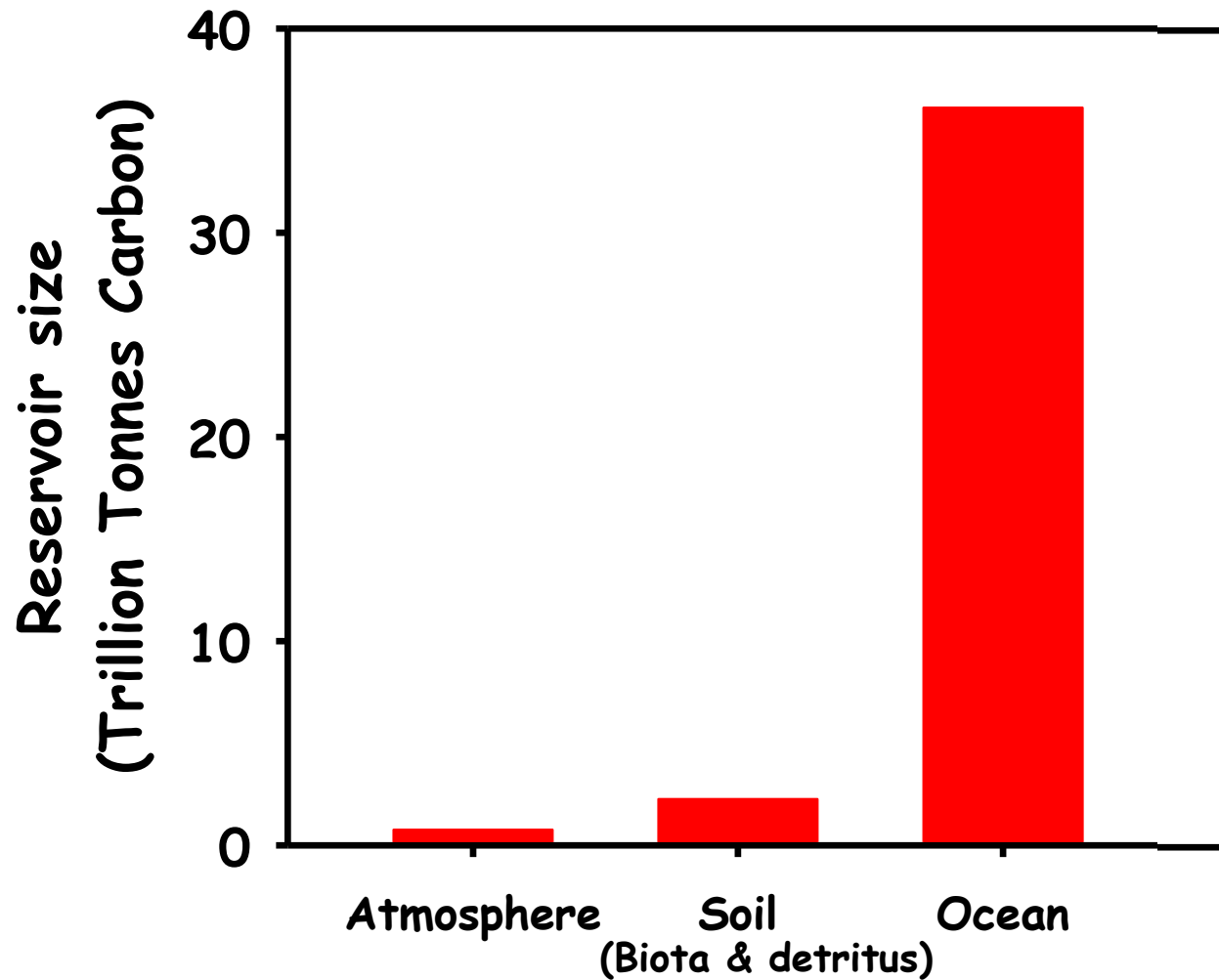


Geoengineering:

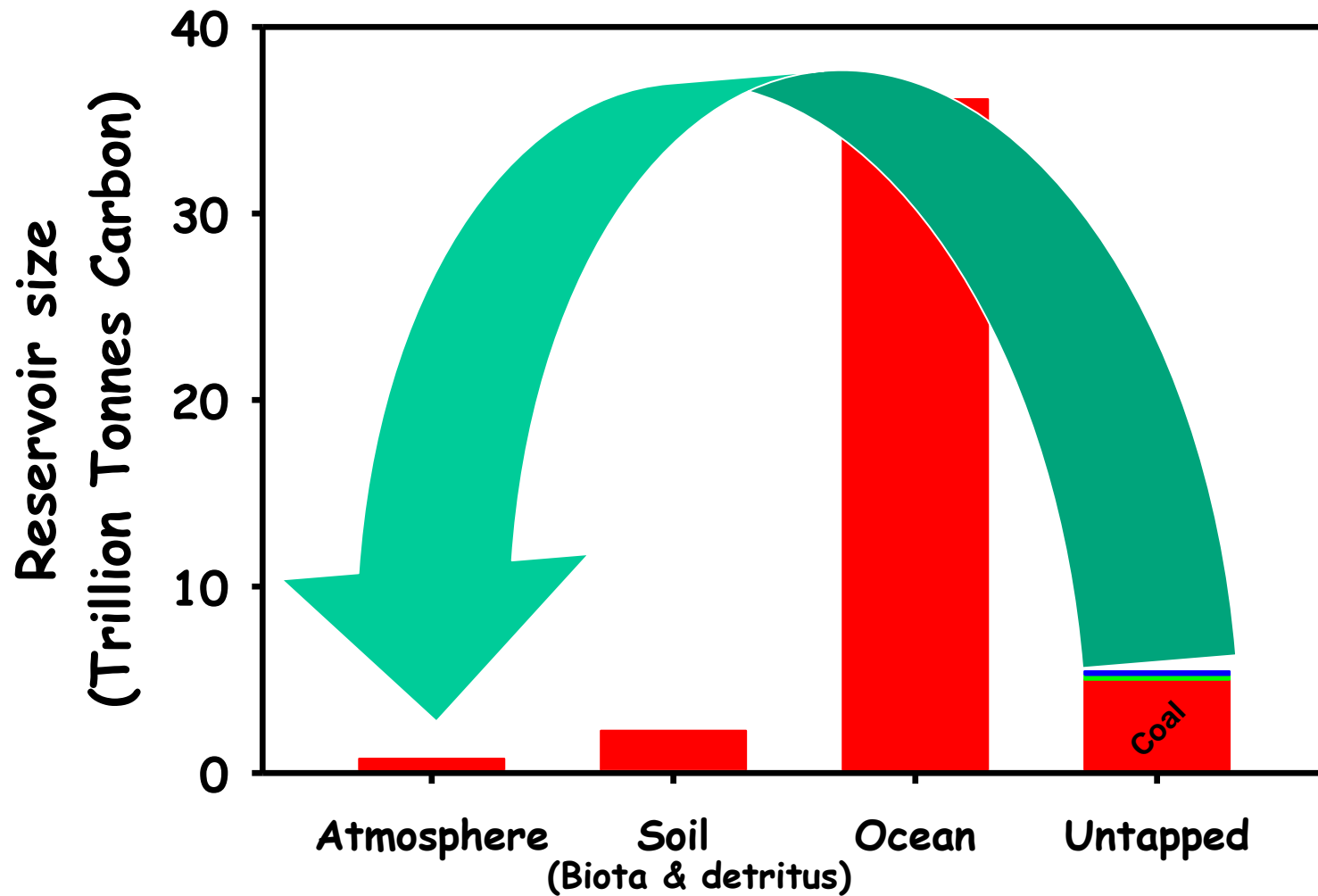
Is this a viable approach to reduce global warming?

Richard Lampitt & Andrew Watson

National Oceanography Centre & Exeter University



Global reservoirs of carbon



Global reservoirs of carbon

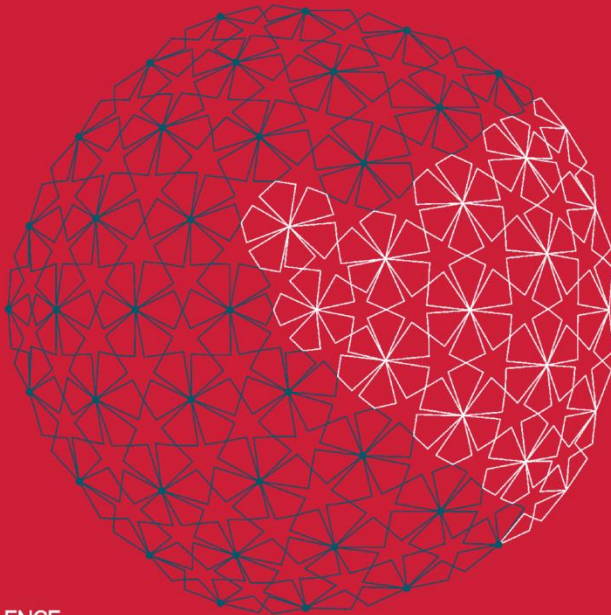
Geoengineering :

Defined by Royal Society as the deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change.

