冬季東アジアモンスーンの変動要因を探る

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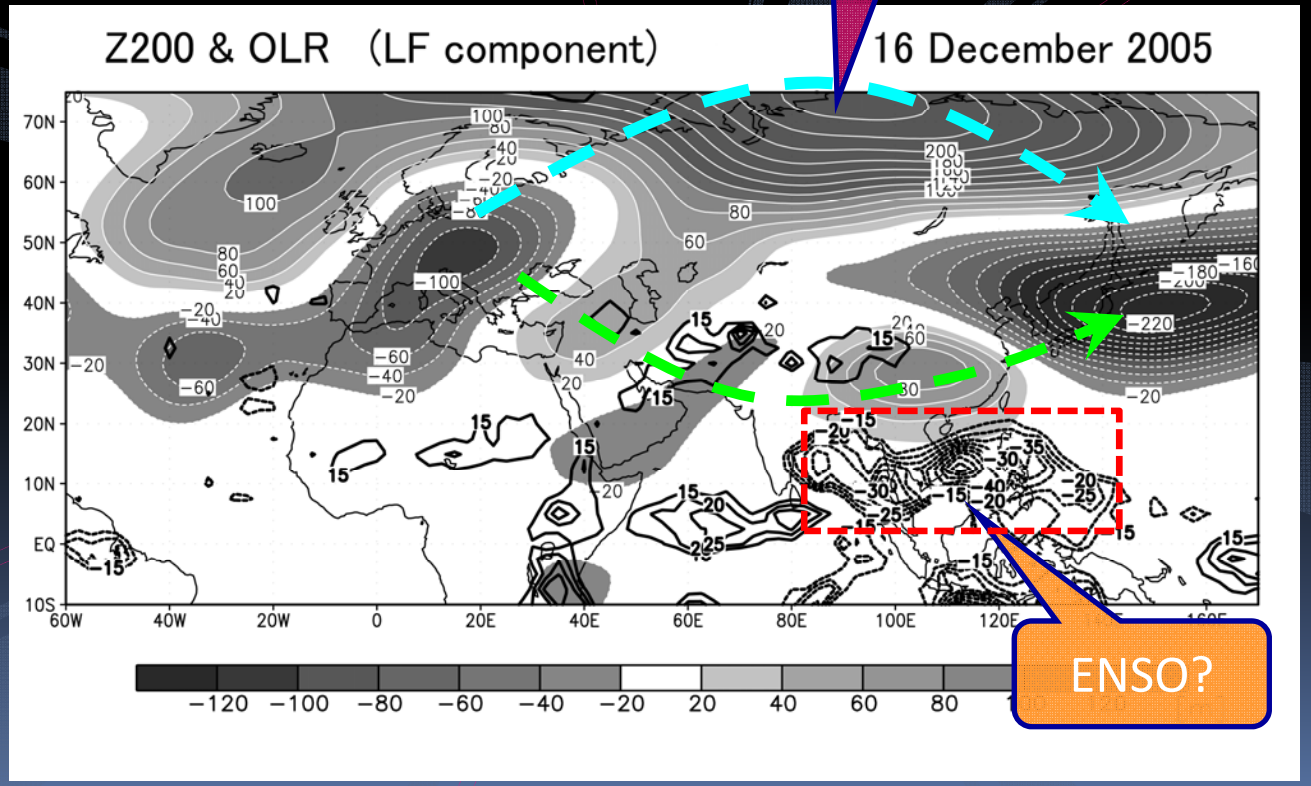
背景①：　平成18年豪雪の複合要因

●豪雪発生の主要因はENSO？ それともAO？
●冬季東アジアモンスーン近傍の二種類の導波管
- 寒帯前線ジェット（subpolar route）
- 亜熱帯ジェット（subtropical route）



2005年12月16日の外向長波放射量（OLR）及び200hPa高度偏差（長周期成分）

ENSO, NAOなどの遠隔影響

降雪をもたらす総観規模擾乱群

局地的な大雪

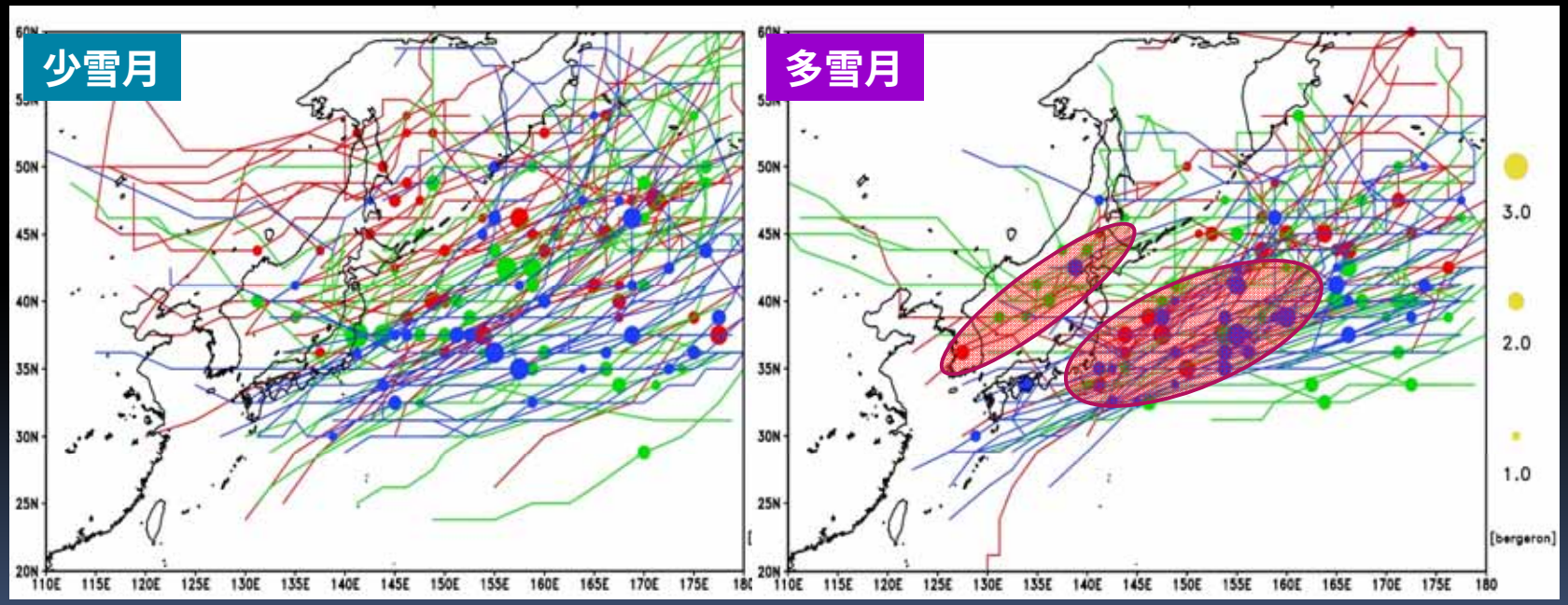
冬季モンスーンの強化

爆弾低気圧の日本近海への集中化

北信越地方を中心に大雪発生

？？？

Yoshiike and Kawamura (2009)

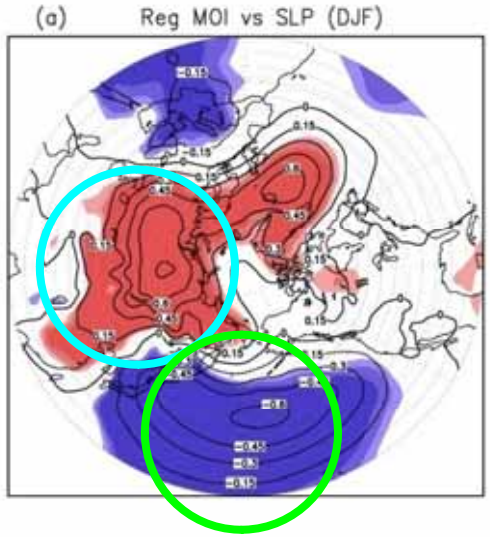


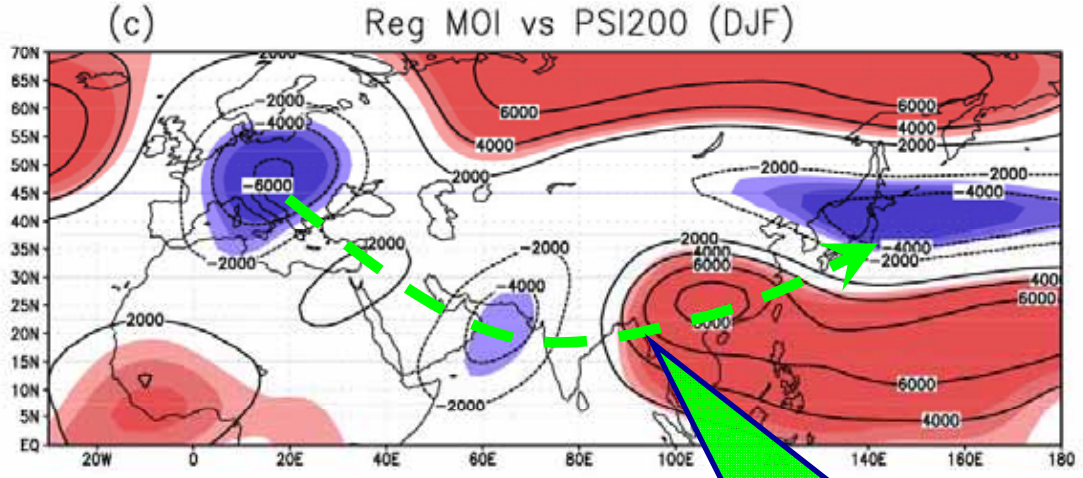
12月　1月　2月

線：経路　丸印：最大発達率の位置 (丸の大きさ：最大発達率)

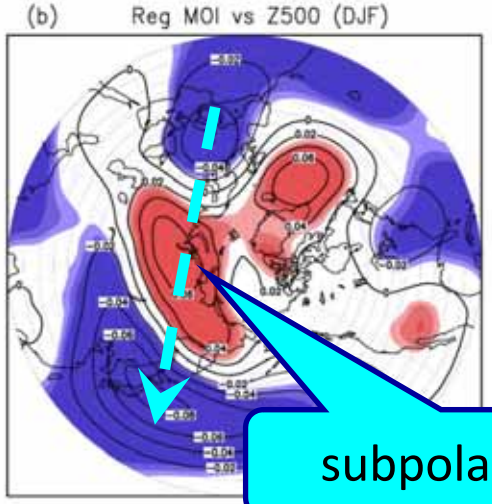
山下ほか(2010): 爆弾低気圧の集中化と北陸地方の大雪の発生について. 日本気象学会2010年春季大会講演予稿集, P302.

