Predictability of explosive cyclones over the northwestern Pacific region using ensemble reanalysis

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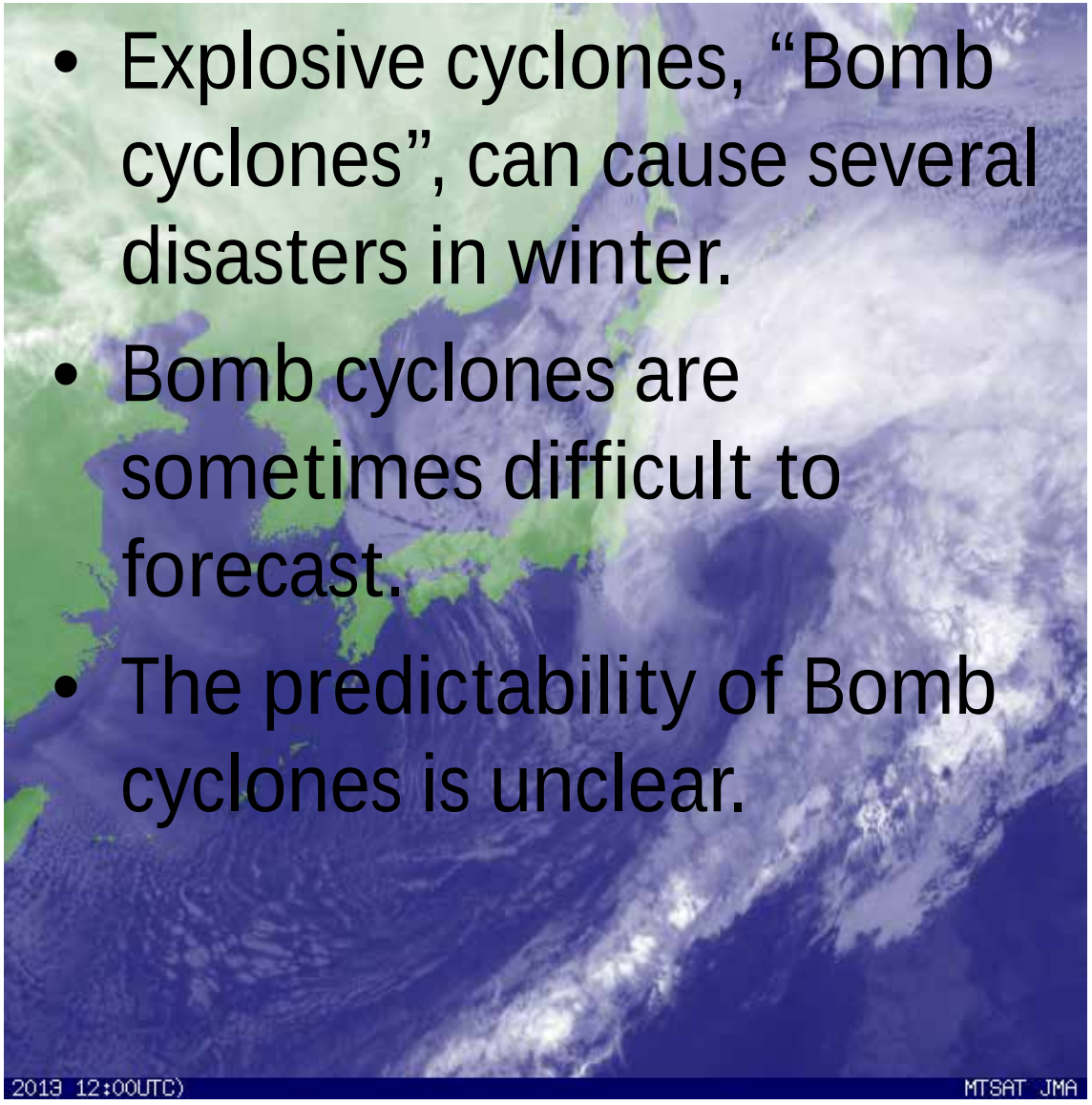
Kuwano-Yoshida, A. and T. Enomoto, Predictability of explosive cyclogenesis over the northwestern Pacific region using ensemble reanalysis, *Mon. Wea. Rev.*, under 2nd review.

Introduction

- Explosive cyclones, “Bomb cyclones”, can cause several disasters in winter.
- Bomb cyclones are sometimes difficult to forecast.
- The predictability of Bomb cyclones is unclear.

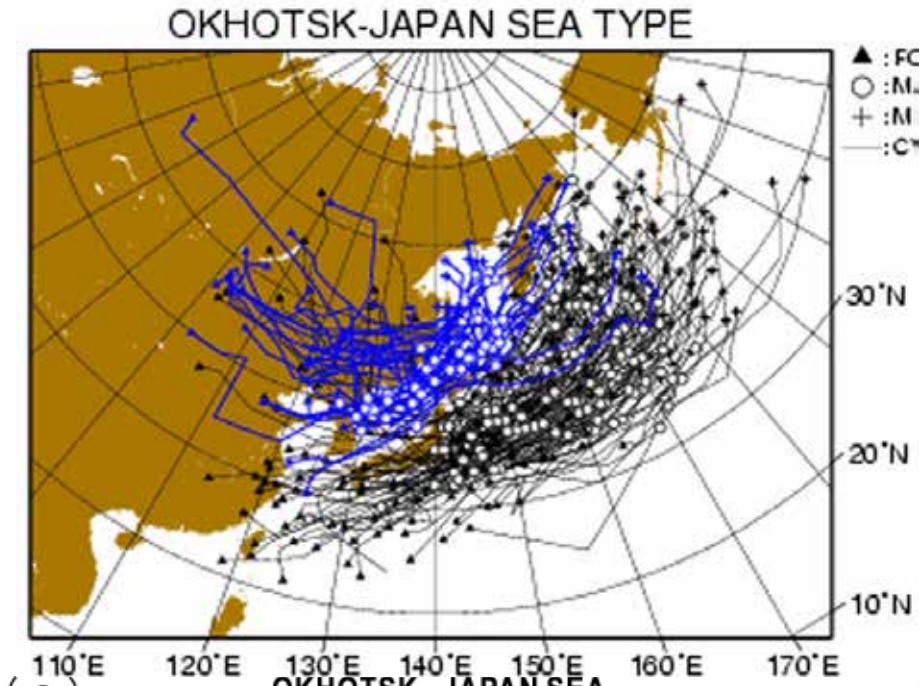


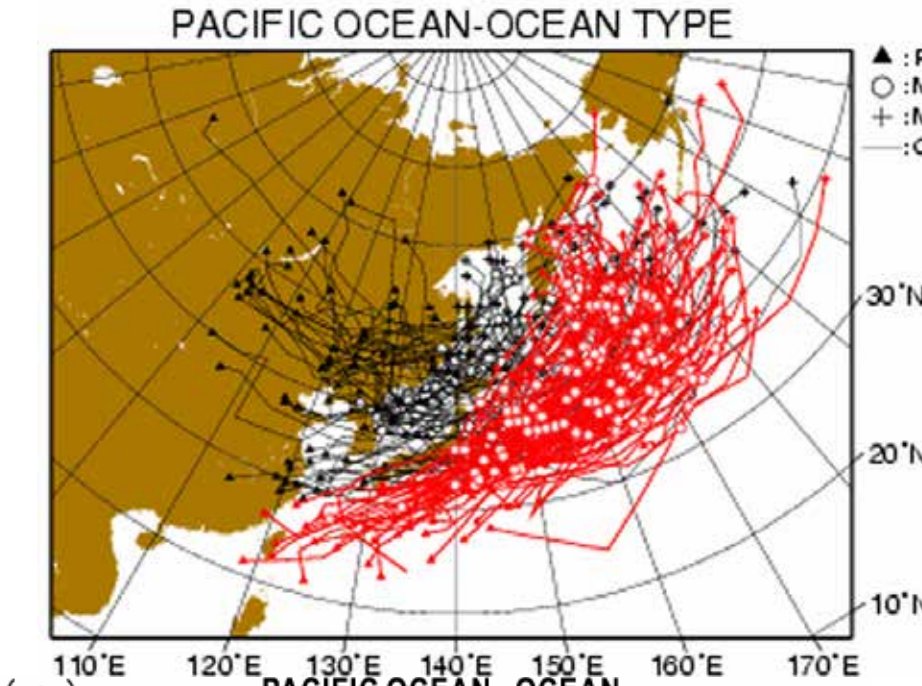
2013. 1. 14
Photo by A. Yamazaki

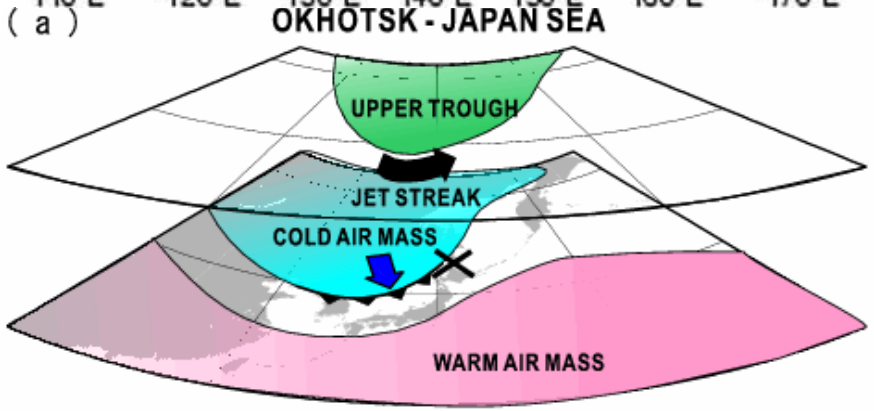
Bomb cyclones in the northwestern Pacific region

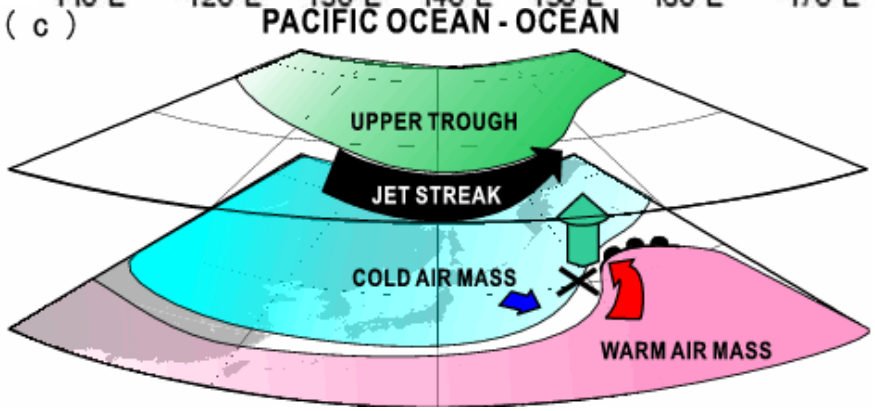
OJ: Dry

PO: Moist









Yoshida and Asuma (2004, MWR)

