The use of supersite data for process-oriented forecast evaluation at ECMWF

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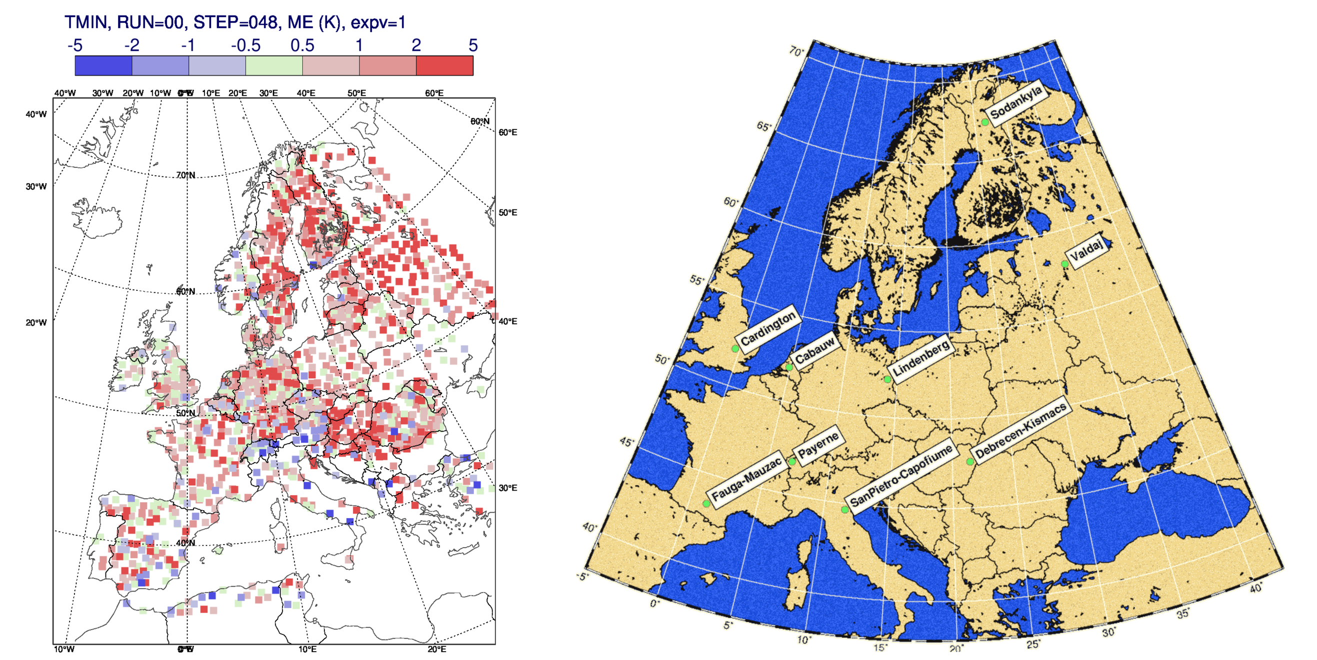
INTERACT

