Probabilistic Wind Speed Downscaling for Future Wind Power Assessment

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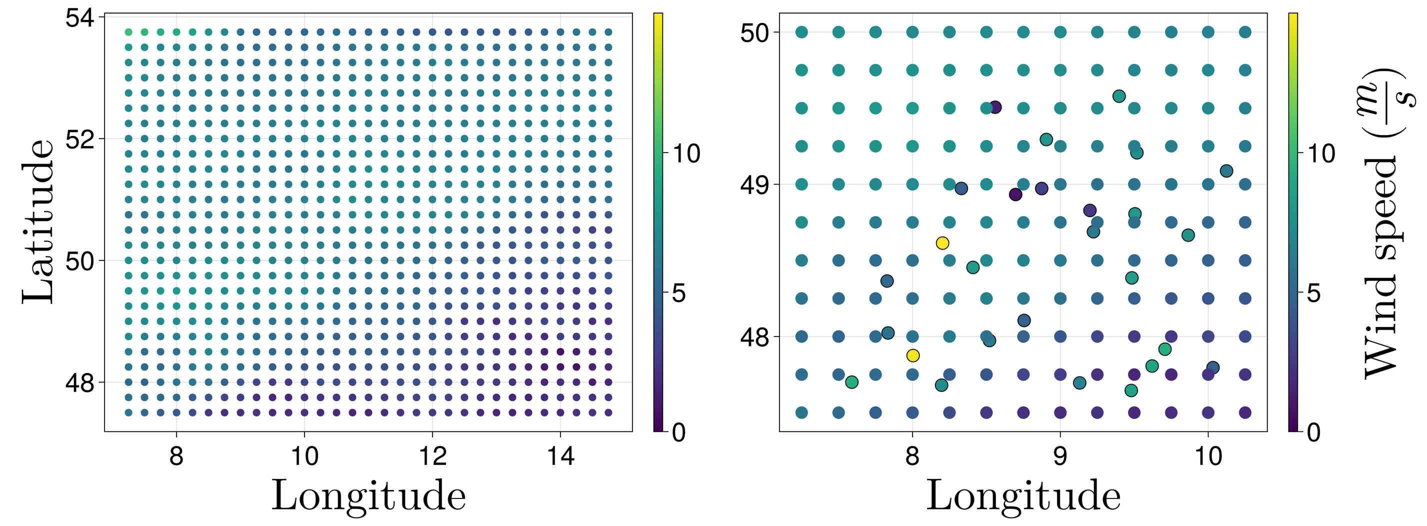
Motivation and idea

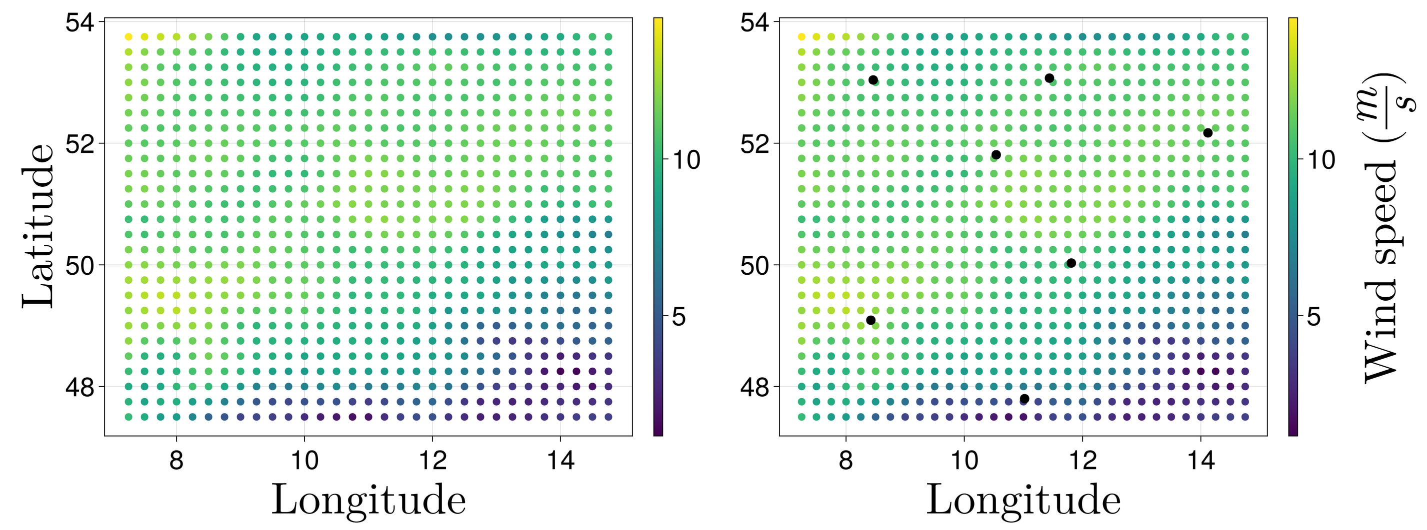
Wind power is dependent on both climate and highly local, variable weather conditions. This makes downscaling crucial for future wind power assessment.

