The Quasi Climatological Intrastasonal Oscillation over the South China Sea and Its Relationship with Summer Monsoon Onset and MJO

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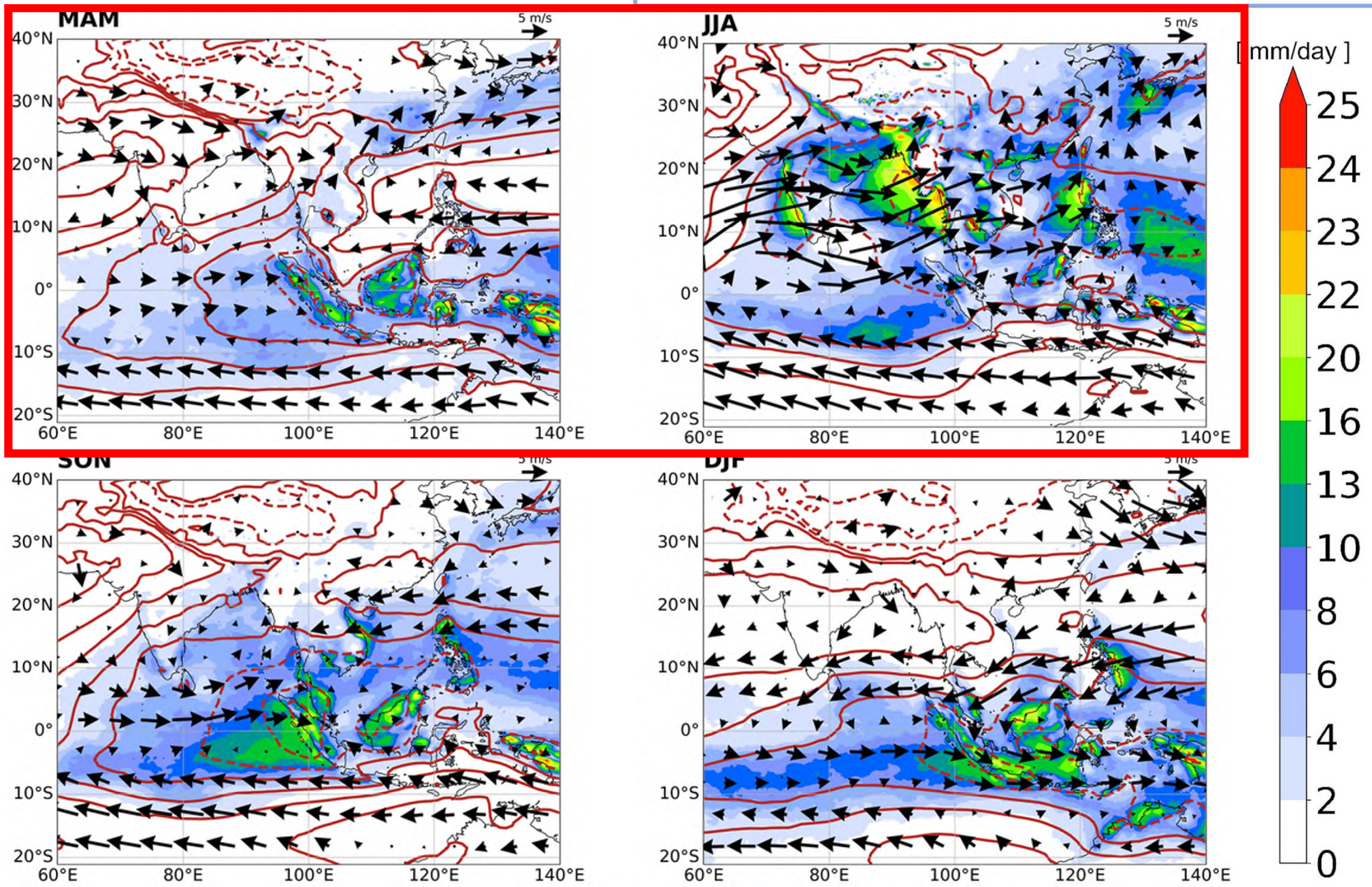
Outlines

1. Introduction
2. Motivation and Objectives
3. Results
   - CISO over the SCS
   - Quasi-CISO “normal” years
   - The feasibility of using quasi-CISO valley pentad to represent the SCSSM onset
   - MJO influence on quasi-CISO and SCSSM onset
   - MJO and convectively coupled equatorial waves
4. Conclusion

Introduction Climatology Map

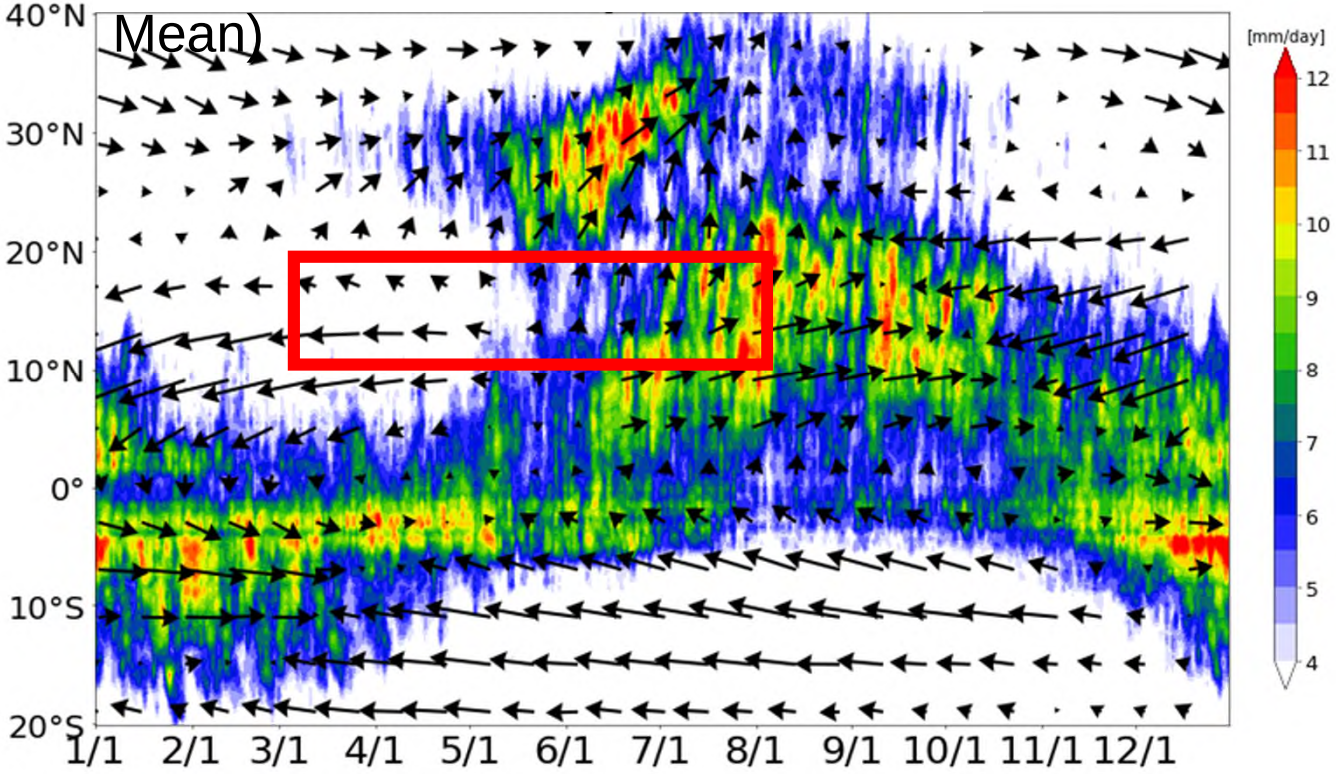
Vector: 1979-2023 850hPa Wind Contour: 1979-2023 OLR
Shaded: 1998-2023 Precipitation (≧235 W m^2: ——— ; <235 W m^2: - - -)



Introduction

Annual Cycle and CISO

Cross-section (100°-140°E Mean)



Vector: 1979~2023 850hPa Wind
Shaded: 1998~2023 Precipitation

annual cycle

Chou et al. 2009; LinHo and Wang 2002

climatological intraseasonal oscillations (CISOs)

Jin et al. 2024; Li et al. 2021; Song et al. 2016; Suhas and Goswami 2008; Wang and Xu 1997

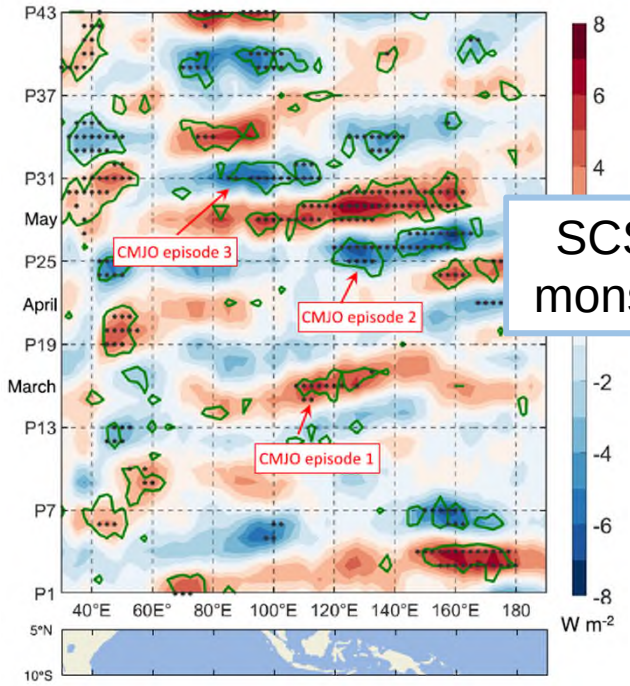
The fast annual cycle
LinHo and Wang 2002

Motivation and Objectives

Motivation

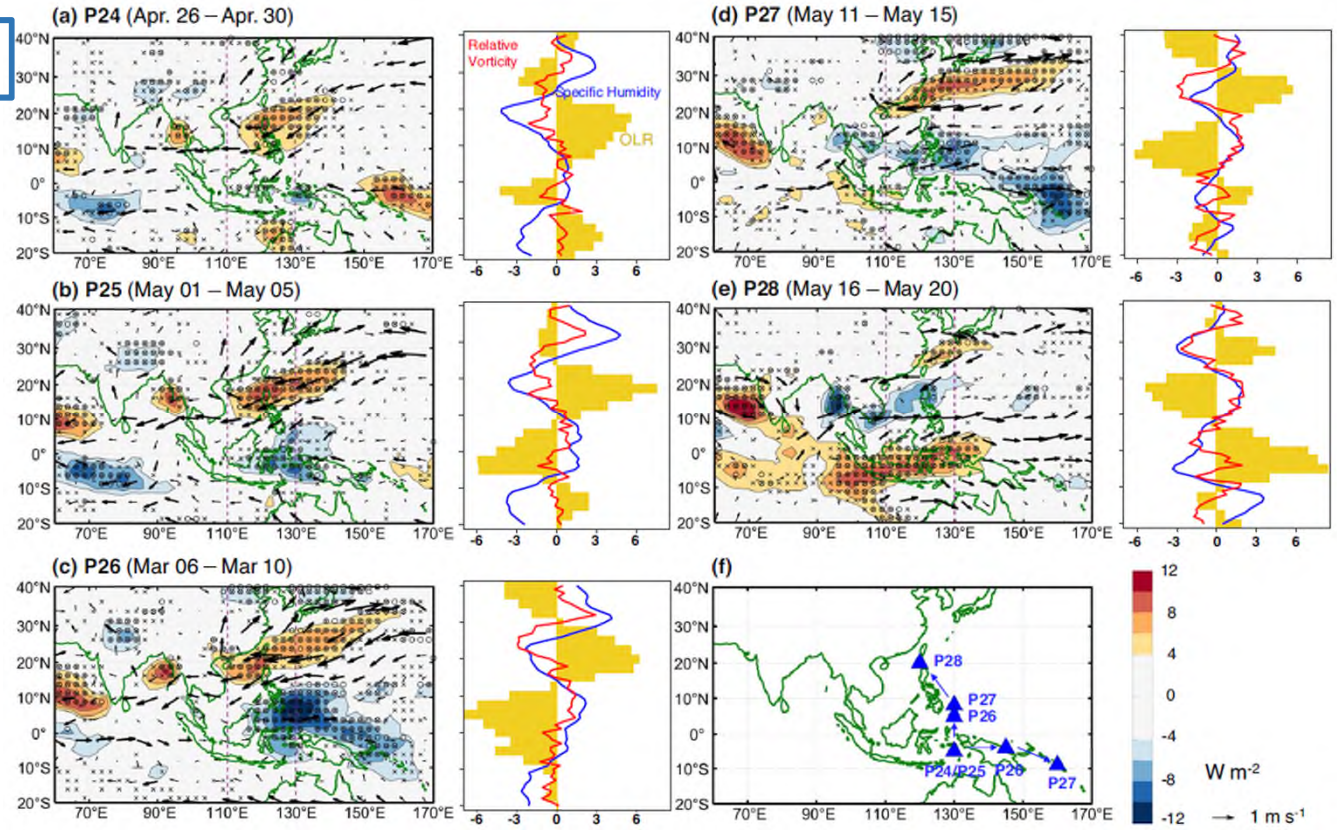
Wang et al. (2024)

The CMJO's eastward propagation along the equator



SCS summer monsoon onset

The CMJO episode triggering the SCSSM onset



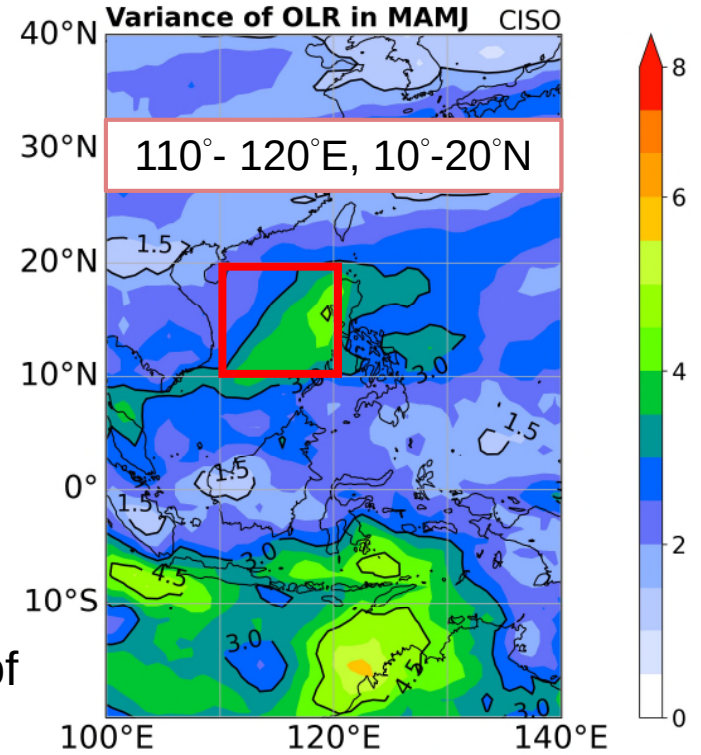
Objectives

- Can the ISO or MJO similar to the CISO be identified in individual years? If yes, such ISO will be called quasi-CISO.
- What is the relationship between quasi-CISO, the SCSSM onset and MJO?

