

# Assimilating Satellite Data into Regional Ocean Models to Support Fisheries Management off the US West Coast

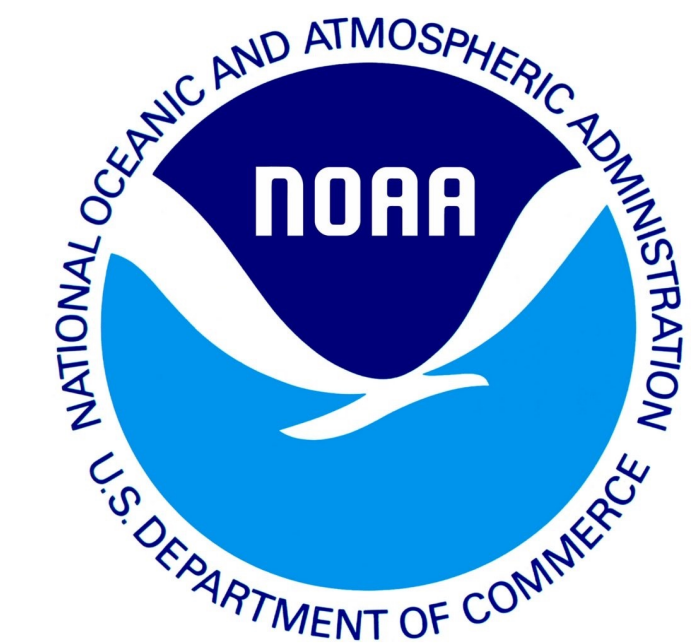
Mike Jacox

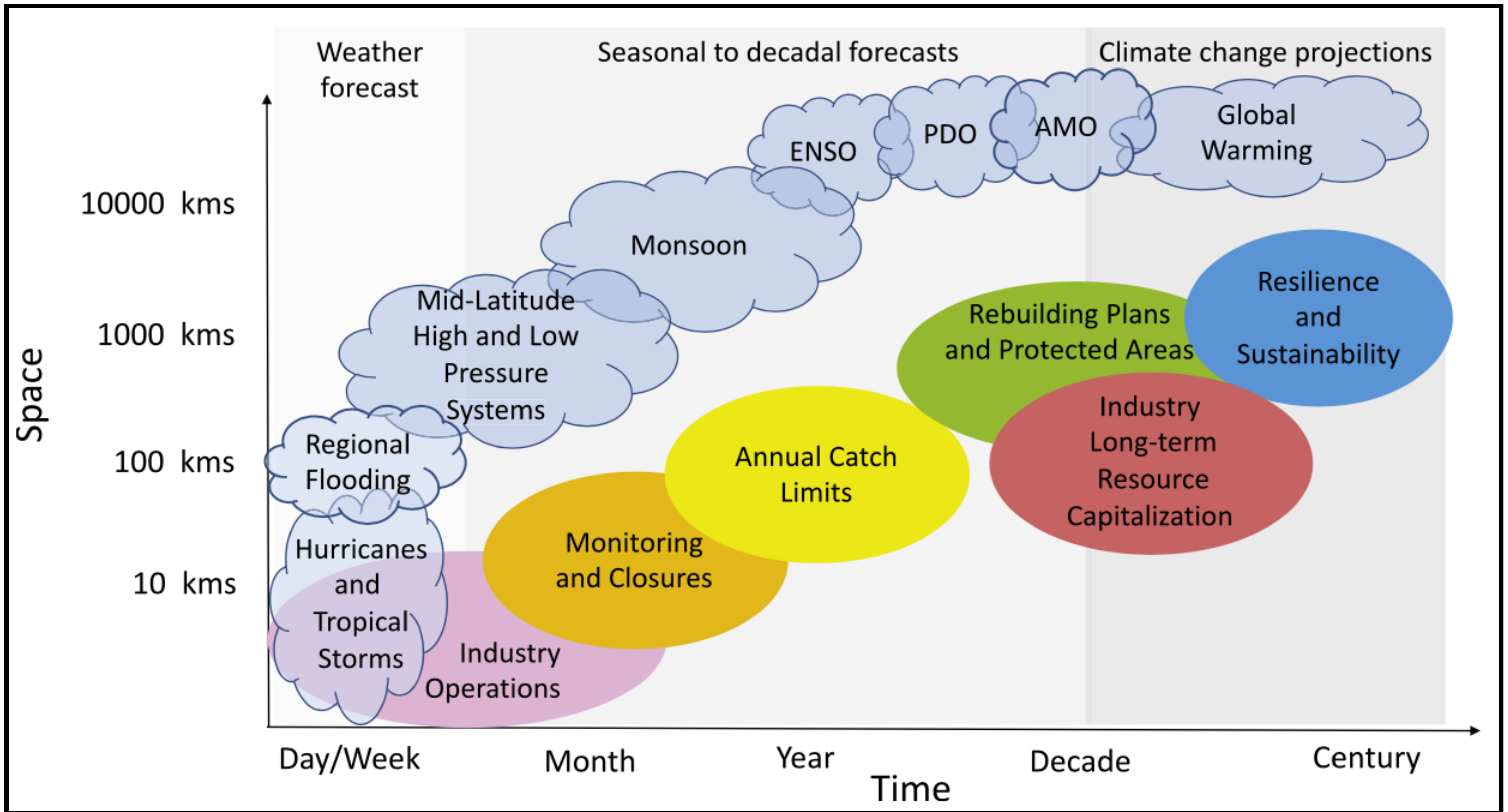
NOAA Southwest Fisheries Science Center  
NOAA Earth System Research Laboratory

Chris Edwards, Andy Moore (UC Santa Cruz)

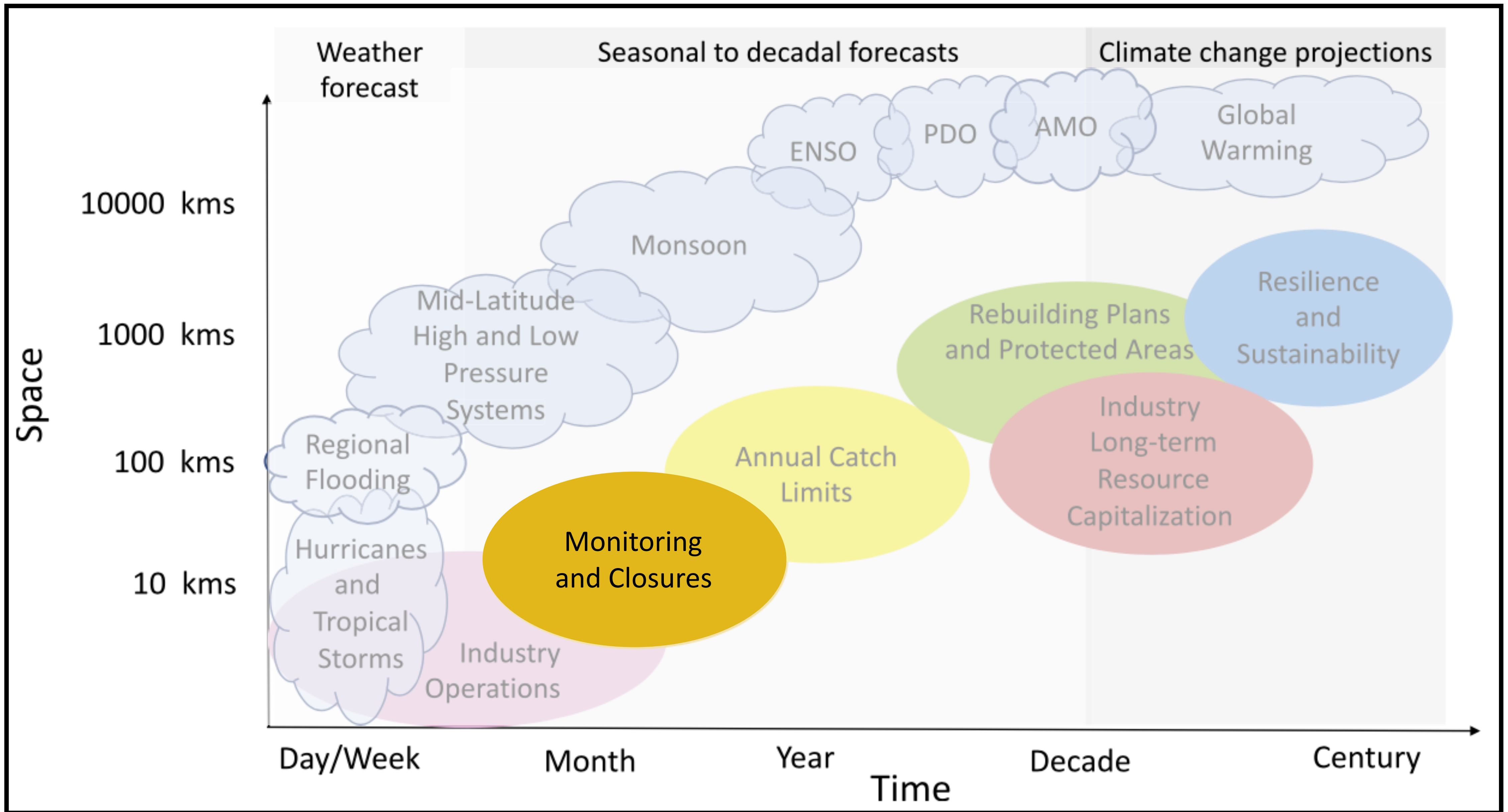
Steven Bograd, Elliott Hazen, Dale Robinson, Cara Wilson (NOAA/NMFS)

NOCCG Seminar  
December 4, 2019

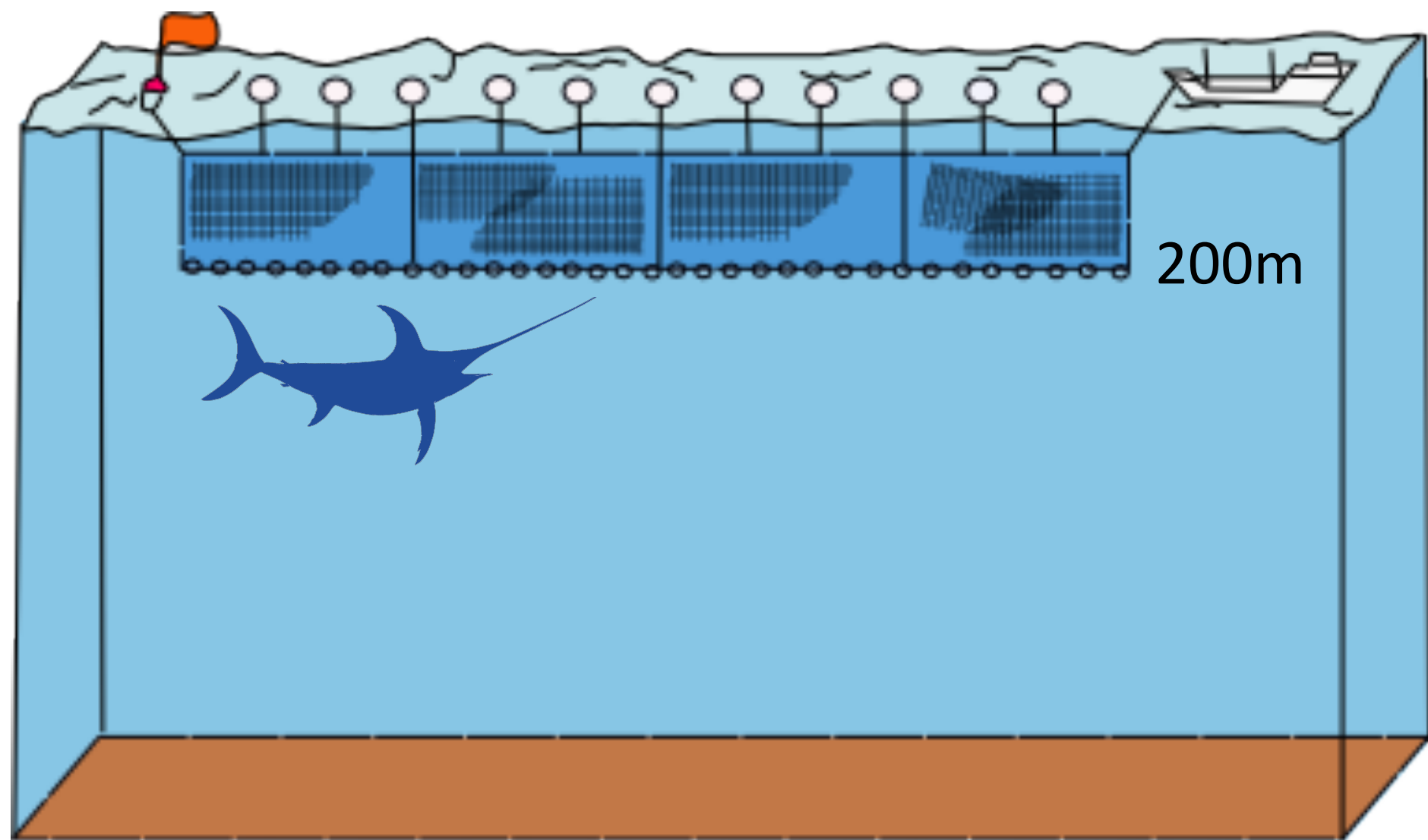


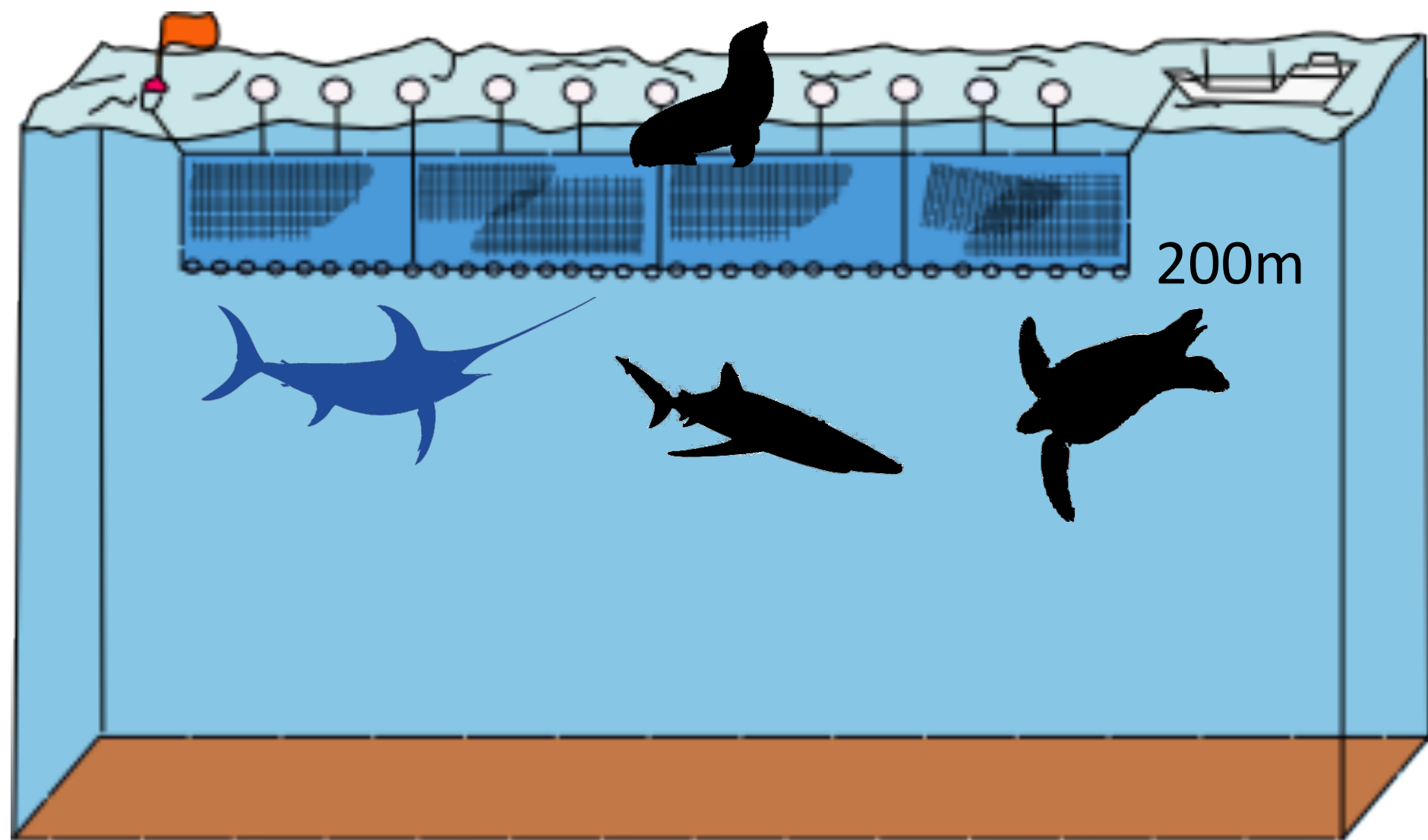


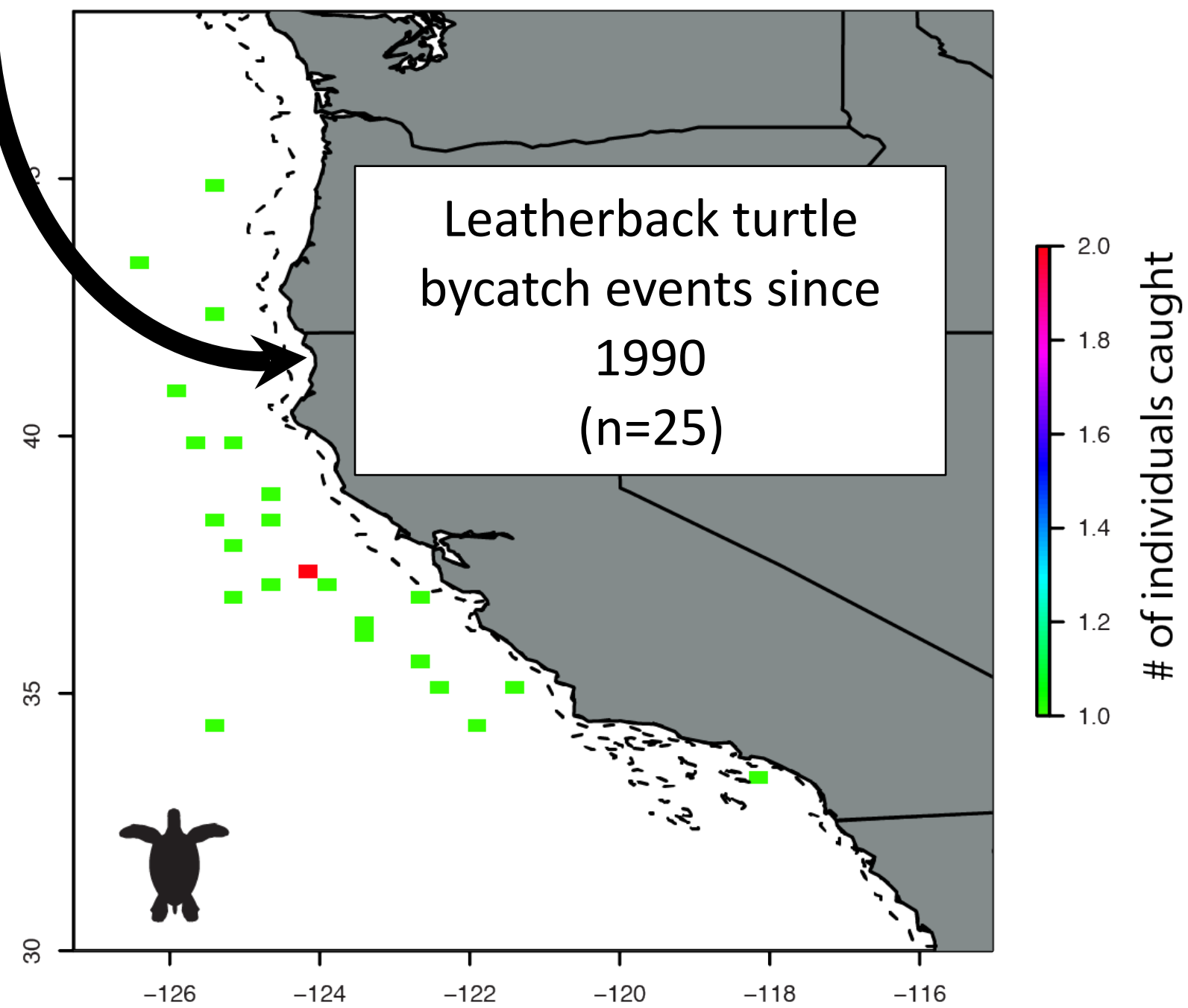
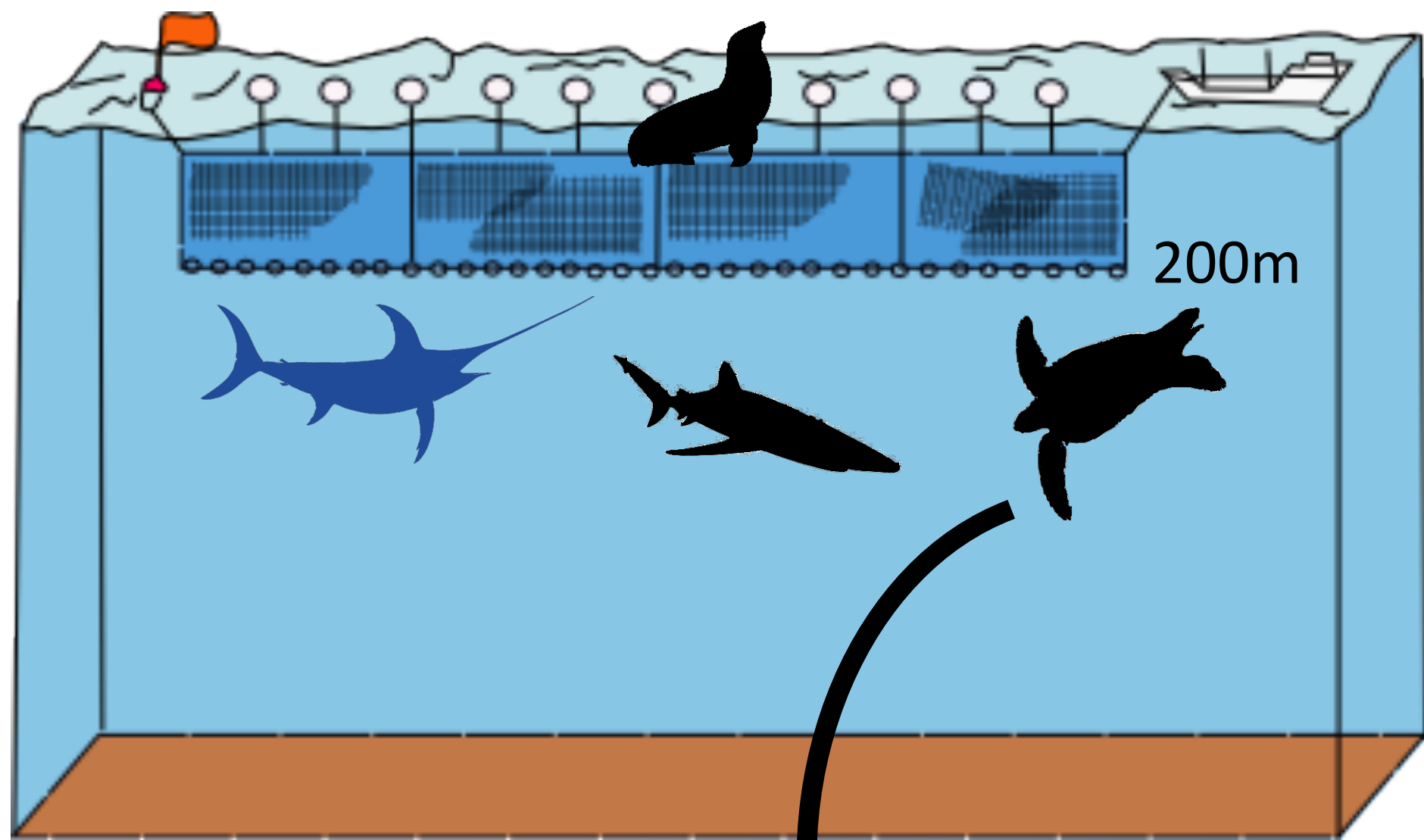
Tommasi et al. (2017)

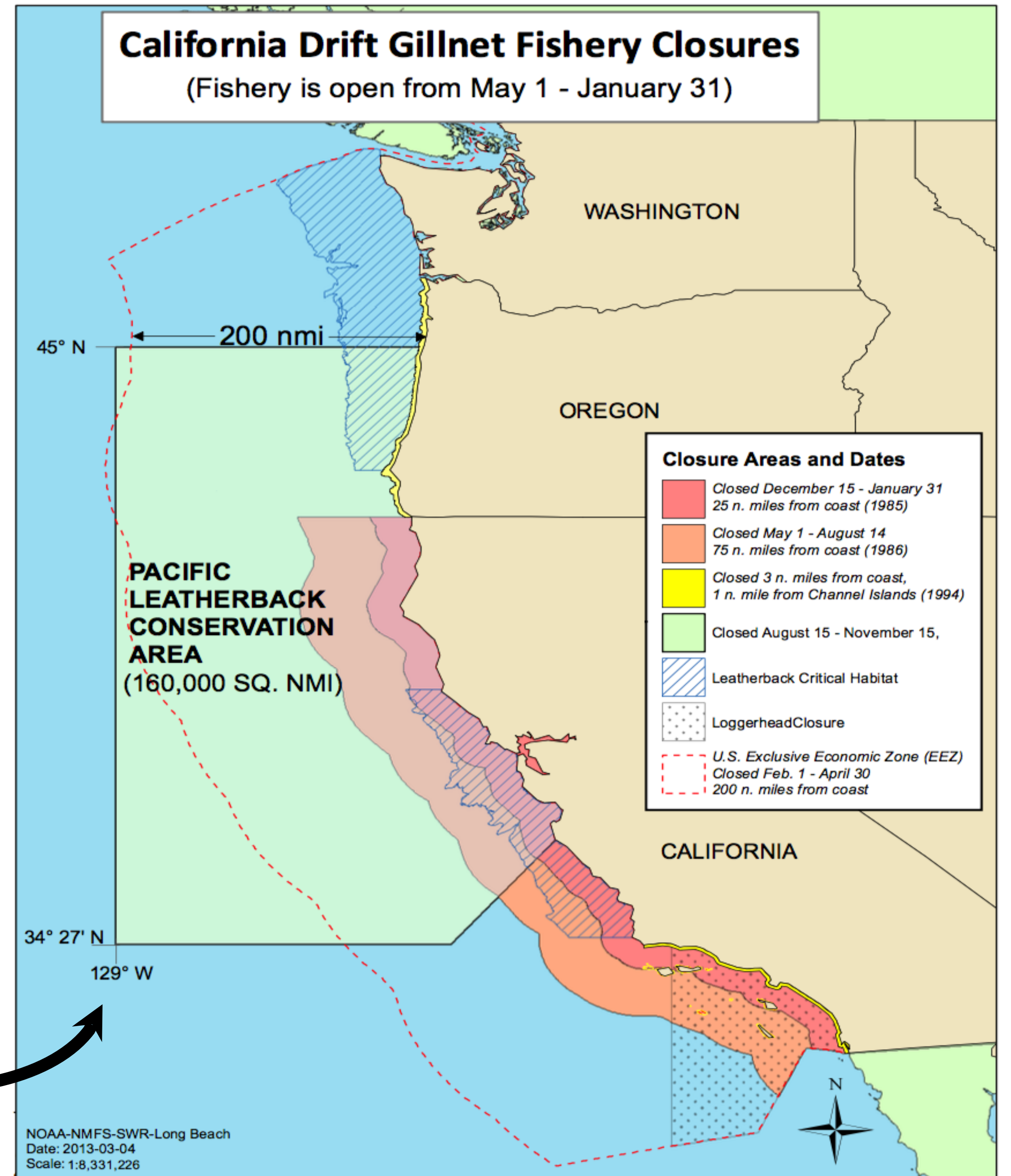
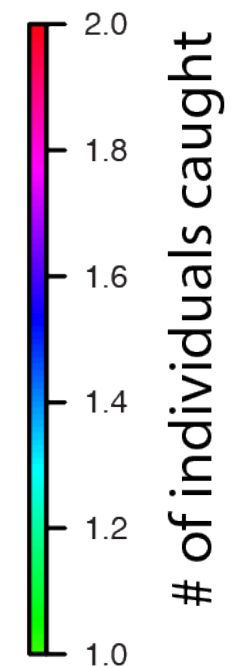
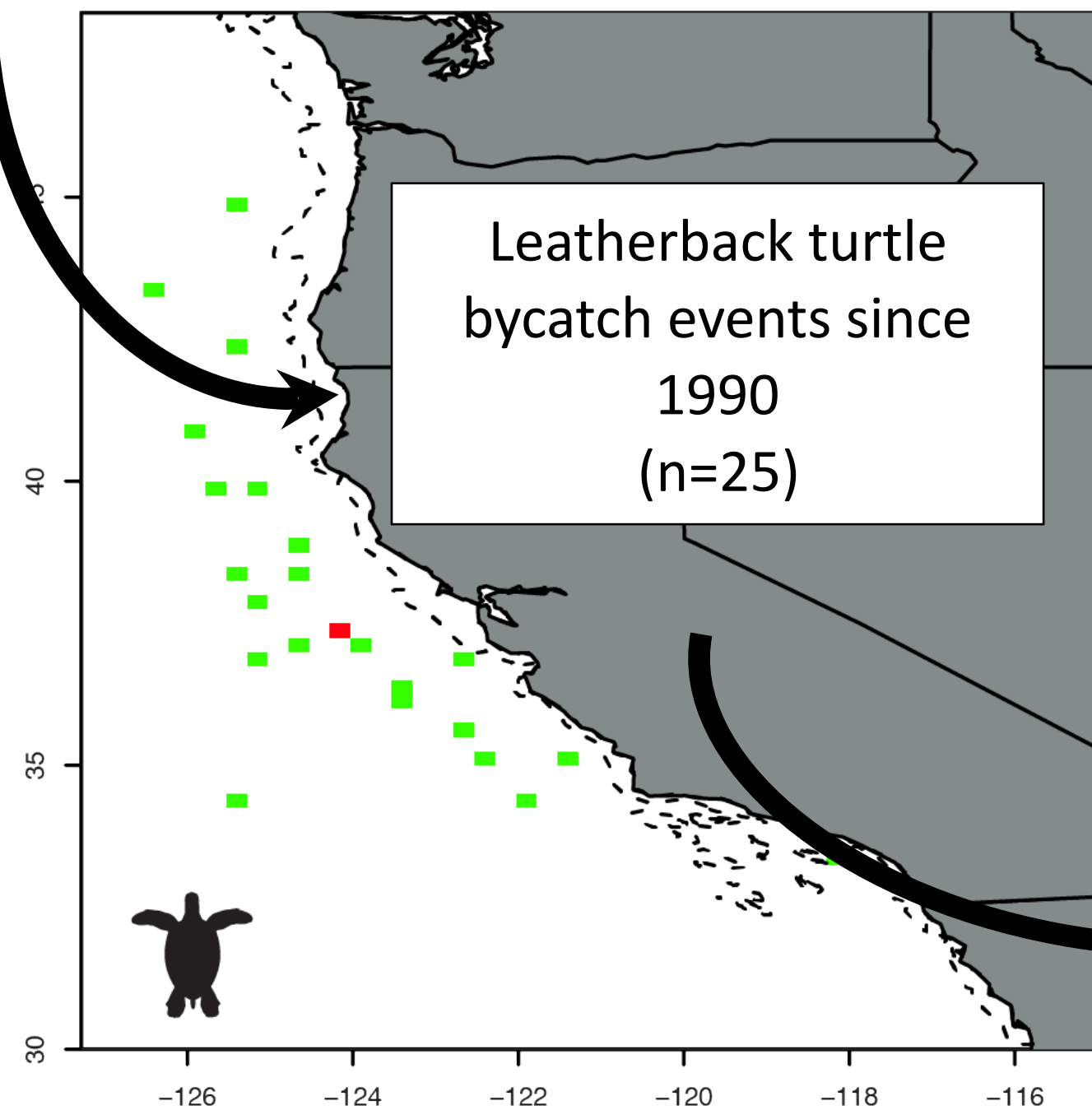
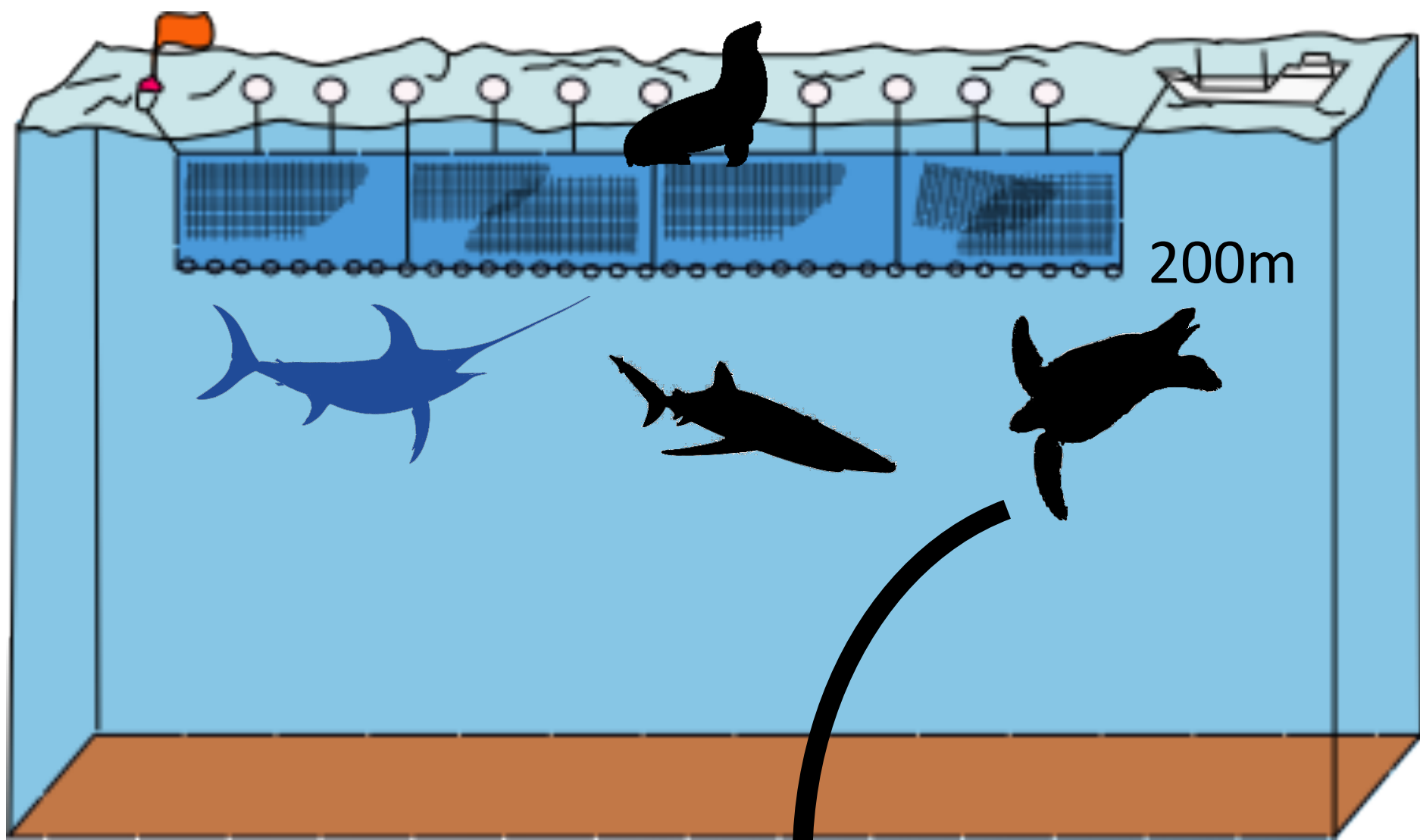


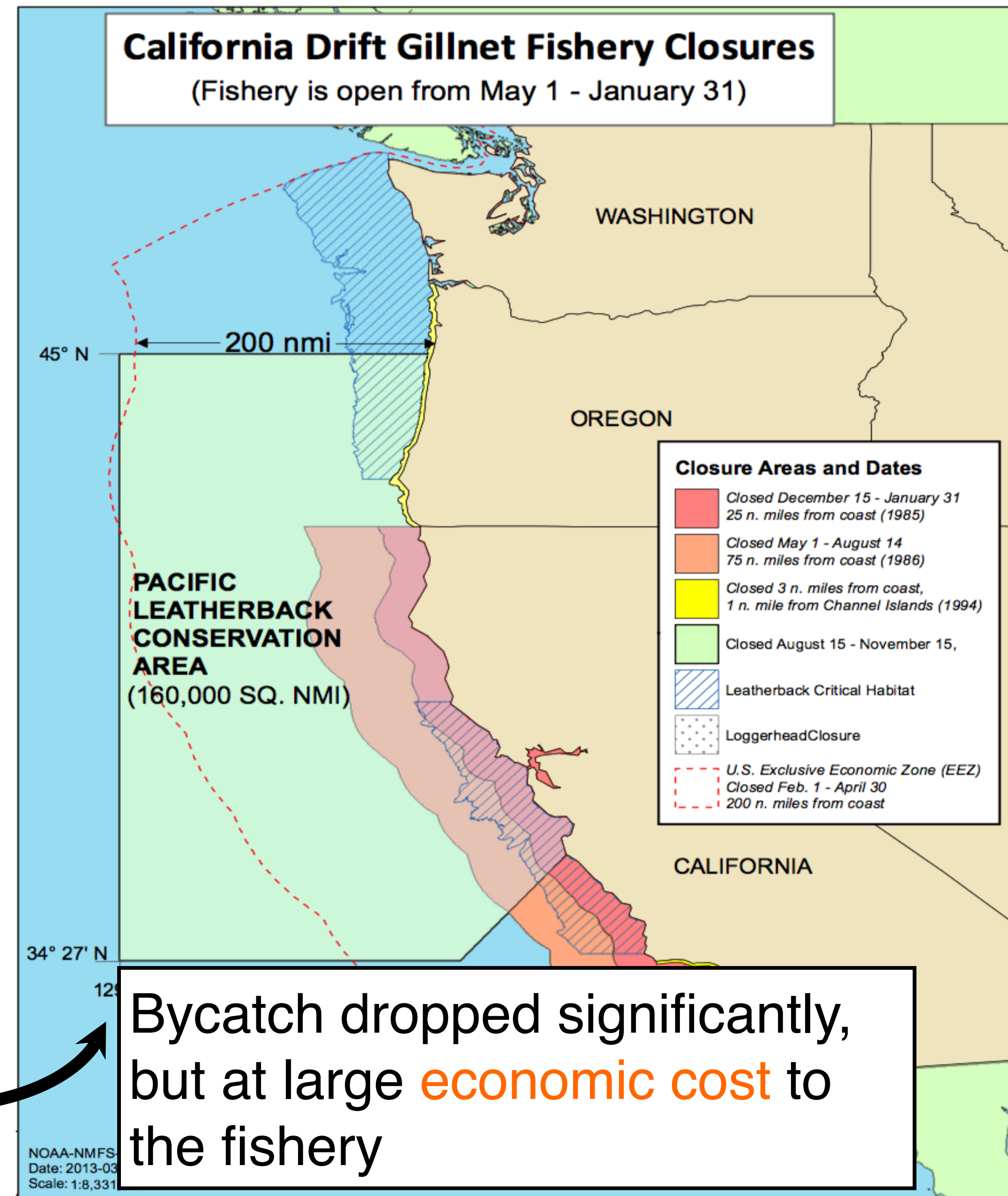
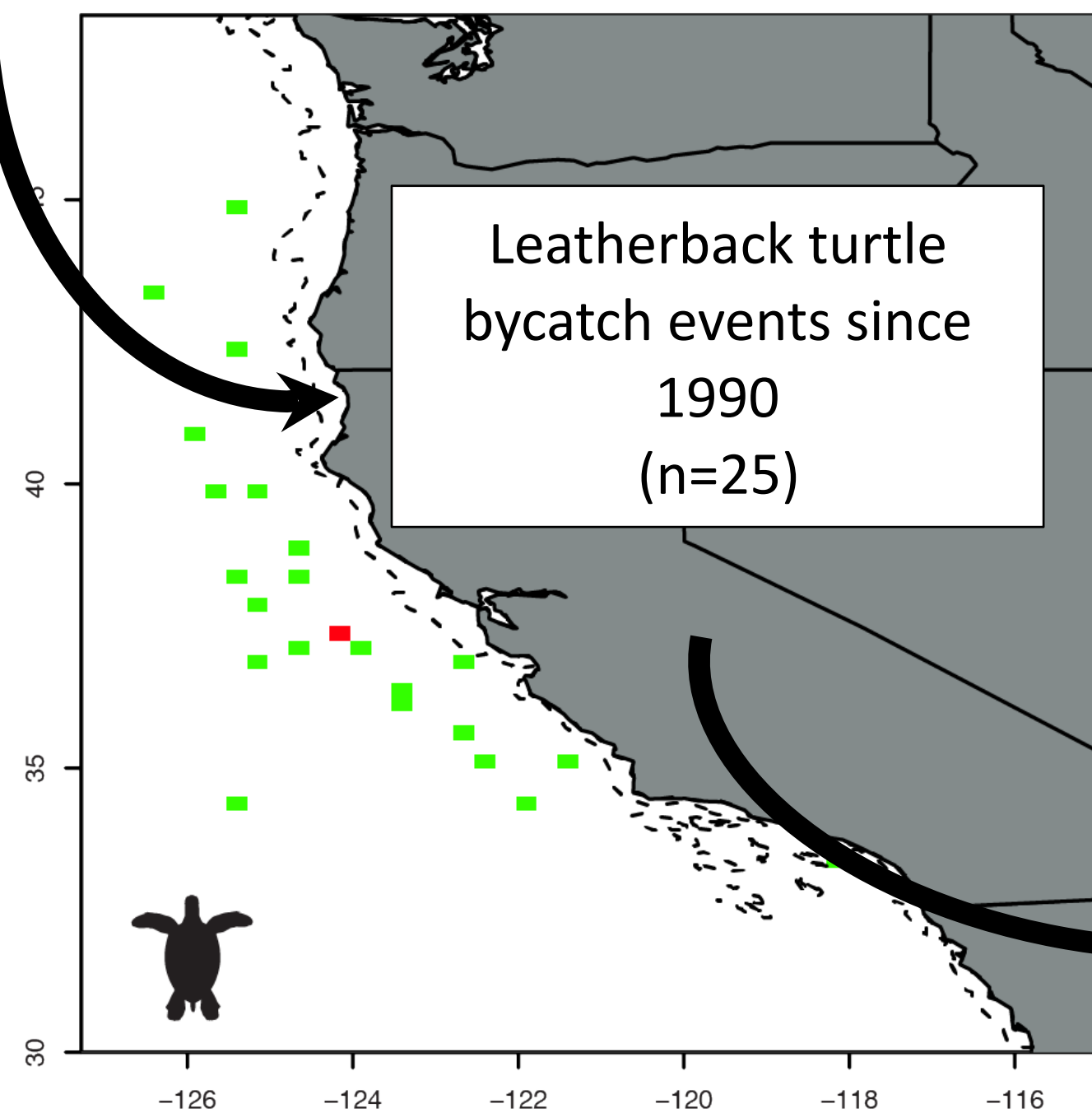
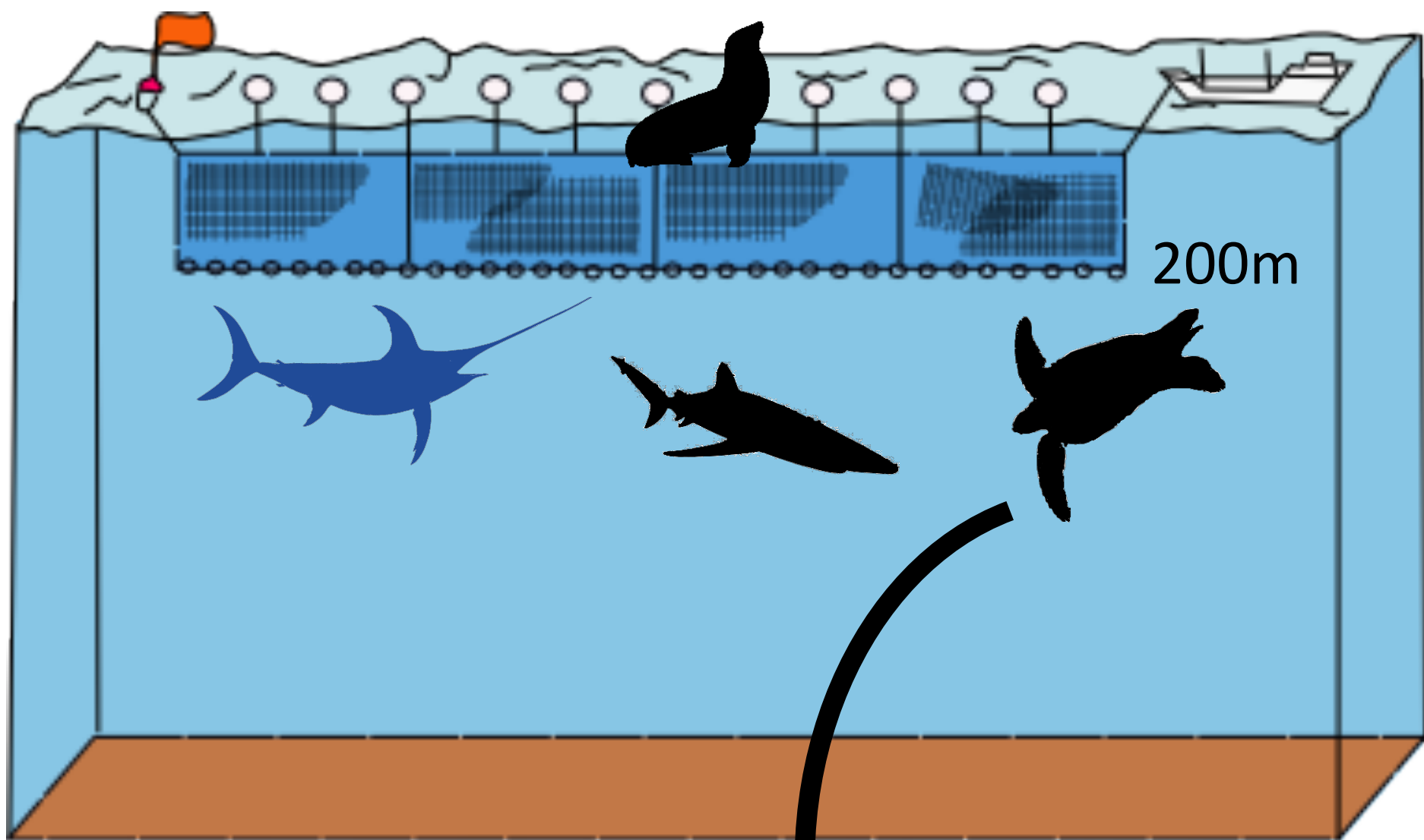
Tommasi et al. (2017)





