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Attention U-Net for groundwater prediction

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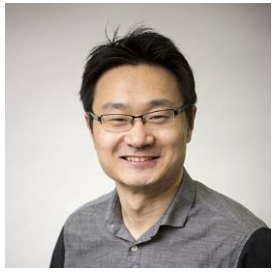

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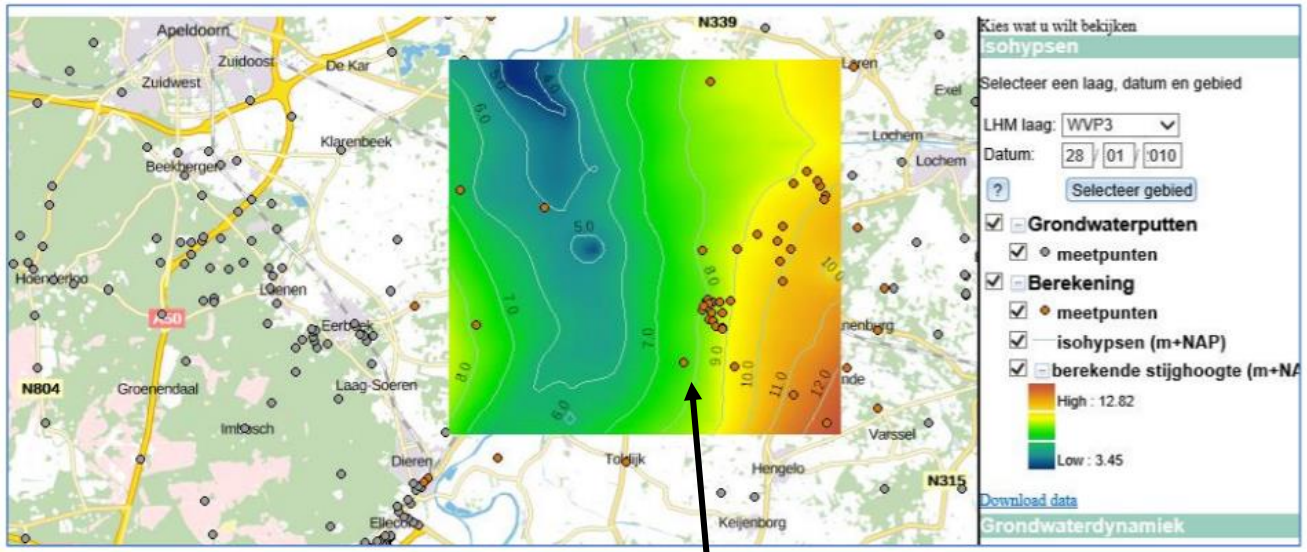
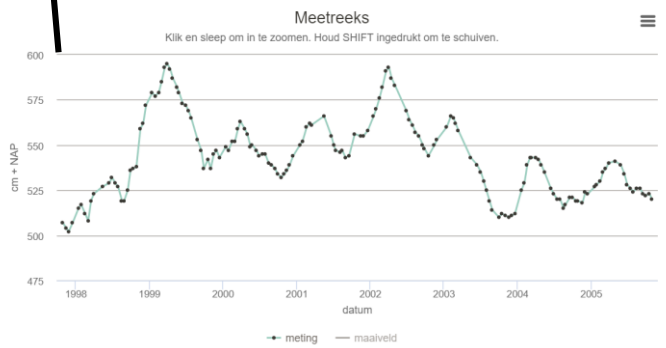
Current groundwater model

Challenges:

