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Earth Explorer 12 Candidate Mission CryoRad: Innovations in Sea Ice Observations

CryoRad

CryoRad consists of a single satellite equipped with a broadband low-frequency microwave radiometer operating in the range 0.4 to 2 GHz with continuous frequency scanning. The CryoRad mission aims to produce key scientific data for advancing cryosphere studies. It will provide temperature profiles of Antarctic and Greenland ice sheets, extending from surface to base, a dataset previously available only through limited borehole observations. The mission will also address uncertainties in sea surface salinity (SSS) measurements in cold waters, overcoming limitations of current L-band radiometers. Furthermore, CryoRad will enhance estimates of sea ice thickness and -volume, and provide information about other state variables like sea ice salinity.

Simulations using ORAS6

The use of prognostic sea ice salinity in the ORAS6 ocean reanalysis allows for more realistic simulations and provides a basis for evaluating retrieval methods. In this study, we use output from ORAS6 as a reference dataset to assess the performance of different retrieval techniques, including Optimal Estimation and Symbolic Regression, across a range of ocean and sea ice scenarios. Simulated brightness temperatures are generated using a one-layer ocean–sea ice emissivity model, allowing the evaluation of retrieval uncertainty with respect to the different parameters.

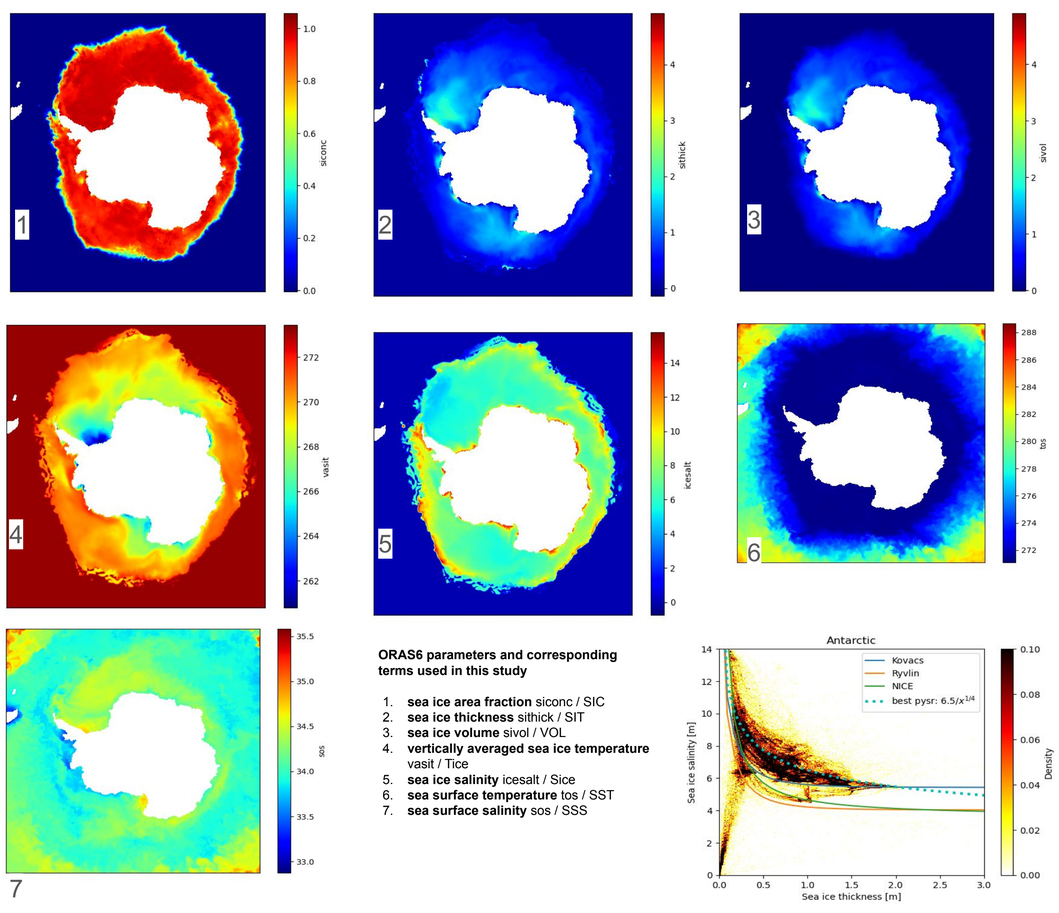

Figure 1: ORAS6 selected sea ice and ocean parameters for 15th August 2020 (daily average) and dependency between sea ice thickness and salinity.

Sensitivities and requirements

Normalized sensitivity functions derived from the emissivity model show how different surface parameters influence the measured brightness temperatures across the CryoRad frequency range, and are compared to those of the CIMR mission. By adding noise to the simulated brightness temperatures, we assess the impact on retrieval performance and define requirements for the radiometer design, including acceptable noise levels and the necessary radiometric accuracy to meet scientific objectives.

