An Overview of Ocean Sequestration Technology

Takashi OHSUMI

Research Institute of Innovative Technology for the Earth, RITE
and

Central Research Institute of Electric Power Industry, CRIEPI

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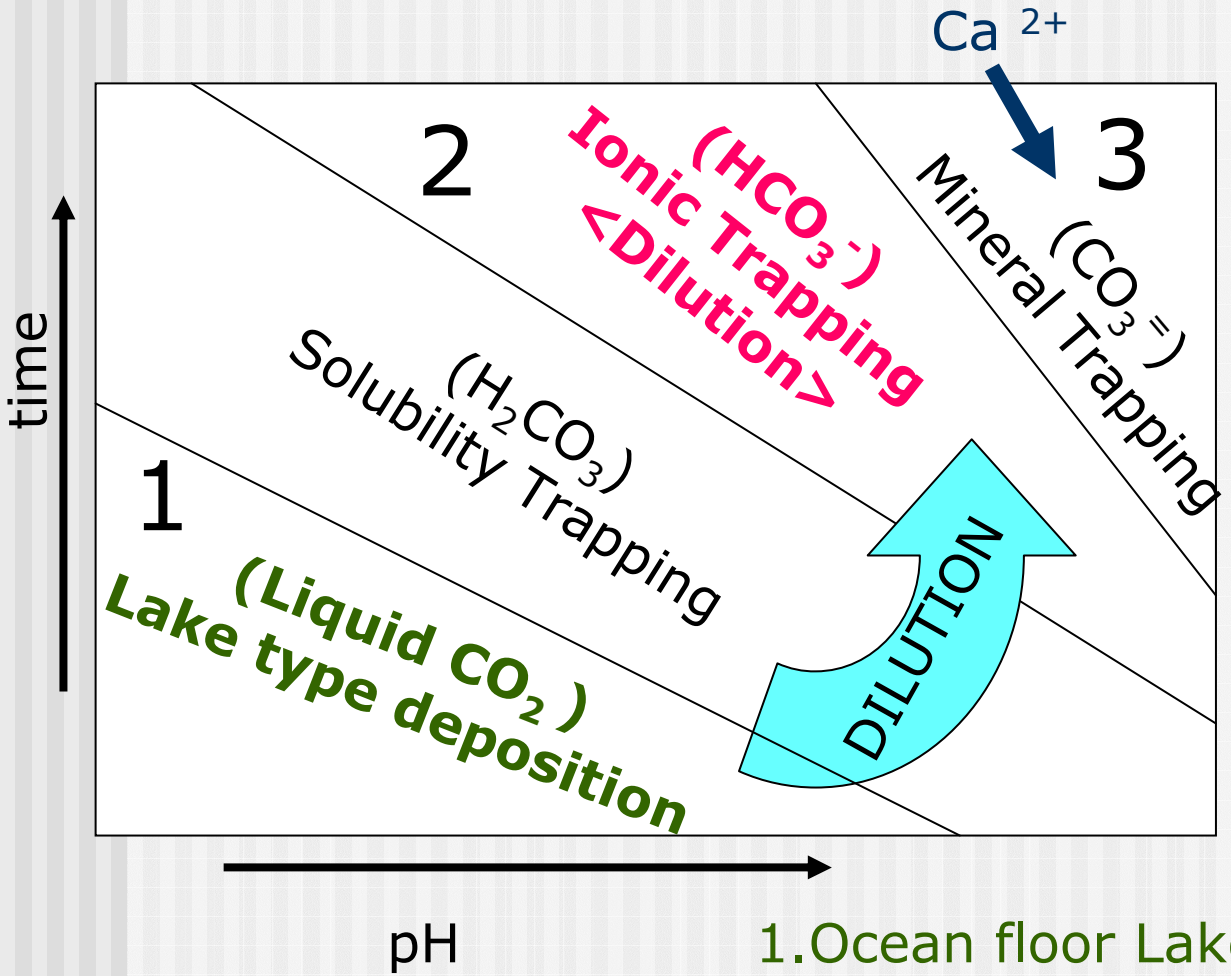
Idea of ocean storage

- Ocean storage is to store CO_2 for a long term by injecting it into the deep ocean in the state of liquid or solid.
- The oceans will eventually absorb most of the excess CO_2 in the atmosphere.
- Ocean storage can be viewed as a way to make this natural process to be accelerated through technology.

Storage mechanism



3. Limestone Neutralization: Storage as $Ca^{2+}_{(added)} + CO_3^{=}$

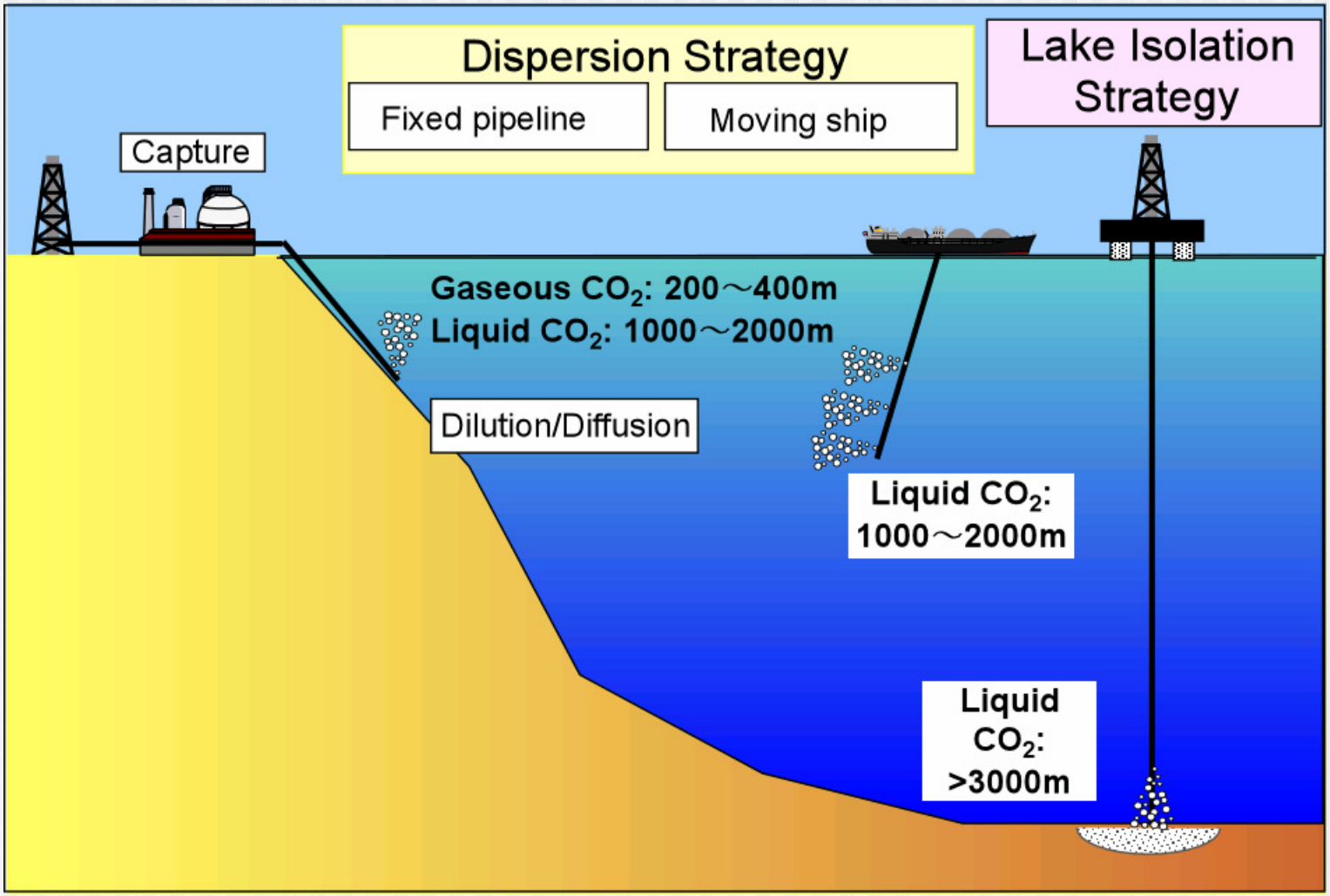
2. Dilution: Stored as HCO_3^- through reaction: $CO_2 + CO_3^{=} + H_2O \rightarrow 2HCO_3^-$

1.Ocean floor Lake or near injection point :Liquid CO_2

Two types of technologies of ocean storage

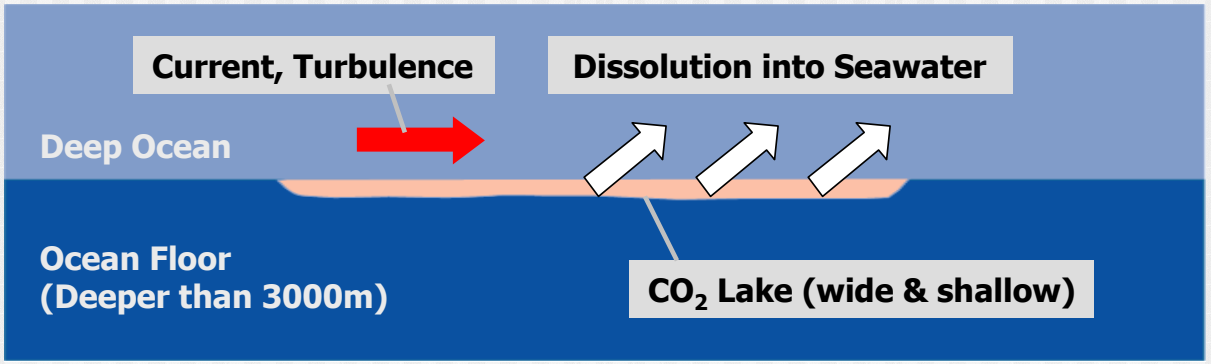
	Outline	Depth	Type	Conditions
Dispersion strategy	Dispersion of CO_2 at intermediate depths	Typically, 1000 - 2500m	Dispersion (dilution)	Plume of liquid CO_2 droplets
Lake isolation strategy	Injection of CO_2 at depths greater than 3000 m	> 3000m	Stay in sea floor	Lake of liquid CO_2 on seabed

