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@Meiji Univ.

Moisture and salt movements in sand during evaporation under reduced pressure

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Background

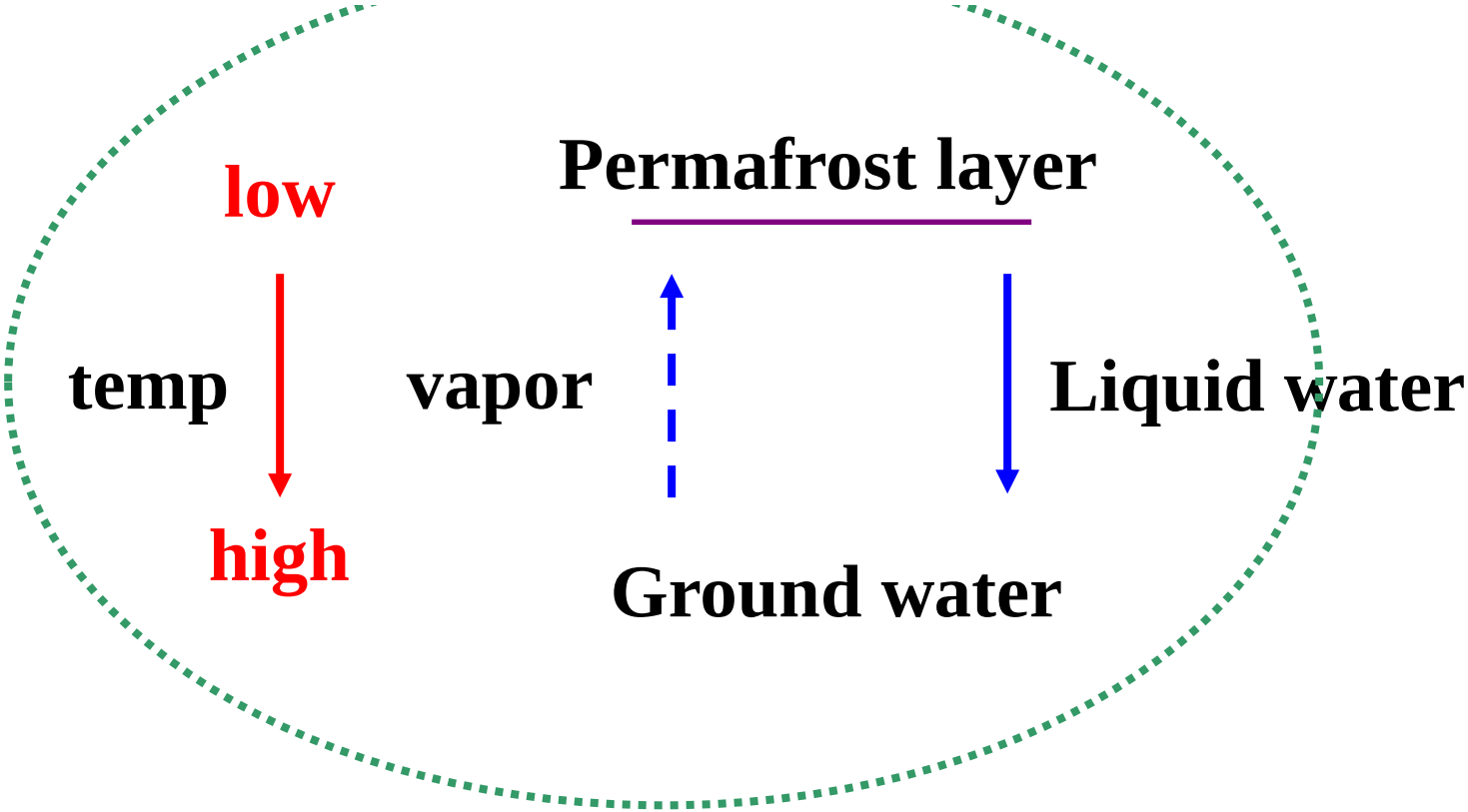
- 2001-2003,
  - I started to study soil on Mars
- 2003-2004,
  - I Stopped the study because my work in Cabinet Office
- After 2005,
  - I ask Dr. Noborio to lead
- New findings are reported
  - I try to remember what I did before
  - This presentation is a review of my work before

