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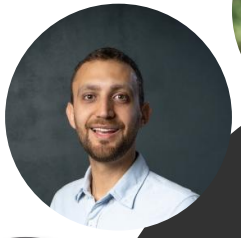


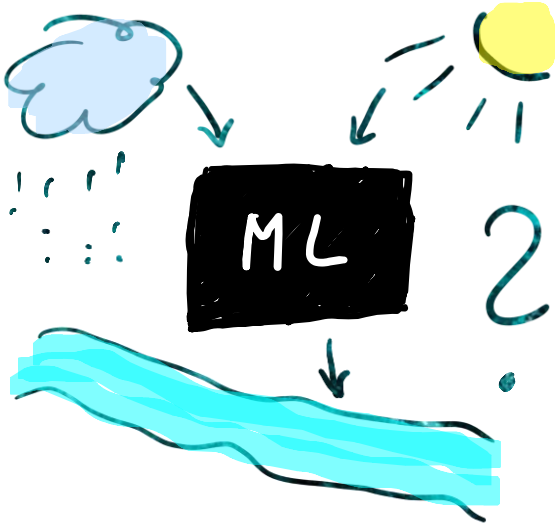
Physics-constrained
or ...
physics-ignored?

An entropy-based approach to diagnose if your hybrid model effectively skips conceptual constraints

Anneli Guthke, Manuel Álvarez Chaves, Eduardo Acuña Espinoza & Uwe Ehret

EGU26 @Vienna, May 4th 2026

Process understanding from data-driven models?



- ML models are great at prediction tasks, ***but***
  - do we understand why the model performs well?
  - can we relate its skill to a faithful representation of the hydrological system?

Interpretability through hybrids

- If we don‘t have good answers to these questions, ***how***
  - ➢ can we we have trust in that model (especially if predicting scenarios of change)?
  - ➢ can it be used for decision-making?

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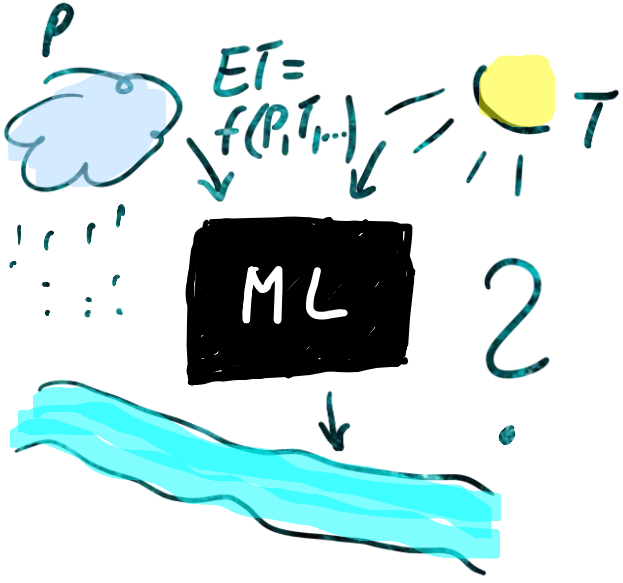