SLP, 500-hPa height and 200-hPa stream function anomalies regressed onto the winter monsoon index



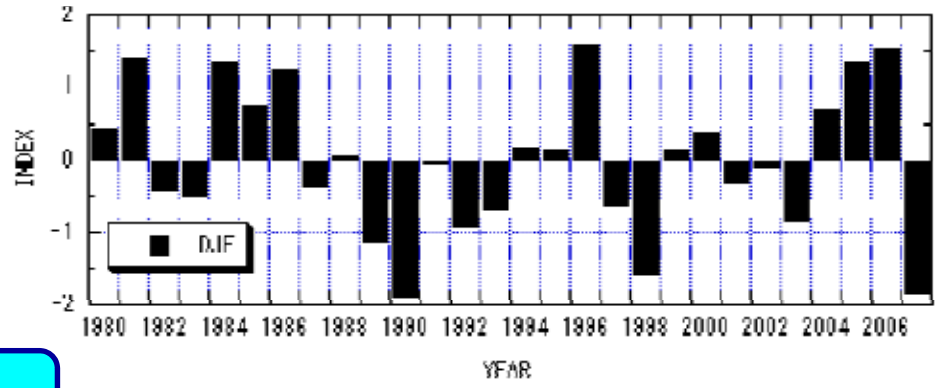


subtropical route



subpolar route

Watanabe (1990)によって定義されたモンスーン指数



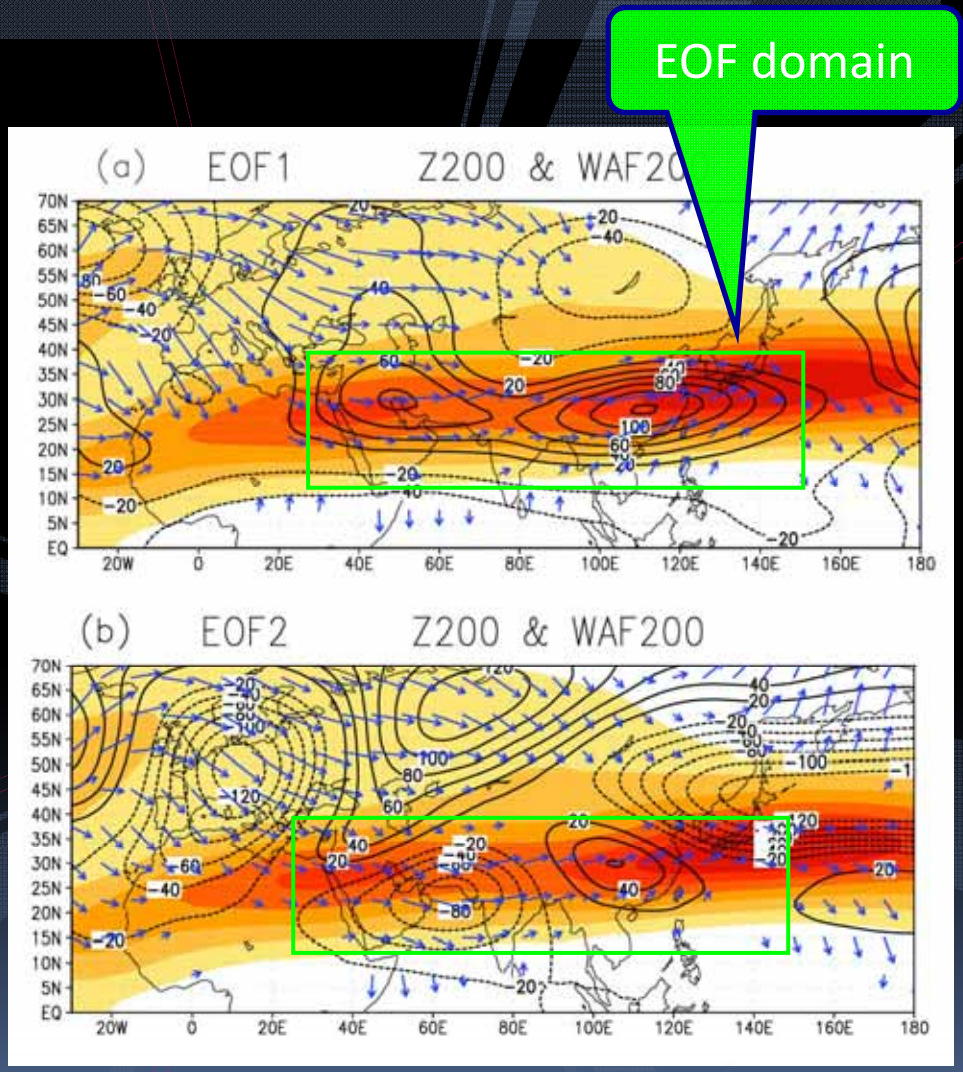
Sakai and Kawamura (2009)

背景②：　アジアジェットの変動とENSO

●冬季はアジアジェットが南偏するため,熱帯対流活動の直接的影響を受けやすい.
●ENSOの遠隔影響を受けやすくなる.

・EOF1は帯状偏差パターン
(zonally symmetric response)
・EOF2は東西非対称偏差パターン
(zonally asymmetric response)

共にENSOと関連した遠隔応答であるが，どちらが効率的に東アジアモンスーンに影響を与えるのか？



アジアジェット域の200hPa高度偏差にEOF解析を適用（ベクトルは波活動度フラックス）

200-hPa height

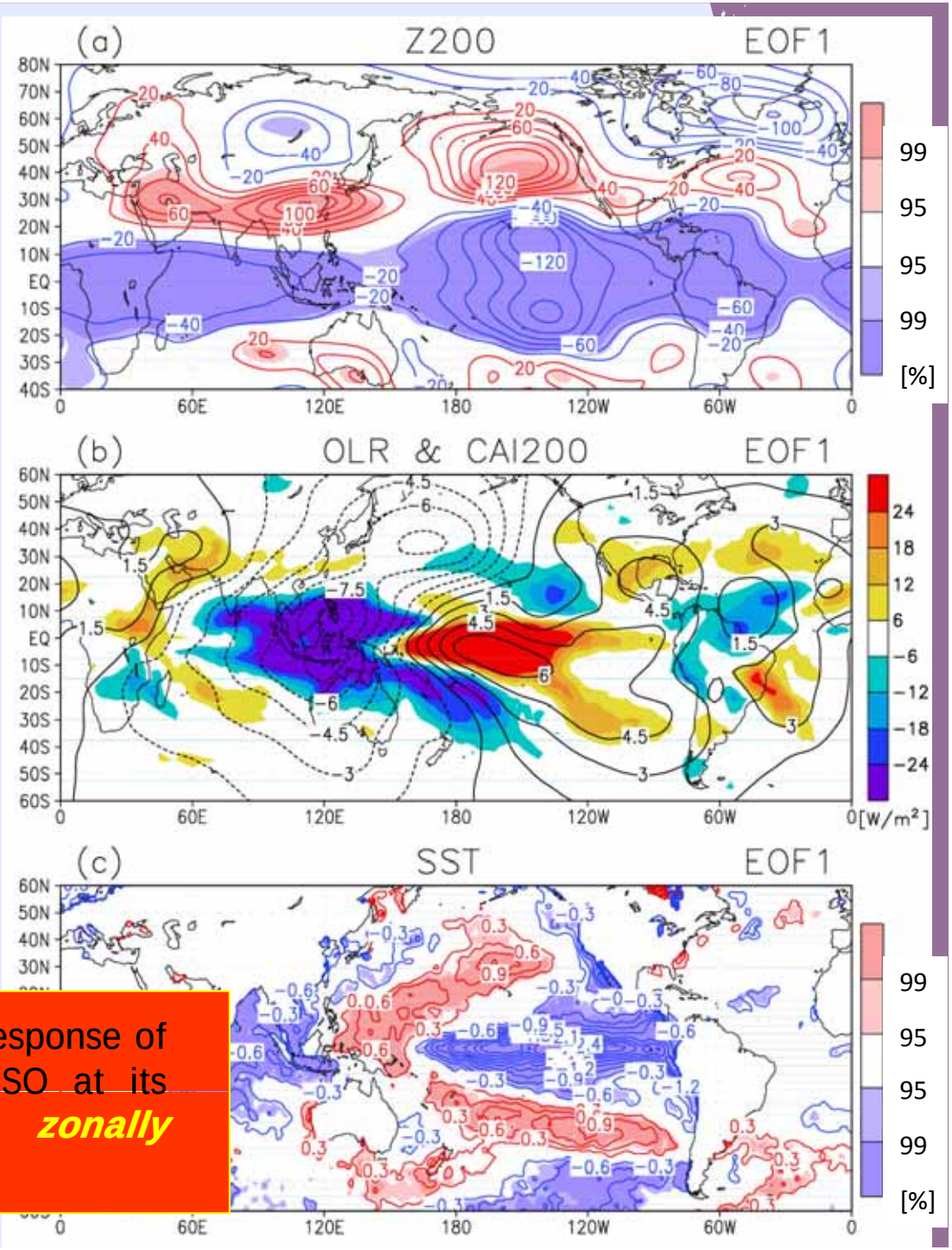
A north-south dipole structure of negative anomalies over the central Pacific is a typical signature of ENSO response.

OLR & veclocity potential

A negative anomaly expands westward into the tropical Indian Ocean from the Philippine Sea, while a positive one is indicated over the central Pacific.

SST

The SST anomaly distribution exhibits a typical pattern of La Nina mature phase.



EOF1 accounts for the major dynamic response of the Asian jet over South Asia to ENSO at its mature phase, which is called the ***zonally symmetric*** response.

200-hPa height

A negative anomaly is dominant in the vicinity of Japan.

OLR & velocity potential

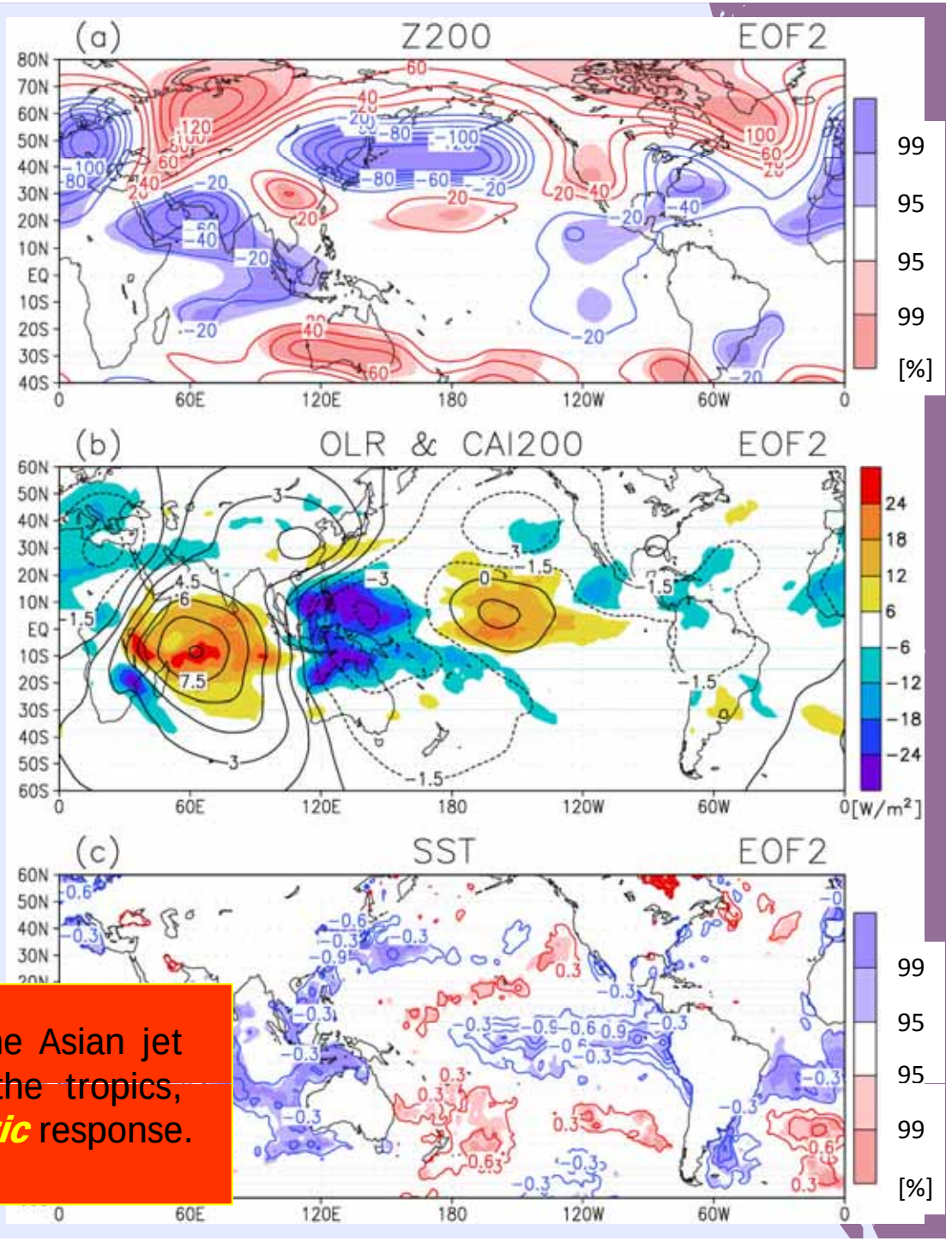
A negative OLR (divergent) anomaly appears over the Philippine Sea, whereas a positive (convergent) anomaly covers the tropical Indian Ocean.