Geoengineering the climate

Science, governance and uncertainty

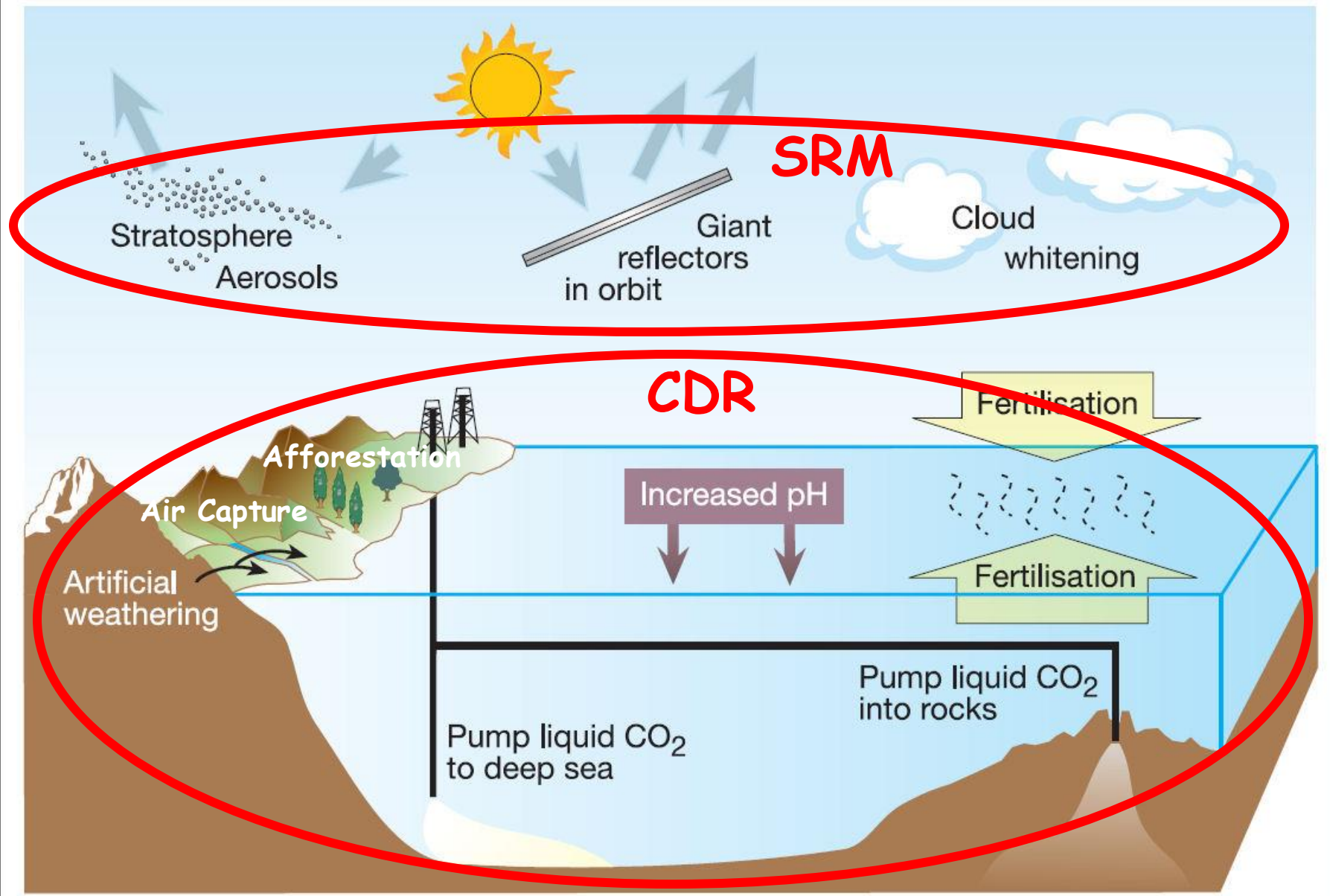
September 2009



THE ROYAL SOCIETY

THE BIPARTISAN POLICY CENTER'S
**TASK FORCE ON CLIMATE
REMEDATION RESEARCH**

Geoengineering: A national strategic plan for research on the potential effectiveness, feasibility, and consequences of climate remediation technologies



SRM

Stratosphere
Aerosols

Giant
reflectors
in orbit

Cloud
whitening

CDR

Fertilisation

Afforestation

Air Capture

Increased pH

Fertilisation

Artificial
weathering

Pump liquid CO₂
to deep sea

Pump liquid CO₂
into rocks

Do we have a good track record of environmental manipulation?



The Cane Toad

Are we good at finding solutions?



The effect of horses in New York 1887

For all schemes proposed:

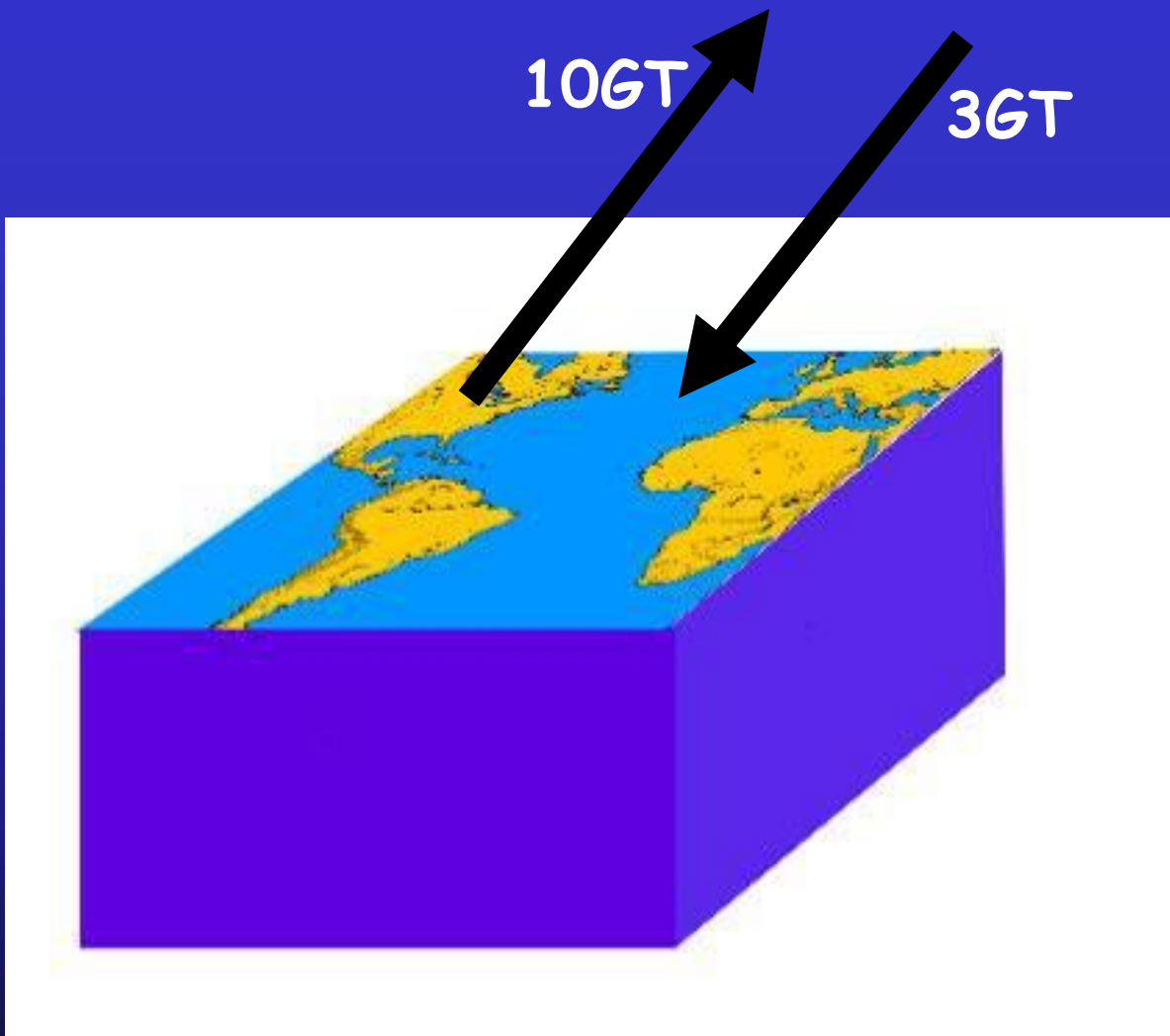
1: Will it work?

2: Is it safe / legal / ethical?

Ocean Fert. and OCCS :