Data

ERA5 10m and DWD met masts



ERA5 100m and tall towers



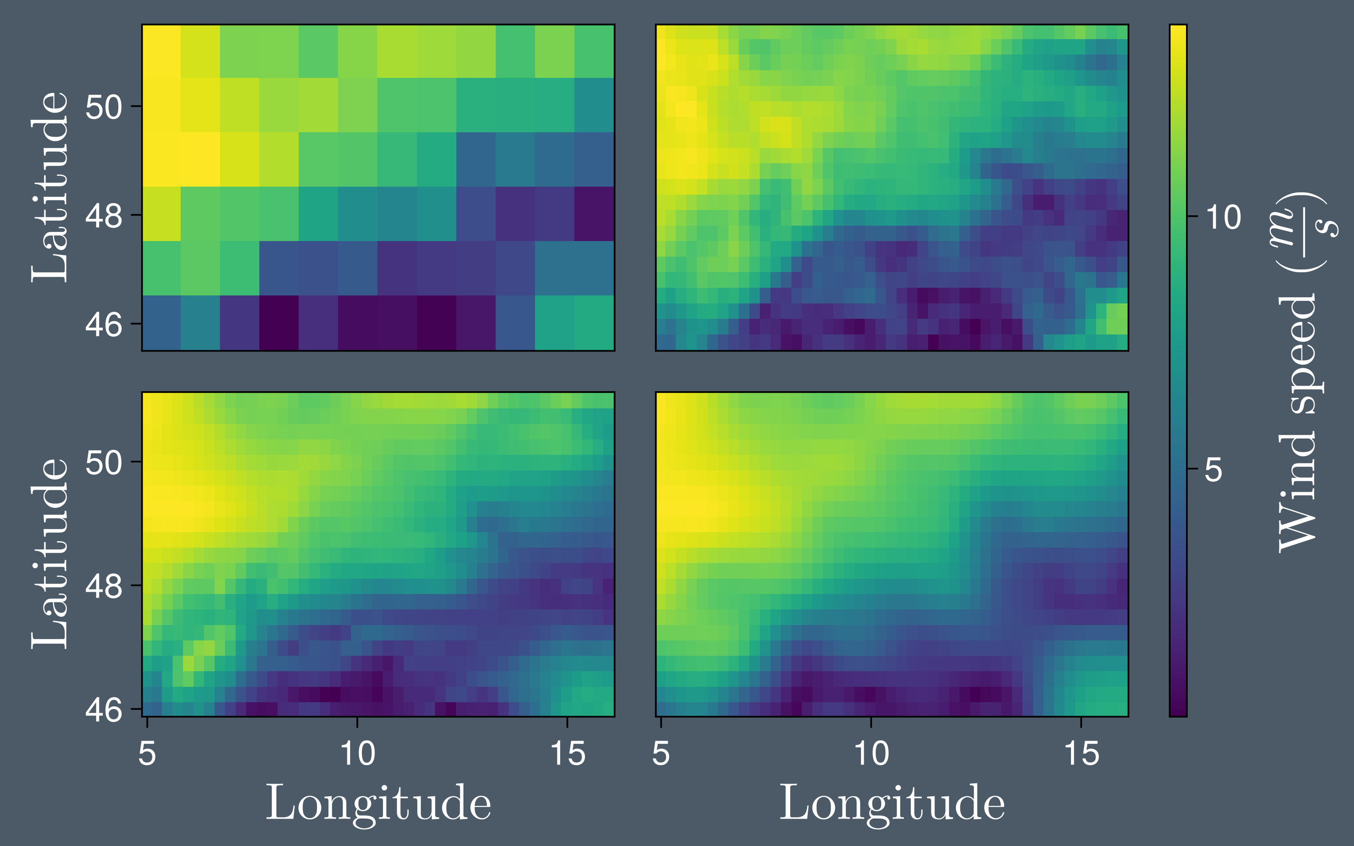
Finding and validating wind (power) data is a big challenge.

