# Dissociation of gas hydrates in marine sediments triggered by temperature increase: a theoretical model

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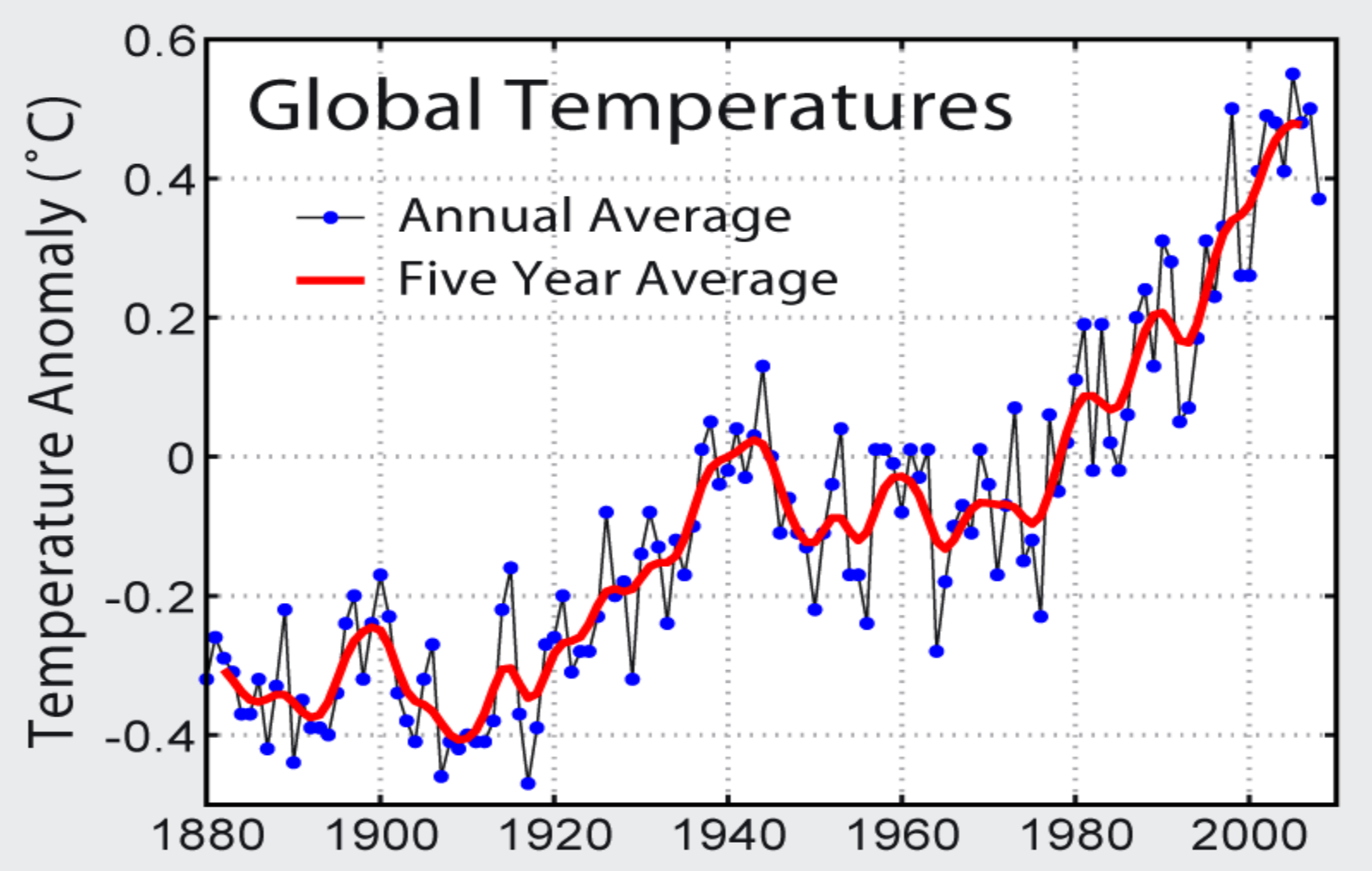
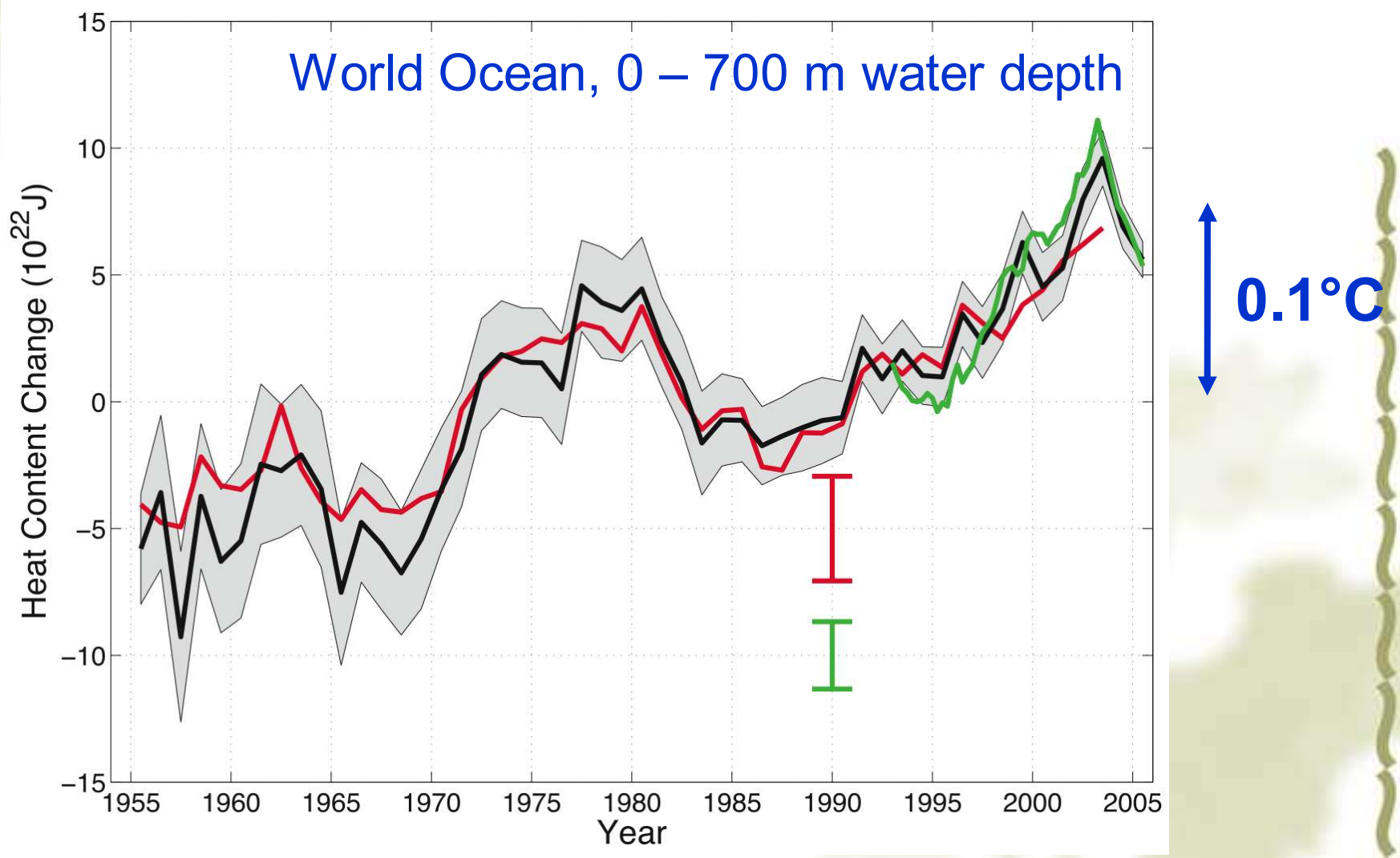
# Introduction: Global warming