Supersites vs SYNOP

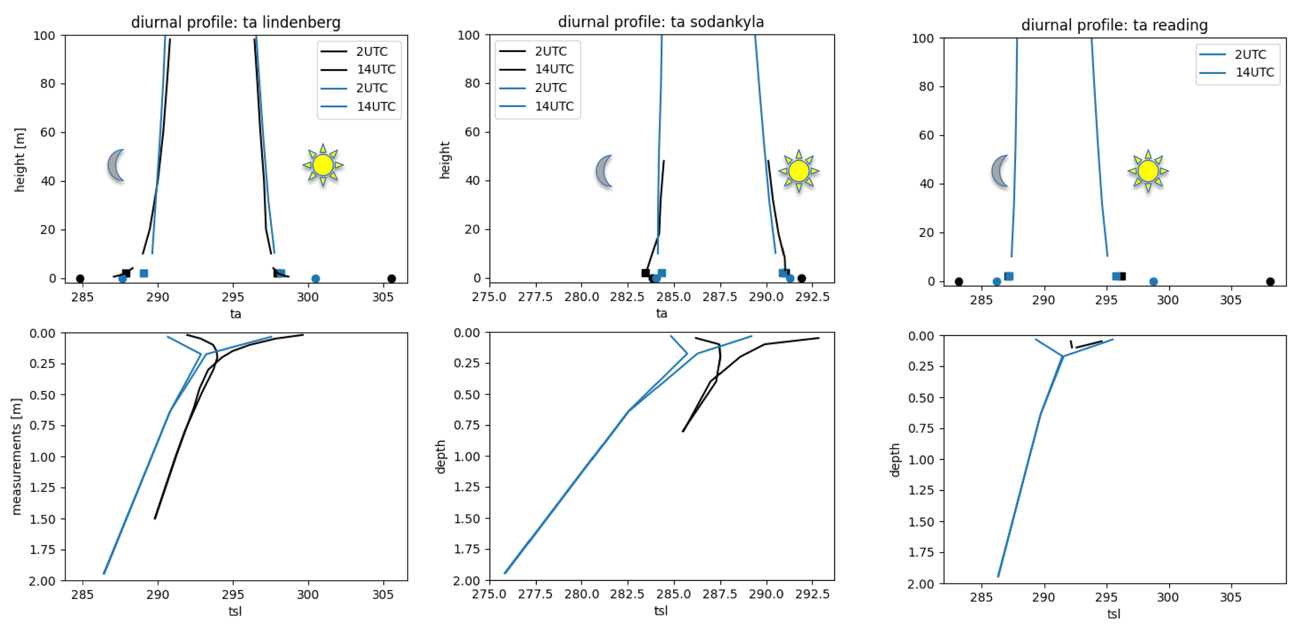
Recent years have seen an increase in the use of supersite data at ECMWF to enhance evaluation activities and provide insights into the causes of forecast error related to the atmospheric boundary layer and land surface processes to achieve ECMWFs main goal of continuously improve medium-range forecast skill for the benefit of its Member and Co-operating States. This work has been supported by the EU's Horizon 2020 programme which funded APPLICATE and INTERACTIII.

Meteorological observatories, or supersites, are locations where a broad range of variables are observed to address scientific challenges in atmospheric science. Many more variables are measured compared to the typical weather station contributing to the WMO's surface synoptic observations (SYNOP) network which typically measure a handful of variables but have a much higher spatial density (see Fig 2). As a result, supersites can help us to gain deeper understanding of weather processes and forecast errors.