Types of technologies of ocean storage

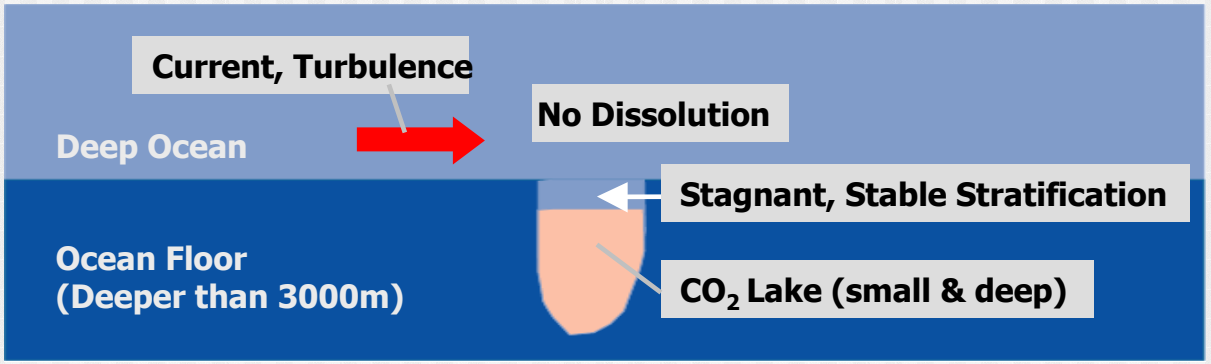


Lake type scenario

Deep ocean dissolution type

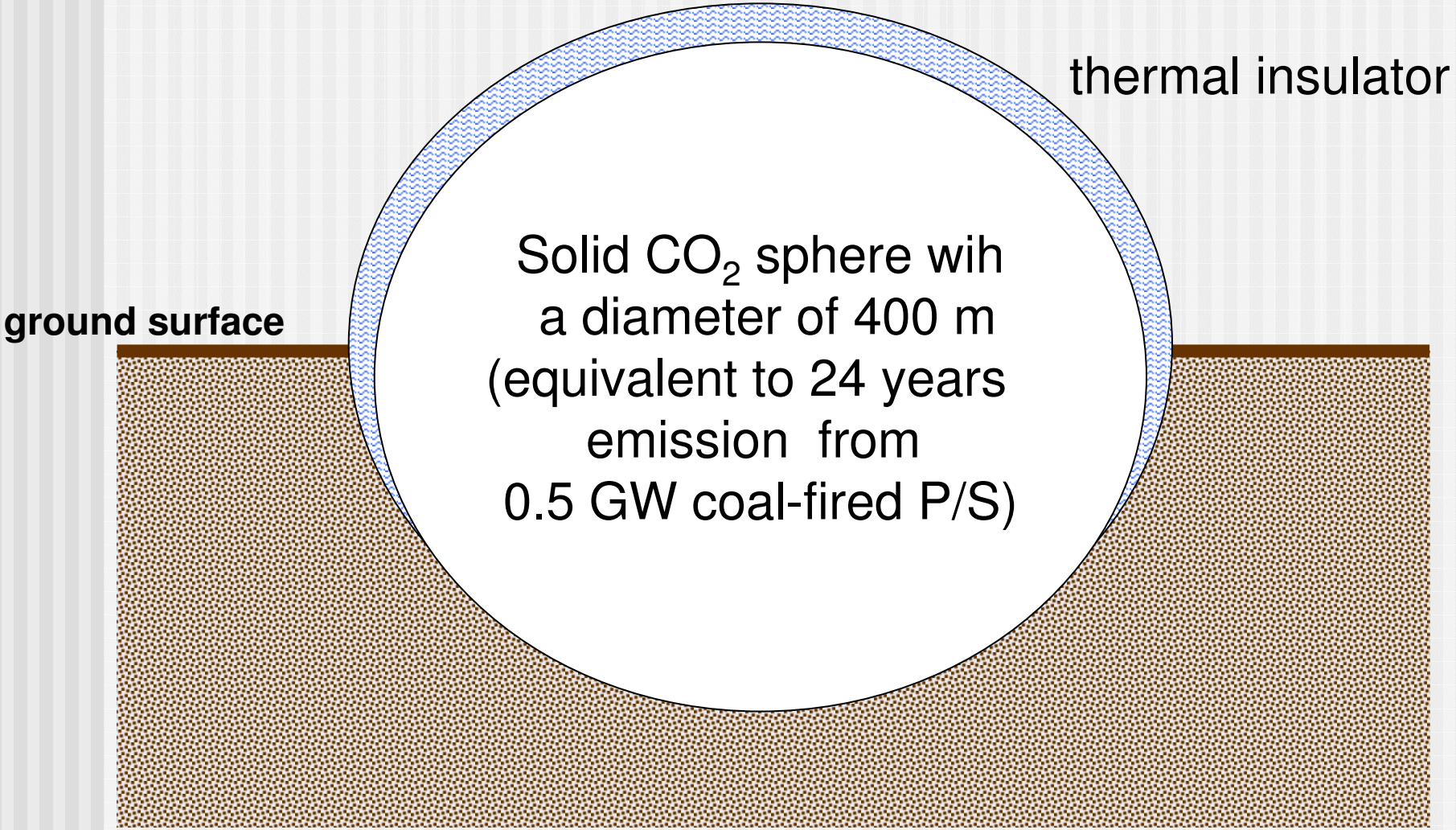


Deep ocean storage type

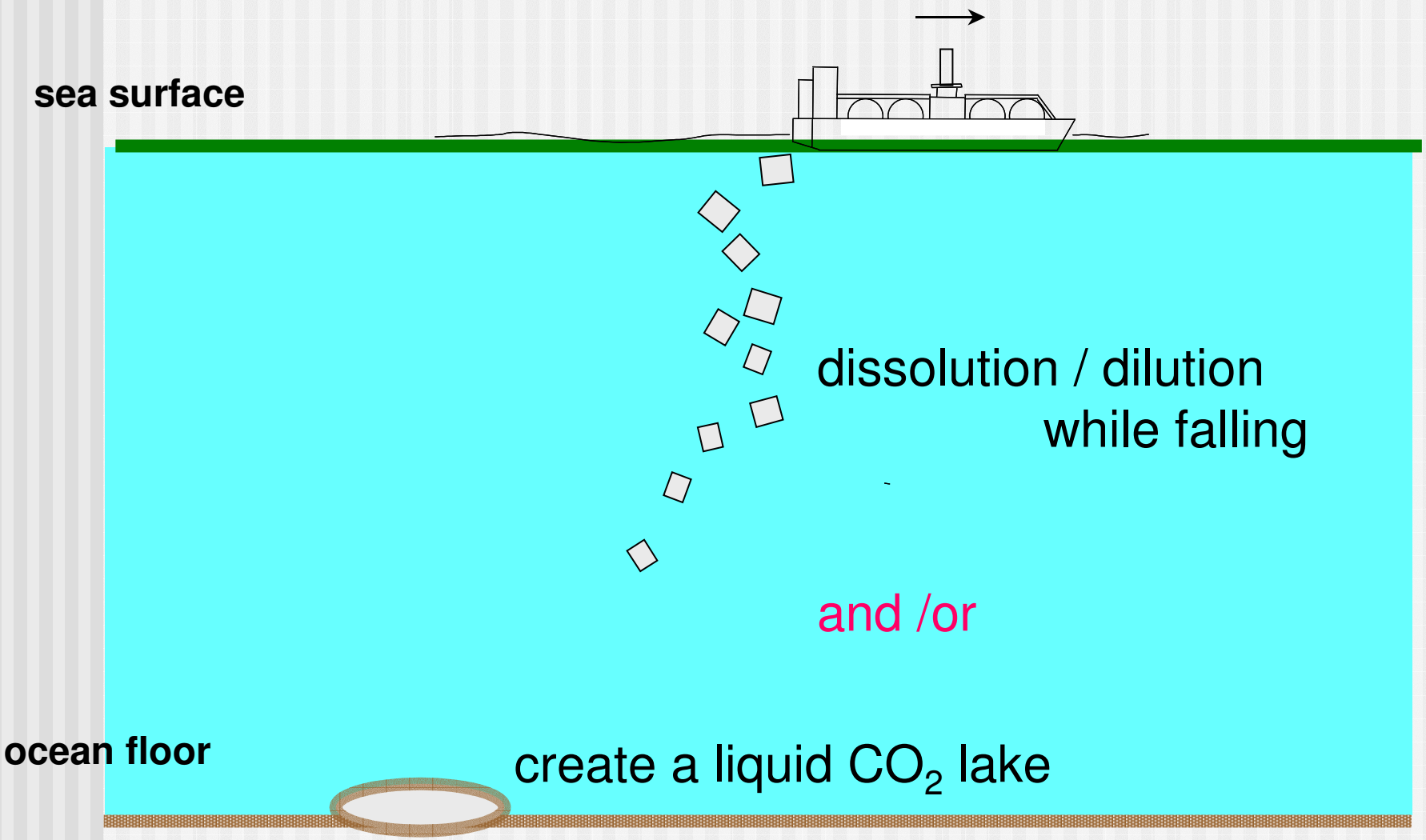


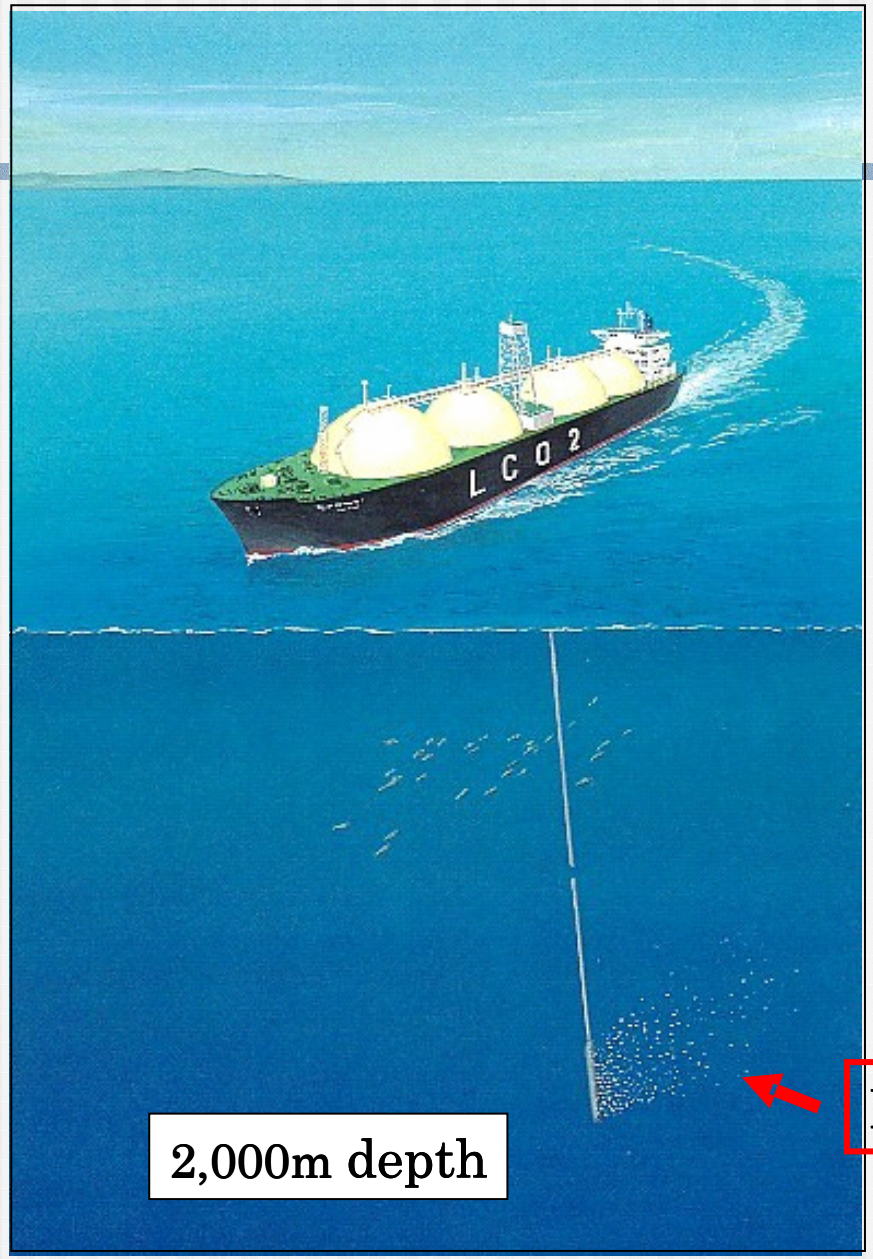
Nakashiki, N. 1997. Lake-type Storage Concepts for CO_2 Disposal Option

