Satellite based detection of snow wetness and wave-induced surface wetness of Antarctic sea ice

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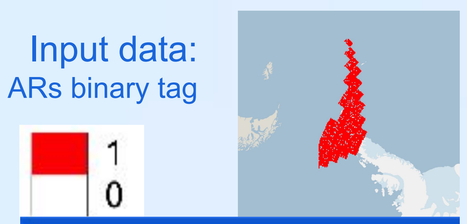
Scientific context and objectives:

Sea ice significantly influences local climate processes as well as the global Earth system. While in recent decades Arctic sea ice has been retreating consistent with global warming, Antarctic sea ice showed an unexpected pattern: increasing until 2014, then sharply declining to record lows by 2023 [9]. This change underscores the need to explore the relationship between sea ice and ocean/atmospheric forcing especially, within the Marginal Ice Zone (MIZ) - a dynamic area between open ocean and dense sea ice. Our research specifically targets the influence of atmospheric rivers (ARs) on sea ice and snow within the low-concentration MIZ, to better understand these interactions in regions most affected by the ocean [1].

Atmospheric Rivers Interaction with Low-Concentration Marginal Ice Zone:

ARs are extreme events in the form of narrow corridors of highly concentrated water vapor that transport water from the tropics to polar regions [2][3].

Input data:
ARs binary tag



- 3-hourly timestep ERA5 reanalysis dataset [6].
- AR detection algorithm based on 98th percentile of monthly integrated water vapor (IWV) from Wille et al. 2019
- Binary tag from grid cells between *45° and 80°S* with a *25 Km x 25 km* spatial resolution

ARs and melting:

ARs trigger sea ice melting trough:

a. Longwave radiation
b. Adiabatic warming due to föhn winds.
c. Intense snowfalls leading to sea ice overloading and subsequent wetting of the snow.
d. Heavy rainfall (more prevalent in summer).

These processes may result in formation of melt ponds and polynyas [4].

