First results of the snow-atmosphere coupling analysis in the CERISE project

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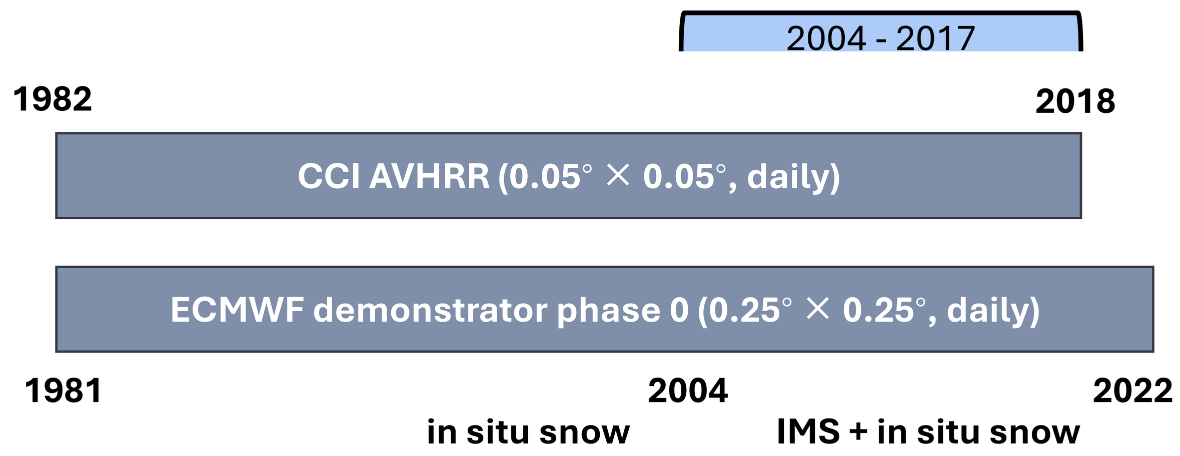
Motivation

- Snow is an important component of Earth's energy budget, hydrological and climate systems.
- Snow cover is coupled locally to the atmosphere but may also cause shifts in atmospheric circulation with potential remote climate impacts.
- It is important to study the role of snow in land-atmosphere interactions, the impacts of snow initialization on (sub-)seasonal atmospheric forecasts and the accuracy of snow forecasts.

Data

- Analysis is conducted on seasonal forecasts from the ECMWF. Phase 0 demonstrators use atmospheric and land initial conditions (including snow) from ERA5, running experiments with IFS Cycle 48R1.1.
- Snow initial conditions in ERA5 comprise assimilation of Interactive Multi-Sensor Snow and Ice Mapping System (IMS) satellite observations (since 2004) and in-situ station data (de Rosnay et al., 2015).
- The 4-month long forecasts with 25 ensemble members are run 4 times per year (months 2, 5, 8, 11). We focus on forecasts with start date 1 November.
- The accuracy of the snow forecasts is examined against snow cover fraction (SCF) observations provided by European Space Agency – Climate Change Initiative (ESA-CCI) (Solberg et al., 2021) in winters 2004 – 2017.



Methodology

Variables:
- Forecast prognostic variables: snow depth (mWE), snow density (kg/m3), 2m temperature (K).
- ESA-CCI: snow cover fraction on the ground.

Conversions:
- SD(m) = 1000 (kg/m3) * snow depth (mWE) / snow density (kg/m3);
- SCF = min(1, SD/0.1); ERA5 conversion (a layer of 10 cm represents 100% snow cover.).

Time averaging:
- Analysis is performed on data averaged in subperiods of 10-days (days 1–10, 11–20, 21–30, etc.)

