

季節内振動と大気大循環変動との関係

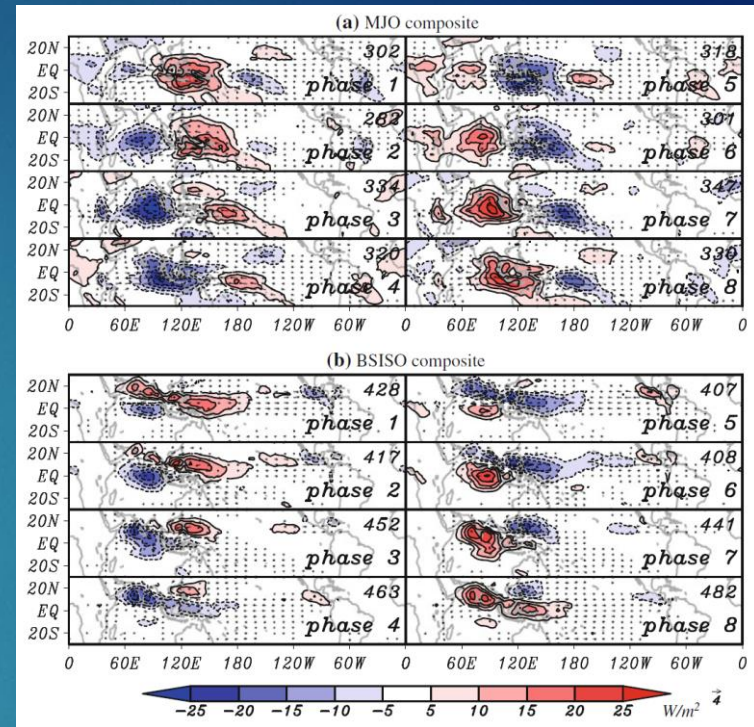
原田やよい（気象研究所）

2017年9月21日

波と平均流の相互作用に関する研究会

Introduction

- ▶ Madden-Julian Oscillation (MJO)...the dominant mode in boreal winter and propagate eastward along the equator
- ▶ Boreal Summer ISO (BSISO)... the dominant mode in boreal summer and active convective region migrates northward in the Indian Ocean and the western Pacific with a period of 30 – 90 days



Composite life cycle of (a) the MJO mode and (b) the BSISO mode. OLR anomalies (shades and contours of 5 Wm^{-2}) and 850 hPa horizontal winds (vectors).

Figure 8 in Kikuchi et al. 2012

- ▶ In this study, statistical relationships MJO and BSISO and the global circulation are examined and clarified, focusing on the variabilities of the zonal mean fields both in the troposphere and stratosphere.

Data and Methods #1

- ▶ Bimodal ISO index (Kikuchi et al. 2012)
 - ▶ Application of the extended EOF to 25-90 band-pass filtered OLR
 - ▶ Projection of the time filtered OLR onto the both MJO and BSISO modes

- ▶ JRA-55 reanalysis
 - ▶ model analysis fields for MIM method, isentropic analysis fields for map composites
 - ▶ Analysis period: Years of 1979-2012

- ▶ Lanczos filter (Duchon 1979)
 - ▶ 25-90 day band pass filter and 90-day low pass filter are applied
 - ▶ No filtered data is also used for composite analysis

Data and Methods #2

- Mass weighted Isentropic zonal Mean (MIM) method (Iwasaki 1989)

$$\overline{A(\phi, \theta, t)^*} \equiv \frac{1}{2\pi} \int A(\lambda, \phi, \theta, t) \left(\frac{\partial p}{\partial \theta} / \frac{\partial \bar{p}}{\partial \theta} \right) d\lambda$$

$$p_{\dagger} \equiv \bar{p}.$$

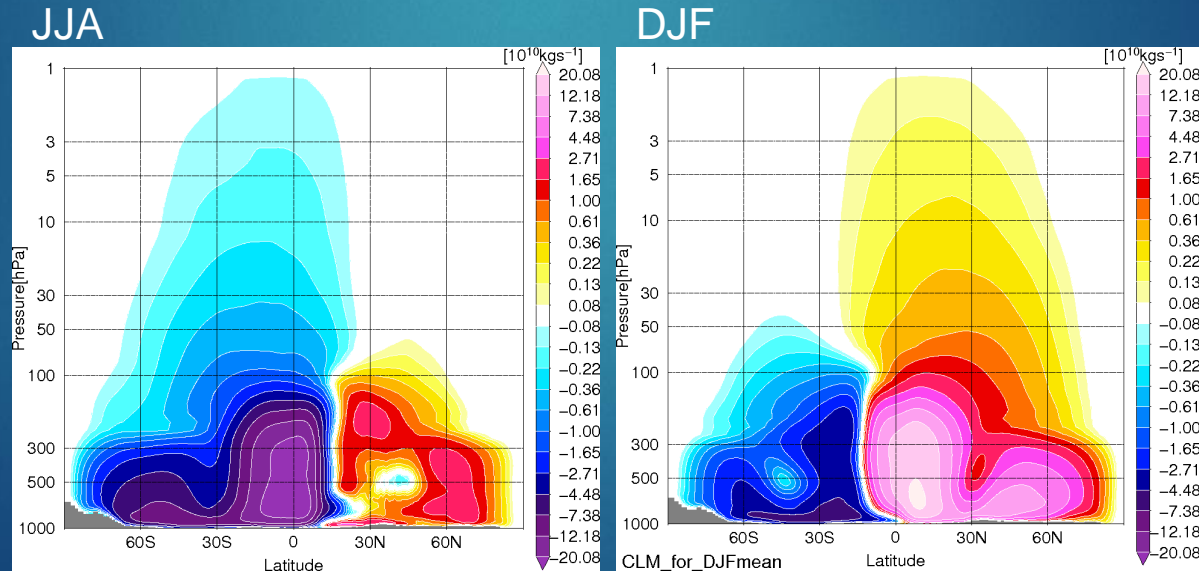
$$z_{\dagger} \equiv -H \log(p_{\dagger}/p_0).$$


Overbar: isentropic zonal mean

Asterisk: local mass weight normalized by its zonal mean

Dagger: isentropic zonal mean

- Vertical coordinate is defined by isentropic zonal mean pressure
- All variables are zonally averaged with normalized weights proportional to the air mass between two isentropic surfaces

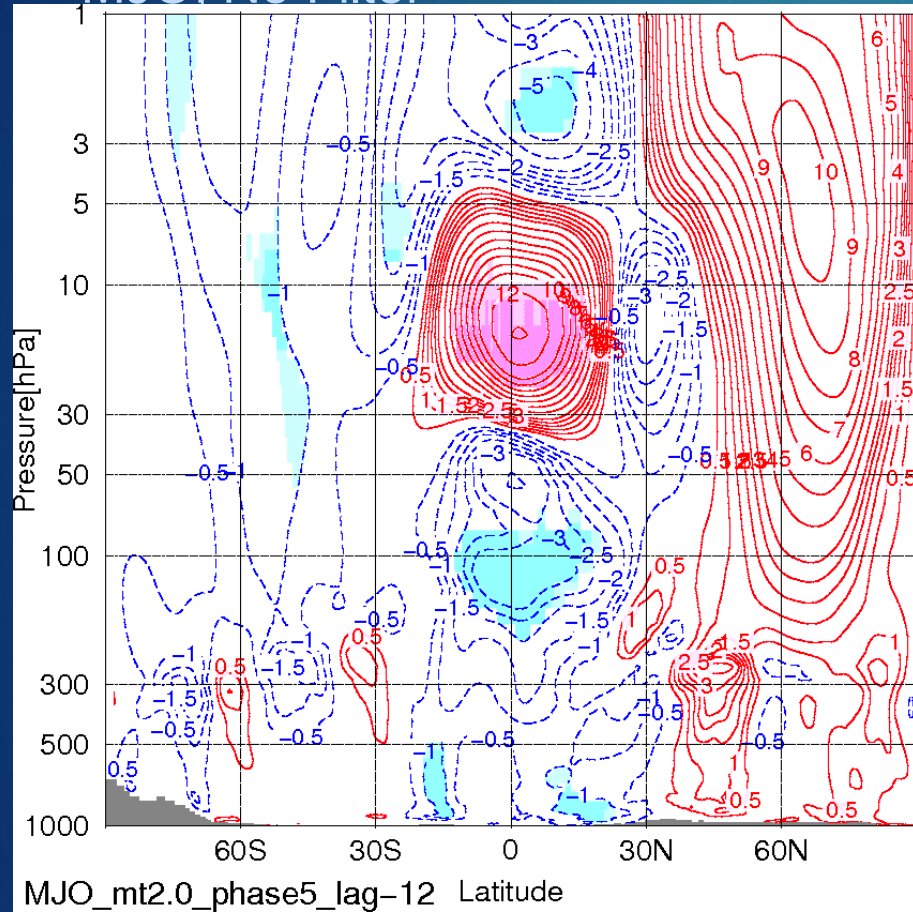




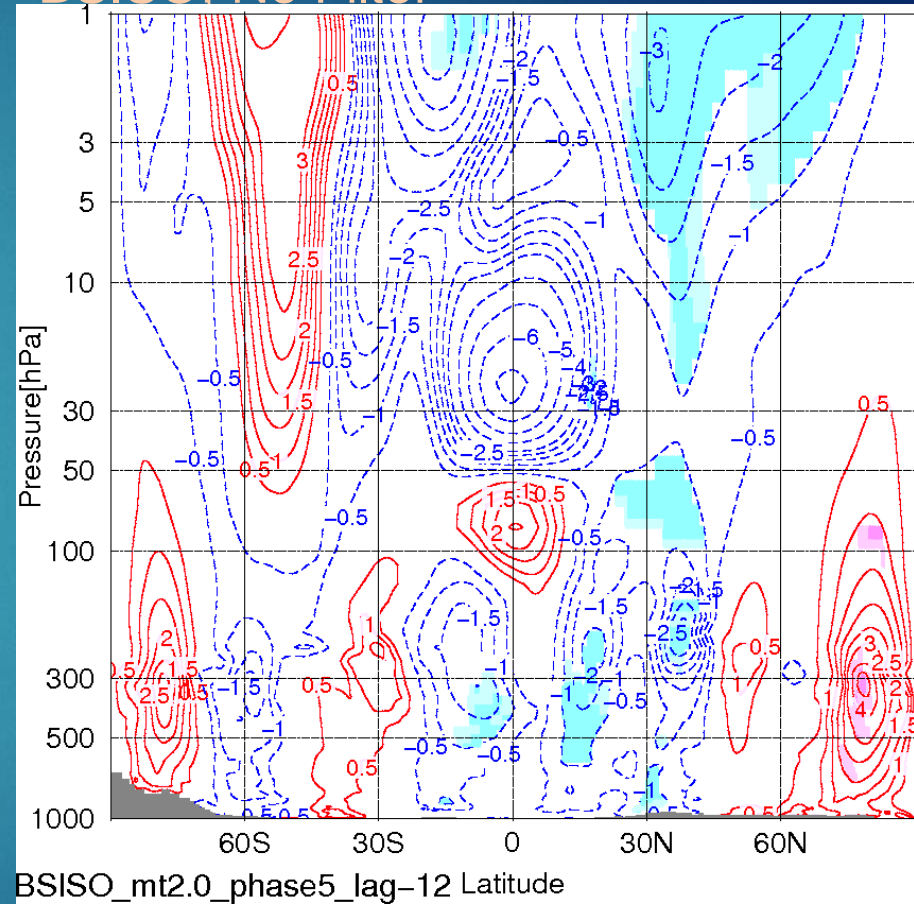
Composite cross-sections of zonal mean fields

Comparison of BSISO with MJO, Zonal Wind [m s^{-1}], amplitude ≥ 2.0 SD, Day -12 to Day +15 for the phase 5

MJO, No Filter



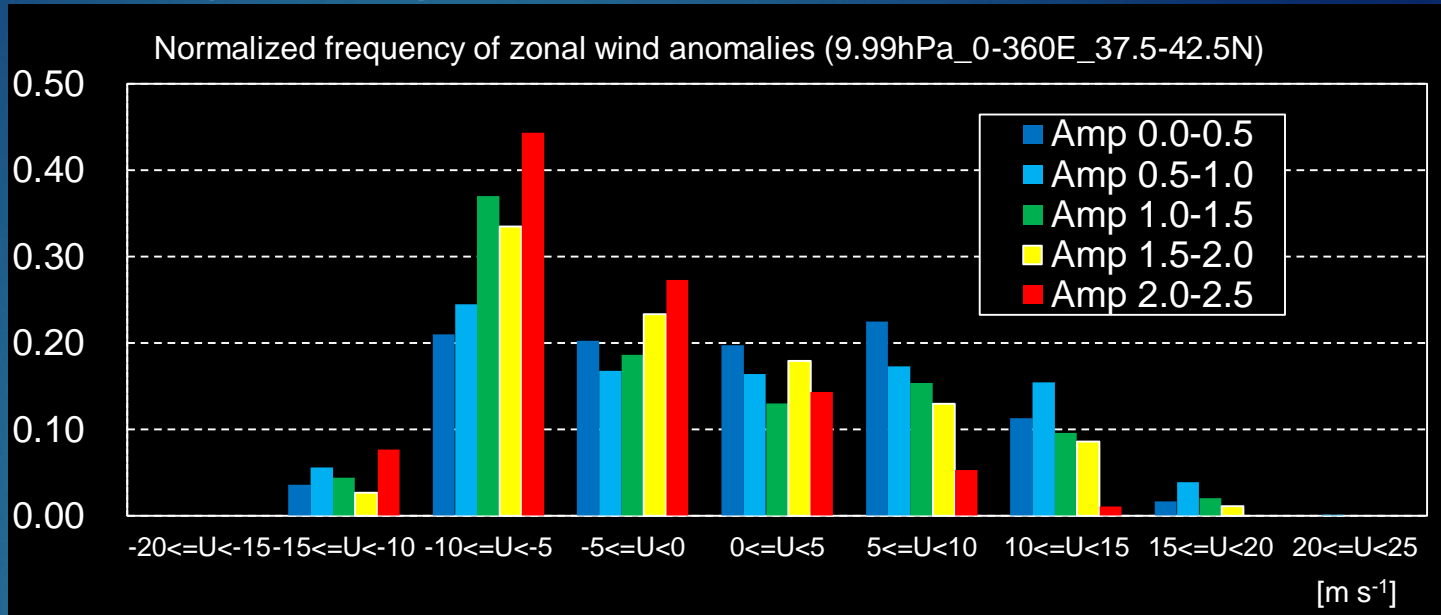
BSISO, No Filter



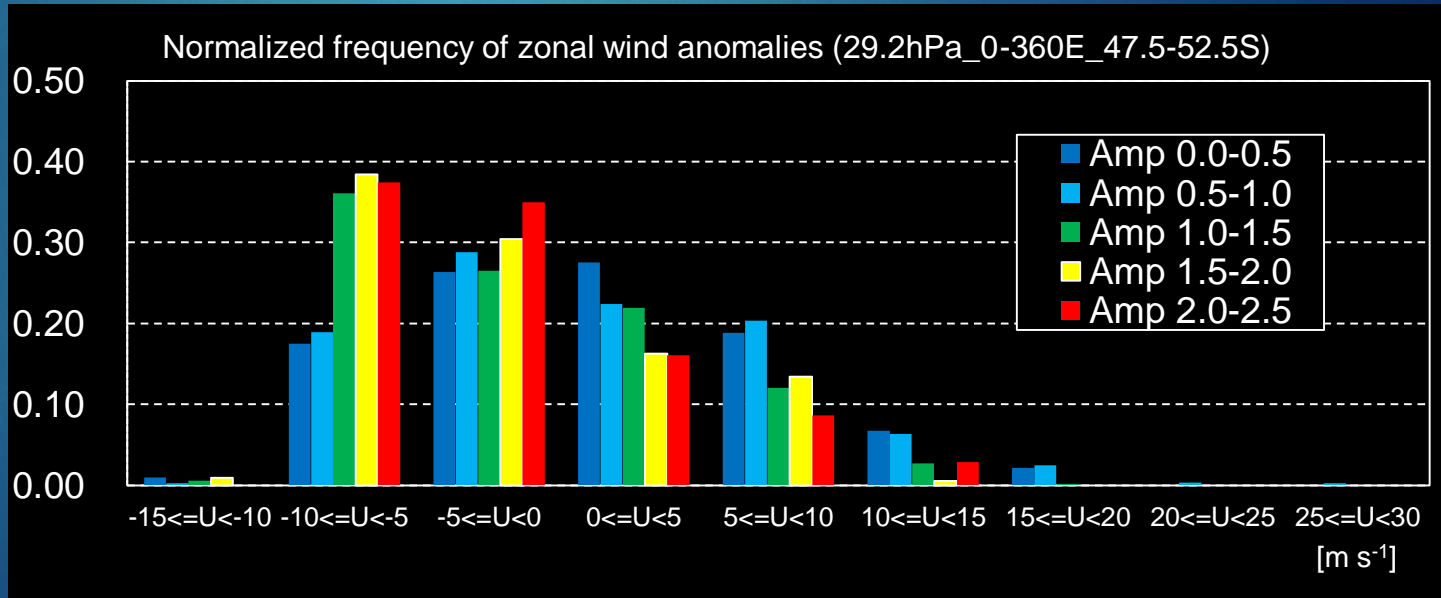
- ▶ Phase 5
BSISO: just after the northward migration of active convective region
MJO: eastward propagation of active convective region over Maritime Continent
- ▶ Light (dark) shadings show statistical significance at 90 % (95 %) confidence levels.

Normalized frequency of zonal wind anomalies# 1

BSISO
9.99hPa, 37.5-42.5N



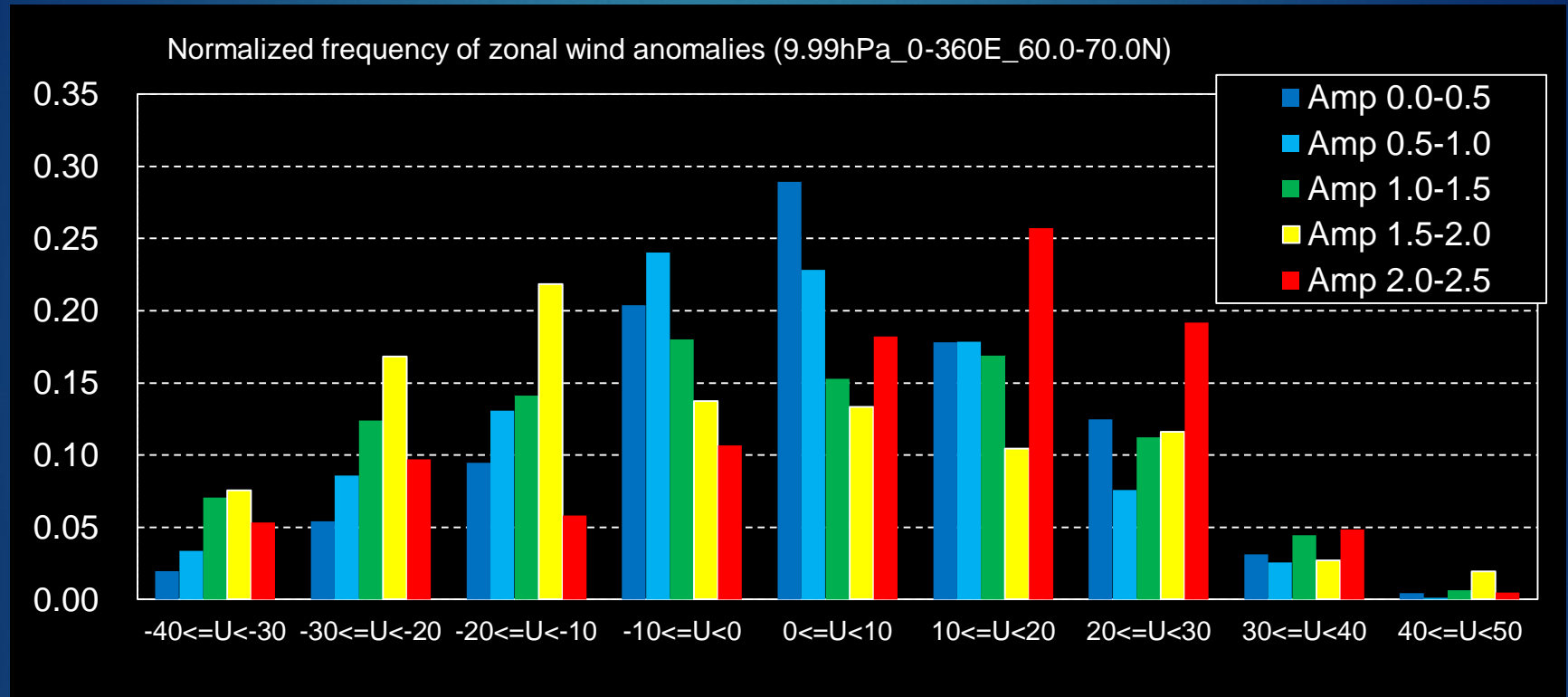
MJO
29.2hPa, 47.5-52.5S



Frequency of easterly (westerly) anomalies in the both summer hemisphere increase as amplitudes of BSISO and MJO become large (small).