Solid CO_2 pile-up on ground proposed by Seyfritz in 1991



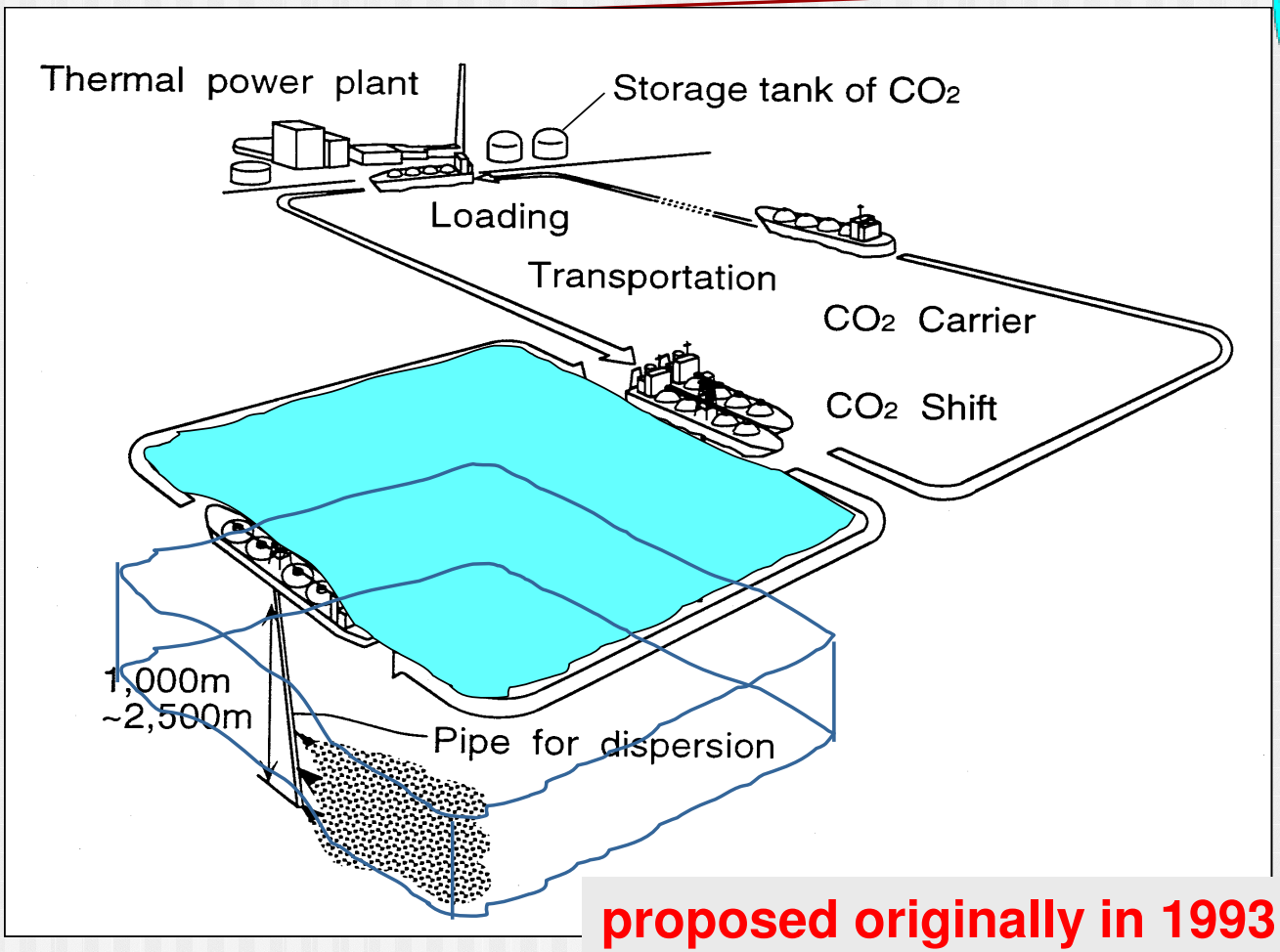
Solid CO_2 blocks dropping to deep sea experimented by CRIEPI in 1990

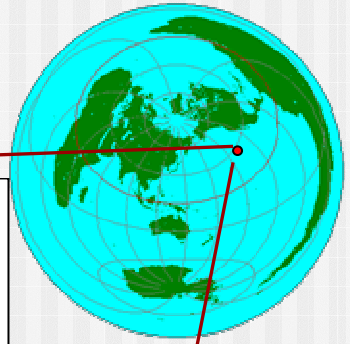



L C O 2
2,000m depth
Liquid CO_2 droplet

CO_2 Ocean Sequestration using Moving Ship:

an example of dilution-type implementation technology with minimum local & short-term impact





proposed originally in 1993 by CRIEPI

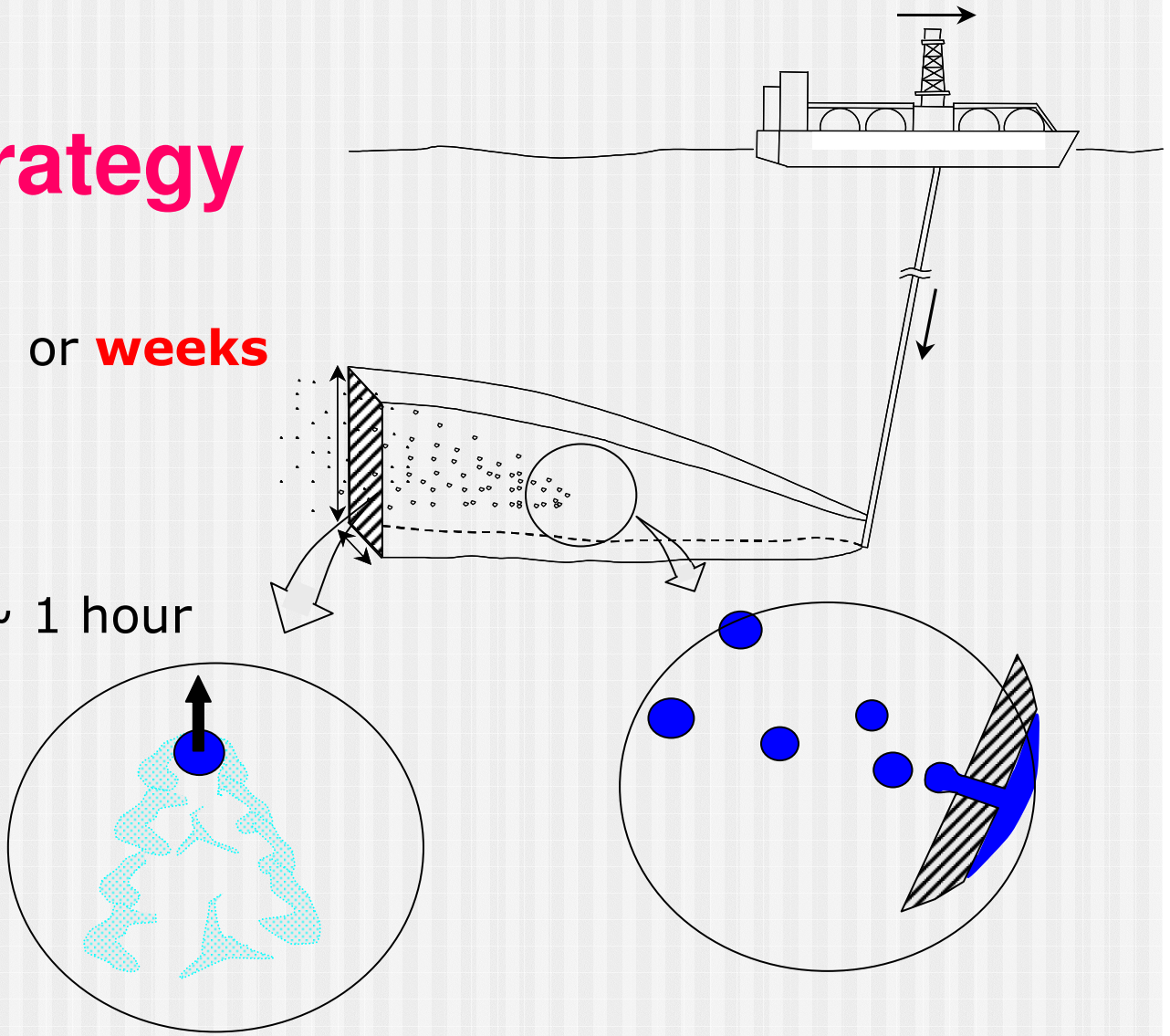
time shift of CO_2 impact

- slow (100's years) to fast (weeks) increase of the impact

dilution strategy

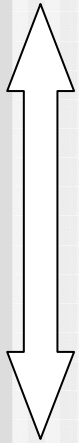
n x 10^5 dilution in days or **weeks**

n x 10^4 dilution in ~ 1 hour



To what extent do we expect human control / management on long term isolation in each CO_2 storage concept?

more **control / management**



Solid CO_2 pile-up on ground (solid CO_2)

Lake type deposition onto seafloor (liquid CO_2)

Subsurface geological storage (supercritical CO_2)

