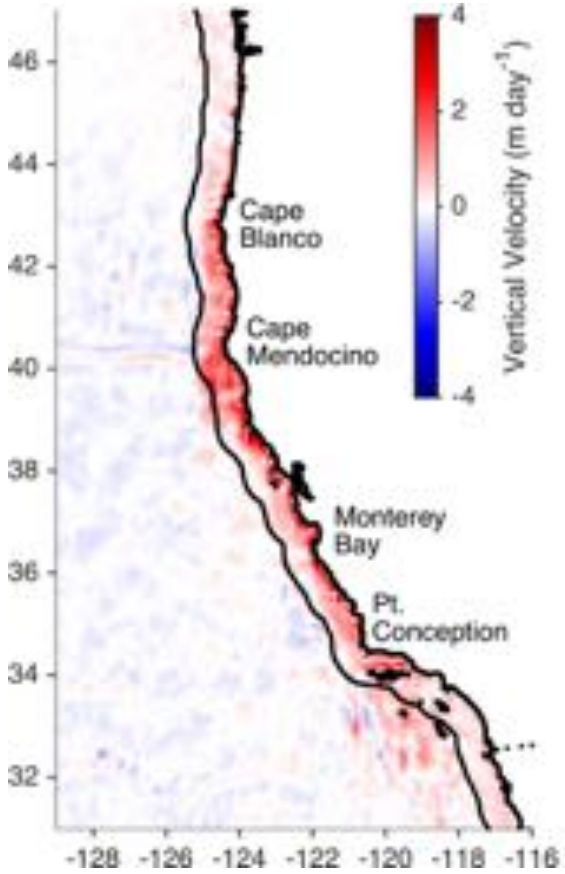
Physical Processes Impacting Ecosystem Indicators

Mike Jacox

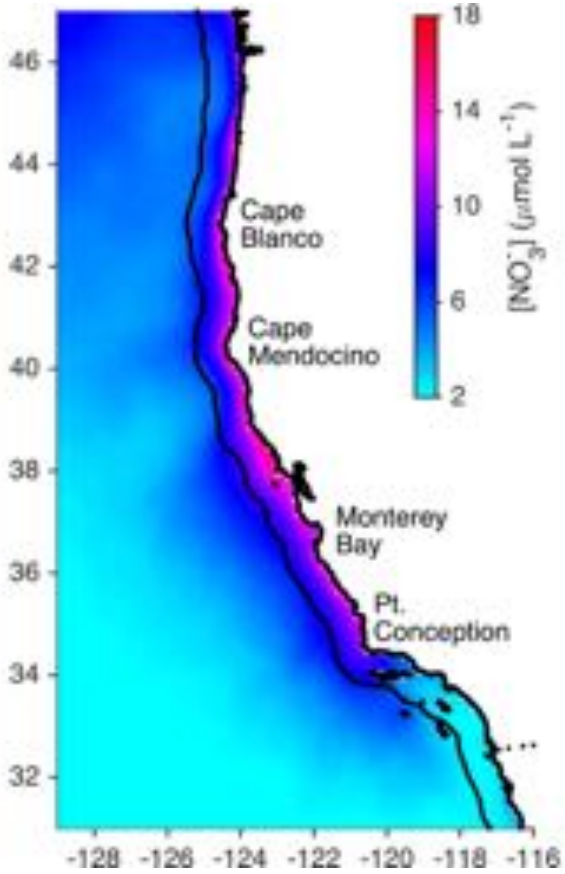
US CLIVAR Workshop:
Forecasting ENSO Impacts on Marine Ecosystems of the US West Coast
August 10, 2016

Upwelling Season (March - July) Mean Conditions

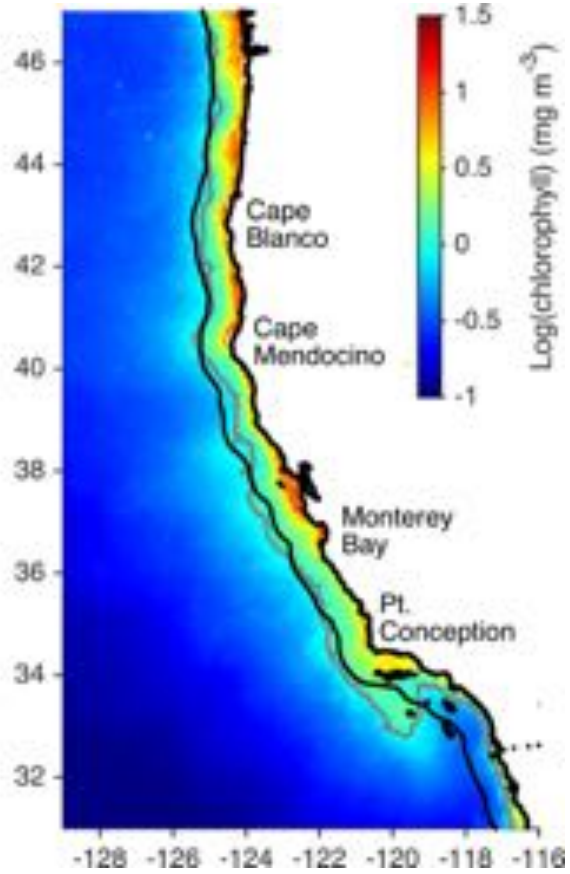
Upwelling



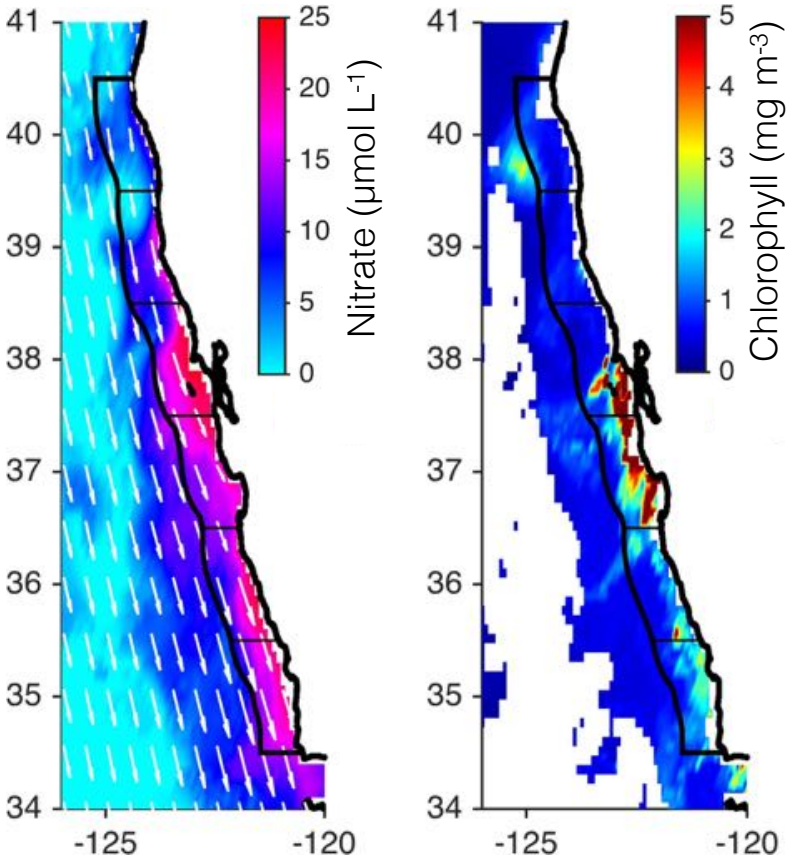
Subsurface Nitrate



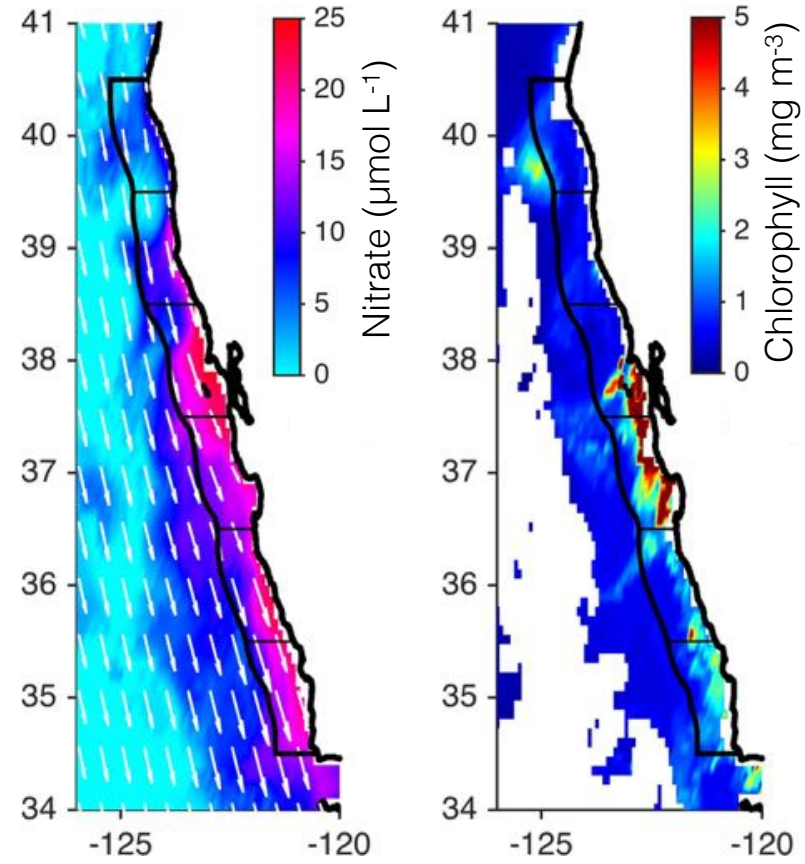
Chlorophyll

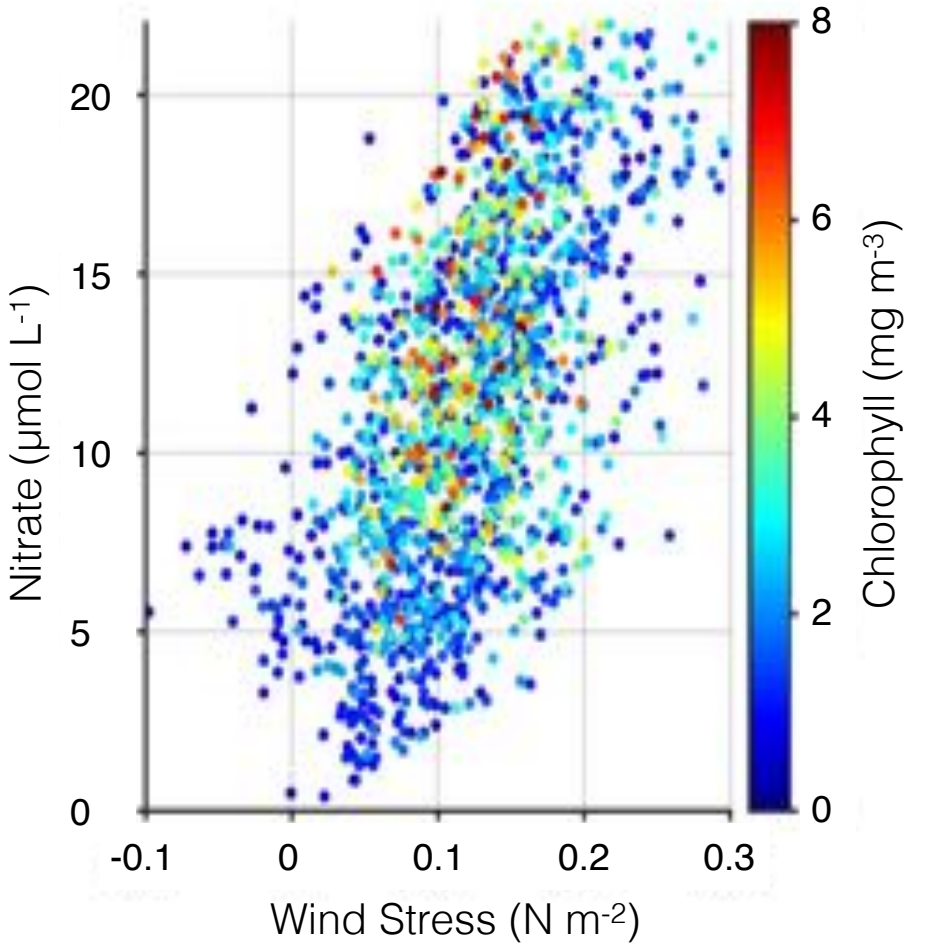


Jacox et al., Sci. Rep. (2016)

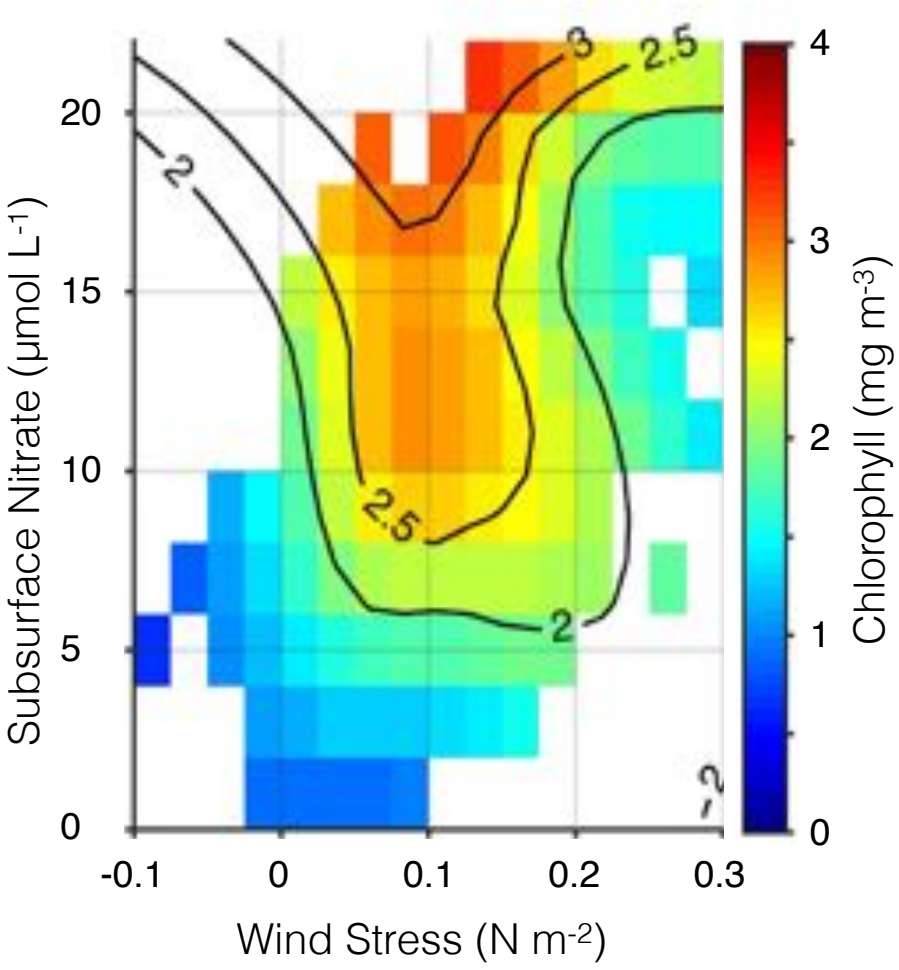


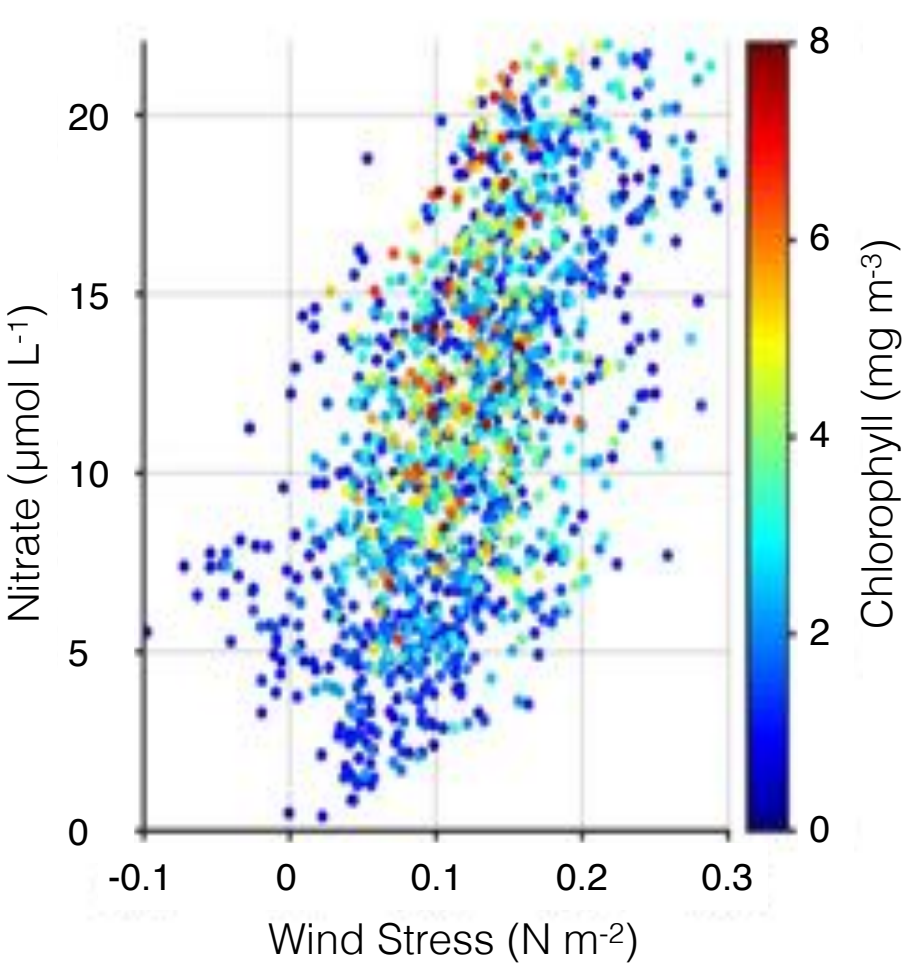
Jacox et al., Sci. Rep. (2016)



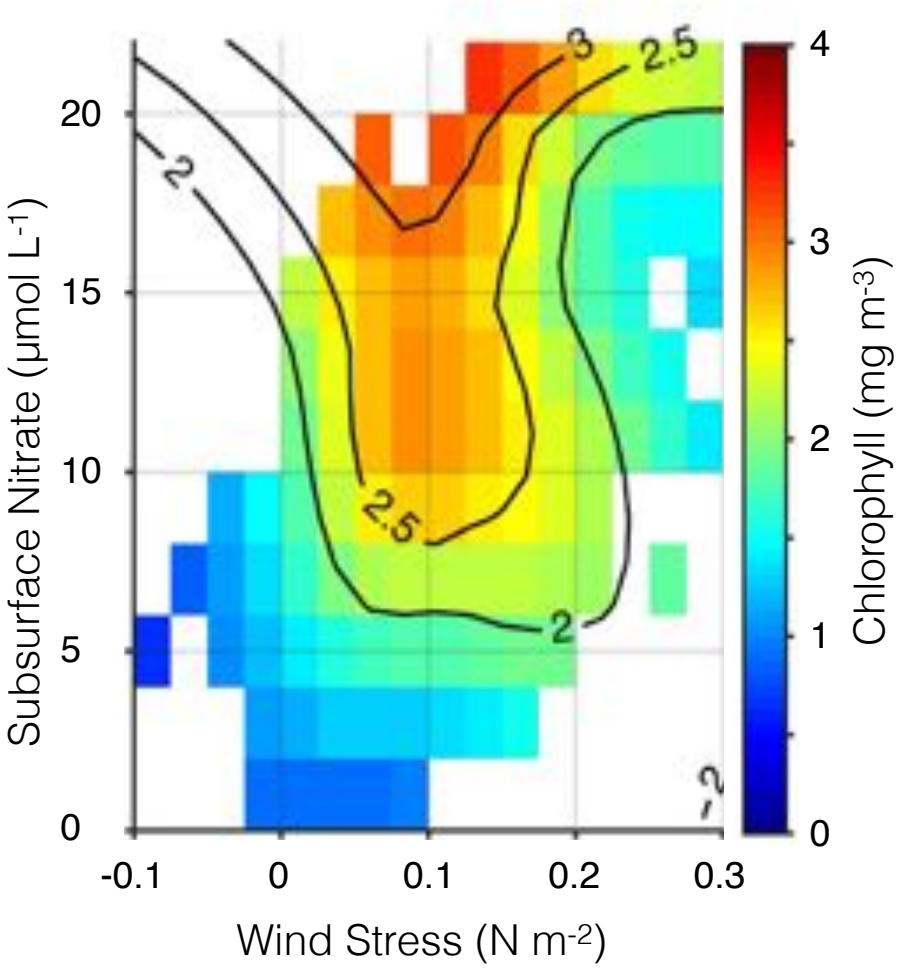


Jacox et al., Sci. Rep. (2016)