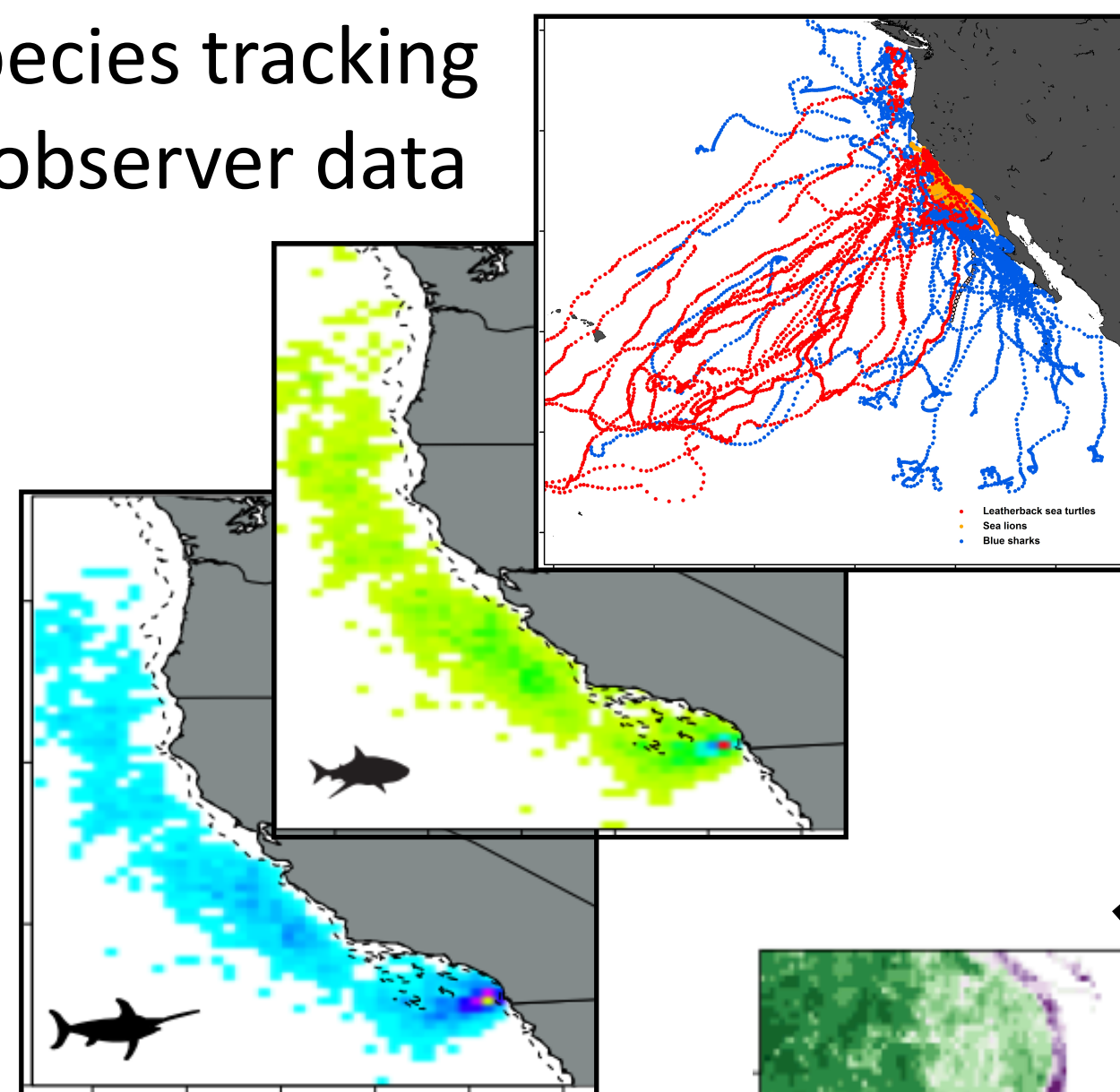




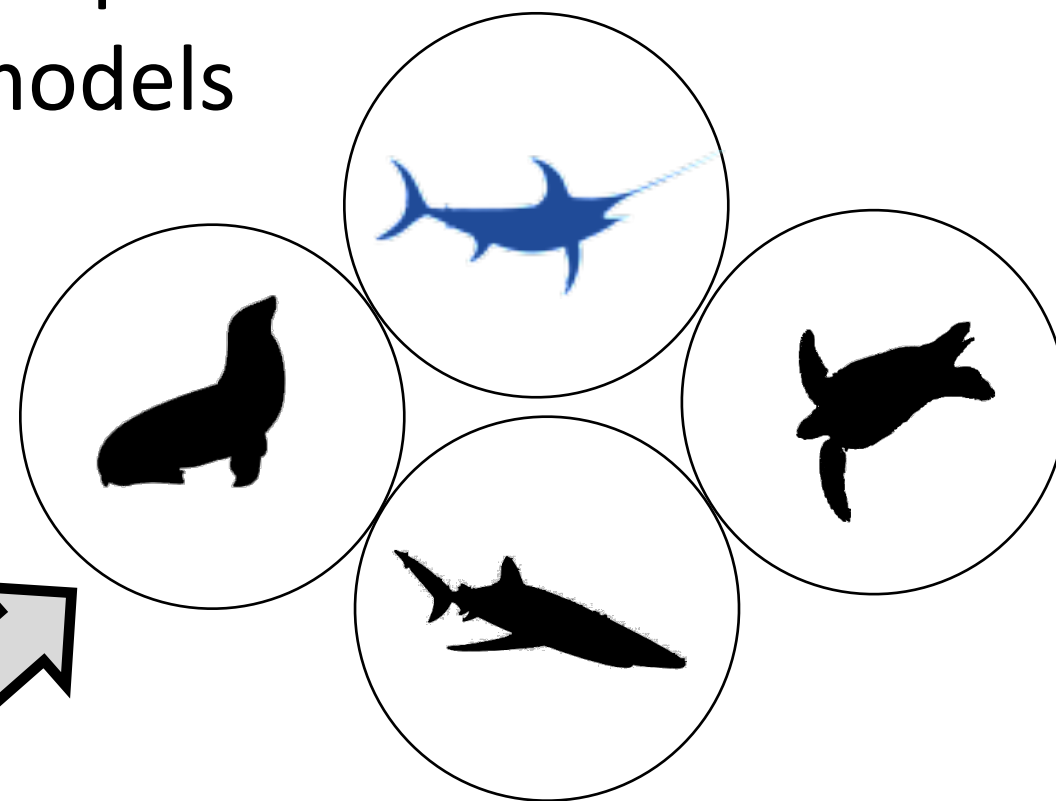




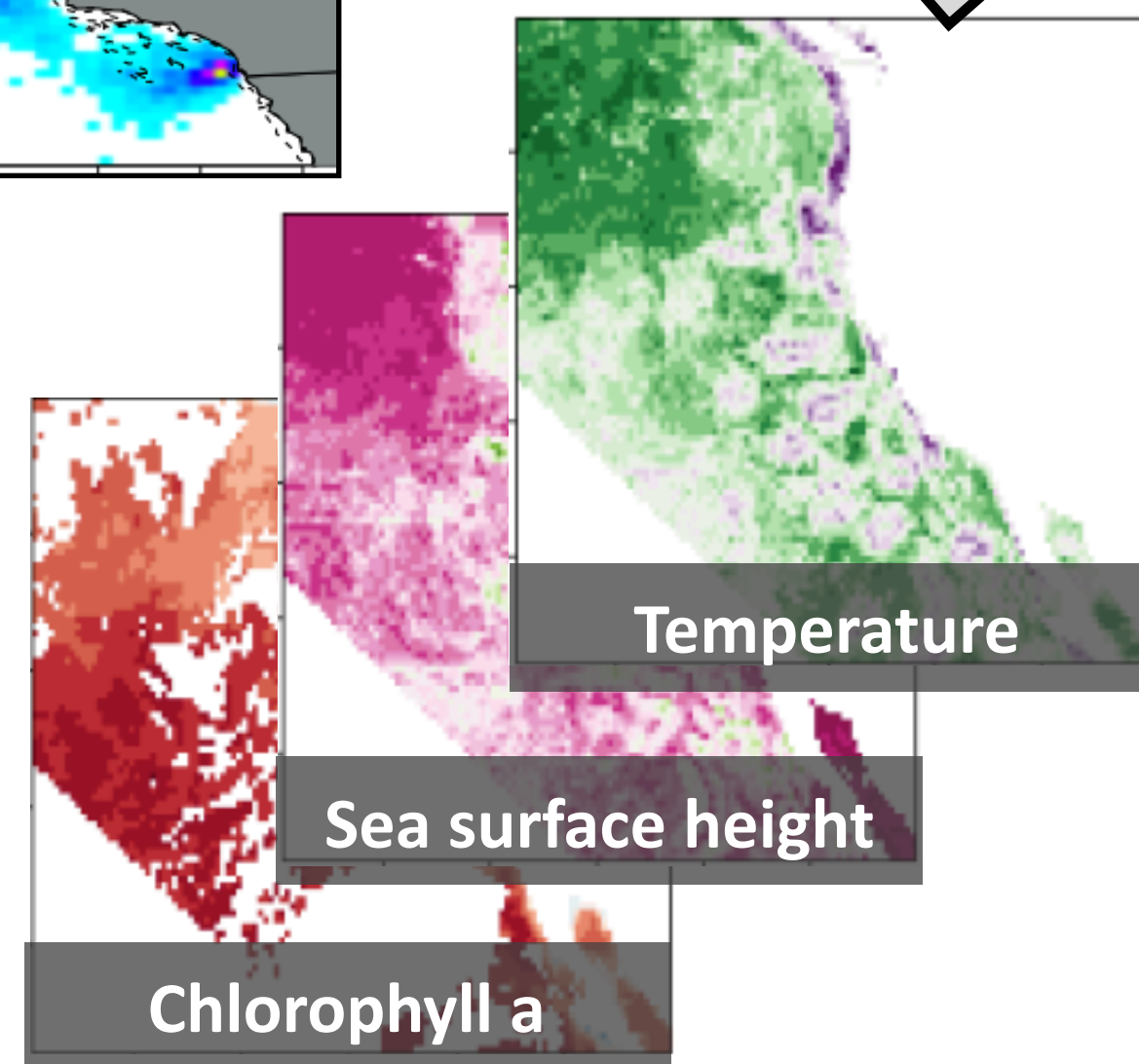
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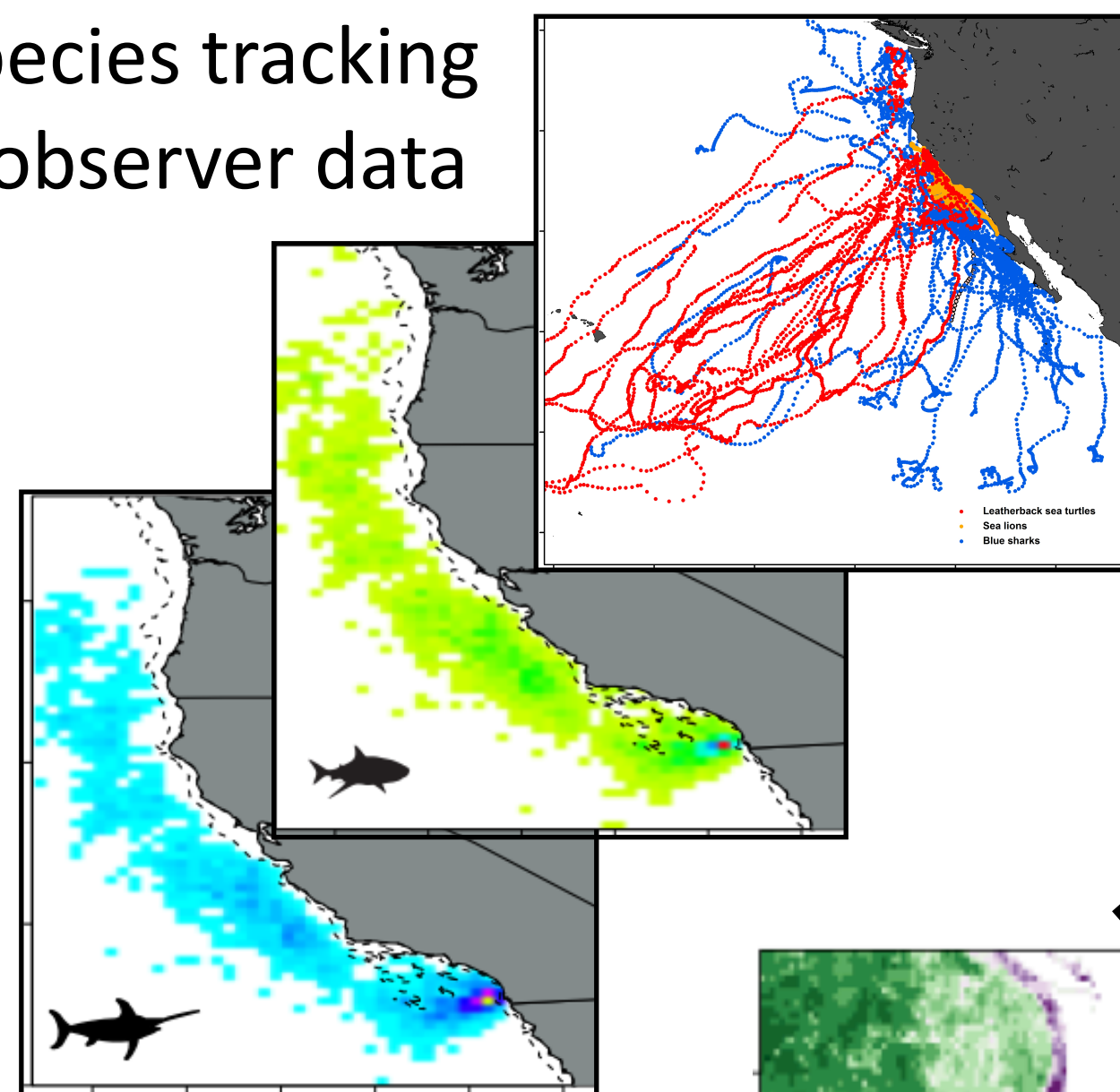
**3. Species distribution models**



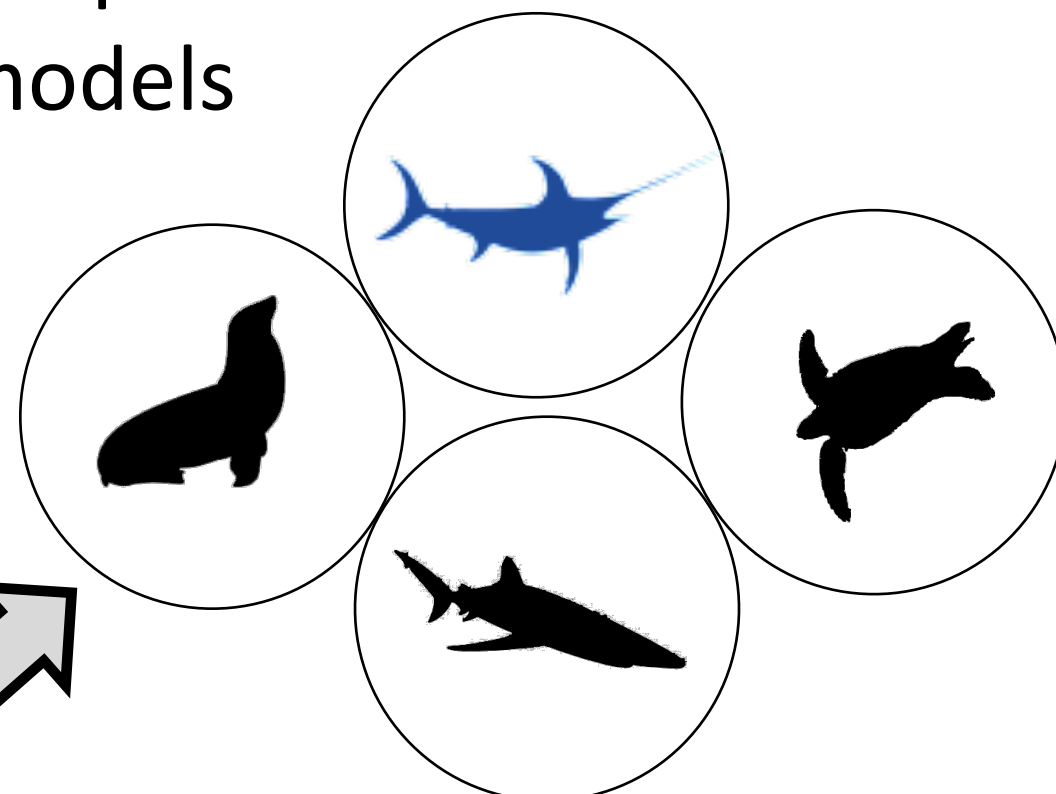
**2. Environmental data from satellites**



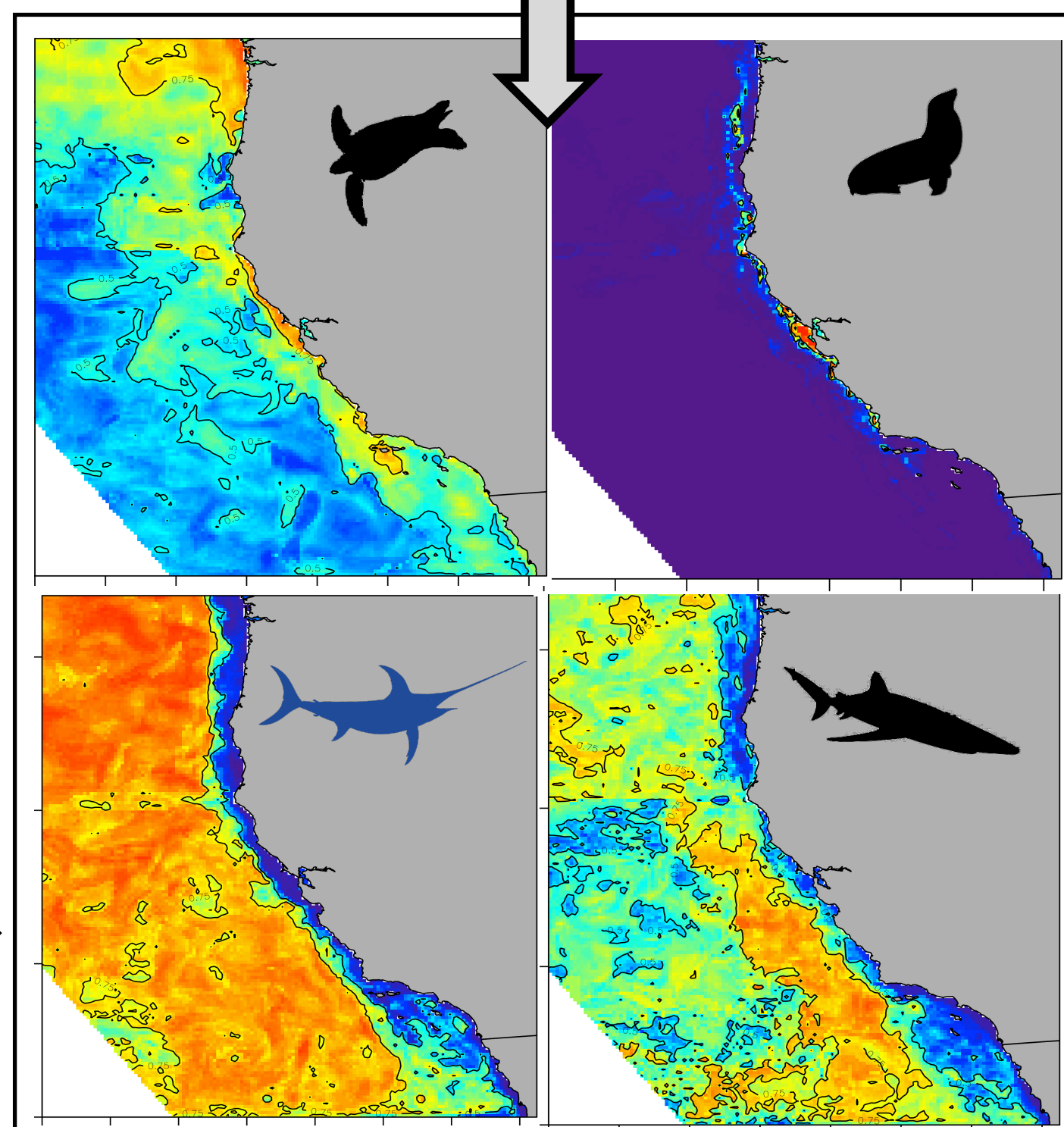
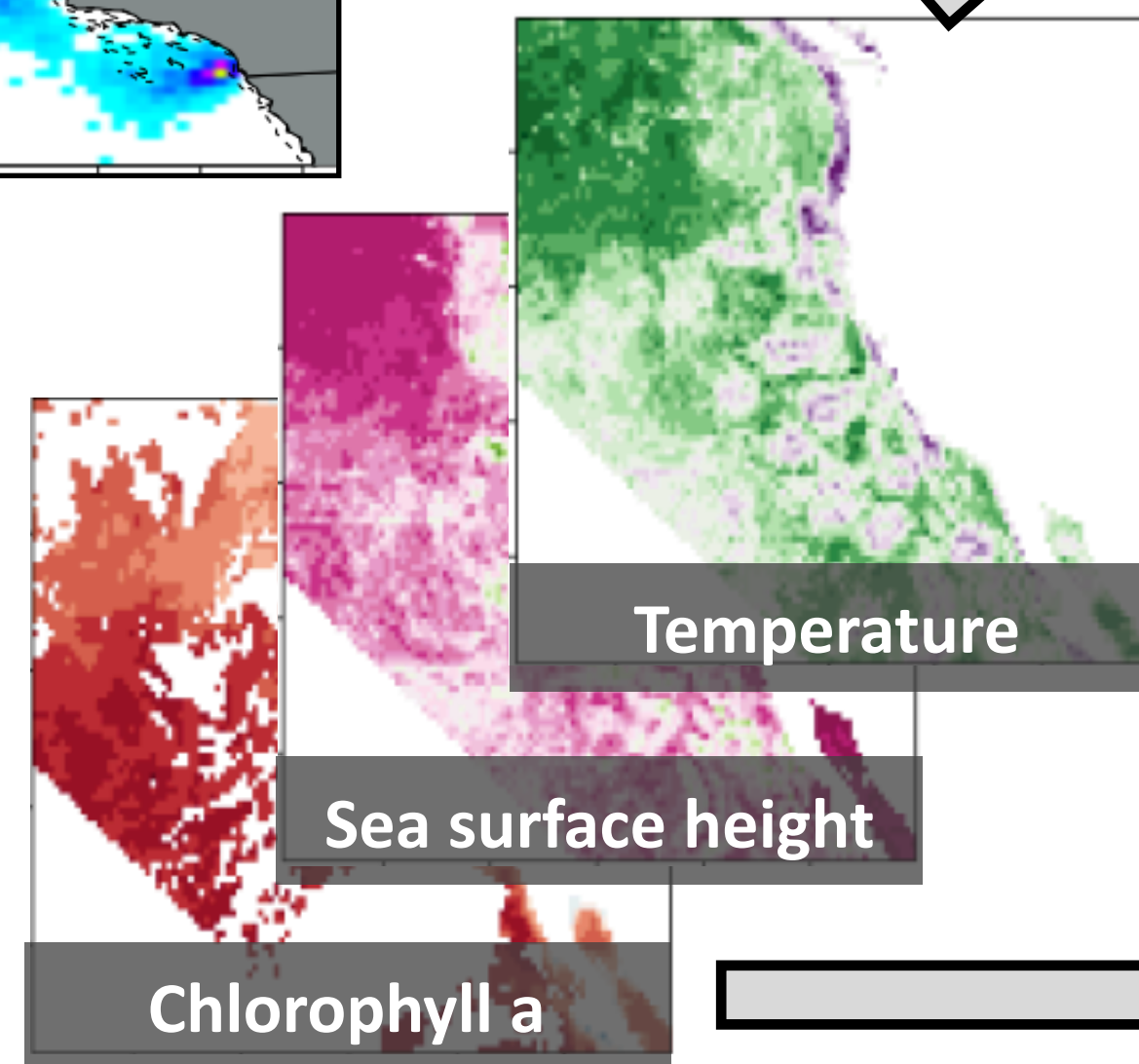
**1. Species tracking and observer data**



**3. Species distribution models**

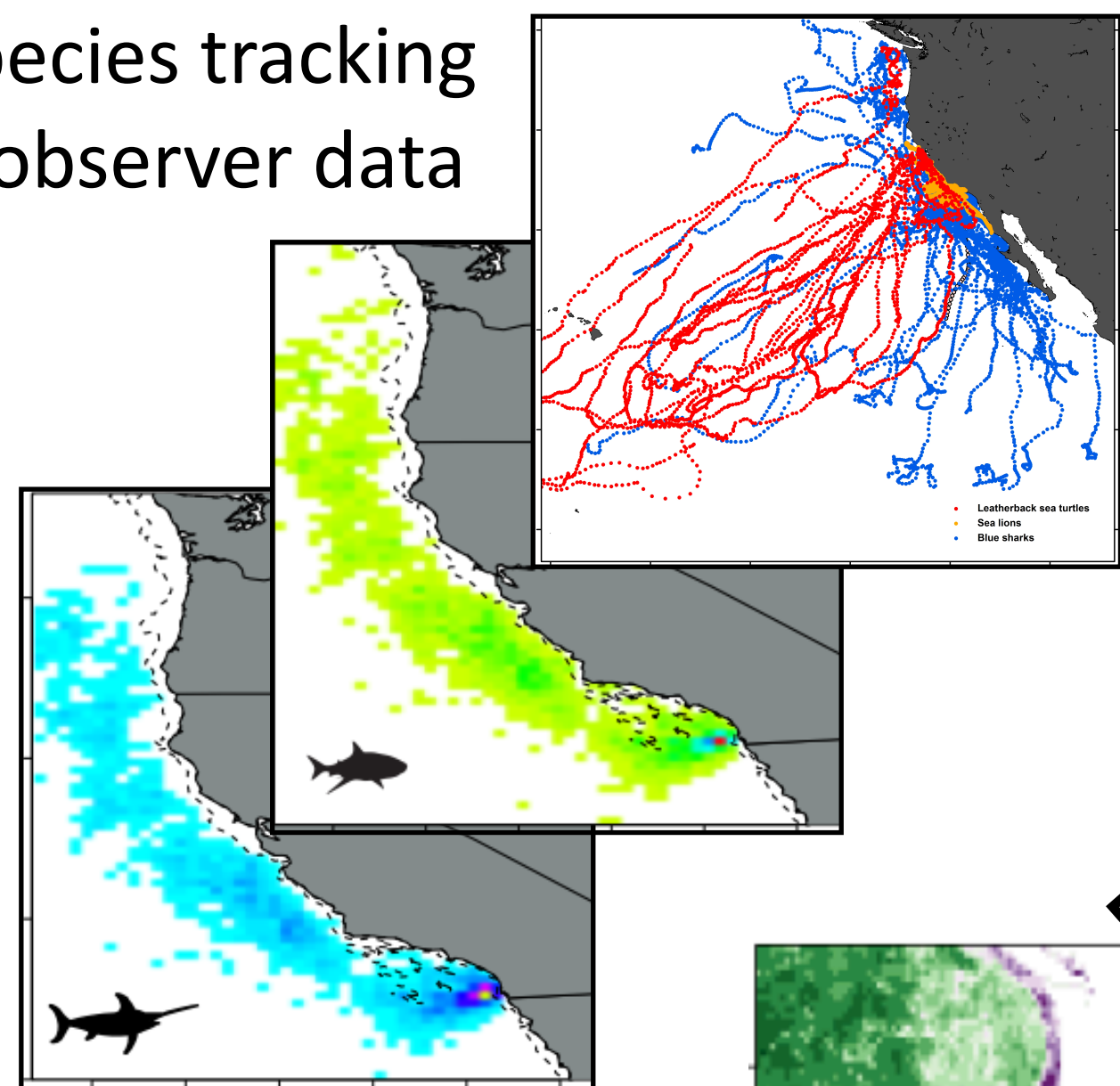


**2. Environmental data from satellites**

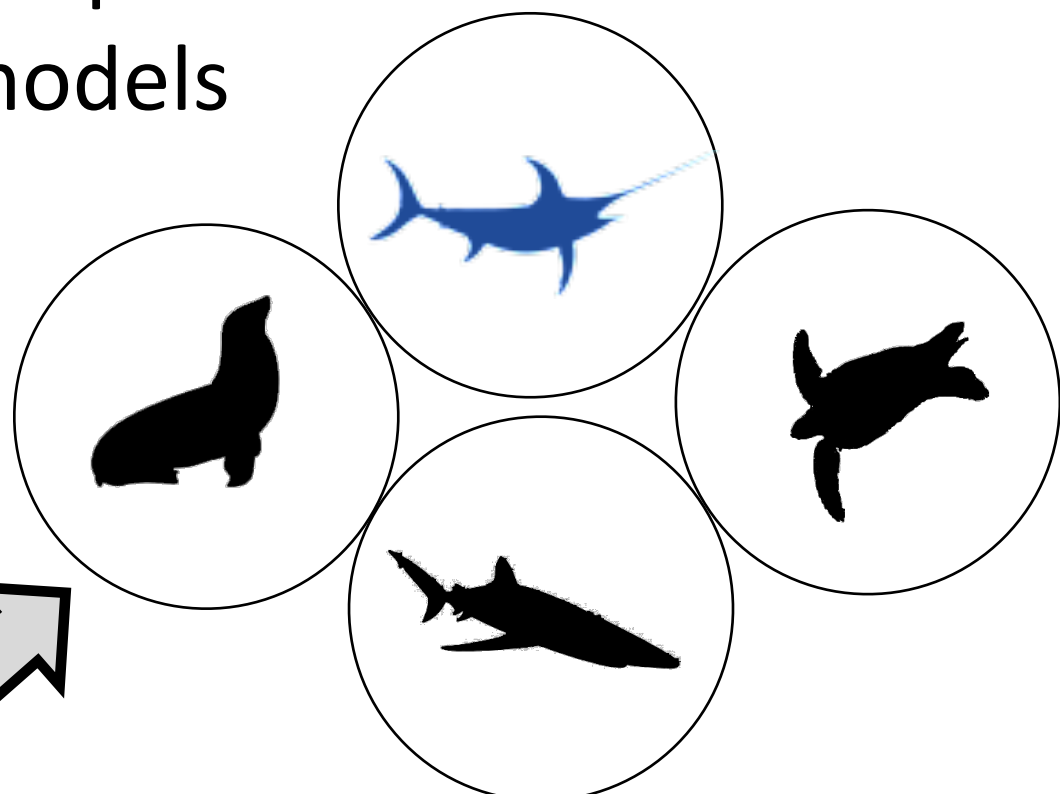


**4. predicted habitat suitability**

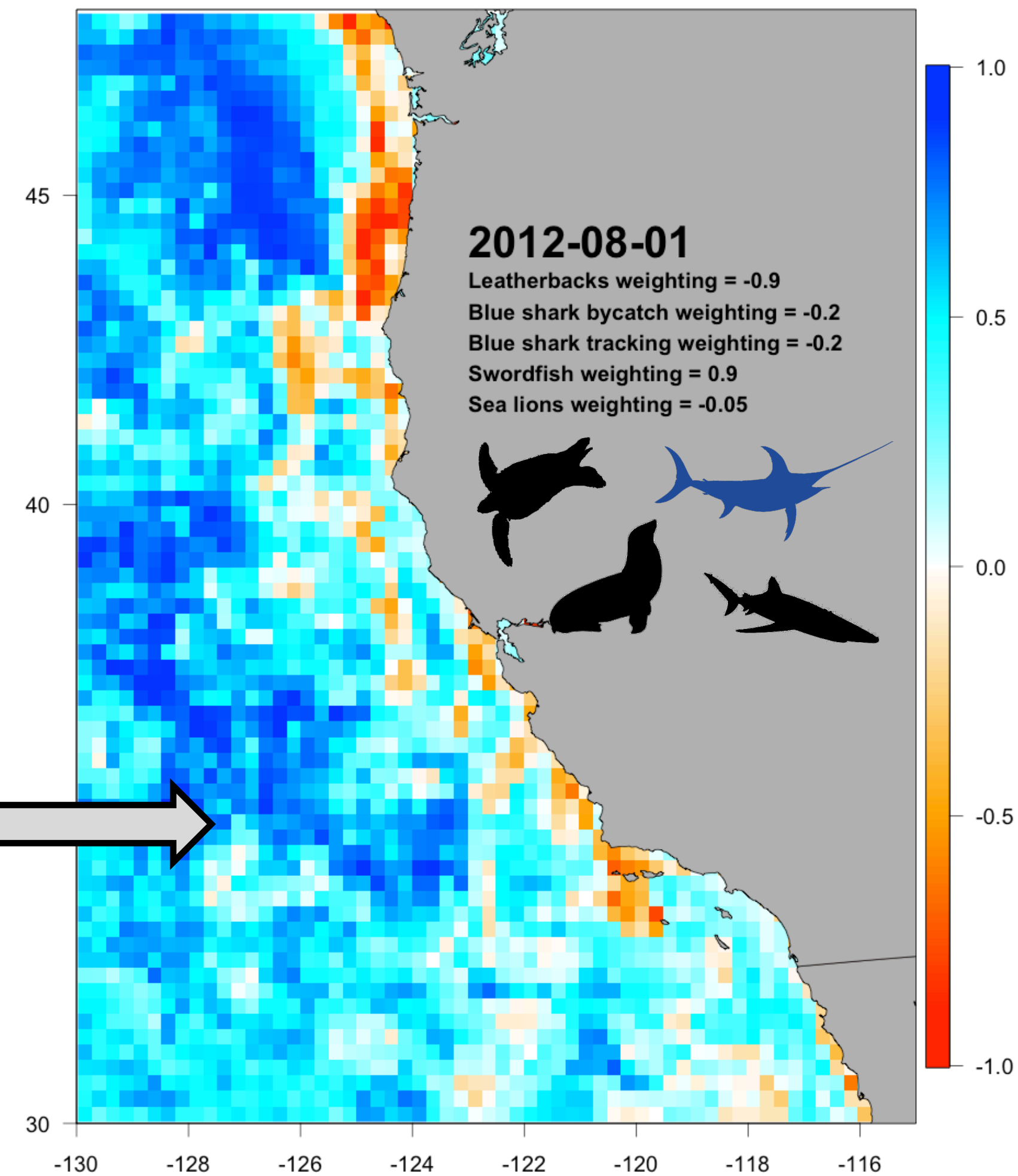
# 1. Species tracking and observer data



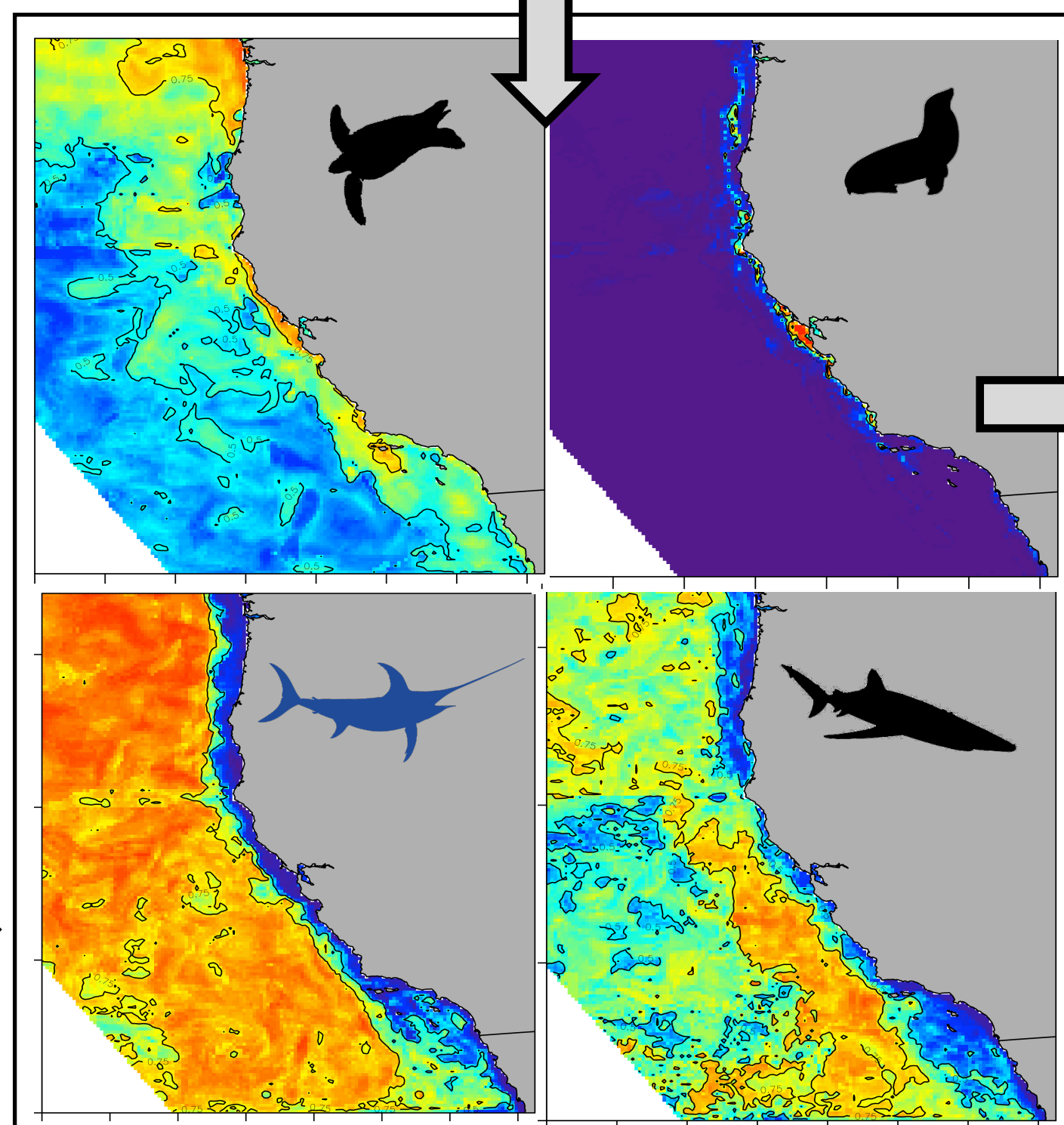
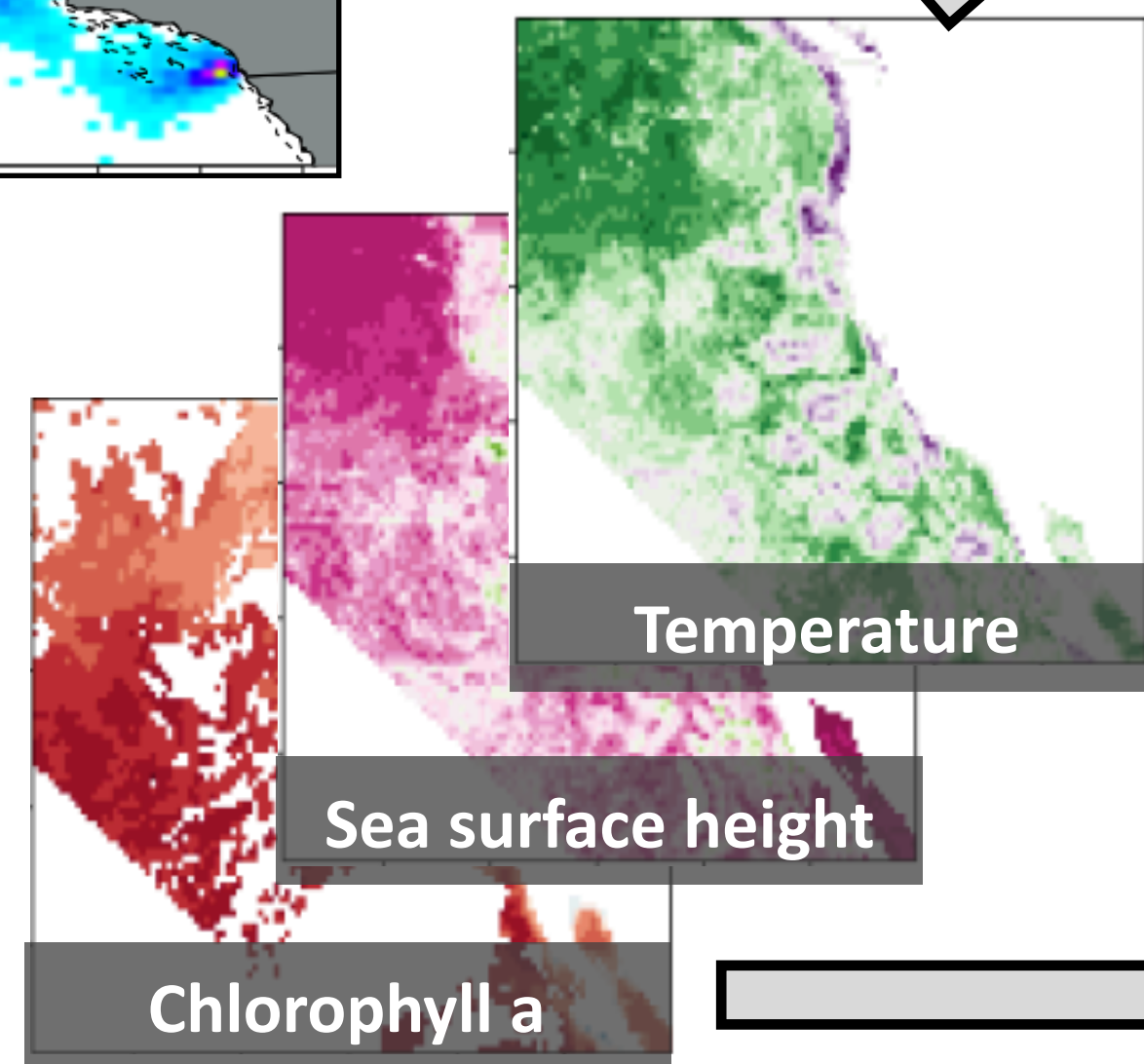
# 3. Species distribution models



# 5. Integrated fishing suitability



# 2. Environmental data from satellites

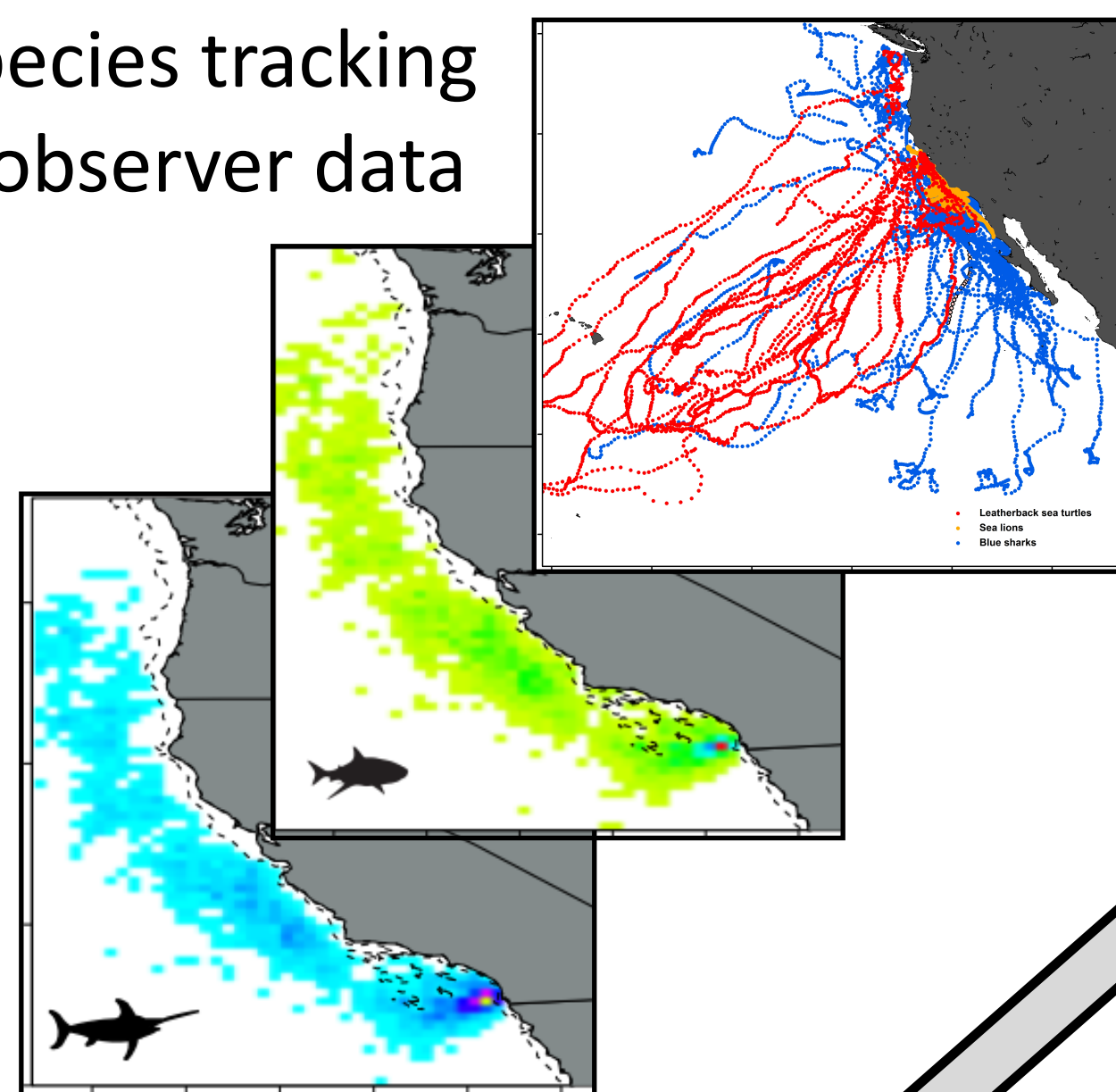


# 4. predicted habitat suitability

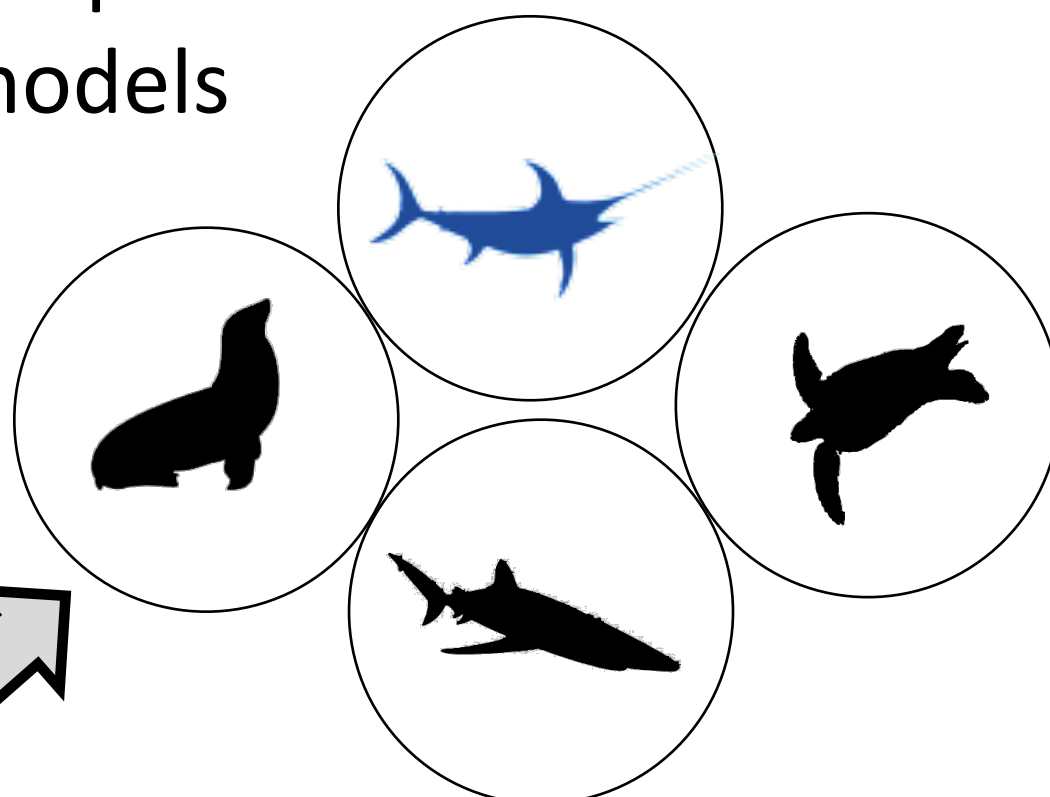
Hazen et al. 2018

<https://coastwatch.pfeg.noaa.gov/ecocast/>

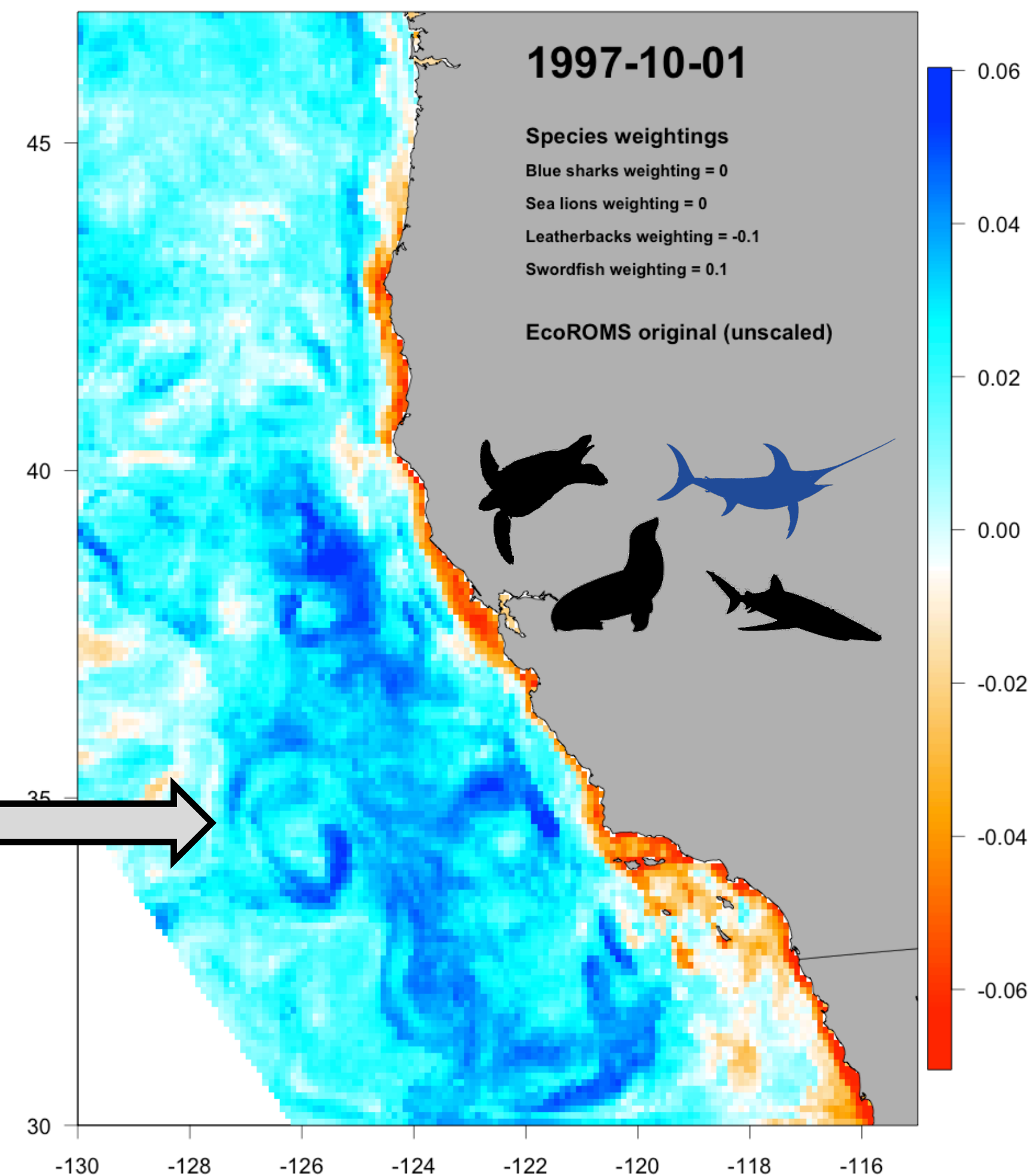
# 1. Species tracking and observer data



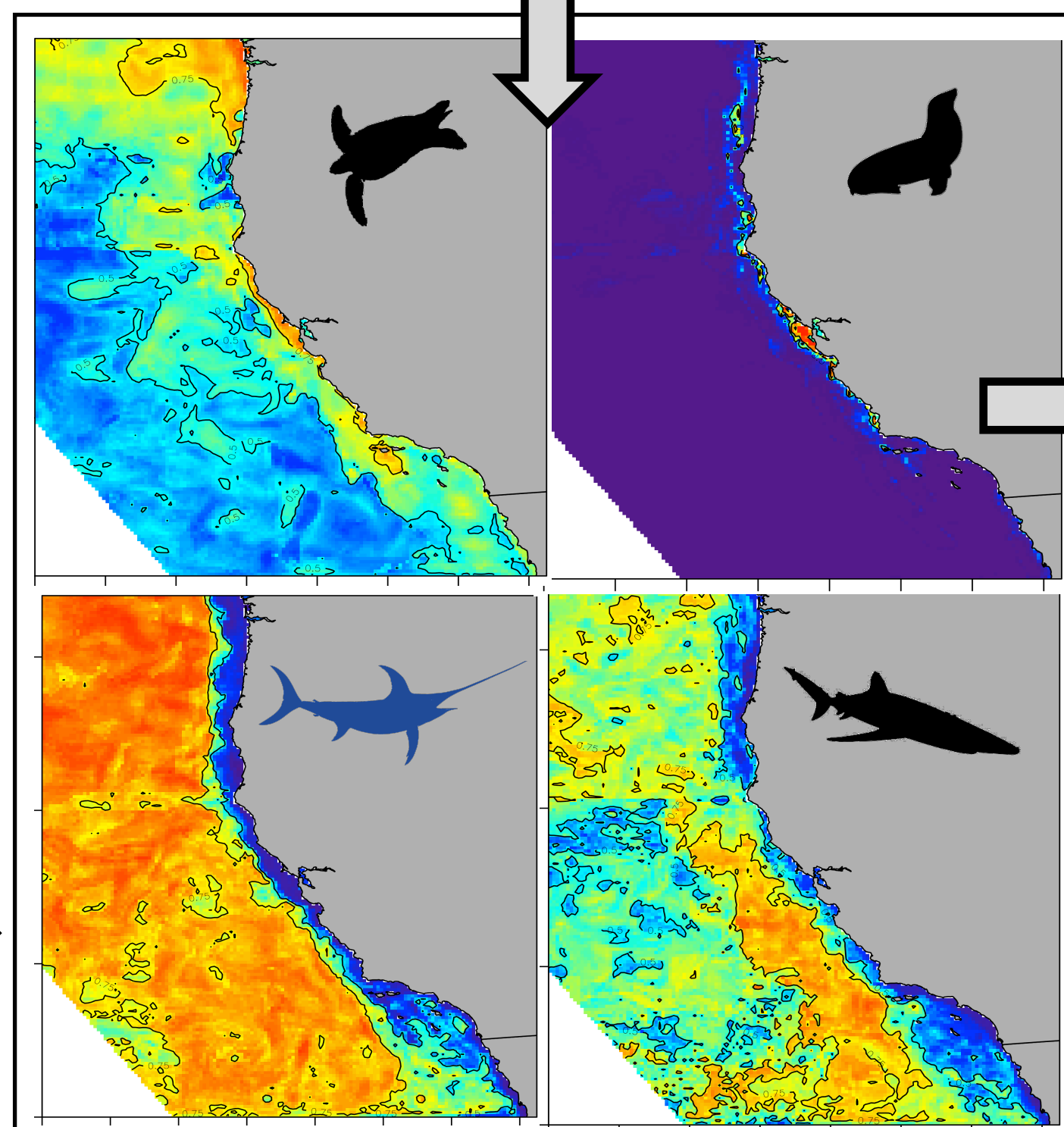
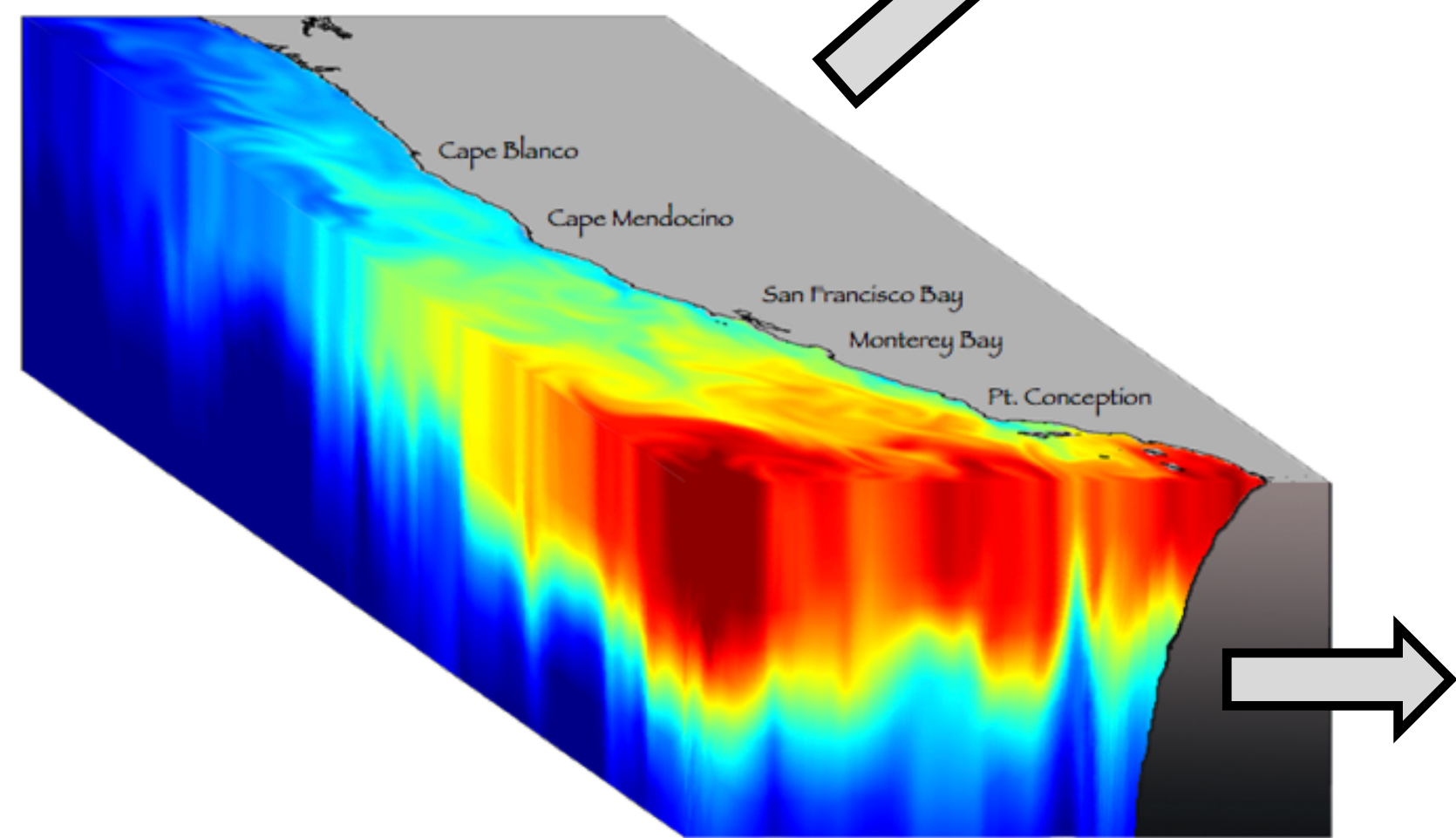
# 3. Species distribution models