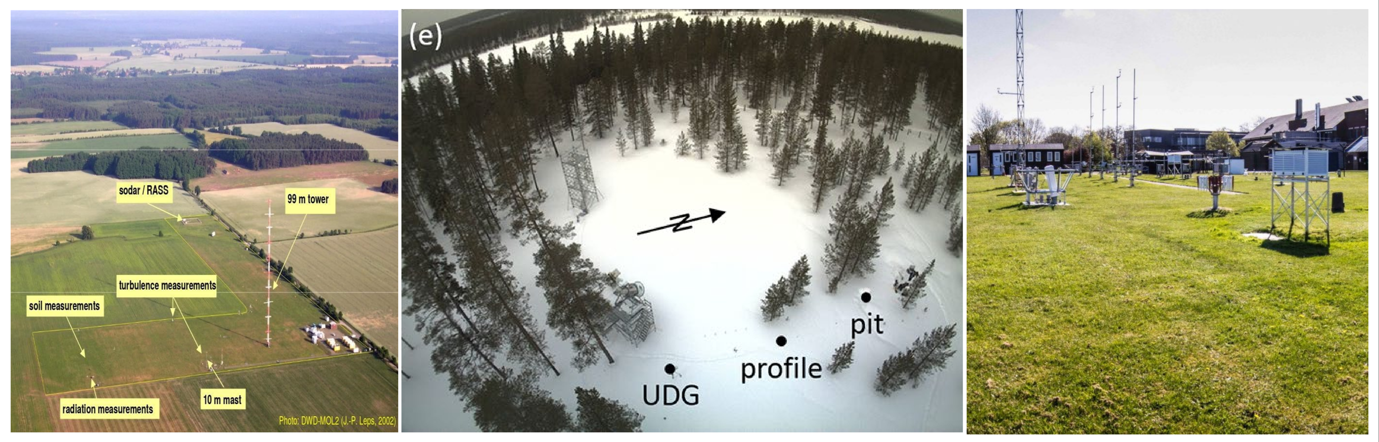


Mean minimum temperature bias for the ECMWF HRES (JJA-2022) calculated against SYNOP stations (left) and the locations of supersites contributing to the EUMETNET C-SRNWP data pool (right).

Enhanced evaluation



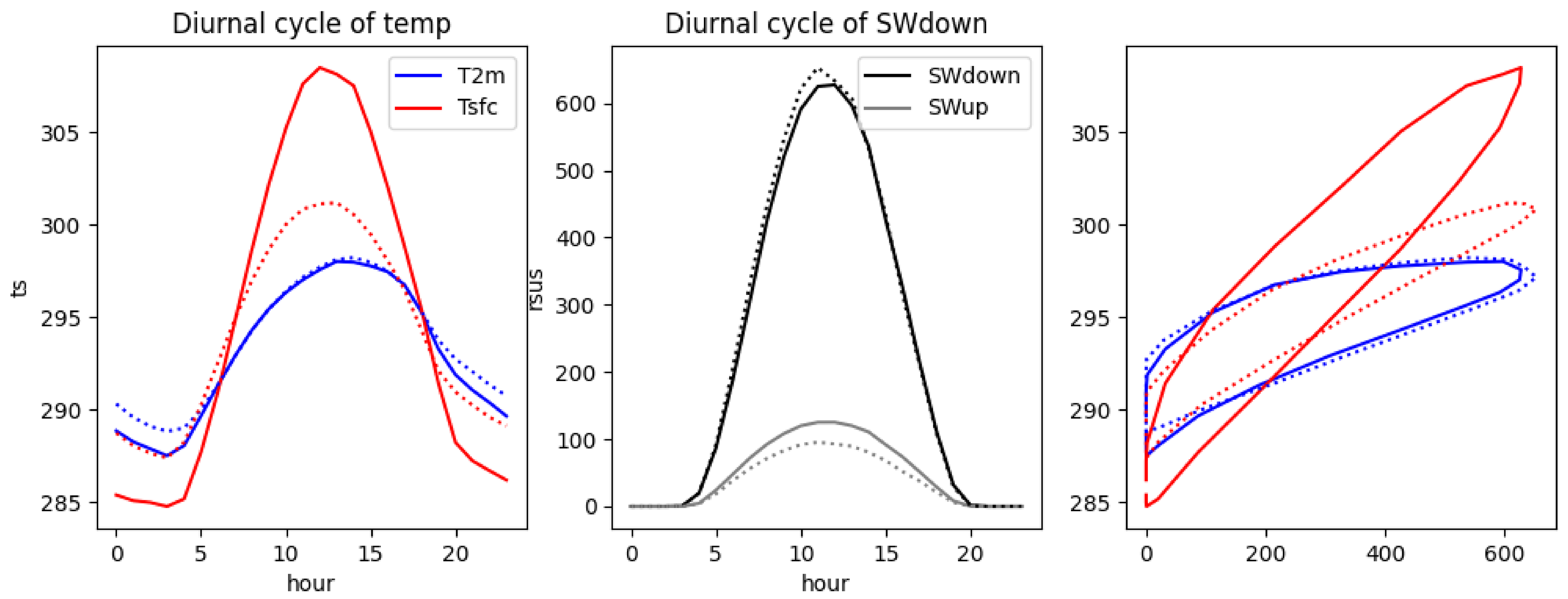
Profiles of observed and forecast air and soil temperature at 2 and 14 UTC at Lindenberg, (Germany), Sodankylä (Finland) and University of Reading (UK) for JJA 2022.