- Large-scale non-linear systems and inverse problems are often prohibitively expensive;
- Cannot easily incorporate noisy data;
- Mesh generation is complex



https://www.grondwatertools.nl/grondwatertools-viewer

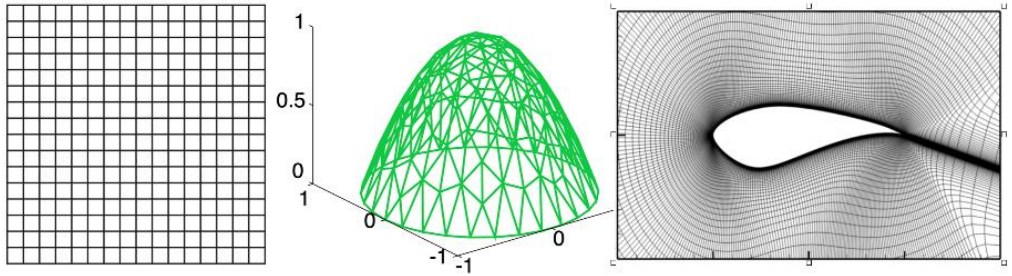


There is a need for a fast quick-scan tool

Solve vs learn

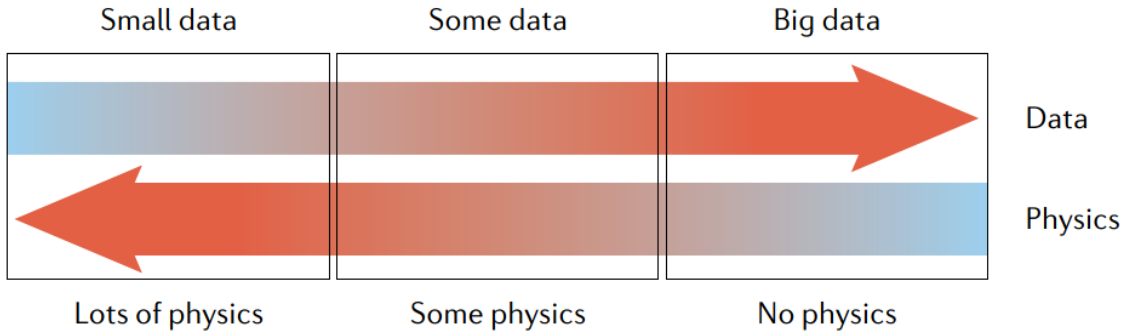
Conventional methods:

- Require the explicit form of the PDE
- Trade-off on resolution
- Slow on fine grids; fast on coarse grids



Data-driven methods:

- Black-box, data-driven*
- It can be resolution-invariant, mesh-invariant
- Slow to train; fast to evaluate
- Incorporate data from real world



Neural Operator For Parametric PDEs (Zongyi Li, et al.), https://www.nature.com/articles/s42254-021-00314-5

Groundwater model

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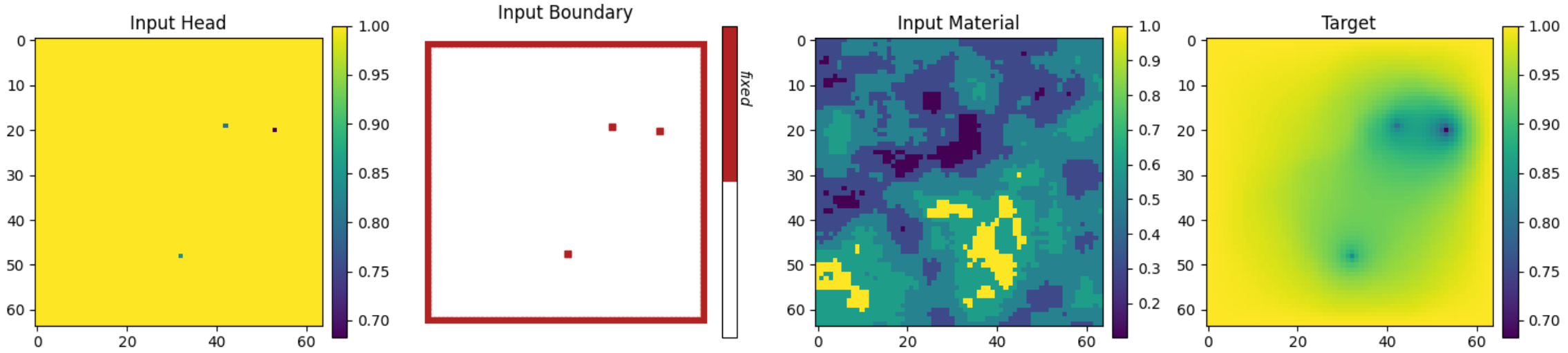
We consider steady-state flow in a single-layer model representing a confined aquifer:



Dataset:

- 32000 train , 8000 validation , 4000 test
- obtained by the fully-implicit finite difference model MODFLOW

Network architecture

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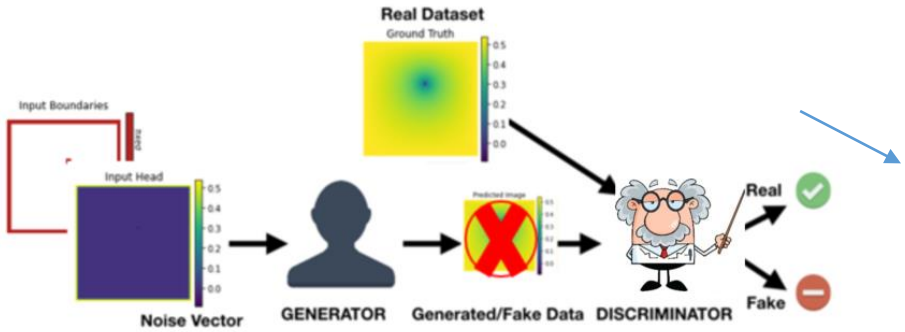
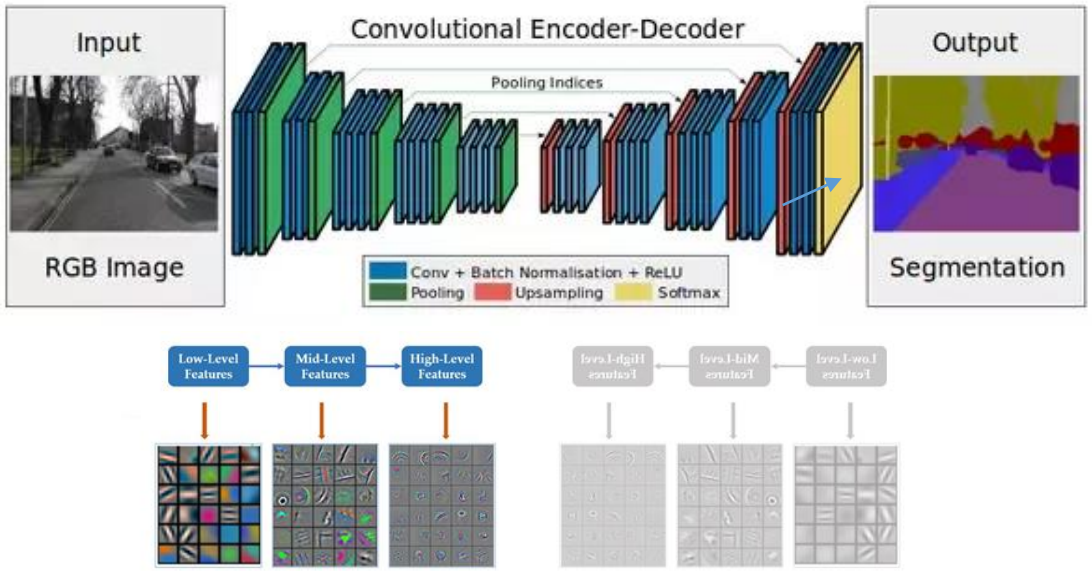
First attempts:

Generative adversarial network (GAN)



