International Institute for Carbon-Neutral Energy Research

I2CNER

CO_2 Storage

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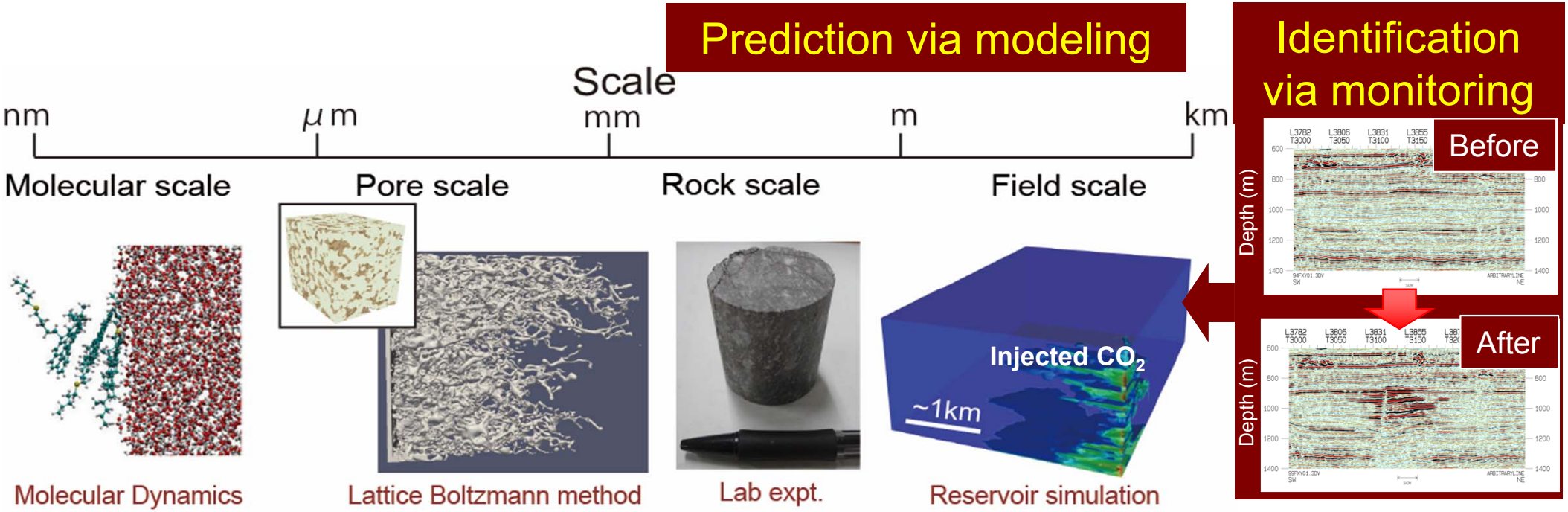
1. Division Objectives

- **Accurately predict CO_2 fate for safe and enhanced CO_2 storage**
  - **Modeling CO_2 behavior in wide range of scale**
- **Continuously identify CO_2 behavior for safe CO_2 storage**
  - **Monitoring CO_2 behavior in field-scale**
- **Explore innovative CCS concepts suitable for geological formations typical of Japan (e.g. heterogeneous formation)**



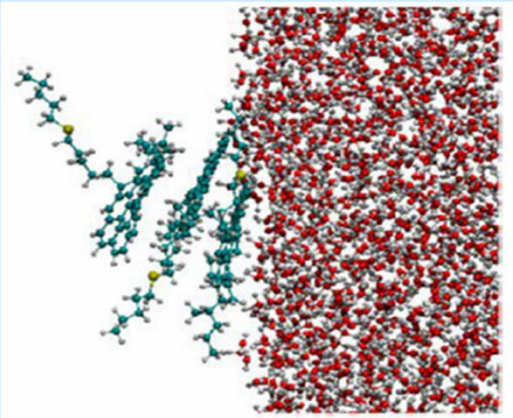
Revised (new) research projects

Project 1

Molecular-scale CO_2 investigation (nm-μm)

Efforts:

- Evaluate influence of slip flow
- Model CO_2 reactions



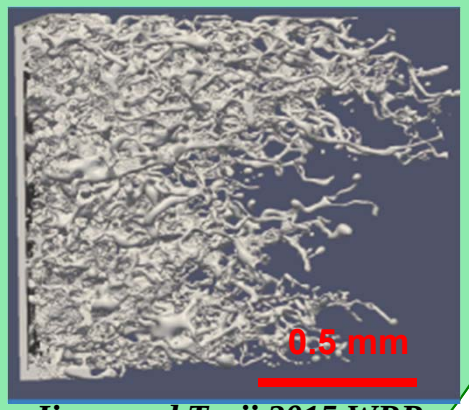
e.g. Jia et al. accepted, Sci. Rep.

