Reconstructing the Monsoons in Historical Times by Using Old Wind Measurements

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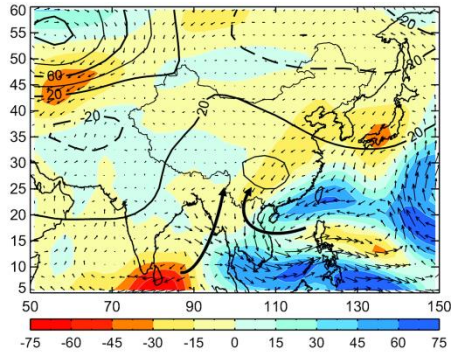
What kind of data you need to understand moisture transport?

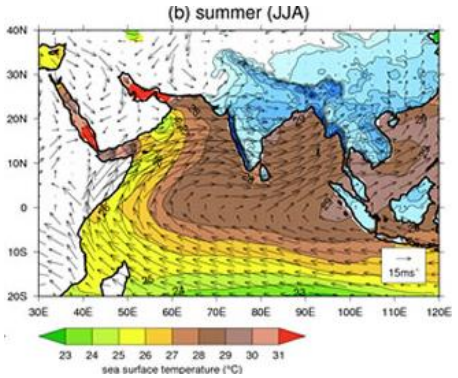
Specific humidity (q)
Wind vector (speed & direction)
In a 3-D grid!

vertically integrated moisture fluxes from surface to 300 hPa (kg m^{-1} s^{-1}, arrows), and total water transport (kg m^{-1} s^{-1}, shading)
Barriopedro et al (2012)



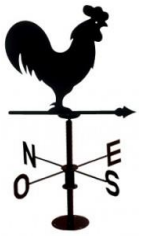
Wind vector (speed & direction)
In a 2-D grid

Wind vector (m s^{-1} arrows and SST (ºC) shading



Wind direction

In a single area… (degrees from the north)



level of happiness

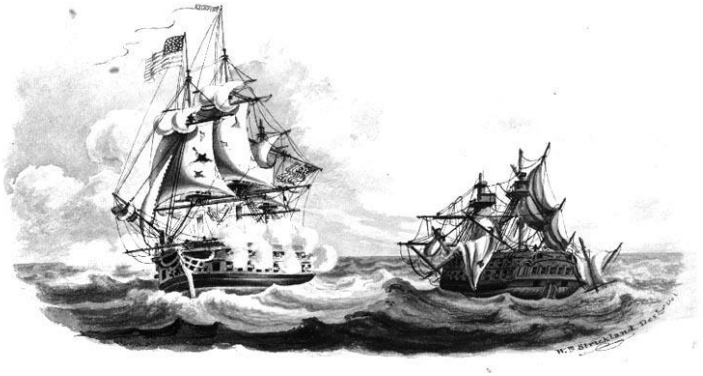
Why are we doing this?

We work in climate reconstruction using historical documents. In particular documentary data contained in ship's logbooks

Now working in Project INCITE (A new generation of INstrumental Climatic Indexes. Application to the study of the monsoon-Mediterranean Teleconection)

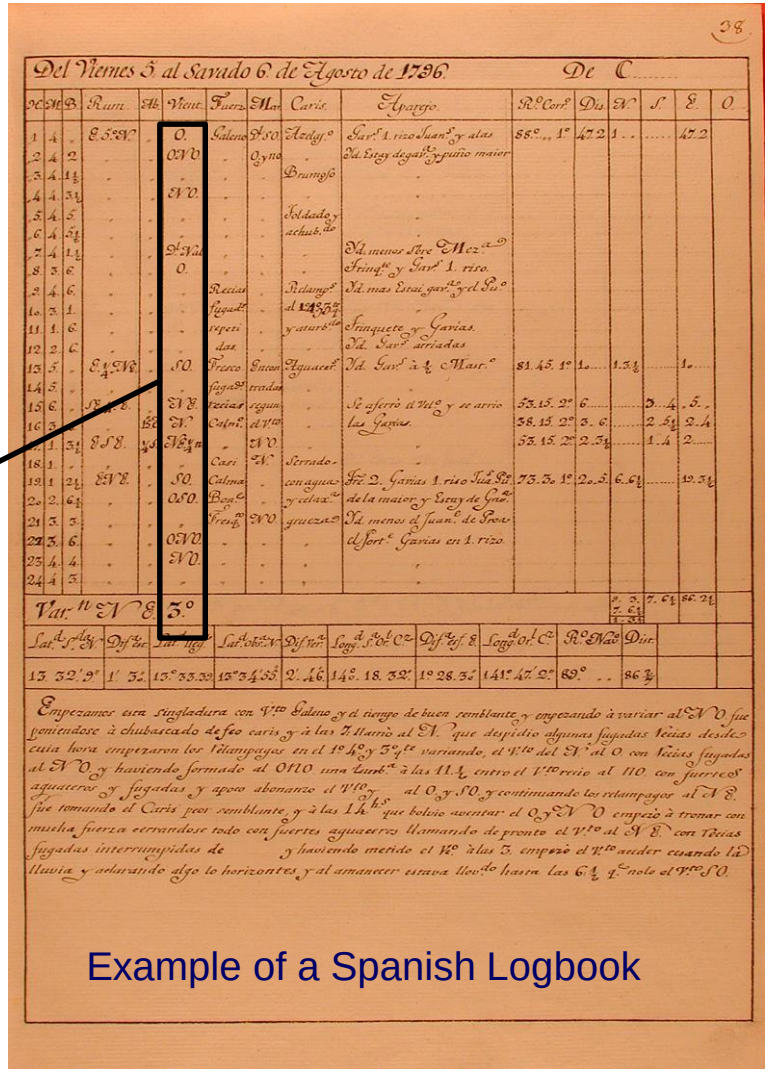
What do ship's logbooks contain and why are they useful for building indices?

The Ship's logbooks



Since at least the 17th Century, it was mandatory for most ships to produce a logbook containing relevant facts of the trip.

Meteorological observations were critical: the survival of the crew depended on the pilot's ability determining the course of the ship.



Example of a Spanish Logbook

The Ship’s logbooks

Astrolabe

Hourglass

Knotted rope

Compass

Meteorological content

RECLAIM

SAMOS

GOSUD

(…)

CLIWOC

ICOADS

International Comprehensive Ocean-Atmosphere Data Set

General state of the weather → Rain, fog, thunder, etc. occurrence. Not very useful for long-term climate studies.

