Synoptic variability in satellite radar altimeter-derived sea ice thickness

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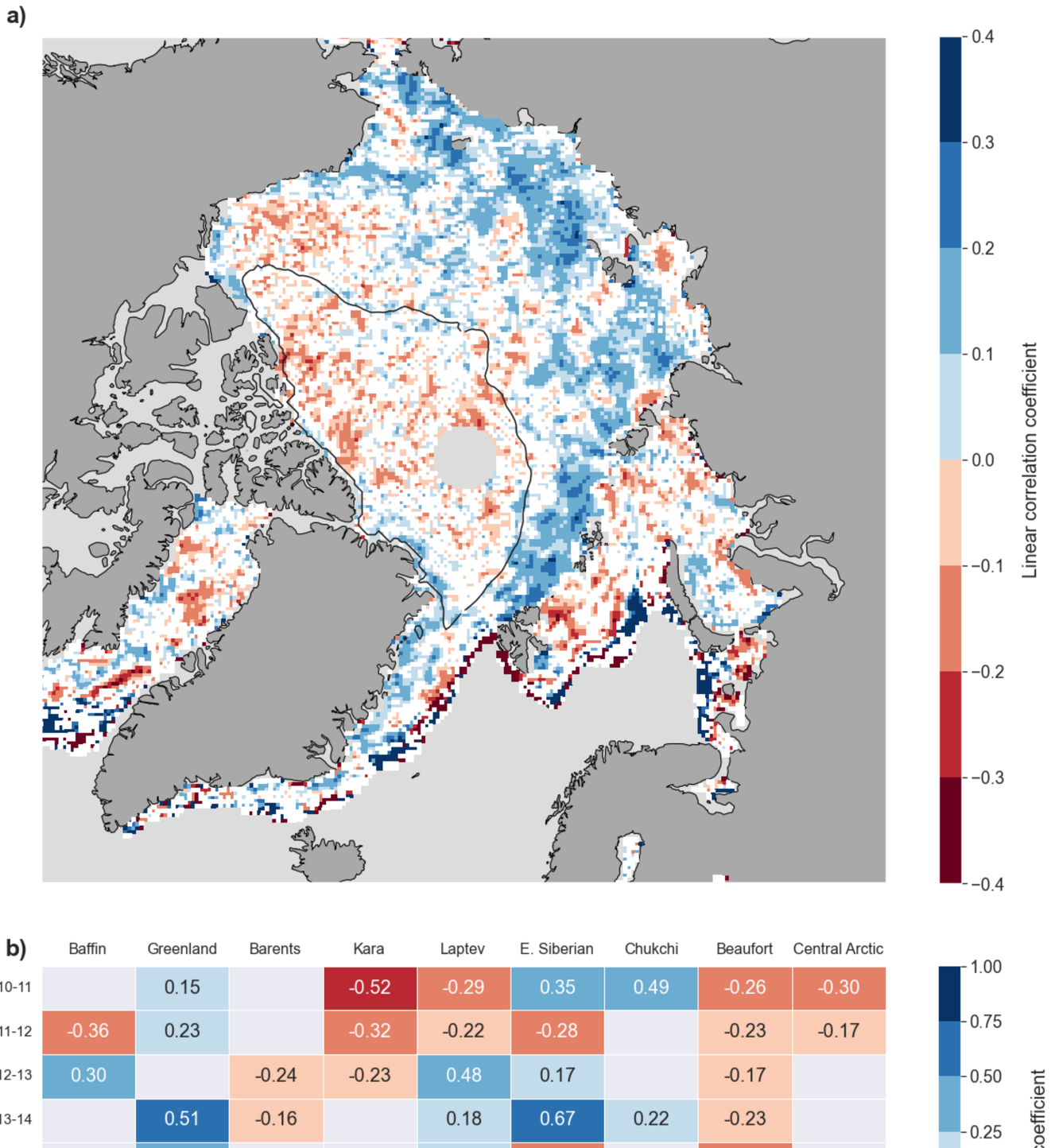
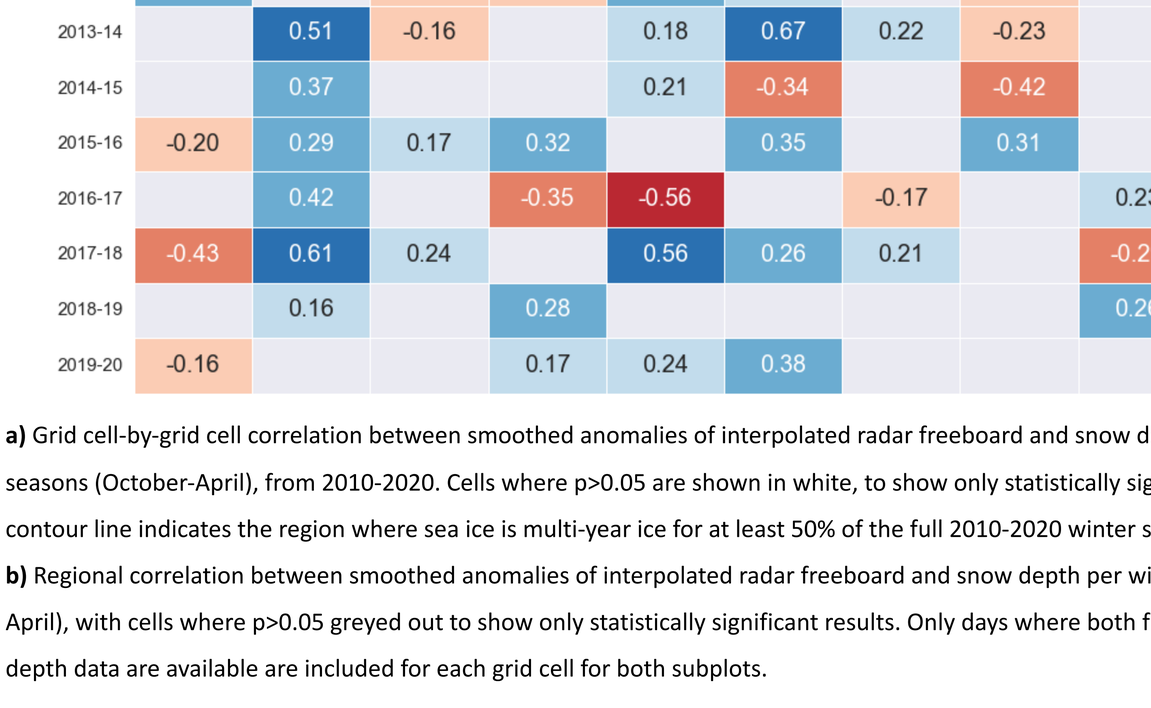


