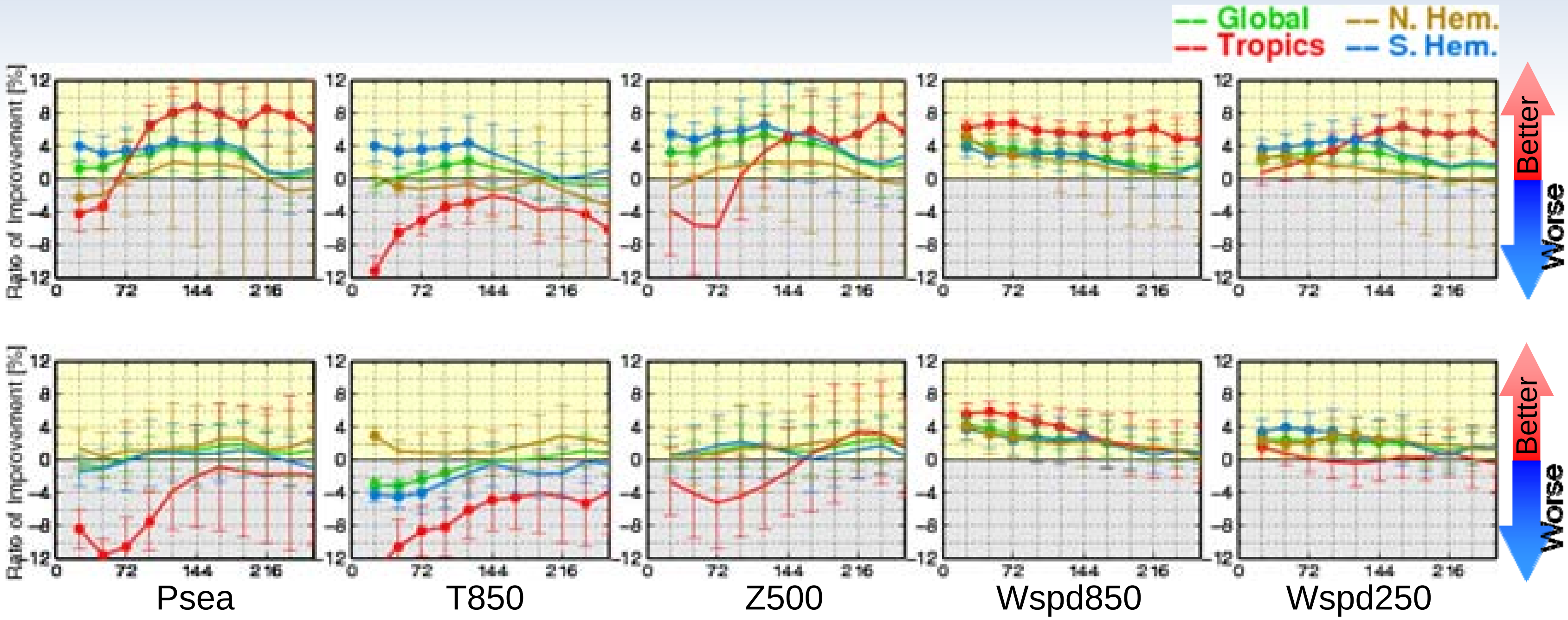


- A six-year integration using low horizontal resolution version (TL159L100) shows upgraded GSM successfully reproduces QBO-like periodic zonal wind oscillation in the tropical

Total Performance
(improvement rate of RMSE against analysis)

Summer (Jun-Sep 2013)

Winter (Dec 2012 -Feb 2013)