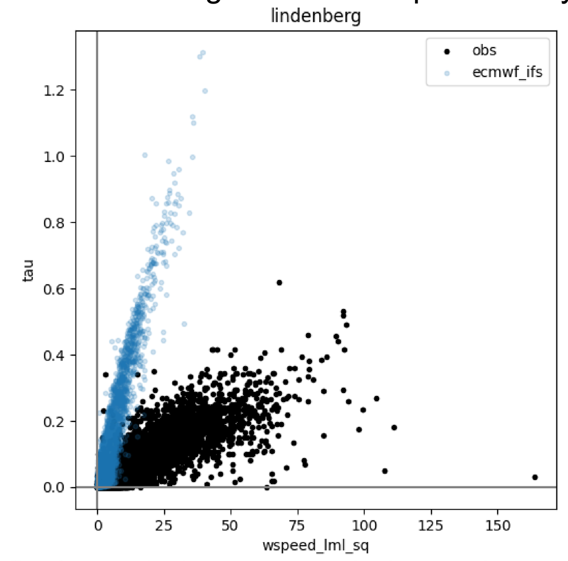
Photos of the sites at Lindenberg, (Germany), Sodankylä (Finland: from Essery et al., 2016) and University of Reading (UK).

Supersites provide data through the atmosphere, snow, soil column allowing errors at the surface to be understood in the context of the wider model environment.

Process-oriented diagnostics



Mean diurnal cycle of observed (solid line) and forecast (dashed line) temperature (left) solar radiation (middle) at Lindenberg and SW-Temp sensitivity diagram (right). Motivated by Renner et al. (2019).



Surface wind stress vs wind speed at Lindenberg. Motivated by Tjernström et al. (2005).

At some supersites radiative and turbulent fluxes are measured in addition to vertical profiles of T, U, q etc. This allows one to design process oriented diagnostics focussed on a specific phenomenon or process.

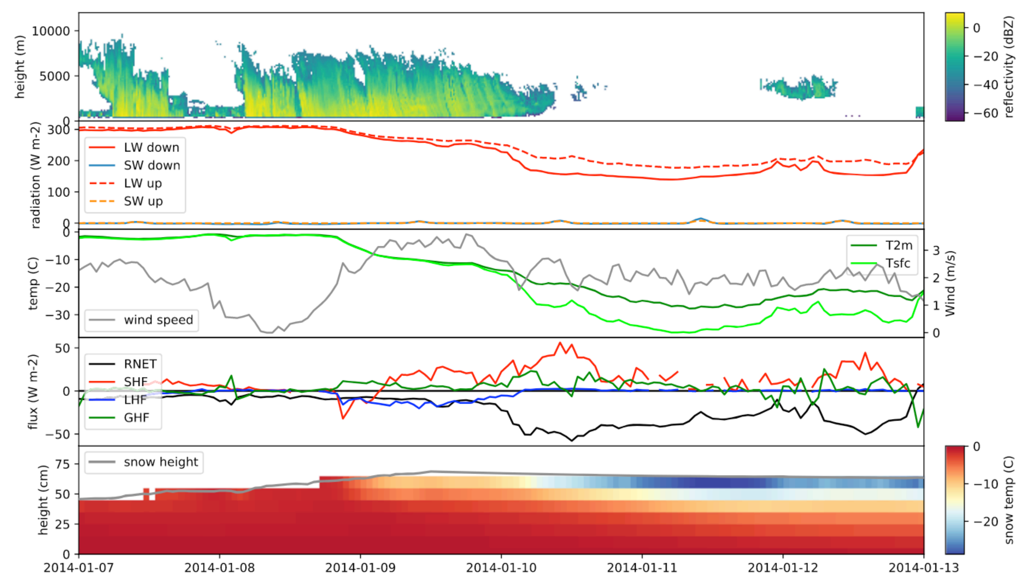
The diurnal cycle example shown above shows that the error in the underestimation of the diurnal temperature cycle is related to the surface temperature responding weakly to variations in solar radiation.