wanted

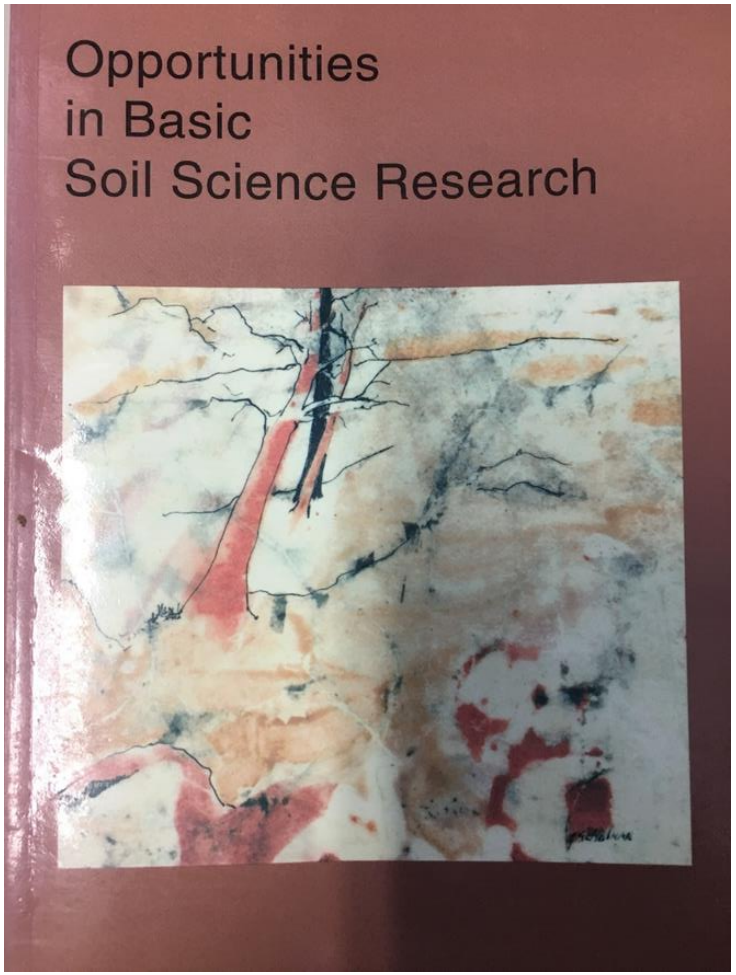
Phenomena that I want to know

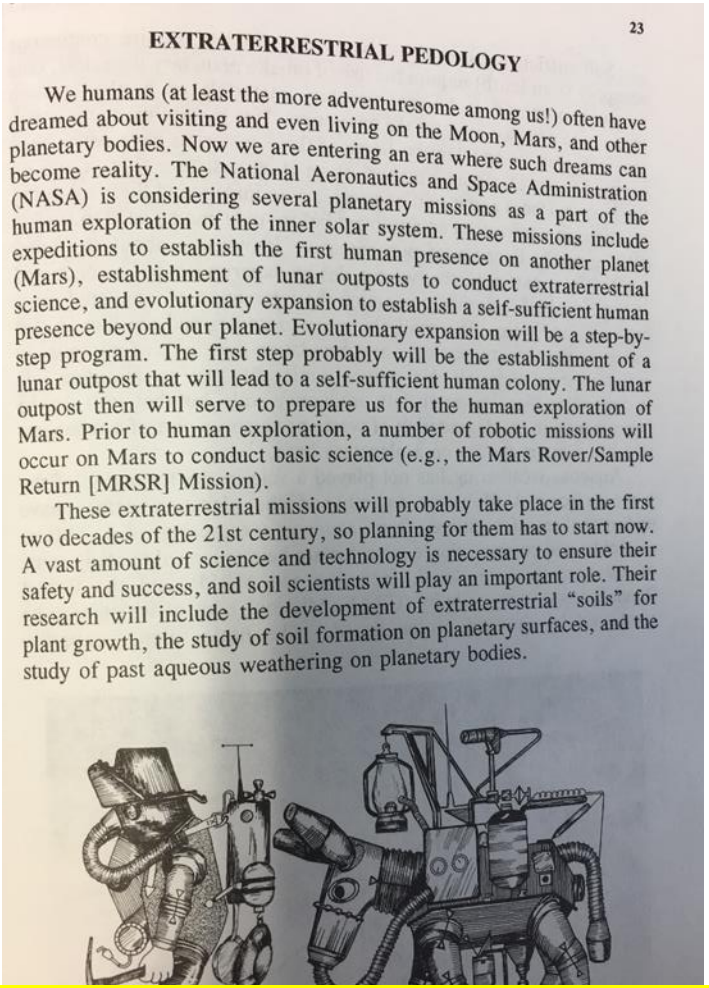
Stephen M. Clifford (1991)

Study on water cycle under ground on Mars



The reason why I started this research





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EXTRATERRESTRIAL PEDOLOGY

We humans (at least the more adventuresome among us!) often have dreamed about visiting and even living on the Moon, Mars, and other planetary bodies. Now we are entering an era where such dreams can become reality. The National Aeronautics and Space Administration (NASA) is considering several planetary missions as a part of the human exploration of the inner solar system. These missions include expeditions to establish the first human presence on another planet (Mars), establishment of lunar outposts to conduct extraterrestrial science, and evolutionary expansion to establish a self-sufficient human presence beyond our planet. Evolutionary expansion will be a step-by-step program. The first step probably will be the establishment of a lunar outpost that will lead to a self-sufficient human colony. The lunar outpost then will serve to prepare us for the human exploration of Mars. Prior to human exploration, a number of robotic missions will occur on Mars to conduct basic science (e.g., the Mars Rover/Sample Return [MRSR] Mission).

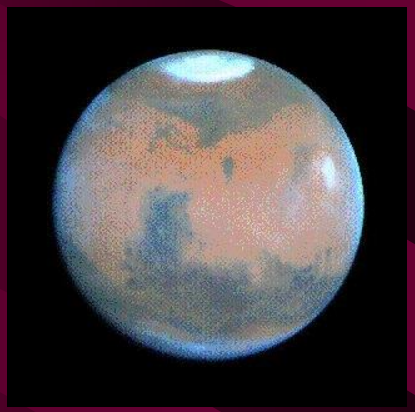
These extraterrestrial missions will probably take place in the first two decades of the 21st century, so planning for them has to start now. A vast amount of science and technology is necessary to ensure their safety and success, and soil scientists will play an important role. Their research will include the development of extraterrestrial "soils" for plant growth, the study of soil formation on planetary surfaces, and the study of past aqueous weathering on planetary bodies.

Opportunities in Basic Soil Science Research
by Garrison Sposito and Robert J. Reginato | Mar 1, 1992

土壌の物理性，vol.74，pp.33(1996)

Life on Mars! ?

- Why is life only on Earth?
- Farming on Mars! (undergraduate 3rd year report)
  - Martian underground frozen soil (M1)
- Soil research
  - As it is under real conditions
  - Should validate physics laws under extreme conditions
    - Water vapor transfer
- Research with dreams



2001.1.16

17th Space Utilization Research Symposium

Heat and moisture transport phenomena in sand during reducing pressure

Masaru Mizoguchi (Univ. of Tokyo)

Kousuke Noborio (Iwate Univ.)

Experiment

- Material
  - Toyoura sand
- Equipment (tool)
  - Decompression chamber
    - Desiccator
  - Insulated water bottle
- ONSET data logger
  - At the Depth of
  - 1cm, 6cm, 11cm, 16cm

Experimental conditions

- Initial conditions
  - Water content
  - (0.5%, 6%, 10%, 20%)
  - Constant temperature (about 18 ° C)
- Boundary condition
  - Evaporable @ top
  - Insulation @ others
- Decompression time
  - 10-20 hours

What's happened?

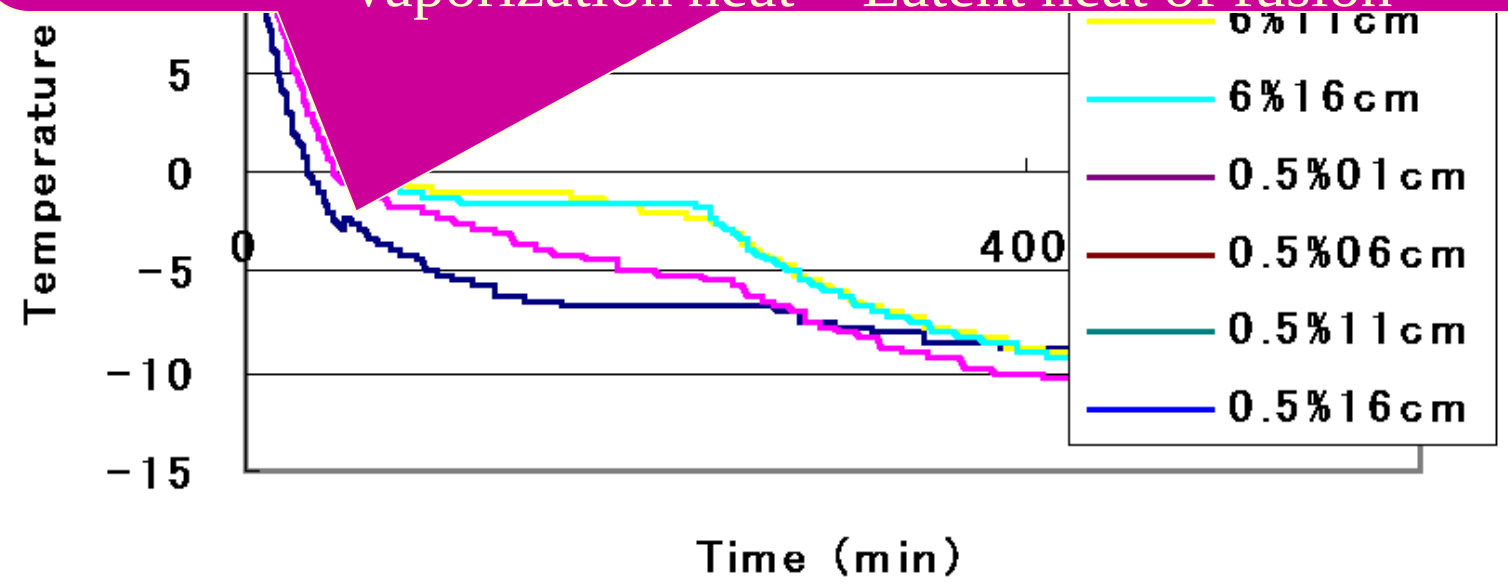
The sand is frozen!

