

Interactions between Pacific decadal modes (IPO, PDO, NPGO) and ENSO

Emanuele Di Lorenzo & Art Miller



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Georgia Institute
of **Technology**

Interactions between Pacific decadal modes (IPO, PDO, NPGO) and ENSO

QUESTION:

What are the sources of Pacific decadal variability?

A null-hypothesis for Pacific Decadal Climate

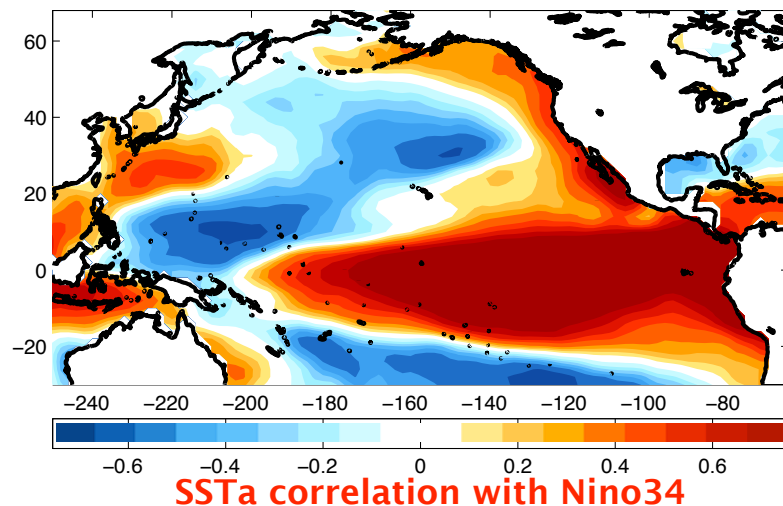
QUESTION:

What are the sources of Pacific decadal variability?

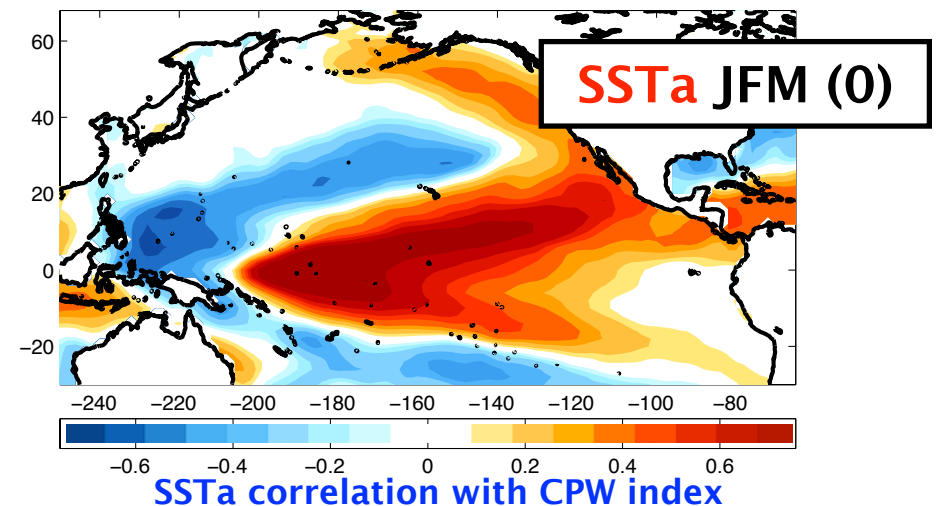
A null-hypothesis for Pacific Decadal Climate

FLAVORS OF TROPICAL VARIABILITY

Canonical ENSO



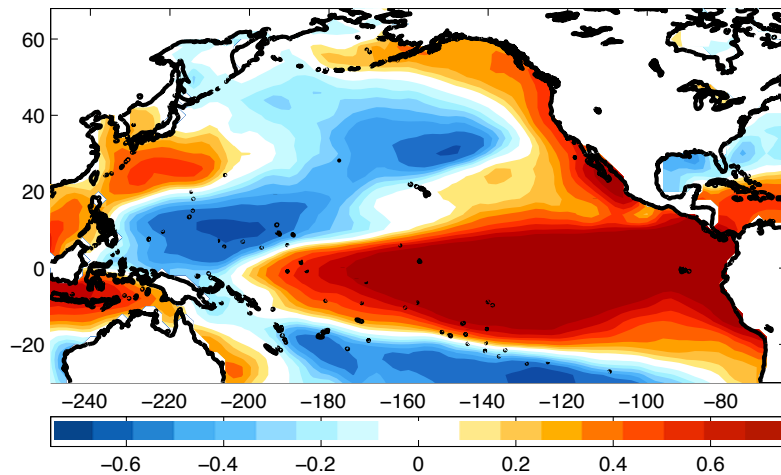
Non-Canonical CPW ENSO or Modoki



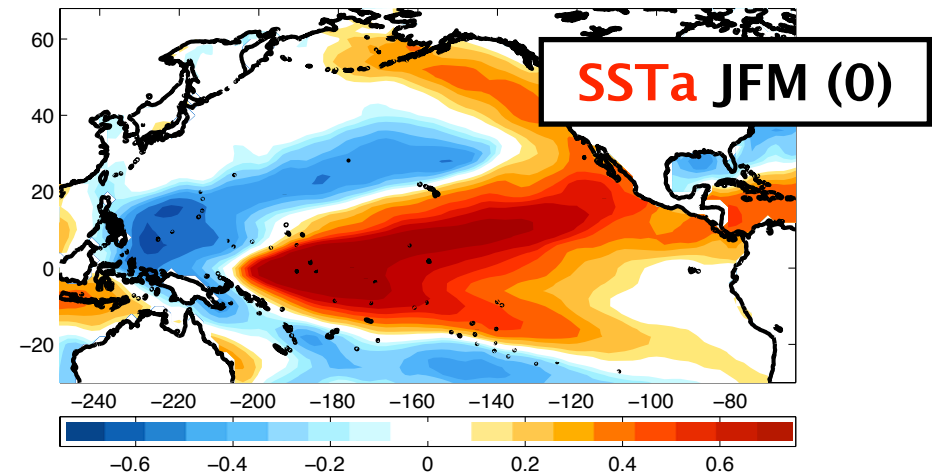
DYNAMIC COUPLING

Feedback mechanism:
equatorial upwelling, winds, thermocline depth, zonal u

Canonical ENSO



Non-Canonical CPW ENSO or Modoki



work by Xie et al.

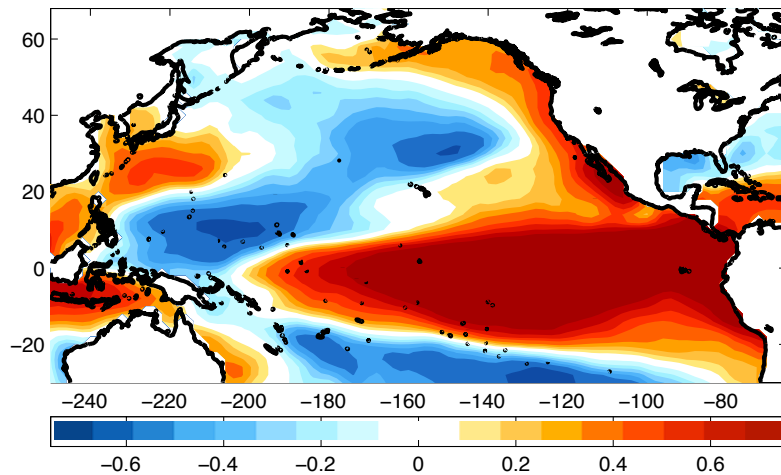
THERMODYNAMIC COUPLING

WES Feedback:
wind-evaporation-sea surface temperature

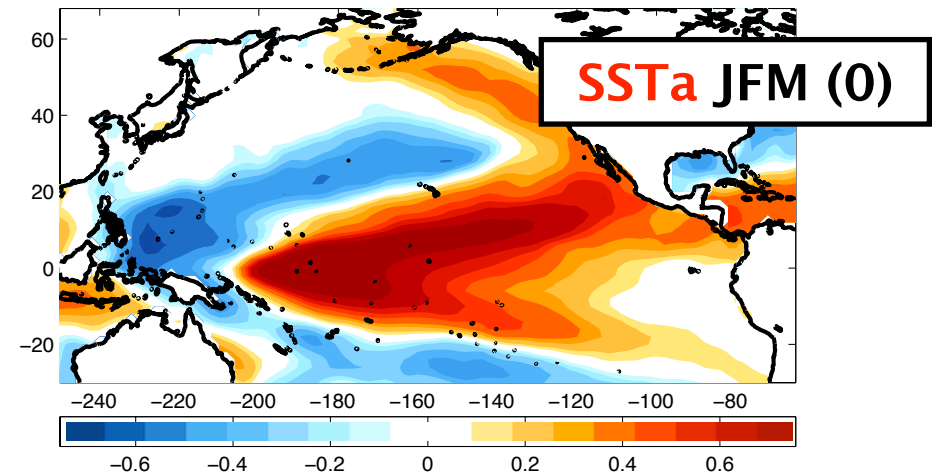
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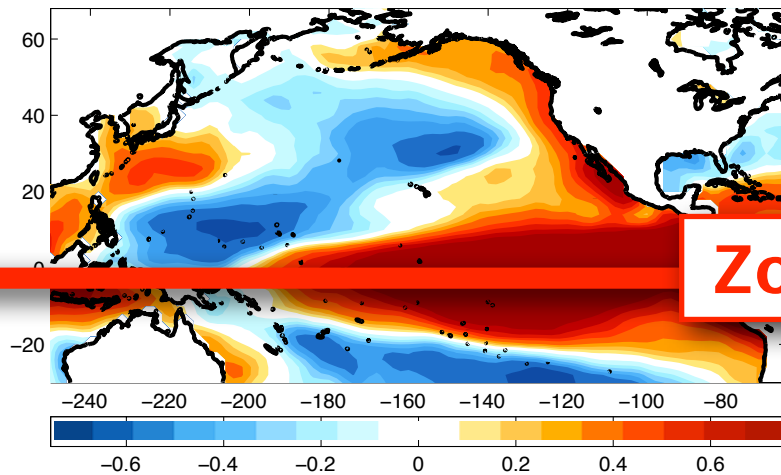
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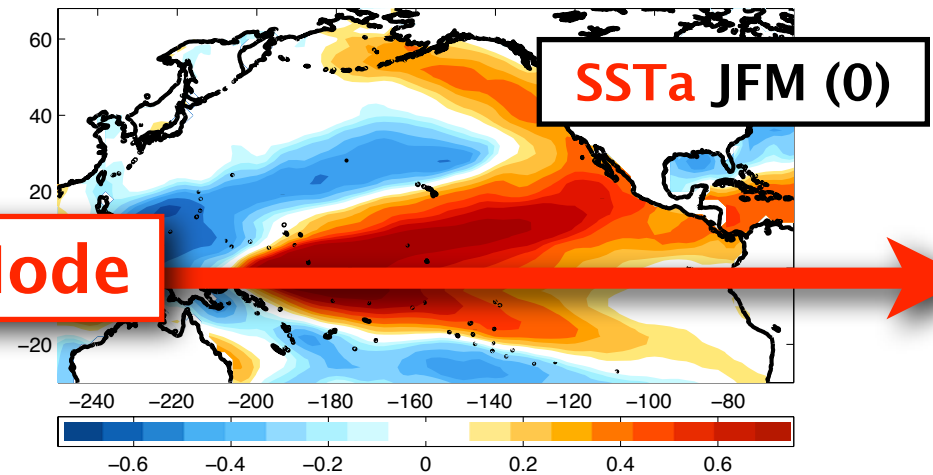
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Canonical ENSO



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SSTA JFM (0)

Zonal Mode

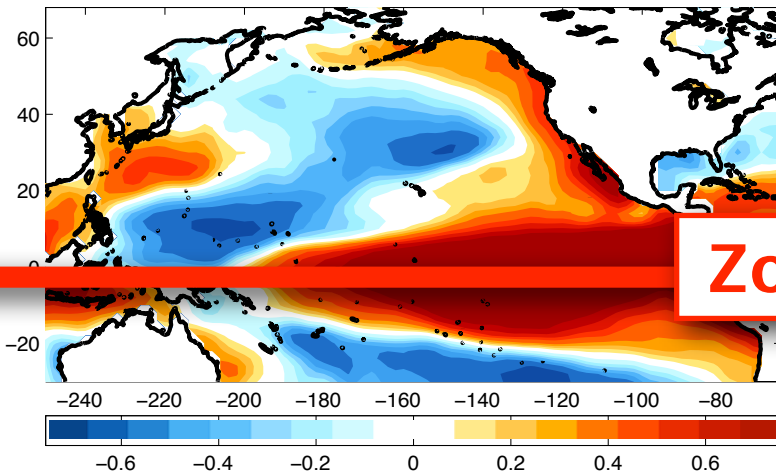
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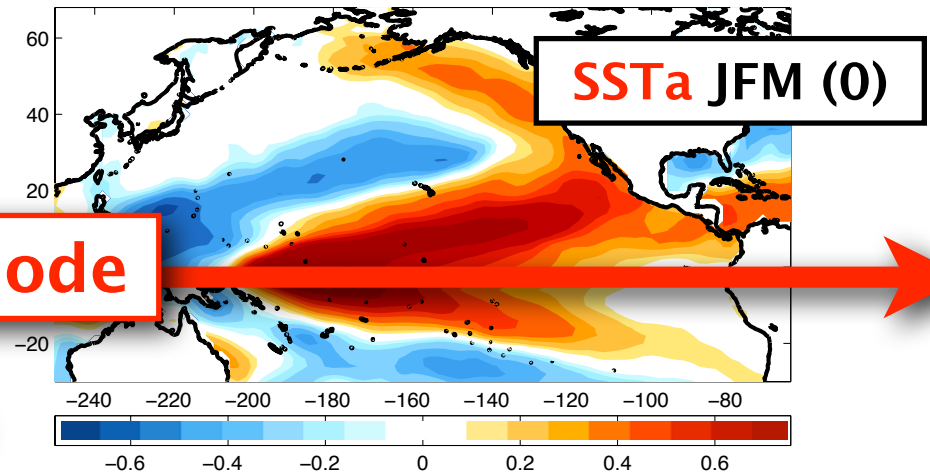
Meridional Mode

*work by Chang et al.
and Vimont, D. J. (2010): 2nd fastest
growing mode in tropical oceans*

Canonical ENSO



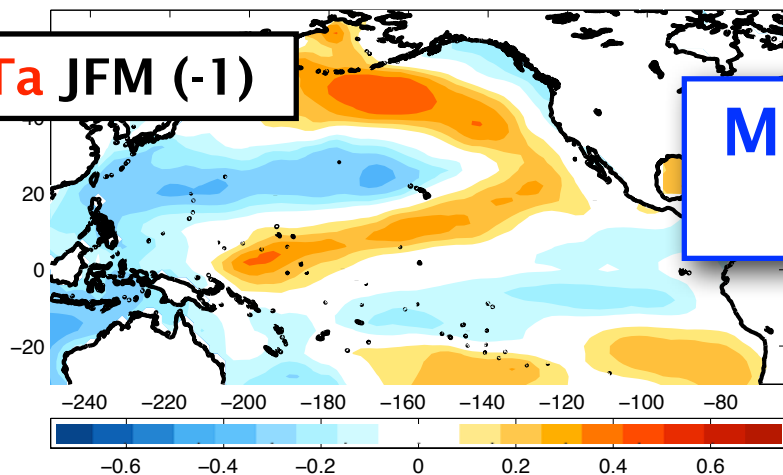
Non-Canonical CPW ENSO or Modoki



Zonal Mode

Previous Winter/Spring
ENSO SST Precursor Pattern
Penland 1995

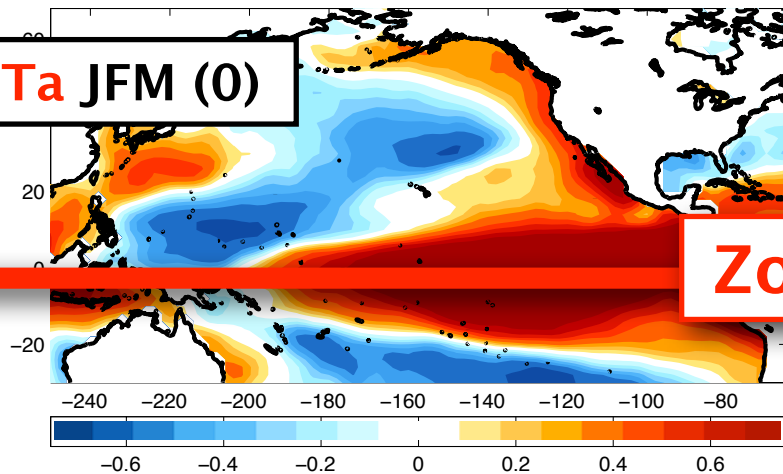
SSTa JFM (-1)



**Meridional
Mode**

Canonical ENSO

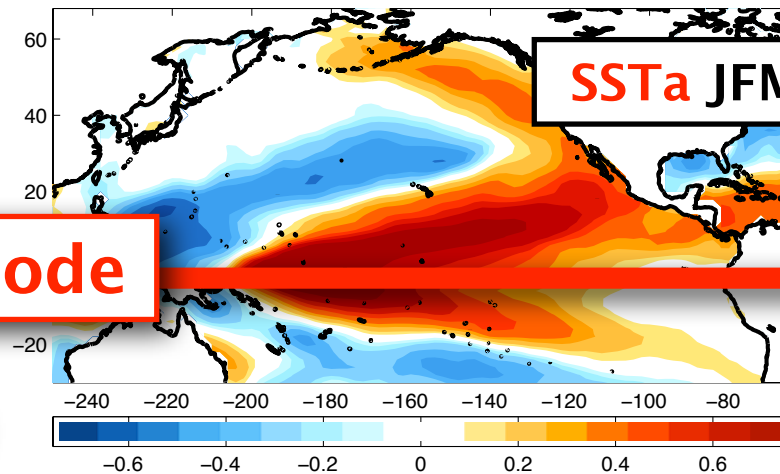
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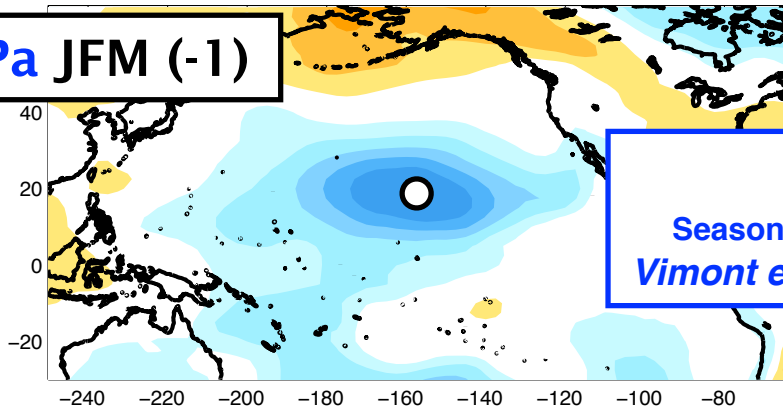
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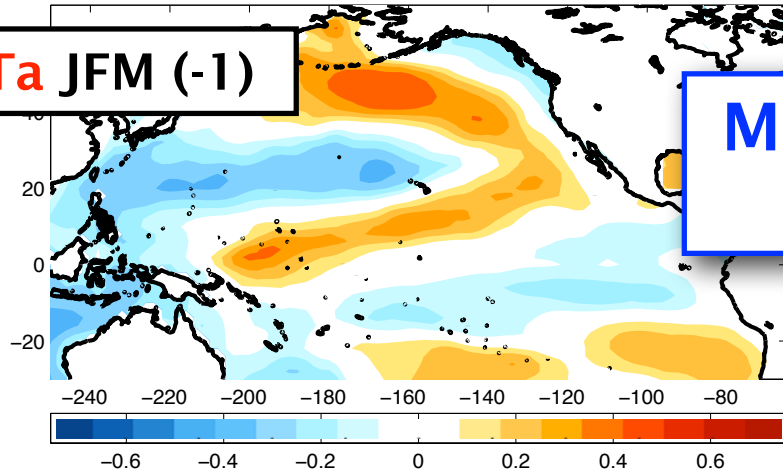
SLPa JFM (-1)



SFM

Seasonal Footprinting Mechanism
Vimont et al. 2003; Anderson 2003

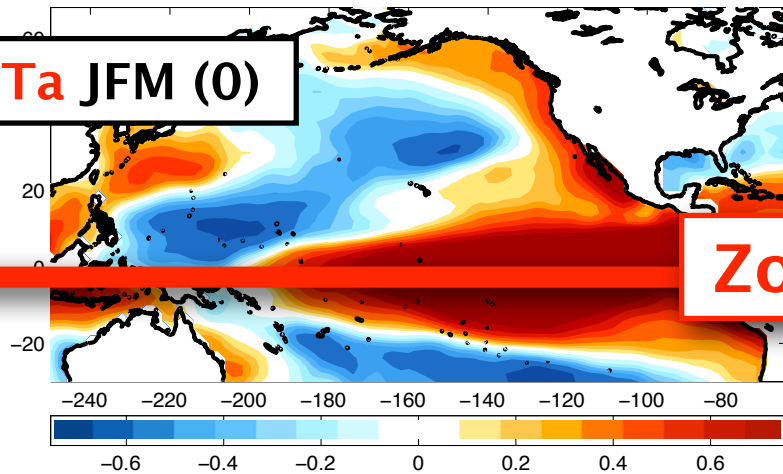
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Meridional Mode

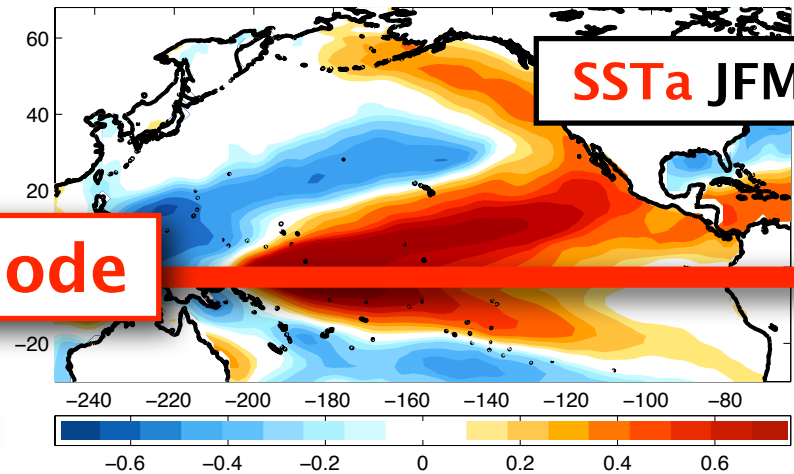
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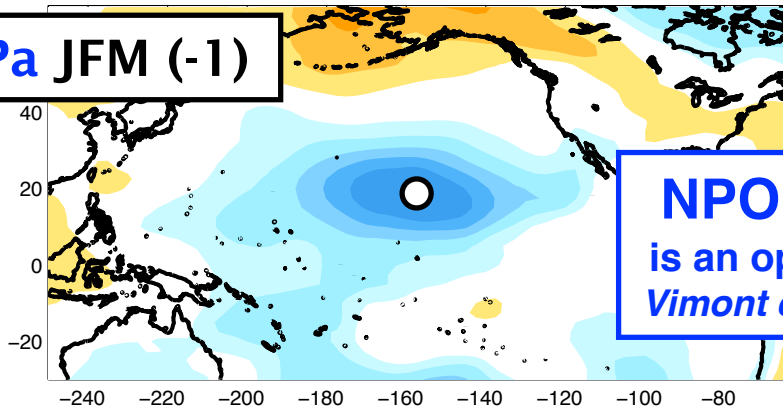
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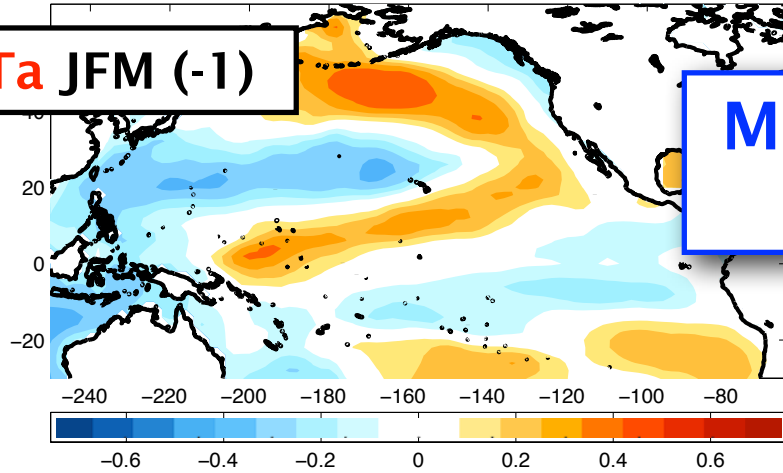
Zonal Mode

SLPa JFM (-1)



NPO (2nd atmospheric mode)
is an optimal excitation pattern
Vimont et al. 2003; Anderson 2003

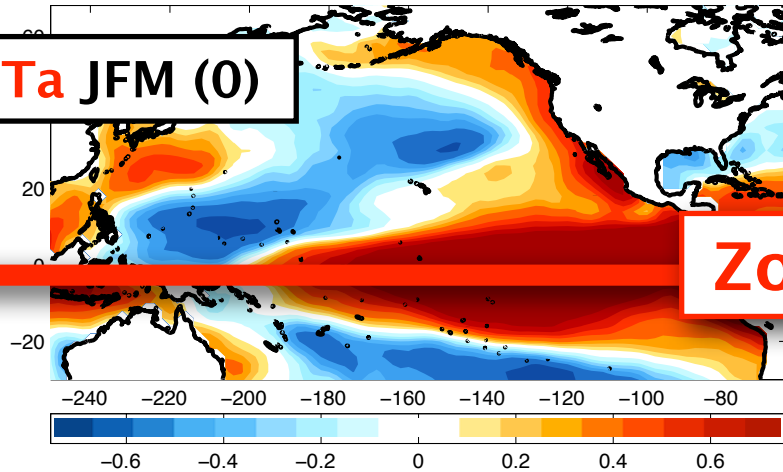
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**Meridional
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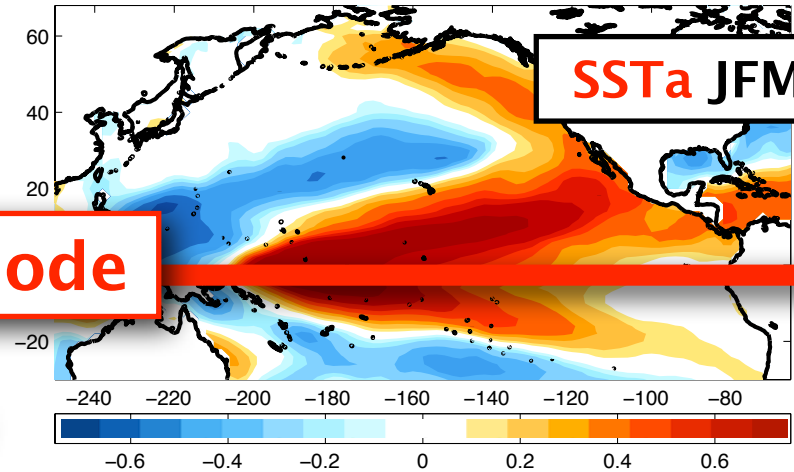
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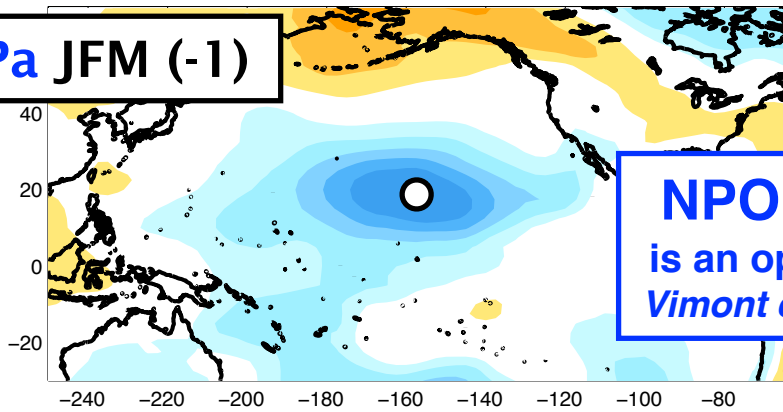
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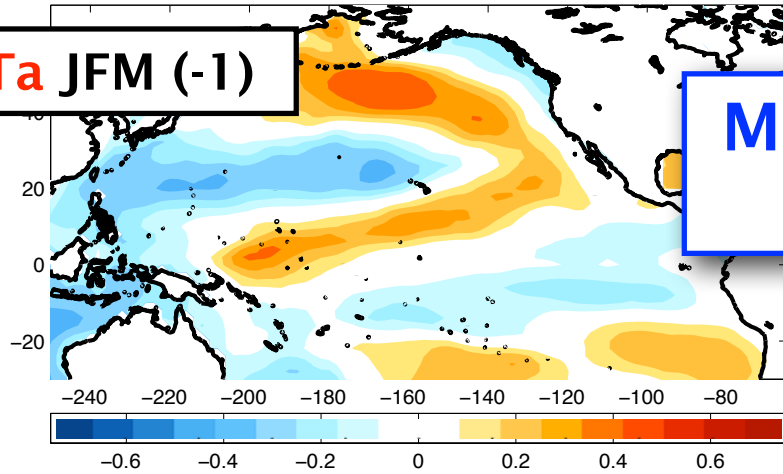
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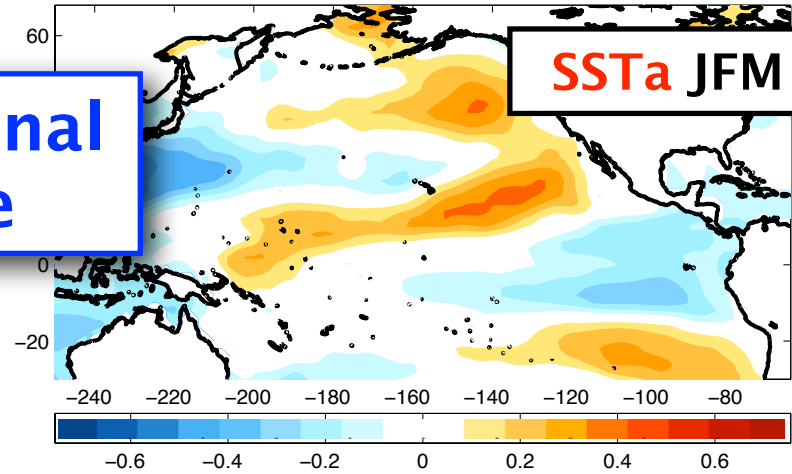
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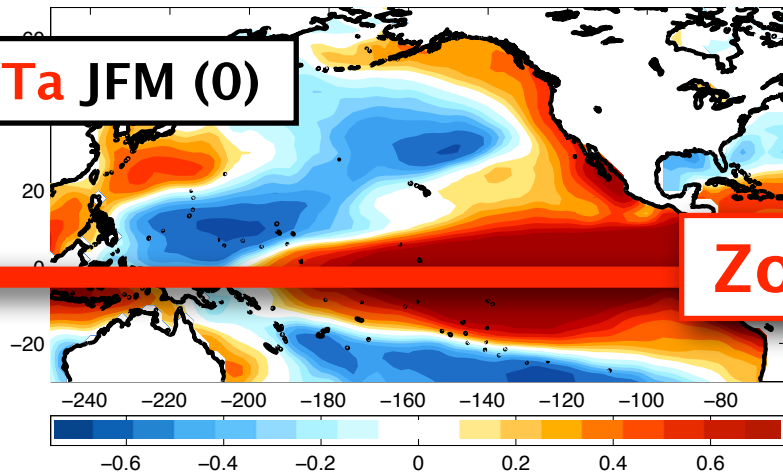
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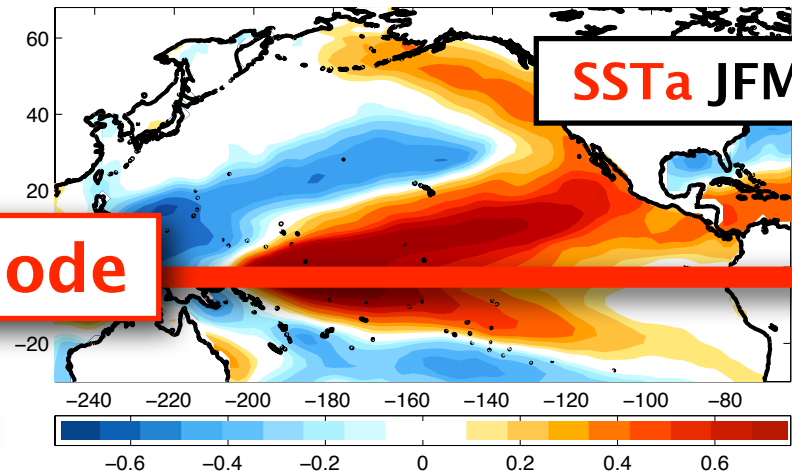
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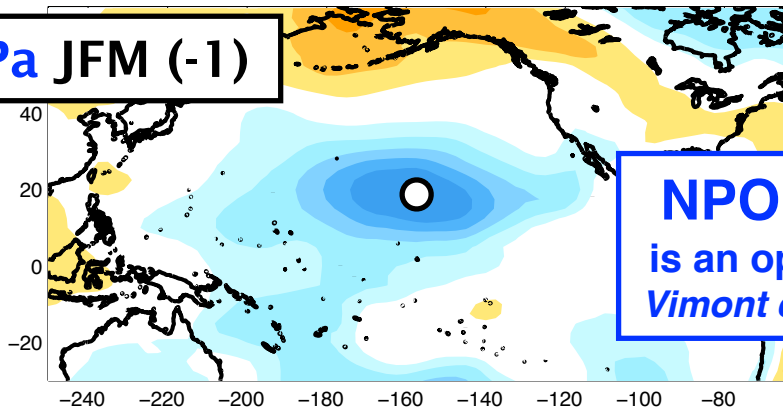
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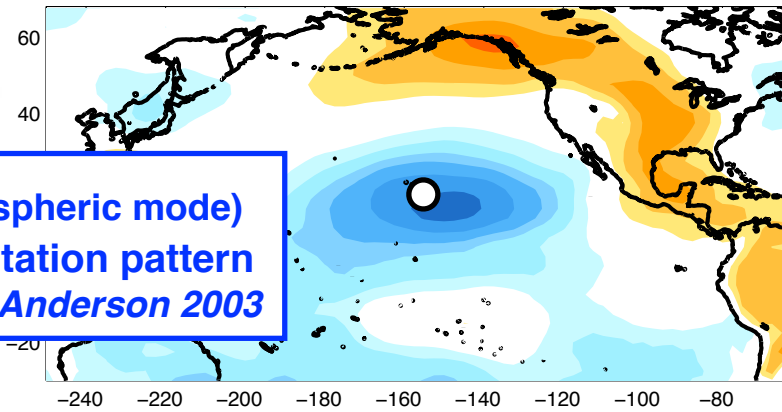
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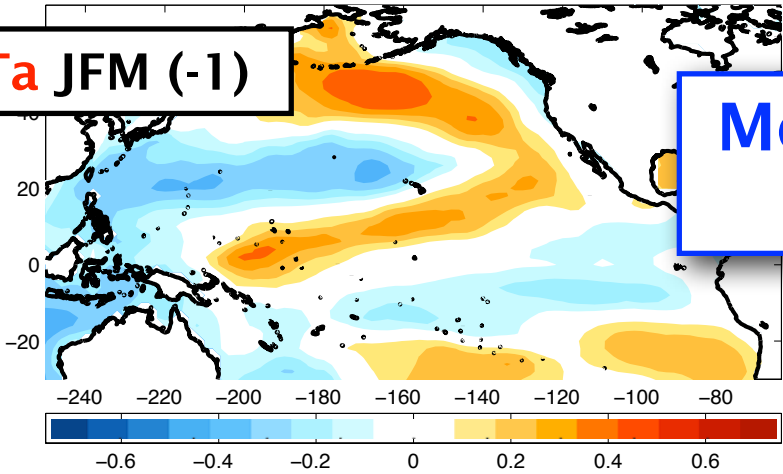
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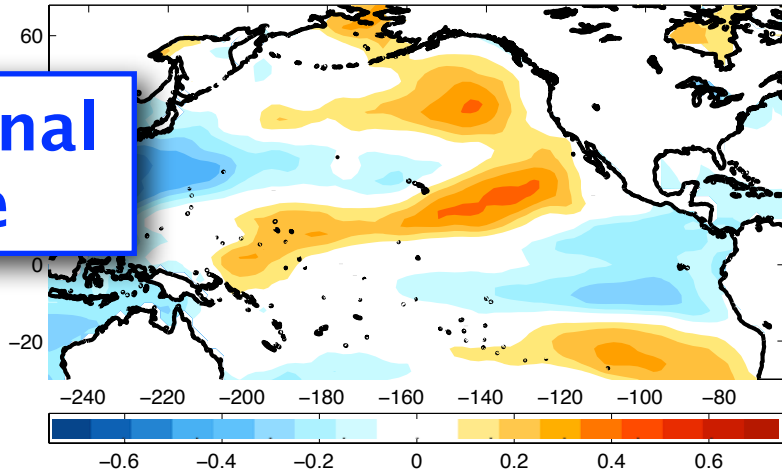
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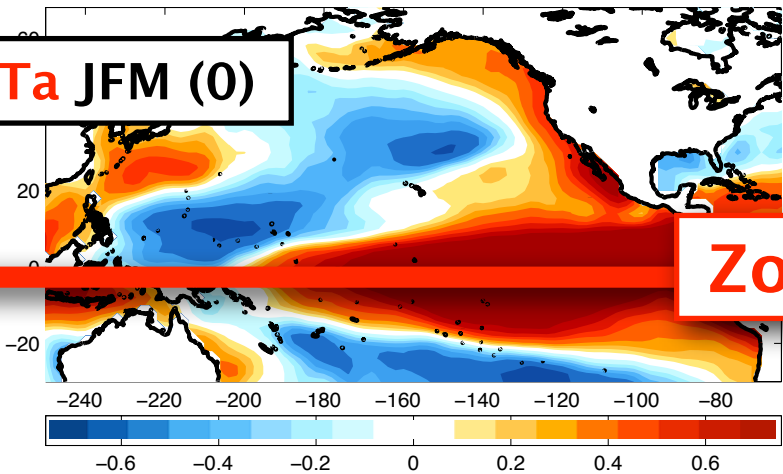


Meridional Mode



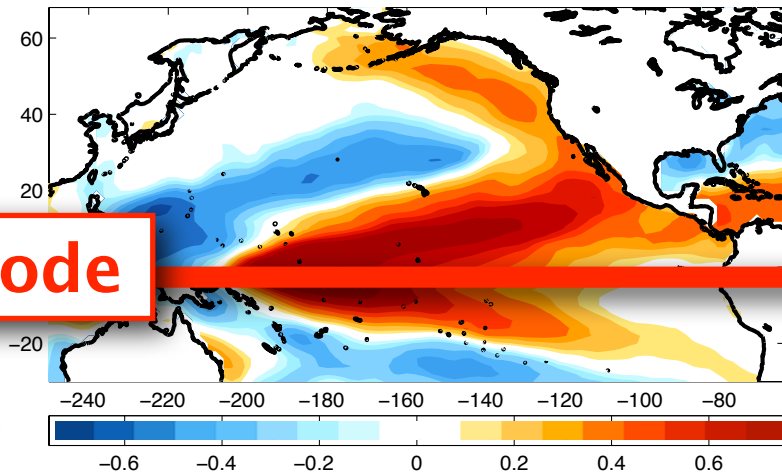
Canonical ENSO

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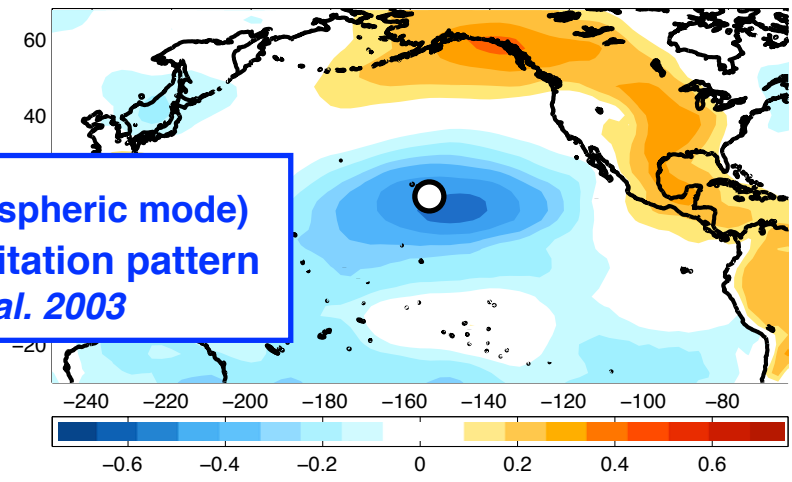


Zonal Mode

Non-Canonical CPW ENSO or Modoki

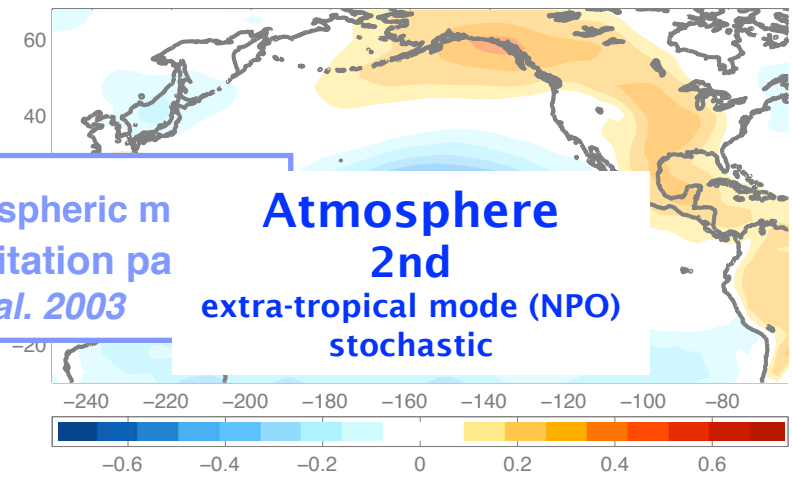


NPO (2nd atmospheric mode)
is an optimal excitation pattern
Vimont et al. 2003



NPO (2nd atmospheric mode) is an optimal excitation pattern
Vimont et al. 2003

Atmosphere
2nd
extra-tropical mode (NPO)
stochastic



A NULL-HYPOTHESIS FOR PACIFIC CLIMATE DYNAMICS

Extra-tropics [Ocean forced by Atmosphere]

Atmosphere
2nd
extra-tropical mode (NPO)
stochastic

Tropics [Ocean-Atmosphere Coupled System]

A NULL-HYPOTHESIS FOR PACIFIC CLIMATE DYNAMICS

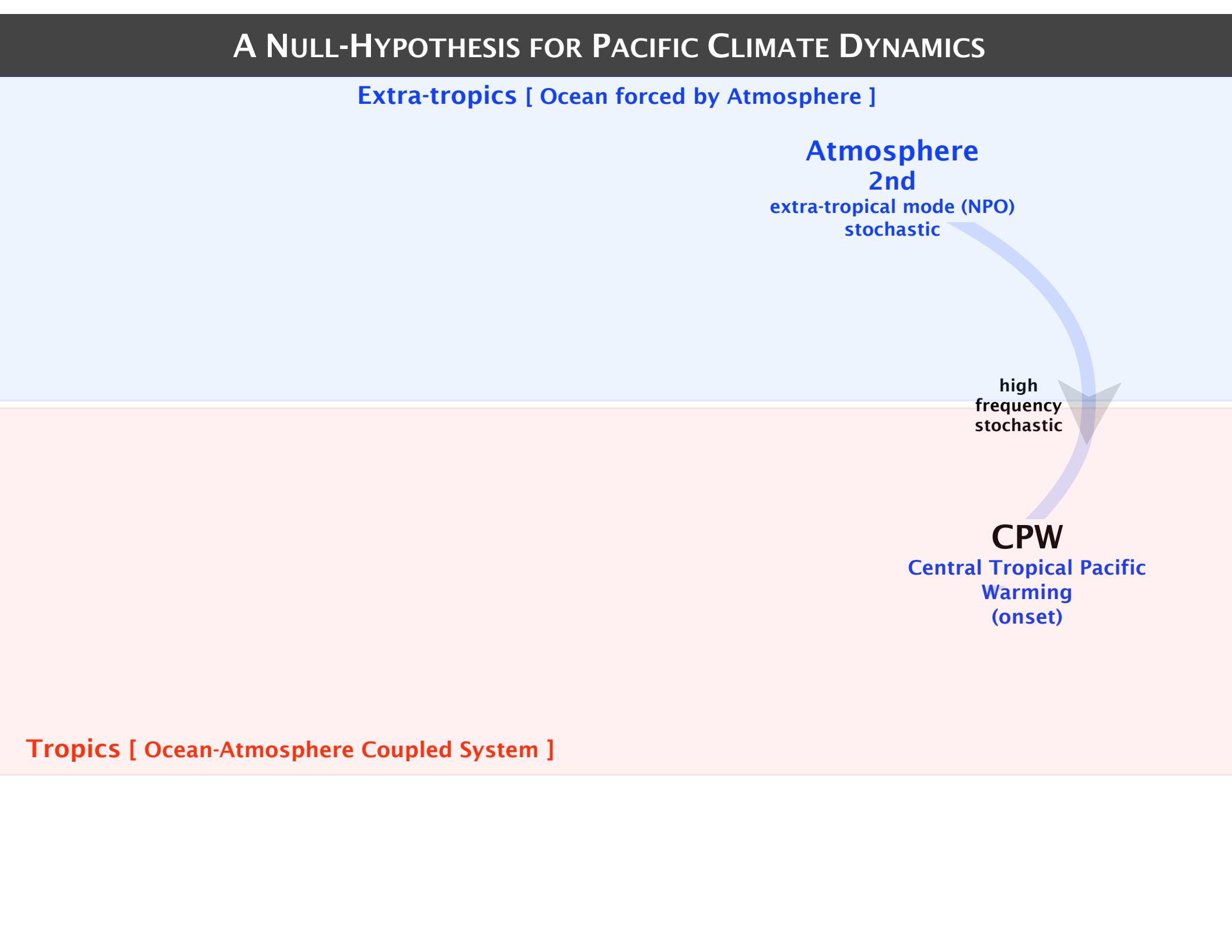
Extra-tropics [Ocean forced by Atmosphere]

Atmosphere
2nd
extra-tropical mode (NPO)
stochastic

high
frequency
stochastic

CPW
Central Tropical Pacific
Warming
(onset)

