Current status and development of medium range EPS at JMA

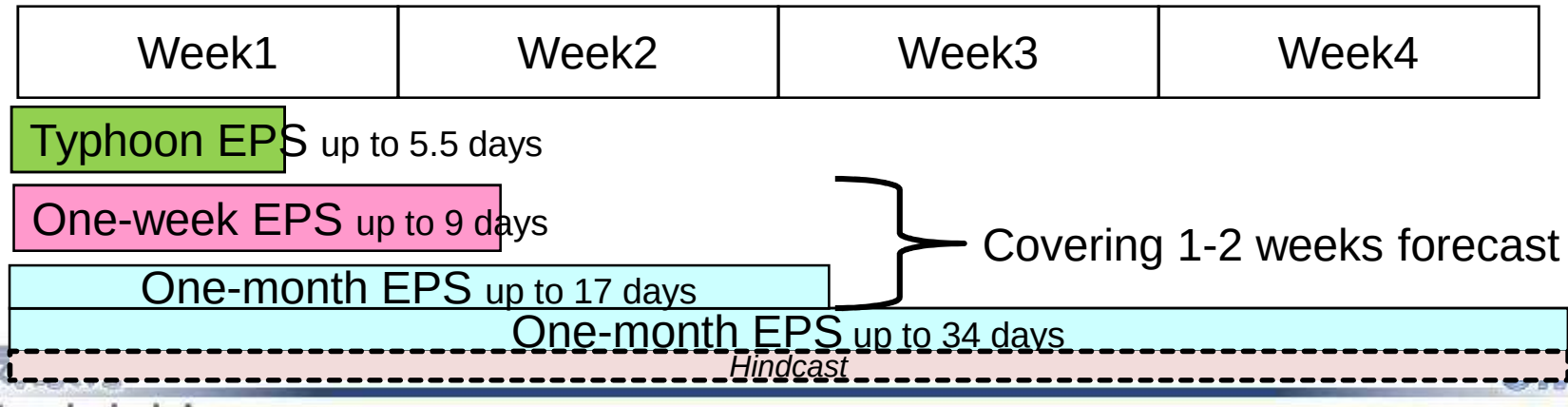
Masashi UJIIE, Haruki YAMAGUCHI, Masakazu HIGAKI
and Masayuki KYOUDA
Numerical Prediction Division,
Forecast Department, Japan Meteorological Agency

Outline of this presentation

- Outlines of the JMA operational EPSs
- A plan of the integrated EPS which covers from 2-3days to 2 weeks
  - Selection of initial perturbation generator.
  - Using hindcast (reforecast) dataset
- Summary

JMA operational EPS

- At present, 11, 51, and 50 initial conditions are integrated by using a low-resolution version of the JMA global NWP model for producing an ensemble of 132-hour forecasts in the Typhoon EPS, 9-day forecasts in the One-week EPS, and 17/34-day forecasts in the One-month EPS.
  - to assess uncertainties of the forecast targeted on specified phenomena.

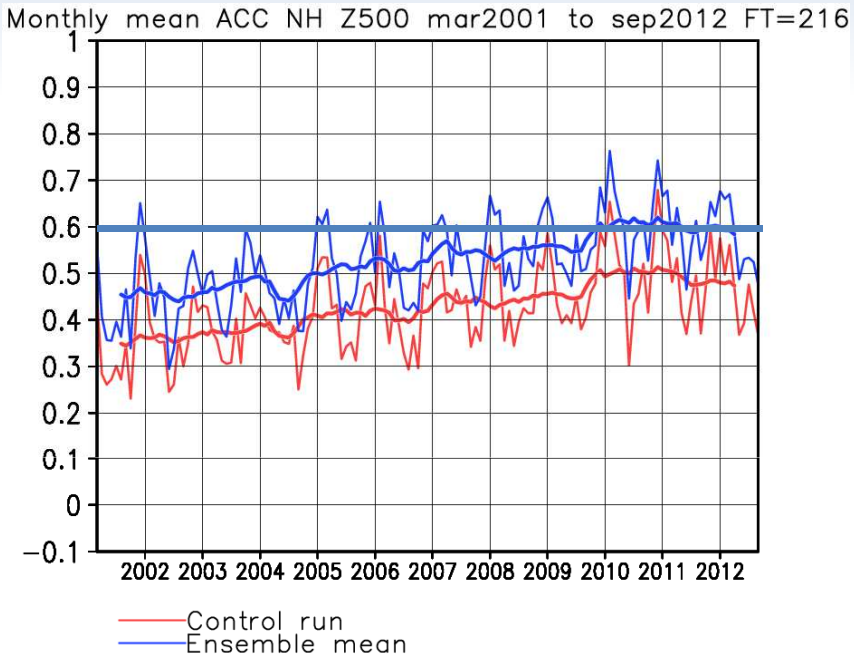


Specification of One month and One week EPSs at JMA

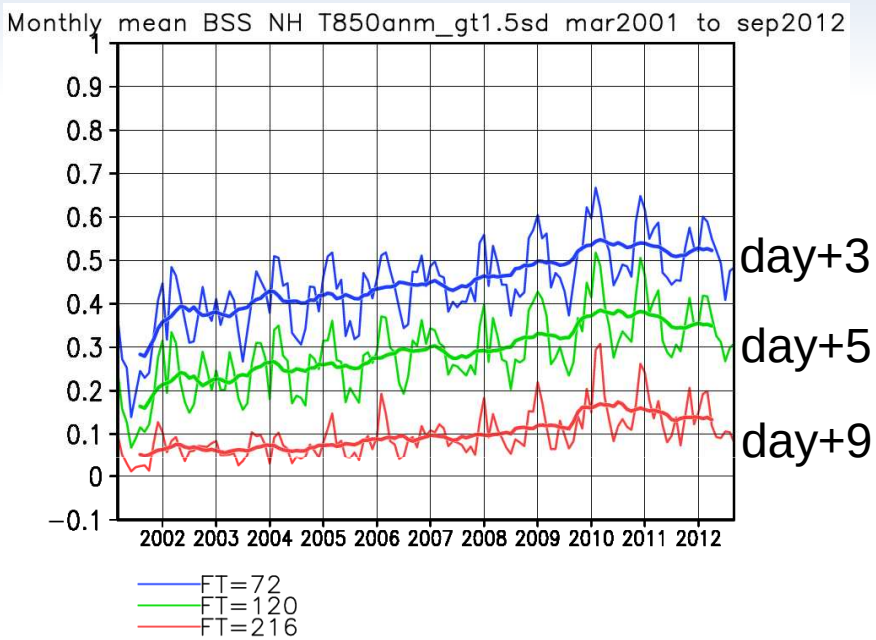
		One-week EPS	One-month EPS
Objectives		One-week forecast	One-month forecast/Early warning information on extreme events
EPS model and its integration	Forecast Domain	The whole globe by using JMA's AGCM, "GSM"	
	Horizontal Resolution	T_L319 (~55km)	T_L159 (~110km)
	Vertical Levels	60 levels, up to 0.1 hPa	
	Forecast Hours	9days(12UTC)	17 days ; Sun. and Mon. 34days ; Wed. and Thu.
Ensemble Settings	Member	1 control run and 50 perturbed runs	1 control run and 24 perturbed runs *x 2 days (LAF)*
	Initial perturbation	SV method, Three target areas (NH,TR,SH)	BGM method, two target areas (NH and TR)
	Model ensemble	Stochastic Physics	Not considered
Hind-cast	Member	none	1 control run and 4 perturbed runs
	Sampling size		3 initials per month x 12 months (the 10th , 20th and end of every month) x 31 years (1979 to 2009)

More detailed information is available at the JMA part of the latest "WMO Technical Progress Report on GDPSF and NWP Research" and the standardized EPS documentation in Excel spreadsheet format at http://tigge.ecmwf.int/models.html

Histories of ACC and BSS of the One week EPS



Time series of monthly mean ACC of Z500 over NH. The red and blue lines show control run and ensemble mean respectively.

