P45- Different regimes of the Western North Pacific Monsoon throughout the 20th Century

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ABSTRACT

The concept of the Western North Pacific Summer Monsoon (WNPSM) appeared for the first time in 1987. It is, unlike the Indian Summer Monsoon (ISM) and the East Asian summer monsoon (EASM), an oceanic monsoon driven fundamentally by the meridional gradient of sea surface temperature. Its circulation is characterized by a northwestsoutheast oriented monsoon trough with intense precipitation and low-level southwesterlies and upper-tropospheric easterlies in the region [100º-130º E, 5º-15ºN].

By using solely daily observations of wind direction from ships' logbooks which circumnavigated Asia for hundreds of years, it has been possible to compute a new index, the Western North Pacific Directional Index (WNPDI), to reconstruct the WNPSM back to the middle of the 19th Century. The WNPDI is defined as the sum of the persistence of the low-level westerly winds in [5º–15ºN, 100º–130ºE] and easterly winds in [20º–30ºN, 110º–140ºE]. It is an instrumental index and widens almost 100 years the Western North Pacific Monsoon Index (WNPMI), an primary index based on reanalysis data which characterises the WNPSM throughout the 1949-2013 period. Both indices show a high correlation ($r=+0.87$, $p<0.01$) for summer of the 1949-2009 period.

Due to the length of the WNPDI, now it is possible to study the multidecadal variability of the WNPSM. Our results show that the WNPDI has a strong impact on the precipitation in densely populated areas in South-East Asia, such as the Philippines or the west coast of Myanmar where the changes in precipitation between well developed and weak monsoons can reach up to 400 mm and seems to be driven by profound changes in the moisture transport from oceanic areas. Besides, two different regimes in the 20th Century have been found. The first period (1919-1939) was characterised by the persistence of strong monsoons whereas the second (1990-2010) shows higher variability and more cases of extremely weak monsoons. The patterns of precipitation, wind and moisture transport anomalies for each period are opposite. The existence of different monsoon regimes, the high temporal variability of the WNPSM and its dependence on the moisture transport from extratropical areas could explain why the relationships between the WNPDI and global climatic patterns such as the PDO, the ENSO or El Niño Modoki are extremely complicated and highly non stationary.

Keywords: Monsoons, Asia, Climate Indices

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¿The Western North Pacific Summer Monsoon?

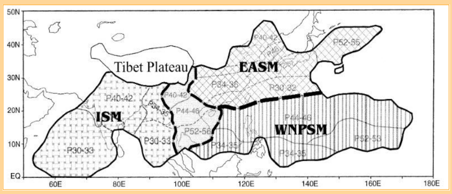


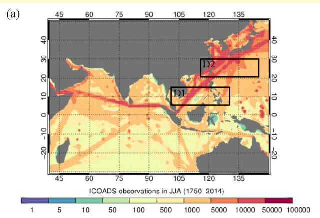
FIG 1: Division of Asian-Pacific monsoon. Taken from Wang and Linho (2002).

The Asian Monsoon region could be divided into three subregions: the Indian, the East Asian and the Western North Pacific. Both the Indian Summer Monsoon (ISM) and the East Asian Summer Monsoon (EASM) are continental while the Western North Pacific Summer Monsoon (WNPSM) is oceanic. Although the WNPSM has more profound impacts on the EASM and ENSO than the ISM, it has not been as studied as the latter, probably, because meteorological variables are required in open ocean to quantify the strength of the WNPSM.

The Western North Pacific Monsoon Index (WNPMI), the main index that has been used to characterize the WNPSM back to 1948, was defined as the difference of 850-hPa westerlies between two regions (D1 and D2 in Fig 2a) by Wang et al. (2001). **Our goal has been to extend this index as back in time as possible by using instrumental meteorological data** such as wind direction. Thus, it allows to study the **multidecadal variability** of the WNPSM.

ICOADS

Our main source of wind data has been the Comprehensive Ocean-Atmosphere Data Set (**ICOADS**) that contains marine surface data from logbooks of thousand of ships which have circumnavigated the globe since at least the 17th century. Fortunately, both domains, D1 and D2, lie over some of the main historical ship routes sailing nearby Asia. Therefore, we define the **Western North Pacific Directional Index** (WNPDI) using **solely wind direction** data as the sum of persistence of the low-level westerly winds in D1 and easterly winds in D2. The WNPDI shows a high correlation with the previous WNPMI ($r = +0.88$, $p < 0.01$) in summer for the concurrent period (1948-2014).



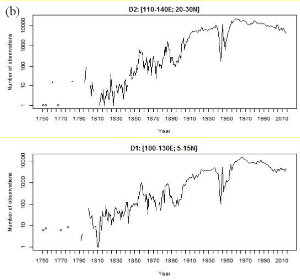
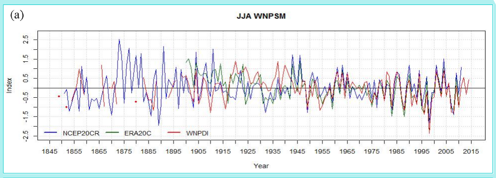


FIG 2: (a) ICOADS v3.0 JJA observations for the period 1750-2014. (b) Evolution of the number of observations inside the regions D1 (bottom) and D2 (top) for the period 1750-2014.

$$\text{WNPDI (monthly)} = \left[\frac{\text{Westerly days}}{\text{Days with observations}} [D1] + \frac{\text{Easterly days}}{\text{Days with observations}} [D2] \right] \cdot 100$$

ICOADS vs 20th Century reanalysis data sets

Figure 3 (a) show three WNPSM indices we have computed by using ICOADS and the wind field at 0.995 sigma-level from the two 20th century reanalysis, the NCEP/NCAR Twentieth Century Reanalysis v2c (20CR; Compo et al., 2011) and the ECWRF ERA-20C (ERA20C; Poli et al., 2013). These indices are similar from 1957 on, however they totally disagree during the first half of the 20th century. In consequence, we have tested the agreement between each of these indices and precipitation in two periods 1901-1950 (above) and 1951-2010 (below). The signal in precipitation is robust for the second period for all datasets, nevertheless this pattern only remains quite similar in the first period for ICOADS, losing signal with both reanalysis.



