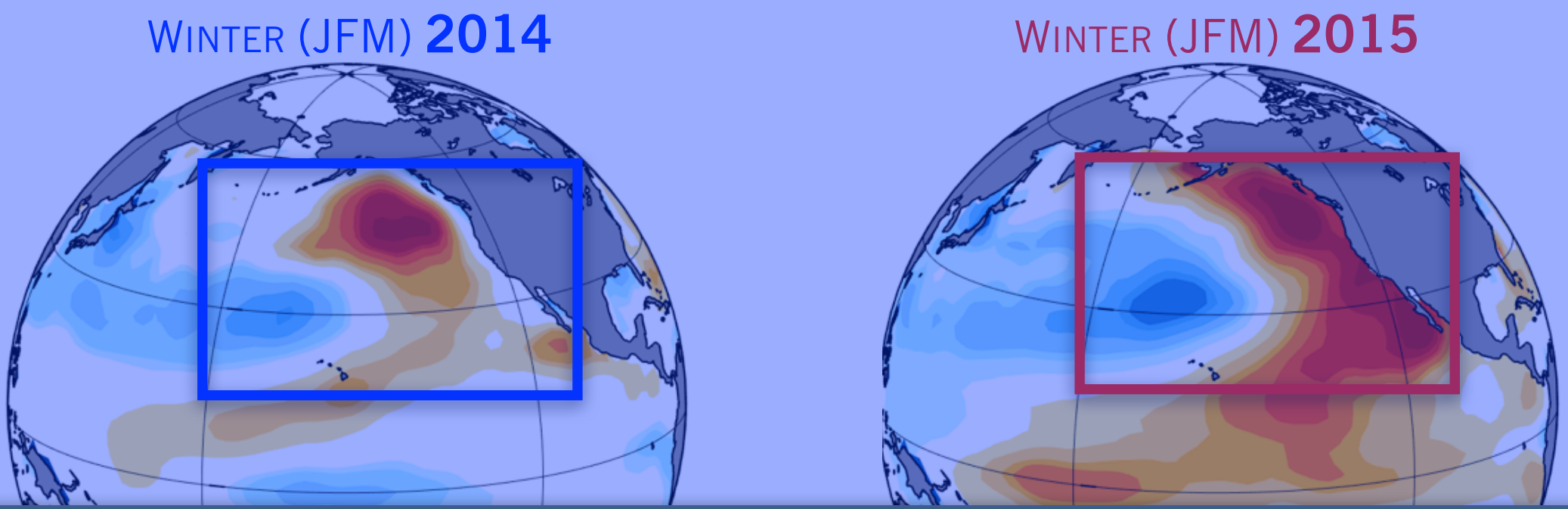
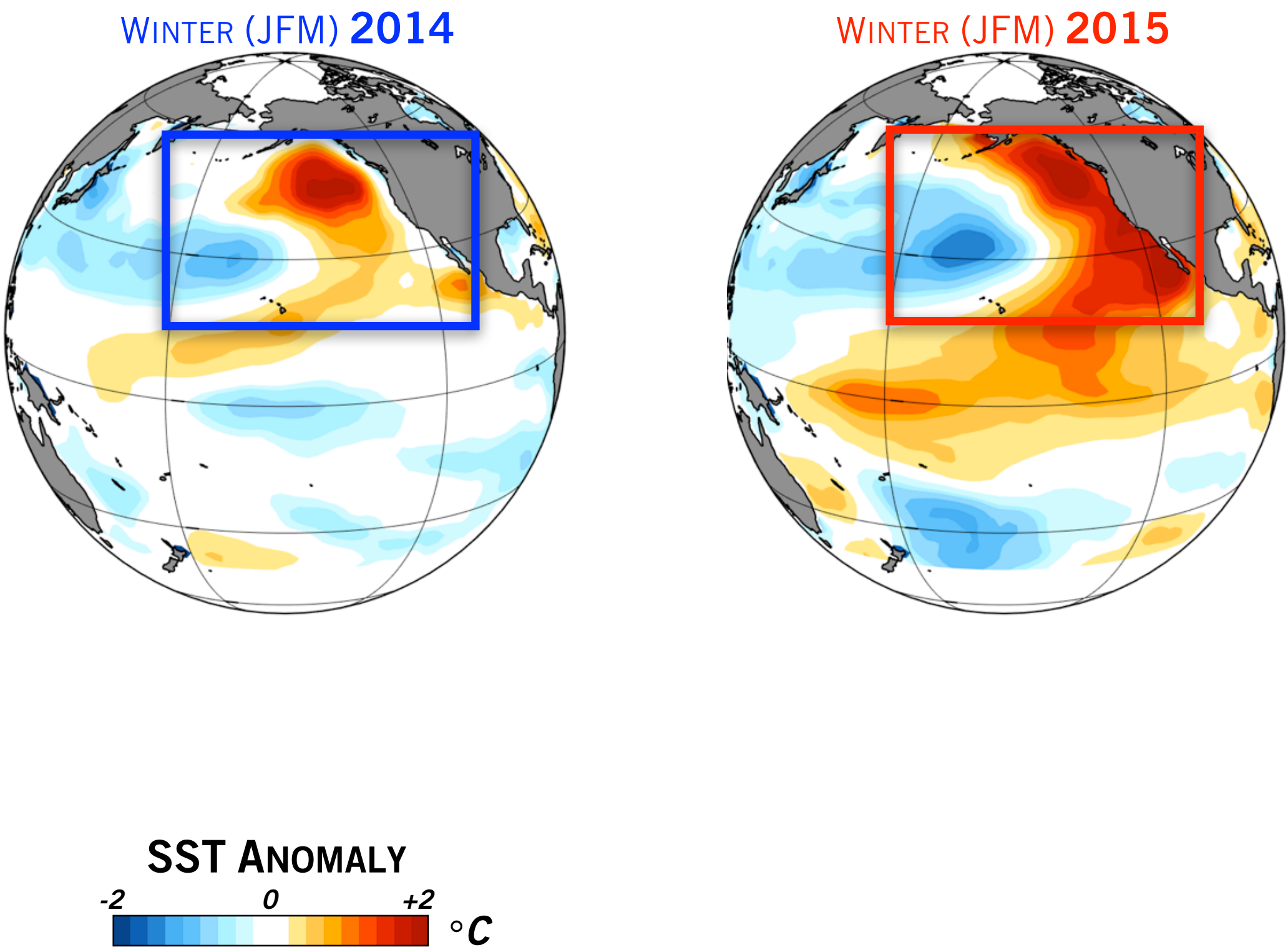
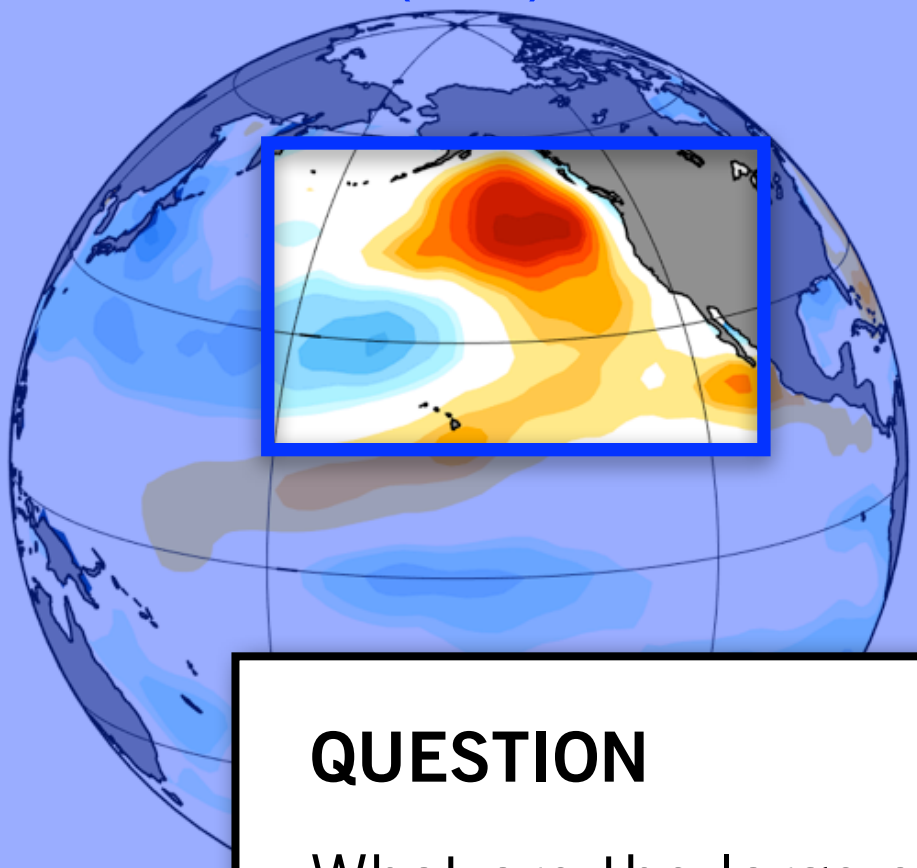


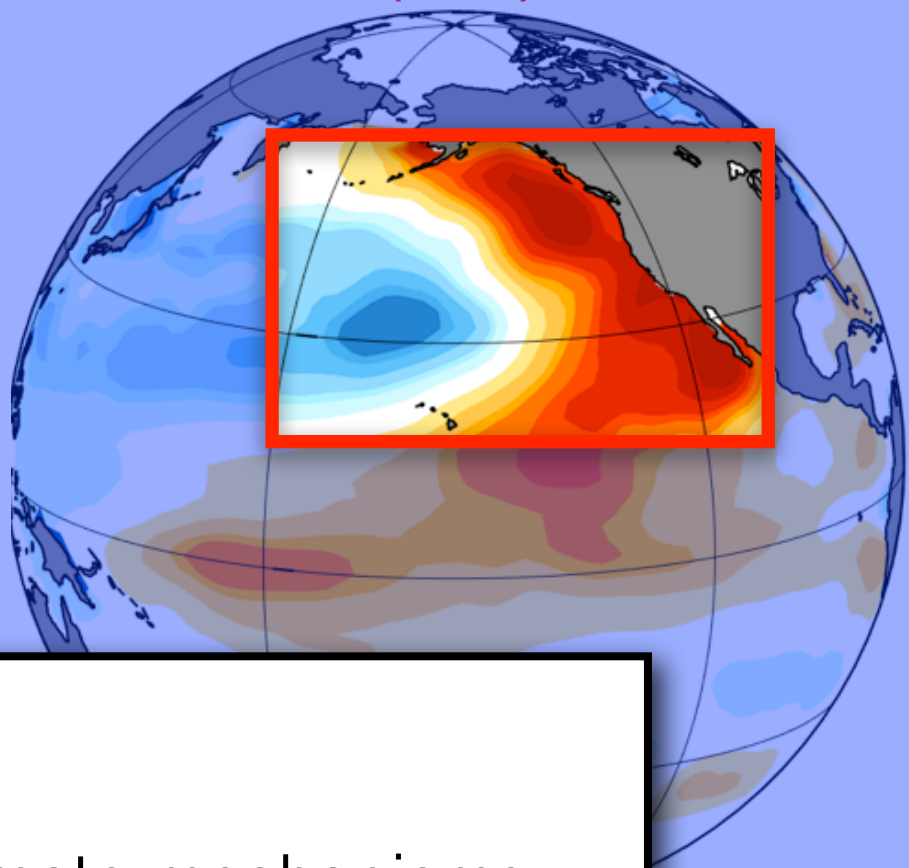
CLIMATE INTERPRETATION OF THE NORTH PACIFIC MARINE HEATWAVE OF 2013-2015

by **Emanuele Di Lorenzo**
Giovanni Liguori
& Nate Mantua

Georgia Institute of Technology


WINTER (JFM) 2014
WINTER (JFM) 2015
SST ANOMALY
-2
0
+2
°C



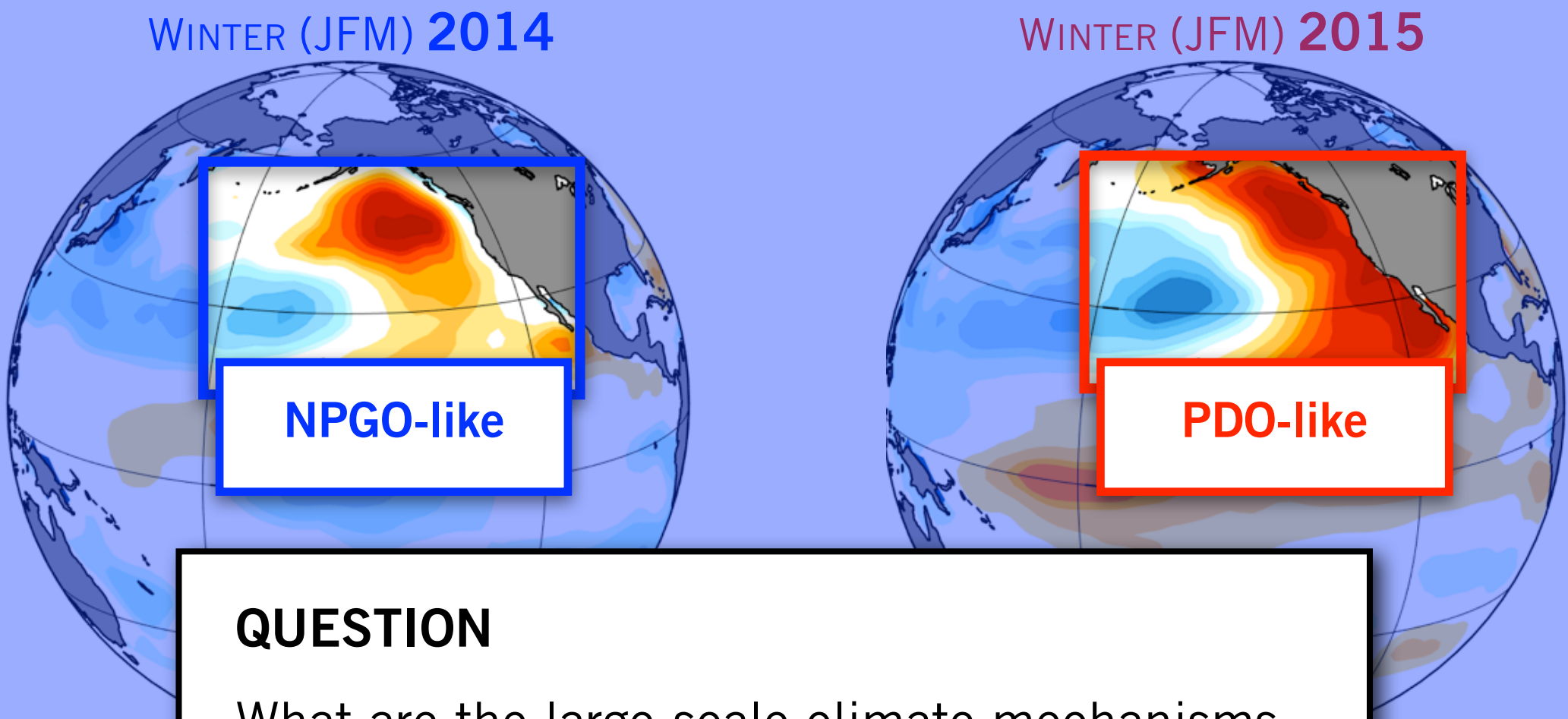


QUESTION

What are the large-scale climate mechanisms linking these two patterns?

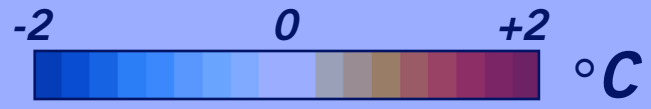
SST ANOMALY

-2 0 +2 °C

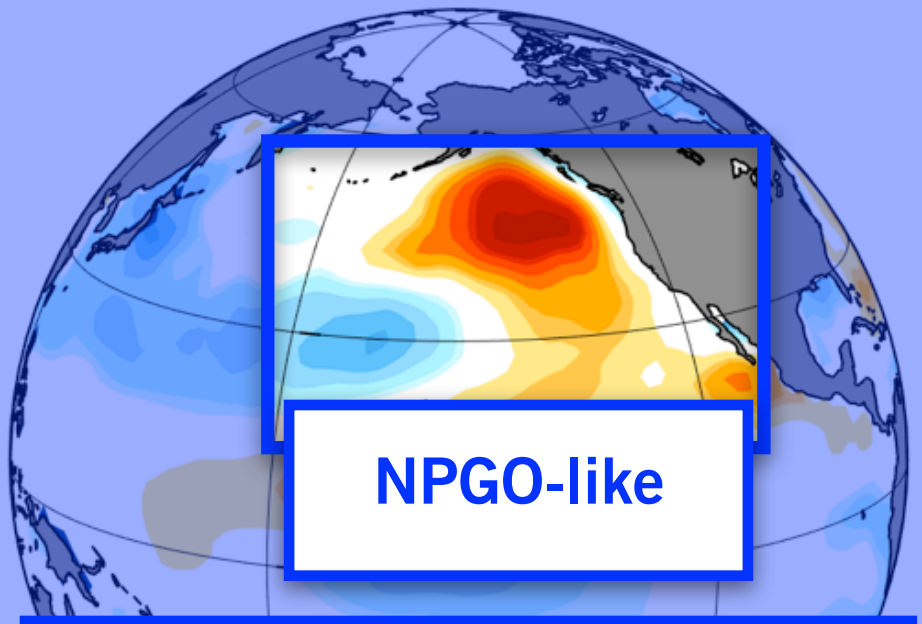


QUESTION

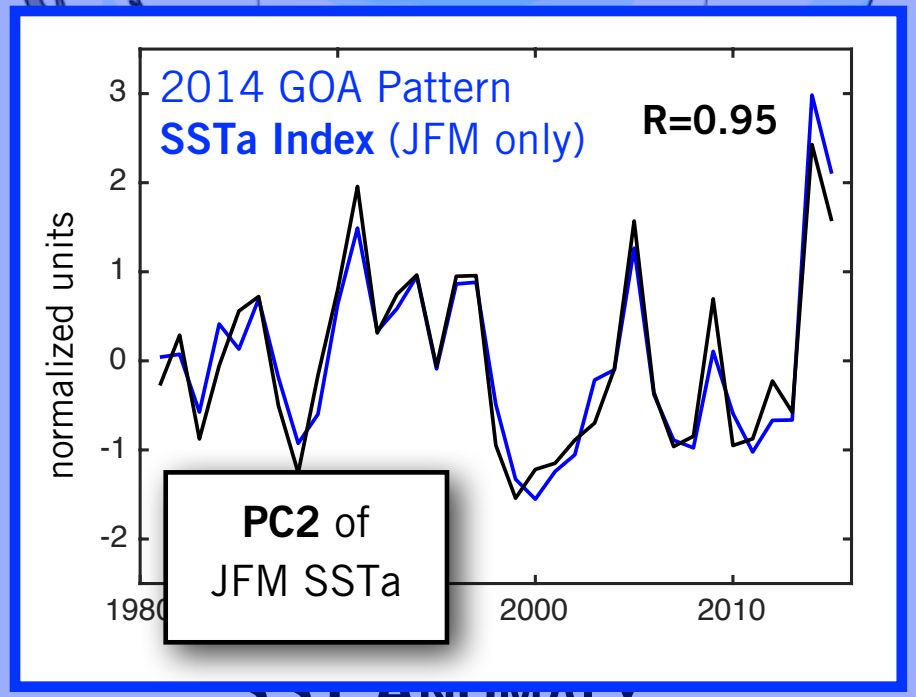
What are the large-scale climate mechanisms linking these two patterns?



