

Mechanisms of Pacific Decadal Variability in ESMs

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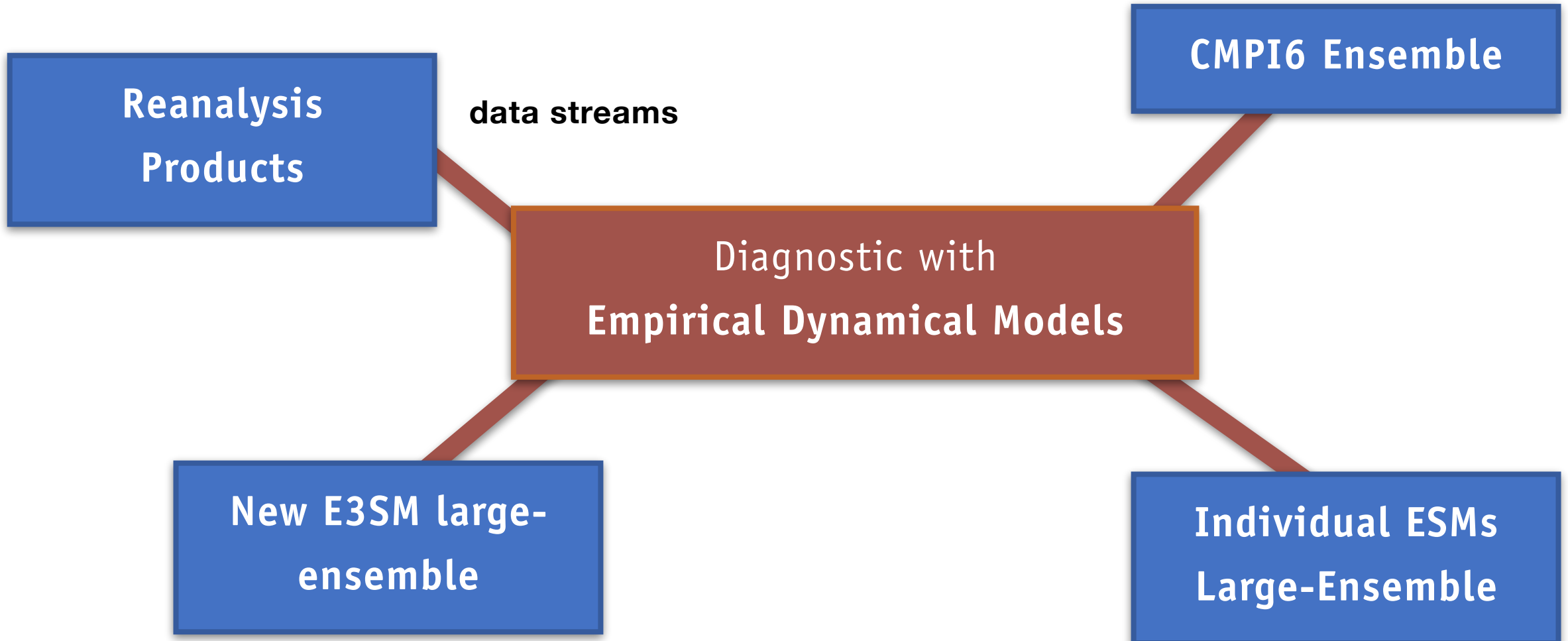
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Luke Van Roekel (DOE)

Sang-Ik Shin and Antonietta Capotondi (NOAA)

Project Objectives

Develop fundamental understanding and synthesis of the **mechanisms that energize Pacific decadal variability (PDV)** in Earth System Models (ESMs)



Project Objectives & Team

Zoo of Pacific Climate Modes

We aim to move beyond the comparisons of the climate modes statistics across ESMs towards identifying and comparing the fundamental mechanisms that energize PDV

Our Hypothesis for Pacific Climate

NORTH PACIFIC

ALEUTIAN LOW (AL)

PACIFIC DECADAL OSCILLATION (PDO)

NORTH PACIFIC OSCILLATION (NPO)

NORTH PACIFIC GYRE OSCILLATION (NPGO)

Zoo of Pacific Climate Modes

NORTH PACIFIC MERIDIONAL MODES (NPMM)

TROPICS

EASTERN PACIFIC EL NIÑO (EP)

CENTRAL PACIFIC EL NIÑO (CP)

SOUTH PACIFIC MERIDIONAL MODES (SPMM)

SOUTH PACIFIC

SOUTH PACIFIC OSCILLATION (SPO)

SOUTH PACIFIC DECADAL OSCILLATION (SPDO)

SOUTH PACIFIC DIPOLE (SPD)

