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

Nitrate (µmol L\(^{-1}\))

Chlorophyll (mg m\(^{-3}\))

Subsurface Nitrate (µmol L\(^{-1}\))

Chlorophyll (mg m\(^{-3}\))

Nitrate (µmol L\(^{-1}\))

Chlorophyll (mg m\(^{-3}\))

Wind Stress (N m$^{-2}$)

Subsurface Nitrate (µmol L$^{-1}$)

Chlorophyll (mg m$^{-3}$)

**Nutrient Limitation**

 Weak upwelling

Nutrient Limitation  |  Physical Limitation

**Nutrient Limitation**
- Weak upwelling

**Physical Limitation**
- Offshore advection
- Subduction
- Deep mixed layer (light limitation)

**Nutrient Limitation**
- Weak upwelling
- Nitrate-poor source waters

**Physical Limitation**
- Offshore advection
- Subduction
- Deep mixed layer (light limitation)

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### Model Summary

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<thead>
<tr>
<th>Model</th>
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<th>Heat/Freshwater Flux</th>
<th>Boundary Conditions</th>
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Jacox et al., GRL (2015)
### Table: Model Specifications

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Jacox et al., GRL (2015)
Upwelling EOF1
Upwelling EOF1
Upwelling EOF1

Rykaczewski and Checkley, PNAS (2008)
Small phytoplankton

Large phytoplankton

r = 0.80  r = -0.72

Upwelling EOF1
### 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)
### Remote Ocean Forcing

#### Vertical Transport (Sv)

![Graph showing vertical transport over time](image1)

#### Subsurface Nitrate (μmol L⁻¹)

![Graph showing subsurface nitrate over time](image2)

### Table: Model and Boundary Conditions

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Jacox et al., GRL (2015)
Vertical Transport (Sv)

Jacox et al., GRL (2015)
REMOTE OCEAN FORCING

Vertical Transport (Sv)

Jacox et al., GRL (2015)

Sea Surface Height (m)

Jacox et al., GRL (2015)
REMOTE OCEAN FORCING

**Vertical Transport (Sv)**

![Graph of Vertical Transport (Sv) from 1980 to 2010](image)

**SSH Gradient (mm km\(^{-1}\))**

![Graph of SSH Gradient from 1980 to 2010](image)

**Oceanic Niño Index**

![Graph of Oceanic Niño Index from 1980 to 2010](image)

- Cape Blanco
- Cape Mendocino
- Monterey Bay
- Pt. Conception

Sea Surface Height (m)

Jacox et al., GRL (2015)
### Remote Ocean Forcing

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Jacox et al., GRL (2015)
REMOTE OCEAN FORCING

Vertical Transport (Sv)

Subsurface Nitrate (µmol L\(^{-1}\))


Weakly Stratified

Strongly Stratified

REMOTE OCEAN FORCING

EL NIÑO

LA NIÑA

Vertical Transport (Sv)

Subsurface Nitrate (µmol L\(^{-1}\))

Distance From Shore (km)

Depth (m)


Model | Wind Stress | Heat/Freshwater Flux | Boundary Conditions
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Jacox et al., GRL (2015)
Nitrate Flux Anomaly (kmol s$^{-1}$)

Oceanic Niño Index

Frischknecht et al., JGR (2015)
Subsurface Nitrate (µmol L\(^{-1}\))

Wind Stress (N m\(^{-2}\))

Wind Stress (N m\(^{-2}\))

1998-2010 Climatology

Subsurface Nitrate (µmol L\(^{-1}\))

Wind Stress (N m$^{-2}$)

Subsurface Nitrate (µmol L$^{-1}$)

1998-2010 Climatology

1998 (El Niño)

Nearshore

1998

1999
Nearshore

1998

Offshore

1999

Chavez et al., Prog. Oceanogr. (2002)
Chavez et al., Prog. Oceangr. (2002)
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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
Narrow band of curl-driven upwelling
Deep mixed layer
Nitrate-rich upwelled water
Shallow nitracline
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)
Advance Warning of Upwelling Season (April-July) Chlorophyll Anomalies

PREDICTIONS

- Linear regression

Jacox et al., GRL (2016)
Advance Warning of Upwelling Season (April-July) Chlorophyll Anomalies

- **Linear regression**
- **Linear regression + Apr-Jul 2015 Chl**

Jacox et al., GRL (2016)
Advance Warning of Upwelling Season (April-July) Chlorophyll Anomalies

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- Linear regression

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Jacox et al., GRL (2016)
Advance Warning of Upwelling Season (April-July) Chlorophyll Anomalies

OBSERVATIONS

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

Jacox et al., GRL (2016)

PREDICTIONS

- Linear regression
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* OBSERVATIONS
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LOCAL WIND FORCING

Vertical Transport
Subsurface Nitrate

Jacox et al., GRL (2015)
LOCAL WIND FORCING

LOCAL HEAT FLUX FORCING

Vertical Transport

Subsurface Nitrate

Jacox et al., GRL (2015)
LOCAL WIND FORCING

LOCAL HEAT FLUX FORCING

REMOTE OCEAN FORCING

Vertical Transport

Subsurface Nitrate

Jacox et al., GRL (2015)
Cape Mendocino

Jacox et al., GRL (2014)
Jacox et al., GRL (2014)