National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

UNIVERSITY OF Southampton

Mechanisms triggering the 1976-77 regime shift in the North Pacific.

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Outline

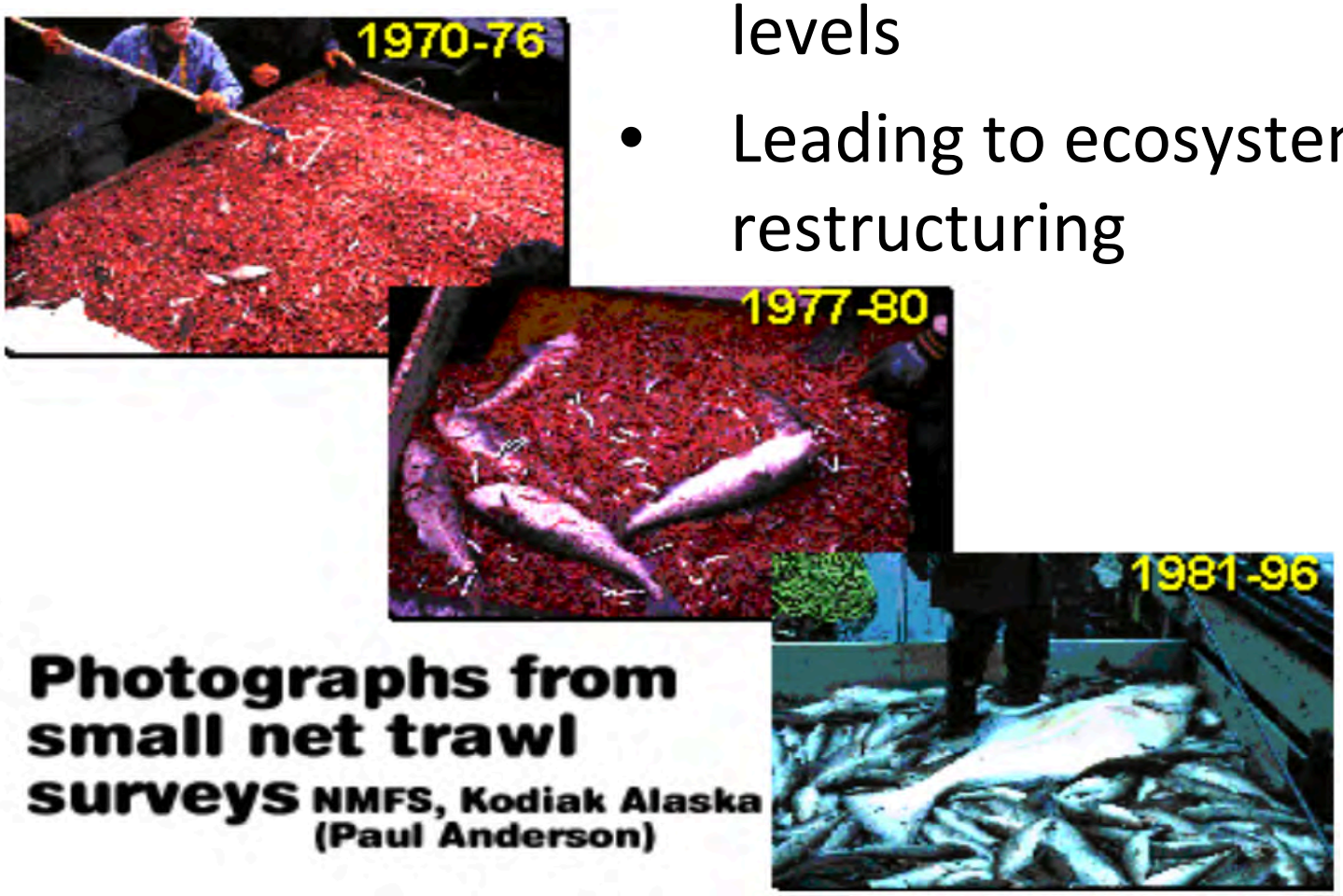
- Introduction
  - Regime Shifts
  - Shift Area
  - Hypothesis

1. Did an extreme atmospheric event initiate the shift?
   - Dynamical Systems Analysis
2. Were there sudden changes in net heat flux that maintained the shift?
   - Empirical Orthogonal Functions (EOFs) & Environmental change-point detection analysis (EnvCpt)

