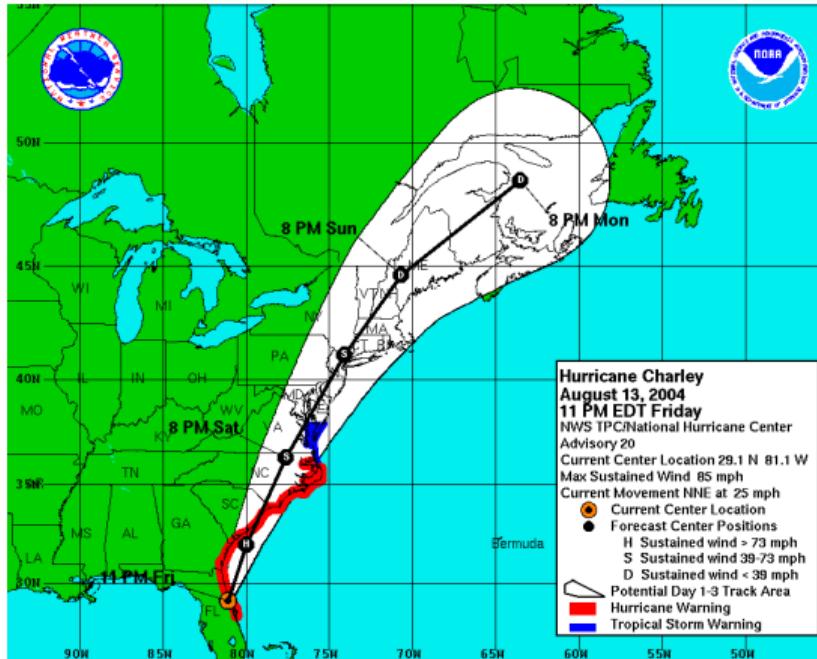


Introduction to UM-Bridge

Linking UQ and Models from Prototype to HPC

Linus Seelinger (Karlsruhe Institute of Technology, Germany)

Why Uncertainty Quantification (UQ)?



- “Don’t focus on the skinny black line”
 - US Hurricane Center
- Uncertain data \Rightarrow uncertain prediction / inferences.

UQ: Quantify this!

How to solve UQ problems?

Many methods:

- MC / MCMC
- Stochastic Galerkin
- Optimization-based MAP point search
- Multilevel / Multiindex MC / MCMC
- ...