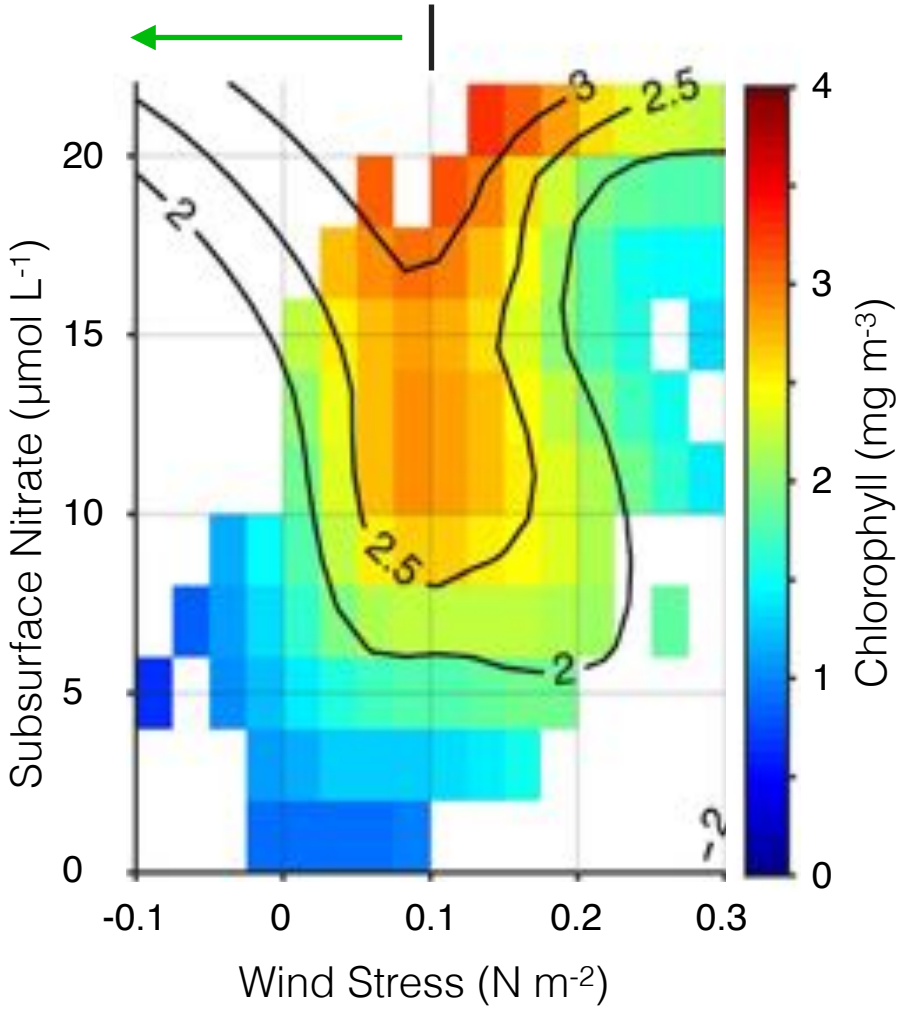


Jacox et al., Sci. Rep. (2016)



Jacox et al., Sci. Rep. (2016)

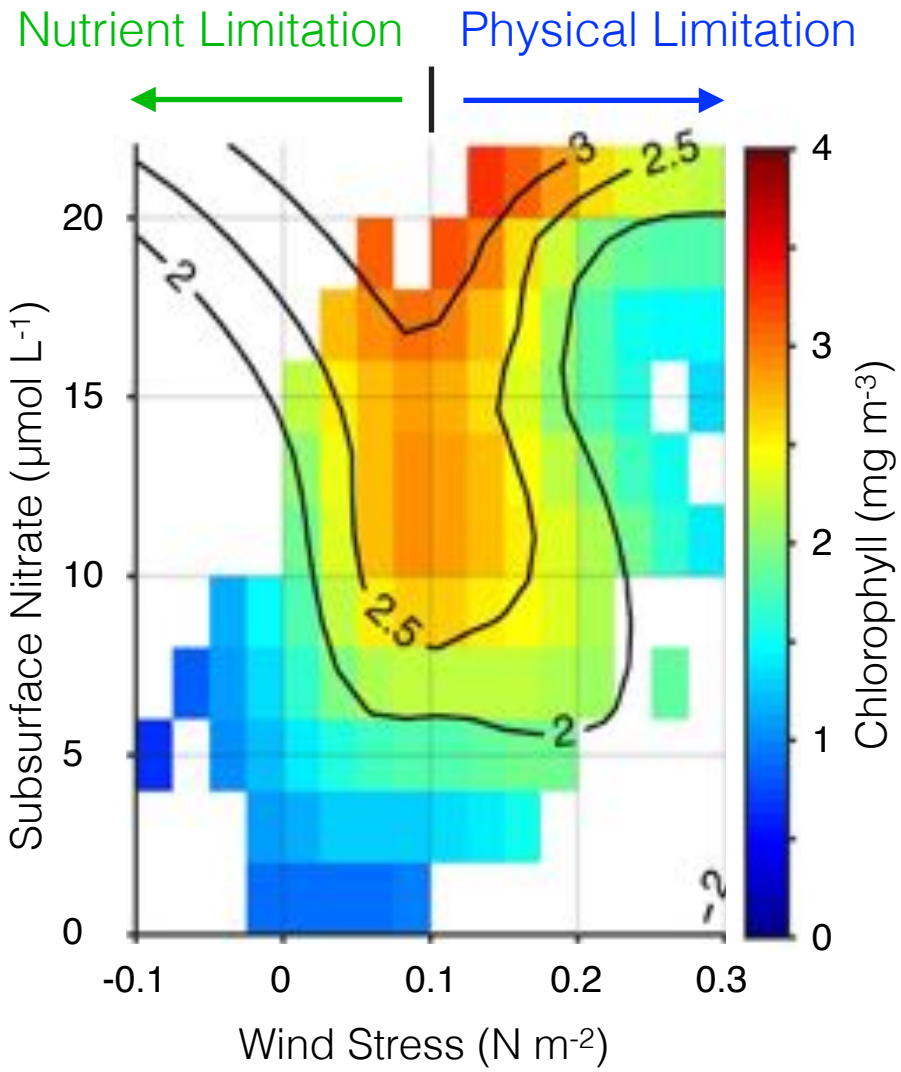
Nutrient Limitation



Nutrient Limitation

Weak upwelling

Jacox et al., Sci. Rep. (2016)



Nutrient Limitation

Weak upwelling

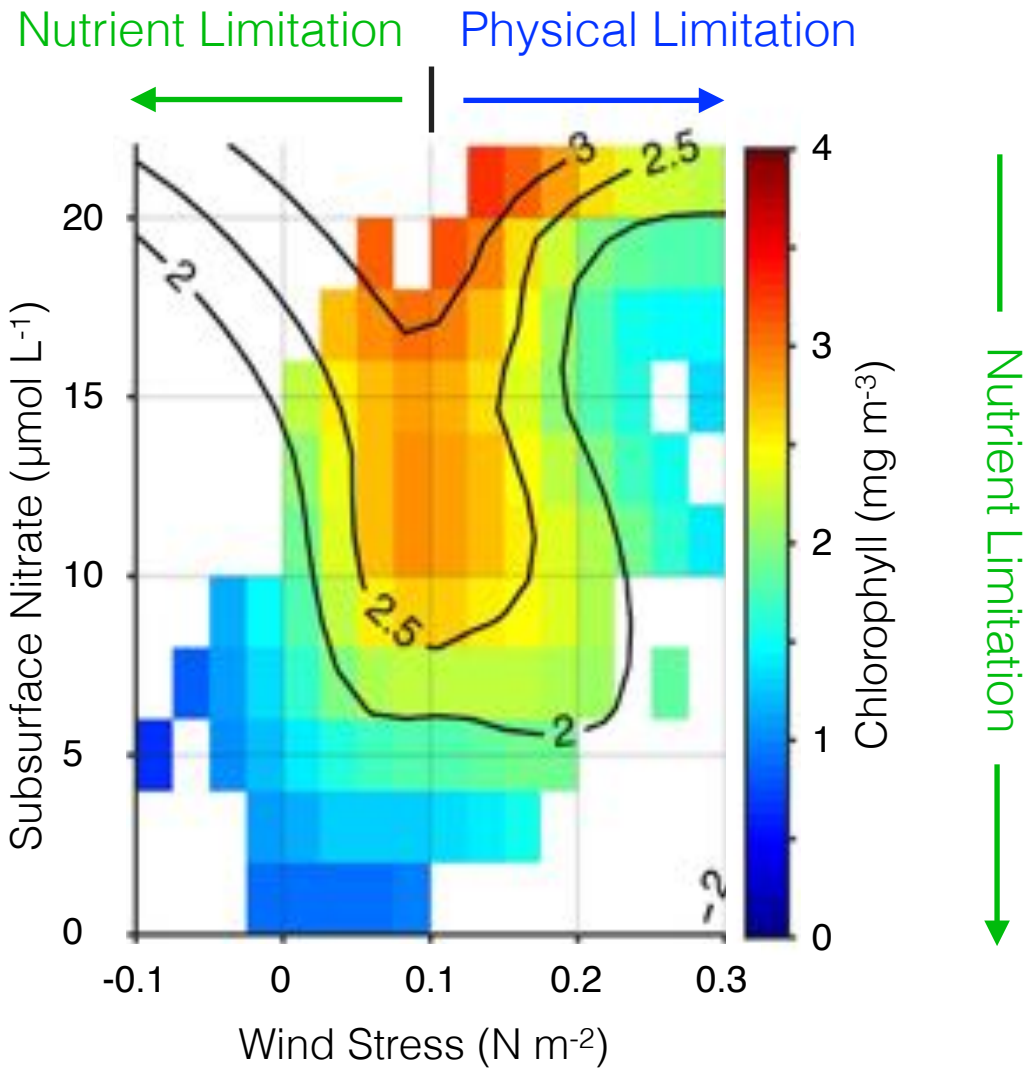
Physical Limitation

Offshore advection

Subduction

Deep mixed layer (light limitation)

Jacox et al., Sci. Rep. (2016)



Nutrient Limitation

Weak upwelling

Nitrate-poor source waters

Physical Limitation

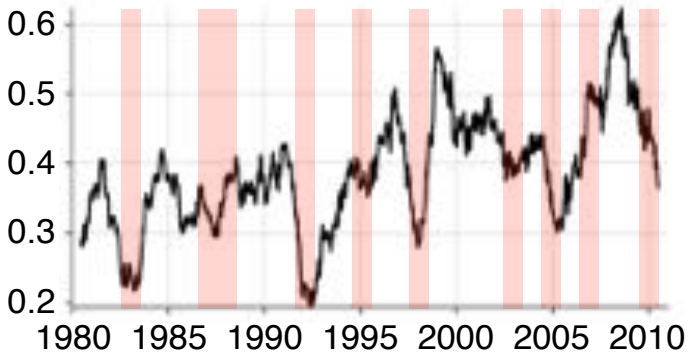
Offshore advection

Subduction

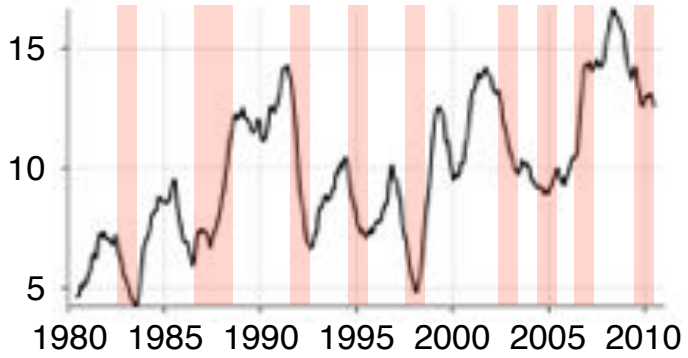
Deep mixed layer (light limitation)

Jacox et al., Sci. Rep. (2016)

Vertical Transport (Sv)



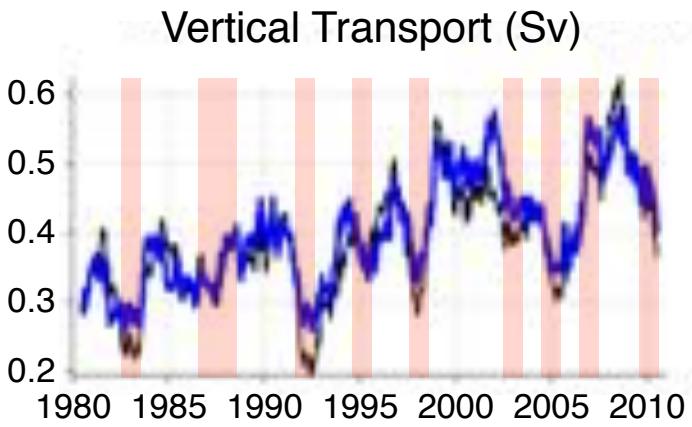
Subsurface Nitrate (μmol L^{-1})

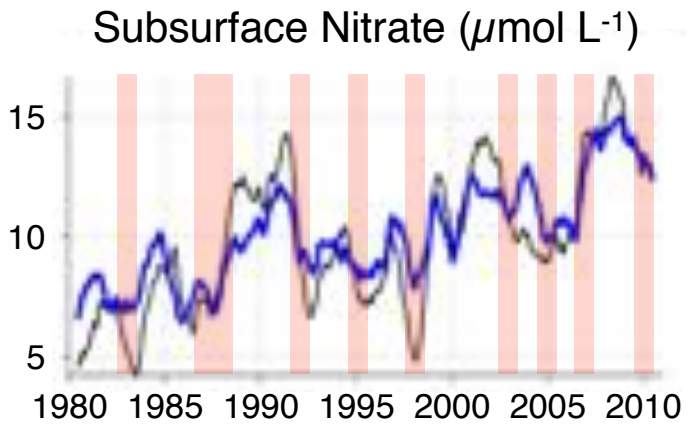


Model	Wind Stress	Heat/Freshwater Flux	Boundary Conditions
Realistic	ECMWF/CCMP	ECMWF	SODA
Wind	ECMWF/CCMP	Climatology	Climatology
Remote Forcing	Climatology	Climatology	SODA
Heat	Climatology	ECMWF	Climatology

Jacox et al., GRL (2015)

LOCAL WIND FORCING





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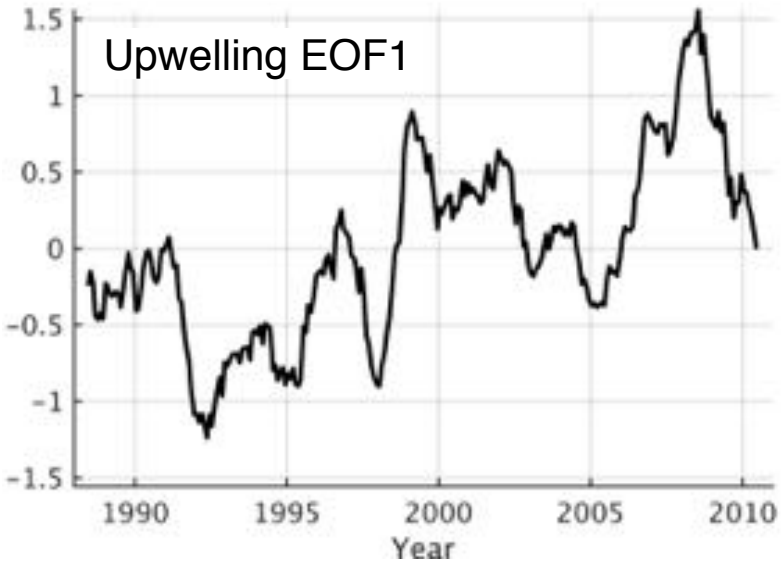
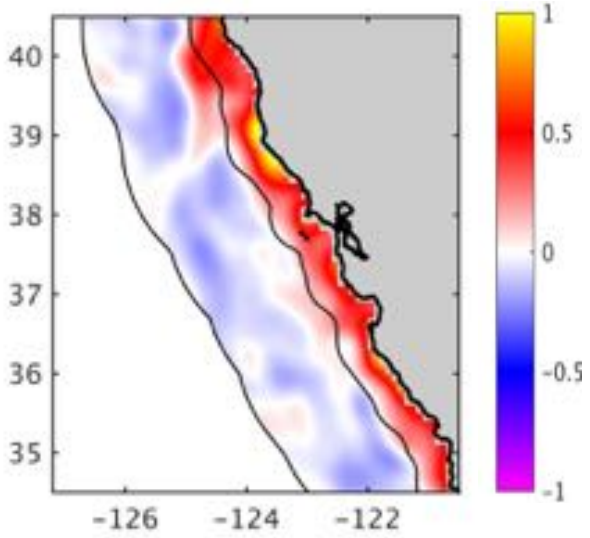
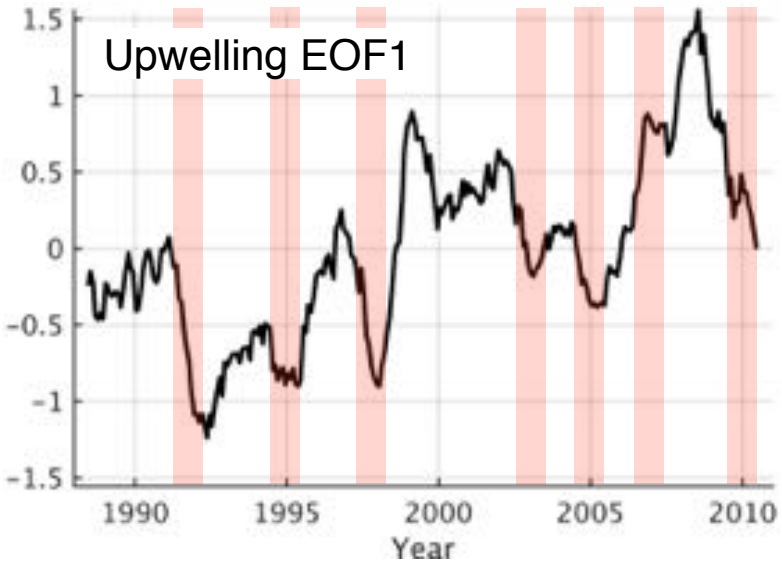
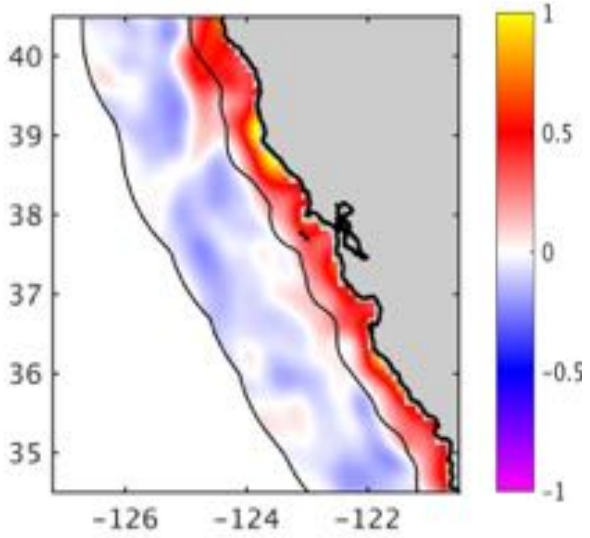
Wind	ECMWF/CCMP	Climatology	Climatology
Remote Forcing	Climatology	Climatology	SODA
Heat	Climatology	ECMWF	Climatology

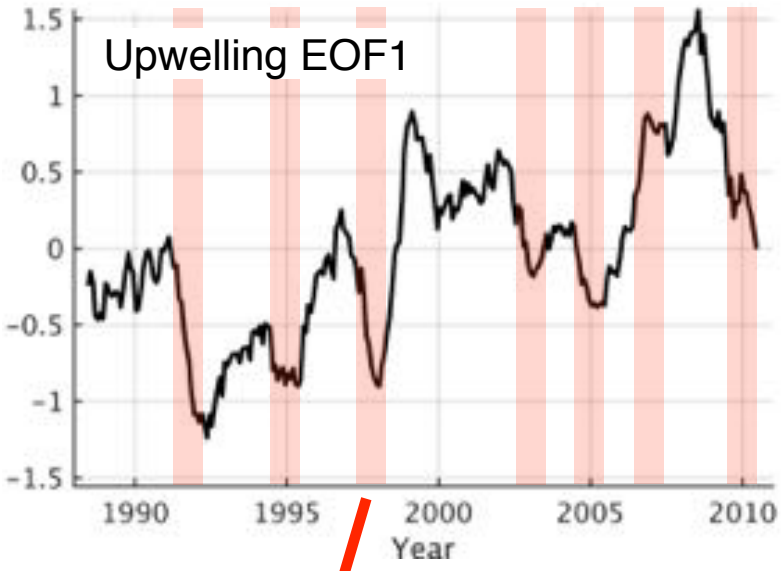
Jacox et al., GRL (2015)

