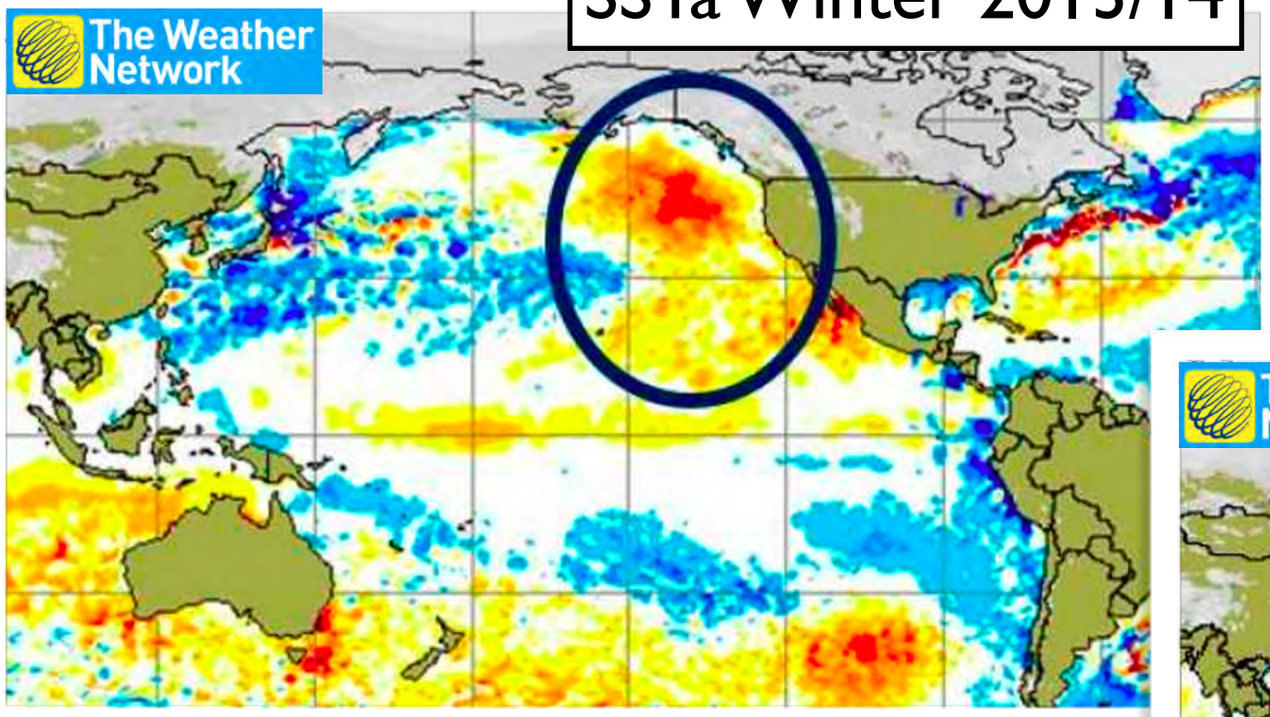
PICES 2016 Annual Meeting

Changes in Ocean Temperatures Extremes in the Northeast Pacific

Youngji Joh and Emanuele Di Lorenzo

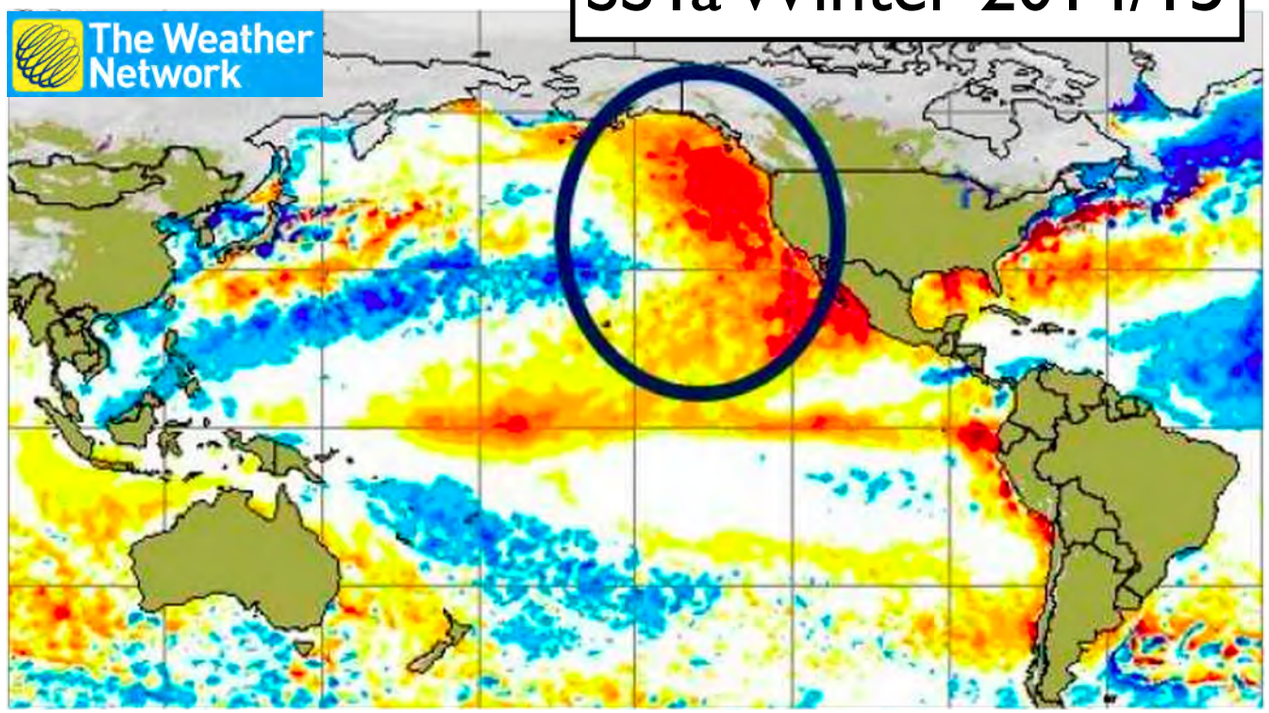
Georgia Institute of Technology

SSTa Winter 2013/14



Warm blob (Bond et al, 2015)
Marine heatwaves (Hobday et al, 2016)

SSTa Winter 2014/15



Impacts

- low primary productivity
- new warm-water copped species
- massive influx of dead/starving sea birds
- unusual mortality of large whales/sea lion
- extreme harmful algal bloom.

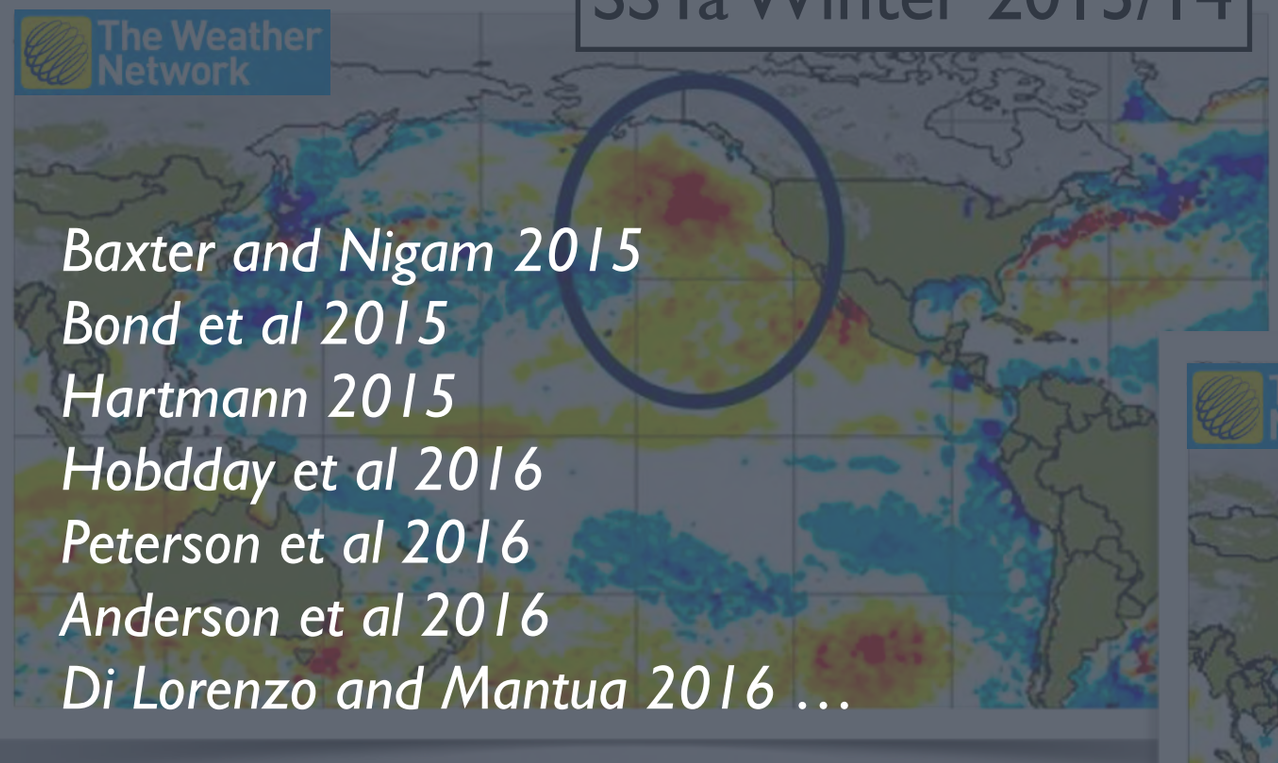
Lee et al., 2015; Wang et al., 2014; Seager et al., 2014; Whitney, 2015; Peterson and Robert, 2016; Opar, 2015

Forcing

- Extremes are consistent with direct forcing by the Atmosphere.

Di Lorenzo and Mantua 2016
Bond et al 2015

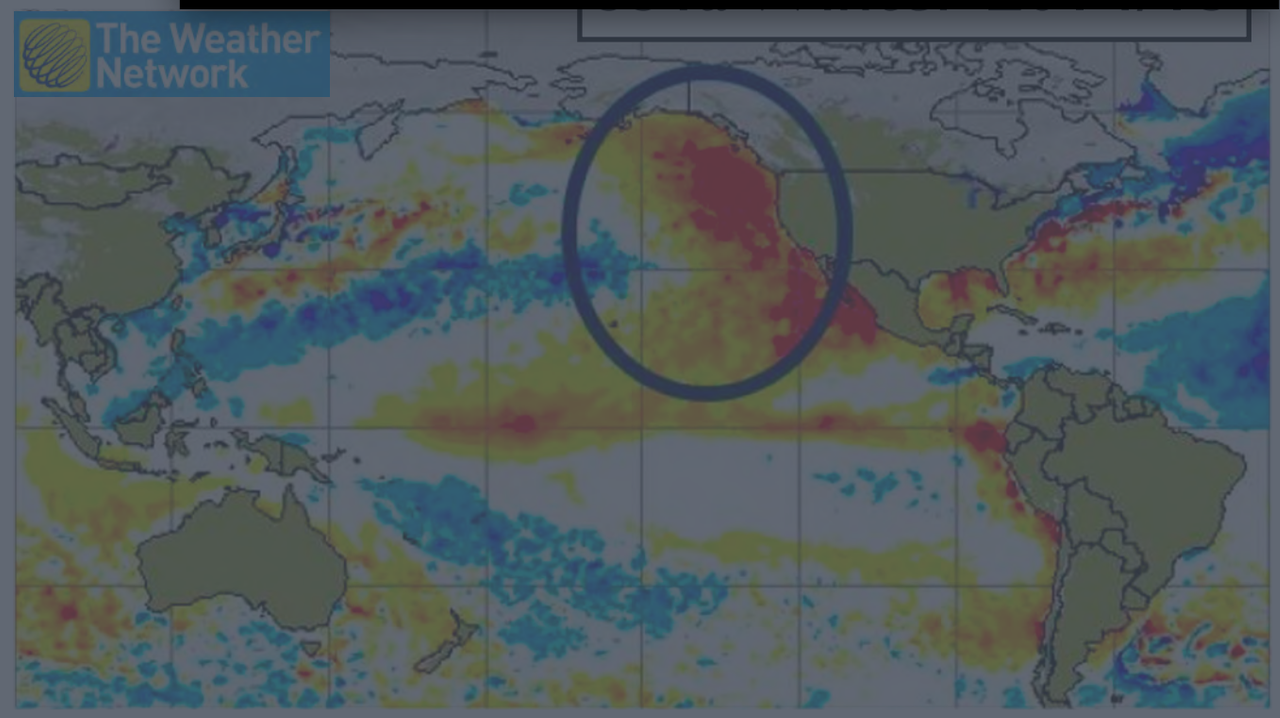
SSTa Winter 2013/14



Baxter and Nigam 2015
Bond et al 2015
Hartmann 2015
Hobdday et al 2016
Peterson et al 2016
Anderson et al 2016
Di Lorenzo and Mantua 2016 …

Properties of recent Marine Heatwaves of 2013~2015

- amplitude
- varying spatial structure
- multi-year persistence



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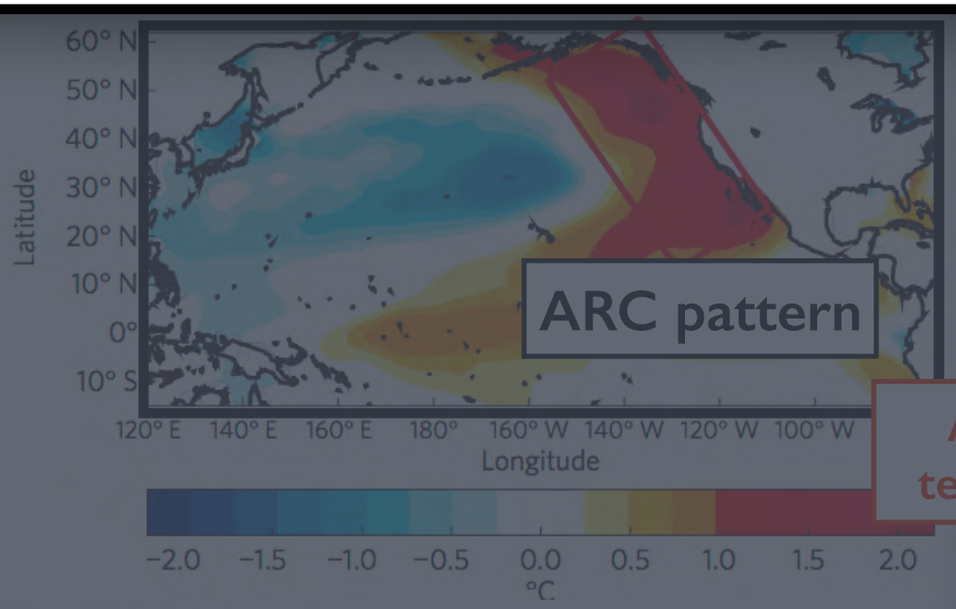
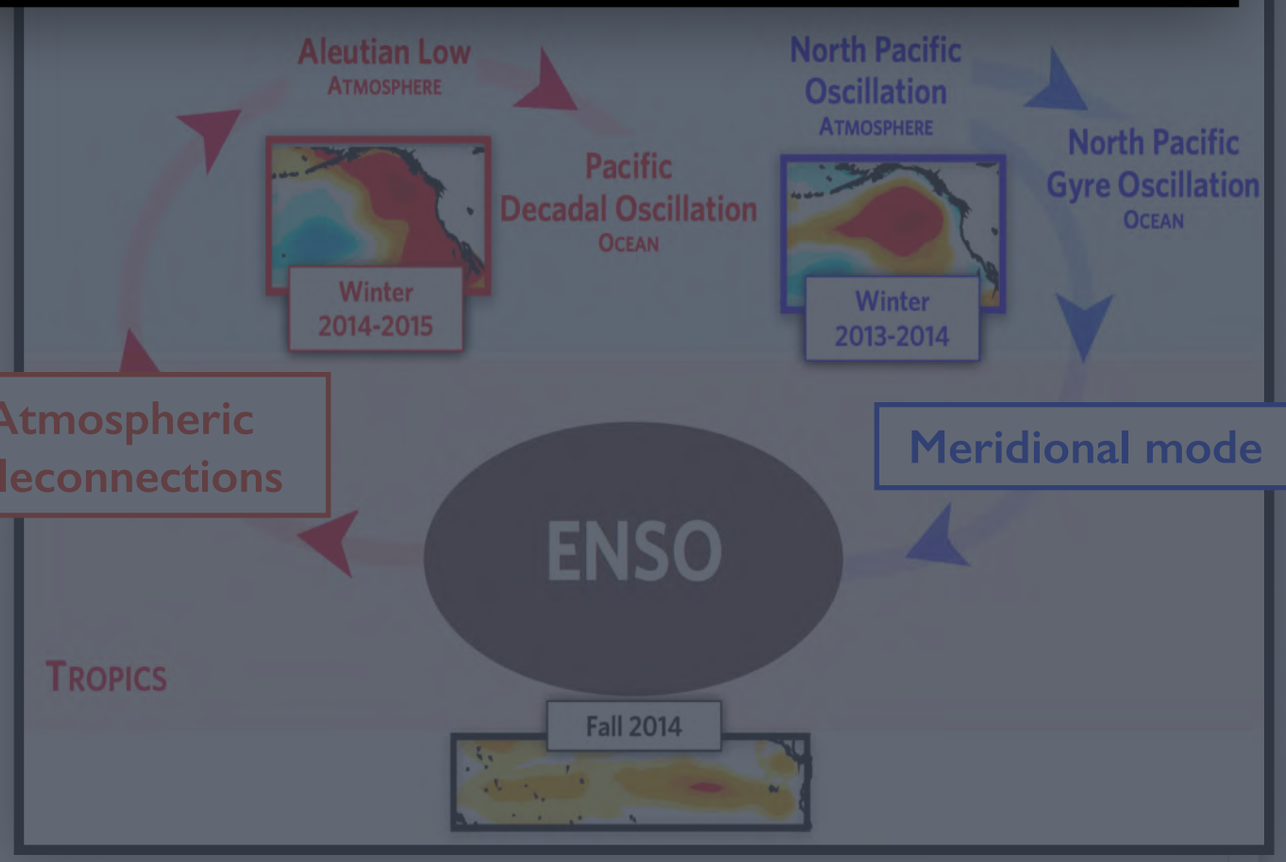
Open questions in North Pacific Climate

