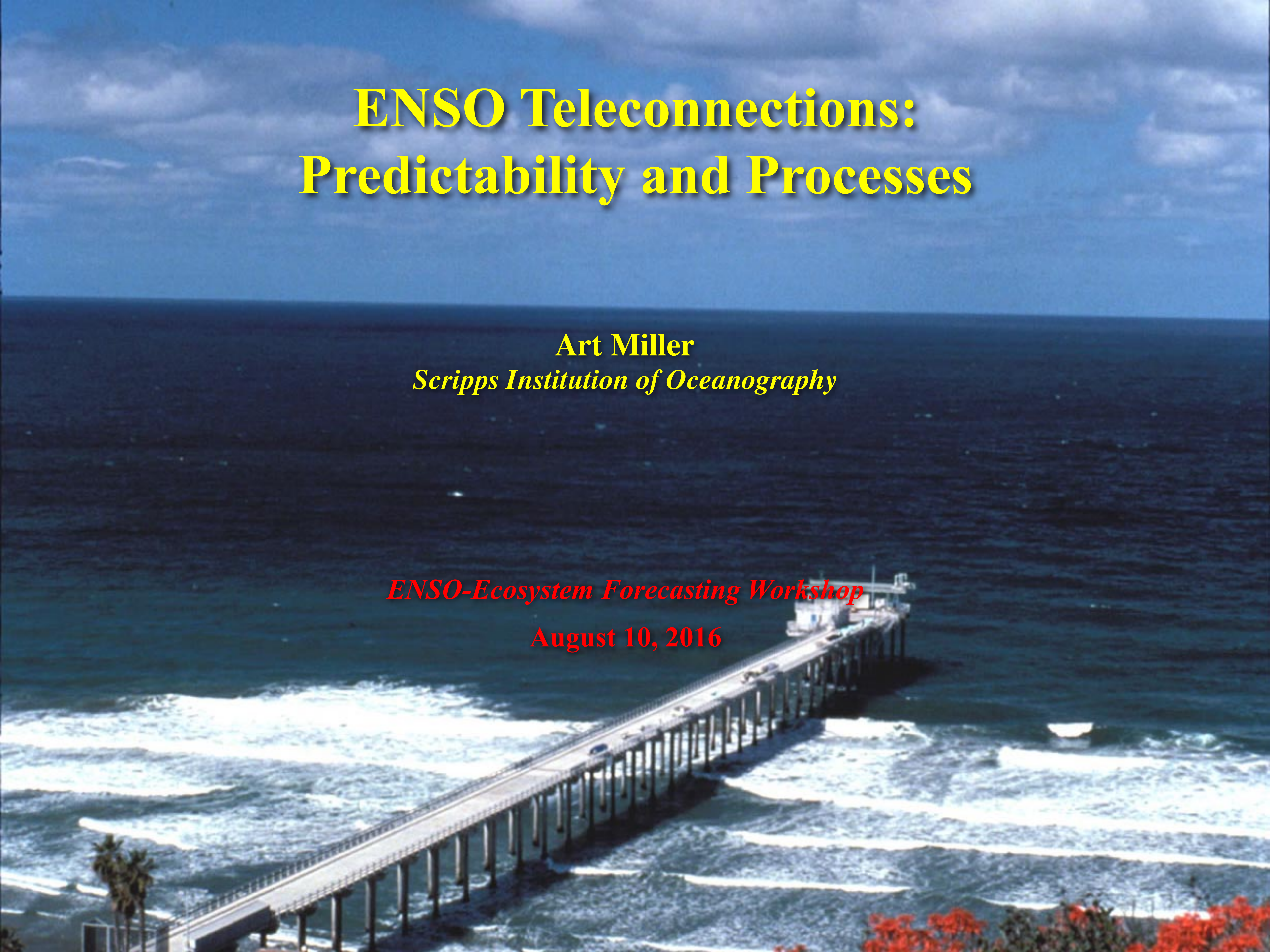
ENSO Teleconnections: Predictability and Processes

Art Miller
Scripps Institution of Oceanography

ENSO-Ecosystem Forecasting Workshop

August 10, 2016



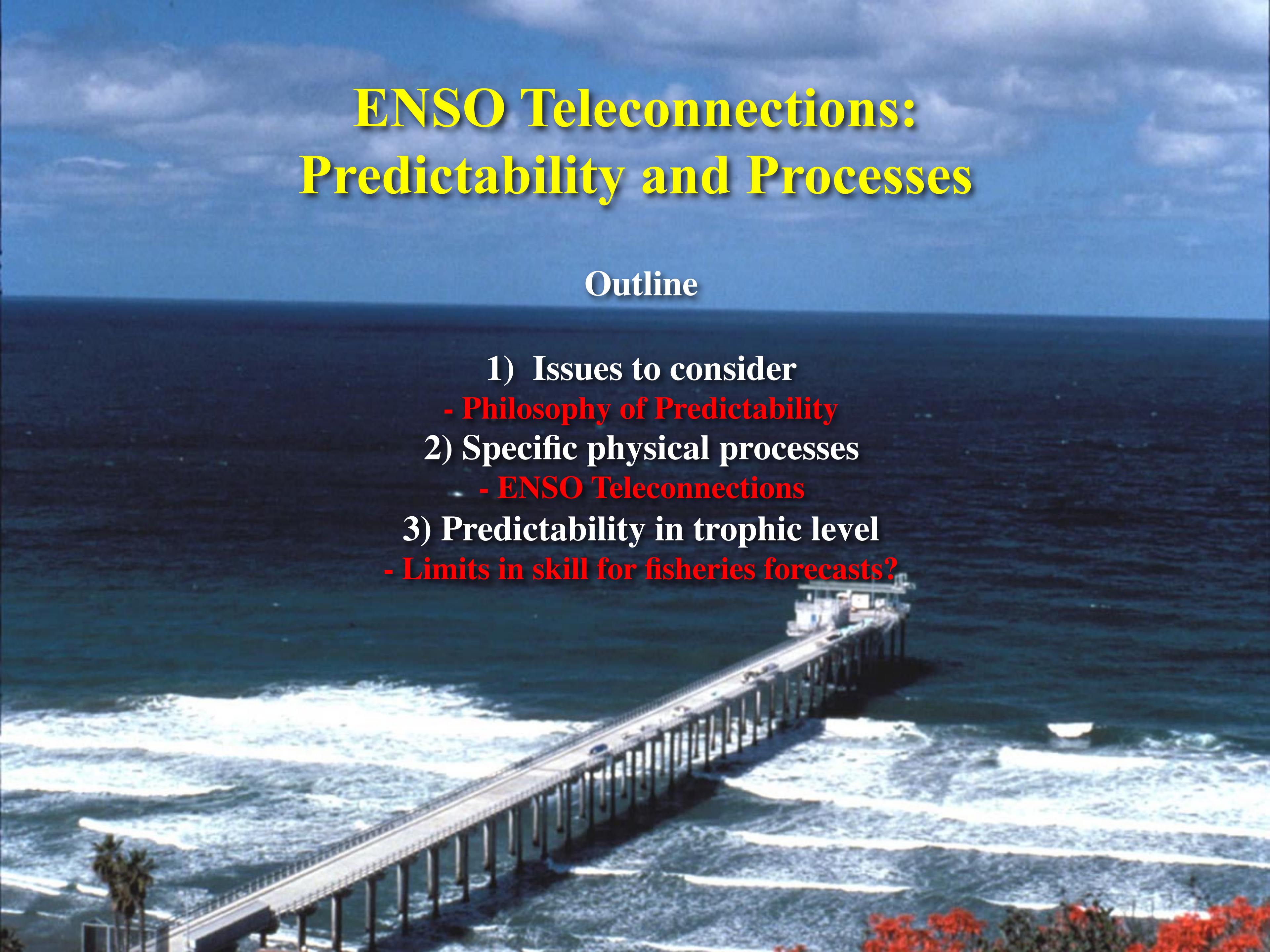
ENSO Teleconnections: Predictability and Processes

Outline

1) Issues to consider
- Philosophy of Predictability

2) Specific physical processes
- ENSO Teleconnections

3) Predictability in trophic level
- Limits in skill for fisheries forecasts?