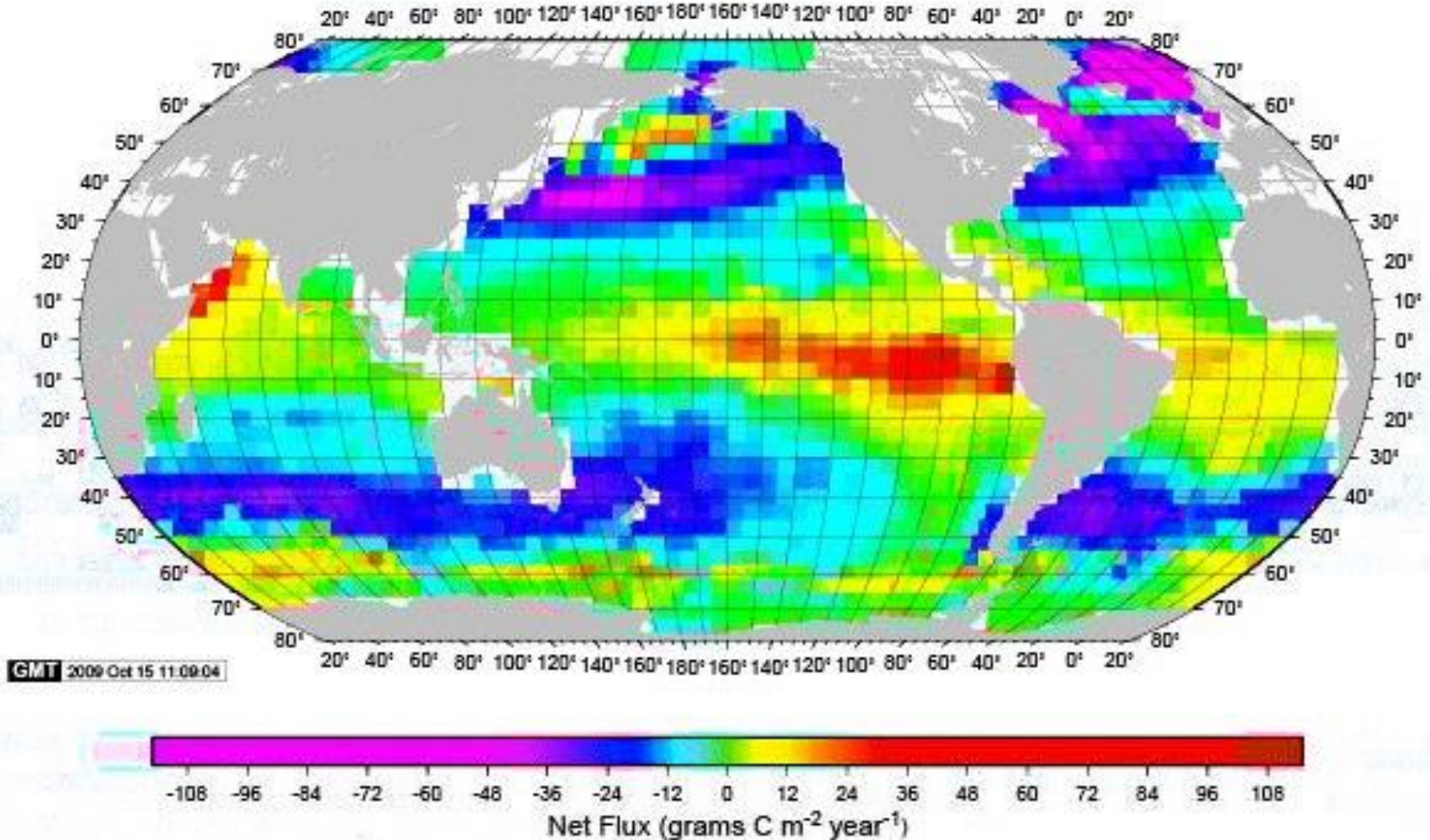
Are these Viable Ways to Enhance
Sequestration of Carbon by the World's
Oceans?

Richard Lampitt



Global carbon fluxes

Mean Annual Air-Sea Flux for 2000 [Rev Oct 09] (NCEP II Wind, 3,040K, $\Gamma=.26$)

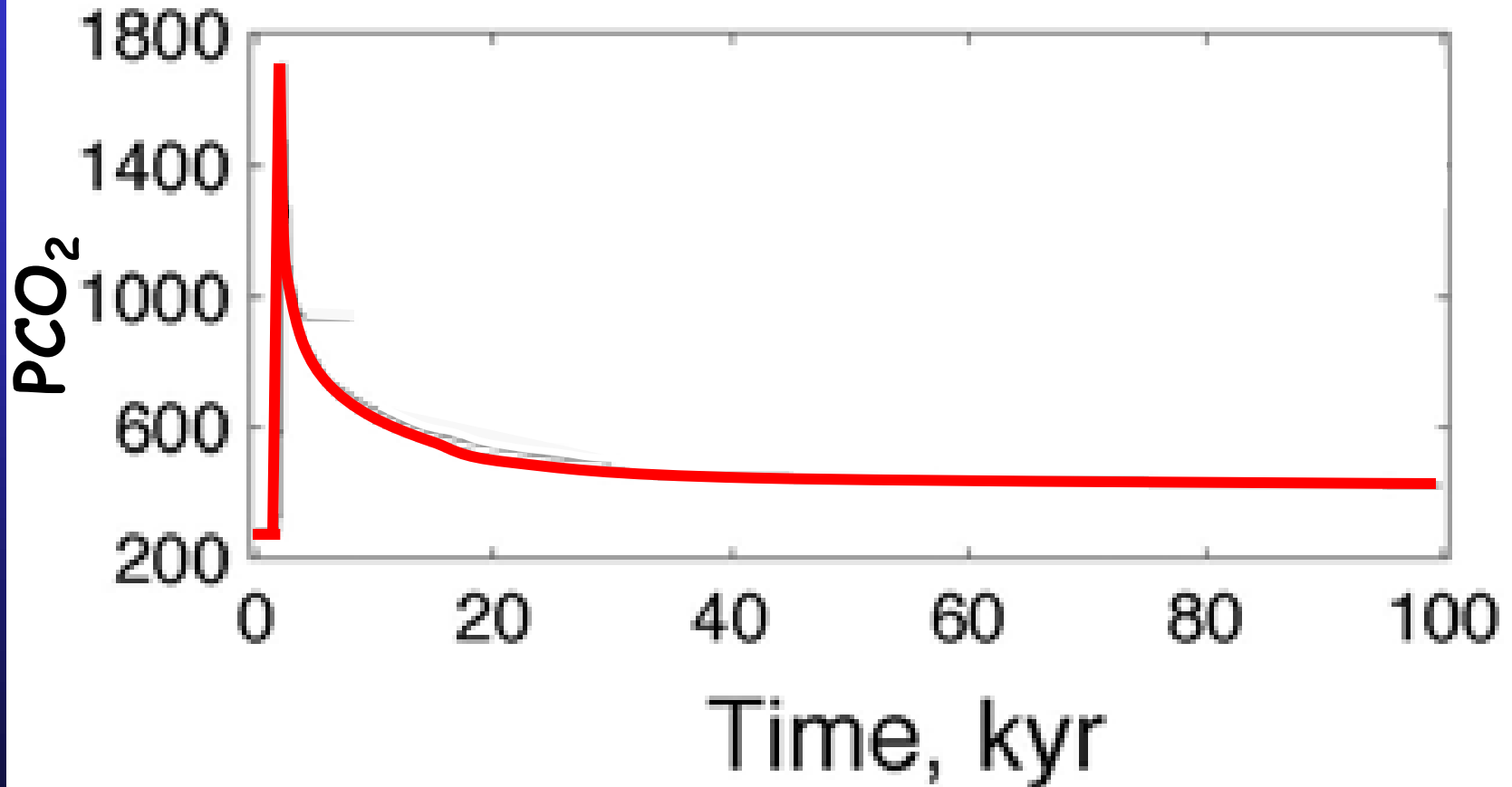


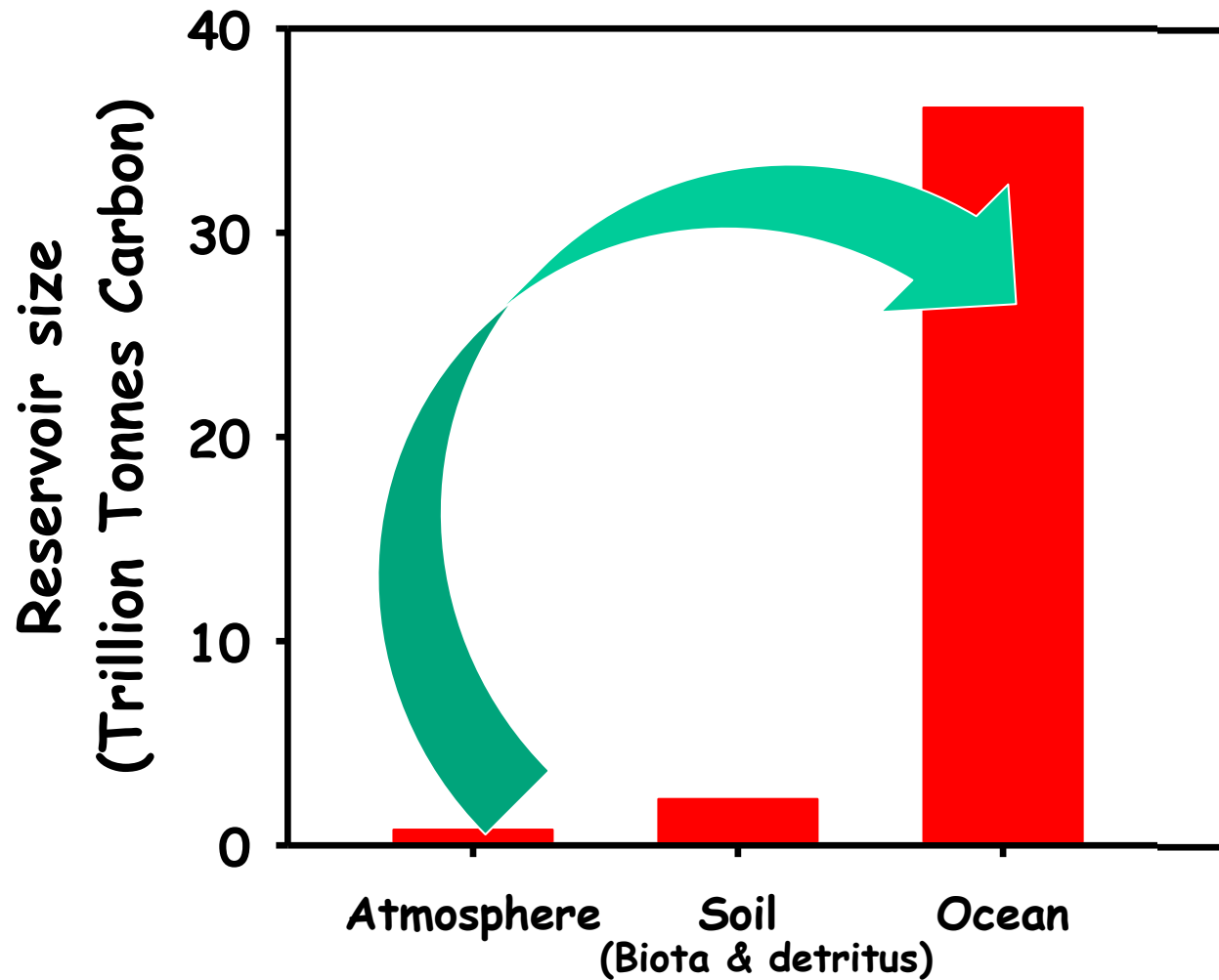
Transfer of CO₂ in and out of the ocean

Almost all of the released carbon will end up in the ocean eventually but before that happens:

Atmospheric CO_2 concentration

If we use all 5 Trillion Tonnes Carbon



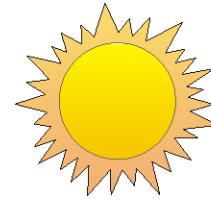


Global reservoirs of carbon

Carbon pumps

Solubility pump

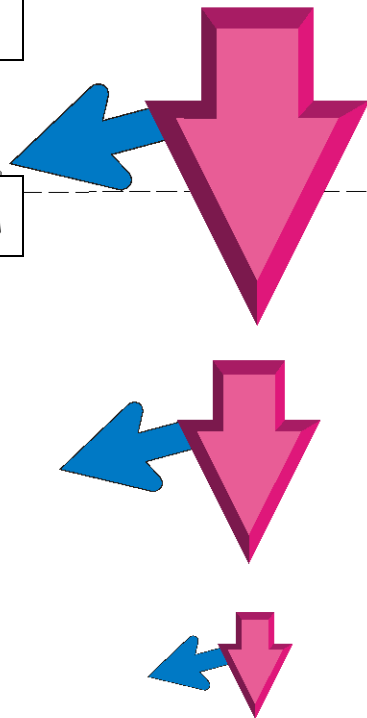
Biological pump



Primary
Production

100m

1000m



Seabed

The Biological Carbon Pump (BCP)

Export

Sequestration



Just like my
vegetable garden,
the oceans need a
range of nutrients

Productivity limited by essential nutrients

Major: Nitrogen, Phosphorus, Silicon

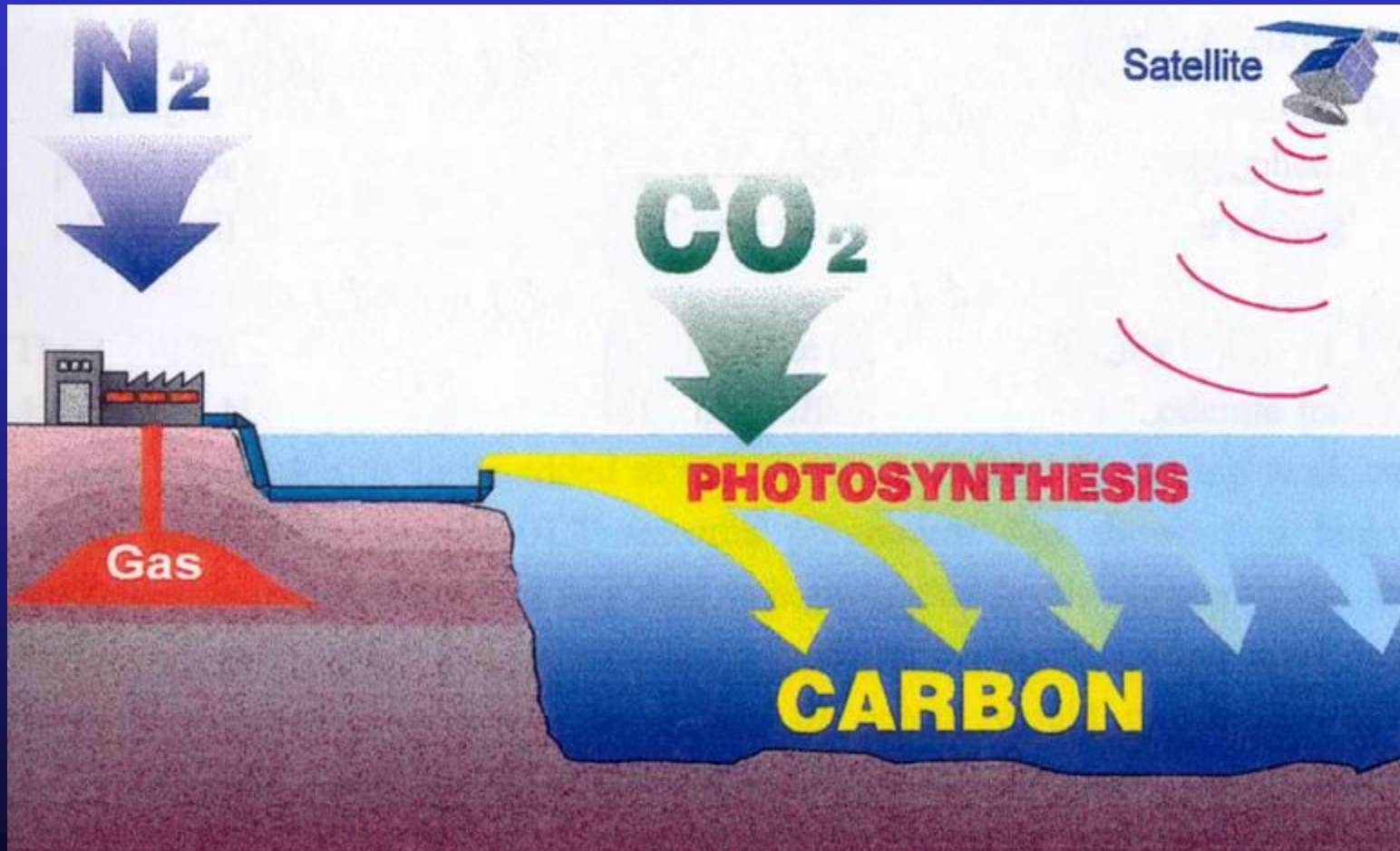
Minor: Iron

When limitation by one factor is removed, productivity increases until another factor becomes limiting

Potential methods of fertilizing the oceans:

1. Nutrient cocktail from coast or ship
2. Nutrient cocktail from deep water
3. Iron fertilization to complete the nutrient pool

The claim:
Fertilization of Ocean Waters with Nitrogen will Provide Food and
Sequester Carbon

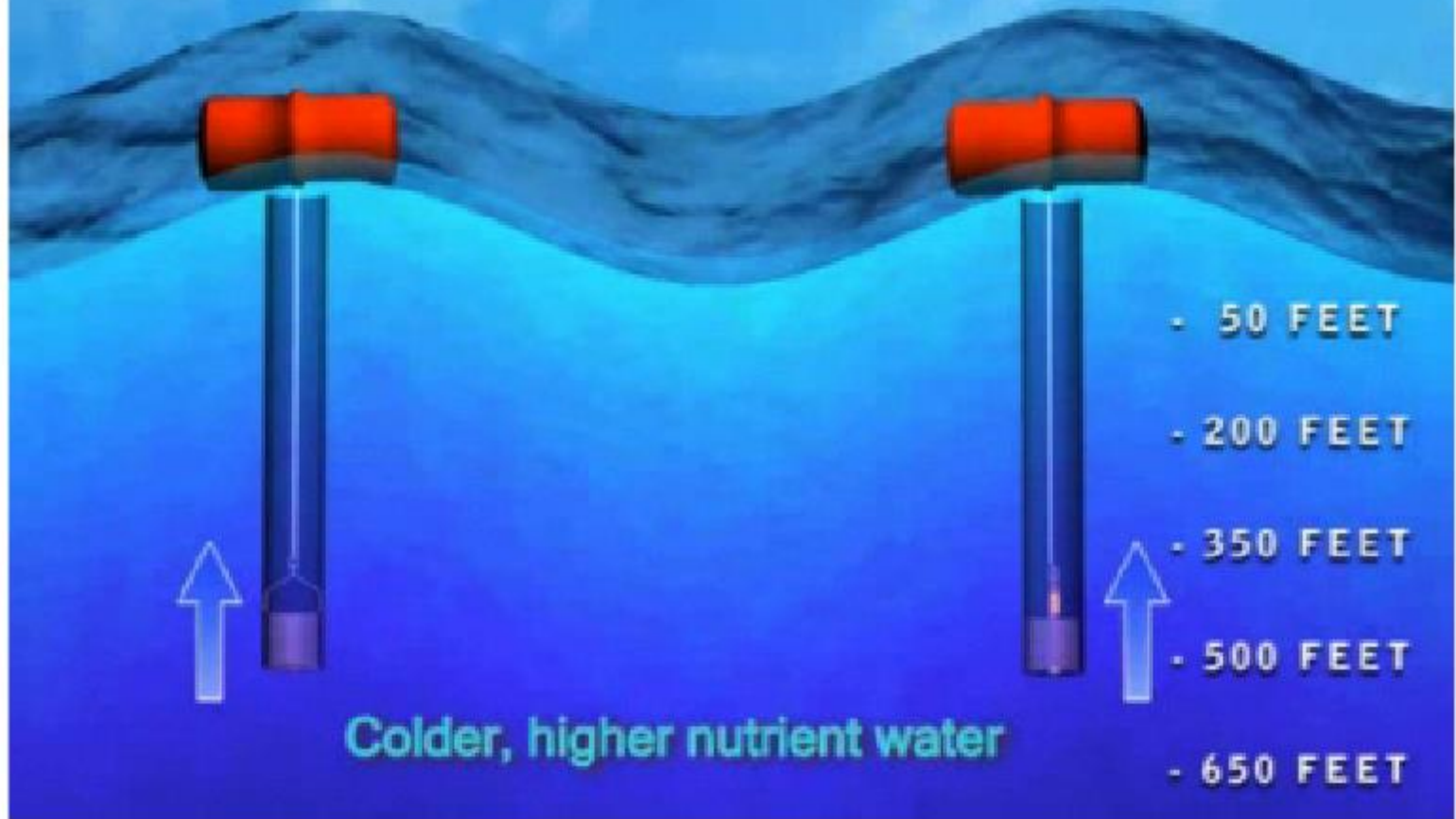


Potential methods of fertilizing the oceans:

1. Nutrient cocktail from coast or ship
2. Nutrient cocktail from deep water
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WAVE DRIVEN OCEAN UPWELLING SYSTEM



Pump Deployment

May 31st 2008 , R/V Kilo Moana



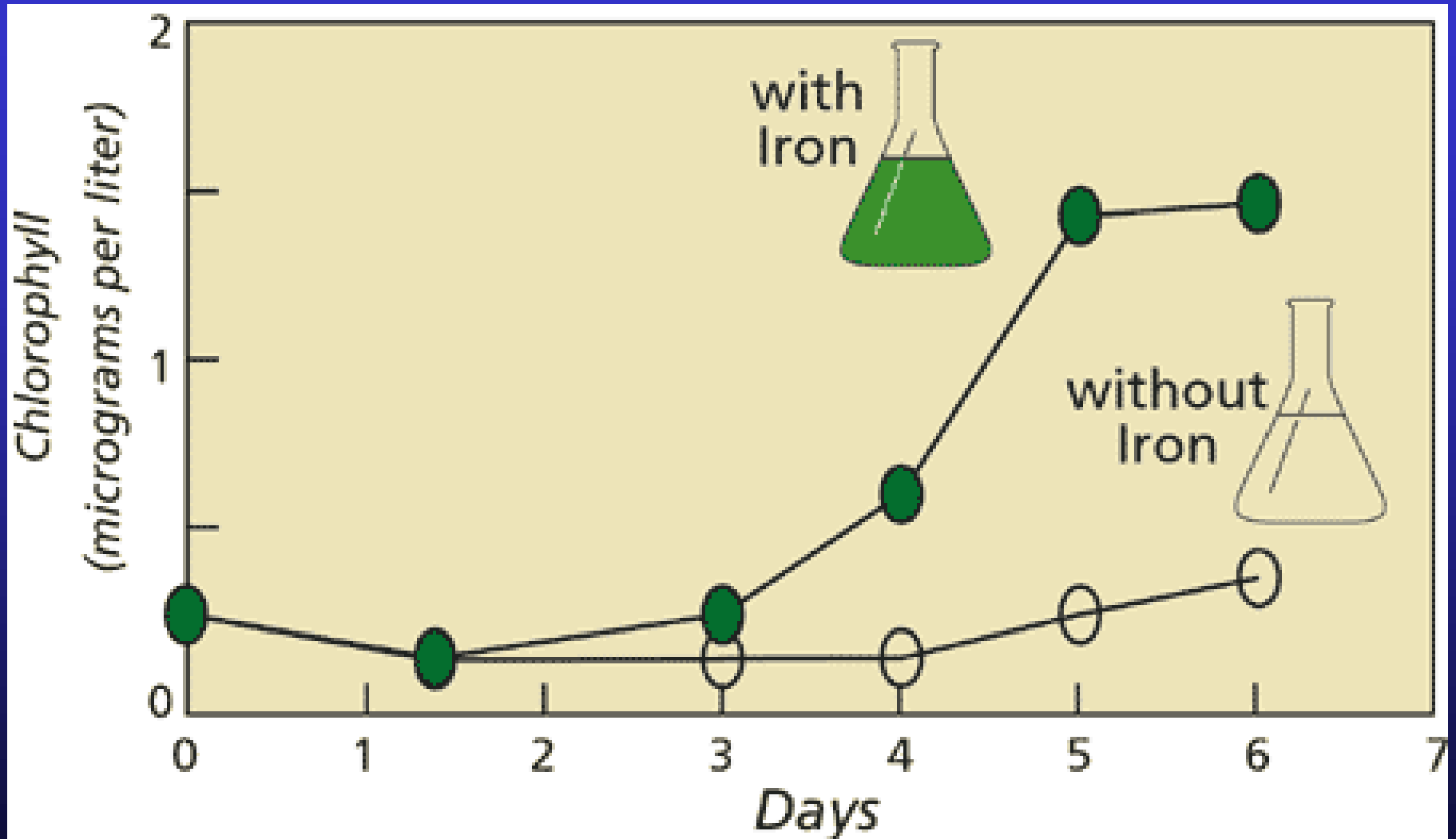
How many pipes of length 1000m
and diameter 1m are needed
to sequester 1 Gt C y^{-1} ?

Pipes required: 800×10^6

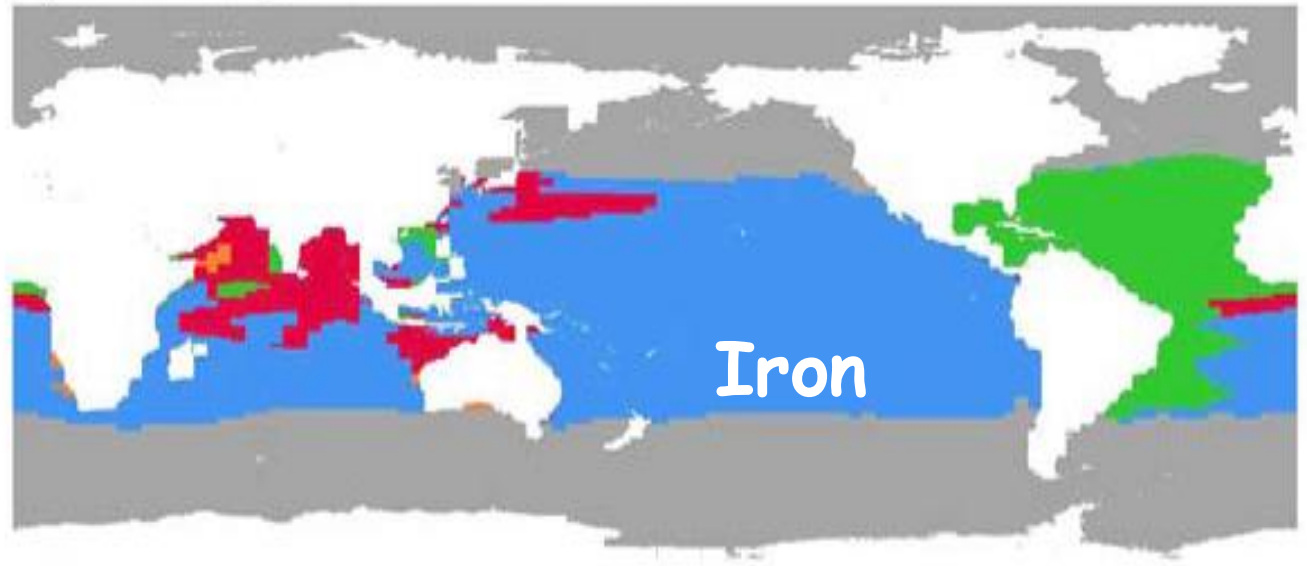
Potential methods of fertilizing the oceans:

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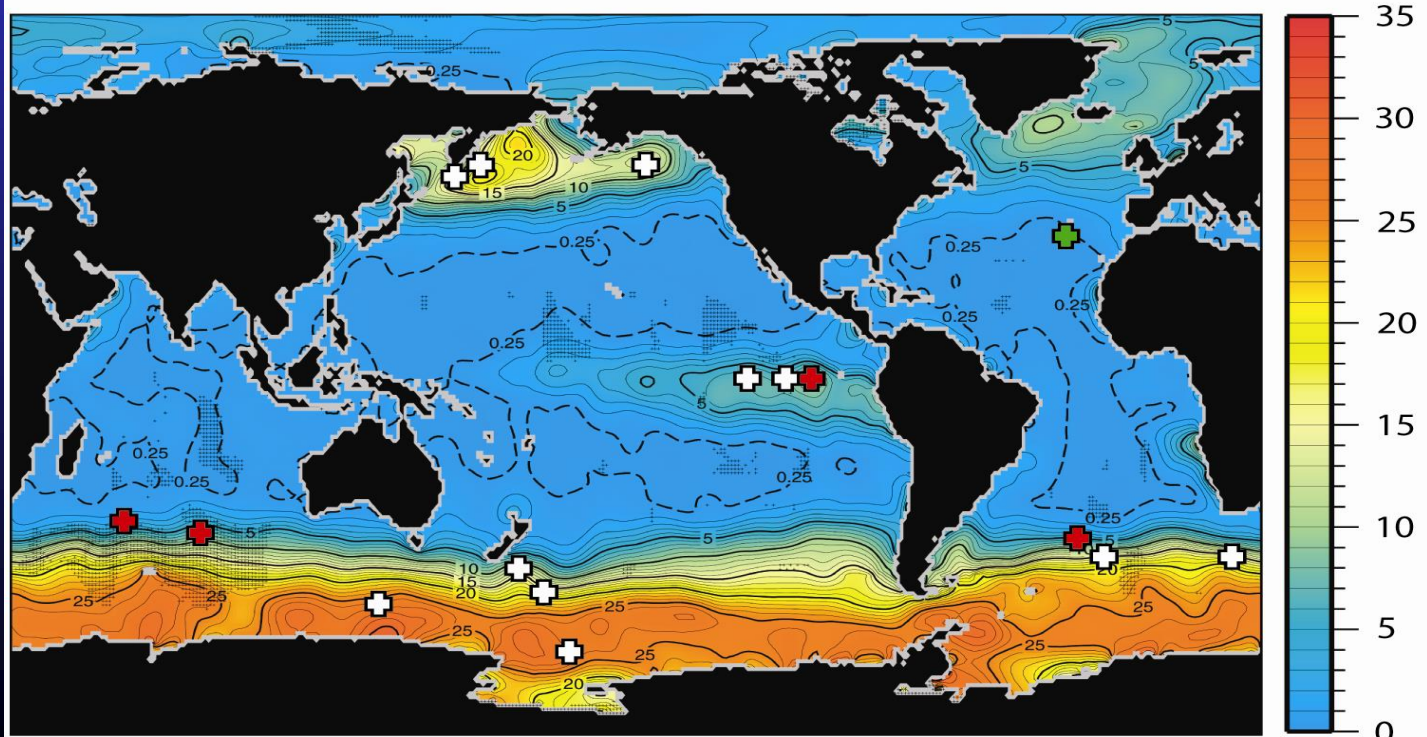
Iron is important for phytoplankton growth.