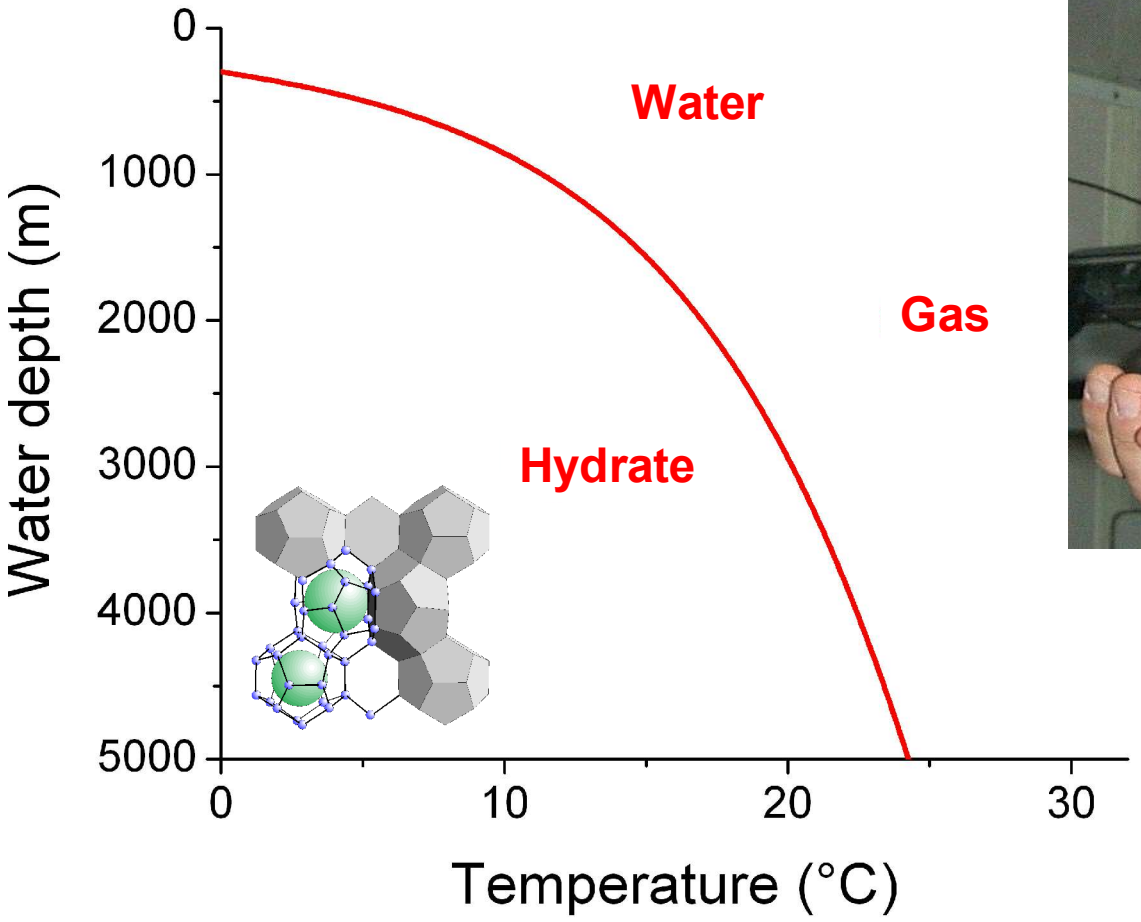

(Source: Climate Research Unit, Univ. of East Anglia, UK)