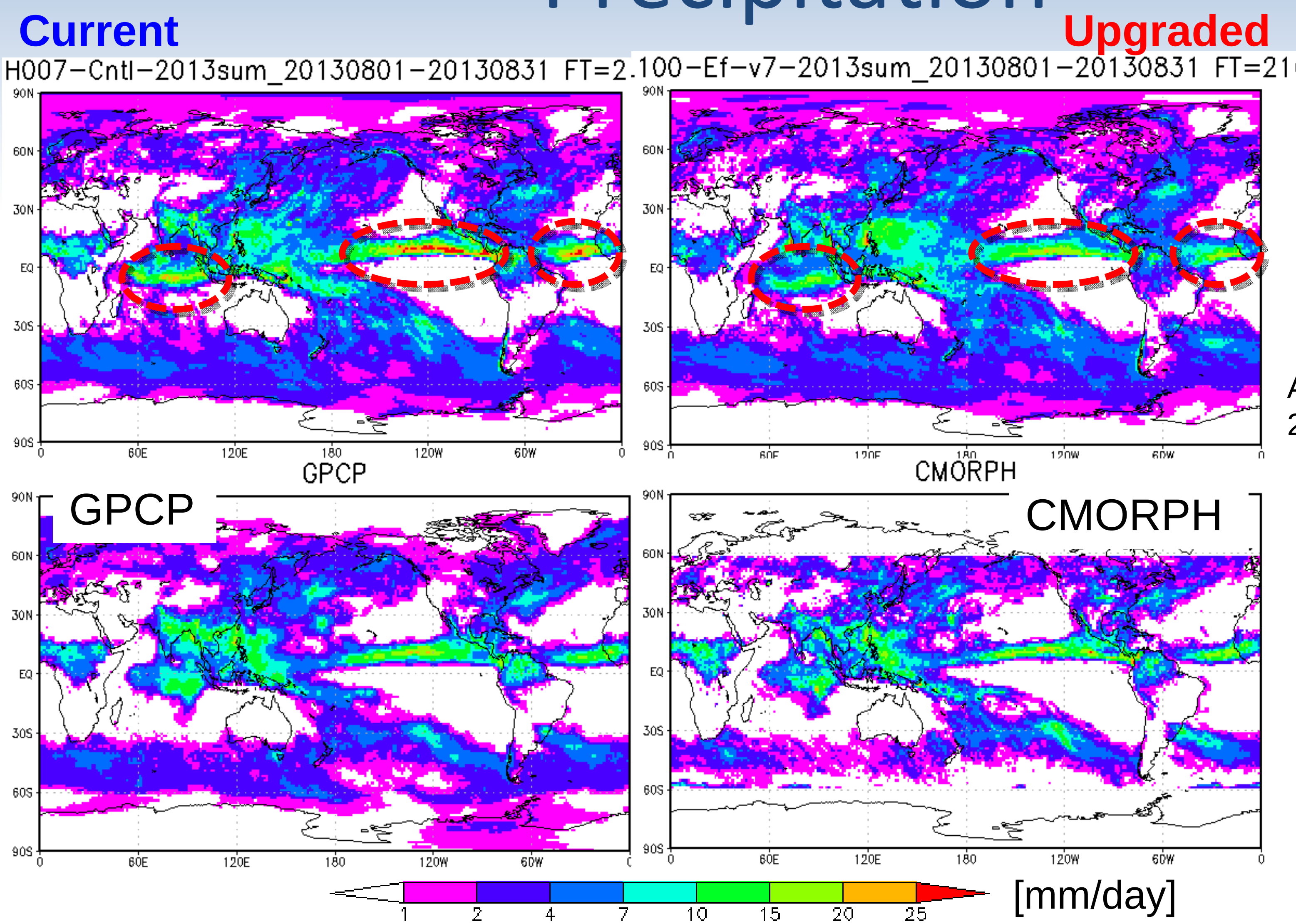


Improvement rate of root mean square errors (RMSEs) against analysis between upgraded GSM and current GSM for Jun-Sep 2013 (top) and Dec 2012-Feb 2013 (bottom). Lines over yellow (gray) background area mean upgraded GSM shows better (worse) scores than current GSM.

The results of experiments show that the upgrade will have a positive impact on forecast scores mainly in the extra-tropics.

Negative impacts are seen for Psea and Z500 in the early forecast hours and for T850 in the tropics.

Precipitation



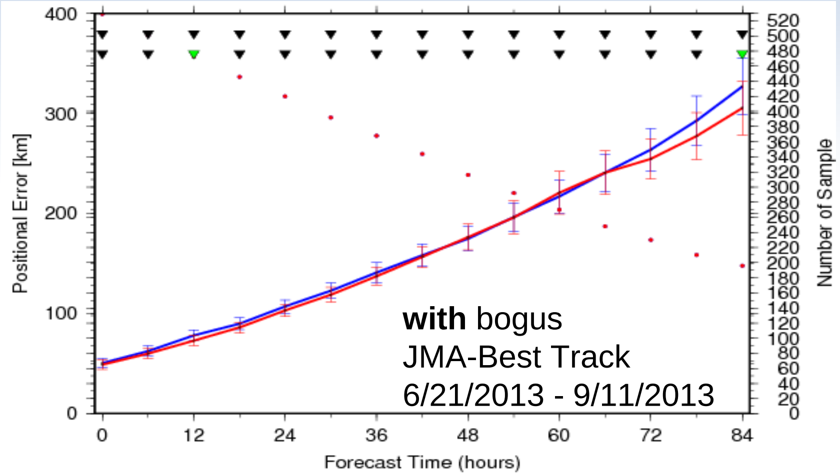
Aug 2013, FT=216
24-hour precipitation

Excessive precipitation over the ITCZ, Indian Ocean and Atlantic Ocean is reduced.

