Work at JMA on Ensemble Forecast Methods

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Contents

Part I

- Evidence of growing bred vector associated with the tropical intraseasonal oscillation
  (JMA monthly forecast group and Kyoto University)

Part II

- Medium-range EPS and Typhoon EPS using initial perturbations with singular vectors
  (JMA medium-range ensemble group)

Part I

Evidence of Growing Bred Vector Associated with the Tropical Intraseasonal Oscillation

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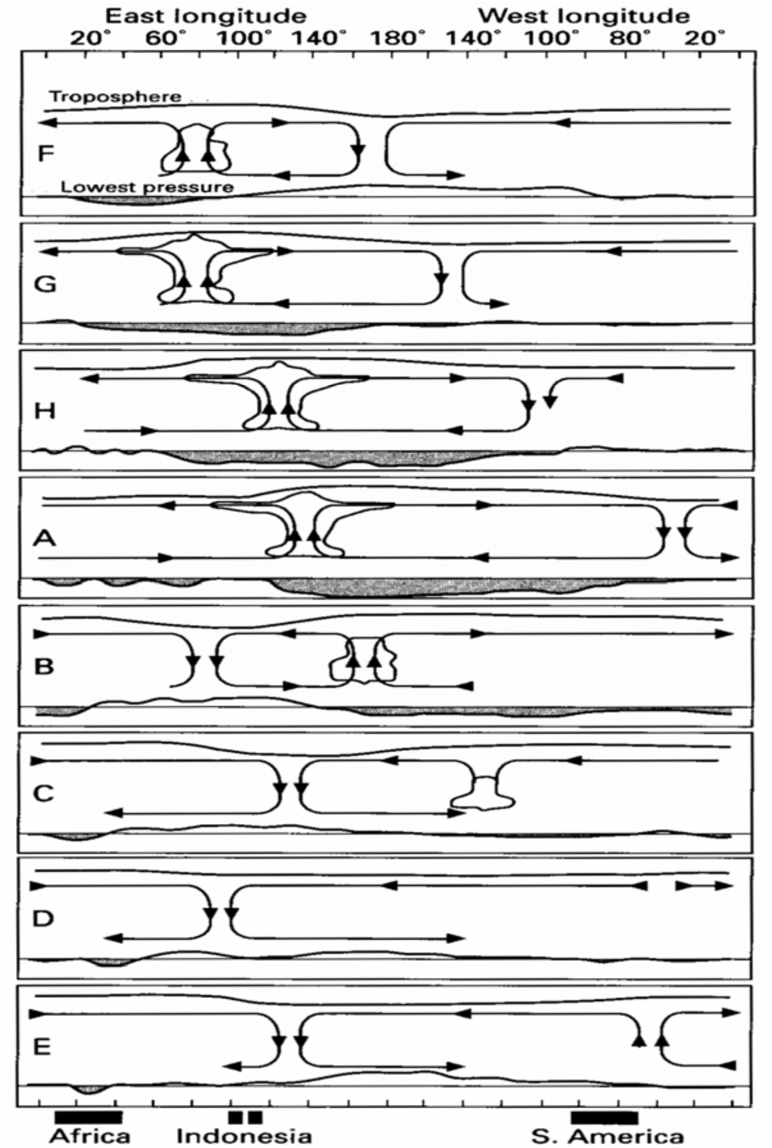
Madden-Julian Oscillation (MJO)

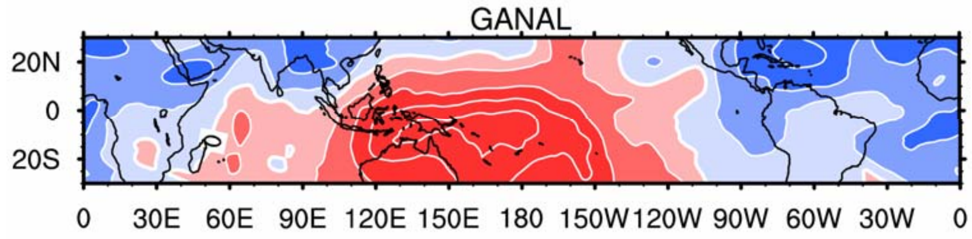


Madden and Julian(1972)

- The mutual interaction between convection and large-scale motions is the key for MJO, but the detailed mechanism for its slow phase speed has not been resolved.
- Predictable period of MJO is about 1 week, very limited compared with its long period.
- Serious problems in initial perturbations for ensemble forecasts of the MJO in the operational JMA Ensemble Prediction System (EPS).

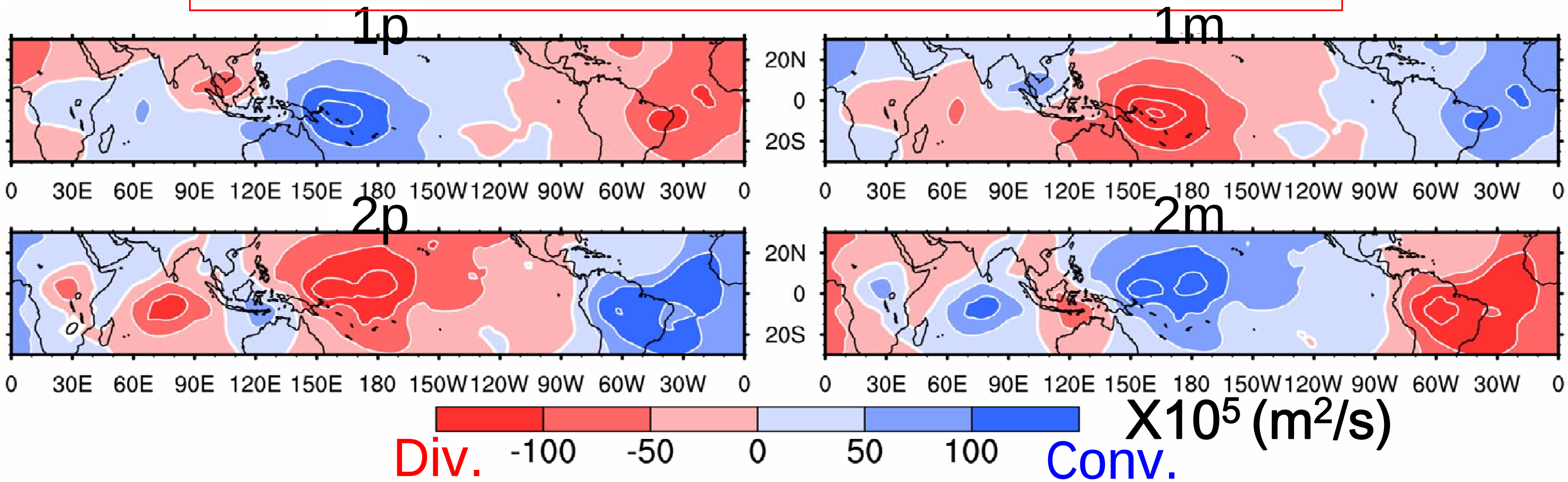
Initial Perturbations of the operational JMA EPS

Observed Velocity Potential at 200hPa (X200)