- Wet sample
  - Freeze to inside
  - Some pores in soil
- Dry sample
  - Not freeze

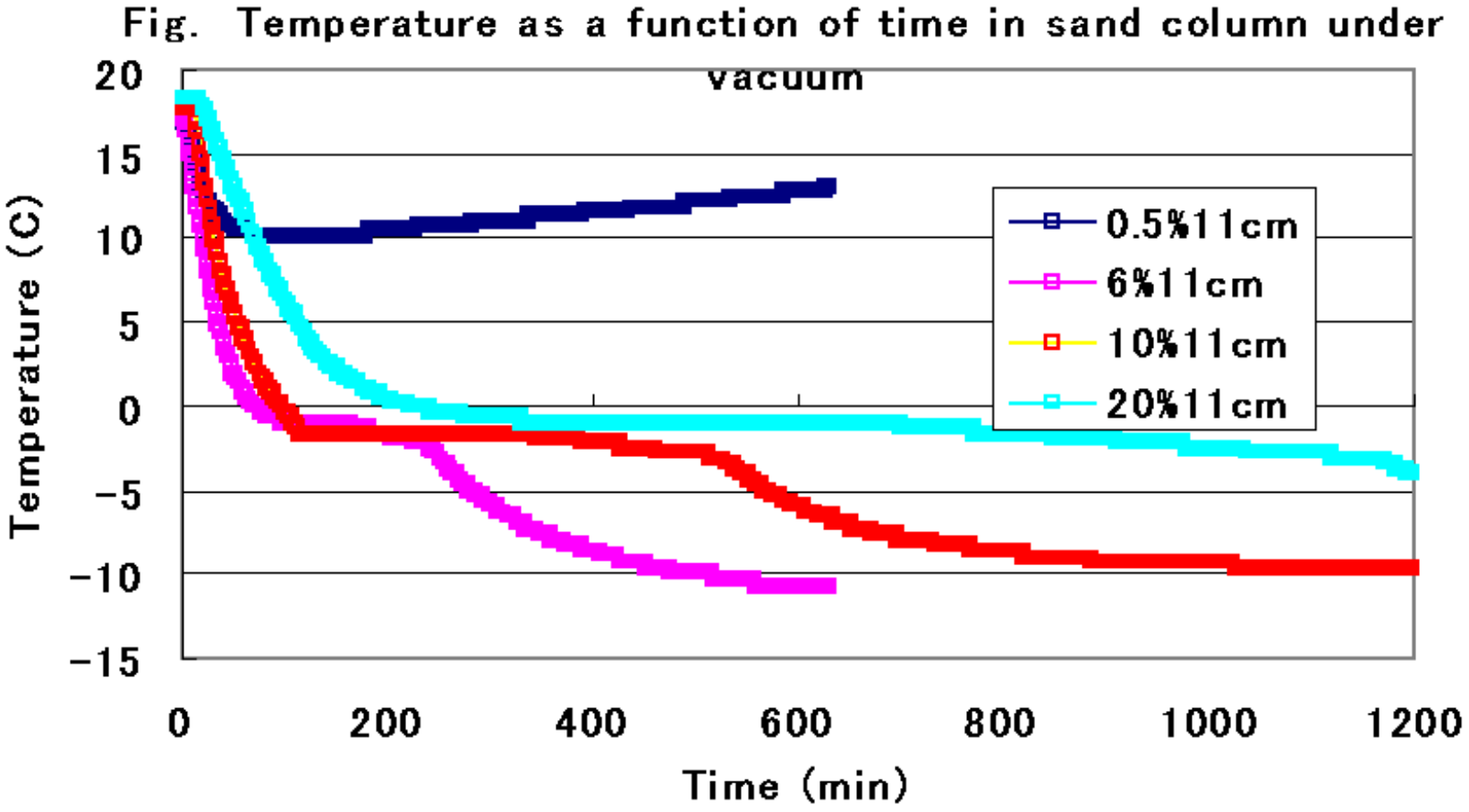
Temperature change

Fig. Temperature as a function of time in sand column under vacuum

50 min: Abrupt increase from -3 ℃ to -2.3 ℃
Supercooling
170 -260 min: constant temperature (-7 ° C)
Vaporization heat = Latent heat of fusion

