Environmental Sensor Placement with Convolutional Gaussian Neural Processes

Tom R. Andersson[1], Wessel P. Bruinsma[2], Stratis Markou[3], Daniel C. Jones[1], J. Scott Hosking[1,4], James Requeima[3,5], Alejandro Coca-Castro[4], Anna Vaughan[3], Anna-Louise Ellis[6], Matthew Lazzara[7], Richard E. Turner[3]

[1]British Antarctic Survey, [2]Microsoft Research, [3]University of Cambridge, [4]The Alan Turing Institute, [5]Invenia Labs, [6]Met Office, [7]University of Wisconsin-Madison

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Summary

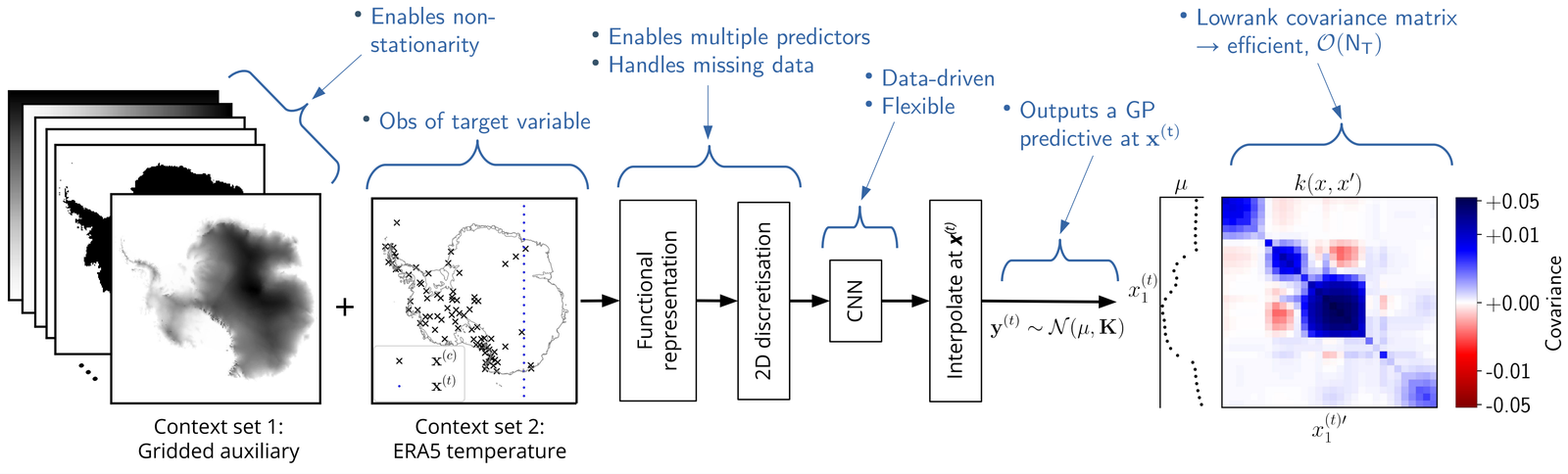
• **Problem**: Sensor placement with spatiotemporal non-stationarity. • **ConvGNP** can *meta-learn* covariance across time. • **Active learning** using mutual information identifies highly informative placements.

Problem setup

- Goal: find optimal locations to measure a complicated, non-stationary spatiotemporal function, $f_\tau(x)$
- Ground truth $f_\tau(x)$: simulated 2D Antarctic air temperature

ConvGNP: A meta-learned mapping from raw data to a Gaussian process (GP) predictive

- ConvGNP[1,2]: Learns a map from context data $C = \{(x_i^{(c)}, y_i^{(c)})\}_{i=1}^{N_c}$ and target inputs $\mathbf{x}^{(t)}$ to a Gaussian over target outputs $\mathbf{y}^{(t)}$
- Train with randomly generated $(\mathbf{x}^{(c)}, \mathbf{y}^{(c)})$ and $(\mathbf{x}^{(t)}, \mathbf{y}^{(t)})$ over period 1980-2013