WINTER (JFM) **2014**



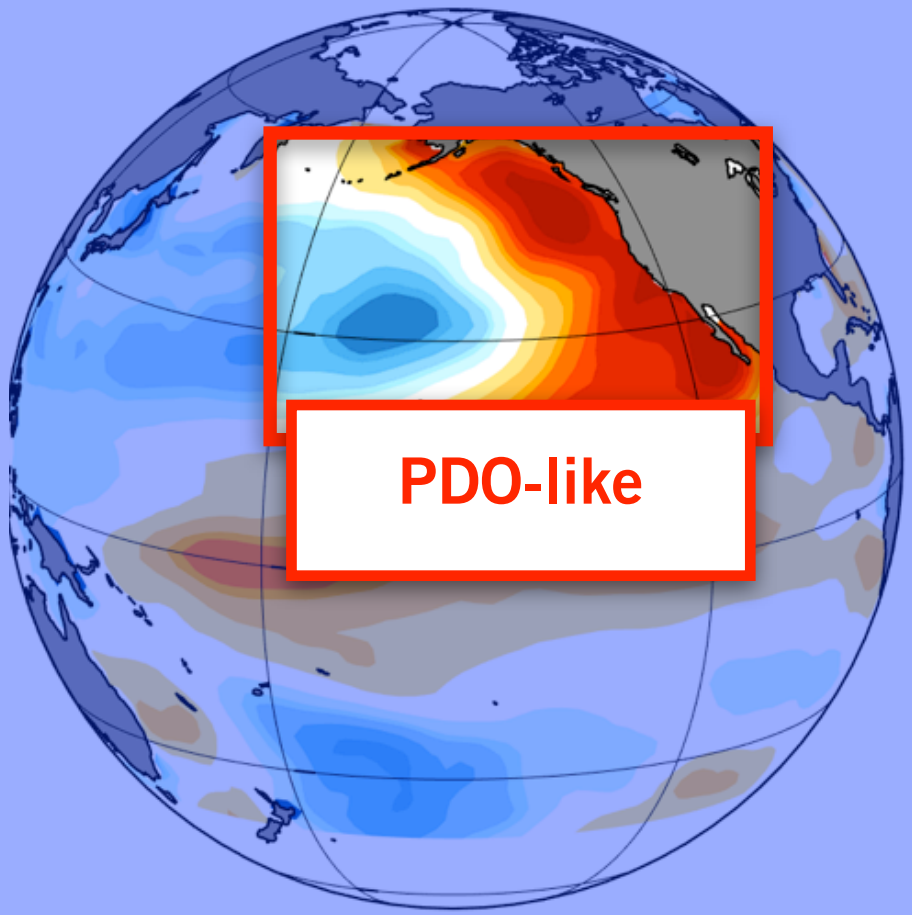
NPGO-like



SST ANOMALY

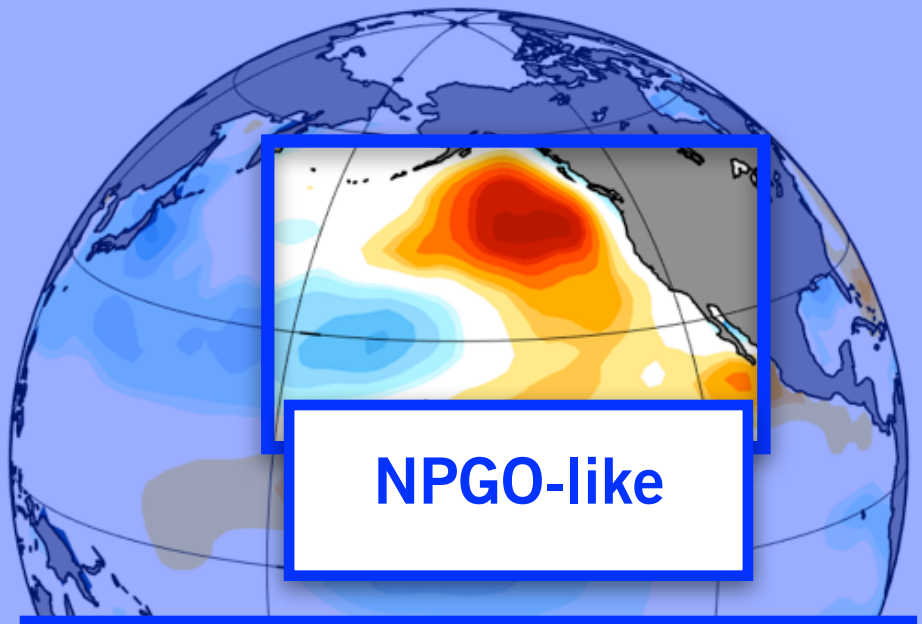
-2 0 +2 °C

WINTER (JFM) **2015**

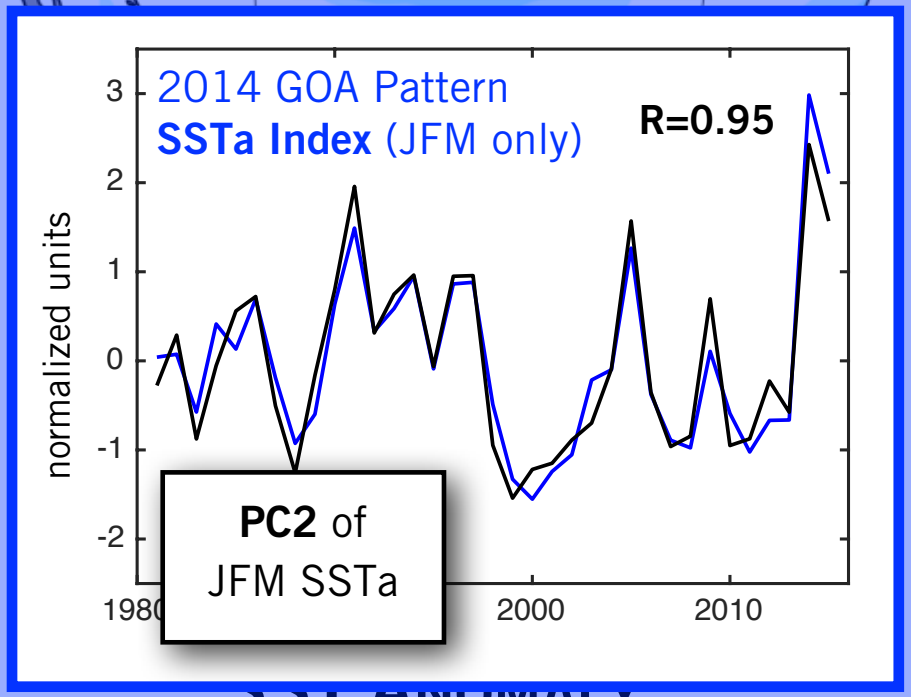


PDO-like

WINTER (JFM) **2014**



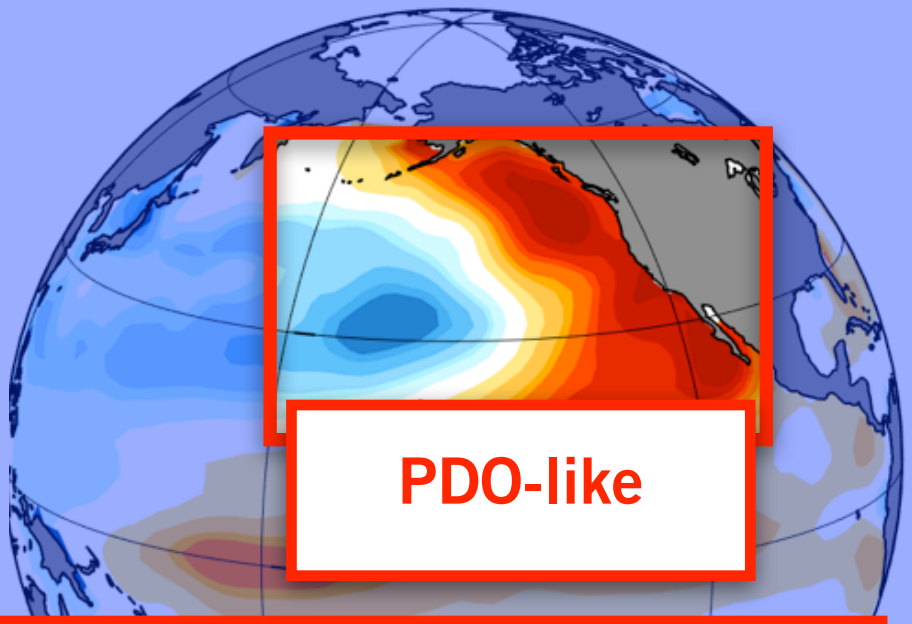
NPGO-like



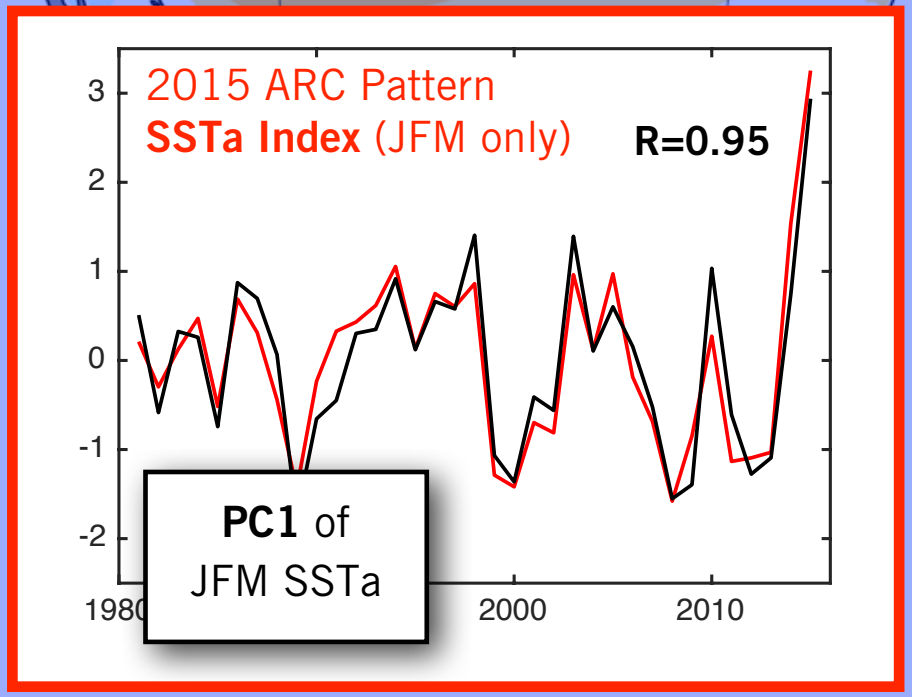
SST ANOMALY

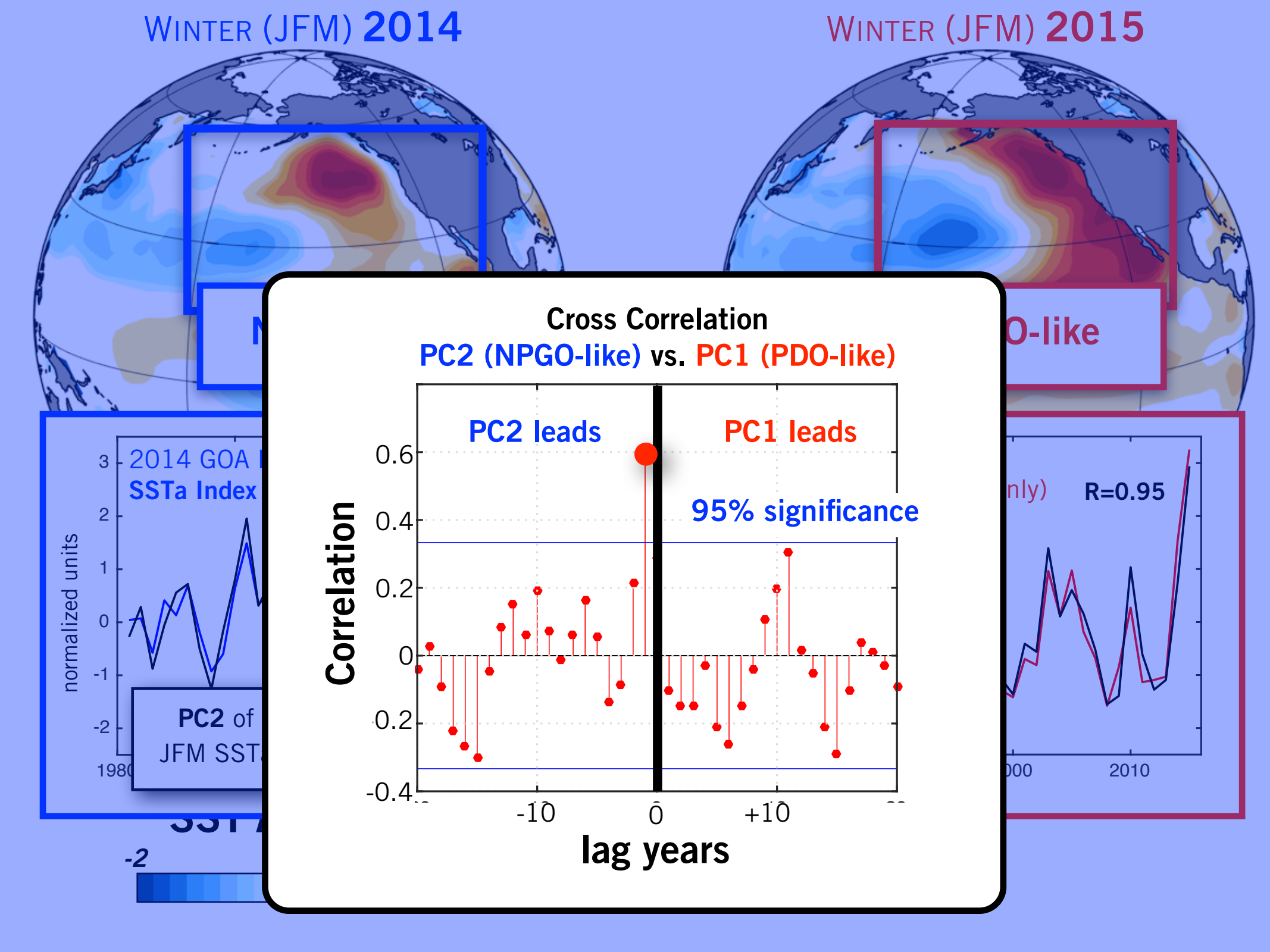
-2 0 +2 °C

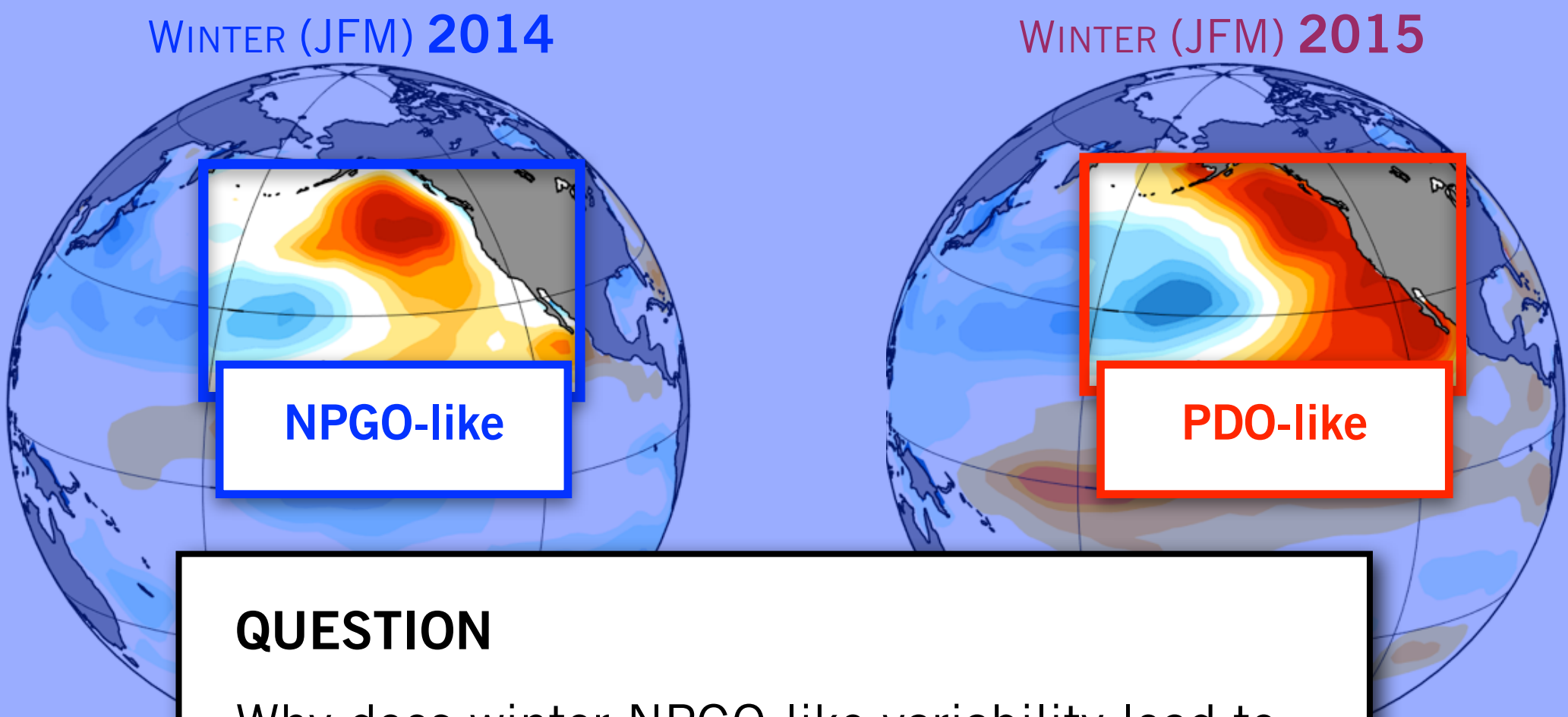
WINTER (JFM) **2015**



PDO-like

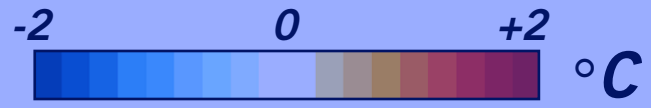



WINTER (JFM) 2014
WINTER (JFM) 2015
O-like
2014 GOA
SSTa Index
normalized units
PC2 of
JFM SST
nly)
R=0.95
000
2010
-2
Cross Correlation
PC2 (NPGO-like) vs. PC1 (PDO-like)
PC2 leads
PC1 leads
95% significance
Correlation
0.6
0.4
0.2
0
0.2
-0.4
-10
0
+10
lag years



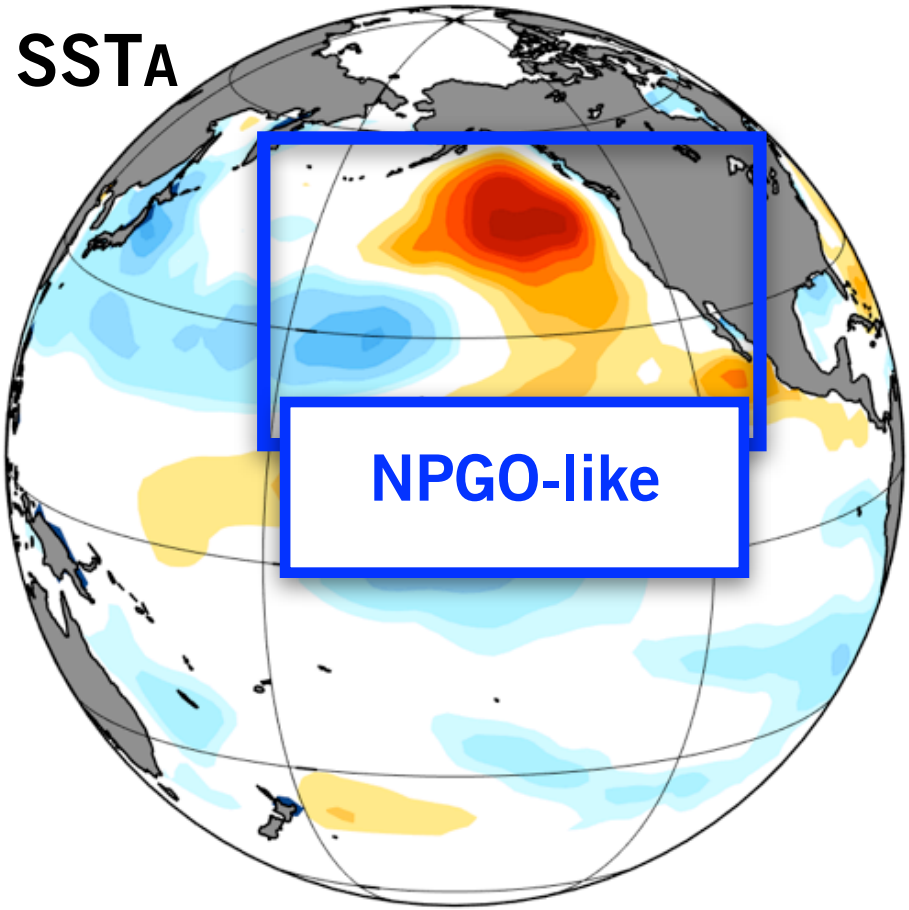
QUESTION

Why does winter NPGO-like variability lead to a PDO-like response the following winter?



Winter (JFM)

SSTA

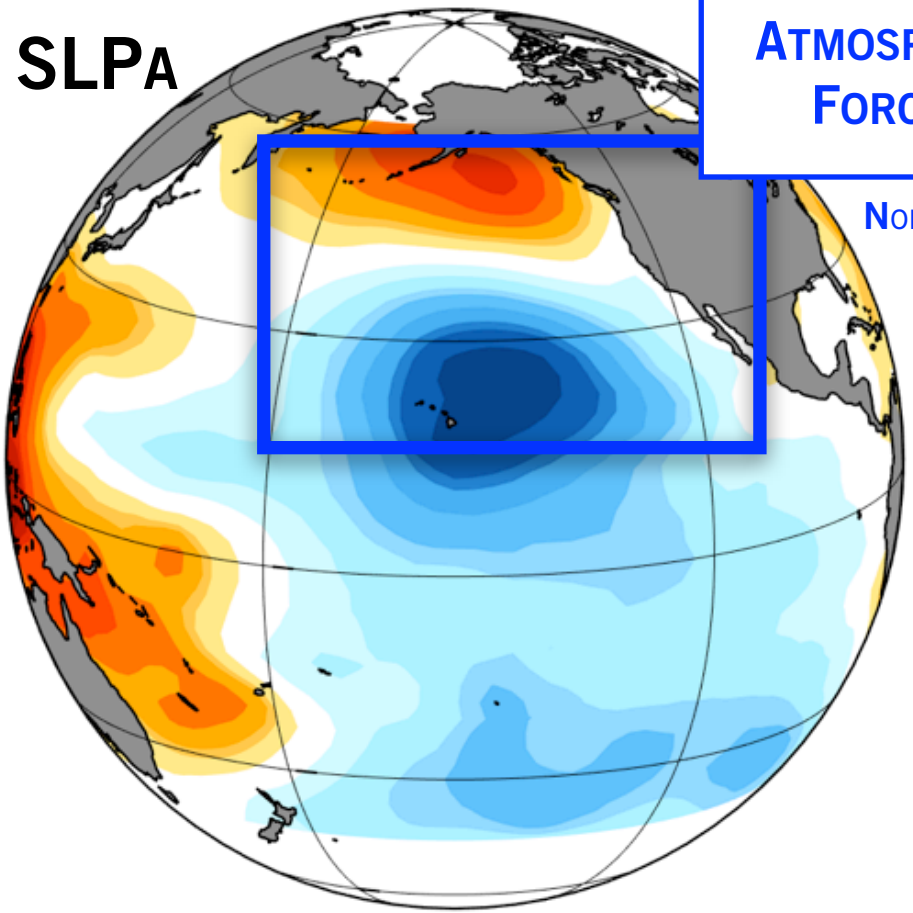


SST Anomaly

-0.5 0 +0.5 °C

WINTER (JFM)

SLPA



ATMOSPHERIC FORCING

North **P**acific **O**scillation

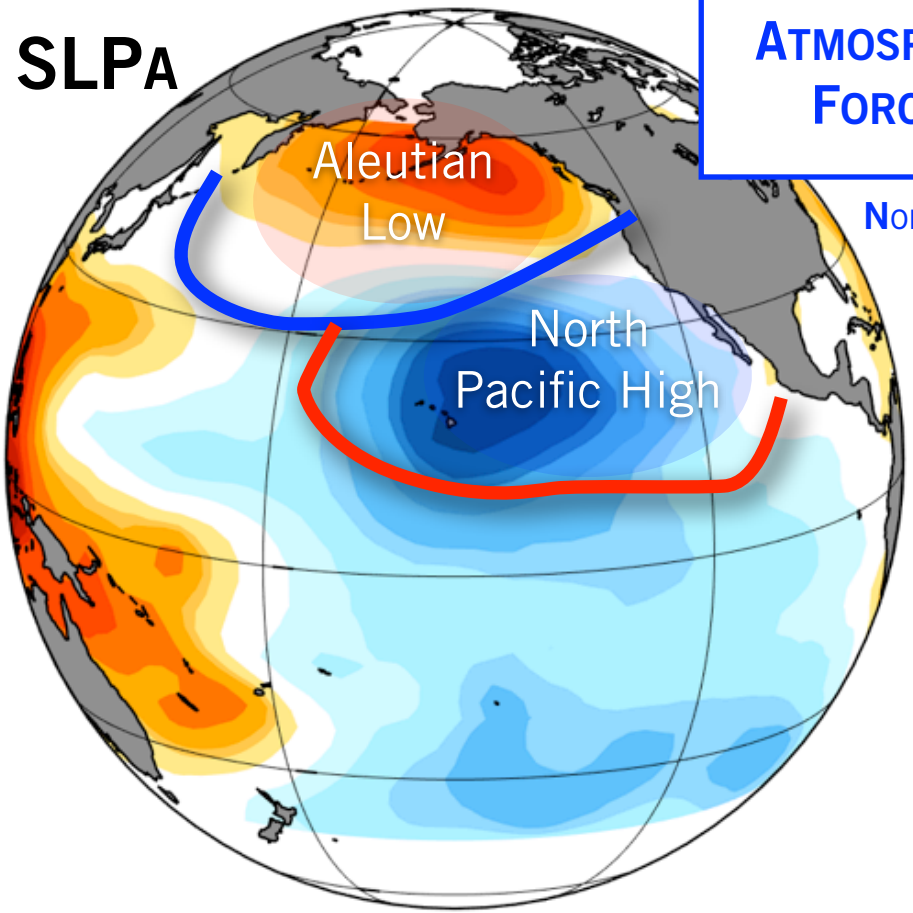
SLP ANOMALY

-2 0 +2

UNITS OF STD

WINTER (JFM)

SLPA



ATMOSPHERIC FORCING

North **P**acific **O**scillation

Change in Strength of mean atmospheric circulation

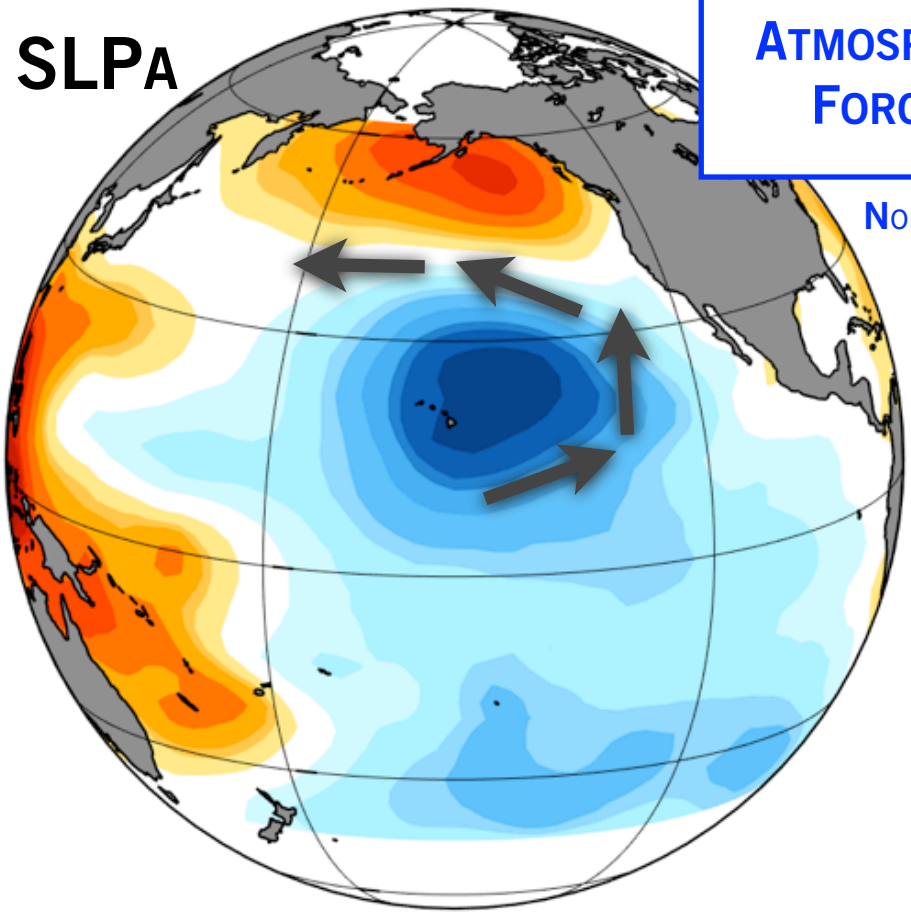
SLP ANOMALY

-2 0 +2

UNITS OF STD

WINTER (JFM)

SLPA



ATMOSPHERIC FORCING

North Pacific Oscillation

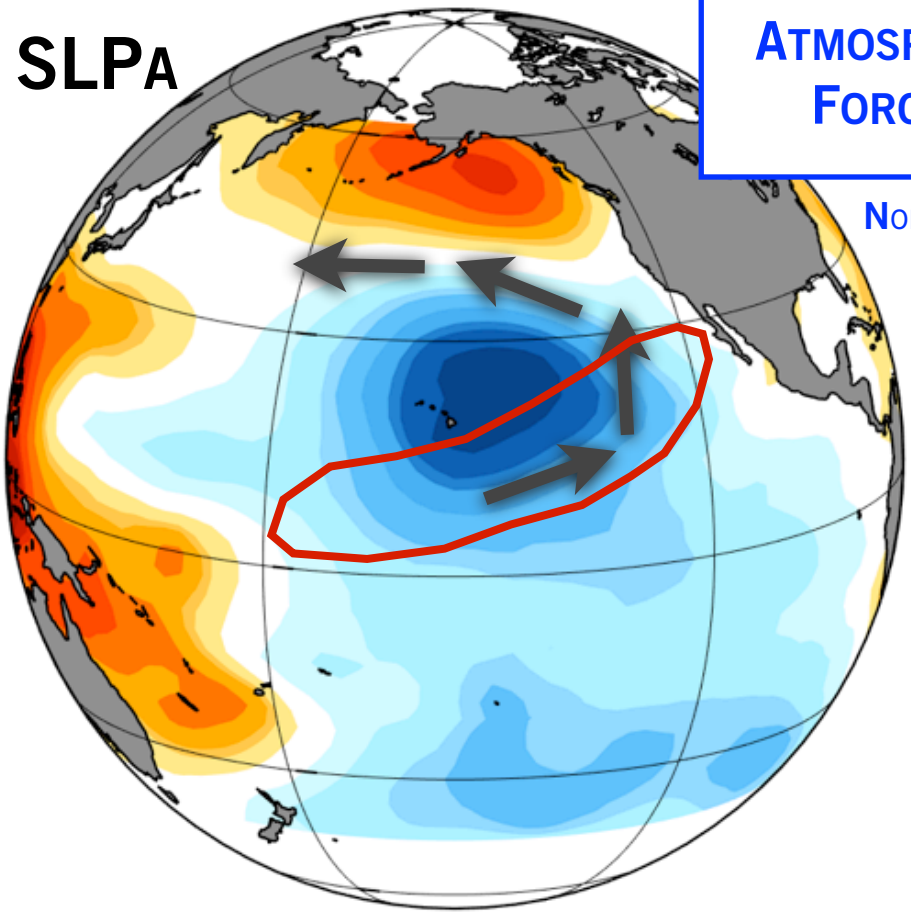
SLP ANOMALY

-2 0 +2

UNITS OF STD

WINTER (JFM)

SLPA



ATMOSPHERIC FORCING

North Pacific Oscillation

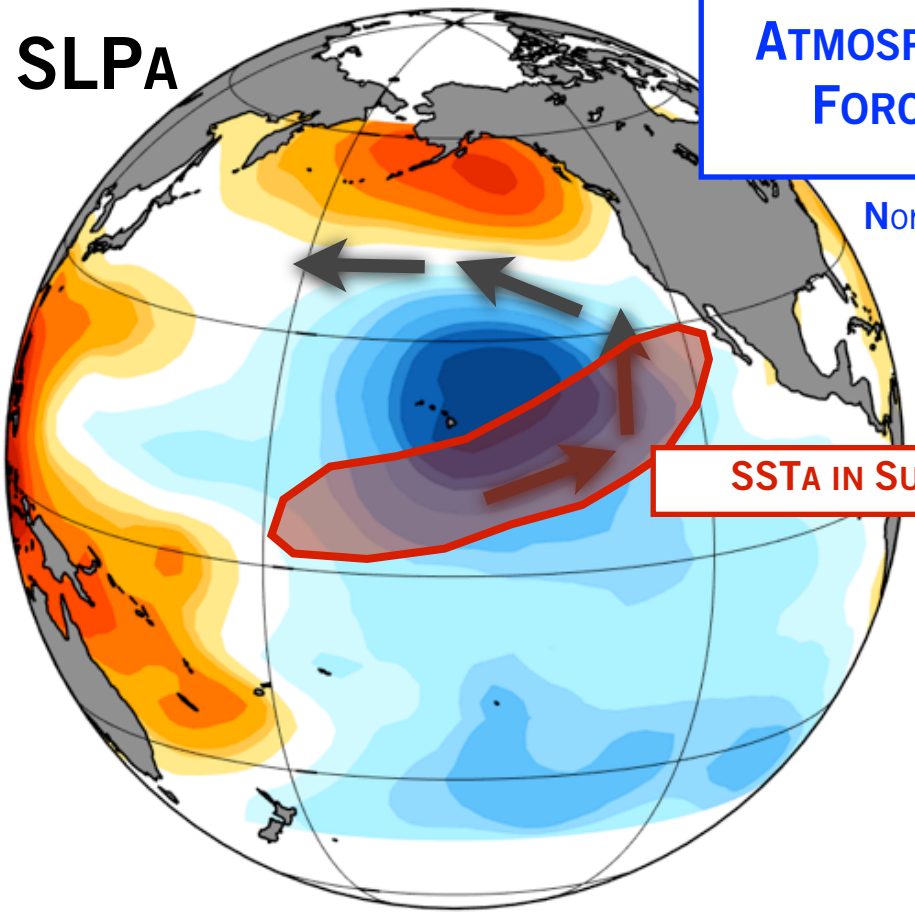
SLP ANOMALY

-2 0 +2

UNITS OF STD

WINTER (JFM)

SLPA



ATMOSPHERIC FORCING

North Pacific Oscillation

SSTA IN SUBTROPICS

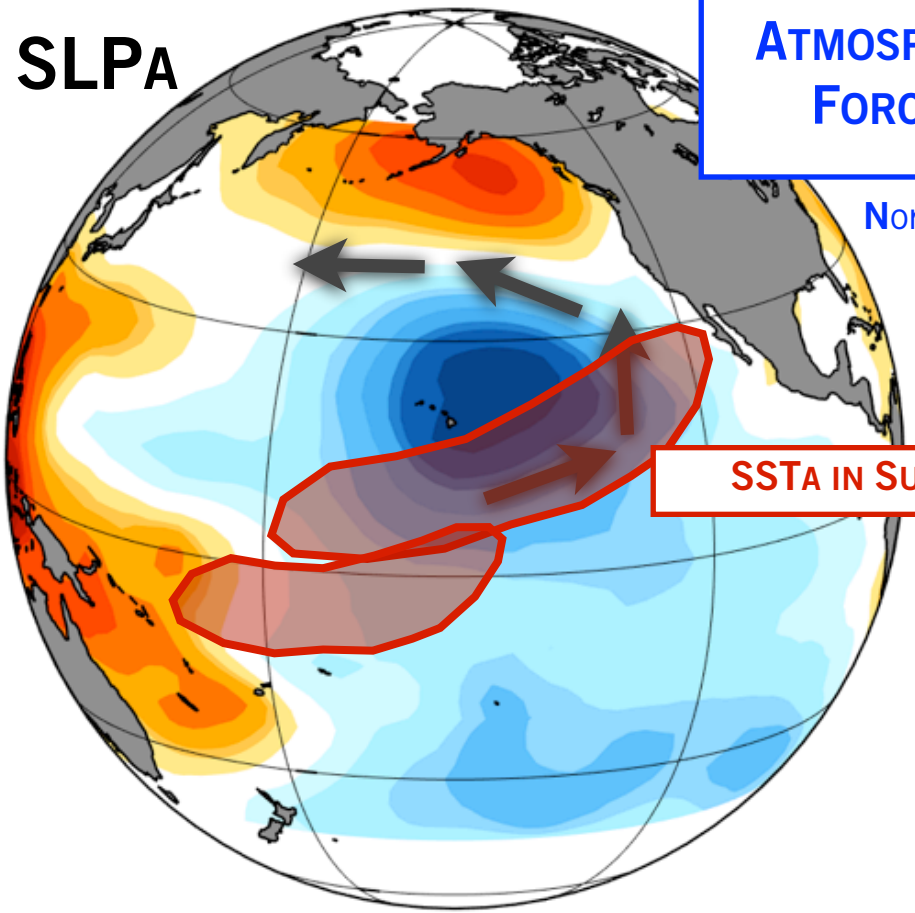
SLP ANOMALY

-2 0 +2

UNITS OF STD

WINTER (JFM)

SLPA



ATMOSPHERIC FORCING

North Pacific Oscillation

SSTA IN SUBTROPICS

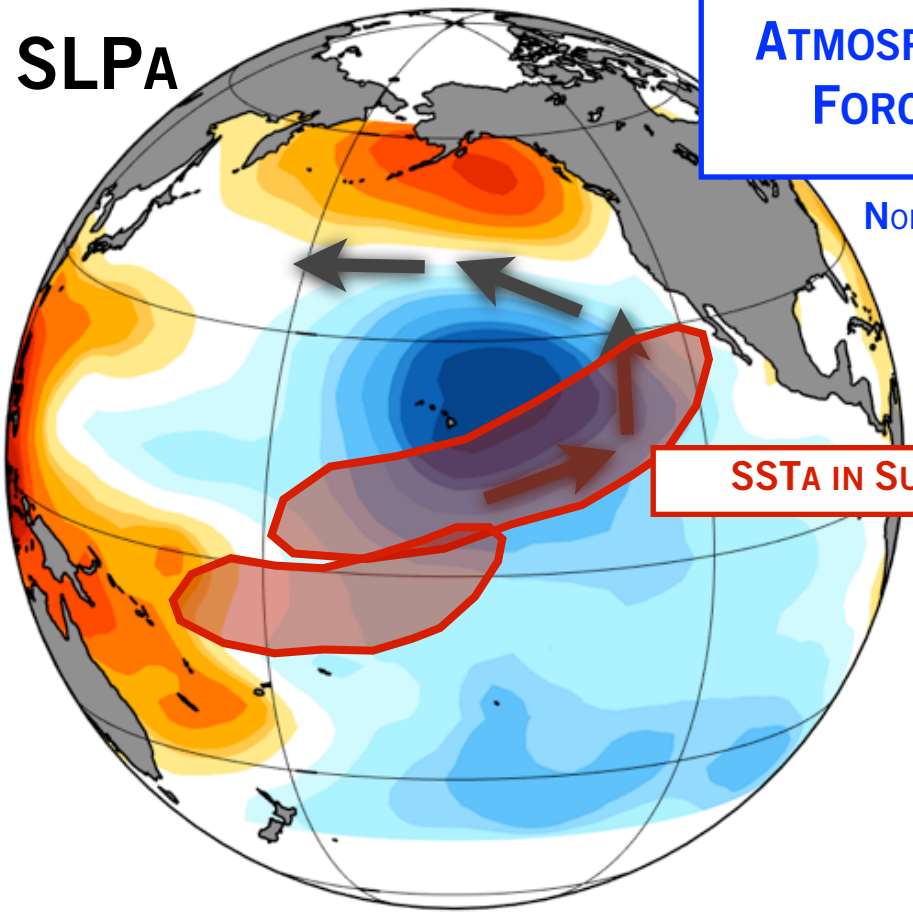
SLP ANOMALY

-2 0 +2

UNITS OF STD

WINTER (JFM)

