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Vertical structure and surface impact of atmospheric rivers reaching Antarctic sea ice and land

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Our understanding of the vertical structure of atmospheric rivers (ARs) in the Antarctic is relatively poor and based on a small amount of case studies. Here we use two reanalyses and six global climate models to robustly study the profile, propagation and energy budget of ARs, which determine their impacts on sea ice and the ice sheet.

This study (in preparation) discusses vertical composites of 3 different AR categories:

- ARs reaching sea ice (SIC ARs)
- ARs reaching Antarctic land from the open ocean (Land ARs, mainly during summer)
- ARs reaching Antarctic land after being advected over sea ice (SIC+Land ARs)

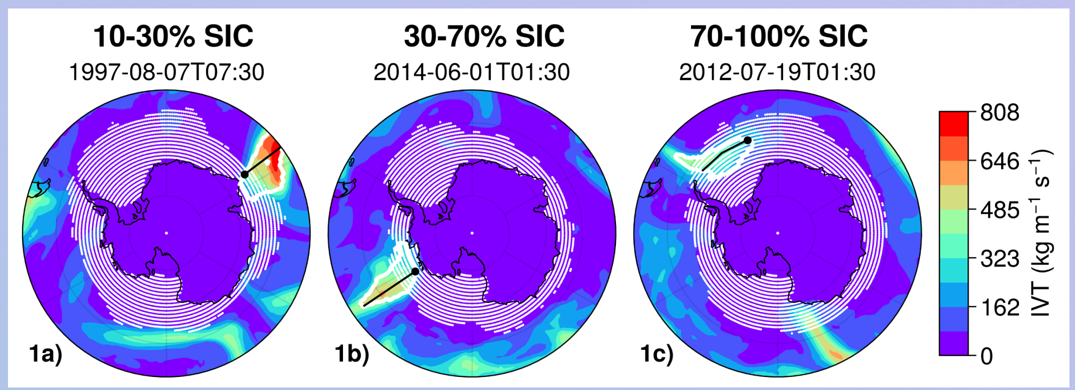
We further bin each AR category into the covered percentage of sea ice/ land in order to analyse how the vertical structure of ARs changes during the advection over sea ice and land. For a composite analysis all meridional (zonal) ARs are interpolated to a fixed length and longitude (latitude) and centered all categories around latitude or longitude 0, representing the sea ice edge or Antarctic land coastline.

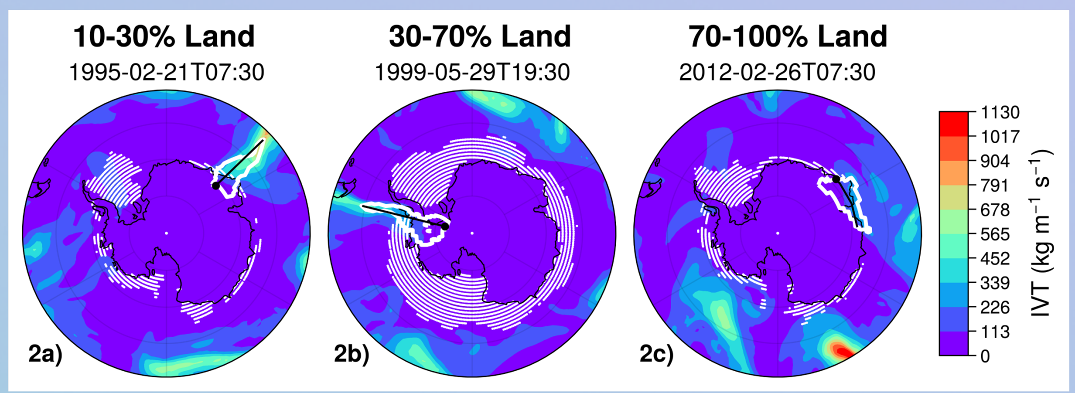
Data (1985-2014)

