





**The big Earth System questions are:
How is the Earth changing and what are the
consequences for life on Earth?**



Yes!!!

Atmospheric concentrations of CO₂ continue to rise inexorably

Global temperatures continue to rise

Land and Ocean are increasingly sources of CO₂ to atmosphere

Arctic ice may disappear in summer

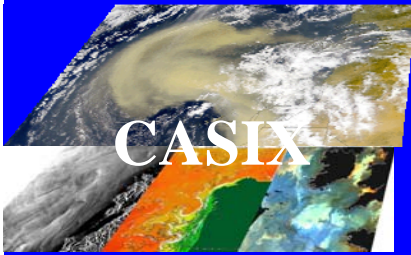
Antarctic ice shelf is fragmenting

Increasing desertification?

Increasing tropical storms?

Consequences – more of the same





For the Marine Environment, surface ocean-lower atmosphere, the questions are:



- How do marine systems vary with time? (e.g. changes of THC, etc?)
- How are marine ecosystems regulated by ocean processes? (physics, structure)
- How do marine ecosystems interact with the global carbon cycle? (CO₂ flux)

Global Carbon cycle and the climate system are intimately linked with the ocean C-cycle through the air-sea exchange of CO₂

The area of the tropical & sub-tropical gyres is increasing (greater stratification); gyres are important ~ 63% ocean area. Result - More picoplankton.

Changes of CO₂ sink or source?

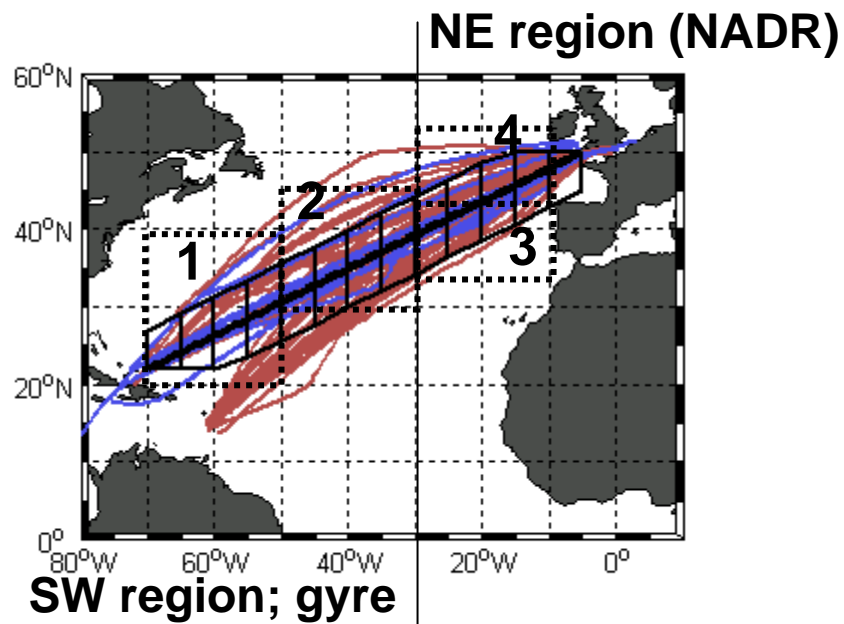
Reduced winter mixing at mid to high latitudes (due to greater stratification) - Less nutrient replenishment.

Earlier stratification and earlier spring bloom

Shorter spring bloom – less diatoms – less CO₂ fixed?

