

# **Pacific Ocean Boundary Ecosystems:** *response to natural and anthropogenic climate forcing*

## **PIs:**

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## **South American Collaborators:**

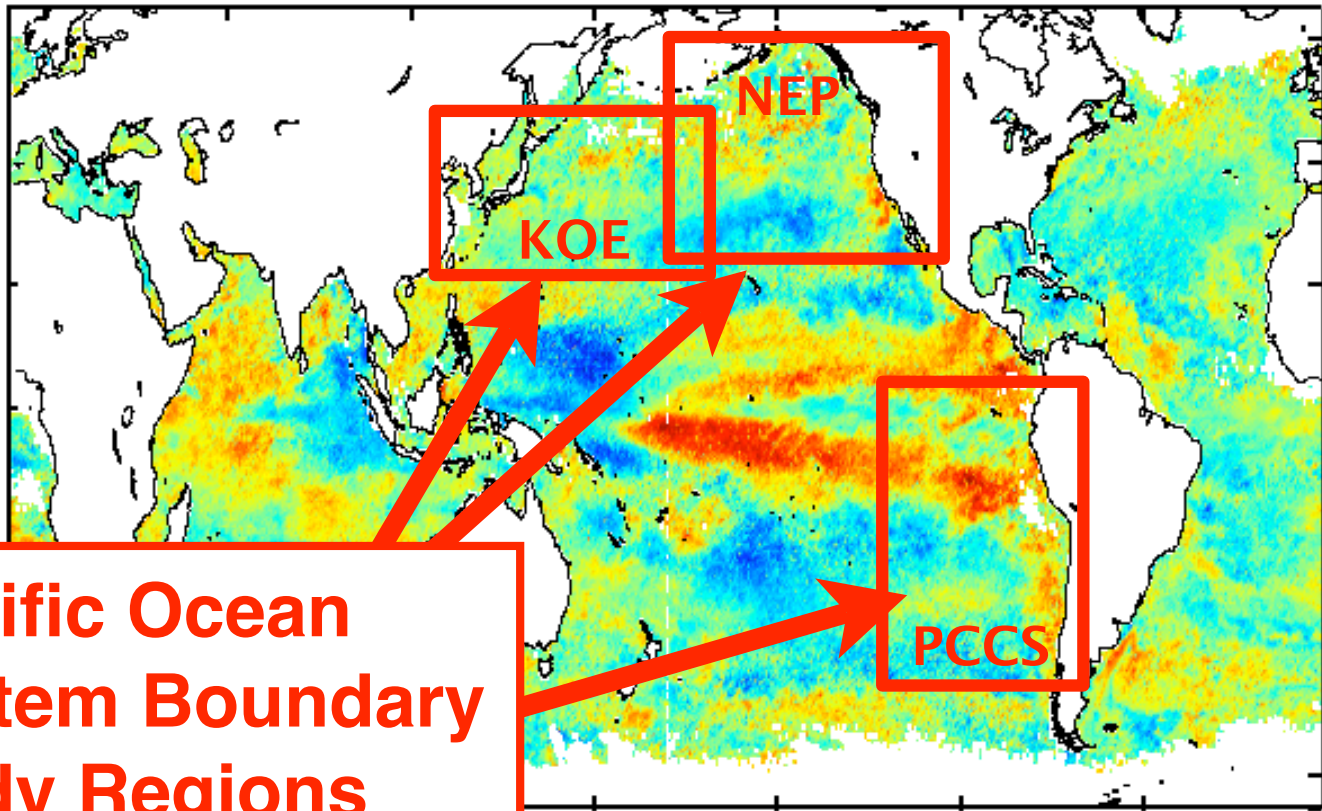
O. Pizarro, R. Escribano, J. Rutllant, S. Hormazabal, V. Montecino

## **Canadian Collaborators:**

D. Mackas, M. Foreman, A. Pena, W. Crawford



# Pacific Ocean Boundary Ecosystems: *response to natural and anthropogenic climate forcing*



**Pacific Ocean  
Ecosystem Boundary  
Study Regions**



- (\* ) Assess to what extent, and by what mechanisms, large-scale climate modes (e.g. PDO, NPGO, ENSO, and potentially others) drove coherent changes across Pacific boundary ecosystems over the period 1960-2007.
  
- (\* ) Quantify and explain how changes in regional ocean processes (e.g. upwelling, transport dynamics, mixing and mesoscale structure) at each boundary control phytoplankton and zooplankton dynamics.
  
- (\* ) Explore the range of uncertainties in the response of regional ocean dynamics and their ecosystems to climate change using forcing scenarios from selected climate model integrations that are part of the IPCC 2007 report.

PACIFIC BASIN-SCALE

Ocean/Atmosphere Coupled Dynamics  
( ENSO, Aleutian/PDO, NPO/NPGO, AO )

Proposal Conceptual Flow  
<http://Pacific-Ecosystems-Climate.Org>



PACIFIC BOUNDARY  
REGIONAL-SCALE

Regional  
Physical variability

Regionally Dependent  
*Local Forcing*

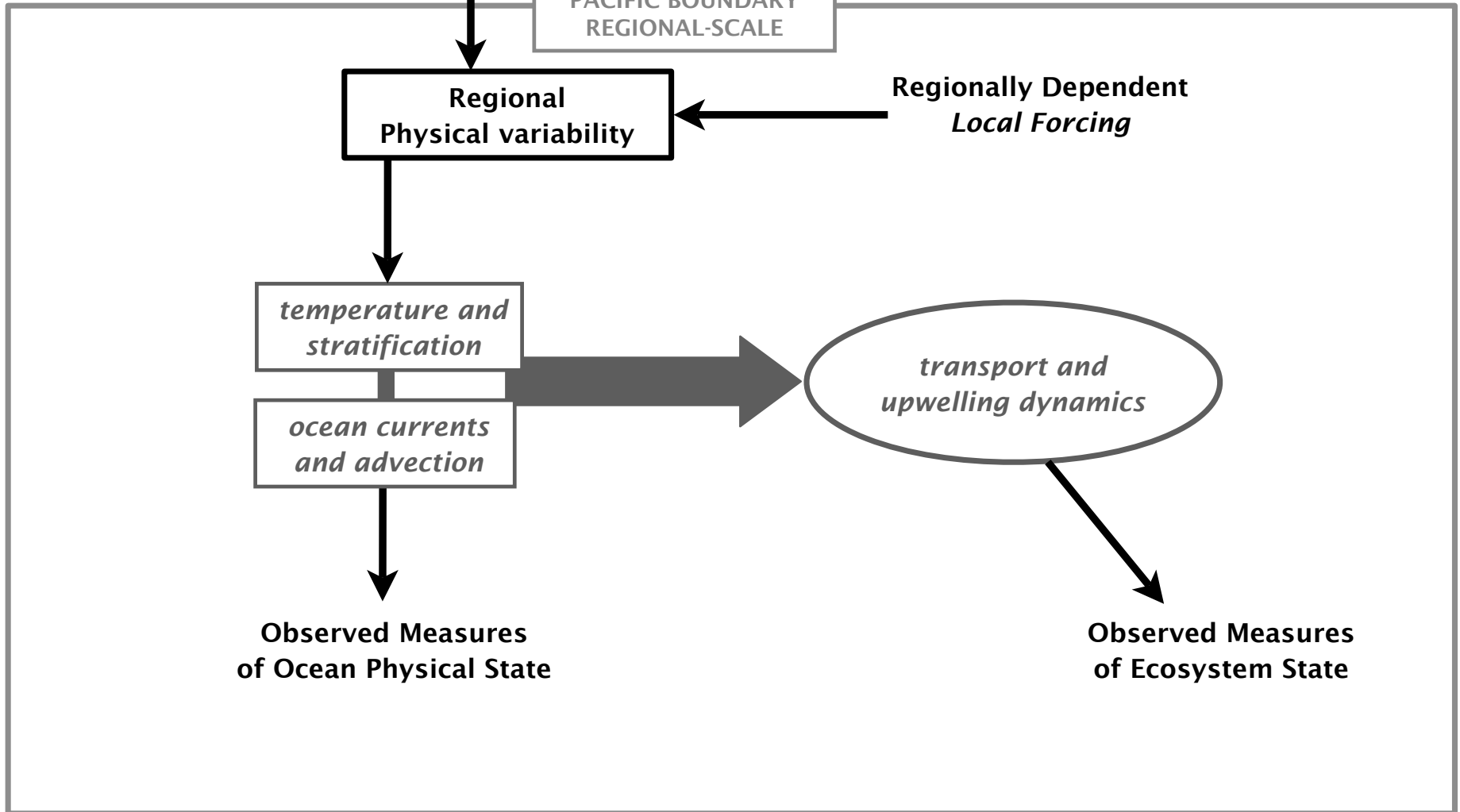
*temperature and  
stratification*

*ocean currents  
and advection*

*transport and  
upwelling dynamics*

Observed Measures  
of Ocean Physical State

Observed Measures  
of Ecosystem State

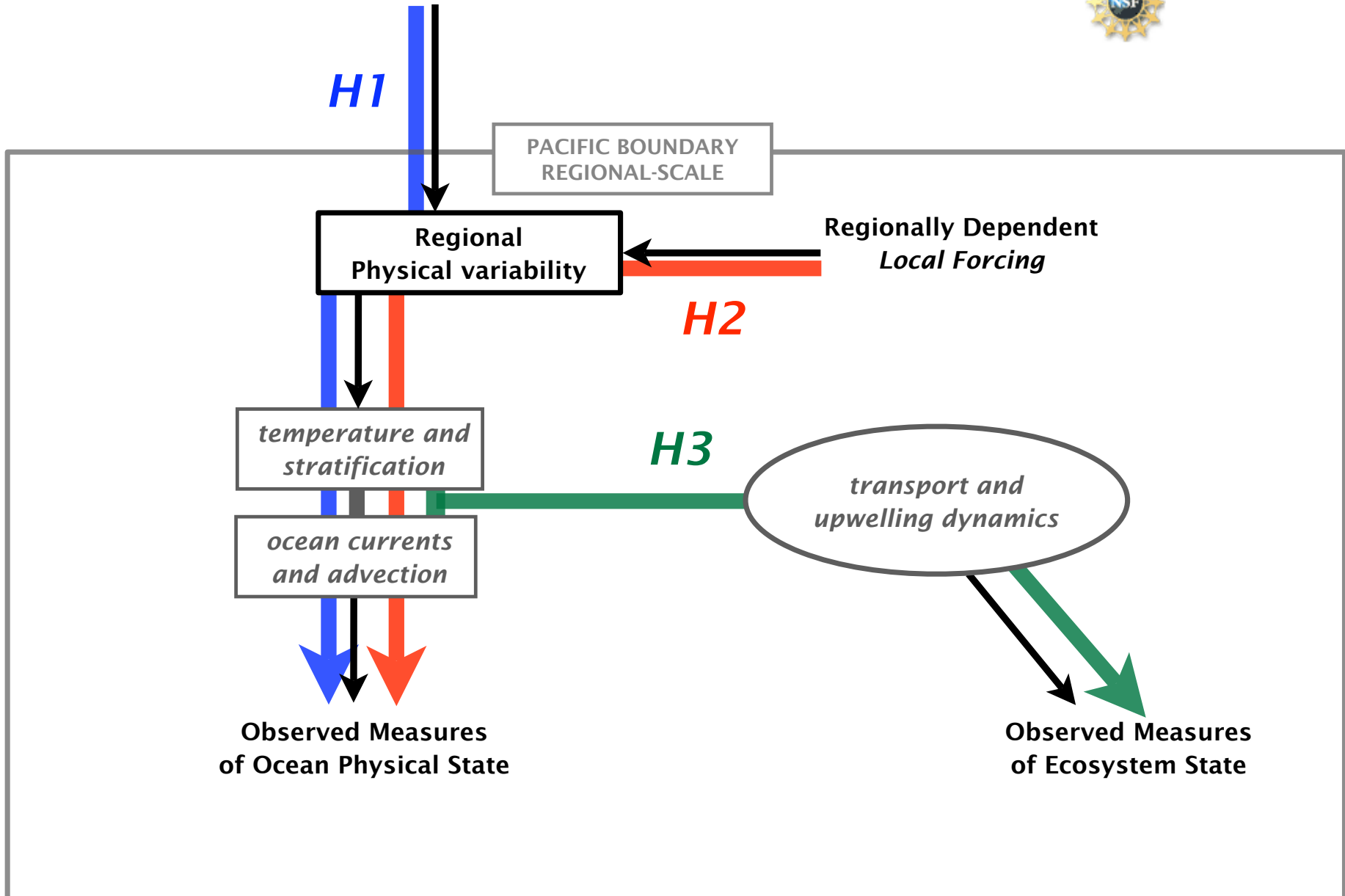


PACIFIC BASIN-SCALE

Ocean/Atmosphere Coupled Dynamics  
( ENSO, Aleutian/PDO, NPO/NPGO, AO )

Main Hypothesis

<http://Pacific-Ecosystems-Climate.Org>



## “In situ” Observed Measures of Physical/Ecosystem State

NEPD

Data Set	Location/Resolution	Time	Properties
CalCOFI	Southern CCS; usually quarterly	1949 – pres. 1984-pres (chl)	Nutrients, chl, pp profiles; zoo biomass+ ichthy species
GLOBEC LTOP	Oregon shelf to 85 miles offshore; quarterly. Gulf of Alaska, along Seward Line.	1997 – 2005, 2007	CTD, nutrient and chl-a profiles, zooplankton species
Newport Line	Newport shelf and slope (quarterly) Newport shelf and slope; ~ monthly	1961-1972  1963-1967	Nansen bottles and reversing thermometers. Krill species
Newport Line	Oregon shelf and shelf break bi-weekly, 7 stations (1 to 25 miles from shore)	1969-1972; 1996– pres.	1969-72 SST only. 1996-present CTD, chl-a, nutrients, zoopl species
Newport Line	Oregon shelf, biweekly, summer	1973,78,83, 90-92	Zoopl only
Washington and Oregon shelf	6-7 stations along 7-8 transects between northern WA and central OR	2x/summer 1998- pres. 1981-1985.	CTD, chl-a and nutrients, zoop. species, trawls for pelagic fish & juv. salmon).
Stn PAPA	N. Pacific subarctic gyre, 3x/year	1956-pres.	Zoopl biomass
BC shelf	Vancouver Island southern shelf, quarterly	1985-pres.	CTD, chl, nutes, zoo species

KOE

Odate	Western N. Pacific, Kuroshio Oyashio, transition regions, monthly	1951-pres.	CTD, chl, zoopl species
Hokkaido University	Western / central subarctic Pacific, annual	1953-2001	Oshoro-Maruo zooplankton Time series
Japan Nat. Fish. Res. Inst.	W. Subtrop. Pac., Kuroshio, 5-8 x per year	1971-pres.	Zoop, fish egg, larvae surveys
Hokkaido Nat. Fish. Res. Inst.	W. Subarctic Pac., Oyashio, 5-8x / year	1987-pres.	Line A monitoring, zoopl.