# Introduction: Ocean warming




Source: IPCC (2007)

# Introduction: Stability of gas hydrates




Tishchenko, Hensen, Wallmann & Wong (2005)

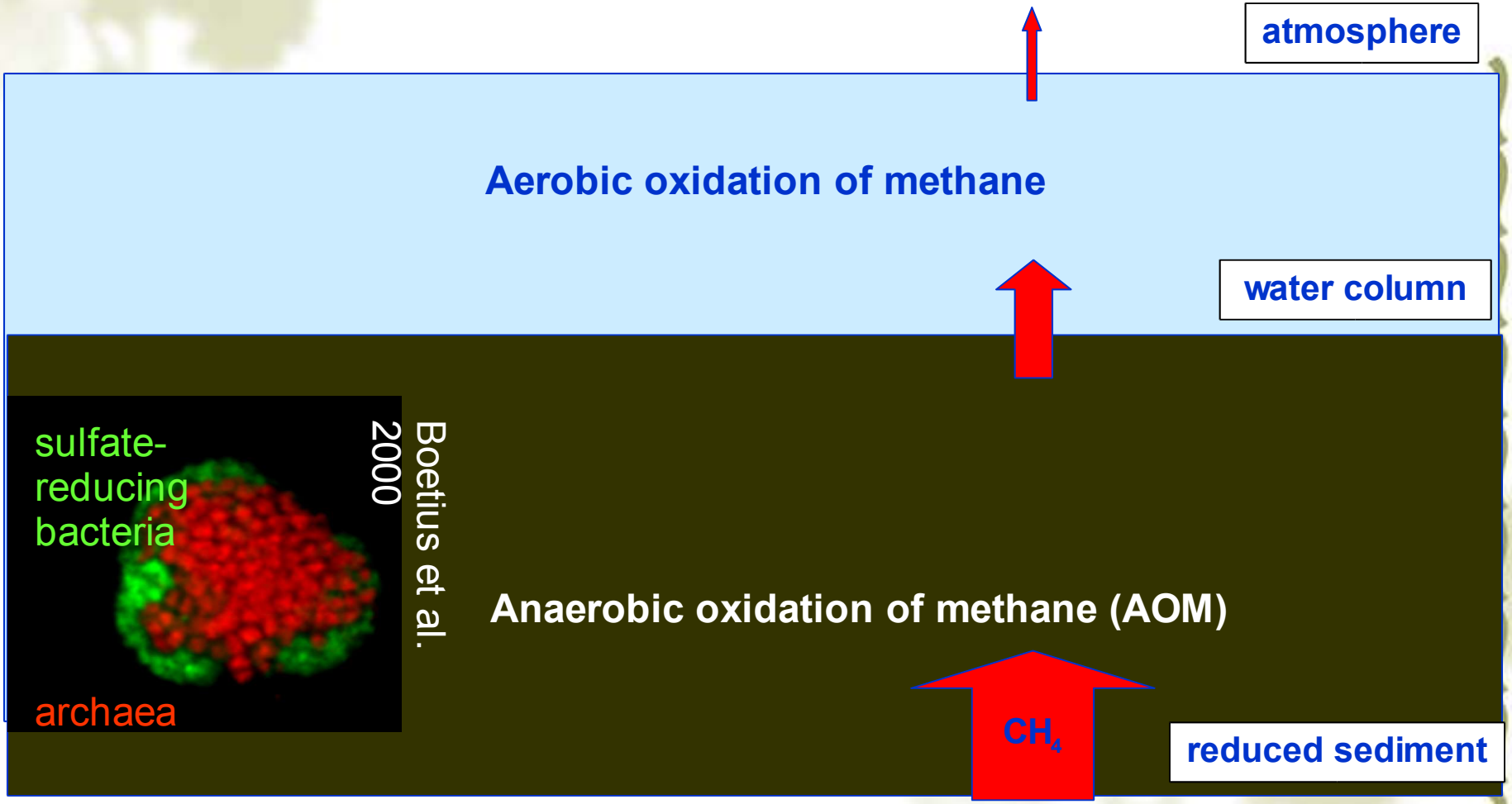
# Introduction: Consequence of ocean warming

- Bottom waters increase 3ºC, 80% of the vast methane reservoir along the continental margins might be destabilized.