Data and Methodology

Data OLR (NOAA), Precipitation (GPCP, CMORPH), UV850 (ERA-5), RMM index (BoM)

The CISO and quasi-CISO the time series of OLR data



1. CISO and climate singularity Wang and Xu (1997)

2. quasi-CISO

the time series of the average OLR over the South China Sea and identified the oscillation pattern as quasi-CISO.

3. quasi-CISO normal years

the occurrence time of the peak and valley of a quasi-CISO is similar to the CISO.

4. quasi-CISO and SCSSM onset

compared the 850-hPa zonal wind index (Wang et al. 2004) and the convective phase of quasi-CISO during the normal years

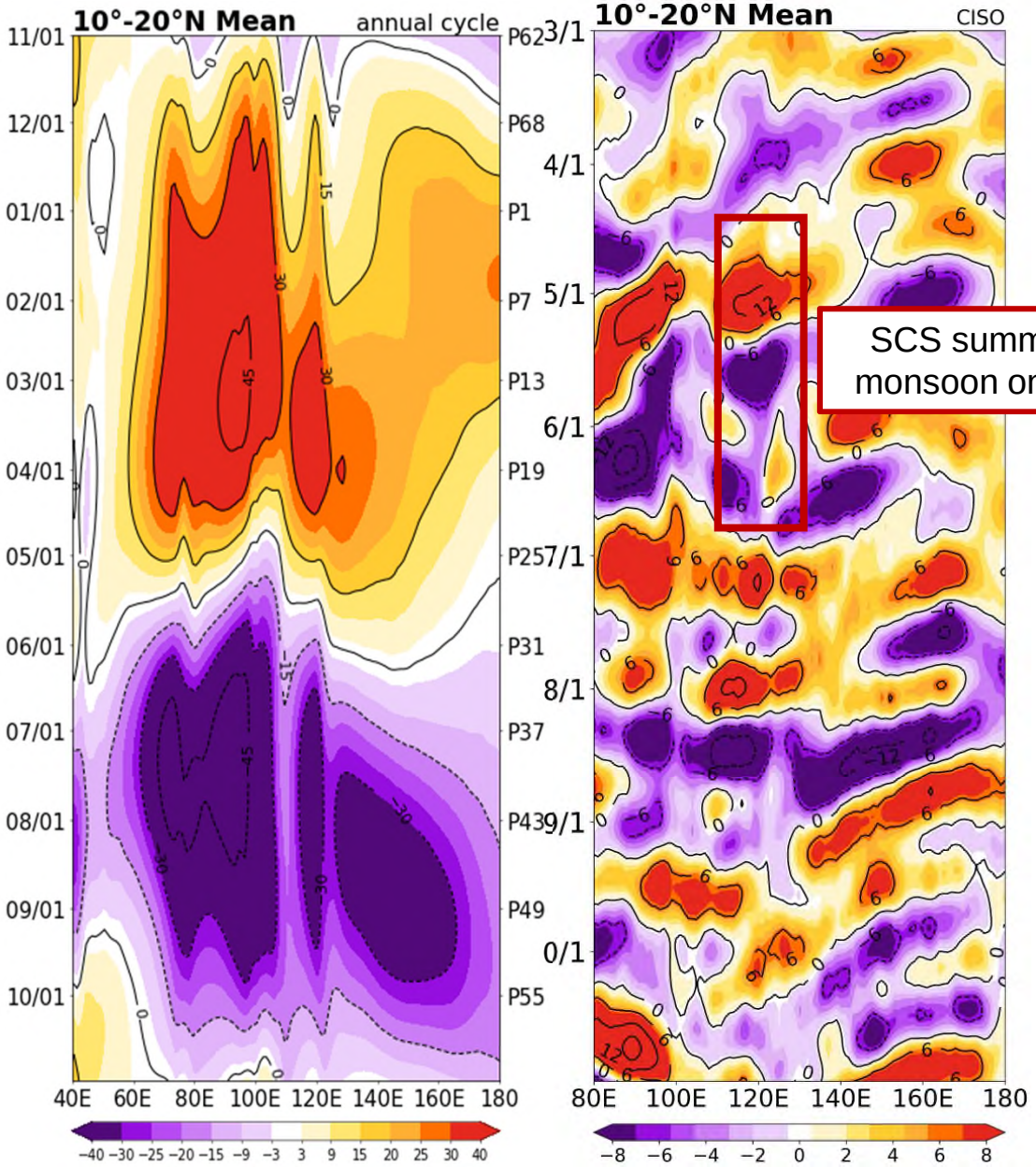
5. MJO relationship with quasi-CISO and SCSSM onset

The MJO strength and phases are investigated to find out to what extent the CISO can be interpreted as a result of **transient MJO phase lock to annual cycle**.

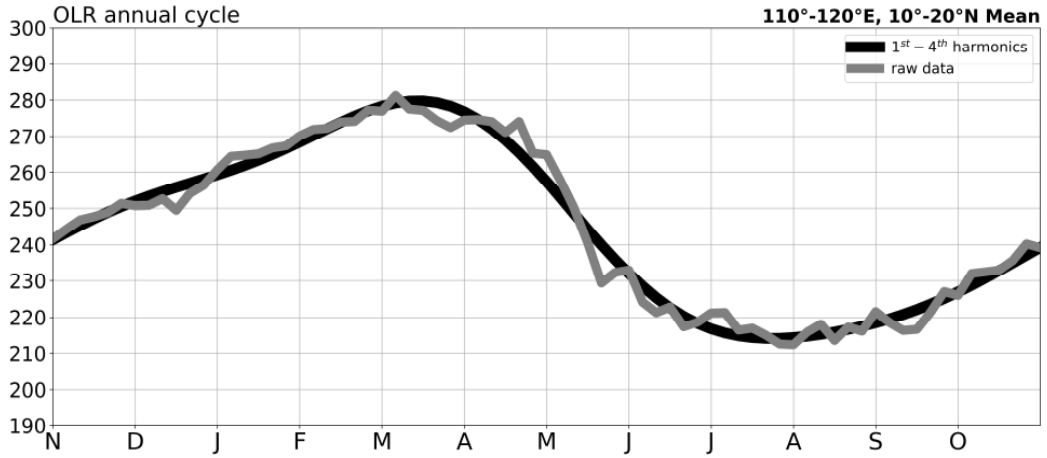
CISO over the SCS

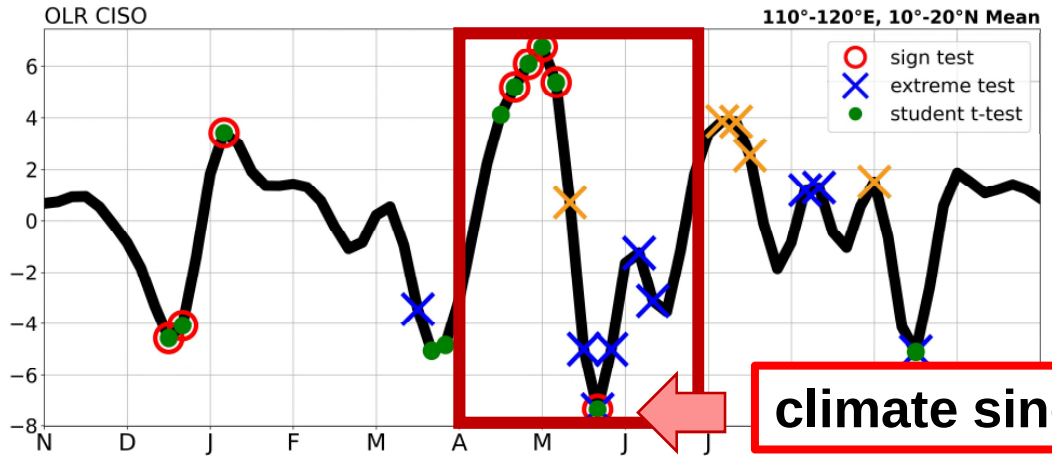
1st-4th harmonics

5th-18th harmonics



SCS summer monsoon onset





climate singularity

Shaded: 1980~2023 OLR daily climatology

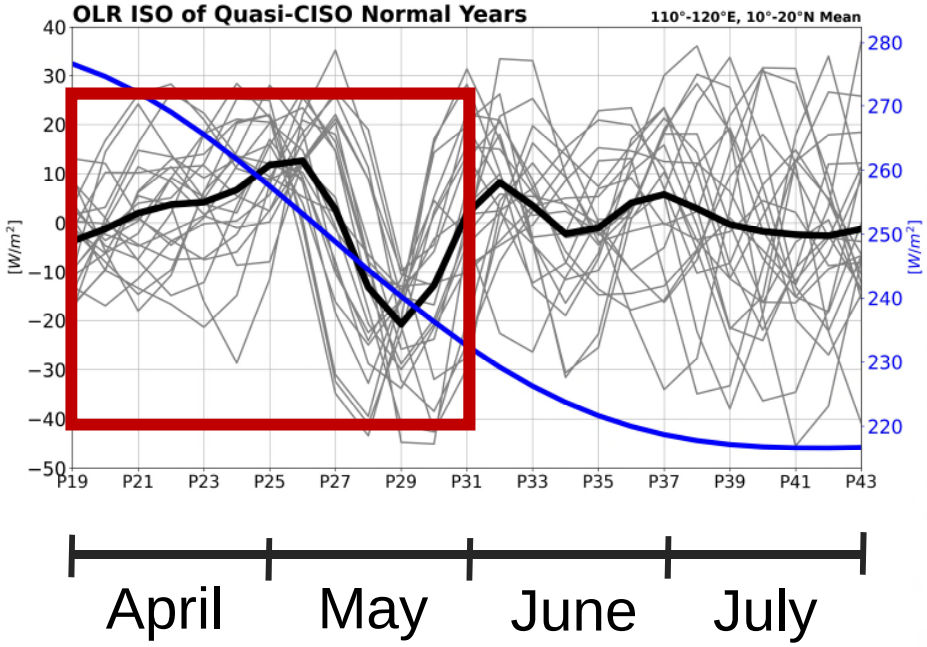
Quasi-CISO “normal” years

Vector: 850hPa Wind
Shaded: Precipitation

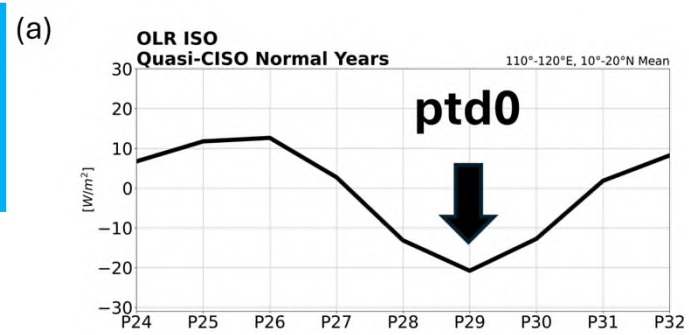
Red arrow: statistically significant areas based on T-test ($p<0.05$)
Stippling: statistically significant areas based on the Monte Carlo method ($p<0.05$)

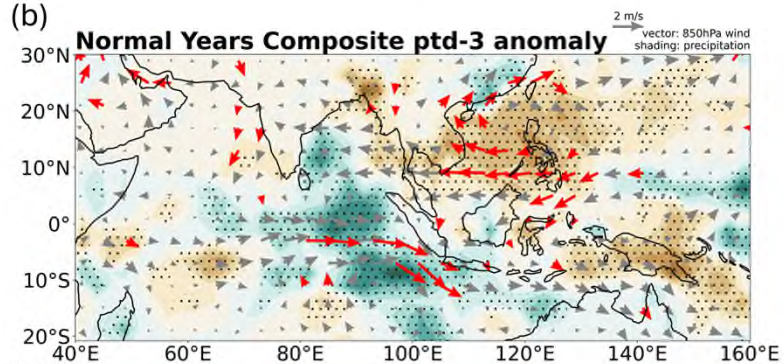
quasi-CISO normal years

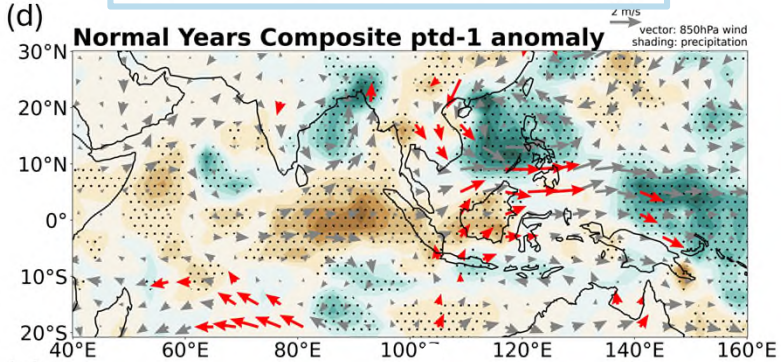
We identified 22 years in which the quasi-CISOs closely resemble the CISO