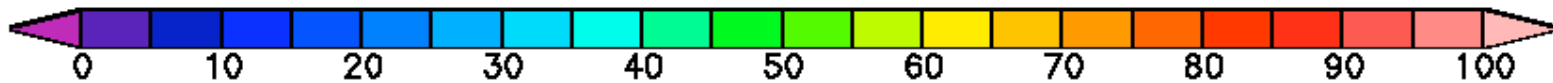
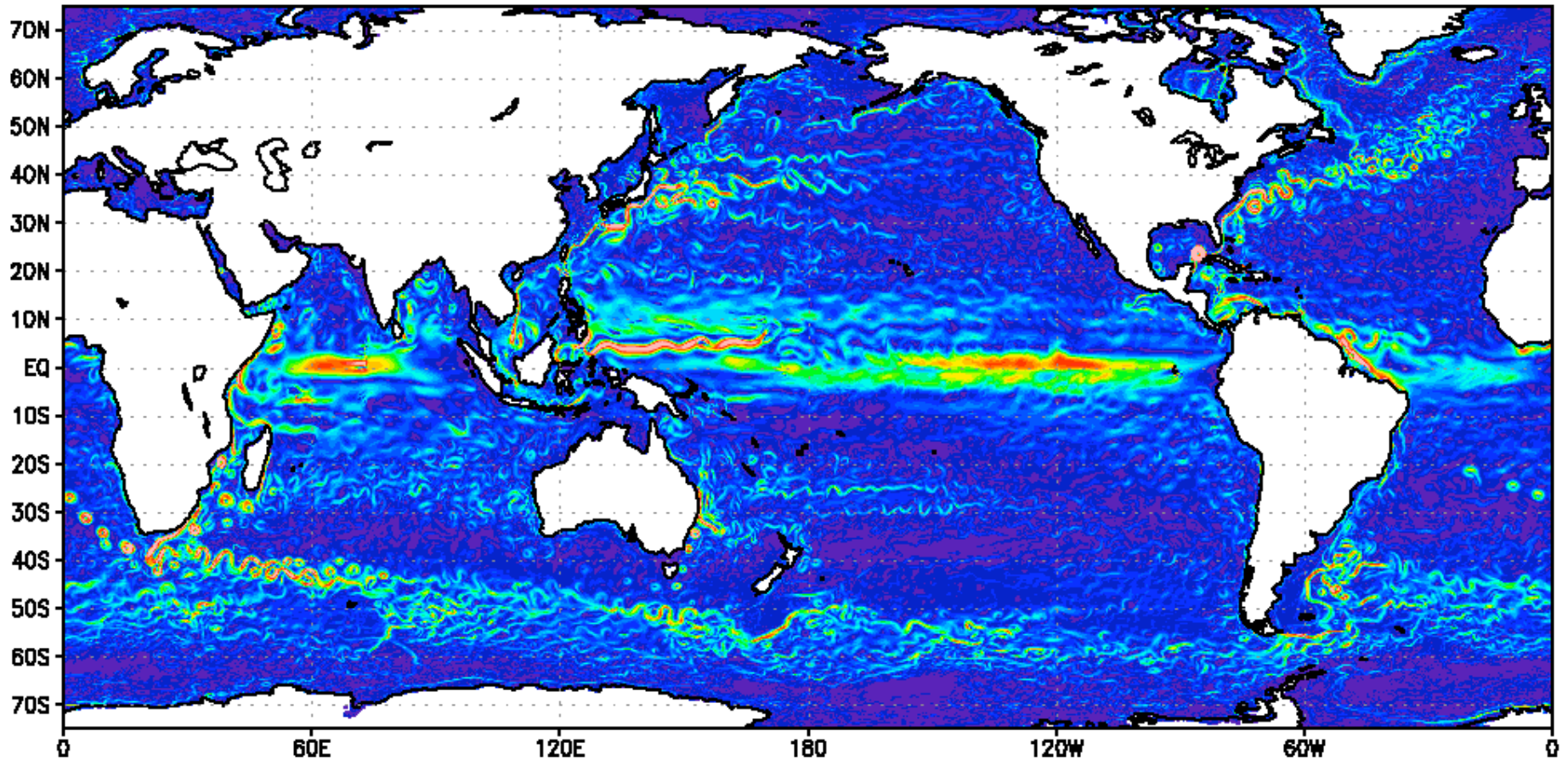
PCCS

IMARPE	Peru upwelling region, seasonal	1964-pres.	zooplankton
IFOP	Northern Chile, cross-shelf surveys, seasonal	1985-pres. 1996-pres (chl)	Zooplankton, www.IFOP.cl
Antofagasta research	Northern Chile coastal, at least annually	1991-2003	zooplankton
COPAS	Central Chile, off Concepcion	2002-pres.	CTD, nutrients, chl-a, zoop

Earth Simulator Ocean General Circulation Model  
10 km resolution 1950-2007

Surface Ocean Currents

OFES Model

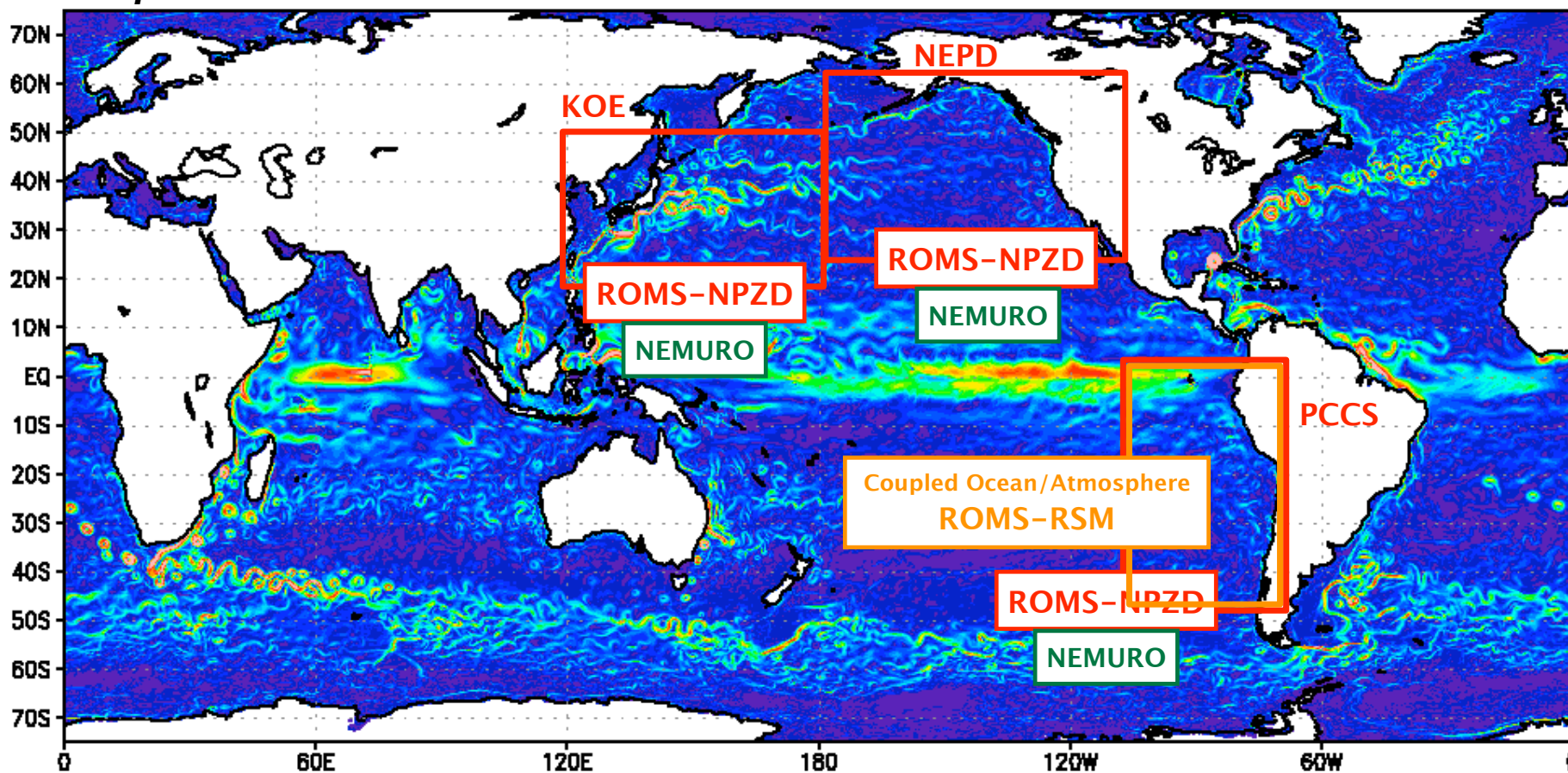


# Earth Simulator Ocean General Circulation Model

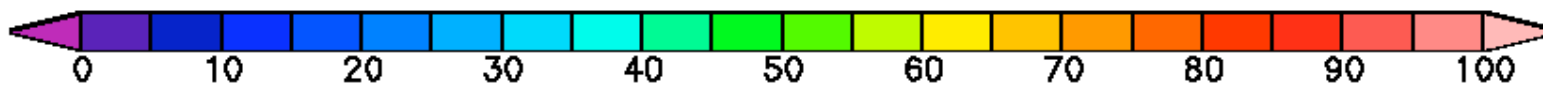
10 km resolution 1950-2007

OFES Model

Surface Ocean Currents



10 km resolution 1950-2007





## Project Website and DATA ARCHIVE

<http://Pacific-Ecosystems-Climate.Org>

- Pacific Ocean Boundary Ecosystems - www.Pacific-Ecosystems-Climate.Org

http://www.pacific-ecosystems-climate.org/data\_model.html

GaTech P.Ubaldi UNIX WkShop Classes Pidocchi Rai.tv User Guide - Share-IT

**Pacific Ocean Boundary Ecosystems**   
<http://Pacific-Ecosystems-Climate.Org>

Home | Research TASKS | Docs | Data Access | Images & Videos | Publications

**GLOBAL-SCALE Modeling Datasets**

**Description:** OFES NCEP HINDCAST 1950-2007  
**Short name:** OFES\_HIND\_NCEP  
**Time range:** Jan 1950 - Dec 2007, monthly averages  
**Space range:** global, 0.1 degree resolution  
**Availability:** on server, data access - [ OpenDAP ]

----- **Variables**

**Grid:** lon, lat, h, mask  
**2D-Variables:** SSH, SST, tau\_x, tau\_y  
**3D-Variables:** T, S, u, v, depth

----- **Model Run Configuration**

**Model:** OFES ocean model  
**Wind Forcing:** NCEP reanalysis, daily  
**Heat Fluxes:** NCEP reanalysis, daily, flux correction  
**Freshwater Fluxes:** NCEP reanalysis, daily, flux correction WOA SSS  
**Open Bound. Cond.:** n/a  
**Comments:** n/a

**Description:** OFES QSCAT HINDCAST 1999-2007  
**Short name:** OFES\_HIND\_QSCAT  
**Time range:** Jan 1950 - Dec 2007, monthly averages  
**Space range:** global, 0.1 degree resolution  
**Availability:** on server, data access - [ OpenDAP ]

----- **Variables**

**Grid:** lon, lat, h, mask  
**2D-Variables:** SSH, SST, tau\_x, tau\_y, Chl-a

# OpenDAP datasever for Modeling DATA

<http://data.Pacific-Ecosystems-Climate.Org>



GEORGIA INSTITUTE OF TECHNOLOGY

OCEAN-CLIMATE DATA SERVER



sponsored by NSF-OCE GLOBEC - maintained by E. Di Lorenzo

[Georgia Tech Data Server - top level](#) - [OFES\\_NCEP](#)

## Georgia Tech Data Server - directory for /OFES\_NCEP : 9 entries

- 1: **eta**: eta monthly means OFES NCEP [info](#) [dds](#) [das](#)
- 2: **hflx**: hflx monthly means OFES NCEP [info](#) [dds](#) [das](#)
- 3: **salinity**: salinity monthly means OFES NCEP [info](#) [dds](#) [das](#)
- 4: **sflx**: sflx monthly means OFES NCEP [info](#) [dds](#) [das](#)
- 5: **taux**: taux monthly means OFES NCEP [info](#) [dds](#) [das](#)
- 6: **tauy**: tauy monthly means OFES NCEP [info](#) [dds](#) [das](#)
- 7: **temp**: temp monthly means OFES NCEP [info](#) [dds](#) [das](#)
- 8: **u\_vel**: u\_vel monthly means OFES NCEP [info](#) [dds](#) [das](#)
- 9: **v\_vel**: v\_vel monthly means OFES NCEP [info](#) [dds](#) [das](#)

[back to parent directory](#)

**Research TASKS**

<http://Pacific-Ecosystems-Climate.Org>



## **Research TASKS during 1st year**



***Pacific Basin Scale  
Analyses***

***North Pacific  
Eastern Boundary***

***South Pacific  
Eastern Boundary***

***North Pacific  
Western Boundary***

***Cross-Boundary  
synthesis***

*Ocean/Atmosphere Coupled Dynamics ( ENSO, Aleutian/PDO, NPO/NPGO, AO )* *E. Di Lorenzo*