Wind

- **Speed** → Not taken with instrument up to the 20th Century. And prior to 1854 there wasn't an uniform terminology for the terms used to describe the wind strength (Beaufort Scale)
- **Direction** → **Truly instrumental measure. It has been taken in essentially the same way since the beginning of time…**

Some early good experiences

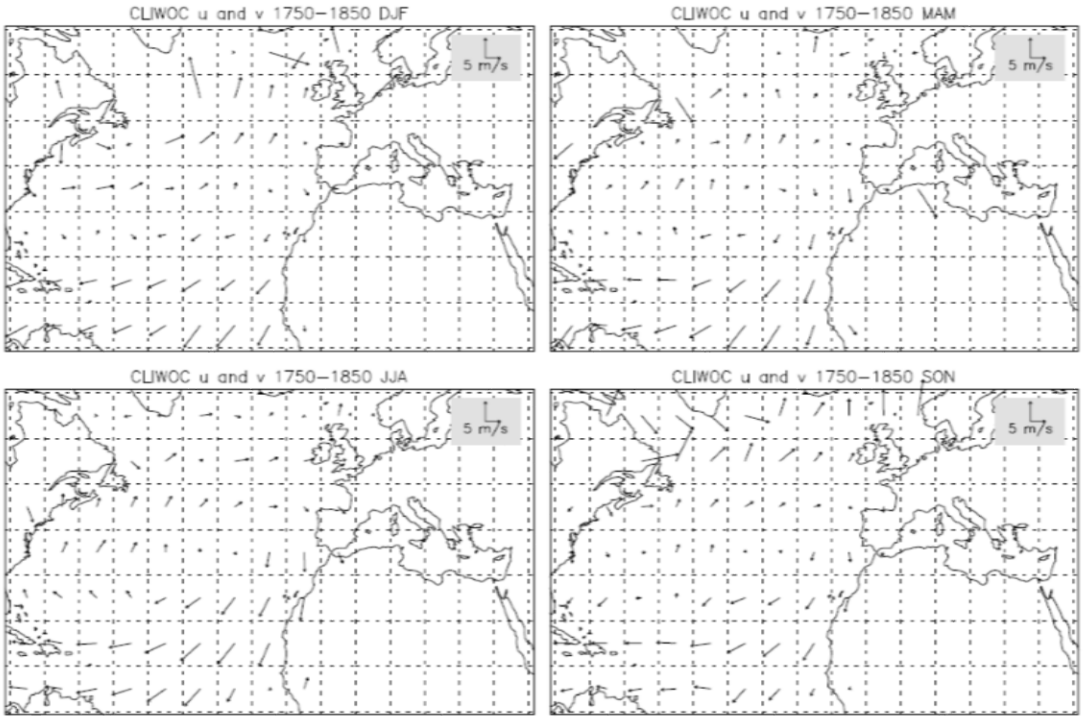


Fig. 3. Initial set of 8°×8° squares over the North Atlantic included in the study. In the center of each square the average CLIWOC wind vectors for the entire 1750–1850 period are shown.

Gallego et al. Clim. Of the Past. 2005

Some early good experiences

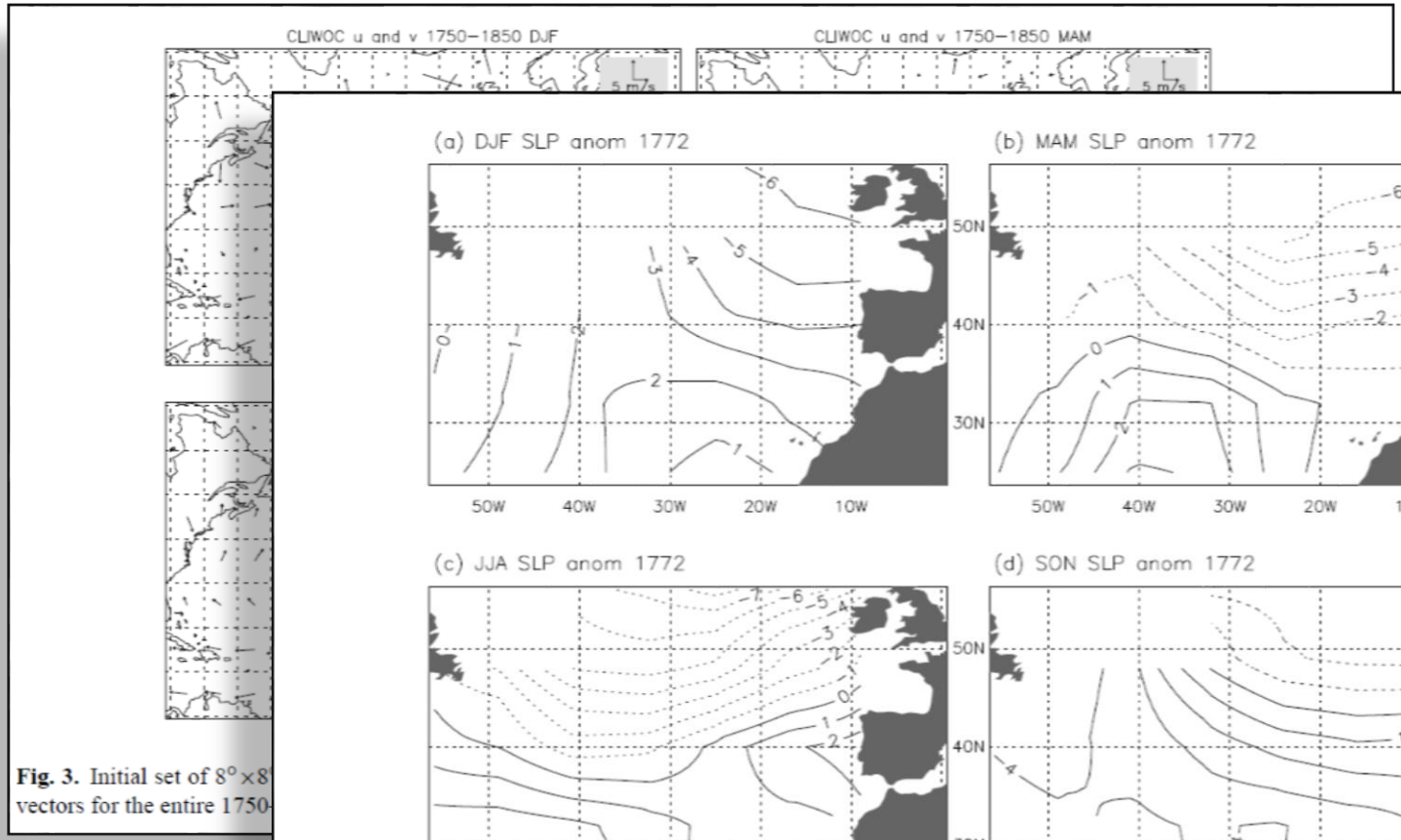


Fig. 3. Initial set of 8°×8
vectors for the entire 1750-

Fig. 9. Reconstructed seasonal SLP anomaly (hPa) relative to the 1961–1990 ICOADS average for 1772. Contours plotted every 1 hPa. Negative SLP anomalies are indicated by dotted contours.

