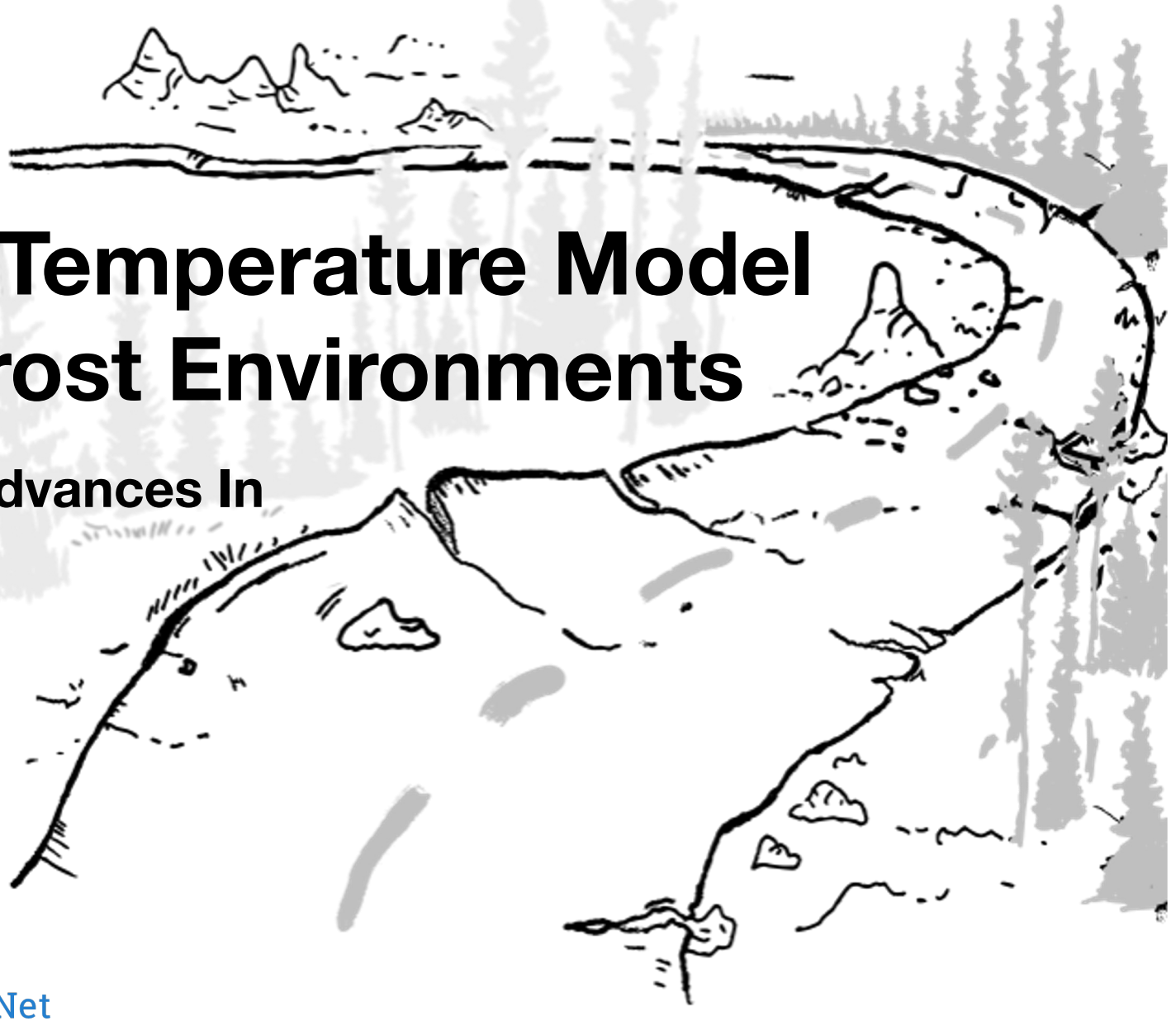
Uncovering Ground Temperature Model Accuracy in Permafrost Environments

EUCOP 2023 Session 7: Recent Advances In Modelling Permafrost Dynamics



Hannah Macdonell June 2023

Carleton University

Northwest Territories

PermafrostNet
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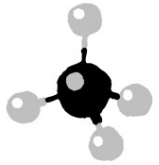
How can modelling help?

Making useful predictions for current and future:

Ground ice content

Active layer thickness



Carbon storage

Ground temperatures

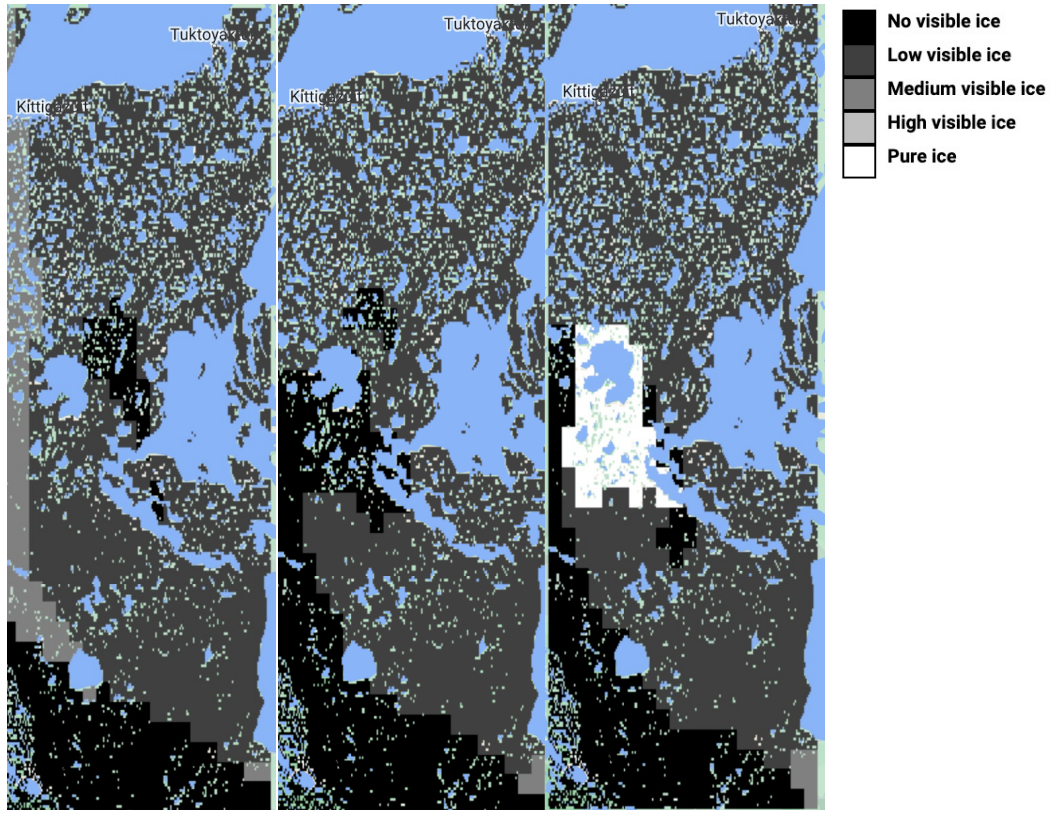


Fig 1. Prototype of 3D Ground-Ice Mapping using machine learning by Bingqiang Zhang