What introduces uncertainties in wind power forecasting?

- Vertical interpolation
- Horizontal interpolation
- Wind power curve used
- Properties of different datasets

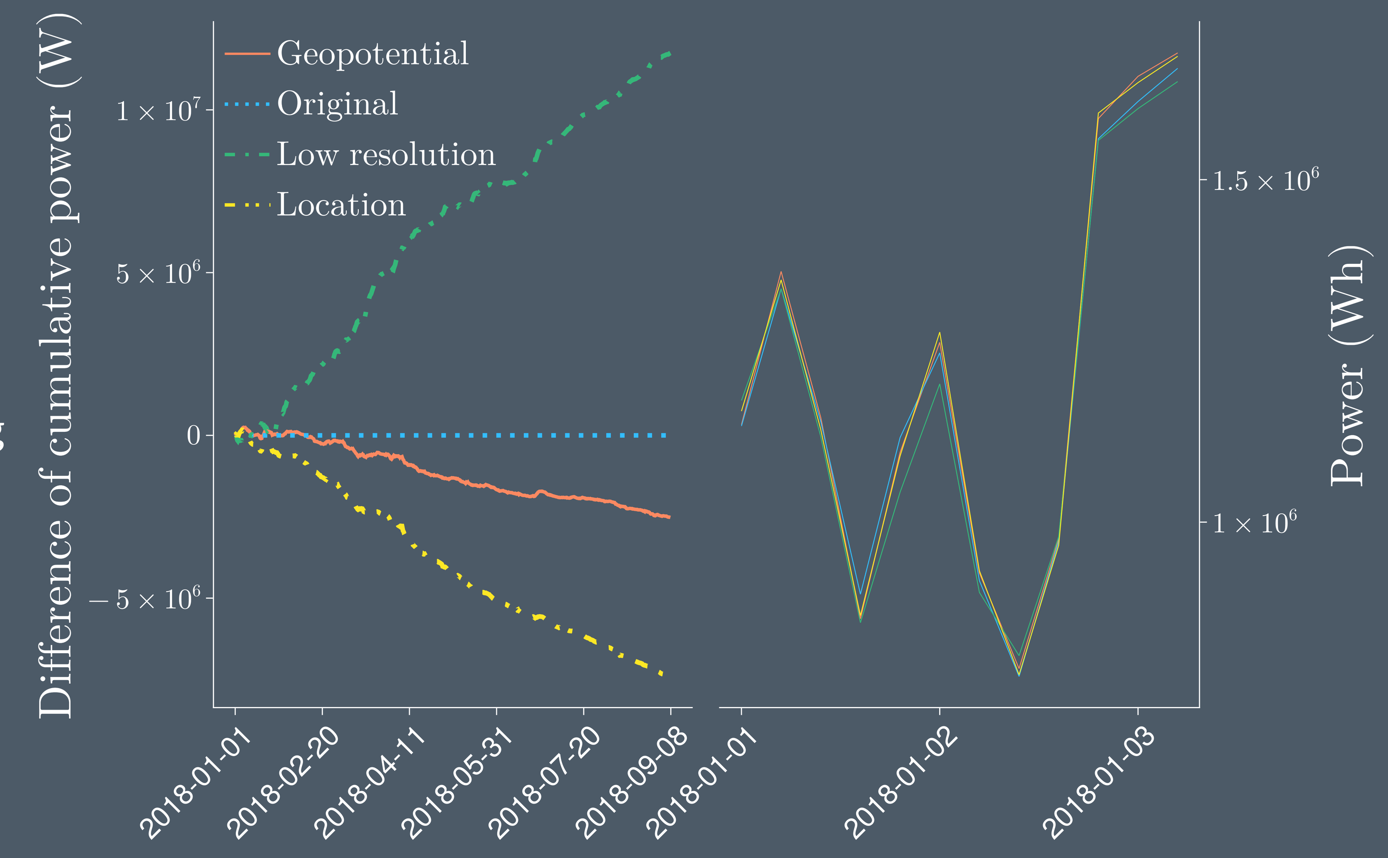
Quantifying this uncertainty is crucial.