Tropics [Ocean-Atmosphere Coupled System]



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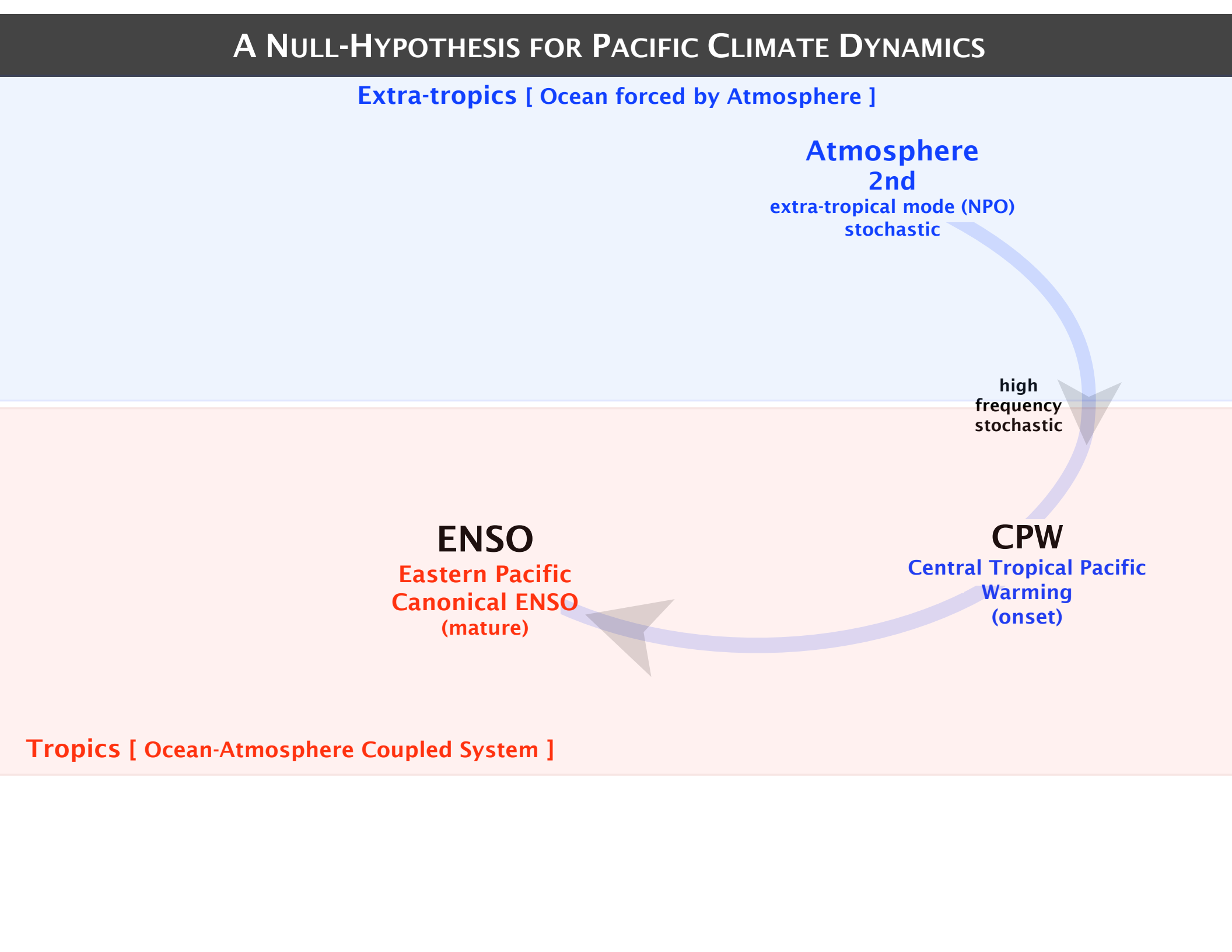
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ENSO
Eastern Pacific
Canonical ENSO
(mature)

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Central Tropical Pacific
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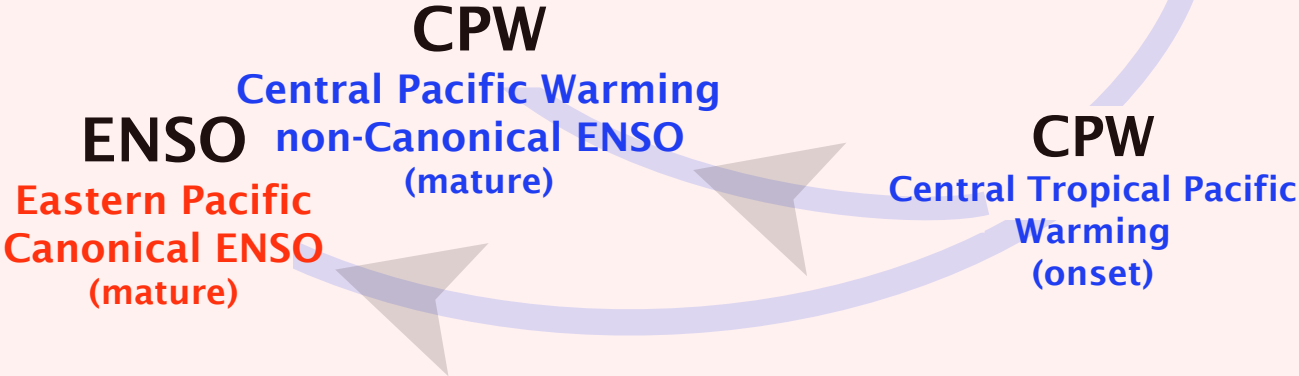


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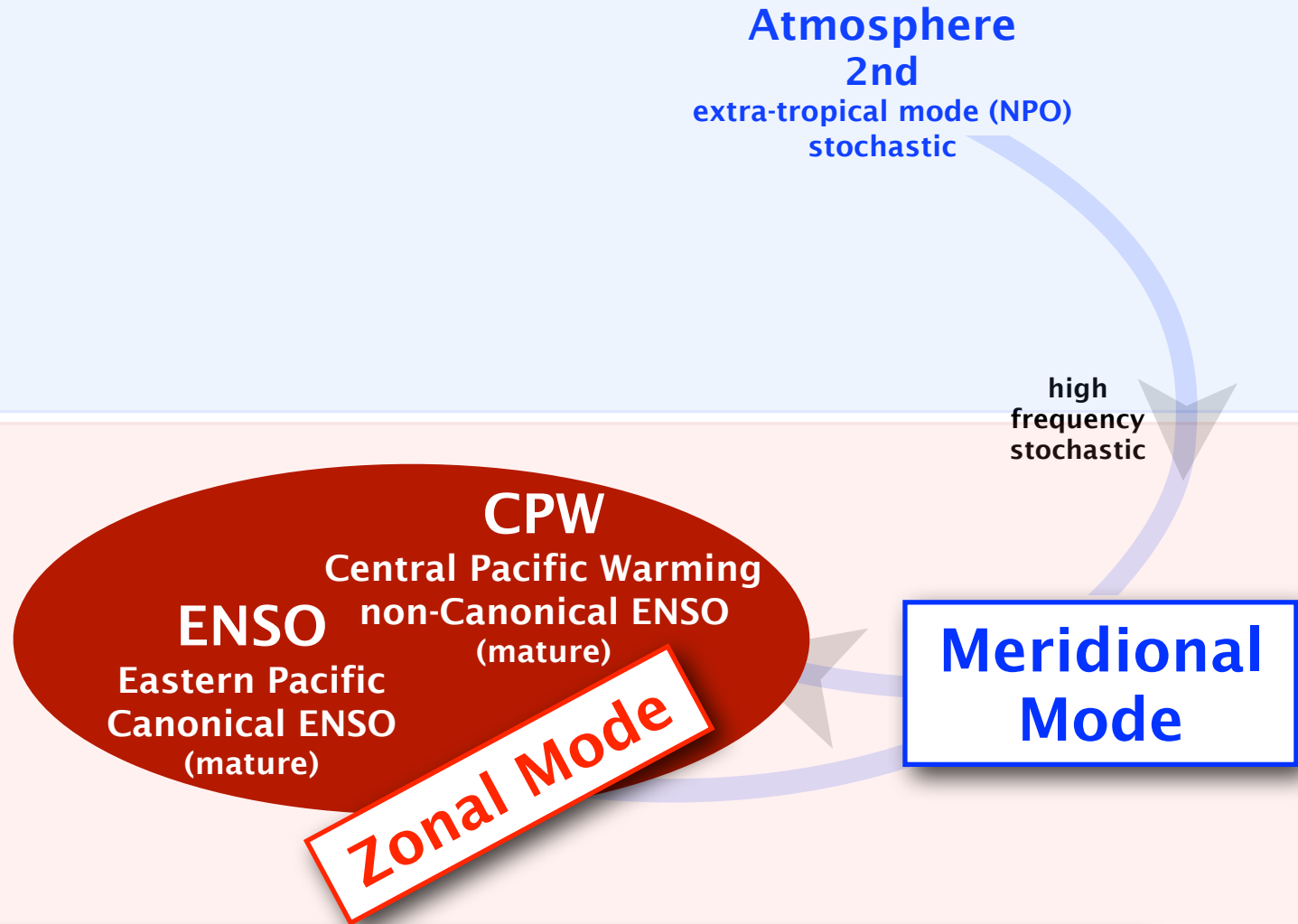
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Tropics [Ocean-Atmosphere Coupled System]

A NULL-HYPOTHESIS FOR PACIFIC CLIMATE DYNAMICS

Extra-tropics [Ocean forced by Atmosphere]



STATEMENT #1:

The Meridional Mode energizes tropical interannual variance by exciting Zonal Mode dynamics responses

A NULL-HYPOTHESIS FOR PACIFIC CLIMATE DYNAMICS

Extra-tropics [Ocean forced by Atmosphere]

Atmosphere
1st
extra-tropical mode (AL)

Atmosphere
2nd
extra-tropical mode (NPO)
stochastic

high
frequency
stochastic



Zonal Mode

**Meridional
Mode**

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Extra-tropics [Ocean forced by Atmosphere]

Atmosphere
1st
extra-tropical mode (AL)

Ocean
1st
extra-tropical mode (PDO)

Atmosphere
2nd
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high
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stochastic



Meridional Mode

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Atmosphere
1st
extra-tropical mode (AL)

Ocean
1st
extra-tropical mode (PDO)

Atmosphere
2nd
extra-tropical mode (NPO)
deterministic + stochastic

high
frequency
stochastic

Di Lorenzo et al. 2010
Furtado et al., 2012

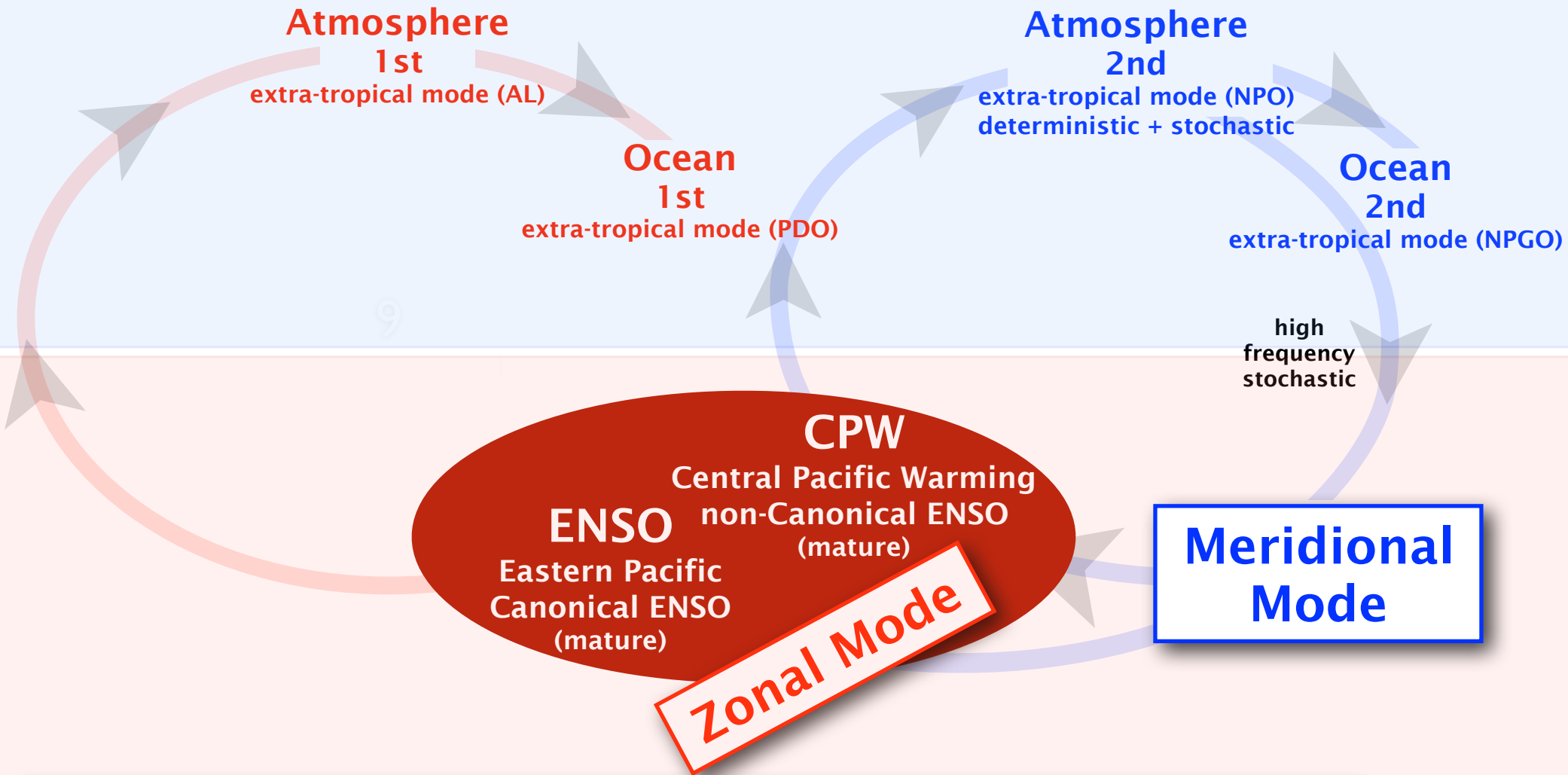


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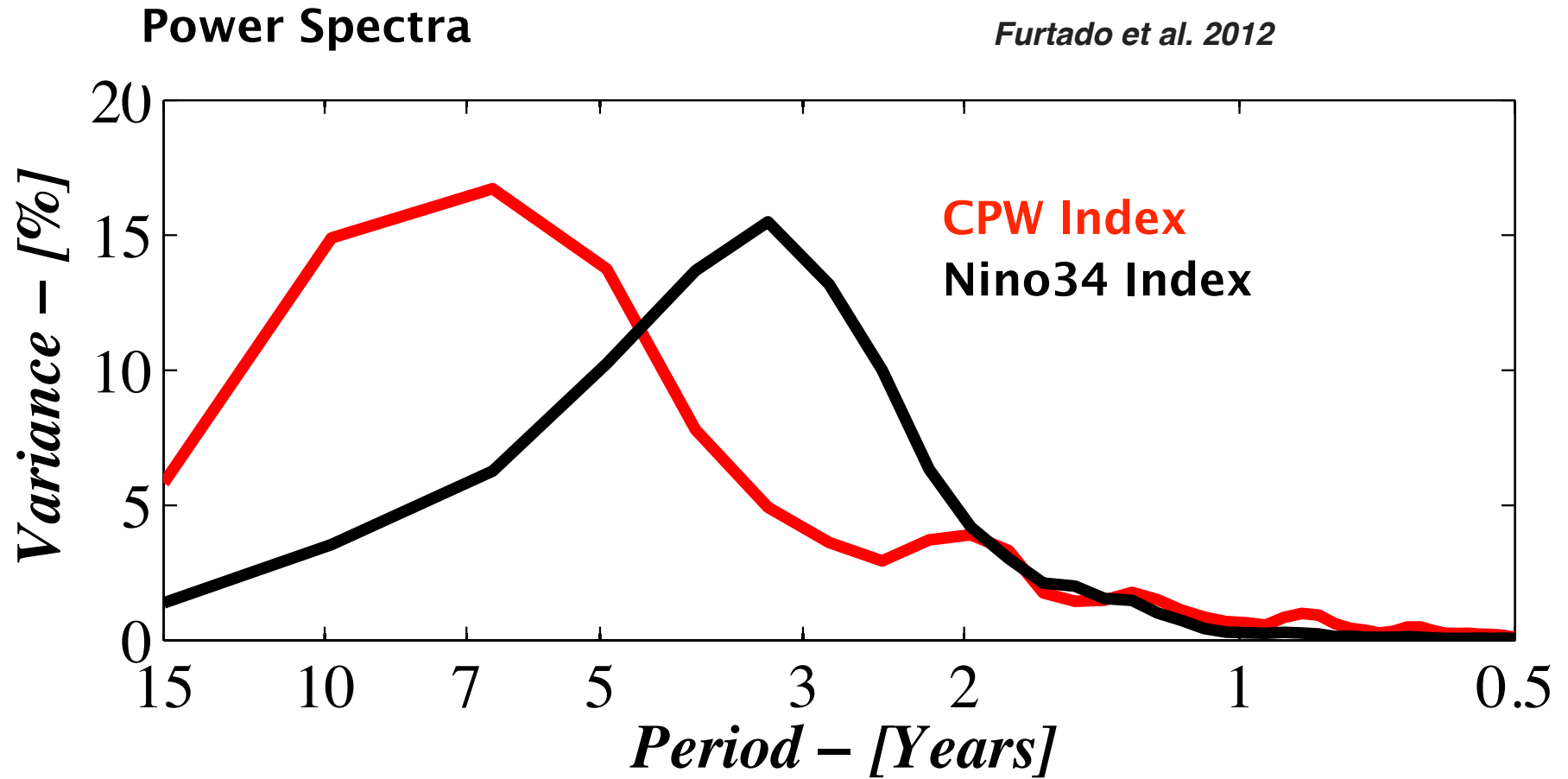
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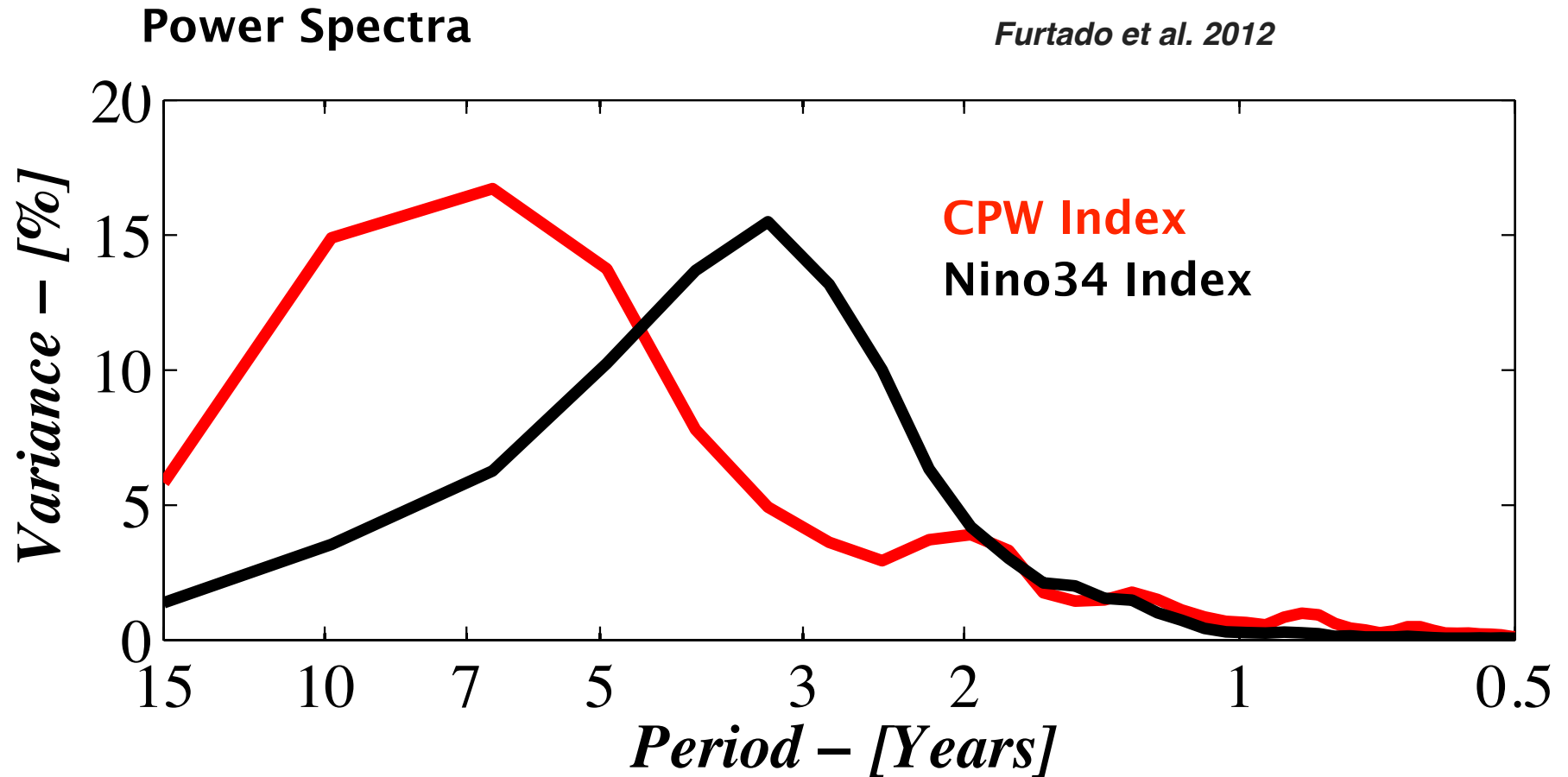
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A NULL-HYPOTHESIS FOR PACIFIC CLIMATE DYNAMICS



Tropics [Ocean-Atmosphere Coupled System]

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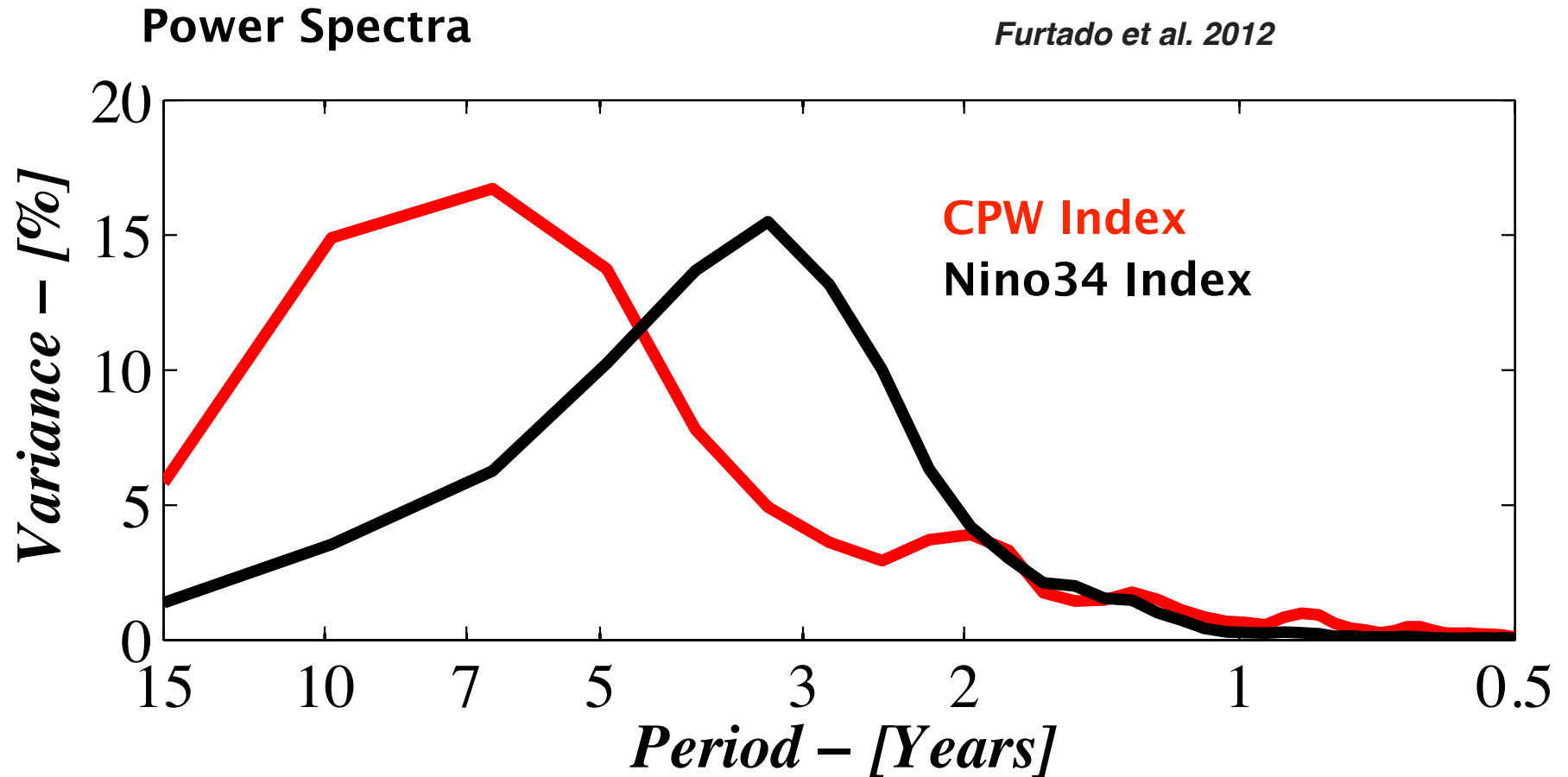


Tropics [Ocean-Atmosphere Coupled System]

QUESTION:

What is the source of this decadal power in the tropics?

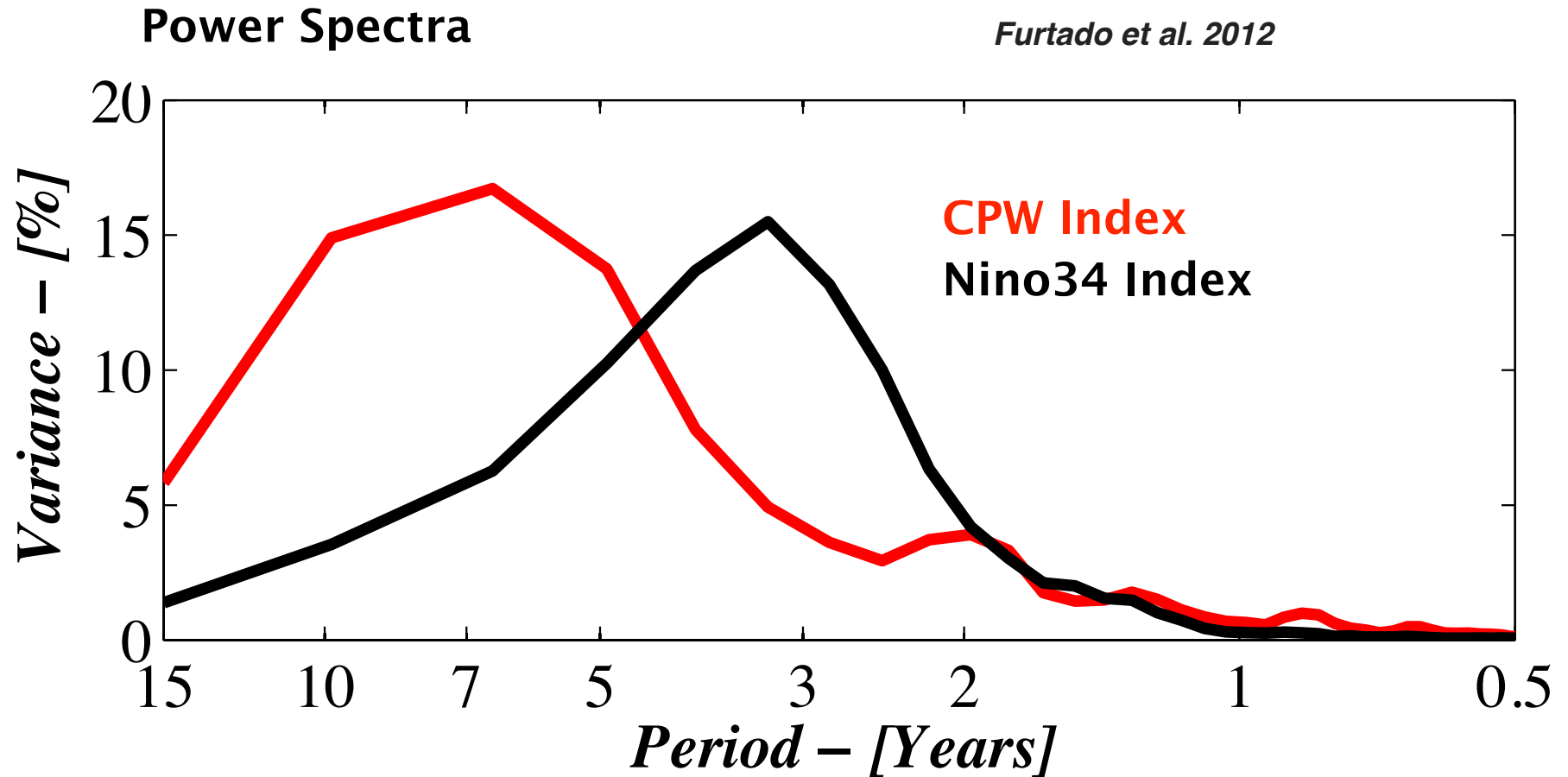
A NULL-HYPOTHESIS FOR PACIFIC CLIMATE DYNAMICS



QUESTION:

Is the decadal power of the tropics controlled by Zonal Mode dynamics (e.g. ENSO)?

A NULL-HYPOTHESIS FOR PACIFIC CLIMATE DYNAMICS

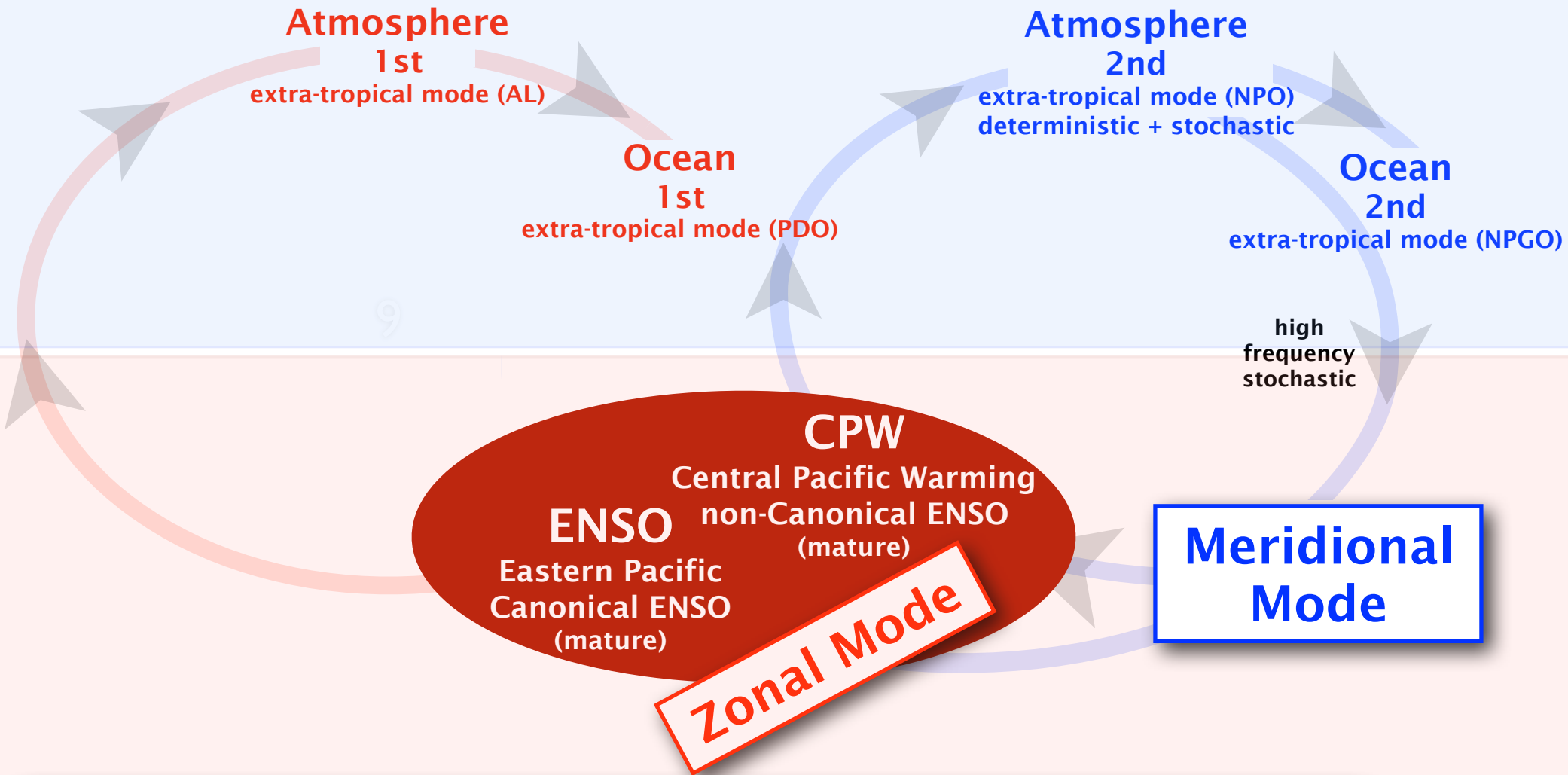


QUESTION:

Can the Meridional Mode act as an independent and primary source of tropical decadal variance?

A NULL-HYPOTHESIS FOR PACIFIC CLIMATE DYNAMICS

Extra-tropics [Ocean forced by Atmosphere]



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Can the Meridional Mode act as an independent and primary source of tropical decadal variance?

A NULL-HYPOTHESIS FOR PACIFIC CLIMATE DYNAMICS

Extra-tropics [Ocean forced by Atmosphere]

Atmosphere
1st
extra-tropical mode (AL)

Ocean
1st
extra-tropical mode (PDO)

Atmosphere
2nd
extra-tropical mode (NPO)
deterministic + stochastic

Ocean
2nd
extra-tropical mode (NPGO)

high
frequency
stochastic

ENSO-like
Decadal Variability

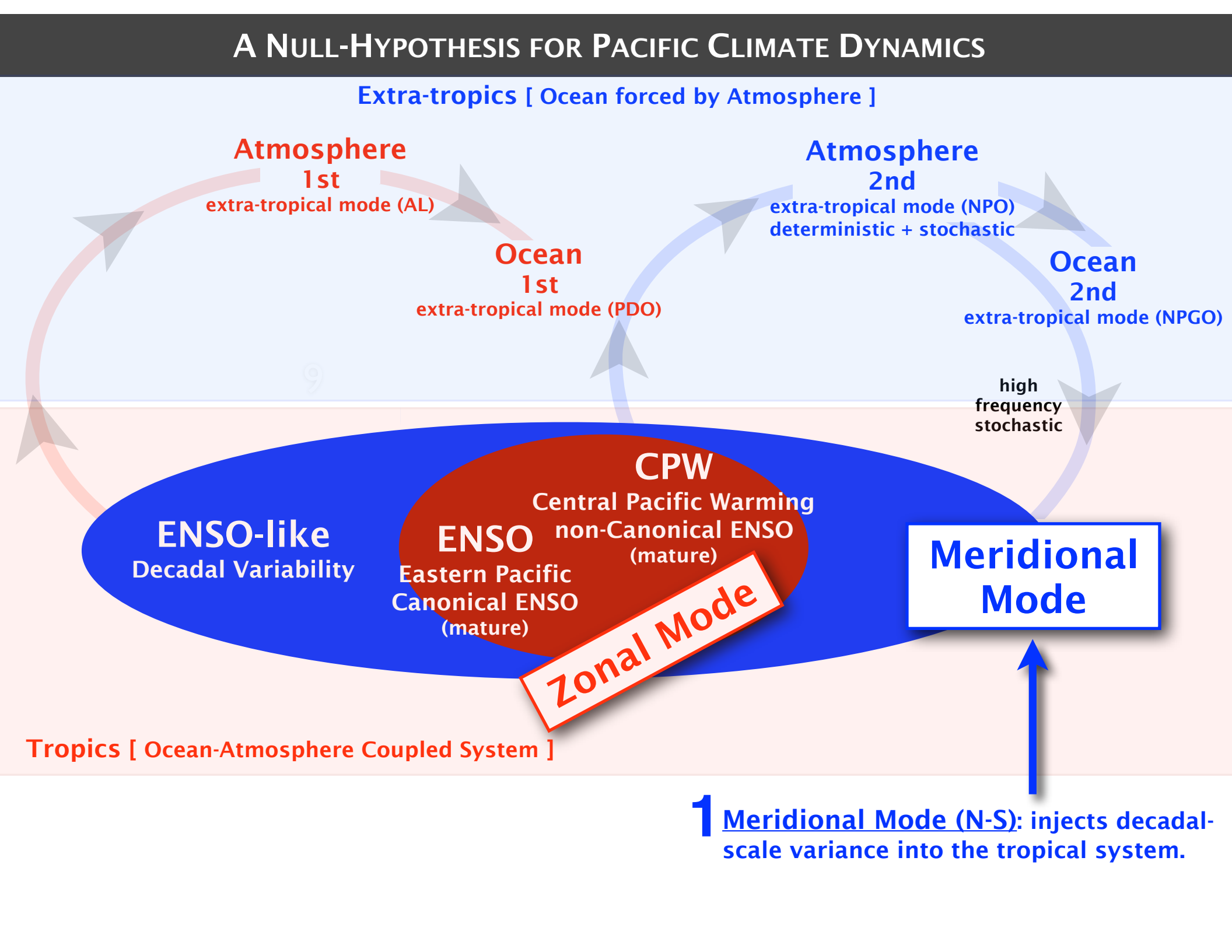
CPW
Central Pacific Warming
non-Canonical ENSO
(mature)
ENSO
Eastern Pacific
Canonical ENSO
(mature)

Zonal Mode

Meridional
Mode

Tropics [Ocean-Atmosphere Coupled System]

1 Meridional Mode (N-S): injects decadal-scale variance into the tropical system.



A NULL-HYPOTHESIS FOR PACIFIC CLIMATE DYNAMICS

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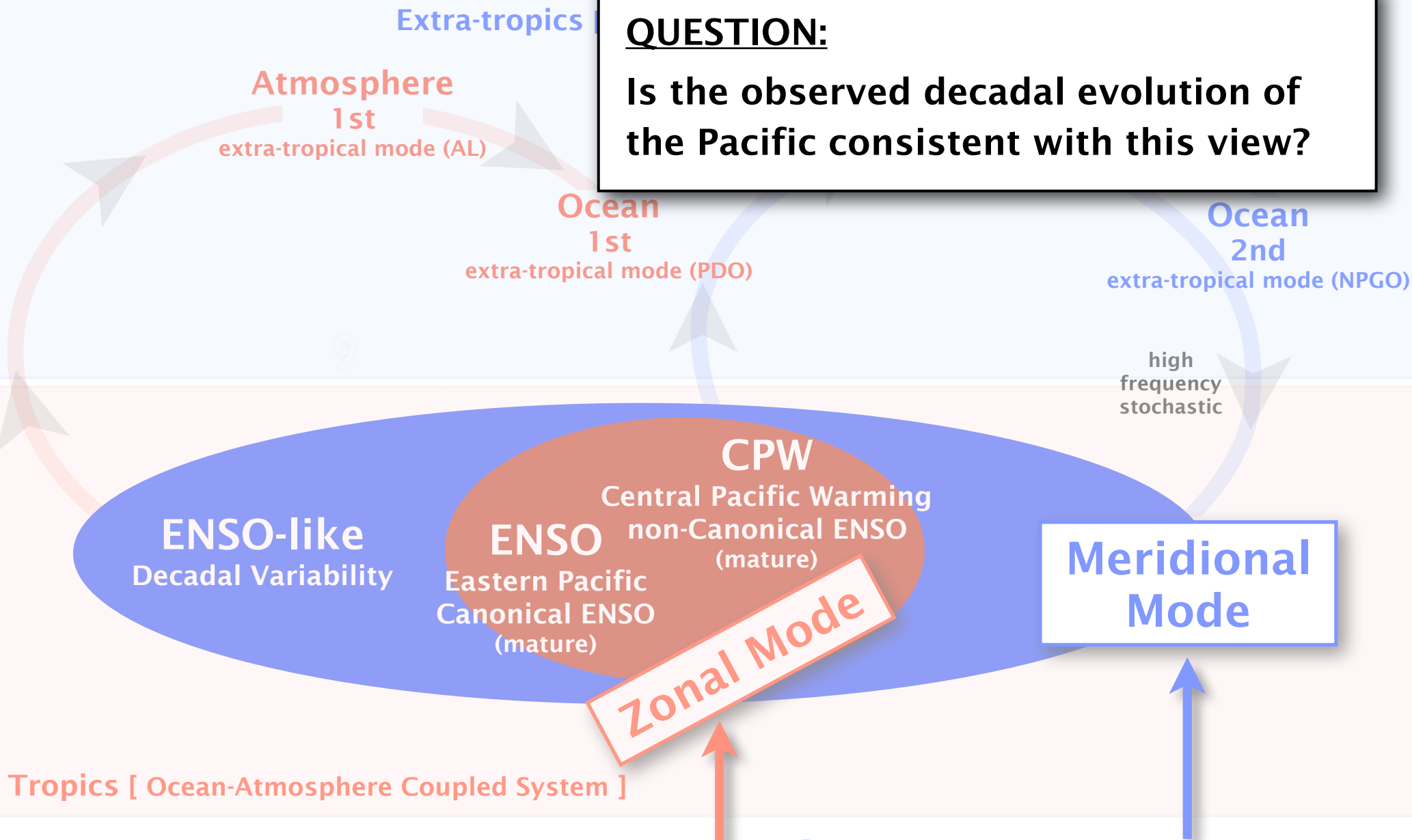
2 Zonal Mode (E-W): respond and amplify the MM anomalies in the tropics and excites teleconnections that add memory to the coupled system.

1 Meridional Mode (N-S): injects decadal-scale variance into the tropical system.

A NULL-HYPOTHESIS FOR PACIFIC CLIMATE DYNAMICS

QUESTION:

Is the observed decadal evolution of the Pacific consistent with this view?



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1 Meridional Mode (N-S): injects decadal-scale variance into the tropical system.

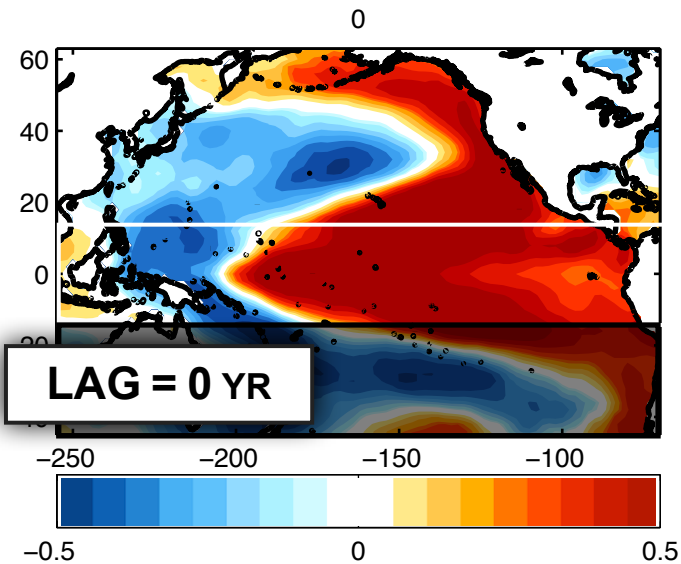
QUESTION:

Is the observed decadal evolution of the Pacific consistent with this view?

