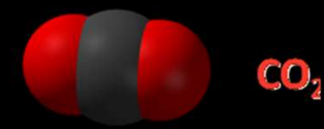
Class-10b
Carbon Sequestration-2

30th October, 2022

Carbon sequestration



Biological processes – Azolla (32.54 metric tonnes CO_2/ha/year after 18 days growth with 10% initial cover of *A. filiculoides*)

Peat Production (store about 455 billion tonnes of carbon)

Reforestation

Agriculture – 1500 gigatons of carbon in soil

1. Reducing emissions

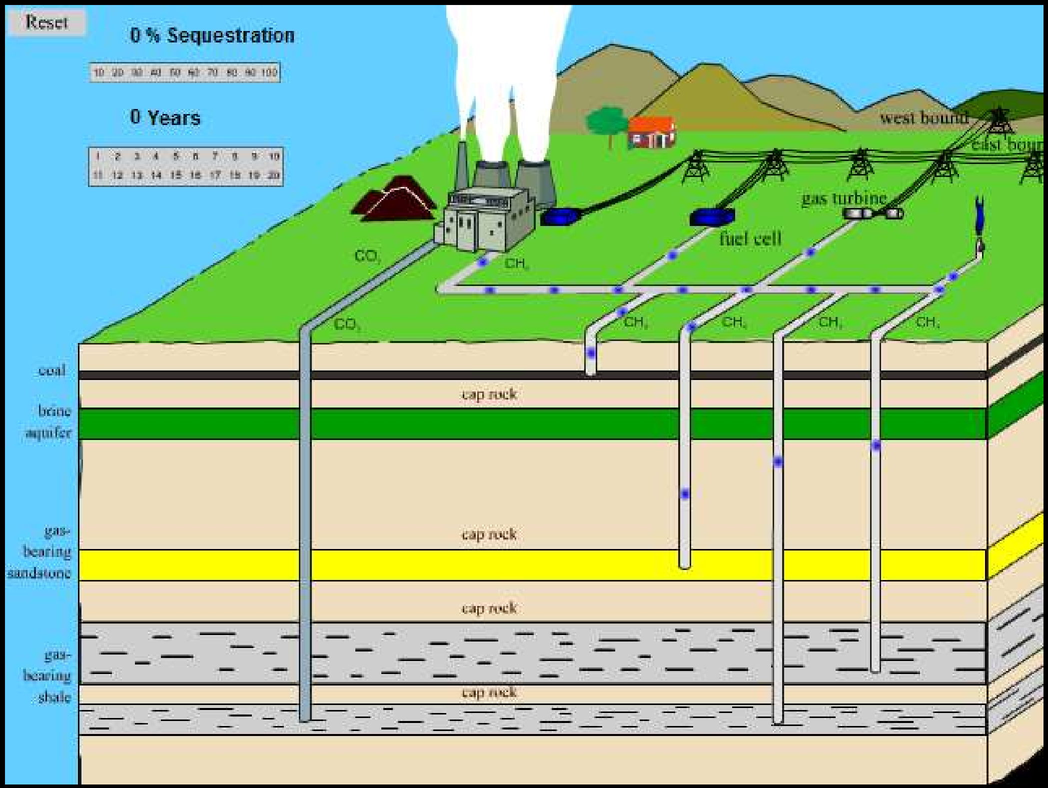
– Accurate use of fertilizers, Less soil disturbances
better irrigation,
Replacing more energy intensive farming operations
Incorporate post harvest residues

2. Enhancing carbon removal

use of cover crops – grass and weeds – planting seasons
Concentrate livestock in small paddocks for days at a time
Cover bare paddocks with hay or dead vegetation – soil moisture
Restore degraded lands

Geological Sequestration

- *Storing of CO_2 underground in rock formations able to retain large amounts of CO_2 over a long time period*
  - *Held in small pore spaces (have held oil and nat. gas for millions of years)*



Midwest Geological Sequestration Consortium (Illinois Basin)

assess geological carbon sequestration options in the 60,000 square mile Illinois Basin (Within the Basin are deep, noneconomic coal resources, numerous mature oil fields and deep saline rock formations with potential to store CO2)

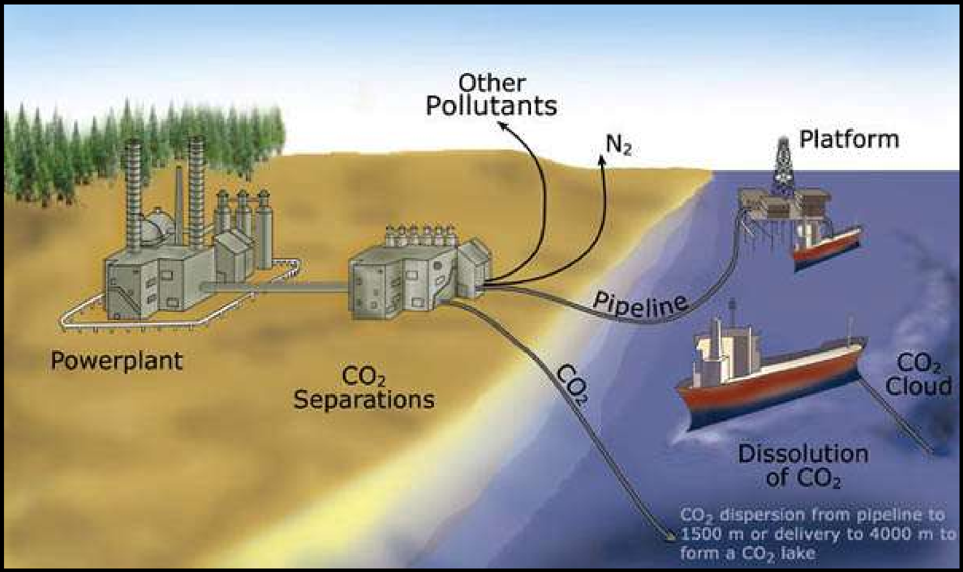
Feb 2009: Successfully completed 8,000 ft deep injection well

By 2013, a total of one million metric tons of CO2(roughly the annual emissions of 220,000 automobiles) is expected to be stored within the formation.

