

The Ocean's least productive waters are expanding

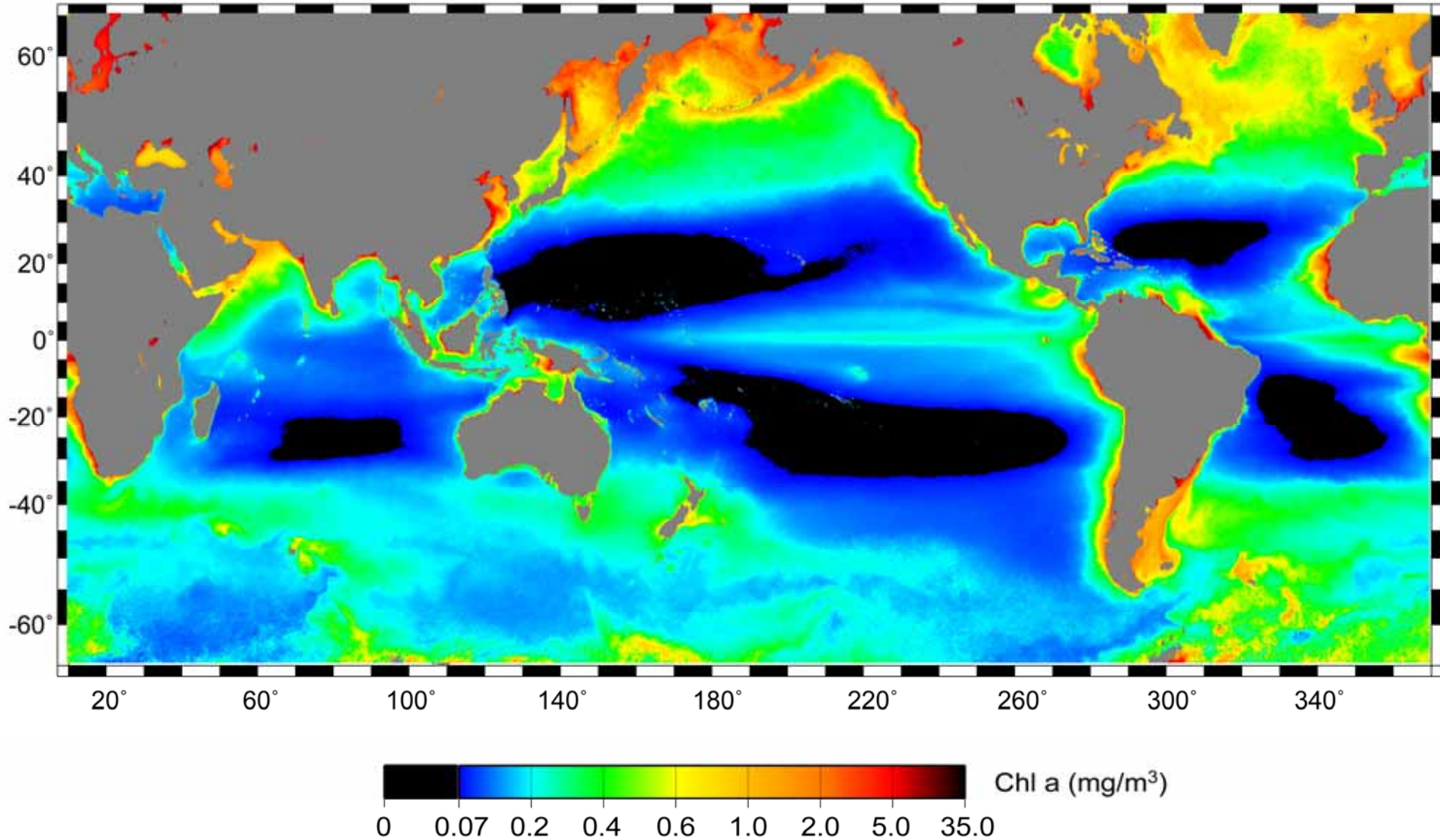
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Pacific Islands Fisheries Science Center
NOAA Fisheries

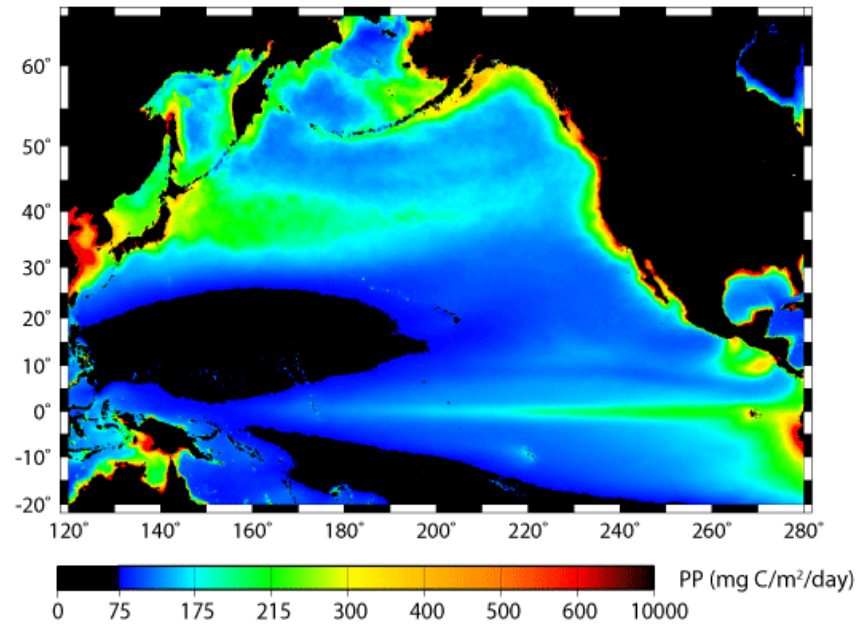
SeaWiFS Data

- Decade-long global surface Chl-a data set (9/97 to present)
- Many reprocessing to incorporate recalibrations, algorithm improvements, etc – thanks to NASA team and collaborators
- This work based on latest reprocessing July 2007, Version 5.2 to correct sensor drift and slight sensor degradation