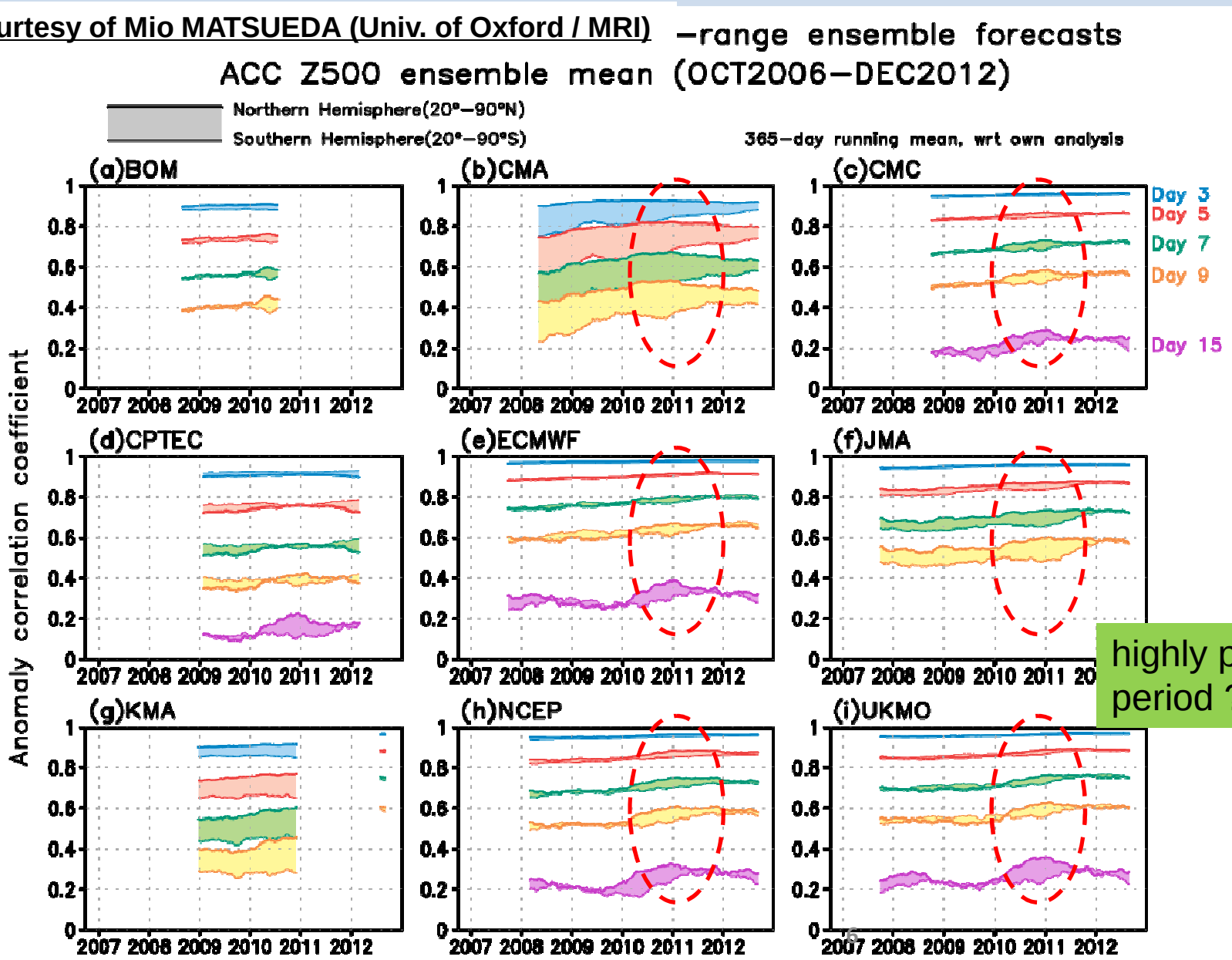


Time series of Brier Skill Scores for the probability of T850 above 1.5 times of climatological standard deviation. Blue, green and red lines show T+72, T+120 and T+216 respectively.

Both deterministic and probabilistic scores have been improved.

Histories of ACC from the TIGGE archives

Courtesy of Mio MATSUEDA (Univ. of Oxford / MRI)



highly predictable period ?

A plan of the integrated EPS: Background

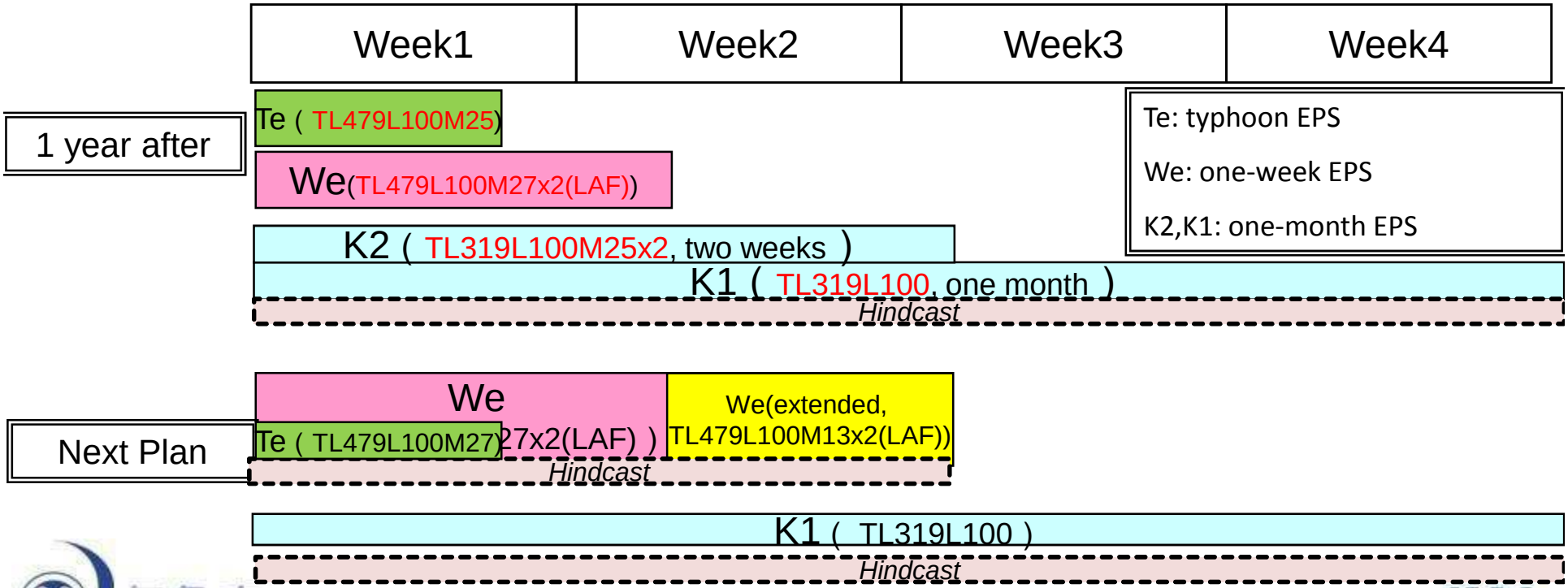
- The one-week EPS has been improved for 10 years. The ACC of Z500 T+216h reached to 0.6 .
- One-month EPS is also operated as two weeks forecast.
  - But two weeks forecasts are influenced by initial condition problems. The targeted phenomena and uncertainties are similar between the two EPSs.
- It is more efficient to unify the One and Two weeks EPSs.
- Consistent (in quality) products of one-week and two-weeks forecast are important for operation.