*IPCC Climate Model downscaling* *J. Furtado*

*Basin-scale SSH/SST Satellite vs. OFES Model* *T. Strub*

*Basin-scale Chl-a Satellite* *A. Thomas*

*OFES and Nested ROMS NEP and KOE* *A. Bracco*

*ROMS Passive Tracer Statistics NEP* *N. Mariani*

*Zooplankton Species Distributions NEP* *Peterson & Keister*

*ROMS NPZD NEP* *P. Franks*

*SCOAR Model PCCS* *D. Putrissan*

*ROMS Passive Tracer Statistics PCCS* *V. Combes*

*ROMS Passive Tracer Statistics KOE* *L. Ceballos*

*Zooplankton Species Distributions KOE* *S. Chiba and P. Franks*

*OFES Model Subsurface NEP and PCCS* *S. Bograd*

**Research TASKS**  
<http://Pacific-Ecosystems-Climate.Org>



**Pacific Basin Scale Analyses**

**North Pacific Eastern Boundary**

**South Pacific Eastern Boundary**

**North Pacific Western Boundary**

**Cross-Boundary synthesis**

PACIFIC BASIN-SCALE

Year 1 TASKS



<http://Pacific-Ecosystems-Climate.Org>

Ocean/Atmosphere Coupled Dynamics  
( ENSO, Aleutian/PDO, NPO/NPGO, AO )

## Pacific Basin Scale Analyses

PACIFIC BOUNDARY  
REGIONAL-SCALE

Regional  
Physical variability

Regionally Dependent  
*Local Forcing*

*temperature and  
stratification*

*ocean currents  
and advection*

*transport and  
upwelling dynamics*

Observed Measures  
of Ocean Physical State

Observed Measures  
of Ecosystem State

PACIFIC BASIN-SCALE

Year 1 TASKS



<http://Pacific-Ecosystems-Climate.Org>

Ocean/Atmosphere Coupled Dynamics  
( ENSO, Aleutian/PDO, NPO/NPGO, AO )

Basin-scale Chl-a  
Satellite vs. OFES  
A. Thomas

T. Strub

E. Di Lorenzo

J. Furtado

Basin-scale SSH/SST  
Satellite vs. OFES Model

IPCC Climate  
Model  
downscaling

PACIFIC BOUNDARY  
REGIONAL-SCALE

Regional  
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Local Forcing

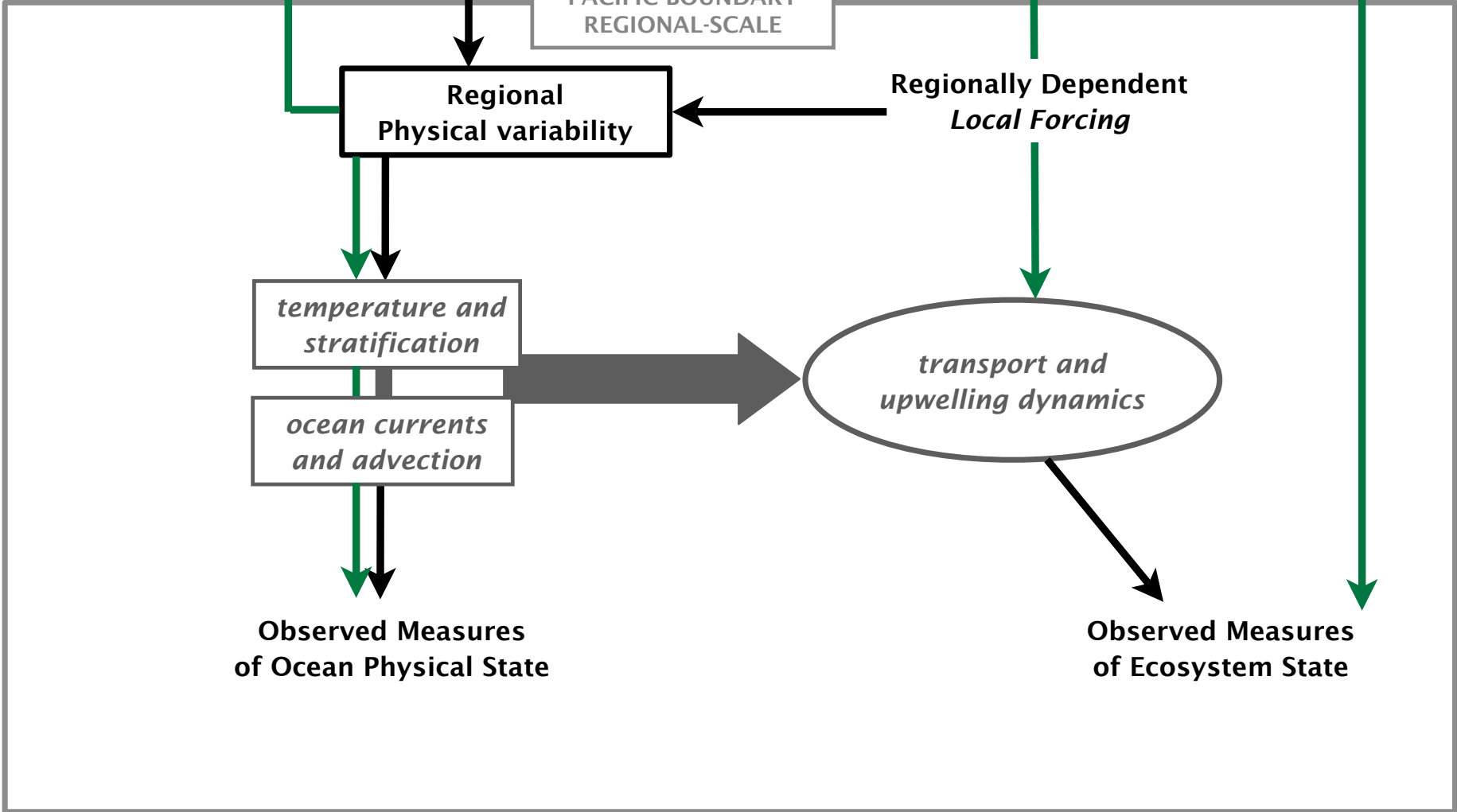
temperature and  
stratification

ocean currents  
and advection

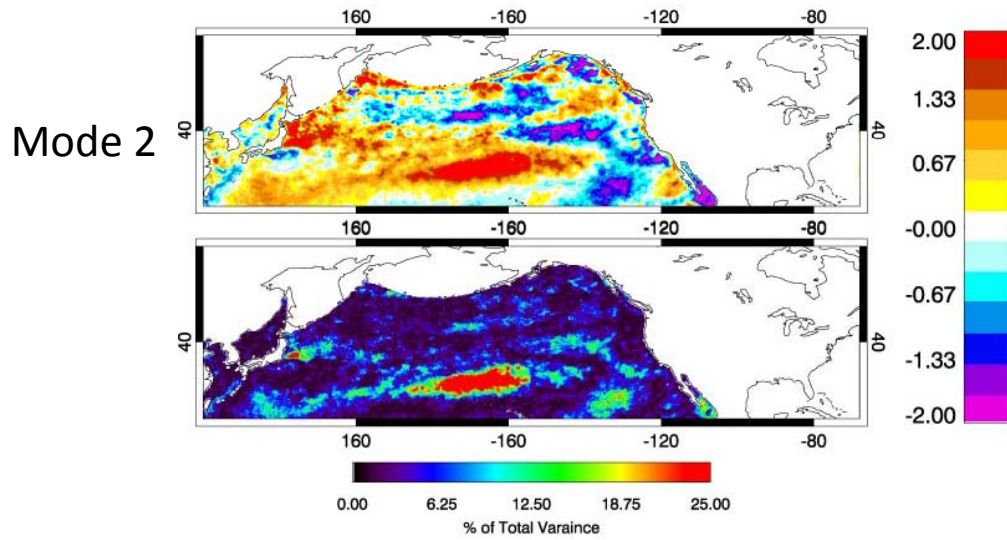
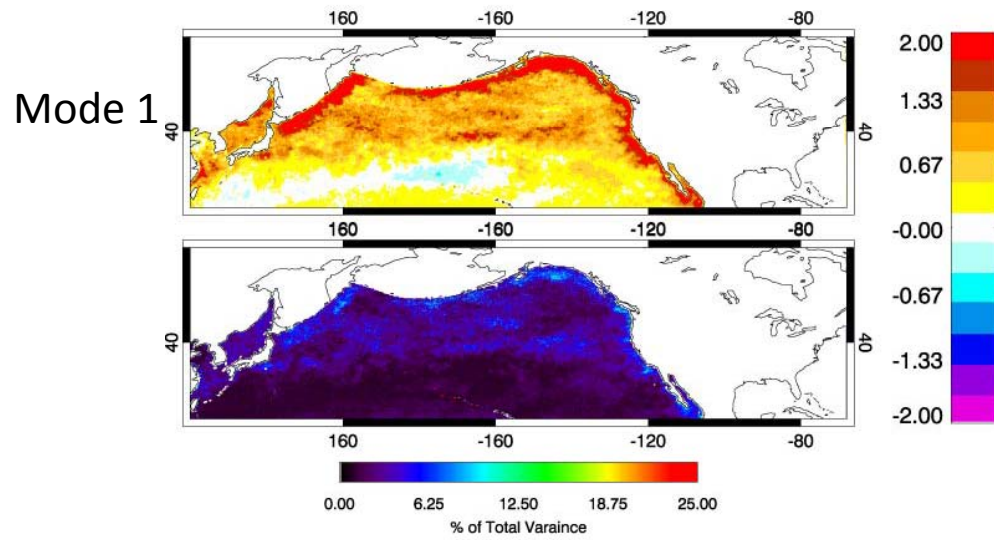
transport and  
upwelling dynamics

Observed Measures  
of Ocean Physical State

Observed Measures  
of Ecosystem State

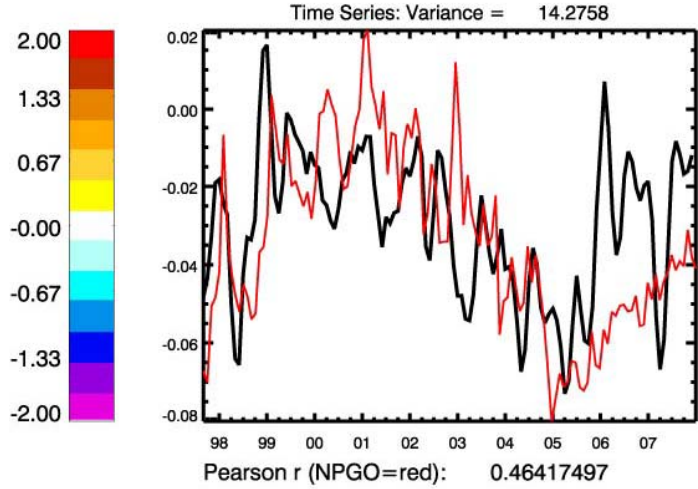
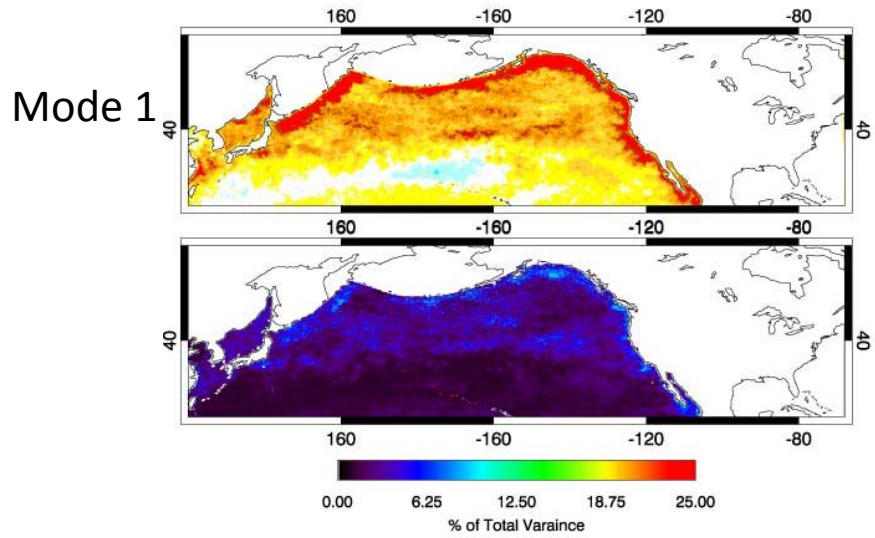


# 1<sup>st</sup> 2 EOF modes of CHL anomalies (1997-2007) for N Pacific:

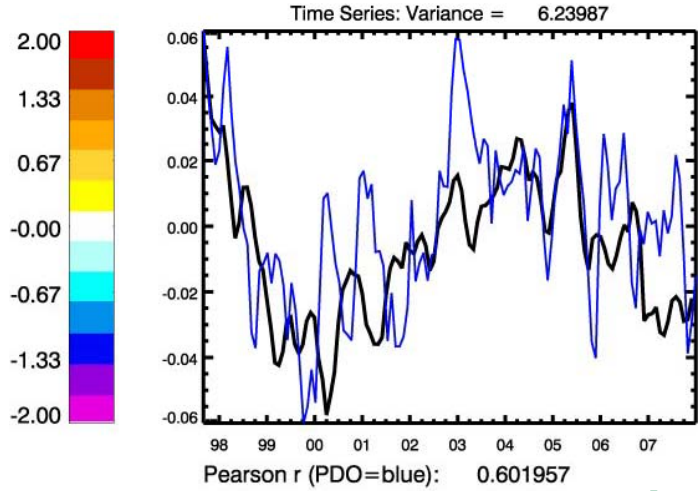
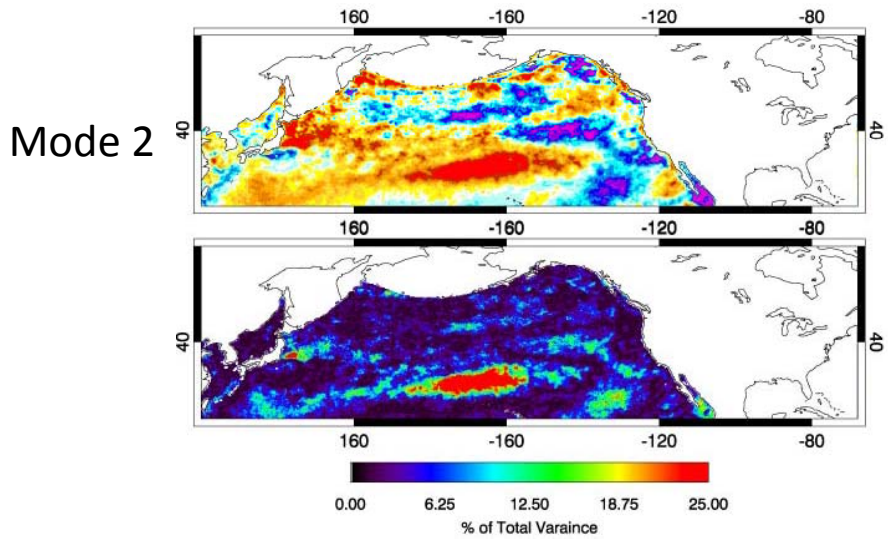