Diazotroph Growth Limitation

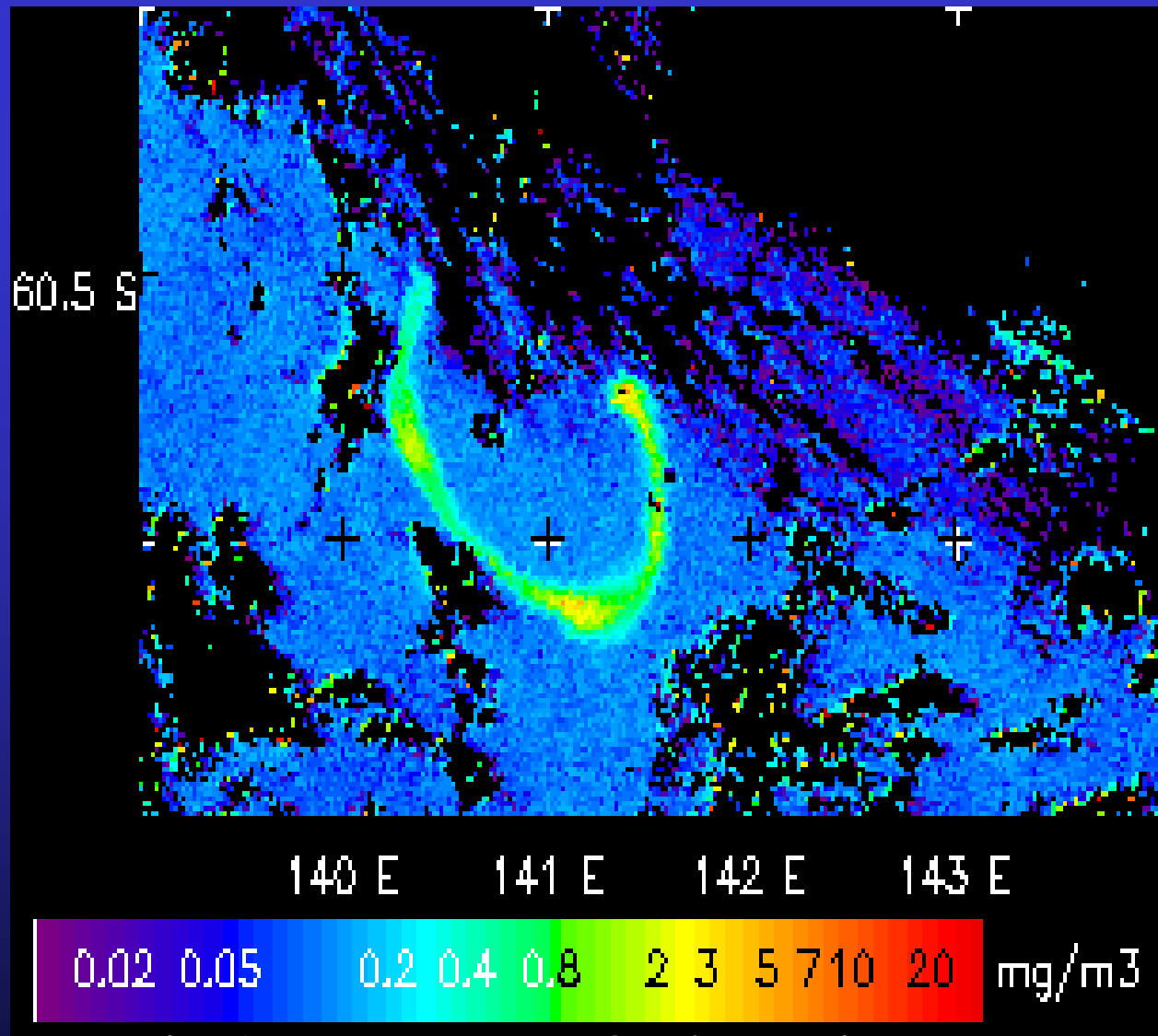


Moore et al., 2004



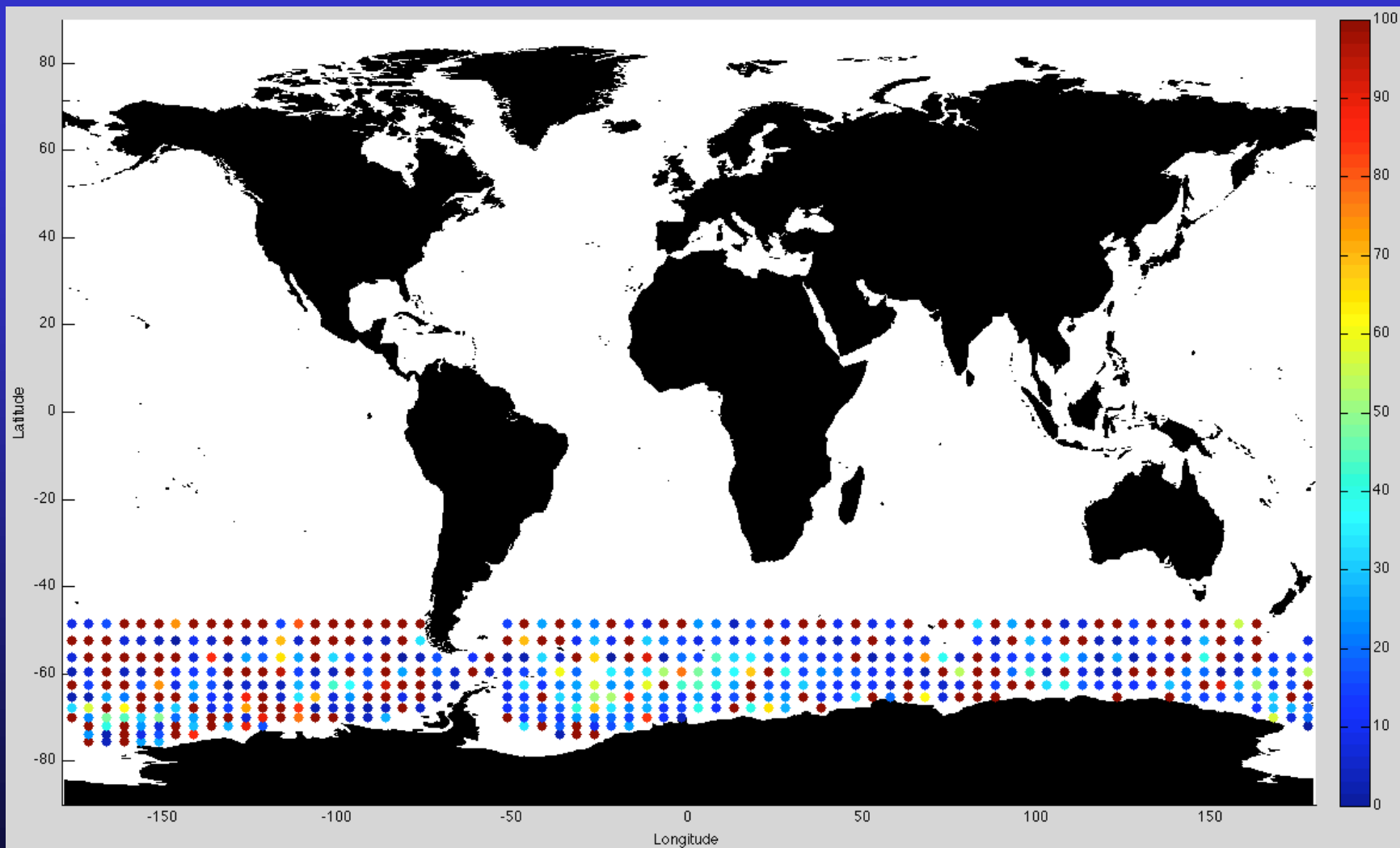
Boyd et al. (2007)