ENSO Teleconnections: Predictability and Processes

Outline

1) Issues to consider
- Philosophy of Predictability

Theoretical Basis for Prediction

- Distinguish between physically forced response of ecosystem and intrinsic variability of biology (nonlinear, dynamical systems theory)
- Persistence forecast is baseline to beat
- ENSO focus is on dynamical (and statistical) predictions of the physical forcing
- Dynamical understanding of the source of skill is desired for plausibility – not just running complicated models or building large DOF statistical models

Theoretical Basis for Prediction

- Note that there are interesting and important biological effects:

  e.g. Biological “memory” through life histories: following Year Classes (No Physics!)

  Also: Non-linear methods (Sugihara, Ye, Deyle, etc.) using phase space information from observations

  Also: Index prediction methods like Bill Peterson’s Salmon Forecasts of Adult Returns based on several biological and physical variables

  N.b. Typical stock assessments (for management) do NOT include any environmental information

ENSO Teleconnections: Predictability and Processes

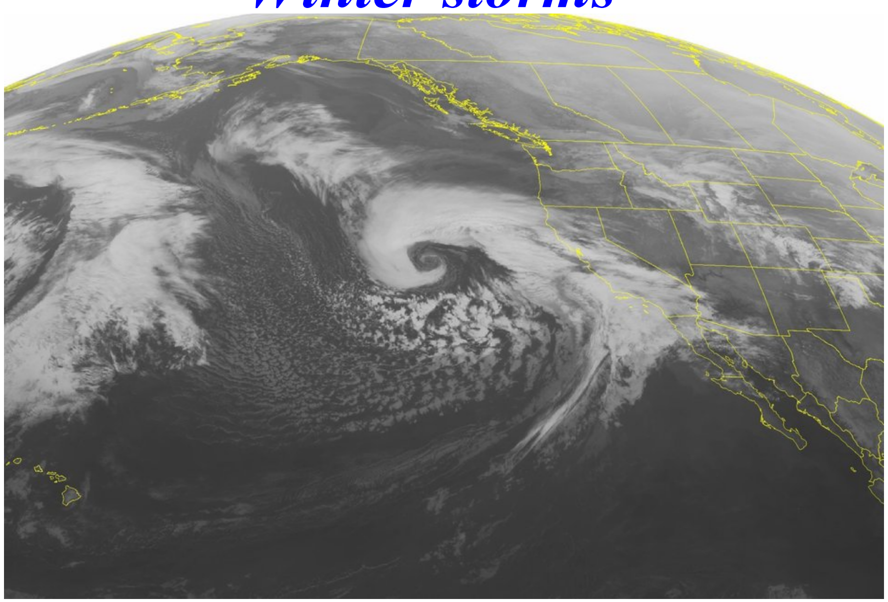
Outline

2) Specific physical processes
- ENSO Teleconnections

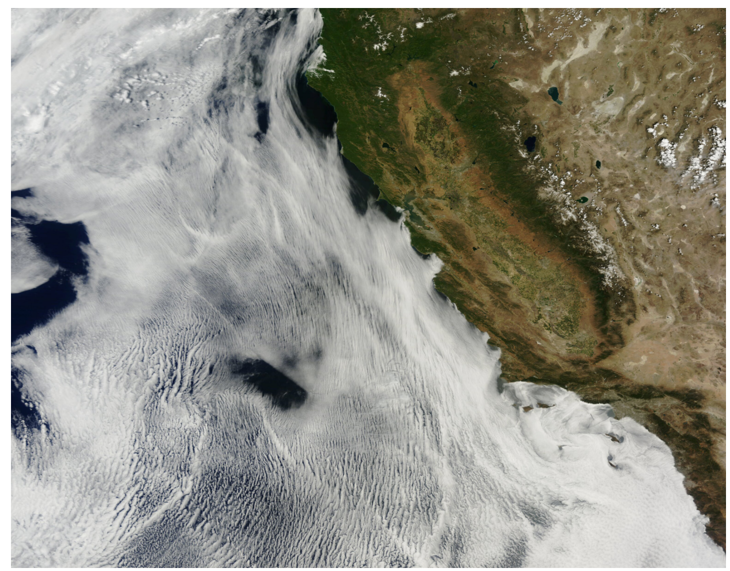
Weather and Climate Affecting the CCS

- Weather: Short time scale (days): Affects things directly - storms, rain, winds, heat waves, extreme events, balmy days

Winter storms



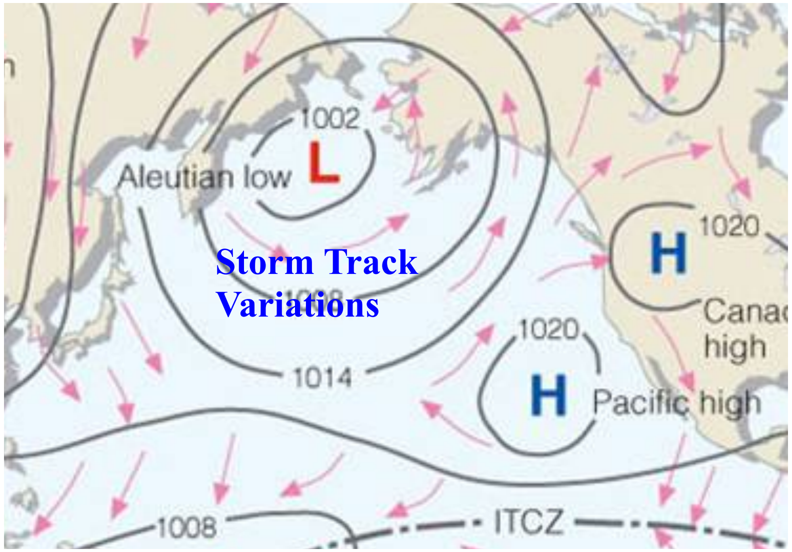
Summer stratocumulus



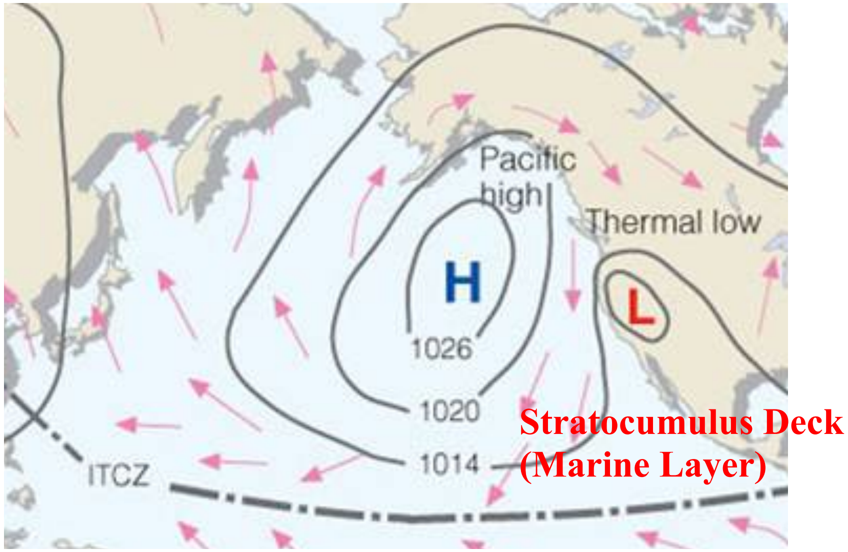
Weather and Climate Affecting the CCS

- Climate: Long time scale (averages over months, seasons, years, trends) accumulation of weather events that we assume to be meaningful

Aleutian Low: Winter



North Pacific High: Summer



ENSO variability around the averages: What controls the oceanic response?