1 Jan 2004

Initial Perturbations of the operational JMA EPS



Initial perturbations have too large amplitude to predict the MJO

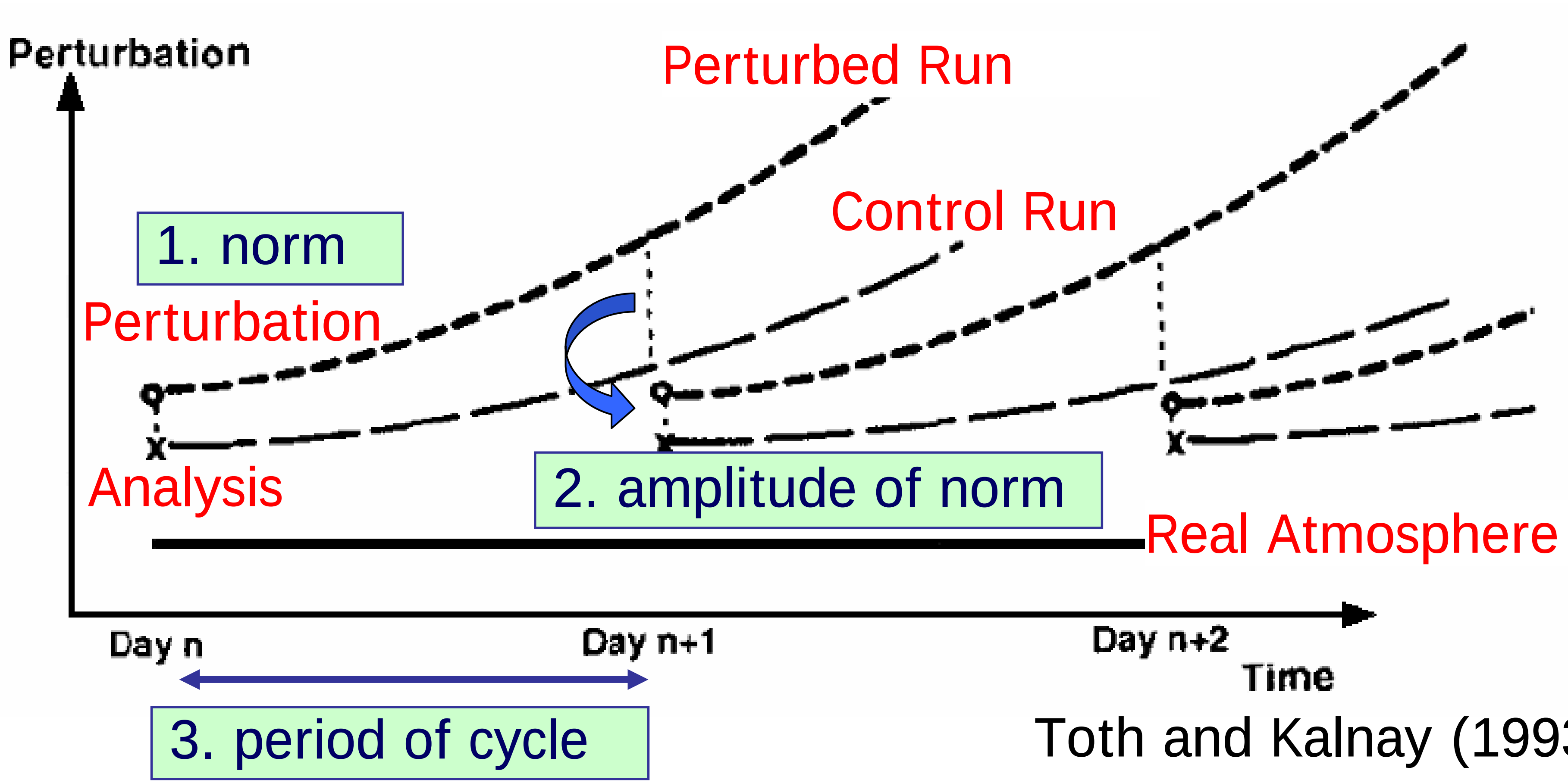
Aim of our study

- We are going to create initial perturbations in the tropics which are adequate to assess the predictability of the MJO.
  - Modify the operational Breeding of Growing Modes (BGM) method to obtain initial perturbations.
  - Obtain growing mode associated with the instability of the MJO (Chikamoto et al., 2007).
- The obtained perturbations are introduced in the operational monthly EPS.

For further studies:

・ Dependence of predictability of the MJO on its phase and activity.
・ Predictability of the influence of the MJO to the extratropical circulation.

Perturbation produced by the BGM method



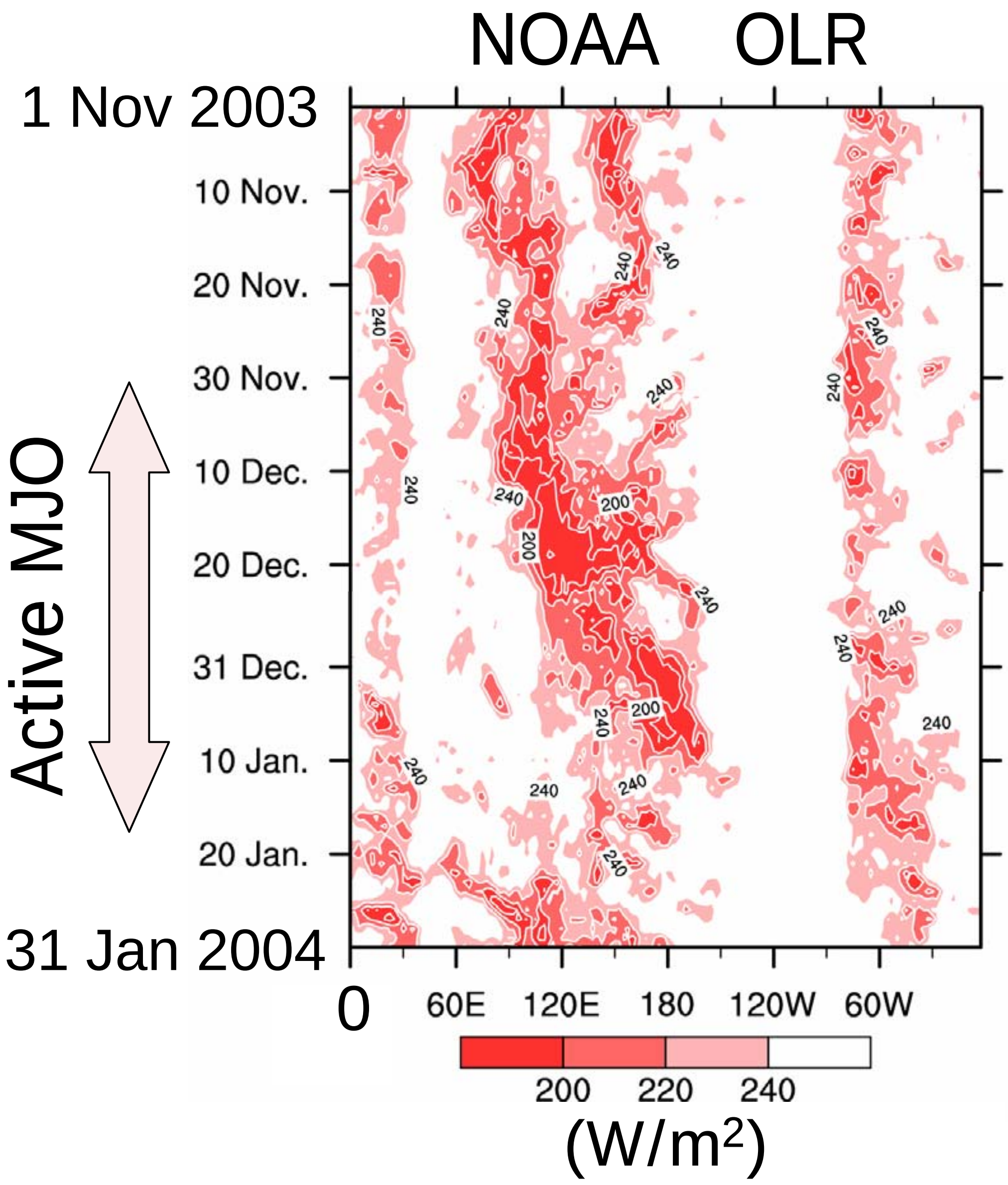
Toth and Kalnay (1993)