The diagnostic to the left examines the parameterization of wind stress, which is calculated according to $\tau = \rho C_M U^2$ suggests that the aerodynamic roughness length in the model is too large, although the representativity of the observations needs to be considered.

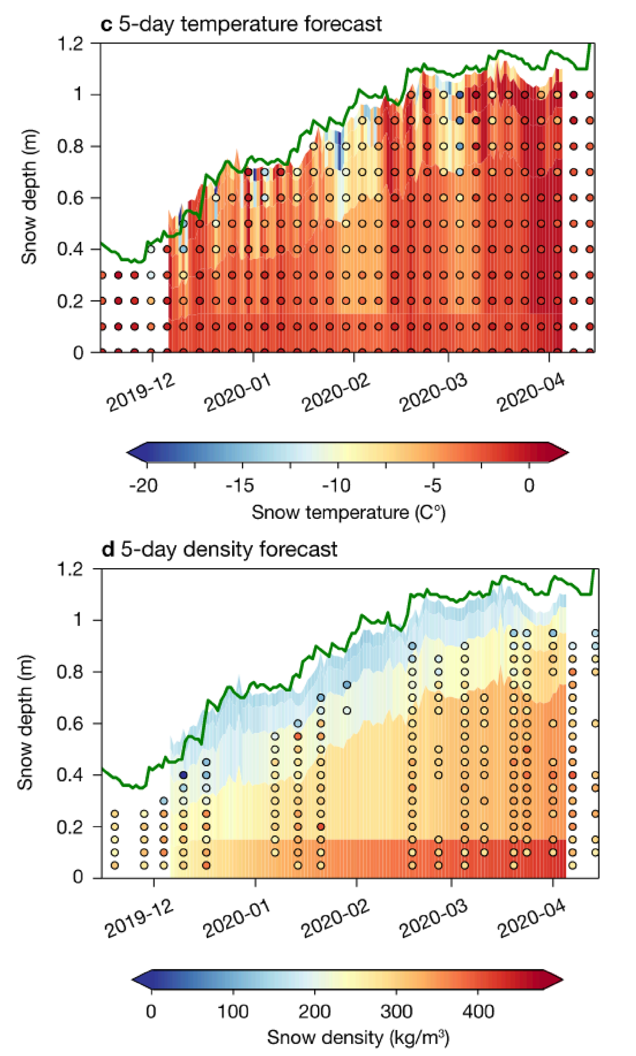
Example 1: Snow on land

Supersite diagnostics can help inform the model development process.

The operational ECMWF snow model (Dutra et al. 2010) makes use of a single-layer with a diagnostic treatment of liquid water content to represent the thermodynamics and mass balance. A refined 5-layer snow model will be implemented in the IFS to enable the thermal gradients observed in deep snow pack (see meteogram below) to be captured (Arduini et al., 2019). This is shown to improve the simulation of snow duration as it permits a more timely representation of the melting phase. It also improves near surface temperature forecasts in high latitudes

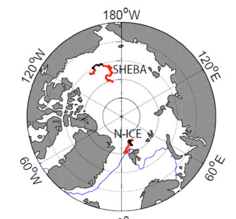


Observed meteogram for a case study at Sodankylä, Finland, in January 2014. It shows (from top-to-bottom) cloud radar reflectivity (from CloudNet; Illingworth et al. (2007)); radiation terms; wind speed, surface, and 2 m temperature; energy balance terms: Total net radiation (RNET), sensible (SHF), latent (LHF) and ground (GHF: Atmosphere snow) heat flux (with the sign convention that terms are positive when directed at the surface); and snow temperature at various heights (above the soil-snow interface). From Day et al (2020).

