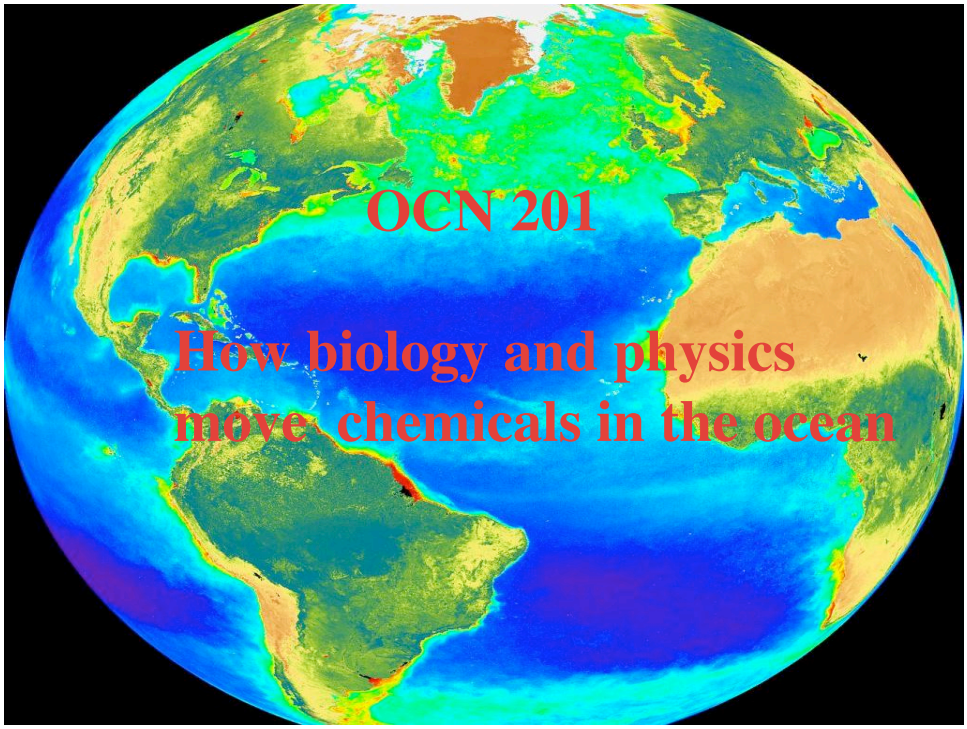


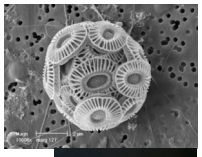
Chemical distributions, the roles of biology and physics

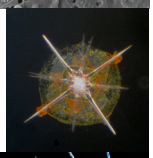
<u>The nutrients</u>

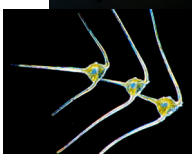
Phytoplankton grow by taking up dissolved chemicals from seawater

<u>Essential nutrients:</u> used for building soft tissue

Carbon:	as bicarbonate ion	HCO_3^-
Nitrogen:	as nitrate	NO_3^-
	as ammonium	NH_4^+
Phosphorous:	as phosphate	PO_4^{3-}







Skeleton building chemicals:

Calcium (Ca^{2+}): needed for calcareous shells
Silica (Si): needed for siliceous shells
Micronutrients: used in very small quantities:

Magnesium:	used in chlorophyll
Iron:	used in photosynthesis
Selenium	used in enzymes
Molybdenum	used in enzymes
etc.	

Other chemicals absorbed by plants for no known reason

Cadmium:	mistaken for PO_4^{3-}
Barium:	mistaken for Si?

Every chemical element on Earth is present in seawater

How many chemical elements are there?

