New Production and Nutrient Availability Estimated from Satellite Altimeter

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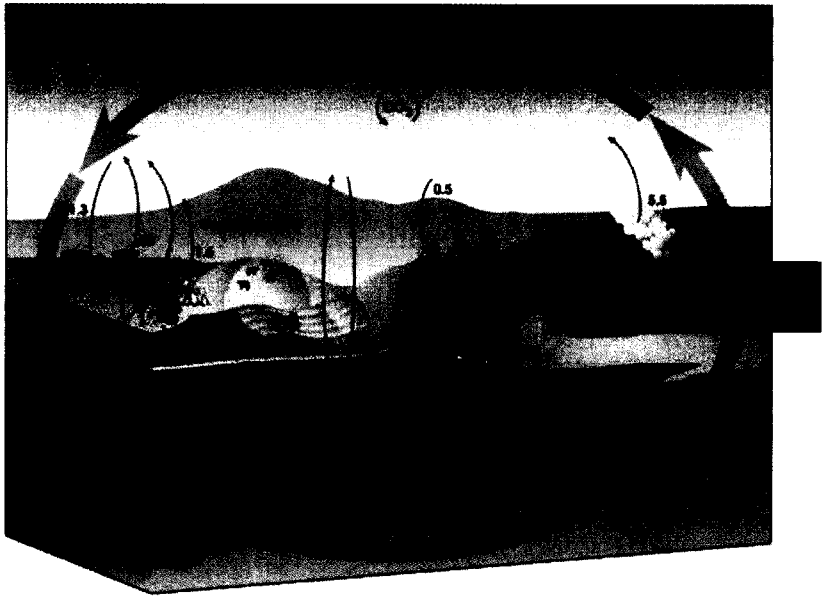


Acknowledgements

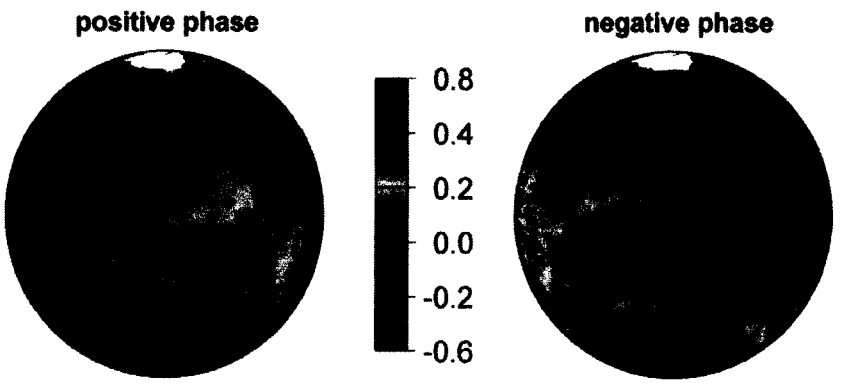
- NASA Oceanography Program, Eric Lindstrom and Paula Bontempi
- Nate Mantua
- http://www.atmos.washington.edu/pdo
- This work was carried at the Jet Propulsion Laboratory under contract with the National Aeronautics and Space Administration.

Introduction

Our objective is to use a long time series (for remote sensing!) of a measurement, that is not obscured by clouds and which can be realistically related to a biogeochemically relevant variable, to study biological-physical dynamics.

We employ an approach which is independent of ocean color-based algorithms of primary production or export production.

Having identified our measurement and developed a method to place it into a biogeochemical context we want to quantify the interannual variability of spatial patterns of nutrient content and drawdown.



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The impact of a shift in environmental conditions in the North Pacific following 1998 can be addressed with our data:

Is there a PDO signal in nutrient content and drawdown?

