Rivers as connectors and integrators of the Land Ocean Continuum

Moyo Ogundipe, Mami Wata, 1999 Acrylic on canvas

Acknowledgments

- Douglas Capone USC
- Edward Carpenter SFSU
- Rachel Foster UCSC
- Claire Mahaffey University of Liverpool
- Joseph Montoya Georgia Tech
- Maren Voss, Joachim Dippner IOW

What’s in a name?

Iteru - Great River
Indus - River (so Indians are river people?)
Ganges - Stream
Mississippi - Big River
Yangtze - Big or Long River
Euphrates - Sweet Water
(and Mesopotamia - Land between Rivers)
Amazon - from stories of women warriors, original name Maranon after a local fruit)

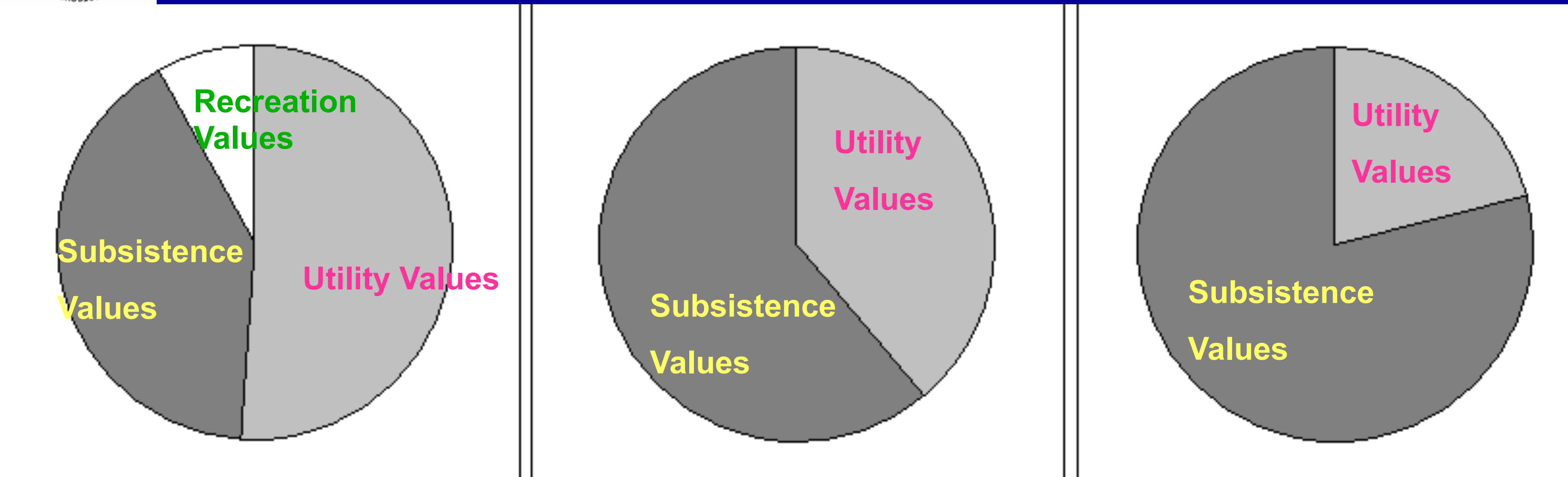
Nile - a greek corruption of nwy meaning water
Original name itwr

Hapi
"The running one"
Predynastic 5500-3100 BC
Son of Horus
Male and female
God of fertility (basket of food)

Ganga symbolizes purity and fertility. Hindu belief holds that bathing in the river on specific occasions absolves you of your sins and helps you attain salvation

Ganga riding on Makara - a vehicle that was half alligator half fish
Beginning of Earth Systems?

Societal Perception of Water Use



Youngest Gen 18-39

Middle Generation 40-59

Elders 60<

Subsistence Uses: drinking, animal and plant habitat, transportation to hunting and fishing, spiritual connection –

"We have always been a salmon people, The salmon come up the river because we are their people and we are grateful for them.

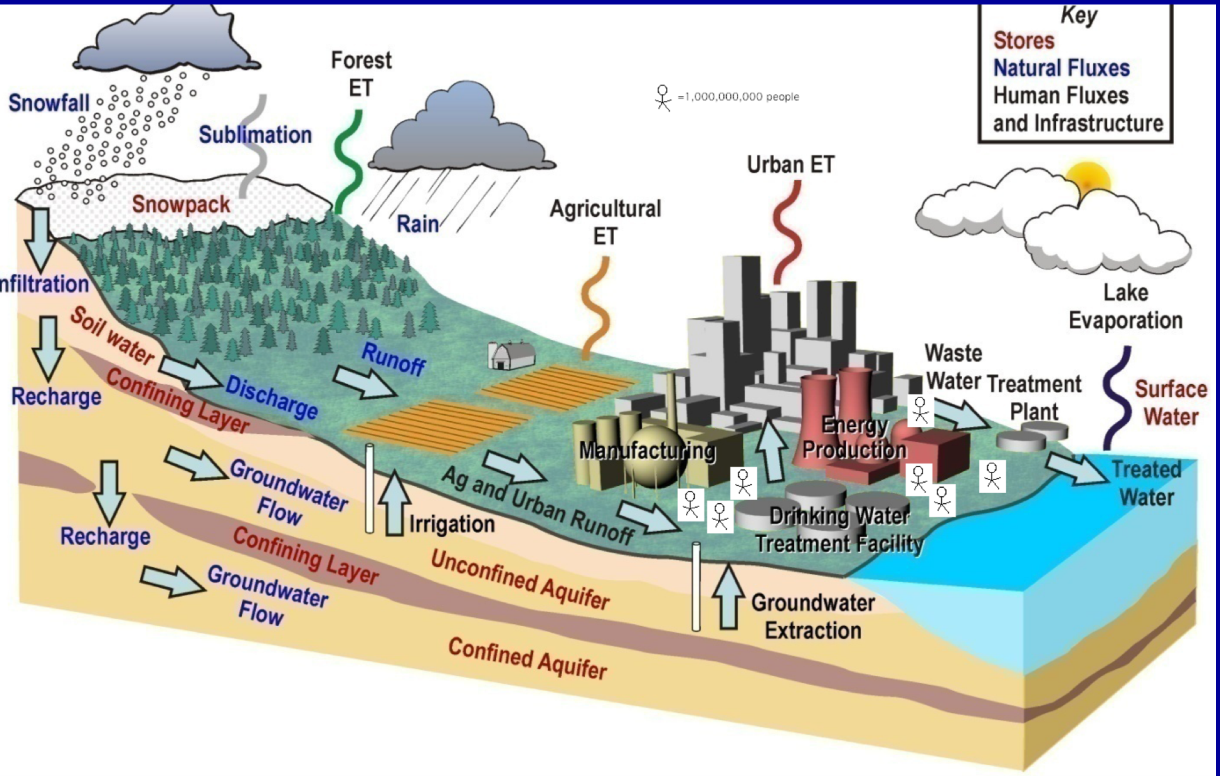
They feed us and we take care of the river."

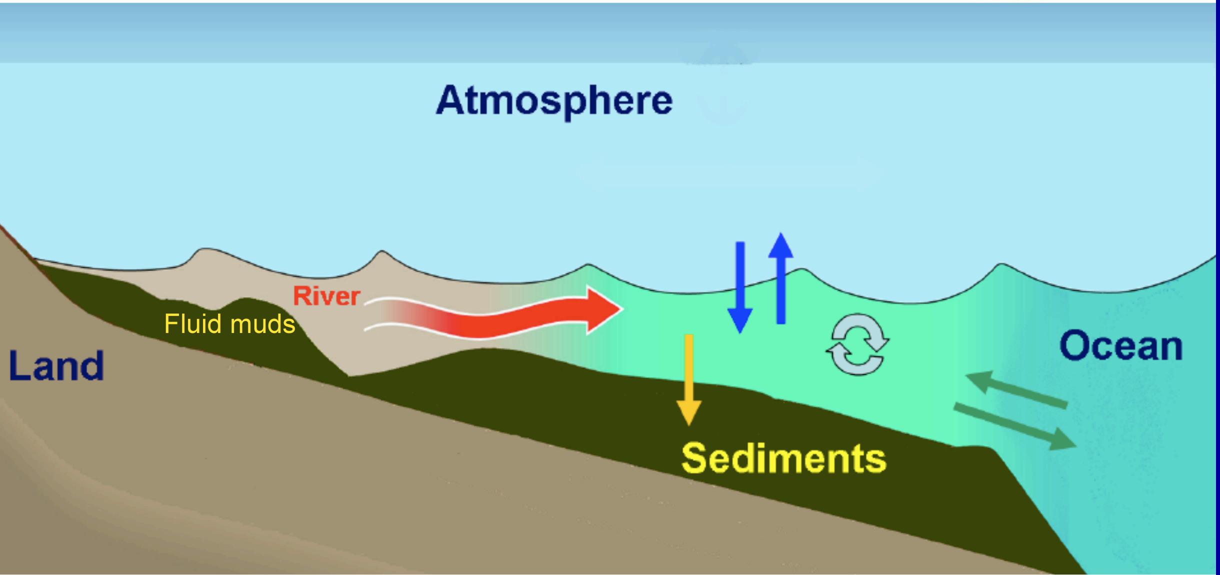
Utility Uses: Transportation, electricity, washing clothes, bathing

Recreational Uses: Swimming, boating, enjoyment/contemplation

Alessa et al. Global Environmental Change 2007

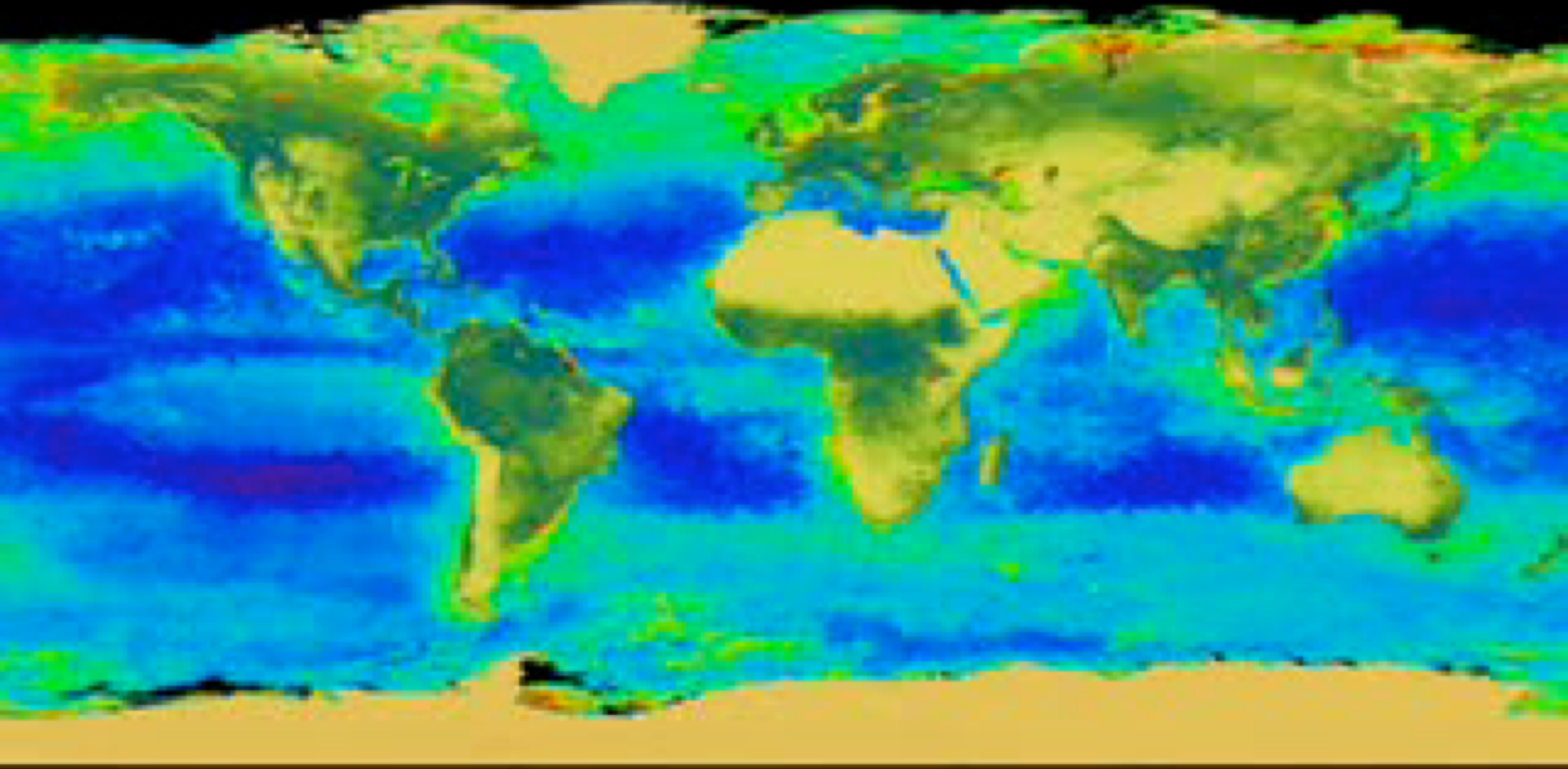
Water Systems Science & Engineering

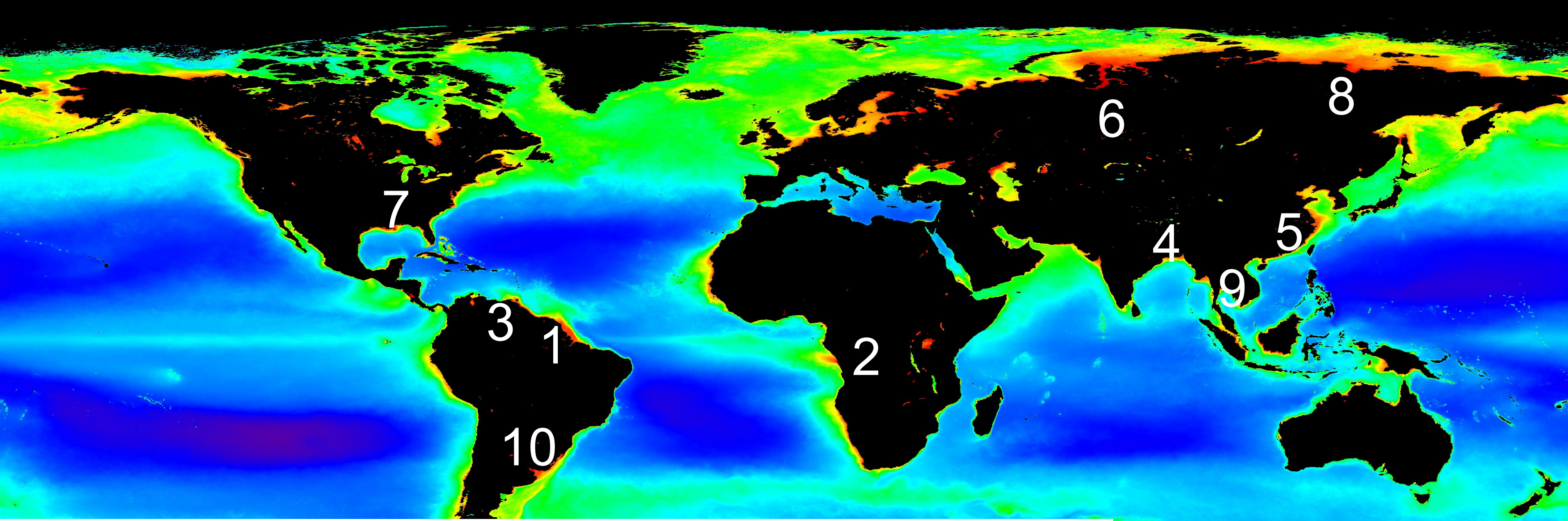




Studying river plumes requires an integrative approach to earth system science - they connect land and water use, and biogeochemical cycling on land, atmosphere, oceans and require knowledge of physical, chemical, biological, and geological oceanography

Need understanding of weathering processes on land and climatic influence of precipitation, feed back loops, economics of land use, sociology of agriculture