Such an east-west seesaw pattern implies an anomalous Walker circulation cell, which is often seen at the growth phase of ENSO.

SST

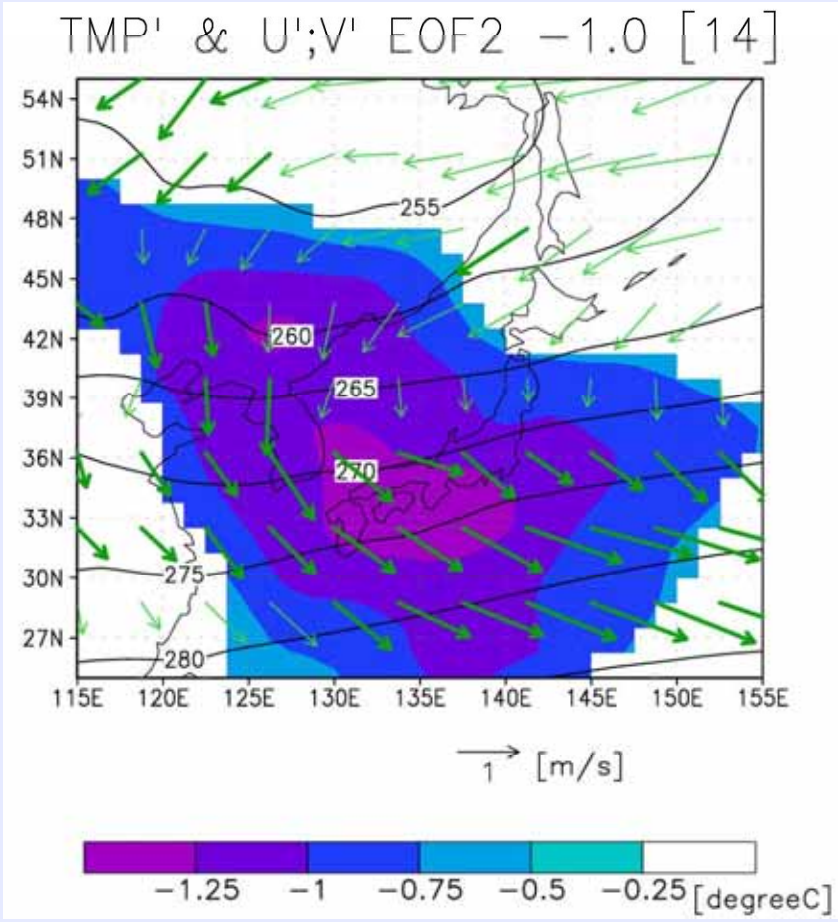
The SST anomaly distribution indicates a La Nina-like situation, but their magnitude is not very large.

EOF2 also captures the response of the Asian jet to anomalous convective heating in the tropics, which is called the ***zonally asymmetric*** response.

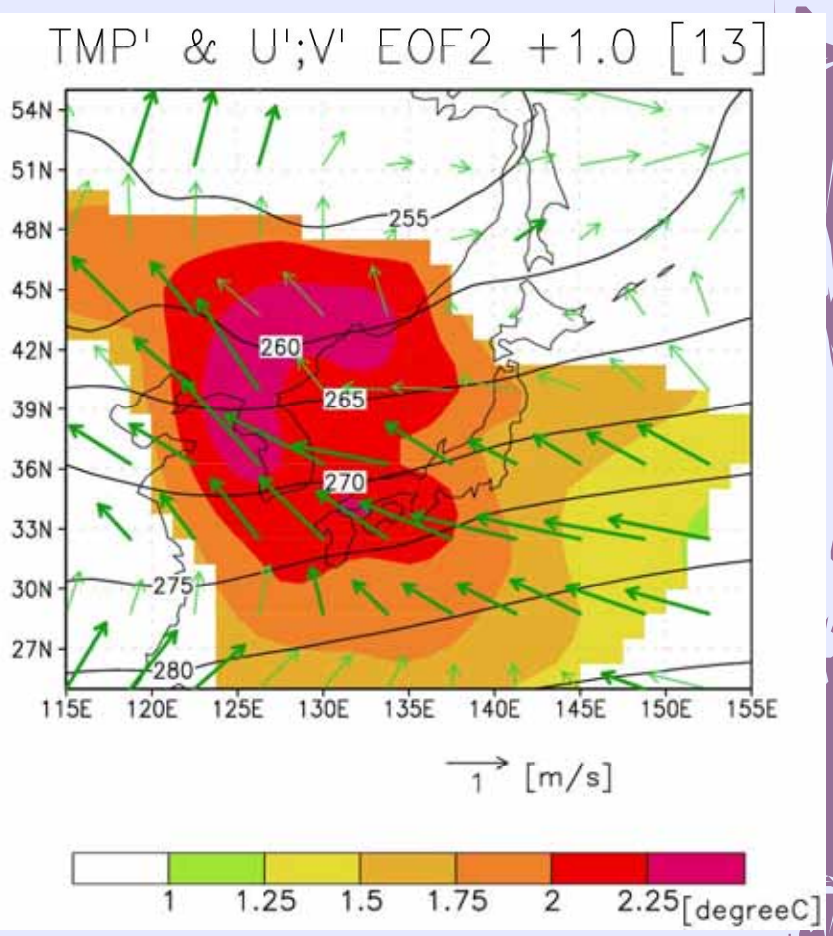


Regional features in East Asia related to EOF2

EOF2 (+)



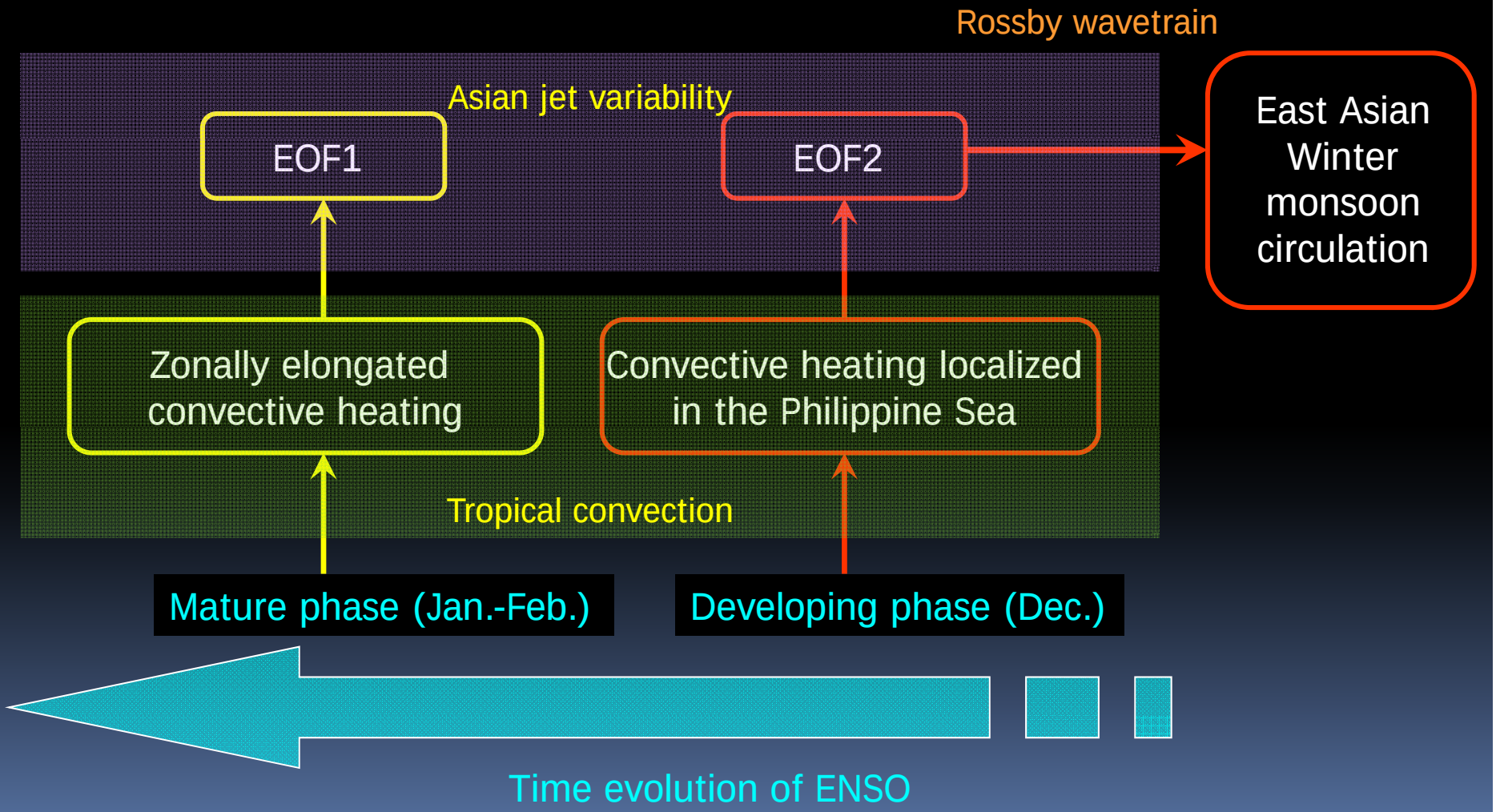
EOF2 (-)



Composite anomalies in 850-hPa temperature and wind vector at the positive and negative phases of EOF2. Also denoted are climatological 850-hPa temperature distributions.

Sakai and Kawamura (2009)

When the response of the Asian jet to anomalous convective heating is zonally asymmteric, the stationary waves affect the East Asian winter monsoon circulation through the subtropical waveguide over South Asia.



新たな疑問

Q1.　西太平洋～インド洋の熱帯対流活動がどのような**地理的分布**を示す時に大きな影響を与えるのか？

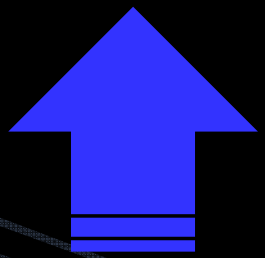
地理的分布の卓越パターンの理解

Q2.　ENSOの影響の与え方は単一のプロセスか？　**複数のプロセス**（あるいは複数のルート）は存在しないのか？

Q3.　エルニーニョ/暖冬は明瞭だが、ラニーニャ/寒冬は必ずしも明瞭ではない。**非対称的な応答**がみられるのはなぜか？

背景③：熱帯インド洋の大気海洋相互作用

Q1.　**西太平洋～インド洋の熱帯対流活動がどのような地理的分布を示す時に大きな影響を与えるのか？**



ENSO, IOD, WES

少なくとも二種類の大気海洋結合現象が存在する．IOD，WES共にENSOとの従属性、独立性に関して議論がある．

- Indian Ocean Dipole (IOD) mode
  東西非対称、夏季～秋季に卓越、ocean dynamics**が重要**
  (Saji et al., 1999; Webster et al., 1999; Yamagata et al., 2004)

- Wind-Evaporation-SST (WES) feedback-driven mode
  赤道非対称、冬季～春季に卓越、surface heat flux**が重要**
  (Xie and Philander, 1994; Kawamura et al., 2001; Wu et al., 2008)

