Machine learning emulation of a local-scale UK climate model

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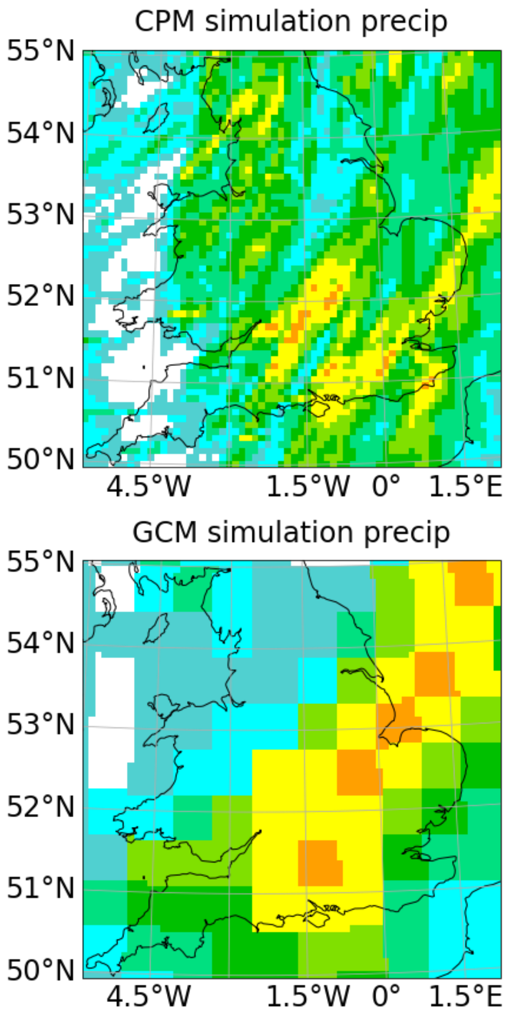
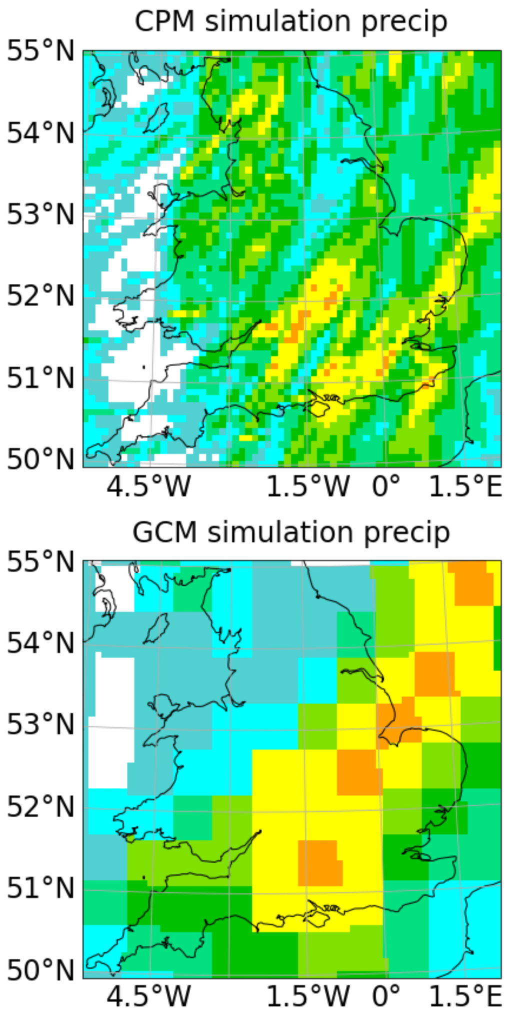
The problem

