Multiscale Emulation and Deep Learning-based Assimilation for Probabilistic Prediction of Hydrologic Phenomena

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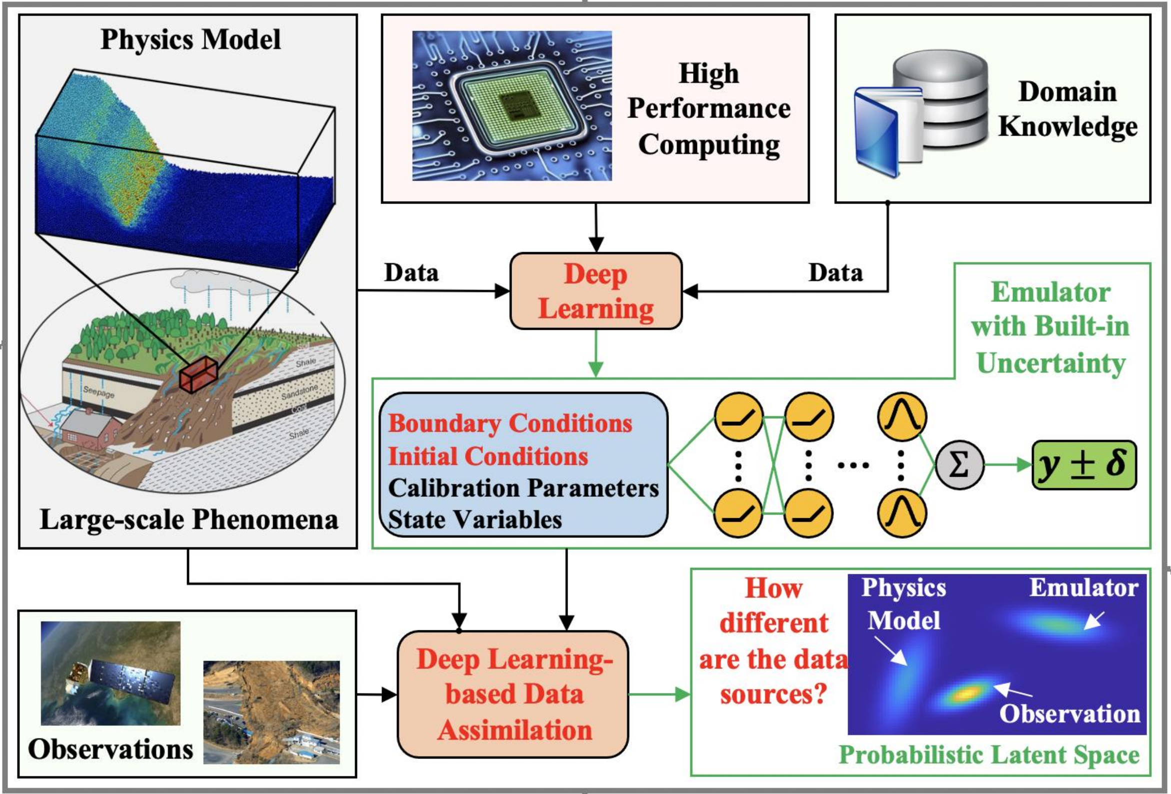
Multiscale Emulation Framework:

- We build an emulator to surrogate an *operator* (i.e., a function of functions & variables) which enables **(1)** uncertainty quantification, and **(2)** probabilistic spatiotemporal extrapolation.
- Our framework is *hypothesis-driven* and systematically integrates deep learning and domain knowledge with distributed computing and curriculum learning.



Deep Learning-based Assimilation Framework:

- We eliminate data assimilation (DA) formulas (e.g., those of Kalman/particle filters) and instead *learn* how different data sources should be integrated.
- Our DA framework **(1)** can *jointly* assimilate *multiple* data sources without explicit instructions, and **(2)** builds a latent space (LS) which not only quantifies but also visualizes the (dis)similarity among different data sources. This LS helps in hypothesizing about the discrepancies between the various information sources.

Research Objectives:

- Scalable and transferable emulation of complex physics models.
- Instruction-free and probabilistic calibration & validation of emulators via assimilation.

Primary Innovations:

- Building emulators that go far beyond surrogating a single run of a physics model.
- Converting data assimilation to a latent space learning problem.

Advantages over SOA:

- Increased modularity, transferability, and accuracy of emulation & assimilation.
- Accelerated emulation-based *quantification of uncertainties* due to, e.g., boundary conditions or state variables.
- *Joint*, multi-data, multi-model assimilation.

Technology Readiness Level (TRL):

- **Start:** TRL1 **End:** TRL2
- Scientific investigations, open-source implementation, dissemination of results via codes, publications, presentations, …

Impact:

- Drastically decrease the evaluation costs of physics models used in space science and engineering → Reduce mission costs and time.
- Increase prediction accuracy → Reduce mission uncertainties.
- Visual diagnostics → Hypothesize about missing physics.

Next-level Tech. Development:

Adaptable and memory/power efficient emulators and assimilators used in:

- Onboard data processing for route planning, multi-agent coordination, satellites, …