*Thomas et al.*

# 1<sup>st</sup> 2 EOF modes of CHL anomalies (1997-2007) for N Pacific:



**PC1**  
**NPGO**



**PC2**  
**PDO**

*Thomas et al.*



PACIFIC BASIN-SCALE

Ocean/Atmosphere Coupled Dynamics  
( ENSO, Aleutian/PDO, NPO/NPGO, AO )

Year 1 TASKS

<http://Pacific-Ecosystems-Climate.Org>



*North Pacific Eastern Boundary*

PACIFIC BOUNDARY  
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PACIFIC BASIN-SCALE

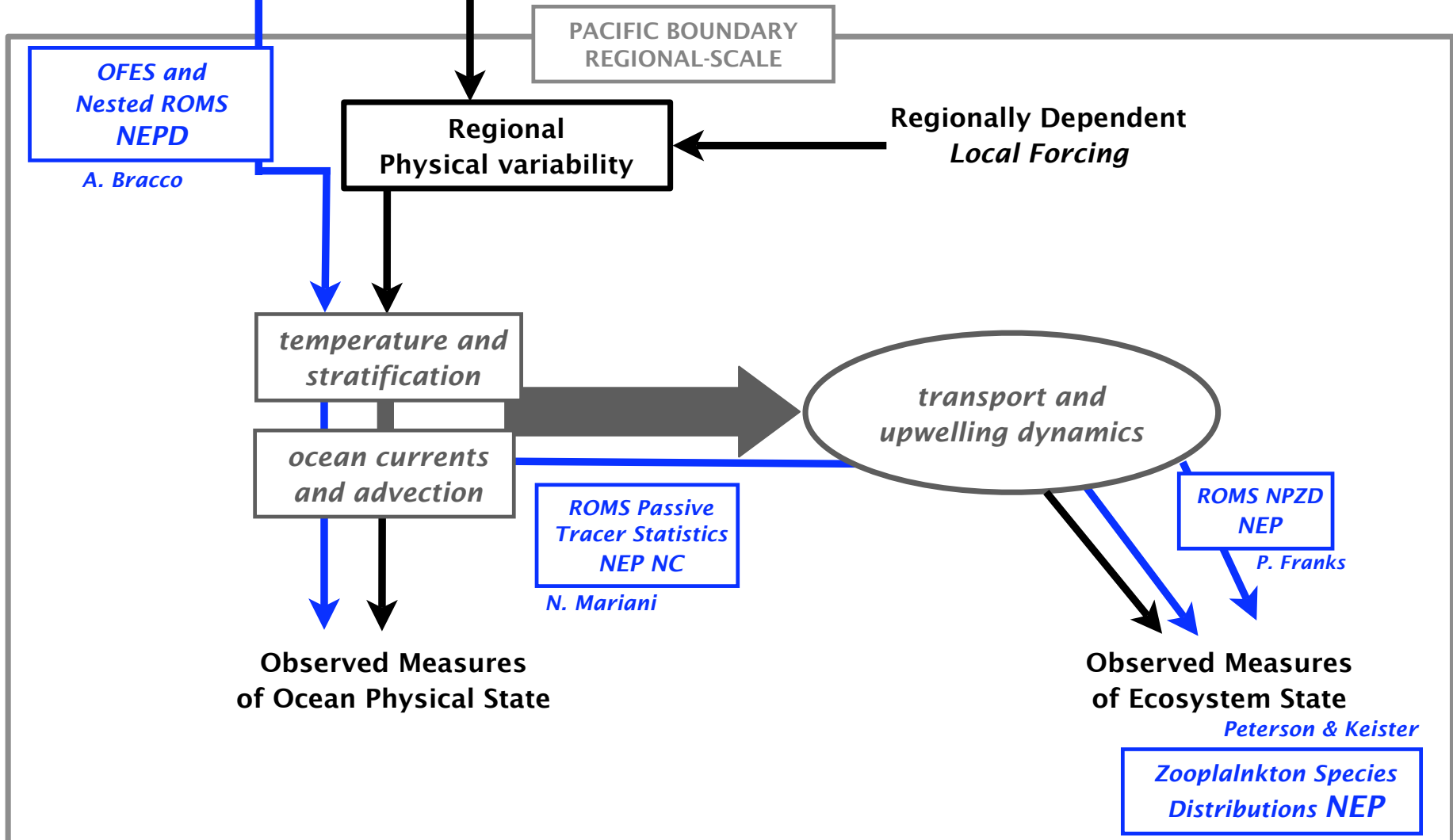
Year 1 TASKS



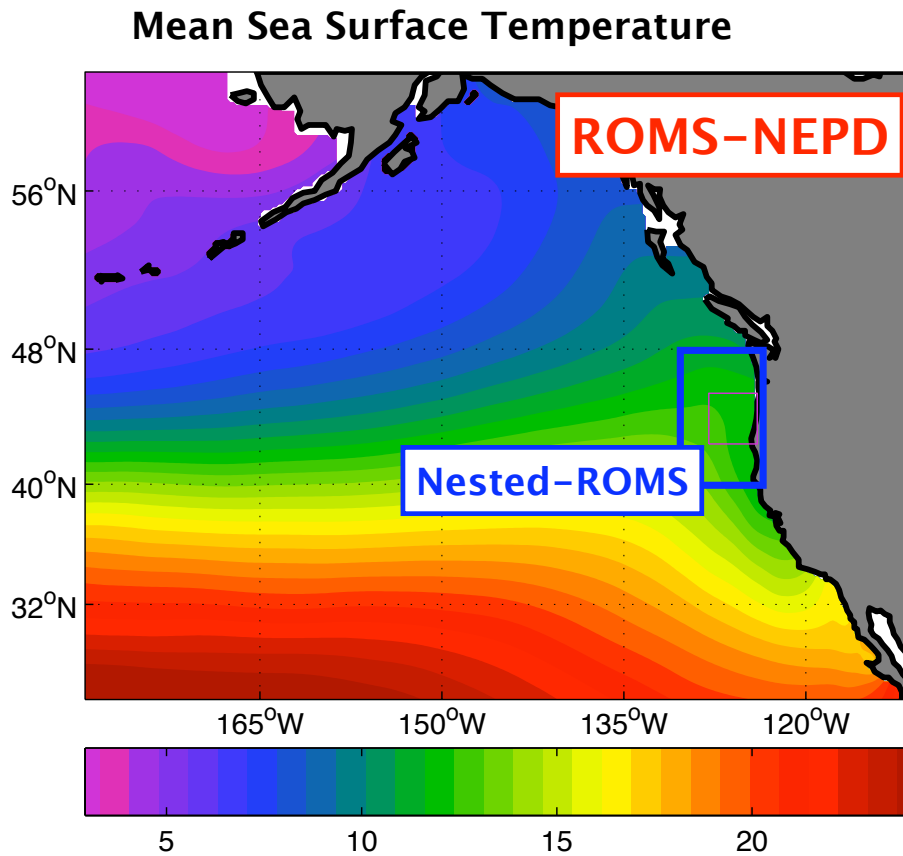
<http://Pacific-Ecosystems-Climate.Org>

Ocean/Atmosphere Coupled Dynamics  
( ENSO, Aleutian/PDO, NPO/NPGO, AO )

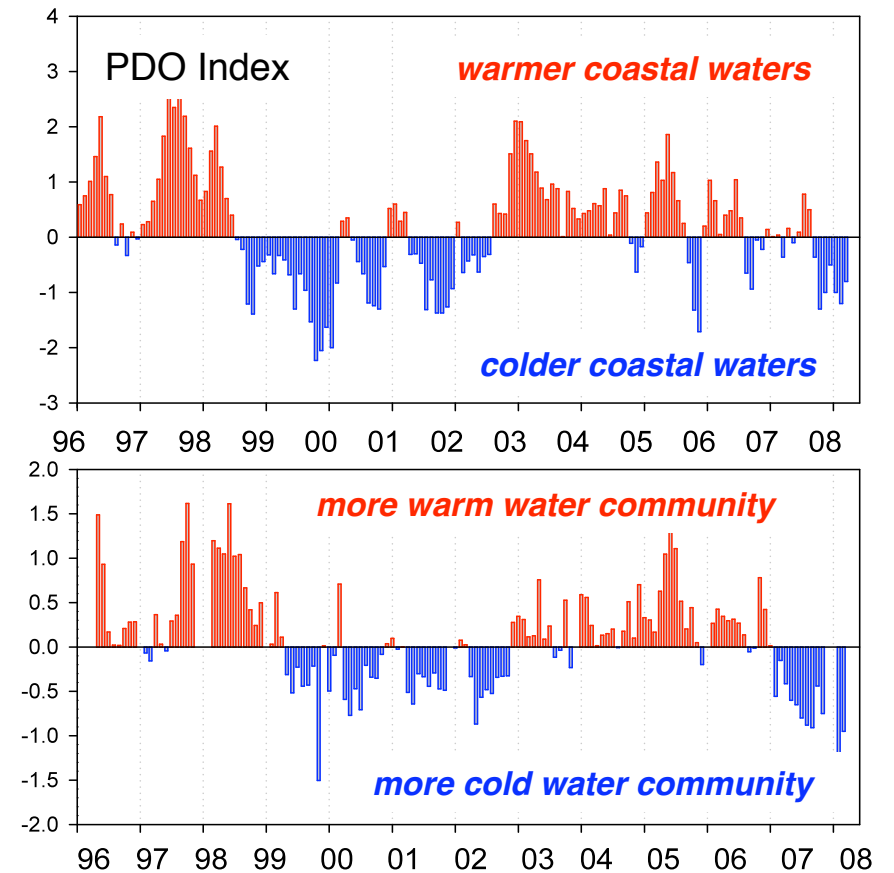
*North Pacific Eastern Boundary*



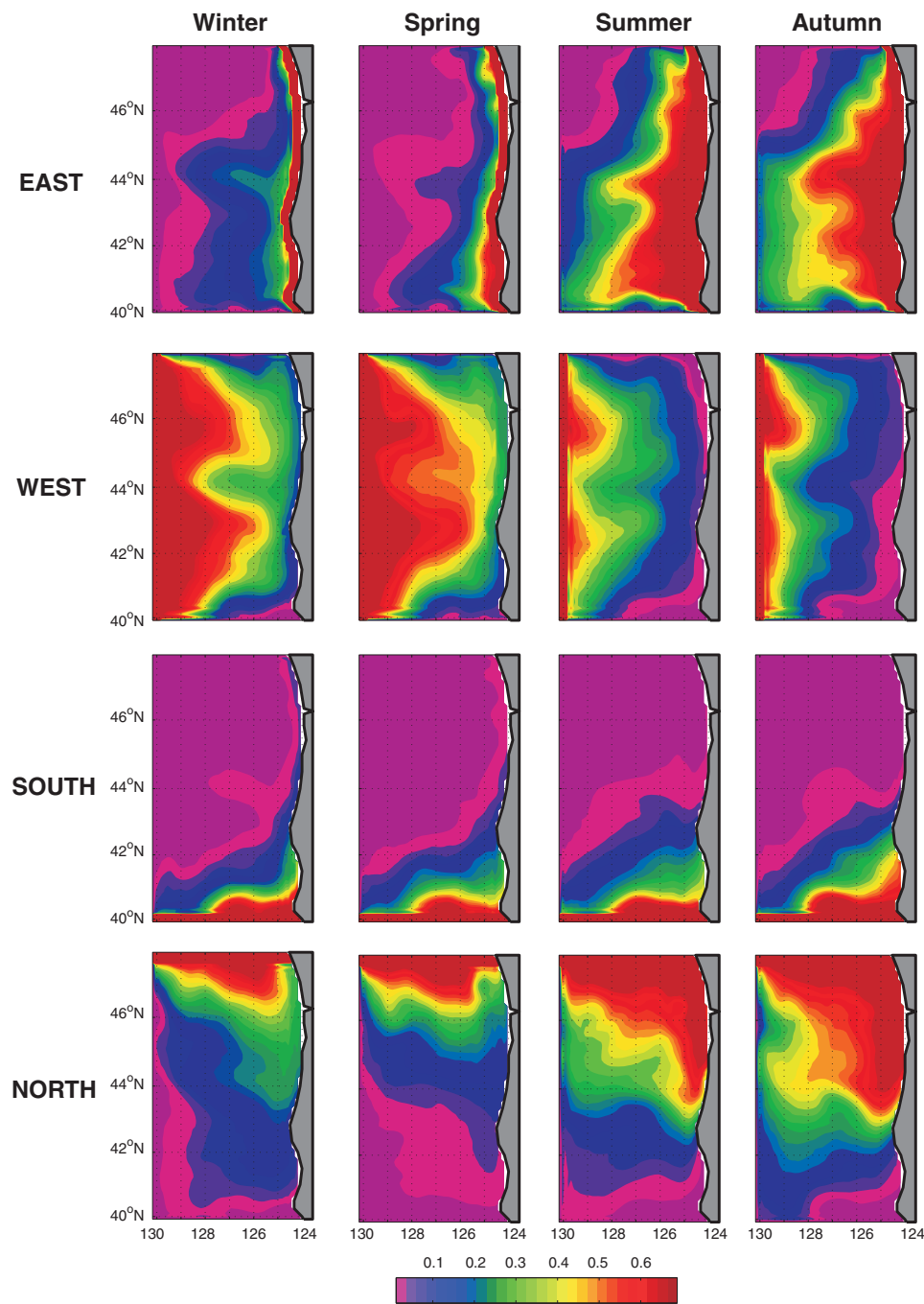
**A) Hypothesis:** Warm/Cold Copepods species abundance on **Oregon Shelf** are associated with advection of warm/cold waters during different phases of PDO.