Dilution / dispersion type disposal (solute CO_2)

less **control / management**

CO_2 capture & storage measure as a climate technology

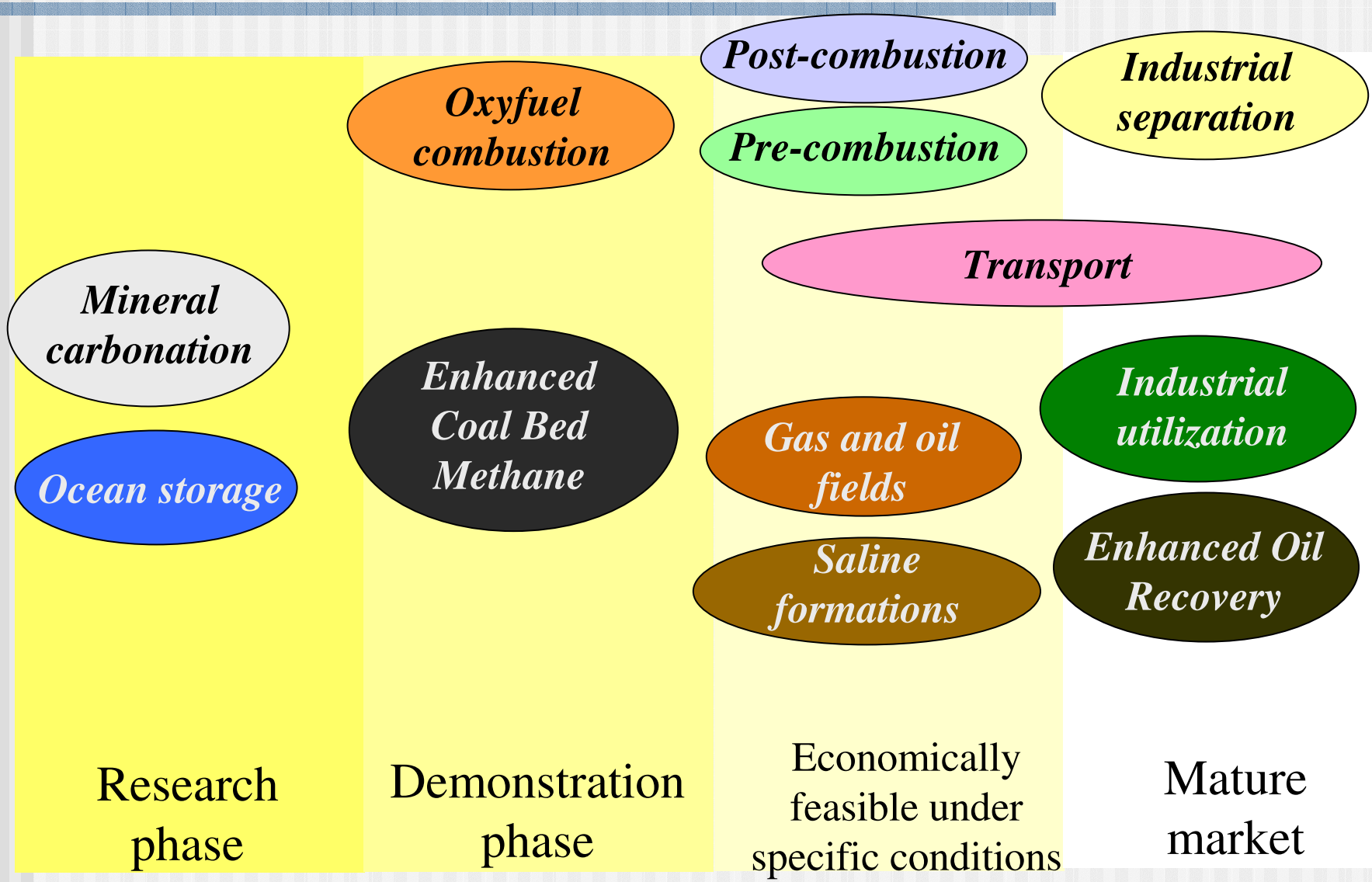
- It is a risk transfer: from climate (impact to the atmosphere for a time duration of several decades, if it is really urgent matter) to underground (more than several millennia) or the ocean (more than a few centuries).

- Nature of the risks associated with these spheres differ; more importantly the mode of public perception of the risk depends much on a social context.

IPCC Special Report on CCS (2005)

- Chapter 6 "Ocean Storage" was carefully drafted objectively and scientifically with no prejudice on public acceptance issue, after the cancellation of the Norwegian permit to the international injection experiment planned in August 2002.
- The ultimate consequences of the CO_2 Ocean Storage is still uncertain as is the case of CO_2 release to the atmosphere.

Maturity of CCS technology



Storage potential

- **Geological storage: likely at least about 2,000 $GtCO_2$ in geological formations**

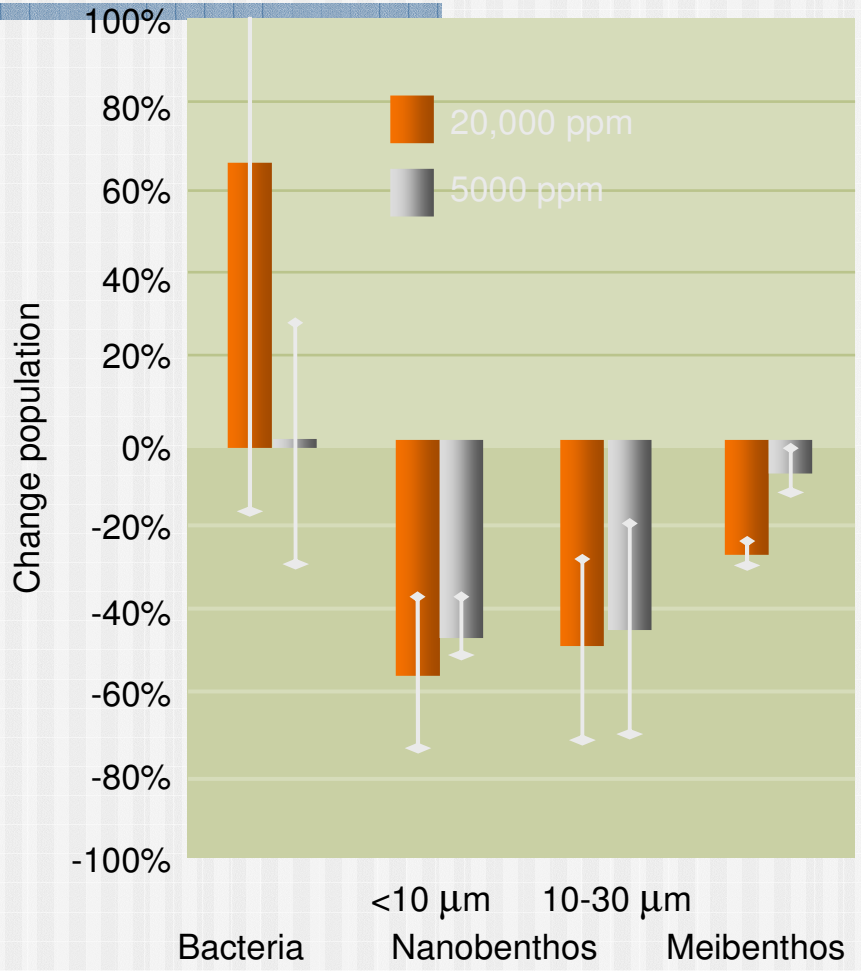
  "Likely" is a probability between 66 and 90%.

- **Ocean storage: on the order of thousands of $GtCO_2$, depending on environmental constraints**
- **Mineral carbonation: can currently not be determined**
- **Industrial uses: Not much net reduction of CO_2 emissions**

Ocean Storage

Impacts

- pH change
- Mortality of ocean organisms
- Ecosystem consequences
- Chronic effects unknown



Change of bacteria, nanobenthos and meiobenthos abundace after exposure to 20,000 and 5,000 ppm for 77-375 hrs during experiments carried out at 2000 m depth in NW Pacific

Typical summary of Storage options in IPCC outreach activity

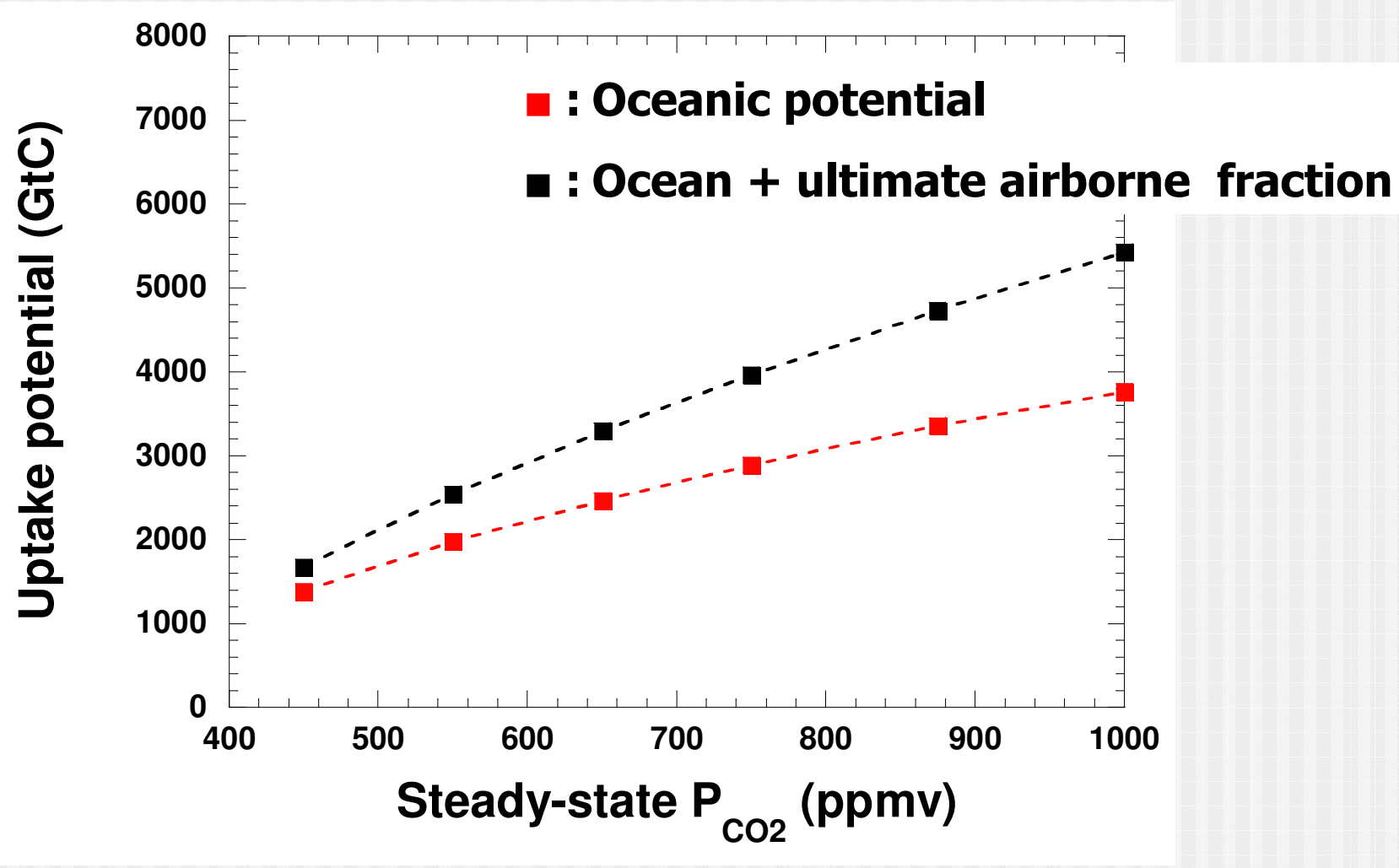
What are the risks?