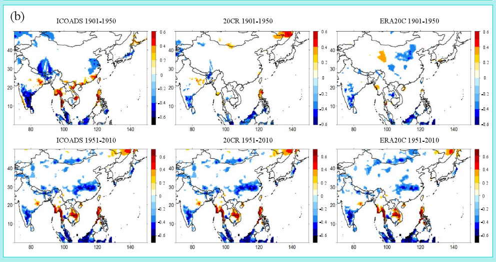


FIG 3: (a) Evolution of the WNPSM indices based on ICOADS (red), 20CR (blue) and ERA20C (green) data; (b) Correlation maps between the WNPSM indices based on ICOADS (left), 20CR (centre) and ERA20C (right) data and precipitation from the 0.5x0.5 gridded GPCCv6 dataset for the 1901-1950 period (top) and the 1951-2010 period (bottom). Shading denotes what is significant at the 95% confidence level.

The JJA Western North Pacific Directional Index

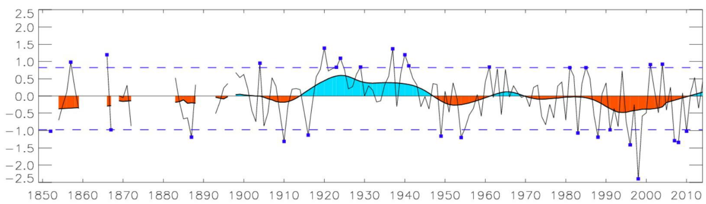


FIG 3: Evolution of the JJA WNPDI (thin black line), robust locally weighted regression with a 21-year window (shaded curve), extreme monsoons (blue squares) based on the 10th and 90th percentiles (dashed blue lines) of the WNPDI for the 1849-2014 period.

Extreme monsoons

15 strong vs **15 weak**

extreme monsoons during the **1849-2014** period

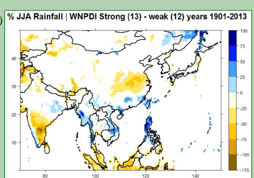
FIG4: Summer composite difference of:

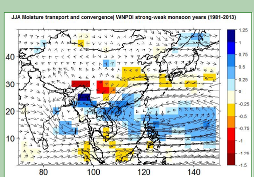
(a) precipitation (in % related to the JJA of the average local precipitation) through the 1901-2013 period,

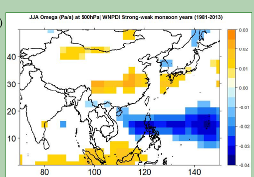
(b) moisture transport and its convergence (in arrows -kg/m·s- and shaded -kg/cm2·s-, respectively) and

(c) vertical velocity (Pa/s) for the 1981-2010 period between strong and weak monsoon years.

Shading denotes what is significant at the 95% confidence level.







Regimes of the WNPSM during the 20th century

Strong monsoons period 1918-1948	Weak monsoons period 1983-2013
7/15 strong extreme monsoons; No weak extreme monsoons; +PDO like conditions	3/15 strong extreme monsoons; 8/15 weak extreme monsoons

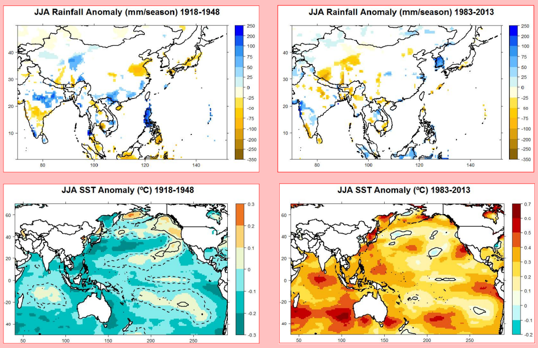


FIG 5: JJA precipitation (top) and SST (bottom) anomaly for the period 1918-1948 (left) and 1983-2013 (right). Shading (top) and contour (bottom) denotes what is significant at the 95% confidence level.

- It is possible to compute a quantitative index of the WNPSM strength without the use of the wind speed, a value usually rather uncertain for historical wind measurements.
- The WNPDI goes back to the middle of the 19th century and is 100 years longer than any previous index characterizing the WNPSM (it would be possible to extend the WNPDI further back in time as soon as more observations in logbooks, preserved in historical archives, are digitized). This allows to study the decadal variability of the WNPSM.
- The WNPDI computed by using ICOADS seems to be the index which captures the WNPSM precipitation signal throughout the entire 20th century much better than the 20th century reanalysis.
- The WNPDI has a strong impact on the precipitation in densely populated areas in South-East Asia, such as the Philippines or the west coast of Myanmar where the changes in precipitation between well developed and weak monsoons can exceed 75% or -100% (related to the summer mean precipitation) in southeast India.

The take-home message

- Two regimes of the WNPSM have been identified in the 20th century: persistence of strong monsoons between 1918 and 1948 when the positive PDO-like conditions were dominant and the accumulation of weak monsoons during the 1983-2013 period what is not associated to a well-known SST pattern due to the high variability of the WNPSM. Both regimes had a strong impact on precipitation.

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