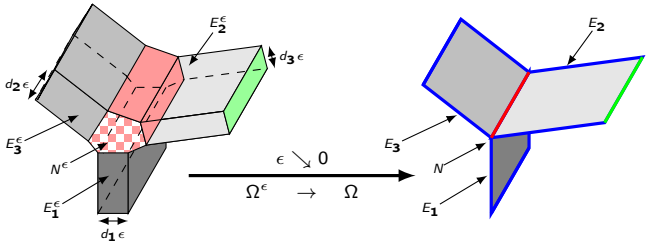
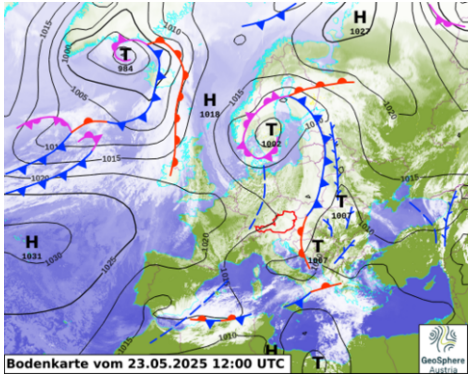
What is going on in applied mathematics in Saarland?

Andreas Rupp, joint work with many colleagues



Xi'an/Helsinki, April 1, 2026

Numerical weather prediction

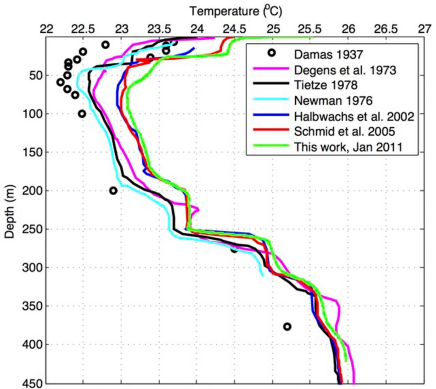


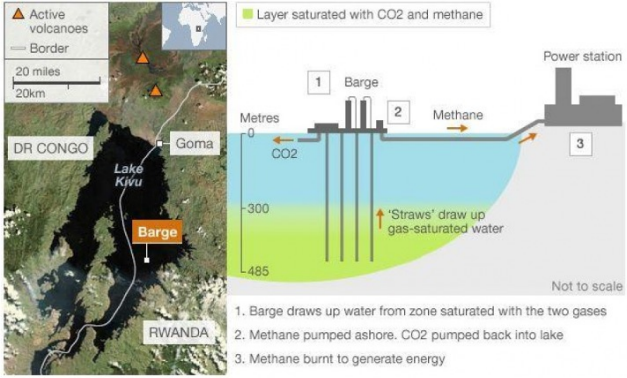
How does numerical weather prediction work?

- Two ingreduents:
  - Basic physical principals and
  - consitutive laws

  transformed into (often partial differential) equations
- Many irrelevant effects (processes) are neglected
- The resulting equation is discretized
  (finite elements, finite volumes, finite differences)
- Computer simulations bring the discretized
  equation to life and allow us to make predictions

A power plant in lake Kivu (with AIMS Rwanda, LUT)

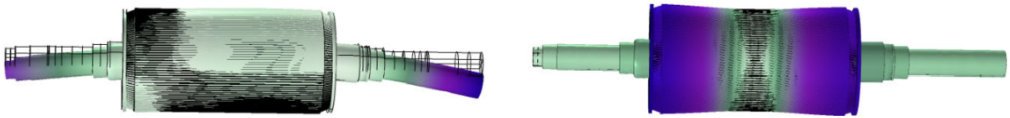




Using mathematical simulations we can ensure that

- the power plant is safe to operate,
- the power plant does not cause environmental damage and
- the power plant is economically viable.

Stability of electric engines (with ABB Helsinki, LUT)

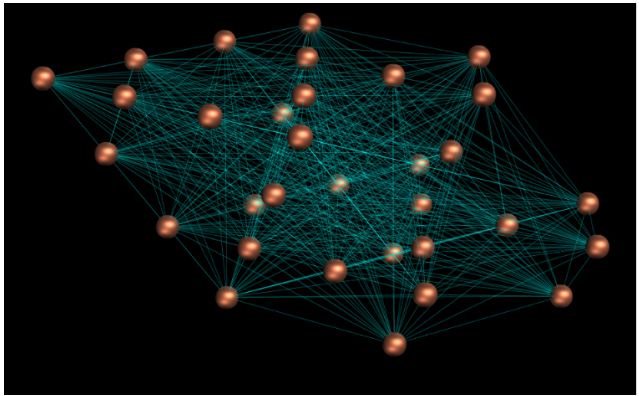


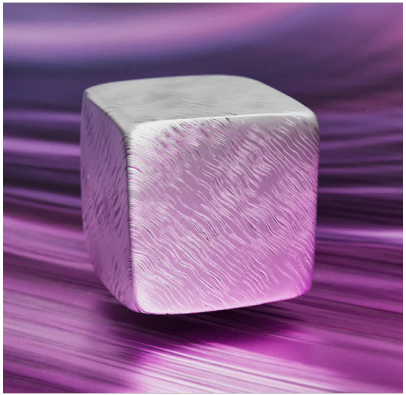
- electric engines prudced by Swiss/Swedish company ABB in Helsinki
- produced in a shrink fit technology
- stability of the shrink fit is crucial for the safety and economic viability of the engine
- measurements of eigenmodes and deducing effective material parameters decide on quality of the engine

Medical drug capsule dissolution (with Bayer, Brinter, LUT, . . .)