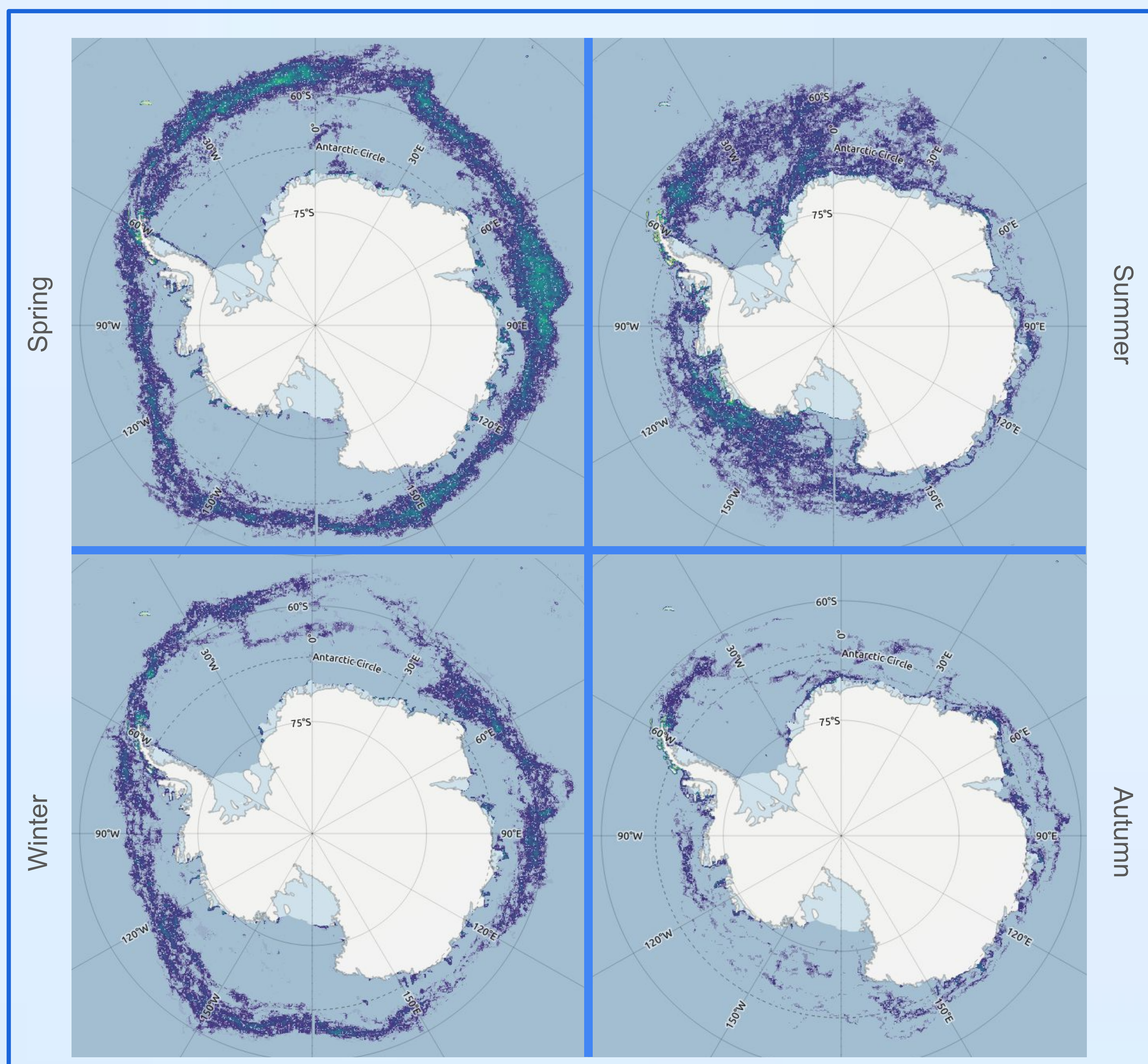


Figure 1: *Localization of the seasonal interaction of the ARs in the low-concentration MIZ over 16 years (2003 – 2010 & 2013 – 2021).*