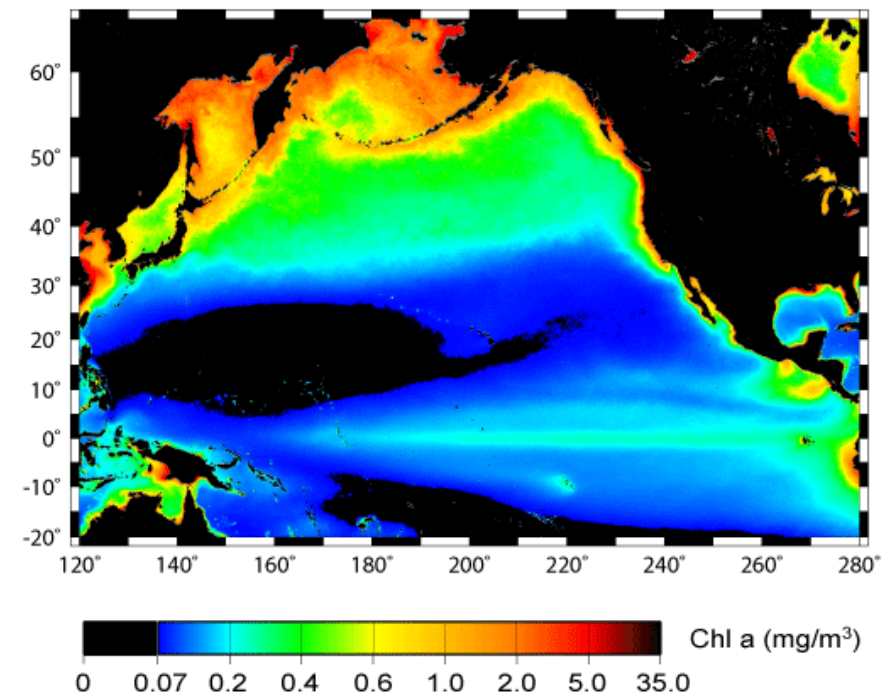
SeawiFS surface chlorophyll climatology with oligotrophic gyres in black



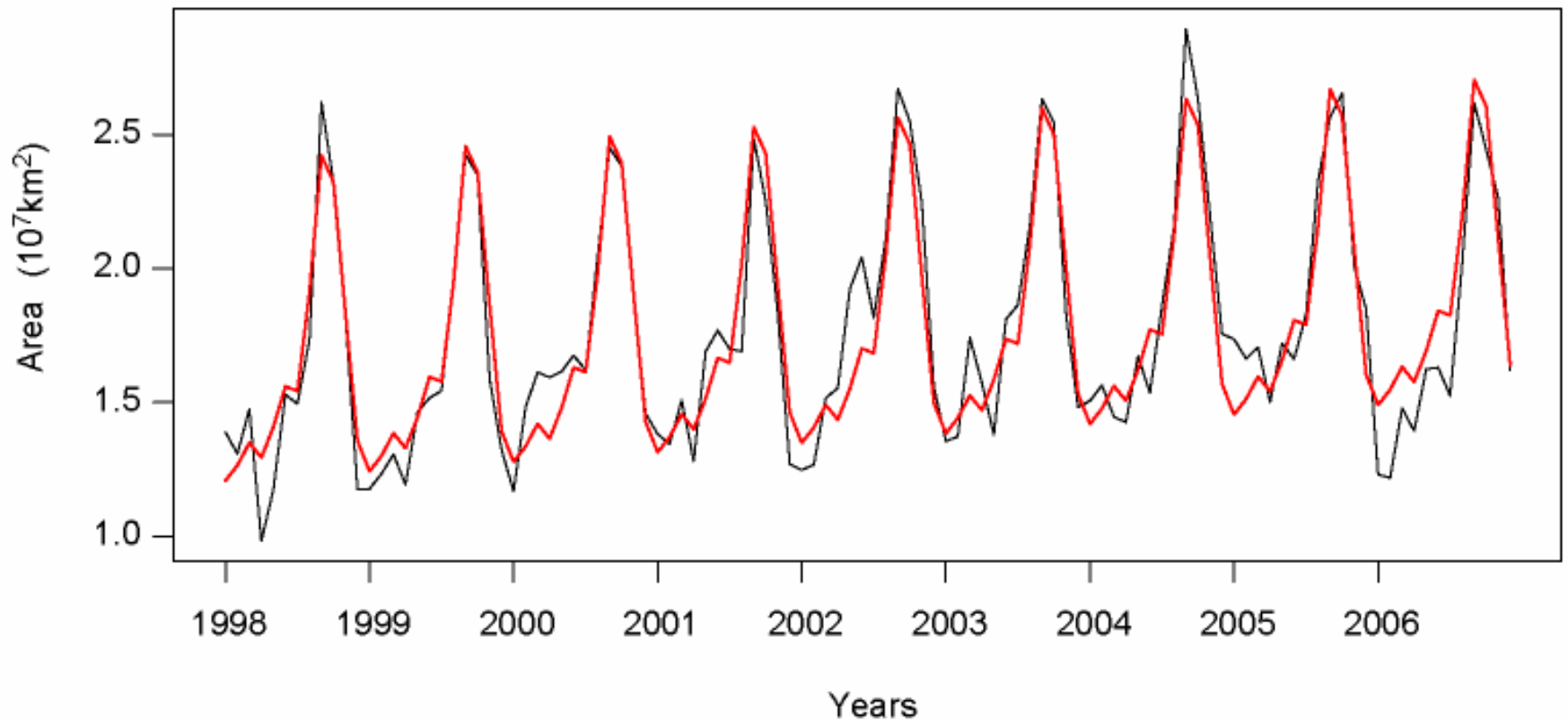
Annual mean depth integrated net primary productivity (data from Behrenfeld 2007)