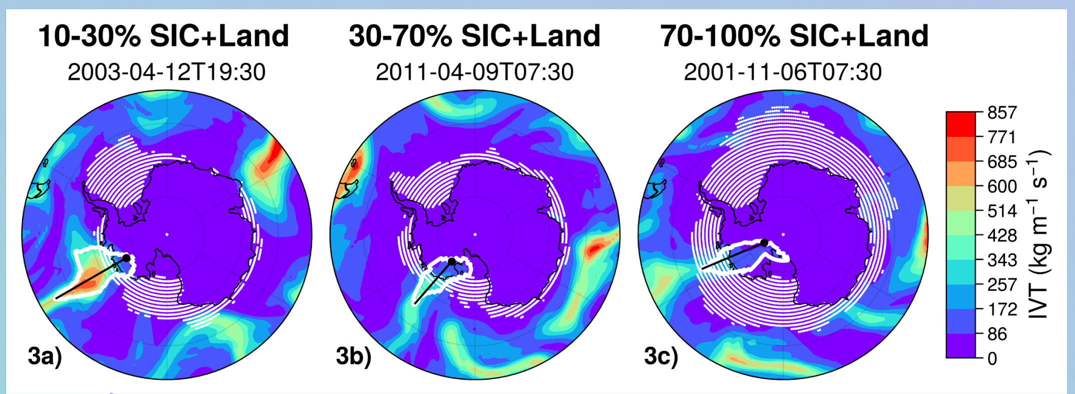
MERRA-2 | ERA5 | 6 CMIP6 Models (MPI-ESM1-2-LR, MPI-ESM1-2-HR, CNRM-CM6-1-HR, MRI-ESM2-0,MIROC6)

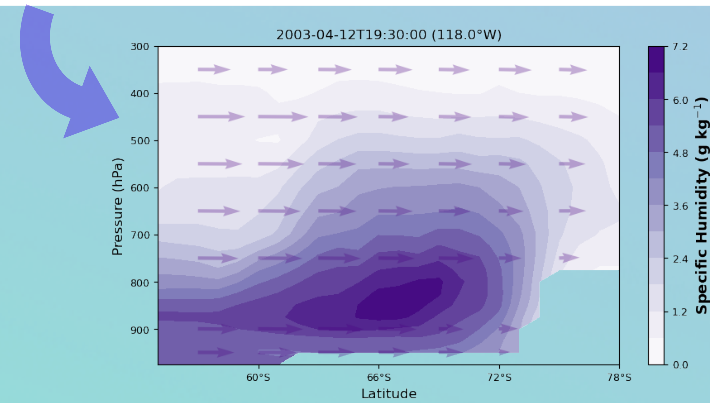
Variables: Specific Humidity, Air Temperature, Horizontal + Meridional Winds, Sea Ice Concentration, Rainfall, Snowfall, Surface Energy Fluxes, Radiative Energy Fluxes, Cloud Ice + Liquid Water Content, Potential Vorticity

AR algorithm: ARs that exceed the climatological 99th integrated water vapor transport ($IVT_{u,v}$) percentile + reach sea ice/land









- The cross-section to the left depicts an AR passing over sea ice in the Amundsen Sea before reaching the West Antarctic Ice Sheet.
- The presence of coastal sea ice limits the continued uptake of moisture and heat from the warmer ocean.
- Still, high amounts of water vapor are transported at higher levels, often resulting in strong humidity and temperature inversions.