Focus on Winter: Strong Forcing => Strong response

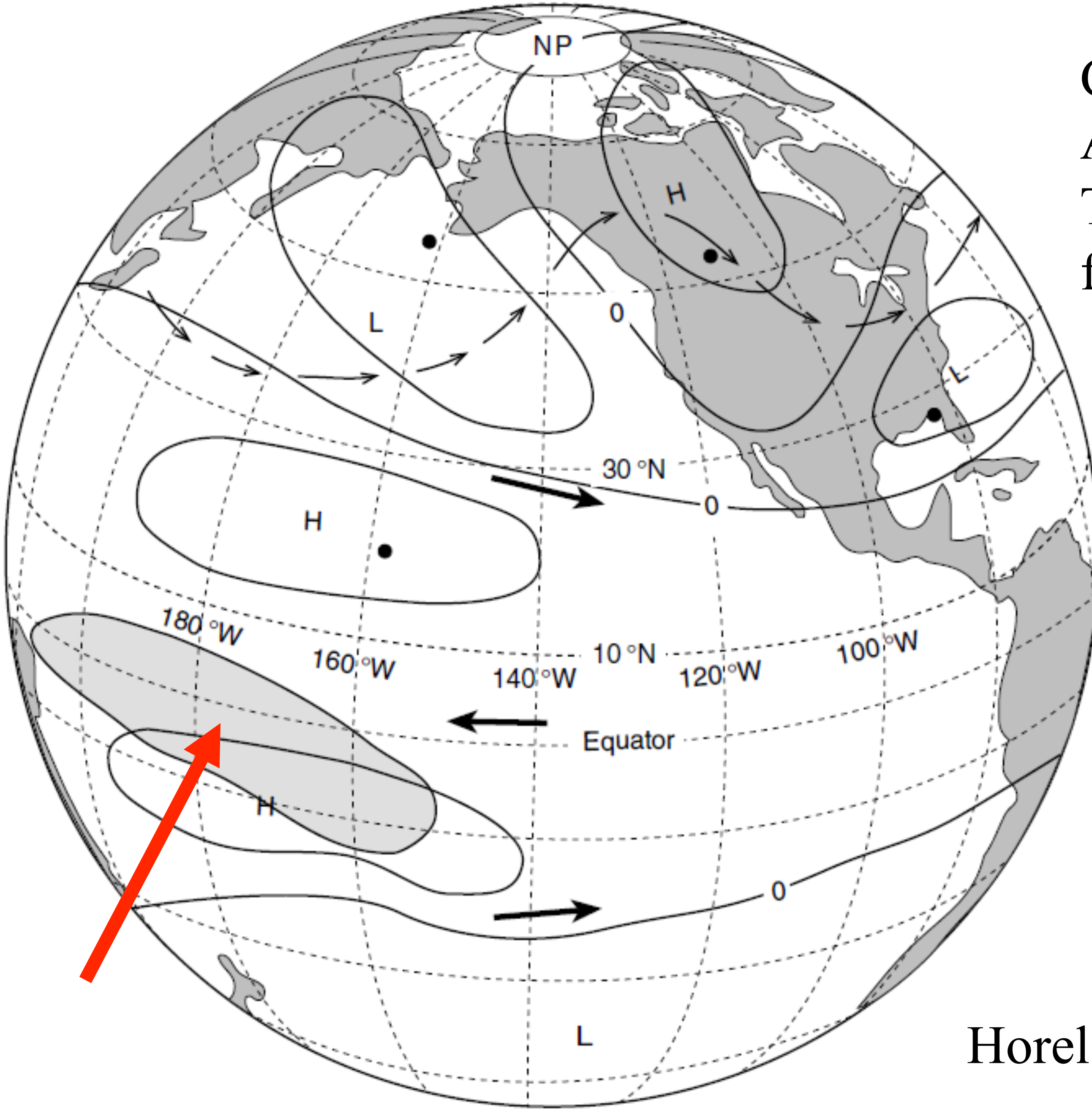
Large-scale climate pattern variations organize the oceanic physical processes that affect ocean biology

-***Defining an ENSO Index*** and relating to biological variables is frequently done, but…

-***Physical processes*** in the ocean can ***vary*** in space and can therefore affect the biology in different ways

-***Understanding*** these processes is therefore critical to unraveling mechanisms of biological variations

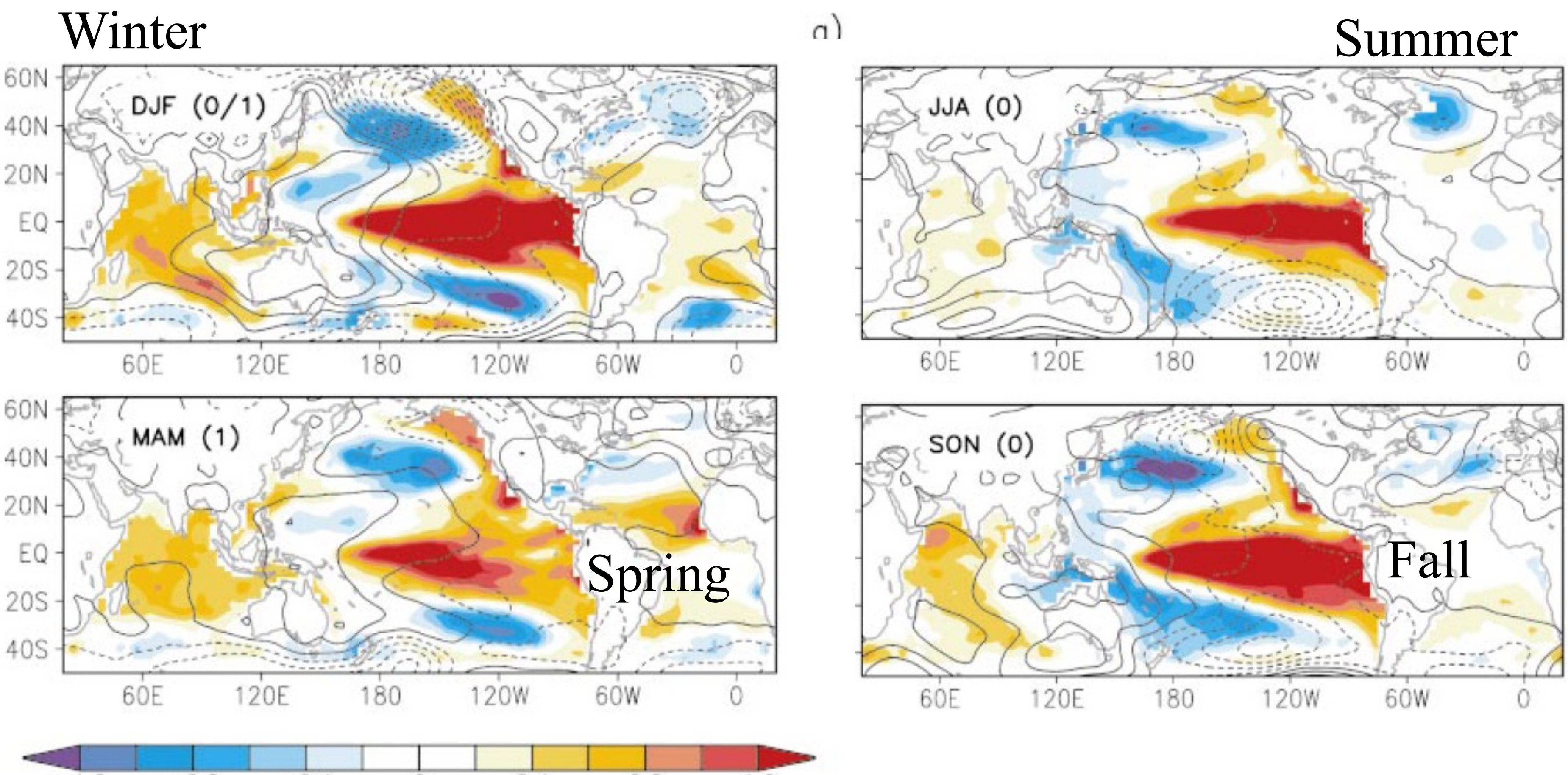
-Plus, lagged effects of ENSO forcing in the ocean may have additional ***predictable components***



