Clustering Event

HPC & Big Data Technologies for Global Challenges

Material Transport in Water

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FAU

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Agenda

- Why HPC in Sediment transport?
- Current use case description
- Introduction to Walberla and Lbmpy
- More Applications in Walberla

Why Sediment Transport Simulations ?

- **Aeolian** – associated with transport in air
- **Fluival** – associated with transport in rivers and streams
- **Coastal** – near coastal environments
- **Glacial** - Occurs in sediment transport in glaciers especially when they melt
- Movement of sediment is important in providing **habitat for fish and other organisms** in rivers
- Extending life of **dams** and other hydraulic structures.
- Helps in study of **Avalanches –** very important especially for people in and around mountainous areas

Current MTW Use Case: Motivation

Importance of Temperature Simulations in riverbed:

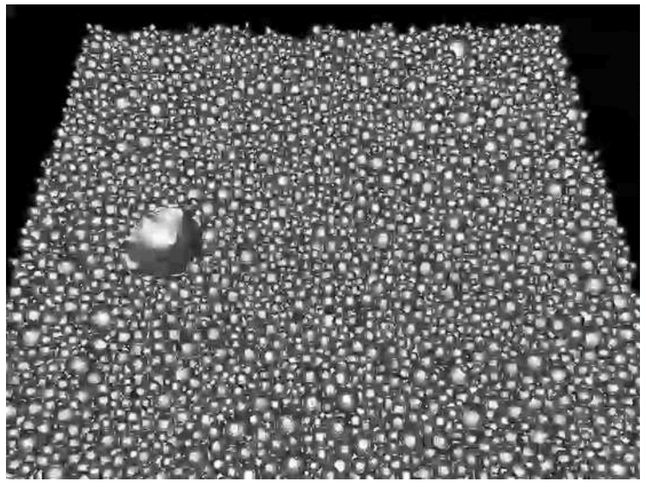
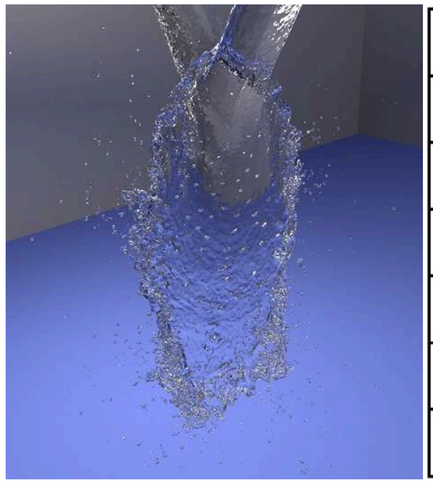
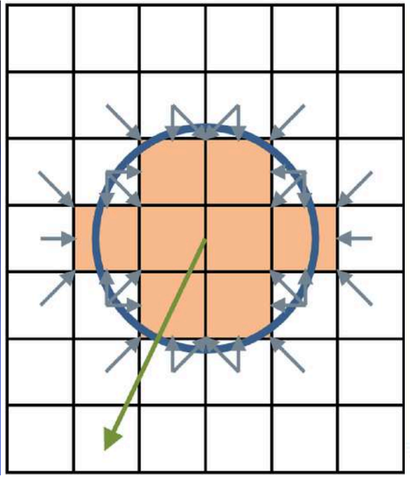
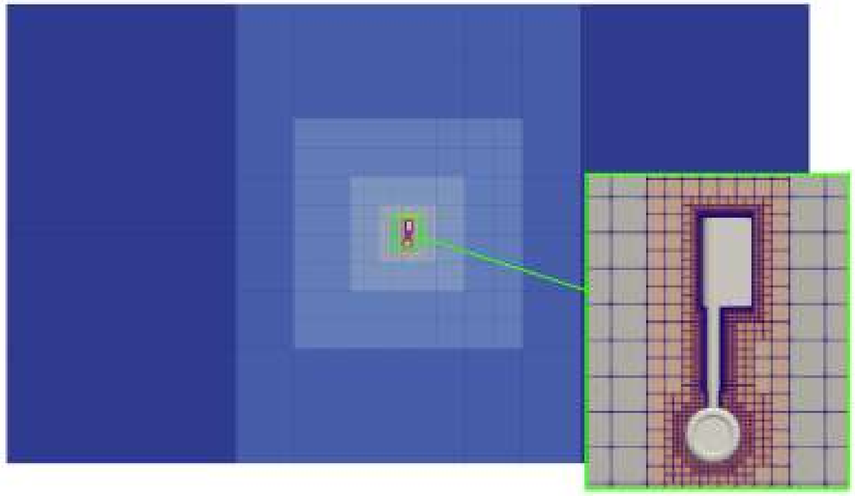
- River temperatures impact ecosystem functioning such as incubation and transport of fish eggs and embryos
- Effect the diversity and structure of the river based fish communities.
- Impacts ecosystem services such as power plant cooling.
- Has a significant impact on transport of sediment particles in rivers.

