

# A reconstruction of Madden-Julian Oscillation variability and global impacts from 1905 to 2011

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- The **Madden-Julian Oscillation (MJO)** is dominant mode of intraseasonal (30-90 day) variability in the Tropics
- Expressed through
  - **Deep convection**, cloud cover
  - **Rainfall**
  - **Low- and high-level winds**
- **Develops** over Indian Ocean and propagates eastward, 5-10 m/s
- Influences generation of **tropical cyclones**, **sea level variations**, **extratropical air temperature**, etc...
- Most widely accepted characterization is the **Wheeler and Hendon (2004) (WH04) index**
- Based partly on remotely-sensed OLR, so *not defined prior to 1974*
- Would be of great interest to **extend index** over the pre-satellite era...

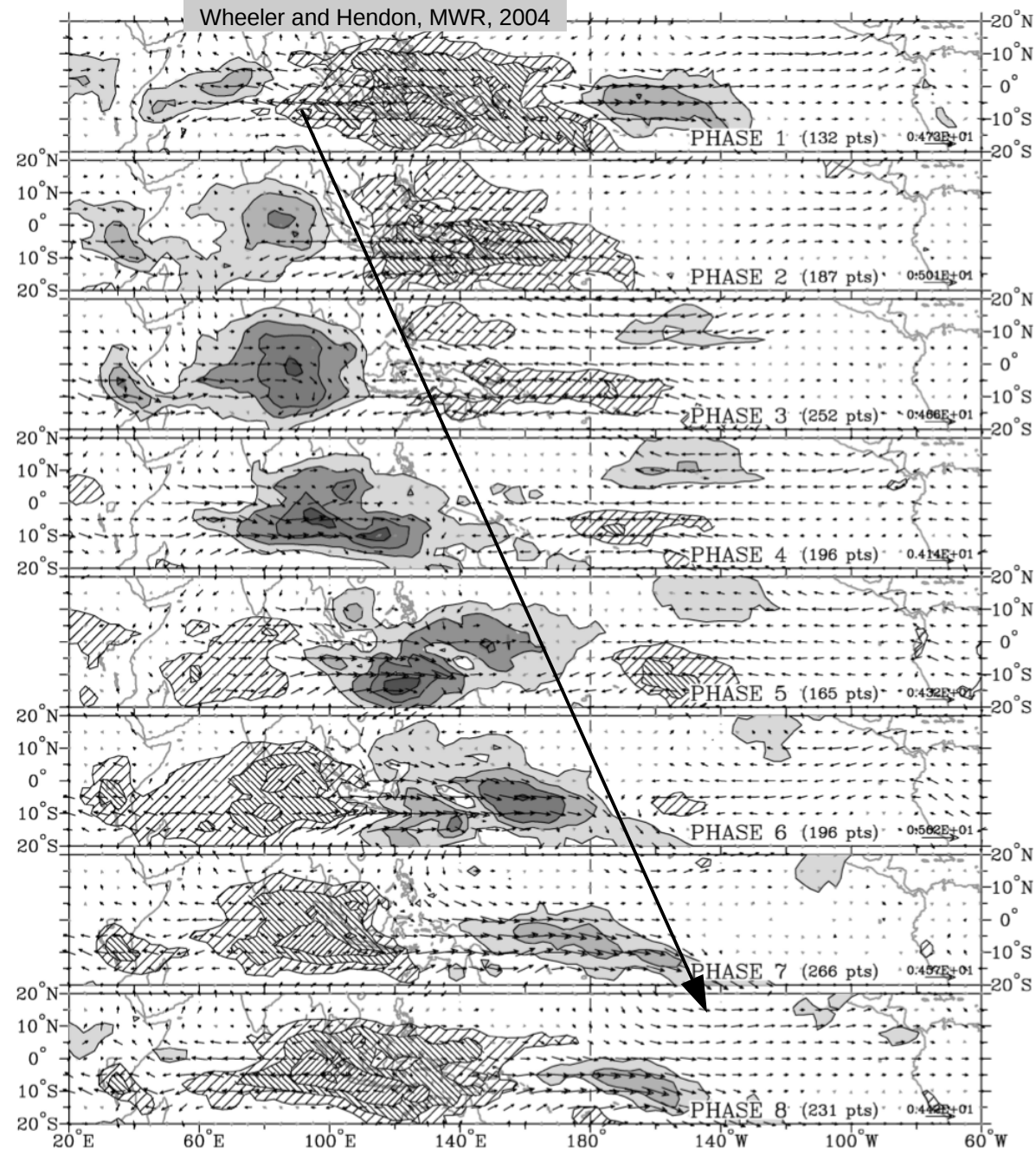
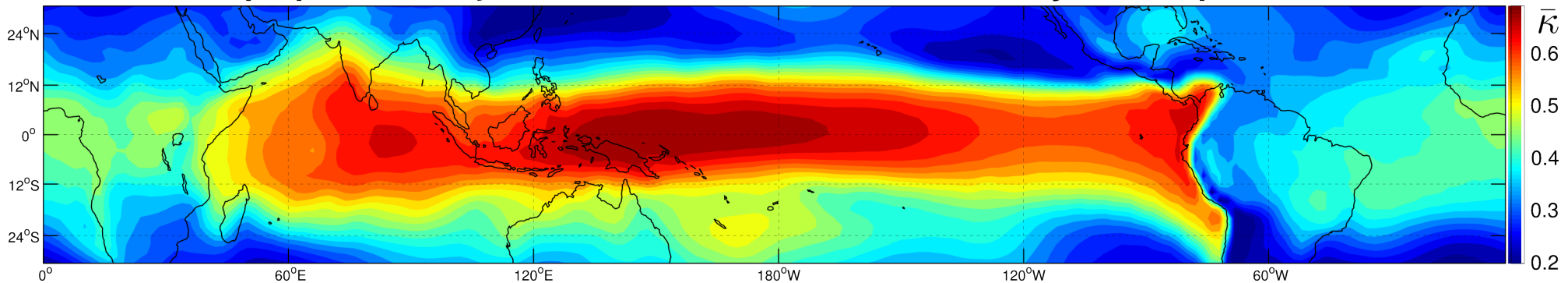


FIG. 8. DJF composite OLR<sup>4</sup> and 850-hPa wind vector anomalies. Shading levels denote OLR anomalies less than -7.5, -15, -22.5, and -30 W m<sup>-2</sup>, respectively, and hatching levels denote OLR anomalies greater than 7.5, 15, and 22.5 W m<sup>-2</sup>, respectively. Black arrows indicate wind anomalies that are statistically significant at the 99% level, based on their local standard deviation and the Student's *t* test. The magnitude of the largest vector is shown on the bottom right, and the number of days (points) falling within each phase category is given.

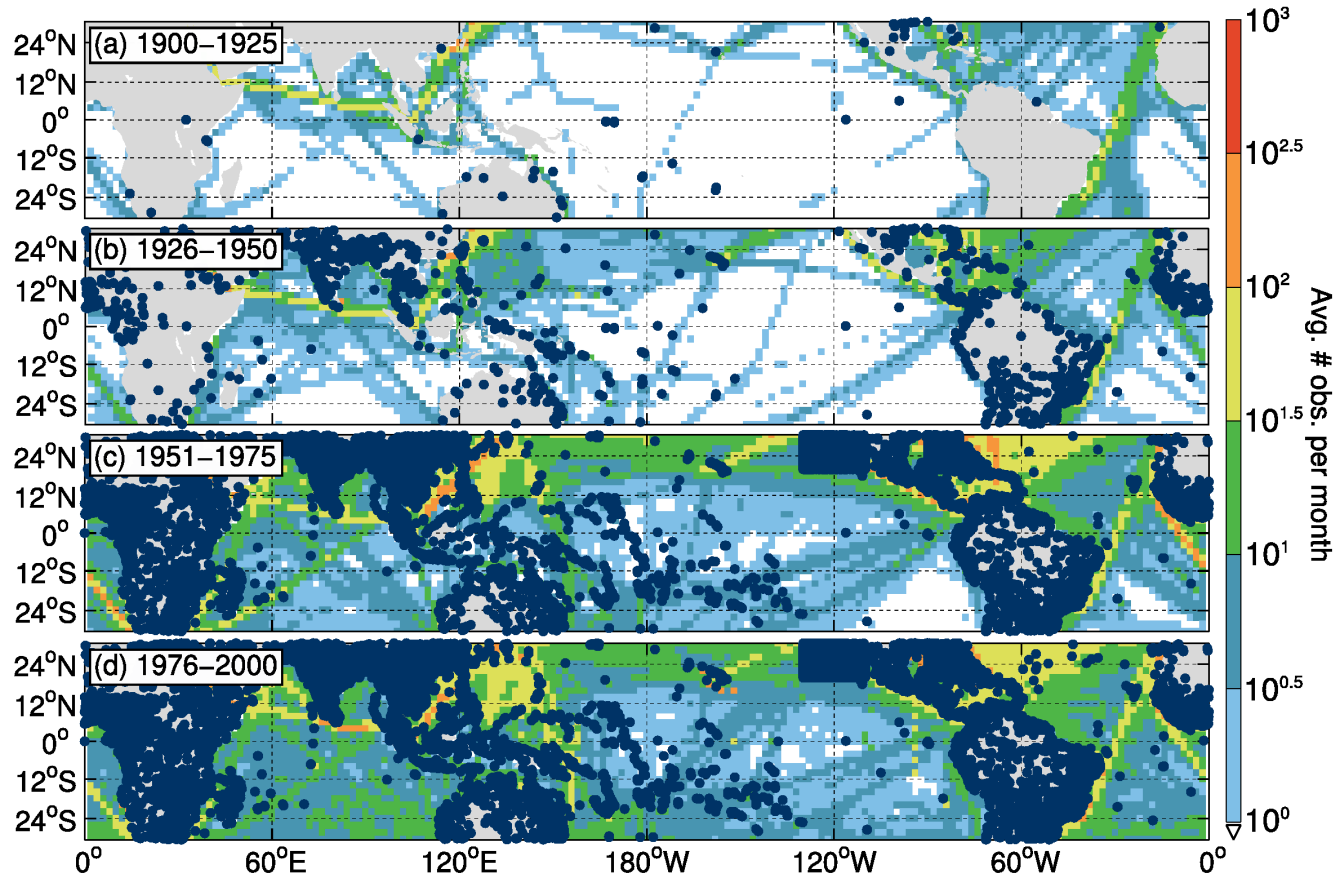
- The MJO has a **strong signature in surface pressure** for which **daily measurements are available for 100+ years**
- We **reconstruct** the Wheeler and Hendon (2004) MJO index **from 1905 to 2011** based on a multiple linear regression of tropical surface pressure from the 20<sup>th</sup> Century Reanalysis Project (**20CR**)

proportion of MJO standard deviation accounted for by surface pressure



- We use time series of pressure at a number of locations as predictors in a **multiple regression model**
- However, need to limit the number of locations to avoid overfitting and data quality issues