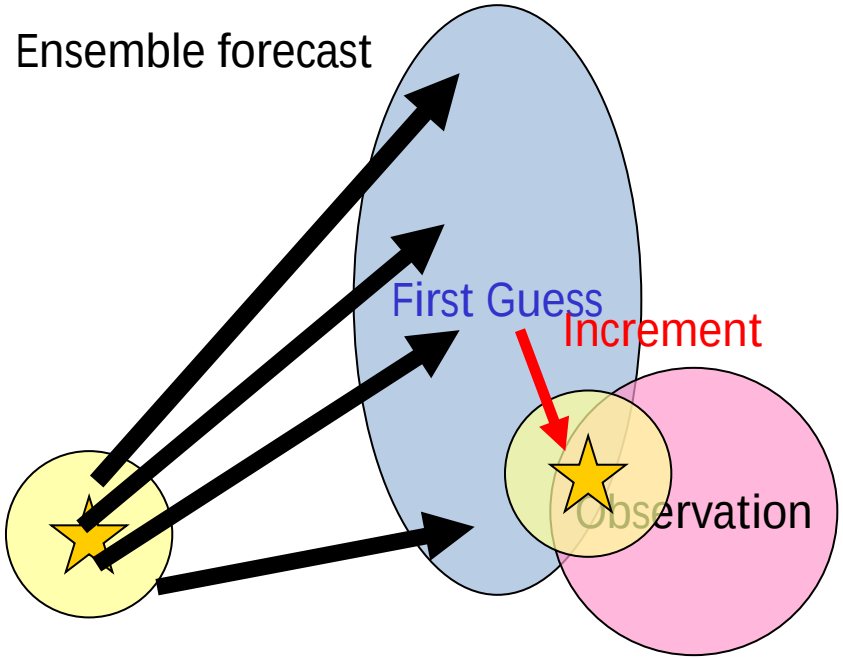
ALERA

(AFES-LETKF Experimental Ensemble Reanalysis, Miyoshi et al. 2007, SOLA)

- AFES2 (T159 (80km) L48) + LETKF
- 40 member ensemble
- 2005.5.1〜2007.1.10
- U, V, T, TTD, Z, SLP(1.25deg, 17 layer)
  - 6 hourly analysis ensemble mean and spread
  - daily 40 member analysis (6-hourly interpolation)
  - 6 hourly first guess ensemble mean and spread
- Available from DODS server
  - http://www.jamstec.go.jp/esc/afes/alera/about.html

Information from ensemble reanalysis

- **Analysis increment**
  - Skill of model forecast (model bias)
  - Assimilated analysis – first guess (6-hour forecast)
- **Guess spread**:
  - Uncertainty of forecast (initial condition error and its growth)
  - Standard deviation of first guess 40-member ensemble
- **Analysis spread**:
  - Uncertainty of analysis (initial condition)
  - Standard deviation of assimilated 40-member ensemble



How do errors distribute and develop associated with phenomena?

Objects

- Uncertainty and skill of 6-h forecast at explosive cyclogenesis in the northwestern Pacific region
- 3D structure of uncertainty in explosive cyclones
- The relationship between developing mechanisms and uncertainty

Zwack-Okossi (1986) development equation

$$\frac{\partial z_g}{\partial t} = P_d \int_{p_t}^{p_.} (-\mathbf{V}\times\nabla z_a)\,dp - P_d \int_{p_l}^{p_t} \left[\frac{R}{f} \int_{p}^{p_t} \frac{\nabla^2(-\mathbf{V}\times\nabla T)}{p}\,dp \right] dp$$

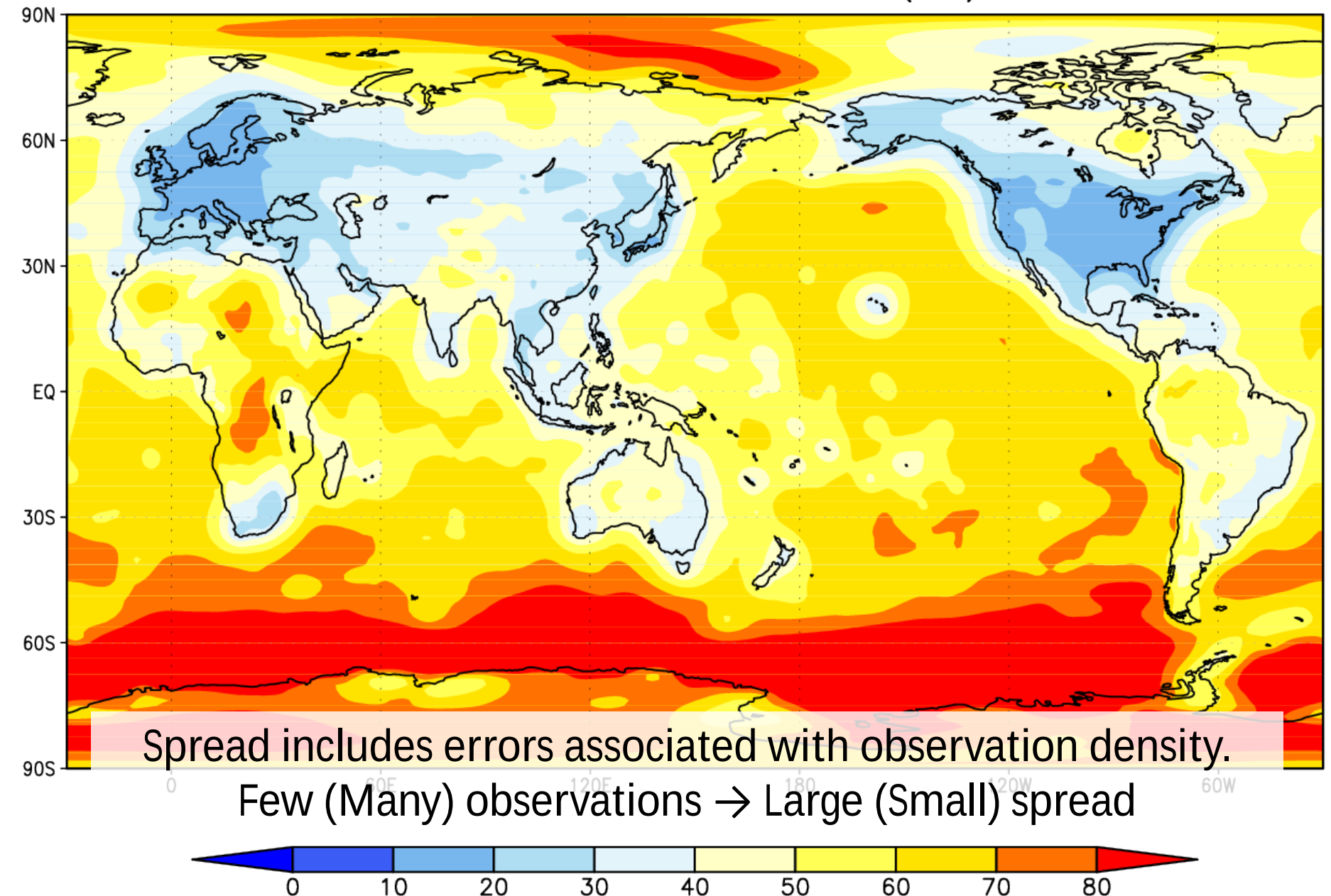
VADV **TADV**

$$- P_d \int_{p_l}^{p_t} \left[\frac{R}{f} \int_{p}^{p_t} \frac{\nabla^2(Q/c_p)}{p}\,dp \right] dp - P_d \int_{p_l}^{p_t} \left[\frac{R}{f} \int_{p}^{p_t} \frac{\nabla^2(Sw)}{p}\,dp \right] dp$$

LATH **ADIA**

- The local tendency of geostrophic relative vorticity at 925 hPa is diagnosed.

Annual mean of surface pressure spread

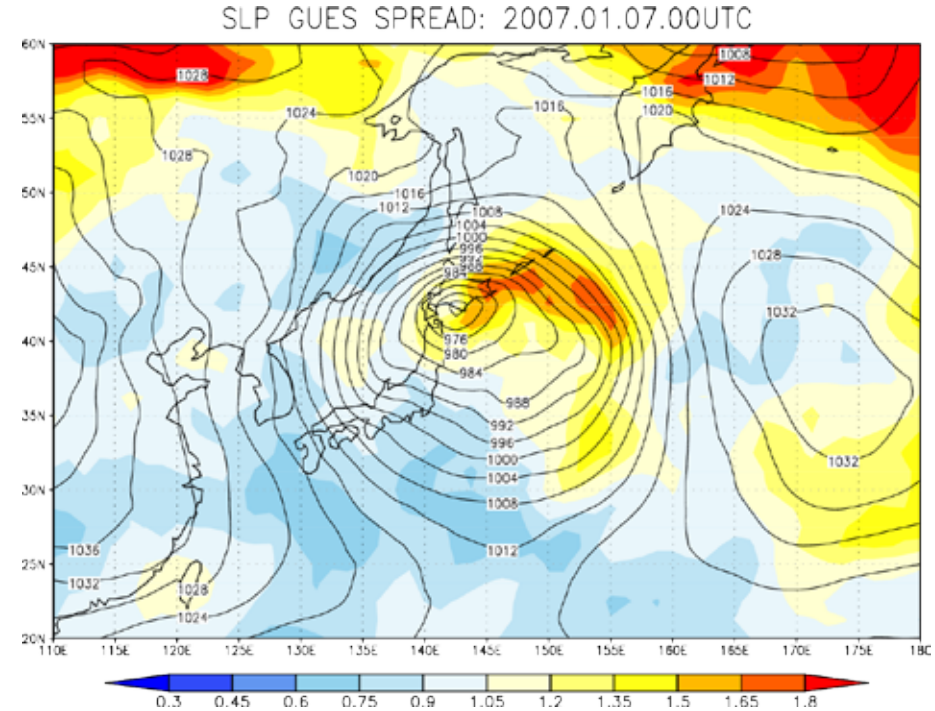


Spread includes errors associated with observation density.