Our Hypothesis for Pacific Climate

NORTH PACIFIC

Internal Stochastic
Variability
ATMOSPHERE



TROPICS

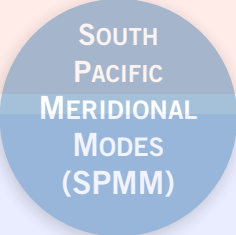
OND



ENSO



OND

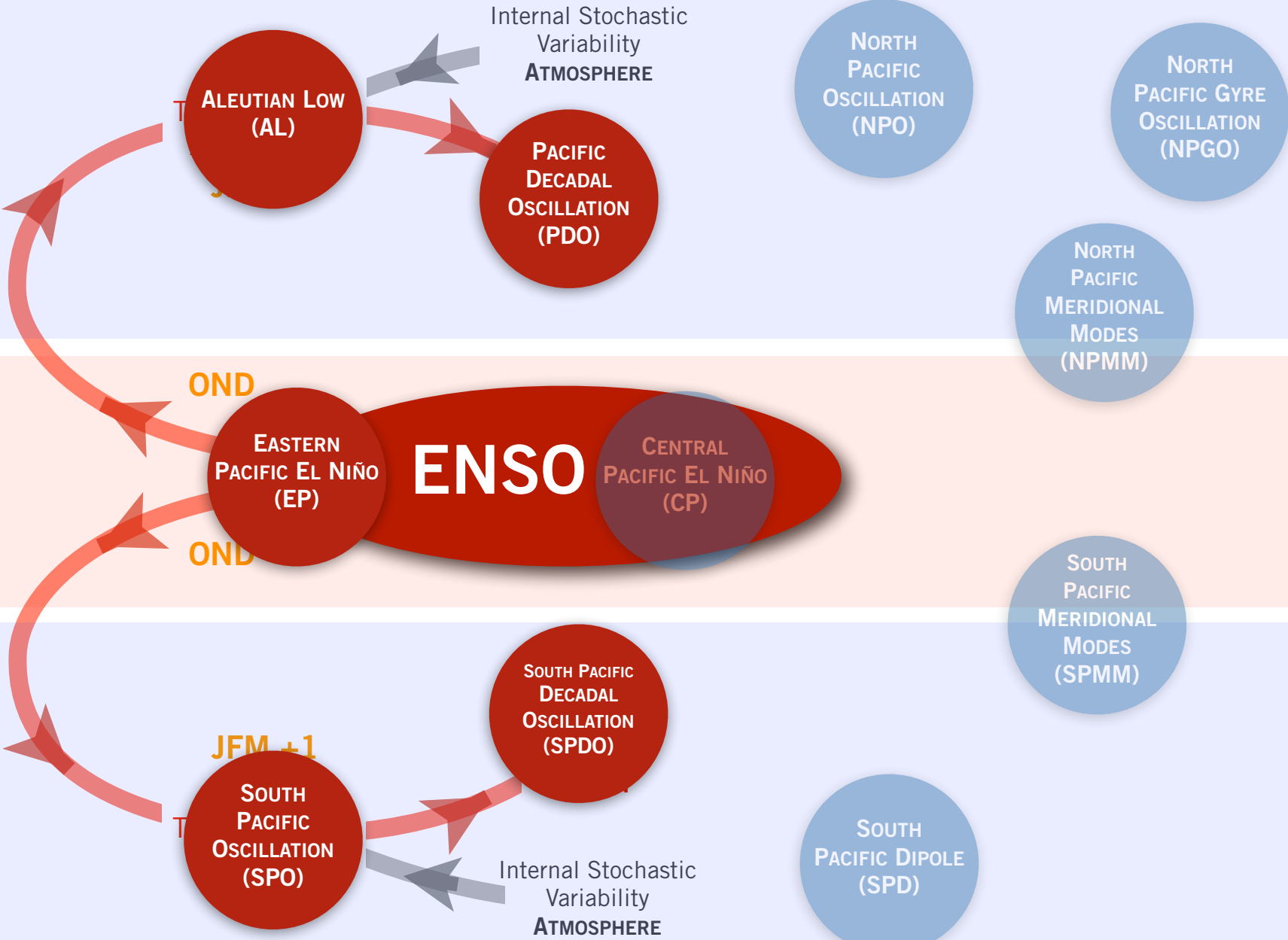


SOUTH PACIFIC

JFM +1



Internal Stochastic
Variability
ATMOSPHERE



Our Hypothesis for Pacific Climate

NORTH PACIFIC

Internal Stochastic
Variability
ATMOSPHERE

ENSO
Teleconnection
ATMOSPHERE
JFM +1

ENSO
Successor
OCEAN

NORTH
PACIFIC
OSCILLATION
(NPO)

NORTH
PACIFIC
GYRE
OSCILLATION
(NPGO)

NORTH
PACIFIC
MERIDIONAL
MODES
(NPMM)

TROPICS

OND

ENSO
CENTRAL
PACIFIC EL NIÑO
(CP)

OND

SOUTH
PACIFIC
MERIDIONAL
MODES
(SPMM)