APPROACH:

- 1. NOAA SSTa 1950-2012 and apply 8YR lowpass filter**
- 2. Compute EOF/PC 1 in tropics [10S 10N] (~50-60% of variance!)**
- 3. Make lead/lag correlation maps of PC1 with 8yr lowpass SSTa**

OBSERVATIONS



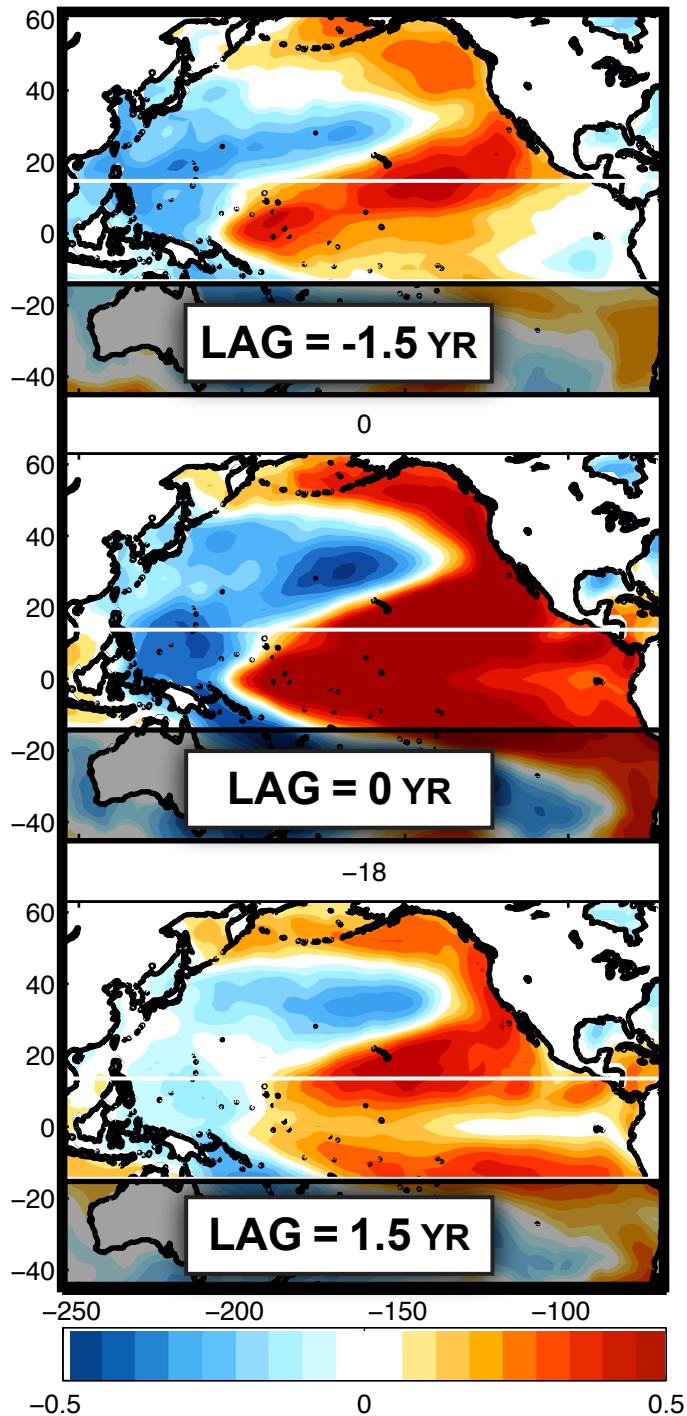
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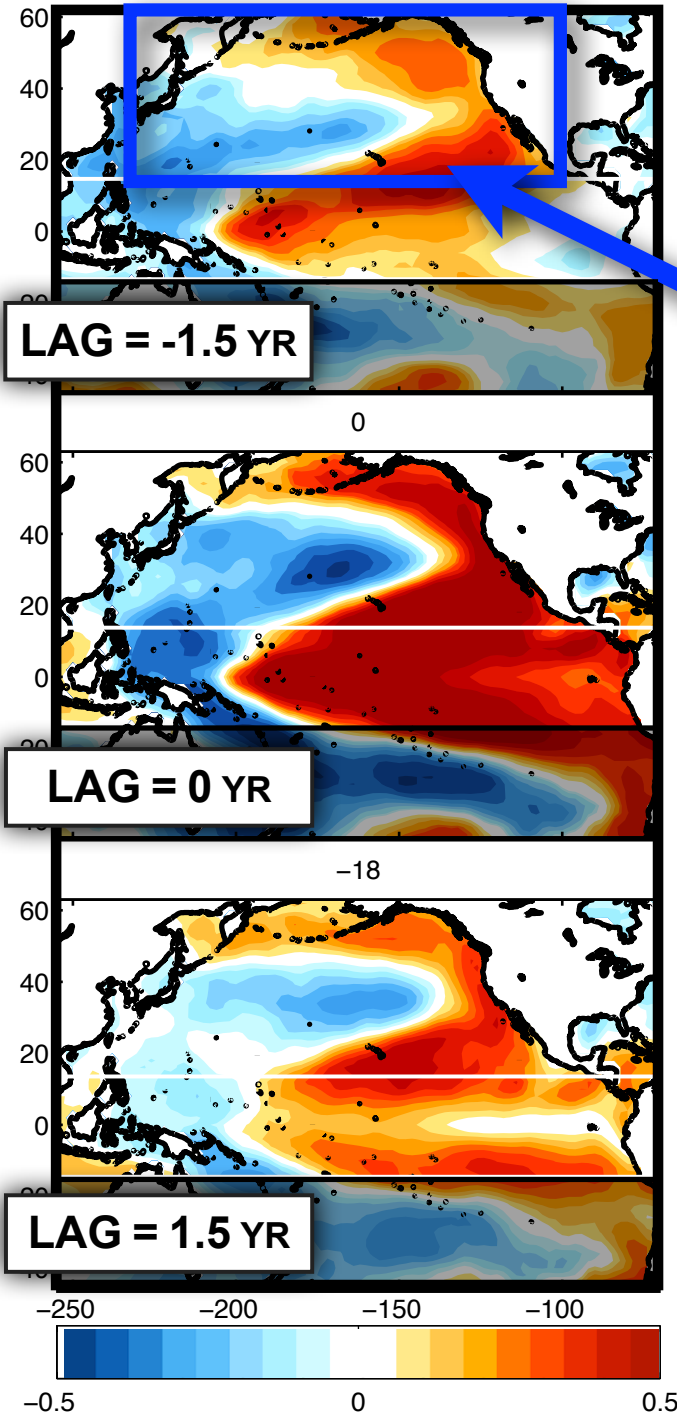
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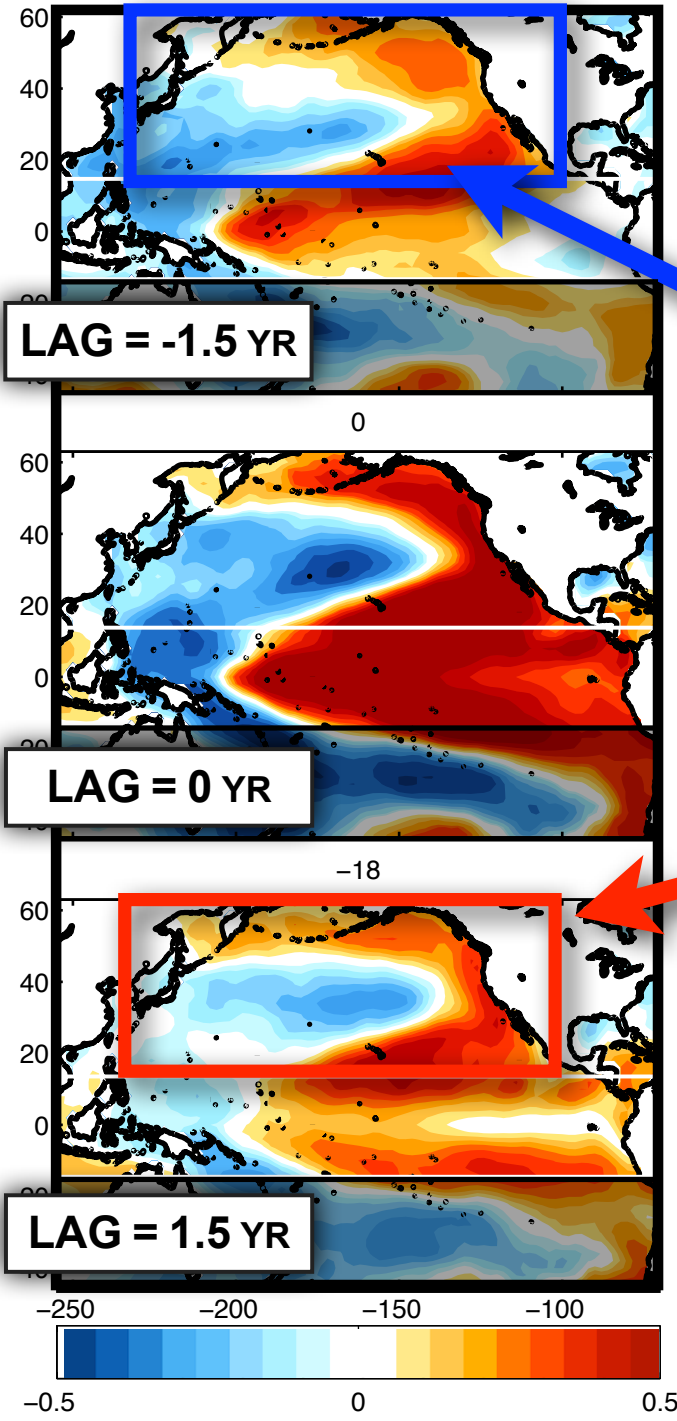


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Is the observed decadal evolution of the Pacific consistent with this view?

1 Meridional Mode (N-S): in the extratropics initiates the evolution of Pacific decadal variability

OBSERVATIONS



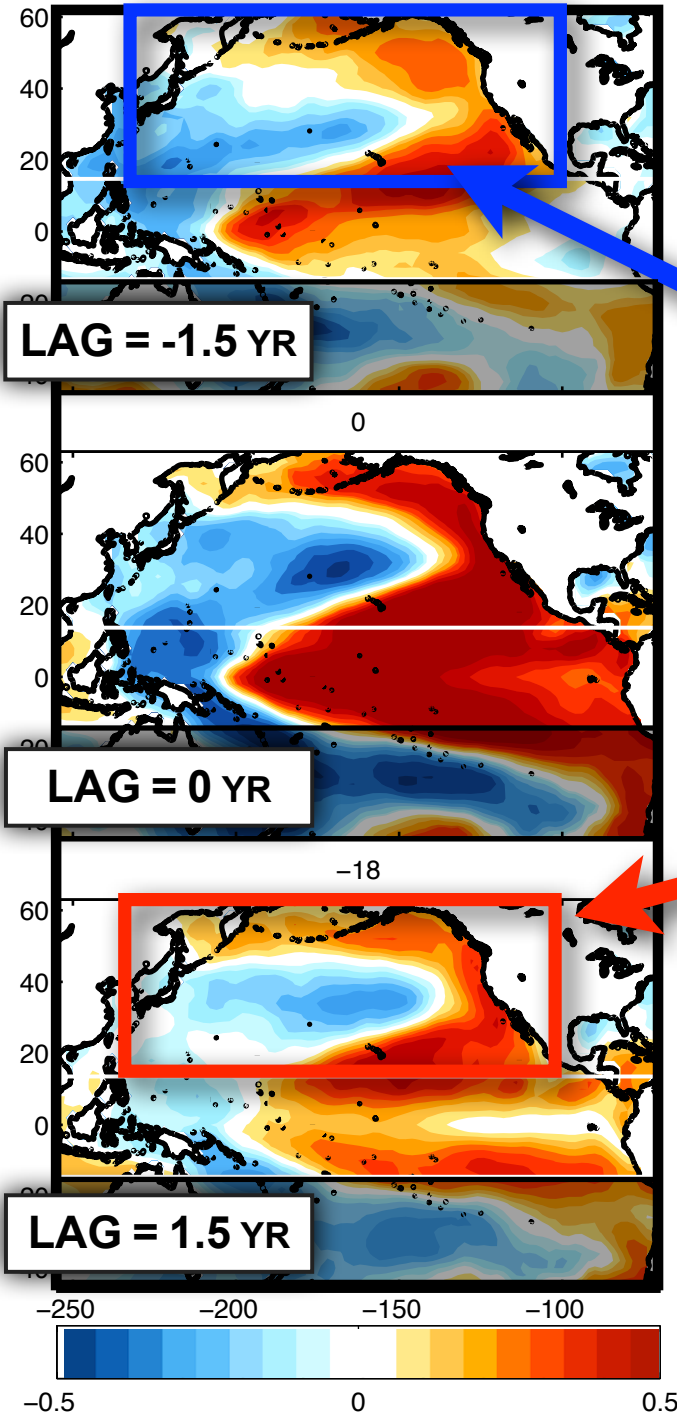
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2 Zonal Mode (E-W): teleconnected responses associated with the zonal mode response

OBSERVATIONS



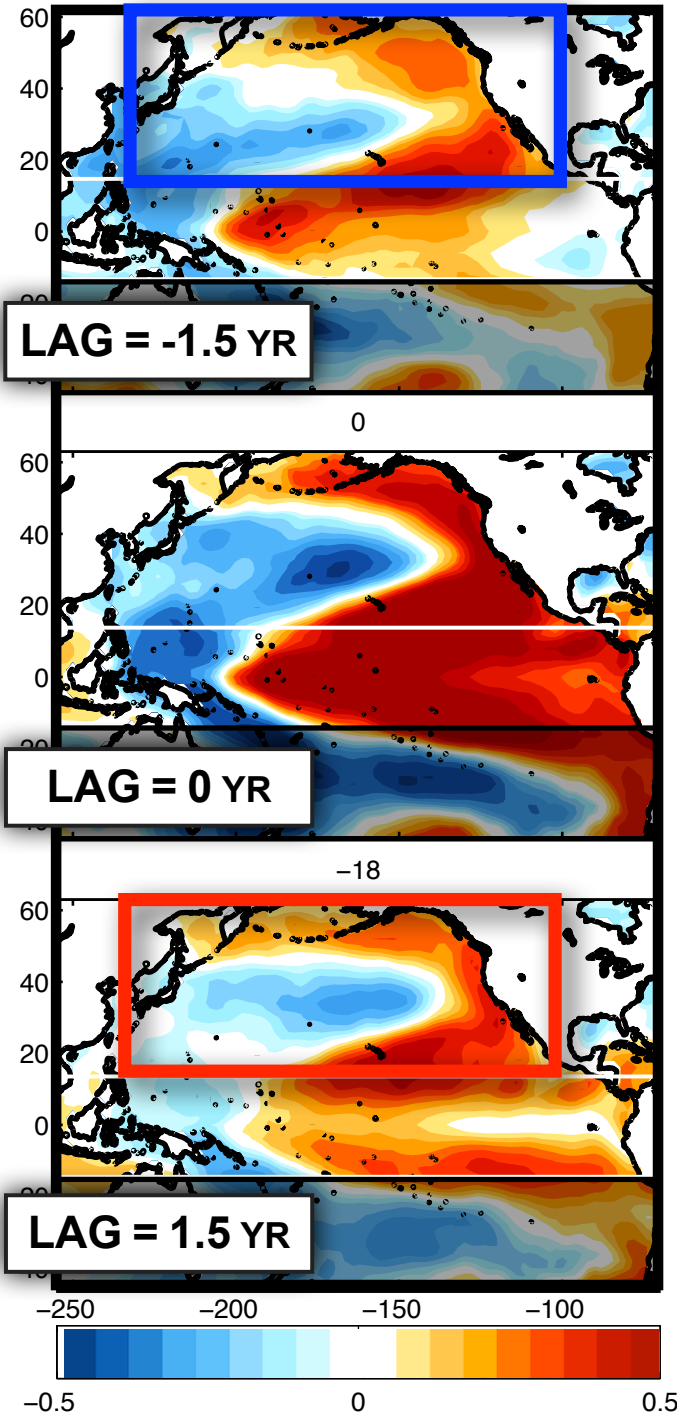
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QUESTION:

How can attribute cause and effect?

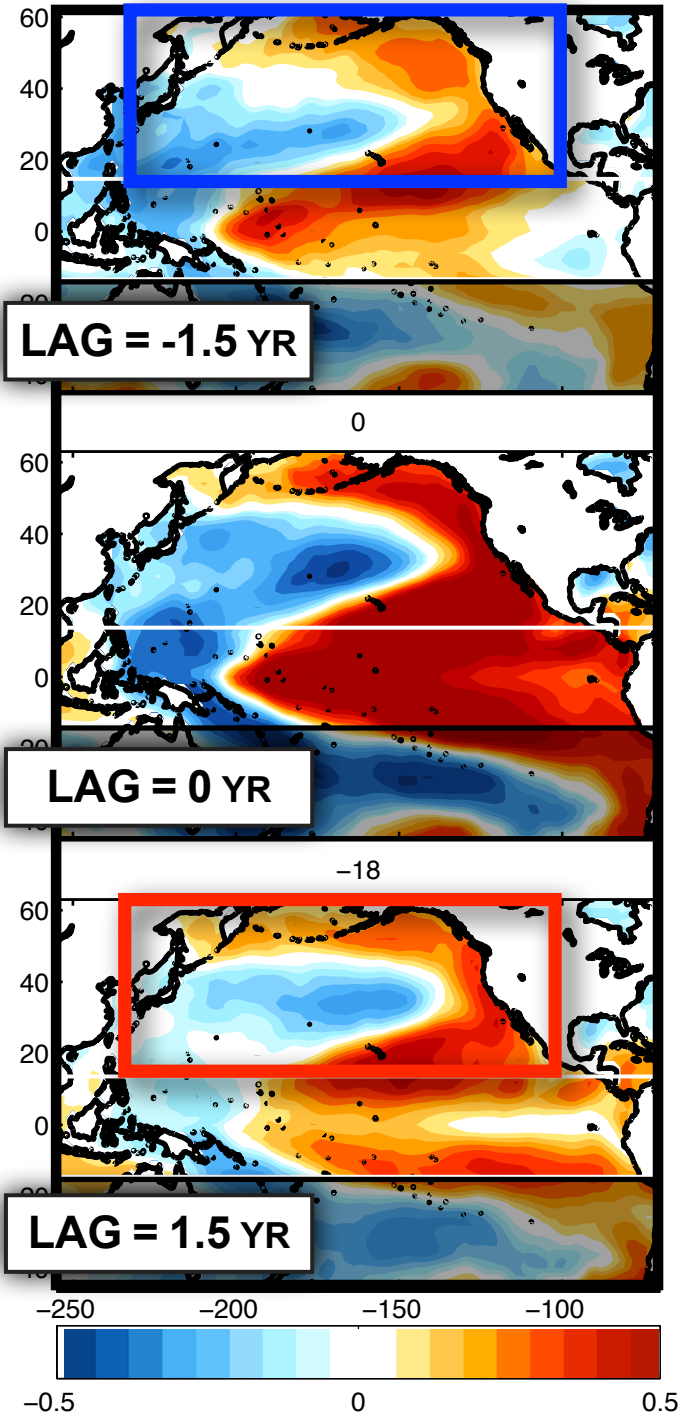
OBSERVATIONS



GOAL:

Isolate fraction of the evolution that is controlled by the **Zonal Mode dynamics**

OBSERVATIONS



ZONAL MODE (EXP)

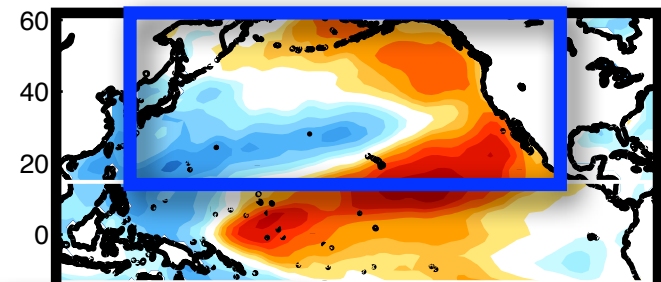
1. AGCM-MLD (SPEEDY)
2. Prescribed time dependent observed SSTa in tropics 1950-2012
3. Ensemble Mean (50 realizations) to filter out extra-tropics stochastic forcing

GOAL:

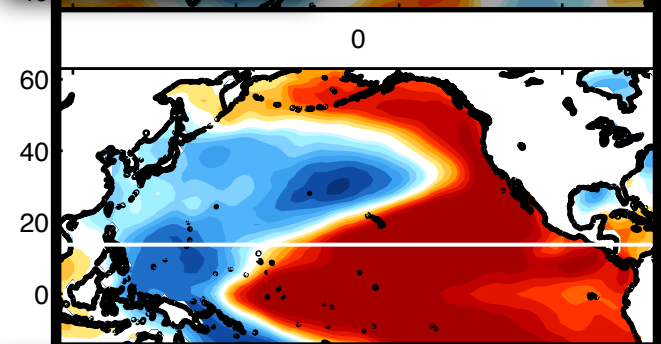
Isolate fraction of the evolution that is controlled by the **Zonal Mode dynamics**

OBSERVATIONS

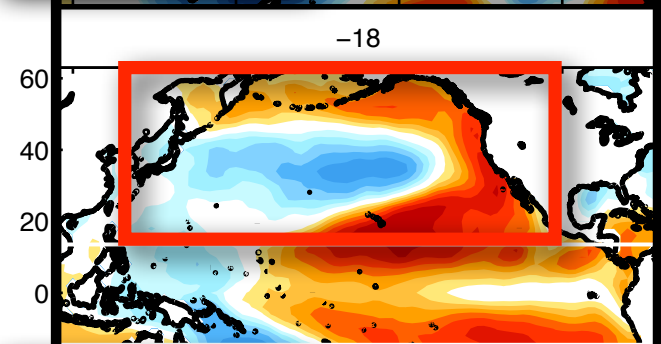
ZONAL MODE (EXP)



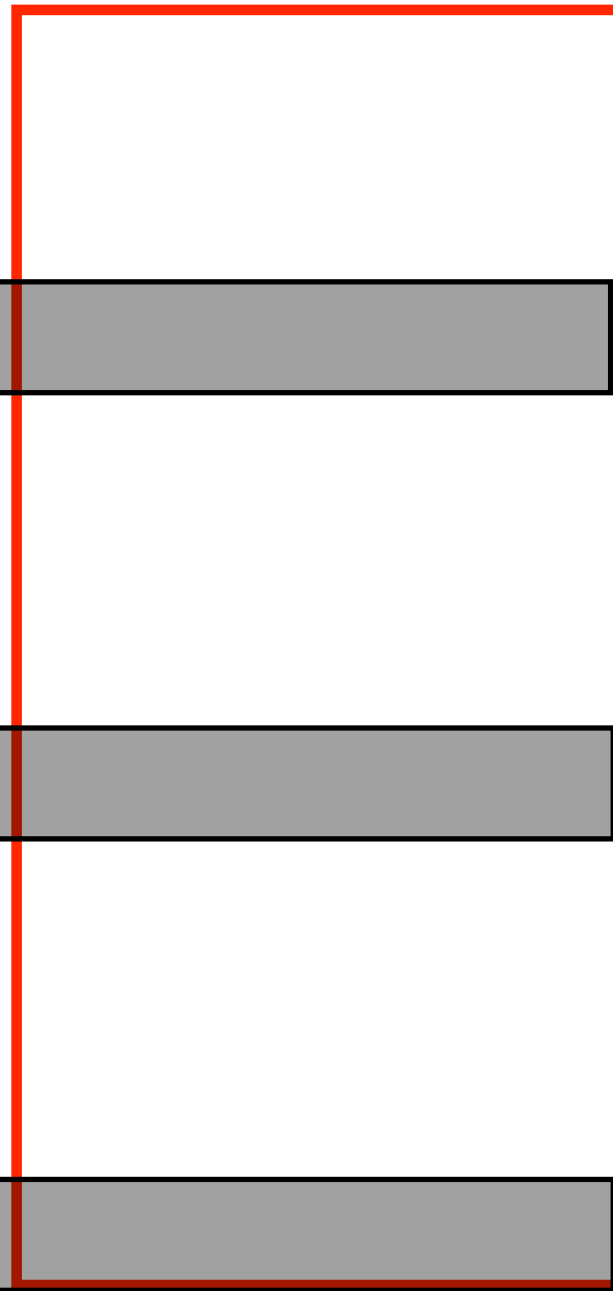
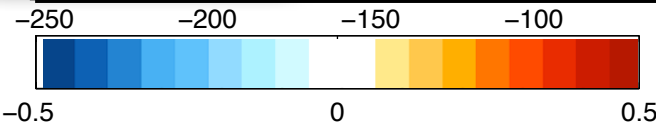
LAG = -1.5 YR



LAG = 0 YR



LAG = 1.5 YR

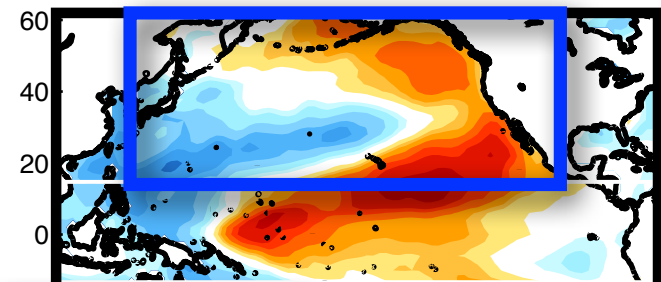


ZONAL MODE (EXP)

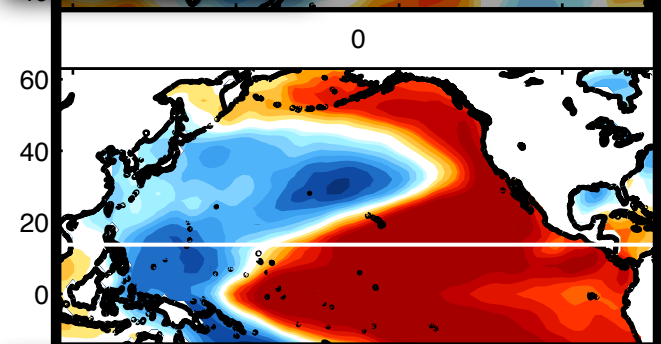
- 1. AGCM-MLD (SPEEDY)
- 2. Prescribed time dependent observed SSTa in tropics 1950-2012
- 3. Ensemble Mean (50 realizations) to filter out extra-tropics stochastic forcing

OBSERVATIONS

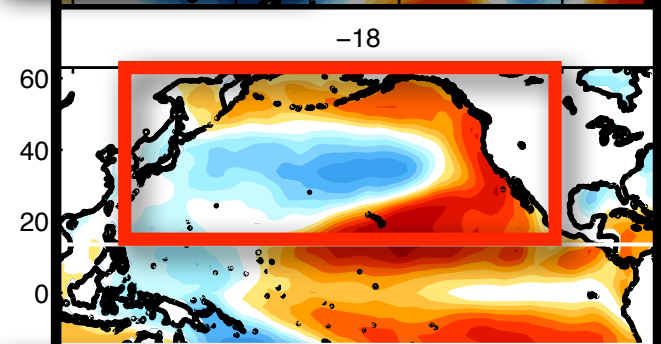
ZONAL MODE (EXP)



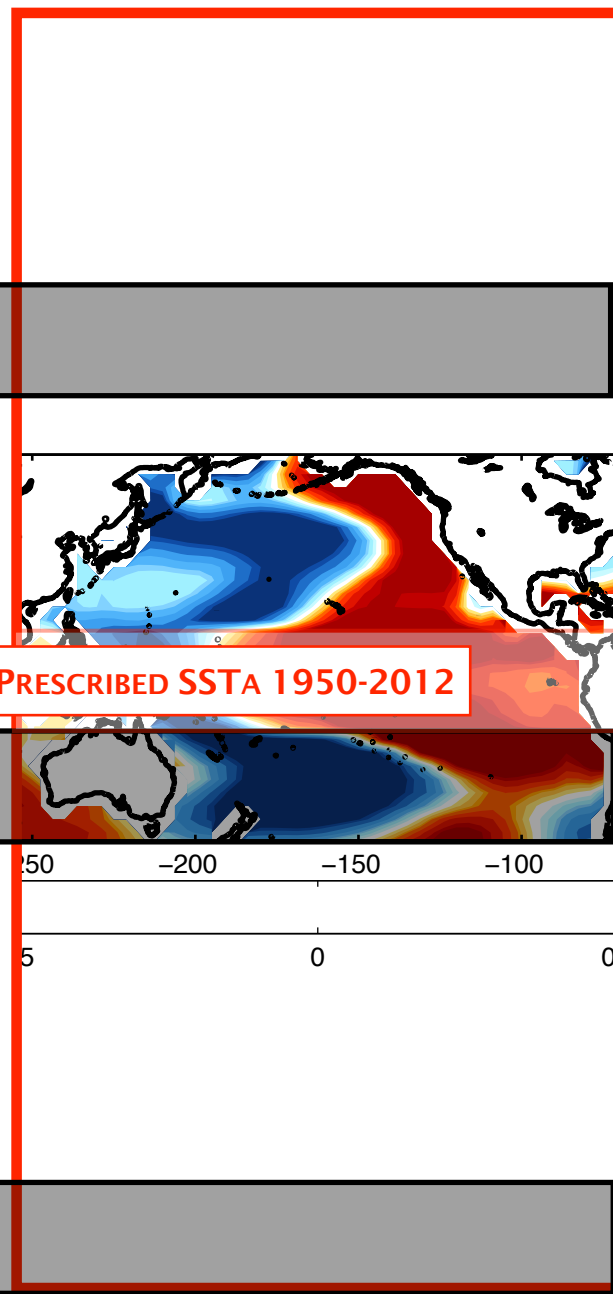
LAG = -1.5 YR



LAG = 0 YR

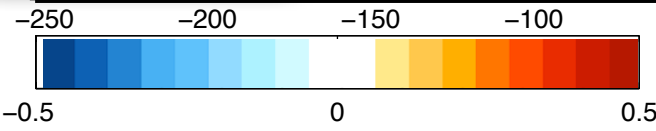


LAG = 1.5 YR



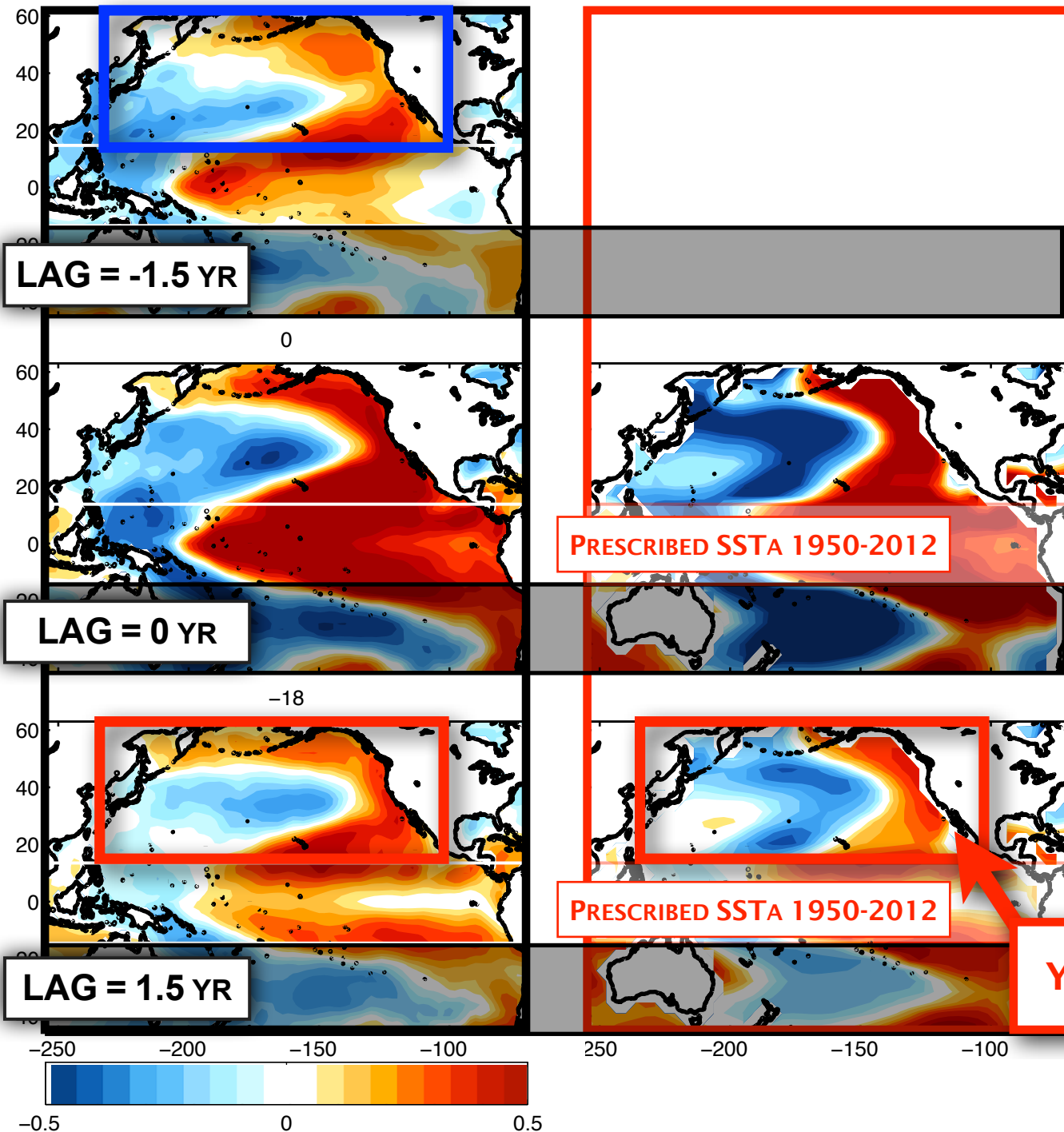
ZONAL MODE (EXP)

- 1. AGCM-MLD (SPEEDY)
- 2. Prescribed time dependent observed SSTa in tropics 1950-2012
- 3. Ensemble Mean (50 realizations) to filter out extra-tropics stochastic forcing



OBSERVATIONS

ZONAL MODE (EXP)



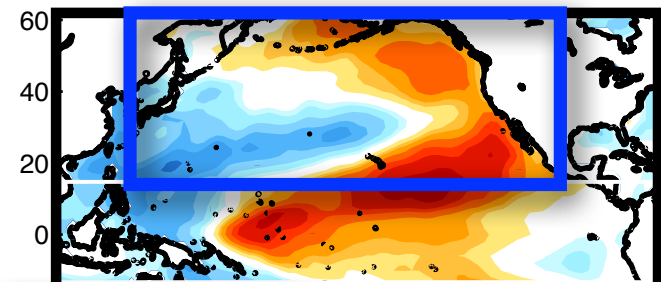
ZONAL MODE (EXP)

1. AGCM-MLD (SPEEDY)
2. Prescribed time dependent observed SSTA in tropics 1950-2012
3. Ensemble Mean (50 realizations) to filter out extra-tropics stochastic forcing

YES Extra-tropical successor

OBSERVATIONS

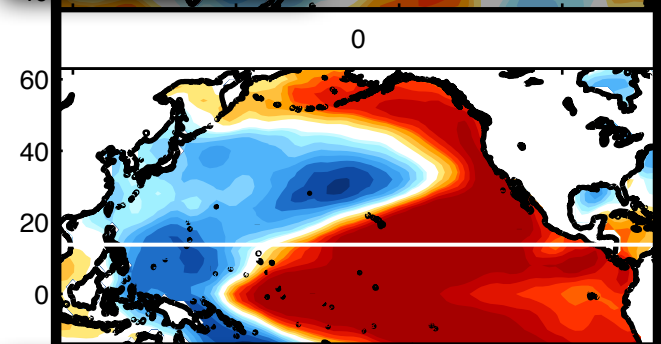
ZONAL MODE (EXP)



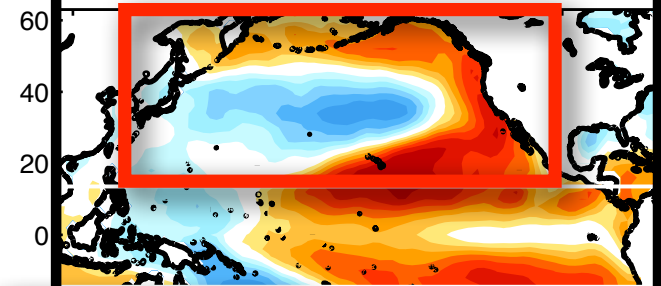
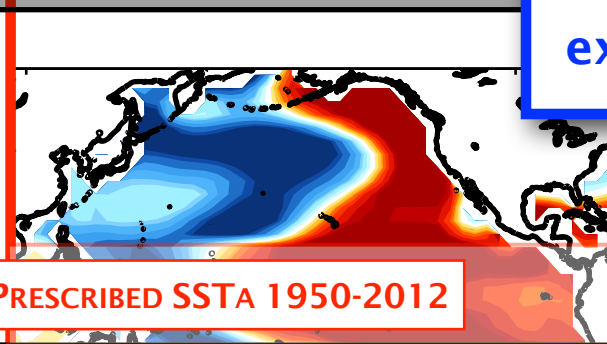
LAG = -1.5 YR



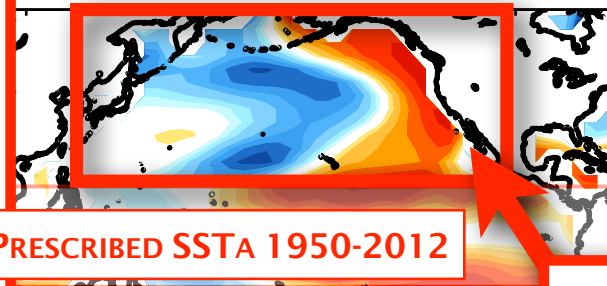
How about the extra-tropical precursor?



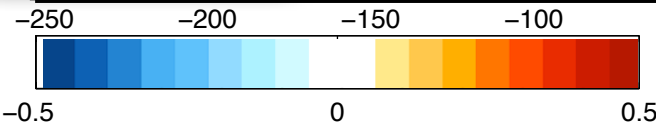
LAG = 0 YR



LAG = 1.5 YR

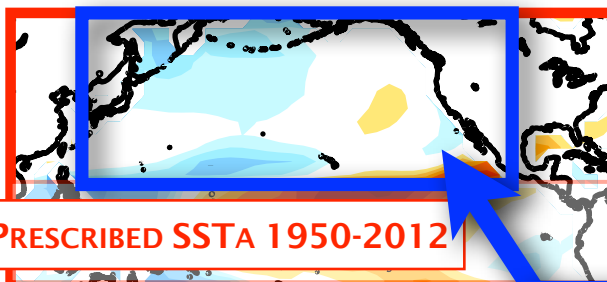
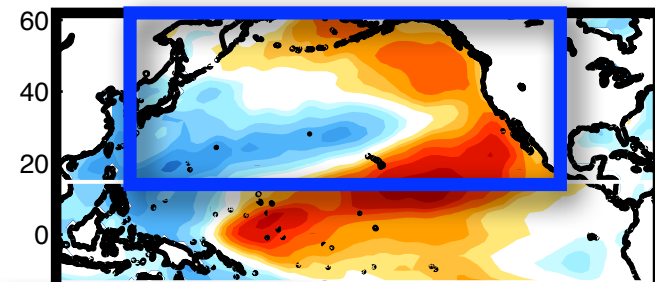


YES Extra-tropical successor



OBSERVATIONS

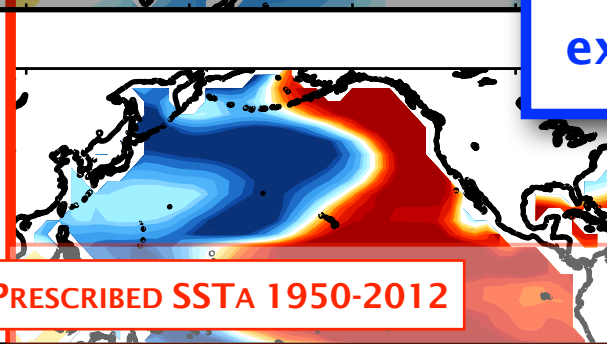
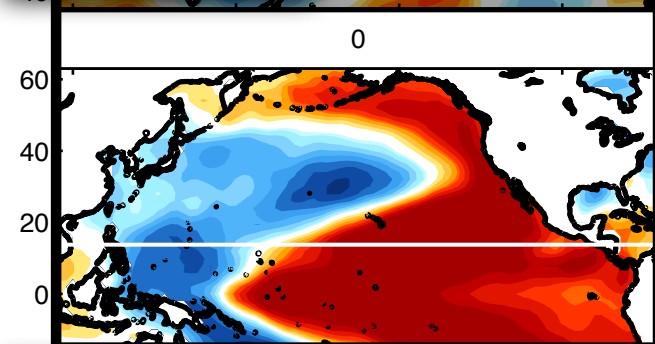
ZONAL MODE (EXP)



PRESCRIBED SSTA 1950-2012

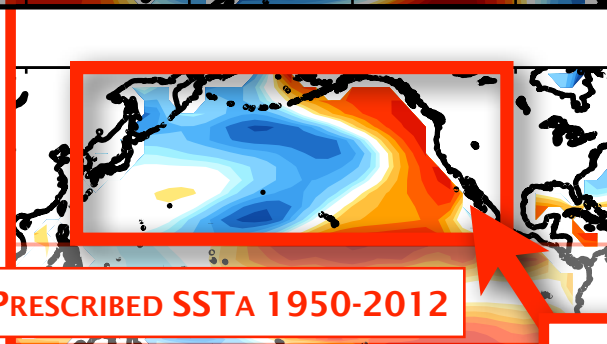
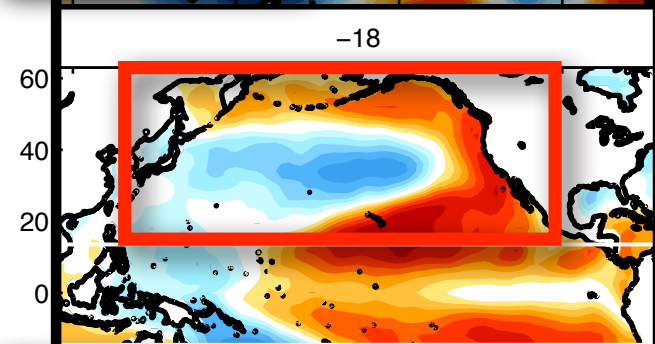
LAG = -1.5 YR

How about the extra-tropical precursor?



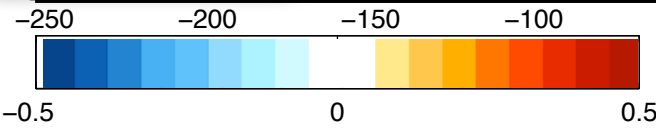
PRESCRIBED SSTA 1950-2012

LAG = 0 YR



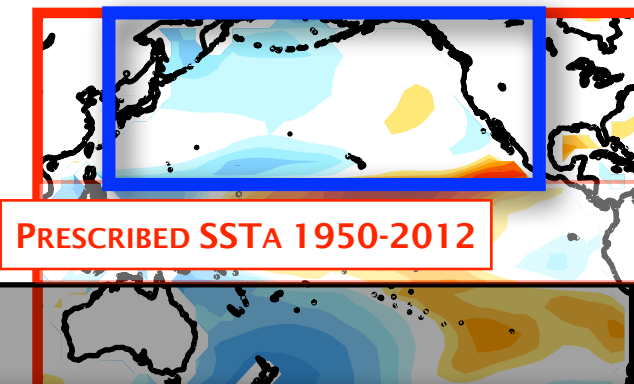
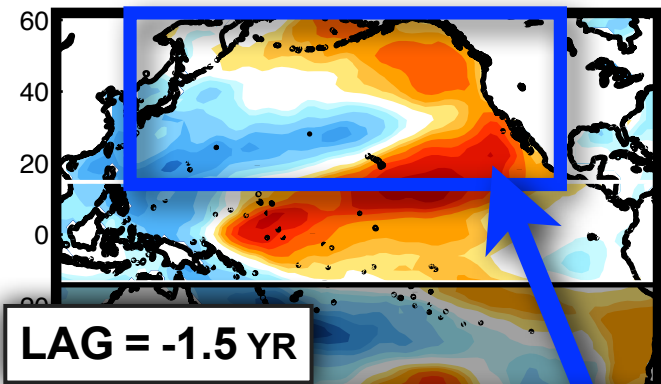
PRESCRIBED SSTA 1950-2012

YES Extra-tropical successor



OBSERVATIONS

ZONAL MODE (EXP)



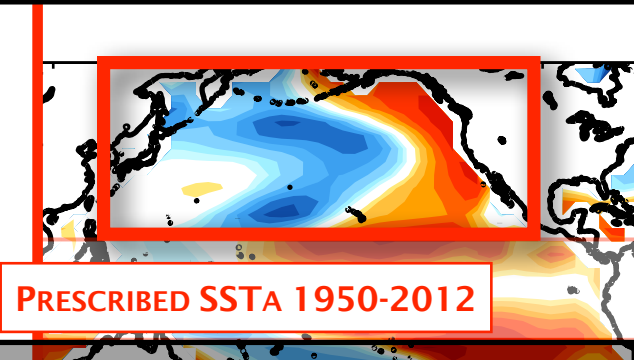
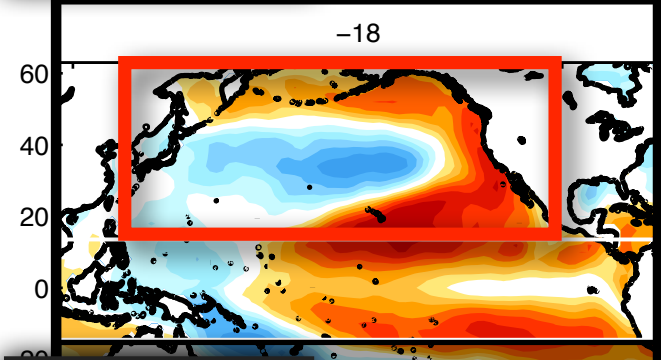
LAG = -1.5 YR

PRESCRIBED SSTA 1950-2012

QUESTION:
Is this precursor controlled by
Meridional Mode dynamics?

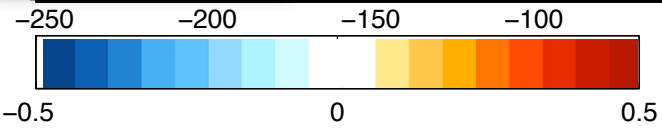


LAG = 0 YR



LAG = 1.5 YR

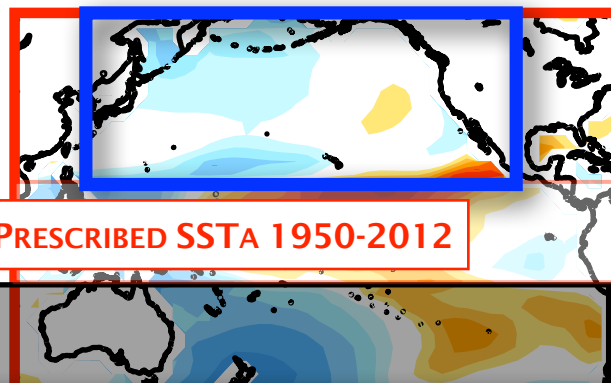
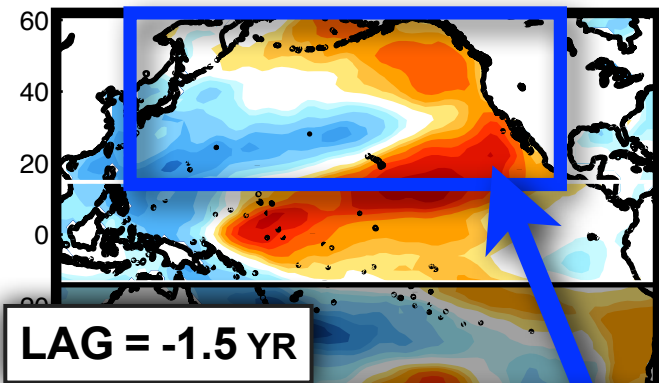
PRESCRIBED SSTA 1950-2012



OBSERVATIONS

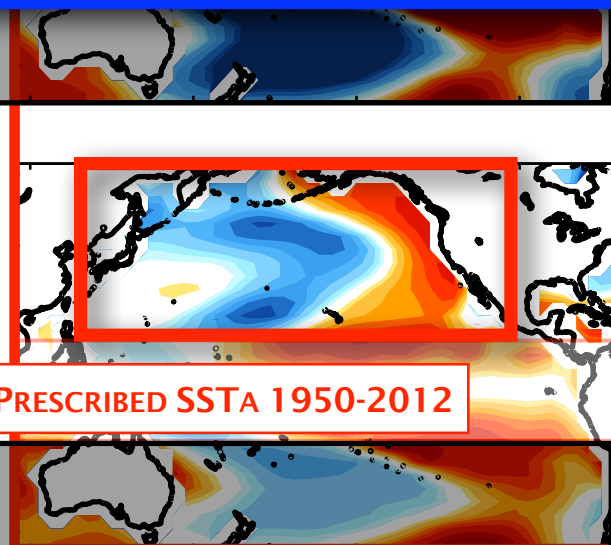
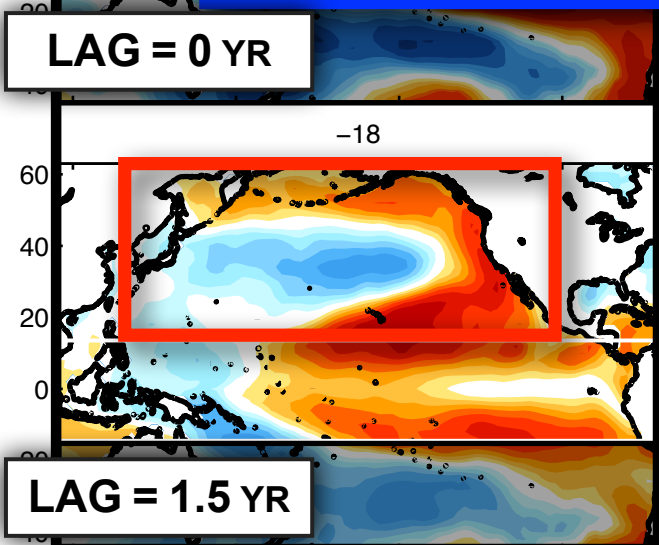
ZONAL MODE (EXP)

MERIDIONAL MODE (EXP)

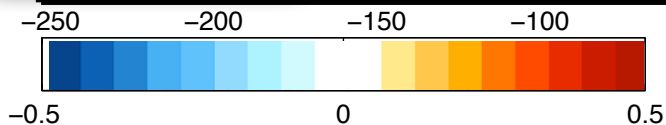


QUESTION:

Is this precursor controlled by Meridional Mode dynamics?

