# UM-Bridge

## Enabling Uncertainty Quantification on Advanced Numerical Models

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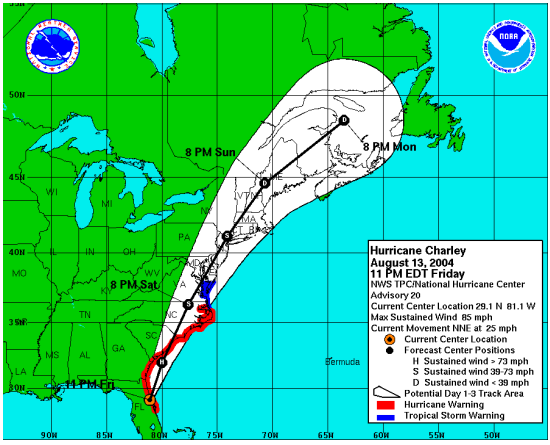
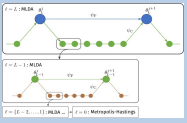
# Why Uncertainty Quantification (UQ)?




- "Don't focus on the skinny black line"
  - US Hurricane Center
- Uncertain data $\Longrightarrow$ uncertain prediction / inferences.
  **UQ: Quantify this!**

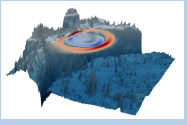
# Outline

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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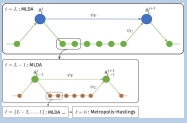

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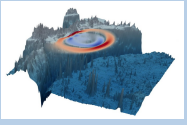

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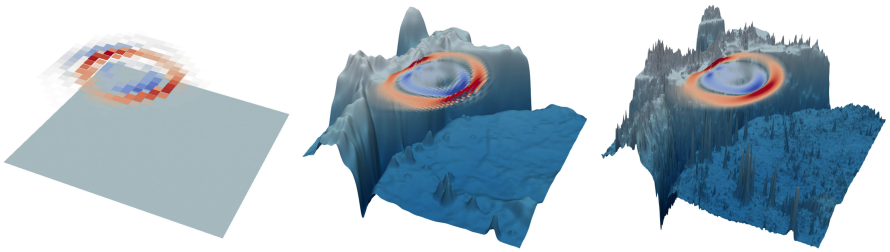
# Markov Chain Monte Carlo (MCMC)

MCMC Demo

# Multilevel MCMC

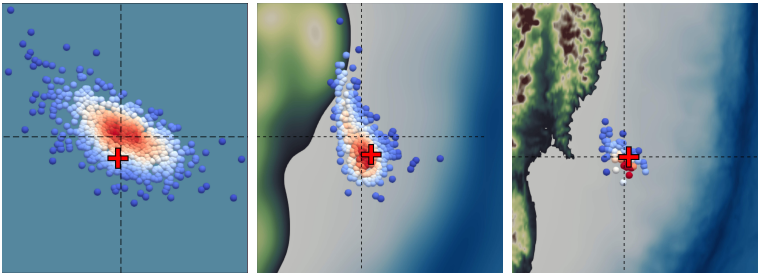
# Model Hierarchy



Across levels, we adapt

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

# Results



| lvl $l$ | $t_l$[s] | $\rho_l$ | $\mathbb{V}[Q_0]$ 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 $F : \mathbb{R}^n \to \mathbb{R}^m$ with some of the following:

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

$\to$ 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)