Tasks to unify the two EPSs

- Unify and verify specifications of the system

  -initial perturbation generator, boundary conditions and etc..

- Using hindcast (reforecast) dataset



Selection of initial perturbation generator

- We have experienced some kinds of methods
  - SV method (employed in the One-week EPS)
    - Successful over the Extratropics (spread – skill relationship).
    - Some difficulties in moist SVs over the tropics.
      - Growing rapidly in the beginning of time integration, but decaying later.
  - Breeding method (employed in the One-month EPS)
    - Over the tropics, using potential velocity norm enables to extract large scale modes (Chikamoto at al. 2007).
    - The perturbation grows naturally, but spread is still small.
  - LETKF(under development)
    - Verified as both an EPS and a data assimilation system.
    - Perturbations which reflect analysis errors
    - As an EPS, perturbations grow naturally, but spread-Skill relationship is still worse than the SV method.

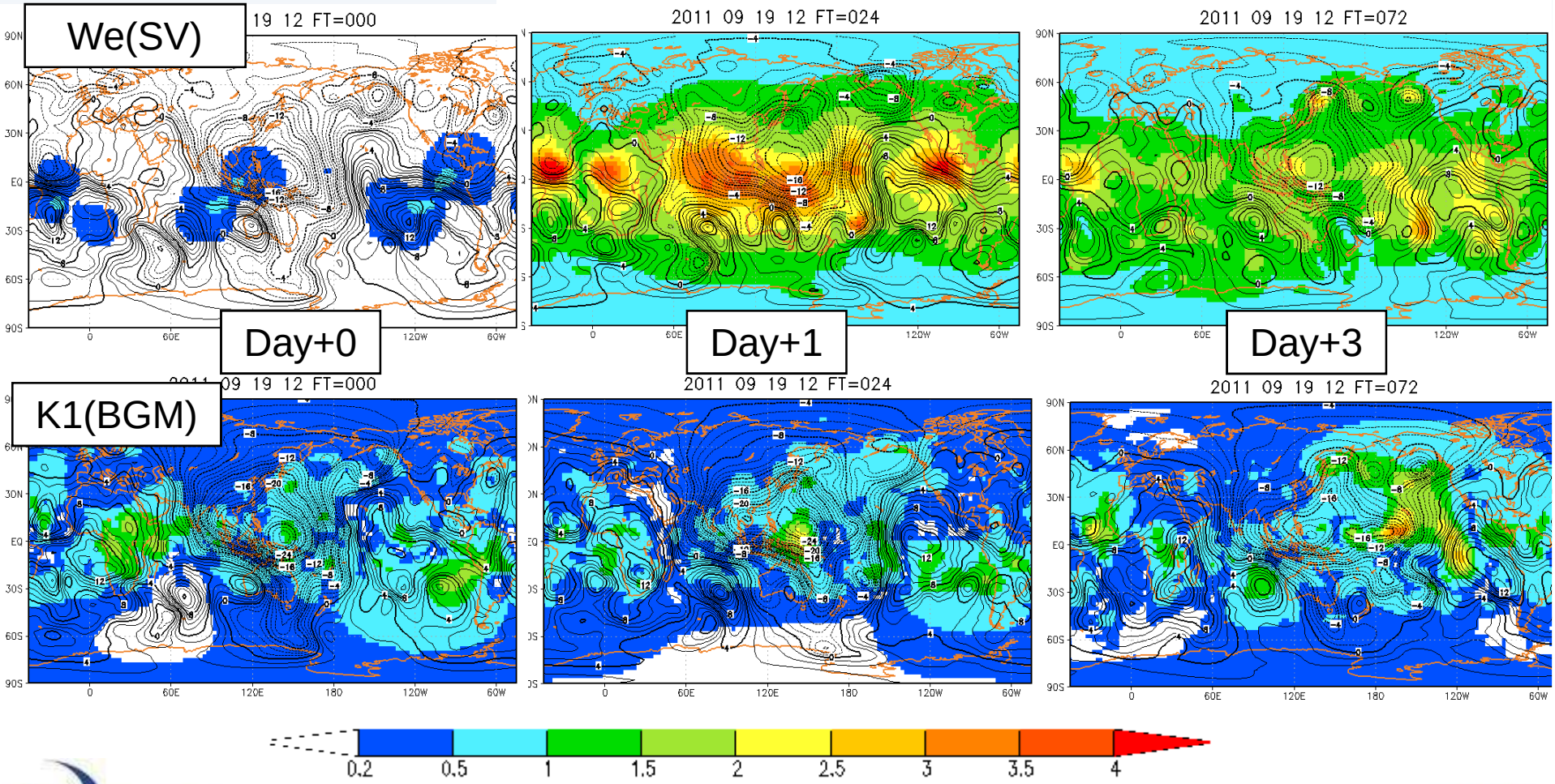
More study and comparison (or combining the methods) are necessary which is better for the integrated EPS

Perturbations grow over the Tropics

200hPa velocity potential(contours) and its spread(color)
Initialized at 12 UTC 21 SEP

