Influence of midlatitude disturbances on the MJO

Hai Lin

Meteorological Research Division,
Environment and Climate Change Canada

Advanced School and Workshop on Tropical-Extratropical Interactions on Intra-seasonal time scales
ICTP, 16-27 Oct 2017

Outlines

- Introduction
- Tropical processes and MJO
- Midlatitude influences
- Dry-model experiment
- MJO-NAO two-way interactions

The extratropical influence on MJO is less well understood than the tropical influence on extratropics

Examples of midlatitude influences

Ray and Zhang (2009)

Tropical channel model, two MJO events

The only factor found critical to the reproduction of the MJO initiation is time-varying lateral boundary conditions from the reanalysis. When such lateral boundary conditions are replaced by time-independent conditions, the model fails to reproduce the MJO initiation. These results support the idea that extratropical influences can be an efficient mechanism for MJO initiation.

Ray and Zhang (2010), importance of latitudinal momentum transport

Examples of midlatitude influences

Hong et al. (2017),

extratropical forcing of 2015 MJO – El Nino event, southward penetration of north wind anomalies associated with extratropical disturbances in the extratropical western North Pacific

Nick Hall's next talk

Tropical-extratropical interactions in a dry GCM

Model and experiment

- Primitive equation AGCM (Hall 2000)
- T31, 10 levels
- Time-independent forcing to maintain the winter climate → all variabilities come from internal dynamics
- No moisture equation, no interactive convection
- 3660 days of perpetual winter integration

Lin et al. 2007, JAS

Model Result

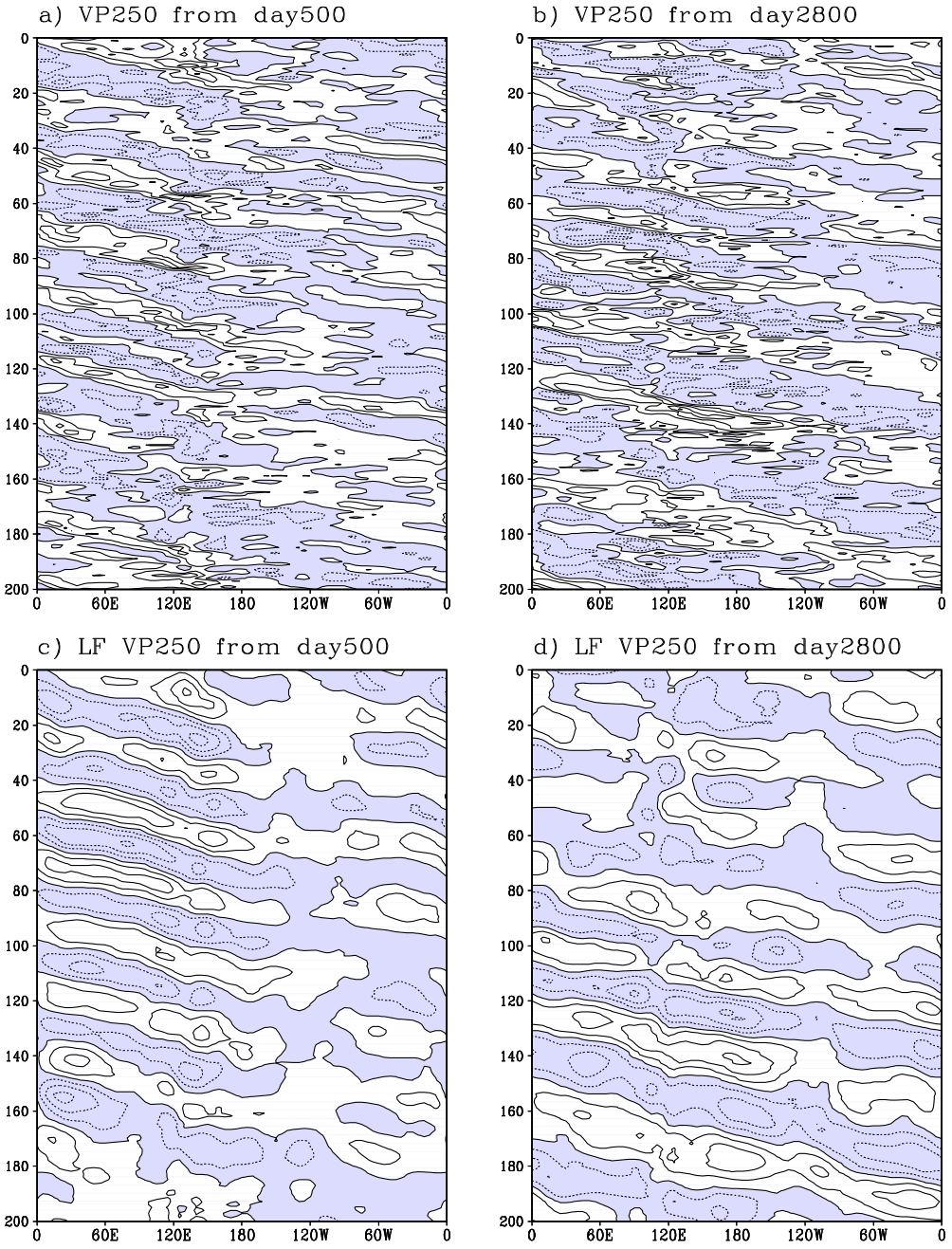
Zonal propagation

10S-10N

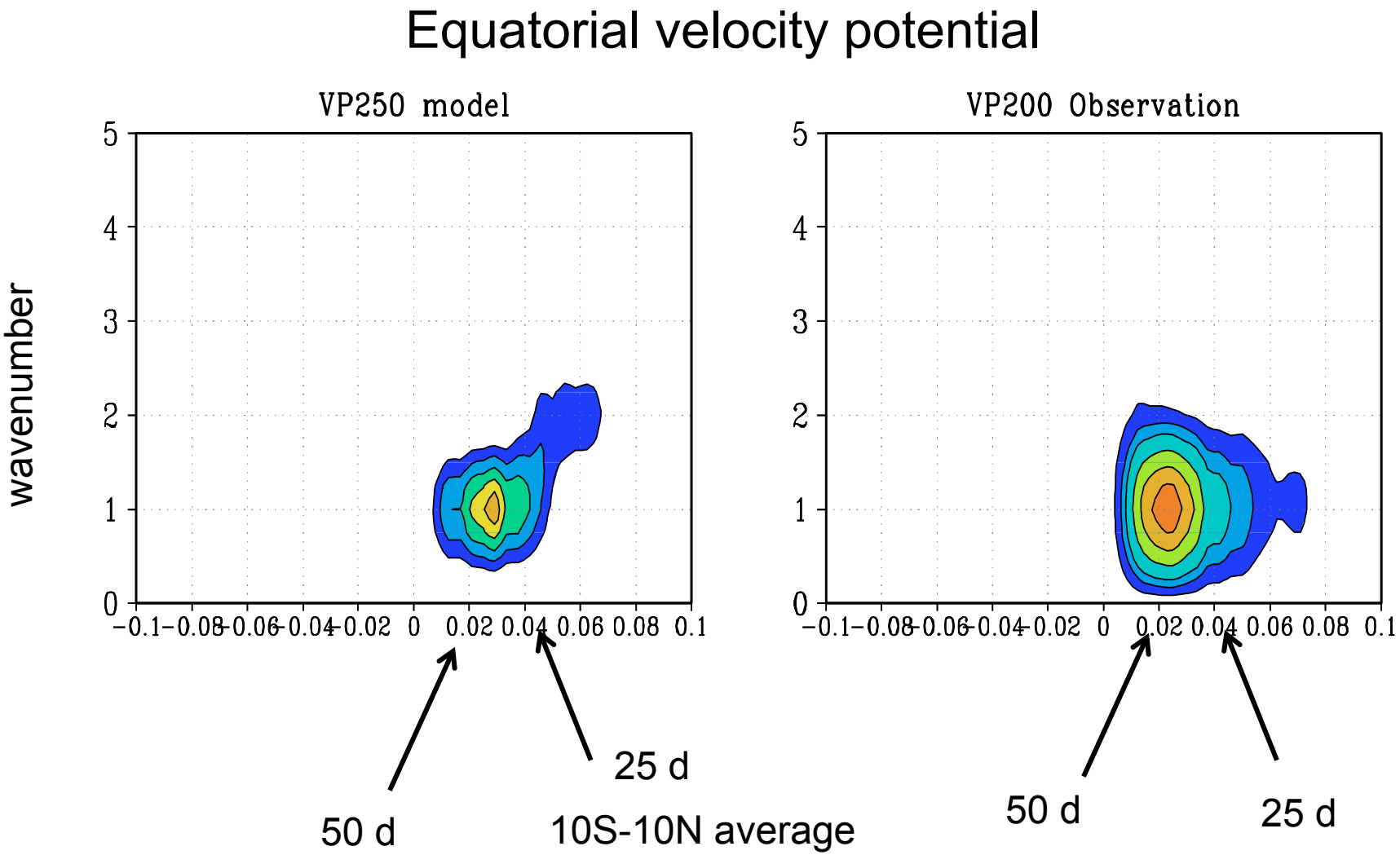
Unfiltered data

20-100 day band-pass

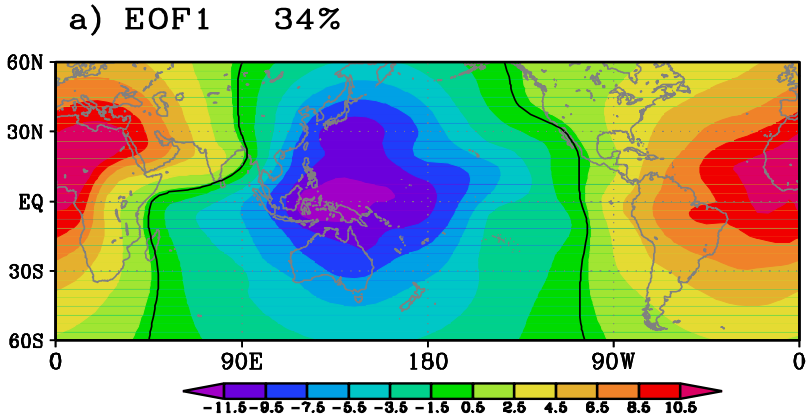
Stronger in eastern Hemisphere

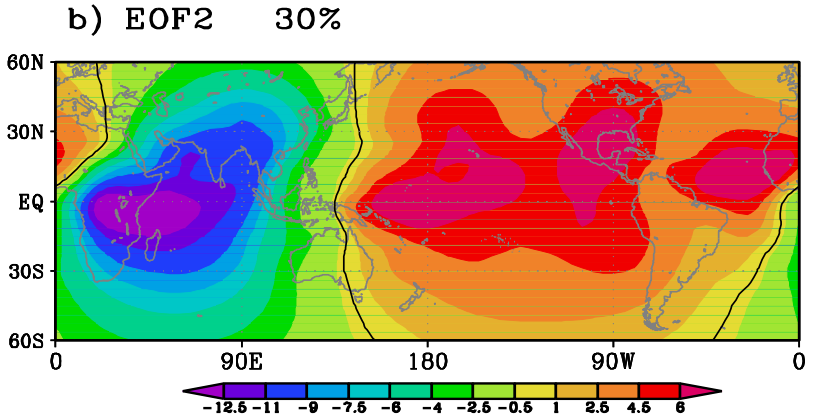


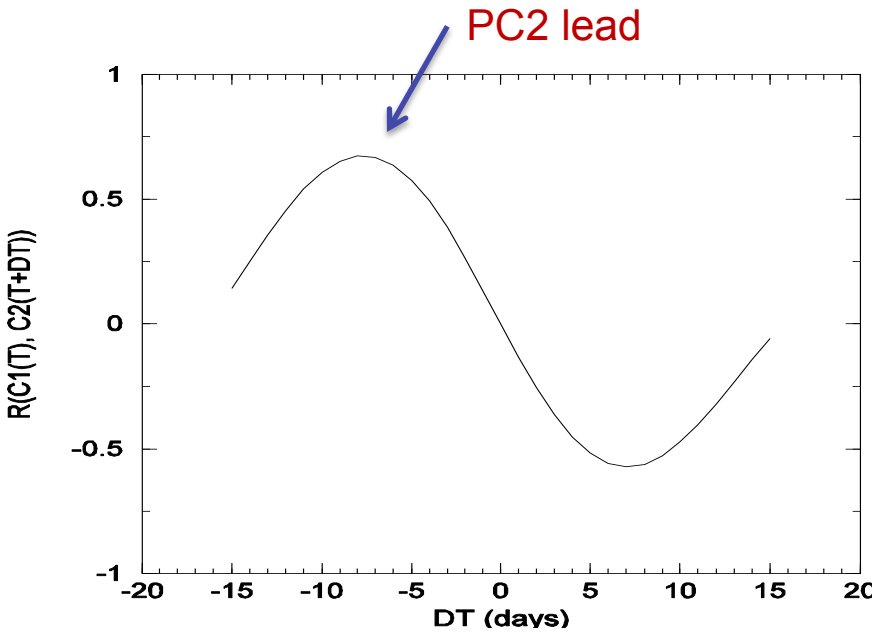
Wavenumber-frequency spectra



EOF analysis of 20-100 day band-passed 250 hPa velocity potential

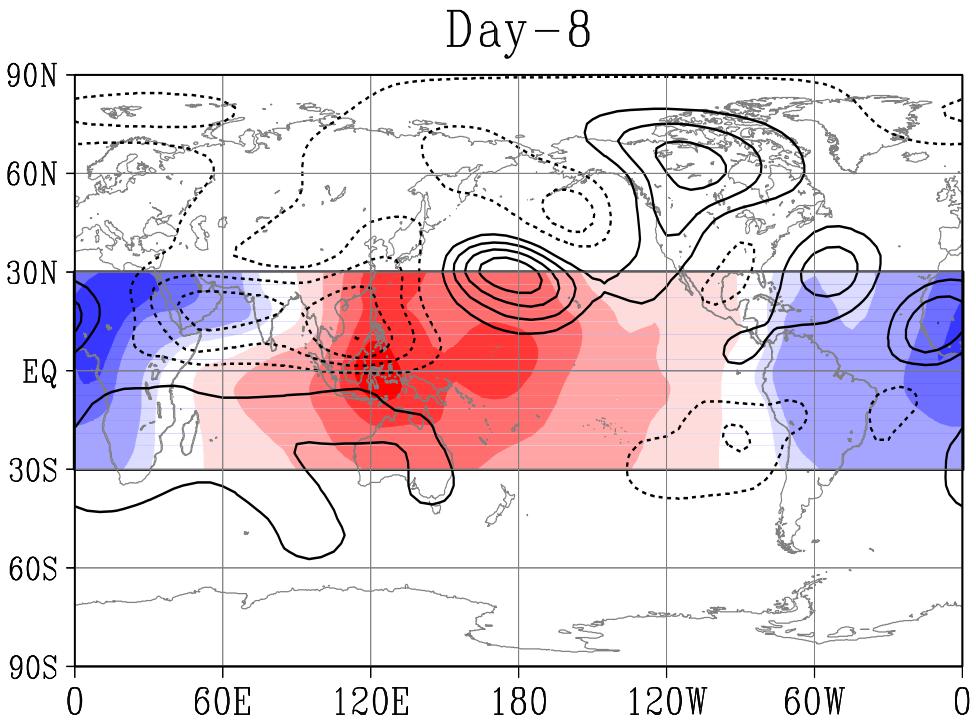






TIV index:

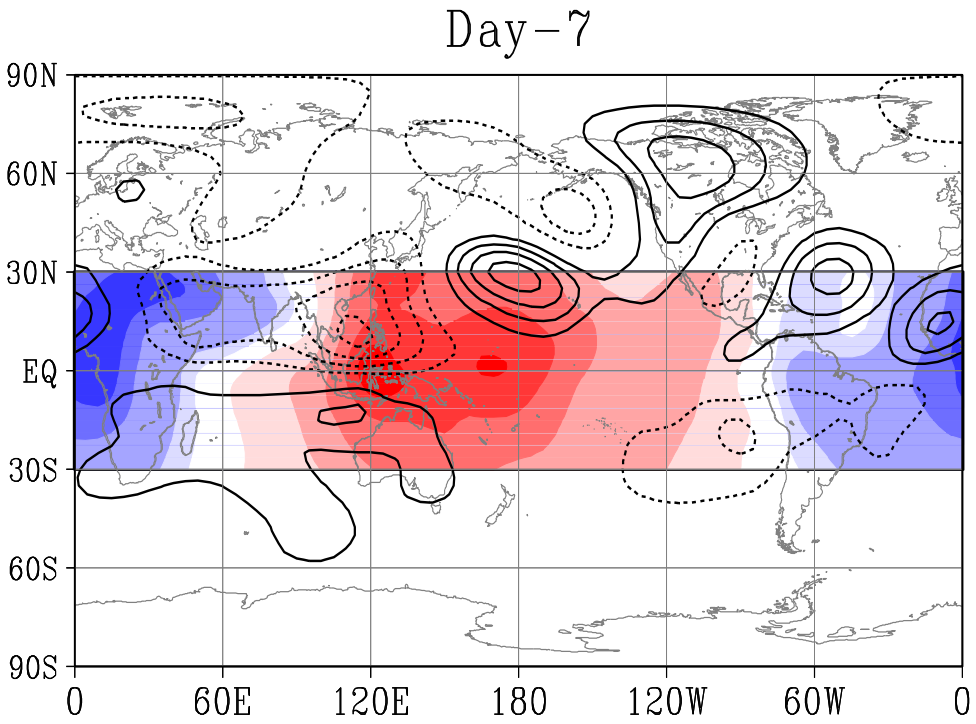
$$I(t) = \frac{PC_2(t) + PC_1(t+8)}{2}$$