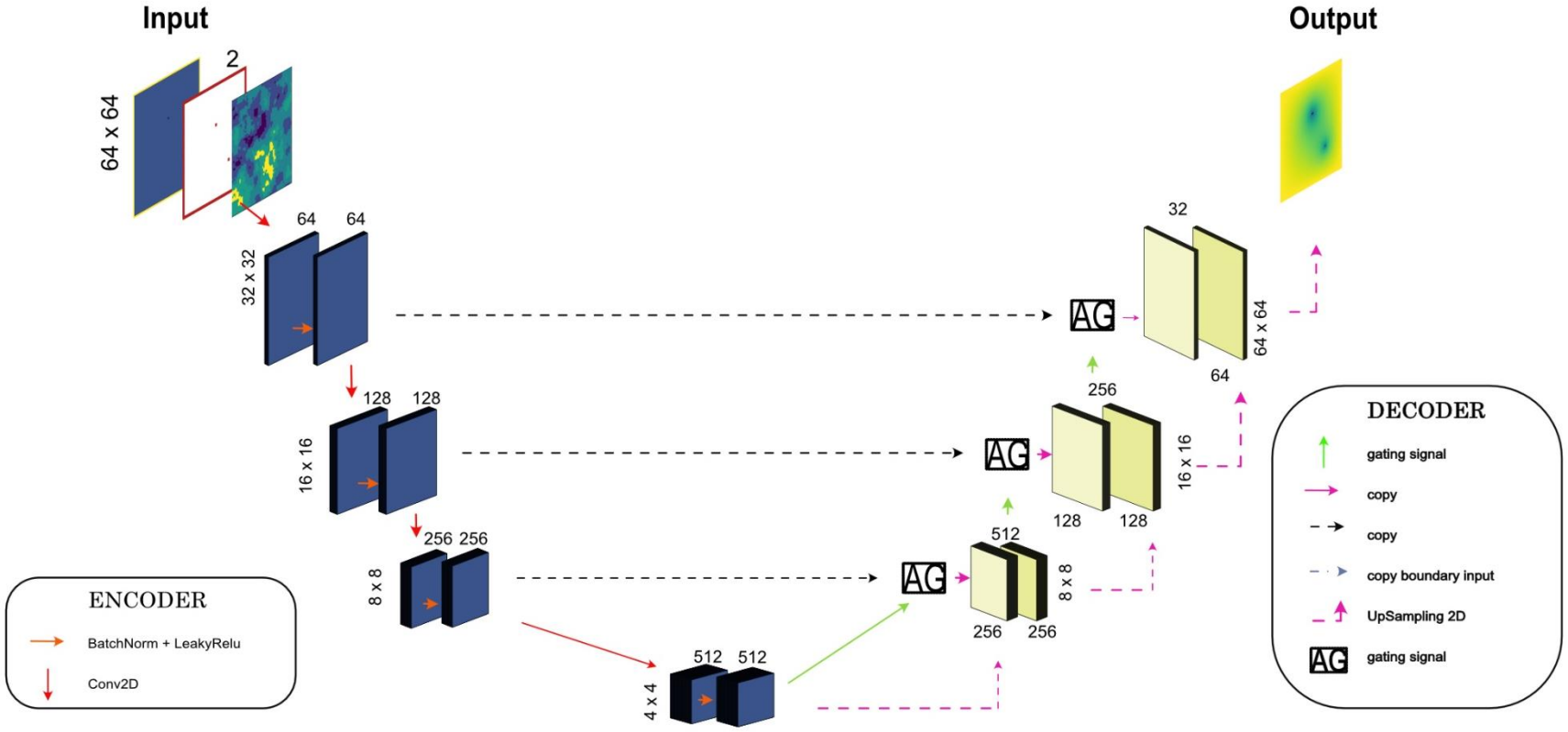
Currently:

Convolutional Encoder-Decoder



https://www.gabormelli.com/RKB/Convolutional_(CNN/CNN)-based_Encoder-Decoder_Neural_Network