1. **Do the characteristics of marine heatwaves change over time. (*e.g. amplitude, spatial structure, multi-year persistence*)?**

2. **Are the characteristics sensitive to greenhouse forcing?**

JFM 2015





Di Lorenzo and Mantua (2016, Nature Climate Change)

Open questions in North Pacific Climate

1. **Do the characteristics of marine heatwaves change over time. (*e.g. amplitude, spatial structure, multi-year persistence*)?**

2. **Are the characteristics sensitive to greenhouse forcing?**

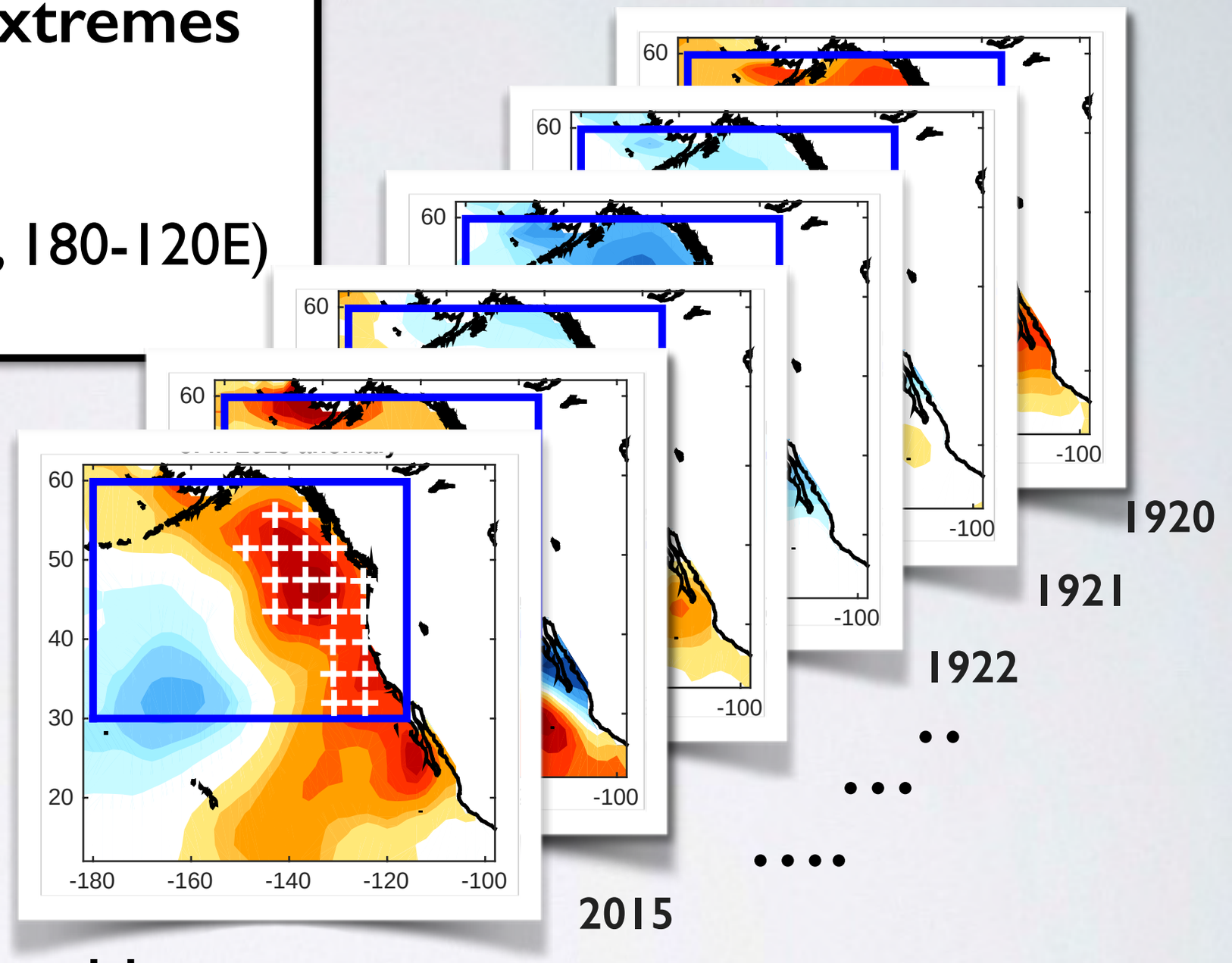
Approach

1. **Define more direct measures of marine heatwaves characteristics**

2. **Explore how they change in observations and large climate model 30-member ensemble forced with greenhouse gases**

Quantifying ocean extremes

ERSST. v3 (**1920-2015**)
JFM mean SSTa (30-60N, 180-120E)