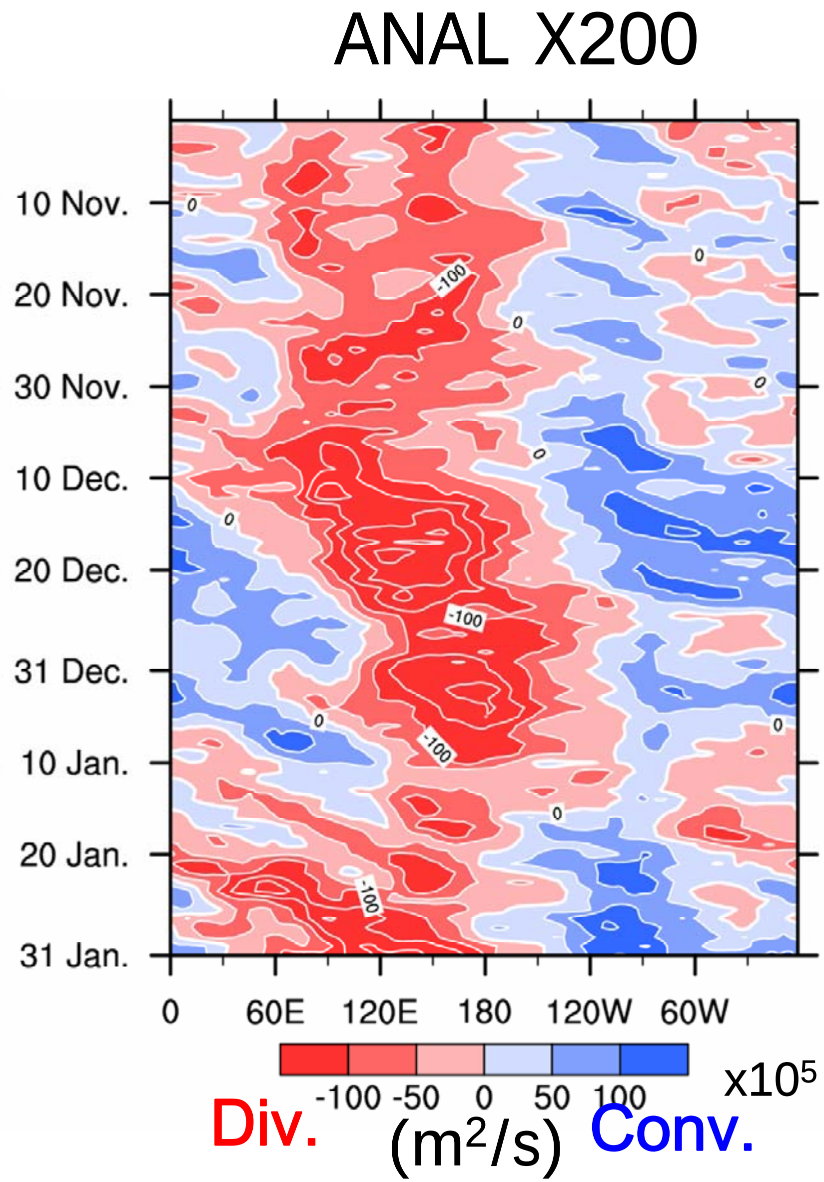
Modification of the BGM method

	Old version for NH+TR	Modified version for the Tropics
Perturbation Area	20S-90N	20S-20N damped in the extratropics
Norm	Z500	χ200
Magnitude of norm (% of the climatological rms variance)	14.5 (%)	0.1～50.0 (%)
Renormalization	every 12hr	every 24hr
Orthogonalization	every 24hr	every 24hr
Ensemble member	24	2

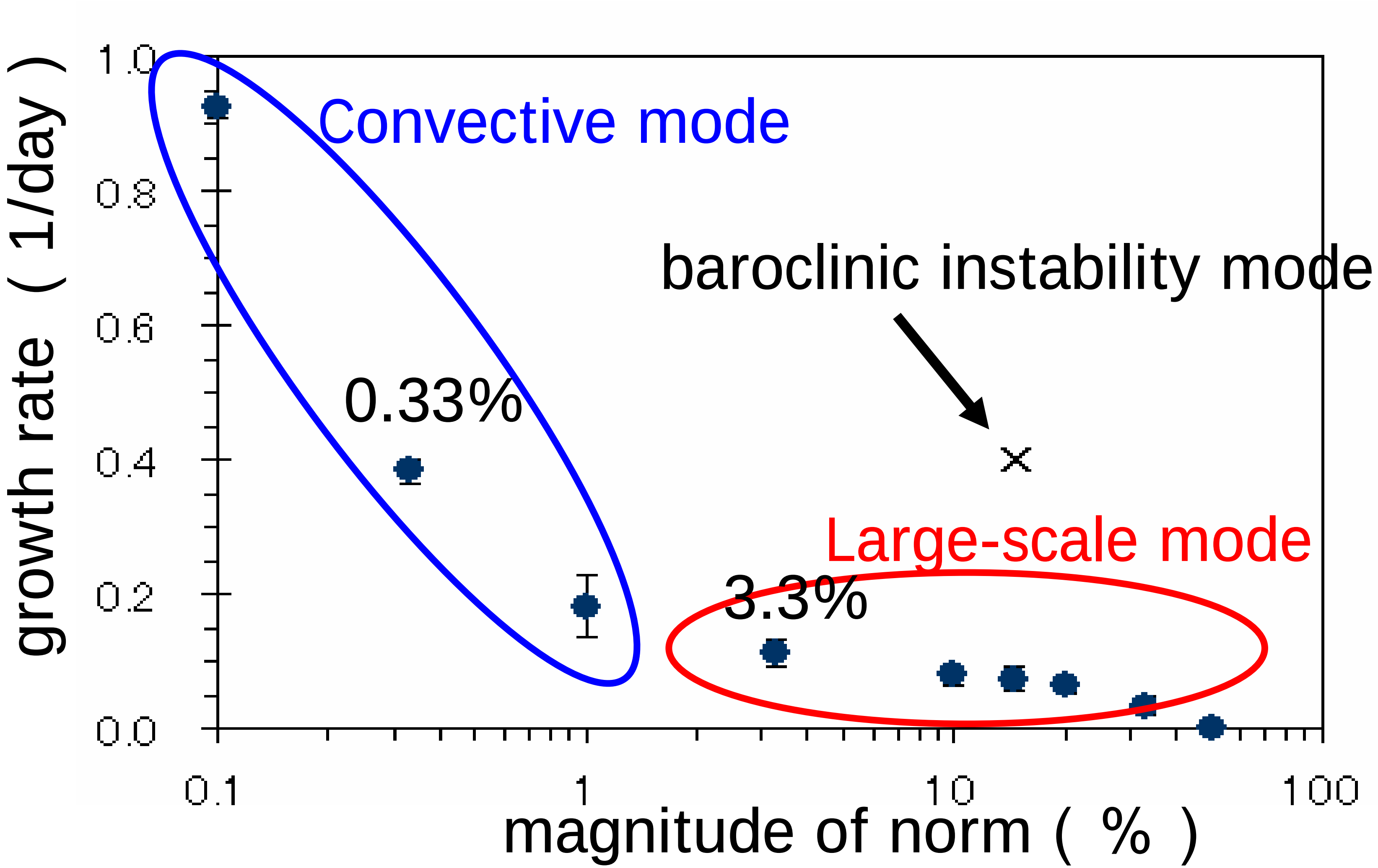
- The model used in this study: T106L40 (JMA-GSM0305)
- The 2nd BV is almost identical to the 1st BV
- Analyzed period: Nov. 2003 - Jan. 2004

Observed MJO (10S-10N)





Growth Rate of the 1st Tropical BV during 24hrs

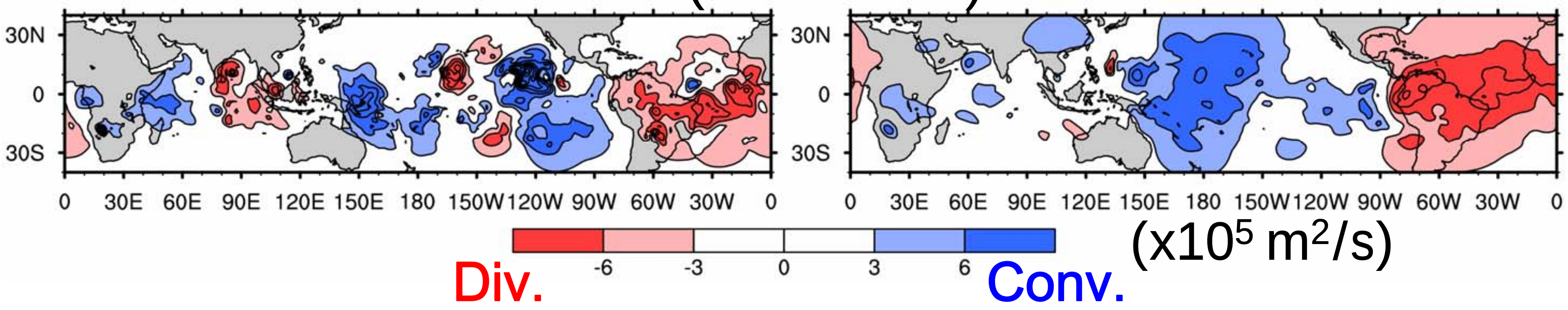


- Existence of large-scale unstable mode in the tropics suggests that the MJO is linearly unstable to infinitesimal perturbations