# 5. Integrated fishing suitability



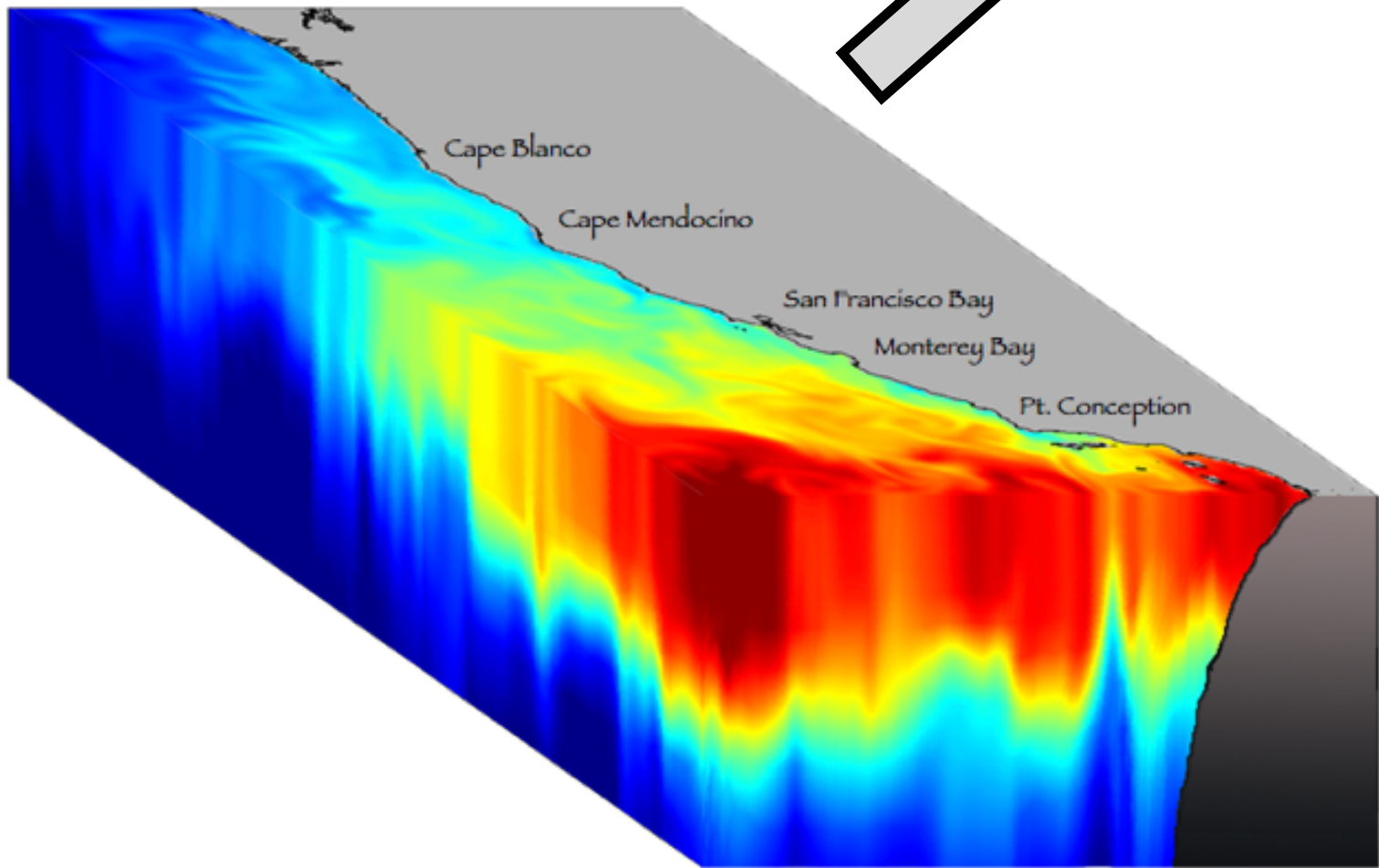
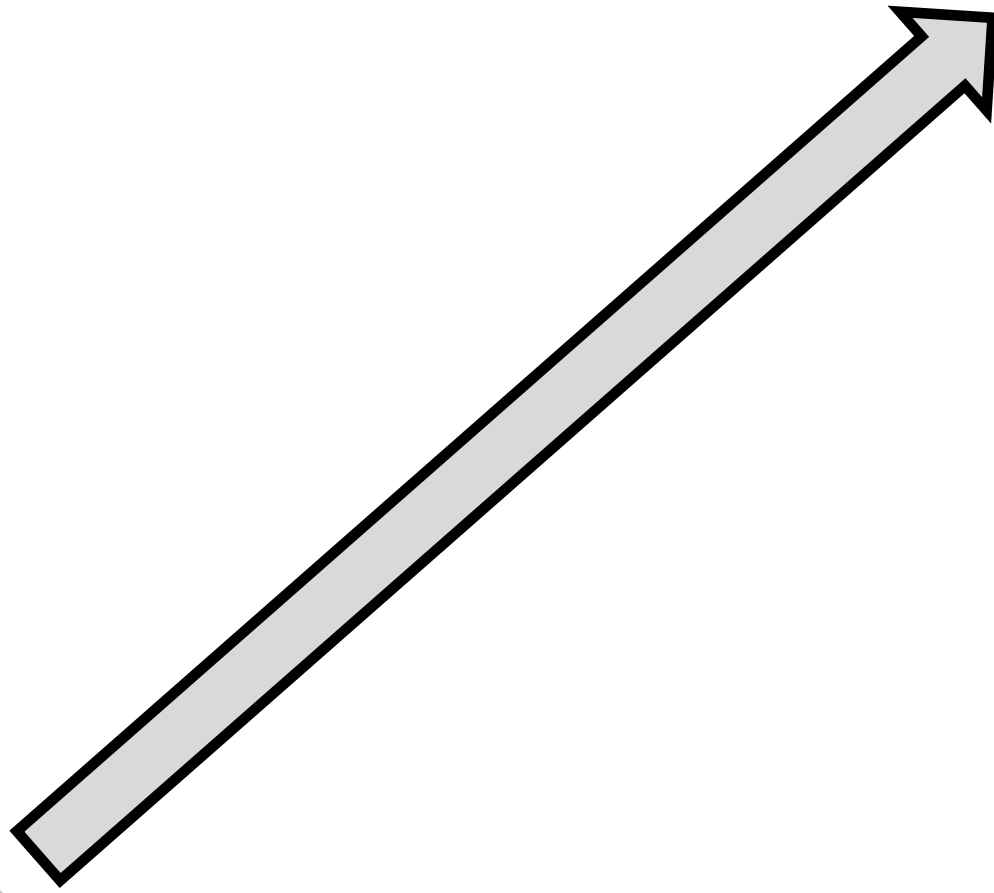
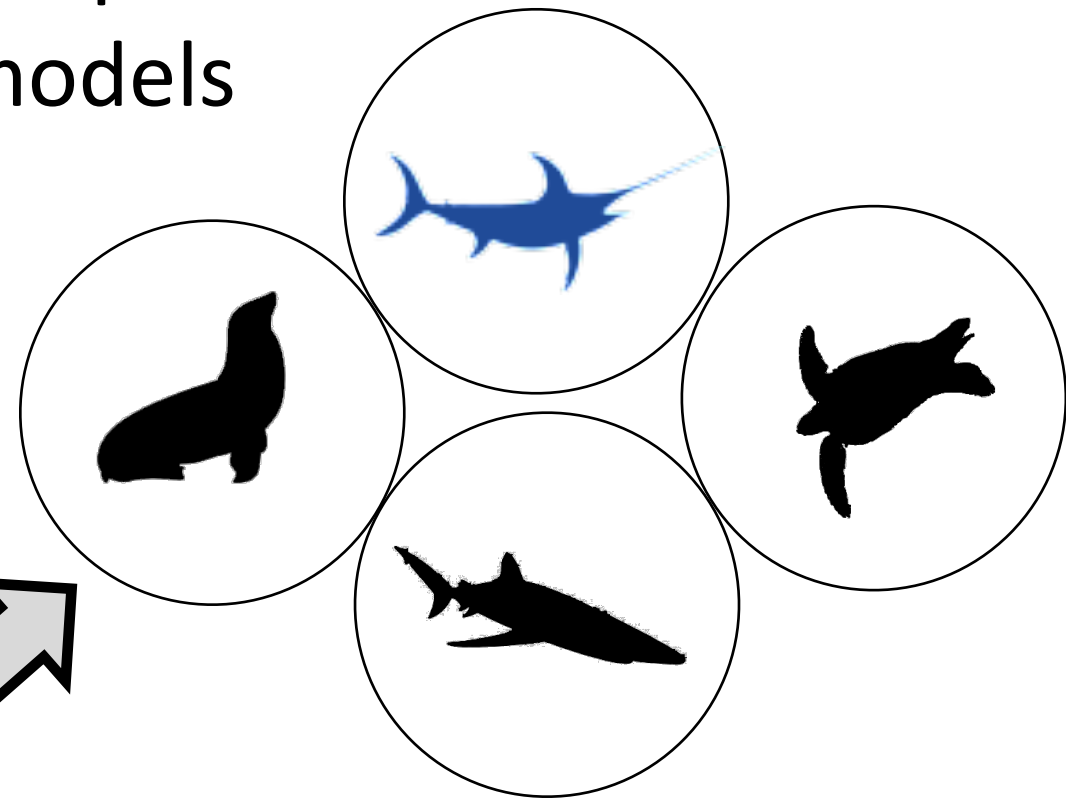
# 2. Environmental data from ocean models



# 4. predicted habitat suitability

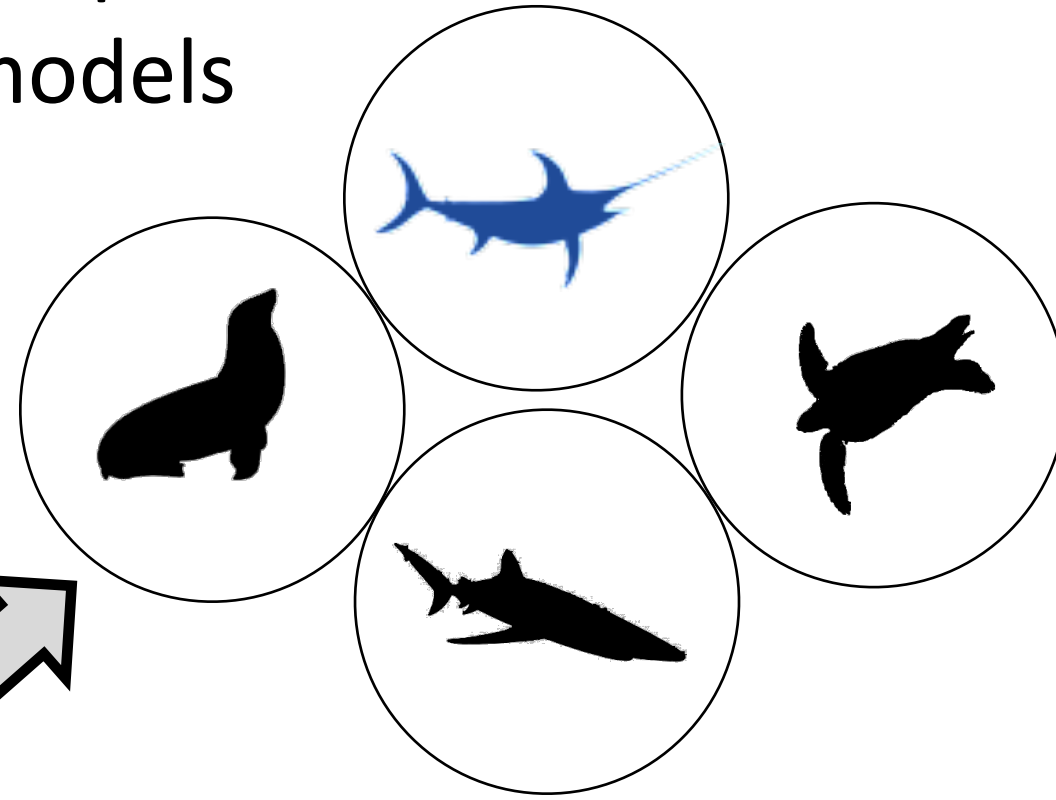
Welch et al 2019  
Brodie et al. 2018

Species distribution models

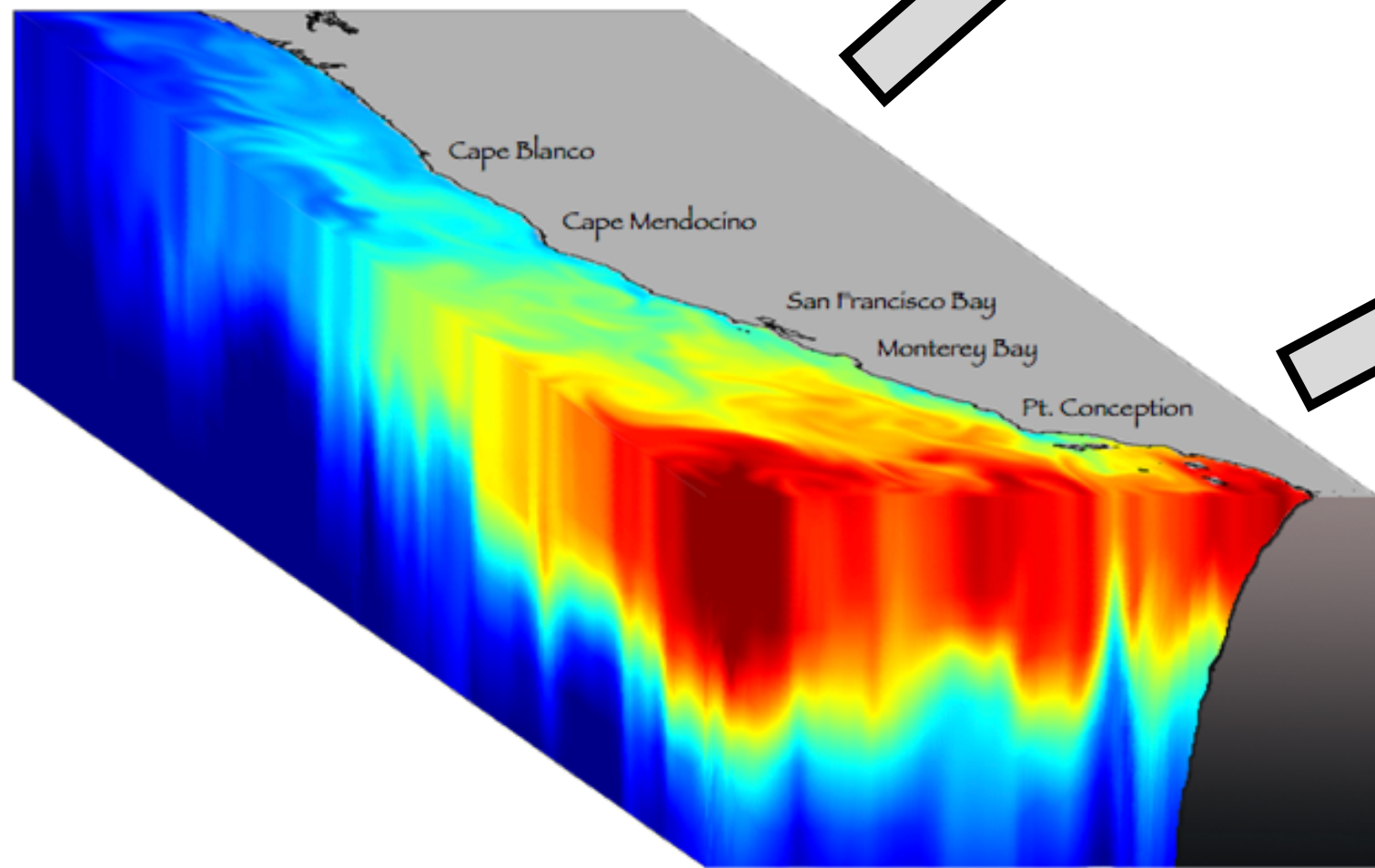
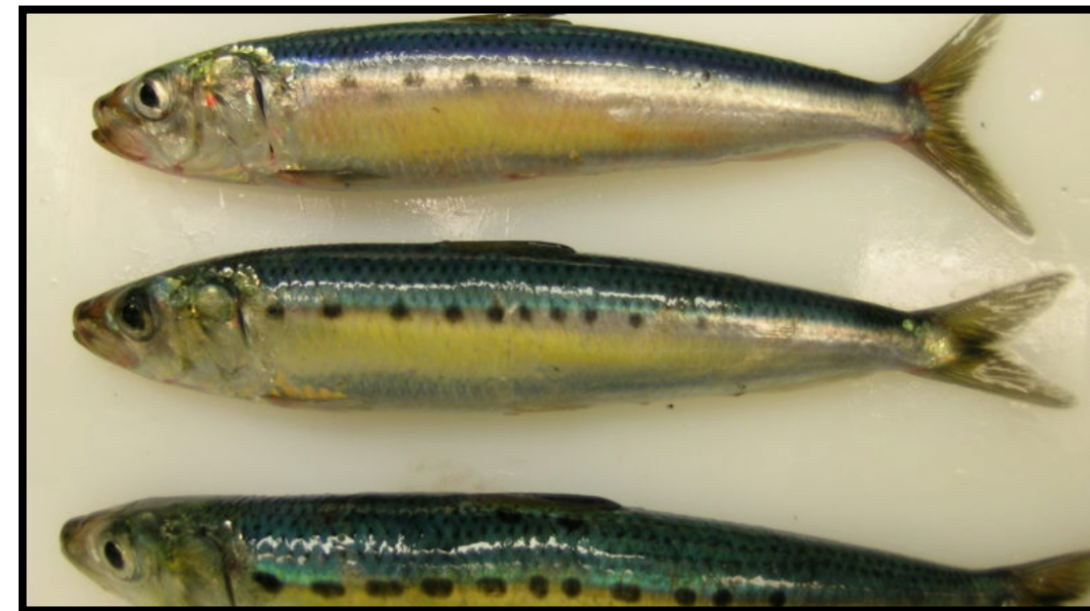


Environmental data from ocean models

Species distribution models

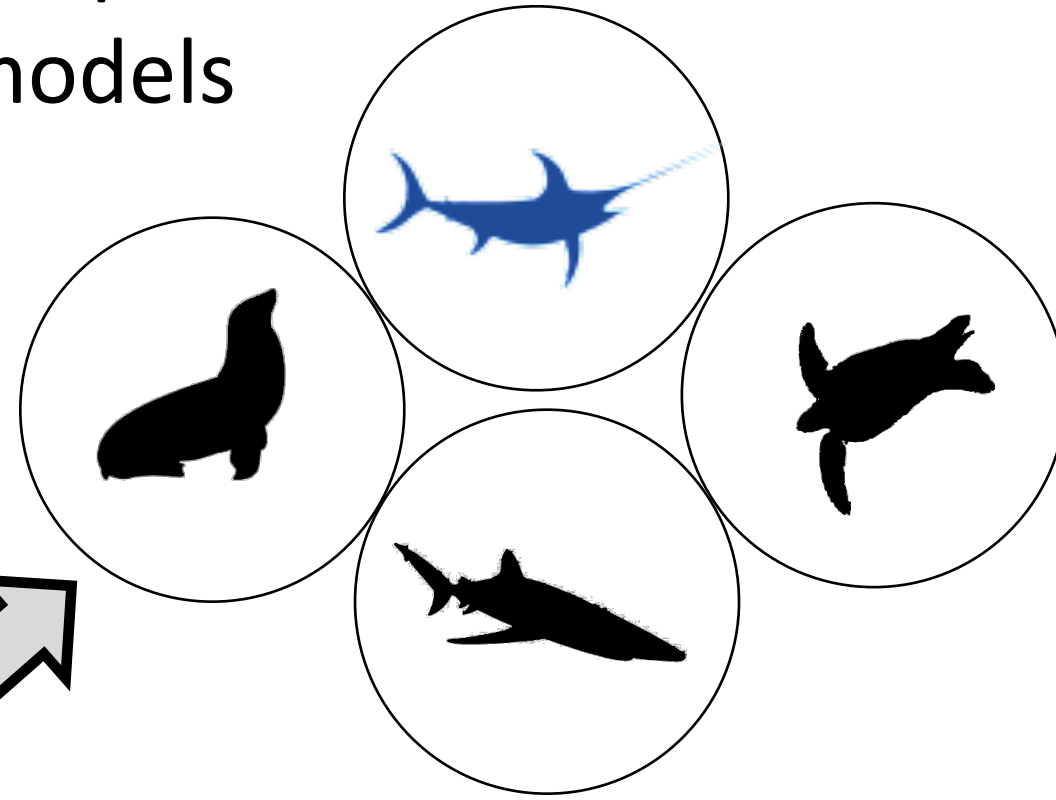


Stock Assessments

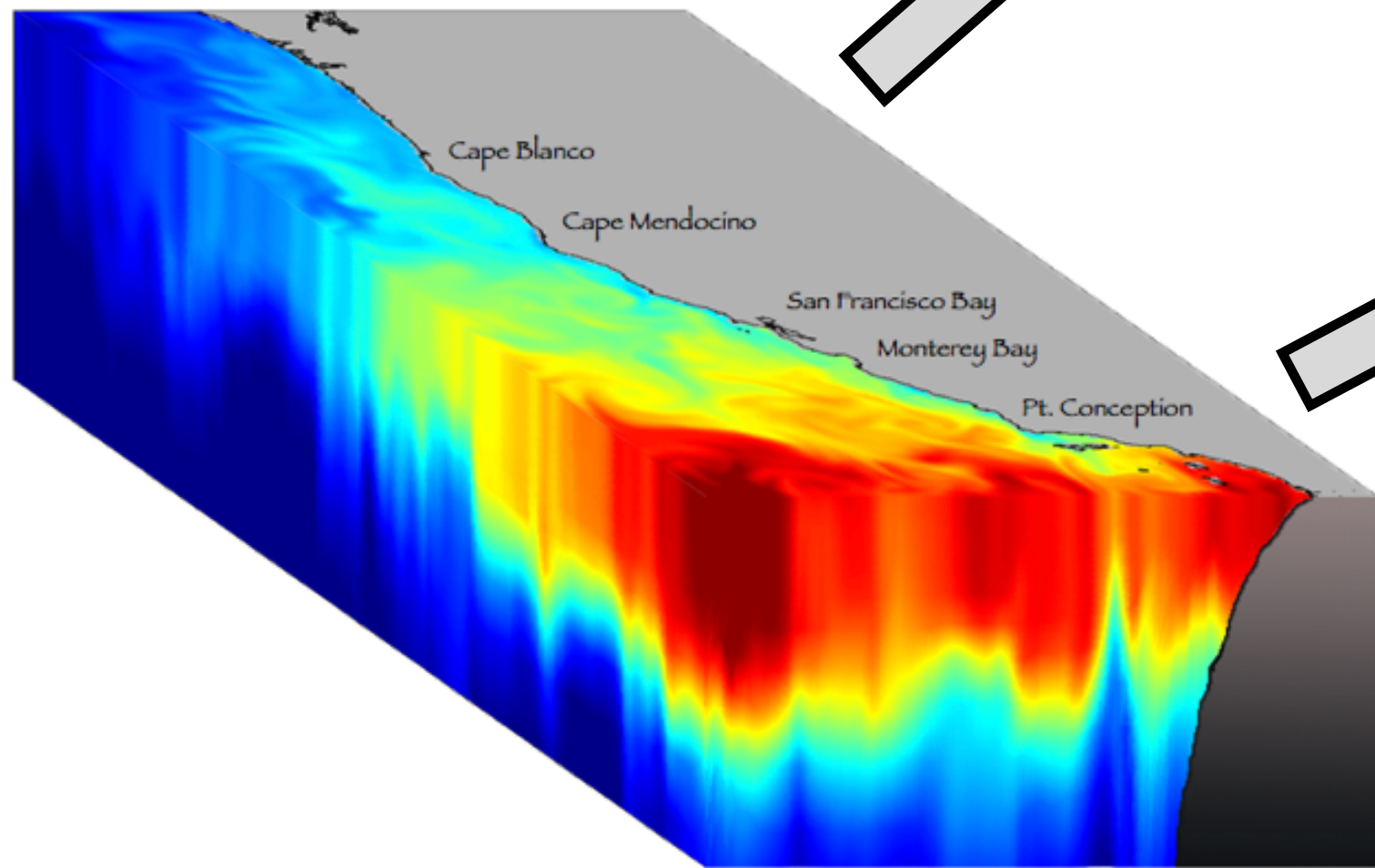


Environmental data from ocean models

Species distribution models



Stock Assessments

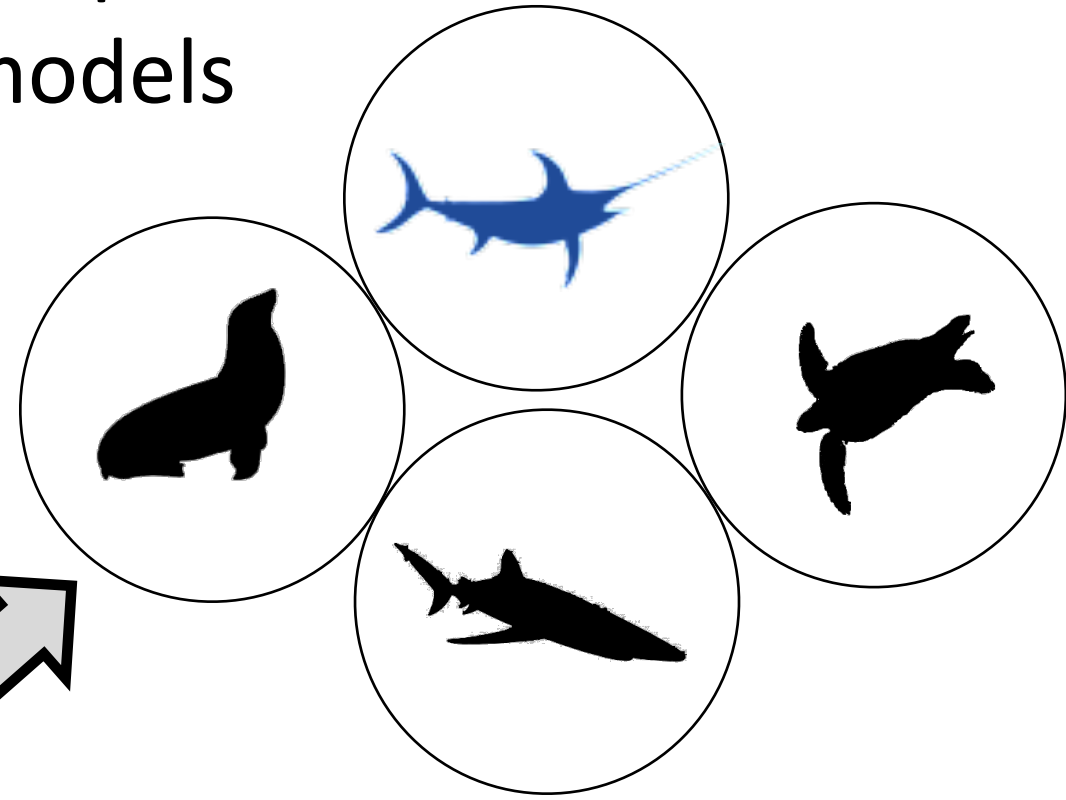


Environmental data from ocean models

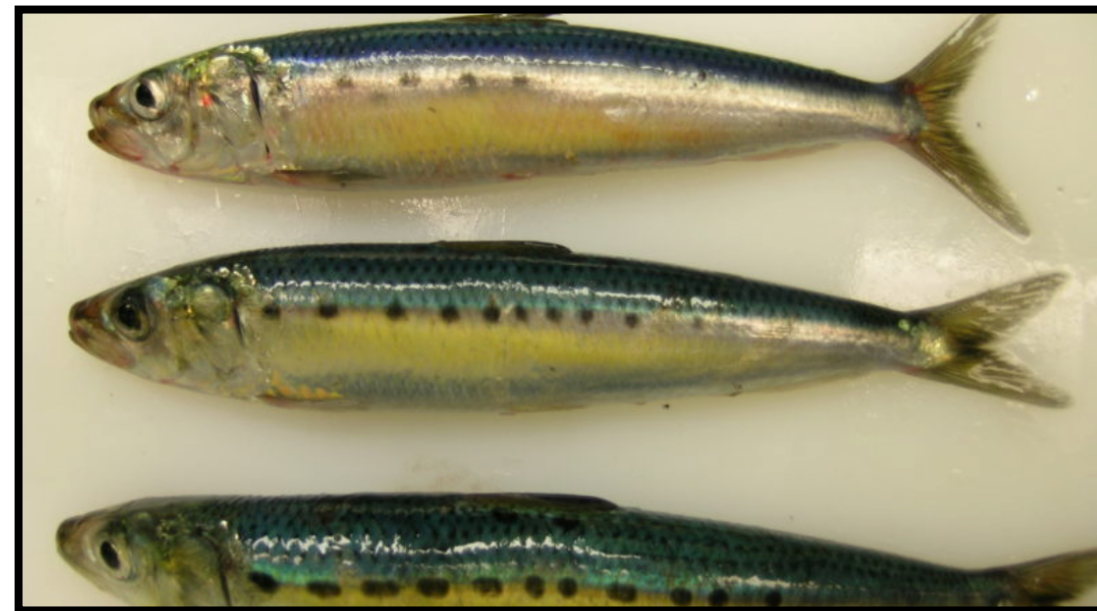


Integrated Ecosystem Assessments

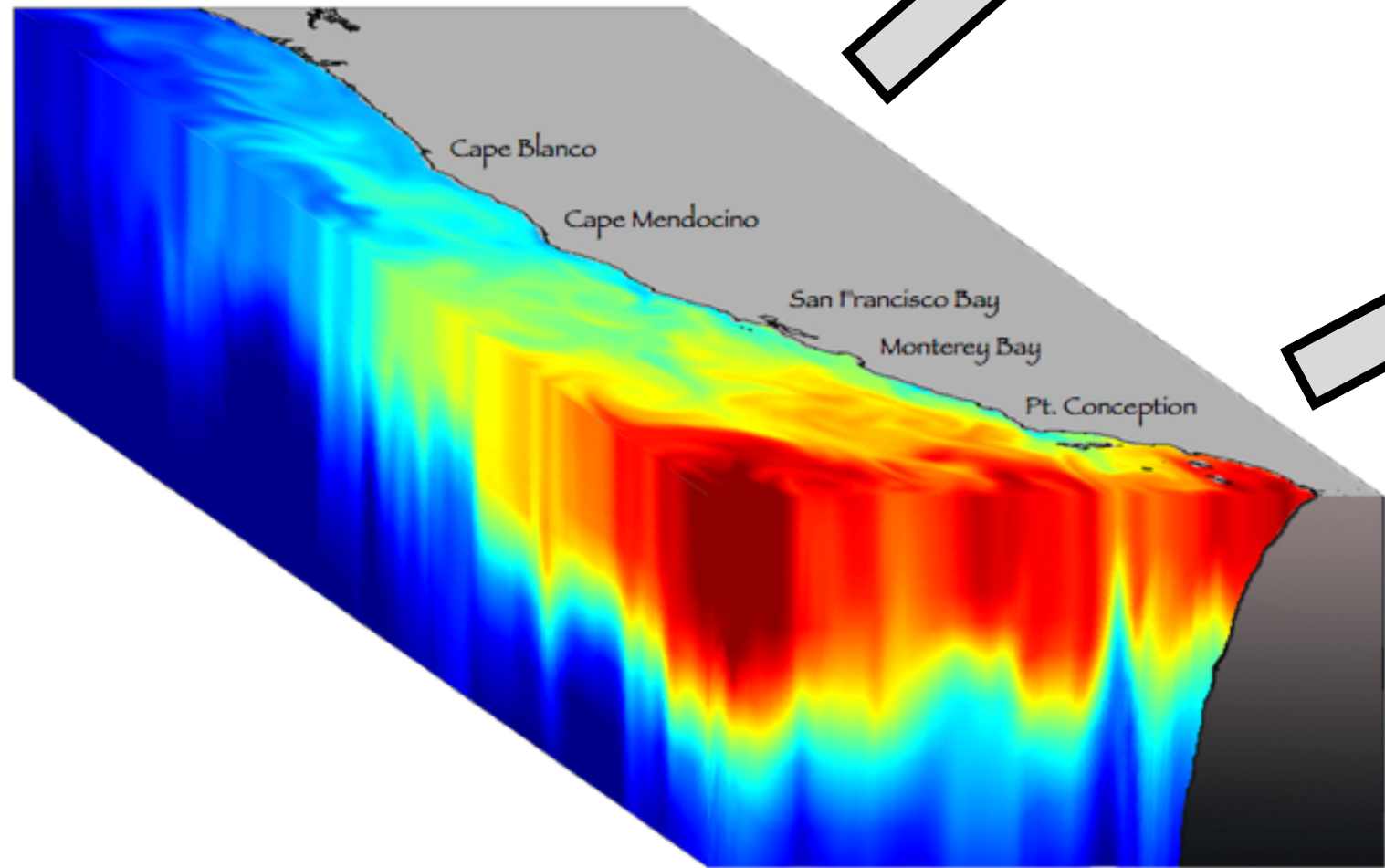
Species distribution models



Stock Assessments



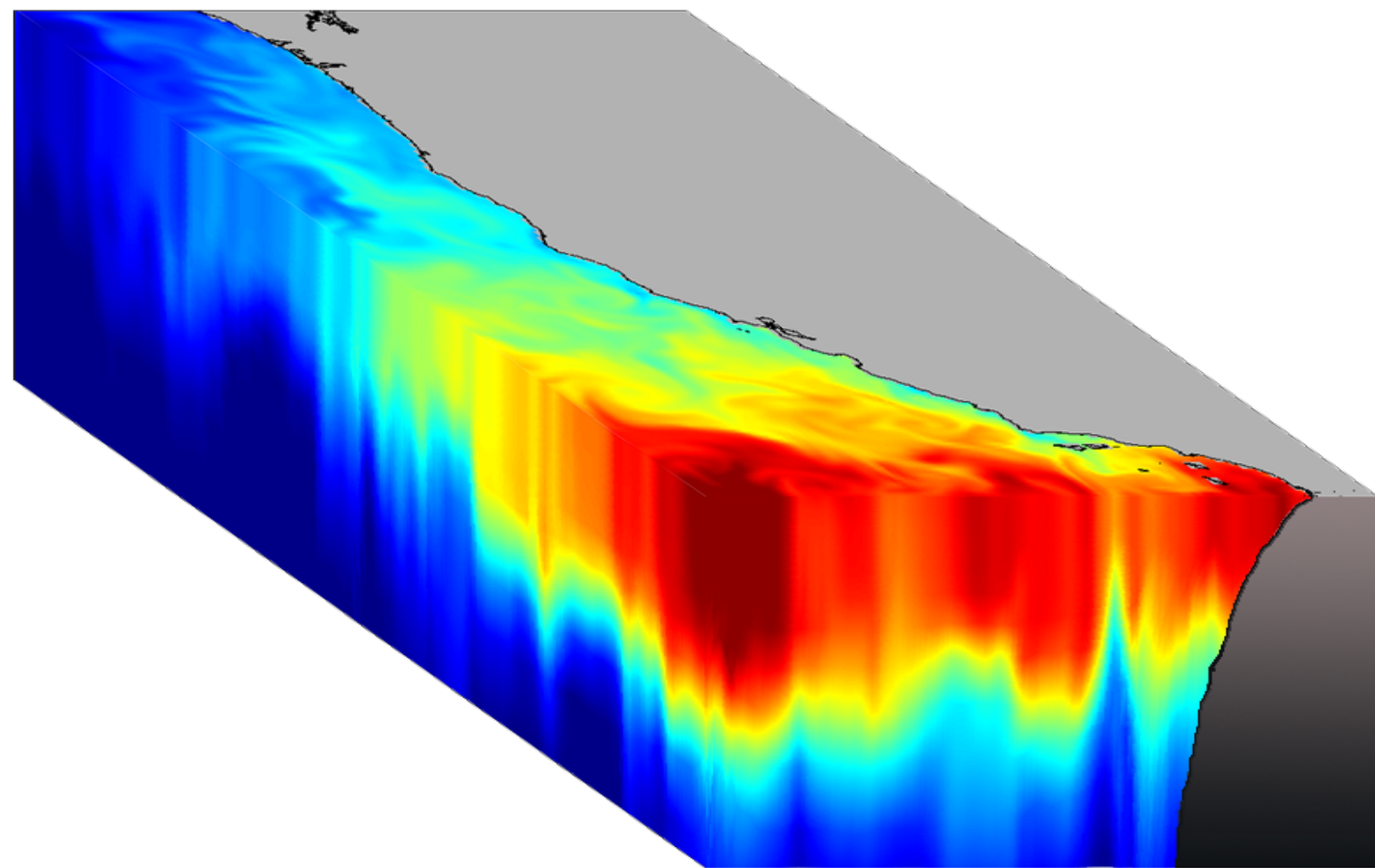
Stakeholders

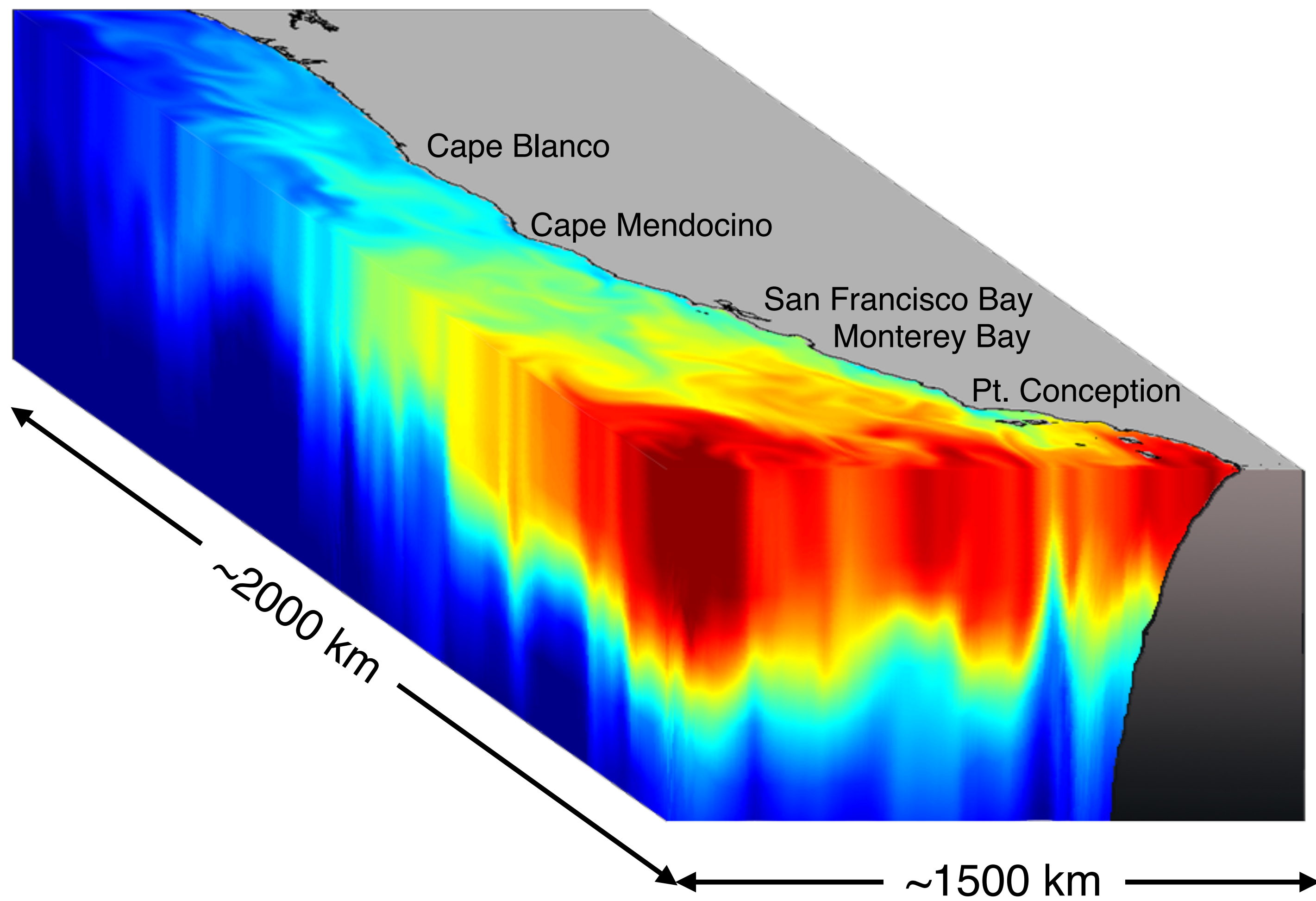


Environmental data from ocean models

Integrated Ecosystem Assessments



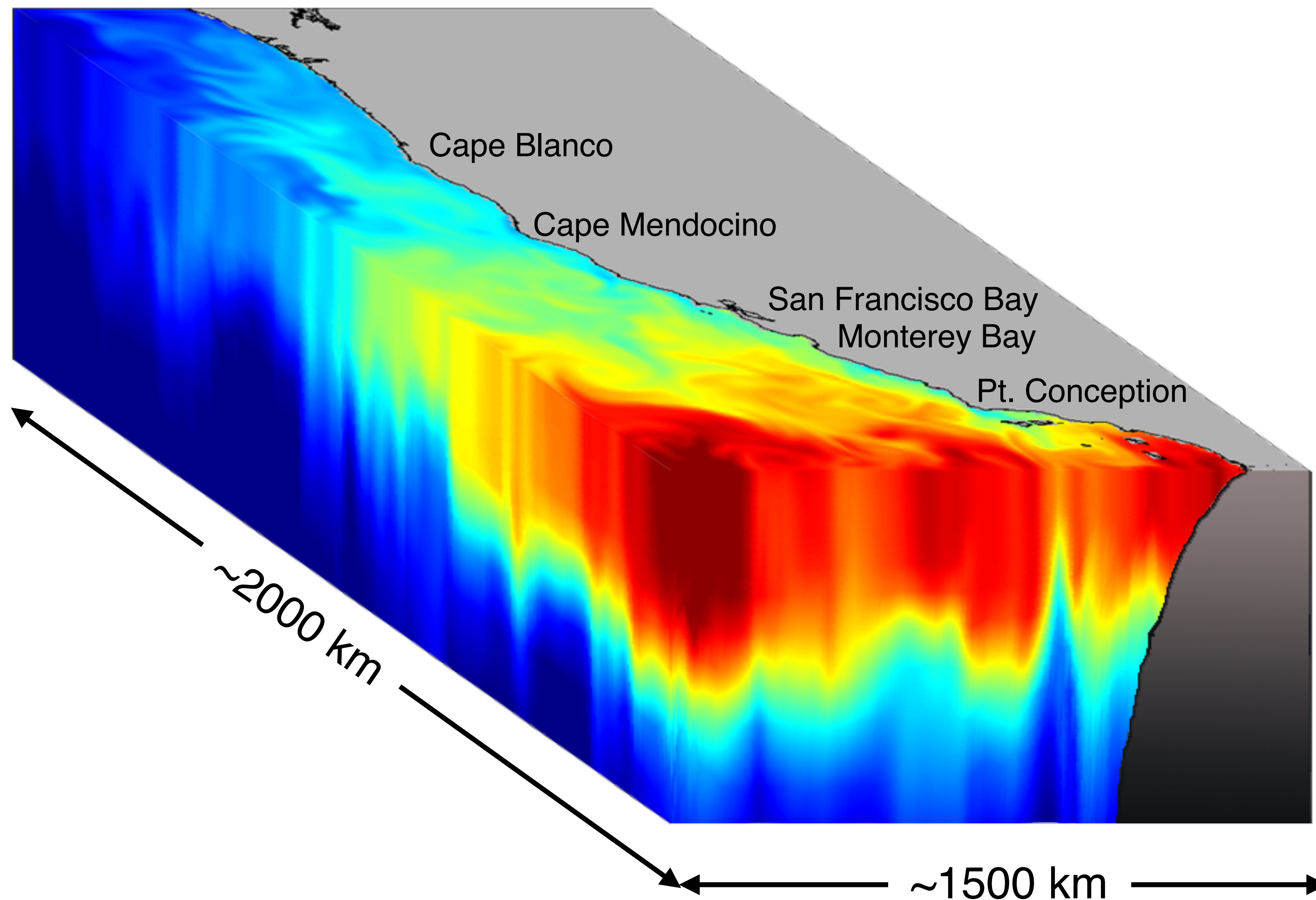




# Regional Ocean Modeling System (ROMS)

1/10° horizontal resolution (~7-11 km)

