Observed Coastal Chlorophyll Anomalies During 1997-2010

Todd Mitchell and Nate Mantua
Joint Institute for the Study of the Atmosphere and Ocean
University of Washington
Chlorophyll in the marine ecosystem

Chlorophyll molecules in phytoplankton trap light in the process of photosynthesis

\[ \text{CO}_2 + \text{H}_2\text{O} + \text{Sunlight} \rightarrow \text{carbohydrates} + \text{oxygen} \]

Also requires iron, nitrogen, phosphorous, silicon

Upwelling --- rising motion in the ocean --- brings nutrients up to the surface where photosynthesis happens
January and July mean chlorophyll (mg m$^{-3}$)
Why chlorophyll and what is the point of this talk?

• Phytoplankton are the base of the marine food-web: they are eaten by zooplankton and some fish, which in turn are eaten by larger organisms
• Phytoplankton are a major producer of oxygen.
• Chlorophyll tracks one key part of ecosystem productivity. It isn’t quite upwelling, but we do have a 13-year record of it so it is useful to characterize its variability.

The goal of this talk:

Characterize patterns of coherent chlorophyll variability and relate to physical variables such as wind, satellite estimates of upwelling, sea surface temperature, and other variables. Ocean dynamical / chemical modelers can use these patterns as targets of variability that their models should capture.
The Details

NASA SeaWiFS observations from September 1997 to December 2010. Daily observations at 9km resolution.
Instrument failure for 1.5 years during that period.
The record is short so analyze the short timescale variability to maximize the number of degrees of freedom in the analysis (and increase the statistical significance of the results).

Average the data into five-day means (pentads) at 0.5° latitude-longitude resolution.
Analyze deviations from the climatology for all pentads of the year.
Use observations within 5° of the coast from the Queen Charlotte Islands to southern Baja

Employ rotated principal component analysis, a form of factor analysis, to characterize the regions of coherent variability. Resulting patterns may spatially overlap, but the time series are required to be independent.
Standard deviation of pentad chlorophyll anomalies (mg m^{-3})
The analysis recovers many of the regions that people have been studying. The value of this analysis is that the different regional patterns of variability are captured in a common analysis.

Expect to see variability of Spring onset everywhere ---- we’re all looking for this!
Patterns explaining 8.8, 4.7, and 7.6 % of the dataset variance.

“broad” pattern

Newport

Northern Oregon / Southern California

Correlation coefficients are plotted
“broad pattern” time series grouped by pentad of the year

Large amplitudes from February through October
--- Spring doesn’t stand out.
Typical sea-level pressure deviations associated with high chlorophyll in

“broad pattern”

Strong southward winds forcing strong upwelling

Newport

Weak southward winds
Gulf of the Farrallones 5.6%
California Bight 4.4%
S. California coast 3.6%
Variable in all pentads
January through May variability
Variable in all pentads
Three patterns necessary to capture variability at the mouth of the Straight of Juan de Fuca

6.5%

4.2%

5.0%

All exhibit March through November variability
What we’ve done:

• Documented coherent patterns of non-seasonal chlorophyll.
• Noted that the patterns have different spatial and temporal scales

What’s next:

• Fill out the description of the variability by relating to surface winds, ocean vertical structure near the coast, sea surface temperature, and other variables.
• Look at the seasonal cycle.