Gallego et al. Clim. Of the Past. 2005

Some early good experiences

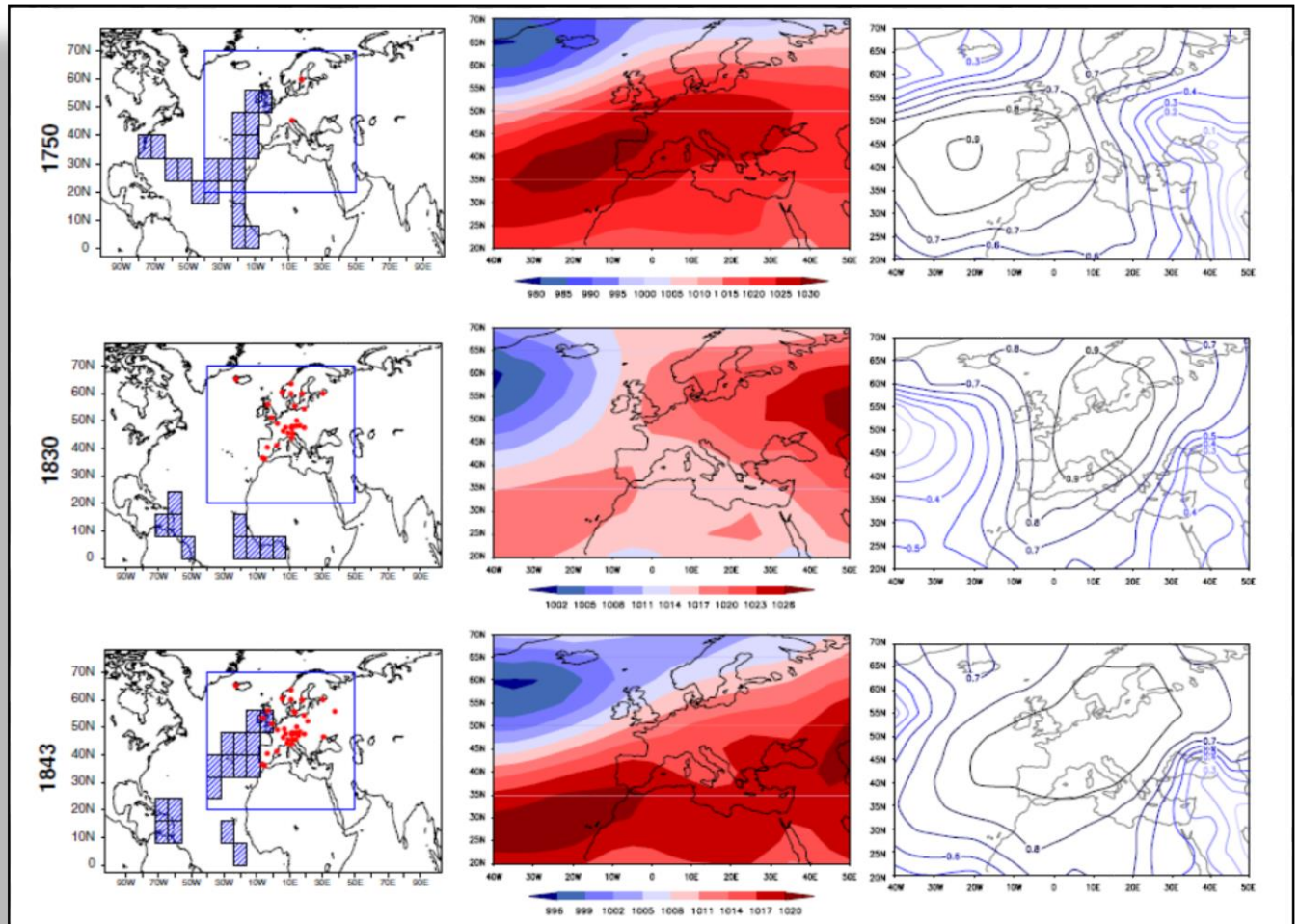
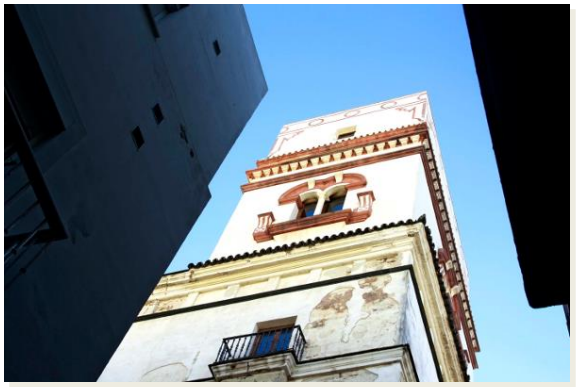


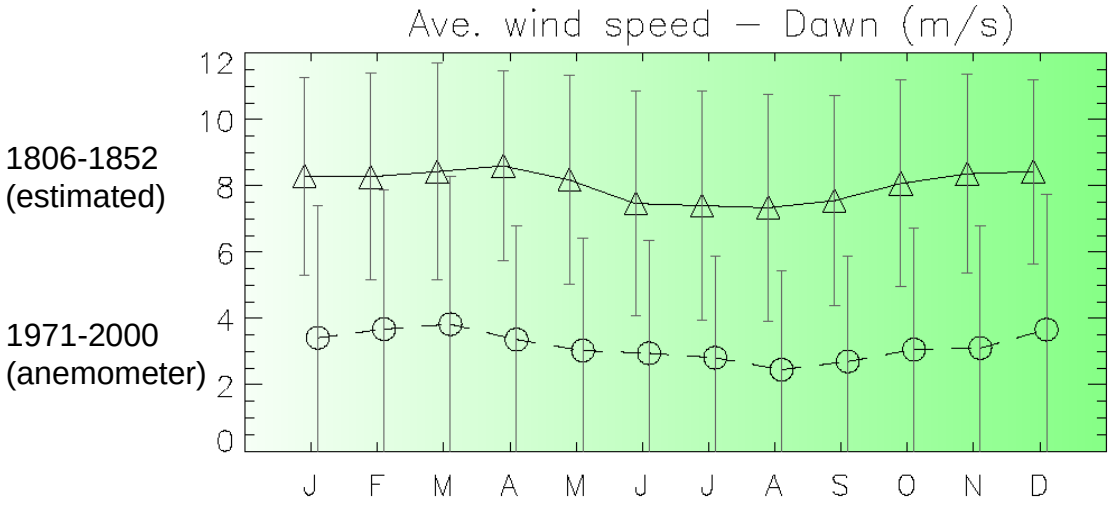
Fig. 5 *Left* predictor network (*blue shaded* boxes denote CLIWOC wind information, *red dots* refer to instrumental pressure series, *blue frame*: reconstruction area); *middle* Reconstructed SLP field; *right* Reconstruction skill expressed as RE values calculated during the verification period 1965–2002 for winter 1750 (*top row*), 1830 (*middle row*), and 1843 (*bottom row*)

Kuttel et al. Clim. Dyn. 2010

And some bad experience



Torre Tavira
Cadiz (Southern Spain)

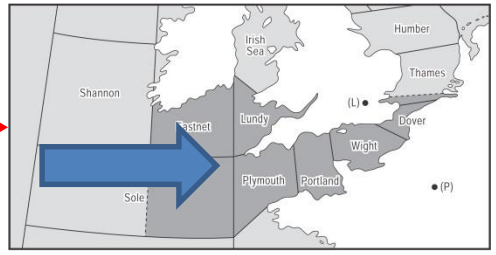


Gallego et al. JGR. 2007

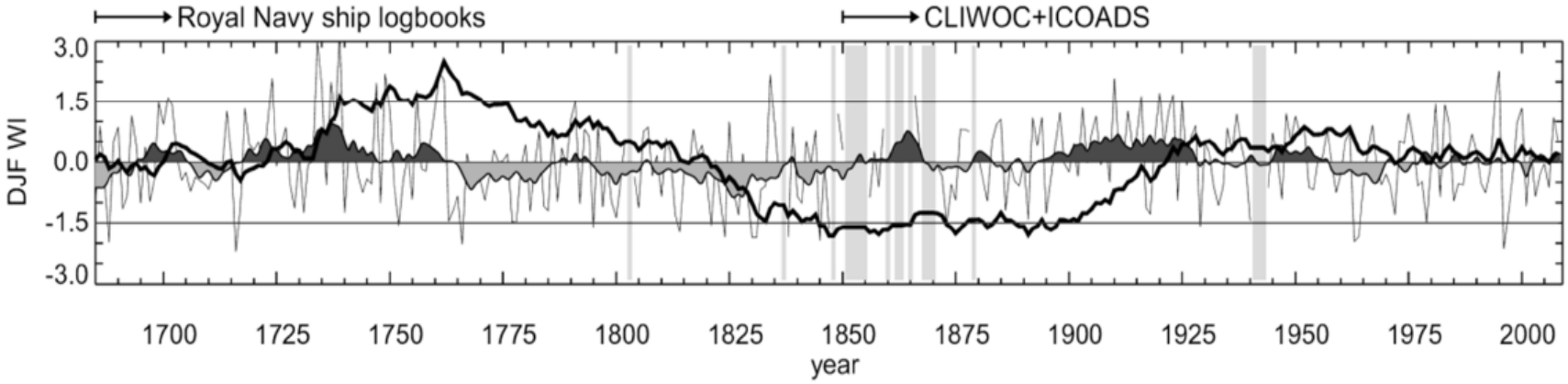
In some cases, we found a significant bias in the estimation of wind force for the first half of the 19th Century and the present-day climatology.