- In general: lack of real data, so comparison with current operations
- Geological storage:
  - appropriate site selection, a monitoring program to detect problems, a regulatory system, remediation methods to stop or control CO_2 releases if they arise:
  - comparable to risks of current activities
  - natural gas storage, EOR, disposal of acid gas
- Ocean storage: pH change, mortality of ocean organisms, ecosystem consequences, chronic effects unknown

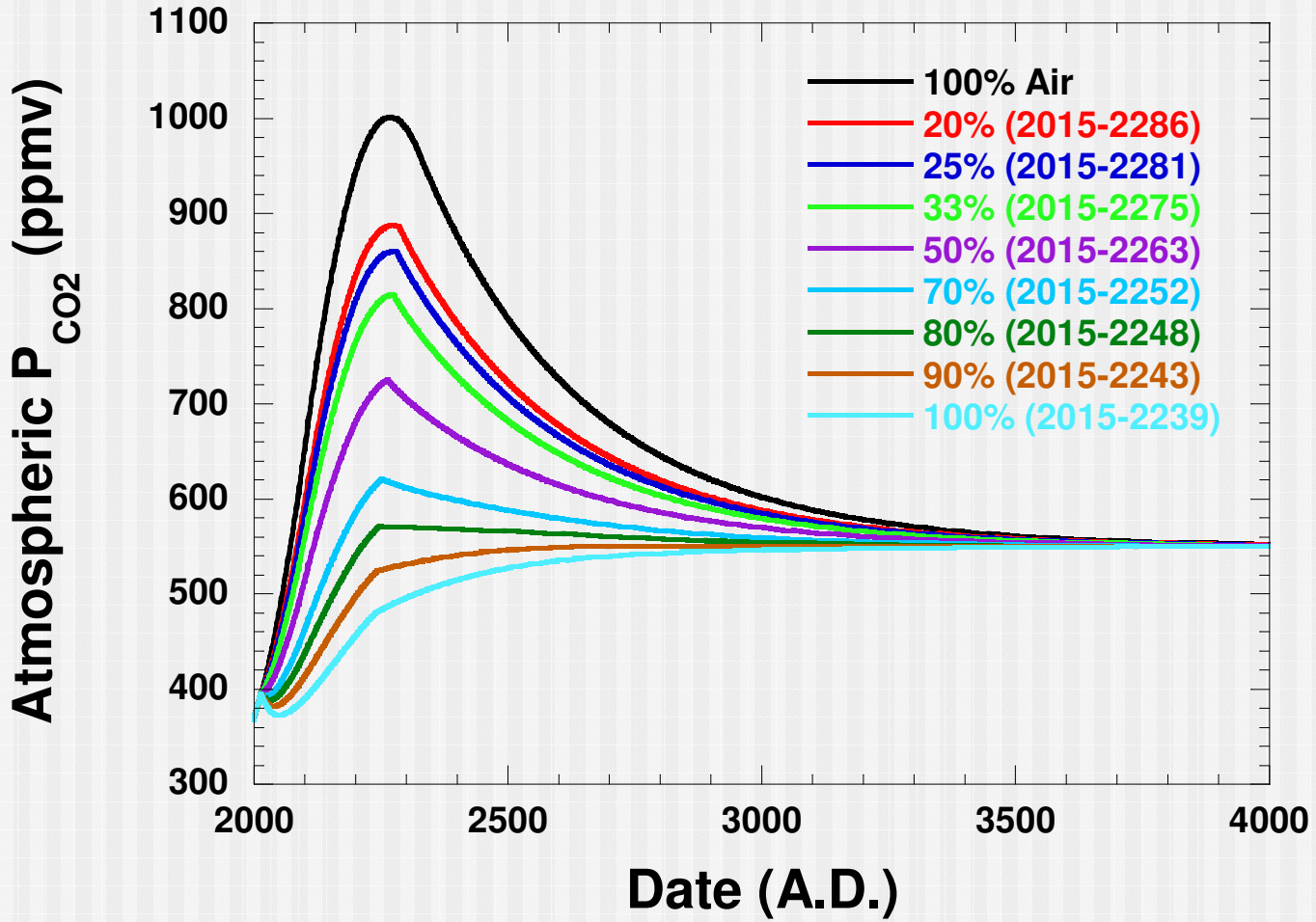
Implication of ocean storage

- **Ocean storage option is one of the global warming mitigation measures through the carbon management activity.**
- **The technology of ocean storage of CO_2 offers the means of "peak-shaving" the time profile of the atmospheric CO_2 concentration before its reaching the long term equilibrium level.**
- **The knowledge of the carbon cycle (on the ocean and the terrestrial biosphere on timescales of years to thousands of years) offers the basis of this future projection of the atmospheric CO_2 concentration.**