*Keister, Mariani, Combes et al.*



*W. Peterson*



## Seasonal Cycle of Surface Passive Tracers

**Figure 3: Seasonal Cycle of surface passive tracers.** Seasonal means surface passive tracer releases from the four boundaries, east, west, south and north. Black vector show the mean seasonal currents. White contours show the topography.

*Keister, Mariani, Combes et al.*

**Zooplankton Species  
Index**

**Passive Tracer**

Linear model reconstruction of *X-Score*

$$\text{Zoop.} = \alpha_N P_{NORTH} + \alpha_S P_{SOUTH} + \alpha_E P_{EAST} + \alpha_W P_{WEST} + \epsilon$$

*Keister, Mariani, Combes et al.*

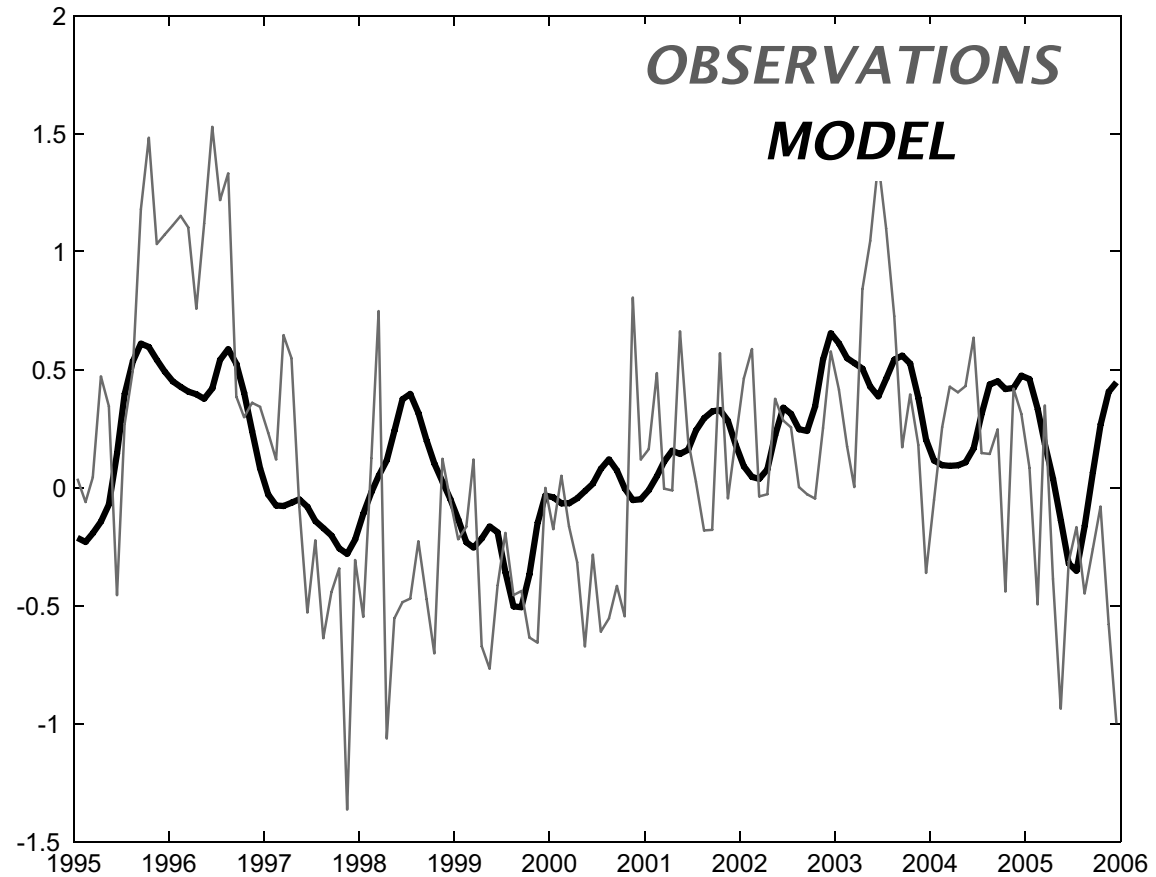
**Zooplankton Species Index**

**Passive Tracer**

Linear model reconstruction of *X-Score*

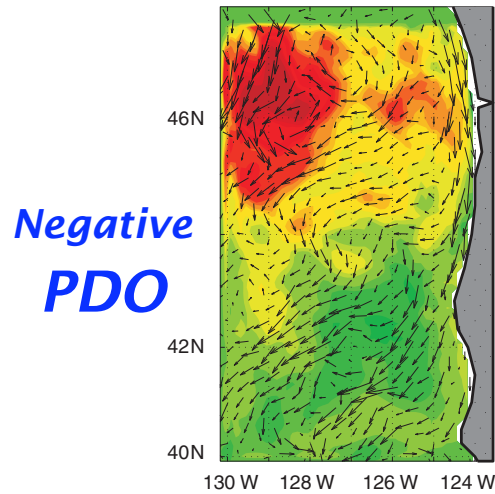
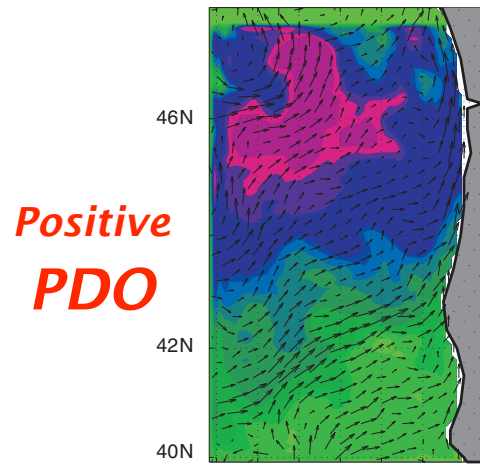
$$\text{Zoop.} = \alpha_N P_{NORTH} + \alpha_S P_{SOUTH} + \alpha_E P_{EAST} + \alpha_W P_{WEST} + \epsilon$$

**$R=0.54$  (explained variance 30%)**

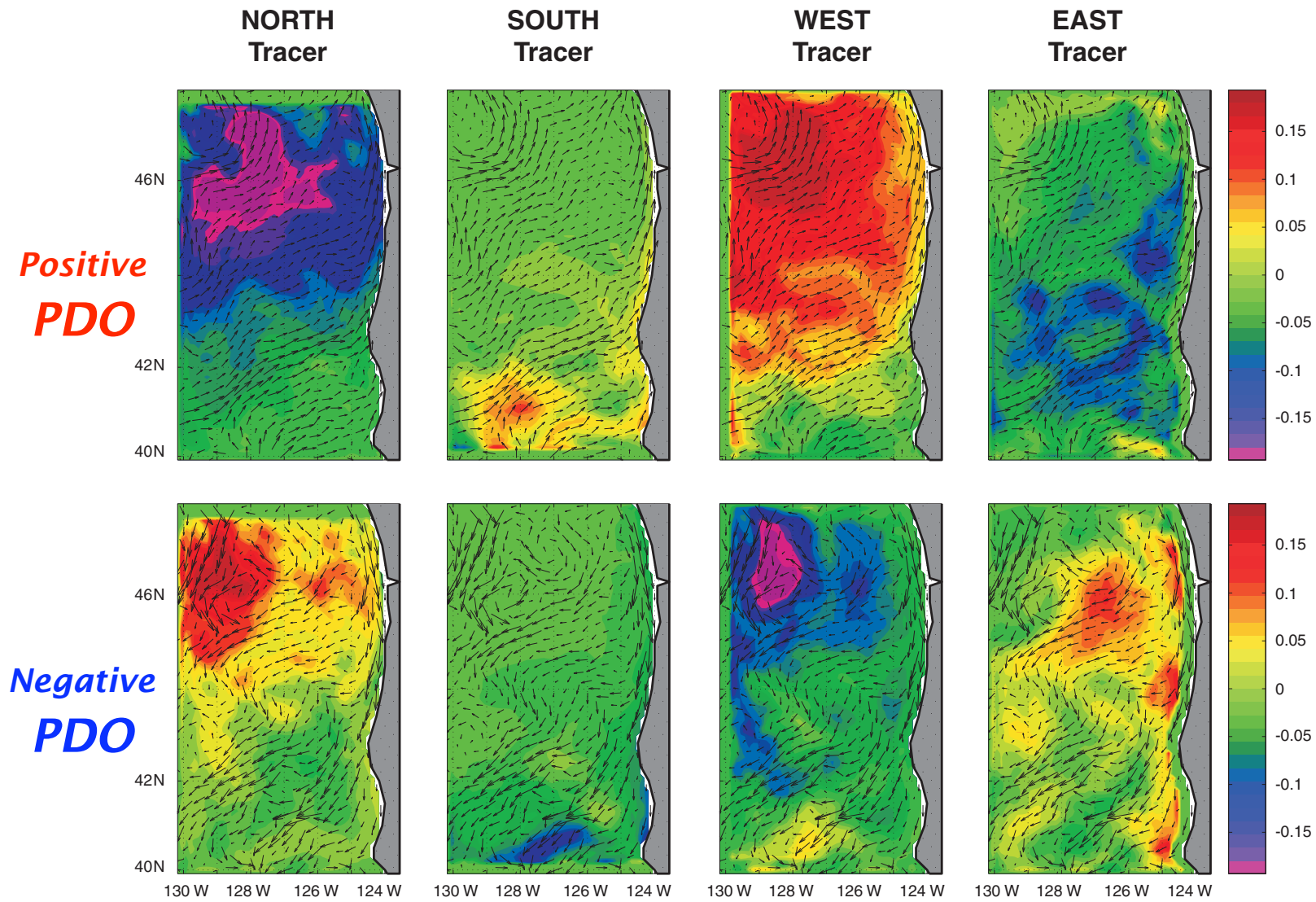


**Keister, Mariani, Combes et al.**

**NORTH  
Tracer**



*Signature of the PDO in the advection*

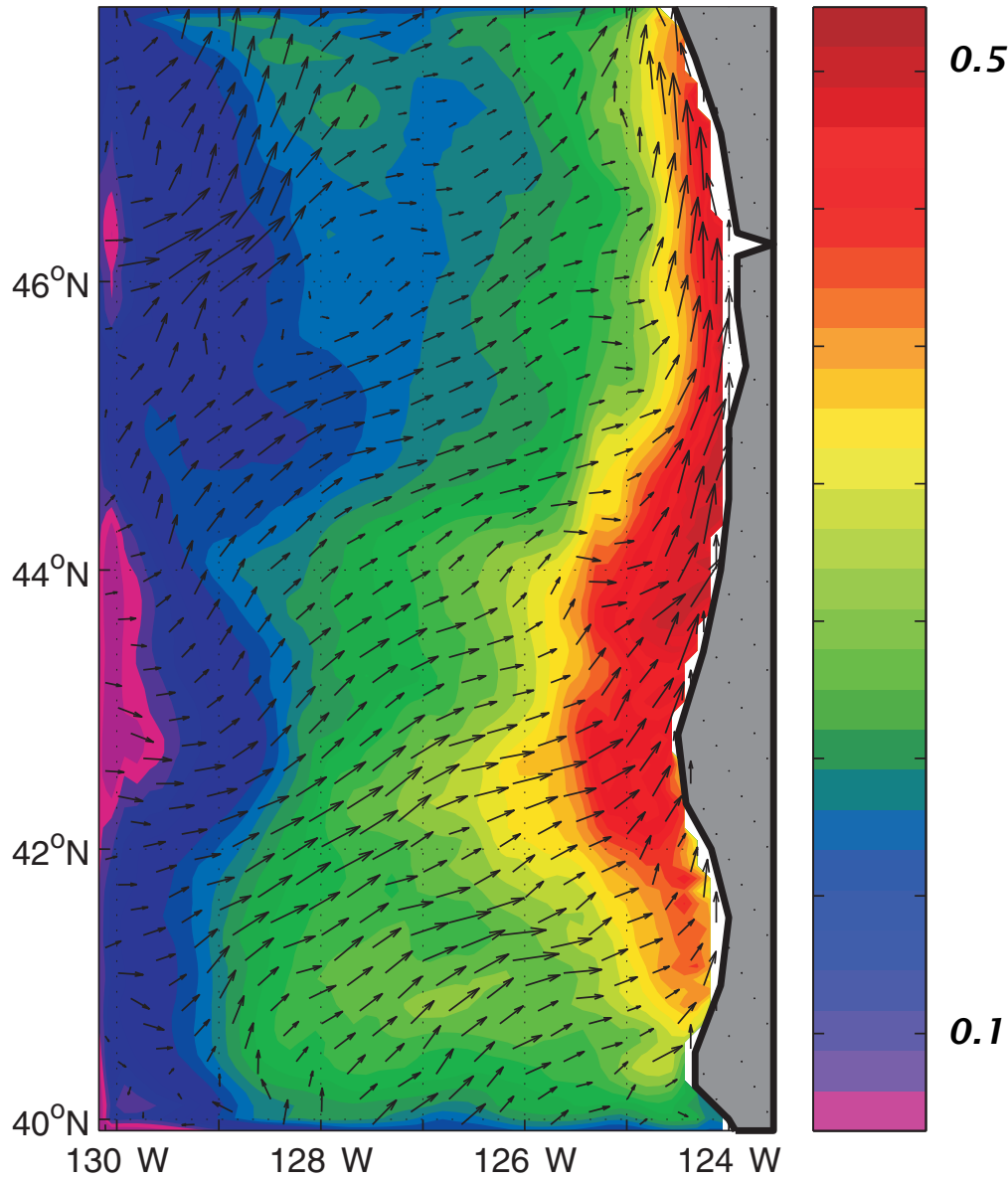


*Keister, Mariani, Combes et al.*



**A**

EOF1 SST 63.7023



*Positive PDO*

*SSTa and Surface  
Currents anomalies*

*Keister, Mariani, Combes et al.*

PACIFIC BASIN-SCALE

Ocean/Atmosphere Coupled Dynamics  
( ENSO, Aleutian/PDO, NPO/NPGO, AO )