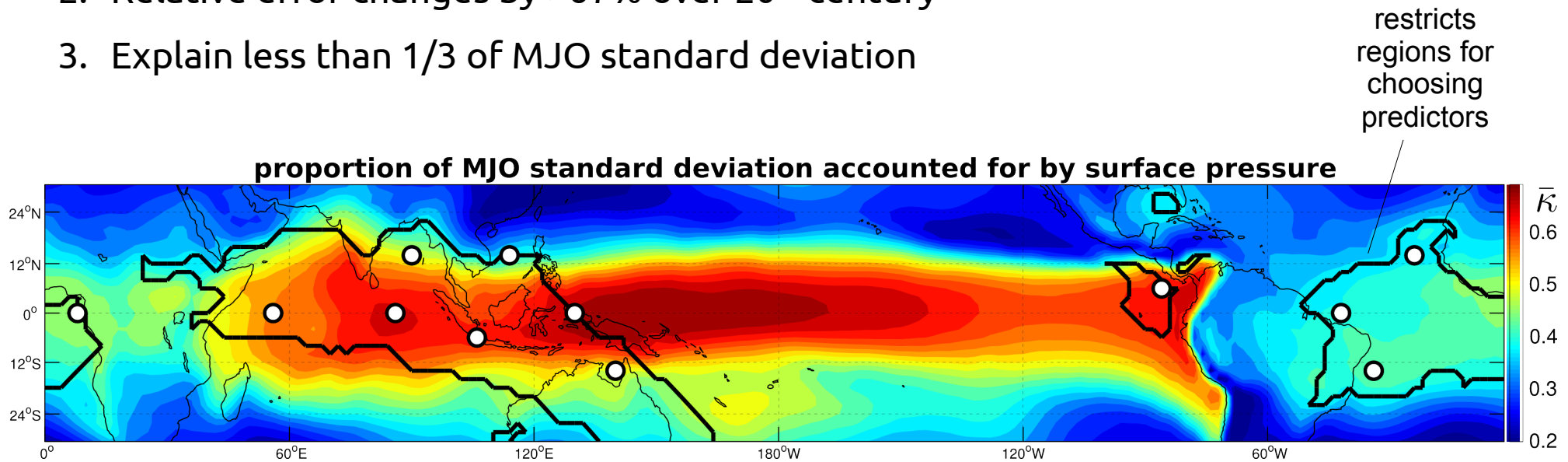
- One problem with doing such a reconstruction is the heterogeneous nature of the observing system ... in time and space:



- 20CR is performed with a 56-member ensemble, yielding ensemble mean and variance
- Ensemble variance can be related to observational density – as the observations become more sparse, the variance (uncertainty within the ensemble) increases
- Relative error = ensemble spread normalized by std. dev. of time series**

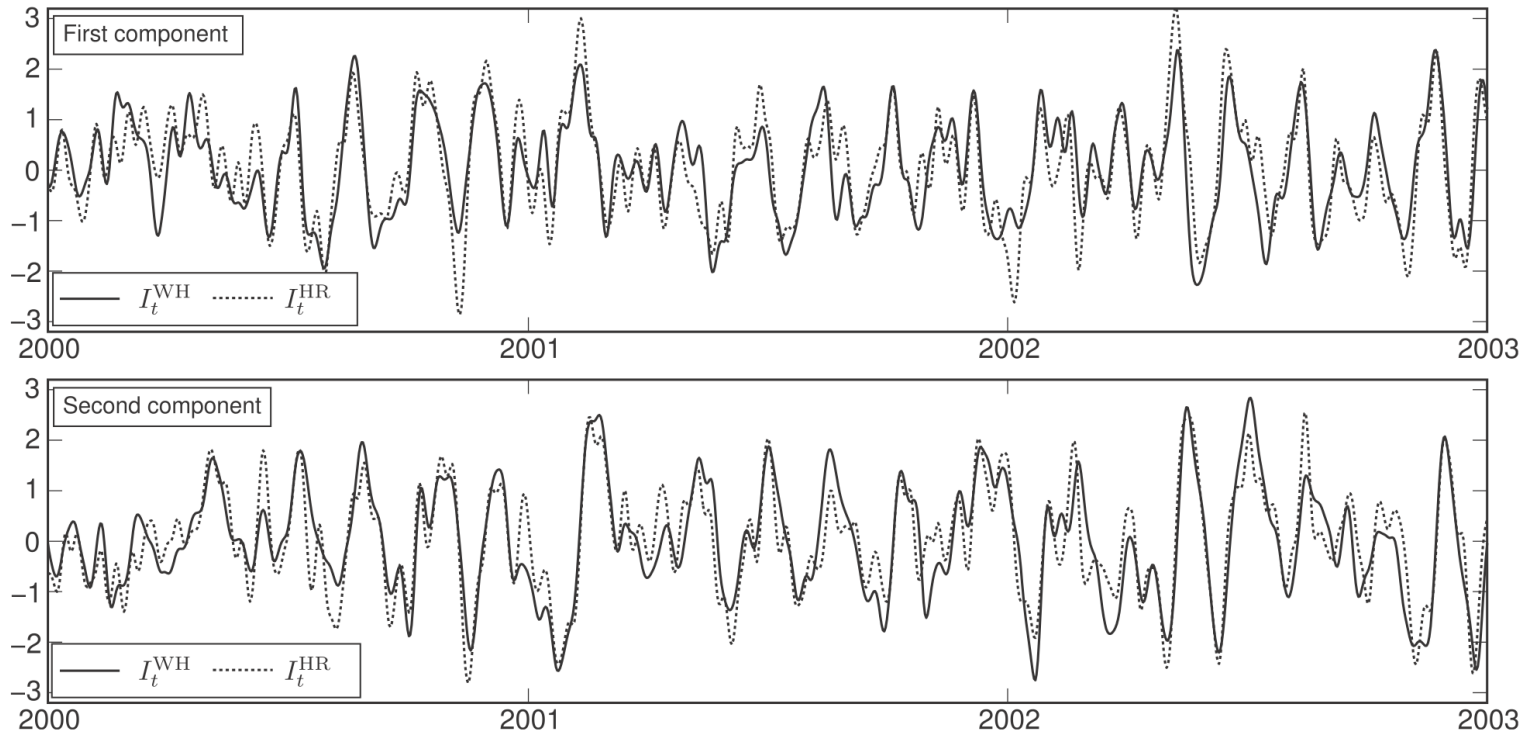
- **Reject regions** if they fail to meet the following restrictions:

1. Mean relative error  $> 0.8$
2. Relative error changes by  $> 67\%$  over 20<sup>th</sup> century
3. Explain less than 1/3 of MJO standard deviation

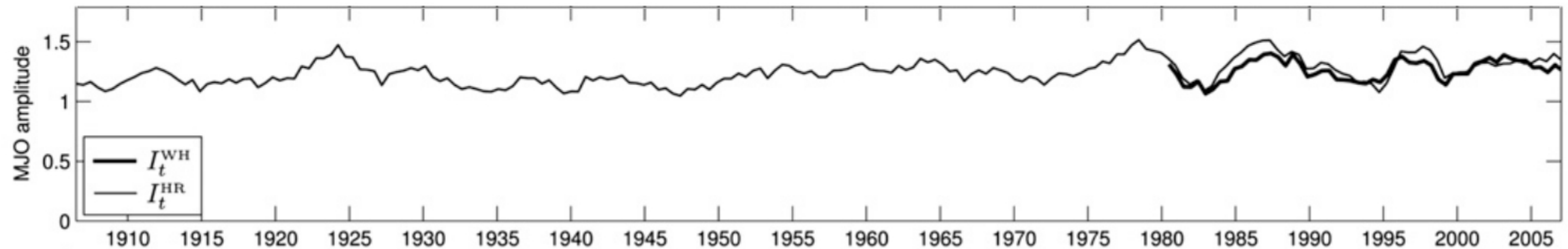


- Chose **12 locations**, also taking into account spatial decorrelation lengthscales
- Pressure time series at these locations, with seasonal, interannual, and high freq. ( $< 10$  days) signals filtered out, were fed into a multiple linear regression model and used to hindcast the MJO index over the 1905-2011 period to give a reconstruction of MJO variability.