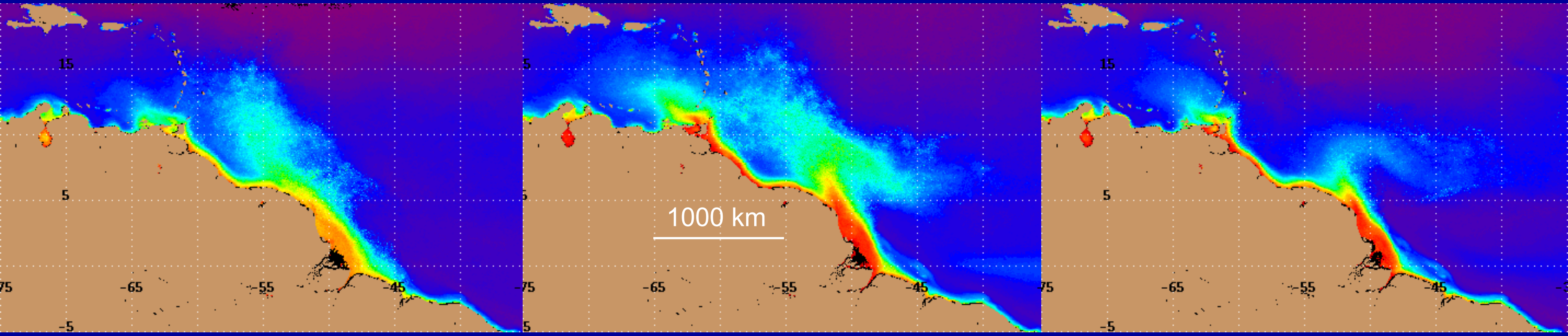


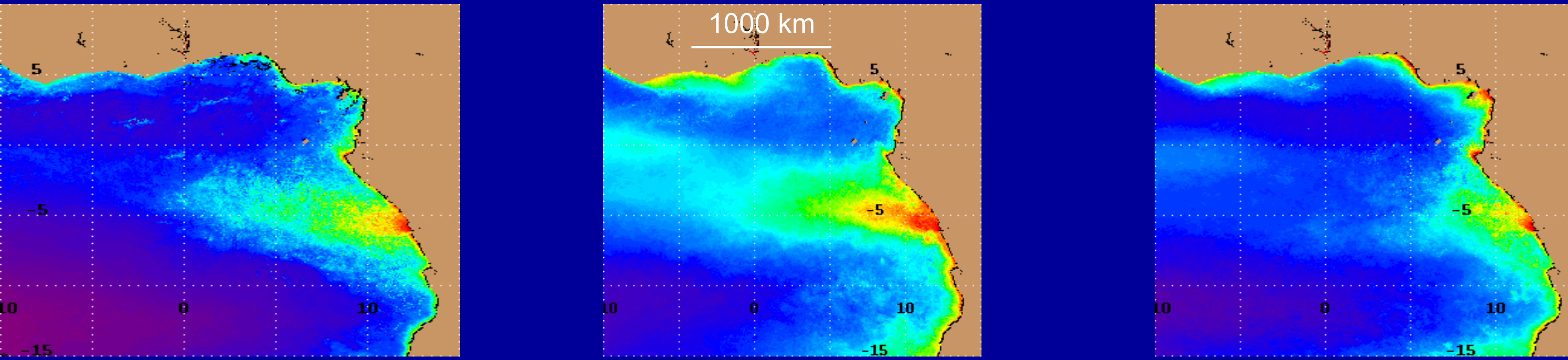


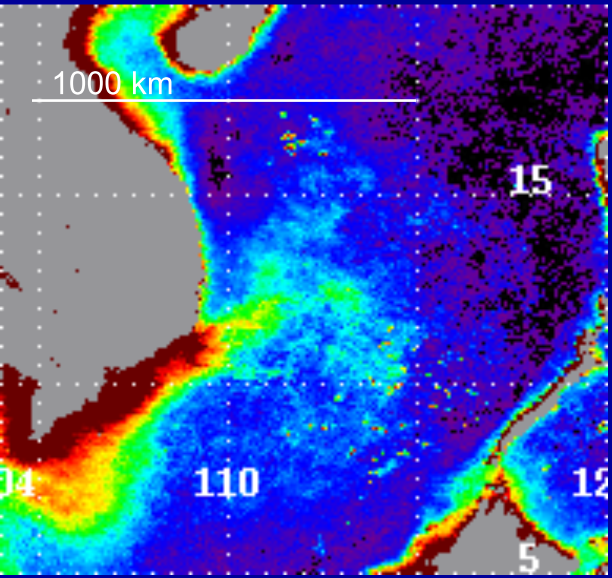
River	Discharge	Cumulative %	Drainage area	DIN yield*	DIP yield*	DON yield**	DOP yield**
Amazon	6300	18	6.15	173	17	327	18
Zaire	1250	22	3.82		4	91.5	
Orinoco	1200	25	0.99		4	313	17
Ganges-Brahmaputra	970	28	1.48		25	164	
Yangtze	900	31	1.94	326	16		
Yenisey	630	33	2.58		1		
Mississippi	530	34	3.27	256	7	54	3
Lena	510	36	2.49	21	2	58	3
Mekong	470	37	0.79				
Parana	470	38	2.83	44	2	61	
All others	21168	100					

* From Dumont et al 2005
** From NEWS Model (Harrison et al 2005)

Yields in Kg N or P/km^2/yr







Big plumes (twice the size of Texas/ size of the Gulf of Mexico) often extending more than 1000 of km offshore and often lasting many months
What sustains these plumes?
What are the biogeochemical consequences?

Phytoplankton – single cell organisms that photosynthesize

Richard Davidson, courtesy of U.K. Fisheries Research Service

Phytoplankton and Nutrients

Macronutrients
Nitrogen
Phosphorus
Ammonium
Silica

Micronutrients
Iron
Vitamin B12

Phytoplankton need nitrogen to make DNA and proteins – amino acids
Nitrogen combines with hydrogen, oxygen, and carbon from glucose

Phytoplankton need phosphorus for production of ATP (energy in the cell)

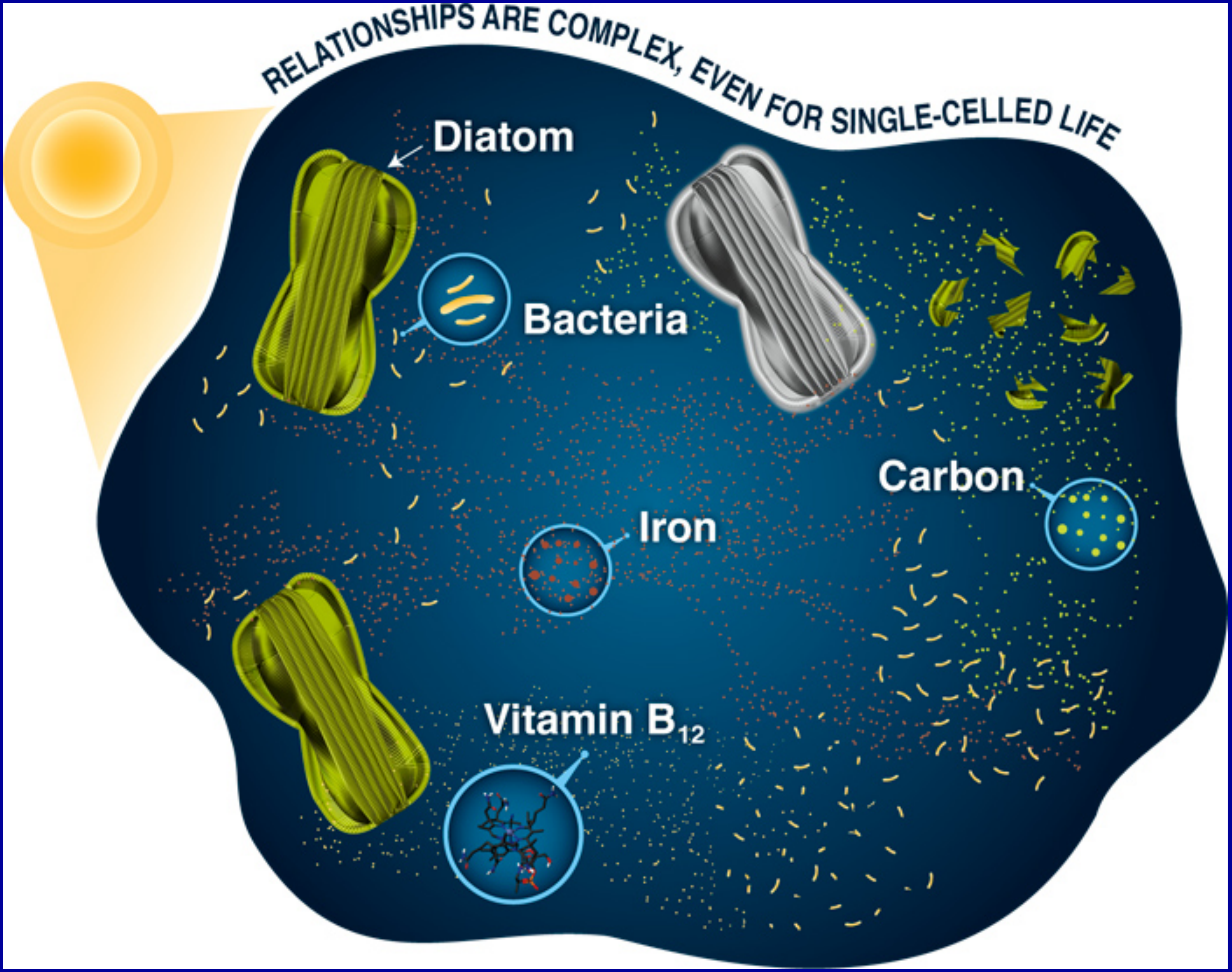


Image courtesy WHOI

THE WALL STREET JOURNAL.

★★★★ $1.50

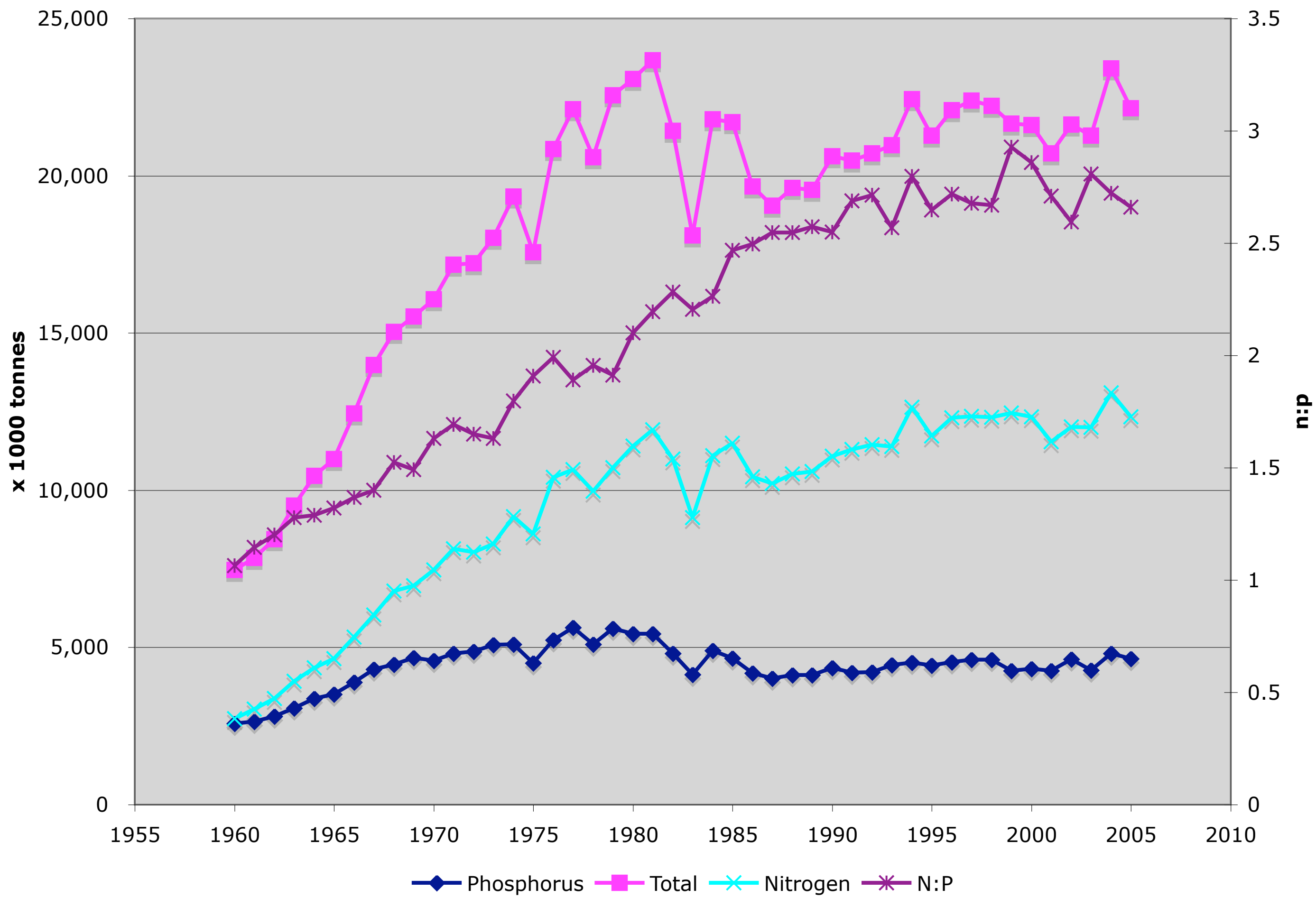
2.70 ▲ $4.10 EURO $1.4147 YEN 115.65

Historic Surge In Grain Prices Roils Markets

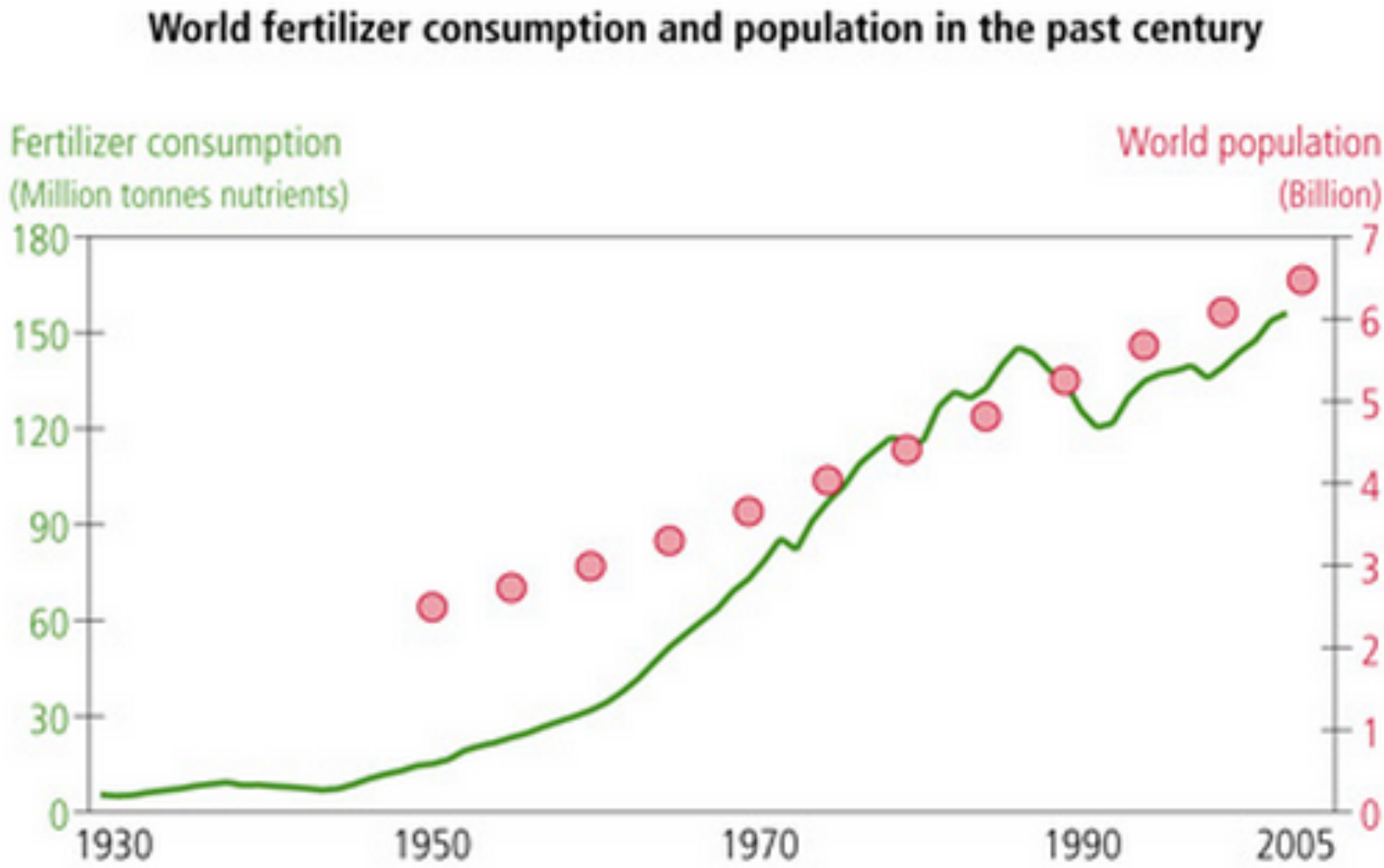
By Scott Kilman

Rising prices and surging demand for the crops that supply half of the world's calories are producing the biggest changes in global food markets in 30 years, altering the economic landscape for everyone from consumers and farmers to corporate giants and the world's poor.

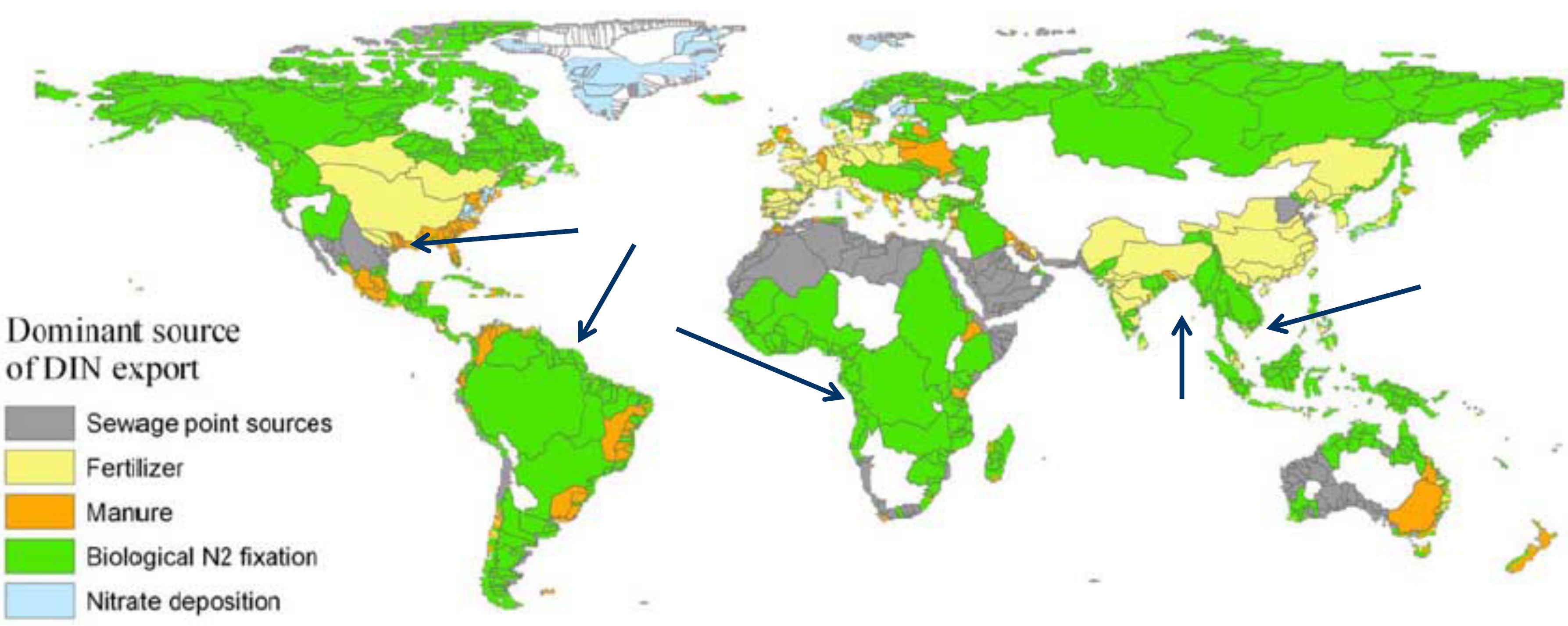
"The days of cheap grain are gone," says Dan Basse, president of AgResource Co., a Chicago commodity forecasting concern.