Regression to TIV index

Color: 250mb velocity potential
Contour: 250mb streamfunction anomaly

TIV index: In phase with PC2



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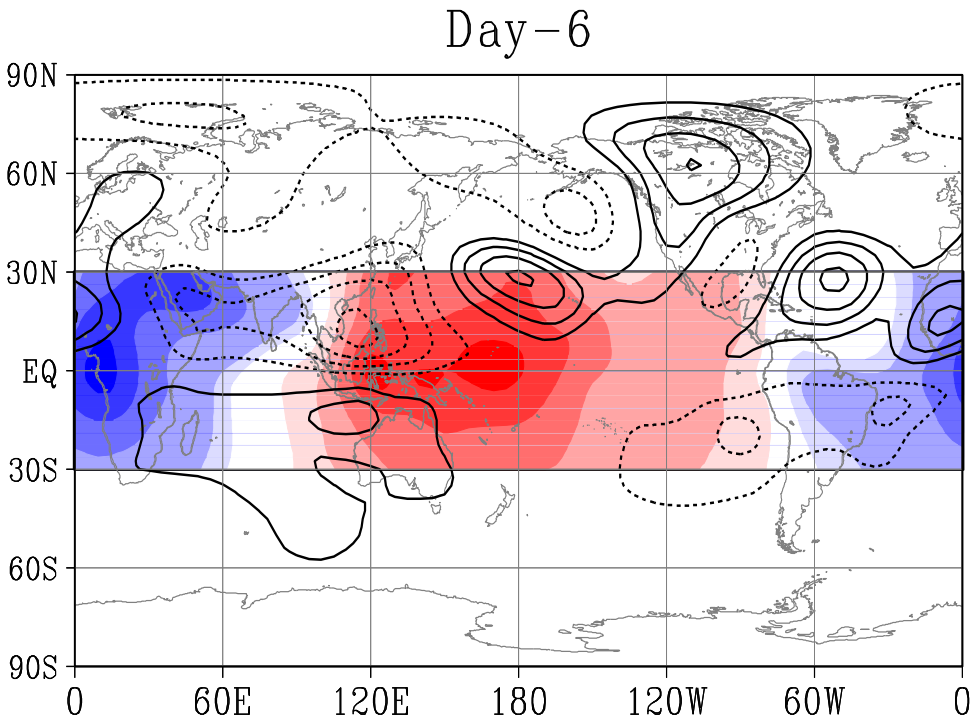

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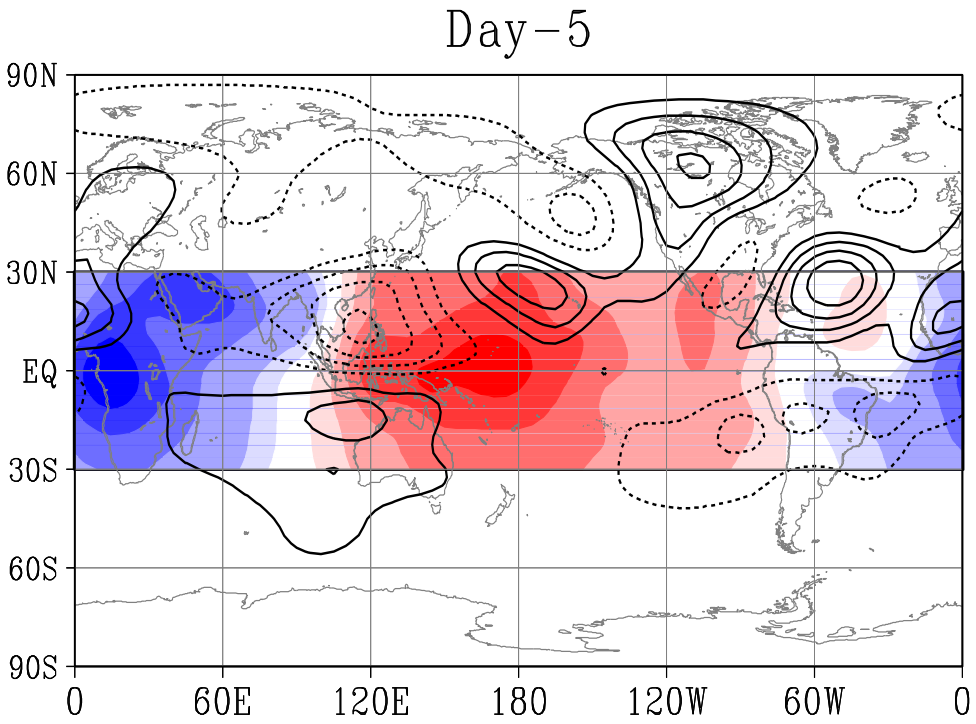

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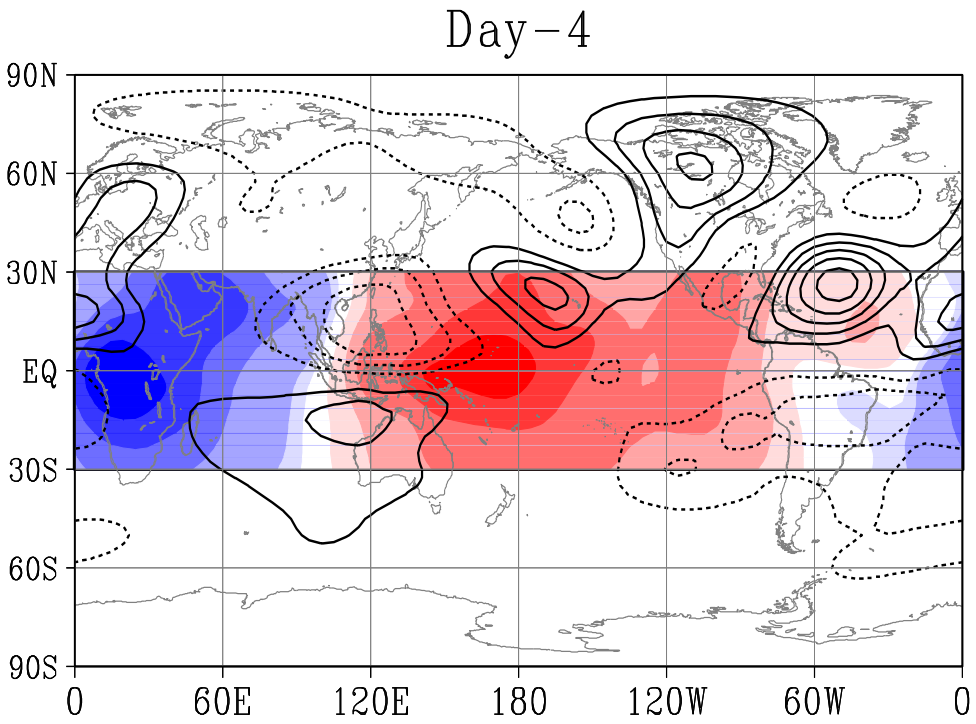

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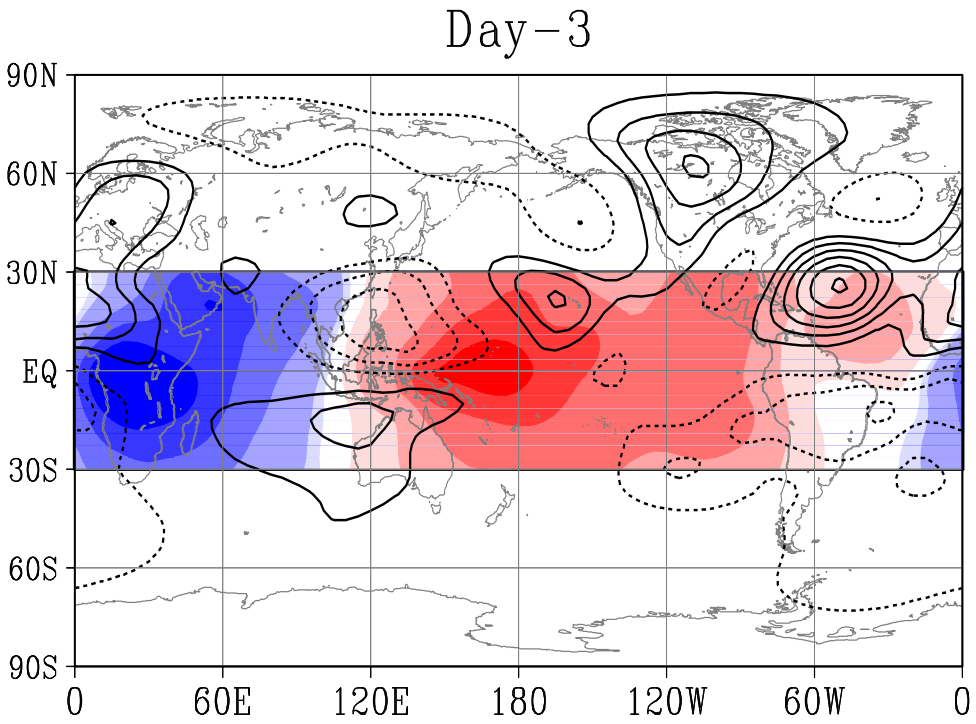

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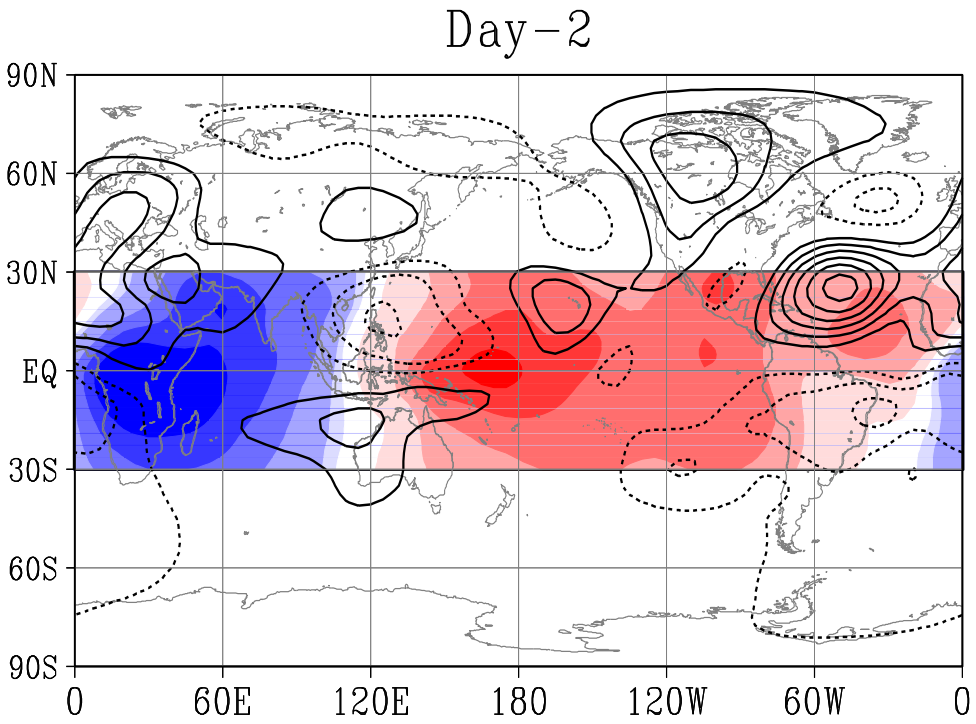

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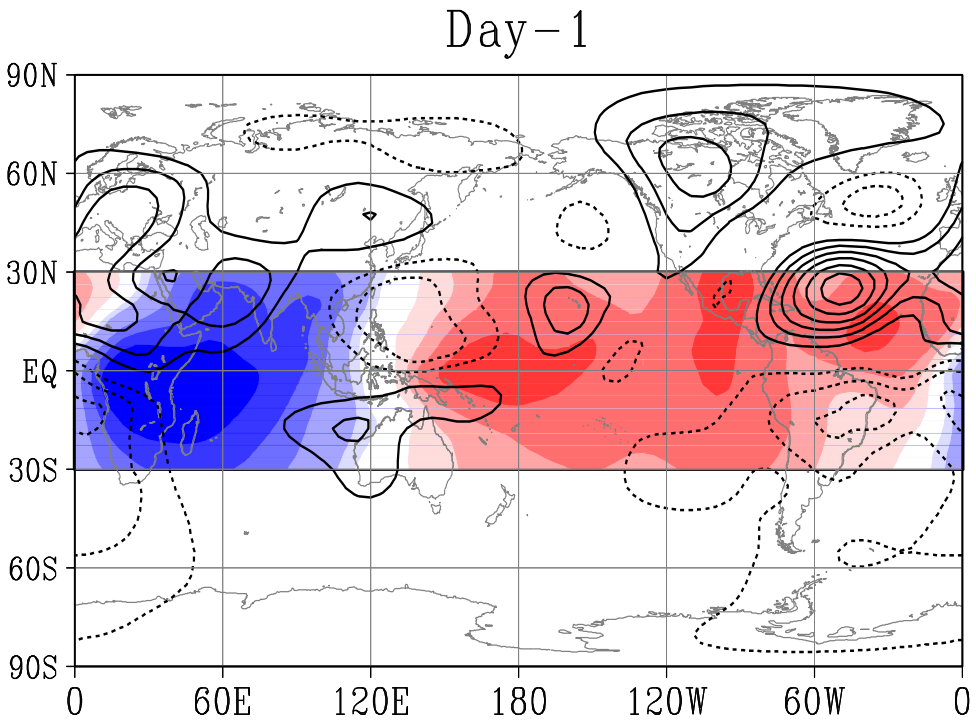

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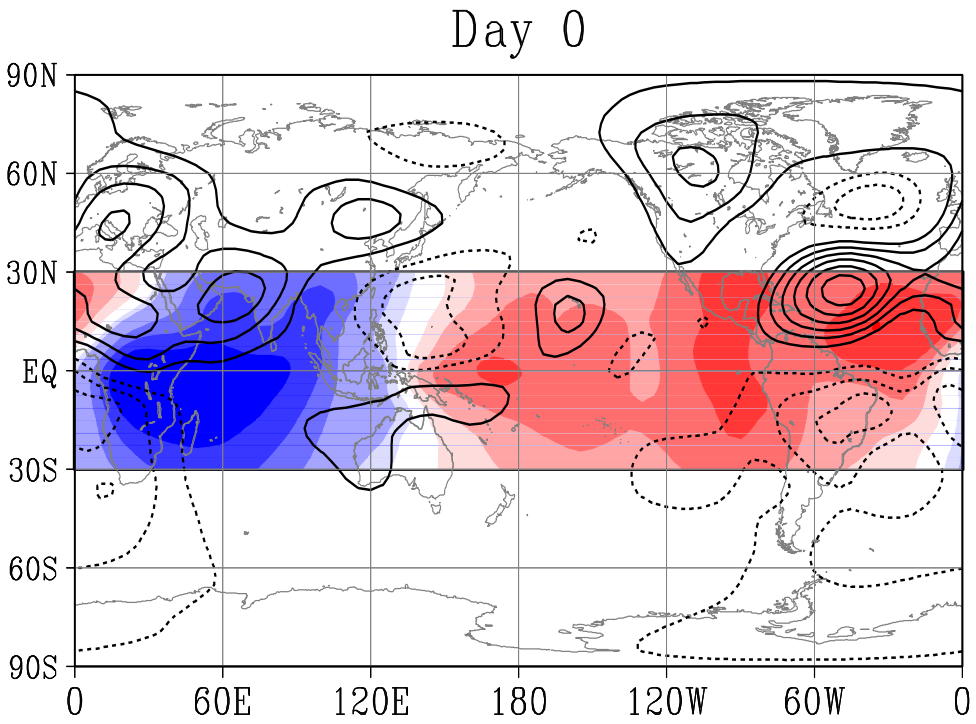