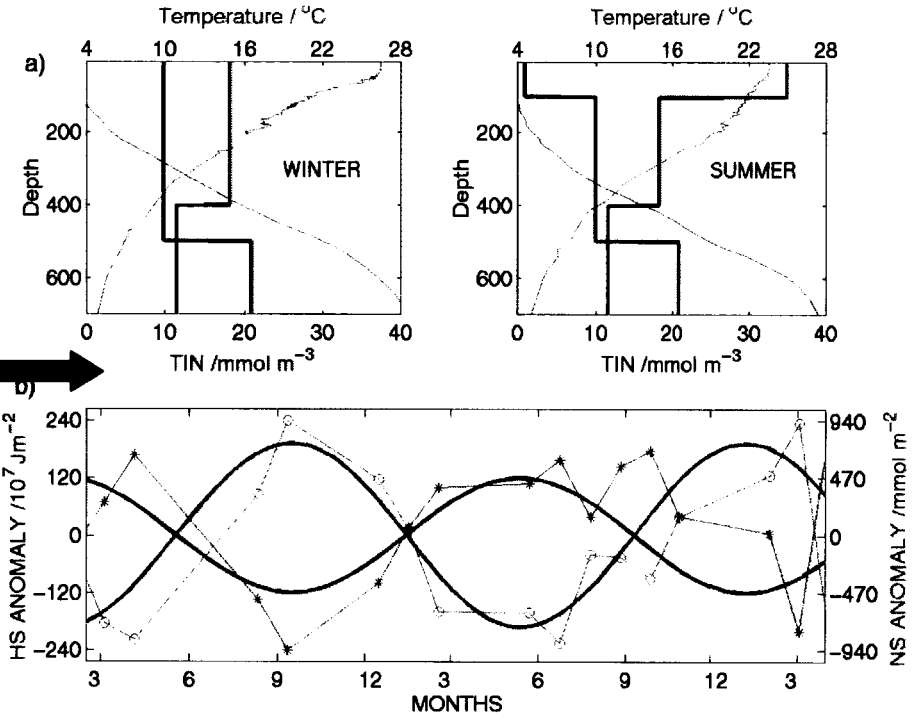
Approach: from altimeter to biogeochemistry

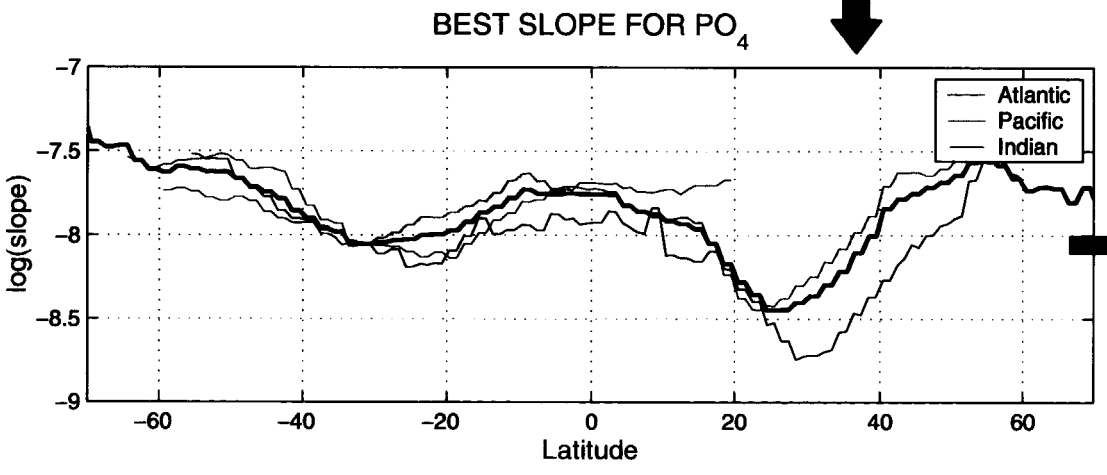
We derive seasonal uptake of nutrients using

1. The anomaly in heat content, estimated by applying a 2D finite impulse response filter to the anomaly of sea surface height measured by TOPEX/ Poseidon.