Classic Winter Atmospheric Teleconnections from El Nino…

Horel and Wallace, 1981

Seasonal Dependence of Sea Level Pressure Teleconnections (composite EN-LN, but actually non-linear)



Alexander et al., 2002

Local Oceanic Response to the Atmospheric Anomalies: Dynamics and Thermodynamics of Upper Ocean Variability

Dynamics of Currents: (**Adiabatic** Forcing)

- Wind Stress (**Ekman transport**: Coastal upwelling)
- Wind Stress Curl (**Ekman pumping**: Open-Ocean upwelling)

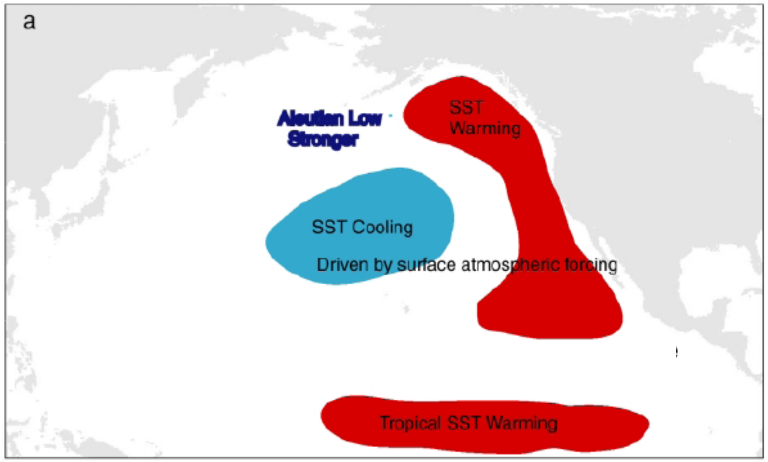
Thermodynamics of Ocean Temperature: (**Diabatic** Forcing)

- Surface Heat Flux (***Latent***, Sensible, solar, radiative)
- Advection (due to currents: ***Ekman***, pressure-gradient, upwelled)
- Vertical turbulent mixing

When the winds change, all these effects act together, but in different relative strength in different places….

ENSO variability around the Averages: What controls the oceanic response?

Focus on Winter: Strong Forcing => Strong response
Focus on Interannual to Interdecadal time scales

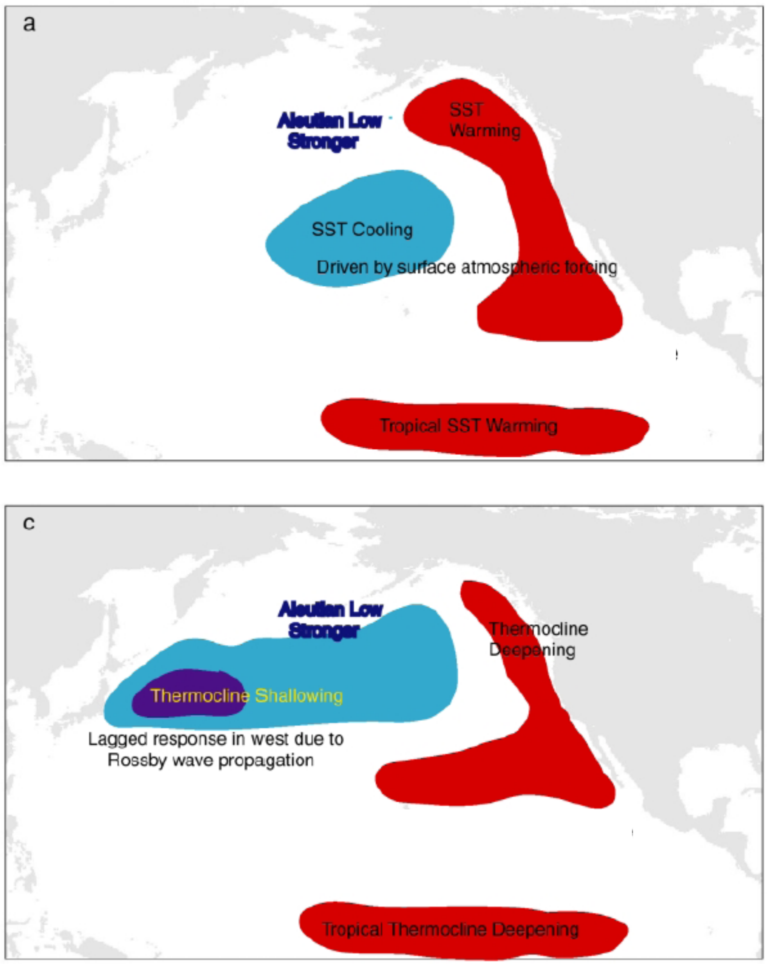


Aleutian Low anomalies force surface heat fluxes, Ekman current advection, and turbulent mixing (**diabatic** effects) to drive ***East-West pattern of SST***

Miller et al. (2004)

ENSO variability around the Averages: What controls the oceanic response?

Focus on Winter: Strong Forcing => Strong response
Focus on Interannual to Interdecadal time scales



Miller et al. (2004)

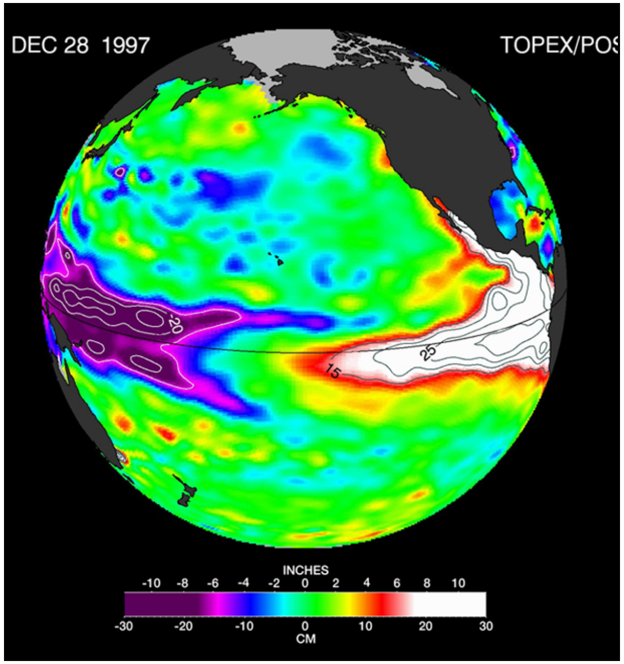
Aleutian Low anomalies force surface heat fluxes, Ekman current advection, and turbulent mixing (**diabatic** effects) to drive ***East-West pattern of SST***

Additionally, **Aleutian Low** wind stress curl anomalies force (**adiabatically**) **thermocline** anoms (Ekman pumping) that change the **circulation** of the CCS and sea level