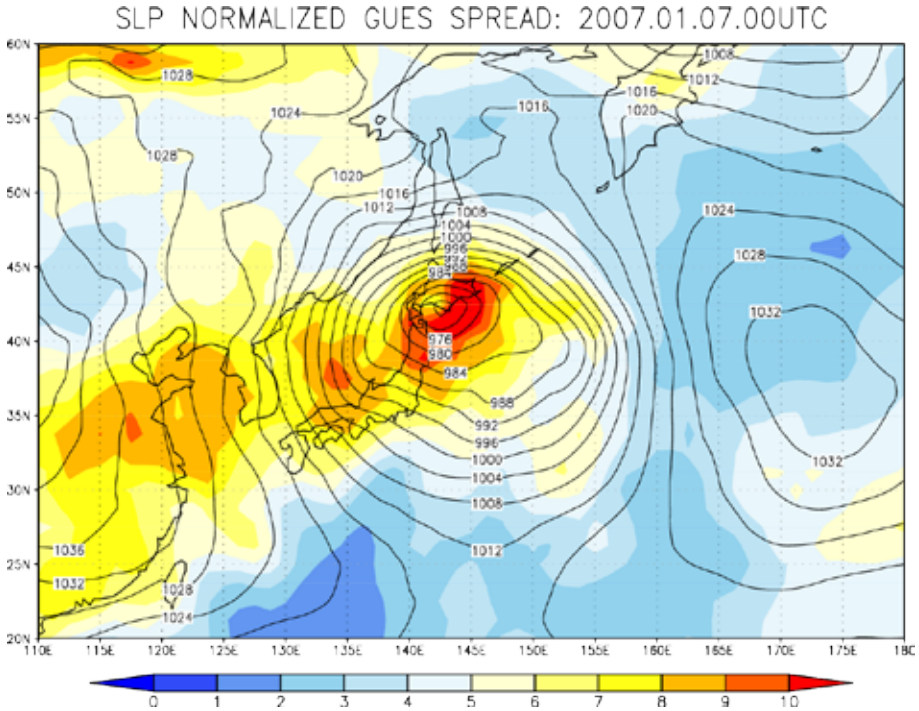
Few (Many) observations → Large (Small) spread

Spread normalization

Guess spread

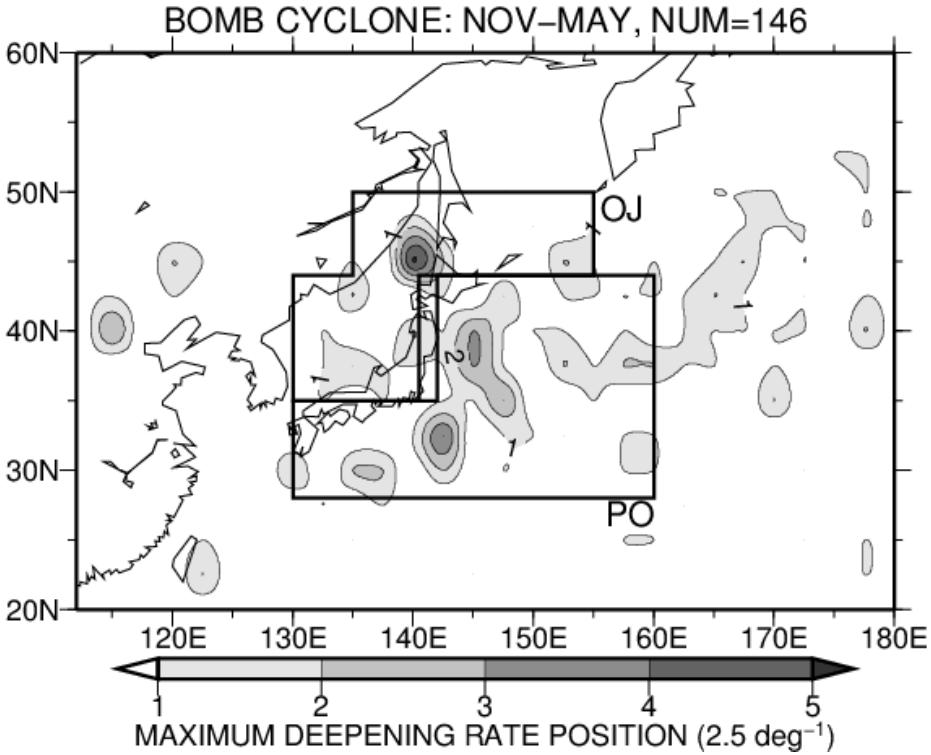


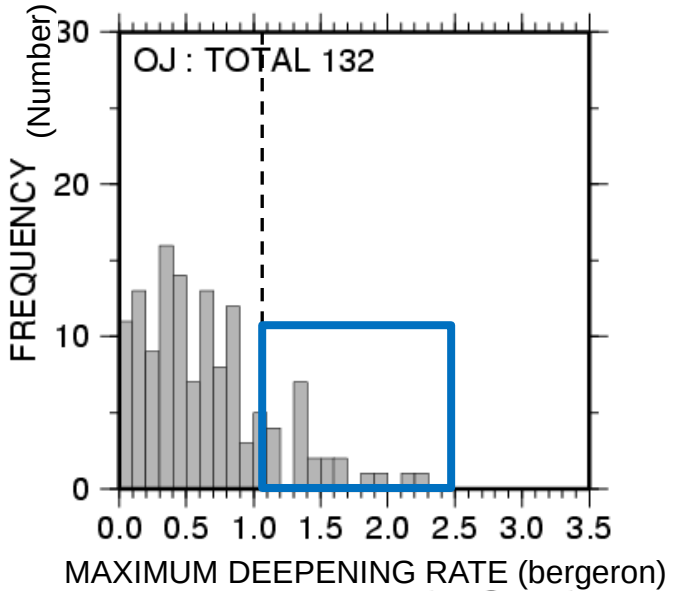
Normalized guess spread

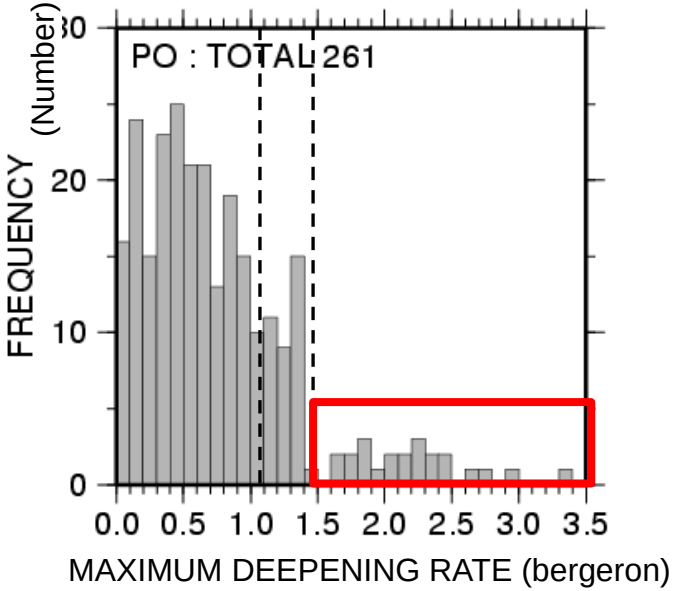


- Normalization of spread by its annual local standard deviation in time extracts the uncertainty depending on flow.