2. Changes in heat content are inversely related to changes in nutrient content.

3. We obtain climatological relationships between heat and nutrient content.





4. We then apply the slope for each latitude and basin to the time series of heat content anomaly from T/P.

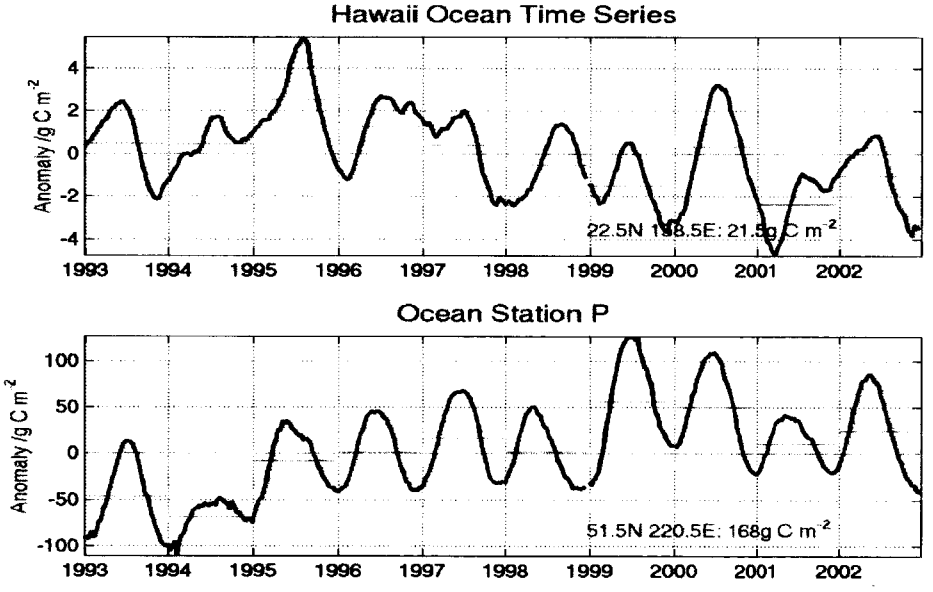
Approach: what variables can we extract from a time series?

0. We transform the PO_4 concentration to carbon using the Redfield ratio of 6.6, so drawdown is in units of export or new production and content in depth integrated concentration of carbon.

1. The amplitude of the annual cycle is the seasonal drawdown of nutrients.

2. The average anomaly of nutrient content for each year provides nutrient availability.

- By adding the climatological nutrient content, we have an estimate of actual nutrient content.

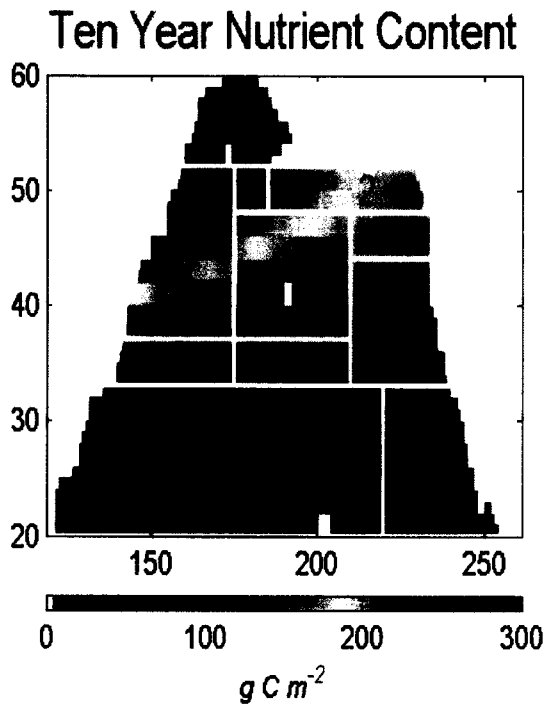


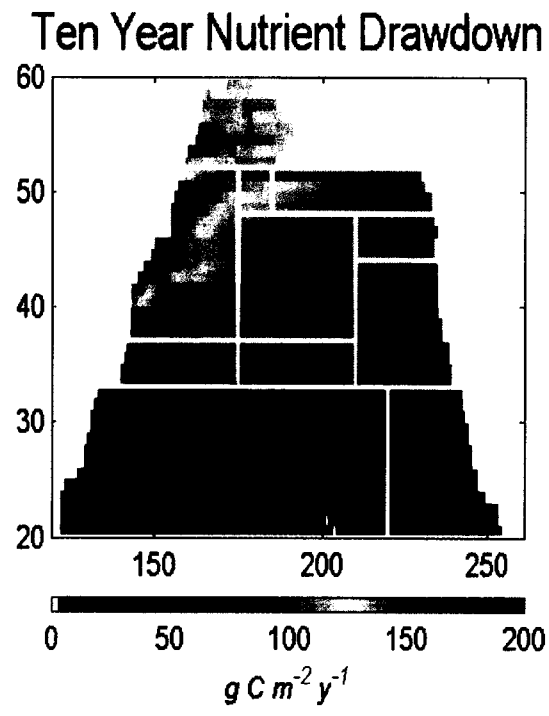
Nota bene: Because we use a climatological relationship between heat and nutrients we cannot estimate possible shifts in the nutrient inventory (such as found at HOT). So we are likely underestimating nutrient variability.