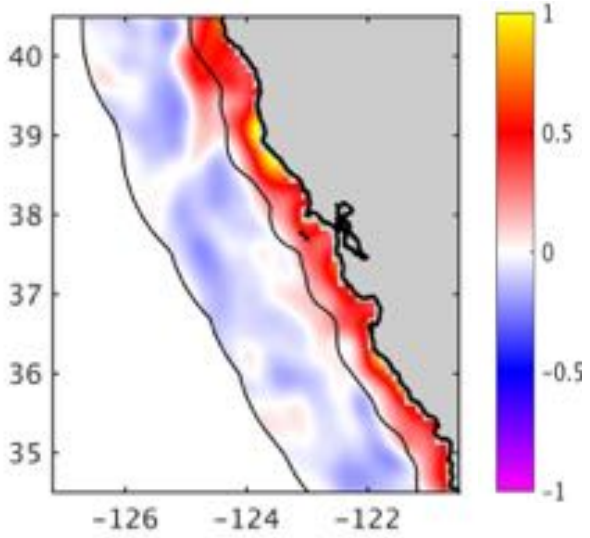

Upwelling EOF1
1.5
1
0.5
0
-0.5
-1
-1.5
1990
1995
2000
2005
2010
Year

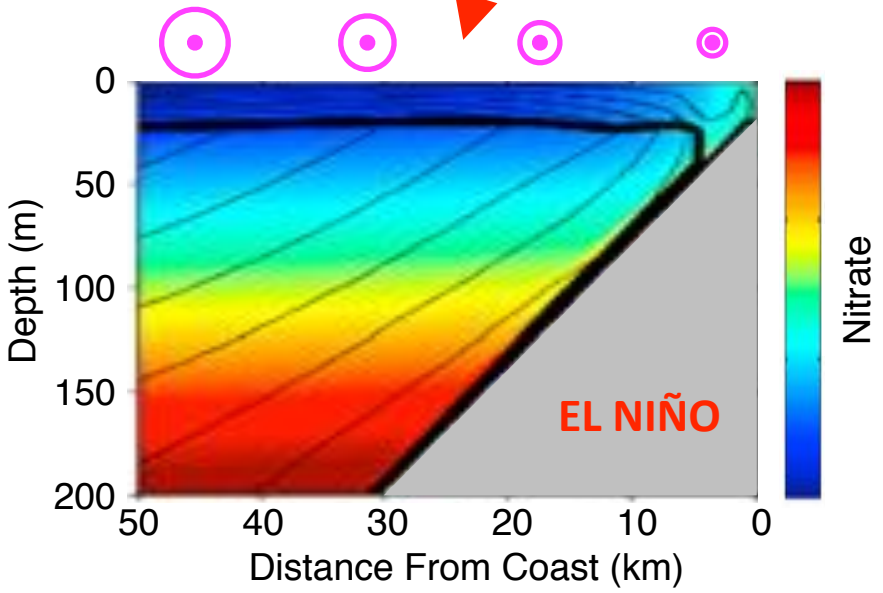

40
39
38
37
36
35
-126
-124
-122
1
0.5
0
-0.5
-1

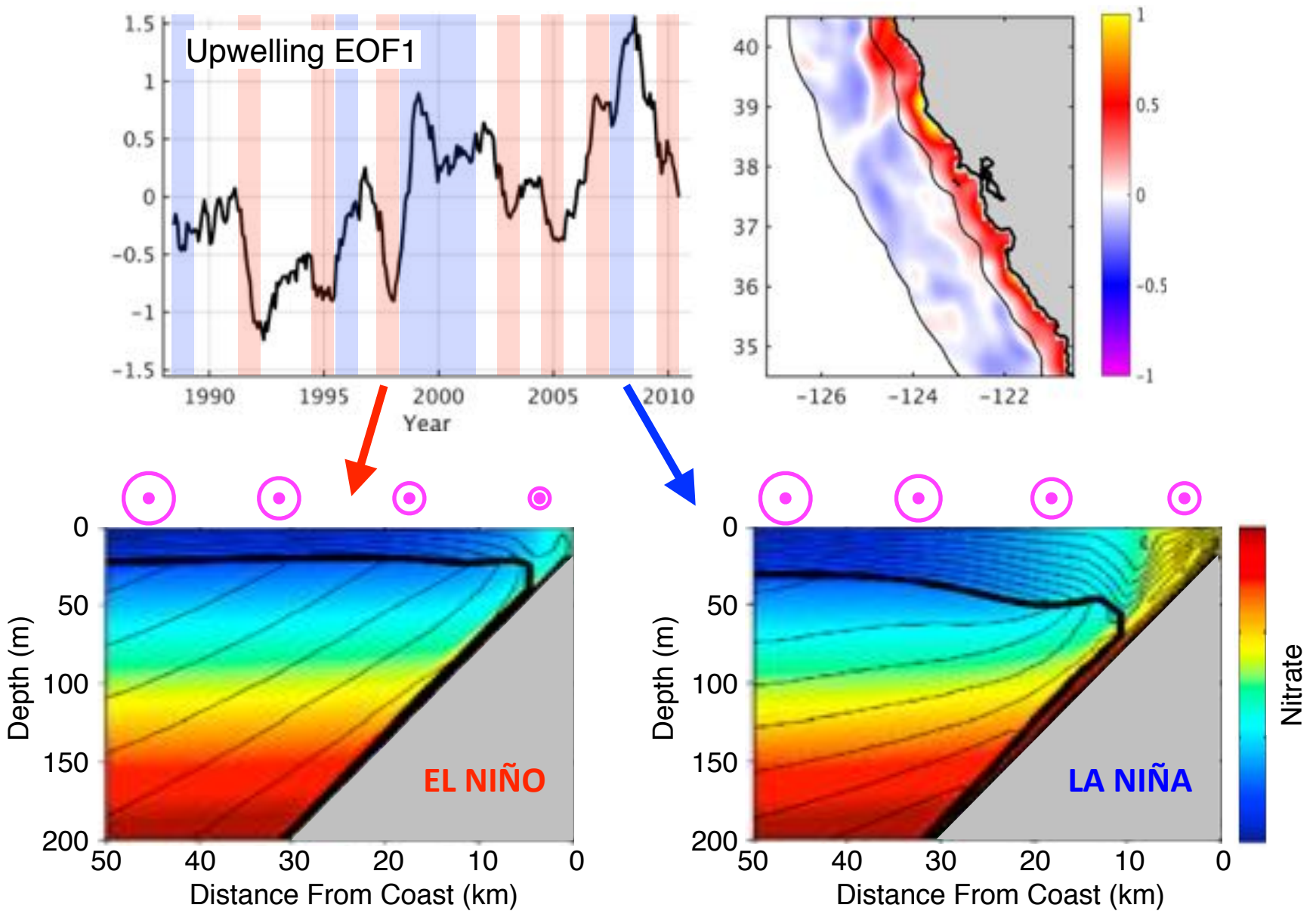

Upwelling EOF1
1.5
1
0.5
0
-0.5
-1
-1.5
1990
1995
2000
2005
2010
Year

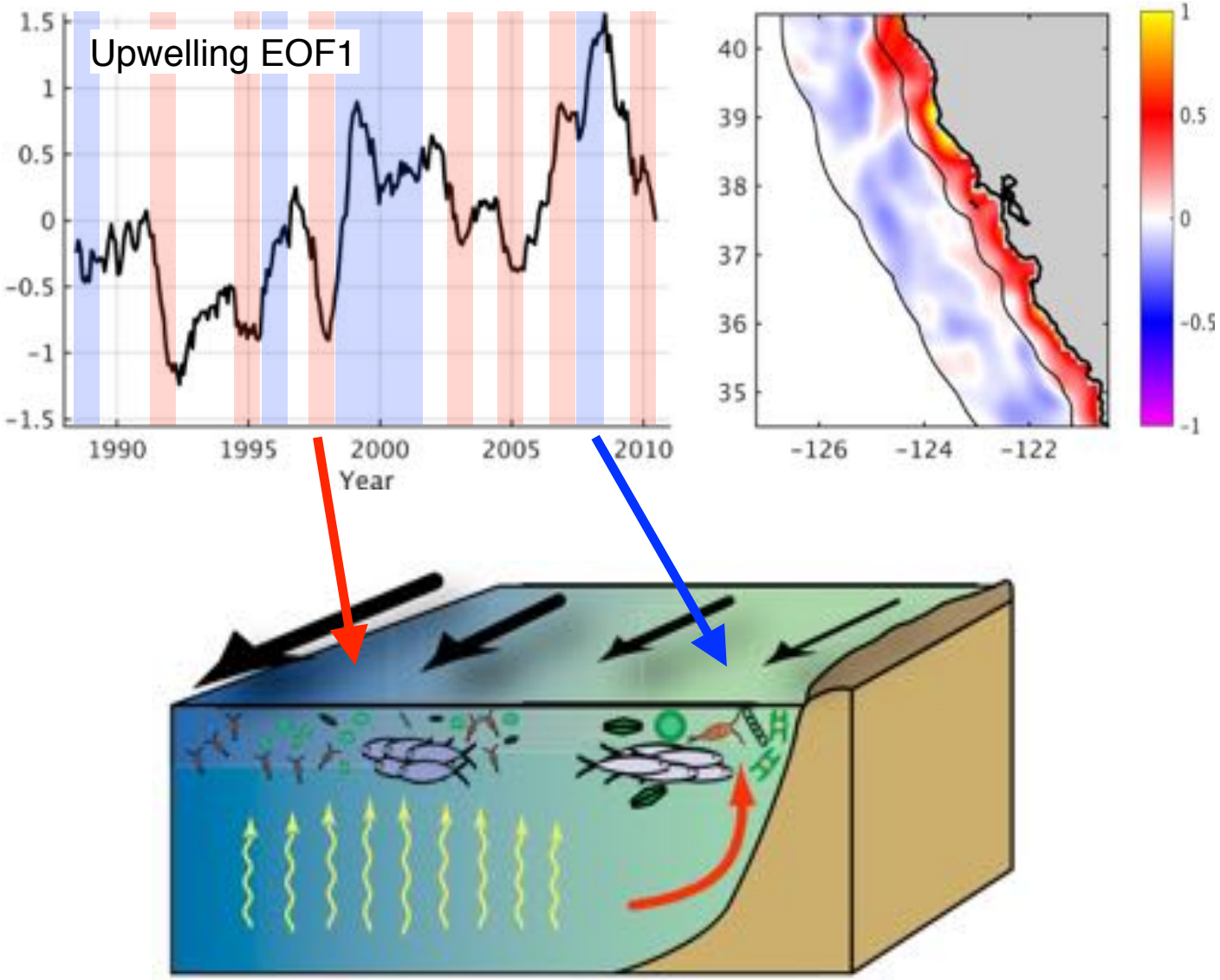

40
39
38
37
36
35
-126
-124
-122
1
0.5
0
-0.5
-1


Upwelling EOF1
1.5
1
0.5
0
-0.5
-1
-1.5
1990
1995
2000
2005
2010
Year

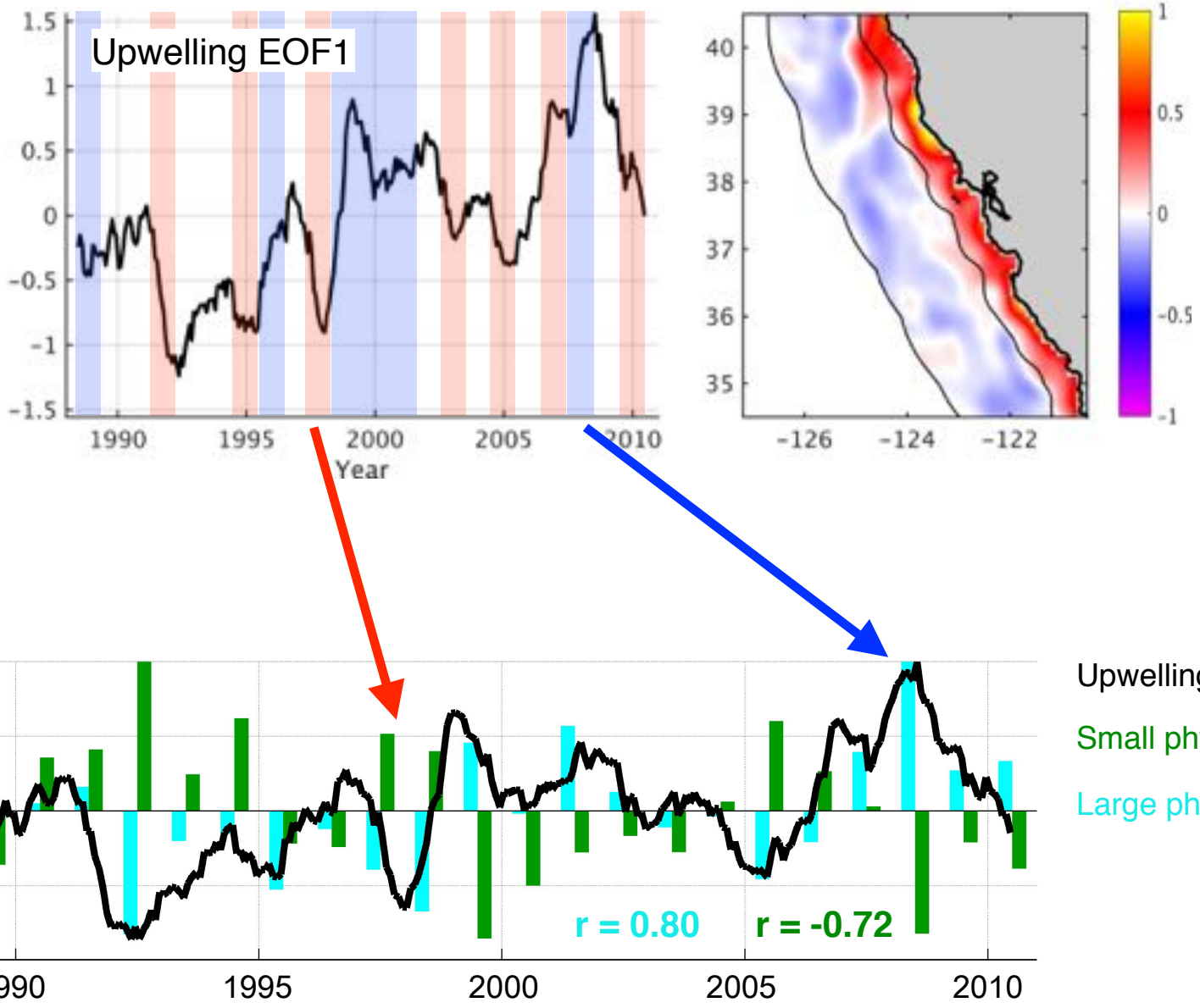

40
39
38
37
36
35
-126
-124
-122
1
0.5
0
-0.5
-1


0
50
100
150
200
Depth (m)
50
40
30
20
10
0
Distance From Coast (km)
EL NIÑO
Nitrate

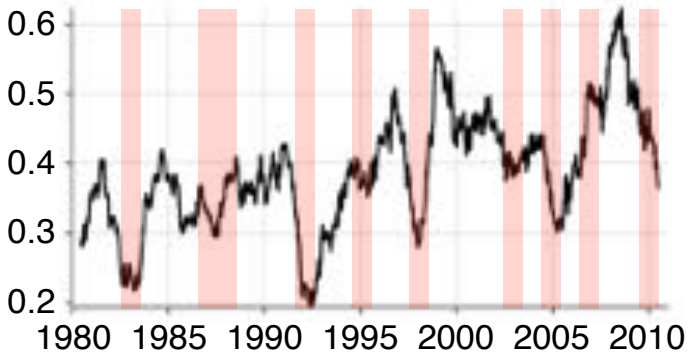

Upwelling EOF1
1.5
1
0.5
0
-0.5
-1
-1.5
1990
1995
2000
2005
2010
Year
40
39
38
37
36
35
-126
-124
-122
1
0.5
0
-0.5
-1
0
50
100
150
200
Depth (m)
EL NIÑO
50
40
30
20
10
0
Distance From Coast (km)
LA NIÑA
Nitrate



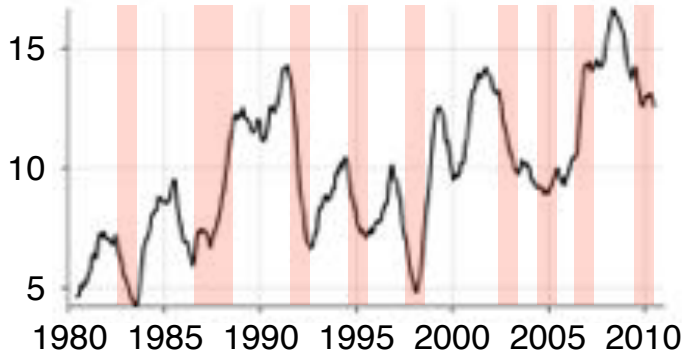
Rykaczewski and Checkley, PNAS (2008)


Upwelling EOF1
1.5
1
0.5
0
-0.5
-1
-1.5
1990
1995
2000
2005
2010
Year
40
39
38
37
36
35
-126
-124
-122
1
0.5
0
-0.5
-1
Normalized Units
1
0.5
0
-0.5
-1
r = 0.80
r = -0.72
1990
1995
2000
2005
2010
Upwelling EOF1
Small phytoplankton
Large phytoplankton

Vertical Transport (Sv)



Subsurface Nitrate (μmol L^{-1})



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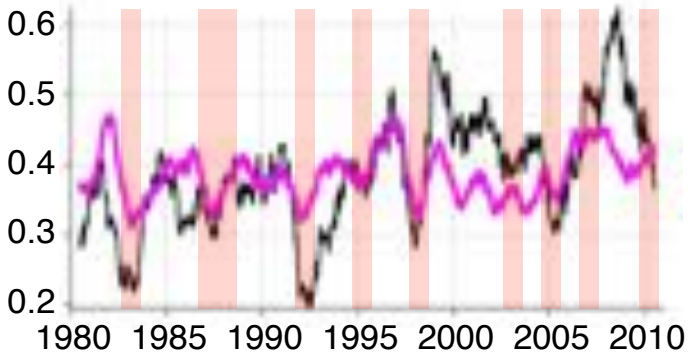
Realistic	ECMWF/CCMP	ECMWF	SODA
Wind	ECMWF/CCMP	Climatology	Climatology
Remote Forcing	Climatology	Climatology	SODA
Heat	Climatology	ECMWF	Climatology

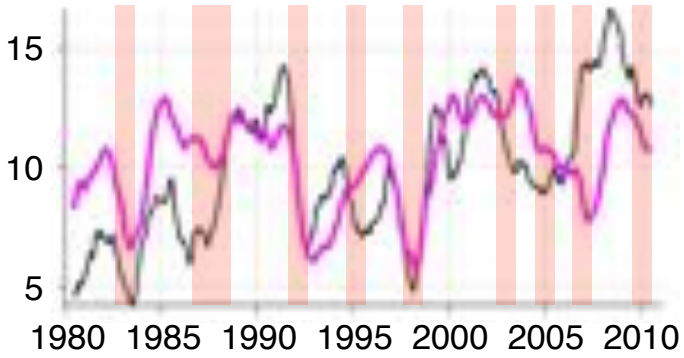
Jacox et al., GRL (2015)

REMOTE OCEAN FORCING

Vertical Transport (Sv)



Subsurface Nitrate (μmol L^{-1})



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Wind	ECMWF/CCMP	Climatology	Climatology
Remote Forcing	Climatology	Climatology	SODA
Heat	Climatology	ECMWF	Climatology

Jacox et al., GRL (2015)

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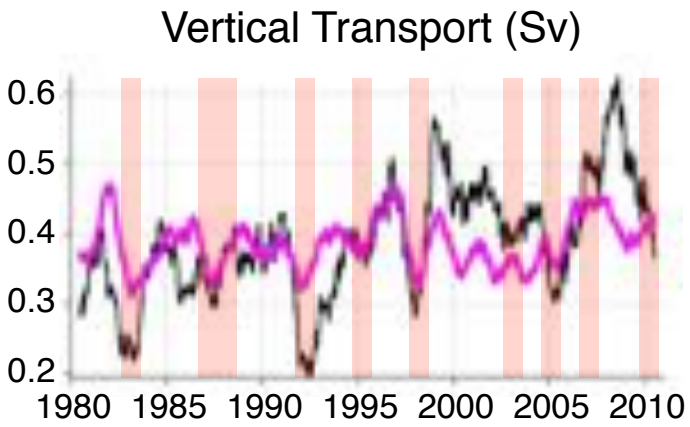