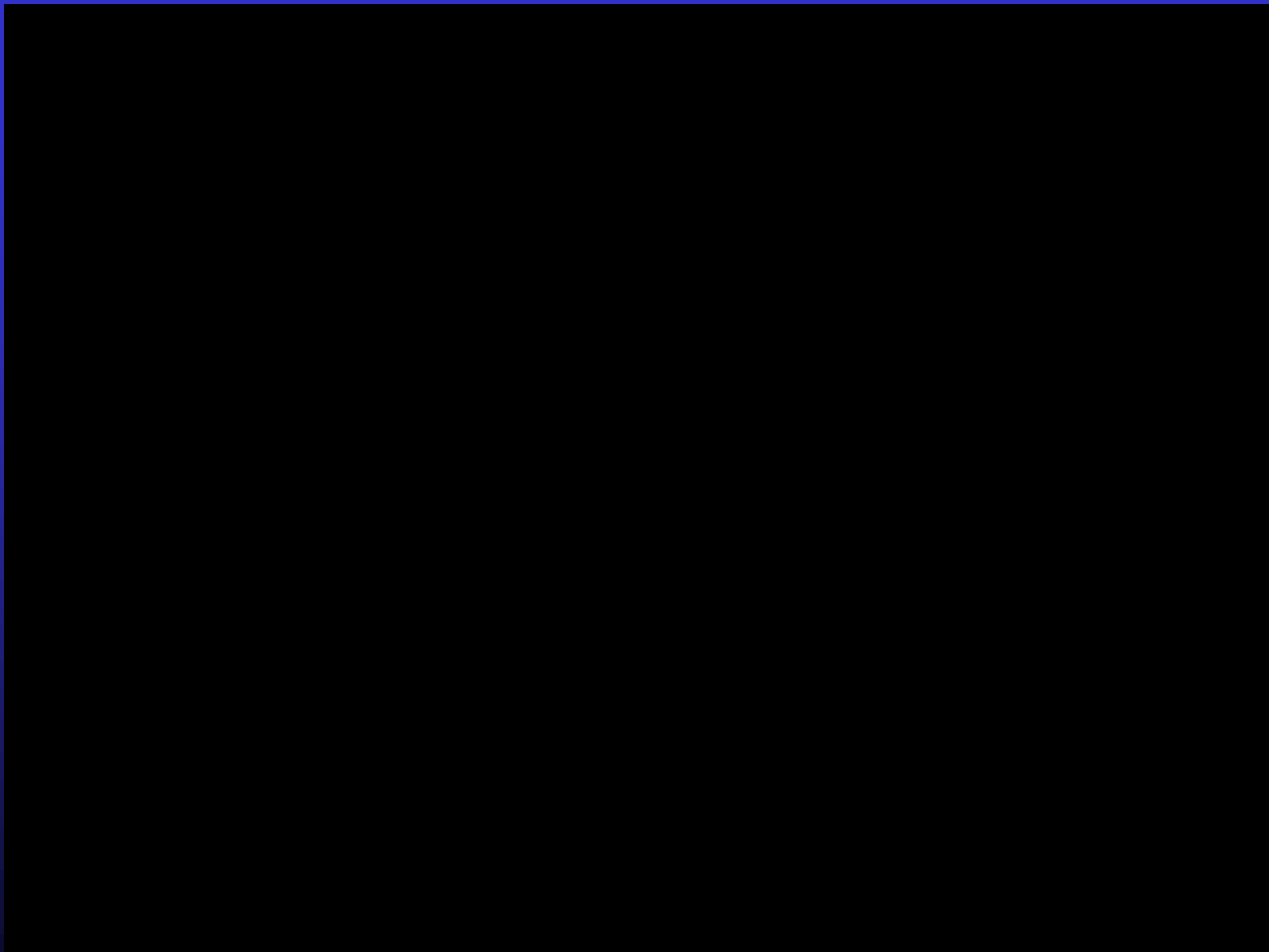
SOIREE



Final dimension of the bloom:

$$\sim 200 \text{ km} * 10 \text{ km} = 2000 \text{ km}^2$$





Conclusions from iron fertilisation experiments:

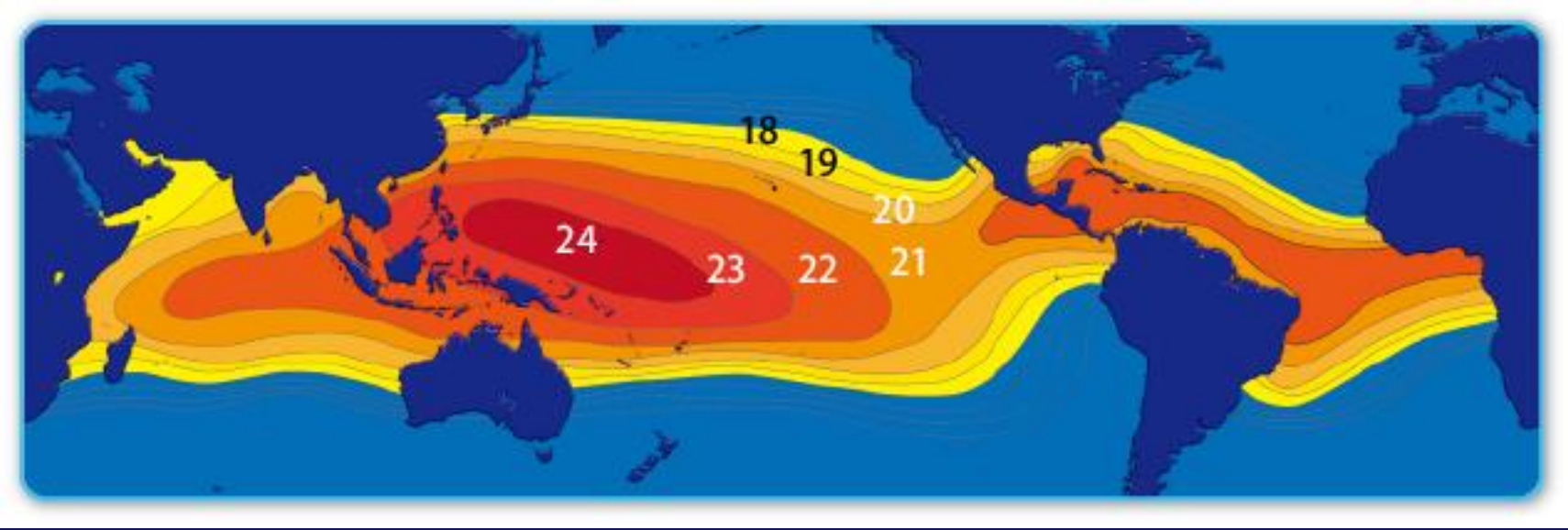
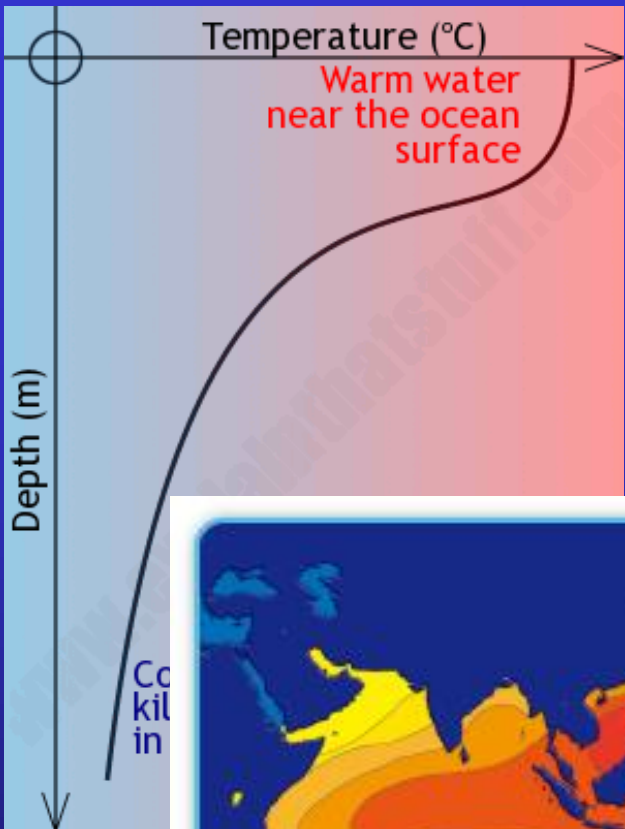
1. Phytoplankton always Bloom
2. Probably enhance export
3. May enhance sequestration.
4. N_2O may be generated
5. Physical and temporal extent of experiments insufficient.
6. Physics not adequately understood
7. Models inadequate

Ocean Carbon Capture and Storage (OCCS)

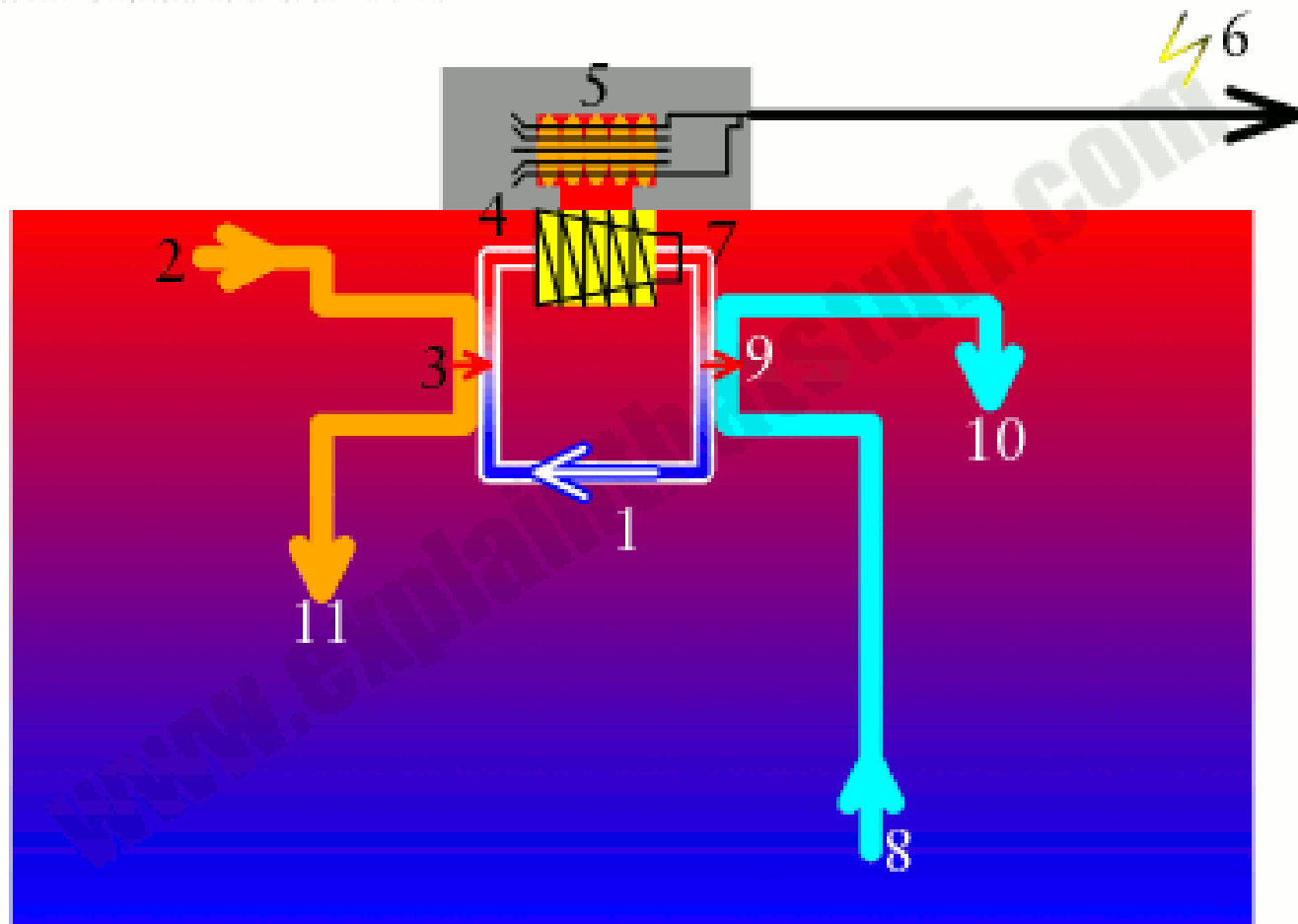
The principle is to remove CO_2 from the ocean so that either outgassing is reduced or uptake is enhanced.