We: one-week EPS

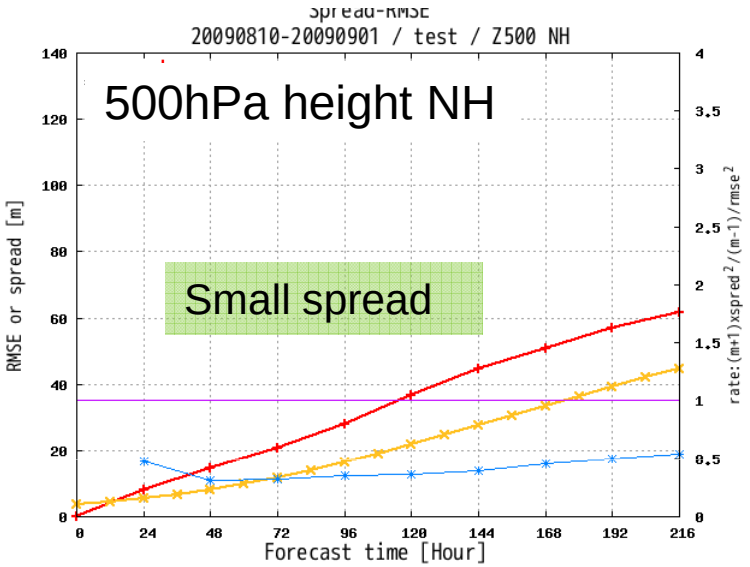
K1: one-month EPS

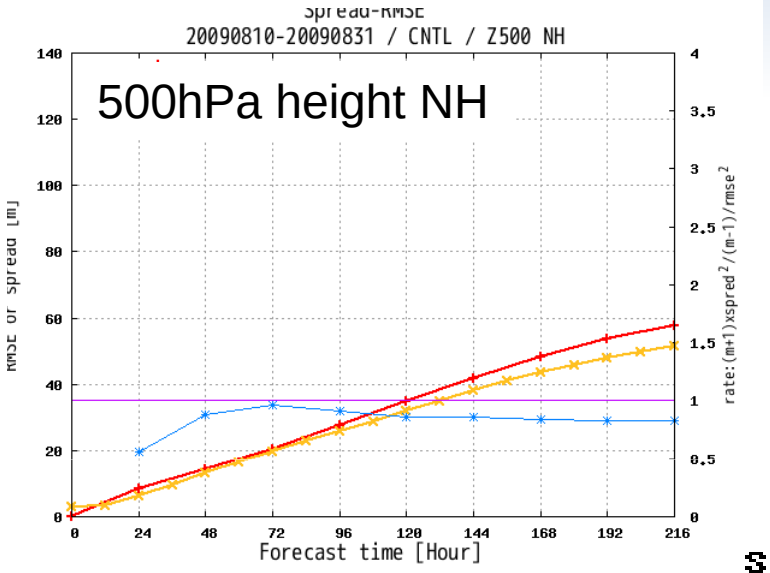


Spread-Skill relationship of LETKF

LETKF TL159 50 members

SV TL159 51 members

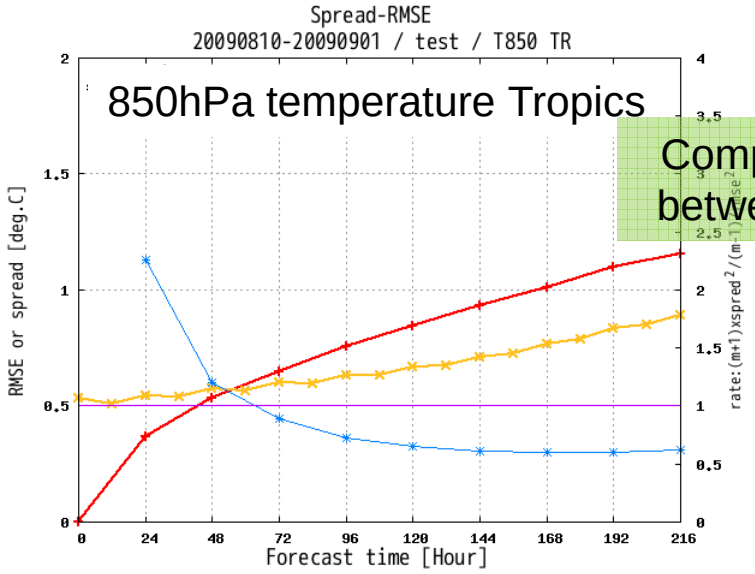




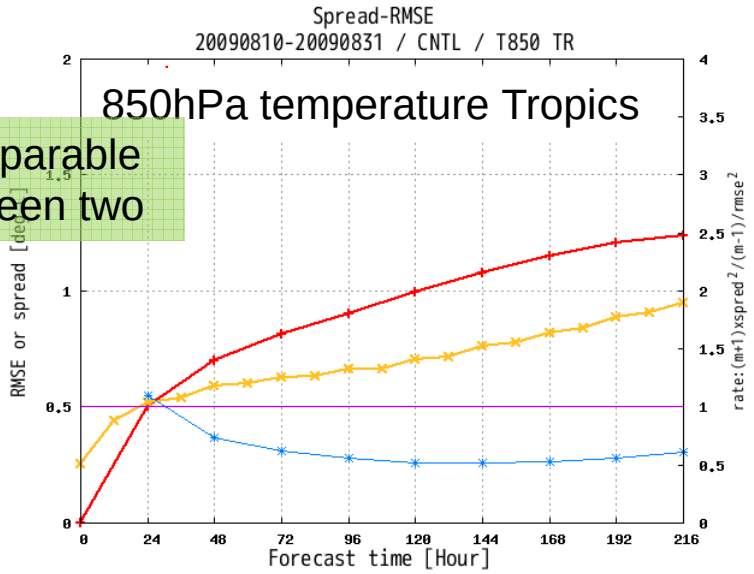
rmse

spread

rate



Comparable between two



Hindcast (Reforecast)

- Forecast dataset initialized from the past using current NWP system.
- The purposes are to …
  - Diagnose performance of the EPS
  - Correct the systematic errors
    - Operationally employed in the One month EPS
  - Estimate probability of extreme events from model climatology (eg: Extreme Forecast Index)
  - Calibrate the PDF of forecasts
    - To improve probabilistic forecast products

Preliminary study of using hindcast dataset as medium range forecast

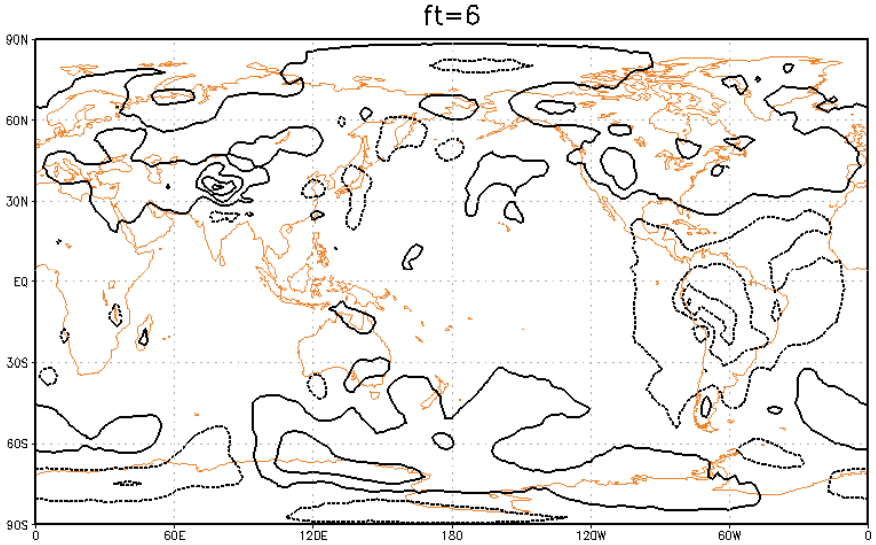
To show usefulness of the reforecast dataset