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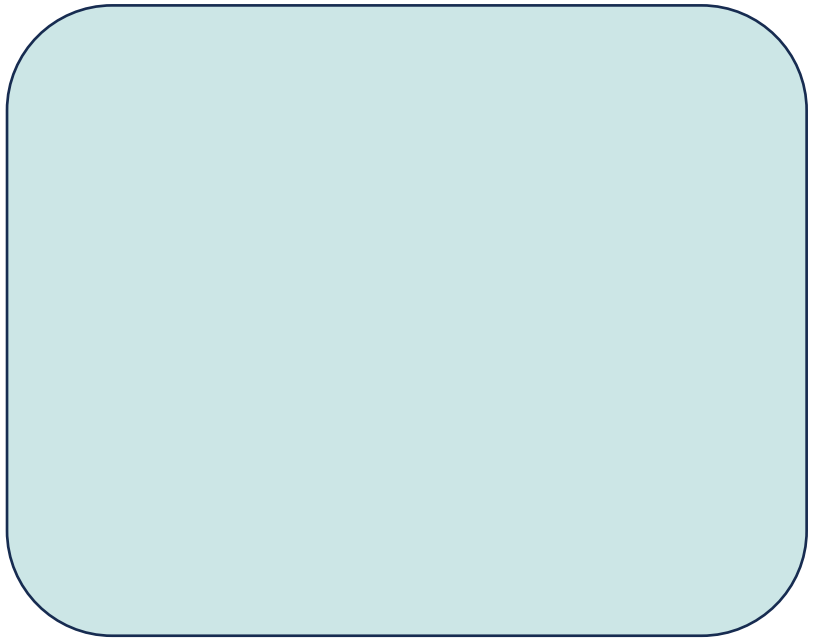
Modelling Obstacles

Statistics

Data Availability



Modelling Obstacles

Statistics

Lack of statistical consensus

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Incomplete observational datasets

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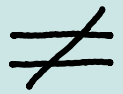

Observations not always variables of interest

Modelling Ground Surface Temperature

~ 10 cm below the ground surface

Mini loggers that are used to measure GST.

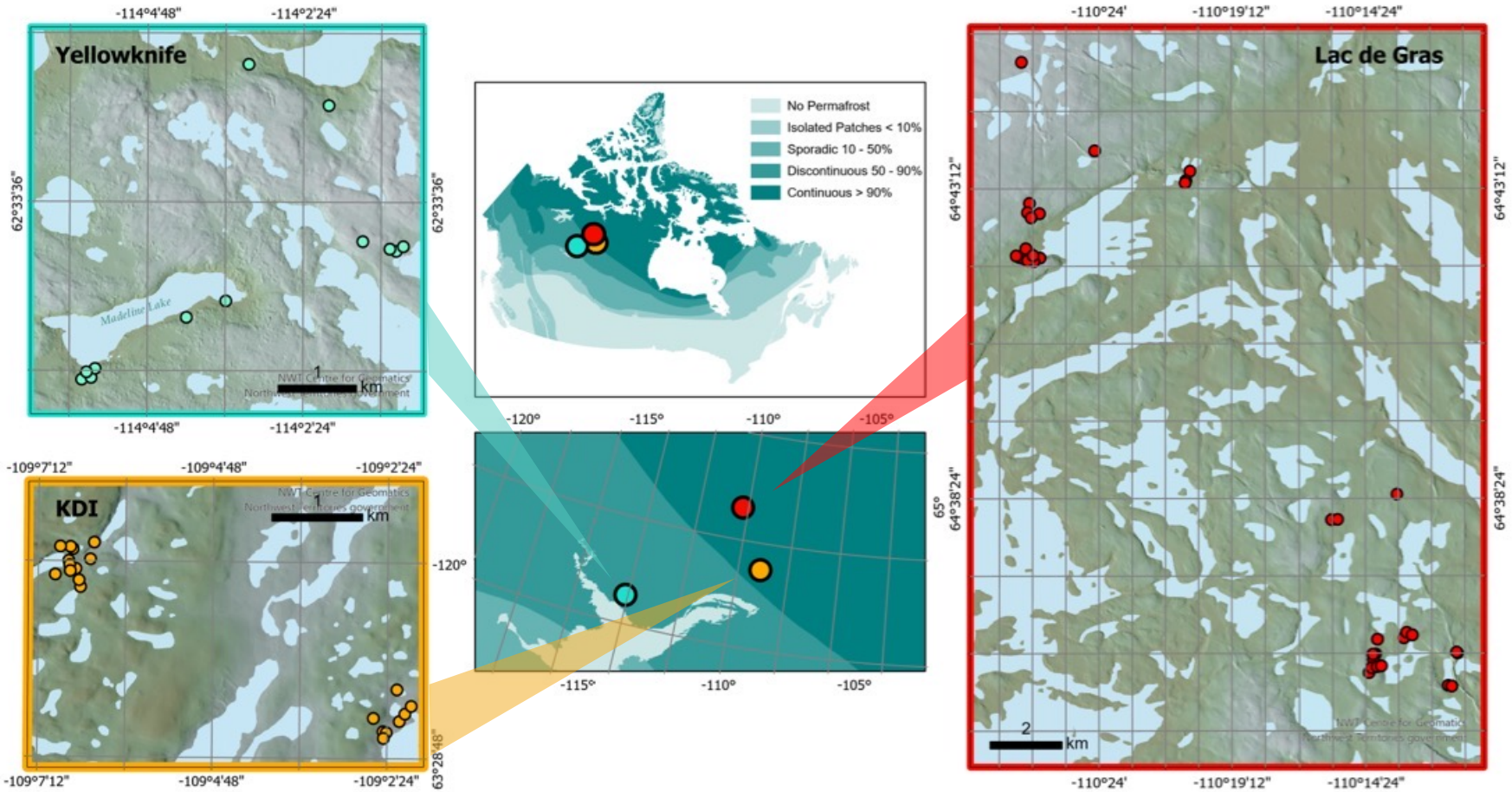

Fig. 2 Map of GST site clusters in Canada.