Increased global demand for animal protein, ethanol, speculation

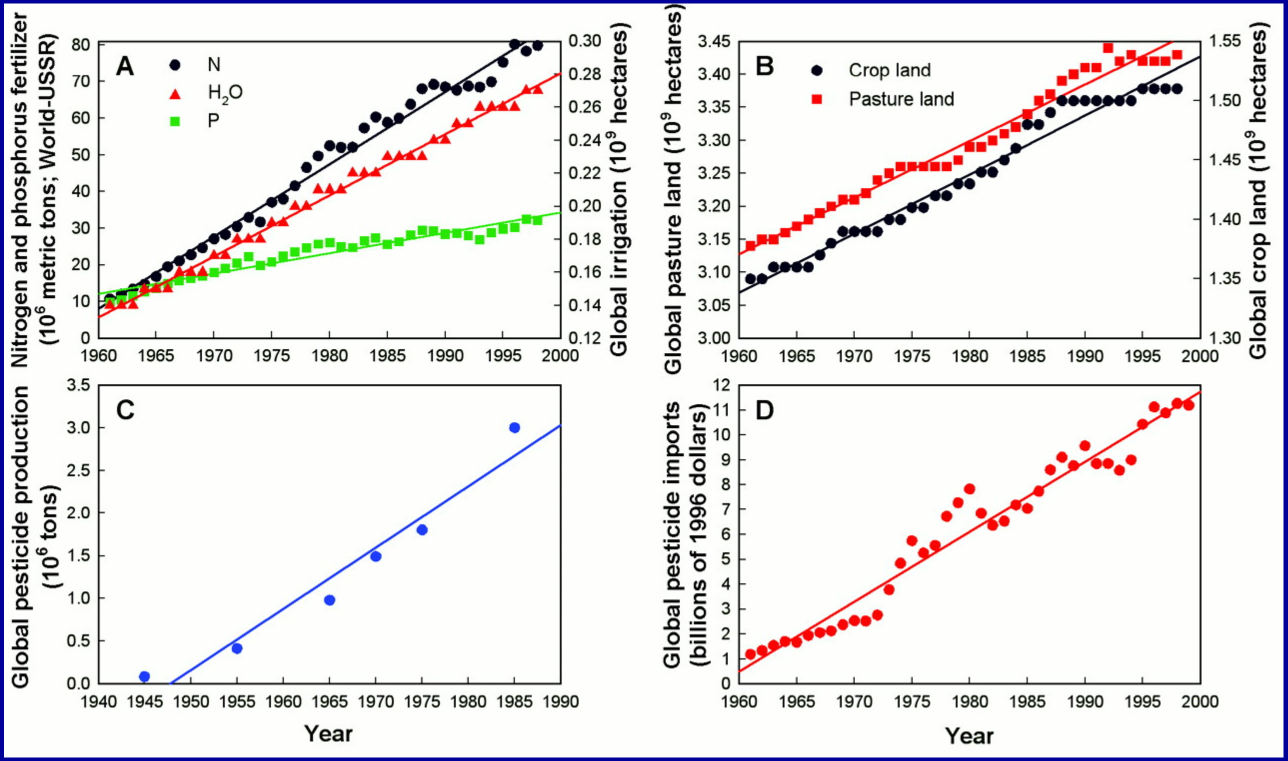

World fertilizer consumption and population in the past century
Fertilizer consumption
(Million tonnes nutrients)
World population
(Billion)
180
150
120
90
60
30
0
7
6
5
4
3
2
1
0
1930
1950
1970
1990
2005

NEWS-DIN-predicted dominant sources of DIN export



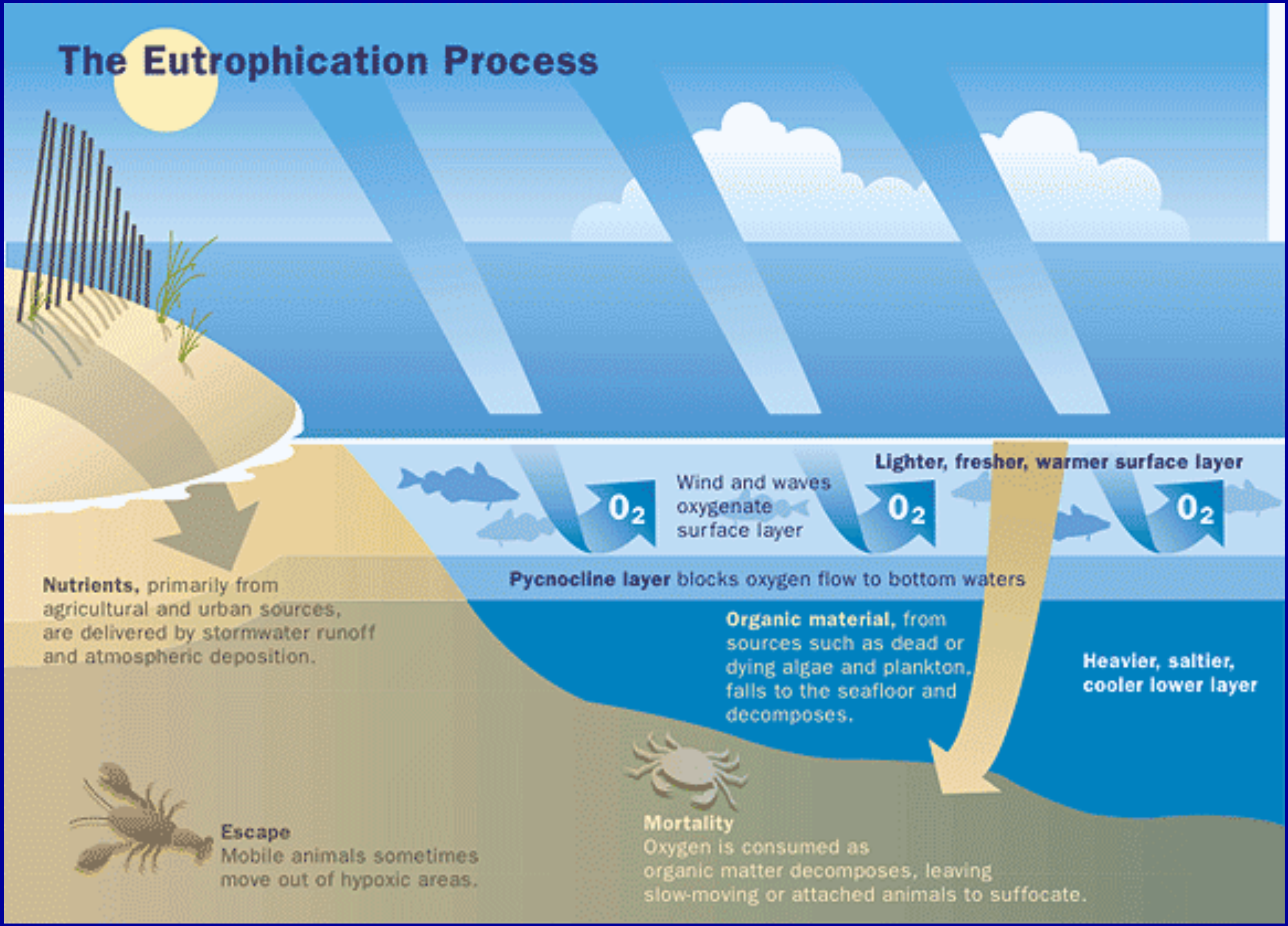
Dumont et al 2005 GBC

Trends in annual rates of application of nitrogenous fertilizer (N) expressed as mass of N, and of phosphate fertilizer (P) expressed as mass of P2O5, for all nations of the world except the former USSR (18, 19), and trends in global total area of irrigated crop land (H2O) (18). (B) Trends in global total area of land in pasture or crops (18). (C) Trend in global pesticide production rates, measured as millions of metric tons per year (30). (D) Trend in expenditures on pesticide imports (18) summed across all nations of the world, transformed to constant 1996 U.S. dollars. All trends are as dependent on global population and GDP as on time (Table 1).



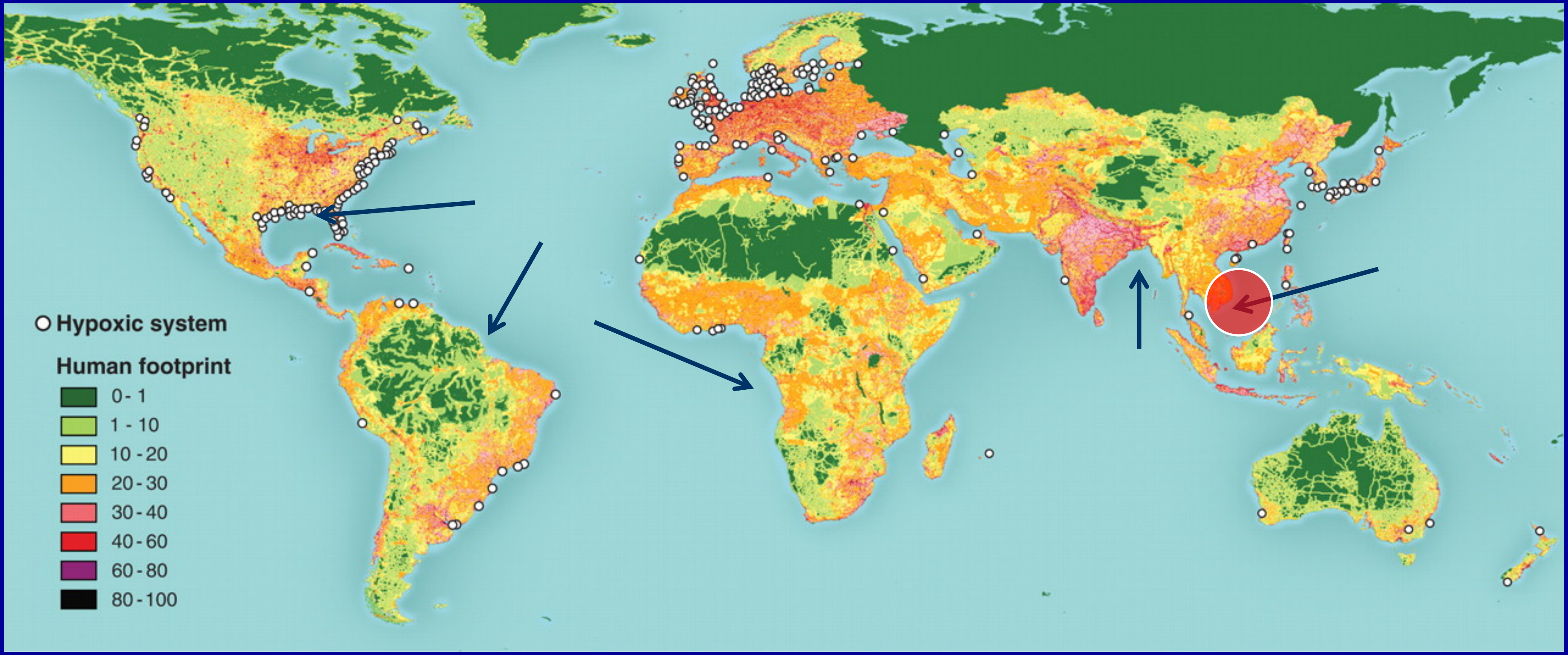
D. Tilman et al., Science 292, 281 -284 (2001)

Eutrophication



Pew Trusts

Global distribution of 400-plus systems that have scientifically reported accounts of being eutrophication-associated dead zones



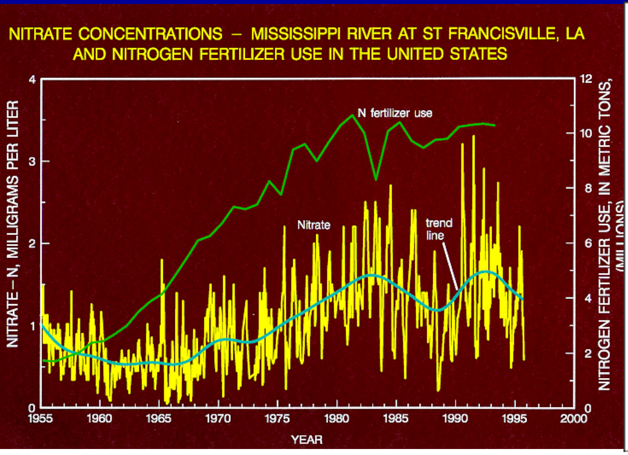
R. J. Diaz et al., Science 321, 926 -929 (2008)

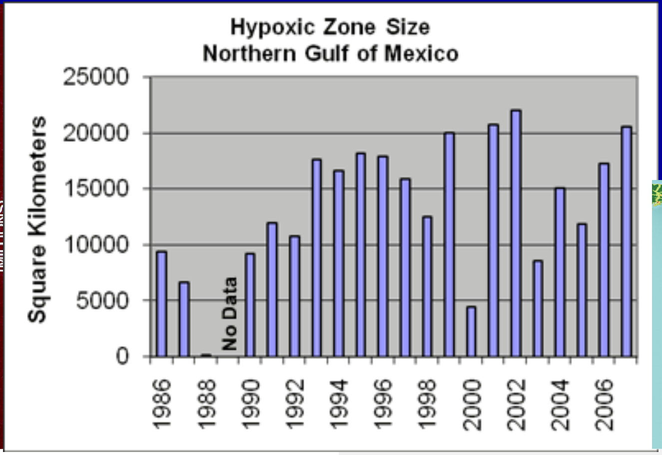
Published by AAAS

Science AAAS

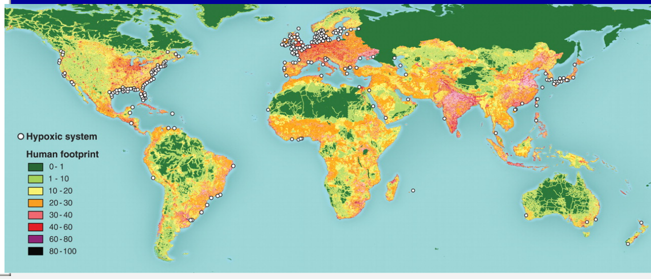
Future changes

- Anthropogenic loading (where does urea from fertilizers fit in the new production paradigm?)
- Climate related changes to the hydrological cycle





R. J. Diaz et al., Science 321, 926 -929 (2008)



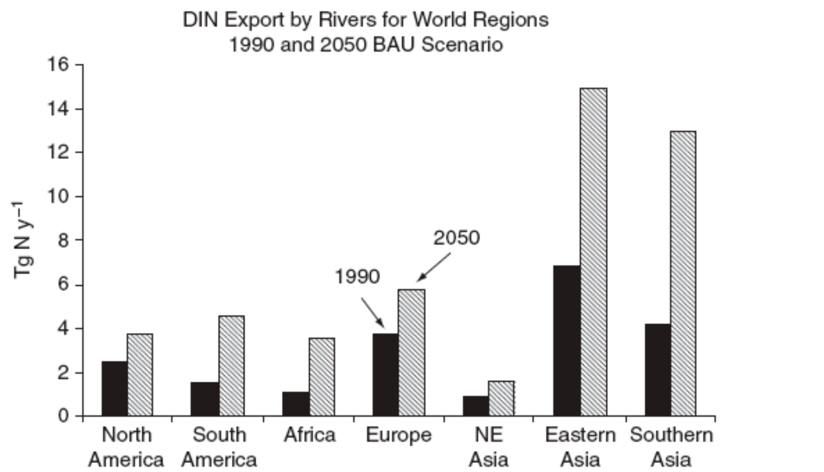
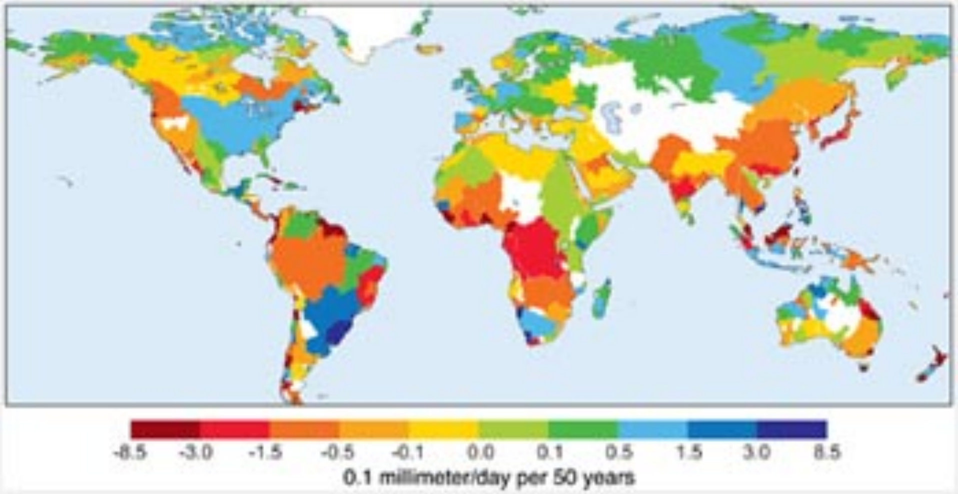


Figure 9.8 Predicted increases in DIN export to coastal systems between the years 1990 and 2050 under a business-as-usual (BAU) scenario. Modified from Kroeze and Seitzinger (1998).