- Using existing hindcast dataset of the one-month EPS
  - TL159L60, 5members
- the effects of removing systematic errors
  - Removing the systematic errors (biases) against the JRA-25 (Onogi, et al 2007) up to 17 days
  - The systematic errors are filtered in forecast time direction by running mean of +- 5days.
    - To reduce transient components
- Correction of probabilistic forecast (on going)

Effect of time filtering

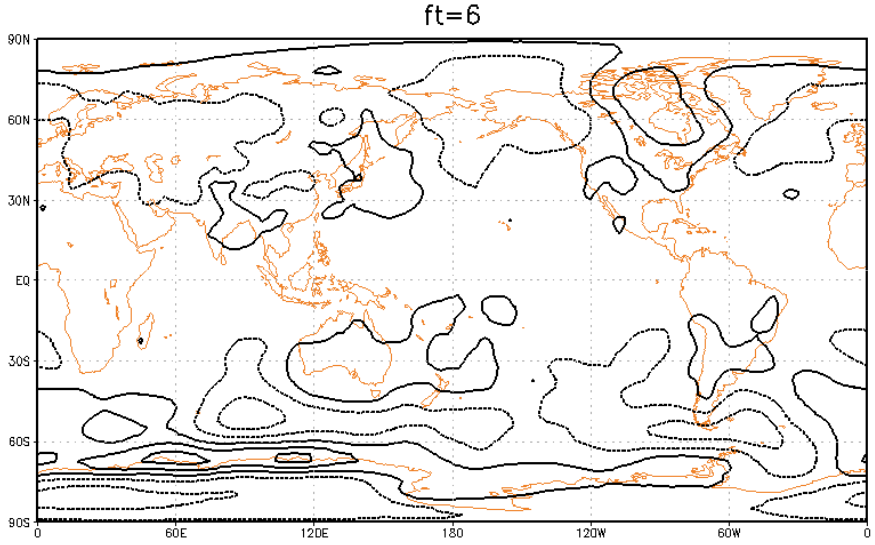
Time evolution(animation) of systematic errors of 500 hPa height in January (1979-2000)

Without running mean



Noisy and transient components of the errors make it difficult to interpret these errors

With running mean(+-5days)

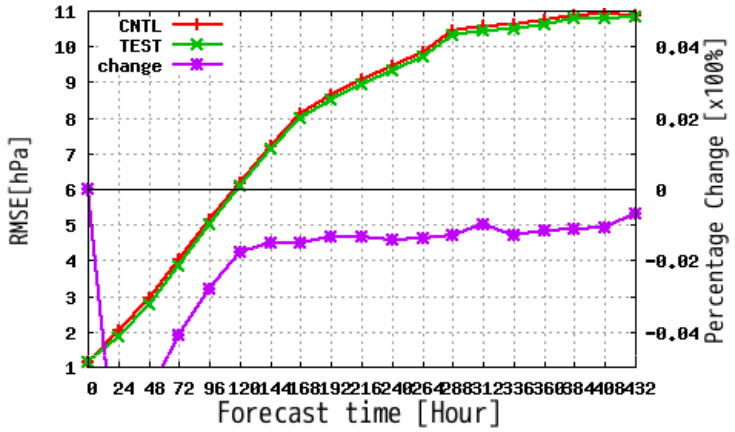


The error are similar to stationary wave patterns

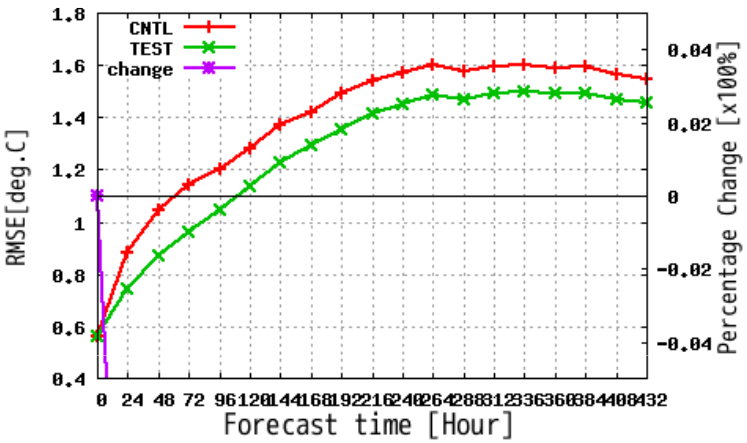
Using running mean enables to extract stationary components of systematic errors.

Daily effect on removing systematic error

MSLP for NH



850 hPa Temp. for Tropics



Time evolution of root-mean-square error of raw ensemble-mean (red lines) and daily bias-removed one (green lines), derived from the One-week EPS with the current hindcast-experiment for the One-month EPS, for mean sea level pressure for the extratropical Northern Hemisphere (left panel) and 850 hPa temperature for the Tropics (right panel).

- Verified period is January 2010 independent from studying period(1979-2000).
- Daily systematic errors are calculated by using the hindcast-dataset for 1979-2000.

Summary

- As predictability varies day to day, to capture the uncertainties, JMA operates several EPSs.
- JMA is planning to extend one-week EPS up to 2 weeks.
- From our experience of several EPSs, we have found advantages and disadvantages of each initial perturbation generator.
- Bias correction of stationary components of systematic errors can efficiently works in short to medium range forecasts (1days ~ 2week)