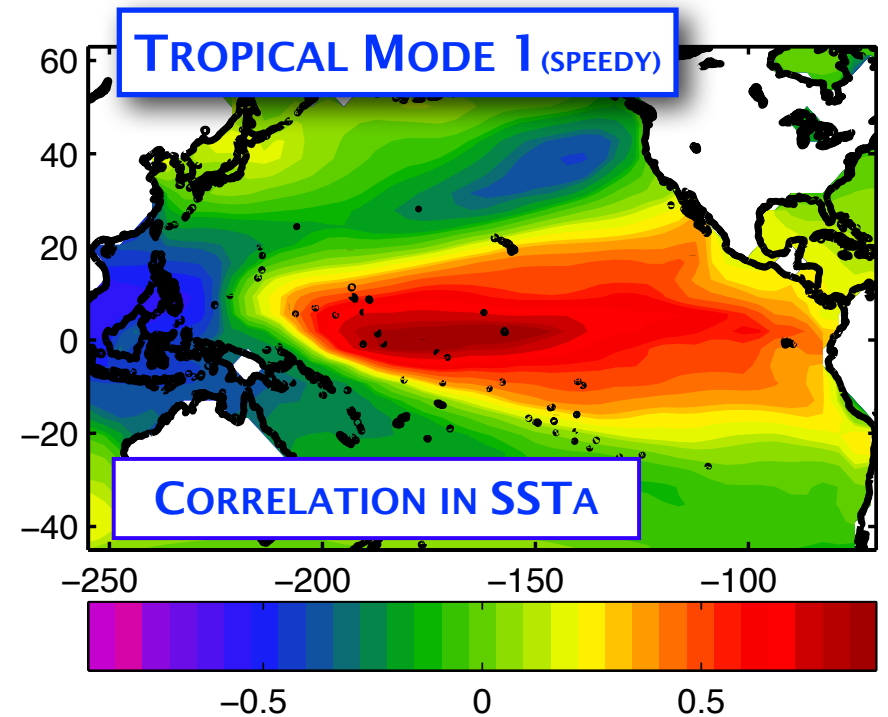
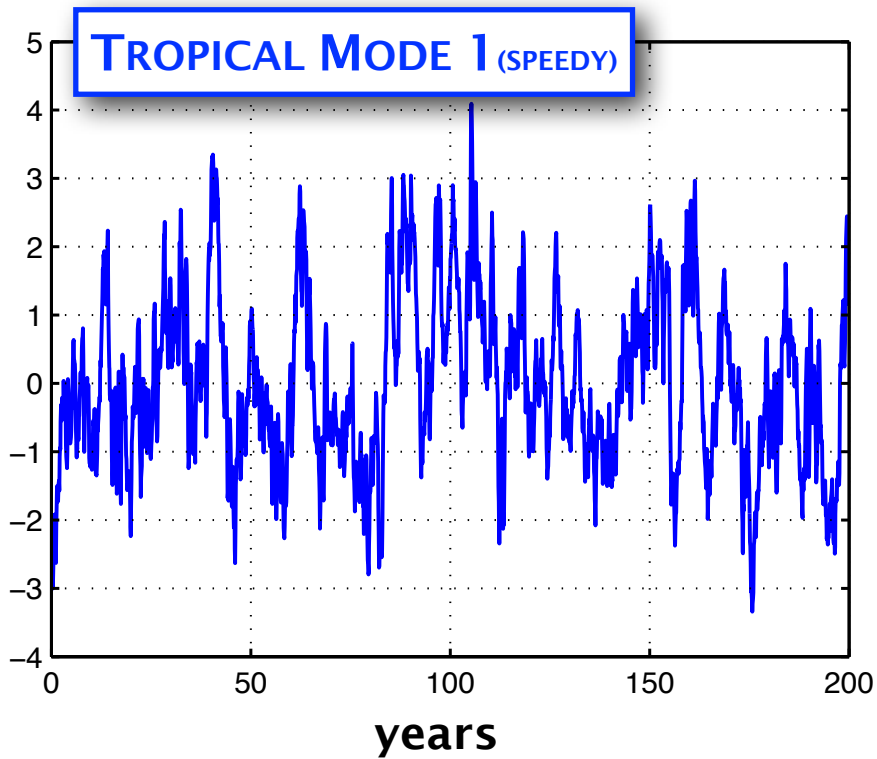


1. AGCM-MLD (SPEEDY)
2. 1000 year run with MLD everywhere
3. NO Zonal Mode dynamics included
NO Cloud feedback
4. Tropical variability is controlled by Meridional Mode

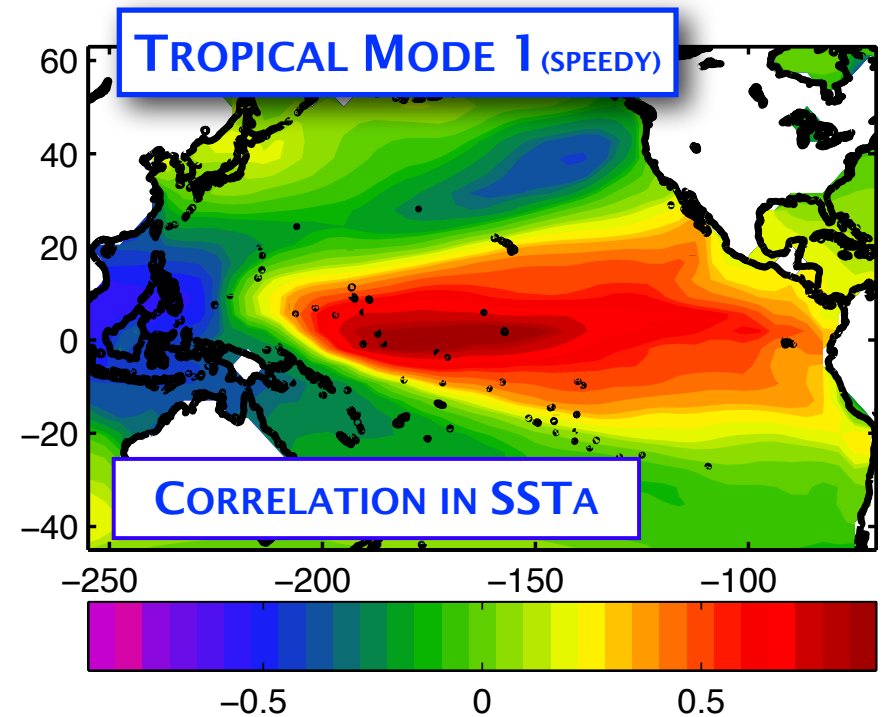
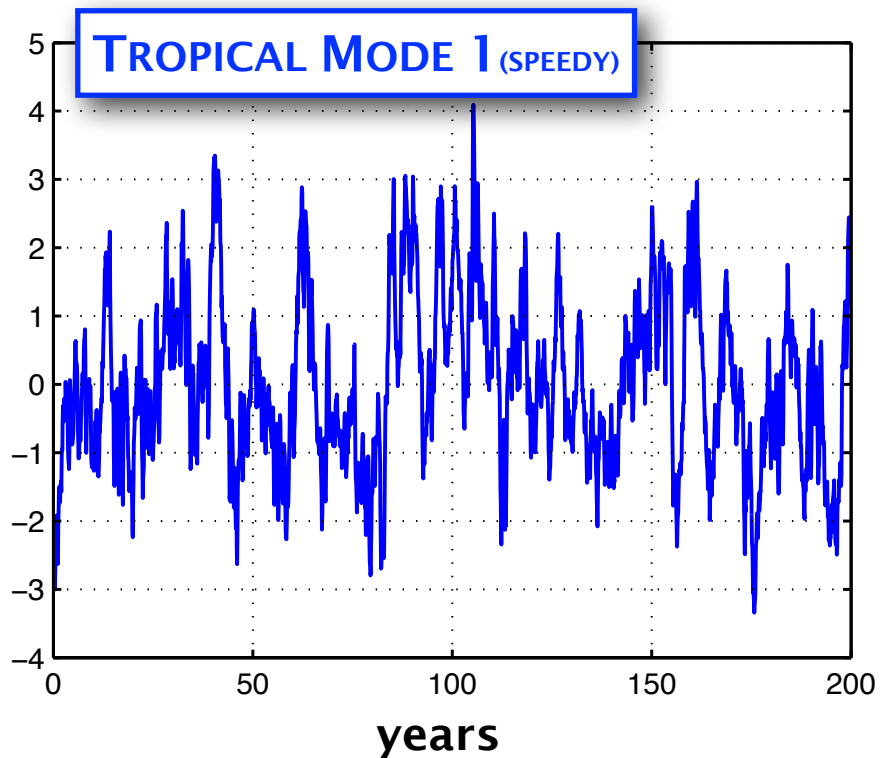


EOF 1 IN TROPICAL PACIFIC [10S 10N]

50% OF VARIANCE



Is there an Extra-tropical Precursor associated with the Meridional Mode?

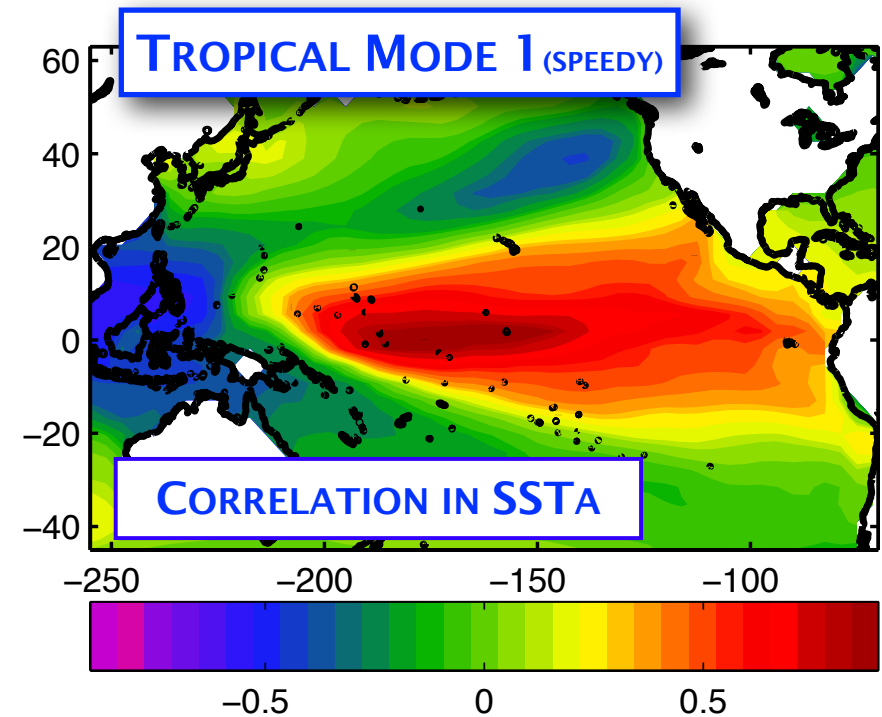
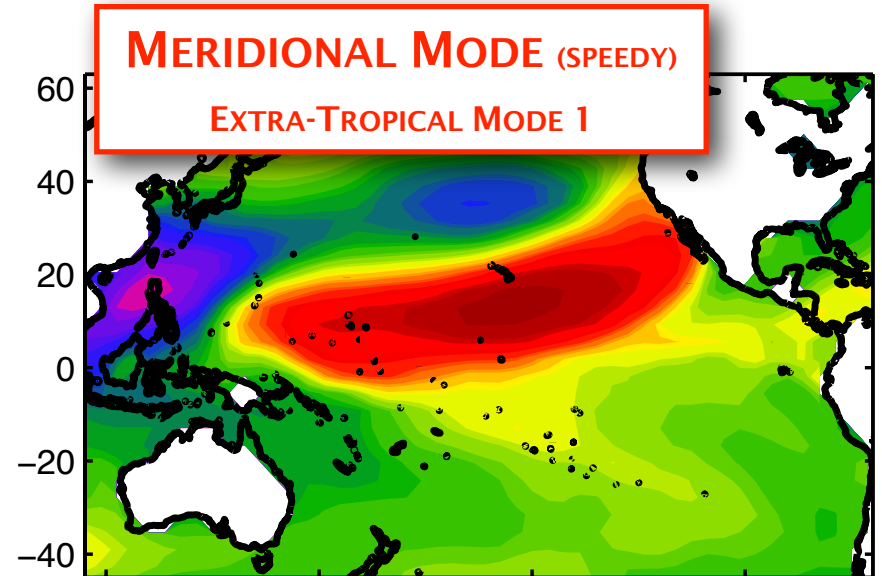
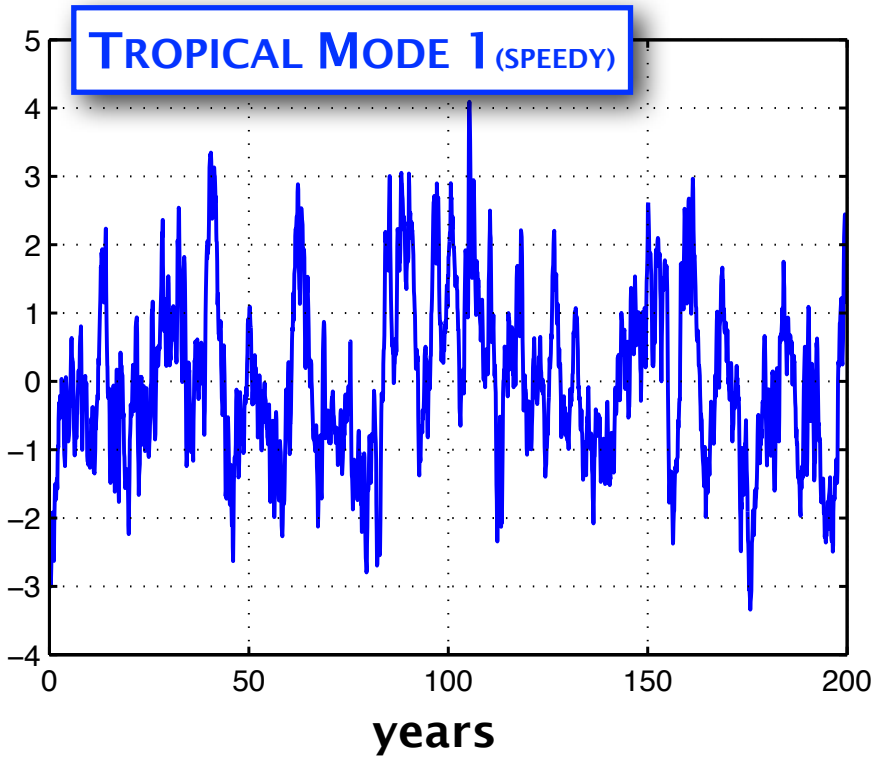


OBSERVATIONS

ZONAL MODE (EXP)

MERIDIONAL MODE (EXP)

Is there an Extra-tropical Precursor associated with the Meridional Mode?

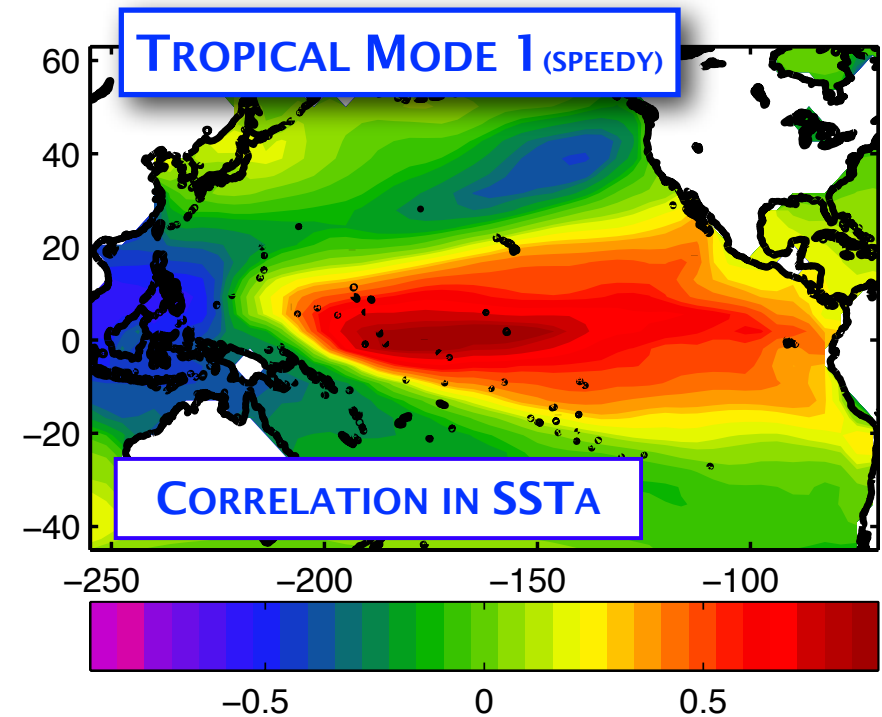
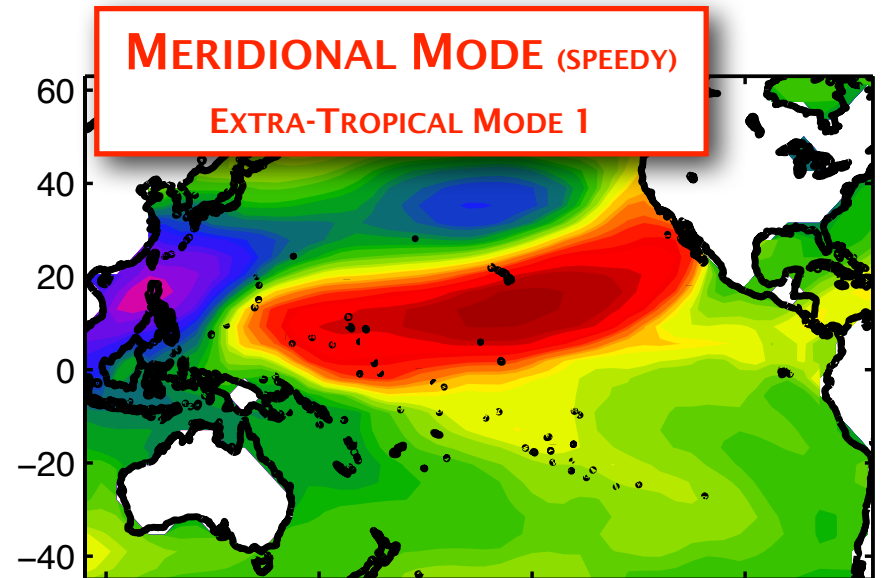
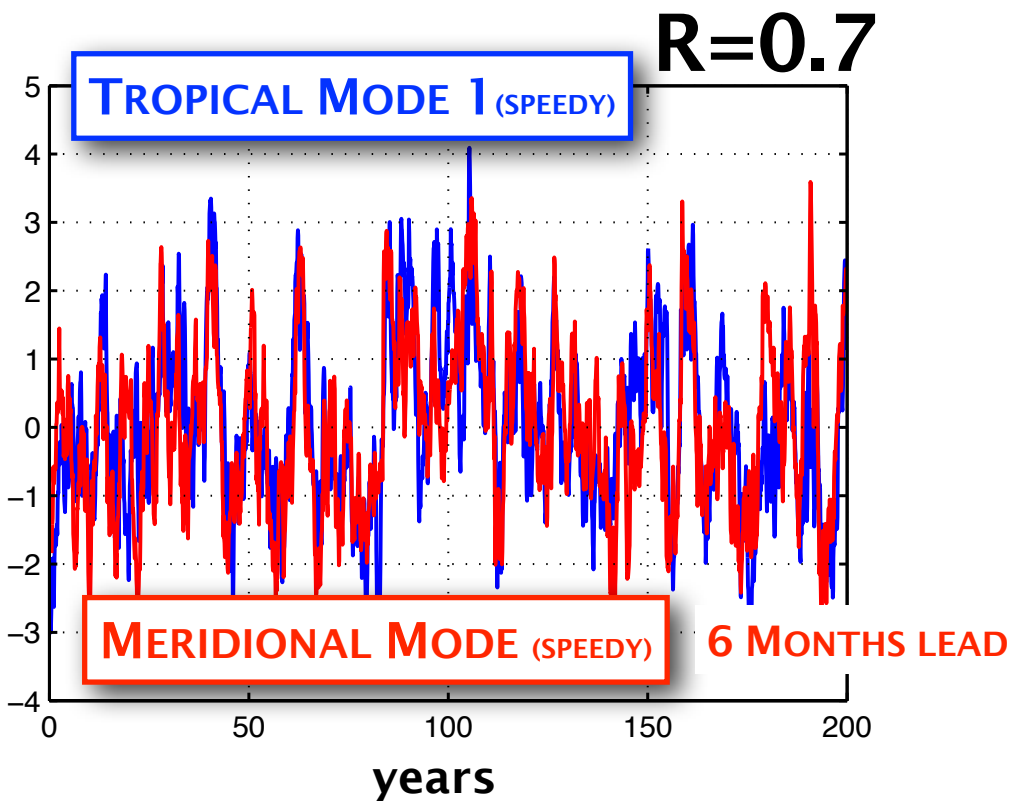


OBSERVATIONS

ZONAL MODE (EXP)

MERIDIONAL MODE (EXP)

Is there an Extra-tropical Precursor associated with the Meridional Mode?

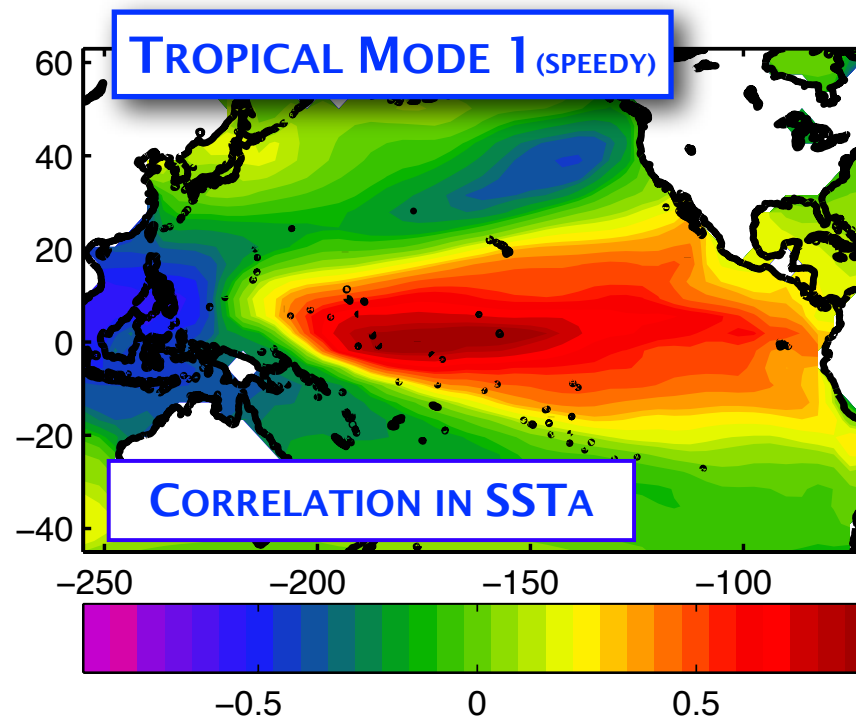
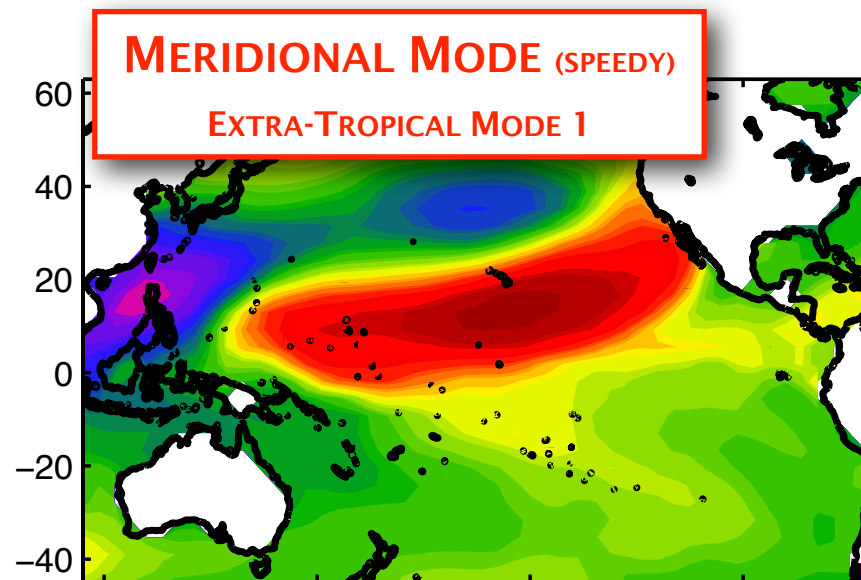
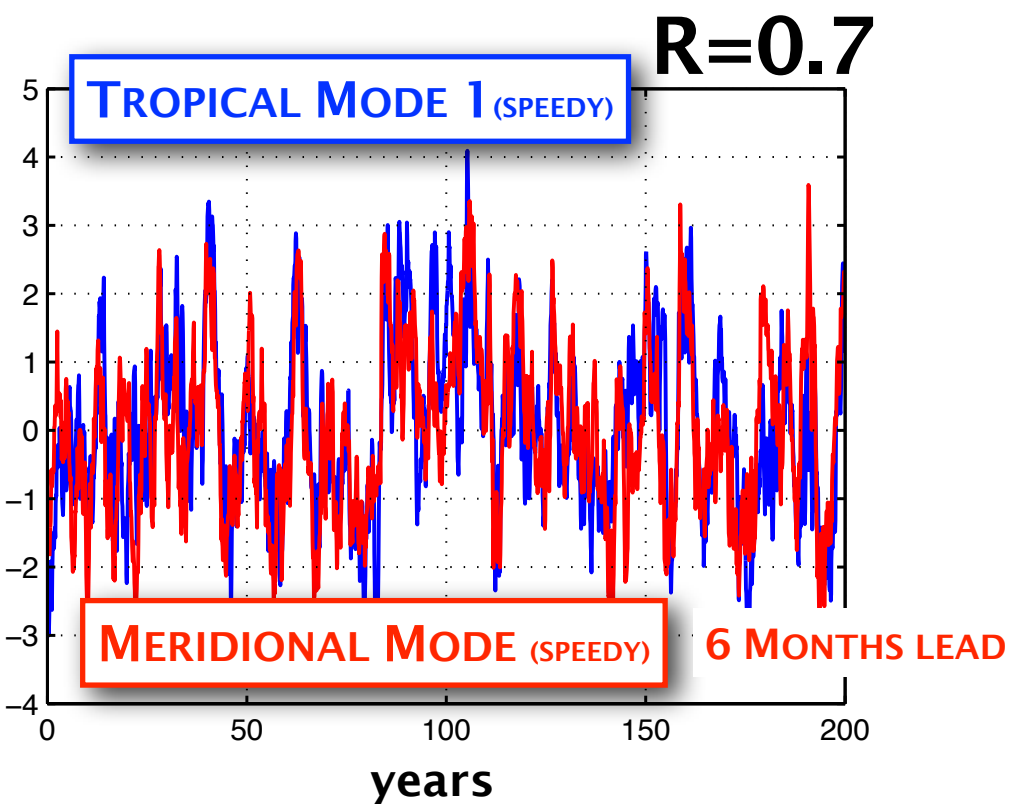


OBSERVATIONS

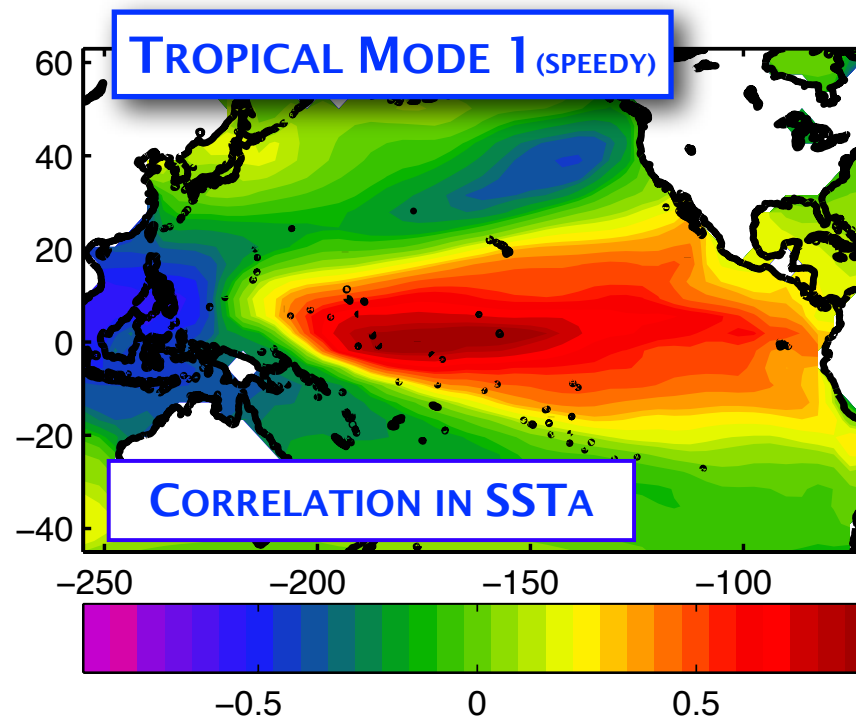
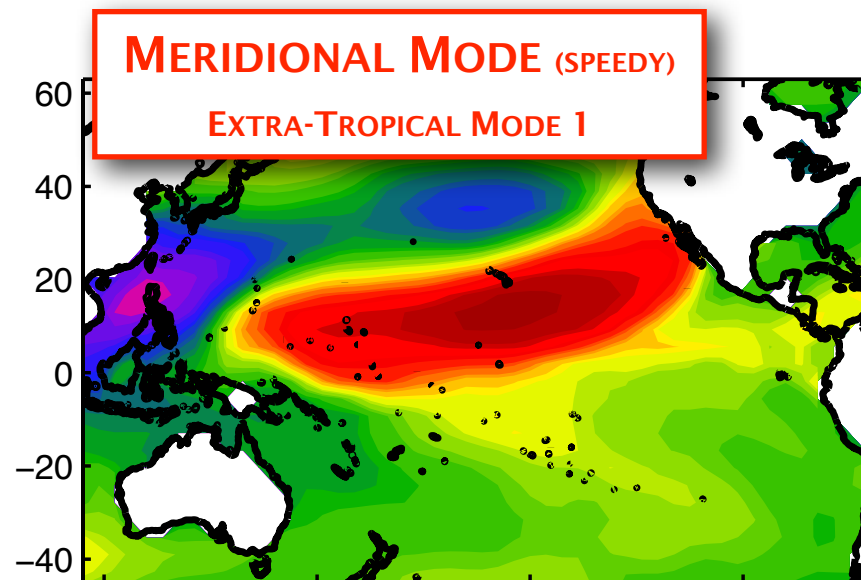
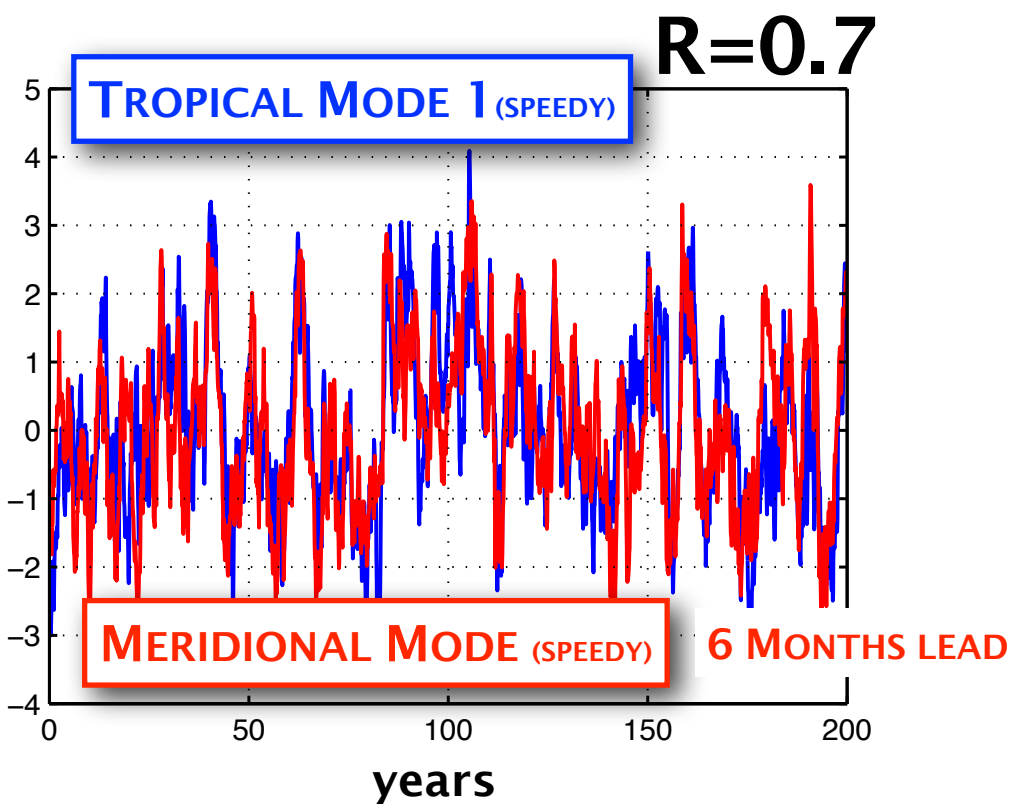
ZONAL MODE (EXP)

MERIDIONAL MODE (EXP)

Extra-tropical stochastic forcing of the Meridional Mode dominates the tropical variability

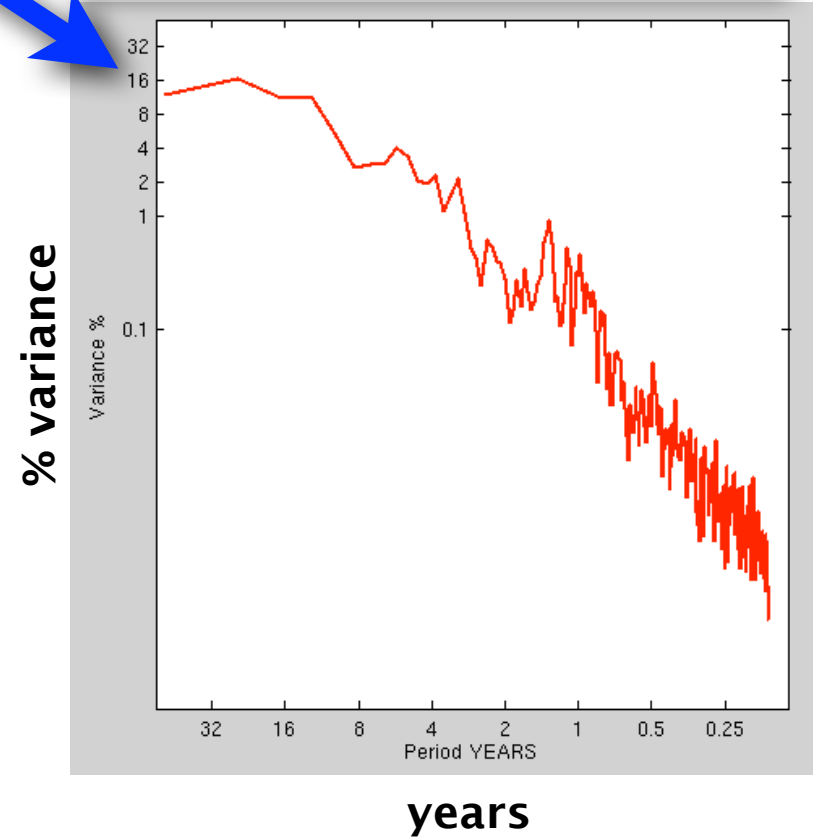
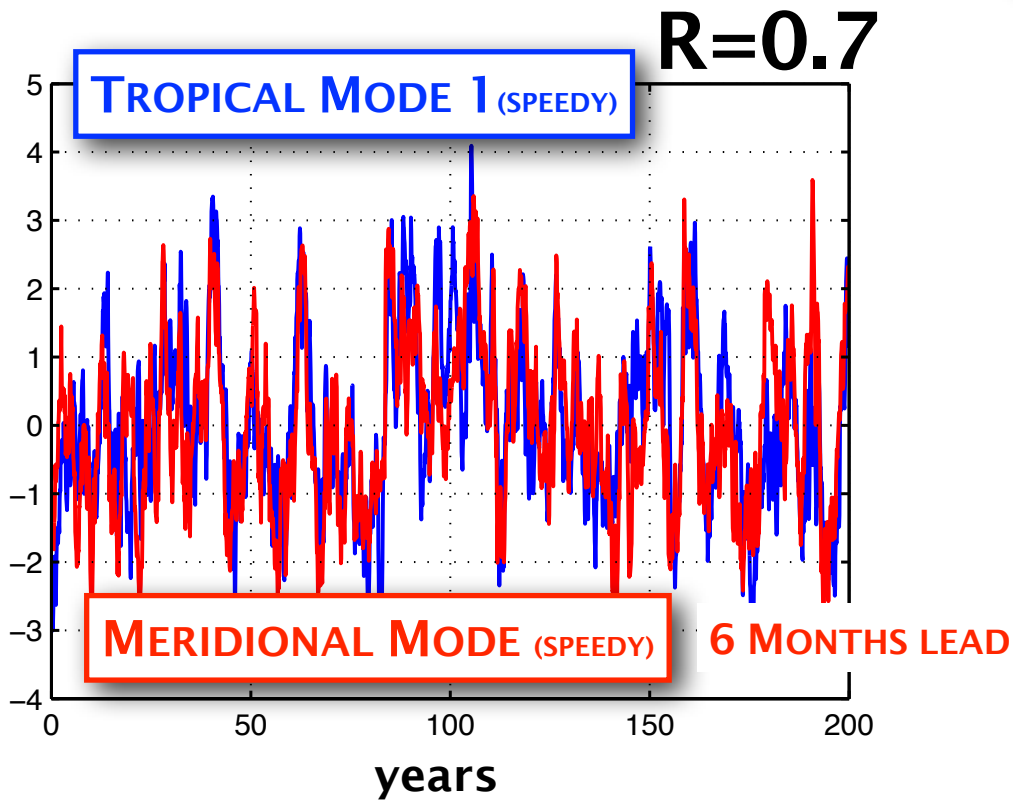


**Meridional Mode
dominates the tropical
decadal variability.**

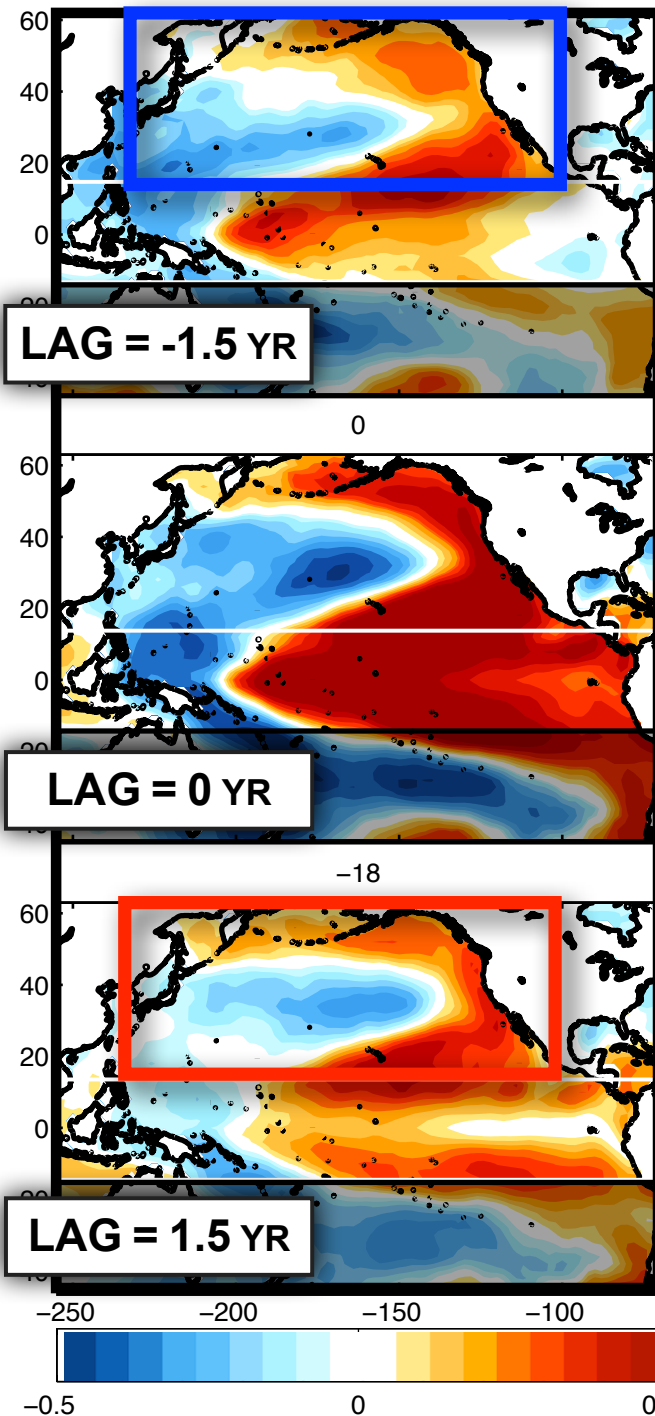


Tropical Variability is characterized by mostly decadal scale variations

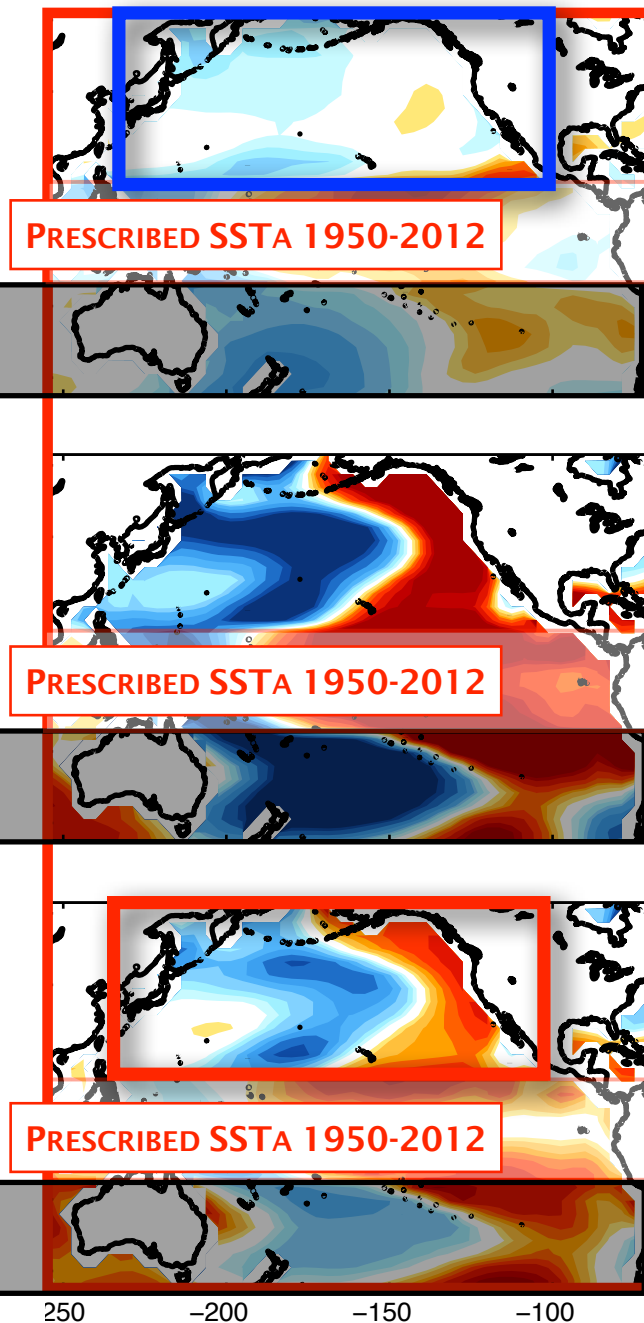
POWER SPECTRUM OF MODE 1



OBSERVATIONS



ZONAL MODE (EXP)



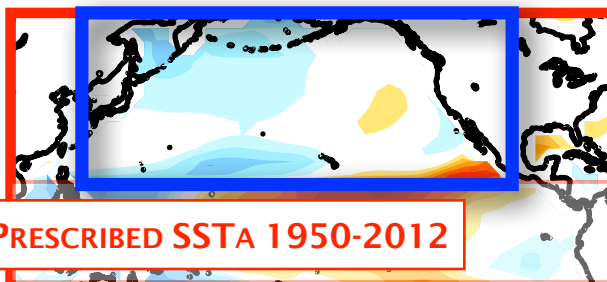
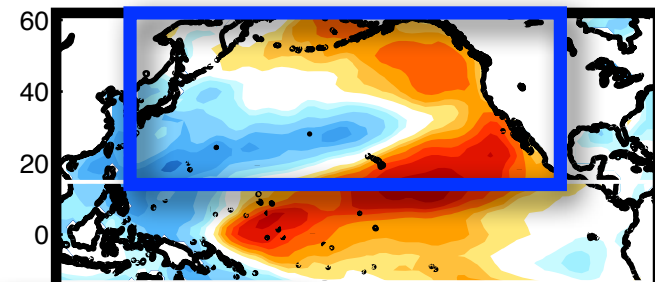
MERIDIONAL MODE (EXP)

- 1. AGCM-MLD (SPEEDY)
- 2. 1000 year run with MLD everywhere
- 3. NO Zonal Mode dynamics included
NO Cloud feedback
- 4. Tropical decadal variability is controlled by Meridional Mode