North Pacific: Ten Year Average Content and Drawdown

The study area is divided into regions to characterize the first-order differences.

	MAX	*MIN*	*OTHER*
Content	N, NW	SW and central	Moderate in California Current.
Drawdown	N, NW	S of 35S	Moderate in northern California Current.





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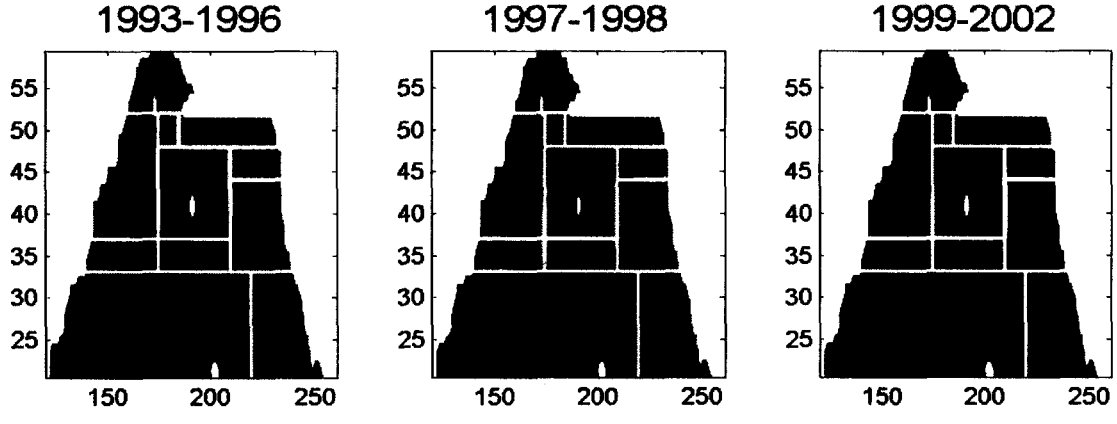
Three periods of physical forcing: impact on nutrient availability

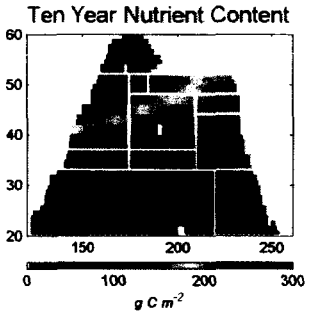
1. We define regimes of low, balanced, and excess availability of nutrients.
   Nutrient-poor or oligotrophic waters (dark blue): very low nutrient content/production
   Excess nutrients (red): so high that biological activity cannot use all available nutrients (High Nutrient Low Chlorophyll)
   Balanced availability (light blue): nutrient supply and drawdown are comparable.



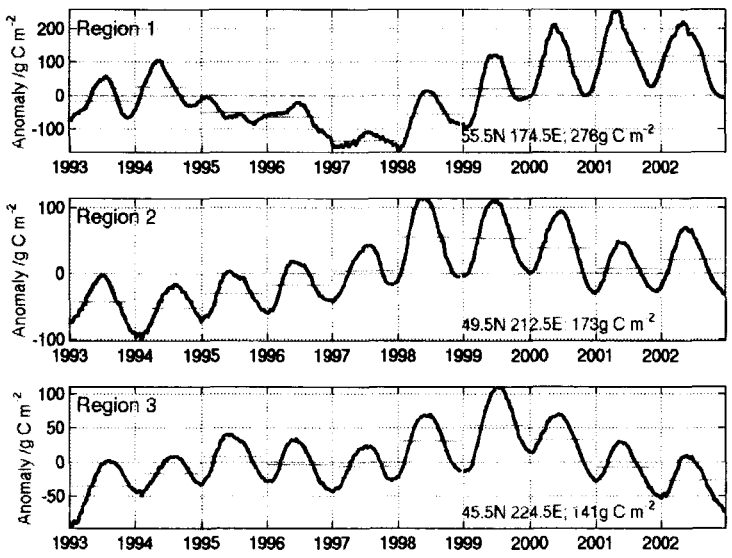
2. Between 1993 and 2002, the regions are consistent in location but not in extent.