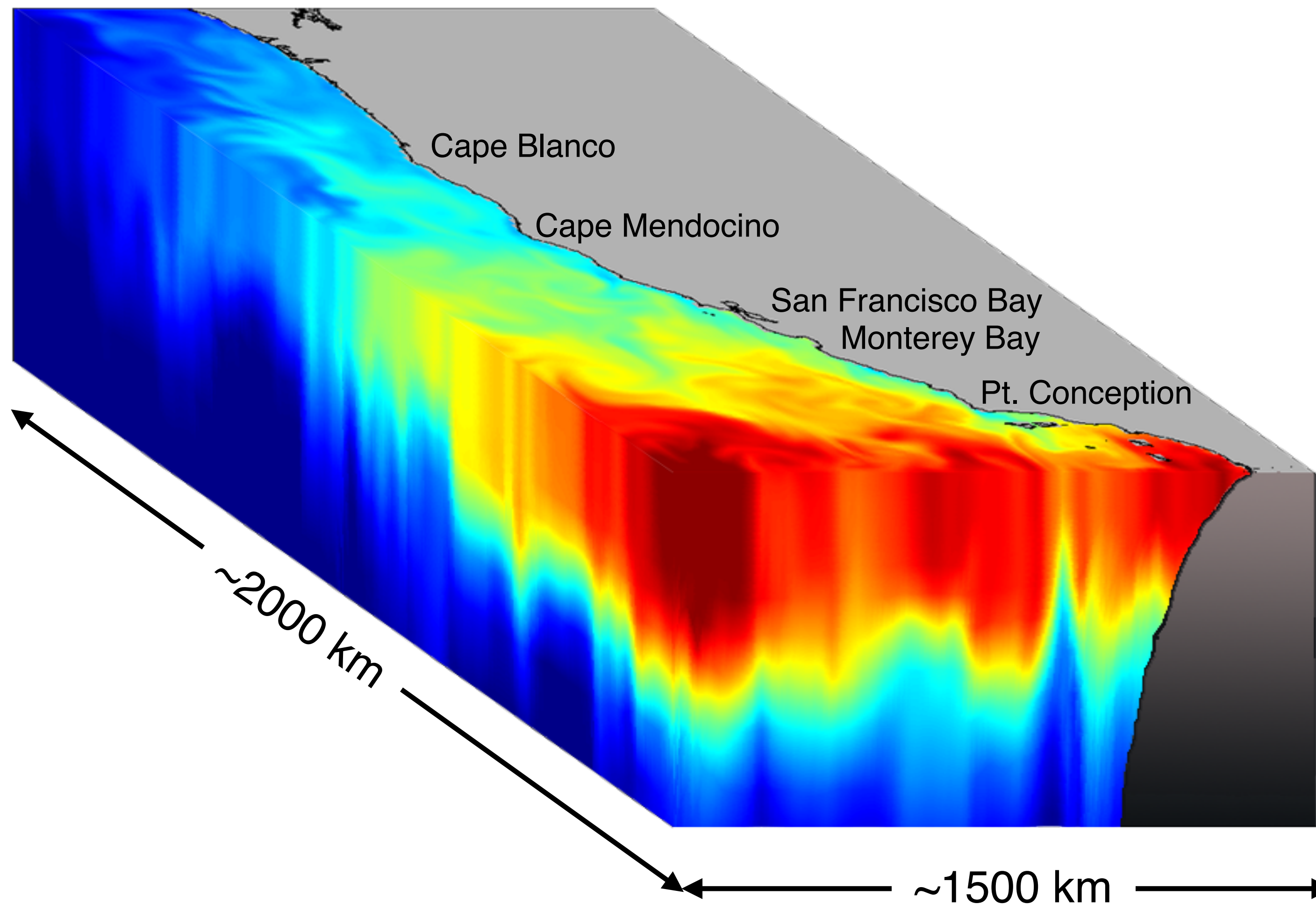
42 vertical levels



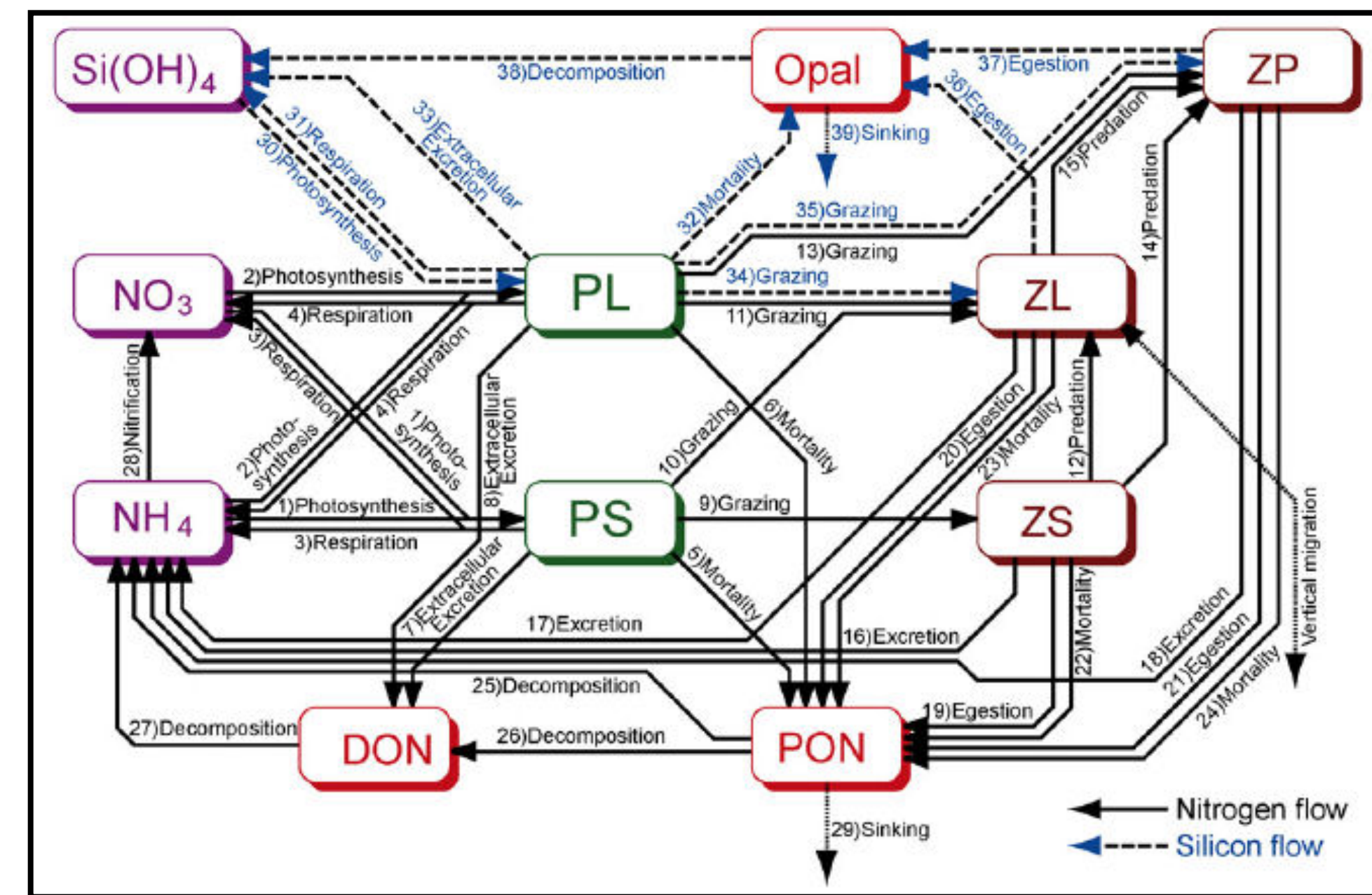
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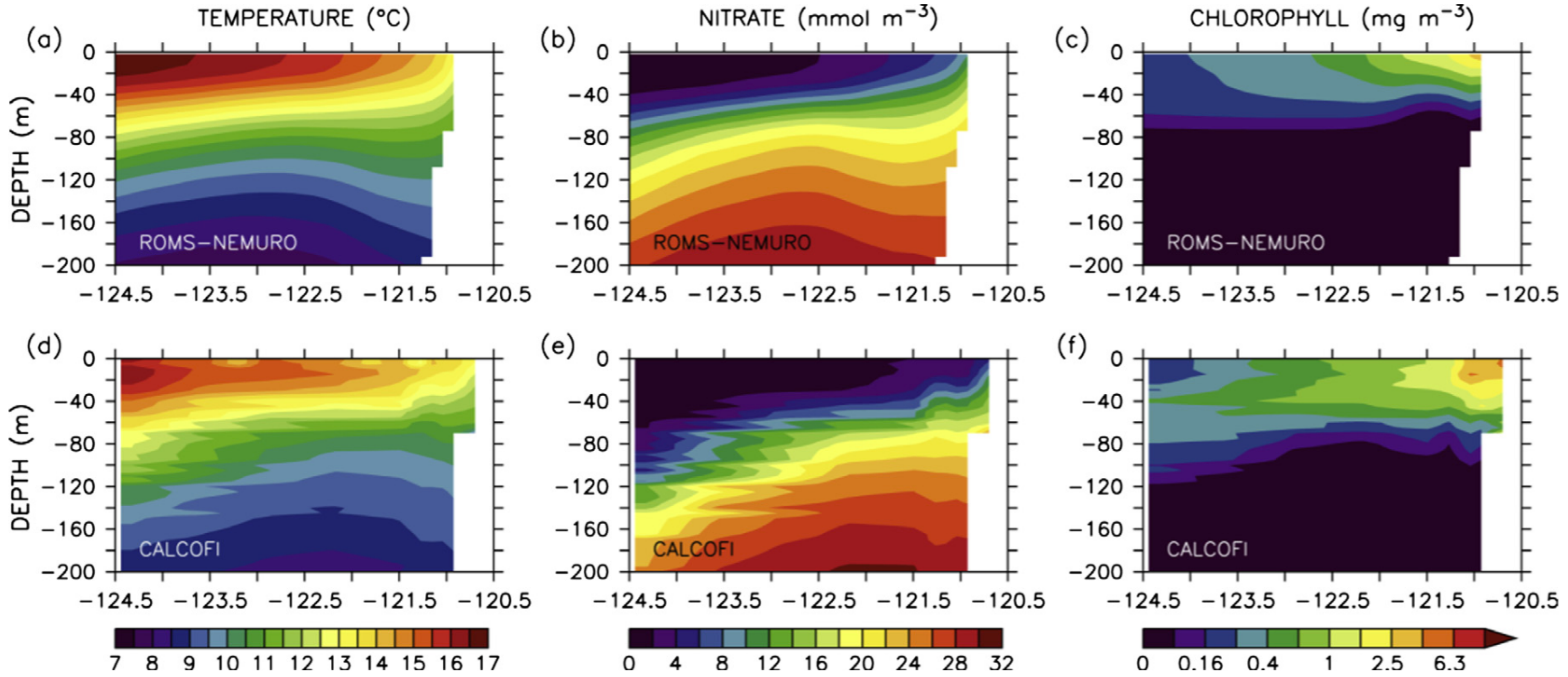


## NEMURO Biogeochemical Model



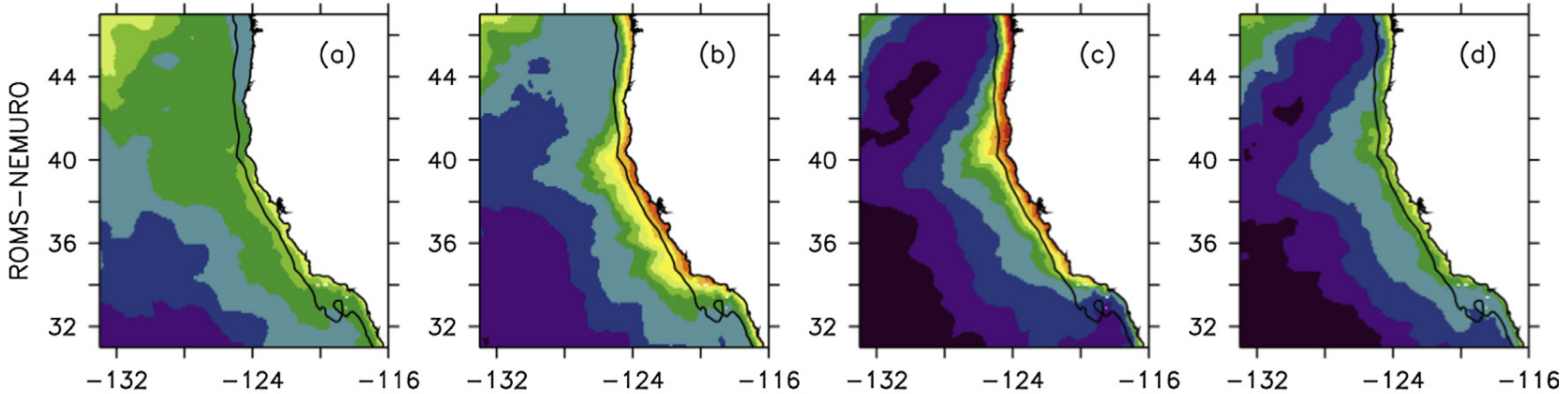
Model

Obs

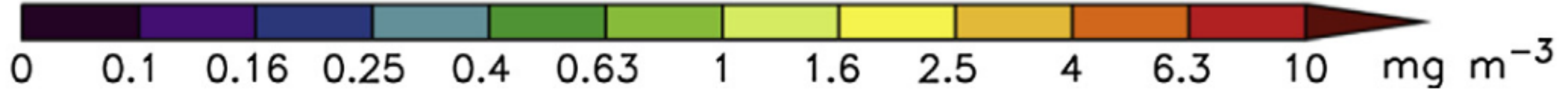
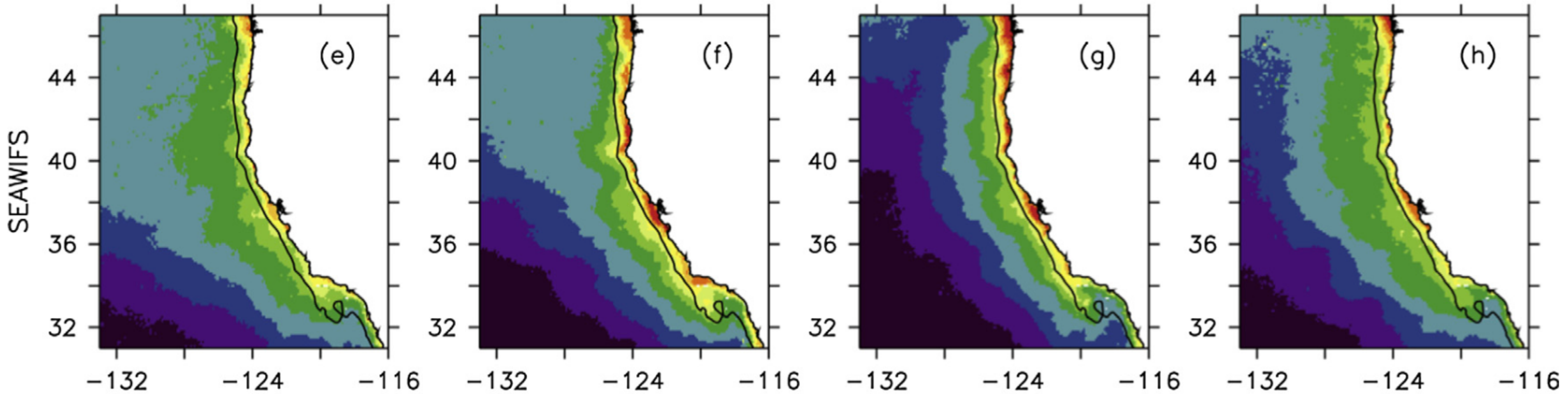


Rose et al. (2015)

Model



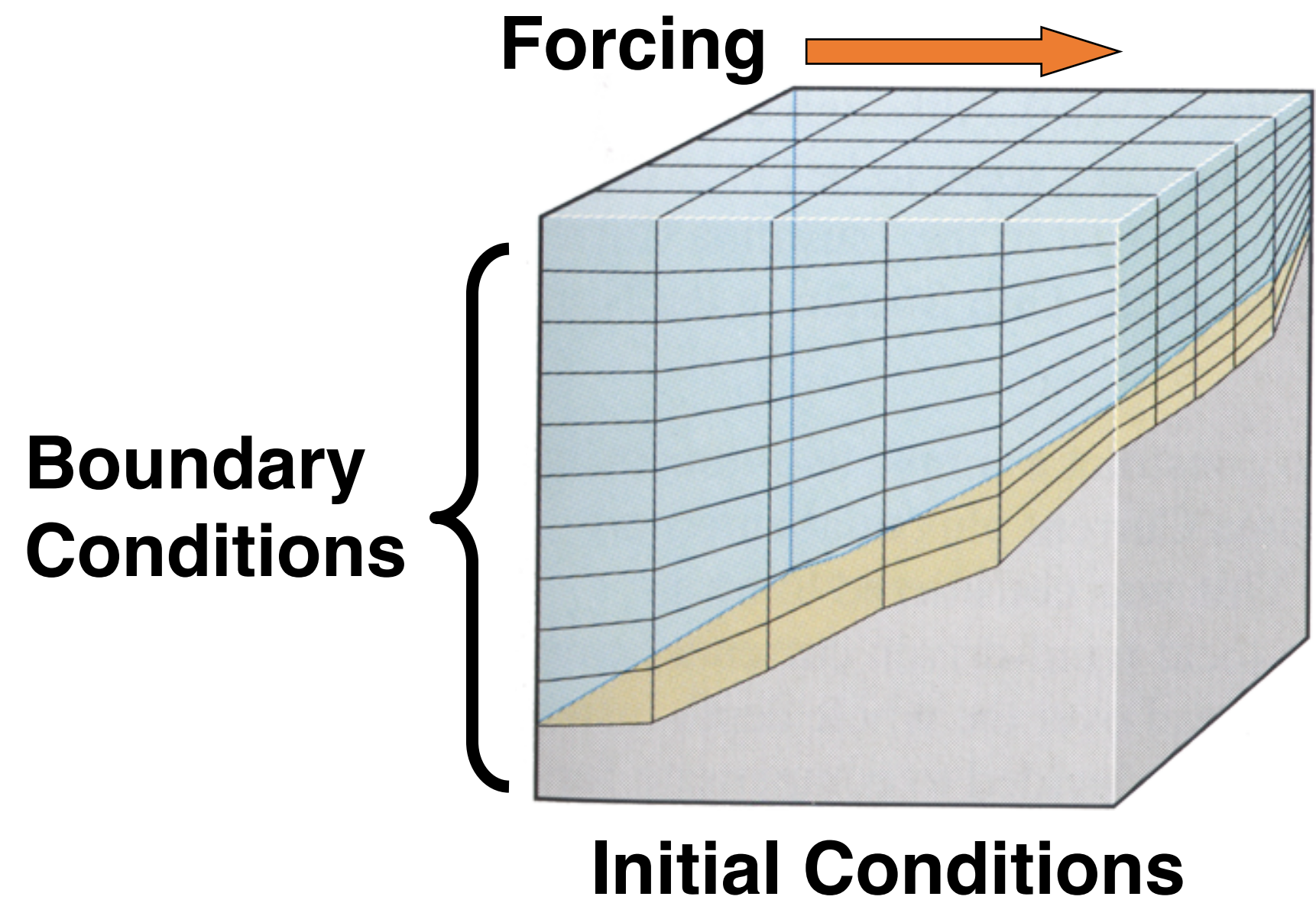
Obs



Surface Chlorophyll Concentration

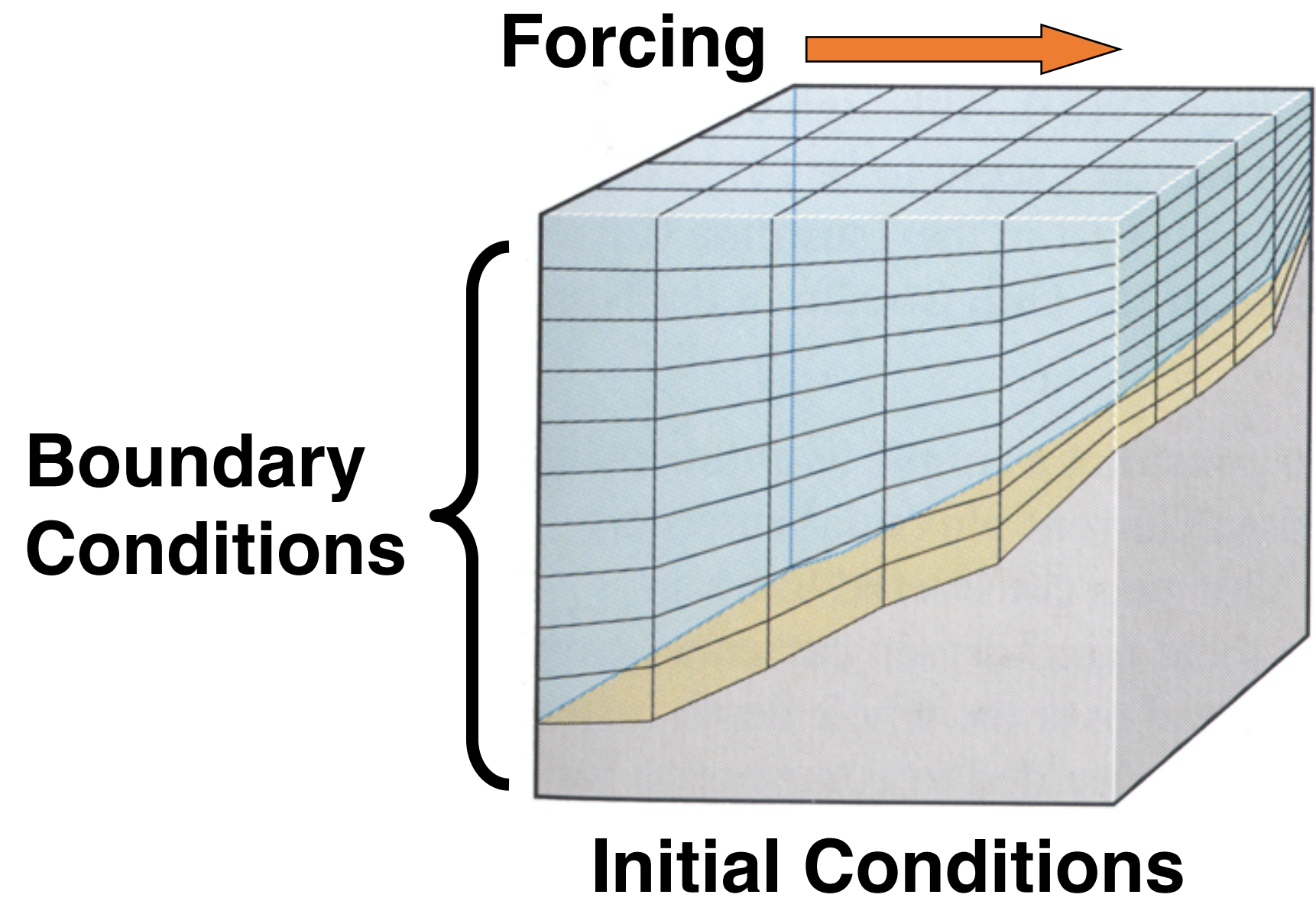
Rose et al. (2015)

# Model



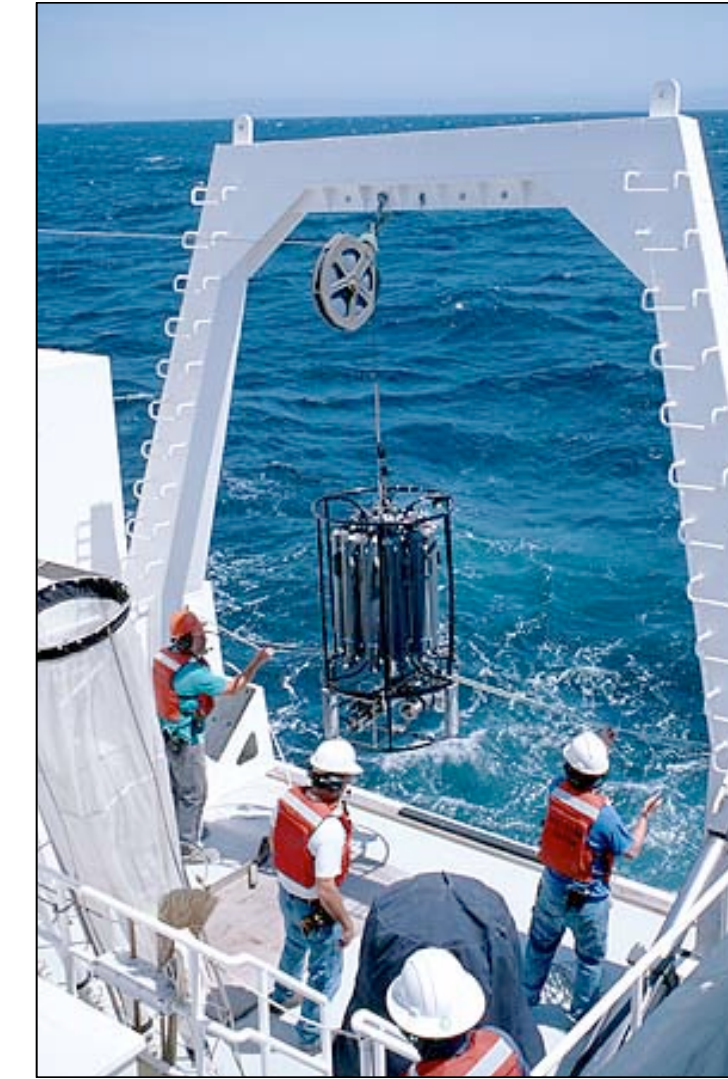
**Complete picture of the ocean but  
subject to errors and uncertainties**

## Model



**Complete picture of the ocean but  
subject to errors and uncertainties**

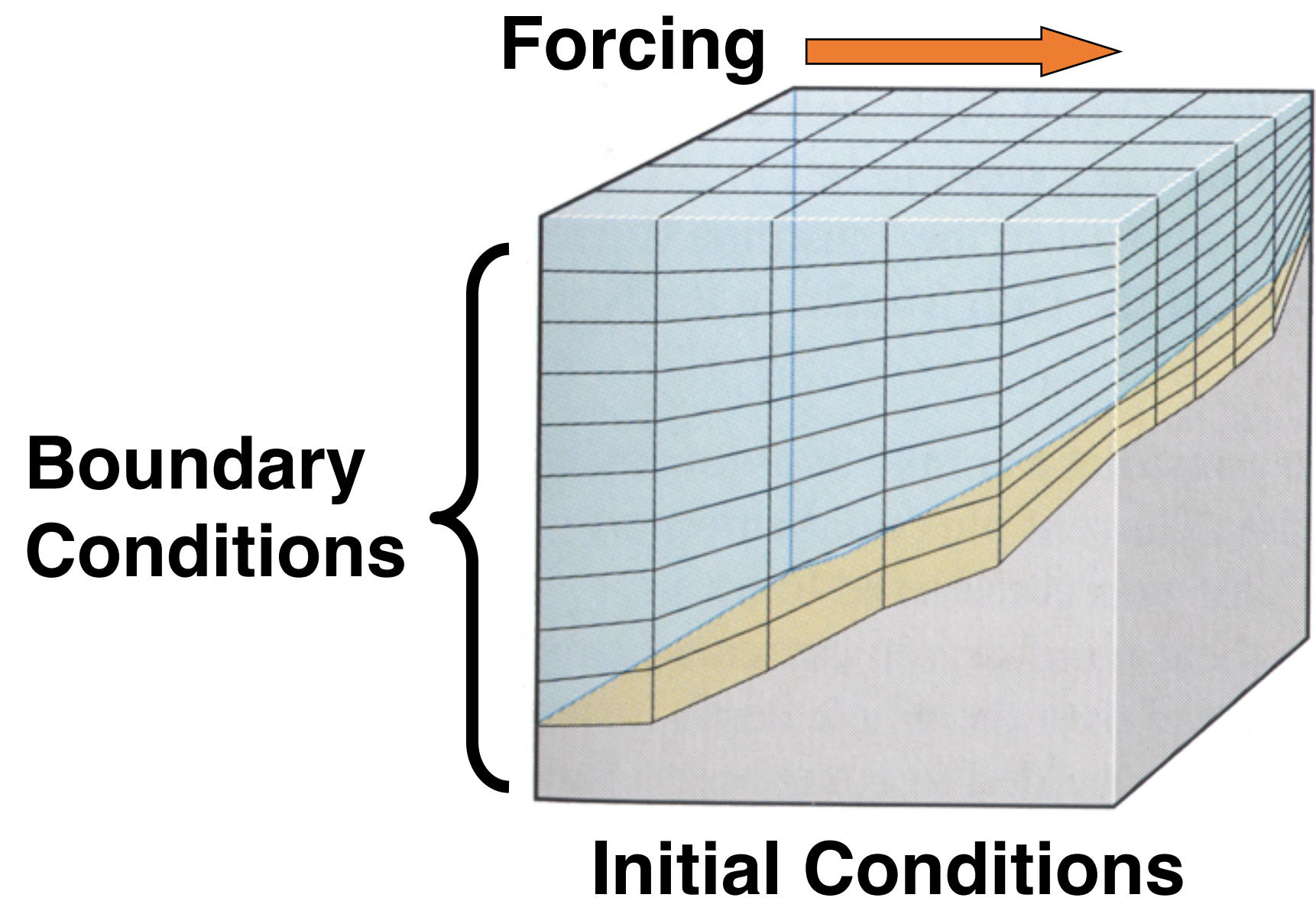
## Observations



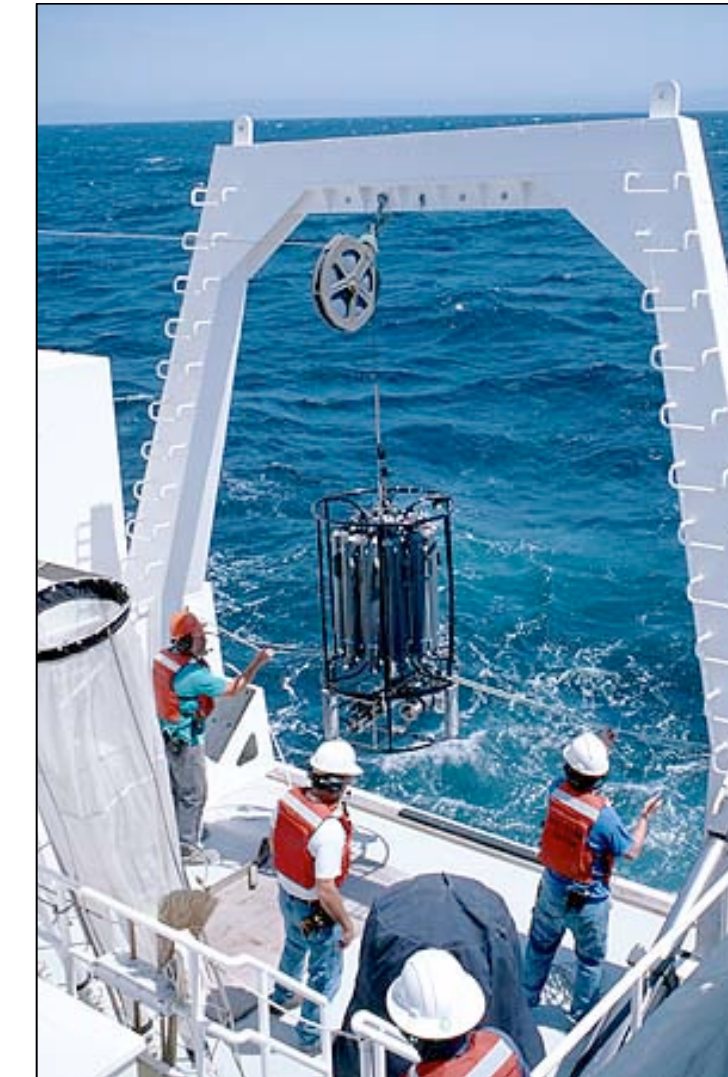
**Incomplete picture of real ocean**



## Model



## Observations

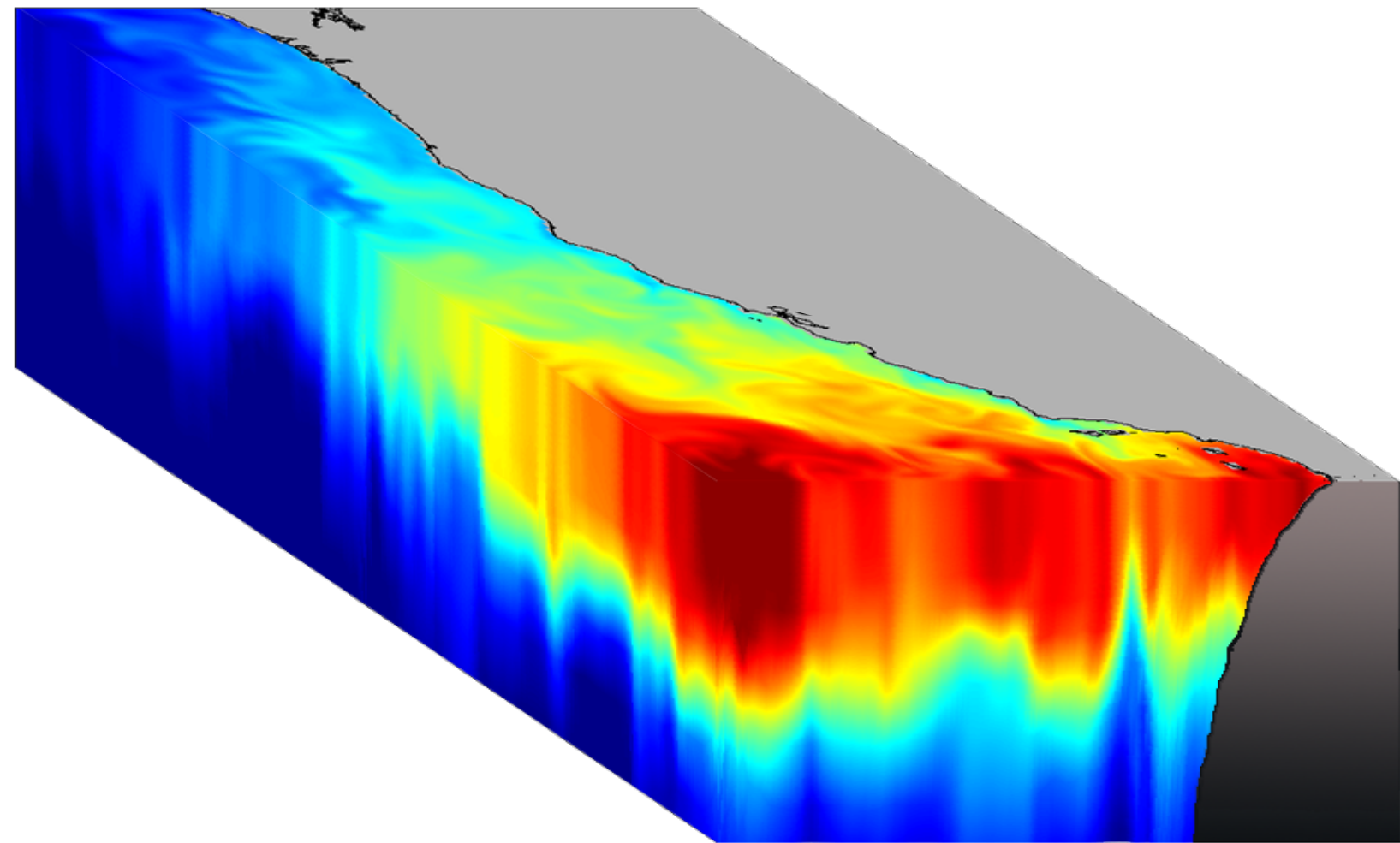
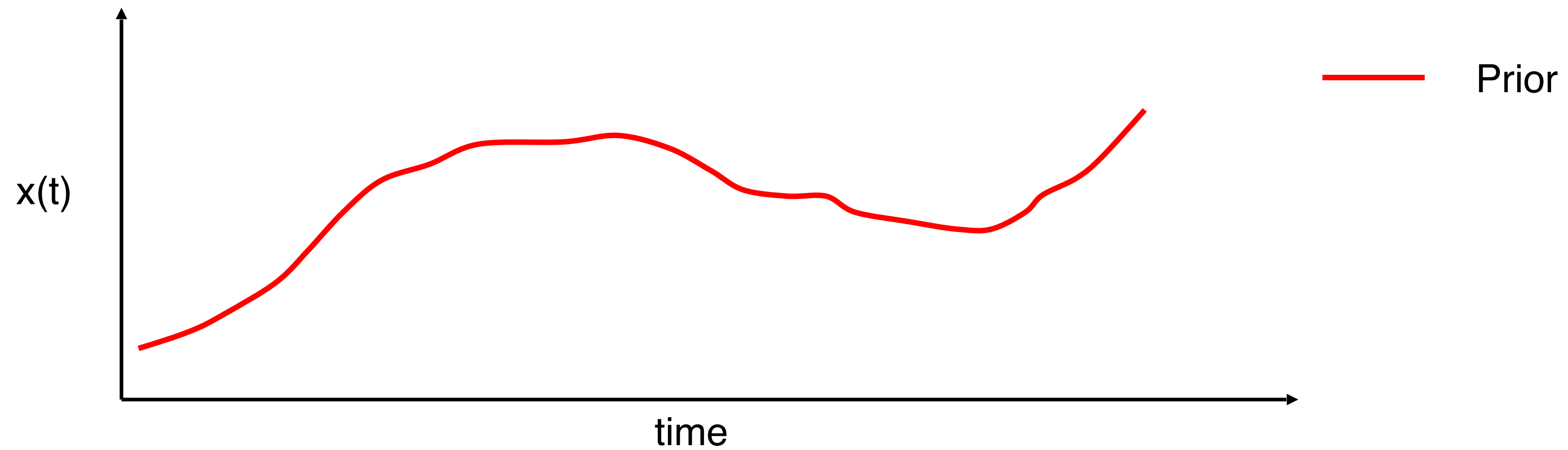


**Complete picture of the ocean but  
subject to errors and uncertainties**

**Incomplete picture of real ocean**

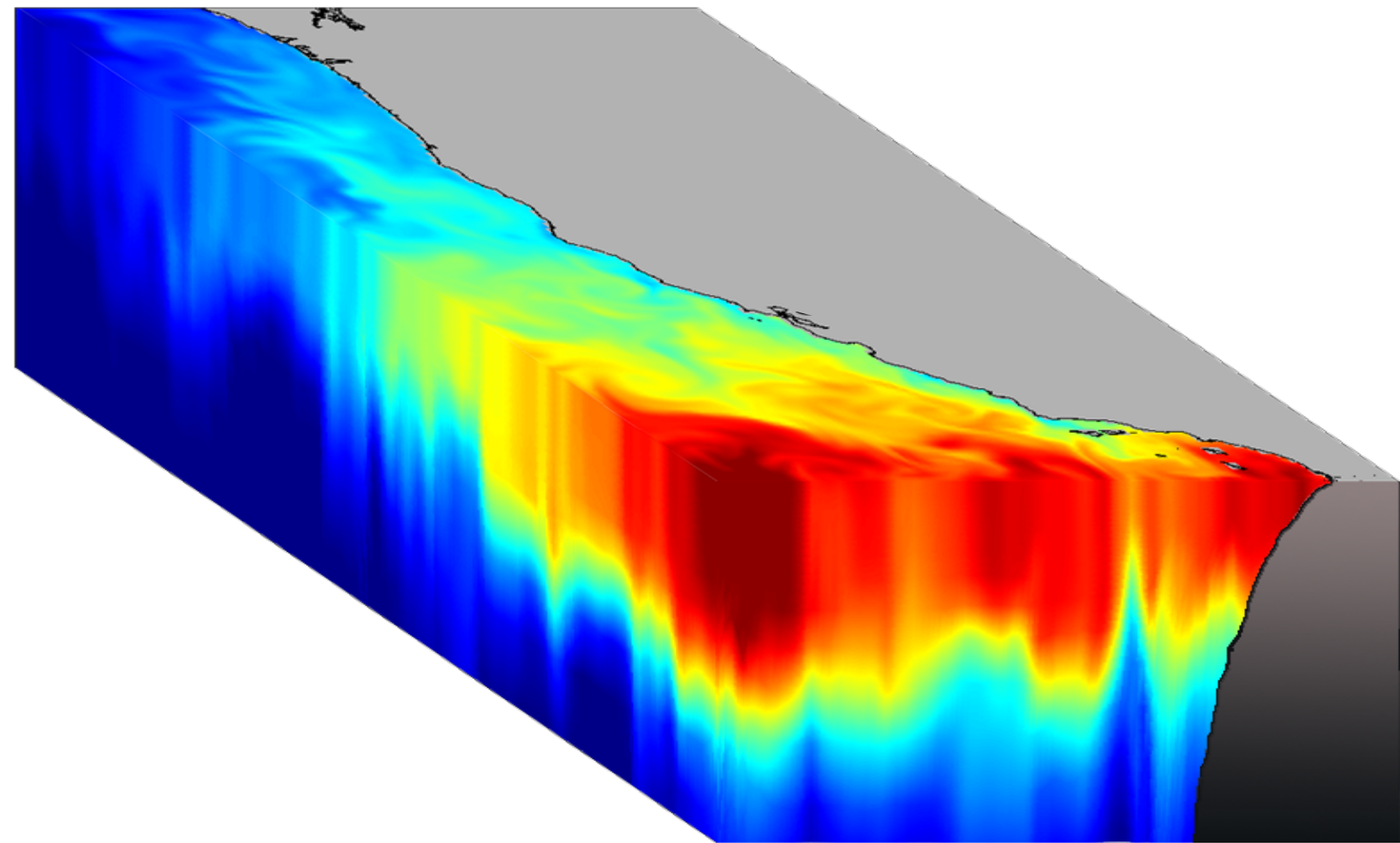
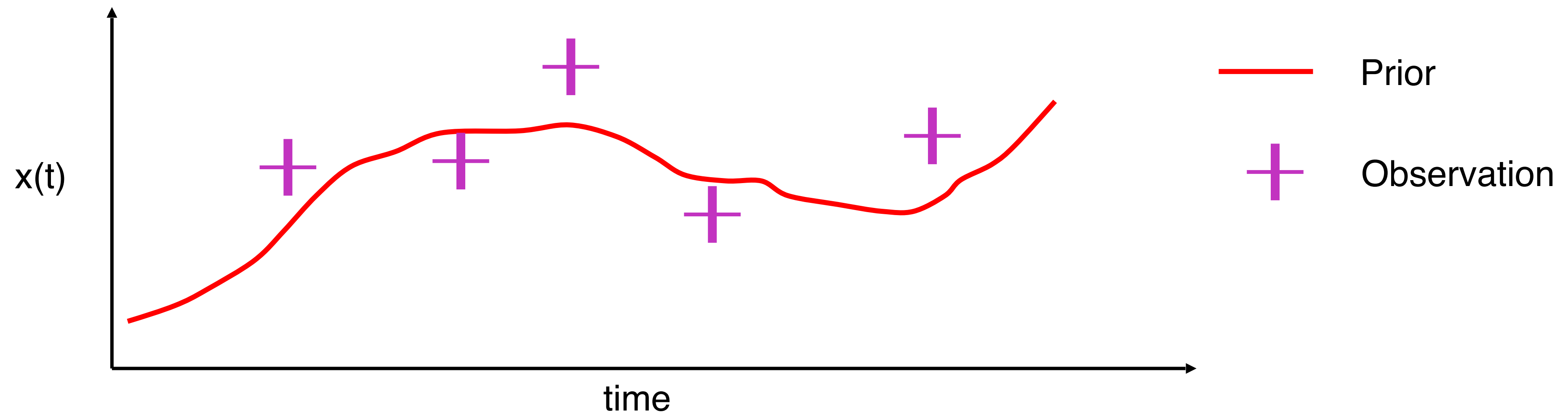


# Data Assimilation for Ocean State Estimation (4DVar)

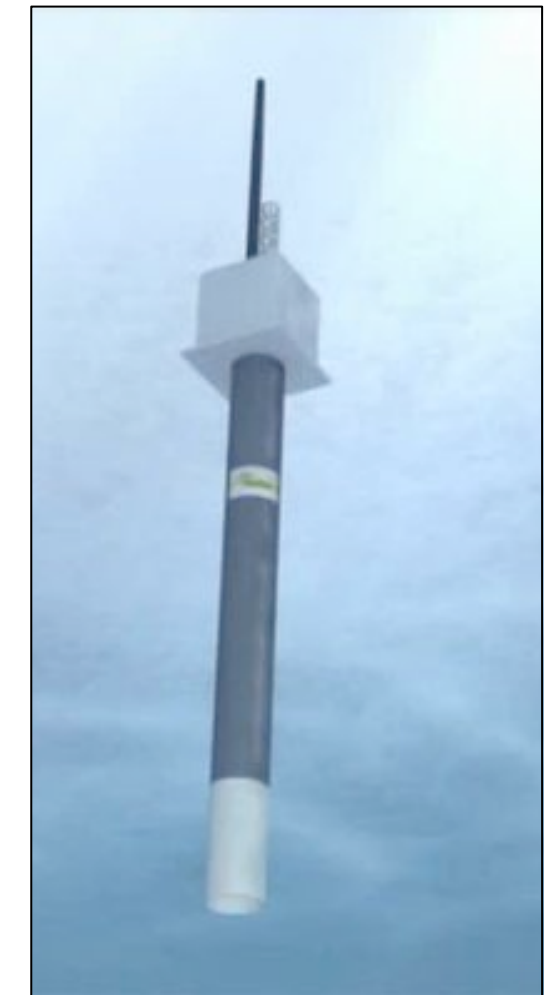
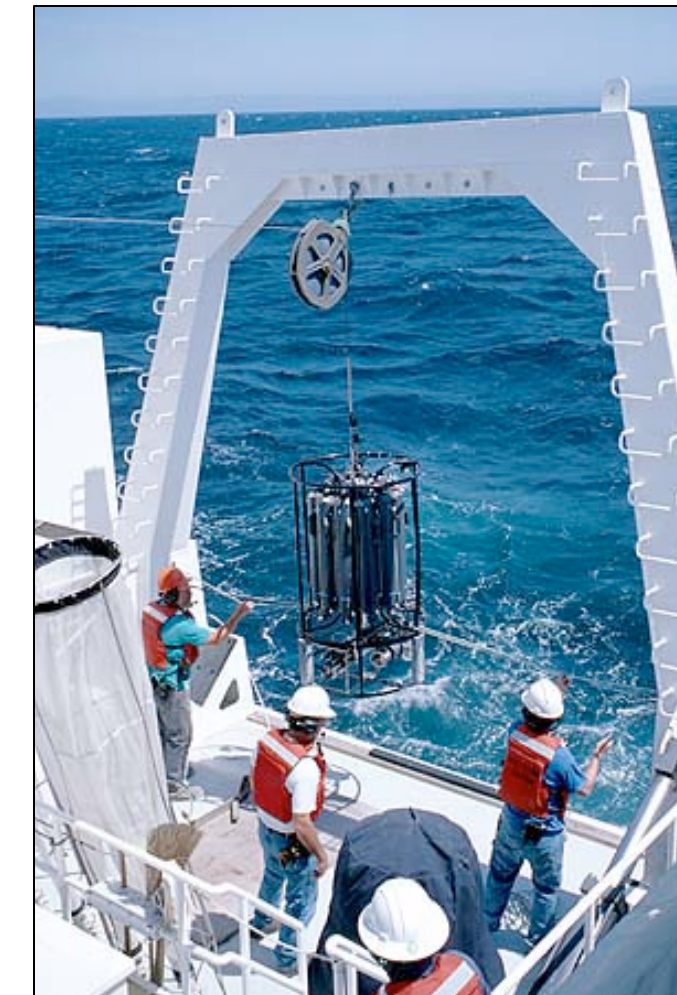


Prior/Posterior (ROMS)

# Data Assimilation for Ocean State Estimation (4DVar)

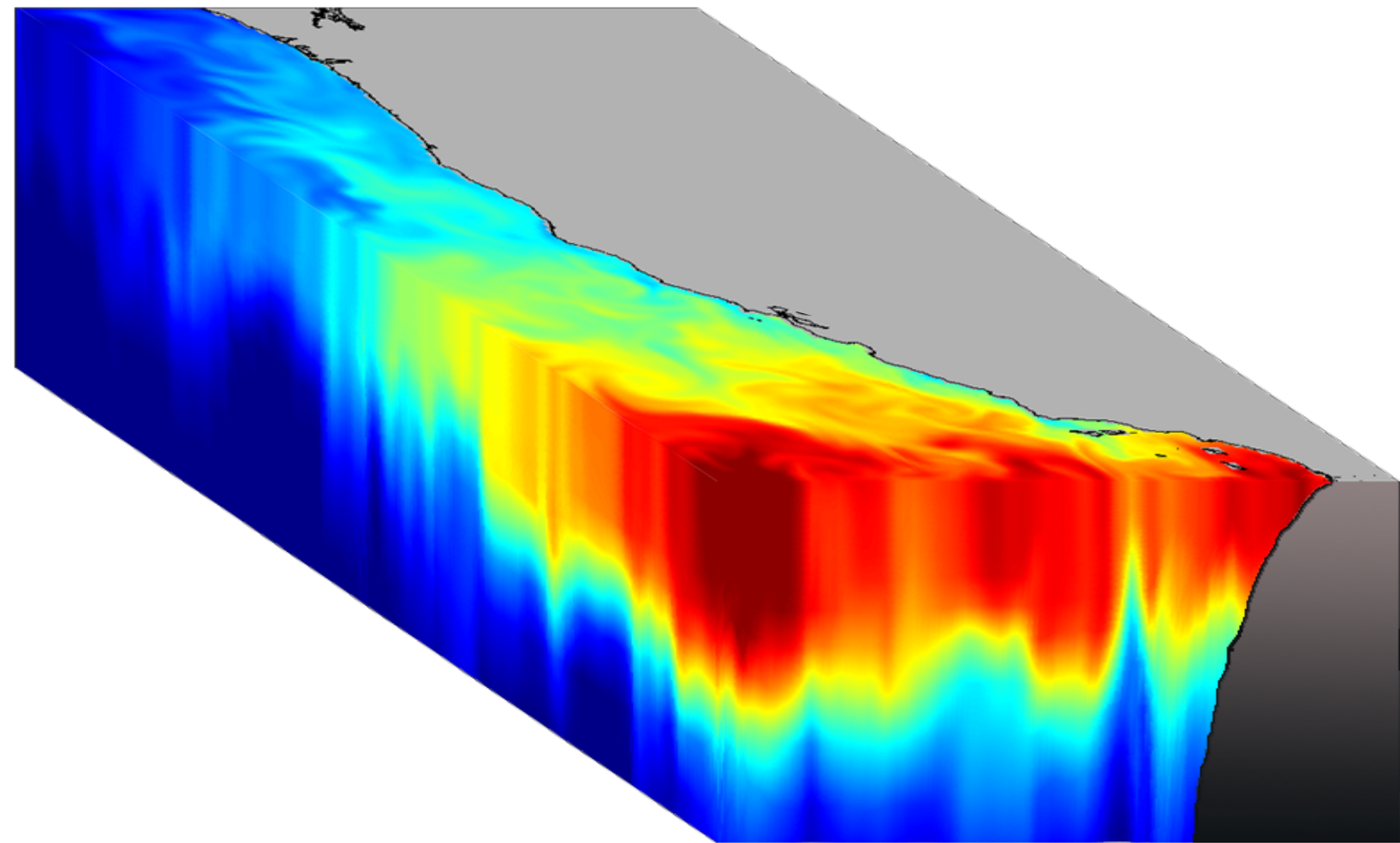
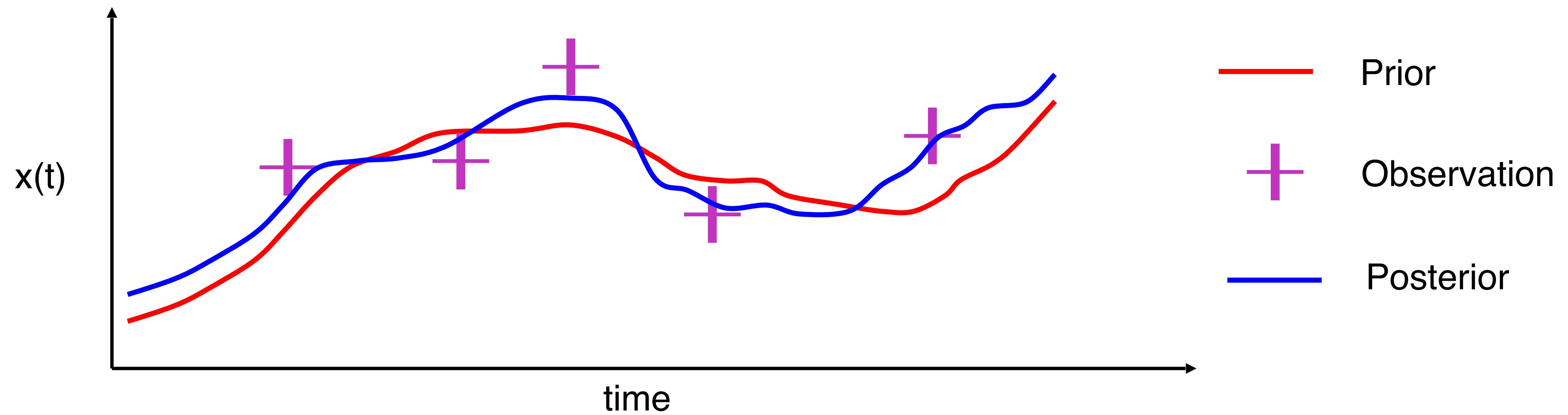


Prior/Posterior (ROMS)

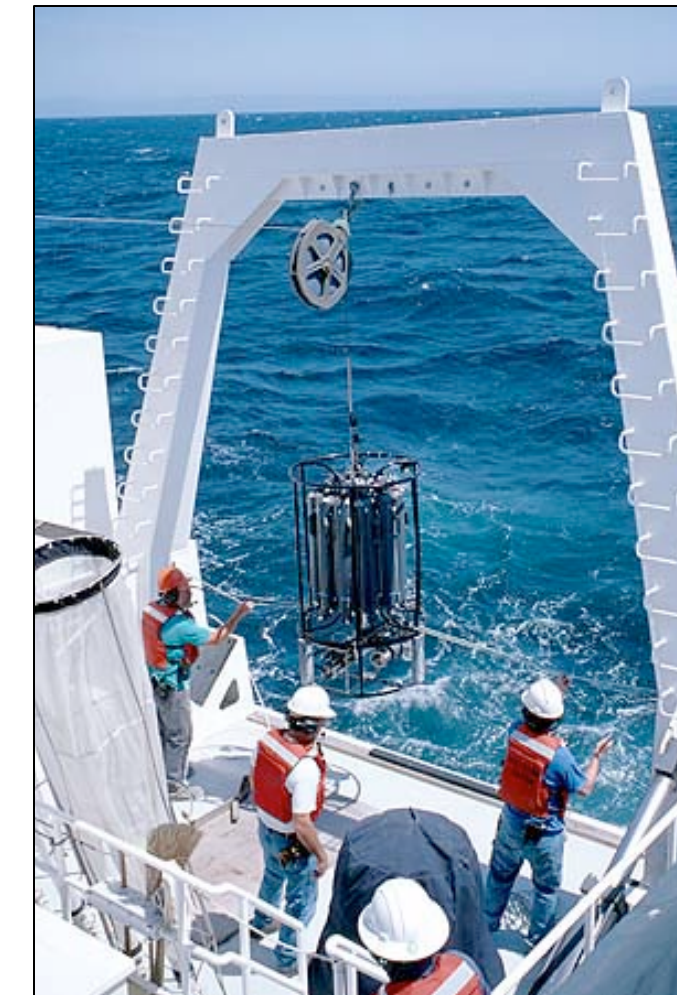


Observations

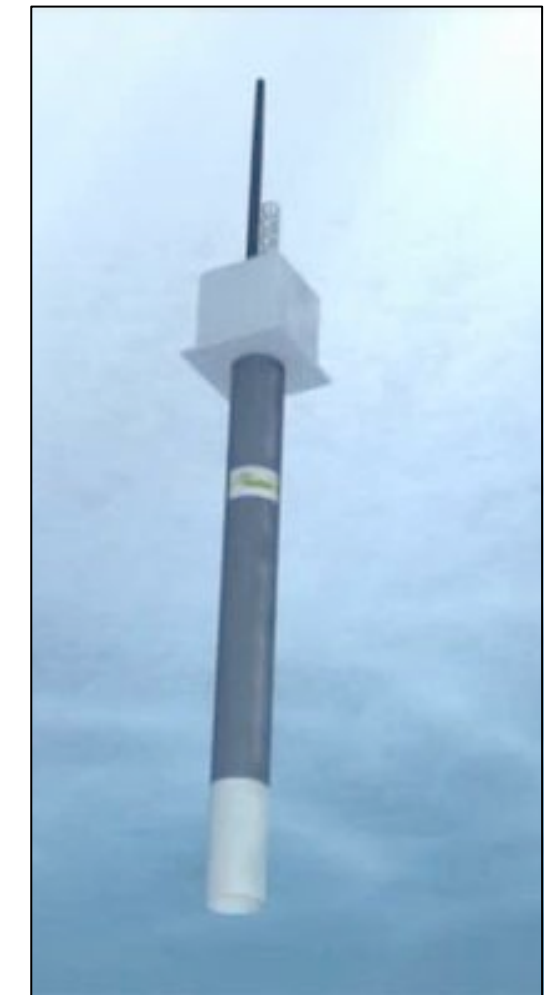
# Data Assimilation for Ocean State Estimation (4DVar)