寒候期の外向長波放射量 (OLR)偏差にEOF解析を適用

EOF domain

EOF1は確かに主要なENSOシグナルを捉えているが，IODやWESは見られない．

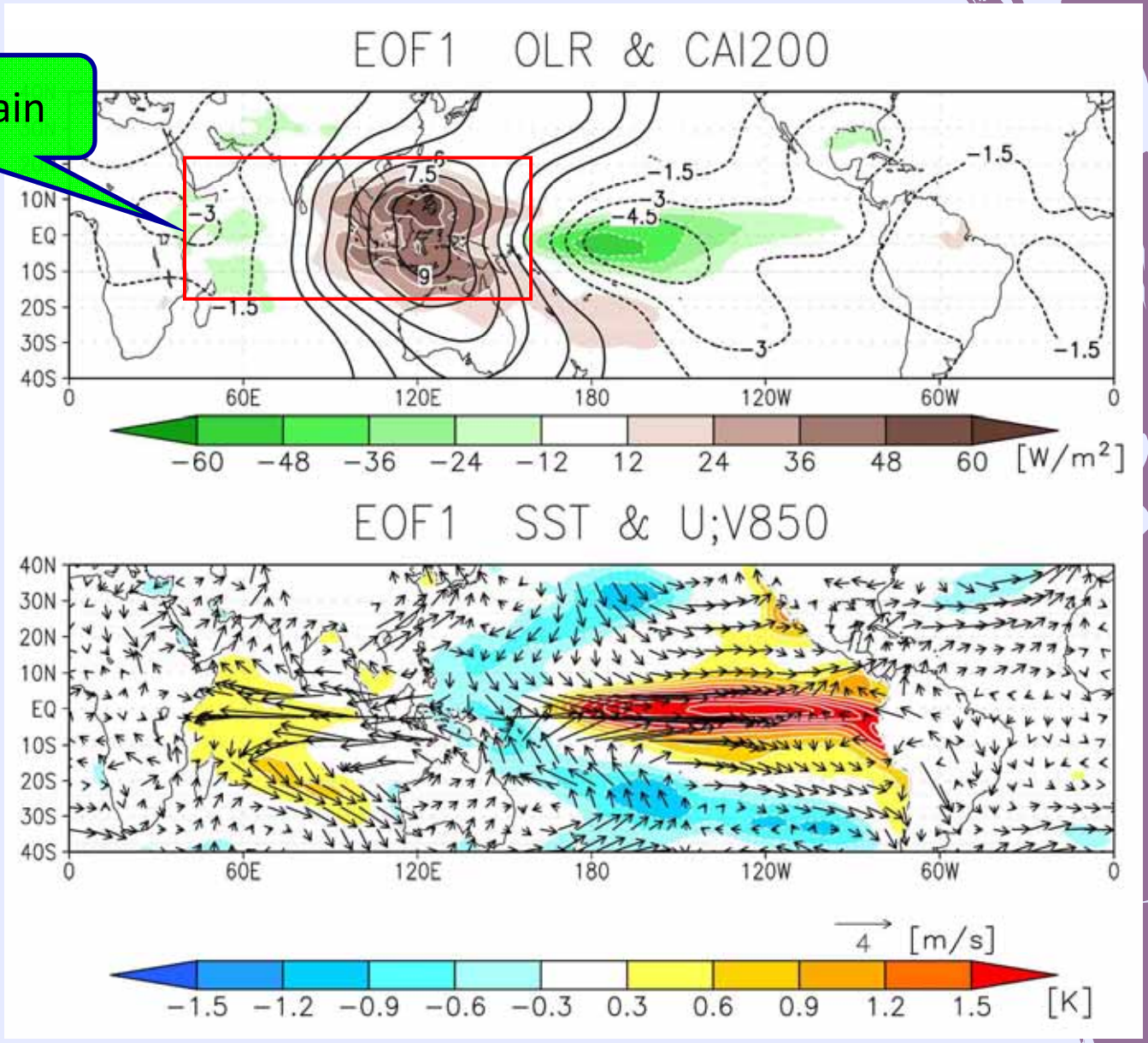


Fig. A (a) Global feature of the composite differences in the filtered 200-hPa velocity potential and OLR between the positive and negative phases of EOF1 (former minus latter). The contour interval for the velocity potential and the OLR is 1.5×10^6 $m^2 s^{-1}$ and 12 W m^{-2}, respectively. (b) As in (a) but for the filtered SST and 850-hPa wind vector. The contour interval is 0.3 K with the zero contour suppressed. The reference arrow is 4 m s^{-1}.

直交性の制約があるため、EOF2はENSOとは無関係に見える．しかし、やはりIODやWESは見られない．

EOF2はENSOの遷移期のパターンを説明している？

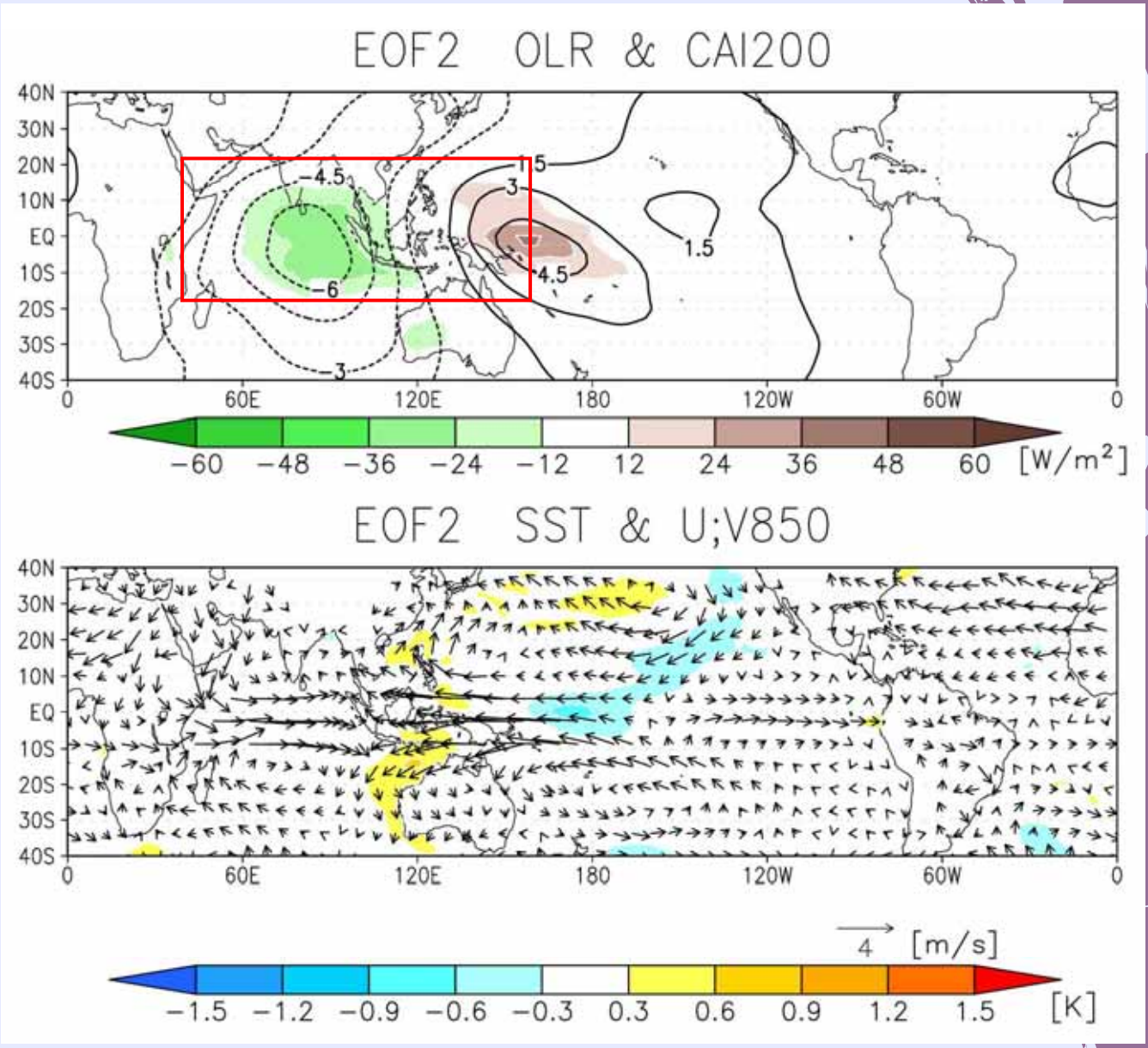
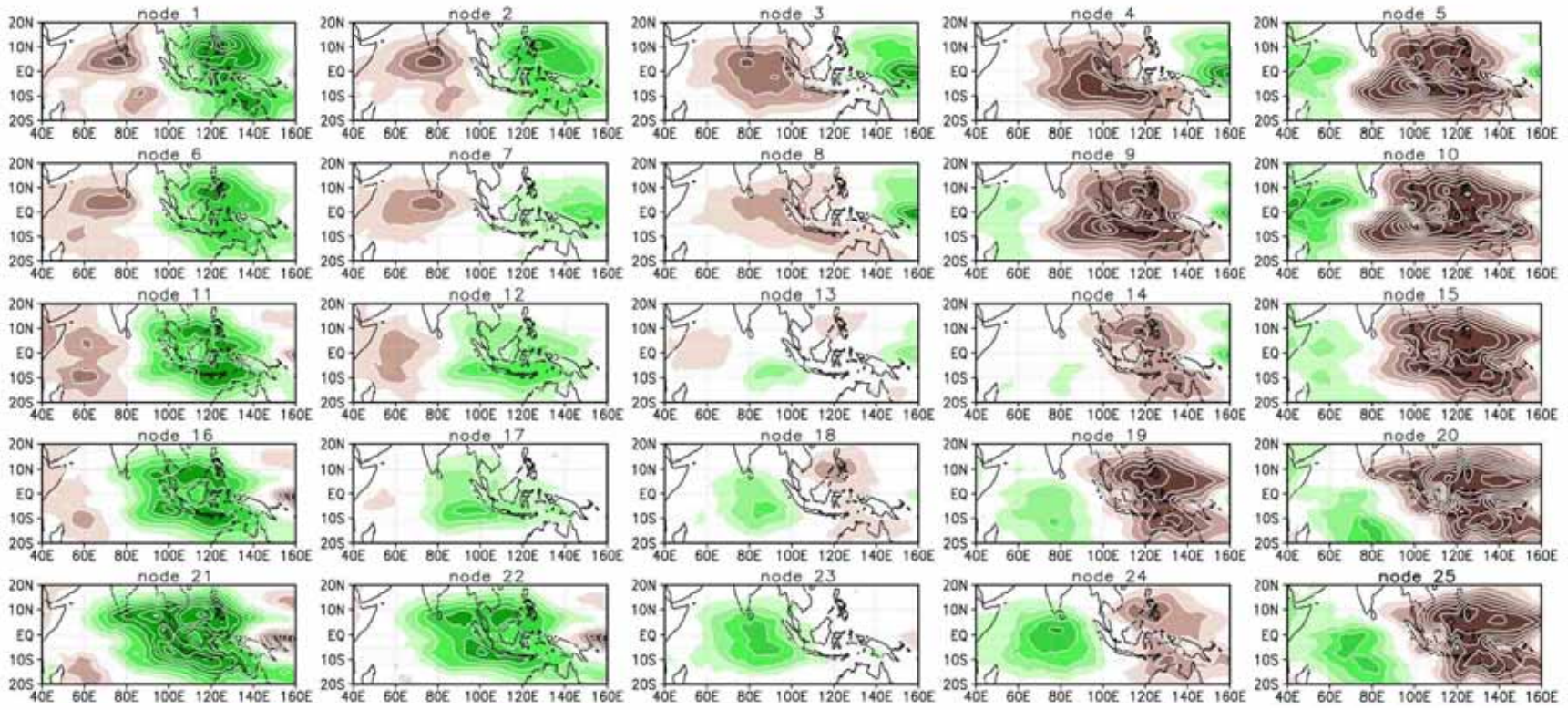


Fig. B (a) Global feature of the composite differences in the filtered 200-hPa velocity potential and OLR between the positive and negative phases of EOF2(former minus latter). The contour interval for the velocity potential and the OLR is 1.5×10^6 $m^2 s^{-1}$ and 12 W m^{-2}, respectively. (b) As in (a) but for the filtered SST and 850-hPa wind vector. The contour interval is 0.3 K with the zero contour suppressed. The reference arrow is 4 m s^{-1}.

自己組織化マップ (Self-Organizing Map: SOM*)

5 x 5 Map (25 nodes)



La Nina?

El Nino?