a) Grid cell-by-grid cell correlation between smoothed anomalies of interpolated radar freeboard and snow depth over 10 winter seasons (October-April), from 2010-2020. Cells where p>0.05 are shown in white, to show only statistically significant results. Black contour line indicates the region where sea ice is multi-year ice for at least 50% of the full 2010-2020 winter season period.

b) Regional correlation between smoothed anomalies of interpolated radar freeboard and snow depth per winter season (October-April), with cells where p>0.05 greyed out to show only statistically significant results. Only days where both freeboard and snow depth data are available are included for each grid cell for both subplots.



Monthly grid cell-by-grid cell dominant scattering horizon (α) for the interpolated radar freeboard over 10 winter seasons, from 2010-2020. α is the fractional depth of the snowpack where the retracker detects the elevation. Black contour line indicates the region where sea ice is multi-year ice for at least 50% of the full 2010-2020 winter season period.

Background

- Satellite altimetry data is used to estimate sea ice thickness
- All current methods assume that Ku-band radar waves travel through the overlying snow and return to the detector from the snow-ice interface, retrieving the *radar freeboard* – the distance between the altimeter and the ice surface
- If the above assumption were true, we would expect there to be a consistent, short-term negative correlation between snow accumulation and radar freeboard, as the weight of increased snow would depress the sea ice into the ocean, reducing the freeboard.
- A positive correlation would suggest the radar scatters from the air-snow interface or within the snowpack, such that the assumption does not hold true.
- The freeboard typically only makes up 5-10% of the total ice thickness, such that errors in the freeboard estimate face a 10-fold magnification in the conversion to thickness.