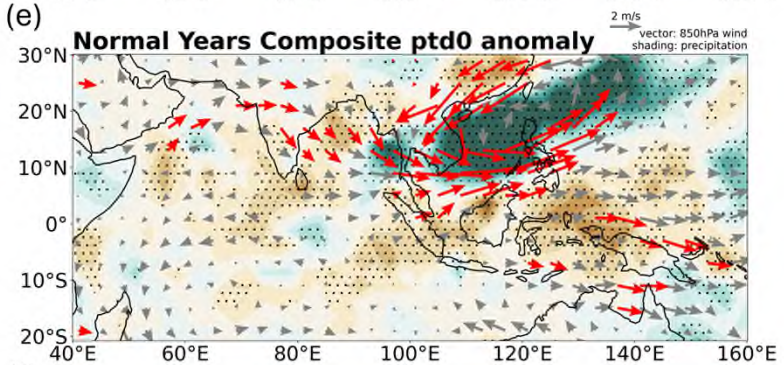


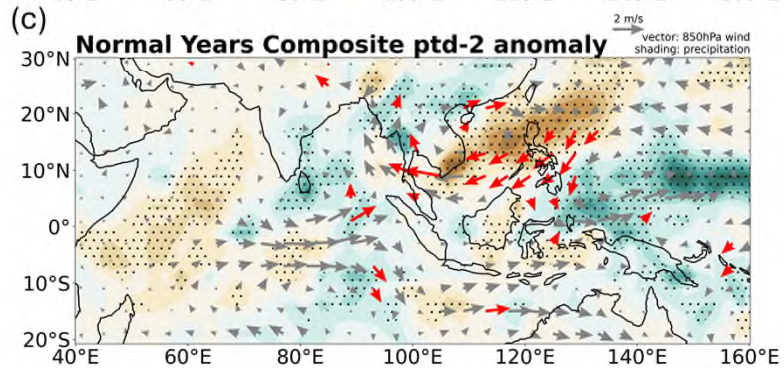
: 22-year ISO mean
: raw ISO
: 22-year annual cycle mean

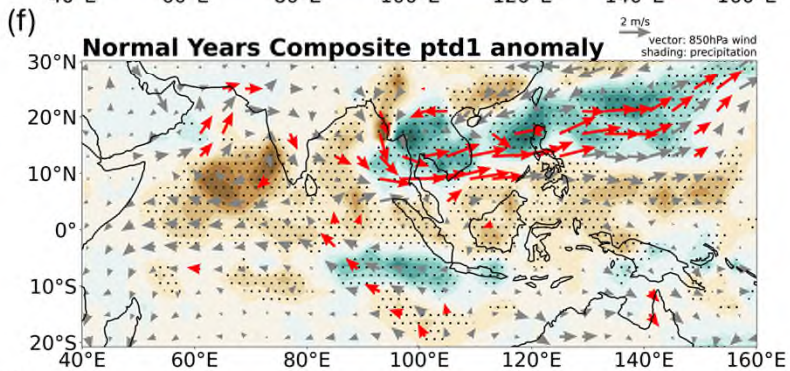




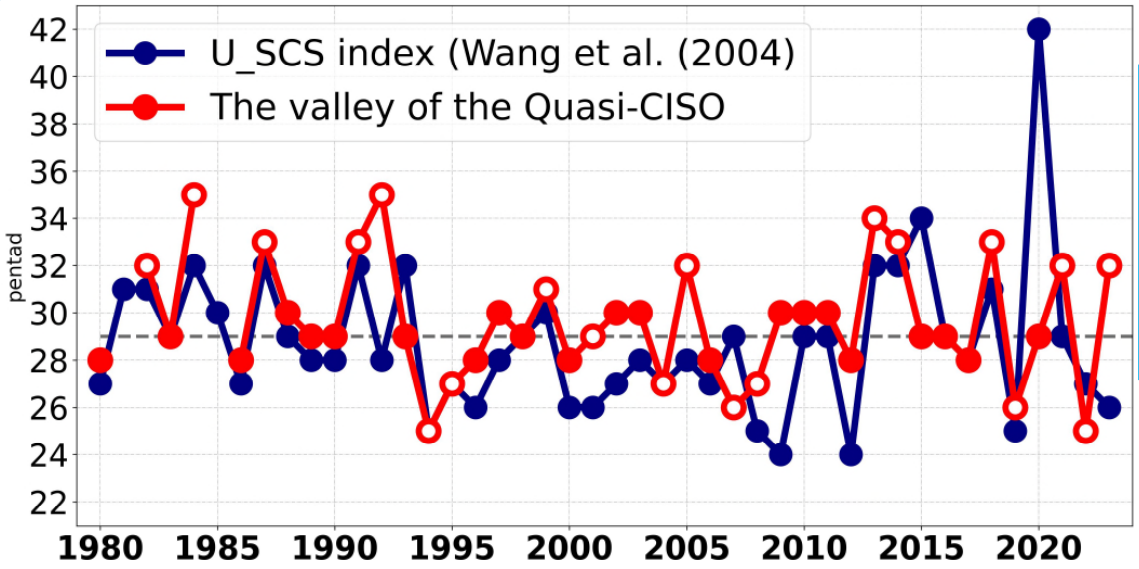






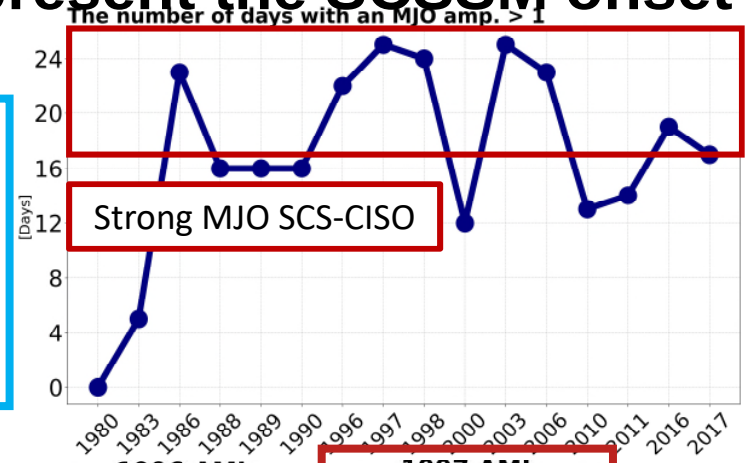


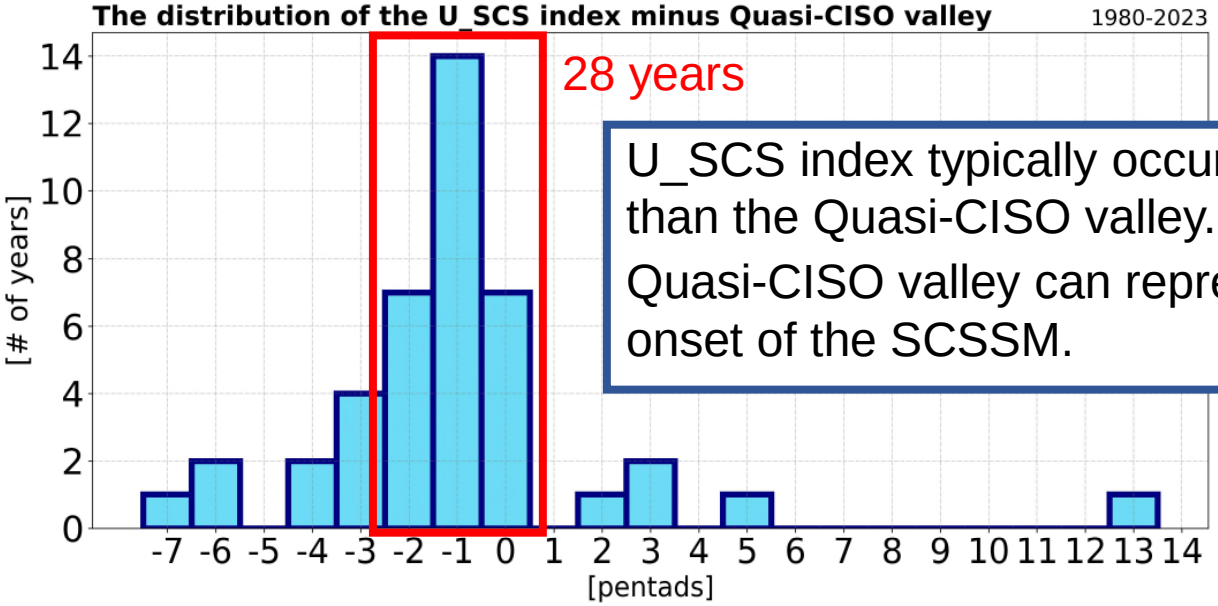
The feasibility of using quasi-CISO valley pentad to represent the SCSSM onset



SCS-CISO years

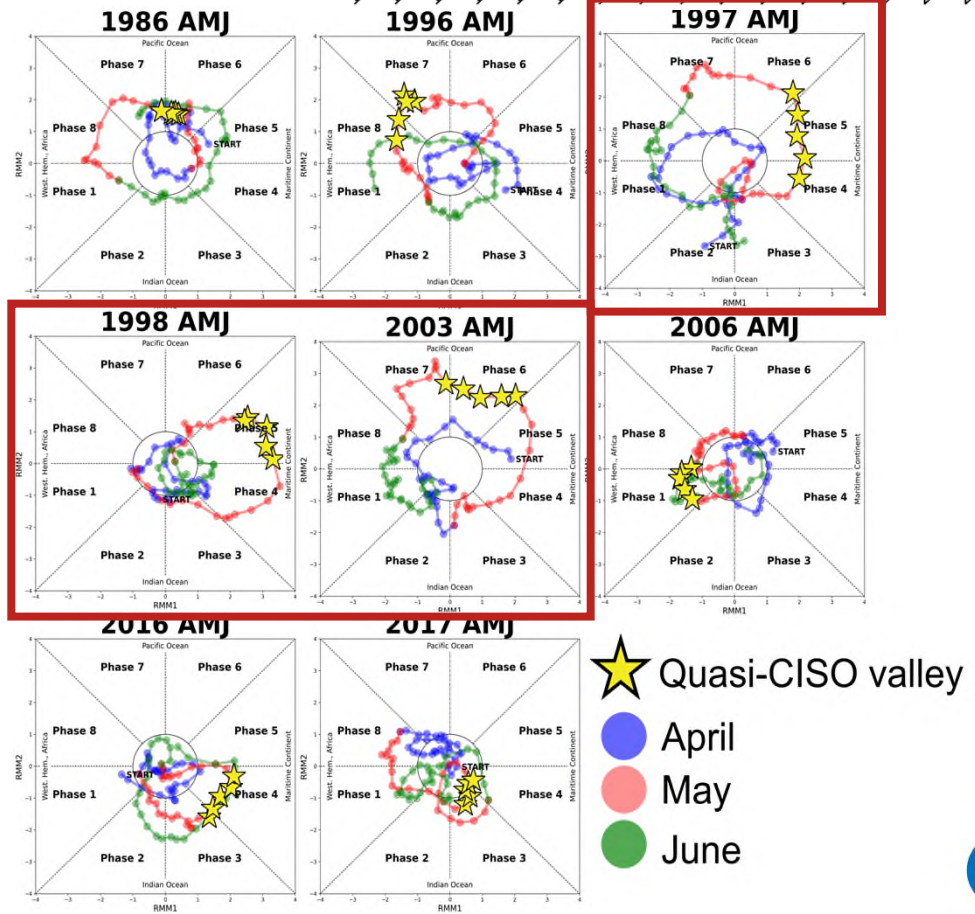
16 of the 22 quasi-CISO normal years show less-than-two-pentad difference in SCSSM onset





U_SCS index typically occurs earlier than the Quasi-CISO valley.

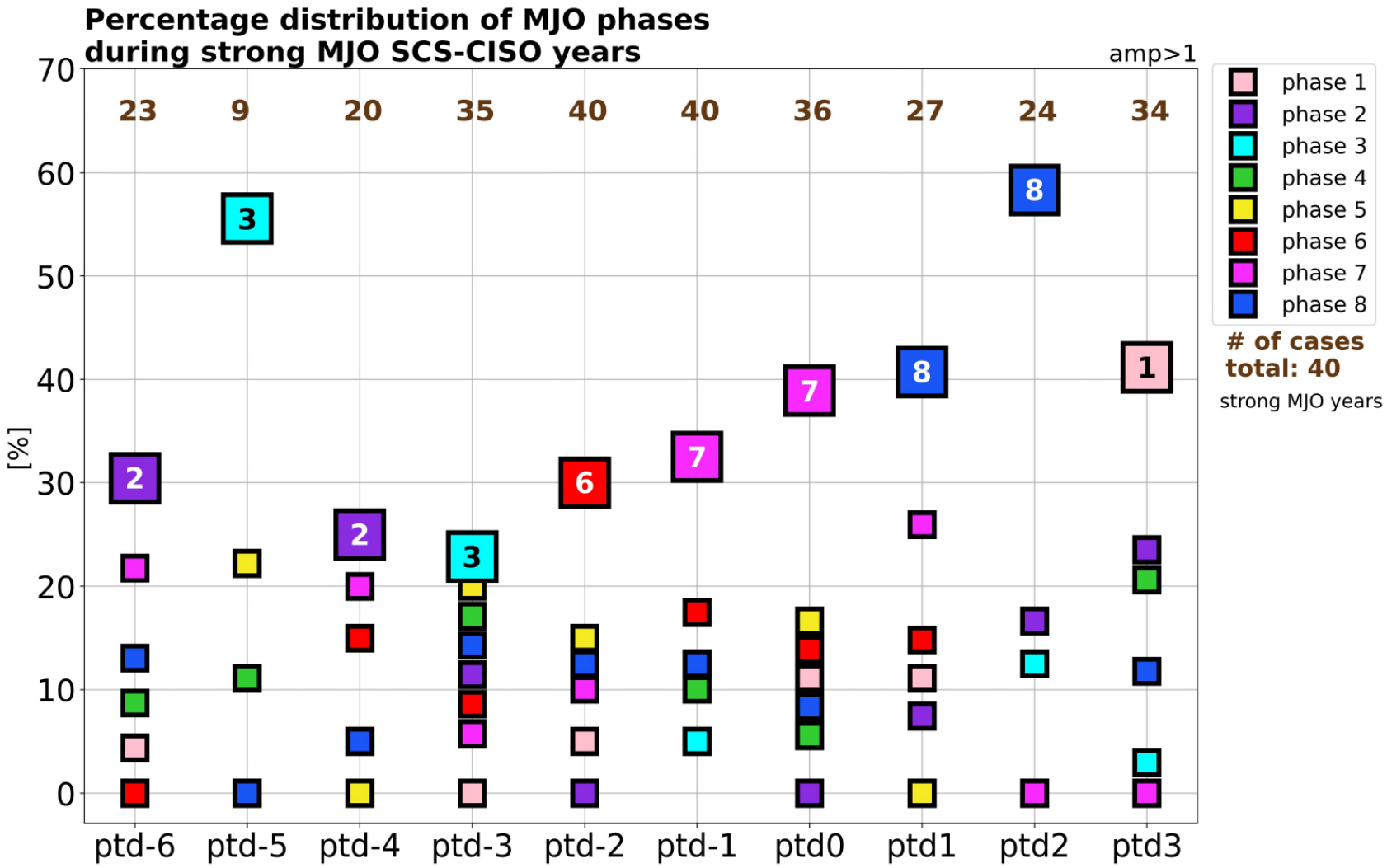
Quasi-CISO valley can represent the onset of the SCSSM.