SOUTH PACIFIC

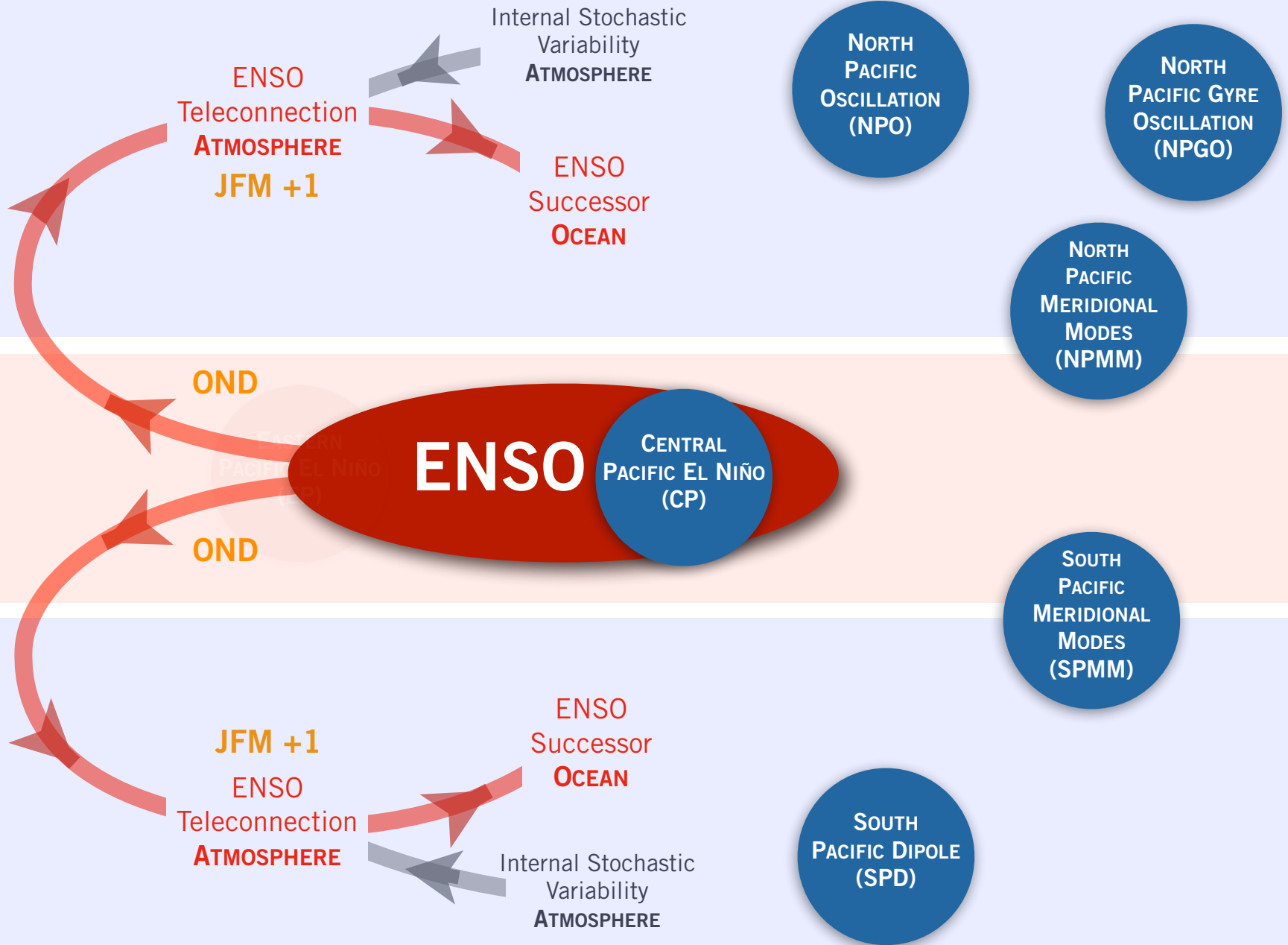
JFM +1

ENSO
Teleconnection
ATMOSPHERE

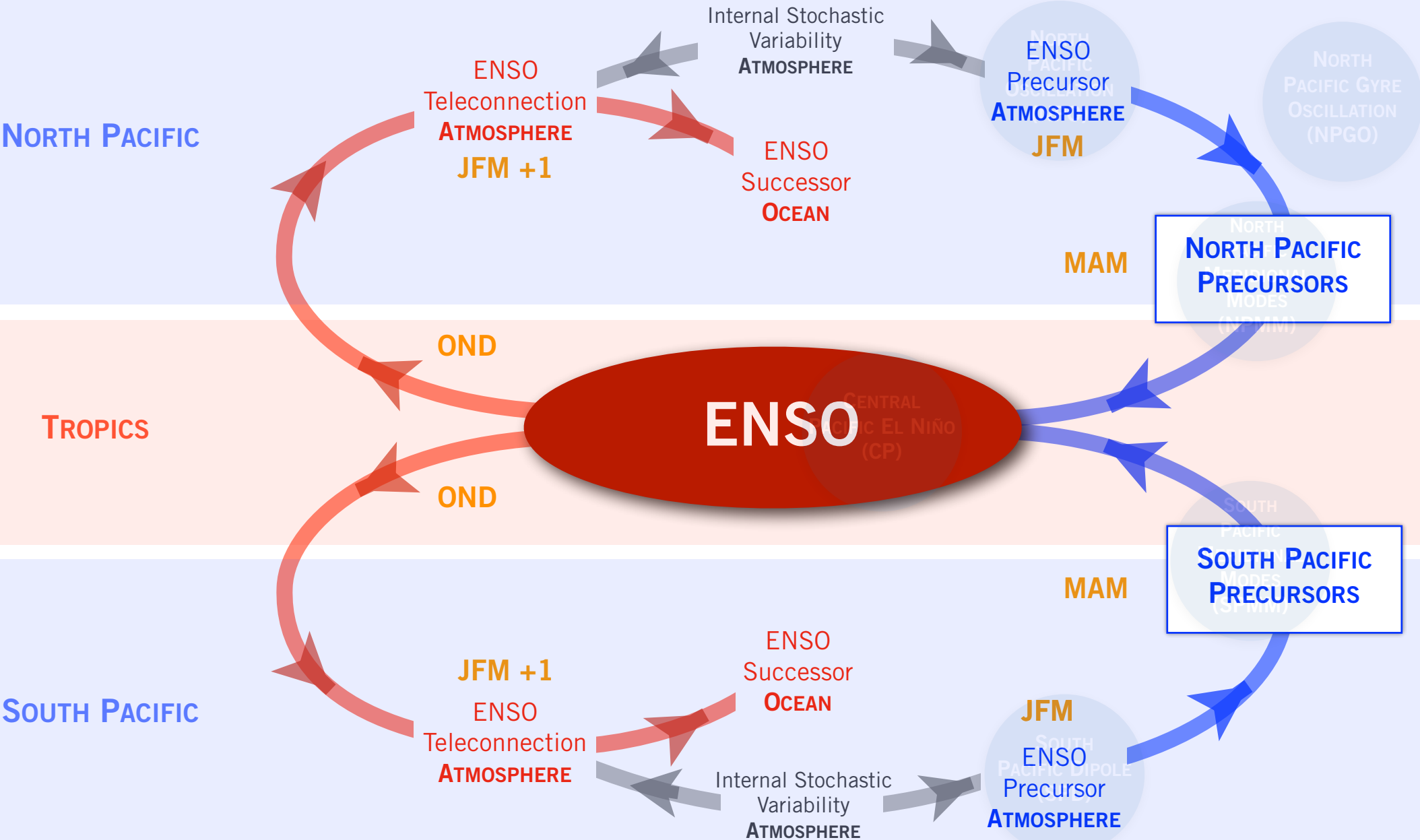
