Data-driven emulation of sea ice albedo and melt ponds

Simon Driscoll (University of Reading, National Center for Earth Observation), Alberto Carrassi (University of Bologna), Julien Brajard (NERSC), Laurent Bertino (NERSC), Marc Bocquet (École des Ponts ParisTech), Einar Olason (NERSC), Amos Lawless (University of Reading, National Center for Earth Observation)
s.driscoll@pgr.reading.ac.uk

1. Role of Sea Ice and Melt Ponds in Climate

Sea ice plays an essential role in regulating Earth's climate and weather.

Averaged globally, the albedo change resulting from sea ice loss is equivalent to **25% of the direct forcing from CO2 during the past 30 years.**

Each year, during sea ice melt, **ponds of melting water cover up to 50% of the sea ice surface**. Their evolution is one of the main factors affecting the polar climate and **the energy balance** of the climate.

Poorly understood, complex and sub-grid scale, they are **parametrised** in models, with considerable **uncertainty**.

Image credit: National Geographic

Image credit: Donald Perovich

2. Uncertainty in Current Sea Ice Models

Icepack is a **state of the art model of sea ice thermodynamics**, capable of representing many crucial processes (right).

We perform perturbed parameter ensembles of its most advanced melt pond parametrisation (the "level-ice" parametrisation). These show that **predicted sea ice thickness** over the Arctic ocean differs by many metres **after only a decade of simulation** – with parameters perturbed within known ranges of uncertainty (right).

With substantial **sensitivity** and **uncertainty** we propose an alternative to the `parametric' parametrisation approach.

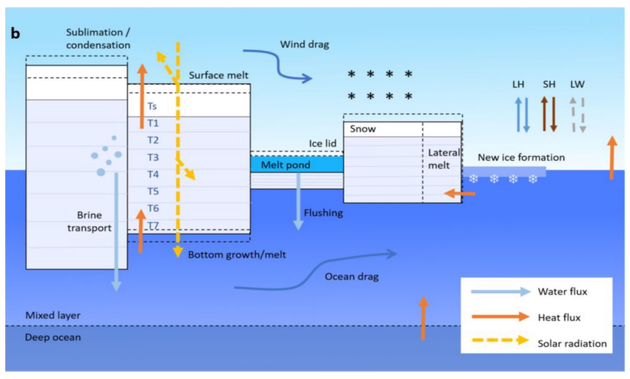
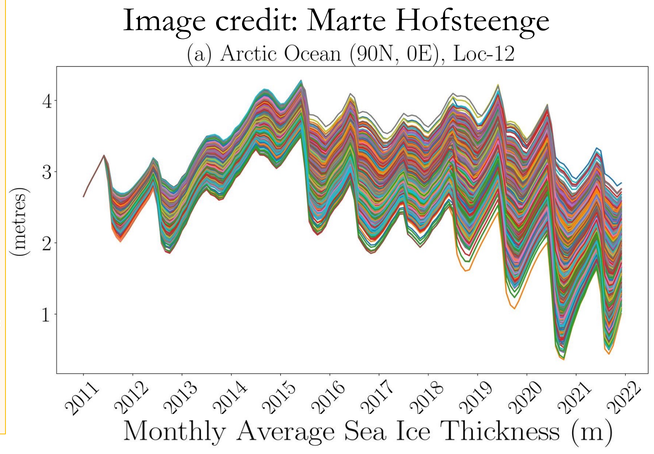