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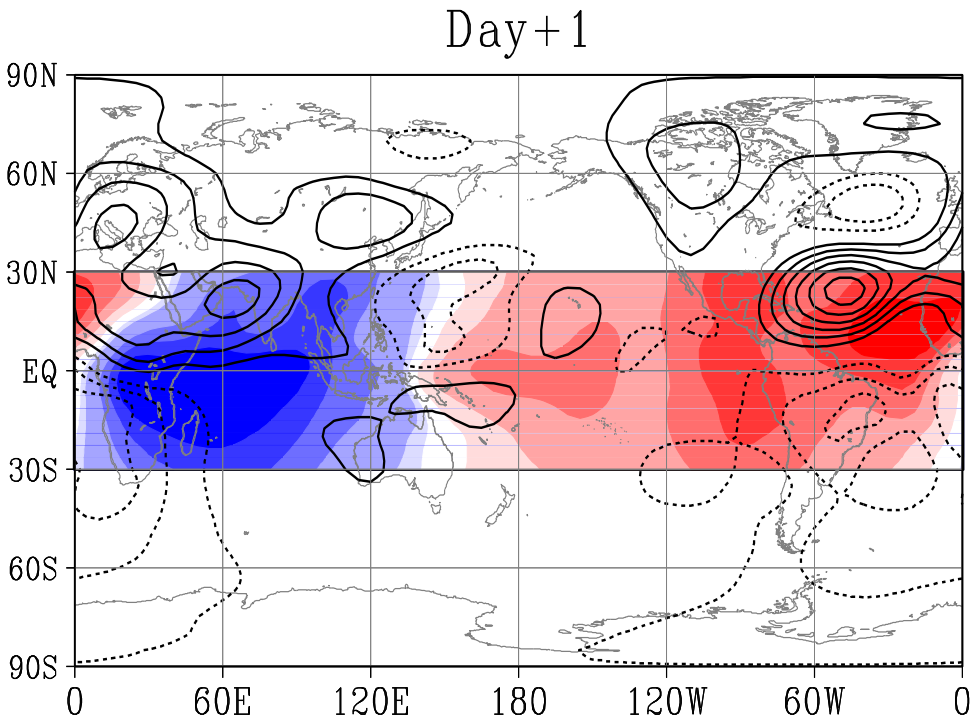

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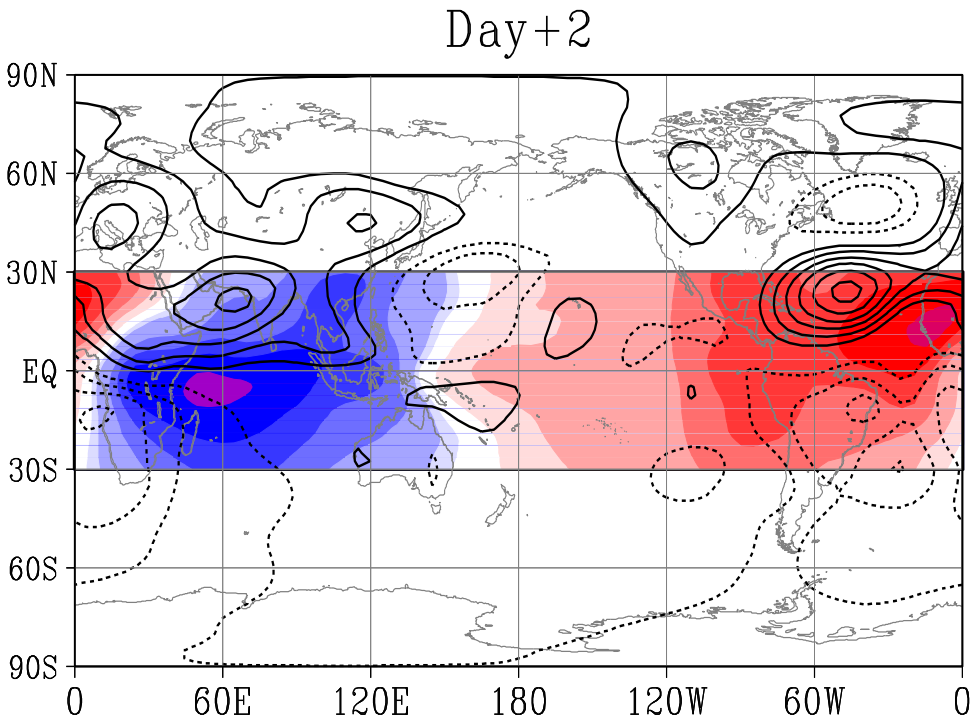
TIV index: In phase with PC2



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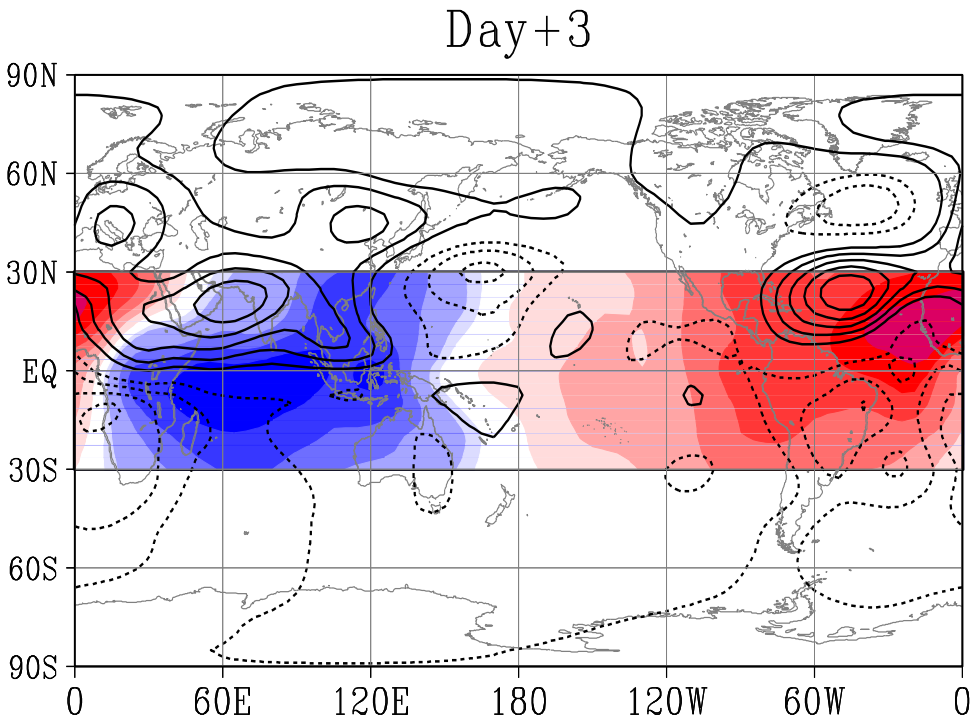
TIV index: In phase with PC2



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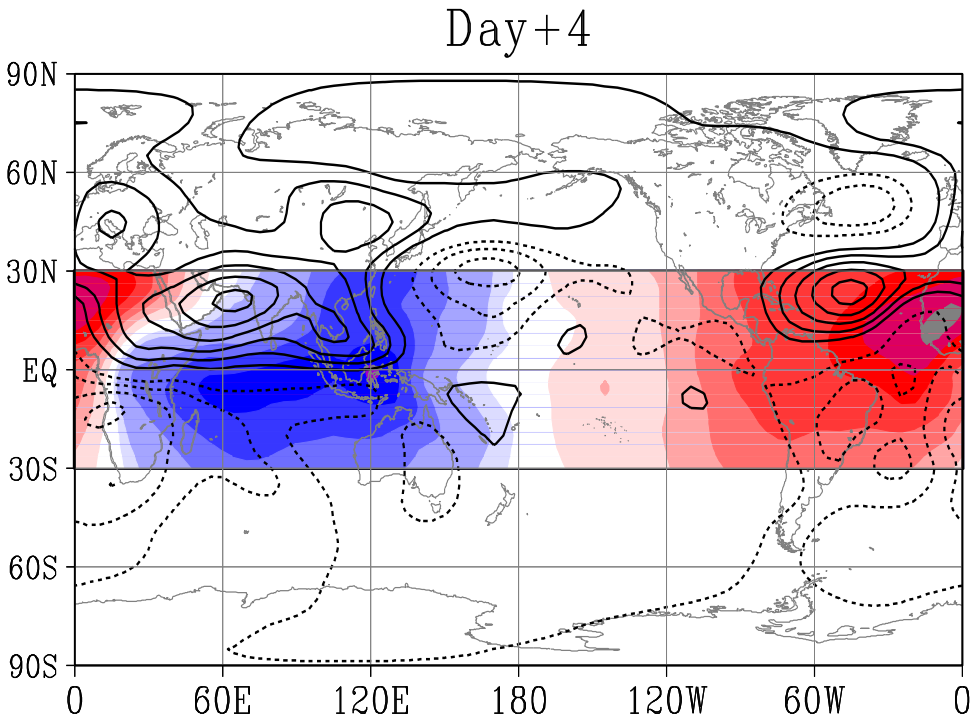

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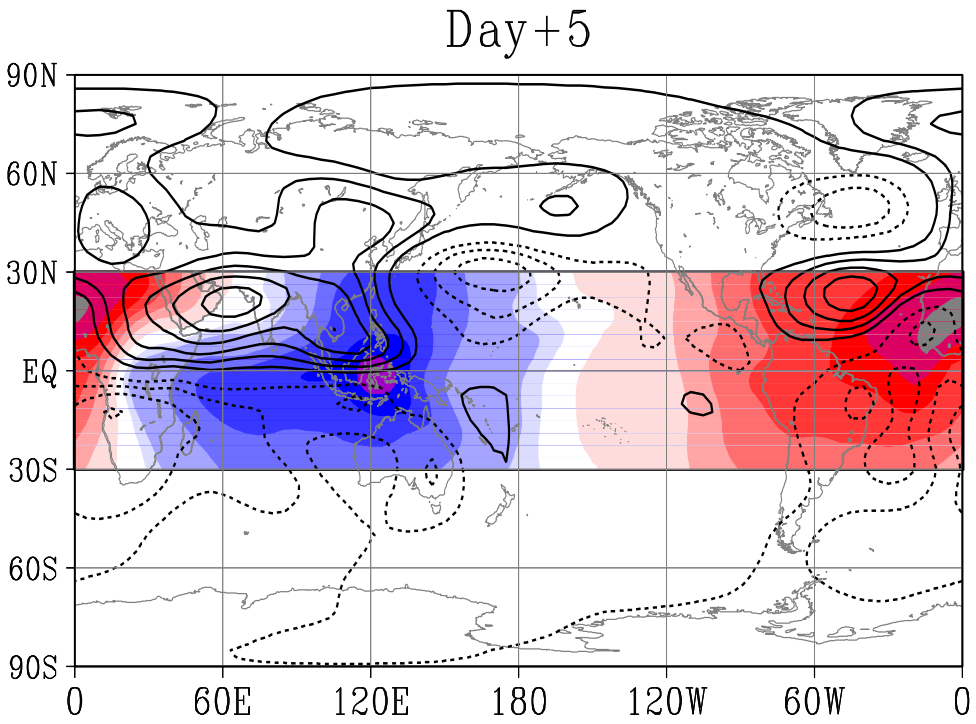

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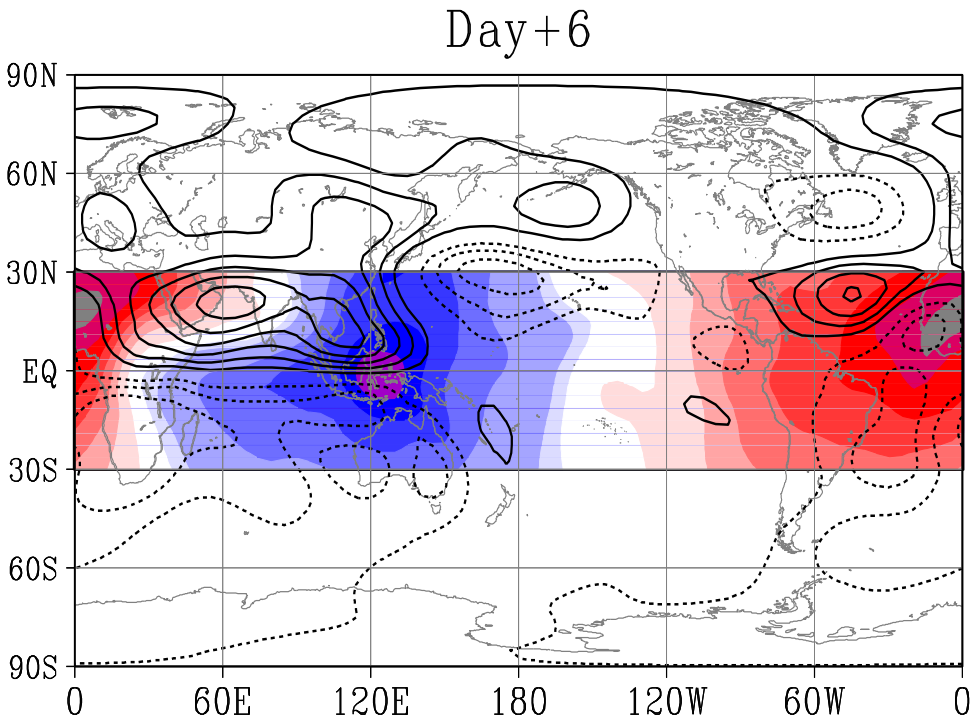

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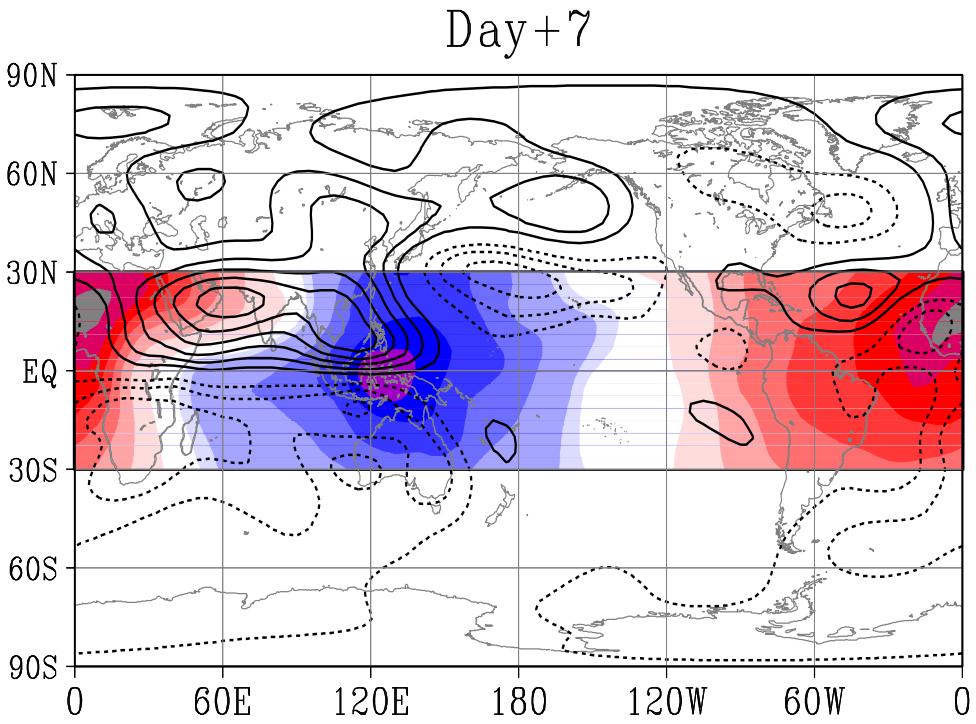

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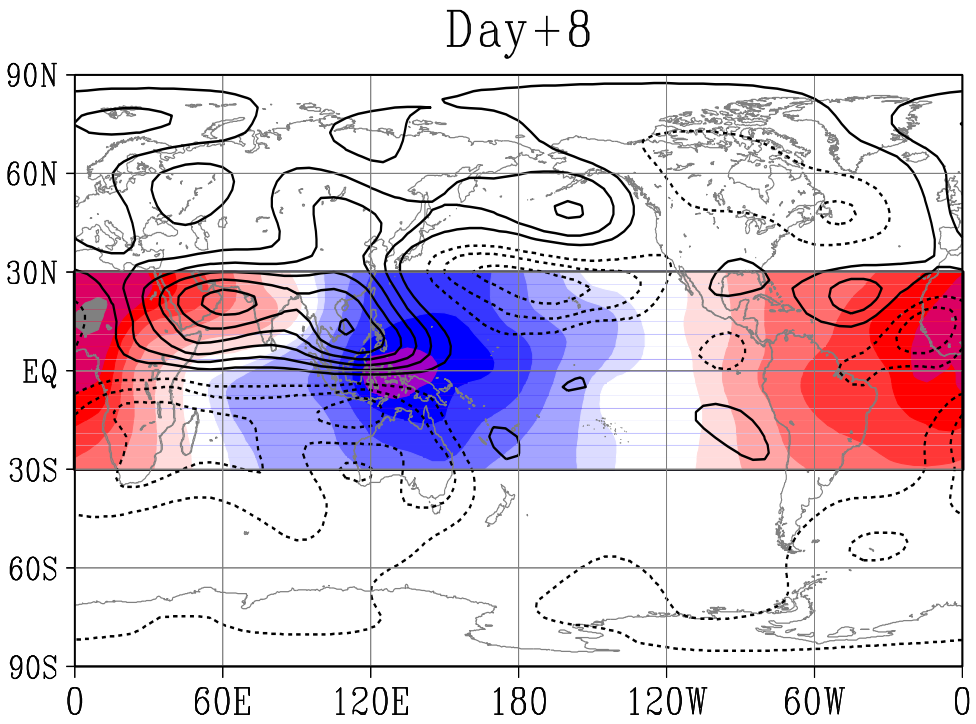

