Development of an assessment methodology for CO_2 leakage from off-shore reservoir

海底下貯留における海域環境影響評価手法の開発

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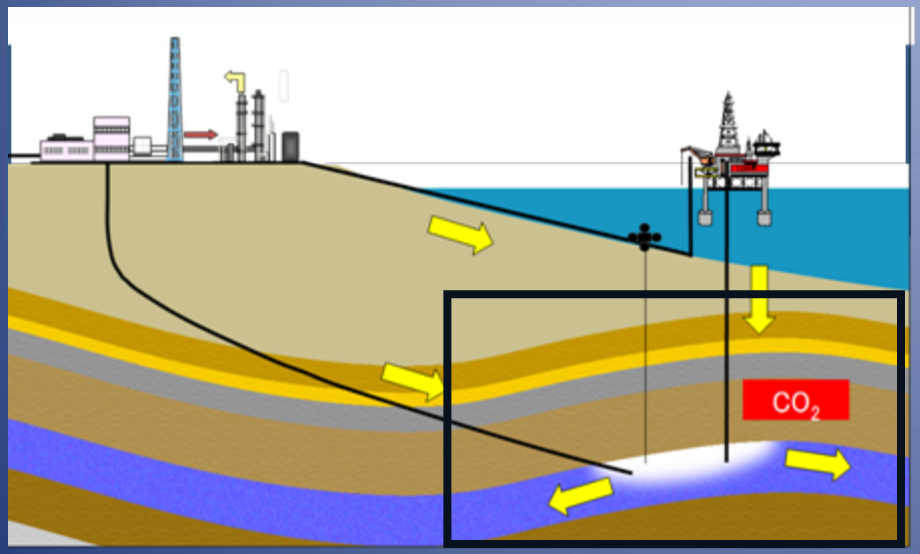
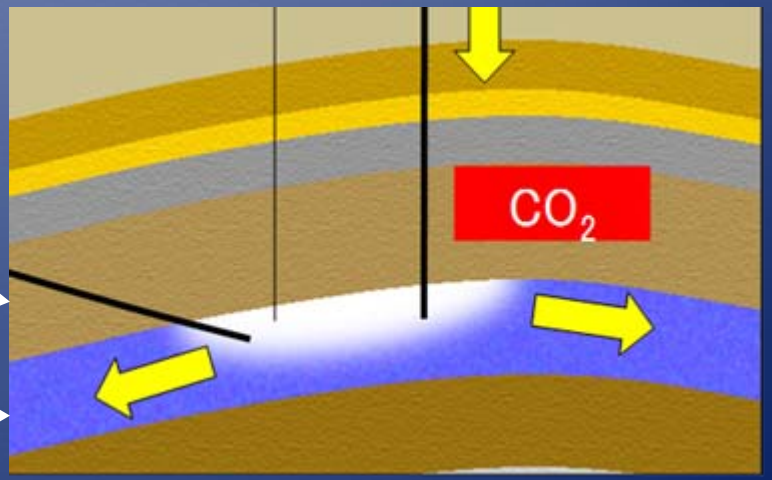
内本 圭亮

Offshore CO_2 storage



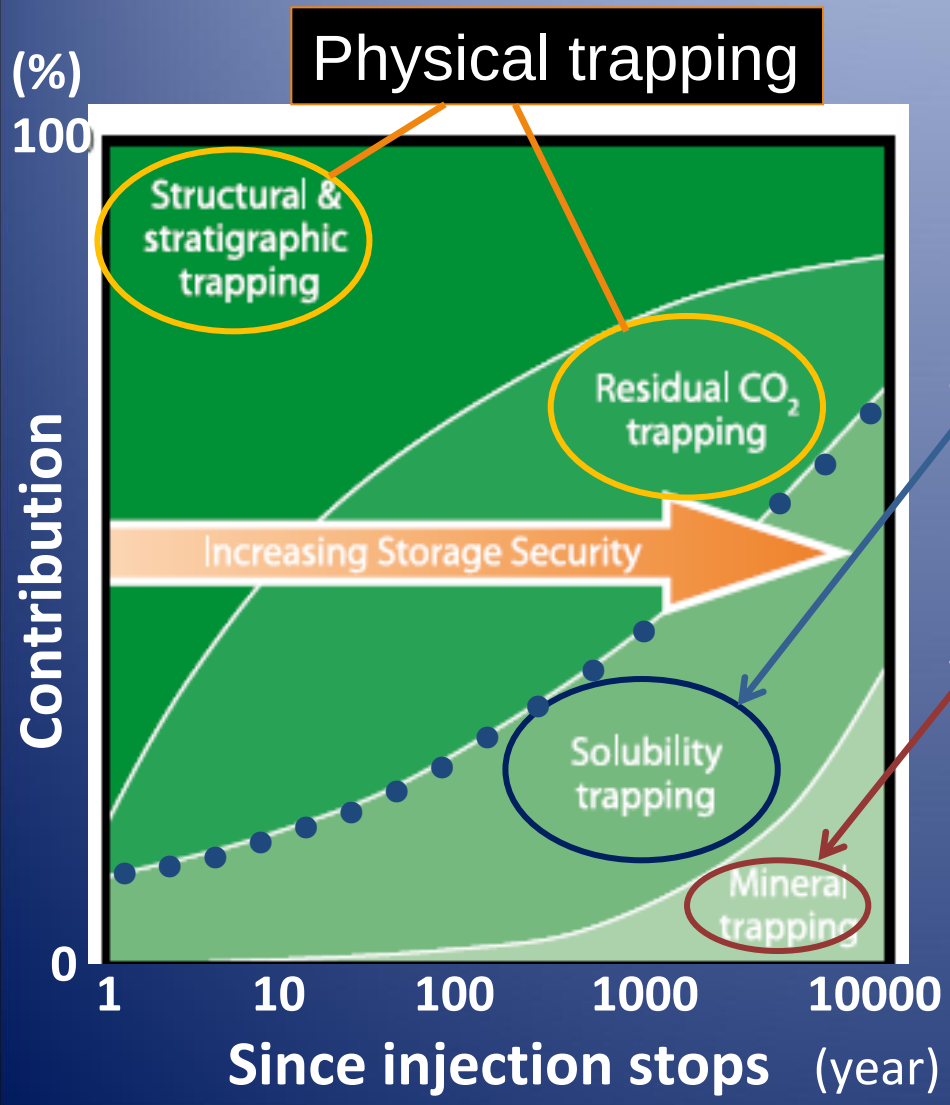
Caprock layer prevents injected CO_2 from leaking



caprock layer

reservoir

Various trapping



In addition to physical trapping

- Solubility trapping: dissolution in formation water
  - ✓ Buoyant forces are eliminated
- Mineral trapping: conversion to stable carbonate minerals

Risk of CO_2 leakage from Reservor is thought to be little.

Why is the assessment necessary?

Science and Technology is not perfect.

Possibility of leakage is thought to be little but not zero.

- Required by law→ talked by Dr. Kita
- To gain Public acceptance

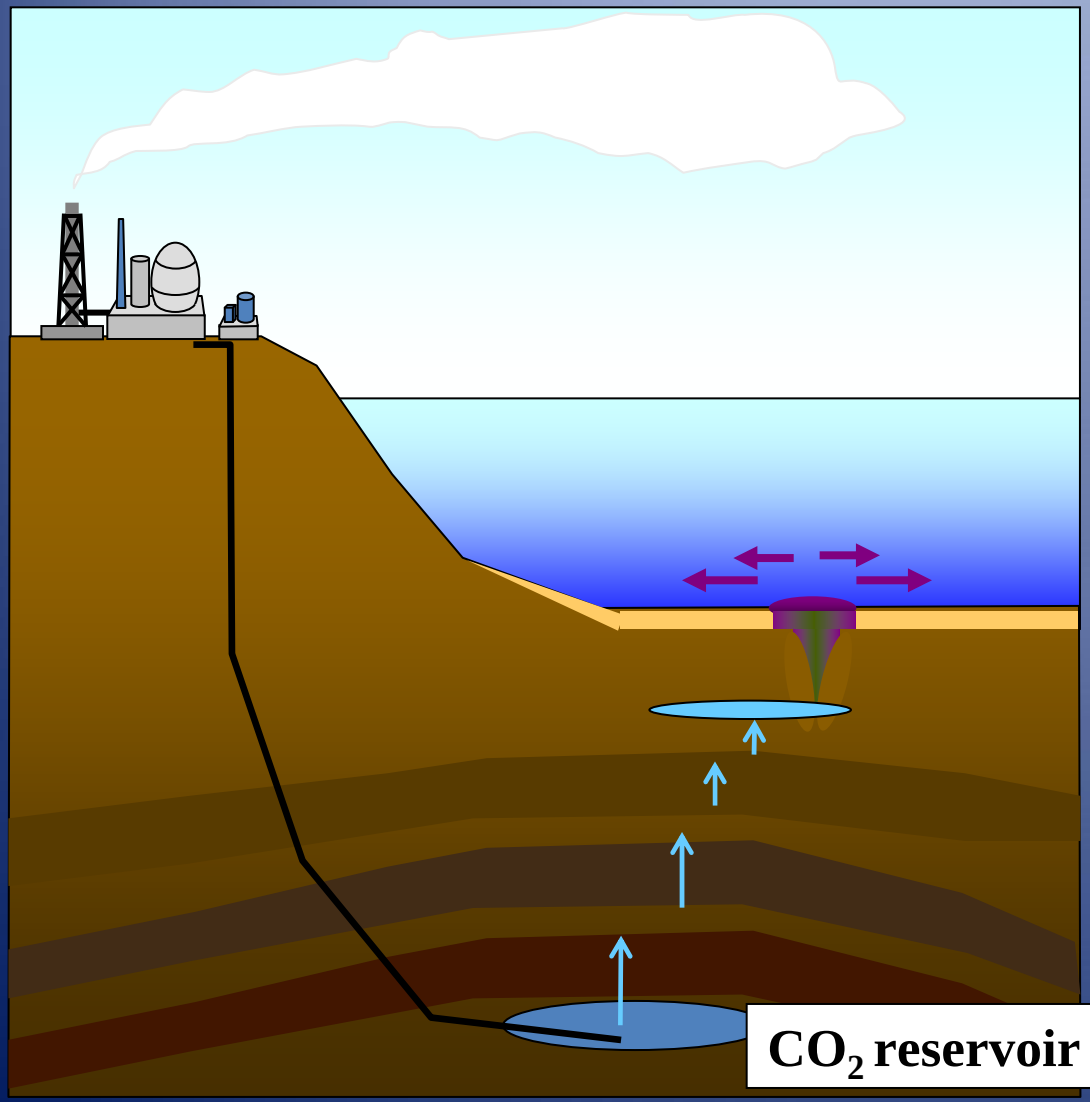
Development of simulation models

If stored CO_2 should leak into the sea,

what would happen?

RITE is developing numerical models to simulate CO_2 behavior from the reservoir to the sea, to assess environmental impacts of leaked CO_2.

CO_2 simulation models



sea **MEC-CO_2**

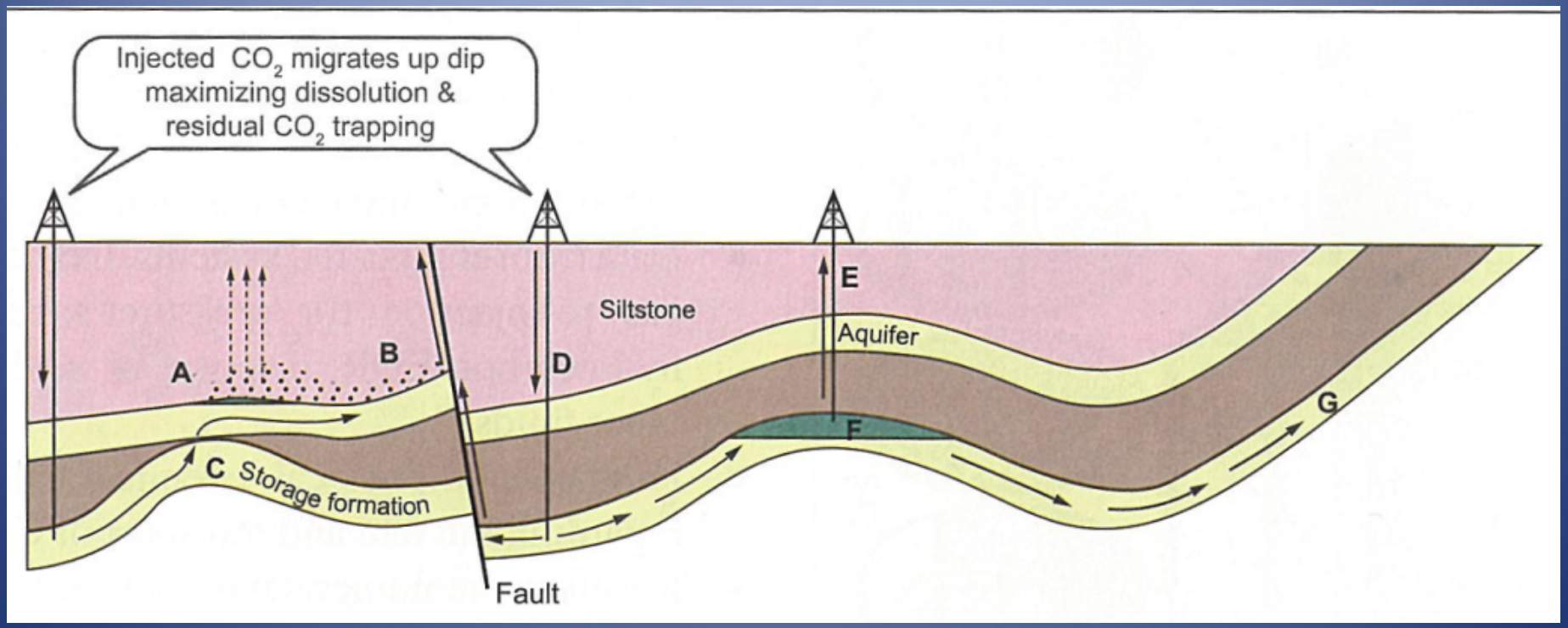
sediment layer

C.CANDI

formations

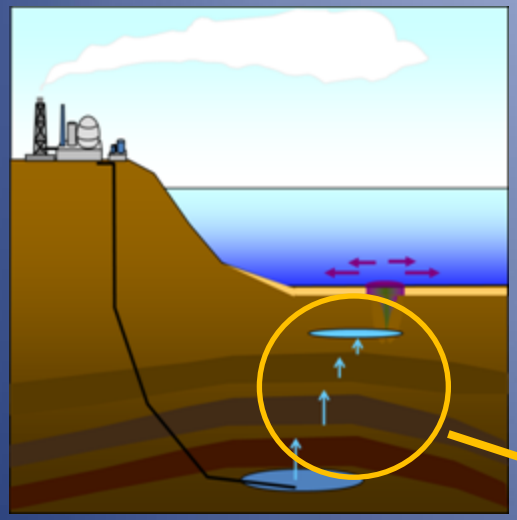
Tough

Potential escape routes



IPCC Special Report on Carbon Dioxide Capture and Storage

Simulation in geological formations (Tough)



Constructing a model for potential escape routes

- bubble CO_2
- dissolved CO_2

seabed

CO_2 migrates according to
- permeability
- buoyancy

CO_2 in the model:
- supercritical
- gas phase
- liquid phase・dissolved

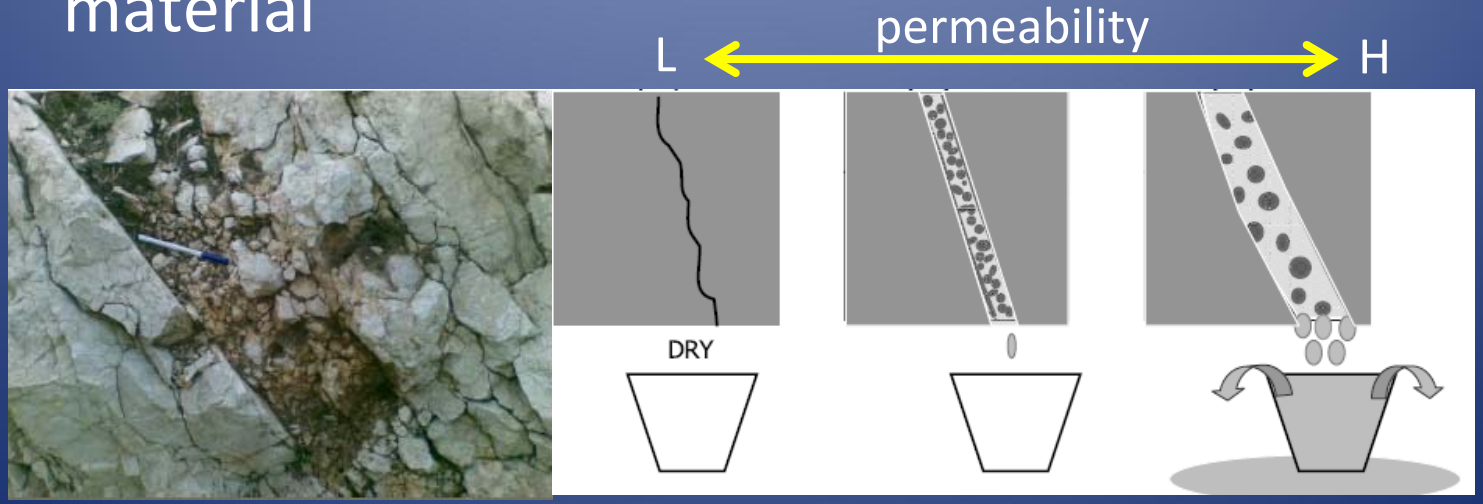
CO_2 (from reservoir)

Model domain

Permeability in escape routes

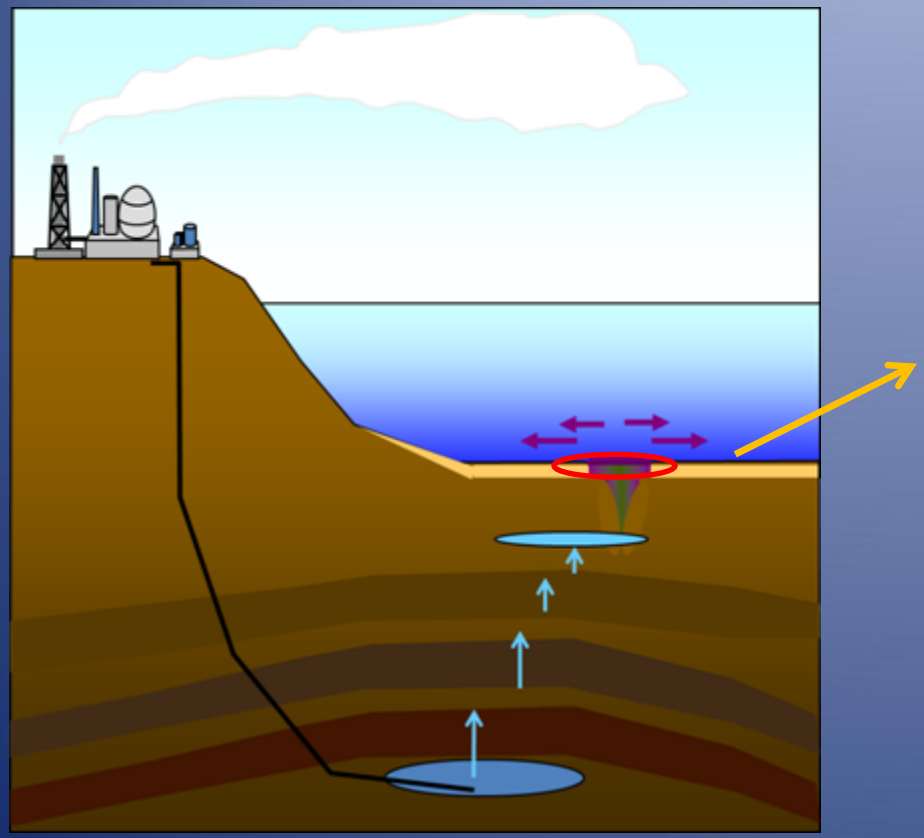
- Appropriate values ?
  - Actually there are no fault near the reservoir through which CO_2 may leak!

- Fault zone modeling
  - Geometry・Complexity・Damage zone・Type of material



Talwani et al. (2007)

Sediment layer



sea

Sediment

formation
s
(overburden)

Tens of meters

Only tens of centimeters

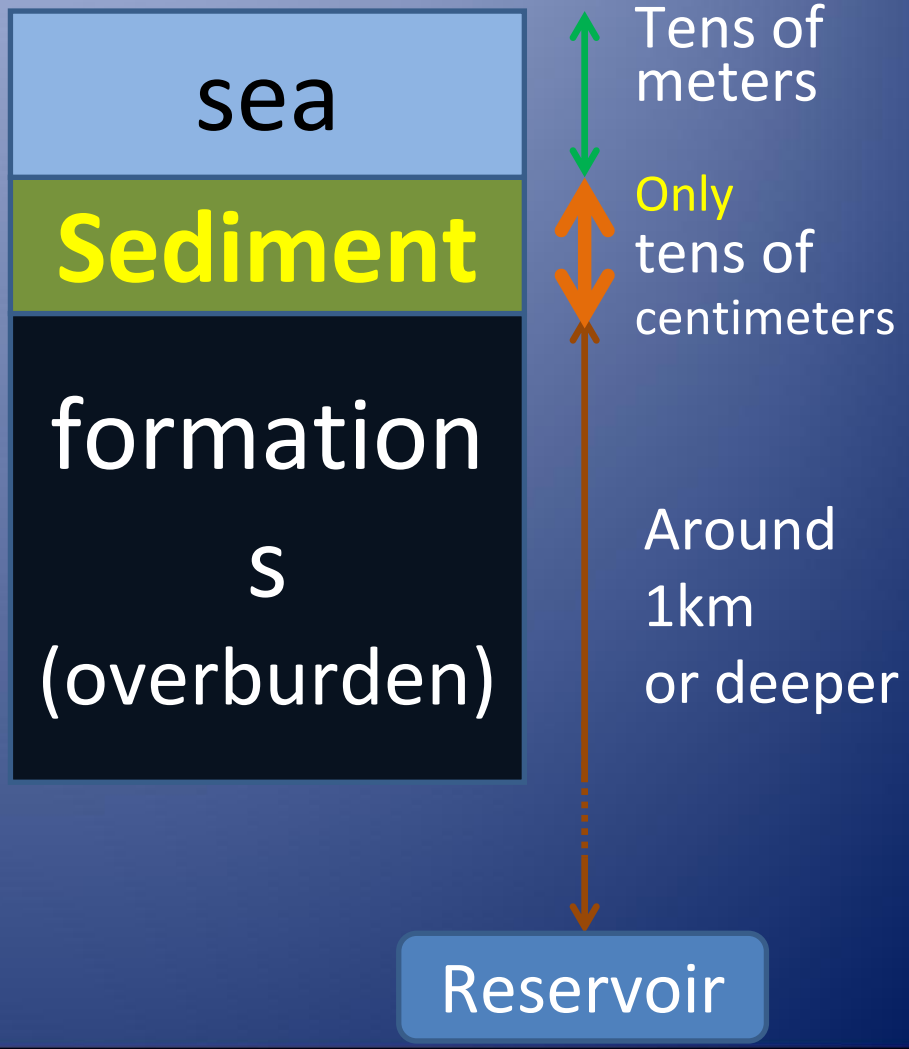
Around 1km or deeper

Reservoir

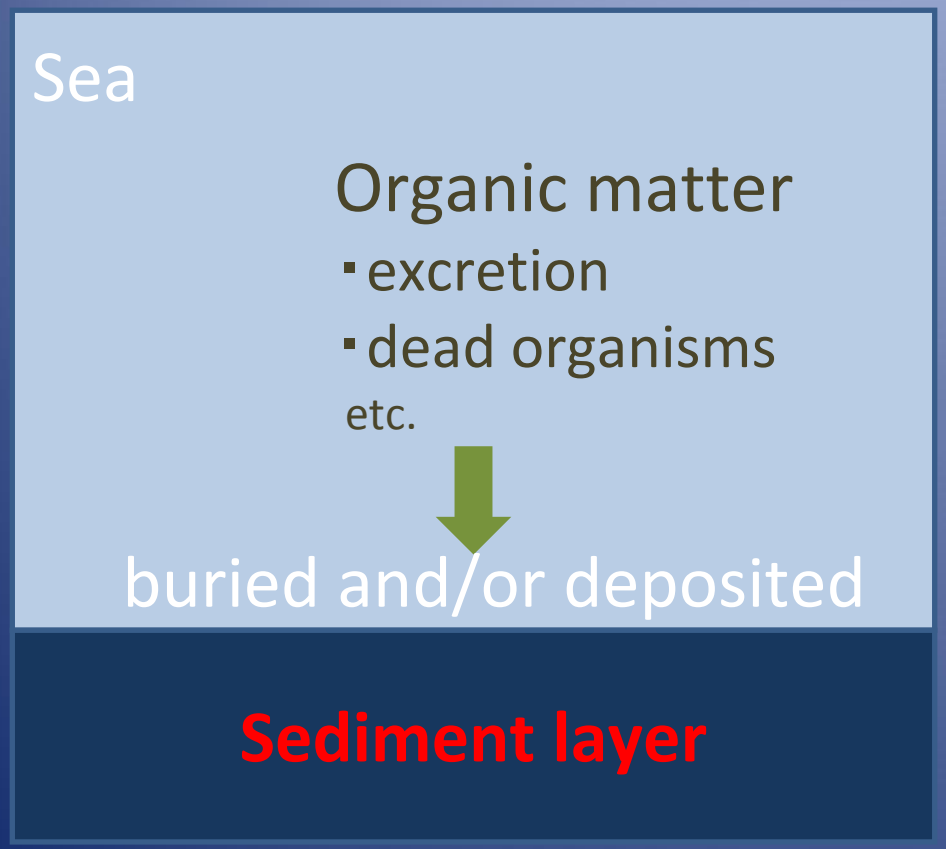
Sediment layer

Is this **thin** sediment layer important?

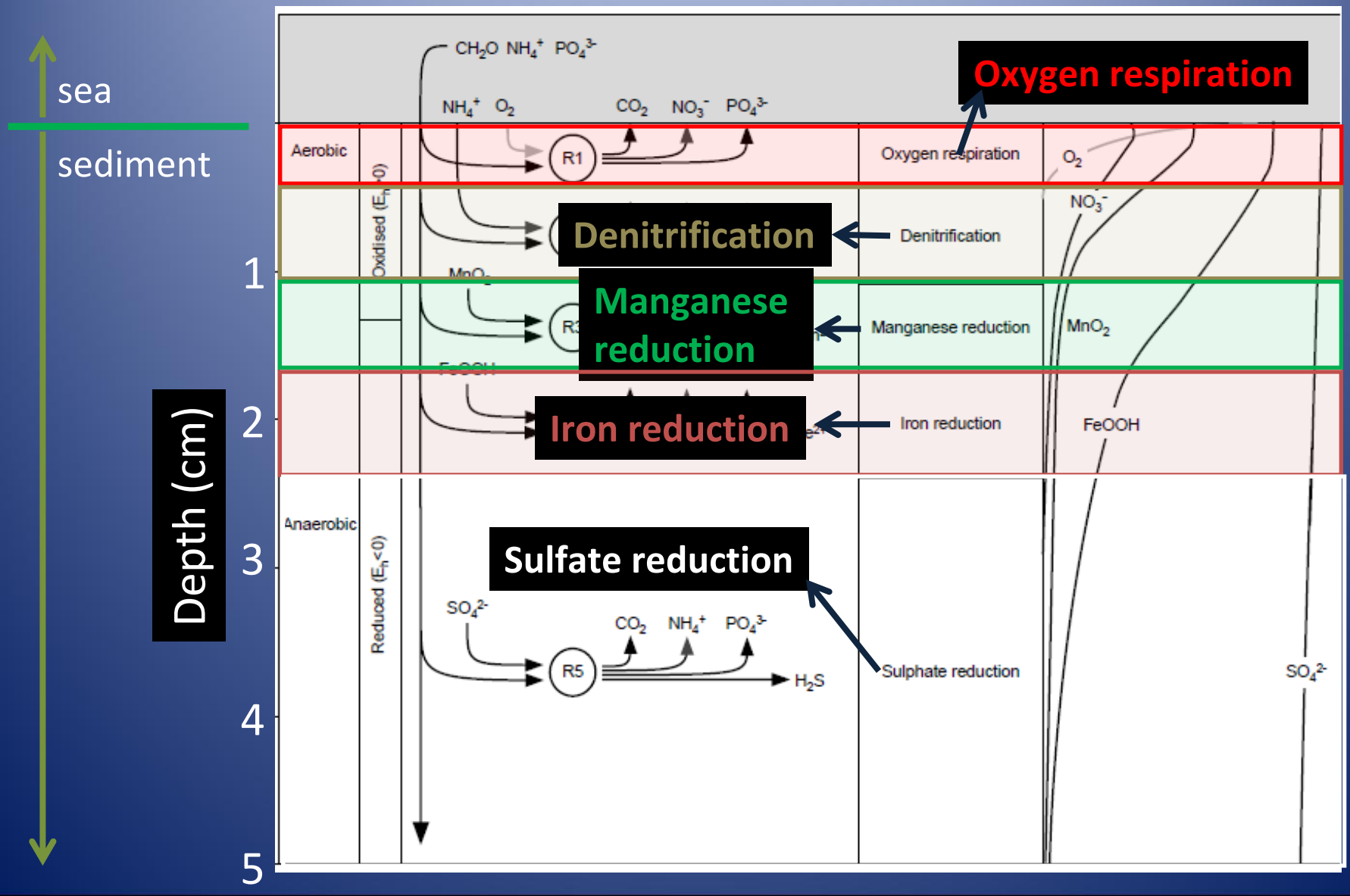
Is the simulation necessary?



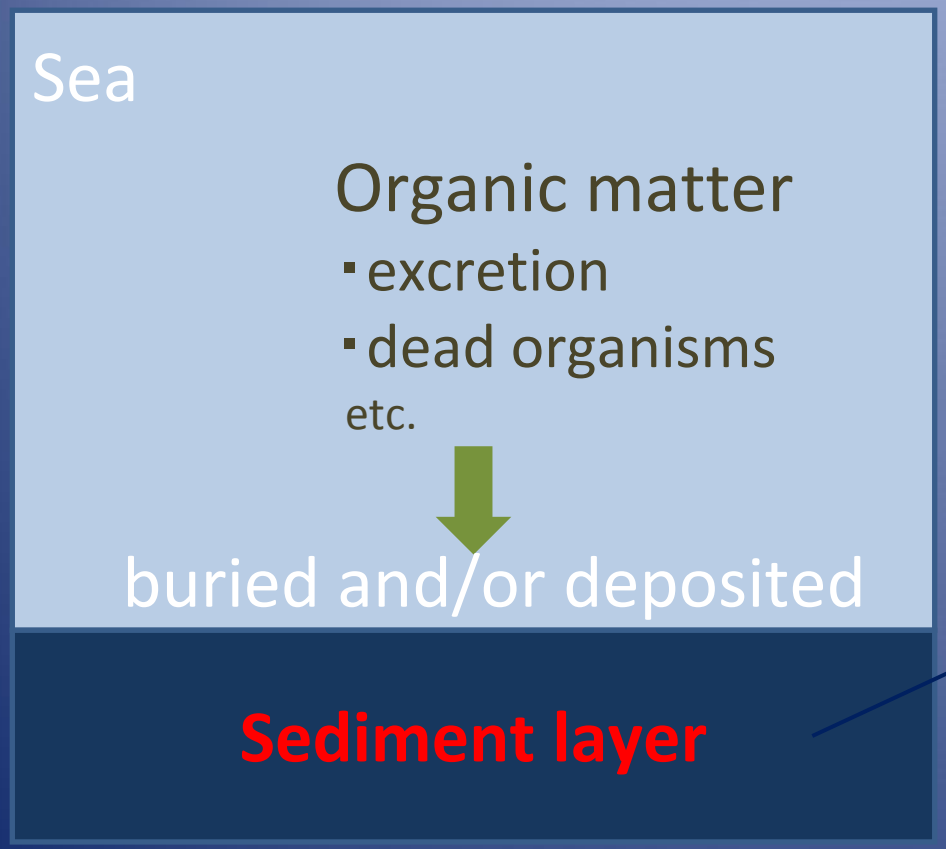
Sediment layer



Sediment layer



Sediment layer



C.CANDI:
A model calculating degradation and diagenesis processes in the sediment layer

Simulation in the sediment layer （C.CANDI）

- Organic and inorganic matters are calculated
  - degradation, redox reaction
  - advection（transport by porewaters）
  - diffusion
  - bioturbation（mixing by benthos）

Simulation in the sediment layer （C.CANDI）

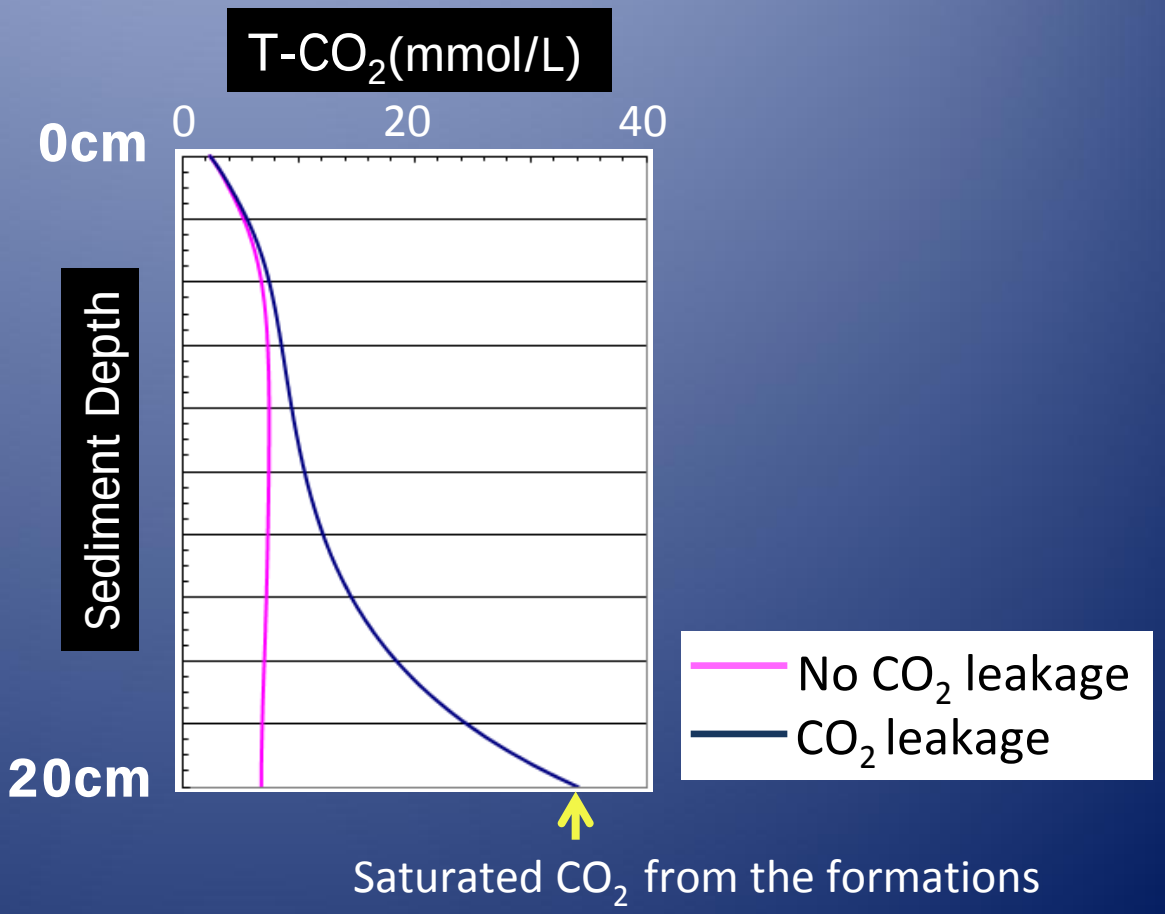
- leaked CO_2 simulation
  - CO_2 from the seafloor :
    - Bubble CO_2 (gas form)

      → without any change within the sediment layer
    - dissolved CO_2

      → great change within the sediment layer

Simulation in the sediment layer (C.CANDI)

CO_2 from the seabed moves upward with the concentration decreased.



Simulation in the seawater

Calculating the distribution and concentration of CO_2 in the sea

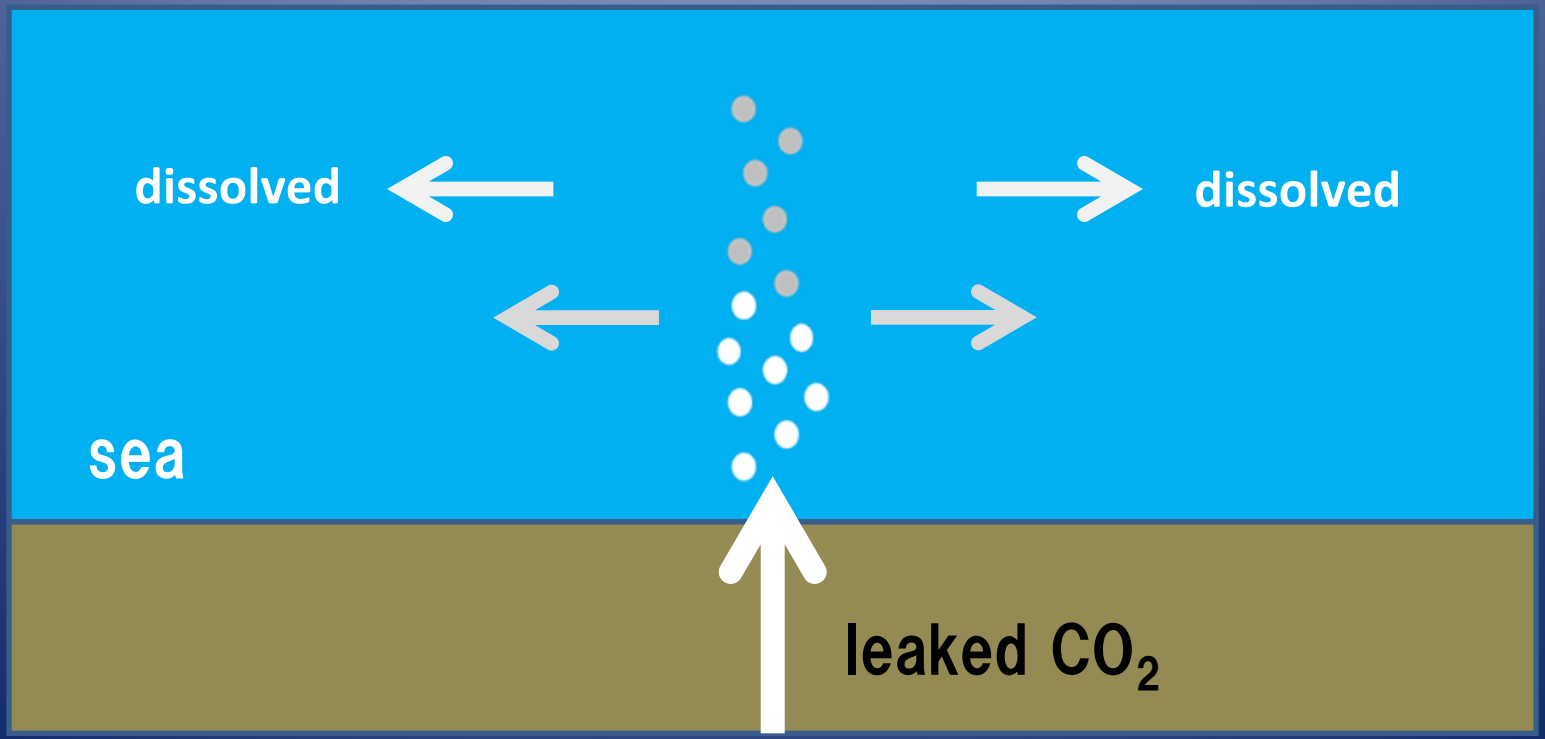
CO_2 in the sea

- Bubble CO_2
- Dissolved CO_2

may influence
the marine environments, ecosystems

Simulation in the seawater

Bubble CO_2 → dissolved CO_2 → distributed in the sea



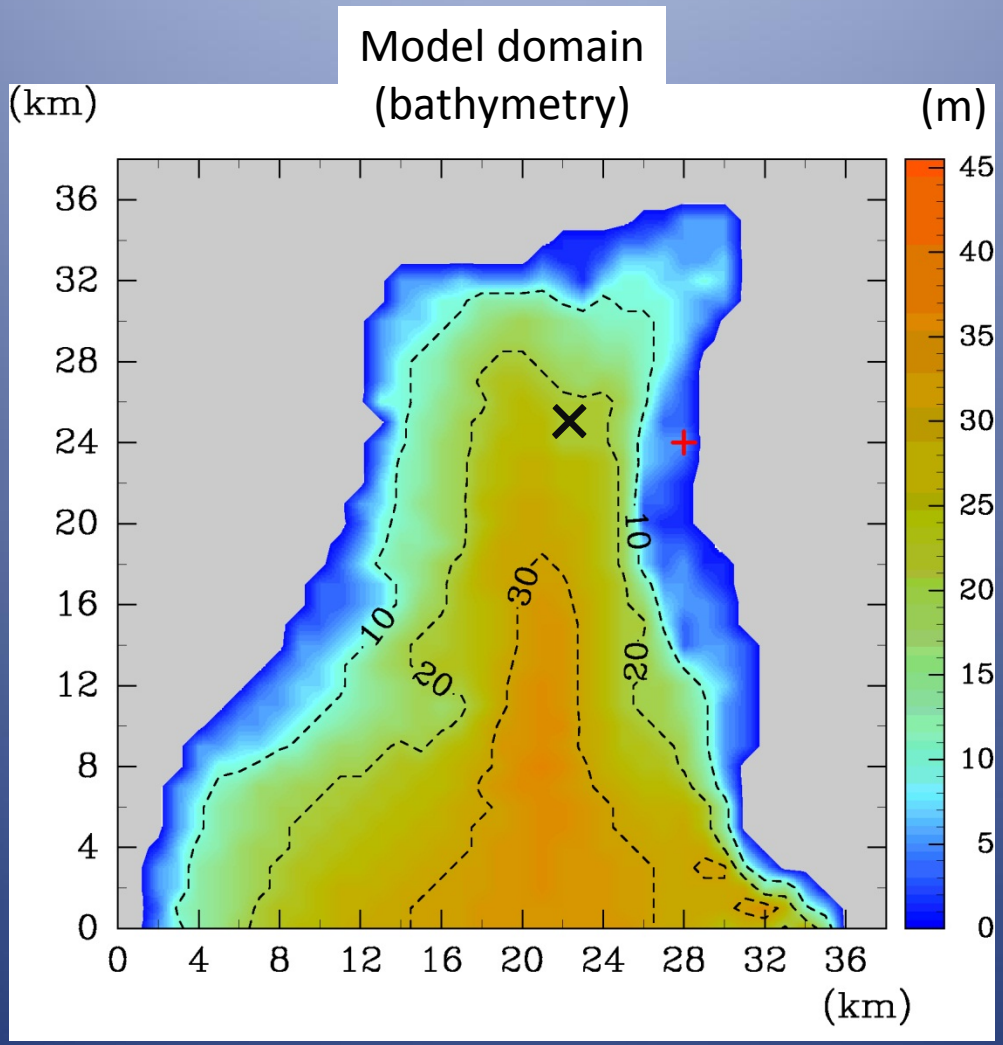
Simulation in the sea（MEC-CO_2）

- MEC-CO_2 model
  - ocean model

    calculating
    - current, temperature, and salinity in the sea
    - *driven by* tides, wind stress, heat flux, freshwater flux (precipitation, evaporation, river runoff)
  - CO_2 two-phase model

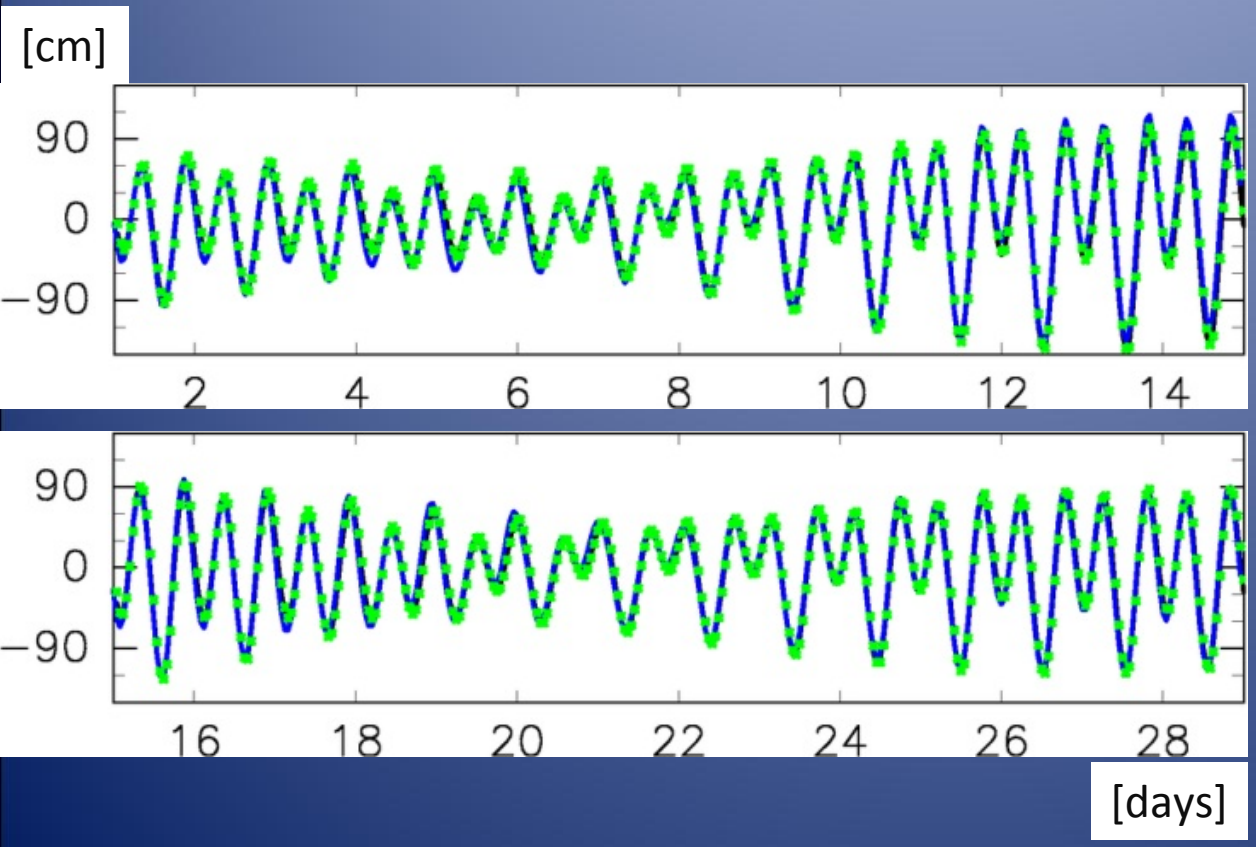
    calculating
    - bubble CO_2
    - dissolved CO_2
    - transfer from bubble to dissolved CO_2

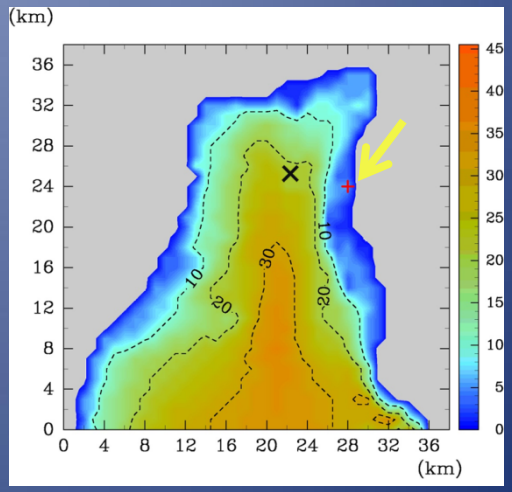
Simulation in the sea（MEC-CO_2）



Simulation in the sea（MEC-CO_2）

- Time series of sea surface height anomaly

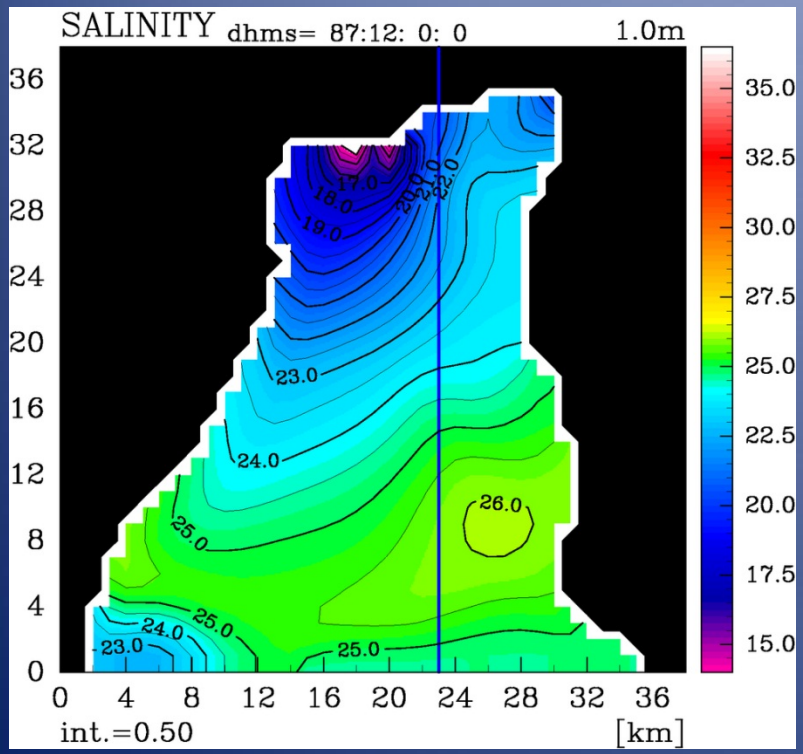


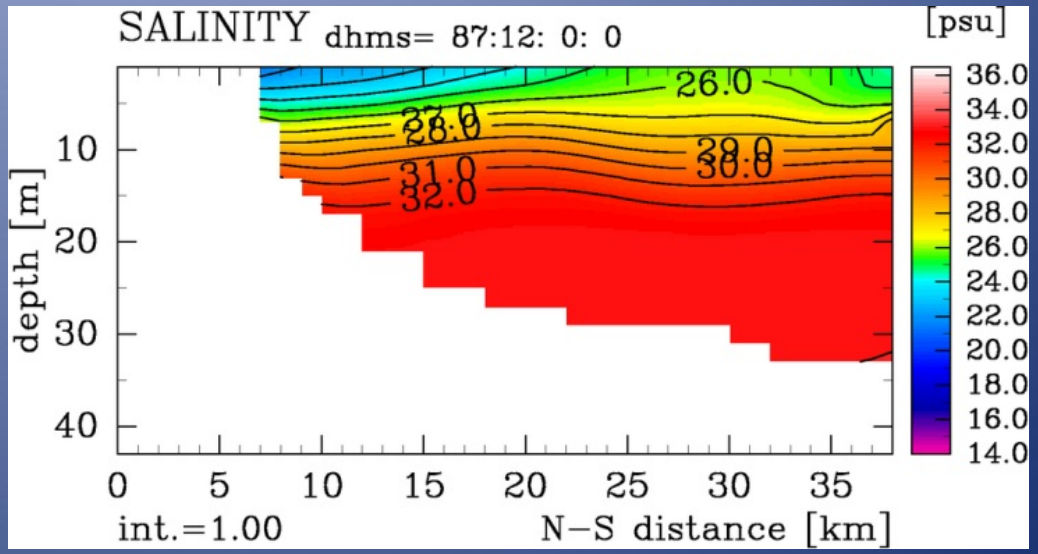


Blue line : observation
Green dots : model results

Simulation in the sea（MEC-CO_2）

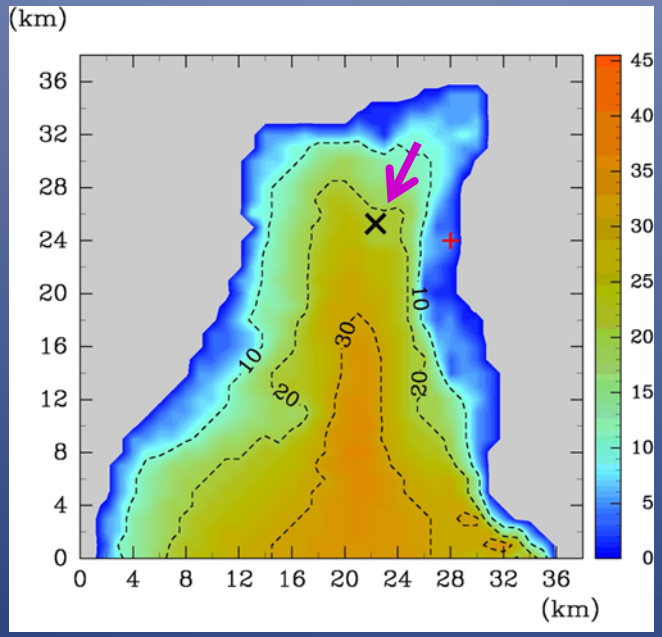
- Salinity (Sea surface, vertical section)





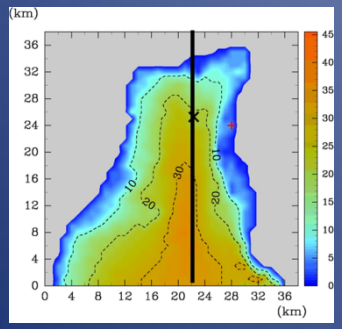
Simulation in the sea（MEC-CO_2）

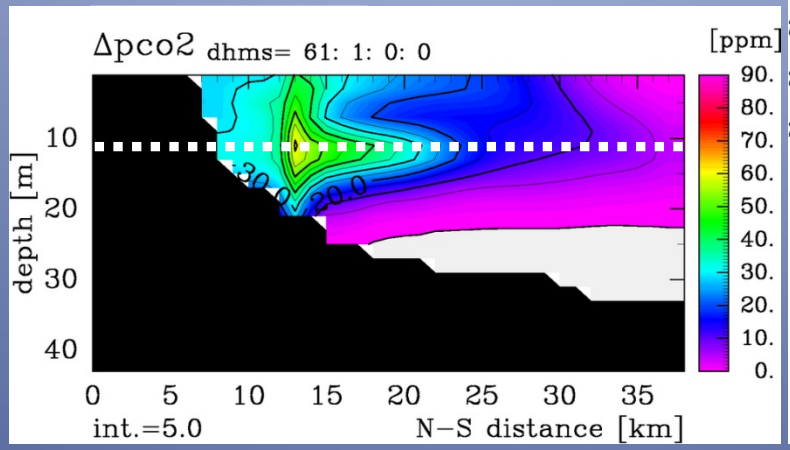
- Leakage rates according to Kano et al. (2010)
  - Reasonable rate: 3,800 t/y
  - Extreme rate: 94,600 t/y

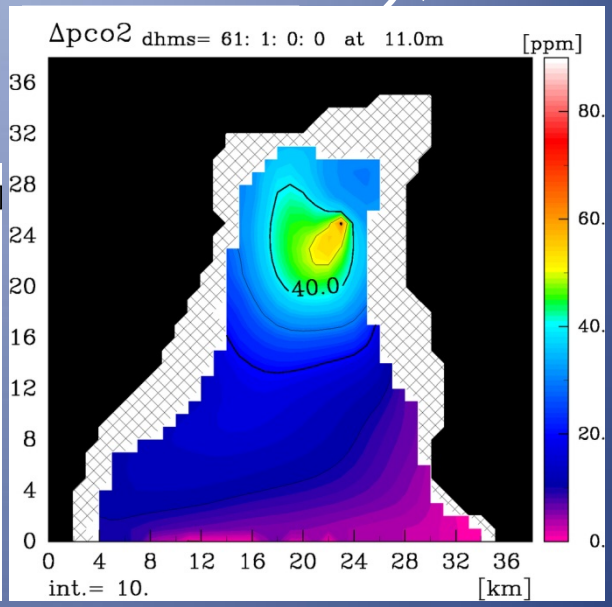


Simulation in the sea（MEC-CO_2）

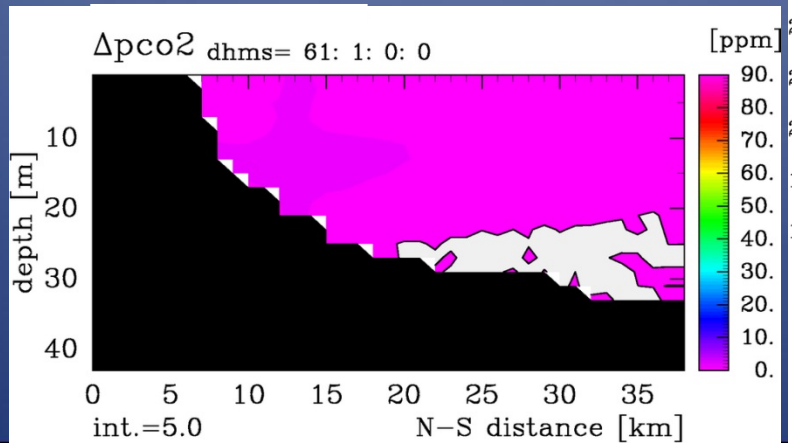
Extreme

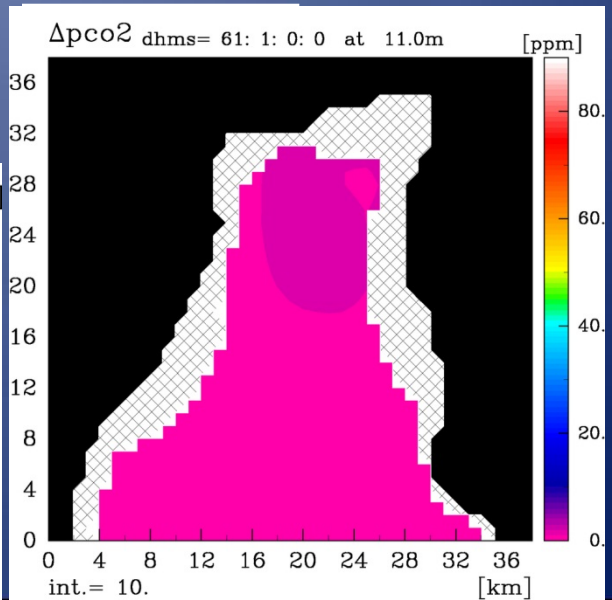






Reasonable





Database of impact assessment on marine organisms

- Accumulating a database
  - Biological impacts of CO_2 -- pCO_2, or resultant pH change
  - Species by species
  - Degrees of impacts; decease, growth problem, etc.

Example of Database

供試生物	対照区pCO_2 (ppm)	実験区pCO_2 (ppm)	暴露期間	影響	参考文献
サンゴ 成体 *Porolithon onkodes*	135-460 (pH 8.00-8.40)	520-705 (pH 7.85-7.95)	8 週間	白化が増加	Anthony et al., 2008
		1,010-1,350 (pH 7.60-7.70)		白化が増加	
サンゴ プラヌラ幼生 *Acropora tenuis*	400-475 (pH 8.03)	905-1,660 (pH 7.64)	7 日間	なし	Suwa et al., 2010
		2,115-3,585 (pH 7.31)		生残率：低濃度区より増加	
動物プランクトン 幼生 *Acartia erythrae*	365	2,365	24 時間	なし	Kurihara et al., 2004
		5,365		生残率減少	
		10,365		生残率減少	
ヨコエビ 成体 *Gammarus locusta*	pH 8.1	～550 (pH 7.8)	28 日間	なし	Hauton et al., 2009
		～980 (pH 7.6)		なし	
巻貝 卵 *Littorina obtusata*	—	1,100 (pH 7.6)	約28 日間	生残率減少	Ellis et al., 2009
イカ類 *Sepia lycidas*	自然海水 (pH 8.12-8.14)	30,000（pH 6.38) 50,000（pH 6.17) 70,000（pH 6.02) 100,000（pH 5.87) 150,000（pH 5.70)	24 時間	半数生存限界（TLm）：84,000ppm	Kikkawa et al., 2008
魚類 *Paralichthys olivaceus*	自然海水 (pH 8.111)	9,900-79,000 (pH 6.233-7.017)	6 時間	LC_{50}：27,600ppm	Kikkawa et al., 2003

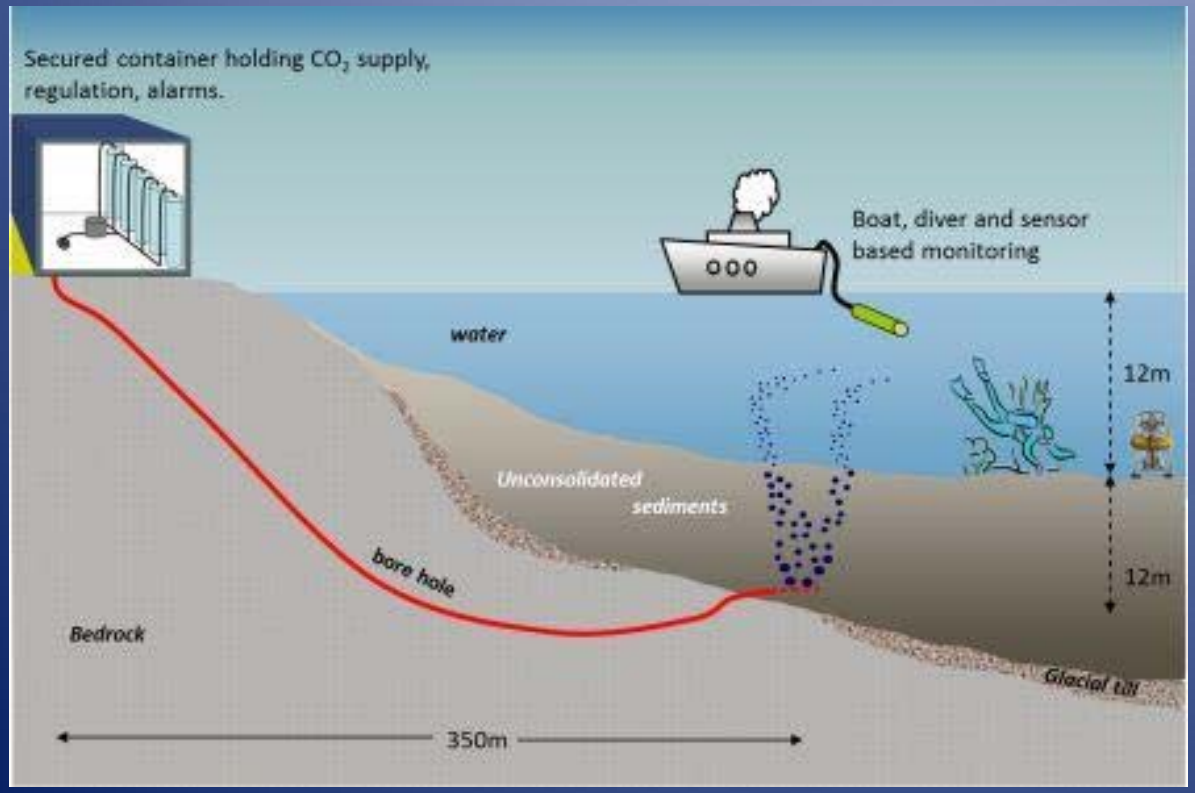
Example of results of database

group	pCO_2	influence
Shellfish Echinoderm Coral Coccolithophore	Δ 200ppm<	Declining calcification
Fish Squid zooplankton	Δ 2,000ppm <	Physiological inhibition

QICS

Quantifying and Monitoring Potential Ecosystem Impacts of Geological Carbon Storage

http://www.bgs.ac.uk/qics/



CO_2 release: 100-200 kg/day

Summary

- Environment assessment for offshore storage
  - Need for Assessment
    - Required by law
    - To gain Public acceptance
  - Methodology
    - Simulation models for leaked CO_2:
      - Seal layer (overburden) →Tough
      - Sediment layer → C.CANDI
      - Sea → MEC-CO_2
    - Database of impact assessment on marine organisms