SLPA



ATMOSPHERIC FORCING

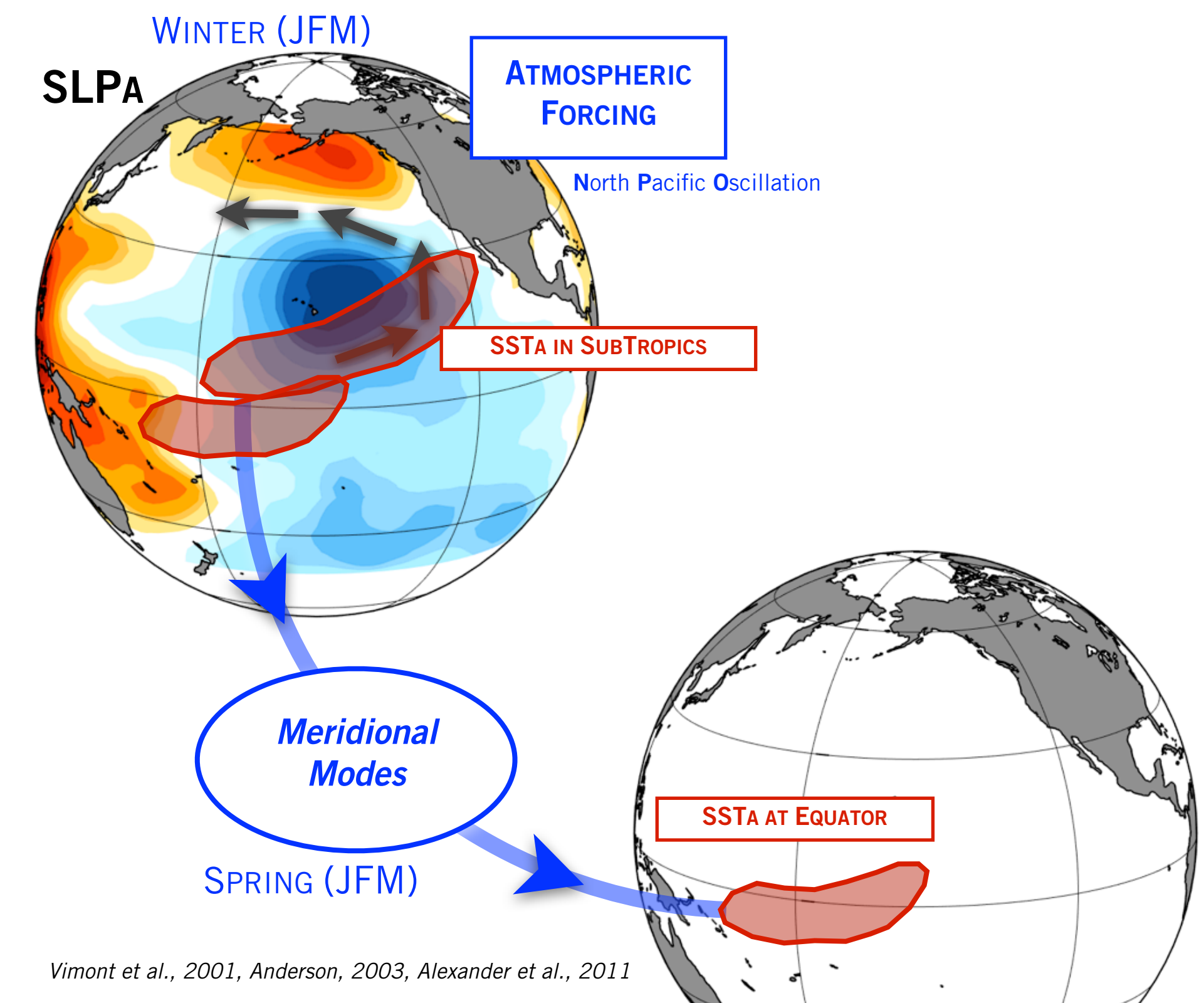
North Pacific Oscillation

SSTA IN SUBTROPICS

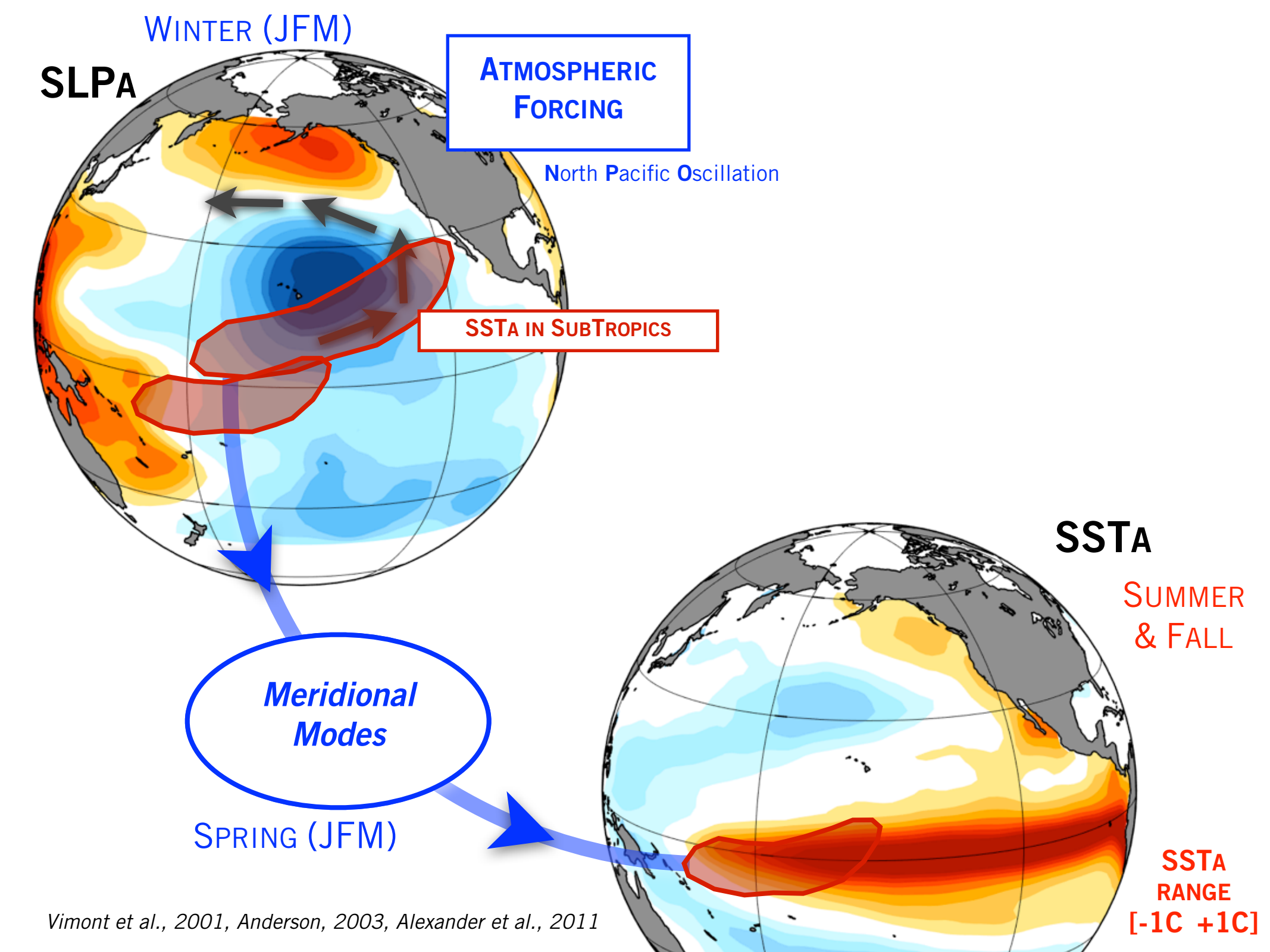
Meridional Modes

SPRING (JFM)

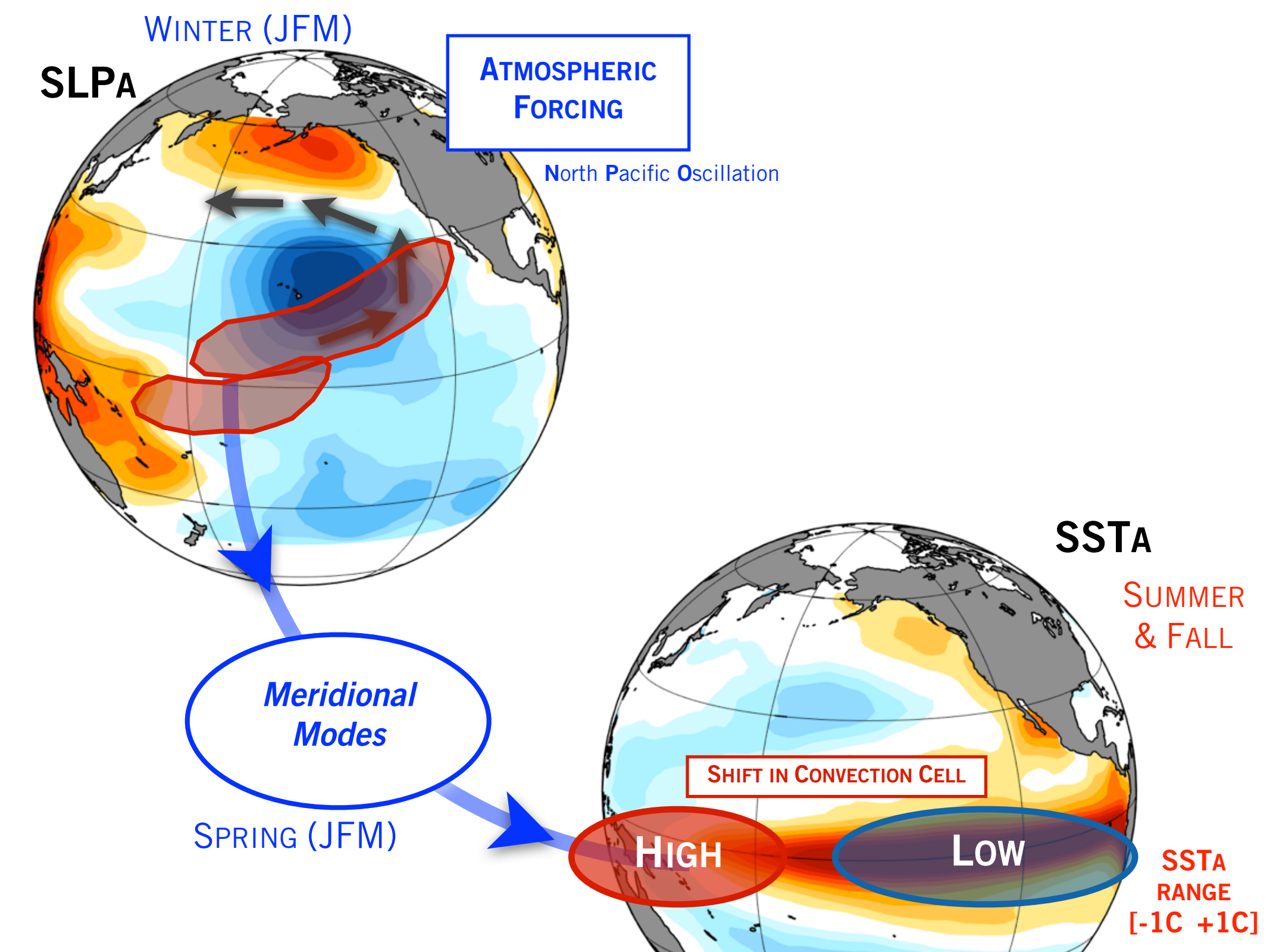
Vimont et al., 2001, Anderson, 2003, Alexander et al., 2011

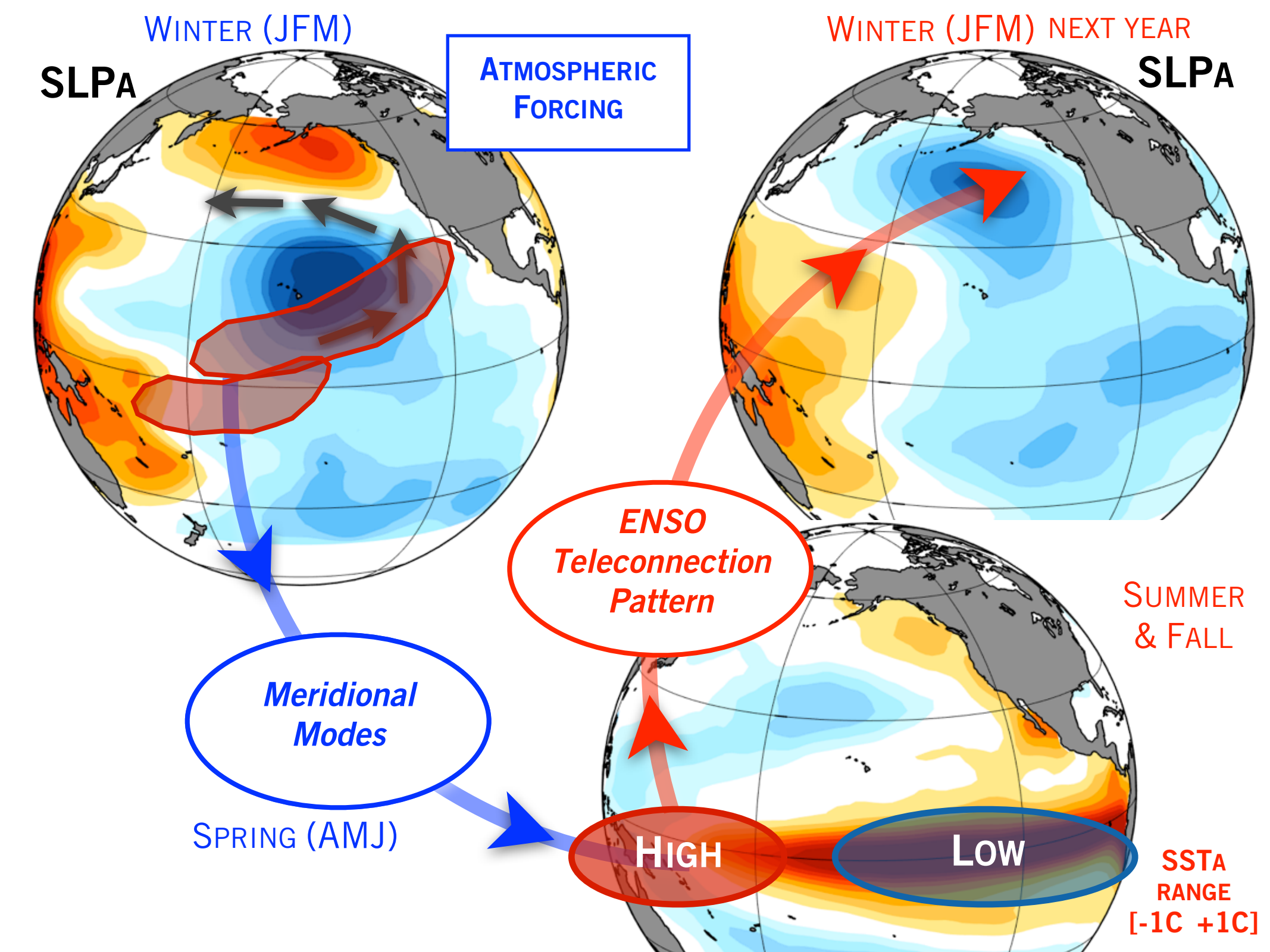


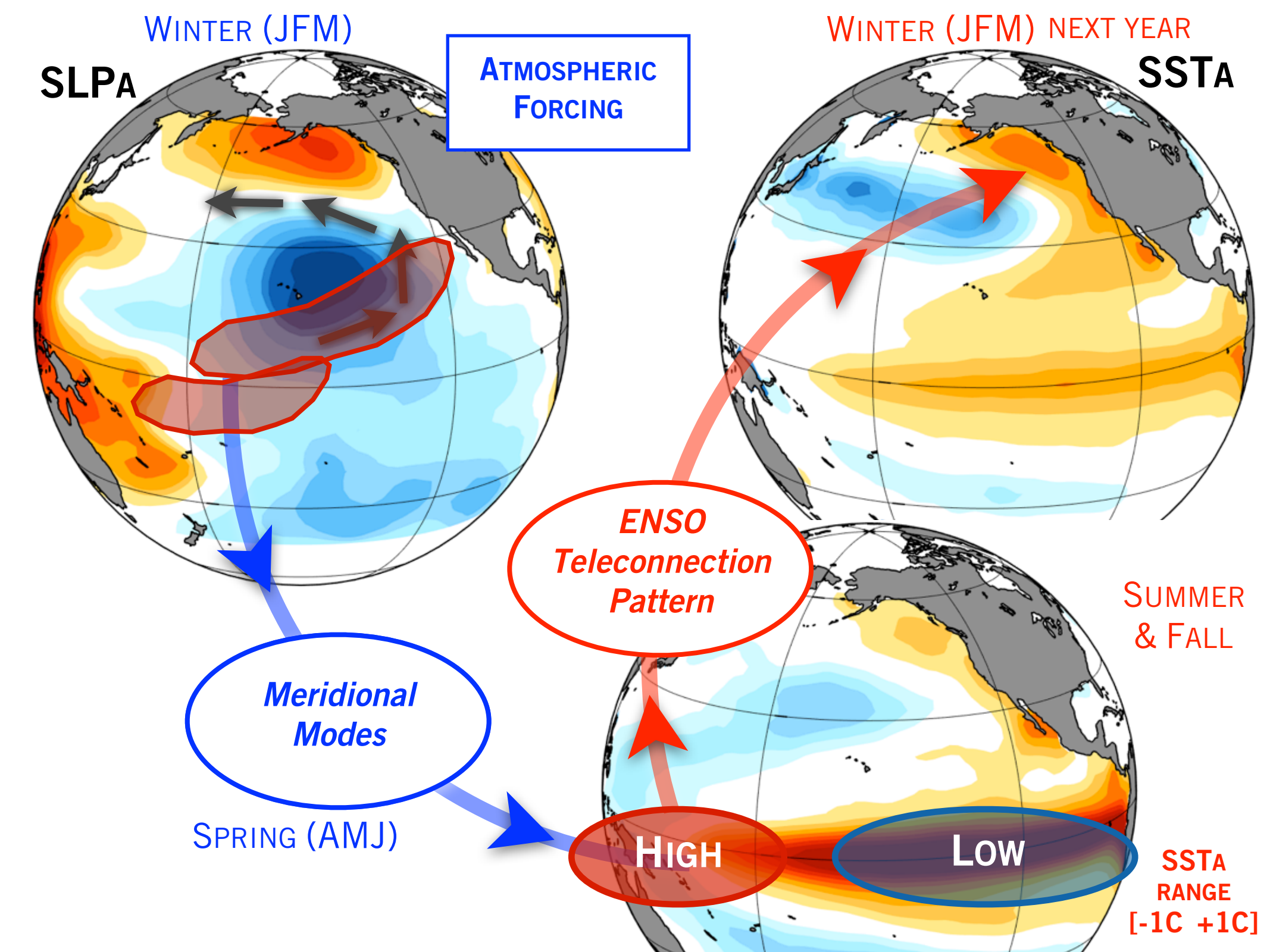
Vimont et al., 2001, Anderson, 2003, Alexander et al., 2011

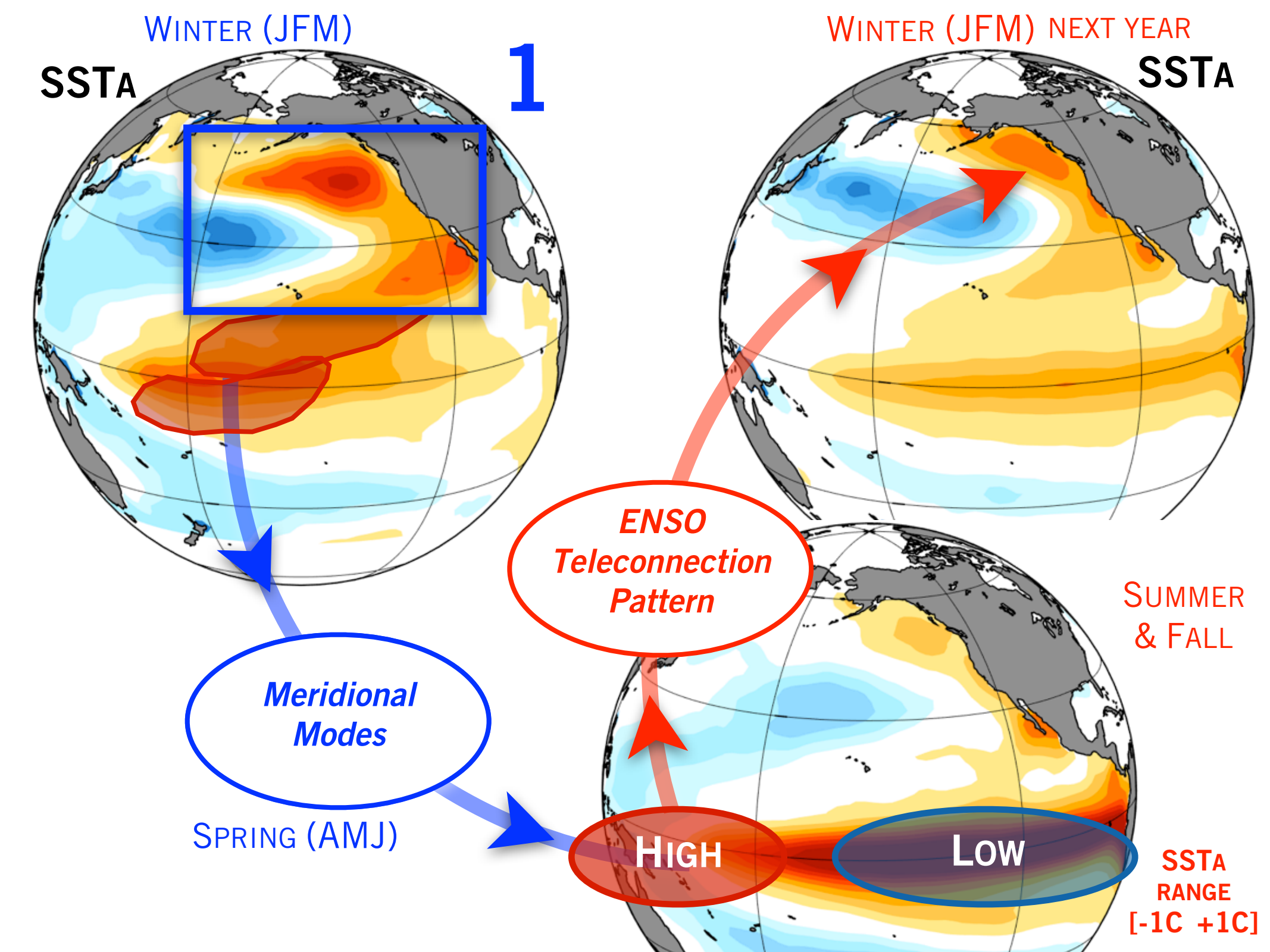


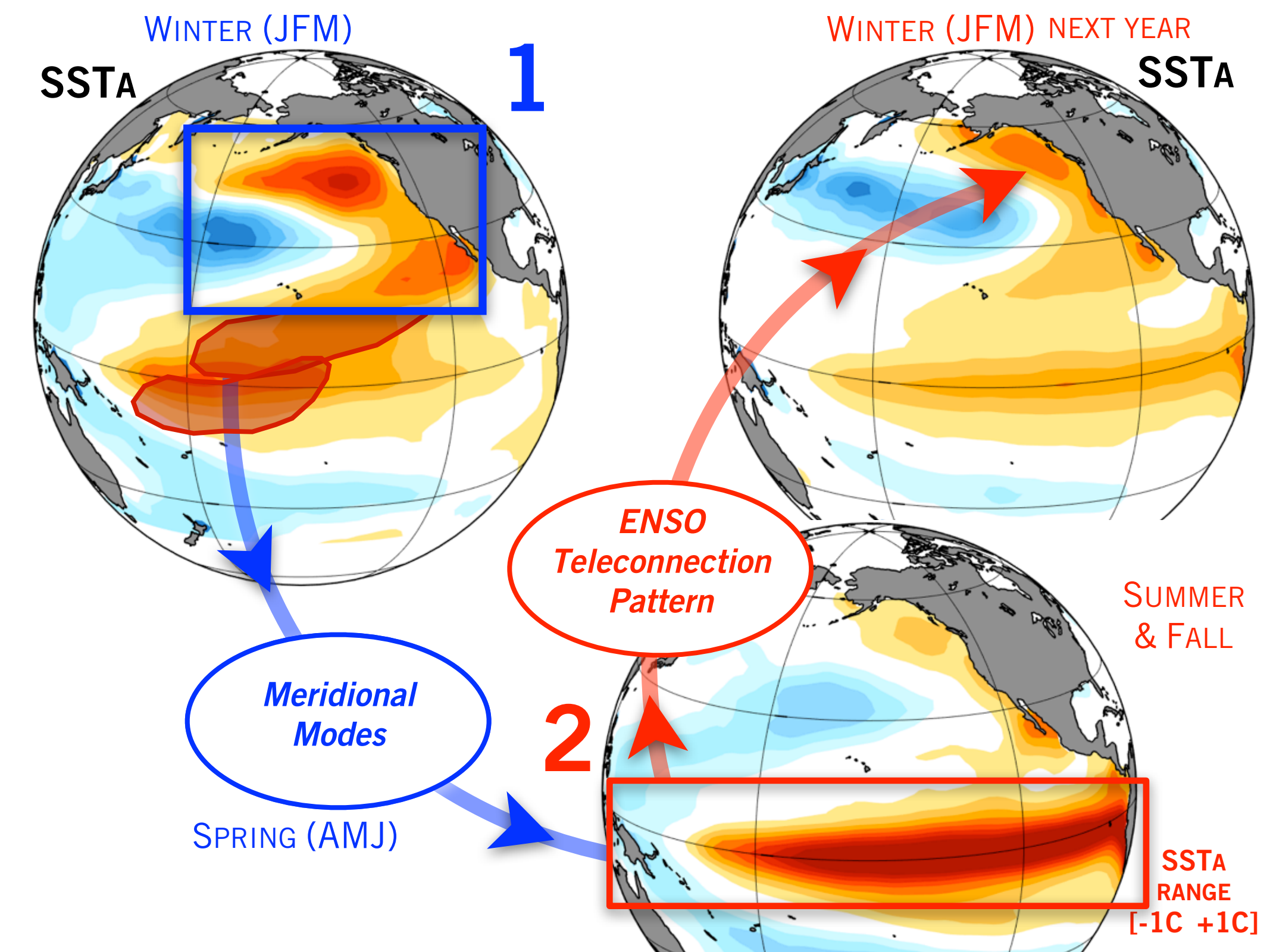
Vimont et al., 2001, Anderson, 2003, Alexander et al., 2011

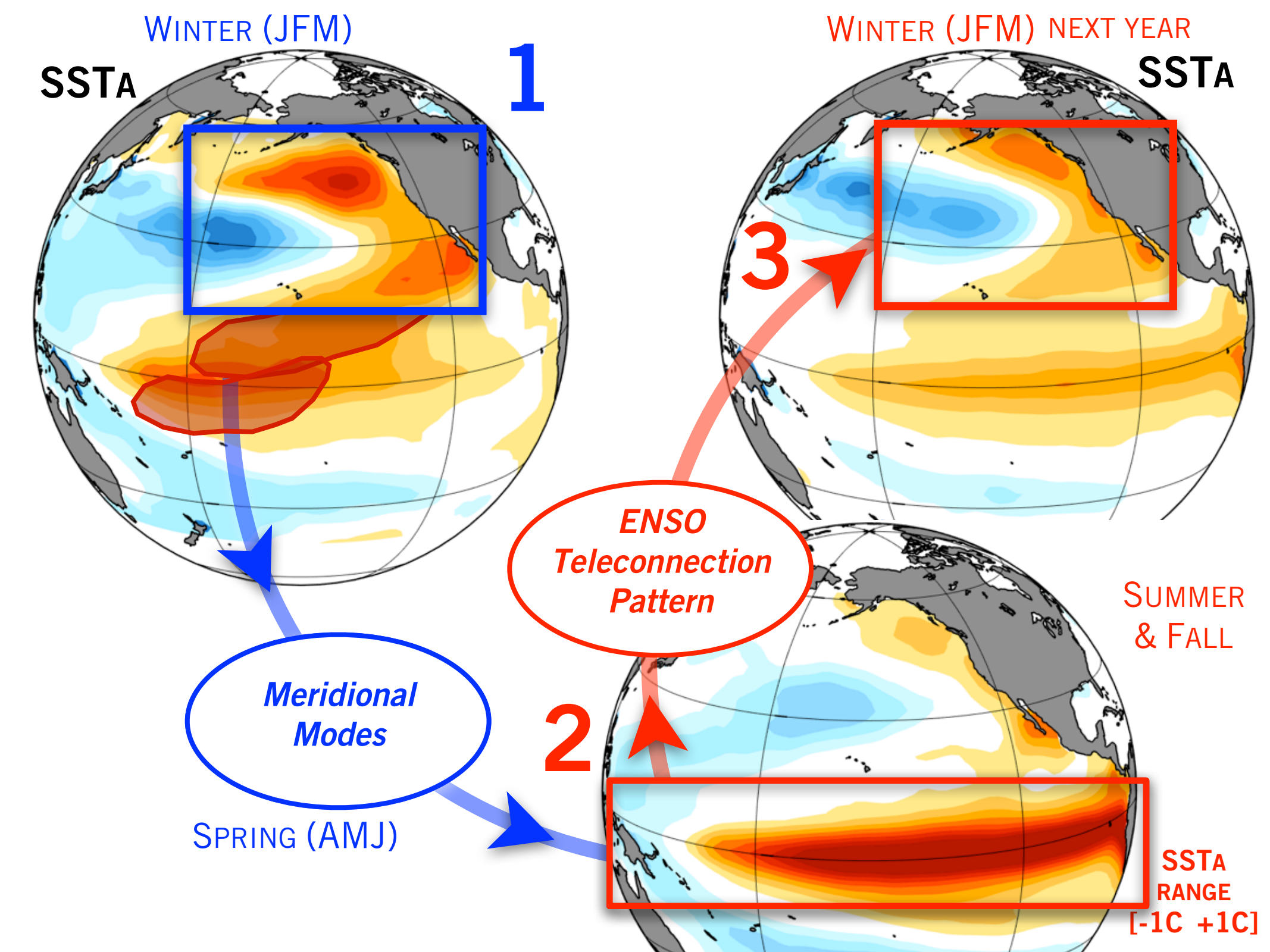

WINTER (JFM)
SLPA
ATMOSPHERIC FORCING
North Pacific Oscillation
SSTA
SUMMER & FALL
Meridional Modes
SPRING (JFM)
SHIFT IN CONVECTION CELL
HIGH
LOW
SSTA RANGE [-1C +1C]