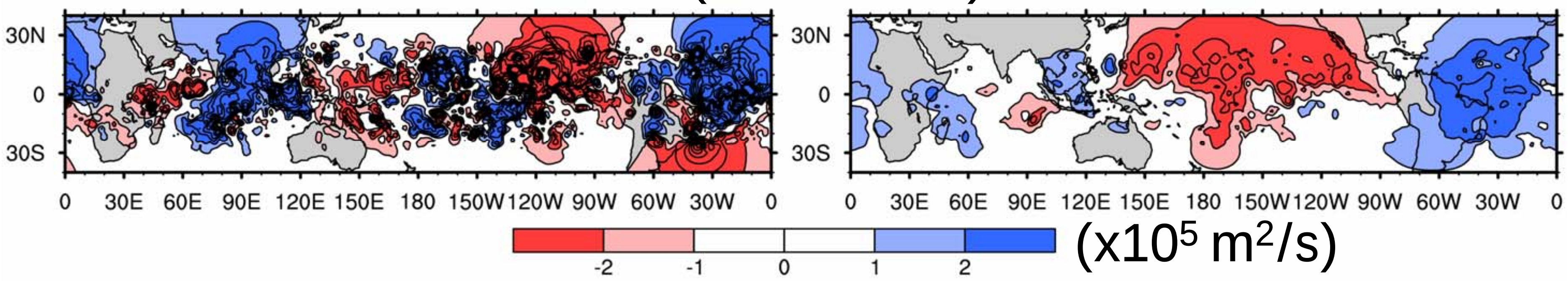
Initial Perturbation (1st BV) on 26 Nov 2003

Convective Mode(0.33%) Large-scale Mode(3.3%)

X200(normalized)

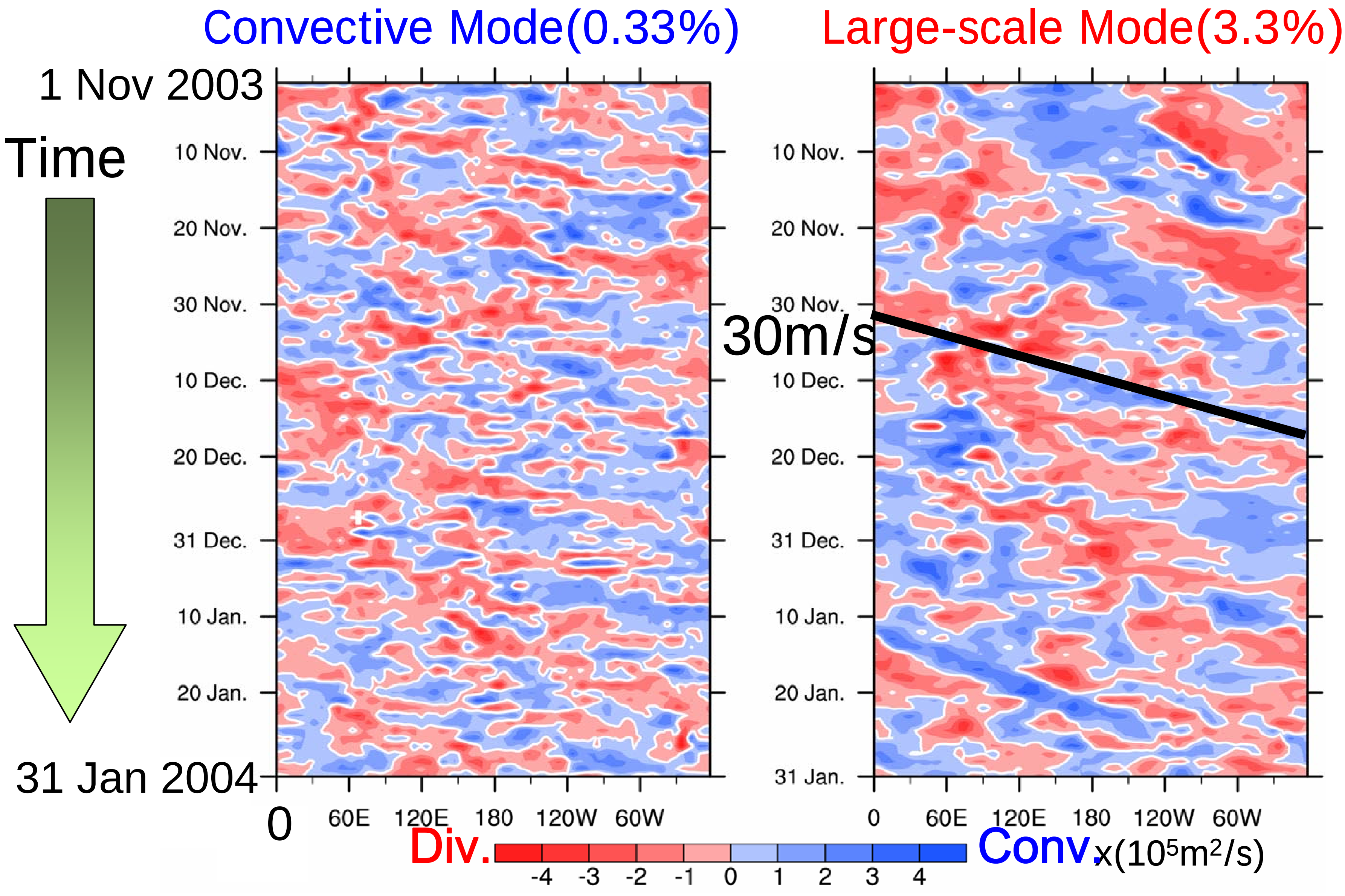


X850(normalized)

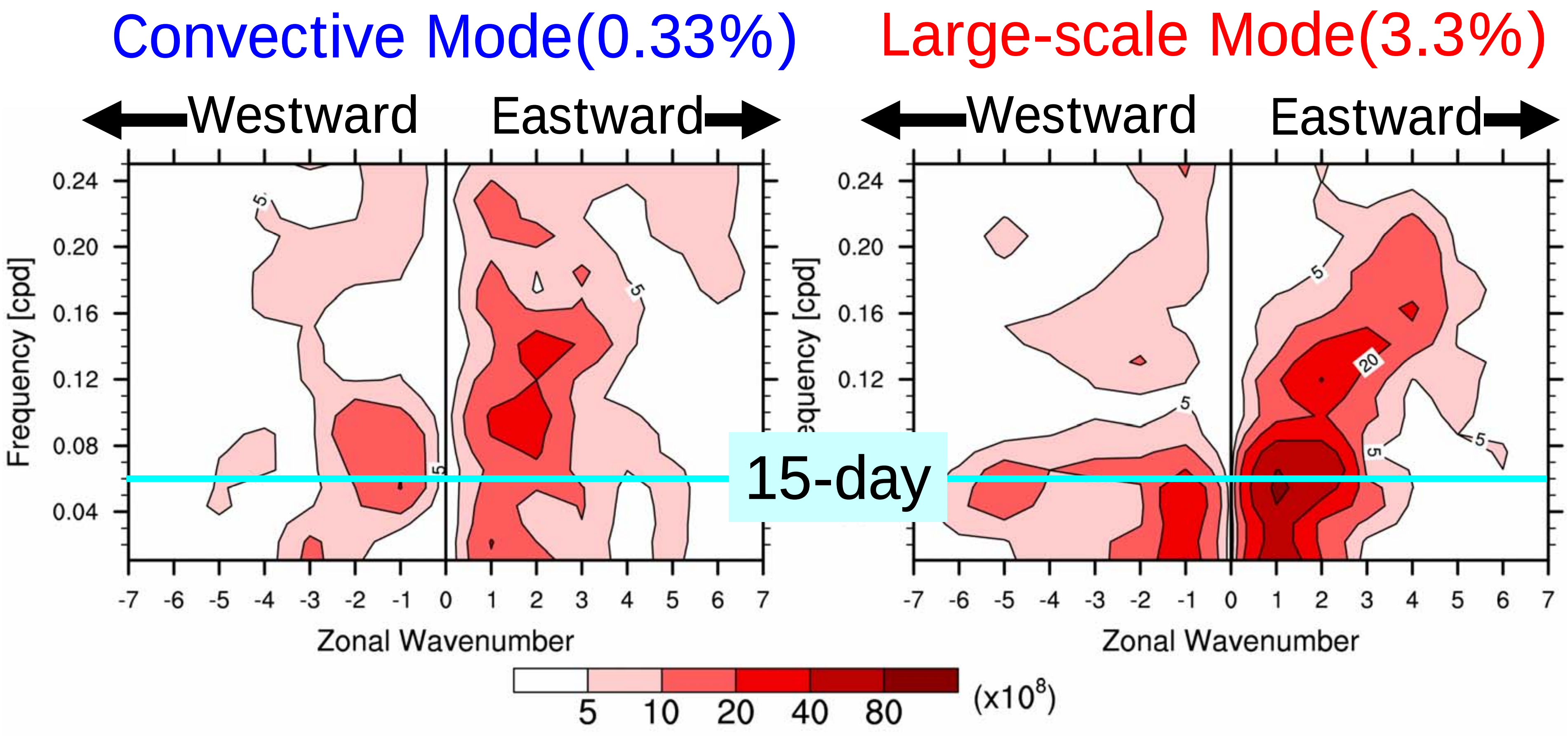


The large-scale mode is characterized by a baroclinic structure with dominant zonal wavenumber 1 components in the tropics.