- How is everything connected? - Conclusions

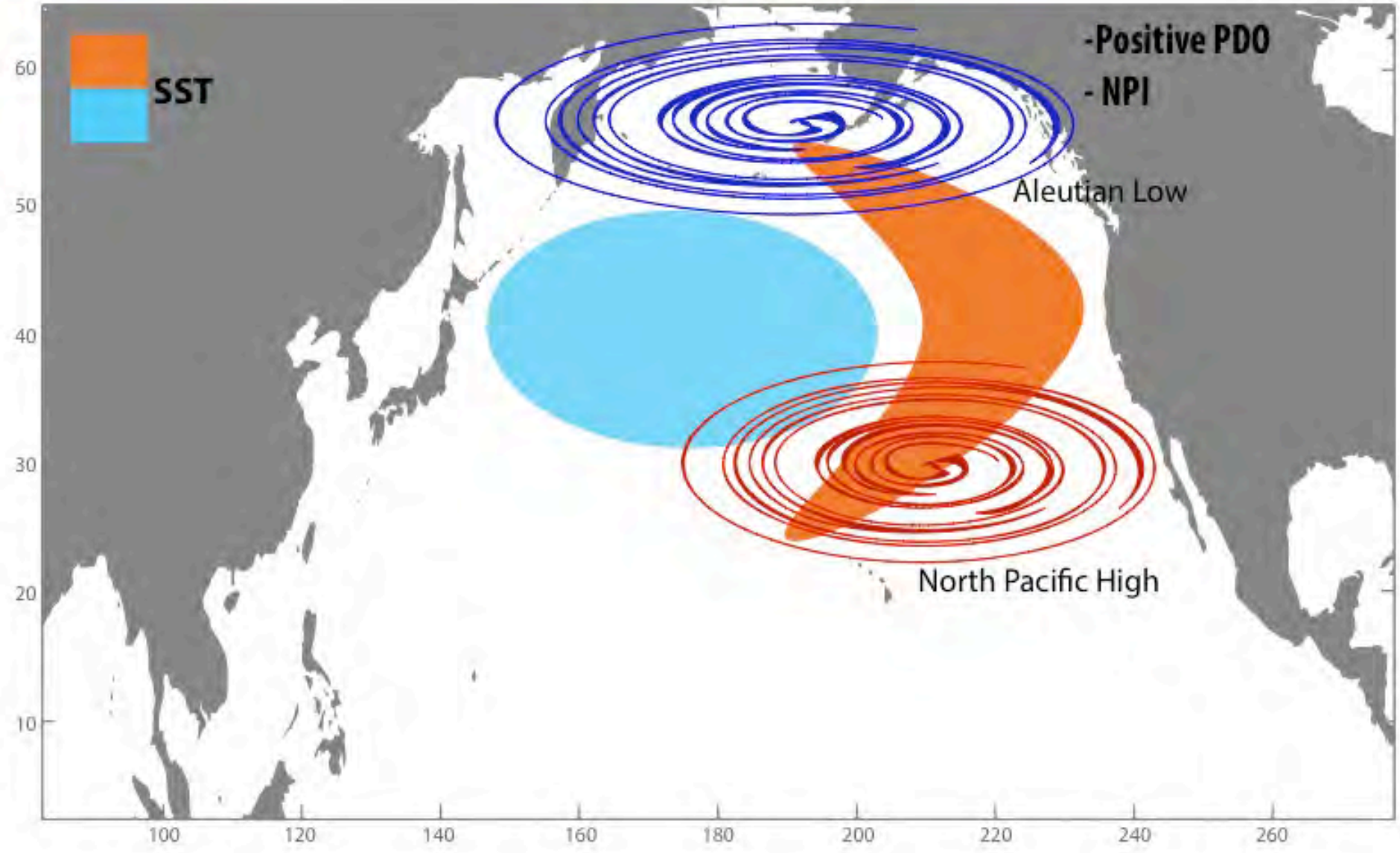
Regime Shifts

- Abrupt changes
- High - amplitude variability
- Propagation through trophic levels
- Leading to ecosystem restructuring

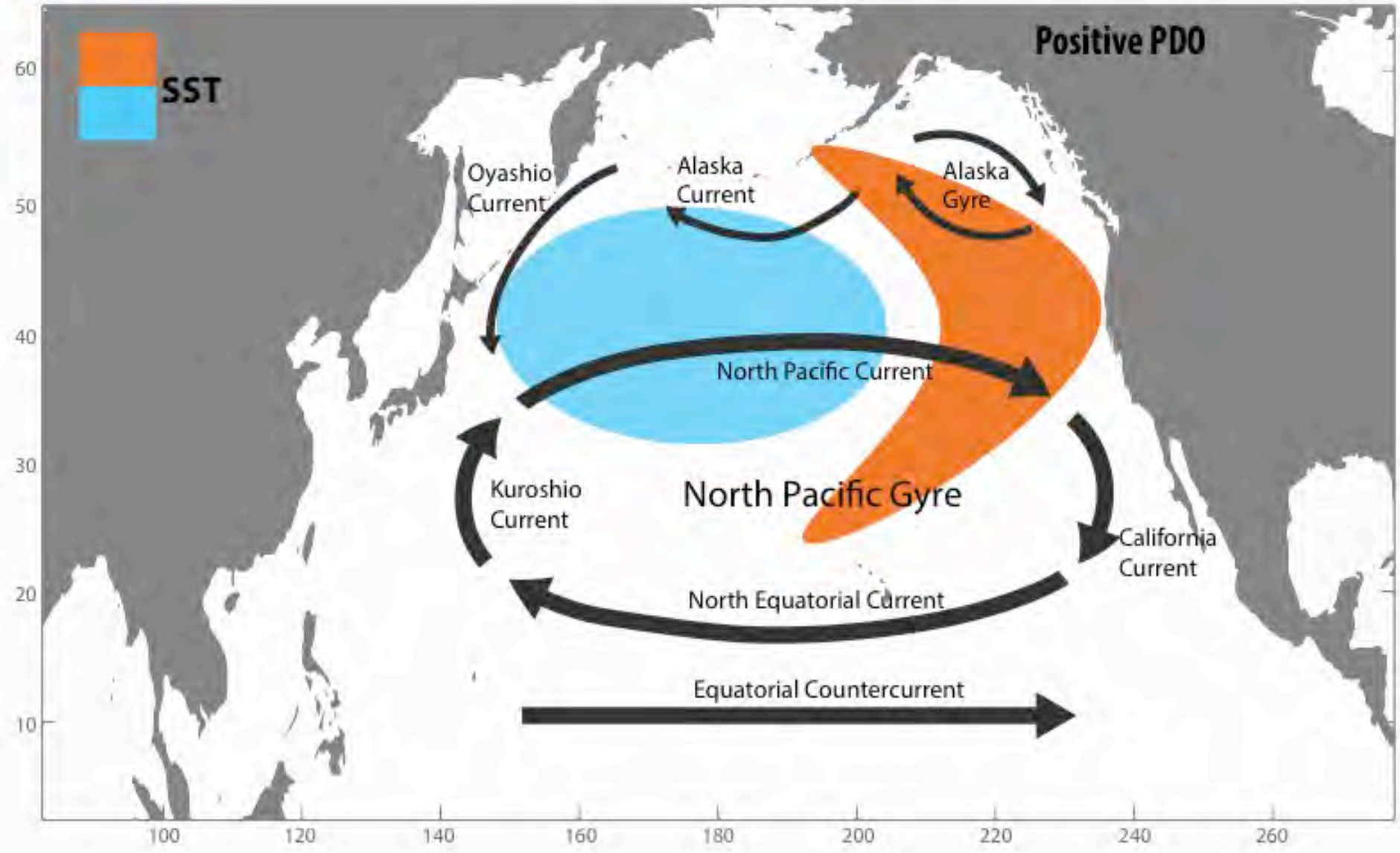


http://www.thenakedscientists.com/HTML/articles/article/brucewrightcolumn1.htm/

Positive PDO - Atmosphere



Positive PDO – Ocean



What caused the 1977 shift?

Examine the potential of dynamical and statistical analyses to reveal new insights.