Use Case Implementation:

- Extend **waLBerla** for advanced sediment and temperature transport modeling
- Employ and expand automatic code generation technology for specialized applications involving temperature effects simulated using the Lattice Boltzmann method.

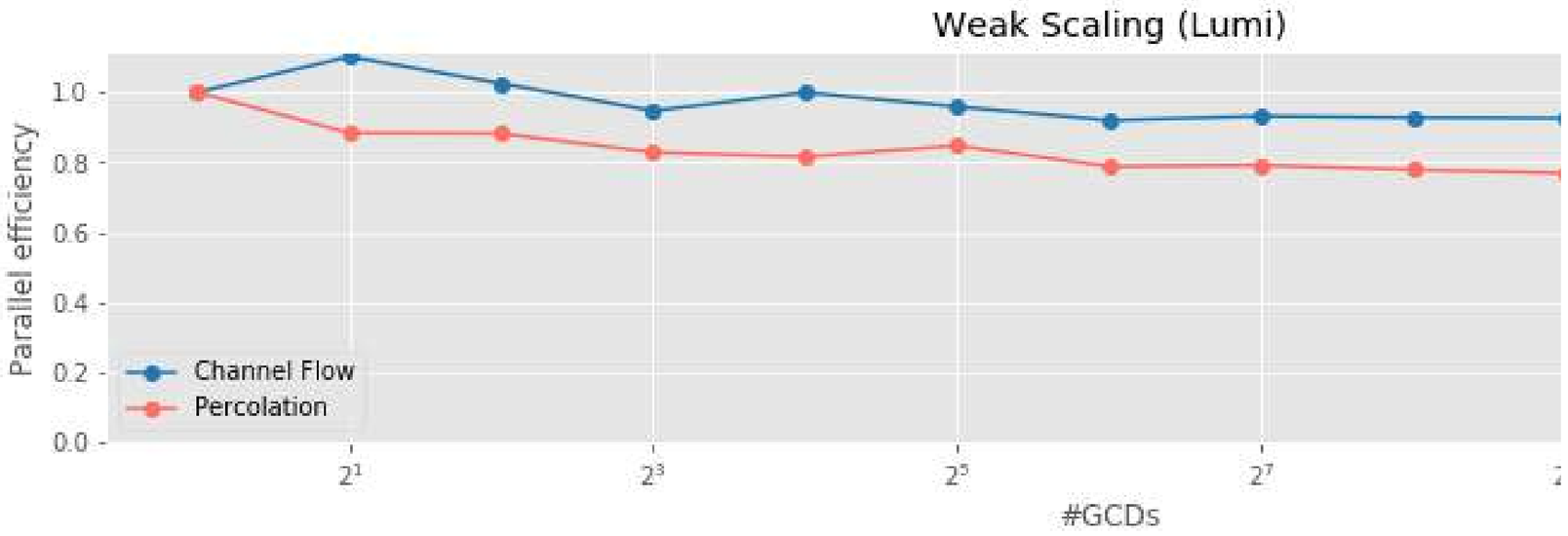
WaLBerla

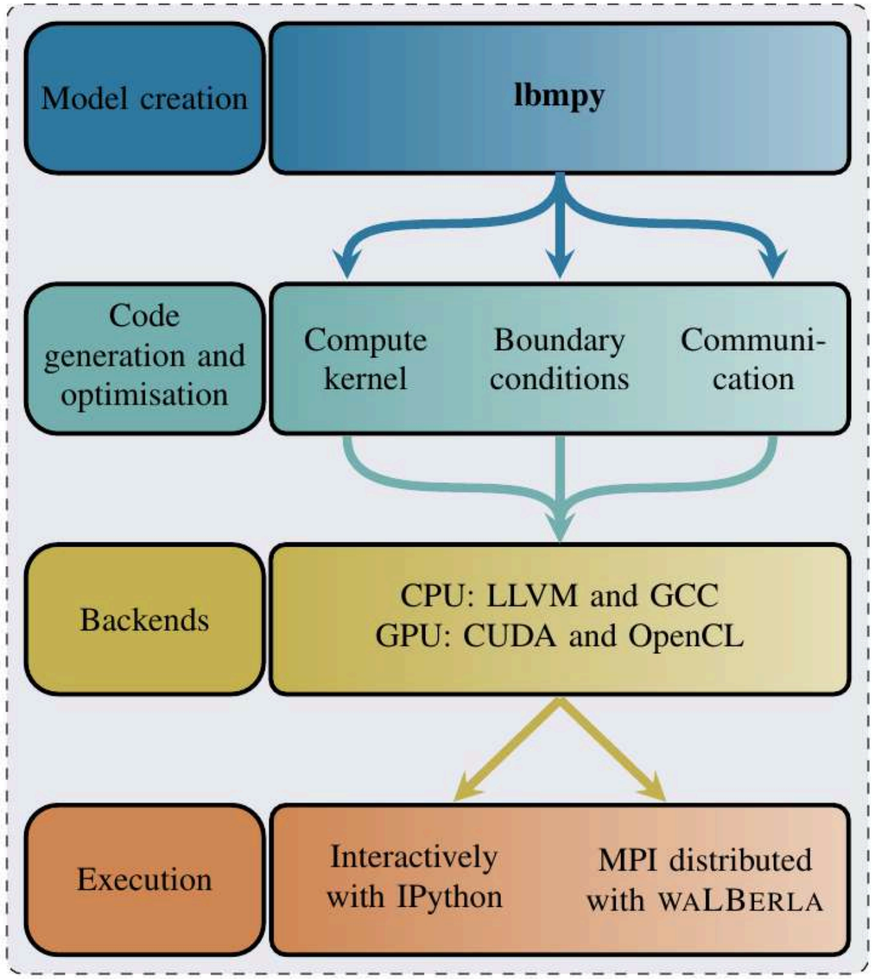
- Written in C++, Python interface, code generation with lbmpy
- Main applications: **CFD** with the lattice Boltzmann method (LBM), **rigid body** dynamics using the Discrete