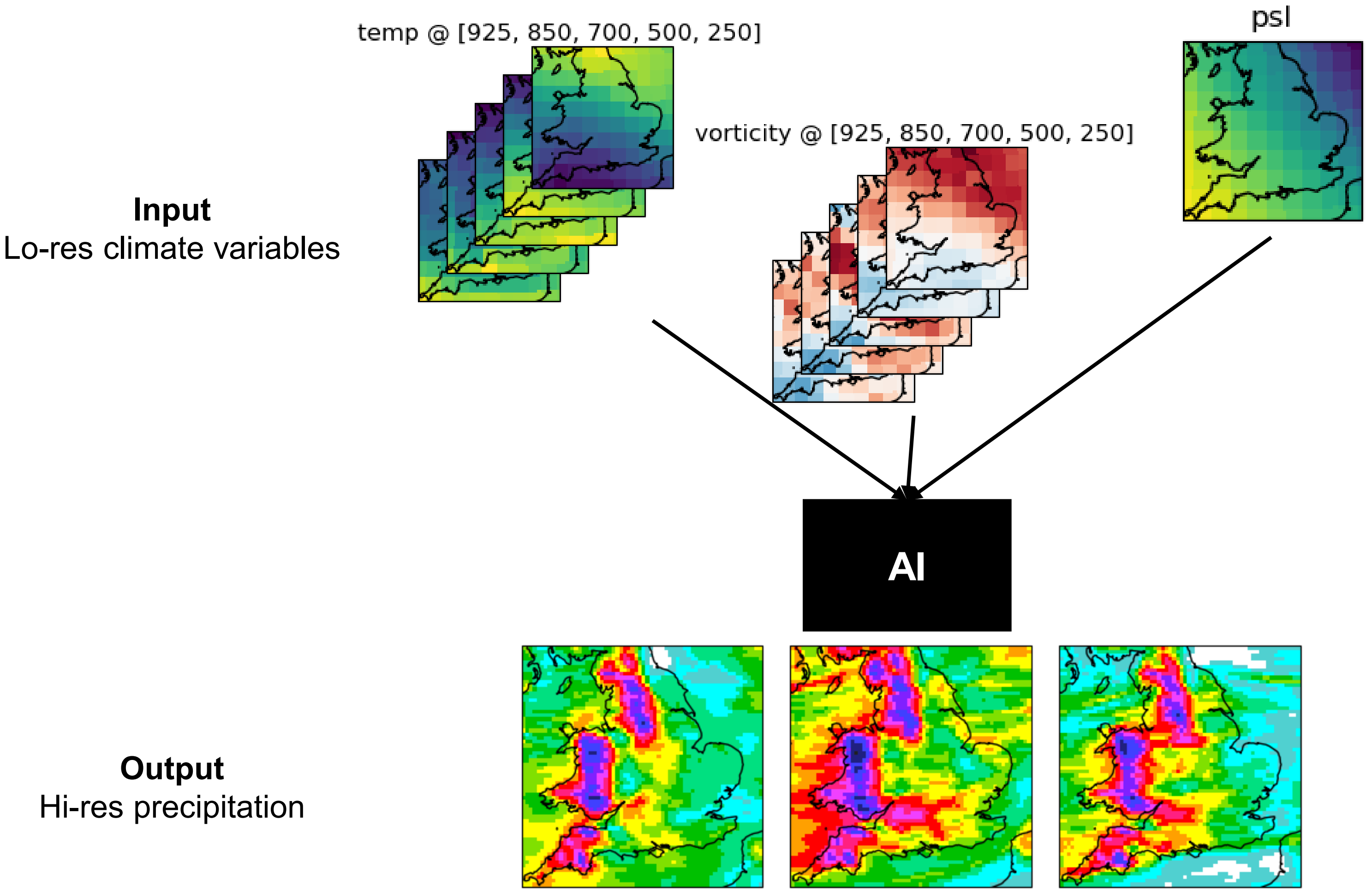
- **Can we learn hi-res precipitation from coarse, GCM climate variables?**
- High-resolution climate simulations are expensive
- New probabilistic ML methods could emulate hi-res, CPM simulator