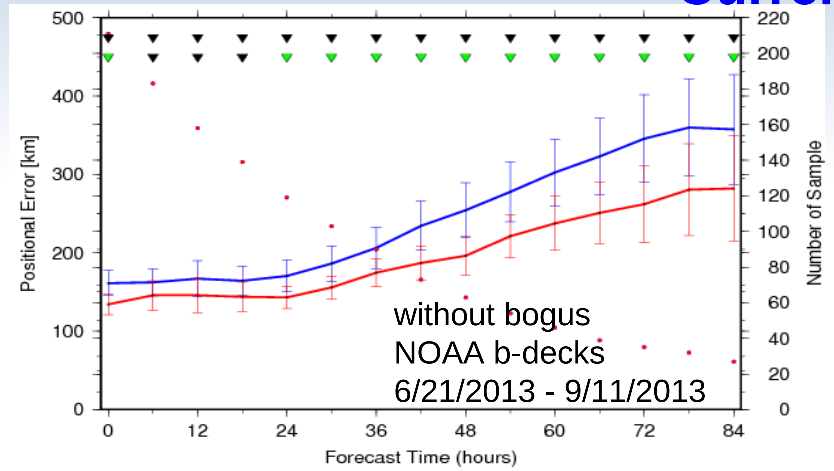
Tropical cyclone track forecast errors

Upgraded
Current

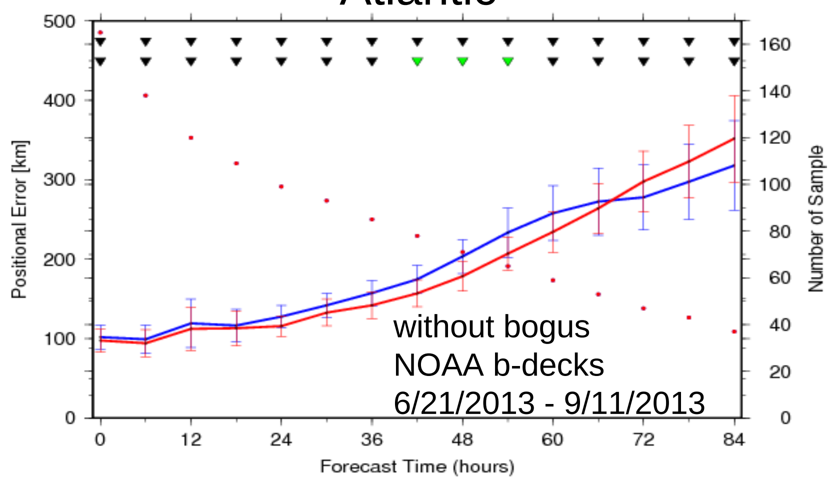
North-Western Pacific



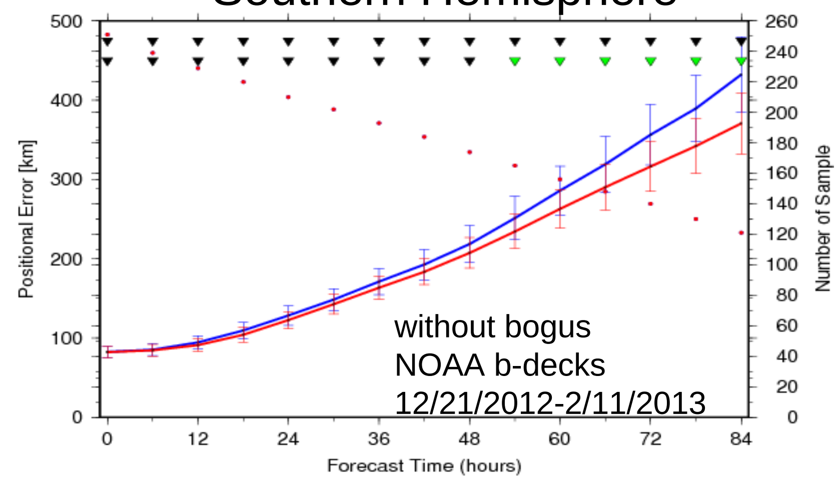
North-Eastern Pacific



Atlantic

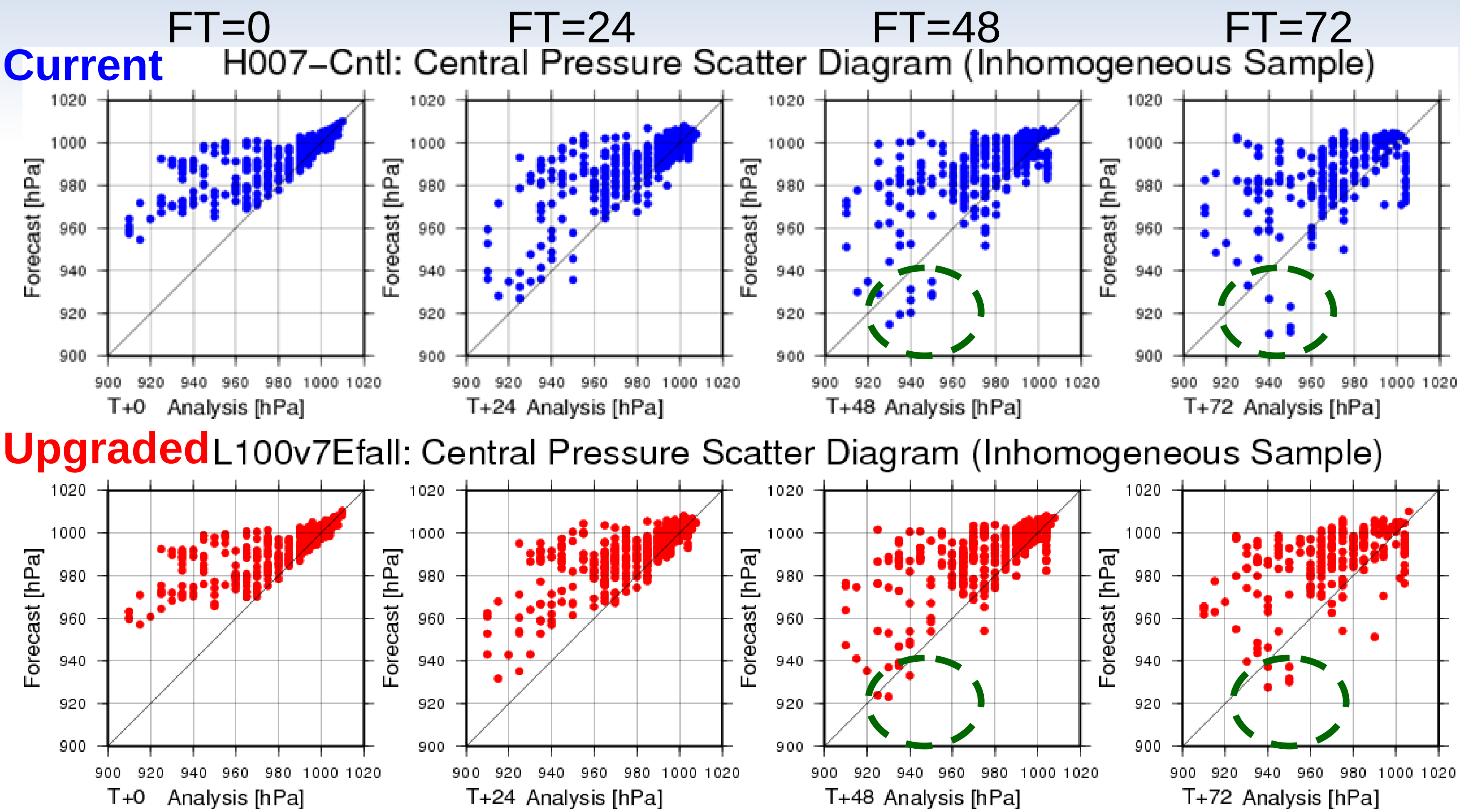


Southern Hemisphere



The upgrade reduces TC track forecast errors in all four regions.

Tropical cyclone intensity errors



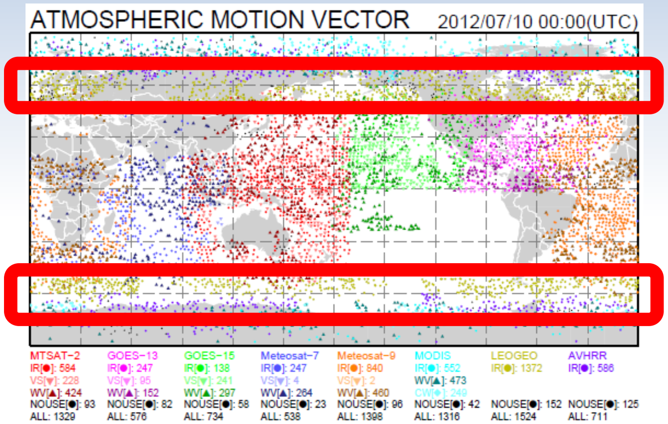
The upgrade reduces excessive development of TC.

Development – assimilation, data-

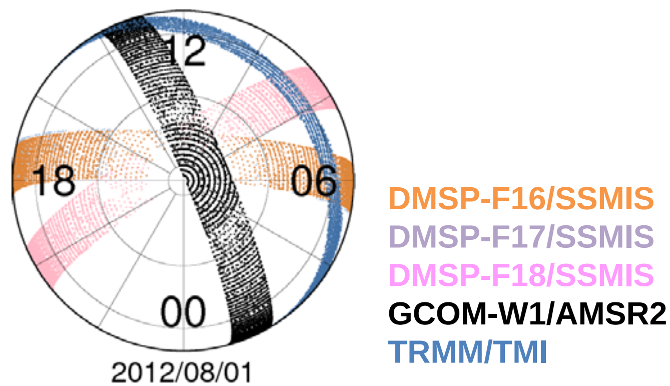
- Recent changes
  - 15 Nov. 2012: RTM upgrades (RTTOVv9.3→v10)
  - 18 Dec. 2012: GNSS-RO observation operator upgrades
  - ***02 Jul. 2013: AVHRR, LEOGEO AMV***
  - ***12 Sep. 2013: Assimilation of JAXA's GCOM-W1/AMSR2 radiance data started***
  - 16 Oct. 2013: Assimilation of SYNOP BUFR started
  - ***28 Nov 2013: Assimilation of GRAS, AMSU-A, MHS, ASCAT and AVHRR-AMV data from Metop-B started.***
  - 17? Mar. 2014:
    - Assimilating AMSU-A channel 14
    - Assimilating GNSS-RO bending angle data at the altitude up to 60km (currently, refractivity data up to 30 km)
    - Assimilating ground-based GNSS-ZTD (Zenith Total Delay) data