Oceanic ENSO Teleconnections

Coastally trapped Kelvin-like waves have potential
to travel from Equator to the California Coast
to alter the thermocline depth and currents

- Difficult to traverse Gulf of California
- Deformation radius ~25km
- More transient
- Radiation into Rossby waves loses energy

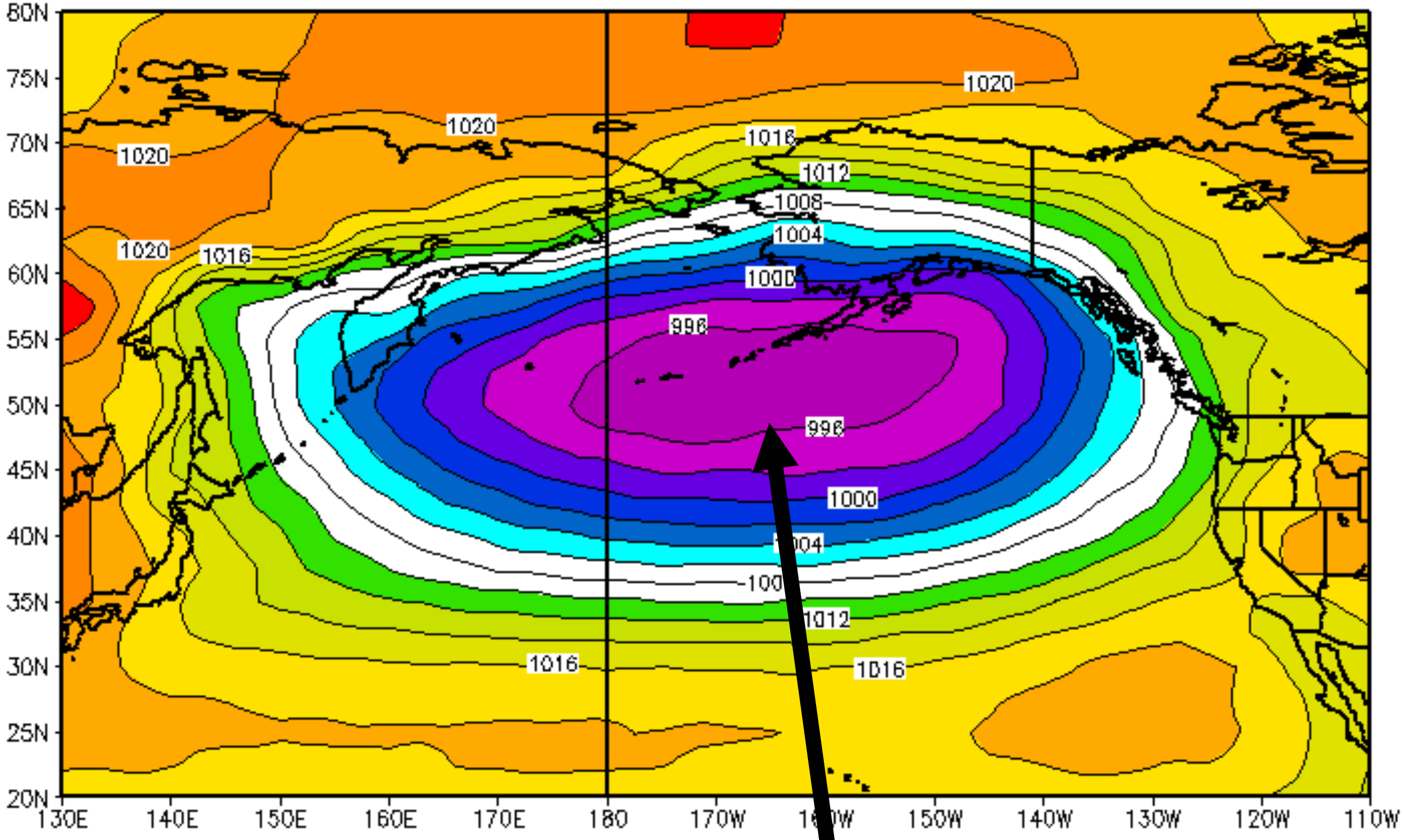


Atmospheric Teleconnections

- More persistent
- Drive thermocline anomalies of same sign
- Broader scale ~1000km

ENSO variability around the averages: What controls the Aleutian Low?

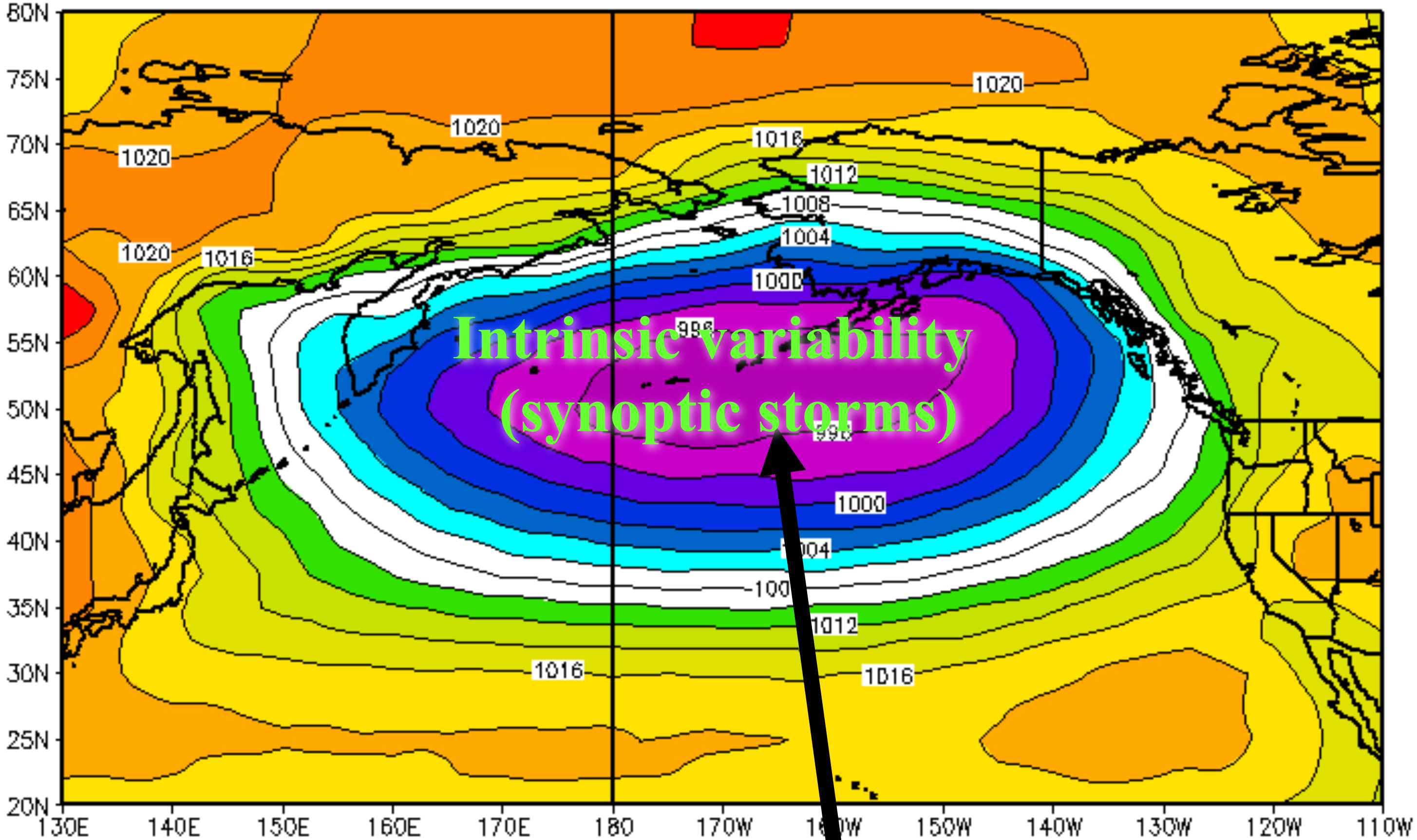
Focus on Winter: Strong Forcing => Strong response



Tropical teleconnections (El Nino/La Nina)

ENSO variability around the averages: What controls the Aleutian Low?