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Limited spatial coverage of observations

Specifying biogeoclimatic zones

Analysing performance **across different terrains** leads to a better understanding of model **strengths** and **weaknesses**.

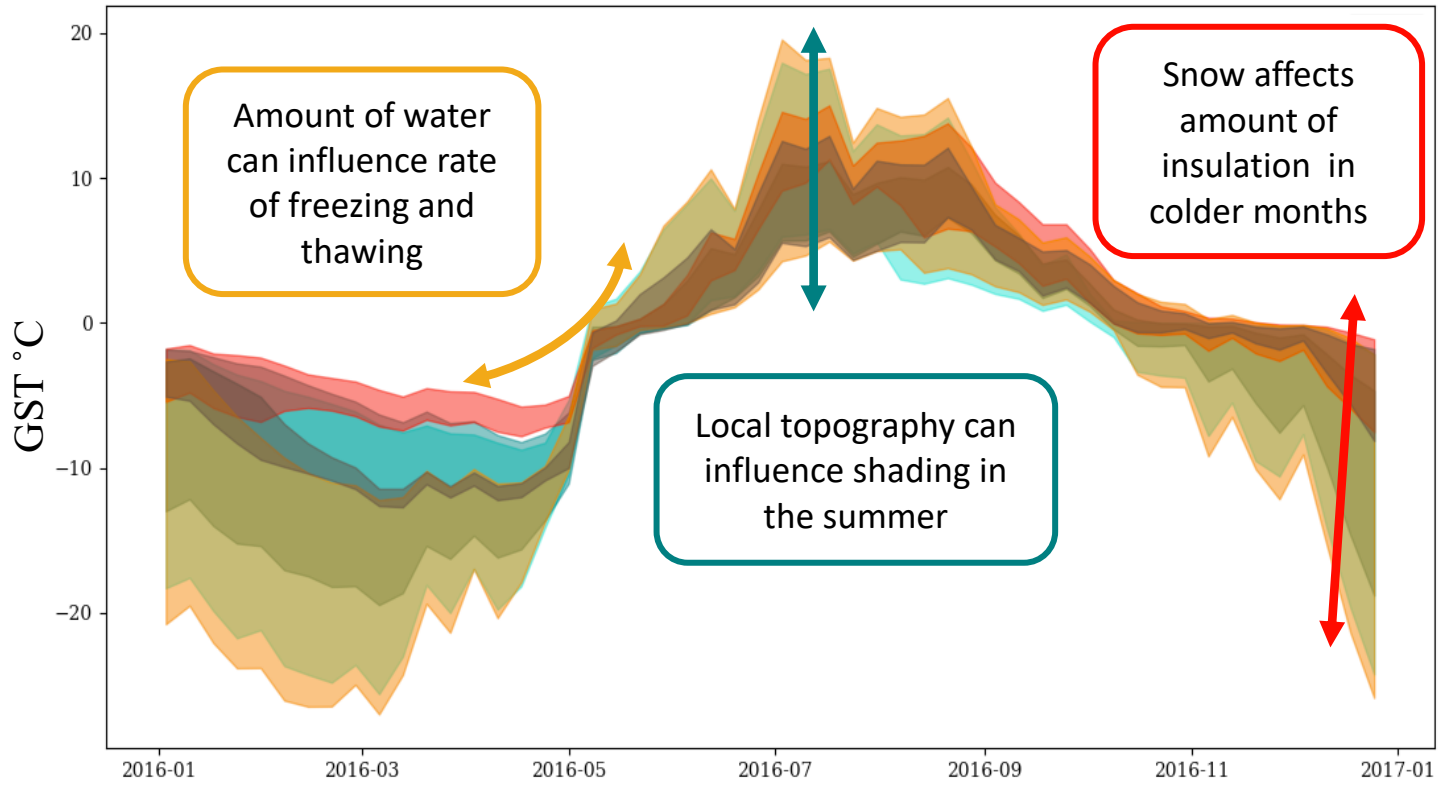

Fig. 3 Range of ground surface temperatures observed across terrain types.

☒ Incomplete observational datasets

t–Interval Bootstrapping

Fig. 4 Sad borehole in Lac de Gras region.