Recent improvements of Global data assimilation system

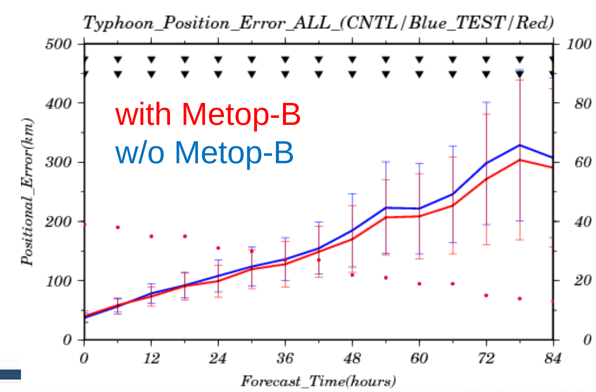
- Enhancement of utilized atmospheric motion vectors (AMVs) (July 2013)
  - AMV data coverage. **The red rectangles** indicate areas covered by LEOGEO AMVs.



- Introduction of AMSR2 onboard GCOM-W1 (Japanese name: Shizuku) (Sep. 2013)
  - MW imager data coverage.GCOM-W1/AMSR2 data fill the gaps. Note: DMSP-F16 and F17 had almost the same coverage as of summer 2012.



- Introduction of data from Metop-B (Nov. 2013)
  - Mean TC position errors (in km) as a function of forecast time up to 84 hours in summer 2013. The red and blue lines indicate errors of forecasts with and without Metop-B data, respectively. The dots correspond to the vertical axis on the right, which represents the number of verification samples.



Japan Meteorological Agency

Development – EPS -

- Recent changes
  - 28 Mar 2013: 11 days forecast (← 9 days) for both deterministic and ensemble system.
  - ***26 Feb. 2014 : Upgrade of One-week EPS***
    - ***Increase model resolution (from TL319L60 to TL479L60)***
  - ***Mar. 2014: Upgrade of Typhoon EPS***
    - ***Increase model resolution (from TL319L60 to TL479L60)***
    - ***Increase ensemble members (from 11 to 25)***
- Under development
  - 2014: Start test operation of Meso-scale regional EPS

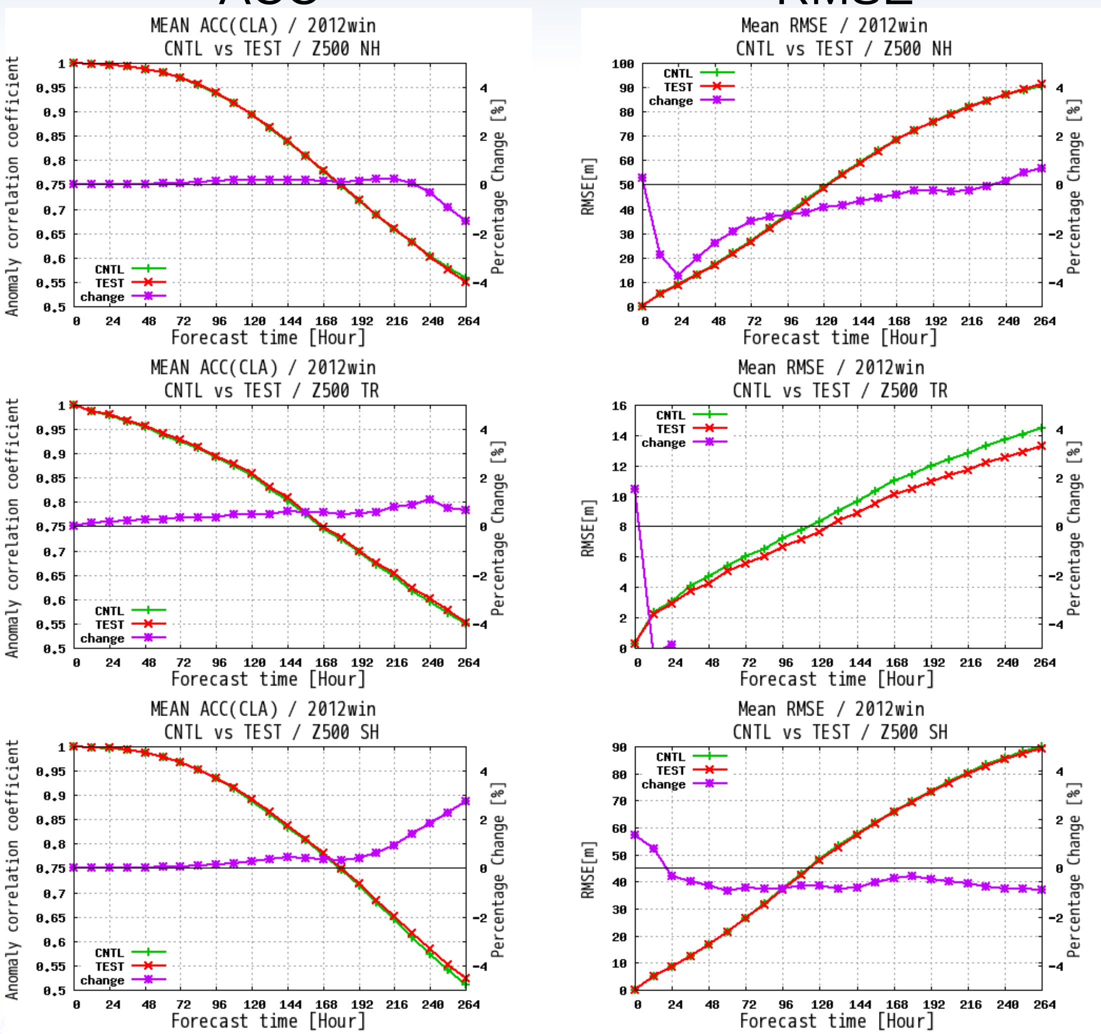
Upgrade of global EPSs (Feb and Mar 2014)