Ocean Sequestration

- "Carbon is naturally stored in the ocean via two pumps, solubility and biological,
- There are analogous man-made methods, ***direct injection and ocean fertilization***, respectively.
- Eventually equilibrium between the ocean and the atmosphere will be reached with or without human intervention and 80% of the carbon will remain in the ocean.
- The rational behind ocean sequestration is simply to speed up the natural process."

- 1/3 of CO2 emitted a year already enters the ocean
- Ocean has 50 times more carbon than the atmosphere



1988

Iron deficiency limits phytoplankton growth in the north-east Pacific subarctic

John H. Martin & Steve E. Fitzwater

Moss Landing Marine Laboratories, Moss Landing, California 95039, USA

An interesting oceanographic problem concerns the excess major plant nutrients (PO_4, NO_3, SiO_3) occurring in offshore surface waters of the Antarctic[1–3] and north-east Pacific subarctic Oceans[4]. In a previous study[5], we presented indirect evidence suggesting that inadequate Fe input was responsible for this limitation of growth; recently we had the opportunity to seek direct evidence for this hypothesis in the north-east Pacific subarctic. We report here that the addition of nmol amounts of dissolved iron resulted in the nearly complete utilization of excess NO_3, whereas in the controls—without added Fe—only 25% of the available NO_3 was used. We also observed that the amounts of chlorophyll in the phytoplankton increased in proportion to the Fe added. We conclude that Fe deficiency is limiting phytoplankton growth in these major-nutrient-rich waters.

The "Iron Hypothesis" gains prominence

Nature 331 p341-343 1988

1990

First surge of publicity

SCIENCE/TECHNOLOGY

Adding Iron to Ocean Makes Waves As Way To Cut Greenhouse CO_2

Approach would increase biological activity and thus CO_2 uptake, but some contend it could impede policies to reduce CO_2 emissions

Rudy Baum, C&EN San Francisco

tant of the greenhouse gases, which also include methane and chlorofluorocarbons (C&EN, March 13, 1989, page 25). A significant increase in the concentration of CO_2 in the atmosphere since the beginning of the Industrial Revolution, because of burning fossil fuels and, more recently, widespread deforestation, has led to fears of possibly dramatic and, at least in the short term, large-

es were primarily responsible for the decrease in CO_2 during ice ages, and several ocean/atmosphere models have been developed in the past decade to account for the change. These models incorporate the notion of a "biological pump"—photosynthetic uptake of CO_2 by the chlorophyll-containing marine microorganisms known as phytoplankton, and subsequent removal of carbon

Professor touts sea flora to curb global warming

By Kirby Moss
American-Statesman Staff

For two years, a University of

tilizers such as phosphate, nitrate and iron, Heller said.

Although he does no research, he has brought together scientists

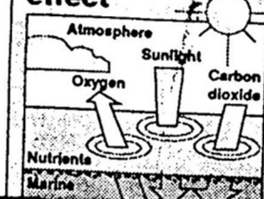
Algae seen as cure for warming

Continued from B1

lieve, as does Heller, that pumping iron particles into the water could yield an underwater forest.

And if that experiment were suc-

Pumping up algae to fight greenhouse effect



OPINION

Manipulation of ocean dangerous

By Rodney M. Fujita, Ph.D.
Special to the American-Statesman

An Aug. 7 *American-Statesman* story ("Professor touts sea flora to curb global warming") discussed a proposal that the oceans be fertilized with iron and other nutrients in order to stimulate enormous blooms of marine plants. Professor Adam Heller and some other scientists believe that this is a promising way to remove carbon dioxide from the atmosphere and thus limit the rate and extent of global warming due to the greenhouse effect. This proposal and Heller's comments raise a number of environmental concerns.