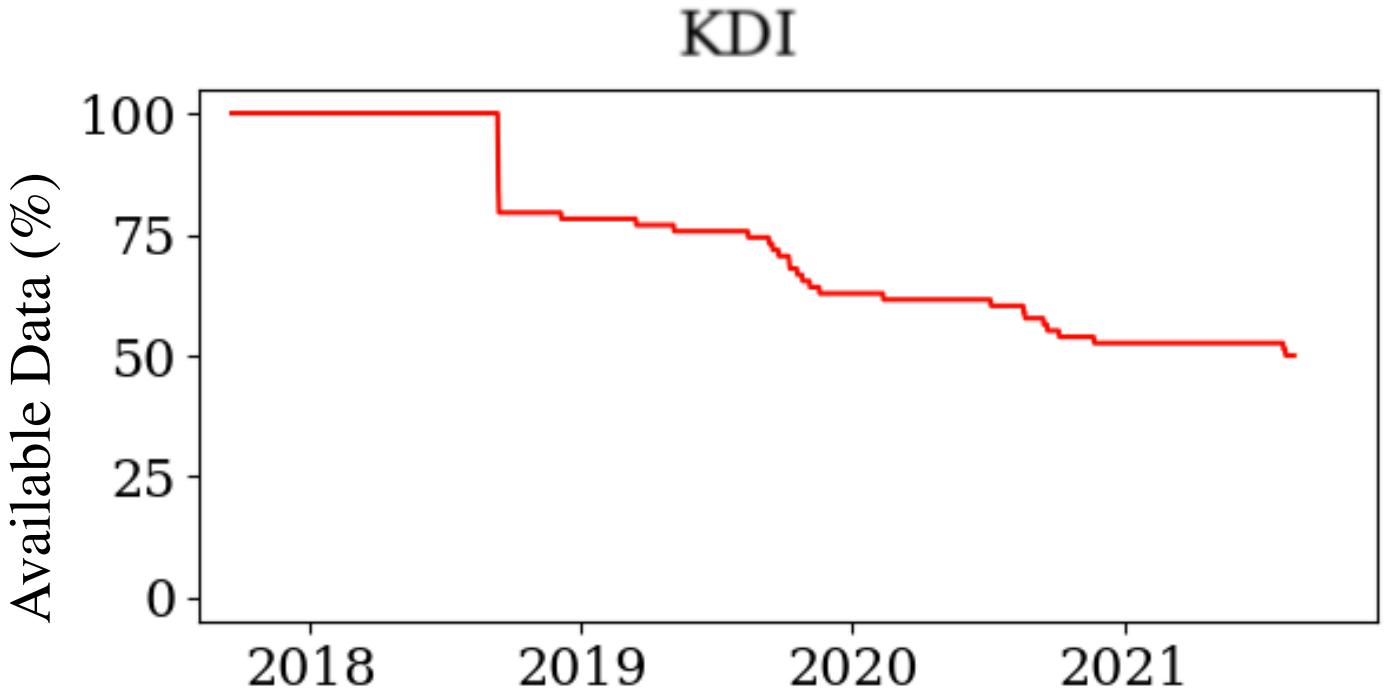

Fig. 5 Percent of available data of GST loggers at KDI

☒ Incomplete observational datasets

t–Interval Bootstrapping

- Observational datasets are often spatially sparse and incomplete
- Bootstrapping: *n* windows of *t* days are randomly selected