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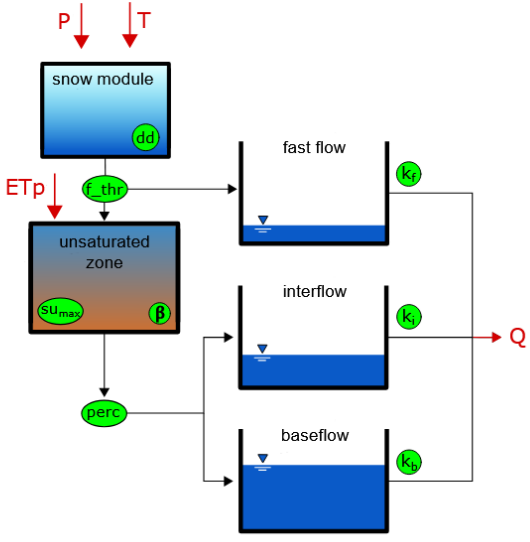
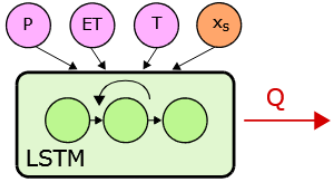
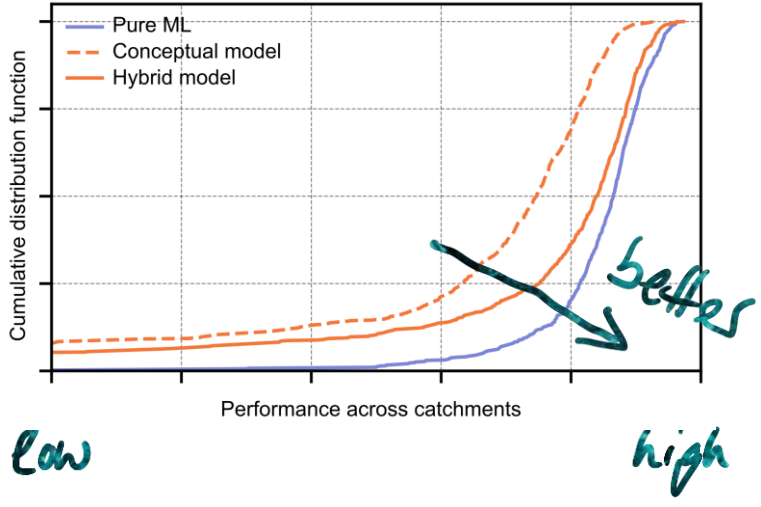
Conceptual models going hybrid

A very constrained type of hybrids?

Acuña Espinoza et al. (Github)

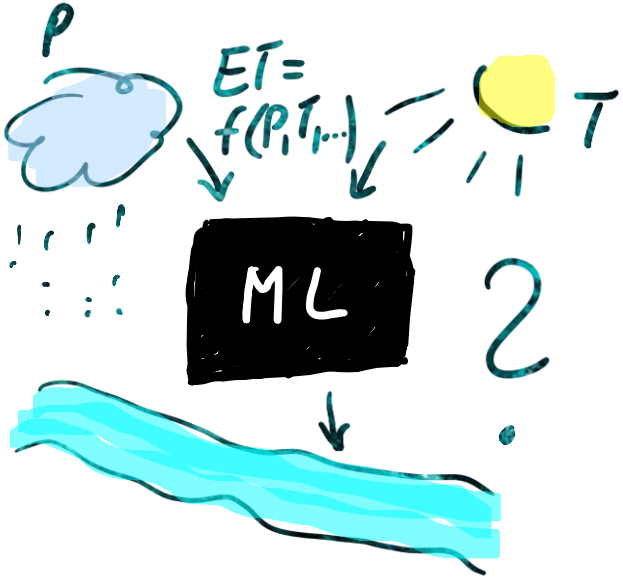






So interpretability comes at a cost...

Process understanding from data-driven models?