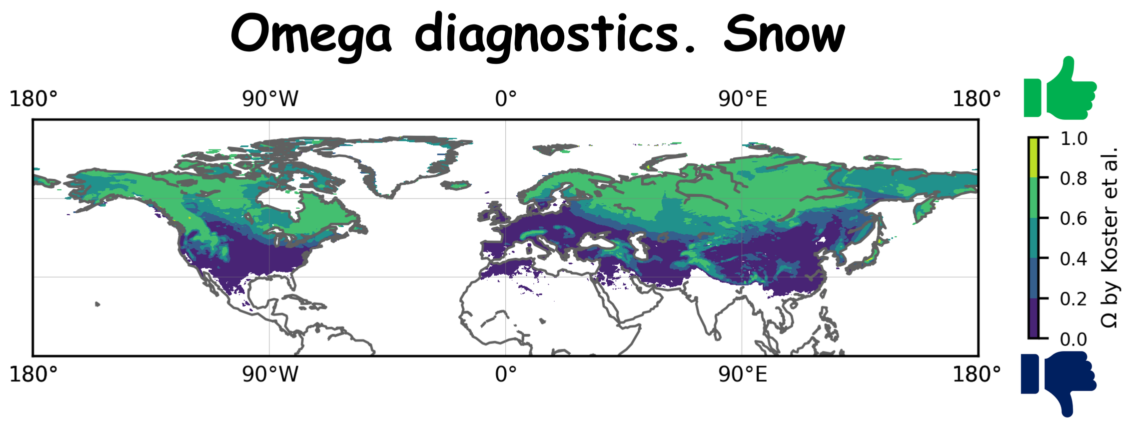
Agreement between ensemble members time series:
- Omega diagnostics (Koster et al., 2006).

Identification of snow-temperature coupling regions:
- Anomaly correlation-square.

Forecast verification vs ESA-CCI SCF:
- Bias and RMSE as a function of lead time.