Dai et al 2009 Journal of Climate

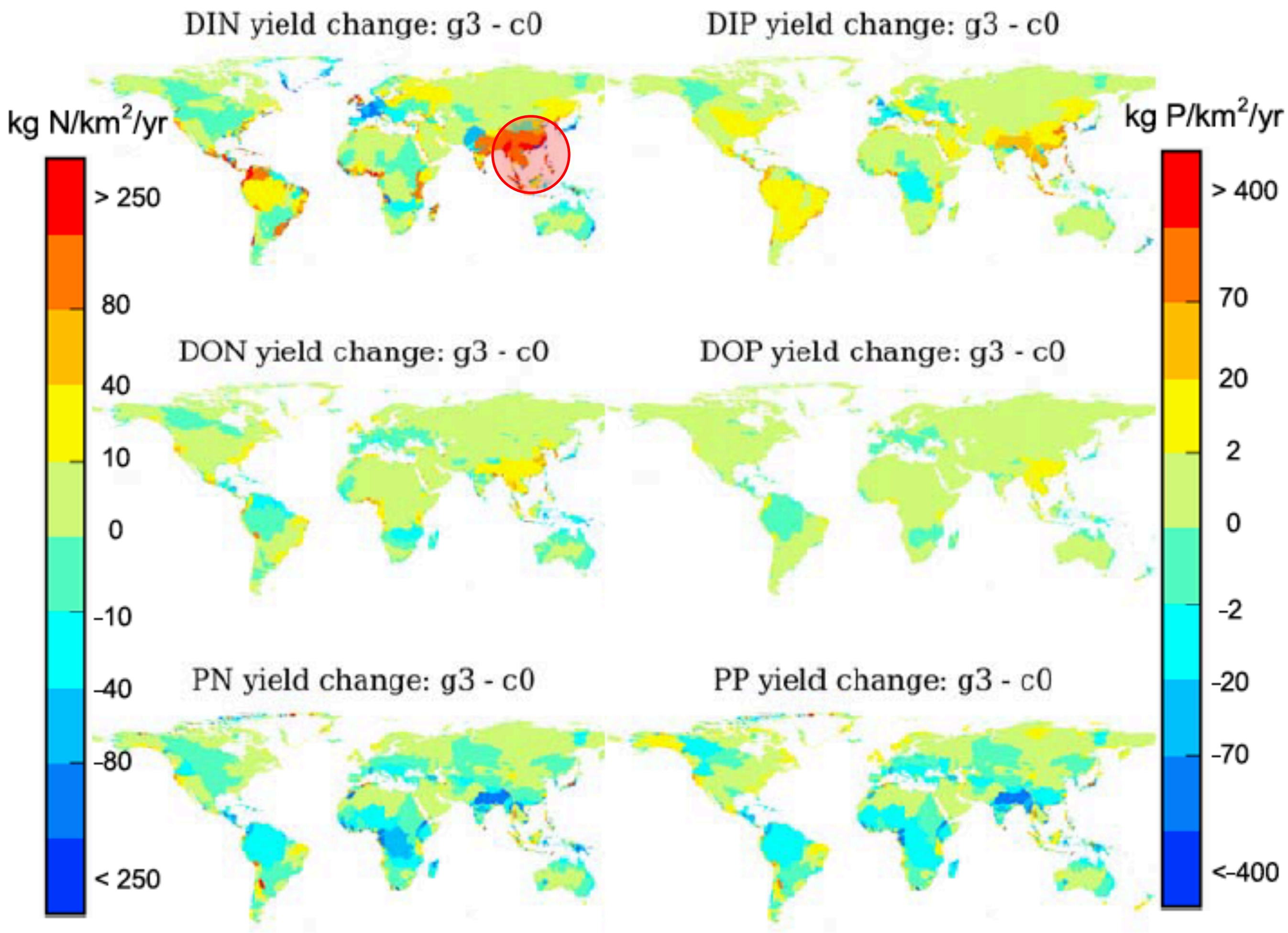


Figure 6. Change in yields (kg km^{-2} yr^{-1}) between 2000 and 2030 from the 5761 basins in the NEWS model for DIN, DON, and PN and DIP, DOP, and PP under the Global Orchestration scenario.

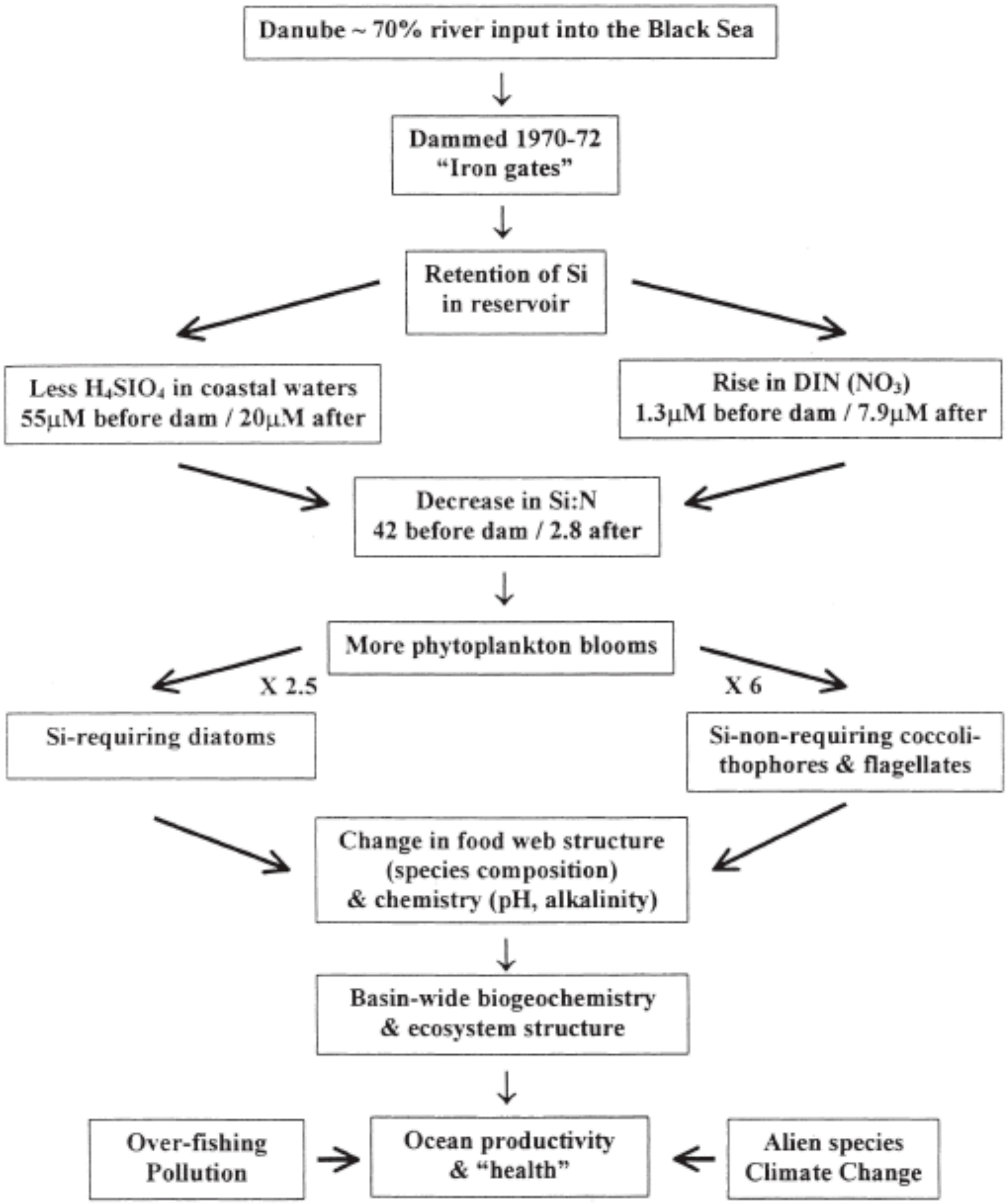
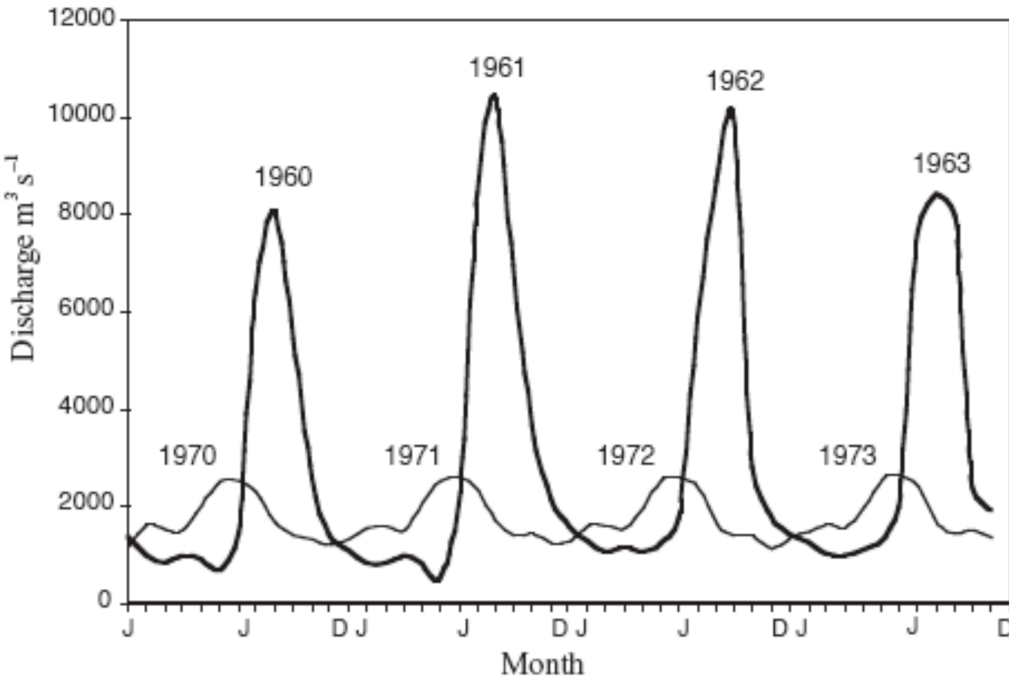
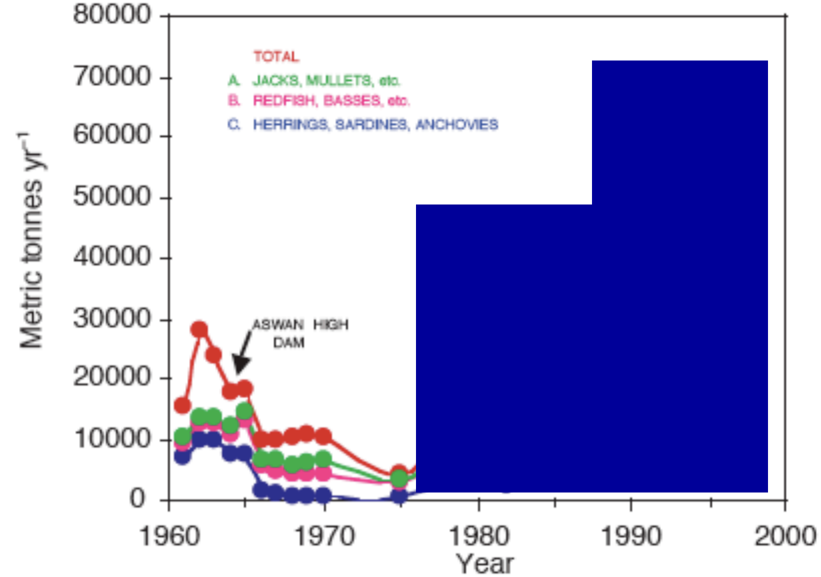

Danube ~ 70% river input into the Black Sea
Dammed 1970-72
"Iron gates"
Retention of Si
in reservoir
Less H_4SiO_4 in coastal waters
55μM before dam / 20μM after
Rise in DIN (NO_3)
1.3μM before dam / 7.9μM after
Decrease in Si:N
42 before dam / 2.8 after
More phytoplankton blooms
X 2.5
X 6
Si-requiring diatoms
Si-non-requiring coccoli-
thophores & flagellates
Change in food web structure
(species composition)
& chemistry (pH, alkalinity)
Basin-wide biogeochemistry
& ecosystem structure
Over-fishing
Pollution
Ocean productivity
& "health"
Alien species
Climate Change

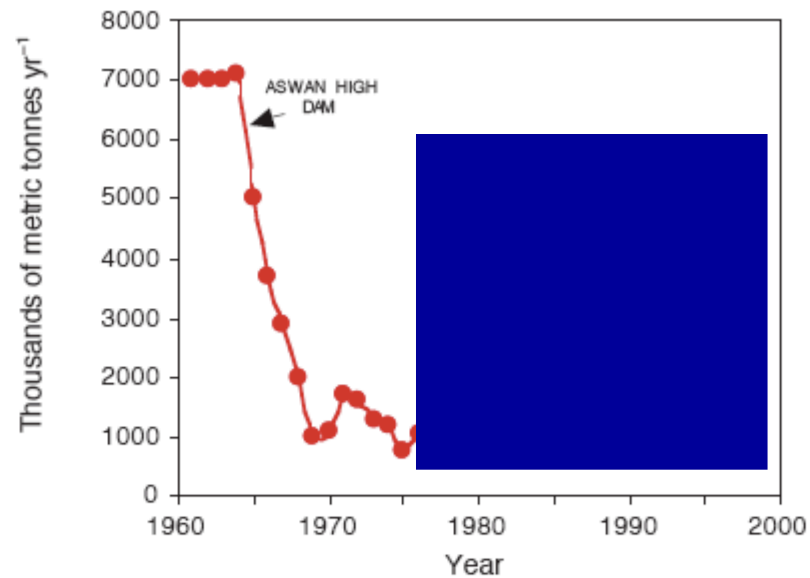
Figure 1. Discharge of the Nile at Aswan before and after closure of the High Dam in 1965 (Data from 14).



Egypt-Mediterranean fisheries landings



Shrimp landings



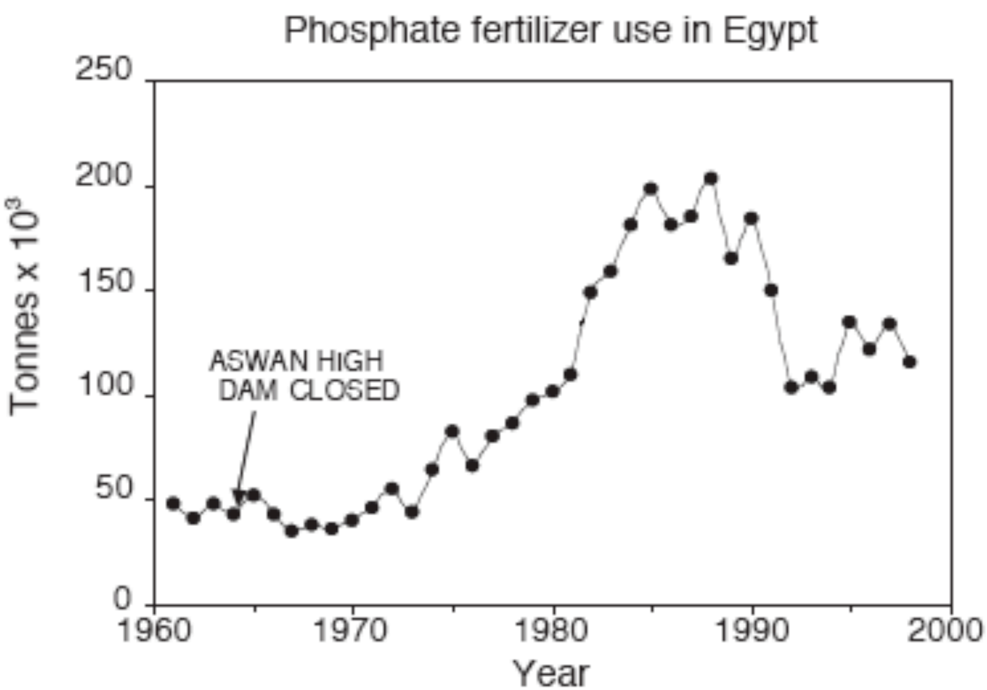
Changes in fisheries landings

Decrease after dam due to reduced productivity of the delta

Increase due to fertilizers

OR

Increase due to better catch per effort, more powerful ships, efficient gear



	10^3 tonnes yr^{-1} P	N
The Nile		
Pre-Aswan High Dam		
Dissolved	3.2	6.7
On sediments	4–8	?
Total	7–11	6.7
Post-High Dam		
Dissolved 0.03	0.2	
On sediment	0	0
Total	0.03	0.2
Human Waste		
Total Generated in Cairo and Alexandria		
1965	4.4	21
1985	8.9	55
1995	12.6	87
Potential N and P in wastewater discharge, Cairo and Alexandria[1]		
1965	1.1	5
1985	3.6	22
1995	9.5	65
Potential N and P in wastewater discharge, Total urban population[2]		
1965	2.4	12
1985	6.7	41
1995	15.8	108

[1]Assuming that the population connected to the sewers was 25% in 1965, 40% in 1985, and 75% in 1995 (52). The 1965 estimate is very uncertain.
[2]Extrapolated from Cairo and Alexandria assuming that the accounted for 45% of the total urban population in 1965, 54% in 1985, and 65%

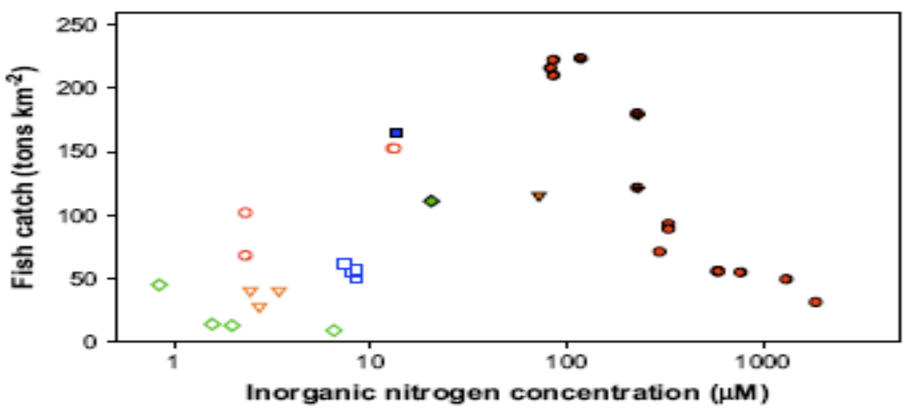
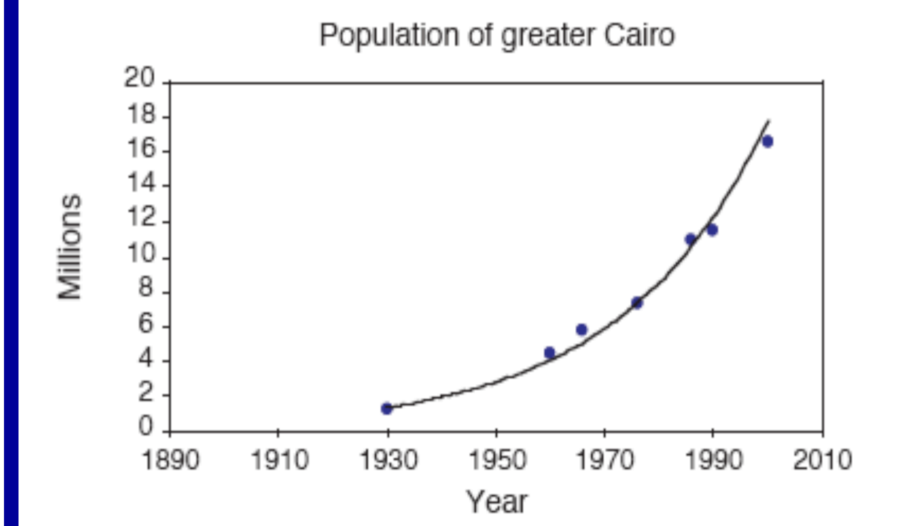
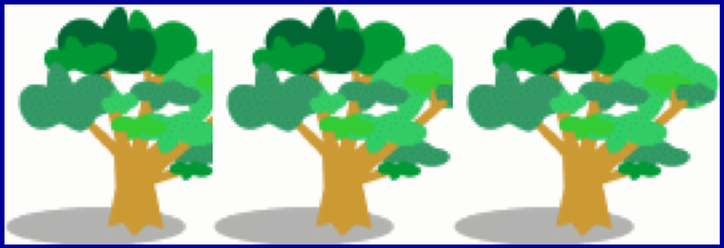


Fig. 6. Inorganic nitrogen concentration and fish catch per unit area for the four coastal lagoons of the Nile Delta—Burullus (diamond), Edku (triangle), Manzalah (square), and Maryut (circle). Open symbols represent combined $NO_3^- + NO_2^-$ concentrations while closed symbols represent total dissolved inorganic nitrogen (DIN, or NO_3^-, NO_2^-, NH_4^+). Gray, cross hatched points are from 1980 to 1983 and have been described as 'unreliable' in terms of DIN concentration by Prof. Youssef Halim (Oceanography Department, University of Alexandria). Data sources in Tables 1 and 2.