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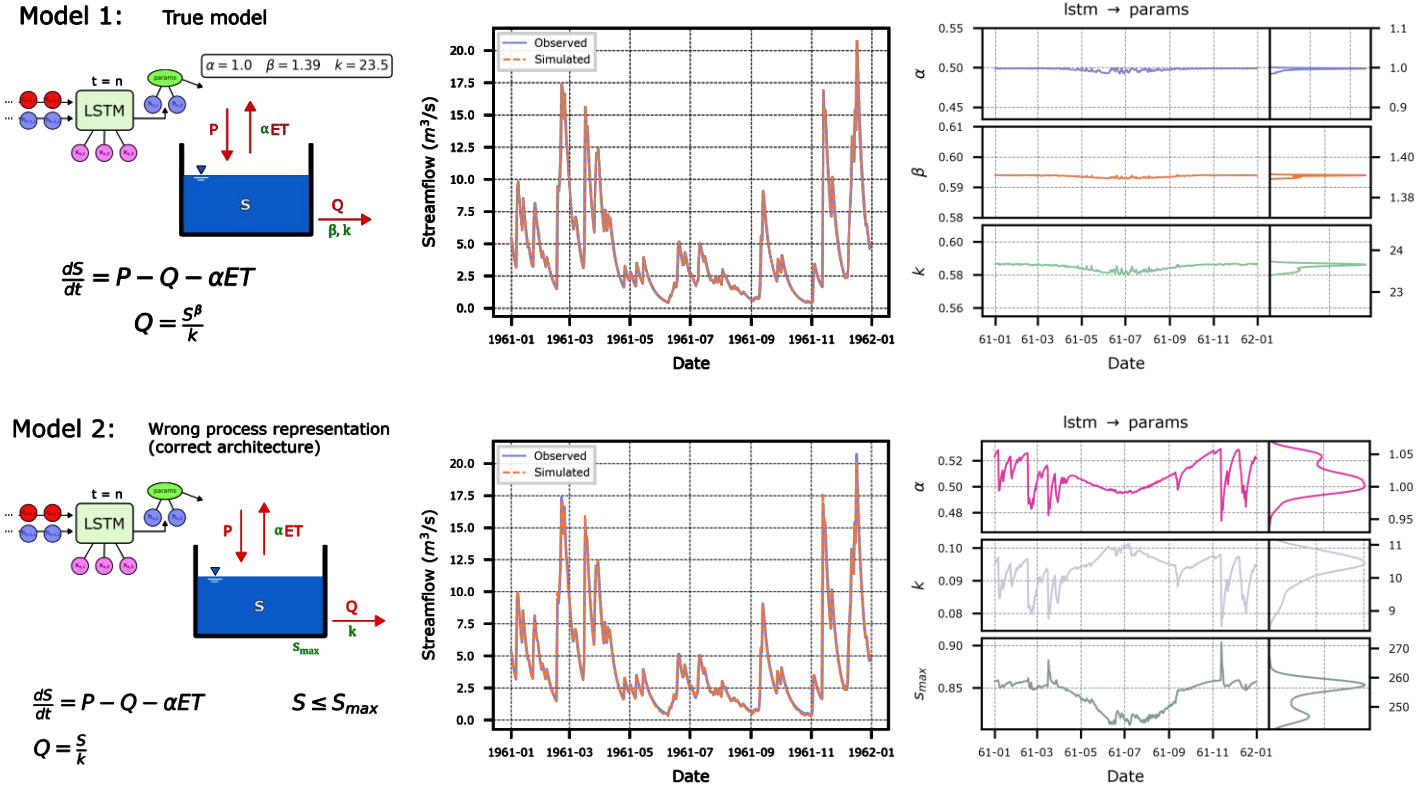
At least: the more "true"/realistic the concept, the easier the job of ML?

→ Let's put this to test!

Hybrid model evaluation: Who is doing the work?