Test the hypothesis:

- Extreme atmospheric event → forcing
- Changes in heat budget → maintenance

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- Introduction
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  - The 1977 regime shift

1. **Did an extreme atmospheric event initiate the shift?**
   - **Dynamical Systems Analysis**

2. Were there sudden changes in net heat flux that maintained the shift?
   - Empirical Orthogonal Functions (EOFs) & Environmental change-point detection analysis (EnvCpt)

- **How is everything connected? - Conclusions**

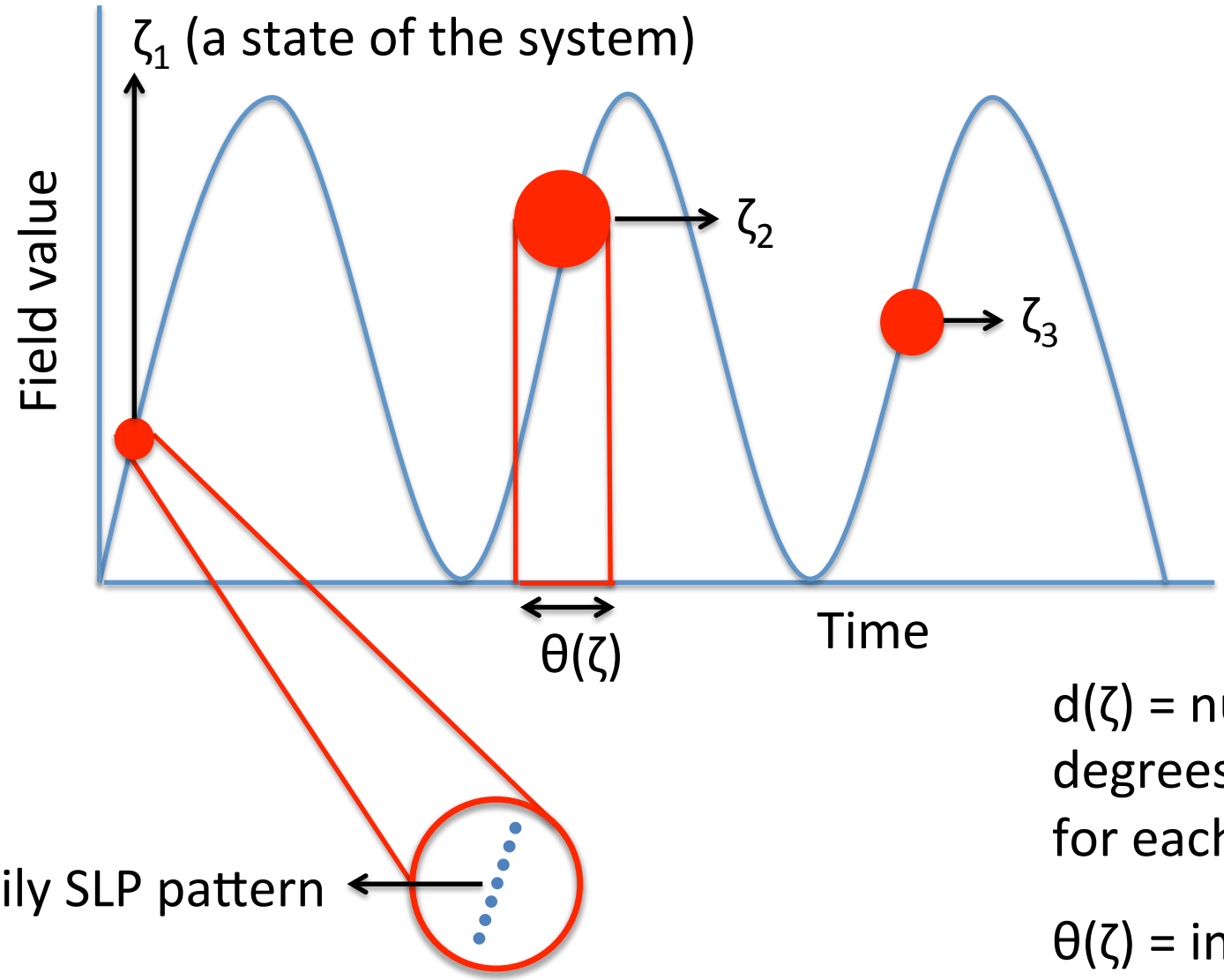
Dynamical system analysis

- Sea Level Pressure (SLP)
  - Daily from January 1948 to August 2016
  - National Centre for Environmental Prediction/National Centre for Atmospheric Research (NCEP/NCAR) reanalysis 2.5°x2.5°

- Calculation of instantaneous properties:
  - Instantaneous dimension d(ζ)
  - Persistence θ(ζ)

(Faranda et al. 2017)