Data: Met Office UKCP18

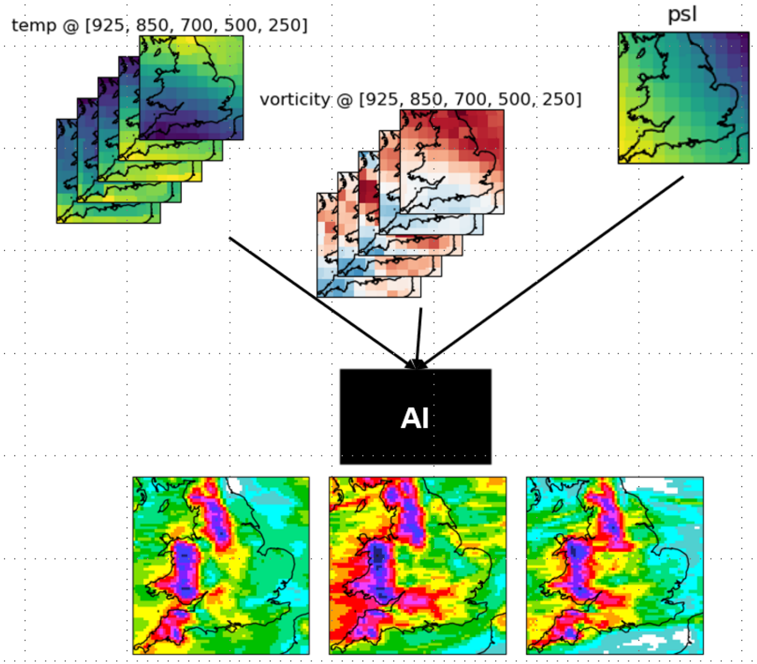
- **Low resolution**
  Global Climate Model (**GCM**) @ **60km**
- **High resolution**
  Convection-Permitting Model (**CPM**) @ 2.2km (using **8.8km**)
- Daily




temp @ [925, 850, 700, 500, 250]
vorticity @ [925, 850, 700, 500, 250]
psl
Input
Lo-res climate variables
AI
Output
Hi-res precipitation

Approach

- Training: coarsened CPM variables → hi-res CPM precip
- Evaluating: coarsened CPM variables or GCM variables → hi-res CPM-like precip
- **Make sure to use variables which are well-represented in GCMs and cause rainfall**
  - Wind
  - Temperature
  - Pressure



Diffusion models

Teddy bears swimming at the Olympics 400m Butterfly event.

A cute corgi lives in a house made out of sushi.

From Figure 1 of Saharia, Chitwan, et al. "Photorealistic text-to-image diffusion models with deep language understanding." *Advances in Neural Information Processing Systems* 35 (2022)