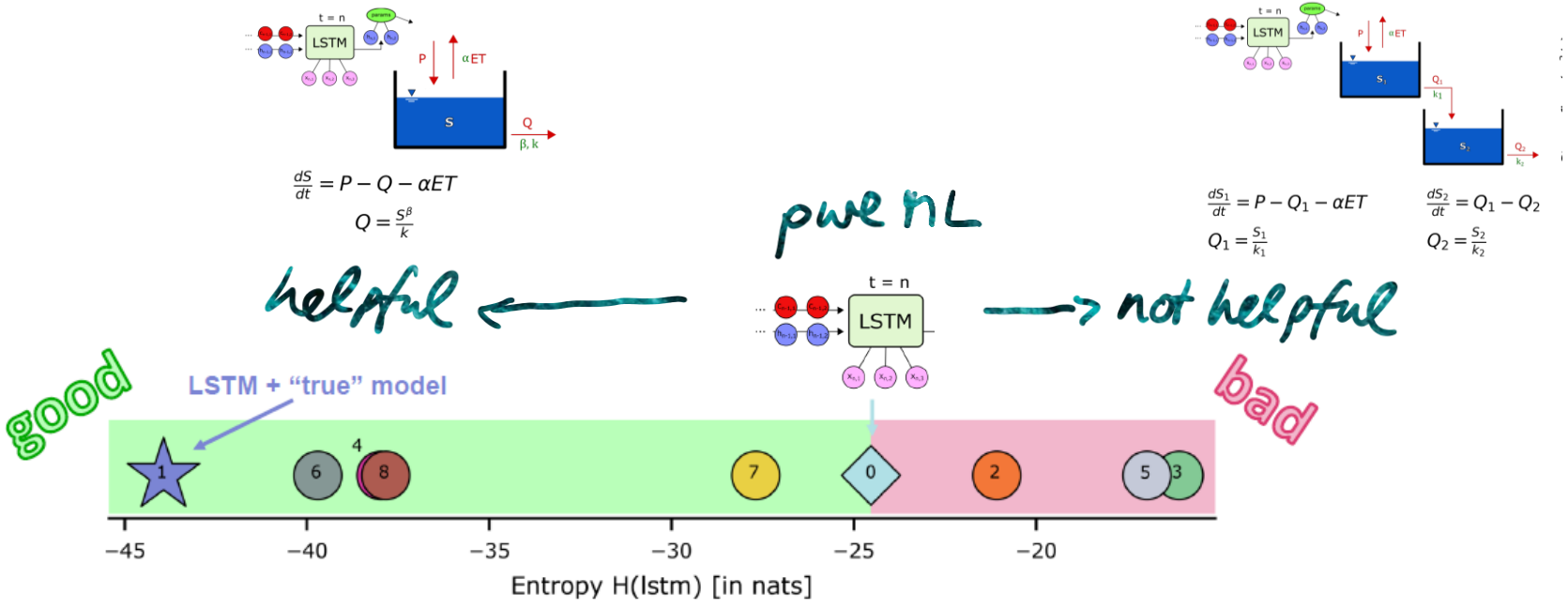
Synthetic experiment



Álvarez Chaves et al. 2026 (HESS)

Hybrid model evaluation: who is doing the work?

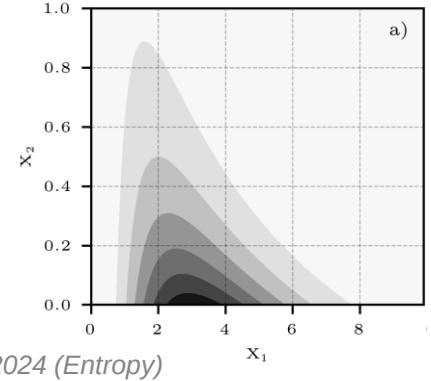
Sorting process-based components according to usefulness



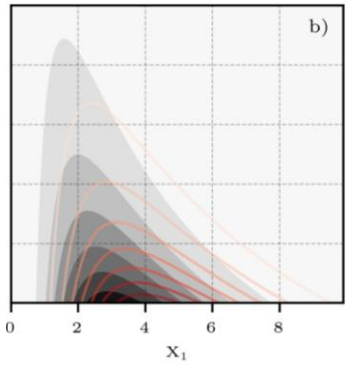
Álvarez Chaves et al. 2026 (HESS)