Focus on Winter: Strong Forcing => Strong response



Tropical teleconnections (El Nino/La Nina)

Uncertainties in ENSO Teleconnection Forecasts (**Nick Siler**, 2016, in preparation)

AGCM forced with observed SSTa for 1997-98 and 2015-16

Rainfall in SoCal (rough indicator for oceanic forcing function)

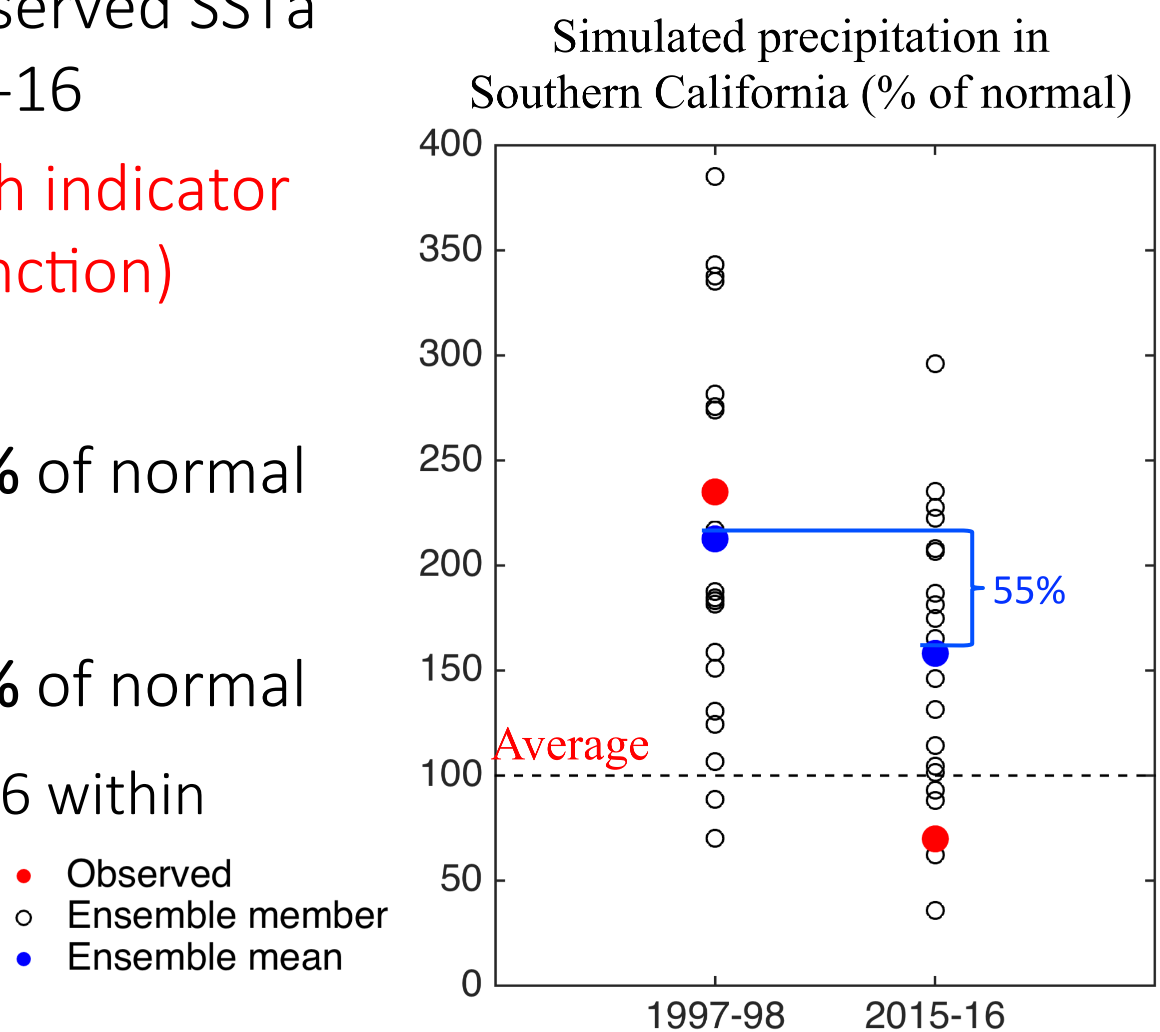
1997-98:

Ensemble mean: **213%** of normal

2015-16:

Ensemble mean: **158%** of normal

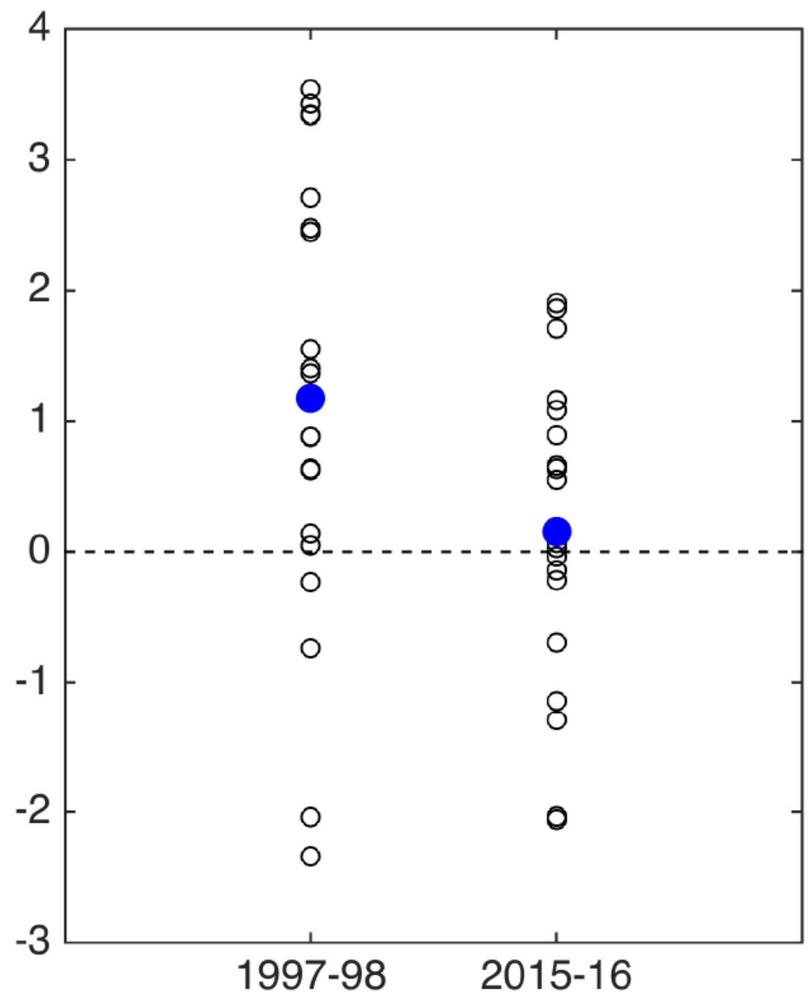
Observations: 2015-16 within simulated range



Uncertainties in ENSO Teleconnection Forecasts (**Nick Siler**, 2016, by request)