Annual mean surface chlorophyll from SeaWiFS

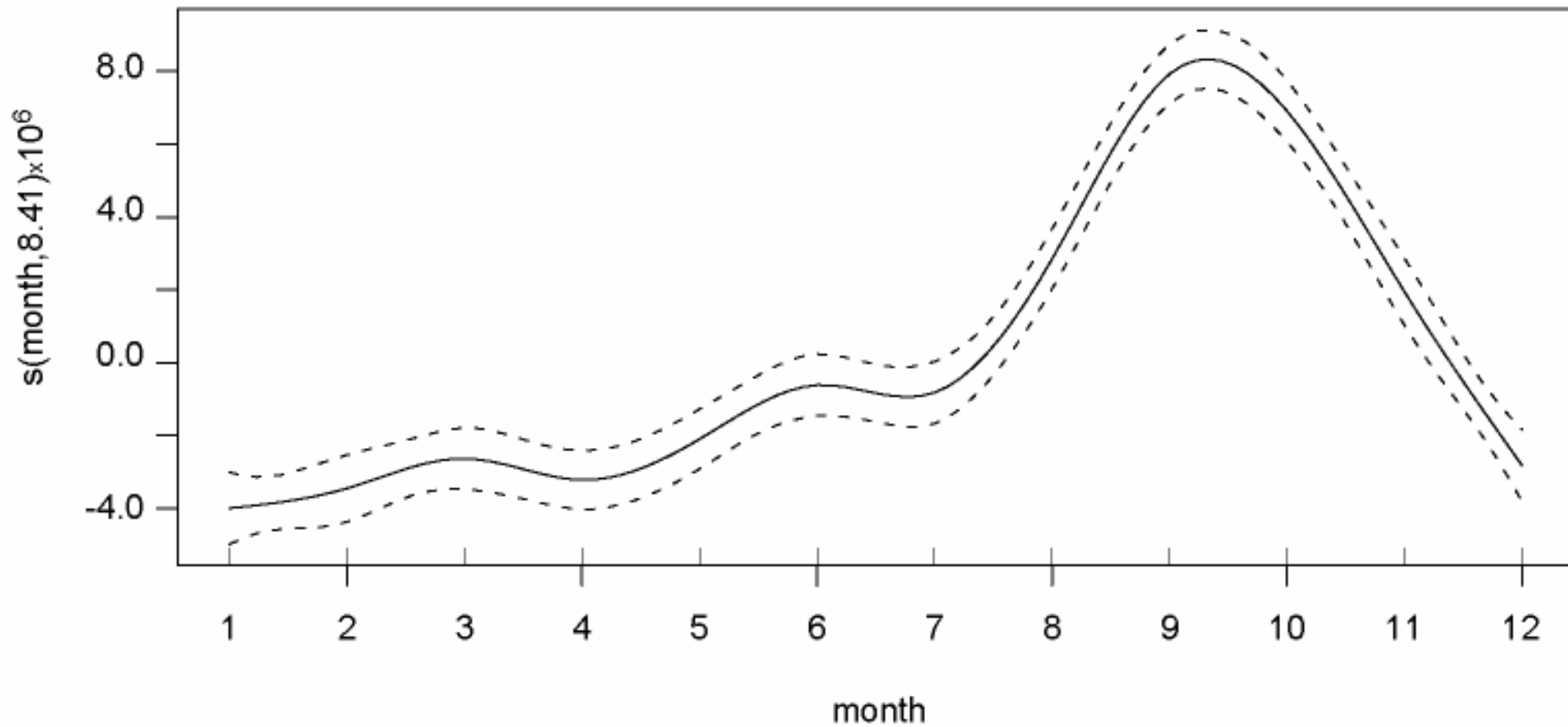


N Pacific Monthly Area with surface chlorophyll ≤ 0.07 mg Chl/m³ 1998-2006 with GAM fit (red)

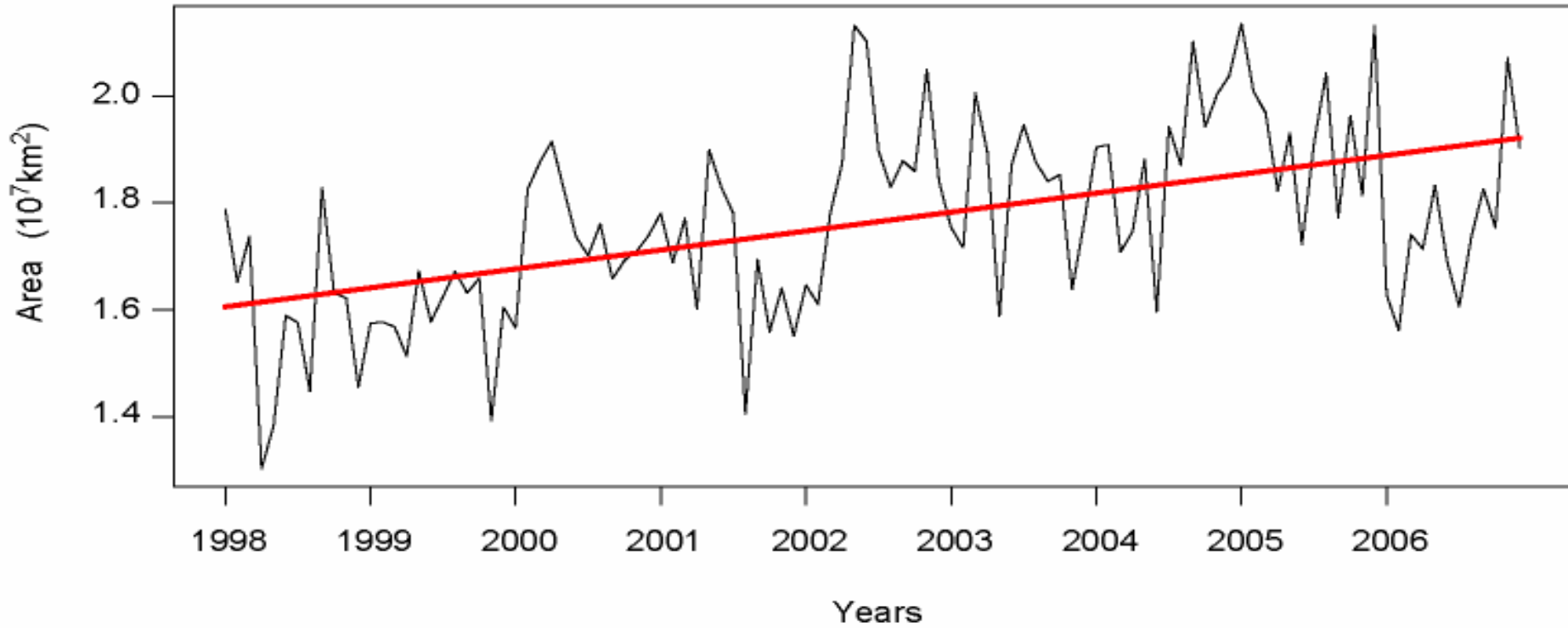


GAM: Monthly Area = $A + B \cdot \text{time} + S(\text{Month}) + \text{error}$

N Pacific Area GAM seasonal term

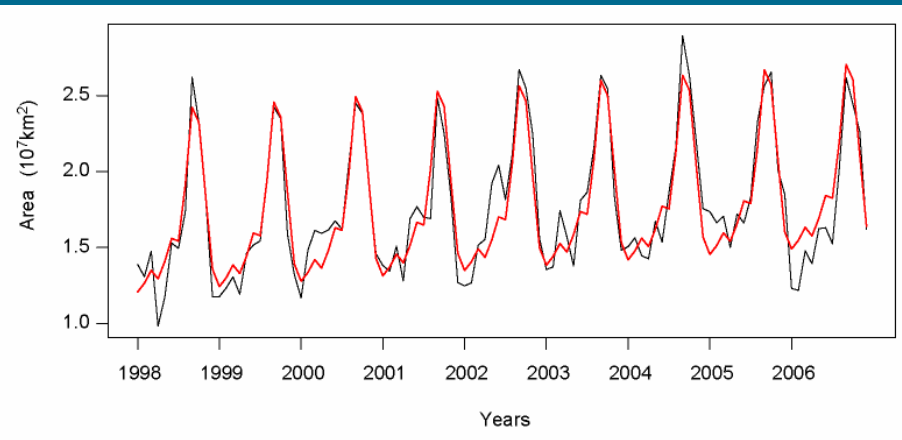


N Pacific Area with seasonal GAM component removed, data and GAM linear term (red)

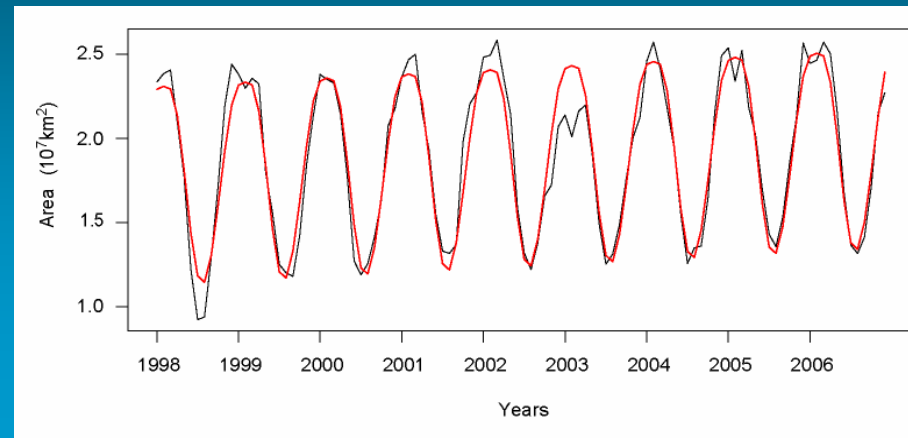


Fit of GAM (linear plus seasonal) (red) to monthly oligotrophic gyre areas, 1998-2006.