Detection of explosive cyclones







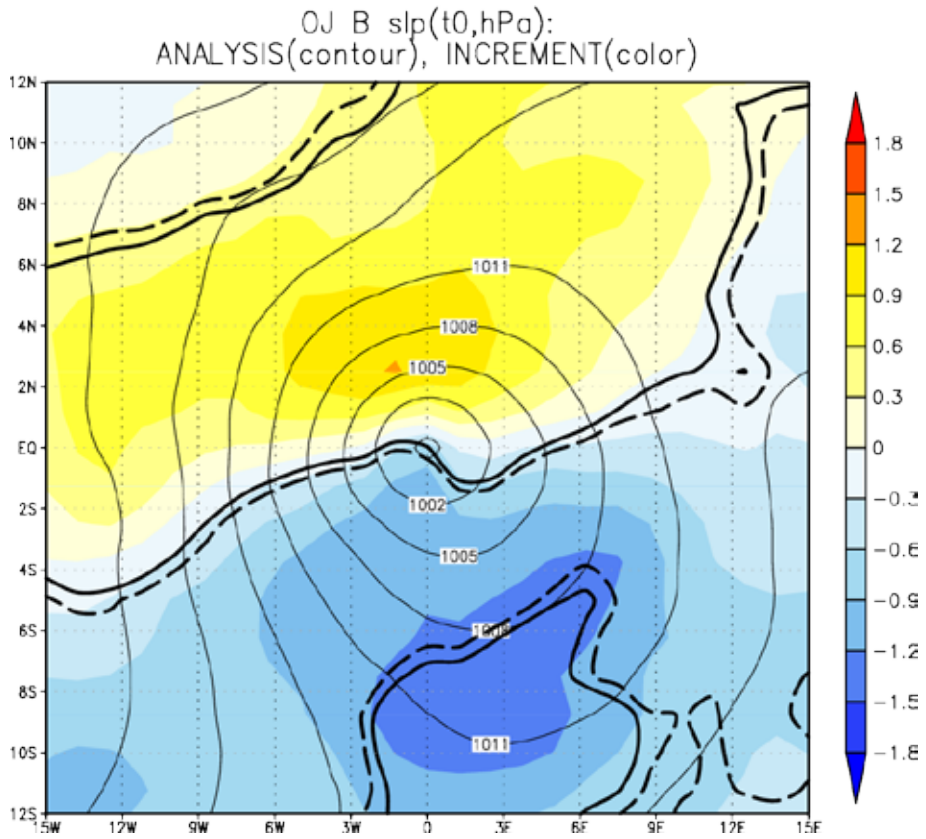
- Tracking local minimum of SLP

$$\frac{Dp}{6}\frac{\sin 60^\circ}{\sin q} \geq 1$$

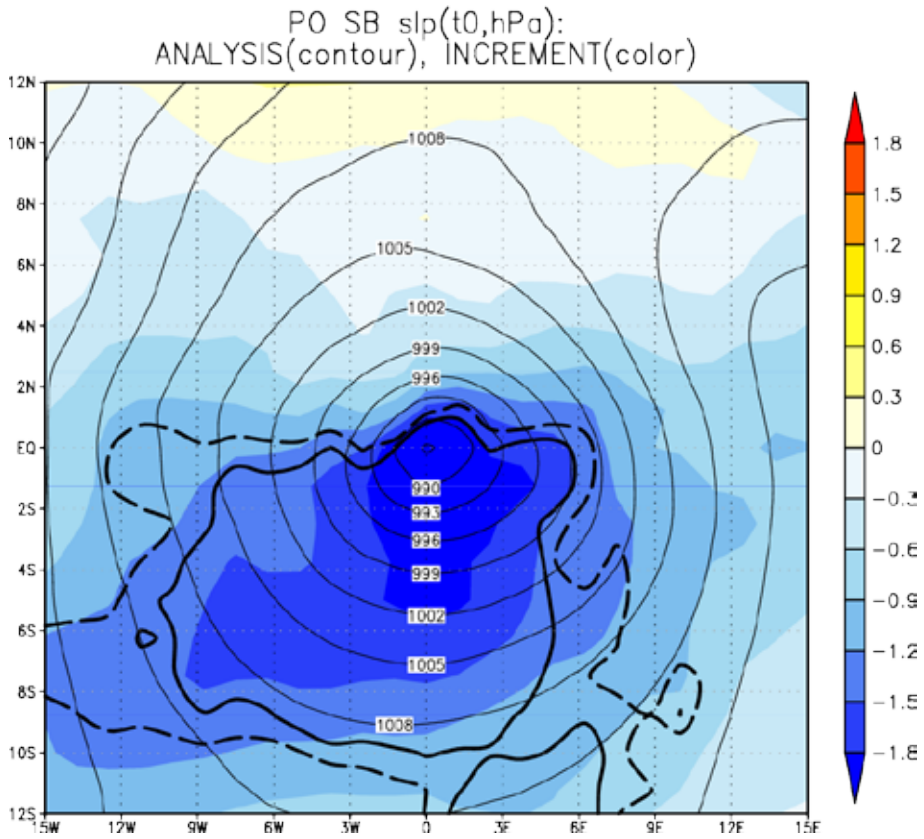
- Making **cyclone-relative composites** for OJ and PO at the time of the maximum deepening rate.

SLP increment

OJ

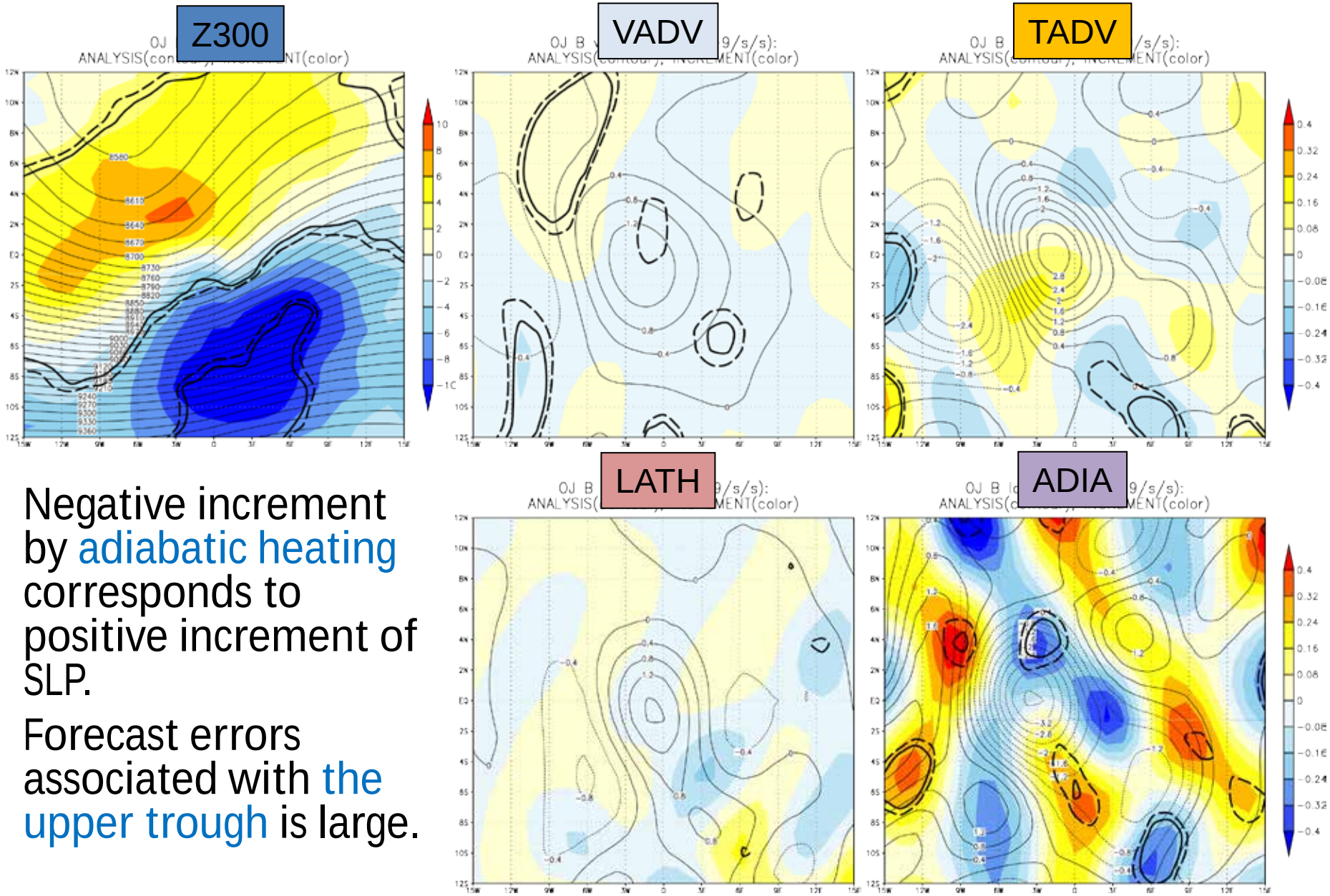


PO



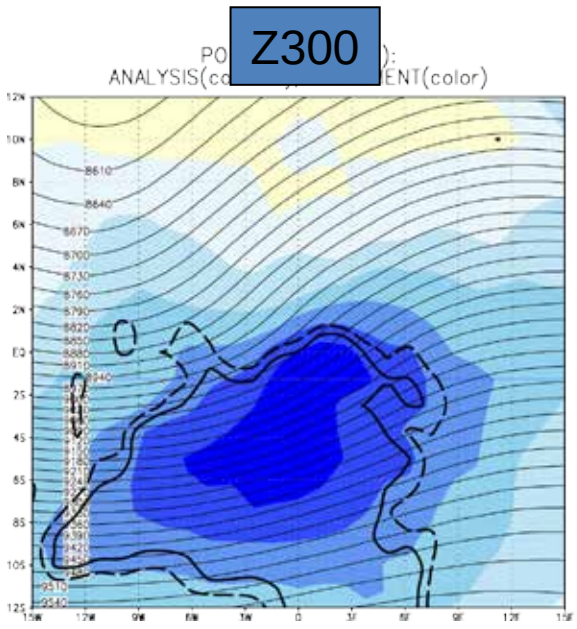
- OJ BOMB is forecast too far north compared to analysis.
- PO BOMB is forecast shallower than analysis.

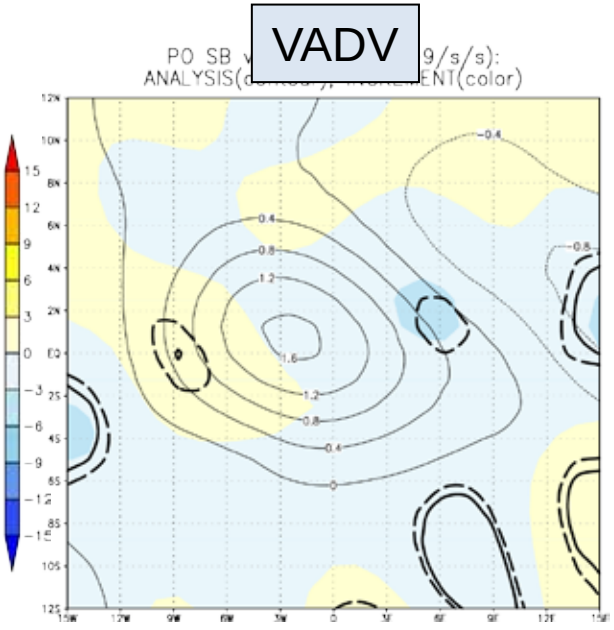
OJ Z-O Eq. increment

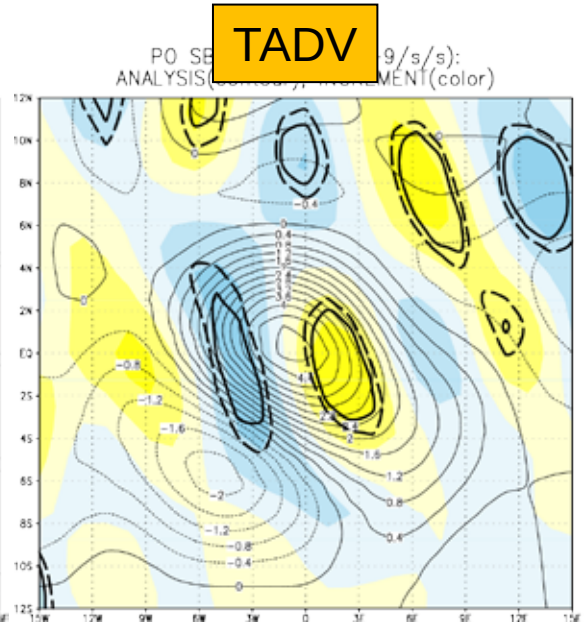


- Negative increment by adiabatic heating corresponds to positive increment of SLP.
- Forecast errors associated with the upper trough is large.