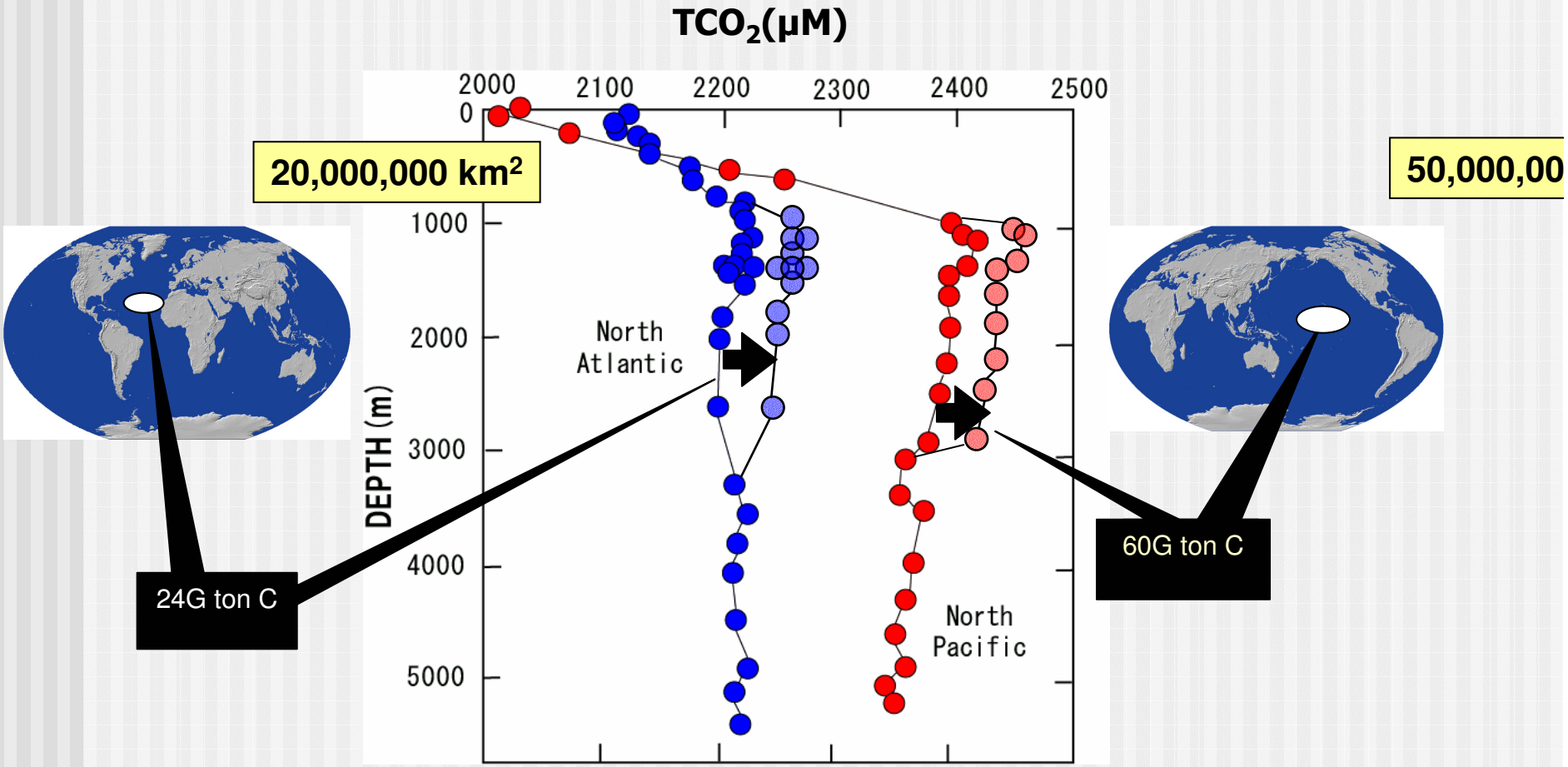
Ocean CO_2 uptake potential



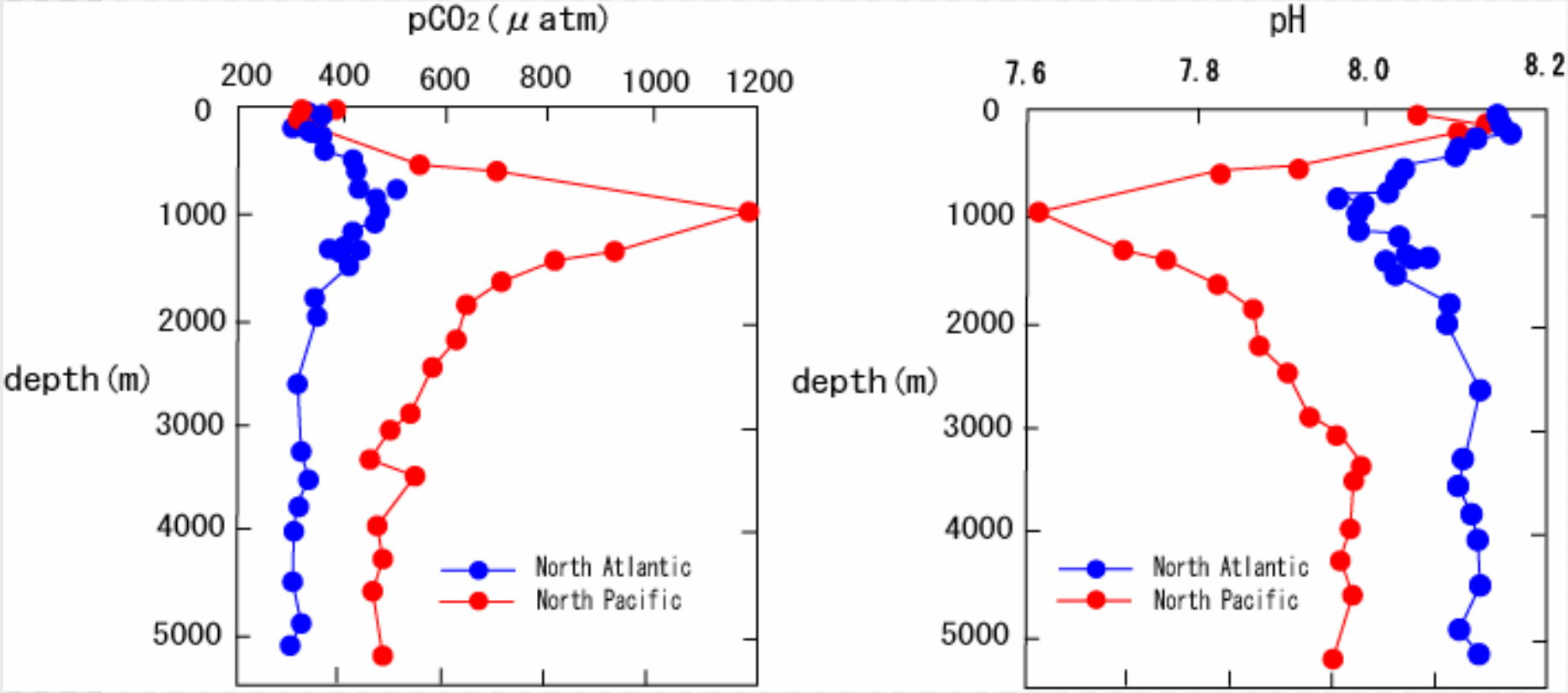
Effect of injected portion on P_{CO2}



CO_2 impact relocation
- from shallow waters to deep waters

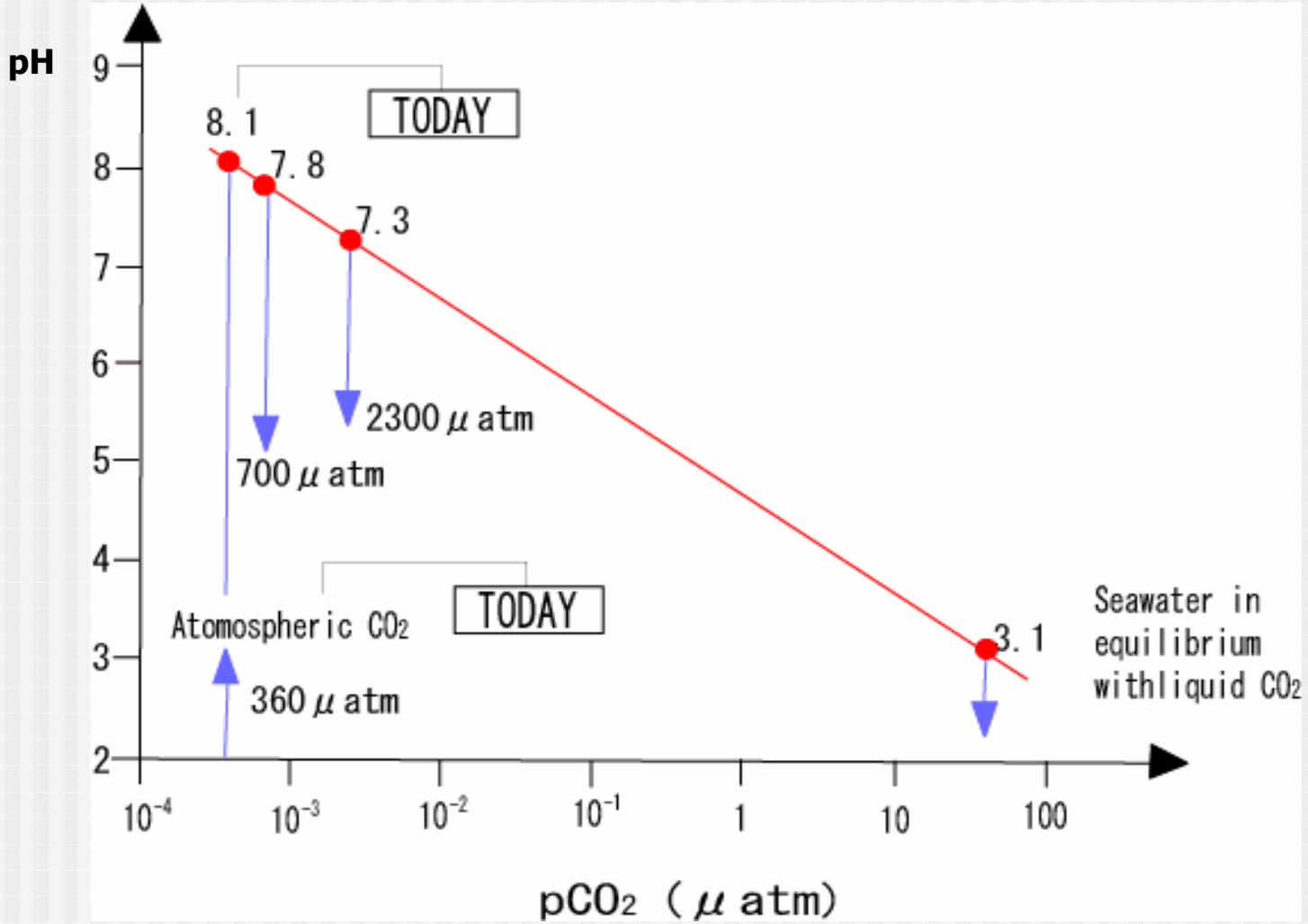


A comparison of the vertical distribution of pCO2, pH



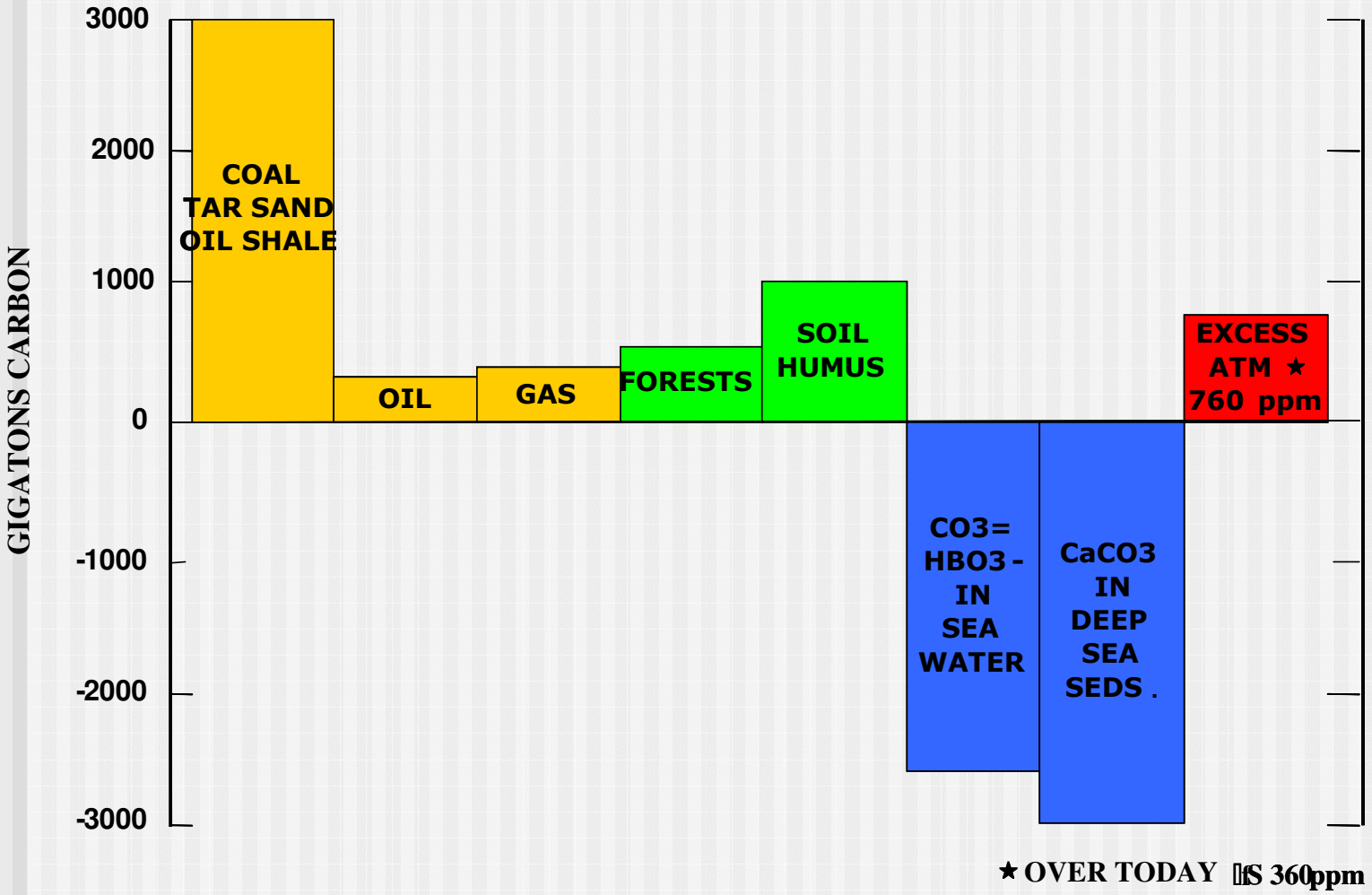
Millero, F.J. 1996. Chemical Oceanography, 2/e. CRC Press, Boca Raton, Florida

Changes in oceanic pH with increasing atmospheric pCO2 in future



Wong, C.S. and Hirai, S. 1997. Ocean Storage of CO_2 : A Review of Oceanic Carbonate and CO_2 Hydrate Chemistry