We aimed to create climate indices based in logbook data that could be considered entirely instrumental. This left us with wind direction alone…

Westerly Index “WI” (English Channel)

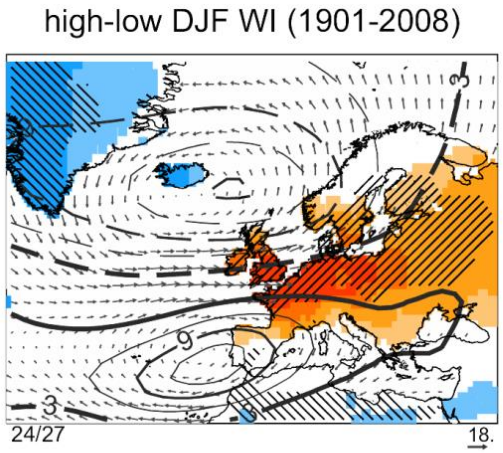


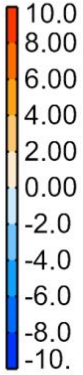
Monthly frequency (%) of westerly winds (225º - 315º) over the English Channel



Westerly Index “WI” (English Channel)

Temperature-related

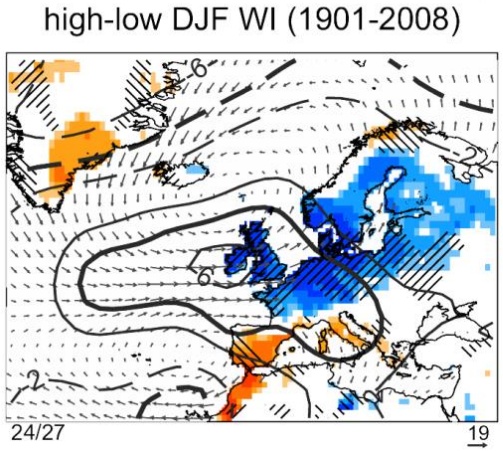


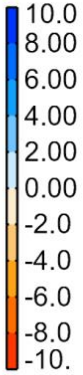


Temp. advection
Temperature
Z500 wind
Z500

P<(0.05)

Precipitation-related



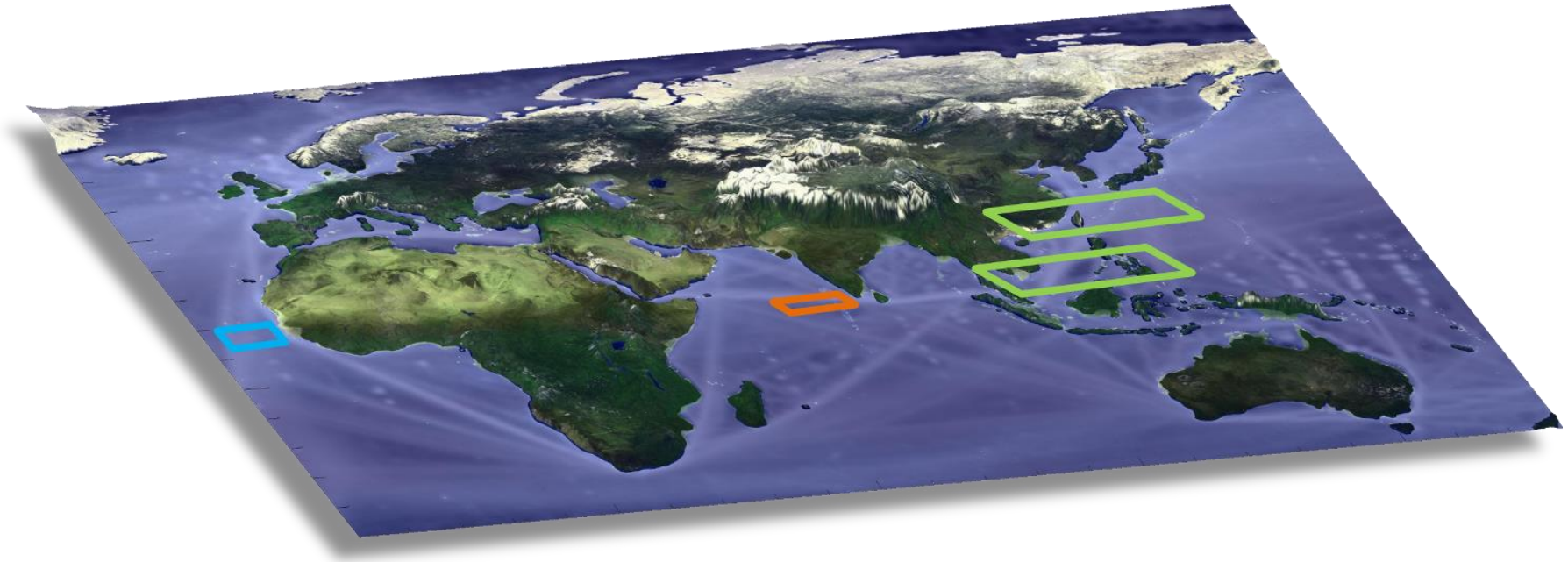


Moisture Conv.
Precipitation
Moisture Flux
Storm Track

P<(0.05)

(Barriopedro et al 2014)

Monsoons



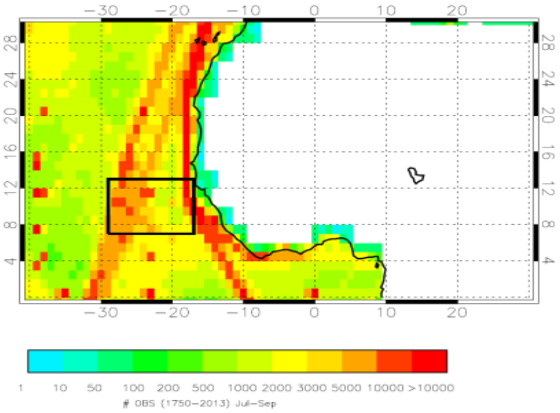
Traditional monsoon definition (based on wind, from Ramage, 1971)

- **Prevailing wind direction shifts by at least 120º between January and July.**
- **Prevailing wind direction persists for at least 40% of the time in January and July.**

