Tropical ISO and Extratropical Extreme Weather during 2009-2011 ENSO cycle

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Acknowledge contributions from
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Outline

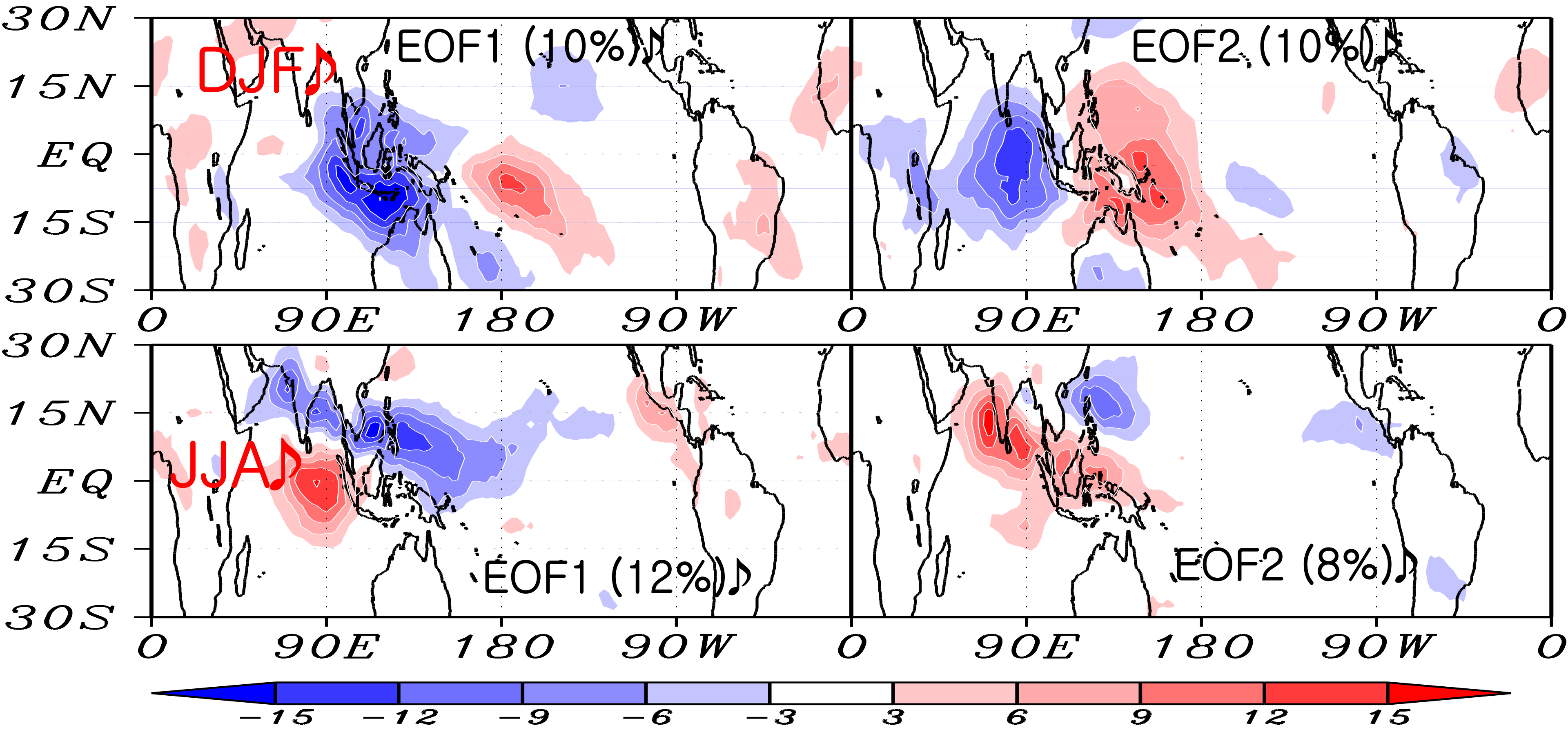
Bimodal representation of the ISO

ISO in the past two years (2009-2011)