A 50
B 100
C 150
D 200
E 250

Limiting nutrient

an essential nutrient that, if missing, limits growth in that water mass

is usually nitrate or phosphate (can be Fe in some places)

Sources of nutrients to the oceans

Carbon: from CO_2 in the atmosphere

Nitrogen: N_2 -gas can't be used by organisms

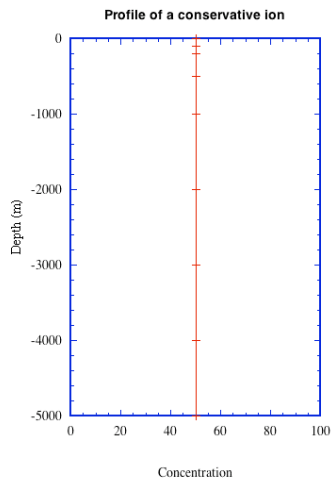
Nitrate and phosphate come from rivers

Where do you think the phosphate in rivers comes from?

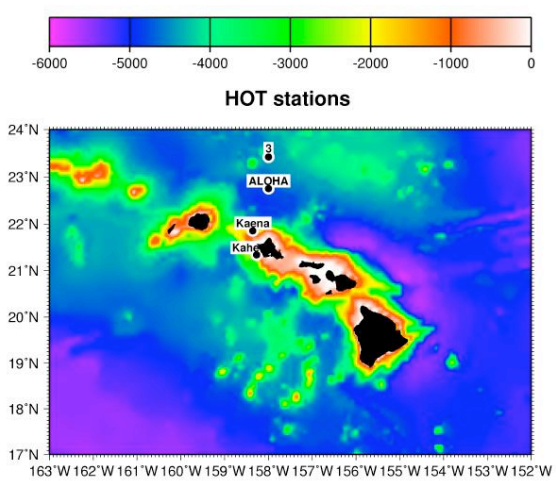
A Volcanoes
B Rock weathering
C Human activities
D Biological organisms

Vertical distributions

Residence times of nutrients long --20-70x ocean mixing time expect straight line profile e.g.

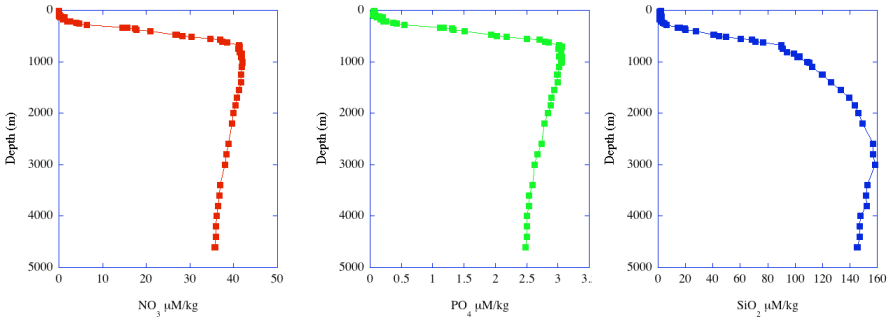


Hawaii Ocean Time-series (HOT)



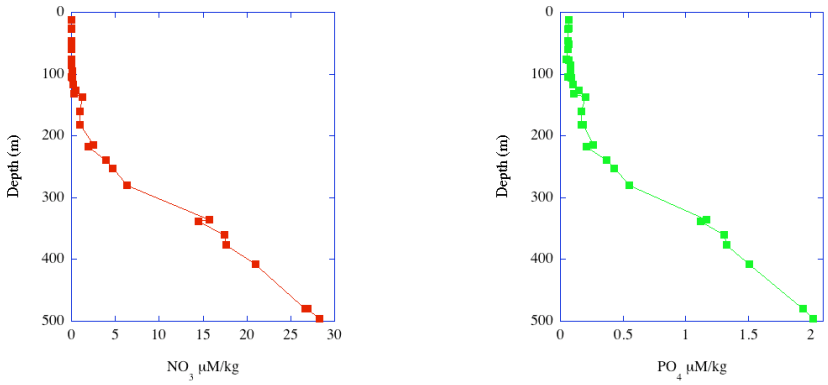
Actual distributions

-- very low in surface waters
-- increase to maximum at mid-depth
-- slight decrease to bottom