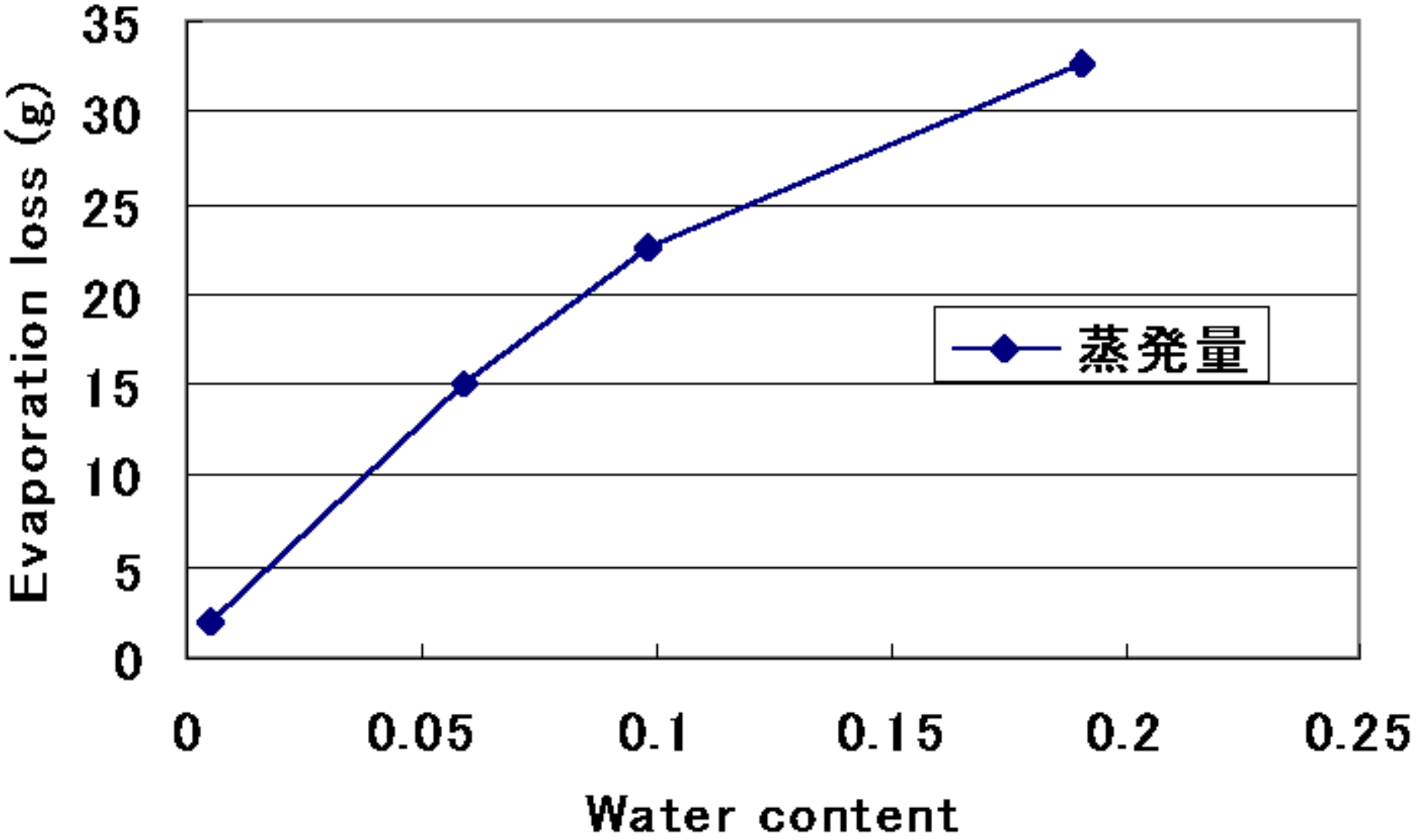


Effect of initial moisture content



Relationship between evaporation and initial moisture

Fig. Evaporation loss vs. water content



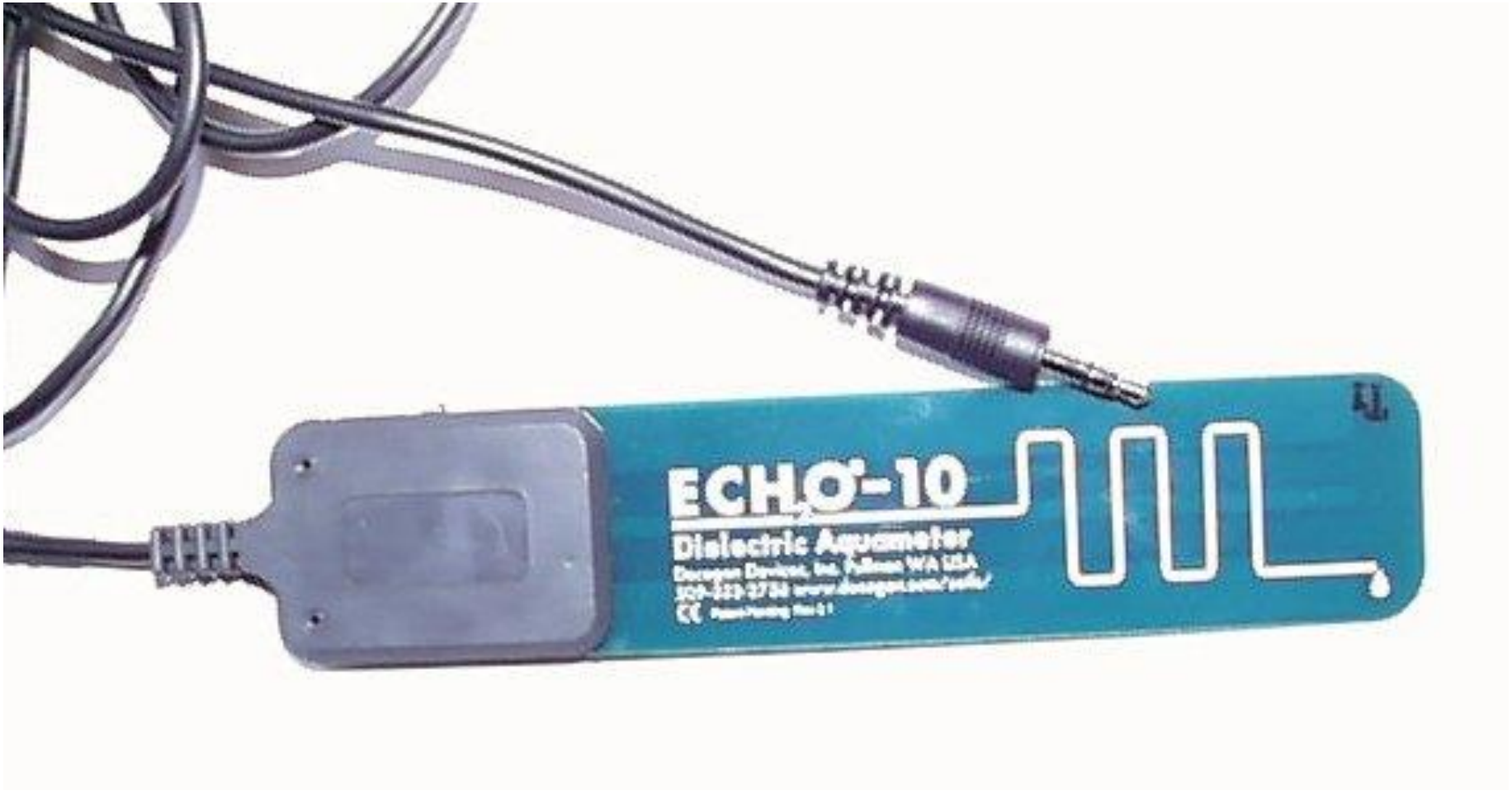
2002.1.11

18th Space Utilization Research Symposium

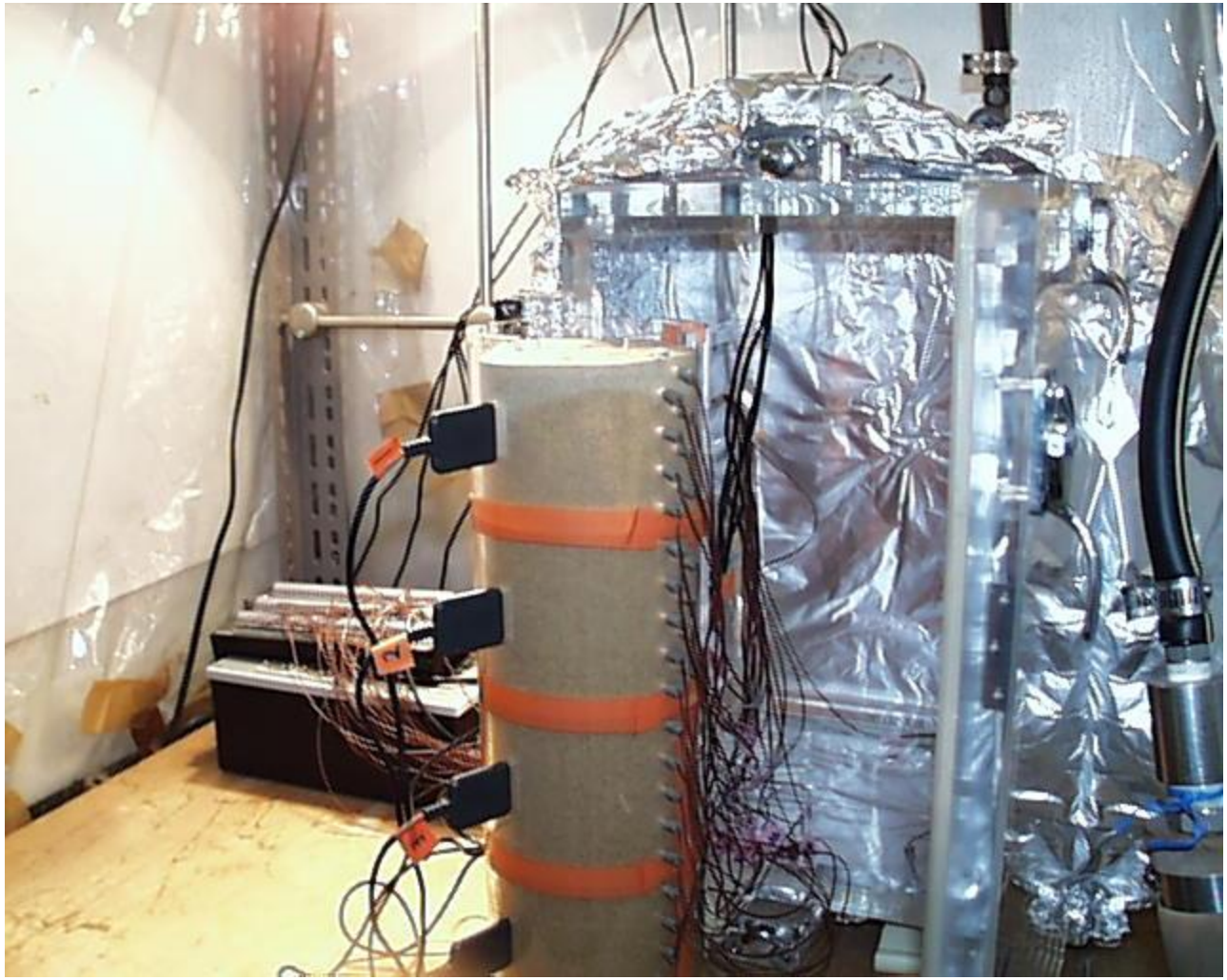
Heat and moisture transport in sand during the evaporation under reduced pressure