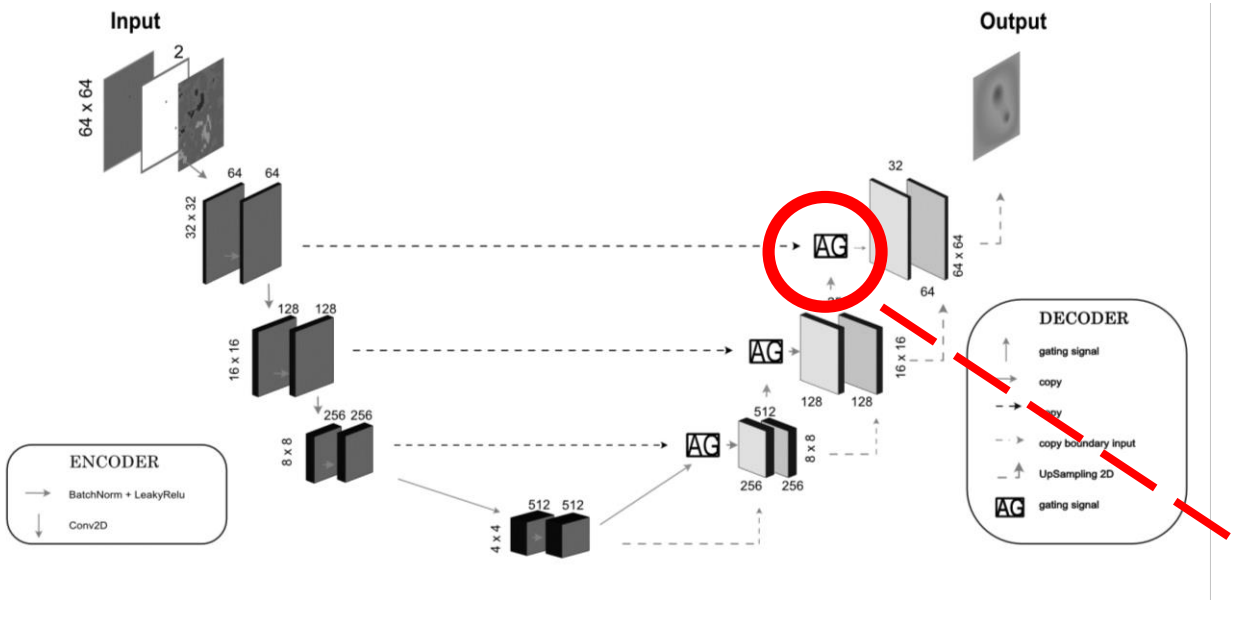
Network architecture: Attention U-Net



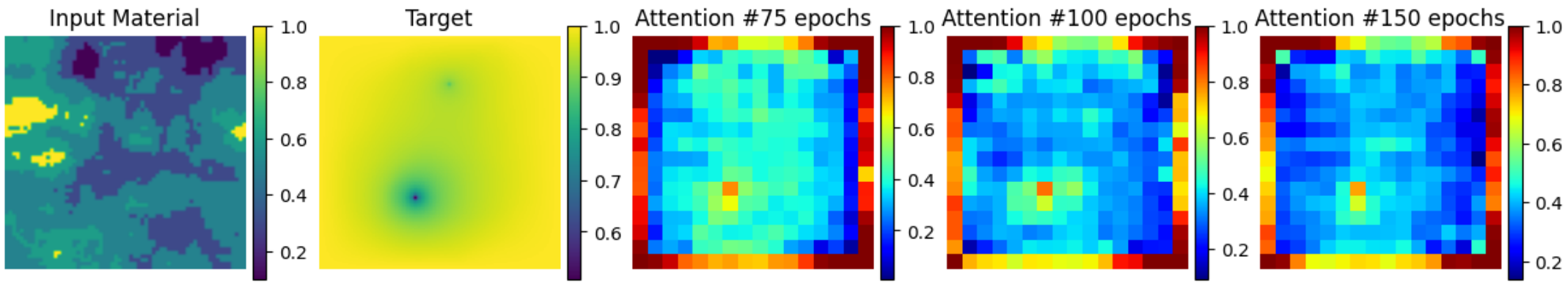
with attention:

http://cs231n.stanford.edu/slides/2021/lecture_11.pdf

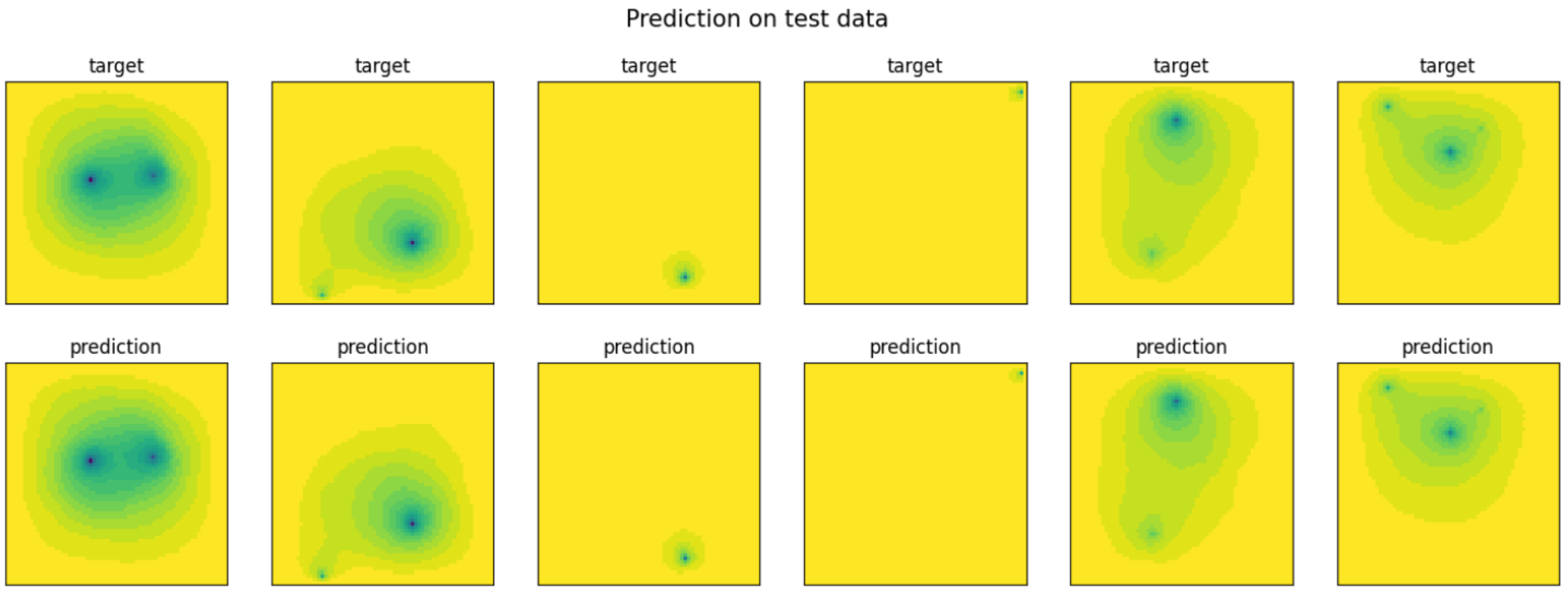
Training



$$\mathcal{L} = \mathcal{L}_{MSE} = \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{n}$$



Results


Prediction on test data
target
target
target
target
target
target
prediction
prediction
prediction
prediction
prediction
prediction