Prior/Posterior (ROMS)



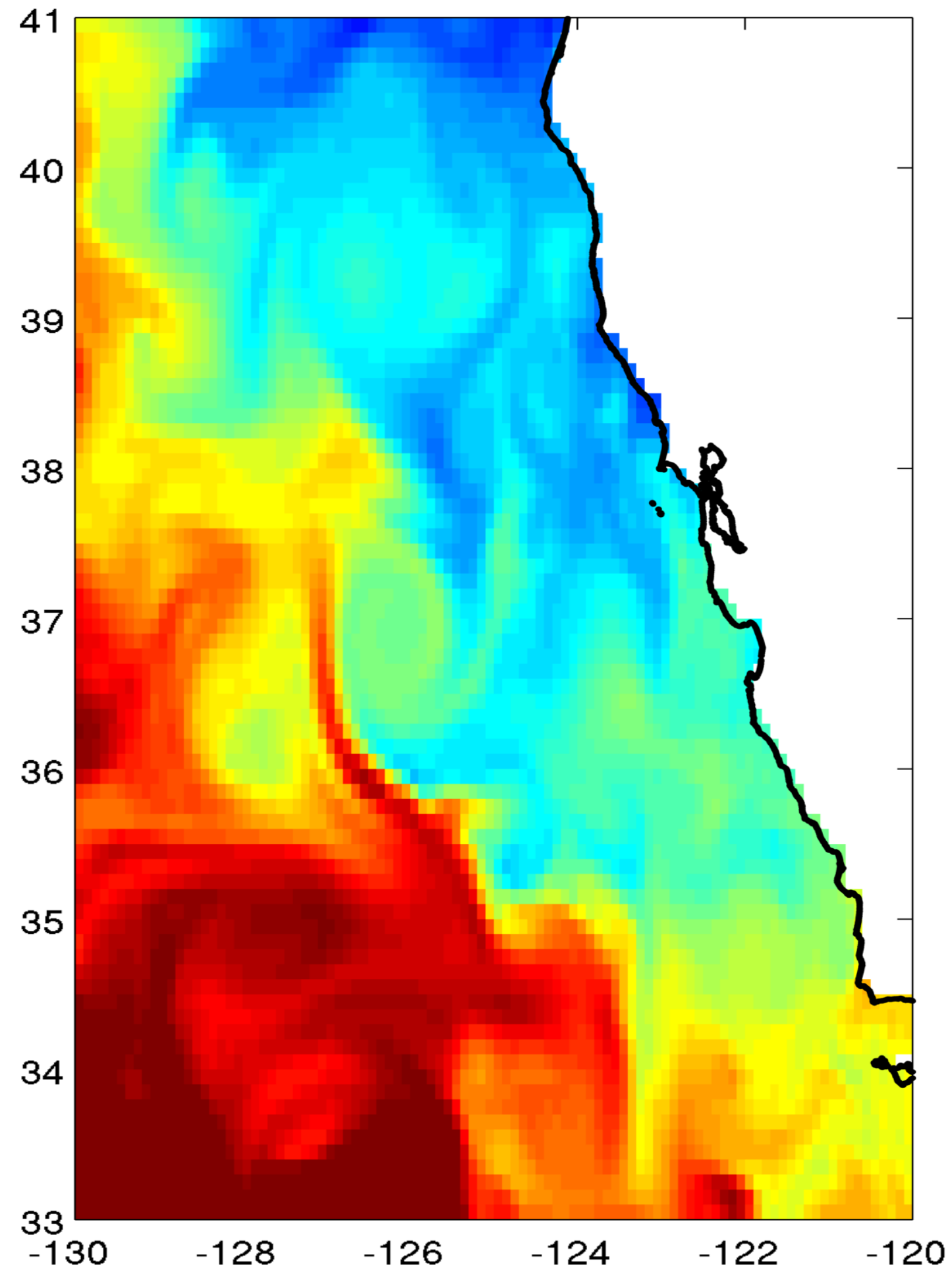
Observations



# Data Assimilation for Ocean State Estimation (4DVar)

Jan. 2010 SST

Prior

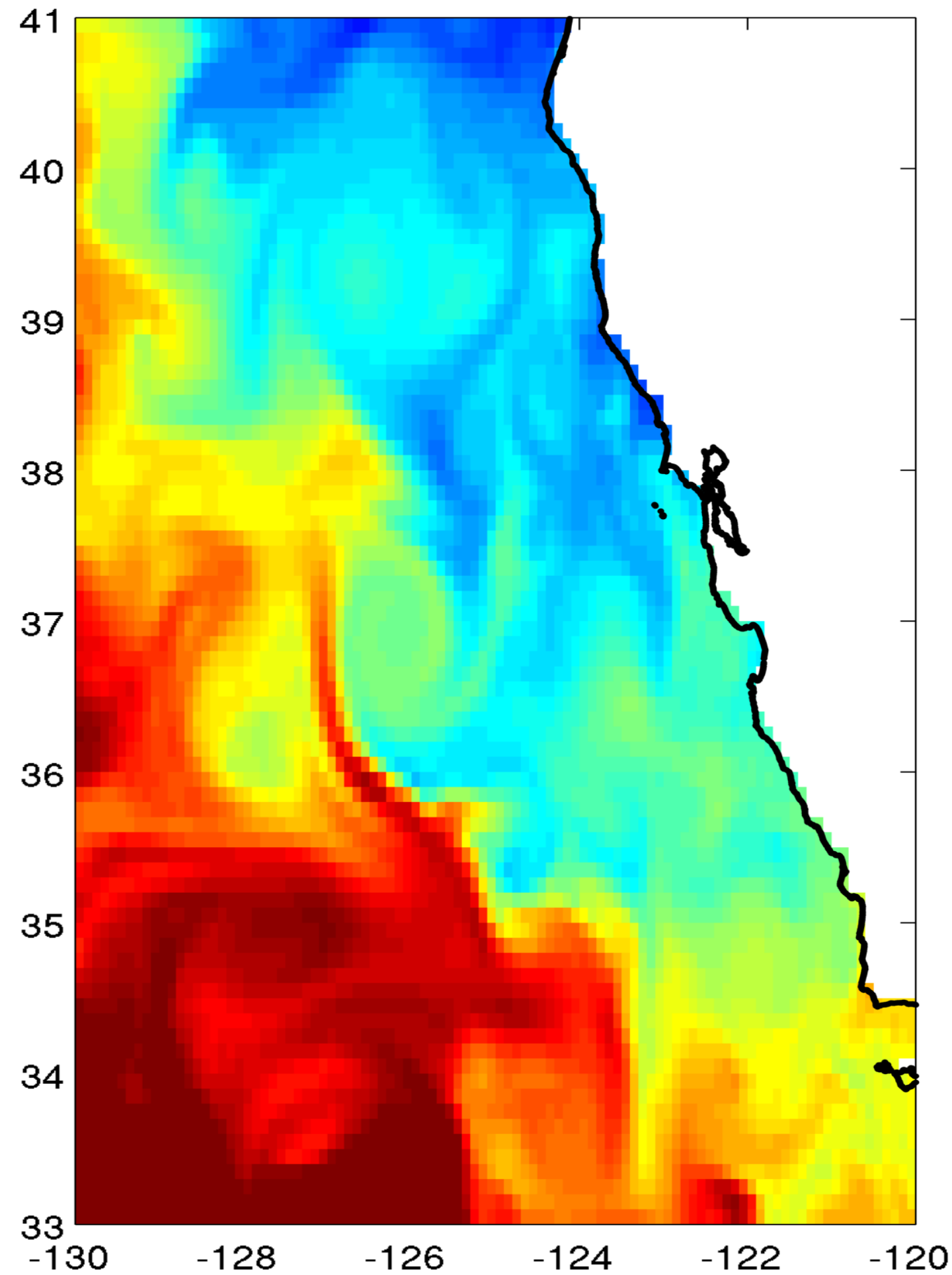


Sea Surface Temperature (°C)

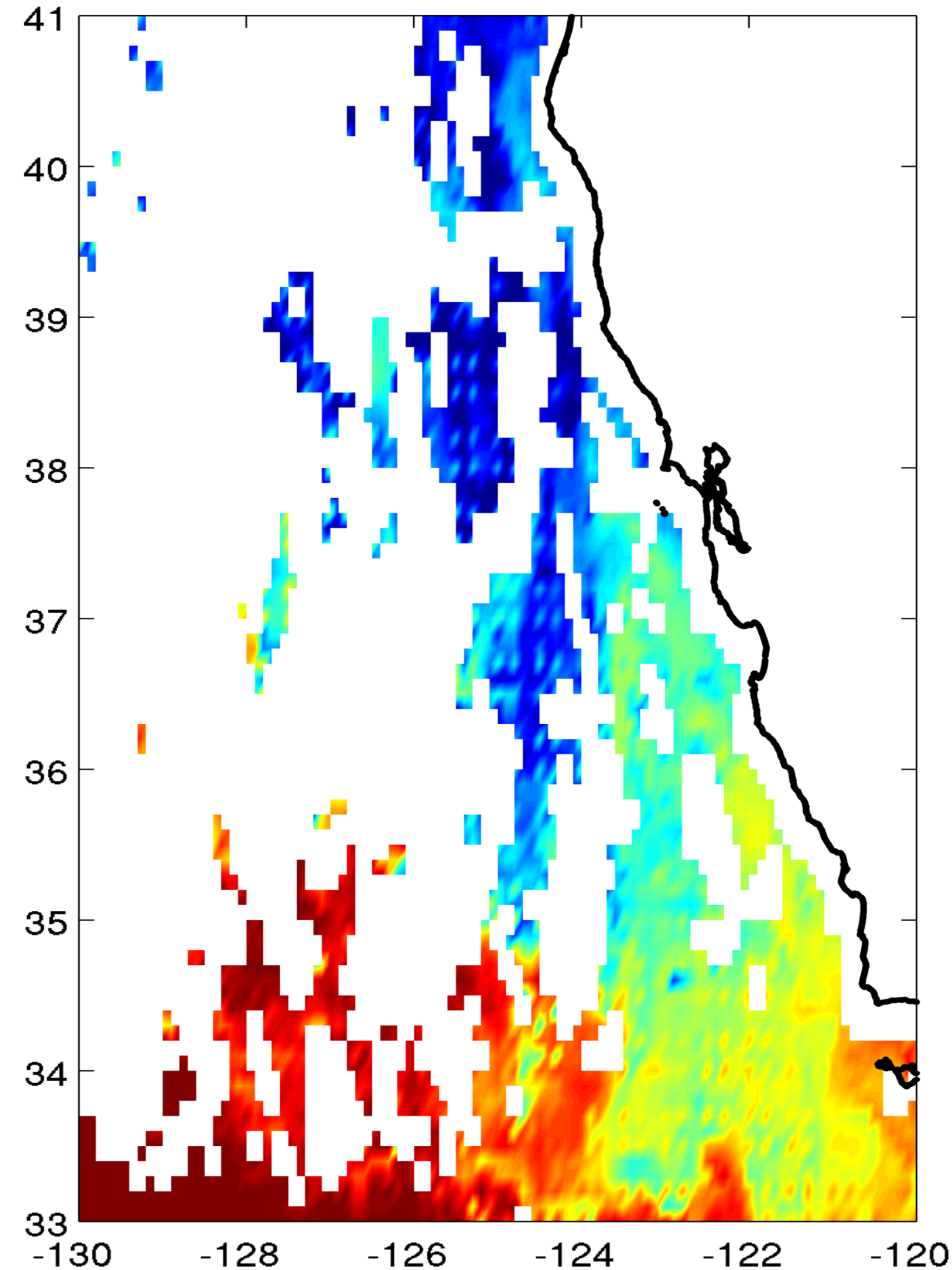
# Data Assimilation for Ocean State Estimation (4DVar)

Jan. 2010 SST

Prior



Observations

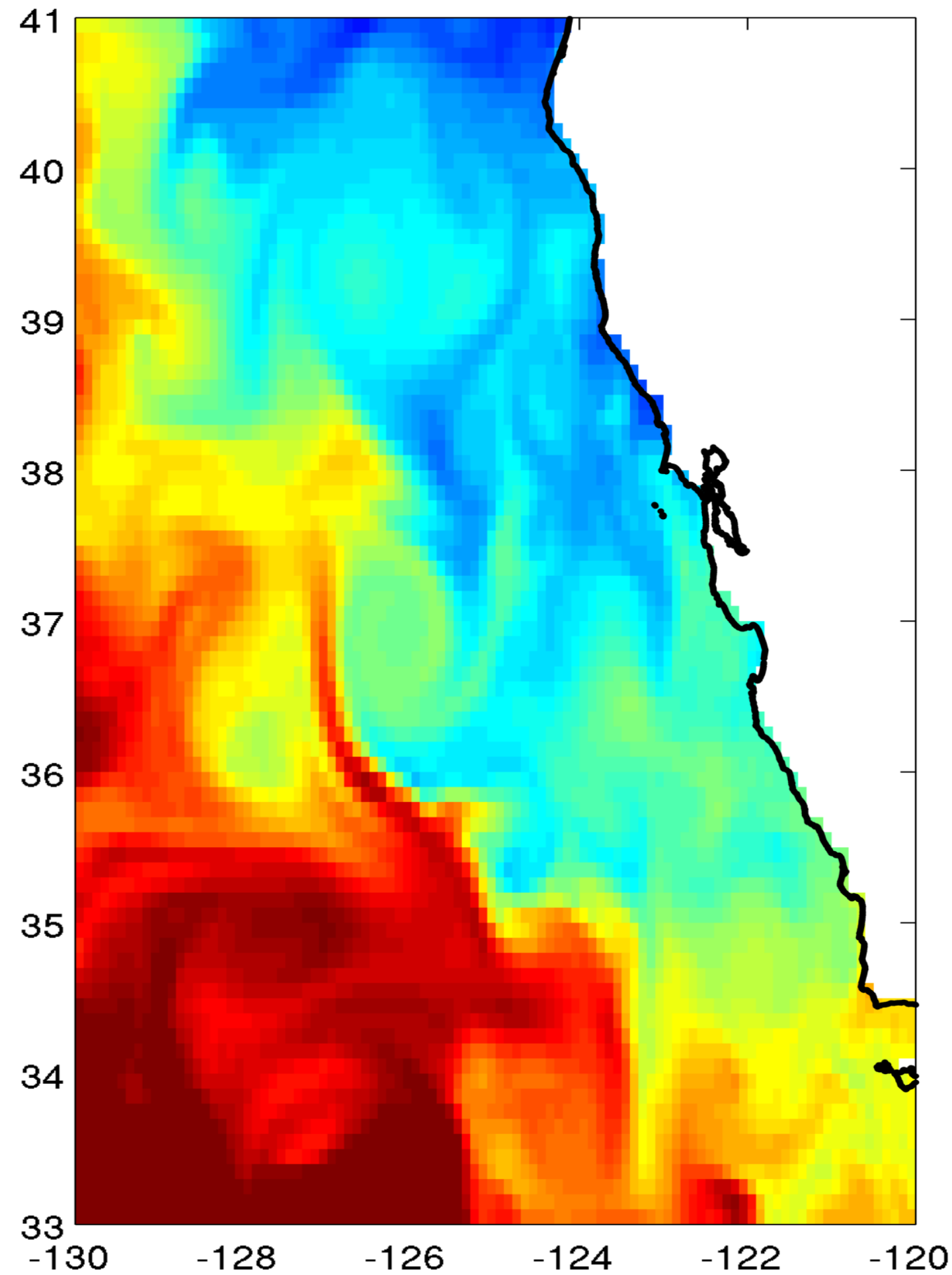


Sea Surface Temperature (°C)

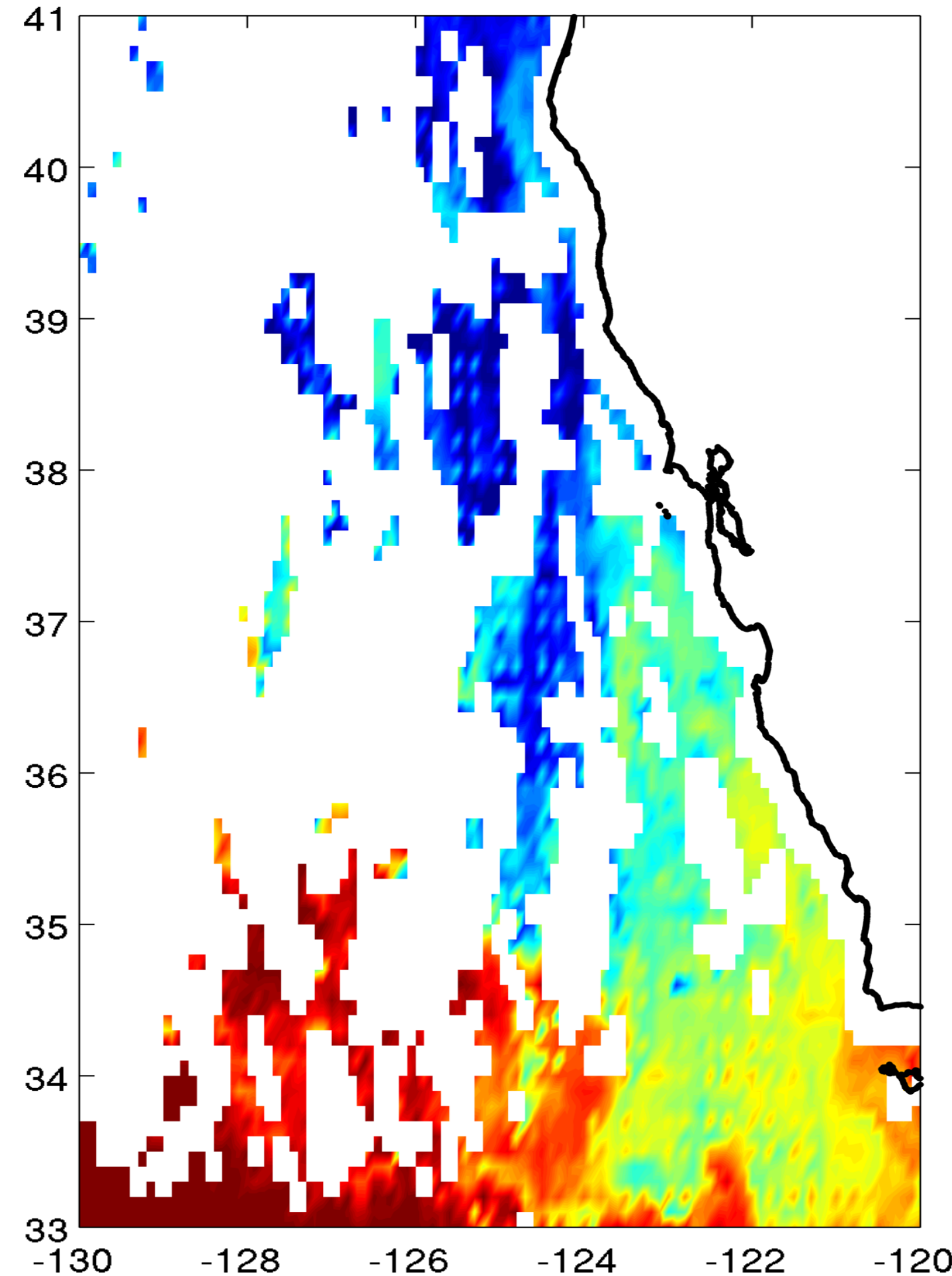
# Data Assimilation for Ocean State Estimation (4DVar)

Jan. 2010 SST

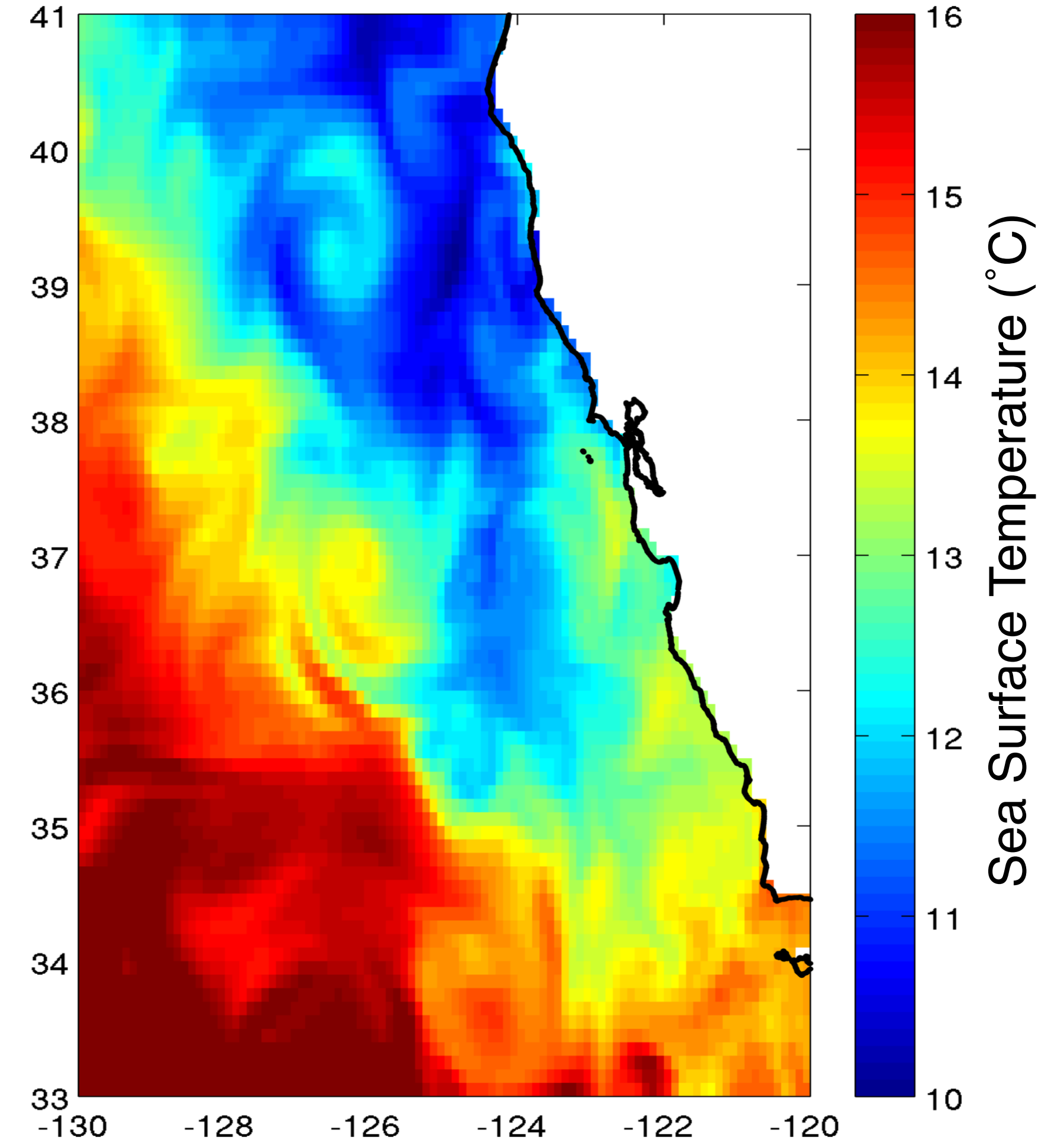
Prior



Observations

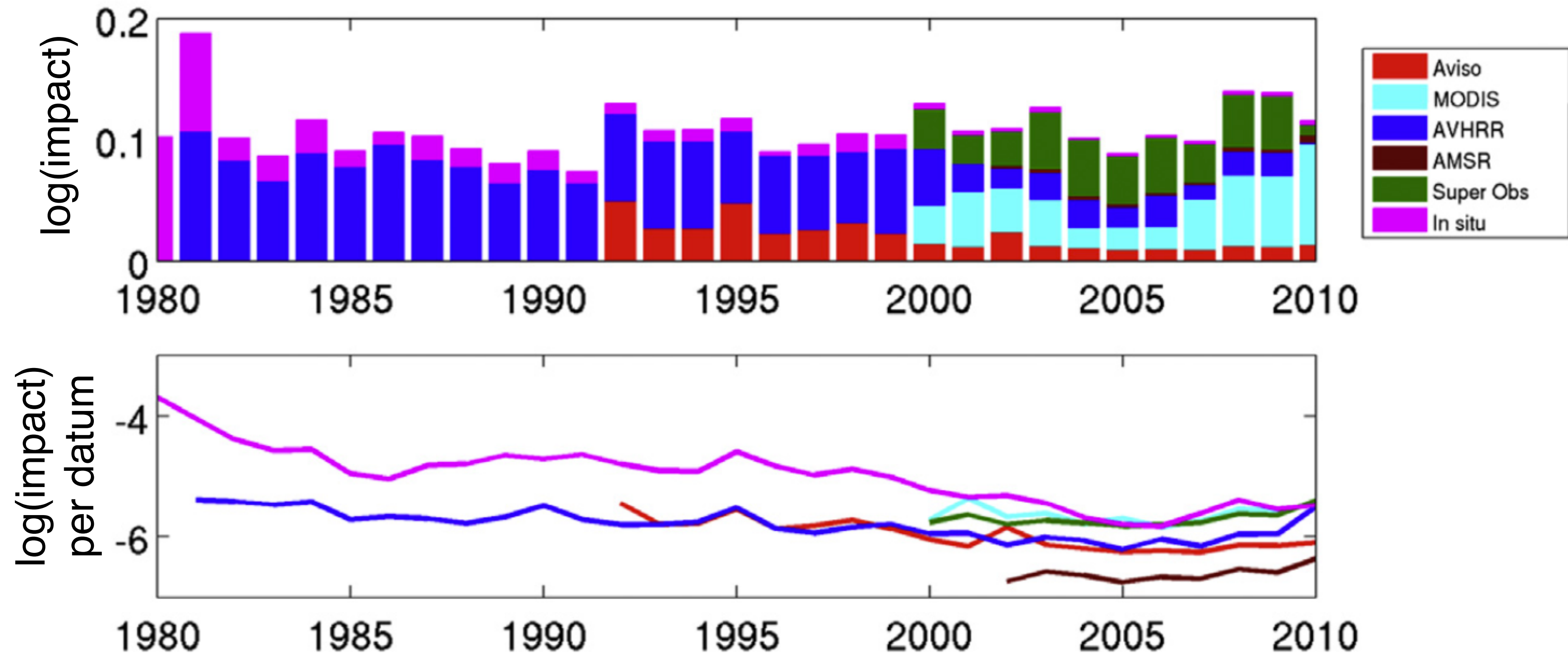
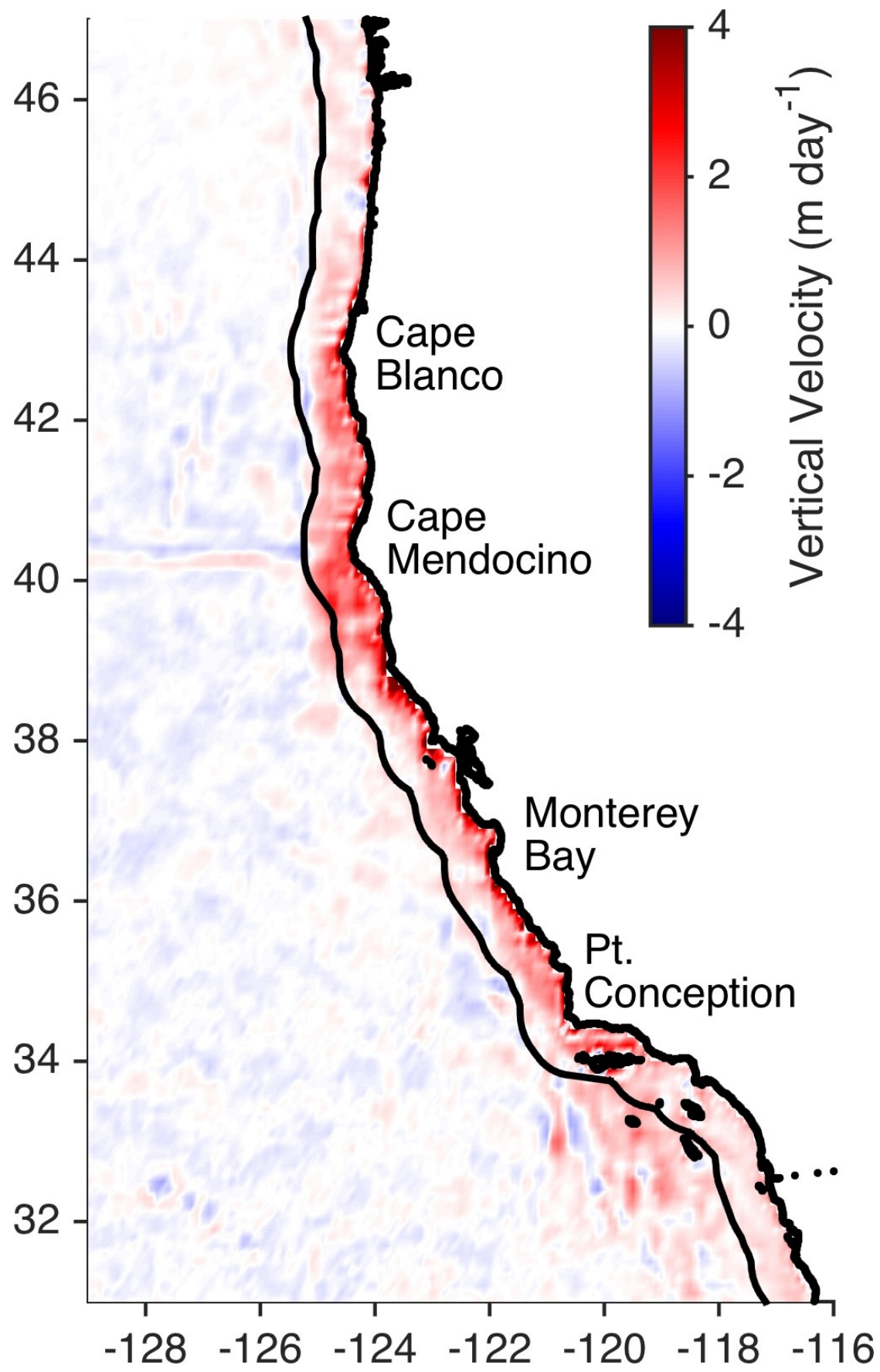


Posterior



Sea Surface Temperature (°C)

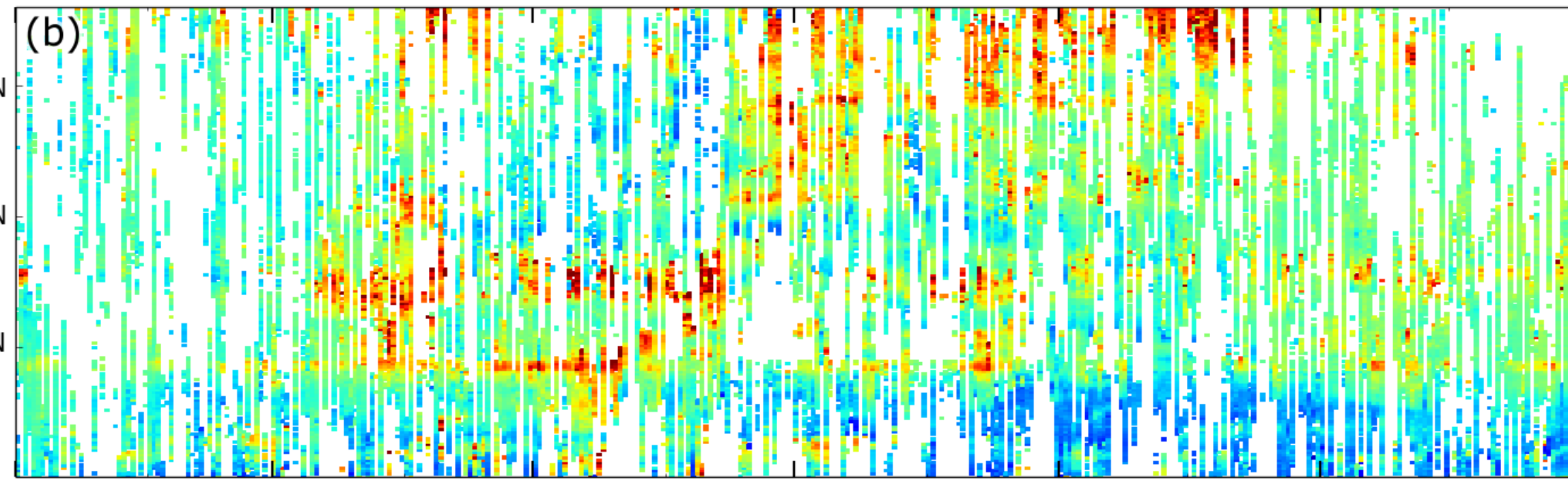
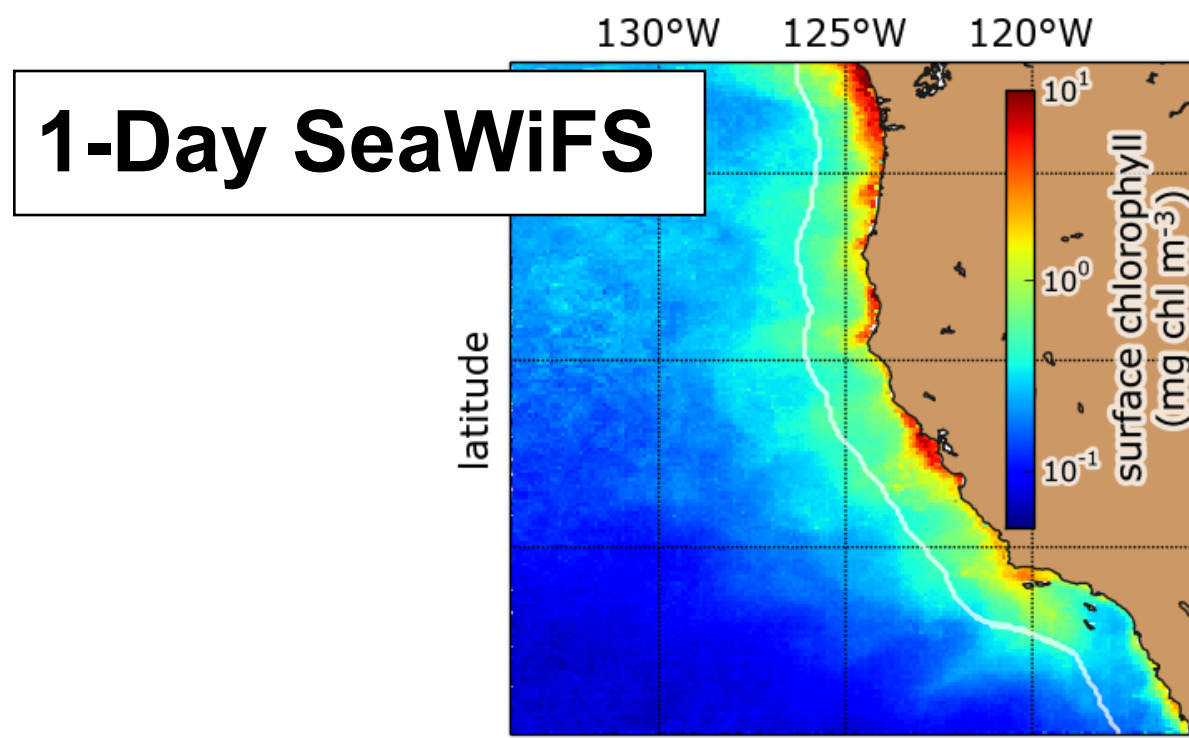
# Impact of Observing Platforms on California Coastal Upwelling Estimates



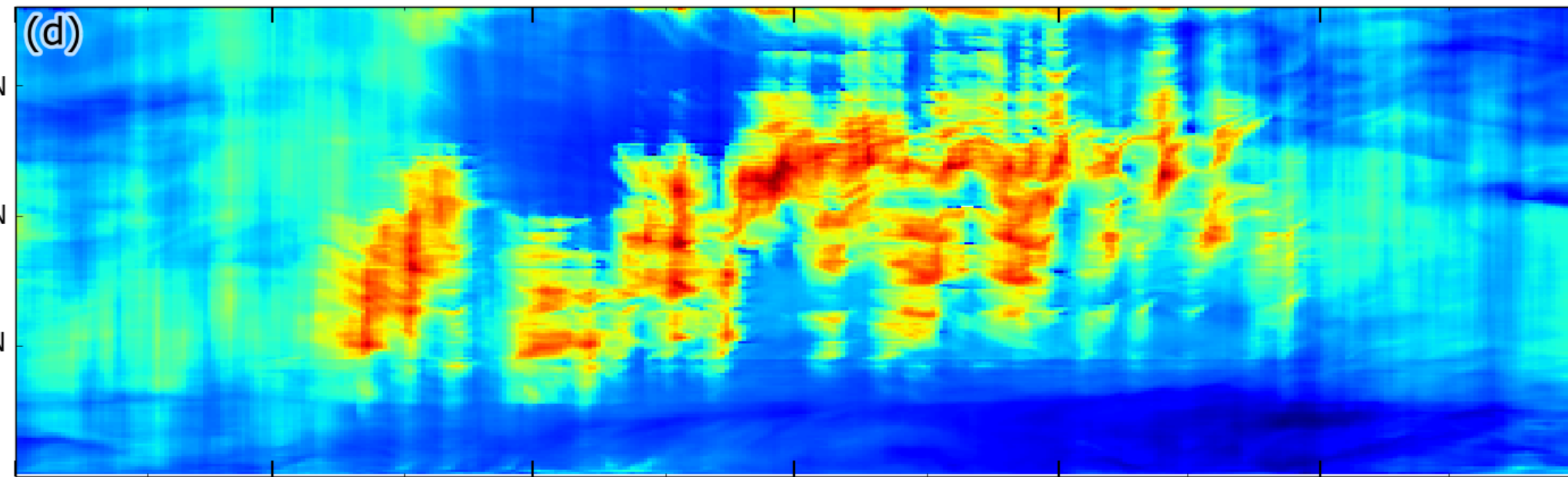
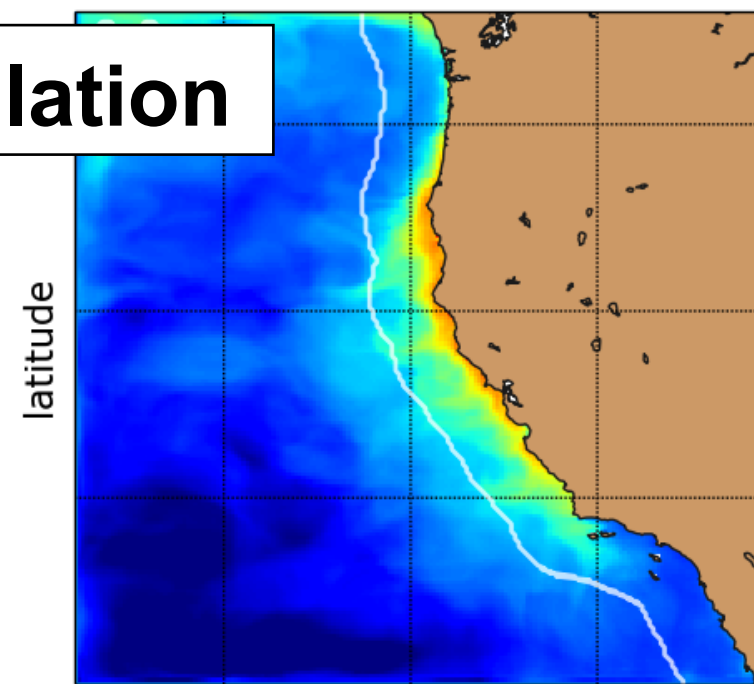
Moore et al. (2017)



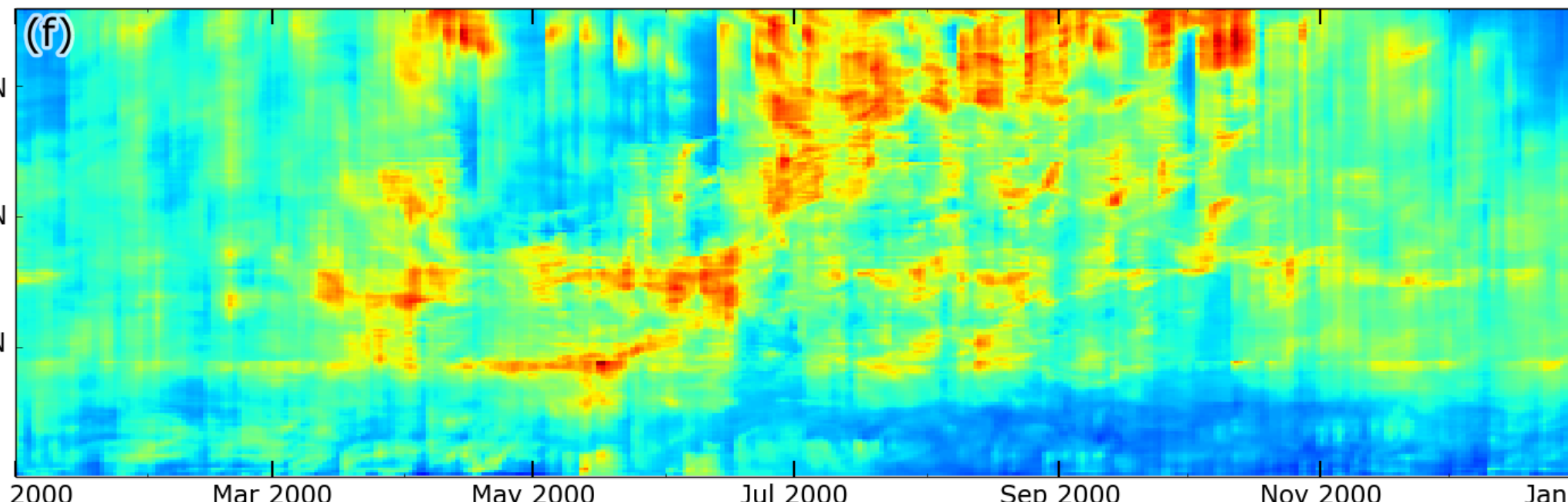
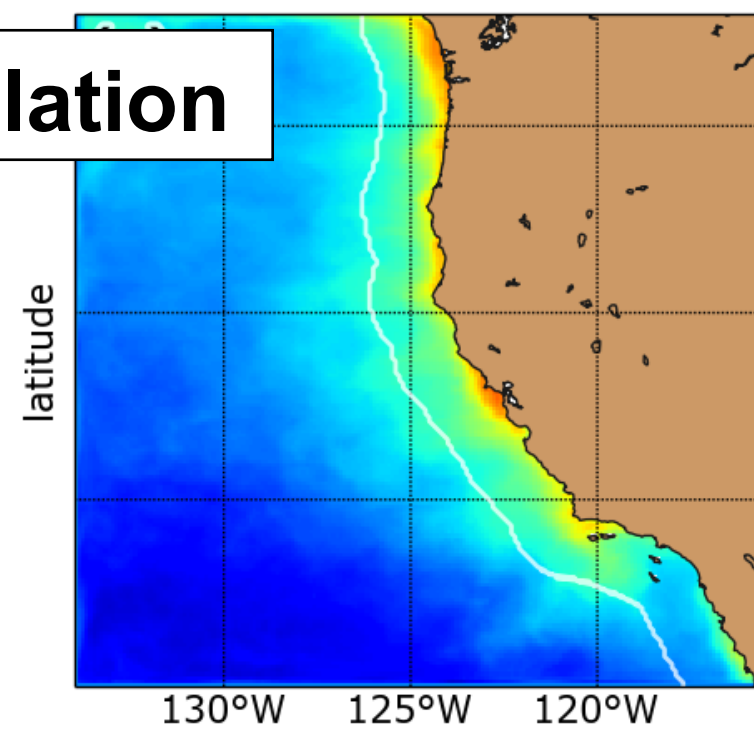
# Data Assimilation for Biogeochemical Ocean State Estimation



**Model – No Assimilation**

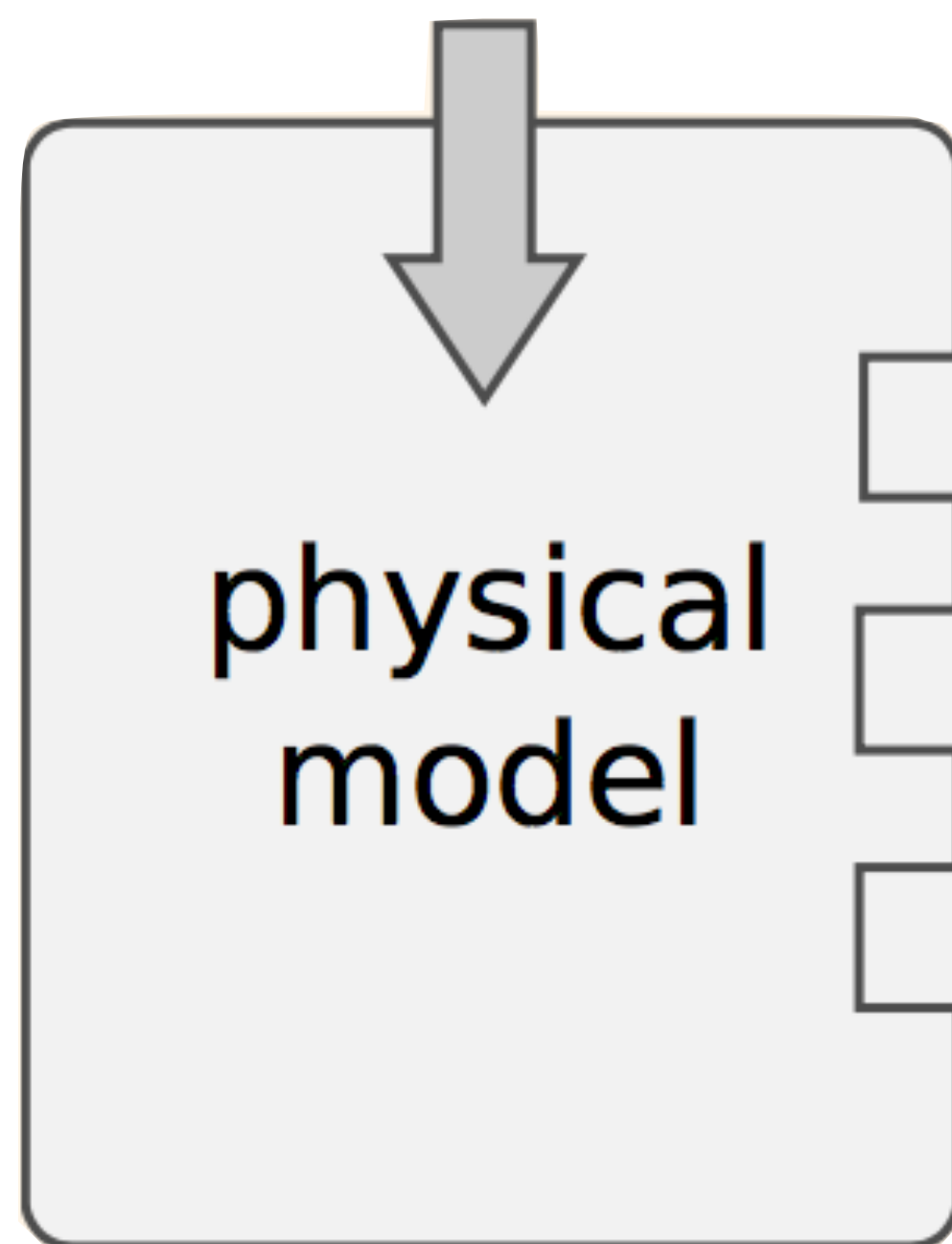


**Model – With Assimilation**

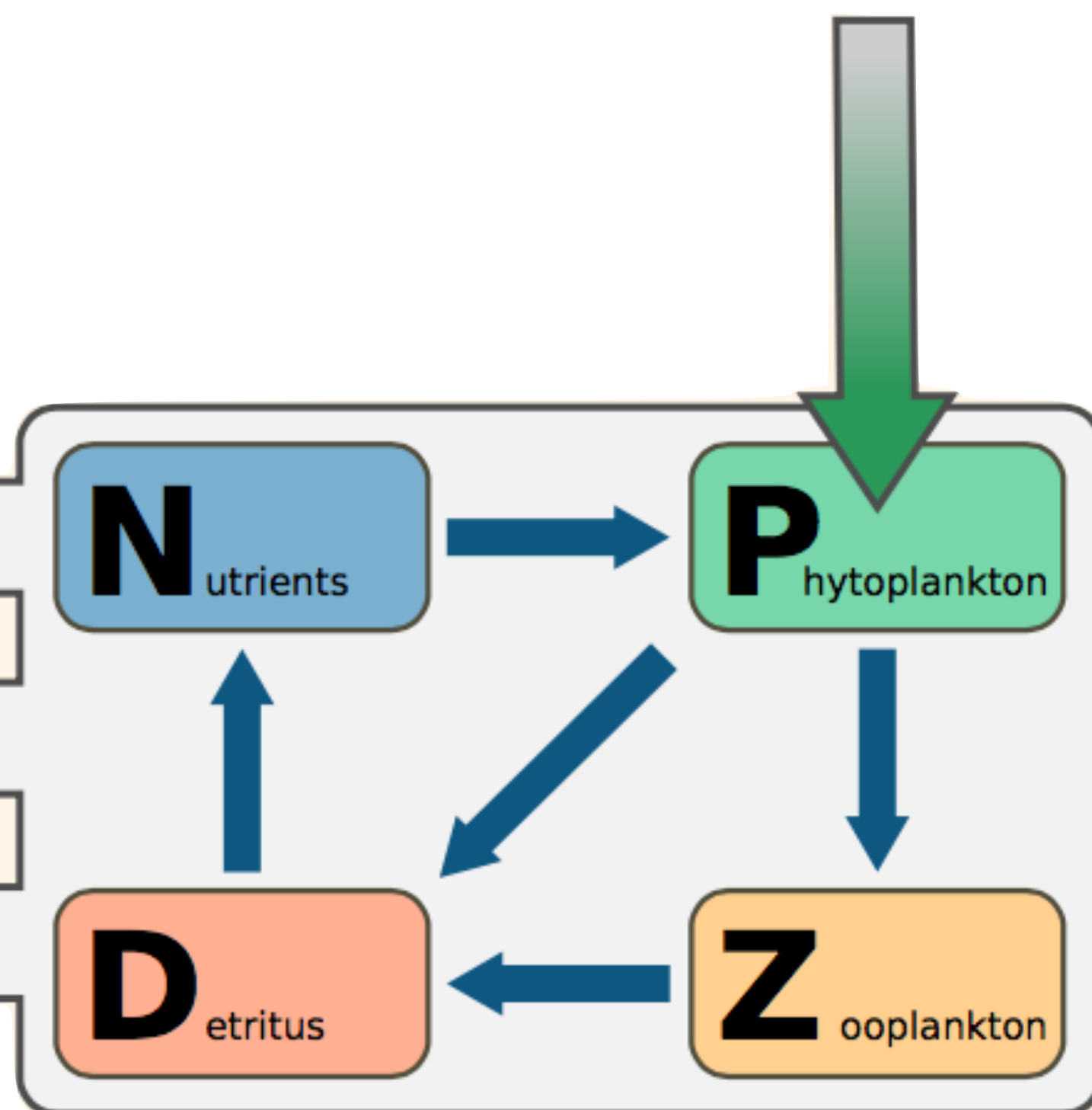


Mattern et al. (2017)