OBSERVATIONS

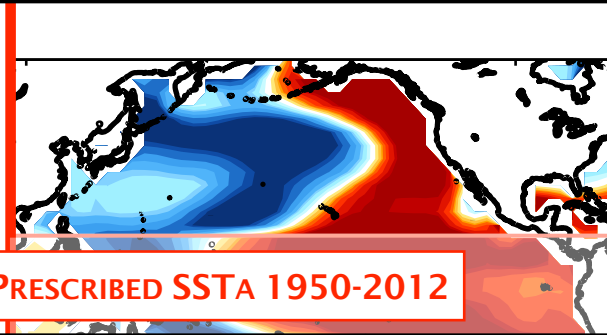
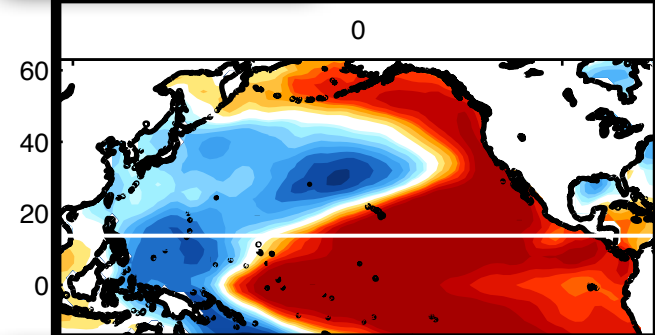
ZONAL MODE (EXP)

MERIDIONAL MODE (EXP)



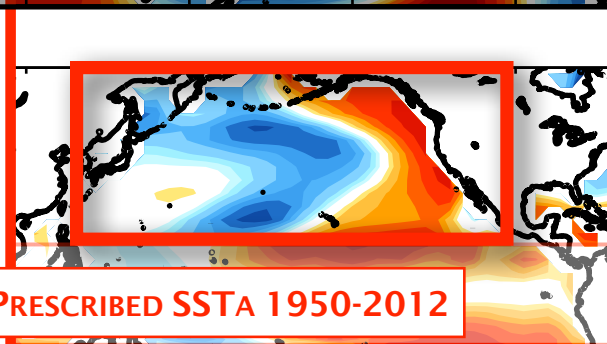
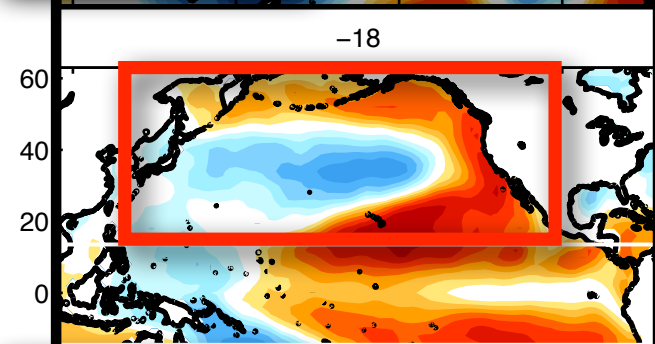
PRESCRIBED SSTA 1950-2012

LAG = -1.5 YR



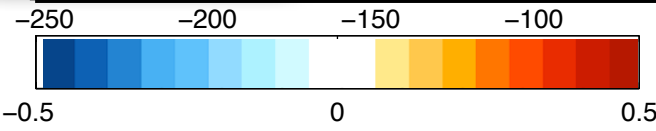
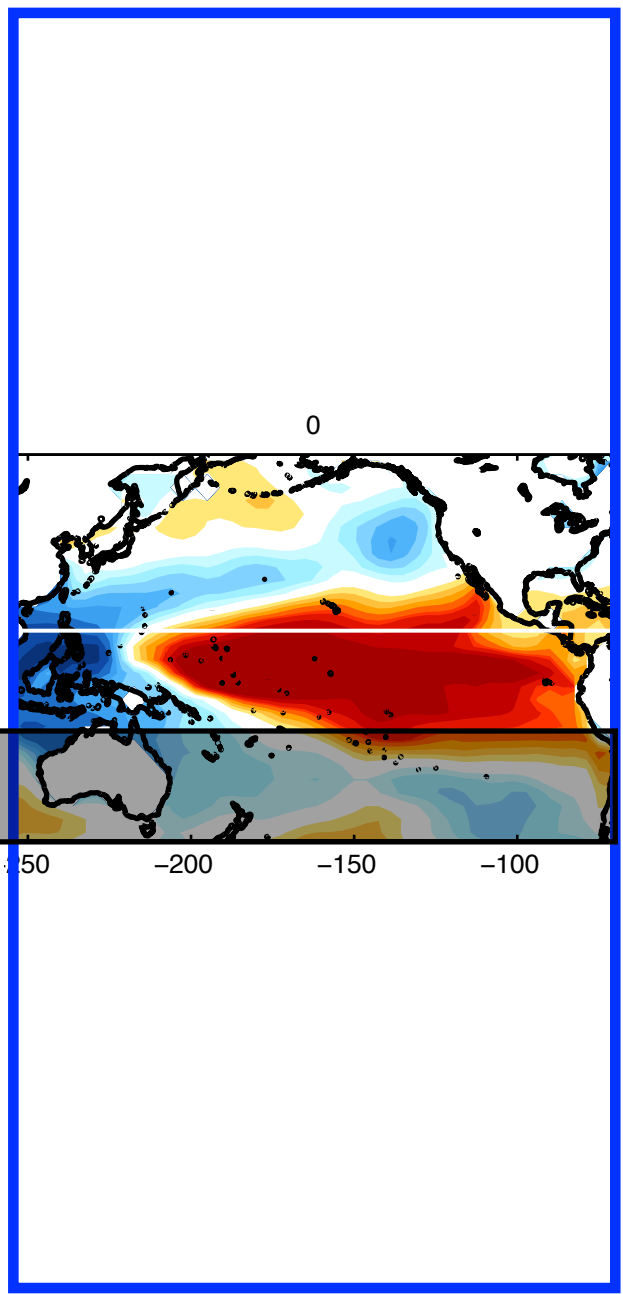
PRESCRIBED SSTA 1950-2012

LAG = 0 YR



PRESCRIBED SSTA 1950-2012

LAG = 1.5 YR



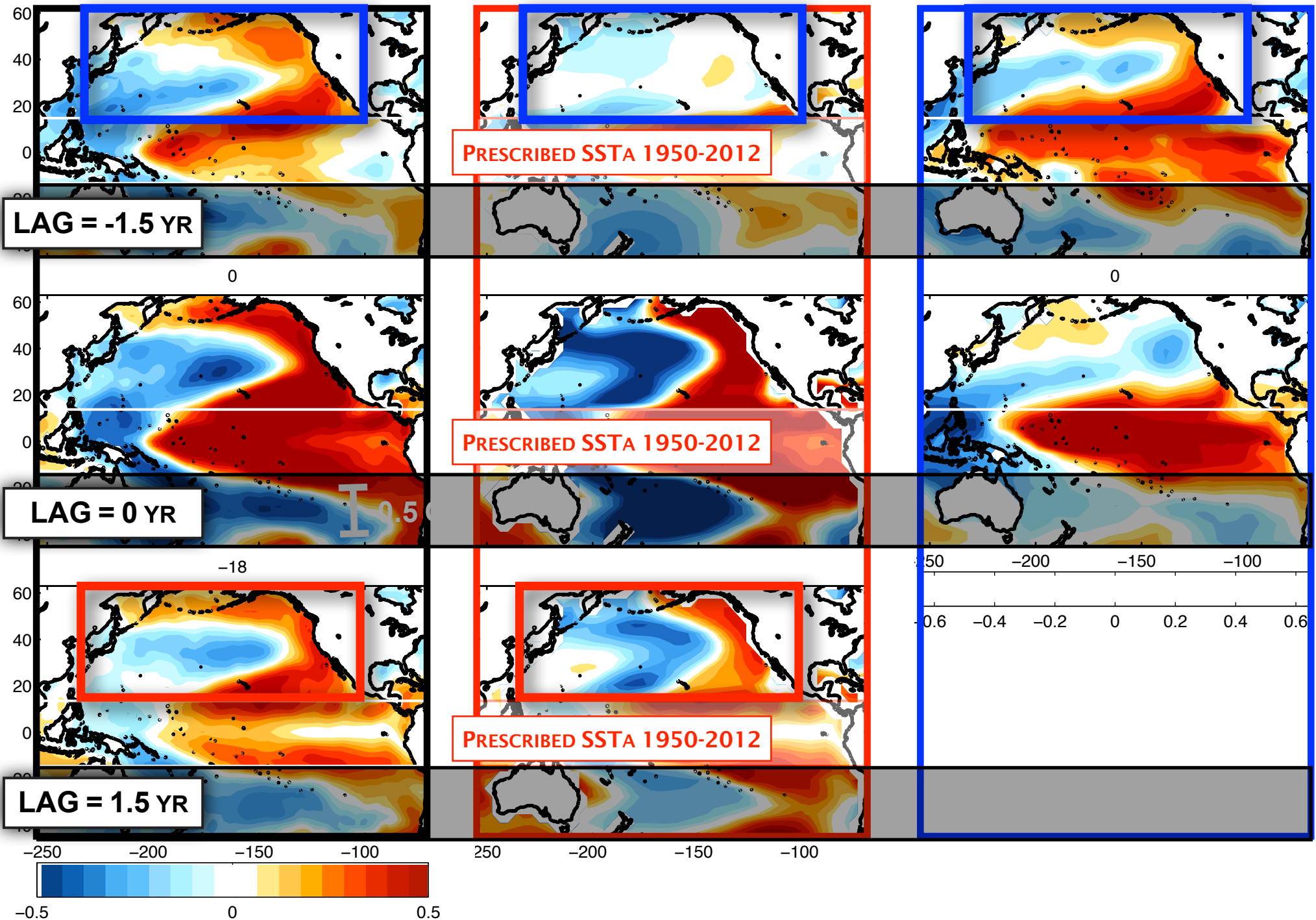
250 -200 -150 -100

50 -200 -150 -100

OBSERVATIONS

ZONAL MODE (EXP)

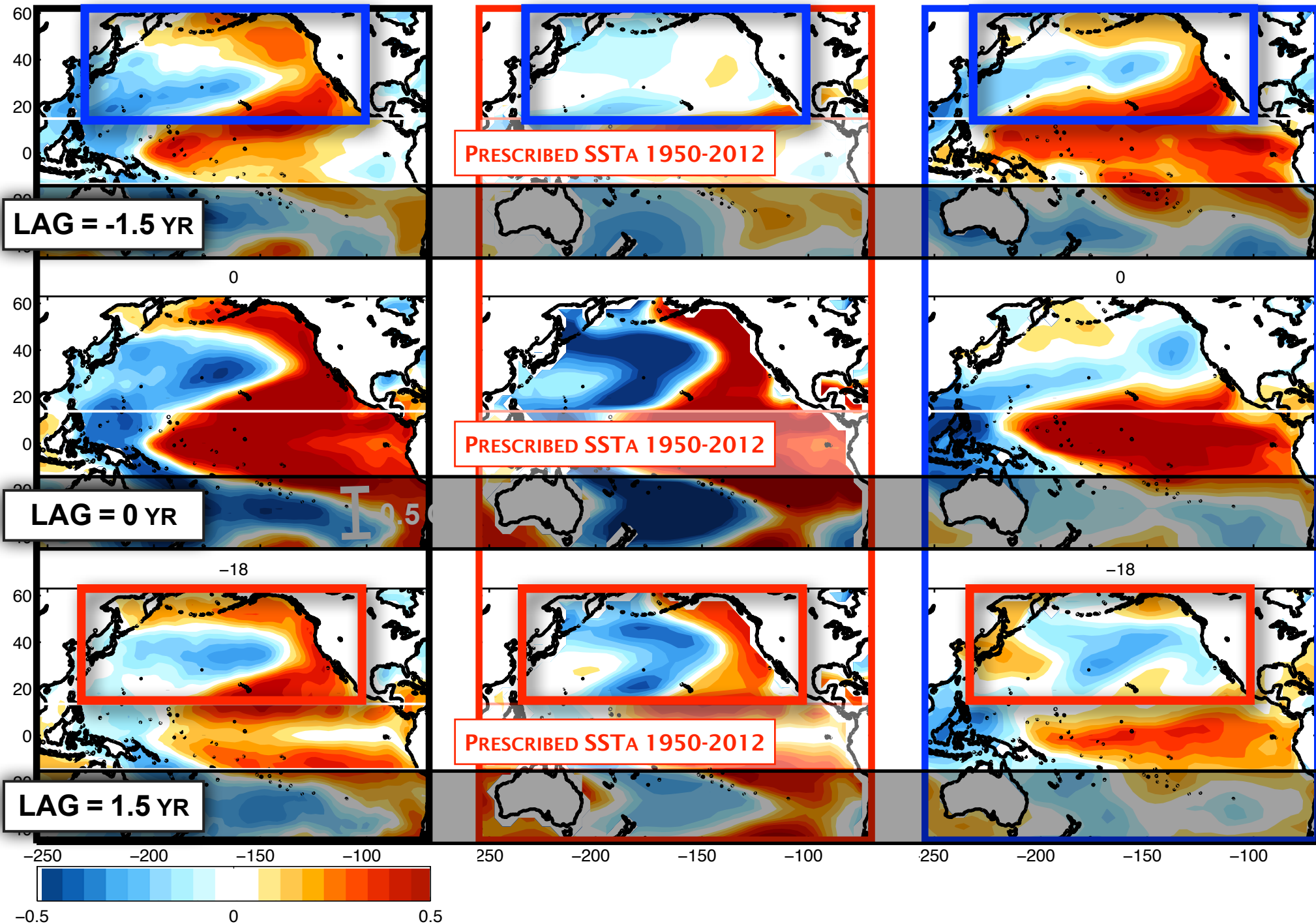
MERIDIONAL MODE (EXP)



OBSERVATIONS

ZONAL MODE (EXP)

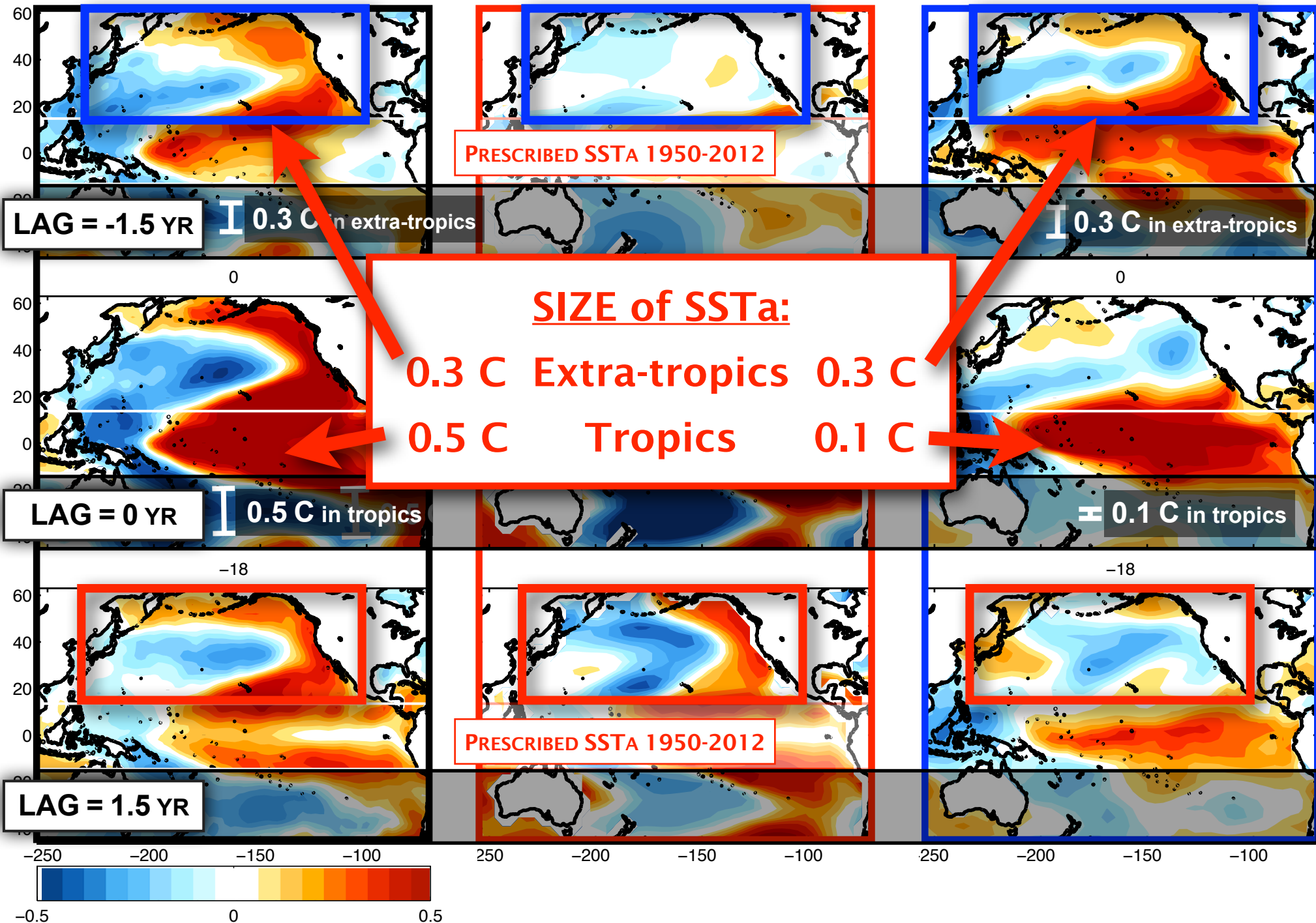
MERIDIONAL MODE (EXP)



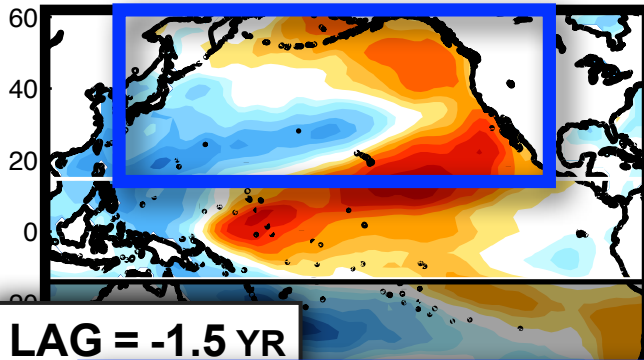
OBSERVATIONS

ZONAL MODE (EXP)

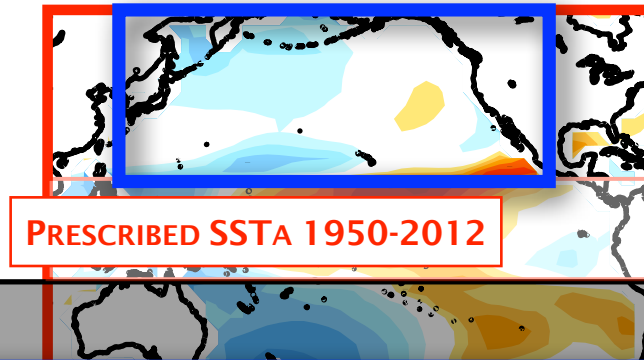
MERIDIONAL MODE (EXP)



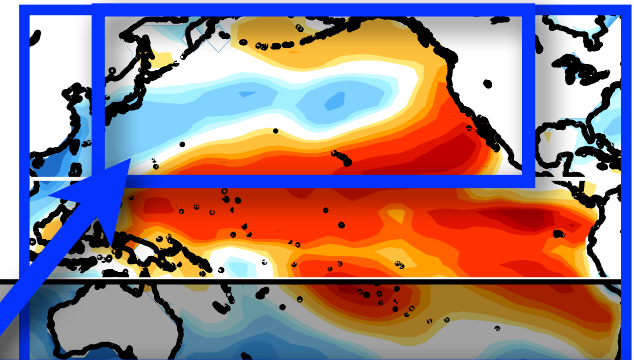
OBSERVATIONS



ZONAL MODE (EXP)



MERIDIONAL MODE (EXP)

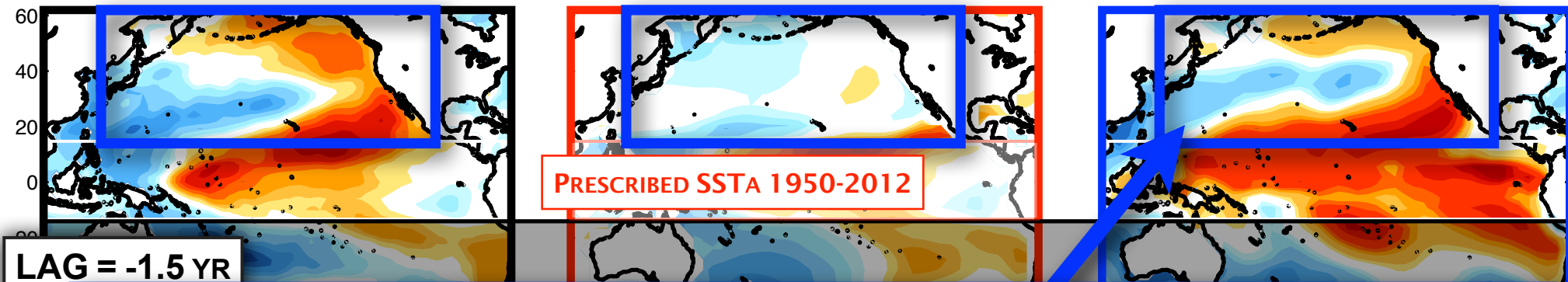


Extra-tropical precursor is not forced by tropics and is likely connected to Meridional Mode dynamics

OBSERVATIONS

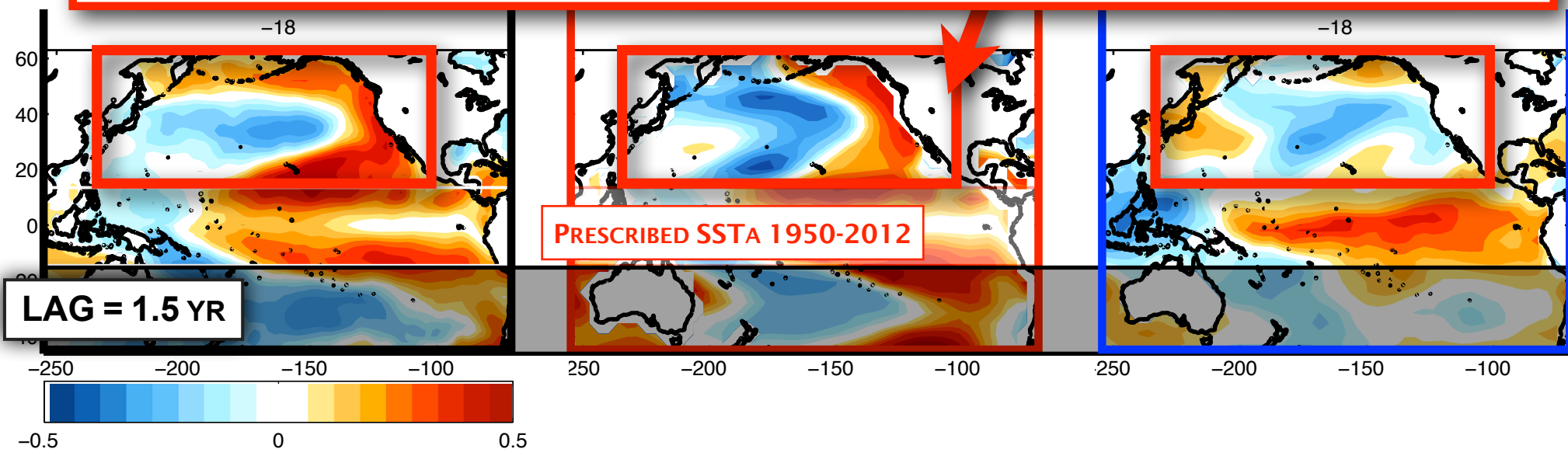
ZONAL MODE (EXP)

MERIDIONAL MODE (EXP)



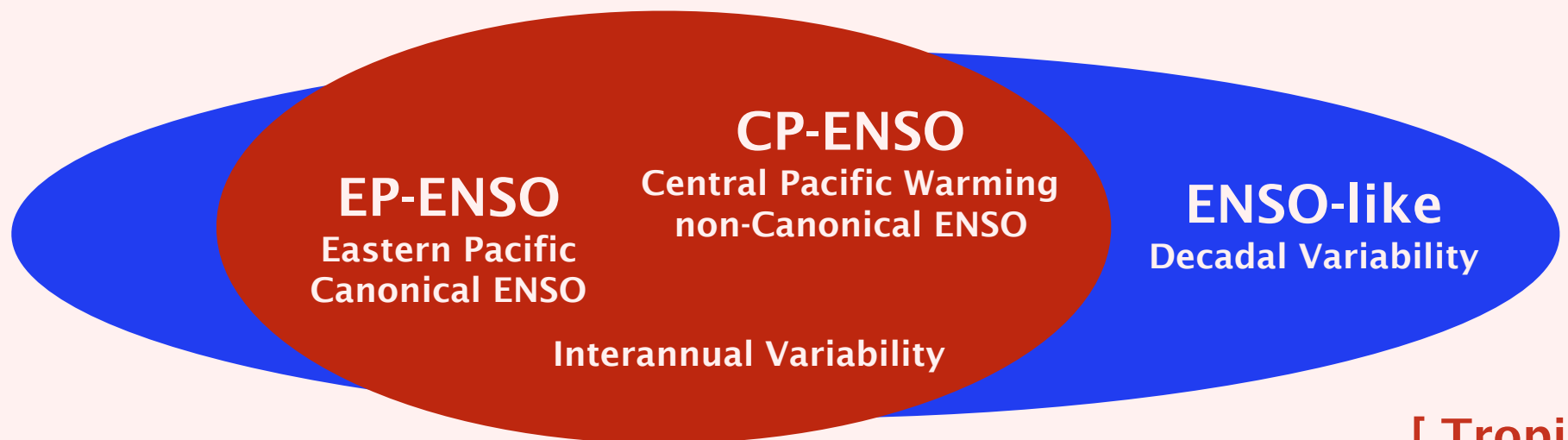
Extra-tropical precursor is not forced by tropics and is likely connected to Meridional Mode dynamics

Extra-tropical successor is forced by tropics and is connected to Zonal Mode response



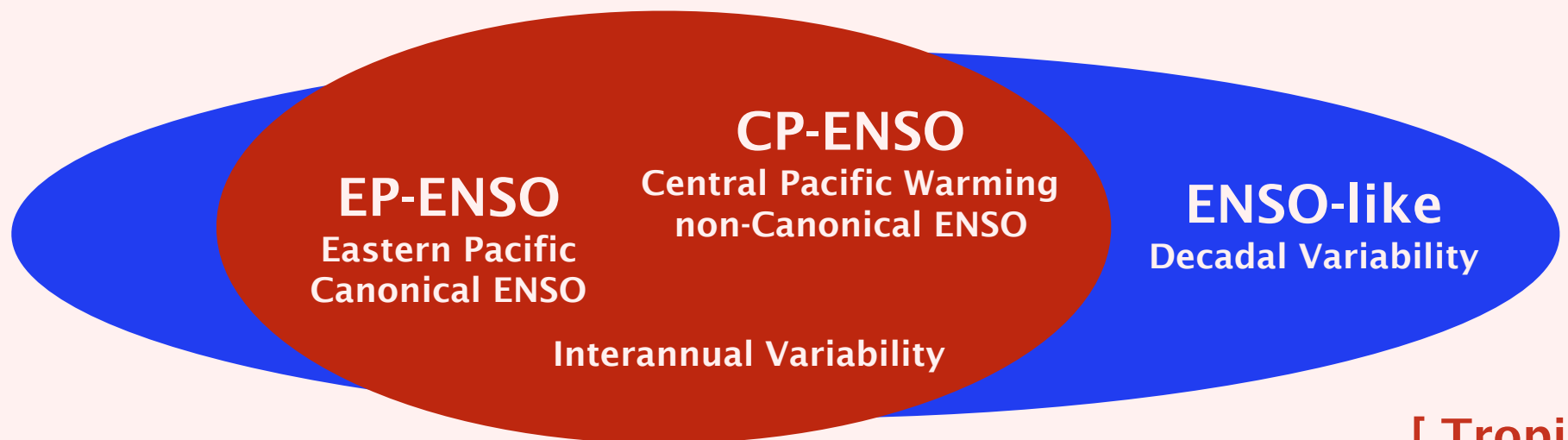
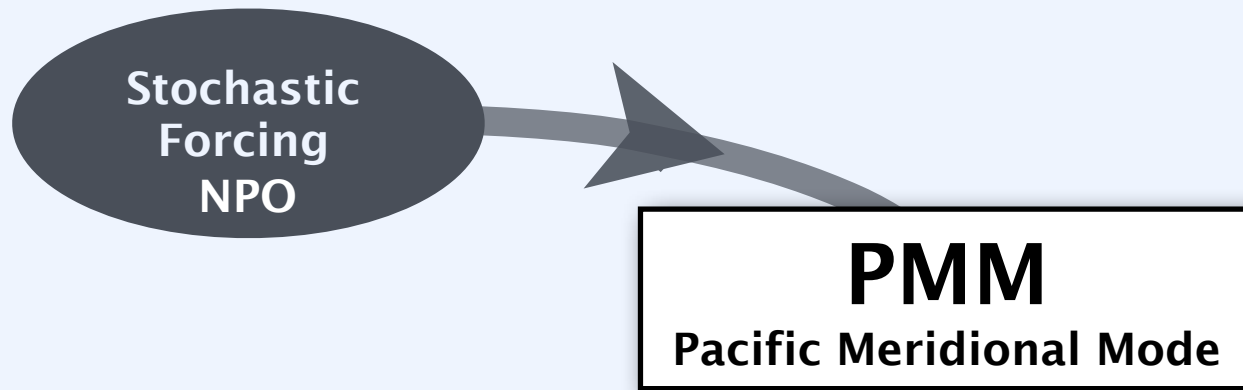
[Extra-tropics]

Stochastic
Forcing
NPO



[Tropics]

[Extra-tropics]



[Tropics]

[Extra-tropics]

Stochastic
Forcing
NPO

PMM
Pacific Meridional Mode

Flavors of ENSO

EP-ENSO
Eastern Pacific
Canonical ENSO

CP-ENSO
Central Pacific Warming
non-Canonical ENSO

ENSO-like
Decadal Variability

Interannual Variability

[Tropics]

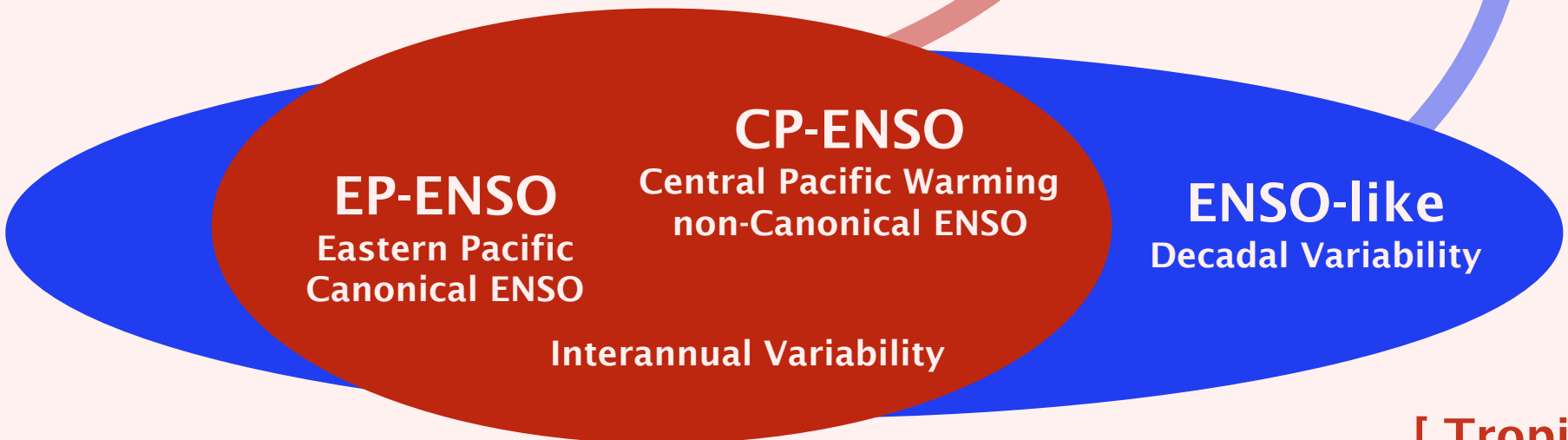
[Extra-tropics]

Stochastic
Forcing
NPO

PMM
Pacific Meridional Mode

Decadal Modulations
of Tropical Pacific

Flavors of ENSO



Interannual Variability

[Tropics]

[Extra-tropics]

Stochastic
Forcing
NPO

PMM
Pacific Meridional Mode

Deterministic
Forcing

Decadal Modulations
of Tropical Pacific

Flavors of ENSO

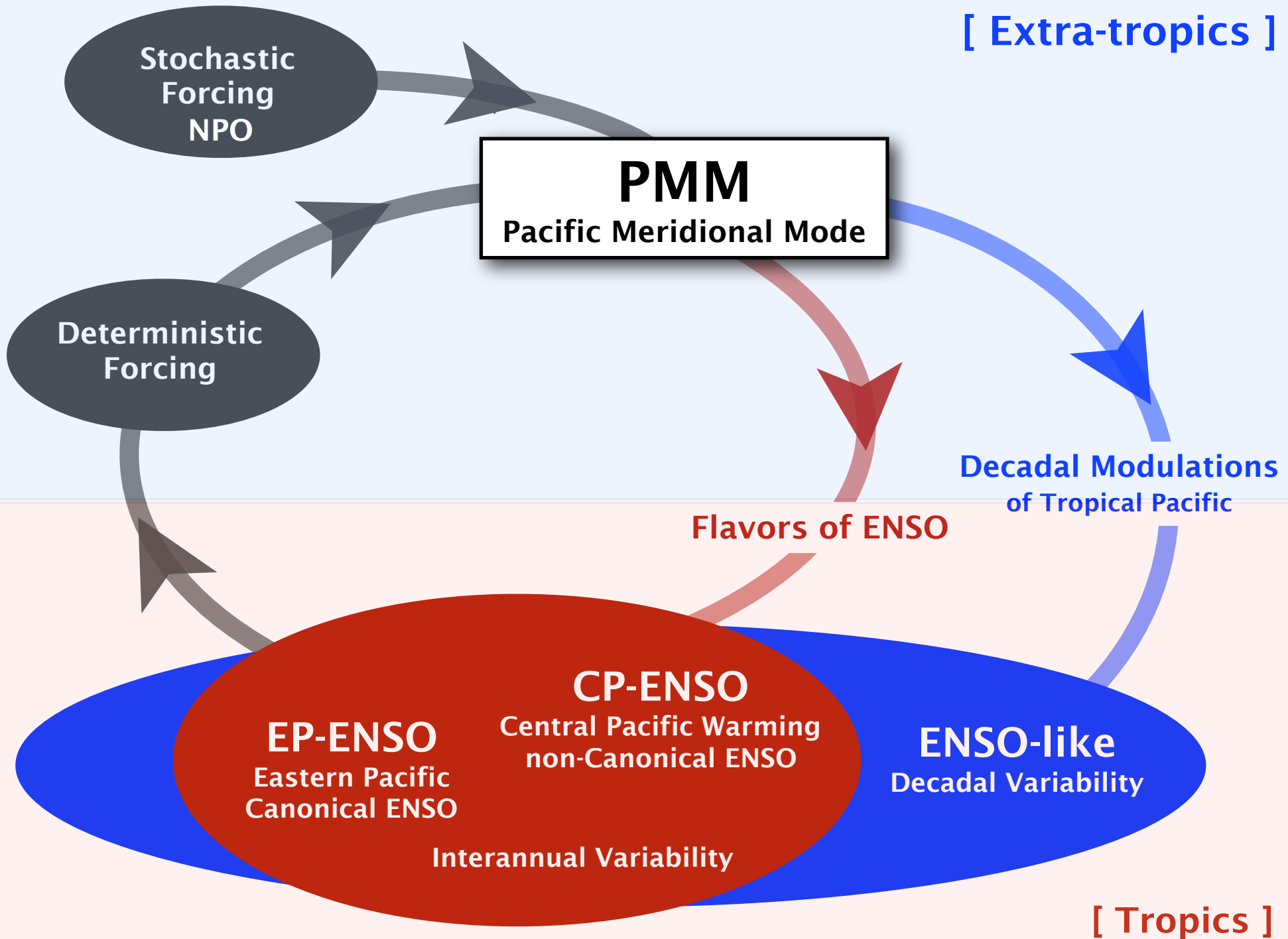
EP-ENSO
Eastern Pacific
Canonical ENSO

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Central Pacific Warming
non-Canonical ENSO

ENSO-like
Decadal Variability

Interannual Variability

[Tropics]



[Extra-tropics]

Stochastic
Forcing
NPO

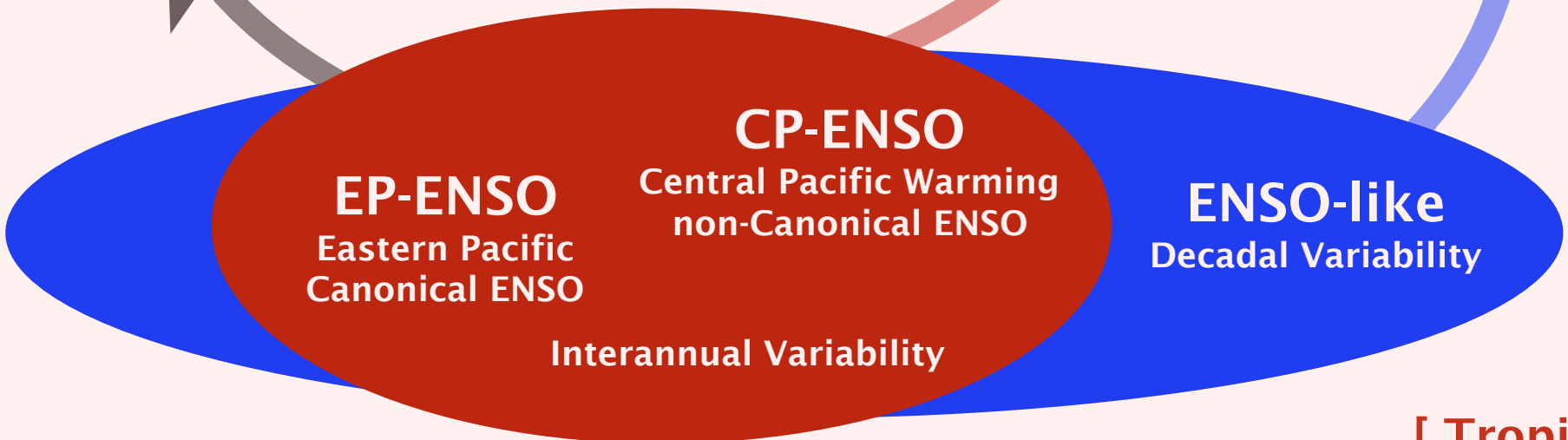
PMM
Pacific Meridional Mode

Deterministic
Forcing

?

Decadal Modulations
of Tropical Pacific

Flavors of ENSO



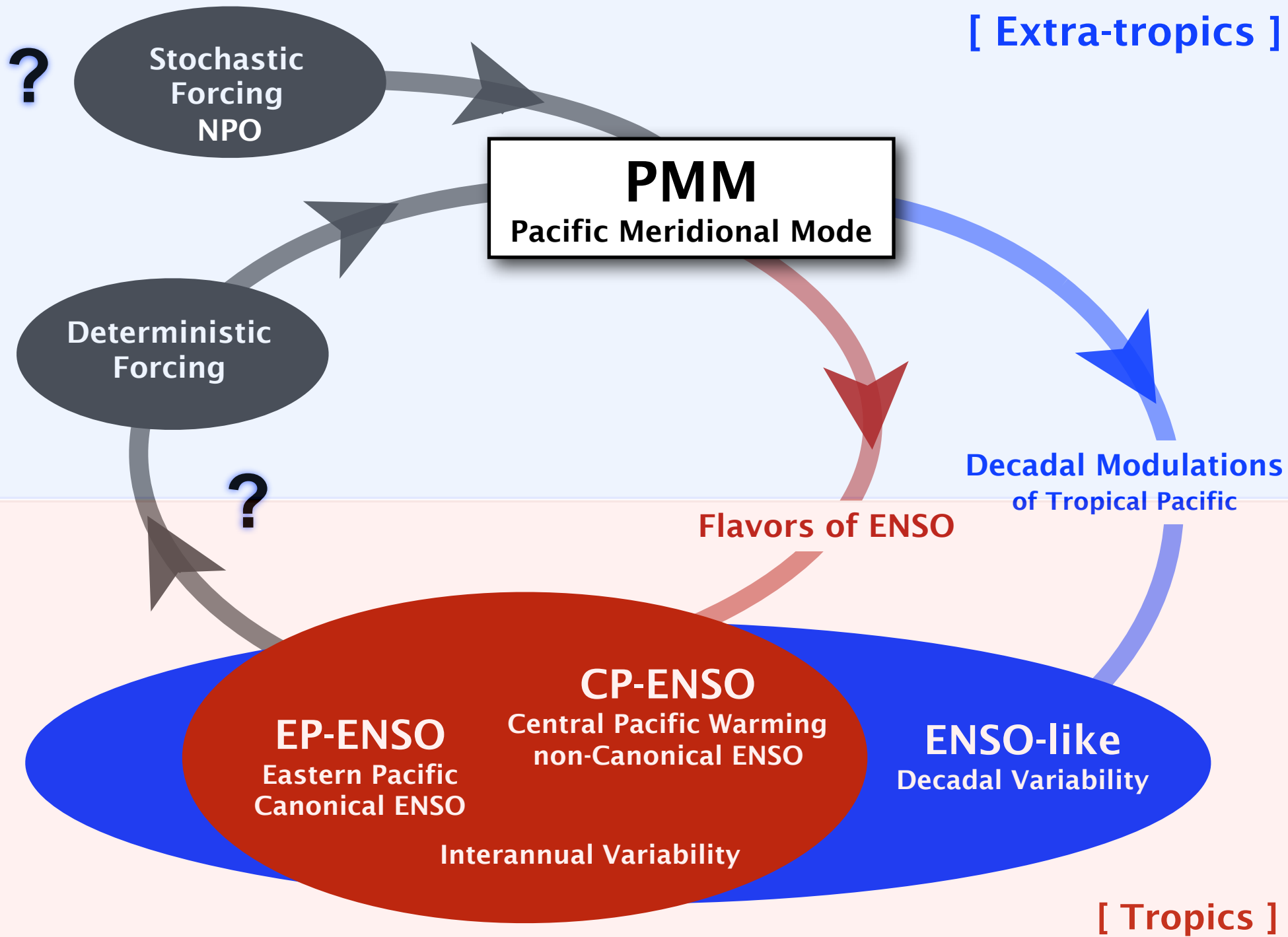
EP-ENSO
Eastern Pacific
Canonical ENSO

CP-ENSO
Central Pacific Warming
non-Canonical ENSO

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Decadal Variability

Interannual Variability

[Tropics]



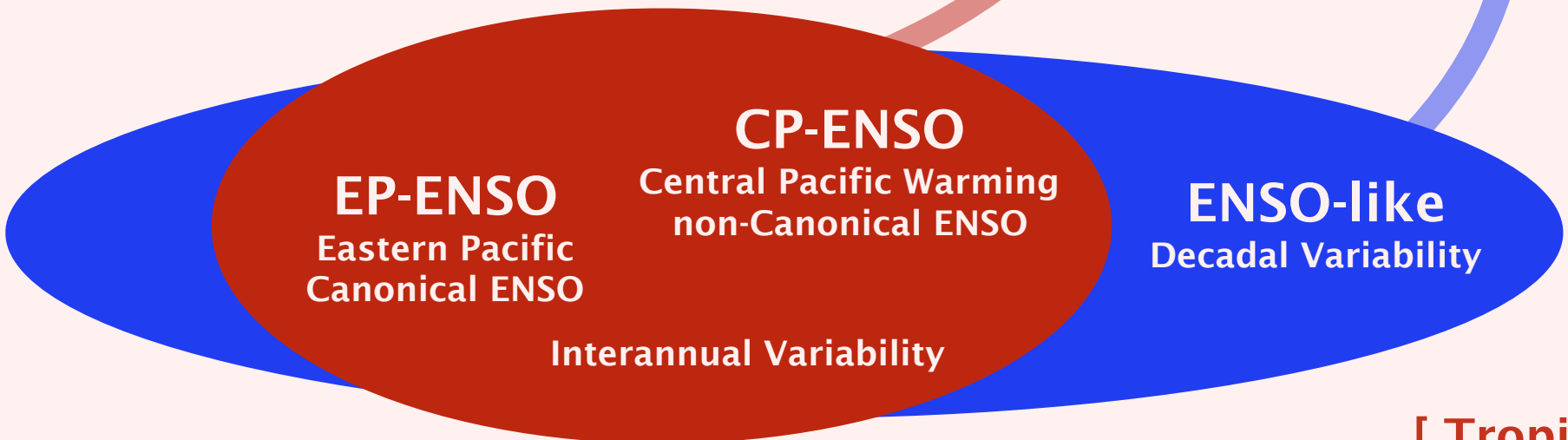
[Extra-tropics]