Element Method (DEM), **particulate flows**, **free-surface flows**, **phase fields**
- **Mesh refinement** capabilities for **turbulent flows**
- Software enables research on a microscopic level.

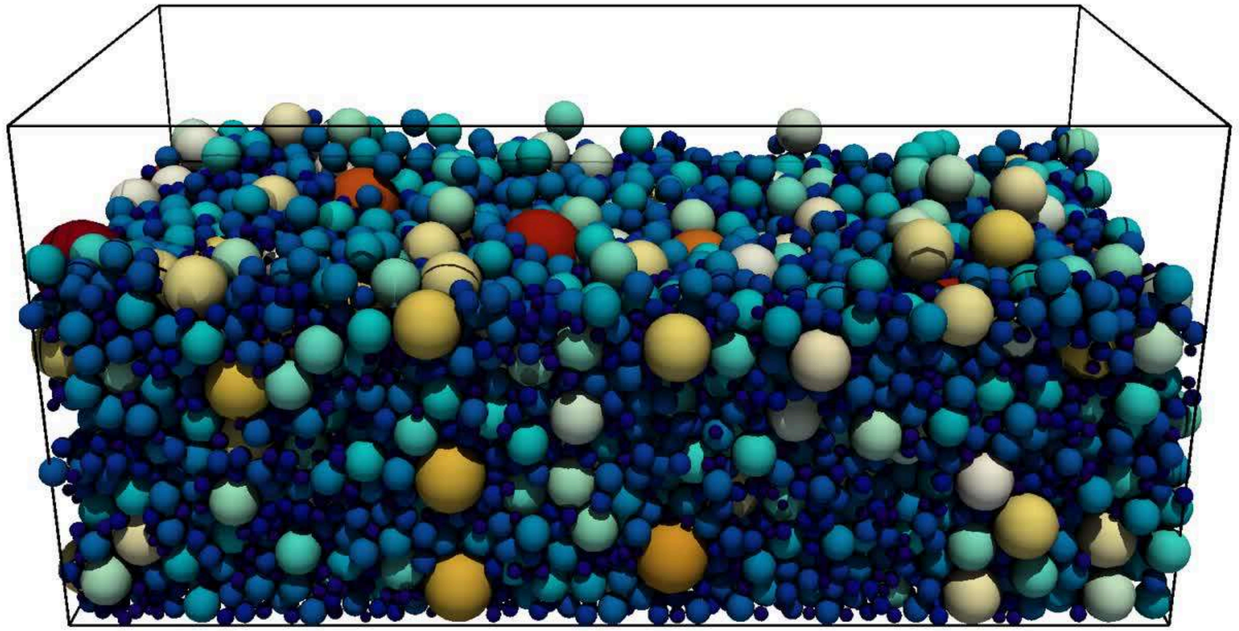
Lbmpy - Code Generation for LBM Kernels

- Motivation: **many** compute kernel **combinations**
- Solutions: models are formulated symbolically
- **Generation** of optimized architecture specific codes
- Highly efficient architecture specific functions are generated
- **Highly Scalable** framework