Year 1 TASKS

<http://Pacific-Ecosystems-Climate.Org>



*South Pacific Eastern Boundary*

PACIFIC BOUNDARY  
REGIONAL-SCALE

Regional  
Physical variability

Regionally Dependent  
*Local Forcing*

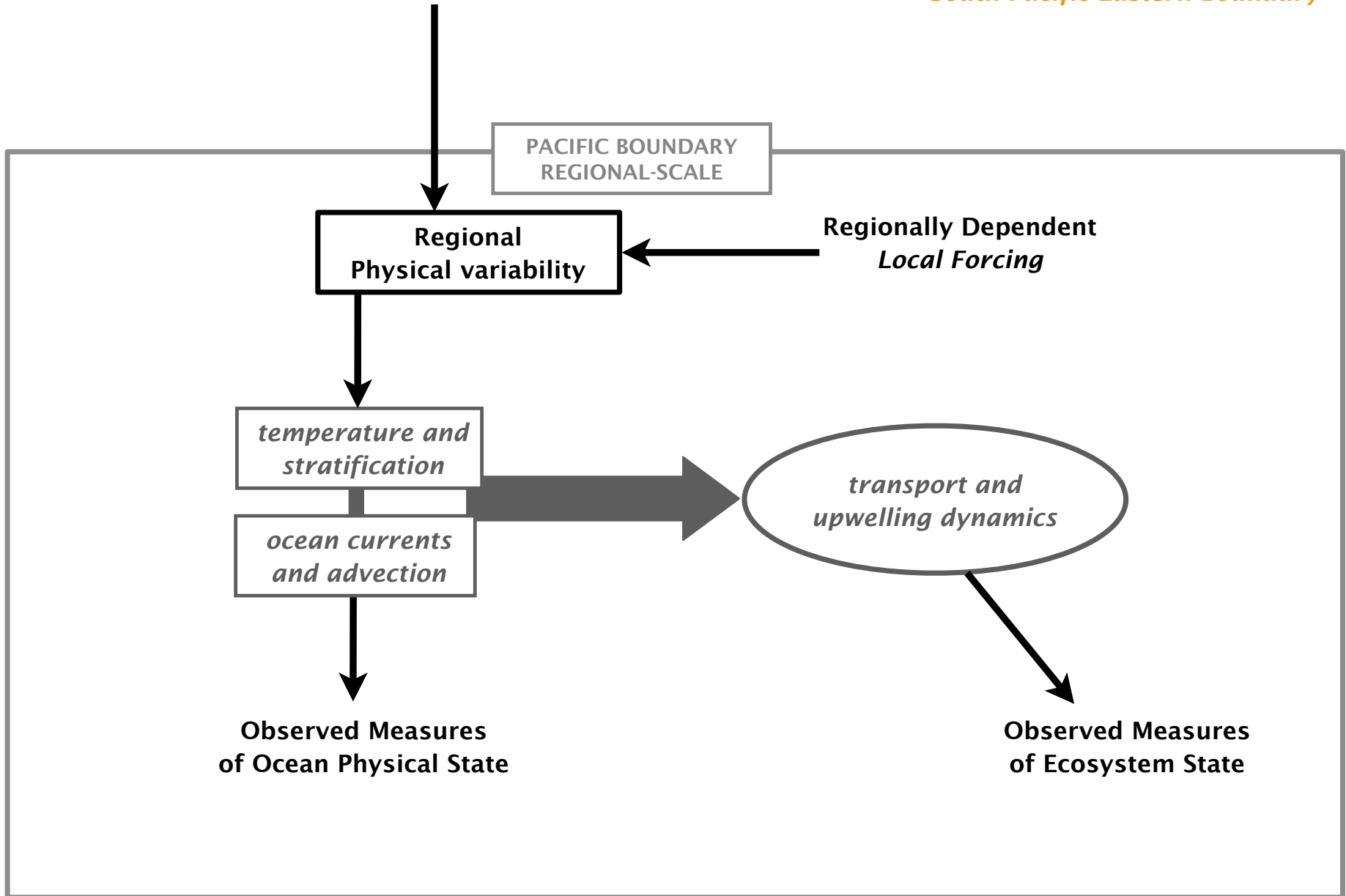
*temperature and  
stratification*

*ocean currents  
and advection*

*transport and  
upwelling dynamics*

Observed Measures  
of Ocean Physical State

Observed Measures  
of Ecosystem State



PACIFIC BASIN-SCALE

Year 1 TASKS



<http://Pacific-Ecosystems-Climate.Org>

Ocean/Atmosphere Coupled Dynamics  
( ENSO, Aleutian/PDO, NPO/NPGO, AO )

*South Pacific Eastern Boundary*

PACIFIC BOUNDARY  
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*SCOAR Model  
PCCS*

*D. Putrissan*

*temperature and  
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*V. Combes  
ROMS Passive  
Tracer Statistics  
PCCS*

*ocean currents  
and advection*

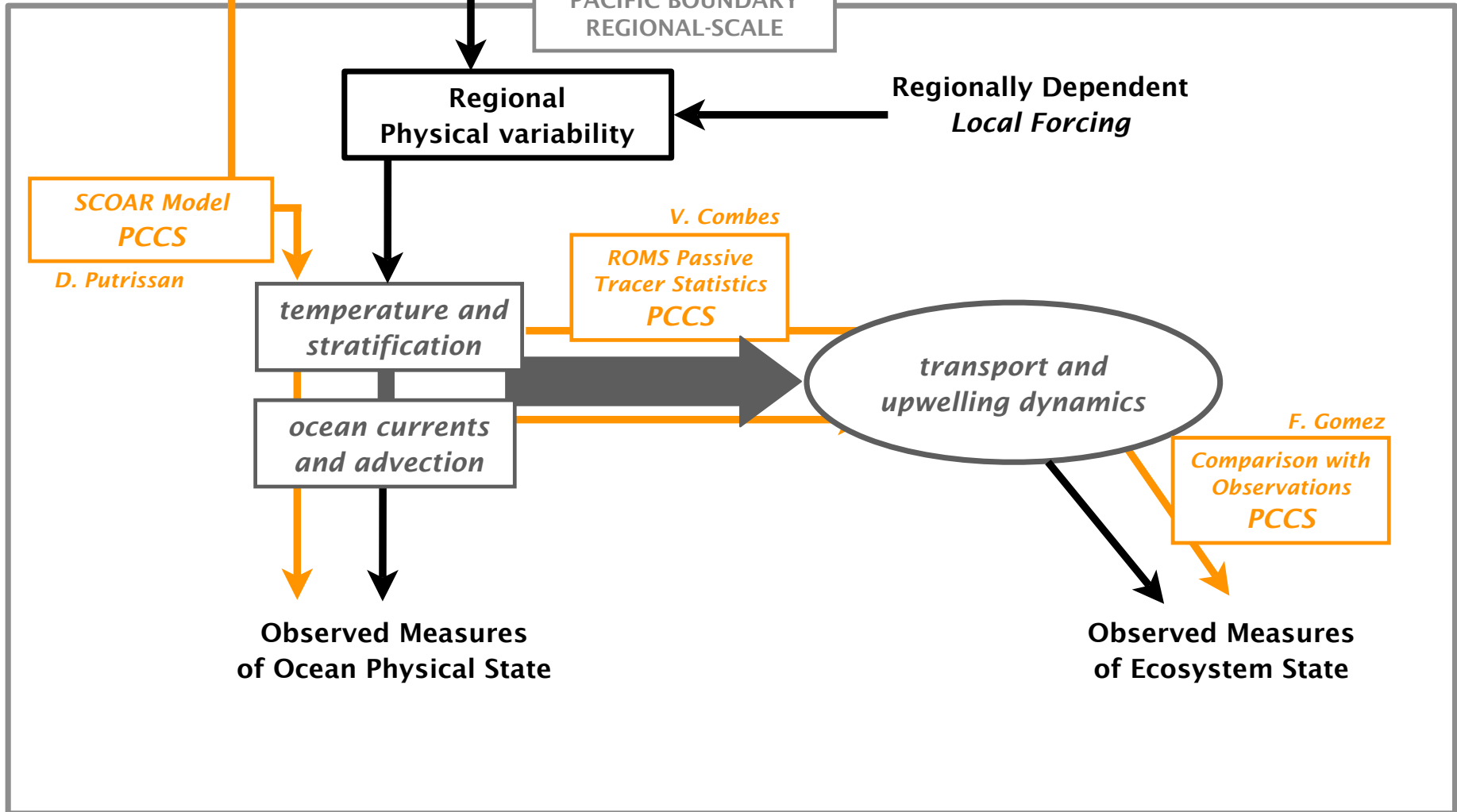
*transport and  
upwelling dynamics*

*F. Gomez*

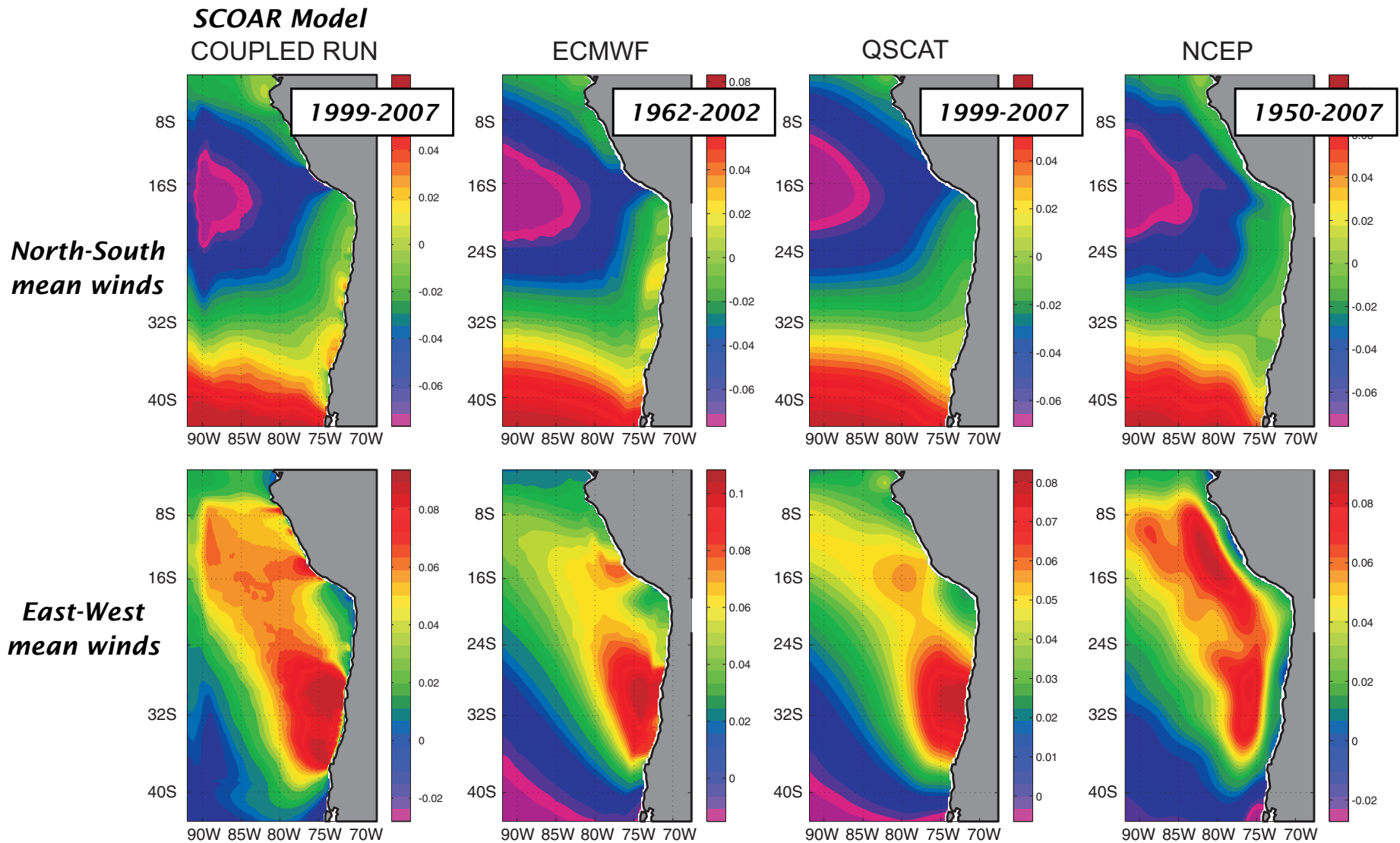
*Comparison with  
Observations  
PCCS*

Observed Measures  
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of Ecosystem State