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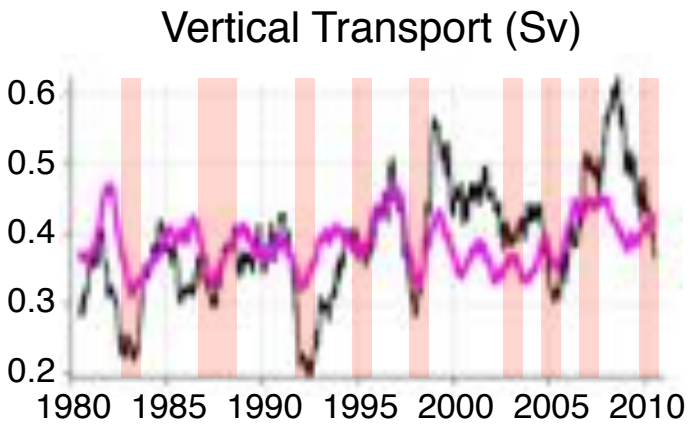
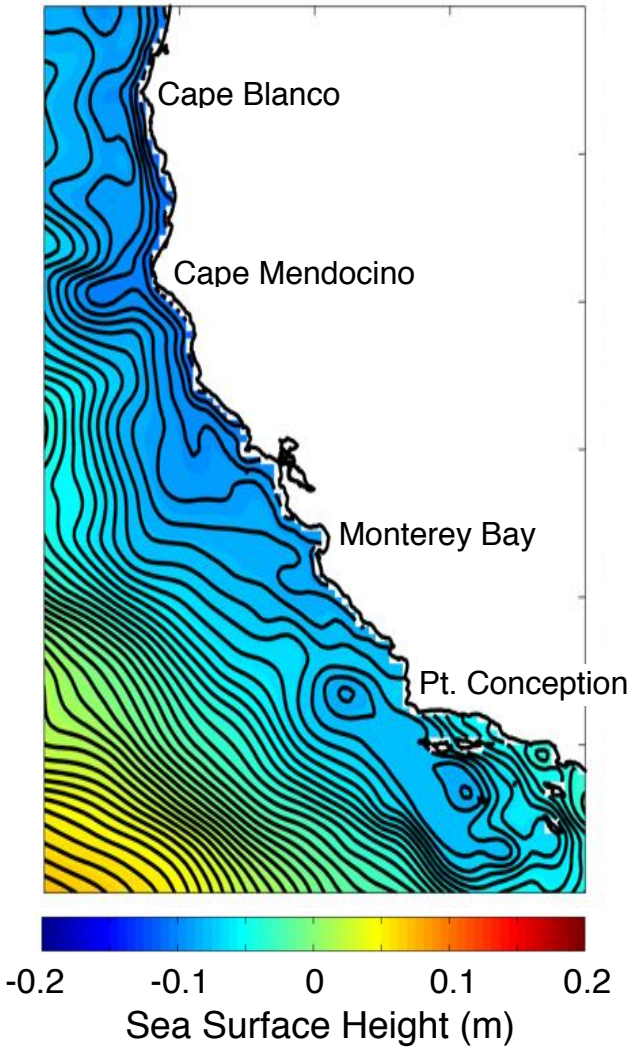
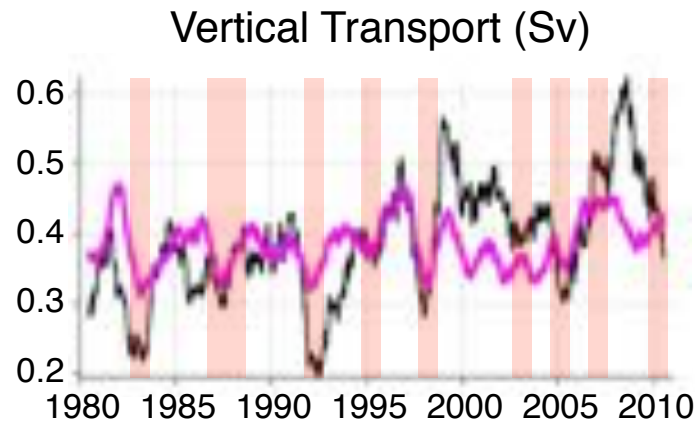
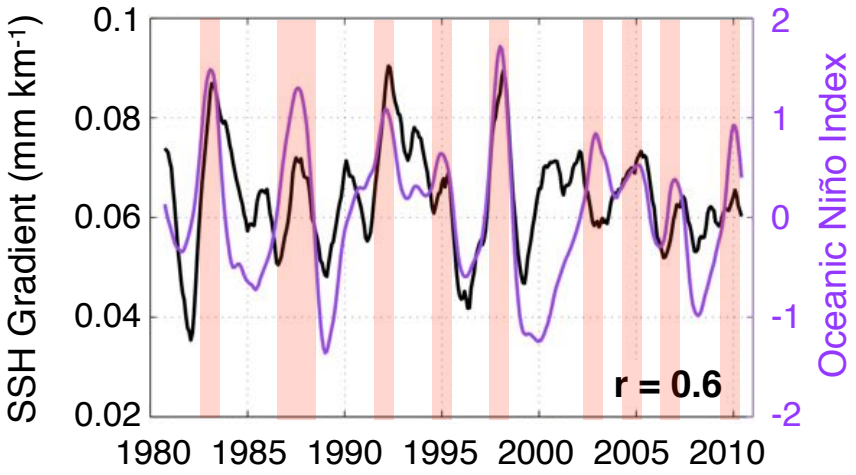


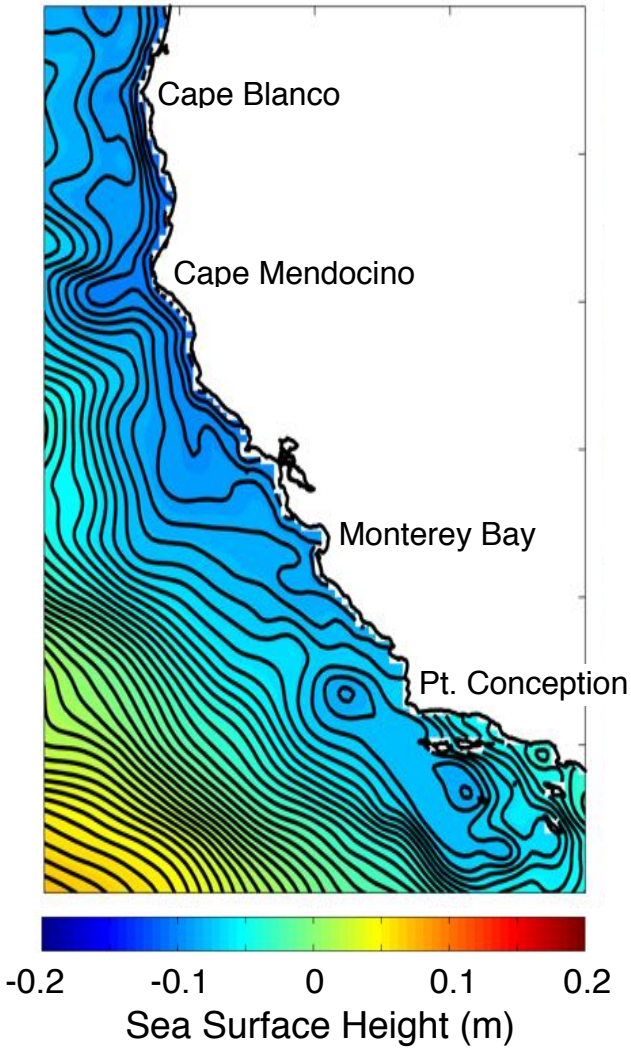


Jacox et al., GRL (2015)

REMOTE OCEAN FORCING



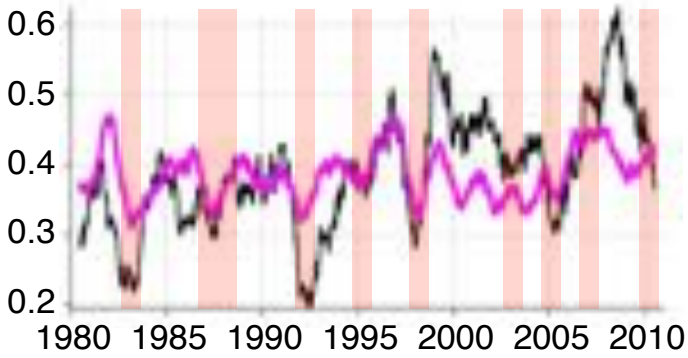




Jacox et al., GRL (2015)

REMOTE OCEAN FORCING

Vertical Transport (Sv)



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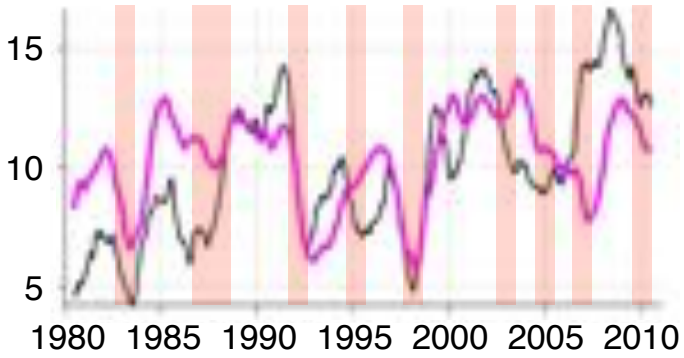

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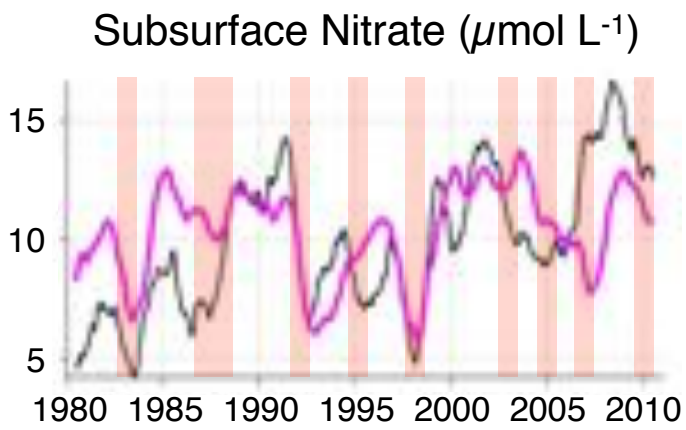
Wind	ECMWF/CCMP	Climatology	Climatology
Remote Forcing	Climatology	Climatology	SODA
Heat	Climatology	ECMWF	Climatology

Jacox et al., GRL (2015)

REMOTE OCEAN FORCING



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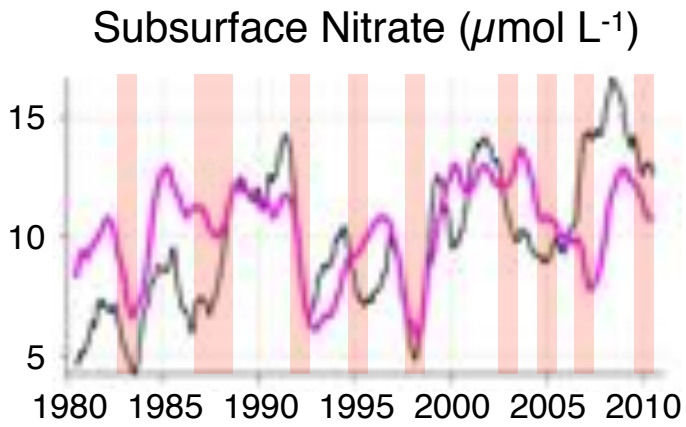

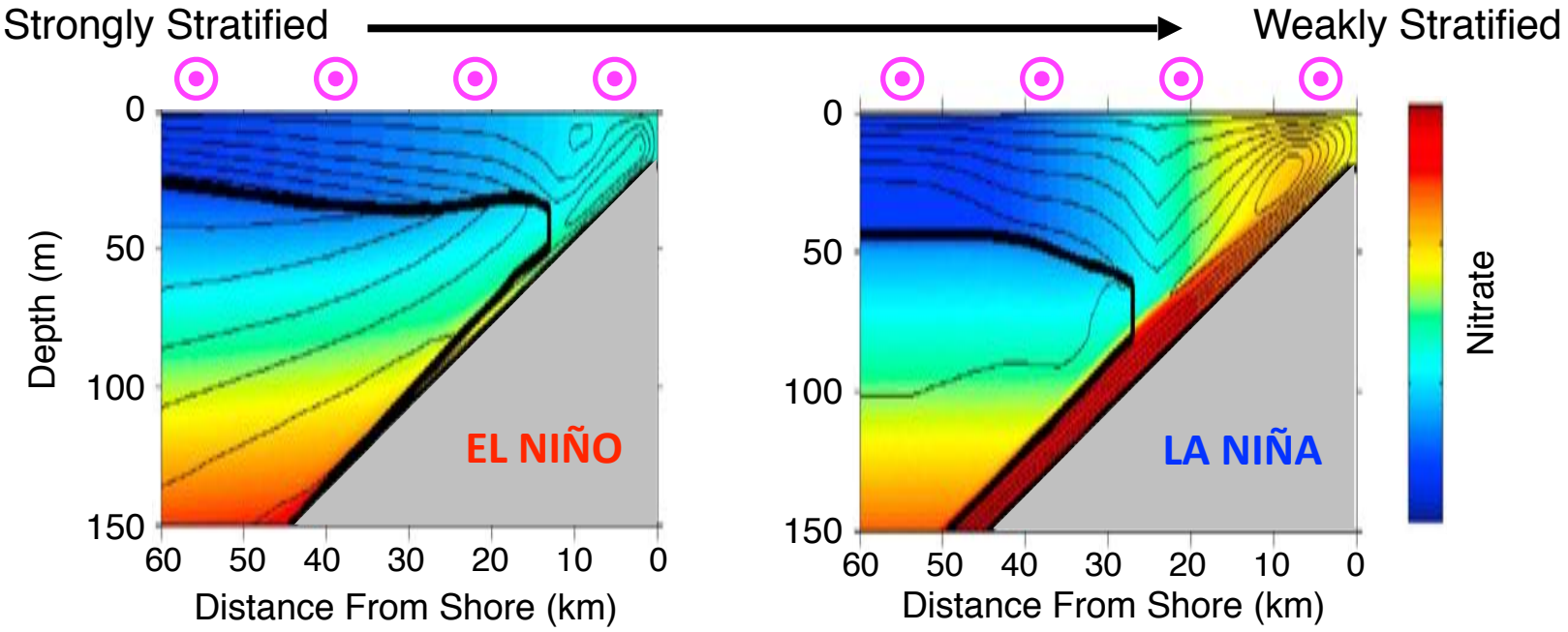

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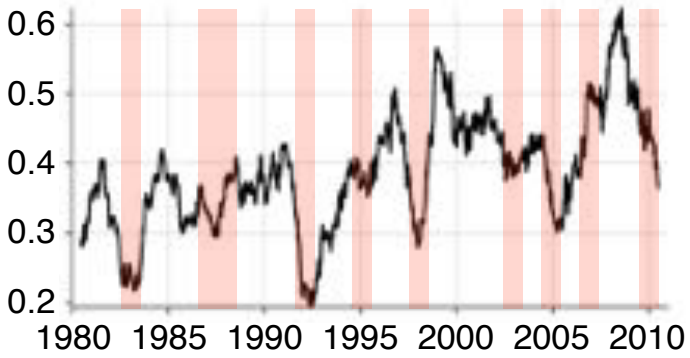

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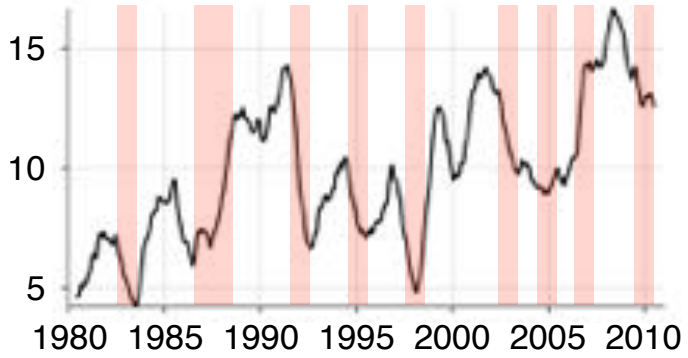

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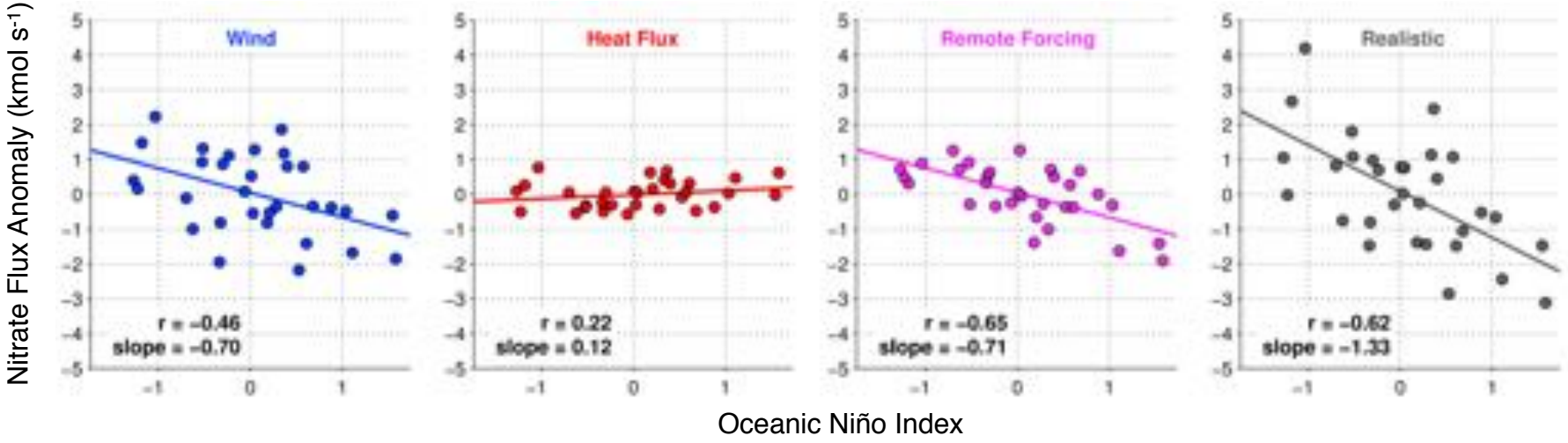
Remote Forcing	Climatology	Climatology	SODA
Heat	Climatology	ECMWF	Climatology

Jacox et al., GRL (2015)



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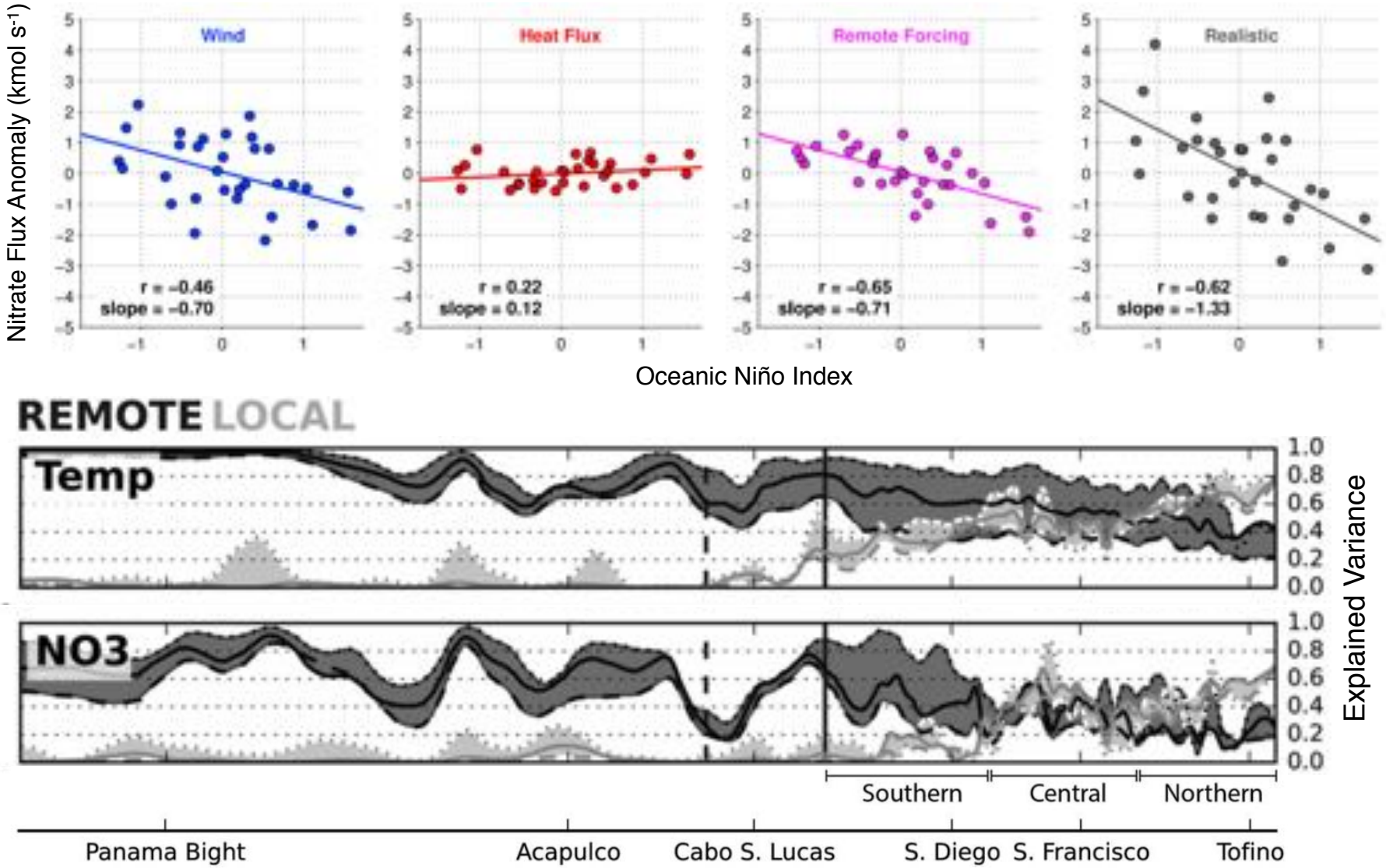
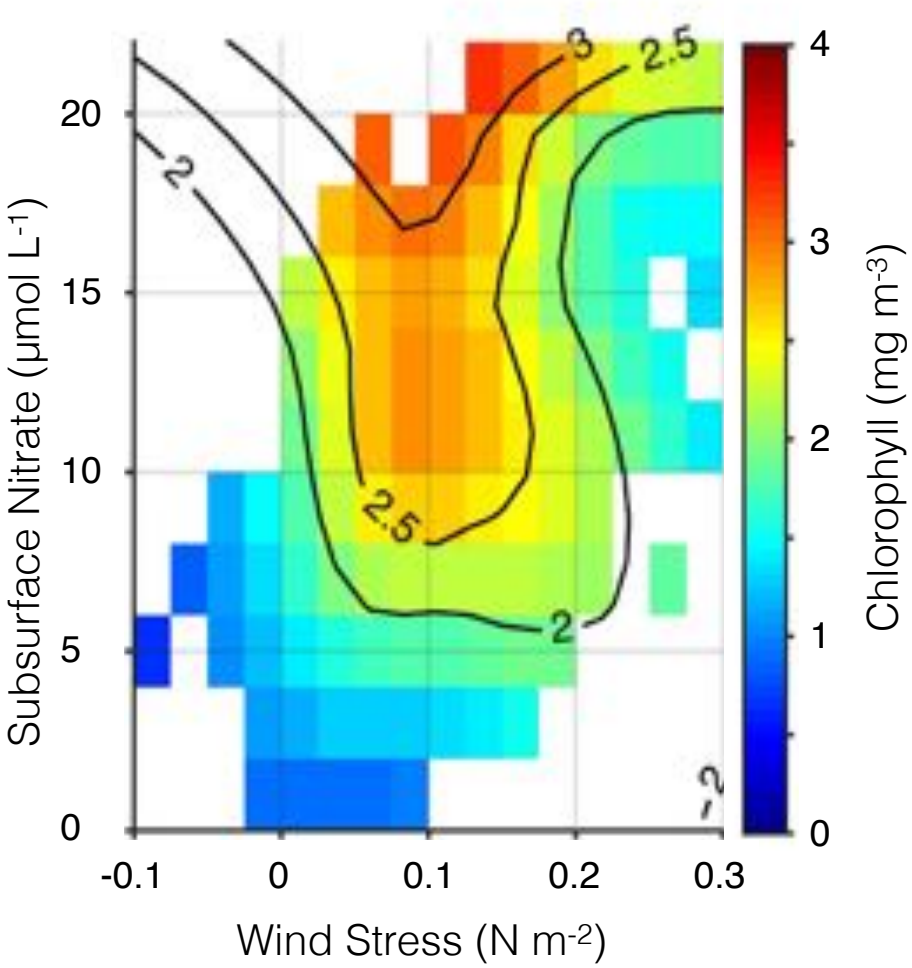
Heat	Climatology	ECMWF	Climatology