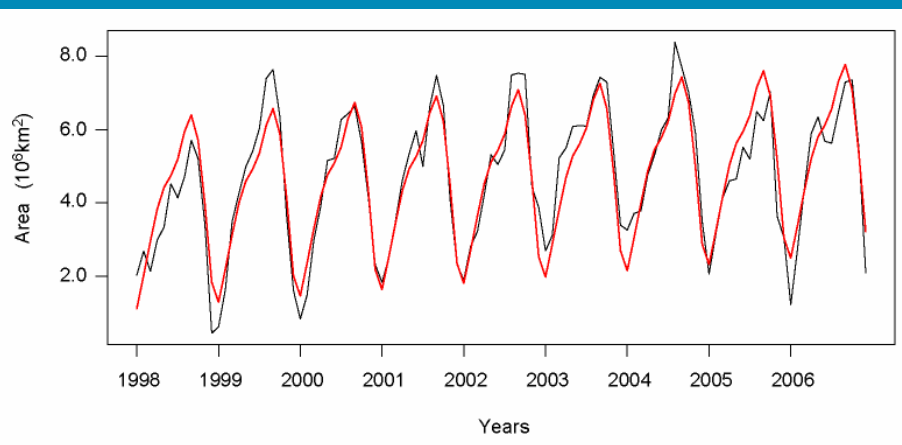
N Pacific



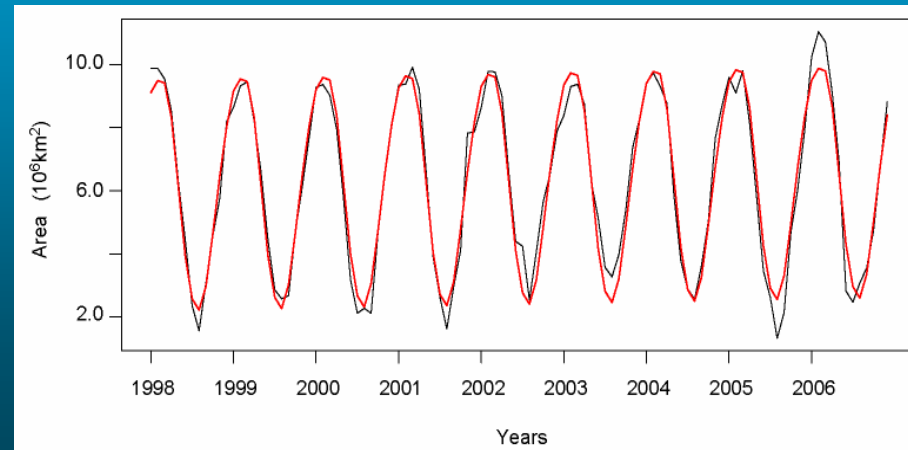
S Pacific



N Atlantic

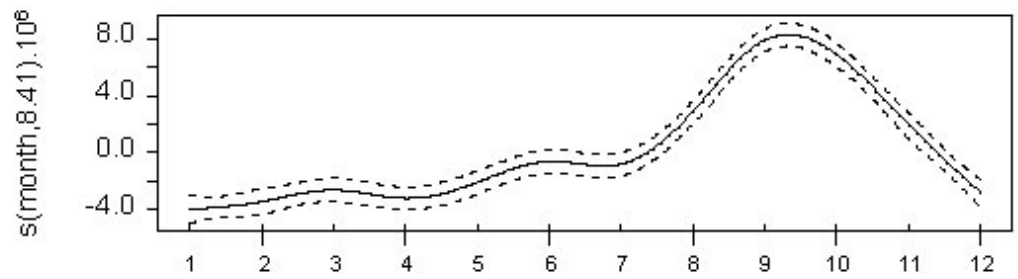


S Atlantic

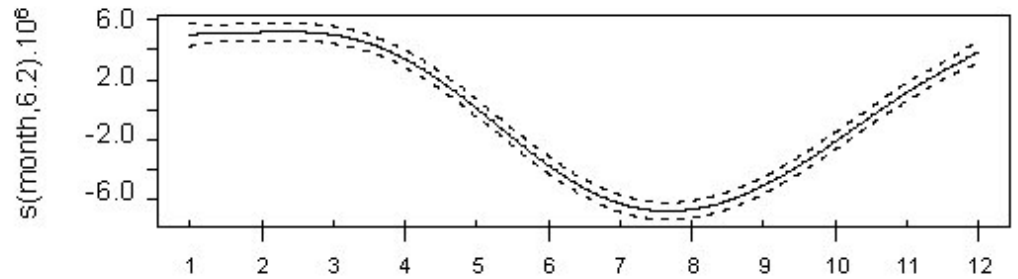


Seasonal term

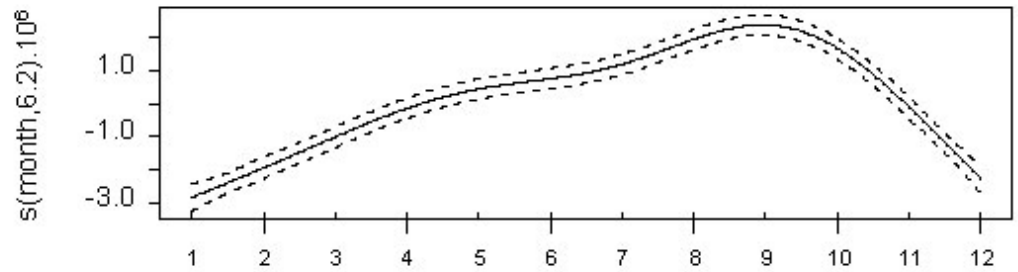
N Pacific



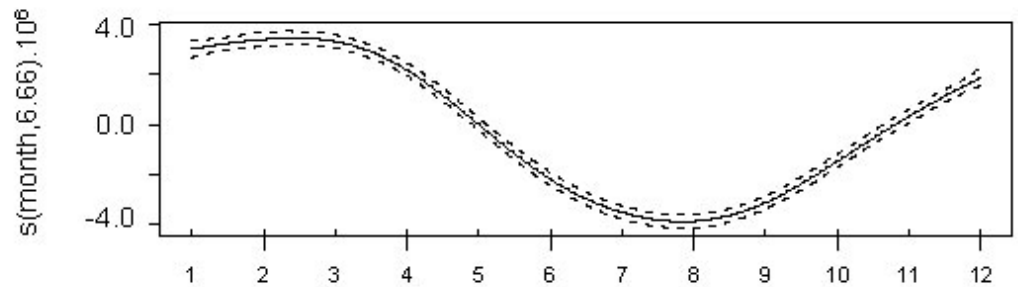
S Pacific



N Atlantic



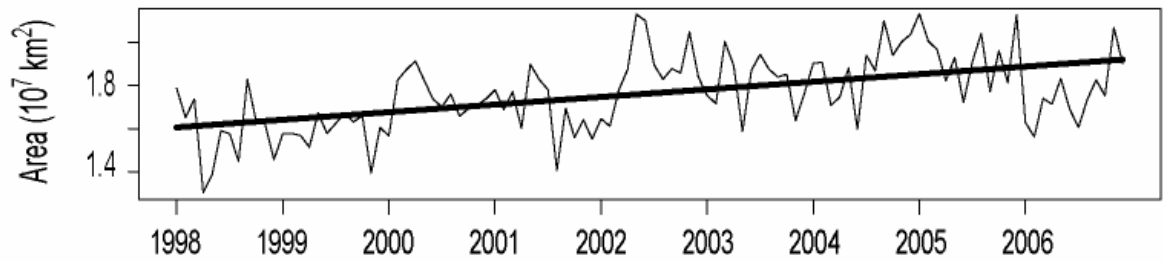
S Atlantic