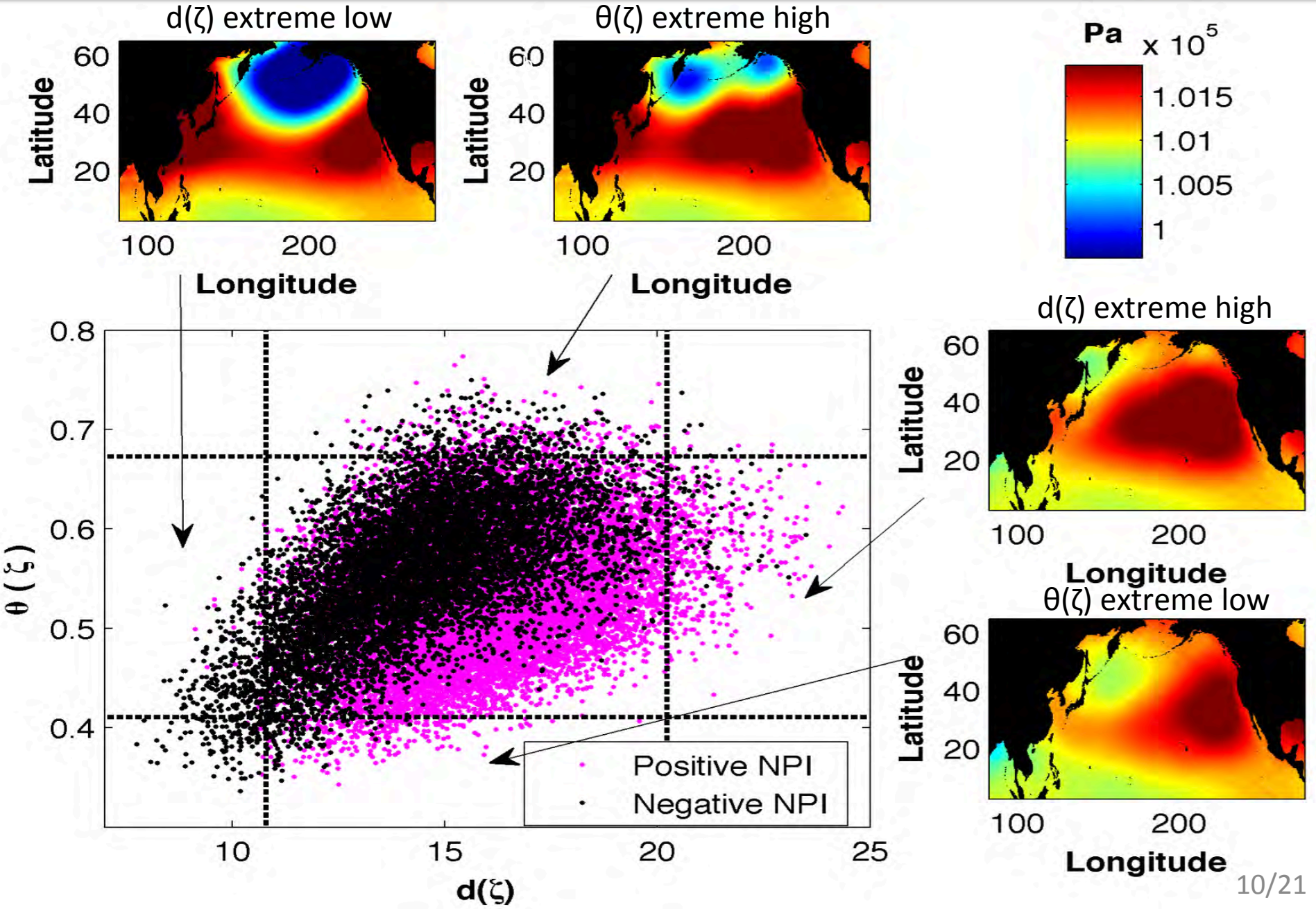
Instantaneous Properties



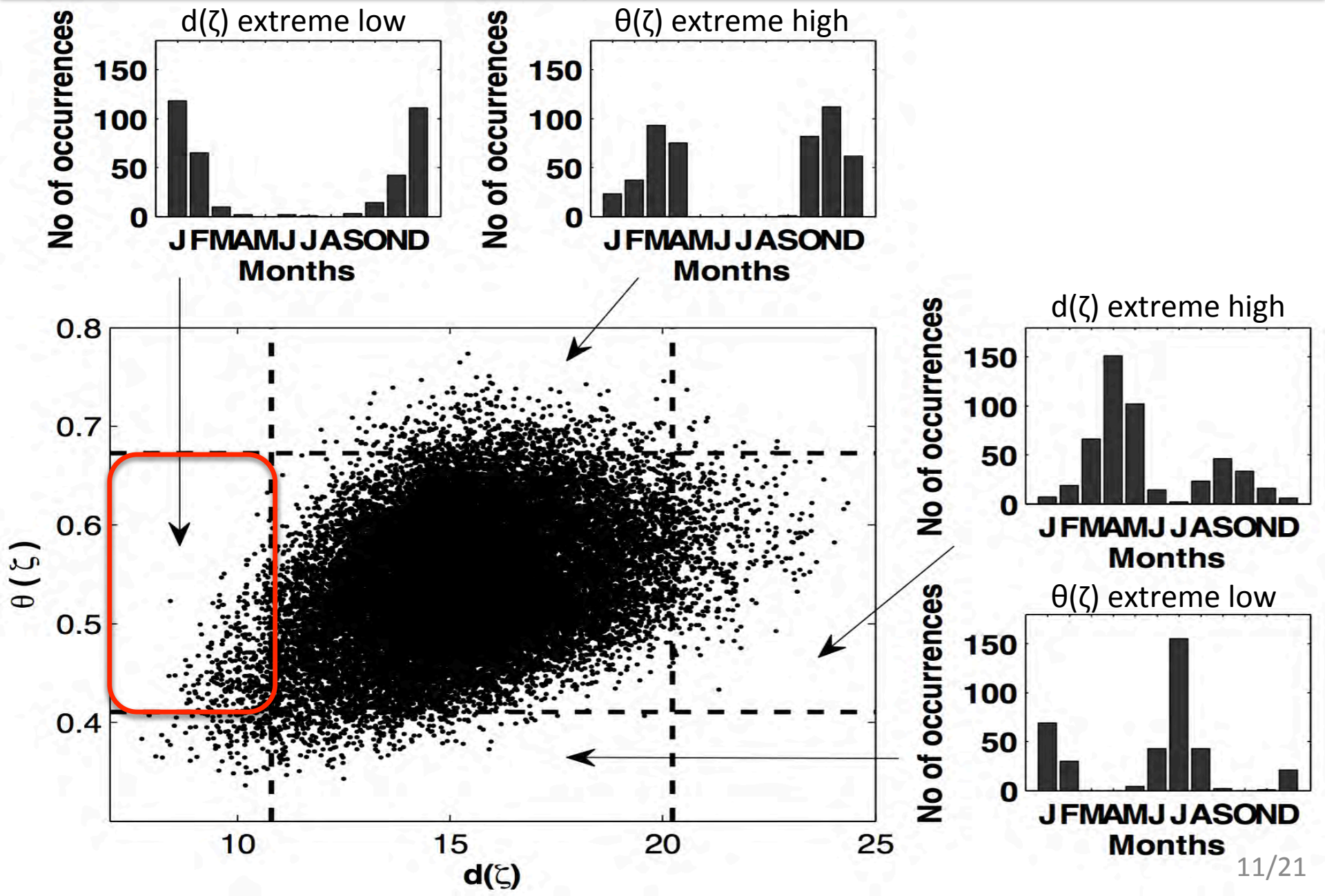
d(ζ) = number of degrees of freedom for each •

