# Practical Conditional Neural Processes Via Tractable Dependent Predictions

Stratis Markou*[1], James Requeima*[12], Wessel P. Bruinsma[12], Anna Vaughan[1], Richard E. Turner[1]
{em626,jrr41,wpb23,av555,ret26}@cam.ac.uk, *Equal contribution, [1]University of Cambridge, [2]Invenia Labs

Paper

**TLDR: We introduce a scalable Conditional Neural Process model which models statistical dependencies and has an analytically tractable log-likelihood.**

## Modelling Statistical Dependencies

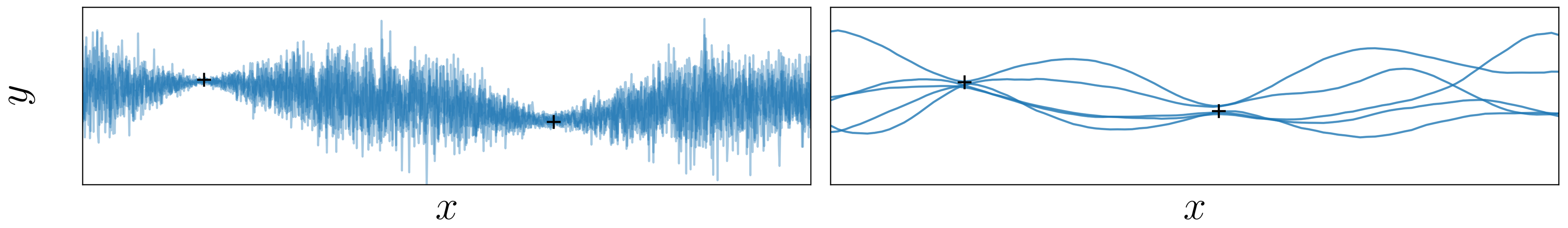


Figure 1: Samples from the predictives of a ConvCNP (left) and a ConvGNP (right).

Directly learn predictive mean $\mathbf{m}$ and covariance $\mathbf{K}$ as function of context $\mathbf{x}_c$ and target $\mathbf{x}_t$

$$\mathbf{m}_i = f(x_{t,i}, \mathbf{r}), \quad \mathbf{K}_{ij} = k(g(x_{t,i}, \mathbf{r}), g(x_{t,j}, \mathbf{r})) \tag{1}$$

where $\mathbf{r} = r(\mathbf{x}_c, \mathbf{x}_t)$, $f$ and $g$ are neural networks, $k$ is positive-definite.

| | Conditional NP | Latent NP | **Gaussian NP** |
|---|---|---|---|
| Exact Likelihood | ✔ | ✘ | ✔ |
| Joint Dependencies | ✘ | ✔ | ✔ |

Applicable to arbitrary architectures, e.g. translation equivariant networks.