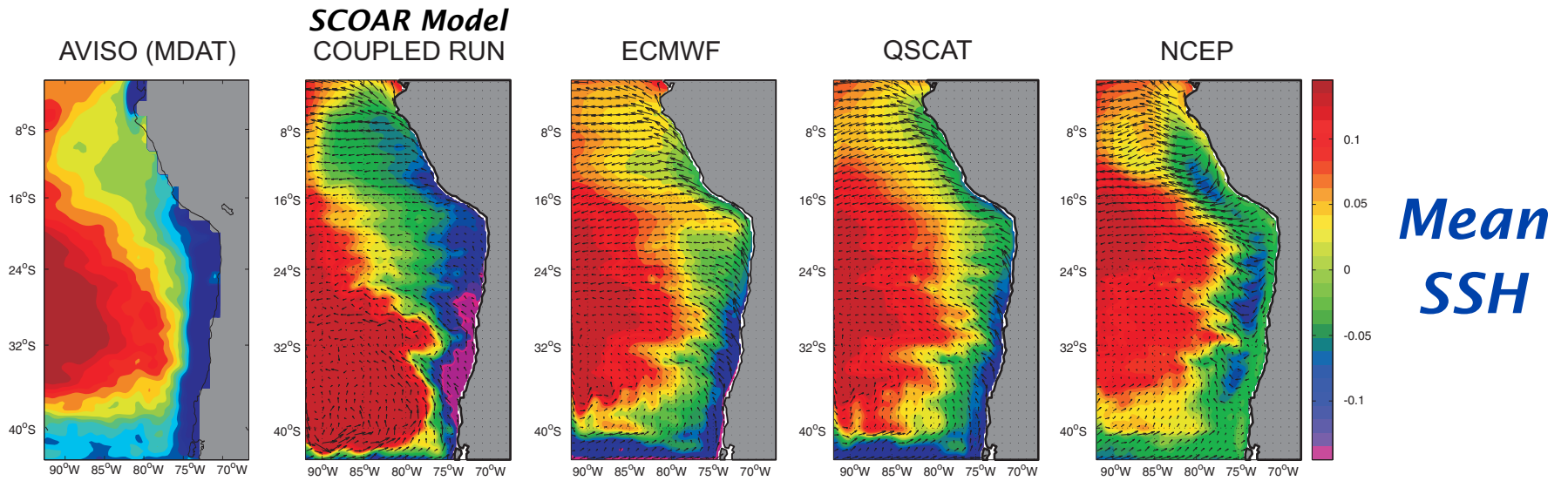


# PCCS Winds

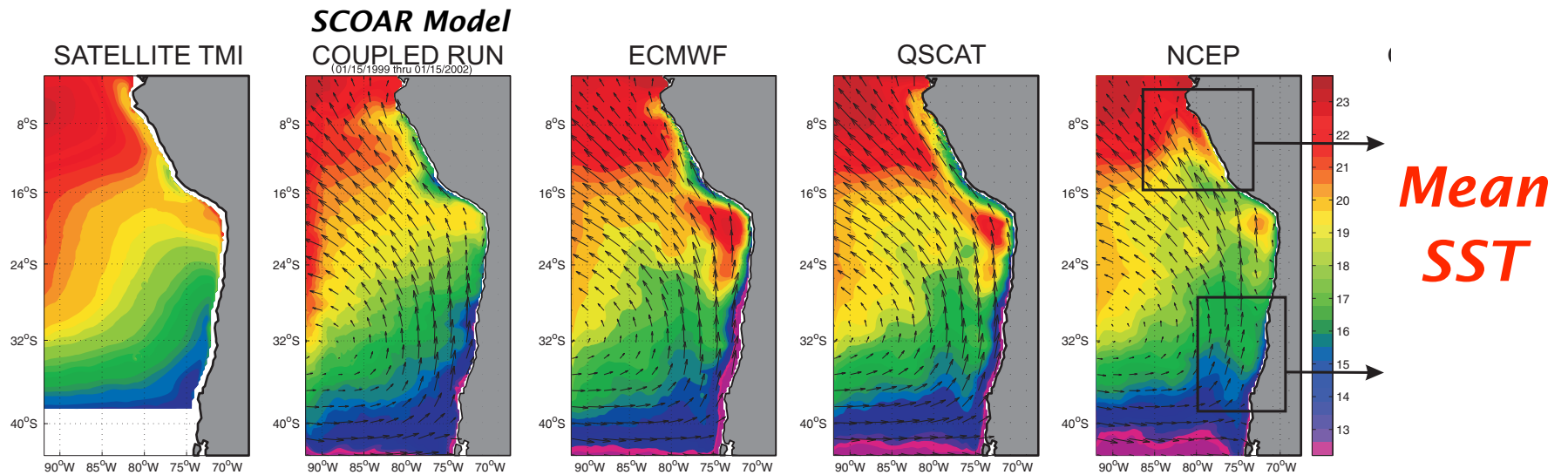


*Combes, Putrissan, Gomez, et al. , Low-frequency variability of the upwelling cells in the PCCS, in prep.*

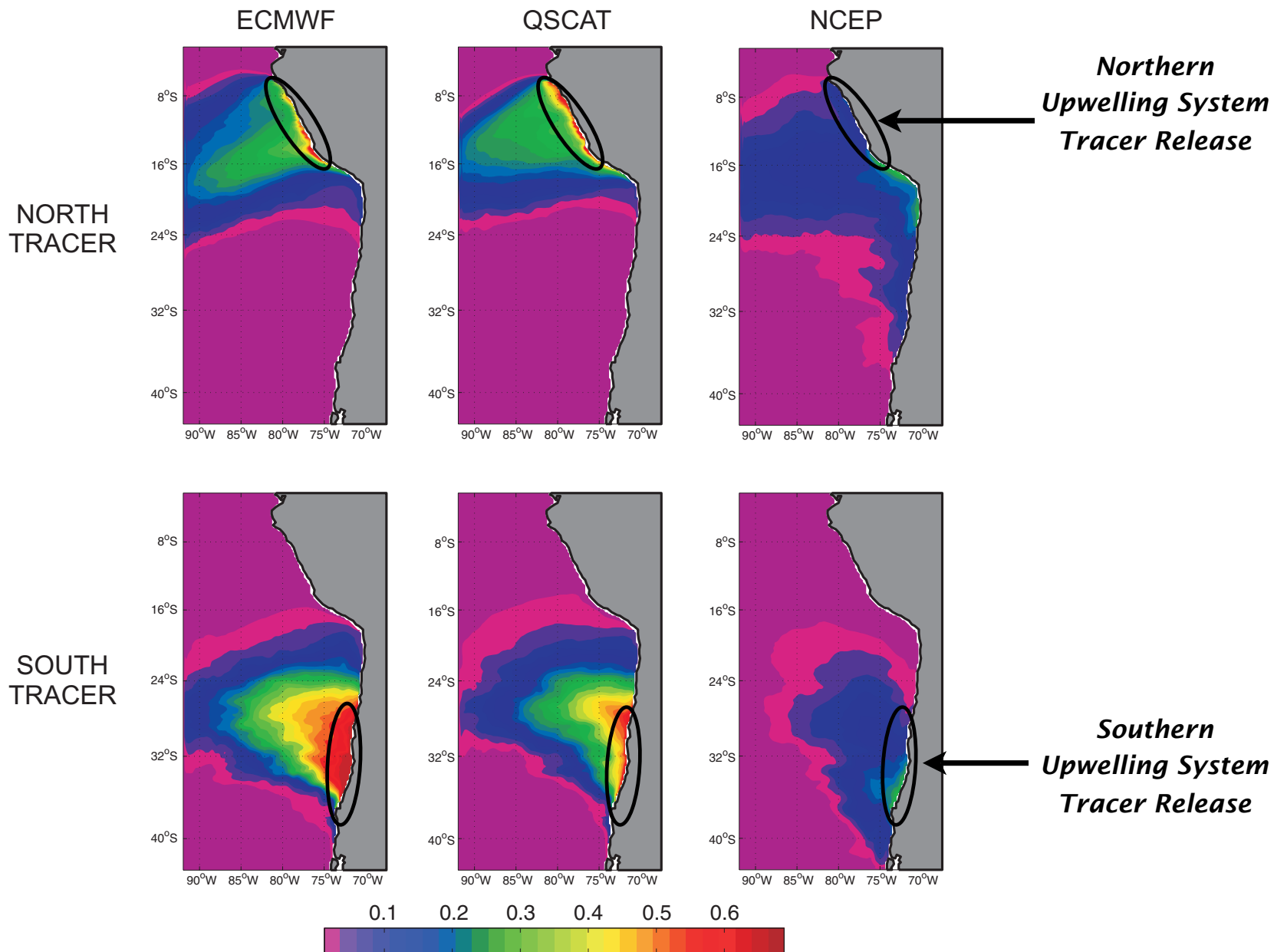
# PCCS Ocean response from ROMS



*Combes, Putrissan, Gomez, et al.*

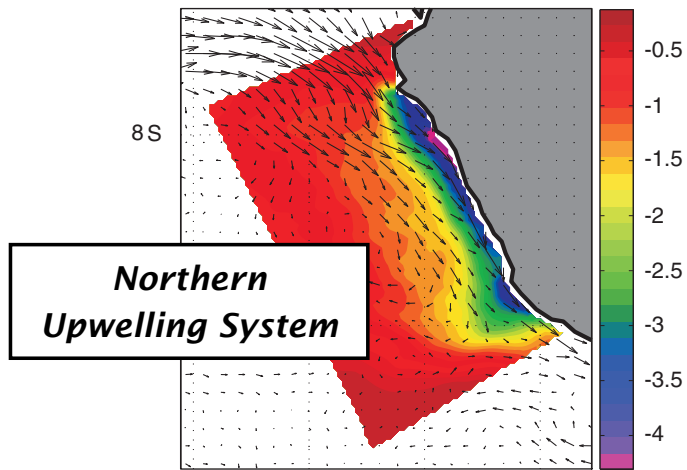


# PCCS *Passive Tracer Simulations (MEAN)*

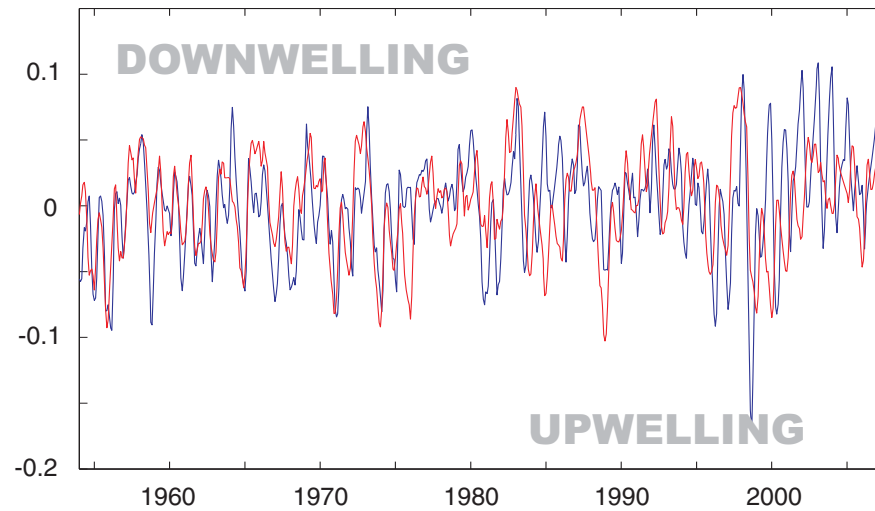


# PCCS Temporal Variability of Upwelling

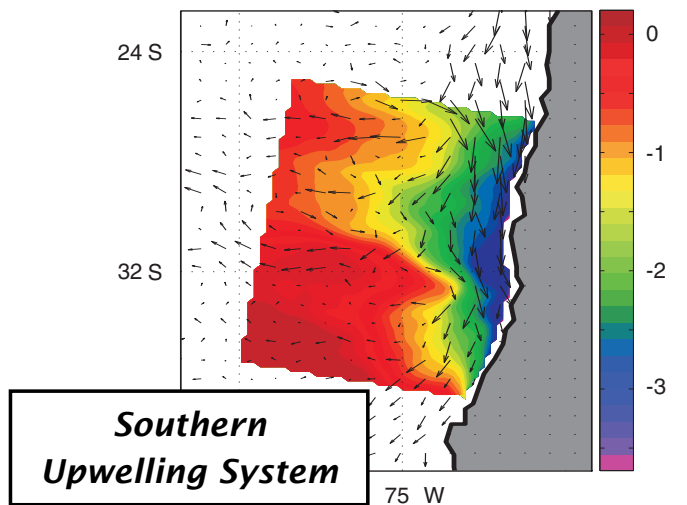
EOF1 of Surface Tracer (51%)



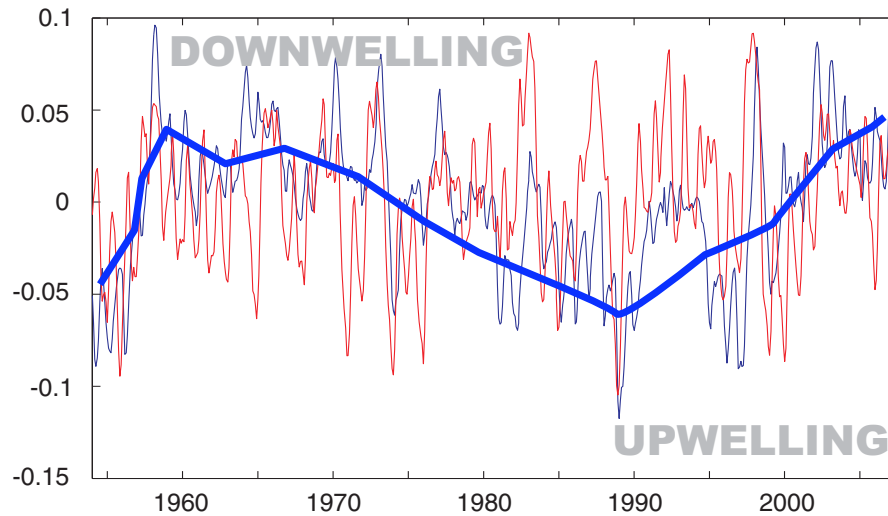
PC1 Nino 34 Index R = 0.40



EOF1 of Surface Tracer (49%)



PC1 Nino 34 Index R = 0.30



PACIFIC BASIN-SCALE

Ocean/Atmosphere Coupled Dynamics  
( ENSO, Aleutian/PDO, NPO/NPGO, AO )

Year 1 TASKS

<http://Pacific-Ecosystems-Climate.Org>



*North Pacific Western Boundary*

PACIFIC BOUNDARY  
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Observed Measures  
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PACIFIC BASIN-SCALE

Year 1 TASKS



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Ocean/Atmosphere Coupled Dynamics  
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North Pacific Western Boundary

PACIFIC BOUNDARY  
REGIONAL-SCALE

OFES and  
Nested ROMS  
KOE

A. Bracco

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ROMS Passive  
Tracer Statistics  
KOE