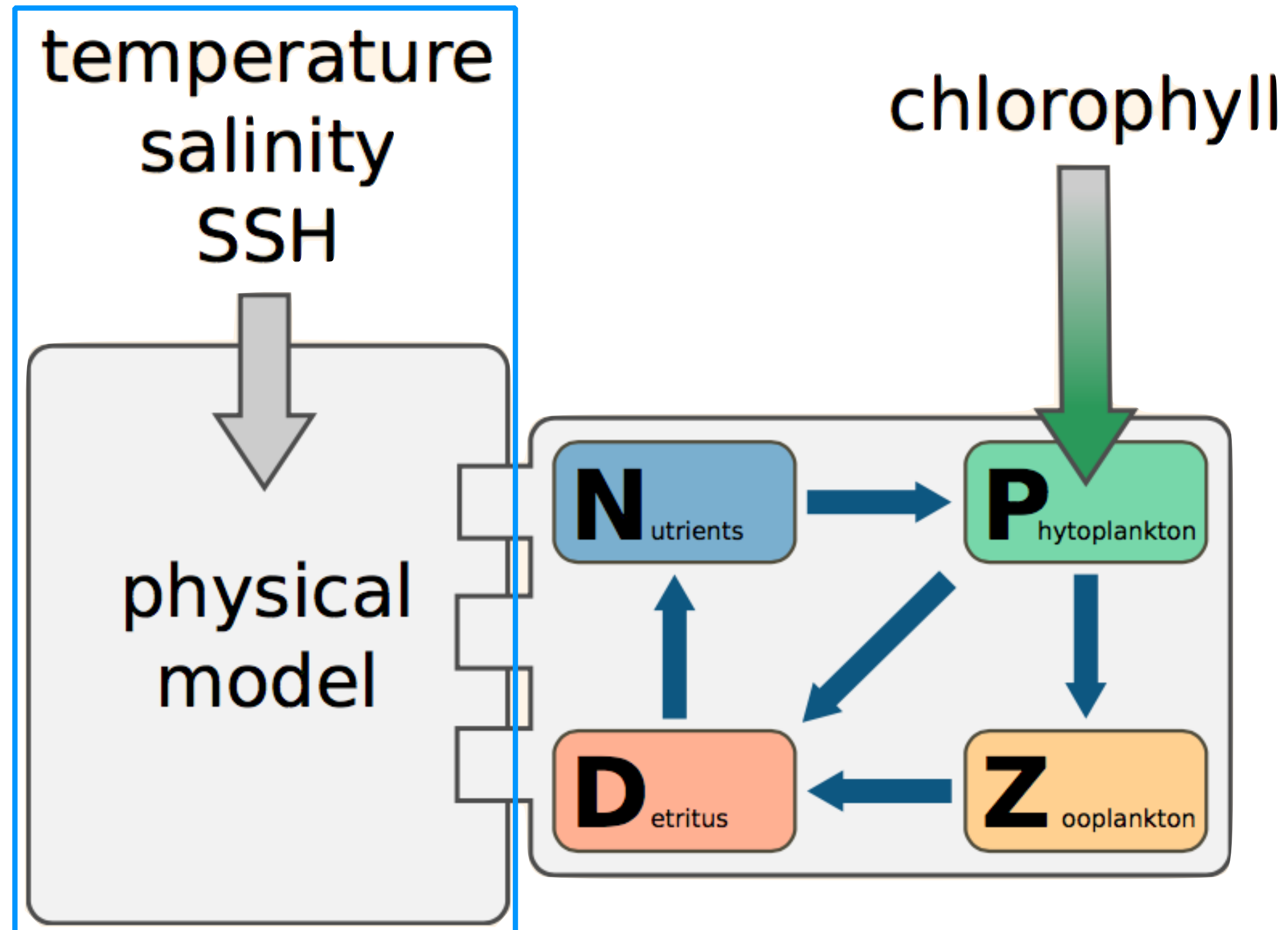
temperature  
salinity  
SSH



chlorophyll

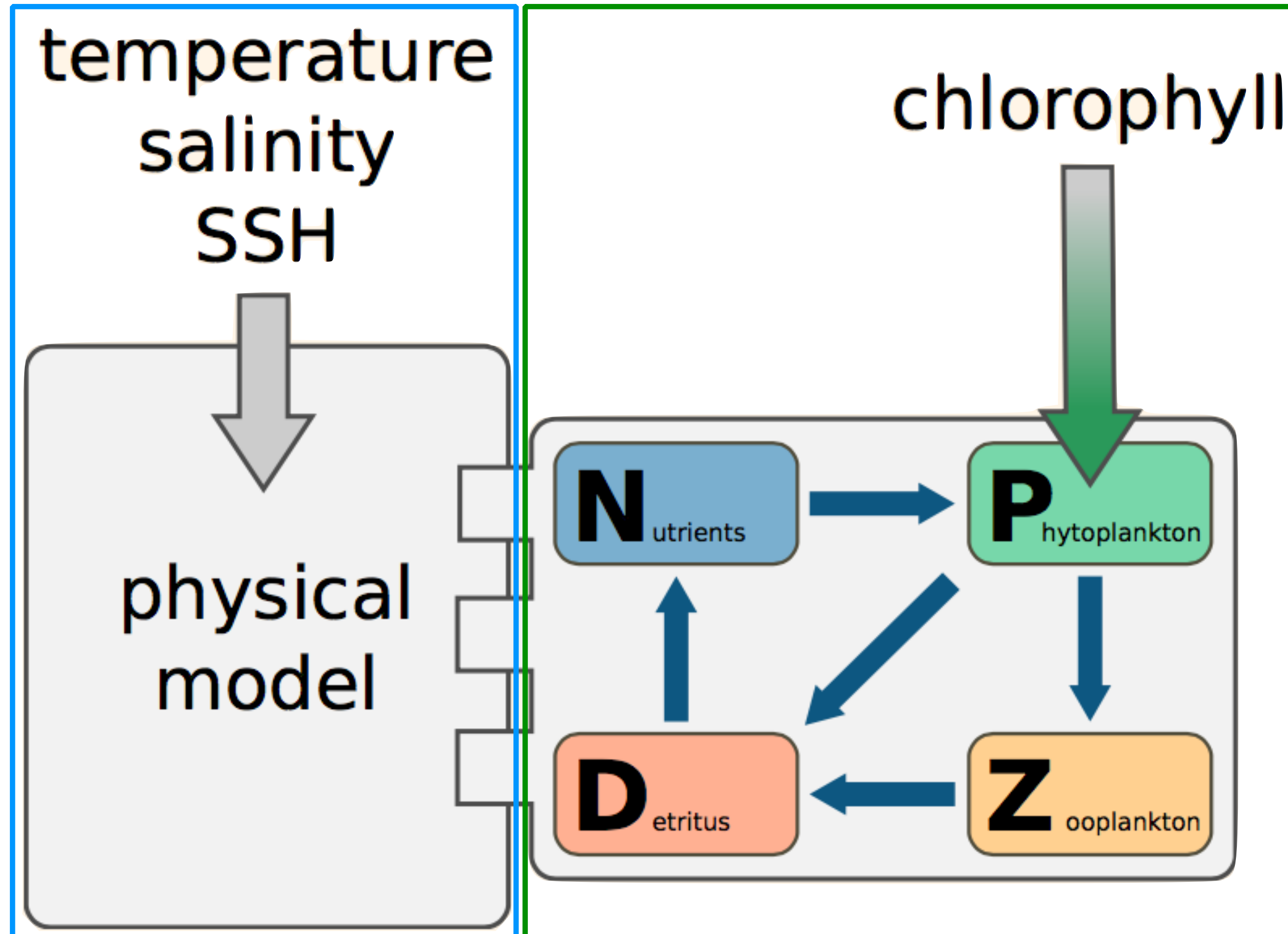


Gaussian  
Positive or negative

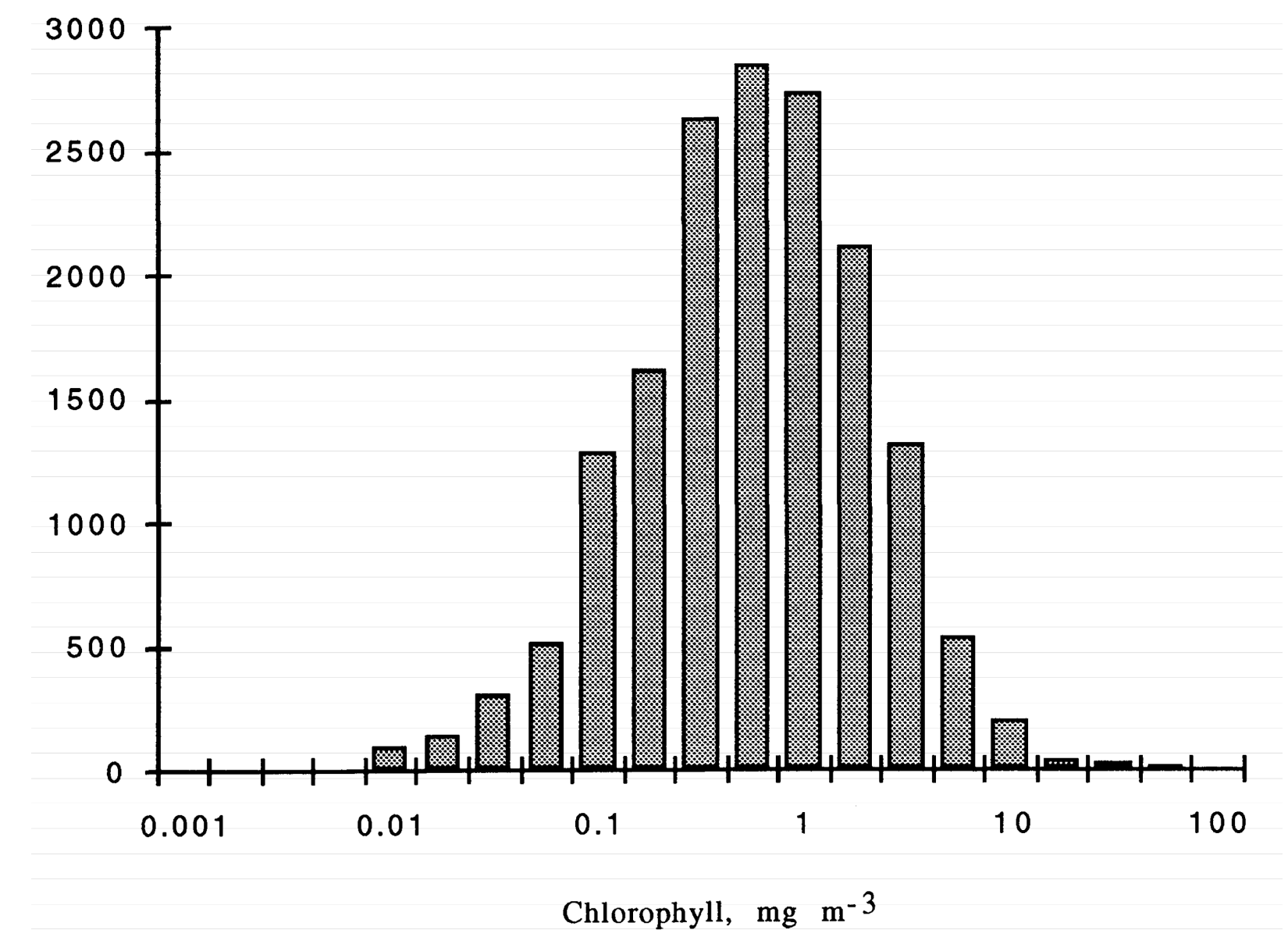


Gaussian  
Positive or negative

Skewed (lognormal)  
Positive definite

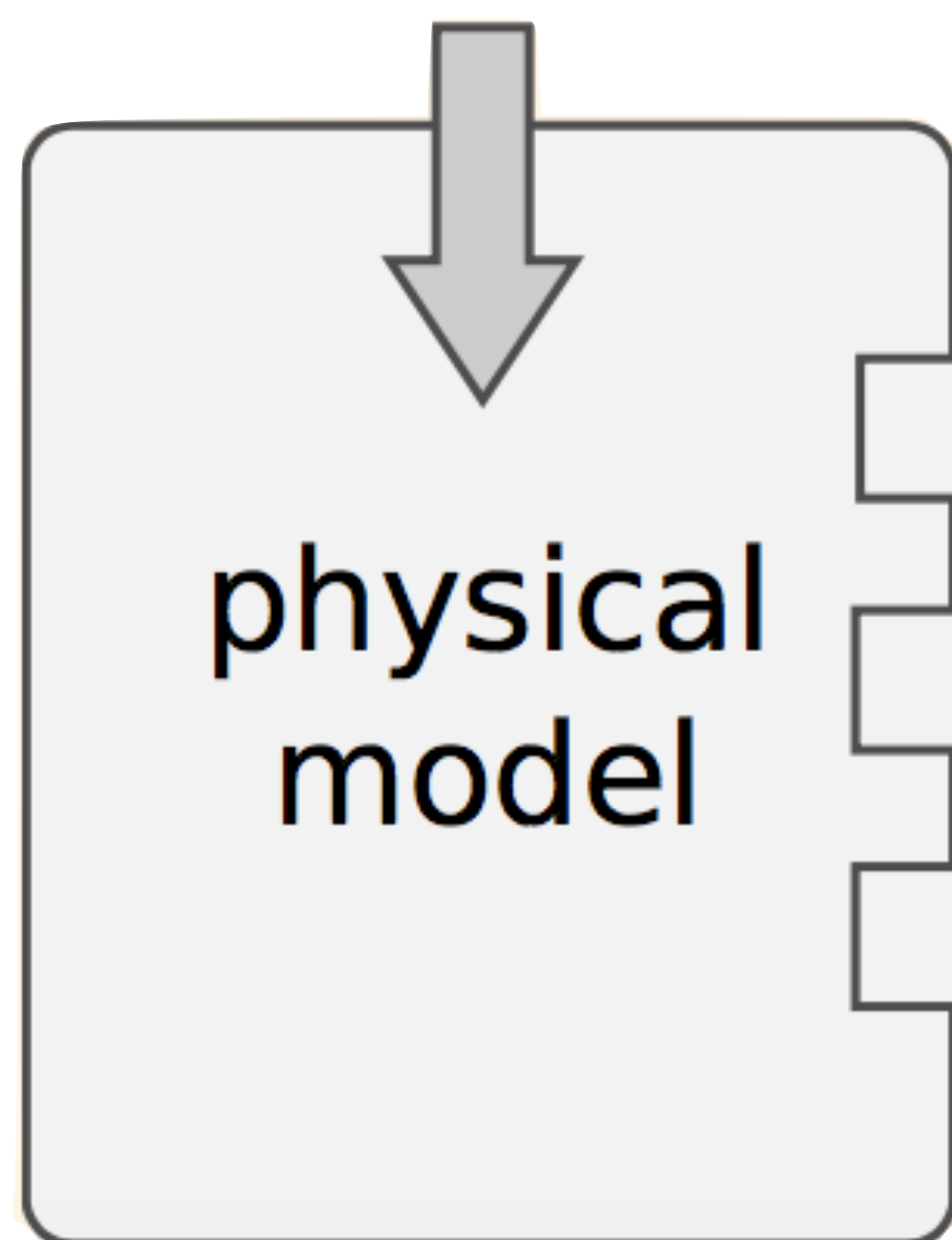


CAMPBELL: LOGNORMAL VARIABILITY IN BIO-OPTICS

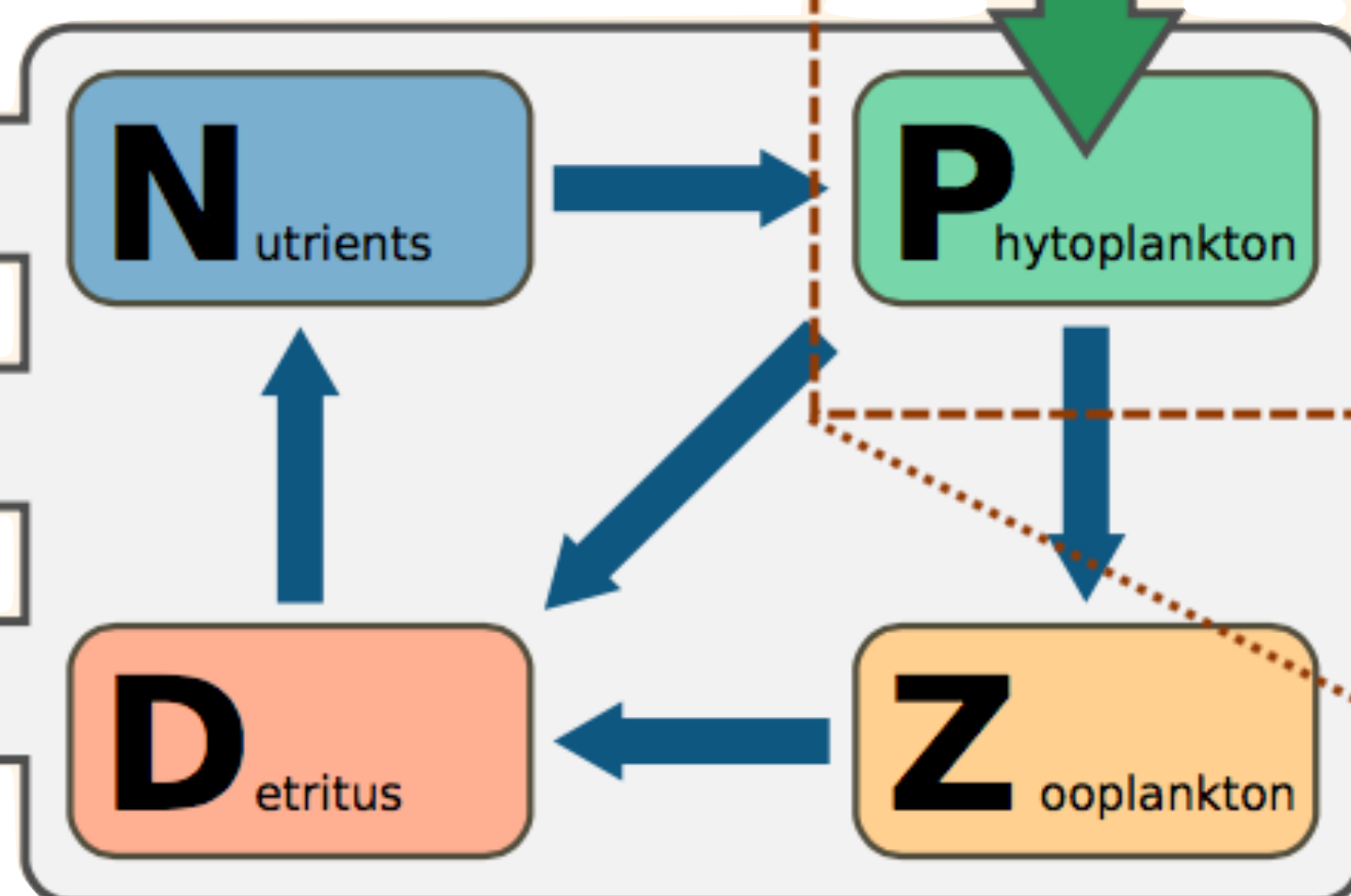


Campbell (1995)

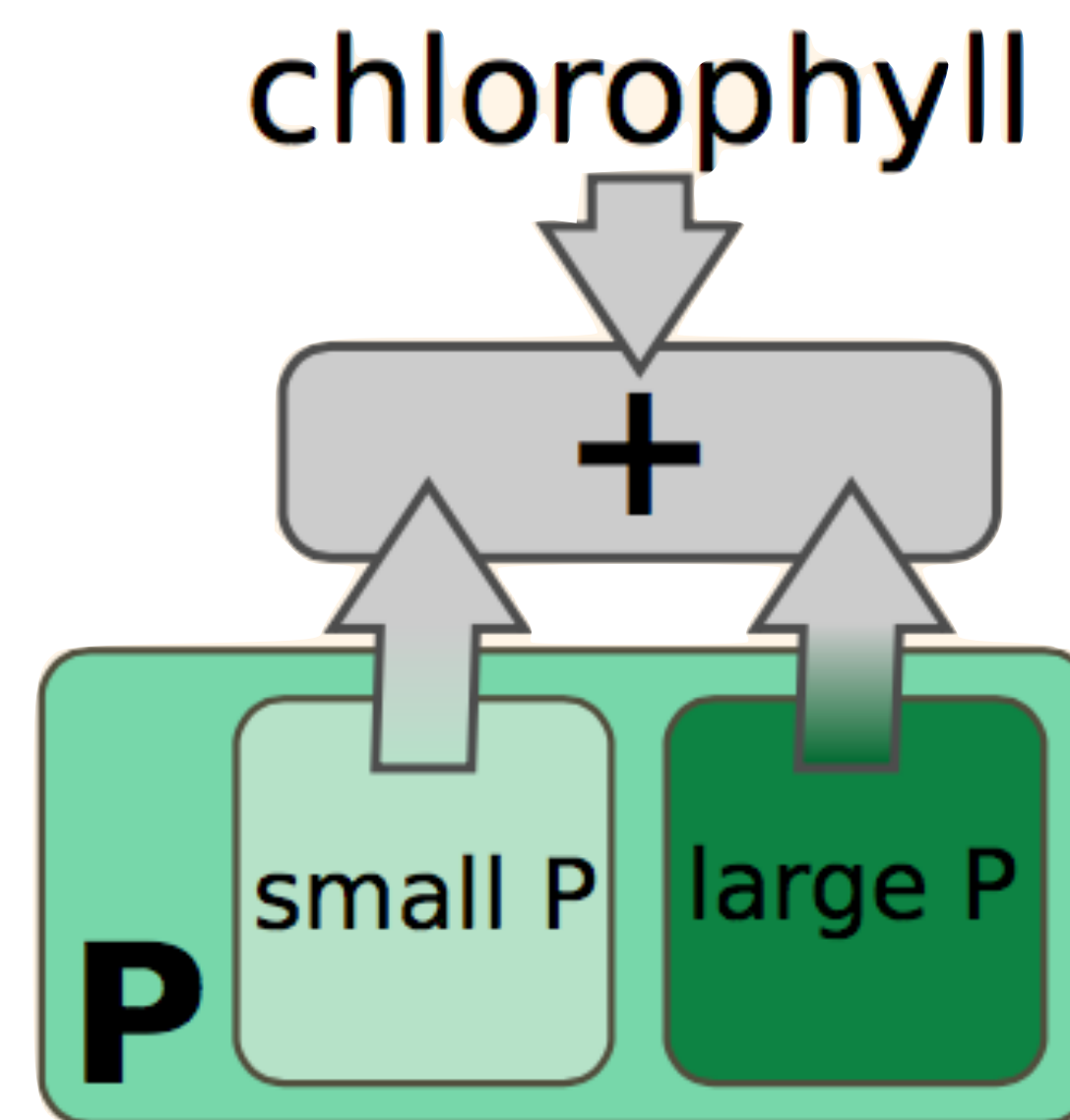
temperature  
salinity  
SSH

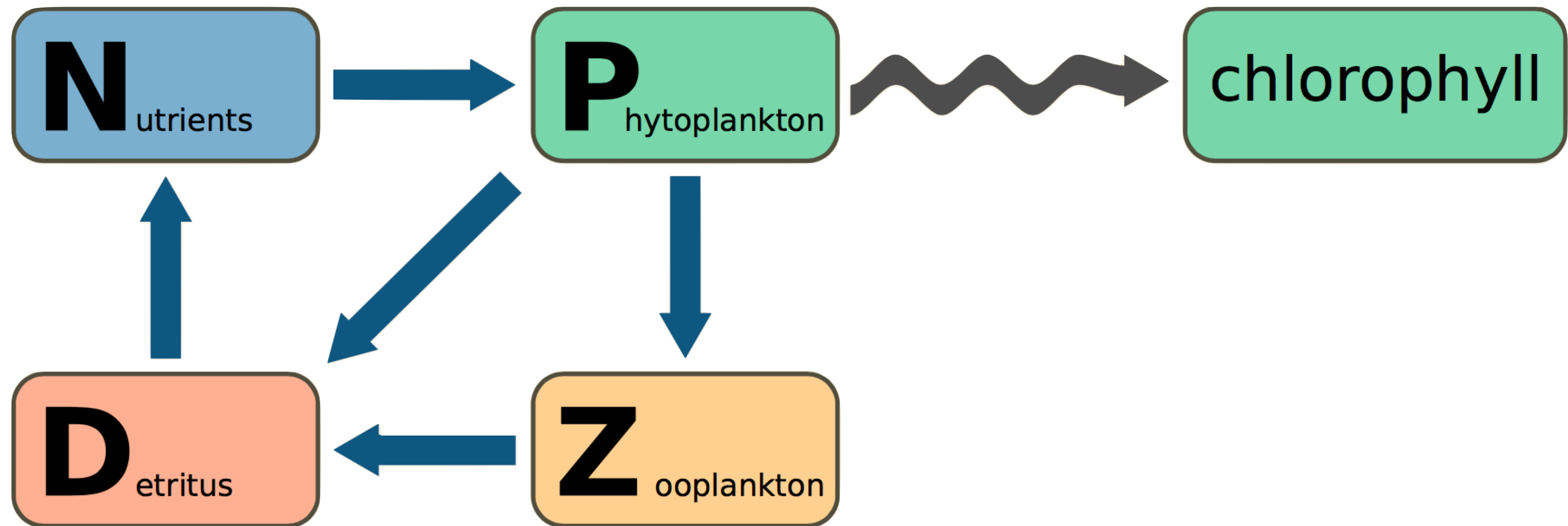


chlorophyll

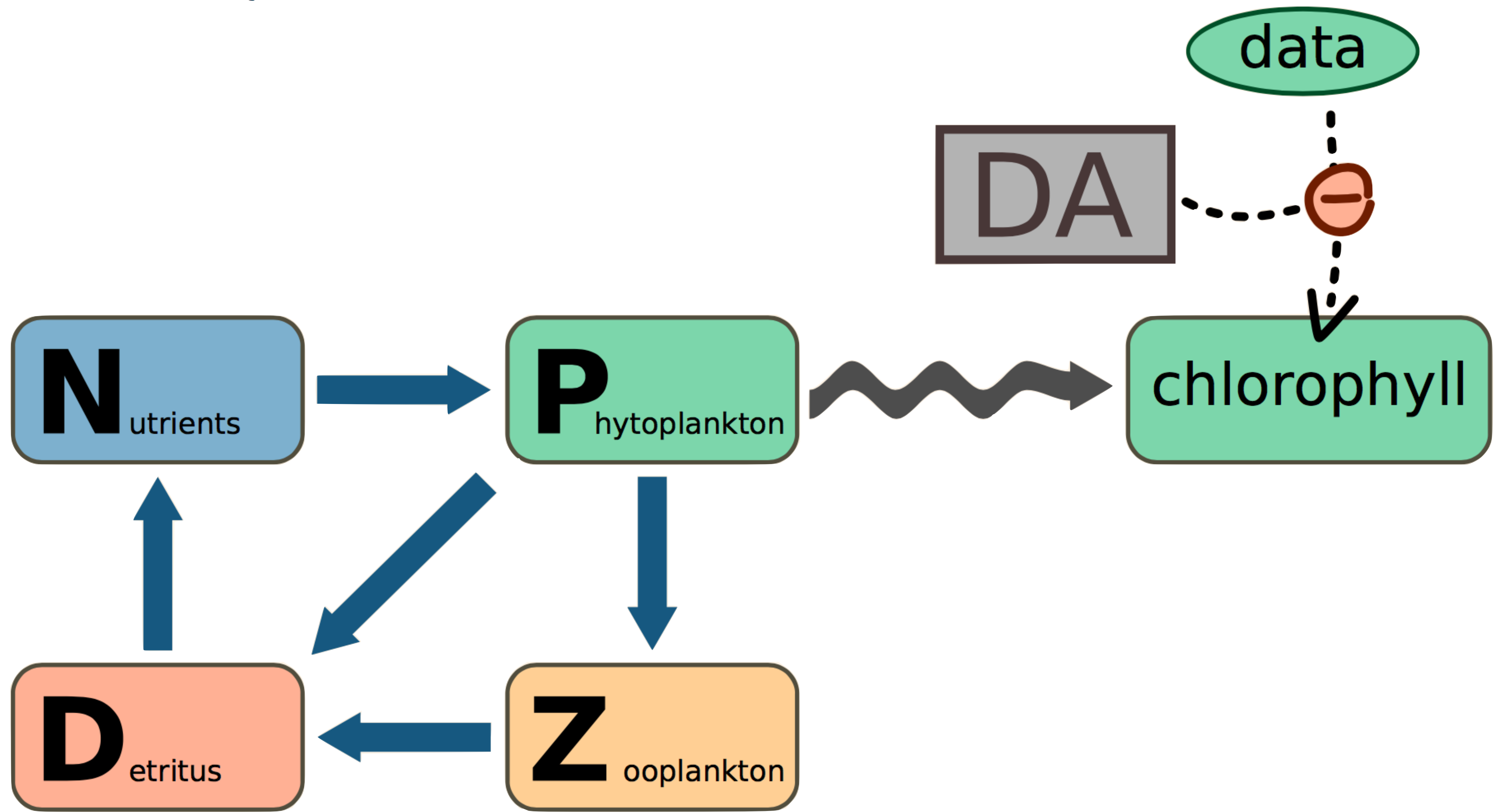


**NEMURO**

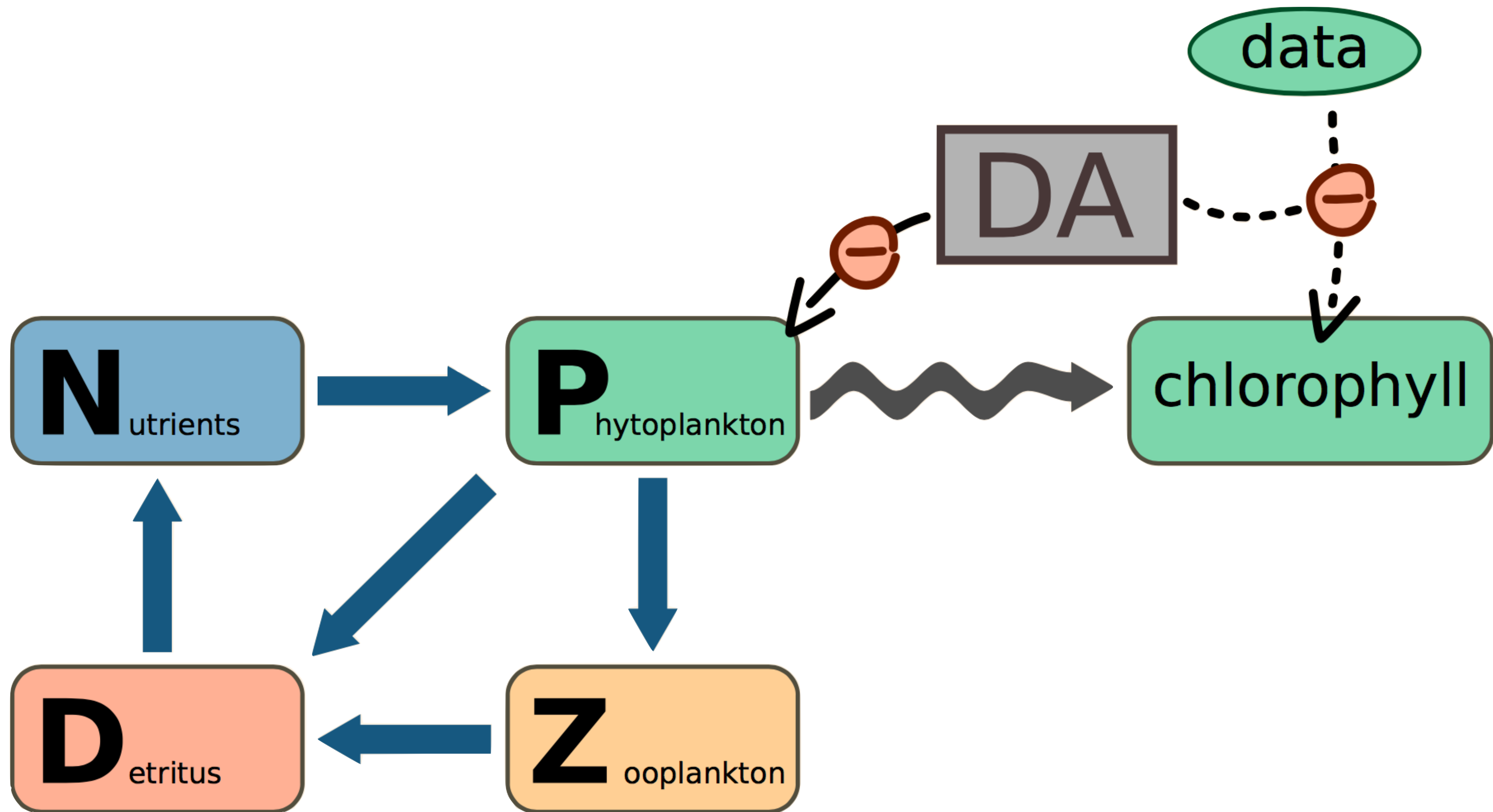




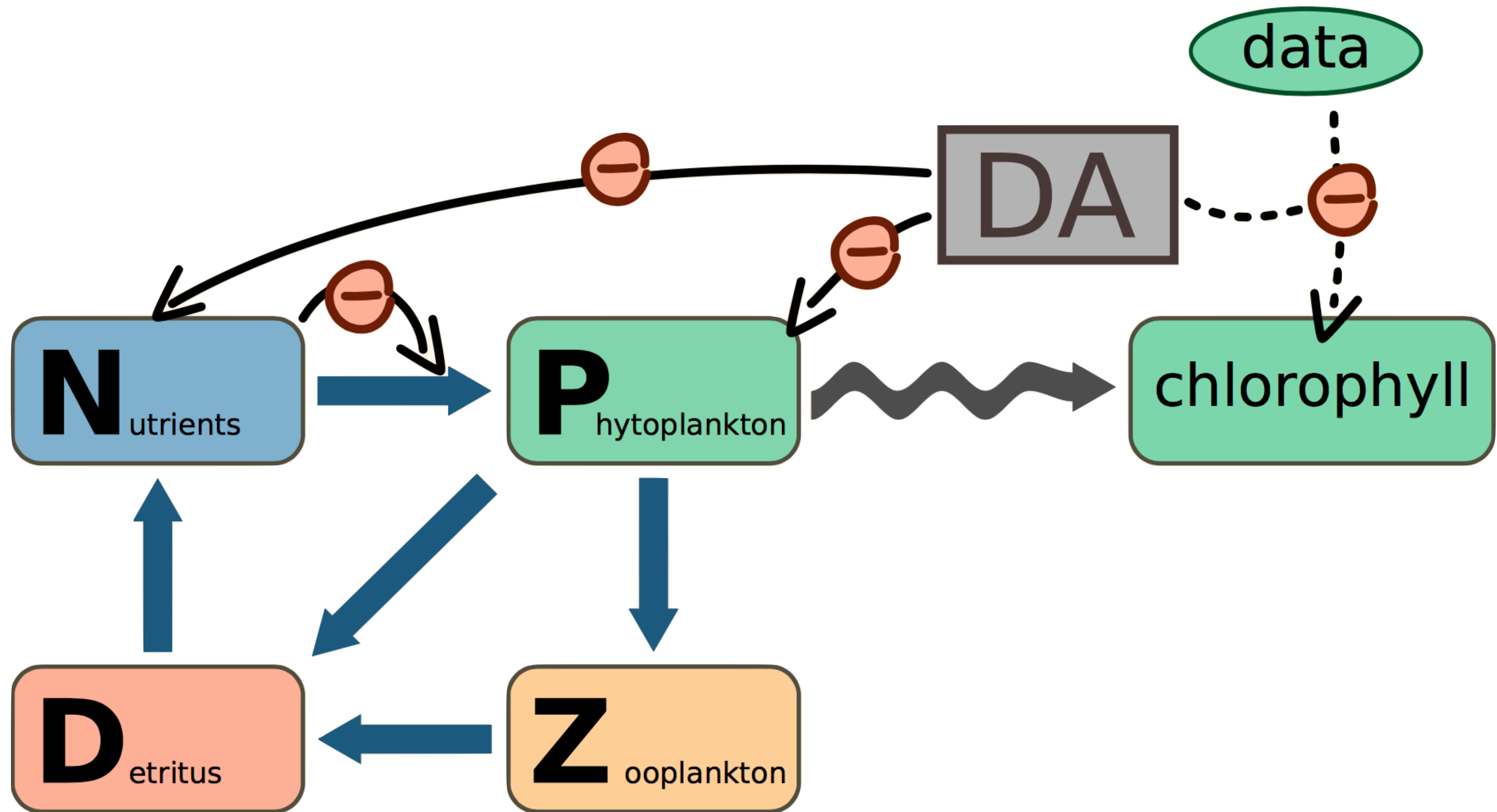
Mattern et al. (2017)

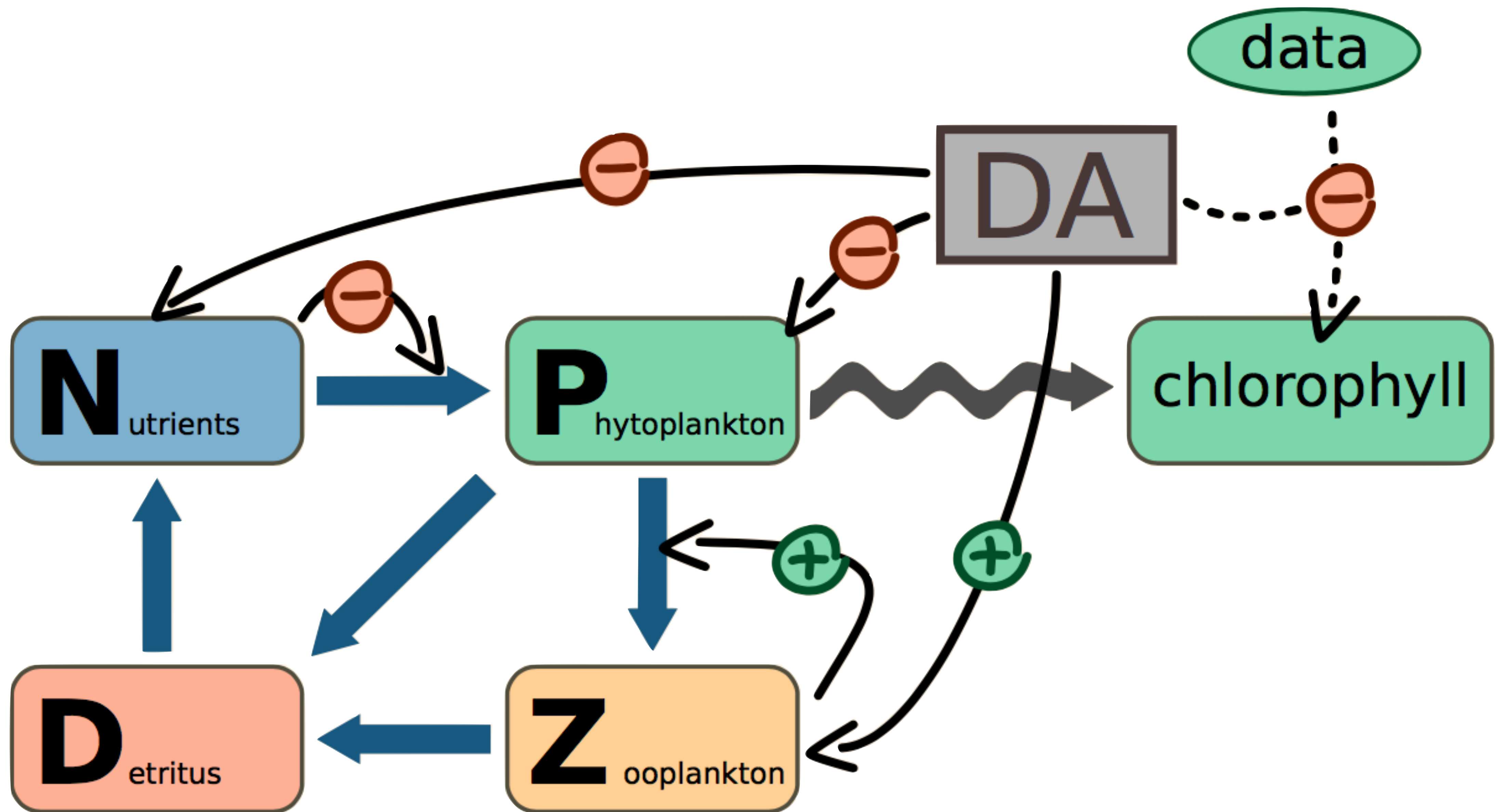


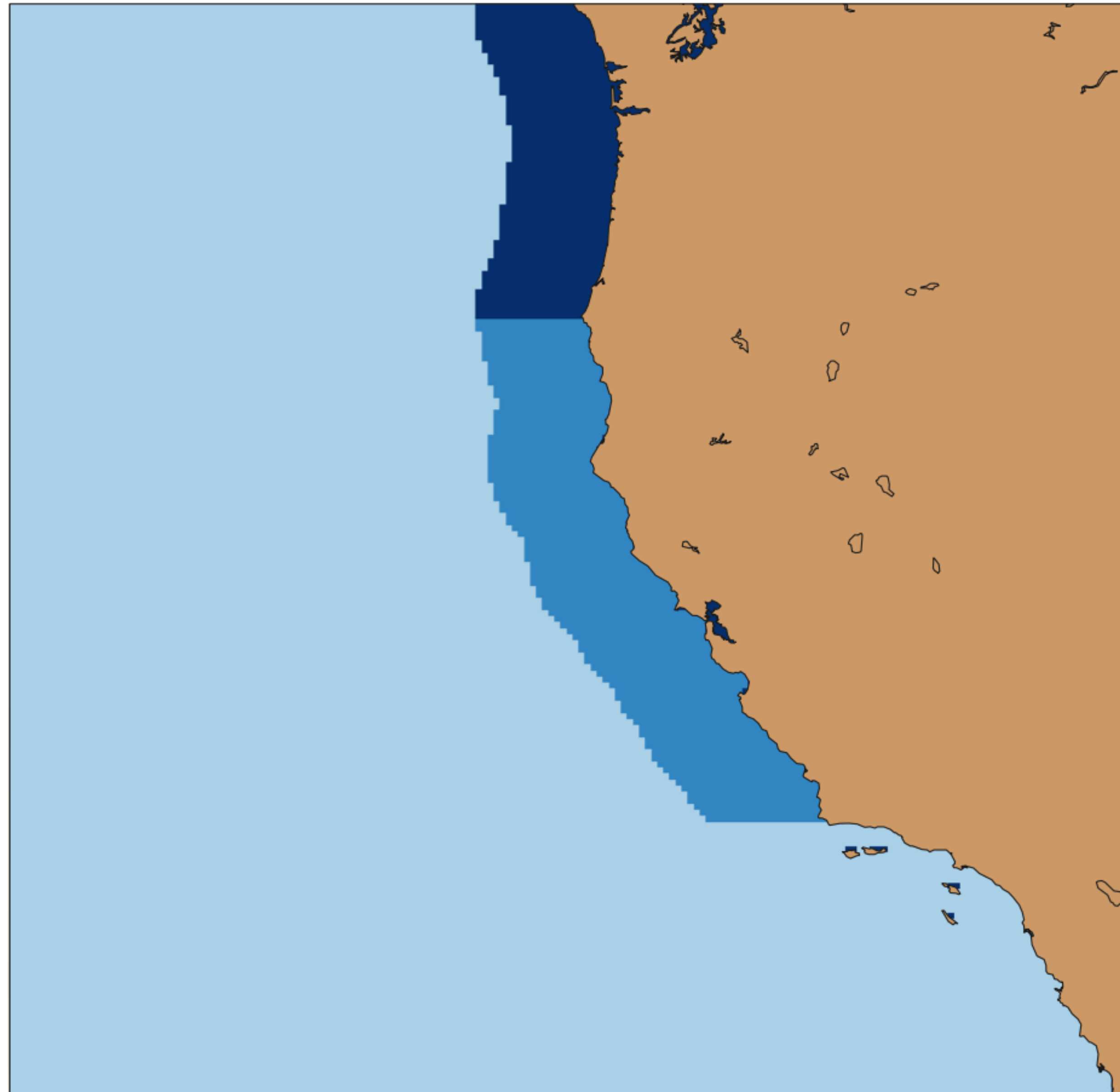
Mattern et al. (2017)