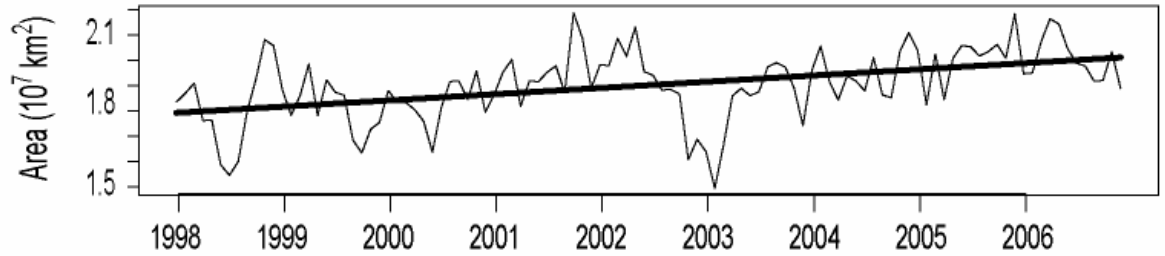
Month

Linear term

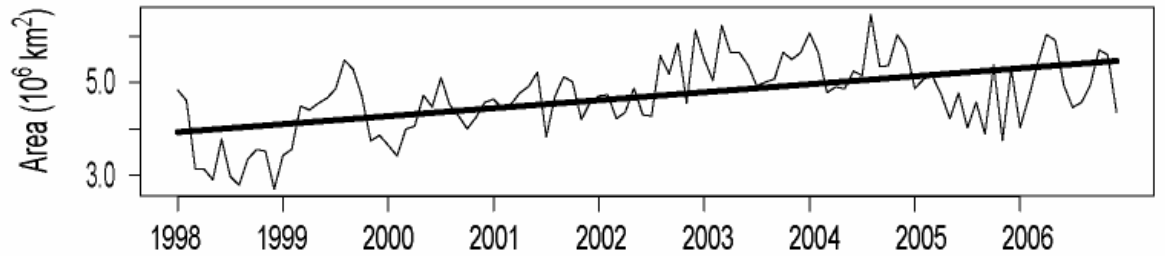
N Pacific



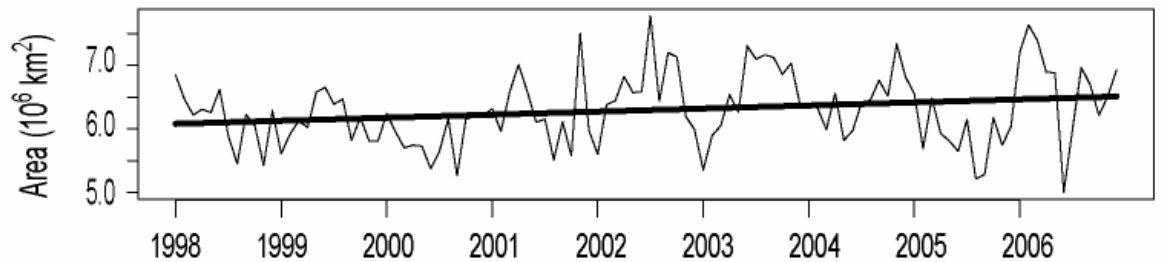
S Pacific



N Atlantic



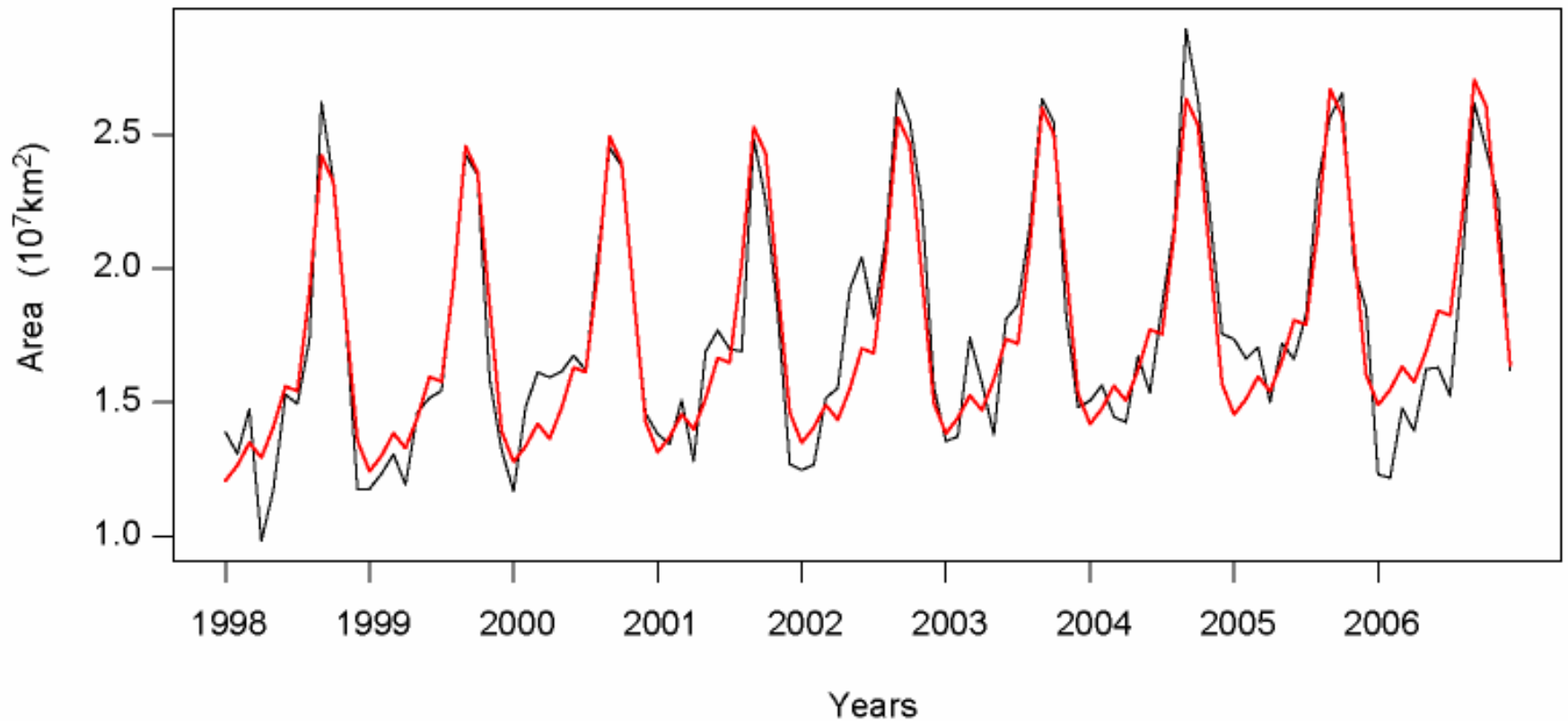
S Atlantic



Trend in oligotrophic gyres based on GAM linear term

Ocean	1998 mean area (km ²)	Increase in area (km ² /yr) (%/yr)	p-value
North Pacific	16,222,653	353,519 (2.18)	2.5e-08
South Pacific	18,041,685	245,766 (1.36)	1.5e-06