θ(ζ) = indicator of the persistence time of each ●

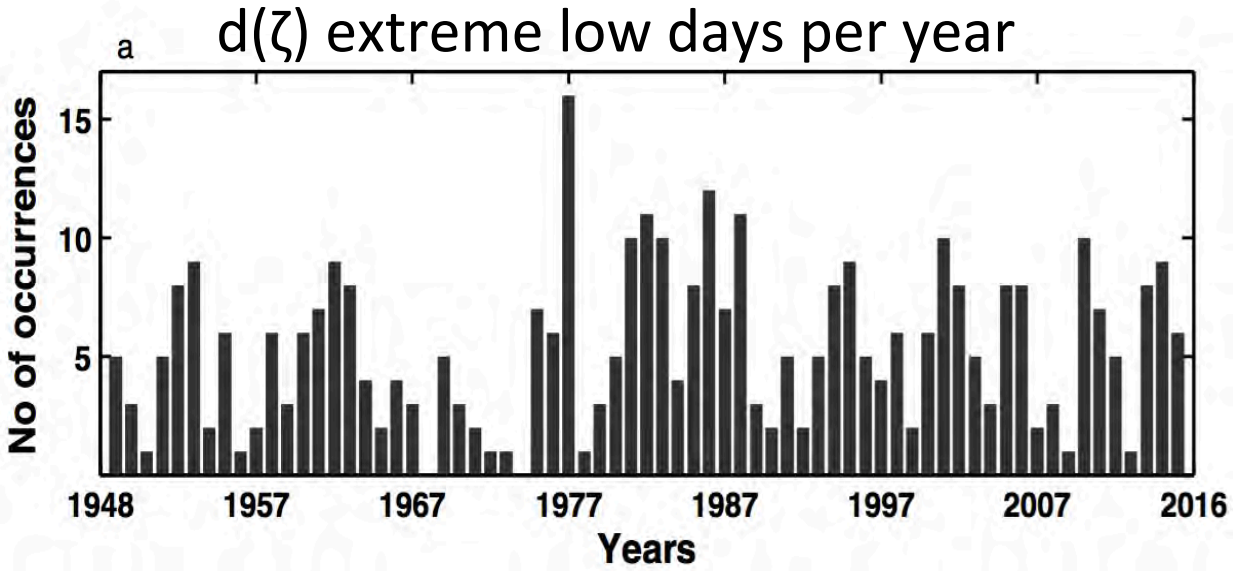
Extreme SLP patterns

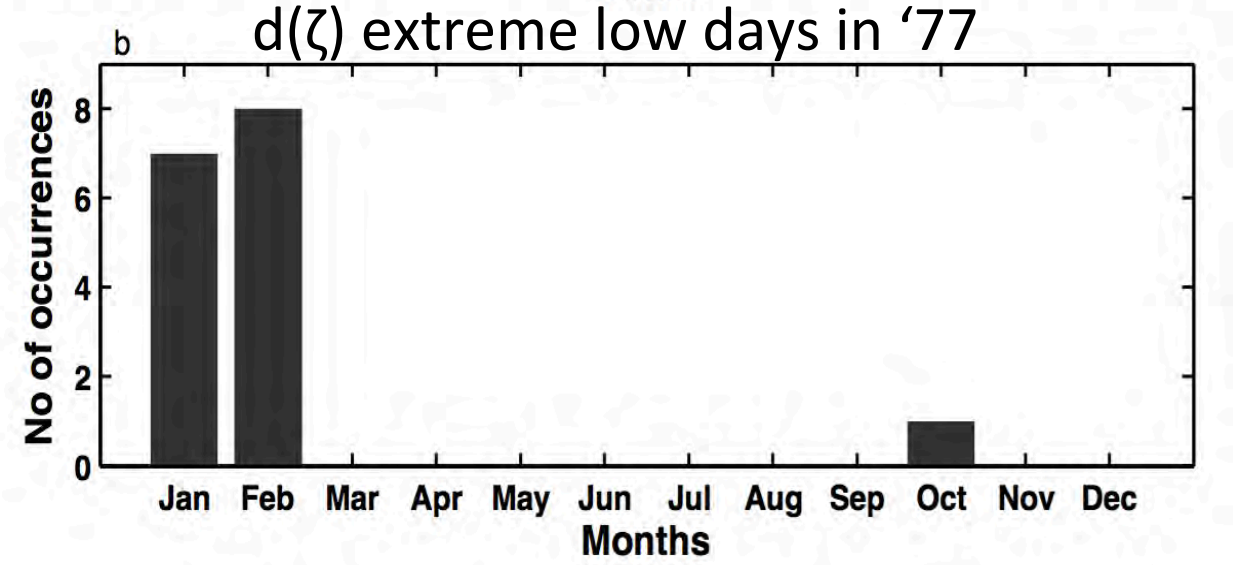


When did the extreme SLP happen?



Is 1977 different?





Average d(ζ) extreme low days per year = **5.3**

94% of extreme days occur in winter (Jan-Feb)

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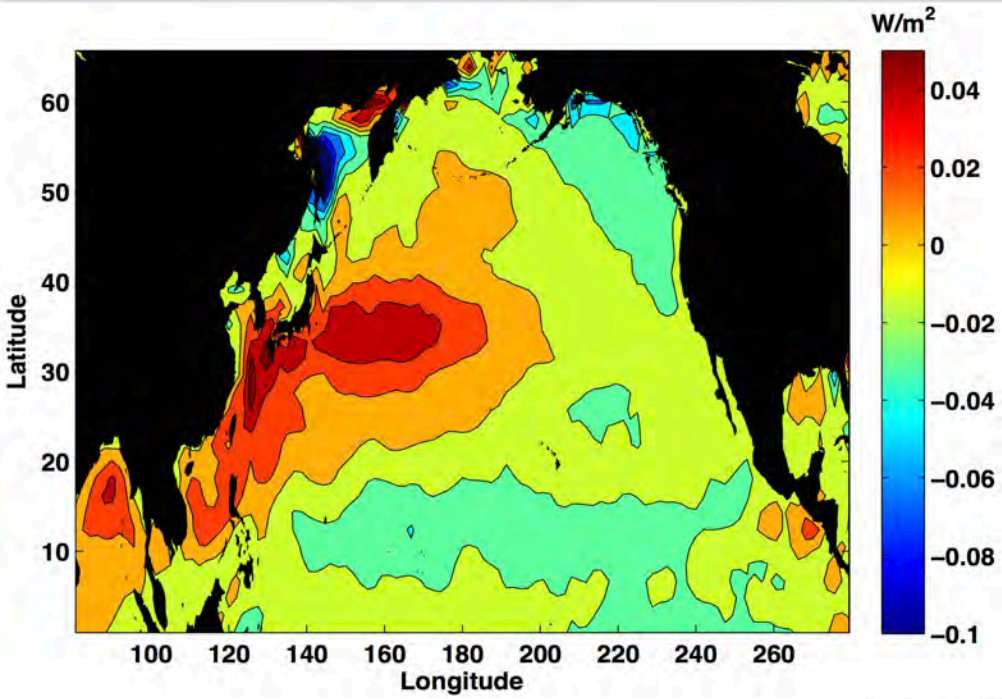
Empirical Orthogonal Functions (EOFs)