ENSO
Successor
OCEAN

Internal Stochastic
Variability
ATMOSPHERE

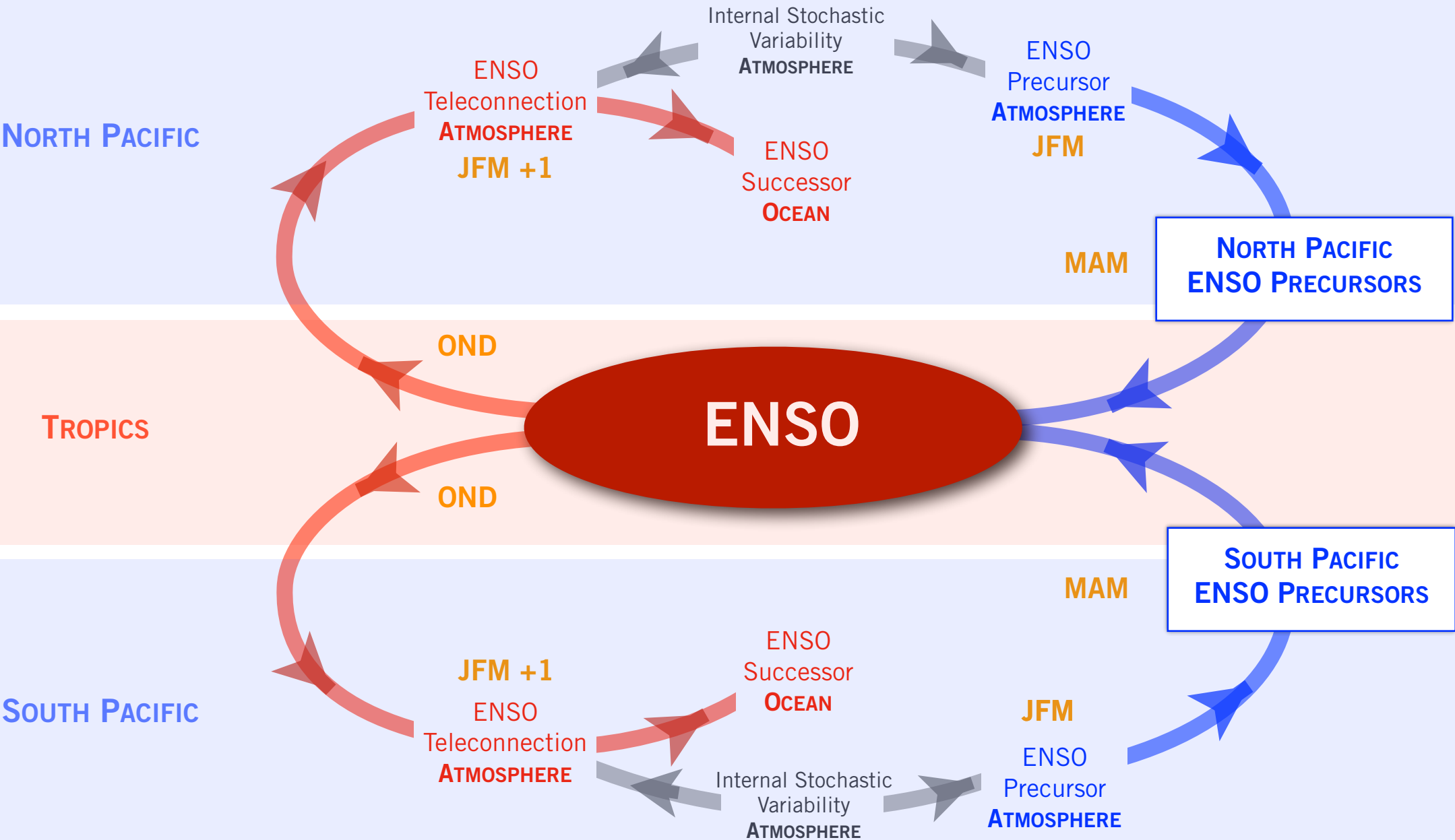
SOUTH
PACIFIC
DIPOLE
(SPD)