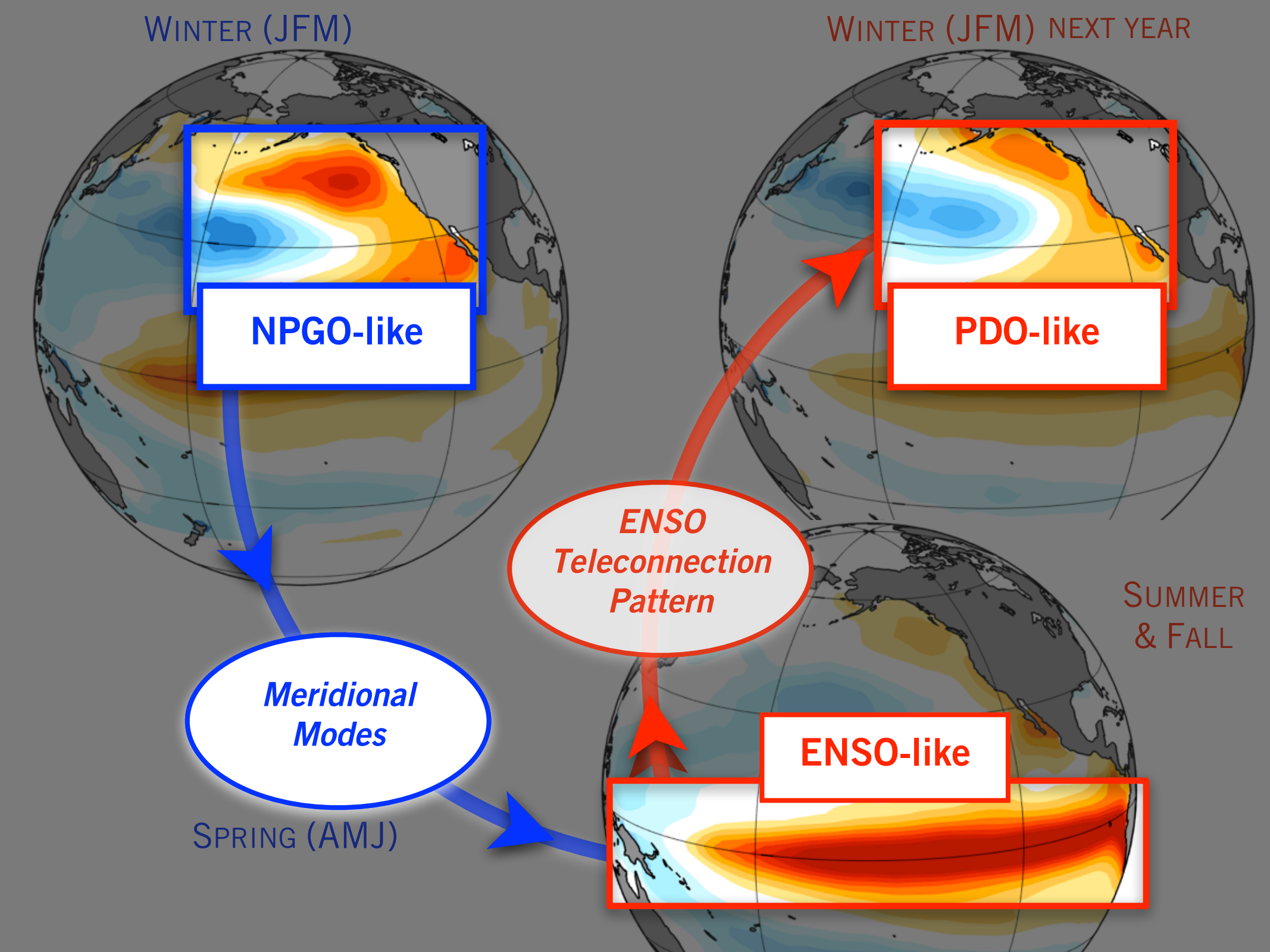

WINTER (JFM)
SLPA
ATMOSPHERIC FORCING
WINTER (JFM) NEXT YEAR
SLPA
ENSO Teleconnection Pattern
SUMMER & FALL
Meridional Modes
SPRING (AMJ)
HIGH
LOW
SSTA RANGE [-1C +1C]

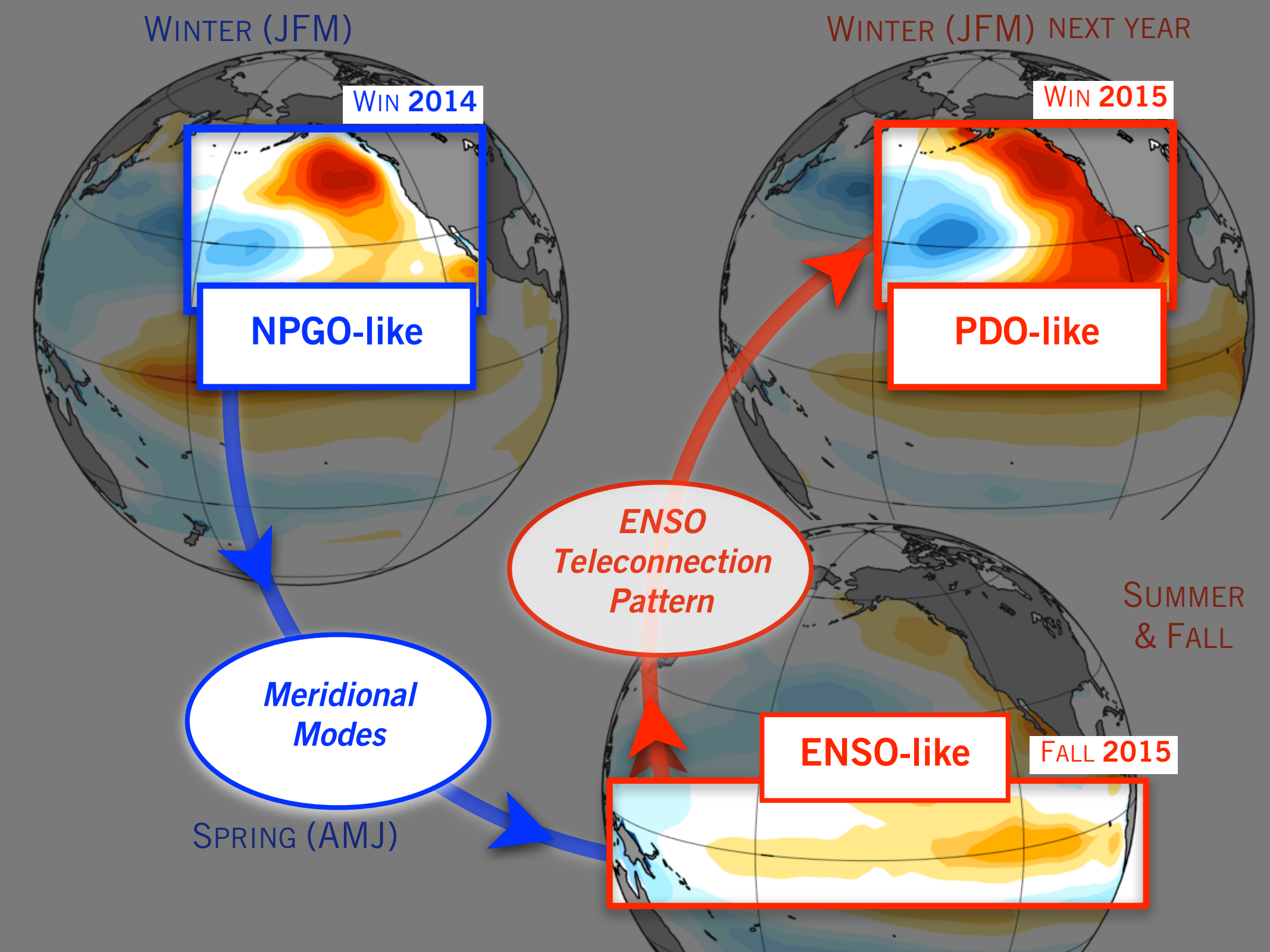

WINTER (JFM)
SLPA
ATMOSPHERIC FORCING
WINTER (JFM) NEXT YEAR
SSTA
ENSO Teleconnection Pattern
SUMMER & FALL
Meridional Modes
SPRING (AMJ)
HIGH
LOW
SSTA RANGE [-1C +1C]


WINTER (JFM)
SSTA
1
WINTER (JFM) NEXT YEAR
SSTA
ENSO
Teleconnection
Pattern
SUMMER
& FALL
Meridional
Modes
SPRING (AMJ)
HIGH
LOW
SSTA
RANGE
[-1C +1C]


WINTER (JFM)
SSTA
1
WINTER (JFM) NEXT YEAR
SSTA
ENSO
Teleconnection
Pattern
SUMMER
& FALL
Meridional
Modes
2
SPRING (AMJ)
SSTA
RANGE
[-1C +1C]


WINTER (JFM)
SSTA
1
WINTER (JFM) NEXT YEAR
SSTA
3
ENSO
Teleconnection
Pattern
SUMMER
& FALL
Meridional
Modes
2
SPRING (AMJ)
SSTA
RANGE
[-1C +1C]


WINTER (JFM)
NPGO-like
WINTER (JFM) NEXT YEAR
PDO-like
ENSO Teleconnection Pattern
SUMMER & FALL
ENSO-like
Meridional Modes
SPRING (AMJ)


WINTER (JFM)
WIN 2014
NPGO-like
WINTER (JFM) NEXT YEAR
WIN 2015
PDO-like
ENSO Teleconnection Pattern
SUMMER & FALL
Meridional Modes
SPRING (AMJ)
ENSO-like
FALL 2015

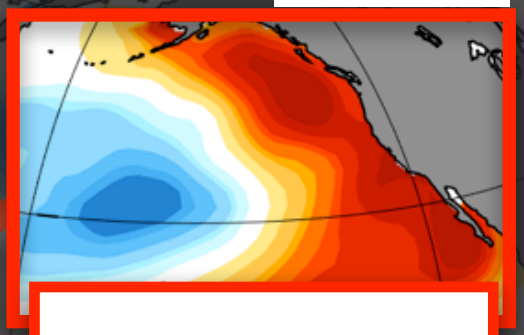
WINTER (JFM)

WINTER (JFM) NEXT YEAR

QUESTION

Was the **ENSO teleconnection** important in persisting and intensifying the **2015 SSTa**?

WIN 2015



PDO-like

ENSO Teleconnection Pattern

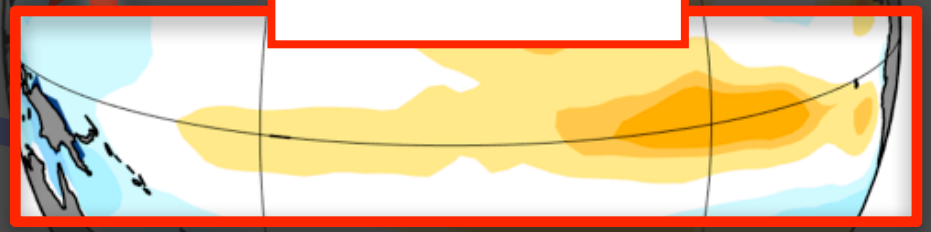
SUMMER & FALL

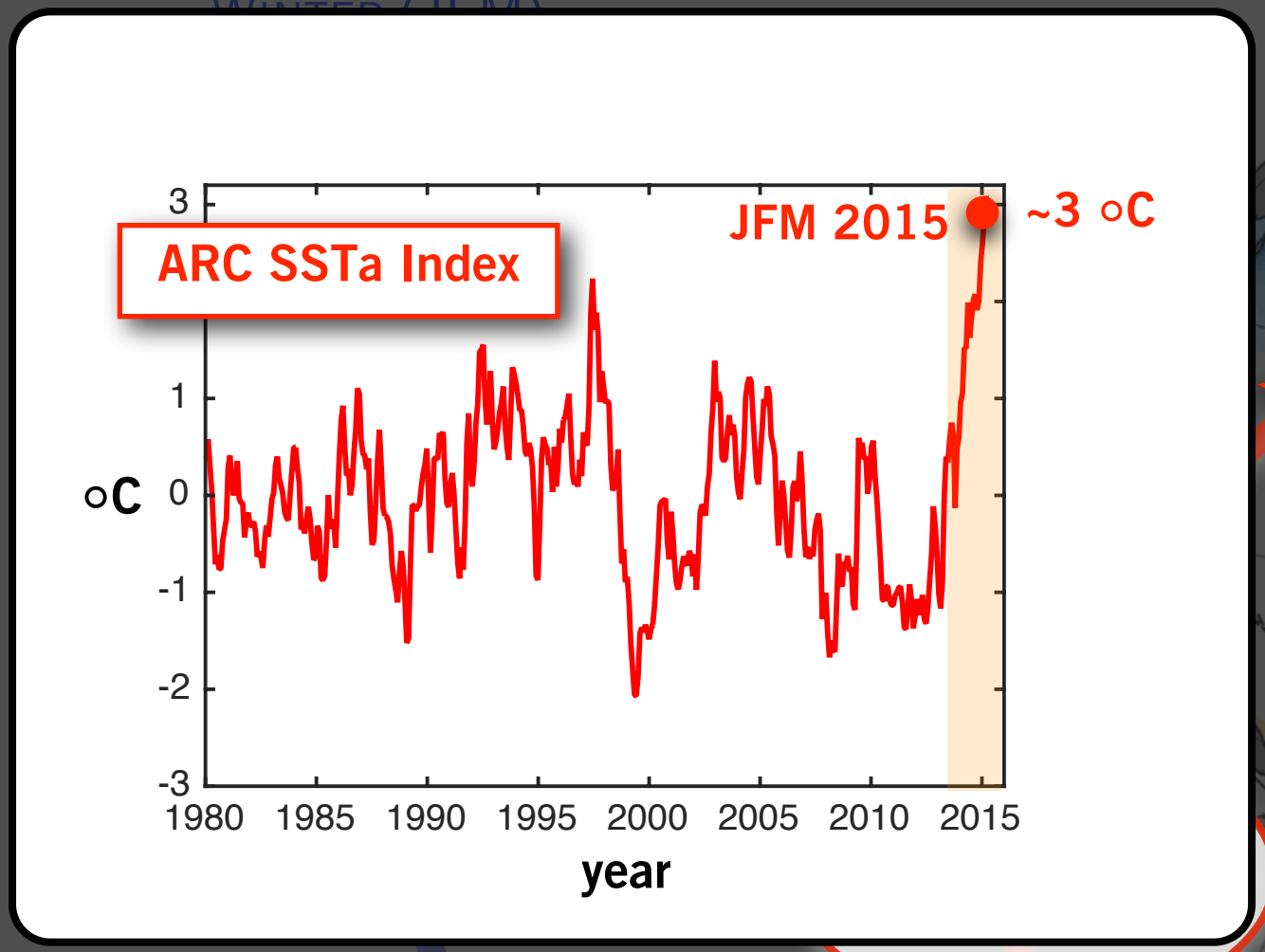
Meridional Modes

SPRING (AMJ)

ENSO-like

FALL 2015





WINTER (JFM) NEXT YEAR

WIN 2015

PDO-like

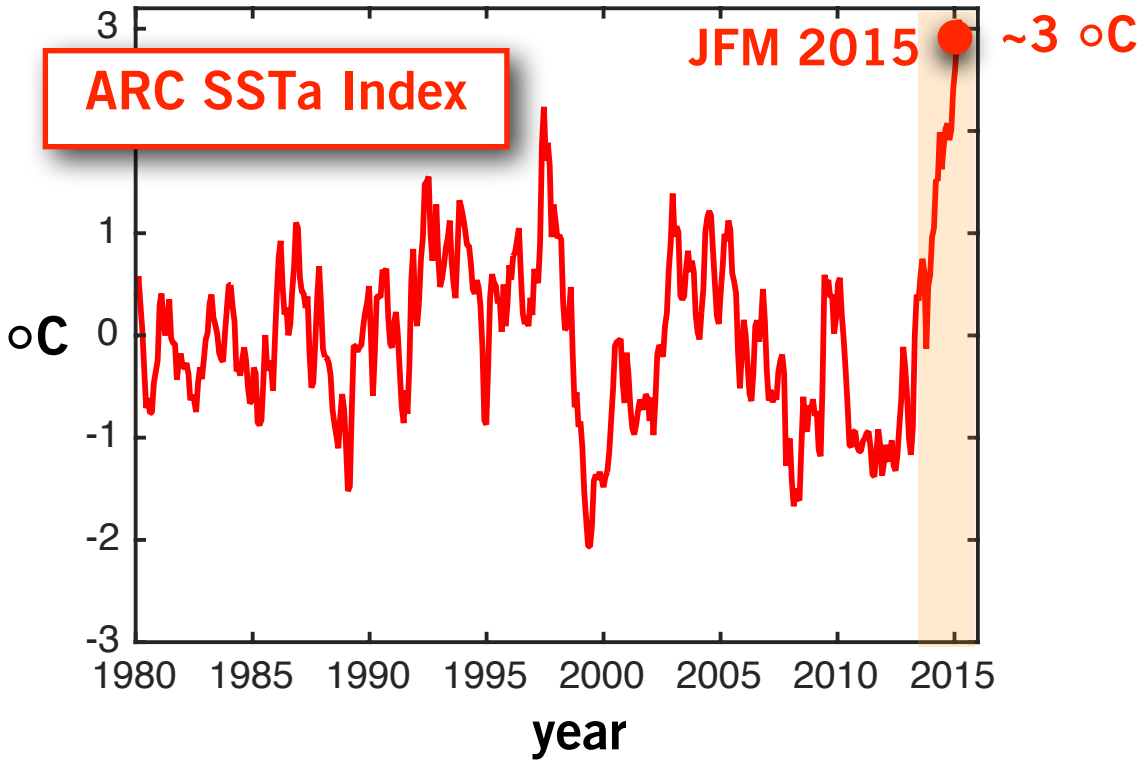
SUMMER & FALL

ENSO-like

FALL 2015

Meridional Modes

SPRING (AMJ)



WINTER (JFM) NEXT YEAR

WIN 2015

PDO-like

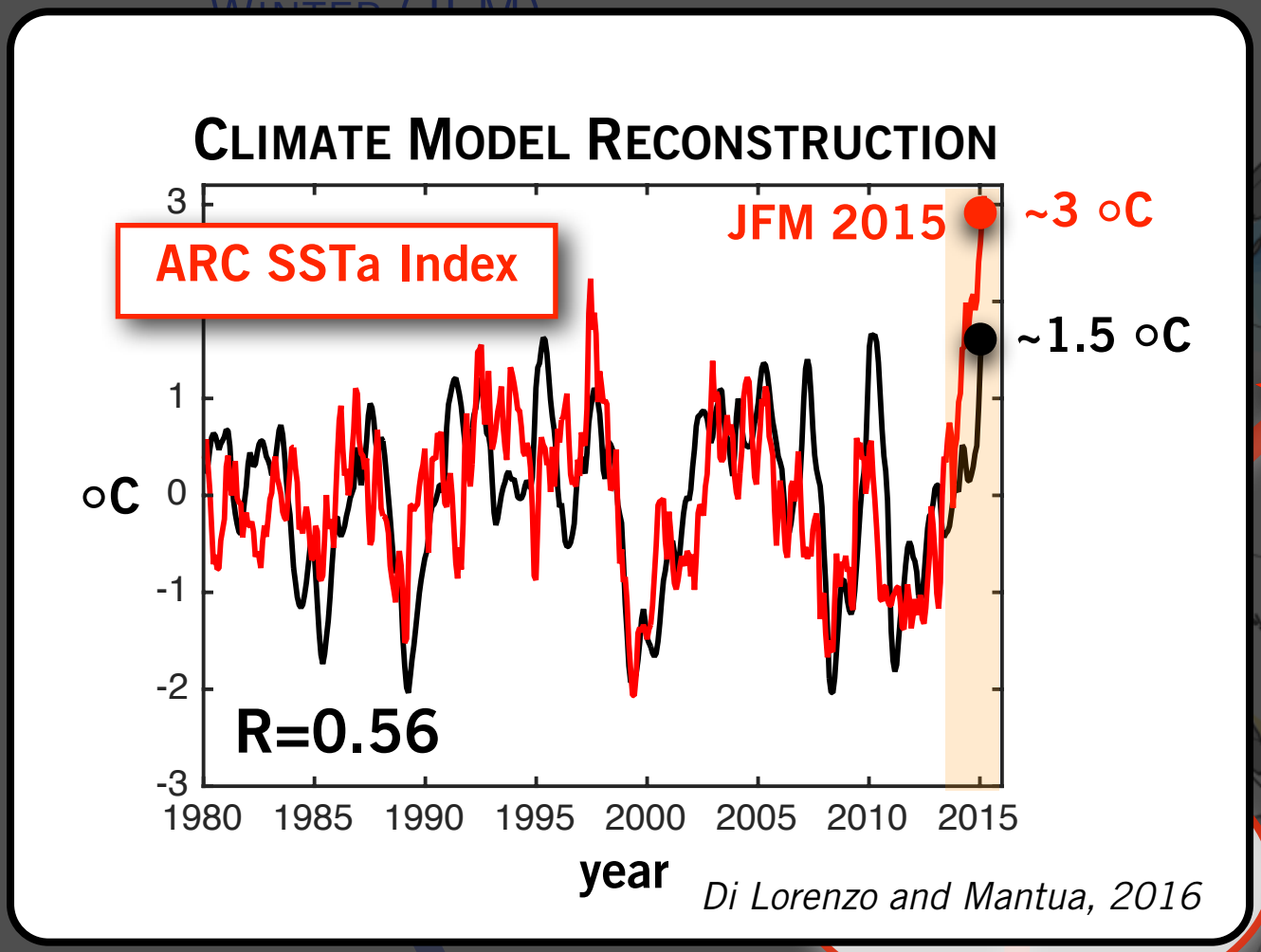
SUMMER & FALL

ENSO-like

FALL 2015

50 SIMULATIONS with CLIMATE MODEL

To extract the fraction of North Pacific atmospheric forcing of tropical origin



WINTER (JFM) NEXT YEAR

WIN 2015

PDO-like

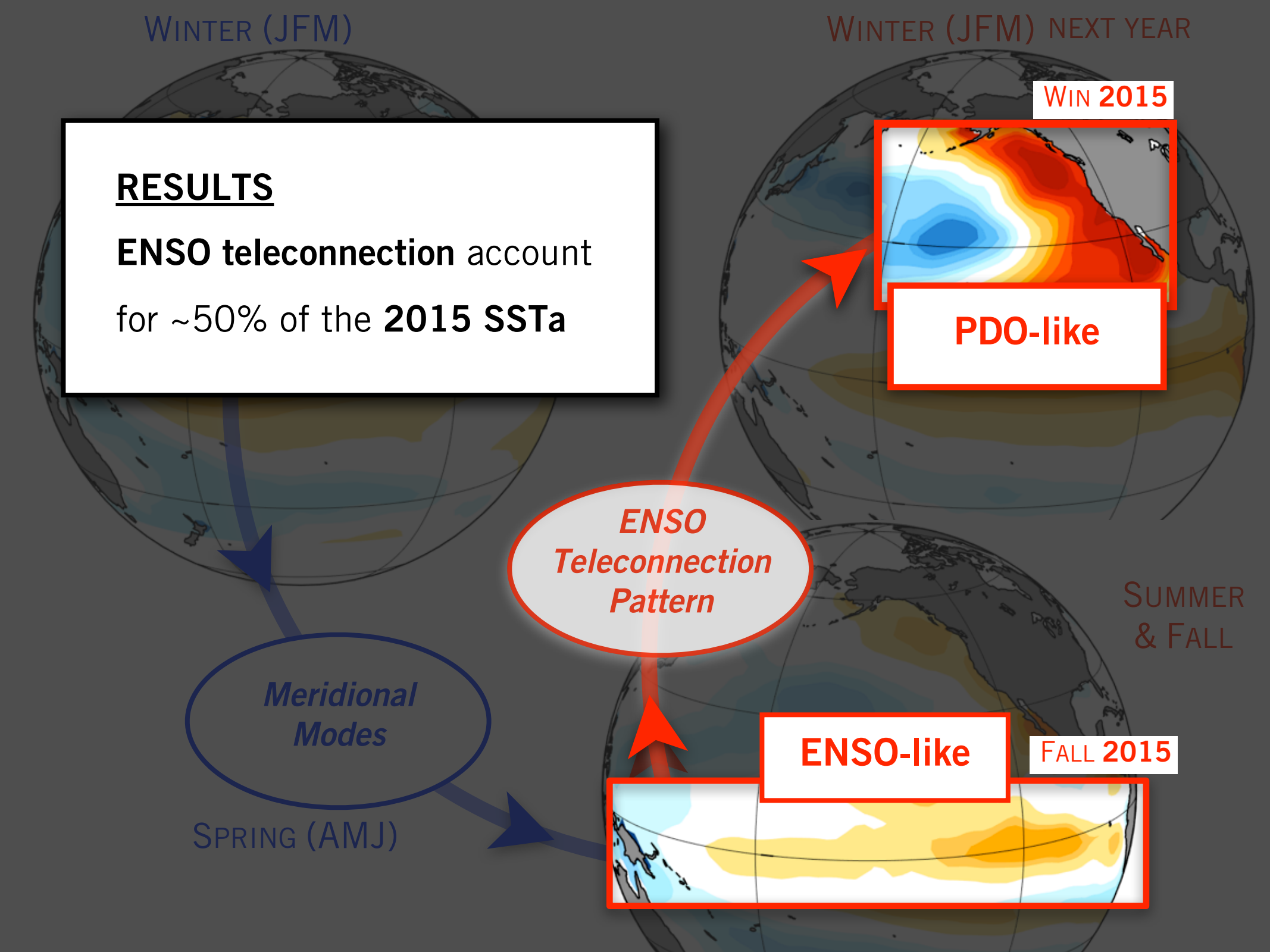
SUMMER & FALL

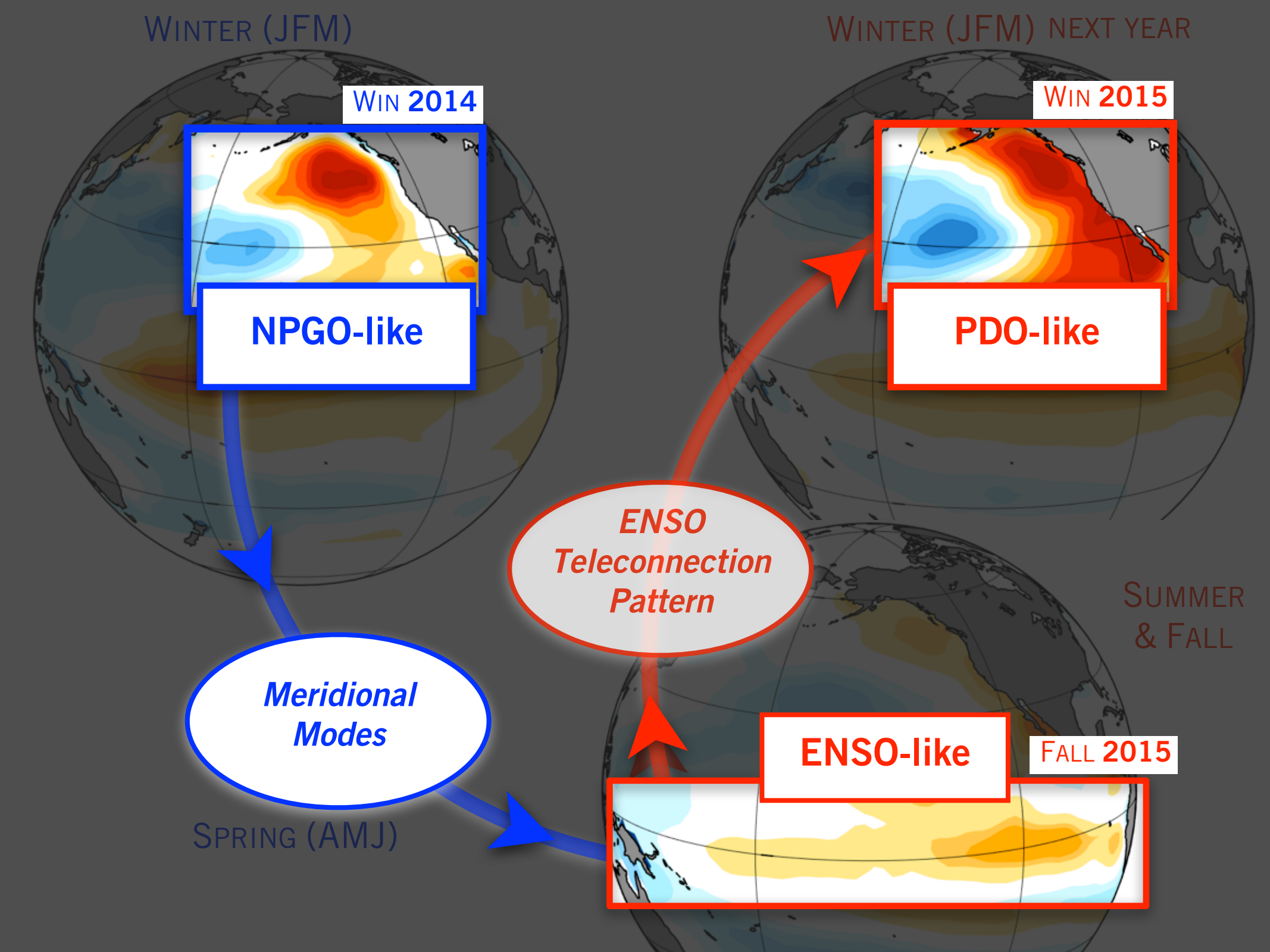
ENSO-like

FALL 2015

50 SIMULATIONS with CLIMATE MODEL

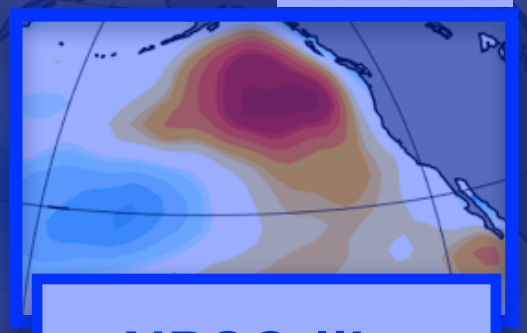
To extract the fraction of North Pacific atmospheric forcing of tropical origin


WINTER (JFM)
WINTER (JFM) NEXT YEAR
RESULTS
ENSO teleconnection account
for ~50% of the 2015 SSTa
WIN 2015
PDO-like
ENSO
Teleconnection
Pattern
SUMMER
& FALL
Meridional
Modes
ENSO-like
FALL 2015
SPRING (AMJ)


WINTER (JFM)
WIN 2014
NPGO-like
WINTER (JFM) NEXT YEAR
WIN 2015
PDO-like
ENSO Teleconnection Pattern
SUMMER & FALL
Meridional Modes
SPRING (AMJ)
ENSO-like
FALL 2015

WINTER (JFM)

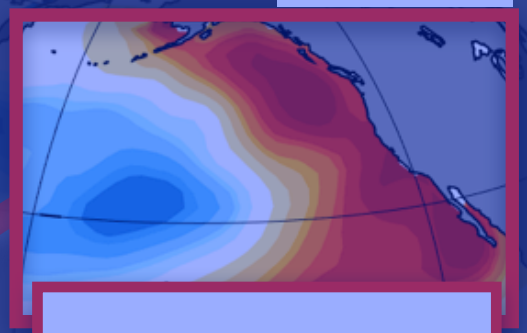
WIN 2014



NPGO-like

WINTER (JFM) NEXT YEAR

WIN 2015



PDO-like

QUESTION

Are these type of climate event becoming more frequent?