North Atlantic	4,010,147	172,455 (4.3)	1.4e-09
South Atlantic	6,100,571	48,075 (0.79)	0.026
Total	44,375,056	807,024 (1.85)	-

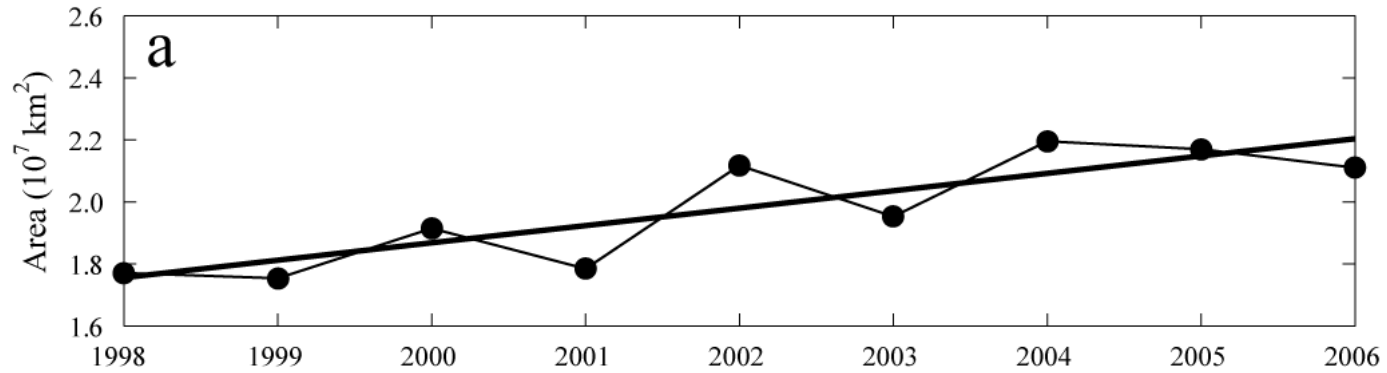
N Pacific Monthly Area with surface chlorophyll ≤ 0.07 mg Chl/m³ 1998-2006 with GAM fit (red)



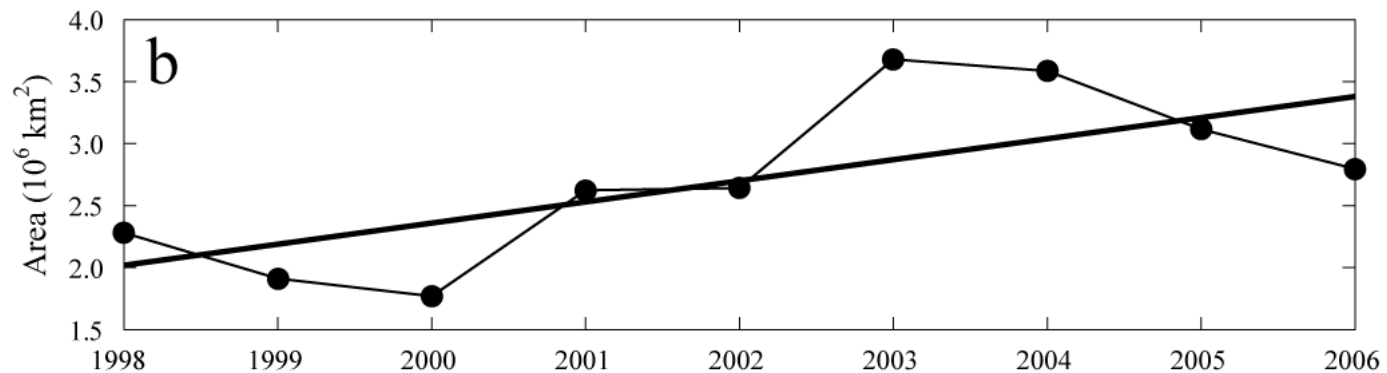
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Change in mean quarterly oligotrophic gyre area