Backup slides

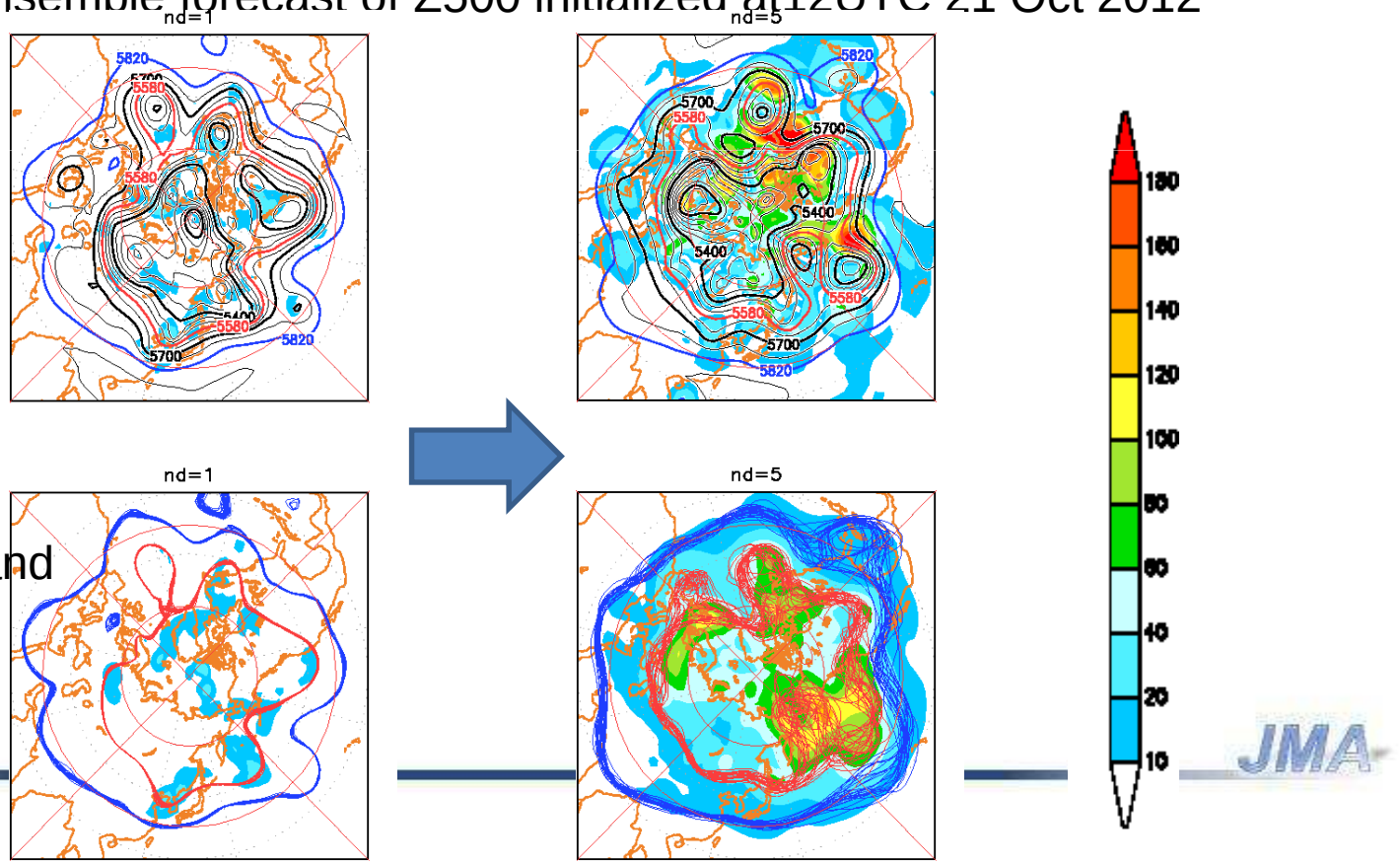
Flow dependent predictability

- small uncertainties in analysis (initial conditions), boundary conditions and NWP models sometimes grow as large forecast errors.

0 to 5days ensemble forecast of Z500 initialized at12UTC 21 Oct 2012

Analysis(contours) and RMSE(shades)

Forecast(contours) and Spread(shades)



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Flow dependent predictability

- The scale of phenomena varies in space and time (precipitation, baroclinic instability, quasi-stationary Rossby waves, MJO etc).
- JMA operates some kinds of EPSs (One-week, Typhoon, One-month and Seasonal forecast EPS)

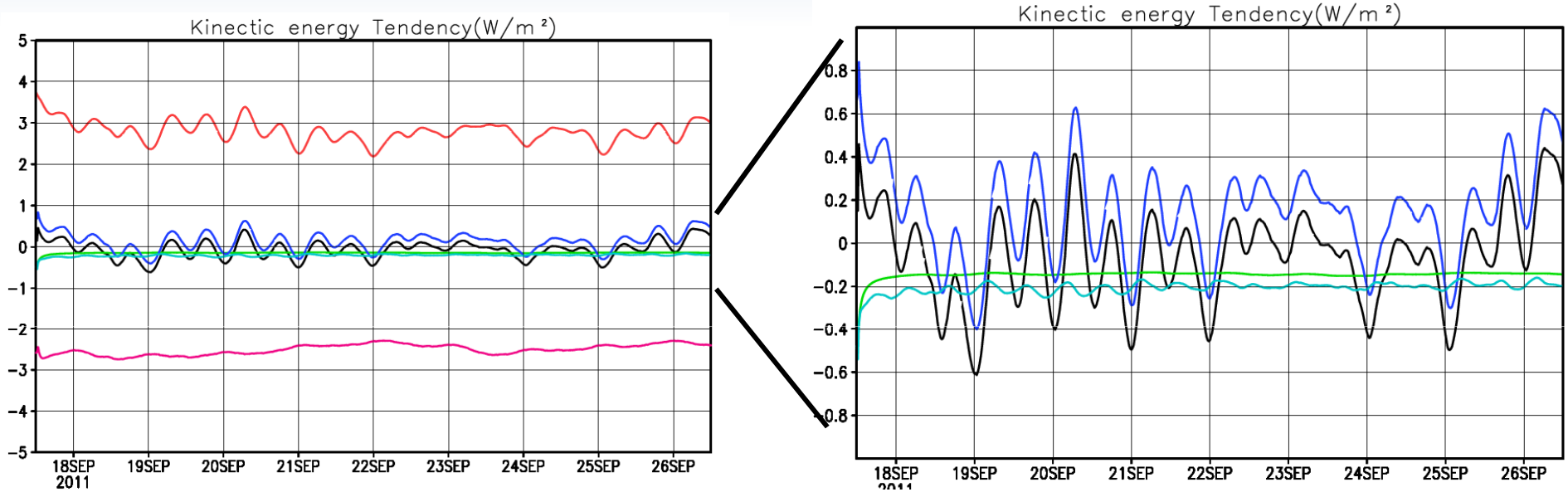
  -to know uncertainties of the forecast targeted on specified phenomena.

Model ensemble methods

- In 2010, a stochastic physics method was implemented into the One week EPS.
  - Improving probabilistic forecast over the tropics.
  - Will be implemented into the One month EPS
- Implementation of the SKEB(Stochastic Kinetic Energy Backscattering method, Shutts 2005) is now considering.
- Before implementing the SKEB, we should investigate energetics of the JMA's model.
  - The kinetic energy budget varied models to models

Kinetic energy budget of the GSM.

TL319 unperturbed run, initialized at 12 UTC 17 Sep 2011



ke tendency	(1)
converted from potential energy	(2)
numerical diffusion	(3)
physical processes (pbl+cmt+gwd)	(4) PBL ,cumulus and gravity wave drag
total tendency due to dynmical and physical processes	(5)=(2)+(3)+(4)
imbalance (regard as semi Lagrangian advection)	(6)=(1)-(5)

The energy dissipation due to numerical diffusion and semi Lagrangian advction is estimated order of 0.1W/m^2 .
Cf: That of the IFS is estimated to 1.2W/m^2 (Shutts 2005)。

Specification of medium-range EPS at JMA

		One-week EPS	Typhoon EPS
Objectives		One-week forecast	Typhoon forecast
EPS model and its integration	Forecast Domain	The whole Globe by using JMA's AGCM, "GSM"	
	Horizontal Resolution	T_L319 (~55km)	
	Vertical Levels	60 levels, up to 0.1 hPa	
	Forecast Hours	216 hours (12UTC)	132 hours(00,06,12,18) 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	1 control run and 50 perturbed runs	1 control run and 10 perturbed runs
	Initial perturbation	**SV method**, Three target areas (NH,TR,SH)	**SV method**, RSMC target (Fixed) and Max. 3 Typhoon Target (Movable)
	Model ensemble	Stochastic Physics	

