Quantifying the Impacts of Atmospheric Rivers on the Surface Energy Budget of the Arctic Based on Reanalysis Data

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Motivations & Hypothesis

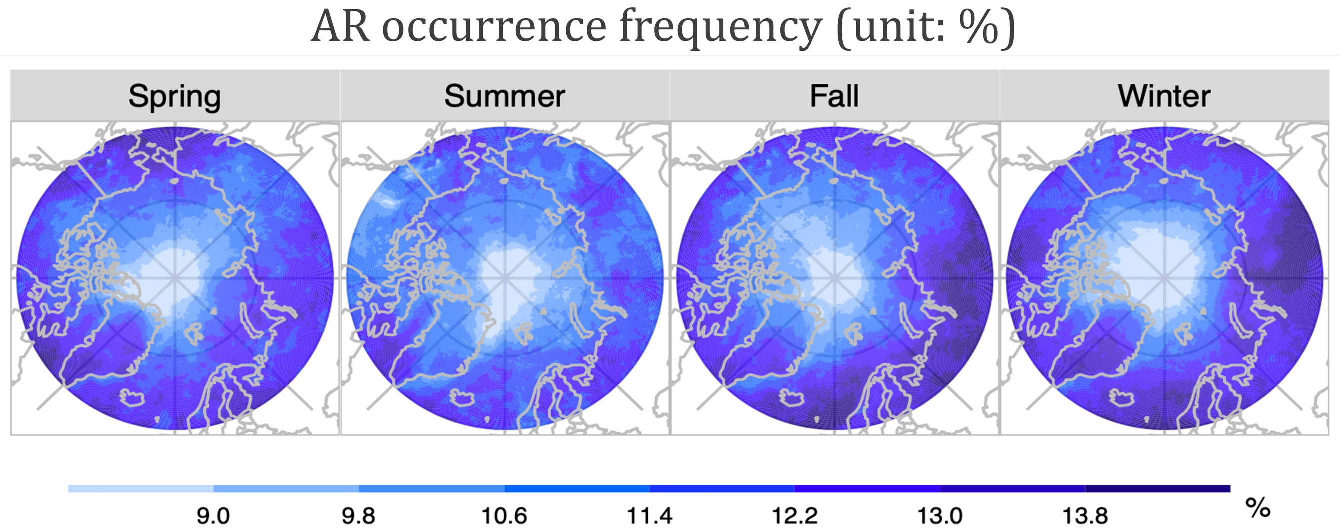
- Atmospheric rivers (AR) are long and narrow synoptic-scale pathways responsible for poleward moisture transport .
- Recent work has shown AR to be one of the factors that influence Arctic warming and sea ice decline through impacts on the surface energy budget
- We hypothesize that short-term perturbations in the surface energy budget (SEB) of the Arctic, as caused by ARs, may be of climatological significance depending on their magnitude and frequency

1. What are the spatiotemporal distributions of ARs and their associated anomalies in surface energy budget?
2. What is the total climatological contributions of ARs to the net surface energy budget of the Arctic?

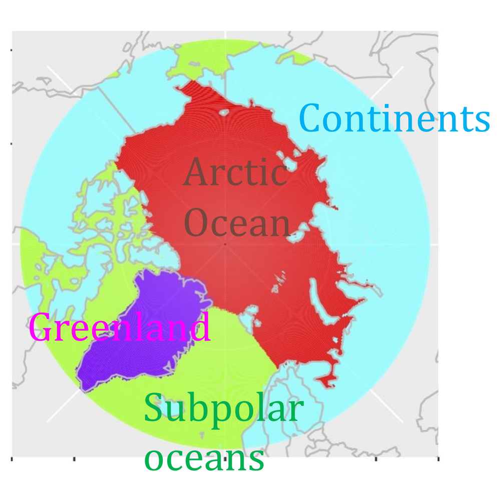
Data & AR detection algorithm

- ERA5 reanalysis data
  - 0.25° latitude x 0.25° longitude
  - January 1980 to December 2019, sampled at 3 hourly intervals
- The integrated water vapor (IVT)-based AR detection algorithm
  - IVT applied with 85th percentile of monthly climate thresholds, geometry (1500 km length & length/width>=2), and event duration (18 h) criteria