MJO modulation of 2009/10 US snowstorms

BSISO and June 2011 flooding in EASM

Principal Modes of ISO (30-60 day) during DJF and JJA, 1979-2010 ♪

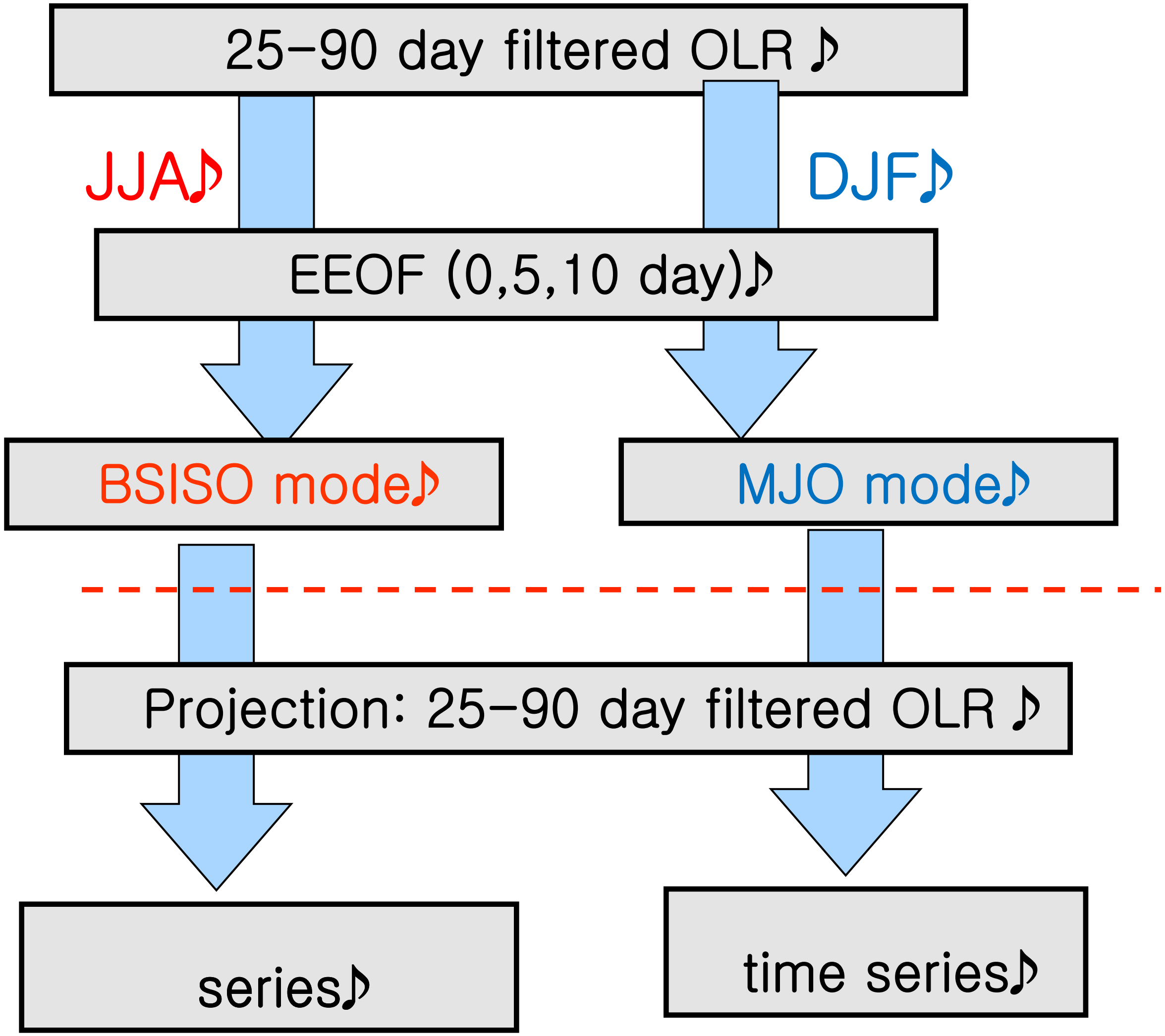


Do we need a bimodal representation of Tropical ISO?♪

Bimodal representation
Bimodal

Kikuchi, Wang, Kajikawa, 2011 Climate Dyn

Define MJO and BSISO modes



25−90 day filtered OLR ♪

JJA♪

DJF♪

EEOF (0,5,10 day)♪

BSISO mode♪

MJO mode♪

Projection: 25−90 day filtered OLR ♪

series♪

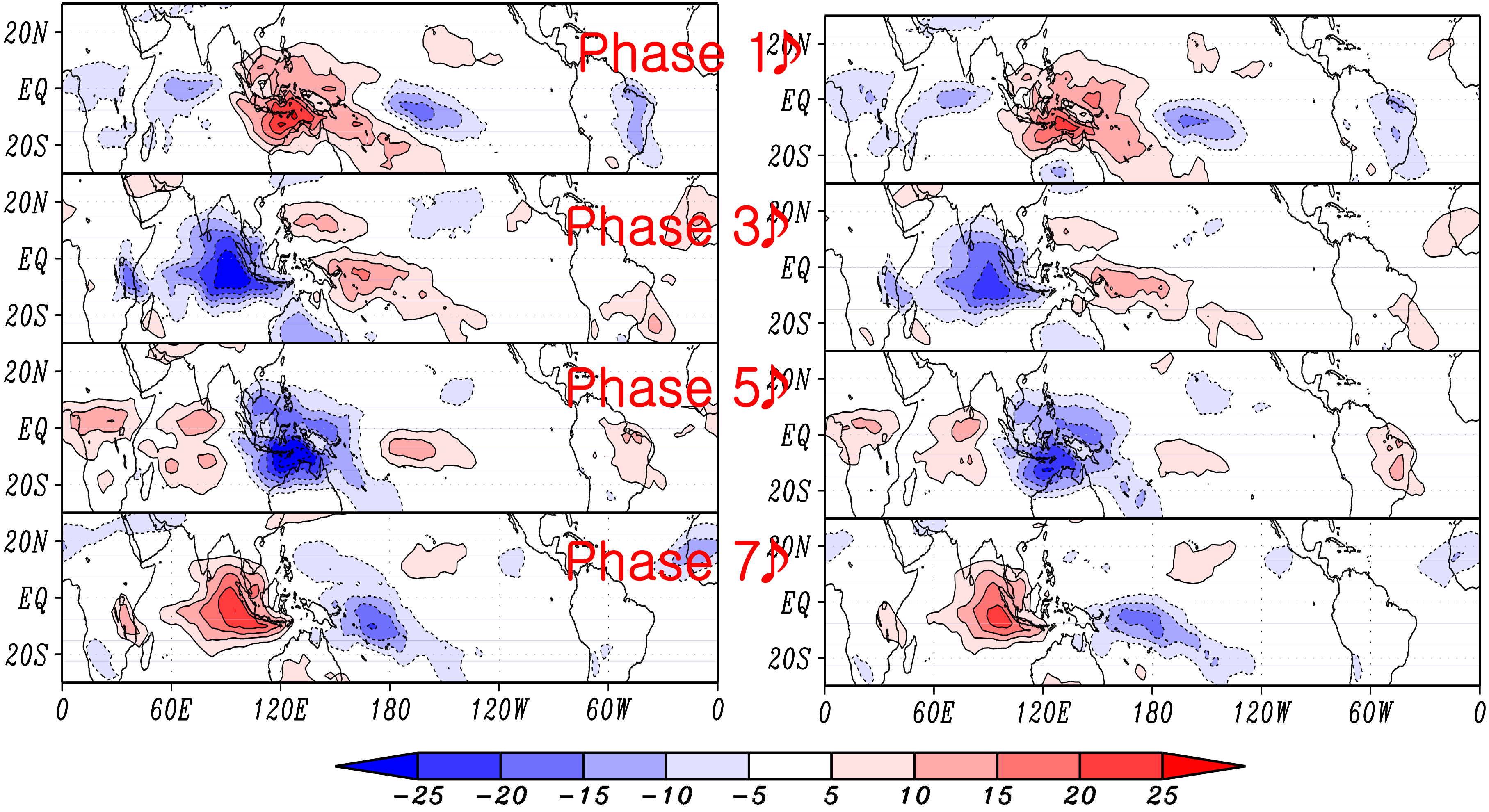
time series♪

*BSISO: Boreal Summer ISO♪

Comparison of DJF composites ♪

BM-MJO index♪

RMM index♪



Phase 1♪

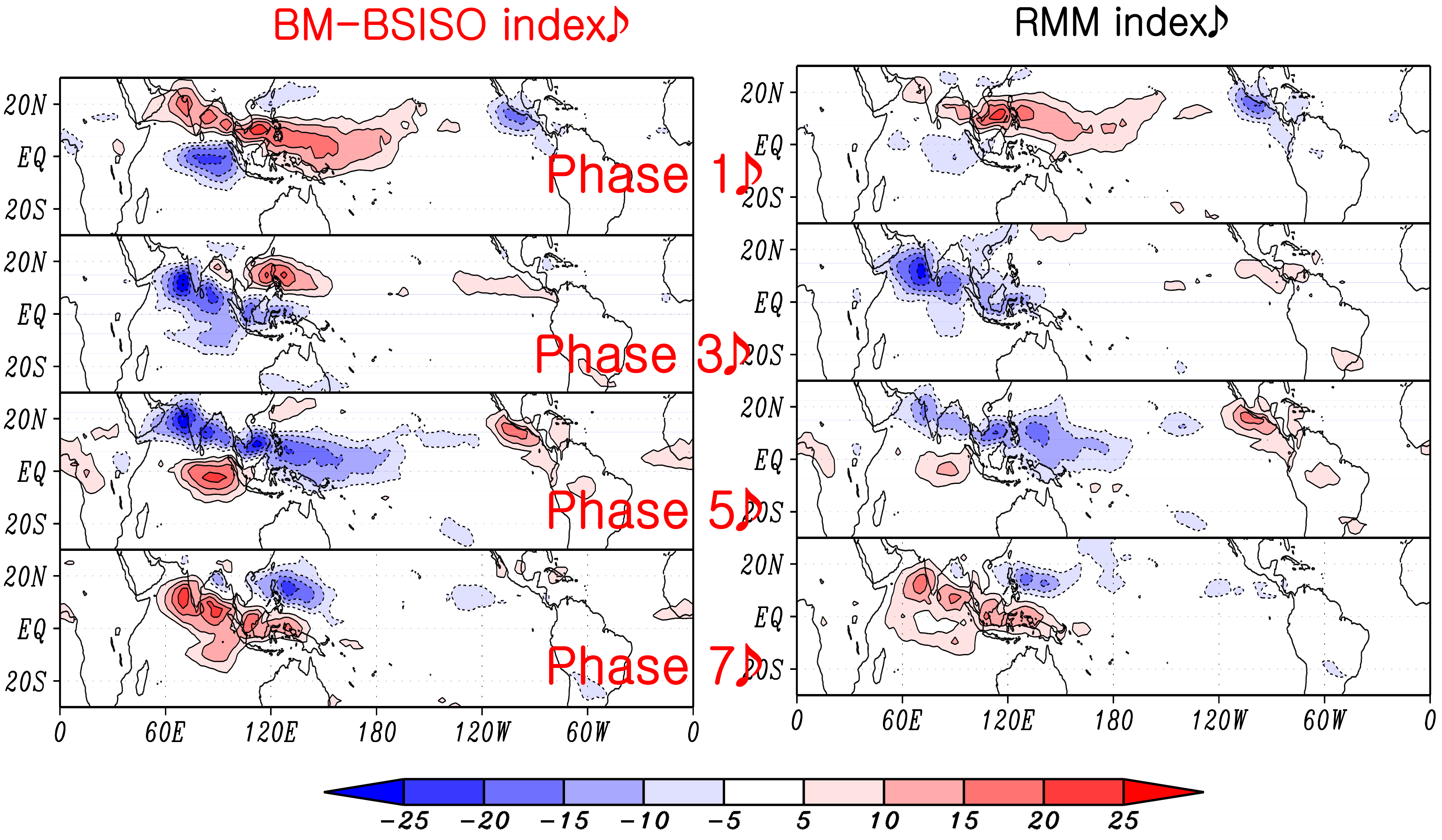
Phase 3♪

Phase 5♪

Phase 7♪

1726 days♪

Comparison of JJA composites♪



BM-BSISO index♪

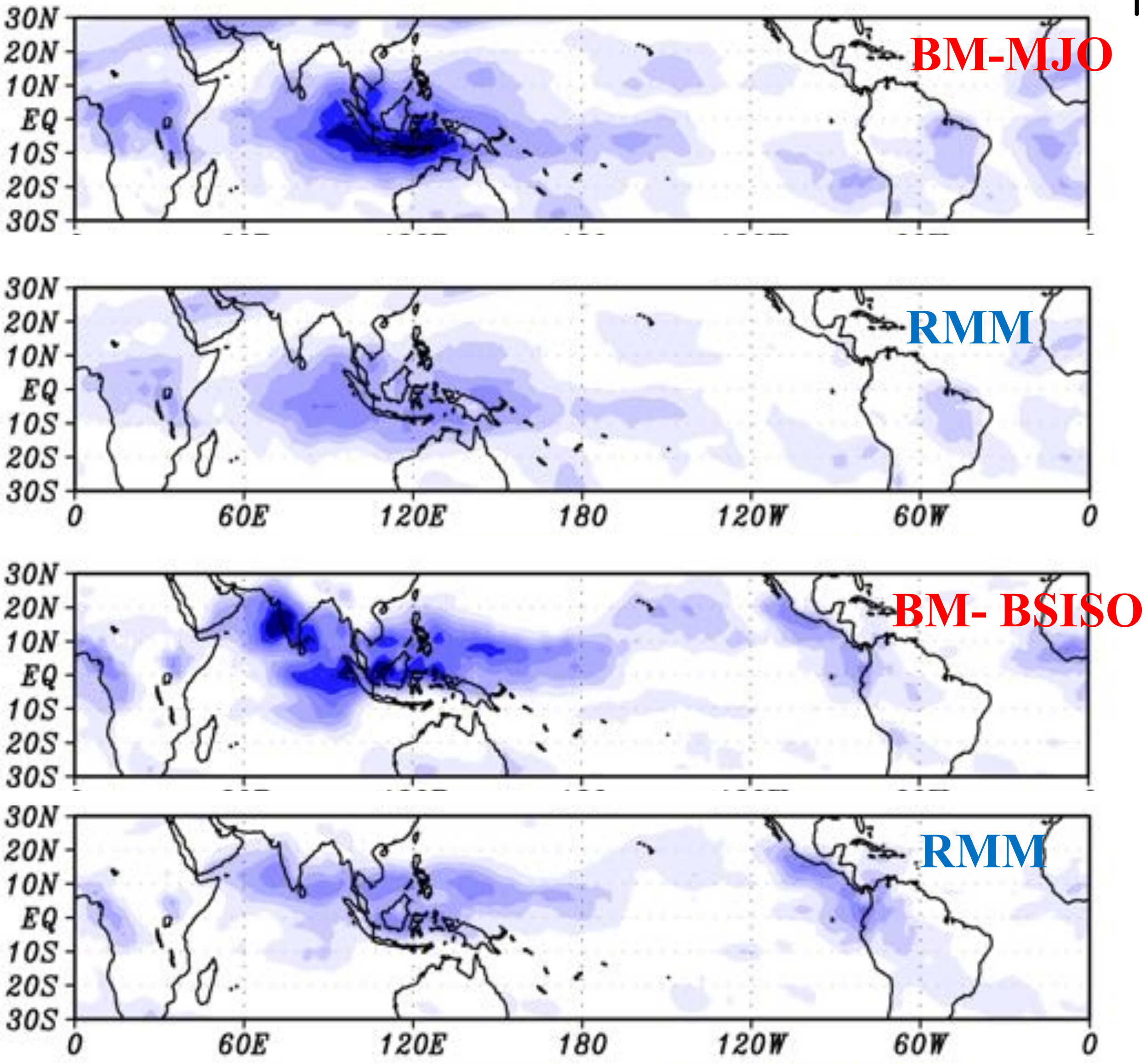
RMM index♪