		One-week EPS	Typhoon EPS
Objectives		One-week Forecasts	TC Information
EPS model and its integration	Model type	GSM (an atmospheric general circulation model)	
	Horizontal resolution	TL319 (~55km) → **TL479 (~40km)**	
	Vertical levels	60 levels, up to 0.1 hPa	
	Forecast range	264 hours (12UTC) → **264 hours (00, 12UTC)**	132 hours(00,06,12,18UTC) only when Tropical Cyclones of TS/STS/TY intensity are present or are expected to appear in the RSMC Tokyo –Typhoon Centre's area of responsibility
Ensemble settings	Member (per day)	51 → **27** (51/day → **54/day**)	11 → **25** (44/day → **100/day**)
	Initial perturbation	SV method, Three target areas (NH,TR,SH)	SV method, One fixed target area (the Northwestern Pacific) and up to 3 movable target areas (vicinities of up to 3 TCs)
	Model ensemble	Stochastic physics	

Ensemble mean Z500

ACC | RMSE

NH / TR / SH



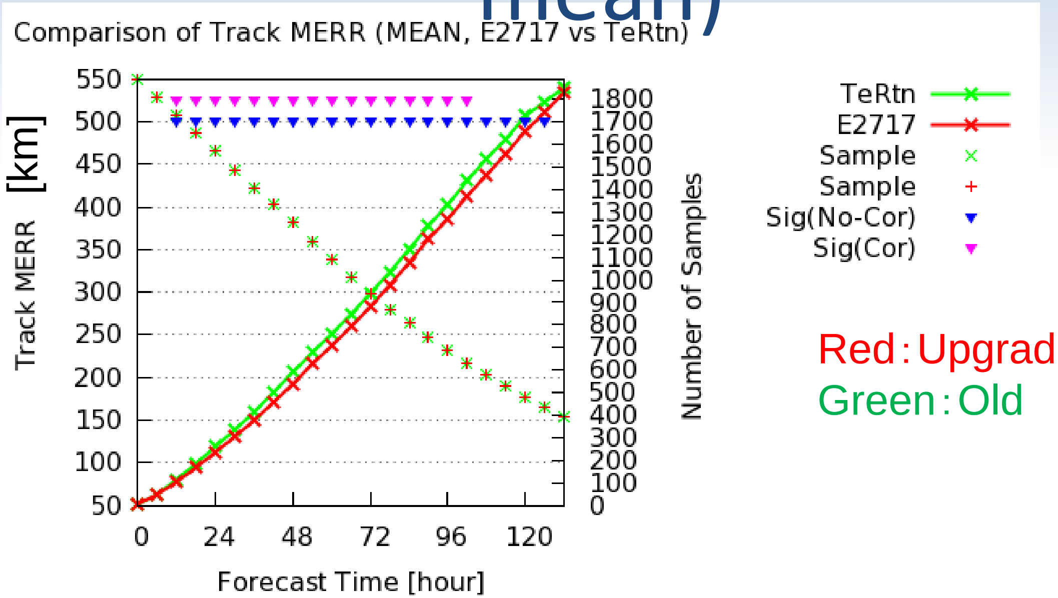
Red : TEST

Green : Control

Purple : improvement ratio

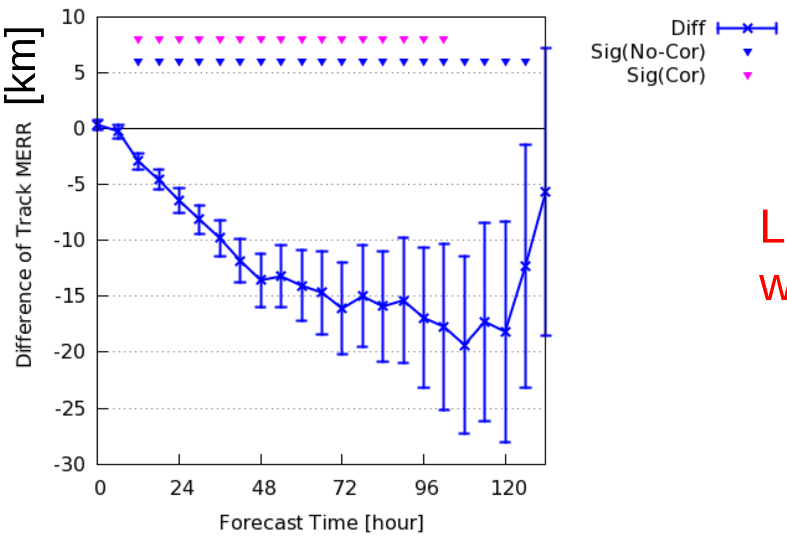
TC track forecast error (Ensemble mean)

Mean Error



Red：Upgraded
Green：Old

Mean Error Difference



Large improvement was confirmed !

