Satellite remote sensing: A window to our changing planet

LETTERS

Climate-driven trends in contemporary ocean productivity

Michael J. Behrenfeld¹, Robert T. O’Malley¹, David A. Siegel³, Charles R. McClain⁴, Jorge L. Sarmiento⁵, Gene C. Feldman⁴, Allen J. Milligan¹, Paul G. Falkowski⁶, Ricardo M. Letelier⁵ & Emmanuel S. Boss⁷
How might ocean warming affect global net primary production (NPP)?
Distribution and trends in global ocean phytoplankton productivity and chlorophyll standing stock

a. Annual average NPP showing high values where surface nutrients are elevated. Low-latitude, permanently stratified waters with annual average surface temperatures over 15°C are delineated by black contour lines.
b. Anomalies in globally integrated water-column chlorophyll concentrations (green line) are dominated by changes occurring in permanently stratified ocean regions (grey circles and black line).

c. Anomalies in global NPP (green line) are likewise driven by changes in the permanently stratified oceans.
Ocean productivity is closely coupled to climate variability

a. NPP anomalies in the permanently stratified oceans are highly correlated \( (r^2 = 0.77) \) with the MEI of climate variability

b. Changes in ocean stratification link climate variability to ocean biology, and are well correlated \( (r^2 = 0.73) \) with NPP anomalies in ocean regions with annual average surface temperatures over 15°C.
Climate controls on ocean productivity cause NPP to vary inversely with changes in SST
VGPM (the model used by Behrenfeld) is not very accurate for some regions. It does not do that much better than taking the square-root of Chlorophyll!
In contrast to Behrenfeld, analysis of the SAME satellite data shows a pattern of INCREASING productivity for the California Current.

(red shows where NPP is increasing)
Global phytoplankton decline over the past century

Daniel G. Boyce¹, Marlon R. Lewis² & Boris Worm¹

In the oceans, ubiquitous microscopic phototrophs (phytoplankton) account for approximately half the production of organic matter on Earth. Analyses of satellite-derived phytoplankton concentration (available since 1979) have suggested decadal-scale fluctuations linked to climate forcing, but the length of this record is insufficient to resolve longer-term trends. Here we combine available ocean transparency measurements and in situ chlorophyll observations to estimate the time dependence of phytoplankton biomass at local, regional and global scales since 1899. We observe declines in eight out of ten ocean regions, and estimate a global rate of decline of ~1% of the global median per year. Our analyses further reveal interannual to decadal phytoplankton fluctuations superimposed on long-term trends. These fluctuations are strongly correlated with basin-scale climate indices, whereas long-term declining trends are related to increasing sea surface temperatures. We conclude that global phytoplankton concentration has declined over the past century; this decline will need to be considered in future studies of marine ecosystems, geochemical cycling, ocean circulation and fisheries.
Using 100 years of Secchi Disk measurements, there is evidence that the oceans, on average, are getting less green (more transparent)

This is consistent with the idea that global warming cuts off the nutrient supply for the phytoplankton.

BUT this is controversial. Why would the coast get more productive?

(if you are interested, there are a series of short that the oceans are greener:

Summary

• Surface warming in the permanently stratified ocean regions is accompanied by reductions in productivity, because warmer temperatures (increased growth rates) are OFFSET but stratified waters which cut off the nutrient supply

• Transition to permanent El Nino conditions will result in decreased Net Primary Production (NPP) and alter global ocean net air–sea CO$_2$ exchange, fishery yields, and dominant basin-scale biological regimes

• BUT: Kahru et al. suggest the models are not very accurate, and that coastal waters are actually getting greener (possibly due to more upwelling)

• **Bottom Line:** even for something as simple as whether the oceans get greener or bluer with climate change, the results are equivocal. Although NPP is controlled by light and temperature, and we would expect high NPP where it’s warm and high light, this also cuts off the nutrients....

What does this mean for models that assume the ocean will mediate rising atmospheric CO$_2$?