Normalized frequency of zonal wind anomalies#2

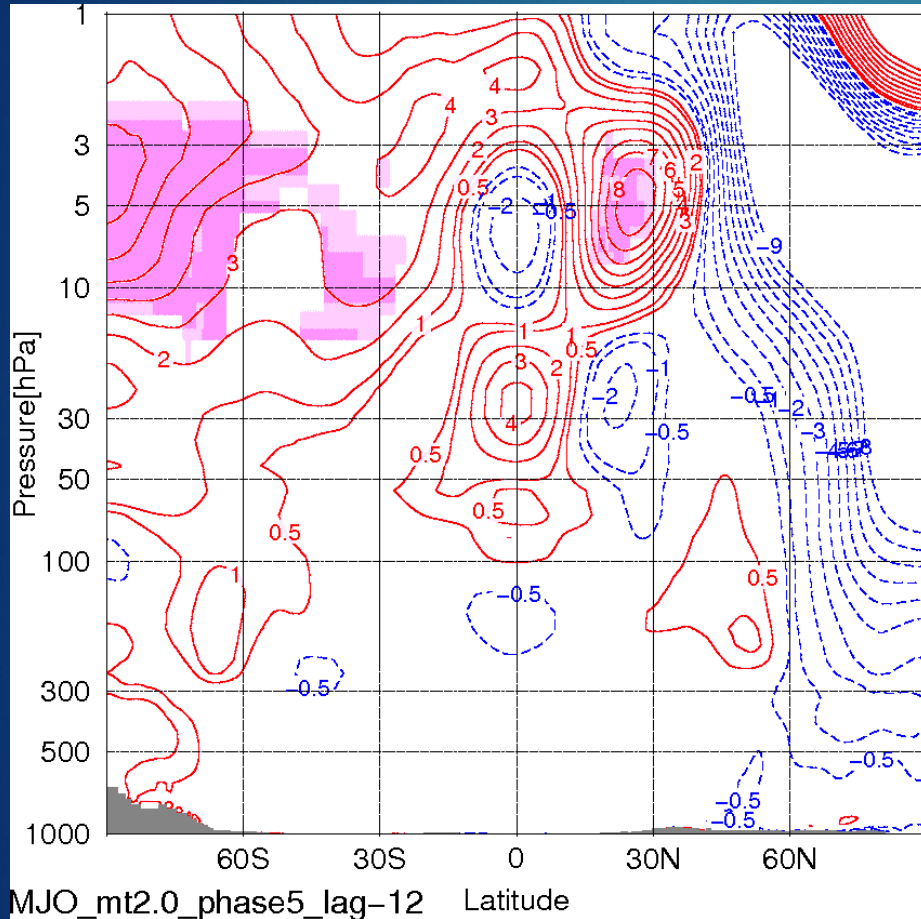
MJO 9.99hPa, 60.0-70.0N



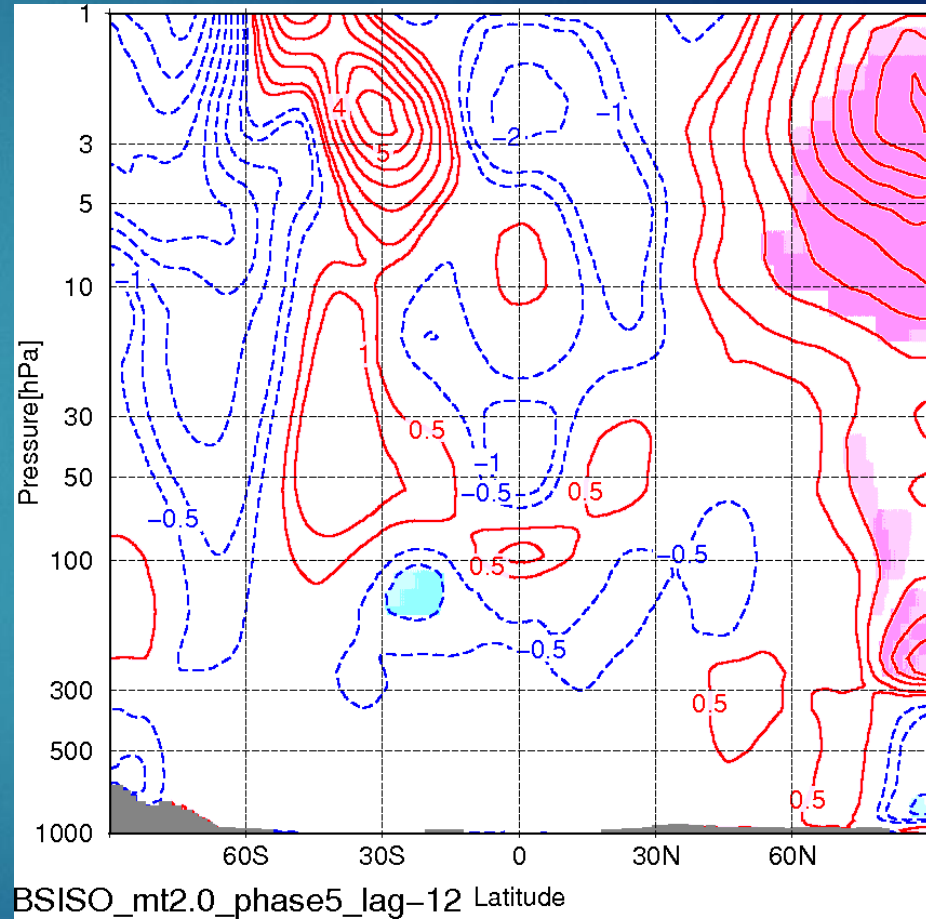
In the case that Amplitude of MJO is more than two stand deviation, frequency of westerly anomalies in high-latitudes of the winter Northern Hemisphere.

Comparison of BSISO with MJO, P. temp. [K], amplitude ≥ 2.0 SD, Day 0 for the phase 5

MJO, No Filter



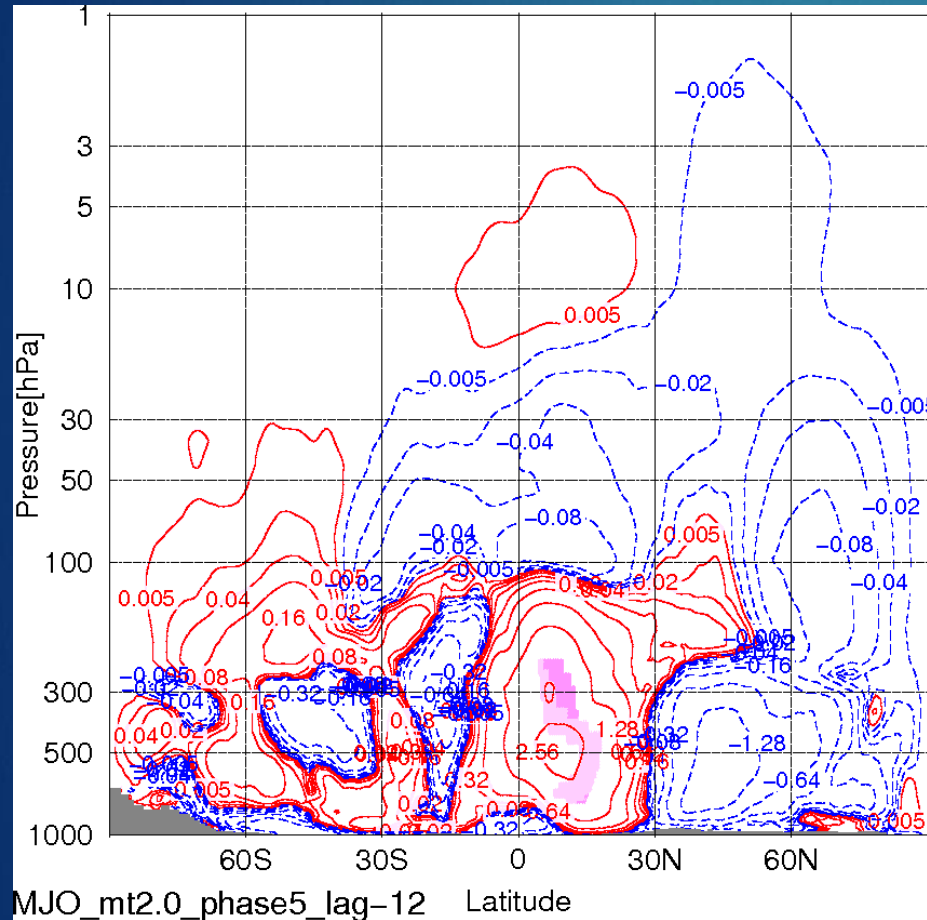
BSISO, No Filter



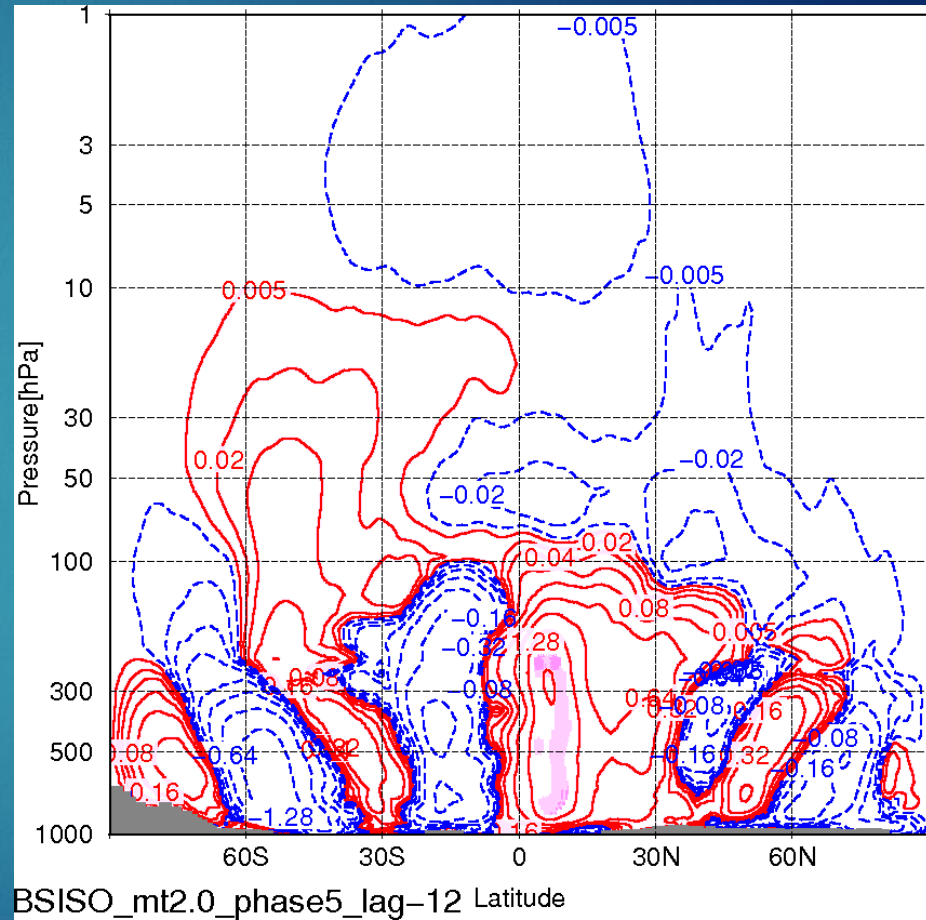
- ▶ Phase 5
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Comparison of BSISO with MJO, M. S. F. [$10^{10} \text{ kg s}^{-1}$], amplitude ≥ 2.0 SD, centered the days in phase 5


MJO, No Filter



BSISO, No Filter



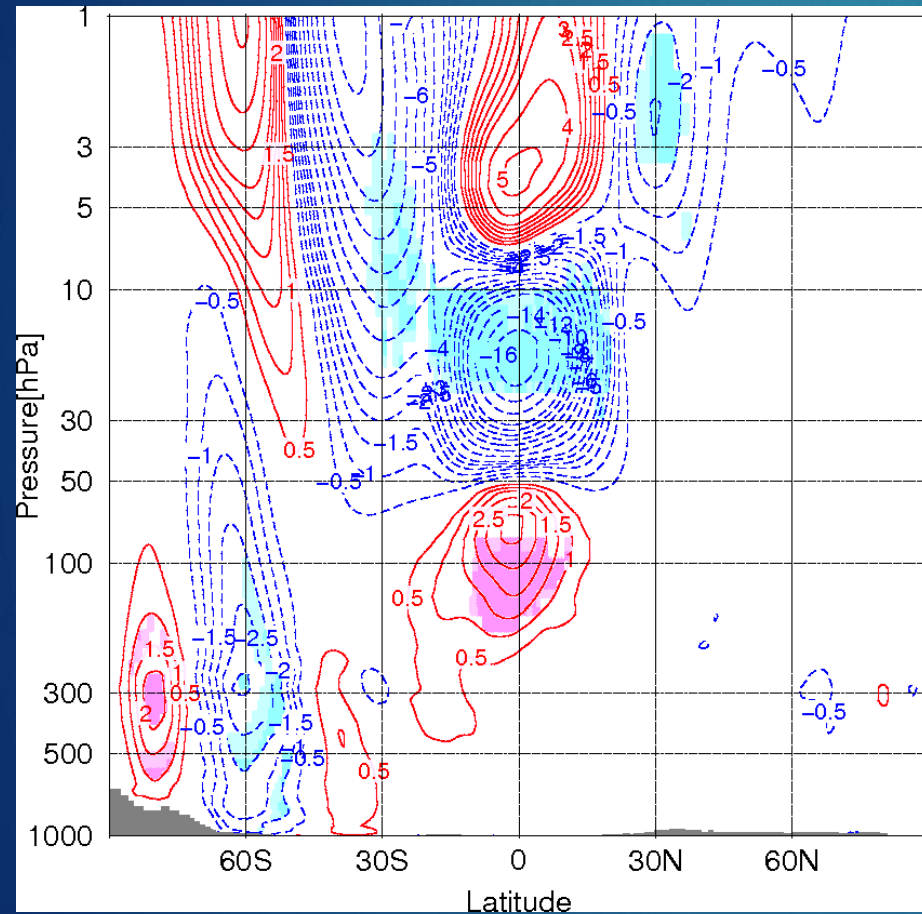
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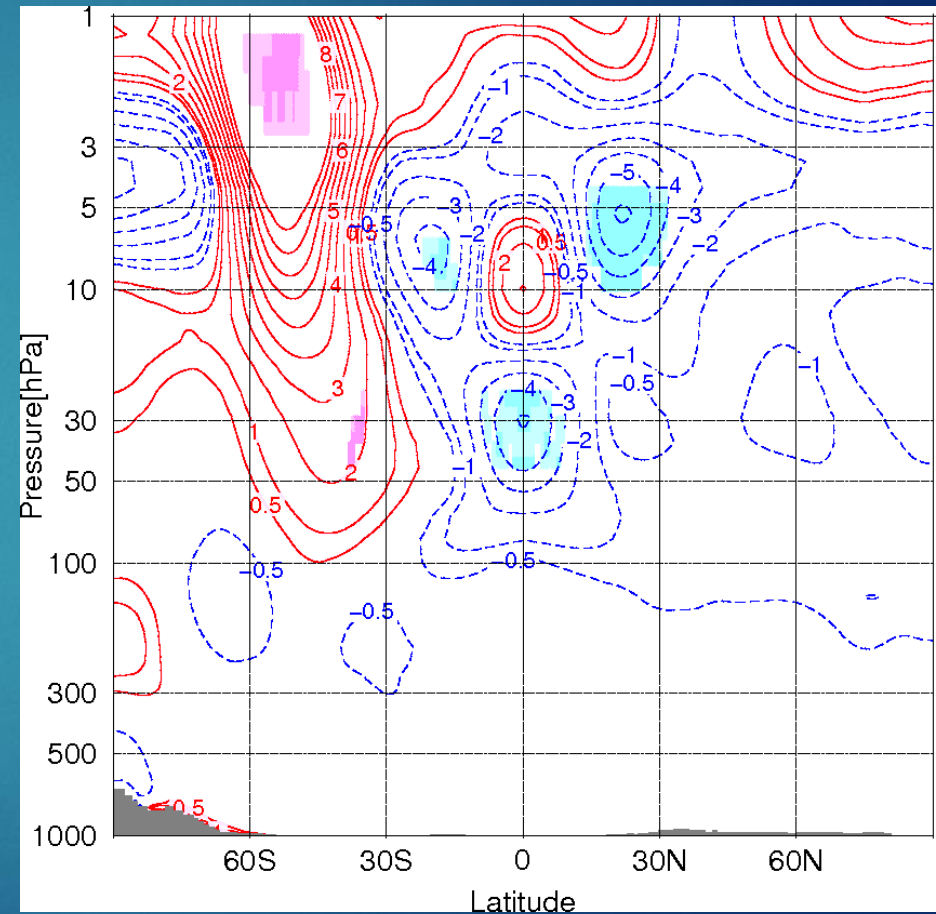
Statistically significant relationship
between the Phase of the Quasi-Biennial
Oscillation (QBO) @20hPa and the
BSISO amplitudes

Composite cross-sections of zonal mean field, 90 day Low-Pass Filter, Amplitude of BSISO ≥ 2.0 SD, Day -4 for the phase 3

Zonal Wind [m s^{-1}]



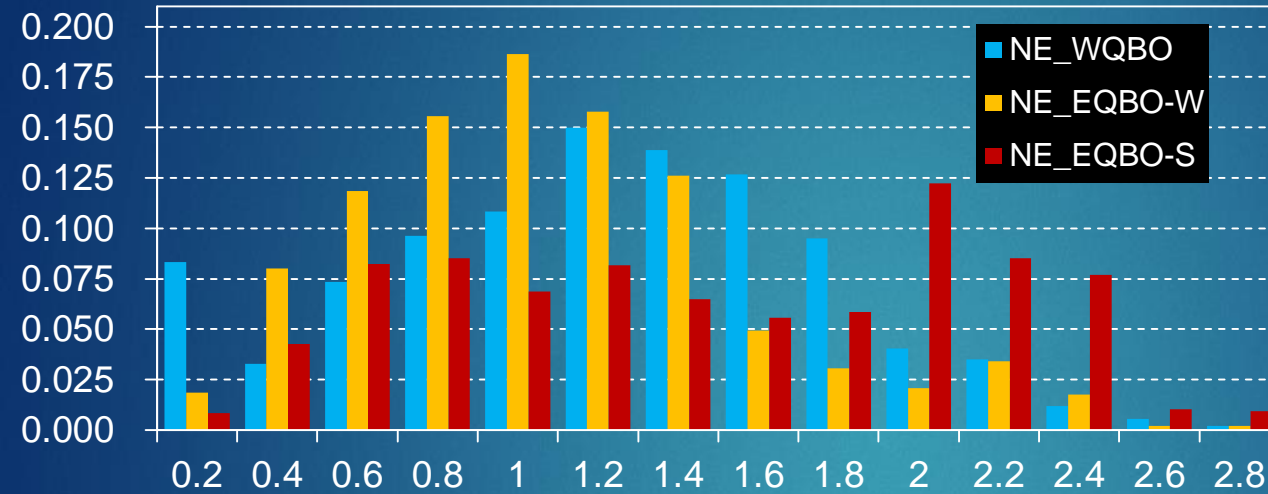
P. Temperature [K]



- ▶ Phase 3
BSISO: starting the northward migration of active convective region
- ▶ Light (dark) shadings show statistical significance at 90 % (95 %) confidence levels.