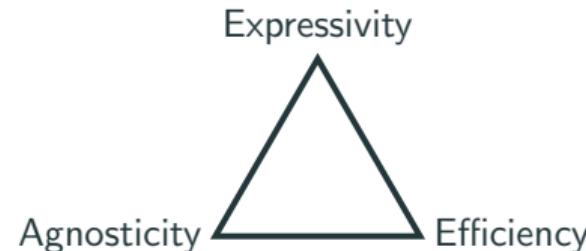


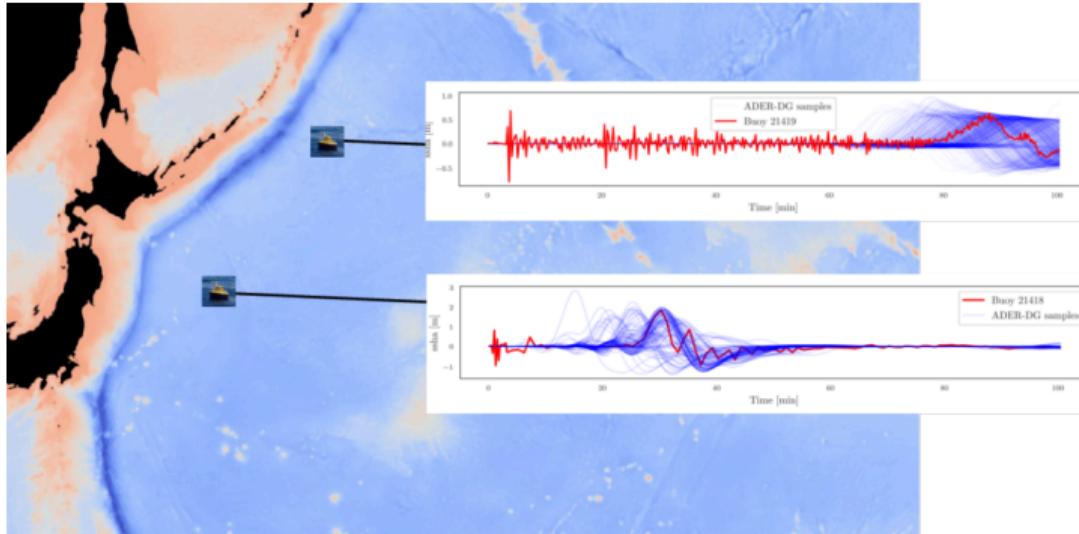
Figure 1: Main aspects of UQ methods

Large-scale problems need HPC!

Example: Markov chain Monte Carlo (MCMC)

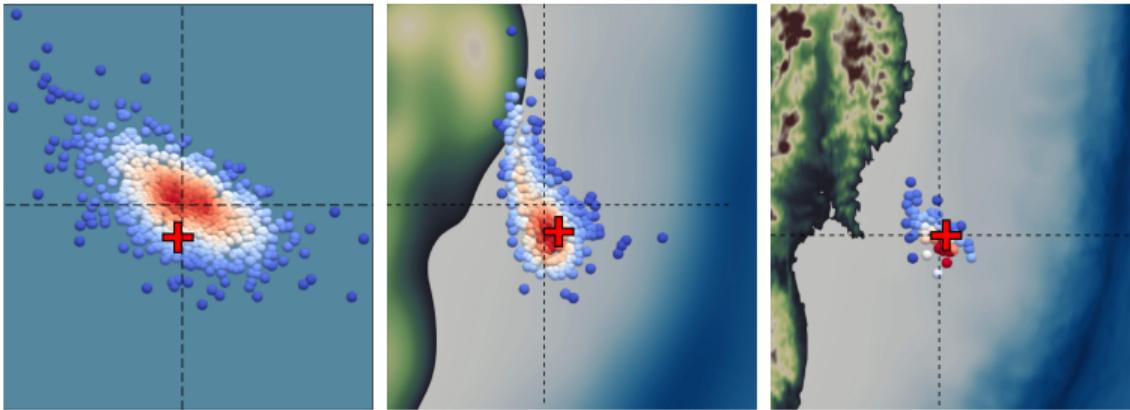
Online demo

Tsunami Problem



- Modelling Tohoku event (2011) using Shallow Water eq. and real bathymetry
- Forward model built on ExaHyPE PDE engine
- Data: Buoy measurements. Parameter: Tsunami source

Results



lvl /	t_l [s]	ρ_l	$\mathbb{V}[Q_0]$ or $\mathbb{V}[Q_l - Q_{l-1}]$		$\mathbb{E}[Q_0] +$ $\sum'_{k=1} \mathbb{E}[Q_k - Q_{k-1}]$	
0	7.38	25	1984.09	1337.42	3.61	27.96
1	97.3	5	1592.17	1523.18	-12.29	23.39
2	438.1	0	340.56	938.53	-5.46	0.12

Run on 3456 cores (72 nodes of 48 cores)

UQ and Model in Math

Model in UQ: (Often) Just a function $F : \mathbb{R}^n \rightarrow \mathbb{R}^m$ with some of the following:

- Model evaluation $F(\theta)$,
- Gradient $v^\top J(\theta)$,
- Jacobian action $J(\theta)v$,
- Hessian action $H(\theta)v$.

→ Simple, model-agnostic interface!

Linking model **software** and UQ **software**: Not that easy!

Complex software stack, conflicts (buildsystems, dependencies, languages, parallelization), need experts from both sides, ...

UQ and Model in Math

Model in UQ: (Often) Just a function $F : \mathbb{R}^n \rightarrow \mathbb{R}^m$ with some of the following:

- Model evaluation $F(\theta)$,
- Gradient $v^\top J(\theta)$,
- Jacobian action $J(\theta)v$,
- Hessian action $H(\theta)v$.