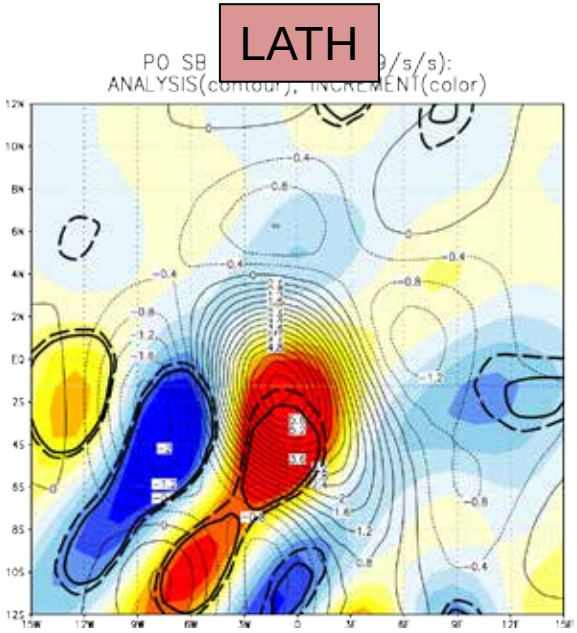
PO Z-O Eq. increment

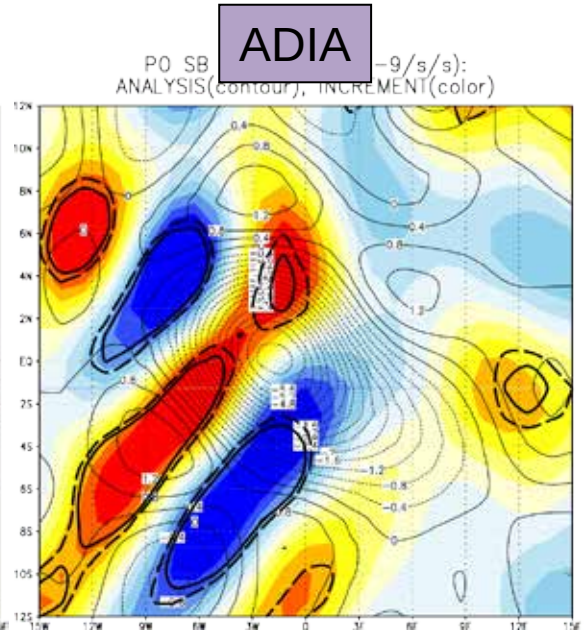






- Positive increment by latent heating is large at the cyclone center.
- Cloud and precipitation cause cyclogenesis forecast error.

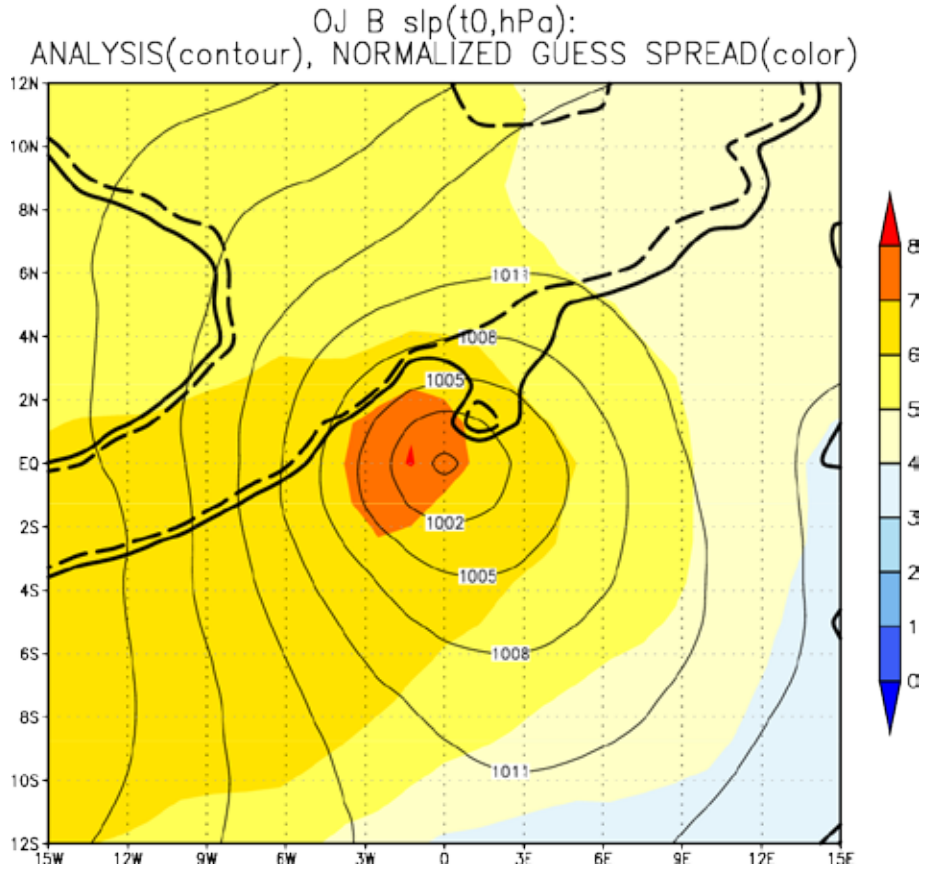


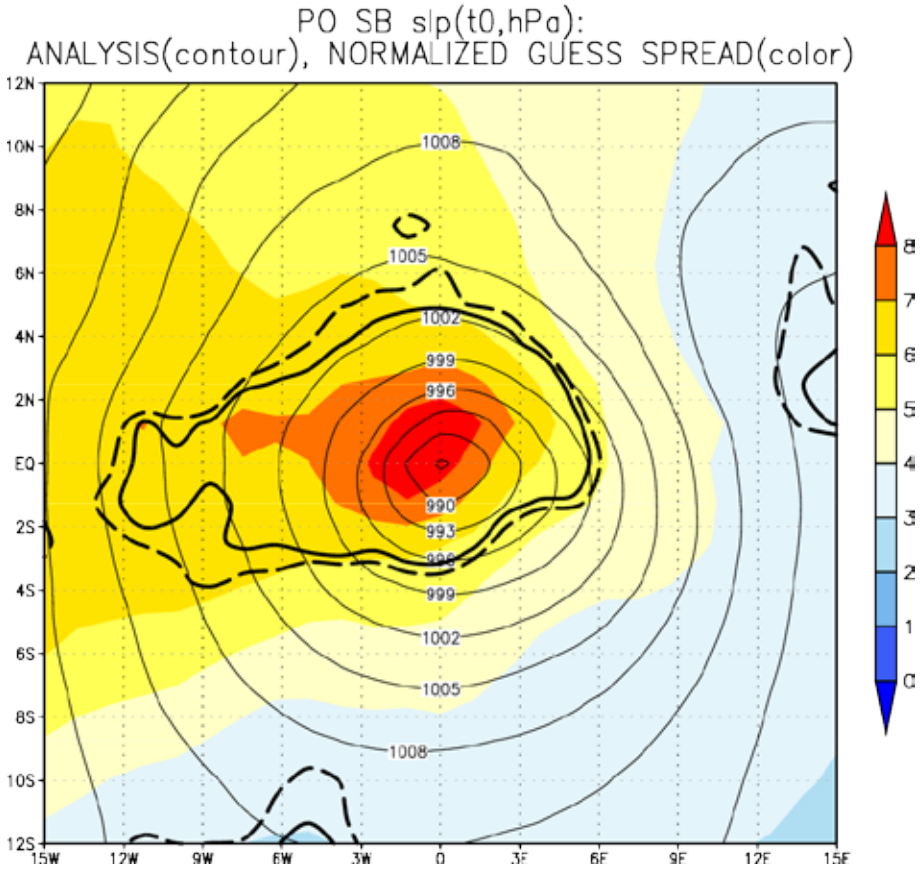


SLP normalized guess spread

OJ

PO

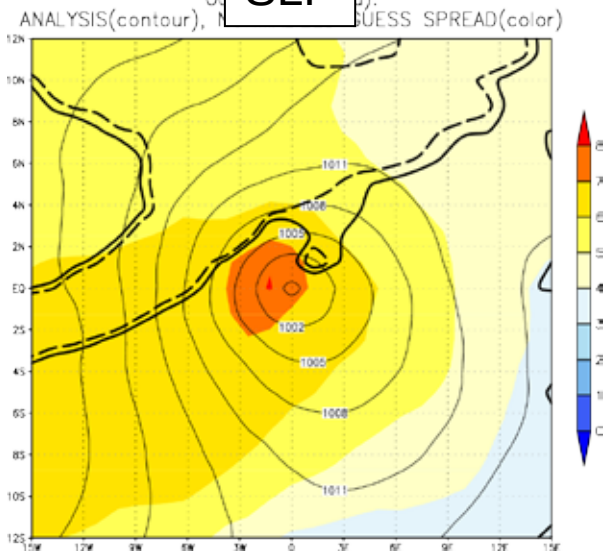




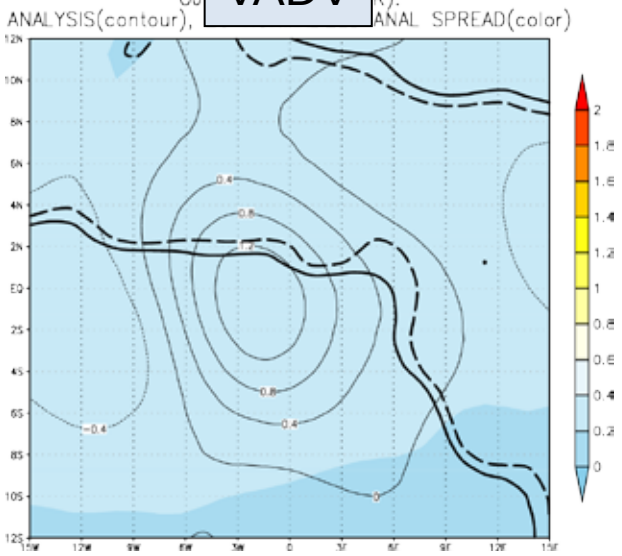
- SLP spread is large southwest of cyclone in OJ BOMB, while west or northwest in PO BOMB.