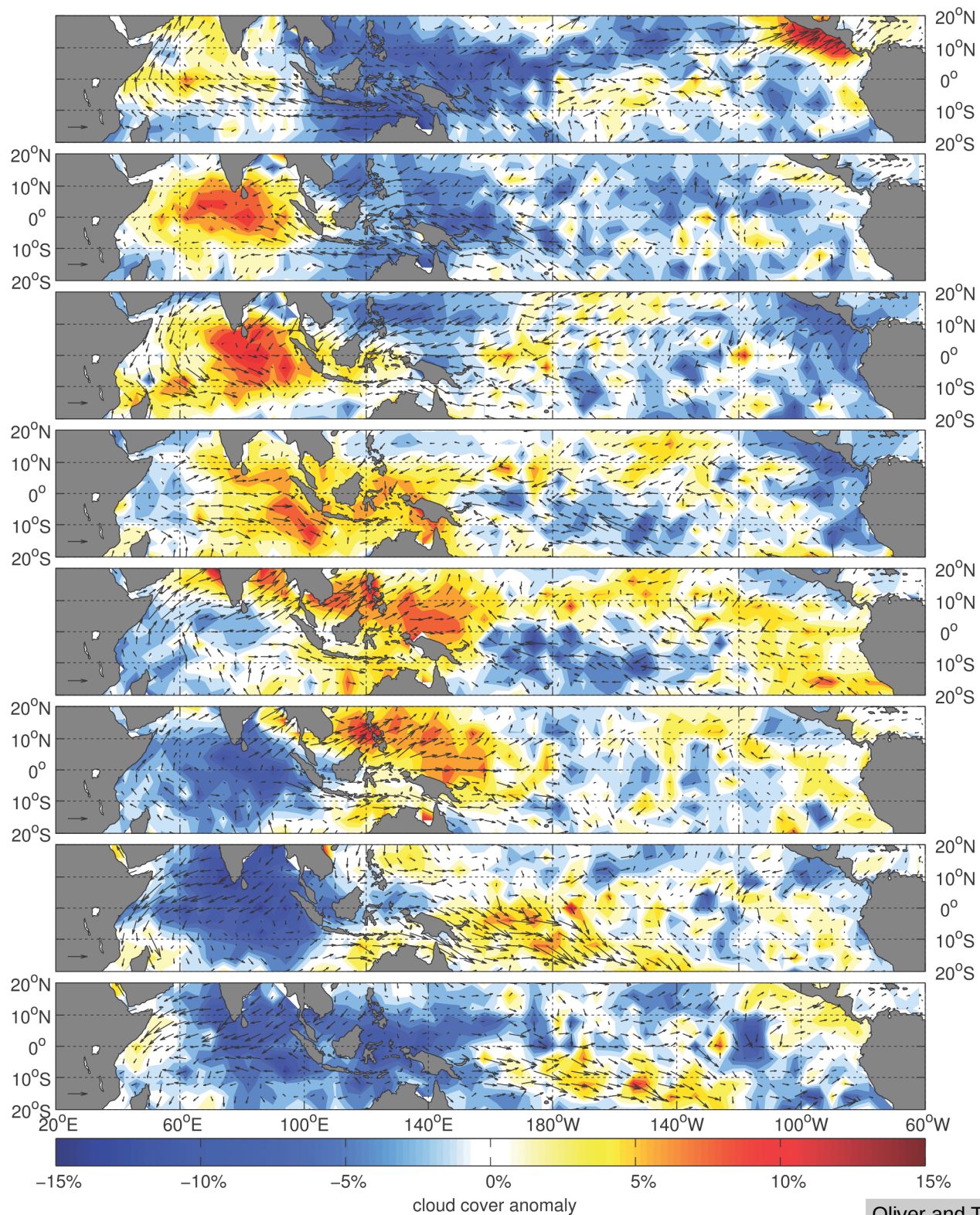
- Reconstruction **well-correlated with WH04 index** over shared period (post-1979)
  - 0.82 for 1<sup>st</sup> component / 0.84 for 2<sup>nd</sup> component



- Regression coefficients used to **hindcast the index back to 1905**

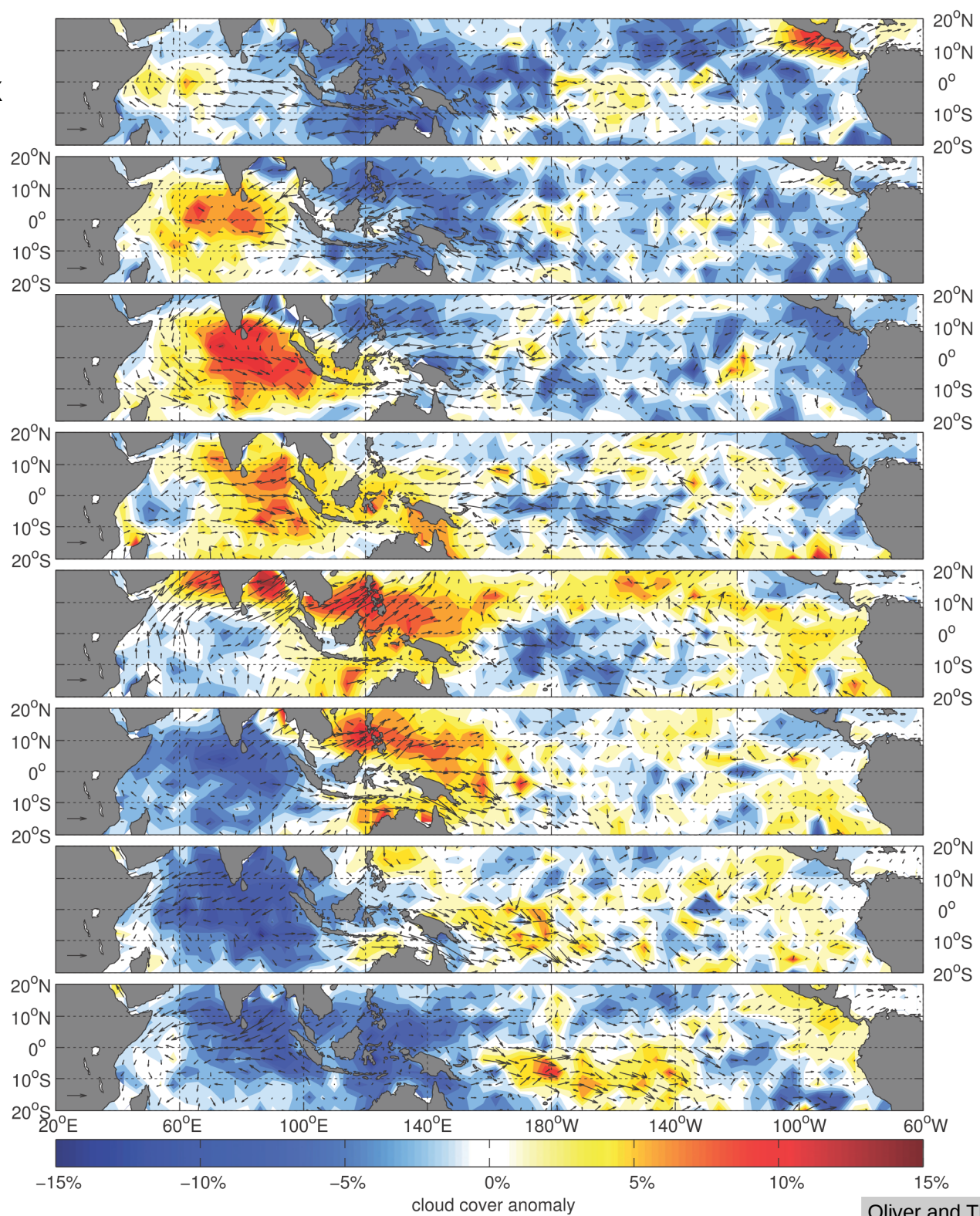


# WH04 index 1979-2008



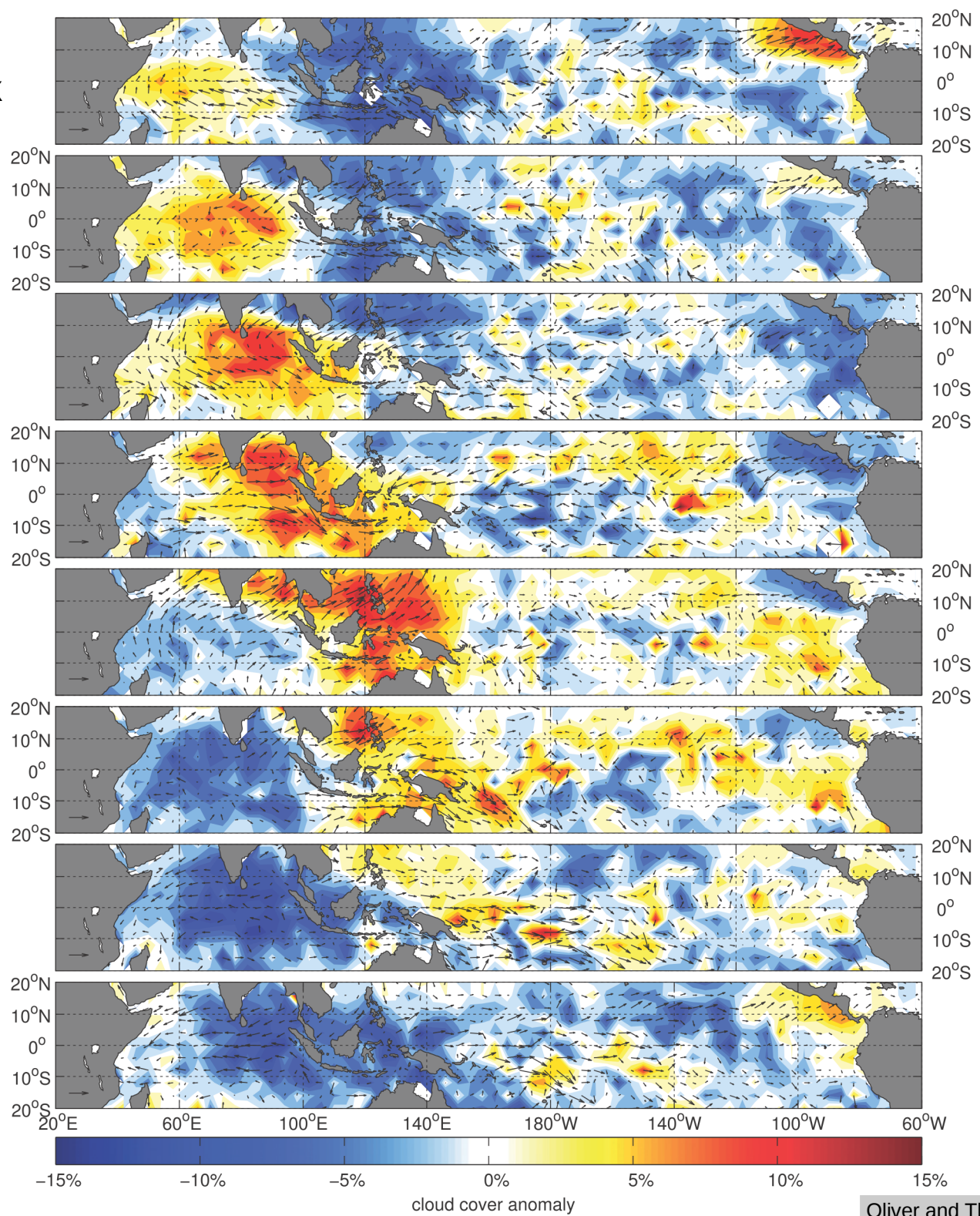
Cloud cover (%) and  
surface wind speed  
from Extended Edited  
Synoptic Cloud Report  
(EESCR)