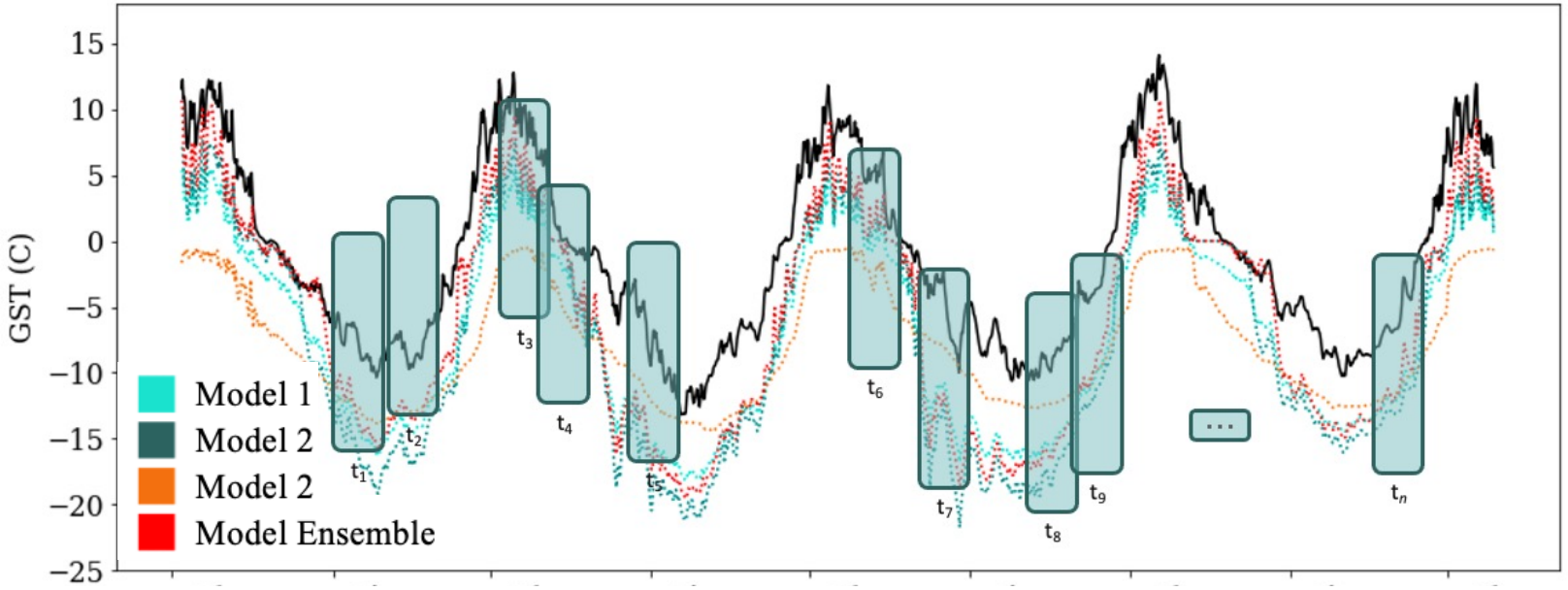

Fig. 6 *t*-Interval bootstrap example: *Visualization*

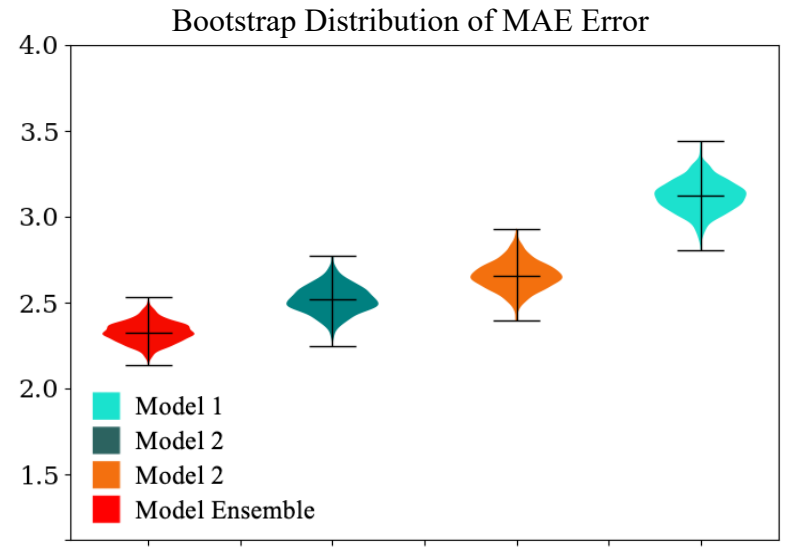

Fig. 7 *t*-Interval bootstrap example: *Results*

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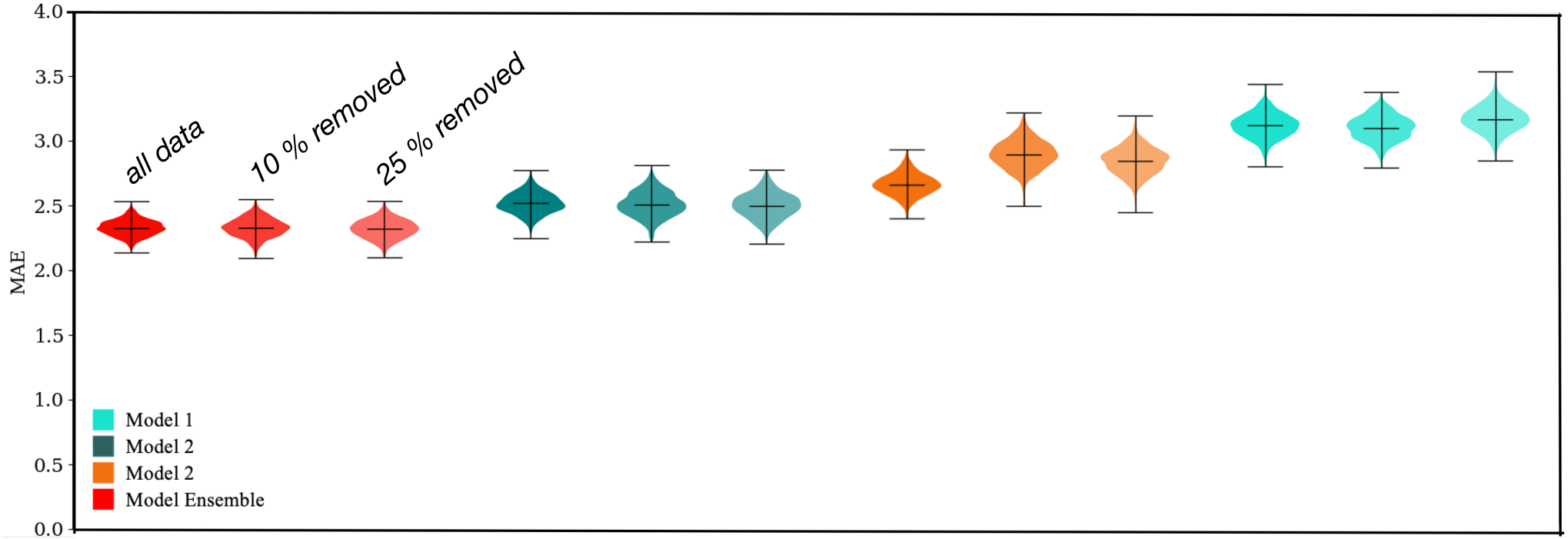
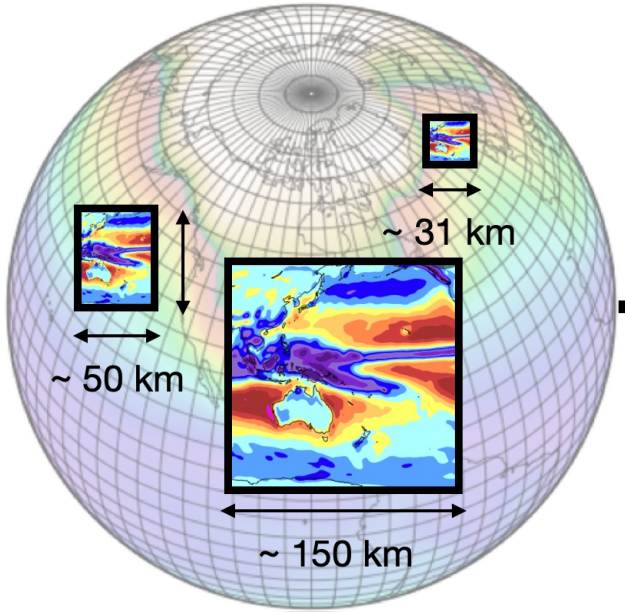


Fig. 8 *t*-Interval bootstrap visualization: randomly removed data.

Driving meteorological data

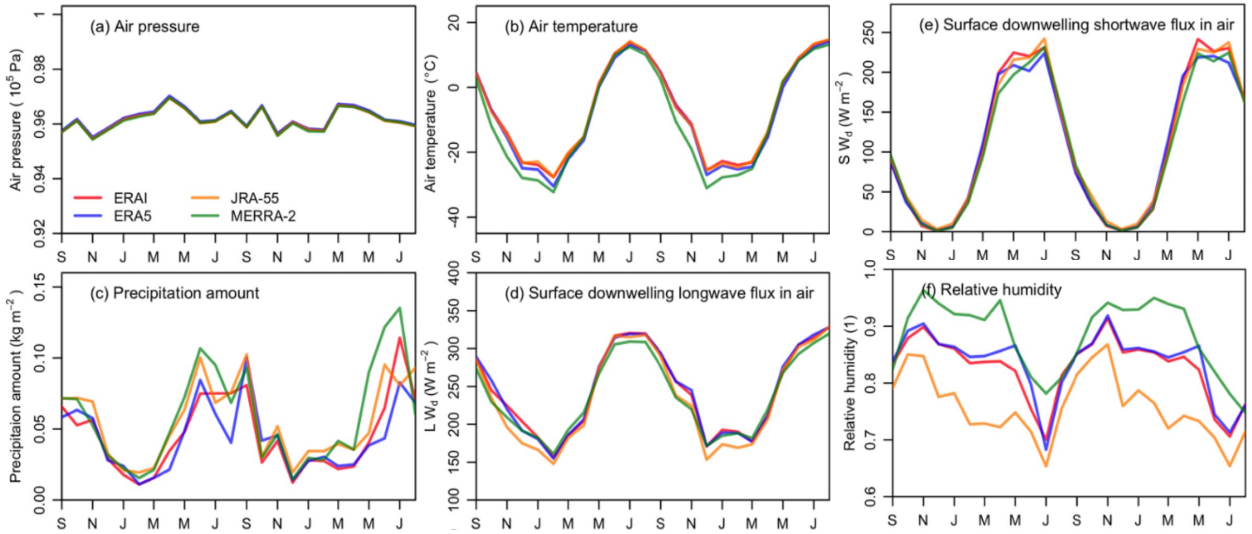
Solution: Reanalysis Data Products using *GlobSim*

- Produced using historical observations and modern forecasting models.
- “Maps without Gaps”: Complete spatial and temporal coverage, multiple variables.