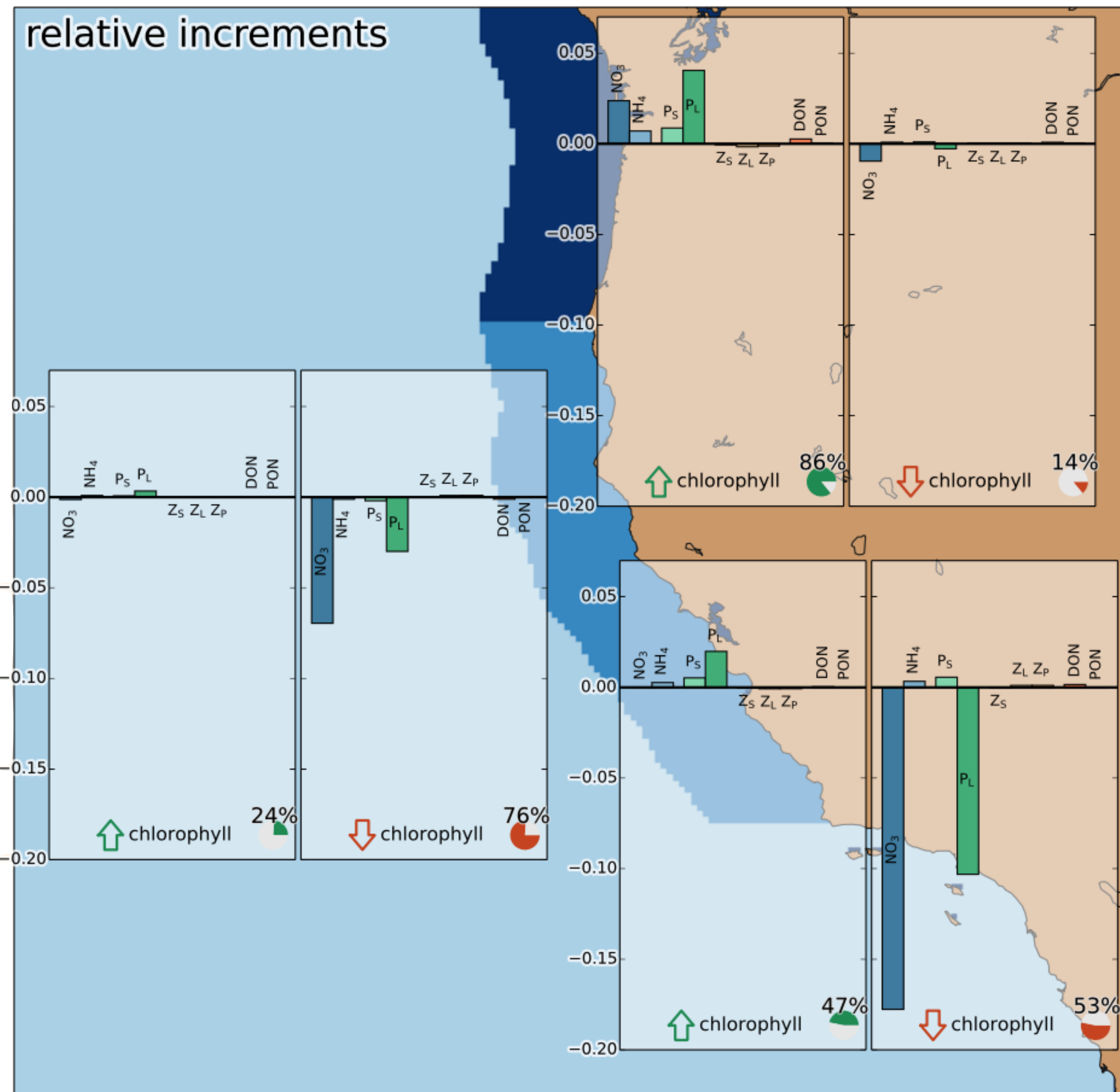








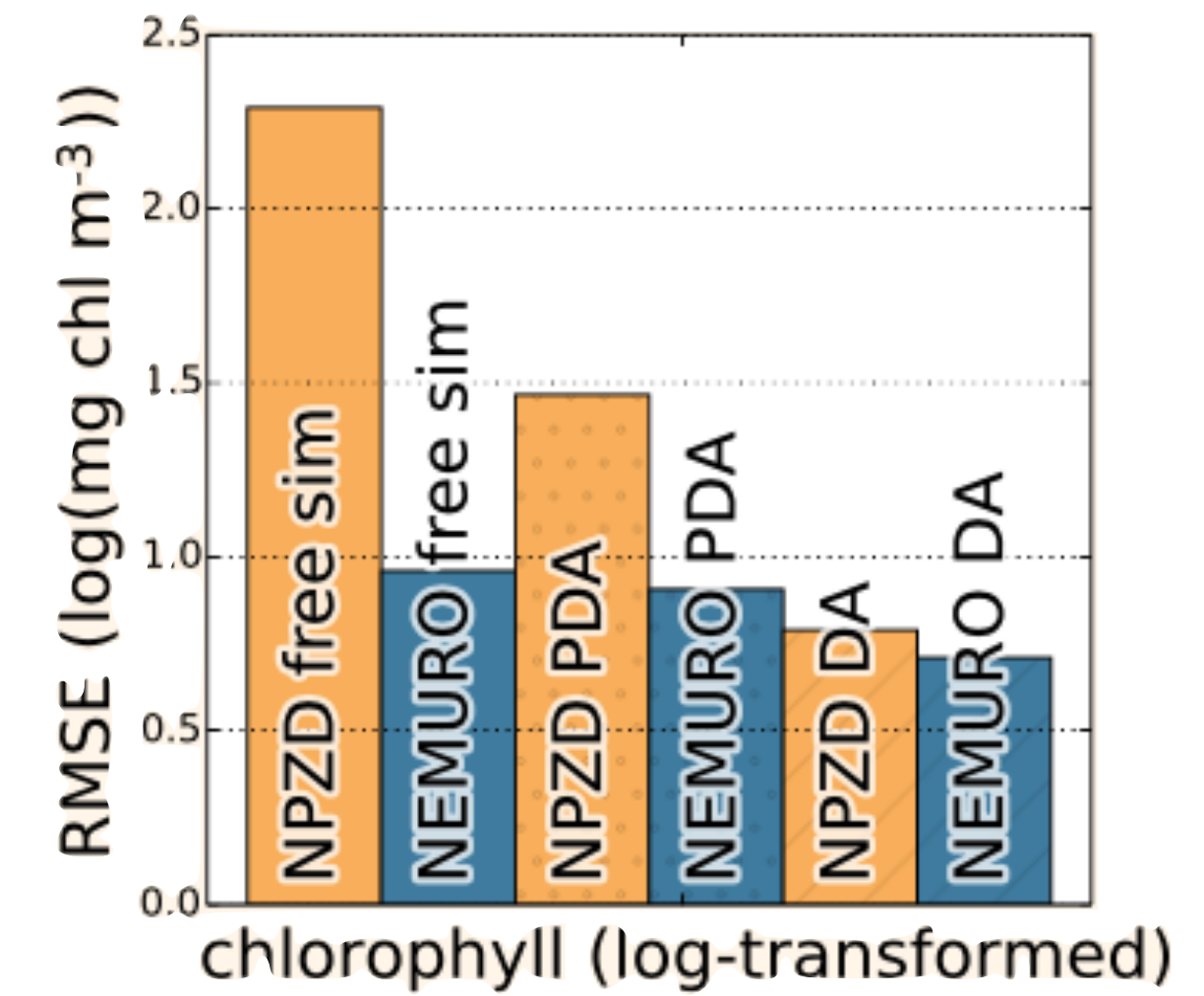
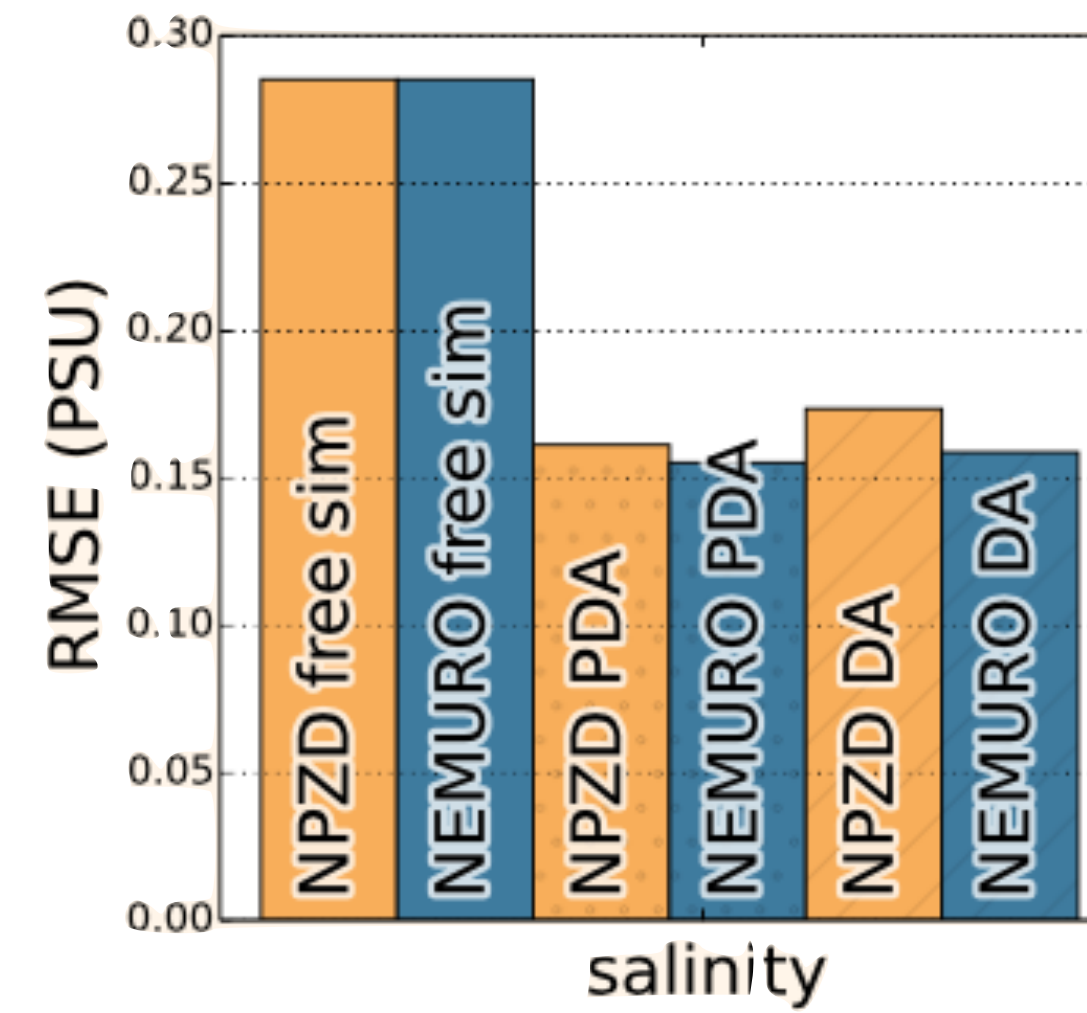
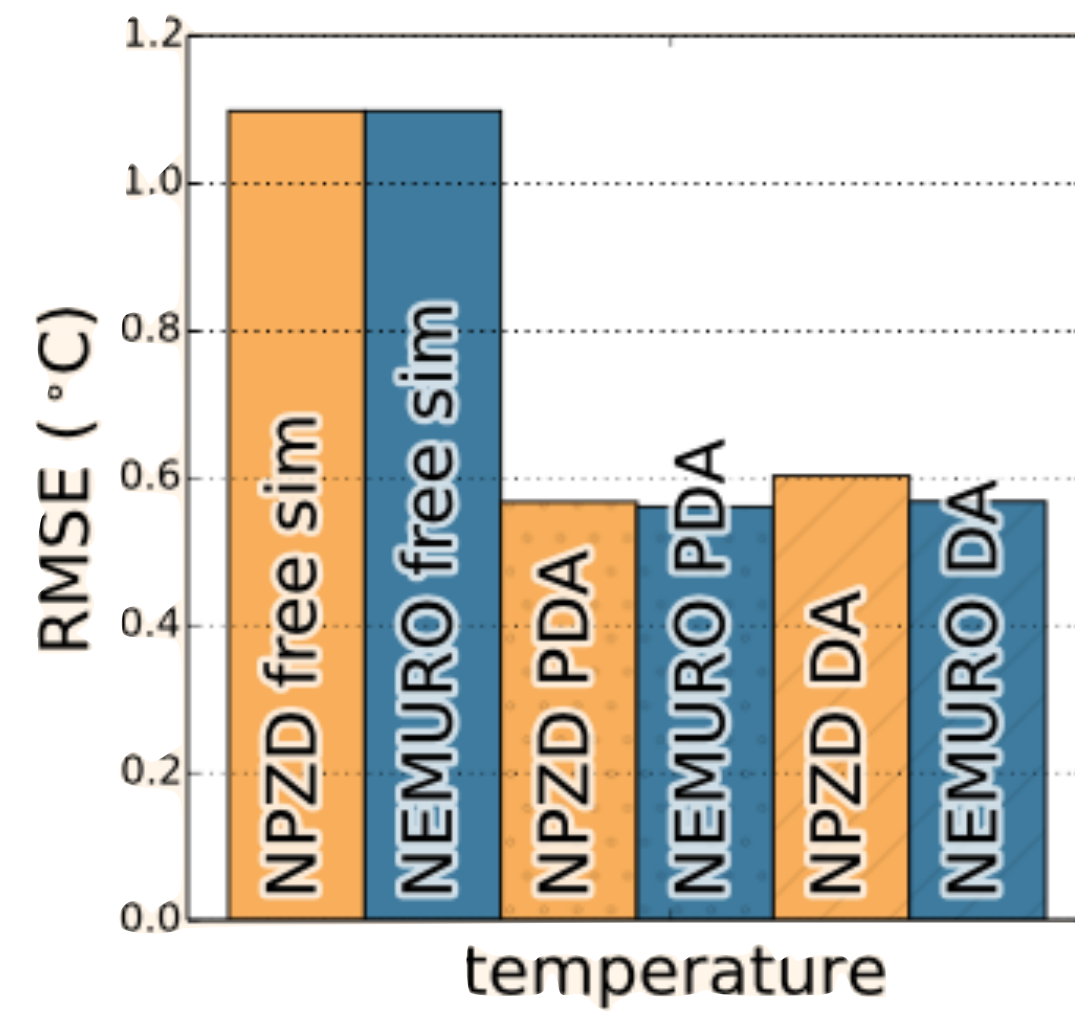
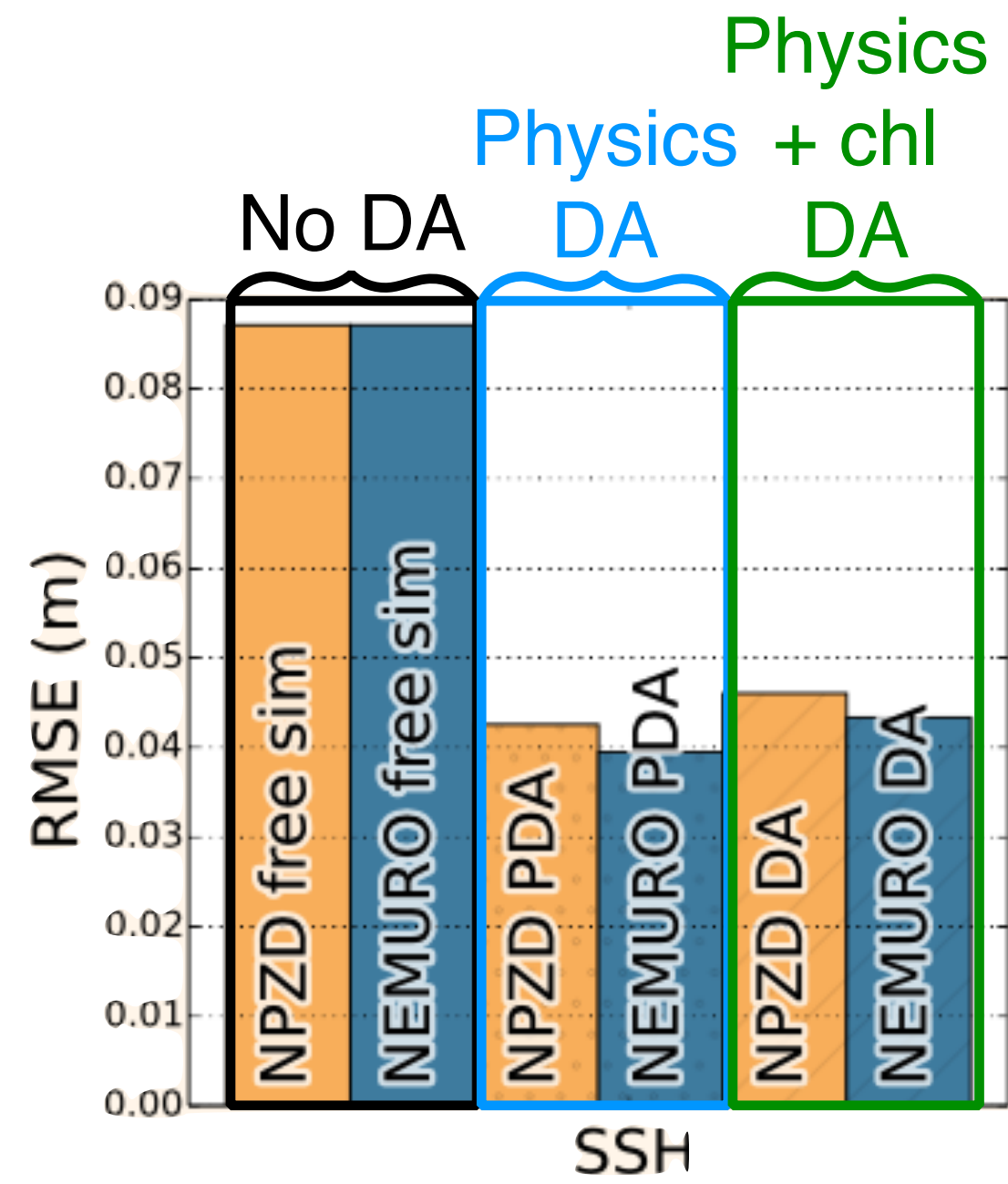
Mattern et al. (2017)



Mattern et al. (2017)

# Model Error Assessment

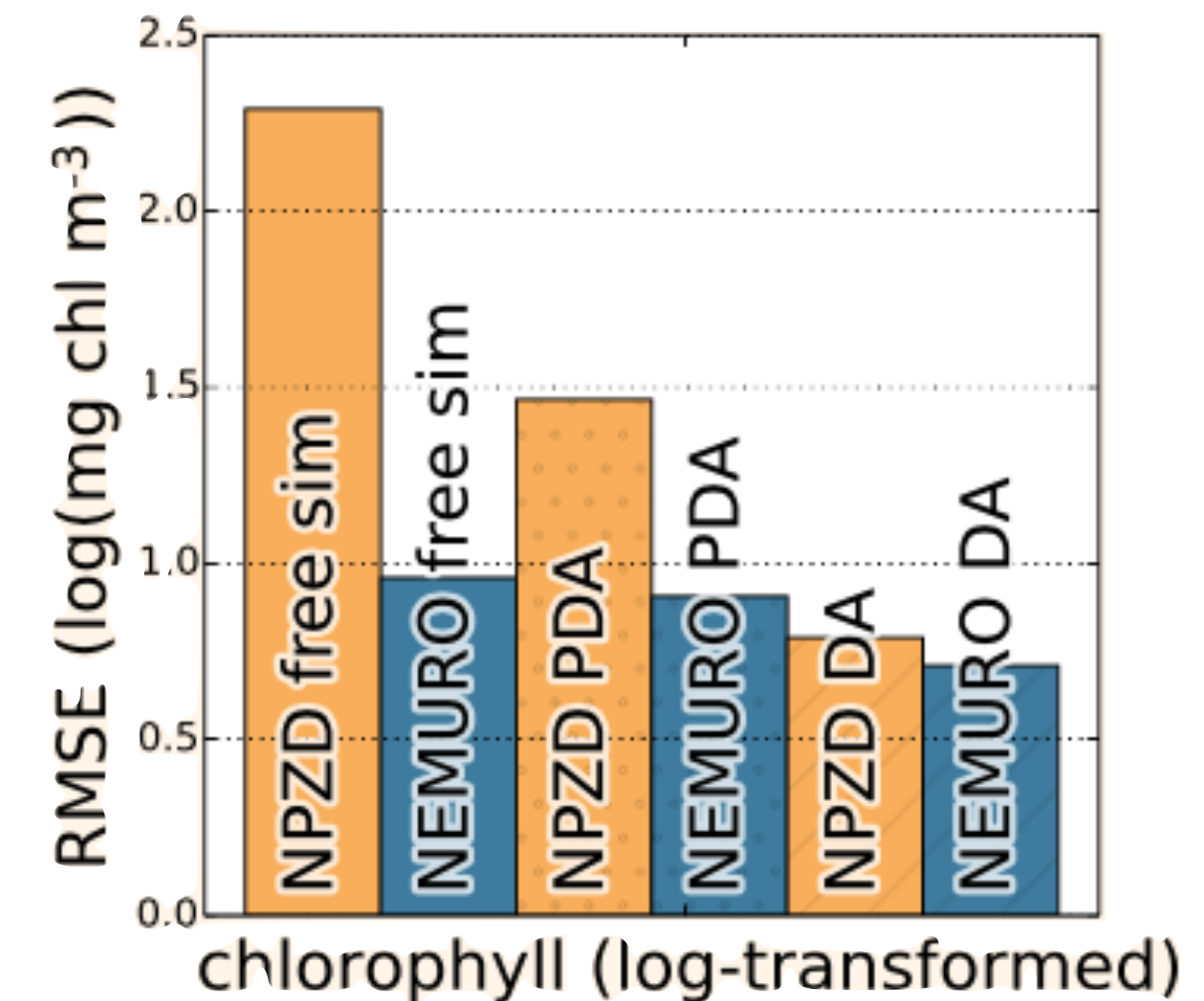
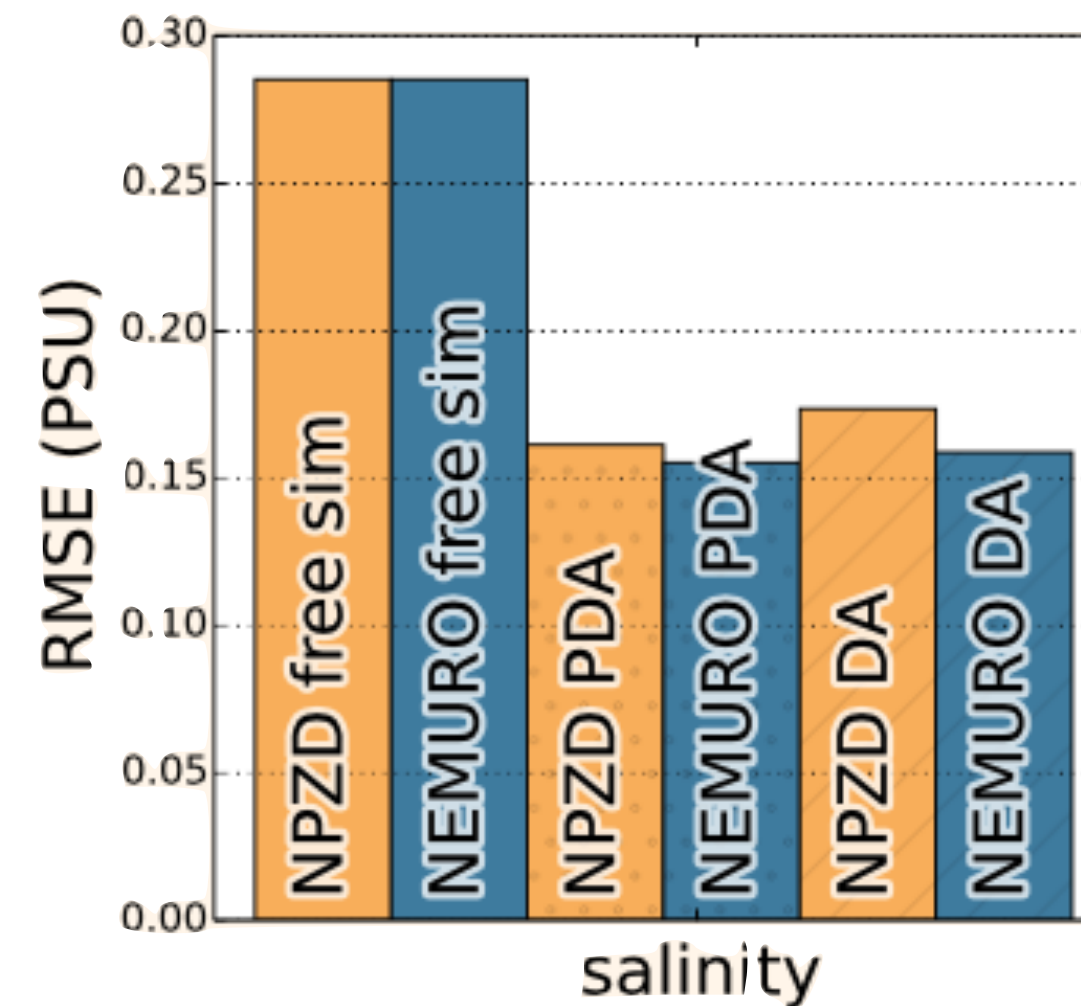
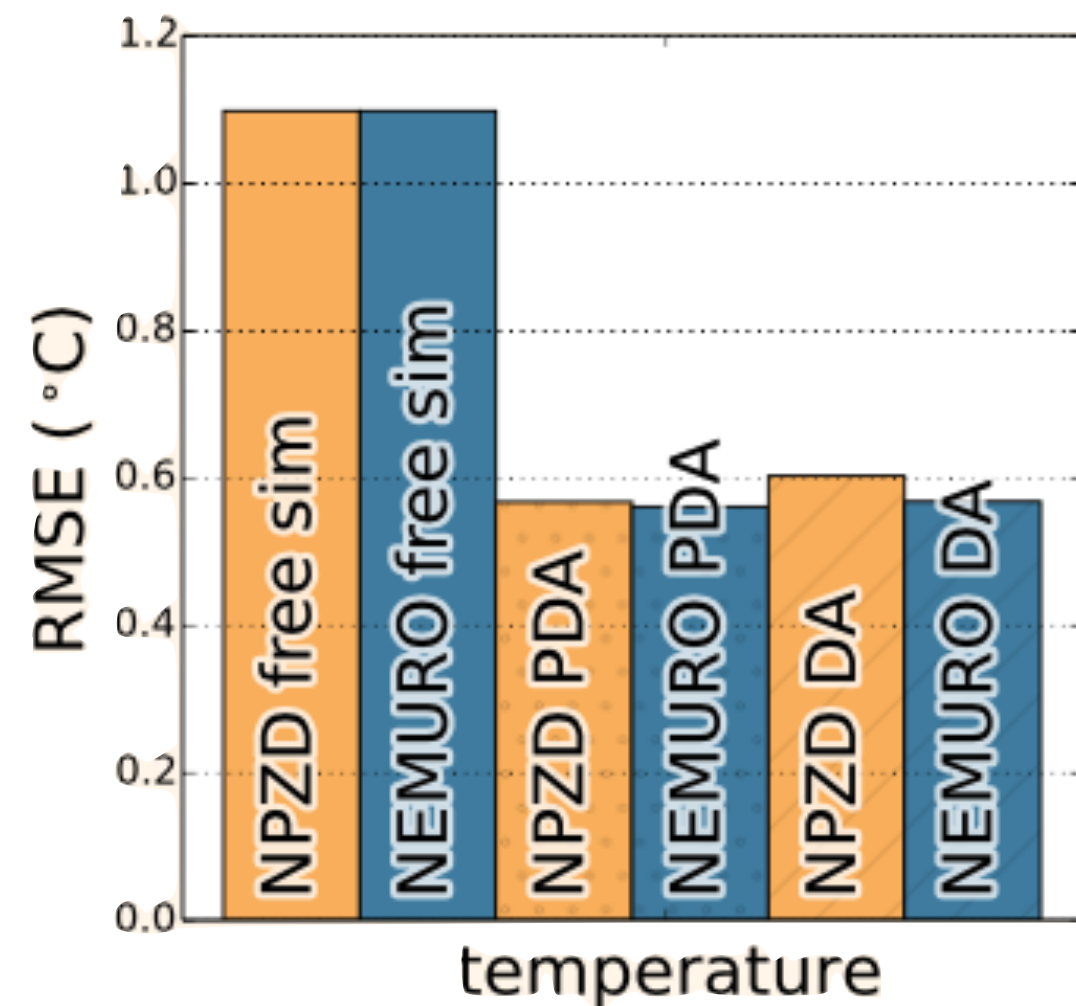
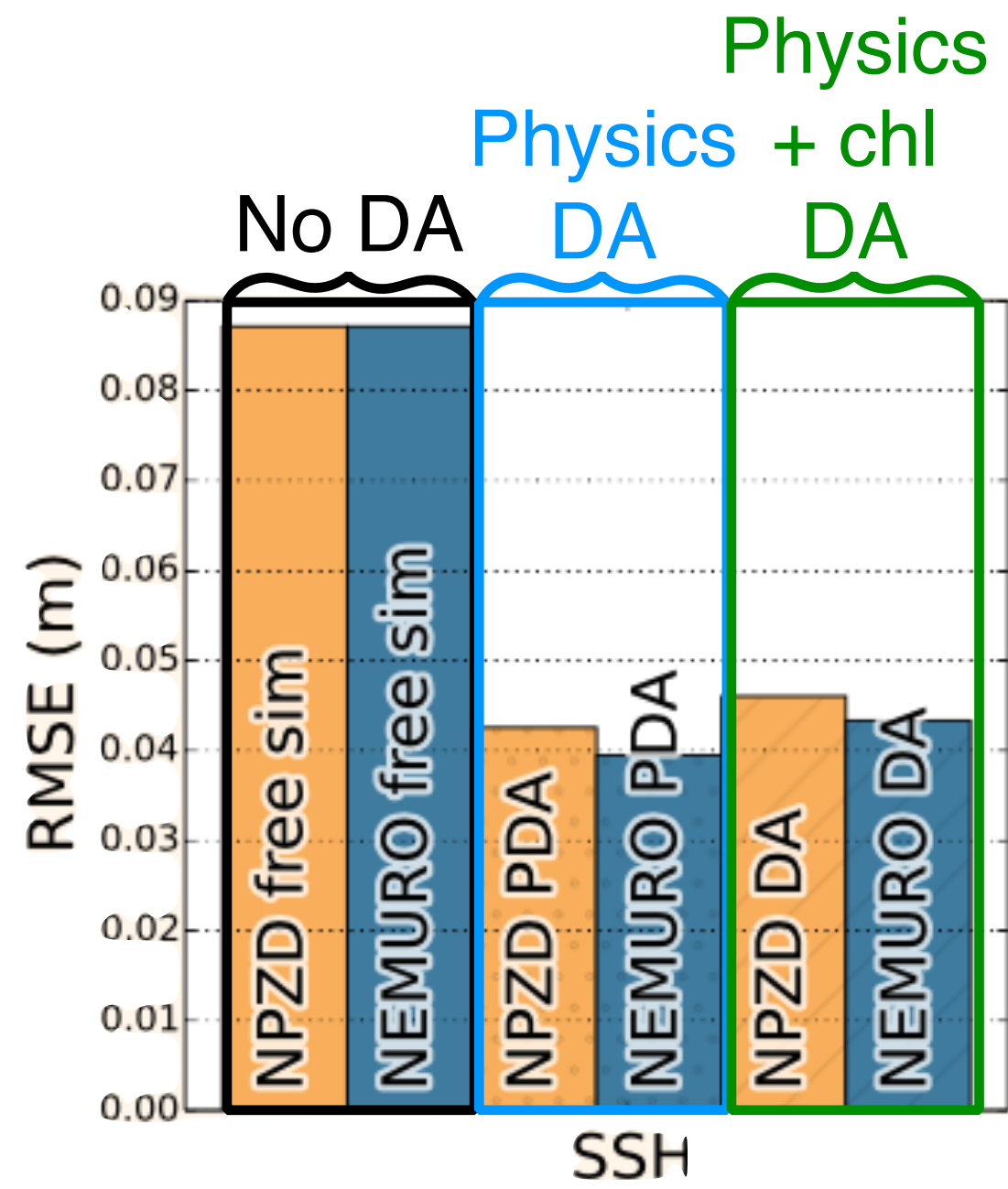
Assimilated  
Observations



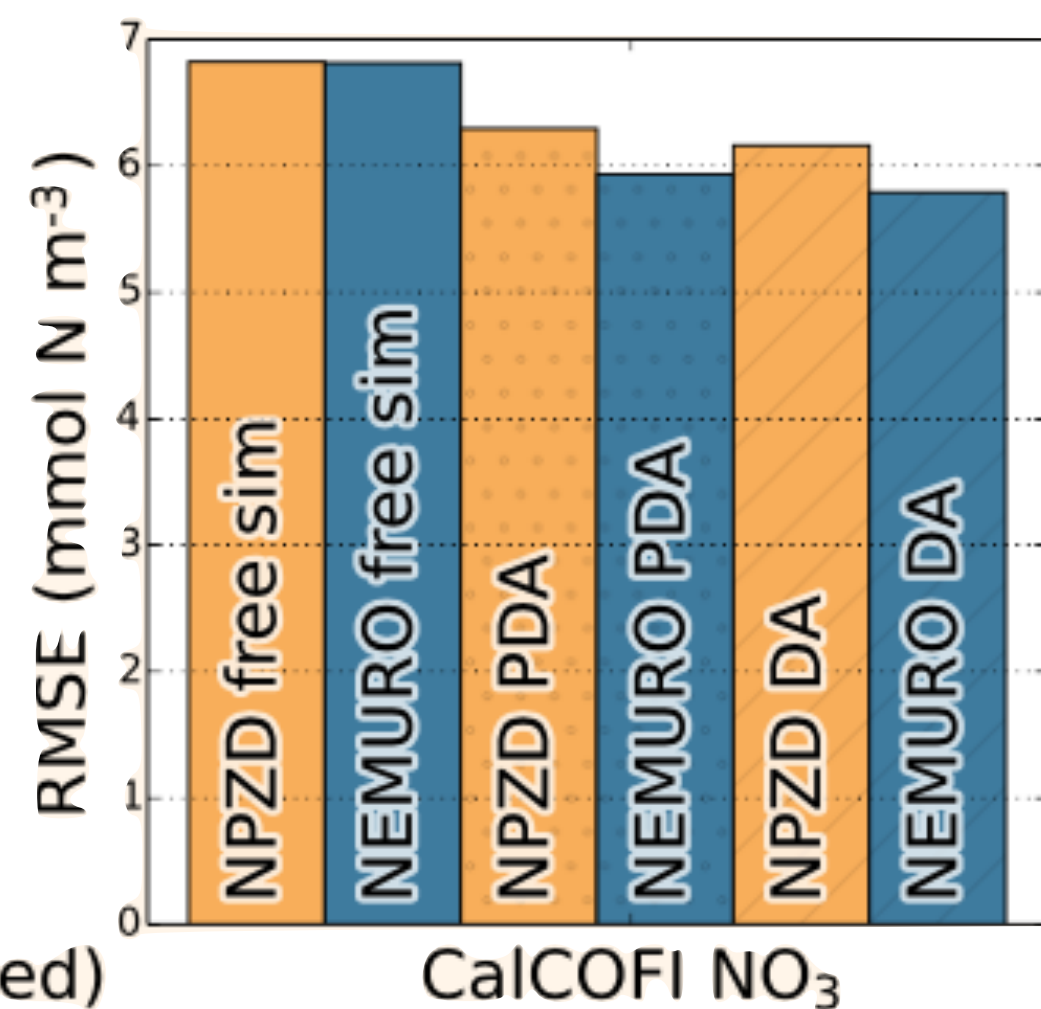
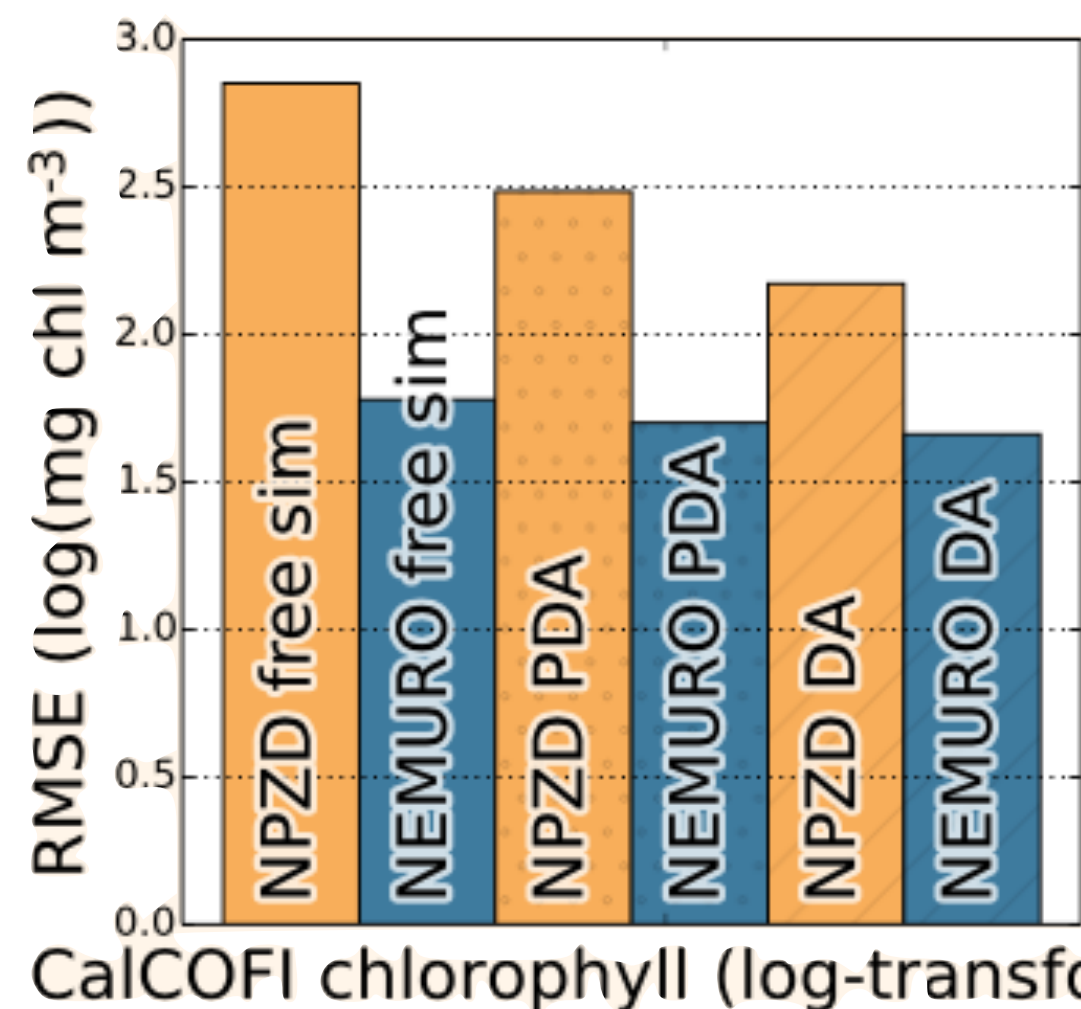
Mattern et al. (2017)

# Model Error Assessment

Assimilated Observations



Independent Observations



Mattern et al. (2017)

# Moving to Near Real Time

Daily physical and biogeochemical ocean state estimate

Currently using  
OSTIA SST (UK Met Office)  
and Modis Aqua Chlorophyll

UC Santa Cruz Ocean Modeling and Data Assimilation

UNIVERSITY OF CALIFORNIA SANTA CRUZ

OVERVIEW | CCS AND MODEL | ASSIMILATION | PUBLICATIONS | MODEL OUTPUT | PEOPLE | CCS NRT ANALYSES

Near Real-time, 4-Dimensional Variational Data Assimilative Physical and Biological Modeling of the California Current System (experimental)

Click on Calendar to change date of plots. Today's Date is Tue Oct 29 2019 .

Figures showing model output for **Tue Oct 29 2019**

October, 2019							
Today							
wk	Sun	Mon	Tue	Wed	Thu	Fri	Sat
39			1	2	3	4	5
40	6	7	8	9	10	11	12
41	13	14	15	16	17	18	19
42	20	21	22	23	24	25	26
43	27	28	29	30	31		

Select date

**Sea Surface Height**  
Prior Model Solution: sea surface height, and horizontal velocity (arrows) at 2 m depth 2019-10-29 00:00

**Sea Surface Temperature**  
Prior Model Solution: temperature and horizontal velocity (arrows) at 2 m depth 2019-10-29 00:00

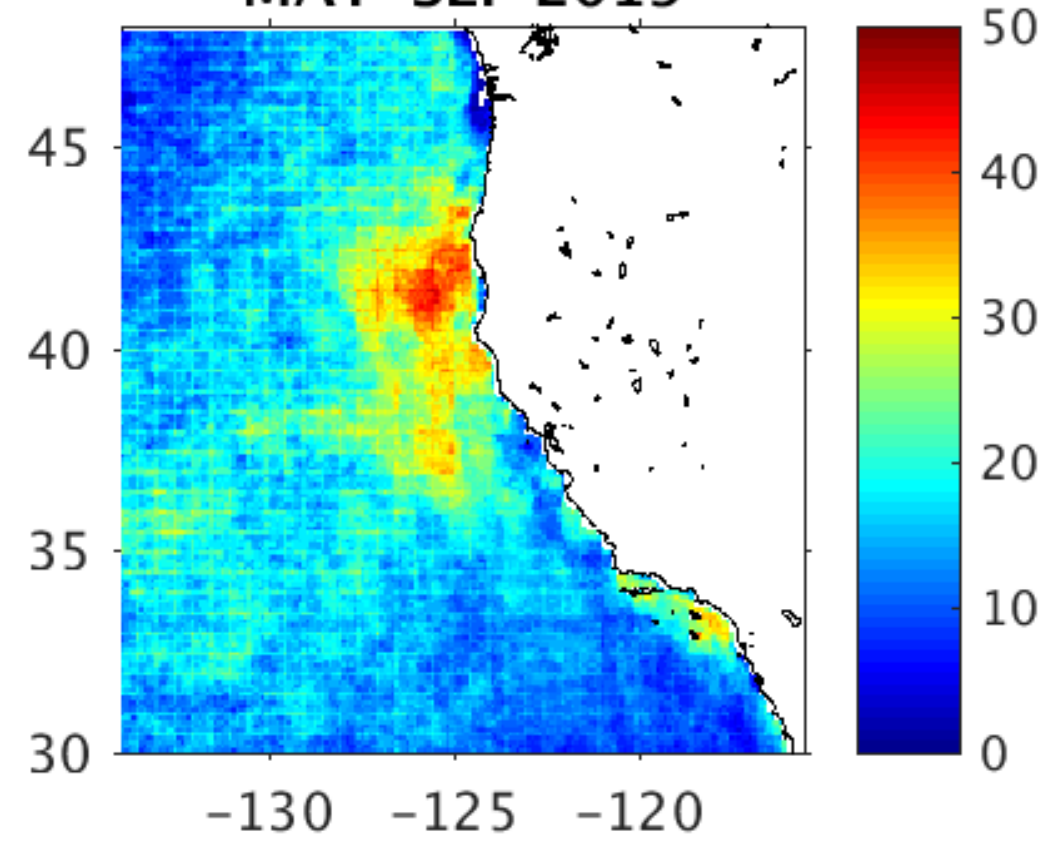
**Sea Surface Salinity**  
Prior Model Solution: salinity and horizontal velocity (arrows) at 2 m depth 2019-10-29 00:00

**Sea Surface Chlorophyll**  
Prior Model Solution: chlorophyll (mg m<sup>-3</sup>) at 2 m depth 2019-10-29 00:00

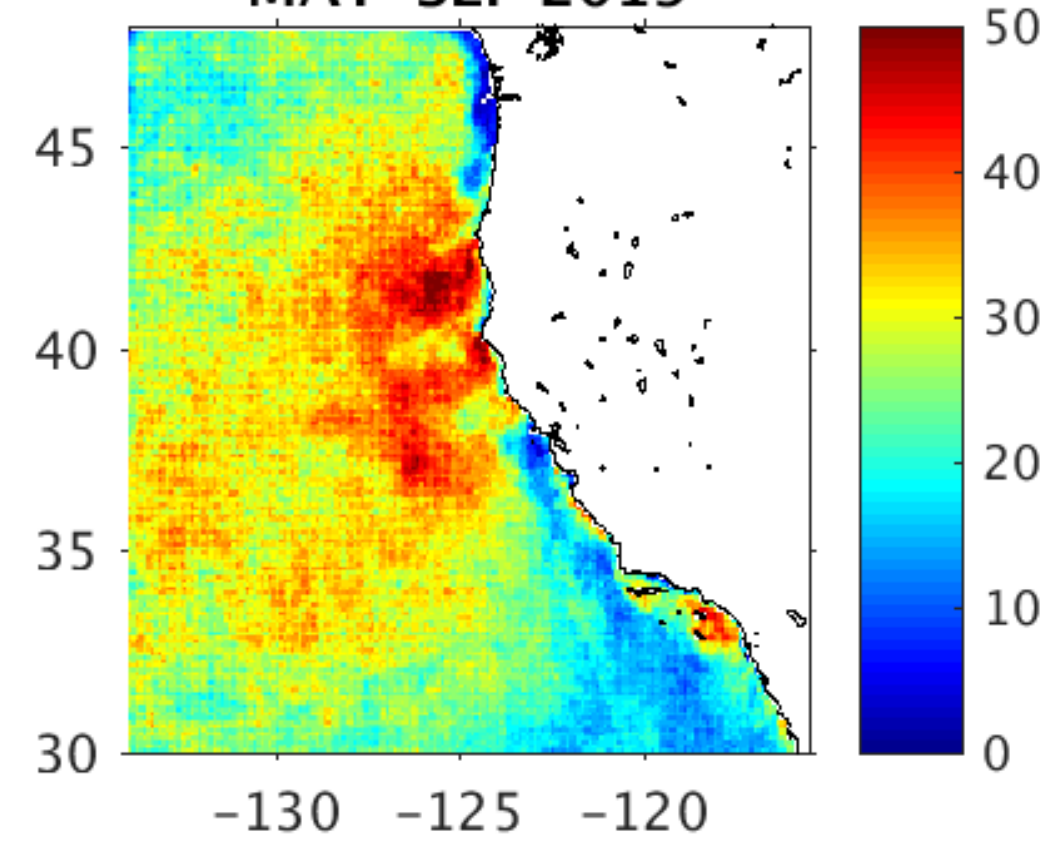
[oceanmodeling.ucsc.edu](http://oceanmodeling.ucsc.edu)

# Moving to Near Real Time with VIIRS

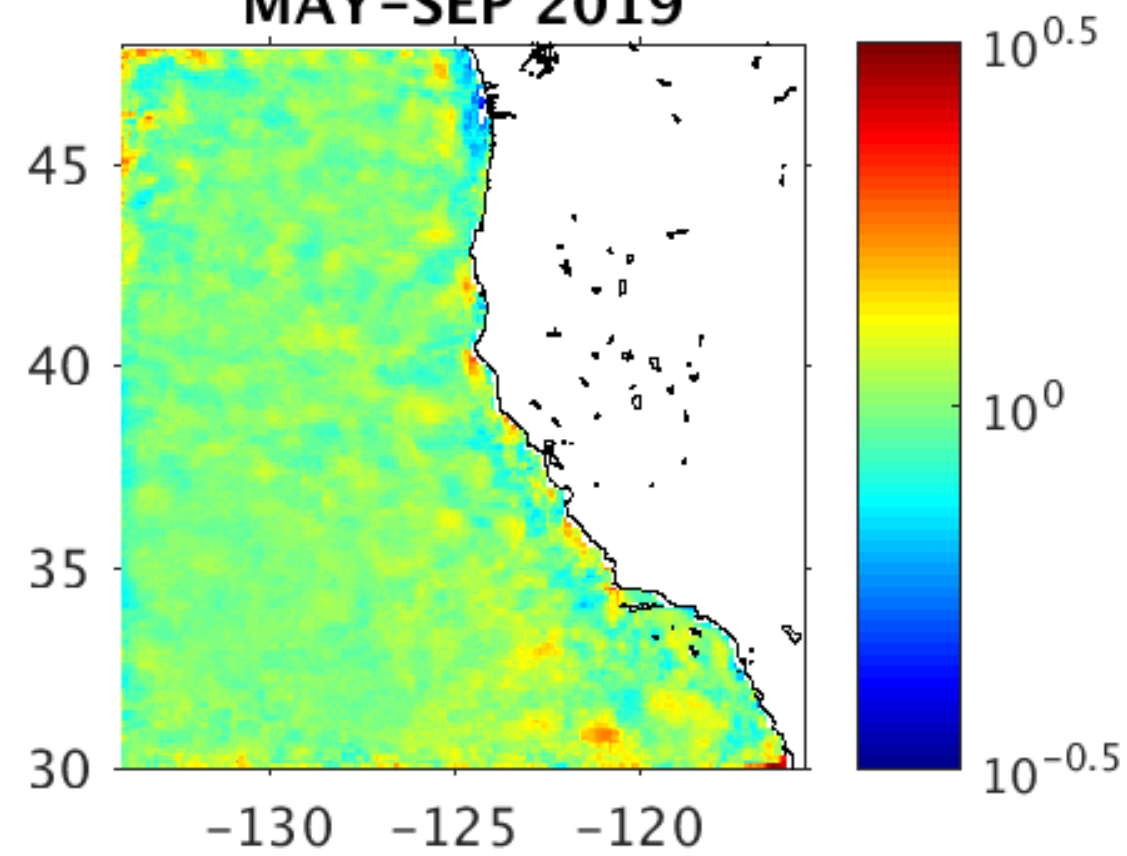
MODIS schl, temporal coverage (%)  
MAY-SEP 2019



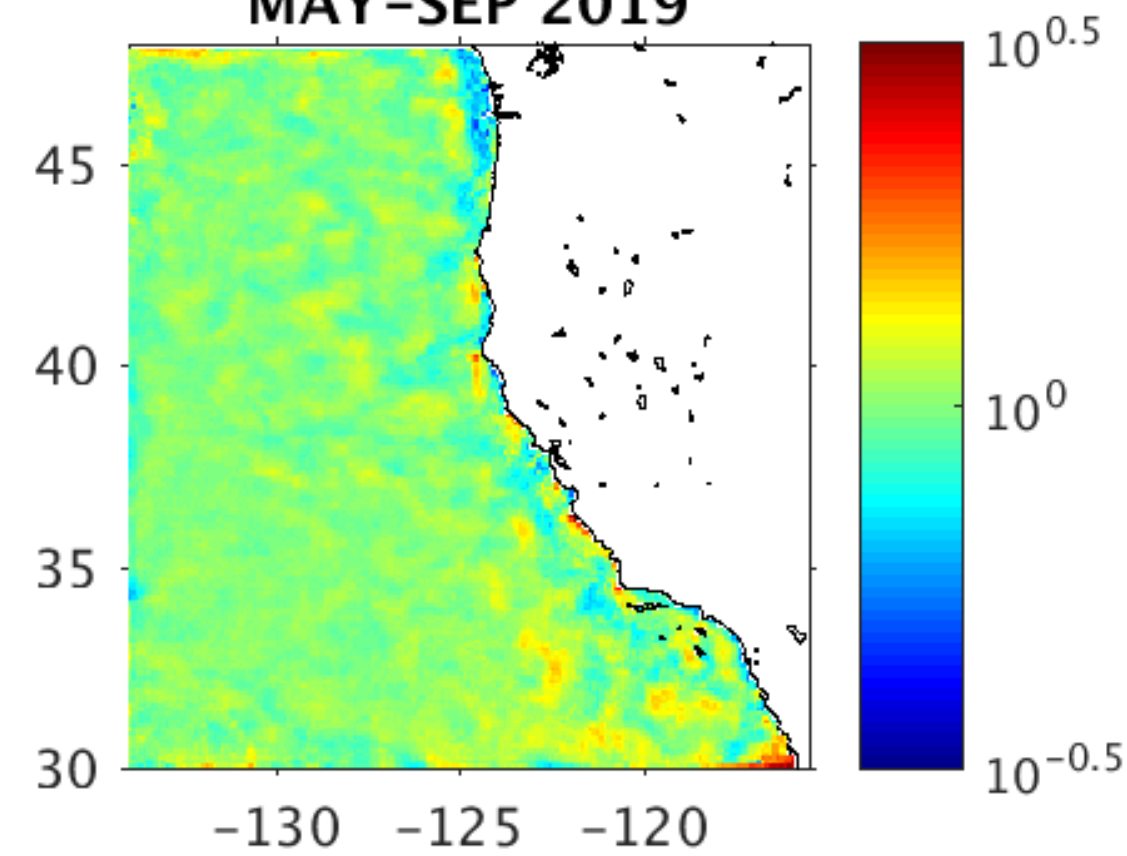
VIIRS schl dt, temporal coverage (%)  
MAY-SEP 2019



log-trans. model bias using MODIS  
MAY-SEP 2019



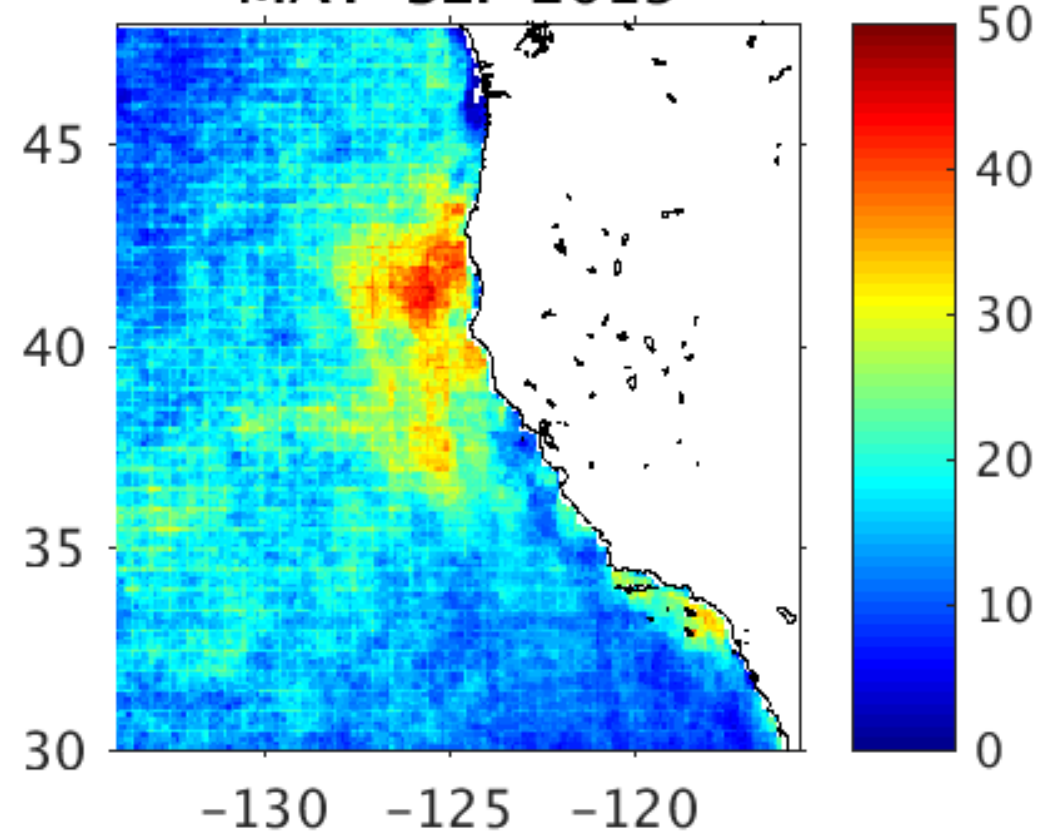
log-trans. model bias using VIIRS  
MAY-SEP 2019



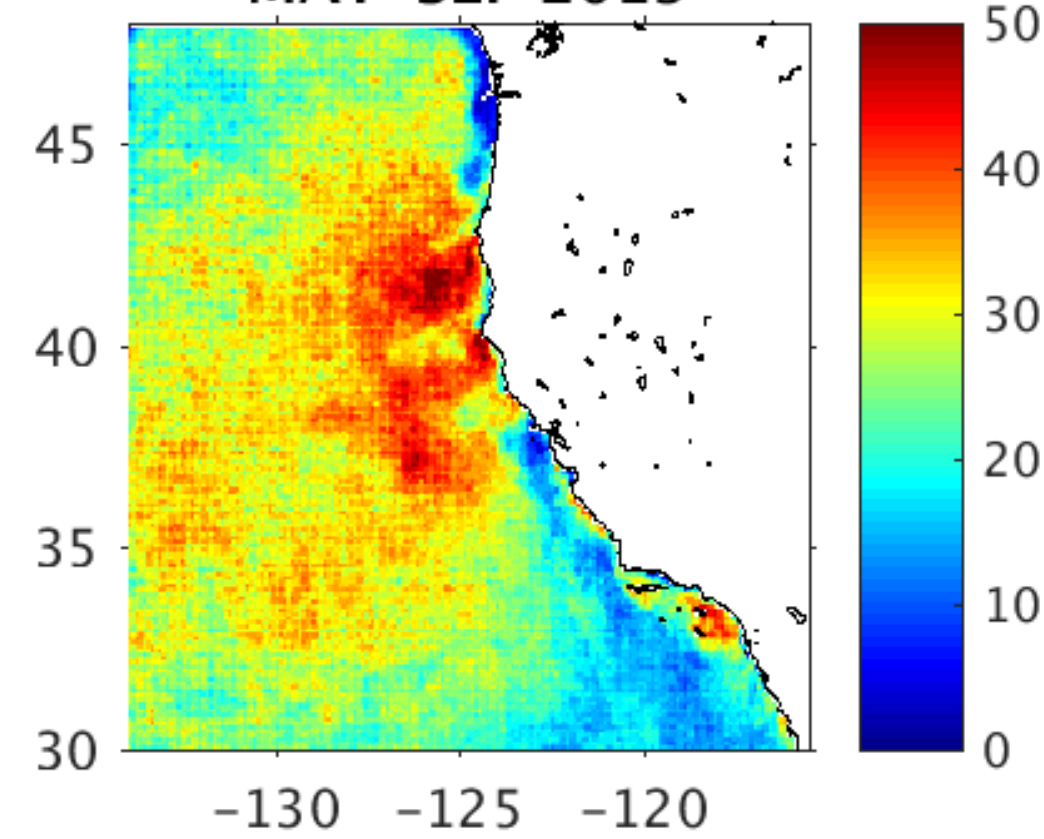


# Moving to Near Real Time with VIIRS

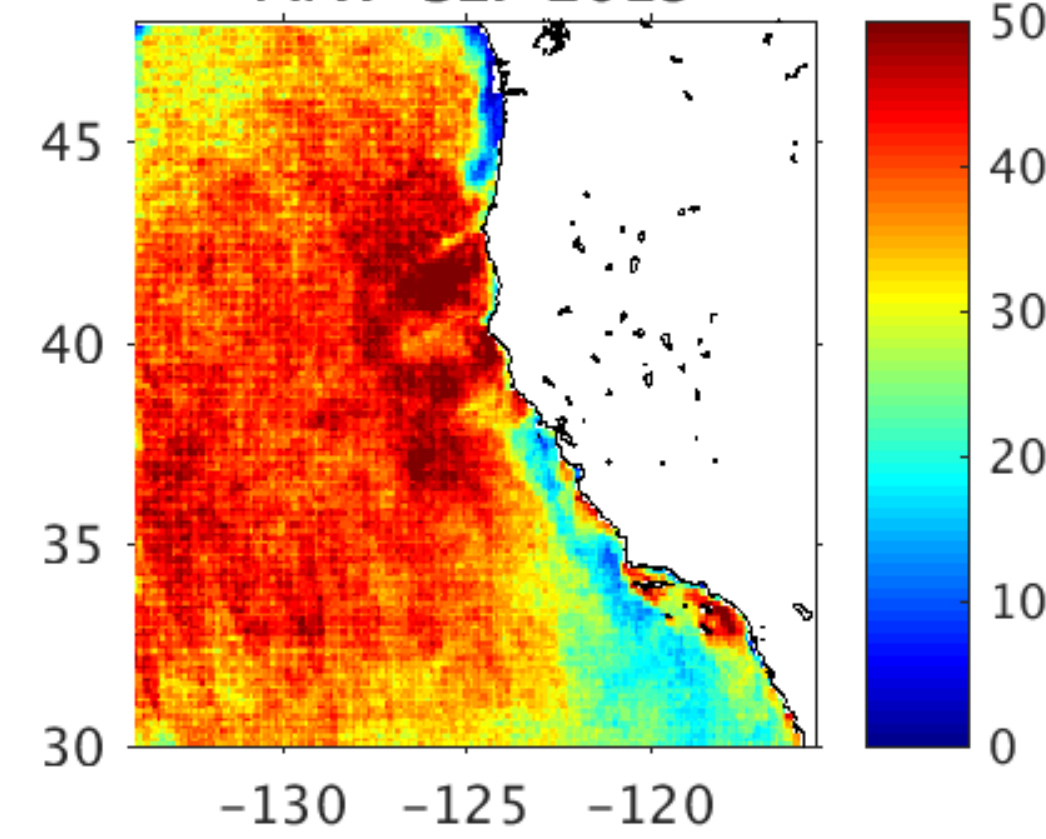
MODIS schl, temporal coverage (%)  
MAY-SEP 2019