Stochastic
Forcing
NPO

PMM
Pacific Meridional Mode

Decadal Modulations
of Tropical Pacific

Flavors of ENSO

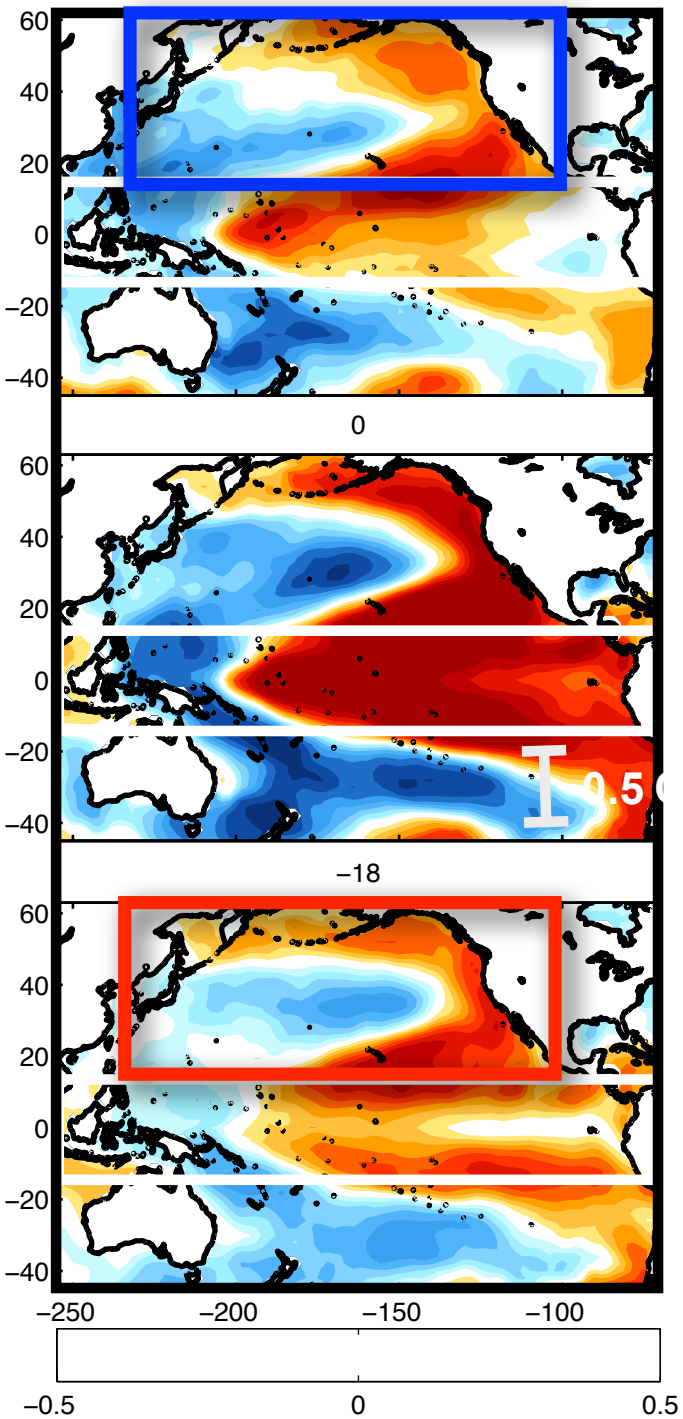


Interannual Variability

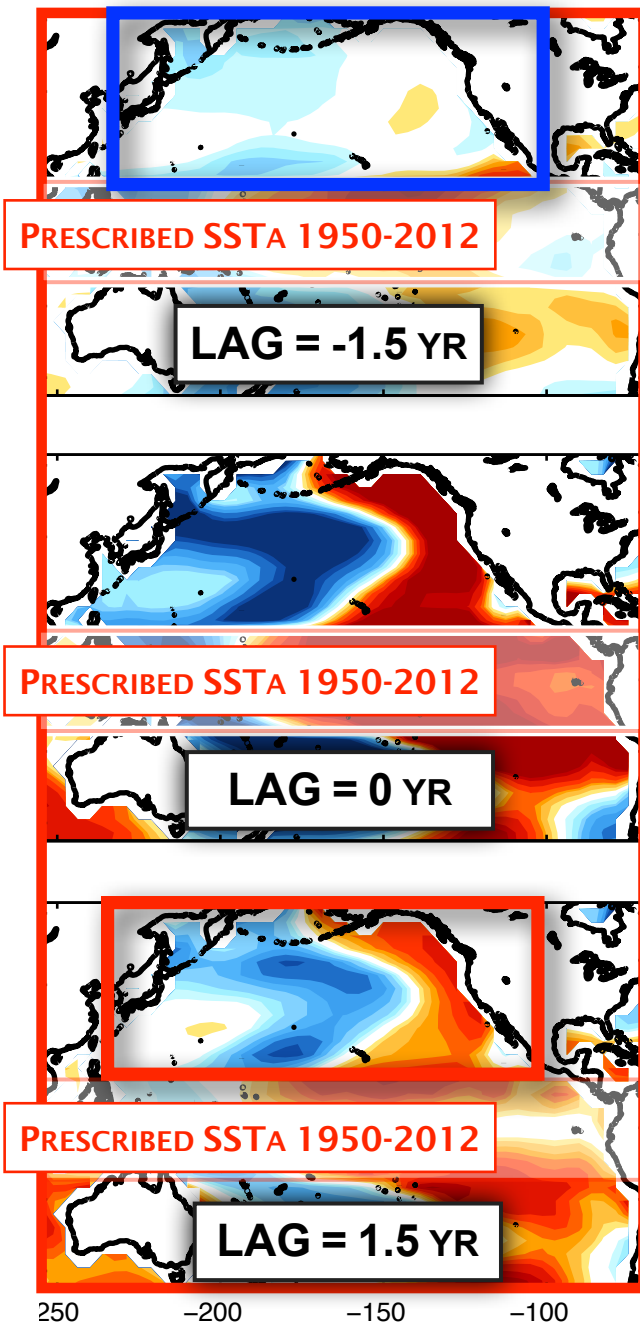
[Tropics]

END

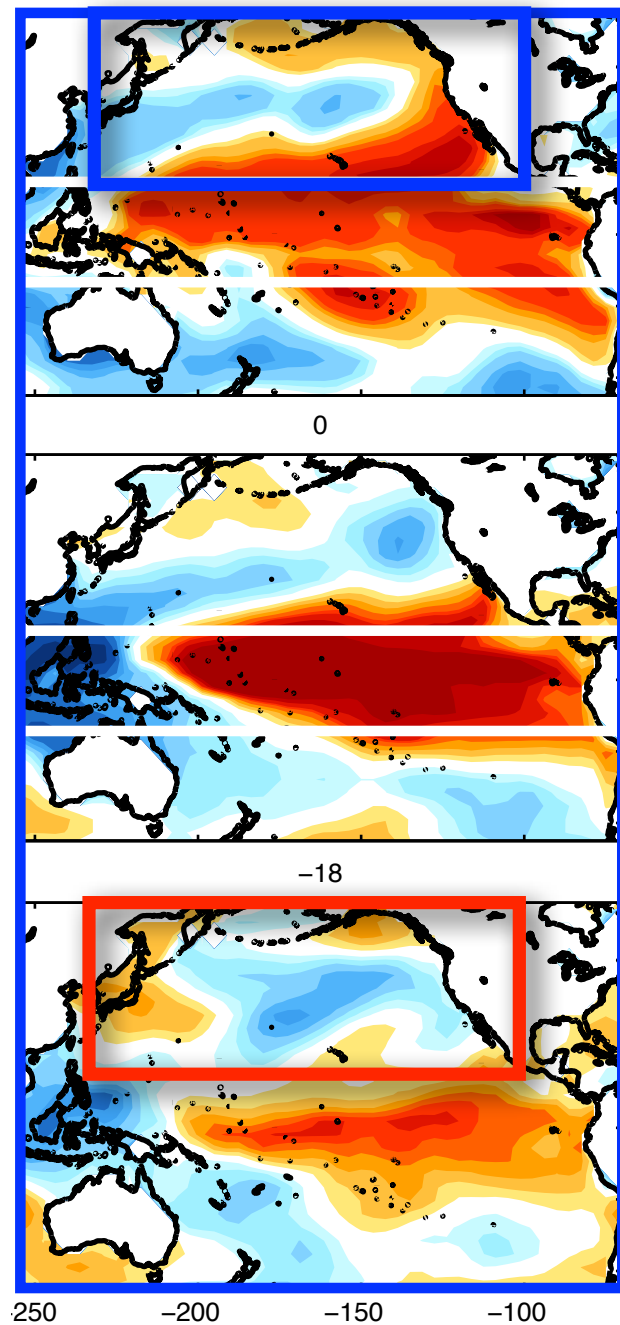
OBSERVATIONS



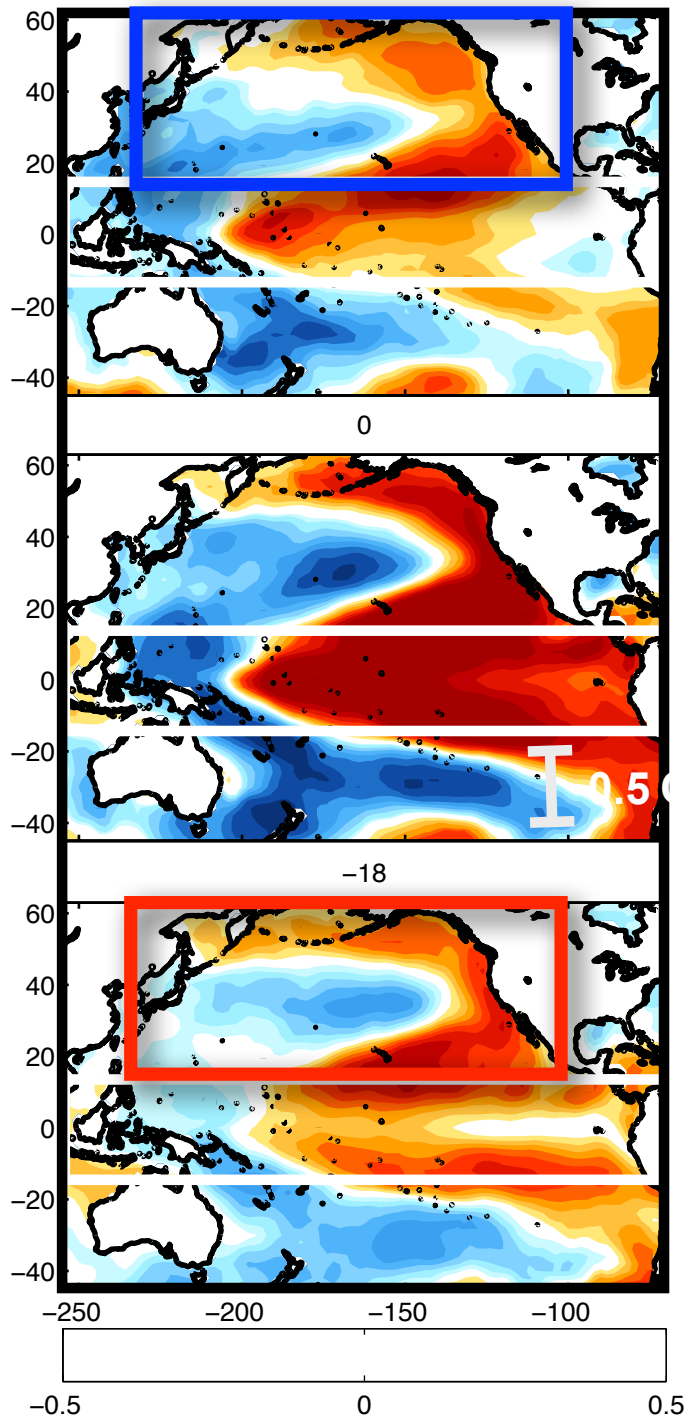
ZONAL MODE (EXP)



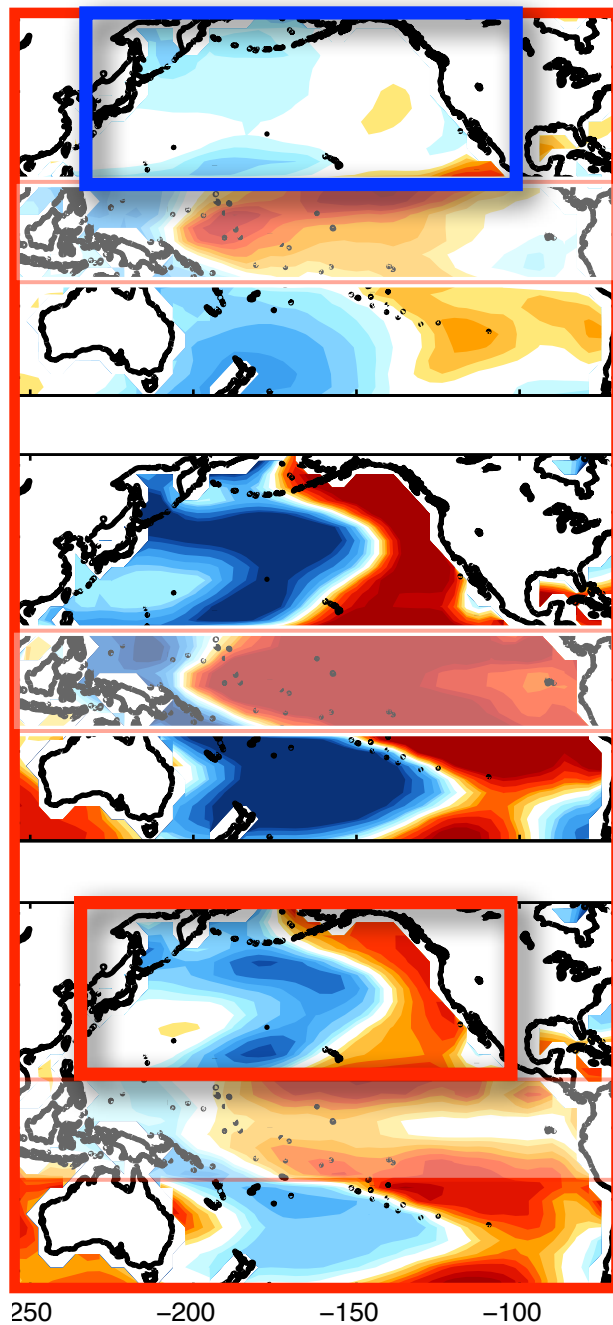
MERIDIONAL MODE (EXP)



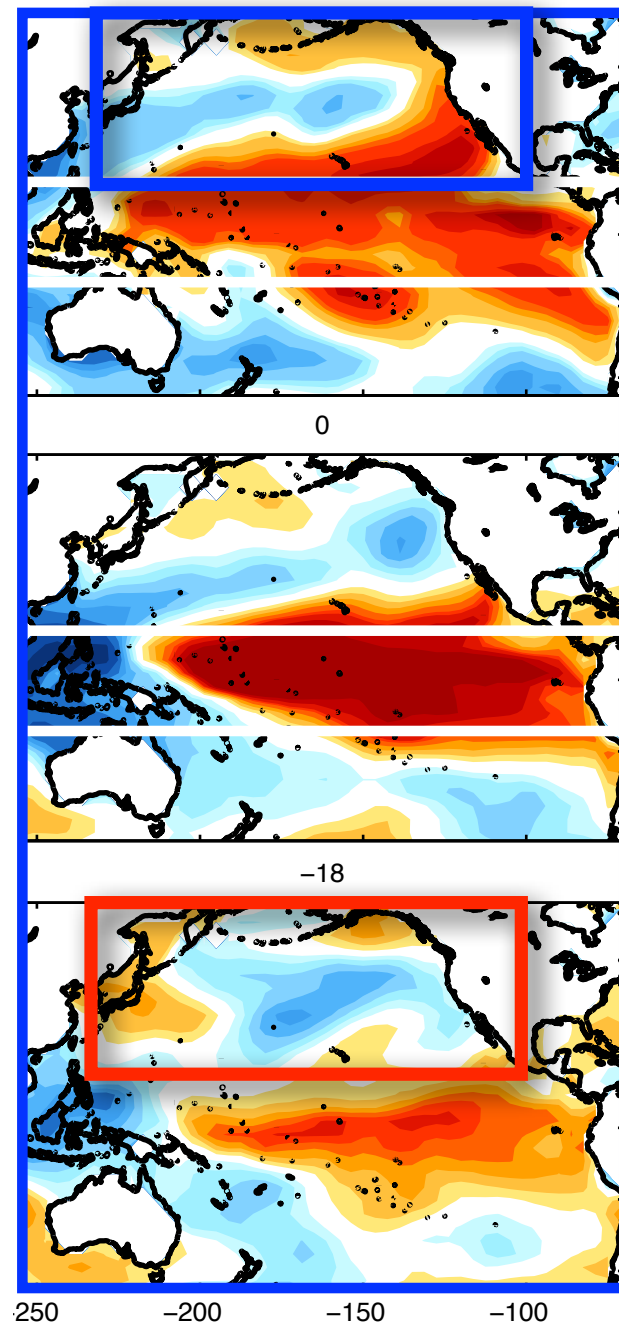
OBSERVATIONS



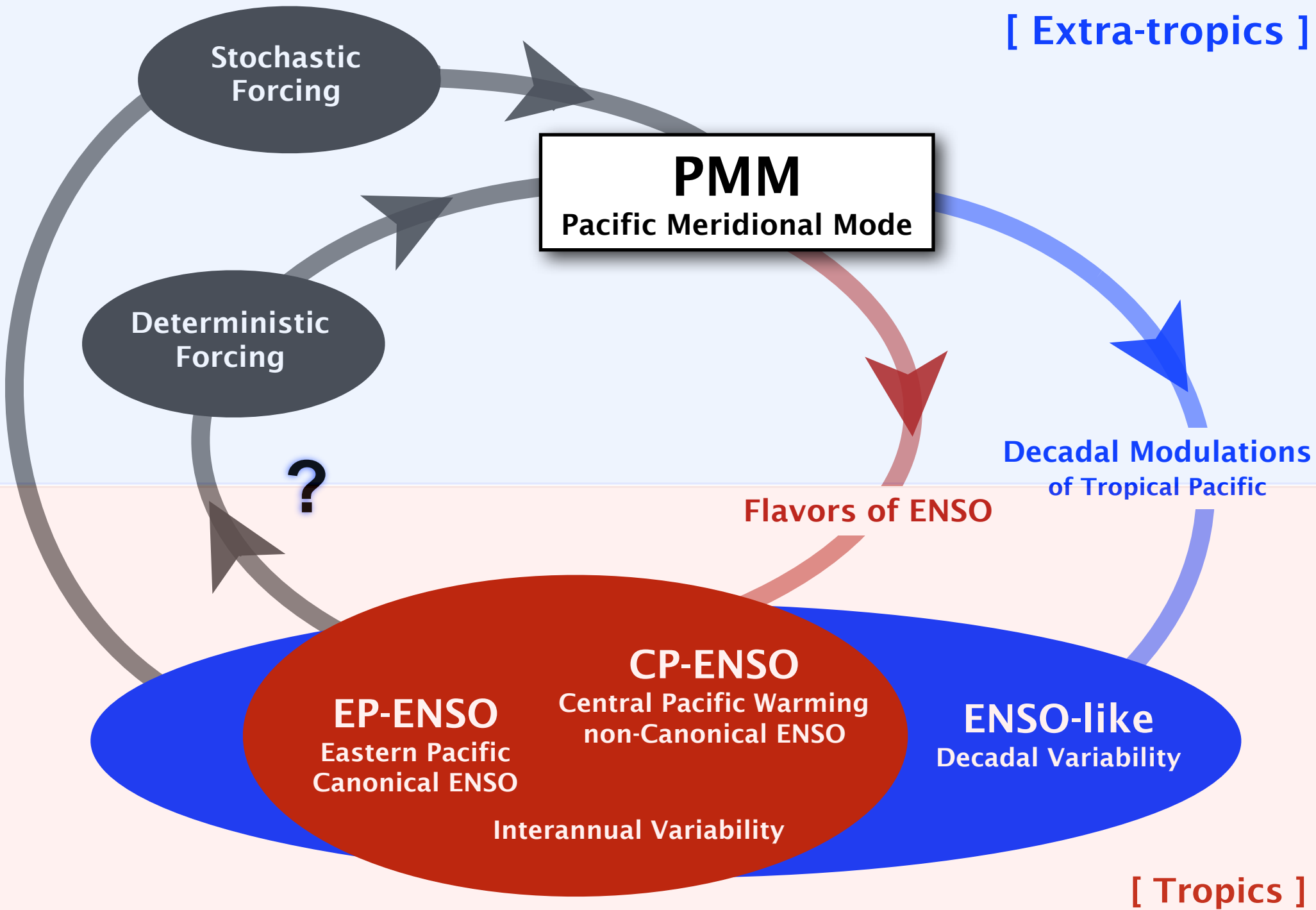
ZONAL MODE (EXP)



MERIDIONAL MODE (EXP)

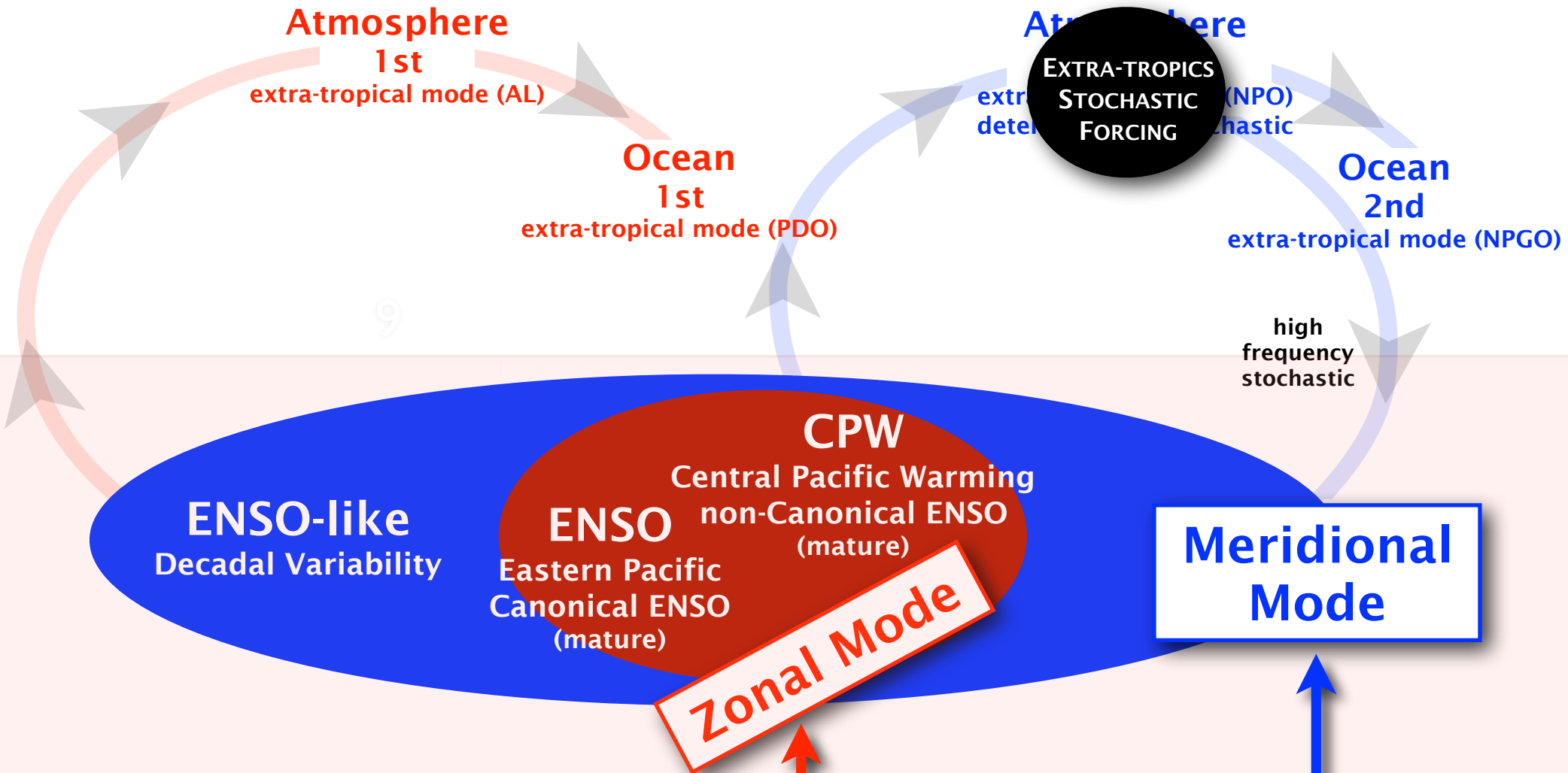


[Extra-tropics]



A NULL-HYPOTHESIS FOR PACIFIC CLIMATE DYNAMICS

Extra-tropics [Ocean forced by Atmosphere]



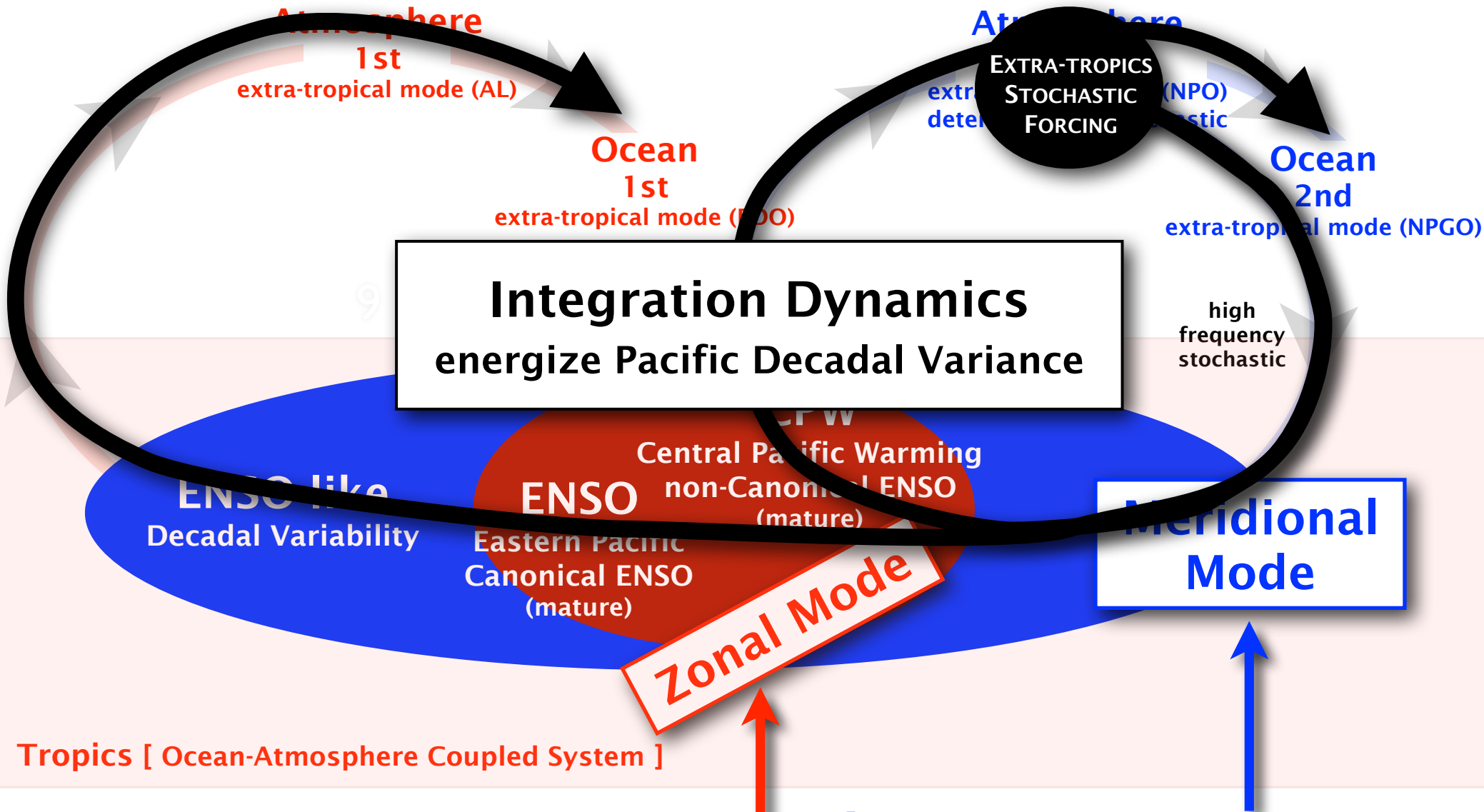
Tropics [Ocean-Atmosphere Coupled System]

2 Zonal Mode (E-W): respond and amplify the MM anomalies in the tropics and excites teleconnections that add memory to the coupled system.

1 Meridional Mode (N-S): injects decadal-scale variance into the tropical system.

A NULL-HYPOTHESIS FOR PACIFIC CLIMATE DYNAMICS

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[Extra-tropics]

Stochastic
Forcing

PMM
Pacific Meridional Mode

Decadal Modulations
of Tropical Pacific

EP-ENSO
Eastern Pacific
Canonical ENSO

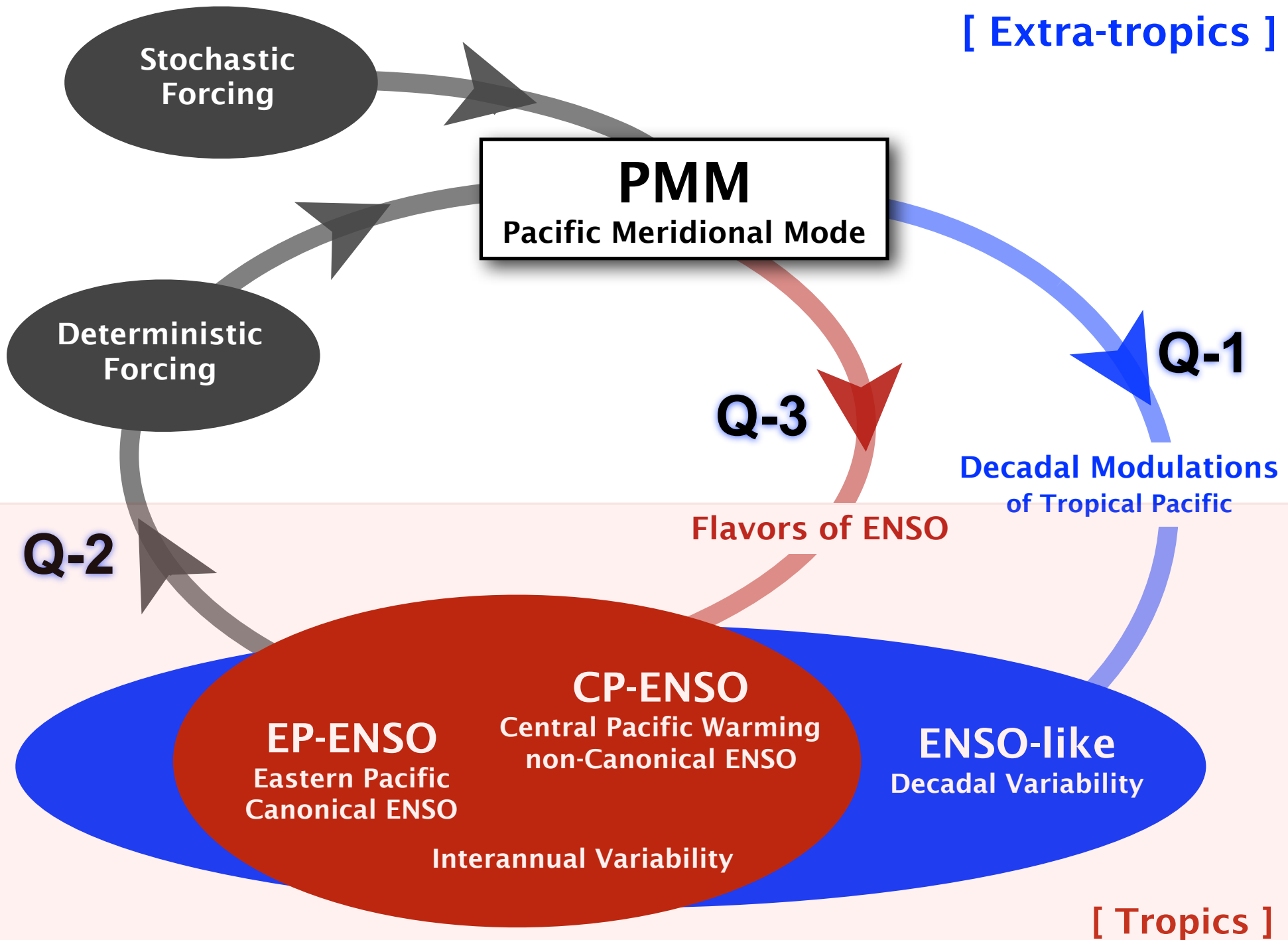
CP-ENSO
Central Pacific Warming
non-Canonical ENSO

ENSO-like
Decadal Variability

Interannual Variability

[Tropics]

[Extra-tropics]



A NULL-HYPOTHESIS FOR PACIFIC CLIMATE DYNAMICS

Extra-tropics [Ocean forced by Atmosphere]

Atmosphere
1st
extra-tropical mode (AL)

Ocean
1st
extra-tropical mode (PDO)

Atmosphere
2nd
extra-tropical mode (NPO)
deterministic + stochastic

Ocean
2nd
extra-tropical mode (NPGO)

high
frequency
stochastic

ENSO-like
Decadal Variability

CPW
Central Pacific Warming
non-Canonical ENSO
(mature)
ENSO
Eastern Pacific
Canonical ENSO
(mature)

Zonal Mode

Meridional
Mode

Tropics [Ocean-Atmosphere Coupled System]

2 Zonal Mode (E-W): can respond & amplify the MM anomalies in the tropics and excites teleconnections that add memory to the coupled system.

1 Meridional Mode (N-S): can be a primary source or energizer of the decadal-scale variance in the tropical system.

FURTADO ET AL., IN PREP

TRENARY ET AL., IN PREP

[Extra-tropics]

Stochastic Forcing

Deterministic Forcing

PMM
Pacific Meridional Mode

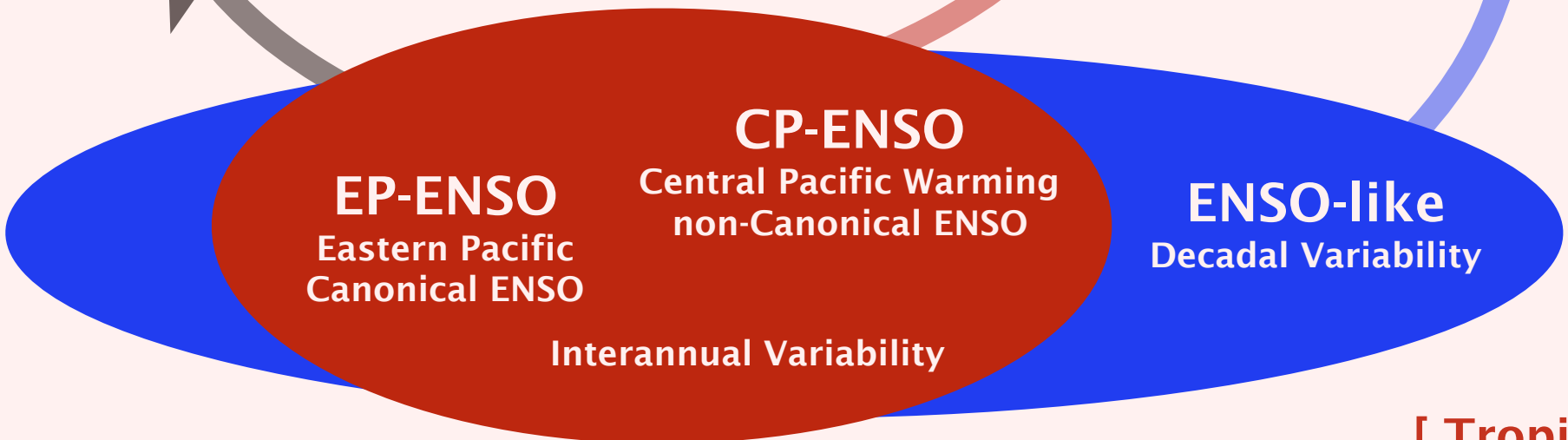
Q-1

Q-3

Decadal Modulations of Tropical Pacific

Q-2

Flavors of ENSO

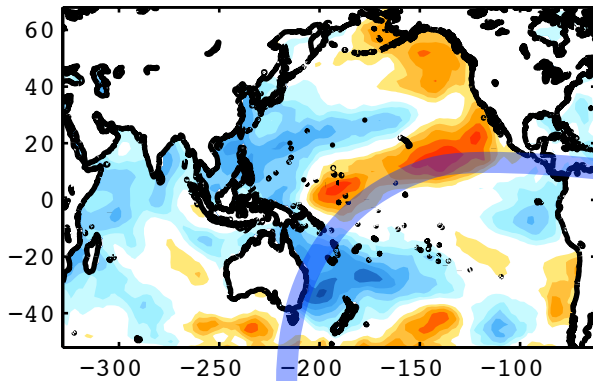


[Tropics]

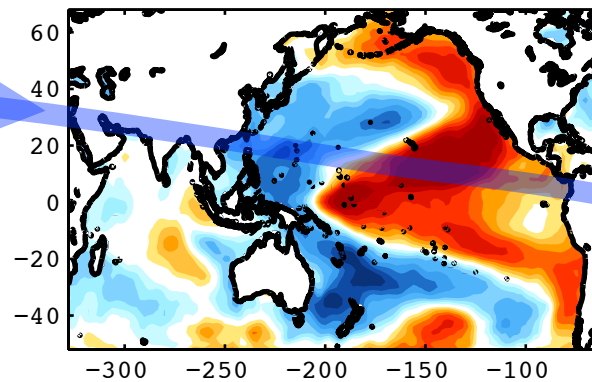
A NULL-HYPOTHESIS FOR PACIFIC CLIMATE DYNAMICS

1 Meridional Mode energizes tropics

LAG -2 YEAR

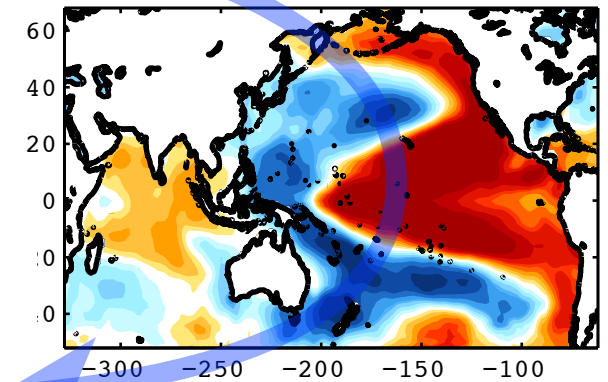


LAG -1 YEAR



2 Zonal Mode (ENSO) response

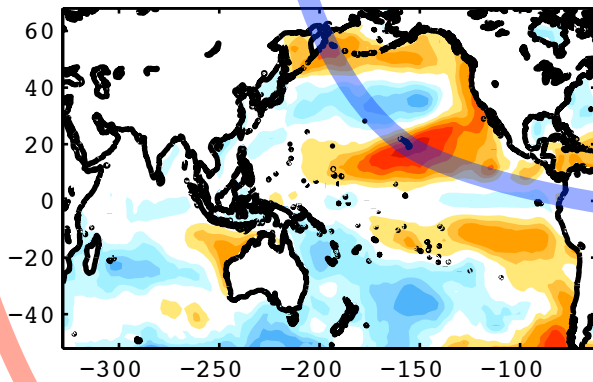
LAG 0



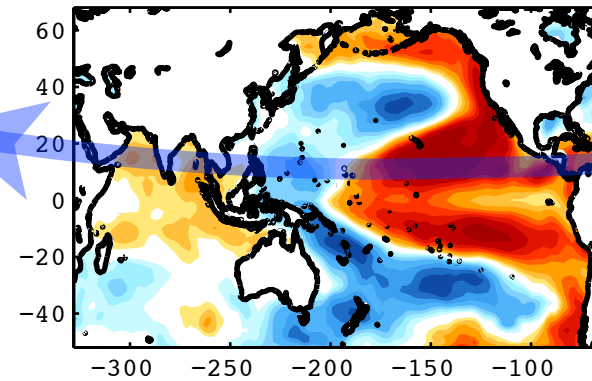
3 Extra-tropical Teleconnection of ENSO add memory

4 Extra-Tropical Residual Variance on Meridional Mode

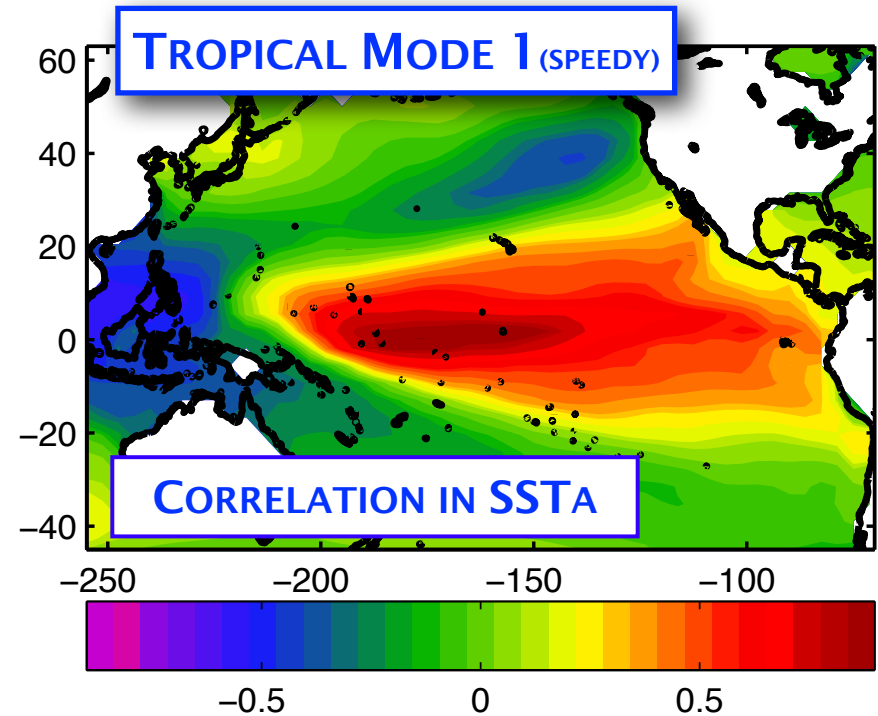
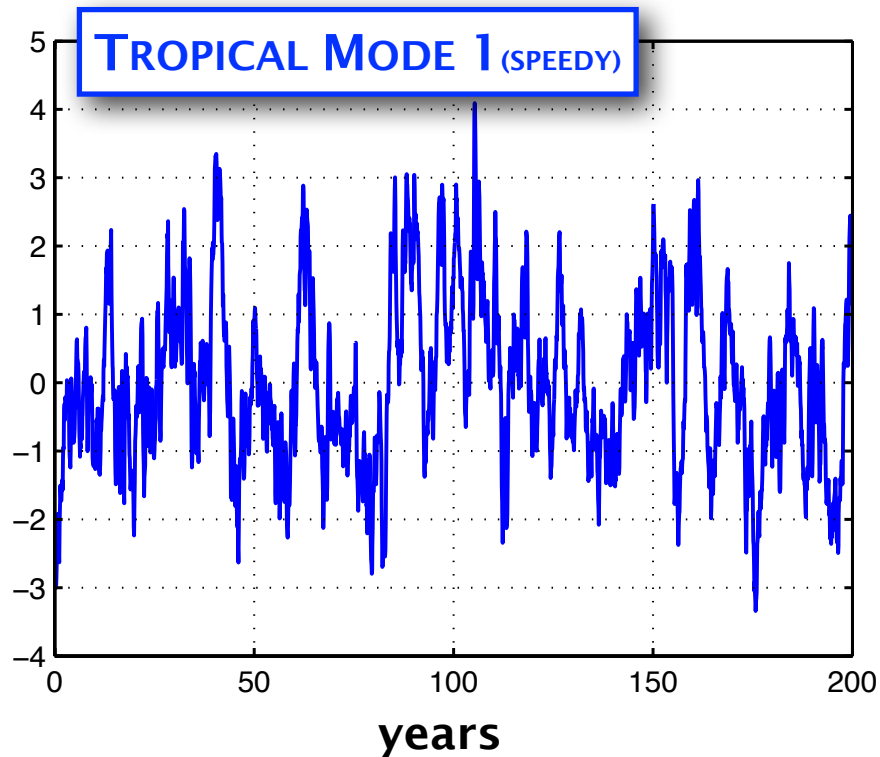
LAG +2 YEAR



LAG +1 YEAR

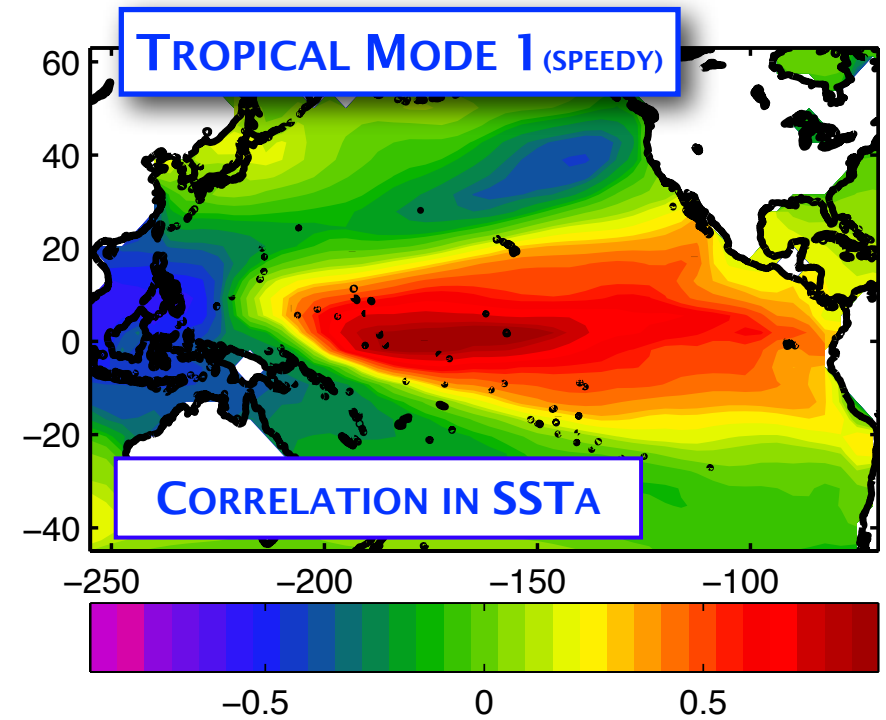
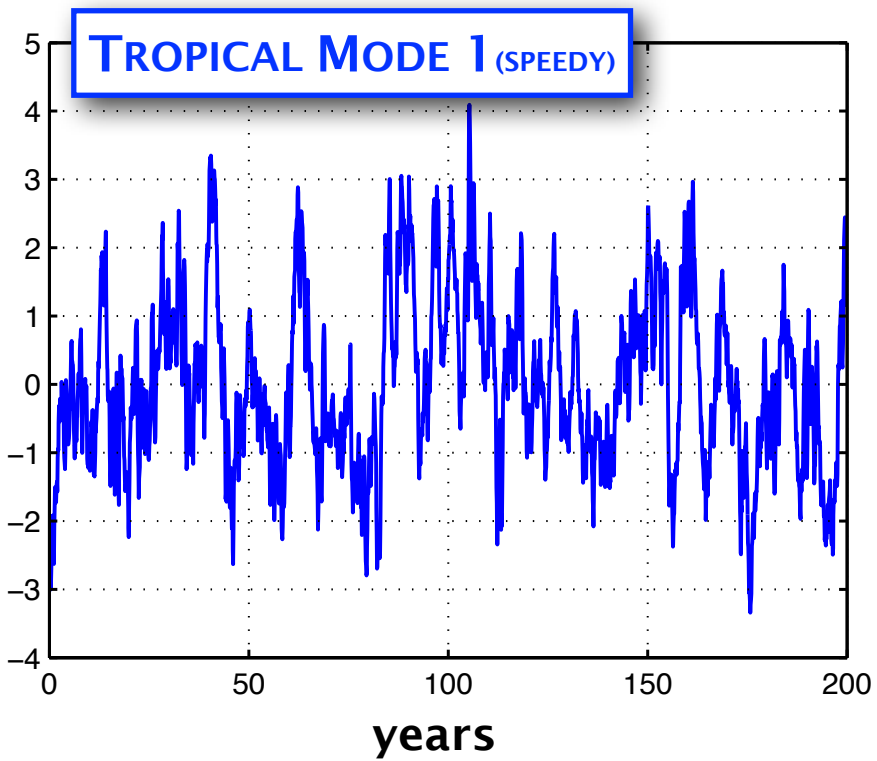
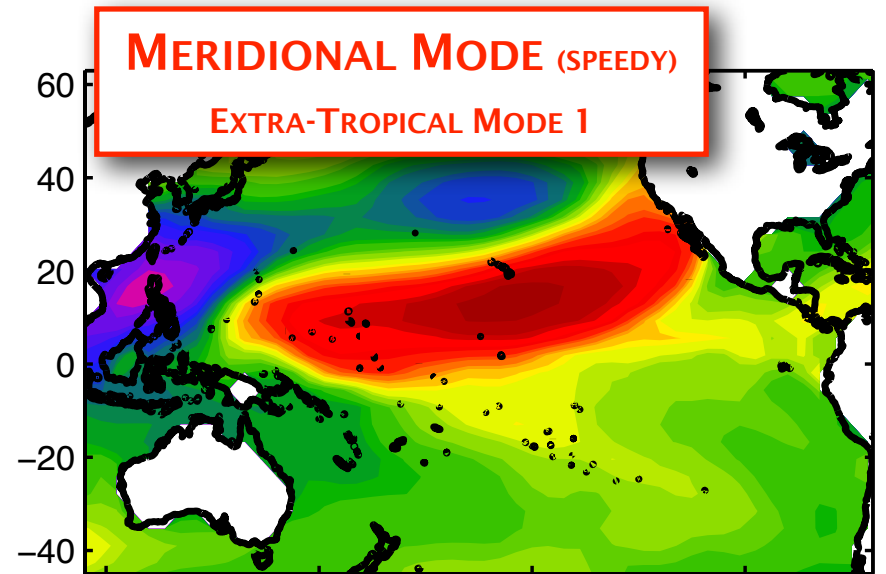