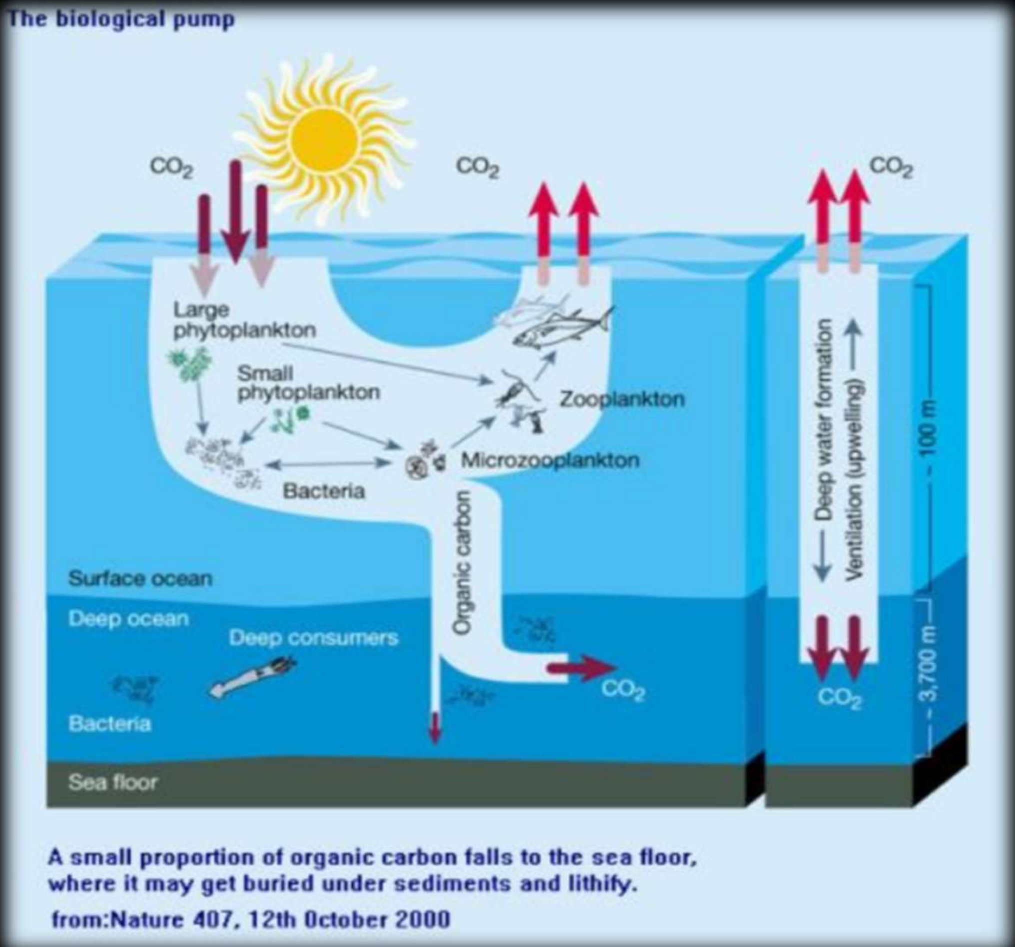
PUBLIC FORUM

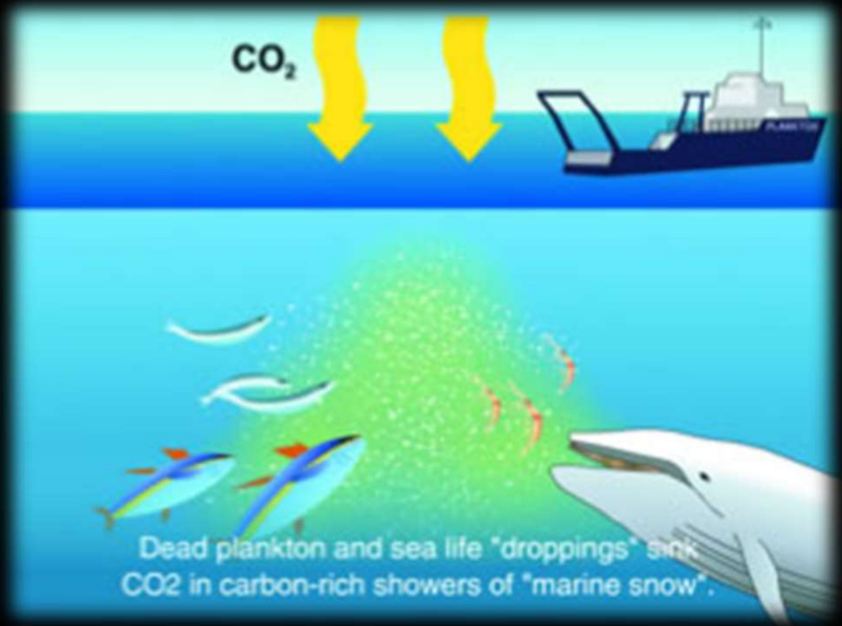
cies must be eaten by larger animals that produce heavy fecal pellets, which transport the carbon to the deep sea. Fertilization can drastically change the kinds of plants that grow in the sea, with no guarantee that they will be the right kinds. Changes in plant species can also result in changes in animal populations, with the result that the large plant populations stimulated by fertilization might remain in the surface waters.

As they are eaten and decompose, the carbon that they took up will be released into the water and into the atmosphere. These changes in species composition would have important and unpredictable effects on marine ecosystems.