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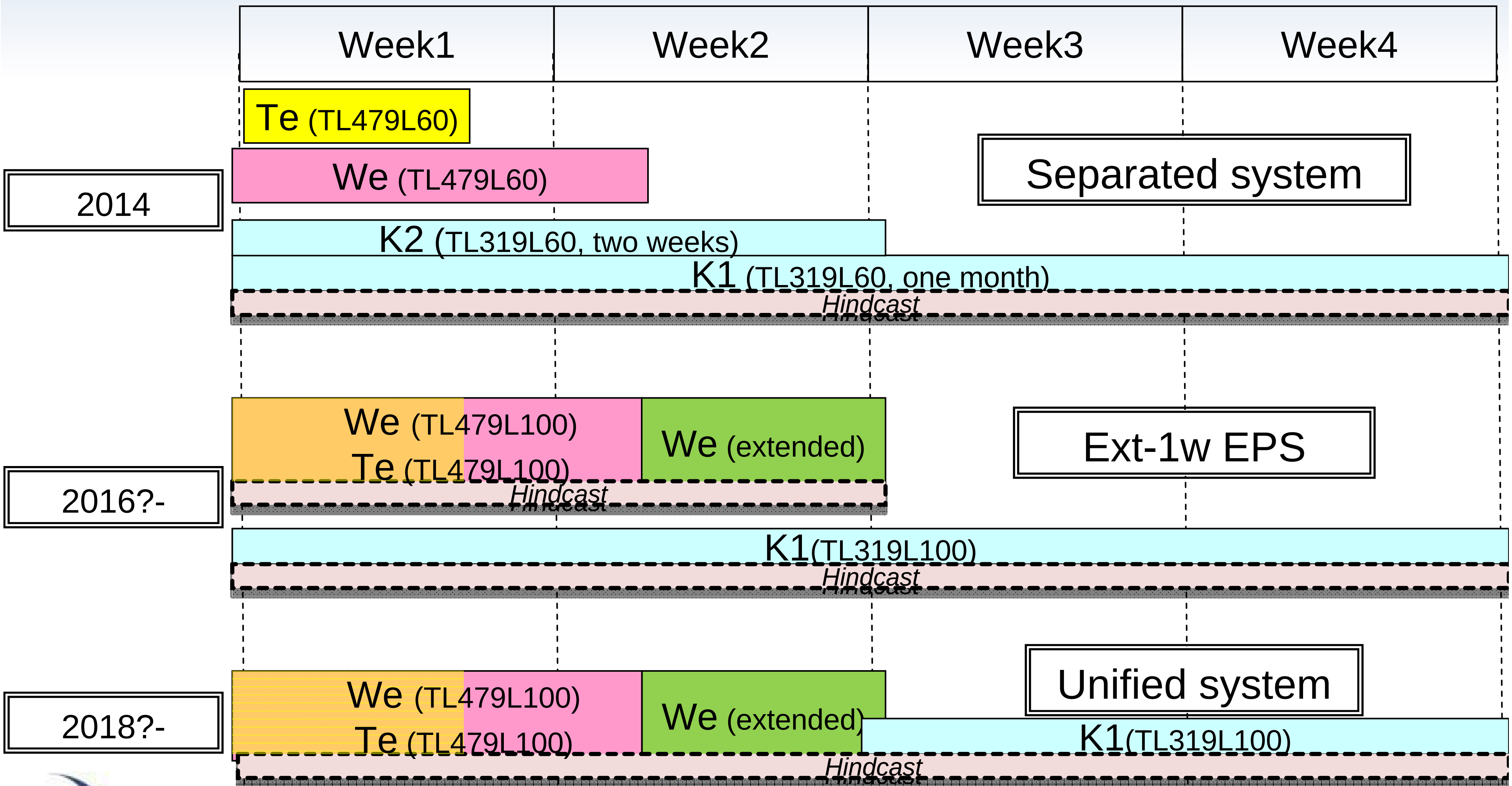
Future plan of medium range and one month ensemble prediction system



Development – regional -

- Recent changes
  - ***28 Mar. 2013:*** 5km-MSM Expand the model domain
  - ***29 May 2013:*** 5km-MSM Extend the forecast range (39 hours ←15hours/33hours)
  - ***29 May 2013:*** 2km-LFM configuration upgrade
    - Increase the operation frequency from 3-hourly to hourly
    - Expand the model domain (whole Japan region <- Eastern Japan)
- Under development
  - new dynamical core for the non-hydrostatic model "ASUCA" for 2km-LFM
  - Increase the model levels (from 50 to 75) for 5km-MSM

Specifications of LFM

	Local Forecast Model (LFM)	**Meso-Scale Model (MSM)**
Horizontal Resolution	2km (1581x1301) 	5km (817x661) 
Vertical Layers	60 Layers, up to 20.2km	50 Layers, up to 21.8km
Integration Time Step	8 second	20 second
Initial Condition	3D-Var	4D-Var
Boundary Condition	MSM	GSM
Forecast hours	9 hours	39 hours
Cloud Physics	Qc, Qr, Qi, Qs, Qg	Qc, Qr, Qi, Qs, Qg and Ni
Cumulus convective parameterization	Not Used	Kain-Fritsch scheme