1579 composite days♪

Comparison of Fractional Variance

Tropical mean♪

DJF



17.3%♪

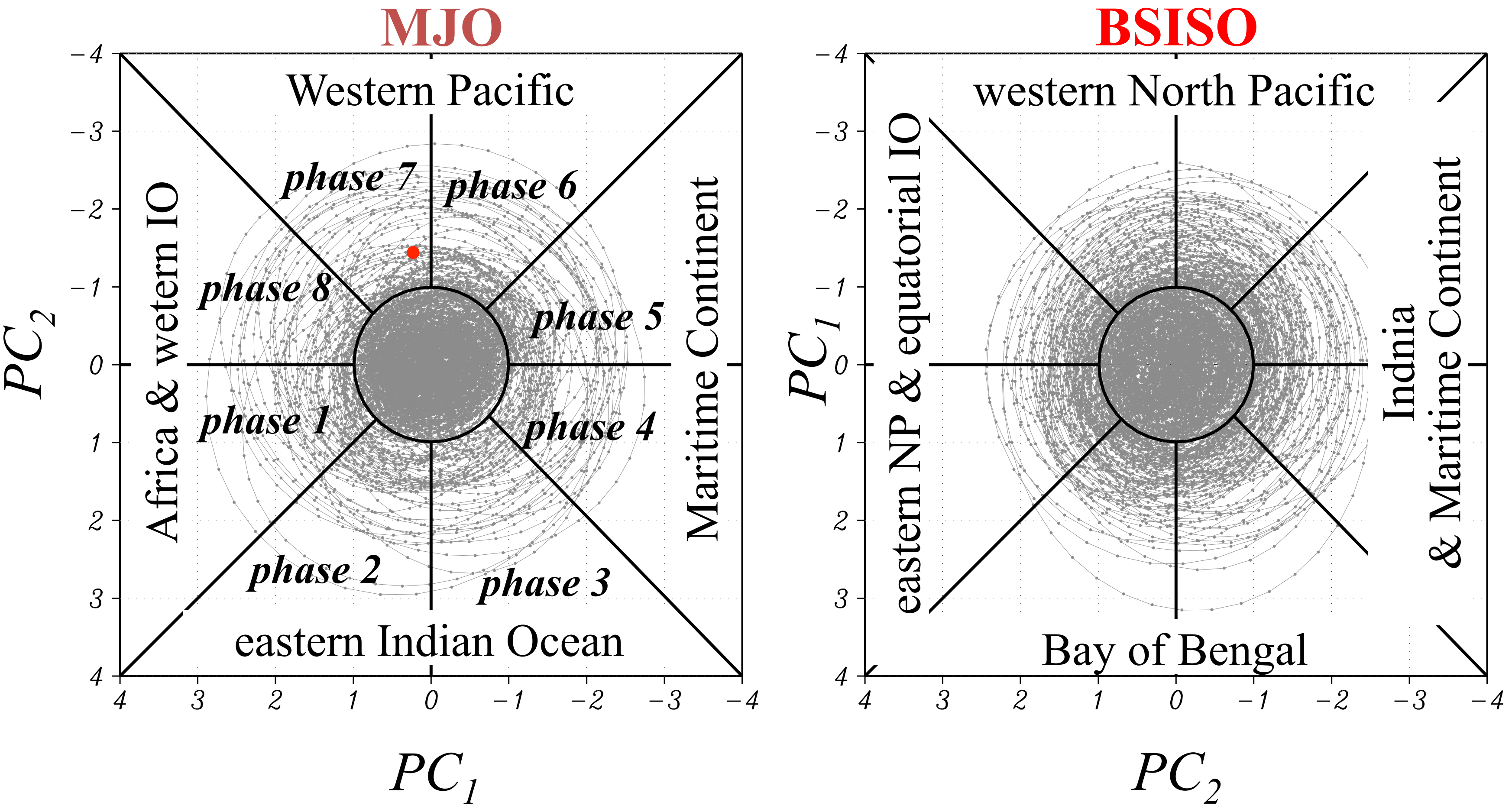
12.9%♪

JJA

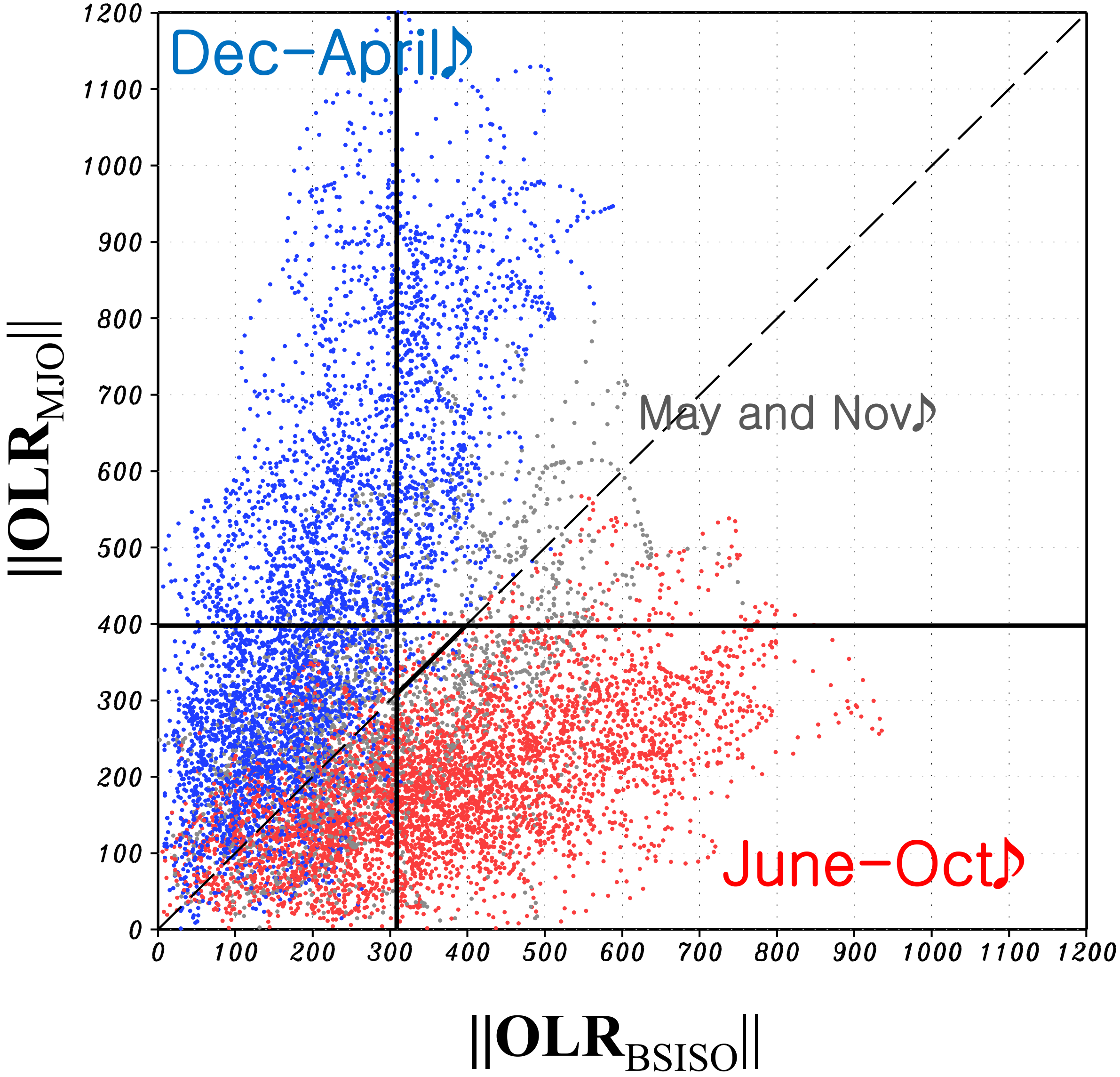
14.6%♪

11.1%♪

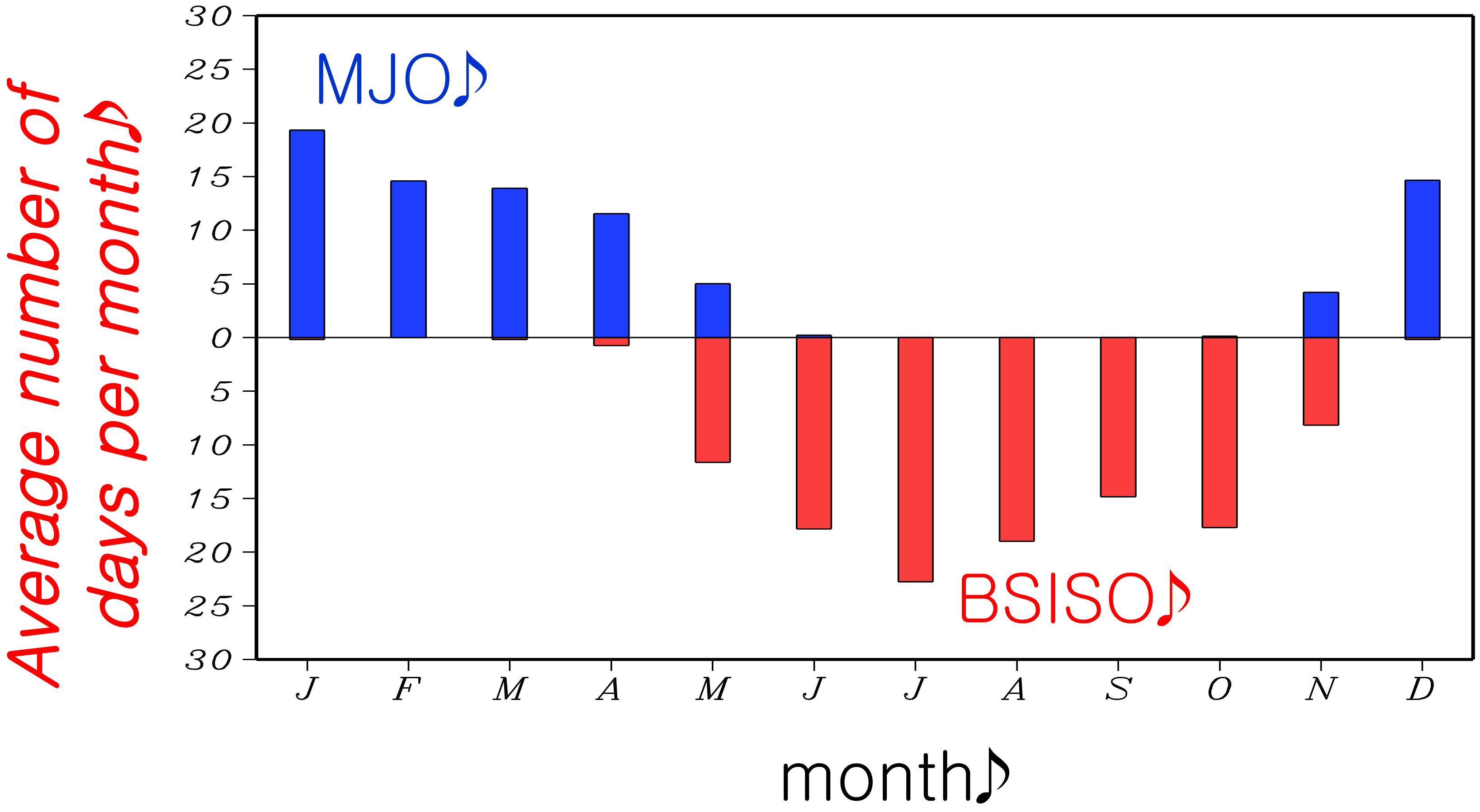
Phase space plots of MJO and BSISO



MJO vs BSISO: Seasonal Separation♪

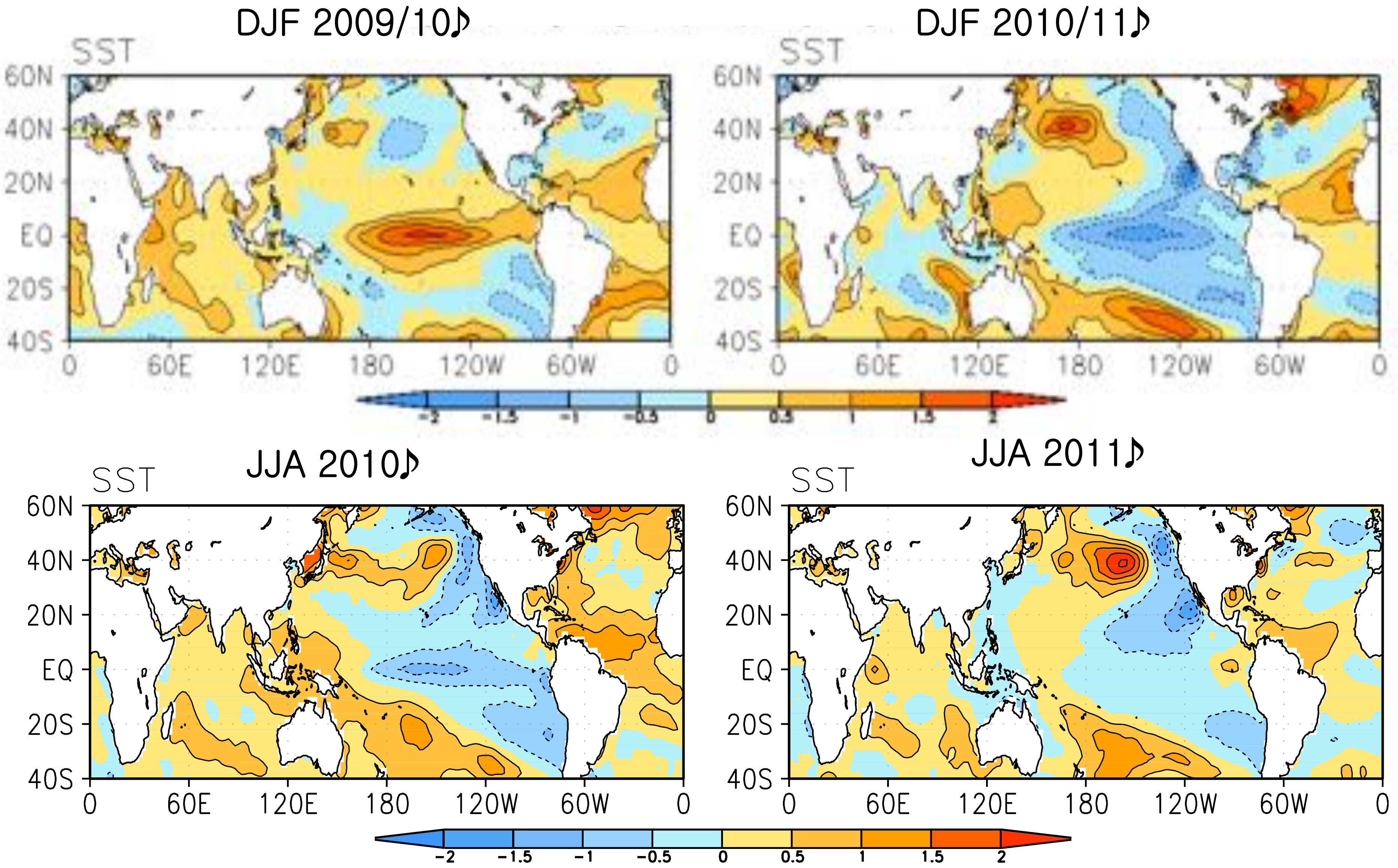


Seasonal variation of MJO and BSISO♪



ISO during **Dec 2009 to August 2011**

Seasonal Mean SST Anomalies: ENSO condition♪



DJF 2009/10♪

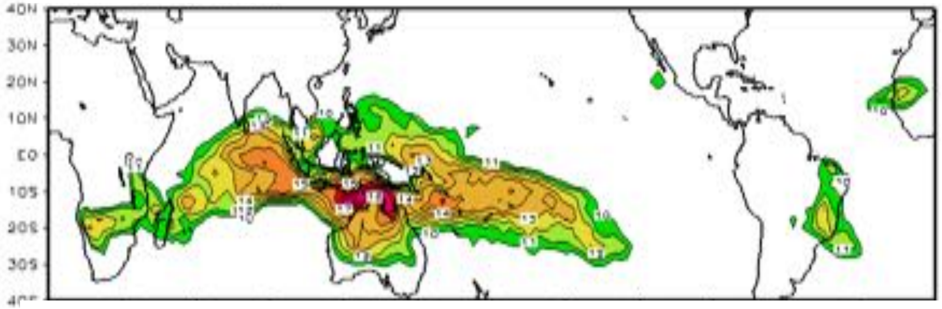
DJF 2010/11♪

JJA 2010♪

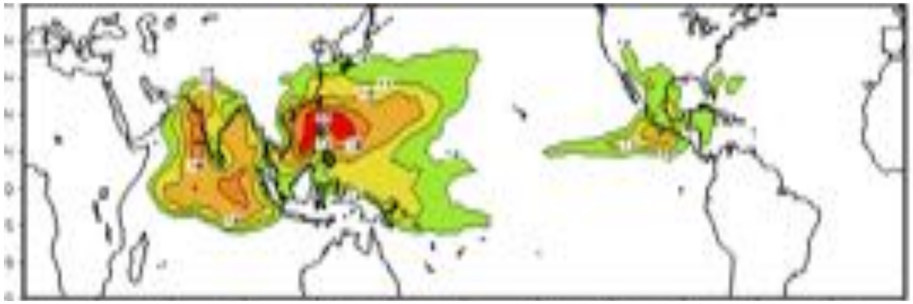
JJA 2011♪

Intraseasonal Variance(OLR) during 2010 and 2011

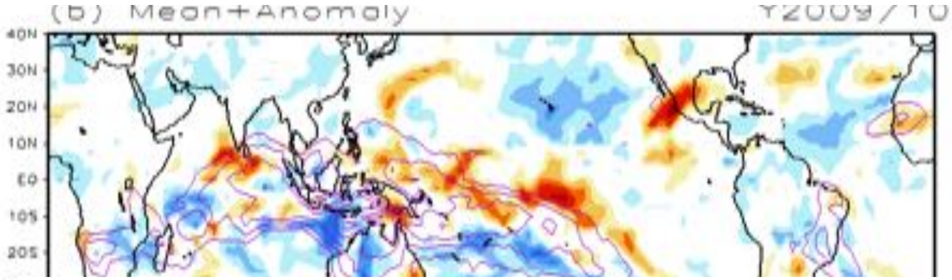
(a) ISV (DJF) Mean



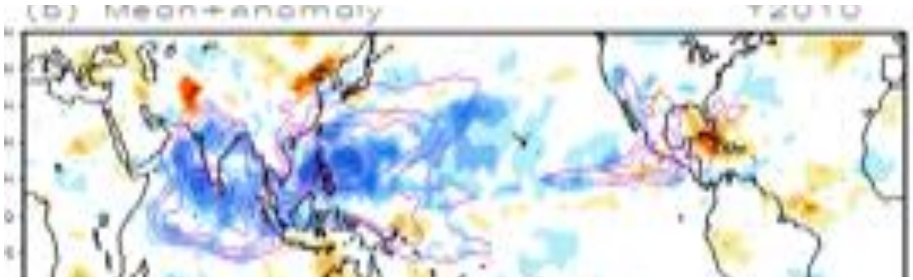
(a) ISV (JJA) Mean♪



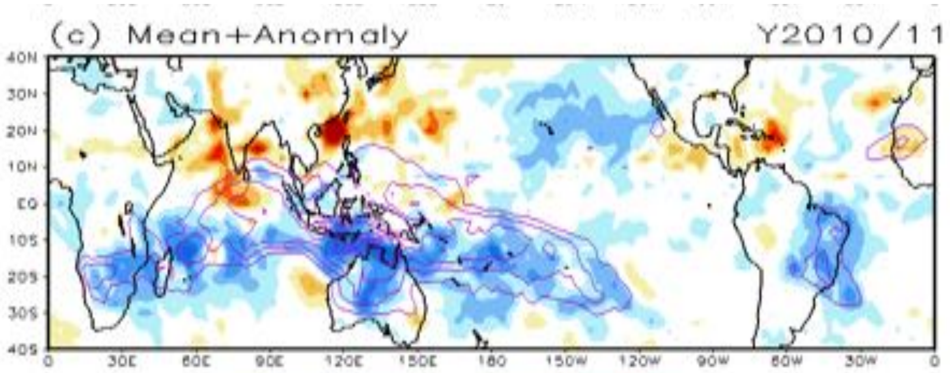