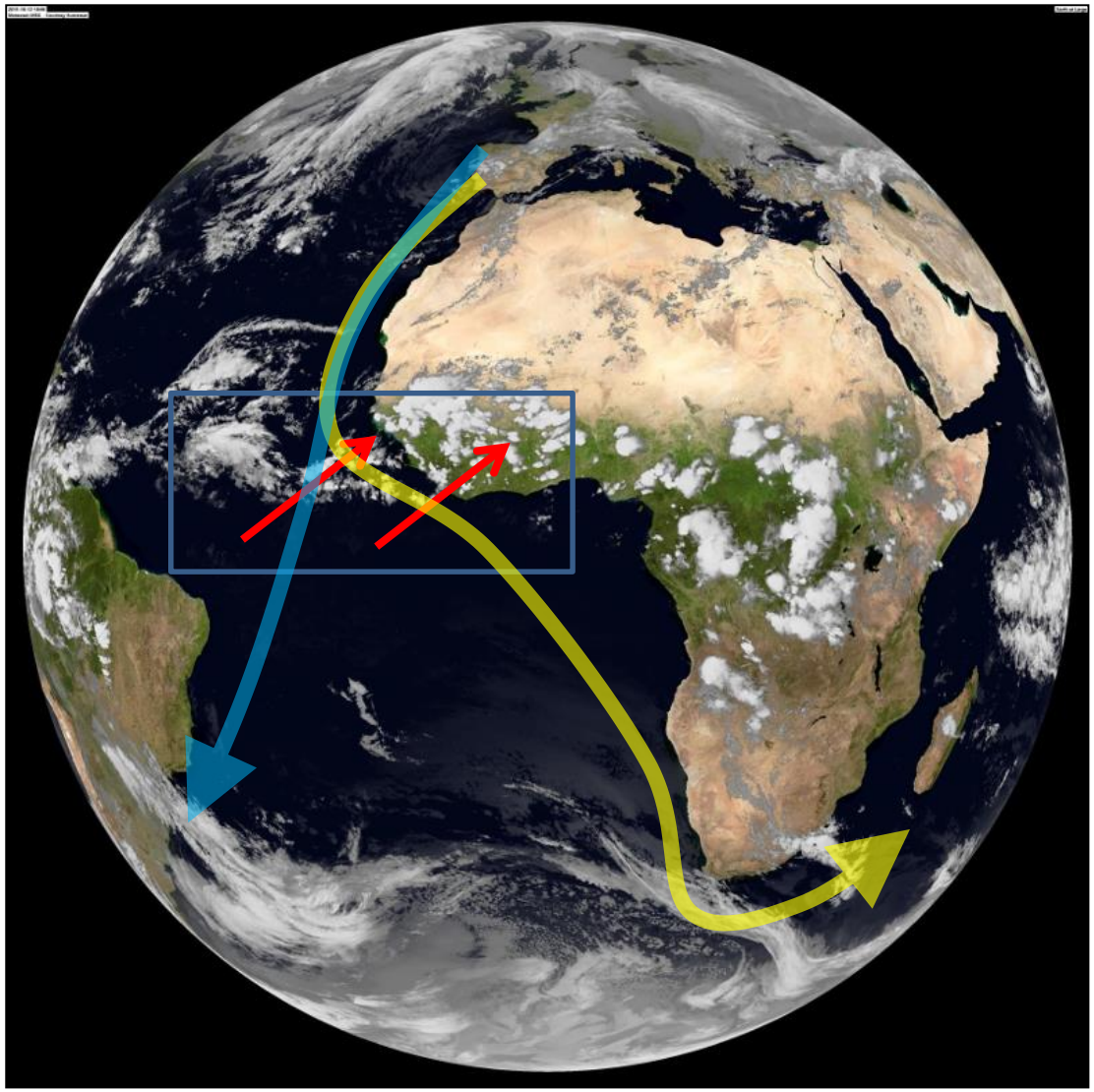
Monsoons are obvious candidates to be quantified by this class of directional indices.

West African Monsoon

The West Africa monsoon is related to SW winds in the coast of Senegal, Gambia and Guinea. The corresponding moisture advection origins most of the annual rainfall in the Sahel area. Millions of people depend on this rainfall.

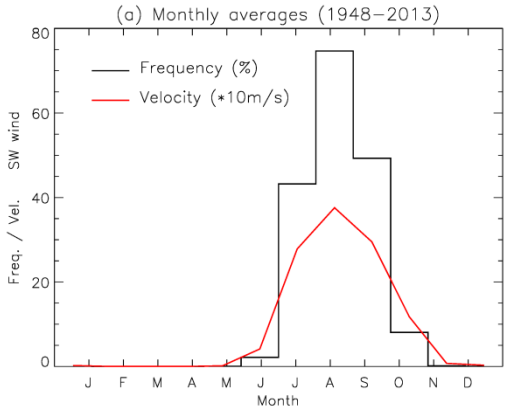


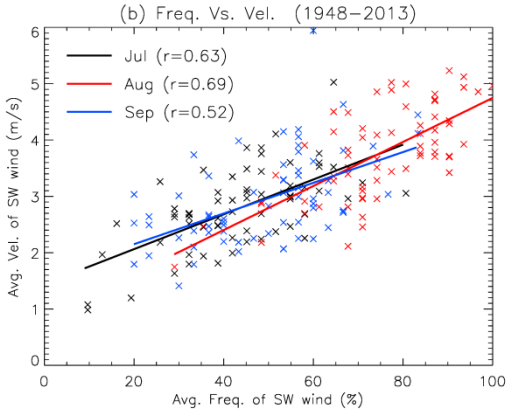
Luckily, thousands of ships have crossed this area going from Europe to Asia and America since the 19th Century.

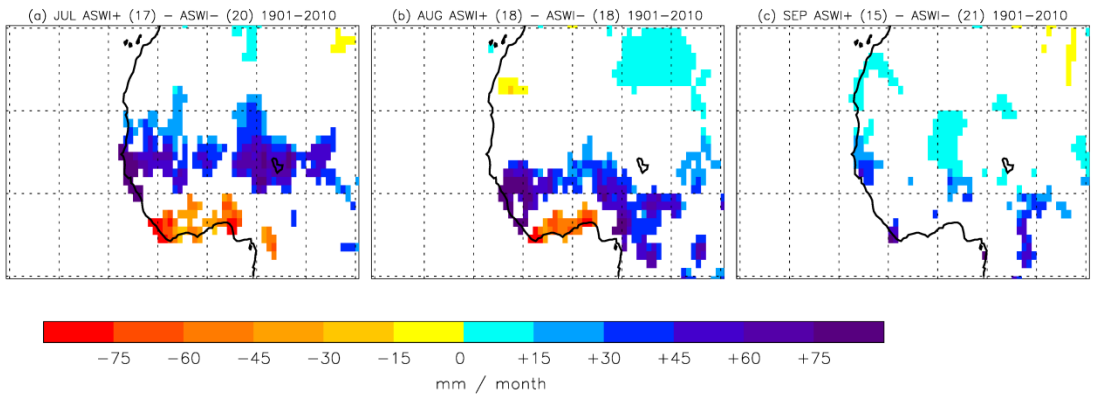


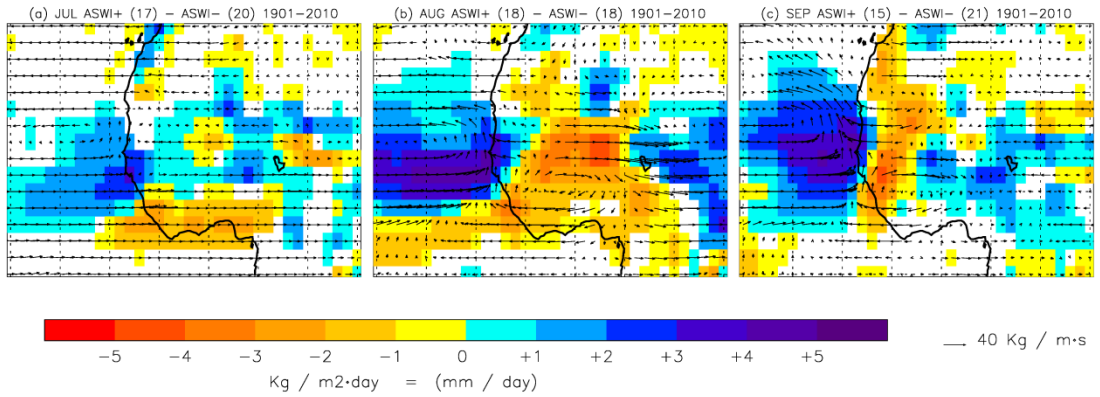
West Africa Monsoon Index

Index = % of days in a month with wind flowing from the SW (180º to 270º)