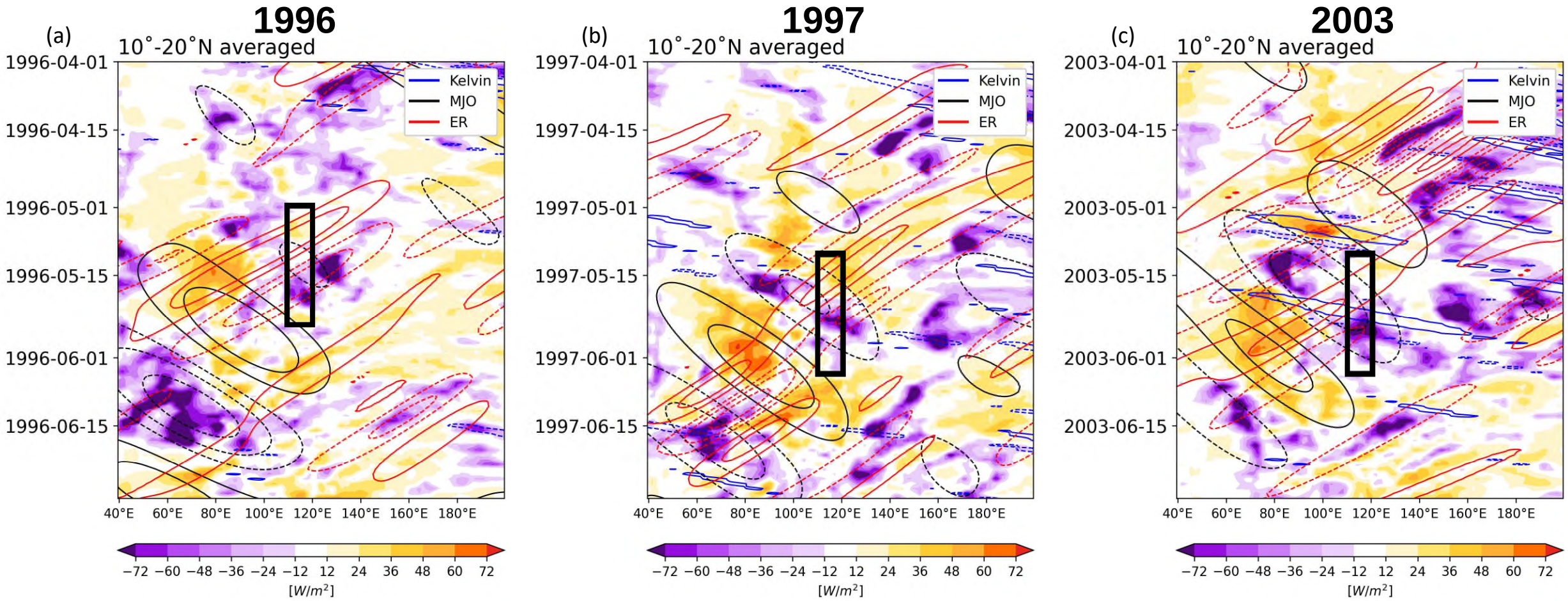
MJO influence on quasi-CISO and SCSSM onset

SCS-CISO with active MJOs (8 years)

The MJO convection appears to continue move eastward from ptd-2 to ptd3



MJO and convectively coupled equatorial waves



three pentads before to one pentad after the quasi-CISO valley

In addition to MJO, the Kelvin waves and equatorial Rossby (ER) waves are quite active during these three years.

Conclusions

- 52% of 42 years of the study shows clear OLR quasi-CISO closely resembling the climatological CISO over the South China Sea.
- Using the U850 SCSSM onset index to represent the monsoon onset, we found 16 years of which the OLR quasi-CISO valley coincide with the onset timing.
- After carefully examining the phase-locking relationship between MJO, quasi-CISO and SCSSM onset, we can conclude that the CISO or the second episode of the CMJO cannot be interpreted as the transient MJO phase lock to annual cycle.
- The MJO partially contributes to the quasi-CISO, but other tropical oscillations also have an impact.

Take-home message

CISO is partially resulted from **transient MJO's phase-lock to the annual cycle** and partially resulted from the intrusion of other tropical and extra-tropical perturbations into the SCS.

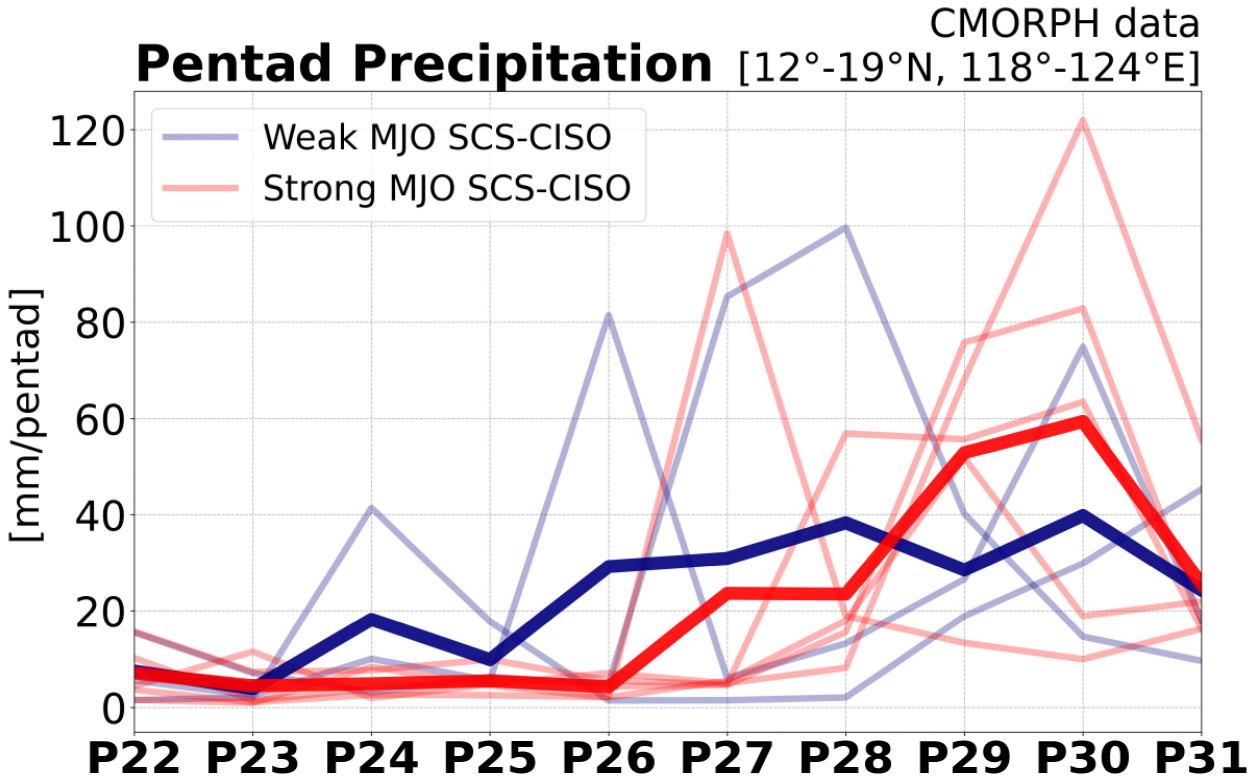
Thanks for listening

Influence of MJO strength on Philippine rainfall

Comparing the dry-to-wet seasonal transition period (Apr.16 ~ Jun.04) in SCS-CISO years

Strong MJO years: 1998, 2003, 2006, 2016, 2017

Weak MJO years: 2000, 2010, 2011



The dry to wet transition can be enhanced by MJO

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Wang et al. 2024

Climatological Madden-Julian Oscillation during boreal spring leads to abrupt Australian monsoon retreat and Asian monsoon onsets

- The convective and westerly anomalies associated with the northward-propagating counterpart of the early-mid May CMJO trigger the climatological SCS summer monsoon onset.

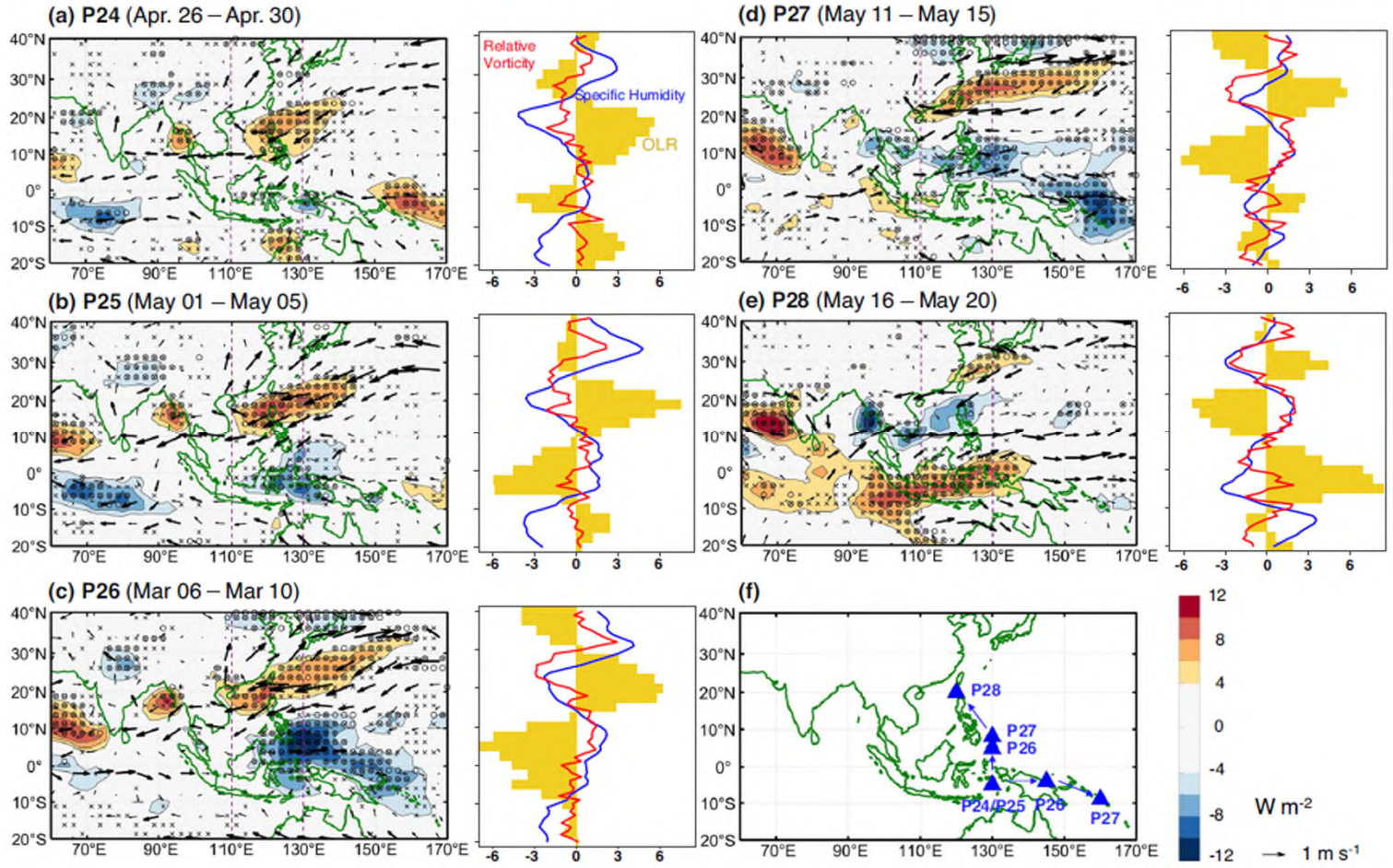


Fig. 6 The CMJO episode triggering the SCS summer monsoon onset. Left panels: The same as in the upper panels in Fig. 5. Right panels: meridional structures of the OLR (yellow bar, units in W m^{-2}), 850-hPa relative vorticity (red line, units in 10^{6}*s^{-1}), and 850-hPa specific humidity (blue line, units in 10*g kg^{-1}). All variables are averaged over 110°E-130°E from (**a**) P24 to (**e**) P28. **f** Blue triangles and arrows indicate the centroids and propagation direction of the wet CMJO signal from P24 to P28, respectively.

Data and Methodology

Data OLR (NOAA), Precipitation (GPCP, CMORPH), UV850 (ERA-5), UV200 (ERA-5), RMM index (BoM)

Climatological annual cycle and intraseasonal oscillations — Wang and Xu (1997); LinHo and Wang (2002)

Fourier Harmonics Analysis

$$y_c(i) = y_{ca}(i) + y_{ciso}(i) + R(i)$$

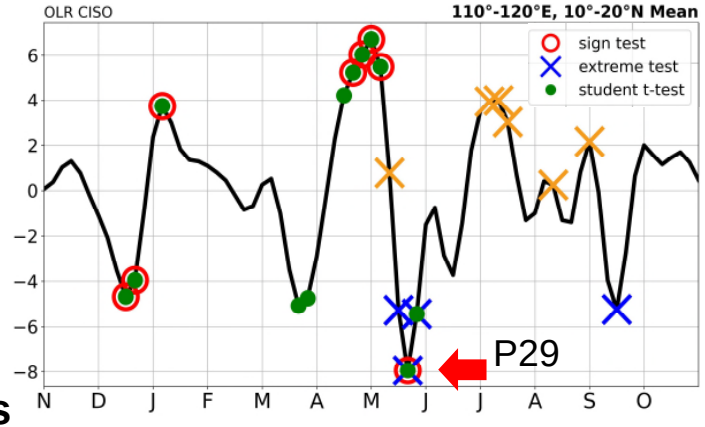
climatology — residual

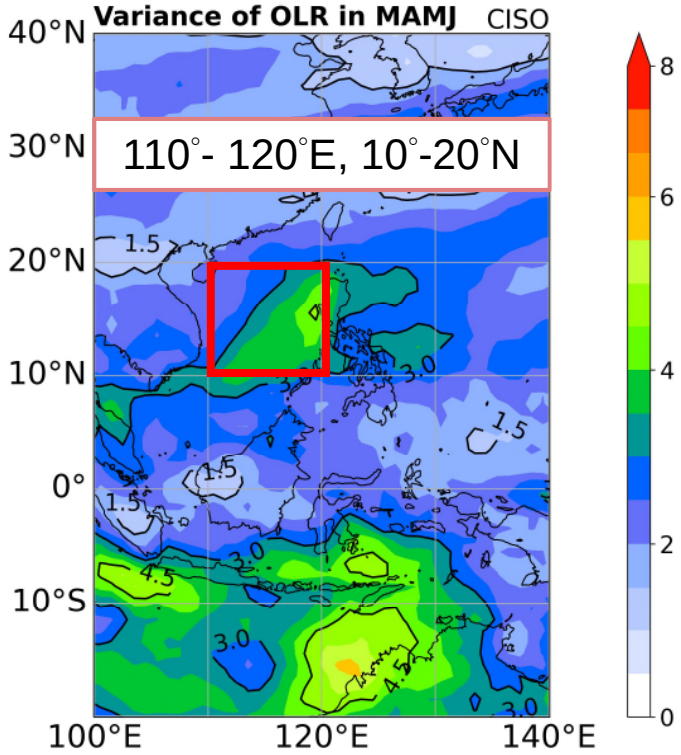
y_{ca}: the sum of the first four Fourier harmonics (period longer than 3 months)

y_{ciso}: the sum of the 5th to 18th harmonics (period ranging from 20 to 73 days)

Climate singularities — Wang and Xu (1997)

- Sign test
- Extreme test
- Student t-test





Quasi-CISO

A quasi-CISO episode refers to **a cycle with peaks and valleys in individual years, whose timing and amplitude are similar to the CISO**

SCSSM onset indexes → **SCS-CISO years**

two types of onset indices:

1. a dynamical index (U_SCS) Wang et al. (2004)
2. a quasi-CISO index the occurrence time of the quasi-CISO valley

The SCSSM onset time defined by **the U_SCS index is similar to that defined by the quasi-CISO**.