(b) ISV (DJF) 2009/10



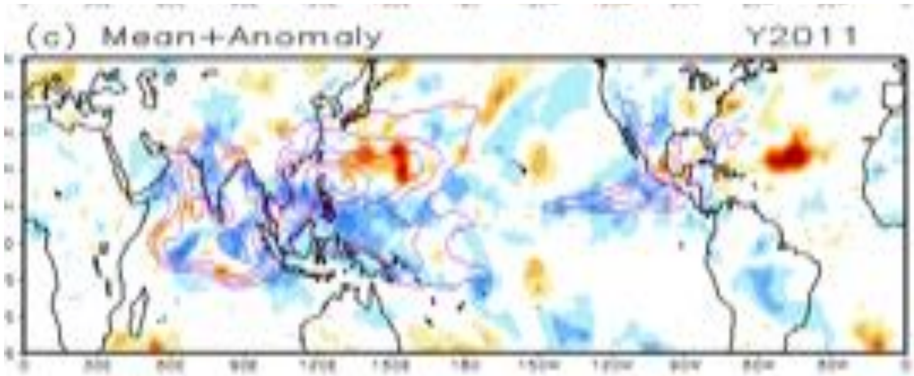
(b) ISV (JJA) 2010 ♪



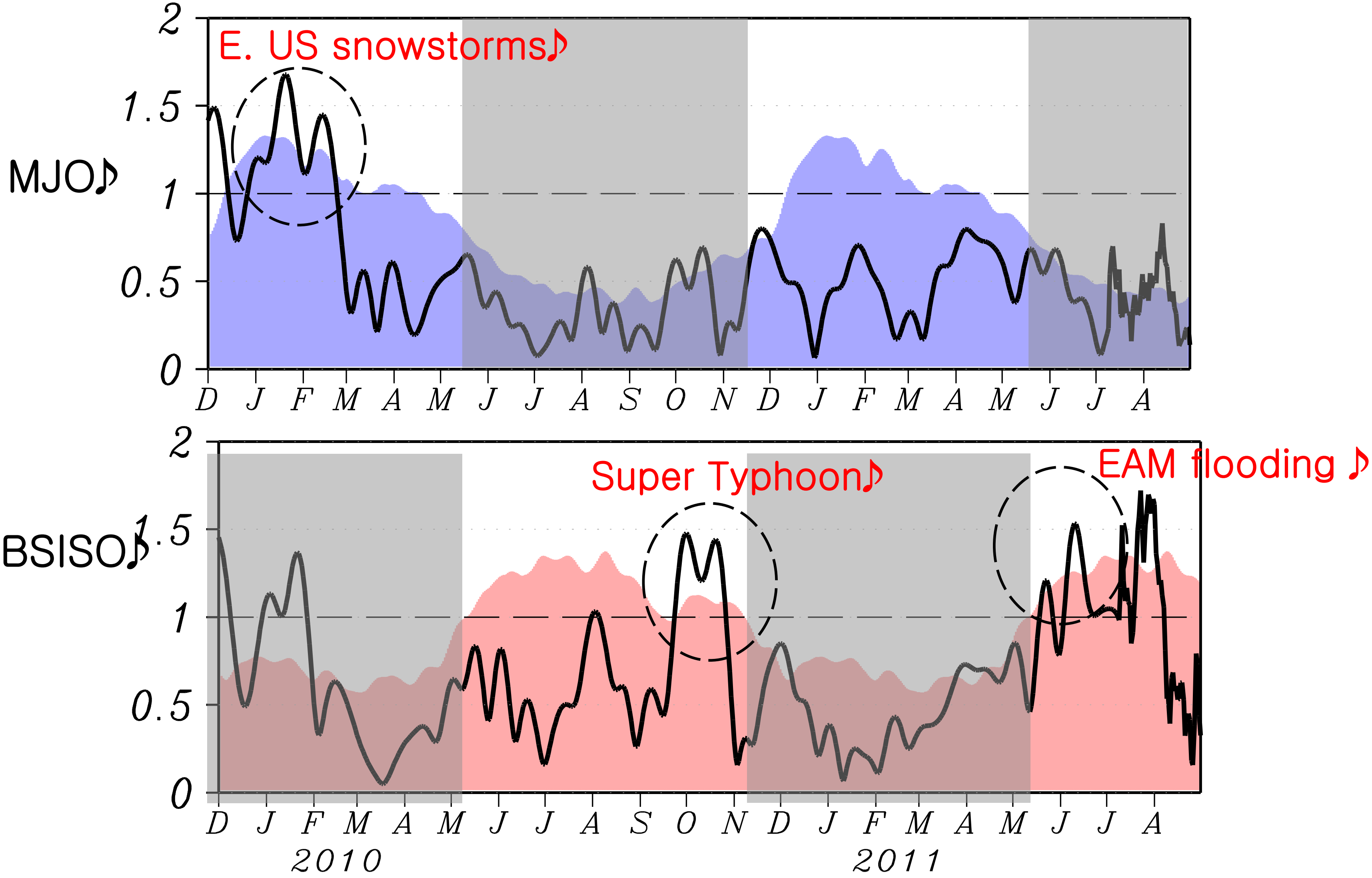
(c) ISV (DJF) 2010/11



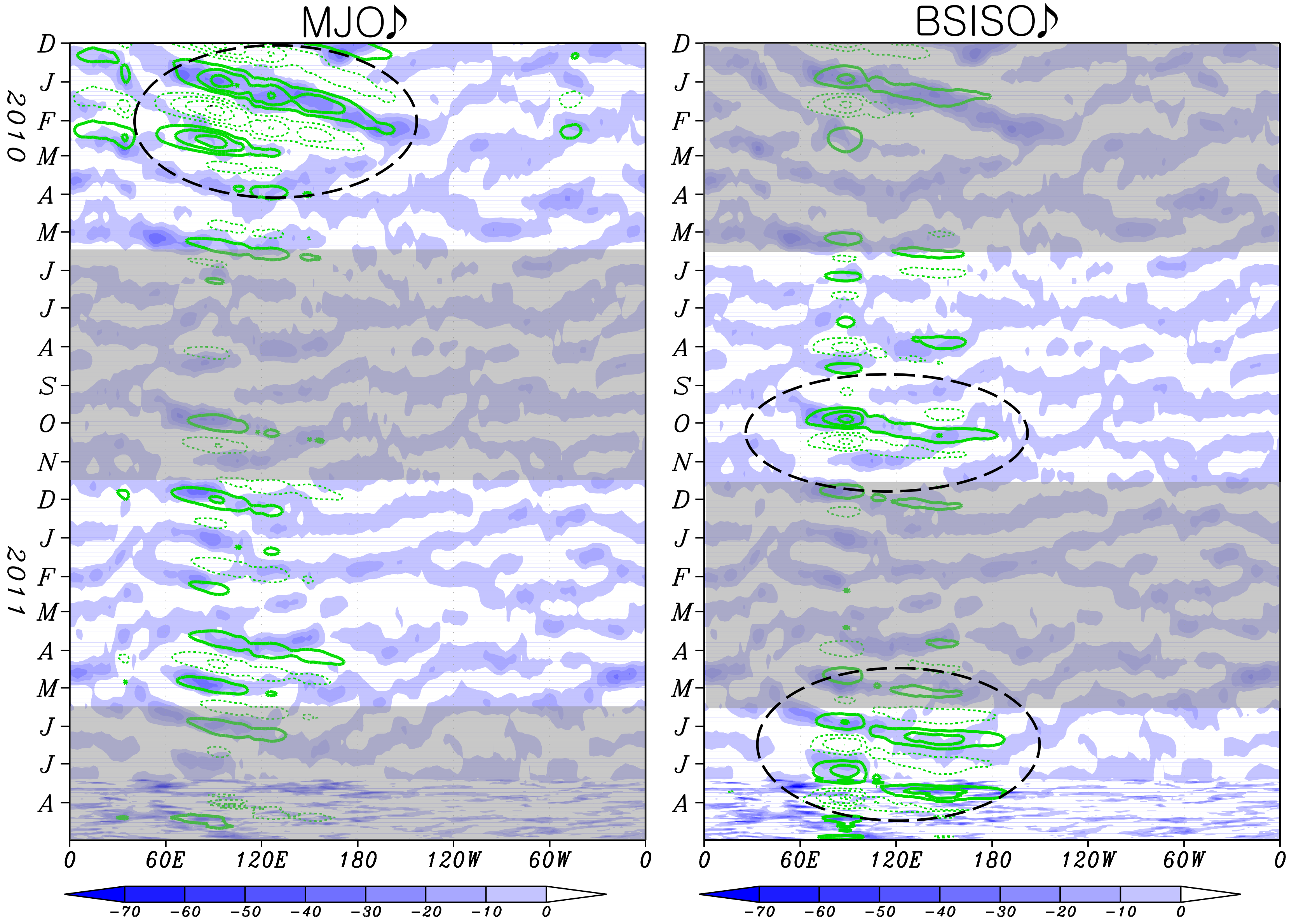
(c) ISV (JJA) 2011♪



Amplitude of two ISO modes: **Dec2009-Aug 2011**



Amplitude of two ISO modes: Hovmöller diagram♪



MJO regulation of DJF 2009/10 Snow storms in US

Moon, Wang and Ha 2011 Climate Dyn

Feb 7-10 snowstorms over eastern US

MJO during DJF 2009/10 and snowfall in eastern E. US

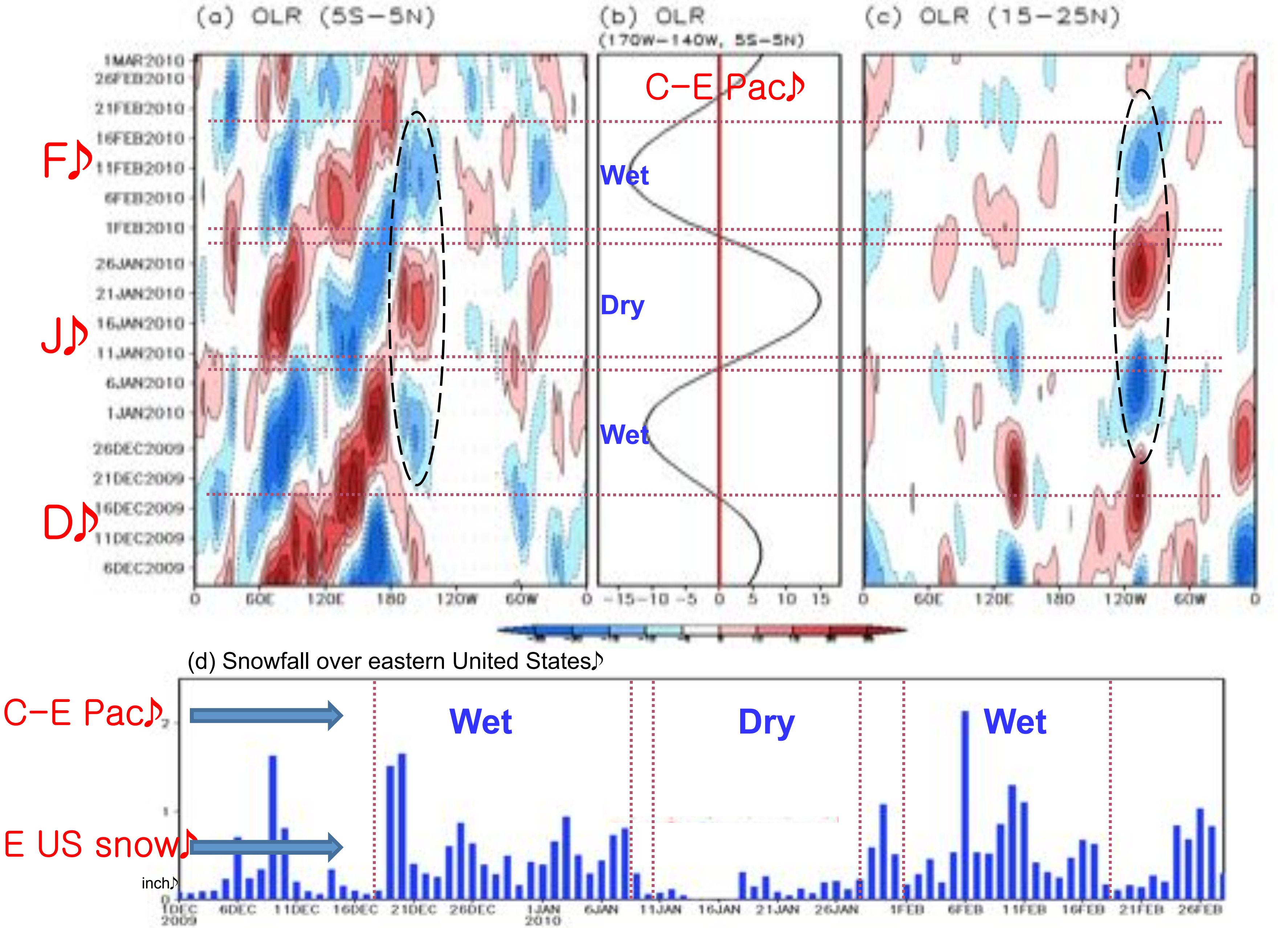
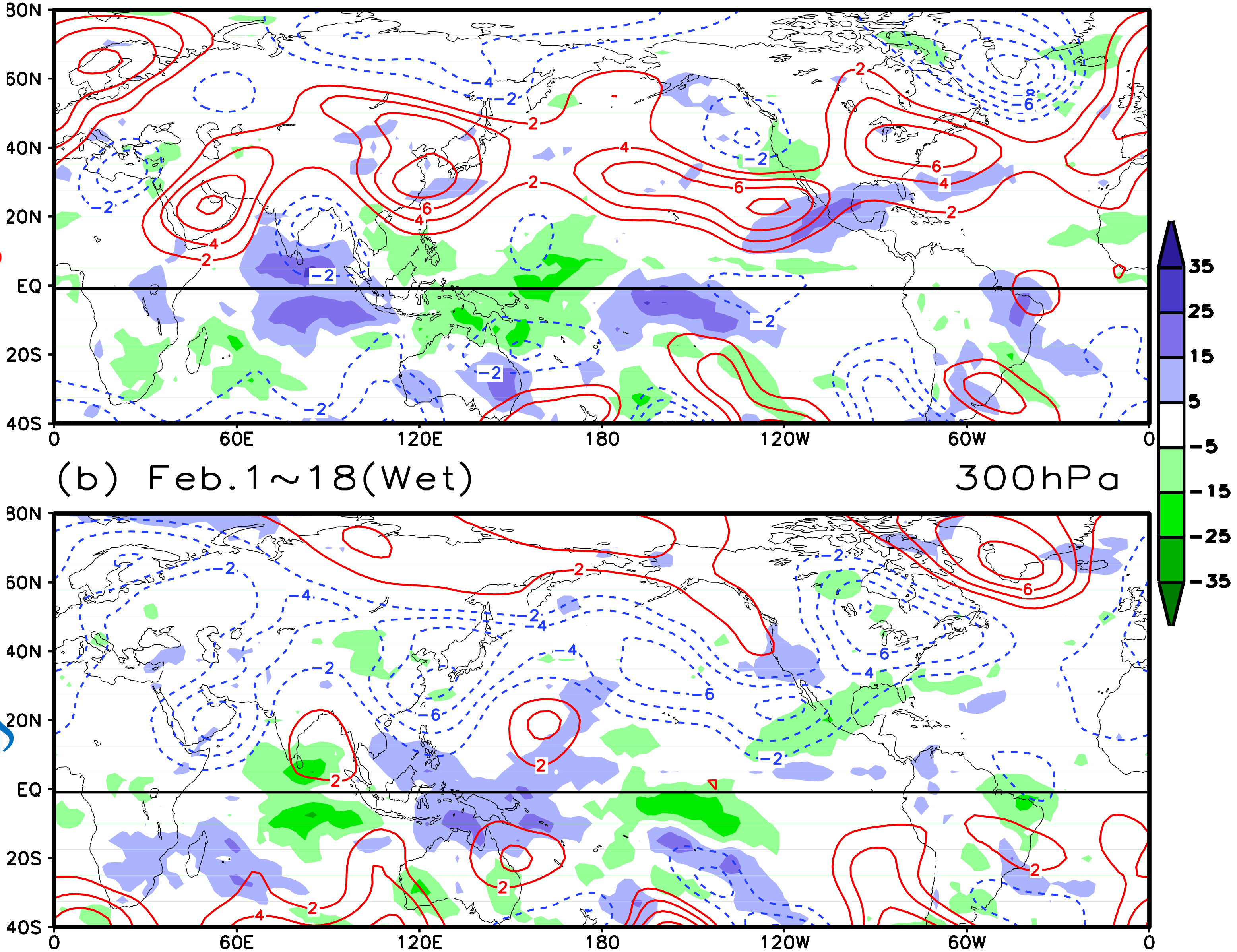


Fig: Time-Longitude Hovmöller diagrams of intraseasonal (contour) and total (shading) OLR over (a) tropics (5°S–5°N) and (c) subtropics (15°–25°N), (b) central tropical Pacific (170-140W, 5S-5N) from 1 December 2009 to 28 February 2010.