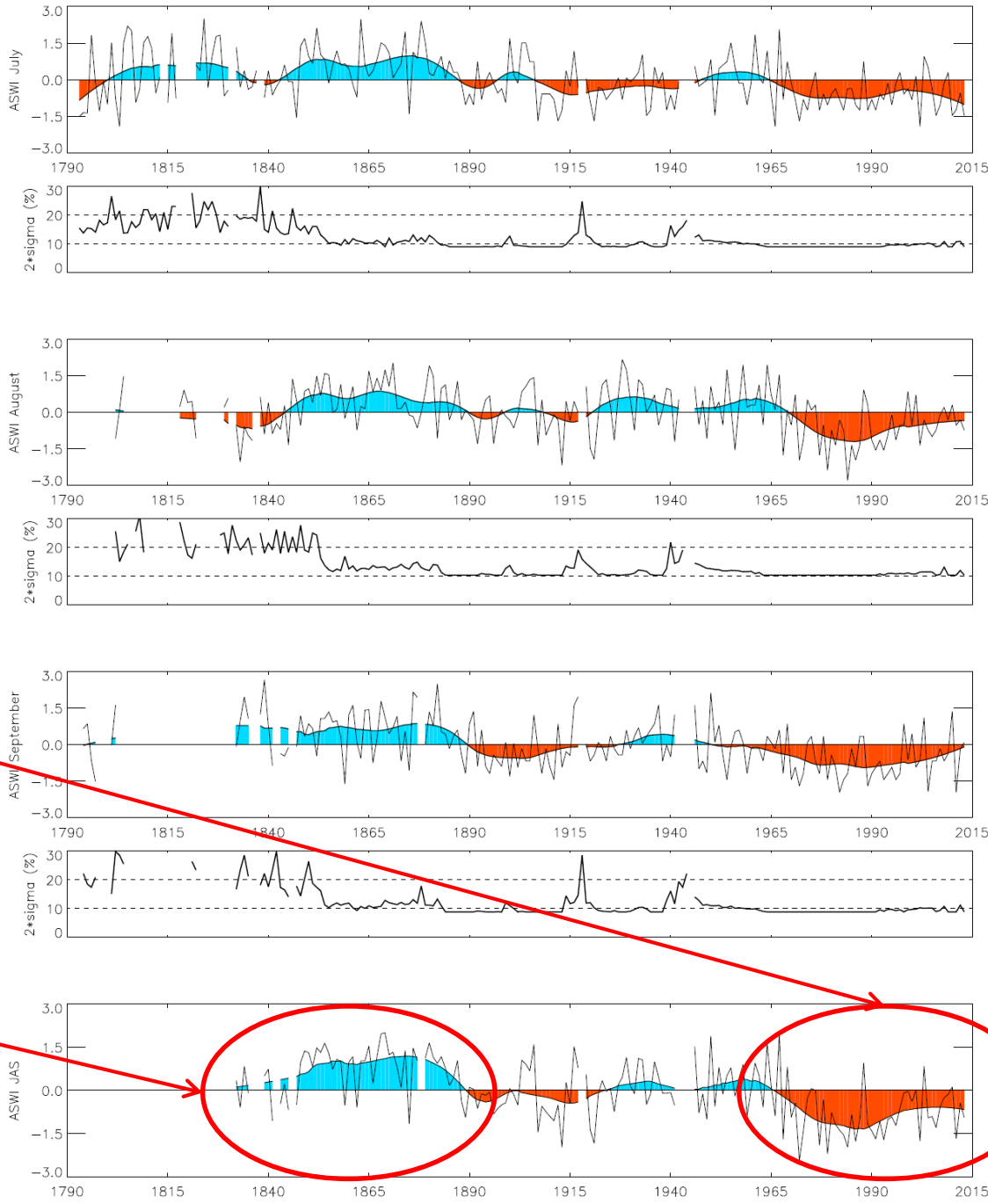


We found that:

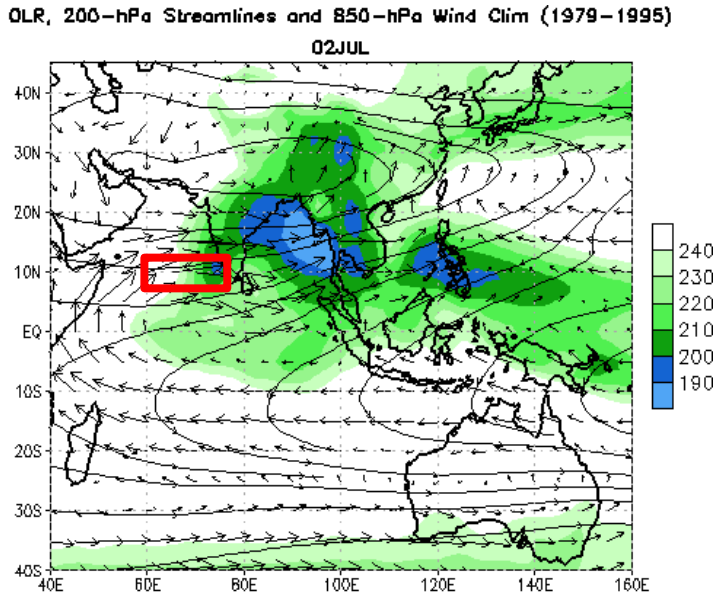
The long dry period in the Sahel which started in the 1970s has no precedent in the last 170 years.

There is a strong evidence of a unknown long wet period in the Sahel from 1845 to 1890.

Gallego et al. QJRMS, 2015



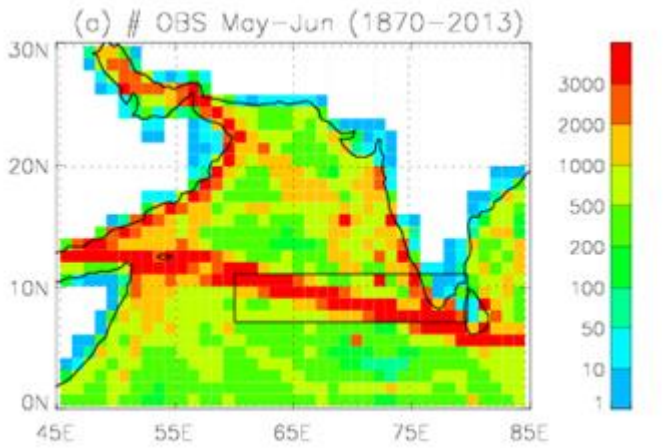
Indian monsoon



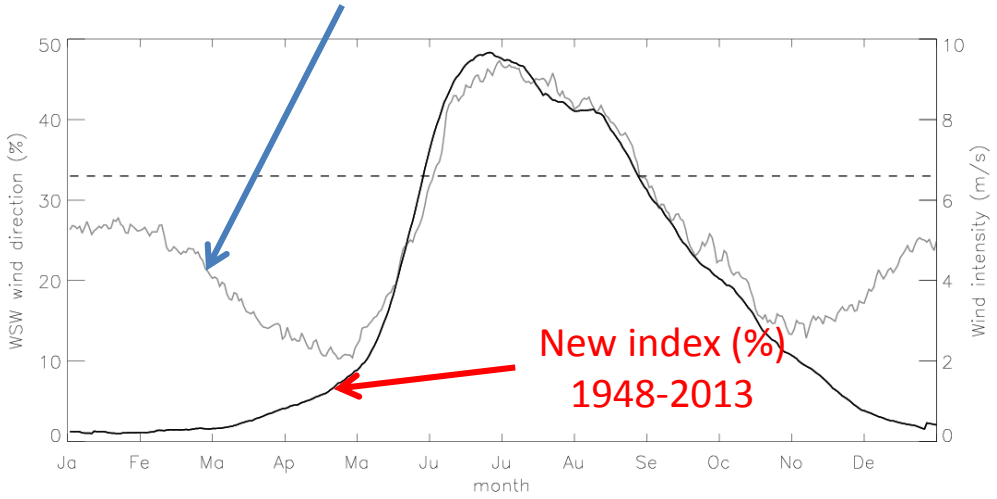
Data Sources: OLR – NESDIS/ORA, Winds – NCEP CDAS/ Reanalysis