X-T Diagram of the 1st BV
X200 averaged over 10S-10N



Time-Space Spectrum of X200 for the 1st BV



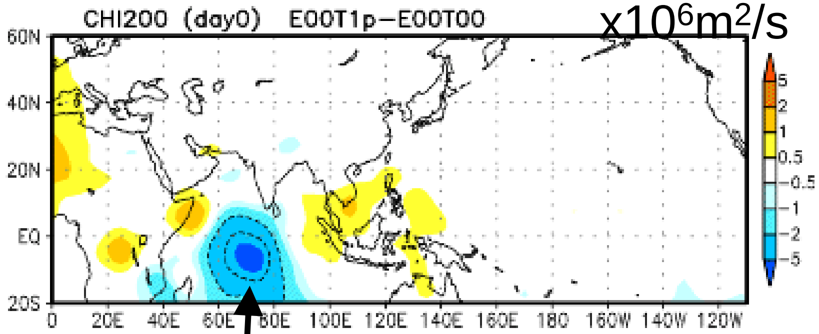
・ Large-scale mode: a clear spectral peak at eastward propagating WN1 component with a period of about 15days (a phase speed of 30m/s).

・ Convective mode: spectral peak is weak, and small-scale components

Influence of Tropical Perturbation to the Extratropics
Time Evolution from 18 Dec 2003

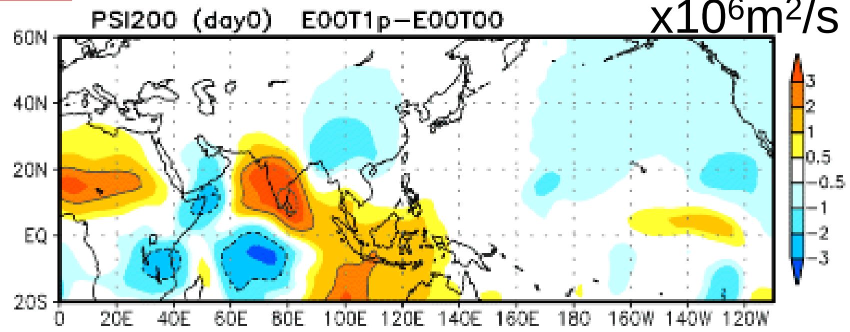
X200 | Perturbation | ψ200

x10⁶m²/s



day 0

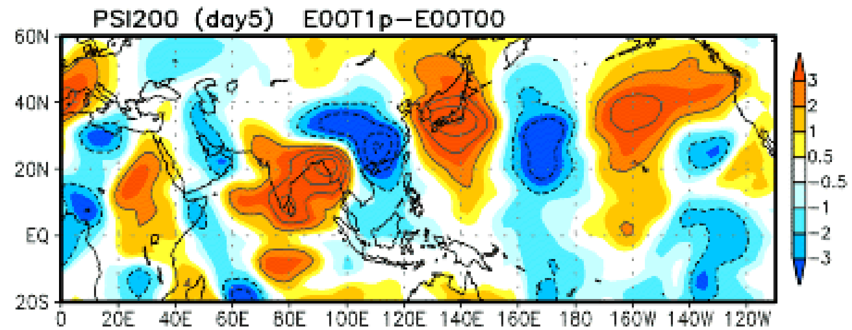
x10⁶m²/s



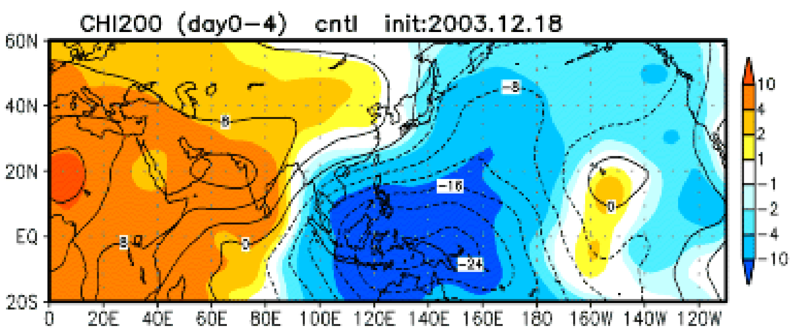
act as the Rossby wave source,

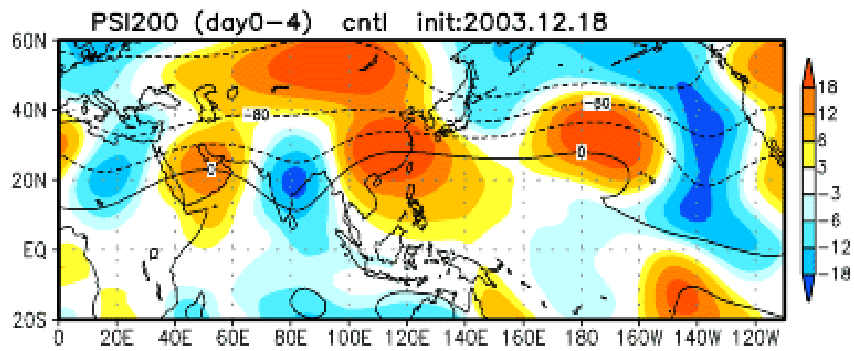
and affect ψ200 field over Japan after 5 days

day 5



Control Forecast averaged over day 0--4 (anomaly from the climatology)





Summary Part I

- We have developed tropical initial perturbations for ensemble prediction by modifying the operational BGM method
  - Obtained perturbations depend on the magnitude of norm:
    larger than 3.3% of clim. variance: large-scale mode
    smaller than 1% of clim. variance: convective mode
  - Large-scale mode is characterized by growing eastward propagating zonal wavenumber 1 components of the first baroclinic structure with a phase speed of 30m/s, which suggests that MJO is unstable to infinitesimal perturbation
- The Obtained perturbations are operational since March 2007.

Part II

Medium-range EPS and Typhoon EPS using Initial Perturbations with Singular Vectors

Acknowledgements:
Munehiko Yamaguchi[(1)], Ryota Sakai[(1)] , and Masayuki Kyouda[(2)]

(1) Numerical Prediction Division, Japan Meteorological Agency
(2) Climate Prediction Division, Japan Meteorological Agency

Specifications of JMA medium-range EPS

		Current Version	New Version (from 21Nov 2007)
EPS model resolution		TL159L40	TL319L60
Ensemble size		51	51
Forecast range		216hours	216hours
Perturbation	Generator	BGM method	SV method
	Resolution		TL63L40
	Area	NH and TR (20S-90N)	NH : 30N-90N TR : 20S-30N
	Physics in linearised model		NH : simplified dry processes TR : full processes
	Optimization time		NH : 48 hours TR : 24 hours
	Evolved SV		used

Total Energy Norm

- Definition to measure perturbation growth :
  total energy norm (Barkmeijer et al. 2001)

$$< \delta x, E_{TotalEnergy}\delta x >= \frac{1}{2}\int_D \int_1^{40} \left[u'^2 + v'^2 + \frac{c_p}{T_r} T'^2 \right] d\eta dD$$

$$+ \frac{\varepsilon}{2}\int_D \int_1^{9} \frac{L^2}{c_p T_r} q'^2 d\eta dD + \frac{1}{2}\int_D RT_r \left(\frac{p'_s}{p_r} \right)^2 dD$$

T_r=300K : reference temperature
p_r=800hPa : reference pressure

<u>weight factor on the moist energy term</u>
ε= 1/25 in the medium-range EPS
(= 1 in the typhoon EPS)