Methodology

1980-2022 OLR pentad data (1981 and 1985 no ISO data)

Statistical Tests

$$y(i) = y_a(i) + y_{iso}(i) + R(i)$$

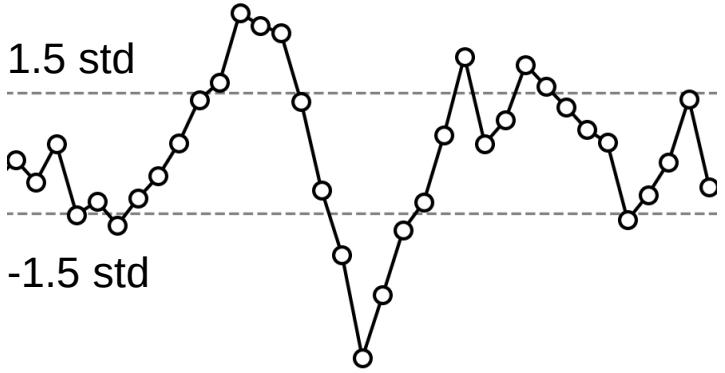
Sign test

Count the number of occurrences of positive or negative anomalies → The 95% confidence interval (≥ 28 occurrences in 41 years)

Extreme test

Select the dry extreme and wet extreme

- The peak/valley values > 1.5 times the standard deviation of the ISO
- The peak should differ from the before and after valley by more than 1.5 times the standard deviation of the ISO



Monte Carlo Test → The 95% confidence interval (Dry extreme ≥ 4 cases, Wet extreme ≥ 5 cases)

Methodology

1980-2022 OLR pentad data (1981 and 1985 no data)

Statistical Tests

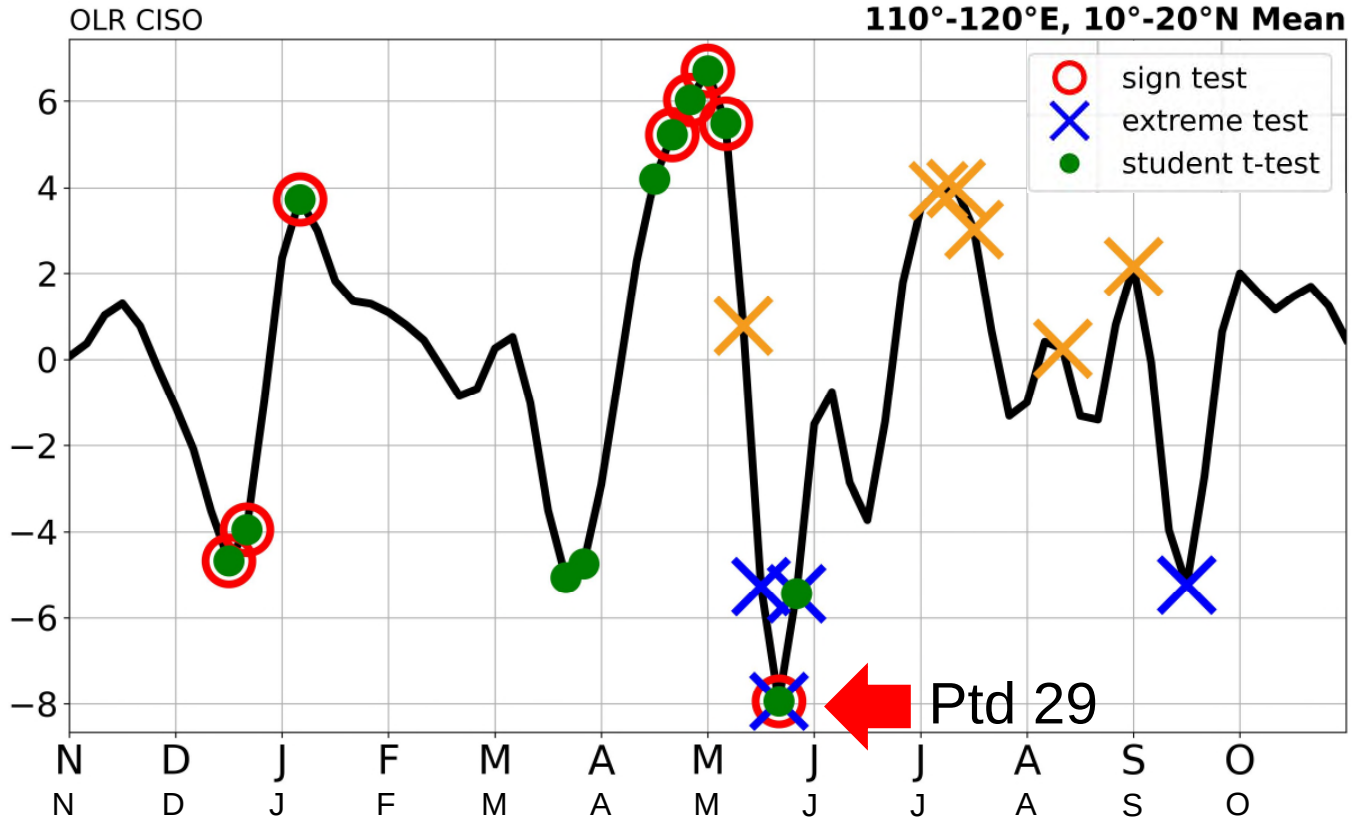
$$y(i) = y_a(i) + y_{iso}(i) + R(i)$$

Student t-test

Compares the amplitude of CISO with its year-to-year variability

The 95% confidence interval
⇒ the CISO cannot be viewed as an ordinary sampling fluctuation

- Define summer monsoon singularities by those extreme phases of CISO that pass **at least two types** of statistical tests at 95% confidence level.



Introduction Climatology Map

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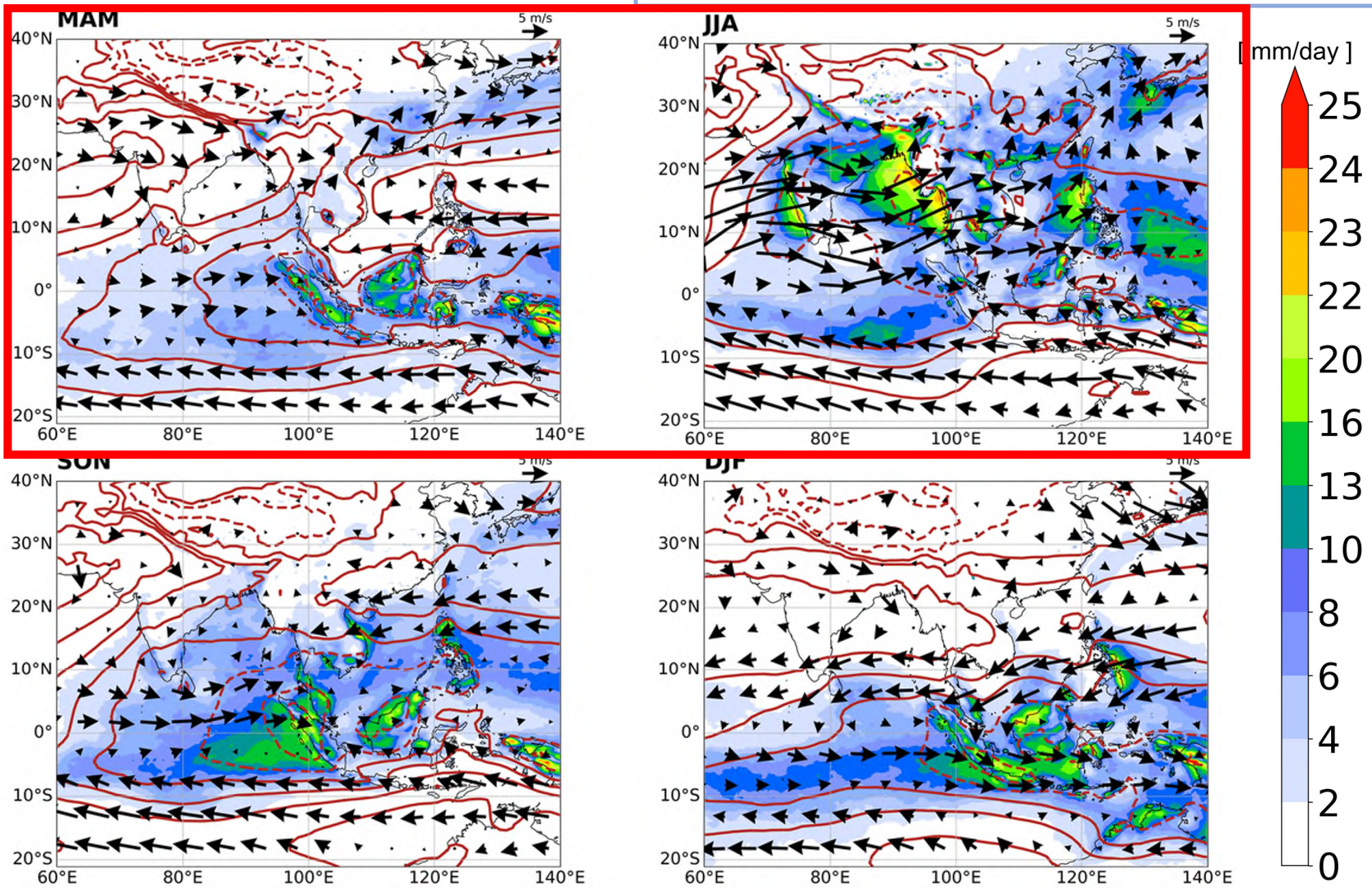
Shaded: 1998-2023 Precipitation
Contour: 1979-2023 OLR
(≧235 W m^2: ——— ; <235 W m^2: - - -)

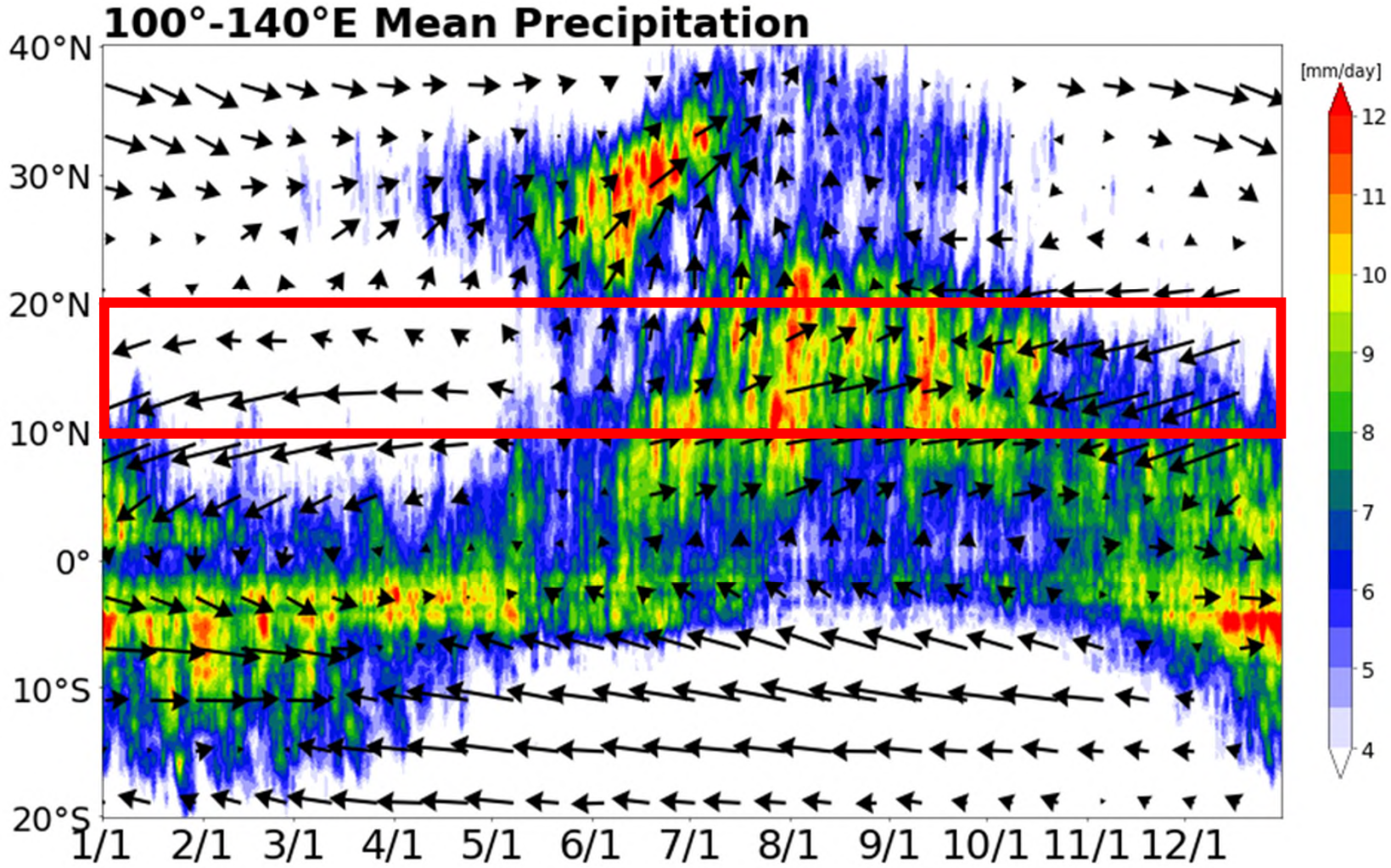


Introduction

Annual cycle

Cross-section
(100°-140°E Mean)

- Precipitation mainly occurs in the equatorial region until April.
- Precipitation near the equator begins to shift northward in May.
- In mid-May, there is a clear signal of precipitation oscillation between wet and dry conditions in the South China Sea region.