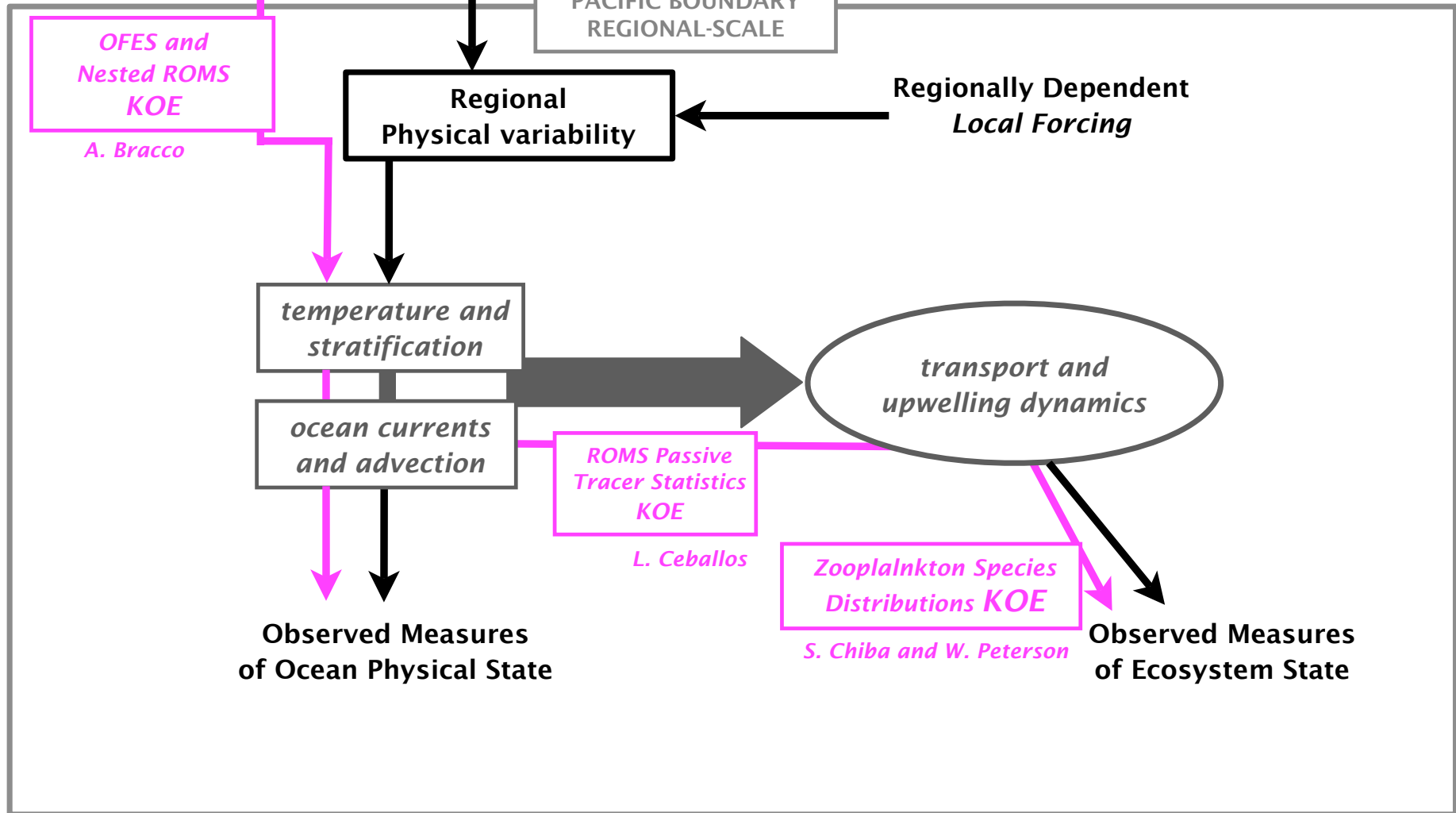
L. Ceballos

Zooplankton Species  
Distributions KOE

S. Chiba and W. Peterson

Observed Measures  
of Ocean Physical State

Observed Measures  
of Ecosystem State



PACIFIC BASIN-SCALE

Ocean/Atmosphere Coupled Dynamics  
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Year 1 TASKS

<http://Pacific-Ecosystems-Climate.Org>



*Cross-Boundary synthesis*

PACIFIC BOUNDARY  
REGIONAL-SCALE

Regional  
Physical variability

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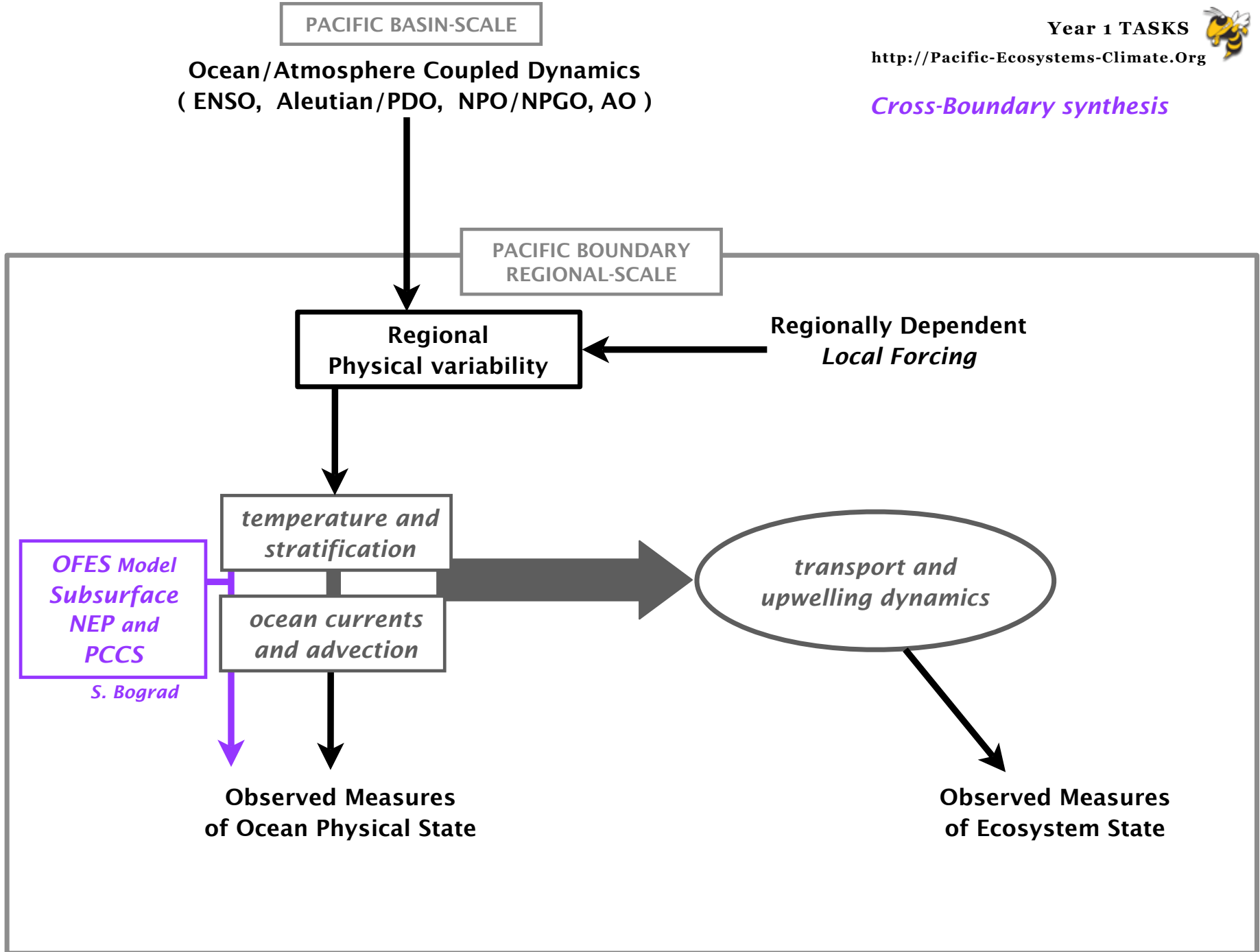
*transport and  
upwelling dynamics*

*OFES Model  
Subsurface  
NEP and  
PCCS*

*S. Bograd*

Observed Measures  
of Ocean Physical State

Observed Measures  
of Ecosystem State



PACIFIC BASIN-SCALE

Year 1 TASKS



<http://Pacific-Ecosystems-Climate.Org>

Ocean/Atmosphere Coupled Dynamics  
( ENSO, Aleutian/PDO, NPO/NPGO, AO )

Basin-scale Chl-a  
Satellite  
A. Thomas

T. Strub  
Basin-scale SSH/SST  
Satellite vs. OFES Model

E. Di Lorenzo

J. Furtado  
IPCC Climate  
Model  
downscaling

PACIFIC BOUNDARY  
REGIONAL-SCALE

Regional  
Physical variability

Regionally Dependent  
Local Forcing

OFES and  
Nested ROMS  
NEP and KOE  
A. Bracco

SCOAR Model  
PCCS  
D. Putrissan

temperature and  
stratification

V. Combes  
ROMS Passive  
Tracer Statistics  
PCCS

transport and  
upwelling dynamics

OFES Model  
Subsurface  
NEP and  
PCCS  
S. Bograd

ocean currents  
and advection

ROMS Passive  
Tracer Statistics  
NEP NC  
N. Mariani

ROMS Passive  
Tracer Statistics  
KOE  
L. Ceballos

ROMS NPZD  
NEP  
P. Franks

Observed Measures  
of Ocean Physical State

Observed Measures  
of Ecosystem State

S. Chiba and W. Peterson  
Zooplankton Species  
Distributions KOE

Peterson & Keister  
Zooplankton Species  
Distributions NEP

## *Work in progress for this proposal*

Thomas A., Brickley and R. Weatherbee 2009: **Interannual variability in chlorophyll concentrations in the Humboldt and California Current Systems**, Progress in Oceanography, in press.

Keister, J.E., N. Mariani, V. Combes, C.A. Morgan, E. Di Lorenzo and W.T. Peterson. **Copepod species composition linked to ocean transport in the Northern California Current**. In prep.

Combes V., Gomez, T. Strub et al.: **Low frequency variability in the upwelling cells in the PCCS.**, TBD

Putrissan D. Combes, T. Strub et al: **Air-sea interaction in the upwelling system of the PCCS.**, TBD

Di Lorenzo E., Fiechter J., Moore A., Pena A., Crawford B., Bograd S. J., and Thomas A.: **Coherent variations of nutrients and salinity in the Gulf of Alaska and California Current**. Geophys. Res. Lett., in prep.

Furtado J. and E. Di Lorenzo: **Past and Future modes of Pacific Decadal Variability**. Journal of Climate, in prep.

Di Lorenzo E., J. Furtado, N. Schneider, N. Bond, M. Alexander, A. Bracco, B. Anderson et al.: **ENSO and the North Pacific Gyre Oscillation: a paradigm for Pacific climate variability**. TBD, in prep.

## *Recent Publications related to this grant*

Menge B.M., F. Chan, K.J. Nielsen, E. Di Lorenzo and J. Lubchenco, 2009: **Climatic variation alters supply-side ecology: impact of climate patterns on phytoplankton and mussel recruitment.** Ecological Monograph, accepted.

Hsieh C., H. J. Kim, W. Watson, E. Di Lorenzo, and G. Sugihara, 2009: **Ocean warming caused changes in abundance and distribution of larvae of oceanic fishes in the southern California region.** Global Change Biology, accepted.

Ceballos L., E. Di Lorenzo, N. Schneider, B. Taguchi, 2009: **North Pacific Gyre Oscillation synchronizes climate fluctuations in the eastern and western North Pacific.** Journal of Climate, accepted.

Chhak, K., E. Di Lorenzo, N. Schneider and P. Cummins, 2009: **Forcing of low-frequency ocean variability in the Northeast Pacific.** Journal of Climate, DOI: 10.1175/2008JCLI2639.1 .

Keister, JE, WT Peterson, and SD Pierce (2008). **Zooplankton distribution and cross-shelf transfer of carbon in an area of complex mesoscale circulation in the northern California Current.** Deep-Sea Research I, 56: 212-231.

Keister, JE, TJ Cowles, WT Peterson, and CA Morgan (2009). **Do upwelling filaments result in predictable biological distributions in coastal upwelling ecosystems?** Progress in Oceanography, In press.

## Project Website

<http://Pacific-Ecosystems-Climate.Org>

Pacific Ocean Boundary Ecosystems  
<http://Pacific-Ecosystems-Climate.Org>

Home | Research TASKS | Docs | Data Access | Images & Videos | Publications

NSF-GLOBEC Pan-regional Synthesis:  
Pacific Ocean Boundary Ecosystems:  
response to natural and anthropogenic climate forcing

PIs: E. Di Lorenzo, J. C. Furtado, A. Bracco, J. Keister, P.T. Strub, A. Thomas, P.J.S. Franks  
NOAA Co-PIs: S. Bograd, W. Peterson, R. Mendelsohn, F. Schwing  
Japanese Collaborators: S. Chiba, Y. Sasai, H. Sasaki, M. Nonaka, B. Taguchi, A. Ishida  
South American Collaborators: O. Pizarro, R. Escribano, J. Rutllant, S. Hormazabal, V. Montecino  
Canadian Collaborators: D. Mackas, M. Foreman, A. Pena, W. Crawford

**Project Goal** - [ POBE-Project-Summary.pdf ]  
Using US and international observational datasets combined with physical and biological models, this project investigates the mechanisms of climate-related variability in three Pacific boundary ecosystems: Gulf of Alaska (GOA) and California Current System (CCS) referred to as the Northeast Pacific (NEP), the Humboldt or Peru-Chile Current System (PCCS), and the Kuroshio-Oyashio Extension (KOE) region.

**1** Large-scale climate mode in the PHYSICS  
NPGO pattern in Global SSTa

**2** ECOSYSTEM footprint along Pacific Boundaries  
NPGO pattern in SeaWiFS CHL-a