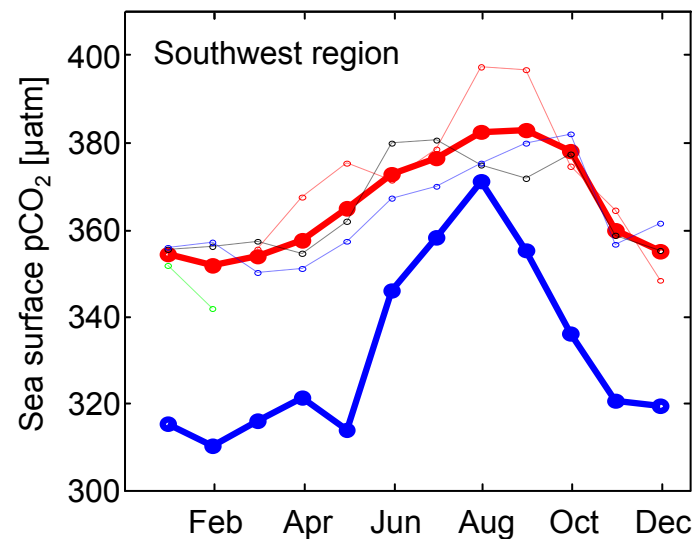
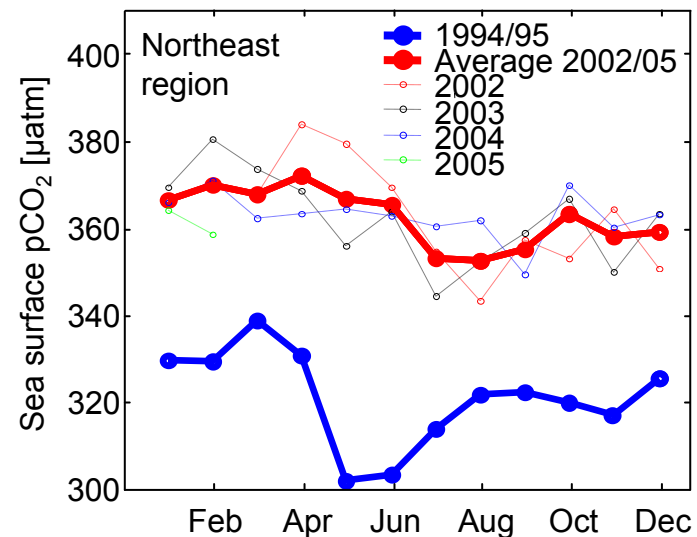