→ Simple, model-agnostic interface!

Linking model **software** and UQ **software**: Not that easy!

Complex software stack, conflicts (buildsystems, dependencies, languages, parallelization), need experts from both sides, ...

UM-Bridge:

Universal interface in software

UM-Bridge: Model Abstraction in Software

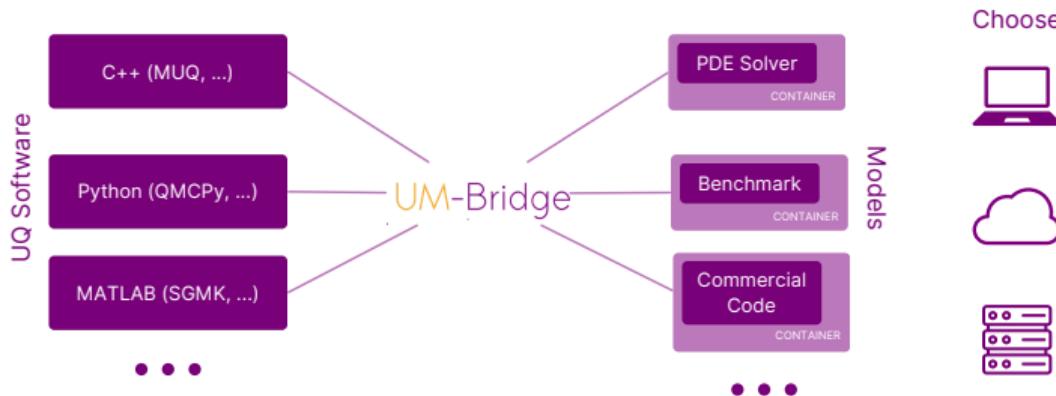


Interface **mimics math**: Model provides pointwise

- evaluation $F(\theta)$,
- Gradient $v^\top J(\theta)$ (optional),
- Jacobian action $J(\theta)v$ (optional),
- Hessian action $H(\theta)v$ (optional).

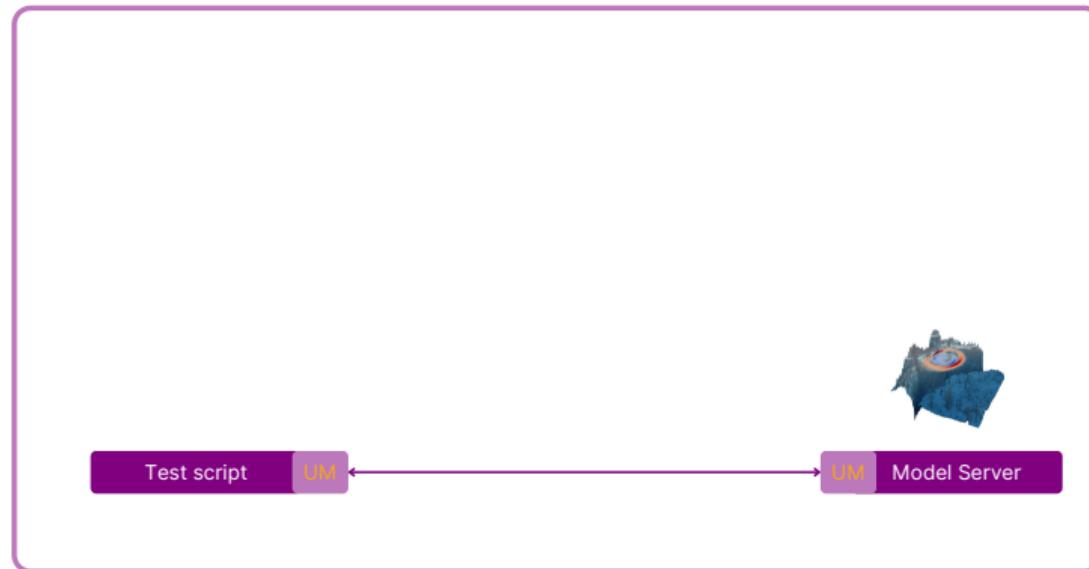
Inspired by microservices (established in software industry)