Regression to TIV index

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TIV index: In phase with PC2

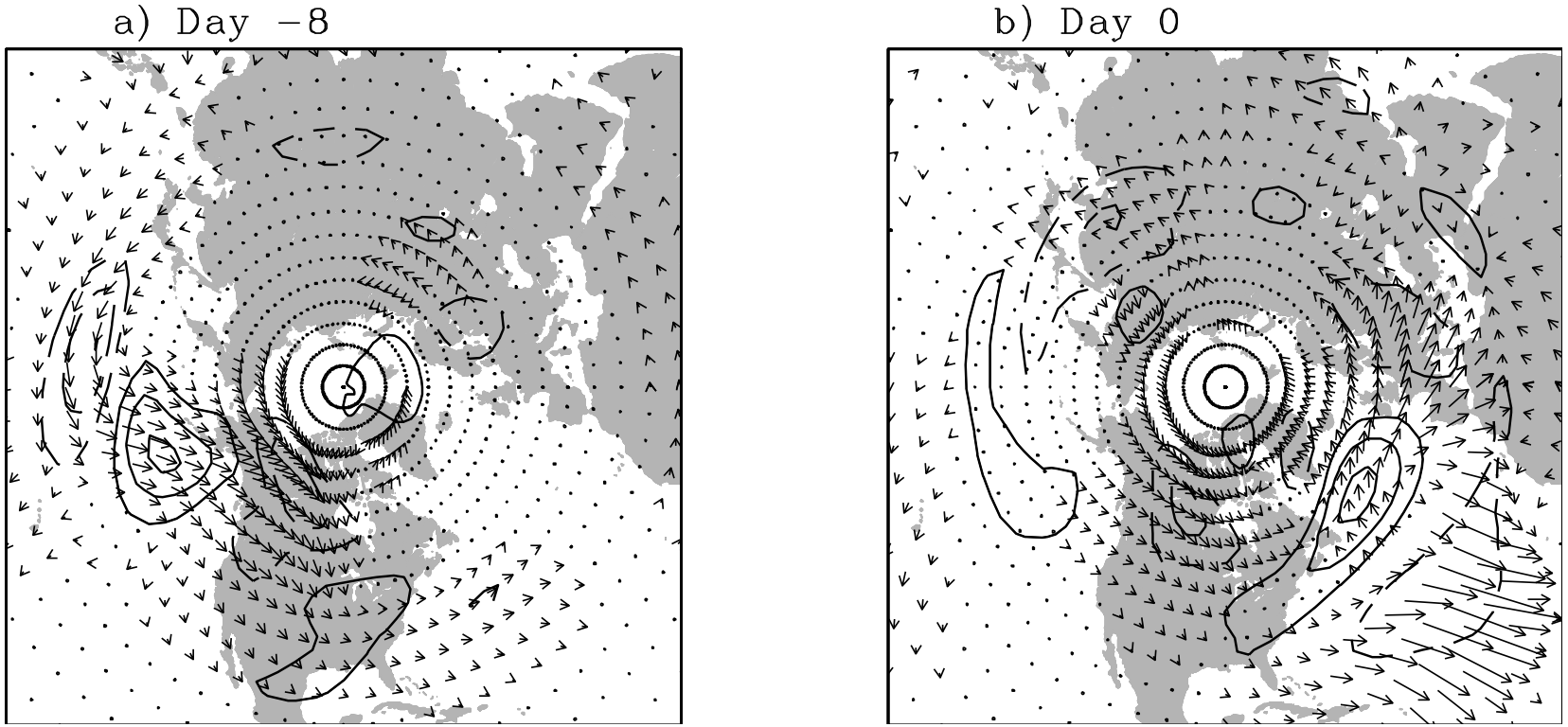
Waveflux - Theory

$$\mathbf{W} = \frac{1}{2|\mathbf{U}|}\begin{bmatrix} U(\psi_x^2 - \psi\psi_{xx}) + V(\psi_x\psi_y - \psi\psi_{xy}) \\ U(\psi_x\psi_y - \psi\psi_{xy}) + V(\psi_y^2 - \psi\psi_{yy}) \end{bmatrix}$$

Takaya and Nakamura 2001 GRL

ISO in a dry model

250 hPa PV' and wave activity flux



Linked to tropical eastward propagation in the eastern Hemisphere → Global propagation of low-frequency wave activity

Summary

- TIV generated in a dry GCM
- Tropical-extratropical interactions are crucial in generating the model TIV
- Extratropical influence on tropical waves

Remaining questions:

- Contribution from moisture and convection
- Mechanism: how do extratropical large-scale disturbances, that are equivalent barotropic, propagate into the tropics to generate tropical waves that are baroclinic?

MJO-NAO two-way interactions

Data

NAO index: pentad average

MJO RMMs: pentad average

Period: 1979-2003

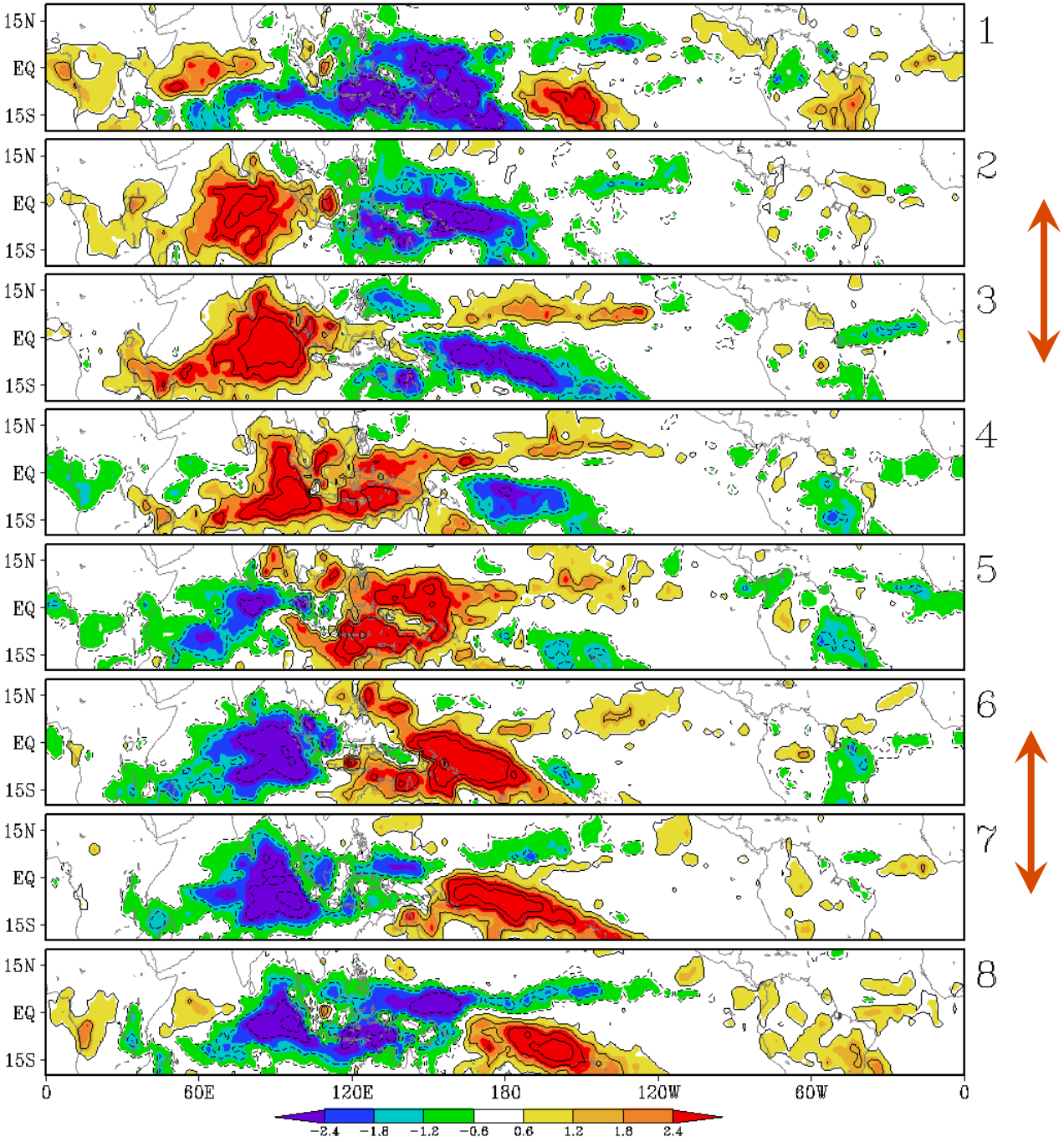
Extended winter, November to April (36 pentads each winter)

Lin et al. 2009, JClim

Composites of tropical

Precipitation rate for 8 MJO phases, according to Wheeler and Hendon index.

Xie and Arkin pentad data, 1979-2003



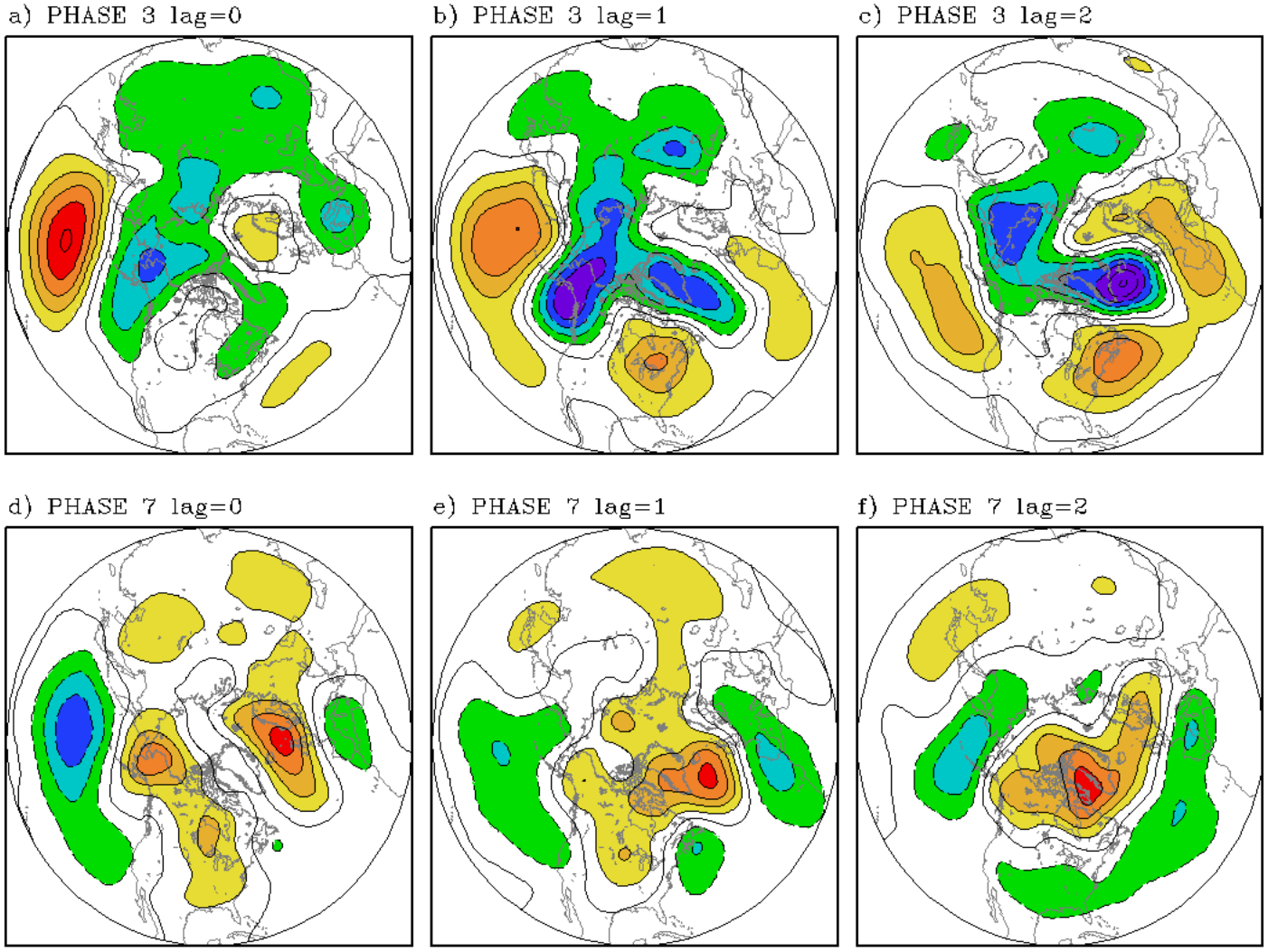
Lagged probability of the NAO index

Positive: upper tercile; Negative: low tercile

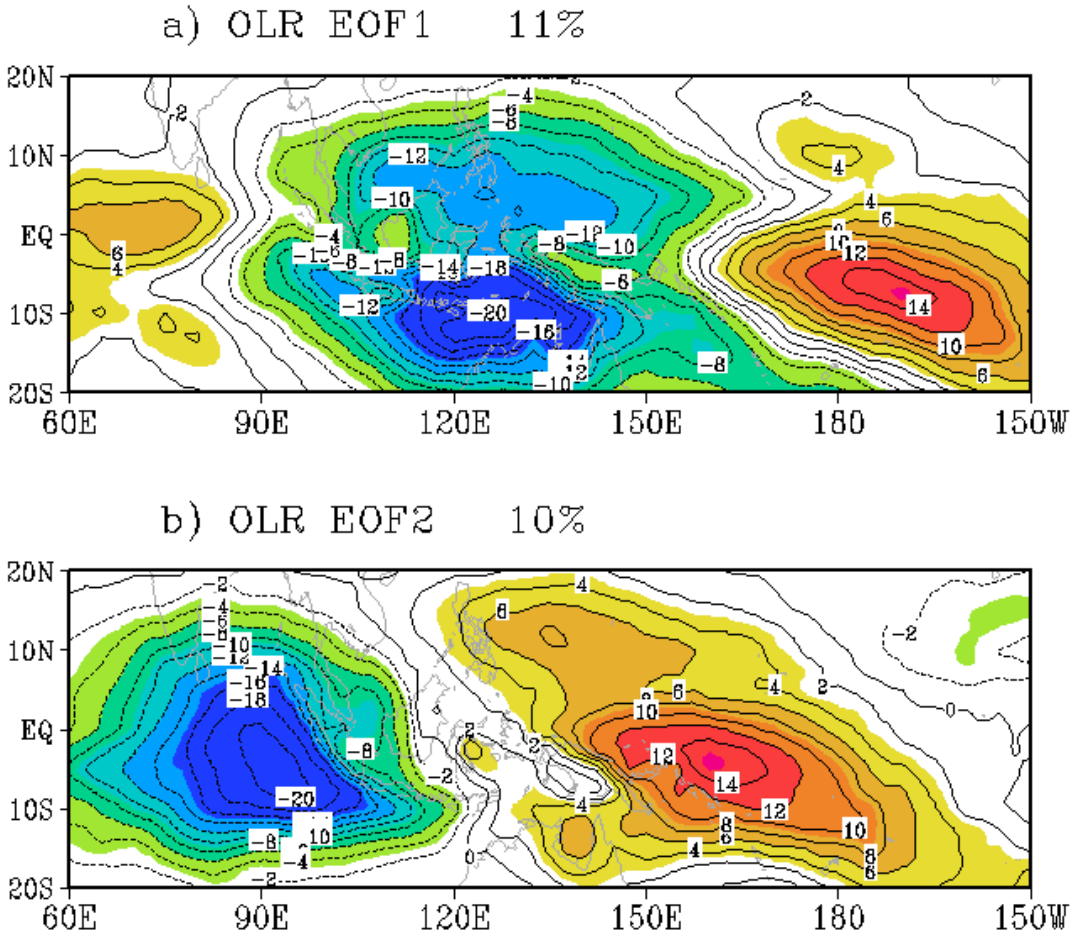
Phase	1	2	3	4	5	6	7	8
Lag −5		−35%	−40%			+49%	+49%	
Lag −4						+52%	+46%	
Lag −3		−40%					+46%	
Lag −2						+50%		
Lag −1								
Lag 0				+45%				−42%
Lag +1			+47%	+45%				−46%
Lag +2		+47%	+50%	+42%		−41%	−41%	−42%
Lag +3		+48%				−41%	−48%	
Lag +4						−39%	−48%	
Lag +5				−41%				

