Sea ice surface emissivity using data assimilation and machine learning

Alan Geer and **Niels Bormann**

Research Department, ECMWF, Reading, United Kingdom; alan.geer@ecmwf.int

Overview

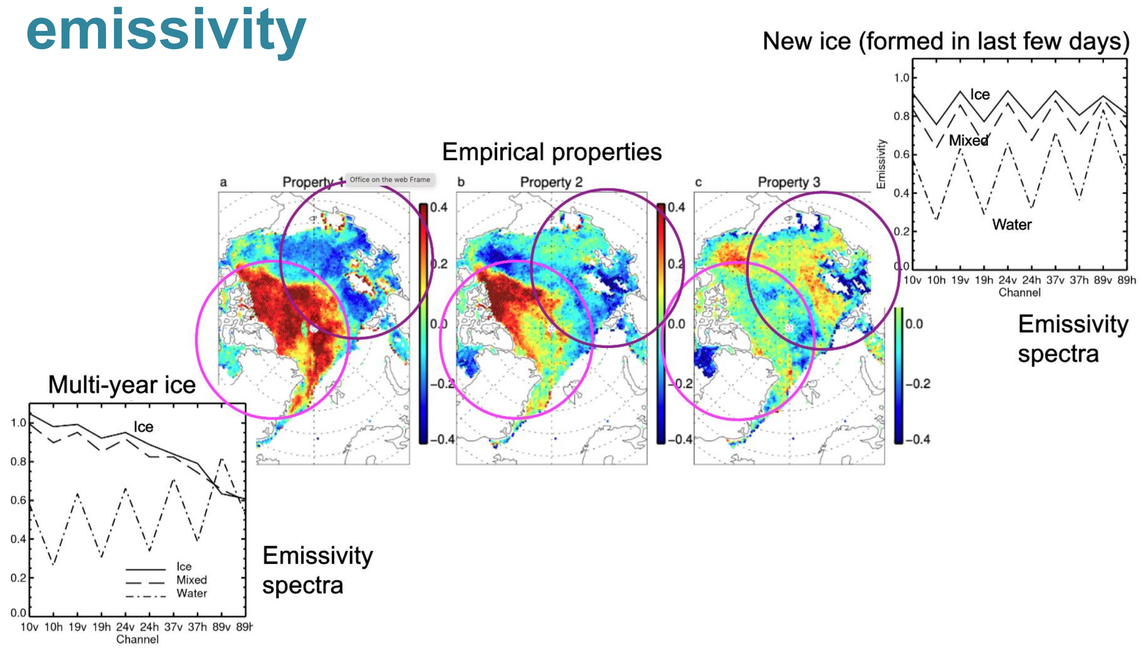
Aim:

- Derive an empirical model for sea-ice emissivity to estimate sea-ice concentration and assimilate strongly surface sensitive radiances over sea-ice

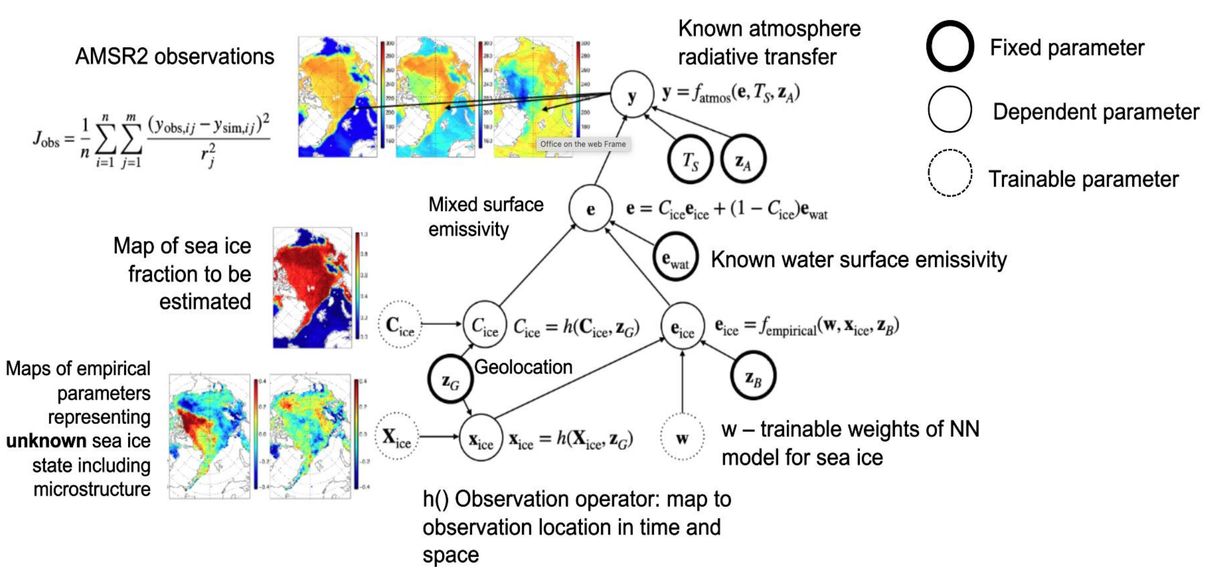
Approach:

- Describe spectral emissivity variations through 3 empirical parameters
- Empirical parameters and their functional form are derived offline using machine learning (ML) and data assimilation (DA)
- The empirical parameters and sea-ice concentration are subsequently estimated as observation-space control variables in atmospheric 4D-Var, allowing addition of extra data near and above sea-ice

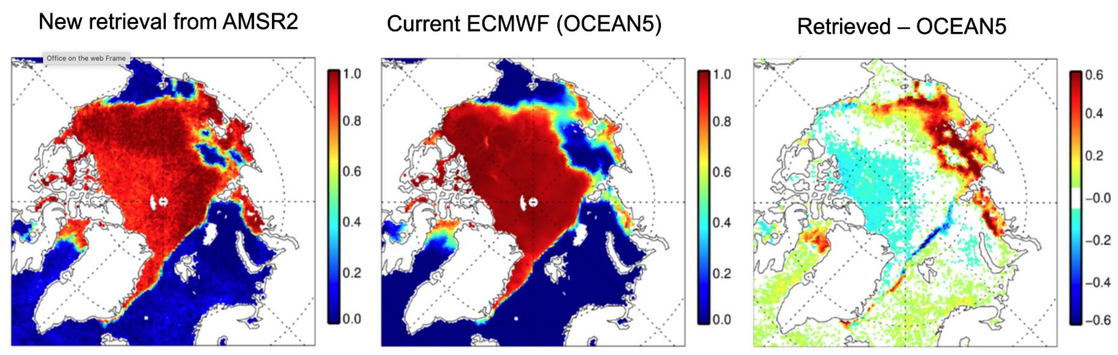
Empirical properties and the sea ice emissivity



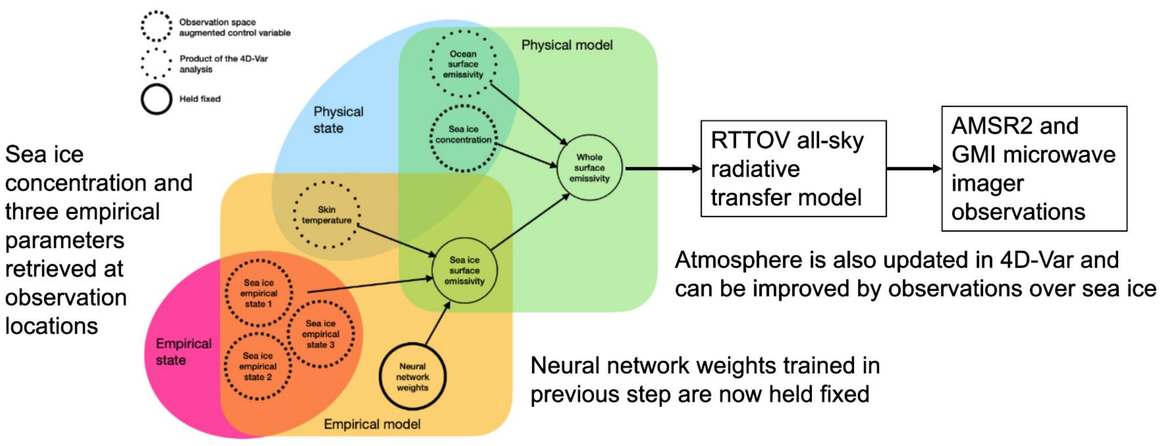
An offline trainable empirical physical network blending ML and DA