➡ Percentage covered by
warm water & **cold** water

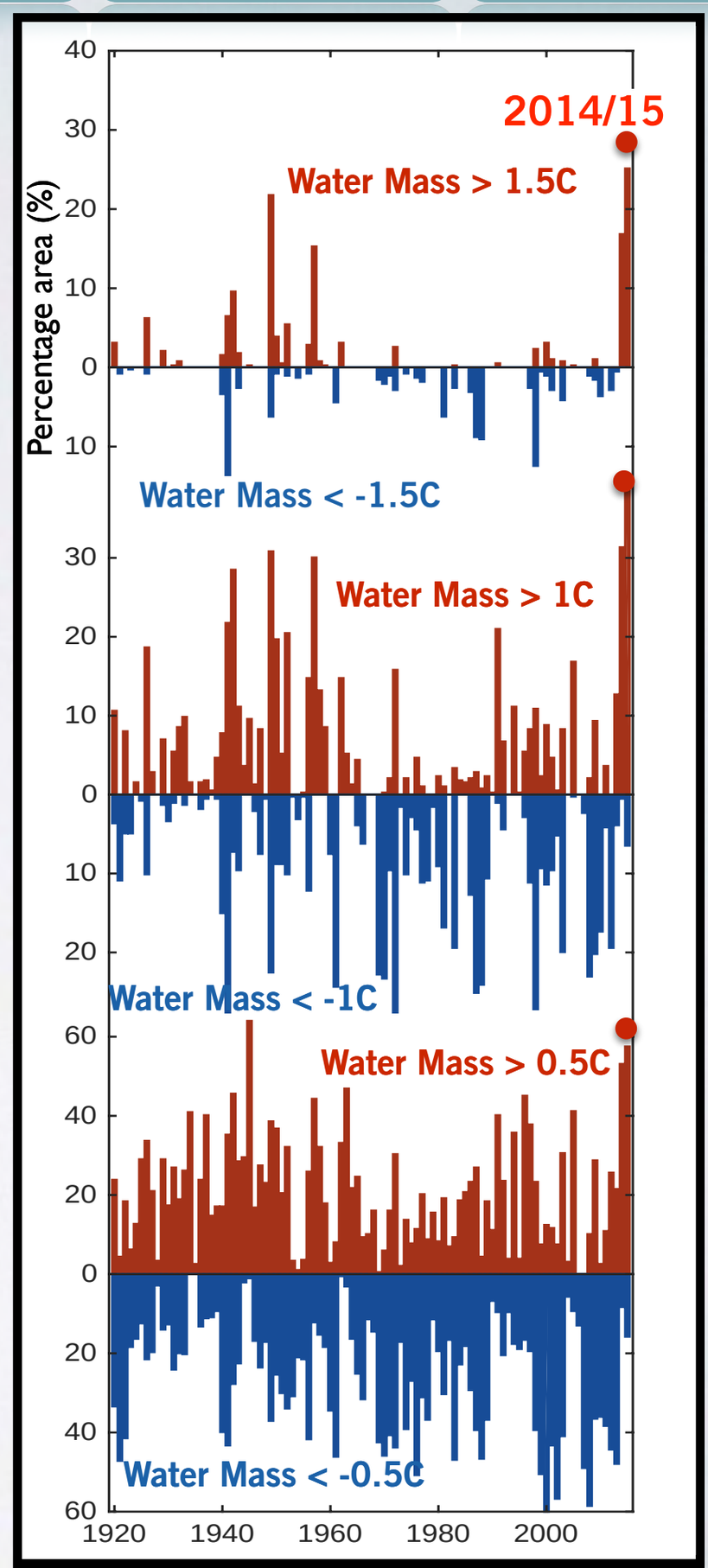
Amplitude ✓

Percentage are covered by
warm water & **cold** water

1.5°C

1°C

0.5°C



Amplitude

Spatial Structure

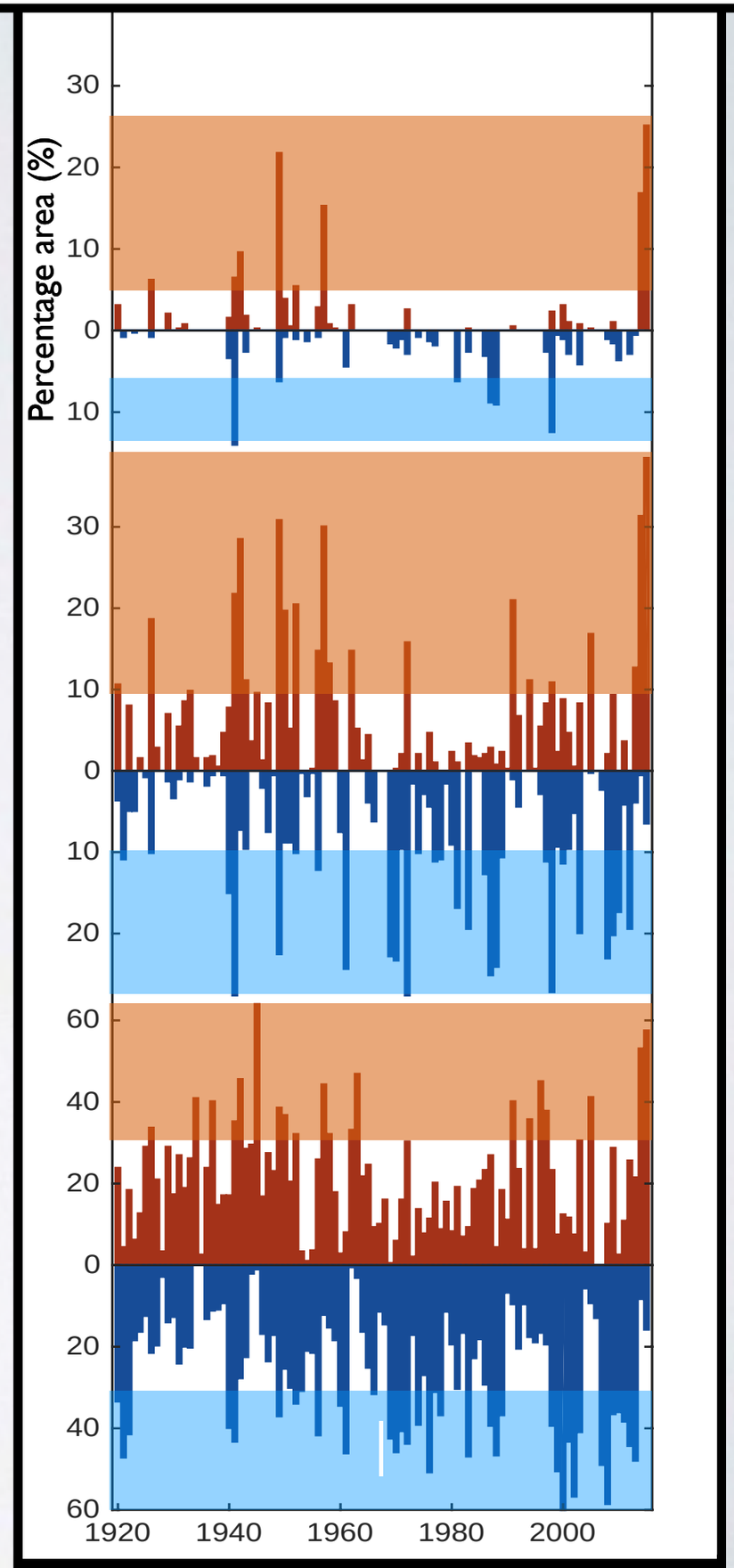
warm events
&
Cold events

1.5°C

1°C

0.5°C

For composite patterns



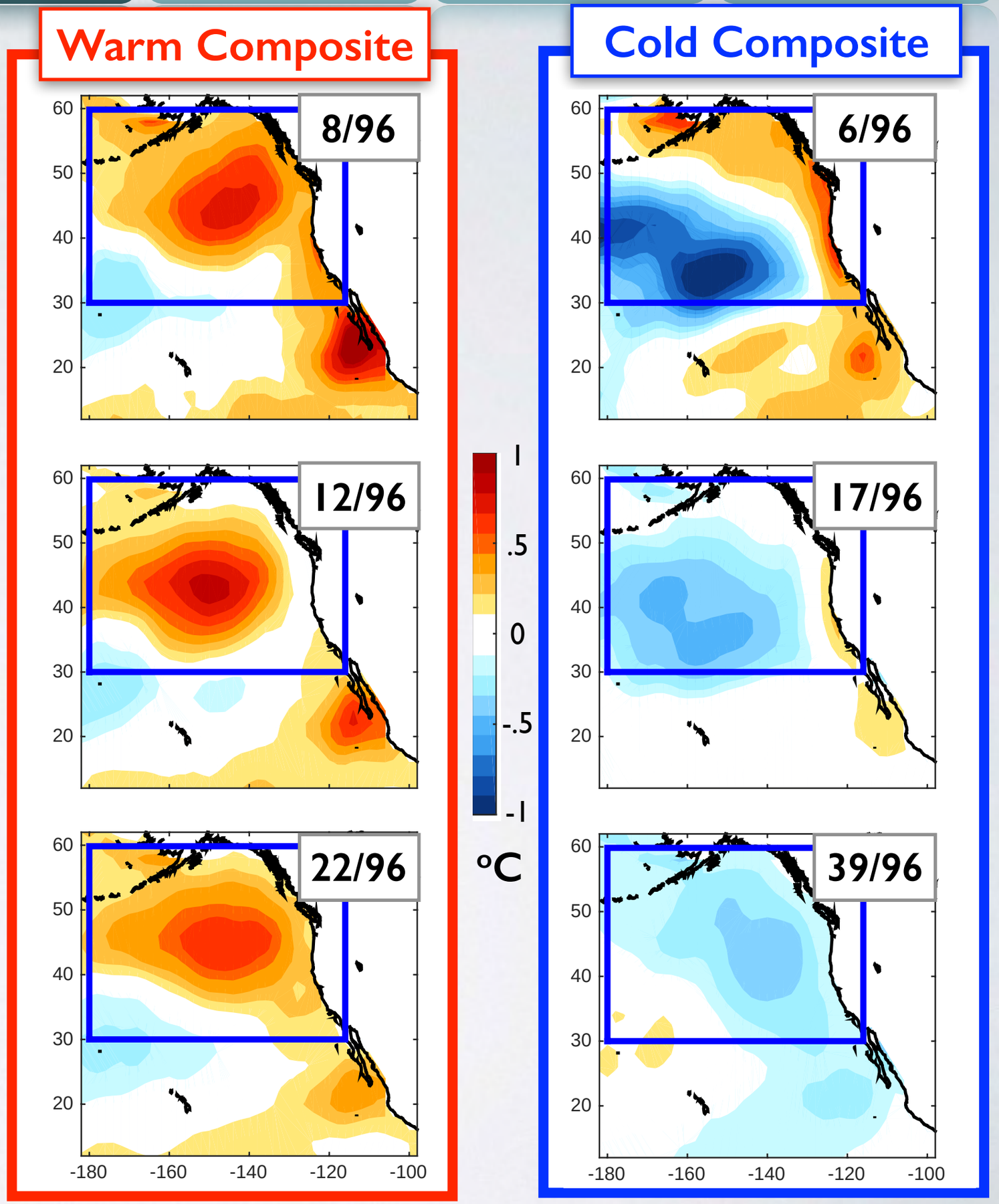
Amplitude

1.5°C

1°C

0.5°C

Spatial Structure ✓



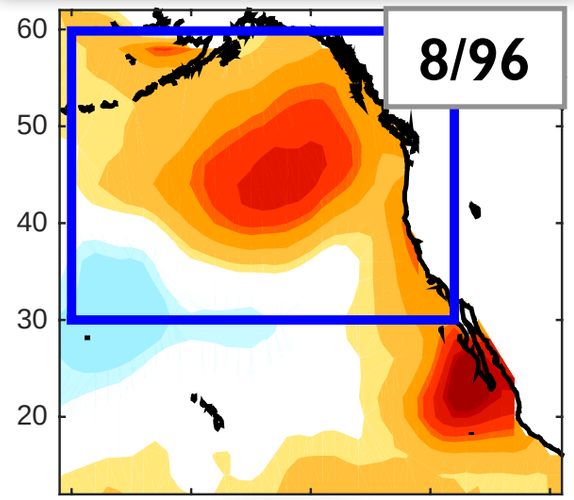
Amplitude

1.5°C

Spatial Structure ✓

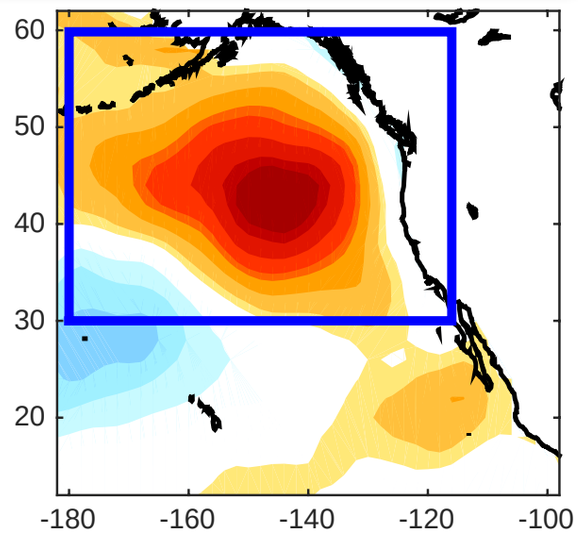
North Pacific decadal variabilities

Warm Extremes

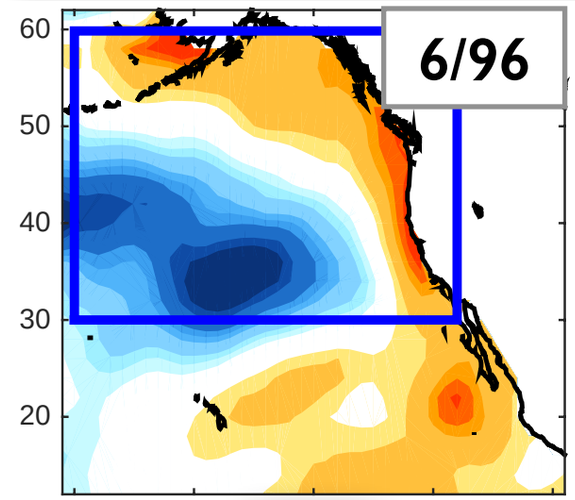


NPGO-like

EOF2 SSTa

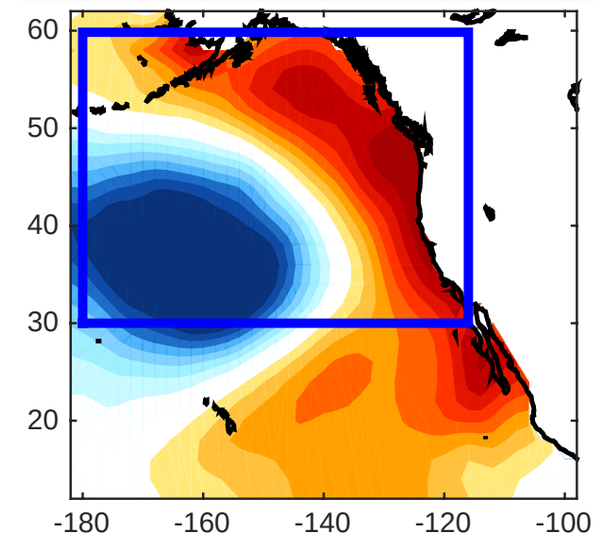


Cold Extremes



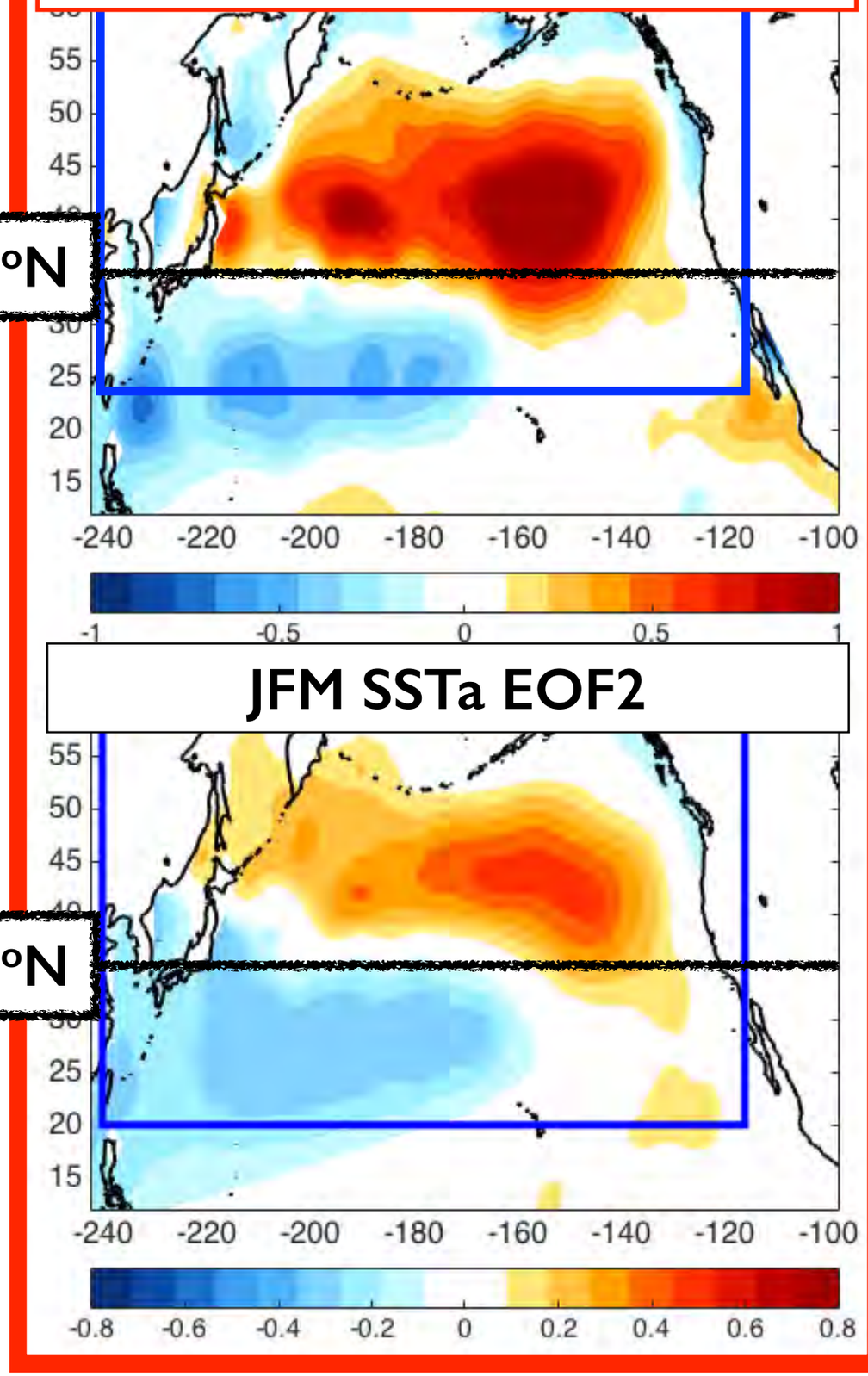
PDO-like

EOF1 SSTa

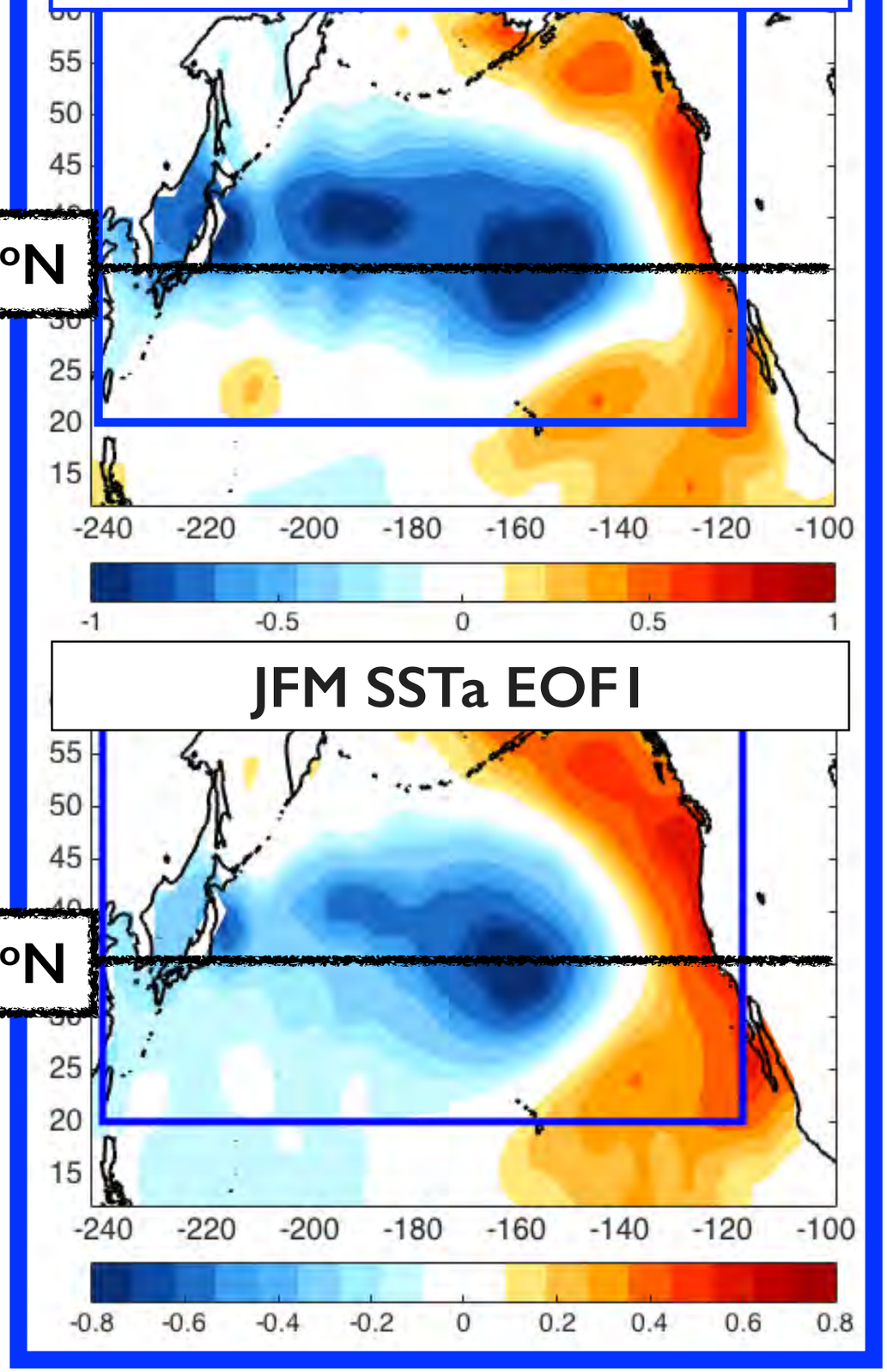


Supplementary slide 1

Warm Extremes (7/96)



Cold Extremes (8/96)