Jacox et al., GRL (2015)



Frischknecht et al., JGR (2015)



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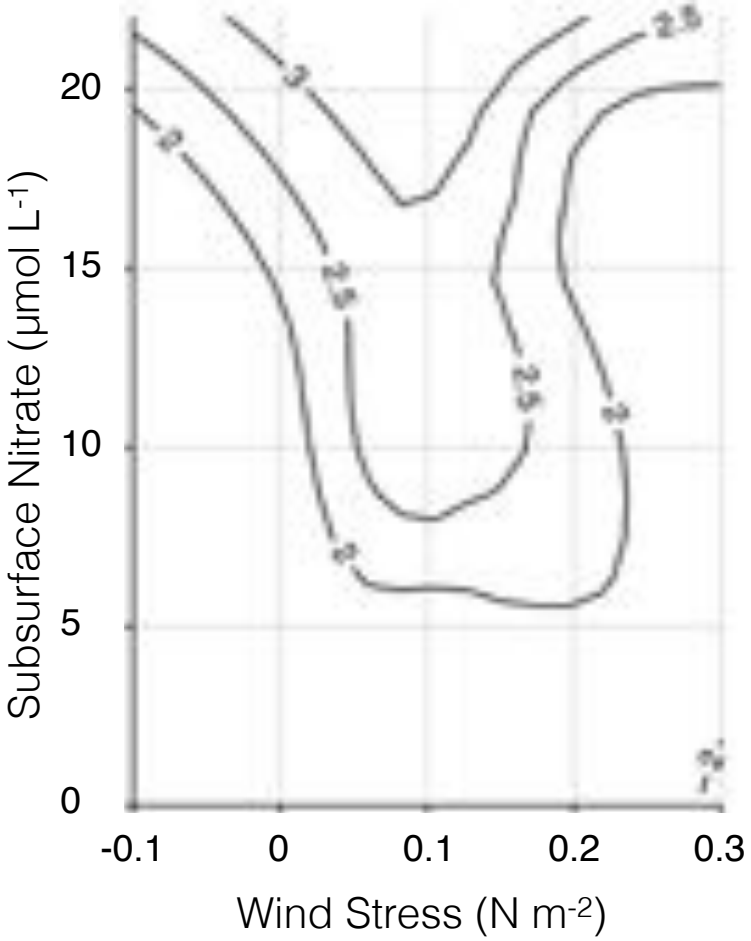
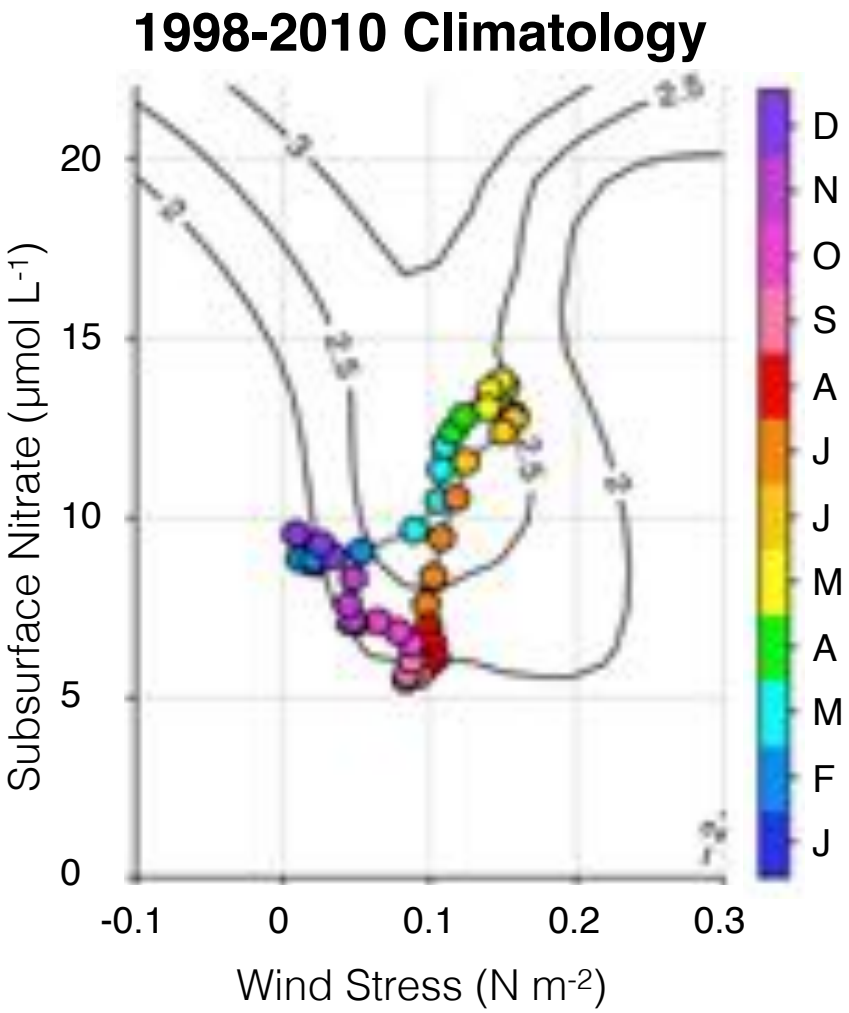
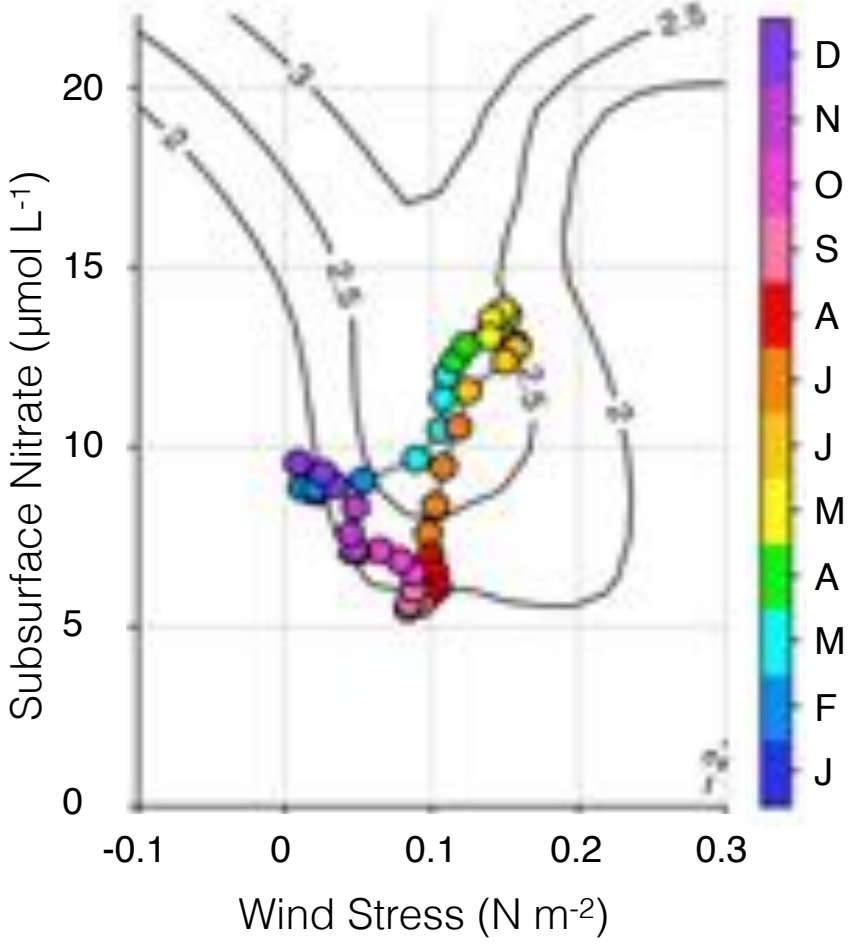


Jacox et al., Sci. Rep. (2016)

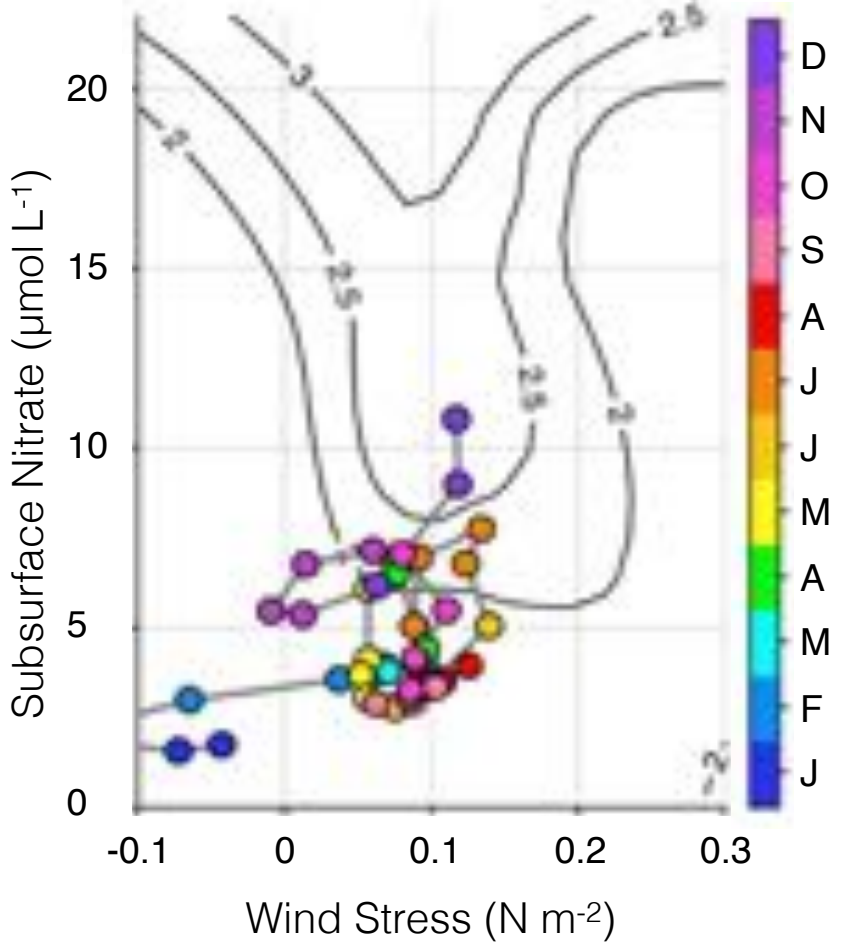


Jacox et al., Sci. Rep. (2016)

1998-2010 Climatology

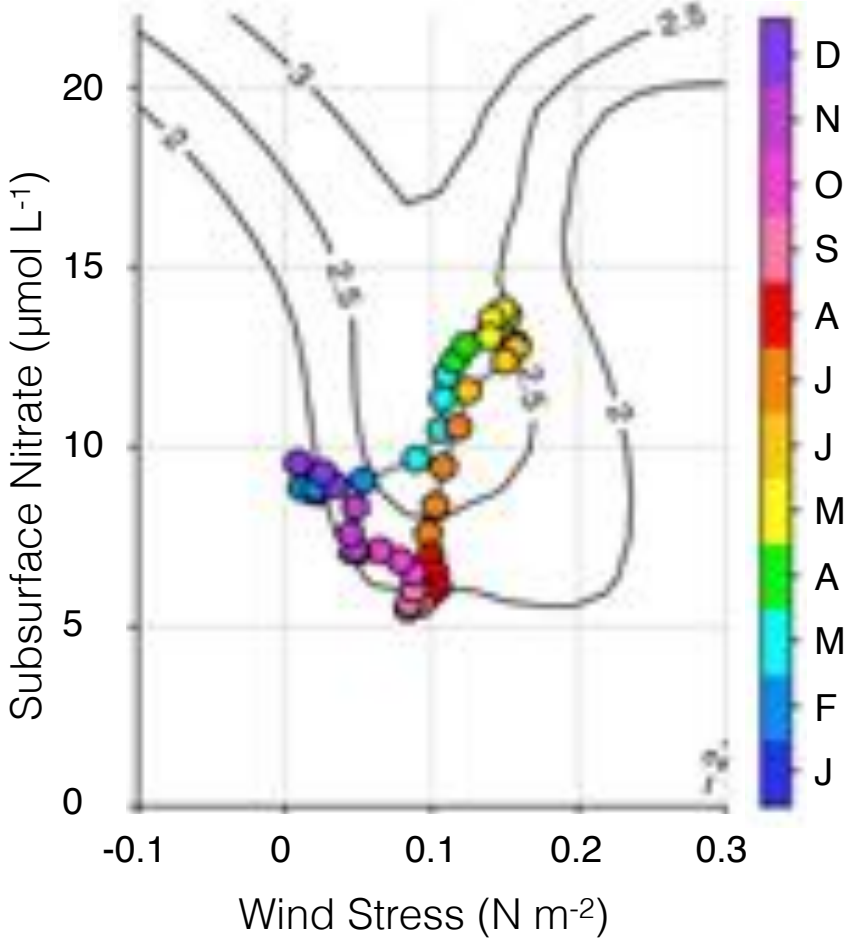


1998 (El Niño)

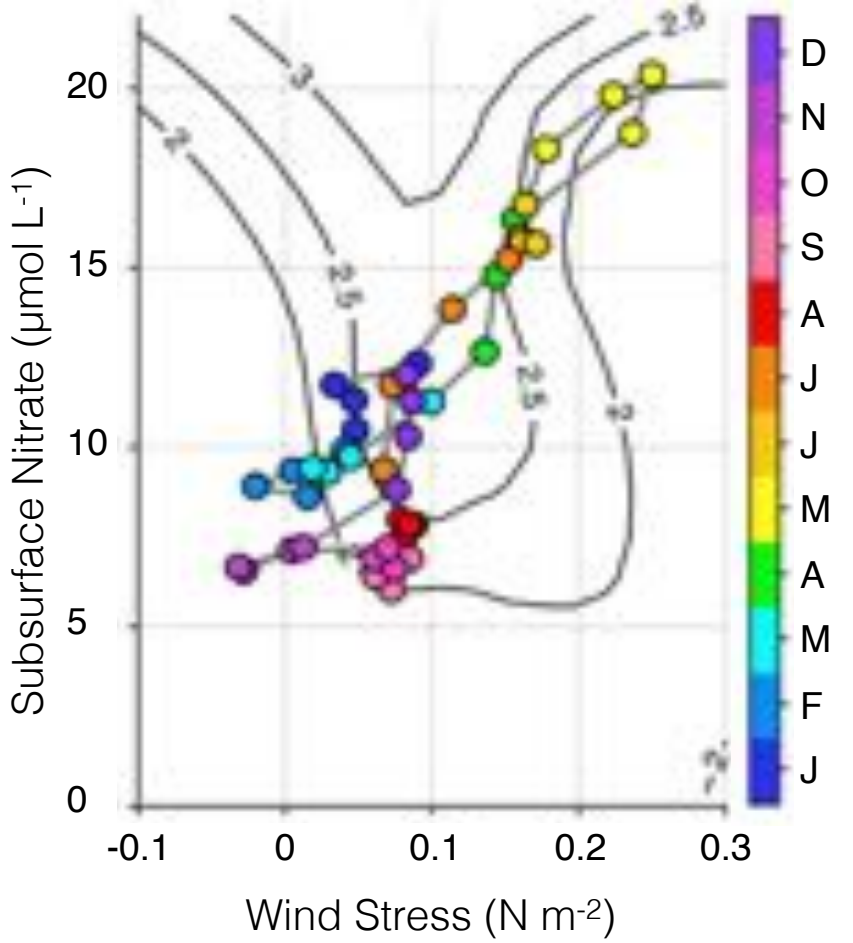


Jacox et al., Sci. Rep. (2016)

1998-2010 Climatology



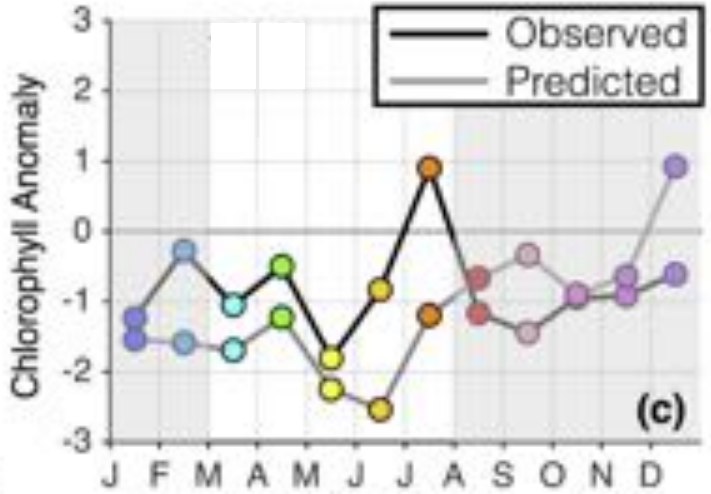
1999 (La Niña)



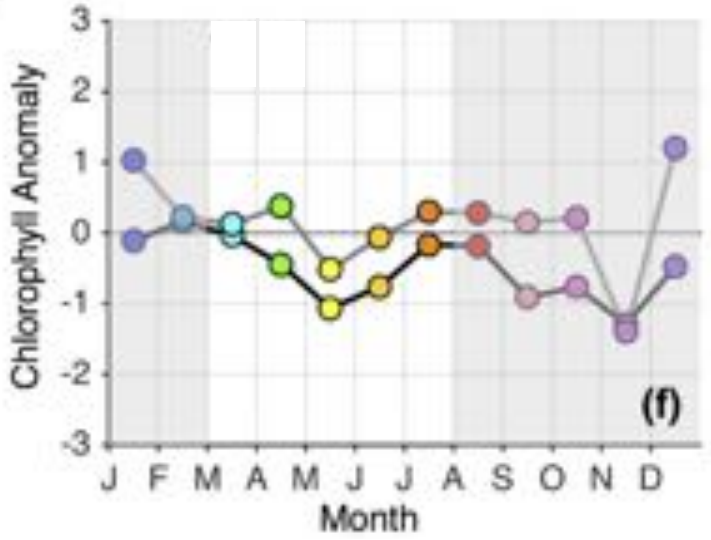
Jacox et al., Sci. Rep. (2016)