Removal of CO_2 on an industrial scale is hard.

Ocean Thermal Energy Conversion (OTEC)



Temperature difference between surface and 1000m depth



Closed circuit OTEC system

830 tonnes/second for 100MW

Cf

Thanet Offshore Wind Project, UK: 300 MW.

Three Mile Island Nuclear plant, USA: 800 MW

Three Gorges hydro-elec. plant, China: 22.5 GW



Victoria Falls (1000 tonnes/sec)

Geoengineering

OCCS could:

1: Reduce CO_2 outgassing/enhance uptake

And if with OTEC

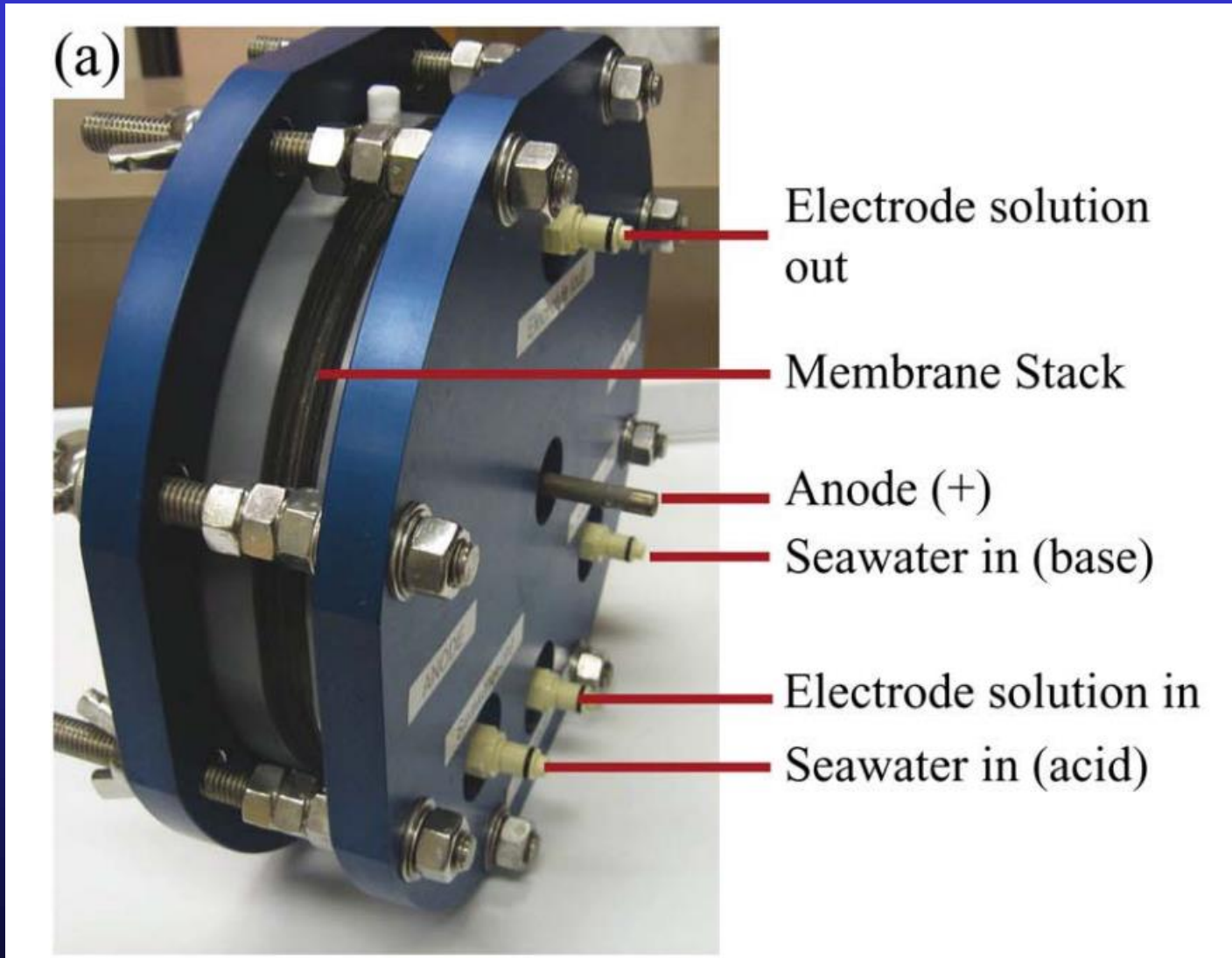
2: Enhance surface productivity

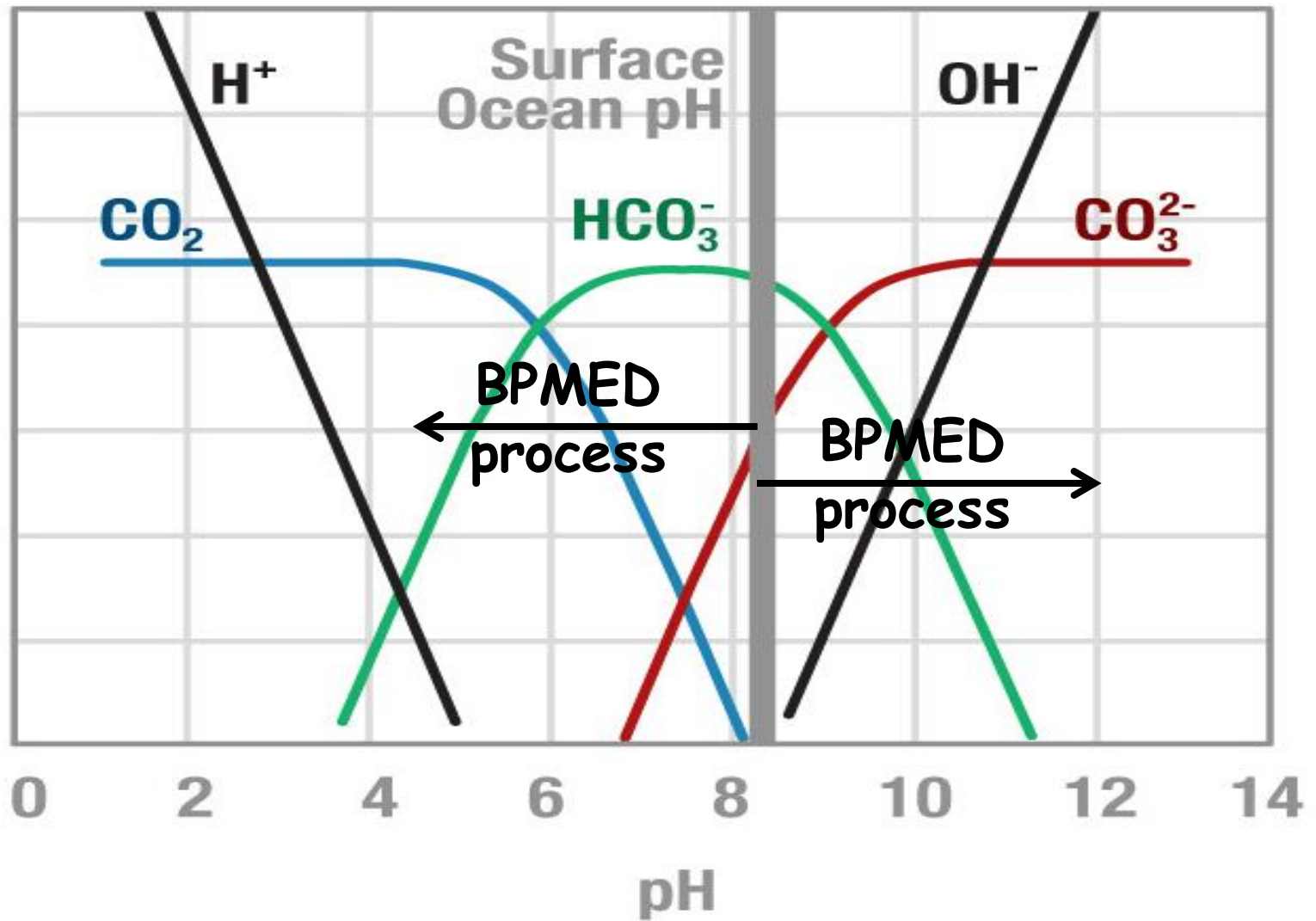
3: Enhance the BCP

Chemical engineering developments required

How to extract CO_2 from seawater

Bipolar Membrane Electrodialysis (BPMED)





Bjerrum plot

Research into carbon storage required

Type of environmental assessment required

- 1: Phytoplankton response to such perturbation
- 2: Effect on the BCP