Results

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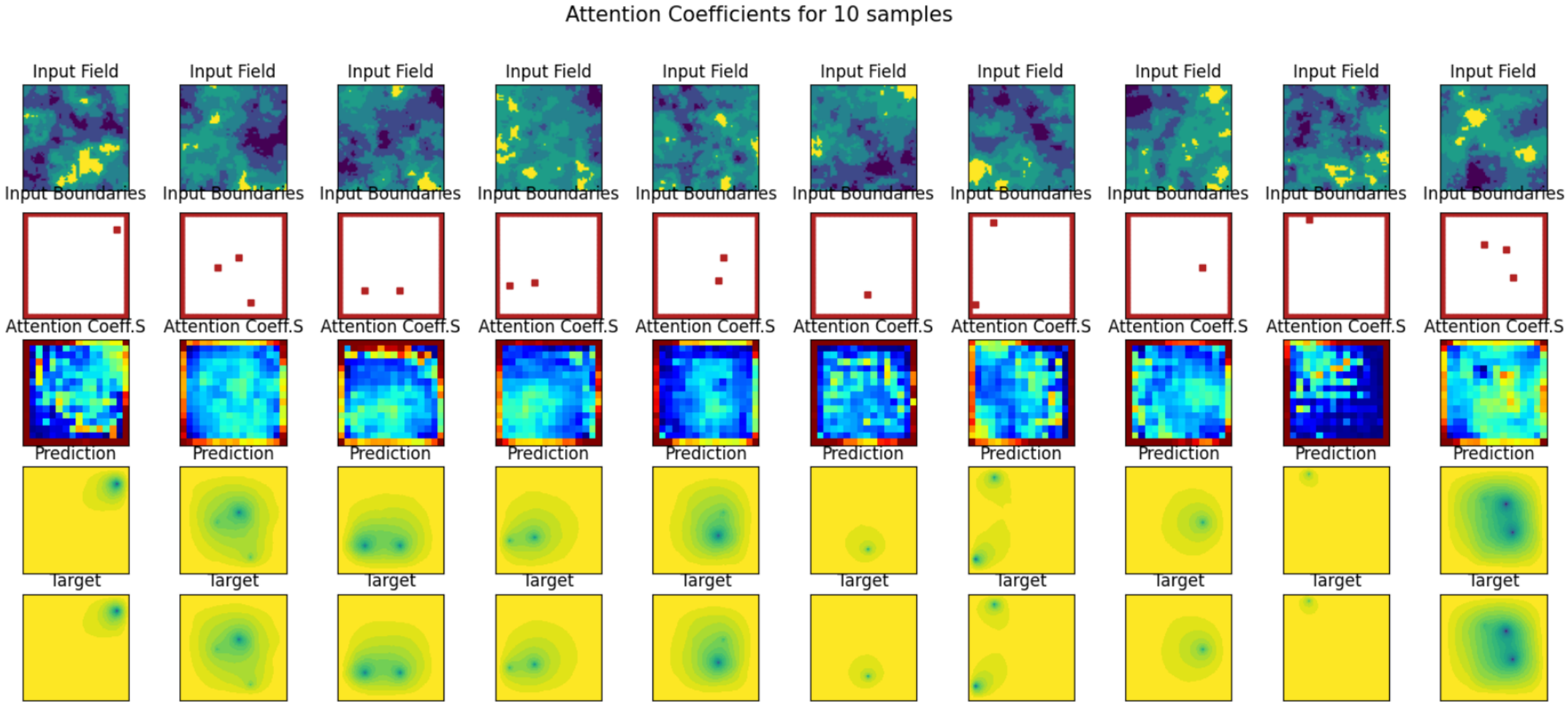

Conclusion and future work

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1. U-Net can be used as a surrogate model for groundwater prediction,
2. The model predicts the correct value of groundwater head at the well locations and the spread of the plume,
3. Attention gate mechanism allows the U-Net to suppress irrelevant regions and focus on salient image regions.

Future work:

1. Incorporate physical constraints (PDE),
2. Increase model complexity and generality (3D, time dependent),
3. Use of attention coefficients as a mask for the loss function.

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Thank you for your attention!

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Acknowledgments:

PANORAMA

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