## Experiments with Synthetic Data

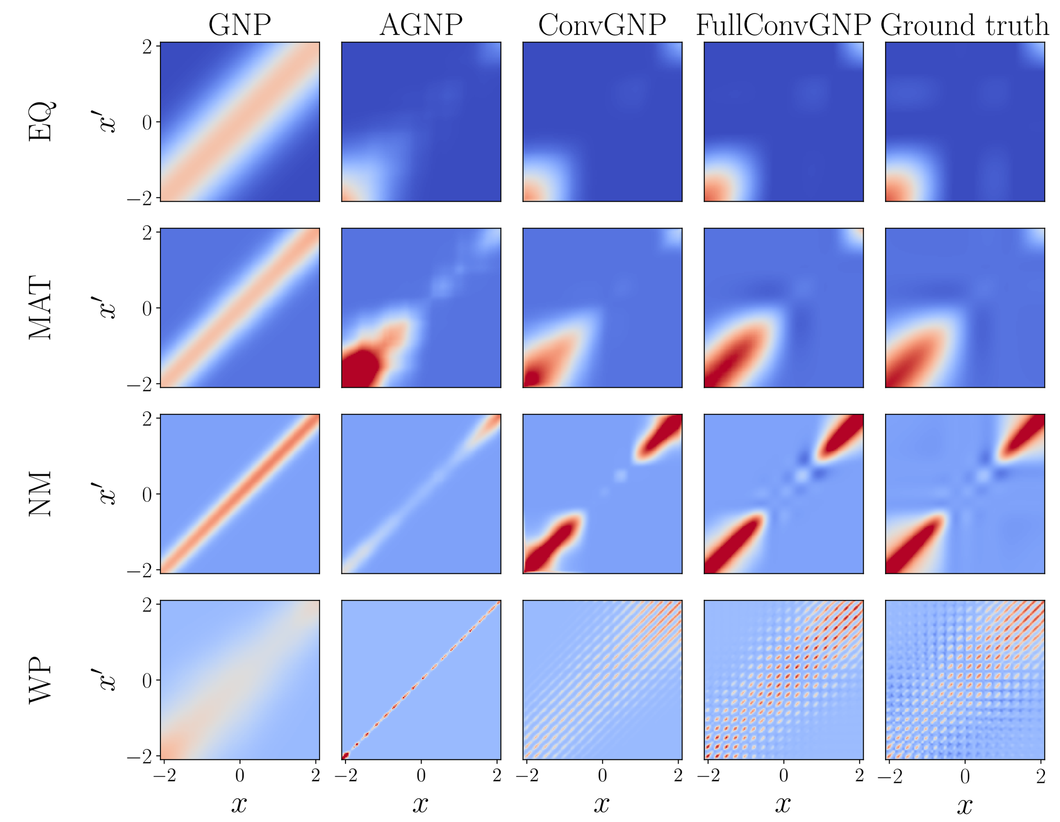


Figure 2: Model predictive covariances on synthetic GP data.

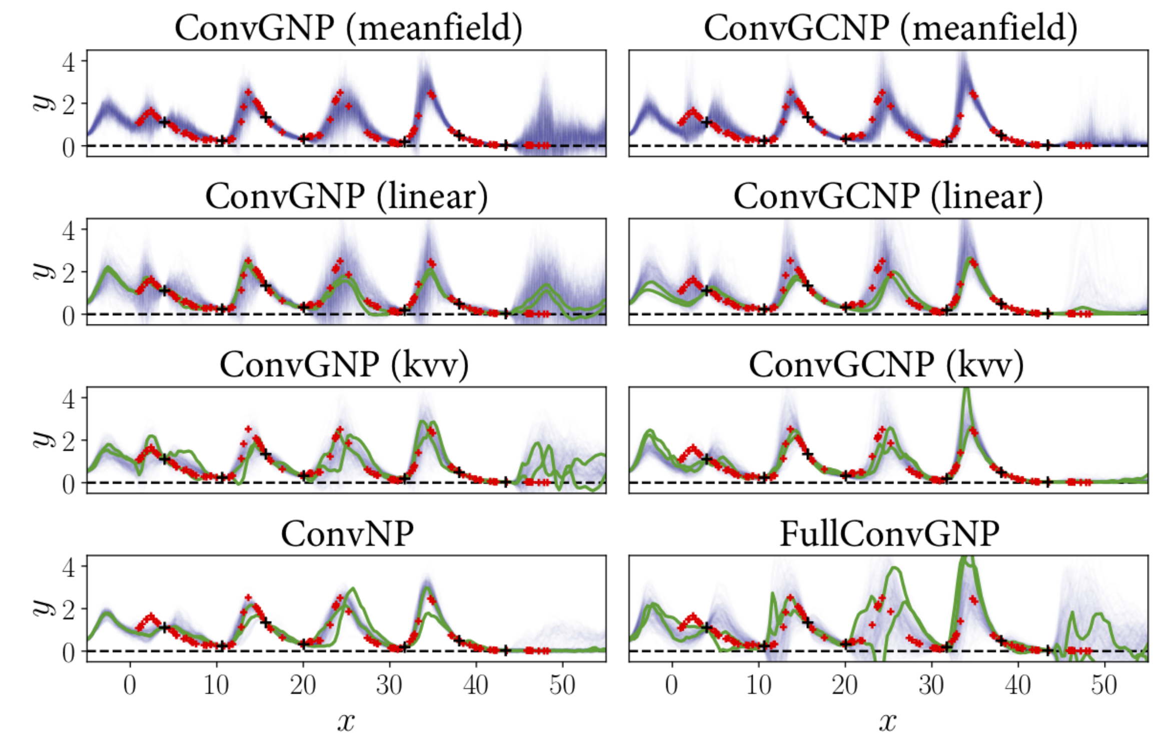


Figure 3: Model marginals and samples on synthetic predator-prey data.