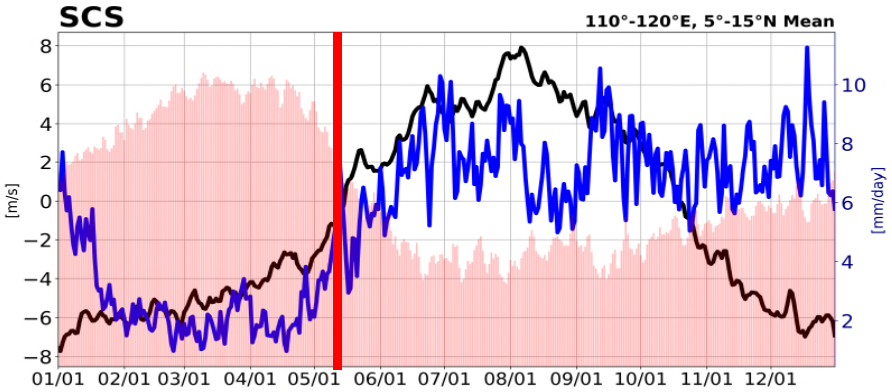


Vector: 1979~2023 850hPa Wind
Shaded: 1998~2023 Precipitation

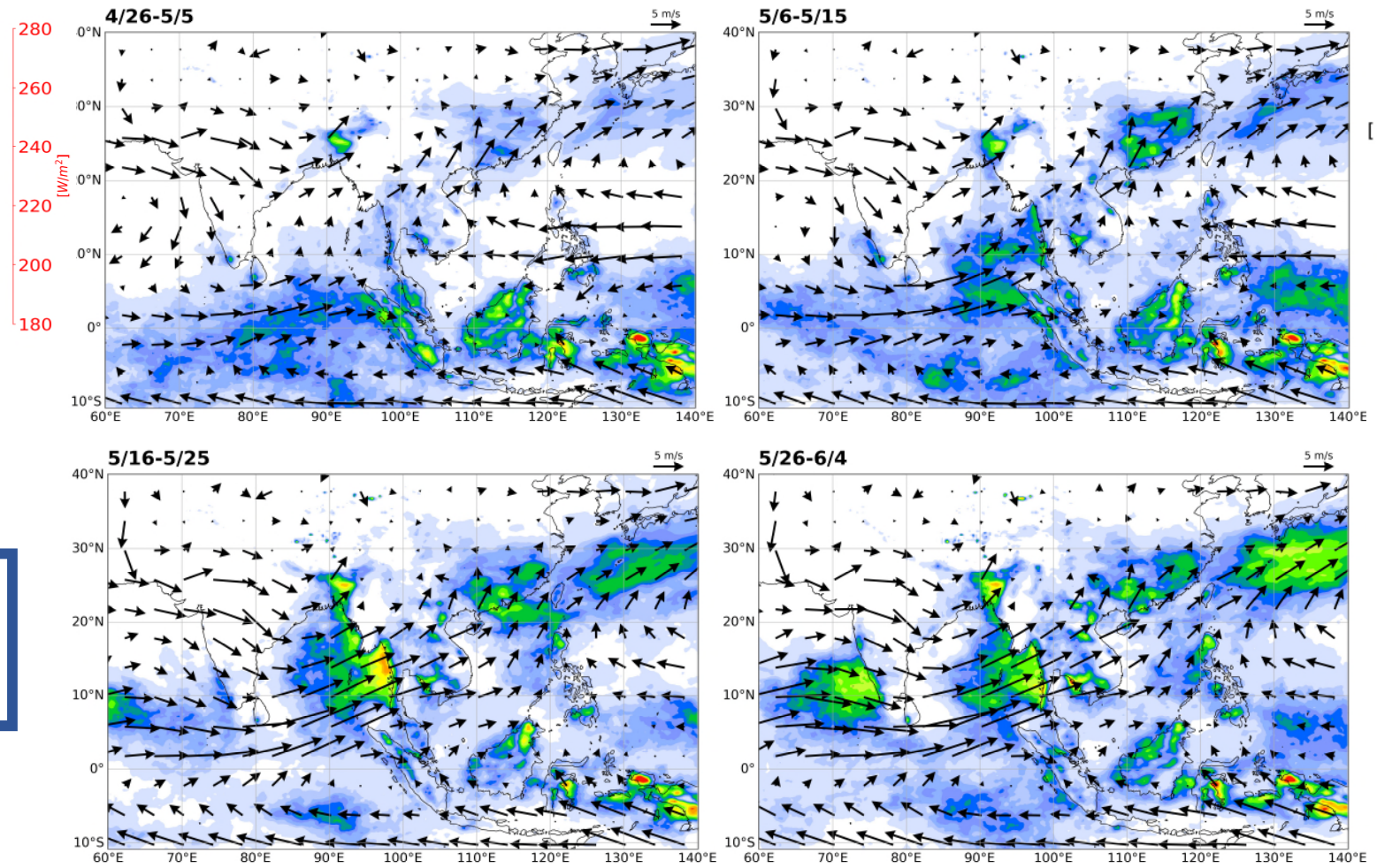
Introduction

South China Sea Summer Monsoon (SCSSM)

Vector: 1979-2023 850hPa Wind
Shaded: 1998-2023 Precipitation



: 1979-2023 850hPa zonal wind
: 1998-2023 precipitation
: 1979-2023 OLR



ISOs affect the SCSSM onset

Li et al. 2021; Lu et al. 2020;
Wang and Xu 1997; Wang et al. 2004

- BSISO
- MJO
  Wang et al. 2024

Methodology Detecting the Monsoon Singularities

- **Monsoon Singularity** are weather events that regularly occur during the same period each year and are usually reflected by the extreme phases of the CISO (Wang and Xu 1997).

1980-2022 OLR pentad data (1981 and 1985 no ISO data)

Sign test

check the probability of a positive or negative anomaly

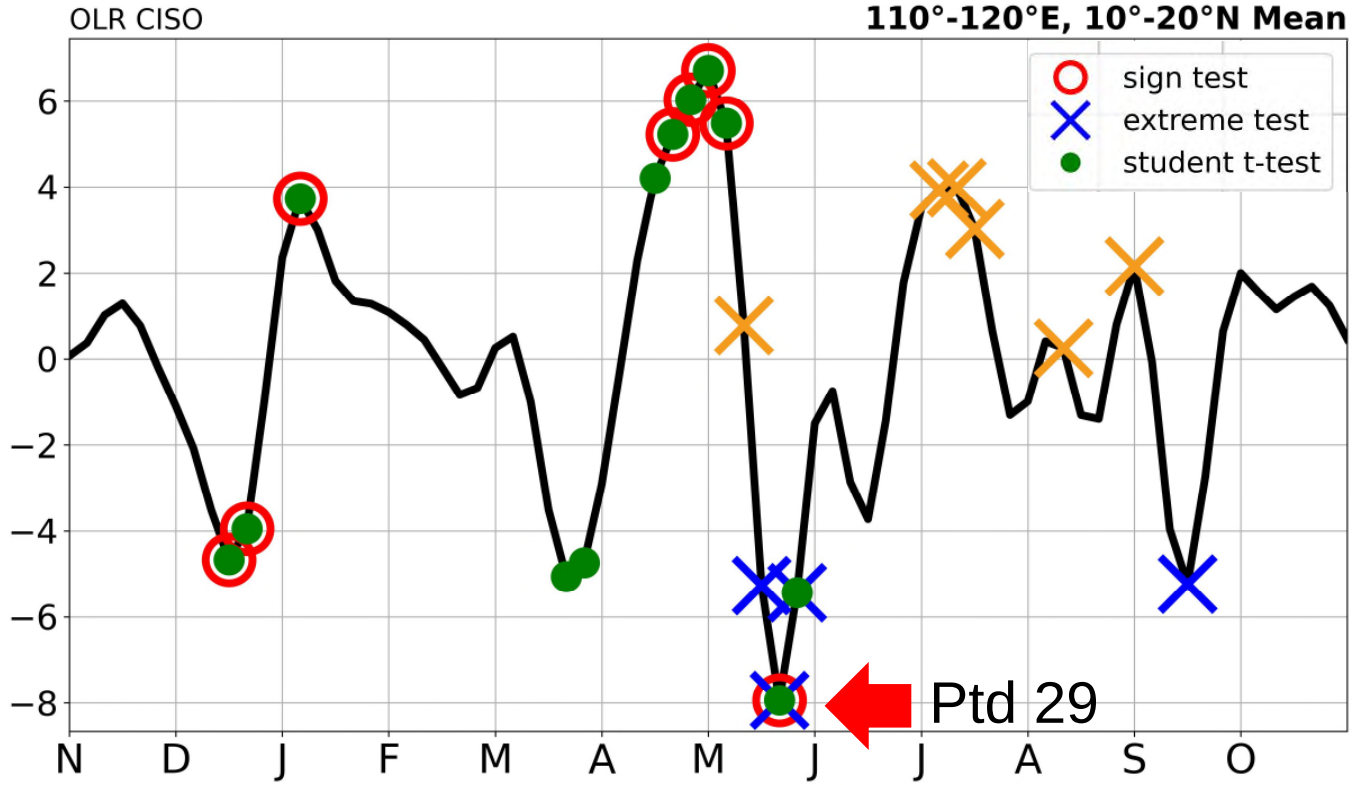
Extreme test

examine the significance of the extreme dry or wet events

Student t-test

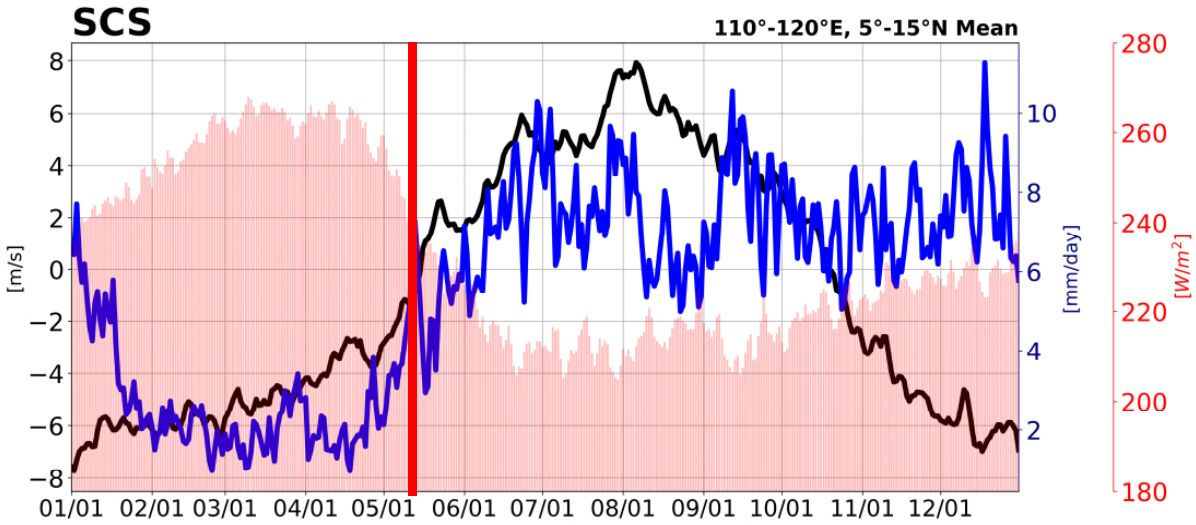
check the ISO anomaly magnitude at a pentad

- Define summer monsoon singularities by those extreme phases of CISO that pass **at least two types** of statistical tests at 95% confidence level.