Heller also claims that because humans have disrupted natural systems, it does not make sense to treat them as pristine. Although it is regrettably true that pristine natural systems are rare, this does not mean that human disruptions can always be corrected with more human intervention. Prevention of pollution is always more certain to protect the environment and the quality of human life than are attempts to manage pollutants once they have been discharged. The root causes of global warming are fossil fuel combustion and the destruction of temperate and tropical forests. These human activities are

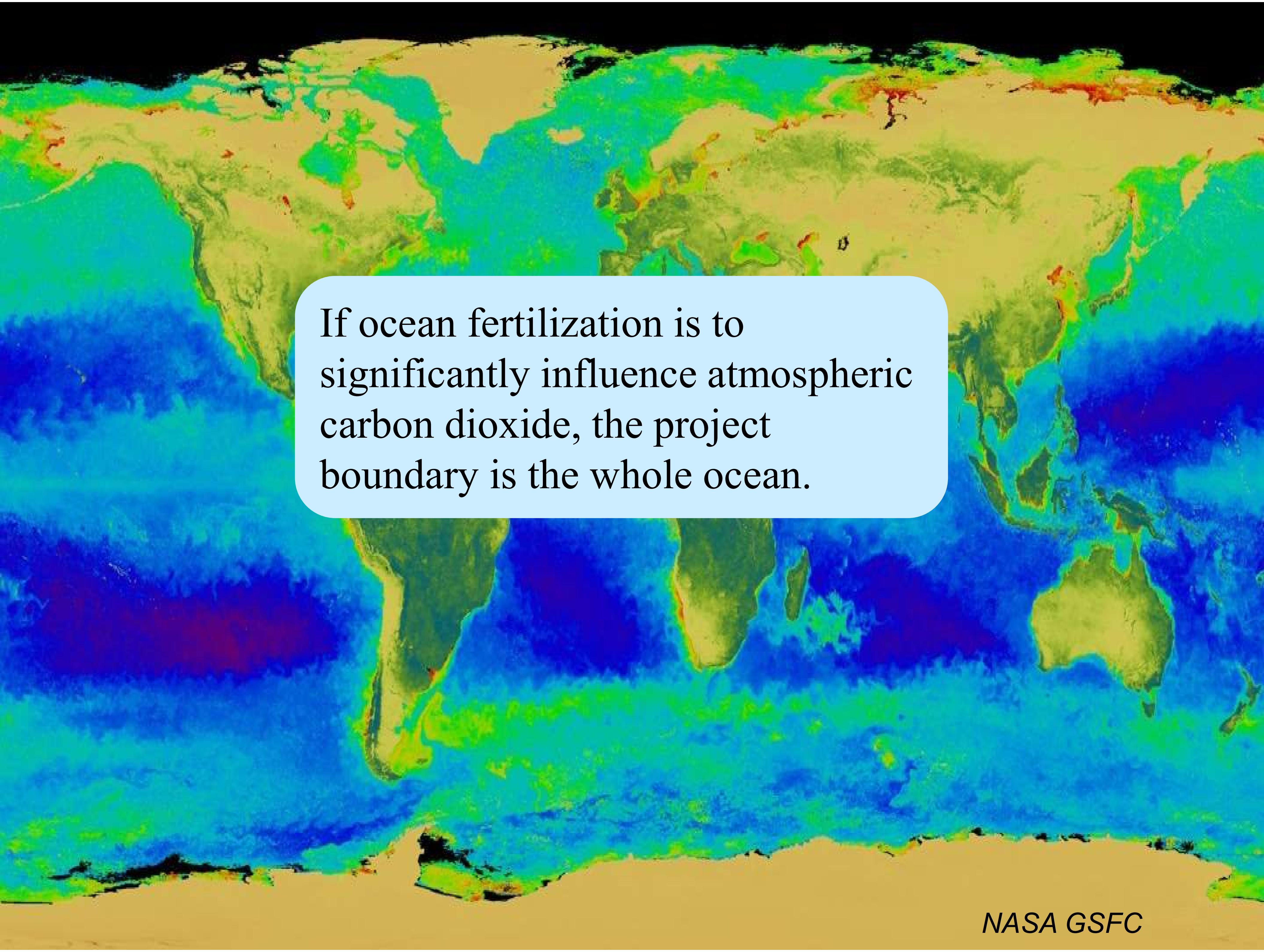
Ocean Iron Fertilization?