Methods

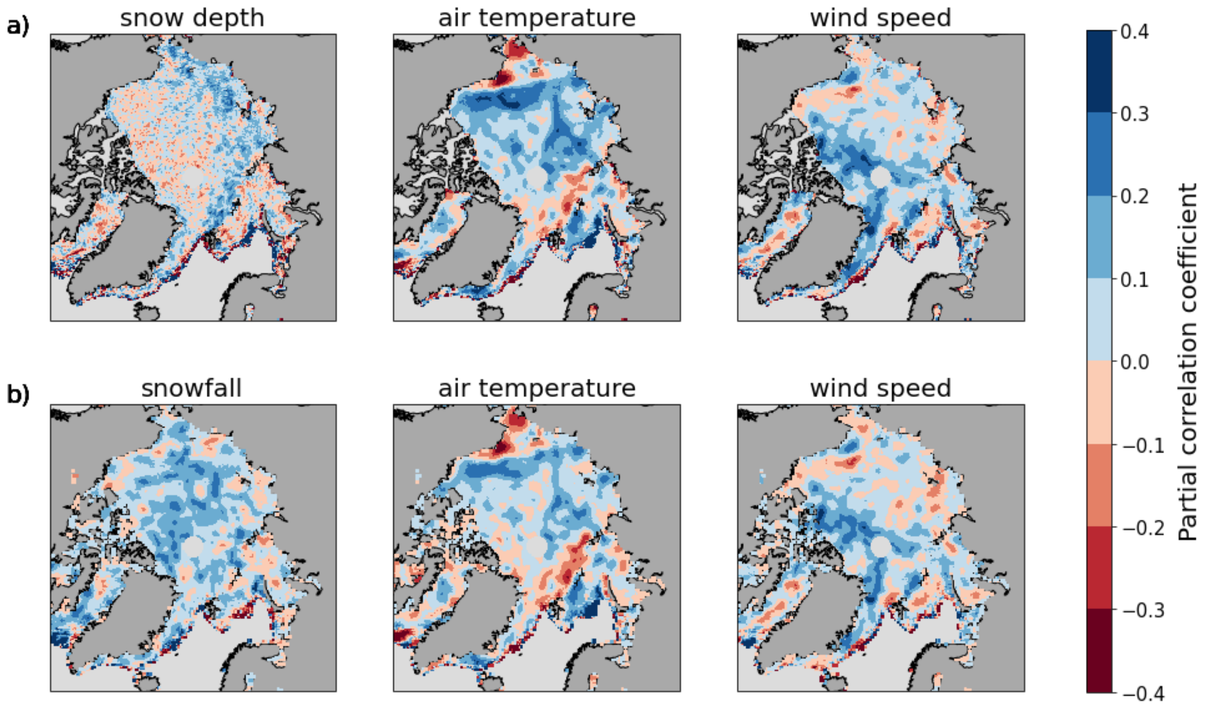
We create daily-resolution pan-Arctic radar freeboard estimates using optimal interpolation (see Gregory et al., 2021) for the 2010-2020 winter seasons.

The interpolated freeboards are compared to pan-Arctic daily snow depth from SnowModel-LG (SM-LG), air temperature and wind speed fields:

- A daily mean and a 30-day running mean was taken of each dataset for each grid cell.
- The difference between the 30-day running mean and the daily mean was taken to calculate anomalies.
- A 9-day running mean of these anomalies was taken for each dataset for each grid cell (further referred to as smoothed anomalies)
- The linear correlation coefficient is calculated between the radar freeboard and snow depth, air temperature and wind speed data.

Key Findings

- We find positive correlations between Cryosat-2 radar freeboard estimates and snow accumulation
- This means Ku-band radar waves do not always reflect off the snow-ice interface
- The radar altimeter's scattering horizon appears between the snow-air and snow-ice interface
- This may help explain the large differences between in-situ and satellite-derived sea ice thickness measurements
- The correlation varies depending on the properties of the snowpack
- These correlations can not be fully explained by the weather that accompanies snowfall



Partial correlation coefficient between smoothed anomalies of interpolated radar freeboard estimate and smoothed anomalies of **a)** snow depth, air temperature and wind speed **b)** snowfall, air temperature and wind speed for the full 2010-2020 data period. This shows the correlation coefficient between one meteorological variable and radar freeboard estimates, while controlling for the remaining meteorological variables. All cells are shown regardless of statistical significance.