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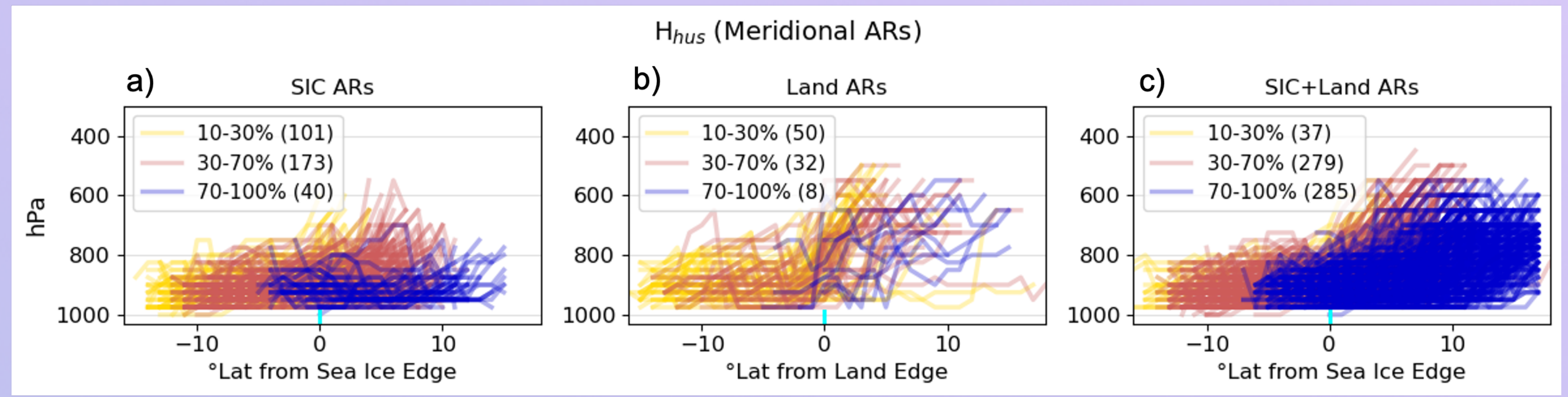
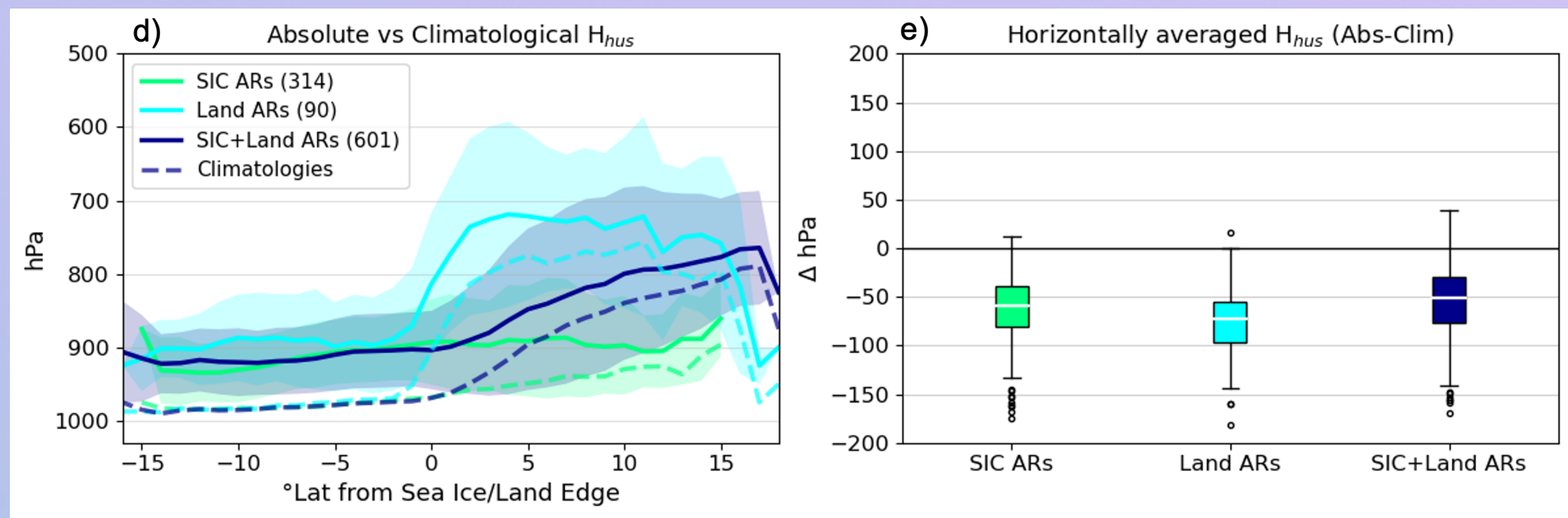
- What is the dominant vertical structure of Antarctic ARs reaching sea ice and ice sheets?
- Which meteorological conditions lead to the most severe impacts?
- How will future warming and sea ice decline influence vertical AR patterns and AR-induced melting and precipitation events? (in CMIP6 SSP5-8.5) Stay updated!





Cross-sections of pressure heights of the humidity maxima (H_{hus}) during AR events for different AR categories (a: SIC, b: Land, c: SIC+Land) and respective percentage bins (followed by the amount of ARs in brackets) for all meridional ARs. All events are interpolated and centered around 0 (=sea ice or land edge). d: As in a-c but here as the average of all combined percentages and their standard deviation (confidence intervals) for all meridional ARs. Dashed lines represent respective climatological means (30-day rolling means around each event at the cross-sections).

- Our preliminary results indicate an increased height of the humidity maximum (H_{hus}) and temperature maximum (H_{ta}, not shown) along most zonal and meridional cross-sections compared to climatological averages (~864 compared to ~923 hPa for H_{hus}; ~886 hPa compared to ~930 hPa for H_{ta}) during AR events.
- This is consistent with the concept that ARs alter the lower boundary layer by transporting very warm, moist air at higher altitudes than the usually warmer and more humid surface.
- AR events are also characterized by an elevated maximum level of the liquid and ice water path, as well as potential vorticity.
- Most ARs show anomalously high positive downward longwave, sensible, and latent heat flux anomalies (due to clouds, turbulent mixing, and enhanced mid-level water vapor) as well as negative shortwave anomalies (due to clouds blocking solar radiation).
- We are now investigating which SEB terms are most important in driving extreme precipitation and melt events, and how this is represented in the vertical structure.