

UM-Bridge

Enabling Uncertainty Quantification on Advanced Numerical Models

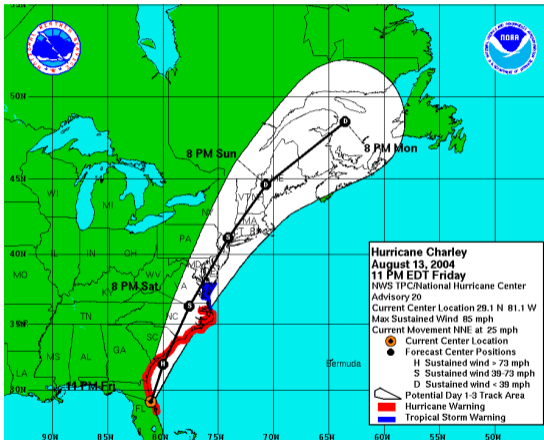
Anne Reinartz¹, Mikkel Lykkegaard², Robert Scheichl³, **Linus Seelinger³**

¹Department of Computer Science, Durham University

²digiLab Solutions

³Institute for Mathematics, Heidelberg University

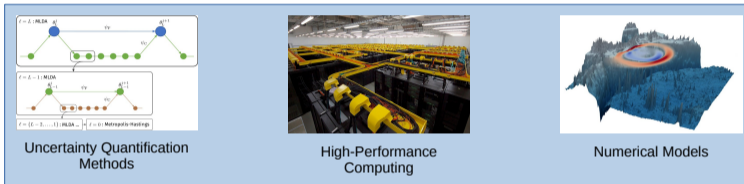
Why Uncertainty Quantification (UQ)?



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

UQ: Quantify this!

Why not done more often?



Uncertainty Quantification Methods

High-Performance Computing

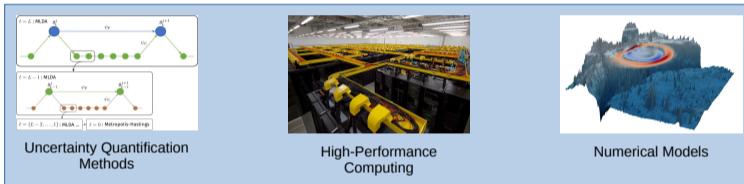
Numerical Models

Complexity holding back UQ method development and applications!

This talk:

- Brief introduction to UQ methods
- UM-Bridge: Universal UQ / model software interface

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Uncertainty Quantification Methods

High-Performance Computing

Numerical Models

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This talk:

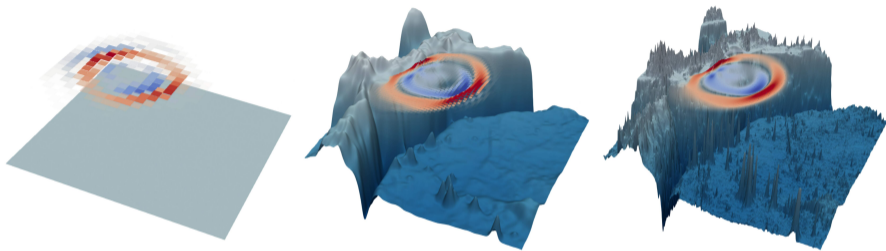
- Brief introduction to UQ methods
- UM-Bridge: Universal UQ / model software interface

Markov Chain Monte Carlo (MCMC)

MCMC Demo

Multilevel MCMC

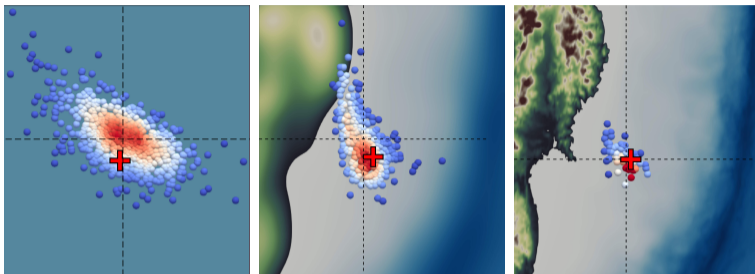
Model Hierarchy



Across levels, we adapt

- mesh size
- bathymetry smoothness (specific to hyperbolic solvers!)

Results



l	t_l [s]	ρ_l	$\mathbb{V}[Q_0]$ or $\mathbb{V}[Q_l - Q_{l-1}]$	$\mathbb{E}[Q_0] +$ $\sum_{k=1}^l \mathbb{E}[Q_k - Q_{k-1}]$		
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!

Model **software** and UQ **software**: Not so easy!