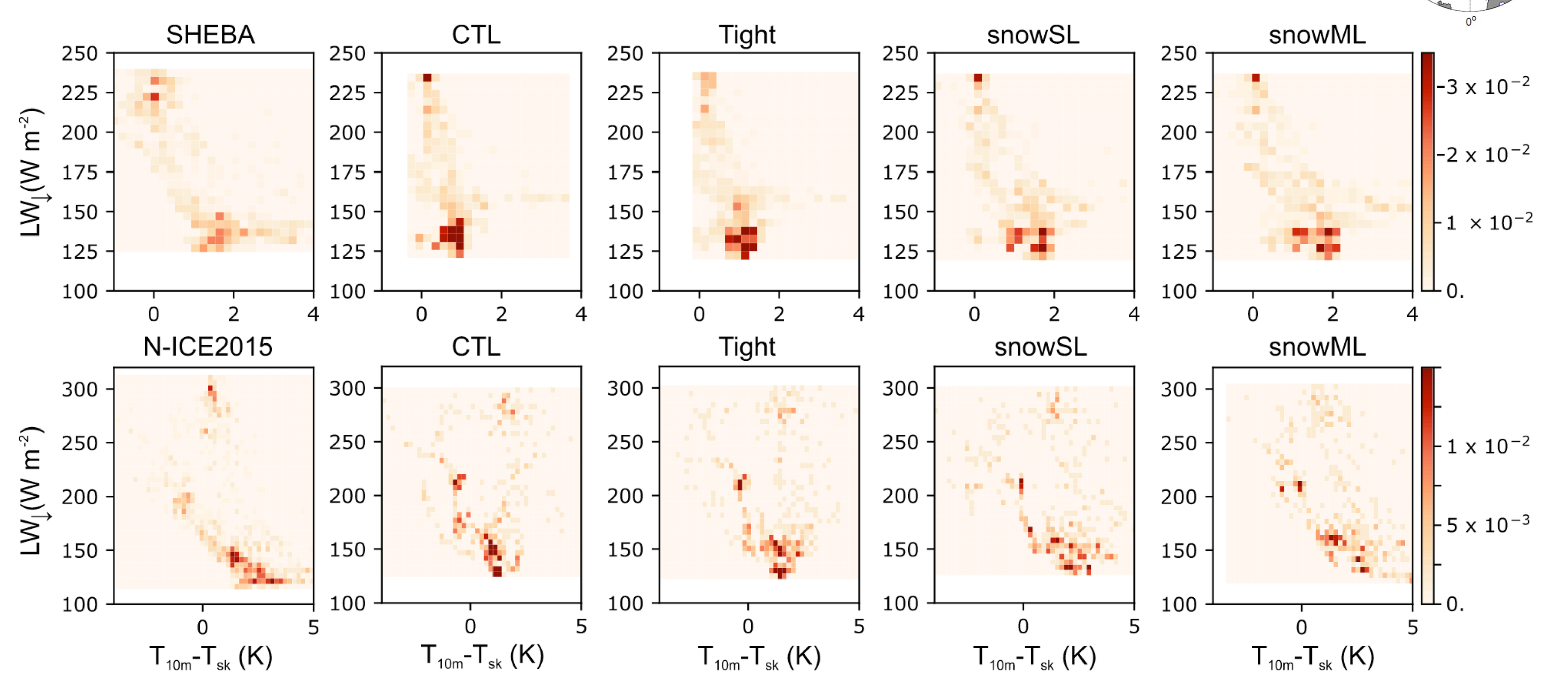


Time-height plots showing 5-day forecasts of (c) snow temperature and (d) snow density at Sodankylä, all with the multi-layer snow model (background colours) and observations (coloured dots, courtesy of FMI) for the 2019/2020 season. From Sandu et al. (2021).