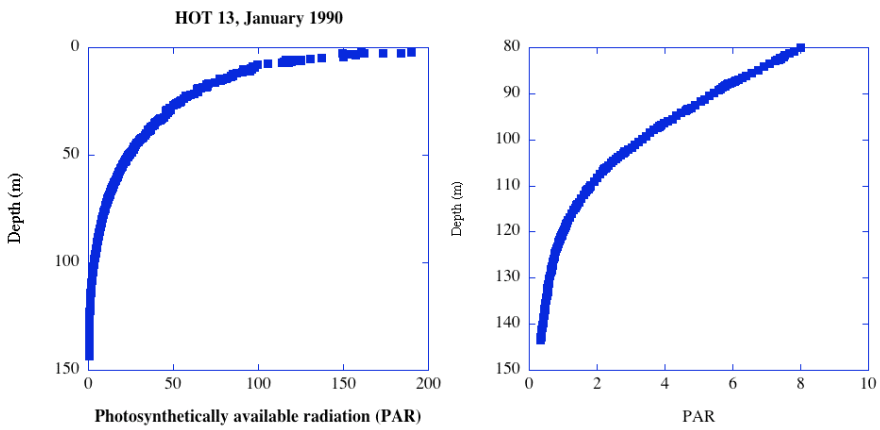
A closer look at the upper waters for
Nitrate and phosphate shows:

-- low to zero in upper 140 metres
-- one goes to zero--is the limiting nutrient



But why are the nutrients only removed to ~ 140m?

-- light level falls to < 1% at 140 m
light is limiting growth (varies from place to place)



In some places neither nitrate nor phosphate goes to zero

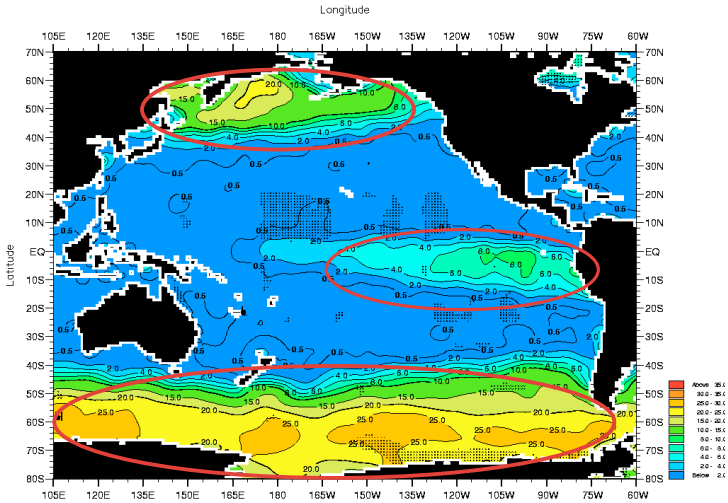
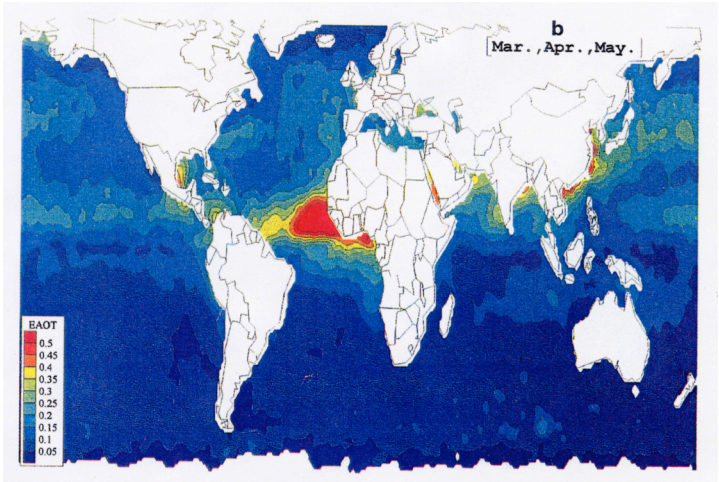


Fig. C2-1. Annual mean nitrate (μM) at the surface.
Minimum Value= 0.00 Maximum Value= 28.89

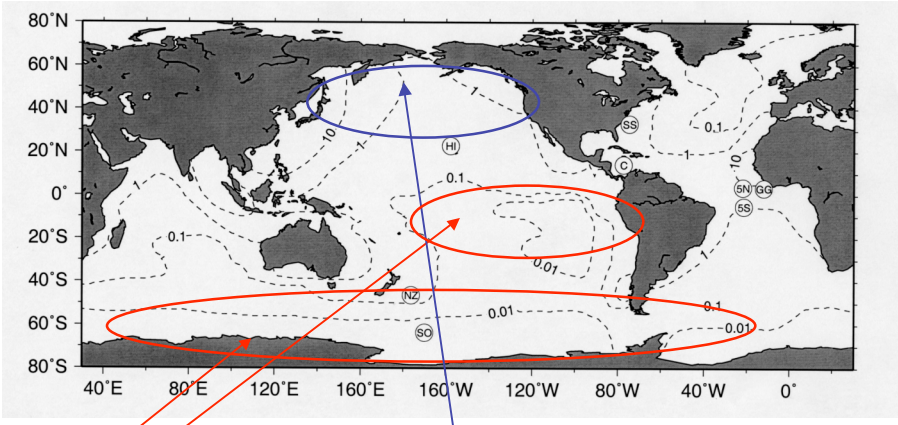
-- Fe may be limiting growth --but why these places?

Satellite imagery shows significant dust transport from the continents over the oceans



(Husar, Prospero and Stowe, 1997

Insufficient dust being delivered to the surface ocean is the likely cause

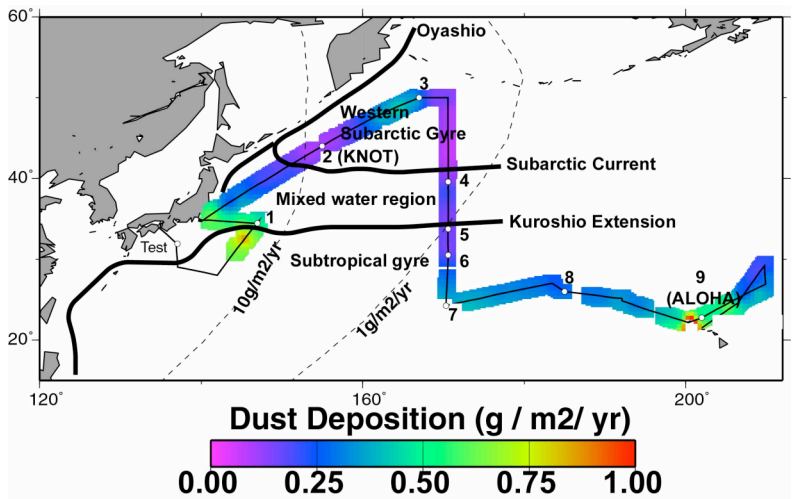


These HNLC regions mostly correspond to low dust deposition regions

HNLC = High Nutrient Low Chlorophyll

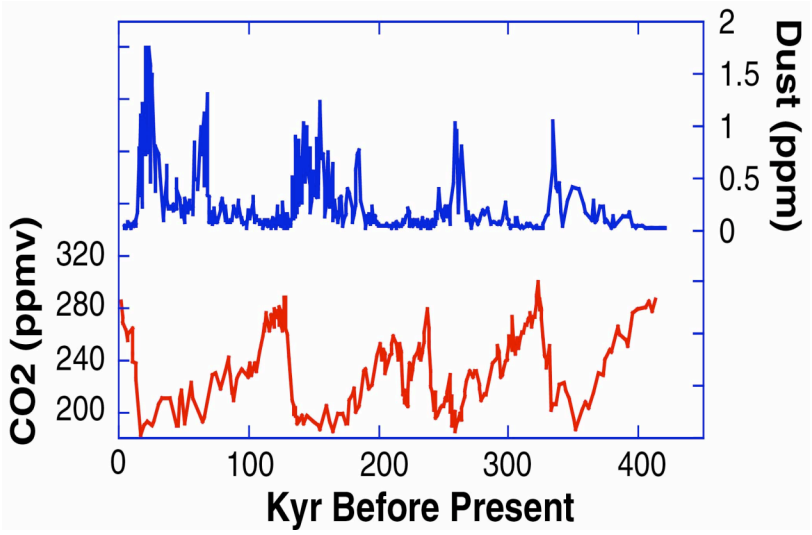
But not this one

Dust deposition maps are wrong in this region,
very little dust makes it to the surface ocean, despite the
large amount that comes off the deserts of Asia in the spring



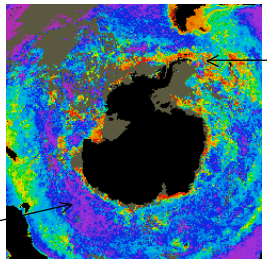
Hawaii gets dust every Spring from Chinese deserts

Paleo records suggest large historical variations in deposition--coincident with glacial-interglacial cycles



Vostok ice core record

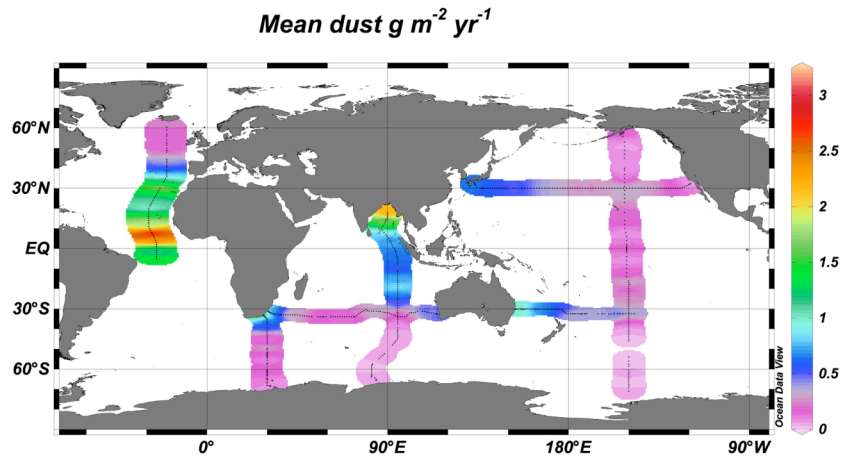
Around Antarctica there are large areas with only low production but some regions have quite high concentrations of phytoplankton



high

low

We can use surface water Al concentrations to calculate dust deposition



How much dust do you think is deposited on the surface ocean each year?

A 10 tons
B 300 tons
C 5,000 tons
D 10 million tons
E more!

Recycling and removal soft tissues

Organisms can remove phosphate and nitrate completely from surface waters

How are nutrients restored so life can continue?

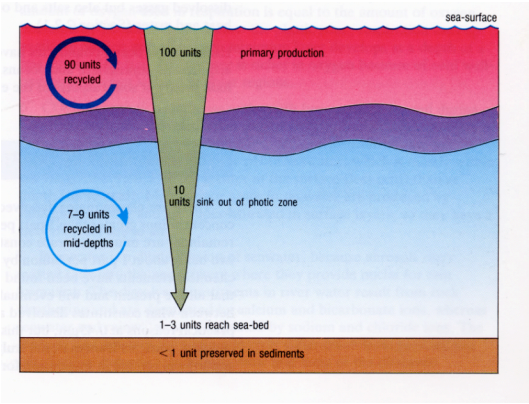
Recycling --90% of plants die and decay in surface layer

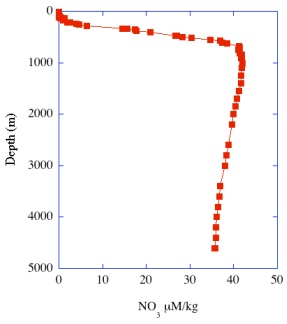
Upwelling -- vertical mixing of nutrient-rich deep water

What happens to the rest?