MJO-US Teleconnection: OLR and H300♪

Dry♪

E. US♪

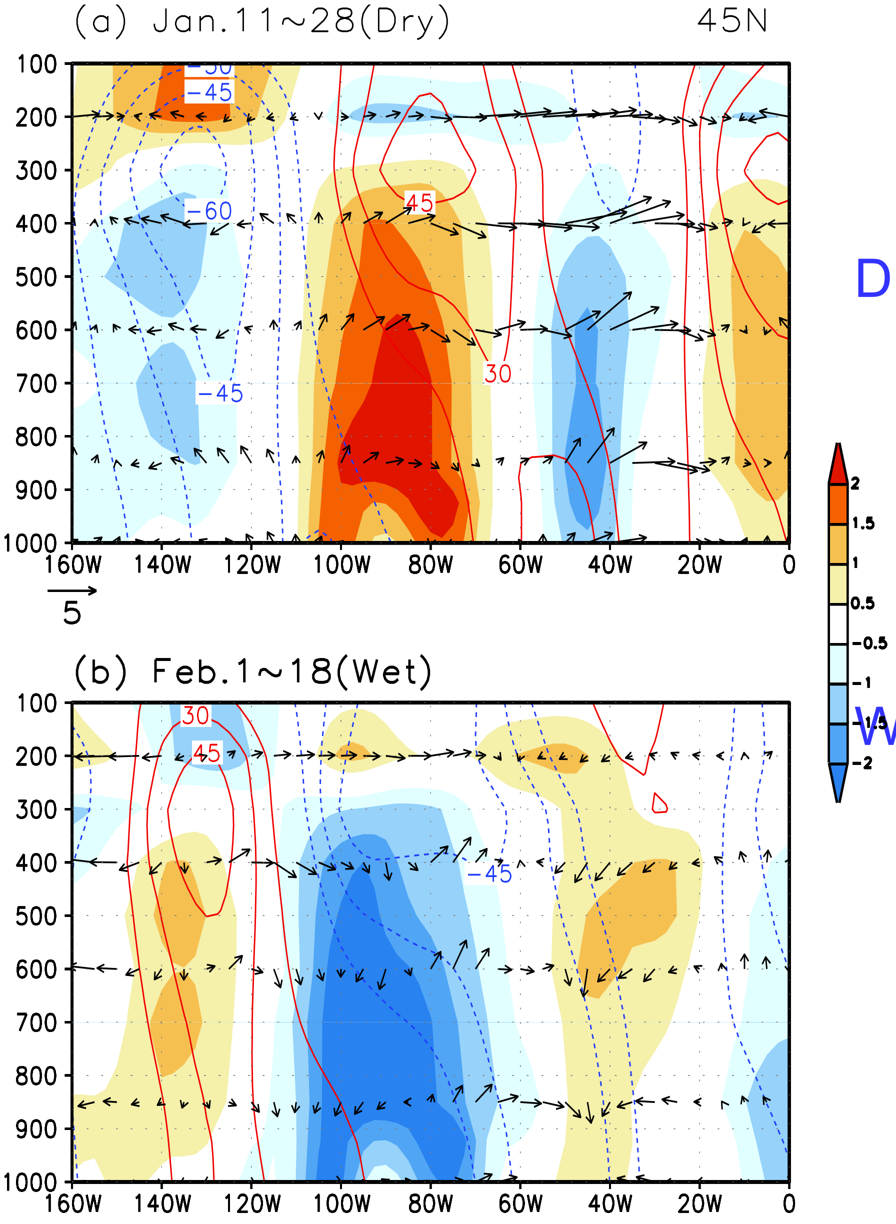

(a) Jan.11~28(Dry) 300hPa

(b) Feb.1~18(Wet) 300hPa

Wet♪

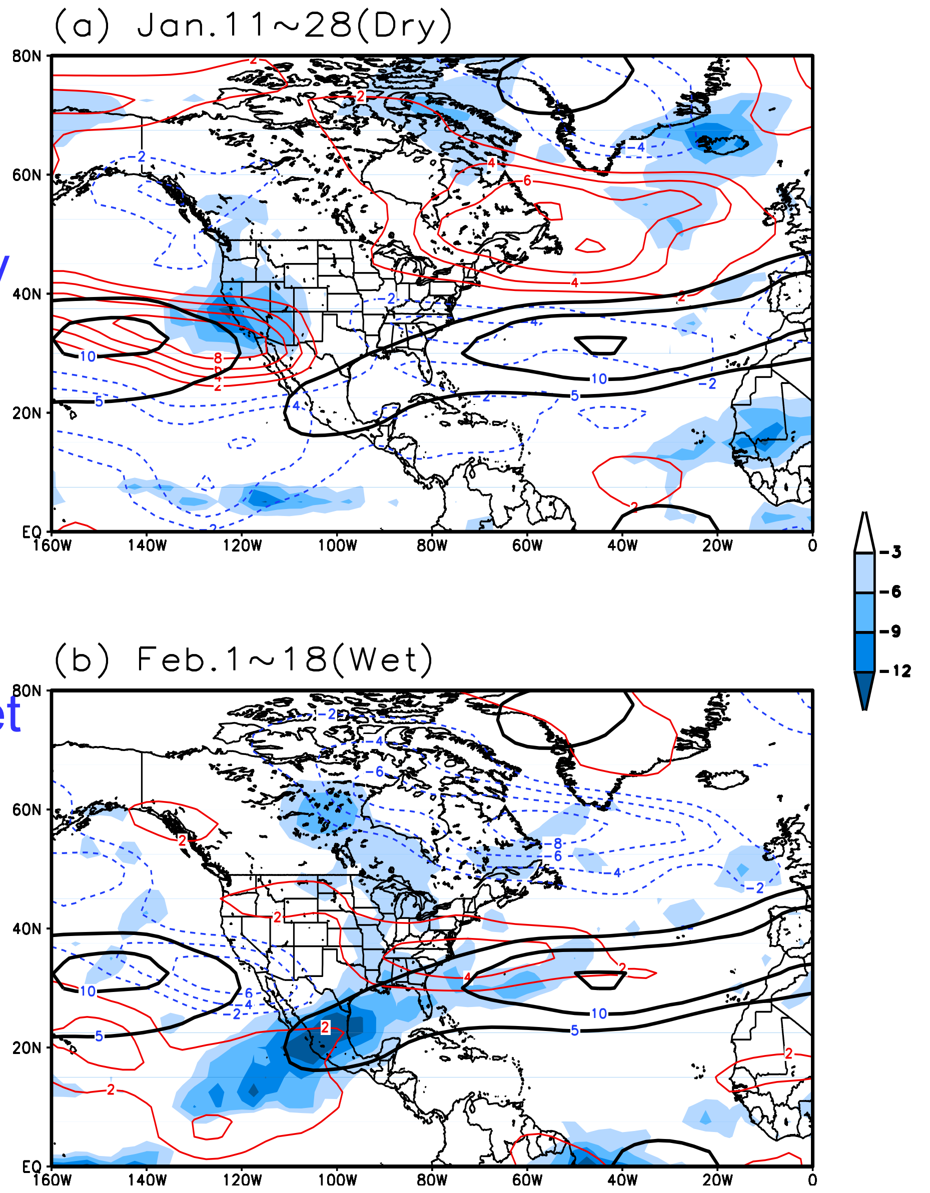
E. US♪

Climate anomalies over North America♪



Dry

Wet



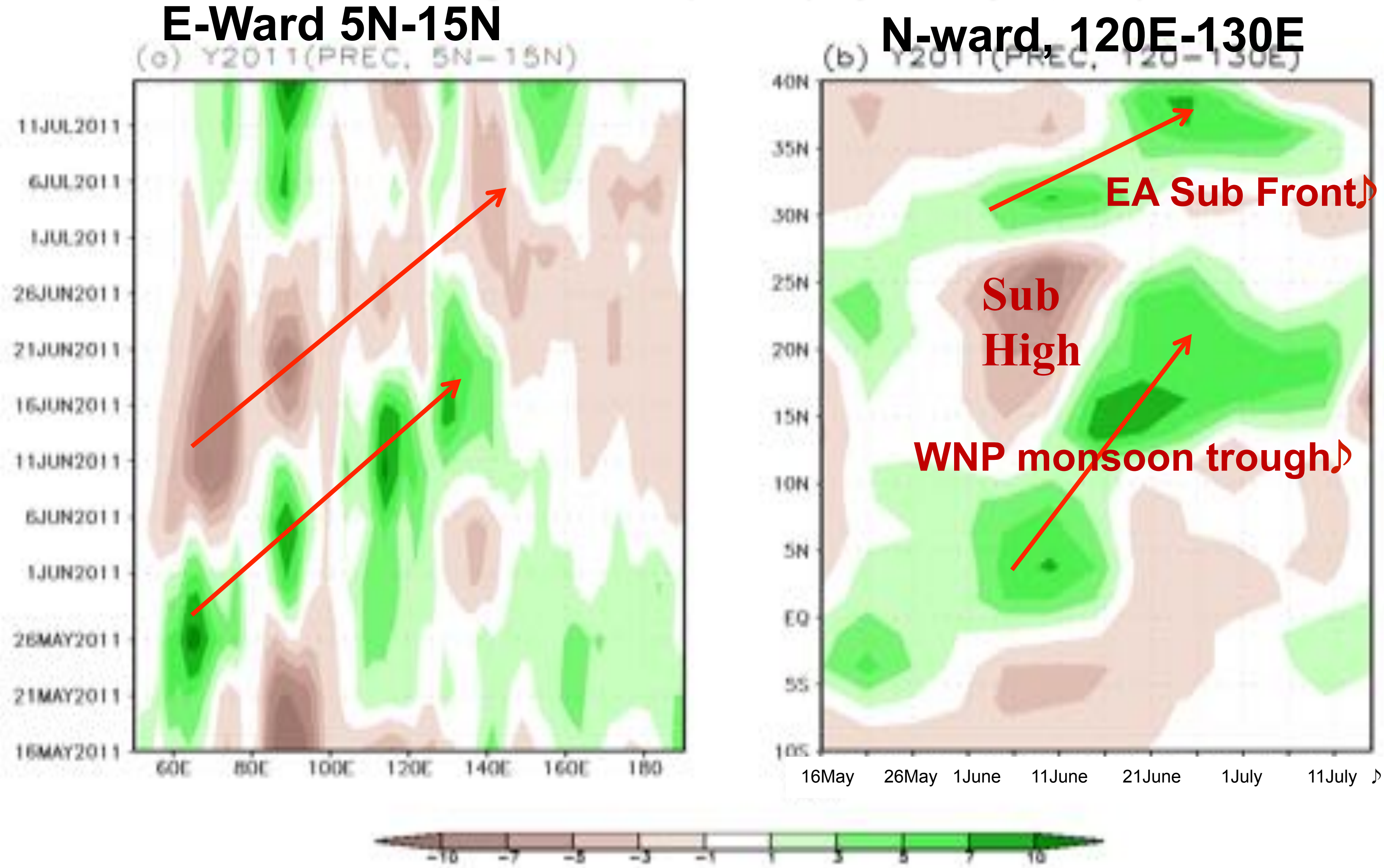
ISO in June 2011 and EASM onset (floods)

Seoul♪

Beijing♪

The June 2011 event and EASM onset

Hovmöller diagram of Precipitation(May. 16~July 16, 2011)