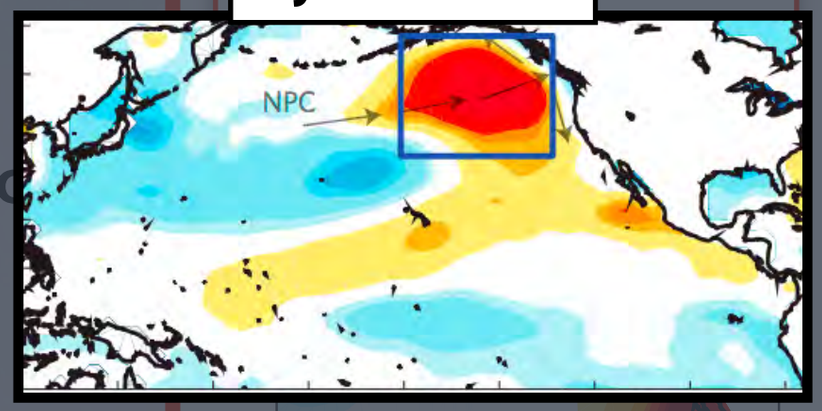
Amplitude

Spatial Structure

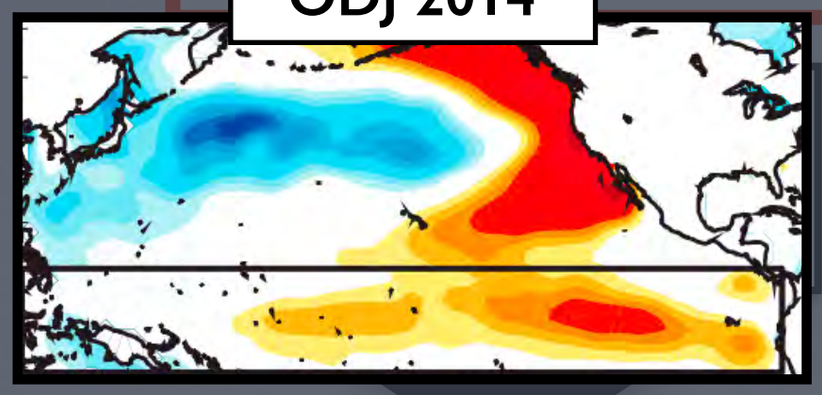
1.5°

North Pac
decadal
variabiliti

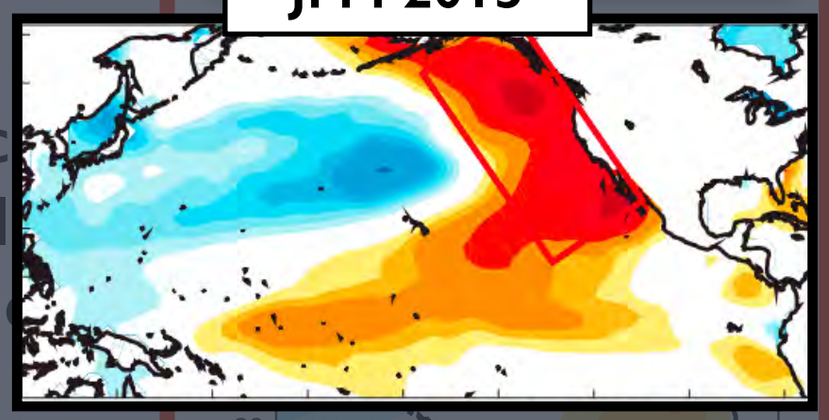
JFM 2014



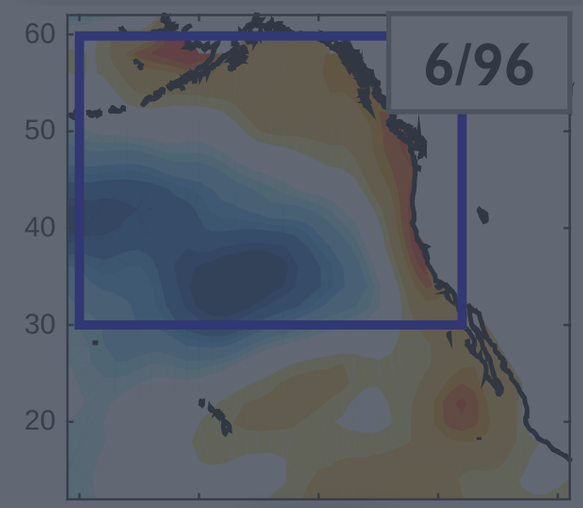
ODJ 2014



JFM 2015

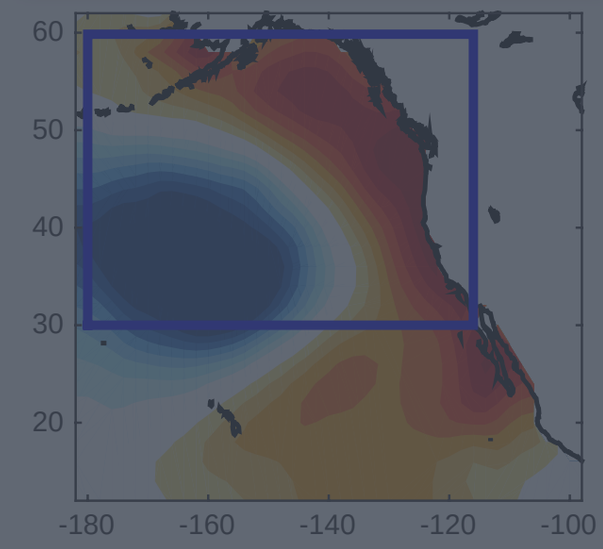


Cold Extremes



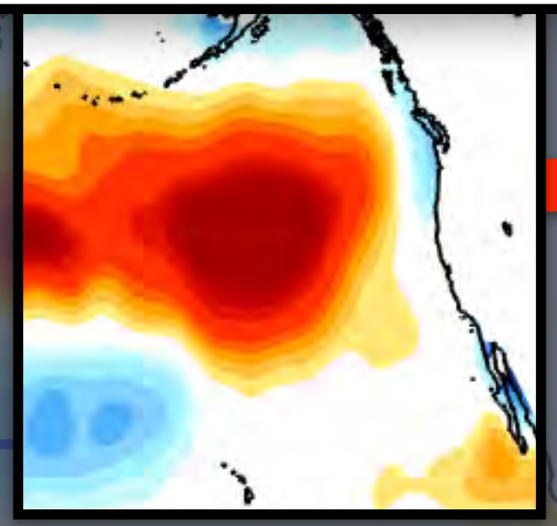
PDO-like

EOF1 SSTa



Di Lorenzo and Mantua (2016, Nature Climate Change)

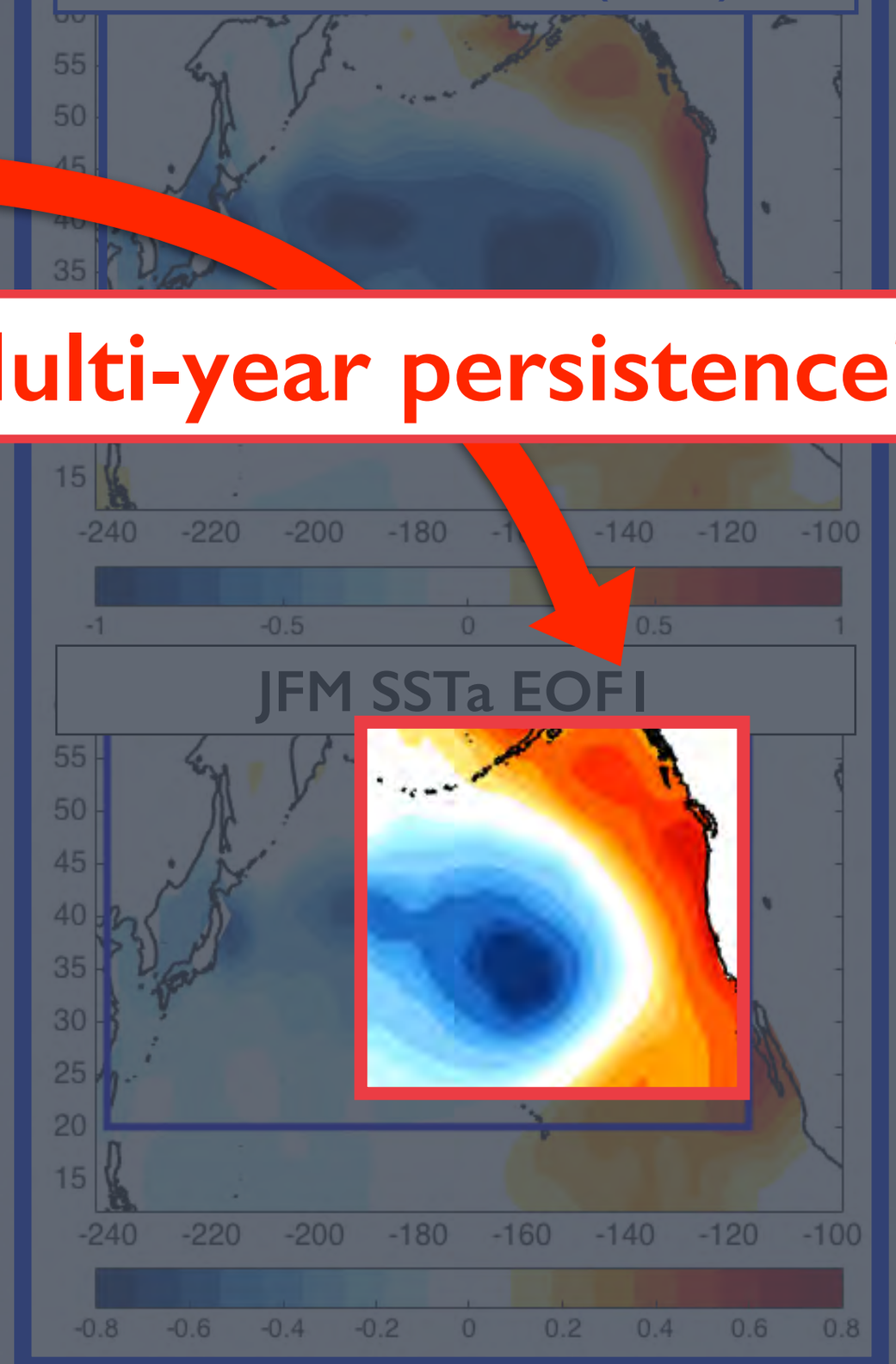
warm events



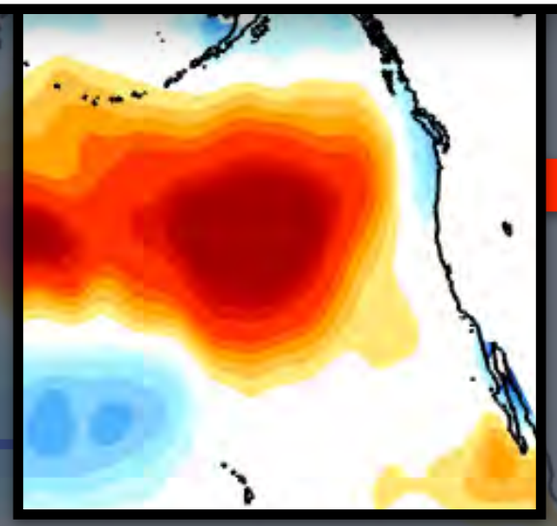
Warm

Multi-year persistence?

Cold Extremes (8/96)