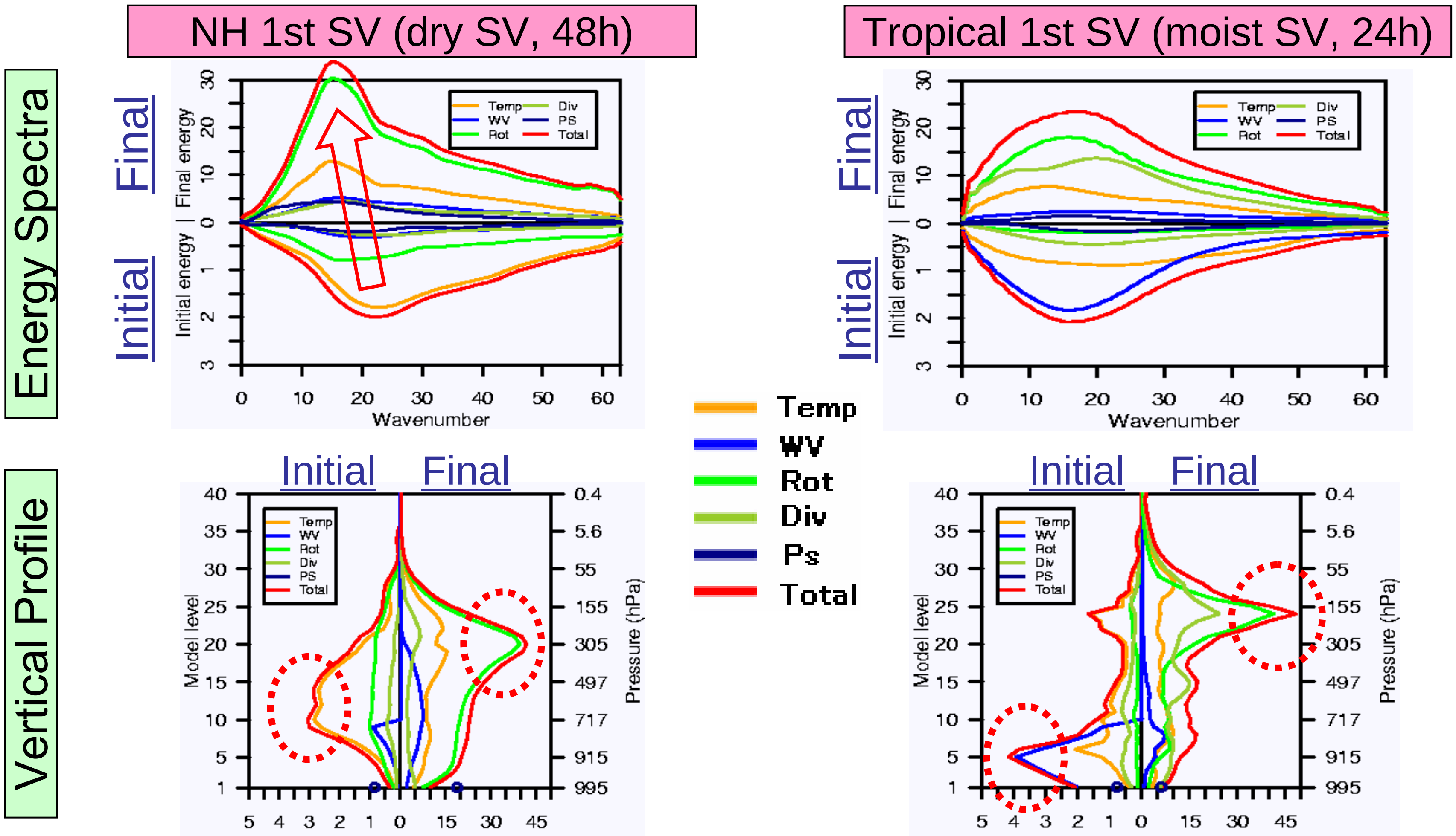
c_p : specific heat at constant pressure of dry air

L : latent heat of condensation

R : gas constant

Energy Spectra and Vertical Profiles of the 1st SV for the medium-range EPS

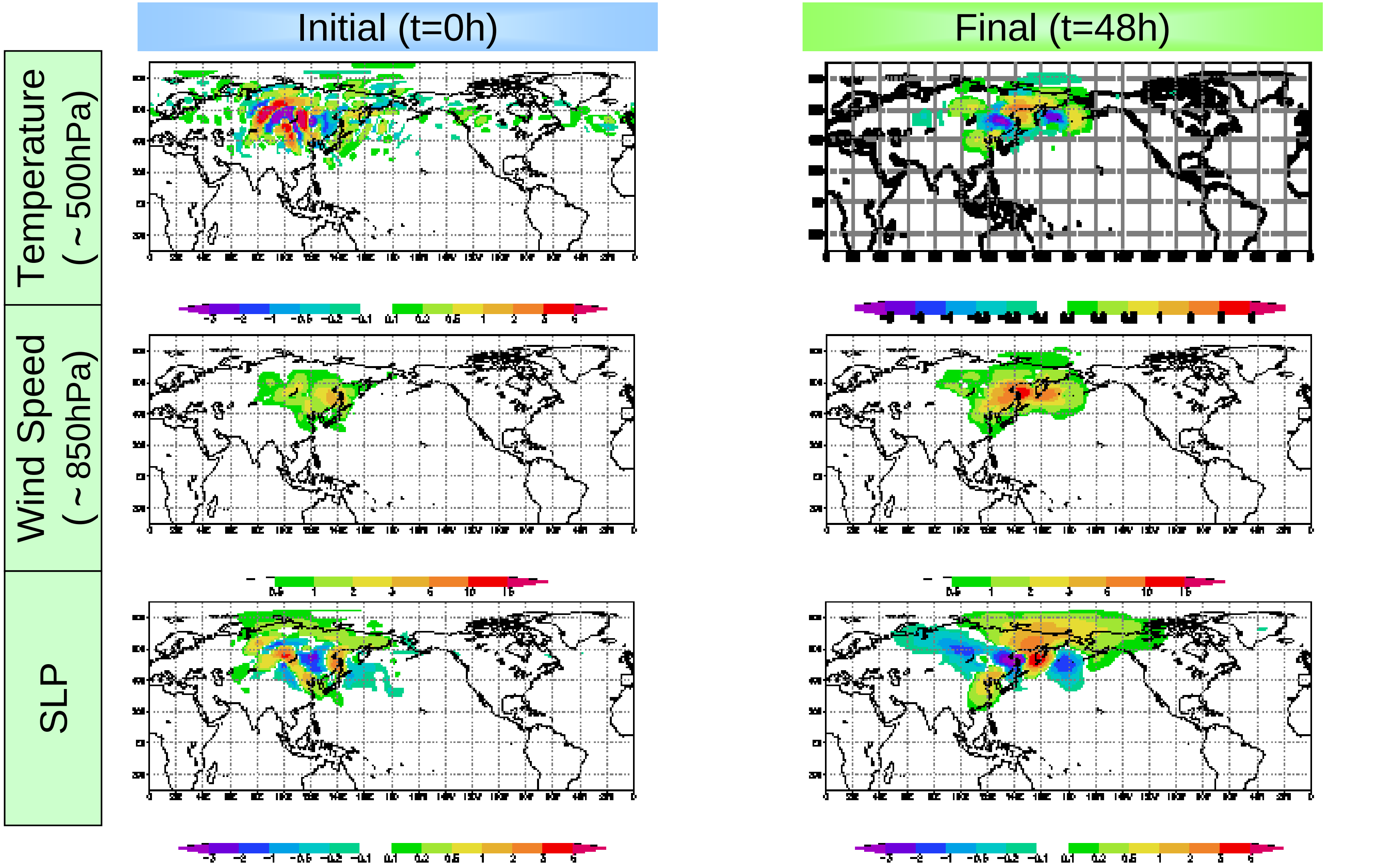
Initial time :12UTC on 2 Aug 2004



- Upscale energy propagation from potential energy at the middle troposphere up to kinetic energy at the upper troposphere.
- The SV structure represents the baroclinic instability
- Upward energy propagation from moist energy at the lower up to kinetic energy at the upper.
- Upscale energy propagation is not remarkable