Example offline sea ice concentration retrieval: rapid freezing 7th Nov 2020



Putting the trained model in 4D-Var

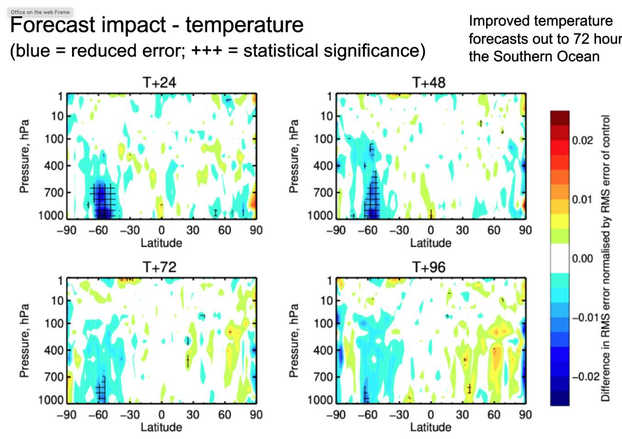


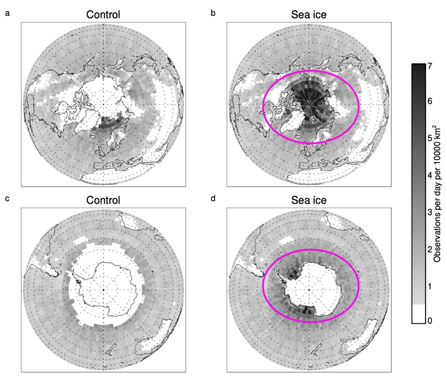
Sea ice concentration and three empirical parameters retrieved at observation locations

Atmosphere is also updated in 4D-Var and can be improved by observations over sea ice

Neural network weights trained in previous step are now held fixed

Results in 4D-Var

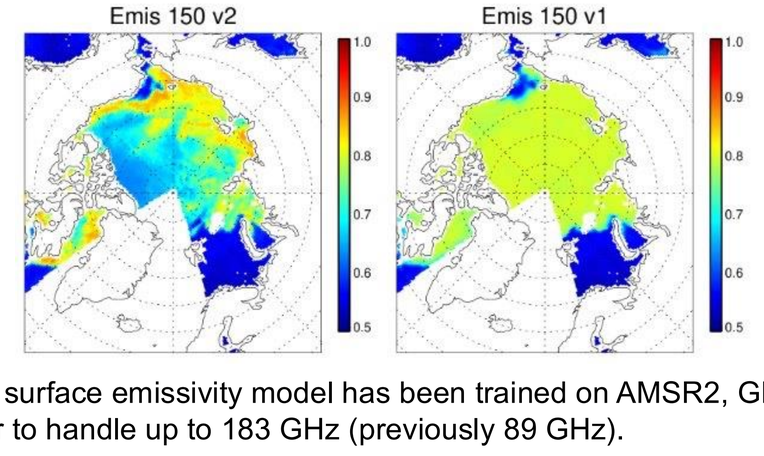




Up to around 7 AMSR2 observations added per day per 100 x 100 km box in polar regions

v2 emissivity model supports up to 183 GHz

Realistic low emissivities suggest scattering from snow on top of multi year ice



Previously a fixed unrealistic surface emissivity at 150 GHz

The v2 sea ice surface emissivity model has been trained on AMSR2, GMI and SSMIS in order to handle up to 183 GHz (previously 89 GHz).

Outlook

- At cycle 50r1, in autumn 2025, the sea ice concentration retrievals from atmospheric 4D-Var will be used to update the sea ice analysis in NEMOVAR using outer-loop coupling. It is hoped eventually to remove the dependence on external sea ice concentration products in the IFS.
- As part of the ESA DANTEX project, the sea ice surface emissivity model will be extended down to 1.4 GHz (currently 10 GHz) to support SMOS, SMAP and (in future) CIMR and hopefully to allow also sea ice thickness retrieval.
- Extension to cross-track sounders such as AMSU-A is envisaged on the 1-3 year timeframe, so that the surface emissivity model will vary according to zenith angle and mixed polarisation signatures.
- To support cross-track sounders it is likely the empirical state variables will need to be moved from observation space to 2D empirical control variables

Further reading

- Geer, A. J. (2024). Simultaneous inference of sea ice state and surface emissivity model using machine learning and data assimilation. Journal of Advances in Modeling Earth Systems, 16, e2023MS004080. https://doi.org/10.1029/2023MS004080
- Geer, A.J.. (2024) Joint estimation of sea ice and atmospheric state from microwave imagers in operational weather forecasting. Quarterly Journal of the Royal Meteorological Society, 150(763), 3796–3826. Available from: https://doi.org/10.1002/qj.4797