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

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UM-Bridge

Universal UQ / Model Software Interface

UM-Bridge: Model Abstraction in Software



Interface mimics math (Pointwise eval. of F , derivatives optional)

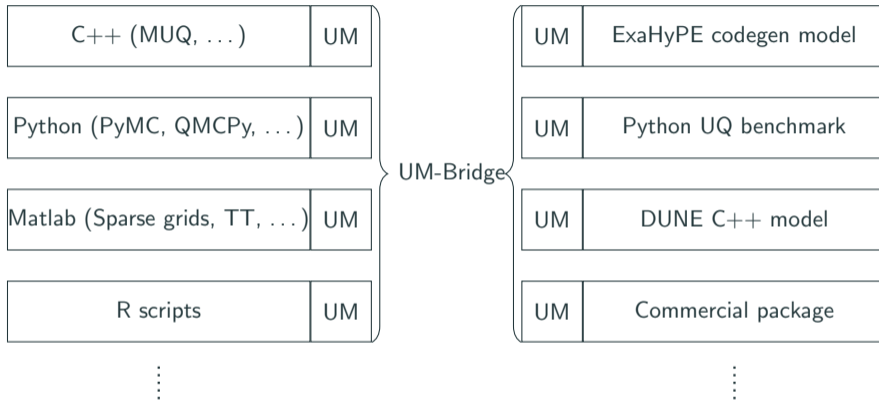
Inspired by microservices (established in industry)

Achieves:

- Level 3: Turn-key HPC setup in the cloud
- Level 2: Portable, reproducible models via containers; Separation of concerns
- Level 1: Coupling across languages

Layer 1: Coupling Across Languages

UM-Bridge: Bridging Languages and Frameworks

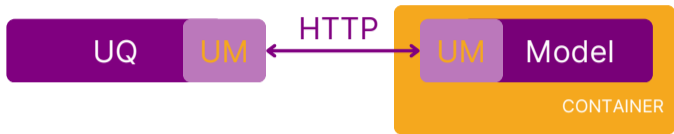


Requires only HTTP and JSON support → almost every language

Existing integrations for various languages and frameworks

Layer 2: Containerized Models

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

Navigation

Quickstart Guide

Analytic-Gaussian-
Mixture Benchmark
ExaHyPE-Tsunami
Benchmark

Inferring material
properties of a
cantilevered beam

Analytic-Banana
Benchmark

Analytic-Donut
Benchmark

Analytic-Funnel
Benchmark

ExaHyPE-Tsunami Model
Euler-Bernoulli Beam

Quick search

**WRITE
THE
DOCS**

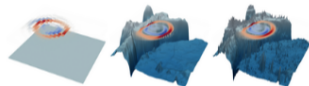
Love Documentation? Write
the Docs Portland is a 3-day
virtual docs event. May
22-24.

Community Aff

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 linuxseelinger/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

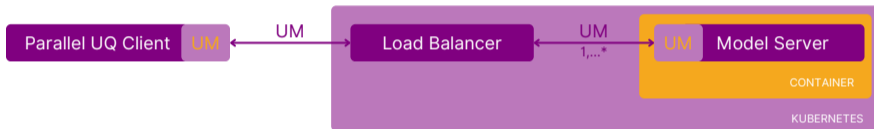
Config	Type	Default	Description
level	int	0	chooses the model level to run (see below for fur-

- Community project:
 - > 20 models and benchmarks,
 - > 15 contributors from
 - > 10 institutions
- Ready-to-run containers
- Automated builds, testing etc.

UM-Bridge Demo

Layer 3: Turn-key HPC Setup in the Cloud

Kubernetes Configuration - Sequential Model

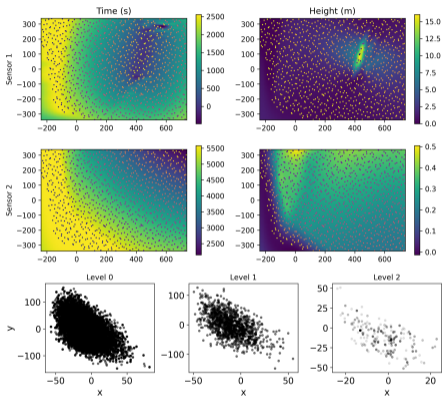


Pre-built configuration, simply plug in your own model container

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

Applications

Multilevel Delayed Acceptance (MLDA) + Tsunami



- Gaussian process (GP) surrogate as level 0, trained on level 1
- GP on workstation, simulation runs on 2800 core cluster on Google Kubernetes Engine

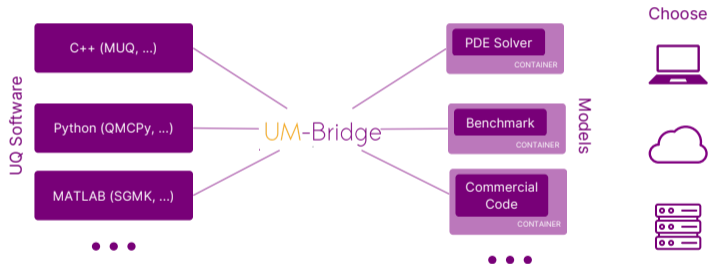
UM-Bridge: No modification to MLDA or model container, separation of concerns

Conclusions

Conclusions / Outlook

UM-Bridge enables complex UQ applications, *Democratizing UQ*

Upcoming: Support for "traditional" HPC systems (SLURM)



- Workshop in December: <https://um-bridge.github.io/workshop/>
- mail@linusseelinger.de
- SC '21: *High Performance UQ with Parallelized Multilevel MCMC*
- JOSS '23: *UM-Bridge: Uncertainty Quantification and Modeling Bridge*