Example 2: snow on sea ice



Field campaigns, involving drifting observatories on sea ice (such as SHEBA and N-ICE2015) perform a critical function allowing us to test different coupling options for the sea ice.

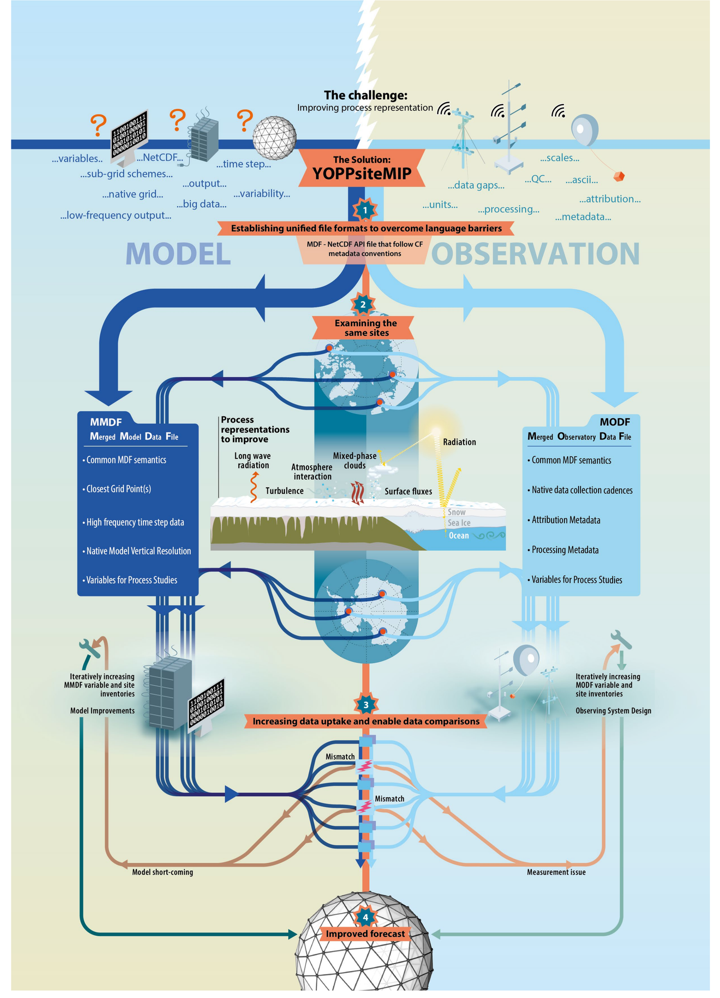


Histogram of downwelling longwave heat flux at the surface and inversion strength, defined as the difference between T10 m and Tsk, for SHEBA (top row) and N-ICE2015 (bottom row) and from the coupled forecast experiments with bare sea-ice (second column), the tight coupling with LIM2 (third column), the single-layer snow scheme (fourth column) and the multi-layer snow scheme (fifth column). From Arduini et al (2022), see also Pithan et al. (2016).

Timeliness, standardisation and coordination

Although supersite data have huge potential to diagnose the causes of forecast error and inform the model development process there remain a number of barriers to their use. Although a number of observatories provide data to ECMWF directly (close to real time) there is no public, multi-site exchange that does this and a lack of standardisation in the format of data that is provided limits interoperability of evaluation software.

However, there are some networks that are working towards solution and standardisation, for example C-SRNWP, ARM, YOPPsiteMIP. The YOPPsiteMIP initiative has taken this standardisation further and put models and observations from Arctic supersites into the same file format so that evaluation of forecasts can be performed in the same way at different sites and across different models, helping to identify common issues that limit forecast skill.



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