GlobSim

Driving data: meteorology at the surface



GlobSim Output ao, B., et al., (2019)

Lack of statistical consensus

Model Evaluation Anarchy

- Models cannot be compared due to the lack of consensus over which statistics to use
- There are problems with commonly used statistics: *RMSE*, *bias*, and *r*

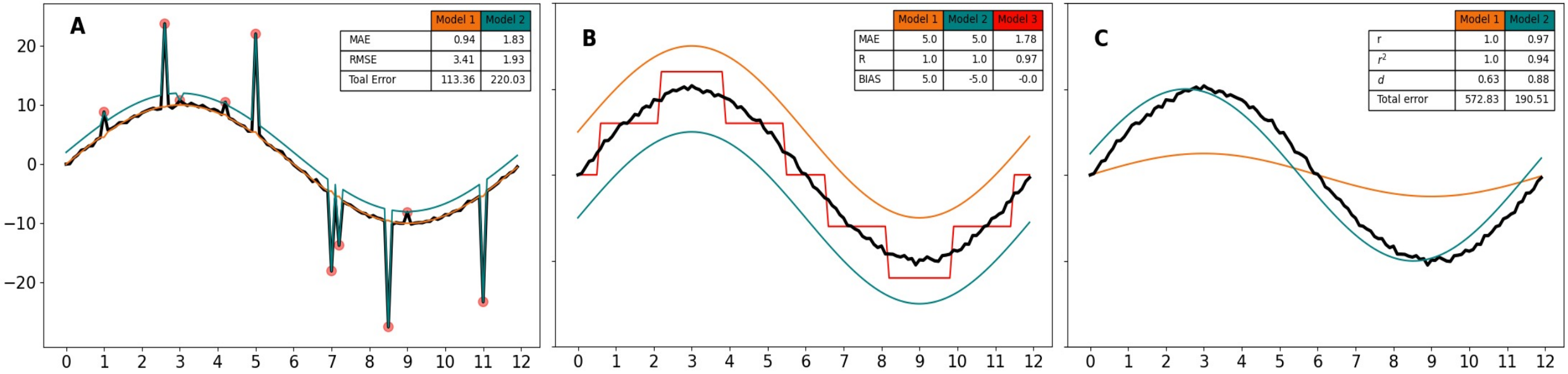


Fig. 9 Dummy data shows the problem with (A) RMSE, (B) Bias and (C) r statistics.[3]

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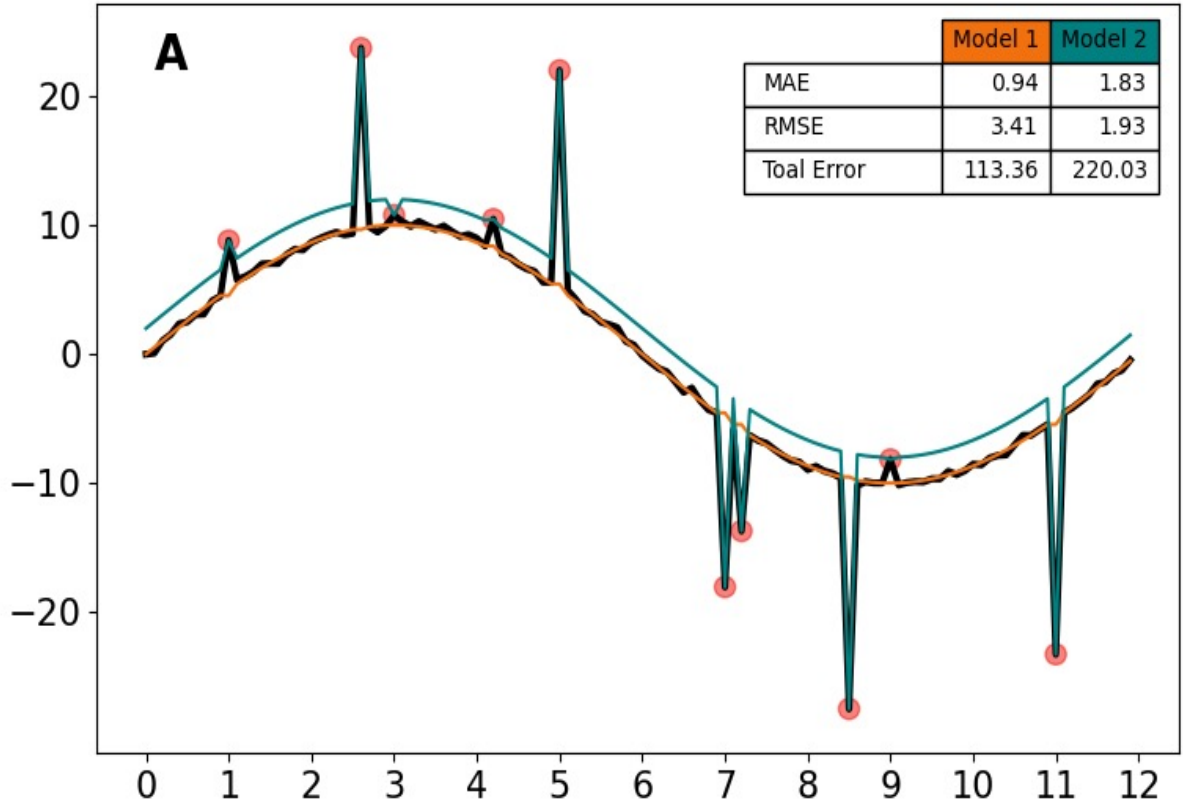

Fig. 9a Dummy data shows the problem with RMSE.[3]

[3] Adapted in part from Willmott (2005)