- Identify large scale patterns governing the region

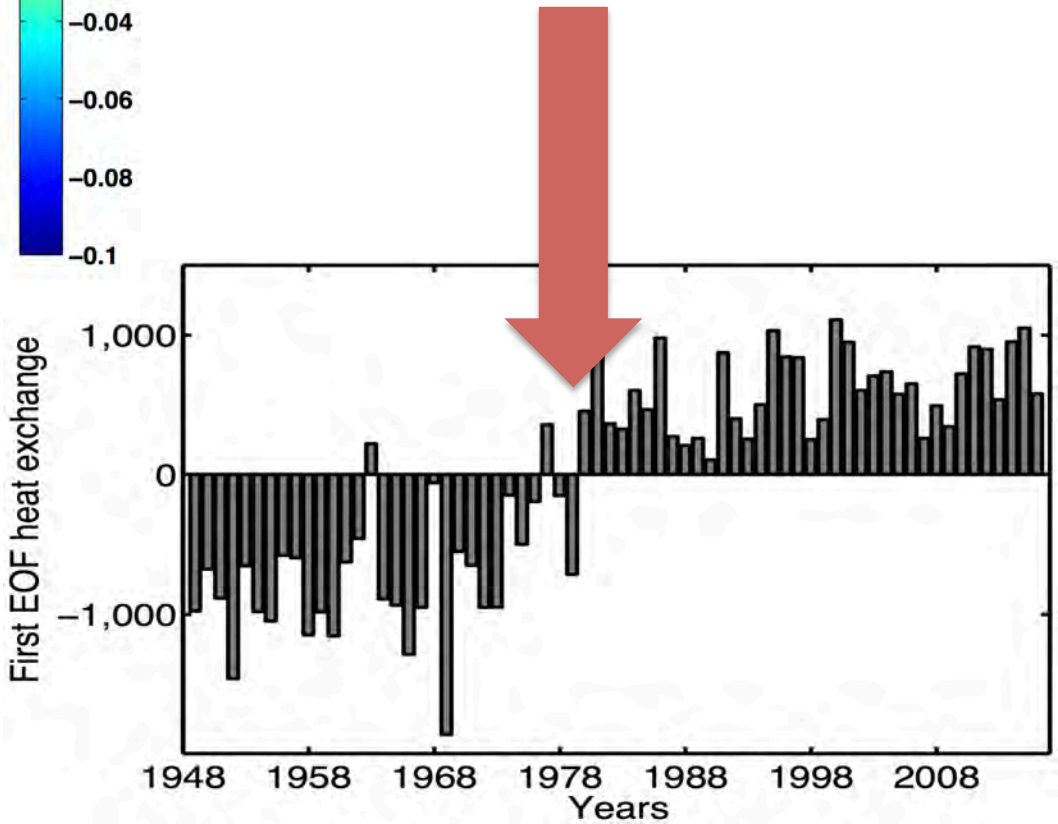
- Net heat flux
  - Winter averages from January 1948 to August 2016
  - NCEP/NCAR reanalysis 2.5°x2.5°

Any sudden changes in the net heat flux ?



EOF 1: 22%

Abrupt change - 1979



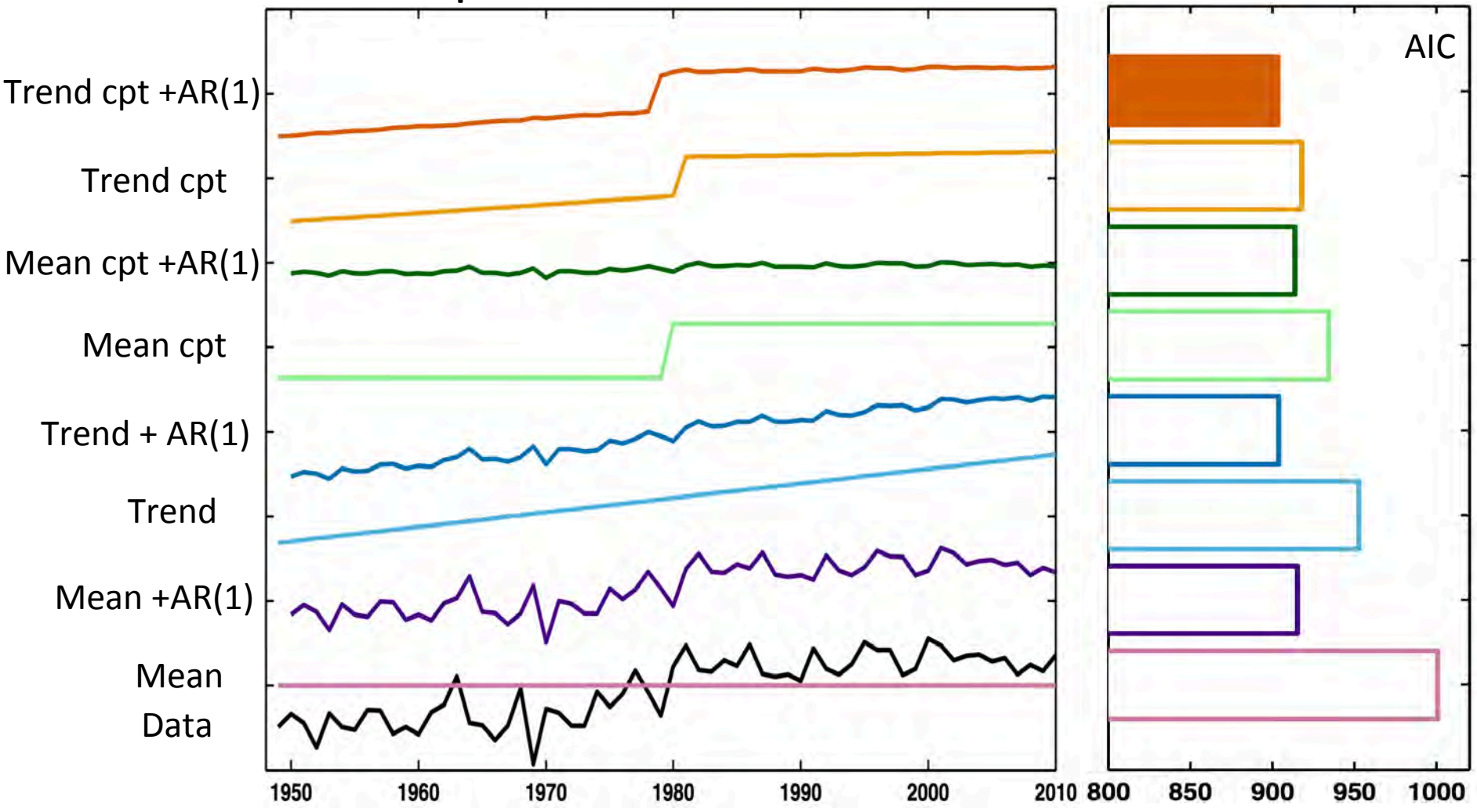
Environmental change-point detection analysis (EnvCpt)

