Early 2000s Regime Shift in the East Asian Summer Monsoon: Detection and Underlying Dynamics

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1. Introduction

- An abrupt change in the structure and function of a complex systems is called as a regime shift (e.g. phase shift of PDO).
- It has been reported that several regime shifts already occurred over EASM (e.g. late 1970s, mid-1990s, and early 2000s) and some of these studies defined or explained shifts with the change of East Asian Jet (EAJ) such as the strength or location.
- For the most recent shift, the regime shift of early 2000s, there was also a study that explained this shift with the change of EAJ [Li and Lu 2020].
- However, the study focuses on the change of meridional teleconnection between western North Pacific and East Asian region at the lower-level (PJ pattern) and explains that change in terms of the position of EAJ.

Motivation

- There is little research on **how the shift of early 2000s has appeared in upper-level flows and the strength of EAJ, especially**.

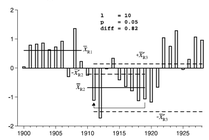
Research question

- **What has changed in the summer East Asian Jet's strength in the early 2000s?**
- **What are the difference(s) between before and after the shift (related to EAJ)?**
- **Why makes that difference (related to EAJ)?**

2. Data and Methods

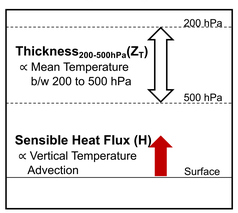
- **JRA 55 reanalysis** (monthly and 6 hourly) dataset with spatial resolution 1.25ºX1.25º from 1958 to 2020 was used and the analysis was mainly conducted in summer season (**JJA**).
- Define East Asian Jet Index (**EAJI**) by area- averaging of **U200** over **90-110 °E, 35-45 °N.**

Regime shift detection algorithm [Rodionov 2004]



- Basically, adopting the **Student's t-test**, check sequentially whether the means of two time series are different significantly in statistics.

Coupling strength b/w upper and lower troposphere



- Based on [Miralles et al. 2012]'s method, we defined a new variable to describe the linkage b/w upper and lower troposphere.
- It's calculated by the **covariance** b/w normalized daily **surface sensible heat flux** (H) and **Thickness$_{200\text{-}500\ hPa}$** (Z_T)

$$\textbf{Coupling Strength} = (H'/\sigma_{H'}) \cdot (Z_T'/\sigma_{Z_T'})$$

3. Results

The variance of EA Jet has rapidly increased since 2002/3

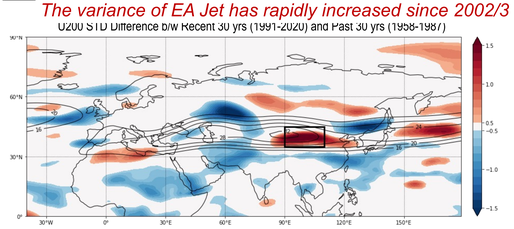


FIG 1. Standard deviation difference between the past 30 years, 1958-1987, and the recent 30 years, 1991-2020, of summer U200 (shaded) and the climatology of summer U200 (contours). The black box is defined as East Asian Jet (EAJ) region.

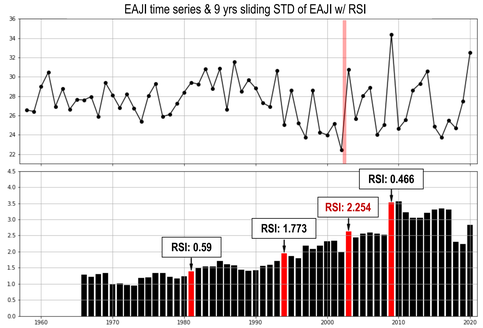
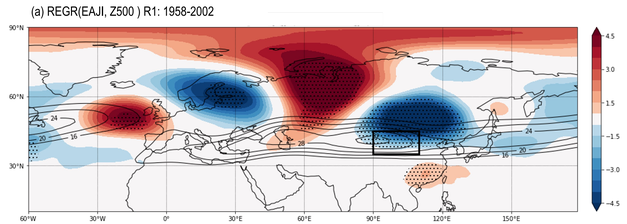


FIG 2. EAJI timeseries (top), and 9 years sliding standard deviation of EAJI (bottom). Red bars indicates when regime shifts are detected and annotations are the regime shift intensity values

- The variability of EAJ has extensively increased in the recent 30 years.
- By using a regime shift detection algorithm on a 9-year sliding standard deviation (STD) of EAJI, it has been determined that **the most intense regime shift in EAJI variance occurred in 2002/3**. In addition, earlier shifts in the late 1970s and mid-1990s were also confirmed to be detected using this approach.
- Define the regimes as R1: 1958-2002 / R2: 2003-2020