Pre Industrial

Modern

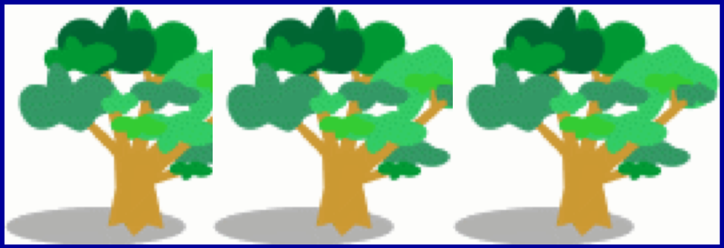
Post modern

All kinds of nuances

- Photoproduction of labile N from DON
- Autotrophic uptake of DON
- Nitrification to produce nitrate
- Size of delta

Importance of the bathymetric kopplung

- Role of mobile muds - time/space buffers?
- Denitrification
- Fe/P interaction in anoxic sediments - source of SRP and labile Fe?

Pre Industrial	Modern	Post modern
Amazon	Mekong	Mississippi

Most important of all – the space to age gracefully

AGU Global Biogeochemical Cycles 10.1002/2016GB005483

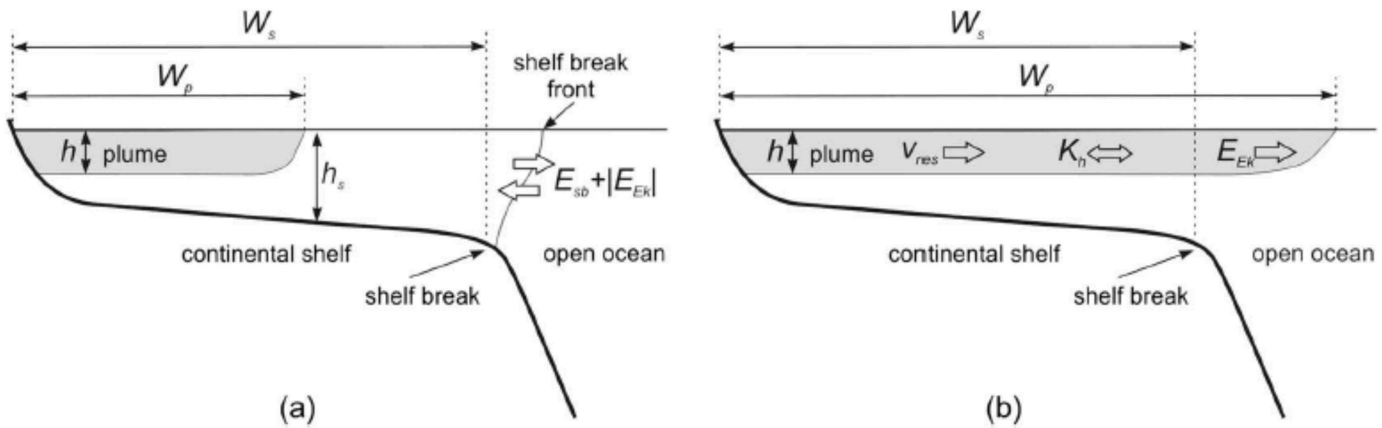
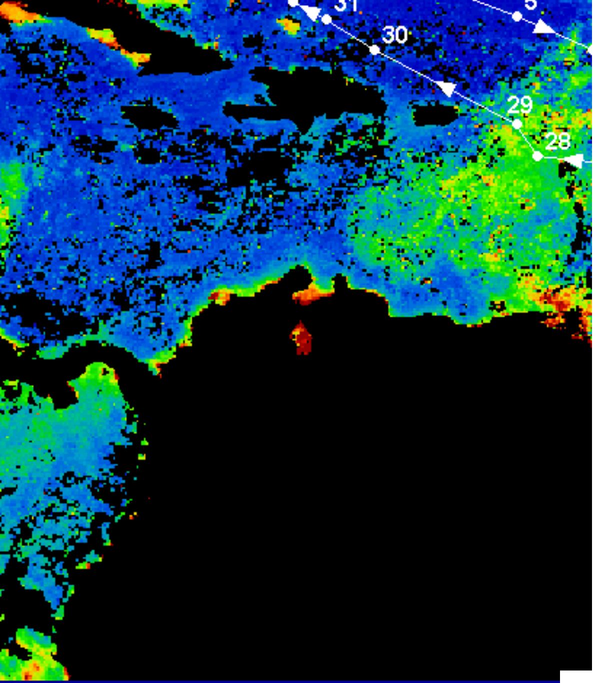
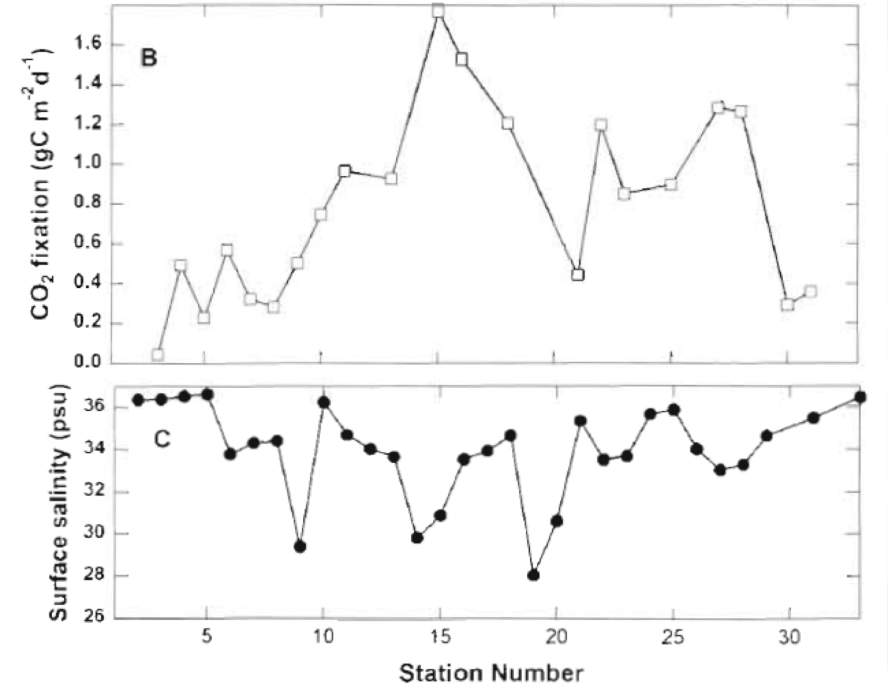


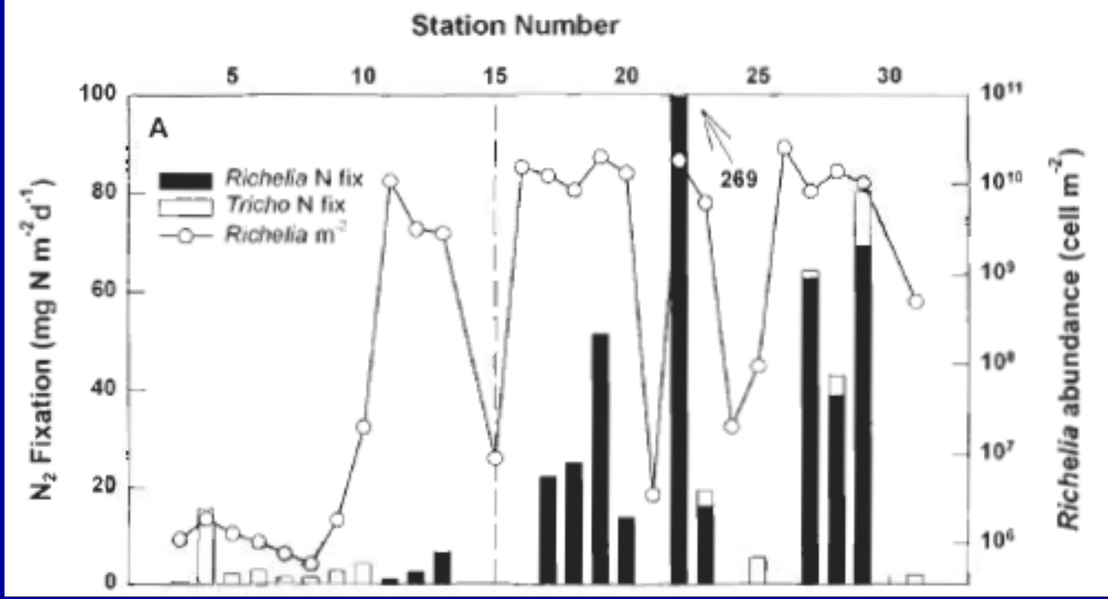
Figure 1. Schematic diagram of the physical framework used to assess plume residence times on the shelf. (a) For a plume with width W_p less than the shelf width W_s plume water is assumed to be relatively efficiently mixed into the shelf water. Exchange with the open ocean is limited by the generally weak exchange processes at the shelf break, taken as a combination of wind-driven Ekman transport (E_{Ek}) and other shelf break processes (E_{sb}). (b) For a plume that extends beyond the shelf break, transport of plume water over the shelf break is taken to be a combination of residual cross-plume flow (v_{res}), horizontal dispersion through the plume (K_h), and wind-driven Ekman exchange driving surface water off the shelf.

Sharples et al GBC 2017

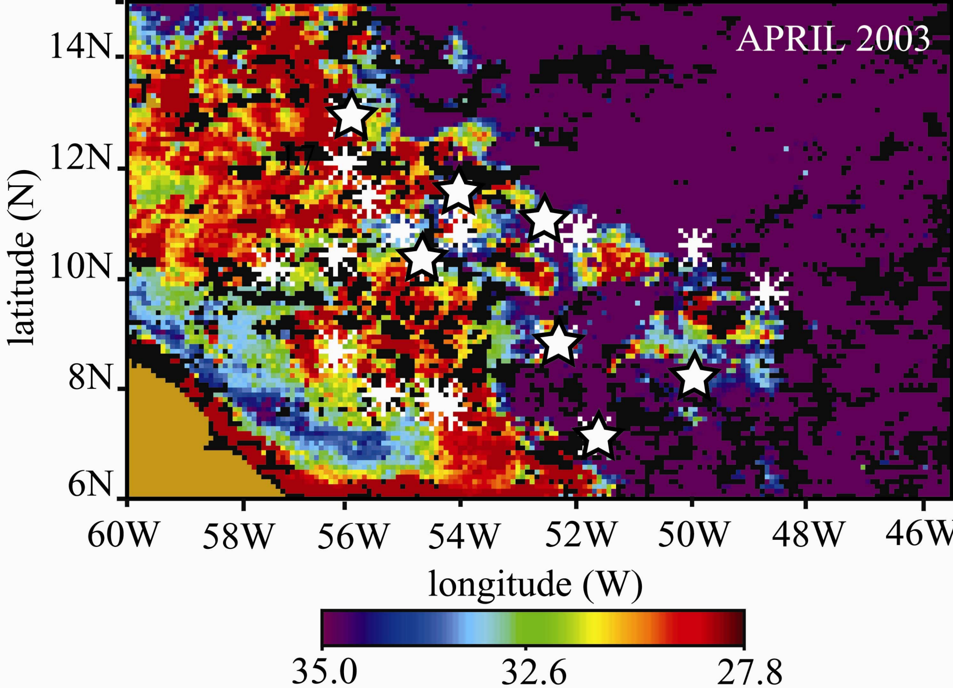


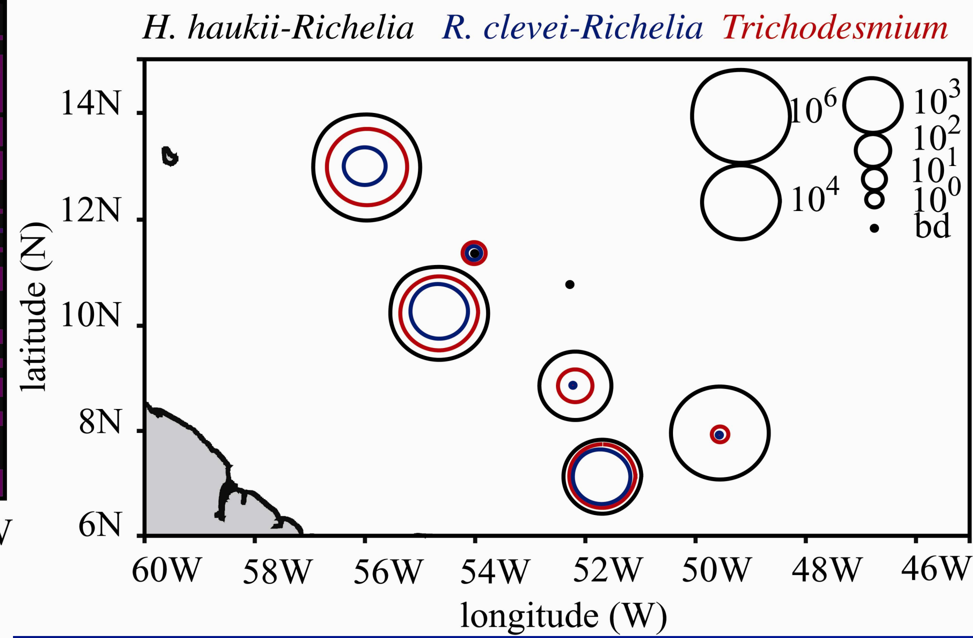


ajor bloom of
lus/ *Richelia* in Oct.
apped using the
satellite off the
f South America,
und to extend all
way into the
ean and involved
oco Plume as well

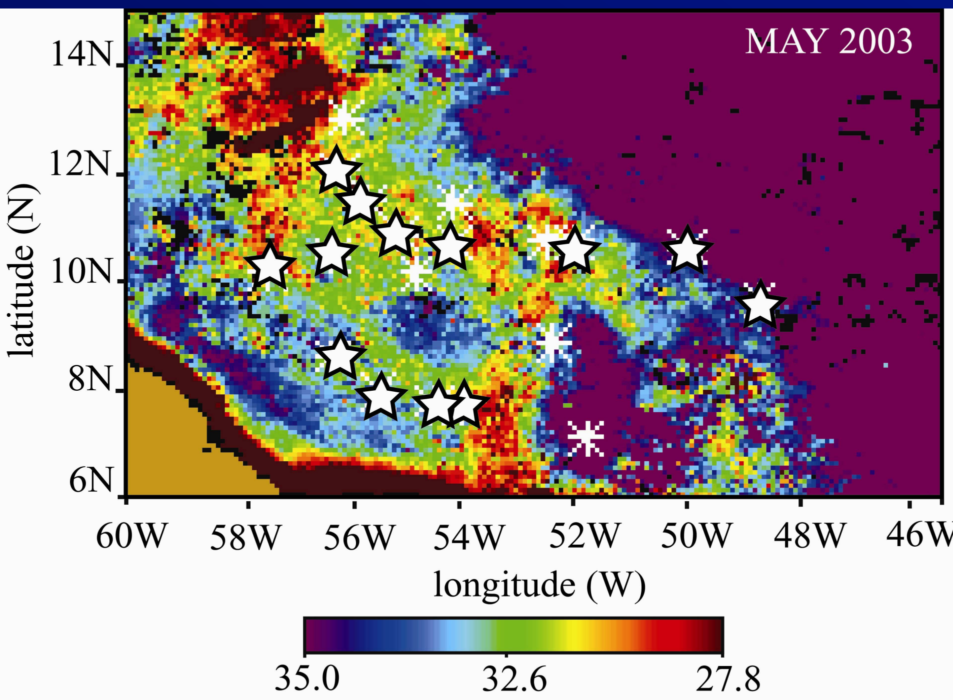


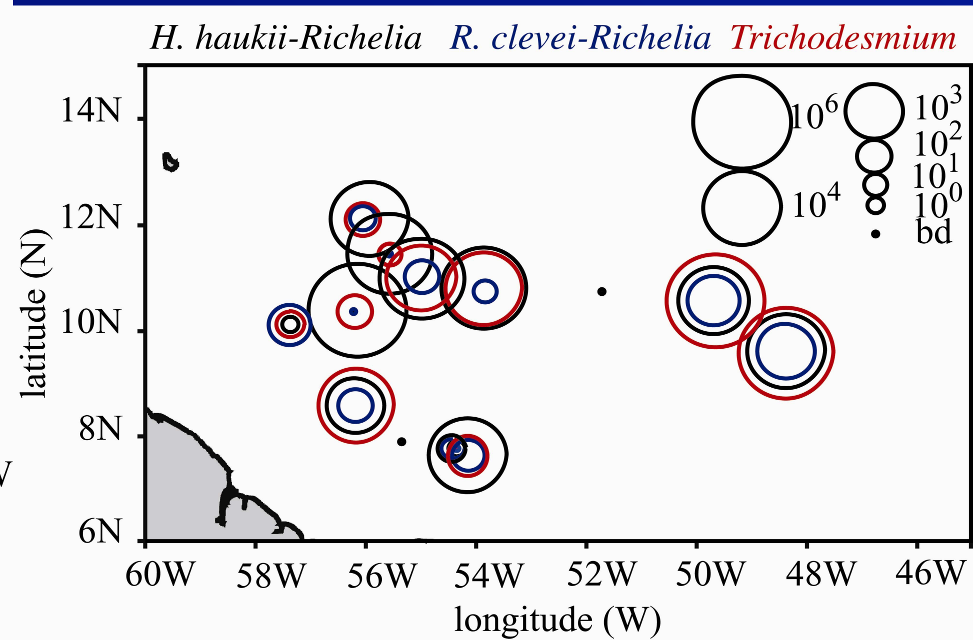
Carpenter, E.J, J.P. Montoya, J. Burns, M.R. Mulholland, A. Subramaniam, and D.G. Capone (1999). Extensive bloom of a N2 fixing symbiotic association in the tropical Atlantic Ocean. Marine Ecology Progress Series. Vol.185:273-283.