- 3D-printed medical drug for rare disease is inserted into body and remains there for longer time
- Task: Design a printable capsule that releases active ingredient in predetermined way

Mathematics and physics (with former group member)





Longrange interations appear in very small scales (quantum physics) and very large scales (astrophysics). Efficient calculations in very small scaless leads to better understanding of superconductors and fancy quantum materials (hopefully), while efficient calculations in very large scales leads to better understanding of the universe.

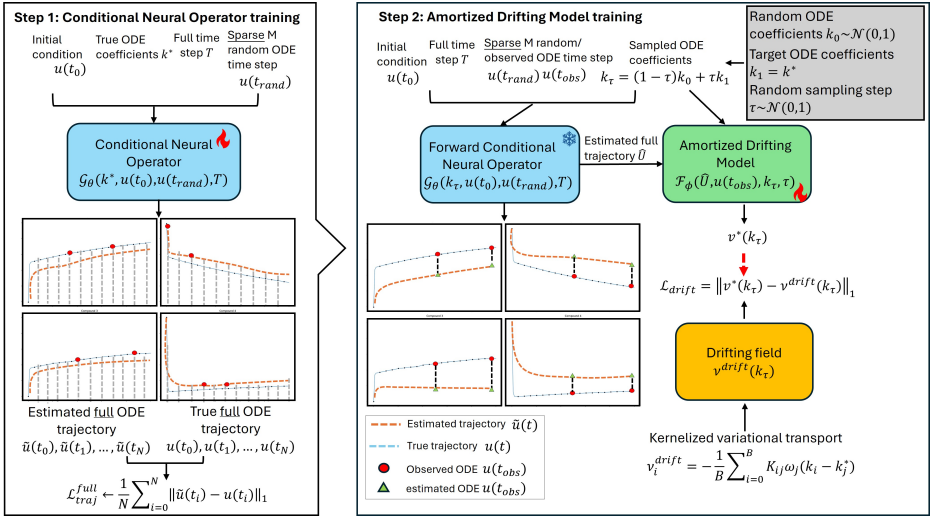
Enhancing speed in computations: Make parameter estimation possible

At least two possible strategies:

- Improve the numerical methods (e.g., better discretization, better solvers, better preconditioners)
  - often only mild speedup possible,
  - often very difficult to achieve,
  - guaranteed to work in predicted way,
  - great for understanding the physics and mathematics, but not necessarily for applications.
- Replace numerical methods by data-driven methods (e.g., machine learning, surrogate models, reduced order models)
  - enormous speedup possible at the cost of significant training time,
  - often (very) easy to achieve (good frameworks like PyTorch available),
  - not guaranteed to work in predicted way (generalization error, adversarial examples),
  - great for applications, but not necessarily for understanding the physics and mathematics.
- Hybrid approaches that have the advantages (and disadvantages) of both methods.

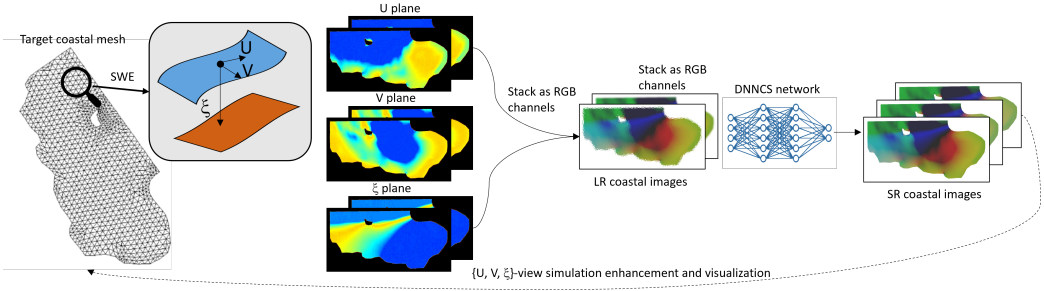
Some of our machine-learning approaches (with Zhi-Song Liu, et al.)

- Inverse neural operator for ODE parameter estimation



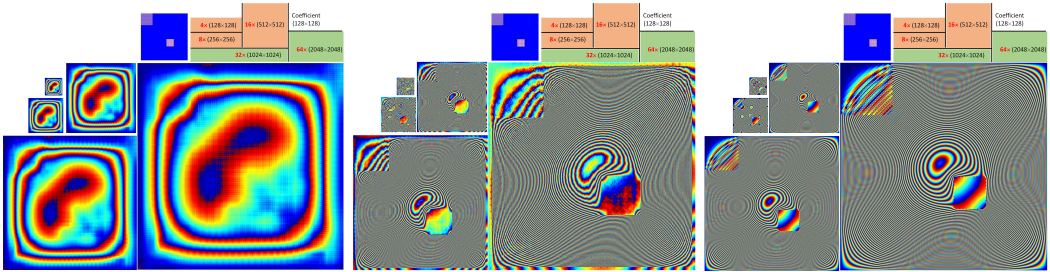
Some of our machine-learning approaches (with Zhi-Song Liu, et al.)

- Inverse neural operator for ODE parameter estimation
- Downscaling neural network for coastal simulations



Some of our machine-learning approaches (with Zhi-Song Liu, et al.)

- Inverse neural operator for ODE parameter estimation
- Downscaling neural network for coastal simulations
- Multiscale corrections by continuous super-resolution



(a) LIIF [51] (b) Ours (c) HR

Some of our machine-learning approaches (with Zhi-Song Liu, et al.)

- Inverse neural operator for ODE parameter estimation
- Downscaling neural network for coastal simulations
- Multiscale corrections by continuous super-resolution