# Reconstructed index 1979-2008

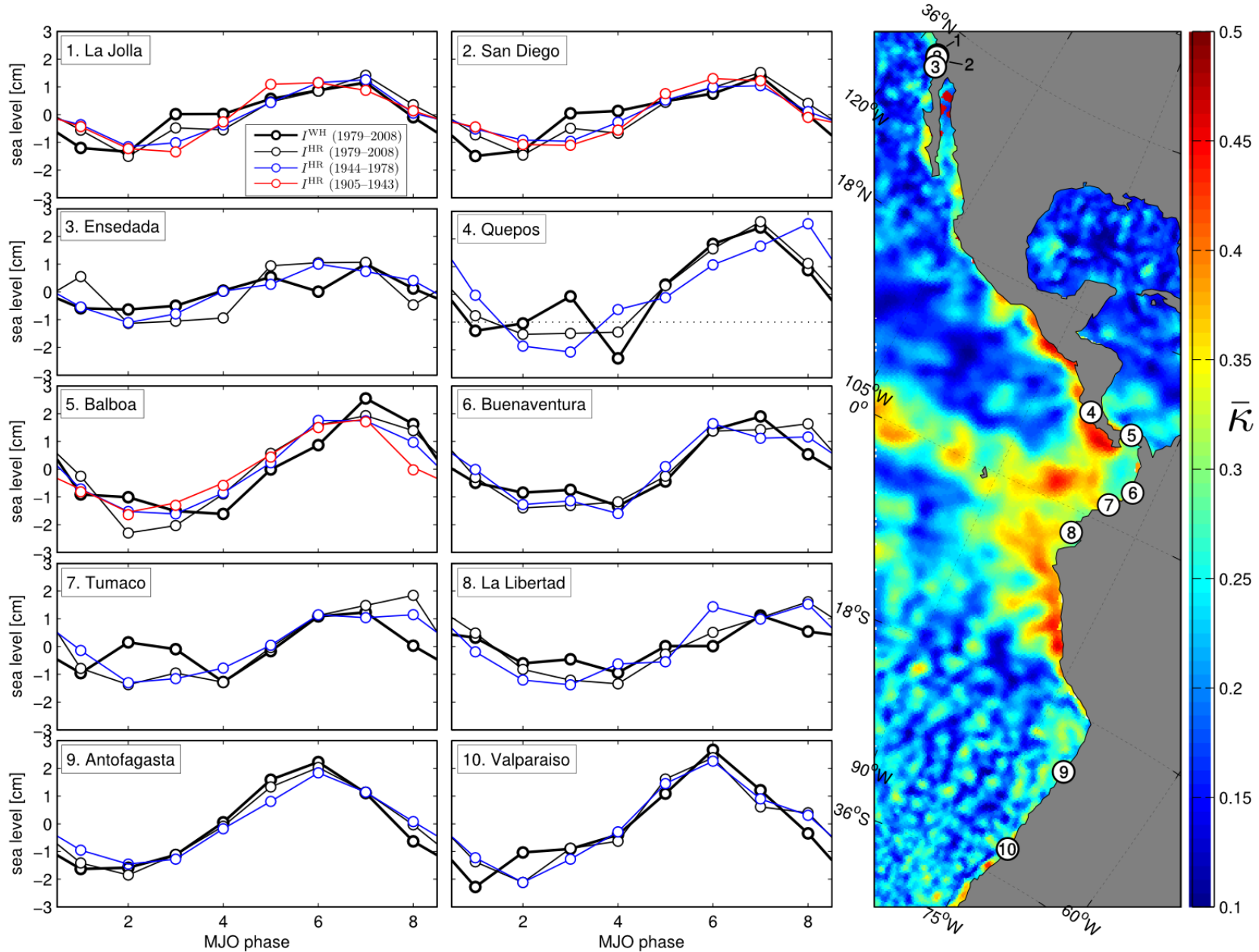




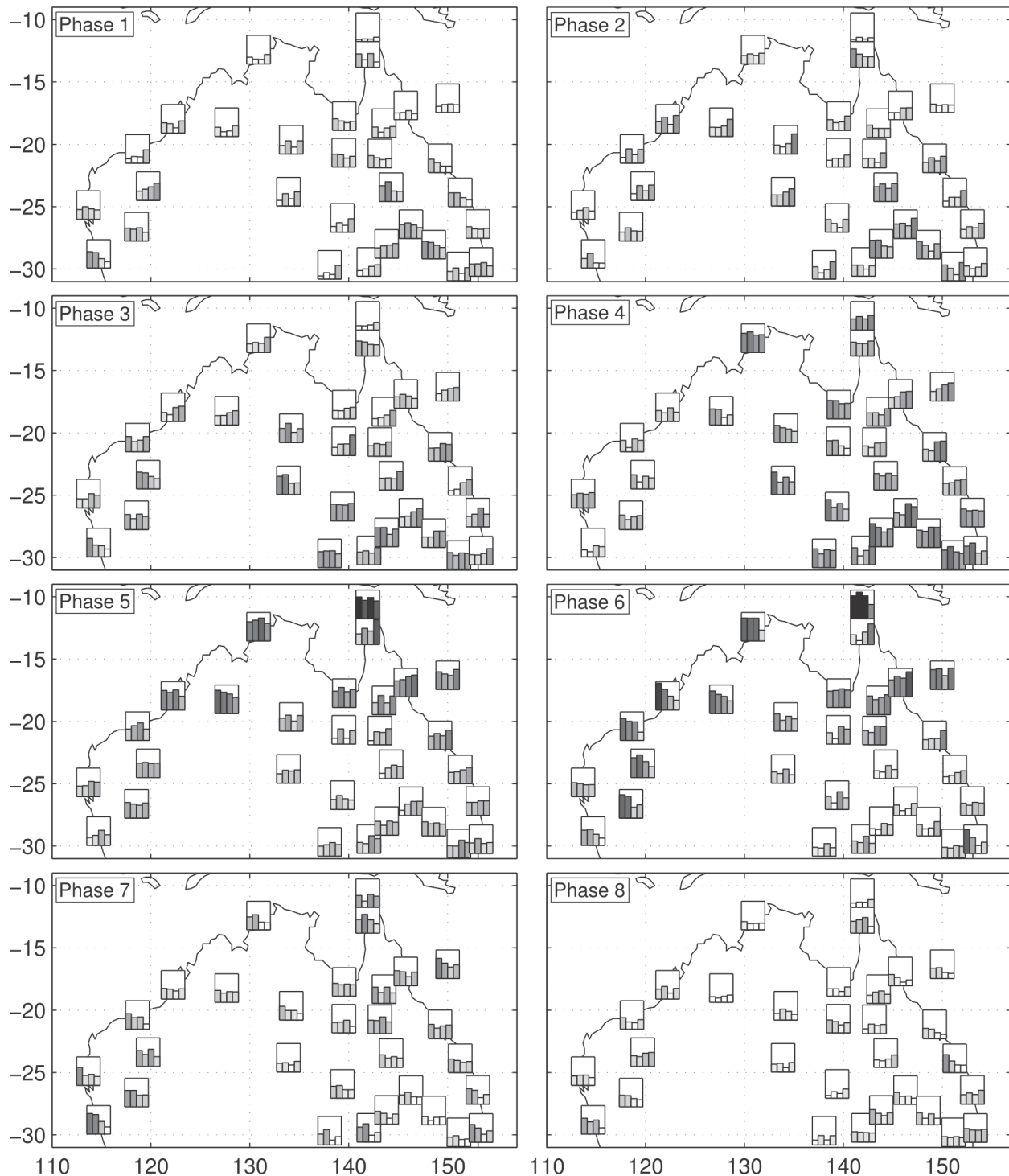
# Reconstructed index 1952-1978



- Sea levels in the eastern Pacific, from long-record tide-gauges



# Probability of extreme DJF precipitation over Australia

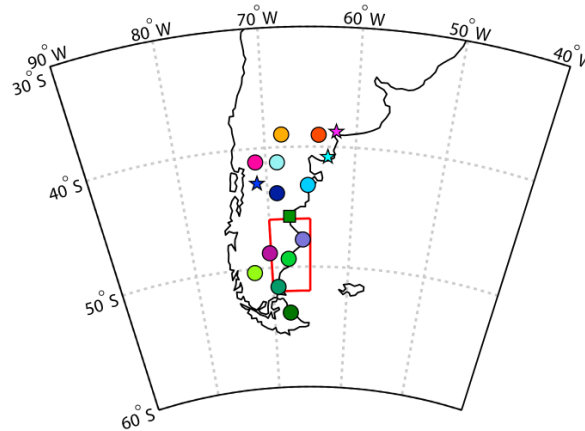


Vertical extent of bar:  
 Probability (0 to 0.45) of rainfall exceeding upper quintile (80 pctile)