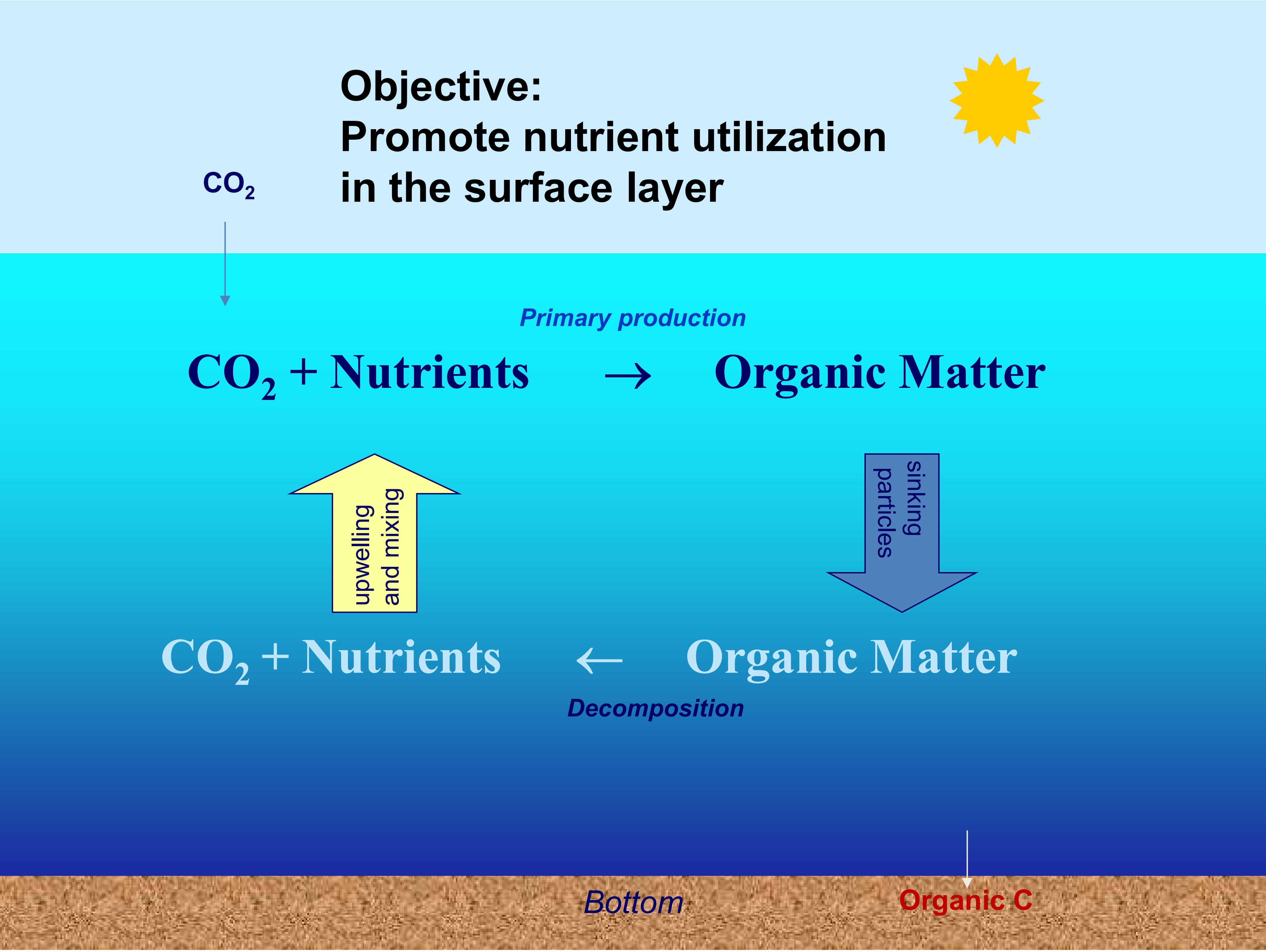


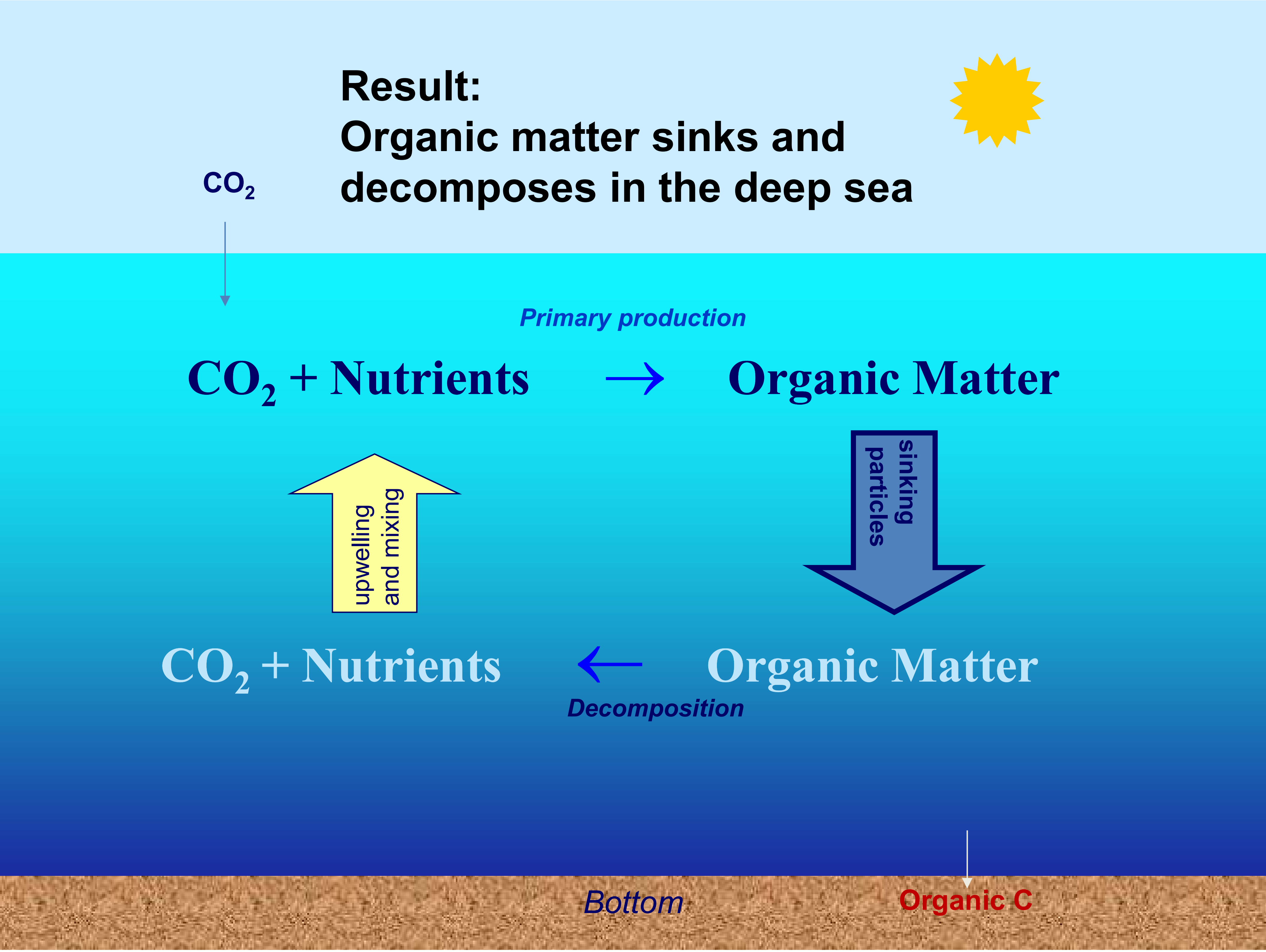
Urea fertilization

*In 2007, Sydney-based ONC (*Ocean Nourishment Corporation) *completed an experiment involving 1 tonne of nitrogen in the Sulu Sea off the Philippines*



If ocean fertilization is to significantly influence atmospheric carbon dioxide, the project boundary is the whole ocean.


Objective:
Promote nutrient utilization
in the surface layer
CO_2
Primary production
CO_2 + Nutrients → Organic Matter
upwelling
and mixing
sinking
particles
CO_2 + Nutrients ← Organic Matter
Decomposition
Bottom
Organic C



Result:
Organic matter sinks and
decomposes in the deep sea
CO2
Primary production
CO2 + Nutrients → Organic Matter
upwelling
and mixing
sinking
particles
CO2 + Nutrients ← Organic Matter
Decomposition
Bottom
Organic C

The proposed plan for enrichment of the Sulu Sea, Philippines, a region of rich marine biodiversity, with thousands of tonnes of urea in order to stimulate algal blooms and sequester carbon is flawed for multiple reasons. Urea is preferentially used as a nitrogen source by some cyanobacteria and dinoflagellates, many of which are neutrally or positively buoyant. Biological pumps to the deep sea are classically leaky, and the inefficient burial of new biomass makes the estimation of a net loss of carbon from the atmosphere questionable at best. The potential for growth of toxic dinoflagellates is also high, as many grow well on urea and some even increase their toxicity when grown on urea. Many toxic dinoflagellates form cysts which can settle to the sediment and germinate in subsequent years, forming new blooms even without further fertilization. If large-scale blooms do occur, it is likely that they will contribute to hypoxia in the bottom waters upon decomposition. Lastly, urea production requires fossil fuel usage, further limiting the potential for net carbon sequestration. The environmental and economic impacts are potentially great and need to be rigorously assessed.

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Proposition:

Ocean fertilization for carbon offsets cannot be verified so it is not a viable technology for climate mitigation.