(Lin et al. JCLIM, 2009)

Tropical influence



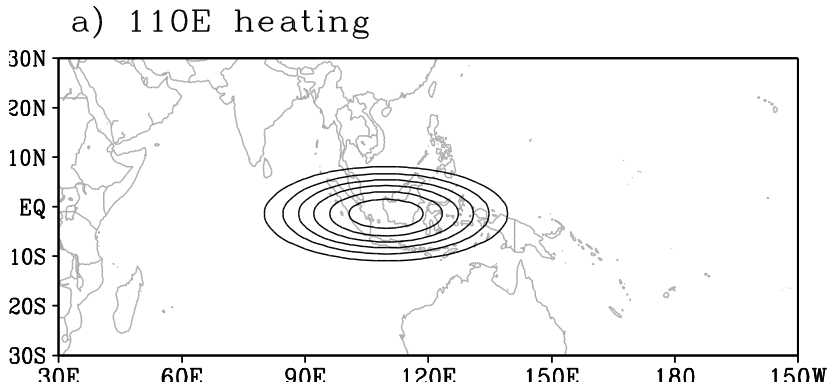
(Lin et al. JCLIM, 2009)



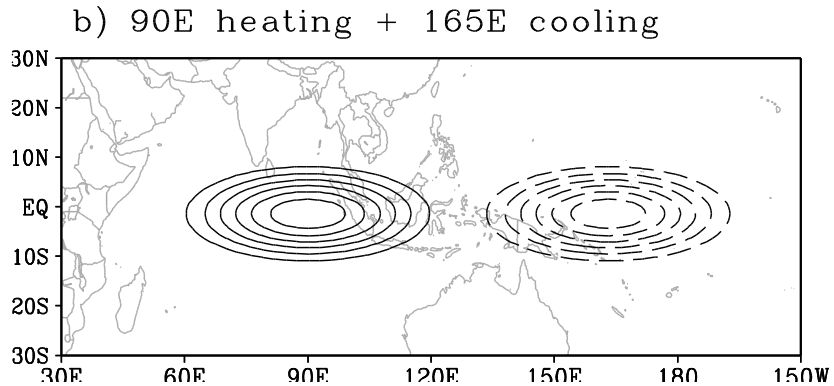
Correlation when PC2 leads PC1 by 2 pentads: 0.66

Lin et al. (2010)

Thermal forcing



Exp1 forcing



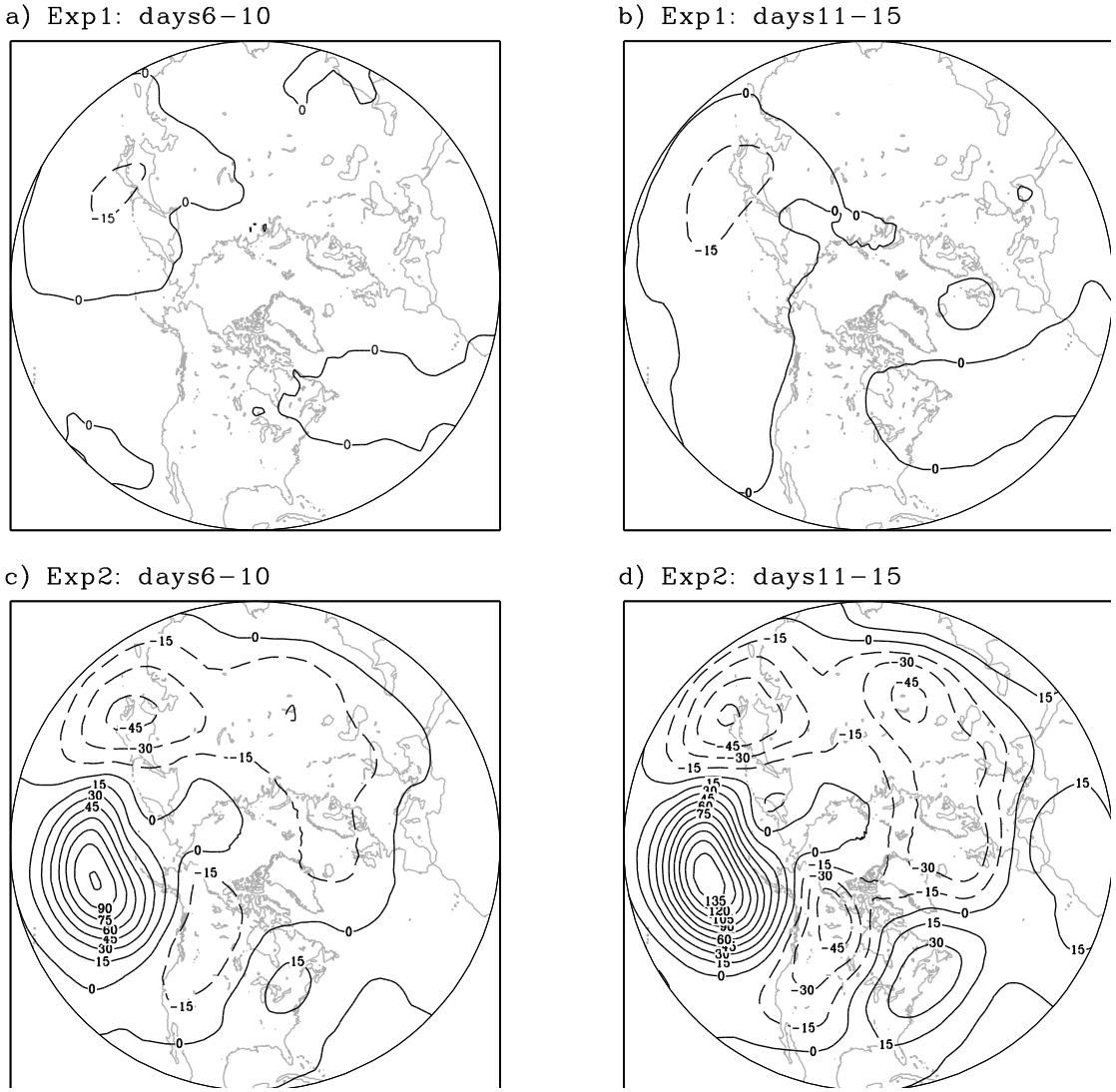
Exp2 forcing

Lin et al. (2010)

Z500 response

Exp1

Exp2

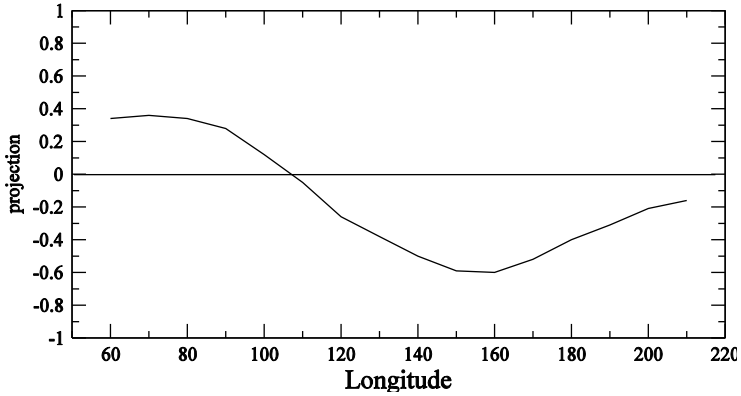


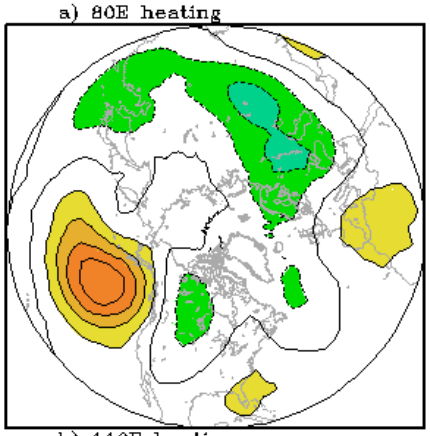
Lin et al. (2010)

Why the response to a dipole heating is the strongest ?

- Linear integration, winter basic state
- with a single center heating source
- Heating at different longitudes along the equator from 60E to 150W at a 10 degree interval, 16 experiments
- Z500 response at day 10