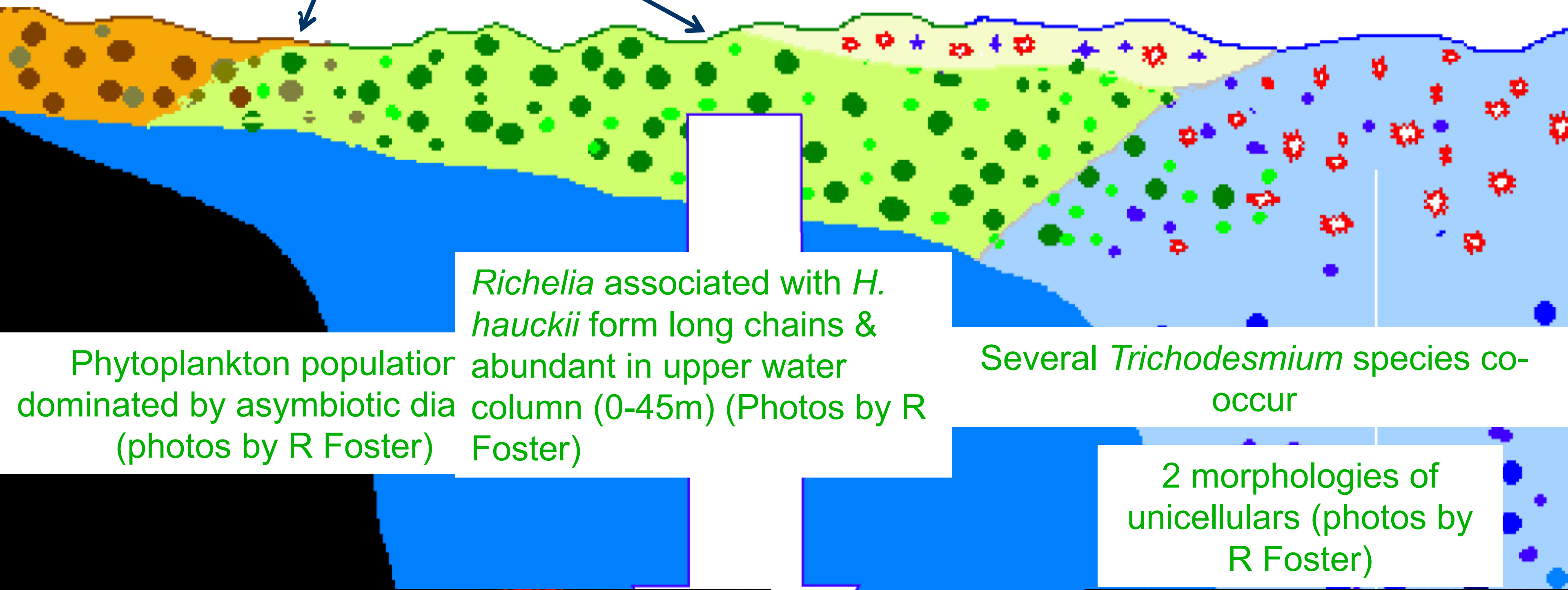
Foster et al., (2007) *L & O.*

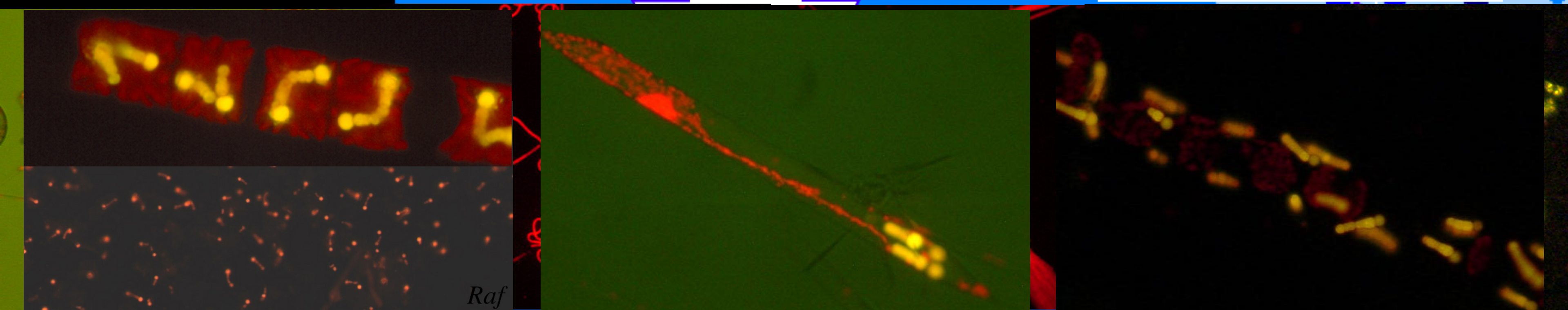




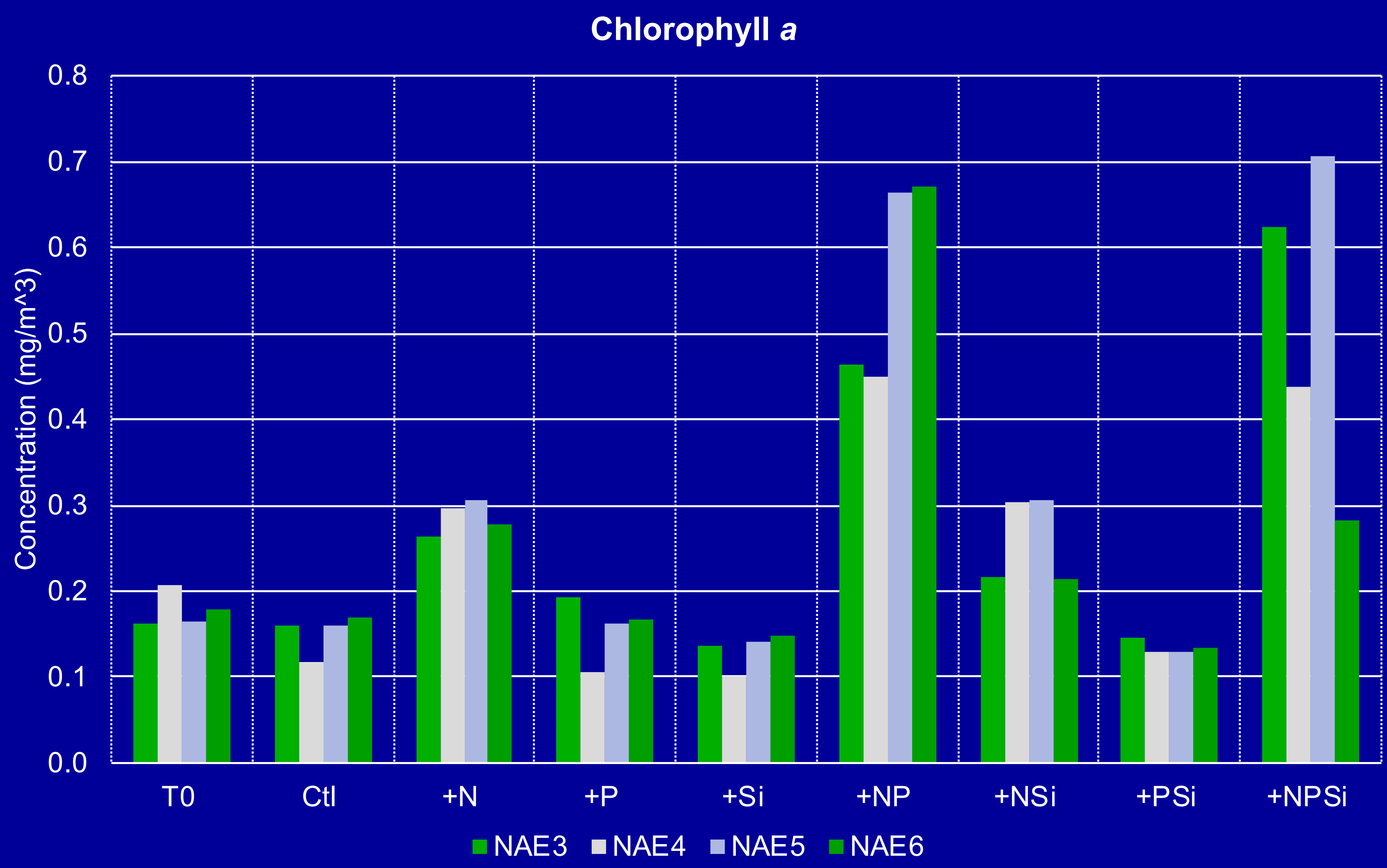
Need to understand oceanic boundaries. How are niches maintained, what allows for diversity? How do they change in space and time over various scales? Can we use biosensors?

P limitation?

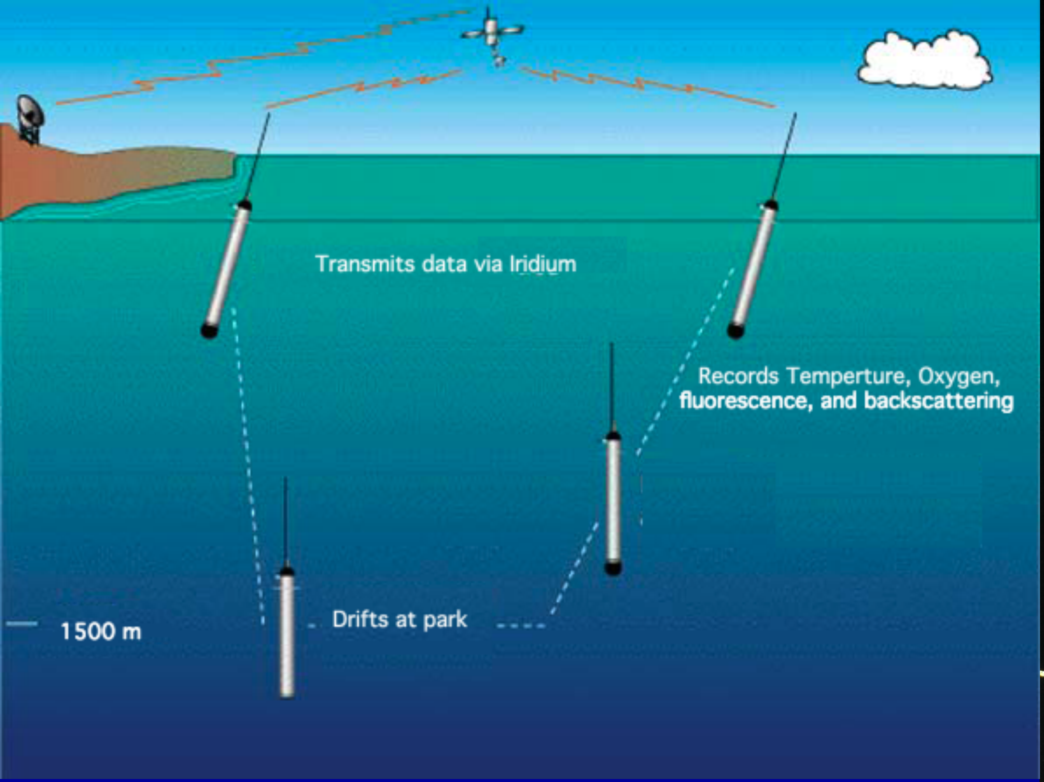




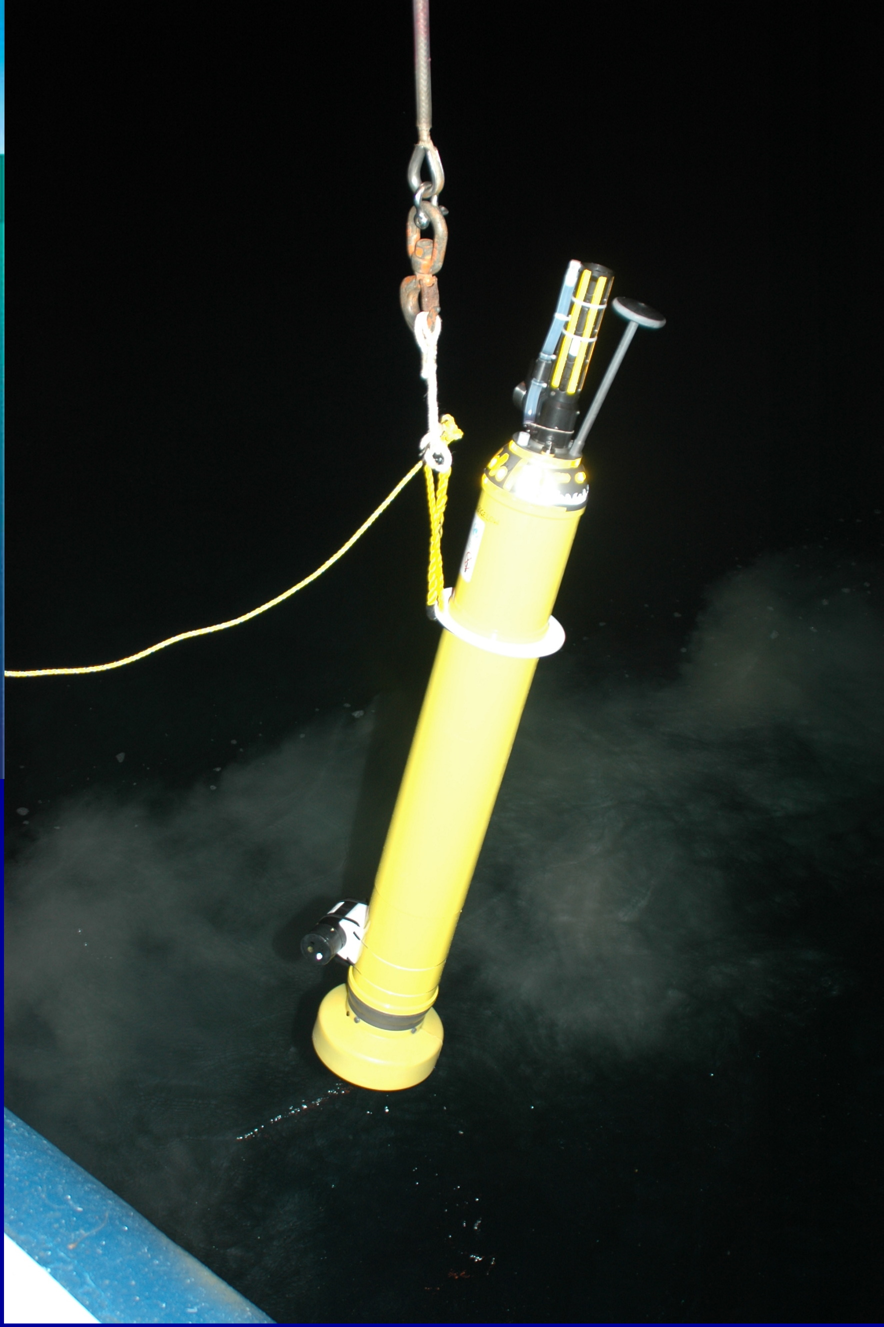
Nutrient Amendments



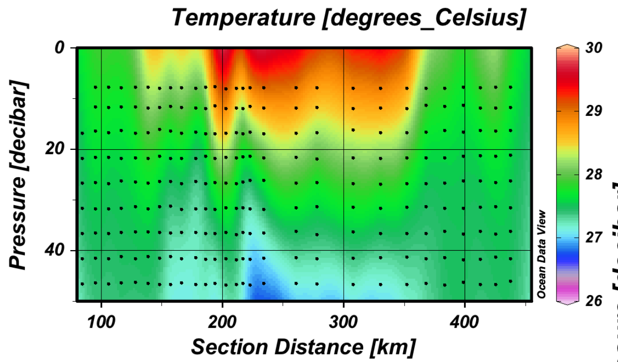

AJIT

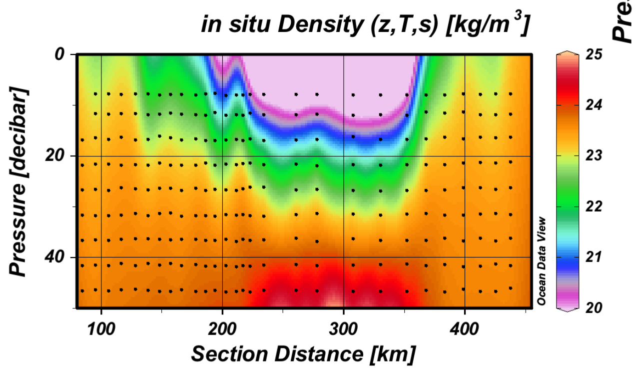


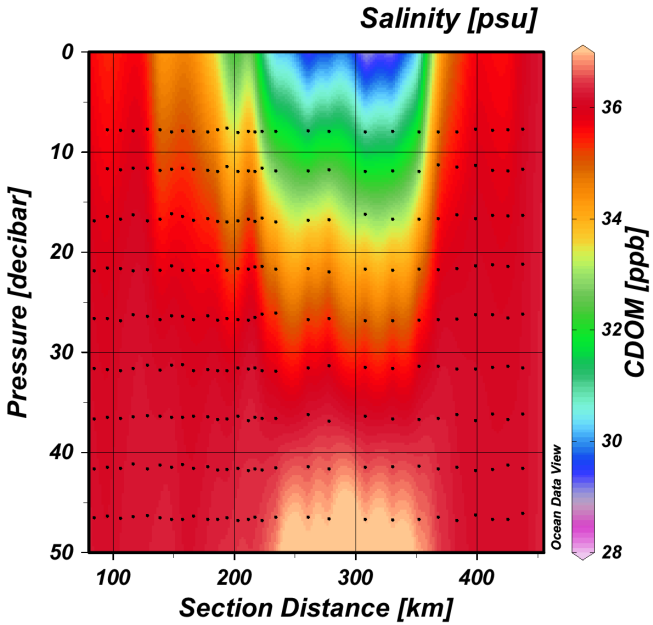
Lobo is an APEX float deployed in the Amazon River plume from 10th to 30th Sept. Lobo did 2 dives a day to 1200m and measured Temp, Sal, Oxy, chl, CDOM, and particle backscatter on each up cast and reported all the data and its GPS position on surfacing