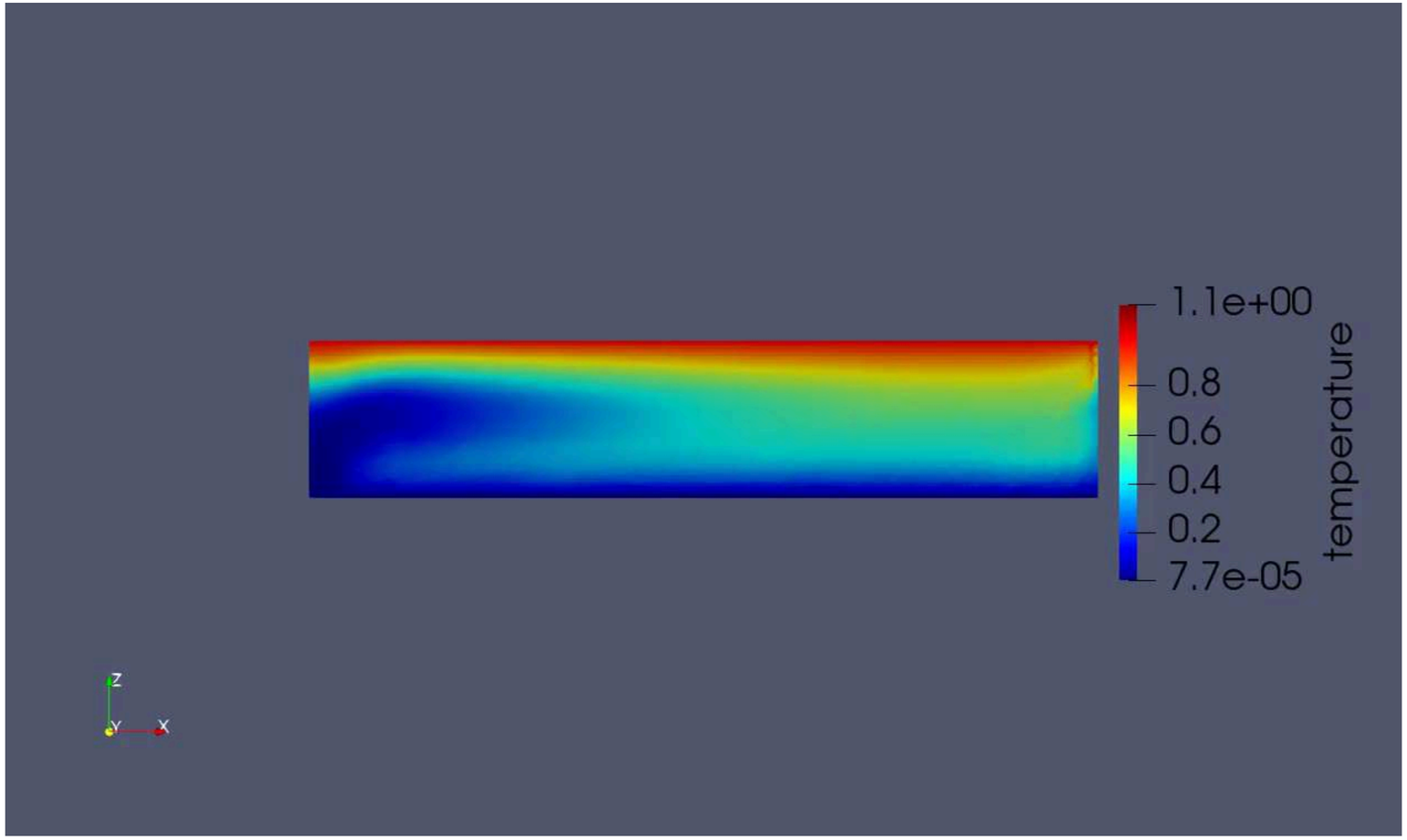




RiverBed Sediment Transport: Base of the current Usecase



Development achieved within Hidalgo2: Extension towards temperature transport simulations