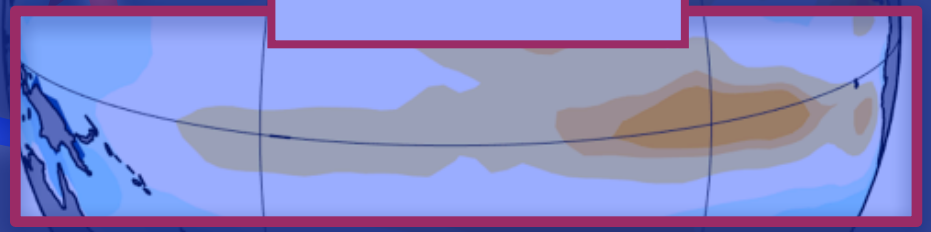
SUMMER & FALL

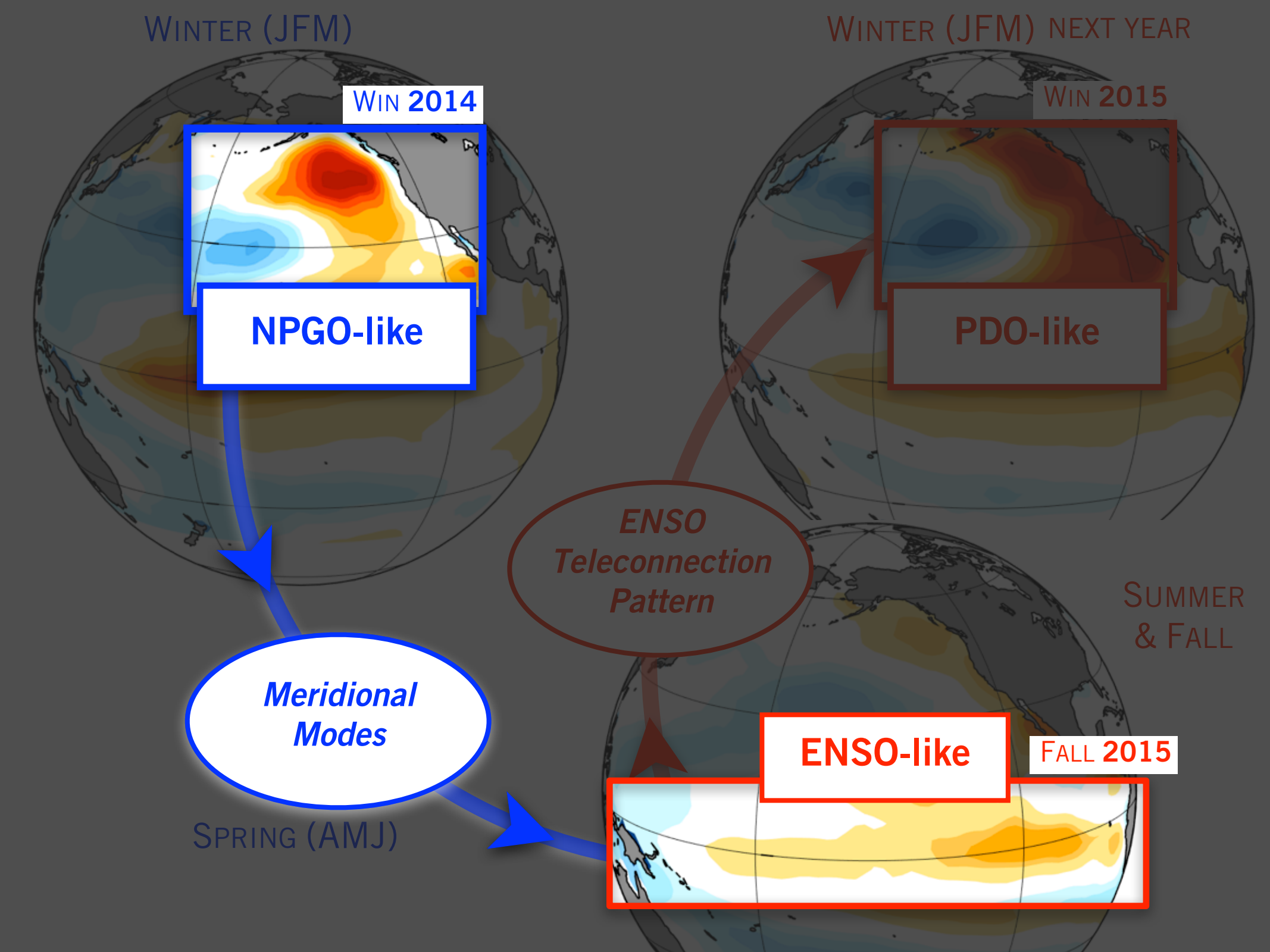
Meridional Modes

SPRING (AMJ)

ENSO-like

FALL 2015




WINTER (JFM)
WIN 2014
NPGO-like
WINTER (JFM) NEXT YEAR
WIN 2015
PDO-like
ENSO Teleconnection Pattern
SUMMER & FALL
Meridional Modes
SPRING (AMJ)
ENSO-like
FALL 2015

WINTER (JFM)

WIN 2014

NPGO-like

Meridional Modes

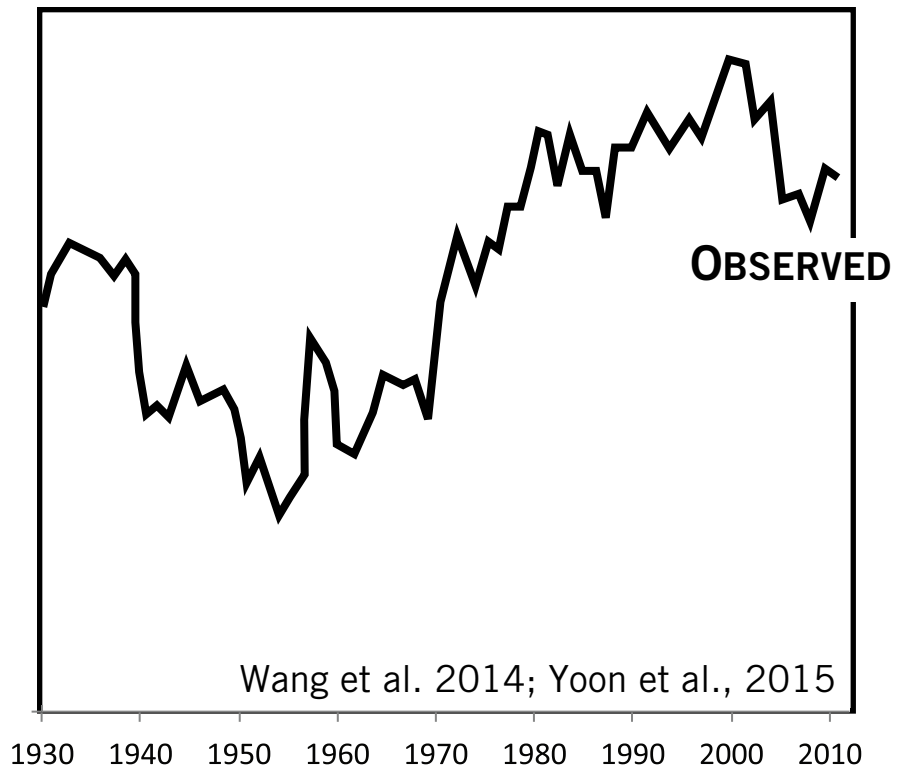
SPRING (AMJ)

ENSO-like

FALL 2015

STRENGTH

of tropical/extra-tropical coupling



WINTER (JFM)

WIN 2014

NPGO-like

Meridional Modes

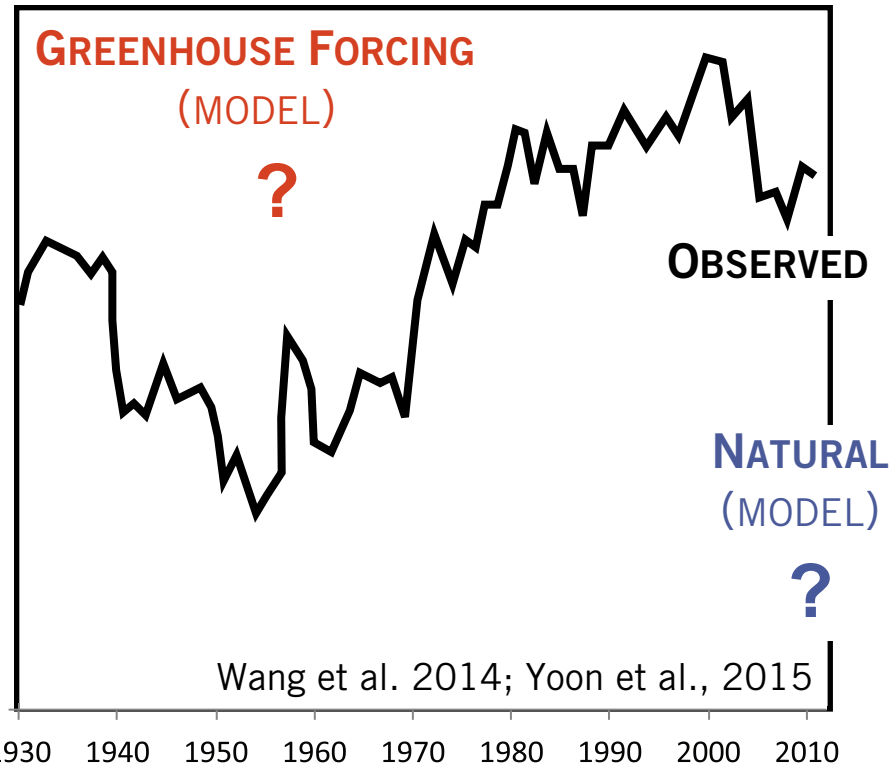
SPRING (AMJ)

ENSO-like

FALL 2015

STRENGTH

of tropical/extra-tropical coupling



WINTER (JFM)

WIN 2014

NPGO-like

Meridional Modes

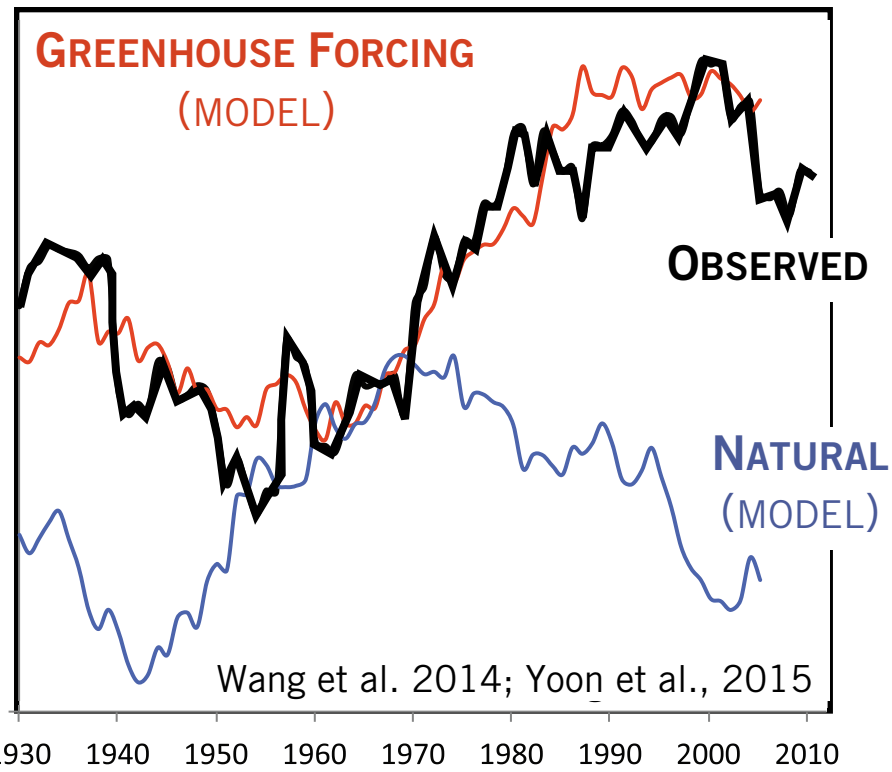
SPRING (AMJ)

ENSO-like

FALL 2015

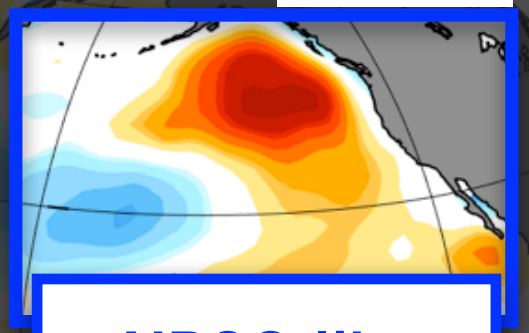
STRENGTH

of tropical/extra-tropical coupling



WINTER (JFM)

WIN 2014



NPGO-like

Meridional Modes

SPRING (AMJ)

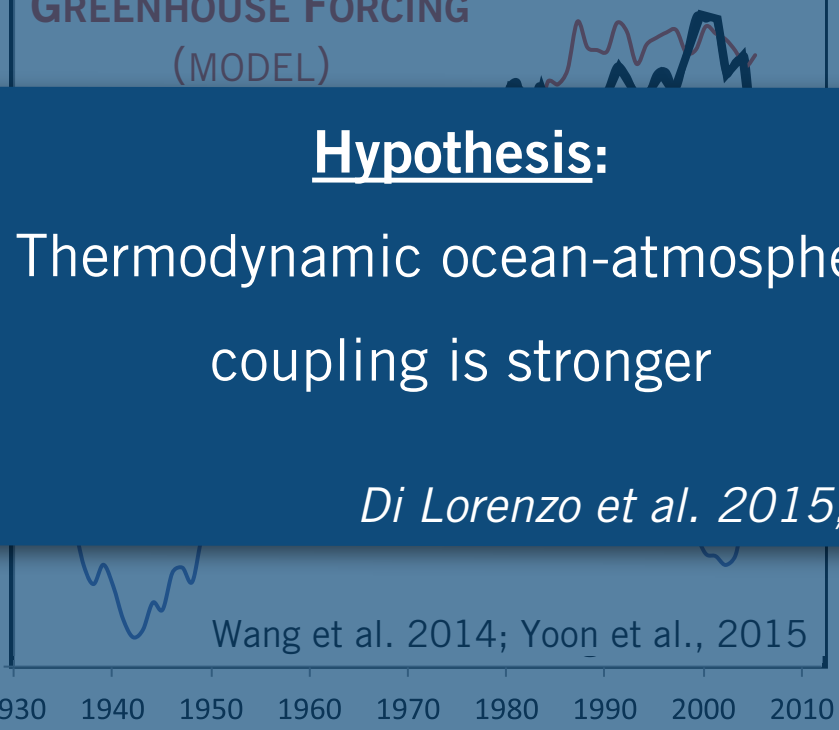
WINTER (JFM) NEXT YEAR

STRENGTH

of tropical/extra-tropical coupling

GREENHOUSE FORCING

(MODEL)



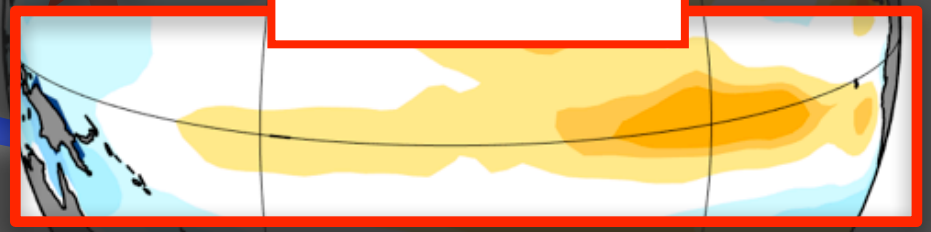
Hypothesis:

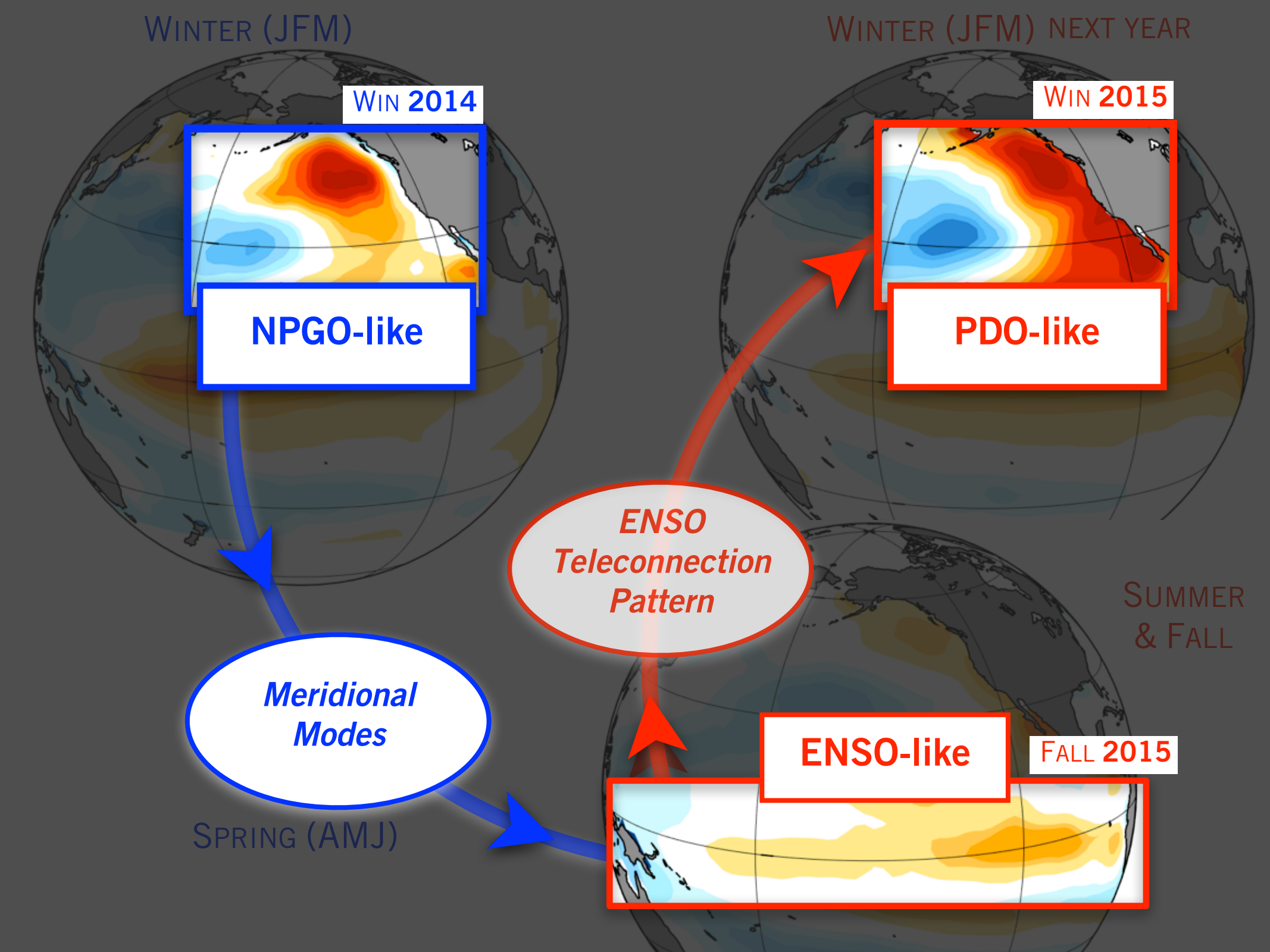
Thermodynamic ocean-atmosphere coupling is stronger

Di Lorenzo et al. 2015, GRL

ENSO-like

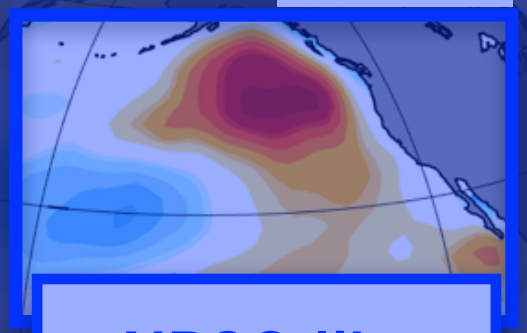
FALL 2015




WINTER (JFM)
WIN 2014
NPGO-like
WINTER (JFM) NEXT YEAR
WIN 2015
PDO-like
ENSO Teleconnection Pattern
SUMMER & FALL
Meridional Modes
SPRING (AMJ)
ENSO-like
FALL 2015

WINTER (JFM)

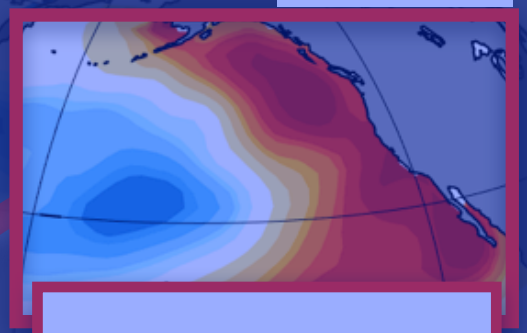
WIN 2014



NPGO-like

WINTER (JFM) NEXT YEAR

WIN 2015



PDO-like

QUESTION

Is the variance of the North Pacific climate modes increasing?

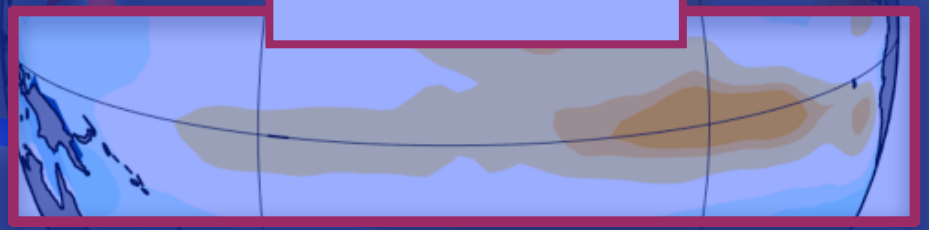
SUMMER & FALL

Meridional Modes

SPRING (AMJ)

ENSO-like

FALL 2015



Warm Blob JFM Patterns under Greenhouse Forcing

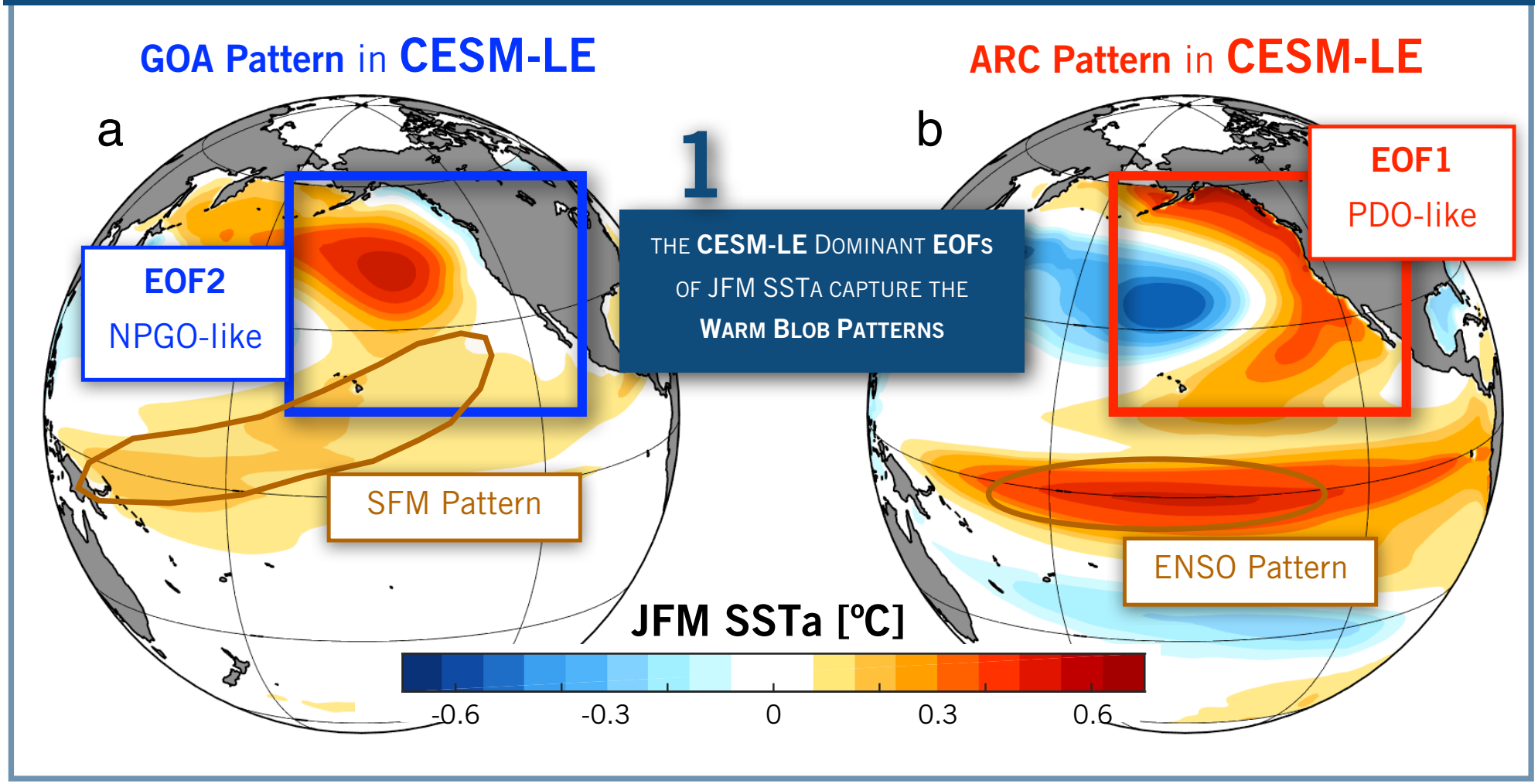
Community Earth System Model

30 members **Large Ensemble (CESM-LE)**

Forced with RCP8.5 greenhouse scenario

1920-2100

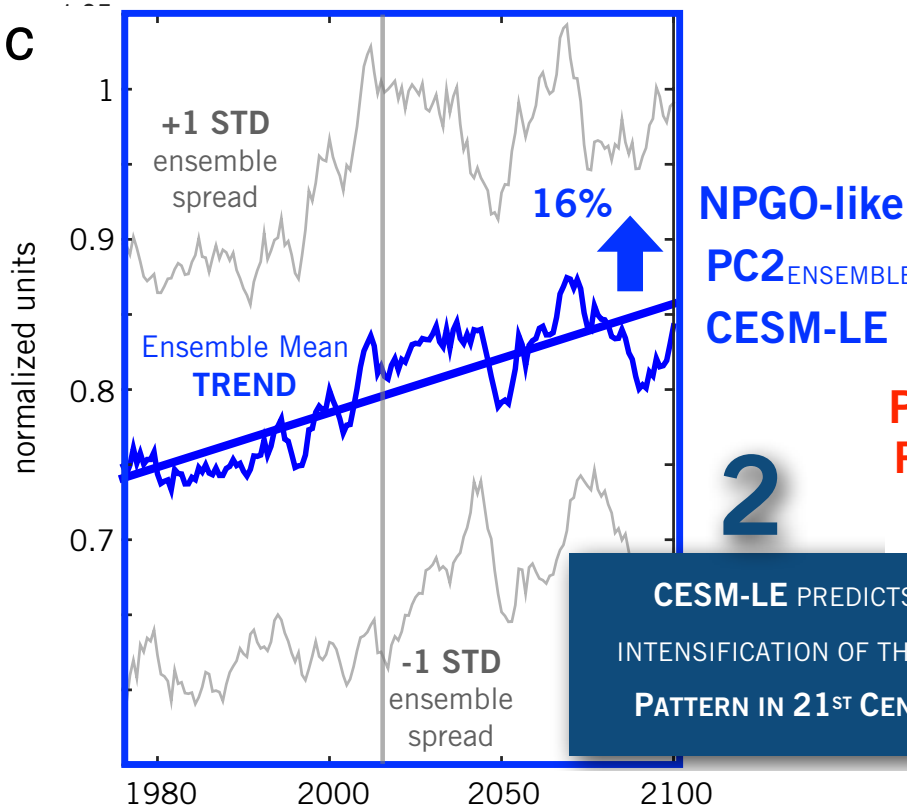
Warm Blob JFM Patterns under Greenhouse Forcing