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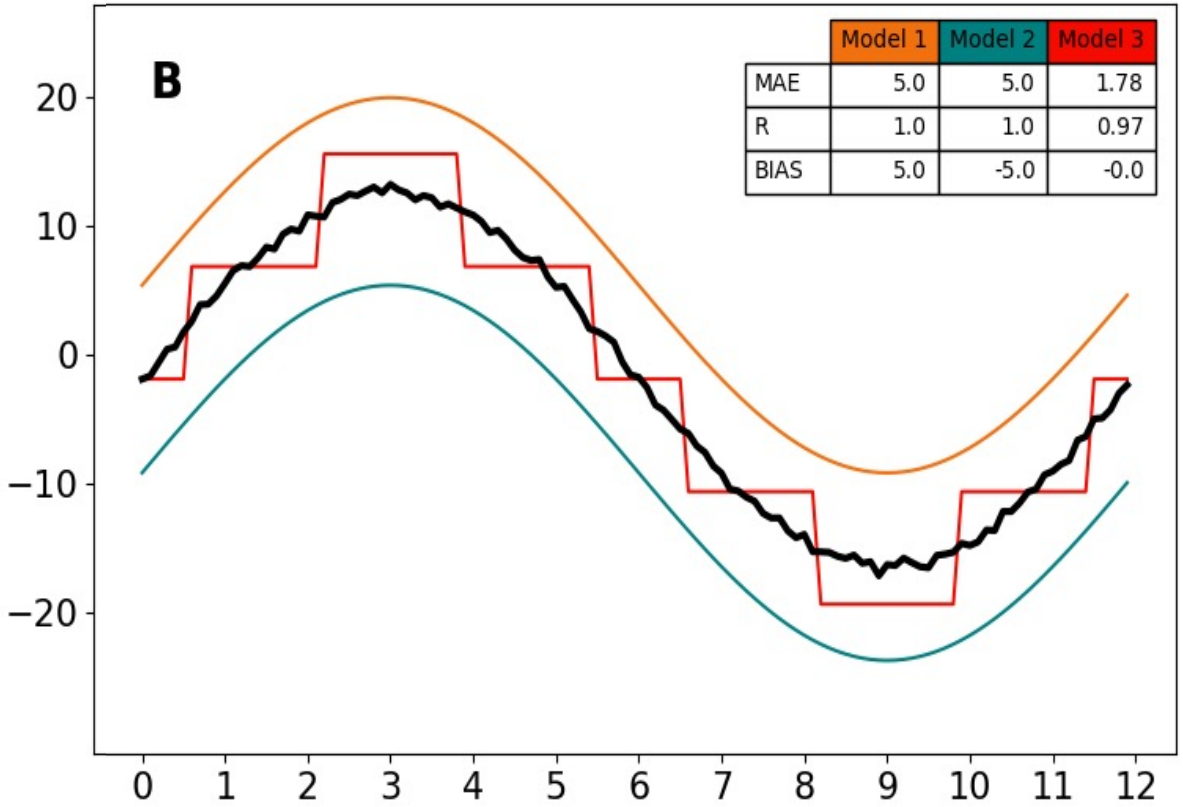

Fig. 9b Dummy data shows the problem with BIAS.[3]

[3] Adapted in part from Willmott (2005)

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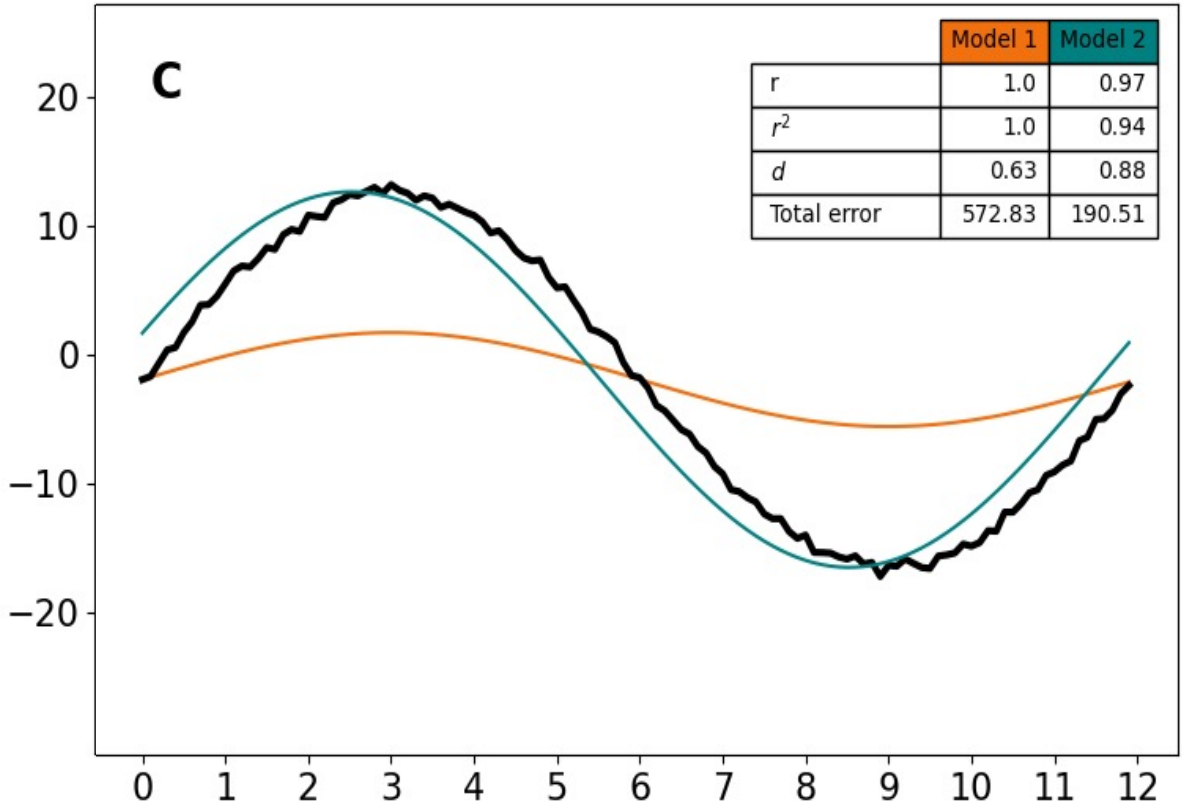

Fig. 9a Dummy data shows the problem with r / r^2.[3]

[3] Adapted in part from Willmott (2005)

Interpretability of statistics

Solution: A Ranking Framework

"Statistics are the grammar of science."

- Karl Pearson

- Most statistical values are **intangible in reality**, and often **mathematically unrelated** to one another
- Many domains rely on **rankings** to establish "the best"

[1] Drew, L. J., & Schuenemeyer, J. H. (2011). *Statistics for earth and environmental scientists*. John Wiley & Sons.