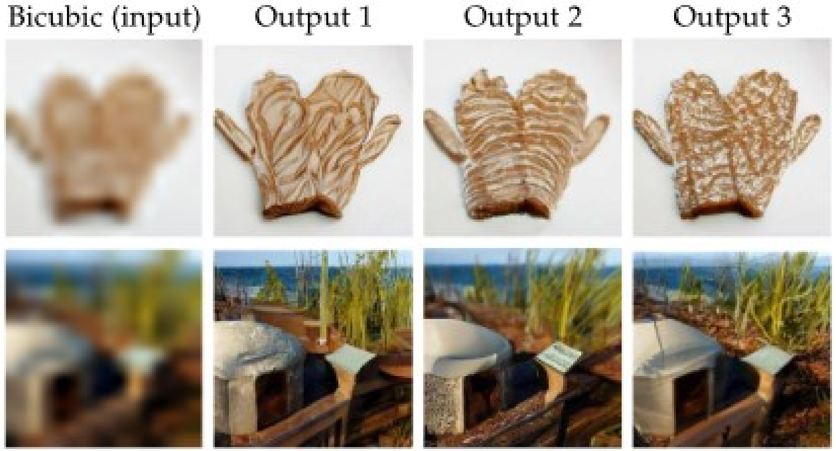
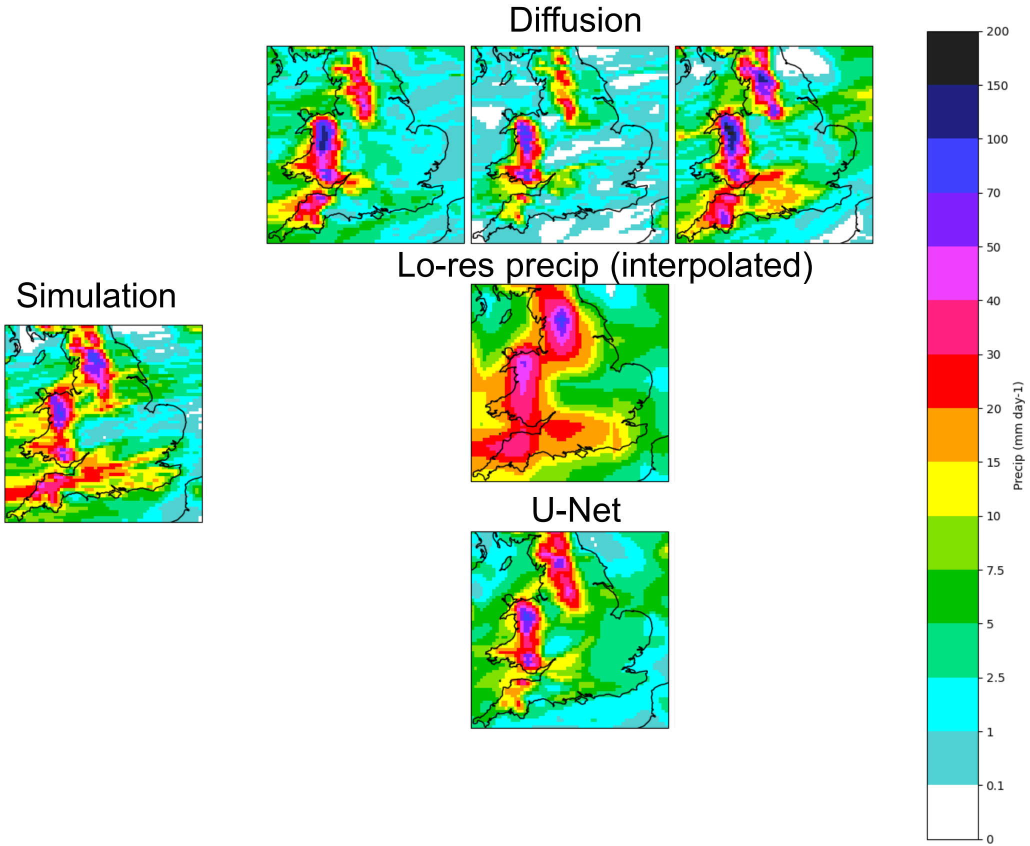


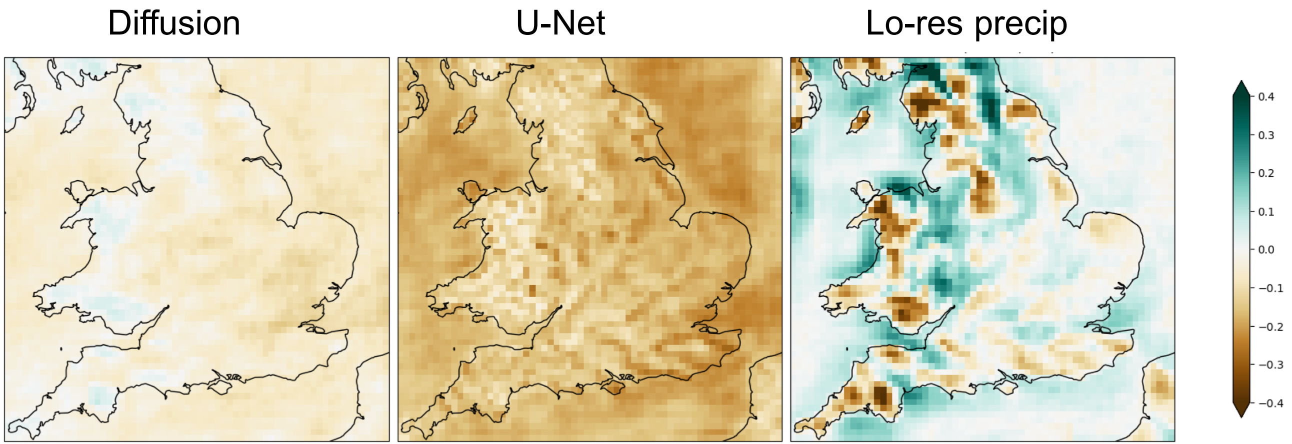
Fig. 5. Three samples from SR3 applied to ImageNet test images ($16 \times 16 \rightarrow 256 \times 256$), demonstrating SR3 diversity.