*SOM: **競合学習型ニューラルネットワークを用いた非線形解析手法**

エルニーニョ･ラニーニャ現象に密接に関連するノードに注目

El Nino type
(node 10, node 20)

La Nina type
(node 1, node 11, node 21)

5x5 SOM

(a) Positive Phase

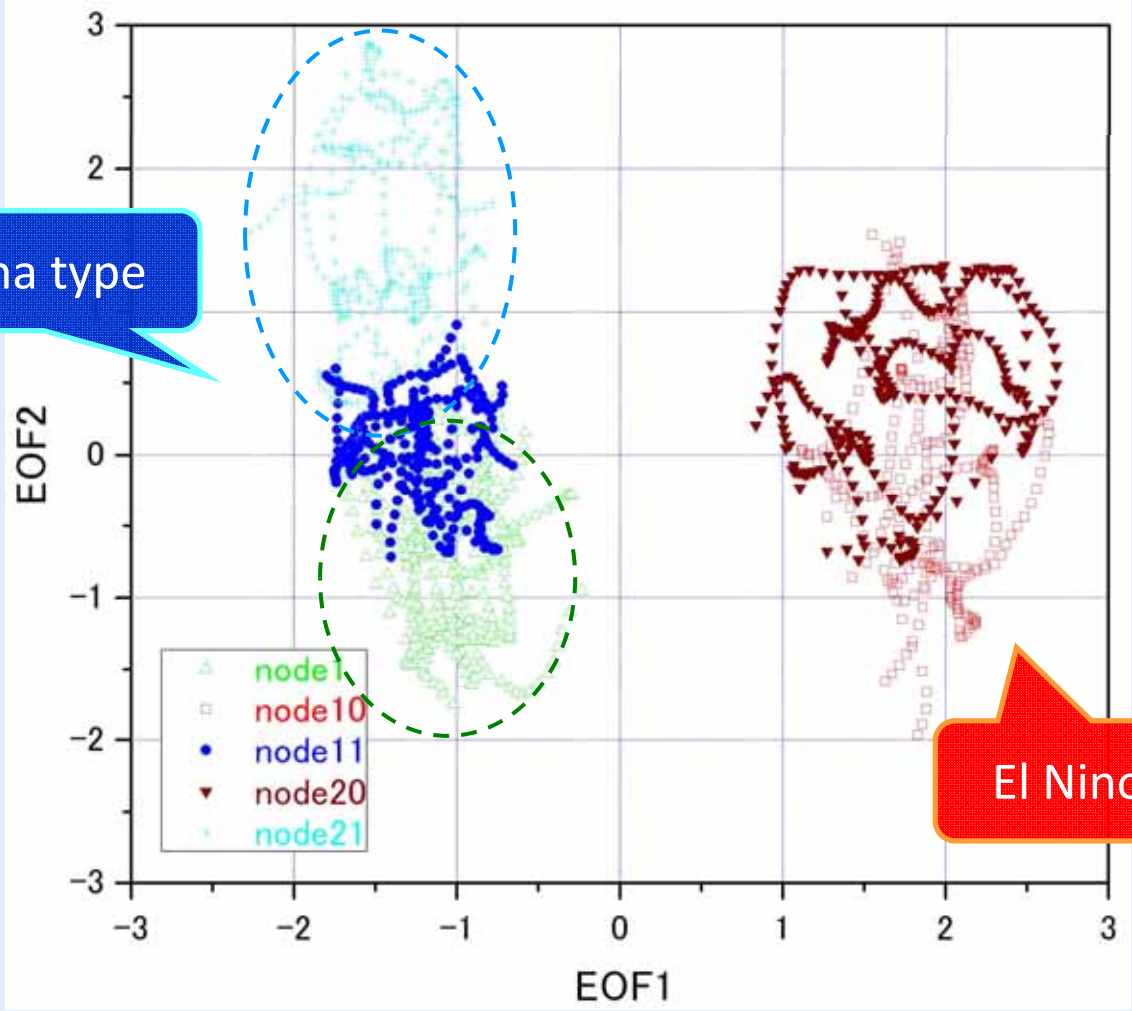
0	0	0	1.6	6.8
0	0	0	4.1	30.2
0	0	0	0	10.2
0	0	0	4.1	29.1
0	0	0	1.8	12.2

(b) Negative Phase

23.3	1.2	0	0	0
8.6	0	0	0	0
22.7	0.5	0	0	0
6.7	0	0	0	0
33.3	3.8	0	0	0

Fig. C (a) Pattern frequencies (%) for positive EOF1 events when the score is greater than 1.0. Heavy and light shadings denote large and small percentages, respectively. (b) As in (a) but for negative EOF1 events when the score is less than -1.0.

EOF位相空間に投影された5つのノード（エルニーニョ型とラニーニャ型）



・EOF2もENSOシグナルの一部を説明している

・EOF1はIODとWESが混在したモードではないのか？

Fig. D　Two-dimensional plot of five ENSO-related nodes projected on the phase space of the leading two modes (EOF1 and EOF2).

Node 10: El Nino type (El Nino + positive IOD)

季節依存性:
10, 11月に出現する傾向

インド洋では, 正のIODイヴェントが見られる. El Nino **と結合したパターン**

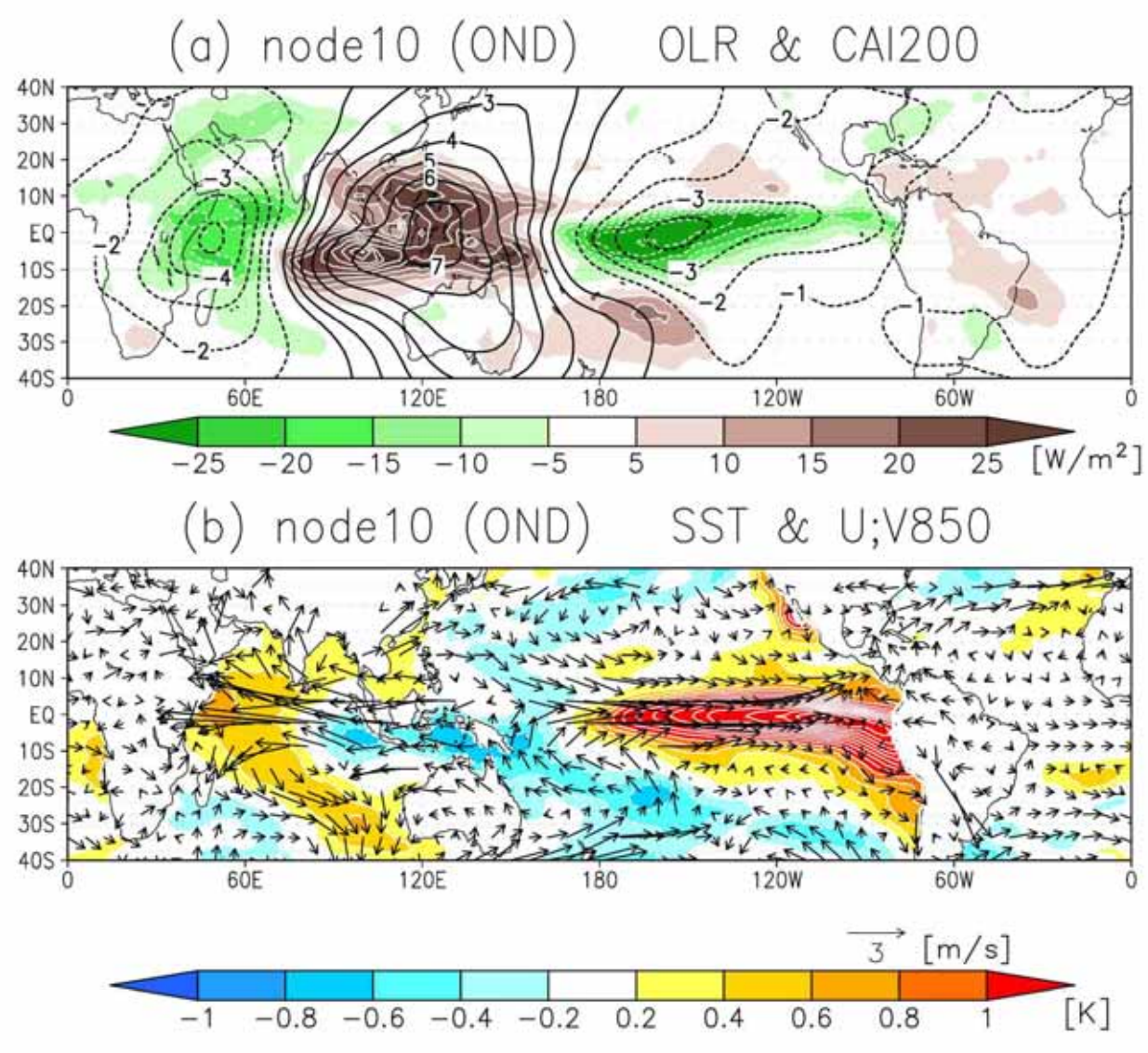


Fig. E (a) Composite anomaly patterns in the filtered 200-hPa velocity potential and OLR for node 10 from October to December (OND). The contour interval for the velocity potential and the OLR is 1×10^6 $m^2 s^{-1}$ and 5 W m^{-2}, respectively. (b) As in (a) but for the filtered SST and 850-hPa wind vector. The contour interval is 0.2 K with the zero contour suppressed. The reference arrow is 3 m s^{-1}.

月別出現比率 Oct: 34.8% Nov: 34.5% Dec: 14.8%

Node 20: El Nino type (El Nino + positive WES)