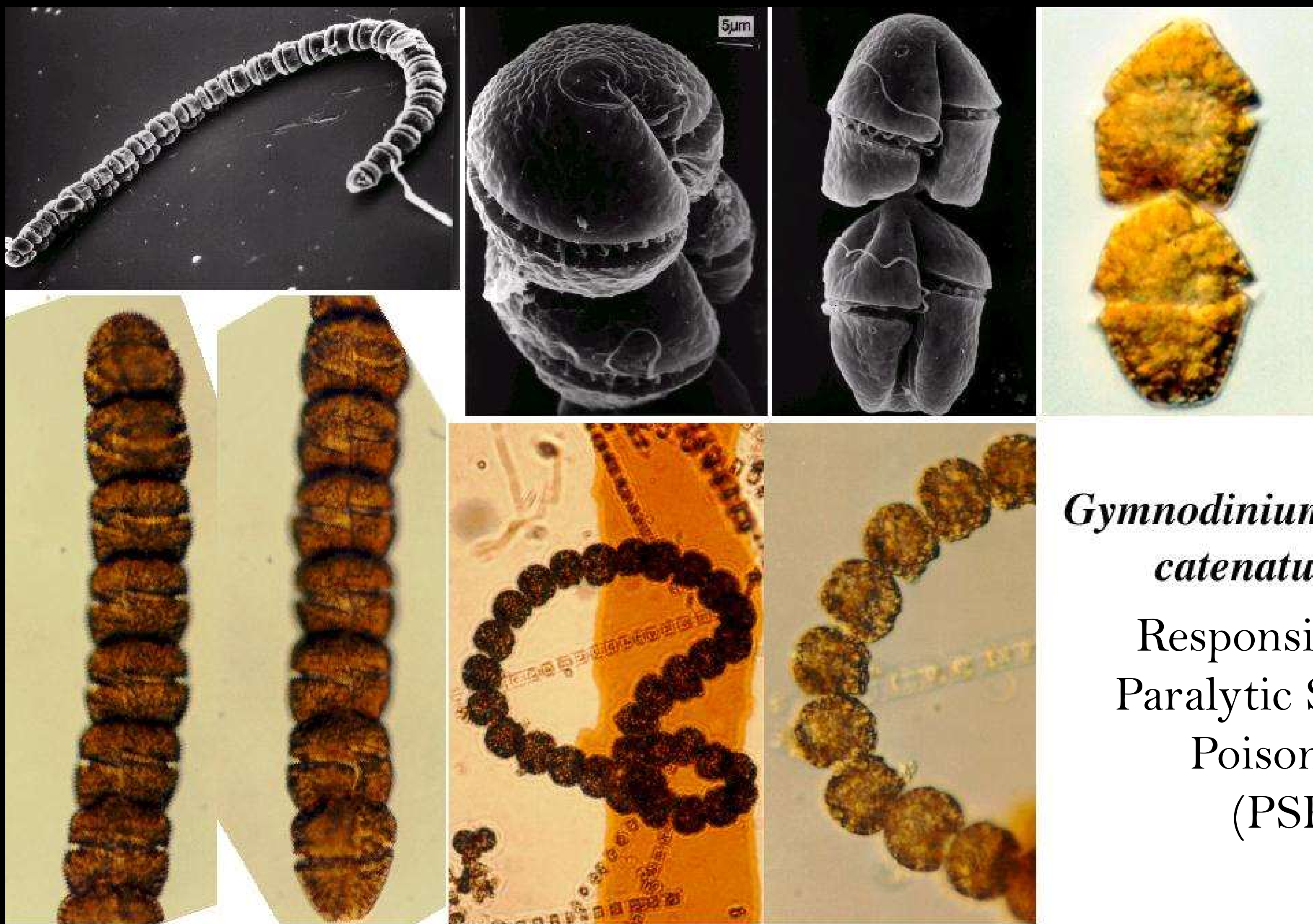
Consequences of fertilizing OS

Few Diatoms, lots of flagellates.
Flagellates were stimulated to grow
- *Respire at > 90% of carbon*
- *Produce GHG that are more destructive than CO_2*

The resulting phytoplankton are a bit suspect

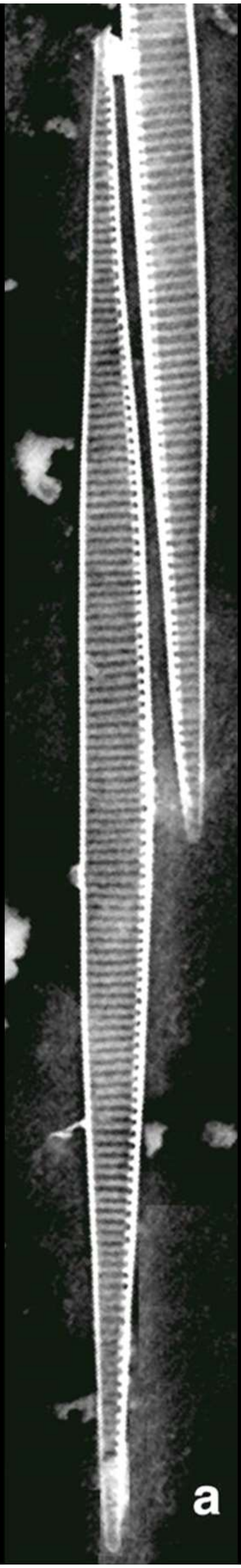
HARMFUL ALGAL BLOOMS

One flagellate that dominated is ....



Gymnodinium catenatum

Responsible for
Paralytic Shellfish
Poisoning
(PSP)



Another was Pseudo-nitzschia …

a toxigenic diatom which produces domoic acid - responsible for Amnesiac Shellfish poisoning (ASP) in local waters