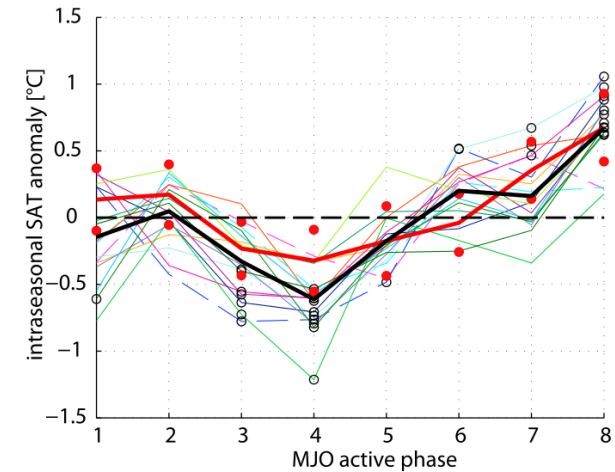
Order of bars:  
 WH04 index: 1979-2008  
 Recons. Index: 1979-2008  
 Recons. Index: 1950-1973  
 Recons. Index: 1905-1949

- Composites of **DJF SAT** across Patagonia from stations (1957-2008)

a) location of stations



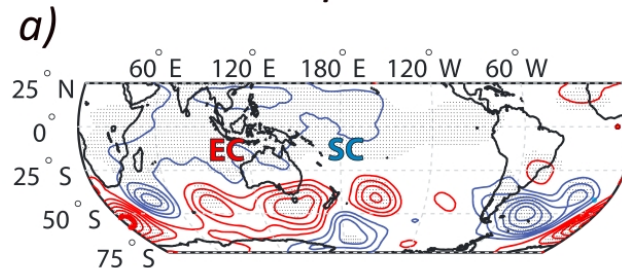
b) MJO signal



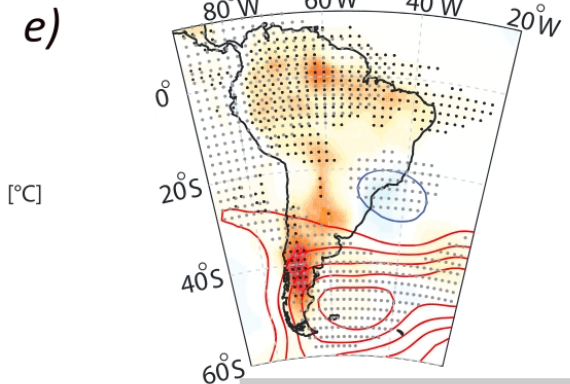
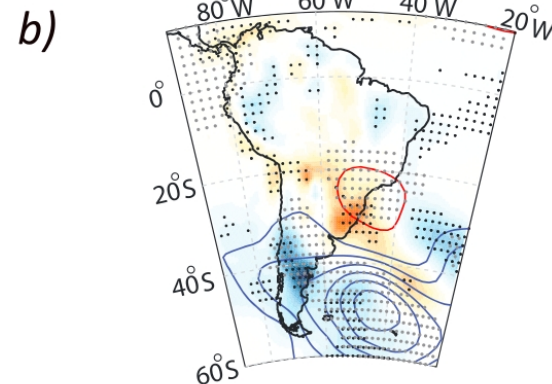
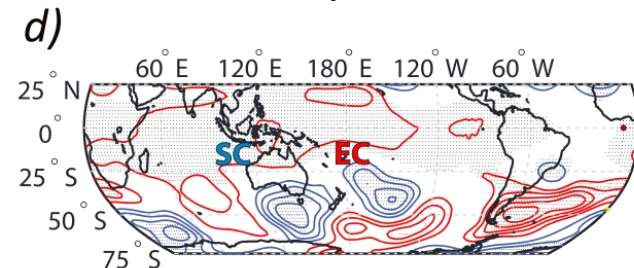
- Composites of 500 hPa geopotential height from NCEP 20CR (1905-2008)

→ **temperature advection**

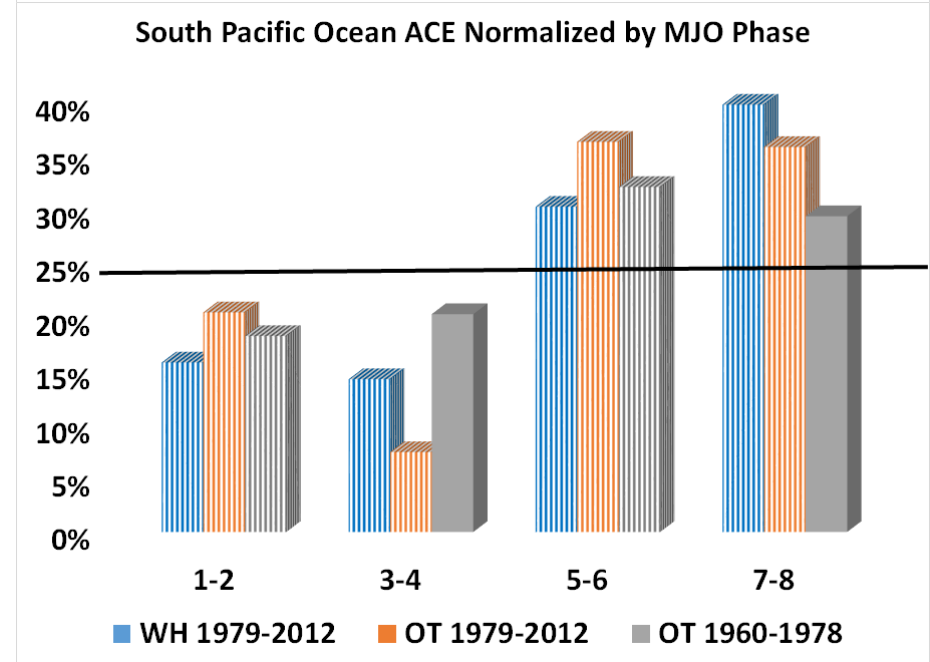
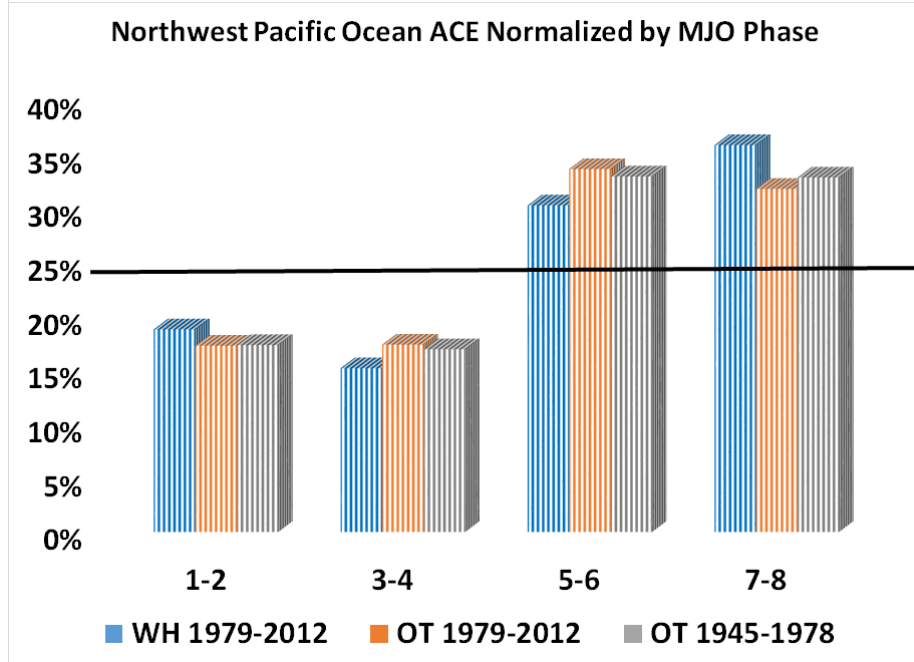
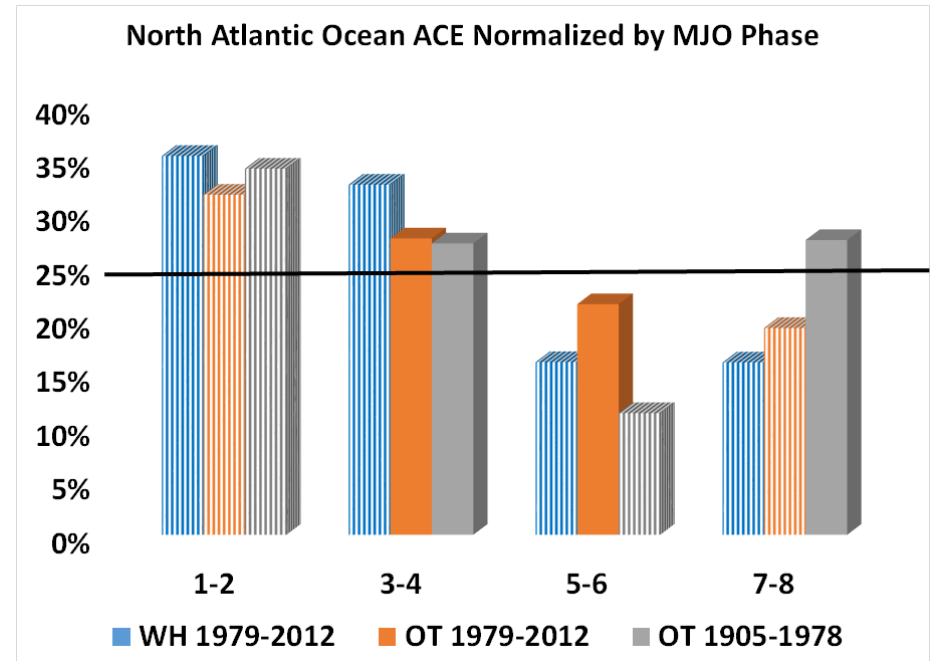
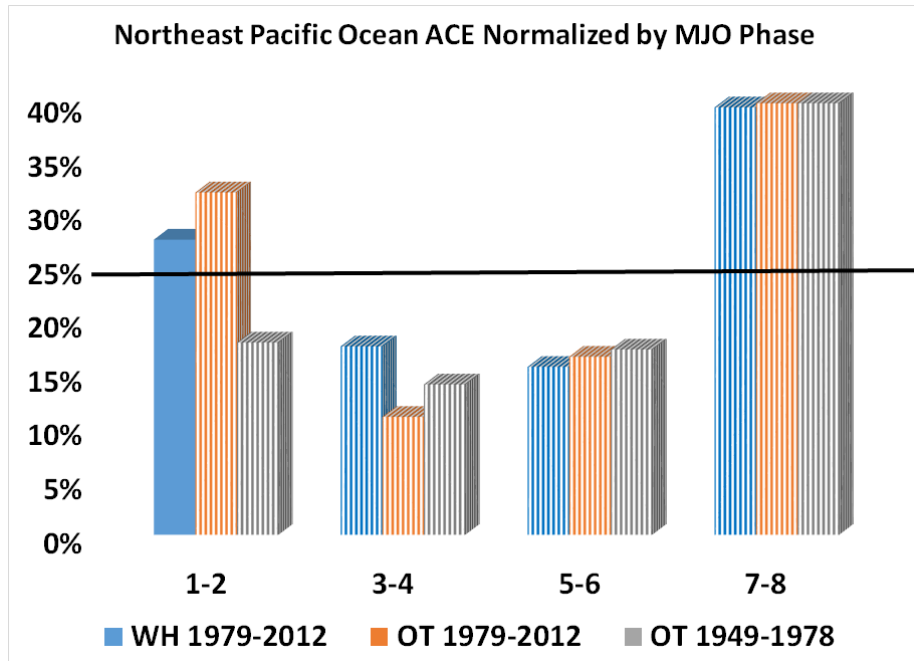
active phase 4