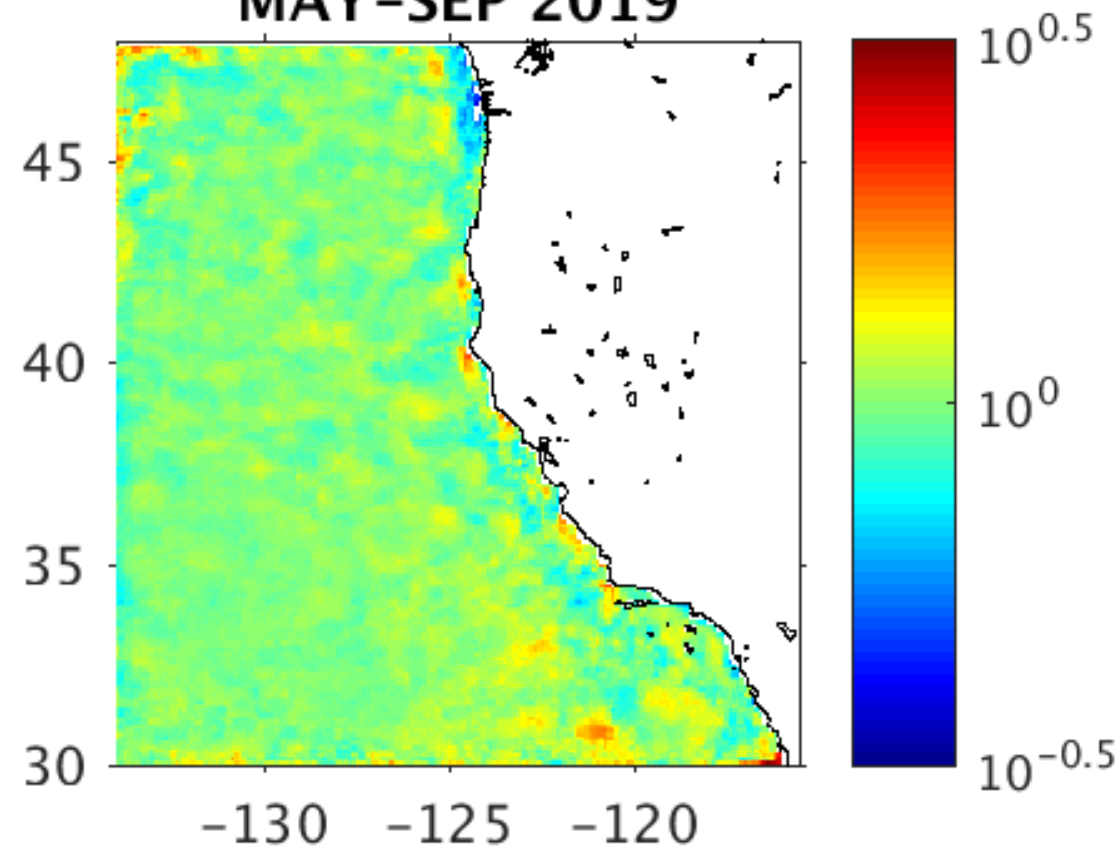
VIIRS schl dt, temporal coverage (%)  
MAY-SEP 2019



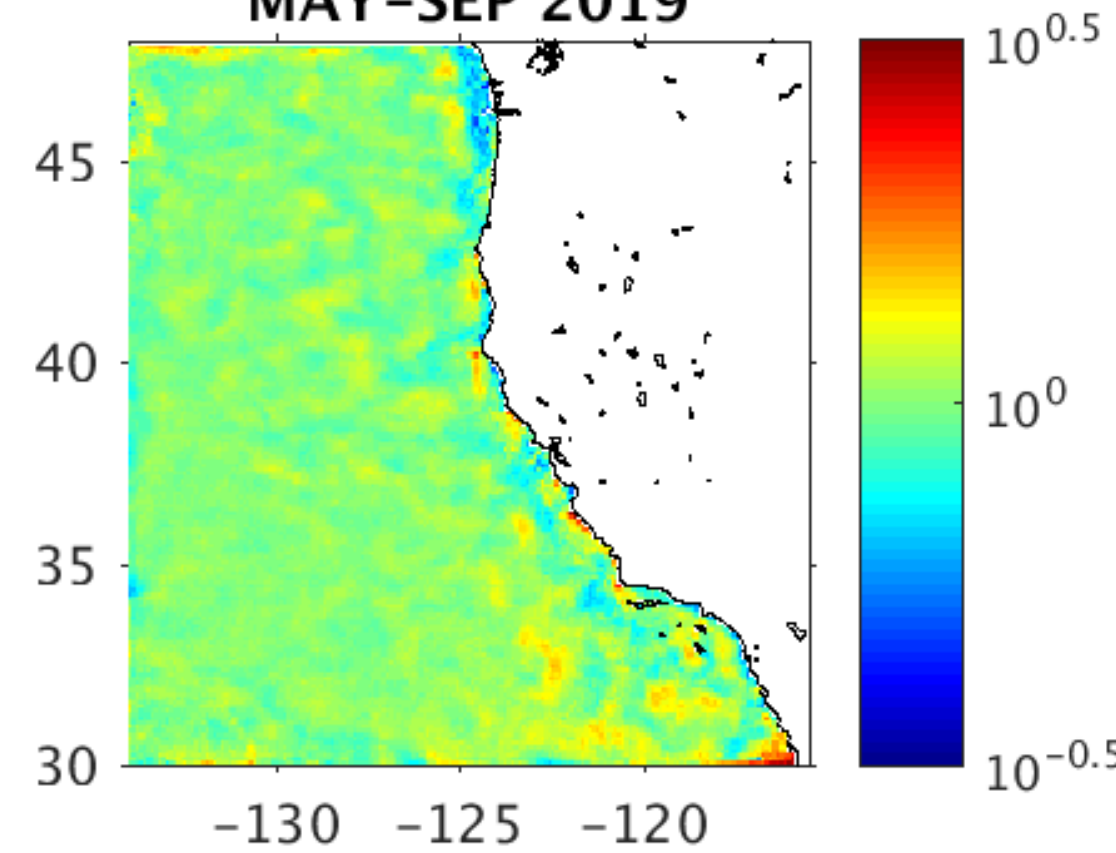
VIIRS schl nrt, temporal coverage (%)  
MAY-SEP 2019



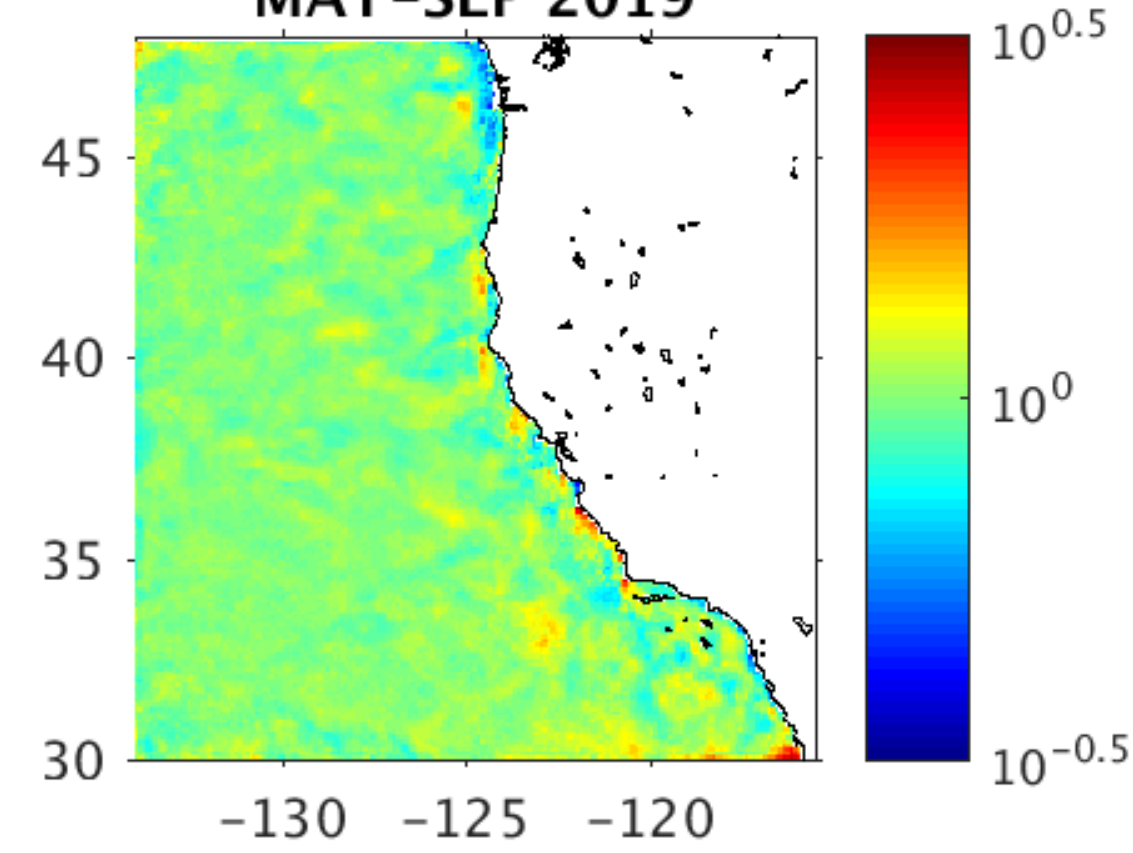
log-trans. model bias using MODIS  
MAY-SEP 2019



log-trans. model bias using VIIRS  
MAY-SEP 2019

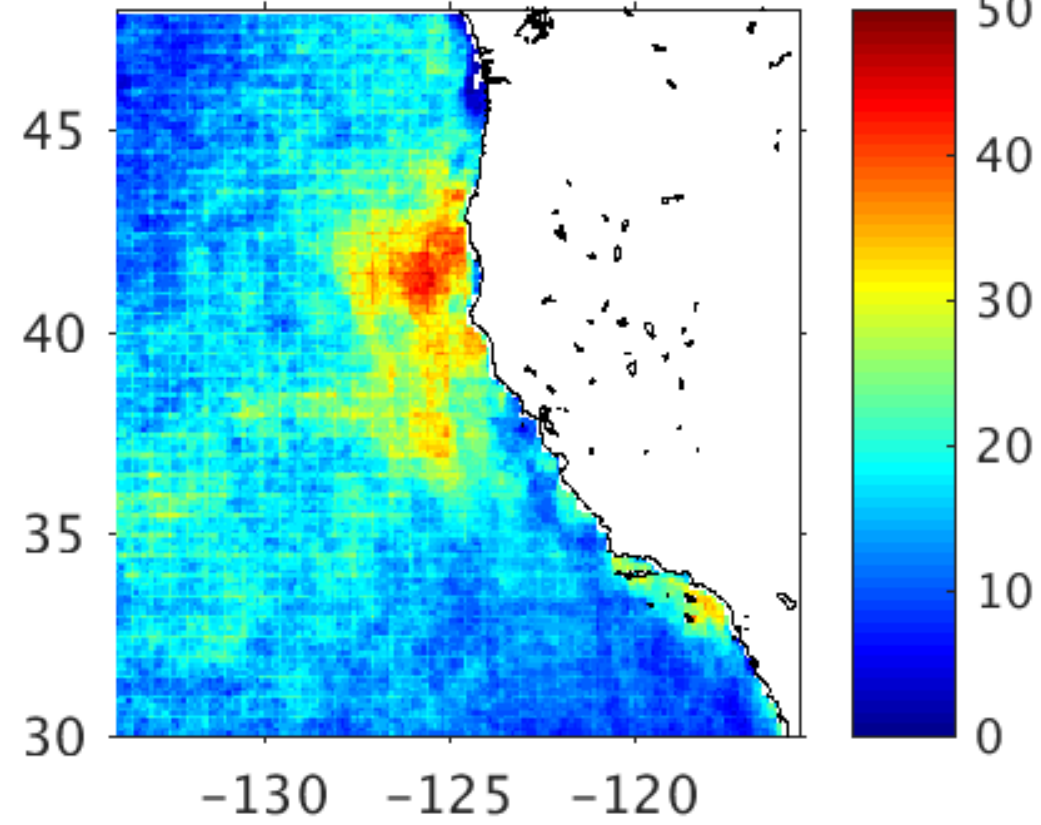


log-trans. model bias using VIIRS  
MAY-SEP 2019

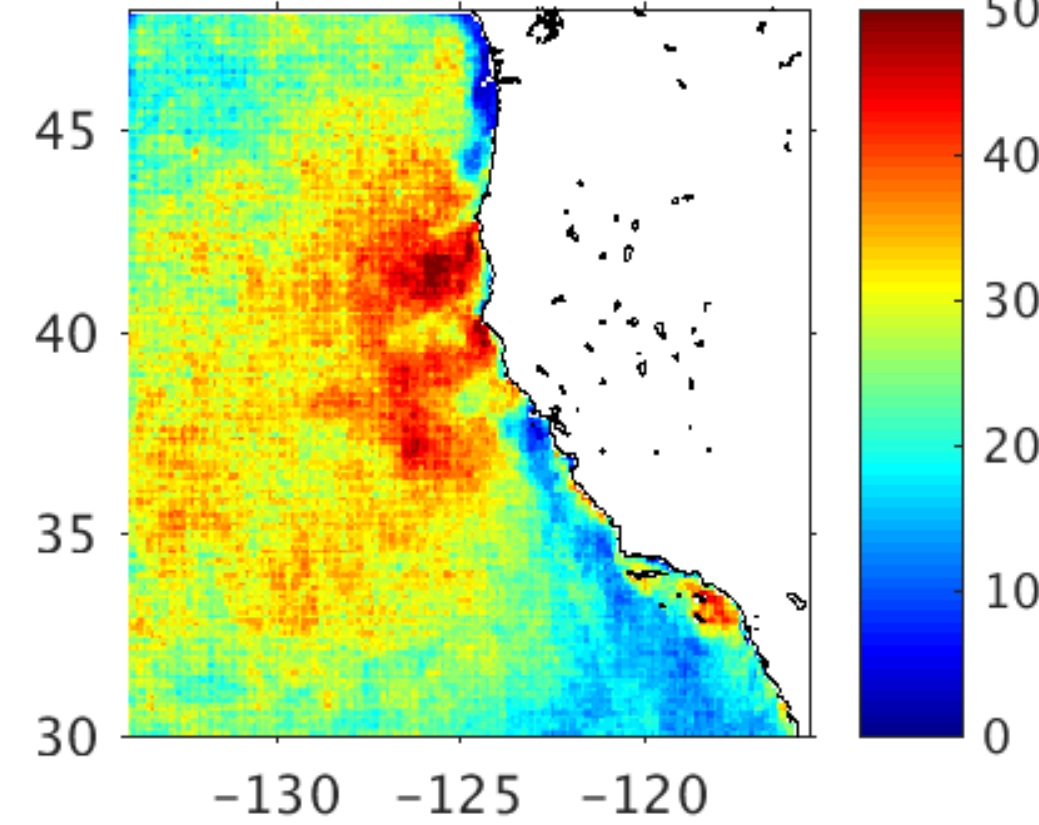


# Moving to Near Real Time with VIIRS

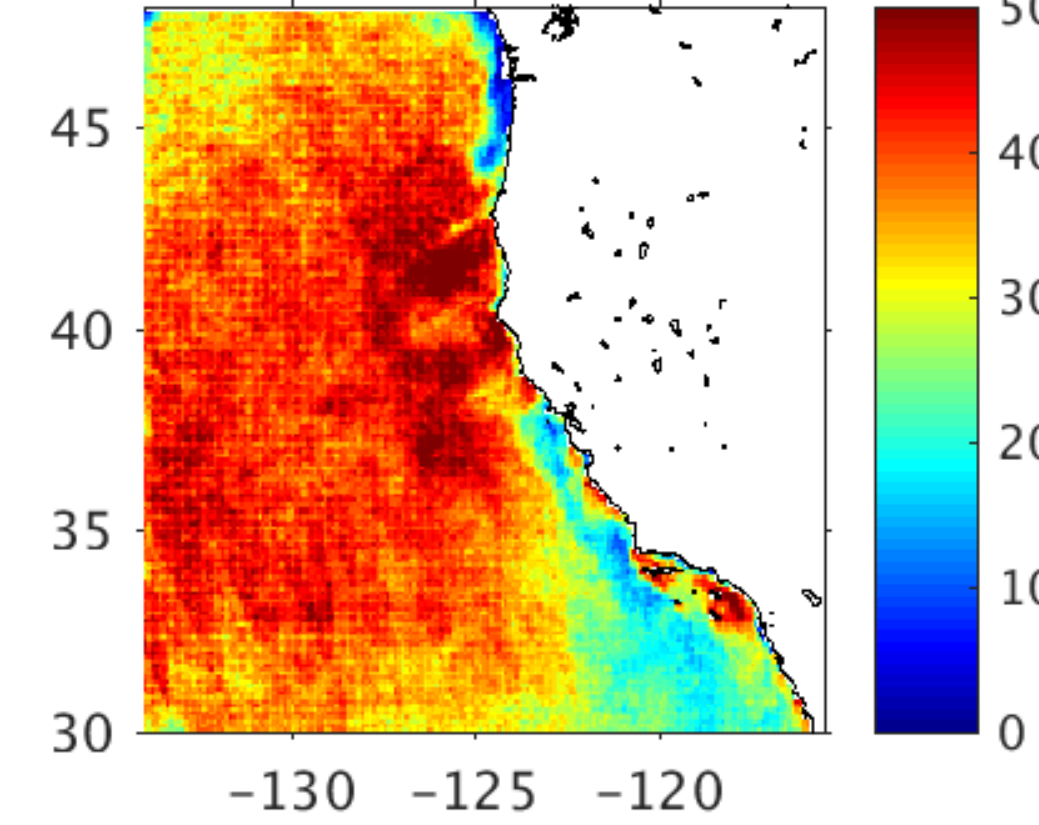
MODIS schl, temporal coverage (%)  
MAY-SEP 2019



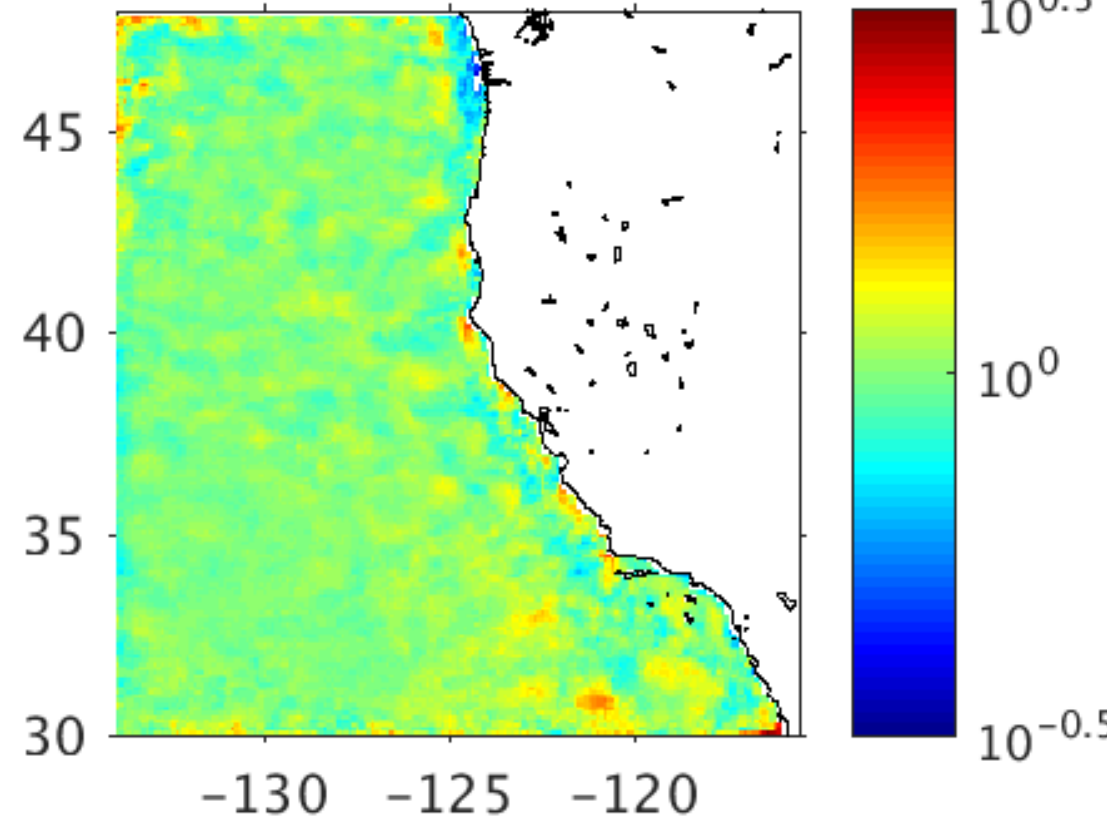
VIIRS schl dt, temporal coverage (%)  
MAY-SEP 2019



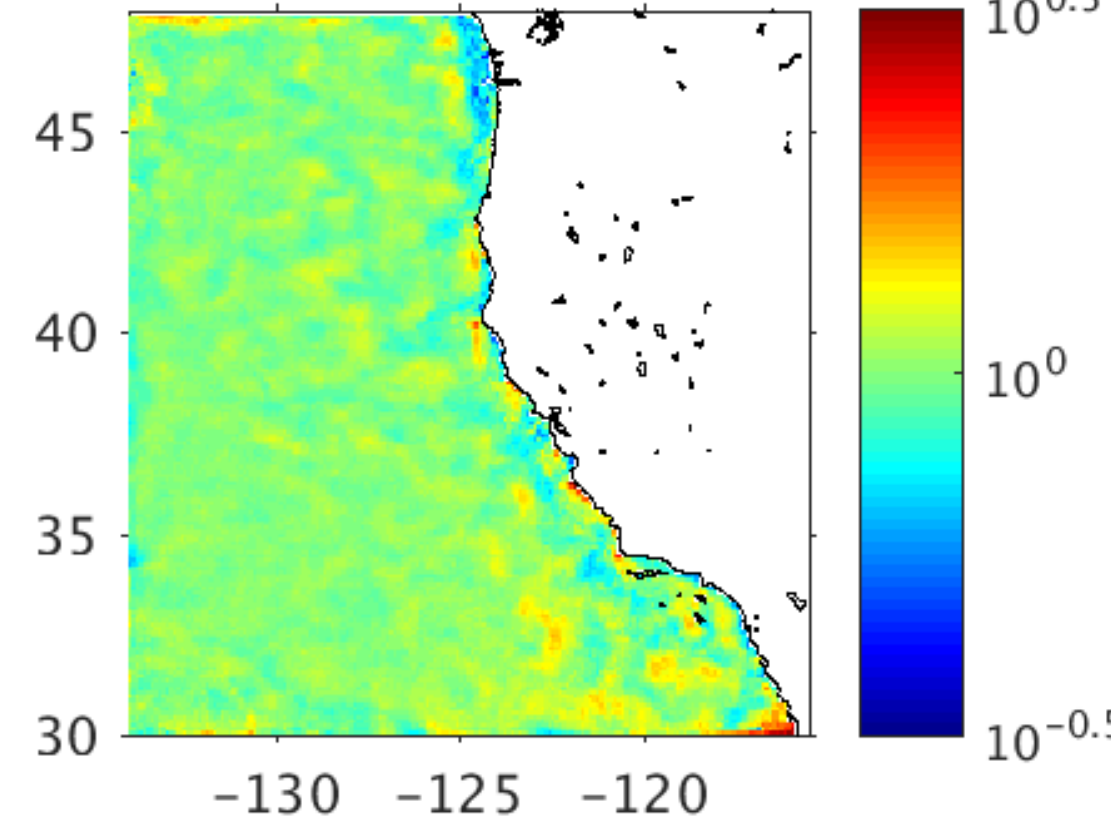
VIIRS schl nrt, temporal coverage (%)  
MAY-SEP 2019



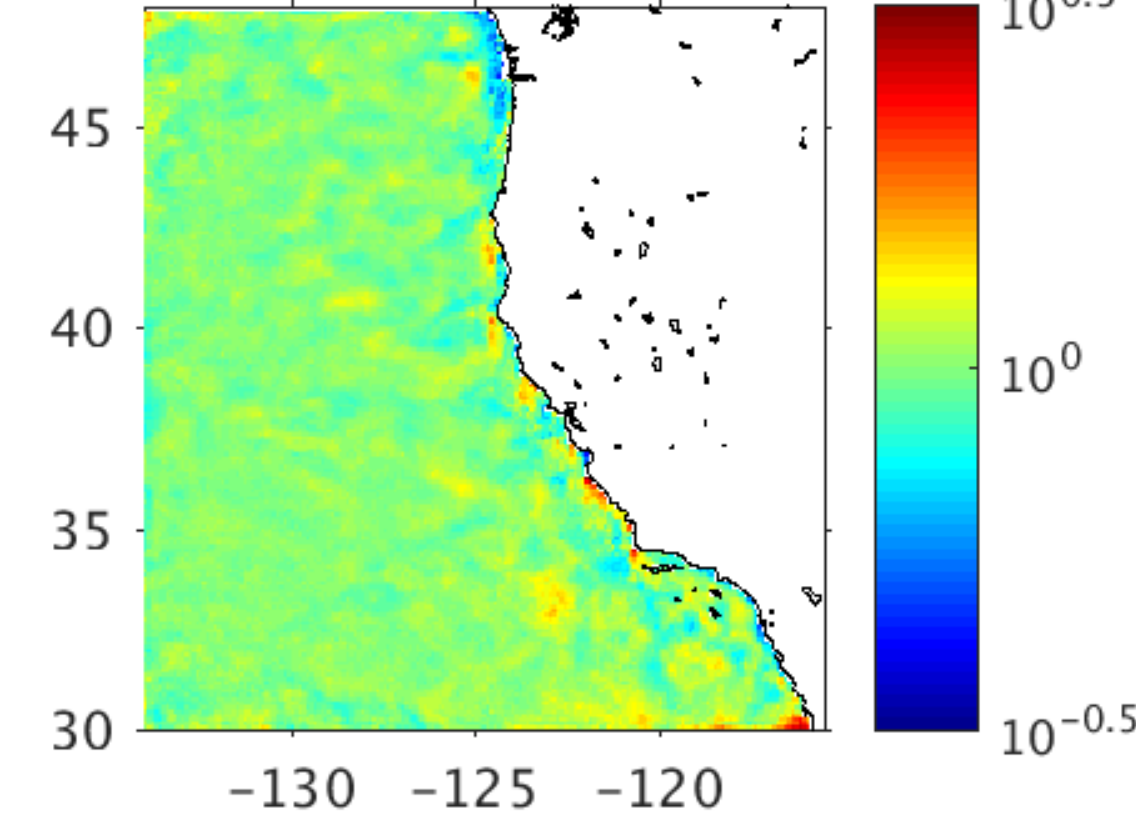
log-trans. model bias using MODIS  
MAY-SEP 2019



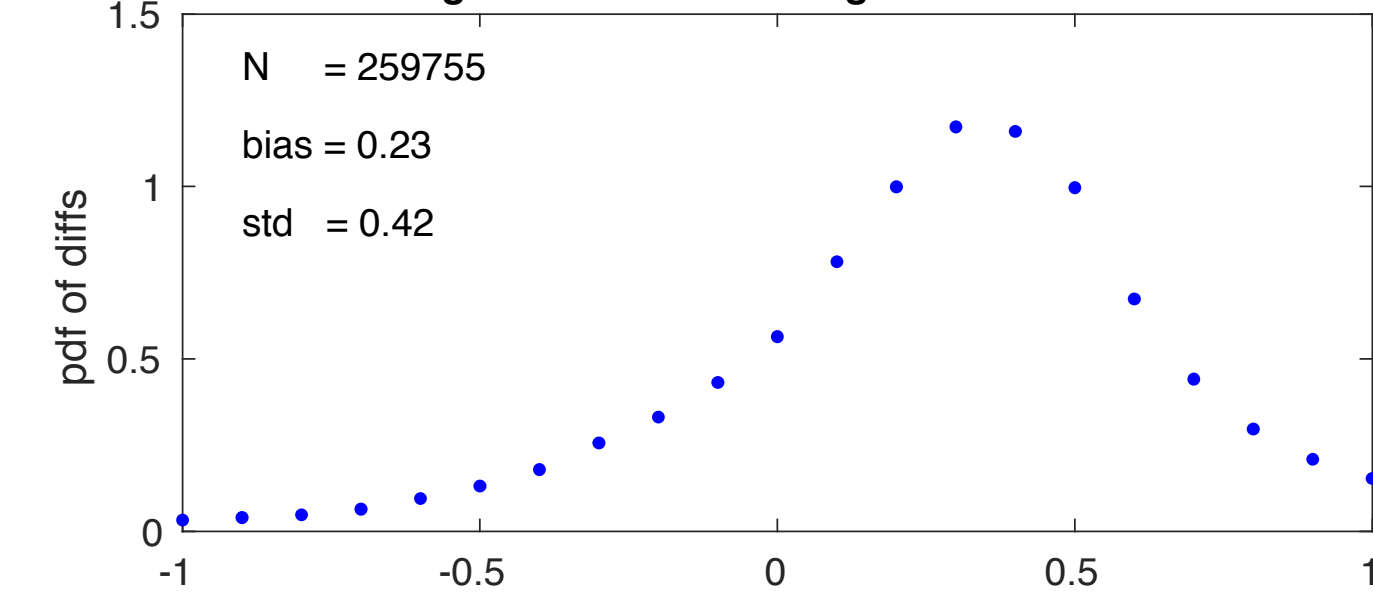
log-trans. model bias using VIIRS  
MAY-SEP 2019



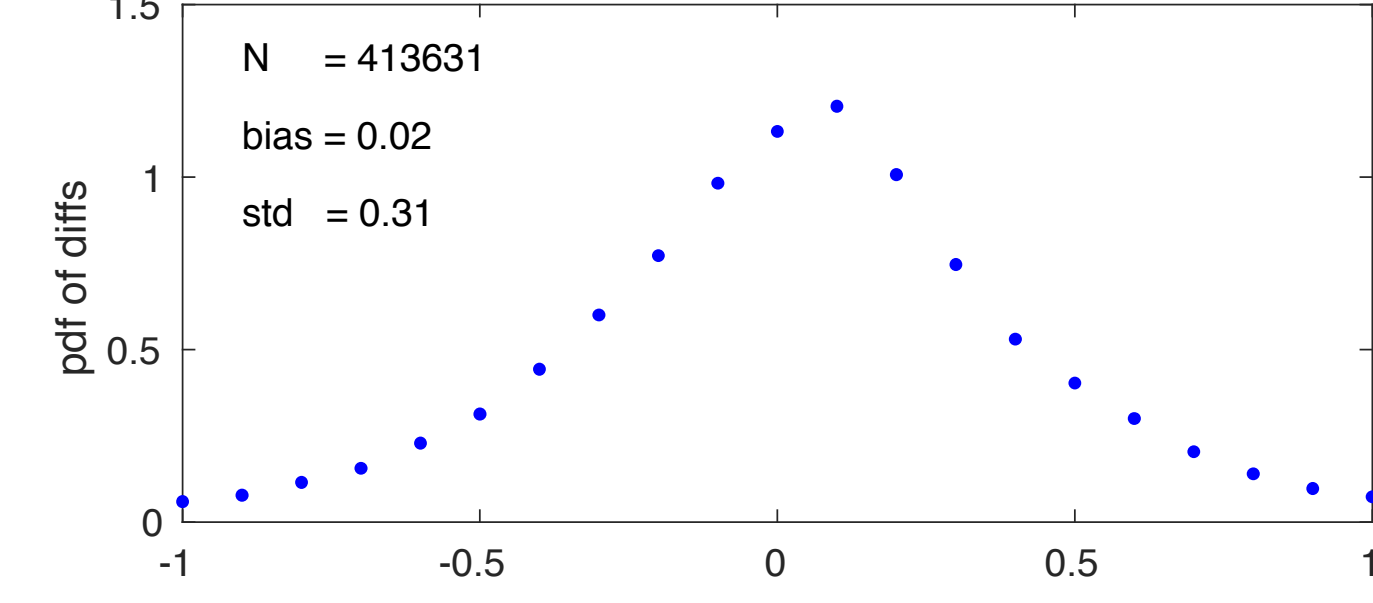
log-trans. model bias using VIIRS  
MAY-SEP 2019



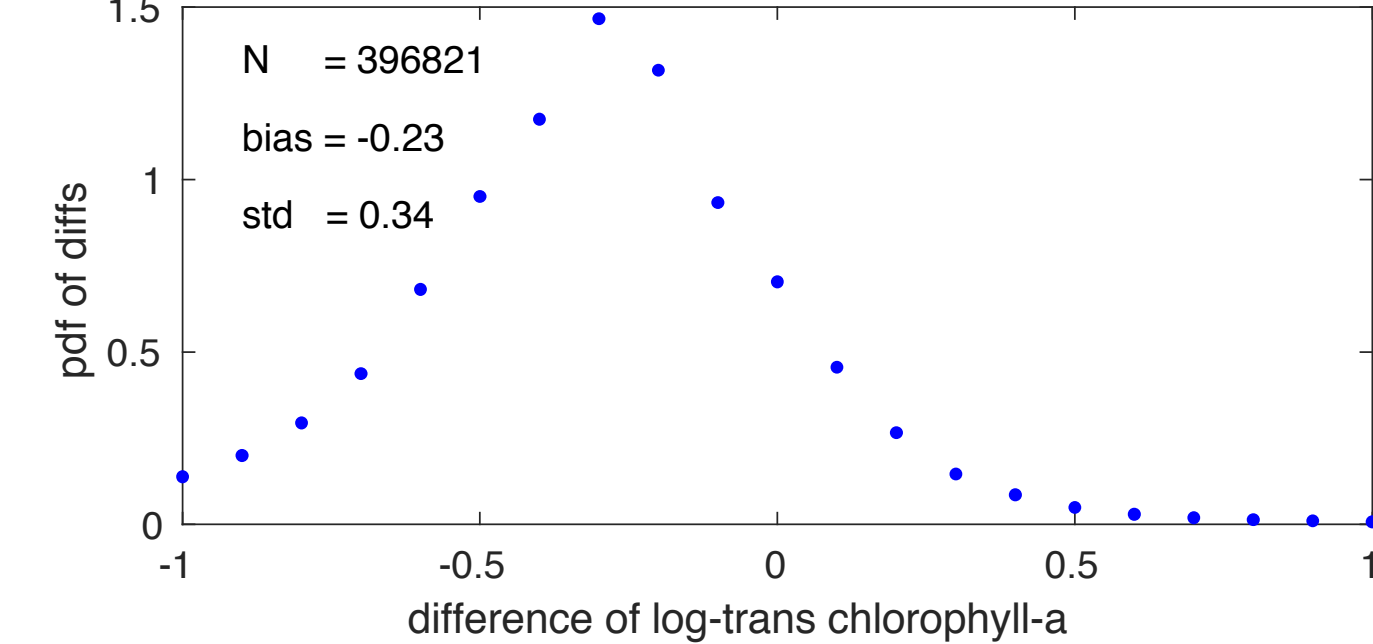
log-trans L3 VIIRS NRT SCHL minus  
log-trans MODIS AQUA gridded SCHL



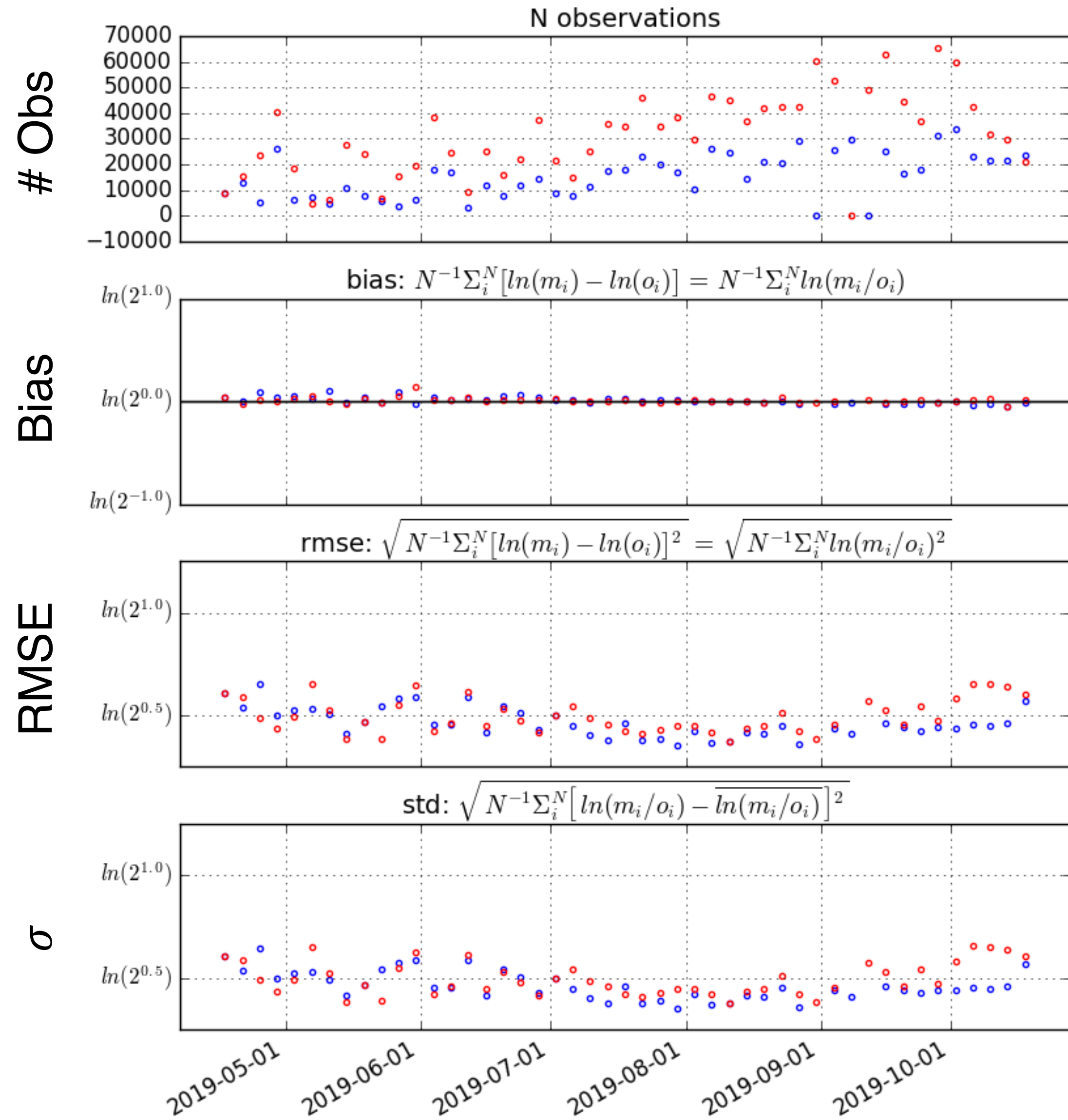
log-trans L3 VIIRS Delayed SCHL minus  
log-trans MODIS AQUA gridded SCHL



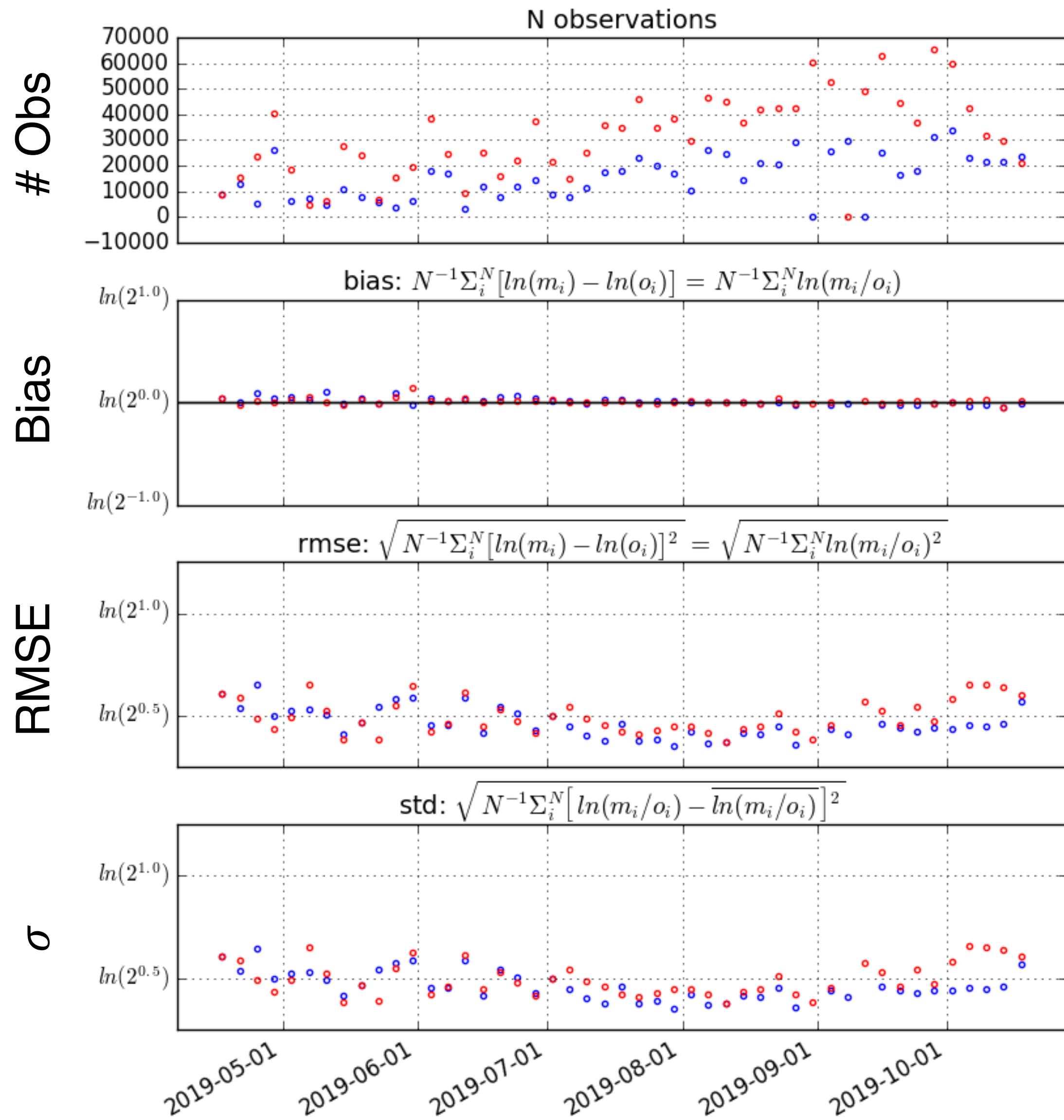
log-trans L3 VIIRS Delayed SCHL minus  
log-trans L3 VIIRS NRT SCHL



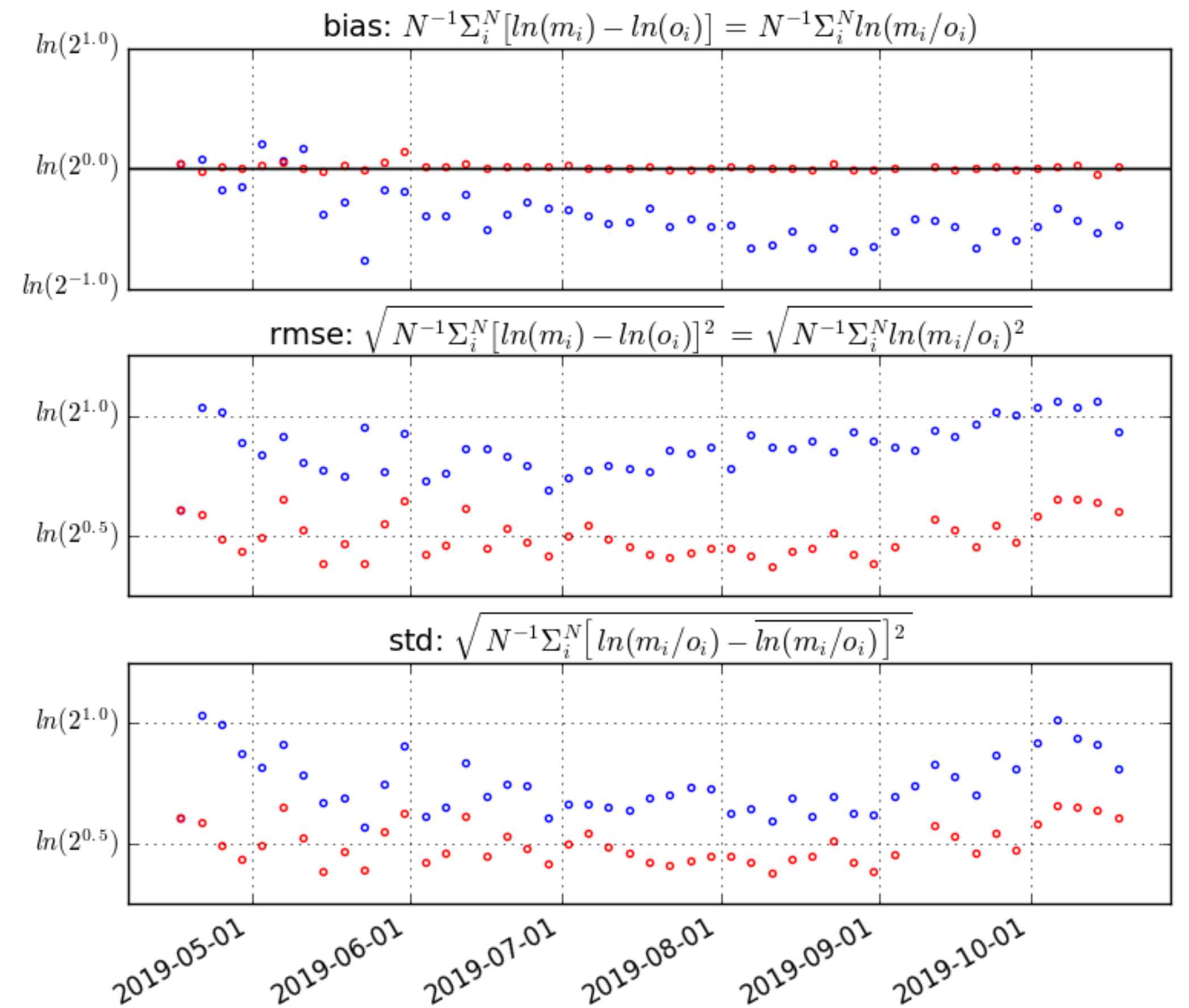
# VIIRS DA vs. MODIS DA



# VIIRS DA vs. MODIS DA



# VIIRS DA vs. No DA



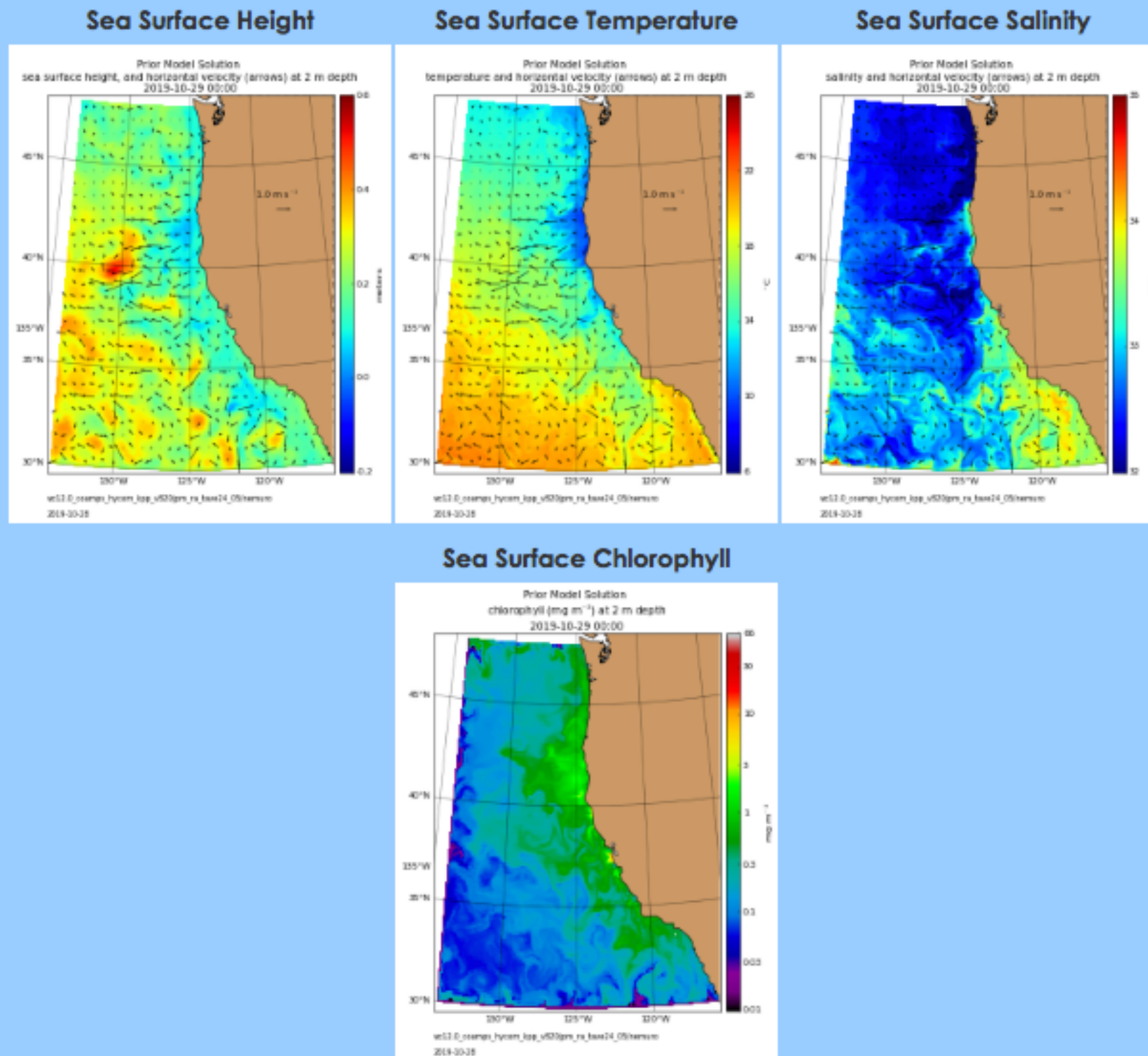
Near Real-time, 4-Dimensional Variational Data Assimilative  
Physical and Biological Modeling of the California Current System  
(experimental)

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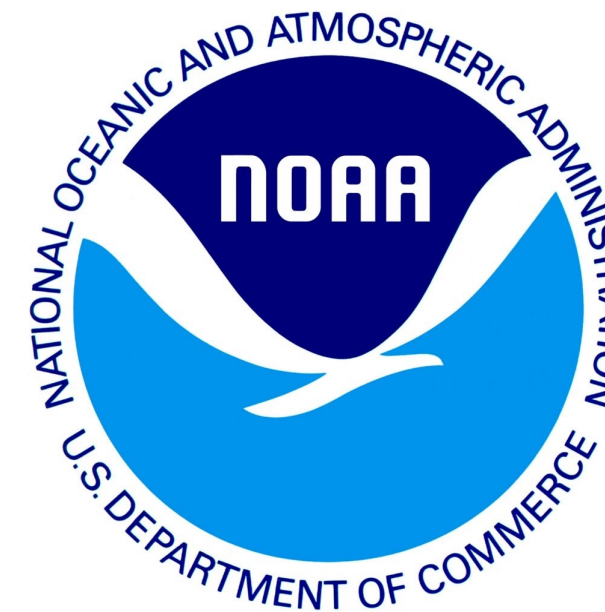
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Select date



# Thank You!



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