Shuster & Watson paper: NE region, 10 – 30 W, > 35N

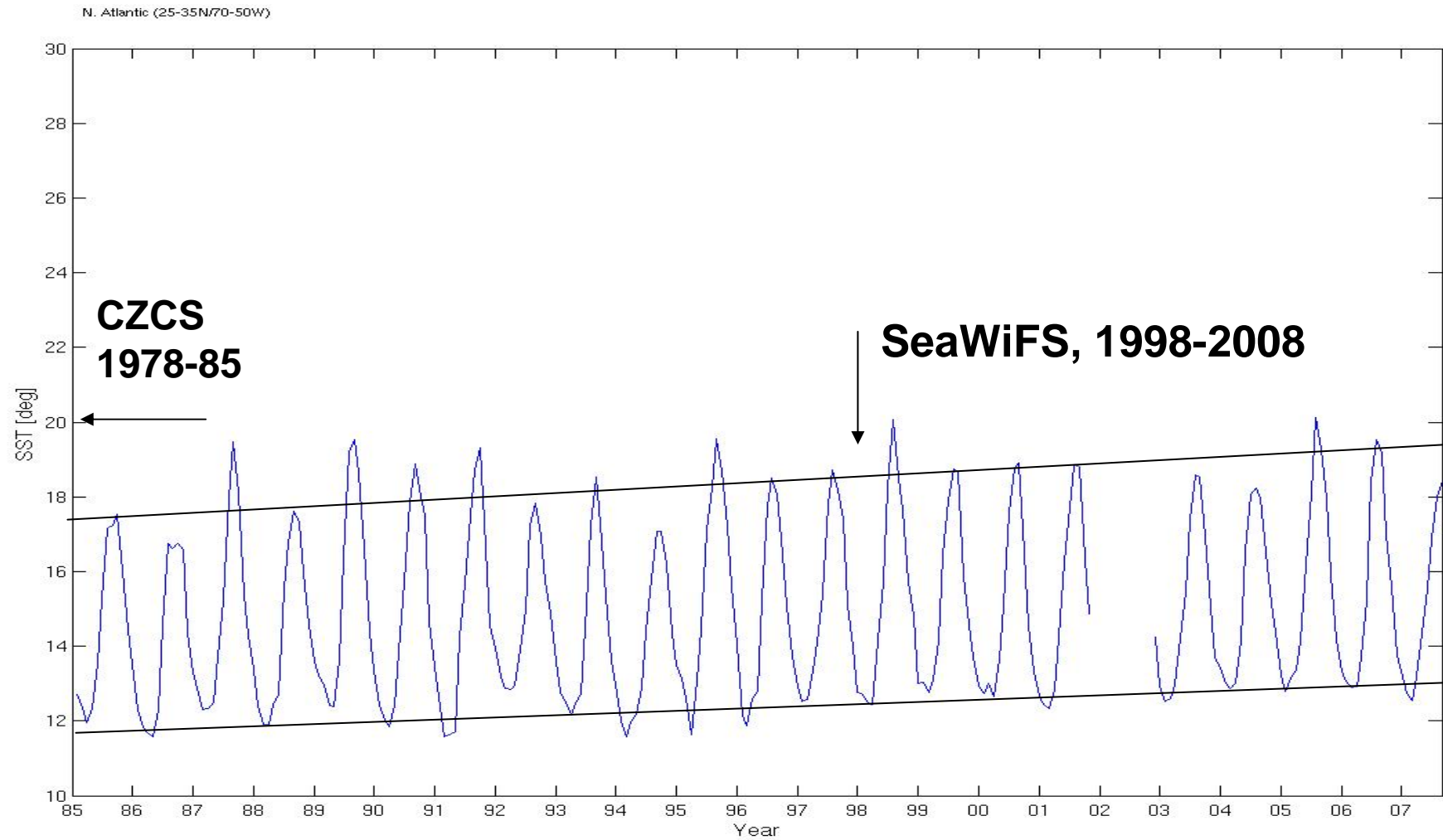


Surface pCO₂ >2002-05 than 1994/95 mean.