AGCM forced with observed SSTa for 1997-98 and 2015-16

Zonal Wind Anoms (925mb) in a box (35-40N, 125-128W) over the California Current

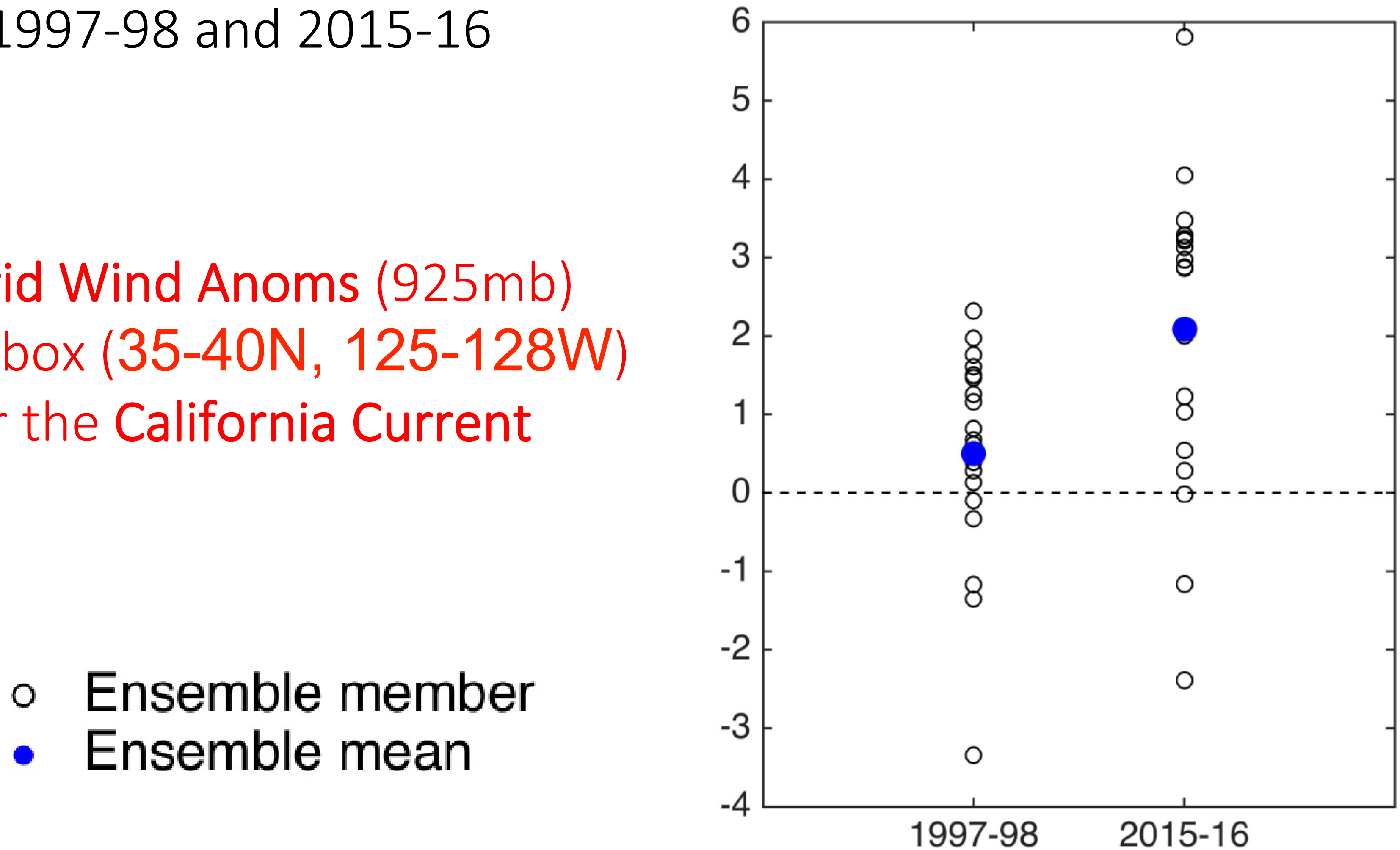


○ Ensemble member
● Ensemble mean

Uncertainties in ENSO Teleconnection Forecasts (**Nick Siler**, 2016, by request)

AGCM forced with observed SSTa for 1997-98 and 2015-16

Merid Wind Anoms (925mb) in a box (35-40N, 125-128W) over the California Current

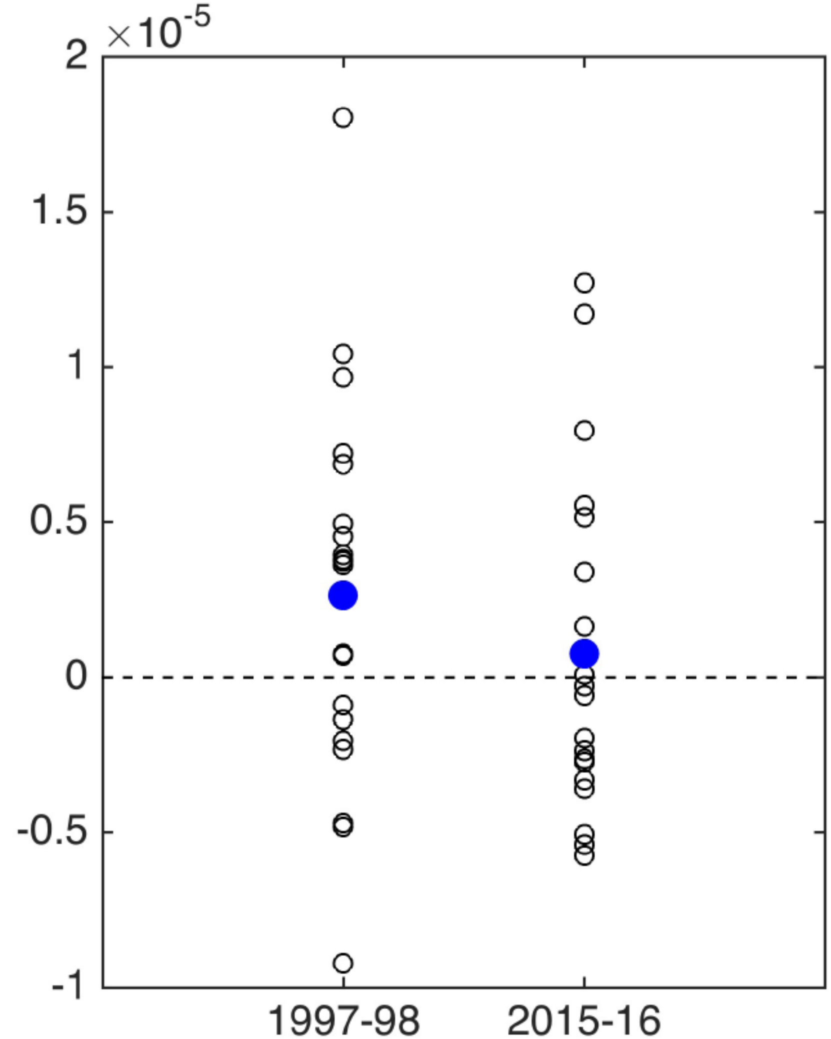


Uncertainties in ENSO Teleconnection Forecasts (**Nick Siler**, 2016, by request)

AGCM forced with observed SSTa for 1997-98 and 2015-16

Vorticity Anoms (925mb)
in a box (35-40N, 125-128W)
over the California Current

○ Ensemble member
● Ensemble mean



ENSO Teleconnections: Predictability and Processes

Outline

3) Predictability in trophic level

- Limits in skill for fisheries forecasts?