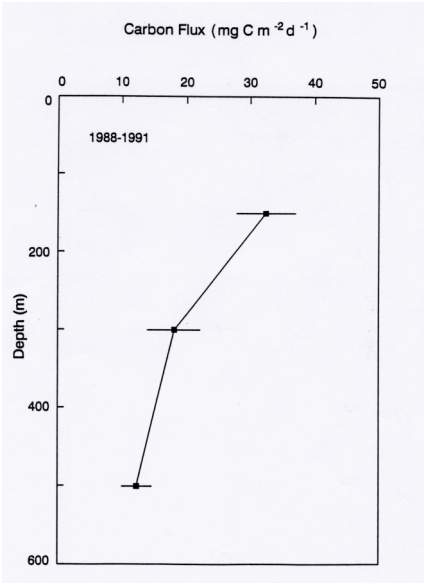
Dead organic matter sinks into the deep ocean

Most recycled in deeper water-hence maximum in nitrate and phosphate
Little (but some) gets to the seafloor
Organic carbon is food for organisms so is not wasted





Amount of carbon caught in a floating sediment trap at the HOT site also decreases with depth due to remineralisation



How much biological material (organic C) do you think is produced in the surface oceans every year?

A 1 thousand tons
B 50 thousand tons
C 1million tons
D 1 billion tons
E 50 billion tons

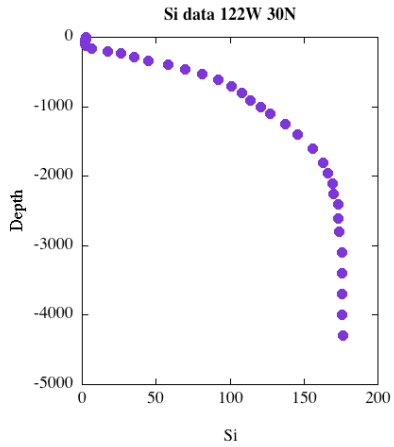
Recycling and removal -skeletons and hard parts

Not eaten -- not an energy source

Just dissolve slowly, mostly at the bottom

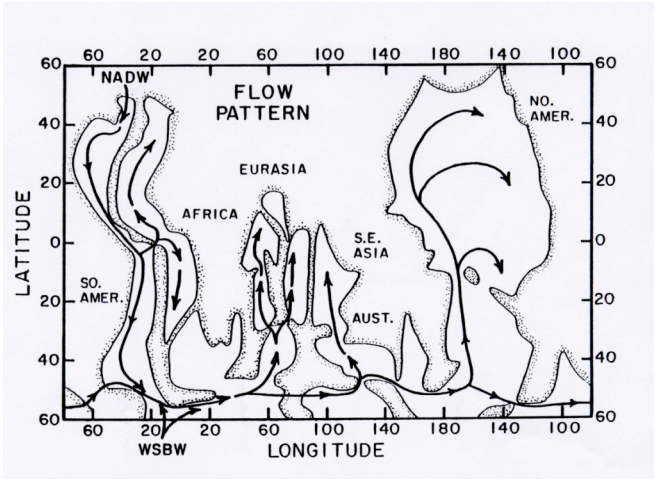
Some get buried in the sediments -- the calcareous and siliceous oozes

Paleo-recorders of ocean chemistry

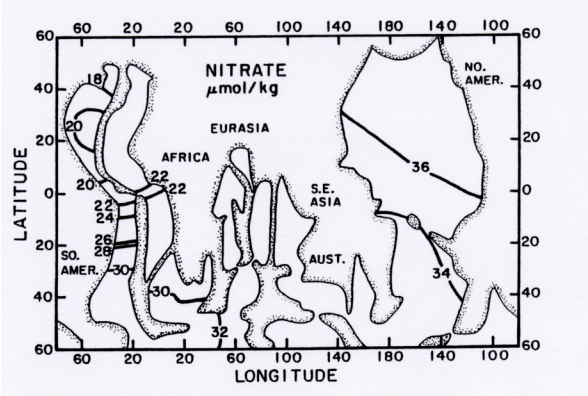


Deep water flows and the role of physics

Deep water flows from North Atlantic to Pacific



Nitrate (and phosphate) accumulate along the flow path



Silicate increases even more, because it dissolves at the bottom

-- can tell which way the ocean flows