季節依存性:
2, 3月に出現する傾向

インド洋では，赤道非対称偏差が見られる（正のWES）．
El Ninoと結合したパターン

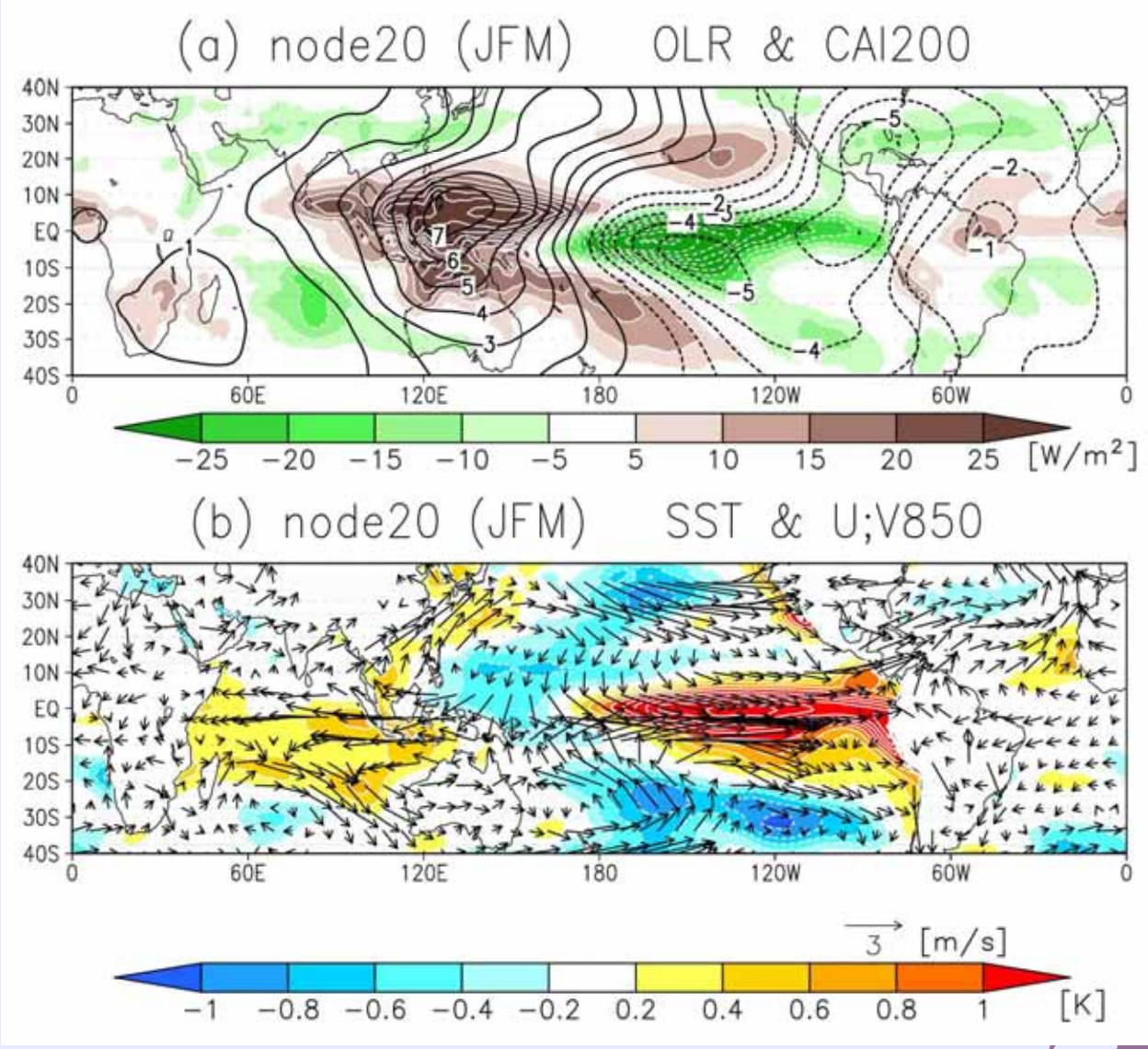


Fig. F (a) Composite anomaly patterns in the filtered 200-hPa velocity potential and OLR for node 20 from January to March (JFM). The contour interval for the velocity potential and the OLR is 1×10^6 $m^2 s^{-1}$ and 5 W m^{-2}, respectively. (b) As in (a) but for the filtered SST and 850-hPa wind vector. The contour interval is 0.2 K with the zero contour suppressed. The reference arrow is 3 m s^{-1}.

月別出現比率 Jan: 18.8% Feb: 41.6% Mar: 39.6%

Node 1: La Nina type

季節依存性:
12月中心に出現する傾向

インド洋では, 顕著な偏差は見られない.
↓
熱帯インド洋との結合は弱い

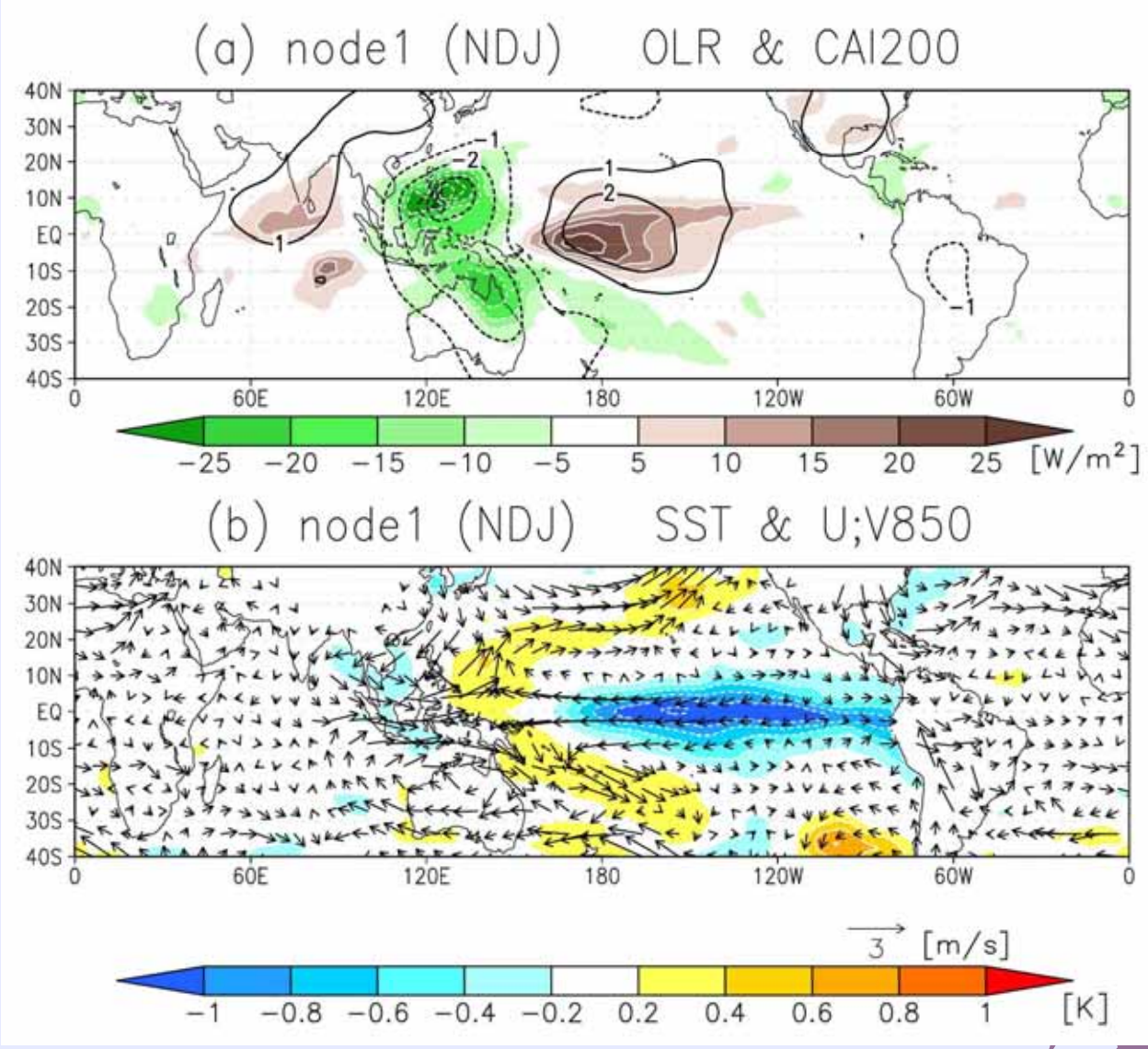


Fig. G (a) Composite anomaly patterns in the filtered 200-hPa velocity potential and OLR for node 1 from November to January (NDJ). The contour interval for the velocity potential and the OLR is $1x10^6$ m^2s^{-1} and 5 W m^{-2}, respectively. (b) As in (a) but for the filtered SST and 850-hPa wind vector. The contour interval is 0.2 K with the zero contour suppressed. The reference arrow is 3 m s^{-1}.

月別出現比率　Nov: 15.2% Dec: 25.1% Jan: 21.4%

Node 11: La Nina type

(平成18年豪雪時に出現)

季節依存性:
11, 12月に出現する傾向

インド洋では, 負のIOD イヴェントは見られない.
↓
Node 10の反転パターンではない.

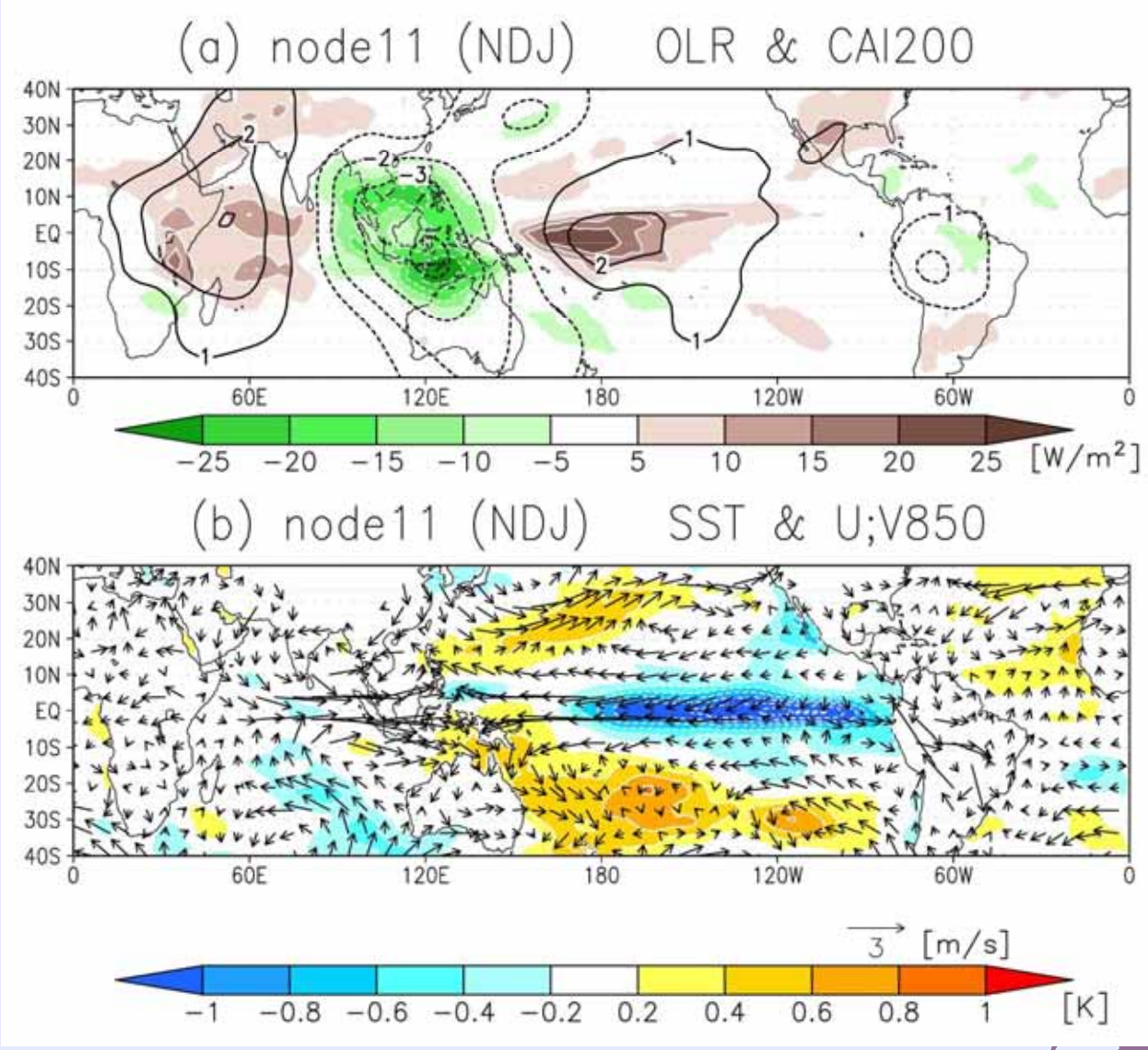


Fig. H (a) Composite anomaly patterns in the filtered 200-hPa velocity potential and OLR for node 11 from November to January (NDJ). The contour interval for the velocity potential and the OLR is $1x10^6$ m^2s^{-1} and 5 W m^{-2}, respectively. (b) As in (a) but for the filtered SST and 850-hPa wind vector. The contour interval is 0.2 K with the zero contour suppressed. The reference arrow is 3 m s^{-1}.