Significant seasonal changes in NW region different

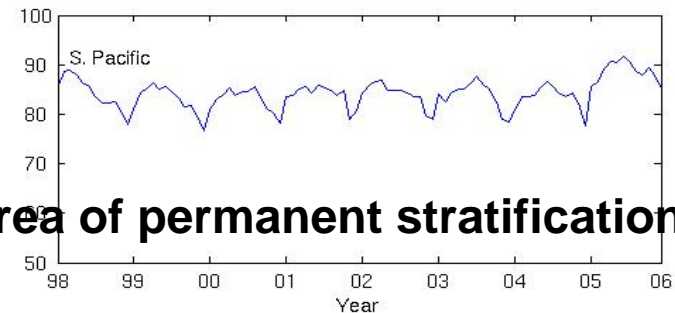
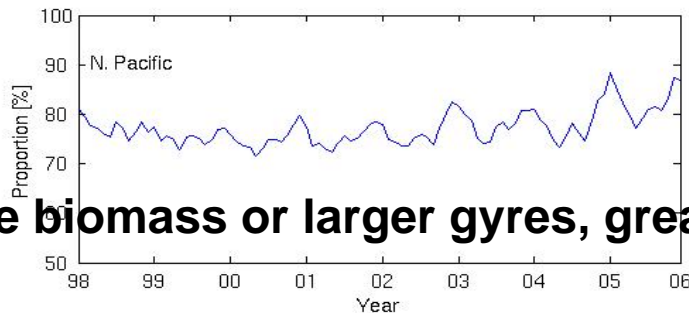
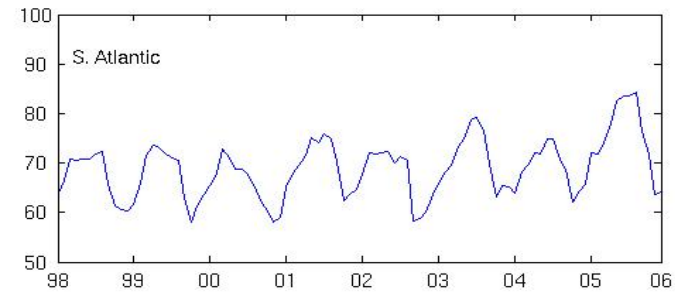
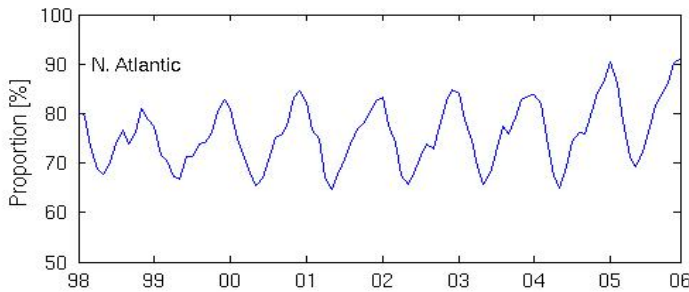
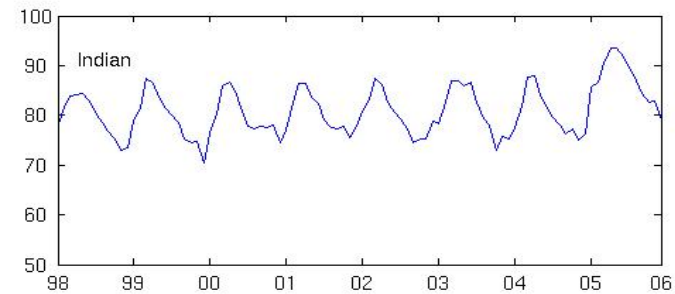
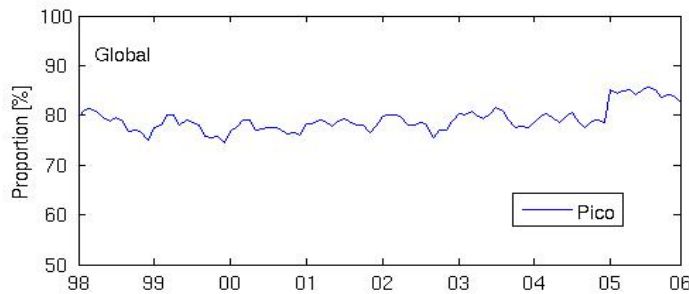


SST, NE Atlantic (Box 4), 23 year trend, 1985 - 2008



How are global marine ecosystems changing?