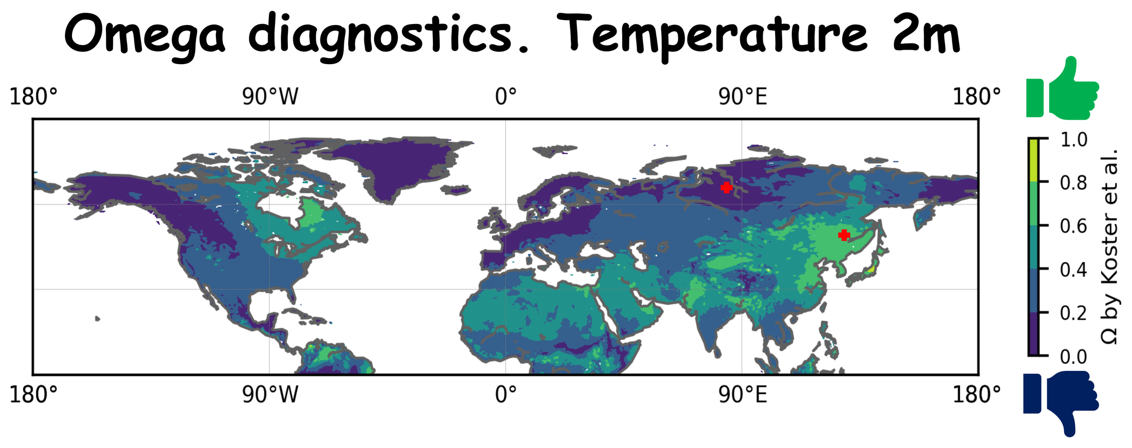
Results

Omega diagnostics. Snow

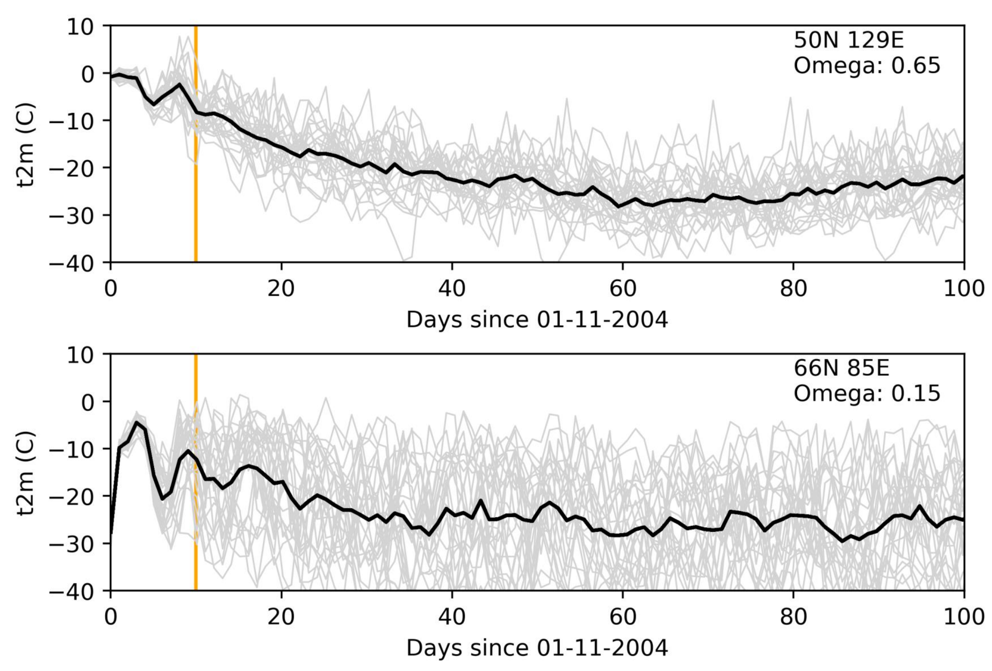


Omega diagnostics for snow depth (mWE) forecast variable over ten 10-day subperiods (first 10 days subperiod is not considered). Averaged over 2004 – 2017.