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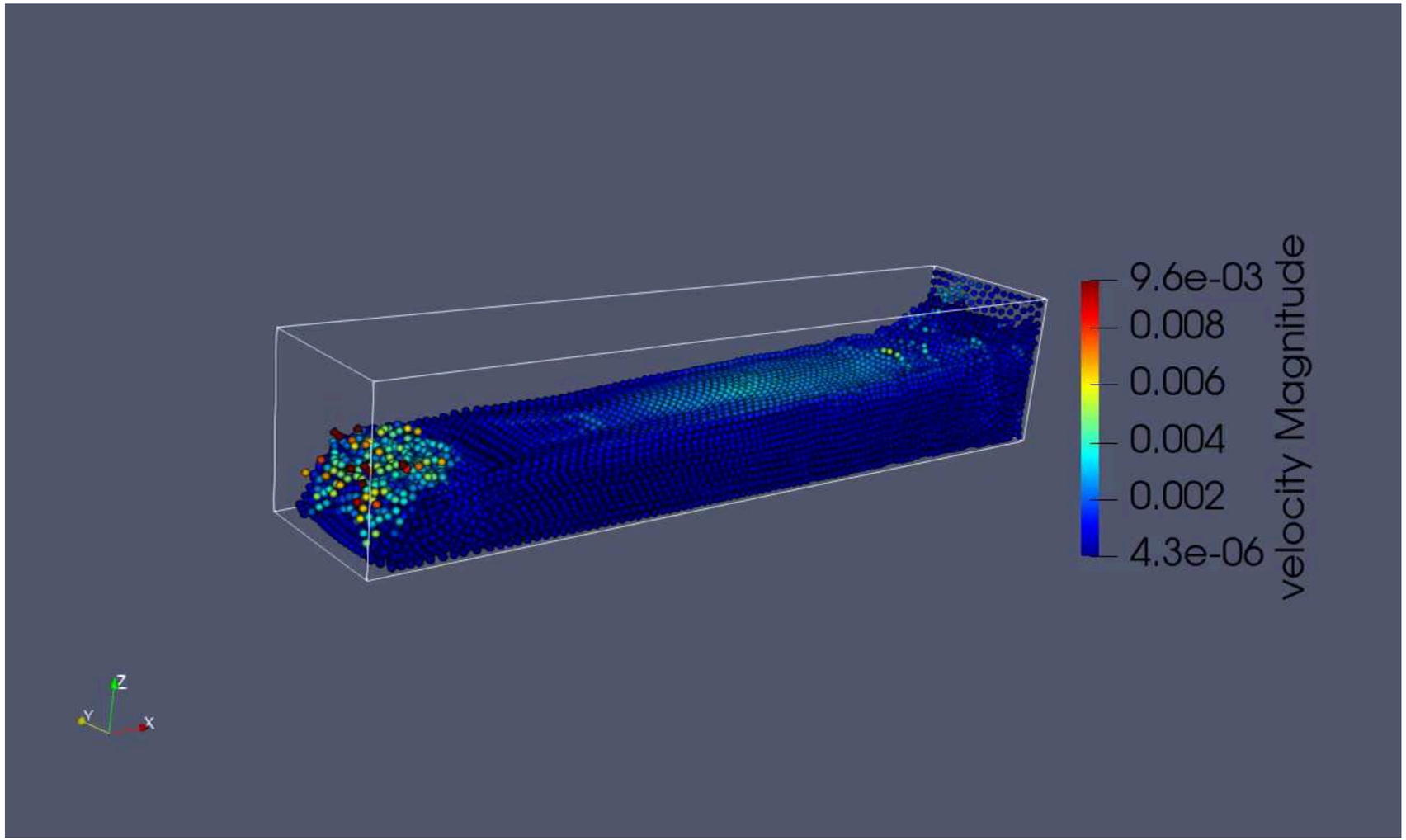