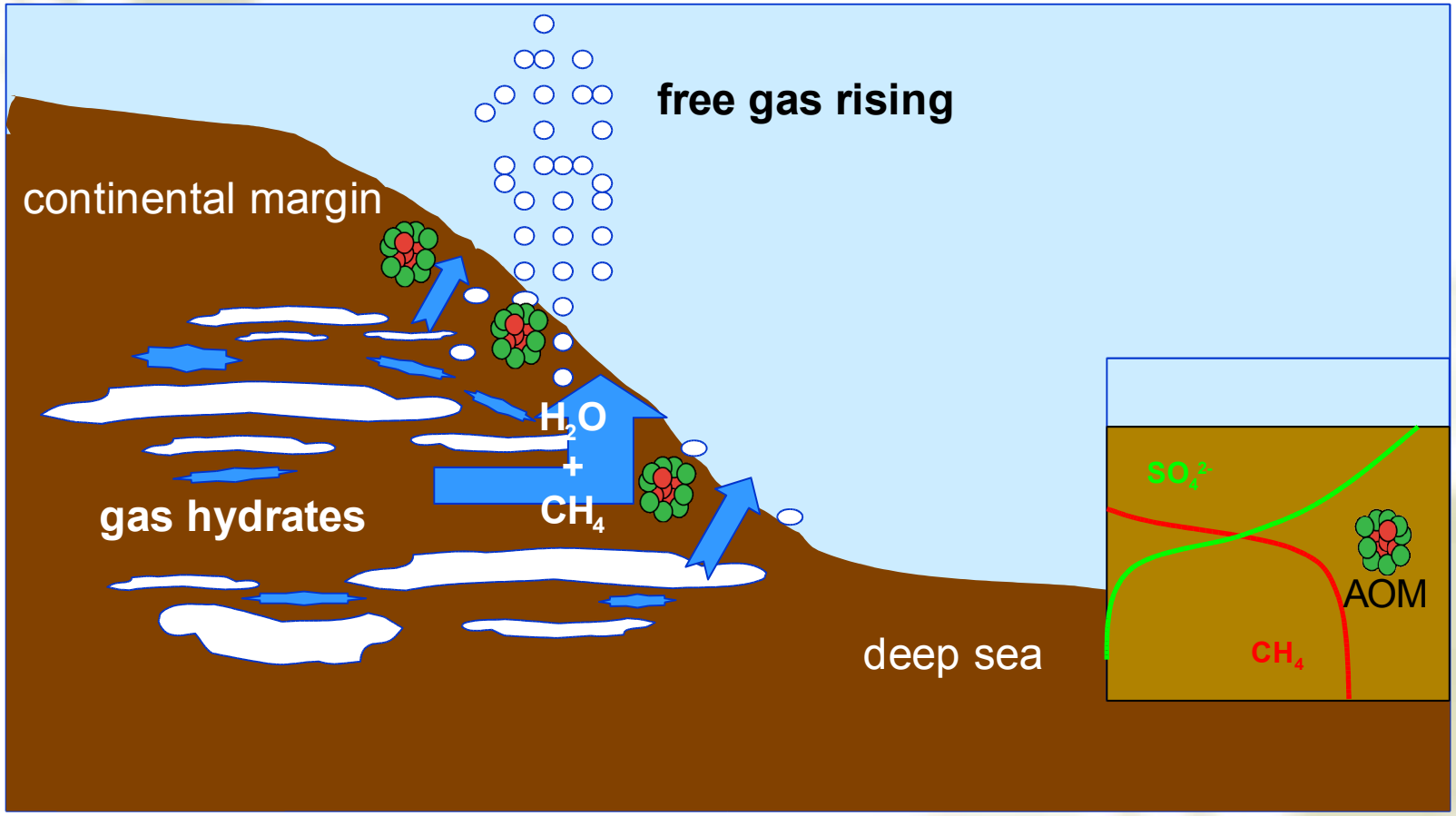
  (Buffett and Archer 2004).

- The Arctic region is particularly sensitive to climate change. Arctic ocean is one the most rapidly warming places on Earth and also a large reservoir of methane.

# Introduction: Important biogeochemical processes



# Hydrate dissociation & methane release



# Questions: Effect of seafloor warming on the stability of gas hydrates

- How will heat be transferred from the water to the sediment column?
- How fast will the gas hydrates dissociate under realistic environmental conditions?
- How much methane will be released?
- How much methane can be dissolved in porewater?
- How much methane can be consumed by microorganism (eg., AOM)?

# Simulation method: 1 D multiphase reactive transport model

- **Model parameters**
  Sediment column: 100 m
  Simulation time: 100 year
  AOM reaction rate constant: $10^{-2}$ $m^3$ $mol^{-1}$ $yr^{-1}$
- **Initial conditions**
  no free gas in the sediment column
- **Boundary condition**
  Upper boundary: increase 3°C/100 yr
  Lower boundary: a constant geothermal gradient