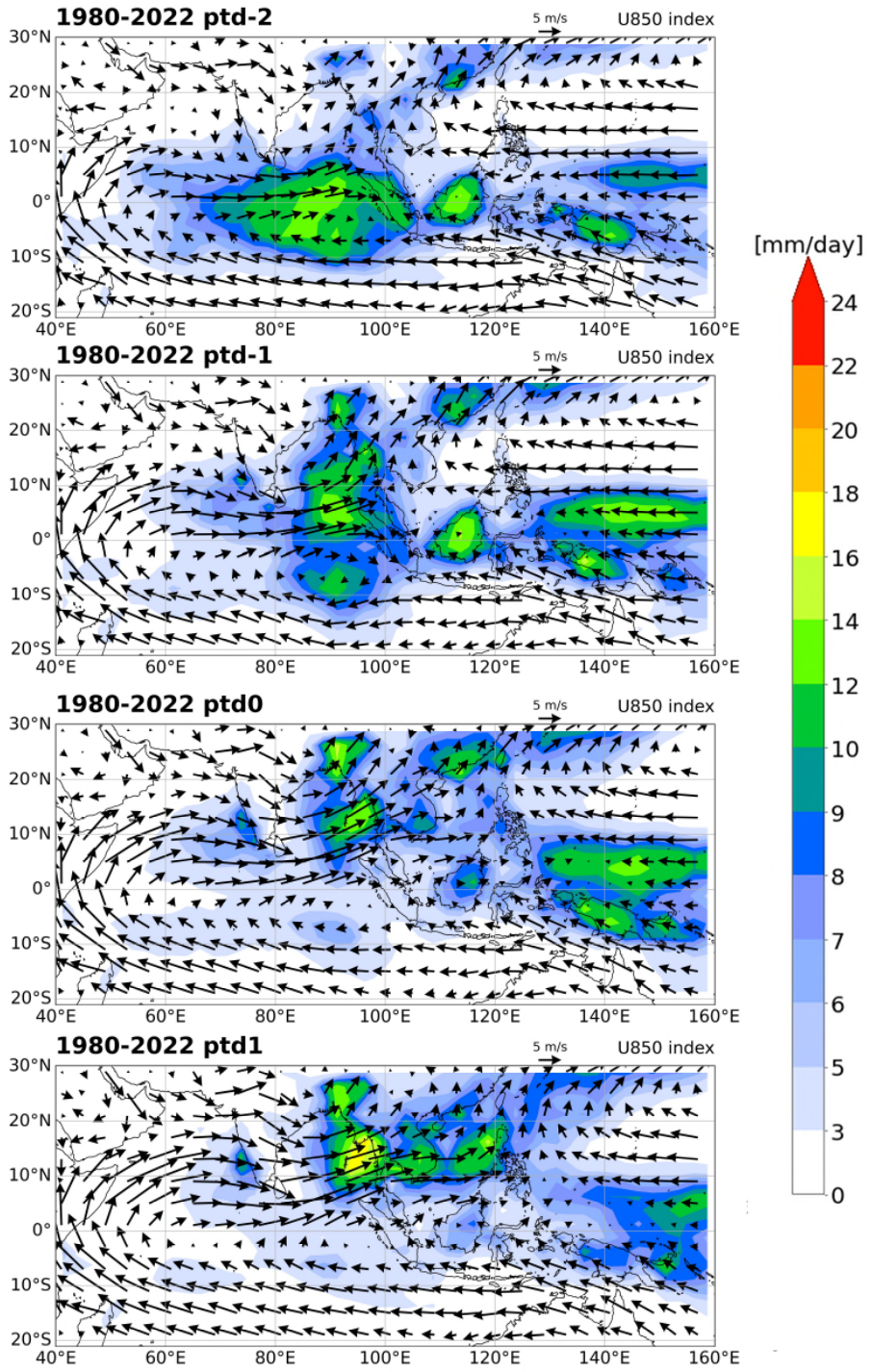


Methodology Onset Date of SCSSM

- Definition of the U850 index (Wang et al. 2004)
  - U_{SCS}: the average of the U850 in 110˚-120˚E, 5˚-15˚N
  1. The first pentad after 4/25 and U_{SCS} >0
  2. In the subsequent 4 pentads U_{SCS} >0 at least 3 pentads and the 4 pentads mean U_{SCS} >1 m/s



: 1979-2023 850hPa zonal wind
: 1998-2023 precipitation
: 1979-2023 OLR

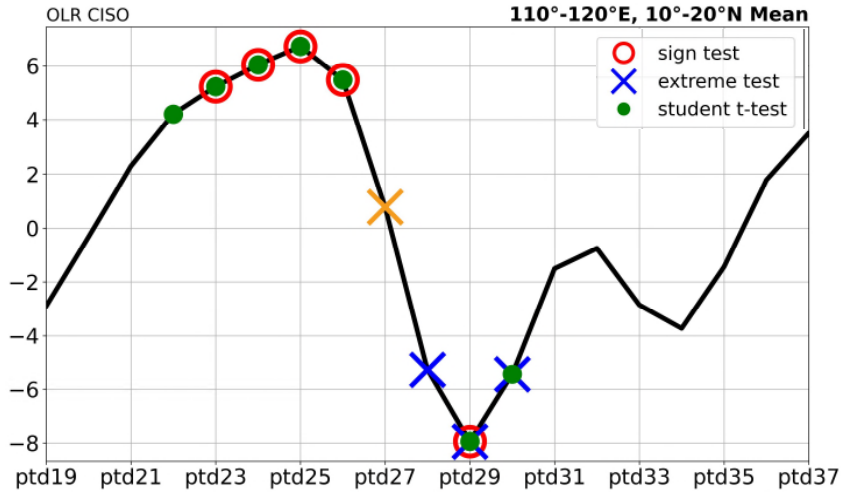


Methodology

Quasi-CISO

1980-2022 OLR pentad data (1981 and 1985 no ISO data)

- Occurrence time of ISOs valleys: ptd25-35
- Distance to the max OLR (ptd19-27) > 22.08 W/m^2



CISO normal year

- Occurrence time of quasi-CISO peak: ptd22-27
- Occurrence time of quasi-CISO valley: ptd28-30
- totaling 22 years

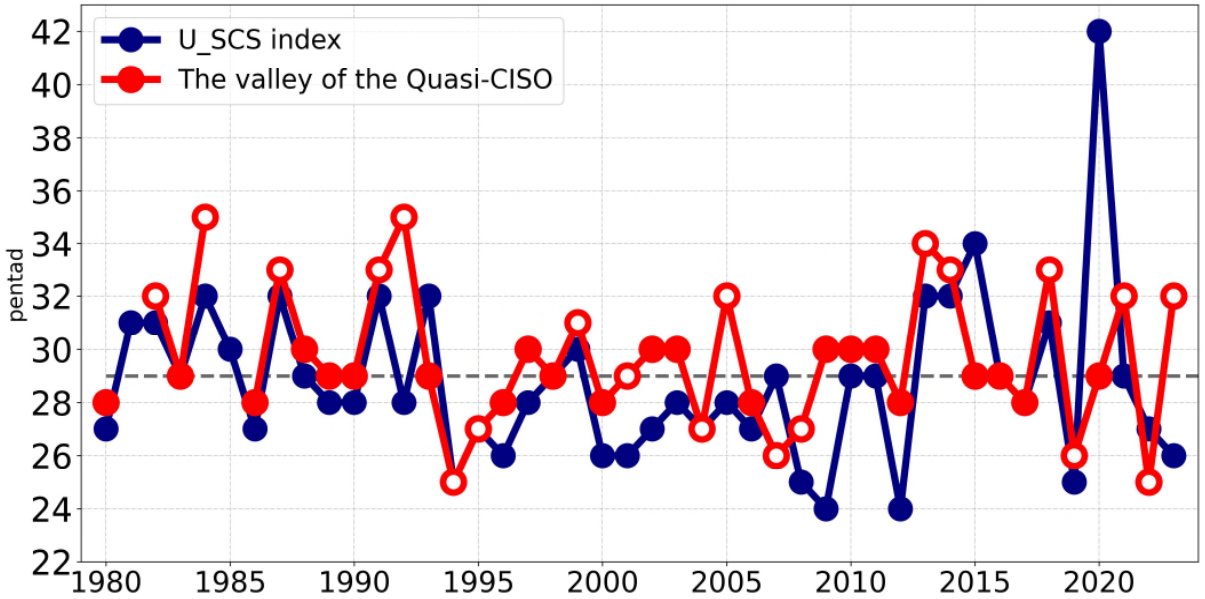
Consistent years

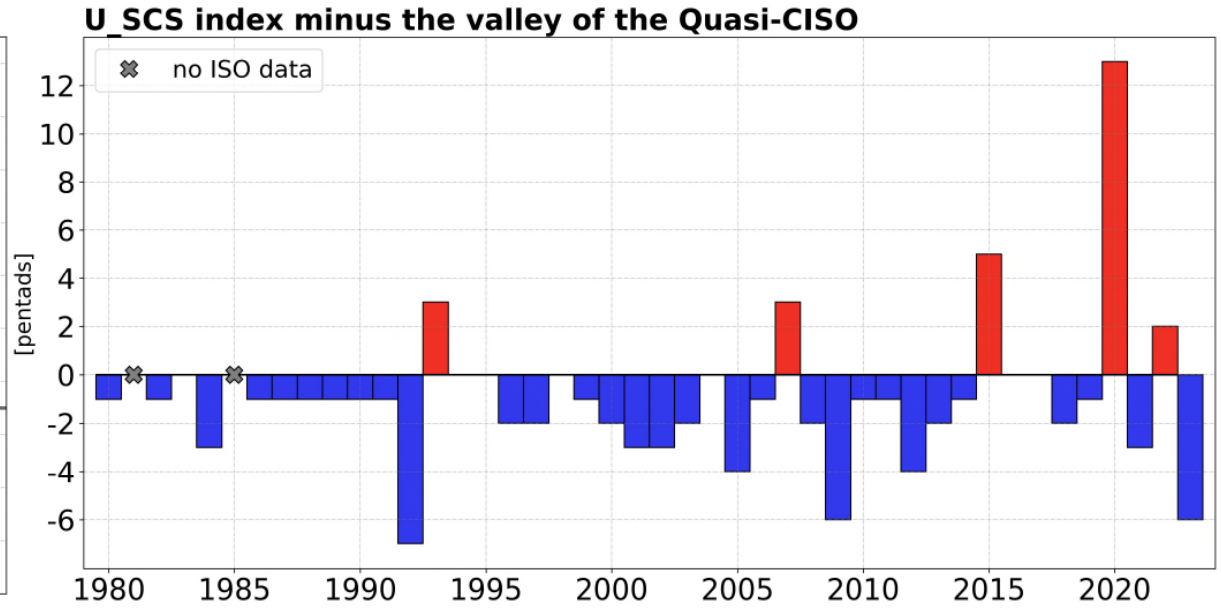
1. Quasi-CISO normal years.
2. The SCSSM onset date determined by the U850 index occurs within two pentads before the quasi-CISO valley.
3. The number of days with an MJO amplitude greater than 1 (ptd-3~ptd1) > 16 days.

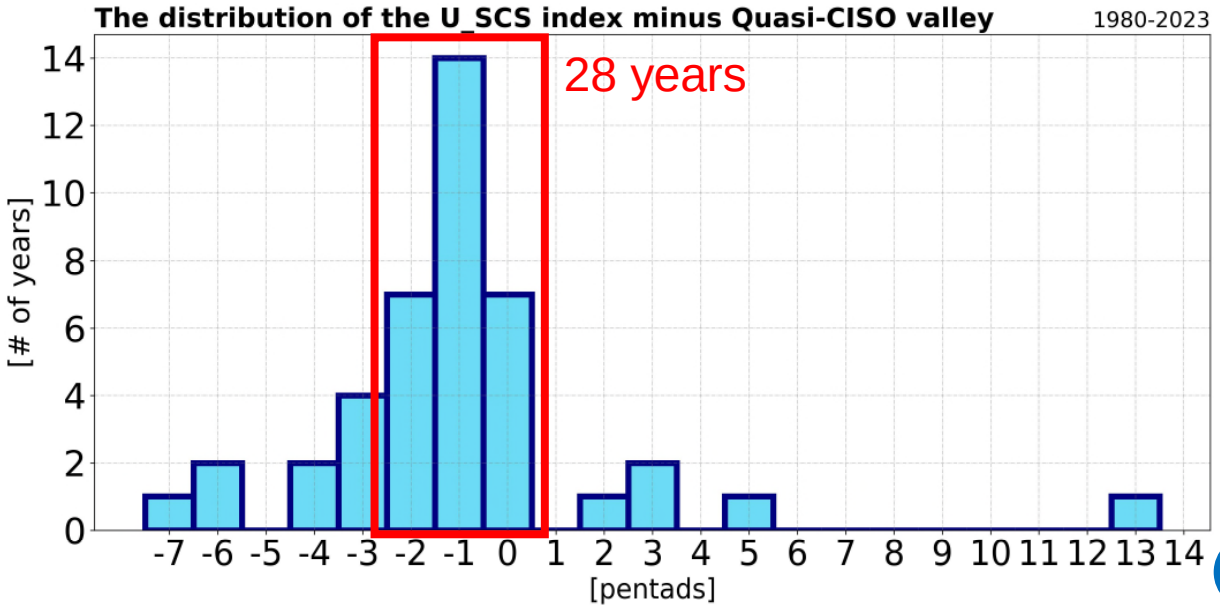
- totaling 8 years (1986, 1996, 1997, 1998, 2003, 2006, 2016, 2017)

Results

SCSSM onset and quasi-CISO



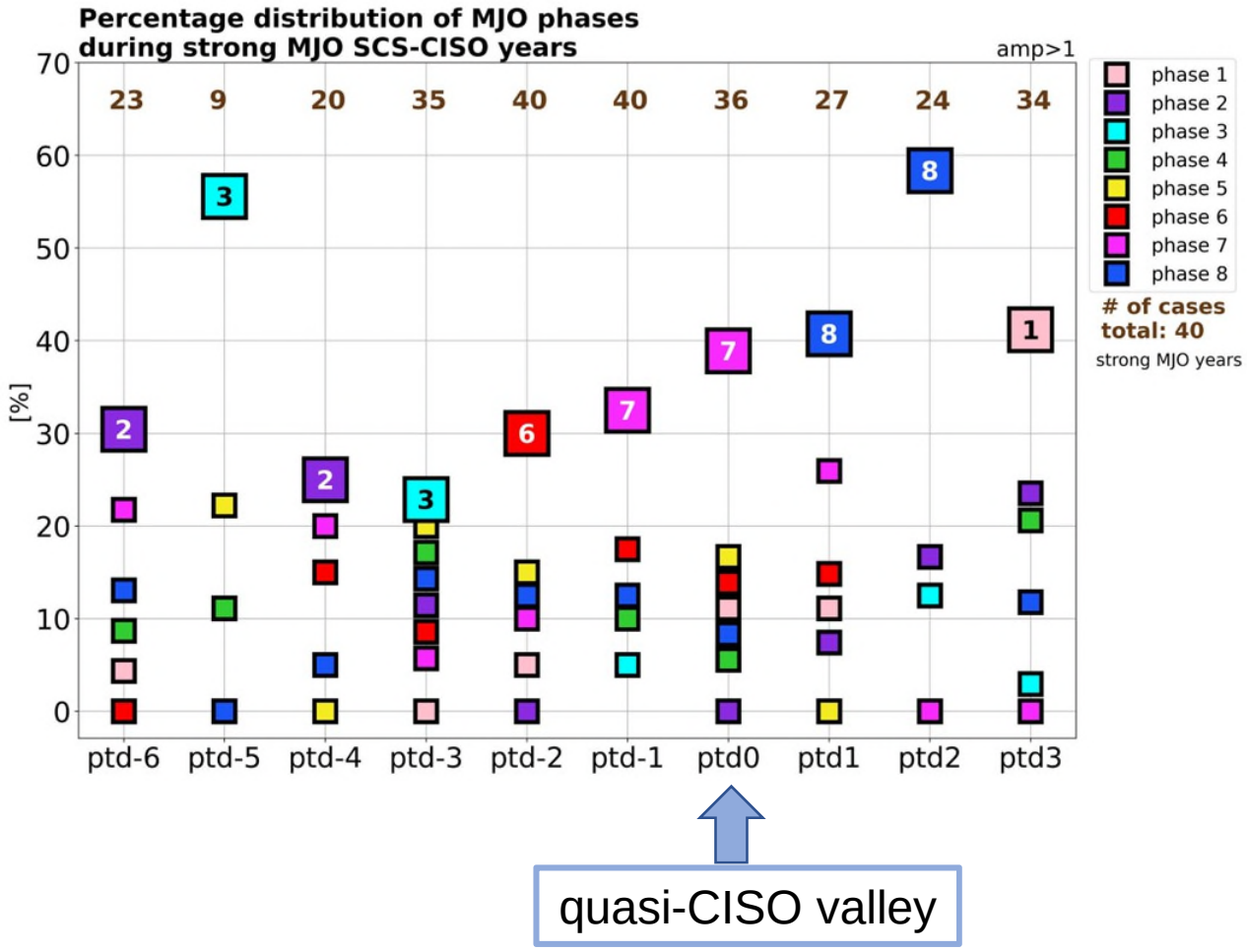




In 28 years, the onset times defined by circulation and convection are similar → quasi-CISO can, to some extent, represent the onset of the SCSSM.