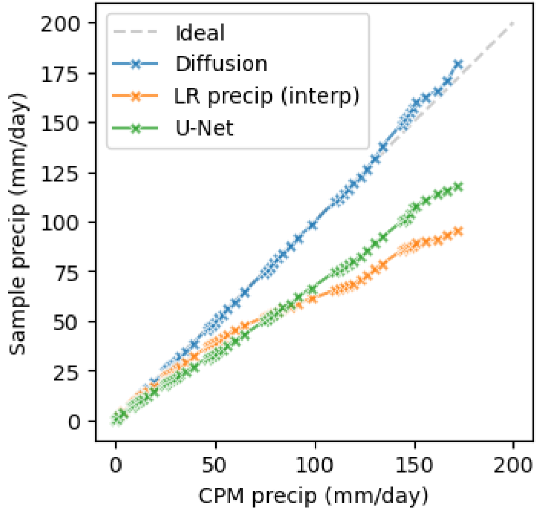
Saharia, Chitwan, et al. "Image super-resolution via iterative refinement." *IEEE Transactions on Pattern Analysis and Machine Intelligence* (2022).

Coarsened CPM → 8.8km CPM rainfall



Are we capturing the distribution of rainfall?



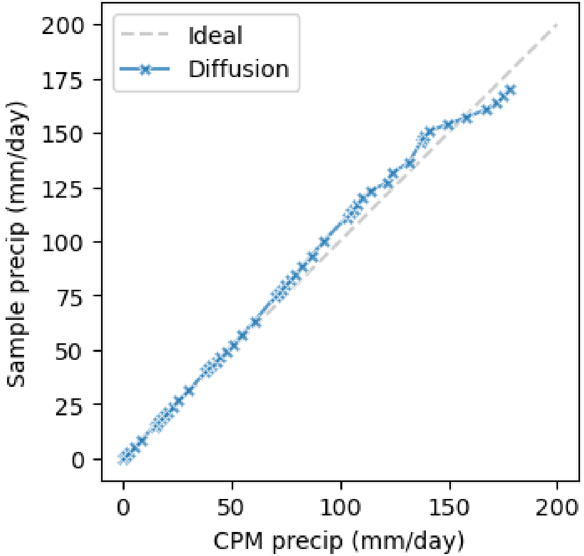


Normalized mean bias

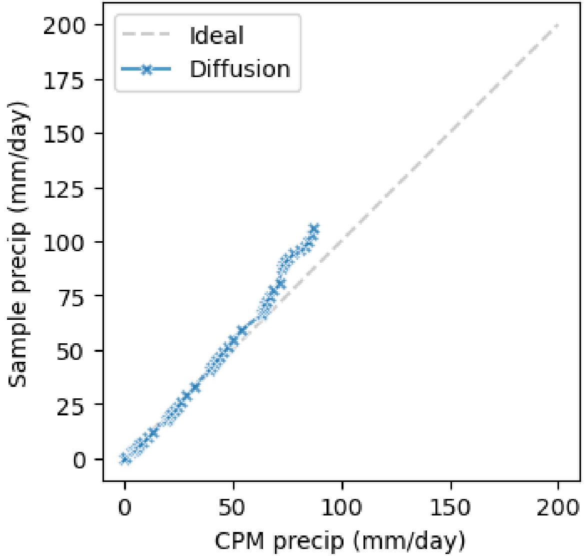
QQ plot

10th to 99.99999th centile

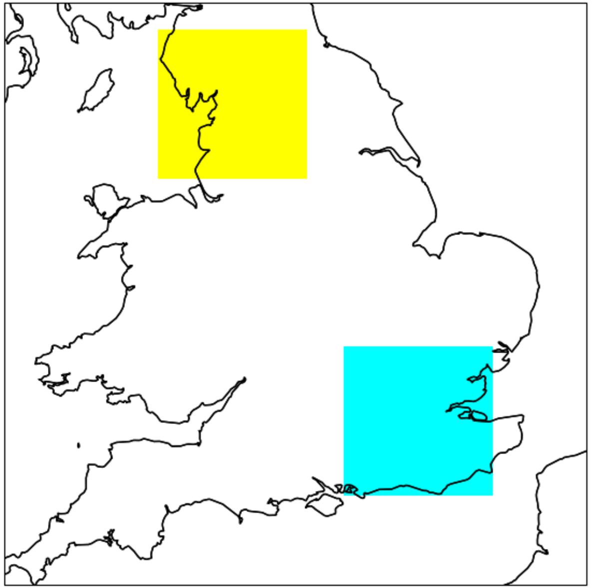
Subregions



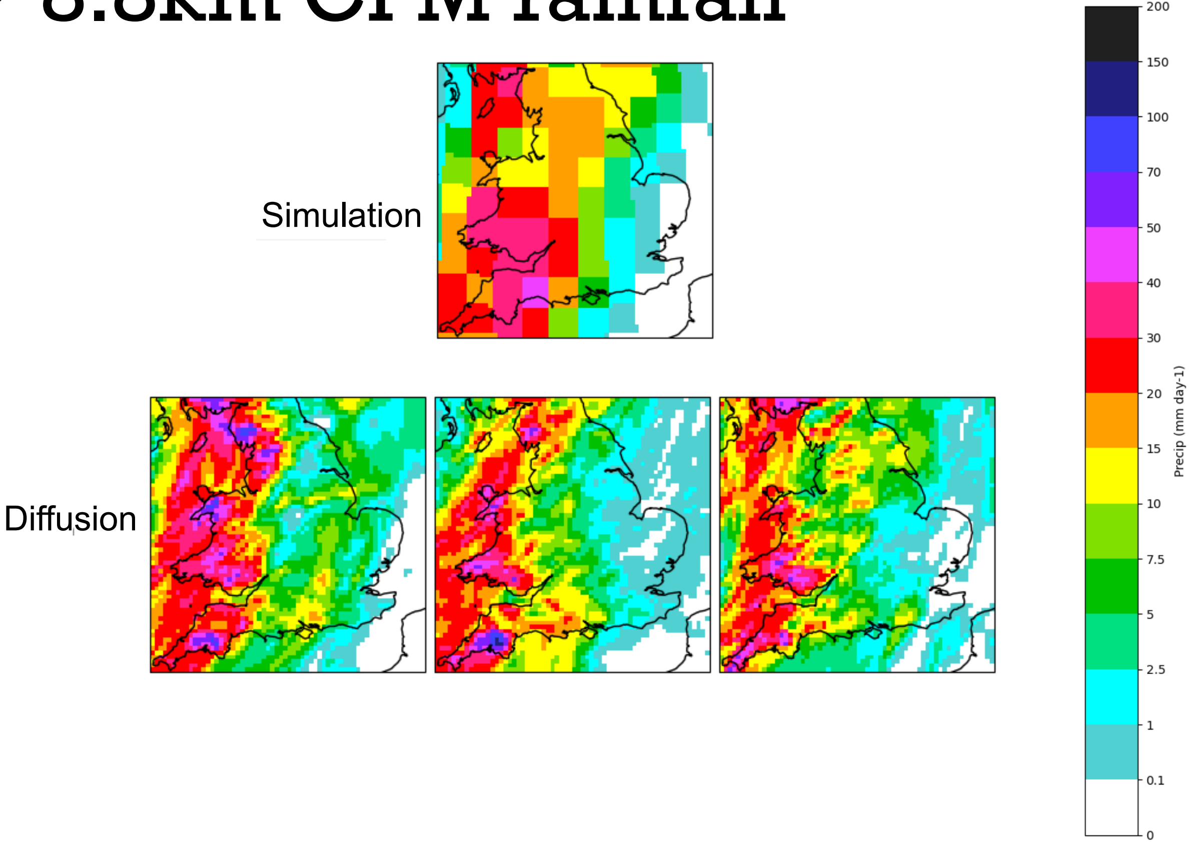