OJ Z-O Eq. spread

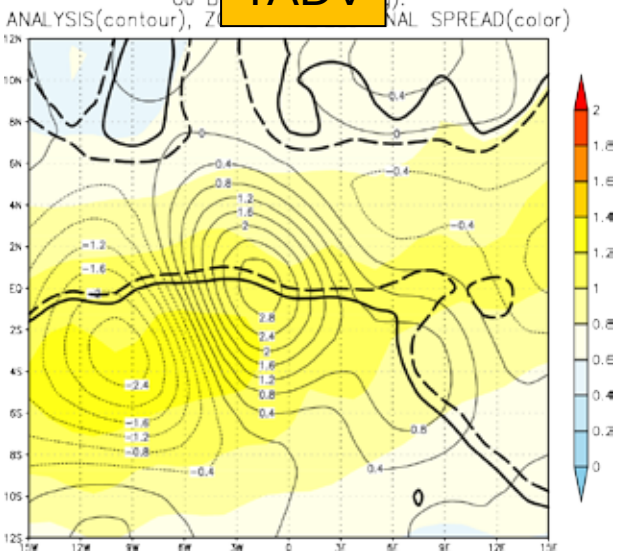
SLP



VADV

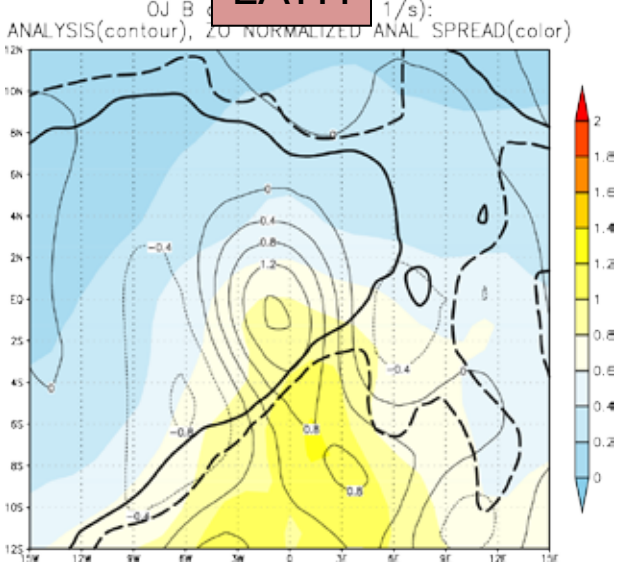


TADV

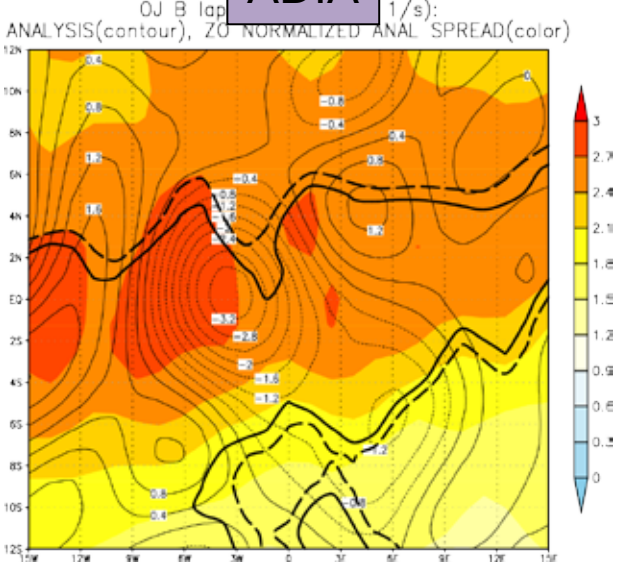


Uncertainty associated with adiabatic heating is the largest among the terms northwest and west of the center.

LATH

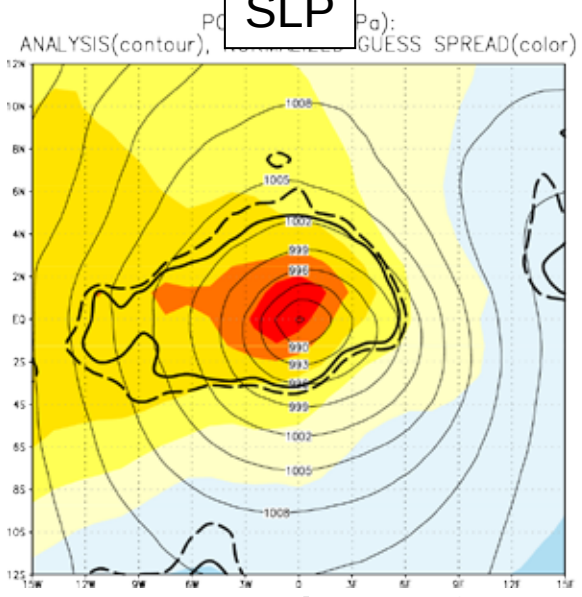


ADIA

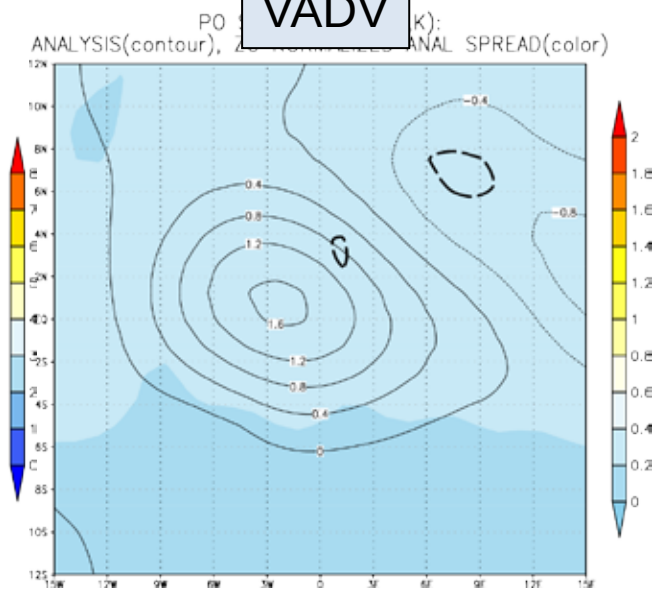


PO Z-O Eq. spread

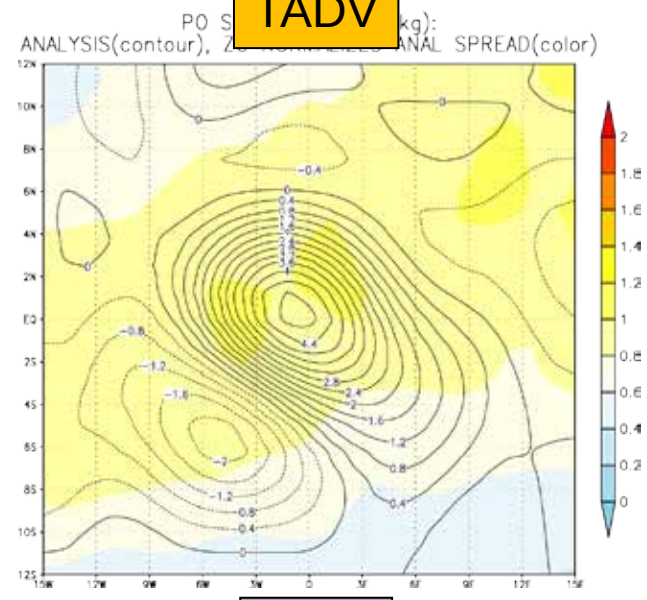
SLP



VADV

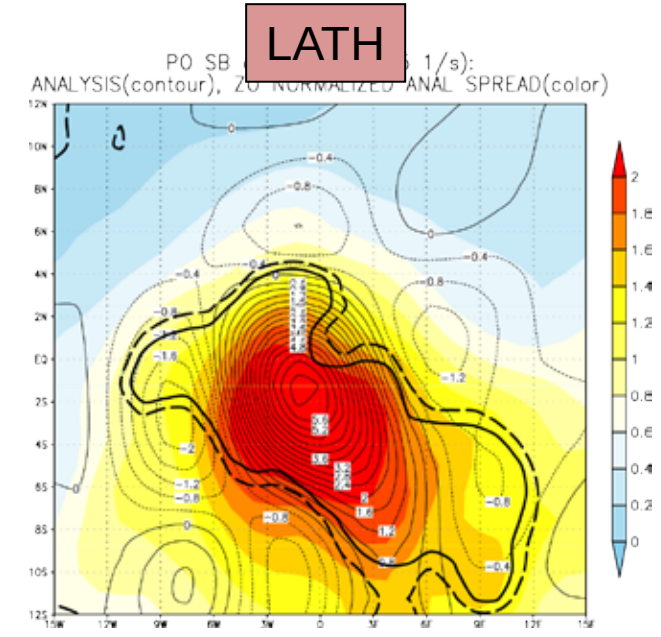


TADV

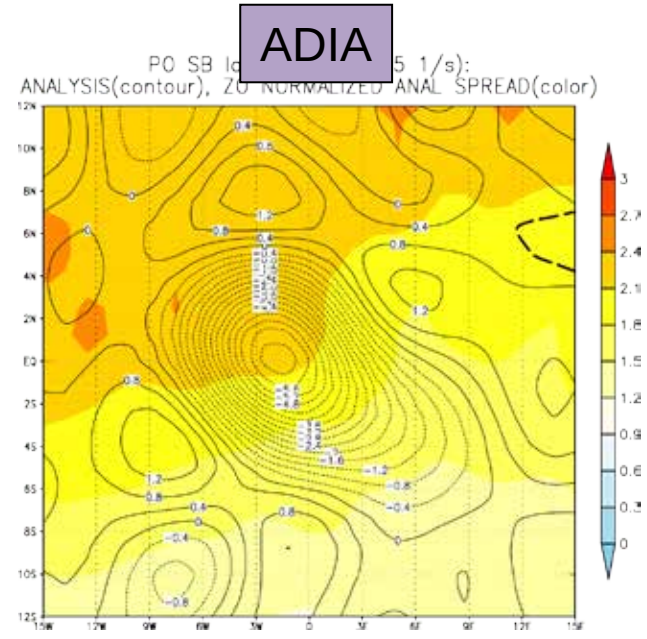


- Uncertainty of latent heating is large around the center.
- In contrast to increment, adiabatic heating shows no significant signal.