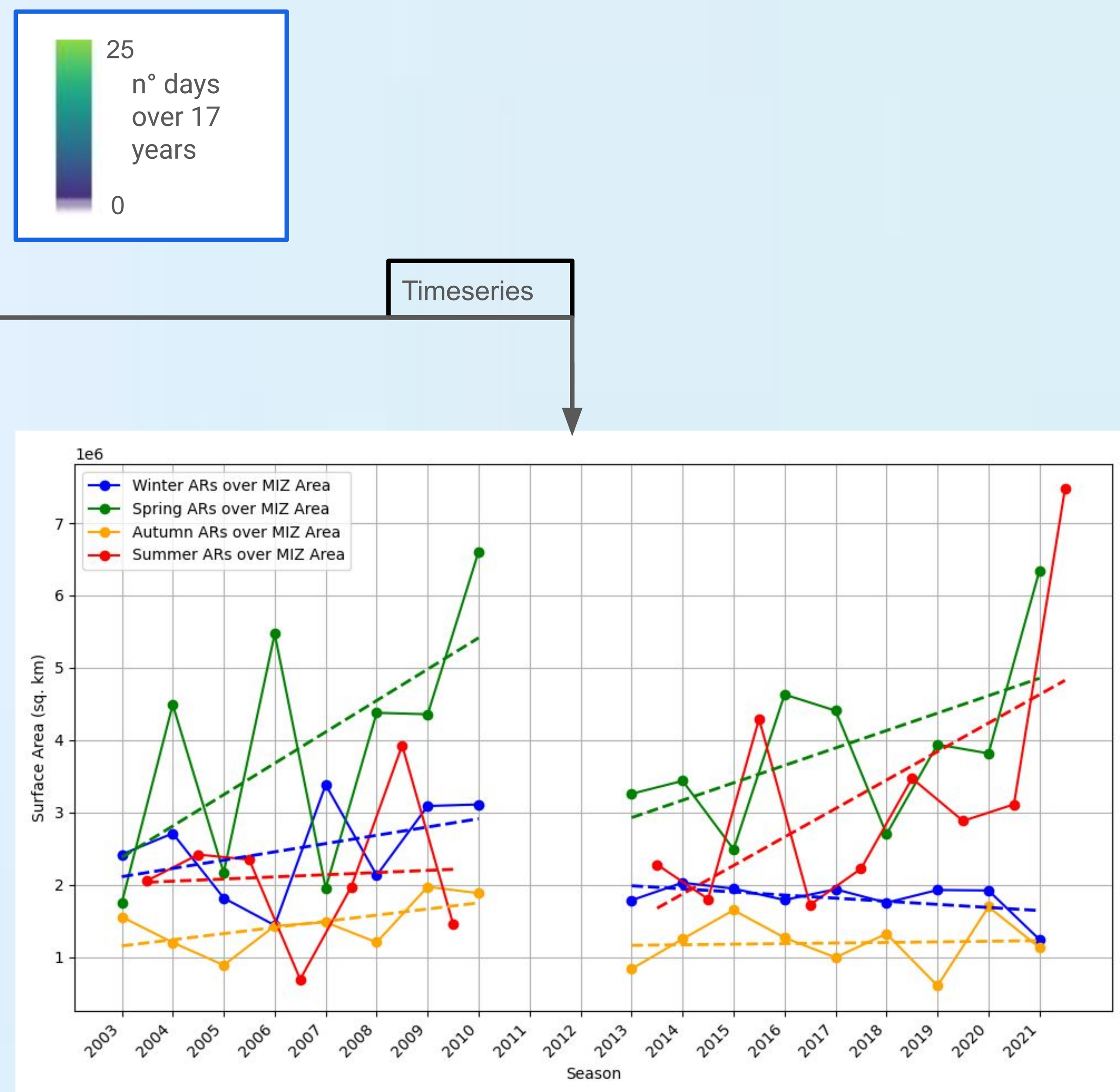


Figure 2: *Seasonal timeseries of the surface area affected by ARs events over the low concentrated MZ for the 17-year time frame.*

Methods: See Fig.1, 2.

- ➢ We define an event as when an atmospheric river is coincident with a pixel (12.5 km² [8]) of the low-concentration MIZ (defined in this case as 15%-80% SIC) [1] .
- ➢ We identified all the events over 17 years i.e.2003-2010, 2013-2021. (Temporal gap due to transition from AMSR-E to AMSR2 satellite).

Statistics of ARs: See Fig.1.

- ➢ Few events per season per year (< 25 in 16 years)
- ➢ Strong winter/spring interactions further from the coast (morphology MIZ).
- ➢ Significant minimum in autumn due to MIZ reduction.
- ➢ Highest AR impact on MIZ: Winter-Spring in West Weddell Sea & East Antarctica.

Timeseries: See Fig.2.

- ➢ Increasing AR impact trend in summer and spring.
- ➢ Increased MIZ-AR interaction tied to documented [2] rising ARs in Western Antarctica.