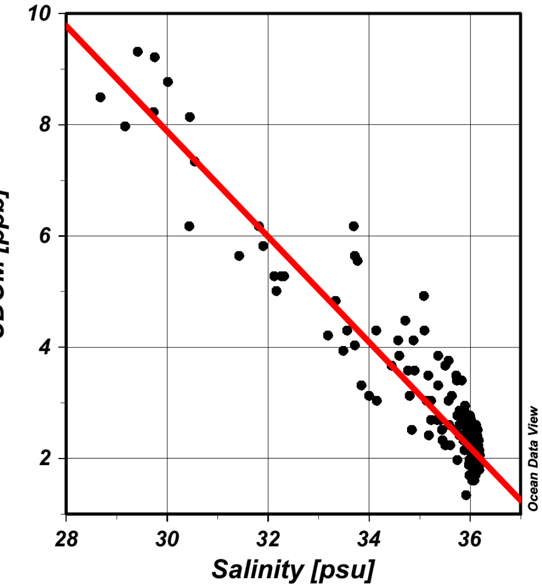


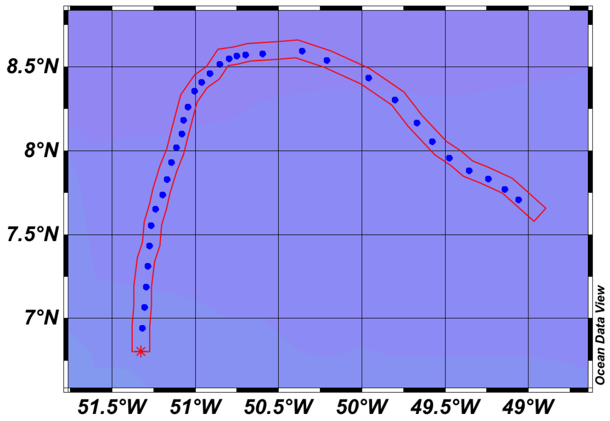
Lobo Trajectory

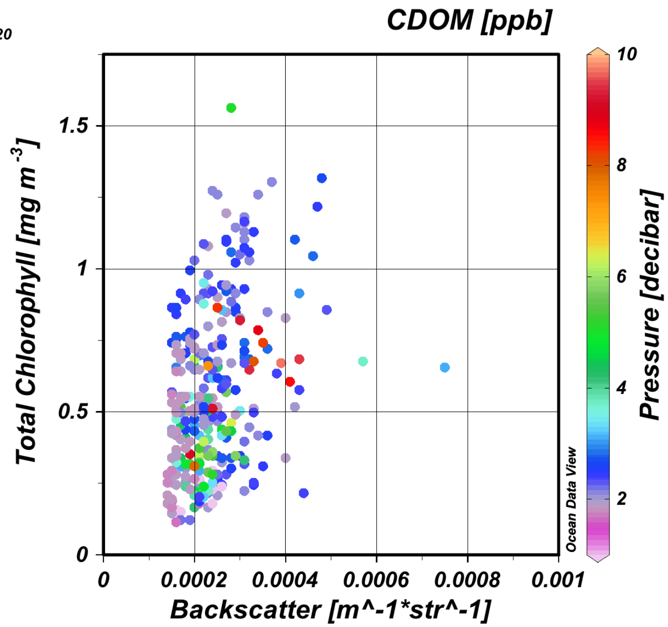


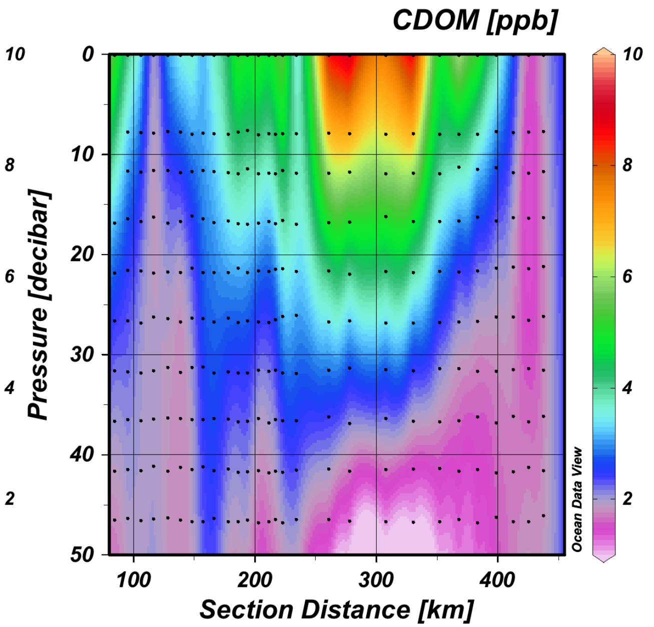


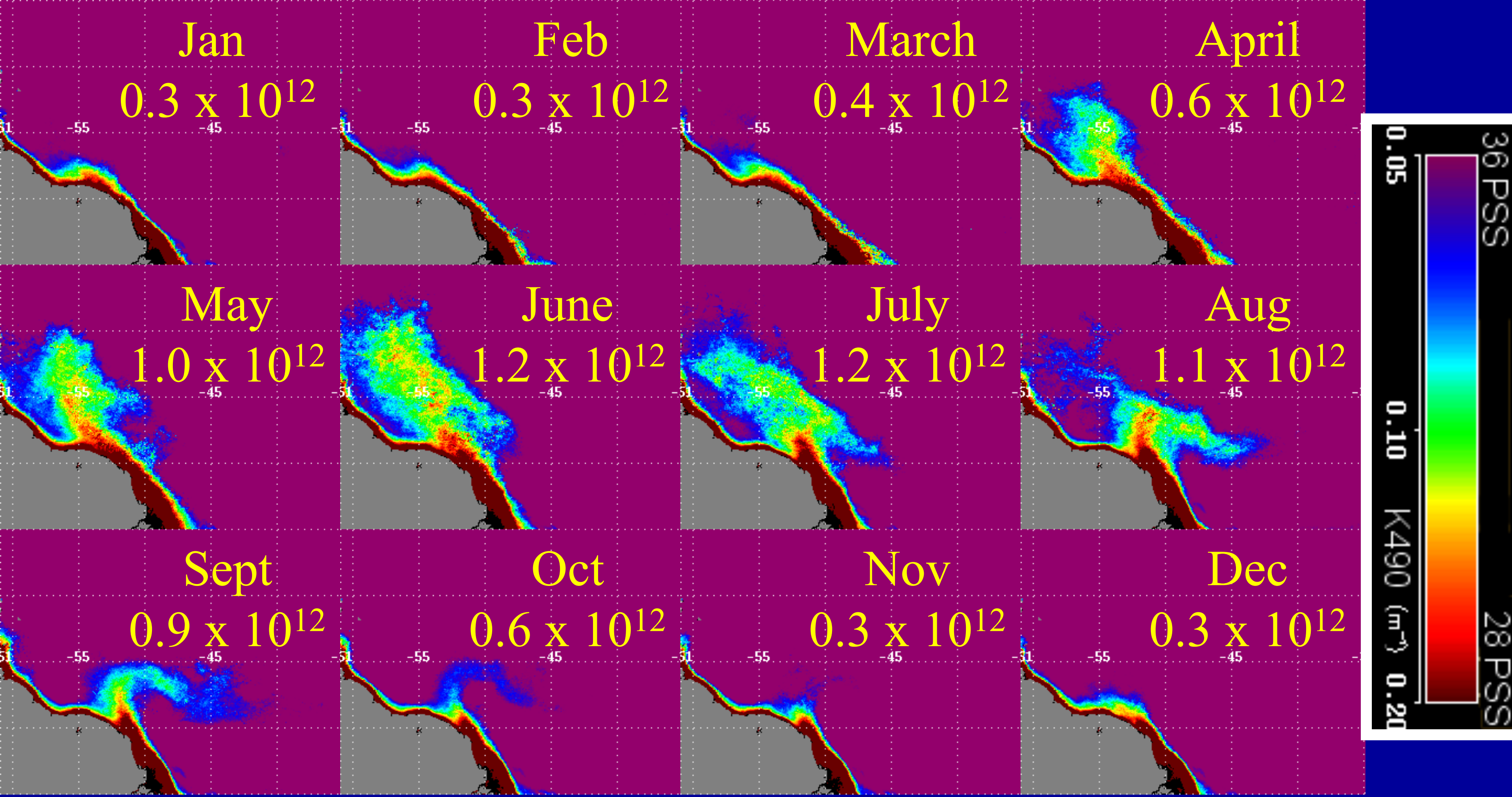












f_{river} for the Amazon calculated using the technique of Muller-Karger et al 1989 was 0.03 for the plume implying that N had to be recycled 39 times to meet the measured primary production demand.

Amazon Annual Hydrological Cycle

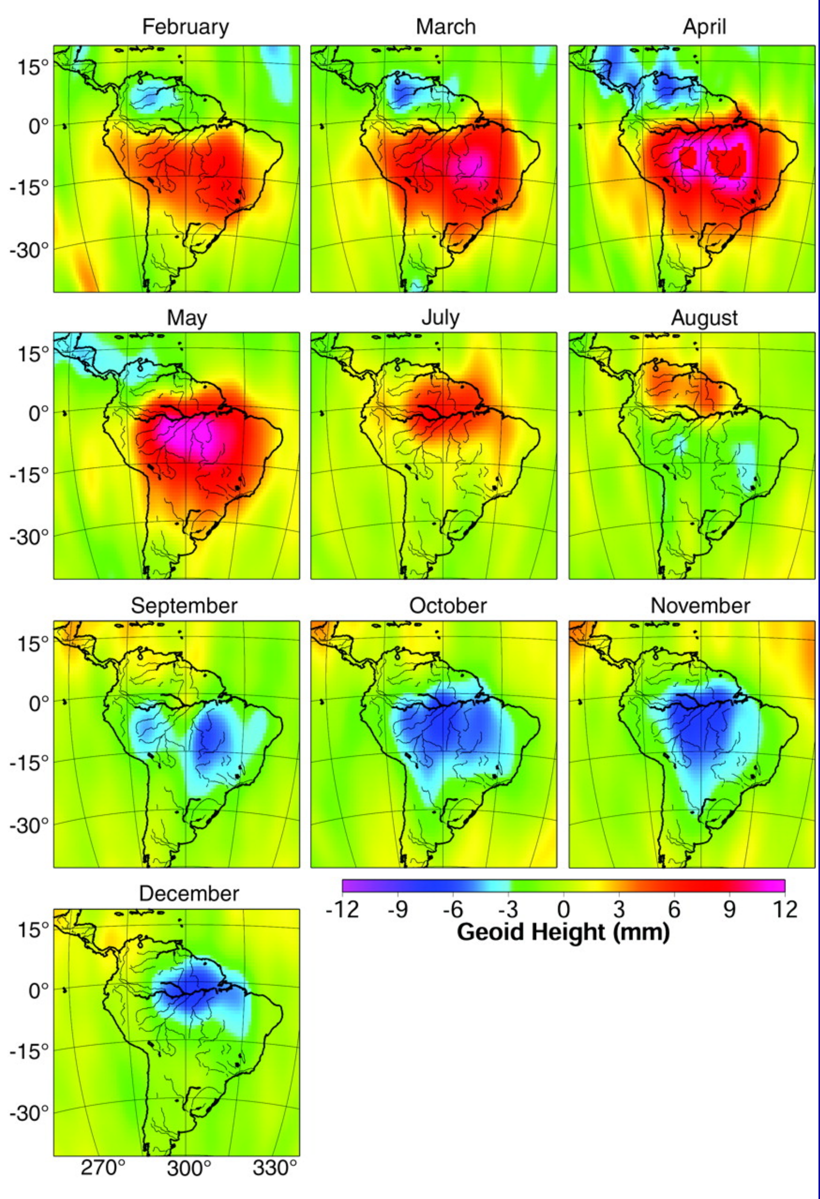
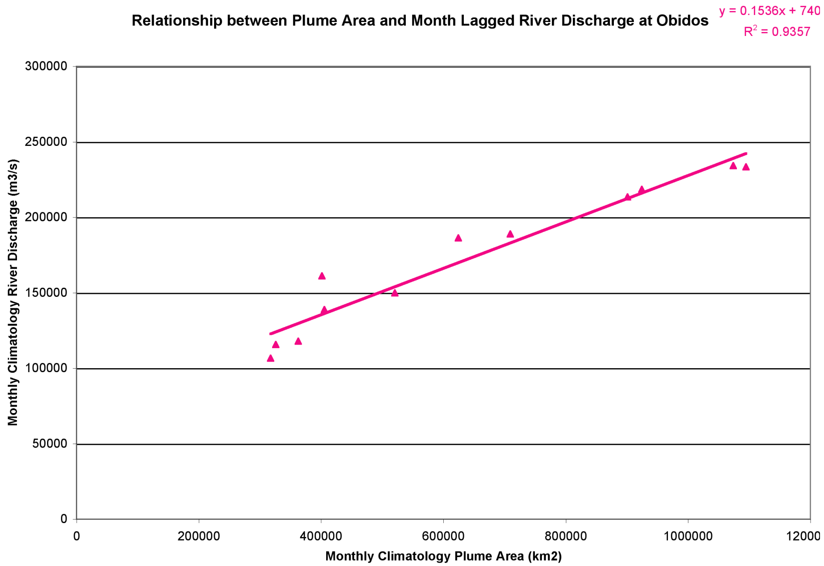
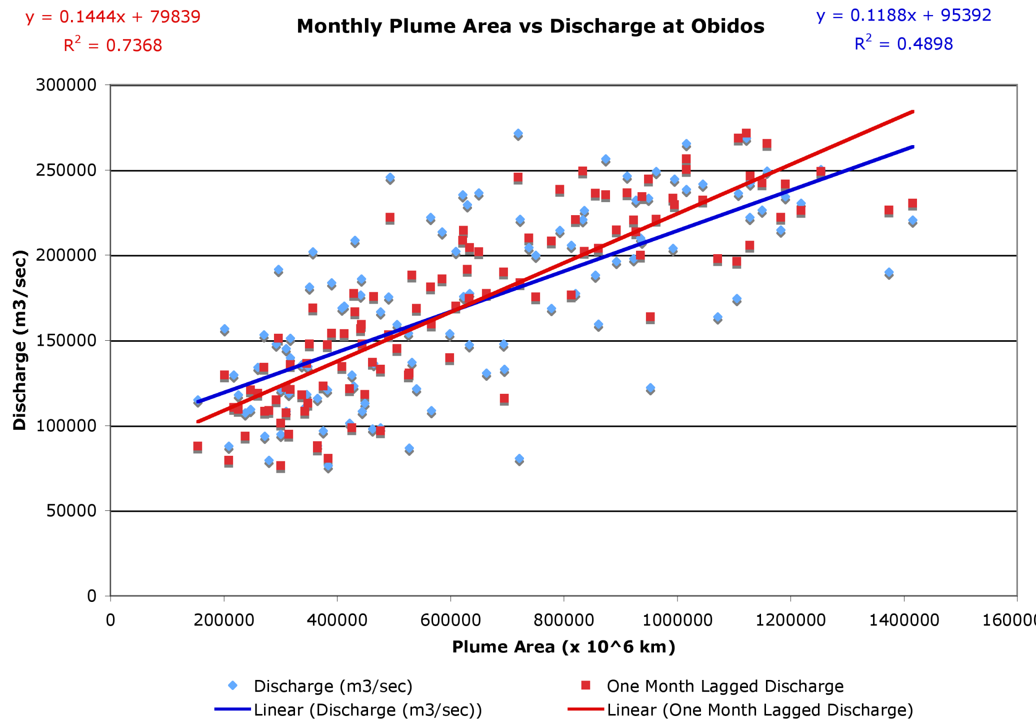


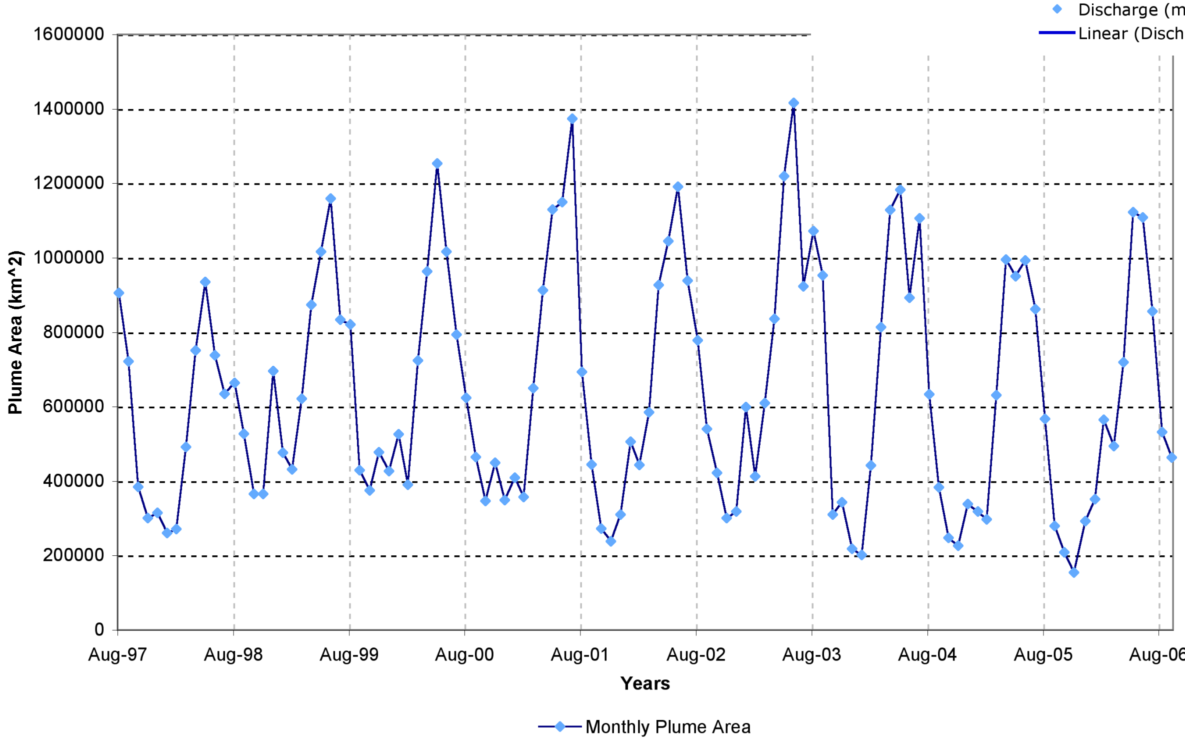
Fig. 2. From Tapley et al 2004 Science

Geoid height differences between each 2003 monthly gravity solution and the 14 month mean for equatorial South America (smoothing radius 400 km; degree-2 coefficients not included). This level of smoothing admits more error from the GRACE estimates, but the large signal in this region allows a higher resolution. Spacecraft events resulted in insufficient ground coverage to resolve the gravity field for the months of January and June.