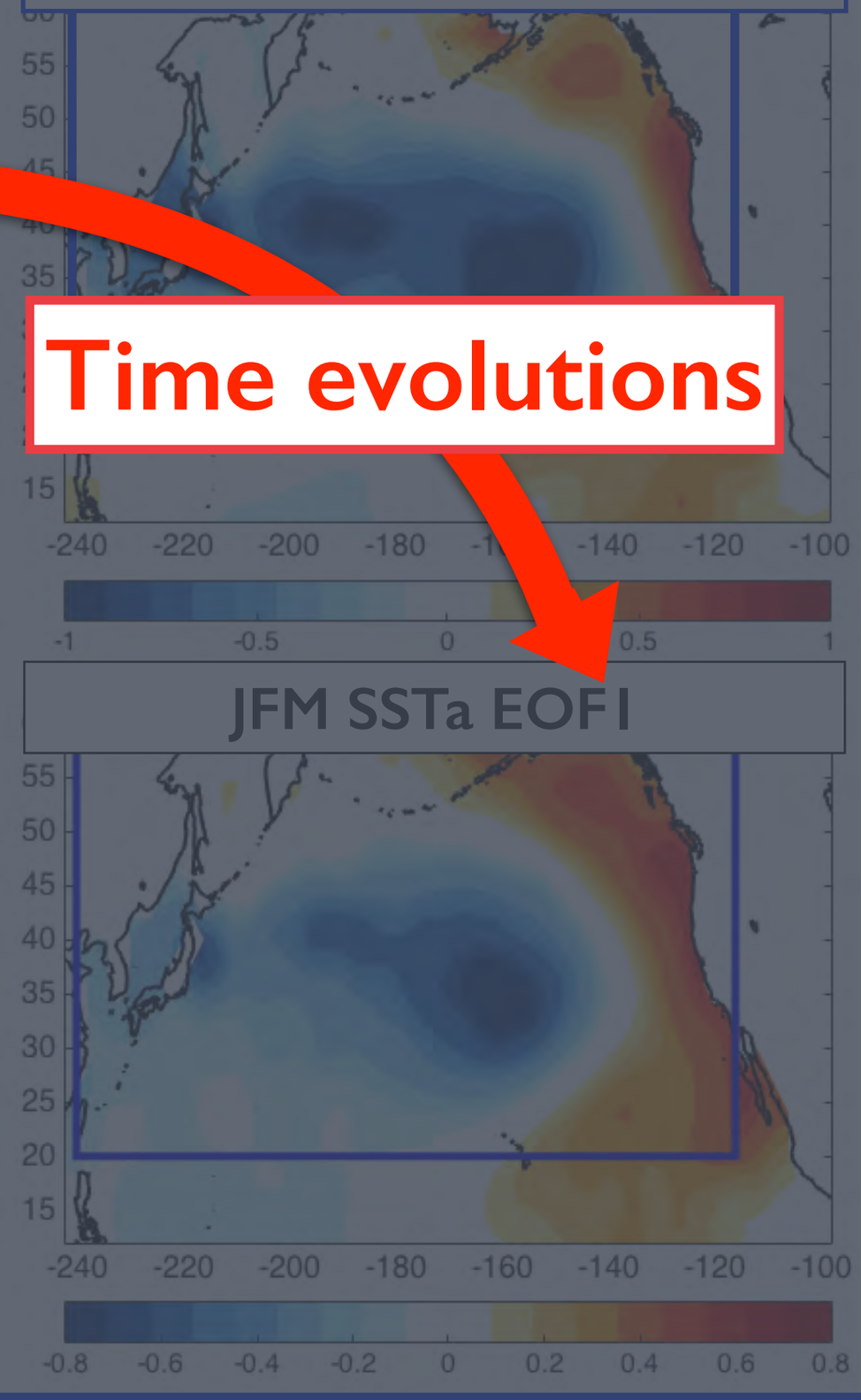
warm events



Time evolutions

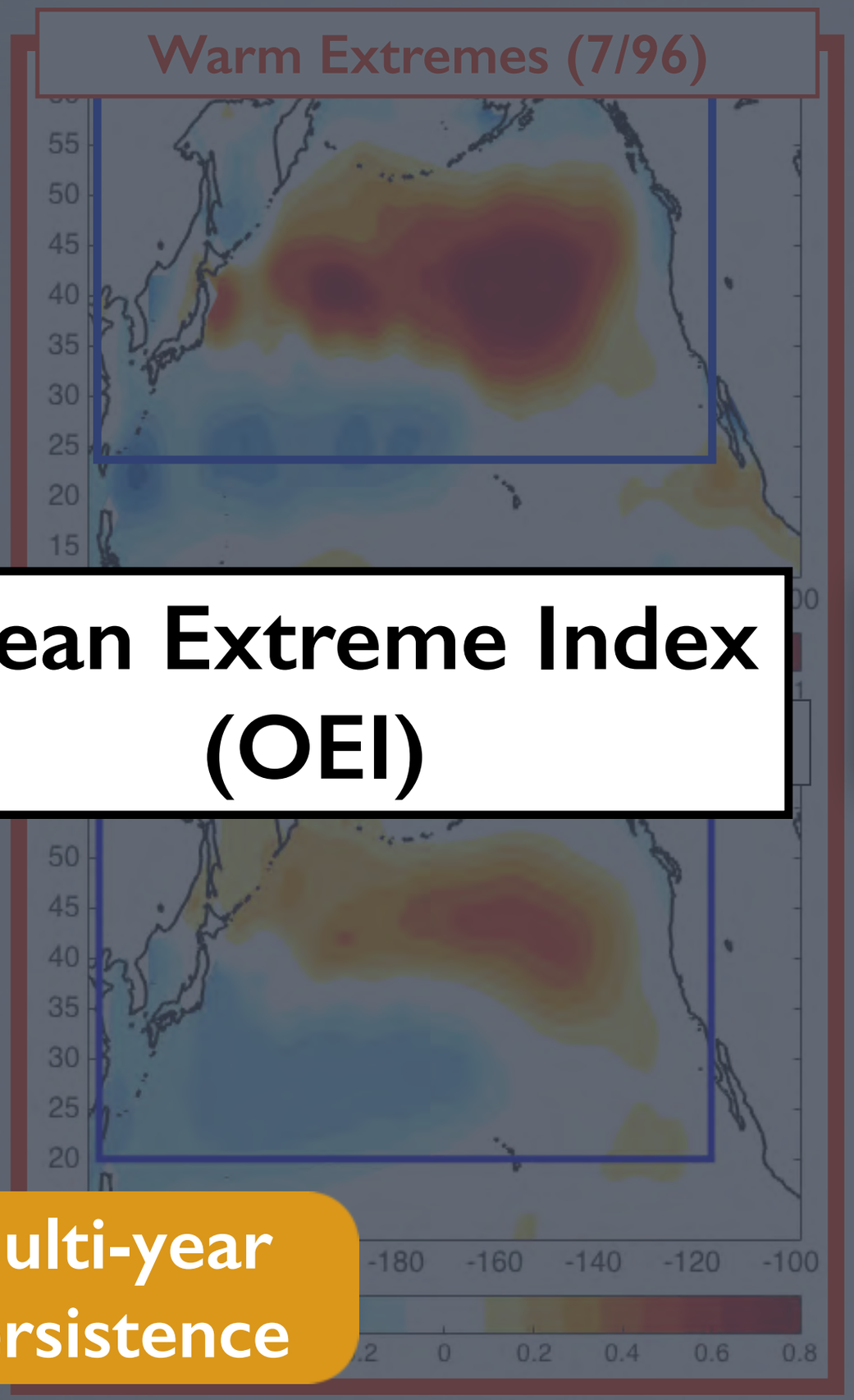
Warm

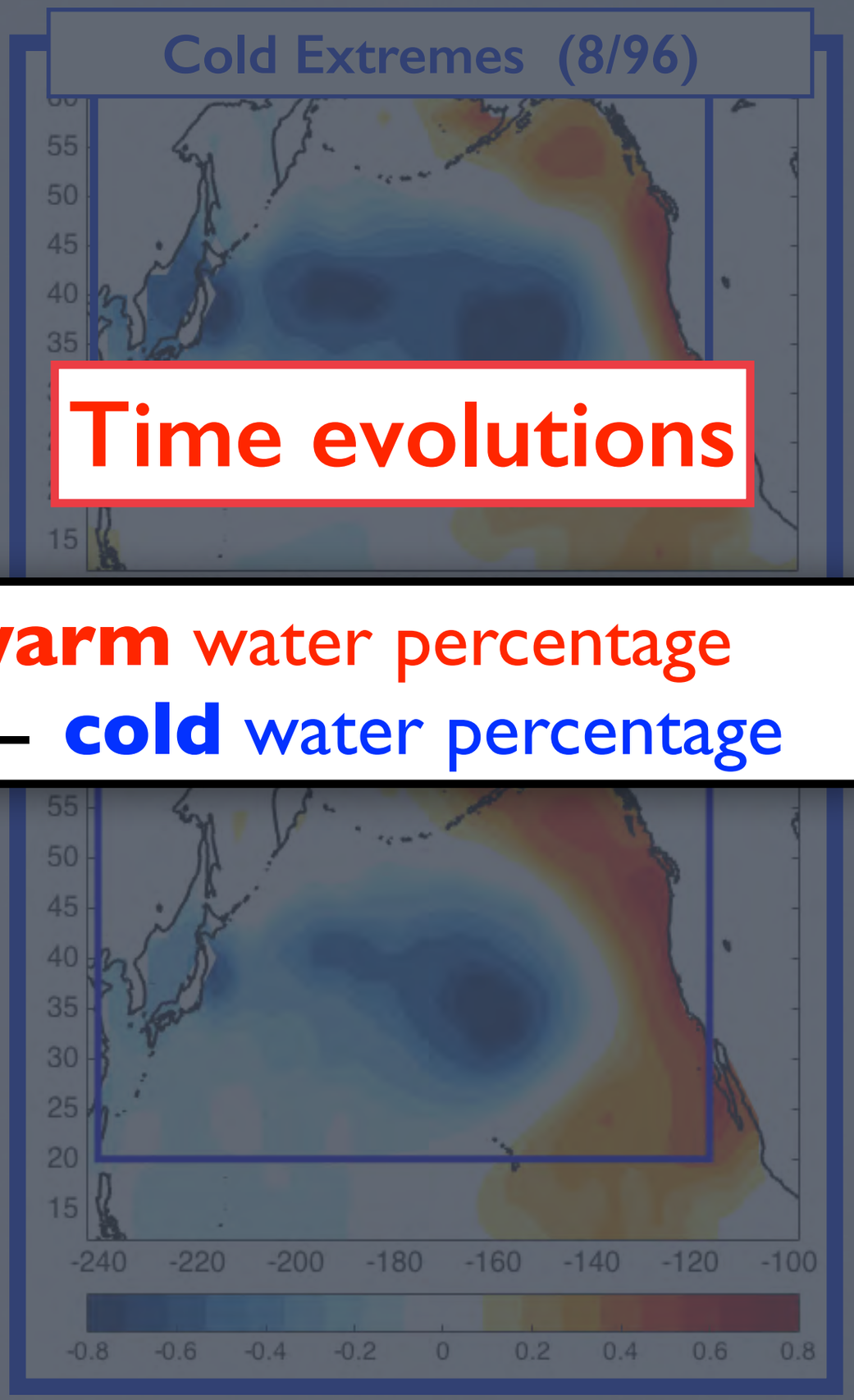
Cold Extremes (8/96)



Warm Extremes (7/96)

Cold Extremes (8/96)





Time evolutions

Ocean Extreme Index (OEI)

warm water percentage
– **cold** water percentage

Multi-year Persistence

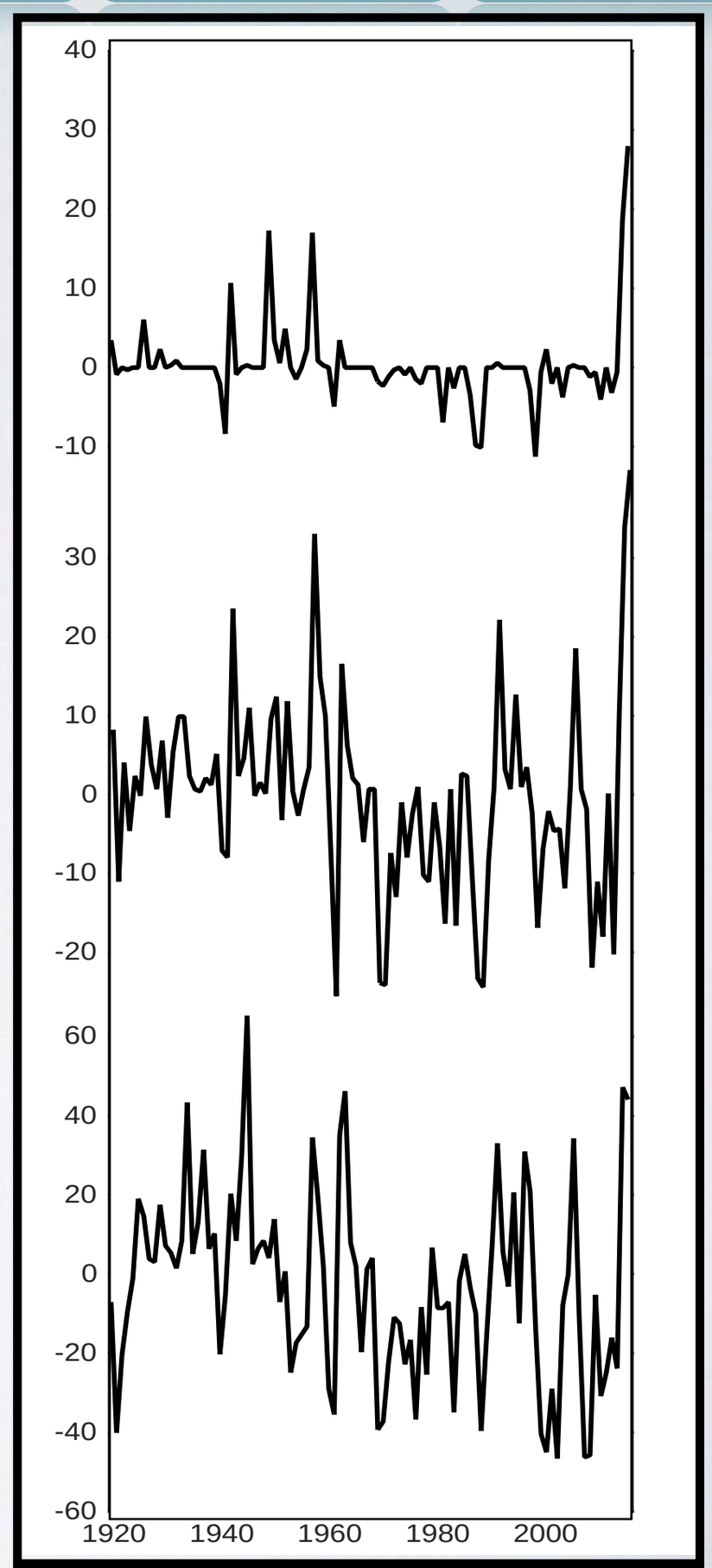
Amplitude

Ocean Extreme Index (OEI)

1.5°C

1°C

0.5°C



Multi-year Persistence

Amplitude

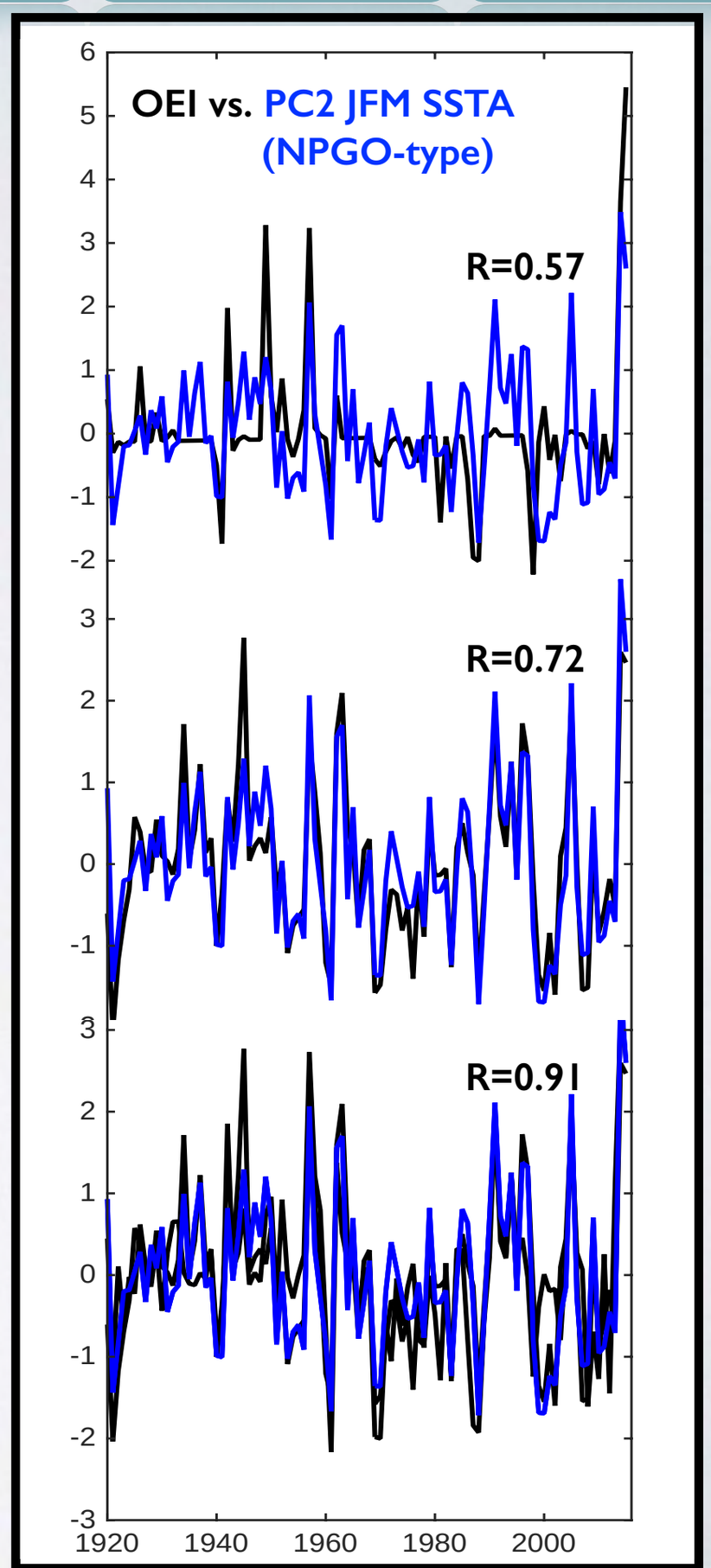
1.5°C

1°C

0.5°C

Ocean Extreme Index (OEI)

Multi-year Persistence



Amplitude

Spatial Structure

Multi-year Persistence ✓

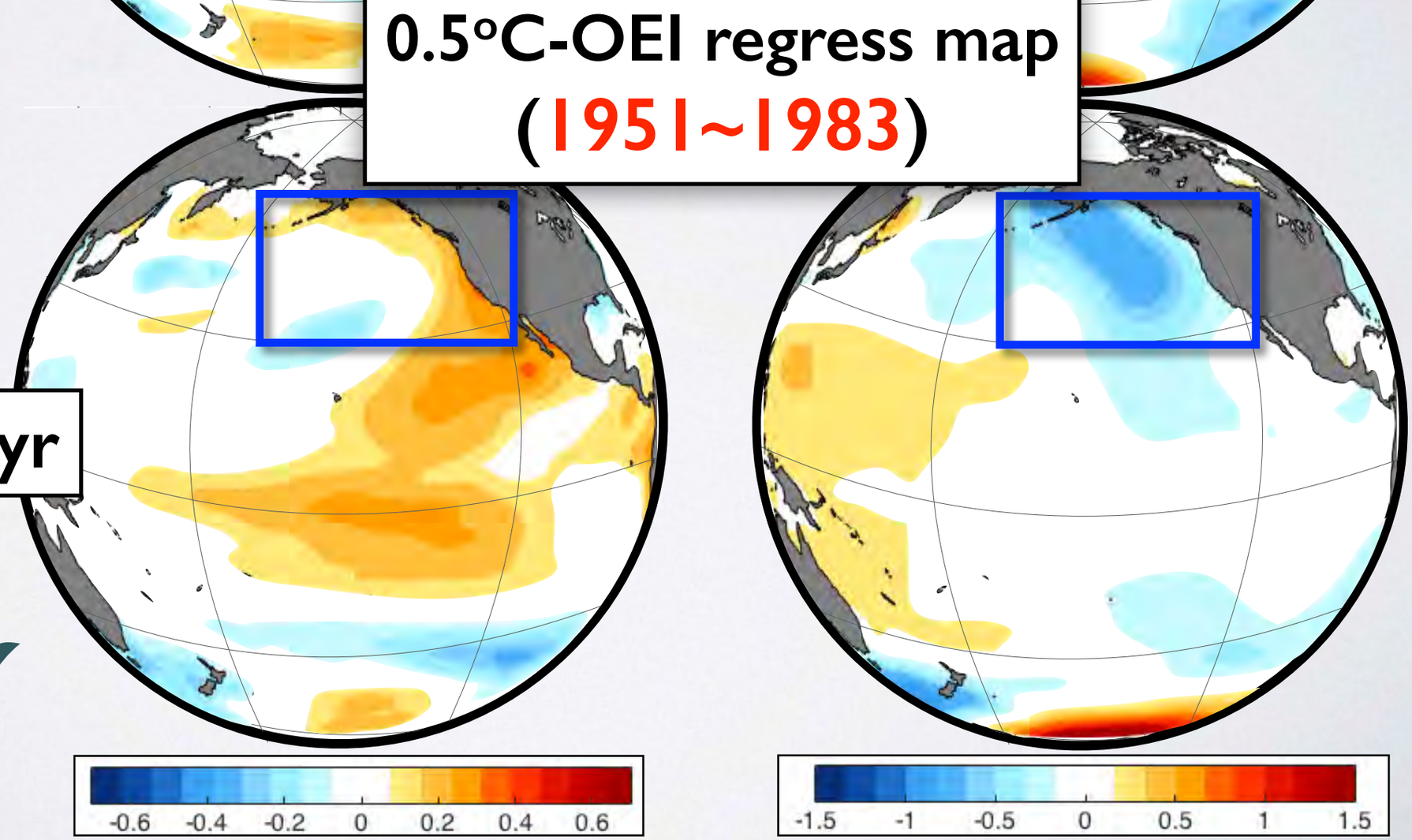
SST

SLP

lag +0yr

lag +1yr

0.5°C-OEI regress map
(1951~1983)