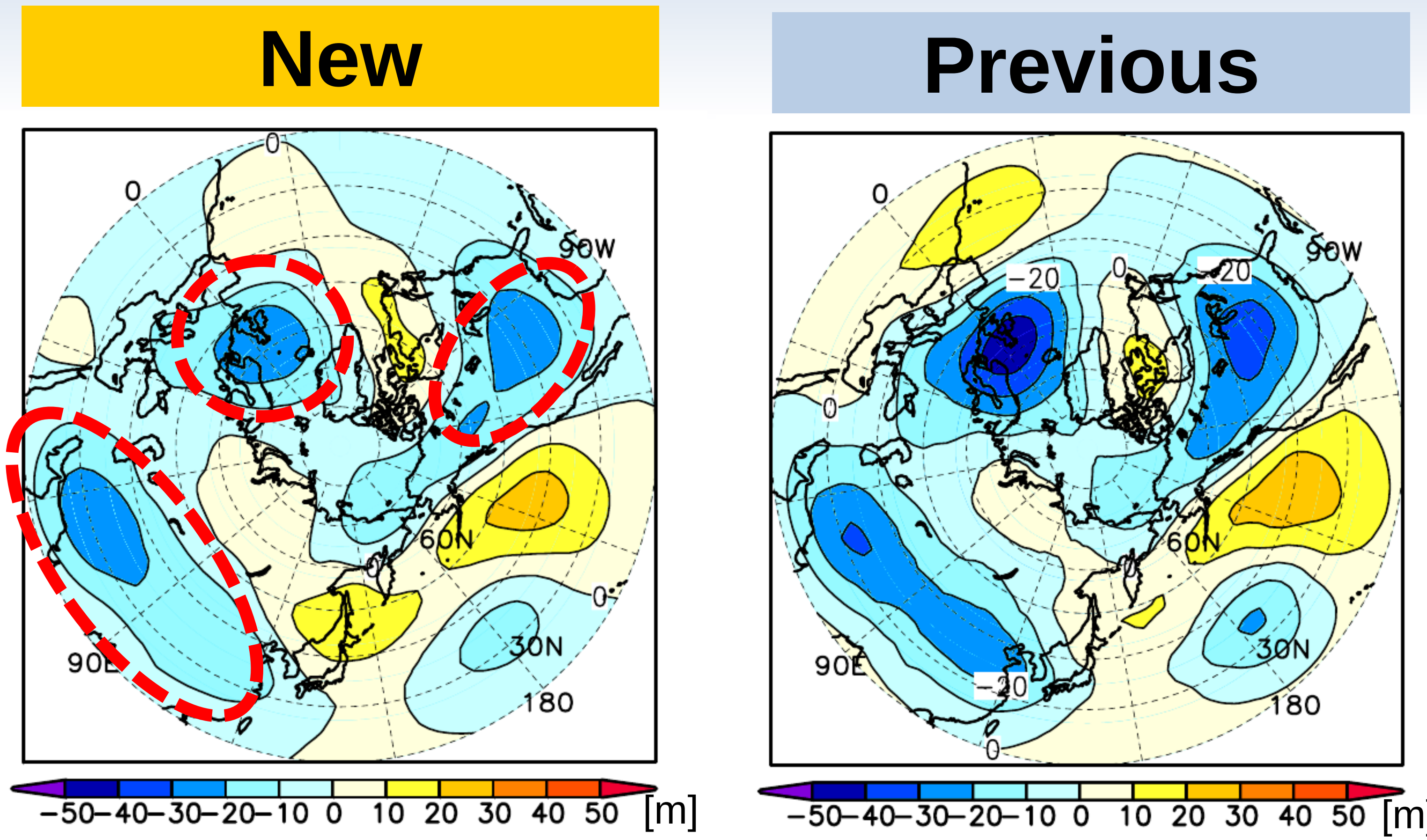
Development – climate -

- Recent changes
  - ***Mar. 2014: Upgrade of One-month ensemble prediction system***
  - ***JRA-55 reanalysis has been completed in 2013.***
- Under development
  - ***Upgrade of the seasonal forecast model probably in 2015***
    - A JRA-55 based initial analysis field is used in the new seasonal forecast model.

Configurations of JMA One-month EPS

Operation	New (Mar. 2014~)	Previous (~Feb. 2014)
AGCM	GSM1403	GSM1103C
Resolution (model top)	TL319 L60 (0.1 hPa)	TL159 L60 (0.1 hPa)
Initial perturbation	BGM and LAF	
Model ensemble	Stochastic physics scheme	-
Forecast Issue day	Thursday	Friday
Ensemble size	50 (25 BGM ensembles and 2 initial dates)	
SST/sea-ice (prescribed)	MGDSST (0.25deg, with satellite obs.)	COBE-SST (1deg, in-situ obs. only)
Hindcast	**New**	**Previous**
Period	1981 – 2010 (3 initial dates in a month)	
Ensemble size	5 (BGM ensembles)	
Initial condition	JRA-55	JRA-25
Verification data	JRA-55, GPCPv2.2	

Systematic biases (Z500, DJF)

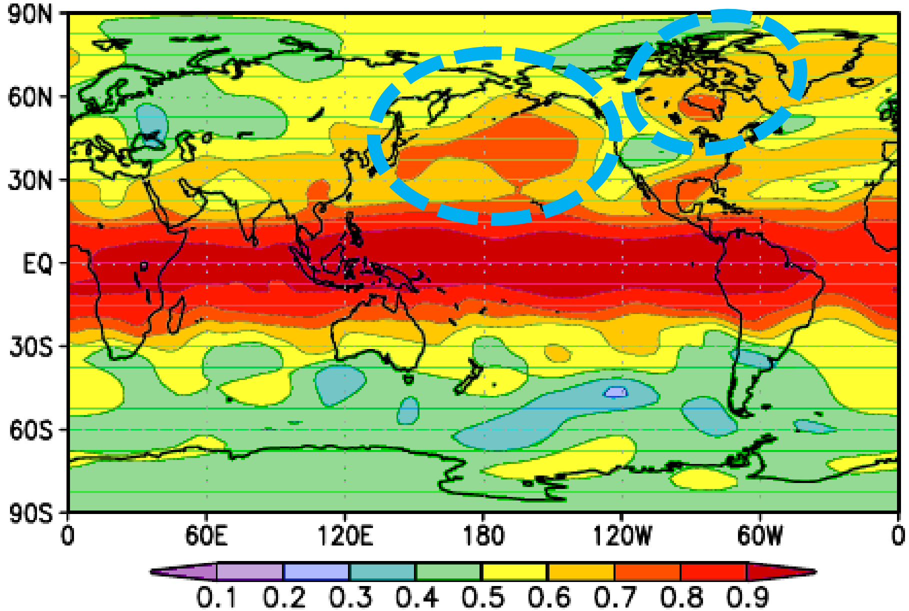


- Systematic biases are reduced in the new JMA One-month EPS.

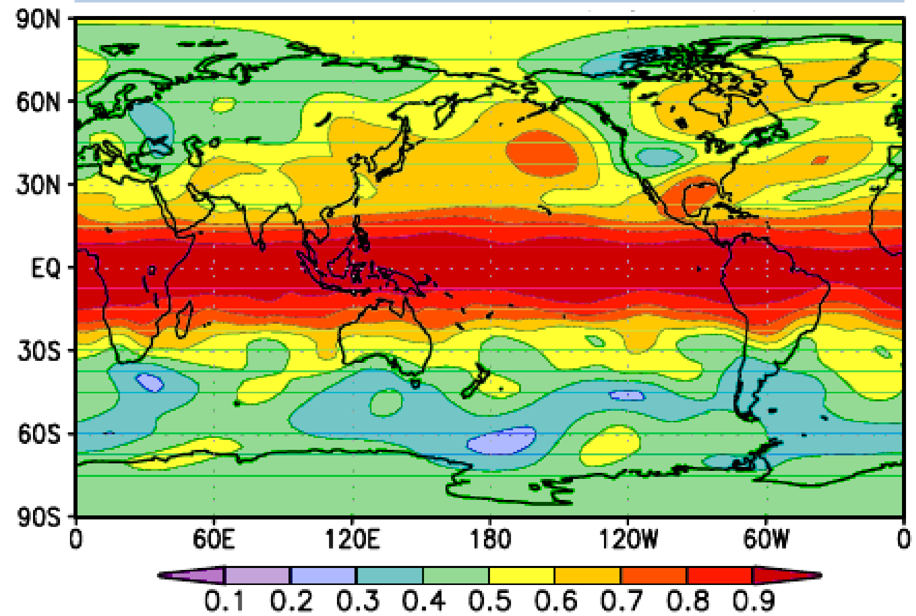
Anomaly Correlation (Z500, DJF)

Anomaly correlations for 4-week mean Z500 at a lead time of 3 days (day 3-30) starting from Dec-Feb

New



Previous



- Forecast skills are also improved in the new JMA One-month EPS.