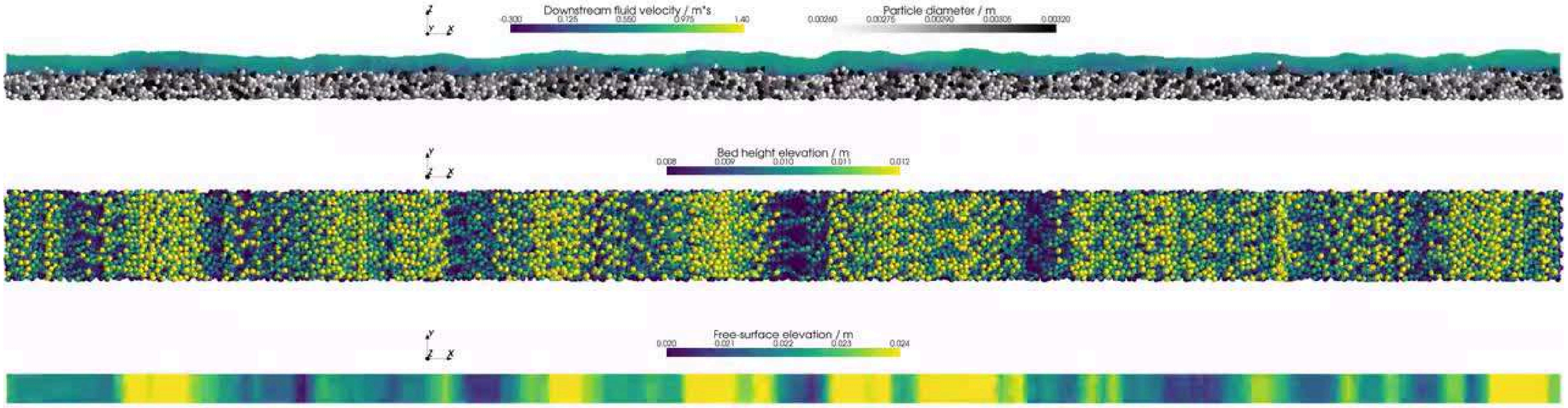
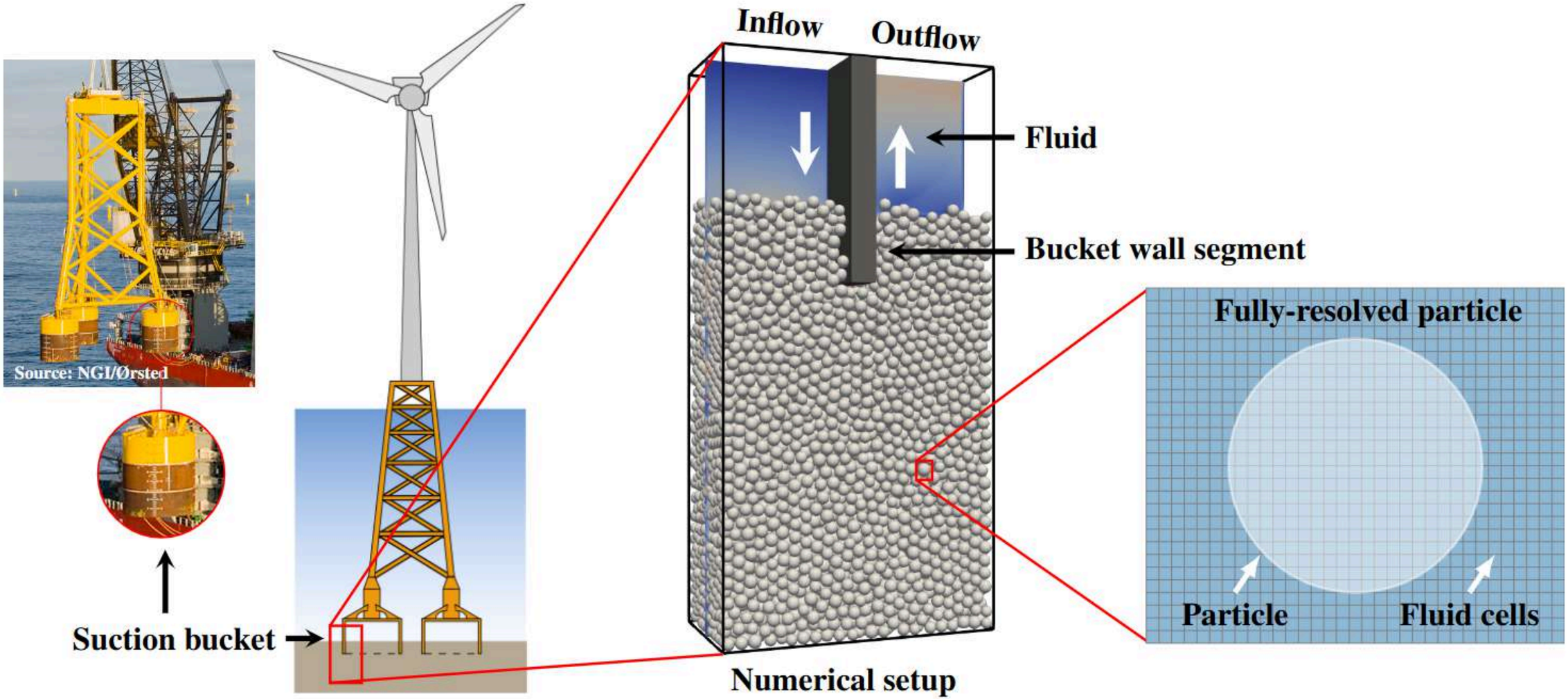