UM-Bridge: Enabling UQ from Prototype to HPC

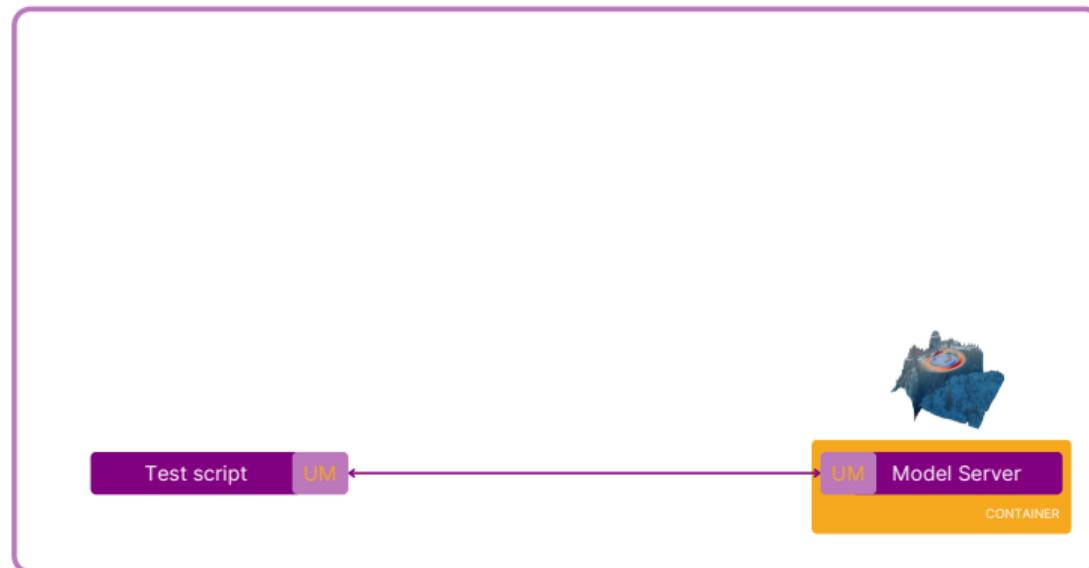


- Single point of entry for UQ and Models
- Separation of concerns
- Straightforward scalability