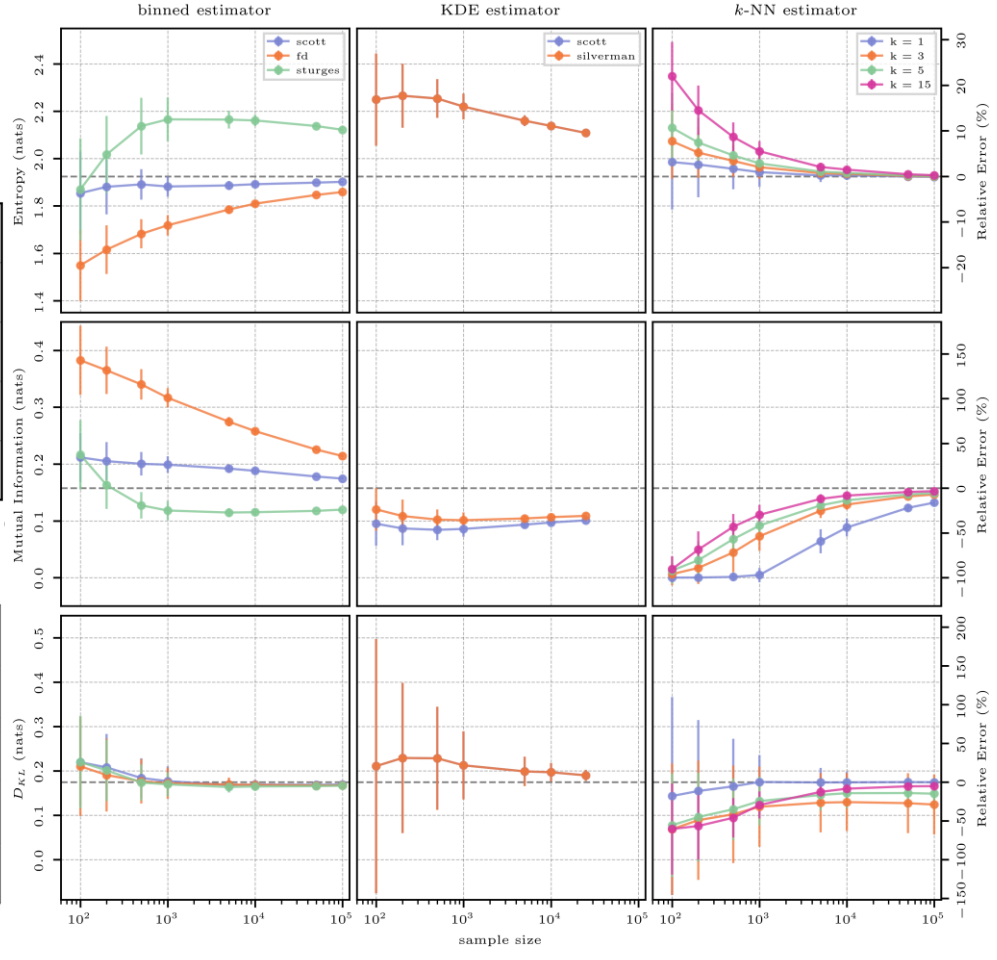
> How to estimate information-theoretic quantities