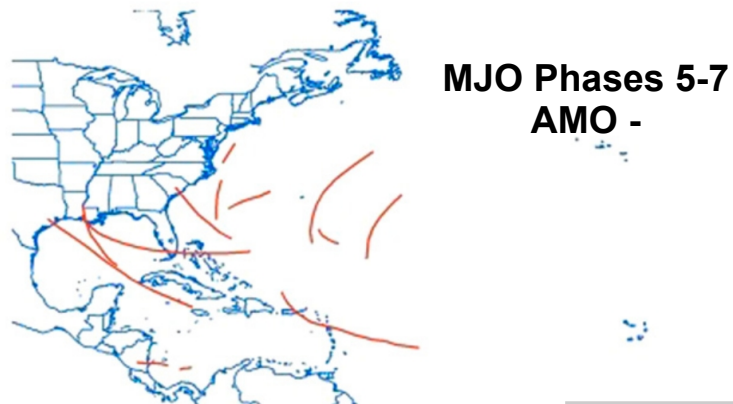
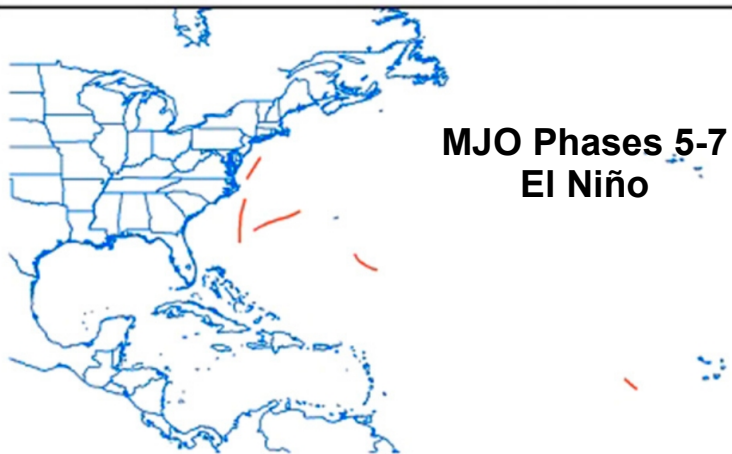
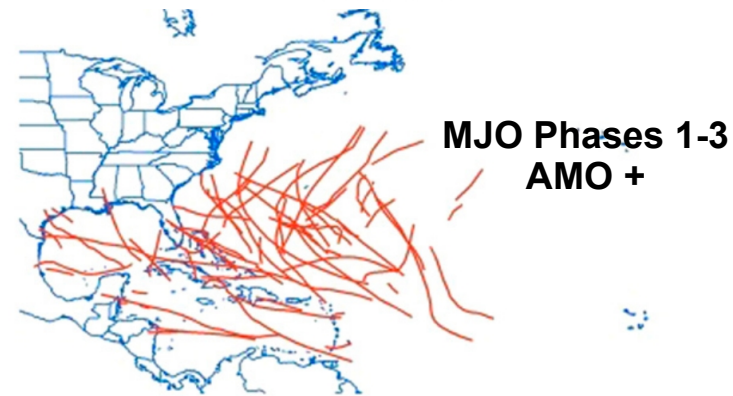
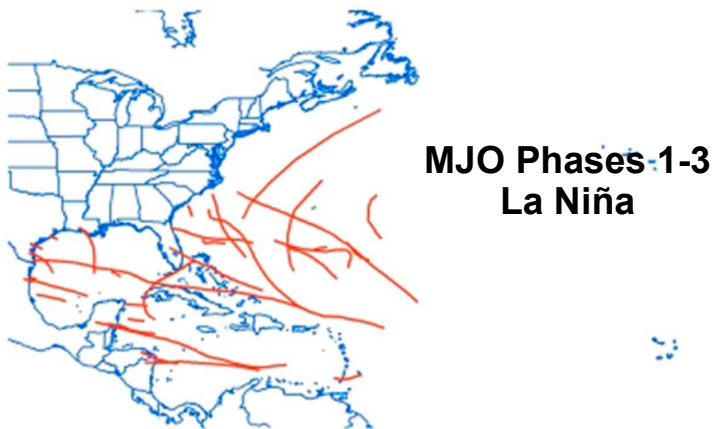
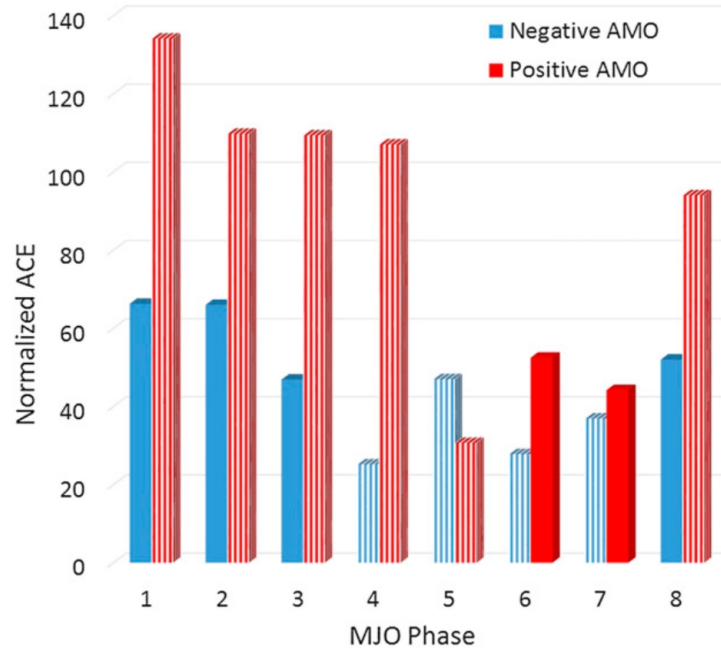
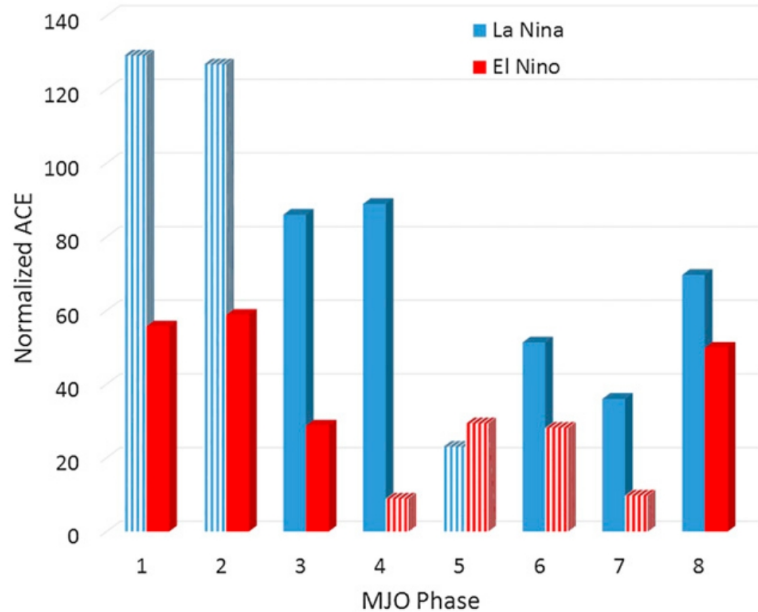