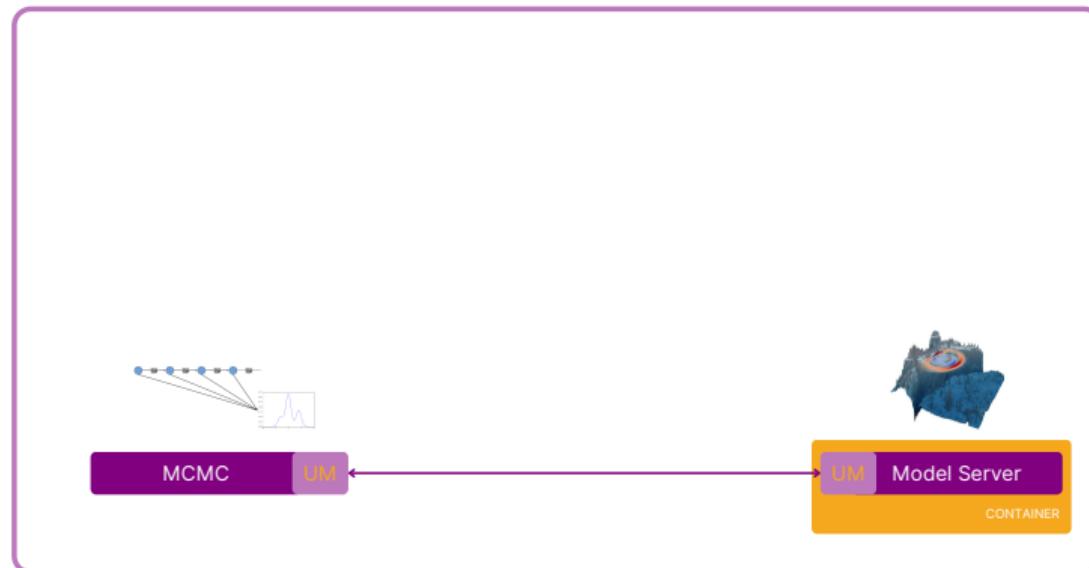
Workflow



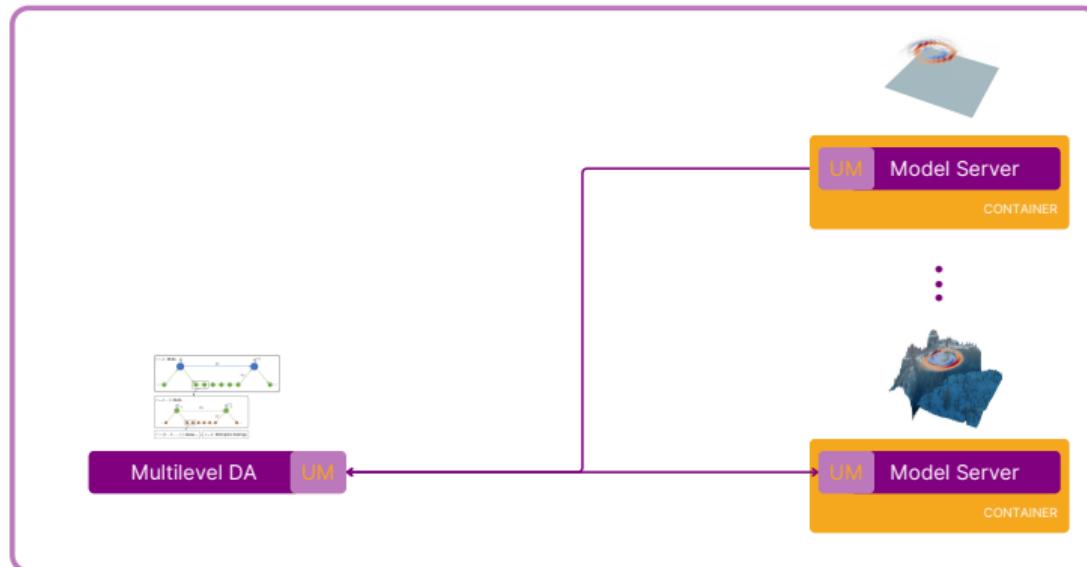
Workflow



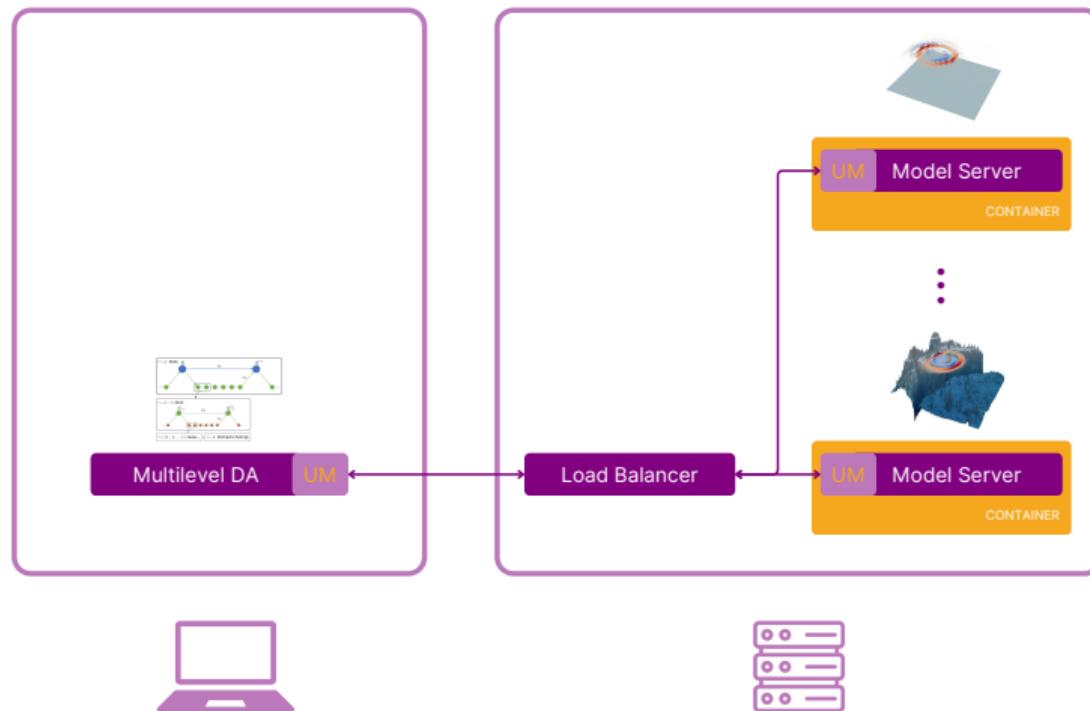
Workflow



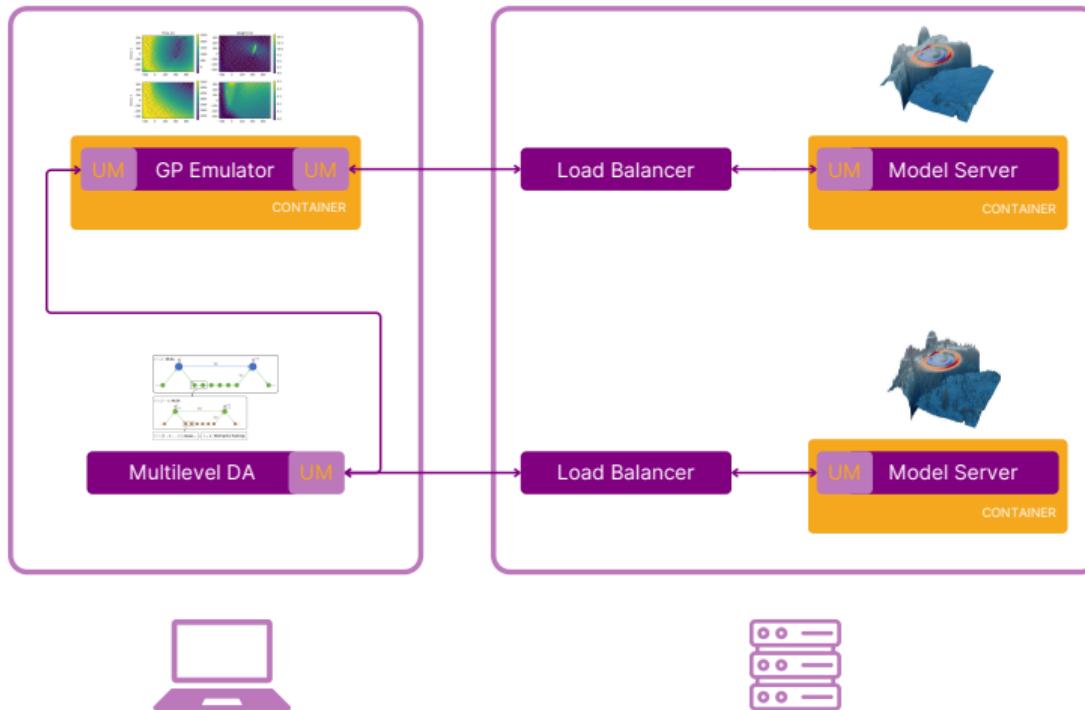
Workflow



Workflow



Workflow



Successfully run on 2800 core Google Kubernetes Engine cluster

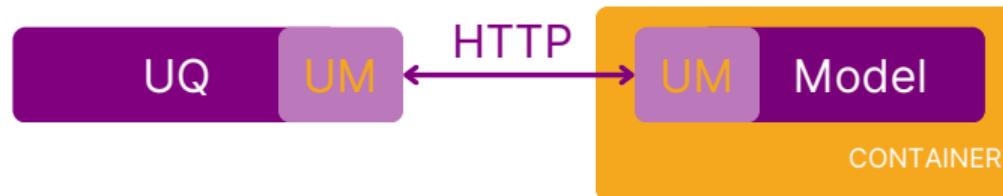
Demo

Demo

UM-Bridge Demo

Upcoming topics

UM-Bridge: Containerization - Portable Models



- Run tsunami model as easy as

```
docker run -p 4242:4242 linusseelinger/model-exahype-tsunami
```
 - Evaluate model in Python:

```
model = umbridge.HTTPModel('localhost:4242', 'forward')
model([[0.1,0.4]])
```
- Separation of concerns!

UQ Benchmarks

UQ Benchmarks

Navigation

Quickstart Guide

Analytic-Gaussian-Mixture Benchmark
ExaHyPE-Tsunami Benchmark

Infering material properties of a cantilevered beam

Analytic-Banana Benchmark
Analytic-Donut Benchmark