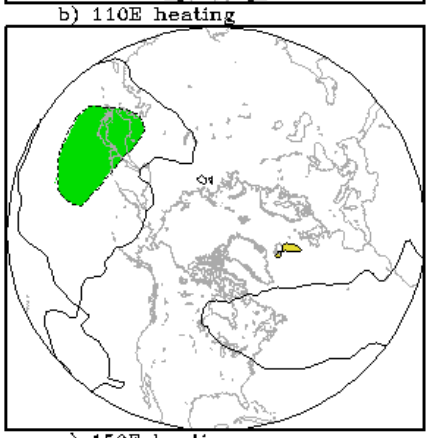
Day 10 Z500 linear response



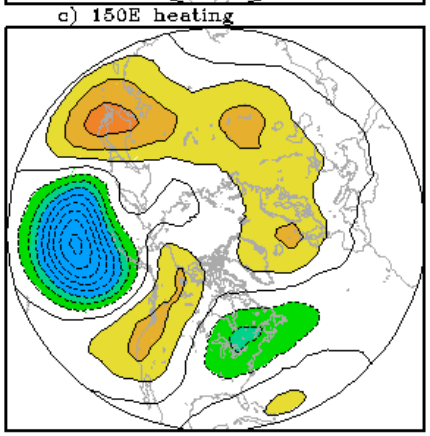


80E

Similar pattern for heating 60-100E



110E

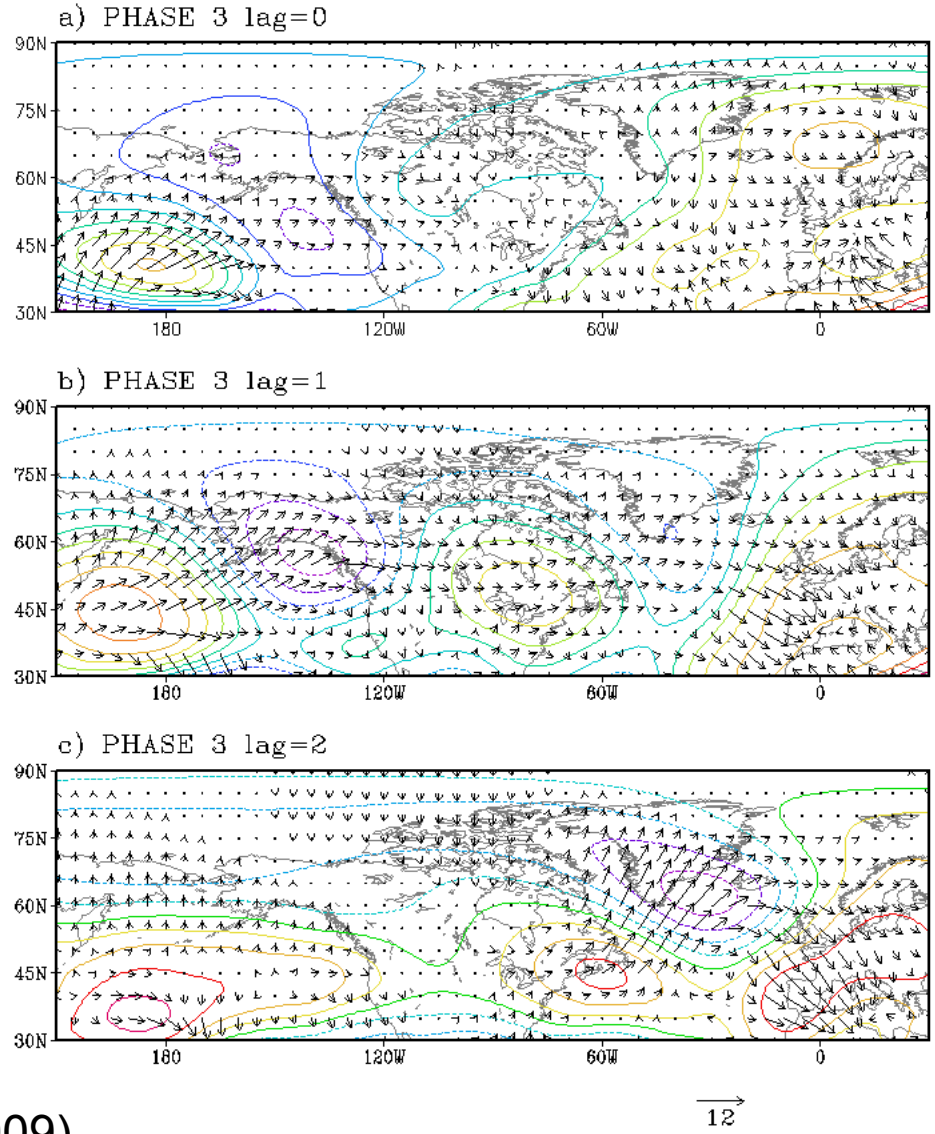


150E

Similar pattern for heating 120-150W

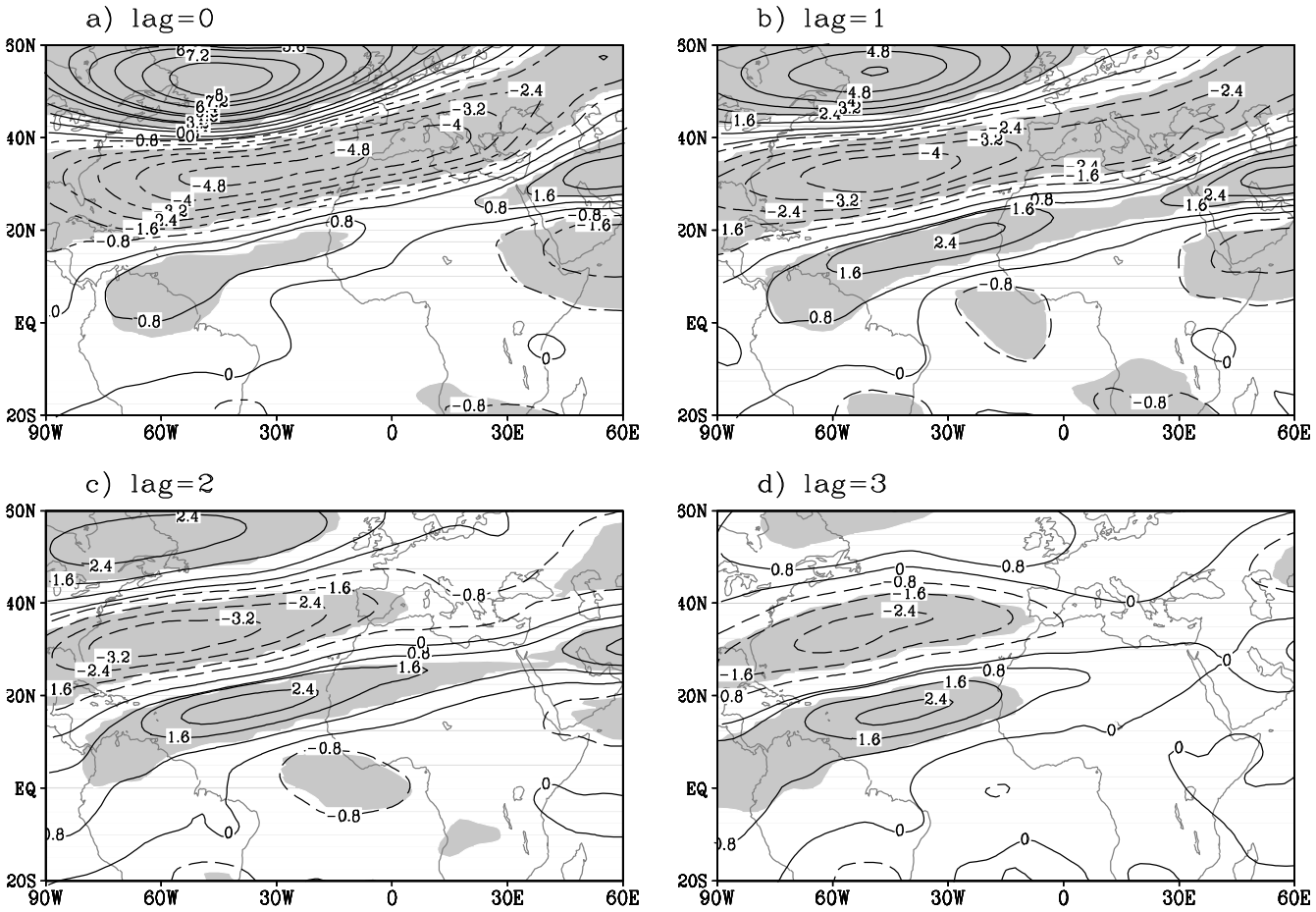
Lin et al. MWR, 2010

Wave activity flux and 200mb streamfunction anomaly



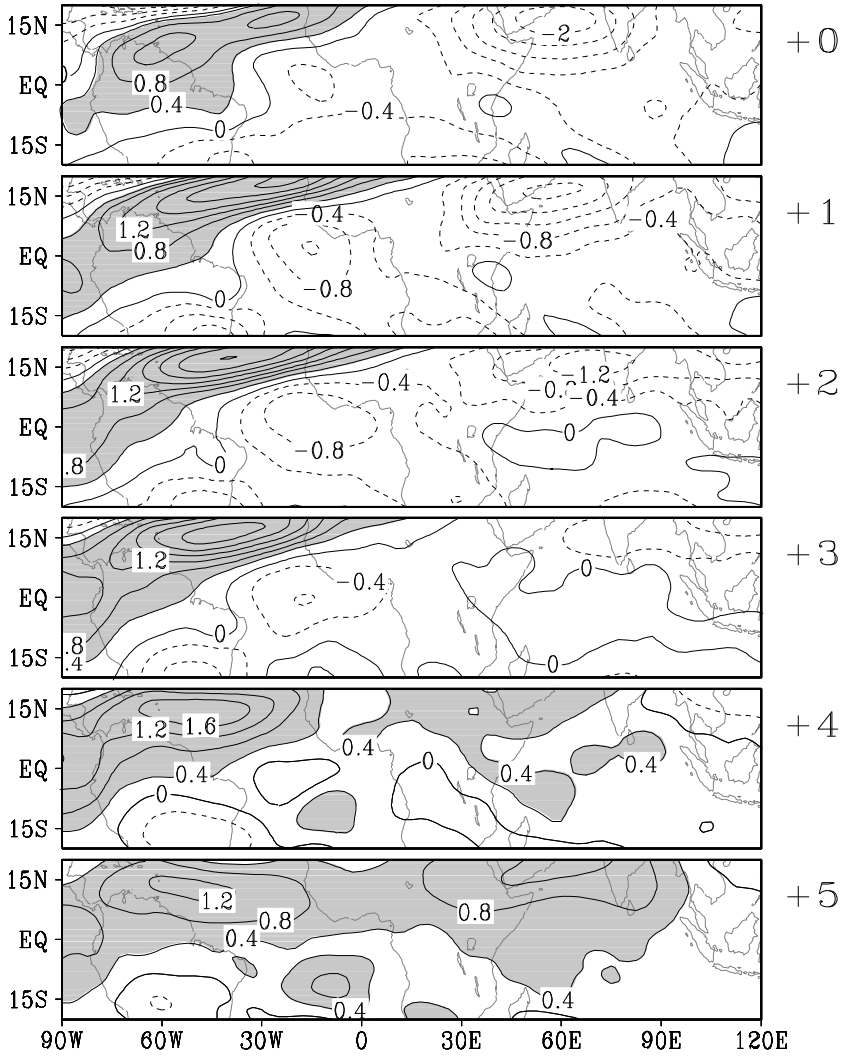
(Lin et al. JCLIM, 2009)

Extratropical influence



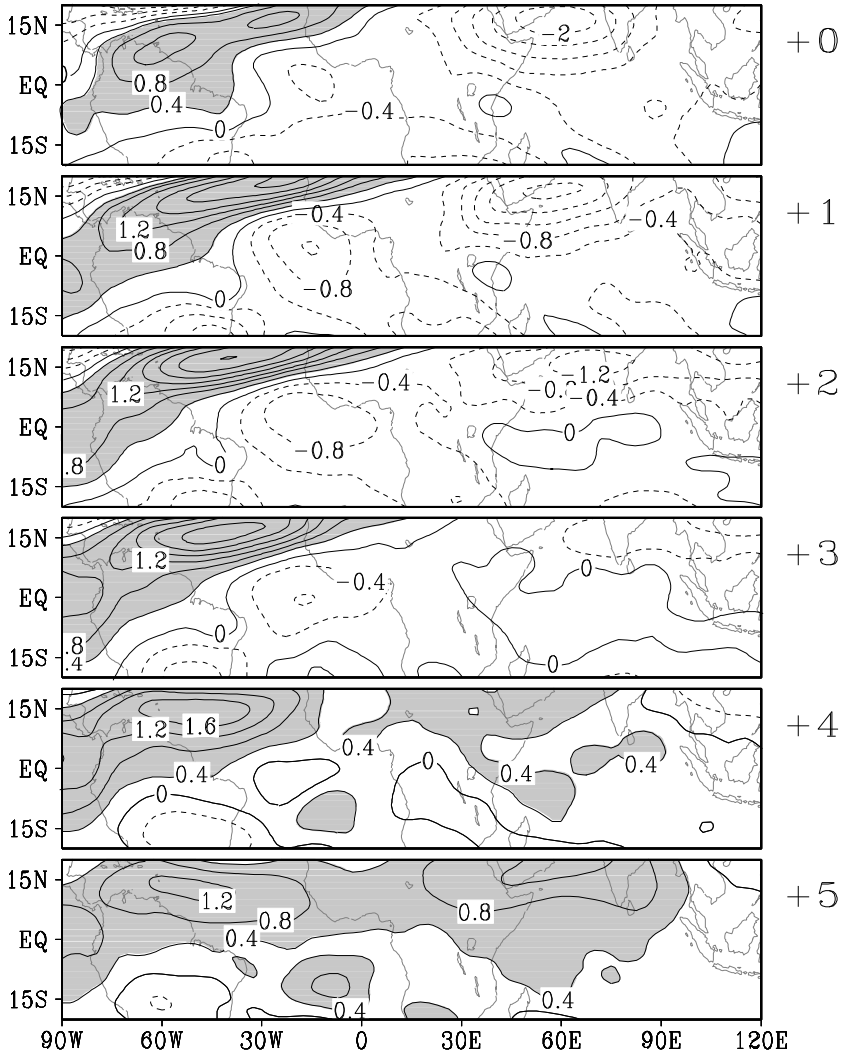
Lagged regression of 200mb U to NAO index