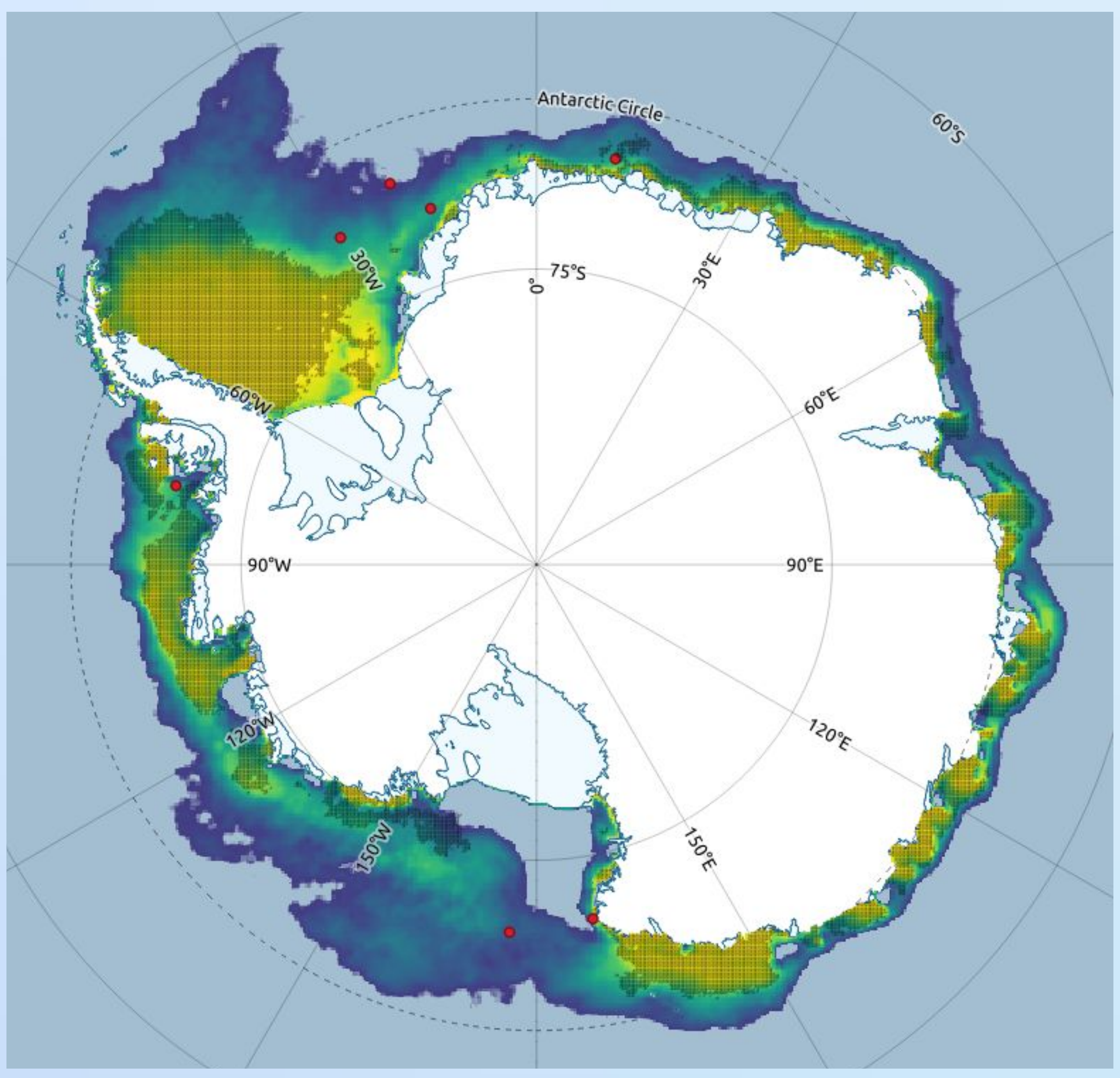
Detecting Melt in Low-Concentration MIZ:

To assess the extent to which atmospheric rivers affect melting, an algorithm is needed to detect it through the microwave signature in the low-concentration MIZ.

Data and Method:

Melt detection algorithm based on Arndt et al. (2016) [5]:

- January mean SIC from ascending orbits (2013-2022) [7][8].
- Computation of the Cross-Polarized Ratio (XPR = 19H/37V) and setting of the melt threshold at 1.
- Checked for pixels in which this threshold was surpassed within the MIZ (15-80%), then expanded the analysis to include sea ice with up to 100% concentration.



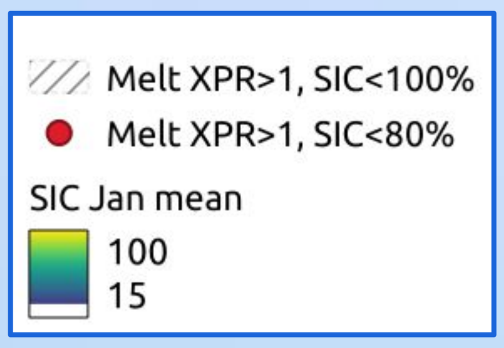


Figure 3: *Effectiveness of melt algorithm (XPR>1) applied to two different SIC areas (15-100)% and (15-80)% over the time window 2013-2022 in the months of January.*

Melt detection: See Fig.3.

- ➢ This method successfully identifies melt events in areas where the average SIC is close to 100% (visible in the black dashed area).
- ➢ When the SIC limit is set to 80%, the algorithm detects only a few locations of melt episodes over 10 years during January - a period when extended melting definitely occurs (visible in the few pixels highlighted by the red dots).

Conclusion:

- It remains a challenge to determine the impact of ARs on low-concentration MIZ.
- New algorithms are needed to detect melt through the microwave signature in the low-concentration MIZ that are robust to brightness temperature of the the open ocean.
- ARs' role in melting could help identify ground truth events for melt detection in the low-concentration MIZ.

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Co-funded by the European Union

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