It has been even posisible to track subtle details of the monsoons as the **Monsoon onset**

INDEX = 21-day running average of the percentage of WSW winds (from 225º to 270º) in the [60ºE-80ºE; 7ºN-11ºN] area.

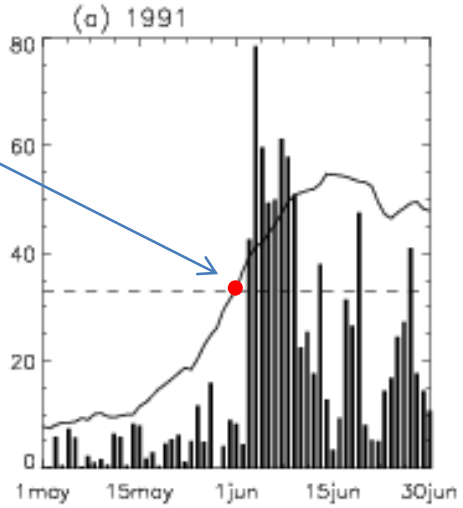


average wind speed from NCEP/NCAR reanalysis (1948-2013)



Indian monsoon

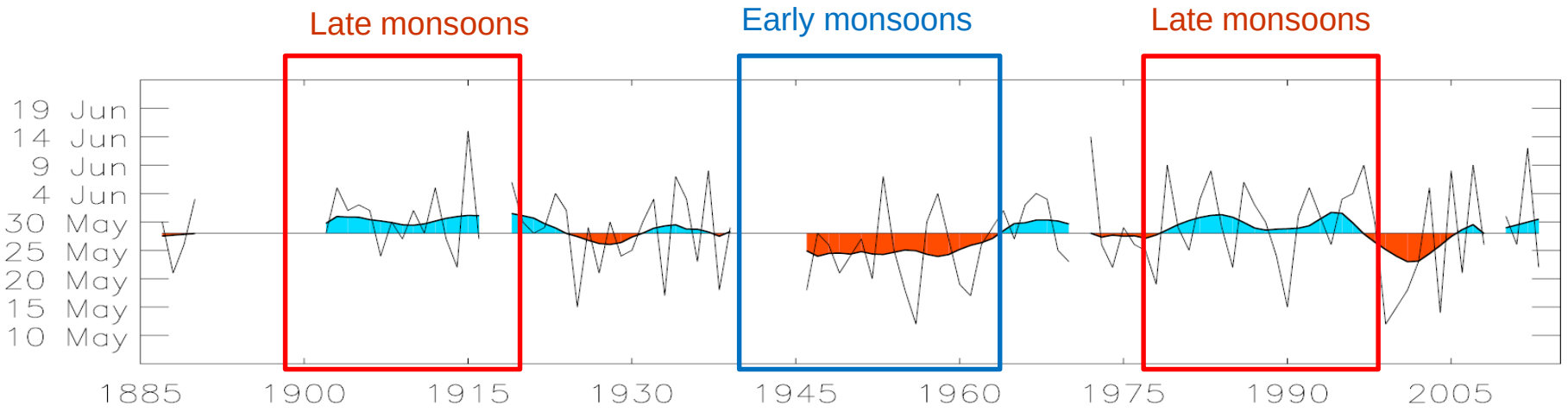
Index >33% marks the monsoon onset!



Daily precipitation at Kerala (mm/day) and index (%)

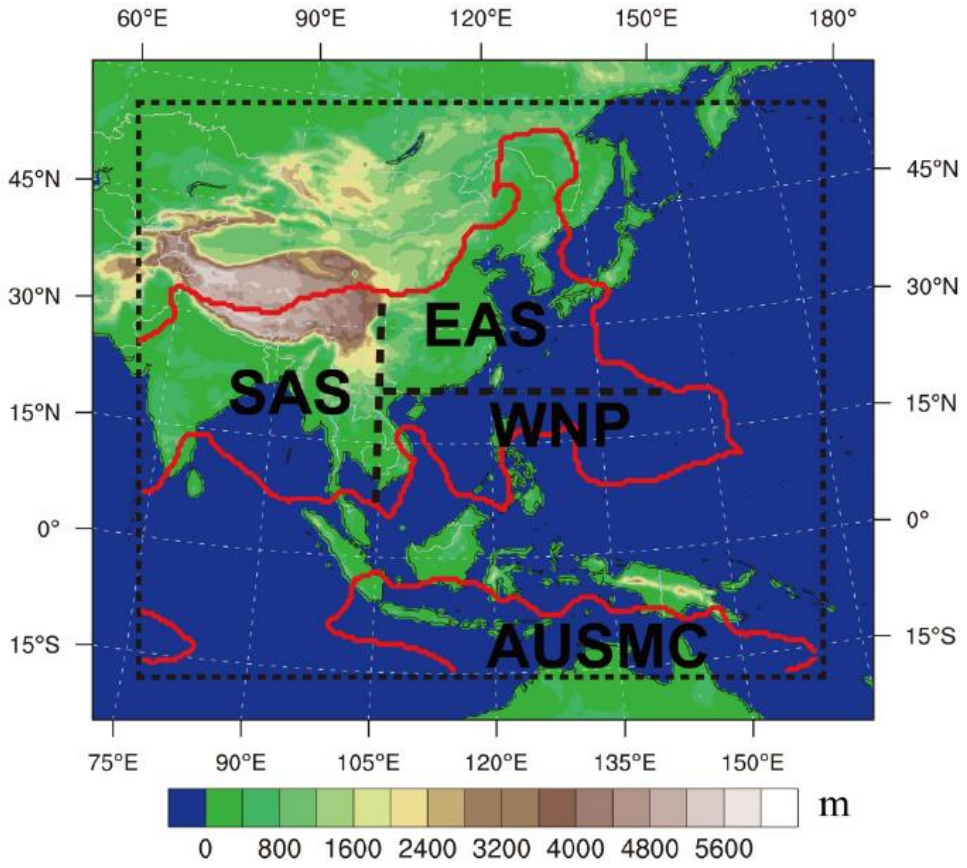
IMDold	IMDup	WA09	JO06	FW03	XA07
0.81	0.85	0.89	0.75	0.56	0.78

ISM onset index	Data source	Dates available
IMDold	Joseph et al. (1994)	1901-2005
IMDup	Pai and Rajeevan (2009)	1971-present
WA09	Wang et al (2009)	1948-2007
JO06	Joseph et al. (2006)	1971-2003
FW03	Fasullo and Webster (2003)	1948-2000
XA07	Xavier et al. (2007)	1950-2003



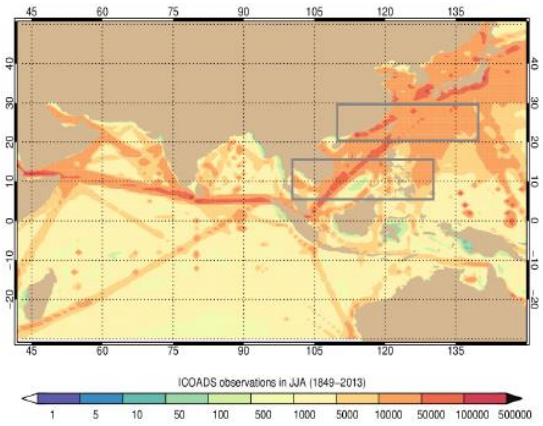
Ordoñez et al. J. Climate, 2016.