Omega diagnostics. Temperature 2m

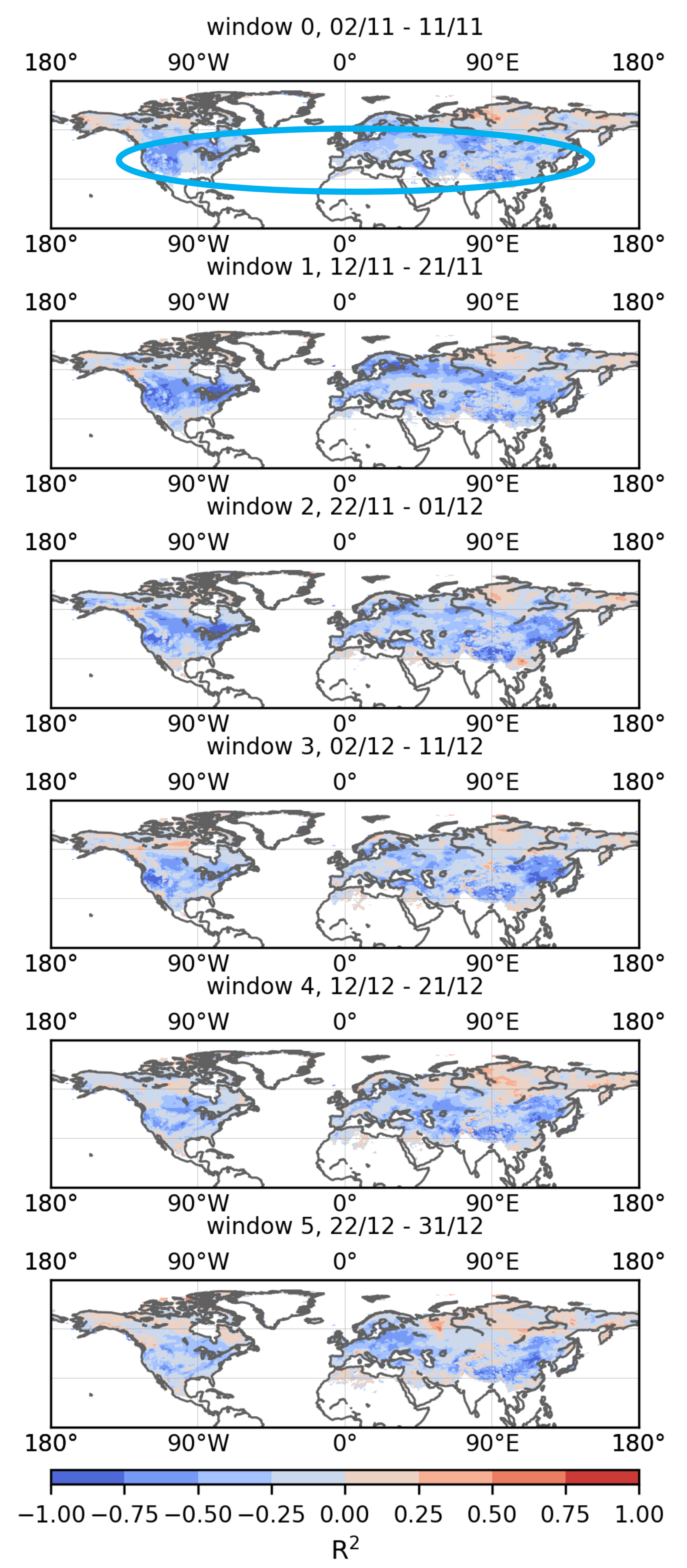


Omega diagnostics for 2m temperature (K) forecast variable over ten 10-day subperiods (first 10 days subperiod is not considered). Averaged in 2004 – 2017. Red crosses indicate locations used in the next plot.



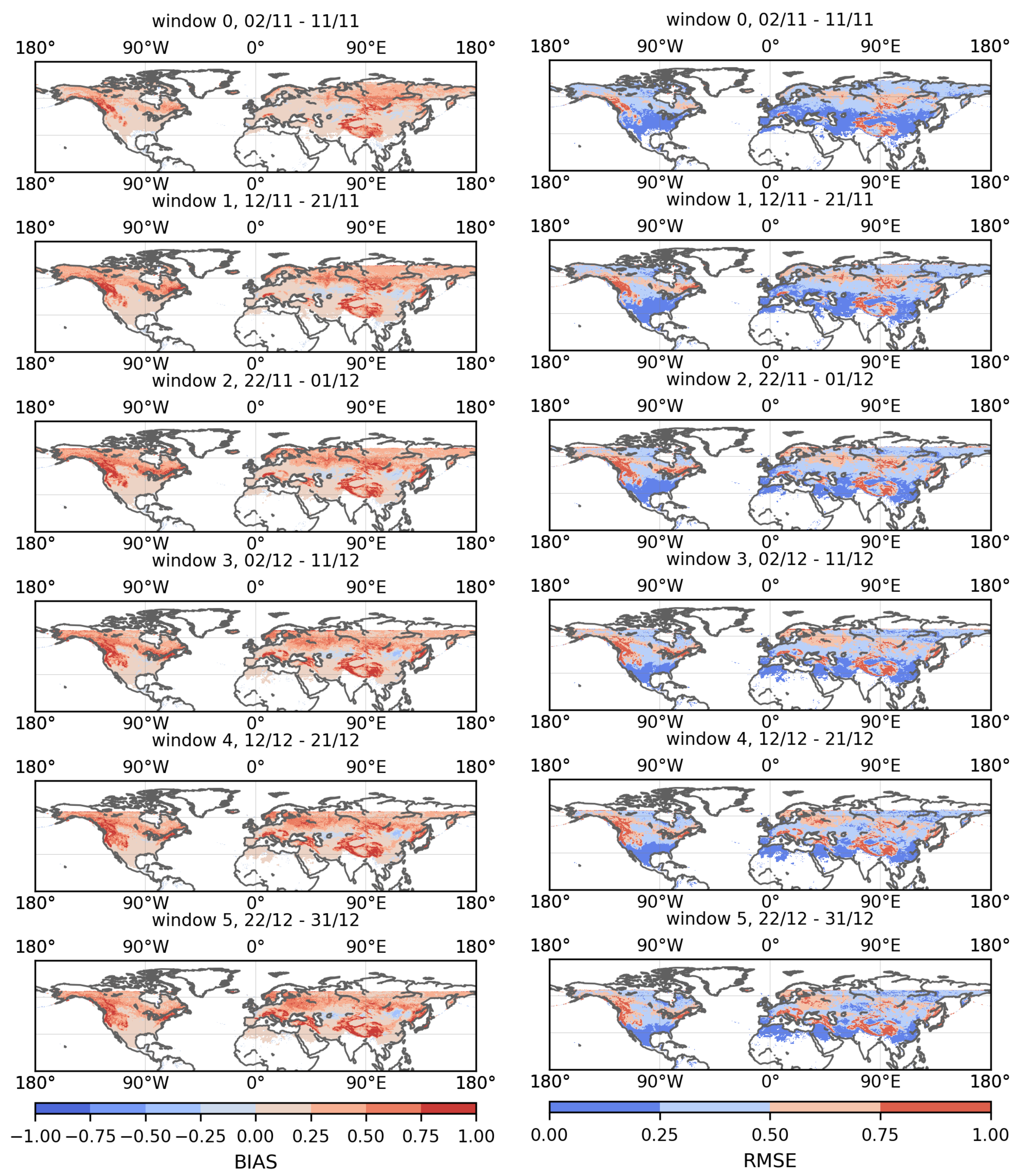
Examples of t2m forecasts for two locations with high (top) vs low (bottom) omega values in 2004.