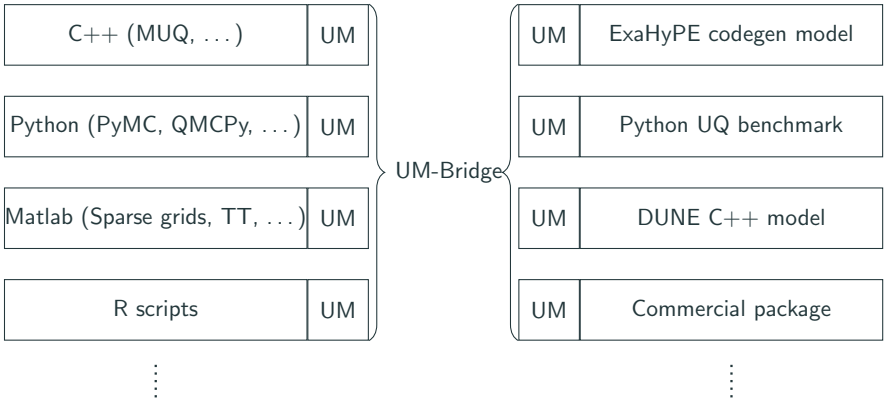
Inspired by microservices (established in industry)

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

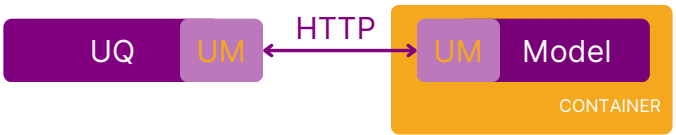



Requires only HTTP and JSON support $\rightarrow$ almost every language

Existing integrations for various languages and frameworks

# Layer 2: Containerized Models

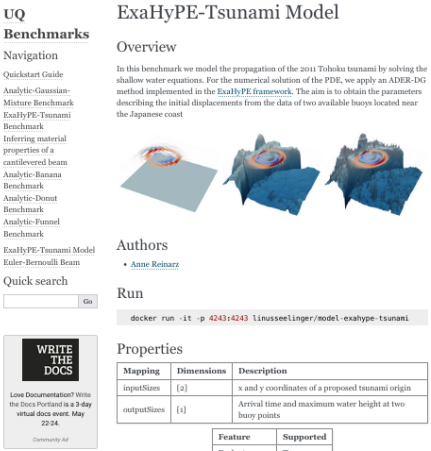
# UM-Bridge: Containerization - Portable Models




- 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



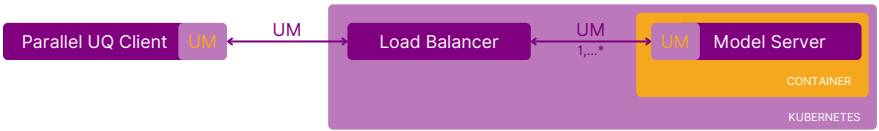

- Community project:
  $>$ 20 models and benchmarks,
  $>$ 15 contributors from
  $>$ 10 institutions
- Ready-to-run containers
- Automated builds, testing etc.

# UM-Bridge

UM-Bridge Demo

# Layer 3: Turn-key HPC Setup in the Cloud

# Kubernetes Configuration - Sequential Model

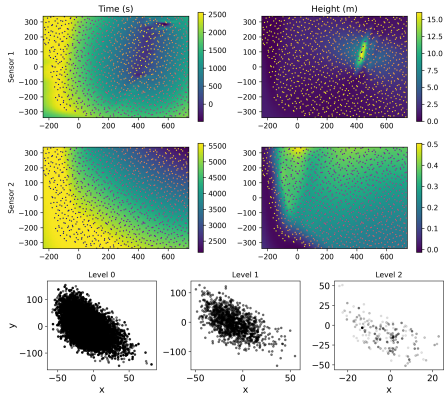



Pre-built configuration, simply plug in your own model container

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

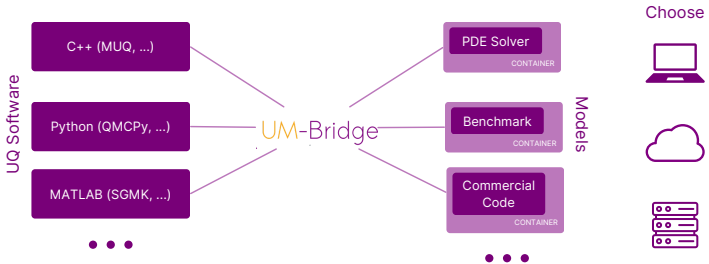
UM-Bridge: No modification to MLDA or model container, separation of concerns

# 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*