AR occurrence frequency (unit: %)



- Arctic Ocean: lowest (10.4% summer-10.8% spring)
- Subpolar: lower in summer (11.1-11.8%) and greater (> 12%) in fall, winter, and spring



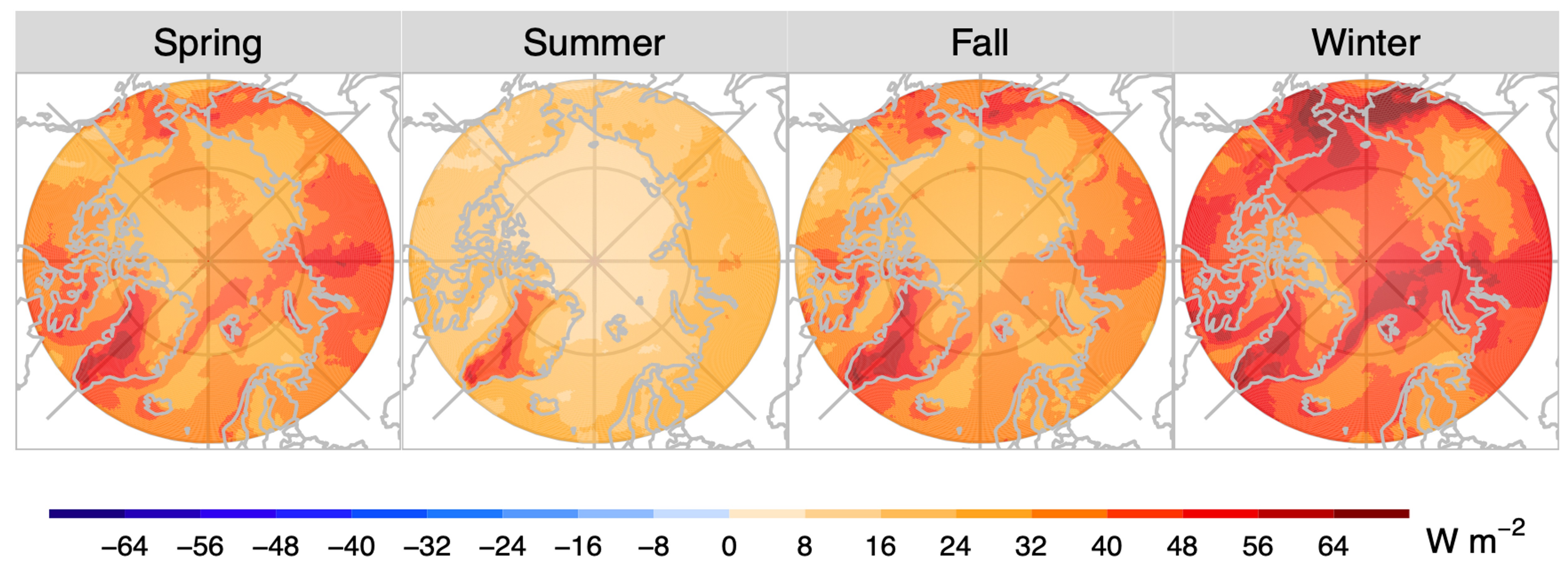
Division of regions for calculating area averages