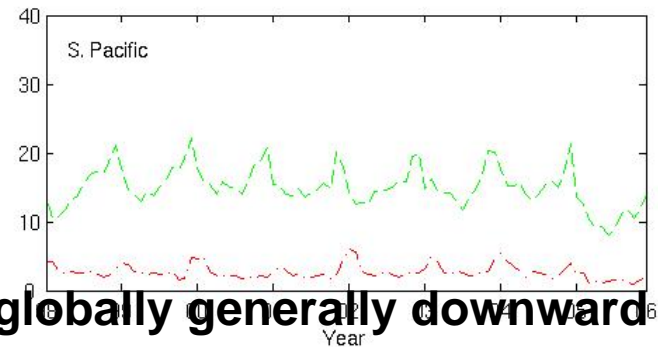
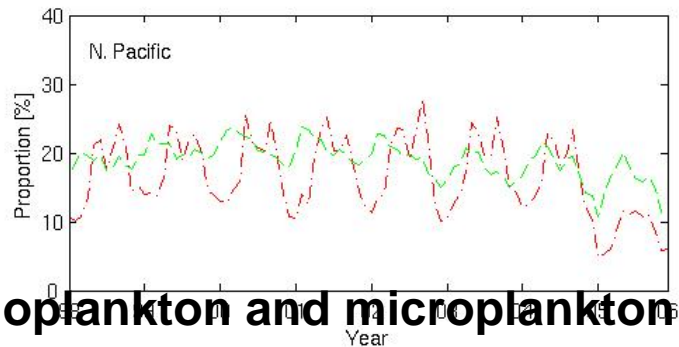
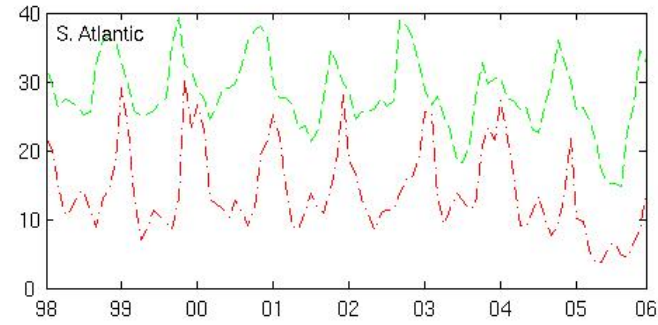
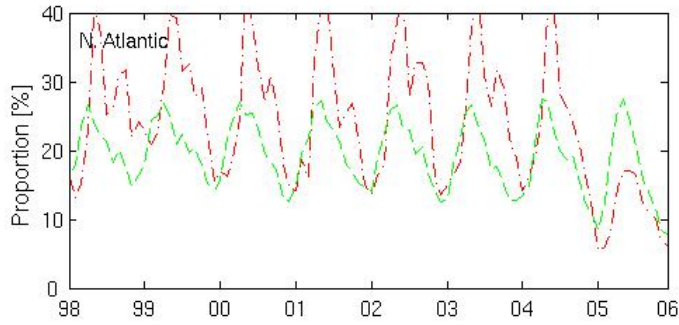
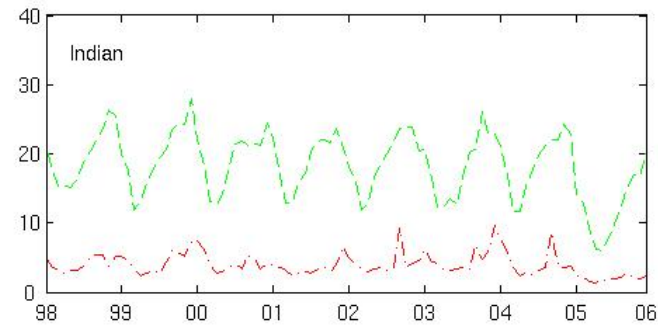
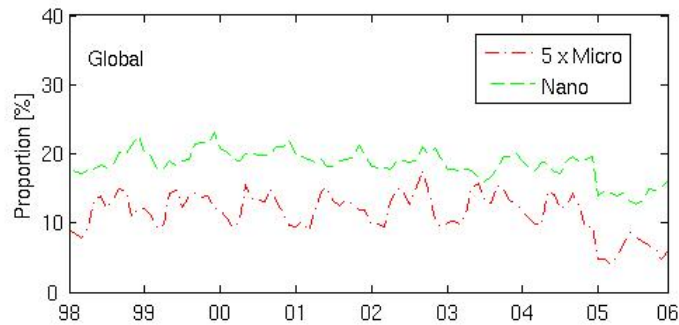
Analysis of PSCs (pico, nano, micro) by Hirata et al; RSE 2008
SeaWiFS 8-year time series, 1998-2006 for 6 ocean basins:
Pico plankton shows upward trend generally; NB N Atlantic.



More biomass or larger gyres, greater area of permanent stratification?

Global Trends – Ecosystem change?