UNITE Python toolbox



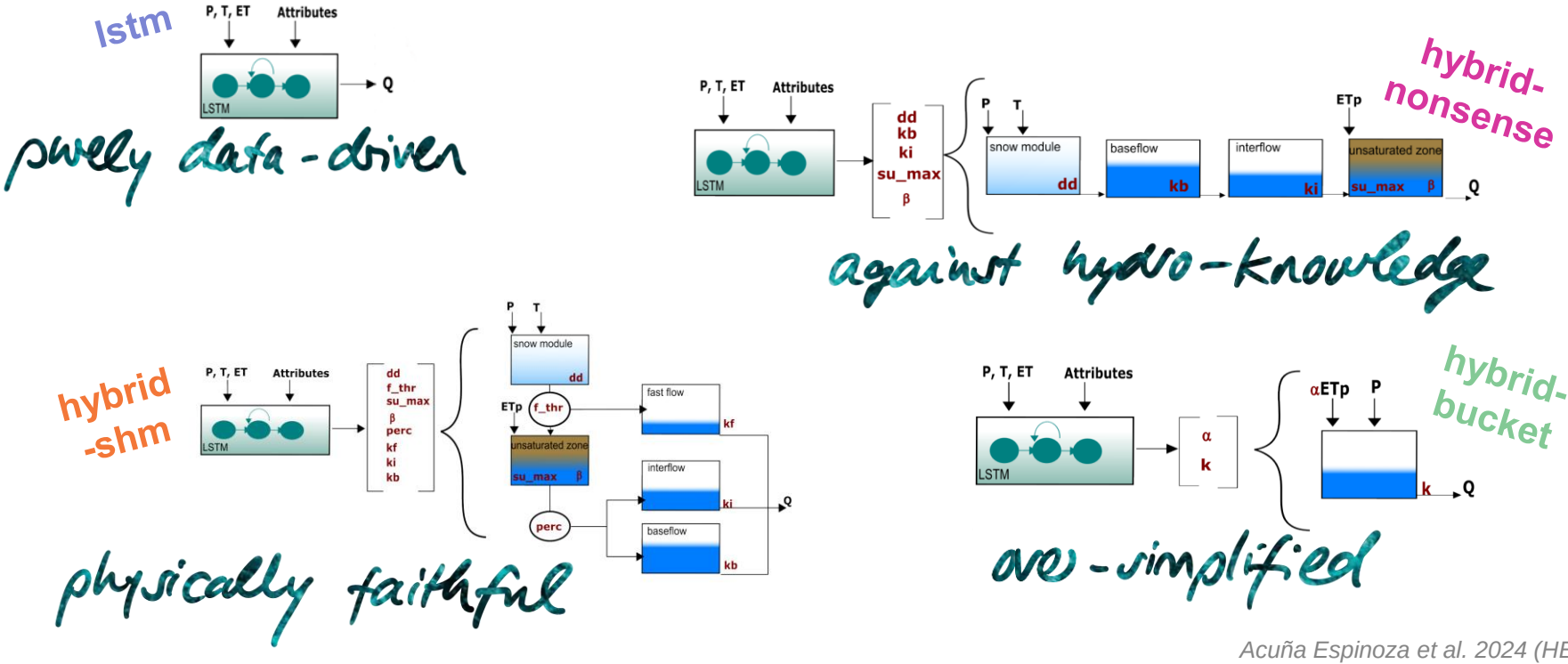
Álvarez Chaves et al. 2024 (Entropy)





Hybrid model evaluation

Real-world case study (CAMELS-GB)



Acuña Espinoza et al. 2024 (HESS)

Hybrid model evaluation

Which conceptual constraint is actually helpful?

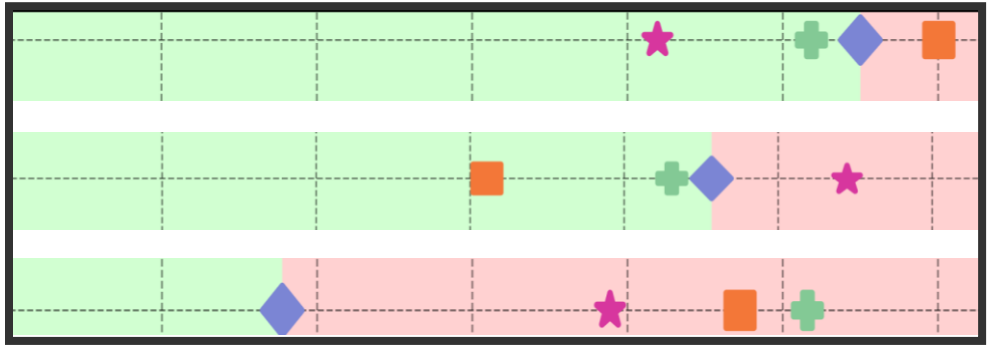
- Pure ML
- Faithful constraint + ML
- Simplified constraint + ML
- Nonsense constraint + ML

what we found repeatedly

What we hoped to find

What we found most often

Results of selected catchments

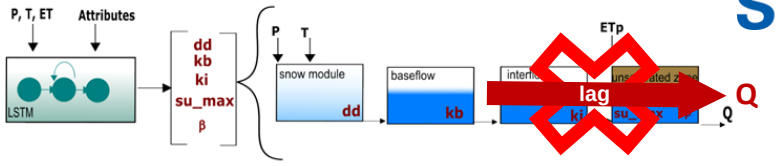


“compensation effort” of neural network from low to high

Álvarez Chaves et al. 2026 (HESS)