LATH

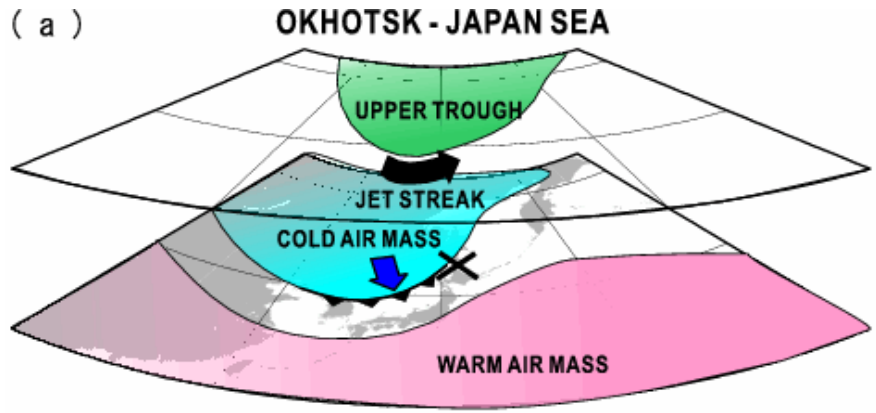


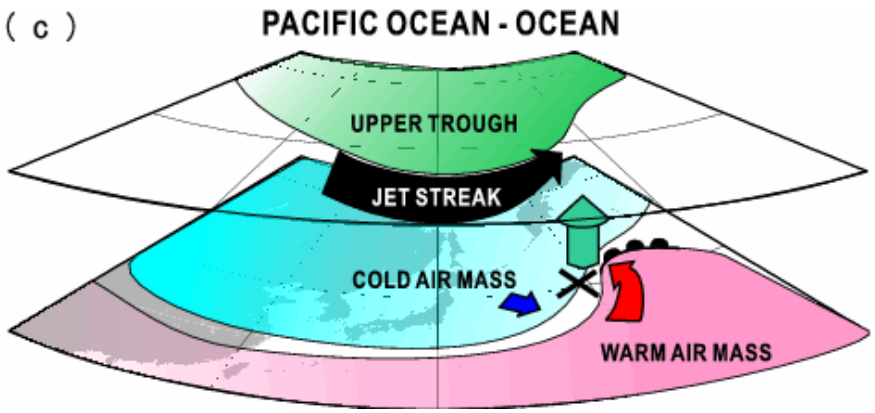
ADIA



Summary

	OJ	PO
Forecast bias	Too far north	Shallower
	Upper trough	Precipitation
Uncertainty	Westside	Center
	Adiabatic heating	Latent heating

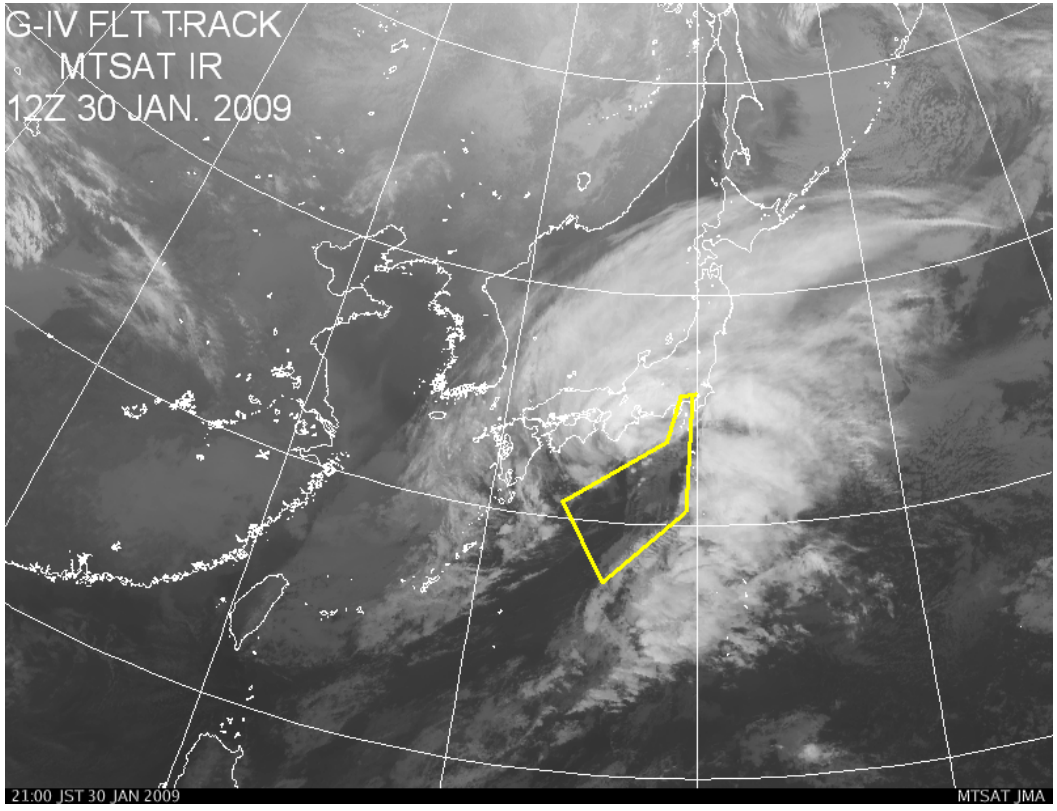


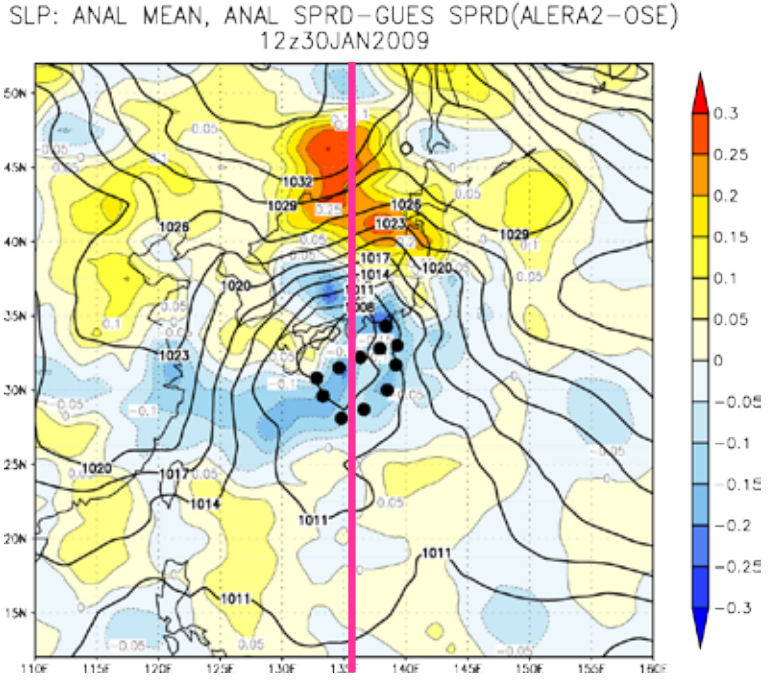


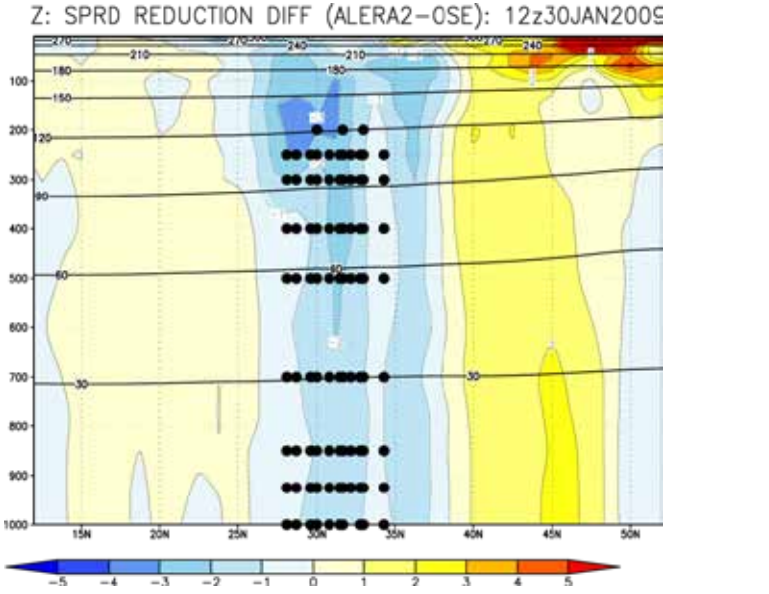
The characteristics are consistent with the most important processes of explosive developments for OJ and PO cyclones, respectively.