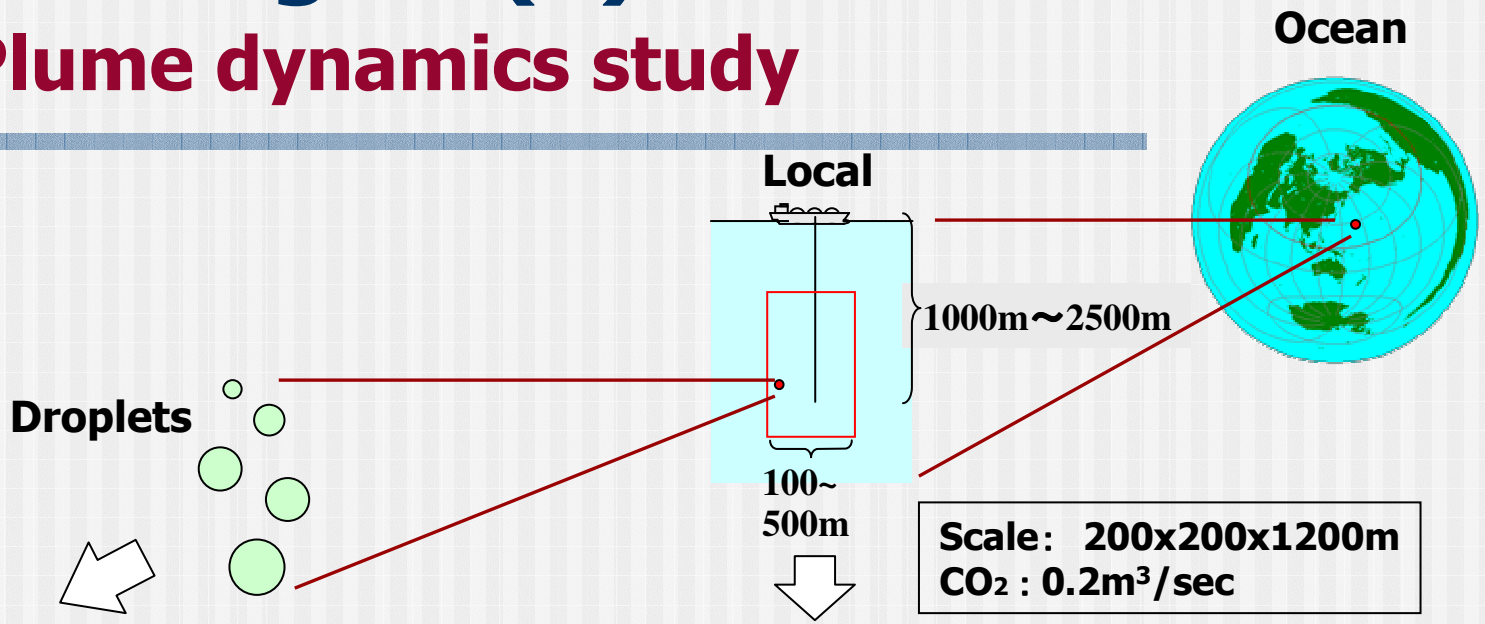
Capacity of ocean storage

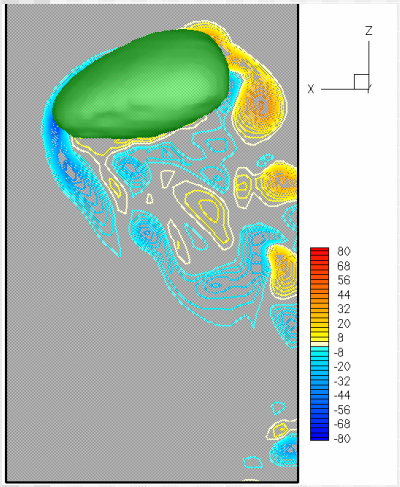


Broecker, W S., 2001. Carbon Future."Geoshere-Biosphere Interactions and Climate

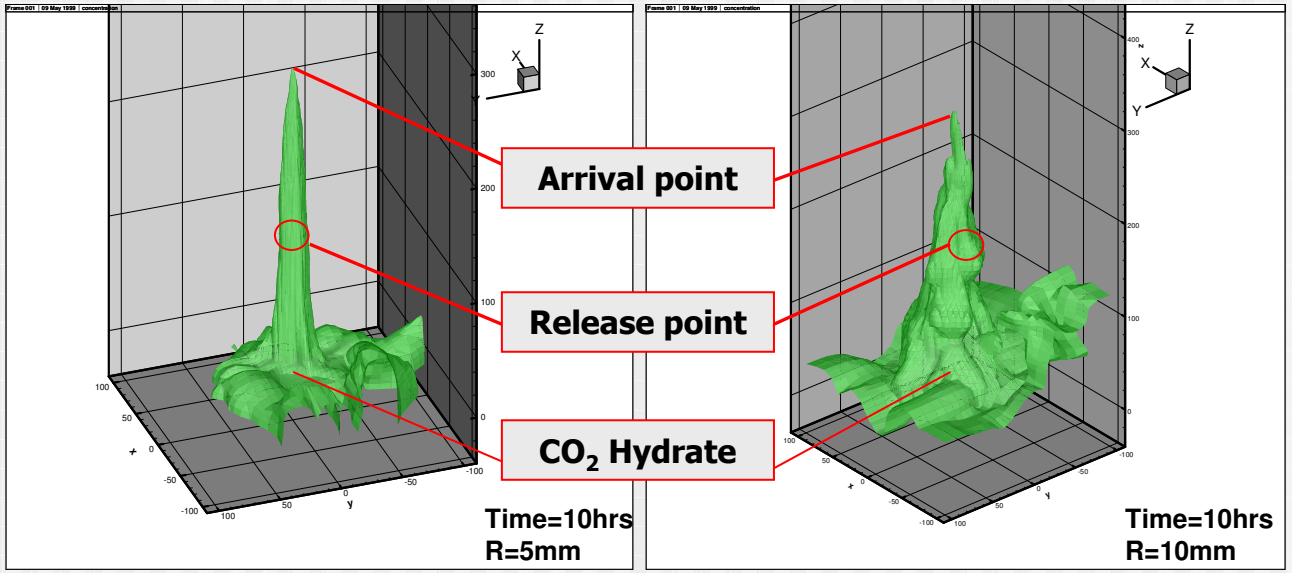
Technologies (1)

– Plume dynamics study





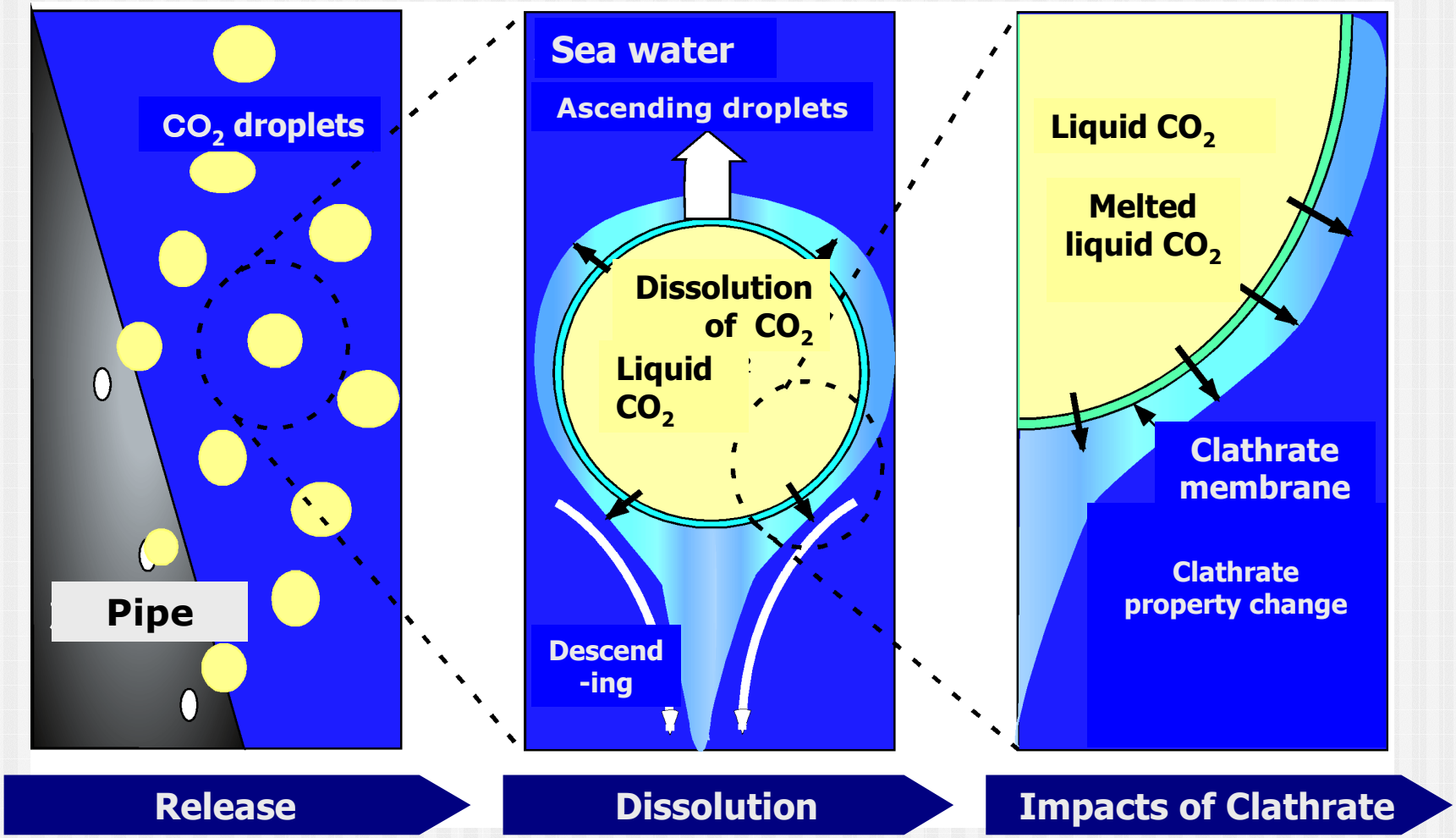
The processes at the surface of the CO_2 droplet



CO_2 distribution by difference of discharge caliber (R)

Technologies (2)

– The processes at the surface of the CO_2 droplet



Technologies (3)

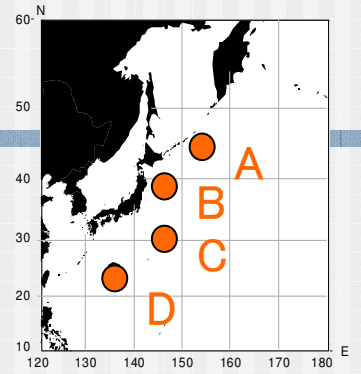
– The transport property of the liquid CO_2 in deep ocean conditions were collected using the high pressure apparatus

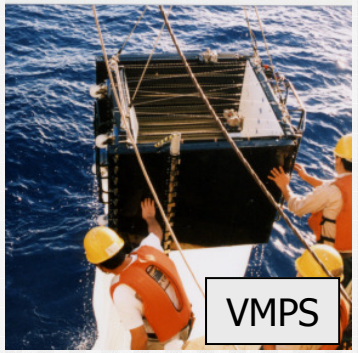
high pressure vessel (SwRI)

Test of the transport property of the liquid CO_2 (depth 800 m, 3.3° C)