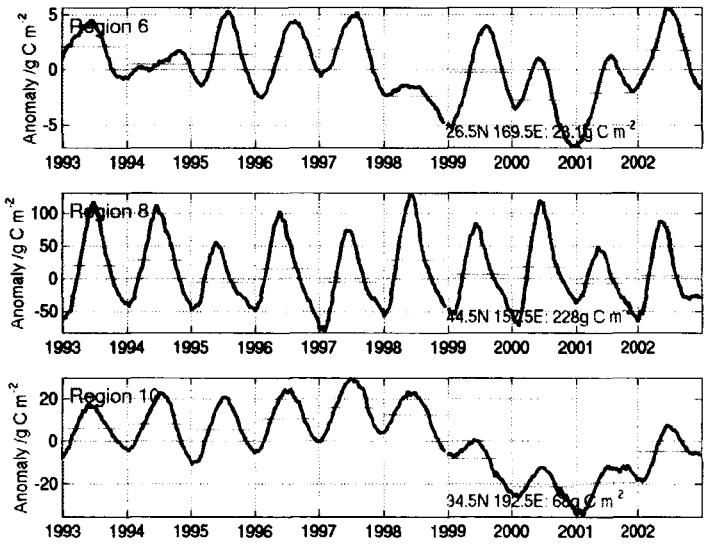
After 1997, the HNLC region extended north and eastward. Even the pattern of availability during the EN period is similar to that after 1998, the content was much greater in the latter period.

Time series of nutrient content anomaly: is there a PDO signal?



1. Considerable variability in nutrient content at different locations.
2. Annual cycle in content.
3. El Nino (EN), 1997-1998, is strong signal (low content and amplitude).
4. Non-zero annual mean (changes in nutrient availability).
5. Different trend pre-EN versus post-EN in the eastern and western basins.



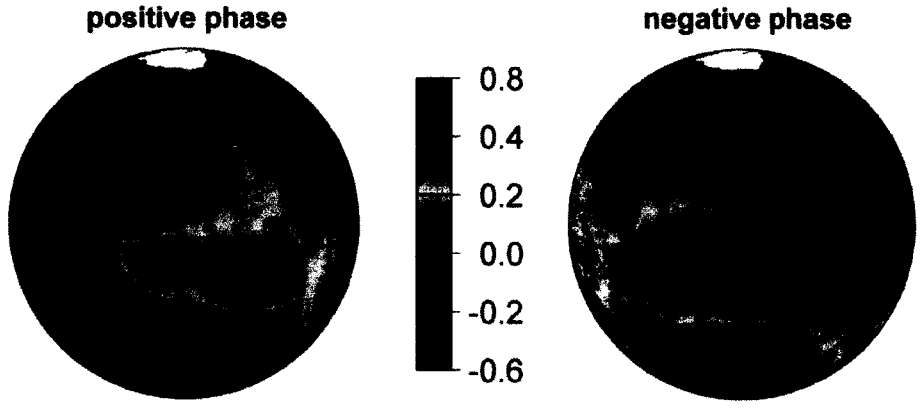


Spatial fields of nutrient content anomaly: is there a PDO signal?

The 'classic' PDO pattern is of higher SST in the north and western Pacific in the 'warm' phase and vice versa in the 'cold' phase.

It is thought that a transition from warm to cold took place at the end of 1998.

If we average the anomaly in nutrient content for the four years preceding ('warm' phase) and following ('cold' phase) the EN (1997-1998), the pattern is generally consistent: positive anomalies shift from south and west to north and east.