E-Ward 5N-15N

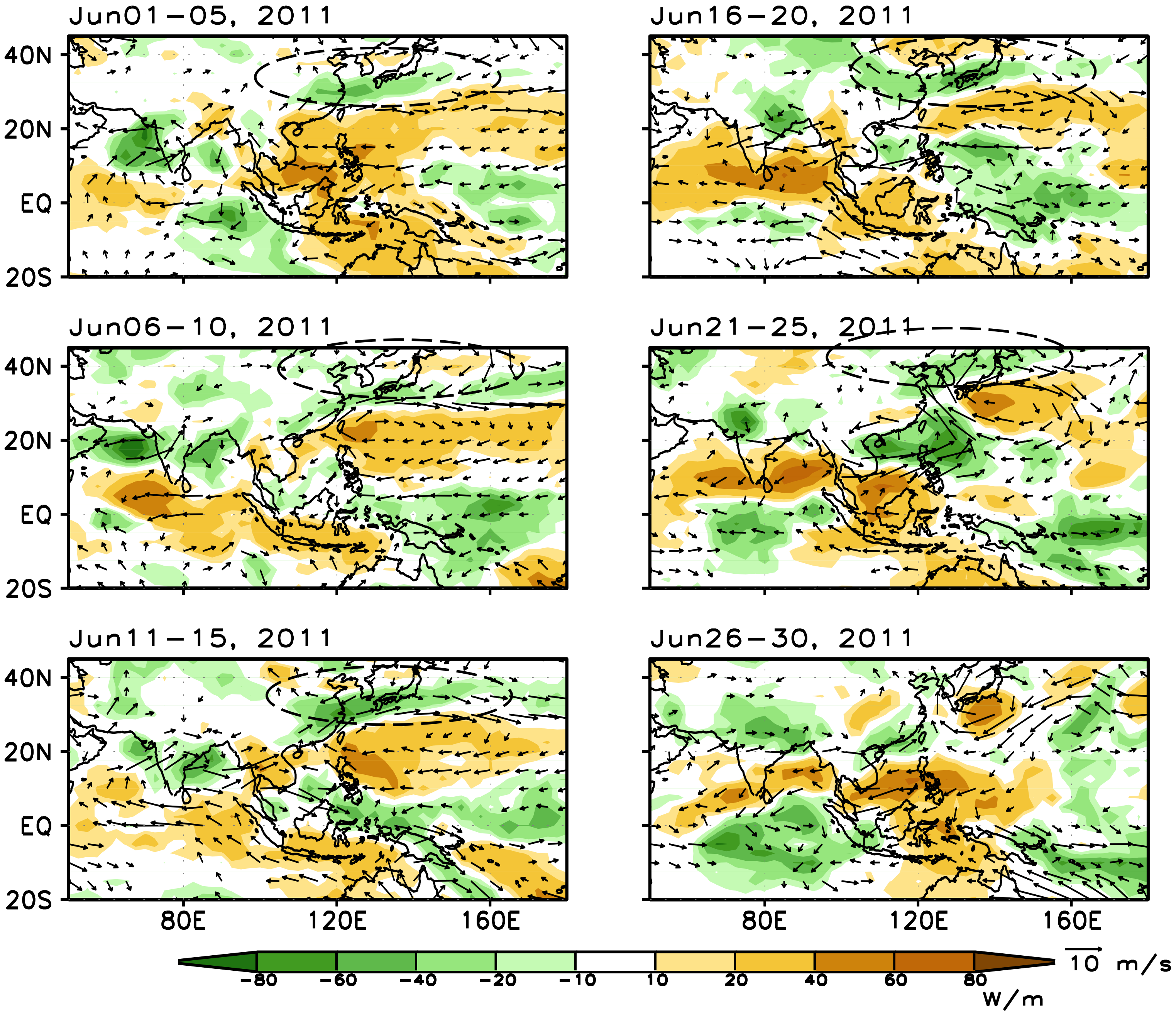
N-ward, 120E-130E

EA Sub Front♪

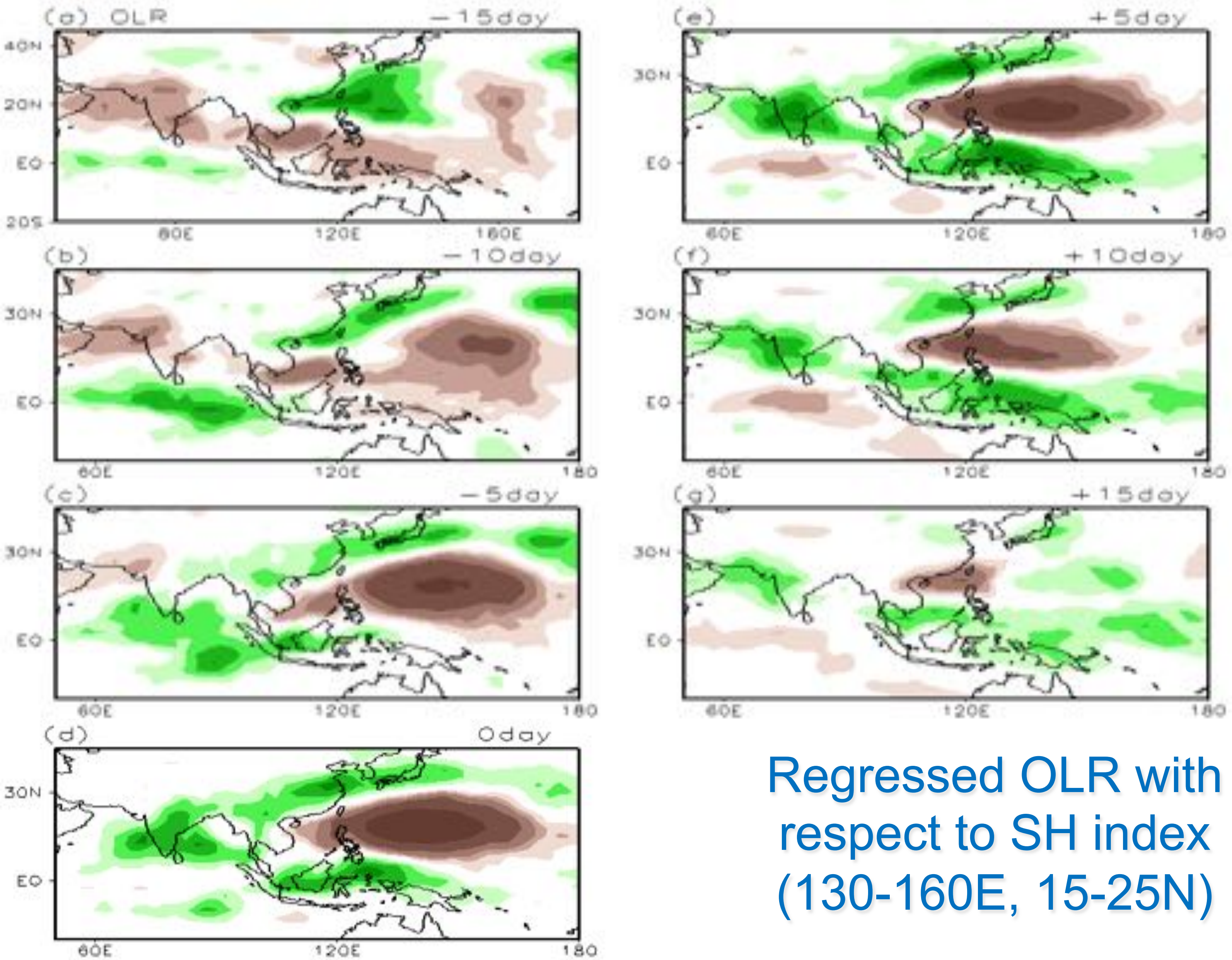
Sub High

WNP monsoon trough♪

Pentad mean anomaly Map (June, 1 – 30, 2011)



Propagation of SH anomaly♪



Regressed OLR with respect to SH index (130-160E, 15-25N)

Summary

1. Bimodal description/mornitoring of ISO
2. ISO during La Nina is suppressed. Three ISO events are all linked to extreme events:
3. The 2009/10 US winter storm activity is strongly regulated by MJO.
4. The 2011 June EA floods/onset is associated with a strong BSISO event.

Thank you
For your comments

What determines the northward propagation of BSISO convective complex?

Easterly vertical shear effects- Easterly wind shear is a necessary condition, providing an environment favorable for the emanation of Rossby waves

Simple and complex GCM’s produce northward propagation when easterly shear is evident (Wang and Xie 1997, Kemball-Cook et al. 2002, Annamalai and Sperber 2005)

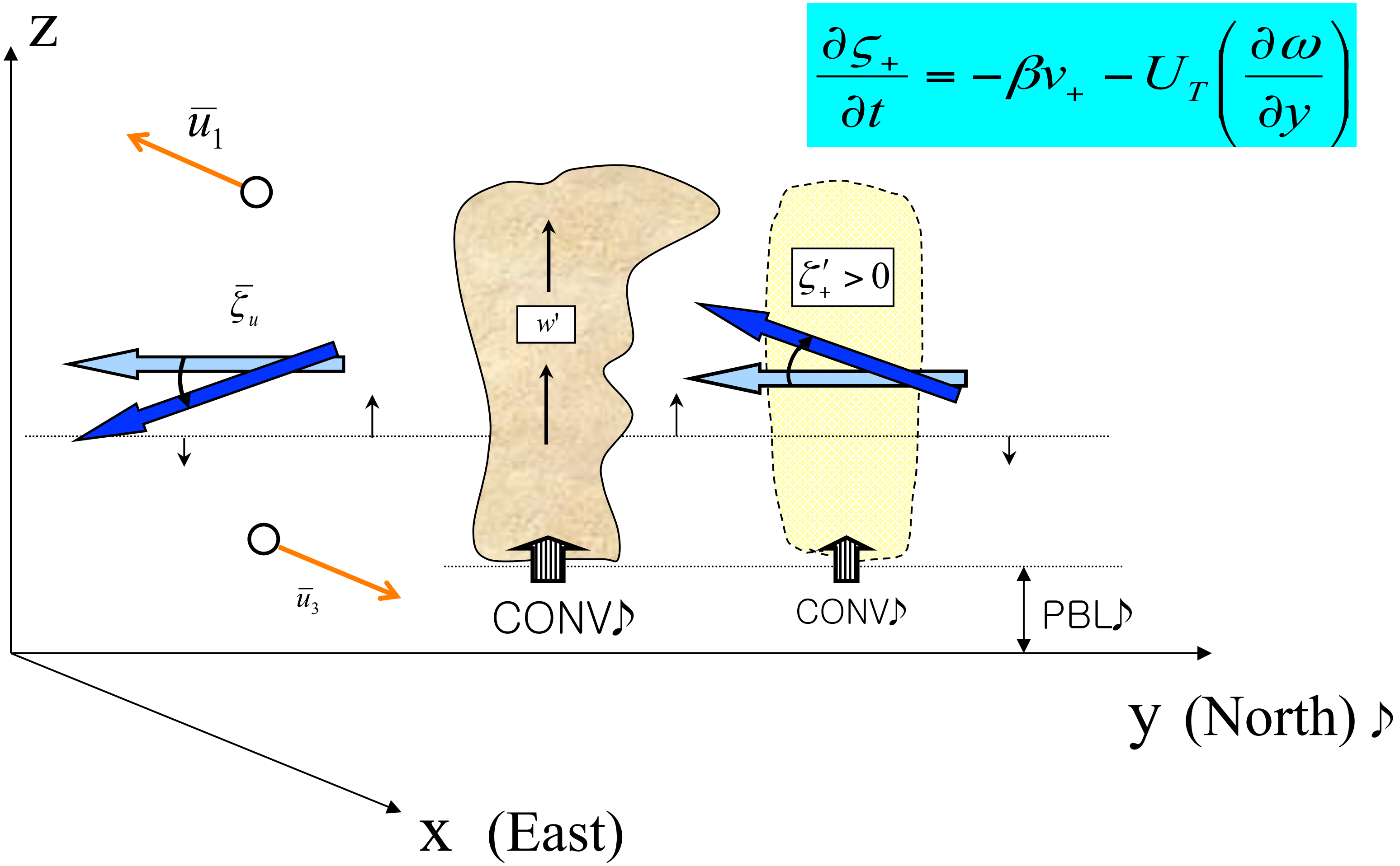
Air-sea interaction-forces or feedbacks to promote northward propagation of convection

Kemball-Cook et al. (2002), Fu et al. (2003),

Rajendran and Kitoh (2006)

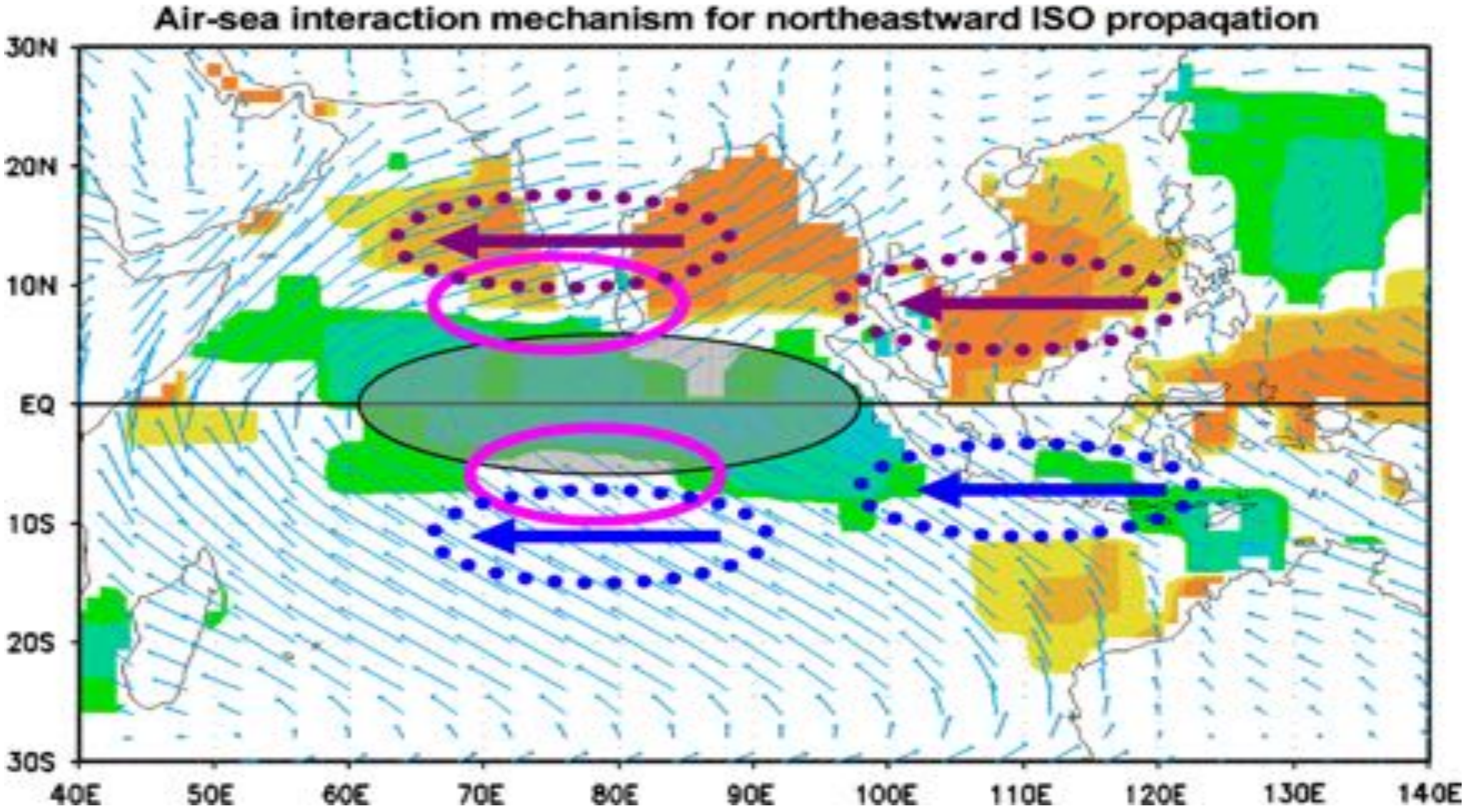
Easterly vertical shear mechanism♪

$$\frac{\partial \varsigma_+}{\partial t} = -\beta v_+ - U_T\left(\frac{\partial \omega}{\partial y}\right)$$