Navier-Stokes with "slip flow"
Molecular dynamics

Project 2

Pore-scale CO_2 investigation (μm-cm)

- Model CO_2 behavior to increase storage capacity and security by enhanced trapping
- Coupled hydrological and geomechanical modeling



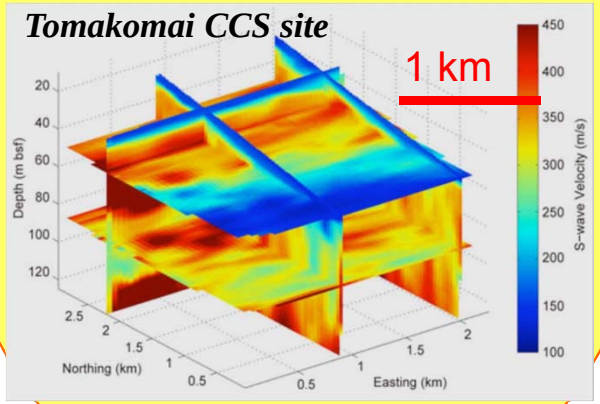
Jiang and Tsuji 2015 WRR

Navier-Stokes
(project 1 in FY2015)

Project 3

Field-scale CO_2 investigation (m-km)

- Construct geologic model with high resolution
- Develop effective monitoring
- Quantitative monitoring (CO_2 saturation)



Ikeda and Tsuji 2015 JGGC

Darcy flow

Geophysical monitoring
(project 2 in FY2015)

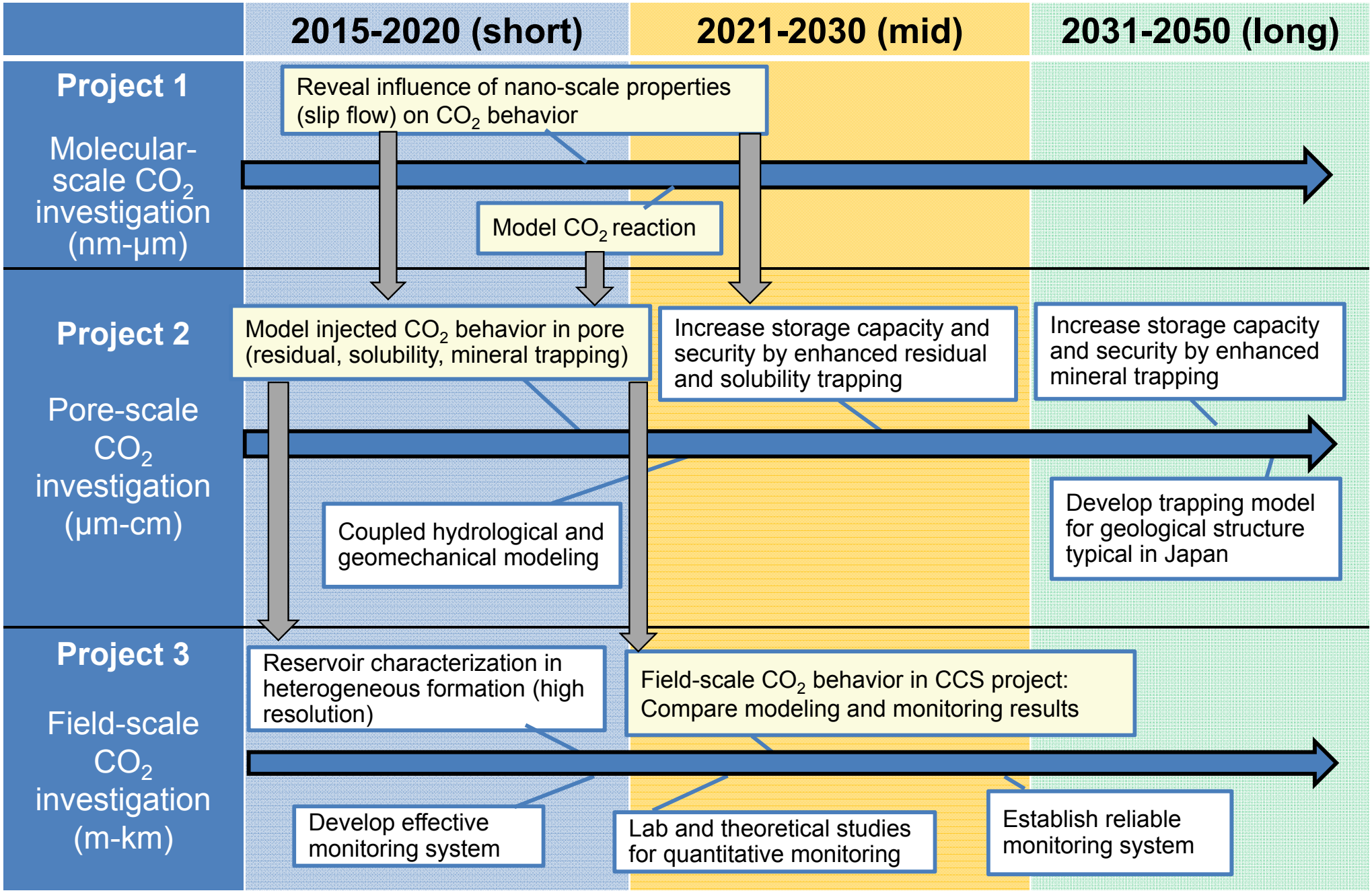
Project 4: Linkage of multi-scale phenomena