- Fits eight models
- Characterizes different types of variability
  - no changes
  - long-term trends
  - changes in mean/variance
  - changes in trend
  - short term memory
- Net heat flux (First EOF & Pixel-wise)
  - Winter averages from January 1948 to August 2016
  - NCEP/NCAR reanalysis 2.5°x2.5°

(Killick, Beaulieu and Taylor, 2016;
https://cran.r-project.org/web/packages/EnvCpt/index.htm)

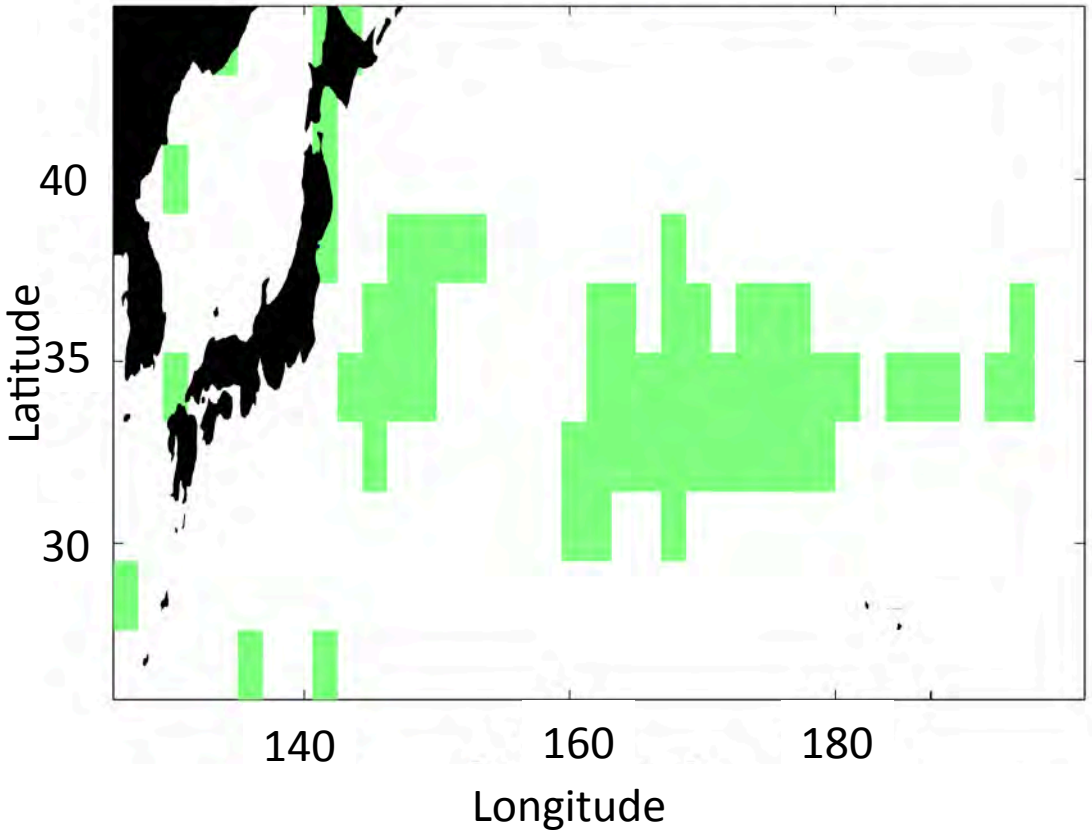
Any sudden changes in the net heat flux ?

EnvCpt → 1st EOF of net heat flux

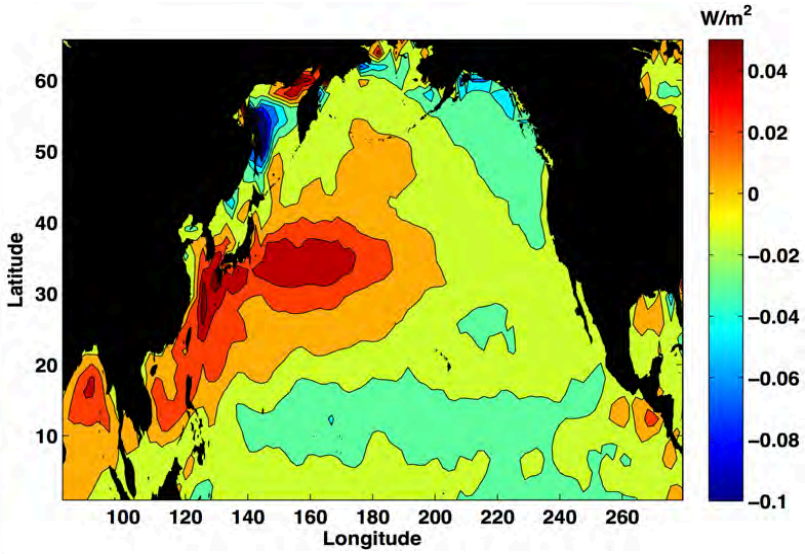


Any sudden changes in the net heat flux ?