active phase 8

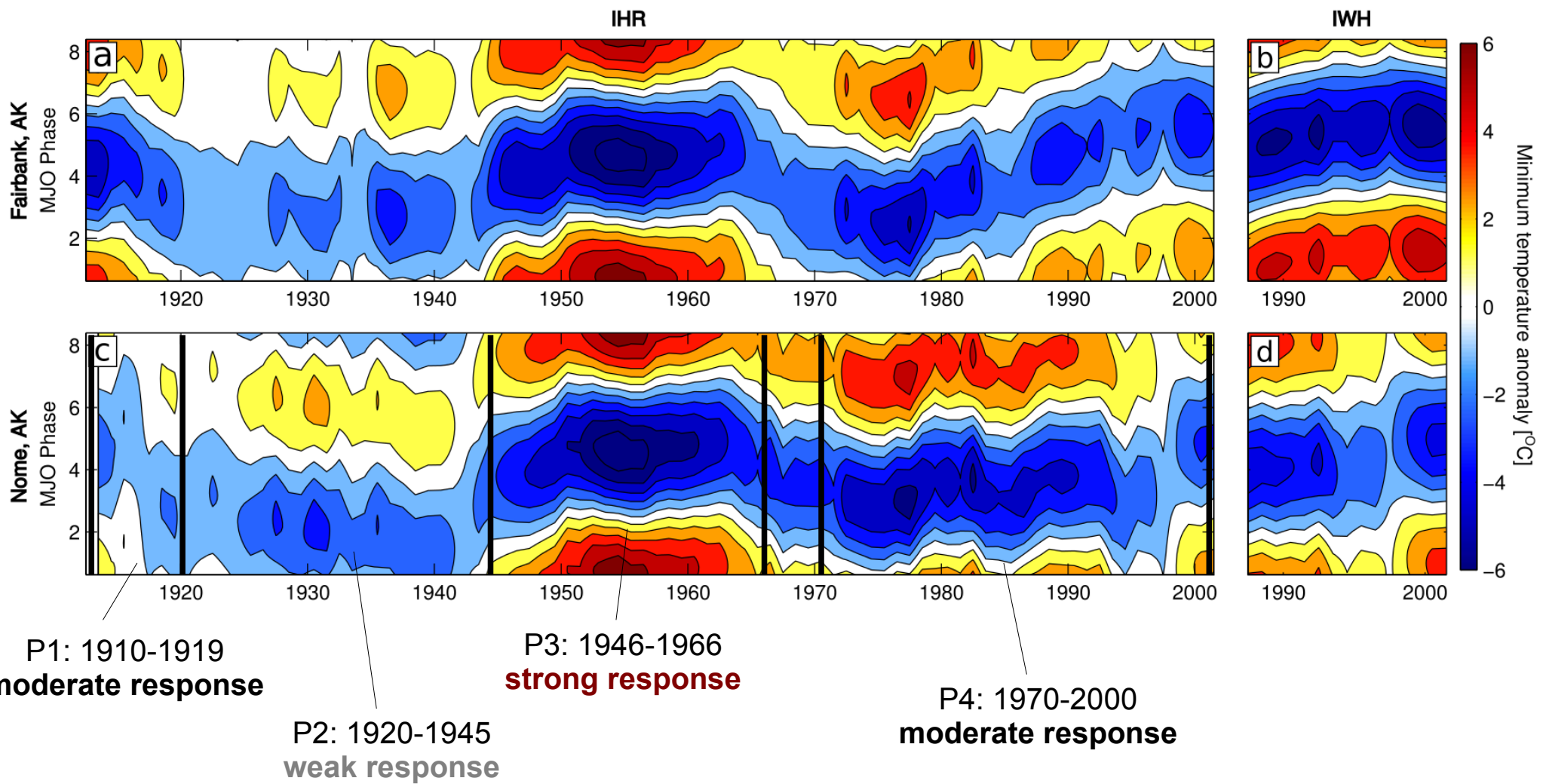


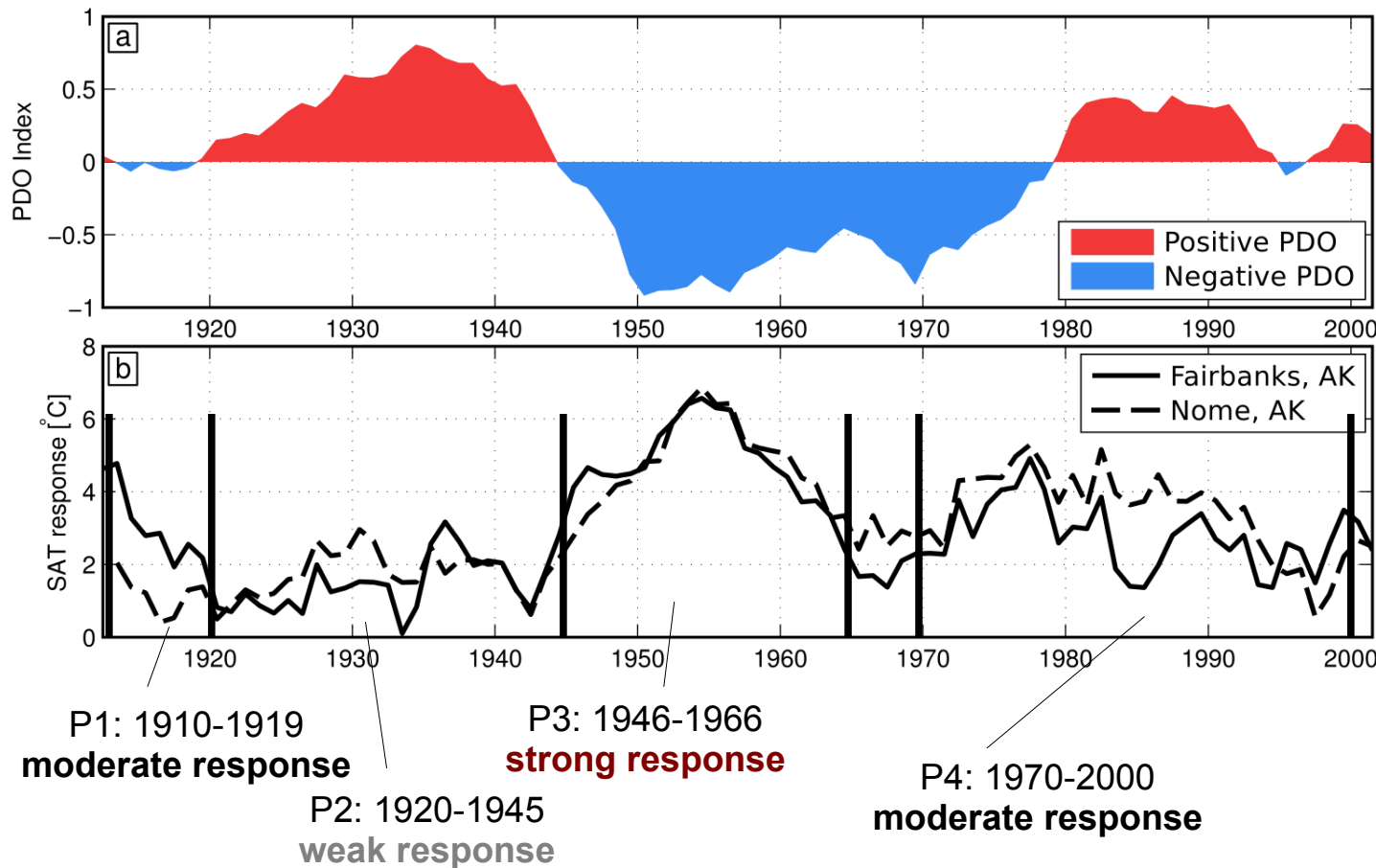
- Tropical cyclones quantified by **Accumulated Cyclone Energy (ACE)**





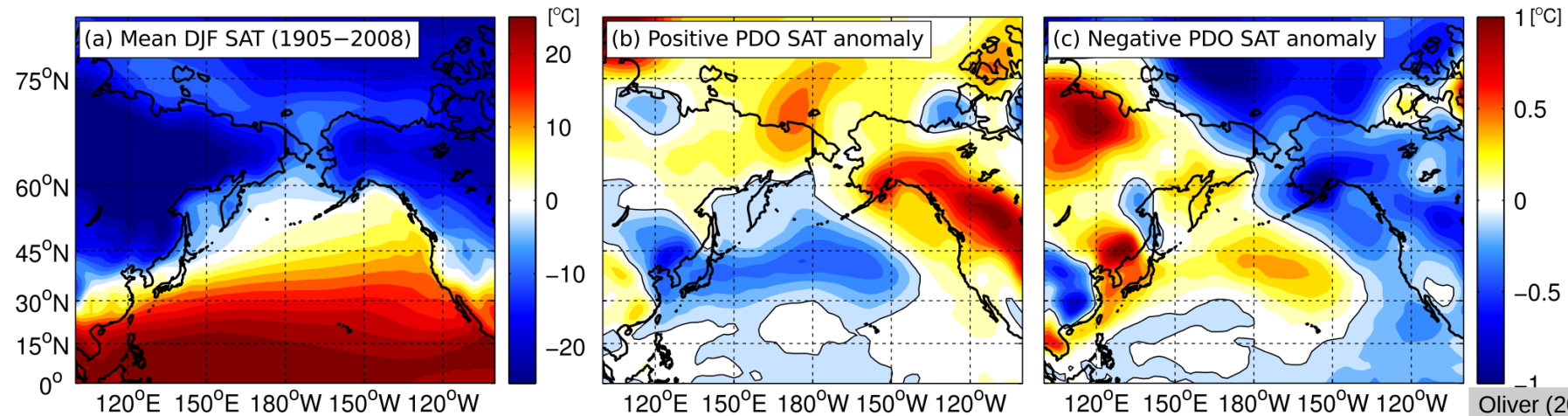
- **Alaska SAT response to MJO** in moving 15-year blocks shows **multidecadal variations**
- This is not due to variations in MJO amplitude (relatively steady, technique controls for this)





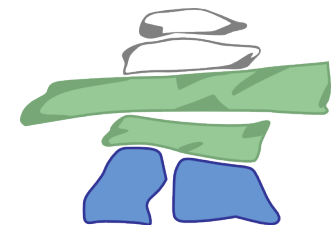
- Amplitude of response **related to PDO**: Correlation is -0.64 (Fairbanks) and -0.56 (Nome)

- PDO influences **cross-shore temperature gradient** (and thus temperature advection)





- Using long records of pressure we **reconstructed the WH04 MJO index** over the **1905-2008** period
- **Predictors were limited** by taking into account (i) the relationship with the MJO, (ii) decorrelation lengthscales, and (iii) the quality of the reanalysis in time and space.
- Consistency with WH04 index demonstrated by relationships to **global cloud cover**, **global surface wind**, **extreme Australian precipitation**, and **Pacific sea levels**
- **Historical connections** with the MJO demonstrated for
  - Tropical Cyclones in all basins
  - Wintertime Alaska air temperatures
  - Summer Patagonian heatwaves
- Long record has utility for understanding **interactions** between **intraseasonal and interannual+ time scales**
- *Index available online:*  
<http://passage.phys.ocean.dal.ca/~olivere/histmjo.html>

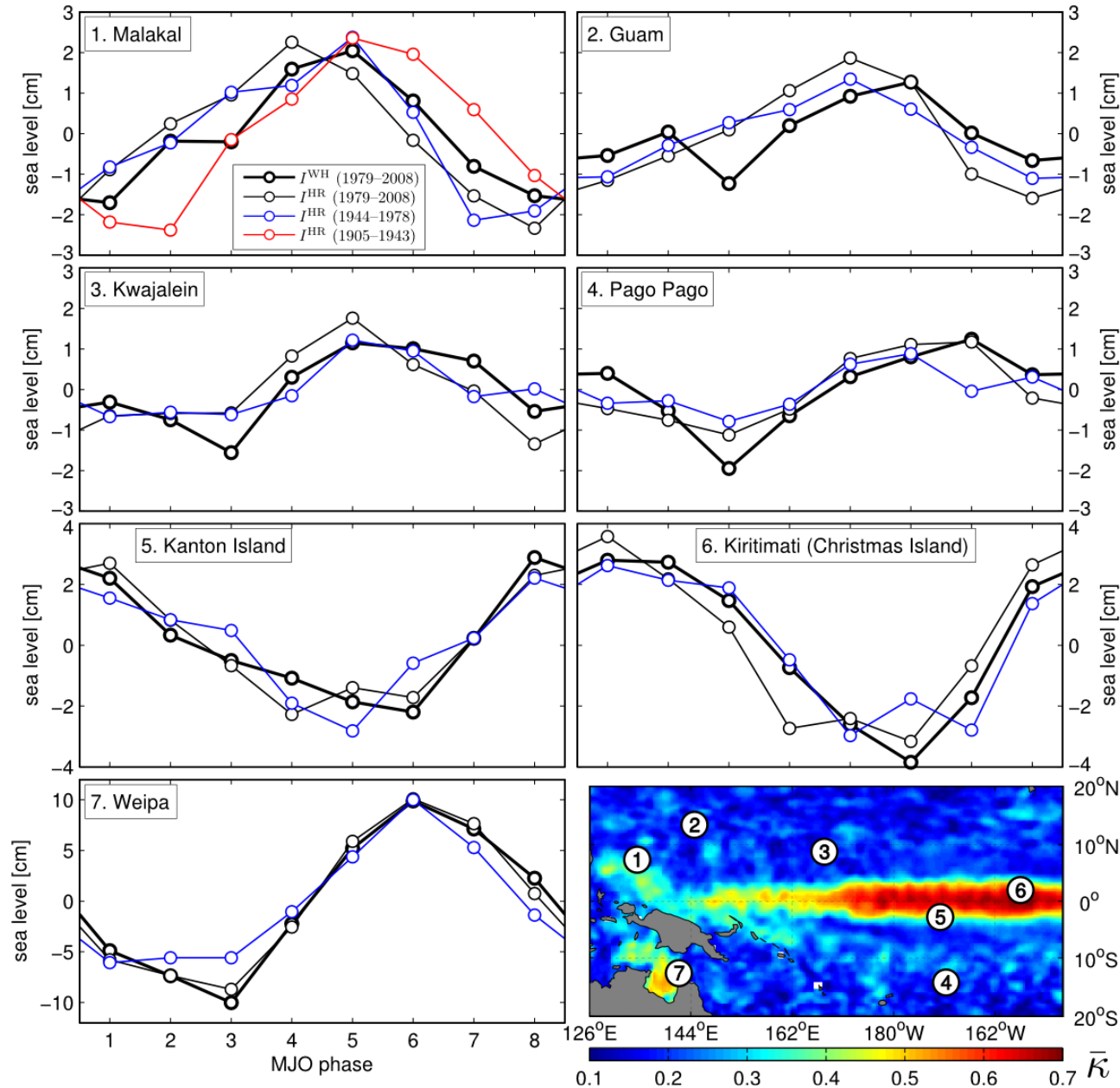


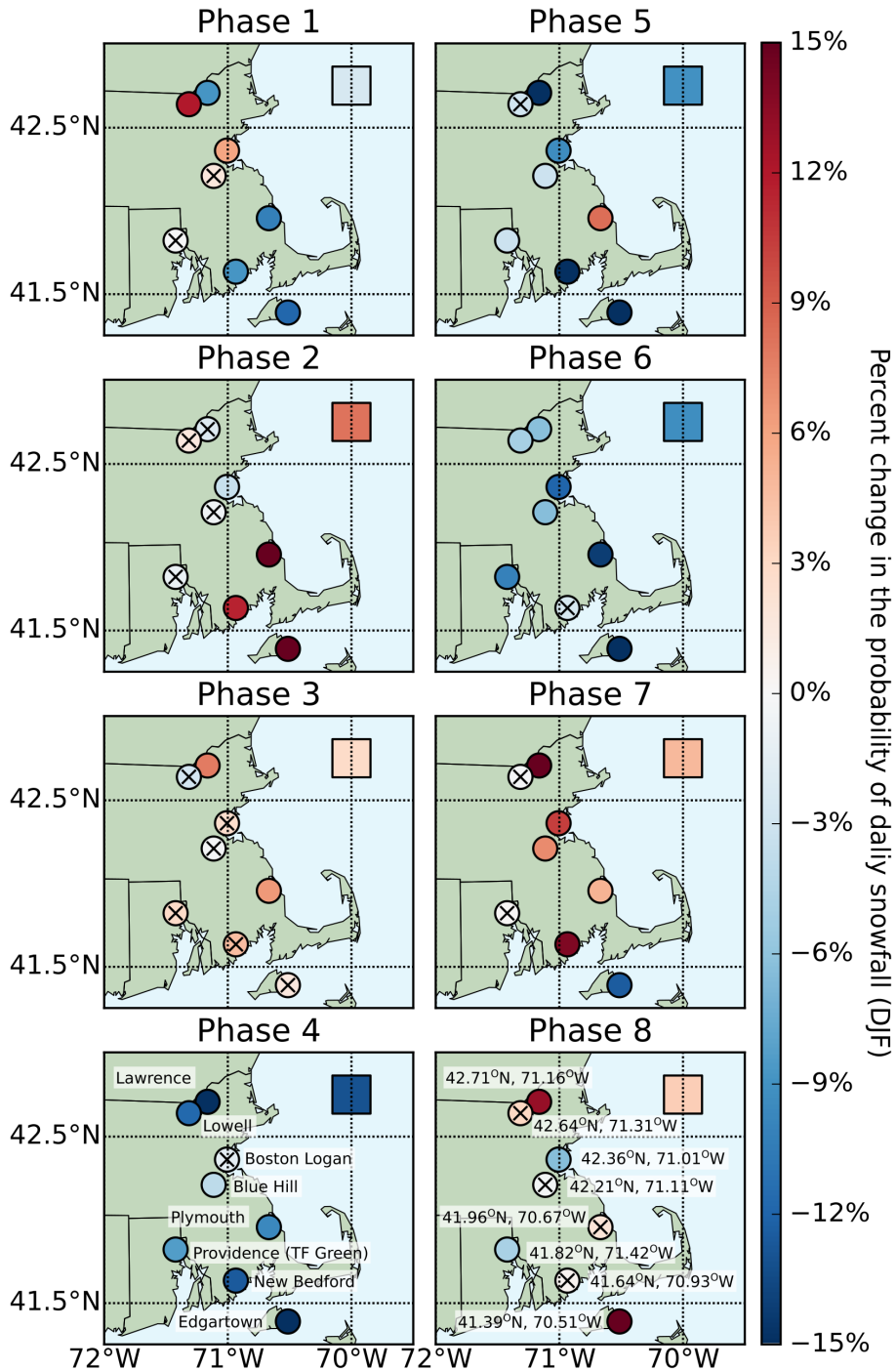
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- Sea levels in the western Pacific, from long-record tide-gauges





- Snowfall records in Southern New England since 1930s
- Probability of snowfall influenced by the MJO
- Linked to changes in probability of “Nor'easters” which tend to dump snow on Southern New England