Results

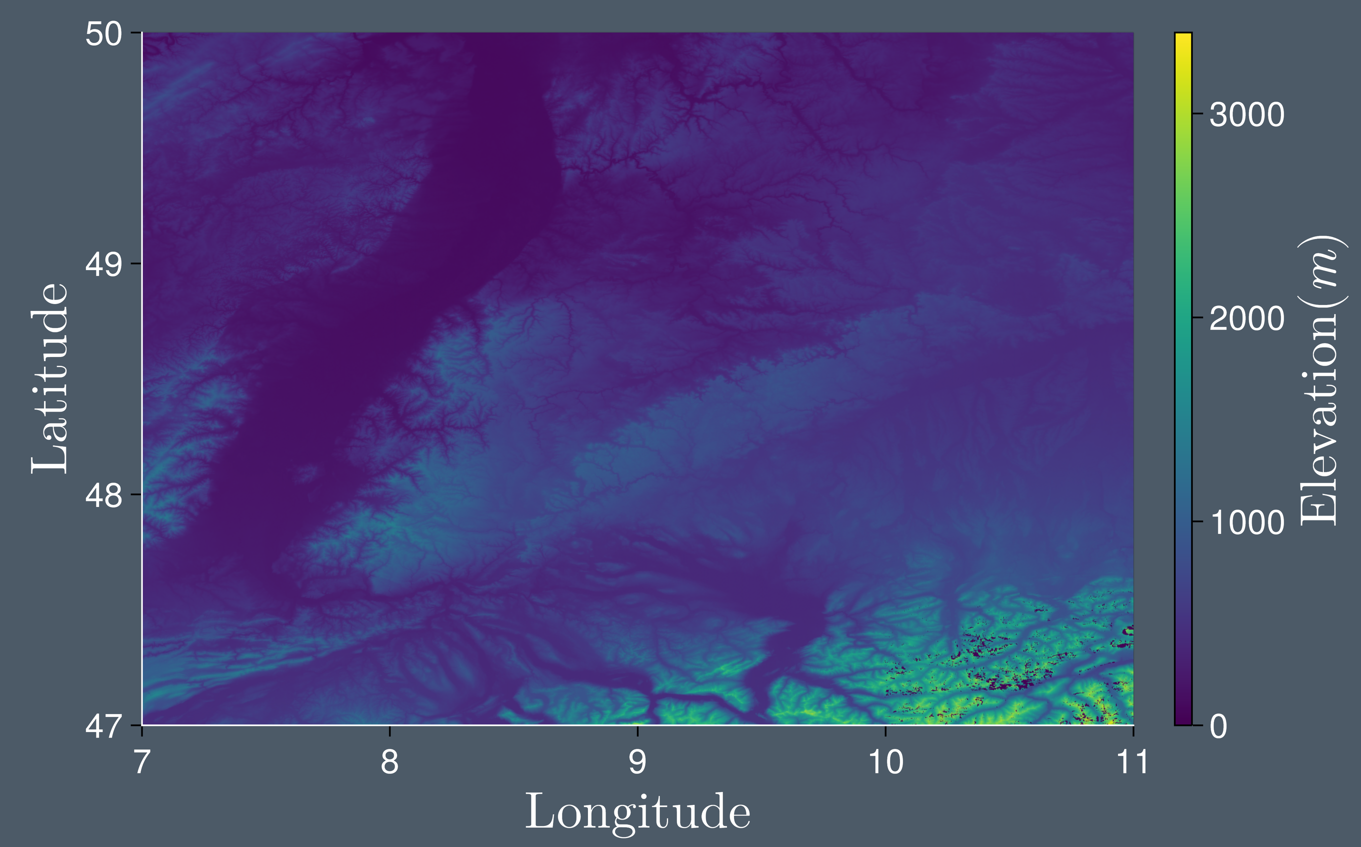


Top left: Coarse-grained data.
Top right: Original ERA5 data.
Bottom left: Mean interpolation using longitude, latitude and geopotential height as input.
Bottom right: Mean interpolation using longitude and latitude as input.

Wind power forecast for Southern Germany: On ERA5, 100m, downscaling using GPs works well.