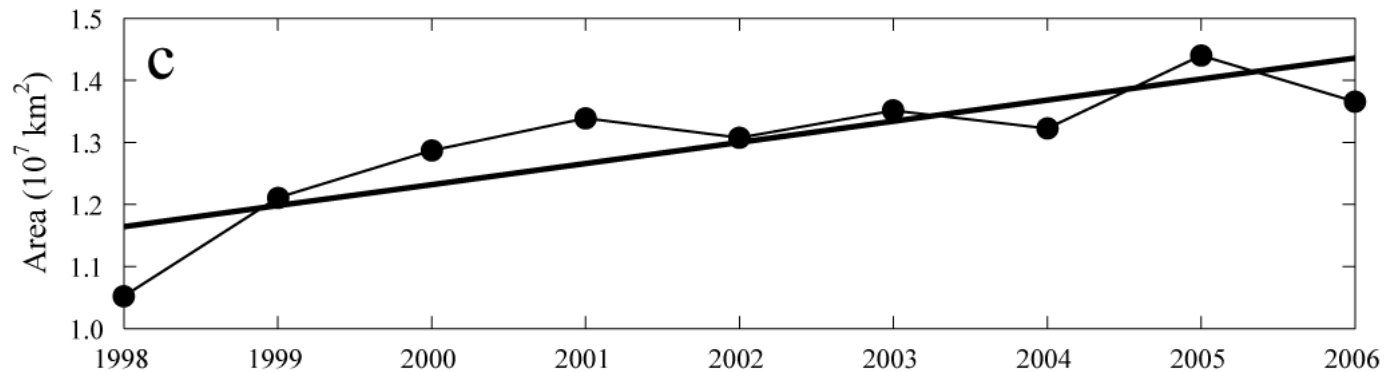
Top: North Pacific, quarter 4



Middle: North Atlantic, quarter 1



Bottom: South Pacific, quarter 3

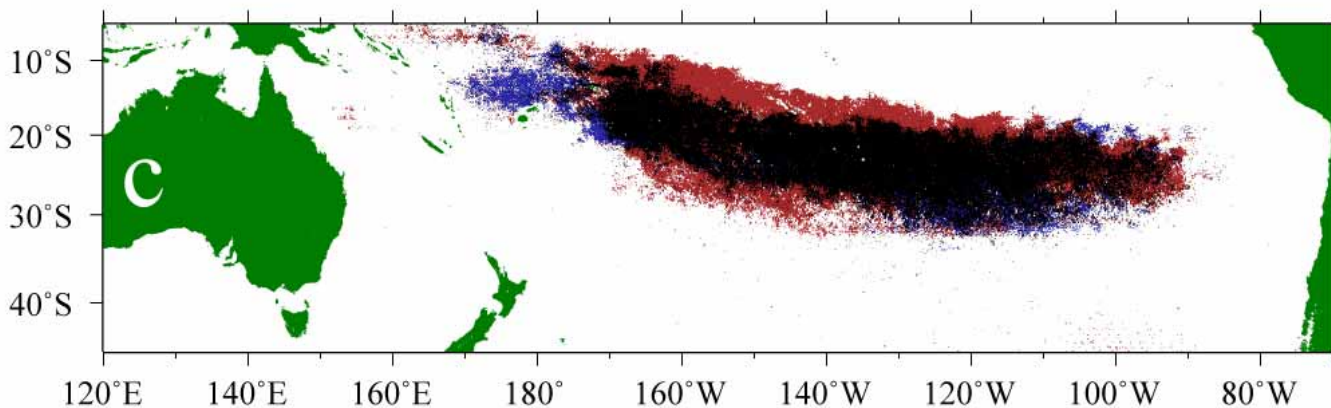
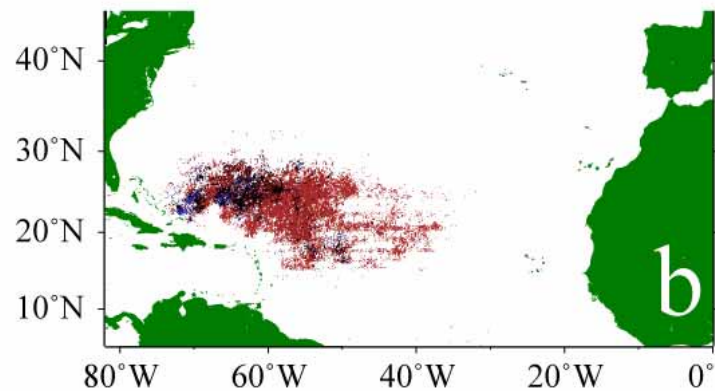
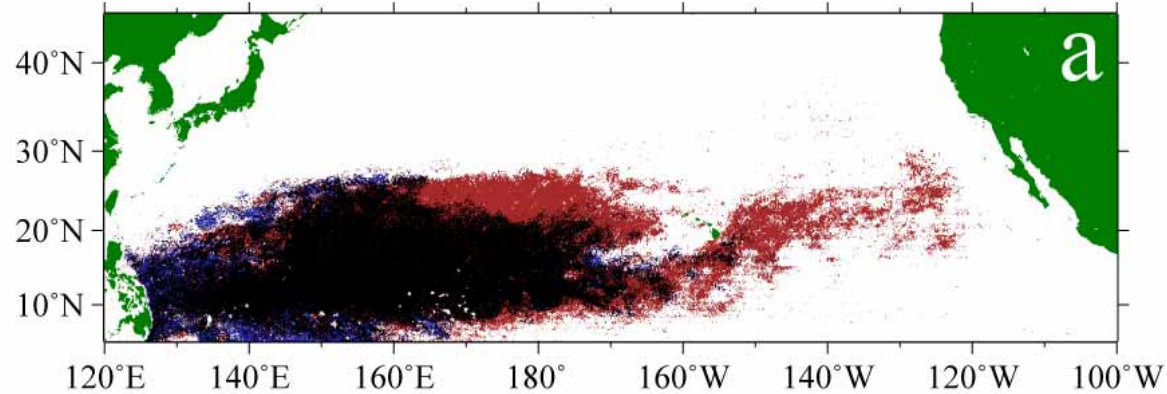


Linear regression of quarterly mean oligotrophic gyre area vs time

Ocean	Quarter with largest rate of increase	Increase in area (km ² /yr) (%/yr)	p-value
North Pacific	4	555,875 (3.17)	0.005
North Atlantic	1	172,609 (8.54)	0.040
South Pacific	3	337,352 (2.90)	0.004
Total	-	1,065,836 (3.42)	-

Changes in oligotrophic areas between
1998-1999 and
2005-2006 in
December:

- a) North Pacific,
 - b) North Atlantic,
- and August:
- a) South Pacific



1998/1999 Only

1998/1999 and 2005/2006

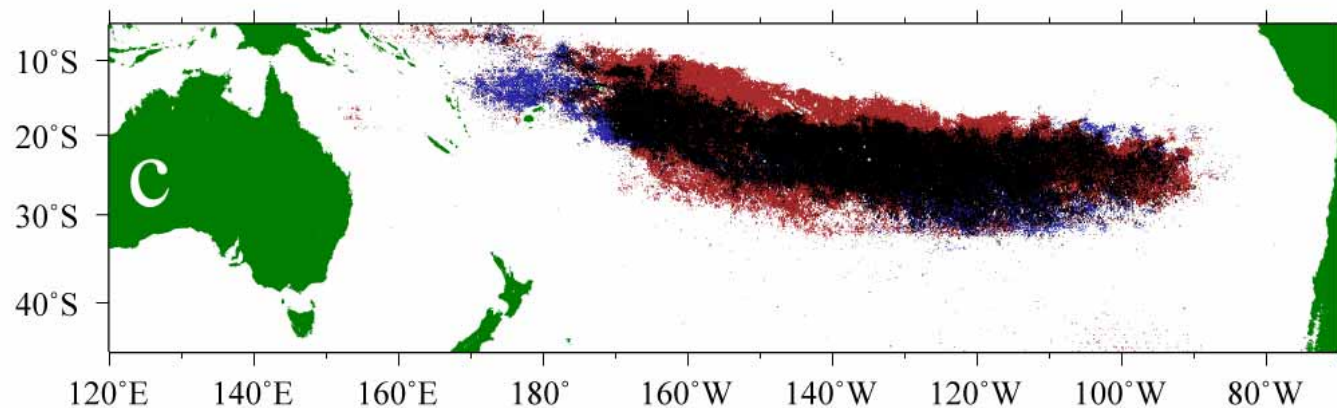
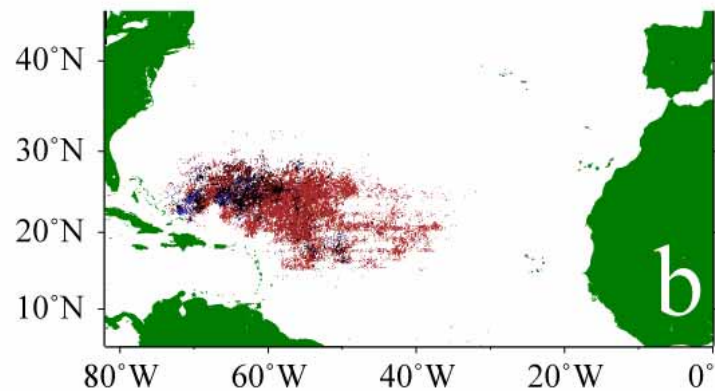
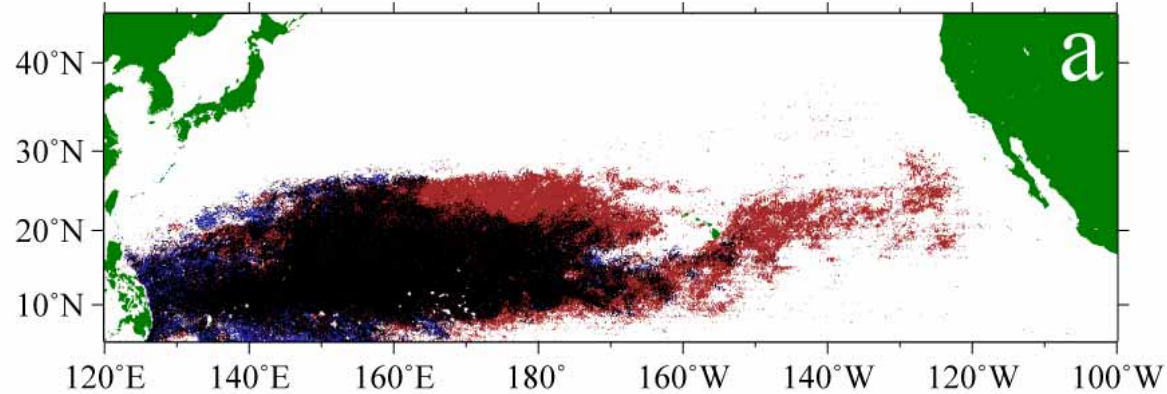
2005/2006 Only

Summary

- Oligotrophic gyres in N Pacific, S Pacific, N Atlantic, S Atlantic show a statistically significant annual increase in area 0.79-4.40 %/yr
- Global oceans have added 6.6 million km² of oligotrophic habitat since 1998
- Oligotrophic gyres expanding faster in winter (2.5-7.0%/yr) or more than 1 million km²/yr
- A statistical significant increase in SST in the oligotrophic gyres as well suggesting increased vertical stratification.

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1998/1999 Only

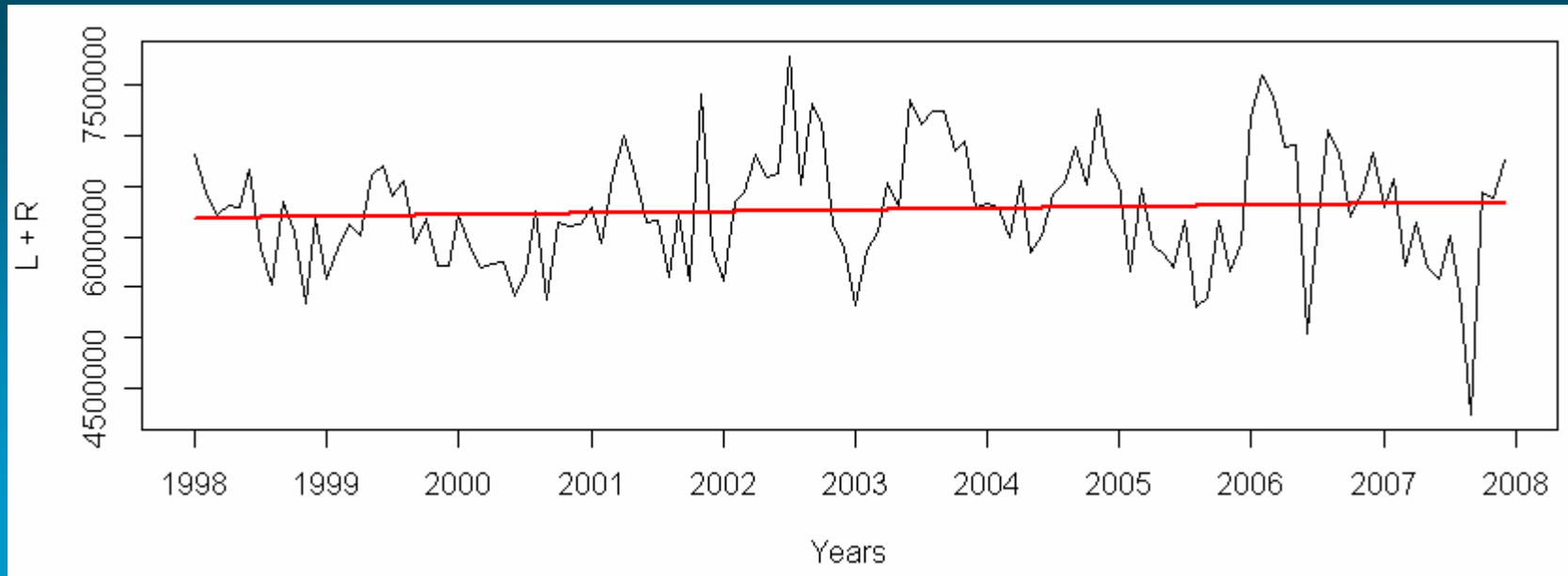
1998/1999 and 2005/2006

2005/2006 Only

Rate of increase in each Oligotrophic area 1998-2006 and 1998-2007

Ocean	Percent per year 1998-2006	Percent per year 1998-2007
North Pacific	2.2	2.2
South Pacific	1.4	1.3
North Atlantic	4.3	4.1
South Atlantic	0.8	0.3 (ns)
South Indian	1.3 (ns)	1.8

South Atlantic 1998-2007



South Indian 1998-2007