Acknowledgement

Visiting Fellows Program

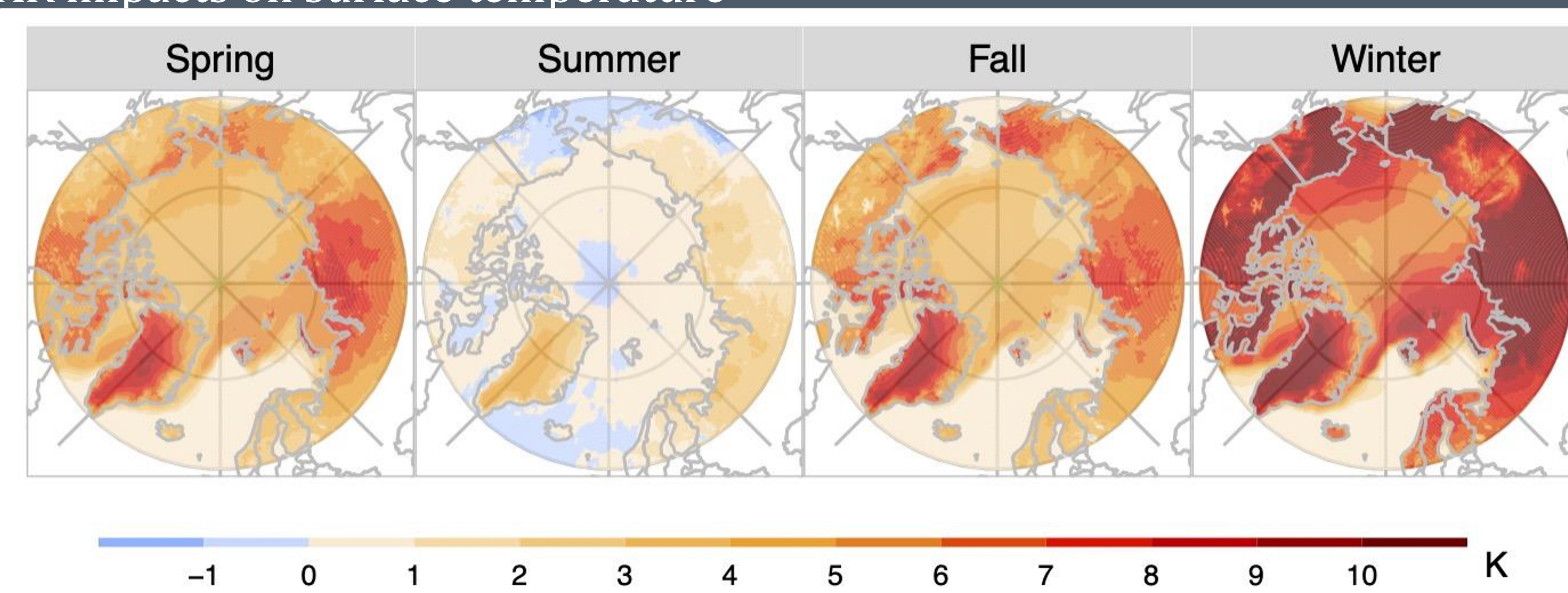
This research has been supported by the CIRES Visiting Fellows Program, funded by NOAA Cooperative Agreement NA22OAR4320151. This work contributes to the DOE HiLAT-RASM project.