Regression pattern (wave structure) has changed after the regime shift



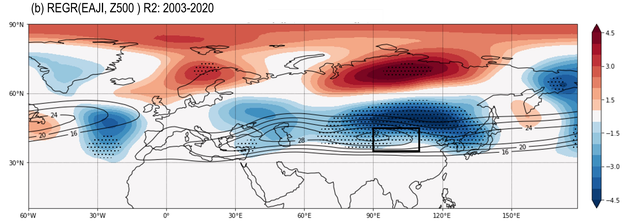
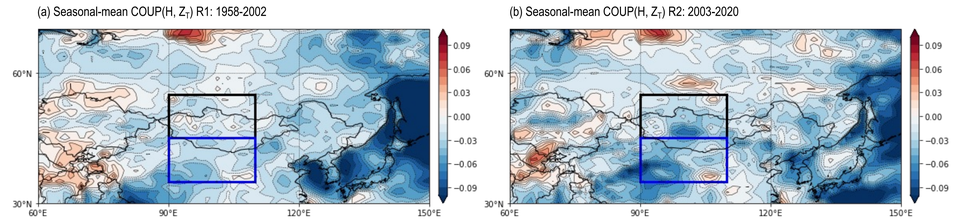


FIG 3. Regression Map between EAJI and Z500 during (a) the first, and (b) the second regime. The contours are the climatology of summer U200 during the whole period. The dots indicate that the coefficients exceed the 95% confidence levels.

- The pattern of R1 is like wave-train pattern, which is also known as Atlantic Eurasian Teleconnection pattern (AEA, [Li and Ruan 2018]).
- **At R2, the pattern is changed to a zonal pattern over Polar and Extratropical region, which is remarkably different to the before.**

Change of EAJ has become more intertwined to the variation in surface heating over Inner EA



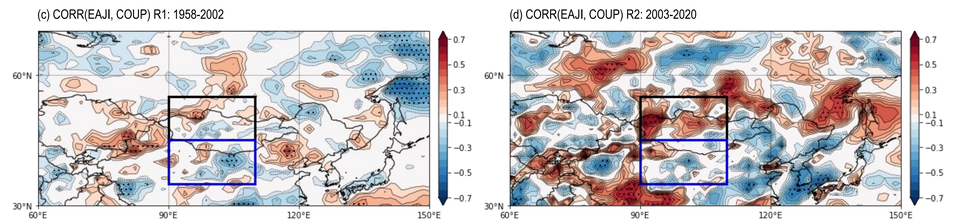
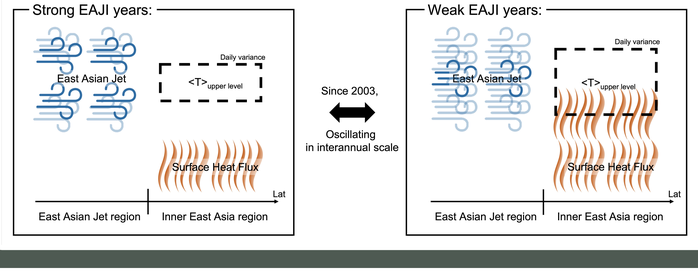


FIG 5. The seasonal-mean (JJA) of coupling strength between surface sensible heat flux and atmospheric thickness from 200 to 500-hPa level during (a) the first regime, R1, and (b) the second regime, R2. The correlation coefficient between the coupling strength and EAJI during (c) R1 and (d) R2. Black and blue boxes indicate the Inner East Asian region and East Asian Jet region, respectively.

- Based on a previous study by Zhang et al. (2020), a regime shift in summer soil moisture and heat wave frequency also occurred around 2000 in Inner East Asia.
- Consequently, we hypothesize that this intensification of land-atmosphere coupling has had an additional impact on the coupling strength between the upper and lower atmosphere, which could be connected to the observed change in EAJ variance.
- The magnitude of coupling strength has experienced a minor increase, and **the correlation with EAJI has significantly risen over the Inner East Asian region**.
- Given that the sign of coupling strength is negative, it indicates that **in R2, the strength of EAJ and the robustness of the connection between the upper and lower atmosphere over Inner East Asia have an opposing relationship**.

4. Discussions



- These findings suggest that in **the newer regime, the circulation of East Asia may respond more sensitively to the change in the surrounding climate than wave structures**.
- To demonstrate this relations dynamically, further sensitivity experiments using climate model are needed.

FIG 6. The schematic diagram of the hypothesized dynamic state at the second regime. The number of opaque wind icons indicates the strength of the daily variance EAJI during JJA.

References

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