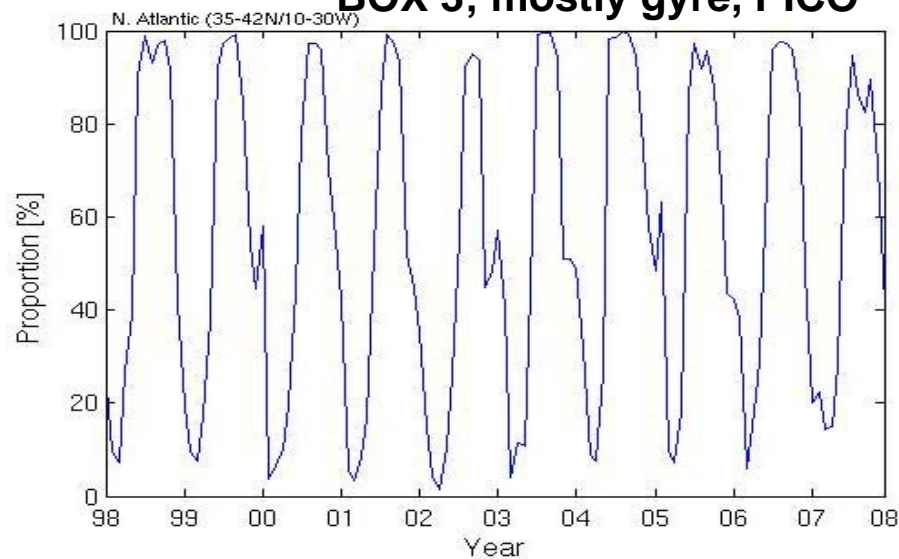
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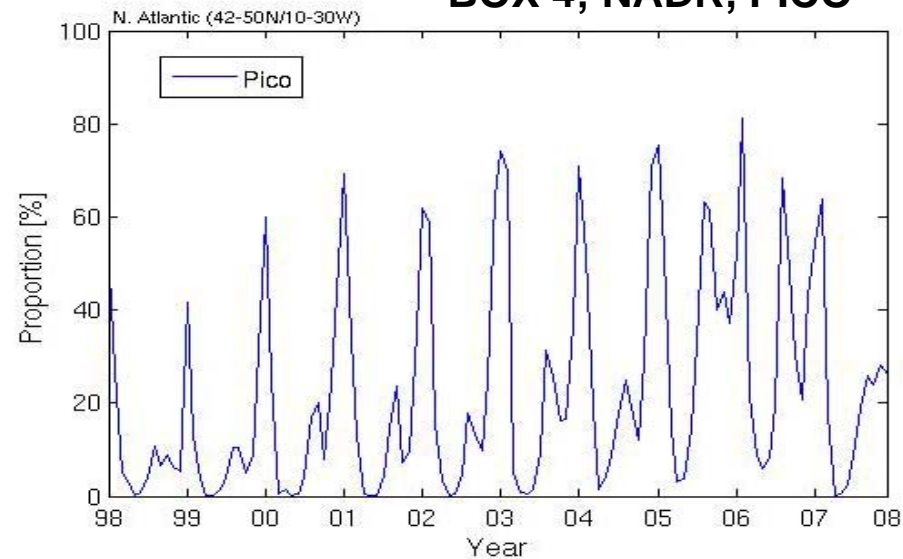
Nanoplankton and microplankton (x5); globally generally downward trend??
NB, N. Atlantic

Trends, NE Atlantic 10 years, 1998 – 2008; ref Watson et al pCO₂.