Amplitude

Spatial Structure

Multi-year Persistence ✓

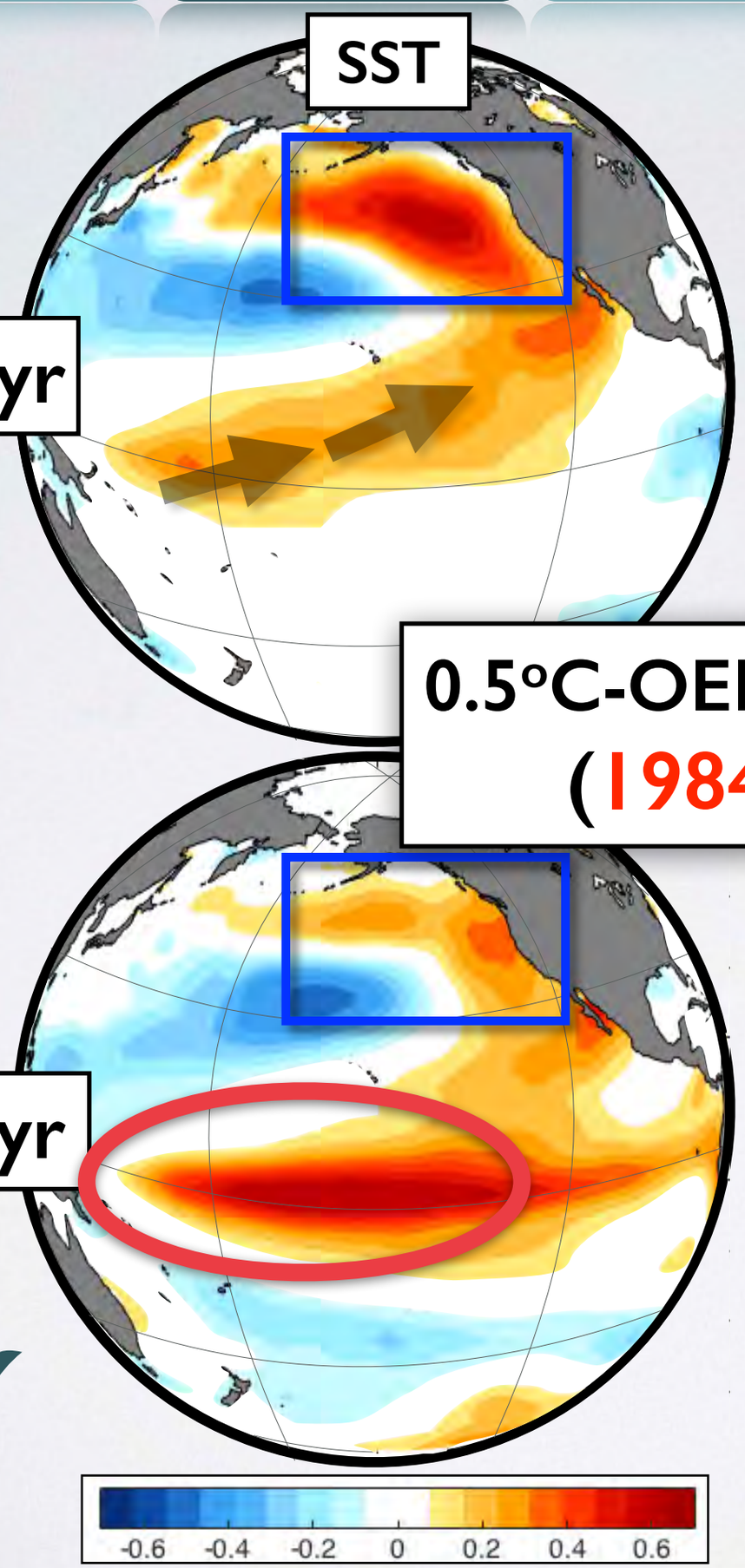
SST

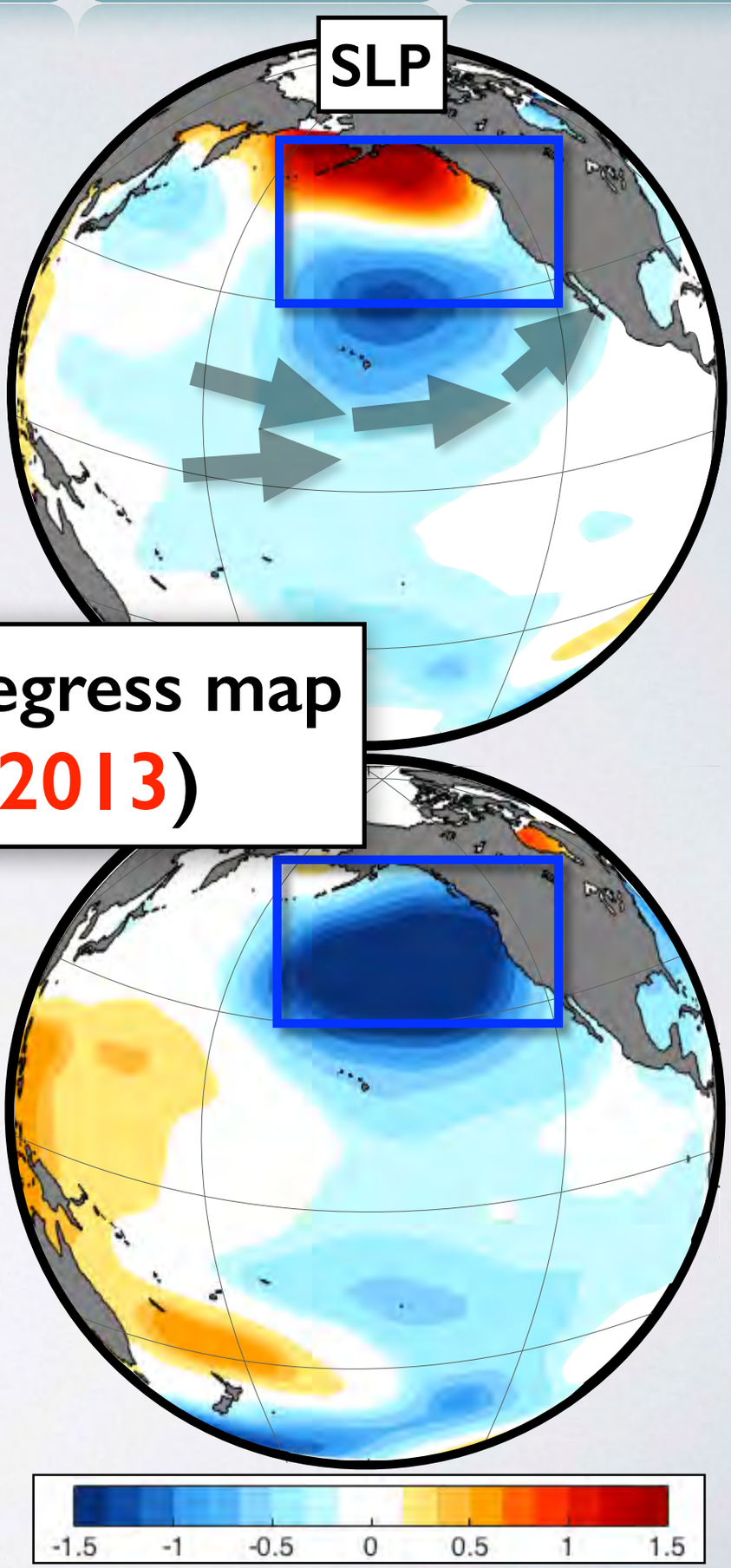
SLP

lag +0yr

lag +1yr

0.5°C-OEI regress map (1984~2013)





Amplitude

Spatial Structure

SST

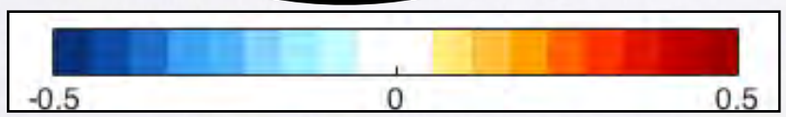
SLP

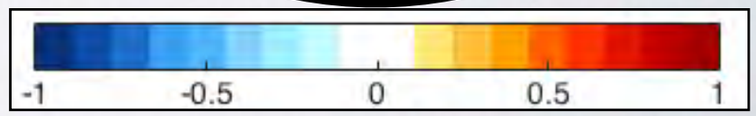
lag +0yr

0.5°C-OEI regress map
(1984~2013) - (1951~1983)

lag +1yr

Multi-year Persistence ✓





Amplitude

lag +0yr

SST

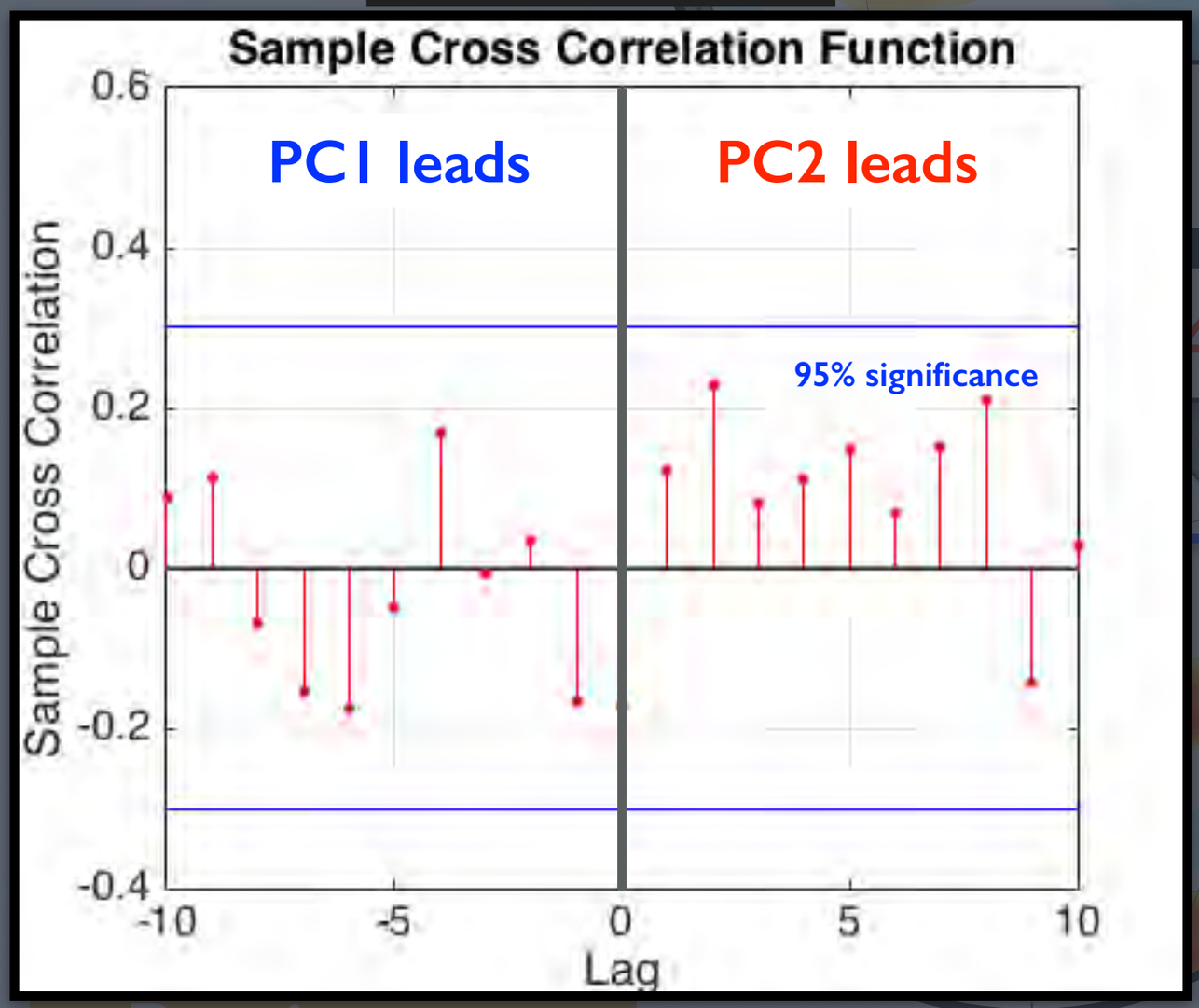
SLP

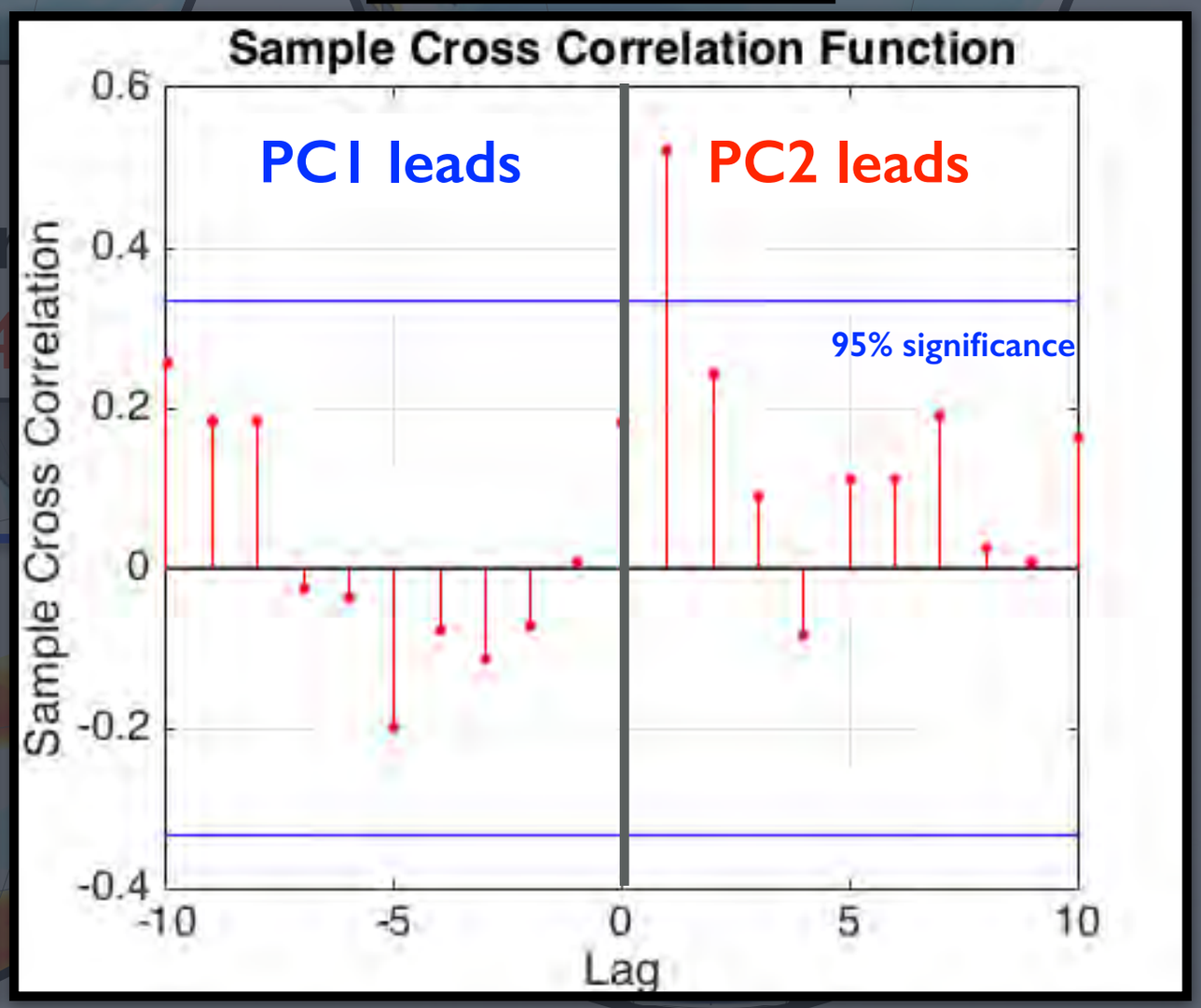
PC1= North Pacific JFM SSTa EOF1
(e.g. PDO-type)

