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Author(s):	Ahmmed, Bulbul Karra, Satish Mudunuru, Maruti K.
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Mass balance of physics-informed and physics-constrained machine learning

Bulbul Ahmmed, Satish Karra
Computational Earth Science Group
Los Alamos National Laboratory, Los Alamos, NM 87545
Email: ahmmedb@lanl.gov

Maruti K. Mudunuru
Pacific Northwest National Laboratory, Richland, WA 99352

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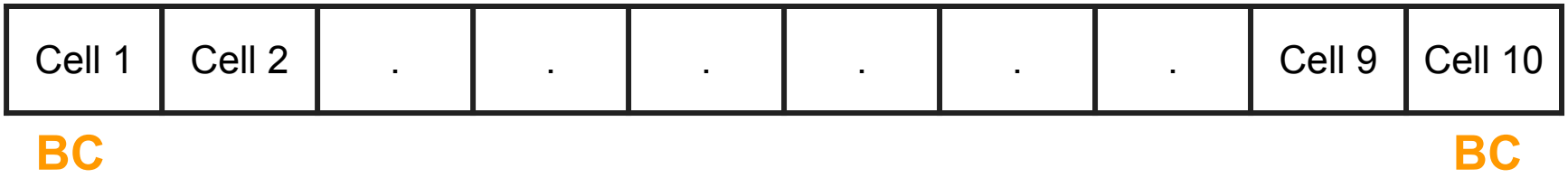
Background: Physics-informed neural networks (PINN)

$$\min_{\boldsymbol{\theta}} \mathcal{L}(\boldsymbol{\theta}) = \frac{1}{N_u} \sum_{i=1}^{N_u} \|\boldsymbol{u}(\boldsymbol{NN}(\boldsymbol{x}^i;\boldsymbol{\theta})) - u^i\|^2 + w\|\mathcal{F}(\boldsymbol{u}(\boldsymbol{NN}(\boldsymbol{x};\boldsymbol{\theta}));\boldsymbol{p})\|^2$$

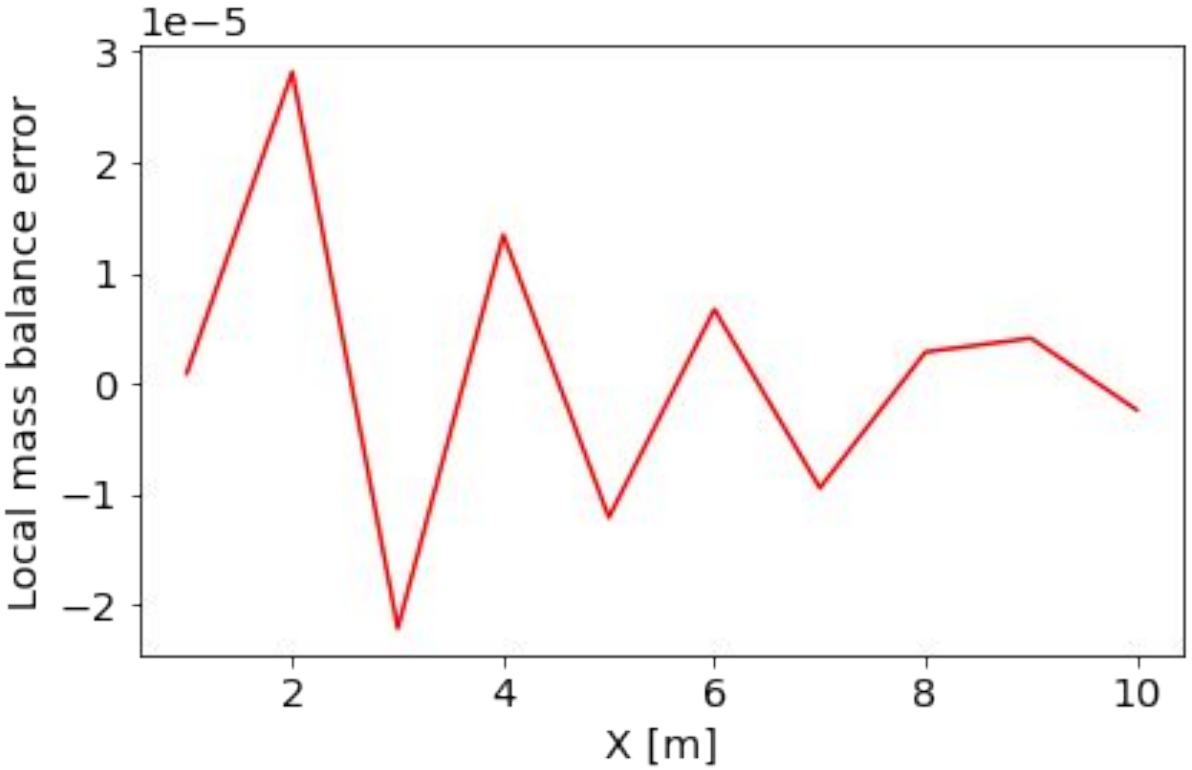
- weights
- collocation point #
- outputs
- Neural network
- True value at collocated point
- penalty
- Model parameter

- Physics code is solved at collocation points
- Then comparison between real and simulated points is calculated
- Optimization problems become stiff
- Training takes a lot of wall clock time even for a simple problem
- Does not always satisfy mass balance and other mathematical properties of physics code?
- **Our goal is to compute the mass balance in Darcy flow equation for a porous media**
- **Also, find when and when not to use PINN**

Steady-state Darcy flow model



Results: Flux



Conclusions

- Mass is not fully conserved
- However, it gives us a good range for parameter search space
- The parameter range can be used in physics model to fine tune the model

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Thanks!

Question?

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