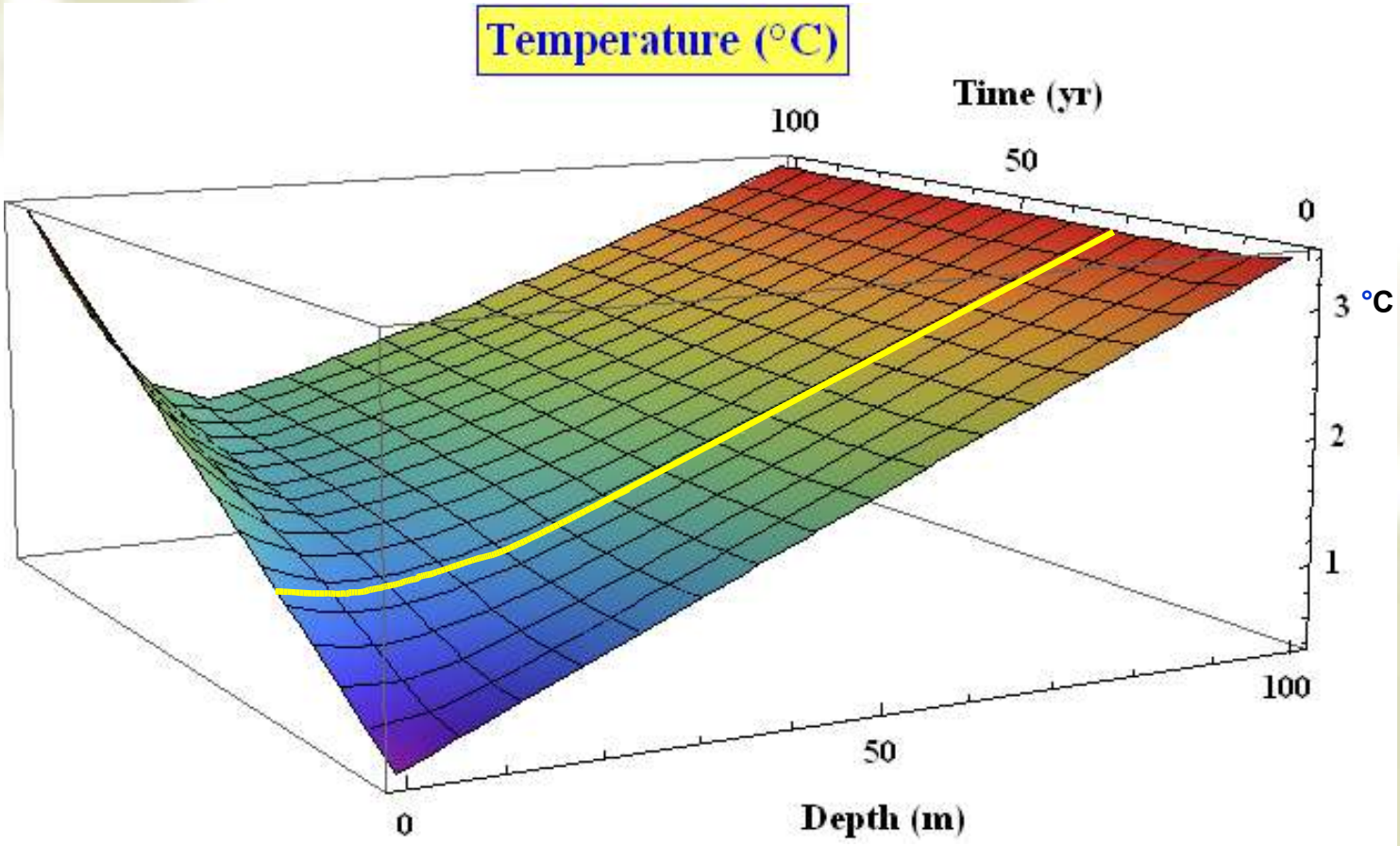
# Simulation method: 1 D multiphase reactive transport model

- Combination of:
  - *heat transfer* from water column to sediment and
  - *mass balance* of gas hydrate, methane (gas and dissolved), water, and sulfate.

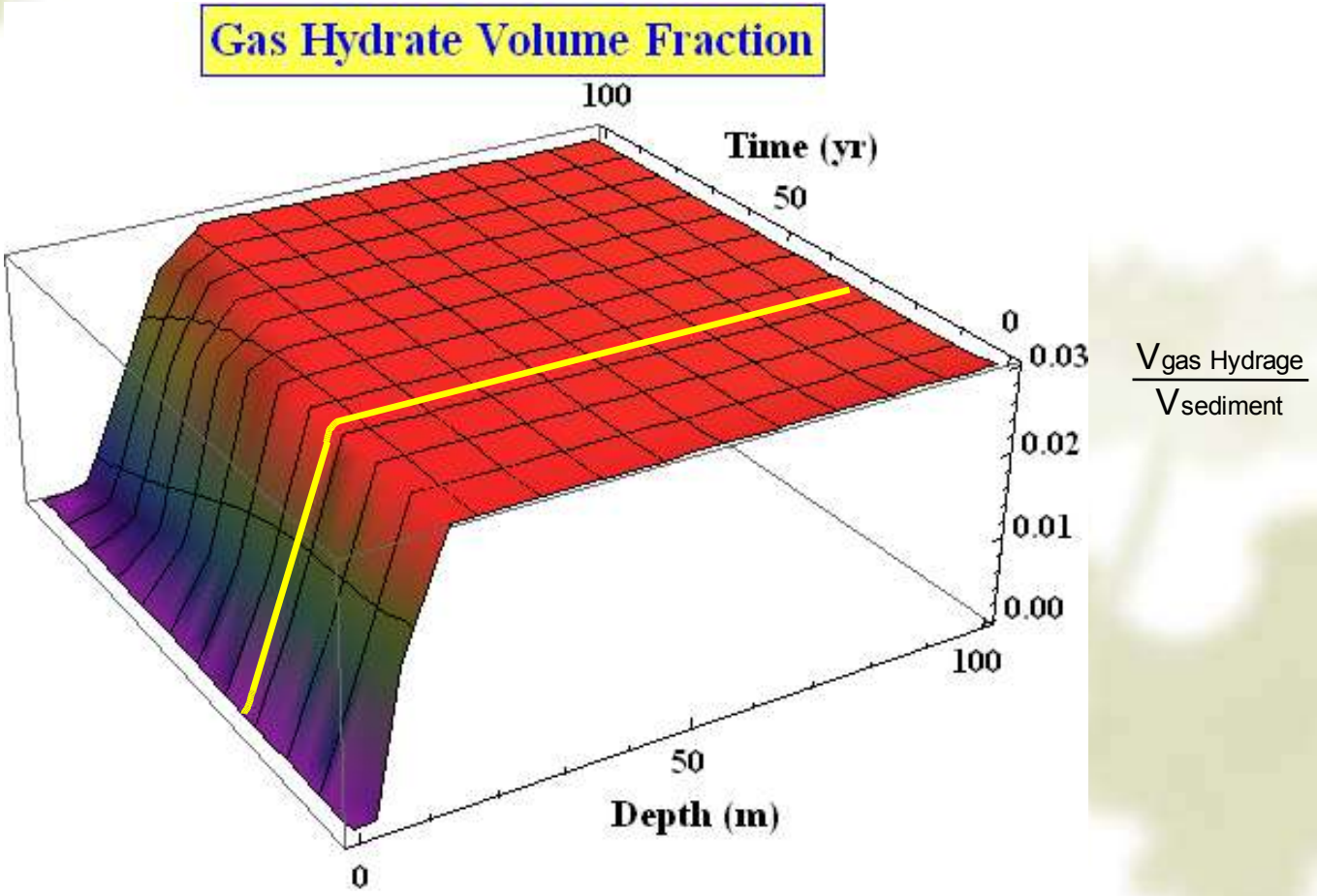
- Multiphase mass transfer and transport, coupled with diffusion and biogeochemical reaction.
  (gas hydrate, dissolved methane, free gas, consumed by AOM)