Initial and Final Fields of the NH 1st SV for the medium-range EPS

Initial time :12UTC on 2 Aug 2004

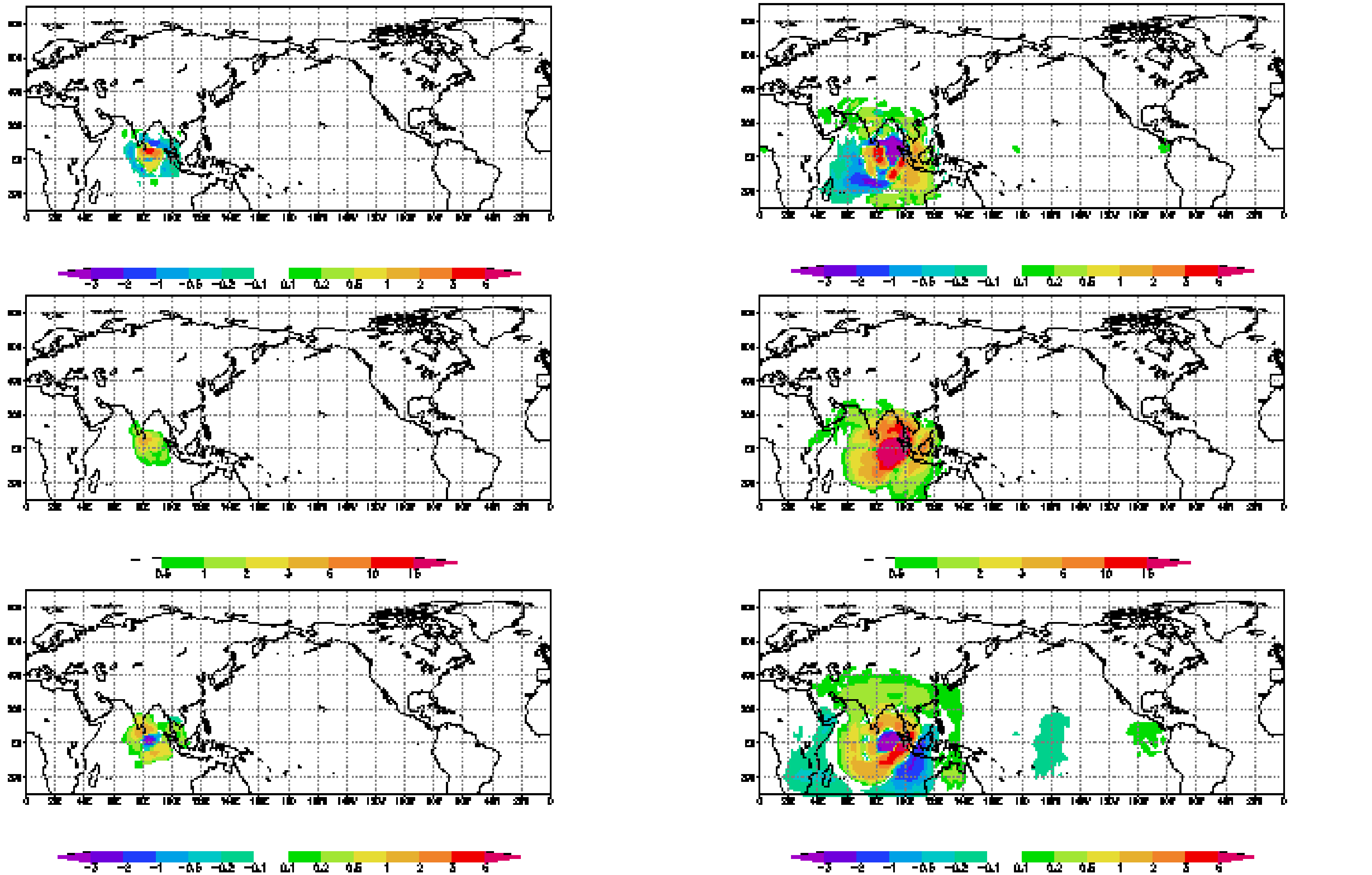


- Baroclinic small-scale structure with a westward tilt with height at the initial time
- Synoptic scale structure at the final time

Initial and Final Fields of the Tropical 1st SV for the medium-range EPS

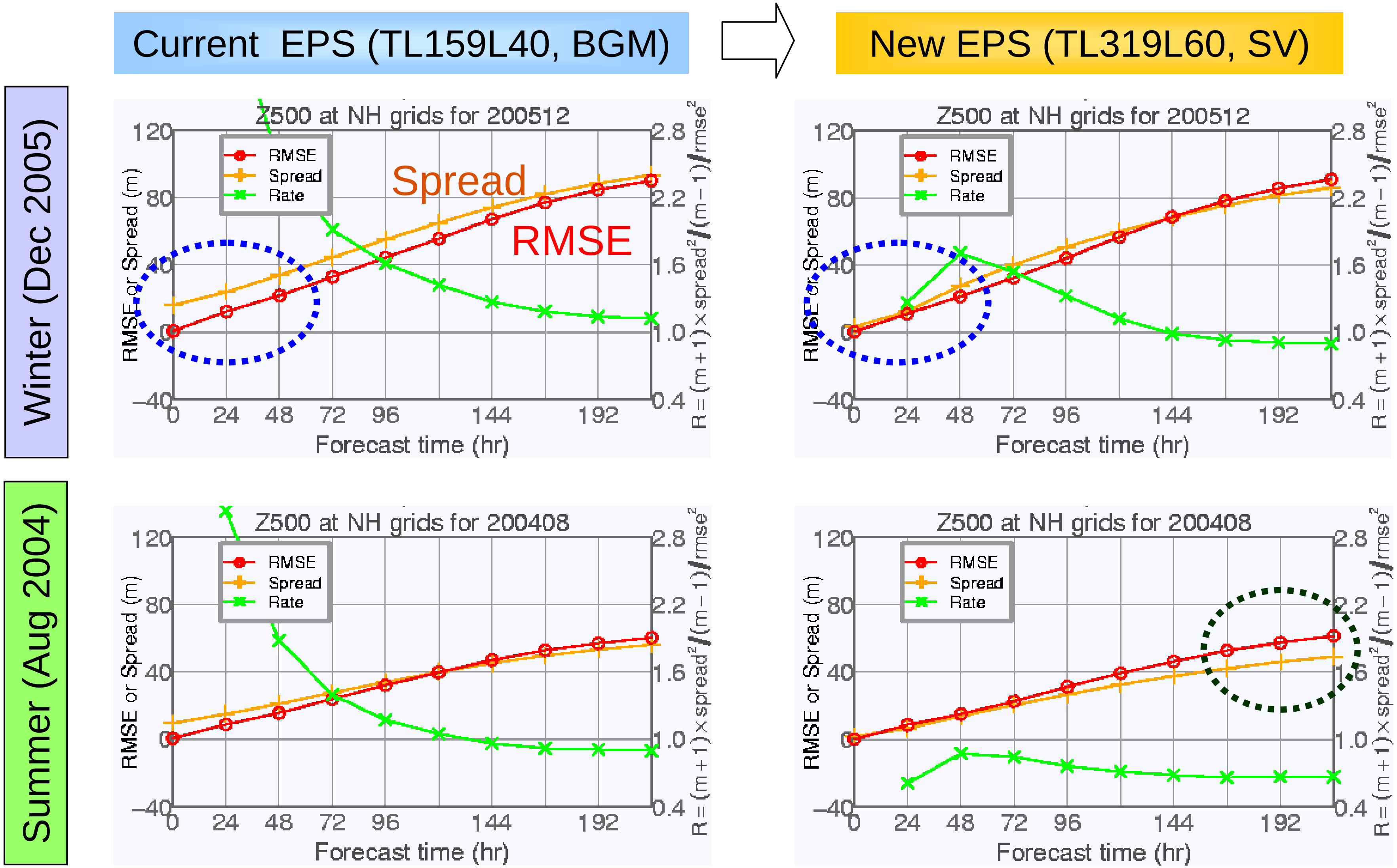
Initial time :12UTC on 2 Aug 2004

	Initial (t=0h)	Final (t=24h)
Temperature (~500hPa)		
Wind Speed (~850hPa)		
SLP		



- Perturbation growth in the kinetic fields during optimization time
- localized over the active convection region

Ensemble Spread versus Ensemble Mean RMSE for NH Z500



- Large spread in the early range is improved.
- Spread in the late range is underestimated in summer.