Mizoguchi, Noborio, Seki, Imoto, Miyazaki

Soil moisture sensor

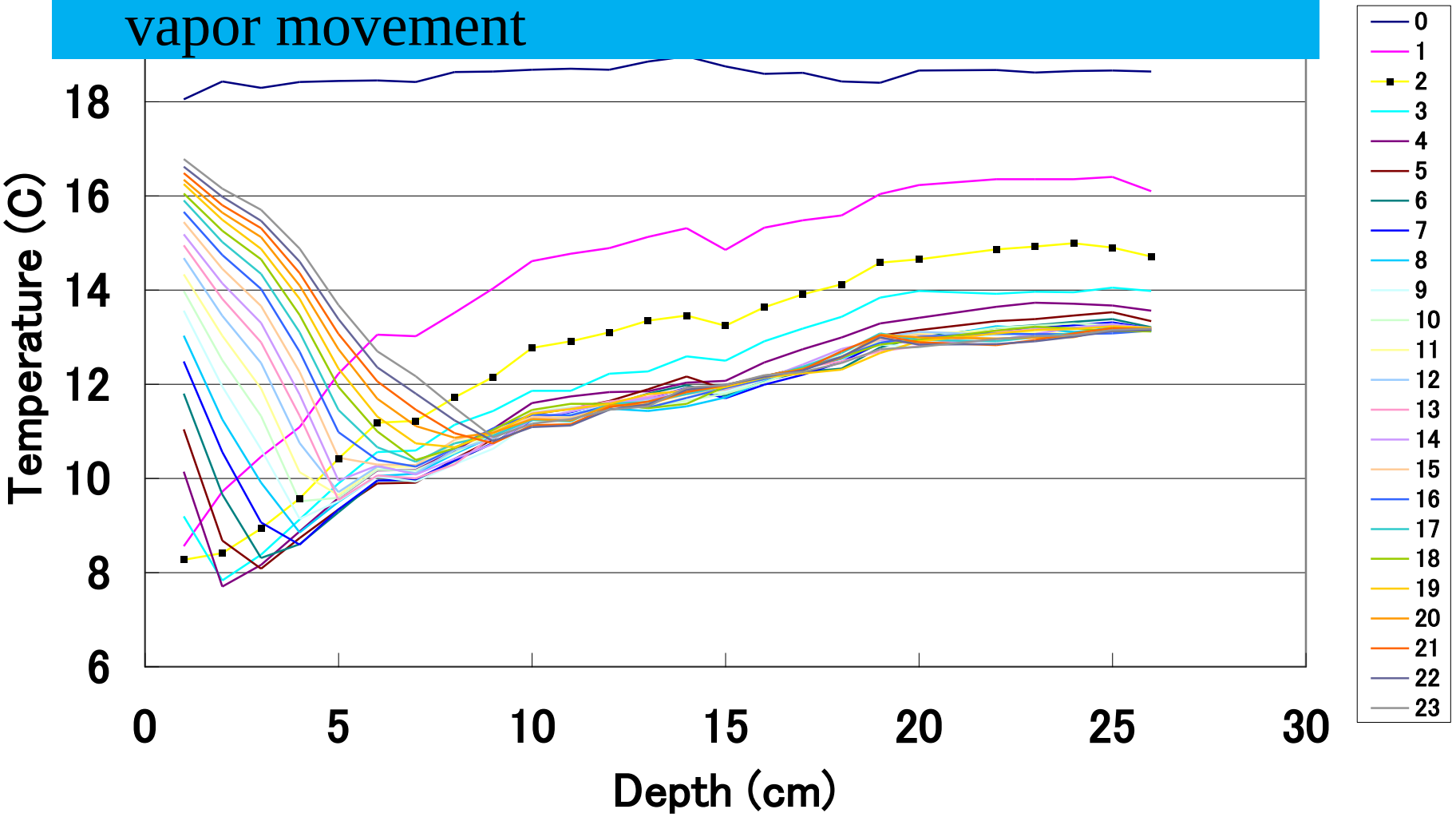


Appratus



Change in temperature distribution

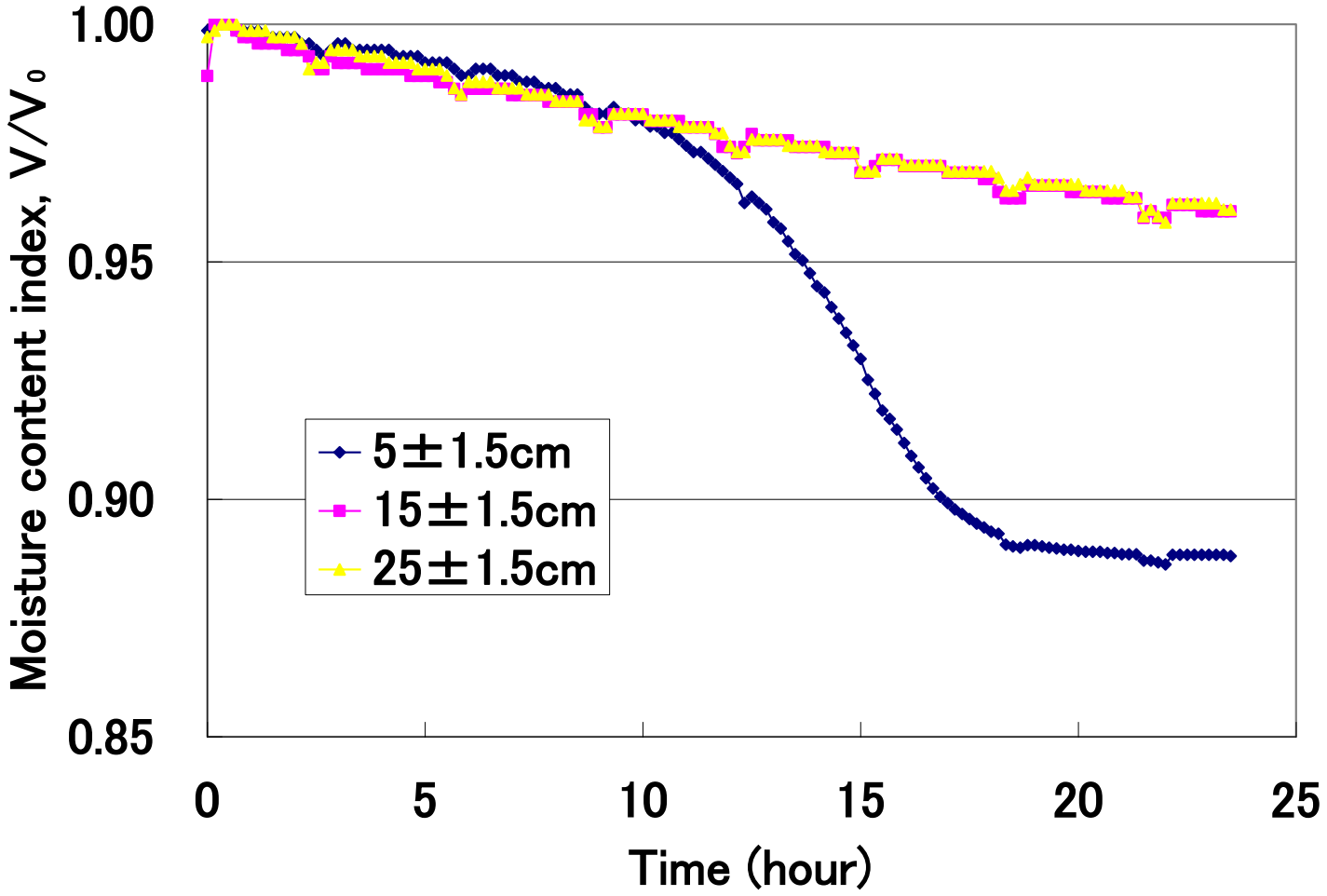
- V-shape : Movement of evaporation surface
- Lower temperature at the bottom of the sample : vapor movement