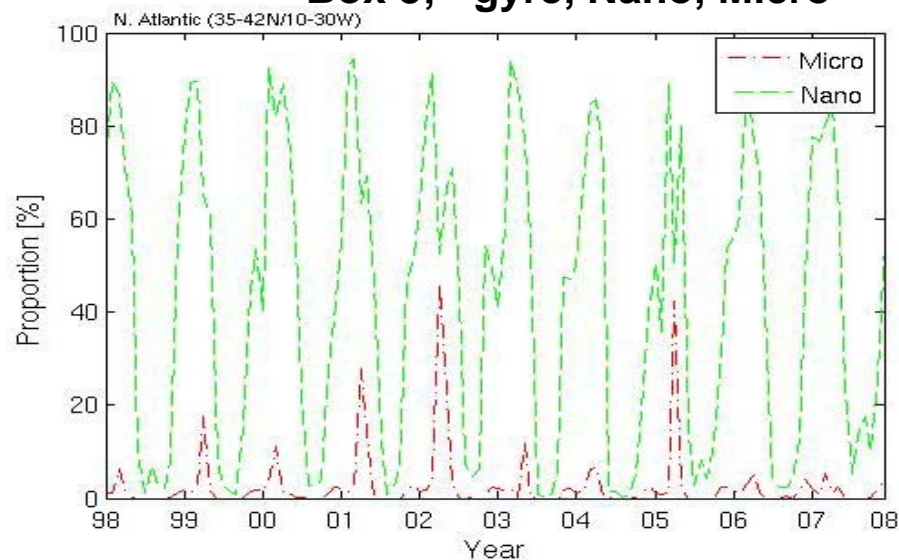
BOX 3; mostly gyre, PICO



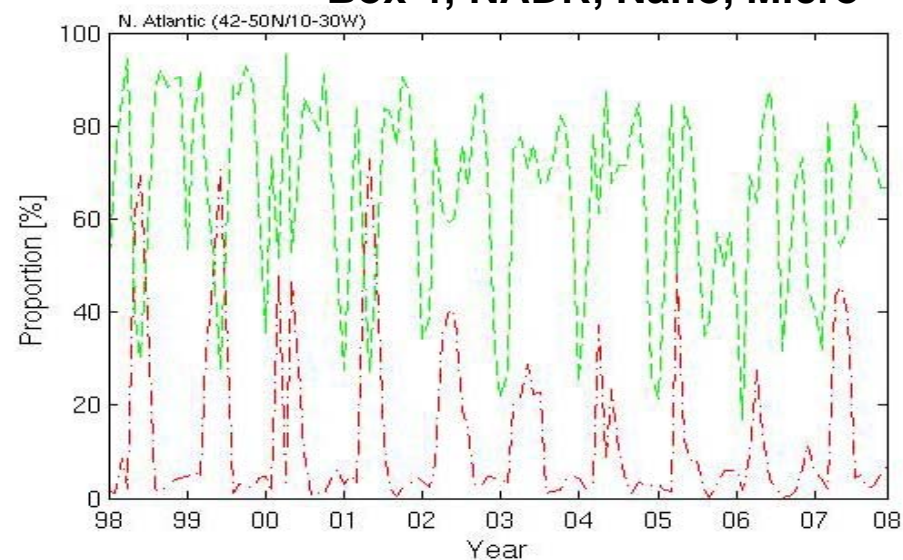
BOX 4; NADR, PICO



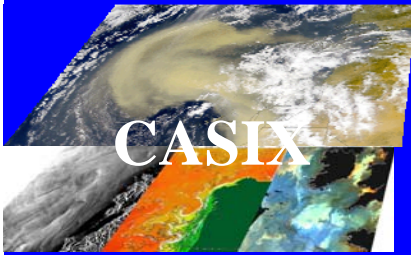
Box 3; ~gyre, Nano, Micro



Box 4; NADR, Nano, Micro



Box 4: patterns change, microplankton decline?



POLICY



To reduce atmospheric CO₂ we can do 2 things:

1. Burn less Carbon (fossil fuels):

Economise;

Nuclear power generation;

alternative power sources, solar, wind and waves;

**[alternative power sources are episodic
and transmission is inefficient]**

2. Capture CO₂ from atmosphere and store.

Be smart:

**Use alternative sources to capture and store CO₂
when energy sources are available.**

Make H₂ – exploit H₂ cycle technology;

Exploit efficient Stirling cycle technology.





POLICY



Are marine ecosystems changing? – YES!

We need to monitor and model change in marine ecosystems – implications are still largely unknown.

Essential we monitor CO₂ in atmosphere and oceans and air-sea fluxes of CO₂

We can understand change in marine systems from:

1. Observations – observatories, WCO, AMT, time series, seasonal measurements of CO₂ and ecosystem variables.

2. Remote sensing observations of pCO₂ from space & biology – interpretations of Phytoplankton Community Structure.

3. Modelling: coupled circulation-ecosystem models with realistic ecosystems, having representative PFTs and PCS.