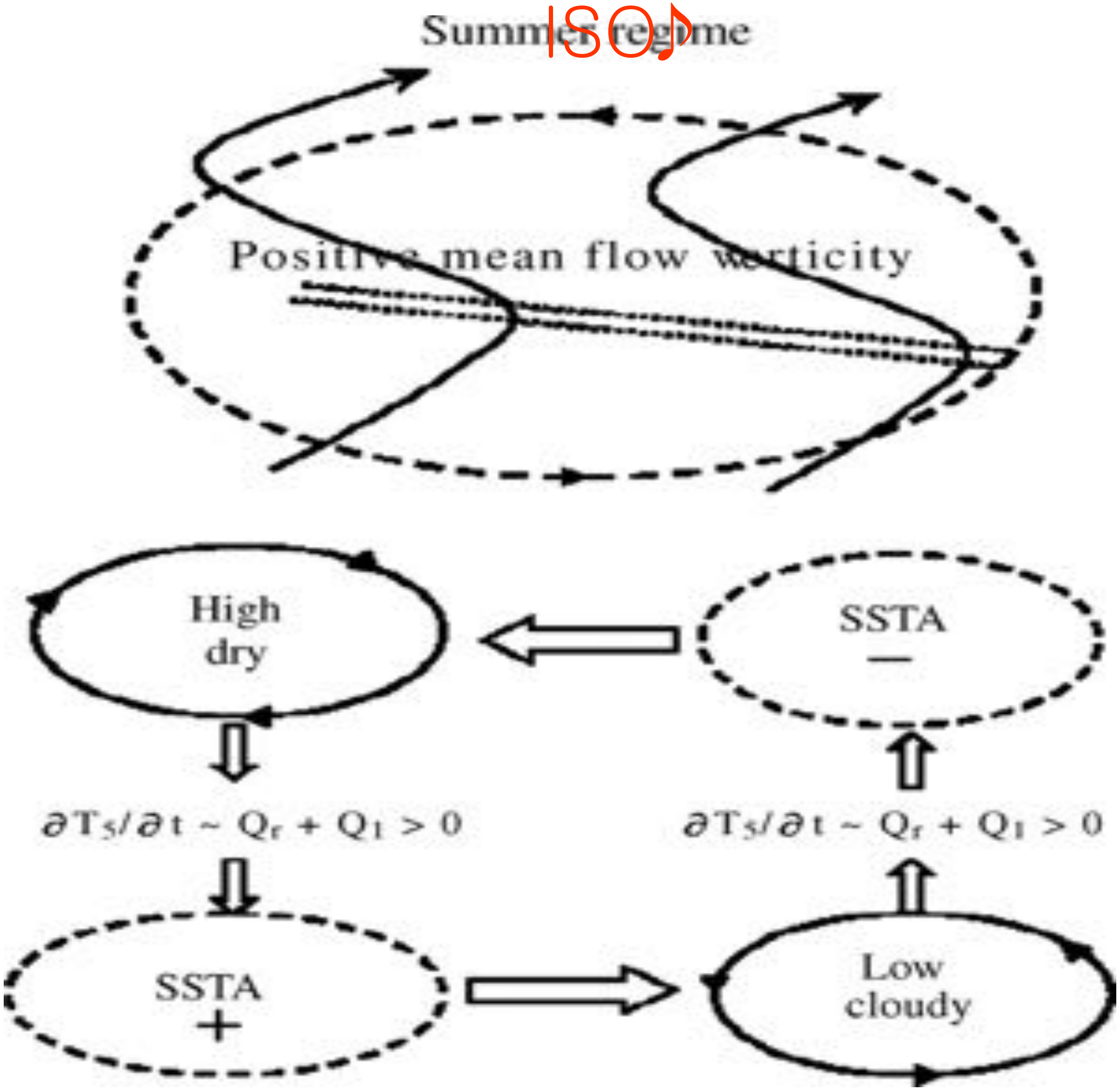
Monsoon easterly vertical shear provides a vorticity source, which, upon being twisted by the north-south varying vertical motion field associated with the Rossby waves, generates positive vorticity north of the convection, creating boundary layer moisture convergence that favor northward movement of the enhanced rainfall.

Propagating Air-sea interaction mechanism♪

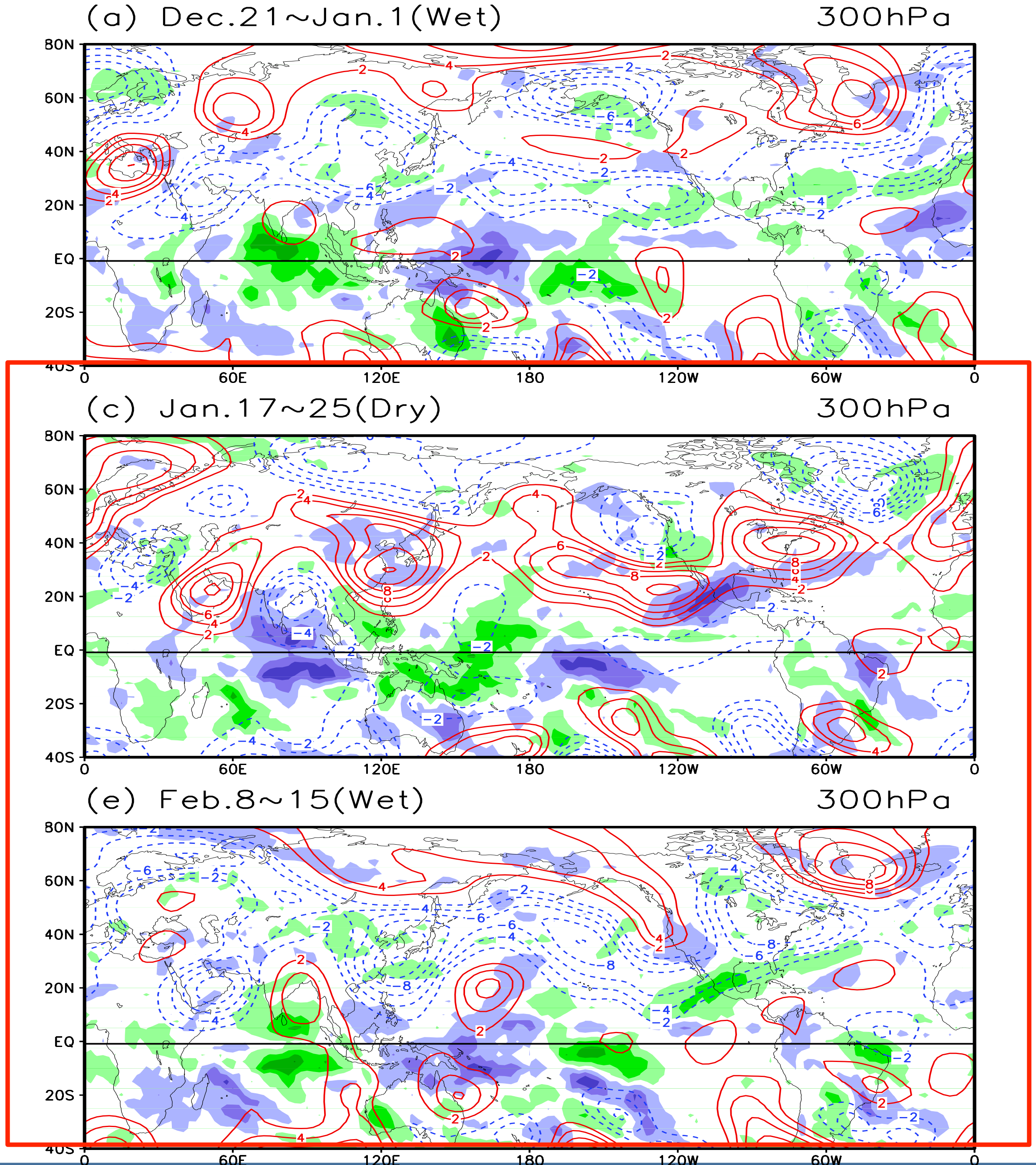


Fu et al. (2003), Wang et al. (2009)♪

Stationary air-sea interaction: Monsoon trough ISO♪



Wang and Zhang 2002



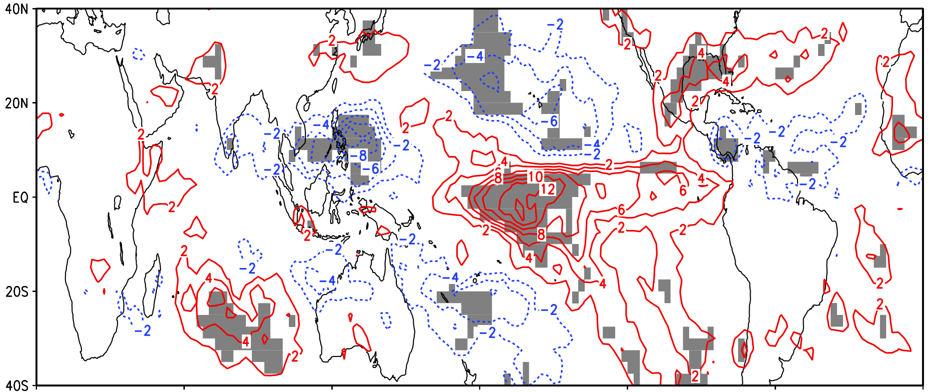
As the MJO convection reached the central Pacific, a teleconnection pattern extends to North America, resulting in a westward-tilted deep anomalous trough anchored over the eastern US, producing a low-level pressure dipole anomaly with an anticyclone (cyclone) centered at the US west (east) coast. The convection over the Indian Ocean varied in phase with the central Pacific convection, reinforcing the extratropical atmospheric teleconnection pattern. As a result, the enhanced high-latitude cold air penetrated southward, affecting the central and eastern US. ♪

Fig: Intraseasonal anomalies of (a)(c)(e) OLR and 300hPa streamfunction on the day when convection over the tropical central Pacific reached its maximum (minimum for dry episode)

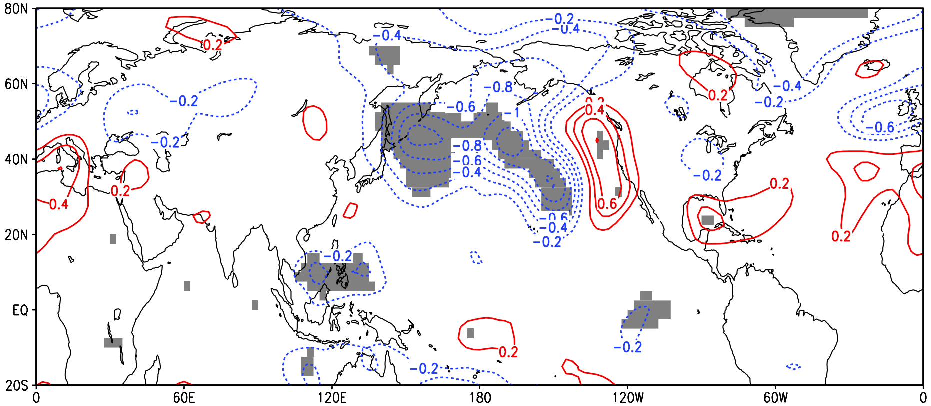
Intraseasonal Variance during ENSO

El Nino

(a) OLR

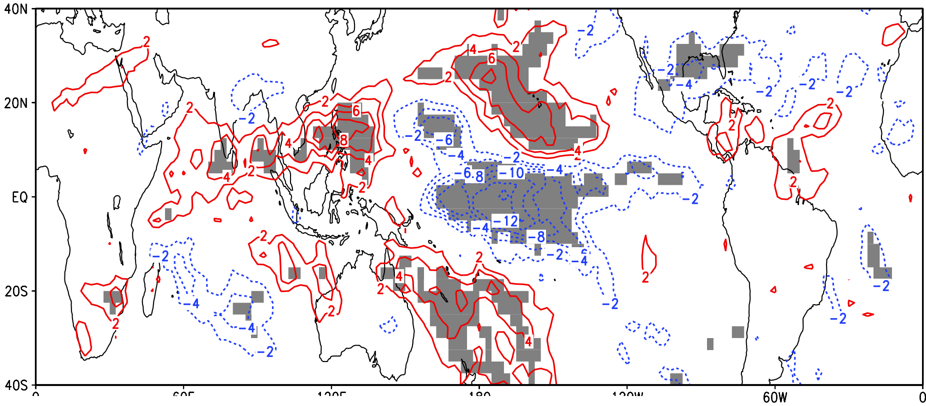


(b) Streamfunction(850hPa)



La Nina♪

(a) OLR ♪



(b) Streamfunction(850hPa)♪

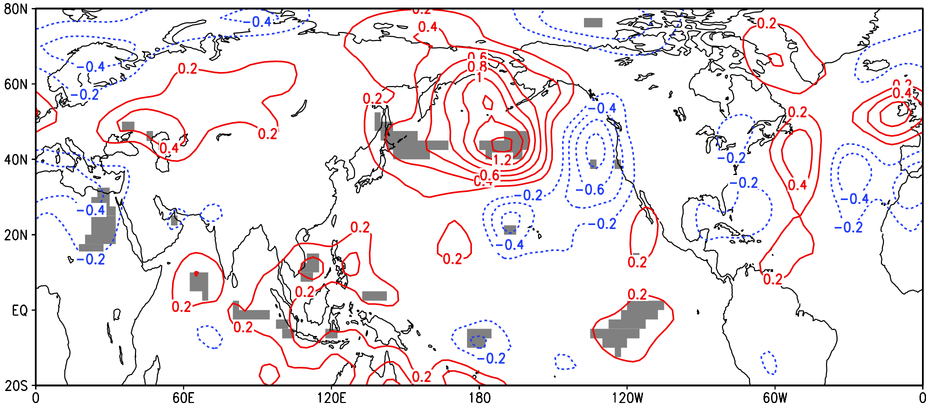


Fig: Climatological winter (December~February) mean intraseasonal variance (ISV, contour) and interannual variation of ISV measured by the standard deviations of 29-year ISV anomalies (shaded) of (a) OLR, (b) 850 hPa streamfuntion (SF850), and (c) 300 hPa streamfunction (SF300).♪