Fluid-Particle Coupling Applications in waLBerla - AntiDunes



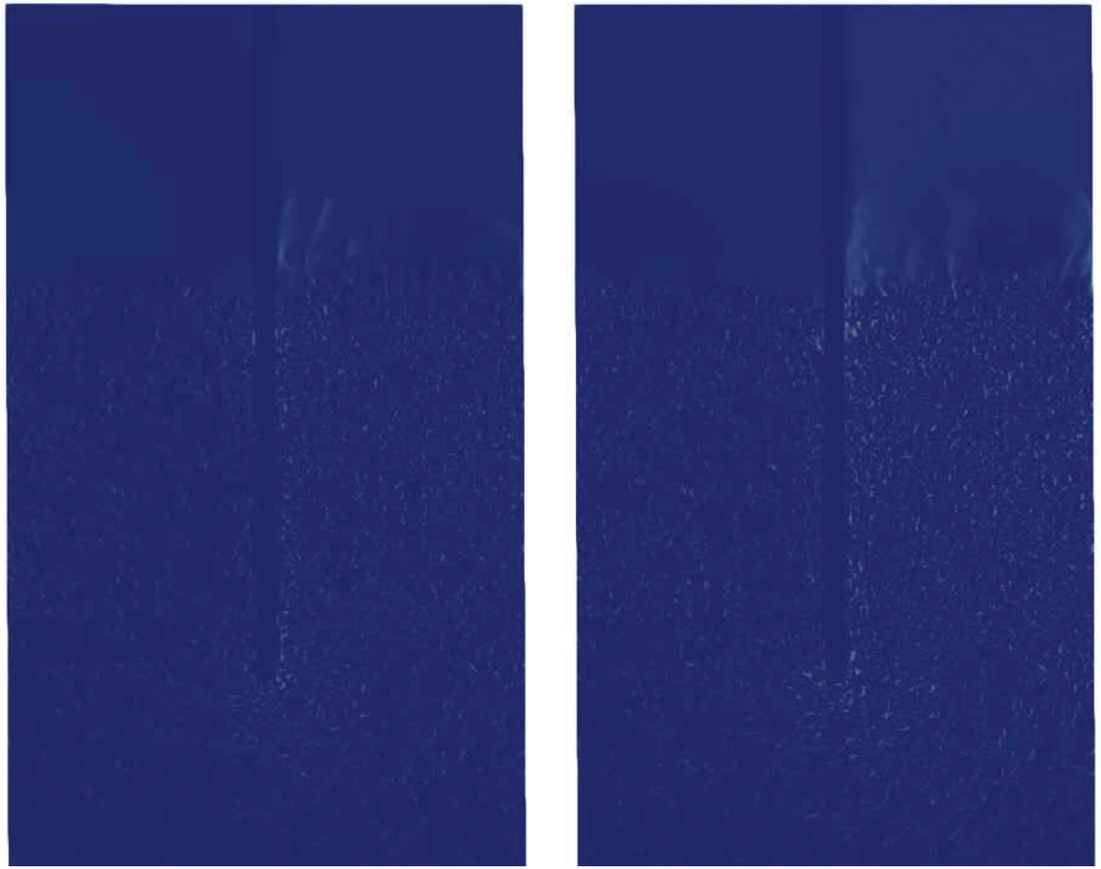
Suction-aided foundations



Source: Kemmler et al., 2025. Towards exascale simulations of granular fluidization in offshore wind turbine foundations.

Suction-aided foundations

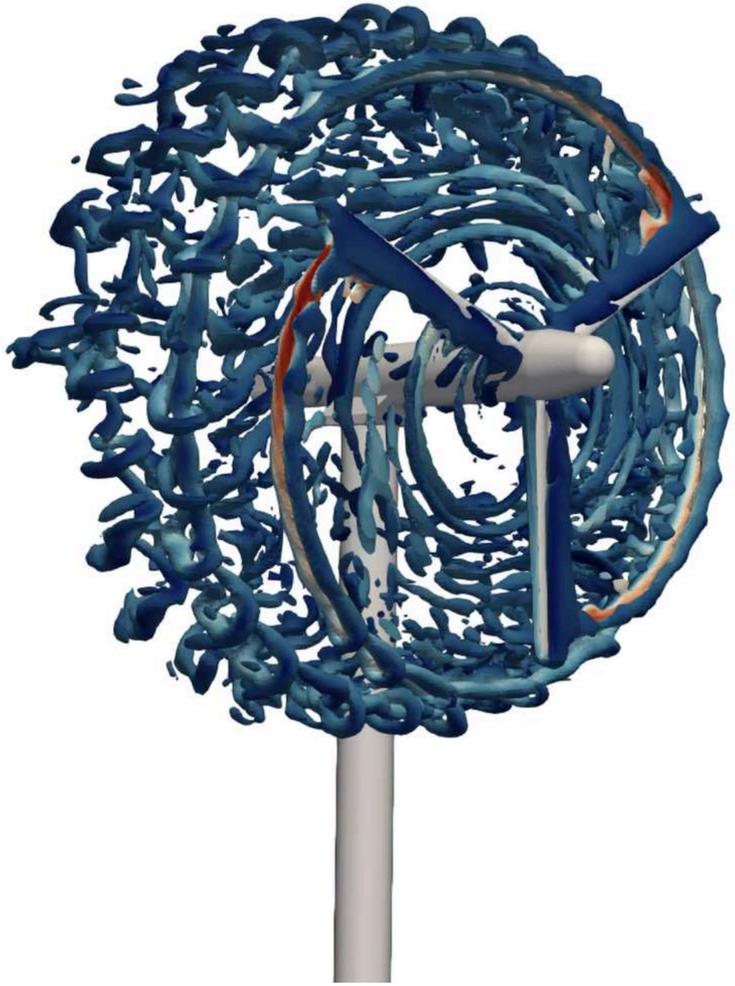
- Increasingly popular method to install offshore structures into the seabed
- **Faster, more cost-efficient, reversible, and environmentally friendly**, e.g., very low noise emissions, when compared to conventional methods like dynamic blow-driving of monopiles
- In addition: flow reduces soil penetration resistance
- Problem: Piping erosion (granular fluidization)
- May lead to a breach of the hydraulic seal, causing a failure of the bucket installation process
- **Simulation Goal:** better understanding of piping erosion using large-scale fully-resolved simulations