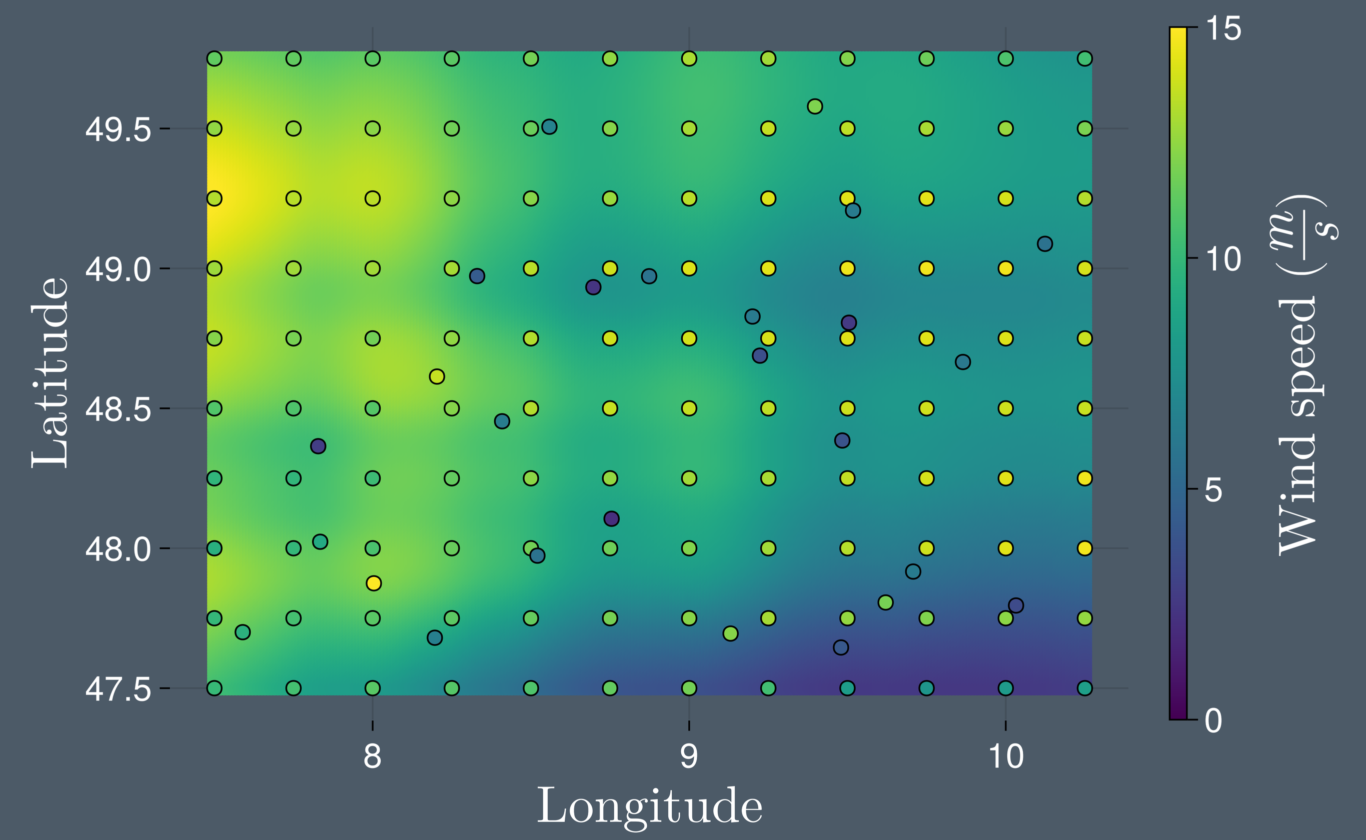


Future Work



Include more fine-grained elevation information.
Include physical knowledge.

Quantify the interpolation uncertainty.