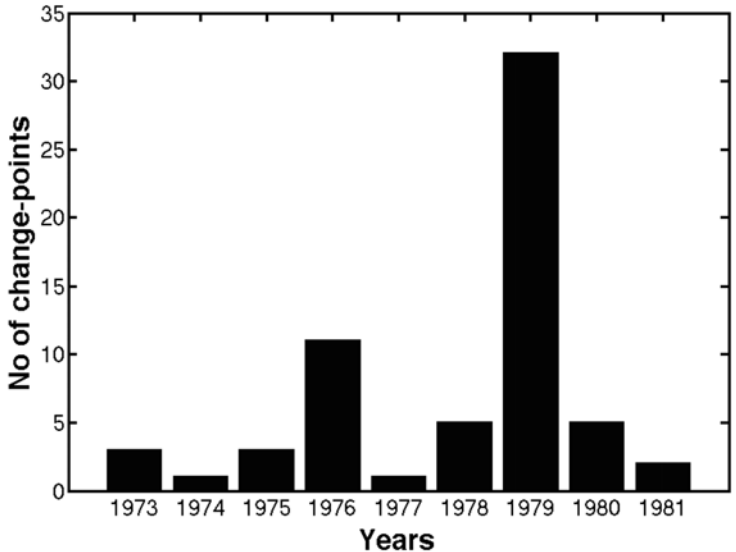
Kuroshio – Oyashio Extension



EOF 1 – Net heat flux



Number of pixels per year



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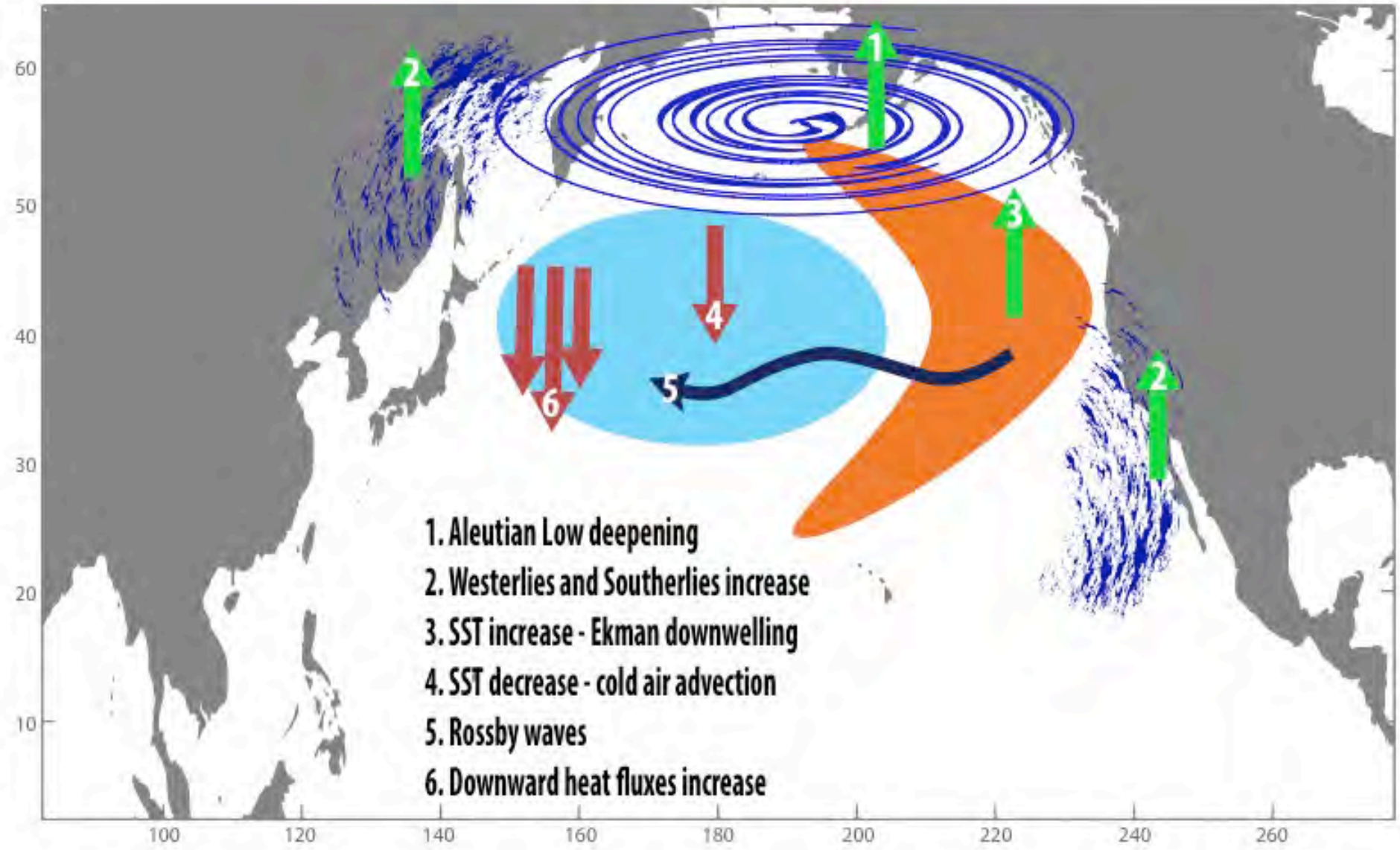

Conclusions

- Novel approaches including Dynamical System and Change-point Detection Analyses showing:

- Statistical evidence that an extreme Aleutian Low occurred in winter 1976-77;

- Strongest and most persistent Aleutian Low throughout the whole study period;

- Abrupt changes detected in the Kuroshio-Oyashio Extension region centred around the year 1977.

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