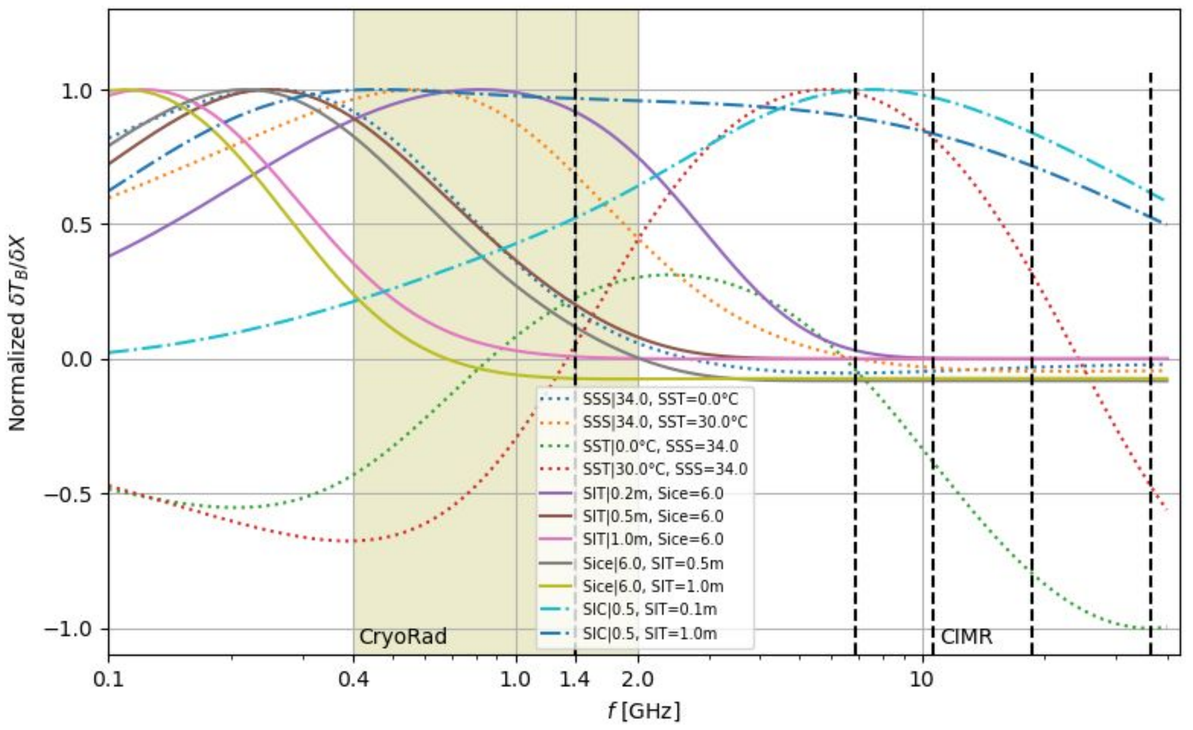

Figure 2: Normalized sensitivities of the measurements to the surface parameters as a function of frequency for the different conditions at nadir incidence angle. The frequency range for CryoRad (colored background) and channels of CIMR (dashed vertical lines) are also indicated.

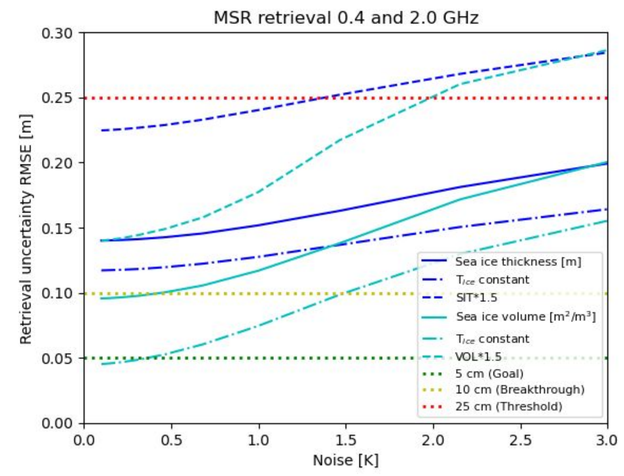

Figure 3: Estimated uncertainty in the retrieval of sea ice thickness and volume, compared with the requirements for climate data records defined by WMO (2022). Three simulation scenarios are shown: (1) using the original ORAS6 parameters; (2) replacing the ice temperature field with its mean value; and (3) scaling thickness and volume by a factor of 1.5 to account for a potentially low-biased mean thickness in ORAS6. Retrieval models for ice thickness and volume were derived for CryoRad's lowest and highest frequency channels using Multivariate Symbolic Regression (MSR).

$$\text{SIT} = 0.053 \cdot \sqrt{-1 + \frac{0.178 \cdot \exp\left(\sqrt{T_B(2.0)}\right)}{T_B(2.0) \cdot (-T_B(0.4) + T_B(2.0) - 1.218)}}$$

$$\text{VOL} = \frac{0.0008 \cdot (T_B(0.4))^{3/2}}{\log\left(-T_B(0.4) + T_B(2.0) - 0.219\right)} - 0.1695$$

Conclusions

- CryoRad frequencies are sensitive to various polar ocean and sea ice parameters.
- Retrievals using ORAS6 show that sea ice thickness and volume meet WMO uncertainty requirements.
- Two-frequency retrieval of thickness and concentration is robust (not shown).
- Ice salinity retrieval remains uncertain; further constraints are needed (not shown).

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