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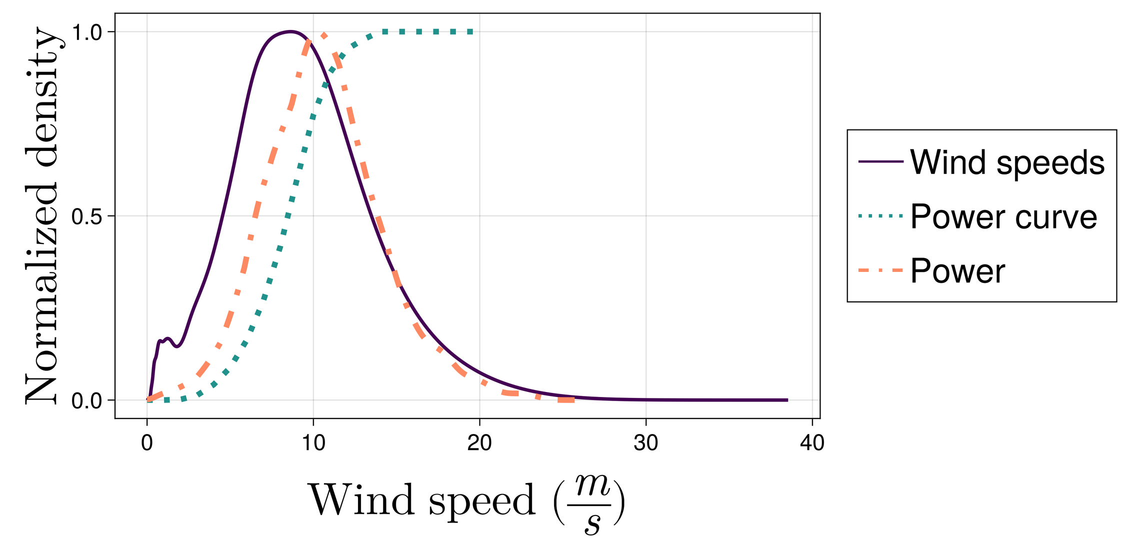
Wind power generation

When transforming wind speed to wind power, some wind speed ranges become *more important*.

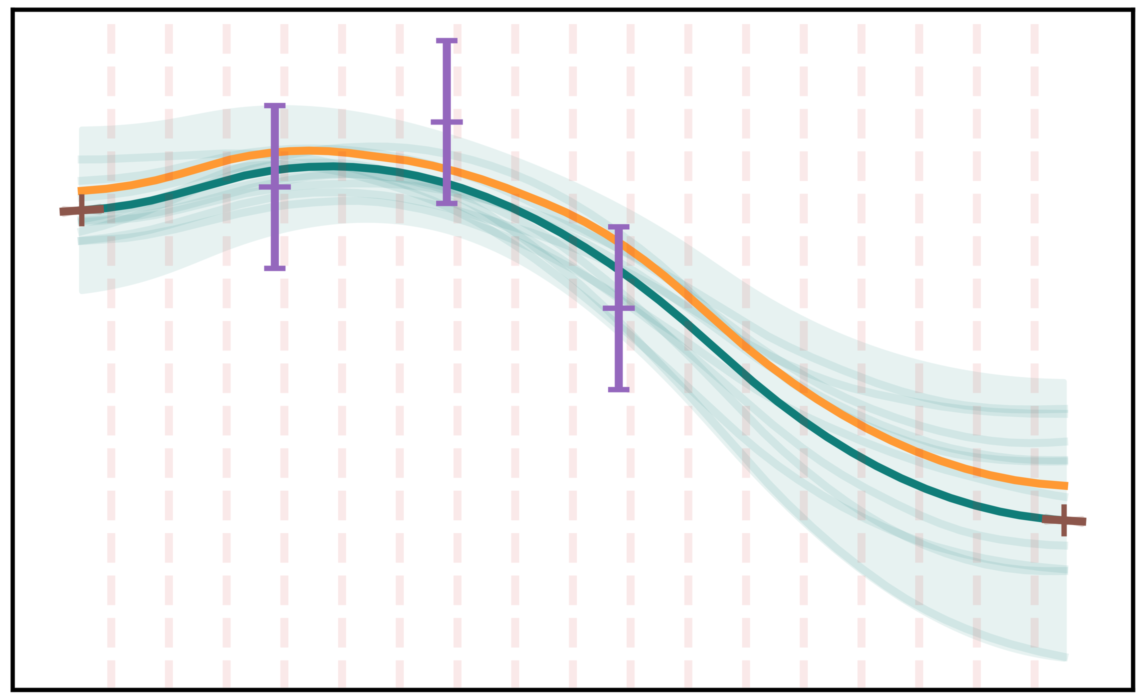


Gaussian Processes (GPs)

A (multi-output) Gaussian Process is a probability measure P over functions $f : \mathbb{R}^d \to \mathbb{R}^{d'}$. For a GP prior, we can compute posterior measures like

$$P(f \mid f(X) + \epsilon = y),$$

or, more generally, $P(f \mid \mathcal{L}[f](X) + \epsilon = y)$ for a bounded linear operator $\mathcal{L}$, in closed form.



GPs naturally allow for quantifying uncertainty and incorporating physical knowledge.

References

[1] https://juliagaussianprocesses.github.io/KernelFunctions.jl/stable/kernels/
[2] windpowerlib.readthedocs.io/en/stable/

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