Intended consequences of large-scale fertilization

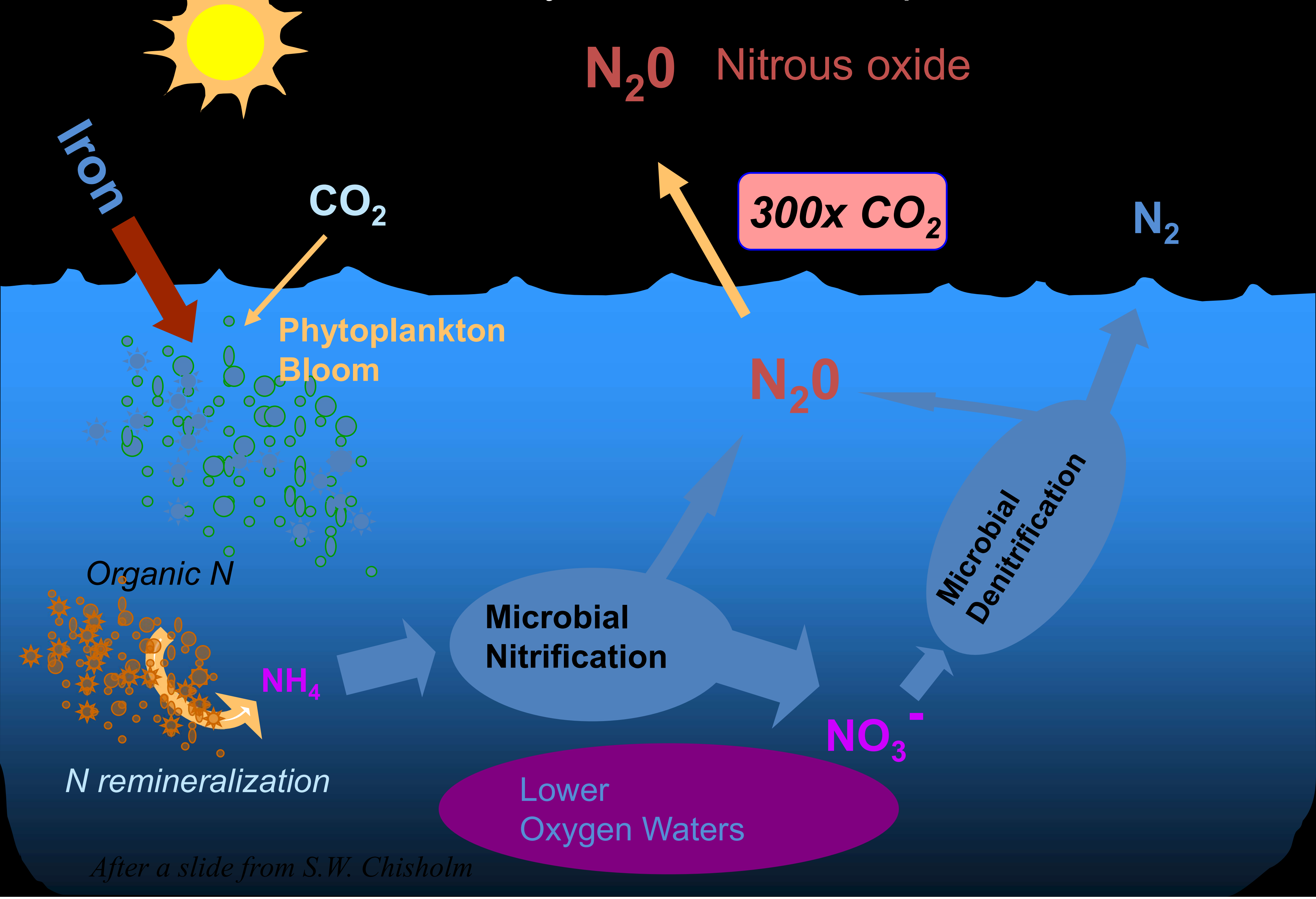
Increased deep ocean concentrations of CO_2, N and P

Decreased deep ocean concentrations of O_2

Decreased surface layer concentrations and ratios of N, P and Si

IMAGE: *NASA Goddard Space Flight Center*

Secondary effects must be quantified



Three Central Questions

What are the effects of large scale ocean fertilization?

Fundamental alterations of marine ecosystems and biogeochemical cycles

Can they be quantified with acceptable accuracy?

No

Can negative outcomes be attributed to individual applications
and remediated?

No

Ocean Acidification

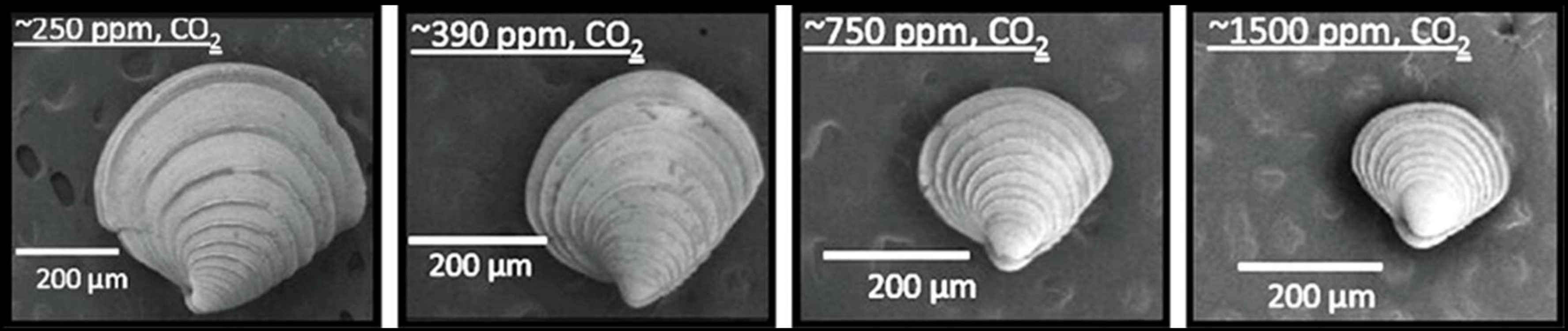
Decrease in ocean pH over decades or more that is caused primarily by uptake of CO_2 from the atmosphere

This is causing global ocean chemistry to change more quickly than ocean systems can handle

Since the Industrial Revolution, the global average pH of the surface ocean has decreased by 0.11, which corresponds to approximately a 30% increase in the hydrogen ion concentration

Why be concerned with a small change in pH?

Issues with lower pH



Shells dissolving in lab-simulated ocean acidification conditions

Changes in ocean chemistry can affect the behavior of non-calcifying organisms as well Ex: larval clownfish

Storage of CO_2 in coal beds

- *Coal usually contains methane that is adsorbed onto the surfaces of micro-pores*
- *This methane is call coal-bed methane, and there can be up to 0.76 GJ methane/tonne of coal (compared to a heating value of coal itself of 32 GJ/t)*
- *CO_2 has a greater affinity for coal, so injection of CO_2 into coal beds will displace methane while being stored in the coal*
- *CO_2 molecules are adsorbed for every CH_4 molecule displaced*
- *The methane would be collected and used as an energy source*

Storage in coal beds

- *A given mass of methane is 72 times as effective as CO_2 in warming the climate over a 25-year time span, so if only a small fraction of displaced methane leaks to the atmosphere rather than being captured and burnt (for energy), the global warming effect would exceed the benefit from capturing and storing CO_2*