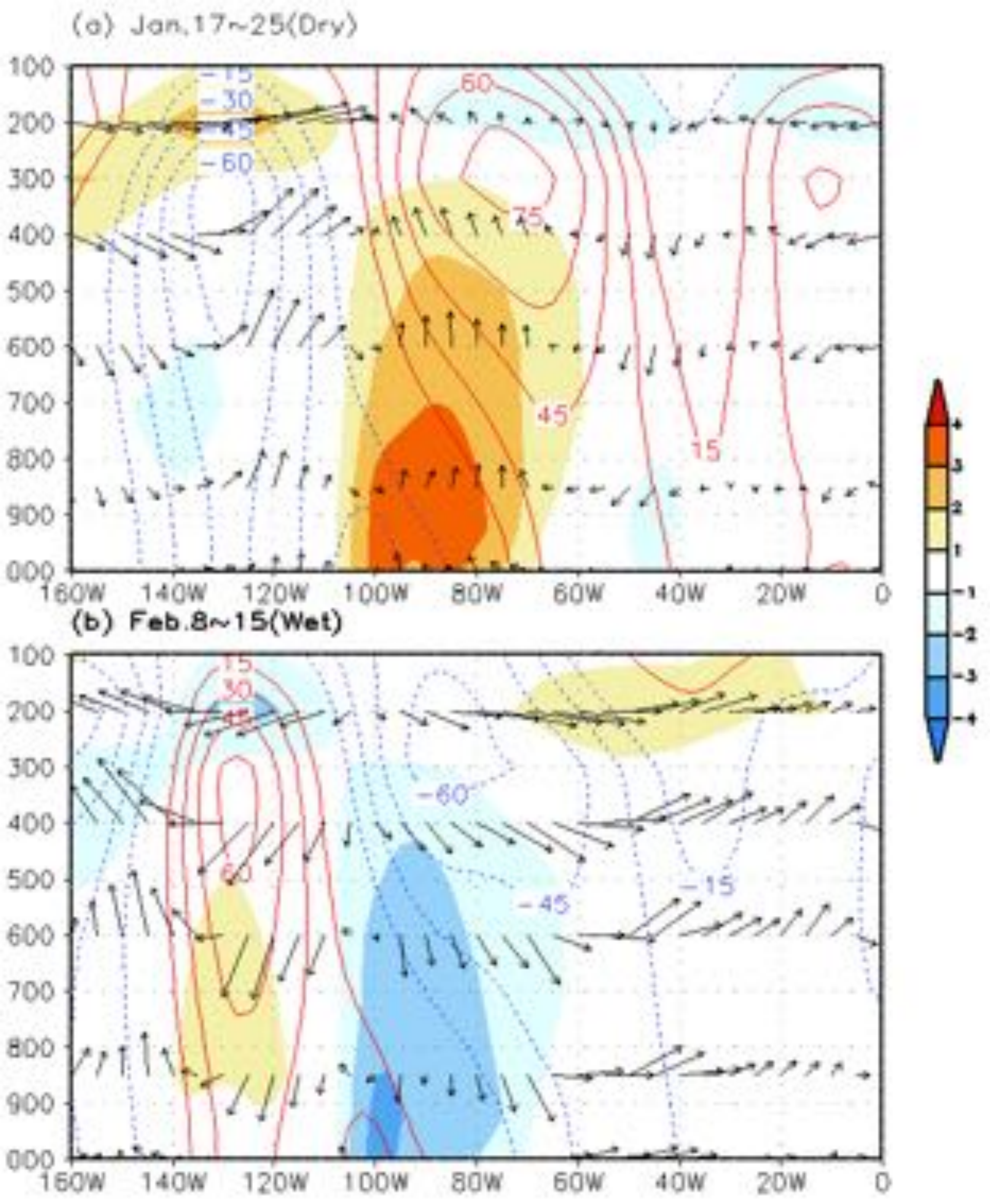


Fig: Zonal vertical cross section of Intraseasonal anomalies of geopotential height (contour), temperature(shading), zonal wind and upward motion(vector) averaged between 30°N and 45°N on (a) dry and (b) wet episodes.

Warm moist air was more transported from the tropical central Pacific by the existing El Niño through Mexico to the southern US along with the upper-level subtropical westerly jet, which extended from the subtropical Pacific to the Atlantic Ocean. ♪

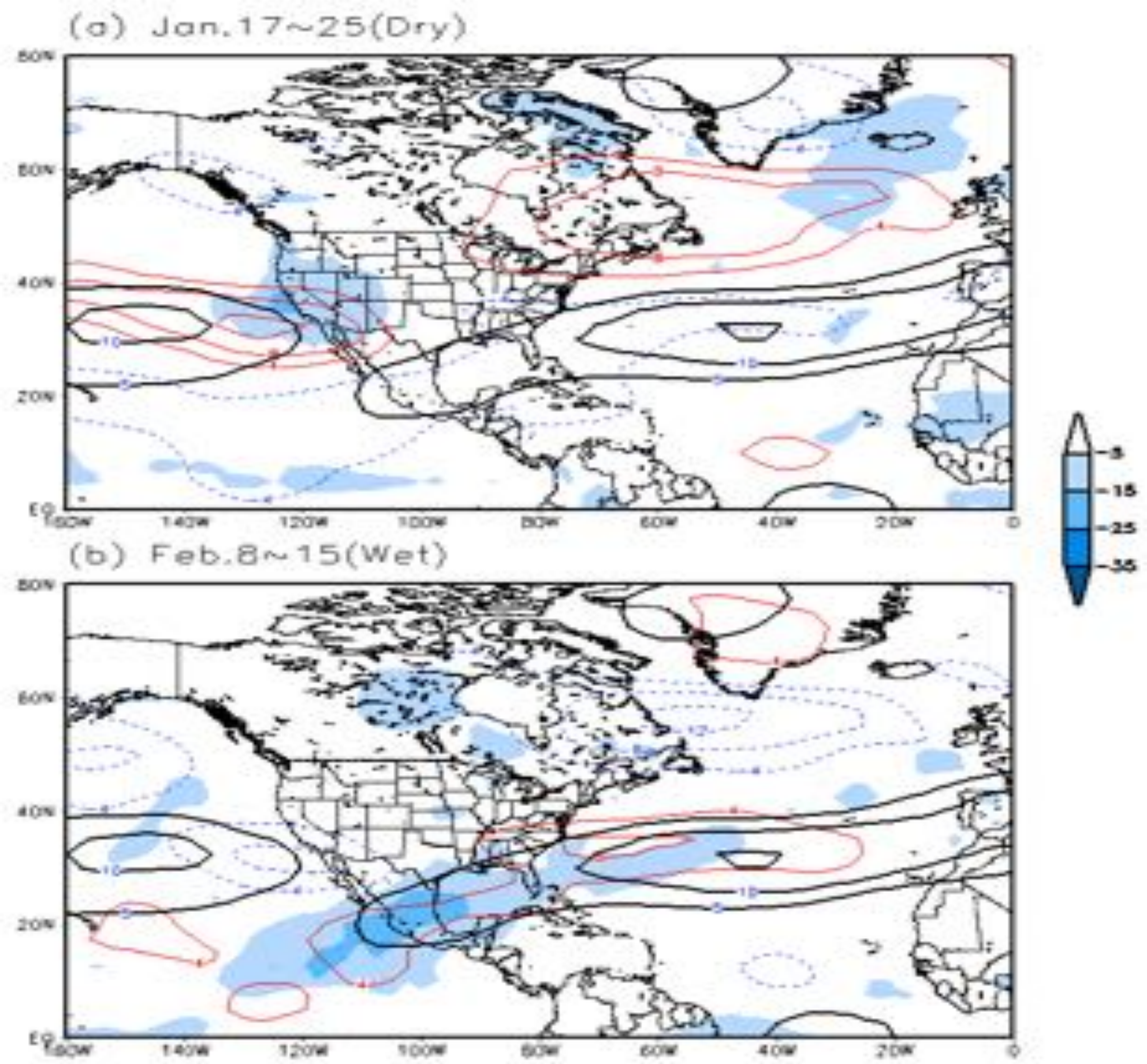
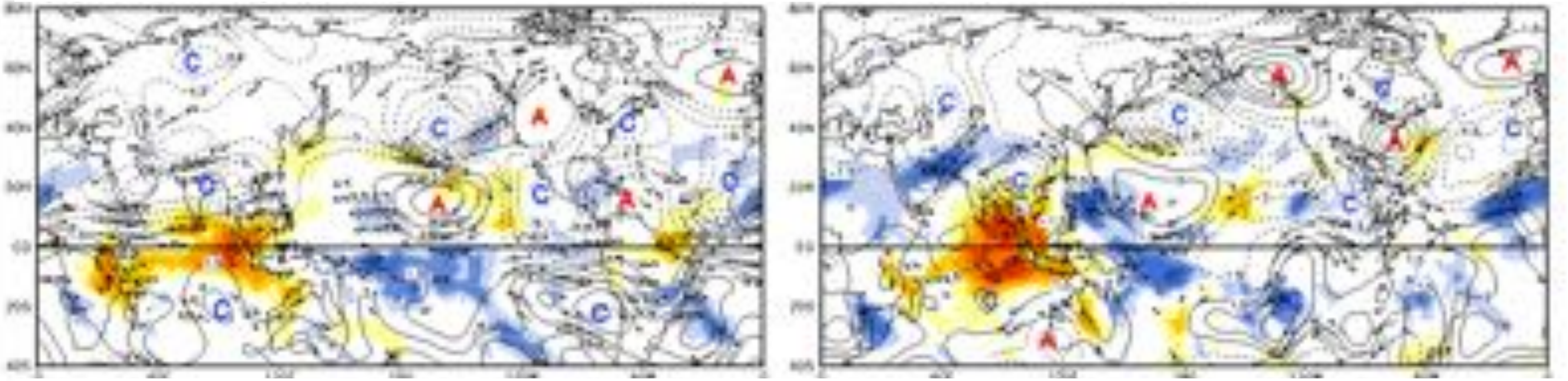


Fig: Intraseasonal anomalies of OLR(only active convection below -5 Wm-2, shading) and 300hPa zonal wind (thin color contour) on (a) dry and (b) wet episodes. The thick black contour denotes the seasonal mean westerly anomalies above 5 ms-1 .♪

ENSO regulation of MJO teleconnection

El Nino La Nina♪

(a) Phase 7 (300hPa) (b) Phase 7 (300hPa) ♪



(c) Phase 7 (850hPa) (d) Phase 7 (850hPa) ♪

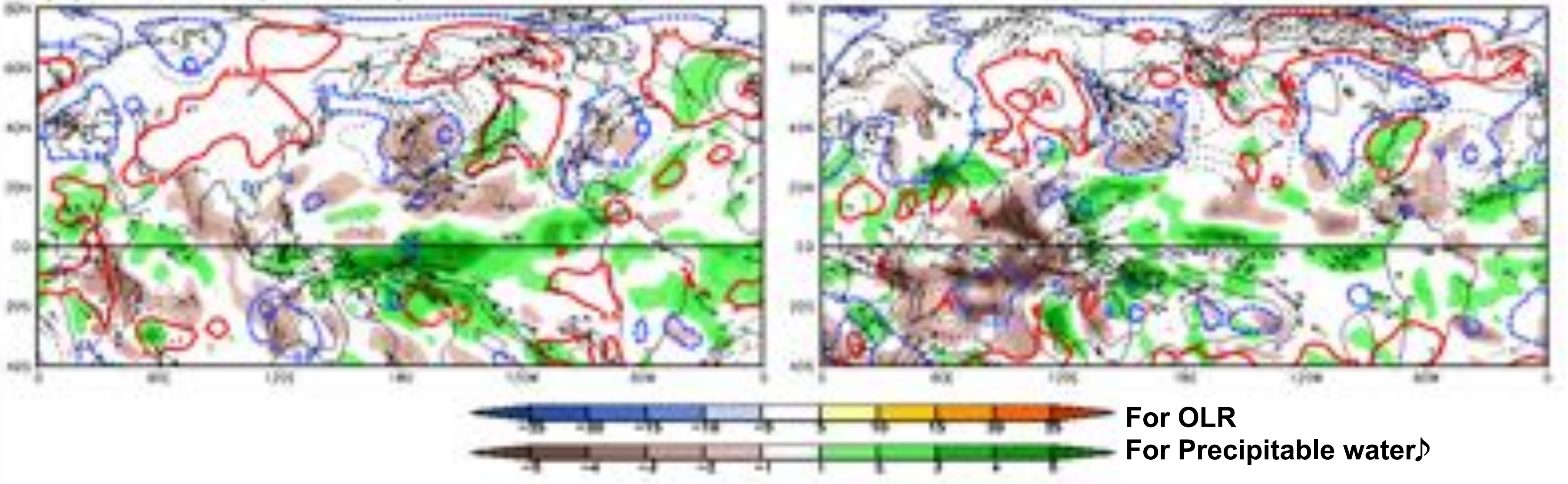


Fig: Composite anomalies of (a)(b) SF300 (contours) and winds and (c)(d) SF850 (contours)and winds during El Niño (left panel) and La Niña years (right panel) at Phase 7 (when the convection is enhanced over western Pacific). OLR and precipitable water during ENSO are shaded in (a)~(b) and (c)~(d), respectively. In (c) and (d) and the red (blue) thick contours denote the 850 hPa temperature anomalies above (below) 0.5 (-0.5) ºC. ♪