Snow-t2m coupling in subperiods



The correlation-square (with the sign of r) between the forecast 2m temperature and snow depth (m) in 10-day subperiods in winters 2004 - 2017.

Forecast vs ESA-CCI SCF in subperiods



Bias (left) and RMSE (right) between SCF predicted by the forecast and observed by ESA-CCI in 10-day subperiods in 2004 - 2017.

Conclusions and outlook

Agreement between ensemble members (Omega diagnostic):
- Snow depth: good agreement in the snow accumulation regions while poorer agreement in the snow transition regions.
- Near surface temperature: large spatial variability with mostly poor agreement.

Snow-temperature correlation in the forecasts:
- Negative snow-t2m correlation in regions with fresh snow in early winter. Weak correlation in regions with persistent snow.
- From around 40 days lead time (as snow accumulates), more regions with near-zero correlation. Whereas snow transition regions (with high variability) still show negative correlation. These snow transition regions represent the "cold spots" of snow-atmosphere coupling (Li et al., 2019).

Snow forecast vs ESA-CCI:
- Forecast overestimates SCF in mountainous areas due to the lack of snow assimilation above 1500 m (de Rosnay et al., 2015).
- Larger bias in the regions with large snow density. Possibly due to the simple conversion between SCF and snow depth.
- Bias and RMSE increase in West Coast of USA and Europe with lead time. May indicate that snow accumulation in winter is faster in the model than in observations.

Future:
IFS cycle 49r1 has an ambition to 1) re-activate snow assimilation above 1500 m and 2) adopt a more realistic snow cover diagnostic conversion compared to a simple relation between snow cover fraction and snow depth used in the Phase 0 demonstrator.

References (APA)

1. de Rosnay et al. (2015). Snow data assimilation at ECMWF. ECMWF Newsletter, 143, 26-31.
2. Solberg et al. (2021). ESA CCI+ Snow ECV: Product User Guide, version 3.1, December 2021.
3. Li, Orsolini et al. (2019). Impact of snow initialization in subseasonal-to-seasonal winter forecasts with the Norwegian Climate Prediction Model. JGR-Atmospheres,124.
4. Koster et al. (2006). GLACE: the global land-atmosphere coupling experiment. Part I: overview. Journal of Hydro-meteorology, 7(4), 590-610.

ESA-CCI SCF from AVHRR

ECMWF IFS description

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