  - Heat transfer in each phase
  - Gas transports in the sediment and into the water column, where gas bubbles rise and dissolve in water synchronously.

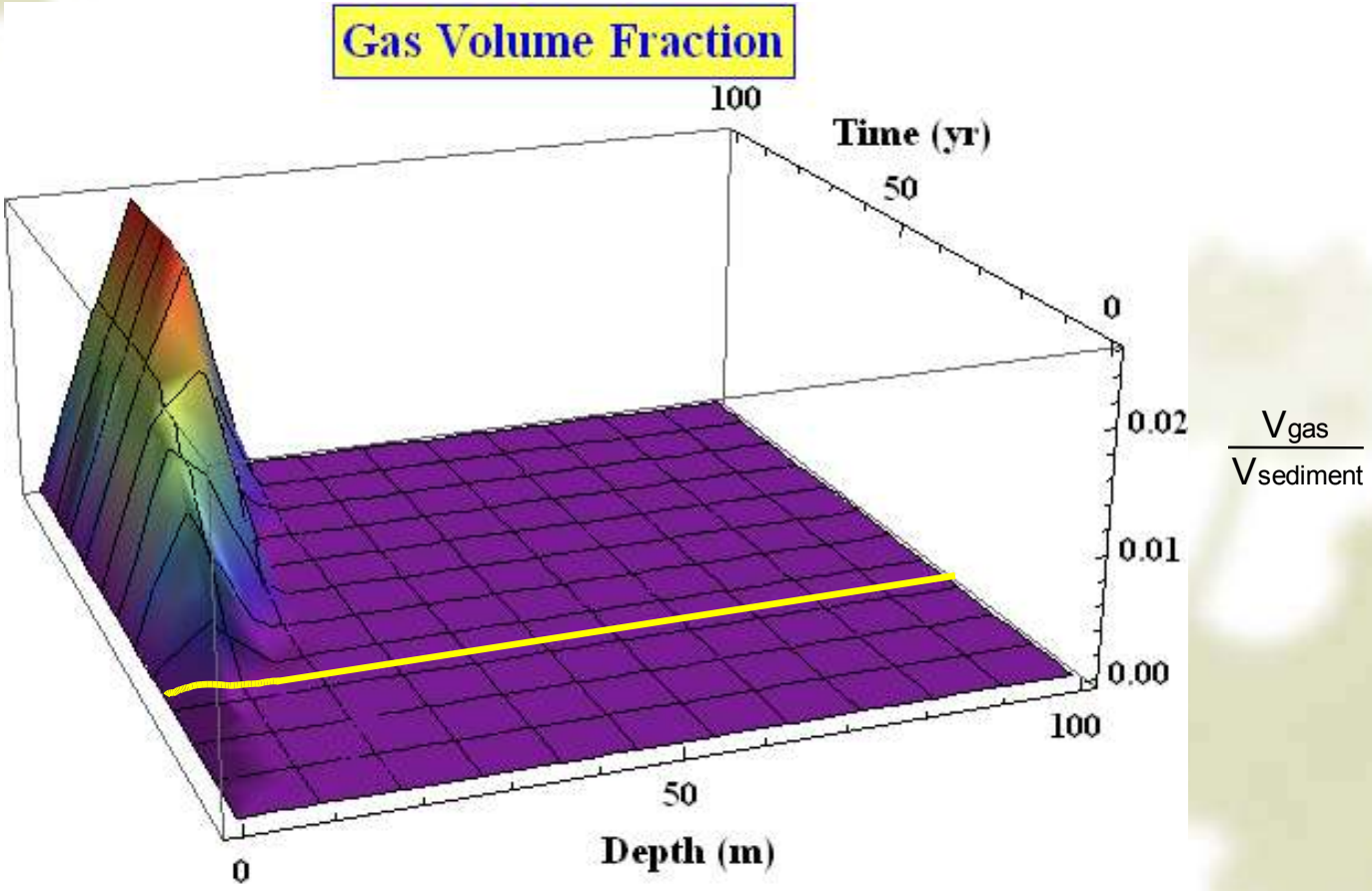
# Simulation results: Temperature profile in the sediment column