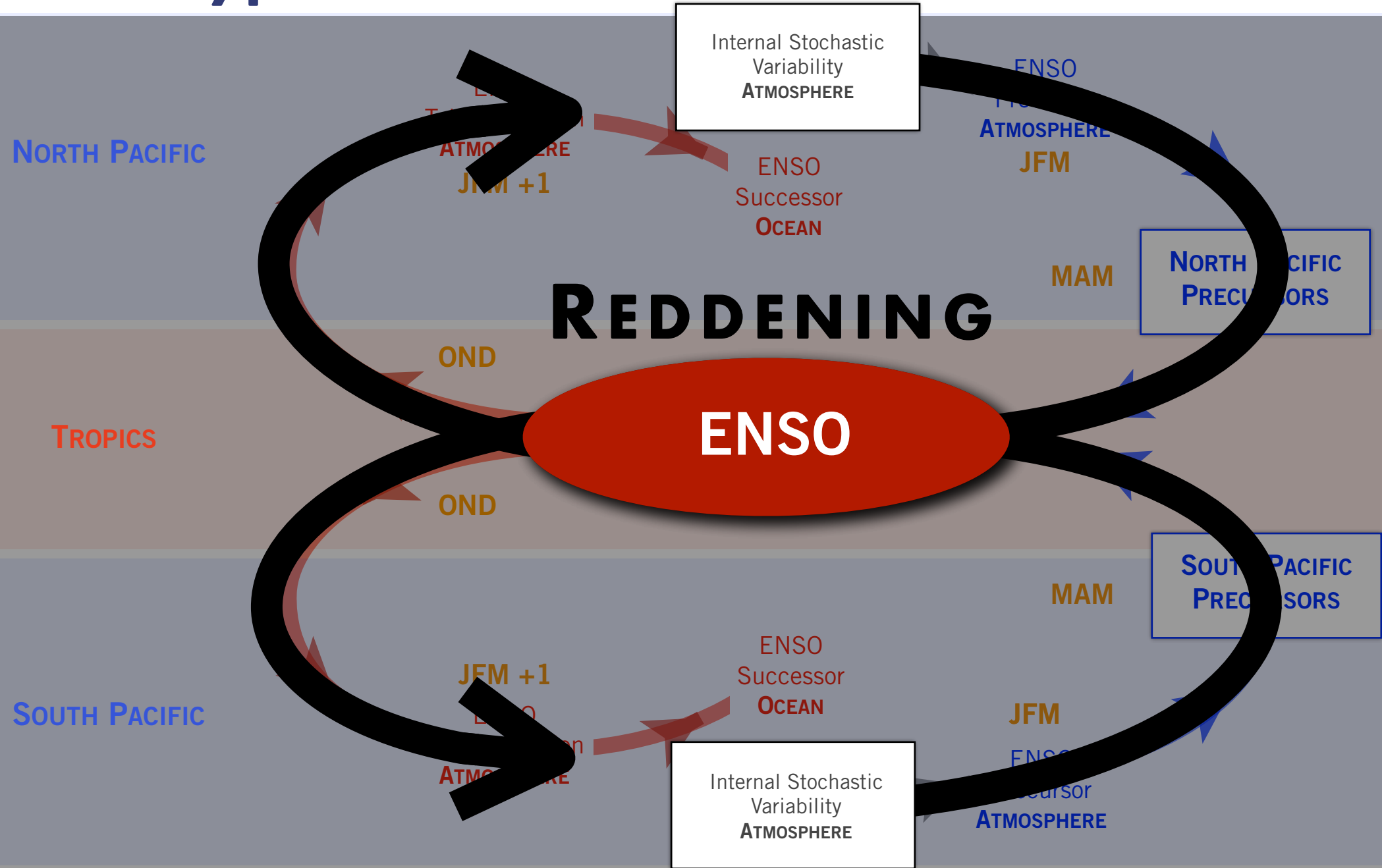
Our Hypothesis for Pacific Climate



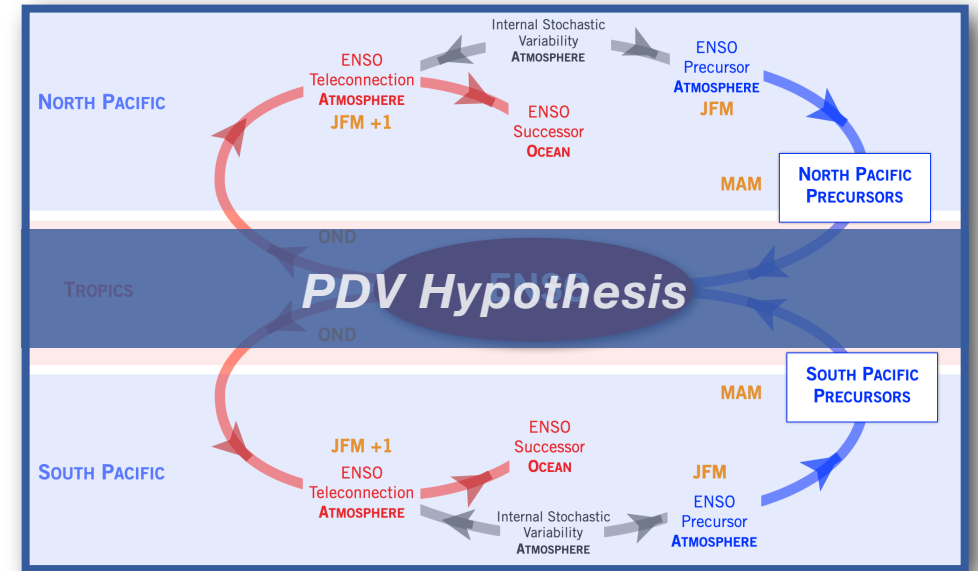
Our Hypothesis for Pacific Climate



Our Hypothesis for Pacific Climate



Our Hypothesis for Pacific Climate



Seasonal coupling between tropics/extratropics

extra-tropical ENSO precursors → **ENSO** → **ENSO Teleconnections**

reddens stochastic variability into basin-scale decadal variance.

Our Hypothesis for Pacific Climate

Reanalysis
Products

Zhao and Di Lorenzo, 2020
Xu, Newman, et al., 2020
Zhao, Capotondi et al., 2020

CMPI6 Ensemble

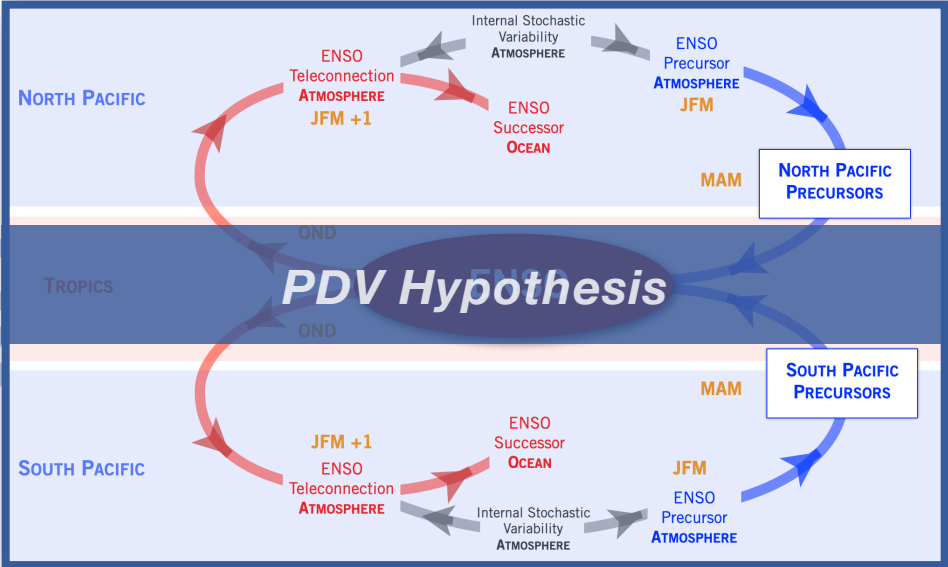
Zhao, Stevenson et al., 2020

Individual ESMs
Large-Ensemble

Liguori and Di Lorenzo, 2019

New E3SM large-
ensemble

Stevenson et al. in prep.



Extremes Breakout
Antonietta Capotondi
Tongtong Xu

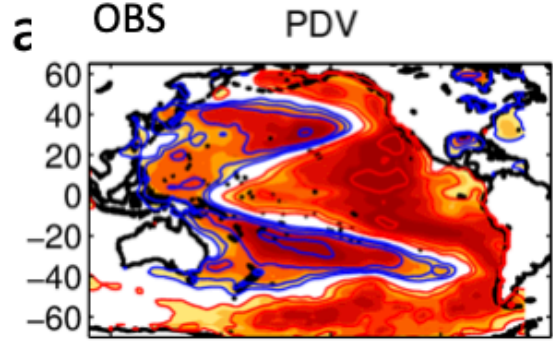
Our Hypothesis for Pacific Climate

Reanalysis
Products

CMPI6 Ensemble

Individual ES
Large-Ensemble

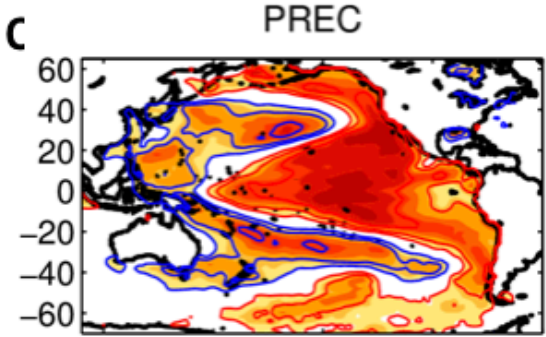
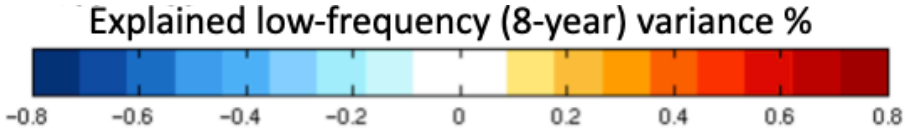
New E3SM large-
ensemble