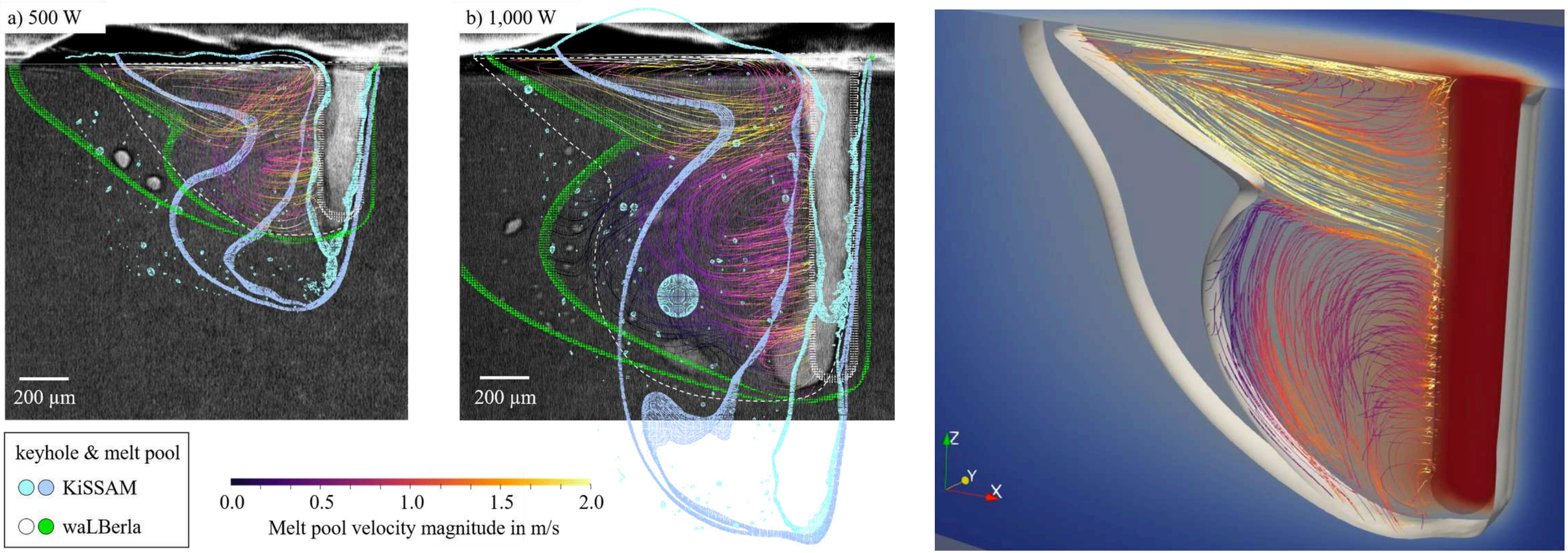
Other waLBerla Applications – Wind Turbine Simulation

Counter-Rotating Open Rotor:

- Renewed interest as CO2 reduced propulsion units for aircraft.
- Fully resolved Blades
- Static Mesh Refinement strategies adopted



Laser Beam Welding Application – Predictions of Melt Pool and Keyhole depths



Research and Collaboration Partners

- Institute of Hydraulic Engineering and Water Resources Management – RWTH Aachen University, Germany.
- Chair of Transport Processes in Hydro Systems, Technical University of Dresden
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