Amazon River Plume Area
Sept. 1997- Oct. 2006



Amazon River Discharge and Climate Variability: 1903 to 1985

JEFFREY E. RICHEY, CARLOS NOBRE, CLARA DESER

Reconstruction of an 83-year record (1903 to 1985) of the discharge of the Amazon River shows that there has been no statistically significant change in discharge over the period of record and that the predominant interannual variability occurs on the 2- to 3-year time scale. Oscillations of river discharge predate significant human influences in the Amazon basin and reflect both extrabasinal and local factors. Cross-spectrum

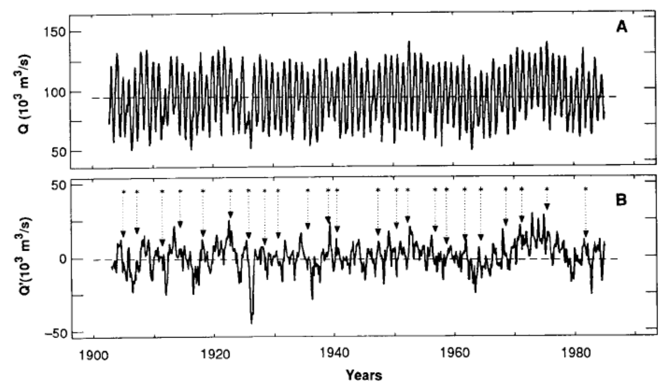
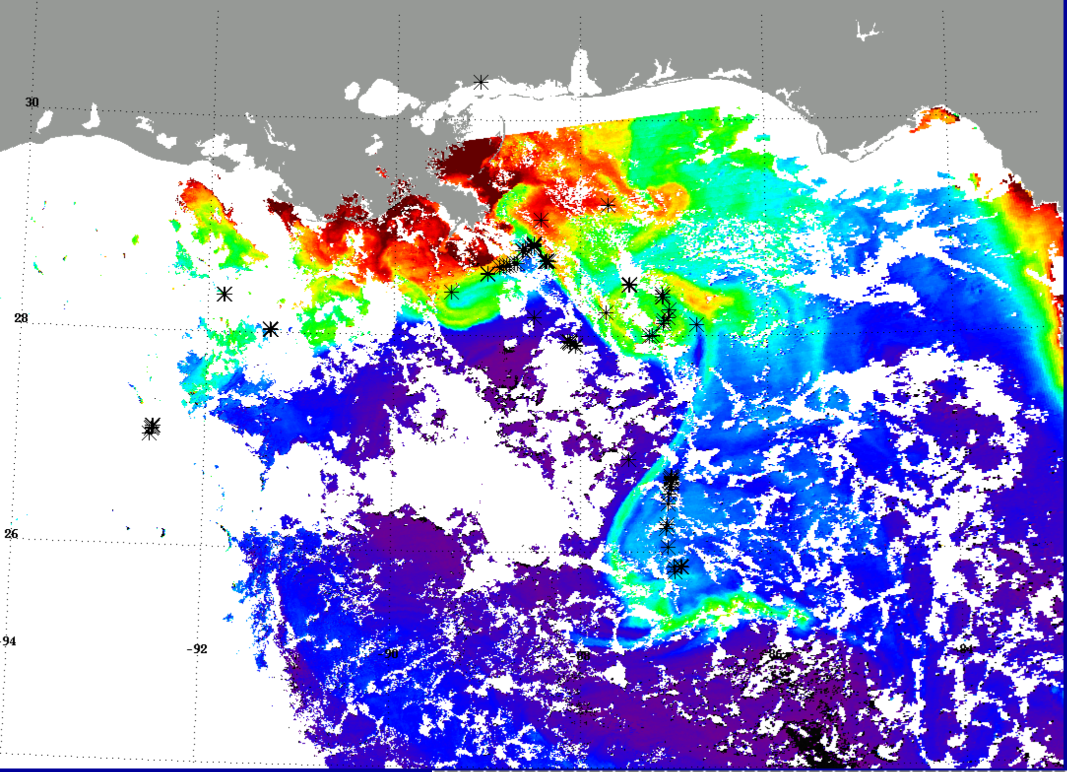
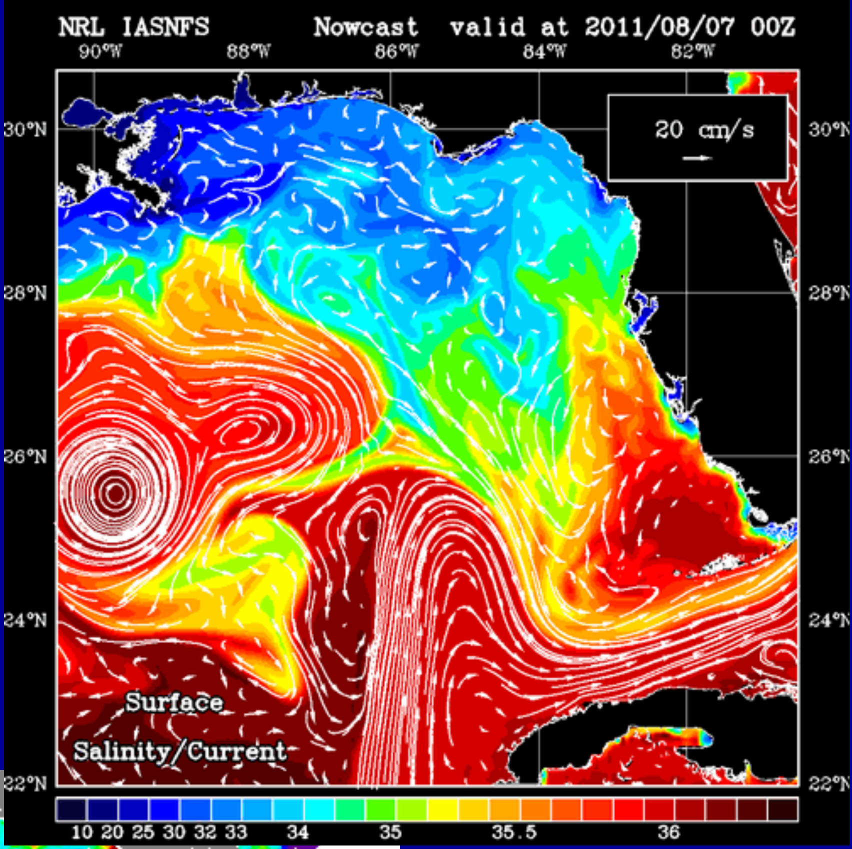
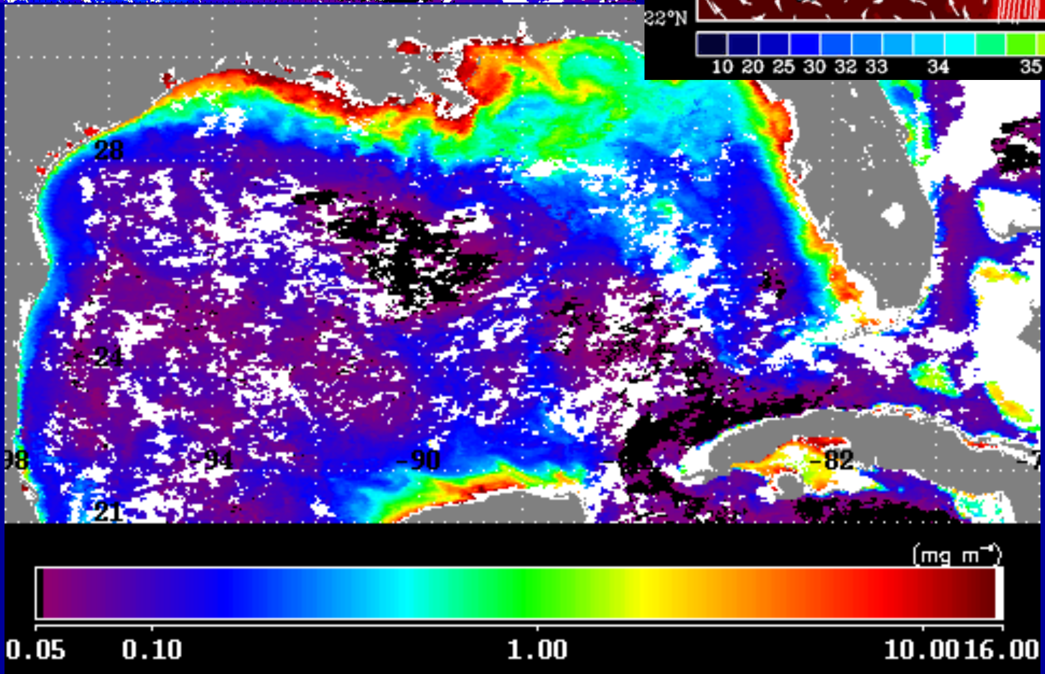
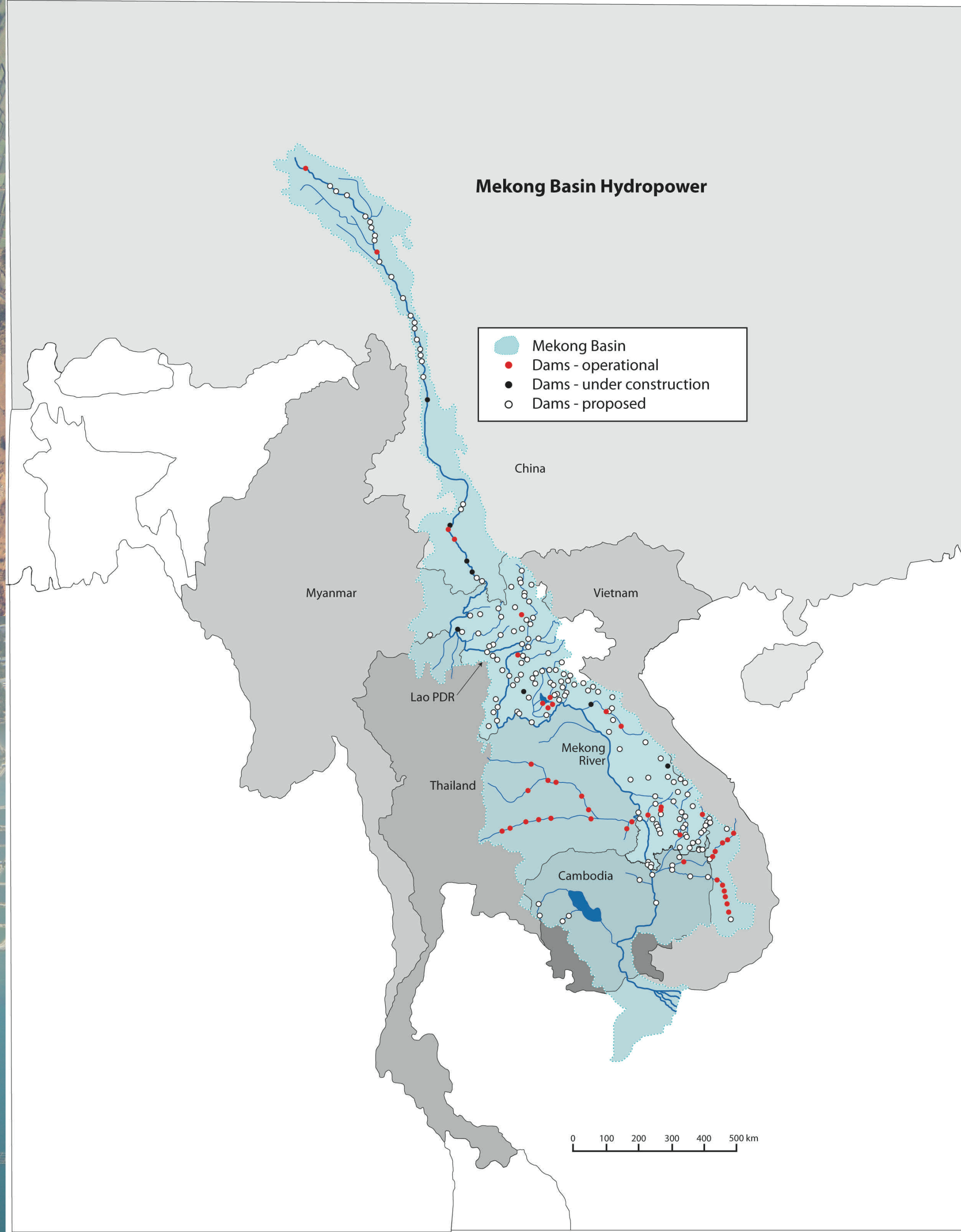


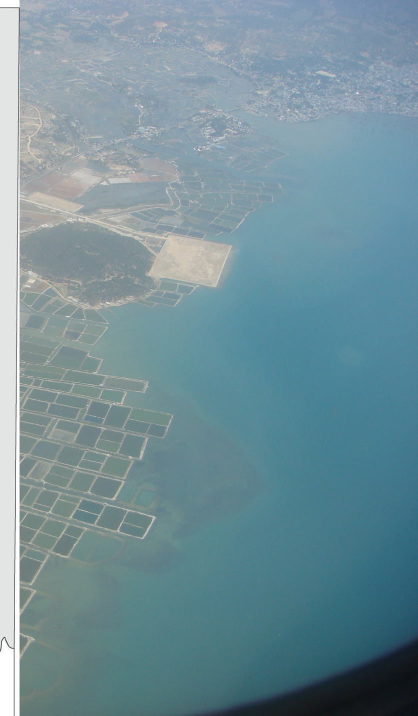
Fig. 2. Discharge of the Amazon River at Manacapurú; (**A**) discharge time series, 1903 to 1985; (**B**) deseasonalized Q′ hydrograph, 1903 to 1985. Arrows indicate occurrence of ENSO events.

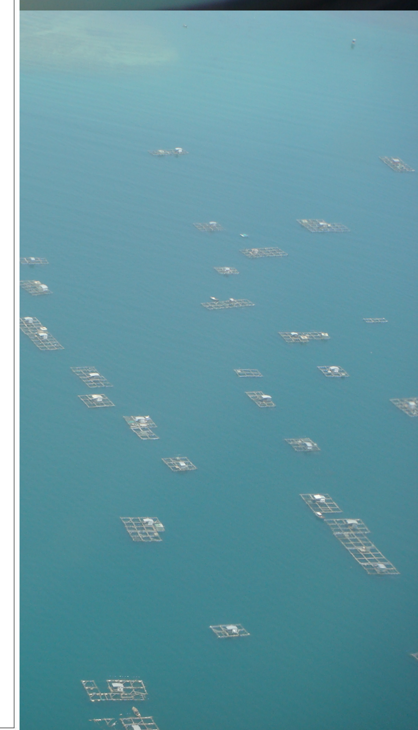

30
28
26
94
-92


NRL IASNFS Nowcast valid at 2011/08/07 00Z
90°W 88°W 86°W 84°W 82°W
30°N
28°N
26°N
24°N
22°N
20 cm/s
Surface
Salinity/Current
10 20 25 30 32 33 34 35 35.5 36


28
24
94
-90
-82
21
(mg m⁻³)
0.05 0.10 1.00 10.00 16.00


Mekong Basin Hydropower
Mekong Basin
Dams - operational
Dams - under construction
Dams - proposed
China
Myanmar
Vietnam
Lao PDR
Thailand
Mekong River
Cambodia
0 100 200 300 400 500 km






Sweet Jubilee

Mami Wata – a symbol of water systems science and engineering?

Who is Mami Wata?

- She is Mother Water, Mother of Fishes, goddess of oceans, rivers and pools, with sources in West and Central Africa and tributaries throughout the African Americas, from Bahia to Brooklyn. Usually shown as a half-woman, half-fish, she slips with ease between incompatible elements: water and air, tradition and modernity, this life and the next.