Downward longwave radiation anomalies during AR events



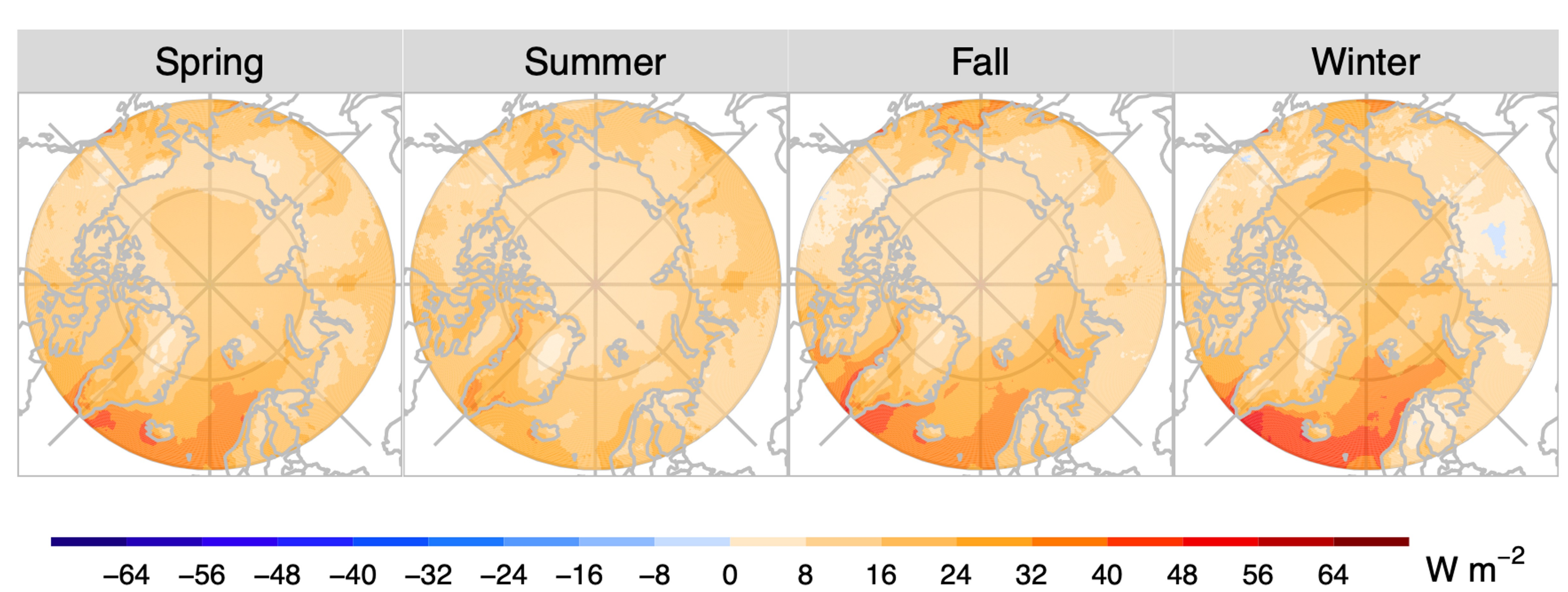
- **Winter:** Largest impacts (>=44 W m^{-2}) for all 4 regions, large impact near sea ice edge in cold seasons
- **Summer:** smallest impacts (from 15 W m^{-2} Arctic ocean to 34 W m^{-2} over Greenland)
  - **Greenland:** consistent large impact triggers melt events over ice sheet