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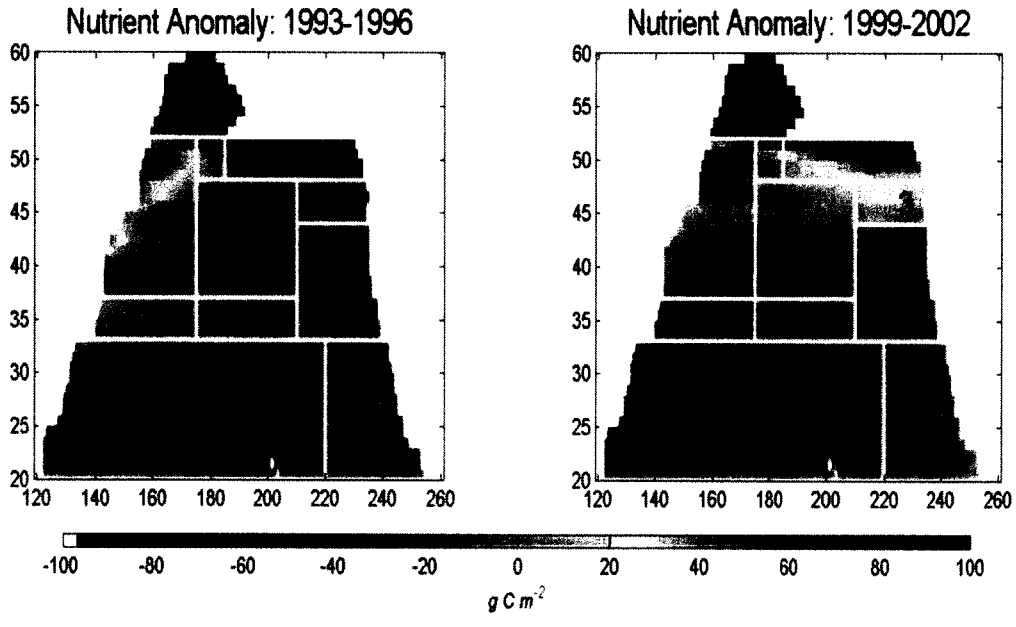

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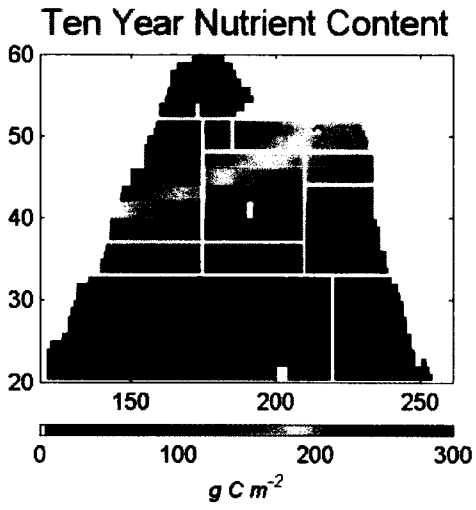
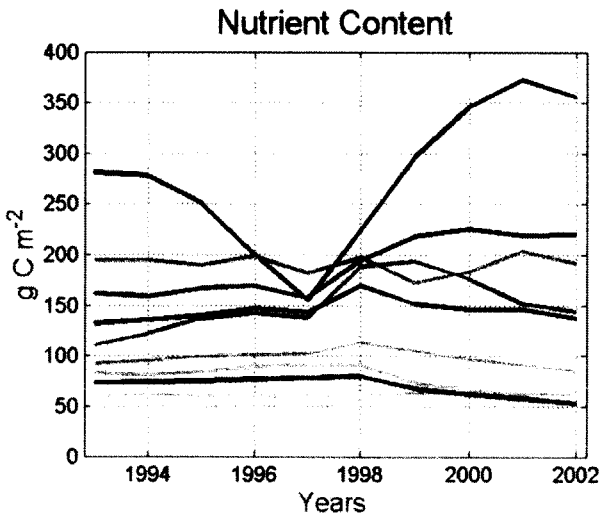
Regional Time Series of Content and Drawdown

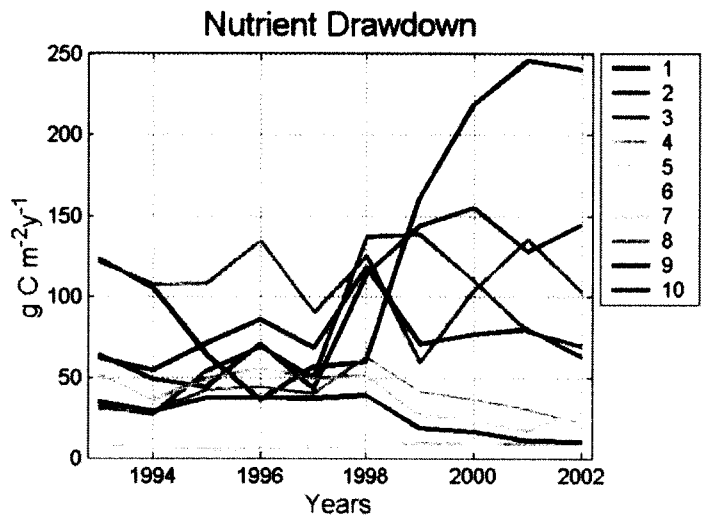


1. Two orders of magnitude variability (>100gCm^2 or gCm^{2}y^{-1})
2. Strong EN signal (1997, 1998)
3. Maximum signal and variability north of 45N

	> PRE-EN	> POST-EN	NO CHANGE
Content	7, 10	1, 2, 3	8, 9, 4, (5, 6)
Drawdown	7, 10	1, 2, 3	8, 9, 4, (6, 5)

4. Oddities: Region 8 (orange) very variable, pattern?
   Region 4 (cyan) no change or 'west Pacific'
   Region 5 (green, low drawdown) vs 6 (yellow).