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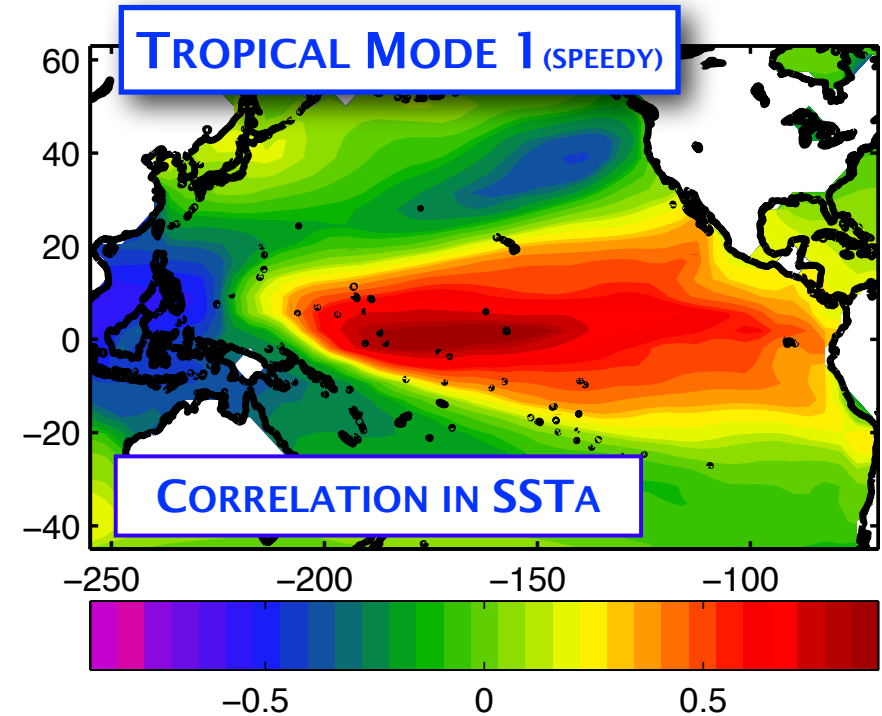
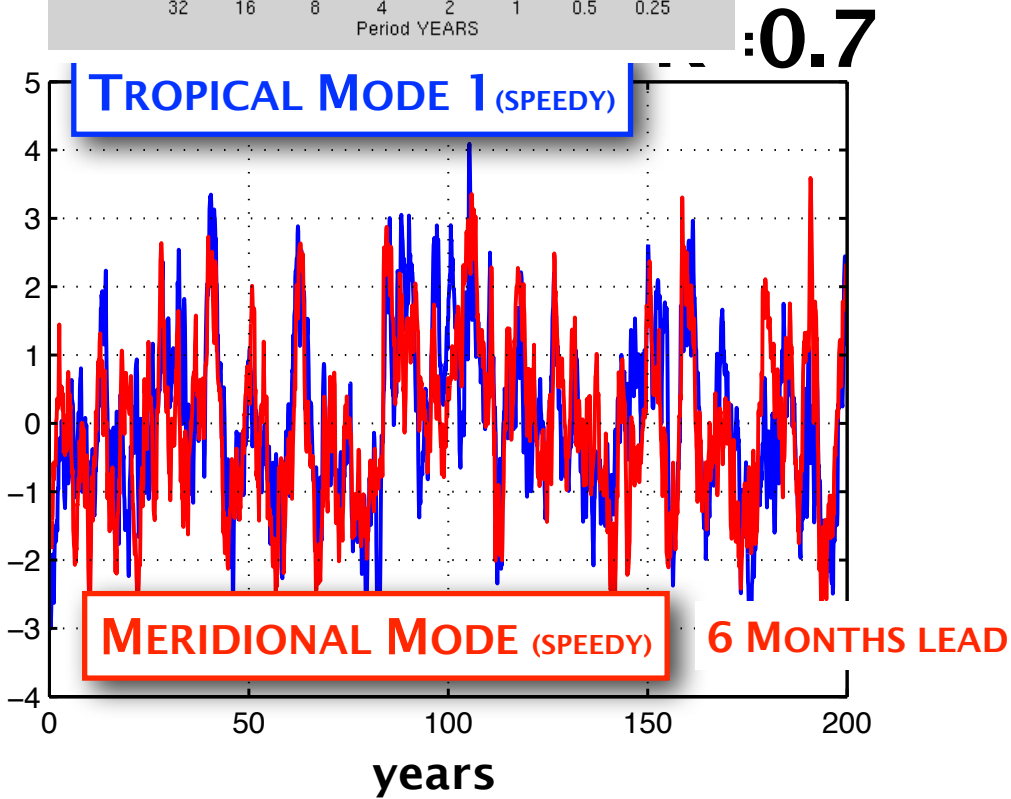
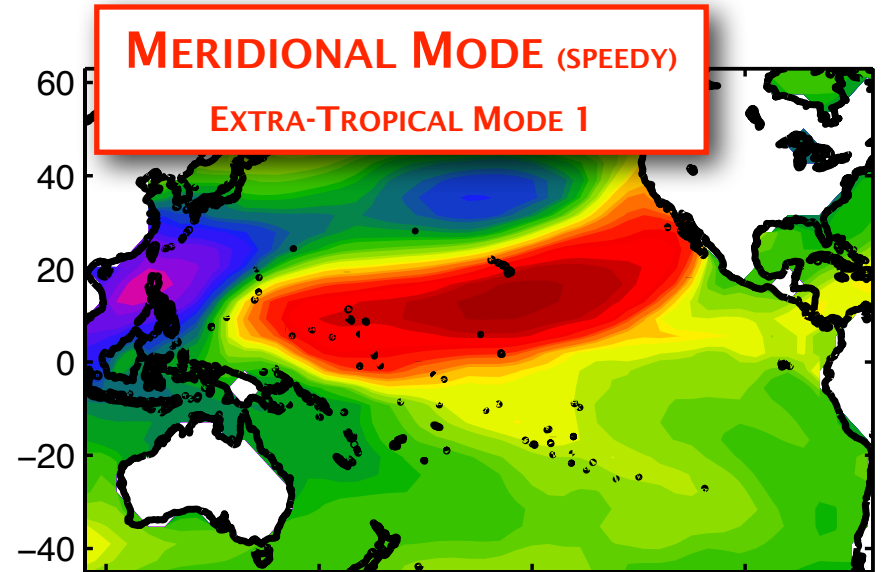
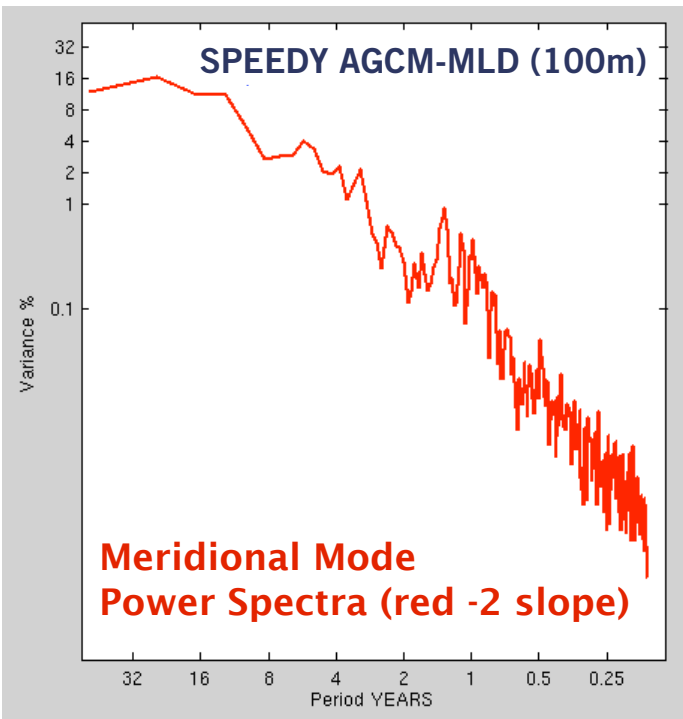


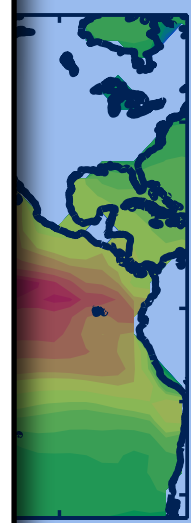
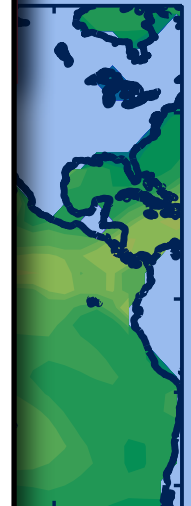
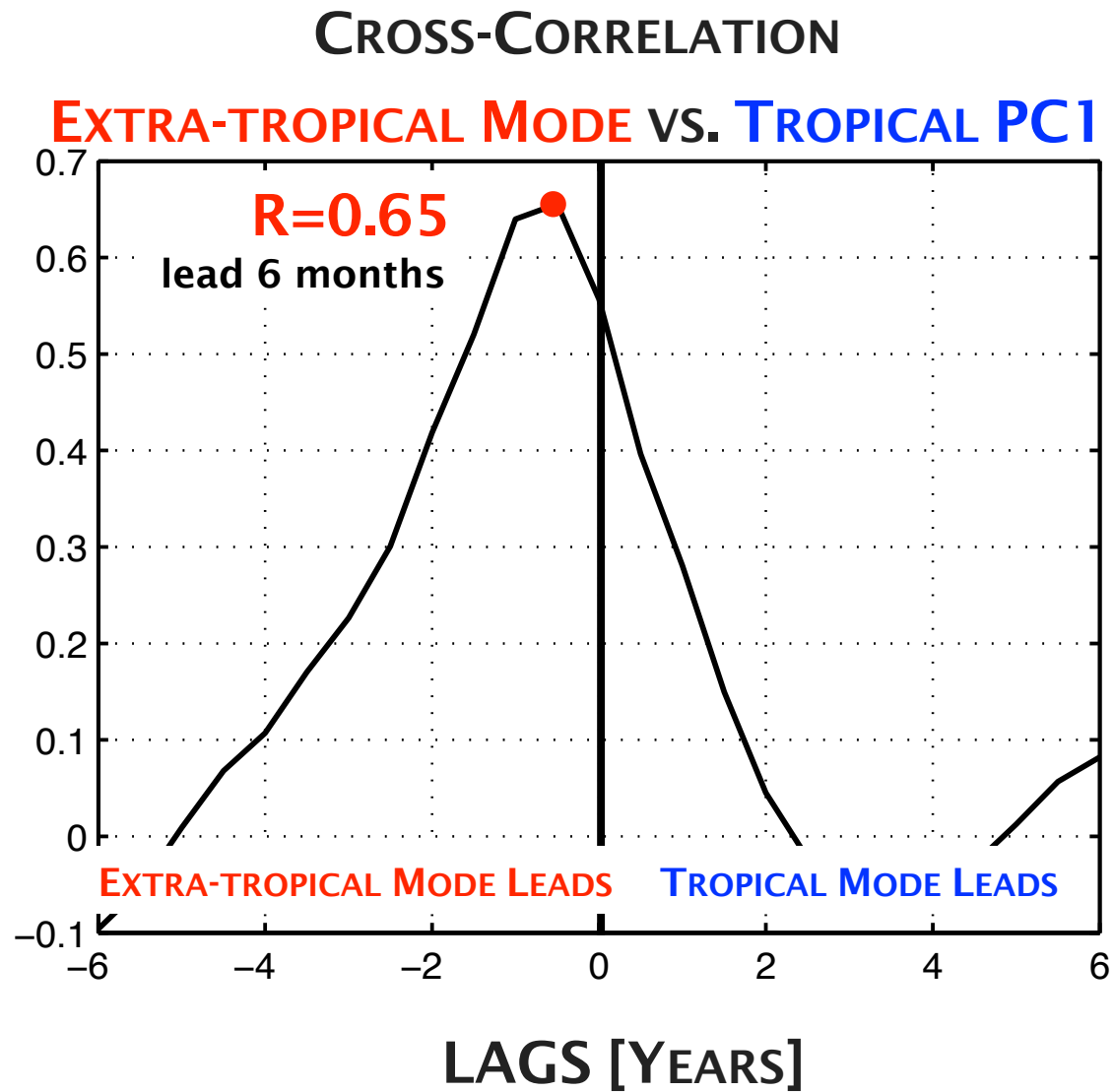
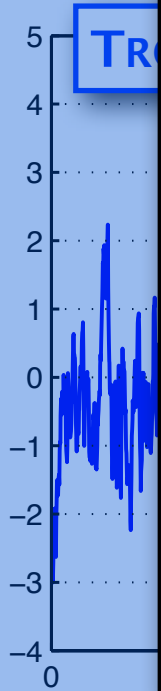
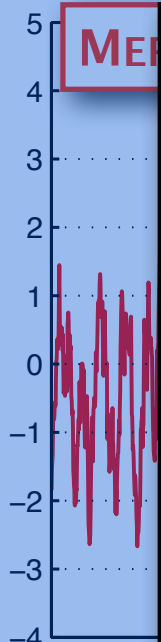
QUESTION:

Can the Meridional Mode act as an independent and primary source of tropical decadal variance?



AGCM-MLD (SPEEDY)



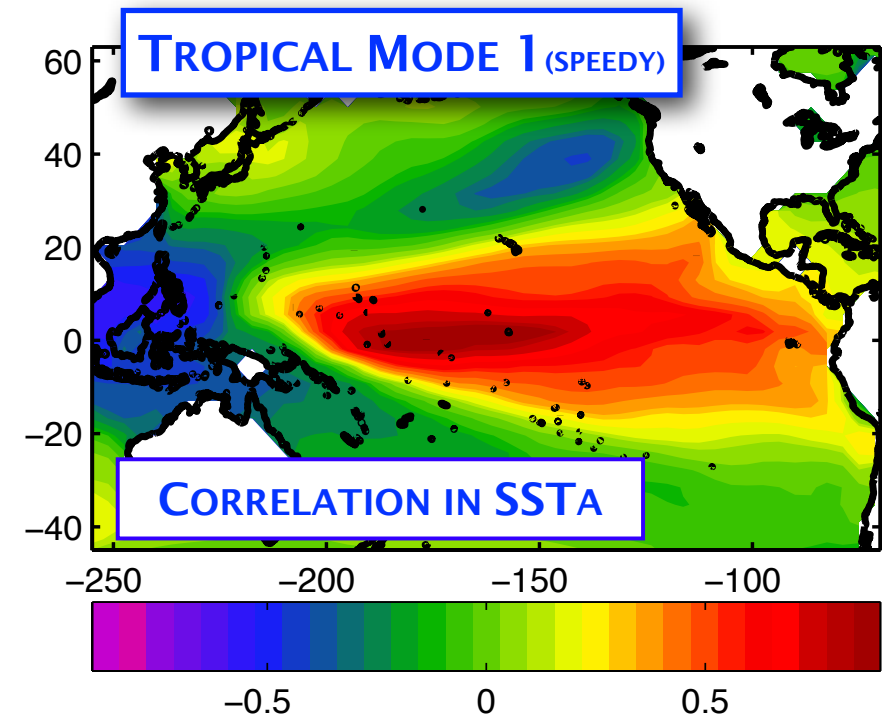
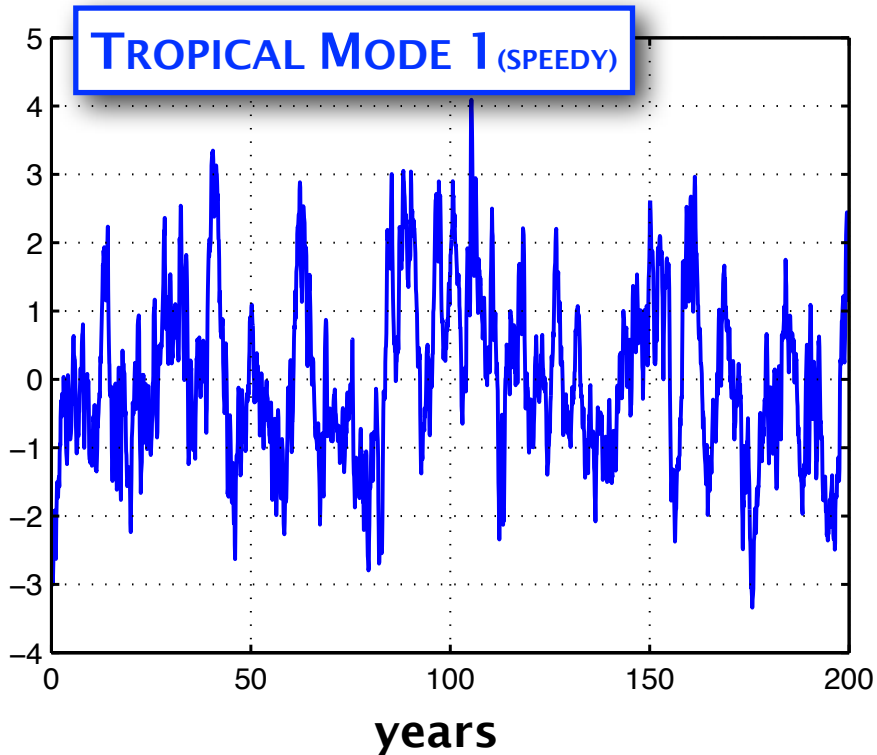
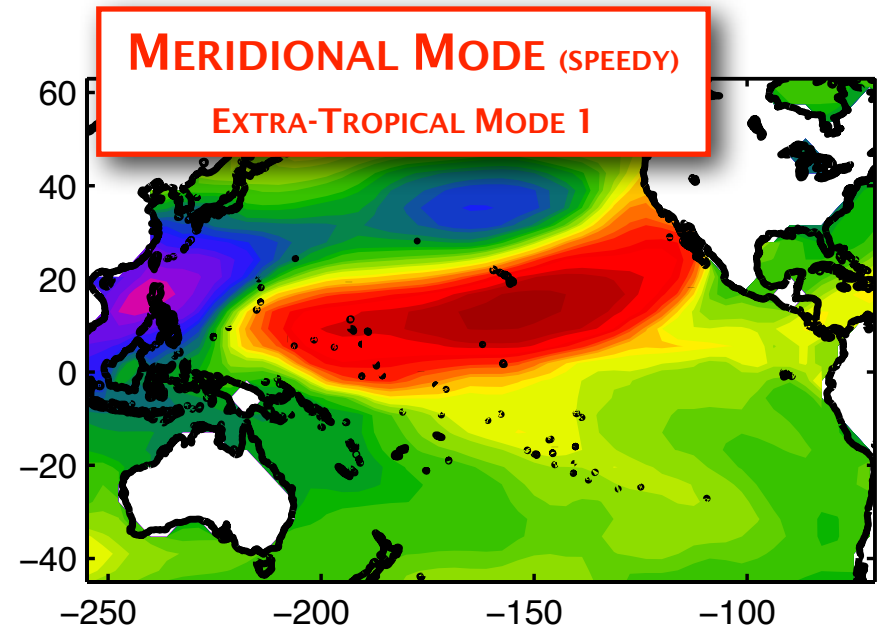
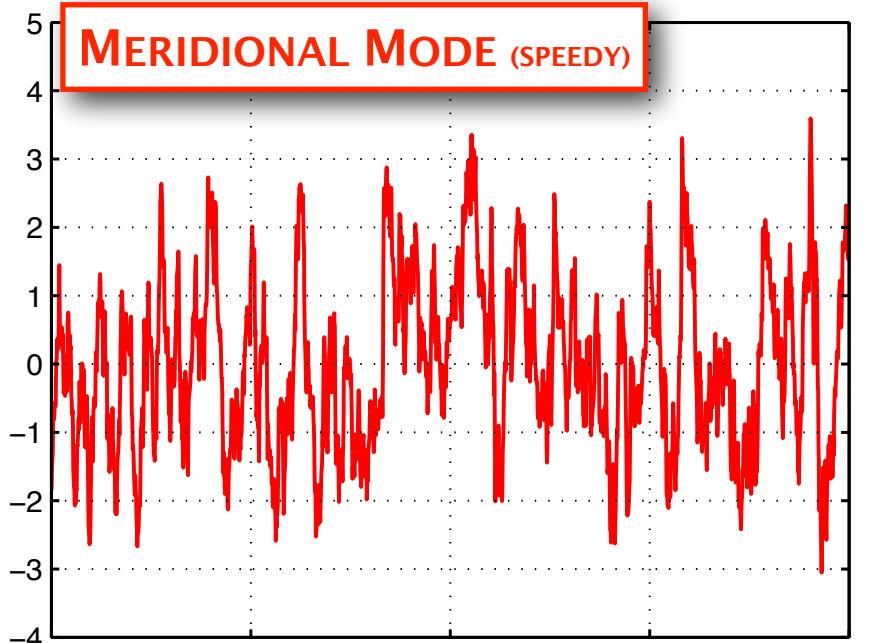


years

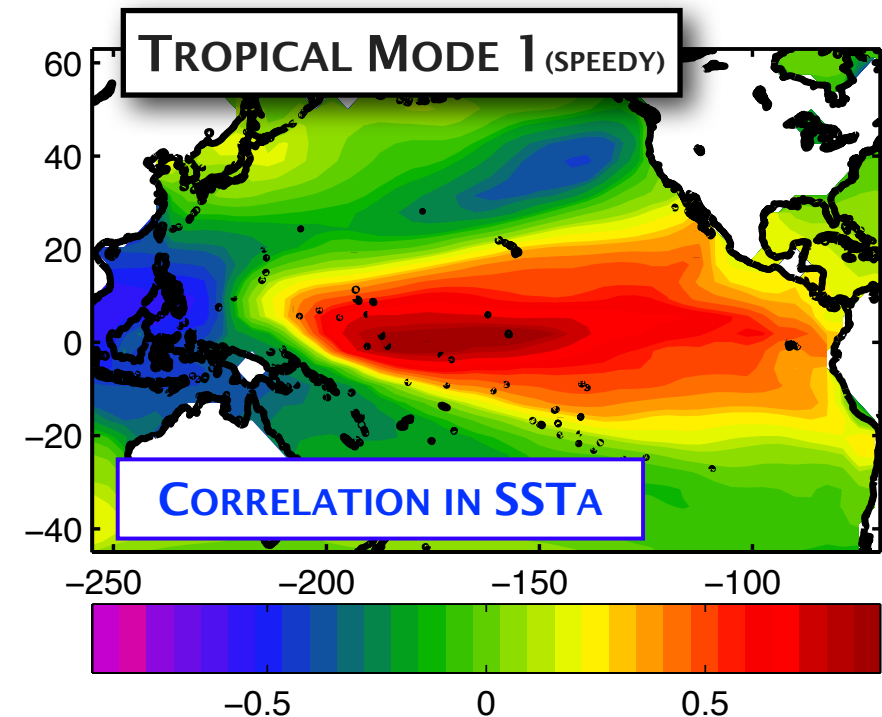
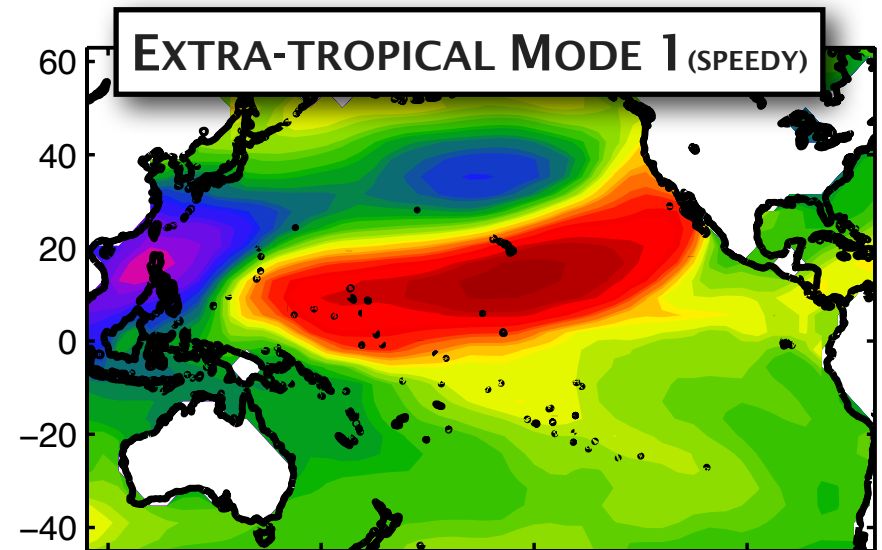
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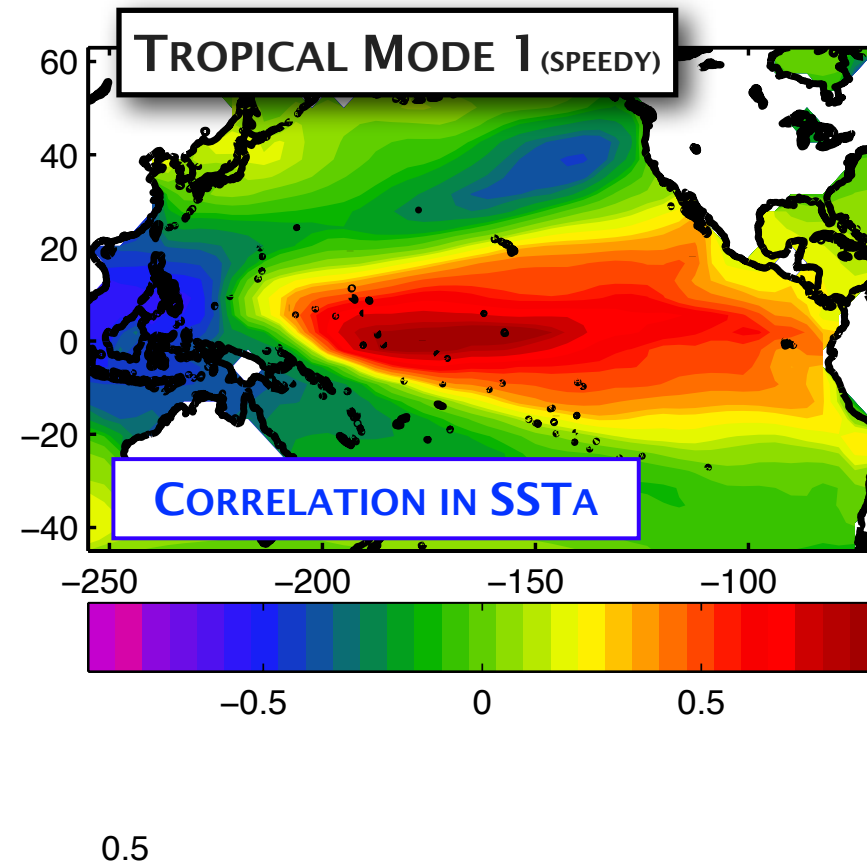
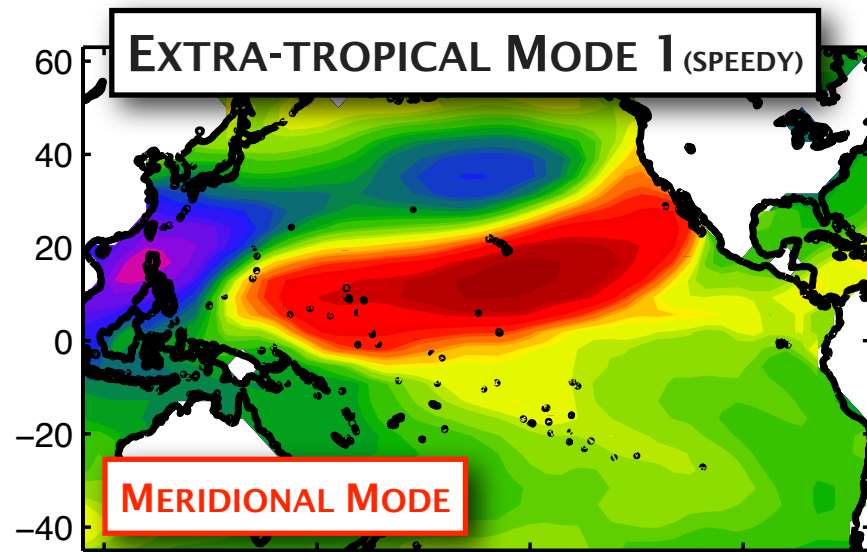
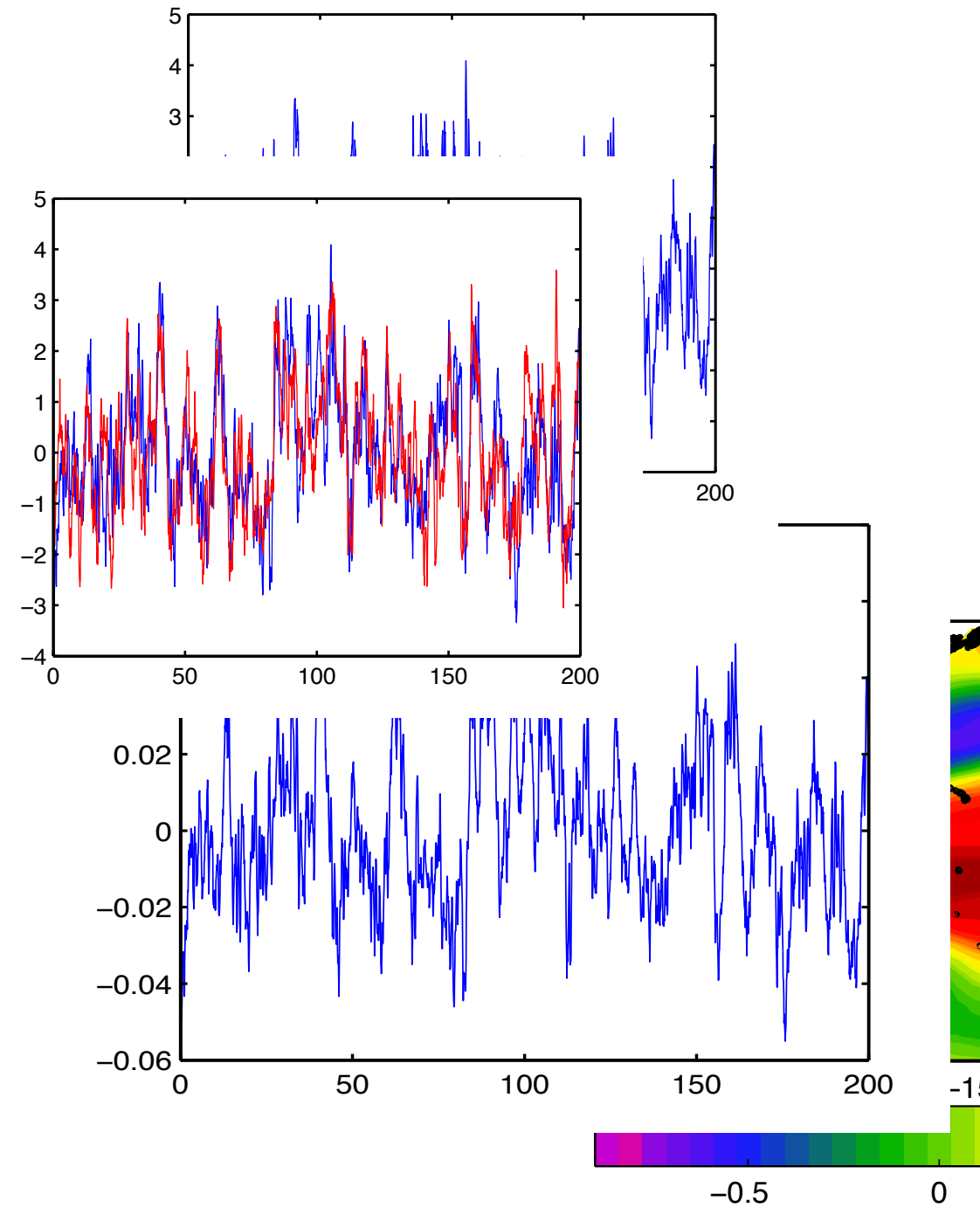
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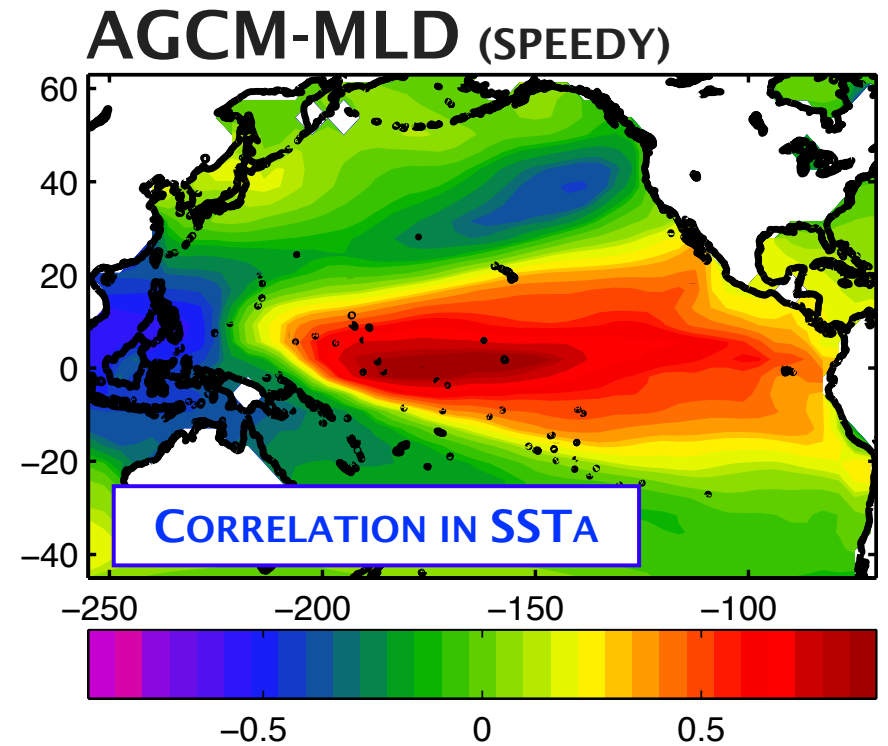
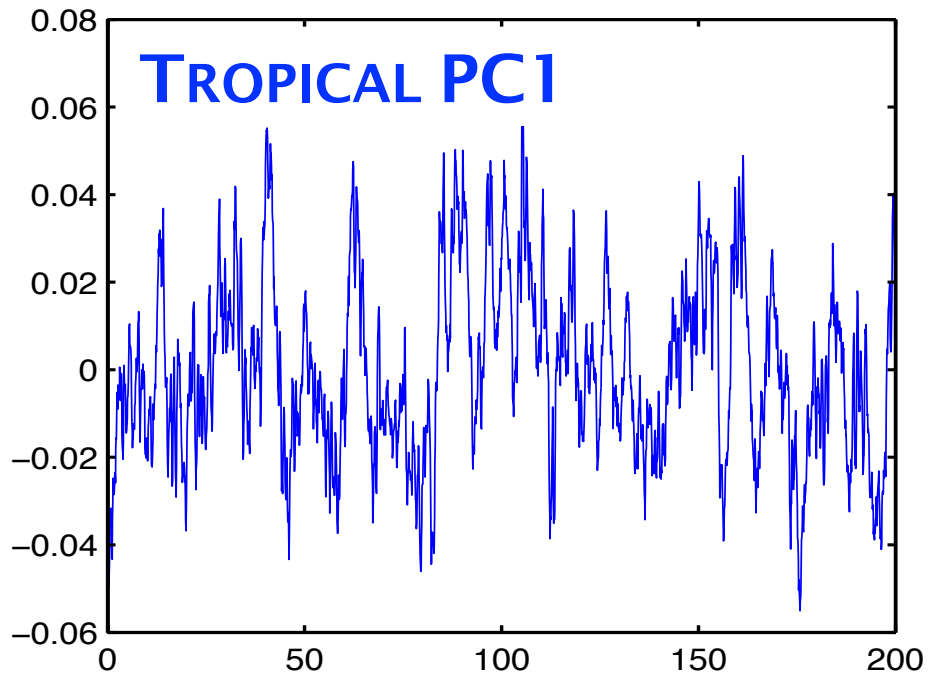
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1. **AGCM-MLD (SPEEDY)**
(no zonal mode dynamics)
2. **1000 years simulation**
(allow for robust decadal statistics)
3. **Diagnose tropical variability**
PC/EOF 1 of SSTa [10S 10N]
4. **Quantify the role of Meridional Mode**





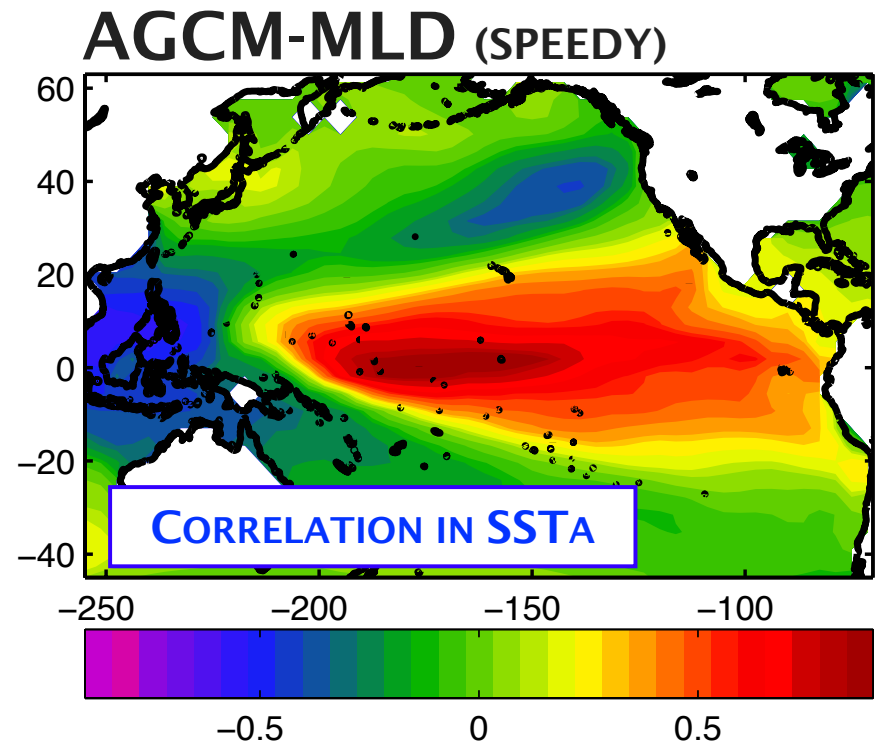
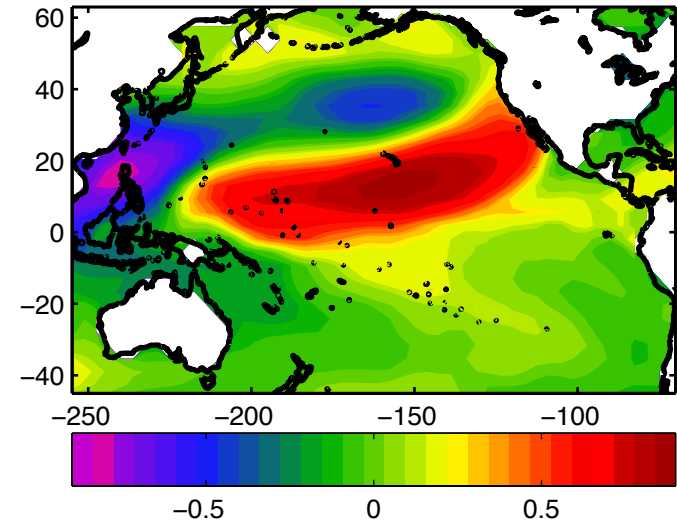
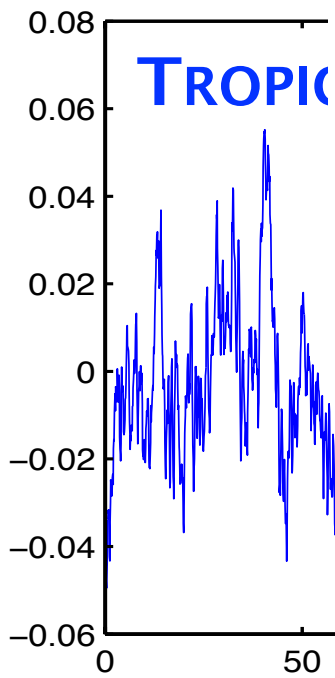
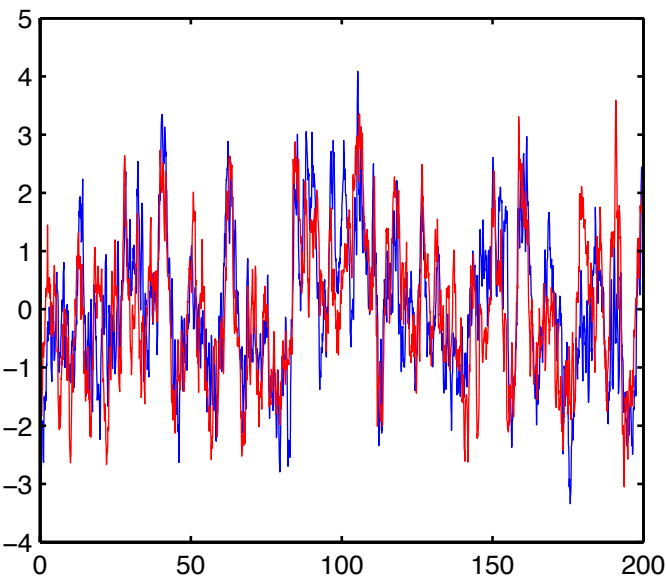
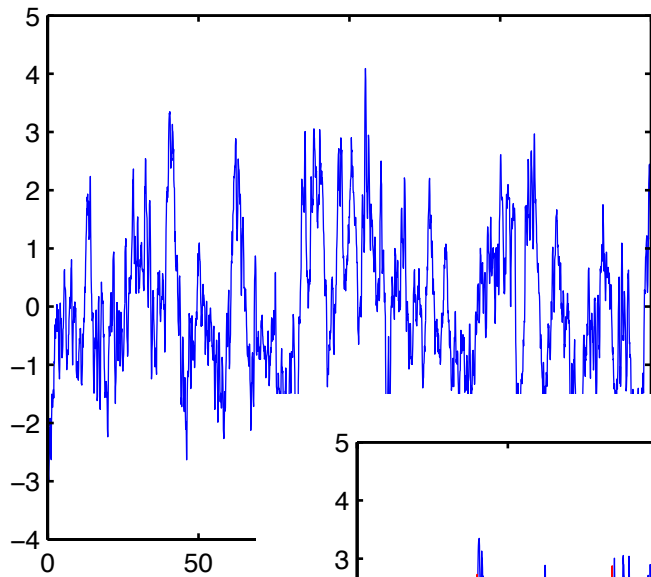