AR impacts on surface temperature



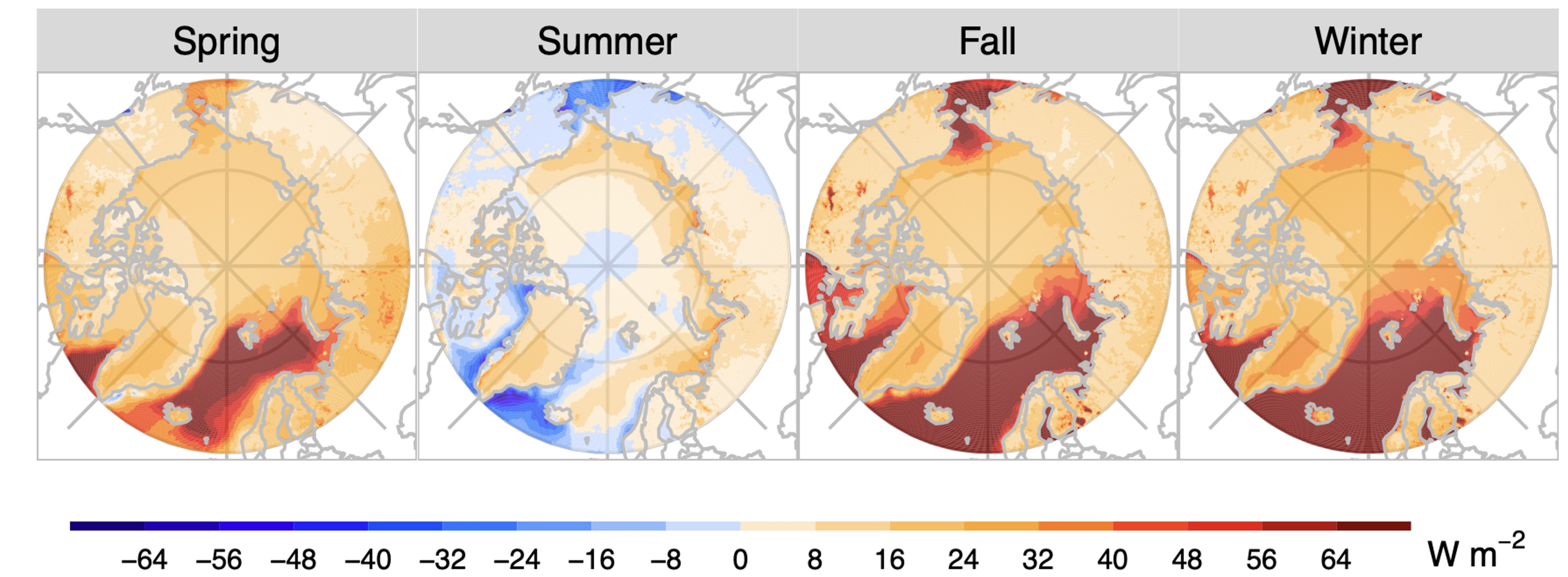
- **Winter:** largest impacts over land (>9 K), next largest over Arctic Ocean (6 K), especially near ice edge
- **Summer:** Smallest impacts over Arctic Ocean (0.1 K) and subpolar oceans (0 K)
- **Greenland:** consistent amplified warming (3-9 K) year-round
- **Subpolar oceans:** Consistent minimal impacts (0-3 K) year-round

Net Longwave radiation anomalies during AR events



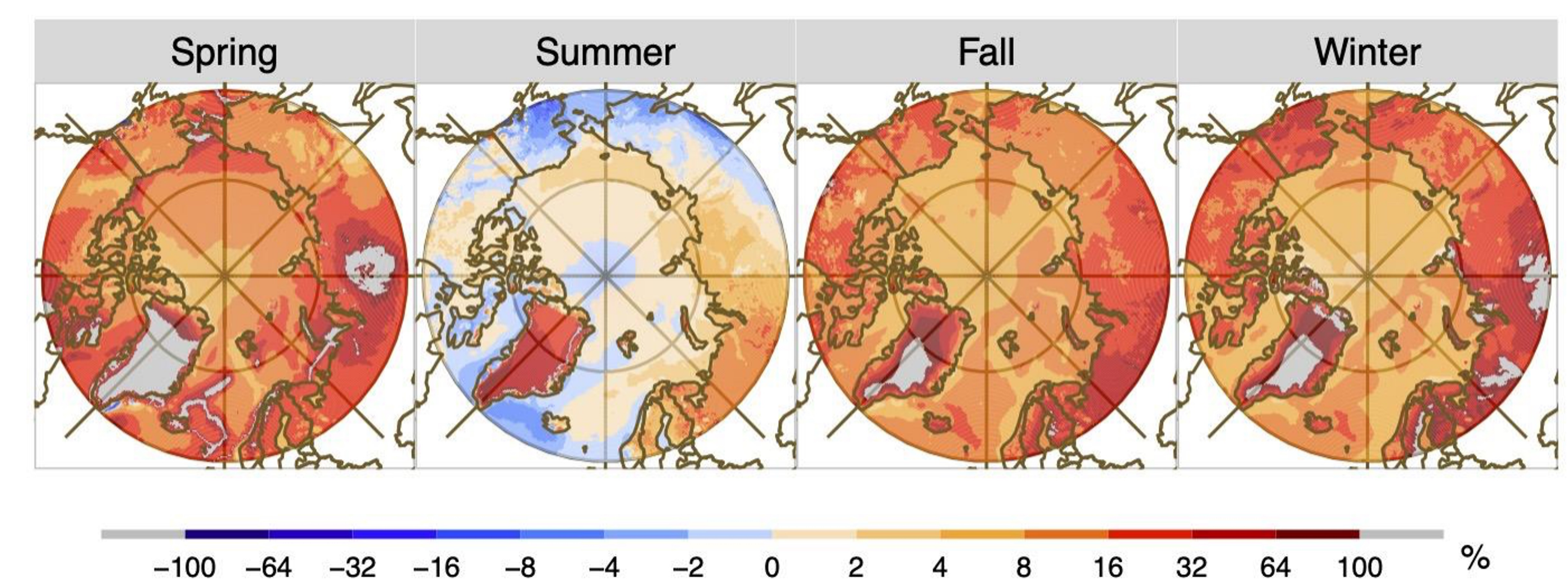
- **Winter:** largest impacts over subpolar oceans in winter (31 W m^{-2}), smallest over continents (12 W m^{-2})
  - **Subpolar oceans:** larger impact in cold seasons: smaller SST response to ARs
  - **Arctic Ocean:** next largest in winter (22 W m^{-2}): large LWD AR anomalies offset by moderate surface temperature increases and increase in upward LW