Ecosystem Response

- Bottom-up versus Top-Down (or “Side-In”)

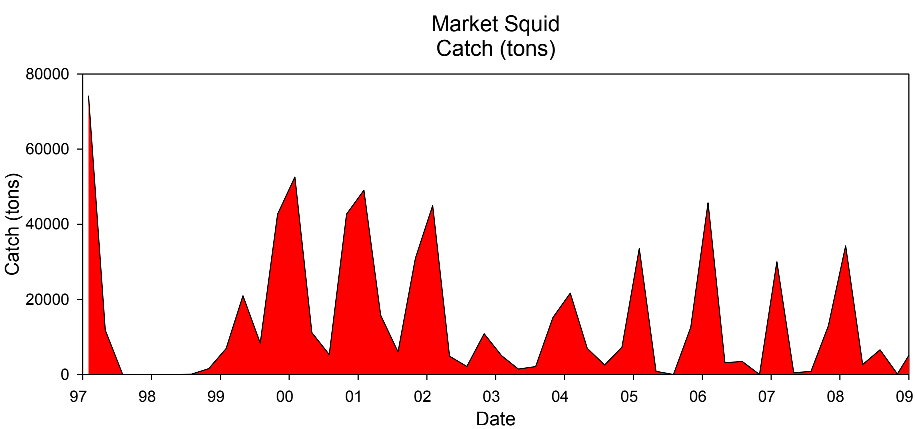
  - Productivity versus Habitat Suitability (spawning especially) and Physiology

  - Hostile environmental changes – acidification, hypoxia, etc.

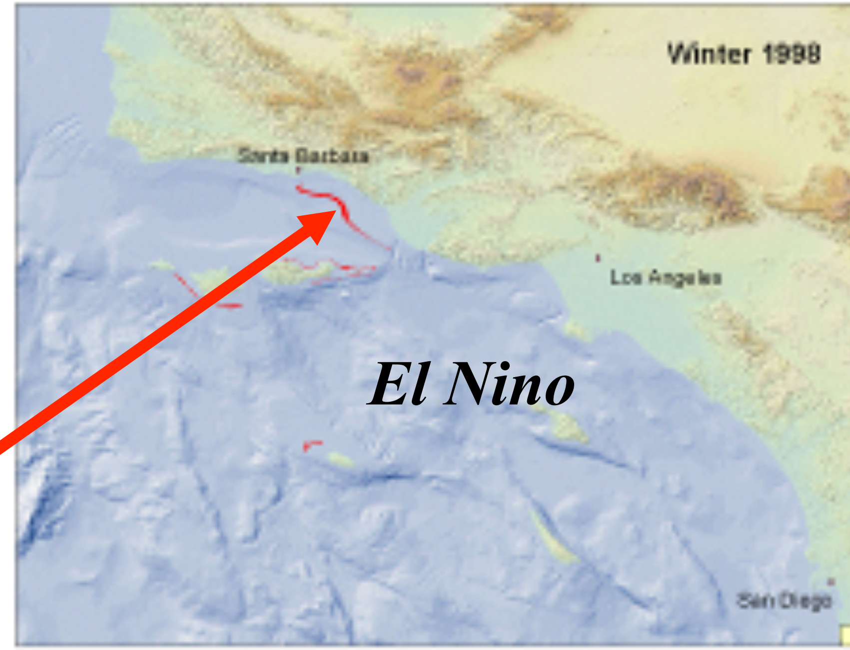
Thermocline Influences on Squid Spawning Habitat

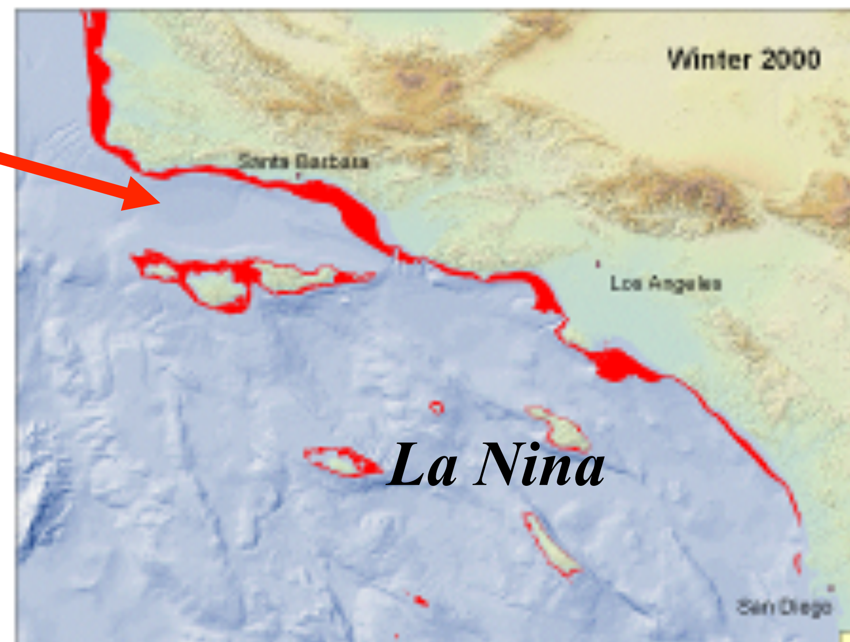
Spawning Squid need sandy bottom, depths of 20-70m and temperatures between 10-14^{o}C.

- Winter 1998, only ~4% of potential habitat was cool enough.
- Winter 2000, nearly all of 20-70m depths and sandy substrates were between 10-14^{o}C.



Zeidberg et al., 2011





Predictability in Trophic Level

- We all love to consider predictability in time (and sometime space)
- Few have considered predictability of ecosystem response to physical forcing as the forced signal cascades upwards

Predictability in Trophic Level

- An ecosystem model response can consist of two parts: Intrinsic biological variations and a physically forced part due to the ocean environment
- Quantifying the physically forced part is vital, since it is unlikely that the intrinsic biological part will have useful skill

Predictability in Trophic Level

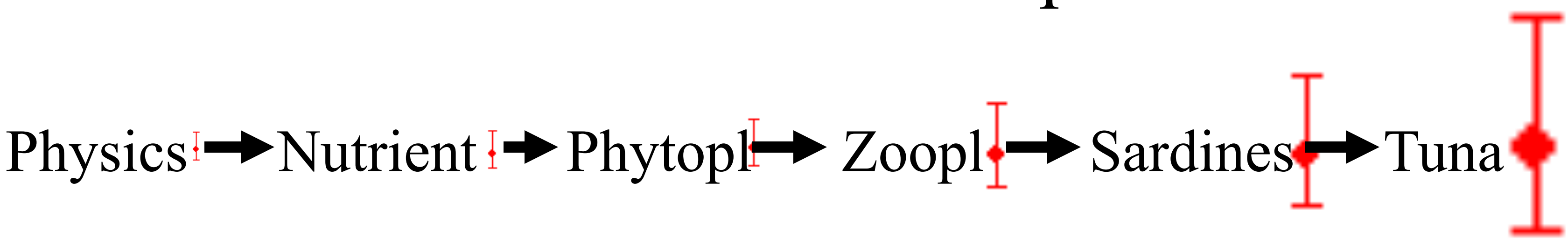
- But how much skill is even possible in the physically forced part?
- Imagine a complicated physical-biological model:

Physics → Nutrient → Phytopl → Zoopl → Sardines → Tuna

Each "level" has its own degree of non-linearity
Consider a "balanced" state of ecosystem for fixed physical forcing
Introduce "small-scale" error(s) in the physical state
Determine the new "balanced" state of the ecosystem
Quantify error growth for each trophic level

Predictability in Trophic Level

- Is there any skill at all in the determination of "managed species" for a given physical state? Or do non-linearities prevent this?



ENSO Teleconnections: Predictability and Processes

Outline

1) Issues to consider
- Philosophy of Predictability
2) Specific physical processes
- ENSO Teleconnections
3) Predictability in trophic level
- Limits in skill for fisheries forecasts?


Art Miller
Scripps Institution of Oceanography
ENSO-Ecosystem Forecasting Workshop
August 10, 2016
Thanks!