Extratropical influence

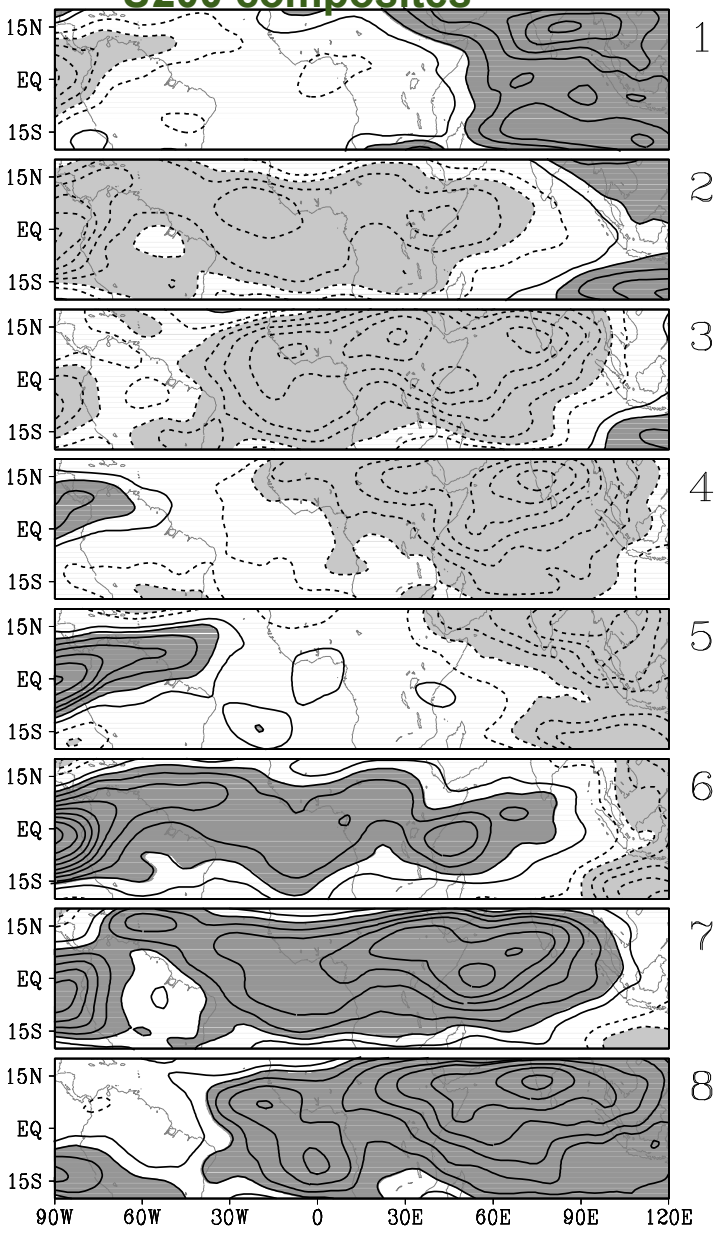


Lagged regression of 200mb U to NAO index

Extratropical influence

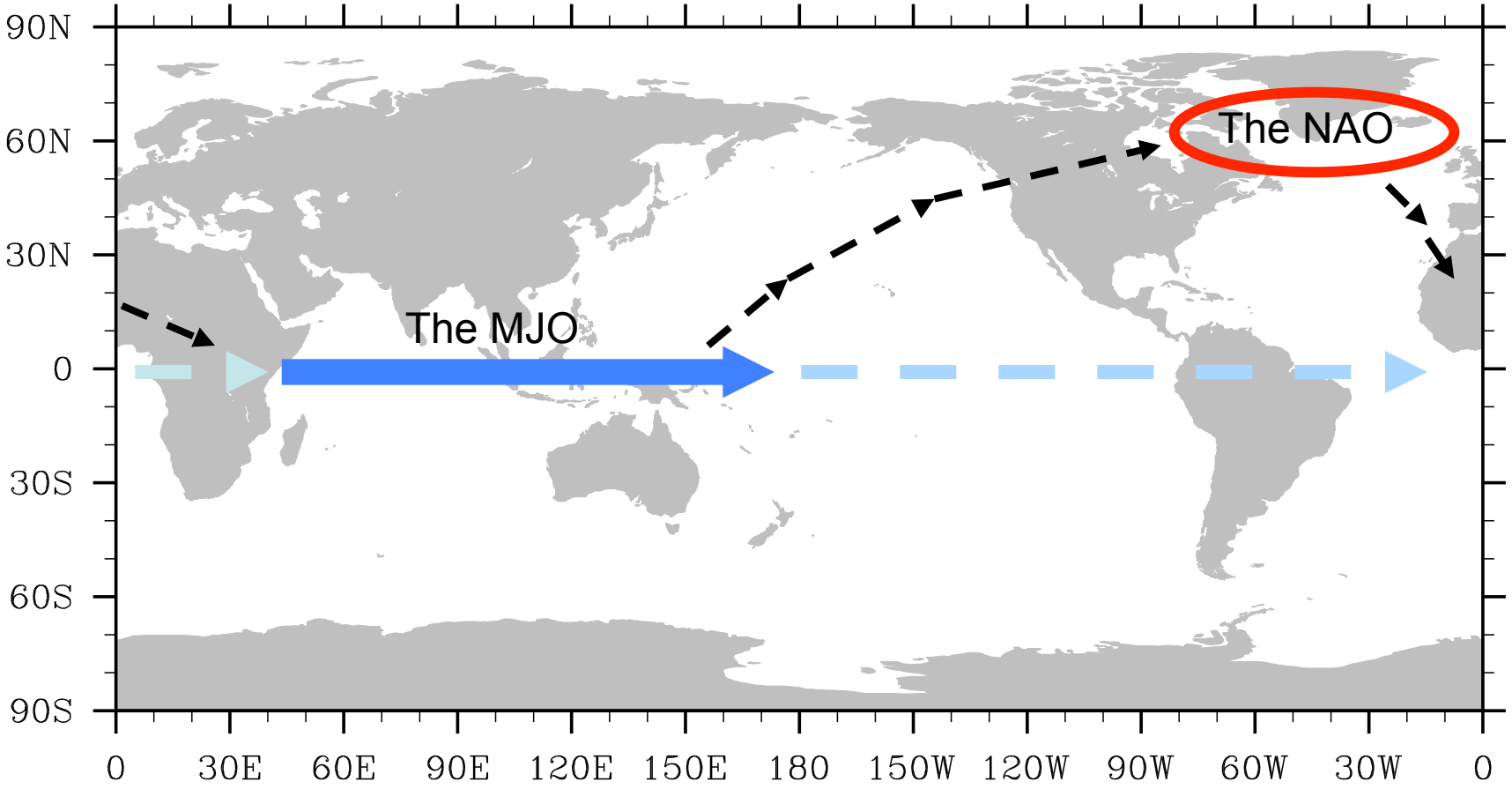


U200 composites

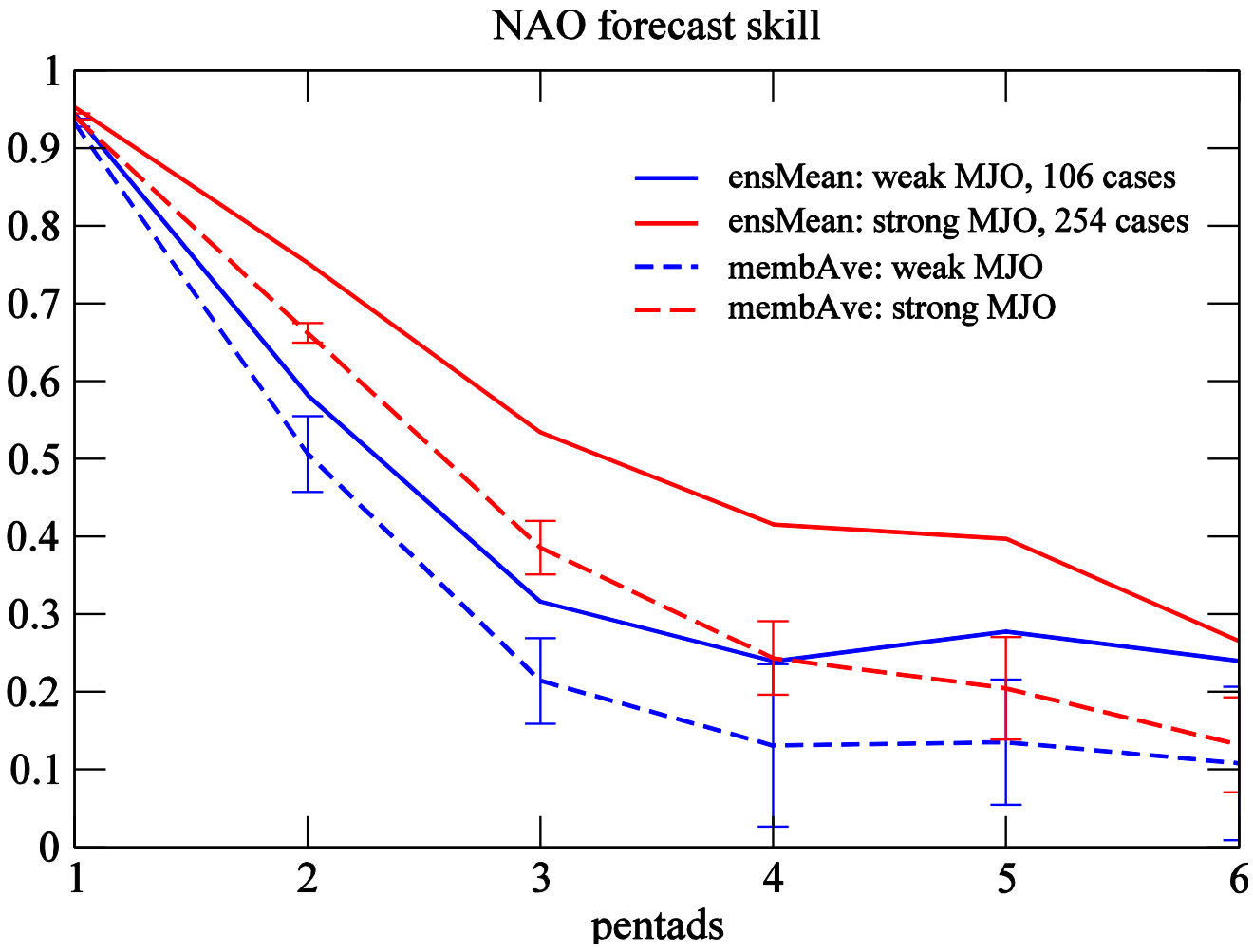


Lagged regression of 200mb U to NAO index

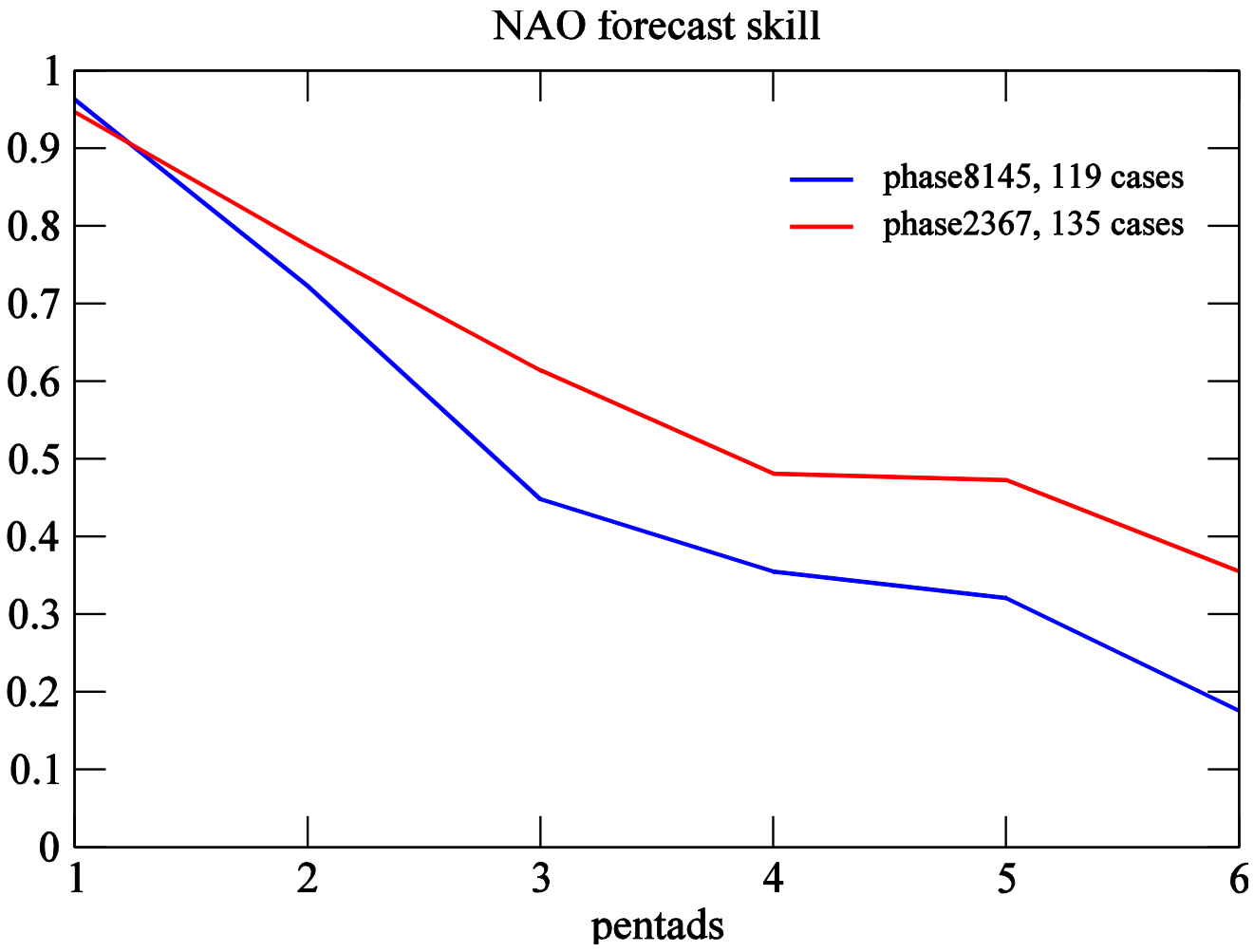
Two-way MJO – NAO interaction



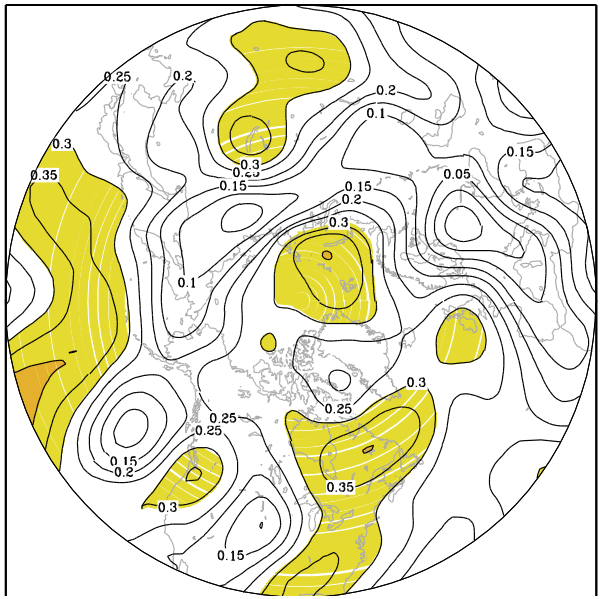
Impact of MJO-NAO interaction on subseasonal predictions



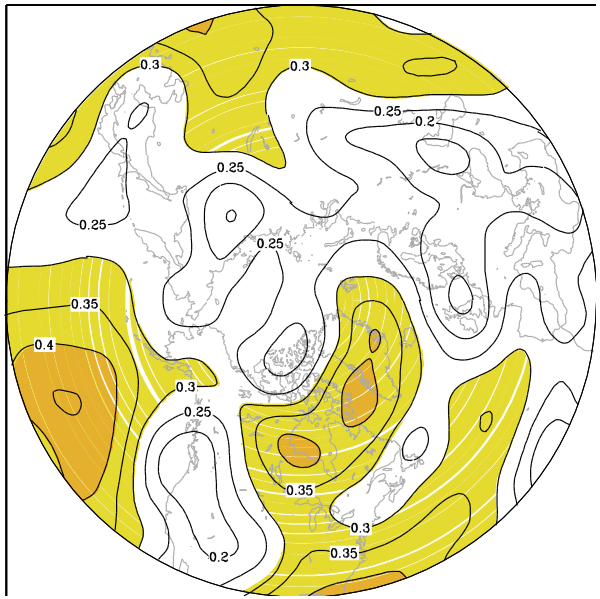
(Lin et al. GRL, 2010a)


NAO forecast skill
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
pentads
phase8145, 119 cases
phase2367, 135 cases

a) weak MJO: Z500 skill



b) strong MJO: Z500 skill



Correlation skill: averaged for pentads 3 and 4

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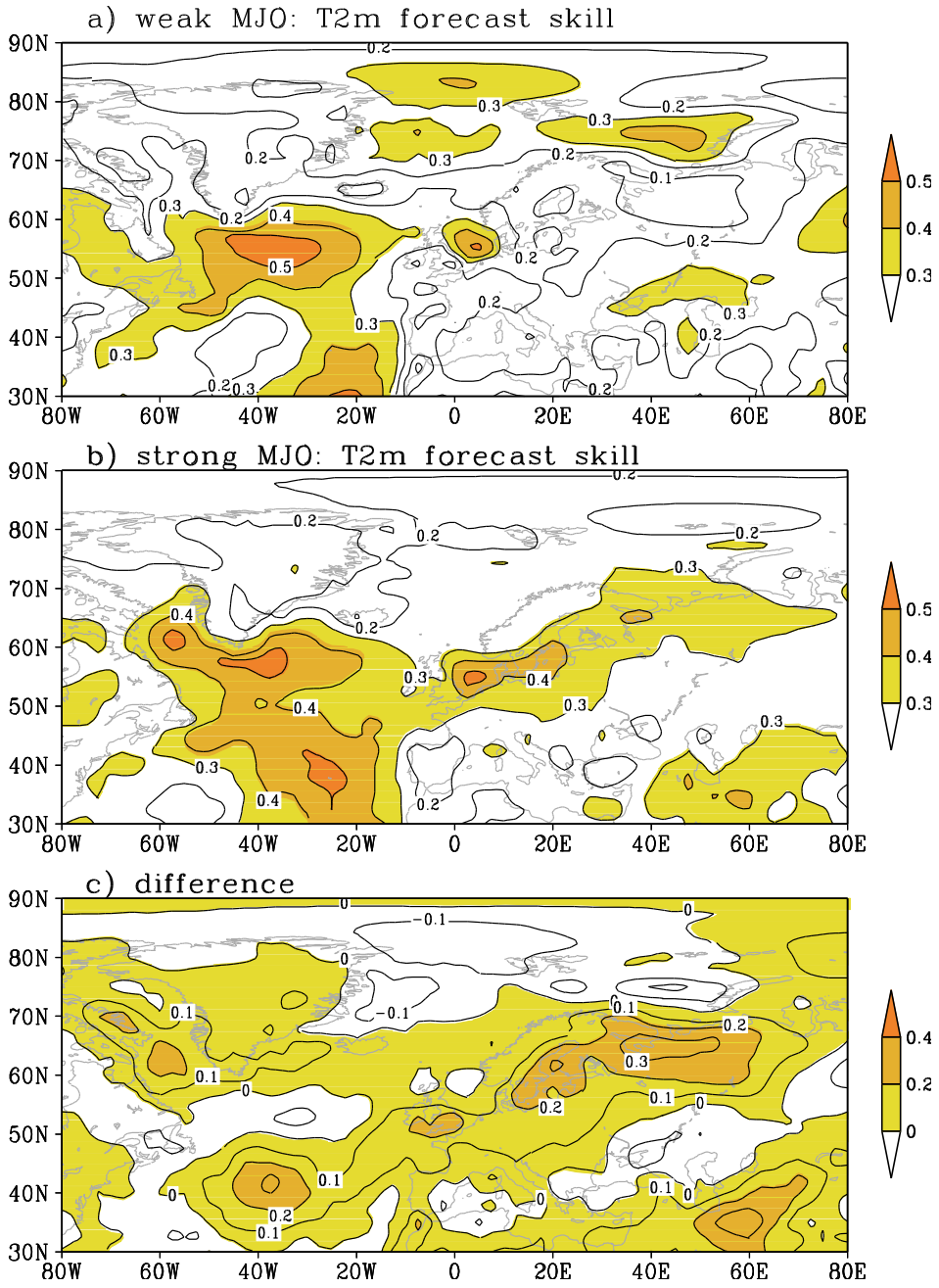
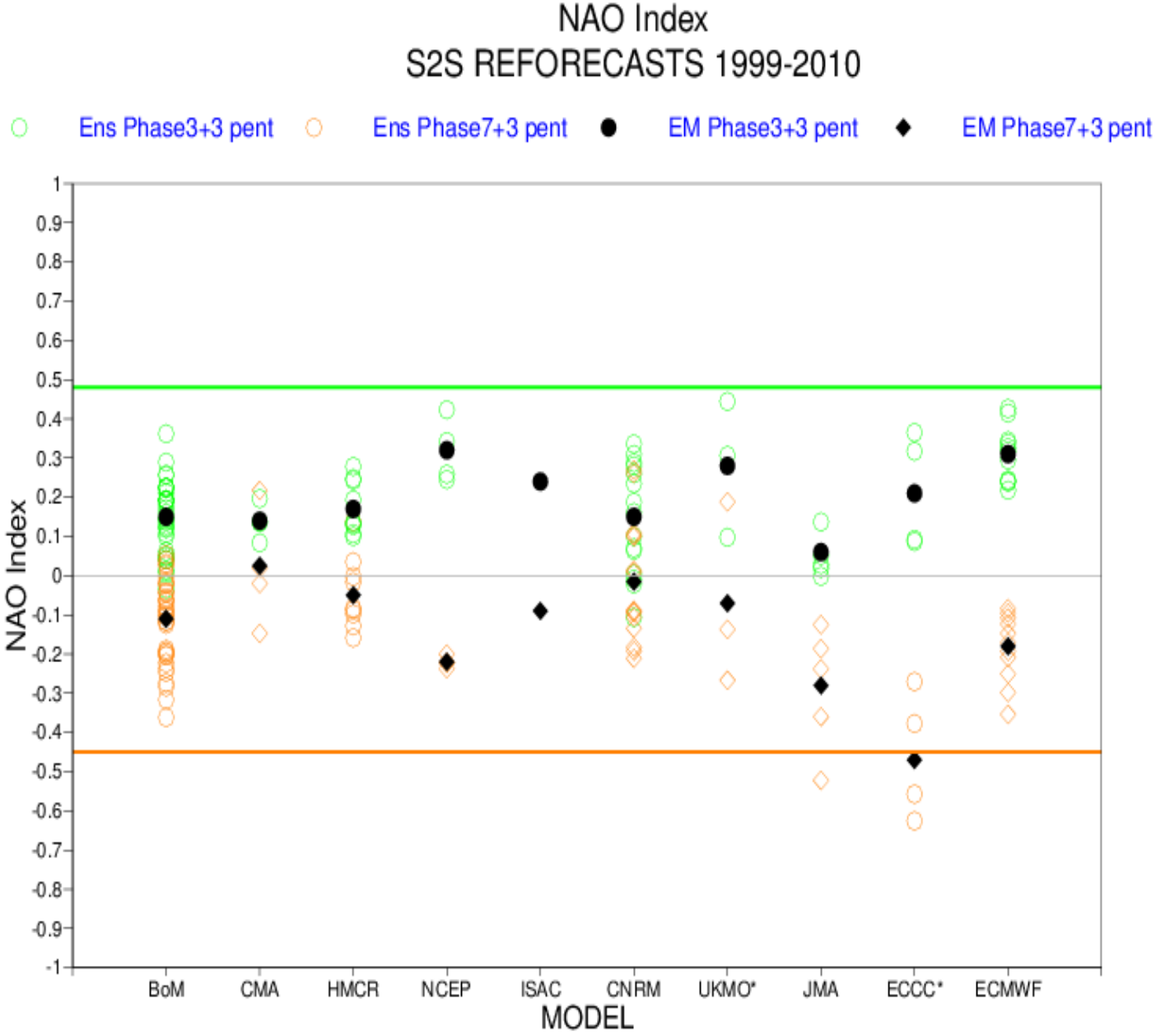
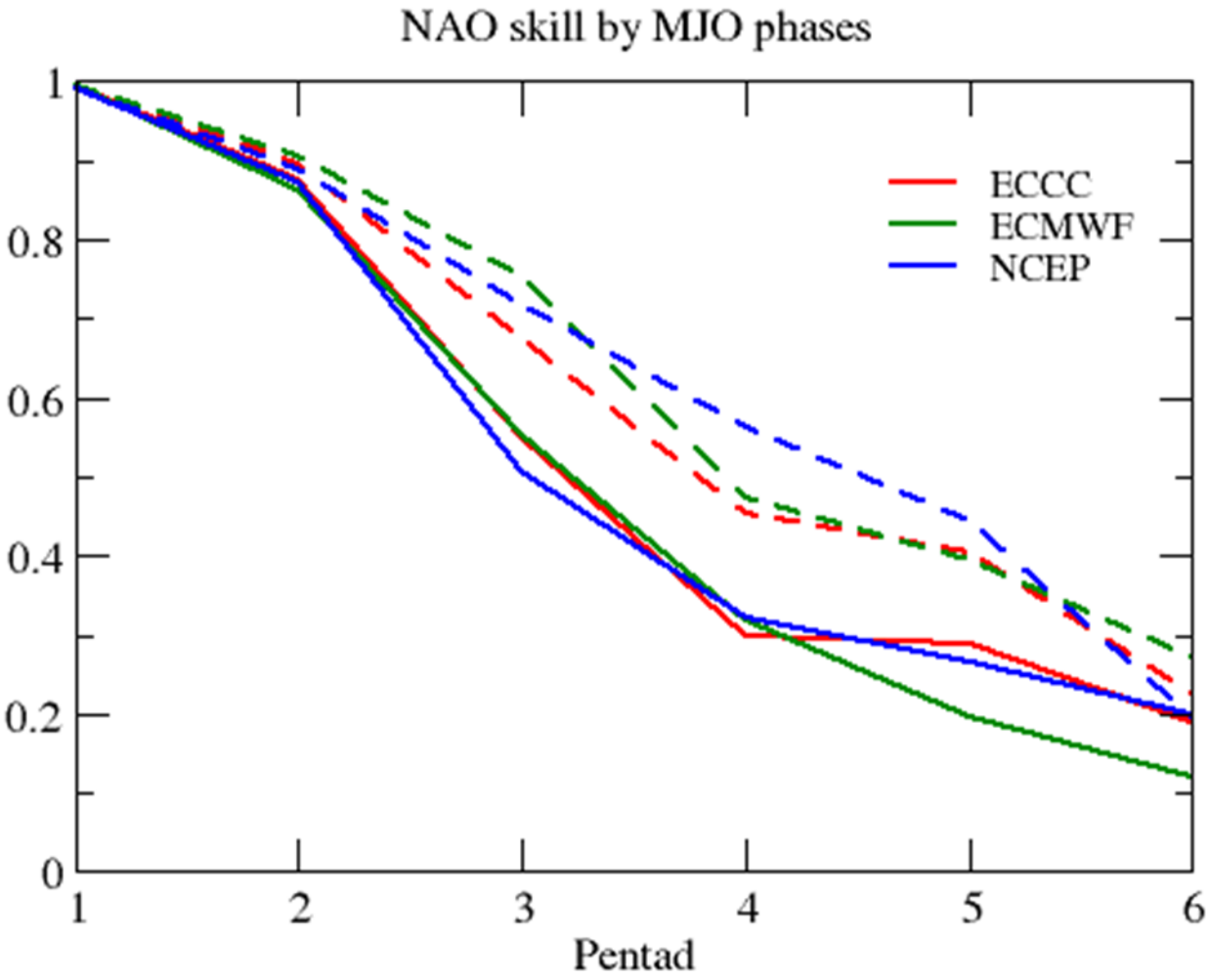