PDV explained by PC1 of
basin-scale lowpass SSTa

Zhao and Di Lorenzo, 2020

64% of the PDV can be accounted
through ENSO Precursor Dynamics



PDV explained by ENSO
Precursors

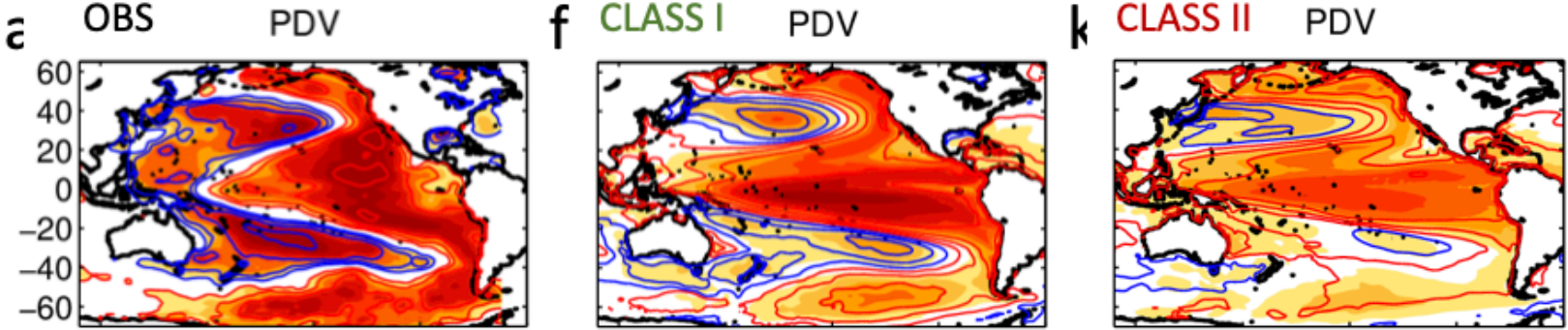
Our Hypothesis for Pacific Climate

Reanalysis Products

CMPI6 Ensemble

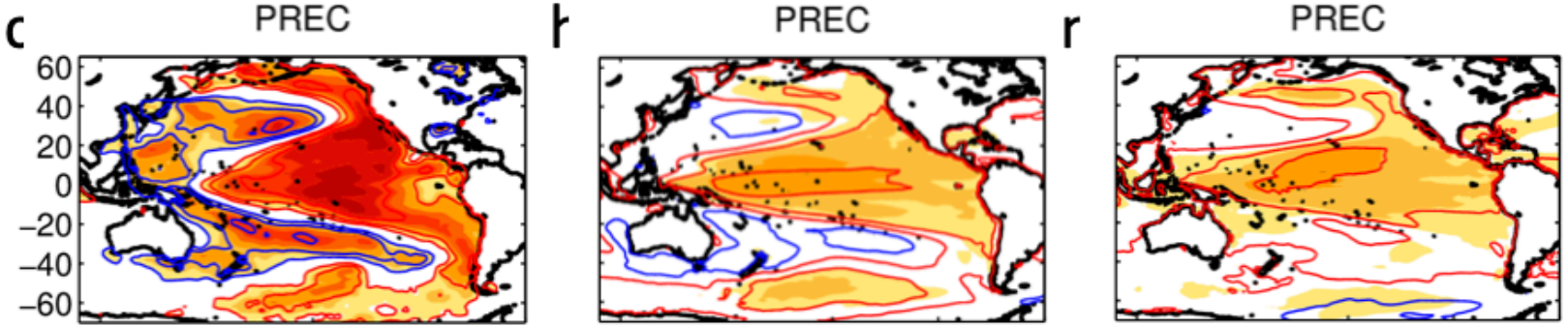
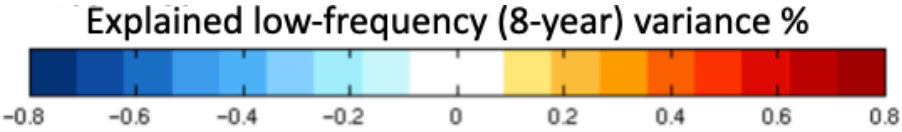
Individual ES Large-Ensem

New E3SM large-ensemble



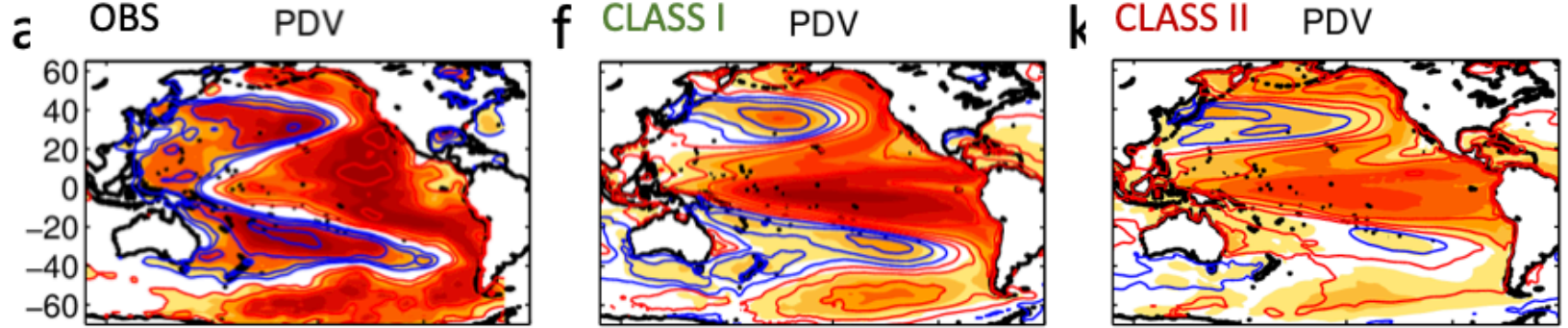
Zhao, Stevenson et al., 2020

CMIP models that capture ENSO Precursors tend to exhibit better PDV



Our Hypothesis for Pacific Climate

Reanalysis
Products



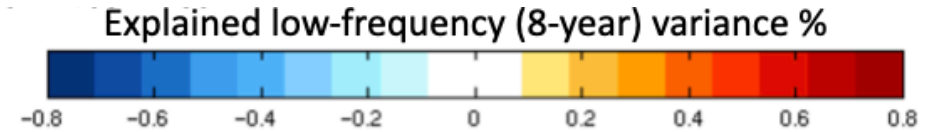
CMPI6 Ensemble

Zhao, Stevenson et al., 2020

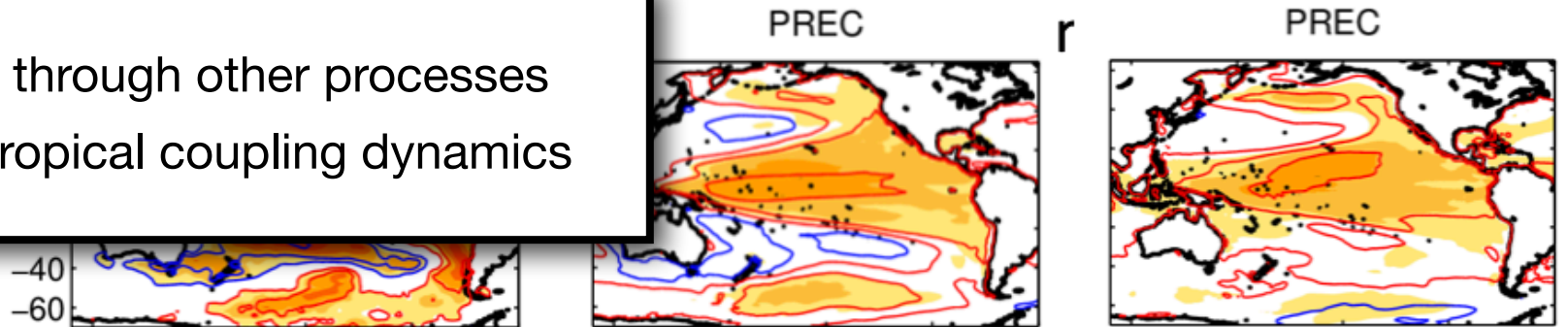
CMIP models that capture ENSO
Precursors tend to exhibit better PDV