Try to identify the important mechanisms for upscaling

Revised (new) projects, objectives, efforts

Projects	Objective	Efforts	Researchers
Project 1 Molecular-scale CO_2 investigation (nm-μm)	Reveal CO_2 interactions and reactions in order to enhance CO_2 trapping	- Reveal influence of nano-scale properties (e.g. slip flow) on CO_2 behavior - Model CO_2 reactions	Singh, Tsuji Singh, Jia, Tsuji
Project 2 Pore-scale CO_2 investigation (μm-cm)	Reveal CO_2 trapping mechanisms in order to predict CO_2 fate and enhance CO_2 trapping	- Understand/model injected CO_2 behavior (residual, solubility, mineral trapping) - Increase storage capacity and security by enhanced trapping - Coupled hydrological and geomechanical modeling for induced seismicity prediction	Christensen, Kitamura, Tsuji, Jiang, Valocchi, Singh Christensen, Kitamura, Tsuji, Jiang, Valocchi, Singh Tsuji, Kitamura, Jiang, Ikeda
Project 3 Field-scale CO_2 investigation (m-km)	Reveal field-scale heterogeneous geological properties and CO_2 behavior	- Field-scale reservoir characterization (Identify heterogeneity) - Develop effective monitoring system - Quantitative monitoring (prediction of CO_2 saturation and reactions)	Tsuji, Ikeda Tsuji, Ikeda Kitamura, Tsuji, Ikeda
Project 4 Linkage of multi-scale phenomena	Investigate scale dependence in order to include smaller-scale phenomena into larger-scale CO_2 behaviors	- Identify important mechanisms in each scale - Upscale for accurate field-scale predictions	All member

Revised (new) milestones



Project 4 "Linkage of multi-scale phenomena" → Gray arrows

Revised Ultimate Targets

	Ultimate targets	Current Benchmarks
Project 1 Molecular-scale CO_2 investigation (nm-μm)	• Model reaction and interaction of CO_2	• Molecular-scale investigation is still new in earth science. • Multiphase flow at nano-scale has not been well revealed.
Project 2 Pore-scale CO_2 investigation (μm-cm)	• Develop predictive framework for accurate reservoir characterization (pre-injection) and long-term CO_2 fate (post-injection) • **Increase storage capacity by >20% and security by enhanced residual, solubility and mineral trapping**	• Current pore-scale models cannot capture dynamic nature of CO_2 migration nor do they embody interconnected nature of pore system and impact on CO_2 migration. • **Residual CO_2 trapping is <30% in Nagaoka CCS project.** CO_2 trapping has not been controlled in CCS.
Project 3 Field-scale CO_2 investigation (m-km)	• **Establish reliable monitoring system to investigate field-scale CO_2 behavior and saturation** ➢ Continuous monitoring ➢ Quantitative monitoring ➢ Cost-effective monitoring	• Injected CO_2 can be clearly monitored by time-lapse seismic survey. **But accuracy (or resolution) of monitoring is not enough to detect small amount of injected CO_2.** • Estimation of CO_2 saturation from monitoring data has not been well succeeded. • Current monitoring cost (time-lapse seismic) is over US$ several million.
Project 4 Linkage of multi-scale phenomena	• Include influence of smaller-scale properties upon field-scale CO_2 behavior	• Current field-scale predictions do not capture CO_2 migration because pore-scale phenomena not accurately modeled in large-scale simulations. • Up-scaling is challenging topic and has not been well solved.