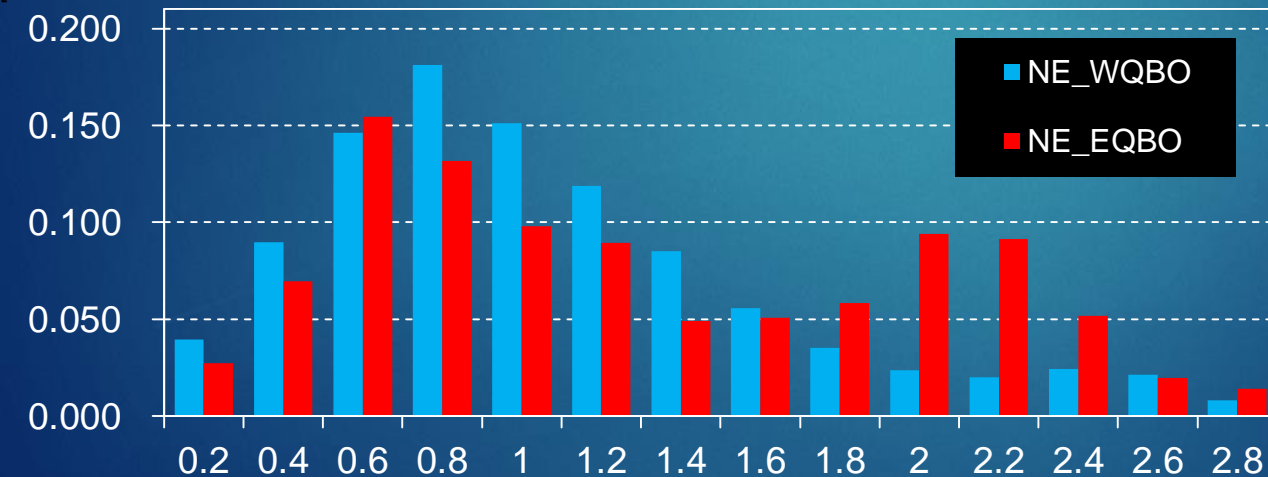
Normalized frequency of normalized BSISO amplitudes for each phase of the QBO@20hPa during the neutral ENSO condition

Frequency of BSISO amplitudes




WQBO... Westerly at 20hPa
 EQBO-W... Weak Easterly at 20hPa
 EQBO-S... Strong Easterly at 20hPa

Frequency of MJO amplitudes



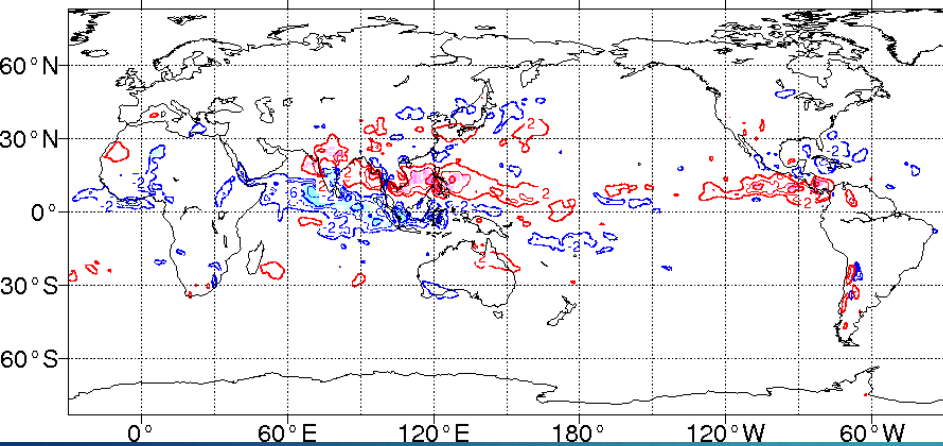
WQBO... Westerly at **50hPa**
 EQBO... Easterly at **50hPa**



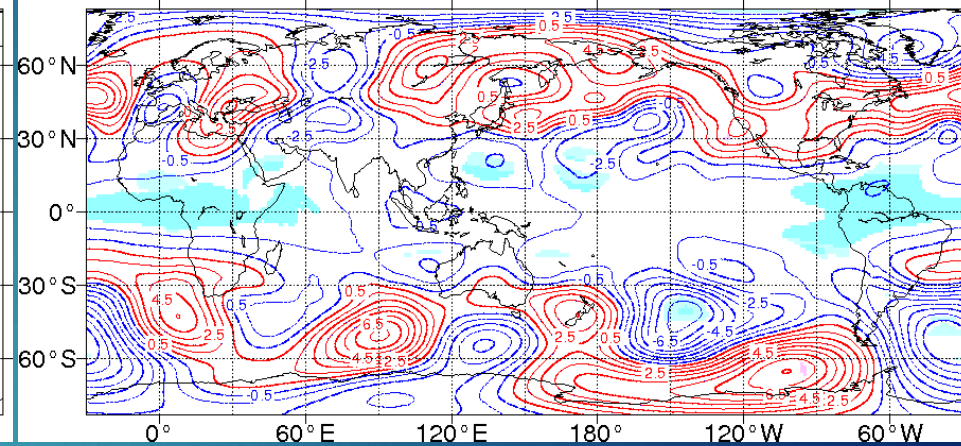
Composite maps on the isentropic surface for phase 5 of BSISO

BSISO, amplitude ≥ 2.0 SD, phase 5 lag -12

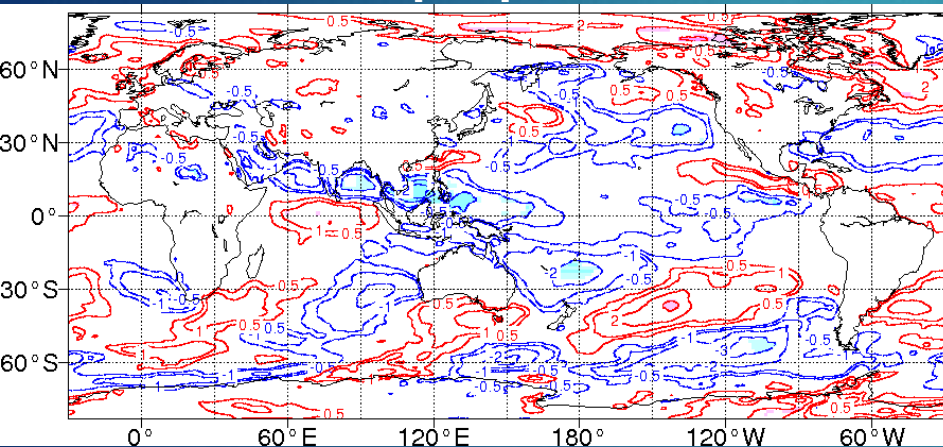
Vertical Velocity [Pa/s] @340K



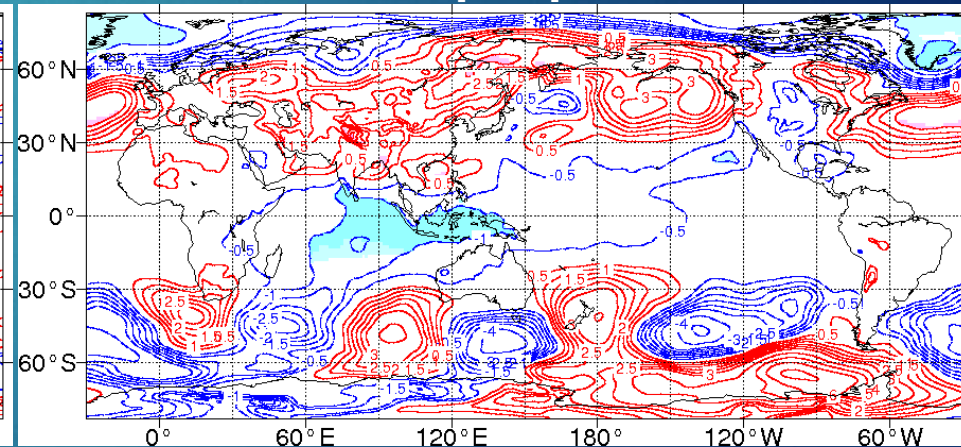
Montgomery Stream Function [m²/s²] @360K



10-m Zonal Wind [m/s]



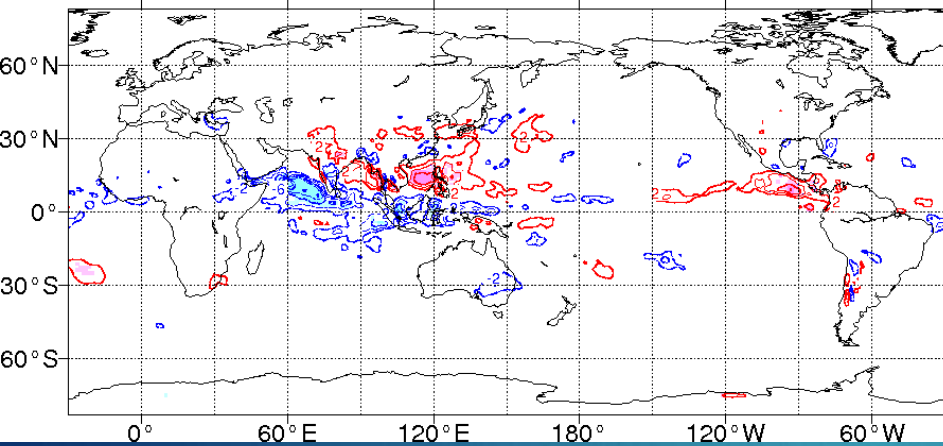
Sea Level Pressure [hPa]



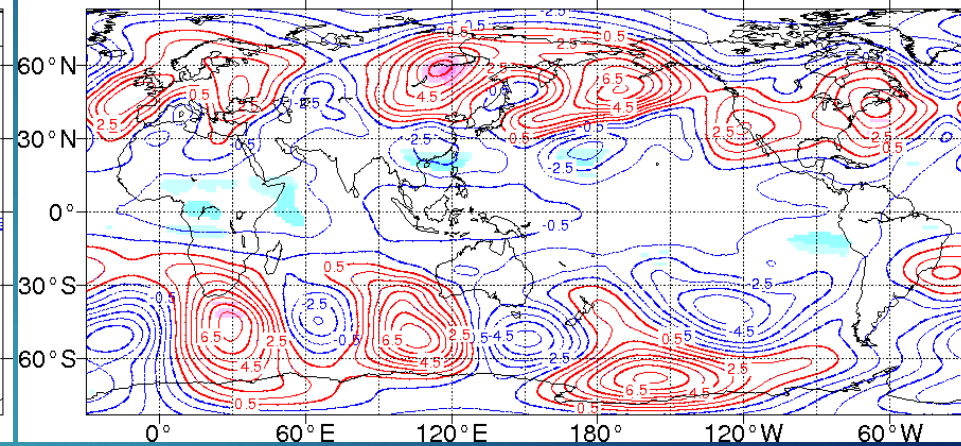
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- ▶ Light (dark) shadings show statistical significance at 90 % (95 %) confidence levels.

BSISO, amplitude ≥ 2.0 SD, phase 5 lag -9

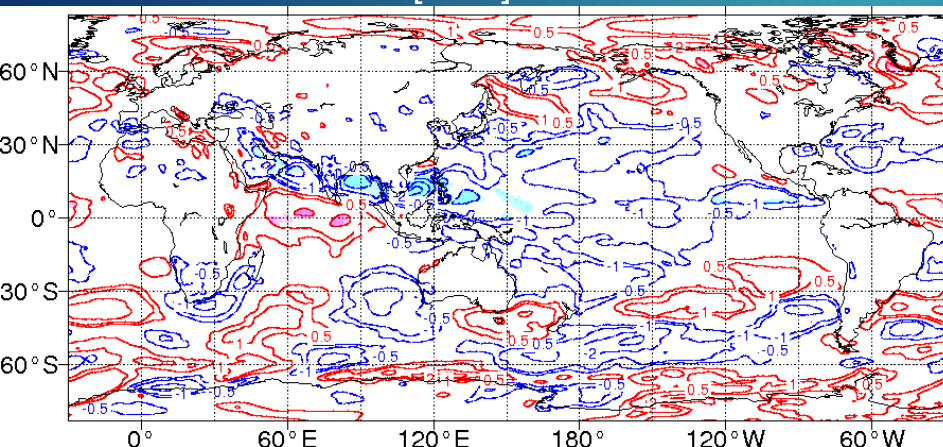
Vertical Velocity [Pa/s] @340K



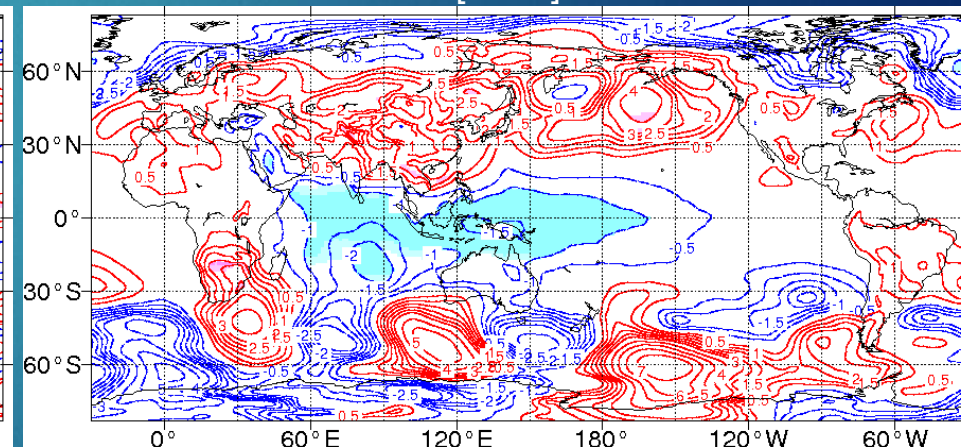
Montgomery Stream Function [m²/s²] @360K



10-m Zonal Wind [m/s]



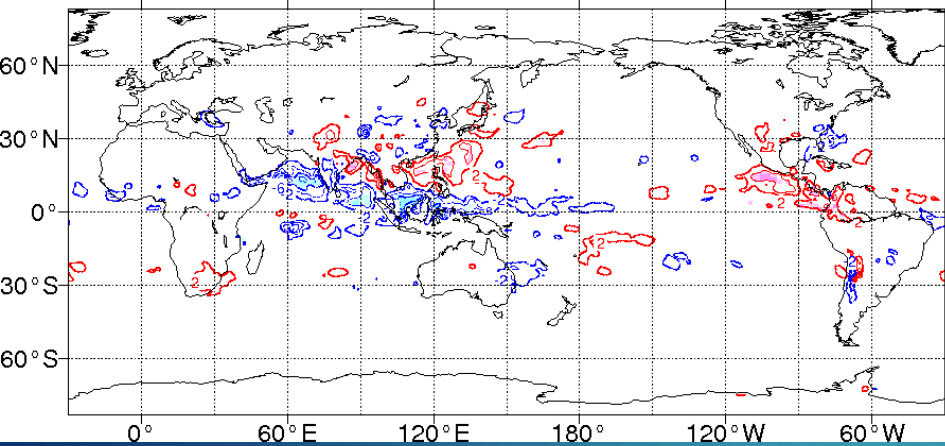
Sea Level Pressure [hPa]



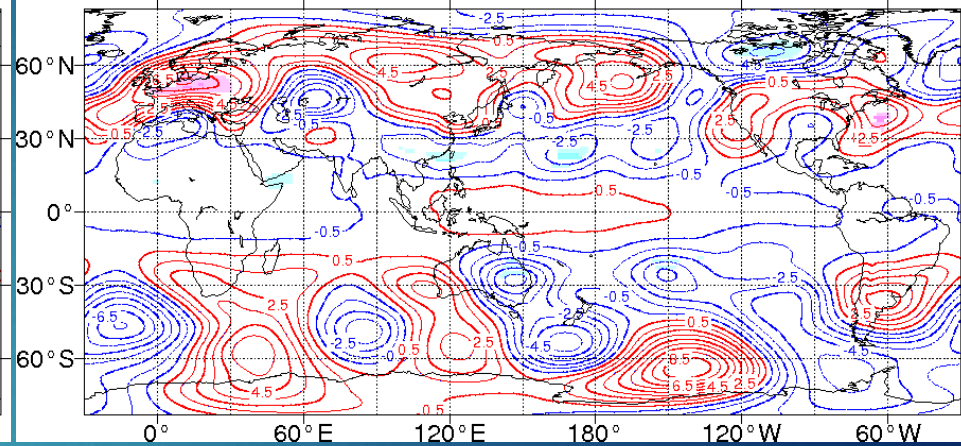
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BSISO, amplitude ≥ 2.0 SD, phase 5 lag -6

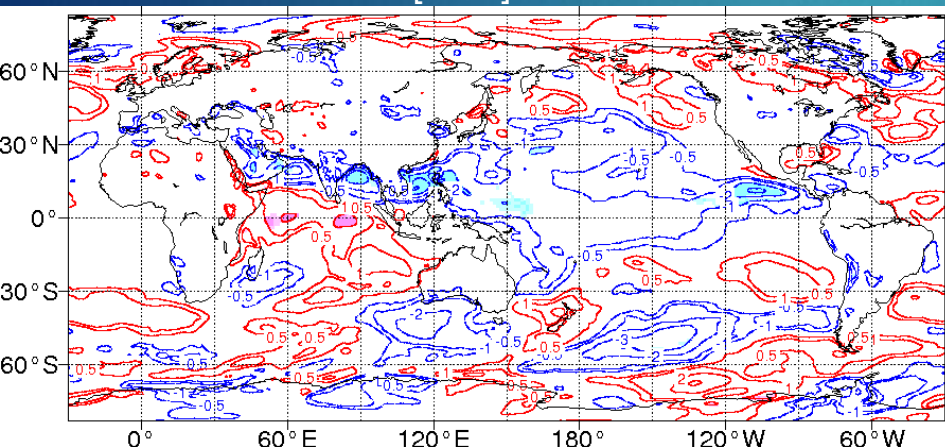
Vertical Velocity [Pa/s] @340K



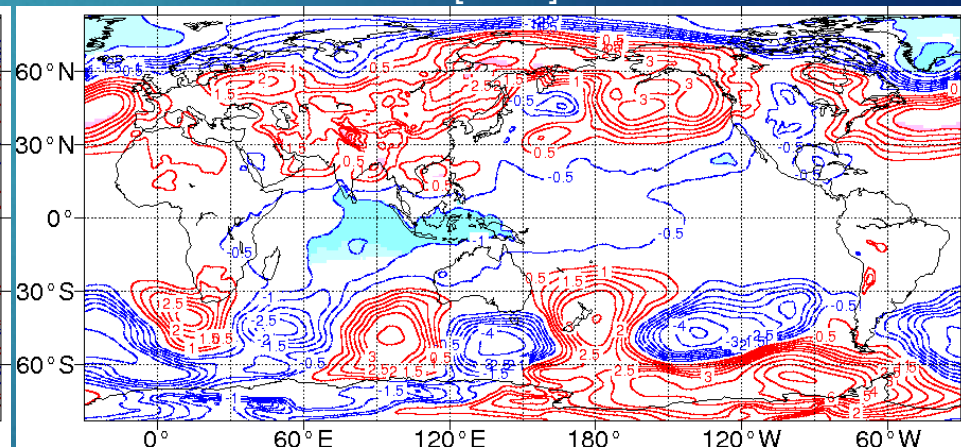
Montgomery Stream Function [m²/s²] @360K



10-m Zonal Wind [m/s]



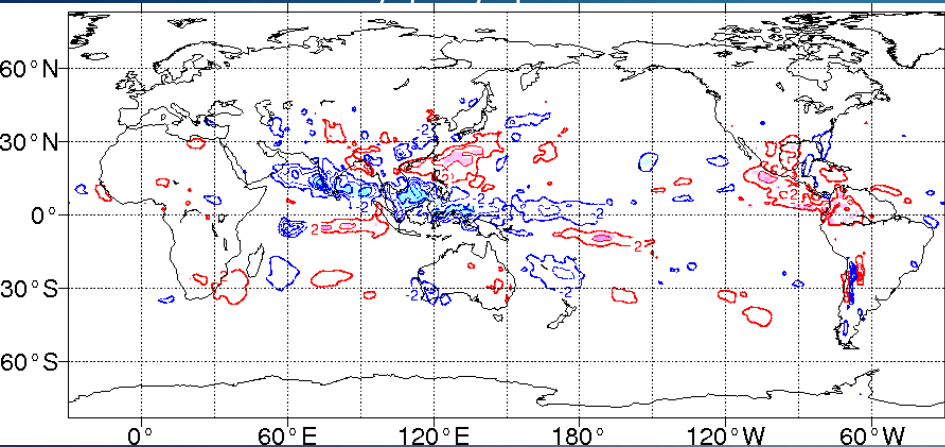
Sea Level Pressure [hPa]



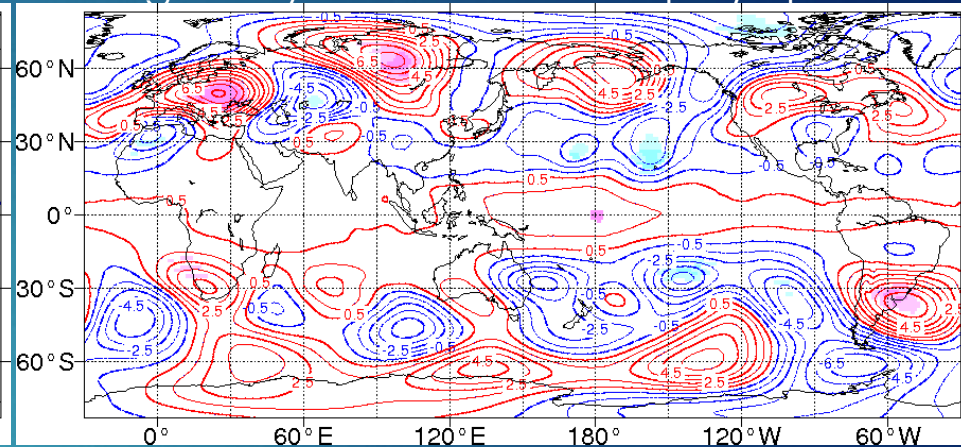
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BSISO, amplitude ≥ 2.0 SD, phase 5 lag -3

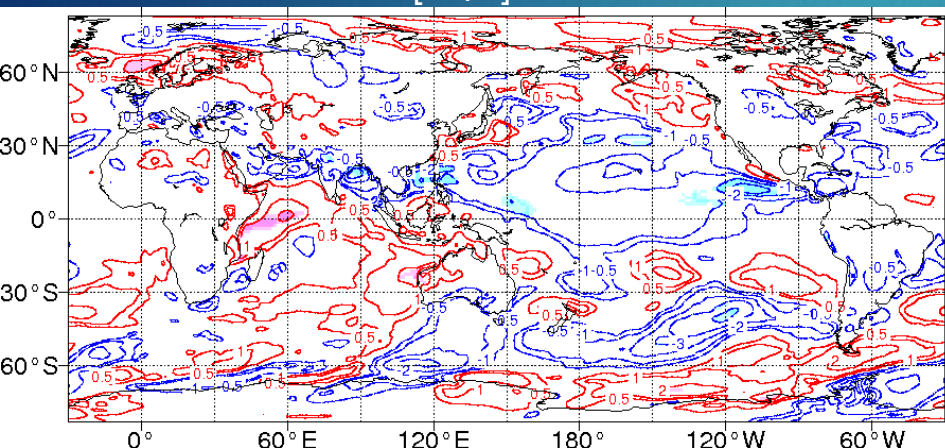
Vertical Velocity [Pa/s] @340K



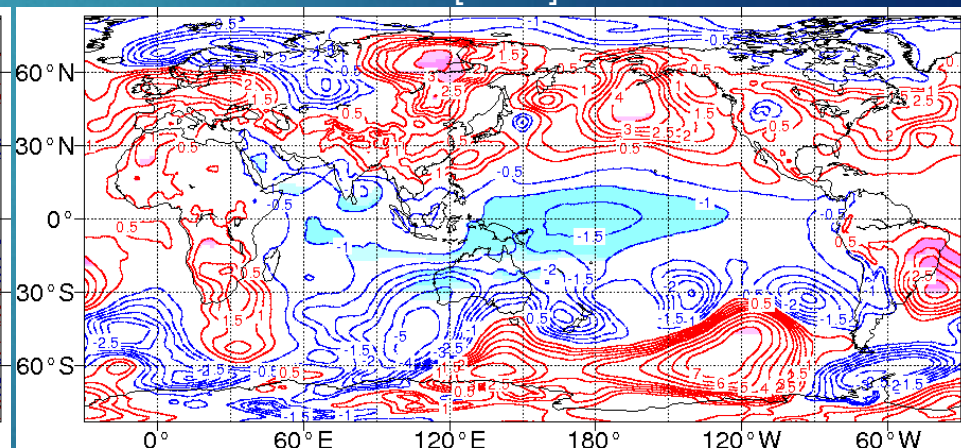
Montgomery Stream Function [m²/s²] @360K



10-m Zonal Wind [m/s]



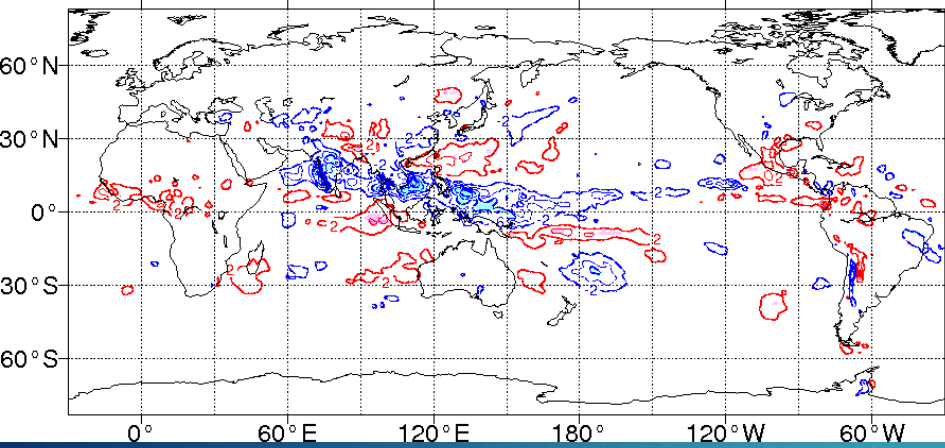
Sea Level Pressure [hPa]



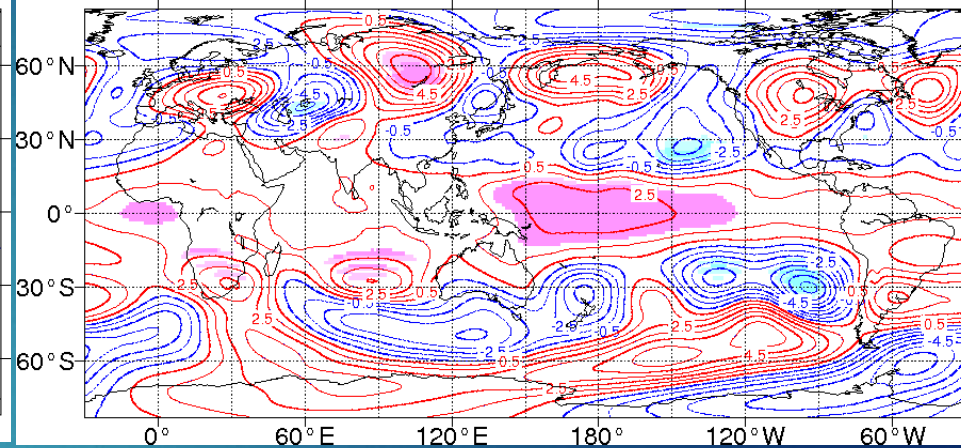
- ▶ Day 0 corresponds to the days in phase 5
BSISO: just after the northward migration of active convective region
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BSISO, amplitude ≥ 2.0 SD, phase 5 lag 0

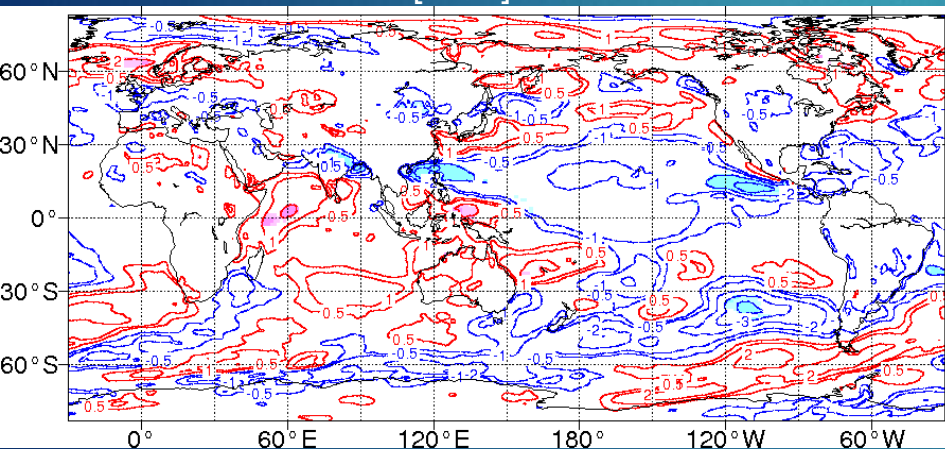
Vertical Velocity [Pa/s] @340K



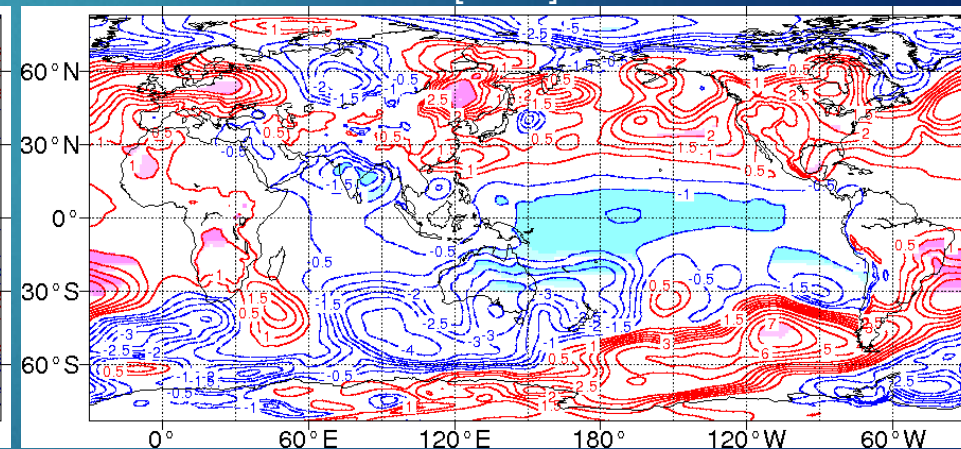
Montgomery Stream Function [m²/s²] @360K



10-m Zonal Wind [m/s]



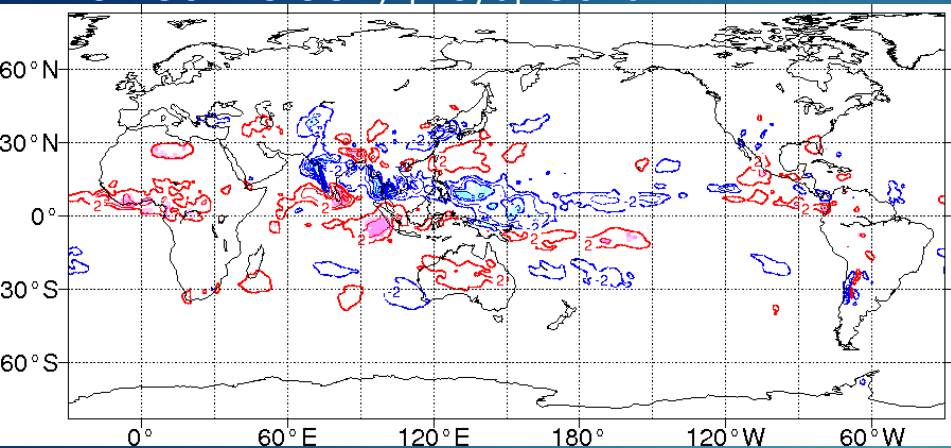
Sea Level Pressure [hPa]



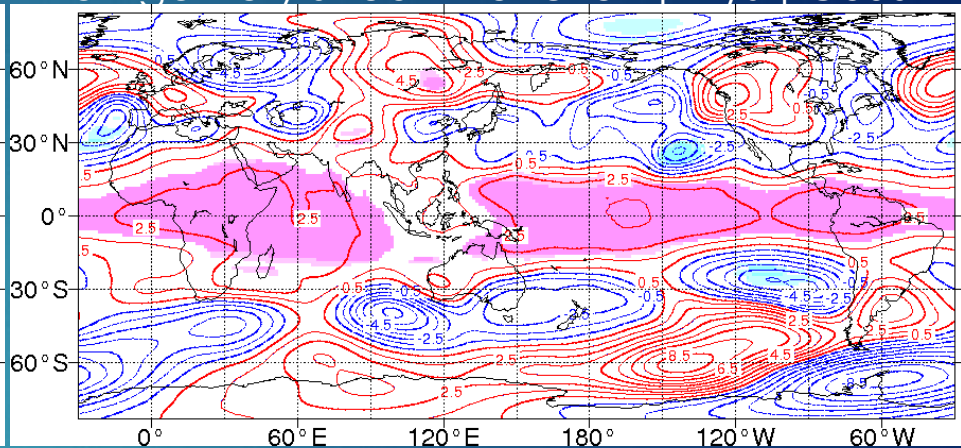
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BSISO, amplitude ≥ 2.0 SD, phase 5 lag 3

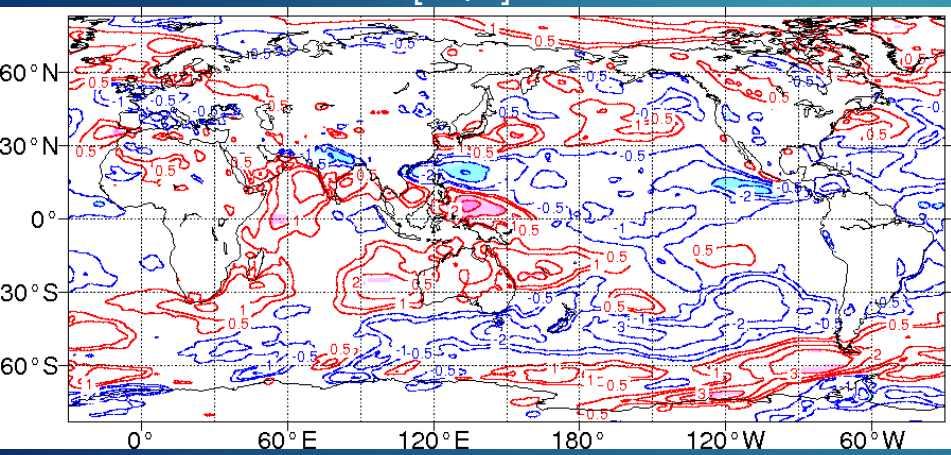
Vertical Velocity [Pa/s] @340K



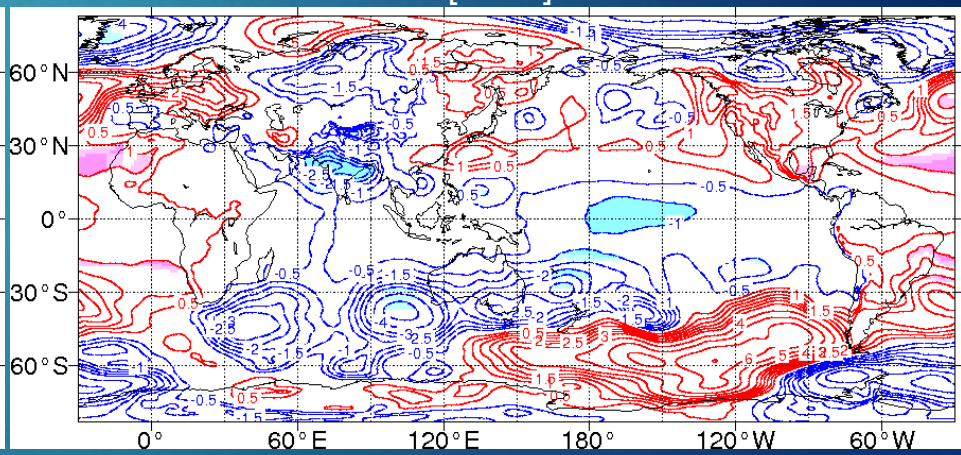
Montgomery Stream Function [m²/s²] @360K



10-m Zonal Wind [m/s]



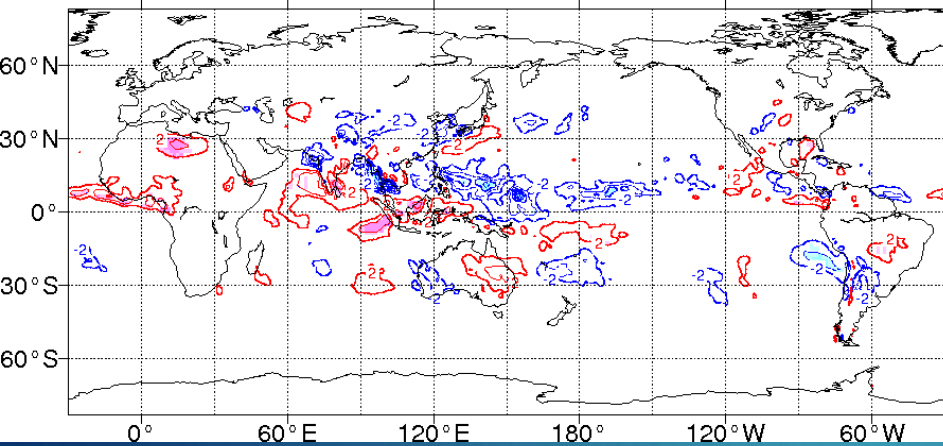
Sea Level Pressure [hPa]



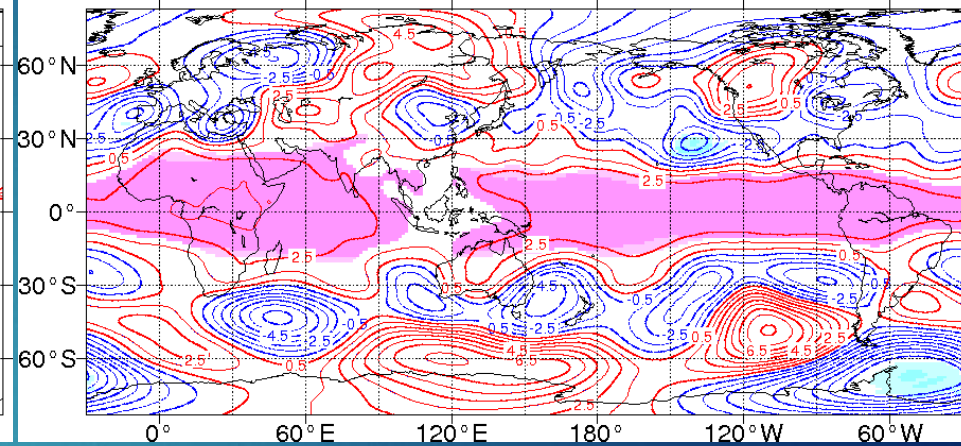
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BSISO, amplitude ≥ 2.0 SD, phase 5 lag 6

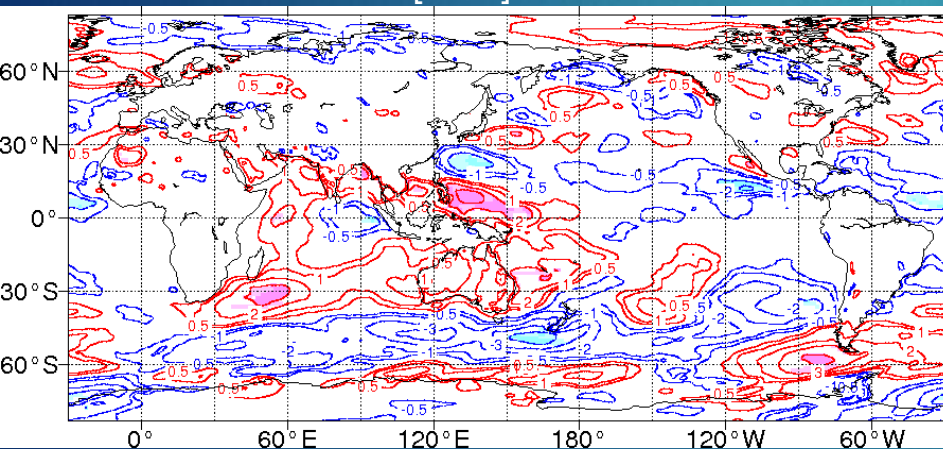
Vertical Velocity [Pa/s] @340K



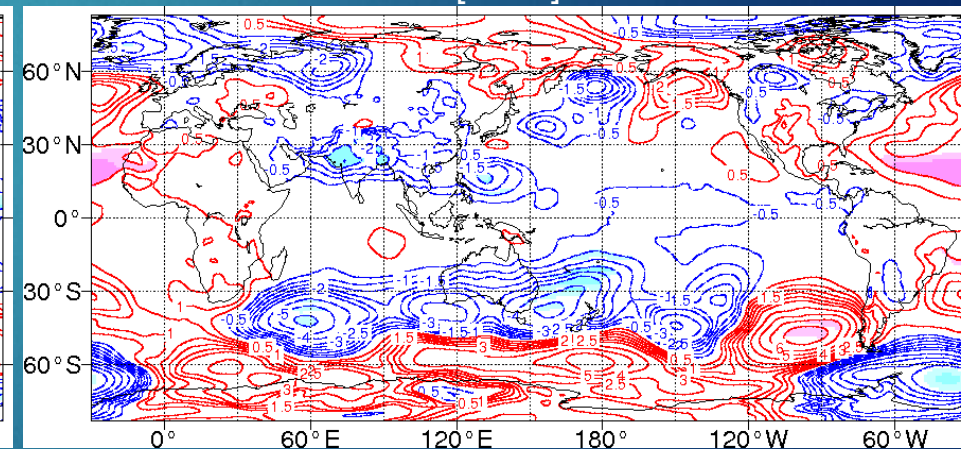
Montgomery Stream Function [m²/s²] @360K



10-m Zonal Wind [m/s]



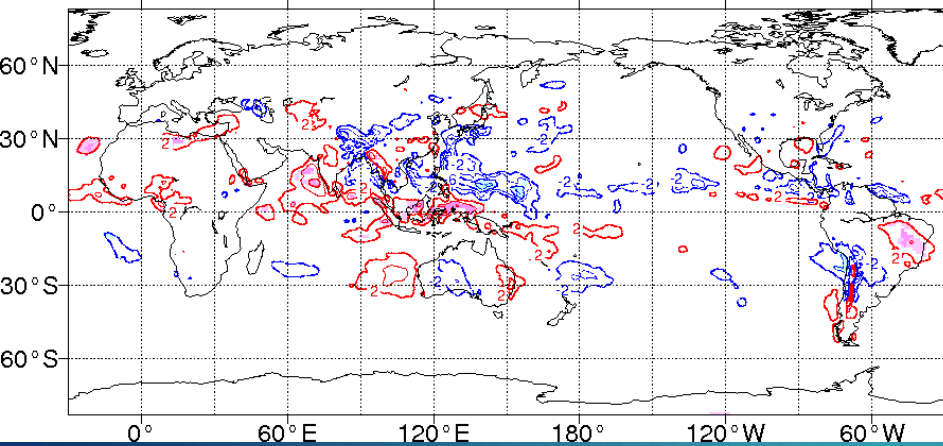
Sea Level Pressure [hPa]



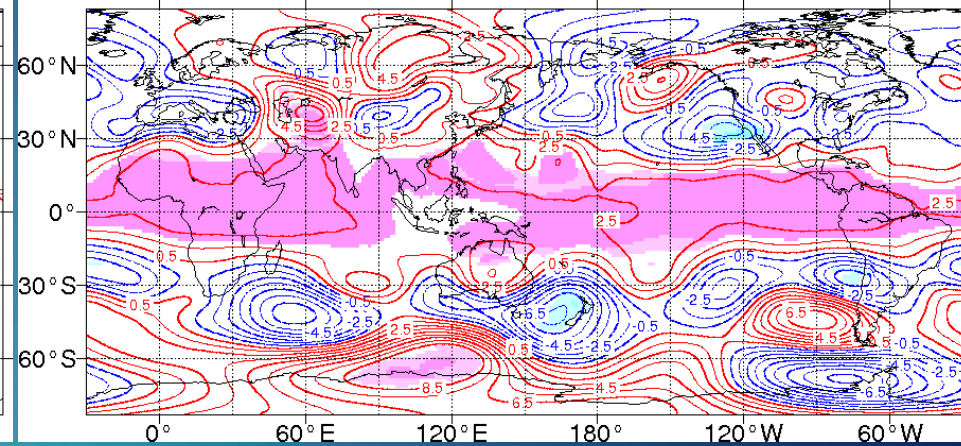
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BSISO, amplitude ≥ 2.0 SD, phase 5 lag 9

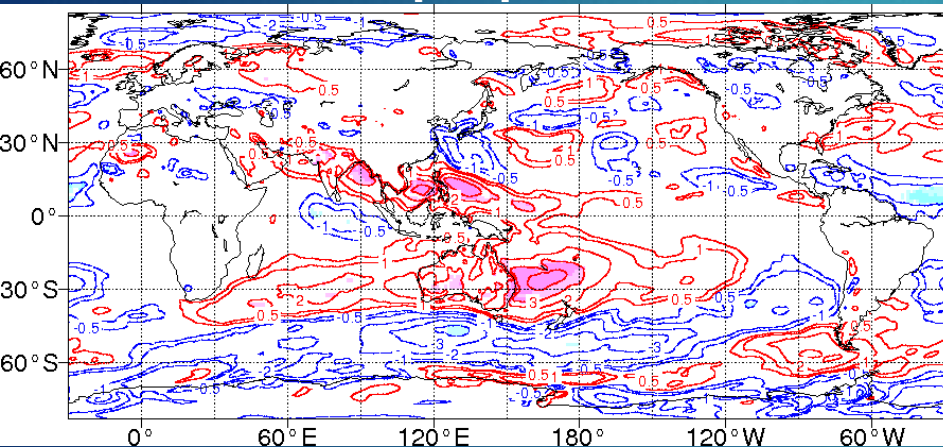
Vertical Velocity [Pa/s] @340K



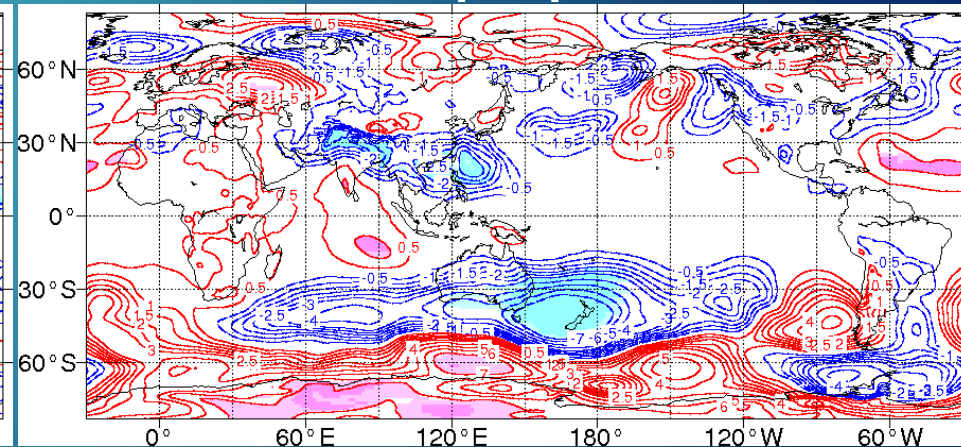
Montgomery Stream Function [m²/s²] @360K



10-m Zonal Wind [m/s]



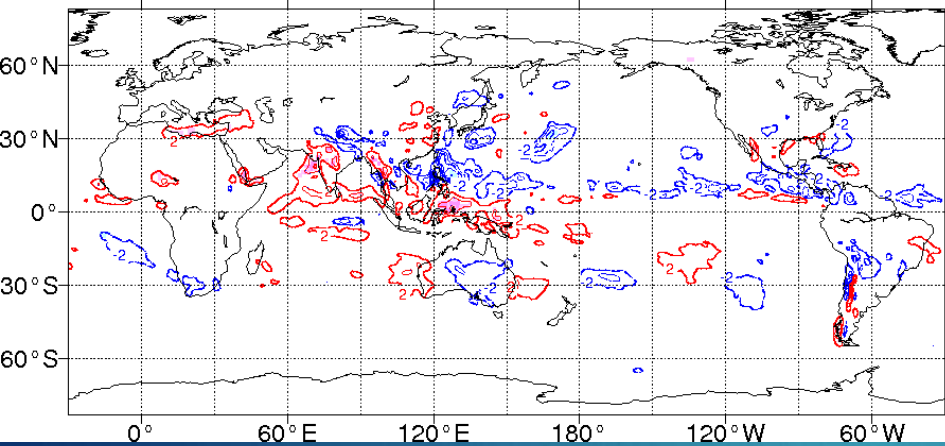
Sea Level Pressure [hPa]



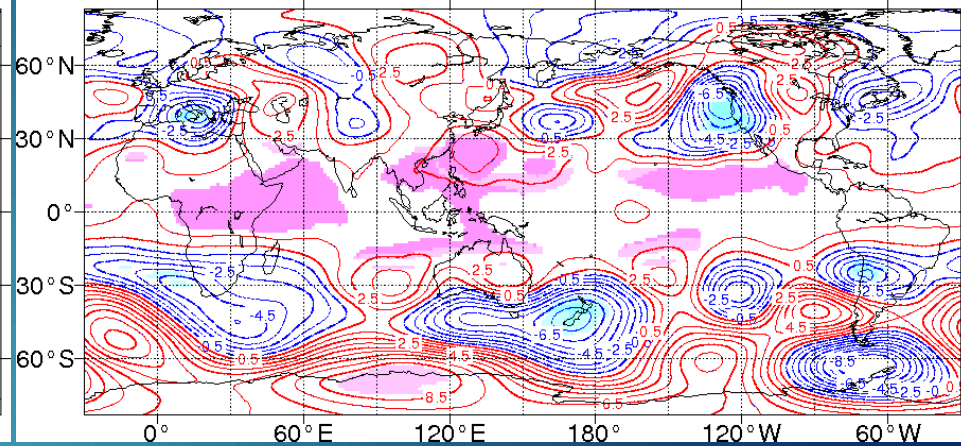
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BSISO, amplitude ≥ 2.0 SD, phase 5 lag 12

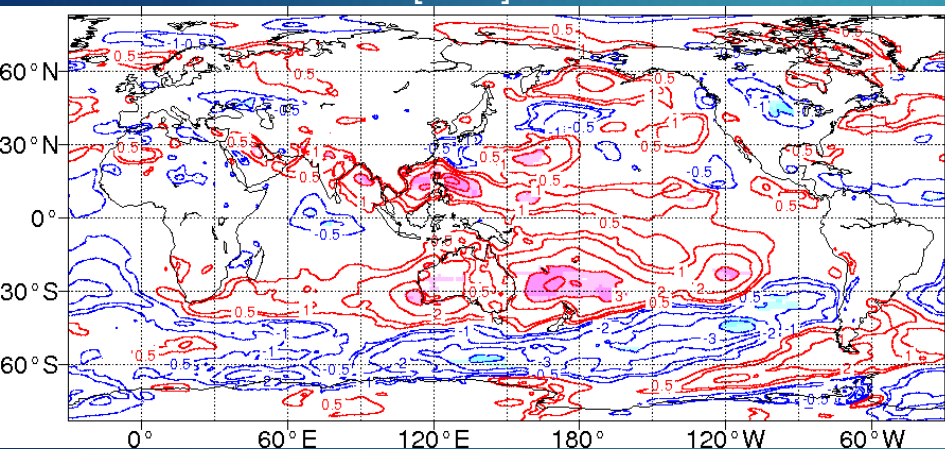
Vertical Velocity [Pa/s] @340K



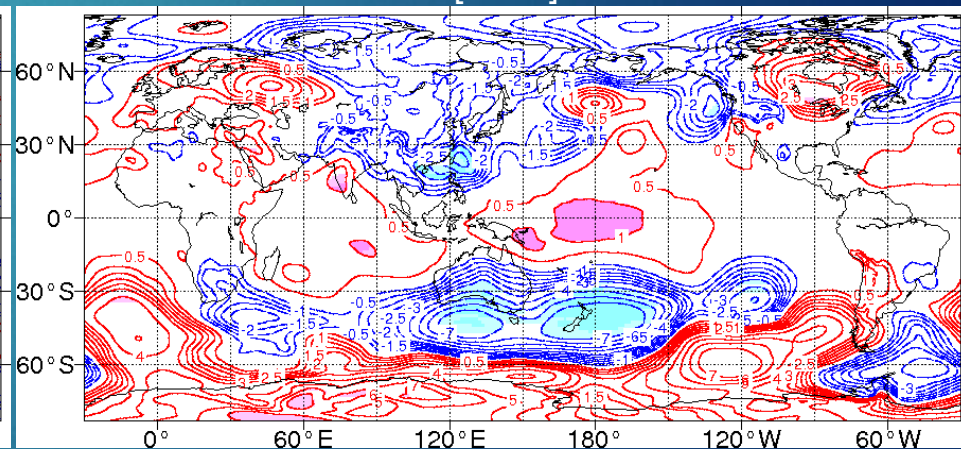
Montgomery Stream Function [m²/s²] @360K




10-m Zonal Wind [m/s]



Sea Level Pressure [hPa]



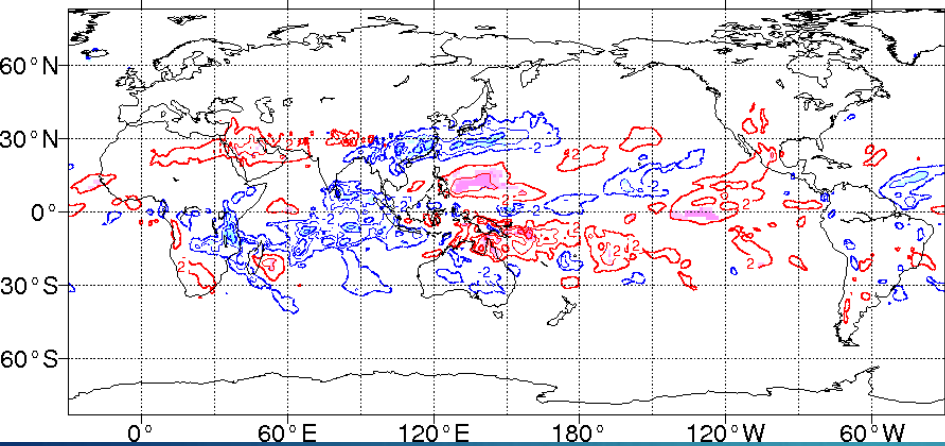
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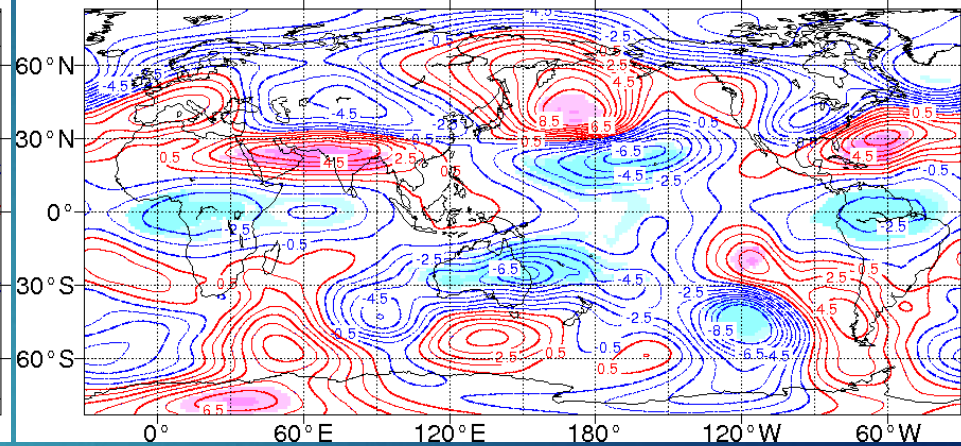
Composite maps on the isentropic surface for phase 5 of MJO

MJO, amplitude ≥ 2.0 SD, phase 5 lag -12

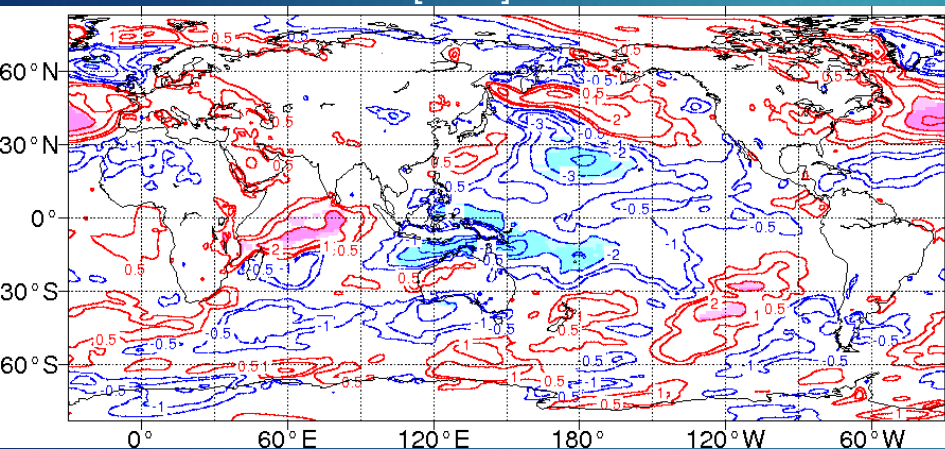
Vertical Velocity [Pa/s] @340K



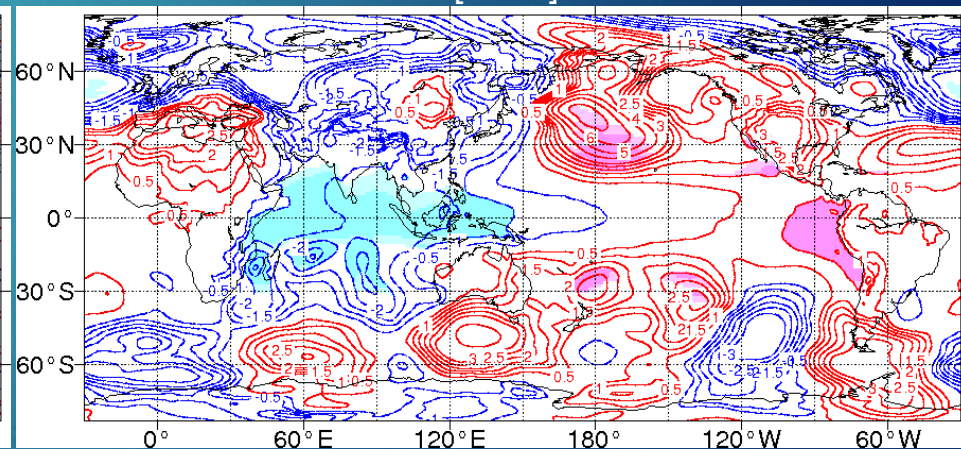
Montgomery Stream Function [m²/s²] @360K



10-m Zonal Wind [m/s]



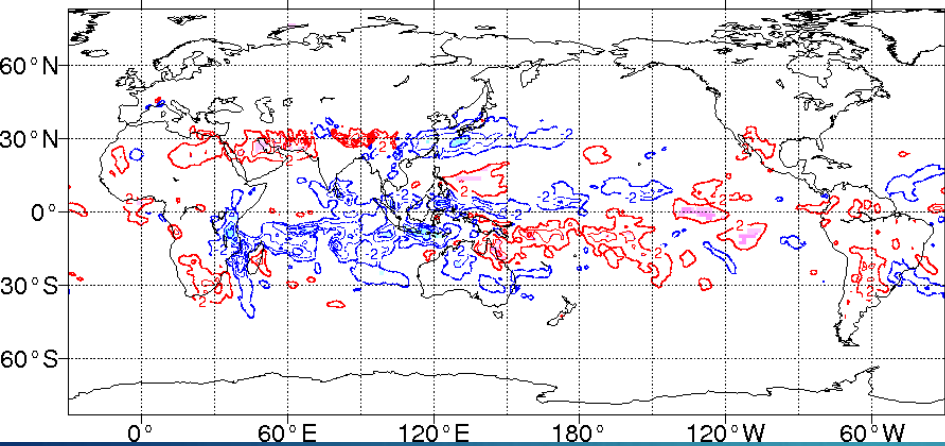
Sea Level Pressure [hPa]



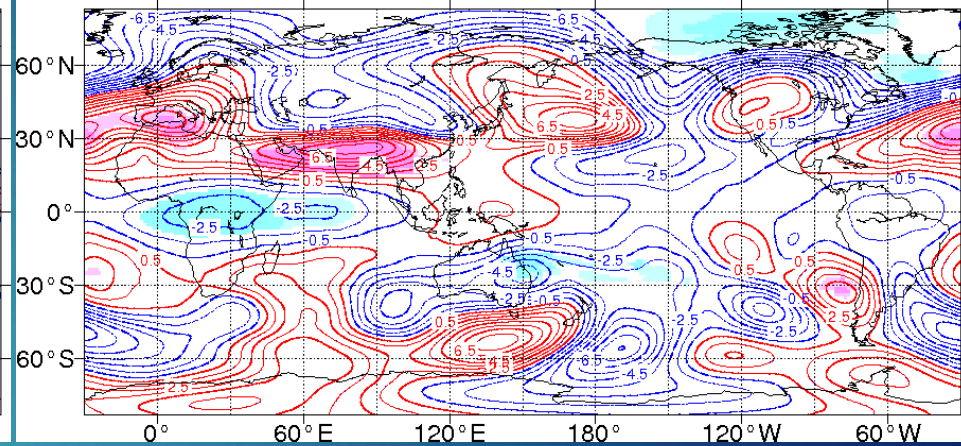
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MJO, amplitude ≥ 2.0 SD, phase 5 lag -9

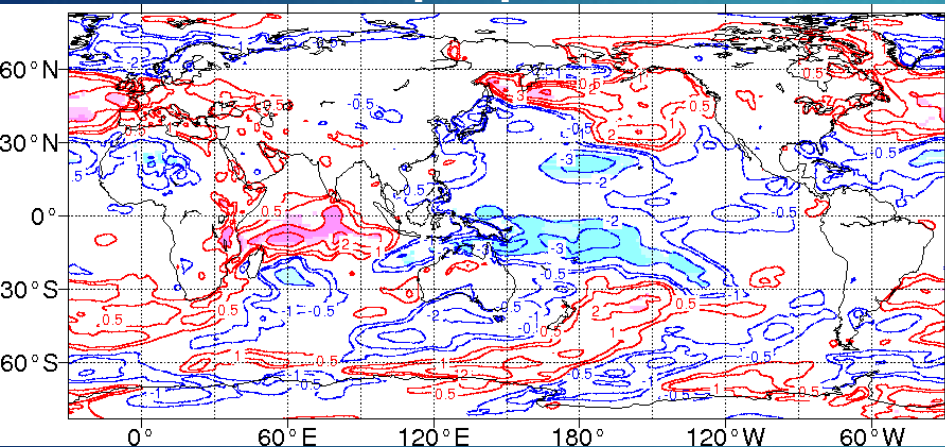
Vertical Velocity [Pa/s] @340K



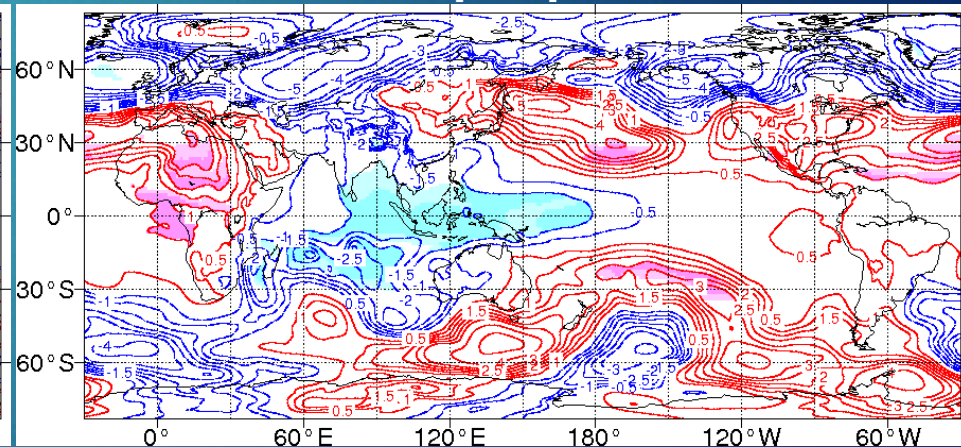
Montgomery Stream Function [m²/s²] @360K



10-m Zonal Wind [m/s]



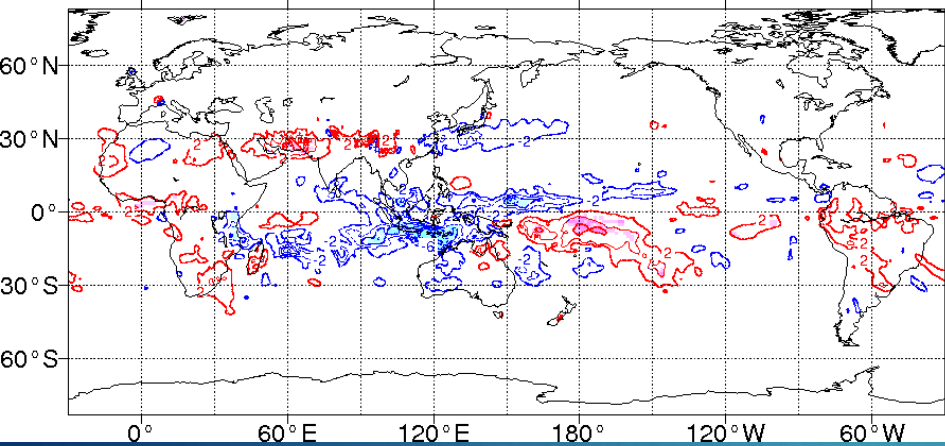
Sea Level Pressure [hPa]



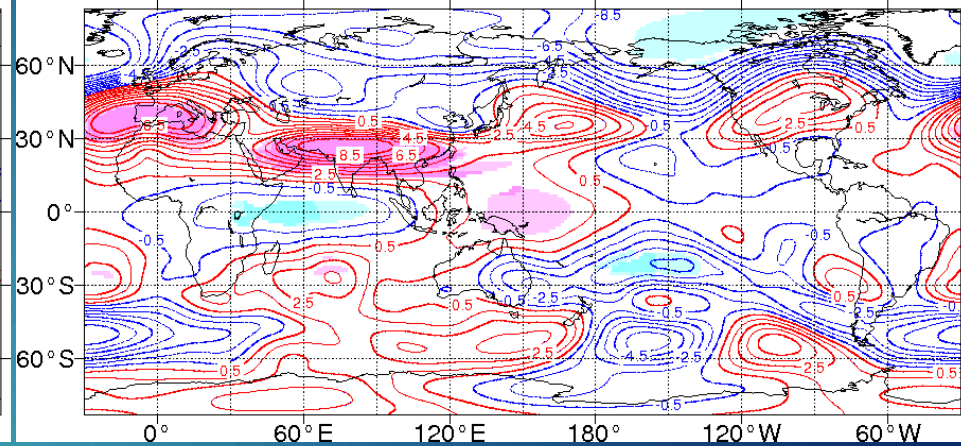
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- ▶ Light (dark) shadings show statistical significance at 90 % (95 %) confidence levels.

MJO, amplitude ≥ 2.0 SD, phase 5 lag -6

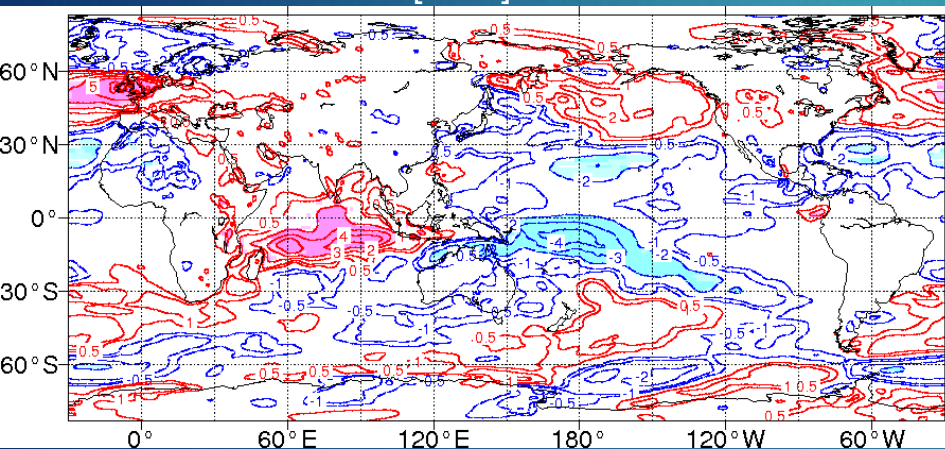
Vertical Velocity [Pa/s] @340K



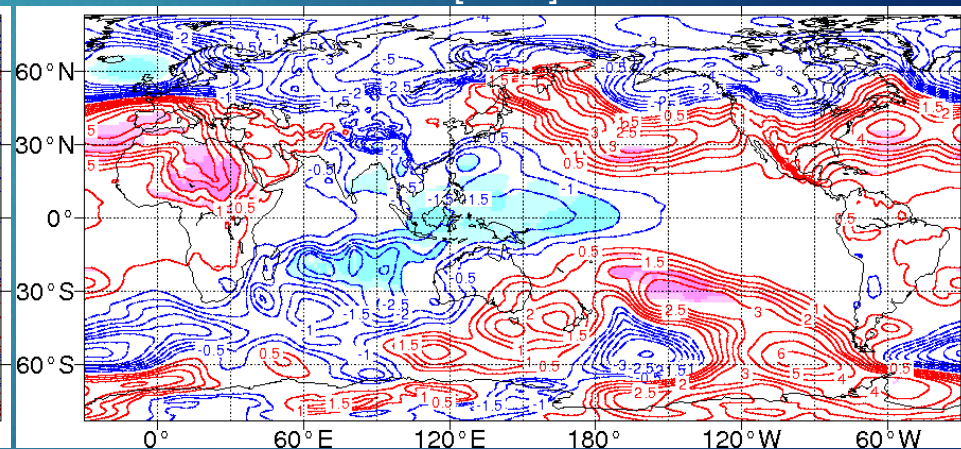
Montgomery Stream Function [m²/s²] @360K



10-m Zonal Wind [m/s]



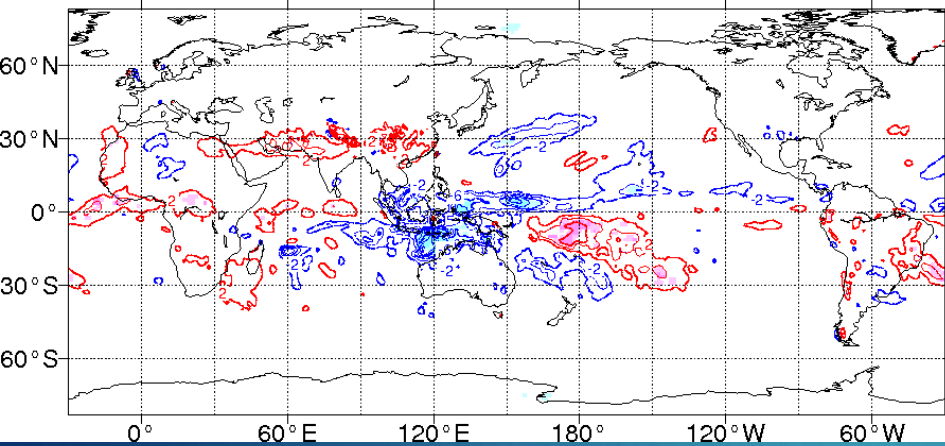
Sea Level Pressure [hPa]



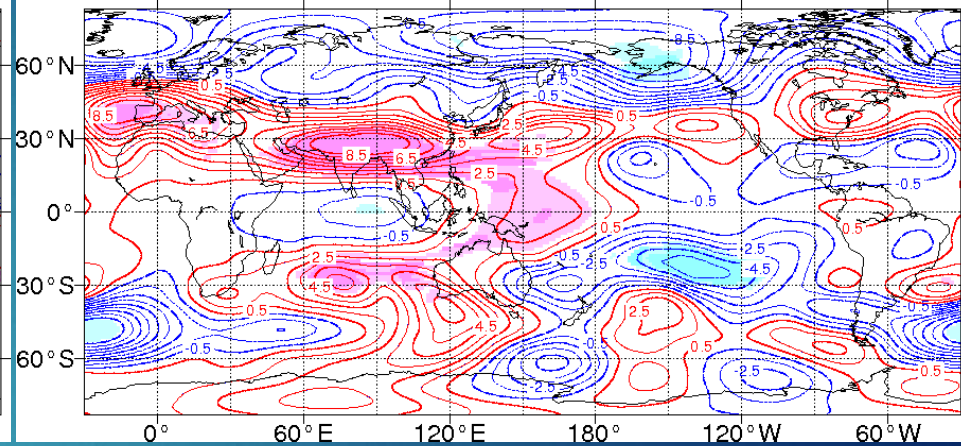
- ▶ Day 0 corresponds to the days in phase 5
BSISO: just after the northward migration of active convective region
MJO: eastward propagation of active convective region over Maritime Continent
- ▶ Light (dark) shadings show statistical significance at 90 % (95 %) confidence levels.

MJO, amplitude ≥ 2.0 SD, phase 5 lag -3

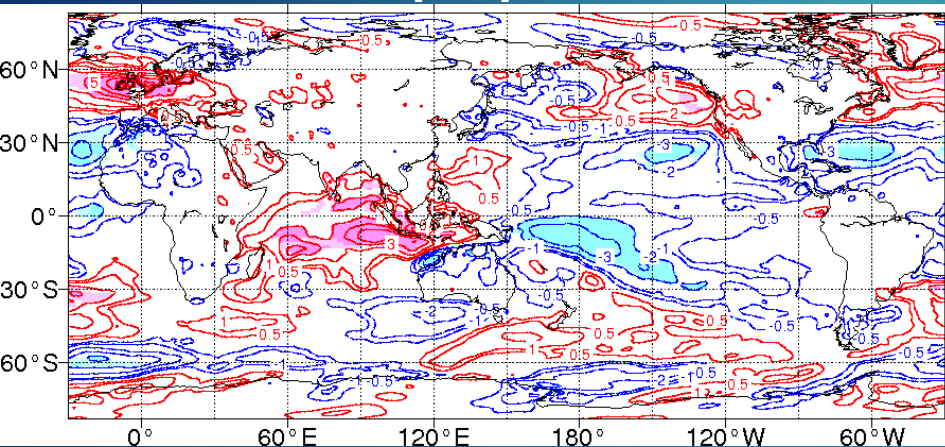
Vertical Velocity [Pa/s] @340K



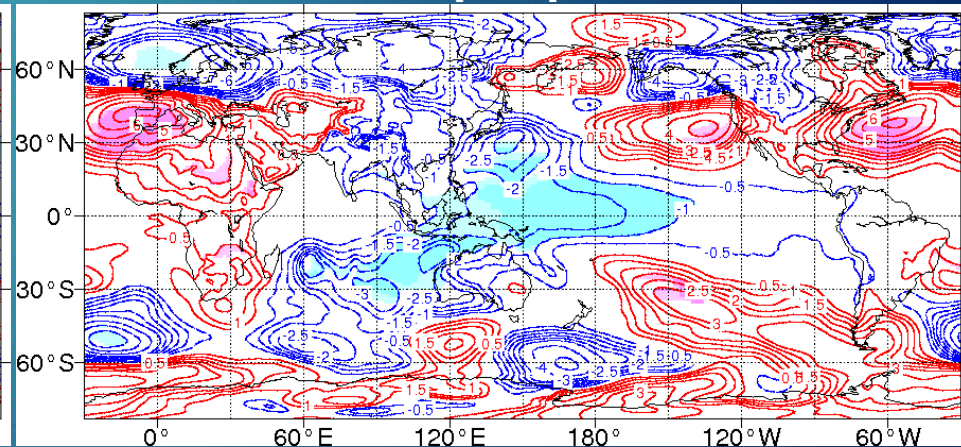
Montgomery Stream Function [m²/s²] @360K



10-m Zonal Wind [m/s]



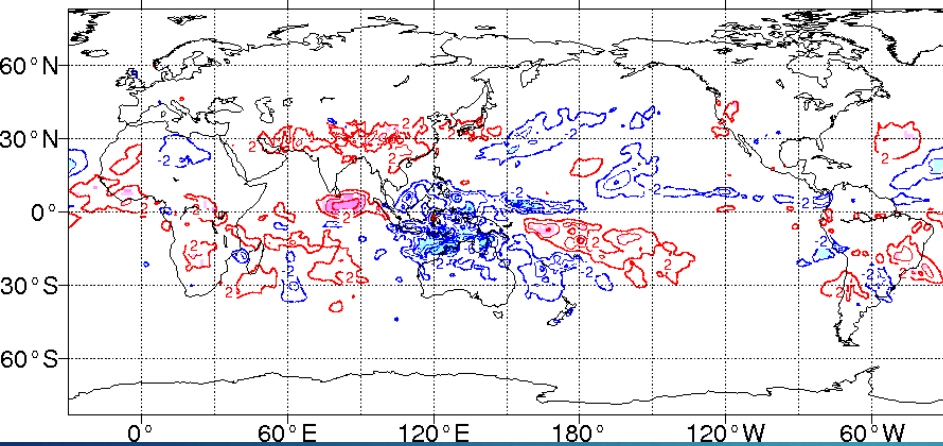
Sea Level Pressure [hPa]



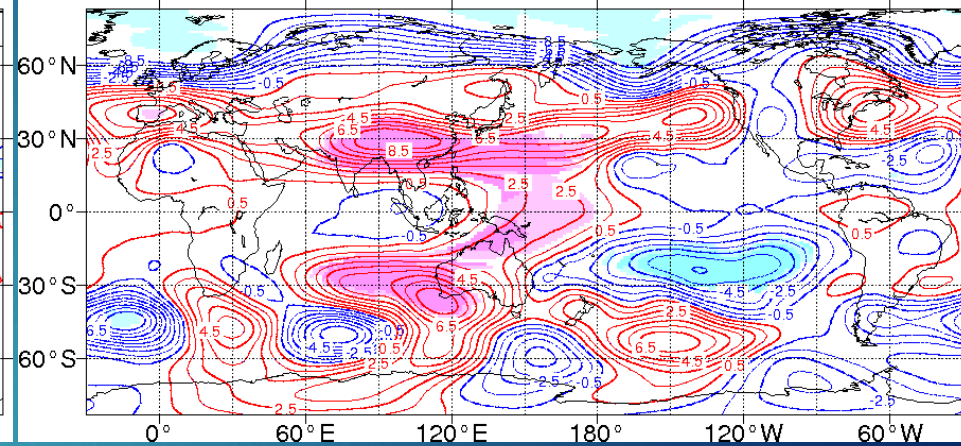
- ▶ Day 0 corresponds to the days in phase 5
BSISO: just after the northward migration of active convective region
MJO: eastward propagation of active convective region over Maritime Continent
- ▶ Light (dark) shadings show statistical significance at 90 % (95 %) confidence levels.

MJO, amplitude ≥ 2.0 SD, phase 5 lag 0

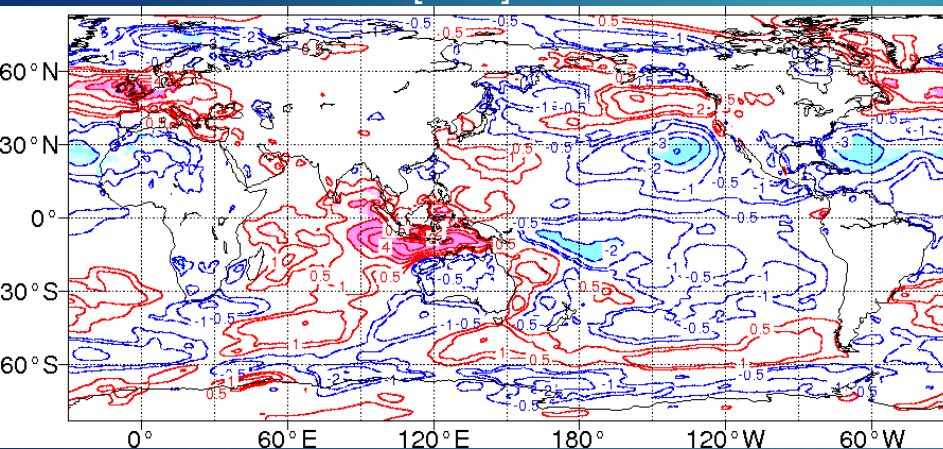
Vertical Velocity [Pa/s] @340K



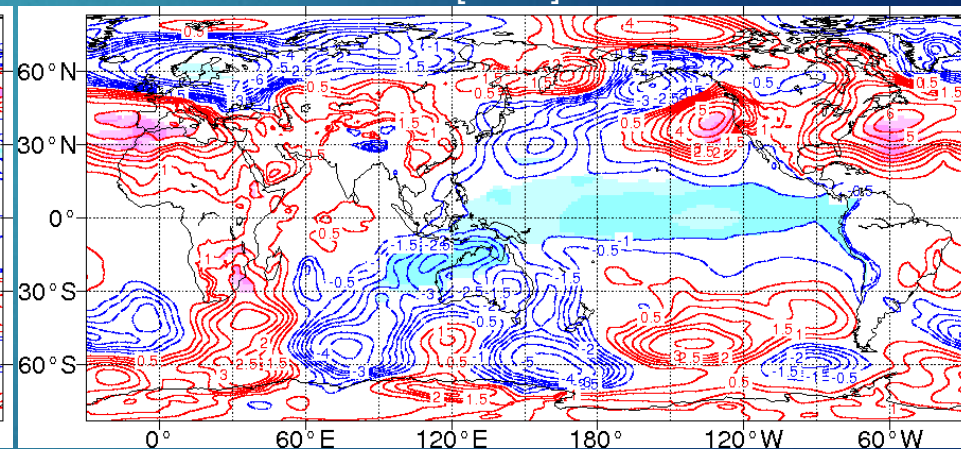
Montgomery Stream Function [m²/s²] @360K



10-m Zonal Wind [m/s]



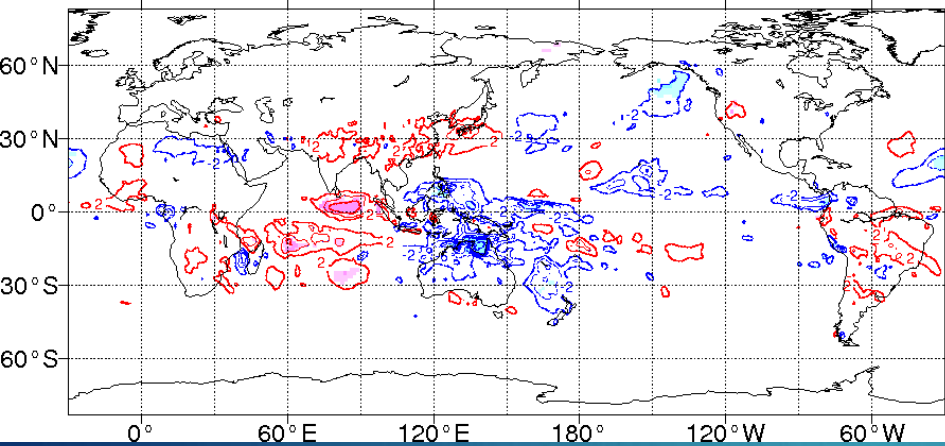
Sea Level Pressure [hPa]



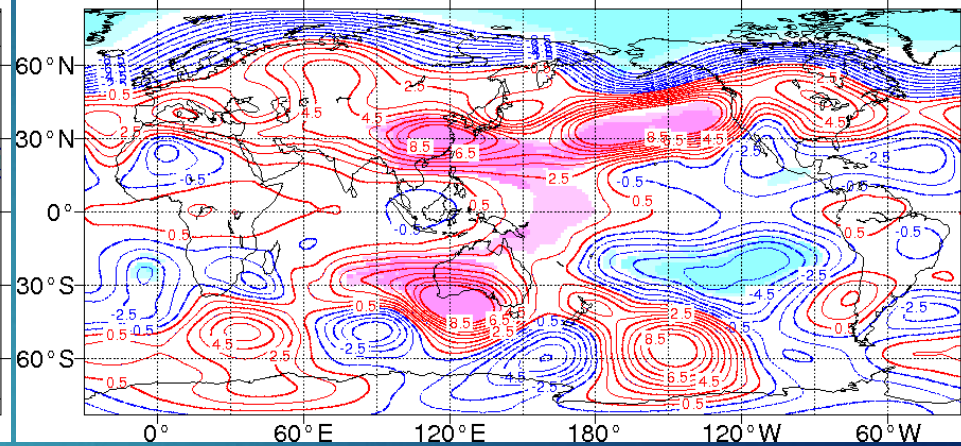
- ▶ Day 0 corresponds to the days in phase 5
BSISO: just after the northward migration of active convective region
MJO: eastward propagation of active convective region over Maritime Continent
- ▶ Light (dark) shadings show statistical significance at 90 % (95 %) confidence levels.

MJO, amplitude ≥ 2.0 SD, phase 5 lag 3

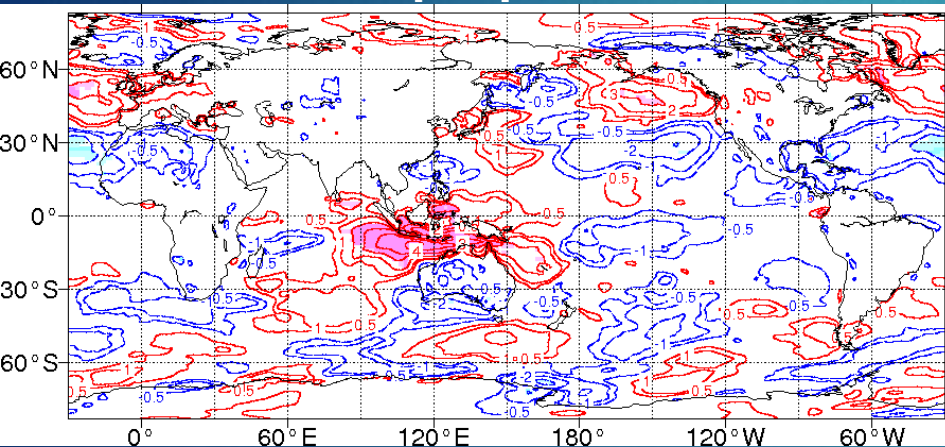
Vertical Velocity [Pa/s] @340K



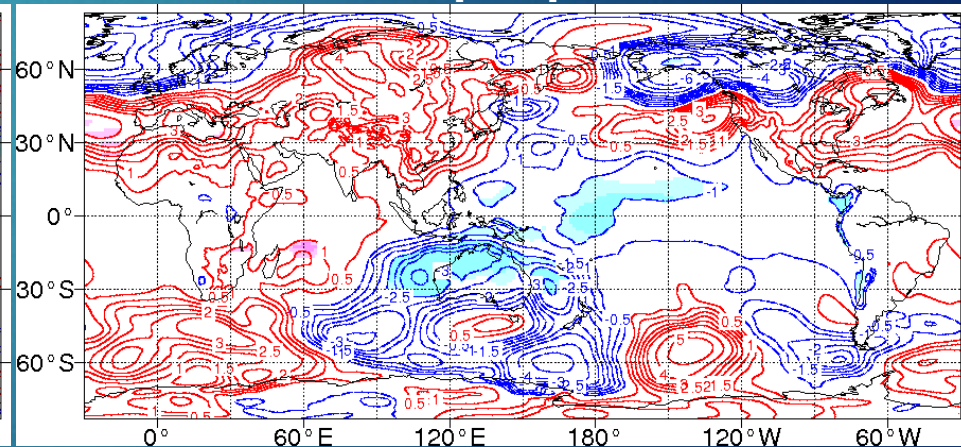
Montgomery Stream Function [m²/s²] @360K



10-m Zonal Wind [m/s]



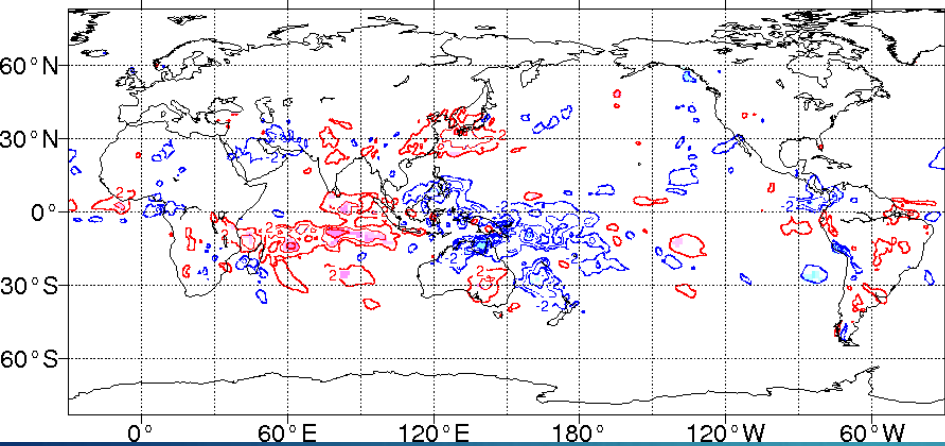
Sea Level Pressure [hPa]



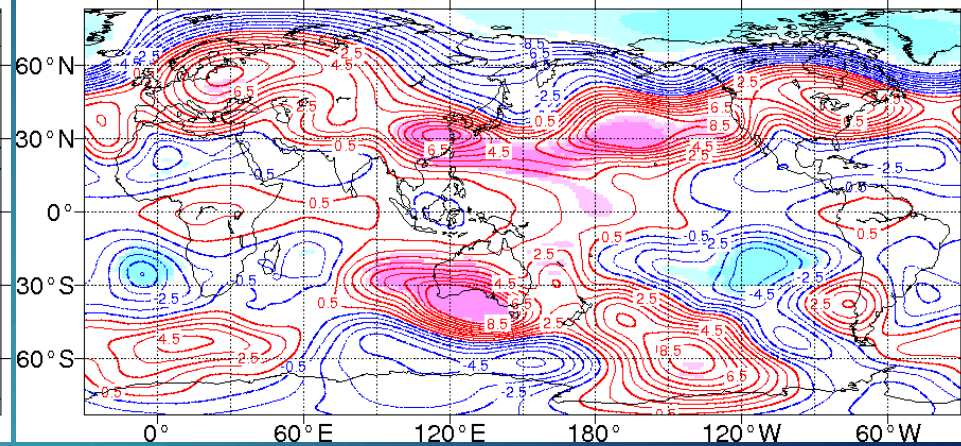
- ▶ Day 0 corresponds to the days in phase 5
BSISO: just after the northward migration of active convective region
MJO: eastward propagation of active convective region over Maritime Continent
- ▶ Light (dark) shadings show statistical significance at 90 % (95 %) confidence levels.

MJO, amplitude ≥ 2.0 SD, phase 5 lag 6

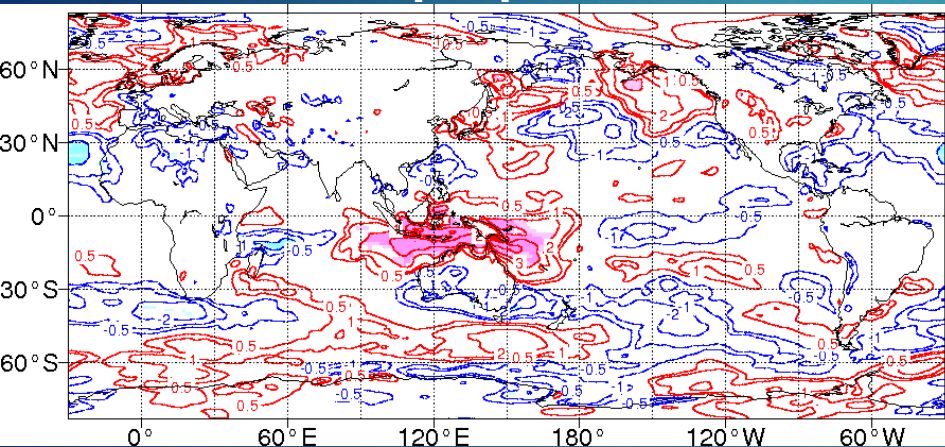
Vertical Velocity [Pa/s] @340K



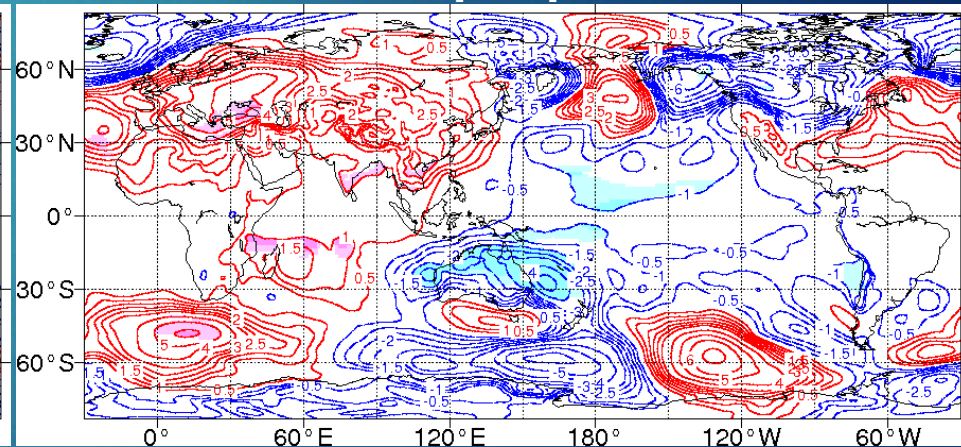
Montgomery Stream Function [m²/s²] @360K



10-m Zonal Wind [m/s]



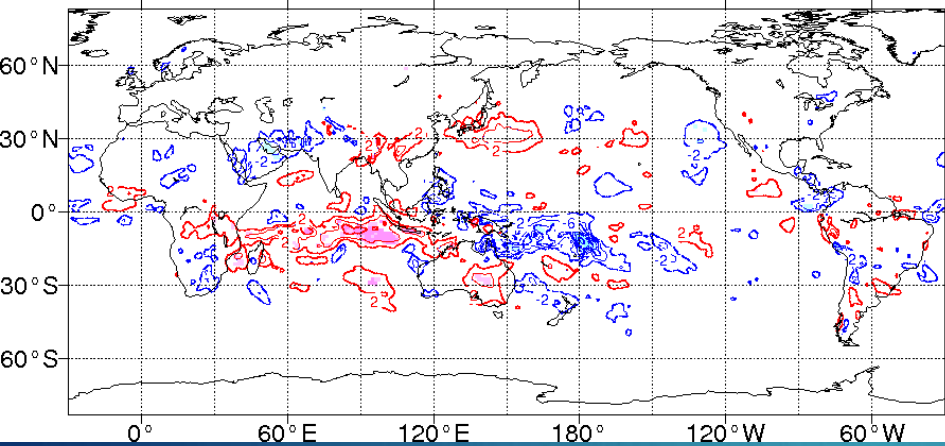
Sea Level Pressure [hPa]



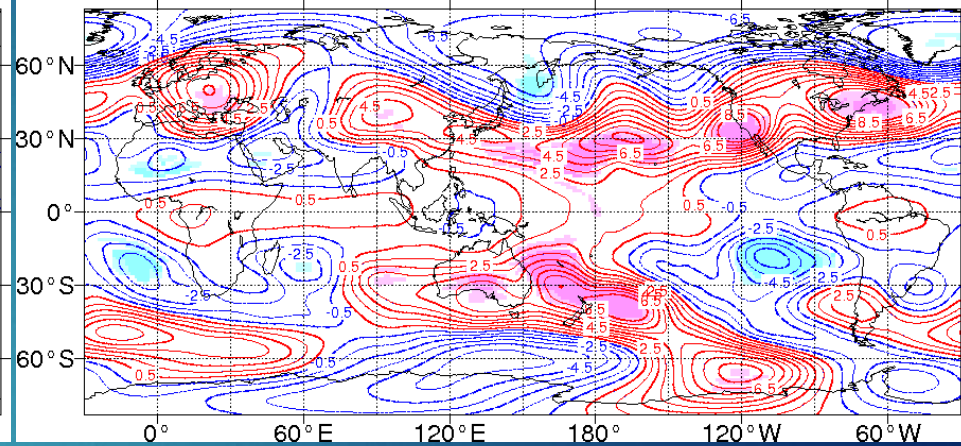
- ▶ Day 0 corresponds to the days in phase 5
BSISO: just after the northward migration of active convective region
MJO: eastward propagation of active convective region over Maritime Continent
- ▶ Light (dark) shadings show statistical significance at 90 % (95 %) confidence levels.

MJO, amplitude ≥ 2.0 SD, phase 5 lag 9

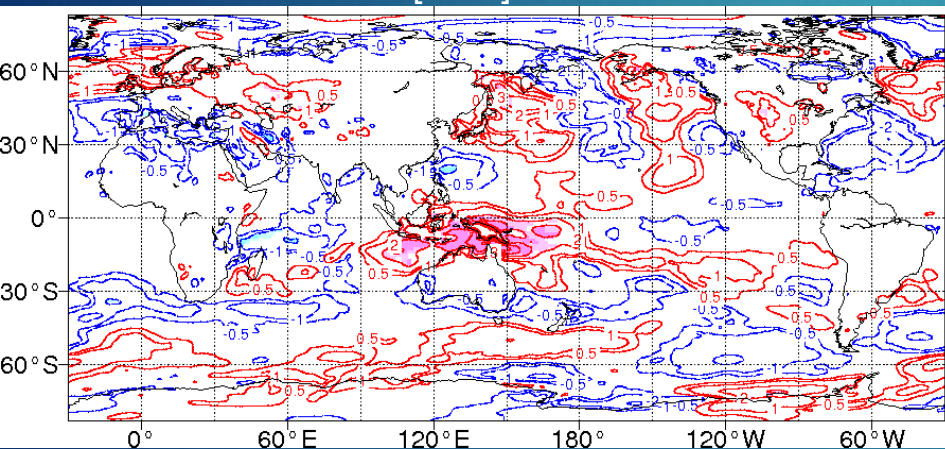
Vertical Velocity [Pa/s] @340K



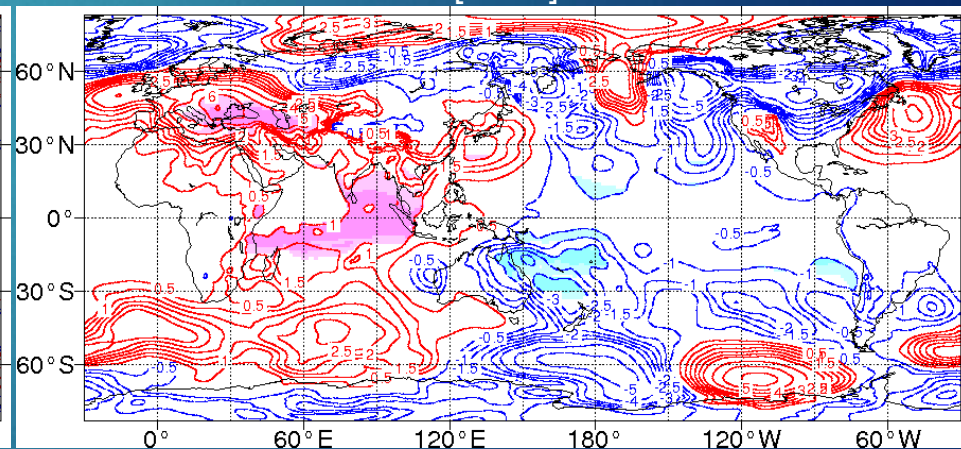
Montgomery Stream Function [m²/s²] @360K



10-m Zonal Wind [m/s]



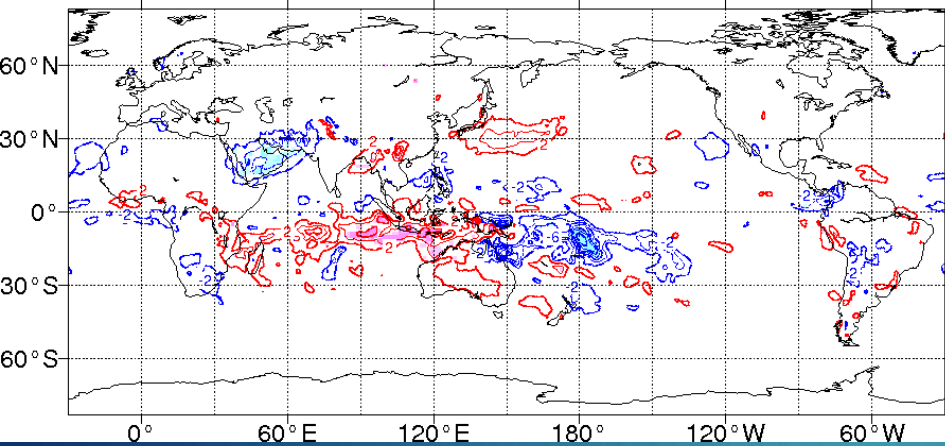
Sea Level Pressure [hPa]



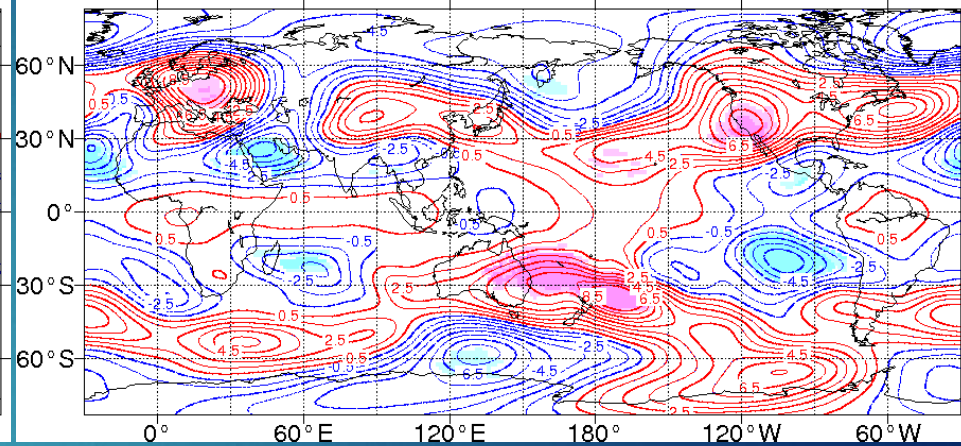
- ▶ Day 0 corresponds to the days in phase 5
BSISO: just after the northward migration of active convective region
MJO: eastward propagation of active convective region over Maritime Continent
- ▶ Light (dark) shadings show statistical significance at 90 % (95 %) confidence levels.

MJO, amplitude ≥ 2.0 SD, phase 5 lag 12

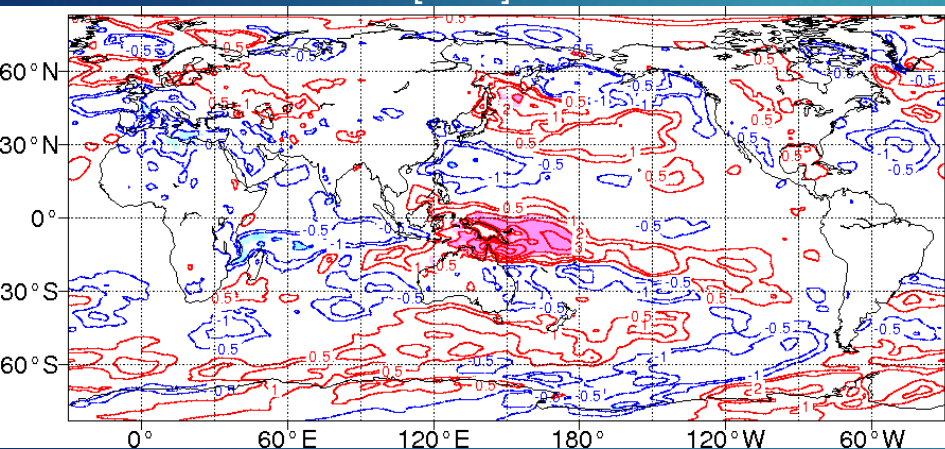
Vertical Velocity [Pa/s] @340K



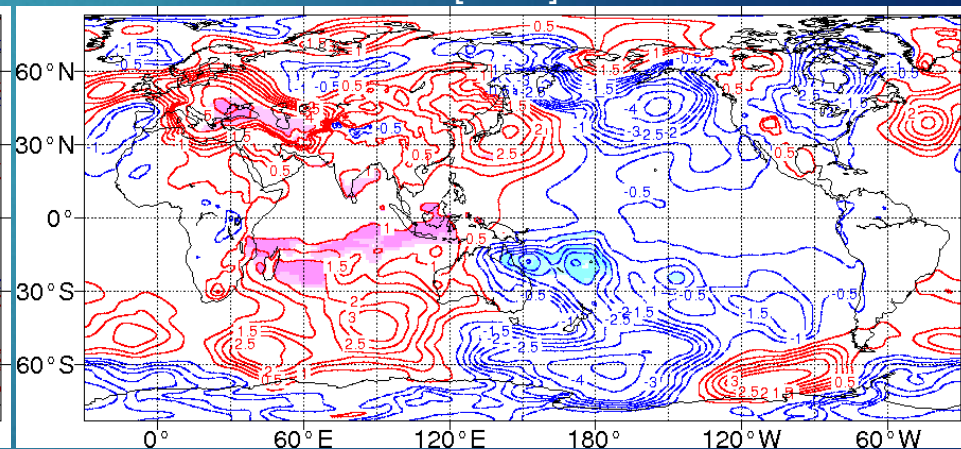
Montgomery Stream Function [m²/s²] @360K



10-m Zonal Wind [m/s]



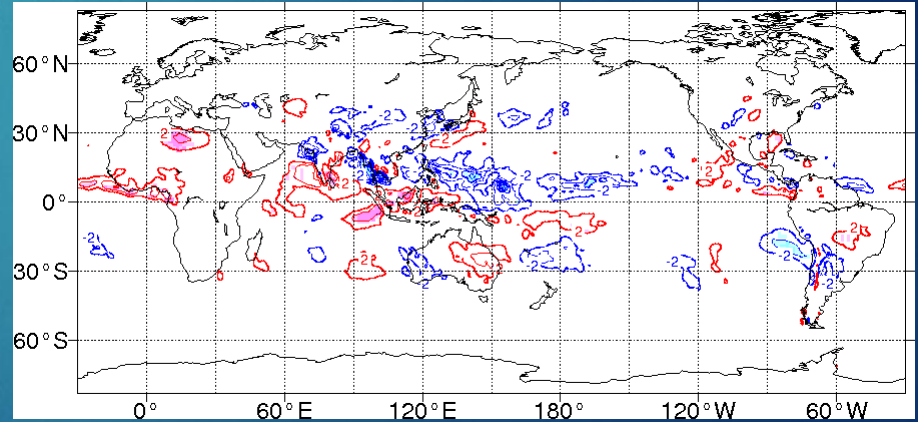
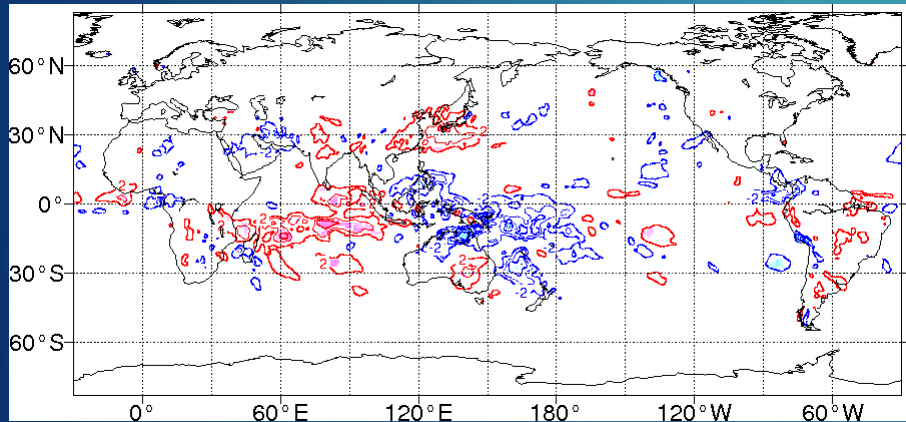
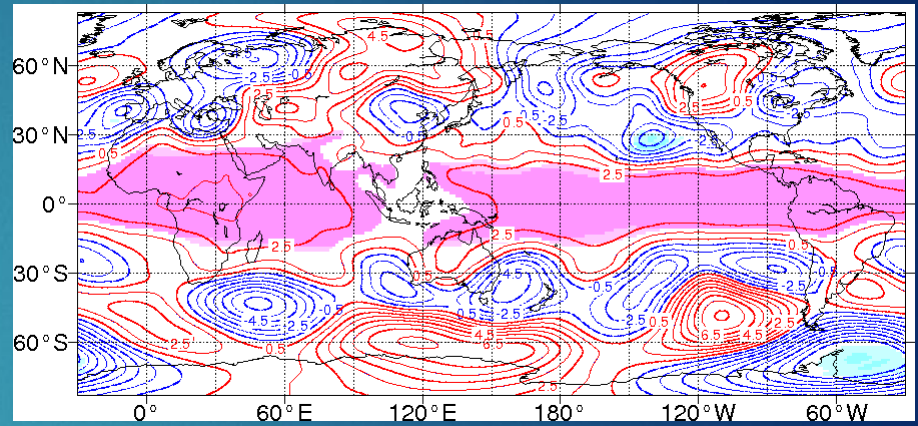
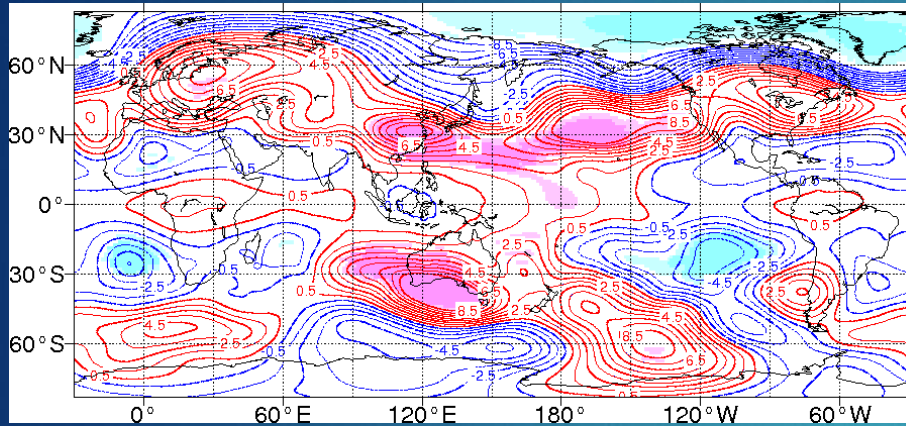
Sea Level Pressure [hPa]



- ▶ Day 0 corresponds to the days in phase 5
BSISO: just after the northward migration of active convective region
MJO: eastward propagation of active convective region over Maritime Continent
- ▶ Light (dark) shadings show statistical significance at 90 % (95 %) confidence levels.

Comparison of BSISO with MJO, Montgomery Stream Function [$\text{m}^2 \text{s}^{-2}$], amplitude ≥ 2.0 SD, centered the days in phase 5

モンゴメリ流線関数偏差 (m^2/s^2) 360K



- ▶ Day 0 corresponds to the days in phase 5
BSISO: just after the northward migration of active convective region
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- ▶ Light (dark) shadings show statistical significance at 90 % (95 %) confidence levels.

まとめ

- ▶ BSISO : 対流圏上層で両半球対称な西風偏差の極向きへの遷移が見られた。
MJO : 西風偏差の極側の東風偏差が明瞭。極向きへの遷移はそれほどでも？
- ▶ MJOとBSISO : 夏半球上部成層圏中高緯度で東風偏差が有意。
- ▶ MJO : 北半球成層圏で西風偏差と極域の低温偏差が有意。
1.5 σ を超える場合にその傾向が顕著で先行研究とは逆の傾向。
- ▶ QBOとの関係
 - ▶ MJO : 50hPa東西風と有意。東風位相時に振幅が大きくなる傾向。
 - ▶ BSISO : 20hPa東西風と有意。強東風位相時に振幅が大きくなる傾向。
- ▶ 対流圏上層の偏差分布の3次元的経過
 - ▶ BSISO : 対流活動活発域の北進後にインド洋MSF正偏差域が発達。
 - ▶ MJO : 海洋大陸東進後にBSISOのような正偏差域の発達は見られない。