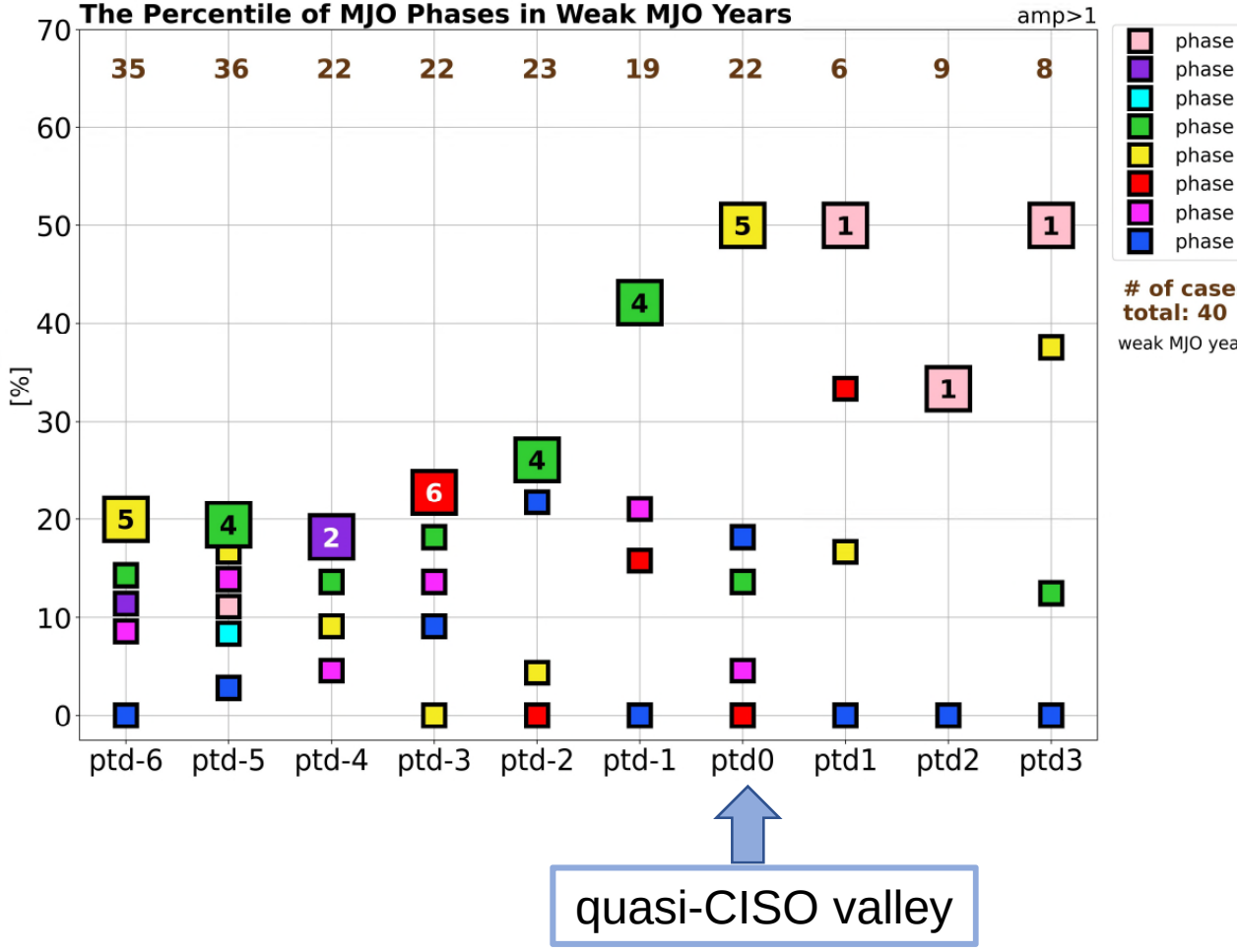
MJO influence on quasi-CISO and SCSSM onset

Strong MJO SCS-CISO years



quasi-CISO valley

Weak MJO SCS-CISO years



quasi-CISO valley

The MJO convection appears to continue move eastward from ptd-2 to ptd3

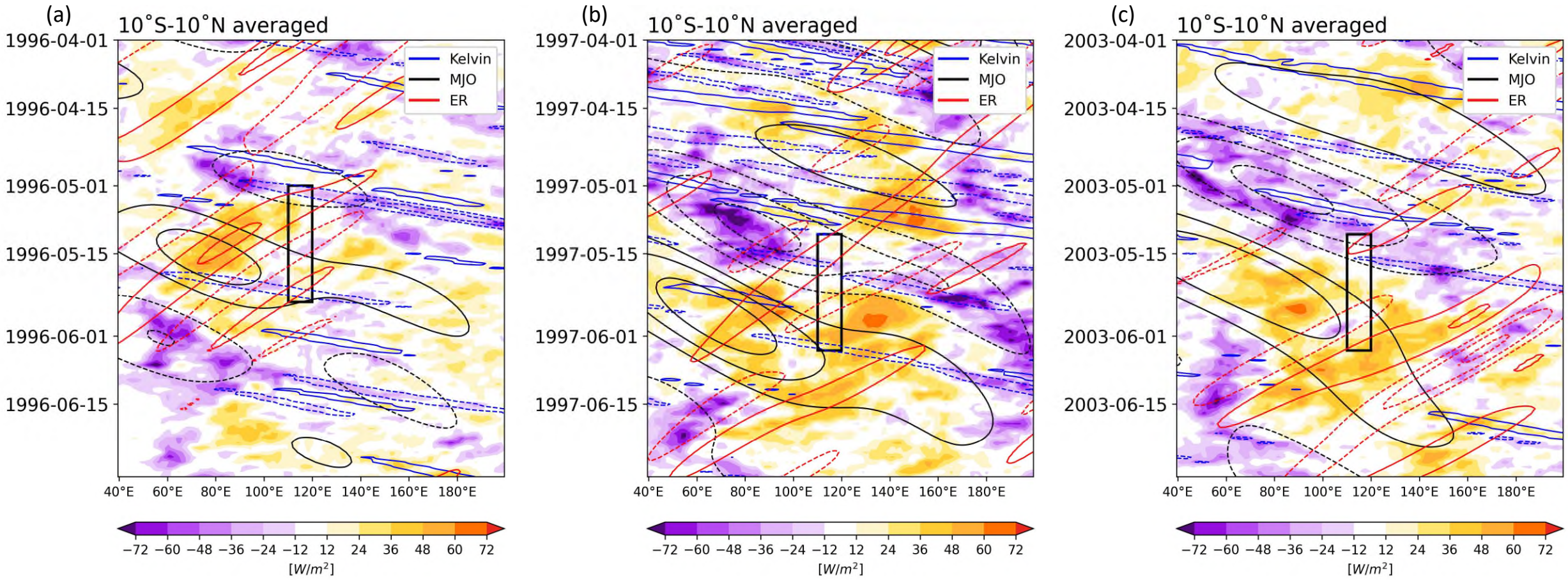


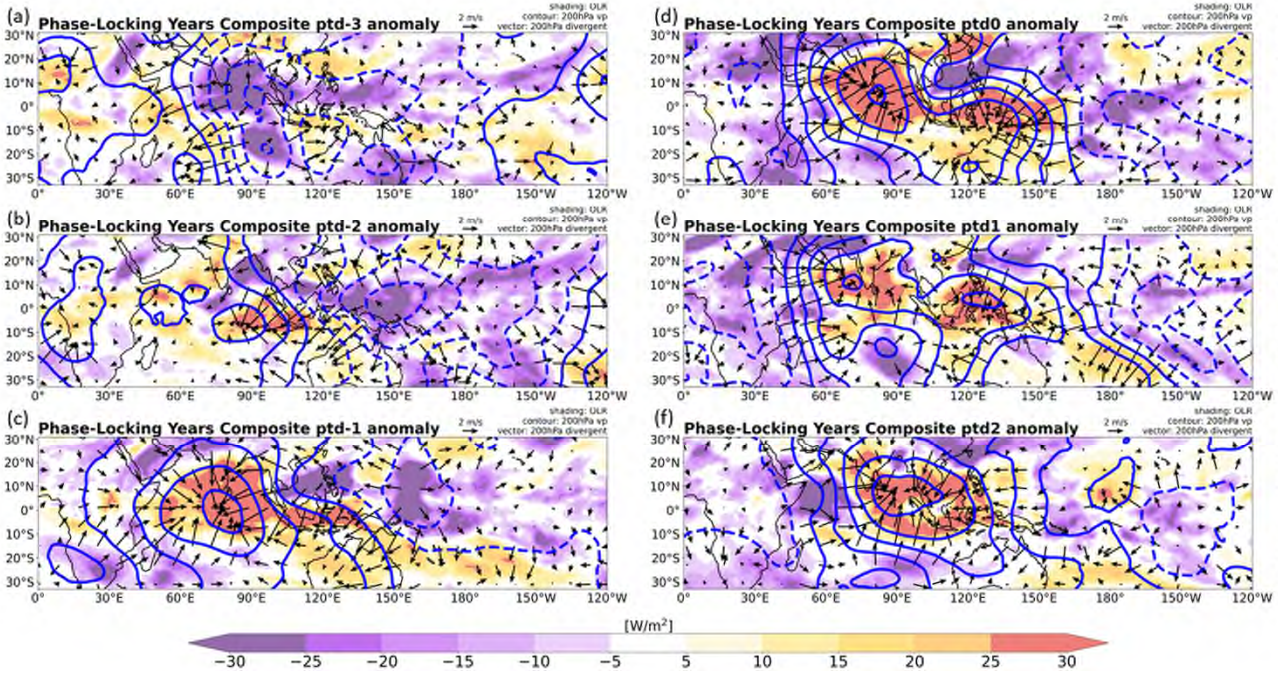
Fig. 10 4至6月10˚S-10˚N平均的 OLR、濾波的MJO、ER波、Kelvin波哈莫圖。(a) 1996年、(b)1997年、(c)2003年 The black lined box in marks the period of three pentads before to one pentad after the quasi-CISO valley at the SCS longitudes of 110°E-120°E .

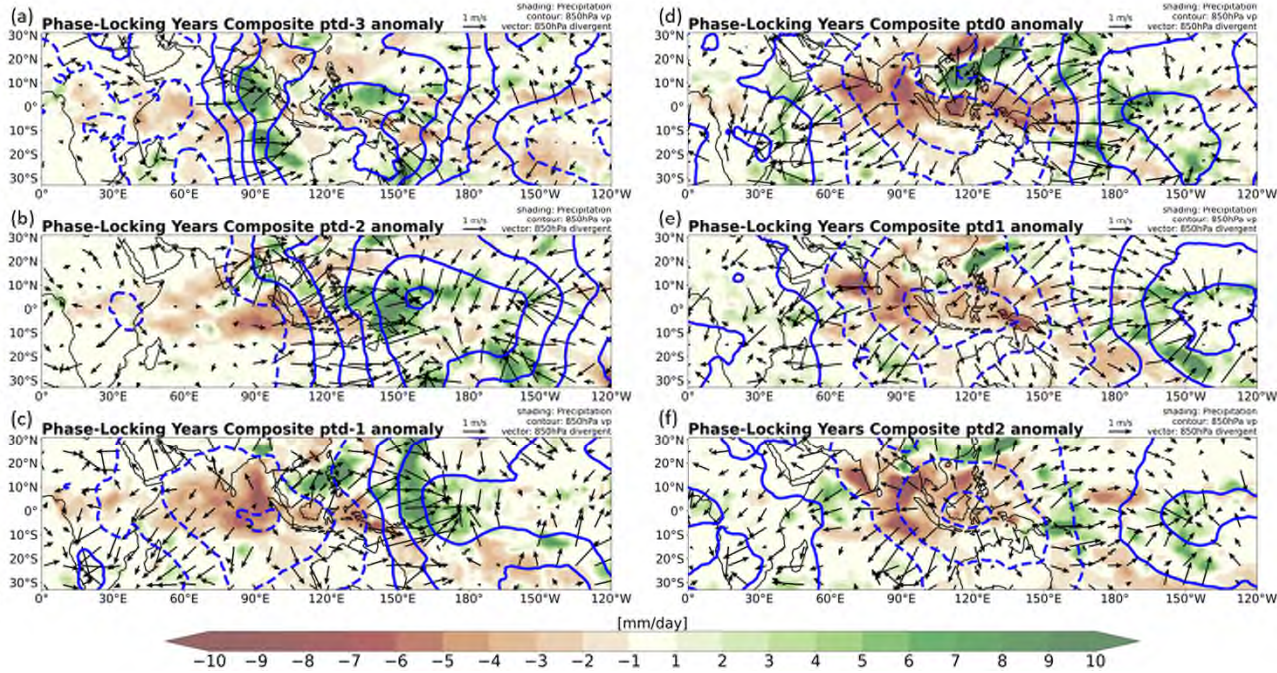
MJO phase-locking features and the associated circulation

(1996, 1997 and 2003)

Vector: 200hPa divergent wind anomaly
Shaded: OLR anomaly
Contours: 200hPa velocity potential anomaly

Vector: 850hPa divergent wind anomaly
Shaded: precipitation anomaly
Contours: 850hPa velocity potential anomaly





ptd-3

the center of convection
(eastern IO and BoB)

convection move to the east of 110˚E

the positive OLR anomaly rapidly enhance and persiste for three pentads

the low-level divergence coupled with upper-level convergence over eastern EIO can enhance surface moisture transport to the SCS during ptd-1 to ptd0