月別出現比率 Nov: 42.5% Dec: 24.0% Jan: 5.5%

Node 21: La Nina type (La Nina + negative WES)

季節依存性:
1〜3月に出現する傾向

インド洋では，赤道非対称偏差が見られる（負のWES）．
La Ninaと結合したパターン
↓
Node 20の反転パターンに対応する．

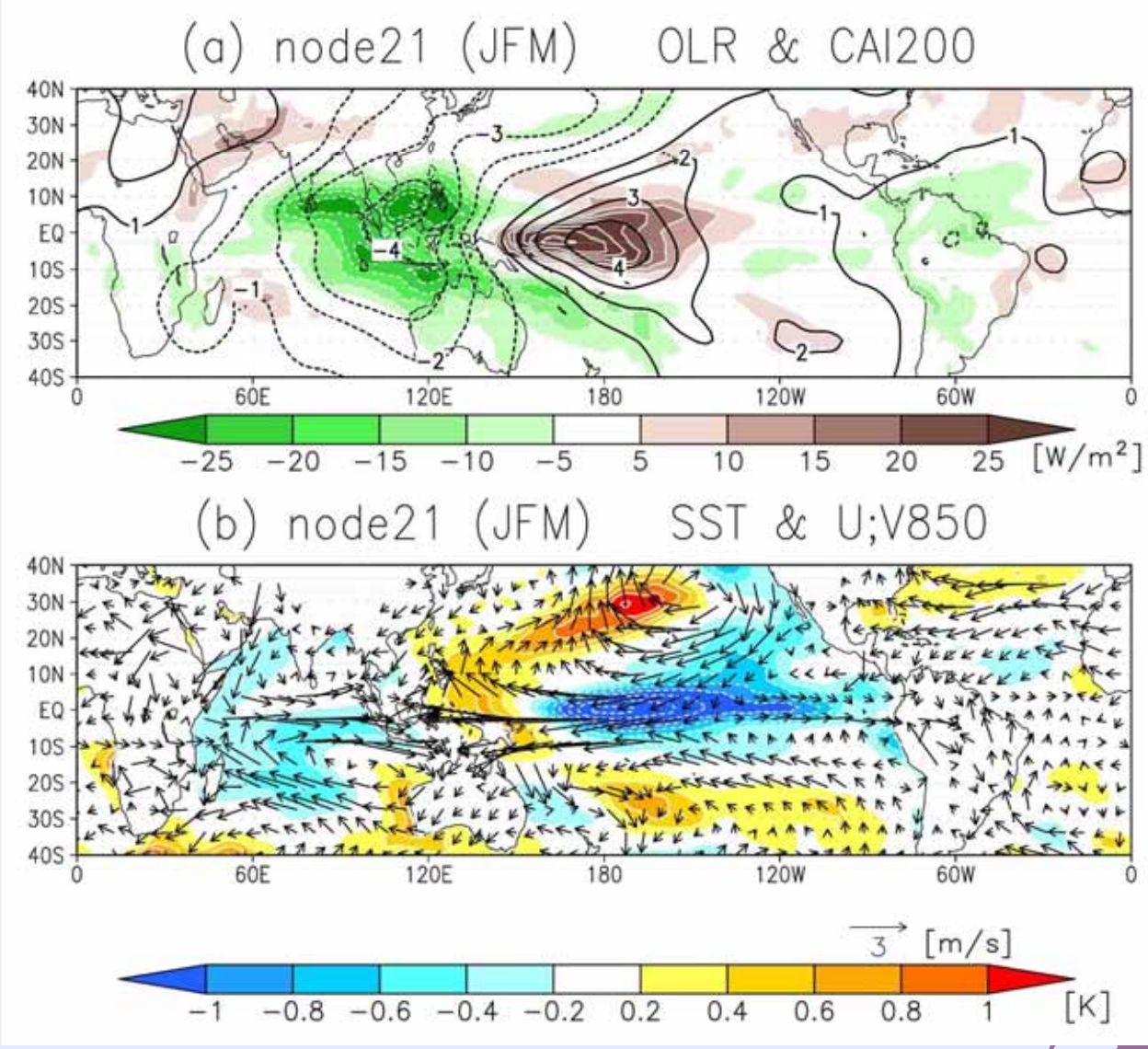


Fig. I (a) Composite anomaly patterns in the filtered 200-hPa velocity potential and OLR for node 21 from January to March (JFM). The contour interval for the velocity potential and the OLR is 1×10^6 $m^2 s^{-1}$ and 5 W m^{-2}, respectively. (b) As in (a) but for the filtered SST and 850-hPa wind vector. The contour interval is 0.2 K with the zero contour suppressed. The reference arrow is 3 m s^{-1}.

月別出現比率 Jan: 24.0% Feb: 29.3% Mar: 25.5%

エルニーニョ型･ラニーニャ型のノードに対する アジアジェット及び冬季東アジアモンスーンの遠隔応答

●ラニーニャ型の中で, node11が最も冬季東アジアモンスーン変動に影響を与えている.
●エルニーニョ型のnode20は対流圏上層の循環場では冬季モンスーンへの影響が弱い.

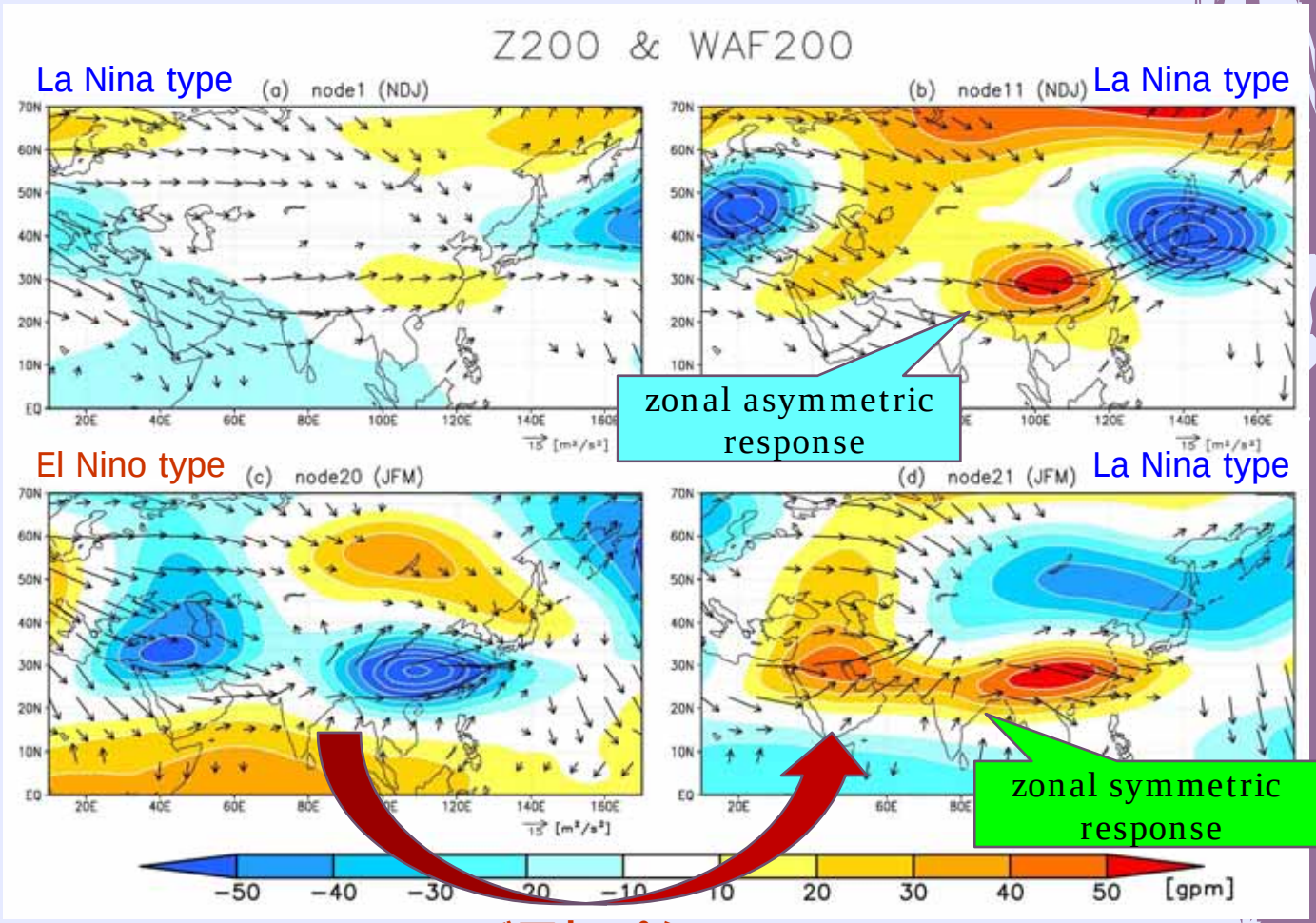


Fig. J (a) Composite maps of the filtered 200-hPa geopotential height anomalies for node 1 during NDJ. The contour interval is 10 m with the zero contour suppressed. Wave activity fluxes are shown at the same level. The reference arrow is 15 m^2s^{-2}. (b) As in (a) but for node 11 during NDJ. (c) As in (a) but for node 20 during JFM. (d) As in (a) but for node 21 during JFM.

ほぼ反転パターン

エルニーニョ型･ラニーニャ型のノードに対する日本付近のモンスーン気流と気温の変化

●ラニーニャ時には，初冬に多いnode11のような熱帯対流活動の空間パターンになると，アジアジェットを導波管として定在ロスビー波束が伝播しやすく，結果的に冬季モンスーンの強化をもたらす．

●エルニーニョ時には，晩冬に多いnode20のような熱帯対流活動のパターンになると，（アジアジェットを介するテレコネクションは不明瞭であるが，）フィリピン東方の下層高気圧が強化されて，冬季モンスーンが弱化する（Wang et al., 2000他）．

冬季モンスーンの非対称的な応答

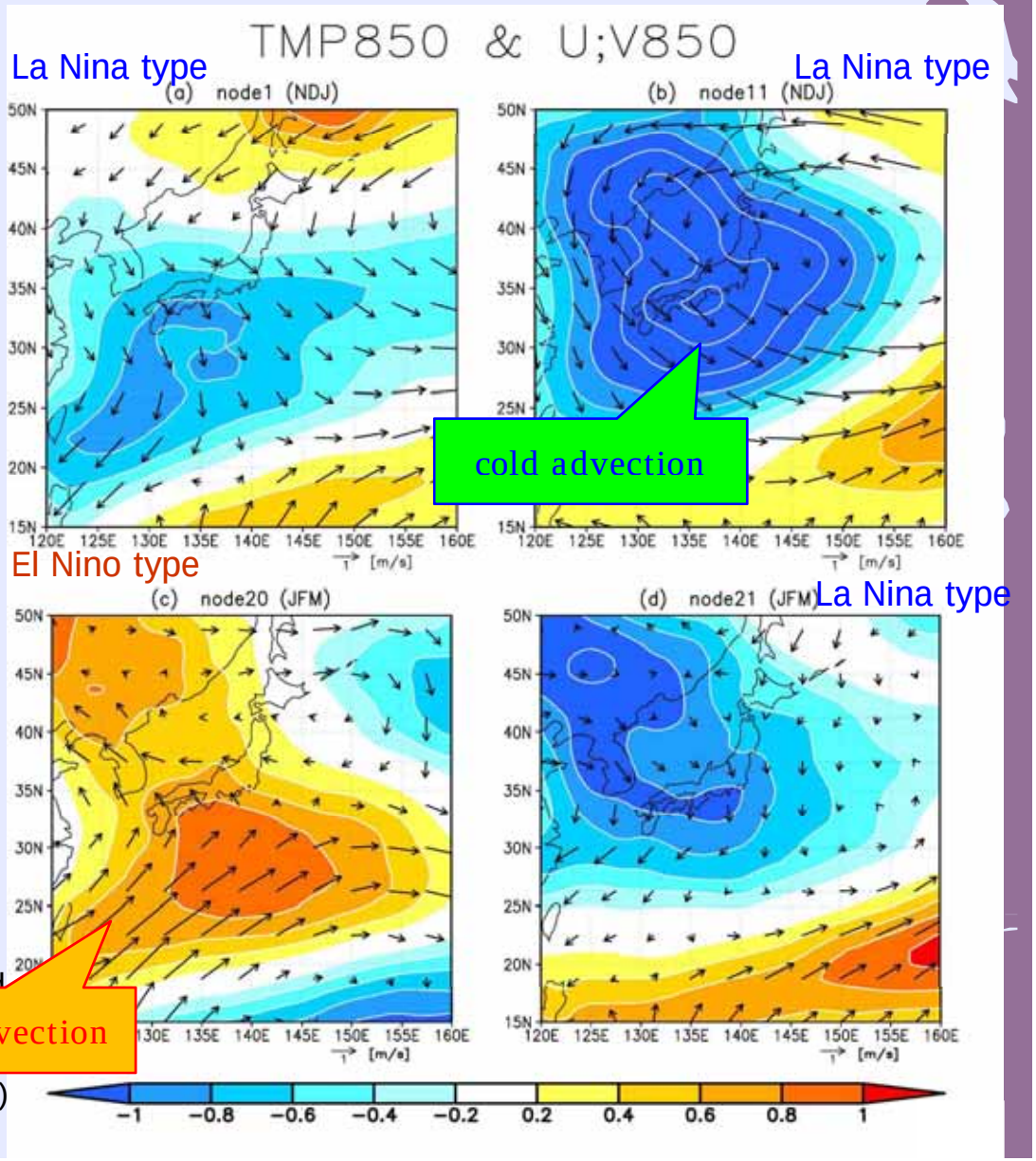


Fig. K (a) Composite maps of the filtered 850-hPa temperature anomalies for node 1 during NDJ. The contour interval is 0.2 K with the zero contour suppressed. Horizontal wind vectors are shown at the sa reference arrow is 1 m s^{-1}. (b) As in (a) but during NDJ. (c) As in (a) but for node 20 during JFM. (d) As in (a) but for node 21 during JFM.