SPRING (AMJ)

Warm Blob JFM Patterns under Greenhouse Forcing

Changes in Variance of GOA Pattern



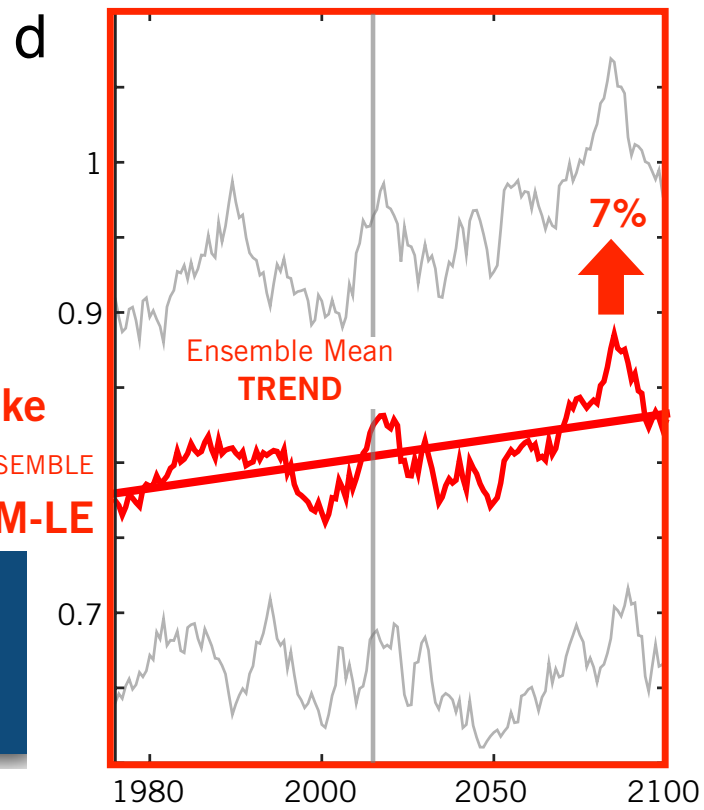
NPGO-like
PC2 ENSEMBLE
CESM-LE

2

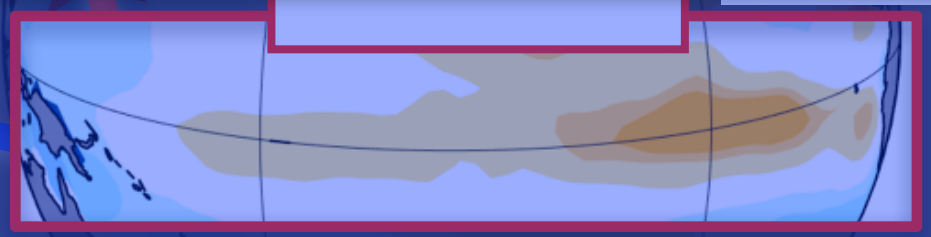
CESM-LE predicts an intensification of the **GOA** Pattern in 21st Century

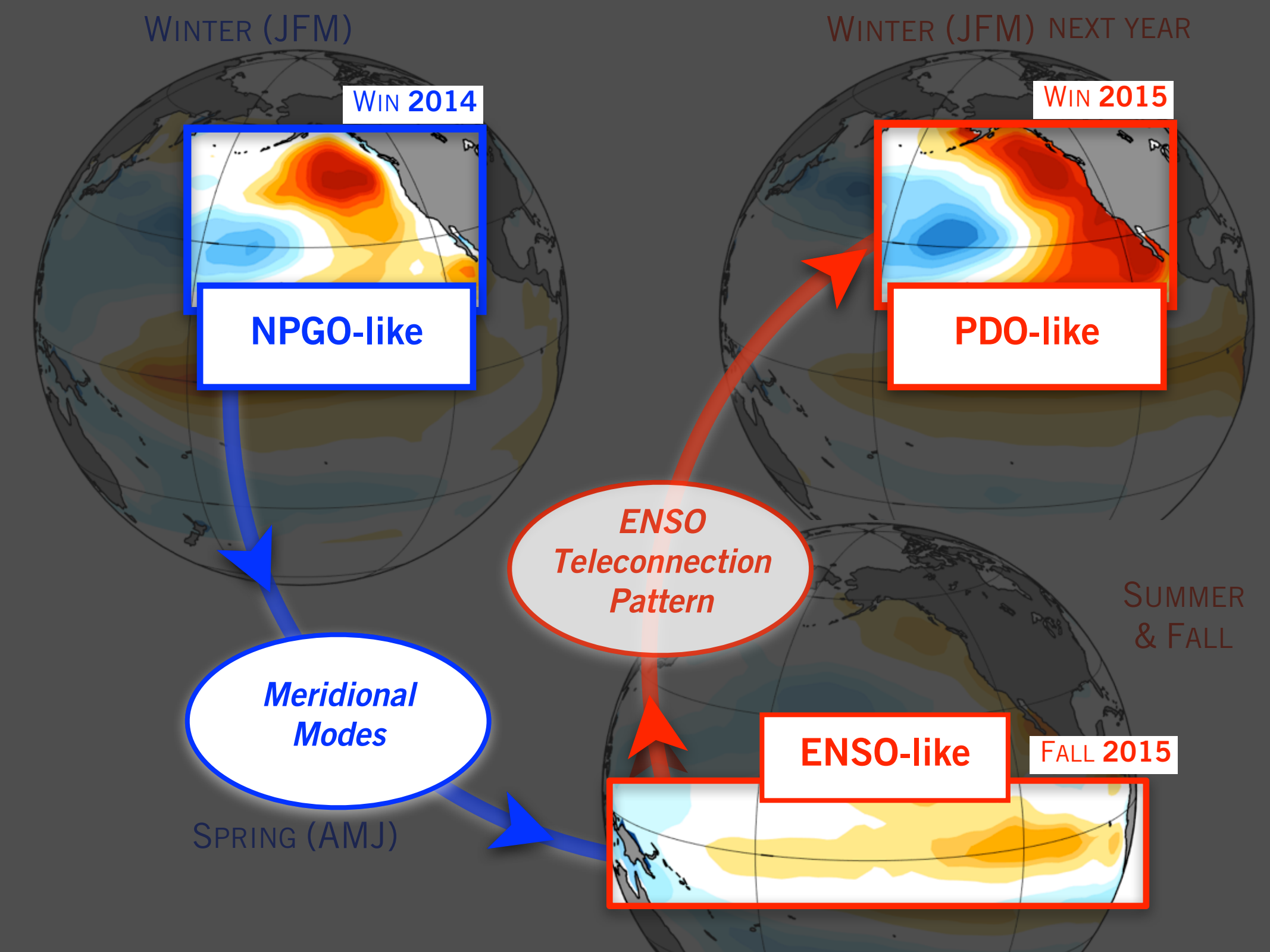
PDO-like
PC1 ENSEMBLE
CESM-LE

Changes in Variance of ARC Pattern

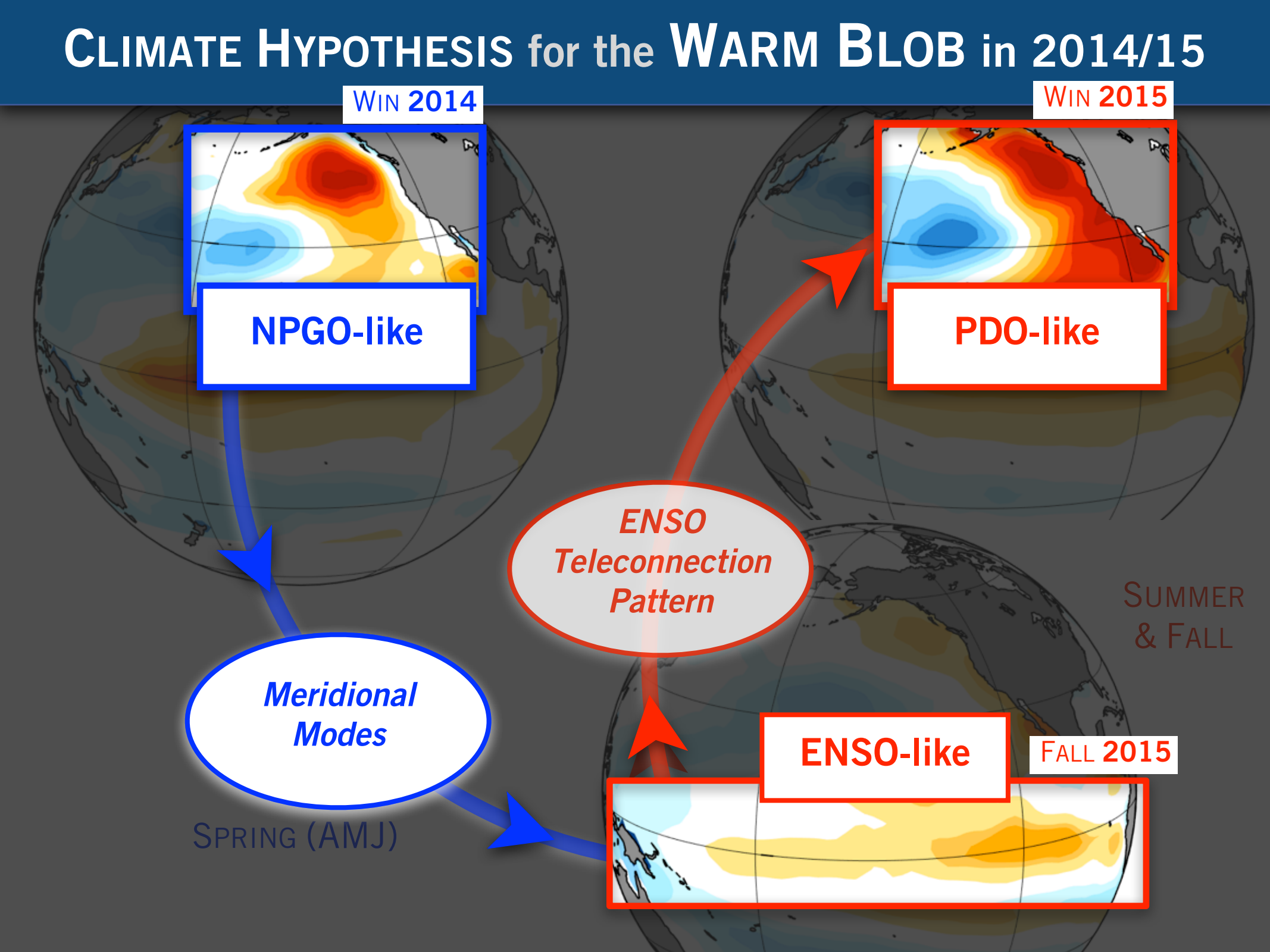


Spring (AMJ)




WINTER (JFM)
WIN 2014
NPGO-like
WINTER (JFM) NEXT YEAR
WIN 2015
PDO-like
ENSO Teleconnection Pattern
SUMMER & FALL
Meridional Modes
SPRING (AMJ)
ENSO-like
FALL 2015

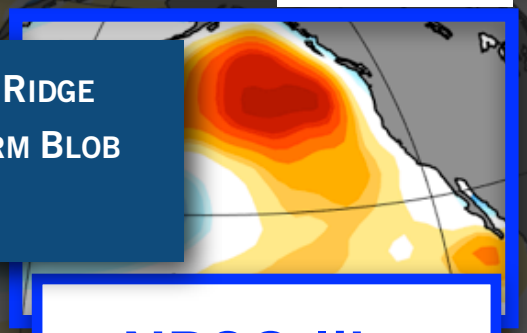
Climate Hypothesis for the Warm Blob in 2014/15



Climate Hypothesis for the Warm Blob in 2014/15

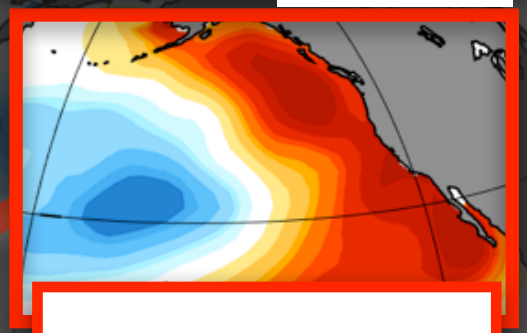
1 Atmospheric Ridge generates Warm Blob Winter

Win 2014



NPGO-like

Win 2015



PDO-like

ENSO Teleconnection Pattern

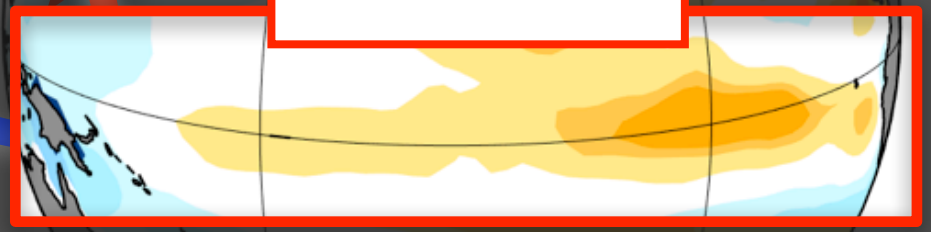
Summer & Fall

Meridional Modes

Spring (AMJ)

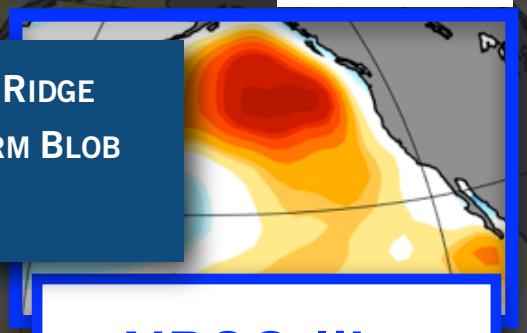
ENSO-like

Fall 2015



Climate Hypothesis for the Warm Blob in 2014/15

Win 2014

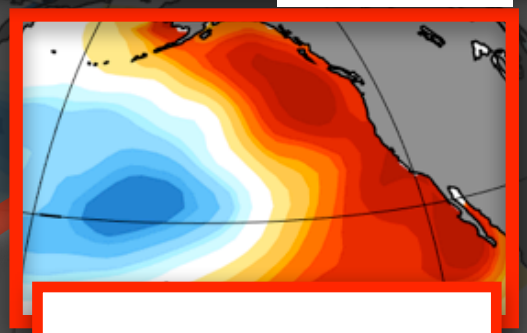


1 **Atmospheric Ridge** generates **Warm Blob Winter**

NPGO-like

2 **ENSO Teleconnections** reinforce and add persistence to Blob **Next Winter**

Win 2015



PDO-like

ENSO Teleconnection Pattern

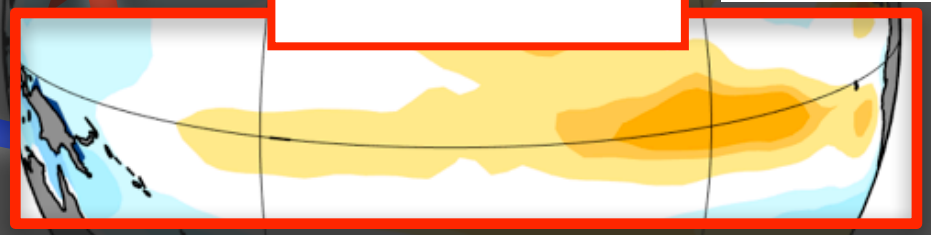
Meridional Modes

Spring (AMJ)

Summer & Fall

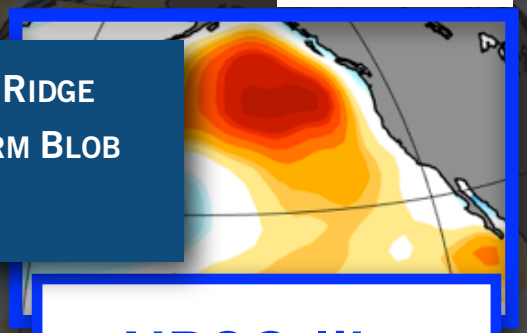
ENSO-like

Fall 2015



Climate Hypothesis for the Warm Blob in 2014/15

Win 2014



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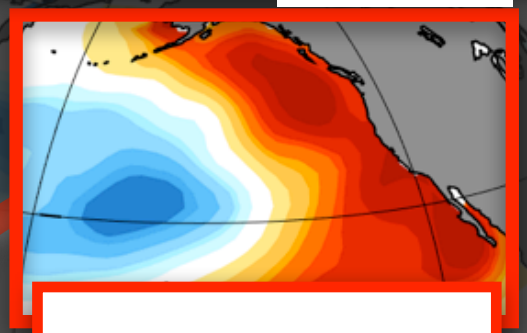


PDO-like

ENSO Teleconnection Pattern

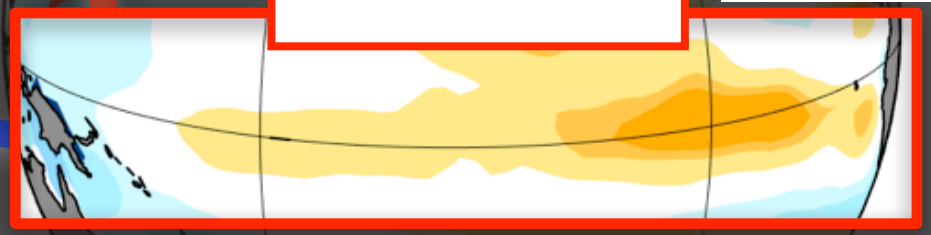
Summer & Fall

Meridional Modes

3 **Thermodynamic Feedbacks** may amplify under **Greenhouse Forcing**

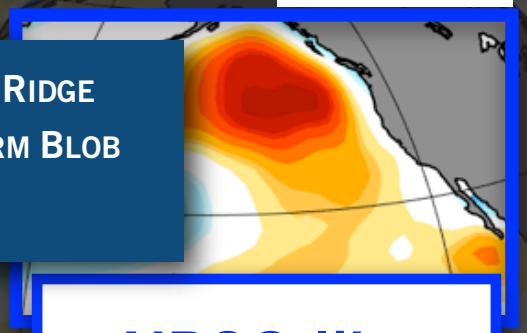
ENSO-like

Fall 2015



Climate Hypothesis for the Warm Blob in 2014/15

Win 2014



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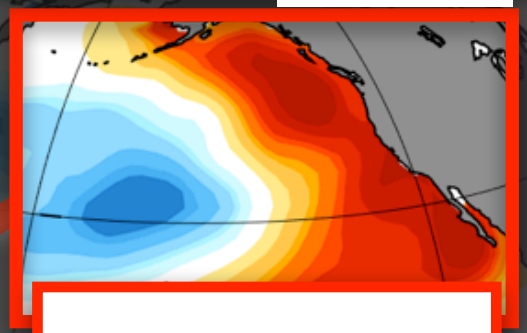
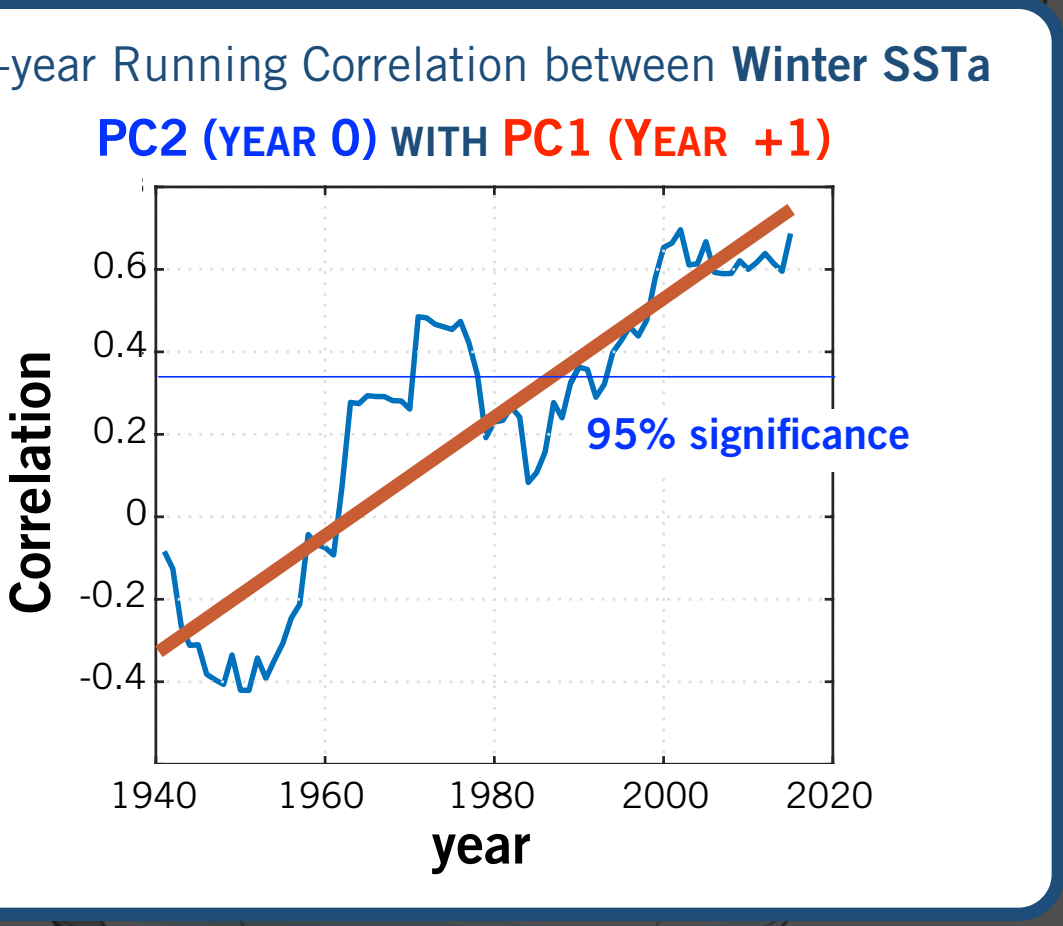
NPGO-like

Win 2015



PDO-like

2 ENSO Teleconnections

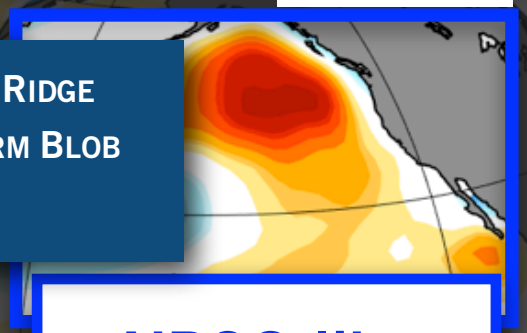


Meridional Modes

3 Thermodynamic Feedbacks may amplify under Greenhouse Forcing

Climate Hypothesis for the Warm Blob in 2014/15

Win 2014



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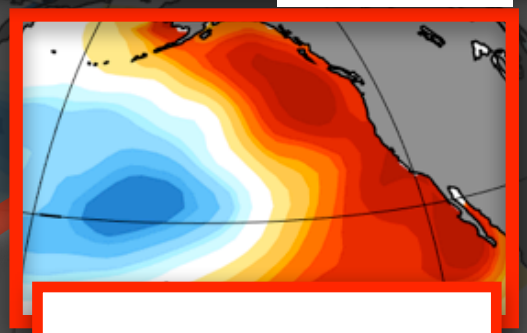


PDO-like

ENSO Teleconnection Pattern

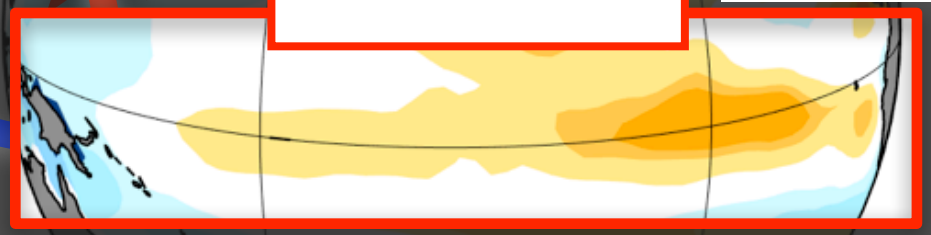
Summer & Fall

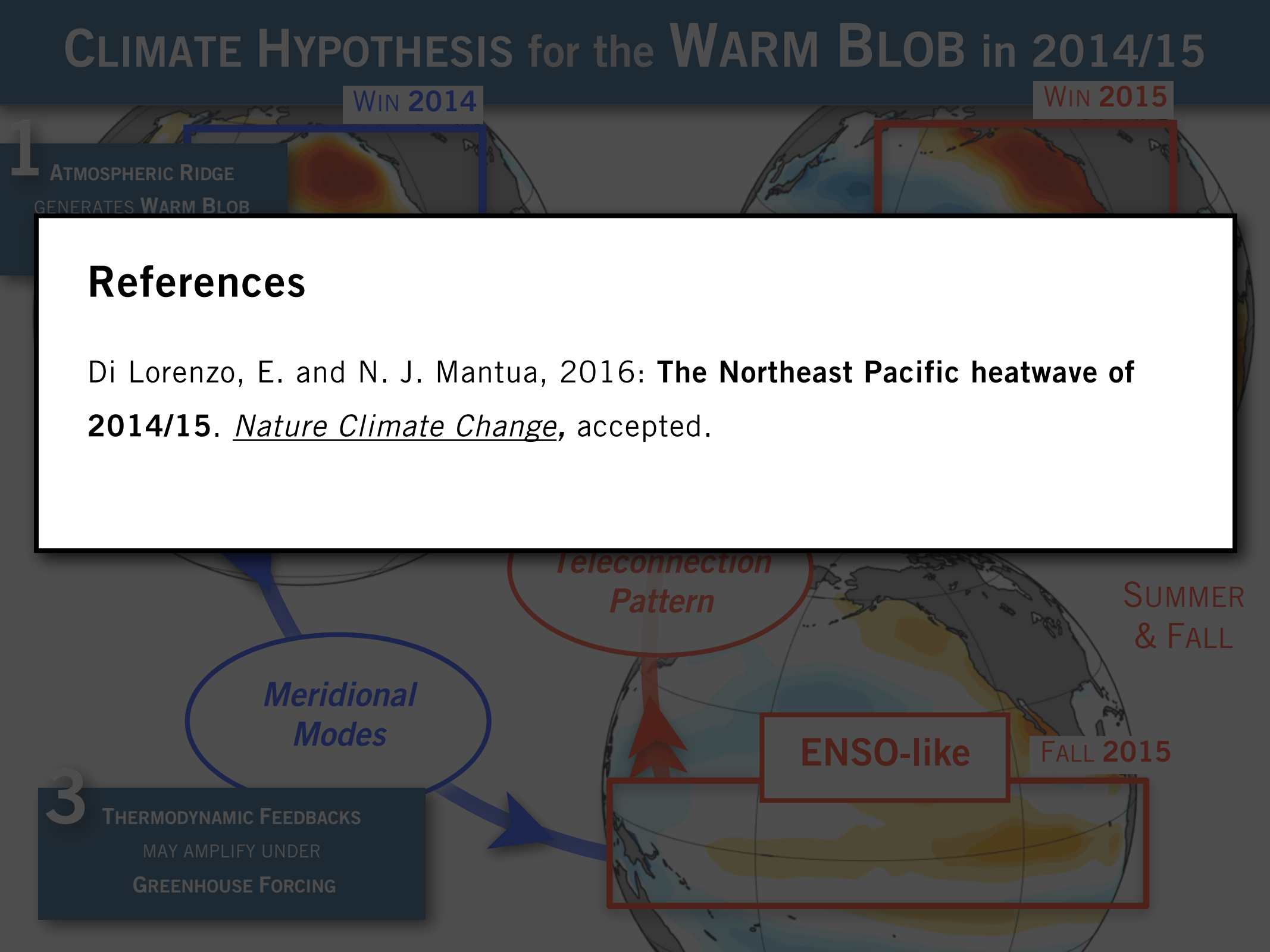
Meridional Modes

3 **Thermodynamic Feedbacks** may amplify under **Greenhouse Forcing**

ENSO-like

Fall 2015





References

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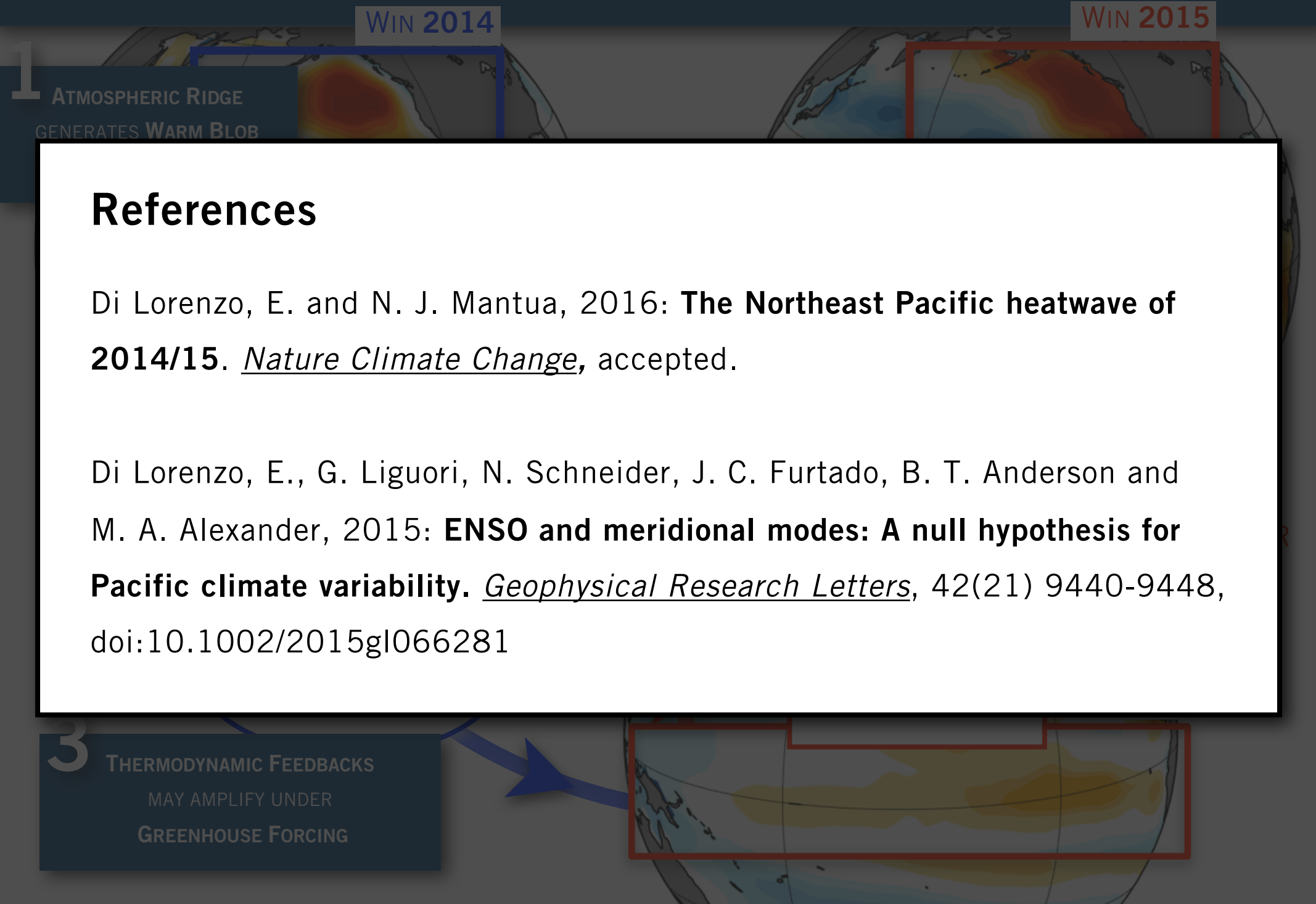
Climate Hypothesis for the Warm Blob in 2014/15