Individual ENSO
Large-Ensemble

But models energize PDV through other processes
with weaker tropical/extratropical coupling dynamics



ensemble



Our Hypothesis for Pacific Climate

Decadal Variance of Tropical SSTa

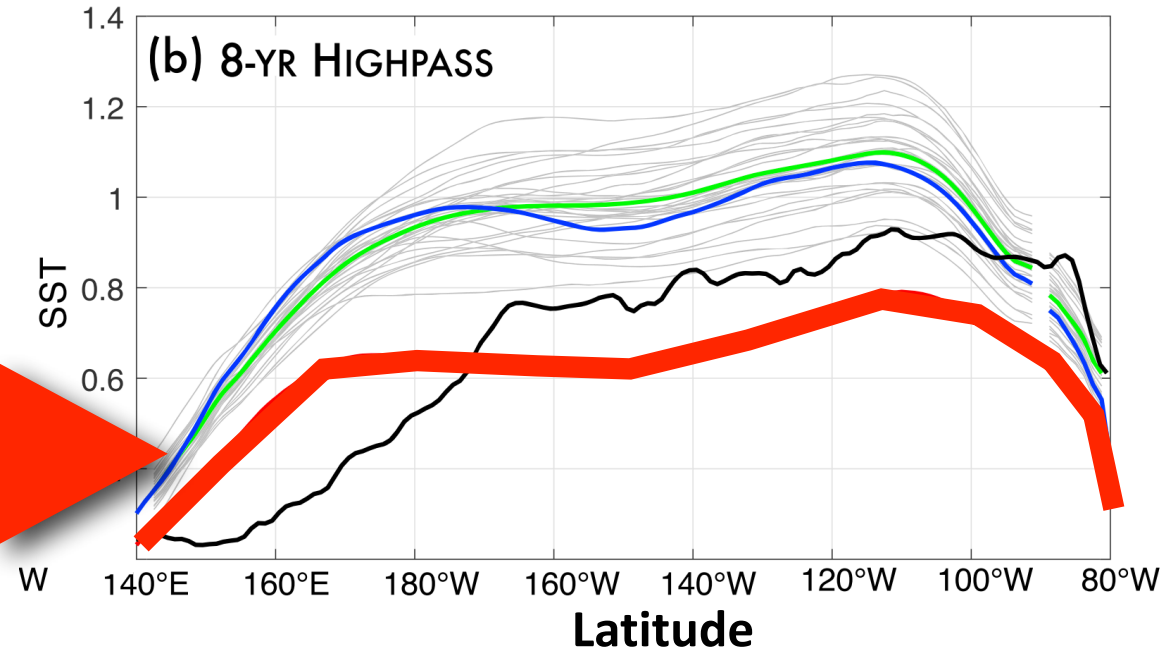
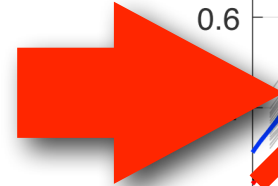
Reanalysis
Products

CMPI6 Ensemble

Individual ESMs
Large-Ensemble

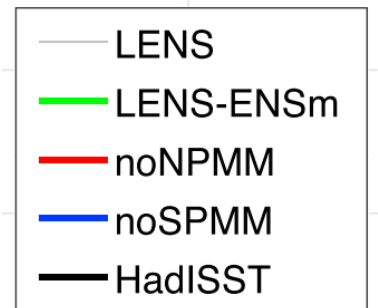
New E3SM large-
ensemble

Variance decreases when
we neglect south Pacific
Precursors



Liguori and Di Lorenzo, 2019

The **South Pacific ENSO Precursor** may have a
stronger impact **on the PDV**



Stevenson et al. in prep.

Our Hypothesis for Pacific Climate



Our Hypothesis for Pacific Climate

Reanalysis
Products

Zhao and Di Lorenzo, 2019
Xu, Newman, and Zhang, 2019
Zhao, Capotondi, and Zhang, 2020

A new 20 members ensemble with the E3SM
(see Stevenson presentation this PM).

CMPI6 Ensemble

Zhao, Stevenson, and Zhang, 2019

**Unique Initialization using
different decadal climate ocean states**

Individual ESMs
Large-Ensemble

Liguori and Di Lorenzo, 2019

**New E3SM large-
ensemble**

Stevenson et al. in prep.

Our Hypothesis for Pacific Climate

Reanalysis
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Zhao and Di Lorenzo 2019
Xu, Newman, and Zhang 2019
Zhao, Capotondi, and Zhang et al., 2020

A new 20 members ensemble with the E3SM
(see Stevenson presentation this PM).

CMPI6 Ensemble

Zhao, Stevenson et al. 2020

**Unique Initialization using
different decadal climate ocean states**

Individual ESMs
Large-Ensemble

Liguori and Di Lorenzo 2019

**Decadal Ocean State matters for 50-100 year
temperature prediction**

**New E3SM large-
ensemble**

Stevenson et al. in prep.

Our Hypothesis for Pacific Climate

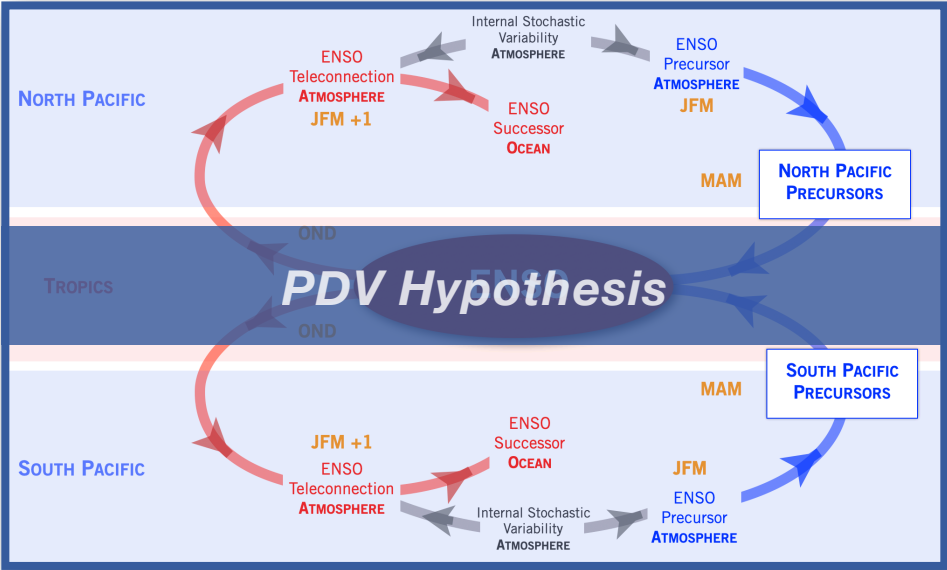
Reanalysis Products

CMPI6 Ensemble

Individual ESMs Large-Ensemble

New E3SM large-ensemble

Diagnostic with Empirical Dynamical Models



Linear Inverse Model (LIM)