Nearshore

1998



1999

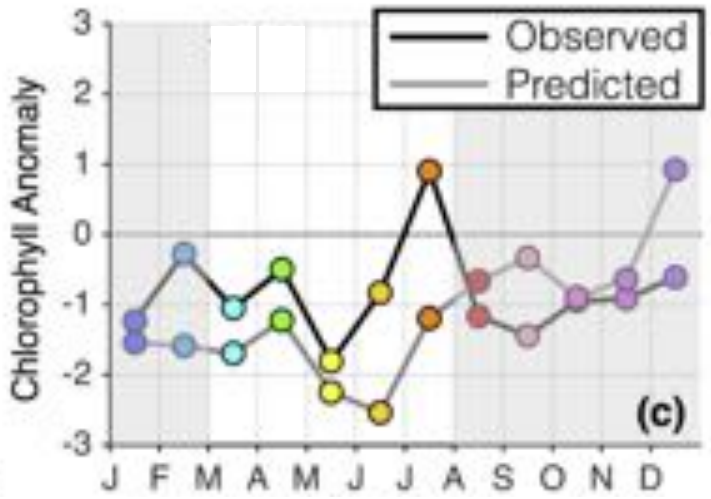


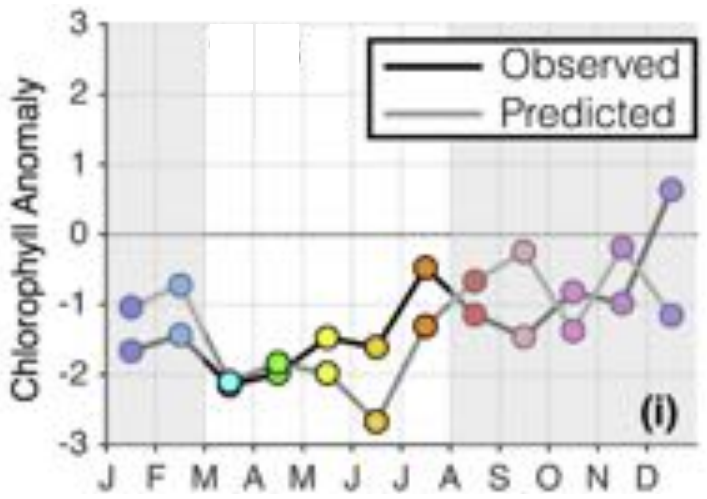
Nearshore

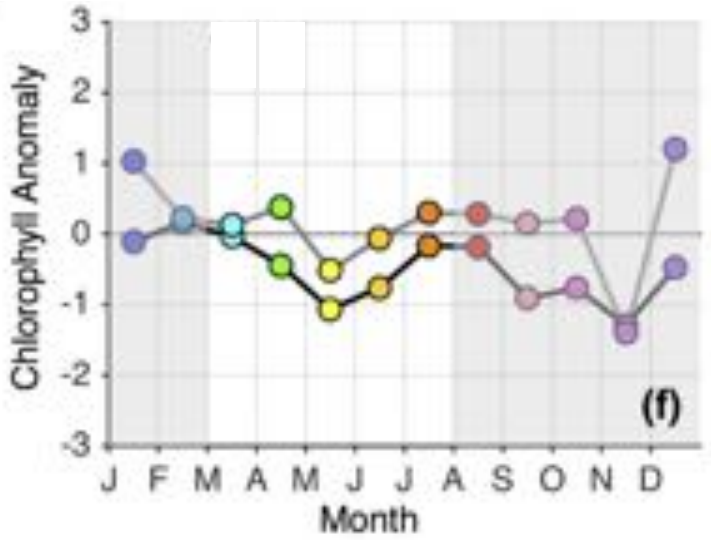
Offshore

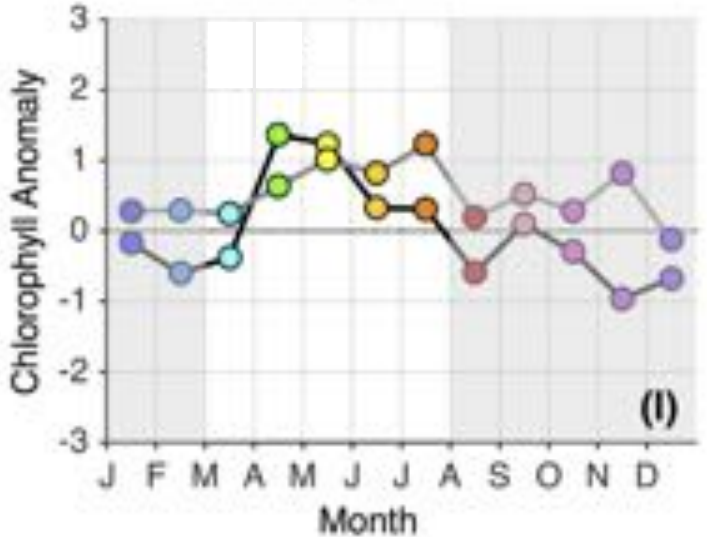
1998

1999

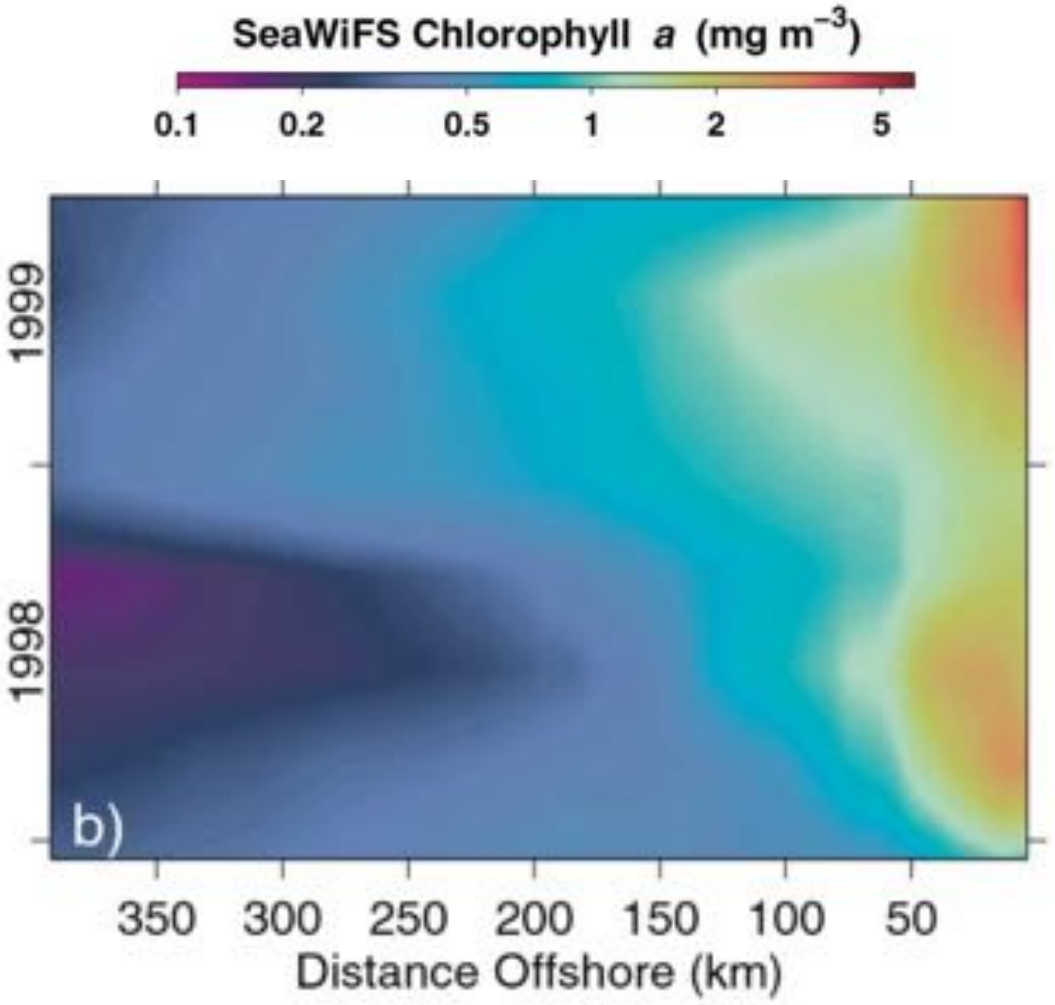




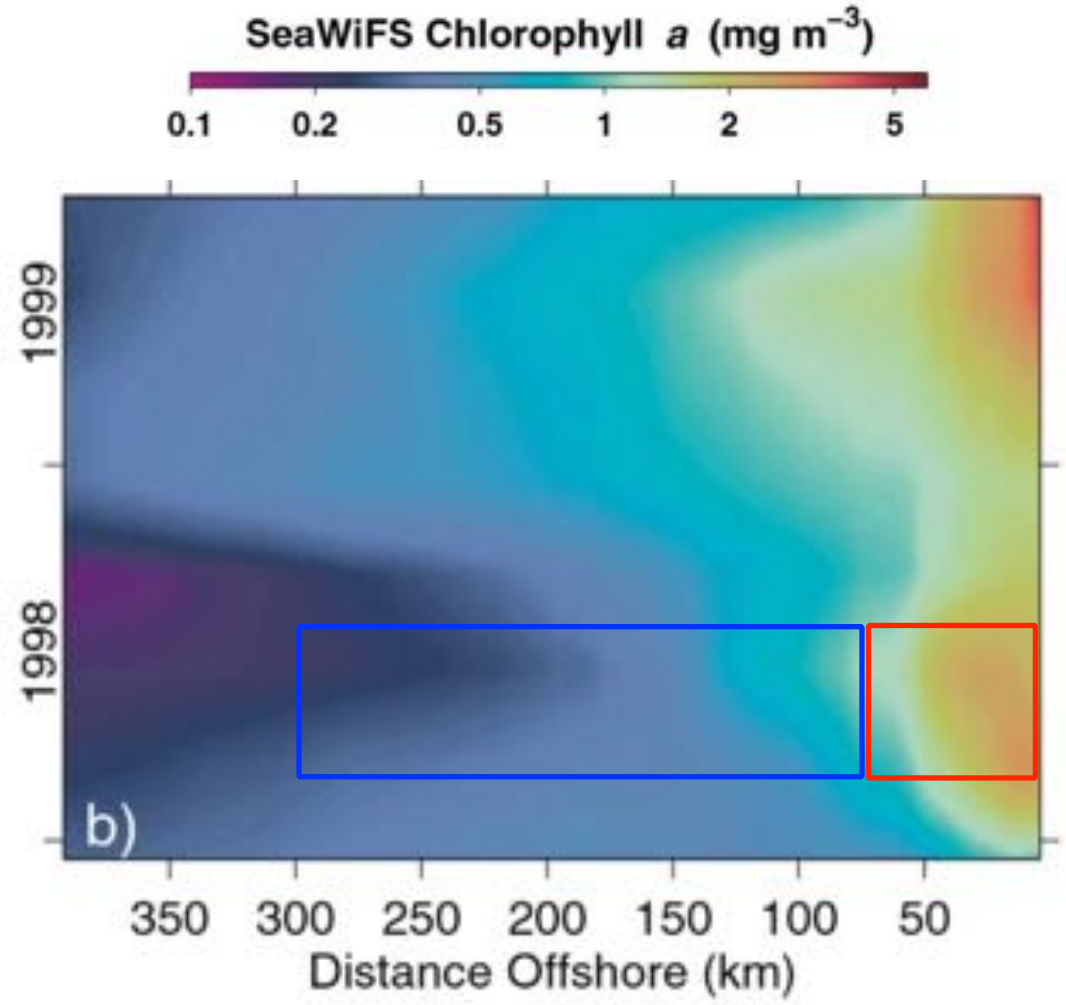


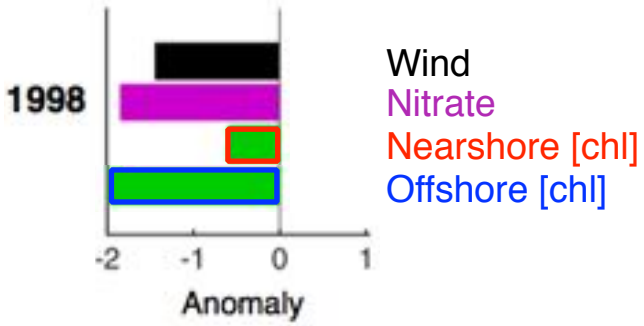


Jacox et al., Sci. Rep. (2016)

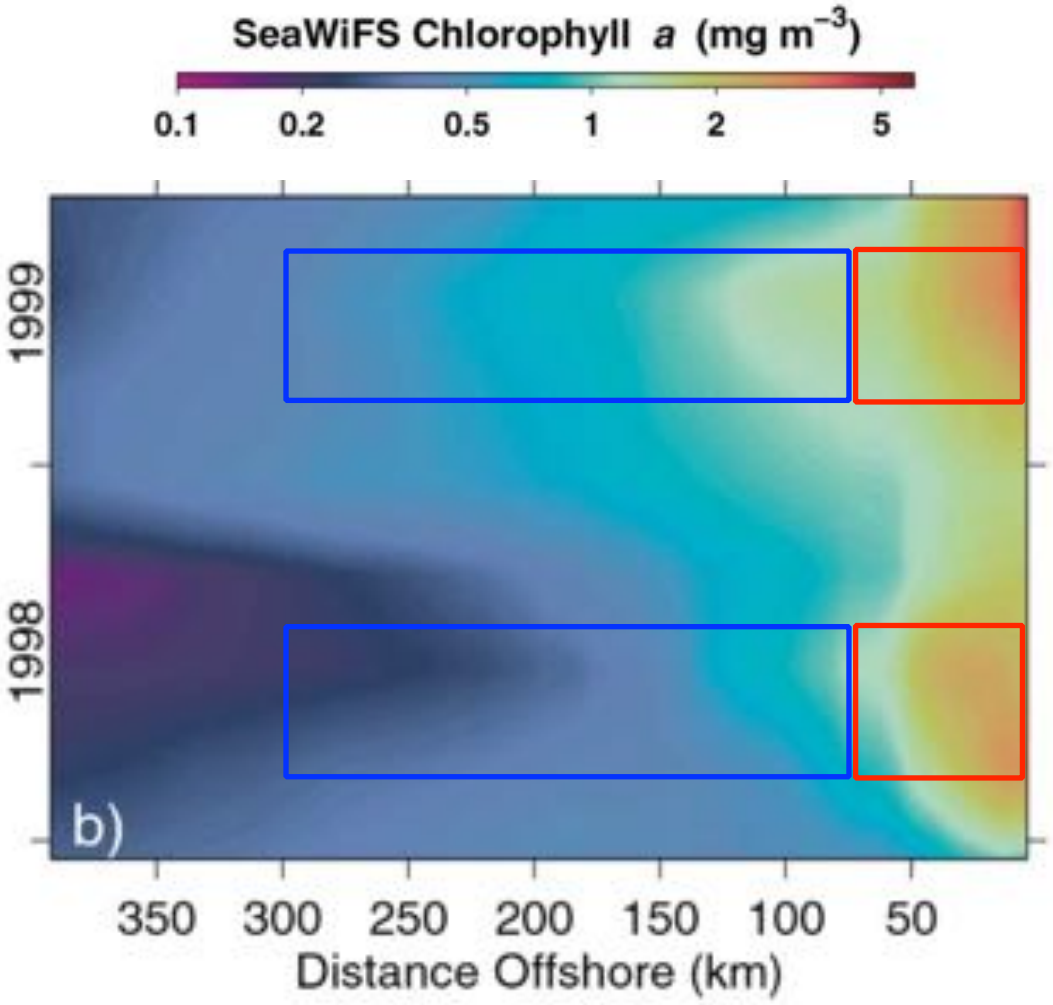


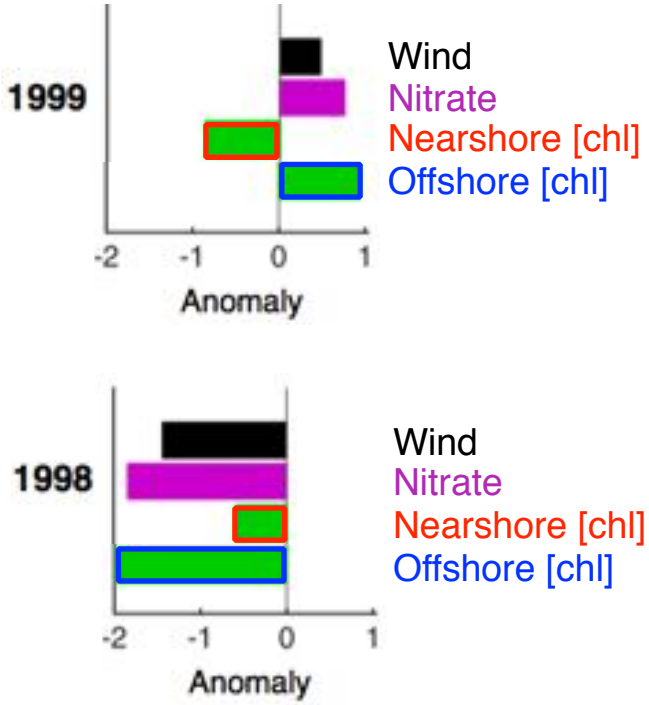
Chavez et al., Prog. Oceangr. (2002)



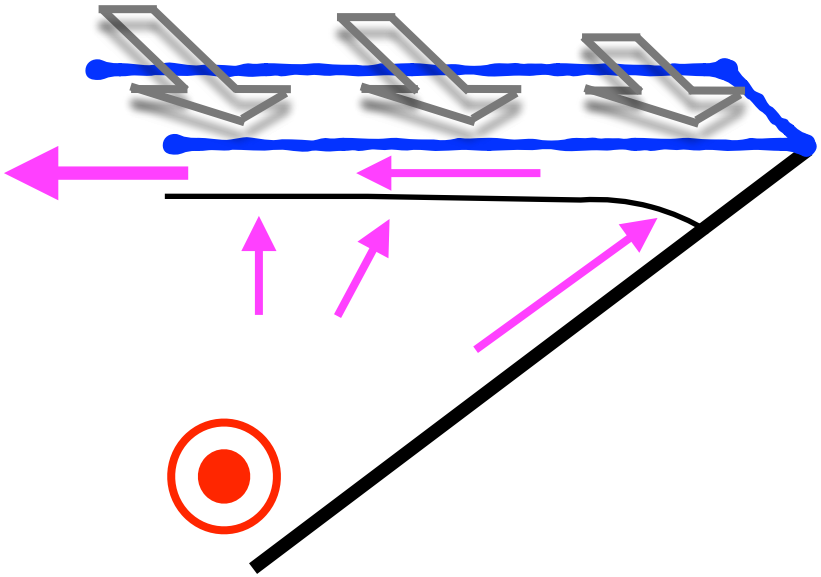


Chavez et al., Prog. Oceangr. (2002)

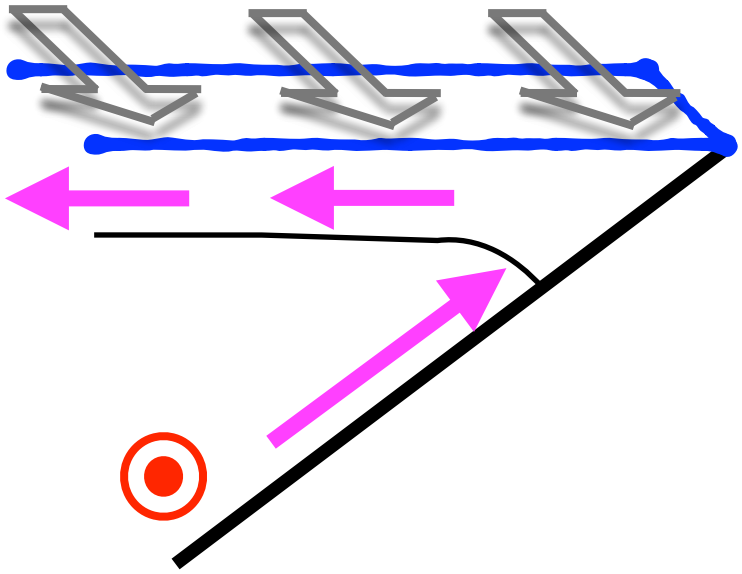




Chavez et al., Prog. Oceangr. (2002)



Weak coastal upwelling
Wide band of curl-driven upwelling
Shallow mixed layer
Nitrate-poor upwelled water
Deep nitracline
Strong Stratification
Low productivity
Small plankton
Anomalous northward advection
Strong poleward undercurrent