Analytic-Funnel Benchmark

ExaHyPE-Tsunami Model
Euler-Bernoulli Beam

Quick search

 Go

WRITE THE DOCS

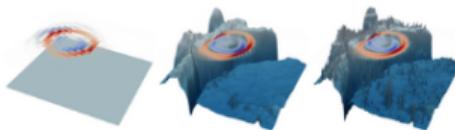
Love Documentation? Write the Docs Portland is a 3-day virtual docs event. May 22-24.

Community Ad

ExaHyPE-Tsunami Model

Overview

In this benchmark we model the propagation of the 2011 Tohoku tsunami by solving the shallow water equations. For the numerical solution of the PDE, we apply an ADER-DG method implemented in the [ExaHyPE framework](#). The aim is to obtain the parameters describing the initial displacements from the data of two available buoys located near the Japanese coast



Authors

- Anne Reinarz

Run

```
docker run -it -p 4243:4243 linusseelinger/model-exahype-tsunami
```

Properties

Mapping	Dimensions	Description
inputSizes	[2]	x and y coordinates of a proposed tsunami origin
outputSizes	[1]	Arrival time and maximum water height at two buoy points

Feature	Supported
Evaluate	True
Gradient	False
ApplyJacobian	False
ApplyHessian	False

Config	Type	Default	Description
level	int	0	chooses the model level to run (see below for further details)

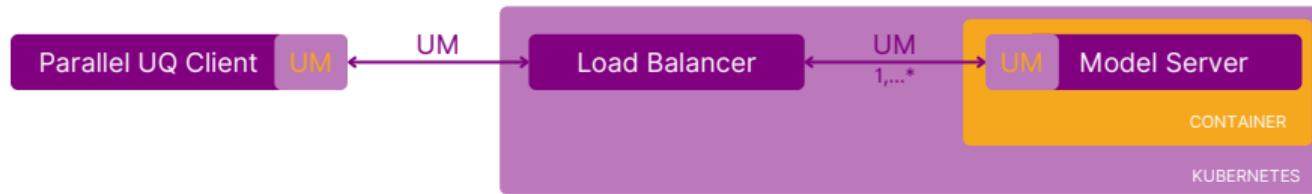
- Community project:

- > 20 models and benchmarks,
- > 15 contributors from
- > 10 institutions

- Ready-to-run containers

- Automated builds, testing etc.

Kubernetes Configuration - Sequential Model



Pre-built configuration, simply plug in your own model container

UQ client only sees an UM-Bridge server. But may make parallel requests!

Conclusions

Conclusions

- Universal UQ / model interface, following maths
- Easy to use in various languages and frameworks
- Opens up new possibilities for UQ:
 - Portable models, separation of concerns
 - Library of reproducible UQ benchmark problems
 - Easy scaling to Cloud / HPC

Practical

Tutorial sections 1-3