Summary

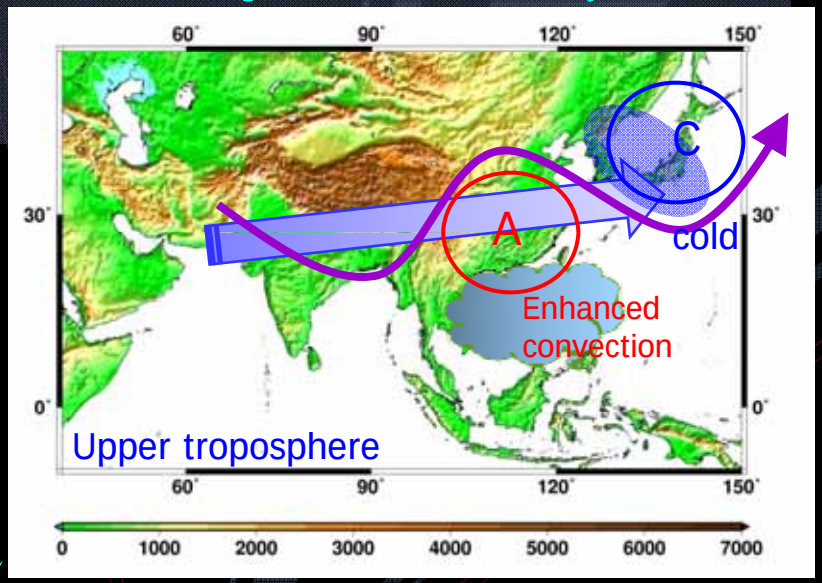
1. ENSOの位相に関して，西太平洋～インド洋の熱帯対流活動は強い非対称性をもっている．
2. ENSO強制による冬季東アジアモンスーンの遠隔応答も，結果的に，**非対称性の強い応答**となっている．

非対称性
- 上層起源 vs 下層起源
- 初冬 vs 晩冬
- 日本全域 vs 主に南部

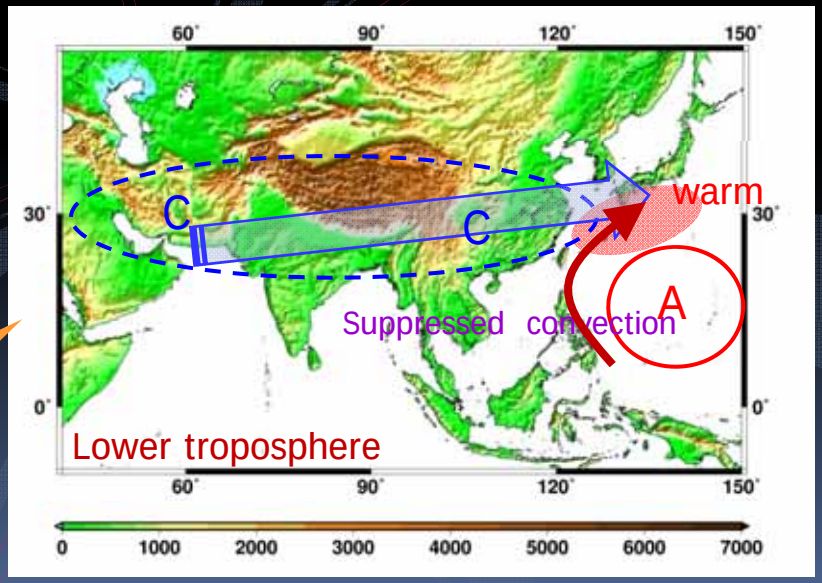
Node 11

Node 20

La Nina/Strong monsoon　early winter

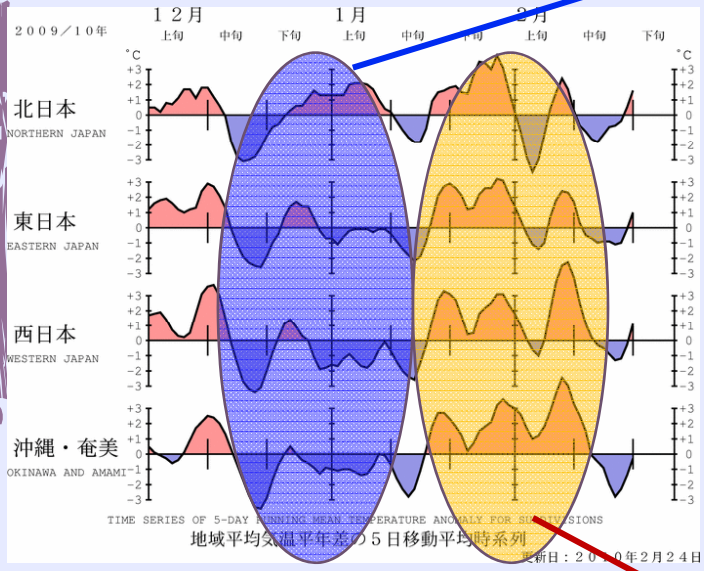


El Nino/Weak monsoon　late winter

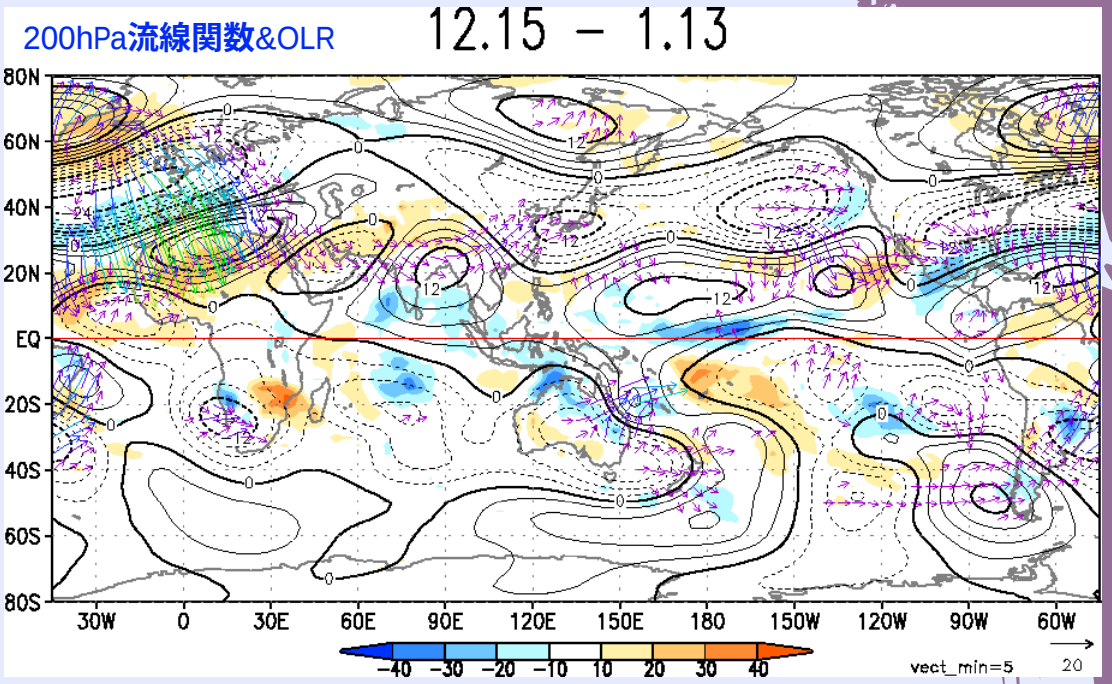


2009/10冬季の様子は？

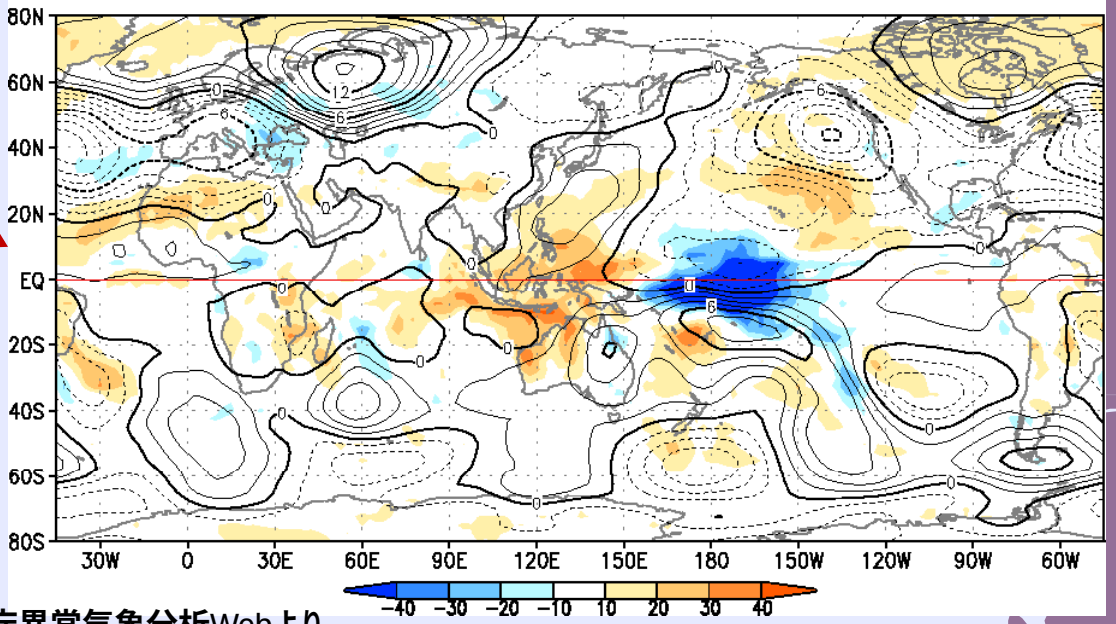
前半は寒冬、後半は暖冬



200hPa流線関数&OLR　12.15 – 1.13



850hPa流線関数&OLR　1.16 – 2.14



・前半は，アジアジェットに沿う波列は見られるが熱帯対流活動の強化は必ずしも顕著ではない。

・後半は，El Nino時の典型的な暖冬例であり，node20に類似。

気象庁異常気象分析Webより

■冬季東アジアモンスーン変動とENSO

Sakai, K., and R. Kawamura (2009): Remote response of the East Asian winter monsoon to tropical forcing related to El Nino-Southern Oscillation. *J. Geophys. Res.,* 114, D06105, doi:10.1029/2008JD010824.

■ENSO起源のインド洋～西太平洋の熱帯対流活動（SOM解析）

Sakai, K., R. Kawamura, and Y. Iseri (2010): ENSO-induced tropical convection variability over the Indian and the Western Pacific Oceans during the northern winter as revealed by a self-organizing map. *Submitted to J. Geophys. Res.*

■冬季東アジアモンスーン変動と日本近海の爆弾低気圧活動

Yoshiike, S., and R. Kawamura (2009): Influence of wintertime large-scale circulation on the explosively developing cyclones over the western North Pacific and their downstream effects. *J. Geophys. Res.,* 114, D13110, doi:10.1029/2009JD011820.

ご清聴ありがとうございました

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