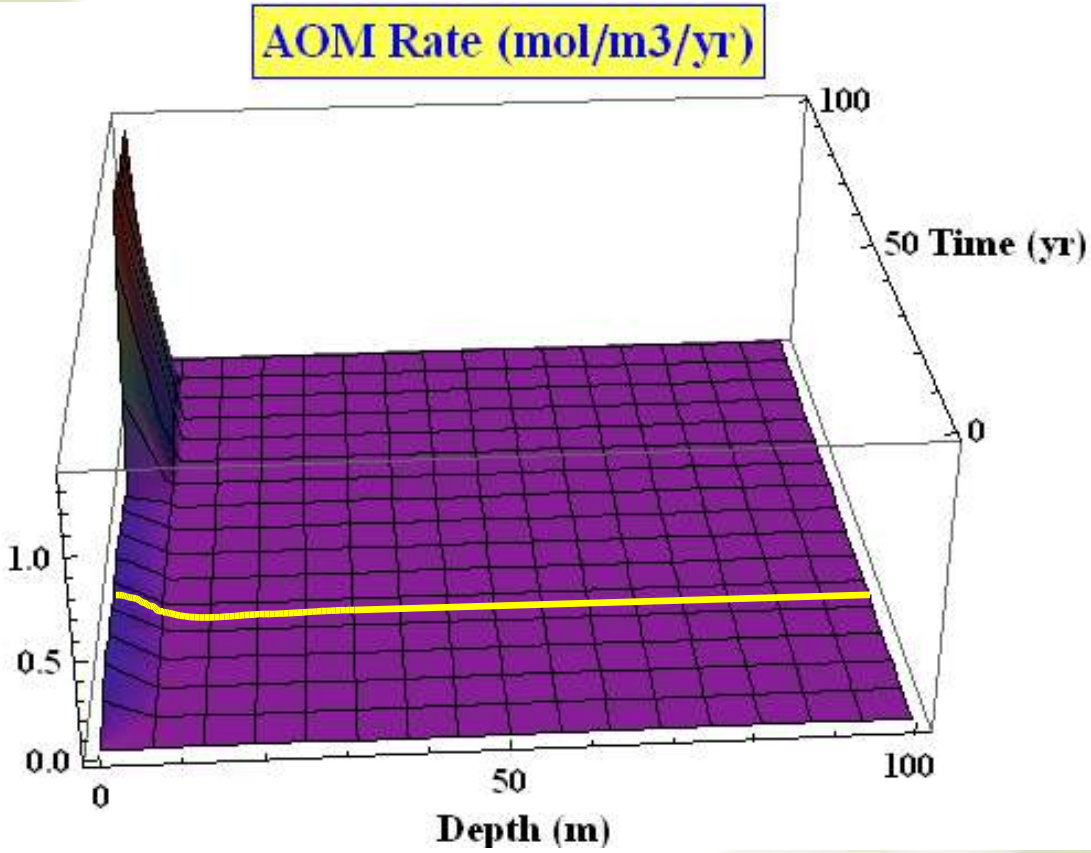
# Simulation Results: Gas hydrate volume fraction profile in the sediment column