Hybrid model evaluation

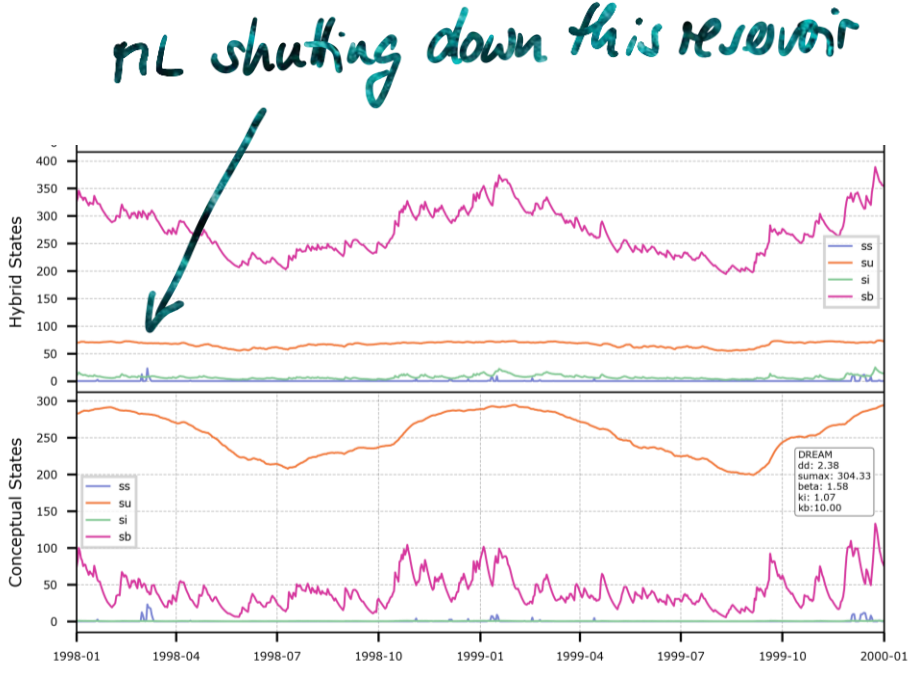
Is Nonsense a good model?!



- No - hybrid-nonsense is a very different model than nonsense!

1. Hybrid does **not** necessarily **mean physics-constrained!**

2. Huge potential in hybrids, but carefully **check what‘s inside before claiming interpretability!**



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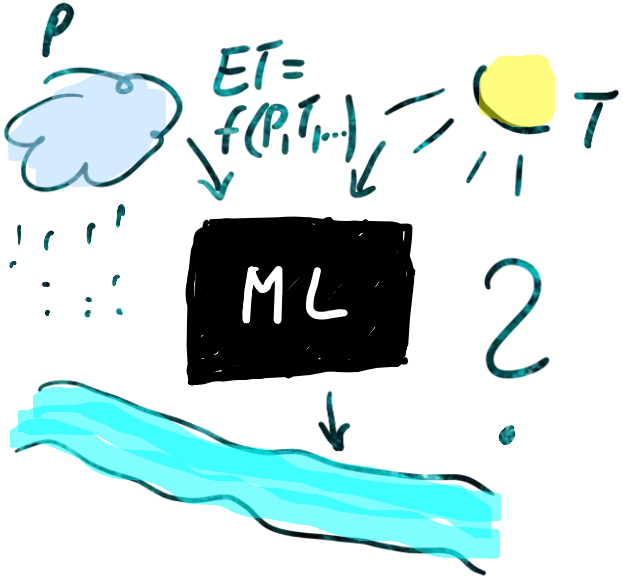

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... and expect them to be respected!

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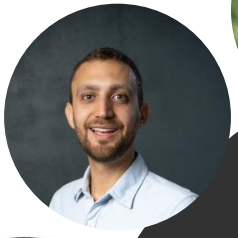
Be prepared that it's ~~physics-constrained~~ or ... physics-ignored?

Find out with this method!



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Find the **paper** and the **toolbox** here: