Characteristics of East Asian monsoon cycle represented by the western Pacific-Indian Ocean regional low-level circulation types and the relationship with ENSO

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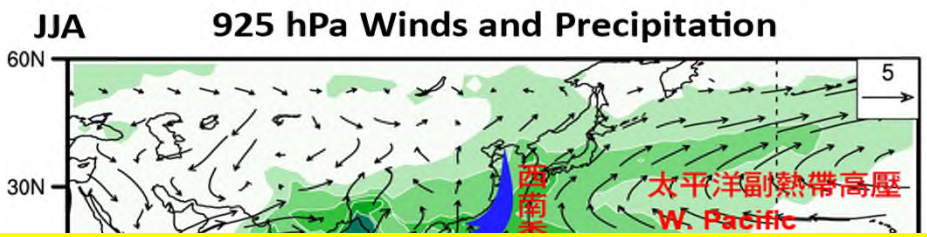
This project is supported by the following grants: NSTC 112-2111-M-002-010, NSCT 112-2811-M-002-069, NSCT 113-2111-M-002-008, NSCT 113-2811-M-002-133

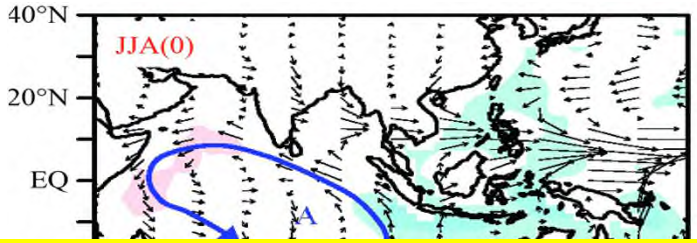
114年天氣分析與預報研討會
04/09/2025

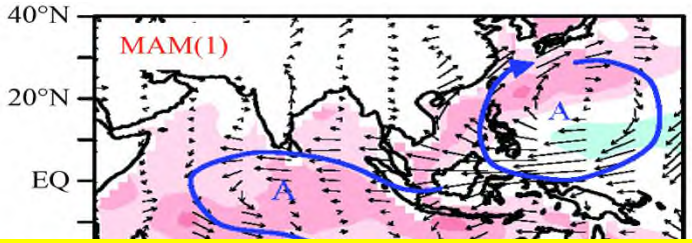
Introduction

Asian-Australian-WNP:
one monsoon system



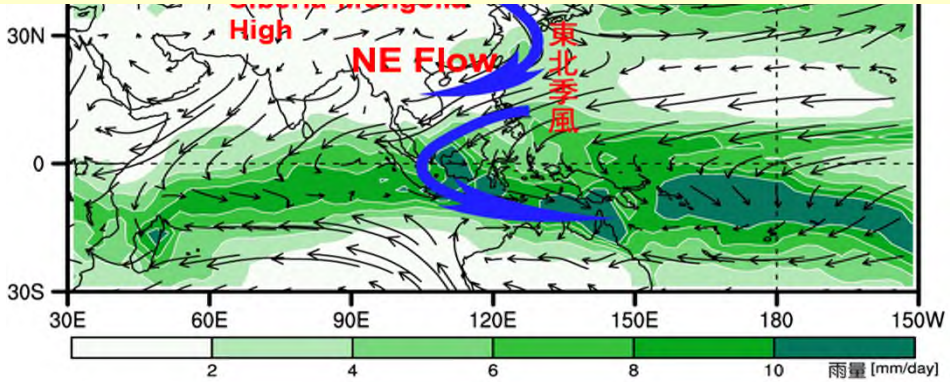
Seasonal evolving patterns of 850-hPa wind and SST anomalies associated with El Niño turnabout from the developing summer JJA(0), to the decaying summer JJA(1) based on the SS-SVD analysis.

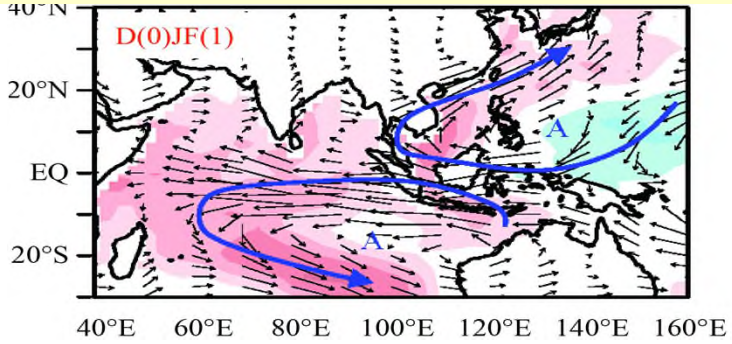


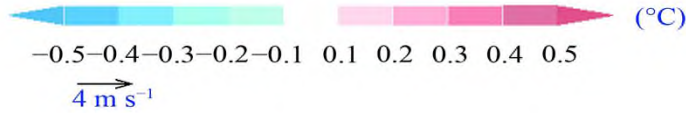


Objectives of the present study:

* Can the seasonal evolving patterns be identified based on the cluster analysis of daily low-level wind data ? Different clusters are termed as different weather types.
* Can East Asian monsoon strength and ENSO influence be observed in the seasonal evolution of weather types? This is the most straightforward way to see how weather changes with climate divers, so called weather in climate.







Wang et al. (2003), Li et al. (2017)

Analysis procedure

Weather Type Analysis

Daily 850hPa winds(U,V)
1979-2024(46 years)
50°E-180°E, 20°S-40°N

K-means Cluster Analysis
46 years of daily data can be group into
9 weather types(WT)

Monsoon Annual Cycle
winter(WT1,WT2,WT9), spring(WT3,WT4)
summer(WT5,WT6), autumn(WT7,WT8)

- Weather Types (WT) in Western Pacific-Indian Ocean
- Monsoon Annual Cycle Represented by WT

This study is the first time to use daily low-level weather type clustering to demonstrate the relationship.

Monsoon Year (MY): May(Yr0)-Apr(Yr1)
strong MY: strong summer and strong winter
weak MY: weak summer and weak winter

- Relationship Between Winter and Summer Monsoon Intensity ➔ Strong/Weak Monsoon Year (MY)

ENSO and MY Variability

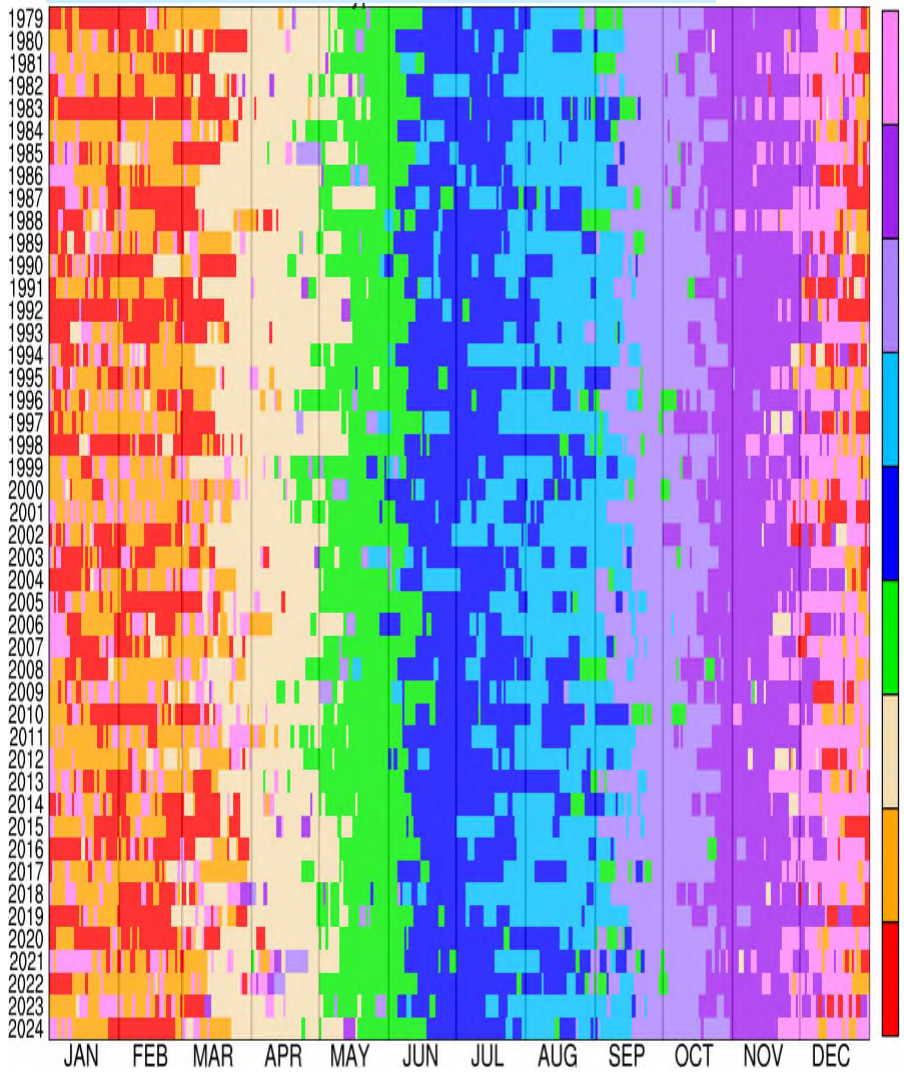
MY Intensity and ENSO Phase
strong MY: La Niña
weak MY: El Niño

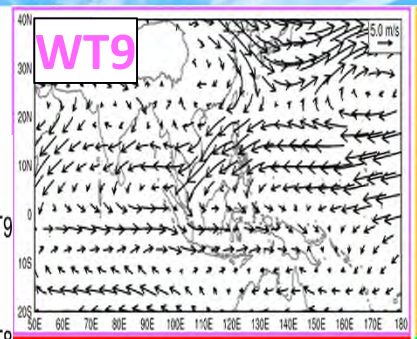
Summer and Winter Linkage through ENSO
circulation and SST analysis
mid-Jul to Aug: the critical time for the linkage

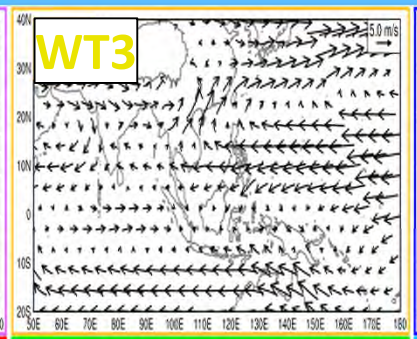
- Key features of summer and winter monsoon connection through La Niña/El Niño evolution

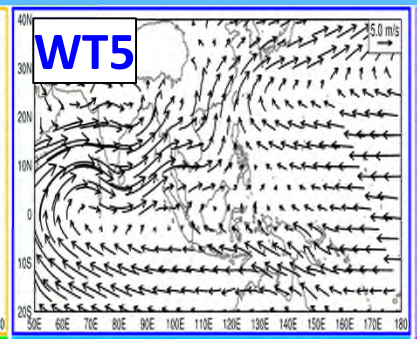
Weather Type(WT) and Monsoon Annual Cycle

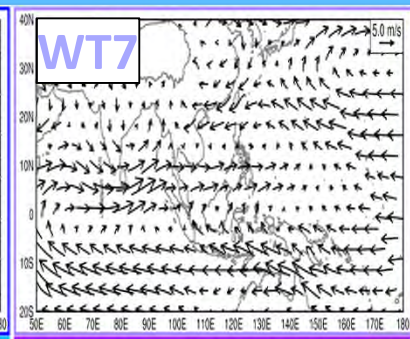
Weather type calendar 1979-2024

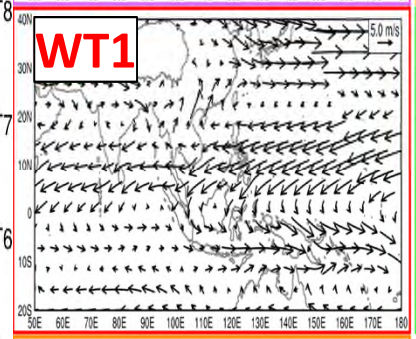


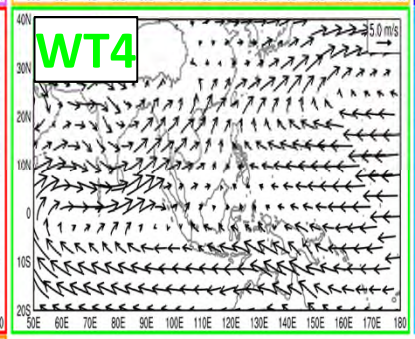


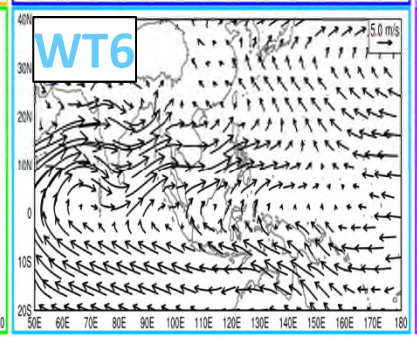


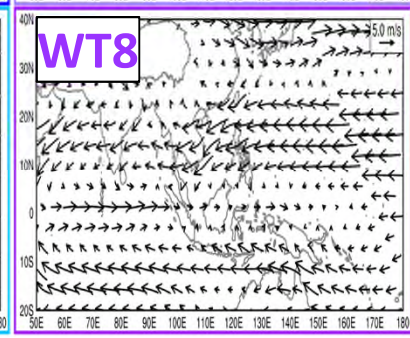


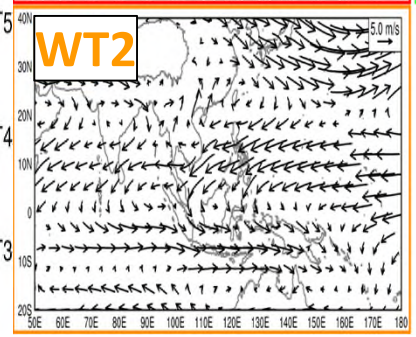






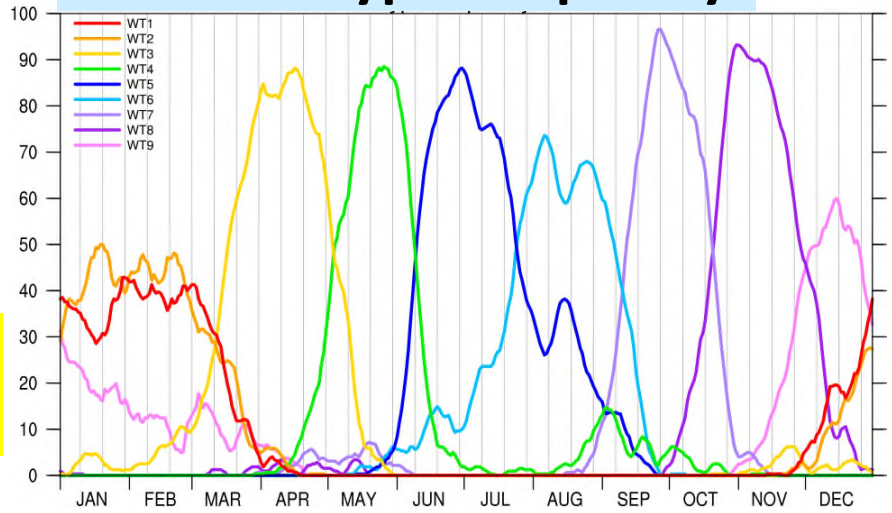




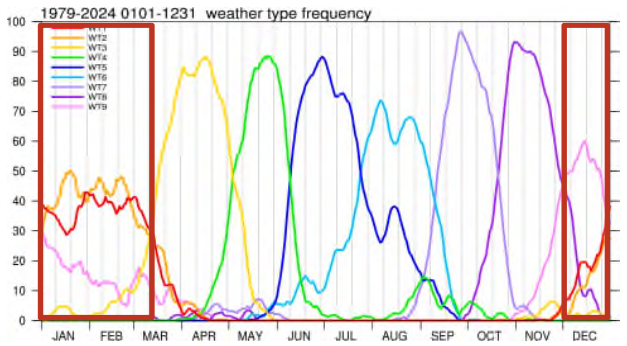


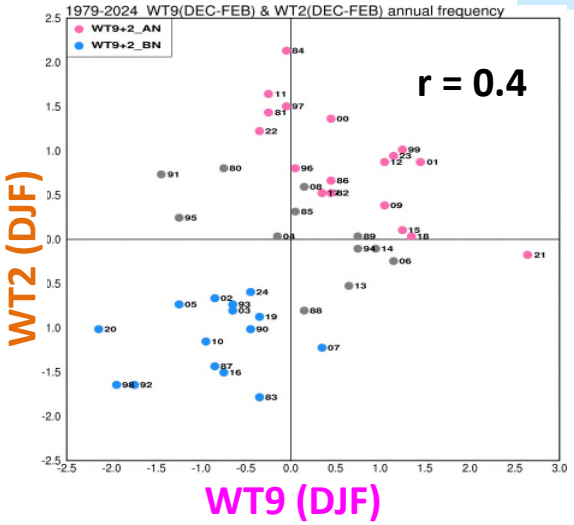
Summer: WT5,WT6
Winter: WT9,WT1,WT2

Weather type frequency

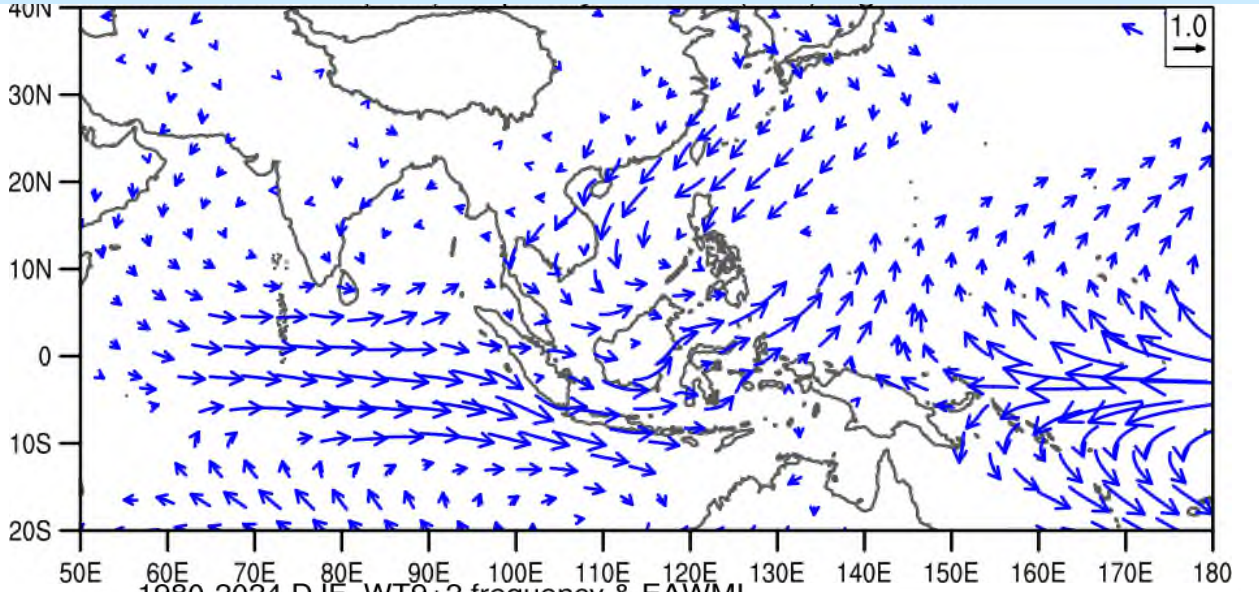


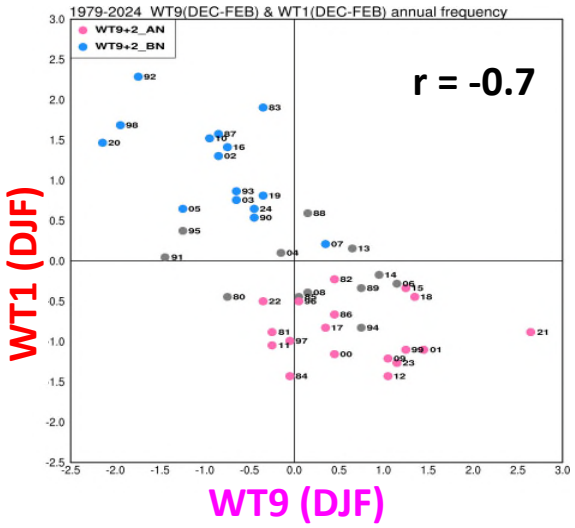
Winter Weather Type Frequency and Monsoon Intensity

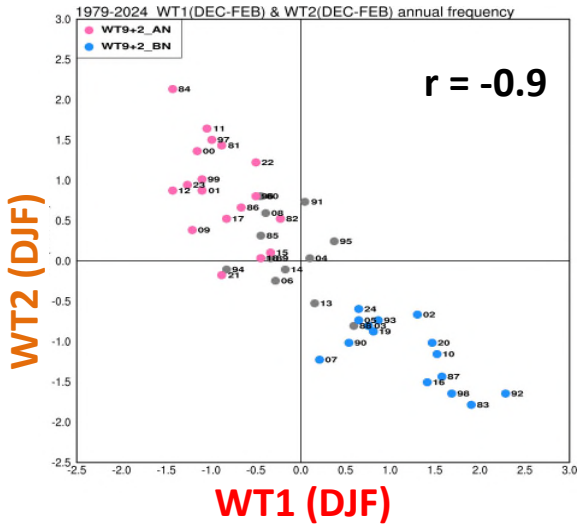


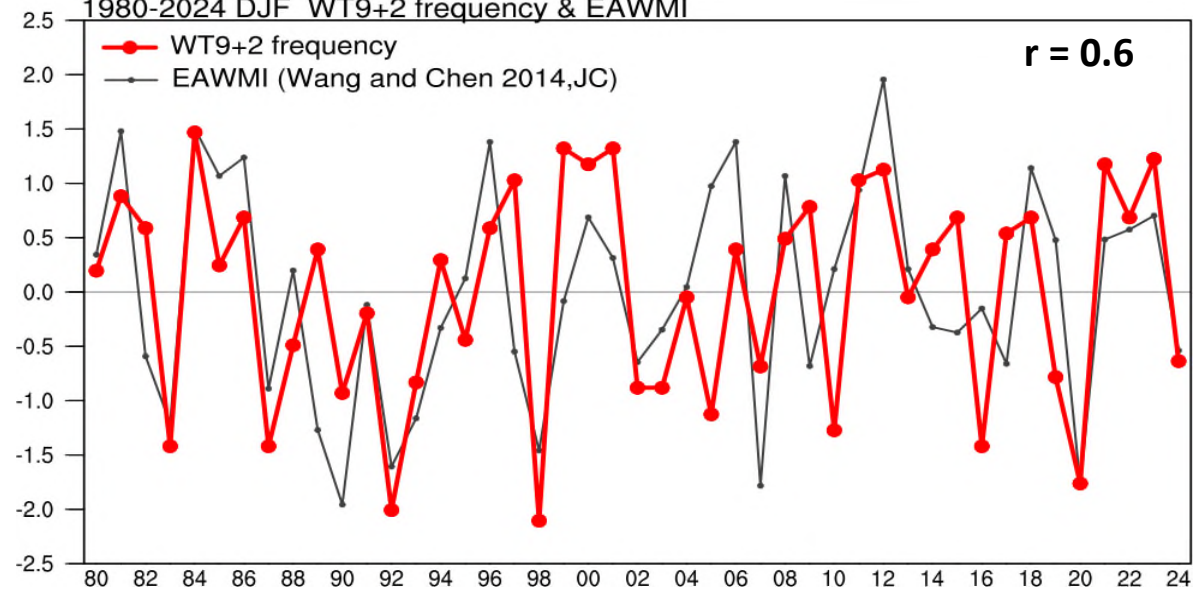


WT9+WT2(DJF) frequency & UV925(DJF) regression

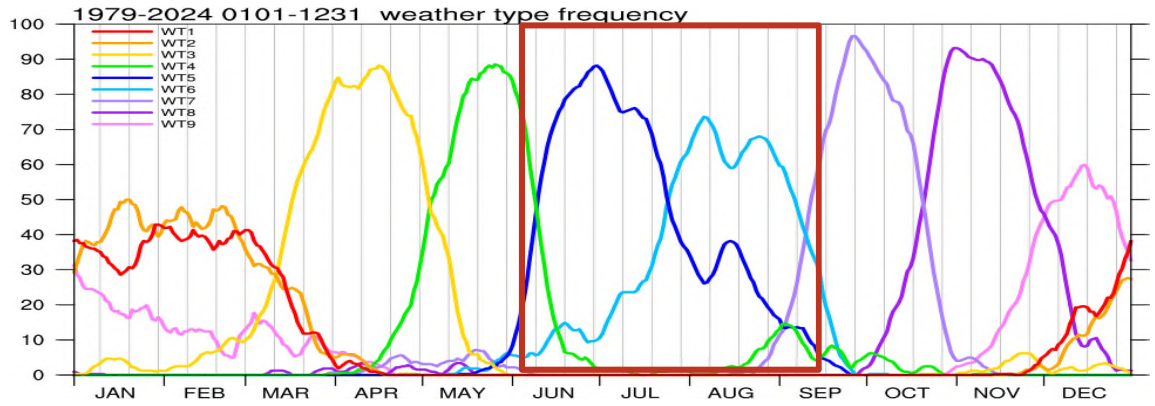




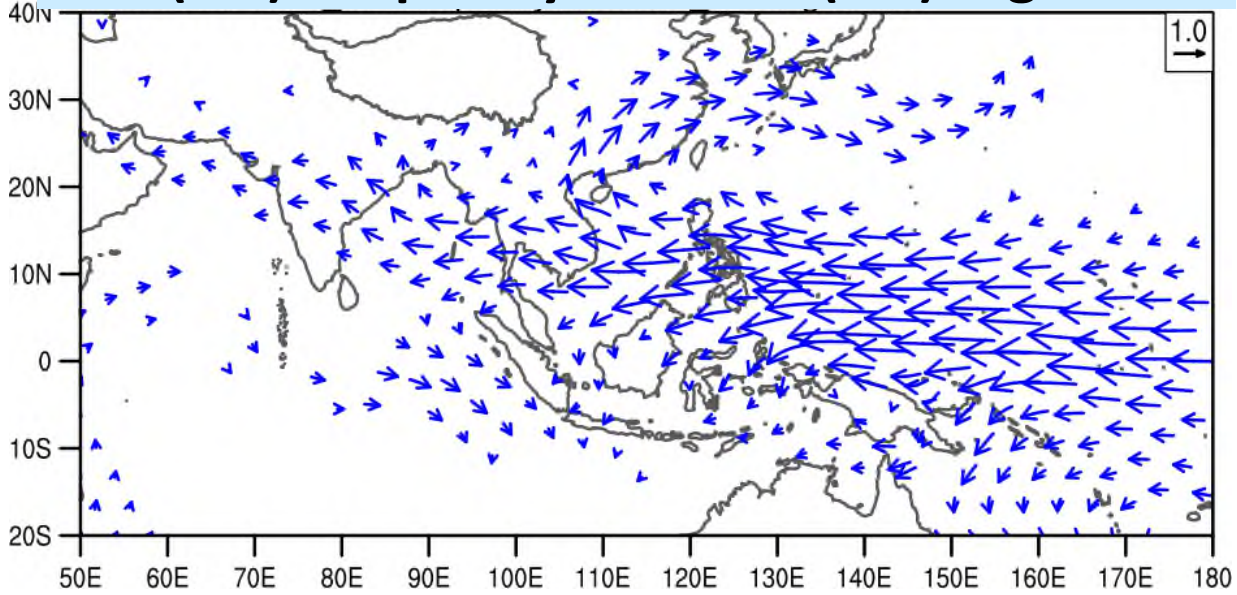


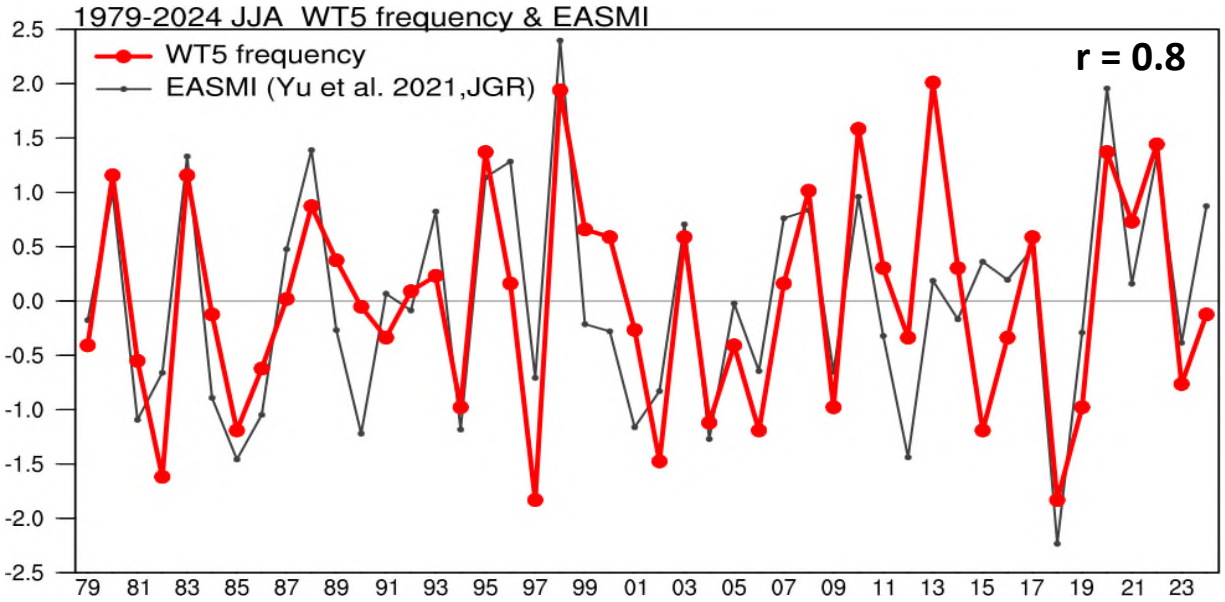


Summer Weather Type Frequency and Monsoon Intensity



WT5(JJA) frequency & UV850(JJA) regression



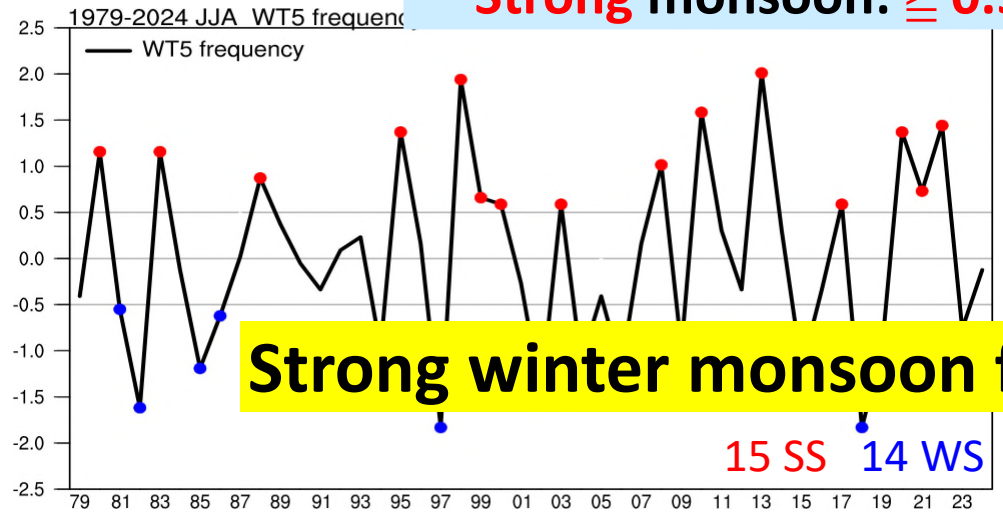


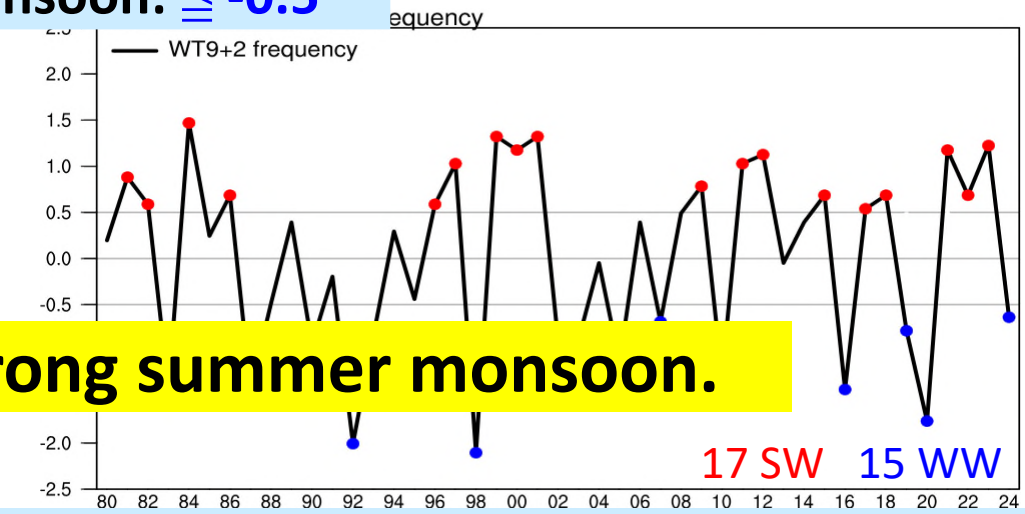
Yu et al. 2021 JGR, Wang and Fan 1999 BAMS

$$\mathrm{EASMI} = \mathrm{U850}(110° - 140°\mathrm{E}, 22.5° - 32.5°\mathrm{N}) - \mathrm{U850}(90° - 130°\mathrm{E}, 5° - 15°\mathrm{N})$$

Relationship between Summer and Winter Monsoon

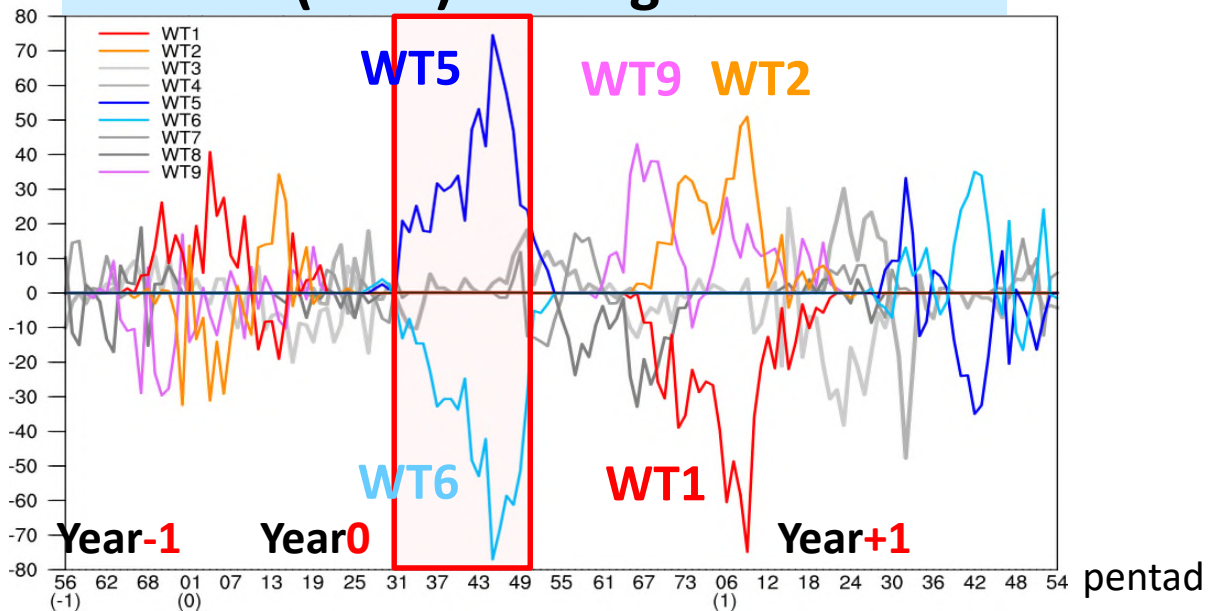
Strong monsoon: ≧ 0.5, Weak monsoon: ≦ -0.5



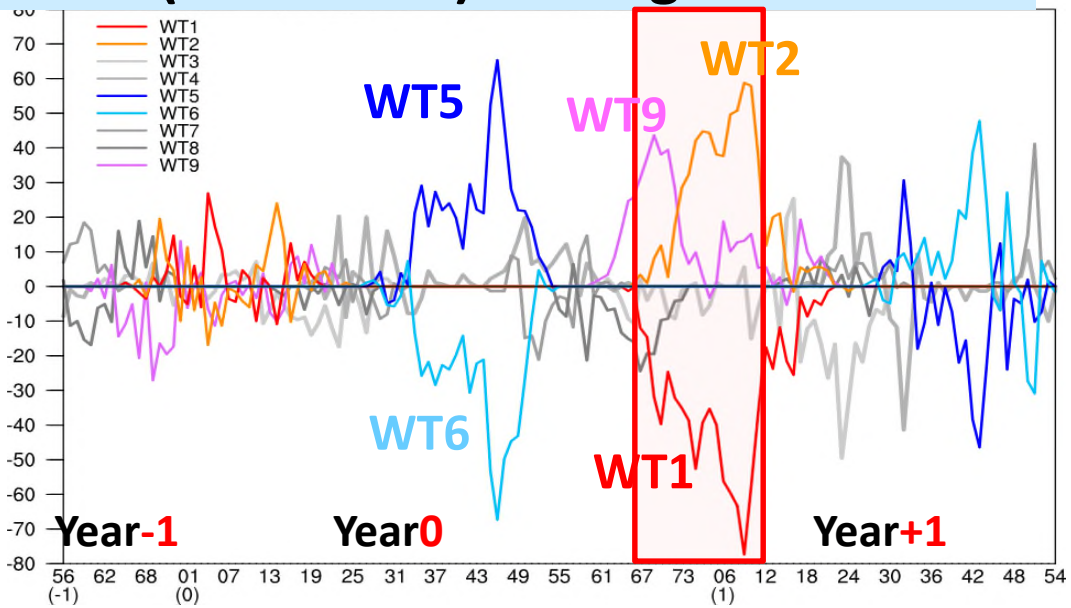


Strong winter monsoon follow strong summer monsoon.

Summer(WT5): Strong minus Weak



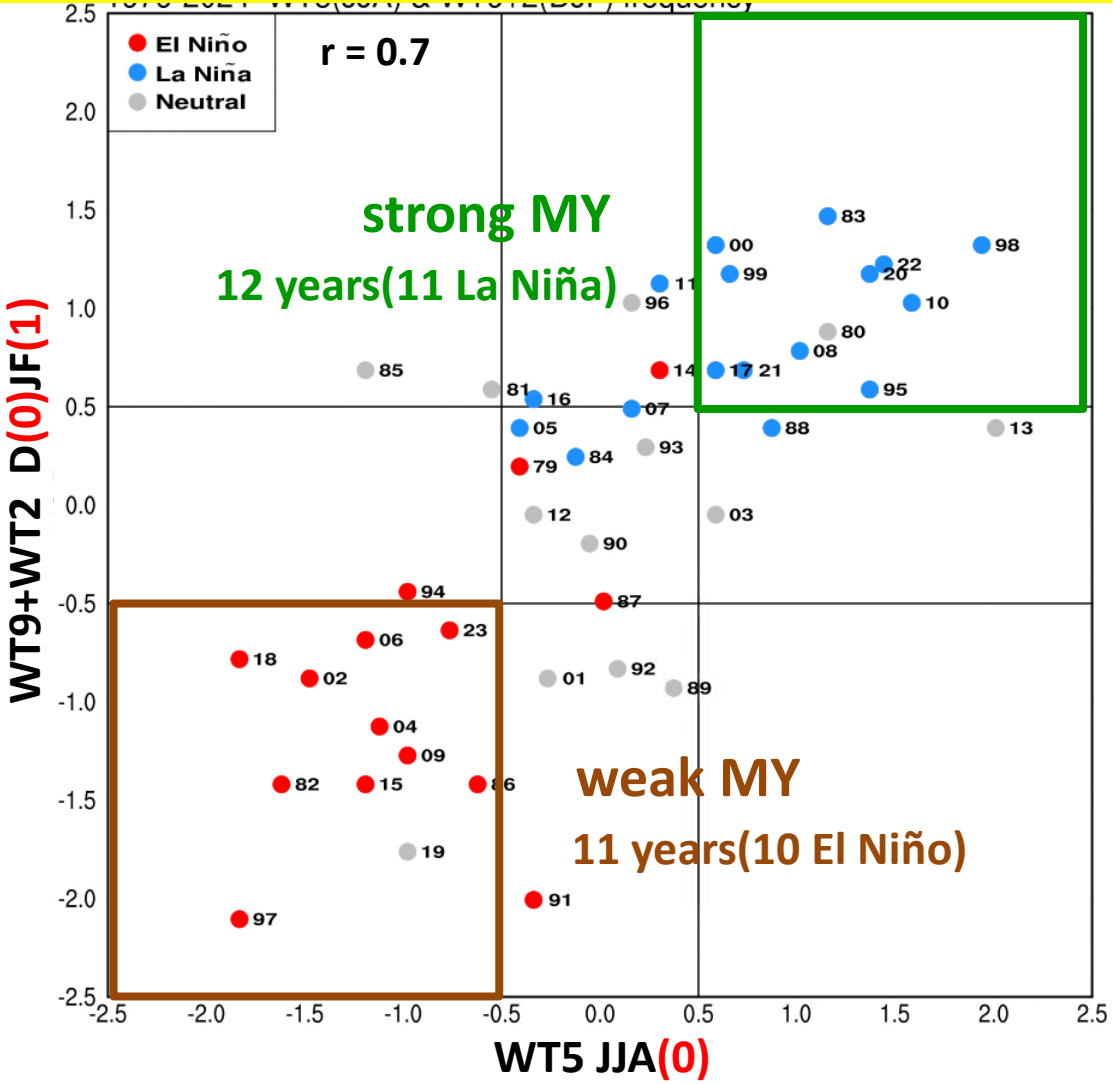
Winter(WT9+WT2): Strong minus Weak



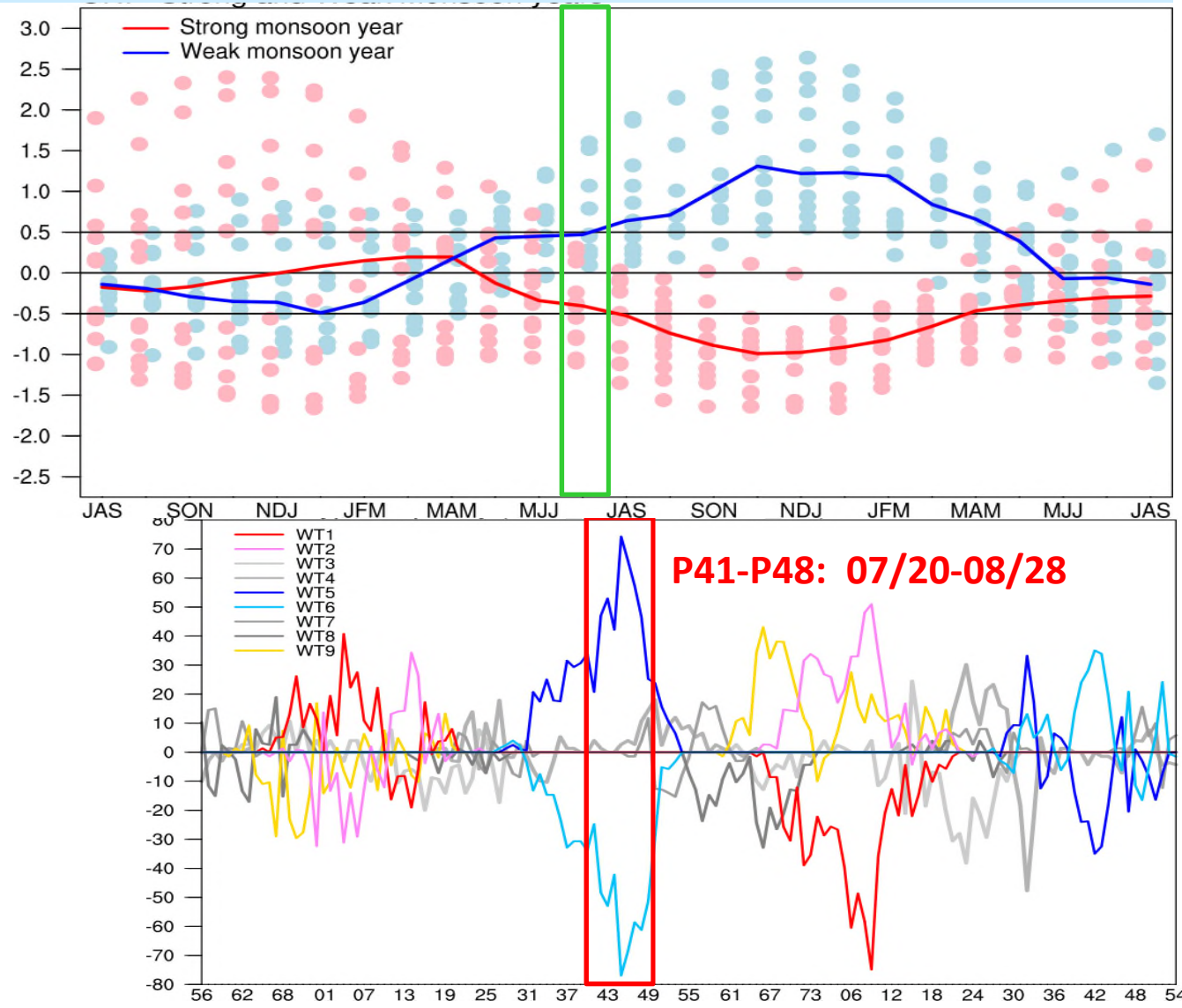
ENSO and Monsoon Year (MY) Variability

Strong MY: strong summer and strong winter

Weak MY : weak summer and weak winter

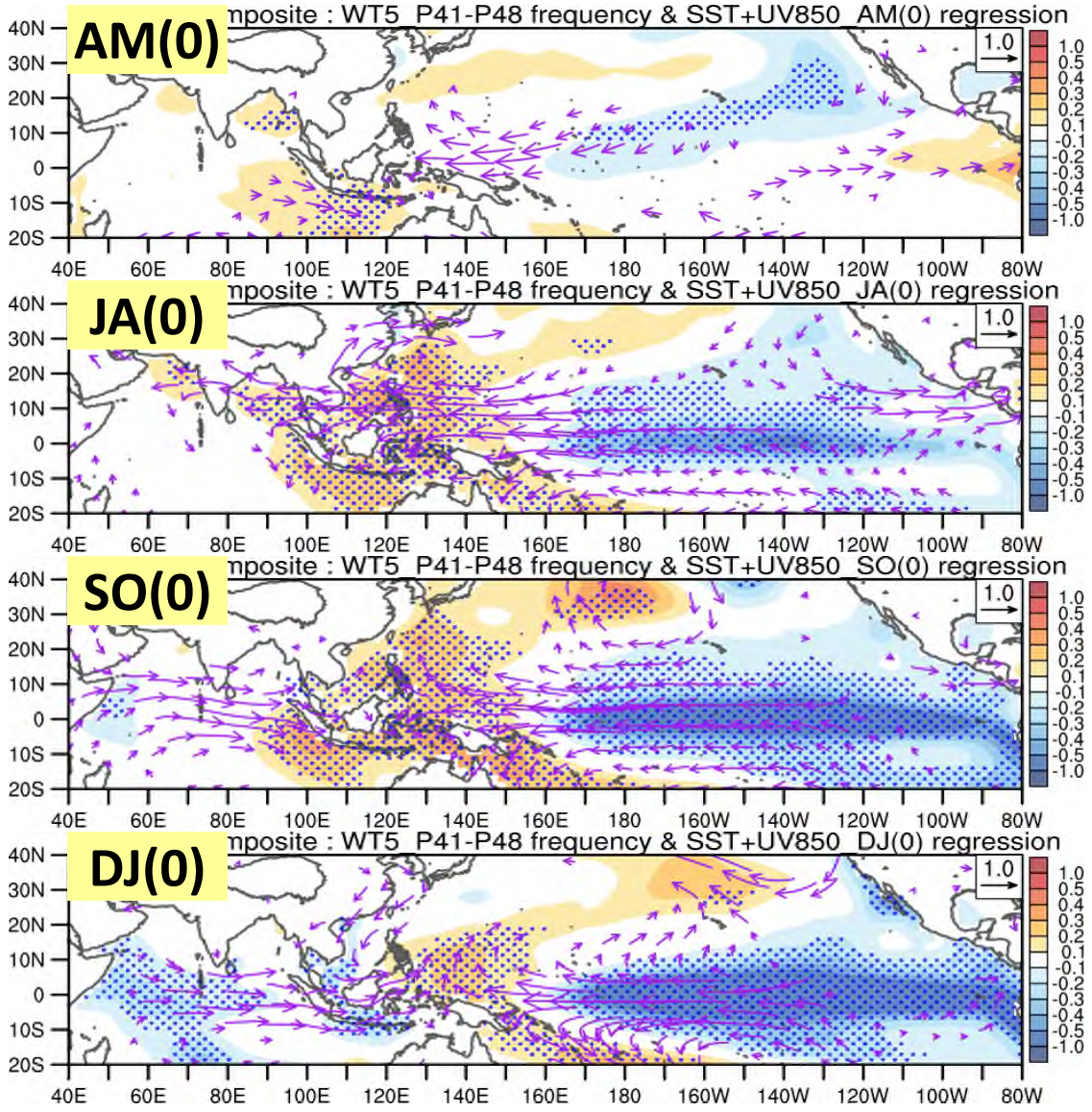


Nino3.4 evolution of strong/weak monsoon years

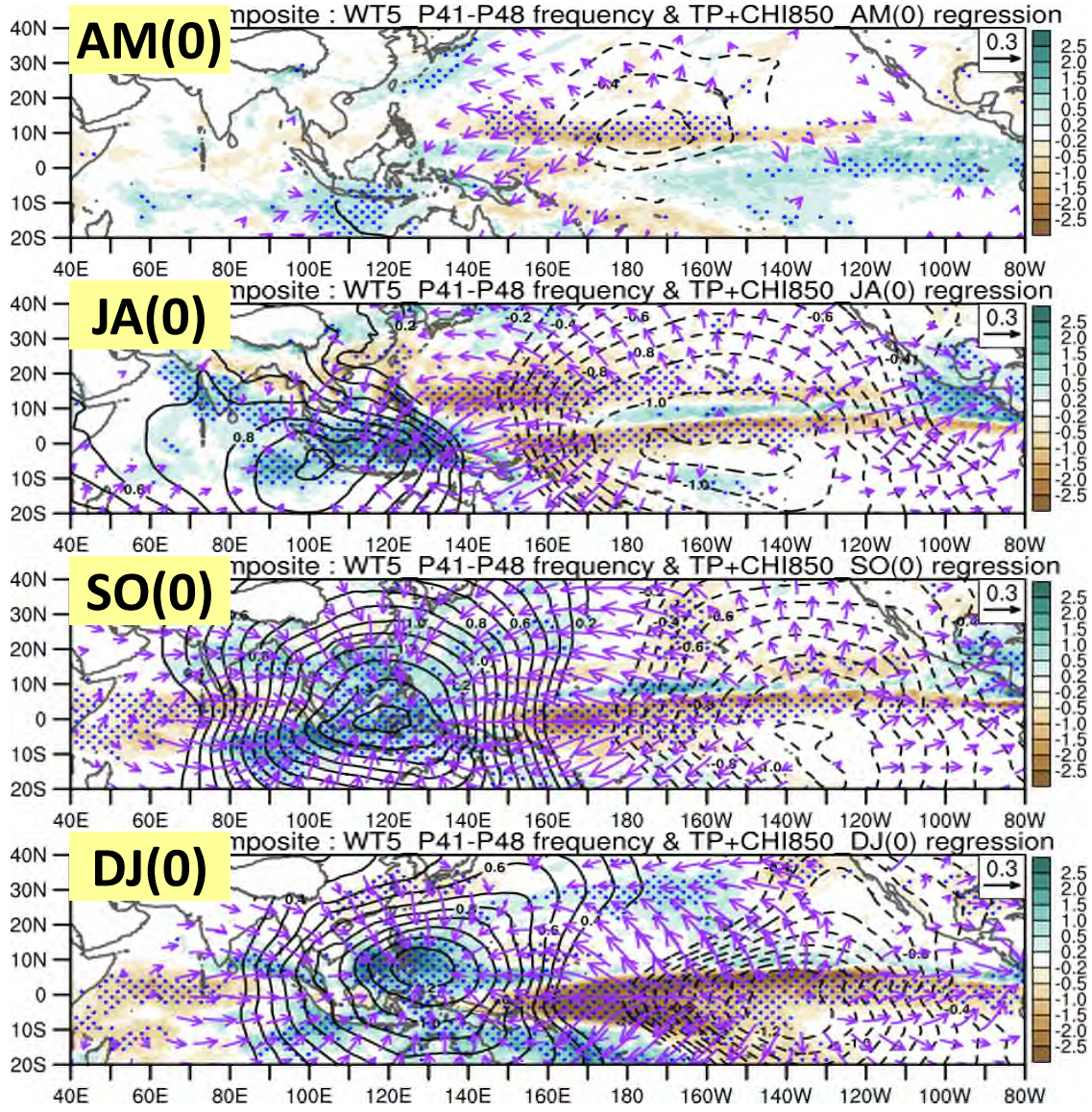


ENSO and Strong/Weak Monsoon Year

SST (color) & UV850 (vector)



Prec.(color)&CHI850(contour)&DIV850 (vector)

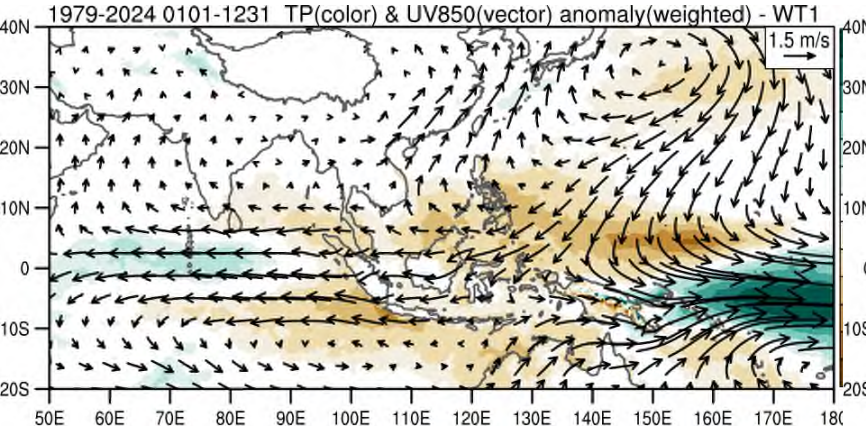


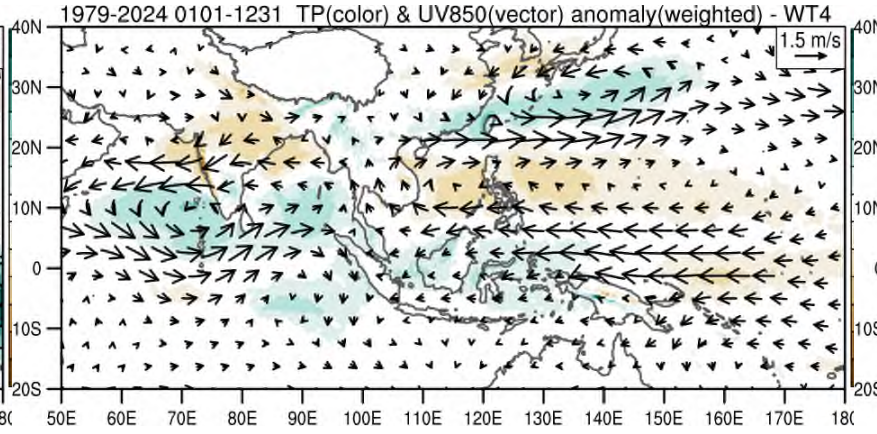
Conclusions

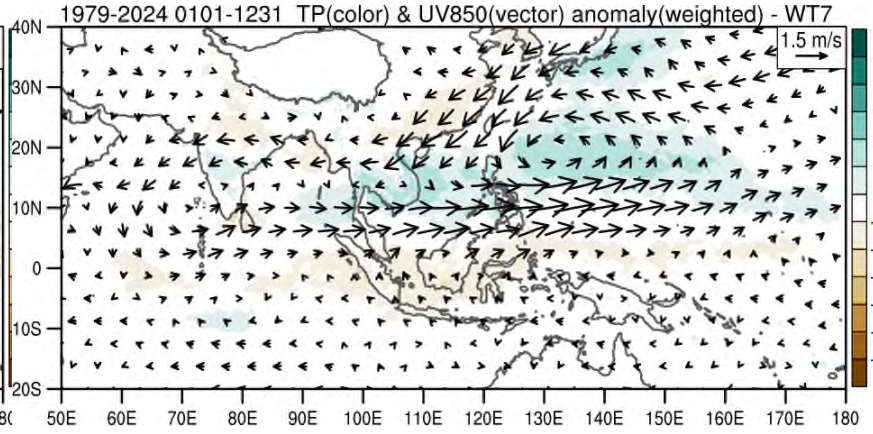
1. Nine low-level circulation weather types are identified based on 46 years of daily 850-hPa wind data. The winter and summer monsoon intensity can be classified based on weather type frequency anomalies.
2. The strong (weak) summer leads a strong (weak) winter monsoon. No discernable relationship between the summer monsoon with its preceding winter monsoon and the winter monsoon with its ensuing summer monsoon was detected.
3. The summer and winter monsoon connection cannot be separated from ENSO evolution. Mid-July and August may be a critical time for the following evolution of the coupling between monsoon convection and circulation with ENSO.
4. This study is the first time to use daily low-level weather type clustering to demonstrate the monsoon-ENSO relationship and reveal these 40 days may be a critical time for the coupling. The findings has important implication for subseasonal to seasonal forecasts.

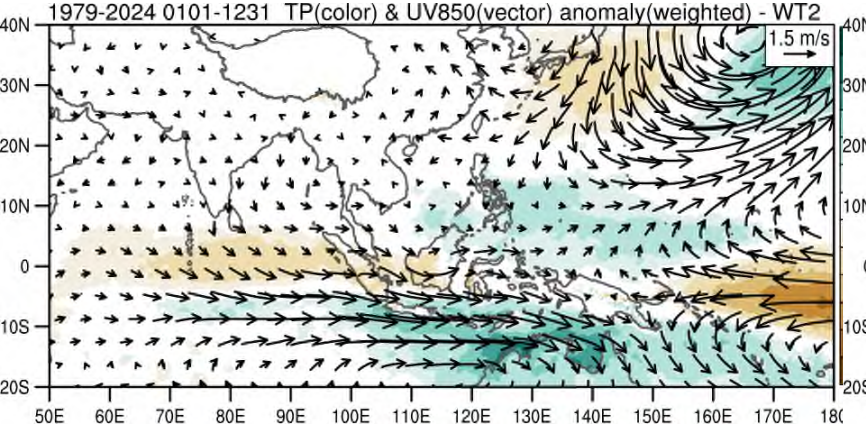
Thanks for your listing !

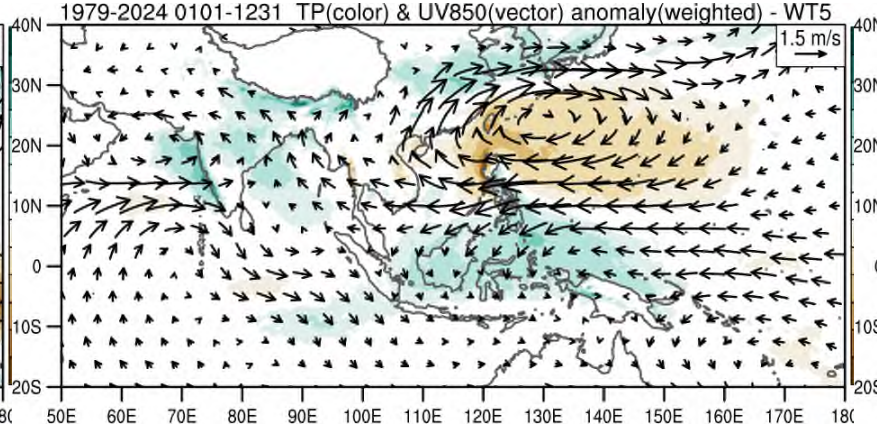
1979-2024 ERA5 TP & UV850 anomaly

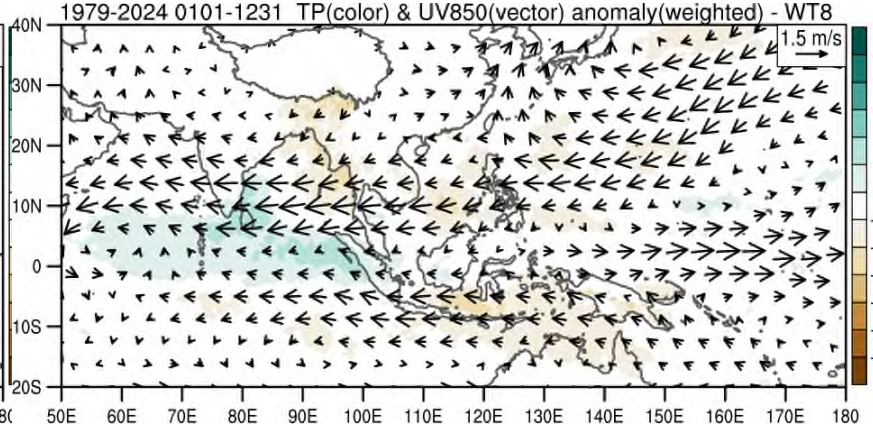


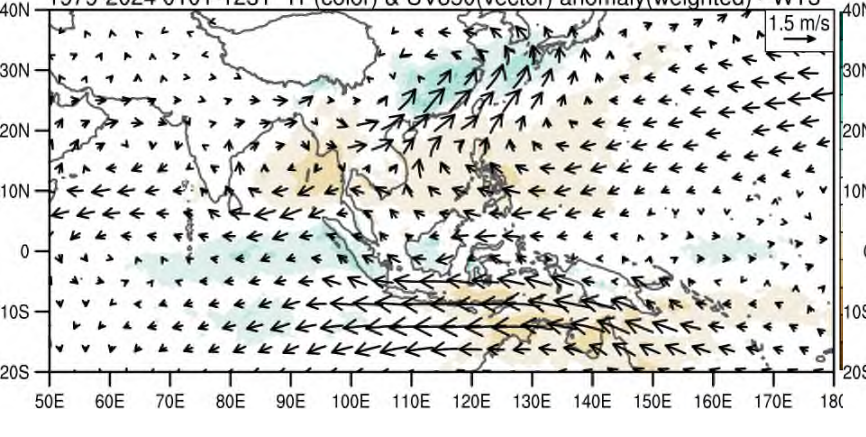


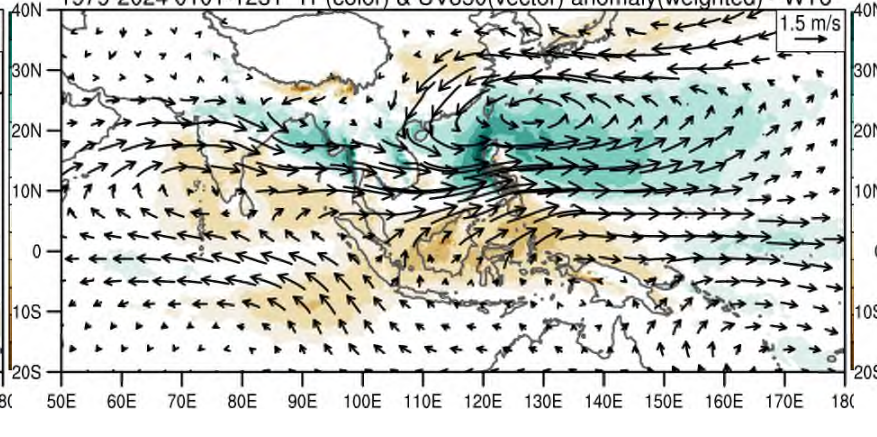


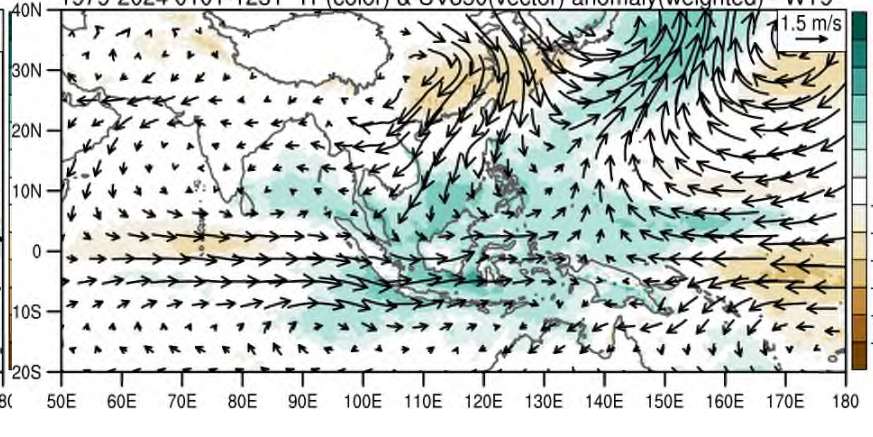




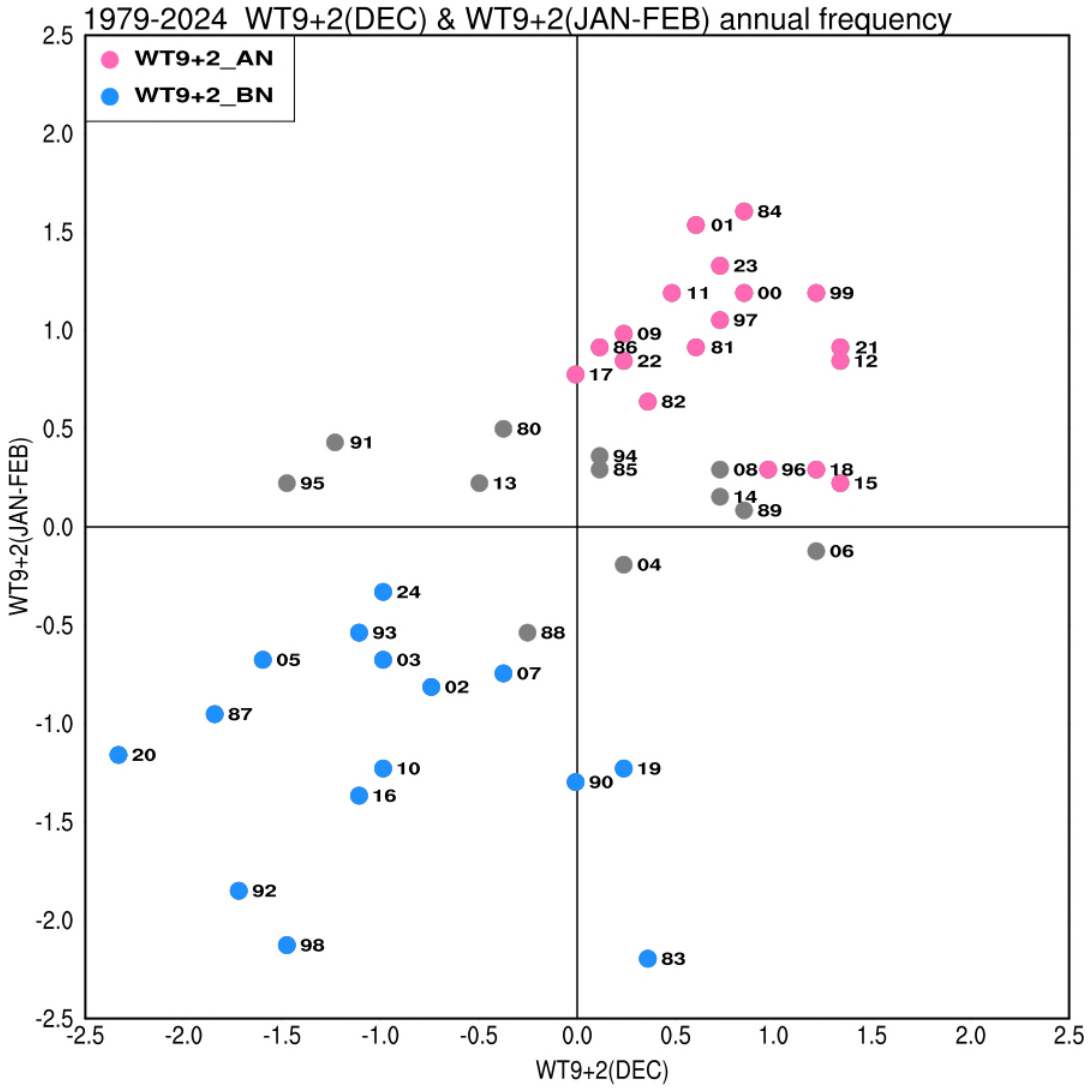




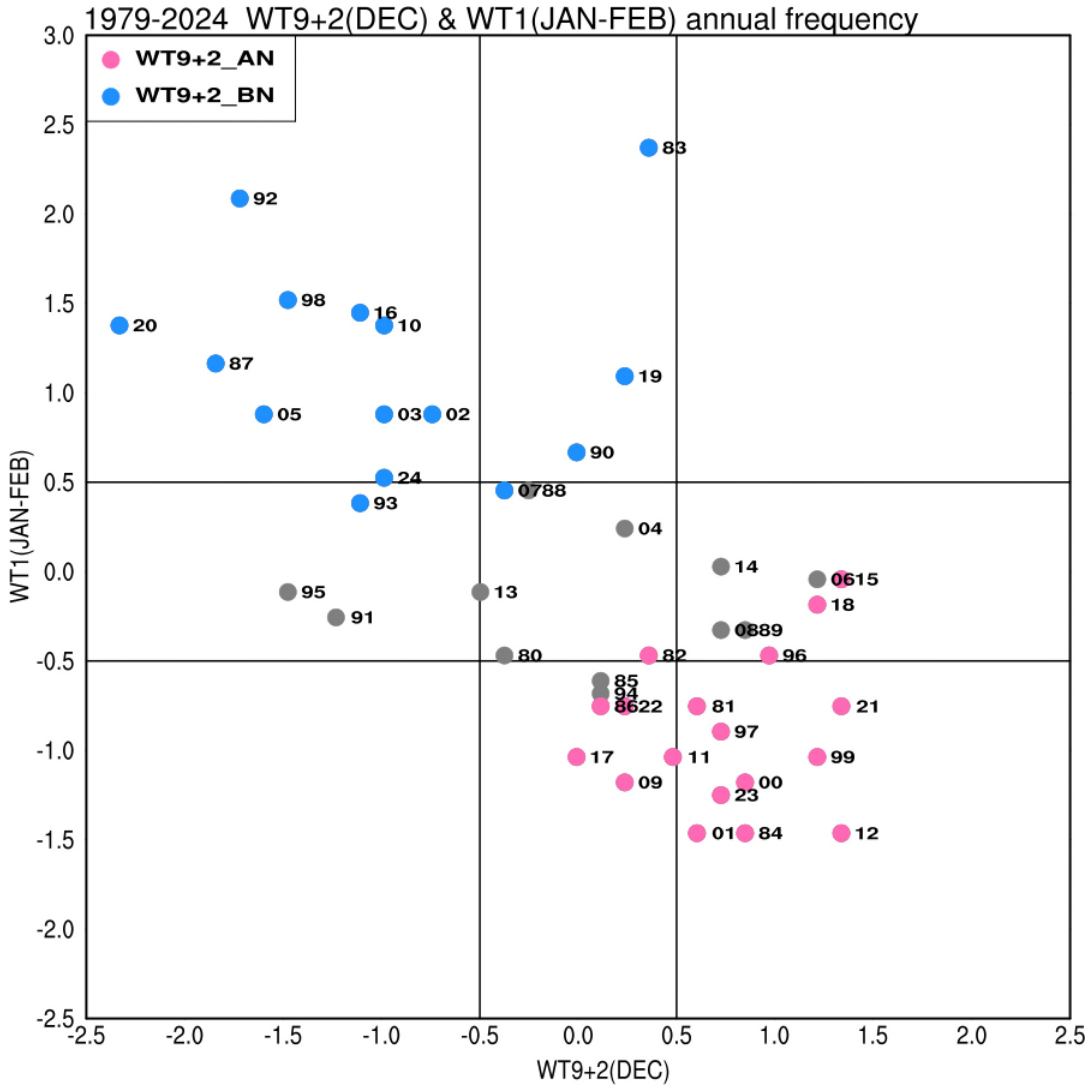




WT9+2的persistent➔ WT9+2在12月偏多(少)，在1-2月也會偏多(少)

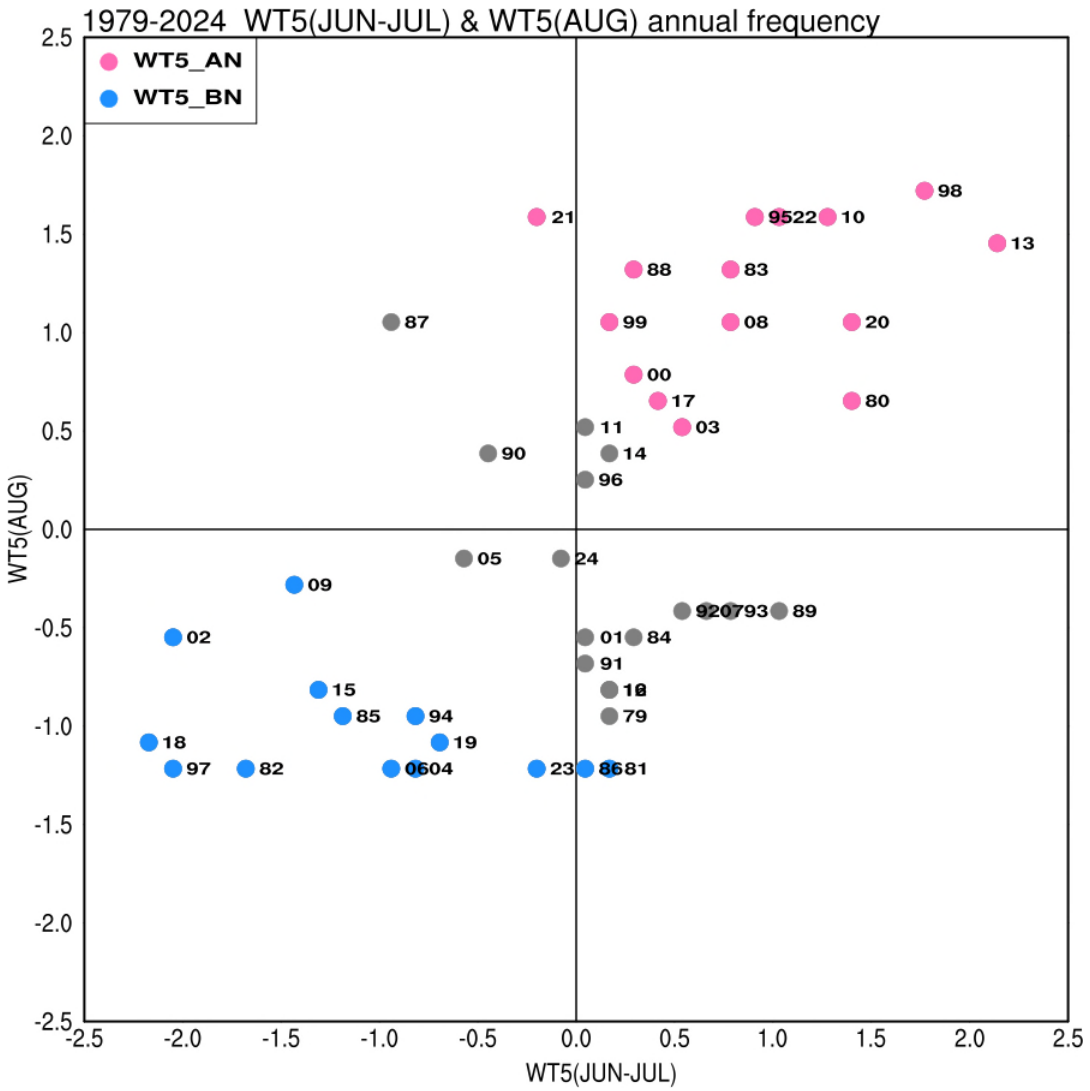


CC = 0.62



CC = -0.66

WT5的persistent➔ WT5在6-7月偏多(少)，在8月也會偏多(少)



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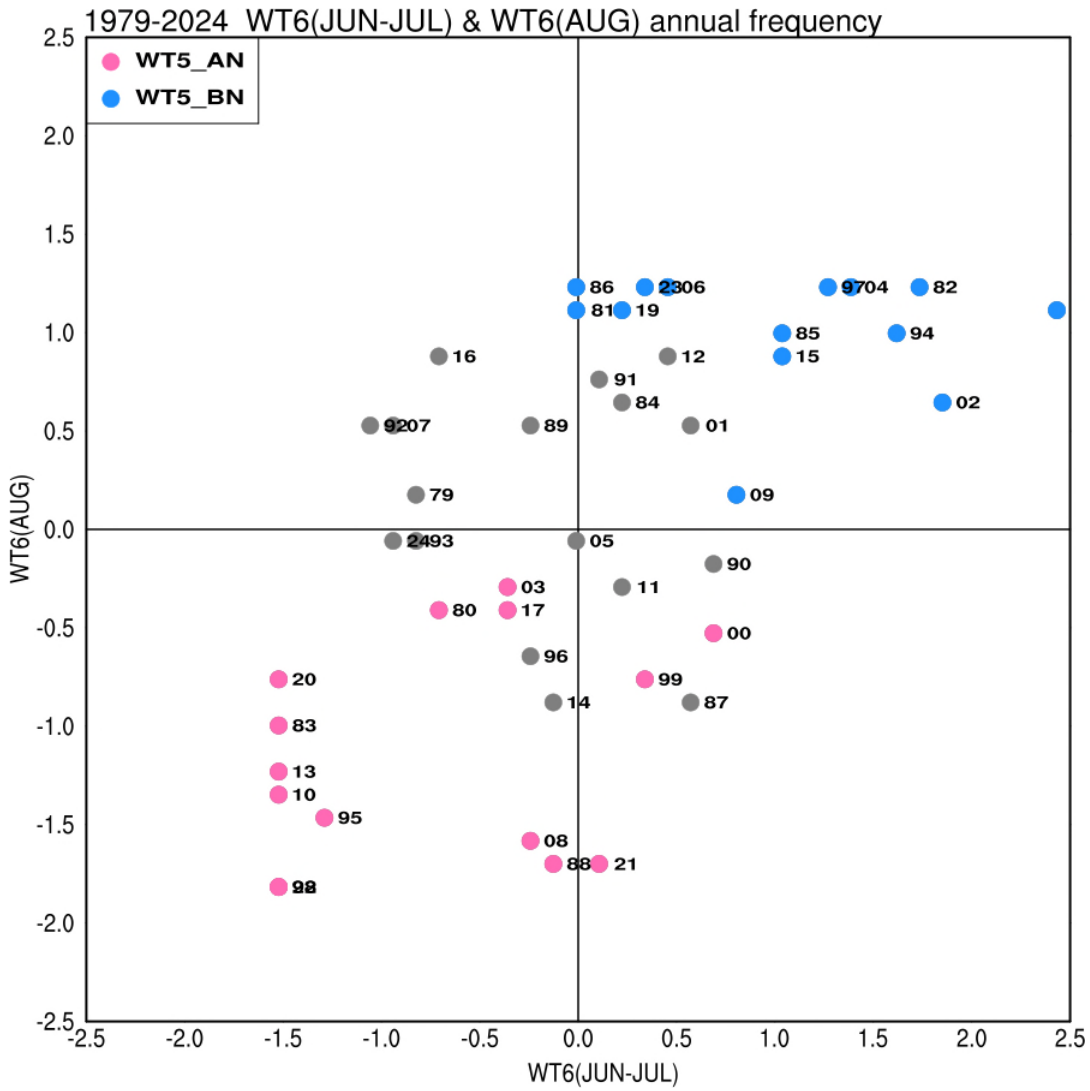

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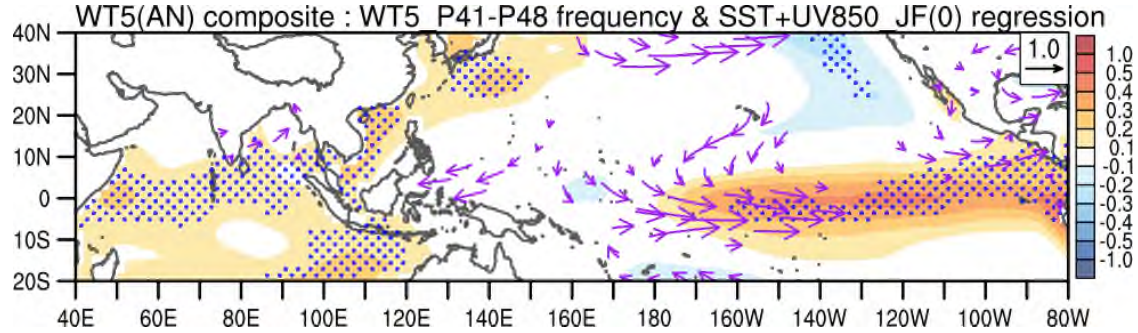
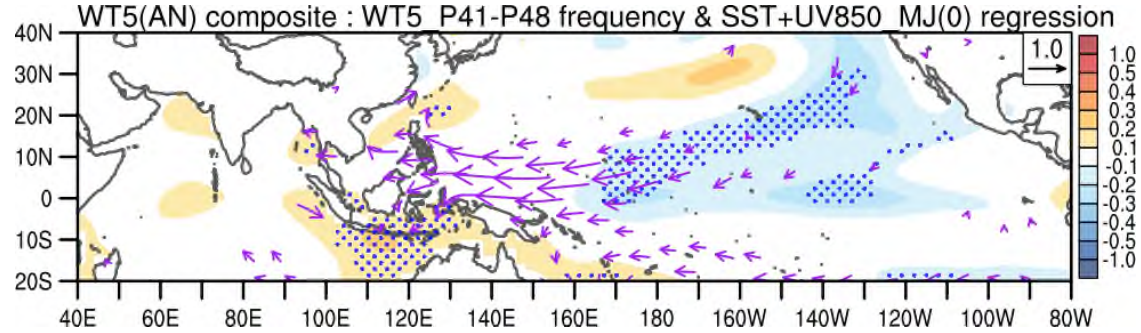
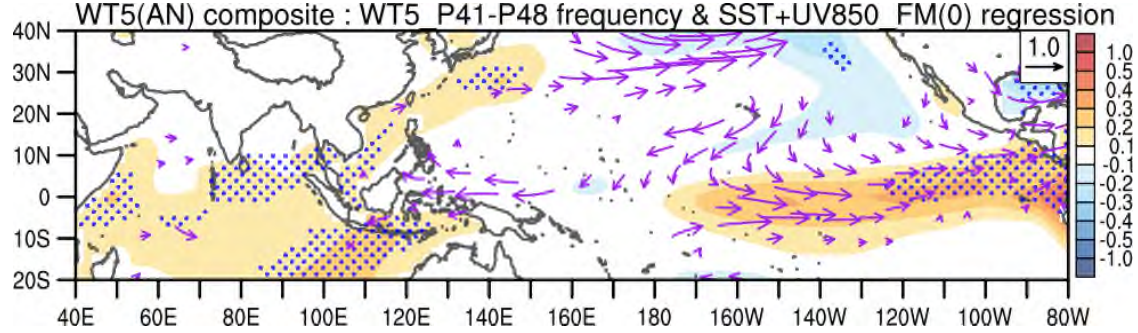
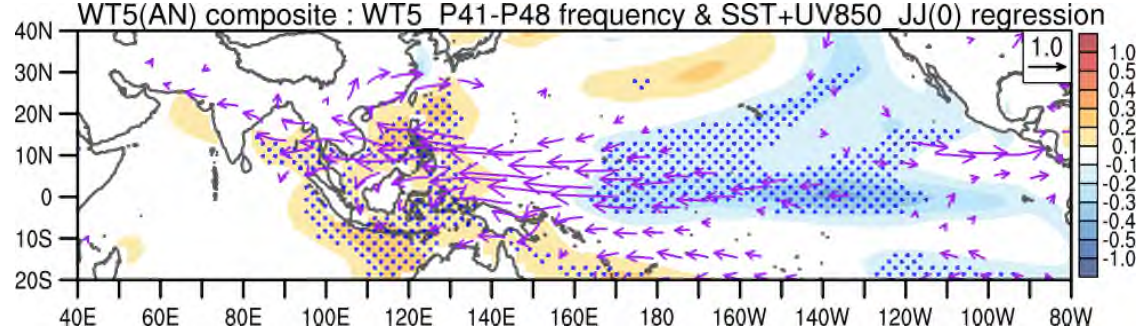
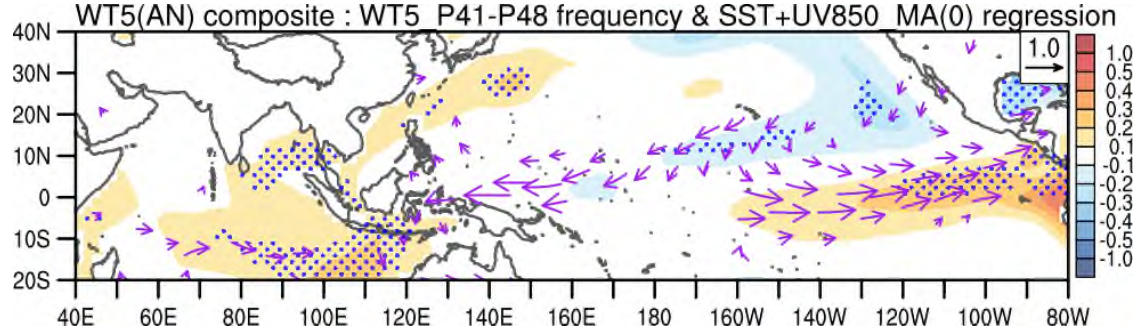
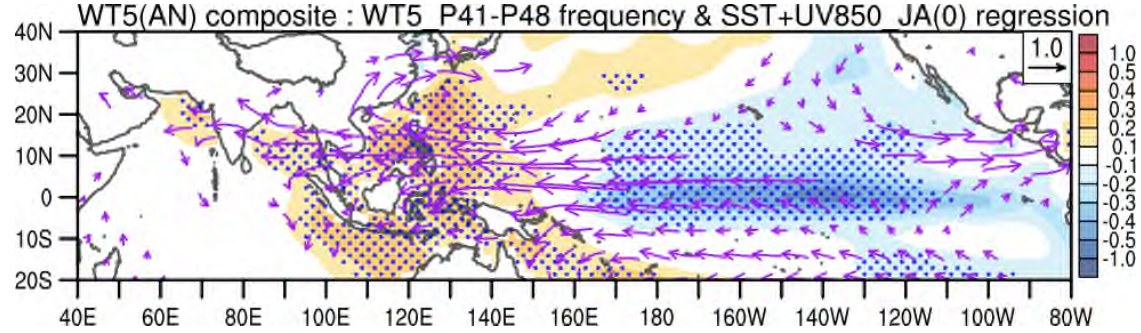

WT5(AN) composite : WT5_P41-P48 frequency & SST+UV850_JF(0) regression
1.0
40N 30N 20N 10N 0 10S 20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
1.0 0.5 0.4 0.3 0.2 0.1 -0.1 -0.2 -0.3 -0.4 -0.5 -1.0

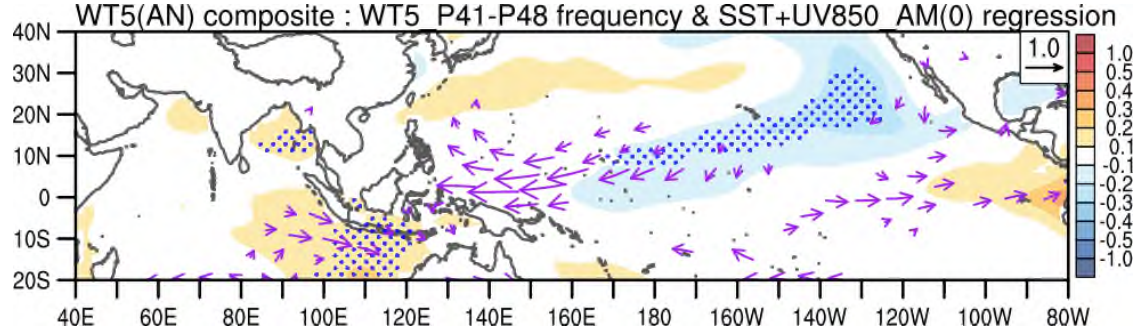

WT5(AN) composite : WT5_P41-P48 frequency & SST+UV850_MJ(0) regression
1.0
40N 30N 20N 10N 0 10S 20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
1.0 0.5 0.4 0.3 0.2 0.1 -0.1 -0.2 -0.3 -0.4 -0.5 -1.0

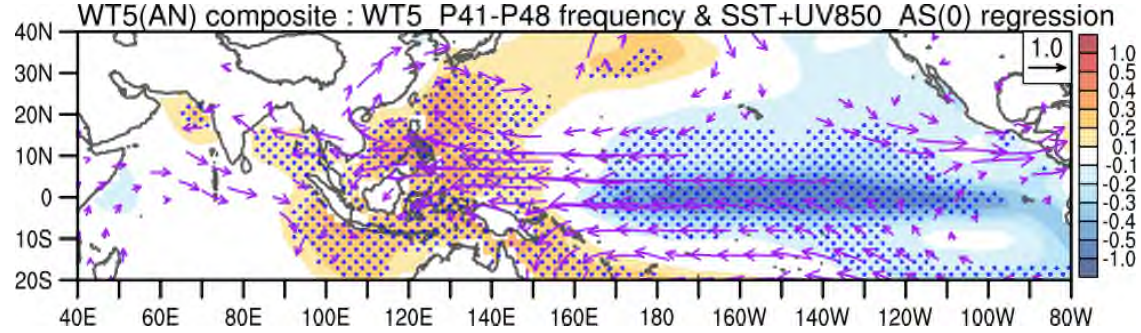

WT5(AN) composite : WT5_P41-P48 frequency & SST+UV850_FM(0) regression
1.0
40N 30N 20N 10N 0 10S 20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
1.0 0.5 0.4 0.3 0.2 0.1 -0.1 -0.2 -0.3 -0.4 -0.5 -1.0

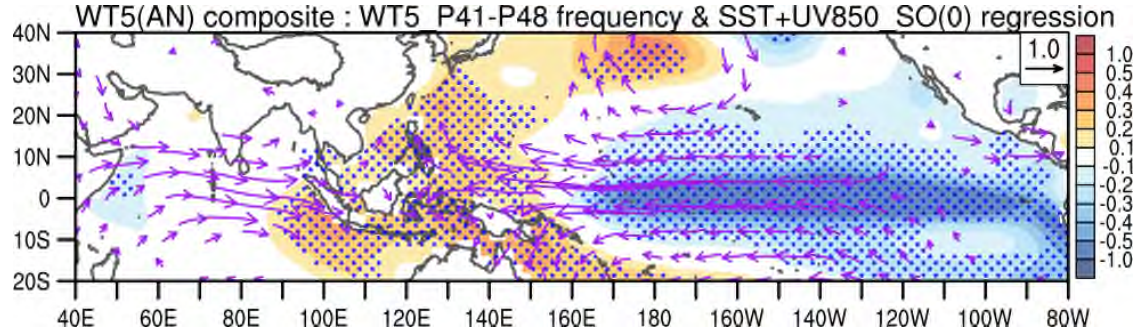

WT5(AN) composite : WT5_P41-P48 frequency & SST+UV850_JJ(0) regression
1.0
40N 30N 20N 10N 0 10S 20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
1.0 0.5 0.4 0.3 0.2 0.1 -0.1 -0.2 -0.3 -0.4 -0.5 -1.0

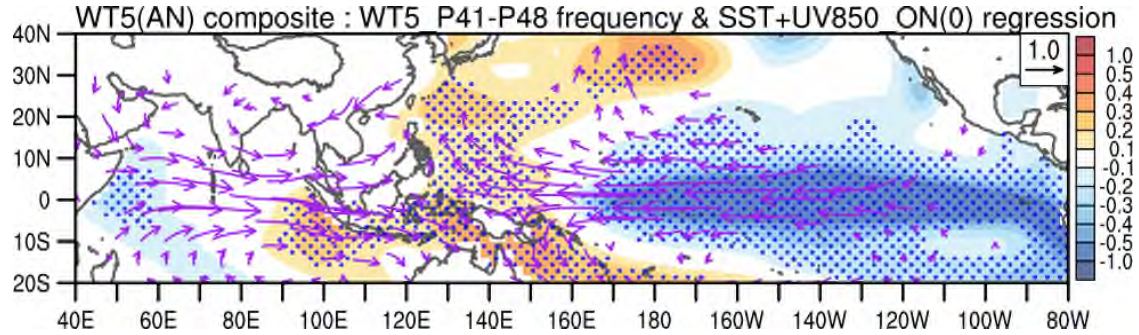

WT5(AN) composite : WT5_P41-P48 frequency & SST+UV850_MA(0) regression
1.0
40N 30N 20N 10N 0 10S 20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
1.0 0.5 0.4 0.3 0.2 0.1 -0.1 -0.2 -0.3 -0.4 -0.5 -1.0

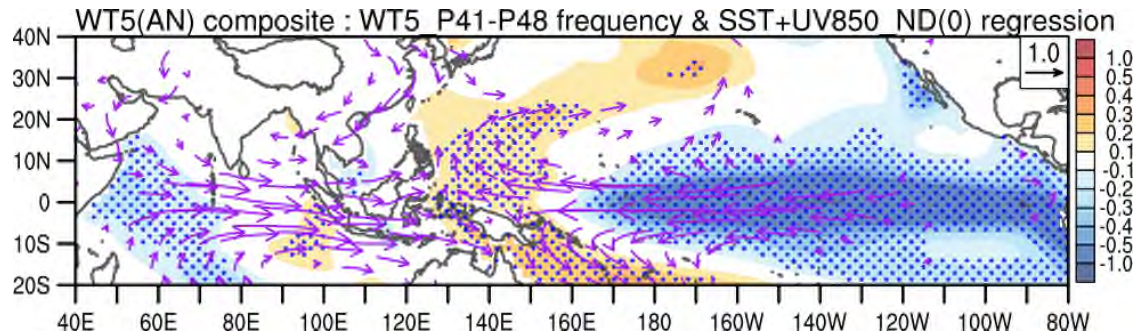

WT5(AN) composite : WT5_P41-P48 frequency & SST+UV850_JA(0) regression
1.0
40N 30N 20N 10N 0 10S 20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
1.0 0.5 0.4 0.3 0.2 0.1 -0.1 -0.2 -0.3 -0.4 -0.5 -1.0

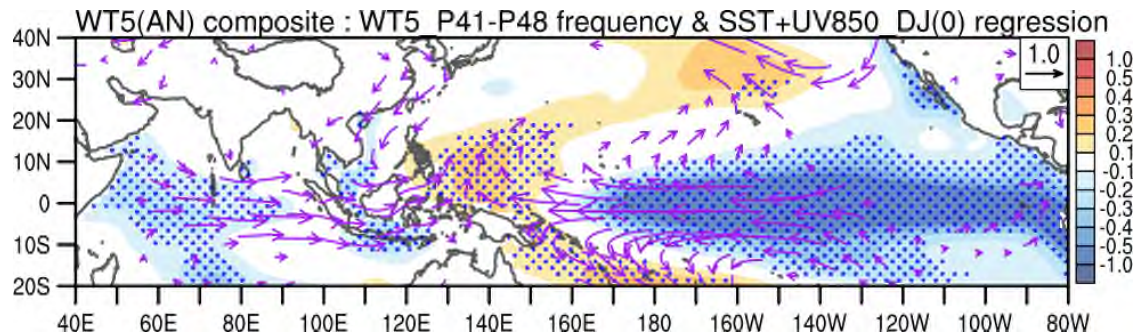

WT5(AN) composite : WT5_P41-P48 frequency & SST+UV850_AM(0) regression
1.0
40N 30N 20N 10N 0 10S 20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
1.0 0.5 0.4 0.3 0.2 0.1 -0.1 -0.2 -0.3 -0.4 -0.5 -1.0

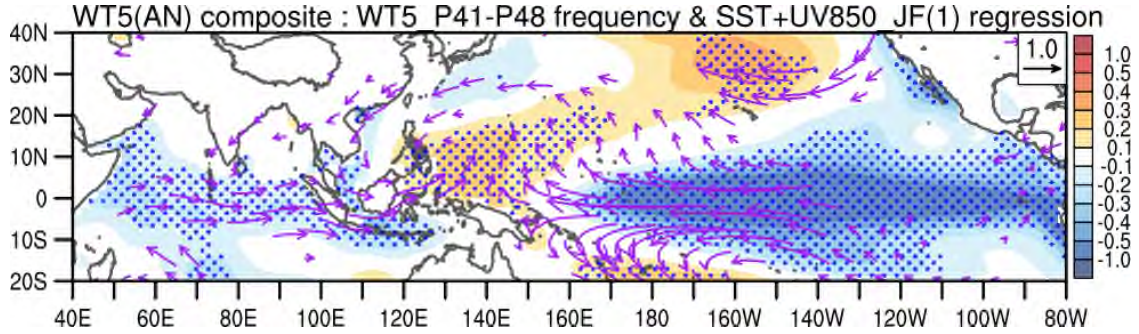

WT5(AN) composite : WT5_P41-P48 frequency & SST+UV850_AS(0) regression
1.0
40N 30N 20N 10N 0 10S 20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
1.0 0.5 0.4 0.3 0.2 0.1 -0.1 -0.2 -0.3 -0.4 -0.5 -1.0

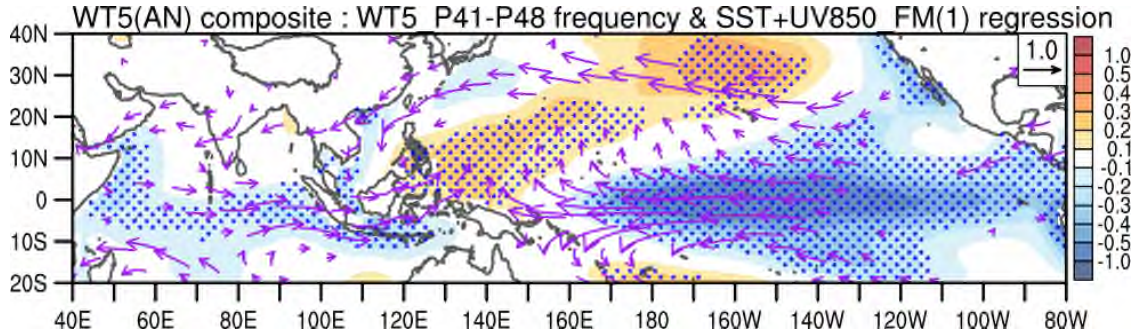

WT5(AN) composite : WT5_P41-P48 frequency & SST+UV850_SO(0) regression
1.0
40N 30N 20N 10N 0 10S 20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
1.0 0.5 0.4 0.3 0.2 0.1 -0.1 -0.2 -0.3 -0.4 -0.5 -1.0

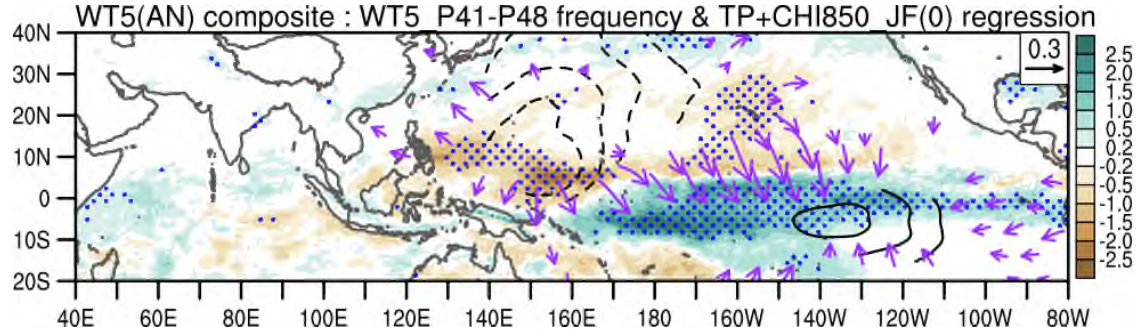

WT5(AN) composite : WT5_P41-P48 frequency & SST+UV850_ON(0) regression
1.0
40N 30N 20N 10N 0 10S 20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
1.0 0.5 0.4 0.3 0.2 0.1 -0.1 -0.2 -0.3 -0.4 -0.5 -1.0

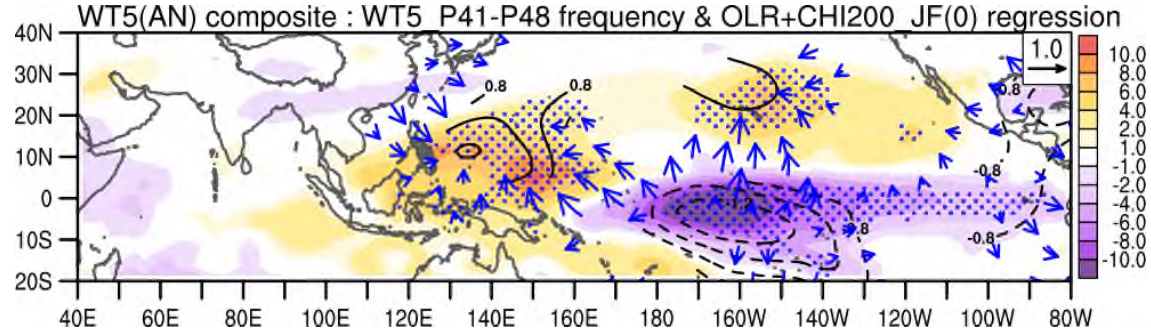

WT5(AN) composite : WT5_P41-P48 frequency & SST+UV850_ND(0) regression
1.0
40N 30N 20N 10N 0 10S 20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
1.0 0.5 0.4 0.3 0.2 0.1 -0.1 -0.2 -0.3 -0.4 -0.5 -1.0

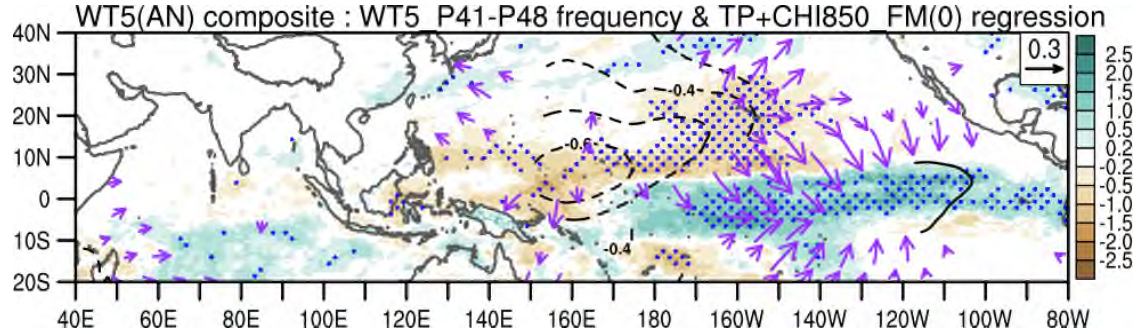

WT5(AN) composite : WT5_P41-P48 frequency & SST+UV850_DJ(0) regression
1.0
40N 30N 20N 10N 0 10S 20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
1.0 0.5 0.4 0.3 0.2 0.1 -0.1 -0.2 -0.3 -0.4 -0.5 -1.0

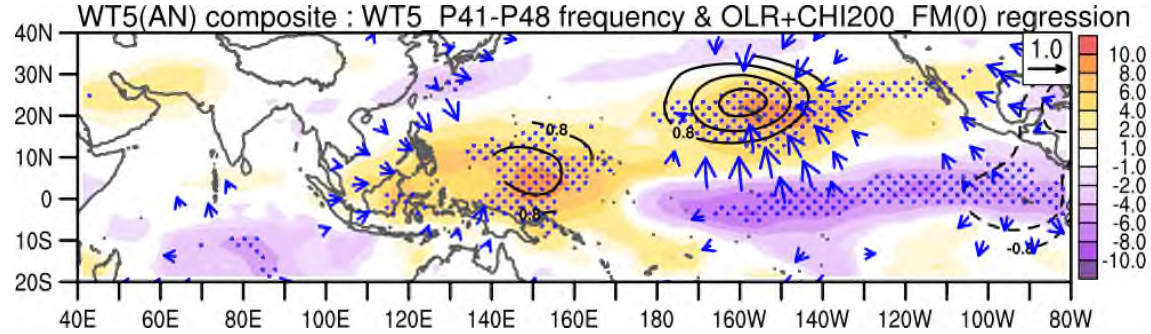

WT5(AN) composite : WT5_P41-P48 frequency & SST+UV850_JF(1) regression
1.0
40N 30N 20N 10N 0 10S 20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
1.0 0.5 0.4 0.3 0.2 0.1 -0.1 -0.2 -0.3 -0.4 -0.5 -1.0

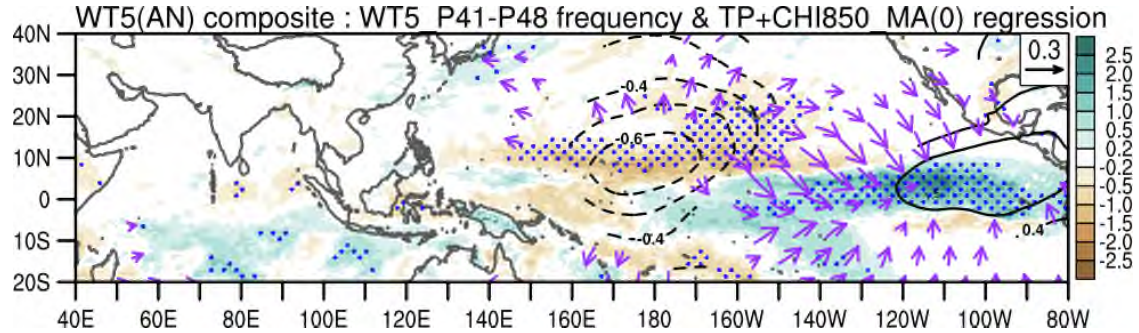

WT5(AN) composite : WT5_P41-P48 frequency & SST+UV850_FM(1) regression
1.0
40N 30N 20N 10N 0 10S 20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
1.0 0.5 0.4 0.3 0.2 0.1 -0.1 -0.2 -0.3 -0.4 -0.5 -1.0

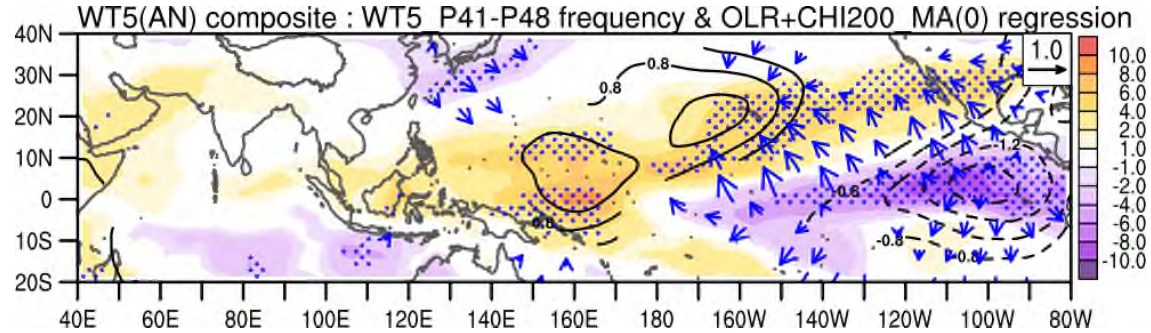

WT5(AN) composite : WT5_P41-P48 frequency & TP+CHI850_JF(0) regression
0.3
40N
30N
20N
10N
0
10S
20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
2.5 2.0 1.5 1.0 0.5 0.2 -0.2 -0.5 -1.0 -1.5 -2.0 -2.5

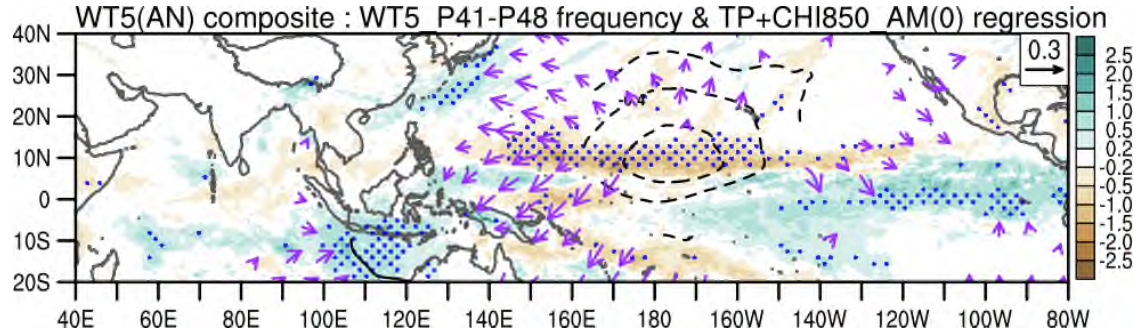

WT5(AN) composite : WT5_P41-P48 frequency & OLR+CHI200_JF(0) regression
1.0
0.8
-0.8
40N
30N
20N
10N
0
10S
20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
10.0 8.0 6.0 4.0 2.0 1.0 -1.0 -2.0 -4.0 -6.0 -8.0 -10.0

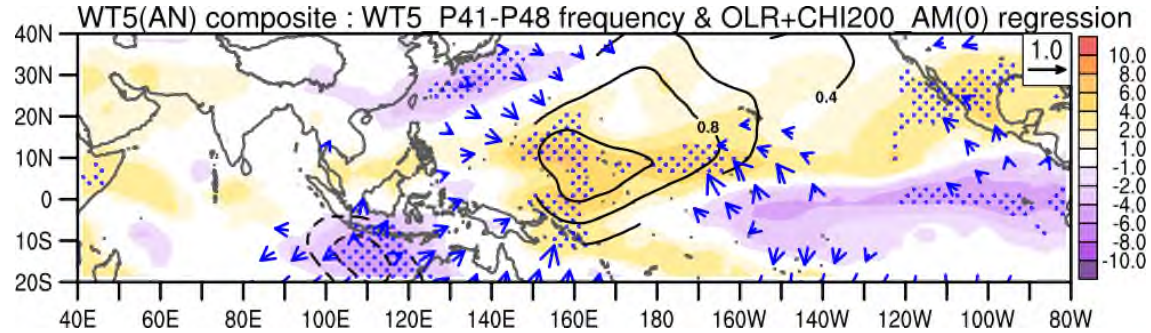

WT5(AN) composite : WT5_P41-P48 frequency & TP+CHI850_FM(0) regression
0.3
-0.4
-0.6
40N
30N
20N
10N
0
10S
20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
2.5 2.0 1.5 1.0 0.5 0.2 -0.2 -0.5 -1.0 -1.5 -2.0 -2.5

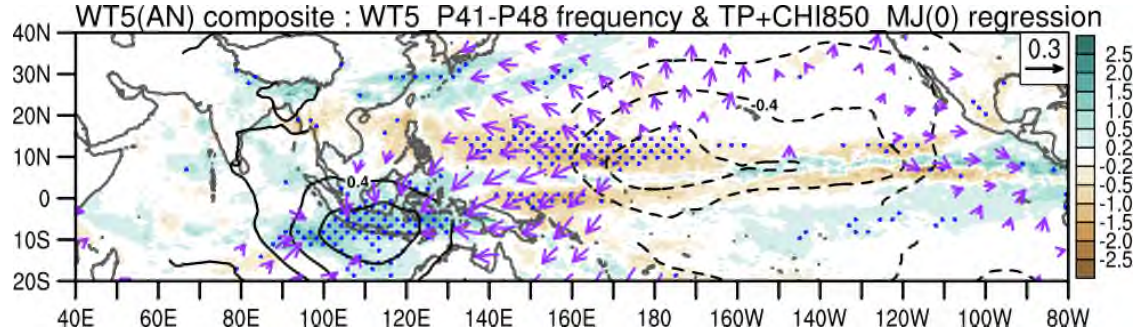

WT5(AN) composite : WT5_P41-P48 frequency & OLR+CHI200_FM(0) regression
1.0
0.8
-0.8
40N
30N
20N
10N
0
10S
20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
10.0 8.0 6.0 4.0 2.0 1.0 -1.0 -2.0 -4.0 -6.0 -8.0 -10.0

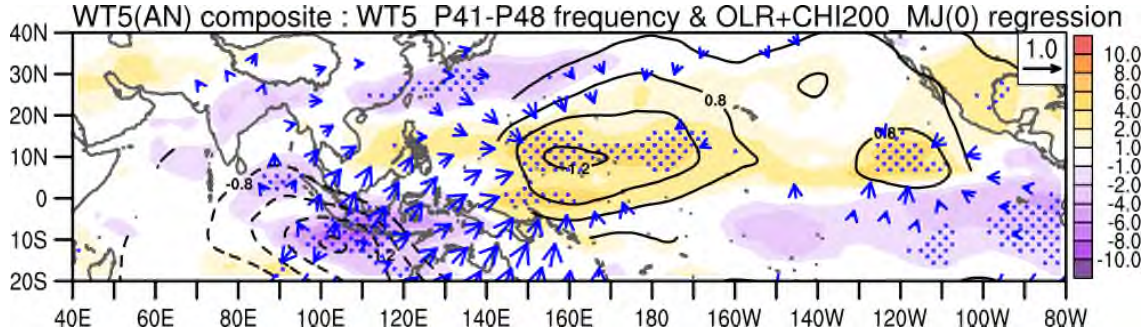

WT5(AN) composite : WT5_P41-P48 frequency & TP+CHI850_MA(0) regression
0.3
-0.4
-0.6
0.4
40N
30N
20N
10N
0
10S
20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
2.5 2.0 1.5 1.0 0.5 0.2 -0.2 -0.5 -1.0 -1.5 -2.0 -2.5

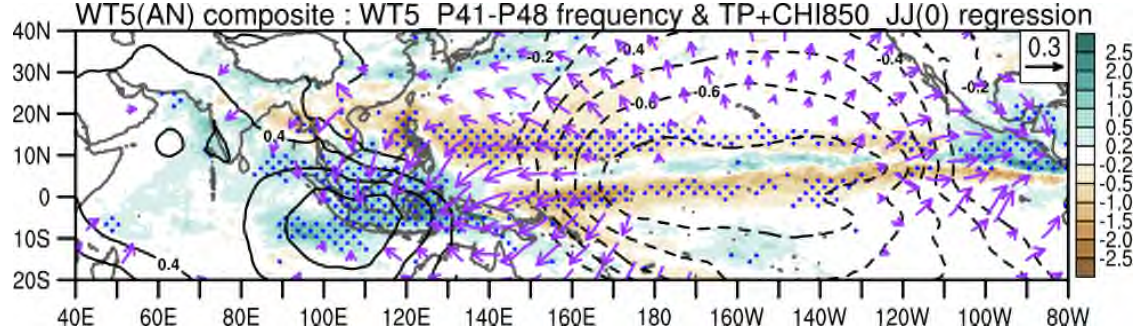

WT5(AN) composite : WT5_P41-P48 frequency & OLR+CHI200_MA(0) regression
1.0
0.8
-0.8
-1.2
40N
30N
20N
10N
0
10S
20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
10.0 8.0 6.0 4.0 2.0 1.0 -1.0 -2.0 -4.0 -6.0 -8.0 -10.0

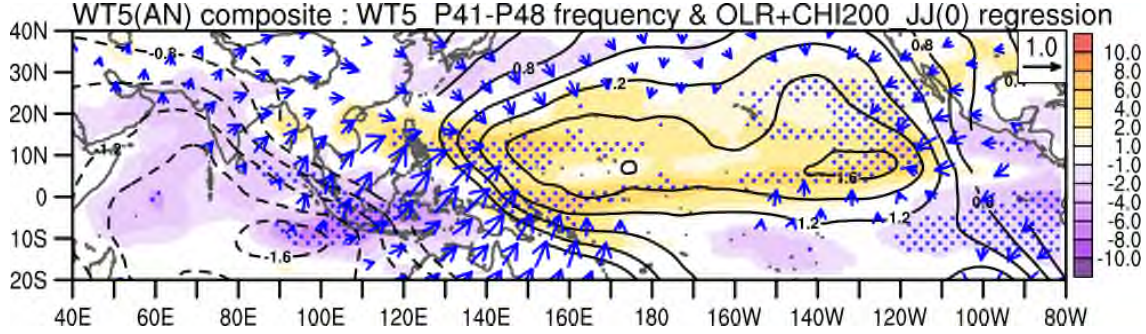

WT5(AN) composite : WT5_P41-P48 frequency & TP+CHI850_AM(0) regression
0.3
40N
30N
20N
10N
0
10S
20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
2.5 2.0 1.5 1.0 0.5 0.2 -0.2 -0.5 -1.0 -1.5 -2.0 -2.5

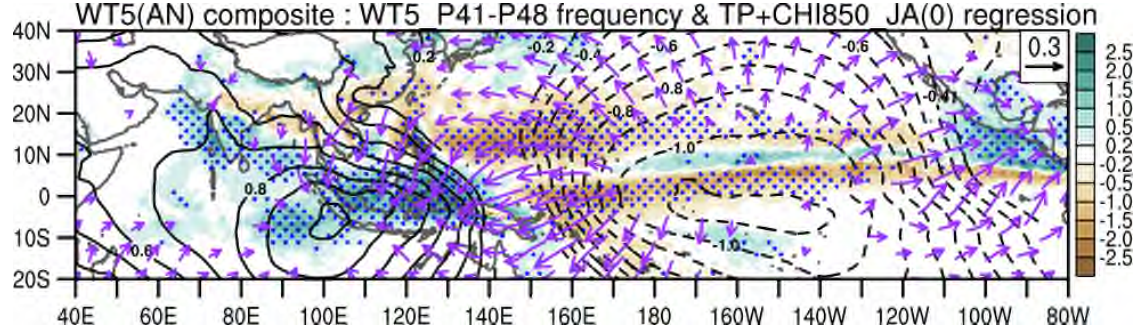

WT5(AN) composite : WT5_P41-P48 frequency & OLR+CHI200_AM(0) regression
1.0
0.4
0.8
40N
30N
20N
10N
0
10S
20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
10.0 8.0 6.0 4.0 2.0 1.0 -1.0 -2.0 -4.0 -6.0 -8.0 -10.0

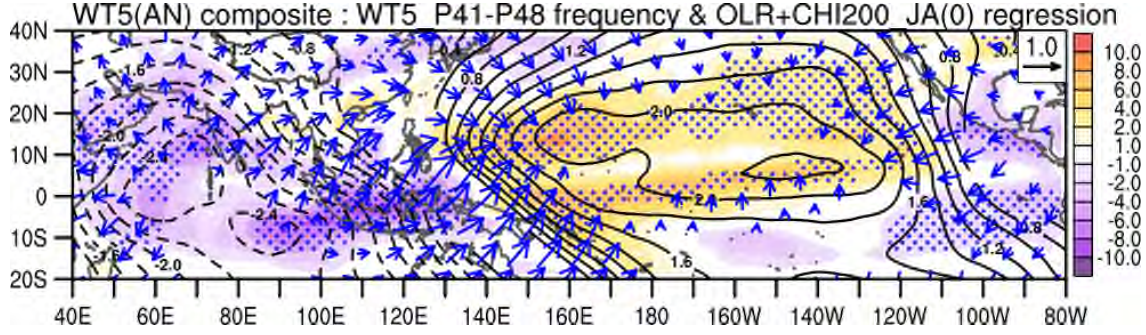

WT5(AN) composite : WT5_P41-P48 frequency & TP+CHI850_MJ(0) regression
0.3
40N
30N
20N
10N
0
10S
20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
2.5 2.0 1.5 1.0 0.5 0.2 -0.2 -0.5 -1.0 -1.5 -2.0 -2.5

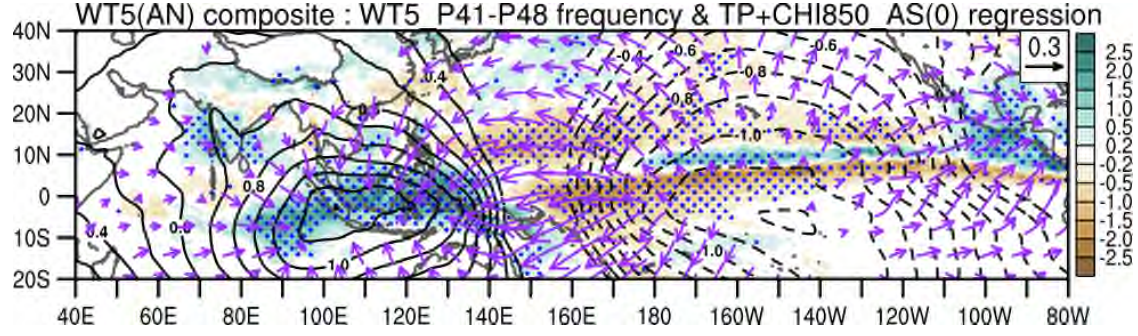

WT5(AN) composite : WT5_P41-P48 frequency & OLR+CHI200_MJ(0) regression
1.0
40N
30N
20N
10N
0
10S
20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
10.0 8.0 6.0 4.0 2.0 1.0 -1.0 -2.0 -4.0 -6.0 -8.0 -10.0

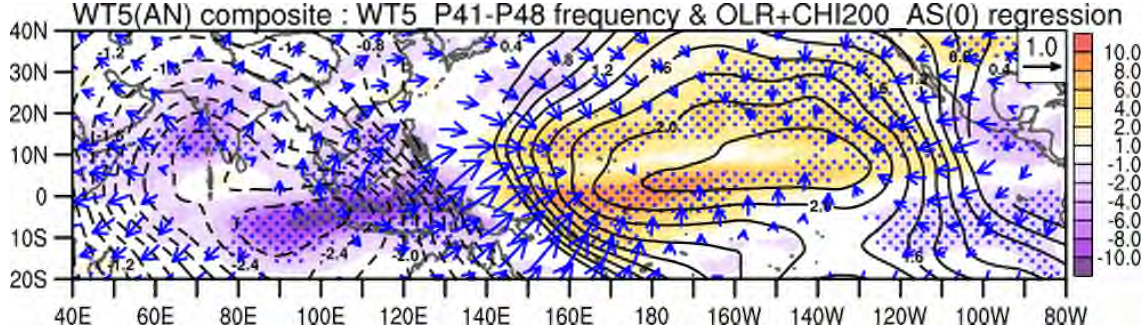

WT5(AN) composite : WT5_P41-P48 frequency & TP+CHI850_JJ(0) regression
0.3
40N
30N
20N
10N
0
10S
20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
2.5 2.0 1.5 1.0 0.5 0.2 -0.2 -0.5 -1.0 -1.5 -2.0 -2.5

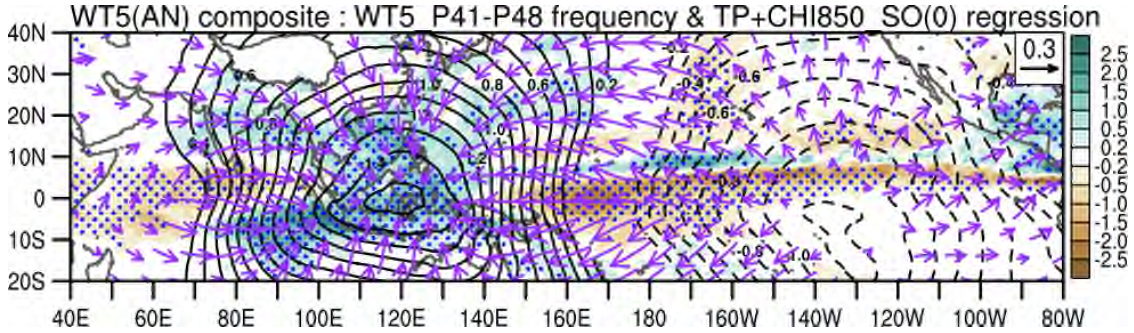

WT5(AN) composite : WT5_P41-P48 frequency & OLR+CHI200_JJ(0) regression
1.0
40N
30N
20N
10N
0
10S
20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
10.0 8.0 6.0 4.0 2.0 1.0 -1.0 -2.0 -4.0 -6.0 -8.0 -10.0