Our Hypothesis for Pacific Climate

*Zhao, Newman, Capotondi and Di
Lorenzo et al. in prep.*

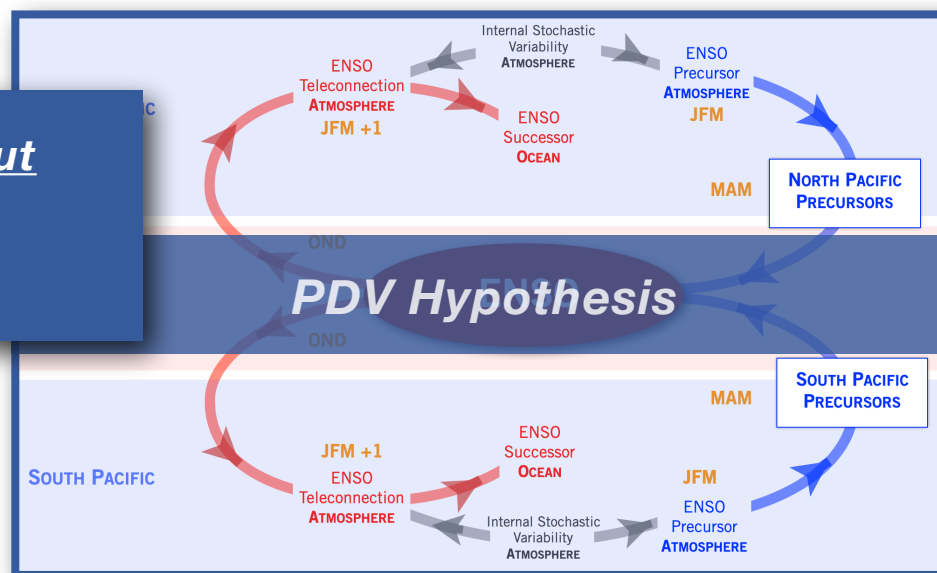
A LIM that selectively includes coupling
between tropics and extra tropics

Multi-Year Breakout

*Yingying Zhao
Youngji Joh*

Changes the character of PDV

Diagnostic with
Empirical Dynamical Models



Linear Inverse Model (LIM)

Our Hypothesis for Pacific Climate

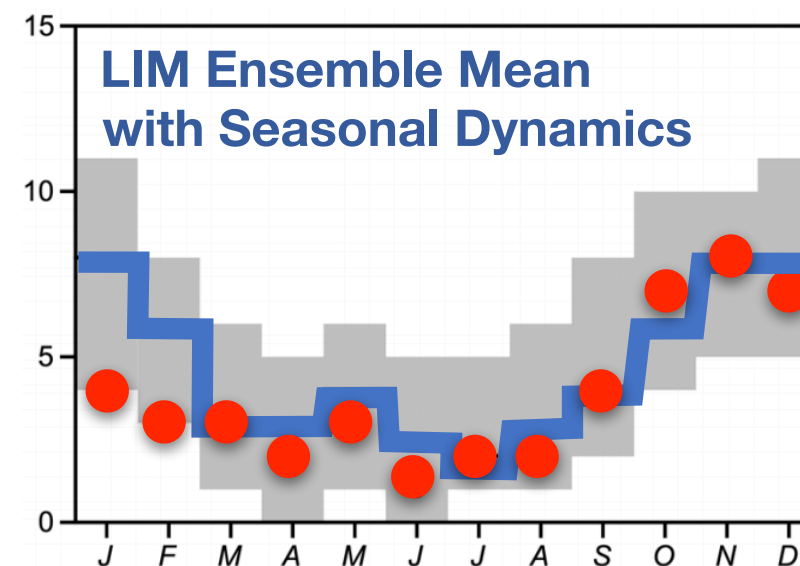
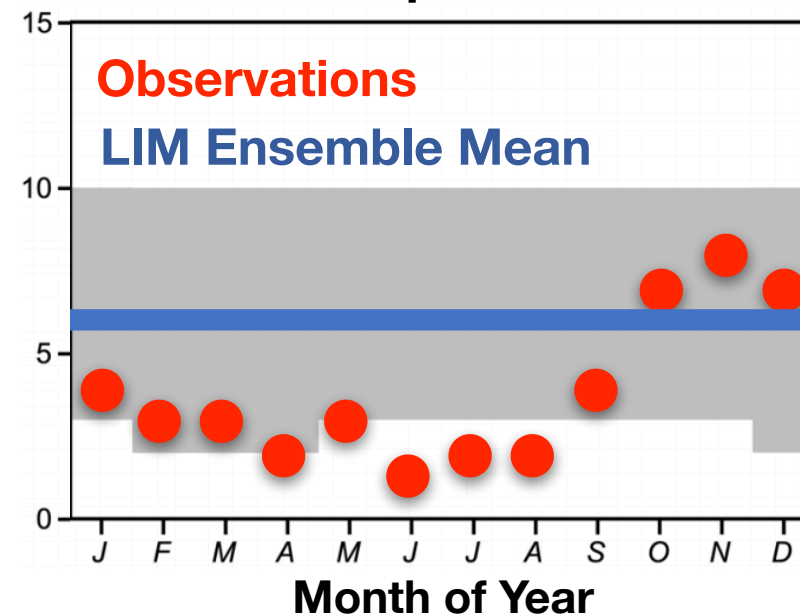
Shin, Newman, al. in press.

A LIM that can account for seasonal dynamics



PDV mechanisms are linked to seasonal dynamics because ENSO is phase-locked with seasonal cycle

Number of Tropical Warm Event



Near Term Objectives 2021

List of Publications and Links on SLACK Channel

GOAL 4: Perform a more comprehensive analysis (CESM, GFDL, E3SM)

Individual ESMs
Large-Ensemble

New E3SM large-ensemble

Diagnostic with
Empirical Dynamical Models

GOAL 2: Make the LIM Diagnostic Toolkit available to the RGMA

GOAL 3: Complete seasonal LIM diagnostics

GOAL 1: Complete the 20-member LENS covering 1850-2100 period