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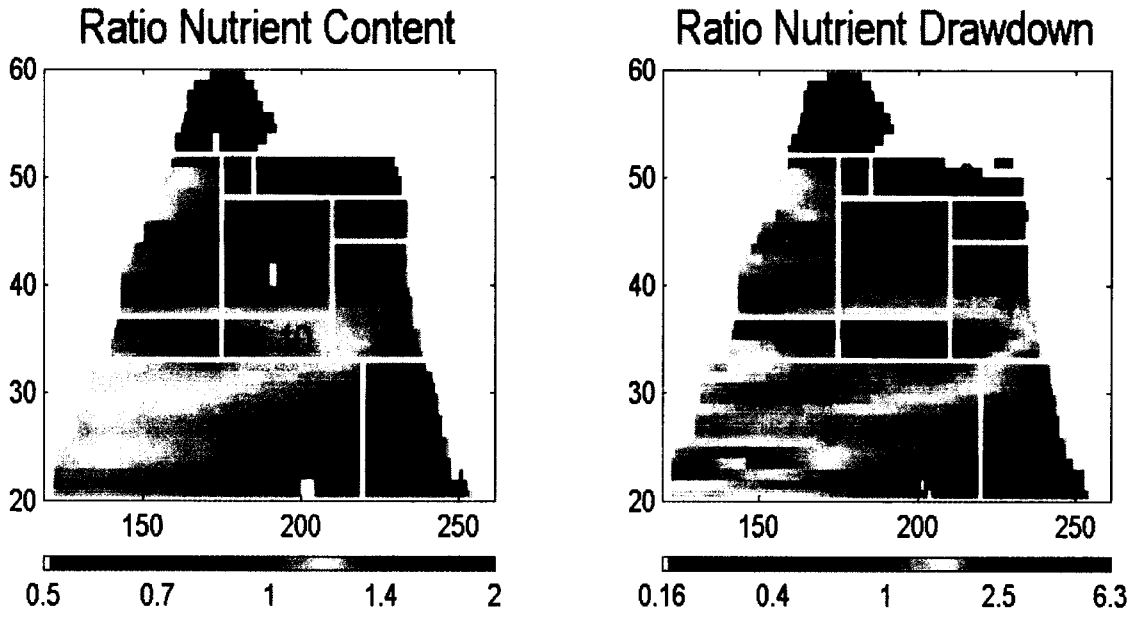
Biogeochemical variability

1. If we simply divide the nutrient content (or drawdown) for 1993-1996 by that of 1999-2002, the observed pattern of variability is reinforced: new production was significantly depressed in the Regions 1, 2, 3, and 5 in 1993-1996 relative to after 1998, while it was enhanced in Regions 7, 10, and 6. *The log scale allows us to see change in regions of very low content/drawdown (5, 6, 10).*

2. Variability is greater in drawdown (peaking at a factor of six) than in content (only a factor of two).

3. Variability in content is more biased to the north, while that of drawdown is evenly distributed.



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Conclusions

Some possible caveats...

1. The temporal patterns of biological uptake and nutrient availability reflect the variability observed by the altimeter.
2. Because of our approach (the digital filter and the altimeter itself) we underestimate nearshore values and variability.
3. Our method ignores interannual variability in biogeochemical inter-relationships.

That said...

1. Our results show a strong response of the entire North Pacific Basin to the 1997-1998 period, during which, perhaps unexpectedly, the extent of the northern HNLC region expanded.
2. There is also a significant change in nutrient content and drawdown between the 1993-1996 period and that between 1999 and 2002, in which availability and drawdown increased significantly in the Bering Sea, Gulf of Alaska, and the Northern and Southern California Currents.
3. These results should be verified by comparison with measurements of the phytoplankton community and rate processes.