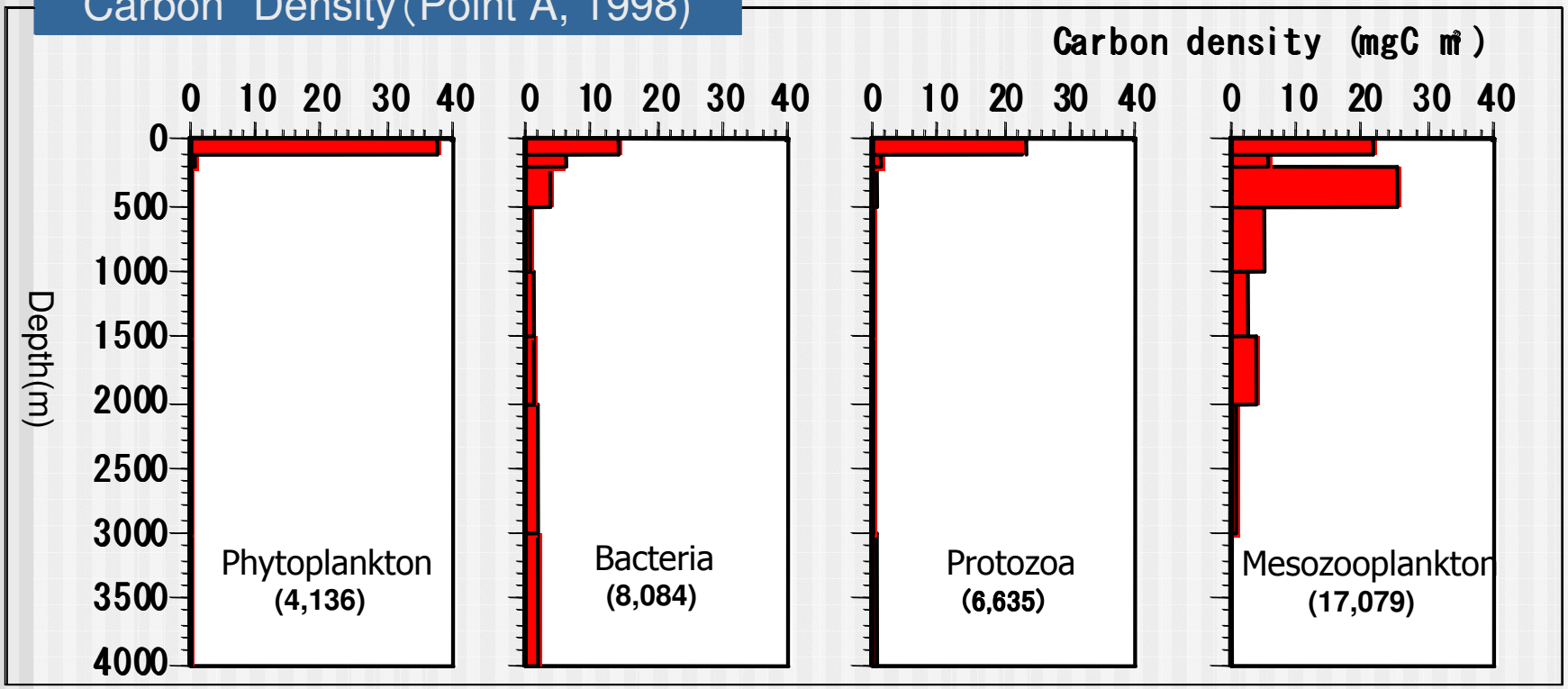
Risks (1)

— Biological studies





Carbon Density (Point A, 1998)



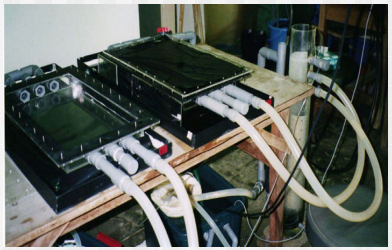
Risks (2)

– CO_2 effect to marine organism

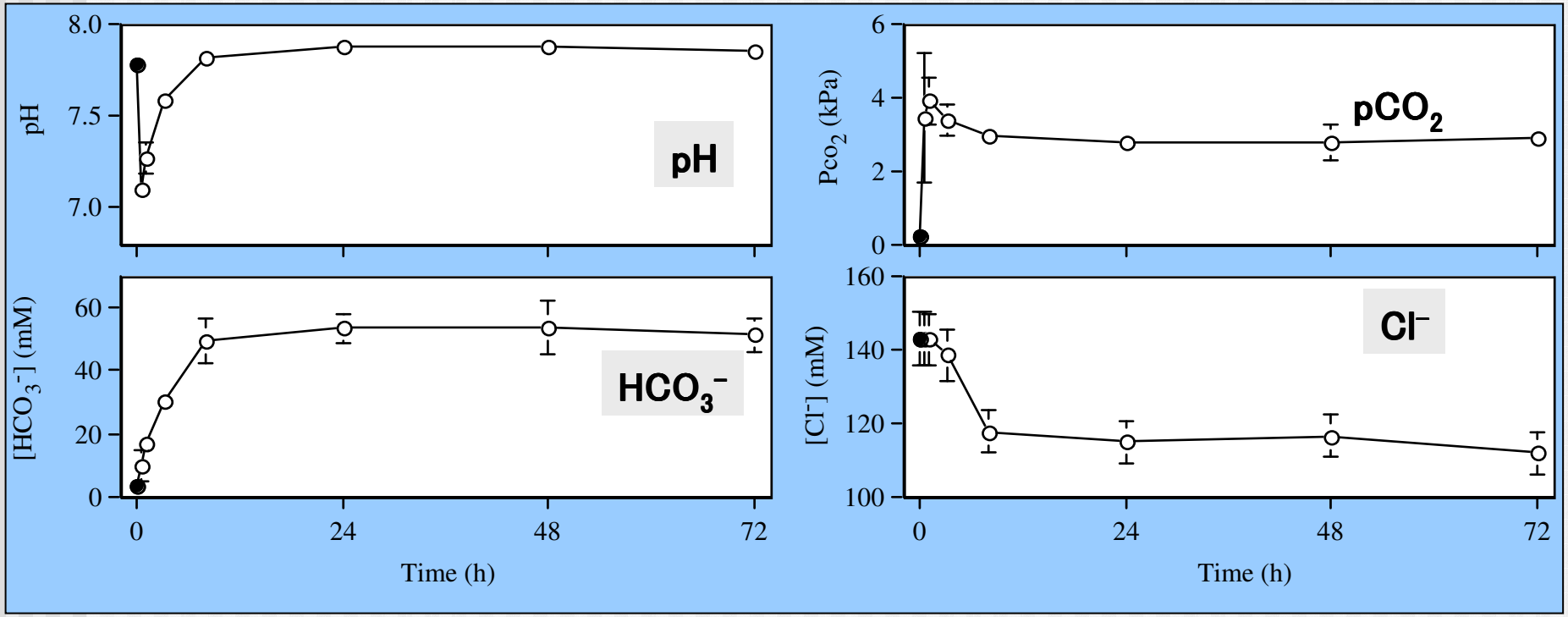
Operation for flatfish collecting blood

Though flatfish's blood ph recovers at once, dies on 5% CO_2

Experiment device

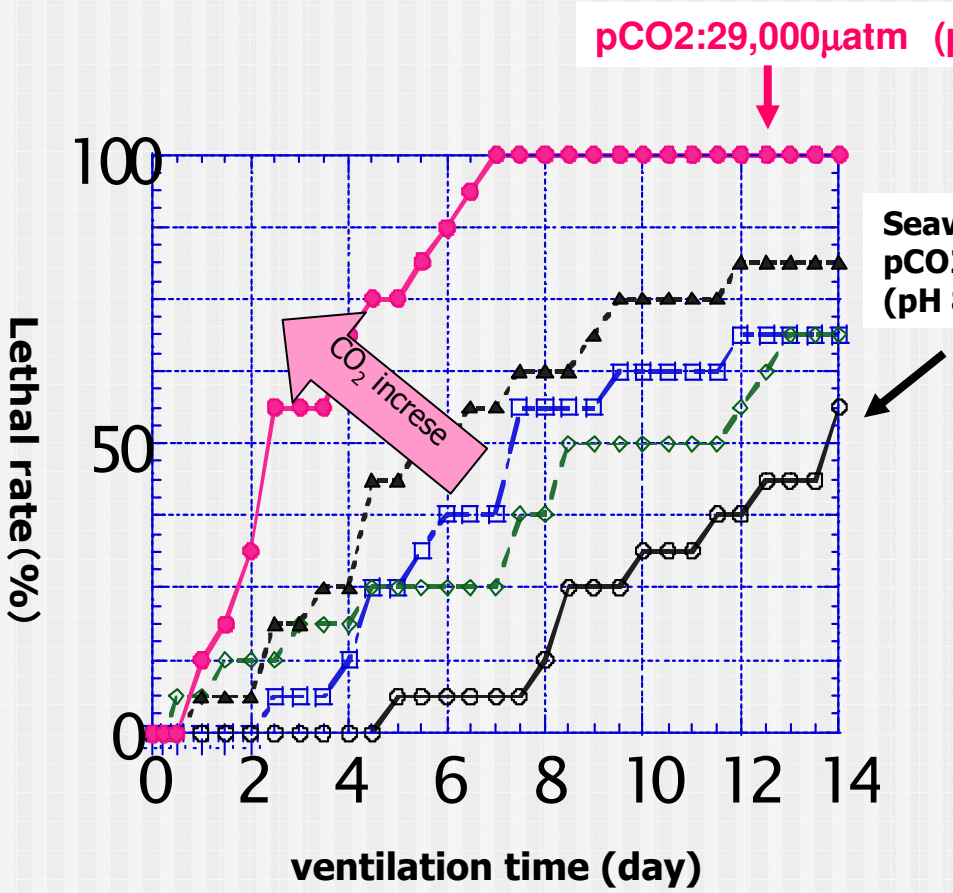


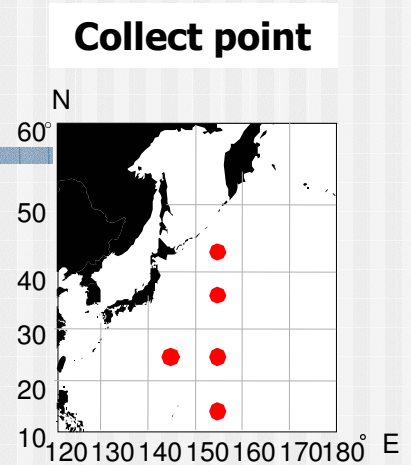
Flatfish's blood pH equilibrium in 3% CO_2

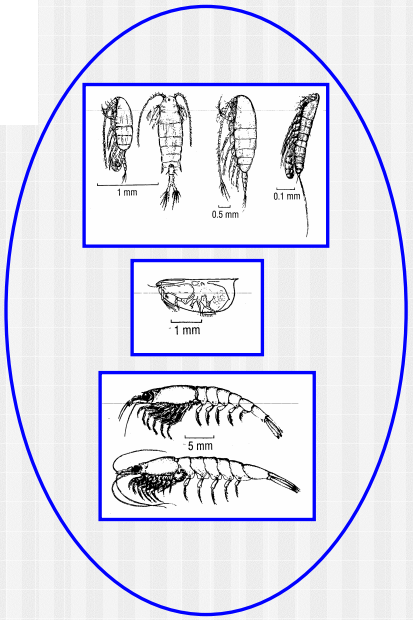


Short term local risks

— lethal effects of CO_2 to plankton







Deep sea plankton

Conclusions (1)

- Where the opportunity for geologic storage is restricted for geographical or geological reasons, ocean storage could be a major constituent in the mitigation policy package.
- Before starting the actual technology development for implementation, knowledge of the CO_2 behavior in the near field region of injection should be confirmed or verified in the actual ocean, through experiment.
- The ecosystem impact needs to be revealed in more detail for the requirement posed in the context of the assessment of technology relating to the ocean.

Conclusions (2)

- **There is much challenge for the implementation of the "lake type" storage where site specificity is the key. In this case, the detailed ocean surveys including baseline studies are very necessary.**

- **The intrinsic advantage of ocean storage over geologic storage is the relative flexibility of the site; the generic assessment methodology may be easily modified to an actual implementation case.**

Perspectives of CO_2 Storage in Ocean

Study: Direct impact of CO_2

- monitoring of ocean environment is anyway necessary
- more reliable and comprehensive monitoring is feasible in comparison with aquifer storage

Legal aspects

- Good lesson from on-going London Convention/Protocol regime, for the technology to be accepted in the international framework (monitoring could be the key)

in Science Community

- Concern on the ocean acidification might overwhelms the climate change !