Strong coastal upwelling
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Deep mixed layer
Nitrate-rich upwelled water
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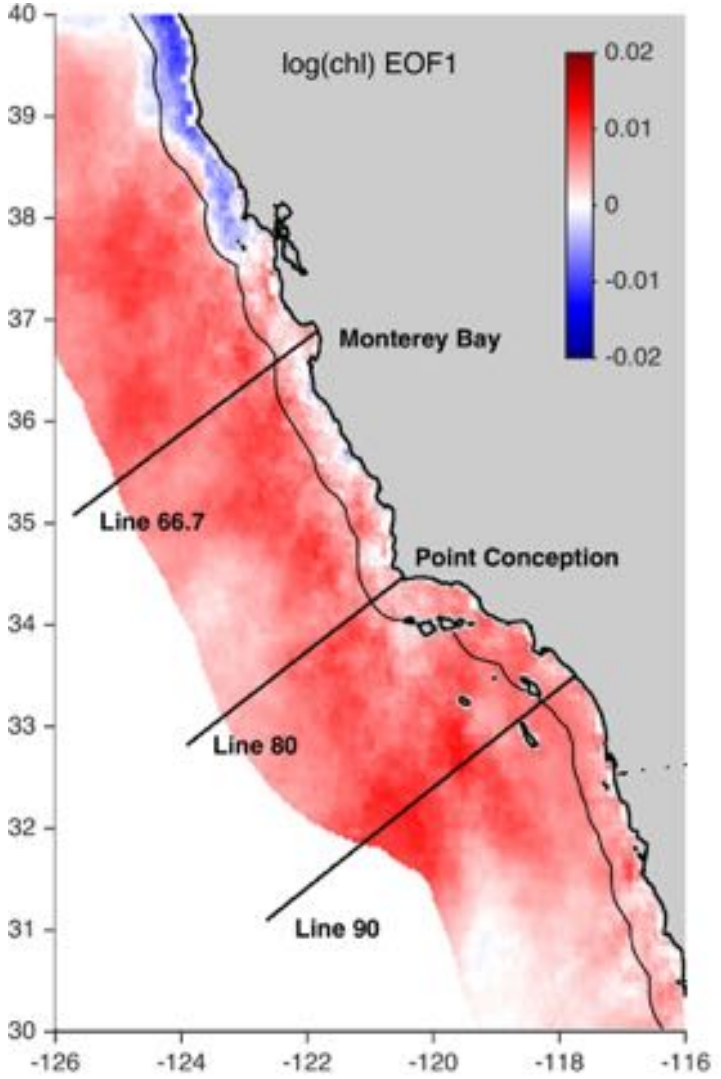
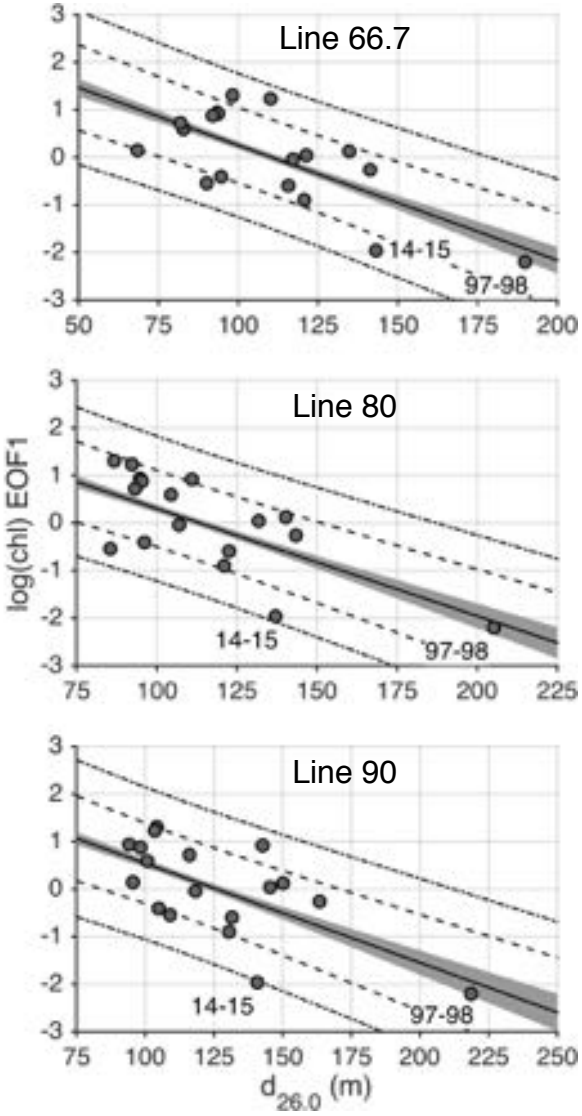
Weak Stratification
High productivity
Large plankton
Anomalous southward advection
Rapid export of nutrients/phytoplankton

Advance Warning of Upwelling Season (April-July) Chlorophyll Anomalies





Jacox et al., GRL (2016)

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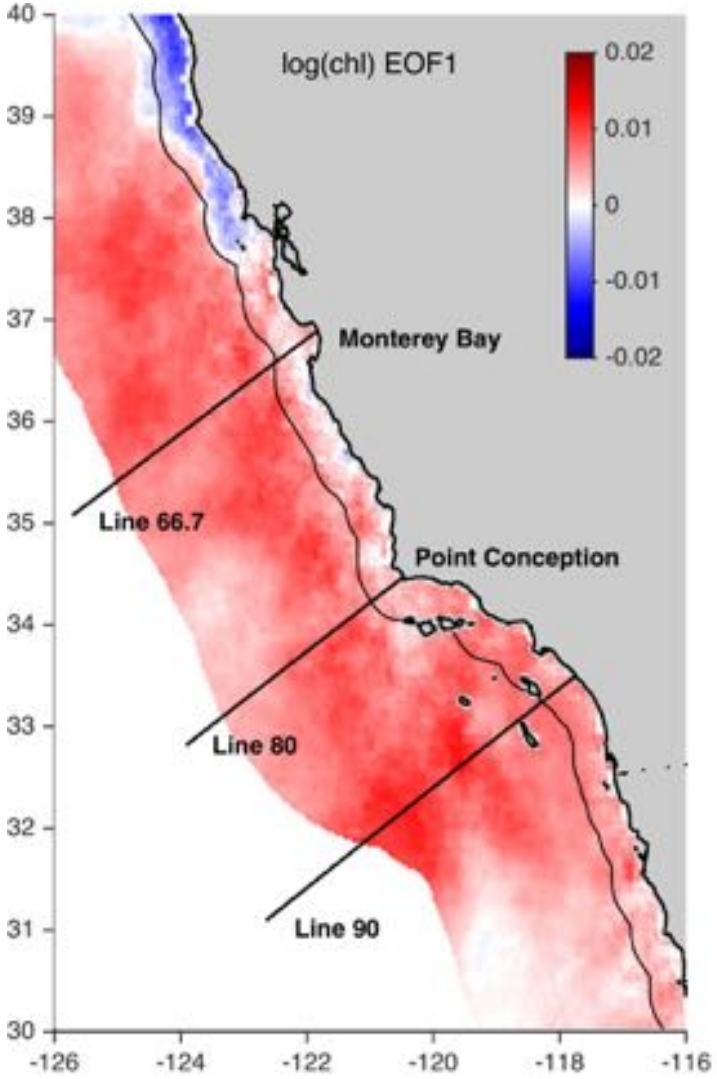
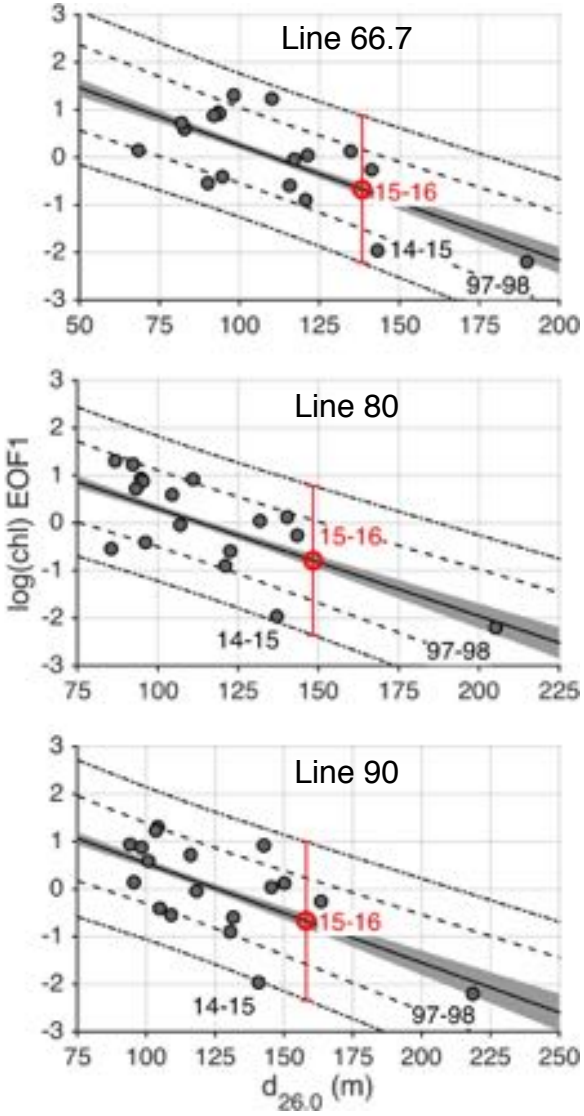


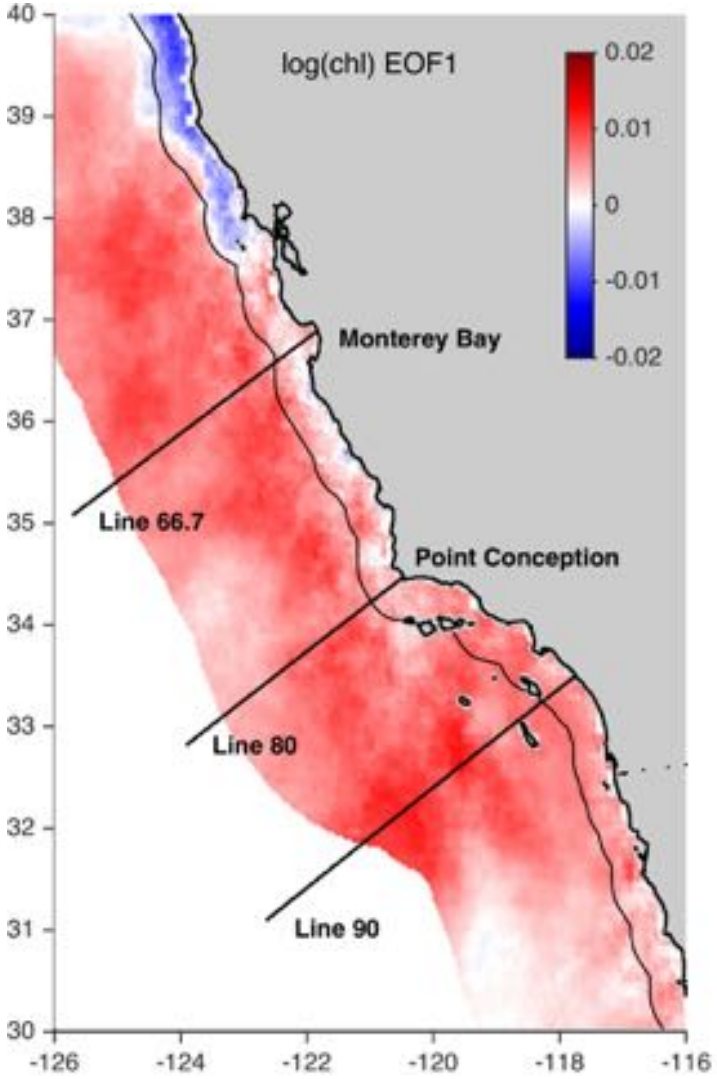


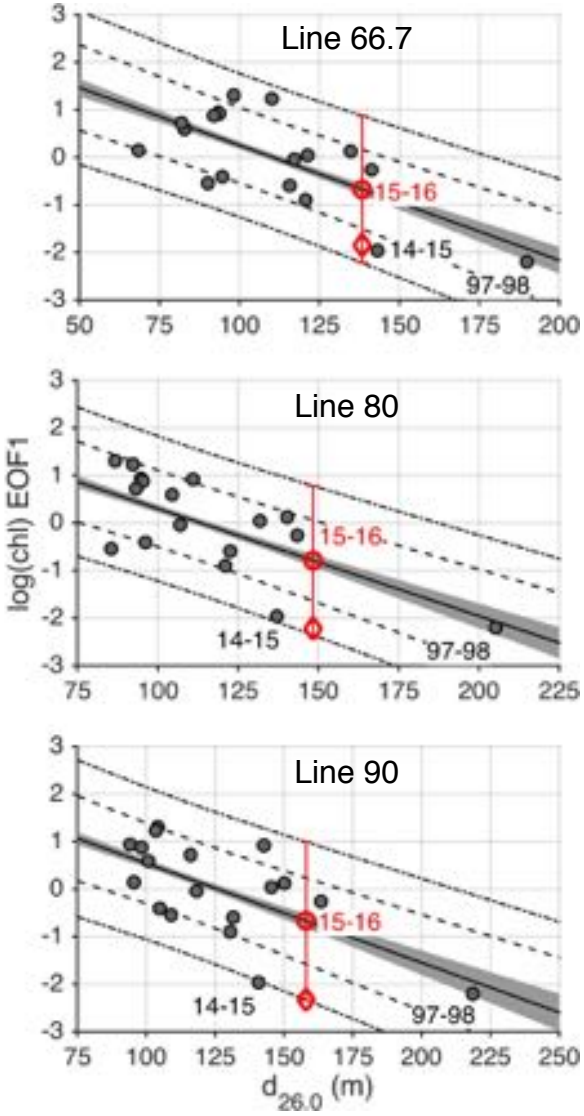
PREDICTIONS

- Linear regression

Jacox et al., GRL (2016)

Advance Warning of Upwelling Season (April-July) Chlorophyll Anomalies





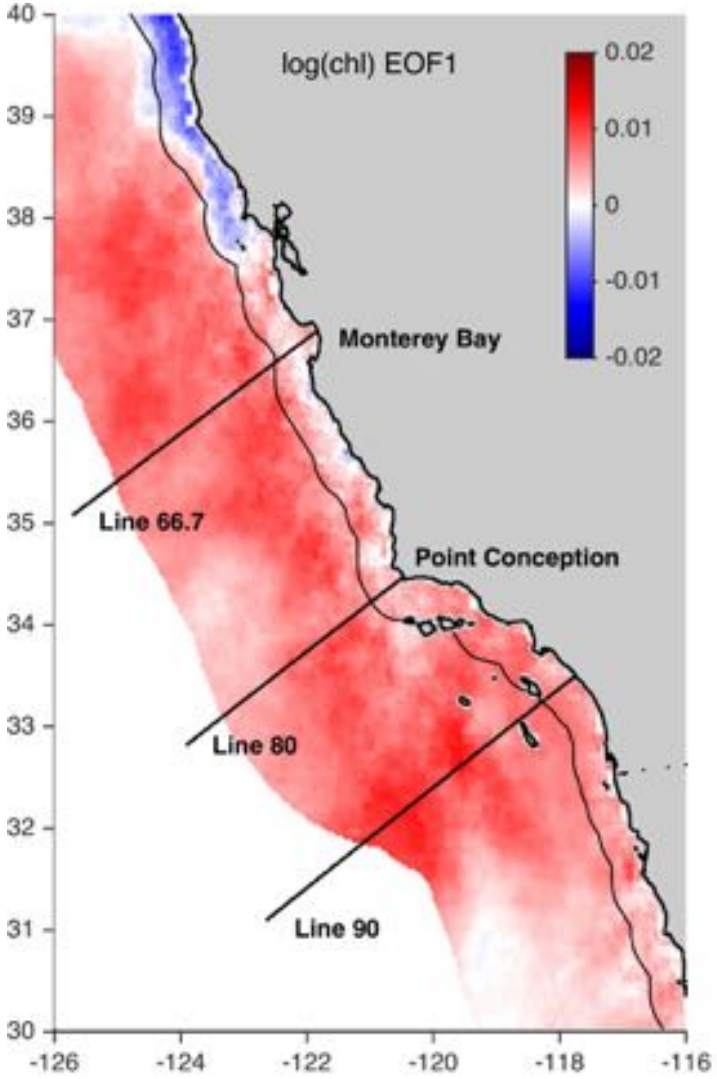
PREDICTIONS

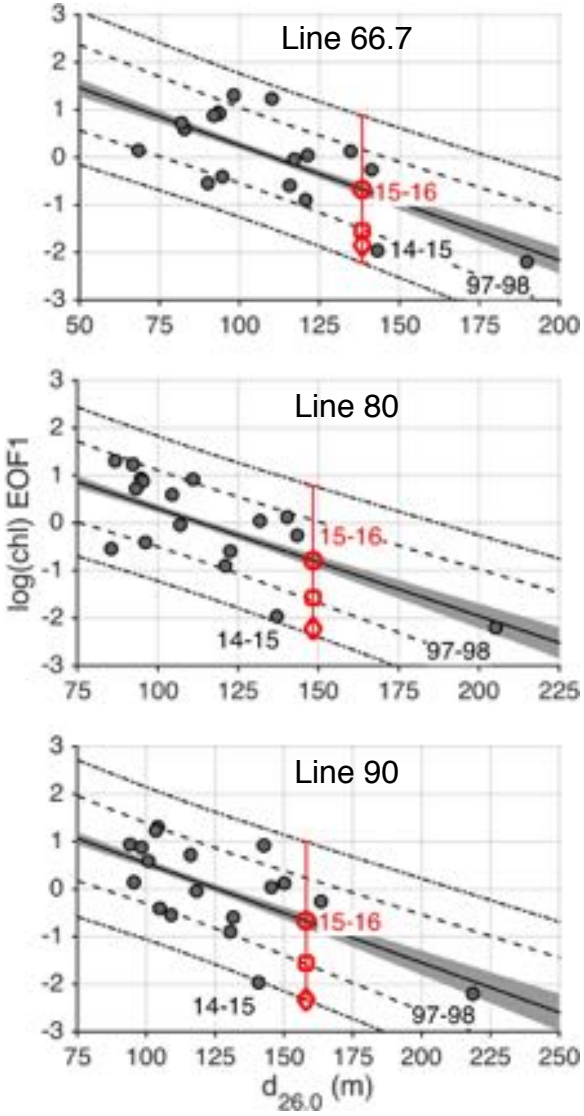
○ Linear regression

◊ Linear regression + Apr-Jul 2015 Chl

Jacox et al., GRL (2016)

Advance Warning of Upwelling Season (April-July) Chlorophyll Anomalies



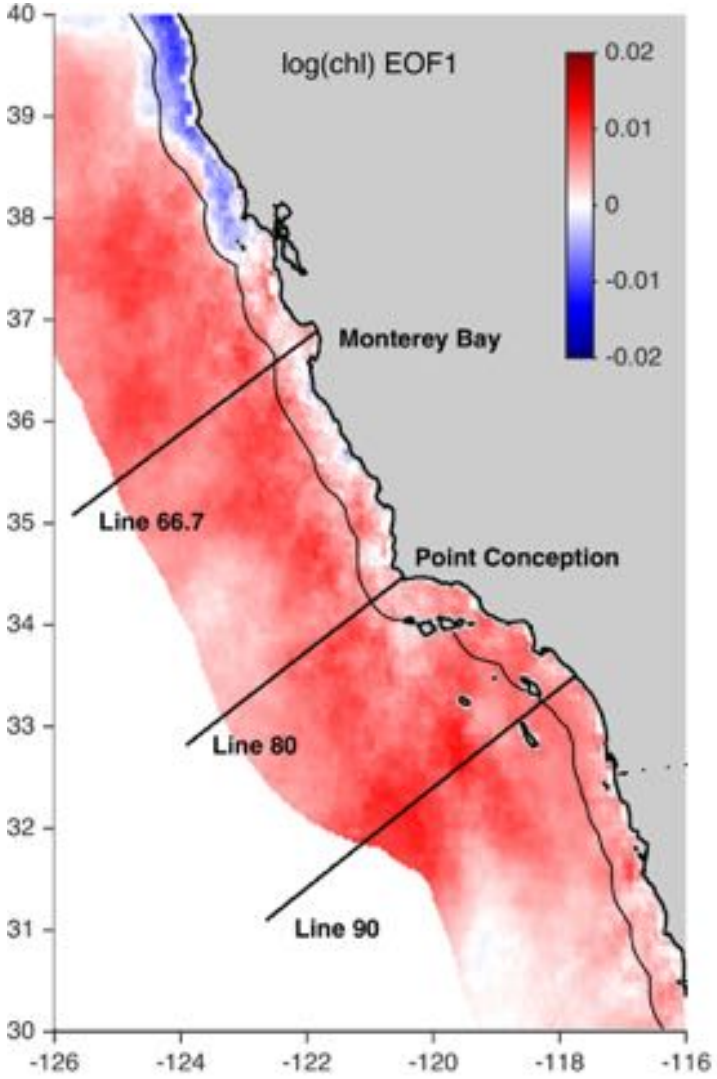


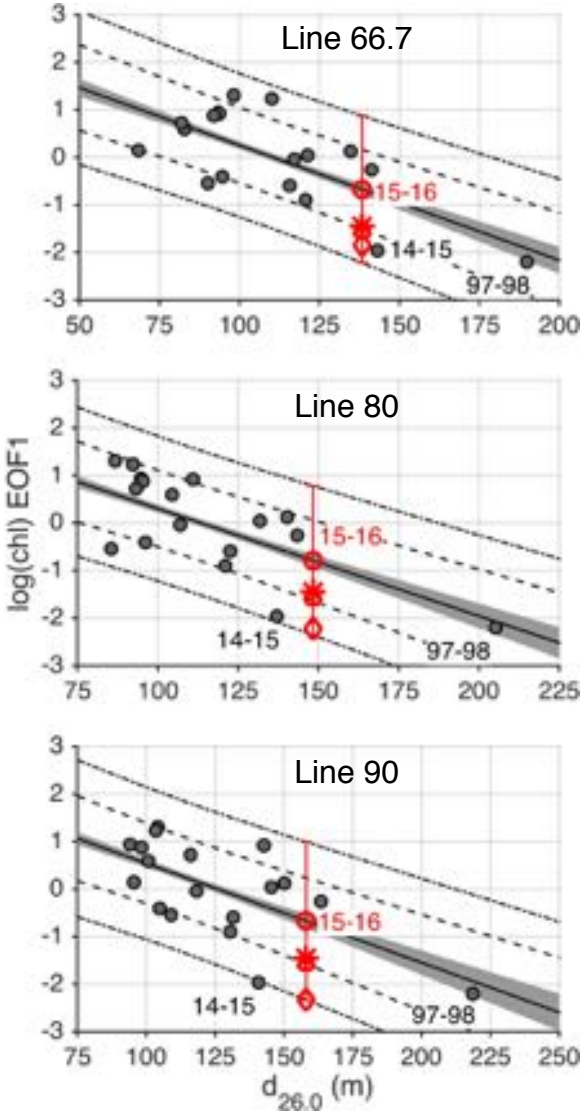
PREDICTIONS

- ○ Linear regression
- ◇ Linear regression + Apr-Jul 2015 Chl
- □ Linear regression + March 2016 Chl