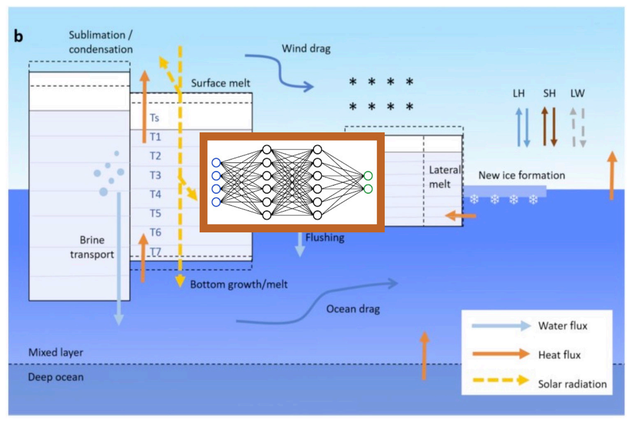
Image credit: Marte Hofsteenge



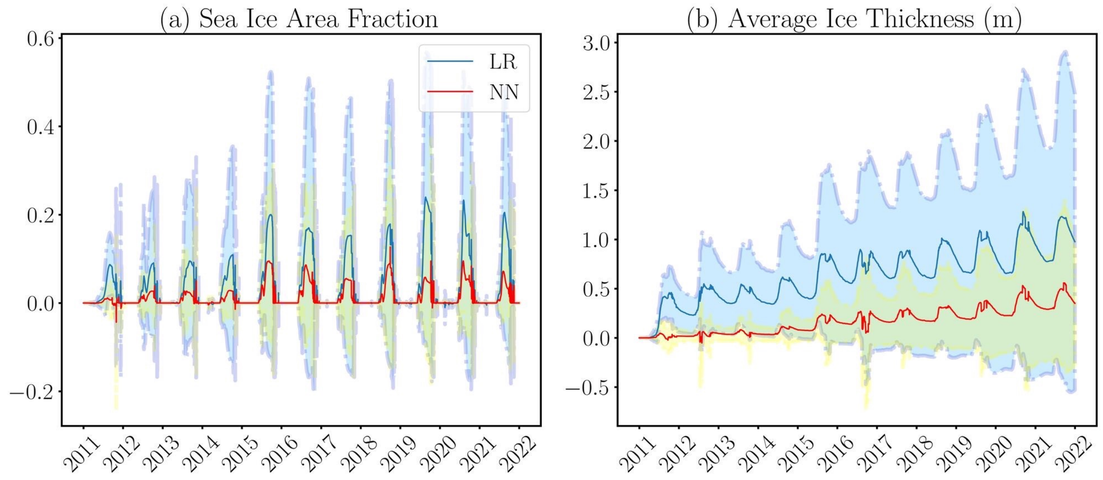
3. A Neural Network Approach to Parametrisation

We propose using neural networks to emulate and replace this melt pond parametrisation.

We show that neural networks can learn and replace this parametrisation, and then run successfully in the Icepack model (bottom panels).



Errors against Icepack-Phys



Work in sections 2-3 is submitted to the Journal of Computational Science, and is available on arXiv, "Parameter sensitivity analysis of a sea ice melt pond parametrisation and its emulation using neural networks".

4. Developing a data driven emulator

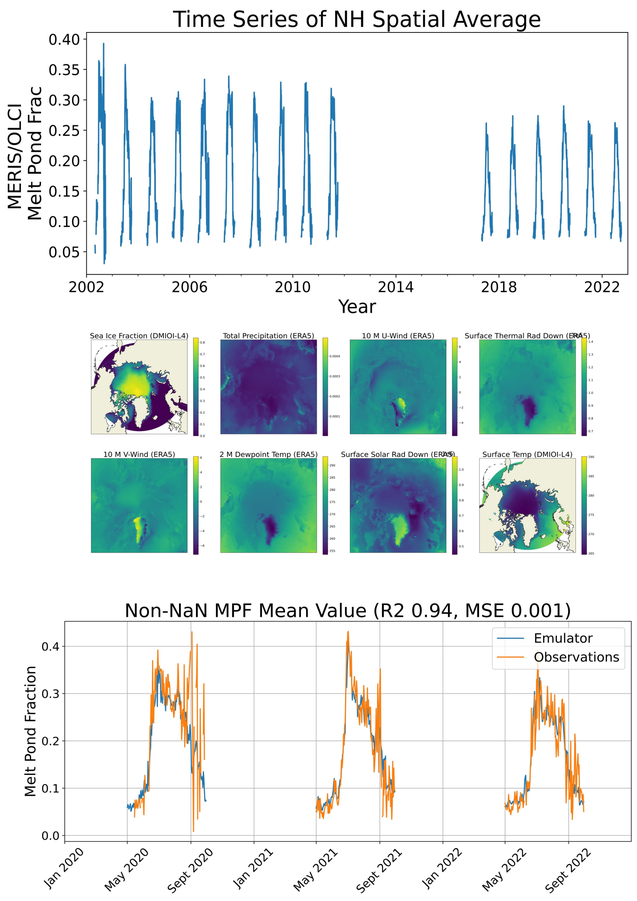
<u>Training Data</u>

We want to predict melt pond fraction (right) and sea ice albedo (not shown) from observed variables.

Time averages of these are shown in the 8 panels on the right.

<u>The Resulting Emulators</u>

MLP Neural Networks can predict melt pond fraction with high R2 test scores for melt pond fraction (right) and sea ice albedo (not shown).



Summary/Conclusions

1) Current representation of melt ponds have considerable uncertainty. This uncertainty has substantial impacts on key predicted sea ice variables.
2) We demonstrate an alternative approach of neural networks replacing the parametrisation is possible, and shift from perfect or model data to observational data.
3) From observational data, we create an emulator of melt pond fraction and sea ice albedo.
4) Using this observational emulator in neXtSIM-DG is one of our next stages of work – and the emulator will be available for modelling centres around the world, and potentially used to fill in gaps in the melt pond observational record.
5) Our work adds to the wider discussion on using machine learning to replace physical parametrisations in climate models.

This project is supported by Schmidt Futures – a philanthropic initiative that seeks to improve societal outcomes through the development of emerging science and technologies.