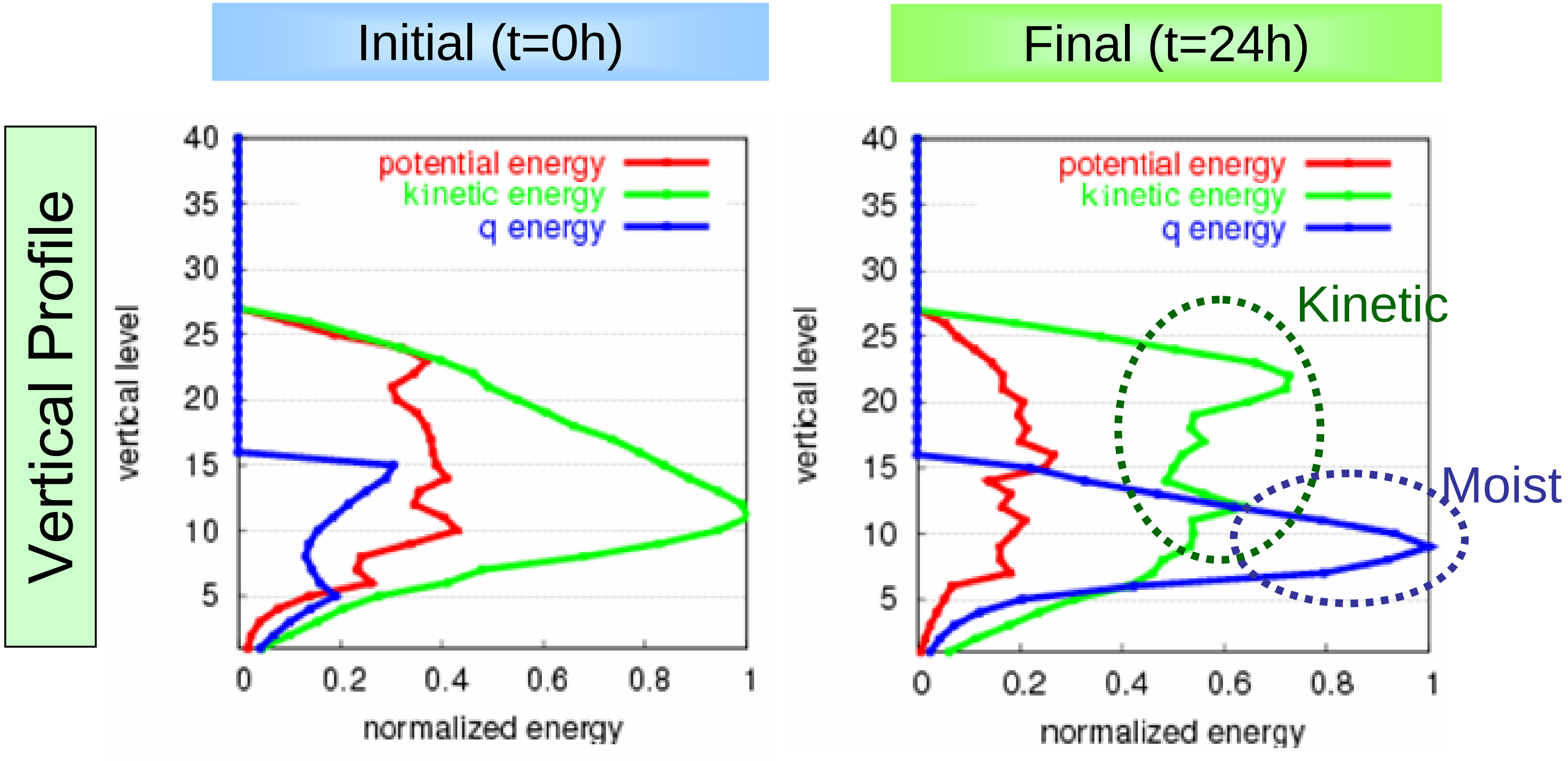
Specifications of the Typhoon EPS

		Typhoon EPS
Resolution		60(km)x60(km) with 60layers
Initial time		00, 06, 12, 18UTC
Forecast time		132 hours (not fixed)
Number of targeted typhoons		3
Ensemble size		11
Perturbation	Generator	SV method
	Resolution	T63L40
	Area	Typhoon: 20° x 10° (target)
		RSMC: 100E-180E, 20N-60N
	Optimization time	24 hours
	Physics in linearised model	Typhoon: Full processes
		RSMC: simplified dry processes

- semi-operational from May 2007
- operational in 2008
- Typhoon intensity forecasting will be supported by 20km-GSM

Energy Vertical Profiles of the 5 leading SVs for Typhoon

Analyzed period: 5 Aug 2005 - 24 Sep 2005

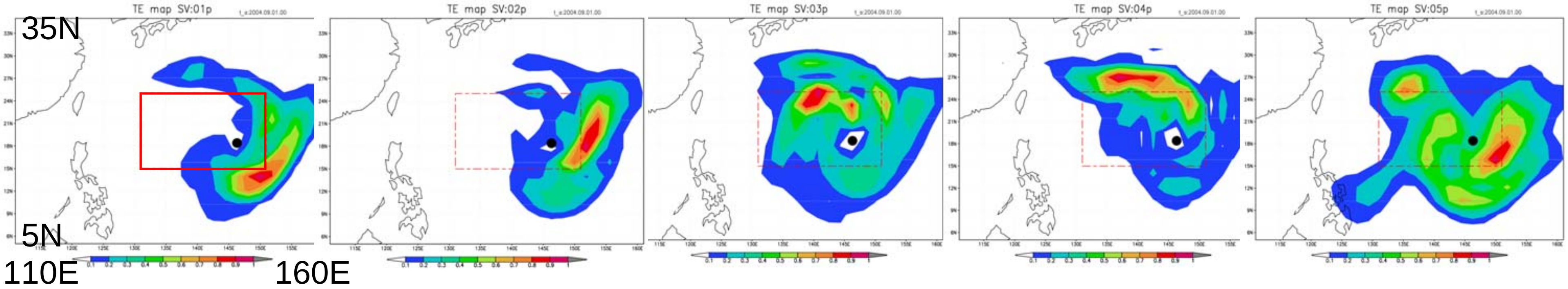


Total Energy of the 5 leading SVs for Typhoon

Vertically accumulated total energy field (Initial time : 00UTC 01 Sep. 2004)

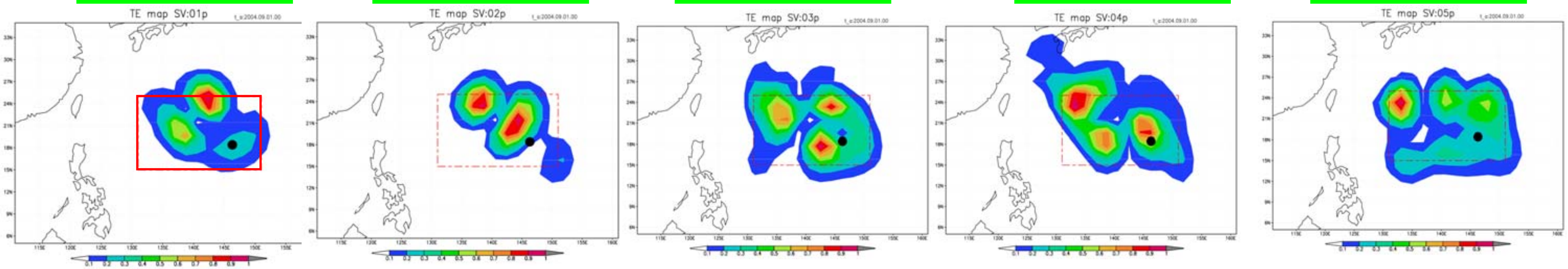
Initial SVs (t=0h)

01p 02p 03p 04p 05p



Final SVs (t=24h)

01p 02p 03p 04p 05p



Summary Part II

- JMA has developed singular vector perturbations for the medium-range EPS and the typhoon EPS.
  - The medium-range EPS will be upgraded on 21 November 2007.
  - The typhoon EPS will be introduced in 2008.
- Two sets of targeted SVs

medium-range EPS	typhoon EPS
Extra-tropical NH (dry SVs)	RSMC
Tropics (moist SVs)	Typhoon

For further studies

- Development of stochastic physics to represent model error
- Improvements of the EPS model