NAO Index
S2S REFORECASTS 1999-2010
Ens Phase3+3 pent
Ens Phase7+3 pent
EM Phase3+3 pent
EM Phase7+3 pent
NAO Index
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1
BoM
CMA
HMCR
NCEP
ISAC
CNRM
UKMO*
JMA
ECCC*
ECMWF
MODEL

F. Vitart

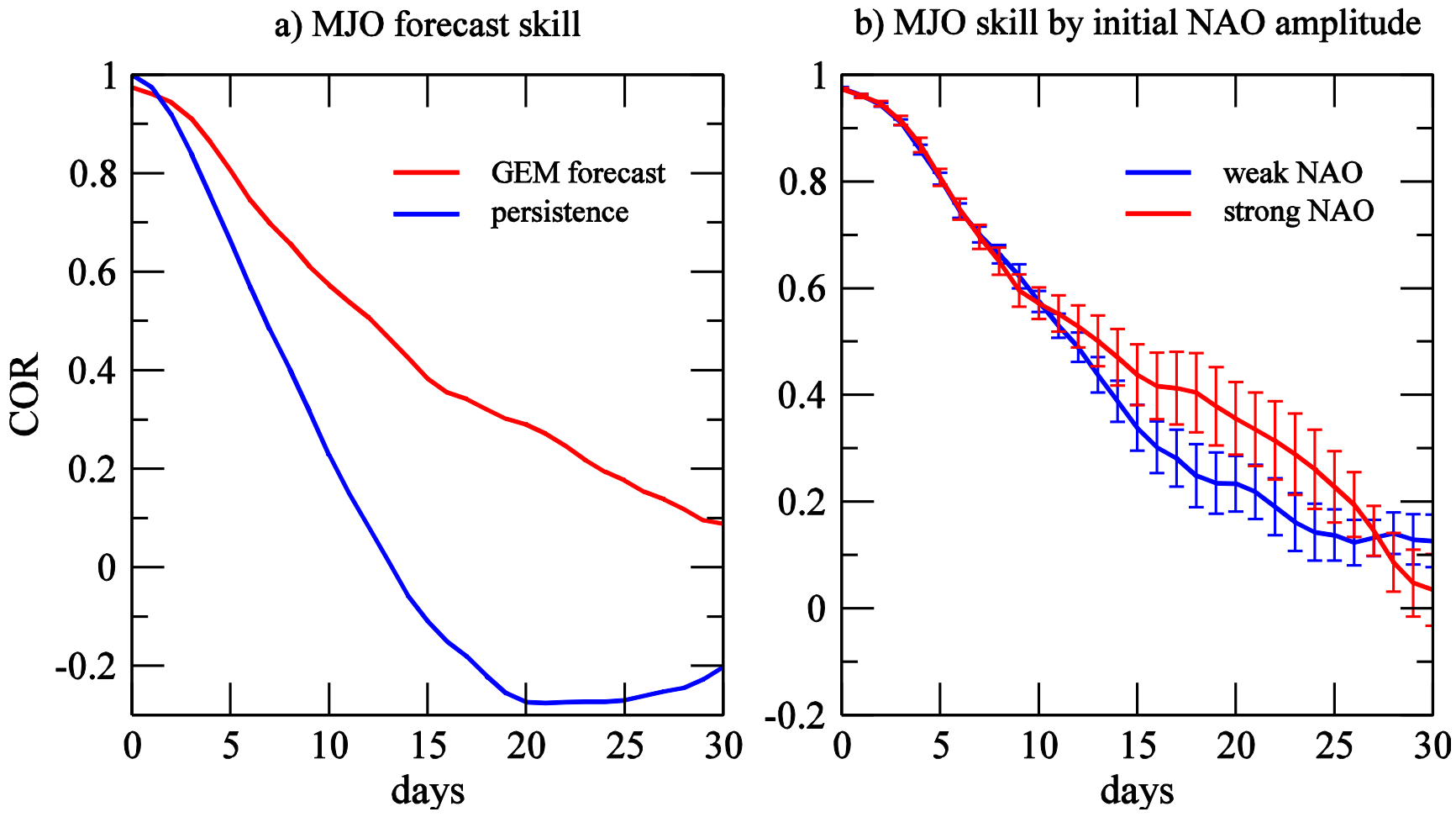
S2S hindcast data



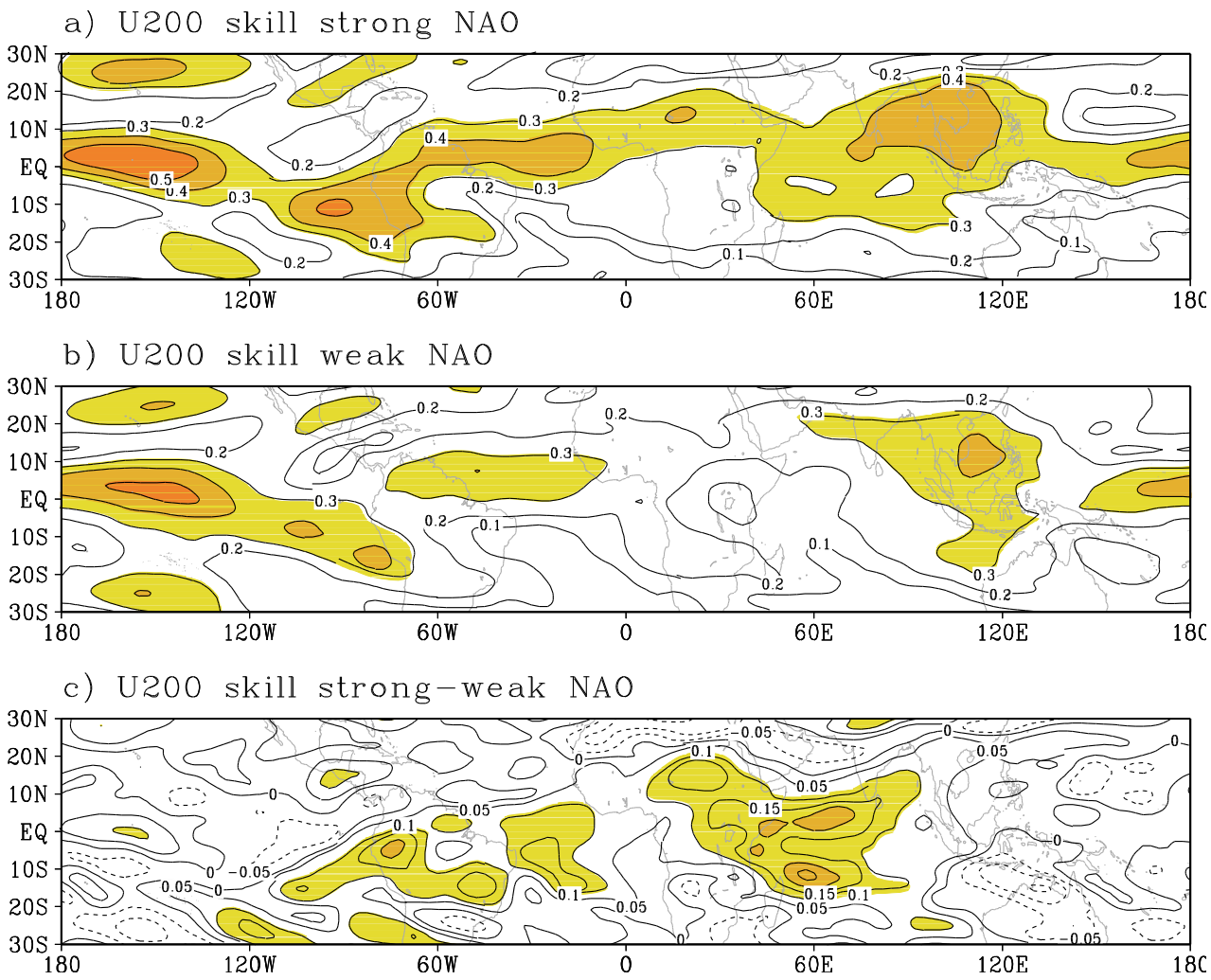
NAO forecast skill when the initial condition is in MJO phase 2367 (dashed) compared with MJO phases 1458 (solid).

MJO forecast skill
--- impact of the NAO

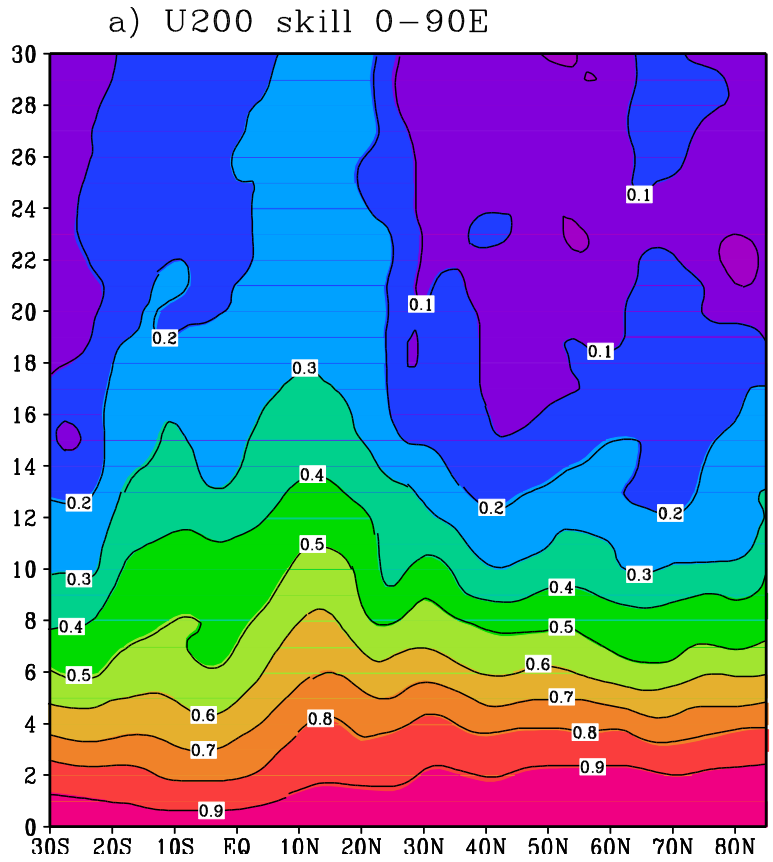
Lin et al. 2010, GRL

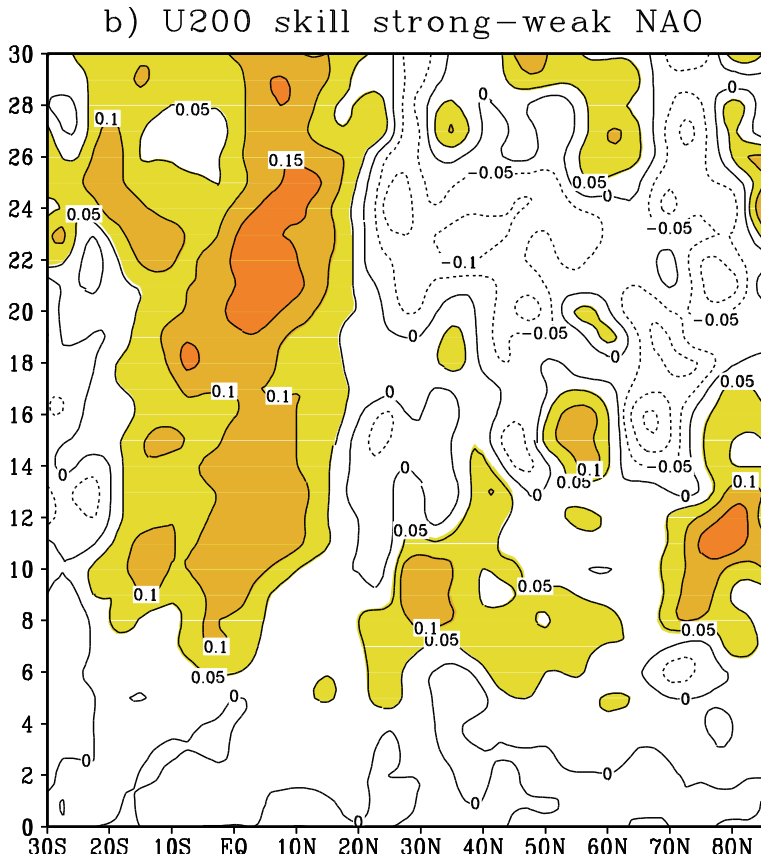


(Lin et al. GRL, 2010b)

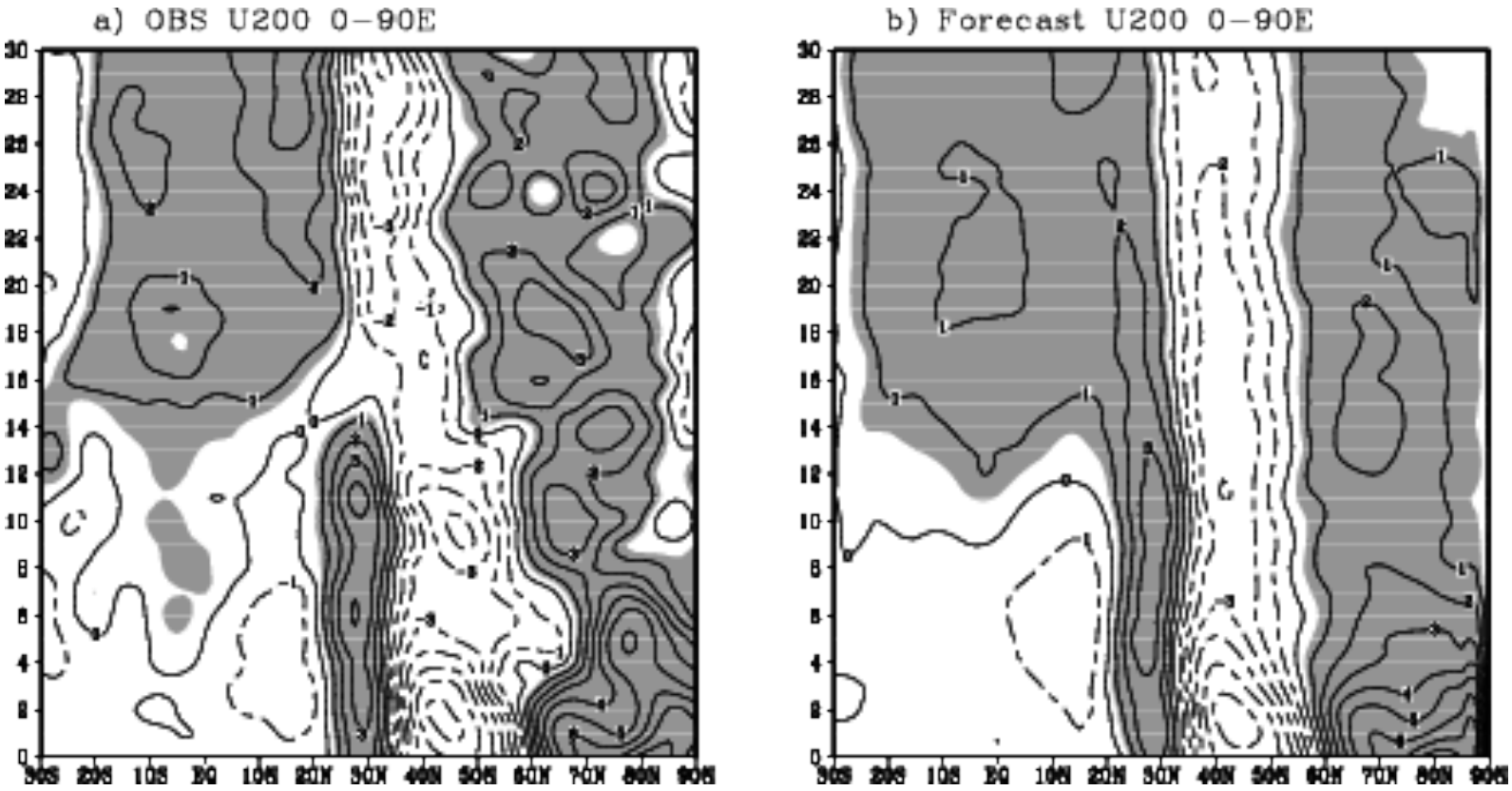


Skill averaged for days 15-25





(Lin et al. GRL, 2010b)



(Lin et al. GRL, 2010b)

Summary

- Two-way interactions between the MJO and NAO
- Lagged association of North American SAT with MJO
- NAO intraseasonal forecast skill influenced by the MJO
- MJO forecast skill influenced by the NAO