JRA-55: Japanese 55-year Reanalysis

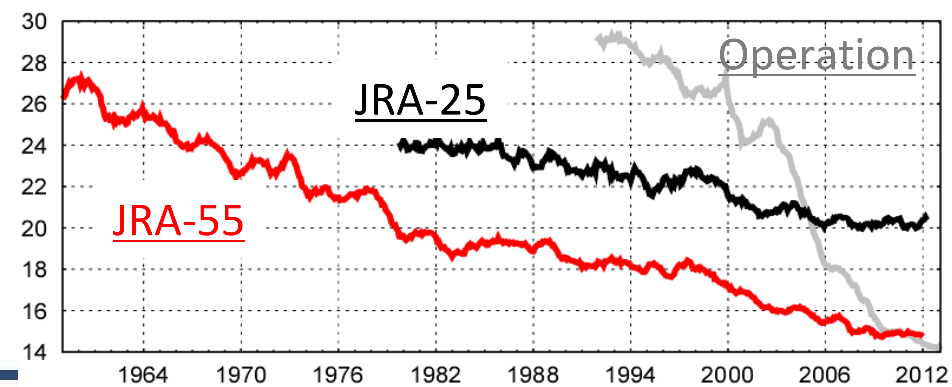
JRA-55 (JRA Go! Go!) (1958~2012)

- ➢ **JRA-55** is the first reanalysis which covers more than 50 years since 1958 with 4D-var data assimilation system.
- ➢ JMA operates **JRA-55** continuously in near real time basis after 2013.

http://jra.kishou.go.jp/

- Much better quality than JRA-25
- JRA-55 data are available from JMA, DIAS, and NCAR.

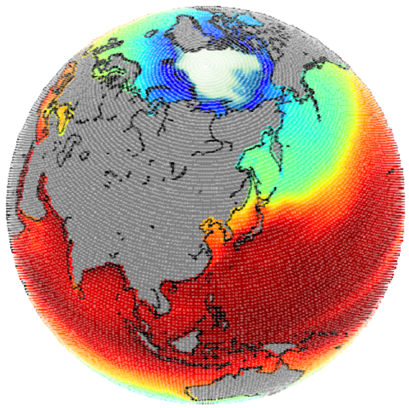
Forecast [FT=48] Scores (RMSE of Z500 for N.H.)

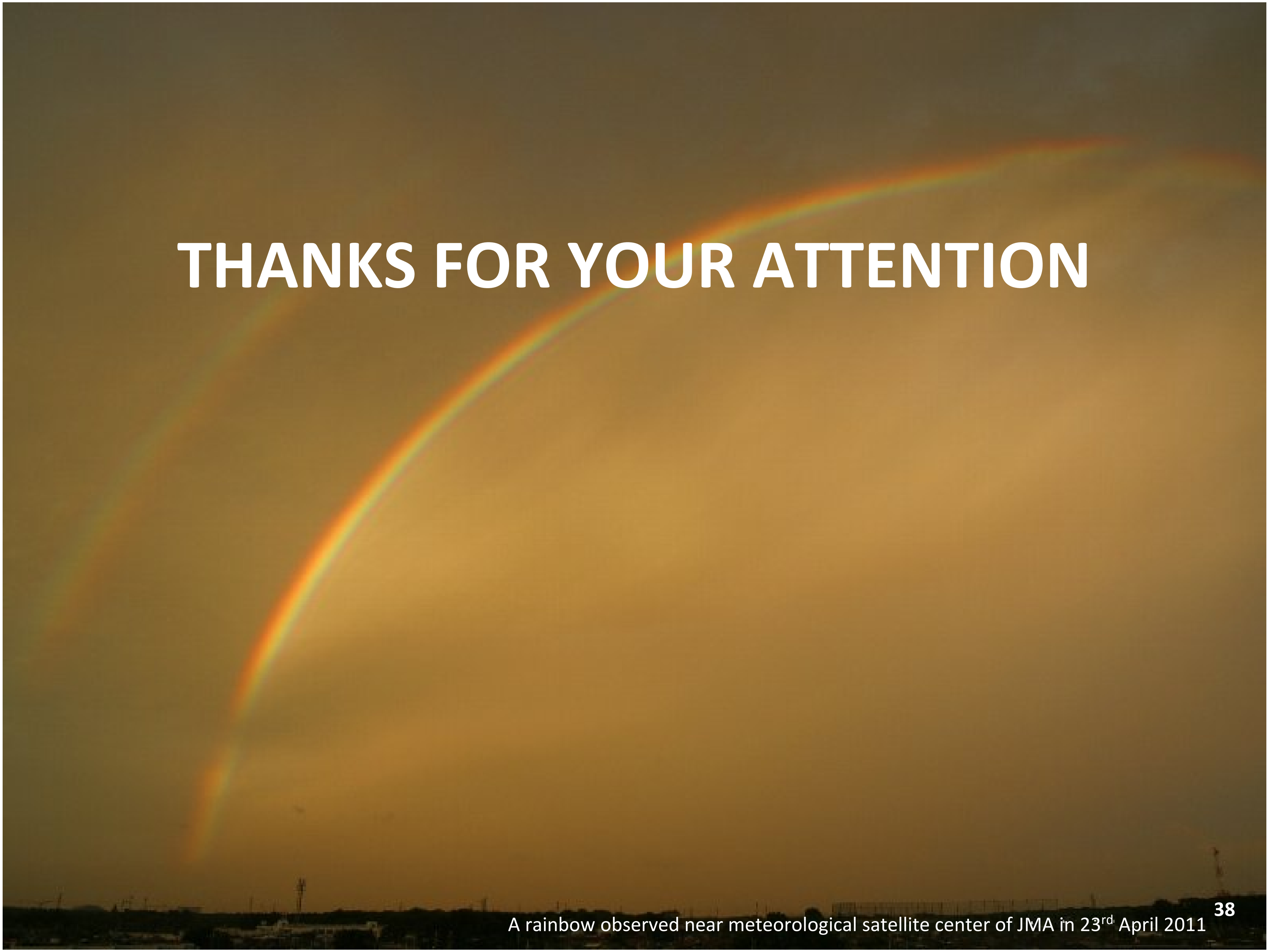


Japan Meteorological Agency 気象庁

Seasonal Forecast Model

- New coupled model for seasonal prediction is being developed.
- It will be implemented to the operation in 2015.
- Atmospheric GCM (AGCM)
  - Higher Resolution (TL95L40 →TL159L60)
  - Initial field is taken from JRA-55 Climate DA cycle.
    - Currently from JRA-25/JCDAS
- Oceanic GCM (OGCM)
  - Global ocean model
  - Improvement of model physics in OGCM
  - Introducing a sea-ice forecast model





A rainbow observed near meteorological satellite center of JMA in 23rd April 2011