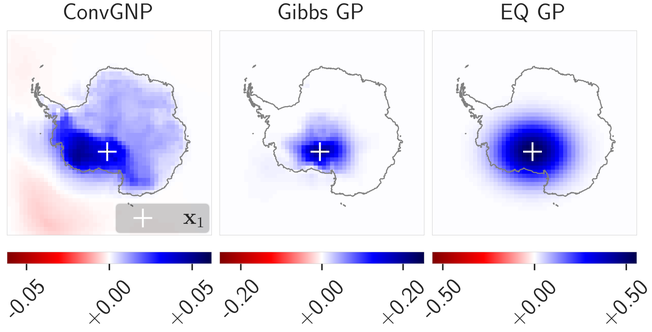


ConvGNP can learn non-stationary covariance structure

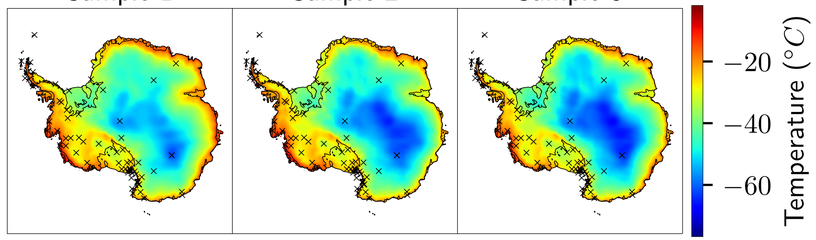
- ConvGNP outperforms a non-stationary GP (Gibbs kernel) and stationary GP (EQ kernel) on test data (2018-2019):

Metric	ConvGNP	Gibbs GP	EQ GP
Normalised NLL	$\mathbf{-1.76}$	-1.15	-0.72
MAE (°C)	$\mathbf{0.93}$	1.34	2.10

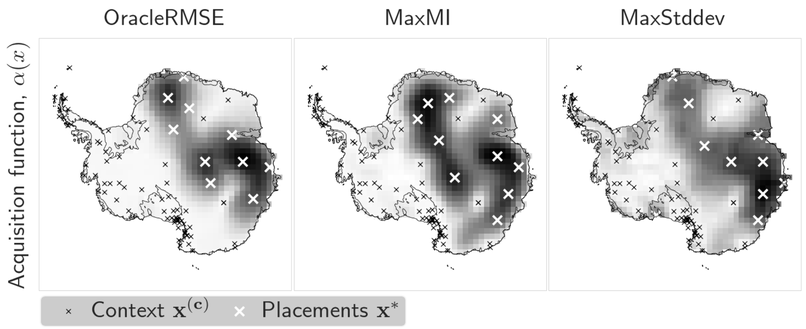
Model covariance, $k(\mathbf{x}_1, \mathbf{x}_2)$, with fixed $\mathbf{x}_1$

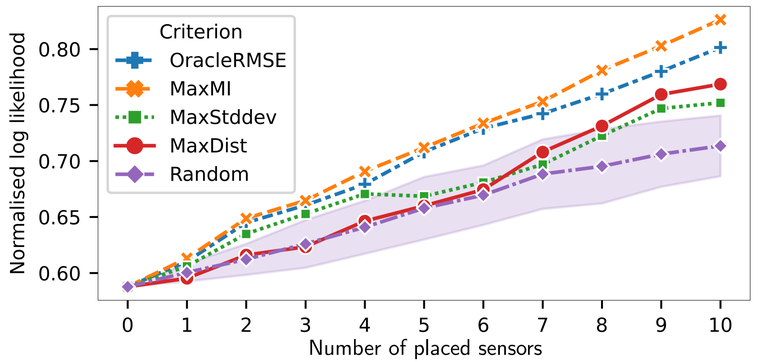


ConvGNP temperature samples over Antarctica



Sensor placement toy experiment





Conclusions

- Vanilla GPs place strong restrictions on the form of the covariance function, $k(\mathbf{x}_1, \mathbf{x}_2)$, unlike the ConvGNP
- With spatiotemporal environmental data, need to *meta-learn* non-stationary covariance structure across time
- ConvGNP can rapidly increase the likelihood of unseen data though active learning using the mutual information.

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References

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