More detailed information is available at the JMA part of the latest "WMO Technical Progress Report on GDPSF and NWP Research" and the standardized EPS documentation in Excel spreadsheet format at http://tigge.ecmwf.int/models.html

Specification of extended-range EPS at JMA

		One-month EPS	
Objectives		Early warning information on extreme events	One-month forecast
EPS model and its integration	Forecast Domain	The whole Globe by using JMA's AGCM, "GSM"	
	Horizontal Resolution	T_L159 (~110km)	
	Vertical Levels	60 levels, up to 0.1 hPa	
	Forecast Hours	17 days ; every Sunday and Monday	34days ; every Wednesday and Thursday
Ensemble Settings	Member	1 control run and 24 perturbed runs *x 2 days (LAF) = 50 (1 dataset) per week produced*	
	Initial perturbation	**BGM method, two target areas (NH and TR)**	
	Model ensemble	Not considered	
Hind-cast	Member	1 control run and 4 perturbed runs	
	Sampling size	3 initials per month x 12 months (the 10th , 20th and end of every month) x 31 years (1979 to 2009)	

Correction of probabilistic forecast using the hindcast dataset

Correction method

1. A gaussian PDF is assumed. Mean and standard deviation of the PDF are derived from linear regression of ensemble mean and spread.

$$PDF = N(\mu, \sigma^2) \qquad \mu = a + b \cdot \bar{x} \qquad \sigma = c + d \cdot s$$

$$\bar{x} = ensemble\_mean \qquad s^2 = spread$$

2. Using regression coefficients from 1. Probabilistic forecast is carried out.

Data, Period and Score

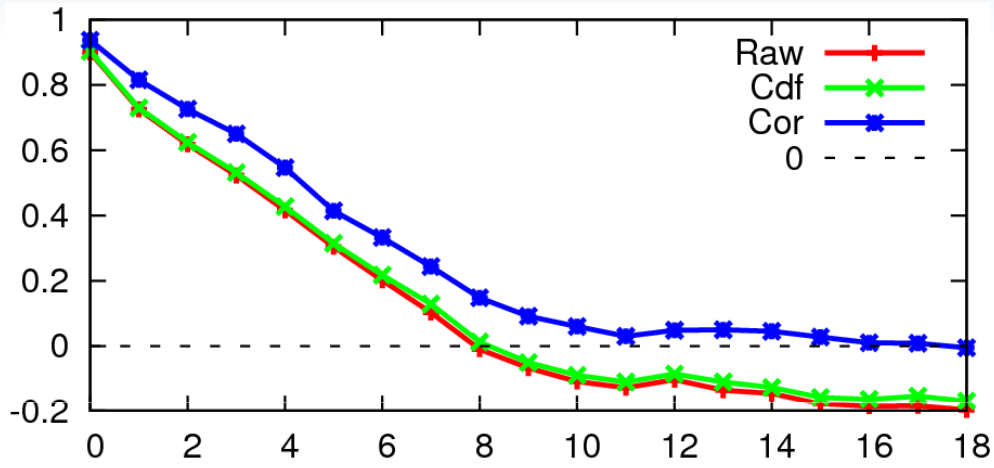
- Hindcast dataset of the One month EPS
  - TL159L60, 5members
- Training period: Jun-Aug, 1979-2000
- Verification period: Jun-Aug, 2001-2010
- Element: T850
  - 12x12 grids(2.5deg) over the Europe
- Verifying probability of T850 anomalies exceeding +1K
- The LBFGS method is used to minimize the Brier Score.
  - Penalty terms are added to prevent negative standard deviation

$$J = BS + Jc$$

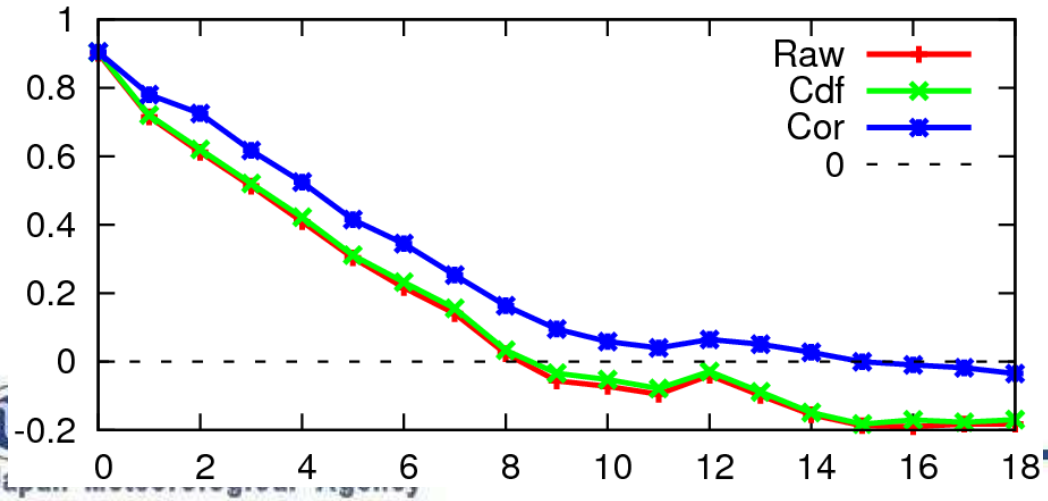
$$Jc = \sum_{sample} \mu\left[\max\left(0, -(c + d \cdot s)\right)\right]^2 \quad \mu > 0$$

Changes of the Brier Skill Scores

Training period



Verification period

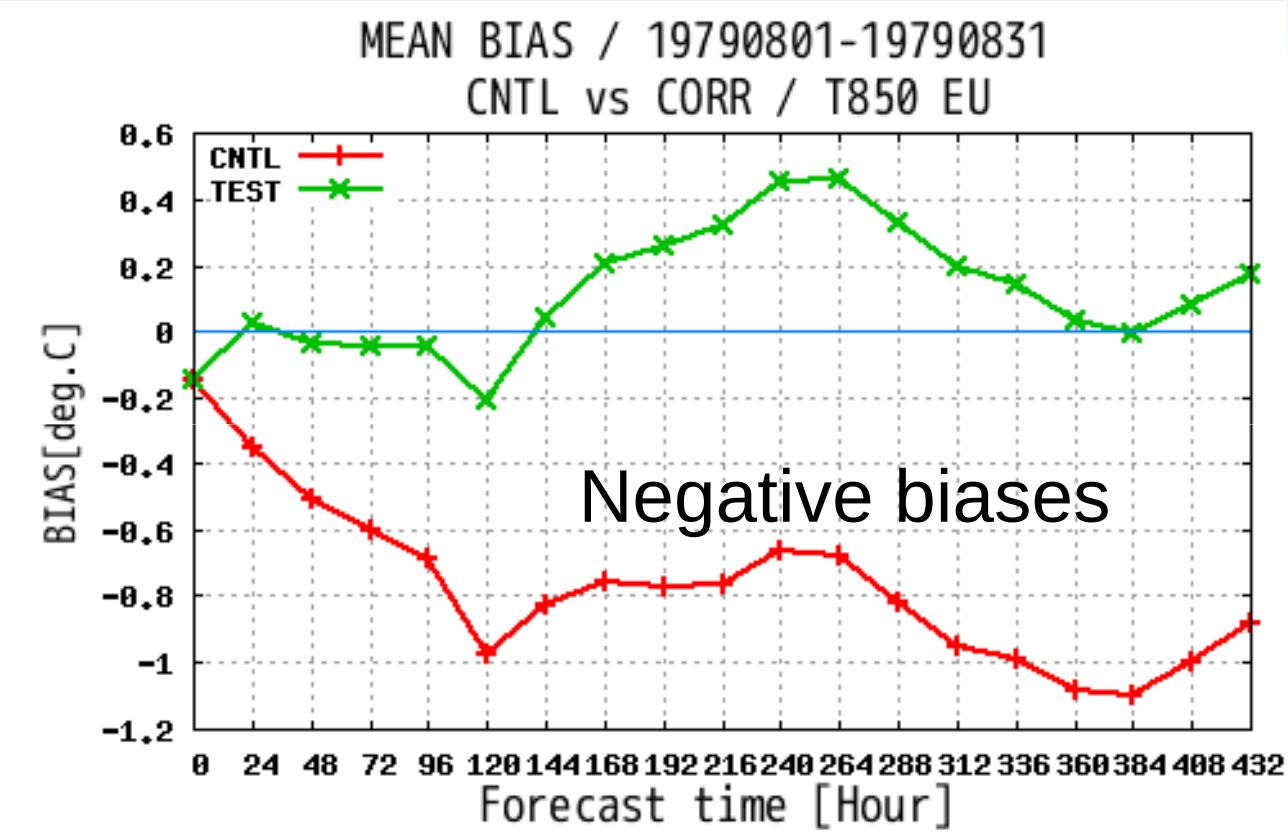


Raw: probabilistic forecast using 5 members directly

Cdf: probabilistic forecast using CDF. Mean and Standard deviation are equal to ensemble mean and spread.

Cor: probabilistic forecast using CDF. Mean and Standard deviation are equal to ensemble mean and spread.

Temperature biases over the Europe

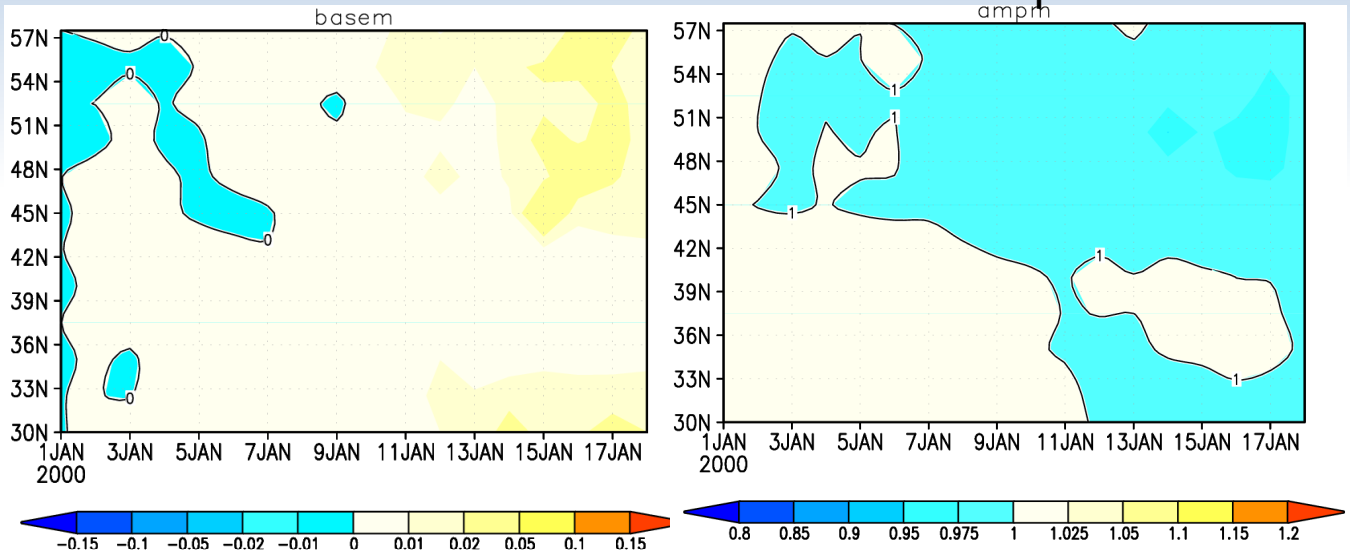


Regression coefficients

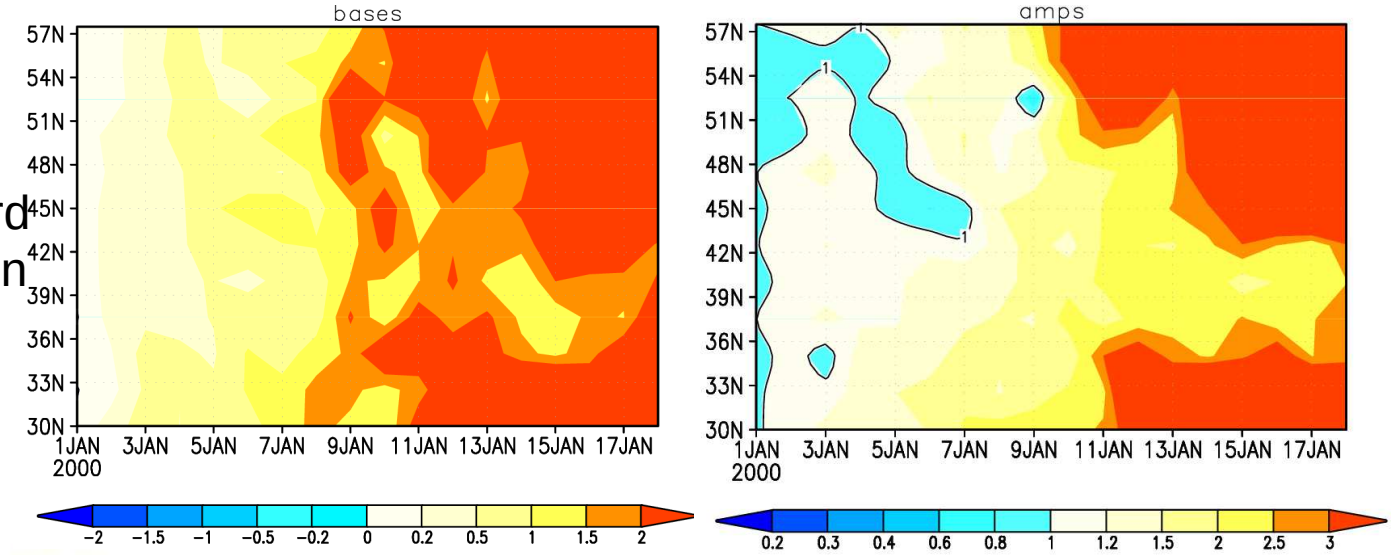
Base

Amp

Mean



Standard deviation



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Enlargement of spread contributes to improving the Brier Scores