- *Injection of CO_2 and capture of released CH_4 would require an dense grid of pipes on the ground over the coal beds that are being used*

Physical processes

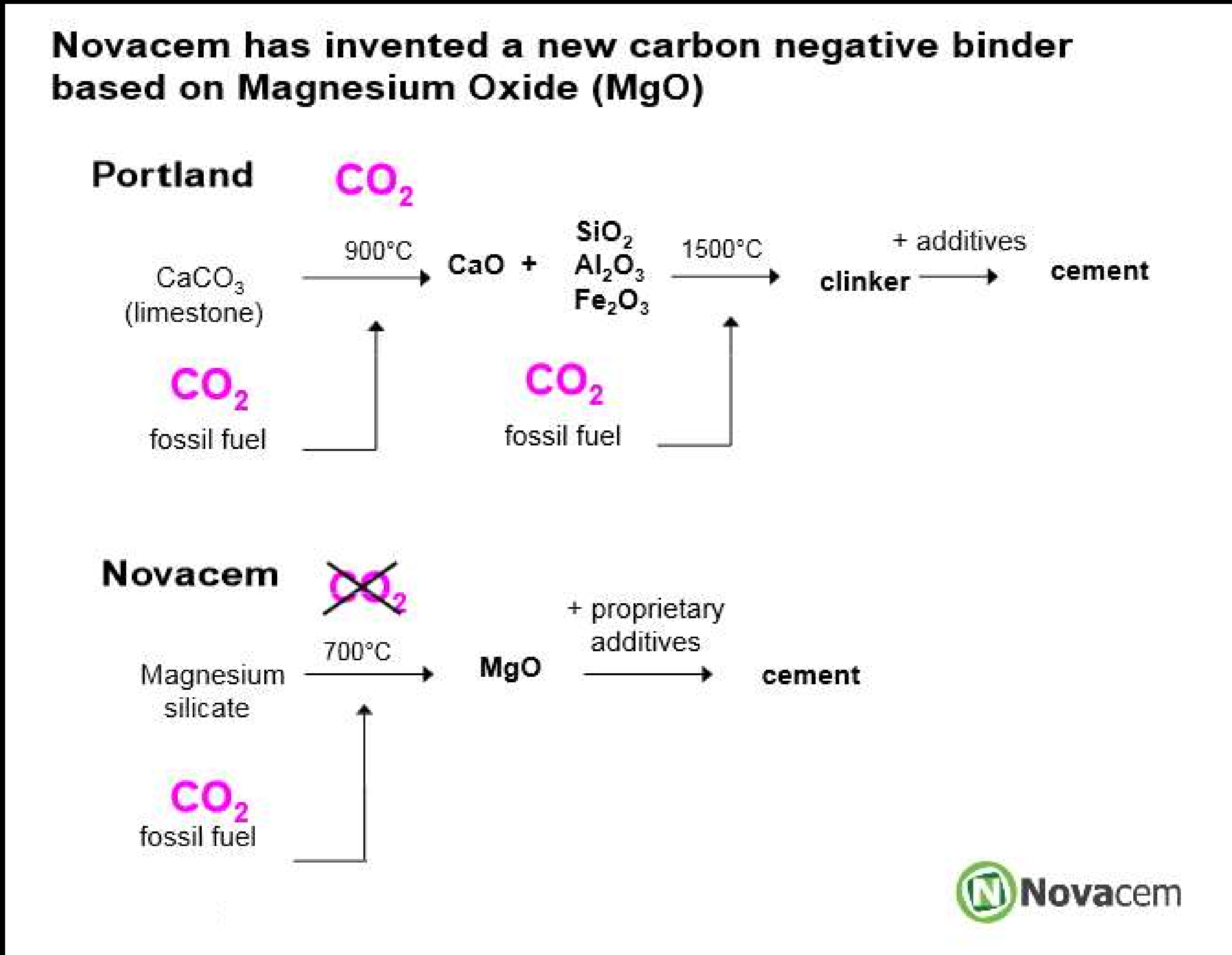
Burial, Ocean storage

Chemical processes

Reacting CO_2 with abundantly available metal oxides–either magnesium oxide (MgO) or calcium oxide (CaO)–to form stable carbonates

Industrial use –
EcoCement
Novacem,

Earthen Oxide	Percent of Crust	Carbonate
SiO_2	59.71	
Al_2O_3	15.41	
CaO	4.90	$CaCO_3$
MgO	4.36	$MgCO_3$
Na_2O	3.55	Na_2CO_3
FeO	3.52	$FeCO_3$
K_2O	2.80	K_2CO_3
Fe_2O_3	2.63	$FeCO_3$
	21.76	All Carbonates



The big win is that if Novacem completely replaced Portland, cement would absorb about 5% of man-made CO 2 emissions rather than generate 5% (http://www3.imperial.ac.uk/pls/portallive/docs/1/50161701.PDF)

Offset Greenhouse Gas Emissions?

At the global level, the IPCC Third Assessment Report estimates that ~100 billion metric tons of carbon over the next 50 years could be sequestered through forest preservation, tree planting and improved agricultural management.

Offset 10-20% of estimated fossil fuel emissions

Carbon Sequestration is not yet viable at a commercial level

Small scale projects demonstrated (lab experiments) but CS is still a developing technology

Concern with injecting CO2 into ground or ocean because fear of leaks into water table or escape of CO2 into a massive bubble that can potentially suffocate humans and animals

https://netl.doe.gov/sites/default/files/netl-file/1100-Greenberg-2019-Pittsburgh-MGSC.pdf

https://www.sciencedirect.com/science/article/pii/S1876610211004486

https://www.youtube.com/watch?v=DeKUlEOJ0p0

https://www.youtube.com/watch?v=SAf5Xdf98tA

https://www.science.org.au/curious/earth-environment/ocean-acidification

https://www.pmel.noaa.gov/co2/story/Ocean+Acidification's+impact+on+oysters+and+other+shellfish

https://www.nasa.gov/feature/goddard/2016/carbon-dioxide-fertilization-greening-earth