Future work 1

- Interpretation of OSE for winter T-PARC cyclones



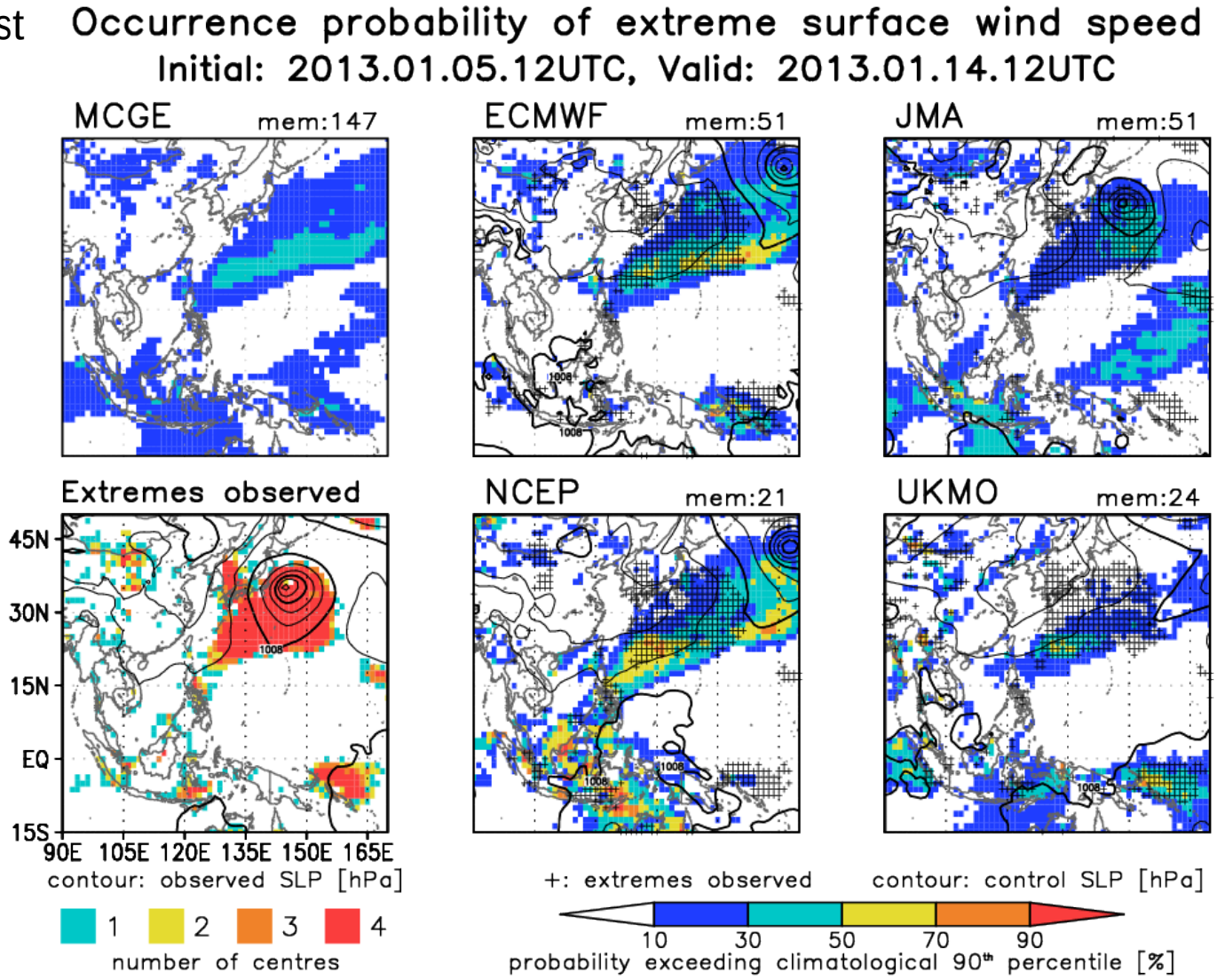




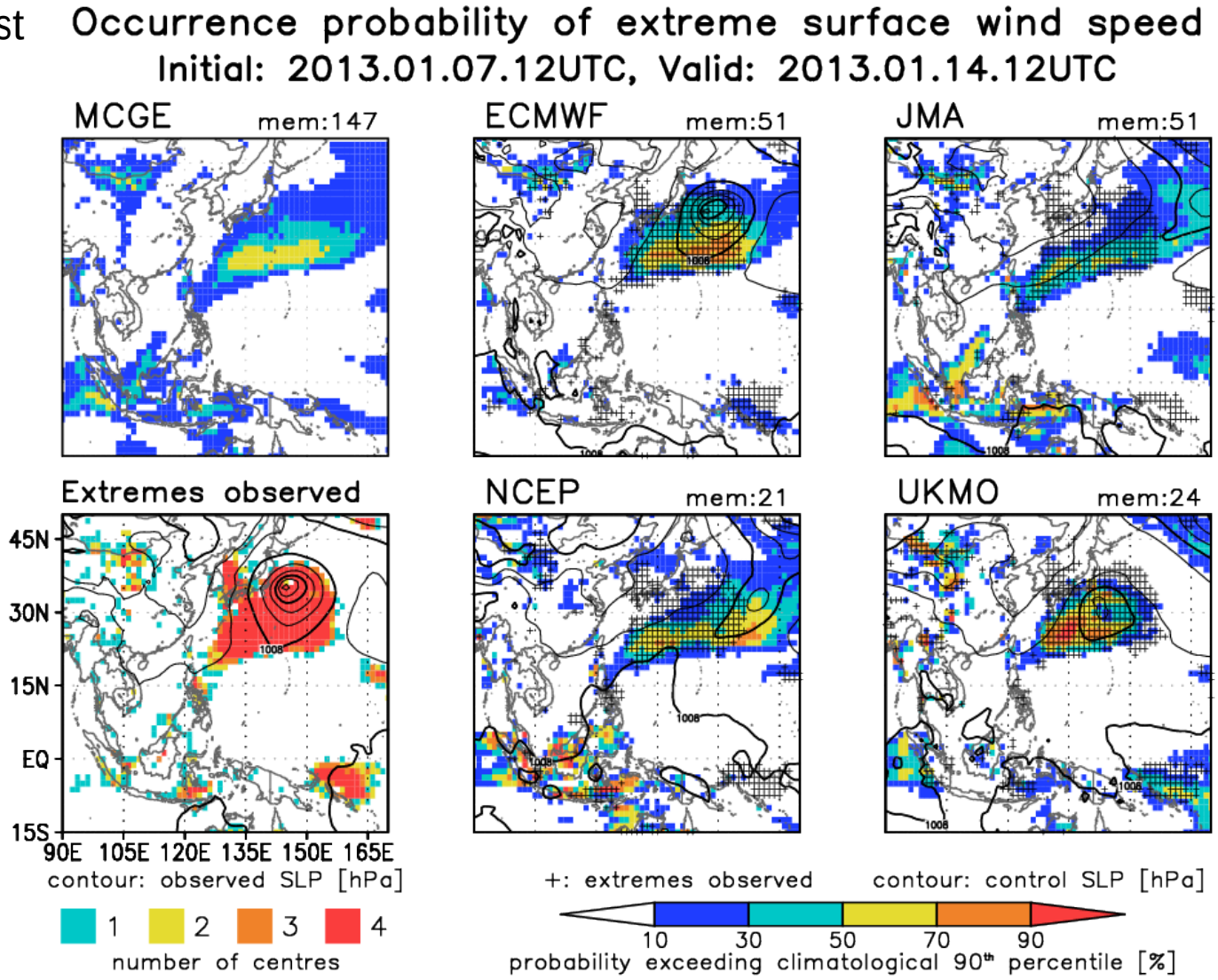
Future work 2

- Similar analysis for longer ensemble forecast using TIGGE
  - Dependency on forecast system.

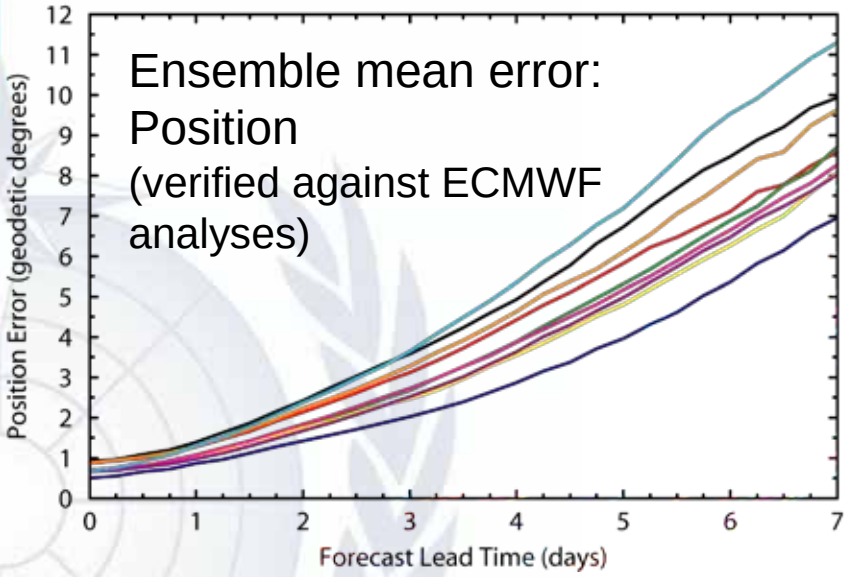
9-day forecast

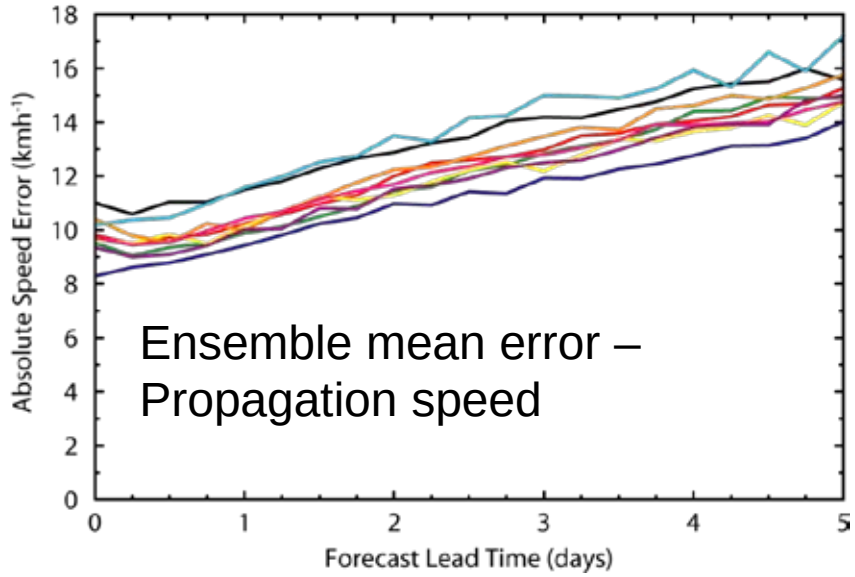


7-day forecast

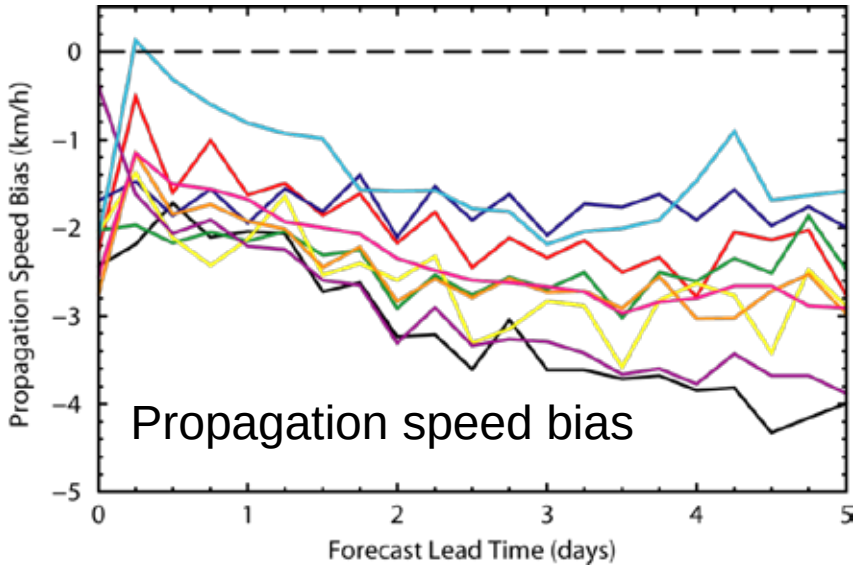


Comparison of extra-tropical cyclone tracks





BoM (Australia)
CMA (China)
CMC (Canada)
ECMWF (Europe)
JMA (Japan)
KMA (Korea)
NCEP (USA)
UKMO (UK)
CPTEC (Brazil)



Lizzie Froude, U. Reading

From Richard Swinbank presentation, GIFS-TIGGE WG Meeting