~~Zonal Mode~~

Meridional Mode

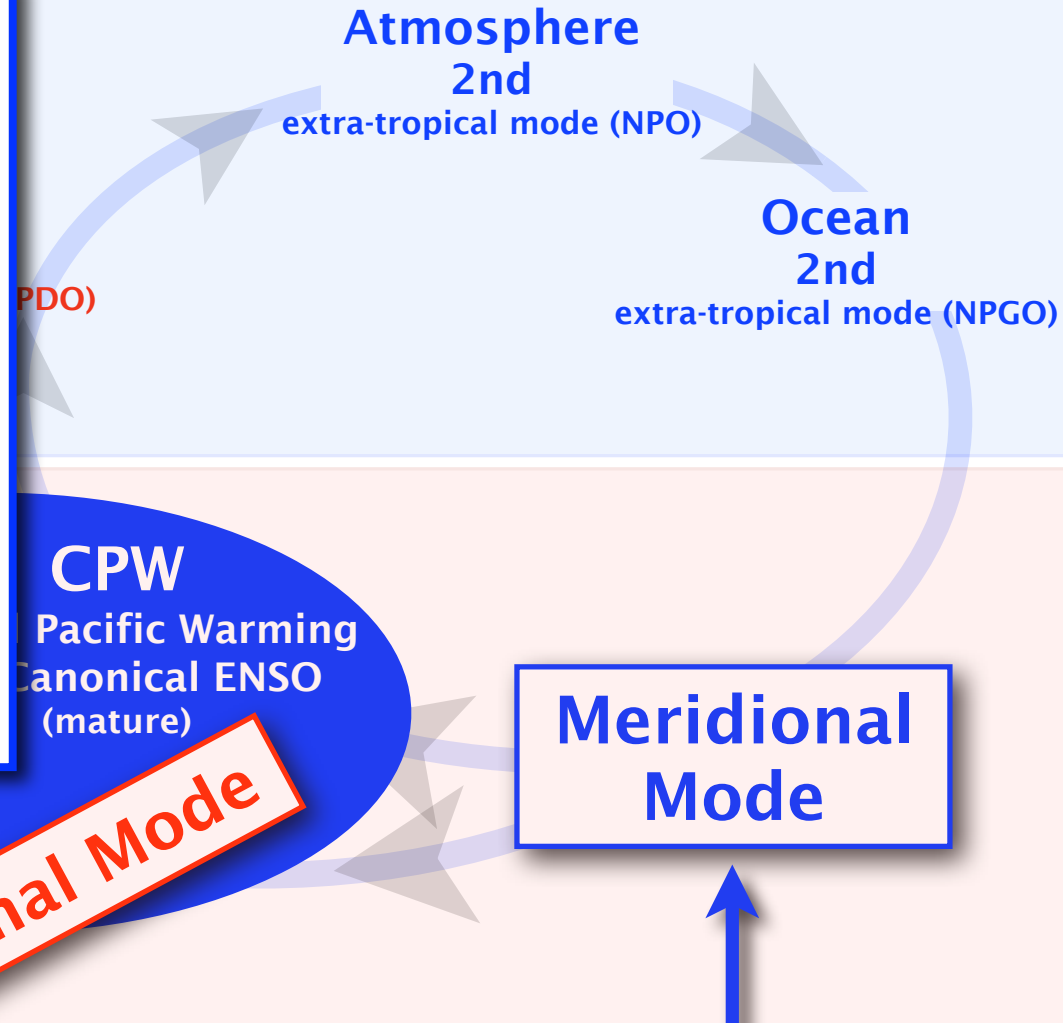
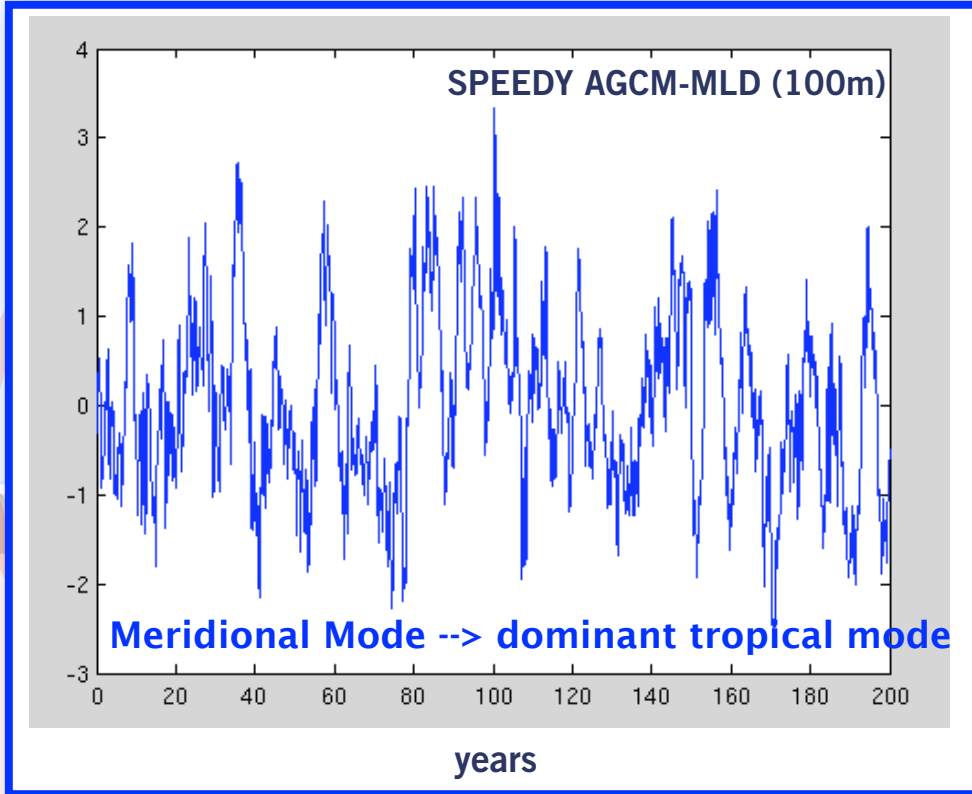
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A MODEL FOR EXPLAINING PACIFIC DECADAL DYNAMICS

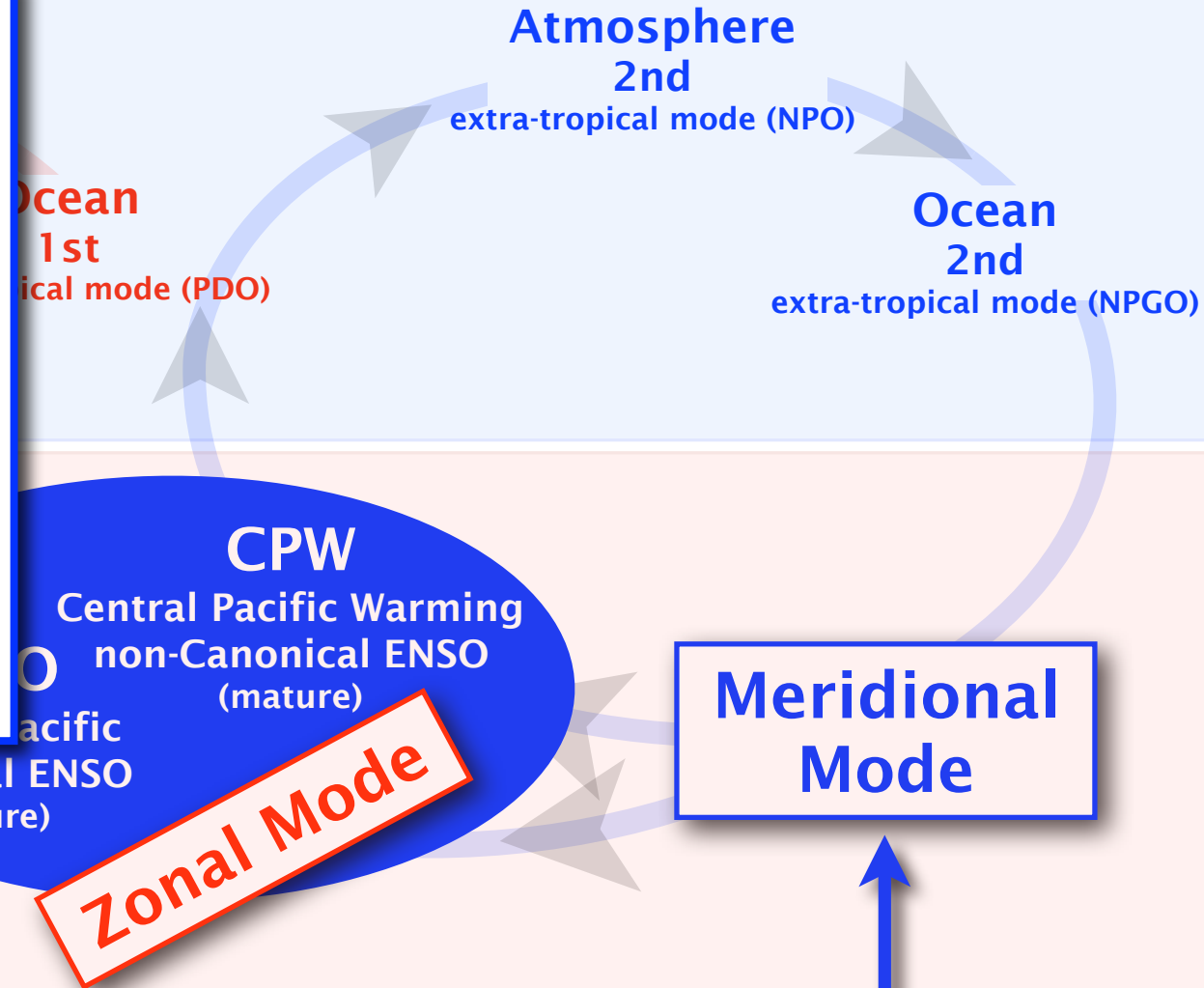
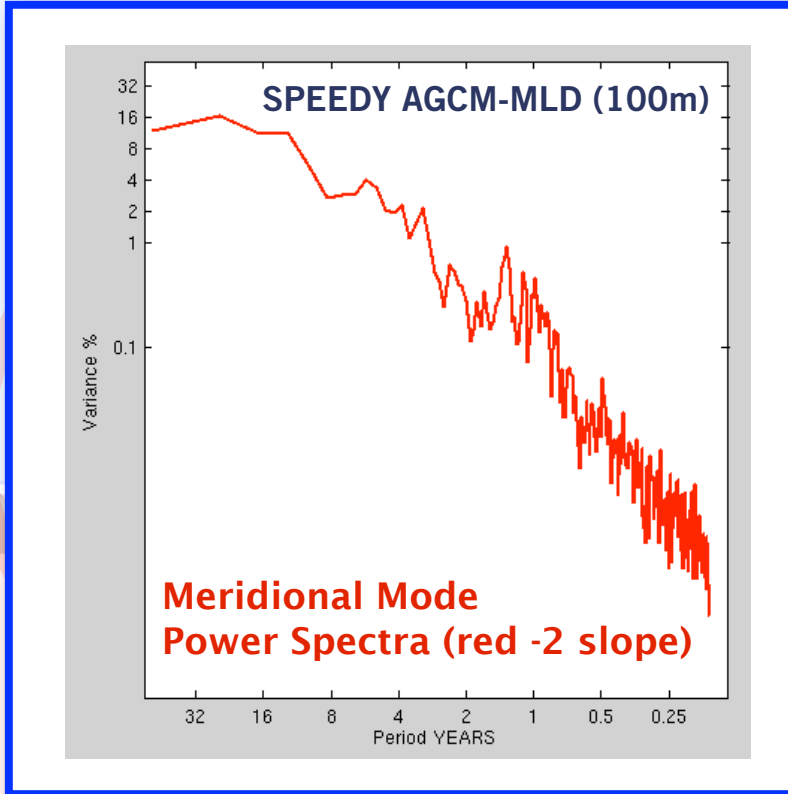
Extra-tropics [Ocean forced by Atmosphere]



Tropics [Ocean-Atmosphere Coupled System]

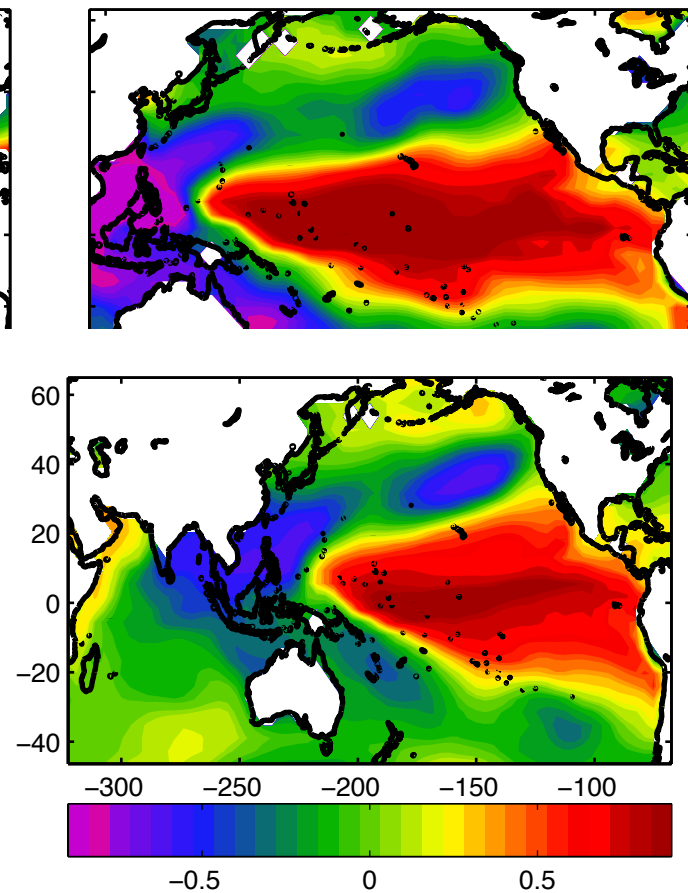
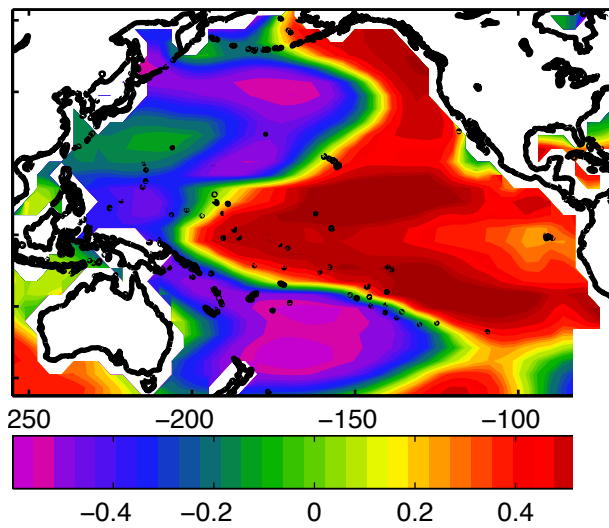
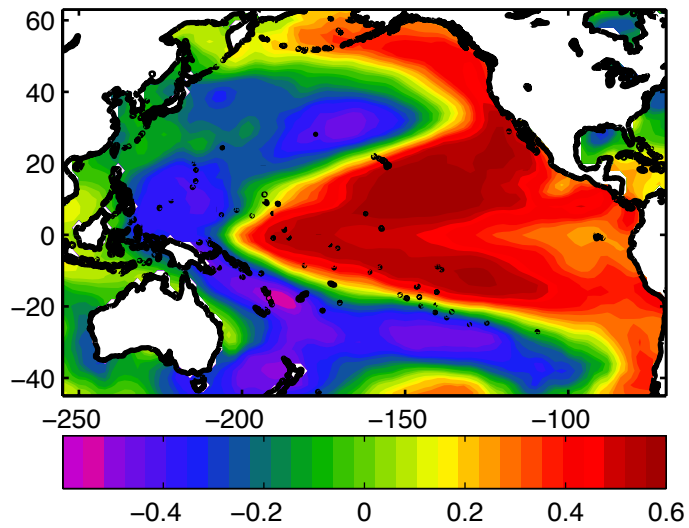
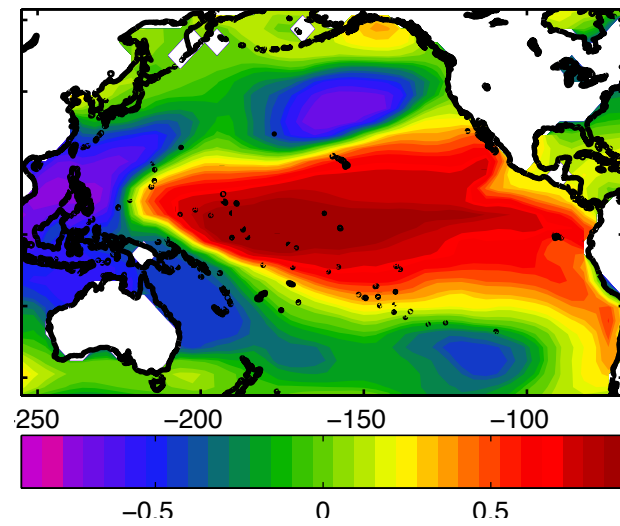
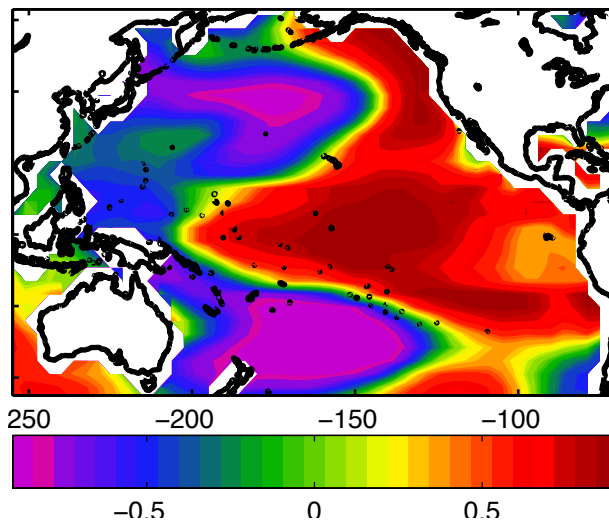
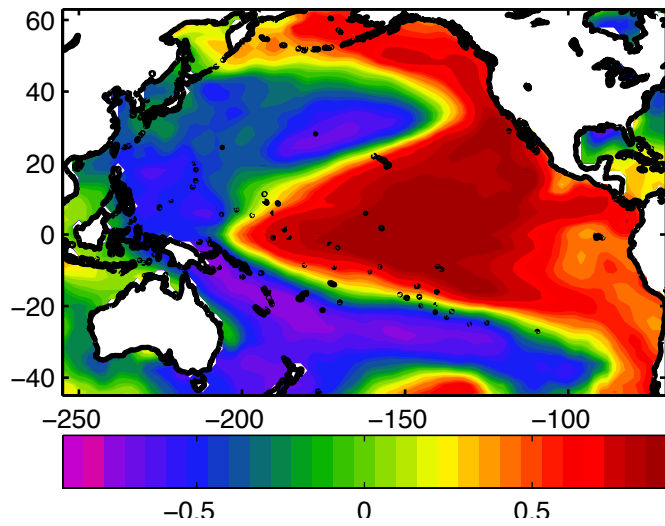
A MODEL FOR EXPLAINING PACIFIC DECADAL DYNAMICS

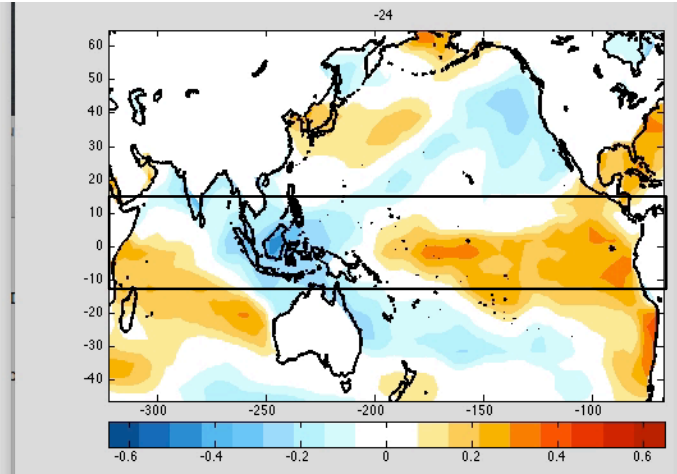
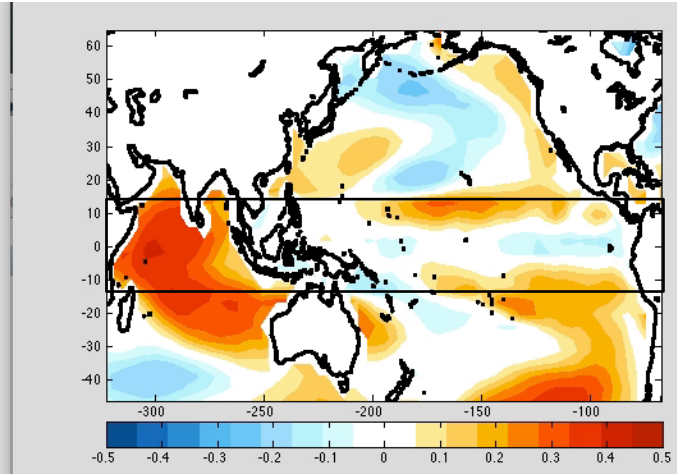
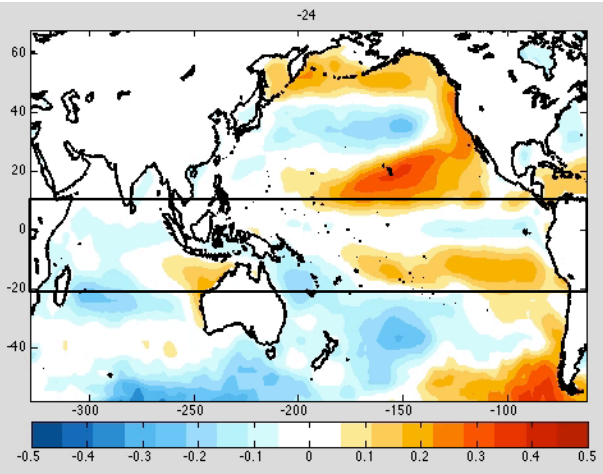
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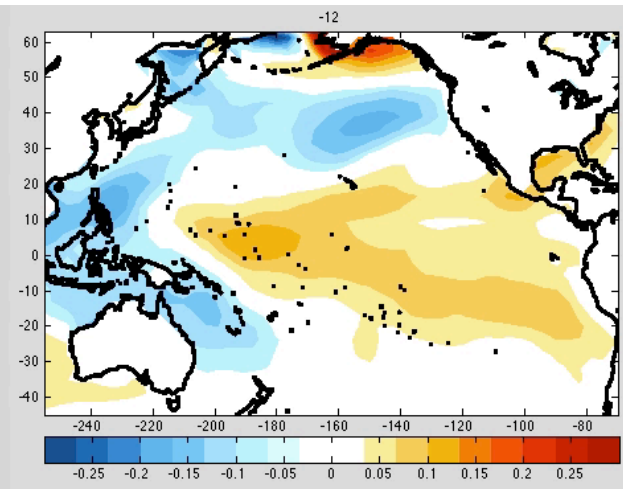
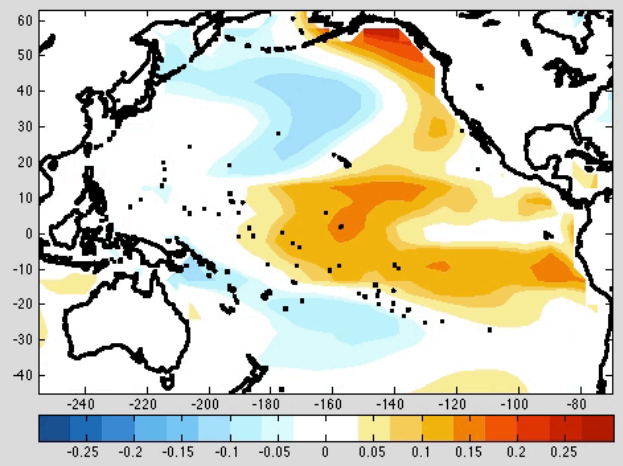
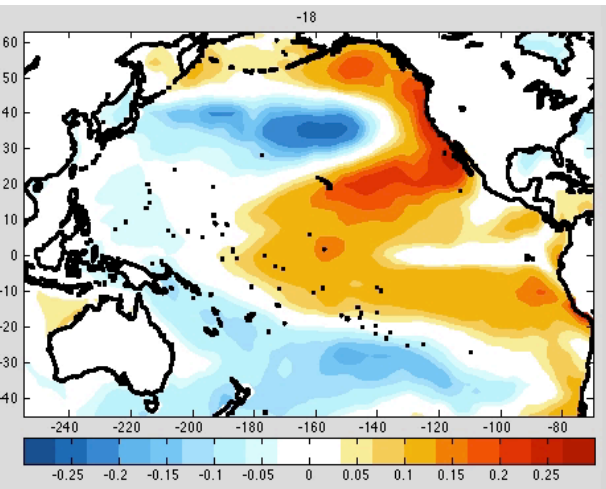
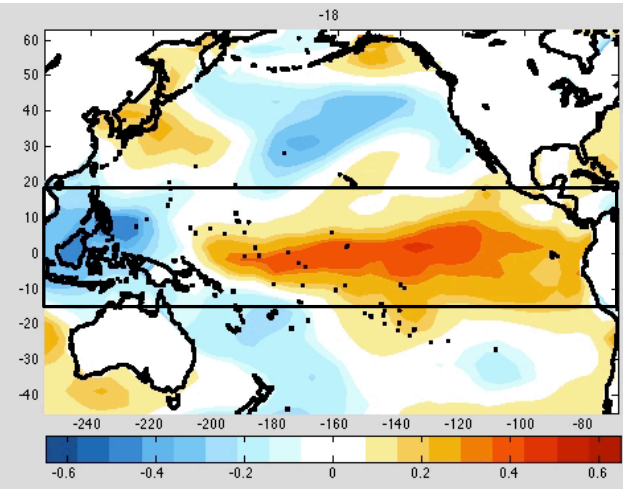
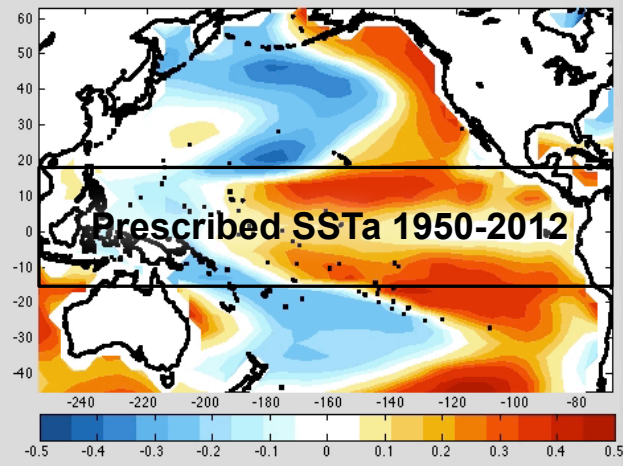
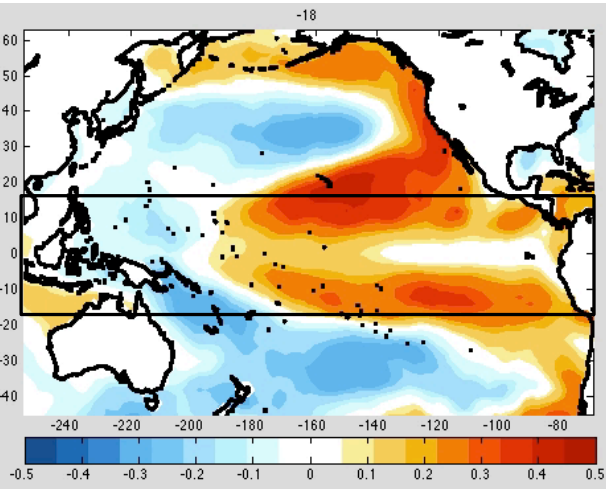


Tropics [Ocean-Atmosphere Coupled System]

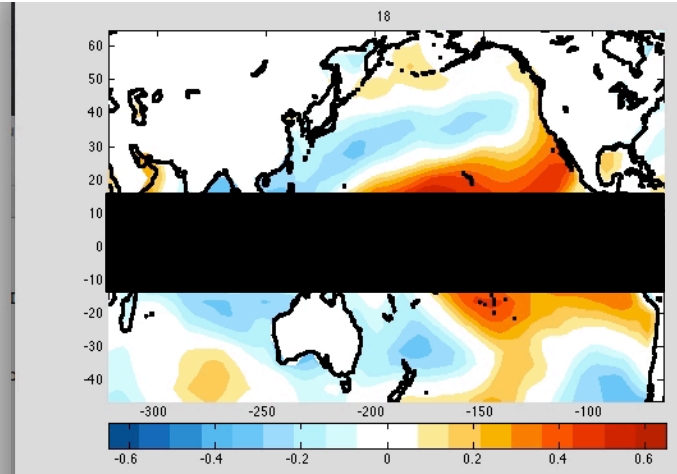
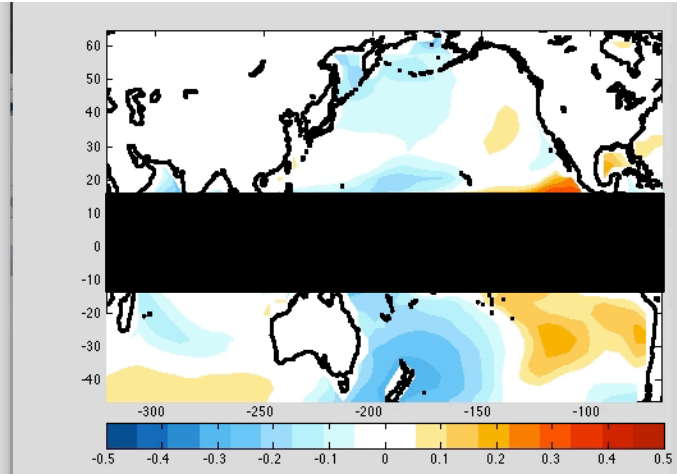
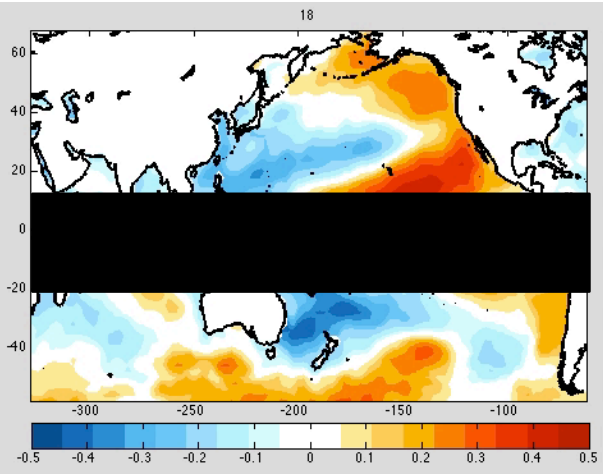
1 Meridional Mode (N-S): injects decadal-scale variance into the tropical system.

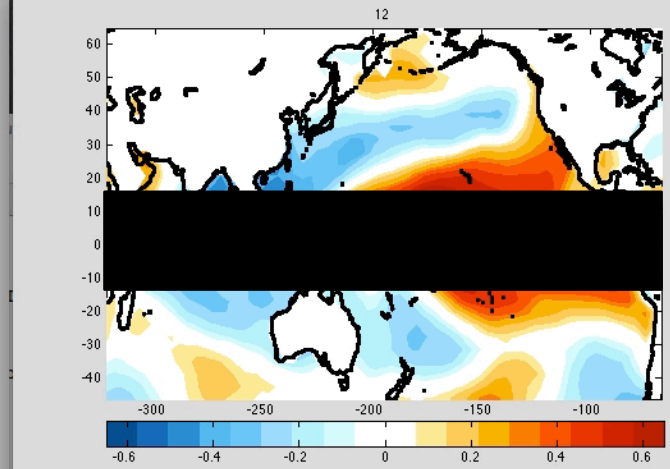
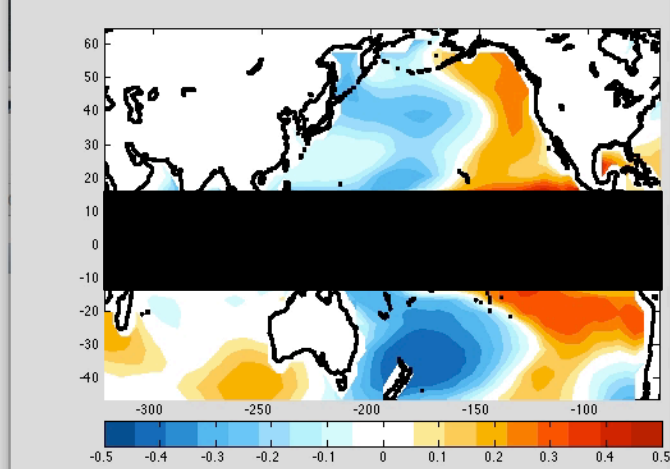
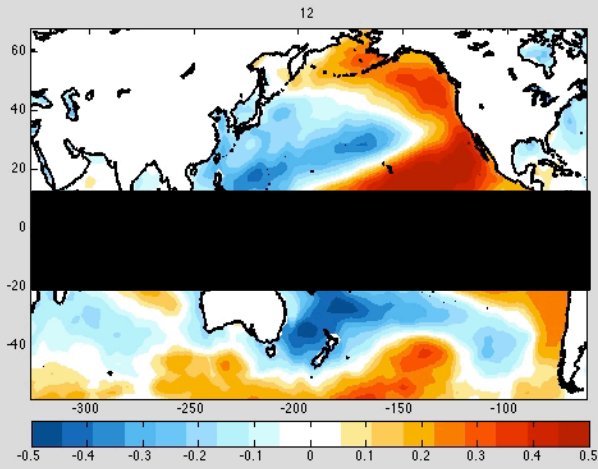




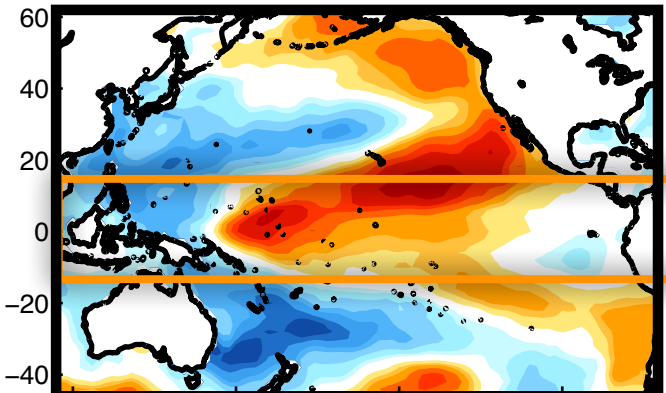


decay in the tropics of MM only
extra-tropical expression in ZM

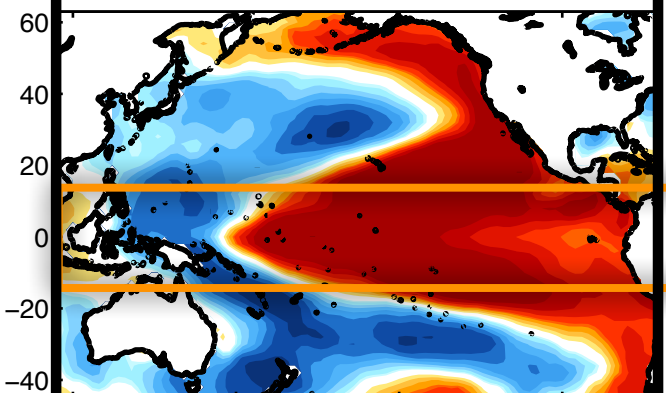




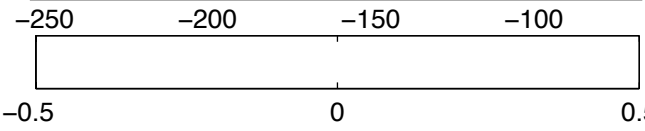
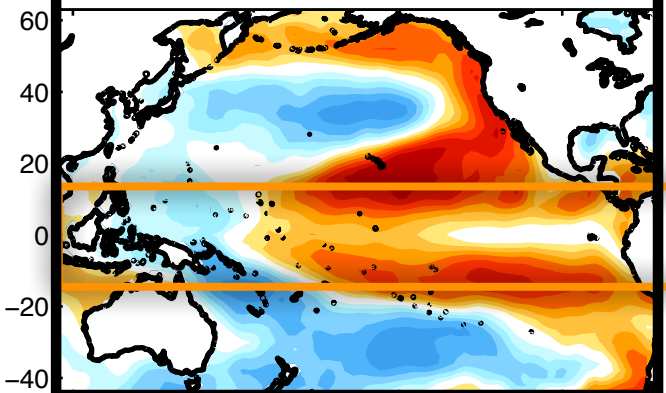
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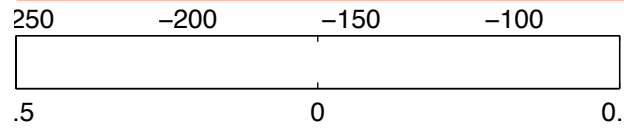
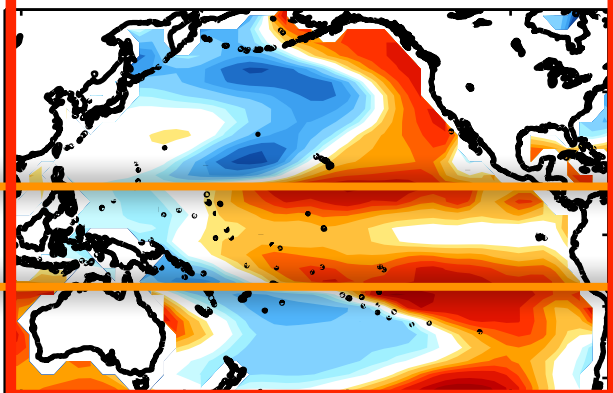
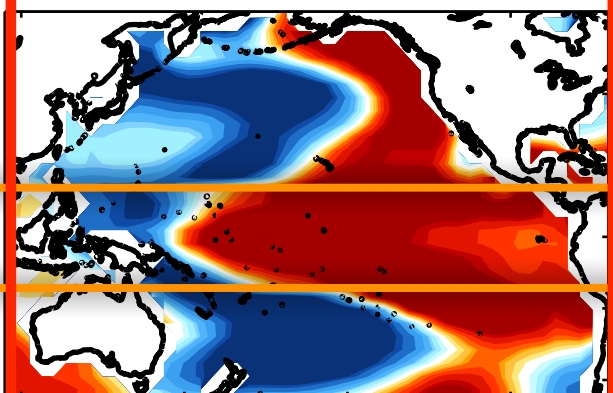
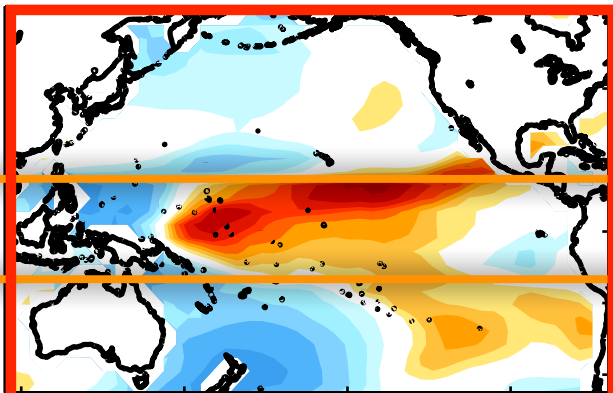
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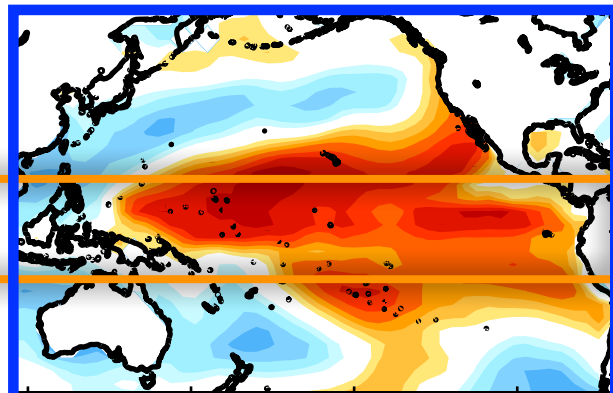
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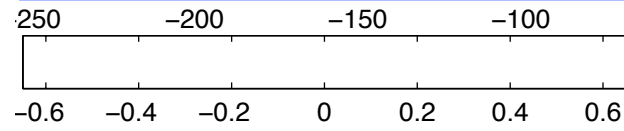
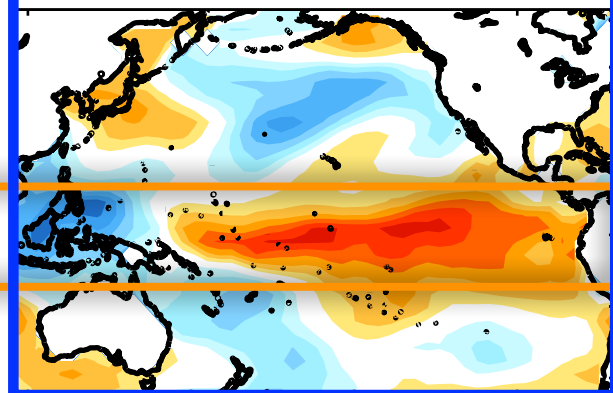
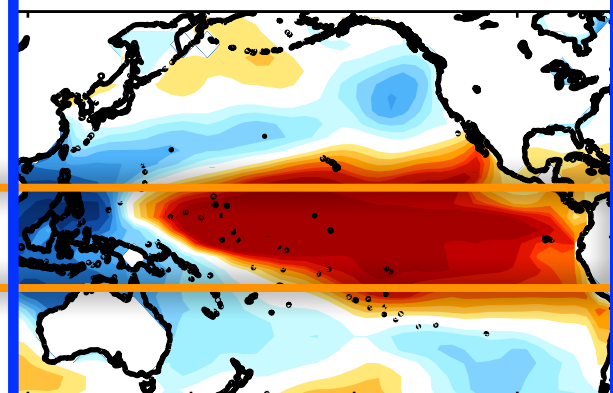
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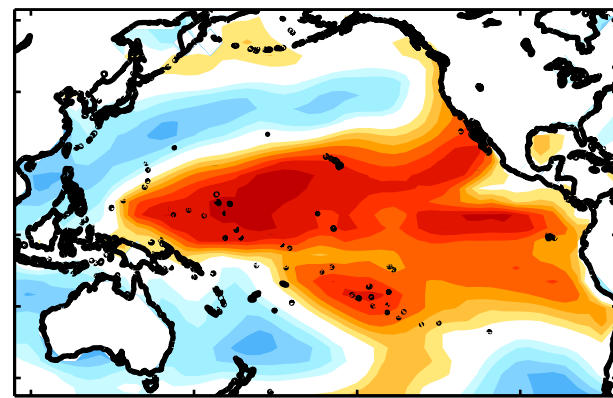
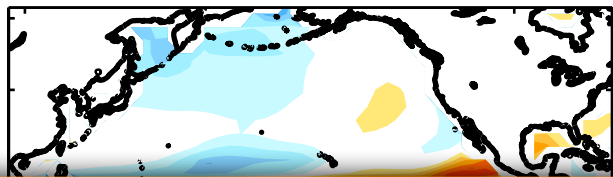
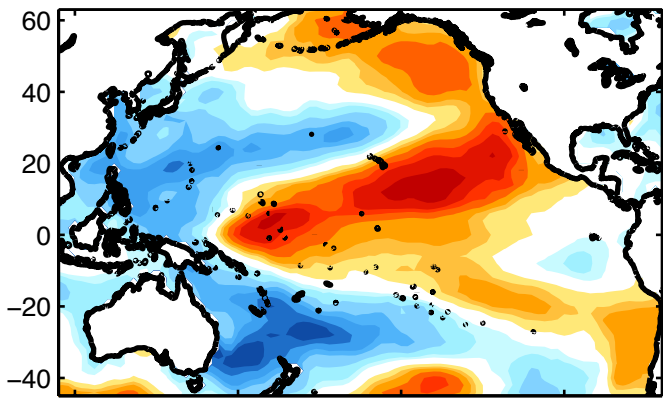
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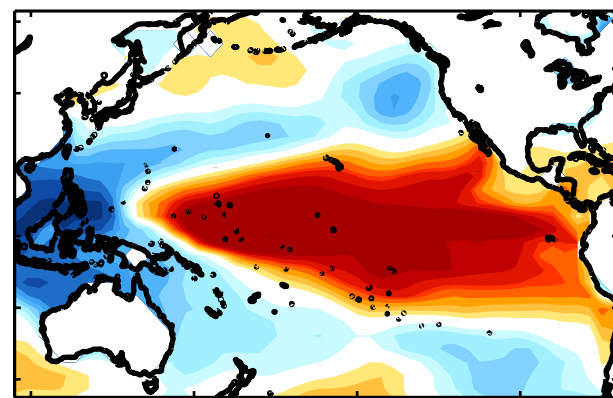
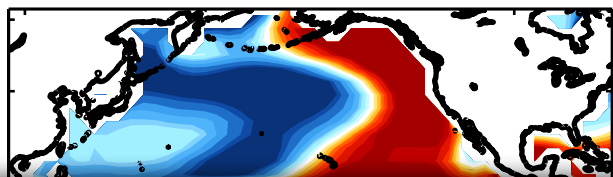
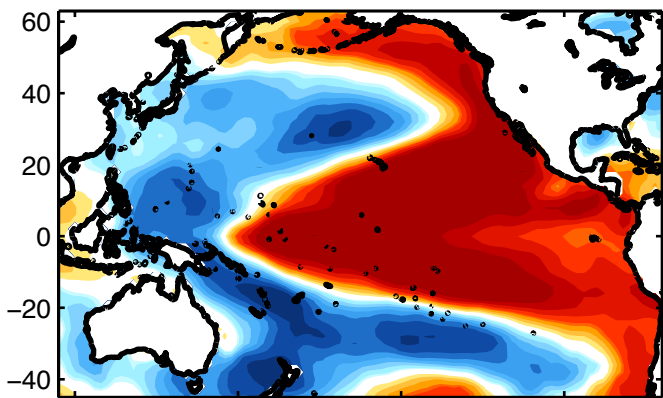


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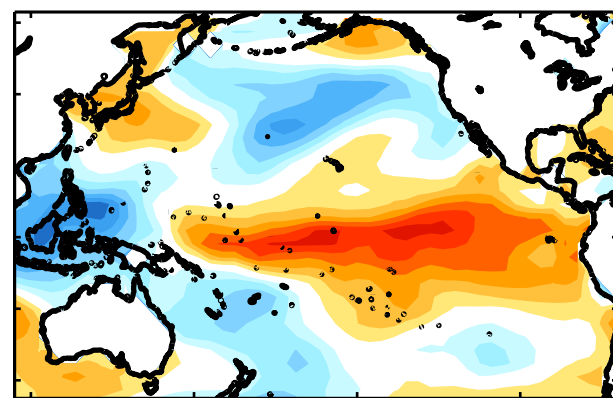
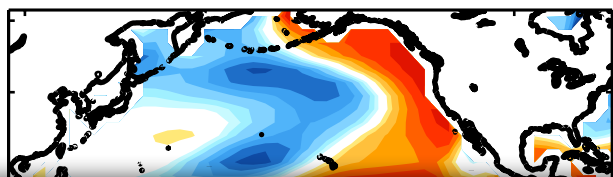
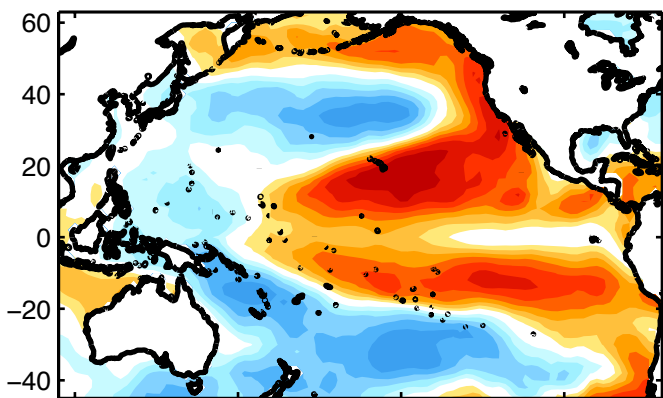
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