Change in moisture content with time

Decrease in 10-15 hours @ 5cm→ evaporation from surface

Linear @ 15cm & 25cm→Water vapor transfer



Conclusion in 2002

- During decreasing pressure in sand (initial WC= 5%)
  - The evaporation surface moves in the sand
  - Moisture is lost even from deep in the sand
  - Vapor transfer is important

2003.1.20

19th Space Utilization Research Symposium

Moisture and salt movements in sand during evaporation under reduced pressure

M.Mizoguchi, A.Suetsugu, H.Imoto and T.Miyazaki

Purpose of the study

Effect of initial moisture content (2000-2001)

- Effect of salt (2002)

Experiment

- Initial conditions:
  - WC=10%, 15%
  - NaCl conc. : 0, 0. 2, 1, 2, 10, 20%
- Boundary conditions:
  - Evaporable @ top
  - Insulation @ Others (Heat loss rate 77 W / m3 · K)
- Decompression time
  - 168 hours (1 week)
- Sampling after decompression
  - Moisture content, Salinity (1: 5EC)

Observations

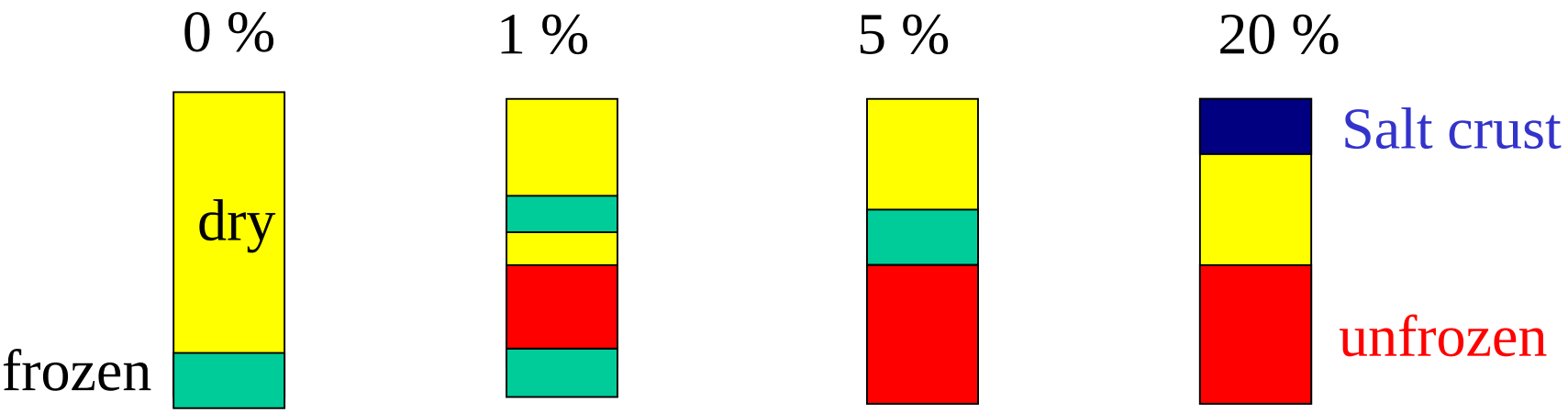
Surface is completely dry

0% :Frozen layer at 17-20cm

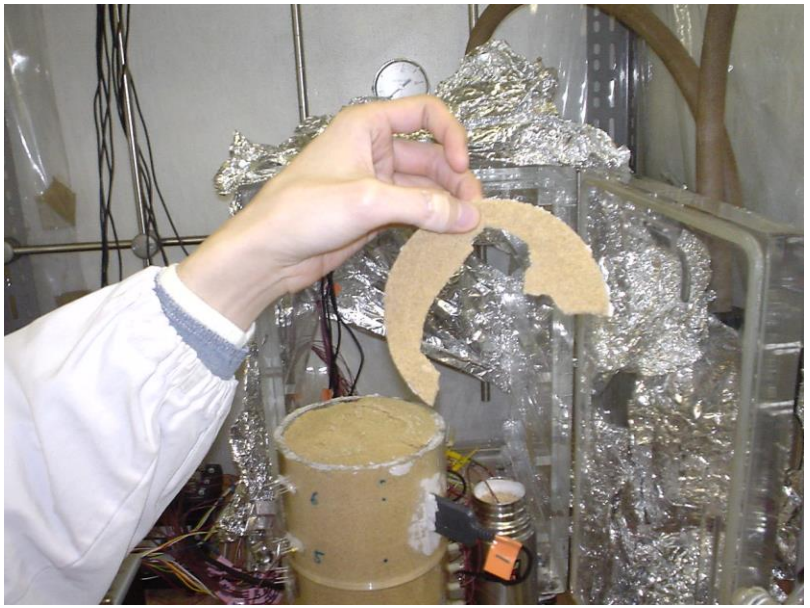
1% :Frozen layer at 5-6cm and 18-20cm

5% :frozen at 8-9cm , unfrozen at deeper that 9cm

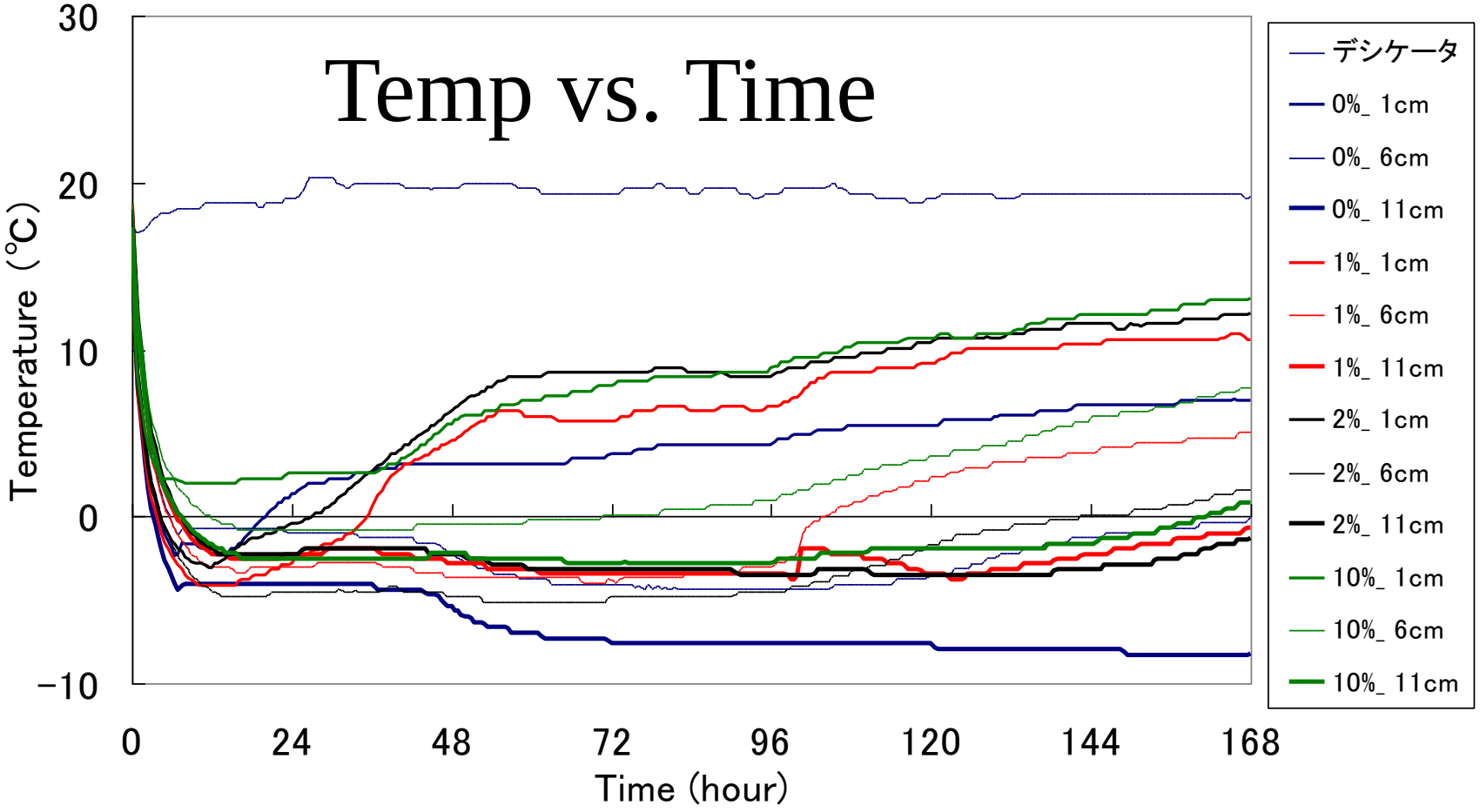
20% :salt crust up to 0-4cm (dry), dry&unfrozen at deeper 4cm