Jacox et al., GRL (2016)

Advance Warning of Upwelling Season (April-July) Chlorophyll Anomalies





PREDICTIONS

- ○ Linear regression
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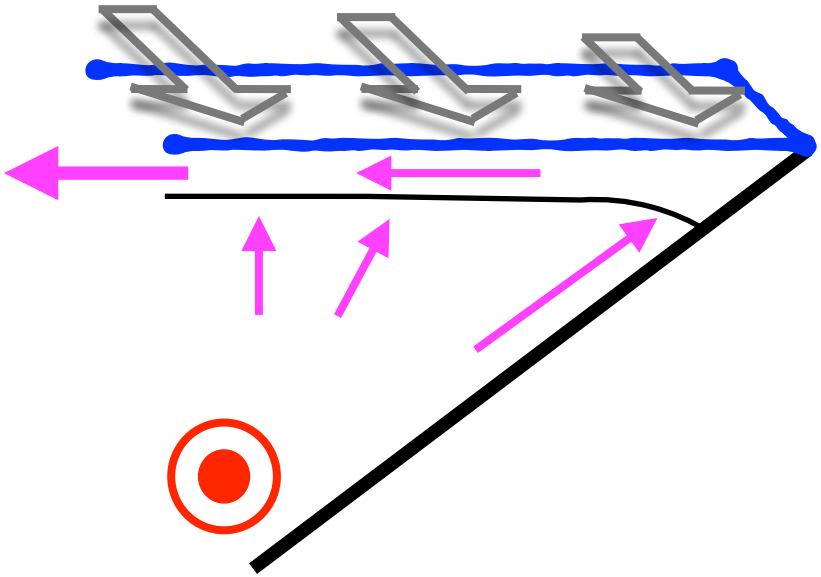
- □ Linear regression + March 2016 Chl
- ∗ OBSERVATIONS

Jacox et al., GRL (2016)



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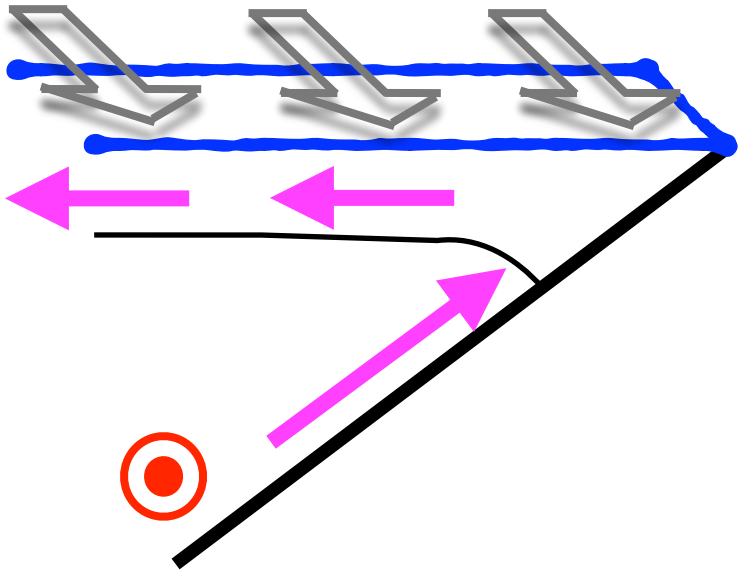

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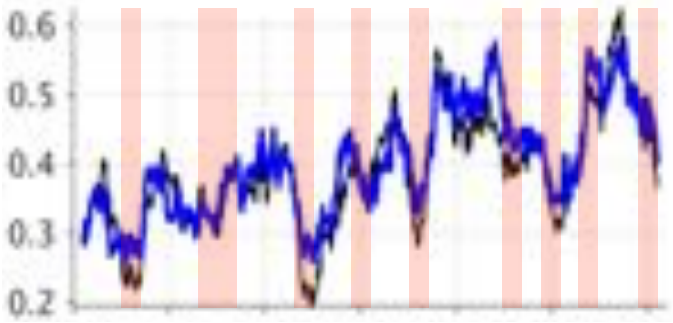
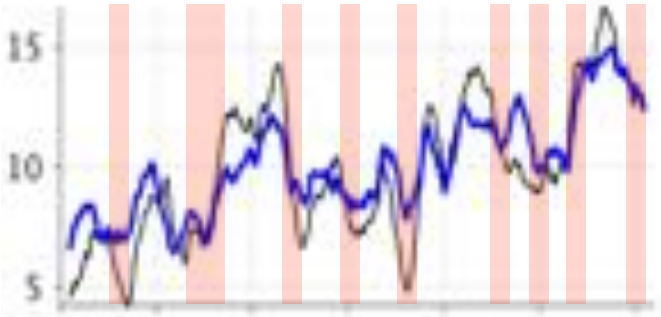
LOCAL WIND FORCING

Vertical Transport



Subsurface Nitrate



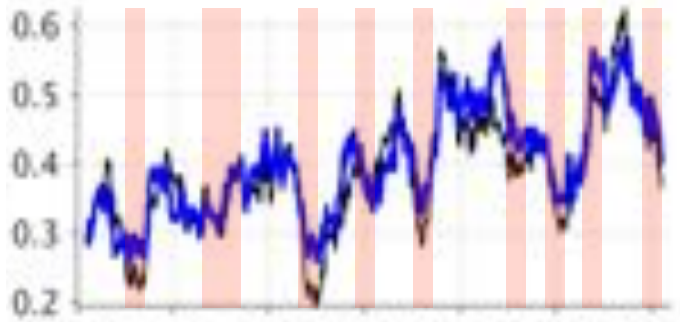
Jacox et al., GRL (2015)

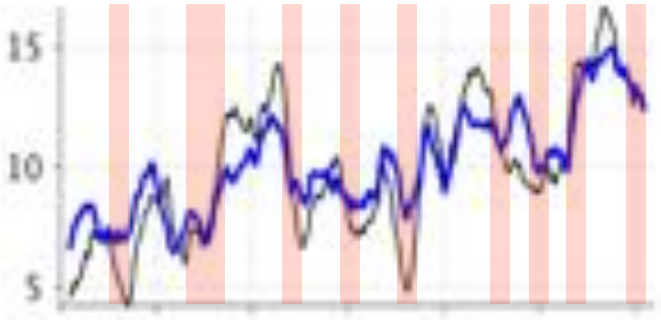
Vertical Transport

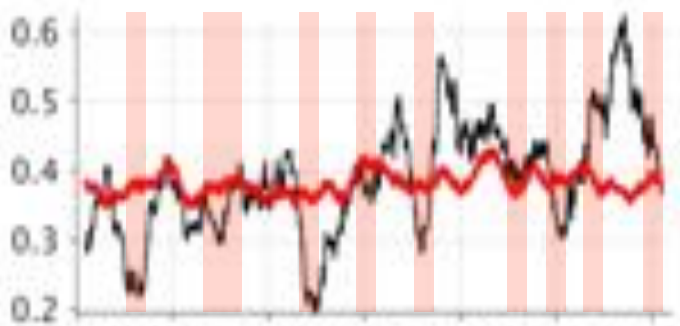
Subsurface Nitrate

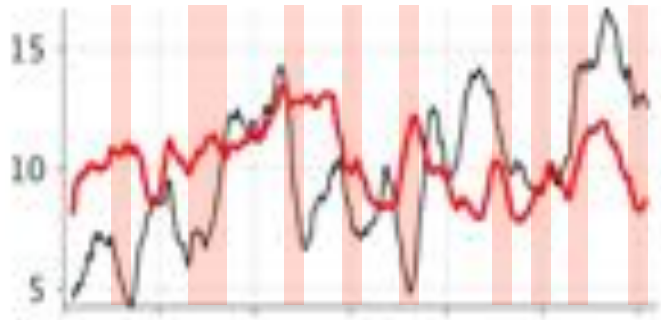
LOCAL WIND FORCING

LOCAL HEAT FLUX FORCING

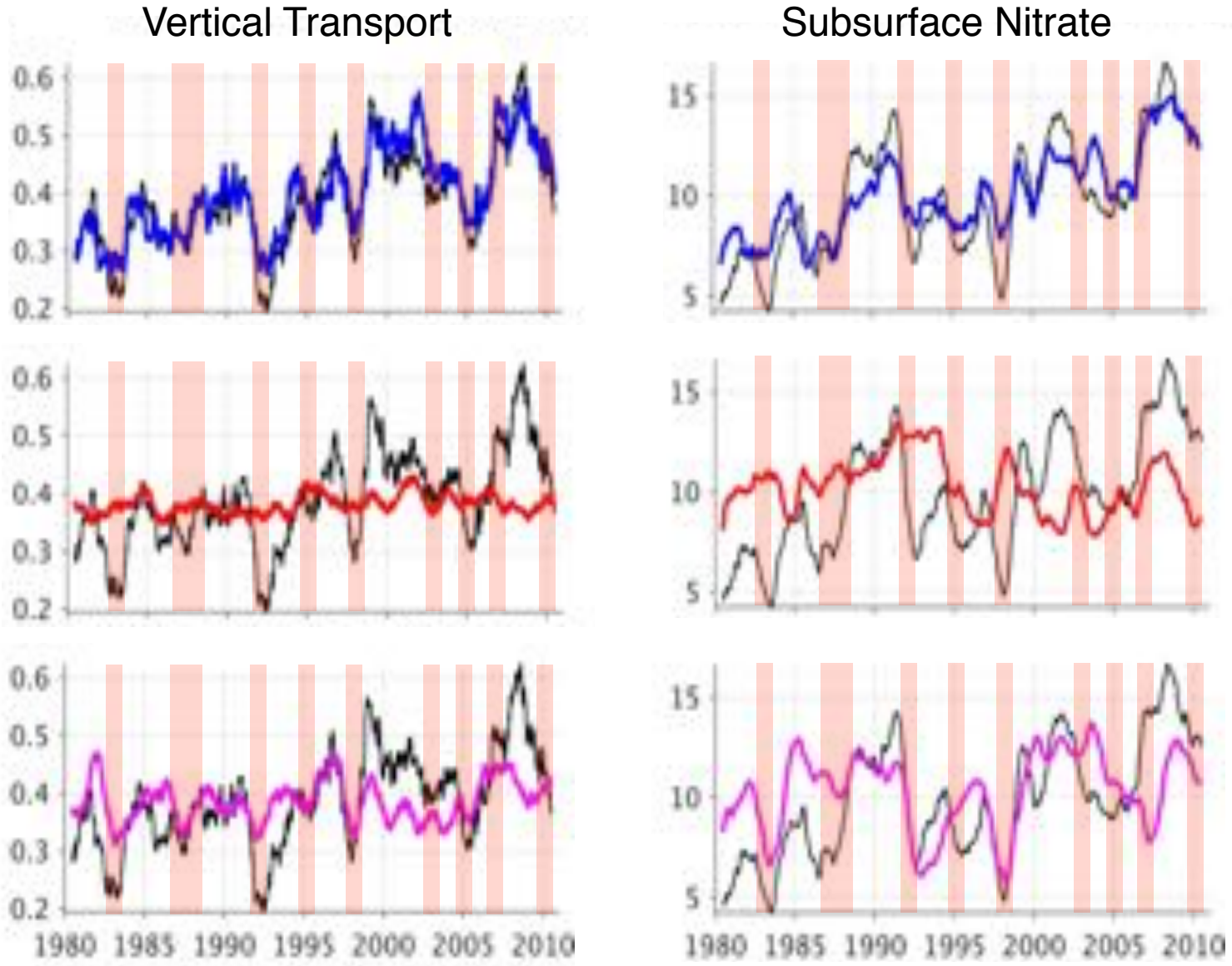








Jacox et al., GRL (2015)



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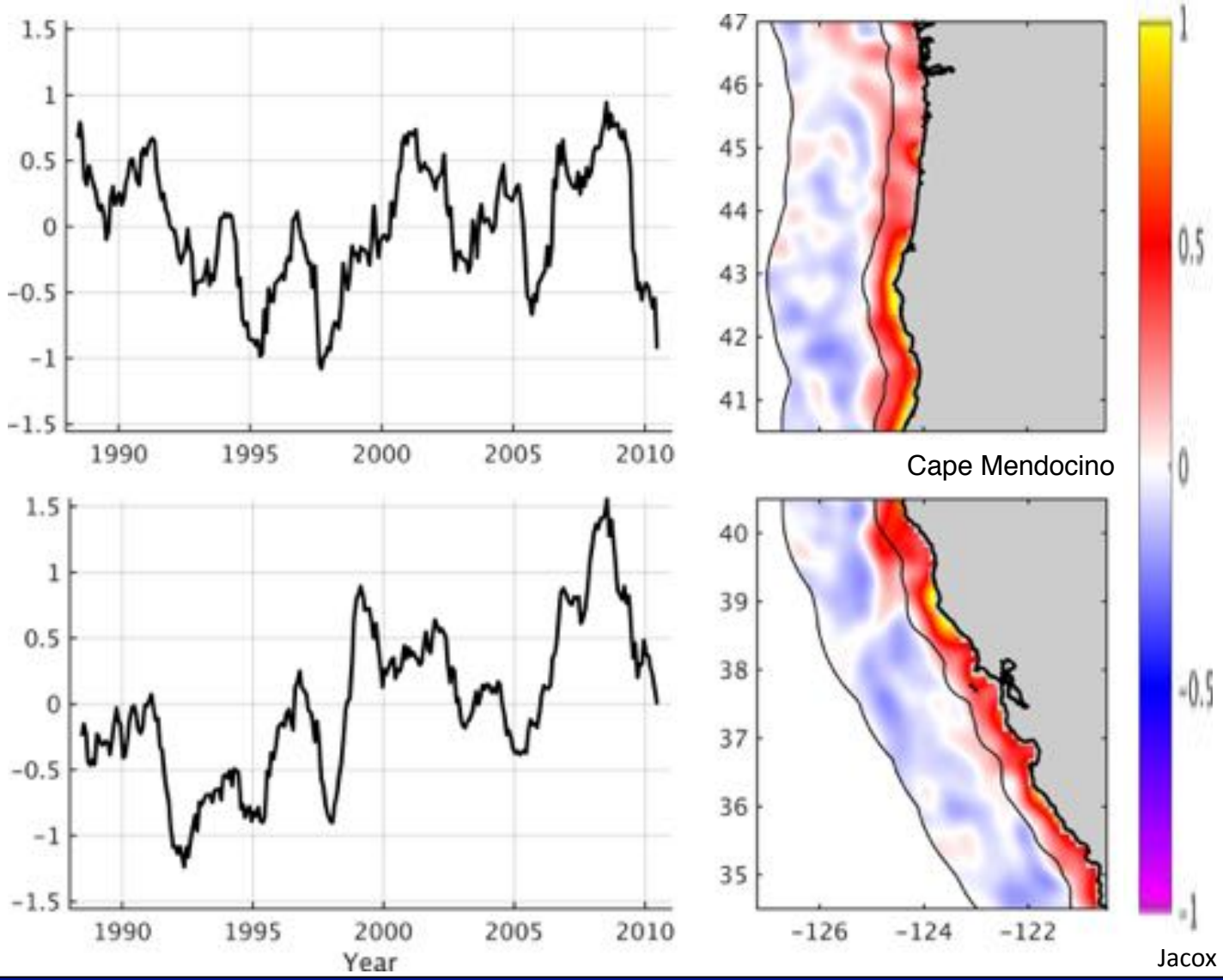

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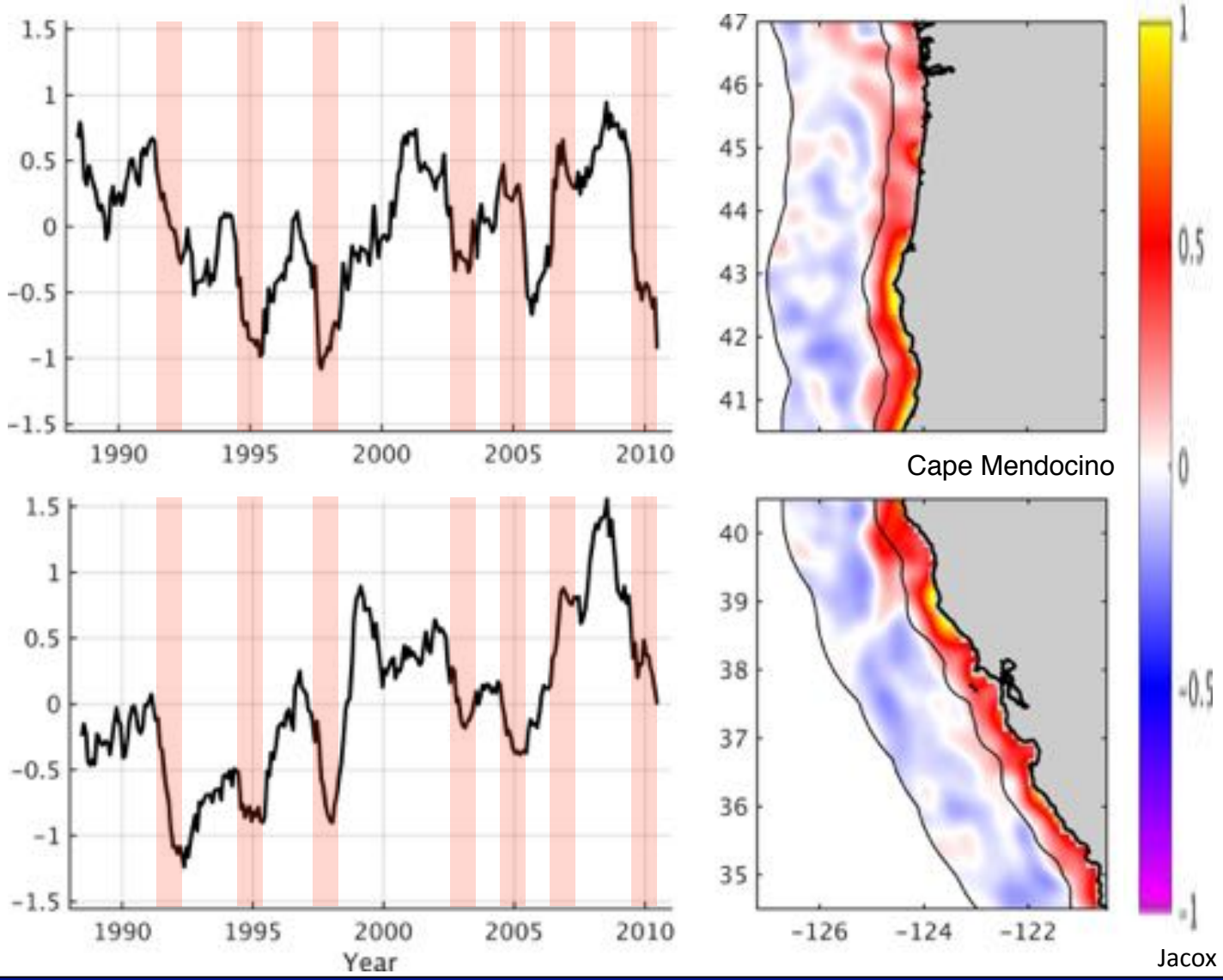

Jacox et al., GRL (2014)