NW Winter



SE Summer



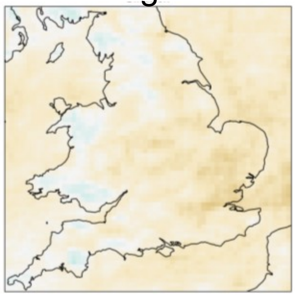
GCM → 8.8km CPM rainfall



GCM → 8.8km CPM rainfall

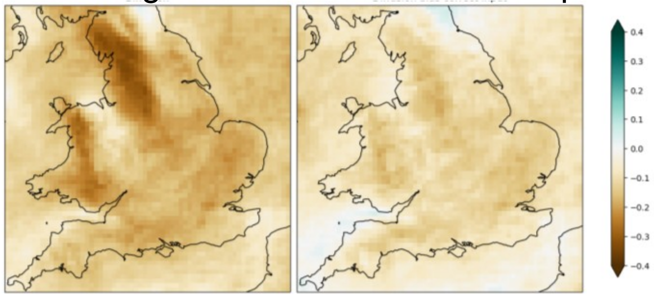
Original

CPM driven

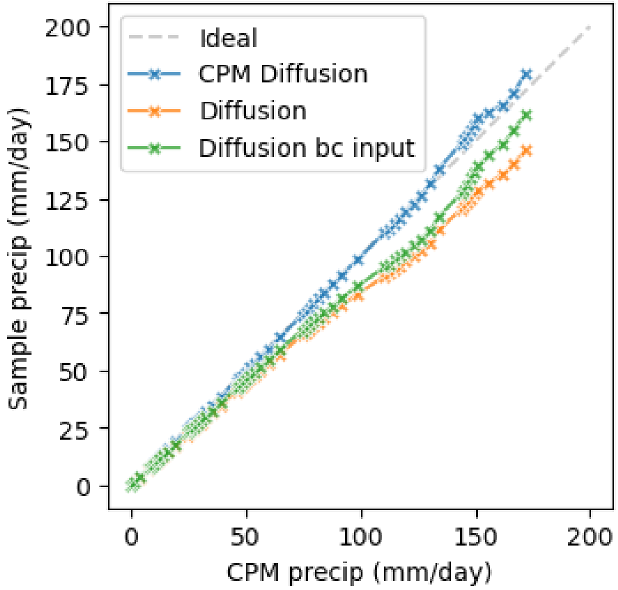


Original | Bias corrected inputs

GCM driven



Normalized mean bias



QQ plot

10th to 99.99999th centile

Future work

- Evaluation
  - Spatial structure
  - Conditioning
  - Probabilistic element
- Generalizing to (large ensembles of) other climate models, time periods, locations
- More extreme Extremes: 1-in-100 years
- Sub-daily frequency and temporal sequences (video)
- Flood modelling applications

Summary

Using SOTA diffusion model to emulate Met Office's hi-res UK climate model

- Reproduces realistic spatial structure and variability of rainfall
- Coarsened CPM driven: good match in mean and quantiles
- GCM driven: extra bias correction of inputs required

Any questions or suggestions? `henry.addison@bristol.ac.uk`

Key references

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