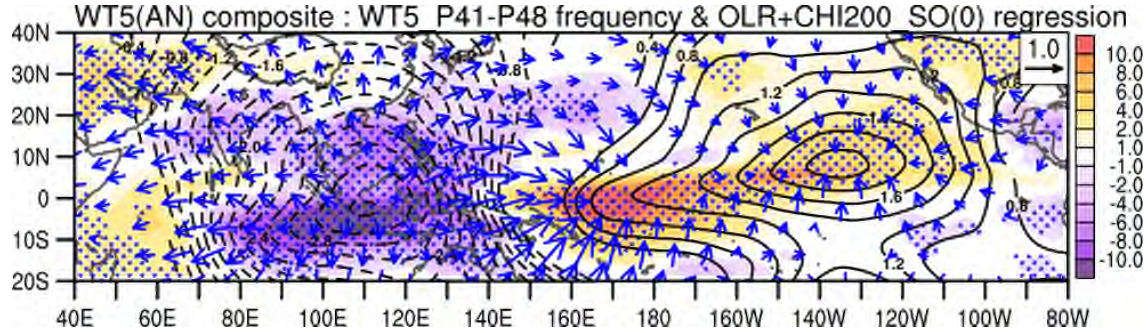

WT5(AN) composite : WT5_P41-P48 frequency & TP+CHI850_JA(0) regression
0.3
40N
30N
20N
10N
0
10S
20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
2.5 2.0 1.5 1.0 0.5 0.2 -0.2 -0.5 -1.0 -1.5 -2.0 -2.5

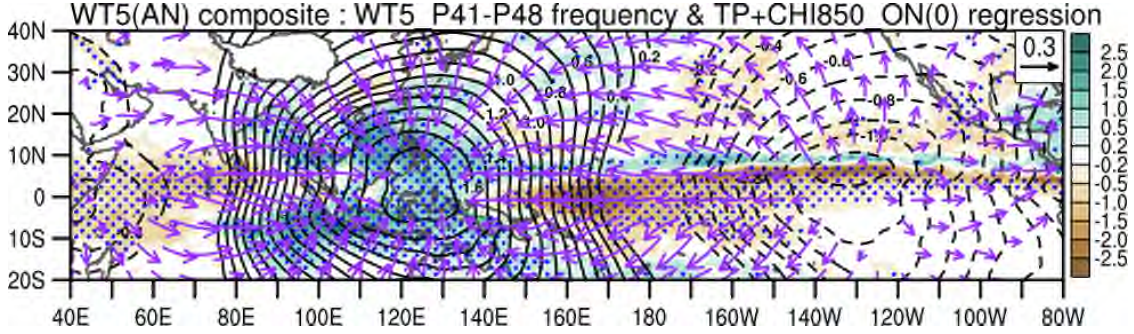

WT5(AN) composite : WT5_P41-P48 frequency & OLR+CHI200_JA(0) regression
1.0
40N
30N
20N
10N
0
10S
20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
10.0 8.0 6.0 4.0 2.0 1.0 -1.0 -2.0 -4.0 -6.0 -8.0 -10.0

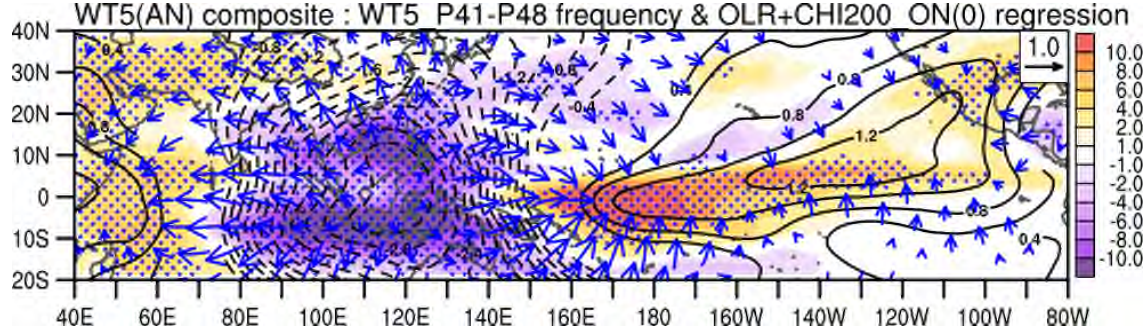

WT5(AN) composite : WT5_P41-P48 frequency & TP+CHI850_AS(0) regression
0.3
40N
30N
20N
10N
0
10S
20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
2.5 2.0 1.5 1.0 0.5 0.2 -0.2 -0.5 -1.0 -1.5 -2.0 -2.5

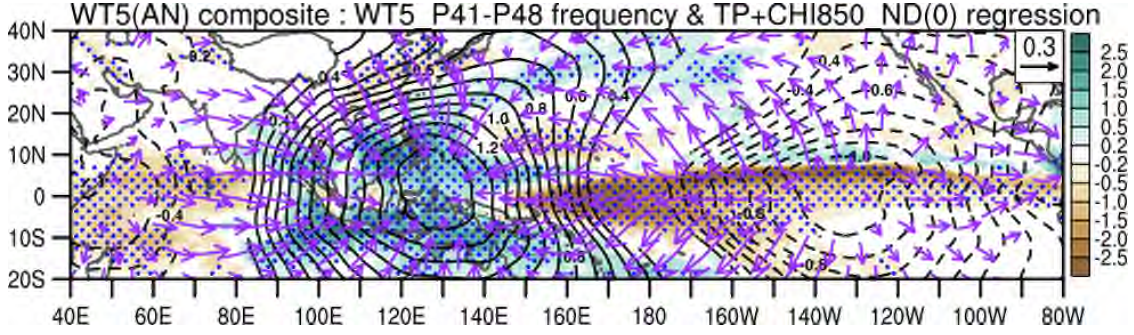

WT5(AN) composite : WT5_P41-P48 frequency & OLR+CHI200_AS(0) regression
1.0
40N
30N
20N
10N
0
10S
20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
10.0 8.0 6.0 4.0 2.0 1.0 -1.0 -2.0 -4.0 -6.0 -8.0 -10.0

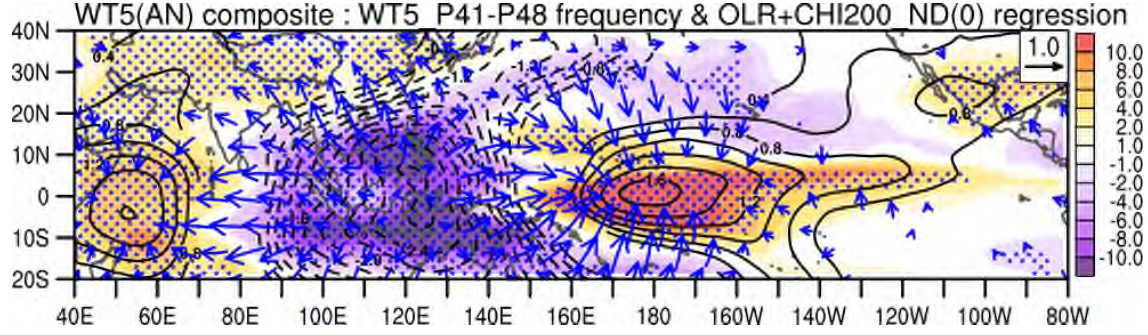

WT5(AN) composite : WT5_P41-P48 frequency & TP+CHI850_SO(0) regression
0.3
40N
30N
20N
10N
0
10S
20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
2.5 2.0 1.5 1.0 0.5 0.2 -0.2 -0.5 -1.0 -1.5 -2.0 -2.5

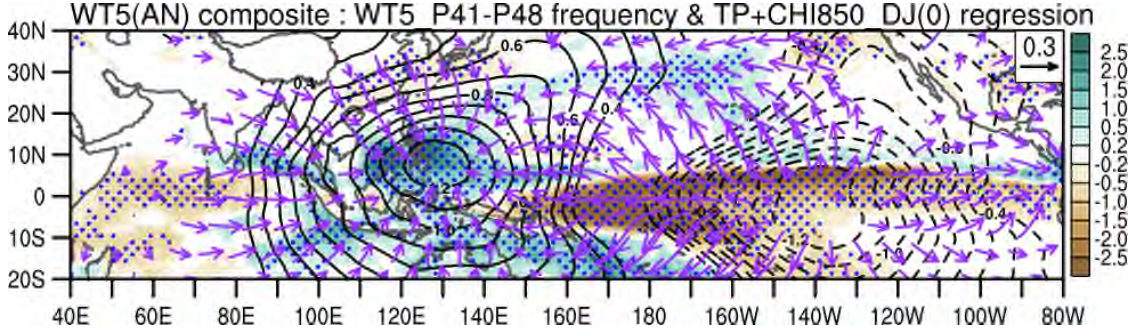

WT5(AN) composite : WT5_P41-P48 frequency & OLR+CHI200_SO(0) regression
1.0
40N
30N
20N
10N
0
10S
20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
10.0 8.0 6.0 4.0 2.0 1.0 -1.0 -2.0 -4.0 -6.0 -8.0 -10.0

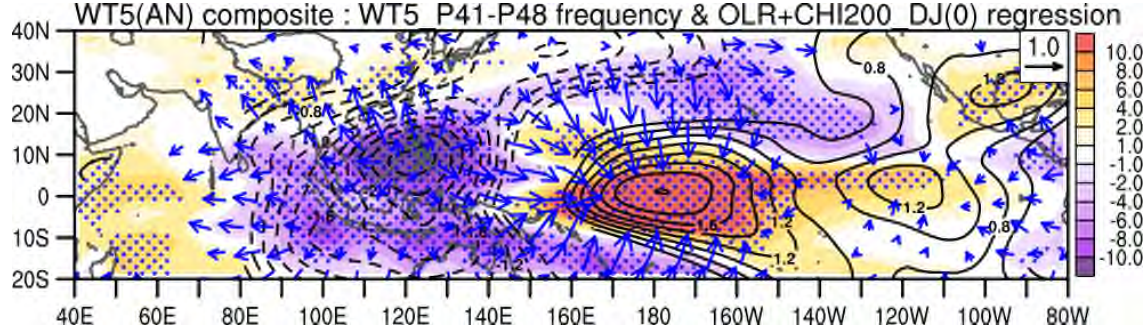

WT5(AN) composite : WT5_P41-P48 frequency & TP+CHI850_ON(0) regression
0.3
40N
30N
20N
10N
0
10S
20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
2.5 2.0 1.5 1.0 0.5 0.2 -0.2 -0.5 -1.0 -1.5 -2.0 -2.5

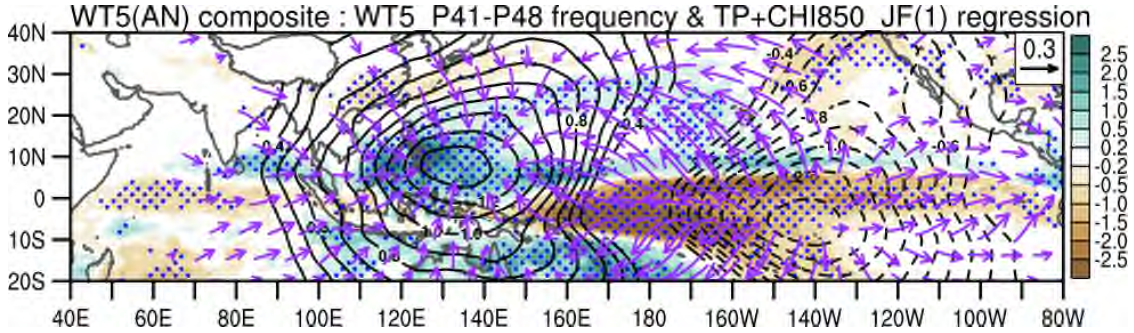

WT5(AN) composite : WT5_P41-P48 frequency & OLR+CHI200_ON(0) regression
1.0
40N
30N
20N
10N
0
10S
20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
10.0 8.0 6.0 4.0 2.0 1.0 -1.0 -2.0 -4.0 -6.0 -8.0 -10.0

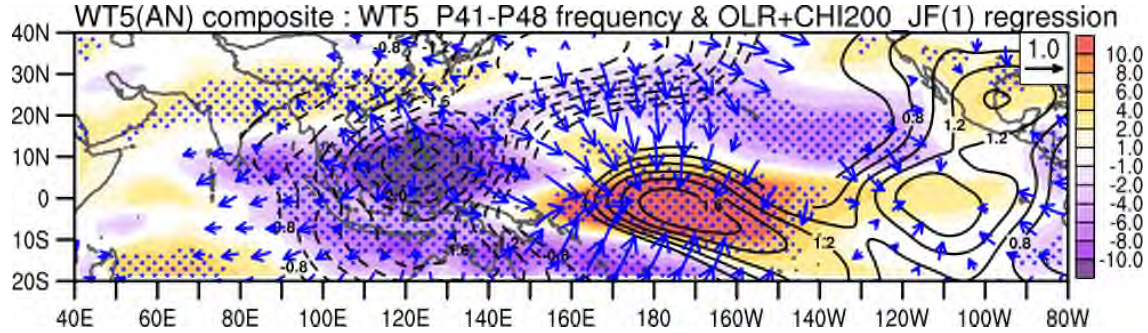

WT5(AN) composite : WT5_P41-P48 frequency & TP+CHI850_ND(0) regression
0.3
40N
30N
20N
10N
0
10S
20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
2.5 2.0 1.5 1.0 0.5 0.2 -0.2 -0.5 -1.0 -1.5 -2.0 -2.5

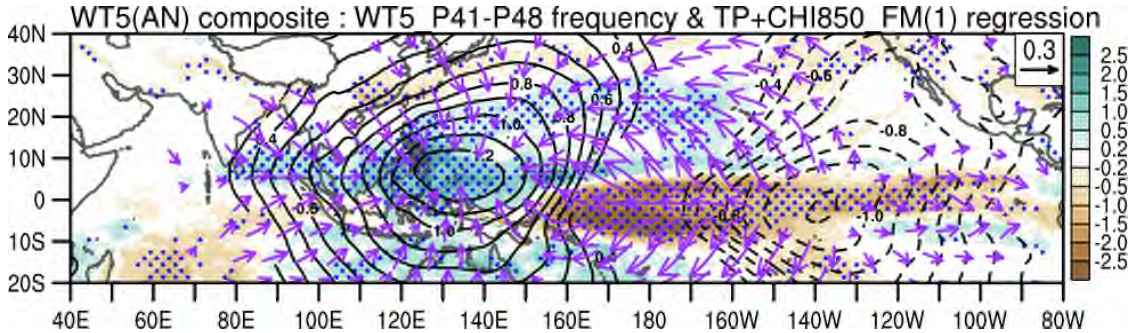

WT5(AN) composite : WT5_P41-P48 frequency & OLR+CHI200_ND(0) regression
1.0
40N
30N
20N
10N
0
10S
20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
10.0 8.0 6.0 4.0 2.0 1.0 -1.0 -2.0 -4.0 -6.0 -8.0 -10.0

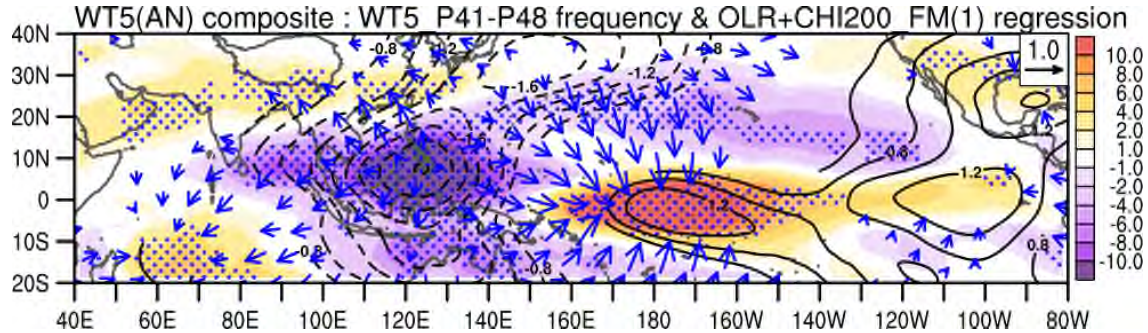

WT5(AN) composite : WT5_P41-P48 frequency & TP+CHI850_DJ(0) regression
0.3
40N
30N
20N
10N
0
10S
20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
2.5 2.0 1.5 1.0 0.5 0.2 -0.2 -0.5 -1.0 -1.5 -2.0 -2.5


WT5(AN) composite : WT5_P41-P48 frequency & OLR+CHI200_DJ(0) regression
1.0
40N
30N
20N
10N
0
10S
20S
40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W
10.0 8.0 6.0 4.0 2.0 1.0 -1.0 -2.0 -4.0 -6.0 -8.0 -10.0


WT5(AN) composite : WT5_P41-P48 frequency & TP+CHI850_JF(1) regression
0.3
40N
30N
20N
10N
0
10S
20S
40E
60E
80E
100E
120E
140E
160E
180
160W
140W
120W
100W
80W


WT5(AN) composite : WT5_P41-P48 frequency & OLR+CHI200_JF(1) regression
1.0
40N
30N
20N
10N
0
10S
20S
40E
60E
80E
100E
120E
140E
160E
180
160W
140W
120W
100W
80W


WT5(AN) composite : WT5_P41-P48 frequency & TP+CHI850_FM(1) regression
0.3
40N
30N
20N
10N
0
10S
20S
40E
60E
80E
100E
120E
140E
160E
180
160W
140W
120W
100W
80W


WT5(AN) composite : WT5_P41-P48 frequency & OLR+CHI200_FM(1) regression
1.0
40N
30N
20N
10N
0
10S
20S
40E
60E
80E
100E
120E
140E
160E
180
160W
140W
120W
100W
80W