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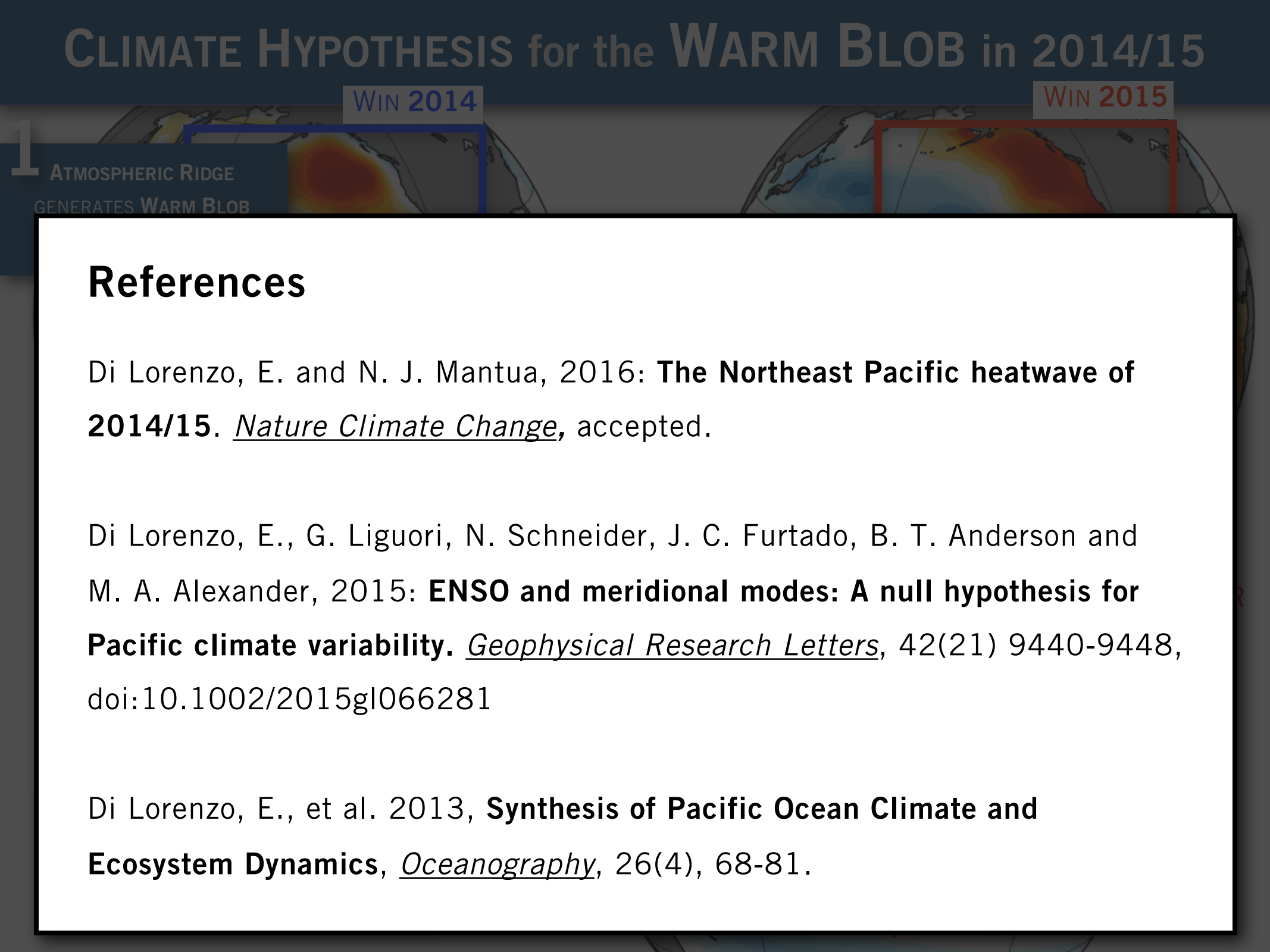

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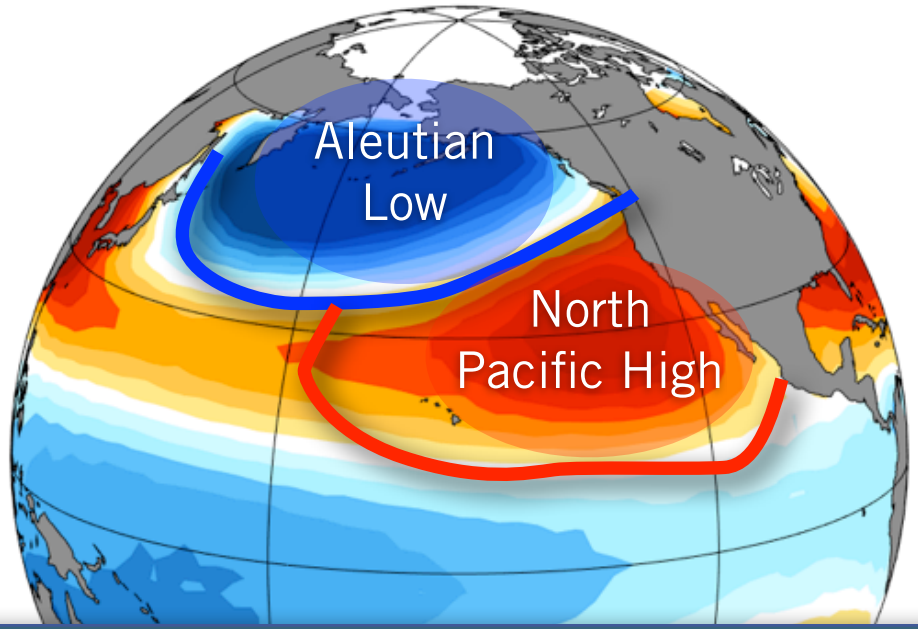
Di Lorenzo, E., et al. 2013, **Synthesis of Pacific Ocean Climate and Ecosystem Dynamics**, *Oceanography*, 26(4), 68-81.

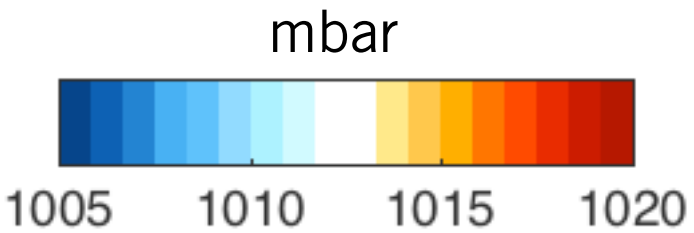


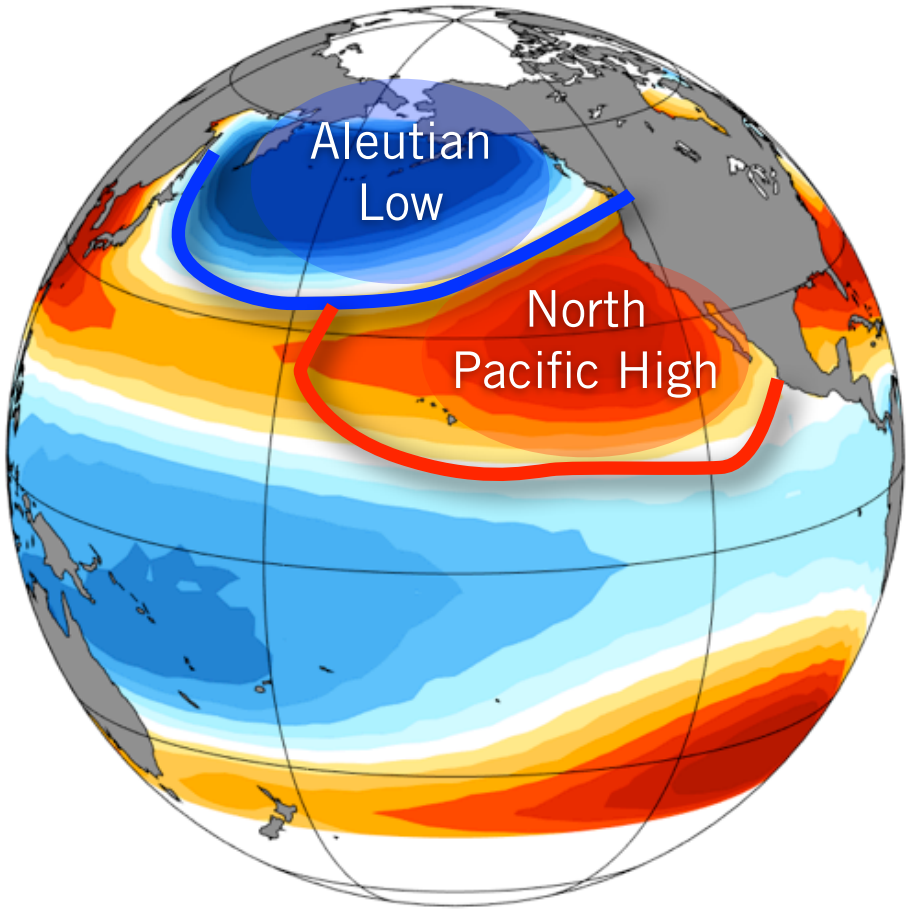
Mean Winter Atmospheric Circulation

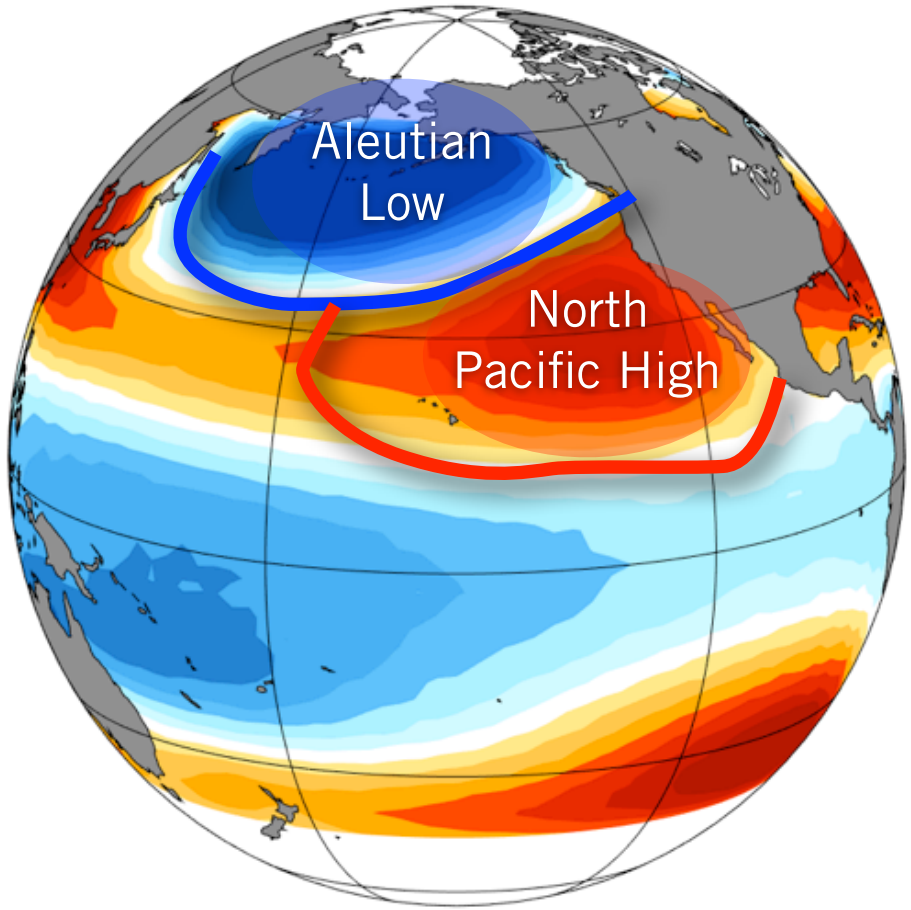
Sea Level Pressure (SLP)