## Experiments with Real Data

Straightforward handling of multi-output regression

$$\mathbf{m}_{ia} = f_a(x_{t,i}, \mathbf{r}), \quad \mathbf{K}_{ijab} = k(g_a(x_{t,i}, \mathbf{r}), g_b(x_{t,j}, \mathbf{r})). \tag{2}$$

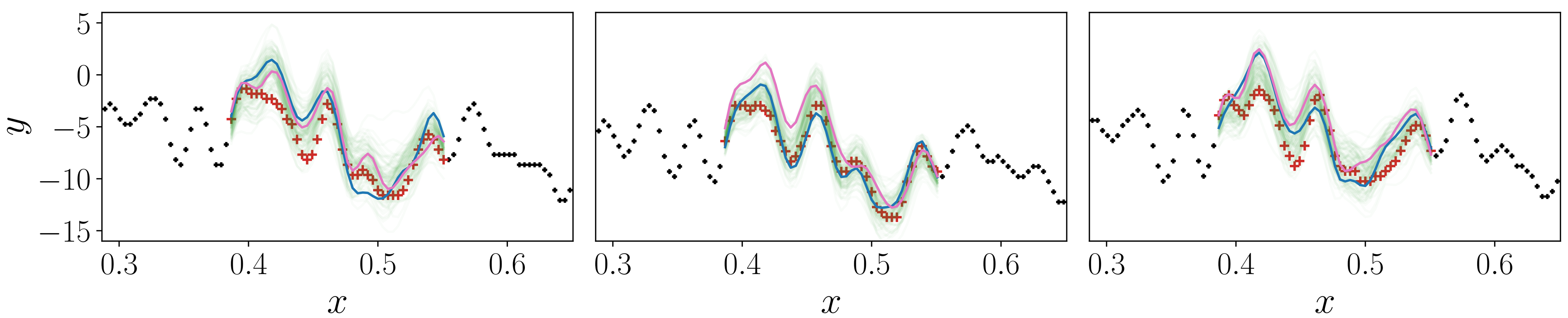


Figure 4: ConvGNP marginals and samples on multi-output regression task with EEG data.

| | MOGP | ConvGNP | ConvNP | ConvGNP |
|---|---|---|---|---|
| Log Lik. | $-12.7 \pm 0.42$ | $-5.27 \pm 0.01$ | $-3.96 \pm 0.01$ | $\mathbf{-1.24 \pm 0.00}$ |

Table 1: Log-likelihoods on multi-output regression with EEG data.

Competitive performance in climate down-scaling. Modelling dependencies:

- ✔ Improves predictive log-likelihood.
- ✔ Enables sampling coherent temperature fields for downstream estimation.

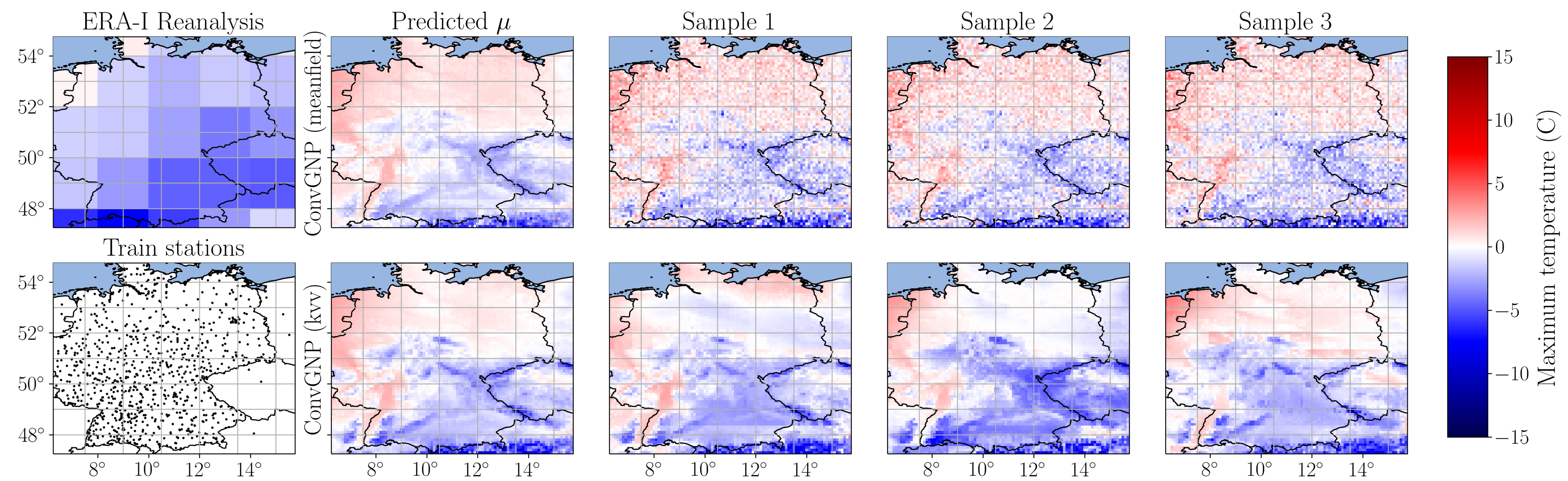


Figure 5: ConvCNP (top) and ConvGNP (bottom) on a larger scale climate down-scaling task.