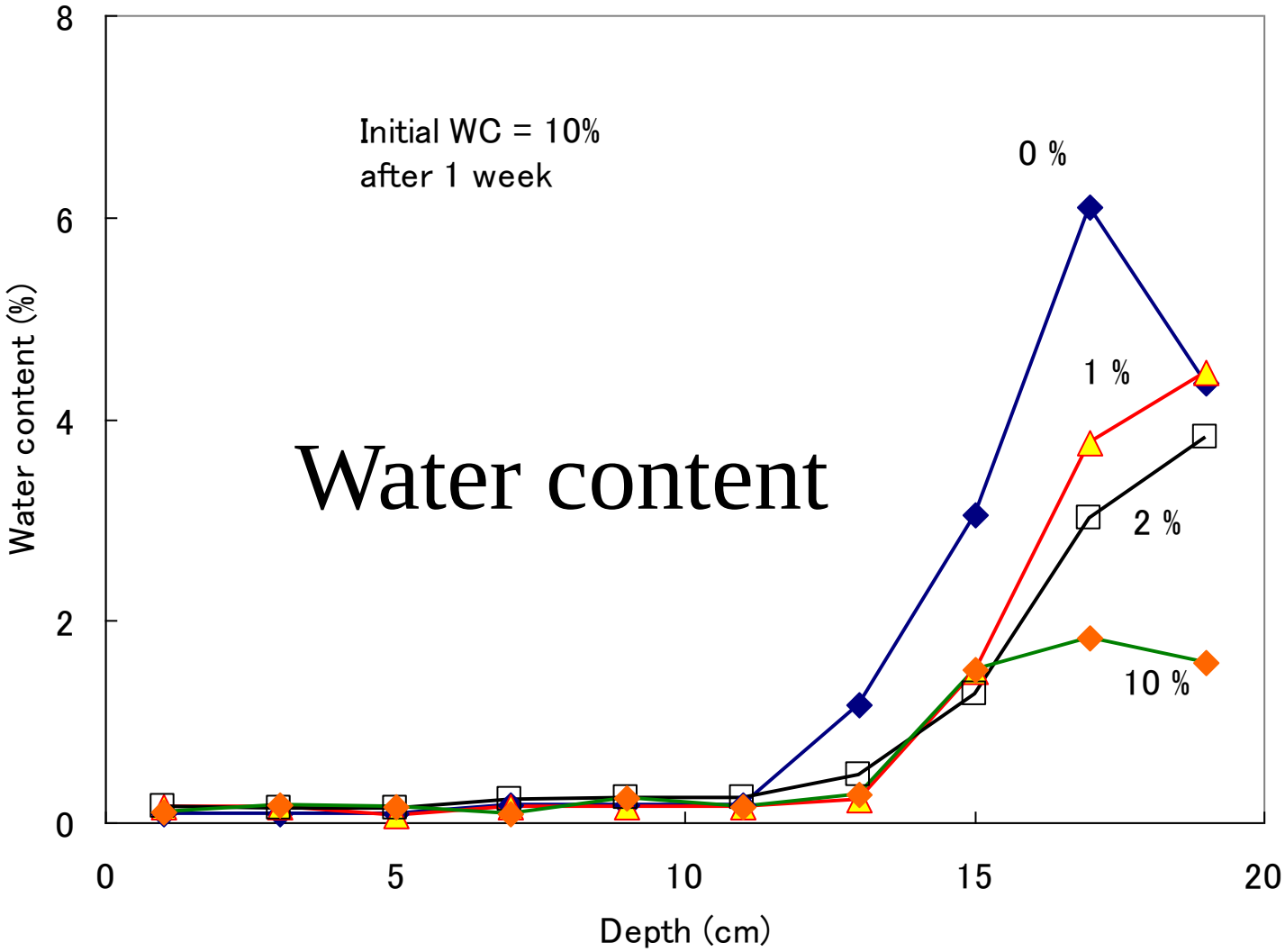
Surface salt crust



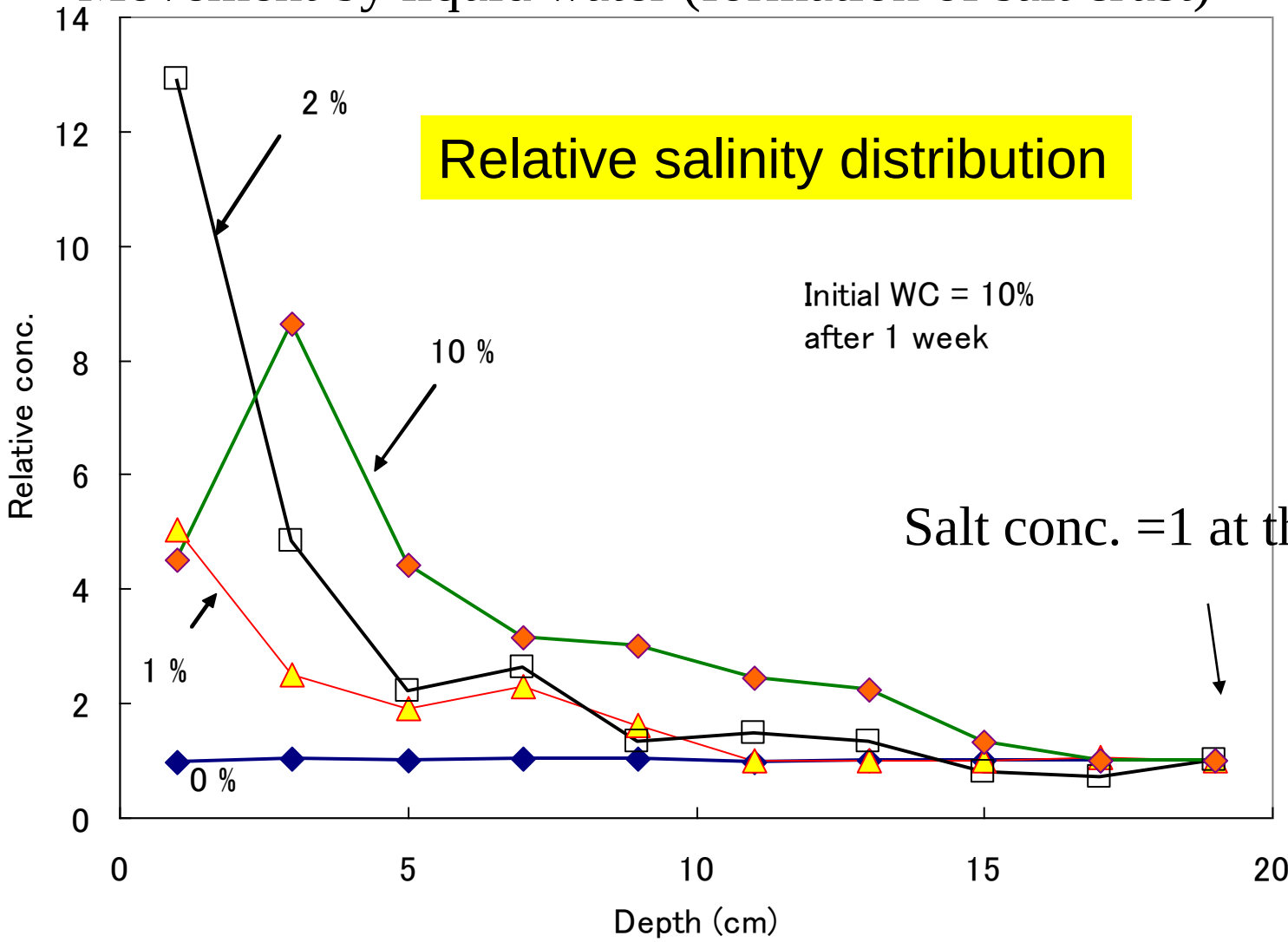
- After the surface temperature drops, it rises in 24 hours
- 10% surface temperature does not decrease below 0 ° C
  - Freezing point
- The lower the salinity, the lower the temperature of the lower layer
  - Freezing by latent heat of evaporation (easy evaporation)



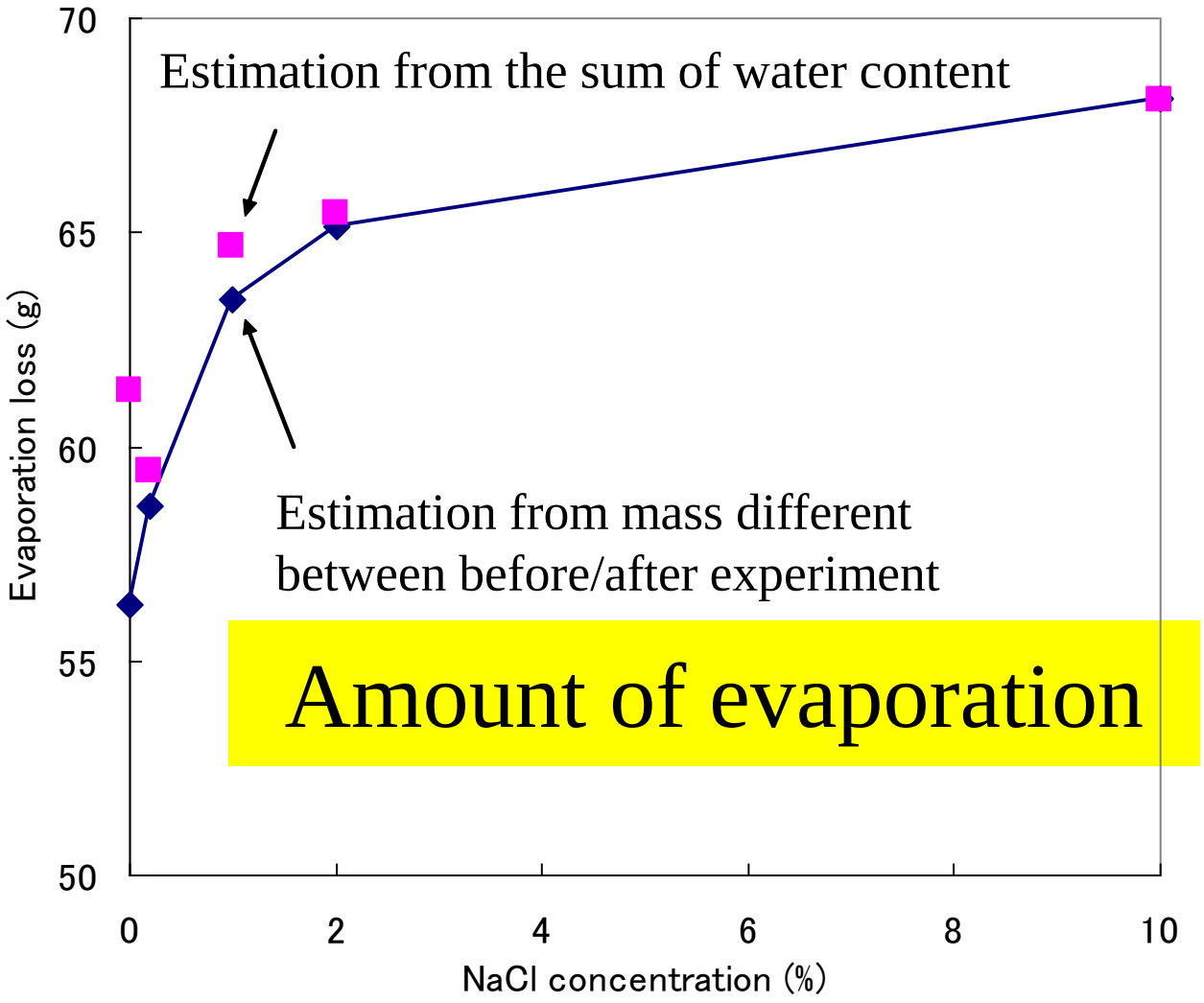
- Supper dry at 0-11cm
- The higher the salinity, the lower the moisture in the lower layer
  - Water moves in liquid form by capillary



- Salt moves toward the surface
- The higher the concentration, the more salt moves
  - except for the 10% surface layer
- Movement by liquid water (formation of salt crust)



- The higher the concentration, the more evaporation.
- The higher the concentration, the more water moves in liquid form



Conclusion in 2003

In the vacuum evaporation process

- Sand does not freeze at high salt concentration
- Sand freezes at low salt concentration
- Salt moves to the surface
- Liquid water moves by capillary effect
- Higher salt conc. results in more evaporation
- The higher the concentration, the more liquid water moves due to freezing point depression.
- If the salt concentration is too high, salt crust is formed on the surface

What kind of new finding will be obtained in the future work? Let’s enjoy it!

Thank you