Western North Pacific Summer Monsoon



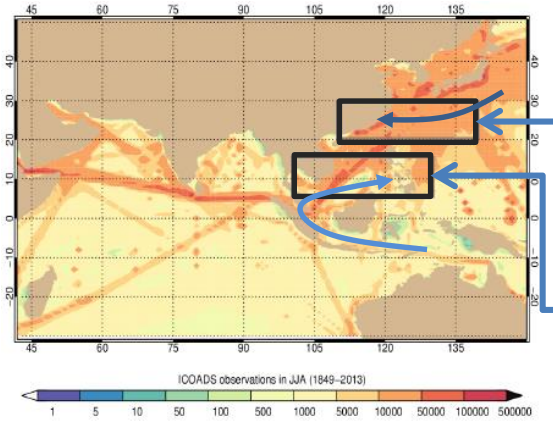
Huang et al. 2016

Mostly an oceanic monsoon, but it impacts millions of people in Philippines, and it modulates a large part of the Pacific Climate



And again, lots of wind measurements!

Western North Pacific Summer Monsoon



D2 = % Easterlies (month)

INDEX = D1 – D2

D1 = % Westerlies (month)

The JJA Western North Pacific Directional Index

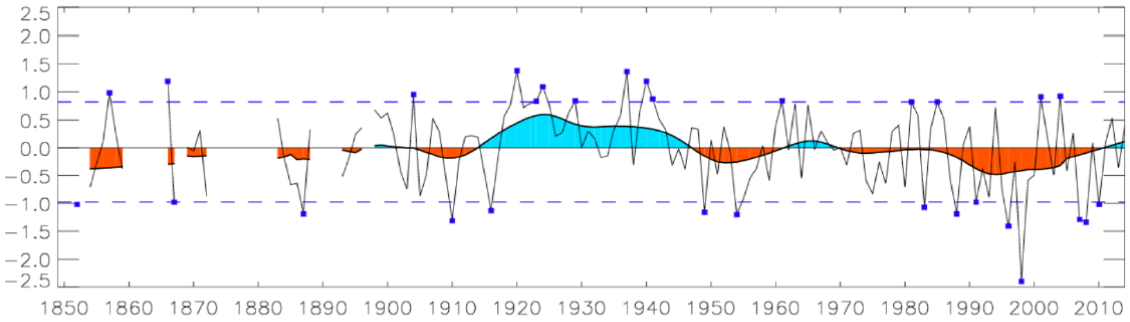
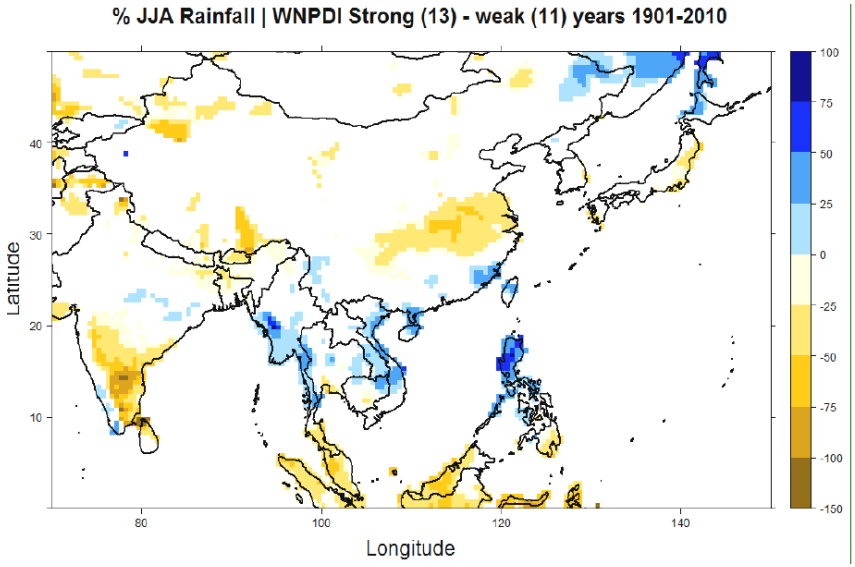


FIG 3: (a) Evolution of the JJA WNPDI (thin black line), robust locally weighted regression with a 21-year window (shaded curve), extreme monsoons (blue squares) based on the 10th and 90th percentiles (dashed blue lines) of the WNPDI for the 1849-2014 period.

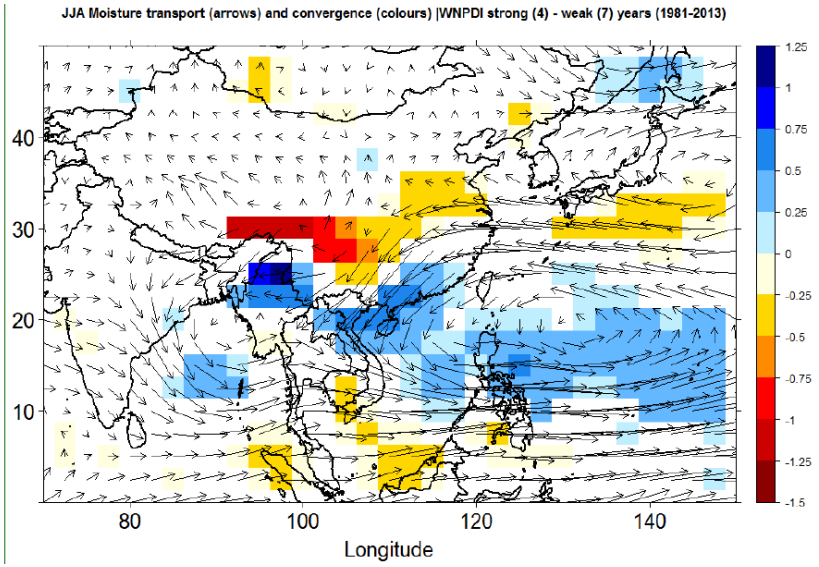
It was 1920-1945 a period of strong WNPSM?

Former longest index for this monsoon (Wang et al 2001) r=0,88 with our new index

Western North Pacific Summer Monsoon



Precipitation differences between strong and weak monsoons (% over the average value) GPCC data 1901-2010



Corresponding moisture transport (arrows in kg/m·s) and moisture convergence (kg / cm2 · s)

Summary

- Against all odds, it is possible to compute instrumental indices bases solely on wind direction directly related to moisture transport and precipitation.
- In the cases already developed, results are always consistent to previous approaches.
- Directional indices could be extended back in time as soon as new data are available (this has been explicitaly done for the Westerly Index to 1685! But it is time and money consuming!!!!)
- Still working!