Net SEB anomalies during AR events



- **Arctic Ocean:** large impacts on SEB (26 -40 W m^{-2}) in fall, winter, and spring
- **Subpolar oceans:** large positive anomalies (40-91 W m^{-2}) in fall, winter, and spring, driven by turbulent fluxes; negative anomalies (-8 W m^{-2}) in summer driven by shortwave radiation
- **Continents:** small impacts (3-16 W m^{-2})
- **Greenland Ice Sheet:** positive net SEB anomalies (10-28 W m^{-2}) year-round : crucial for summer melting

The contribution of net SEB anomalies to mean SEB



- **Arctic Ocean:** smaller relative contribution that are less than AR occurrence frequency in all seasons (7-8% in fall/winter, 1% in summer), except for spring (32%). Local maxima over sea ice margins in spring
- **Subpolar oceans:** ranging 65 % in spring to 8-9% in fall/winter, while cooling effects in summer (-8%)
- **Continents:** largest contribution in cold seasons (spring: 90%, winter: 50%, fall: 24%), far exceeding corresponding AR frequency, while lower in summer (3%)
- **Greenland Ice Sheet:** Consistent year-round large contribution (>54%), suggesting to trigger melt

Conclusions

AR impacts on SEB reveal clear seasonality and distinct land-sea-sea ice contrast patterns:

- **Arctic Ocean:** Large absolute AR impacts on SEB and surface temperature in fall, winter, and spring, dominated by LWD. Most relative contribution to the mean SEB in spring, but negligible in other seasons
- **Subpolar oceans:** large positive anomalies fall, winter, and spring, driven by turbulent fluxes and large relative contribution to net SEB in spring. Negative anomalies in summer driven by shortwave radiation with weak contribution.
- **Continents:** smaller absolute anomalies in net SEB, but substantial relative contribution to the mean SEB, particularly in cold seasons.
- **Greenland Ice Sheet:** large AR impact and amplified surface warming year-round, crucial for summer melt events

References

Zhang, C., Cassano, J. J., Seefeldt, M., Wang, H., Ma, W., and Tung, W.: Quantifying the Impacts of Atmospheric Rivers on the Surface Energy Budget of the Arctic Based on Reanalysis Data, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2024-320, 2024.