# Simulation results: gas volume fraction profile in the sediment column

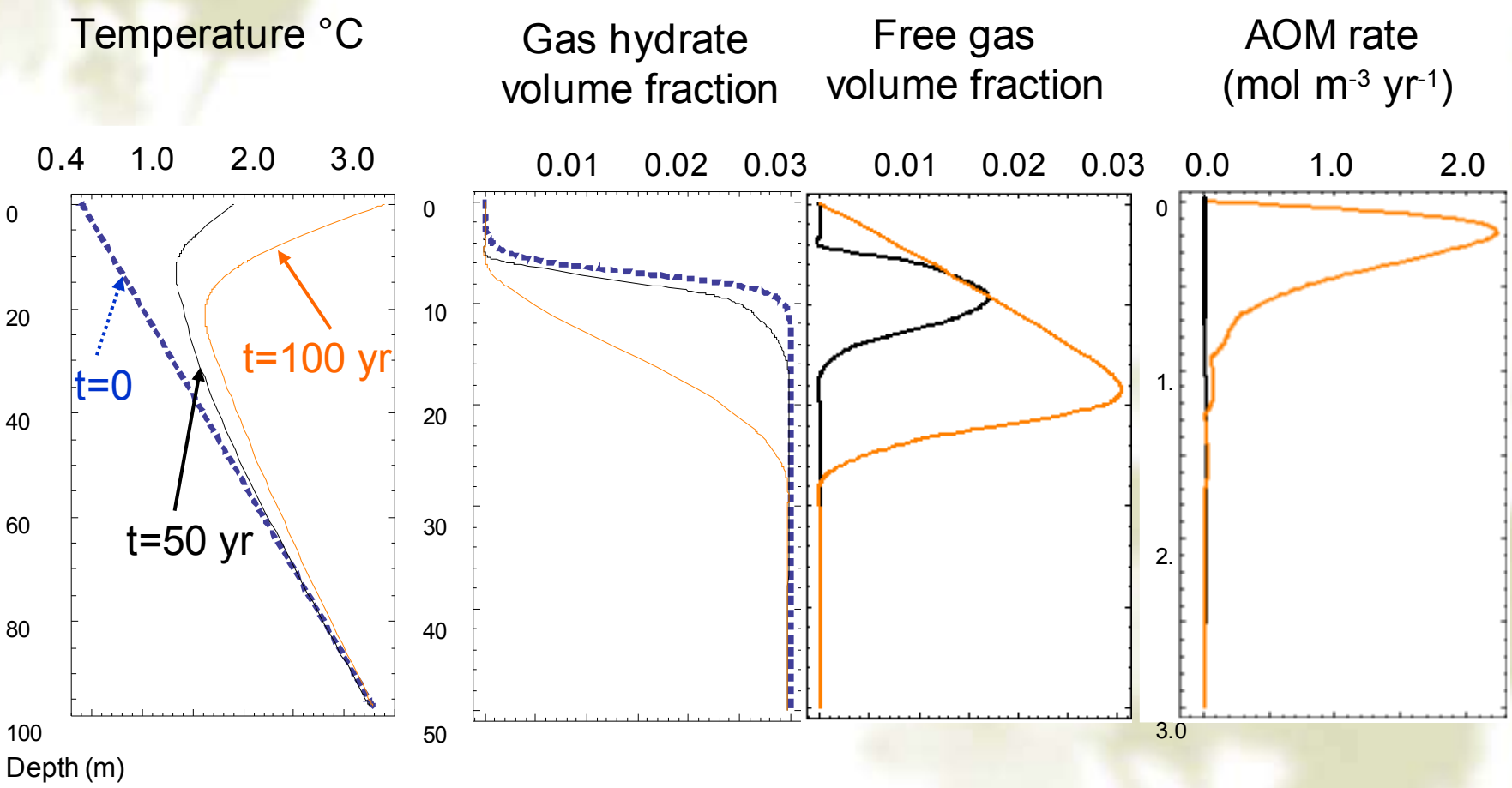


# Simulation results: AOM rate profile in the sediment column

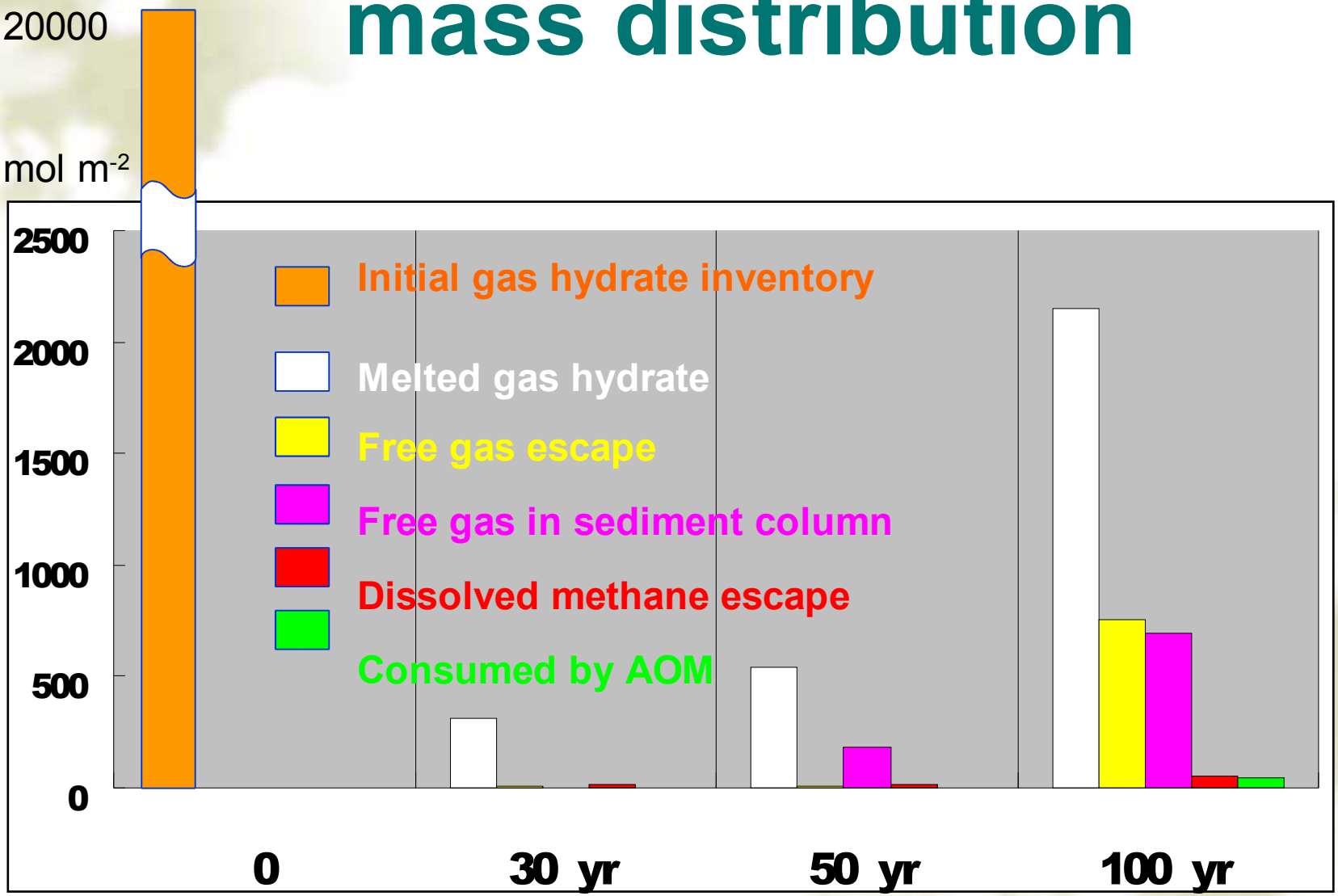



$\frac{mol}{m^3.yr}$

# Simulation results



# Conclusion: Methane mass distribution



# Conclusions: Answer the questions

- The dissociation of gas hydrate slows down temperature increases in the seafloor.
- Under simulation conditions, 10 % of the gas hydrates will melt in 100 yr. Of the released methane:

  > 30 % rises into water column as gas bubbles

  > 30 % remains in the sediment column as free gas.

  ~ 30 % dissolves into the sediment porewater

  ~ 3 % diffuses into the water column and

  > 2 % is consumed by AOM.

# Outlook

Future work will focus on the Arctic shelf, where gas hydrate destabilization caused by bottom water temperature increases could become a major problem in the near future.

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