PC2= North Pacific JFM SSTa EOF2
(e.g. NPGO-type)

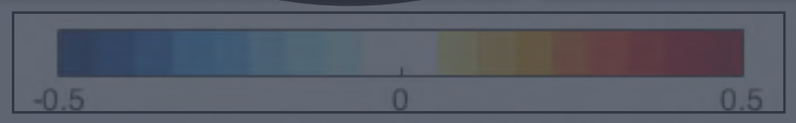
1930~1976

1977~2013





Persistence



Amplitude

SST

SLP

lag +0yr

lag +1yr

Multi-year Persistence

-0.5 0 0.5

-1 -0.5 0 0.5 1

Question

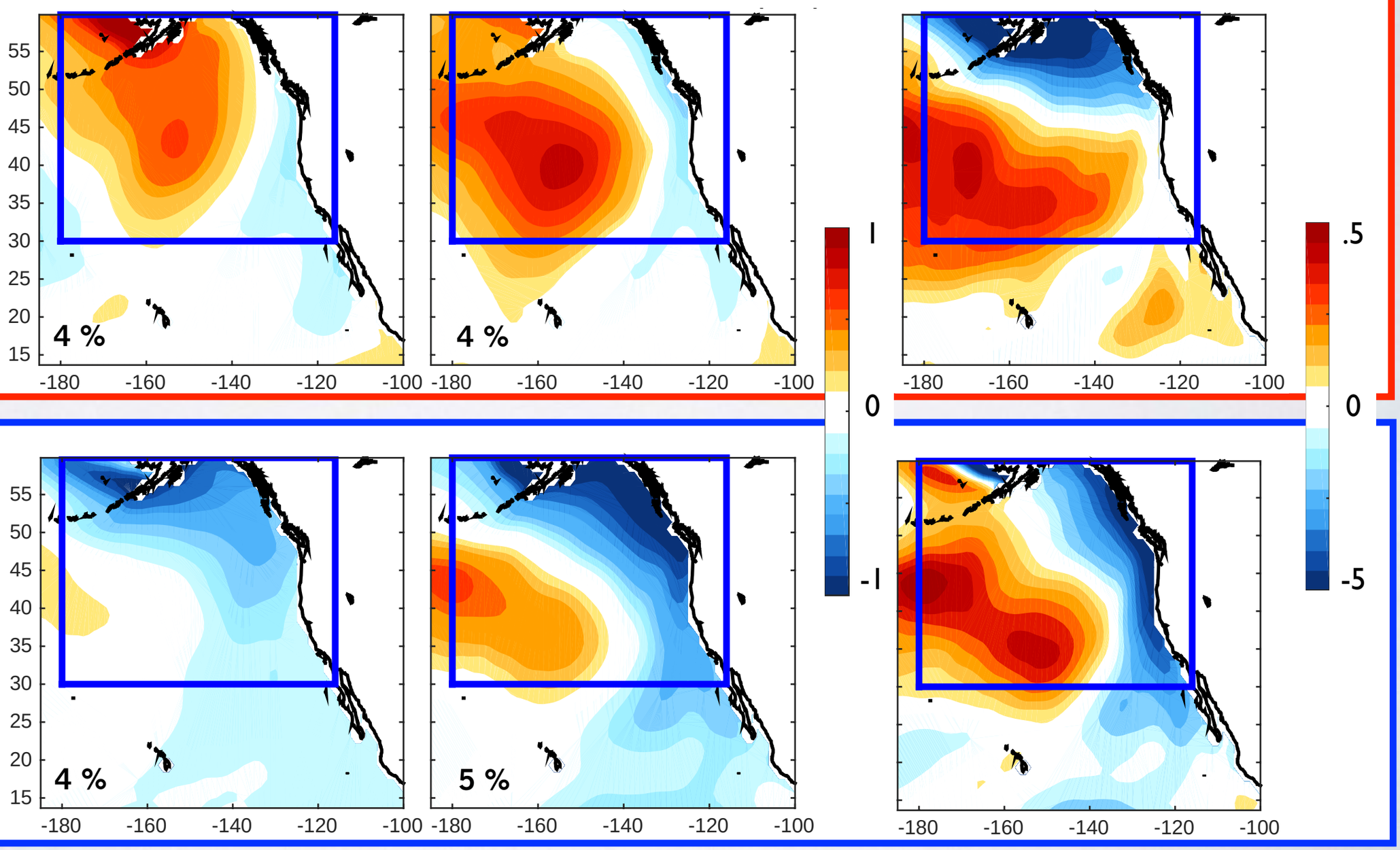
How do the characteristic of marine heatwaves look like in CESM-LE (e.g. amplitude, spatial structure, persistence)**?**