A BRIEF PRIMER ON

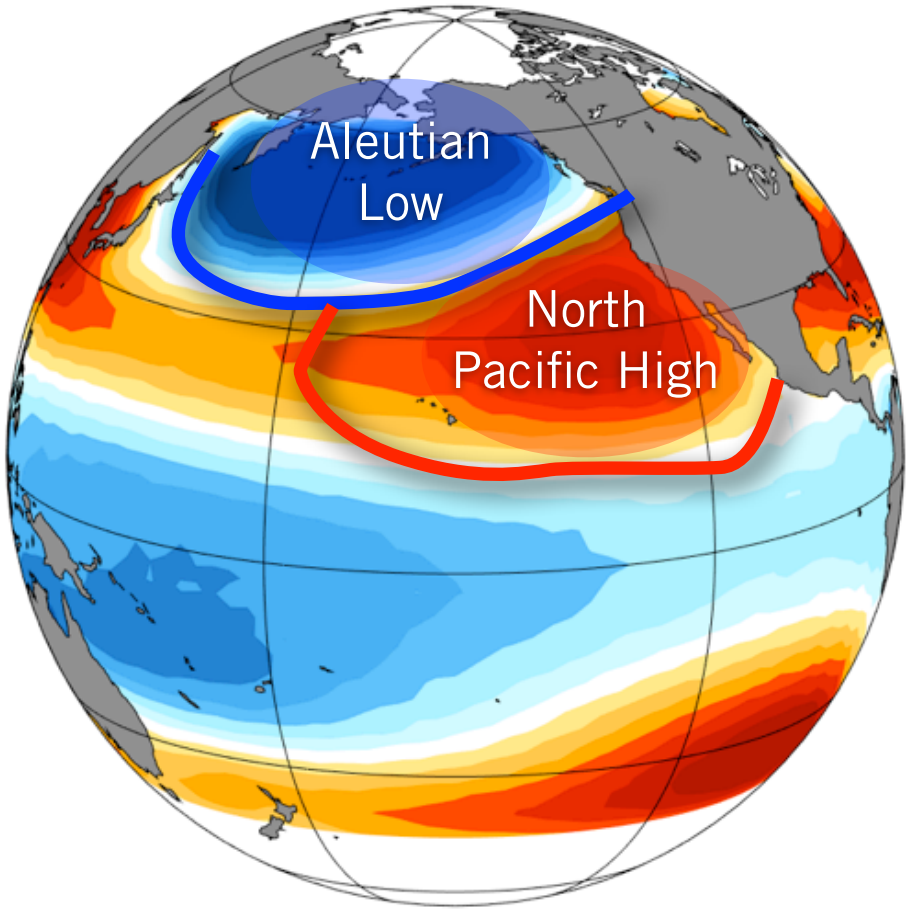
NORTH PACIFIC CLIMATE VARIABILITY



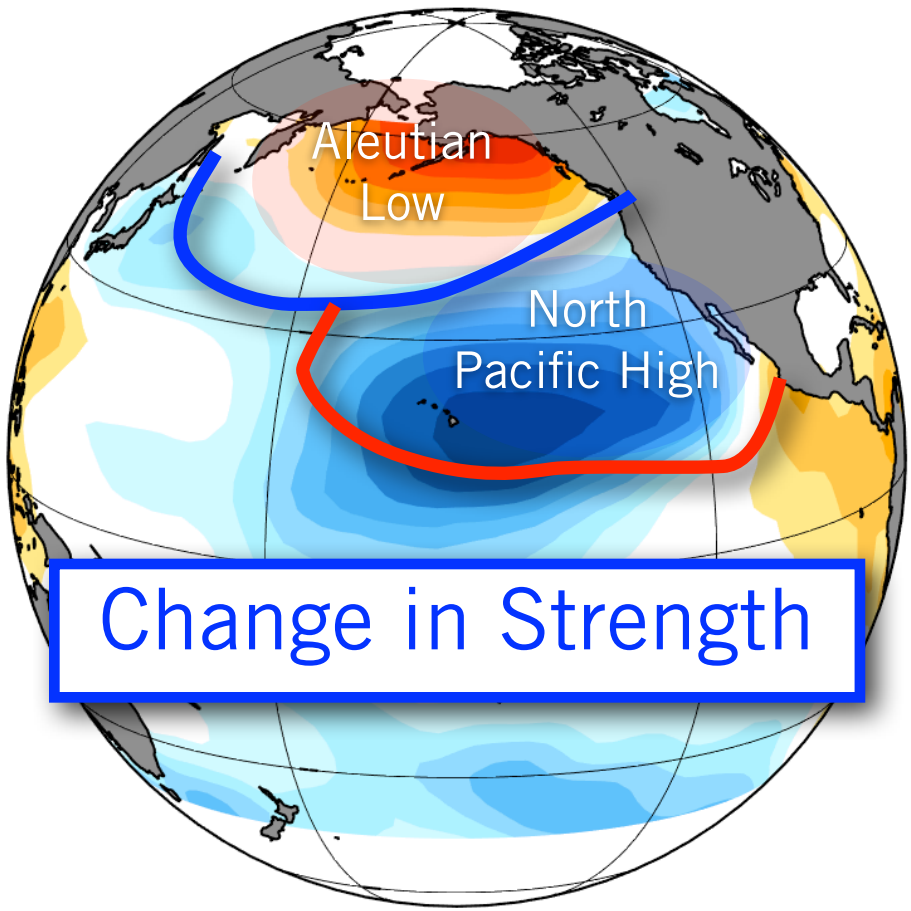




2 dominant types of changes

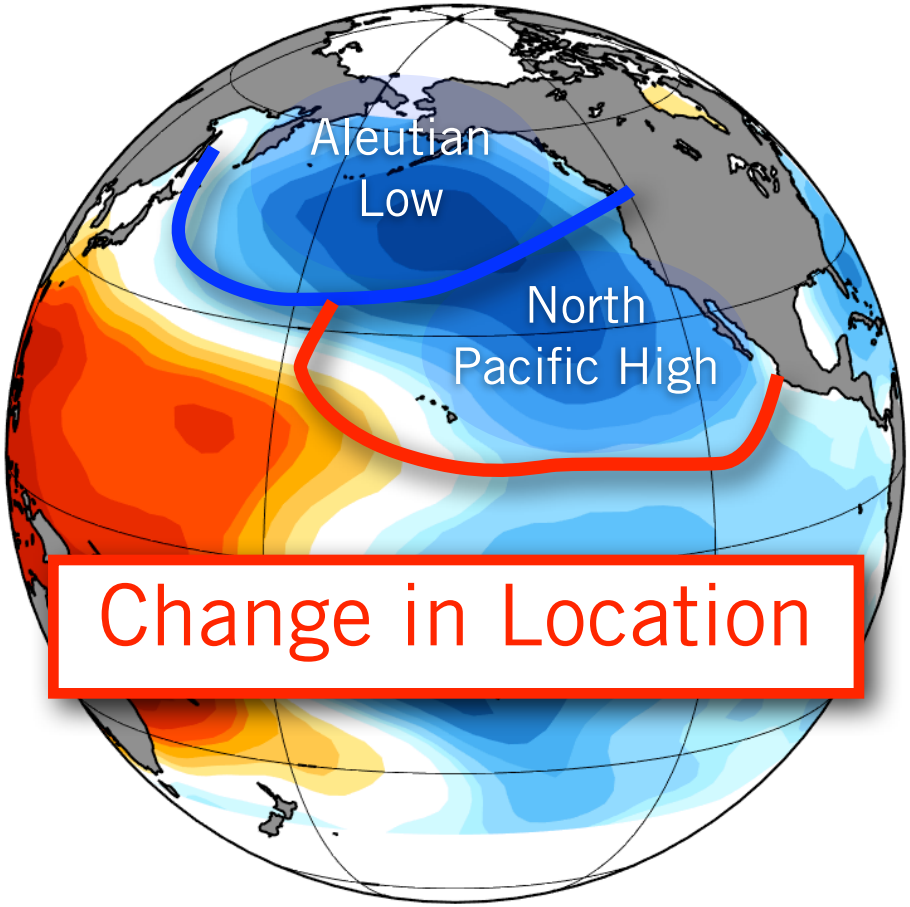


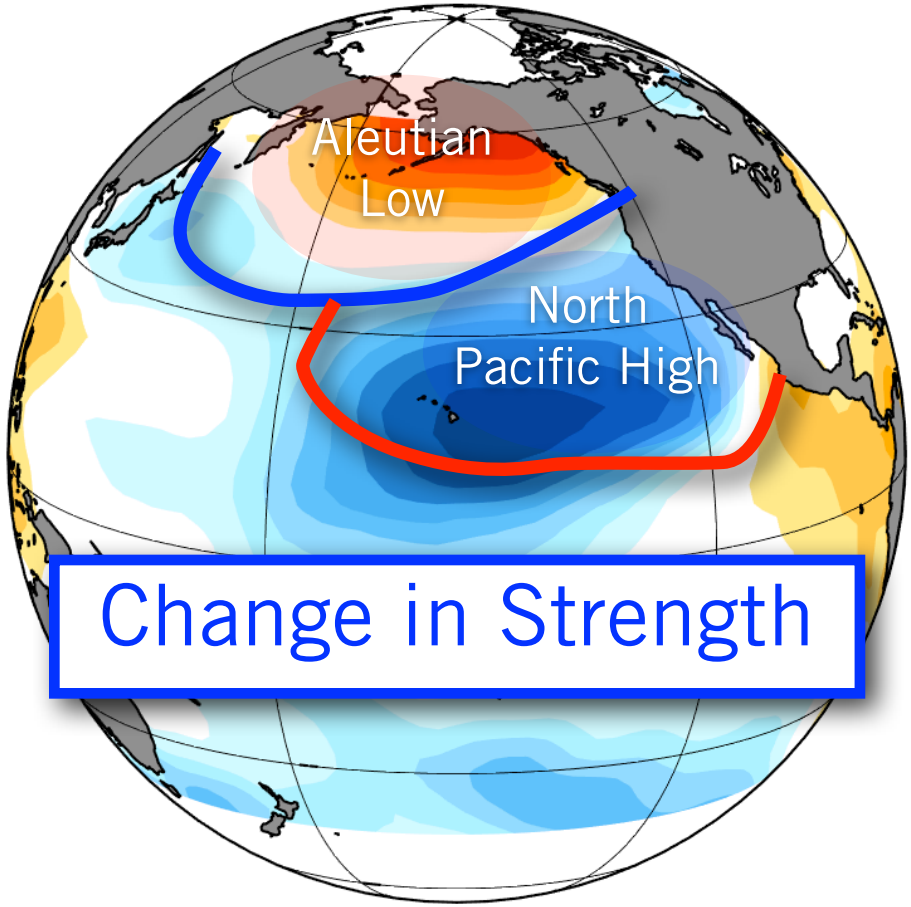
SLPa



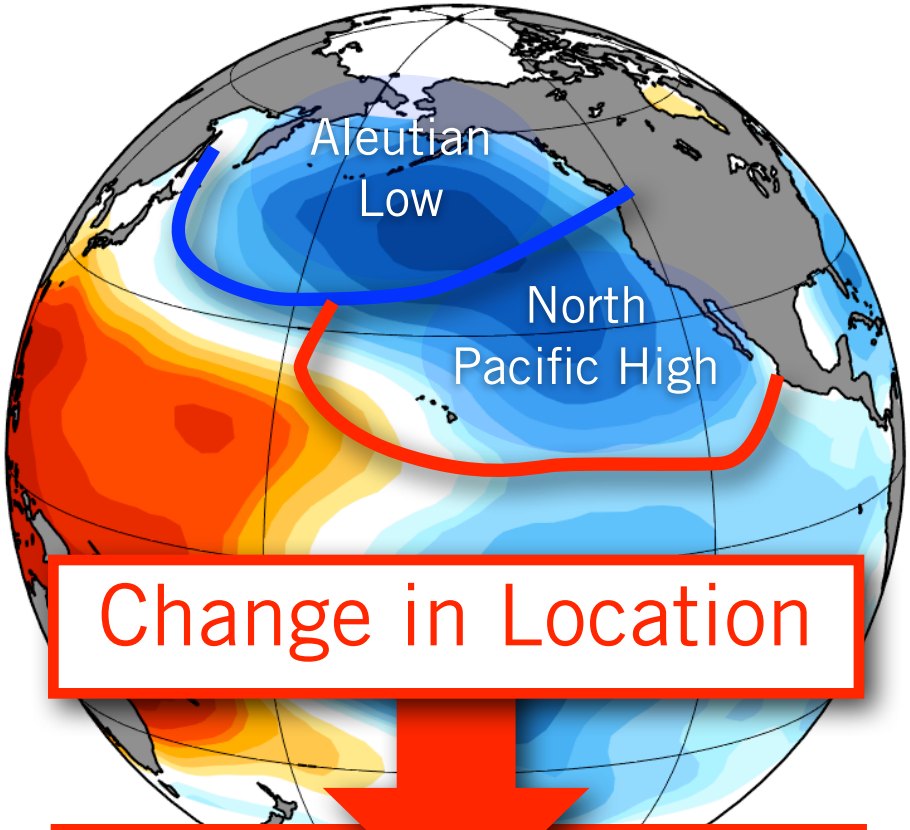
2 dominant types of changes

SLPa

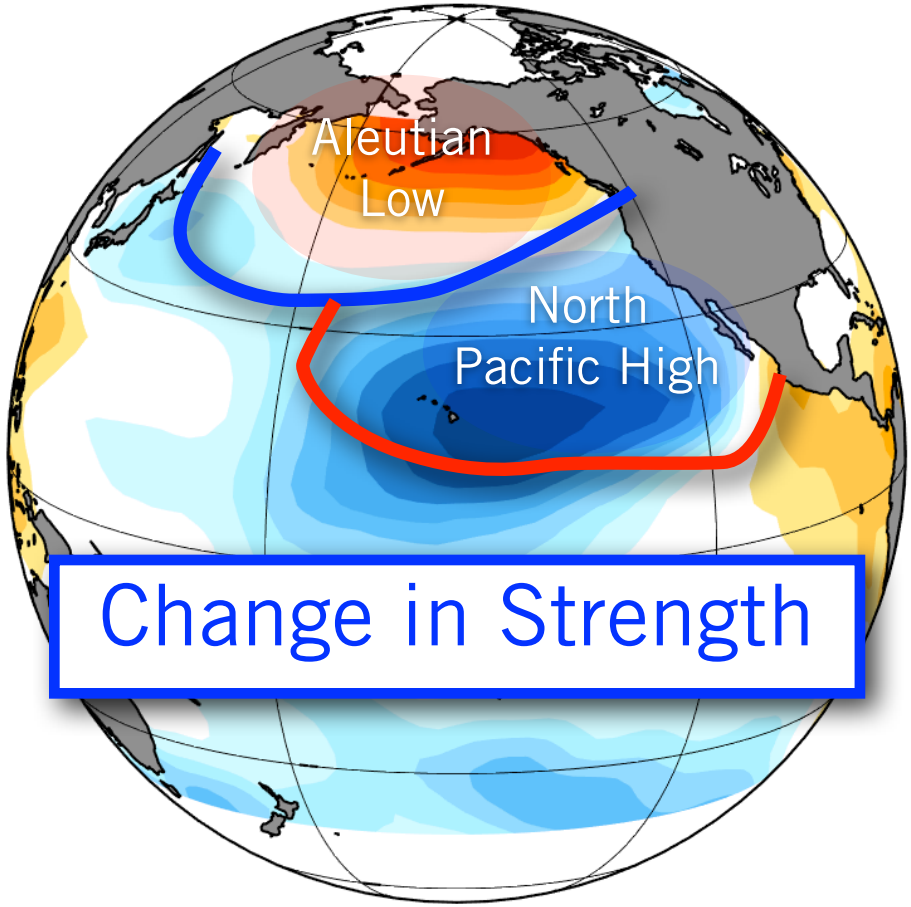




2 dominant types of changes

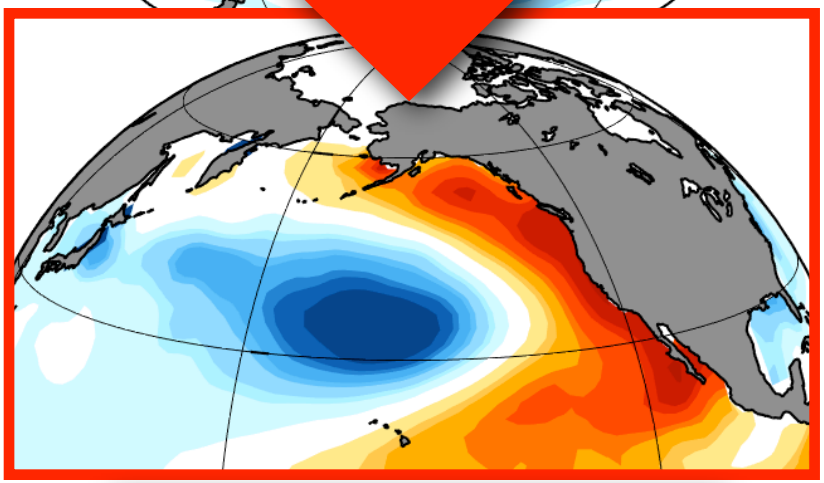


SLPa



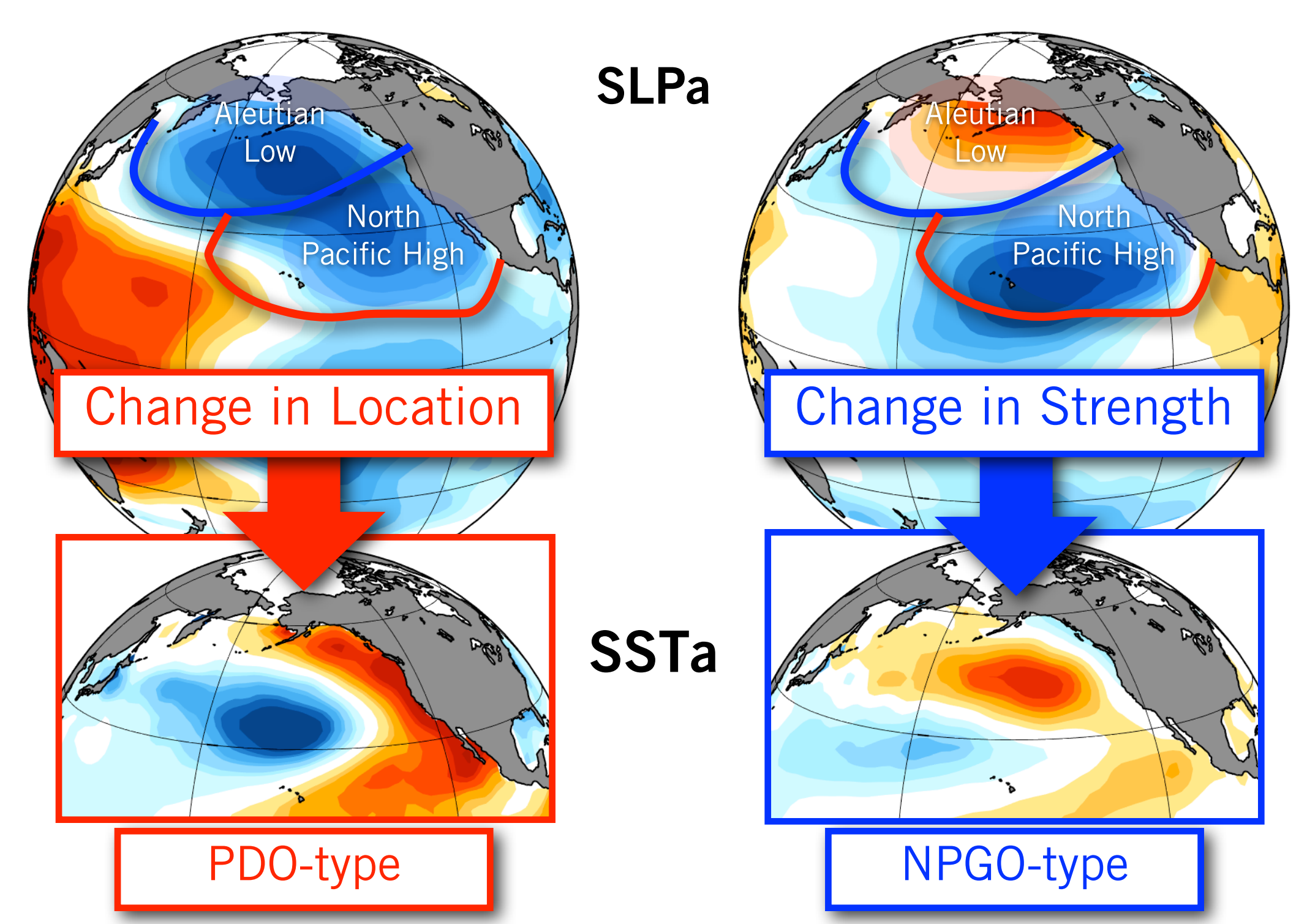
Change in Location

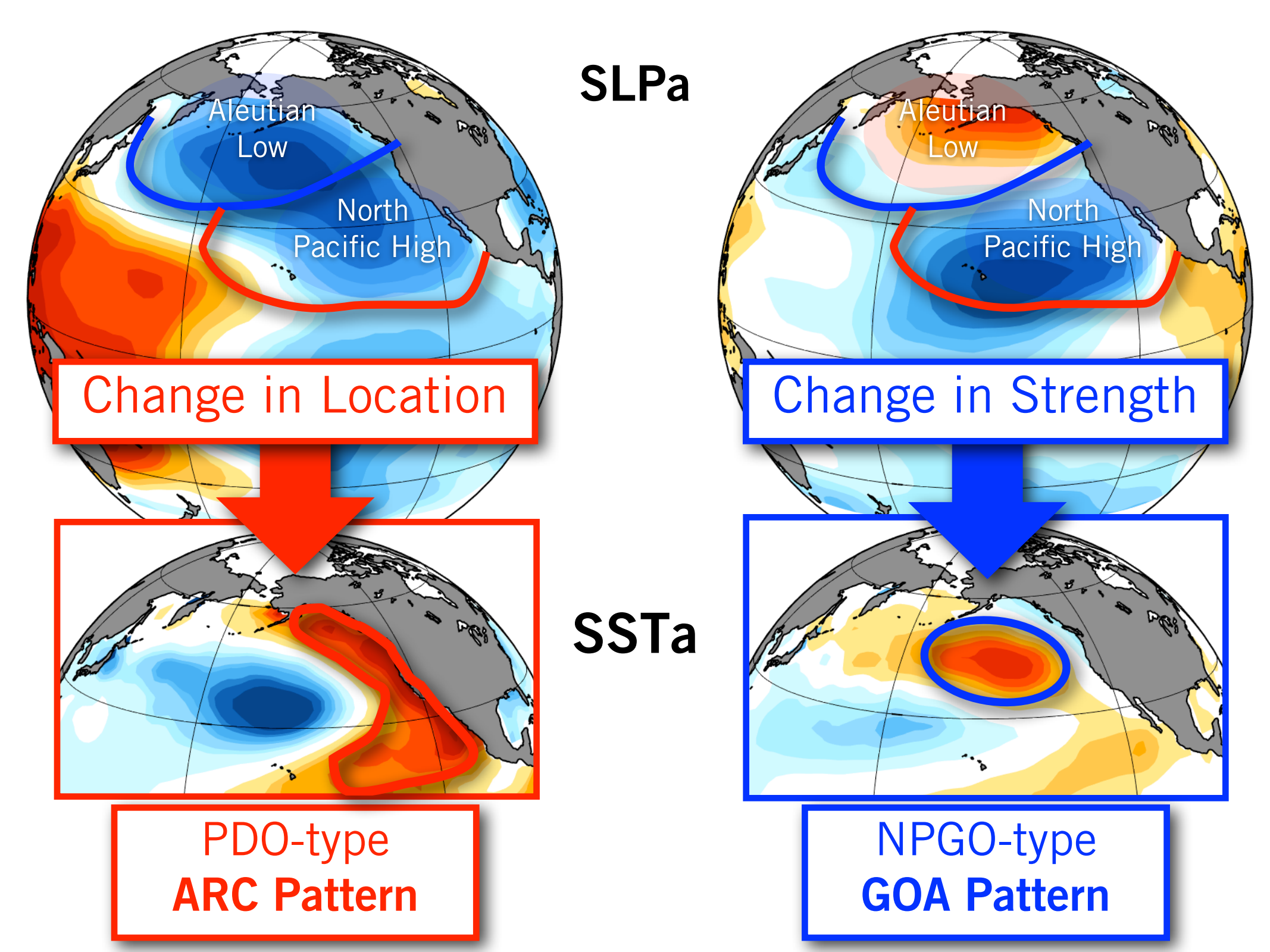
Change in Strength

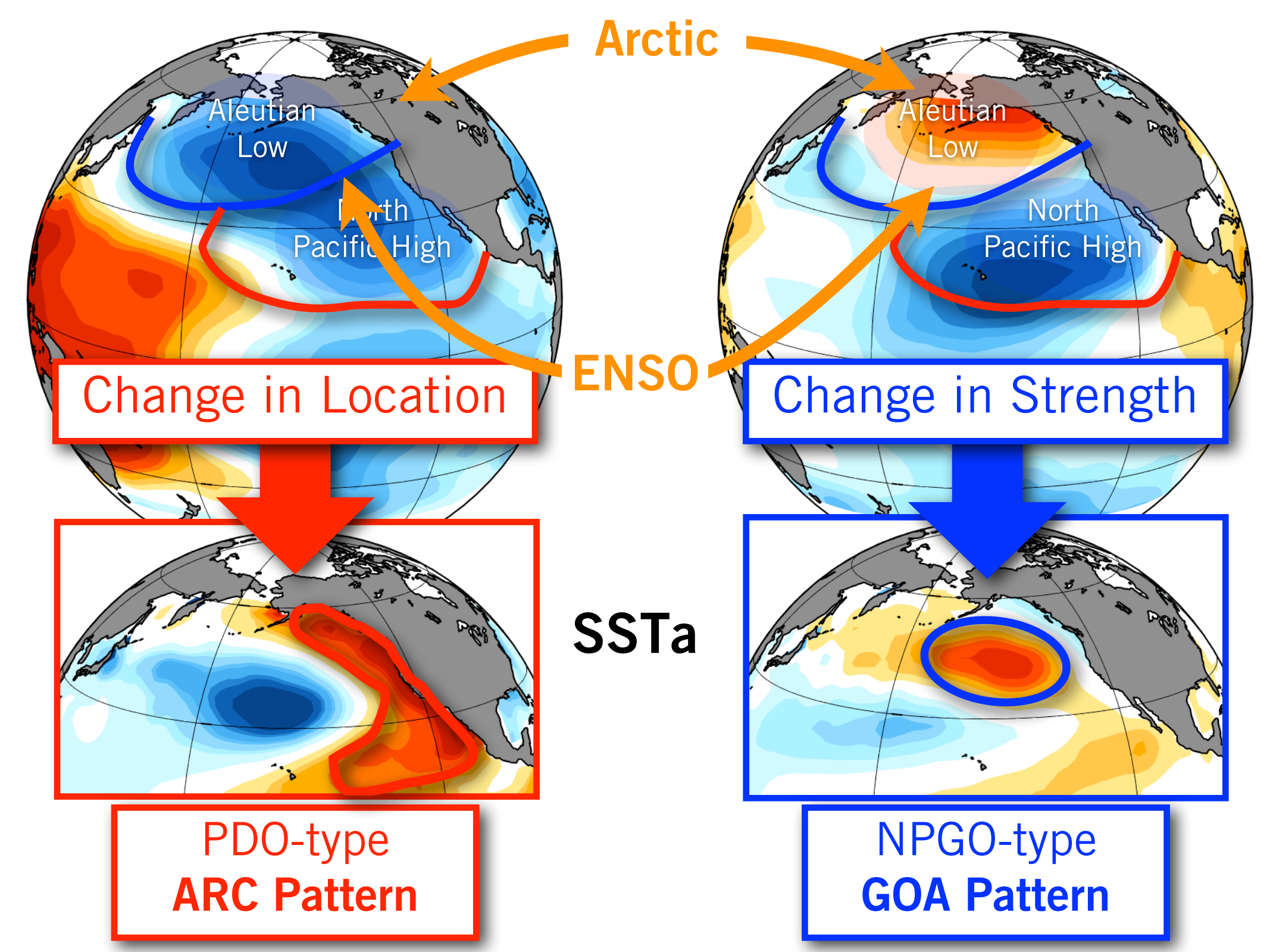


SSTa

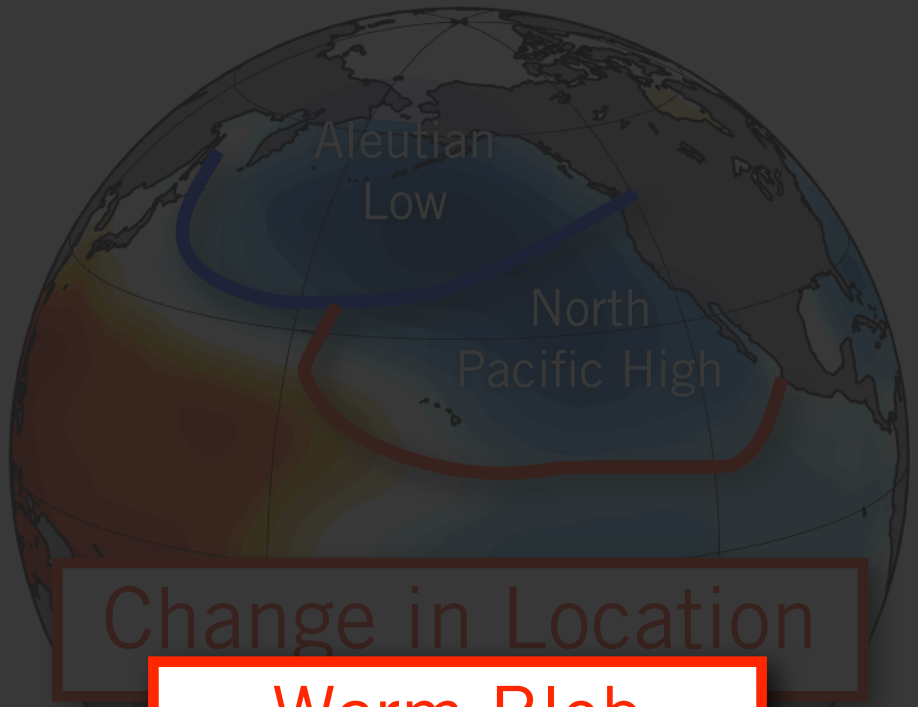
PDO-type


SLPa
Aleutian Low
North Pacific High
Change in Location
Change in Strength
SSTa
PDO-type
NPGO-type

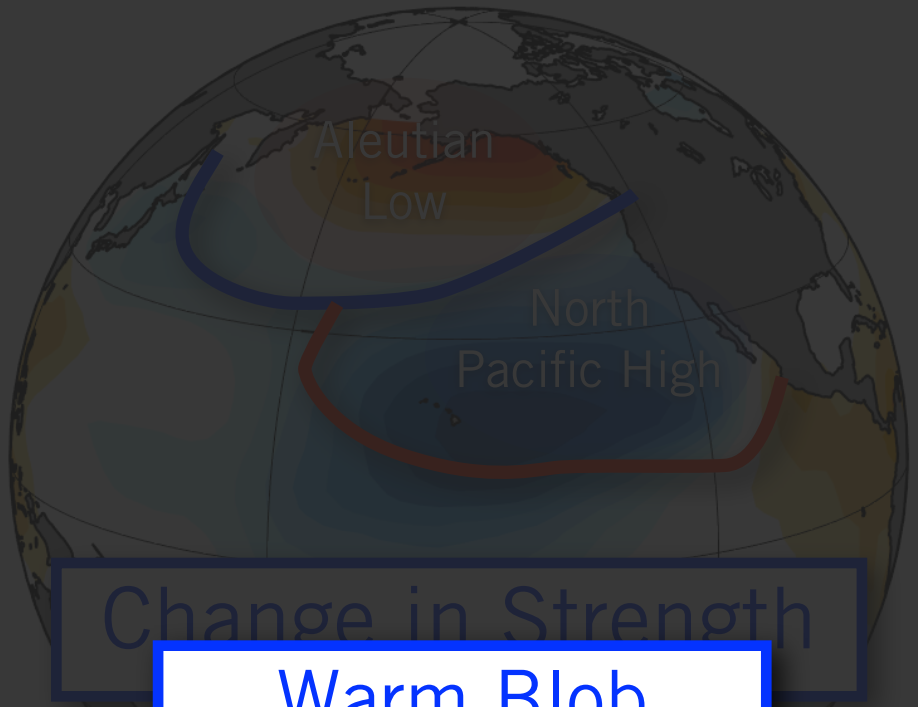

SLPa
Aleutian Low
North Pacific High
Change in Location
Change in Strength
SSTa
PDO-type
ARC Pattern
NPGO-type
GOA Pattern


Arctic
Aleutian Low
North Pacific High
ENSO
Change in Location
Change in Strength
SSTa
PDO-type
ARC Pattern
NPGO-type
GOA Pattern

SLPa



Change in Location

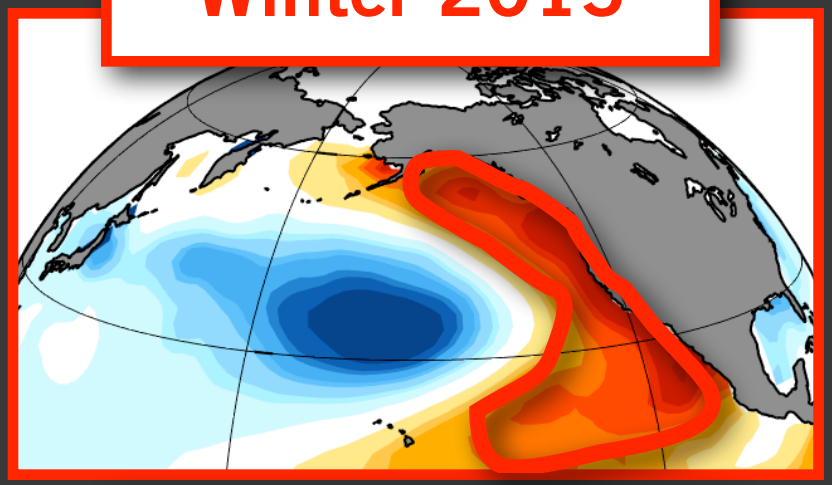


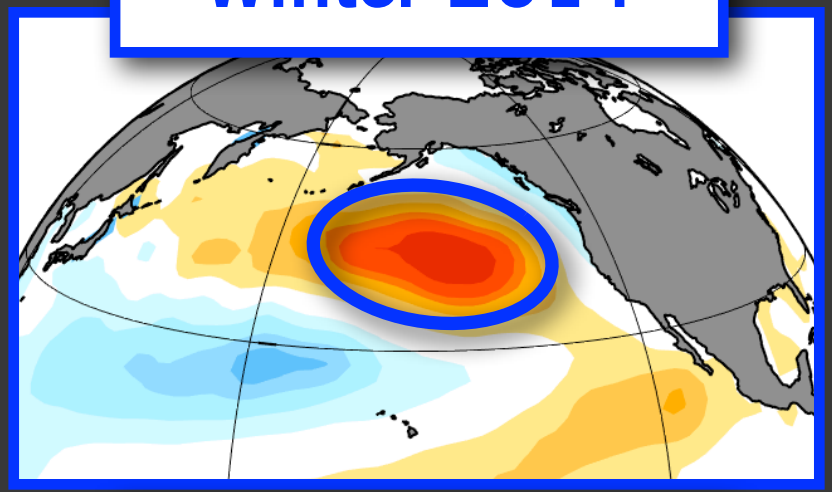
Change in Strength

Warm Blob
Winter 2015

Warm Blob
Winter 2014

SSTa





PDO-type
ARC Pattern

NPGO-type
GOA Pattern

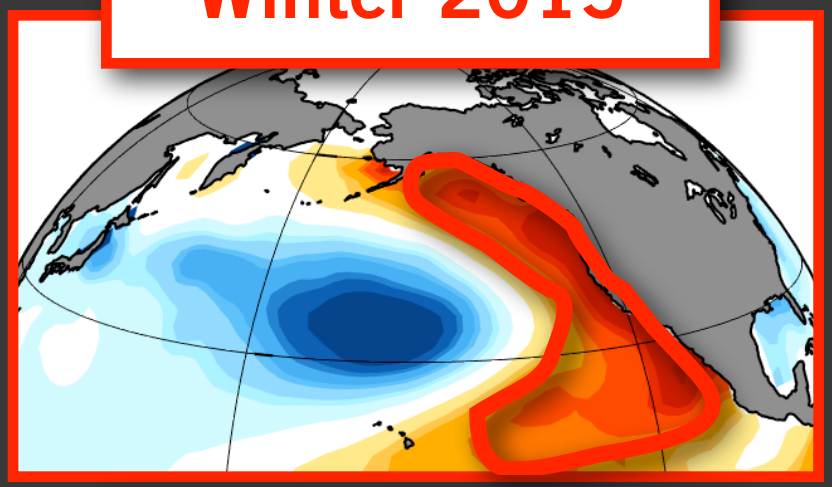
DISCUSS

- Atmospheric forcing of warm blob patterns

Change in Location

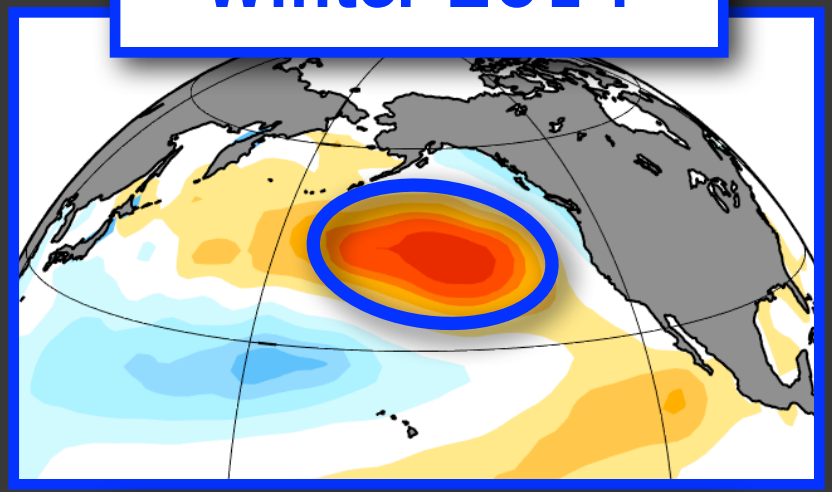
Change in Strength

Warm Blob
Winter 2015



SSTa

Warm Blob
Winter 2014



PDO-type
ARC Pattern

NPGO-type
GOA Pattern

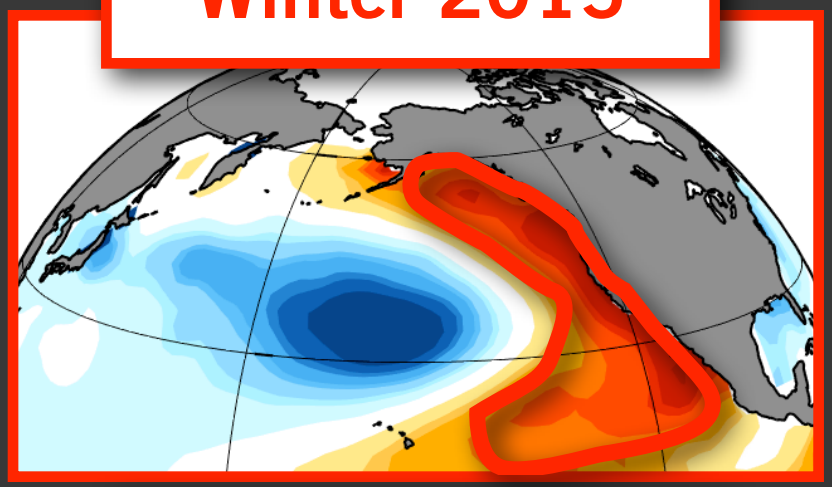
DISCUSS

- Atmospheric forcing of warm blob patterns
- Mechanisms linking 2014/15 patterns & multi-year persistence

Change in Location

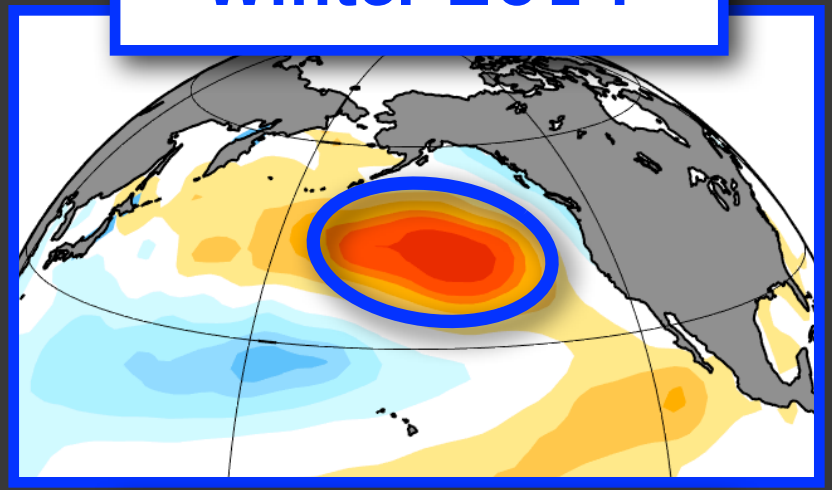
Change in Strength

Warm Blob
Winter 2015



SSTa

Warm Blob
Winter 2014



PDO-type
ARC Pattern

NPGO-type
GOA Pattern

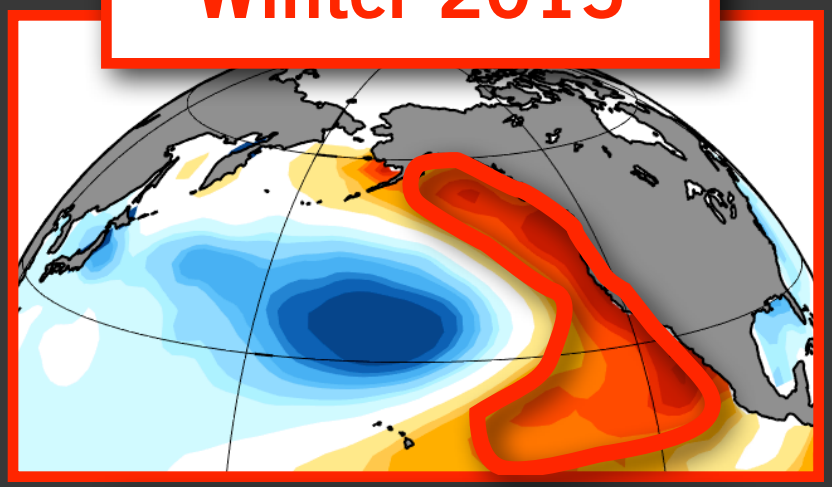
DISCUSS

- Atmospheric forcing of warm blob patterns
- Mechanisms linking 2014/15 patterns & multi-year persistence
- Increase in variance and coupling of North Pacific modes

Change in Location

Change in Strength

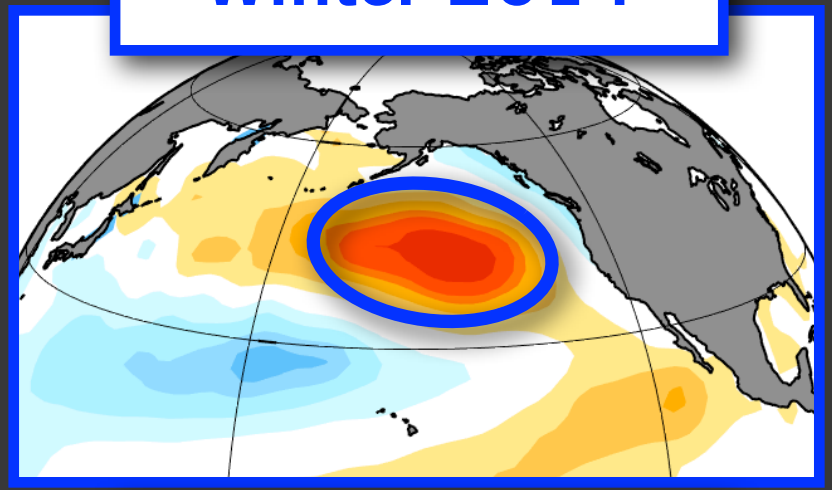
Warm Blob
Winter 2015



PDO-type
ARC Pattern

SSTa

Warm Blob
Winter 2014



NPGO-type
GOA Pattern