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≠ Observations ≠ variables of interest

Extension of simulations to greater depths

- Essentially: are our “best” simulations able to be “best” elsewhere
- How can we measure our ability to predict deeper temperatures?

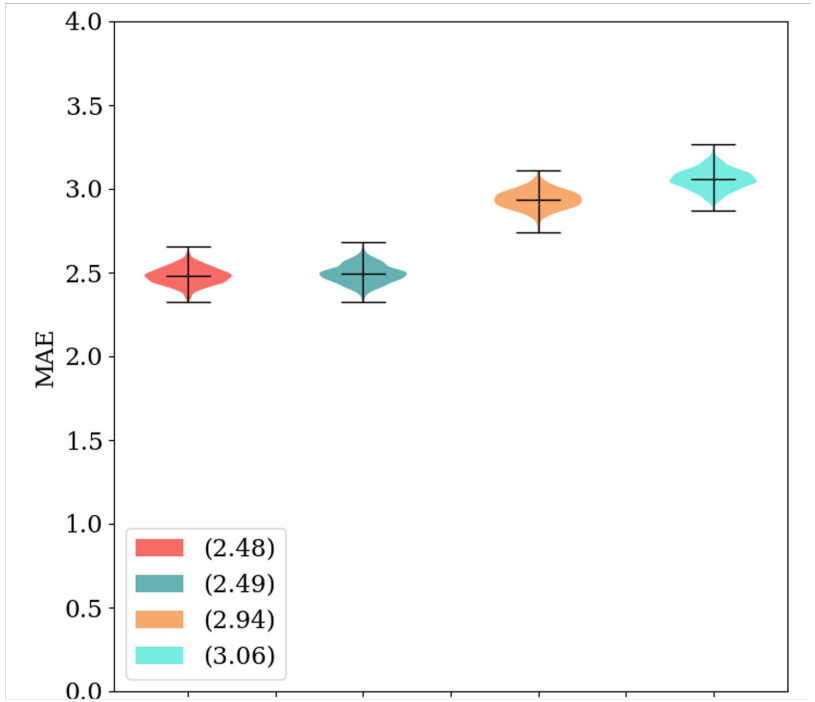
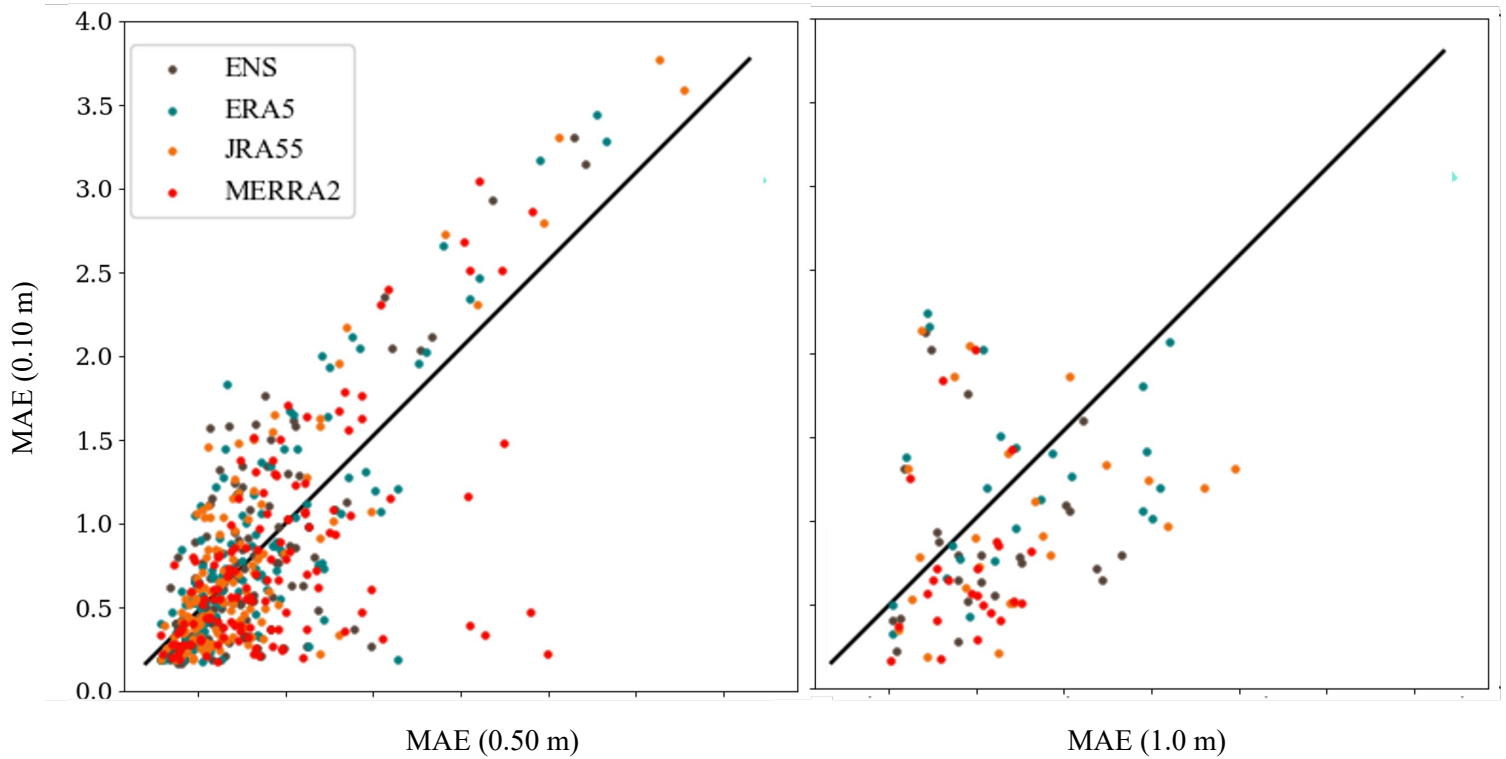


Fig. 10 Simulation results at 1.0m depth



Recap

Modelling and evaluation challenges… and their solutions

	Challenge	Solution
	Limited spatial coverage	Sub setting and weight model performance by terrain type
	Incomplete datasets	*t*-interval bootstrapping
	Missing meteorology	Reanalysis data products!
	Lack of statistical consensus	Fit statistics to your variable of interest
	Interpretability of statistics	Rank models
	Observed ≠ Interesting	Do model results extend to greater depths?

Gracias por su atención.

Thank you for listening.

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