CESM Large-Ensemble (CESM-LEN) 30 members

Amplitude & Spatial structure

CTRL 1951-2000 | RCP8.5 2051-2100 | RCP8.5-CTRL

2°C threshold Warm extremes



2°C threshold Cold extremes

CESM

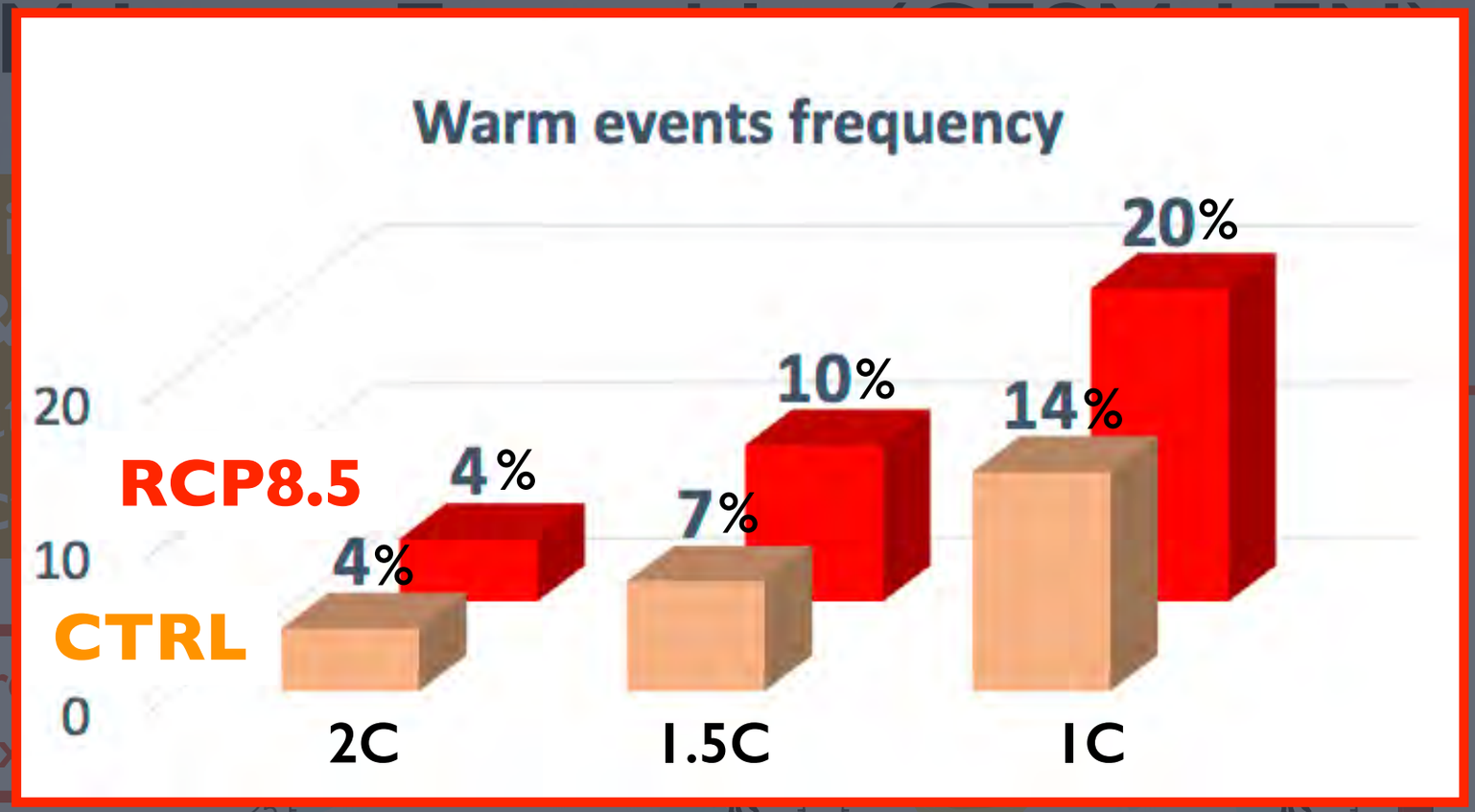
30 members

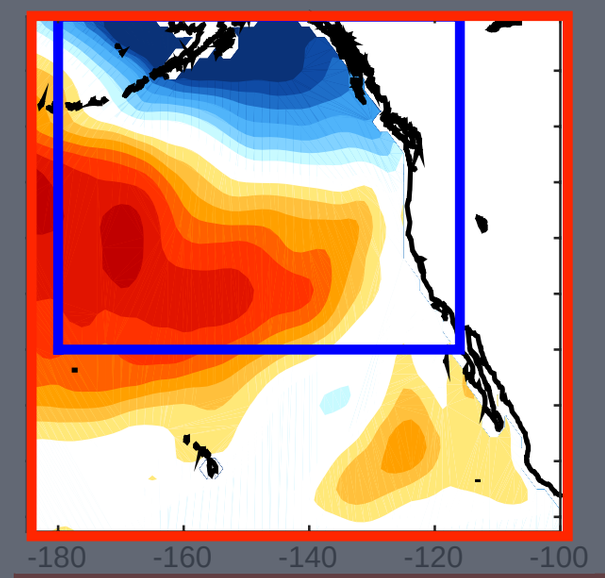
Ampli & Spa struc

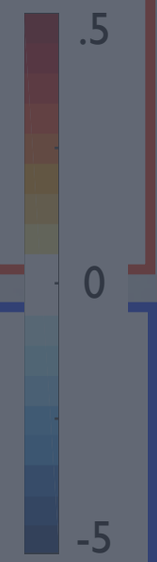
2°C thr Warm ex

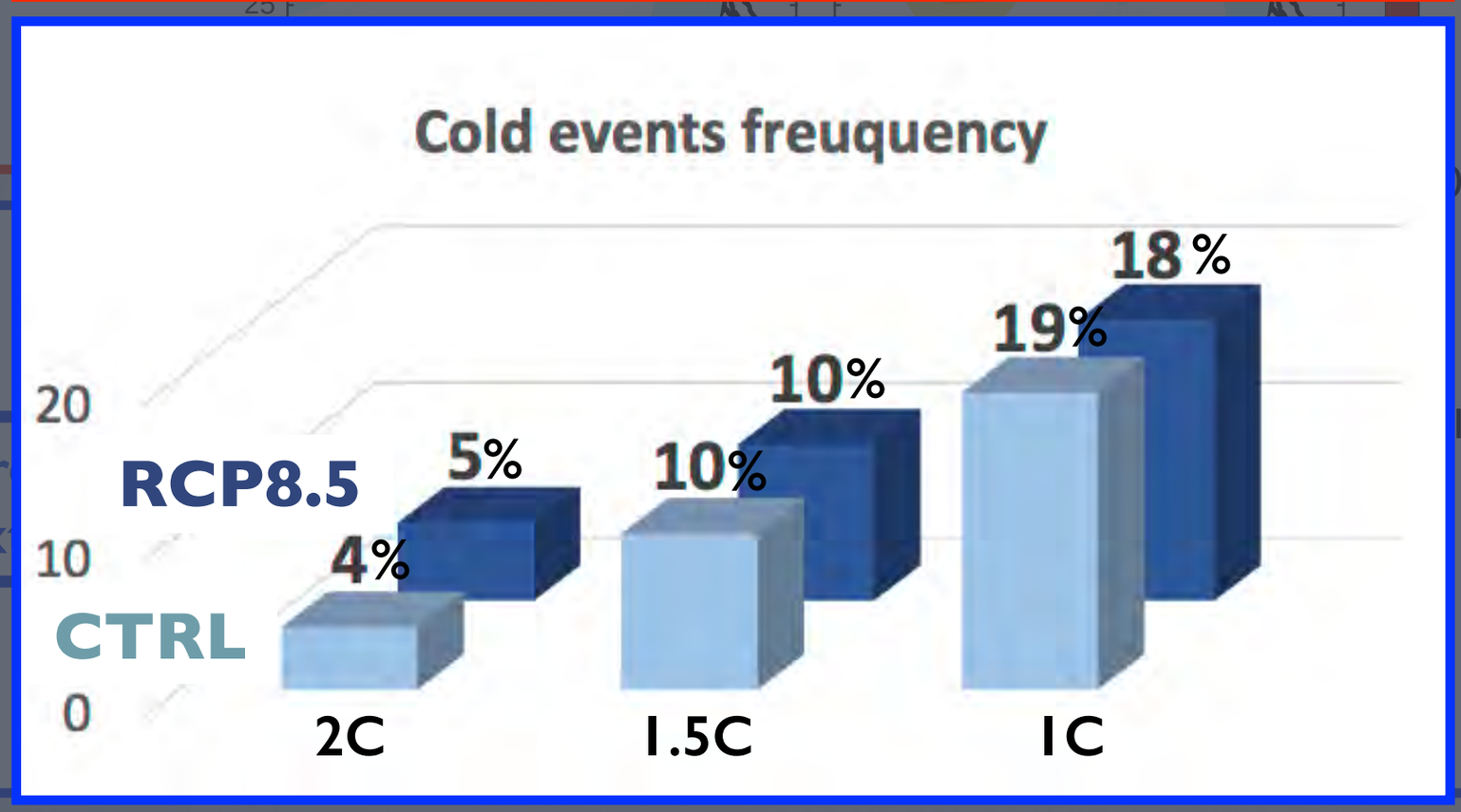
2°C thr Cold ex

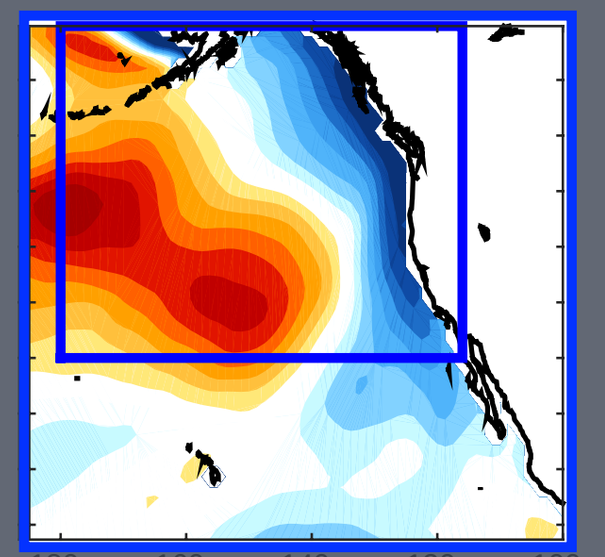
RCP8.5-CTRL











Amplitude
&
Spatial stru

Multi-year
Persistence

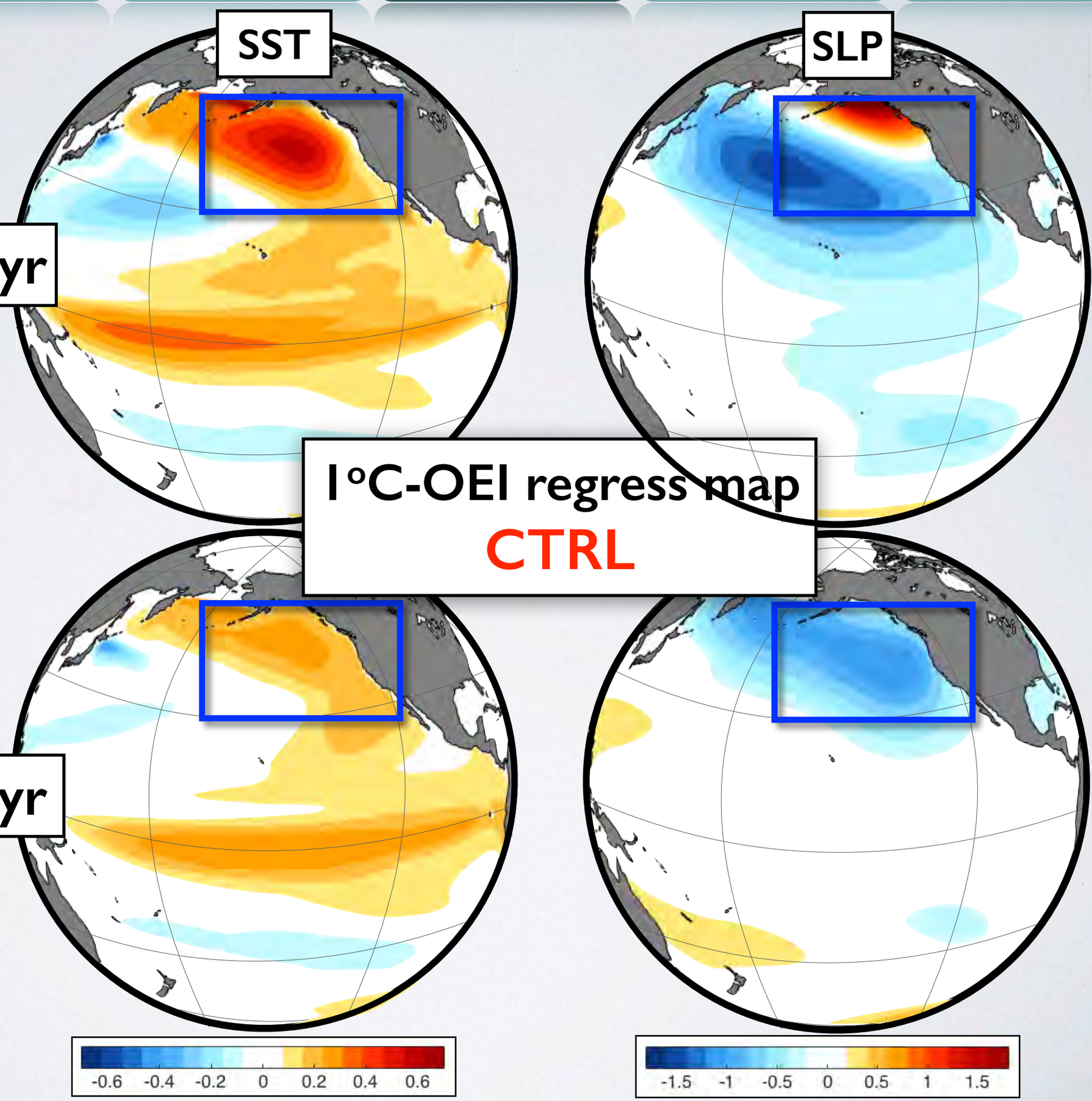
lag +0yr

lag +1yr

SST

SLP

1°C-OEI regress map
CTRL



Amplitude
&
Spatial stru

Multi-year
Persistence

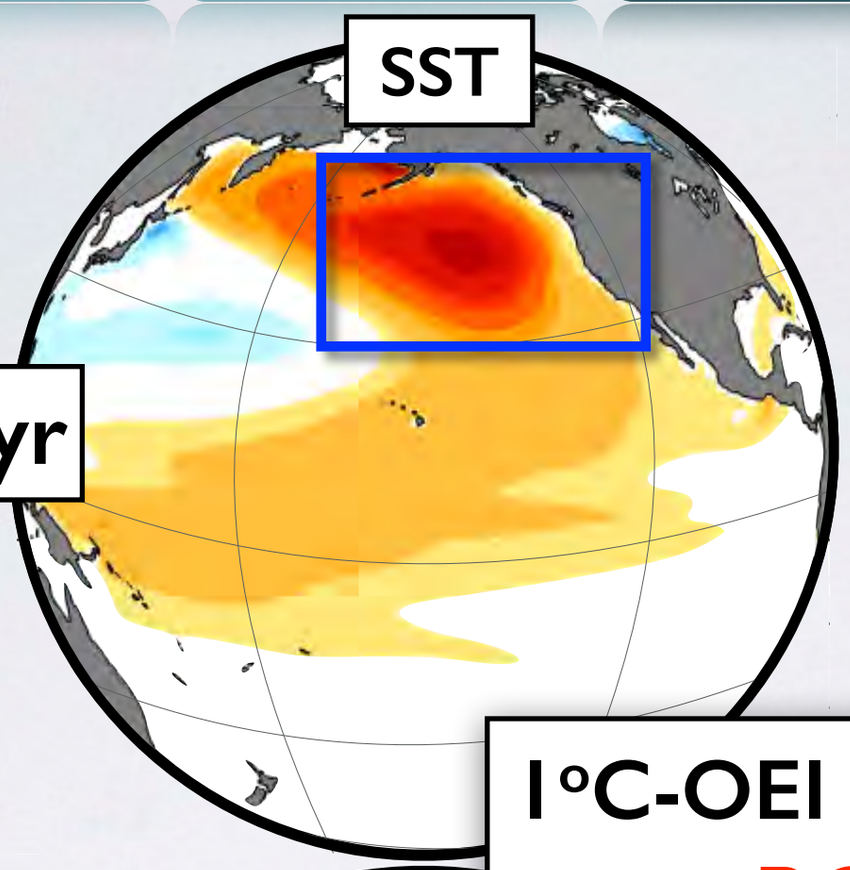
lag +0yr

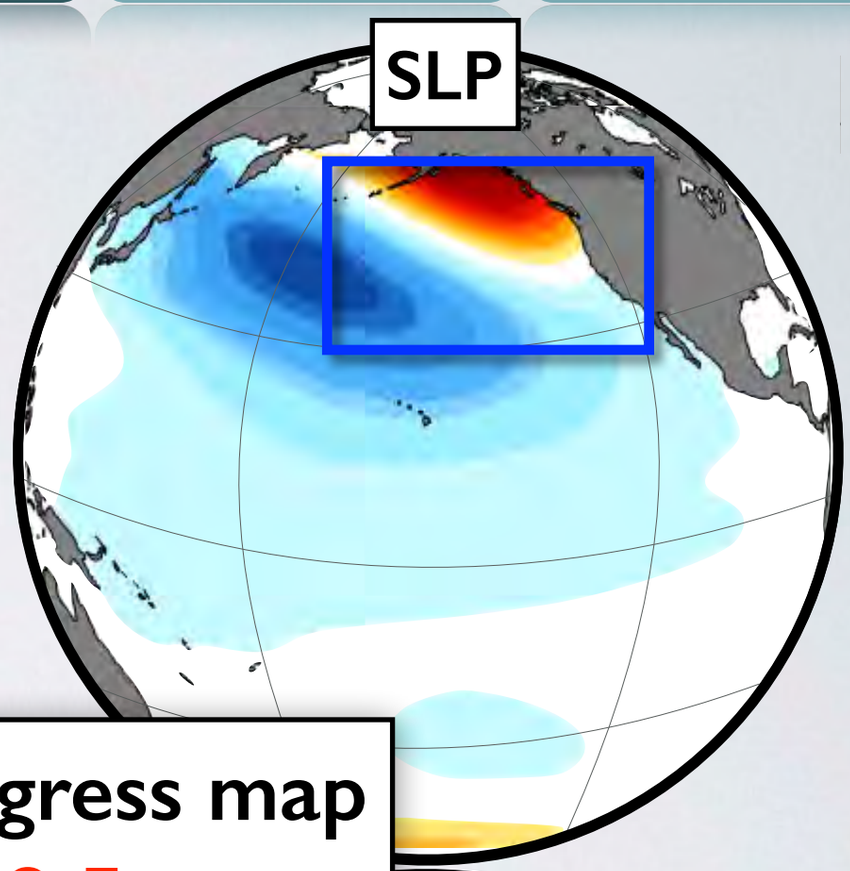
lag +1yr

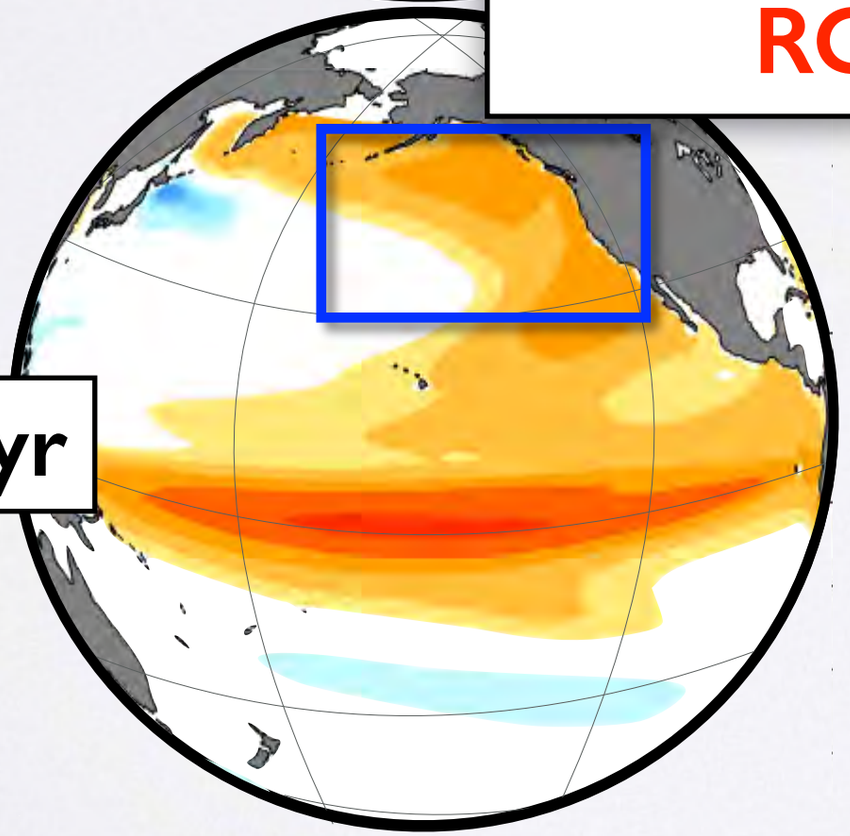
SST

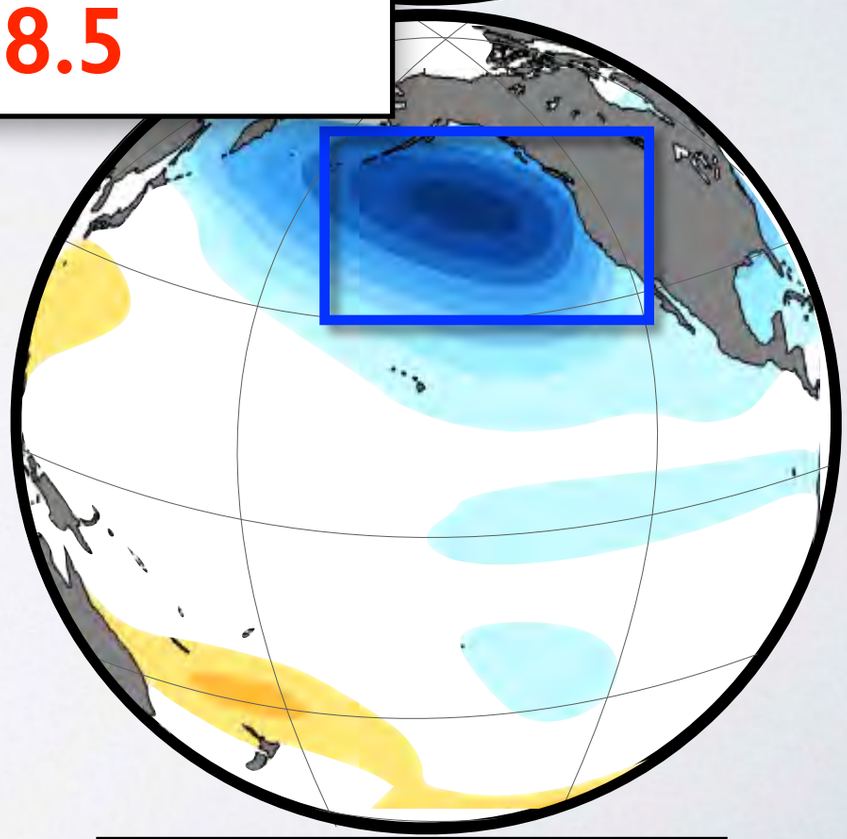
SLP

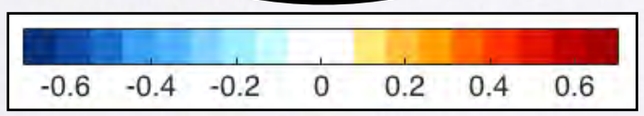
1°C-OEI regress map
RCP8.5

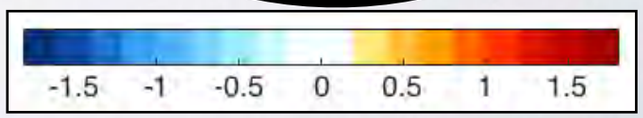












Amplitude & Spatial stru

Multi-year Persistence

SST

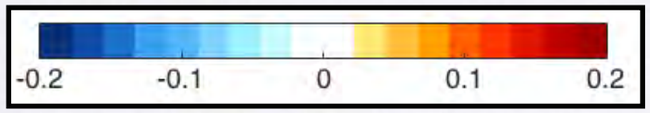
SLP

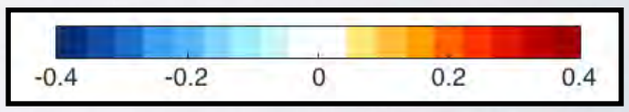
lag +0yr

1°C-OEI regress map

RCP8.5 - CTRL

lag +1yr





Spatial Structure

- Extremes always begin as a NPGO-like pattern.
- This pattern is robust in both observations and CESM-LENS.
- Both model and observation show a stronger sub-tropical footprint of the extremes.

Amplitude

- Observed warm events increase in the amplitude during recent 30 yrs.
- CESM-LENS suggest an increase in amplitude.
- CESM-LENS suggest a 3-6% increase in frequency.

Multi-year Persistence

- Both models and observation suggest a significant increase in the persistence from NPGO-like to PDO-like under greenhouse forcing.

Although the robustness of the model results remains uncertain, the observed and predicted increase in amplitude of occurrence in NPGO-like warm events suggests that the ecologically-relevant ecosystem threshold will be exceeded more frequently under greenhouse forcing.