Impact of Atmospheric Rivers on the Arctic Surface Energy Budget

A MOSAiC Case Study during Mid-November 2019

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1. Introduction & Motivation

- Majority of poleward moisture transport occurs via Atmospheric Rivers (ARs)
- ARs are long, narrow structures that carry anomalously large amounts of water vapor and heat from the lower latitudes towards the polar regions
- Earlier studies show that ARs impact the surface energy budget (SEB) by increased sensible heat and downward longwave radiation [1,2], they can trigger melting events in the Greenland ice sheet interior [3] as well as tropospheric heating over Arctic sea ice [4] and slow the recovery of Arctic sea-ice [5]

2. Methodology

Datasets:

- ERA5 reanalysis for comparison with climatology (1979-2021)
- ICON-LAM simulations (driven by ICON Global) for sensitivity studies with 6km horizontal resolution [6], applied over the circum-Arctic domain (>65°N)

Detection of AR: Via algorithm presented by Gorodetskaya et al [7] using a threshold on the Integrated Water Vapor (IWV) amount and before the geometrical criteria application

Trajectories: Calculated with LAGRANTO tool [8]

3. AR in Mid-November 2019 - Synoptics

Synoptic Situation:

- Moisture intrusion during the period from 2019-11-15, 0 UTC to about 2019-11-16, 21 UTC, driven by low pressure system north of Greenland, with extensive high-pressure blocking to the east
- The layer of moisture maximum stays shallow (~500m ASL) when AR flows over the sea ice edge

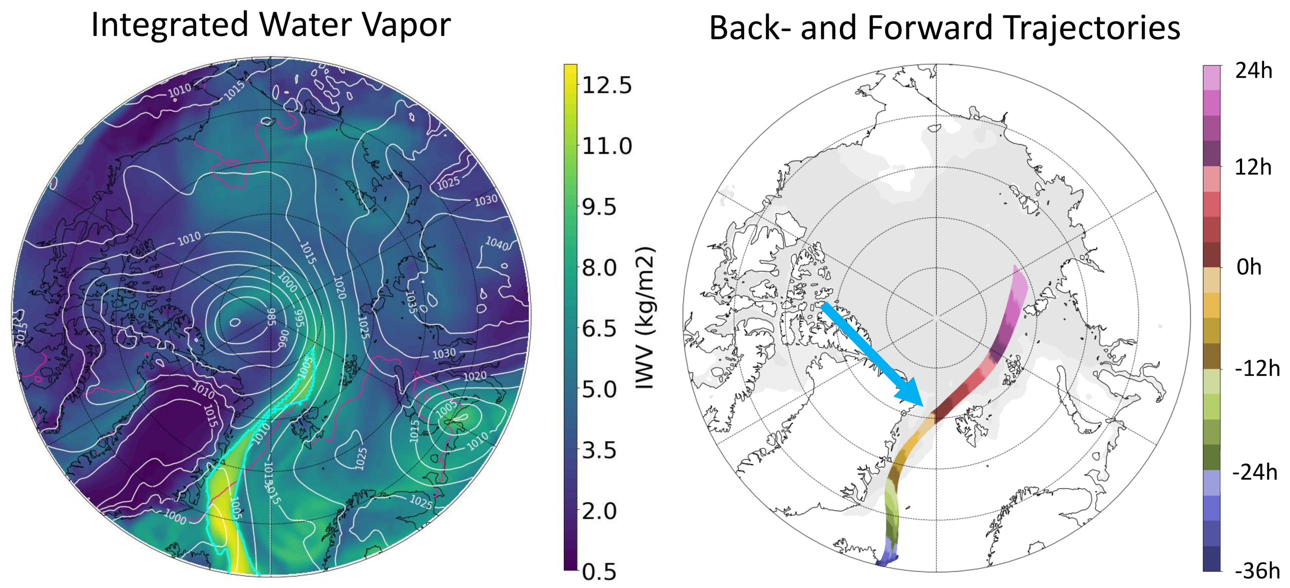


***Fig. 1: left:** IWV at 2019-11-16 12 UTC, sea ice edge (pink), mean sea level pressure (white), detected AR shape (cyan); **right:** Trajectories at height 400-600m, started at 2019-11-16 12 UTC at marked position, time of flight (colored), sea ice concentration (0.15-0.85: light gray, 0.85-1: dark gray)*

4. Impact on the Surface Energy Budget

surface energy budget (SEB) = solar radiation (=0 fall/winter case) + terrestrial radiation (LW) + sensible heat (SH) + latent heat (LH)

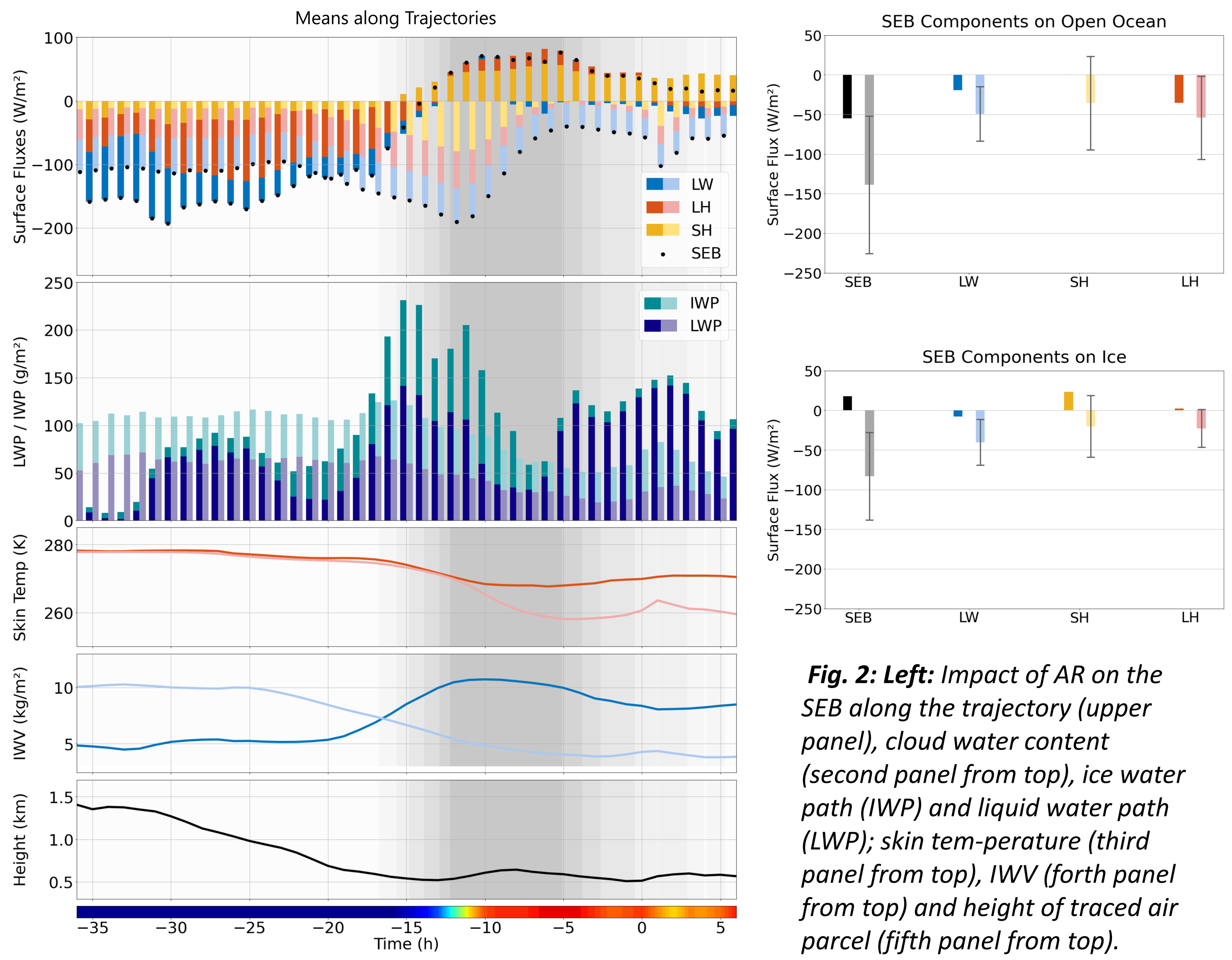


***Fig. 2: Left:** Impact of AR on the SEB along the trajectory (upper panel), cloud water content (second panel from top), ice water path (IWP) and liquid water path (LWP); skin tem-perature (third panel from top), IWV (forth panel from top) and height of traced air parcel (fifth panel from top).*

Colored bar at the bottom shows the sea ice concentration along the trajectory (blue=0, red=1). Background shading indicates whether trajectory is within the detected AR shape (white=false, gray=true). Values are means of all trajectories.

***Right:** Average of SEB components of grid points within AR shape, for duration of the event (2019-11-15 0 UTC until 2019-11-16 21 UTC), separated for grid points with open ocean (upper panel) and with sea ice (bottom panel).*

In all plots denote dark colors event and light colors the climatology, the errorbars (right panels) show the standard deviation of climatology.

5. Sensitivity Study: Altered Moisture Inflow

- **Idea:** Simulate similar AR with reduced (increased) strength by decreasing (increasing) moisture inflow at the lateral boundaries
- **Implementation - Experiments with ICON-LAM:** Modify specific humidity at all vertical levels of lateral boundary data (3 hourly) with at AR-relevant longitudes
- **Purpose:** Investigate the role of moisture for the SEB, especially compared to the effect of clouds

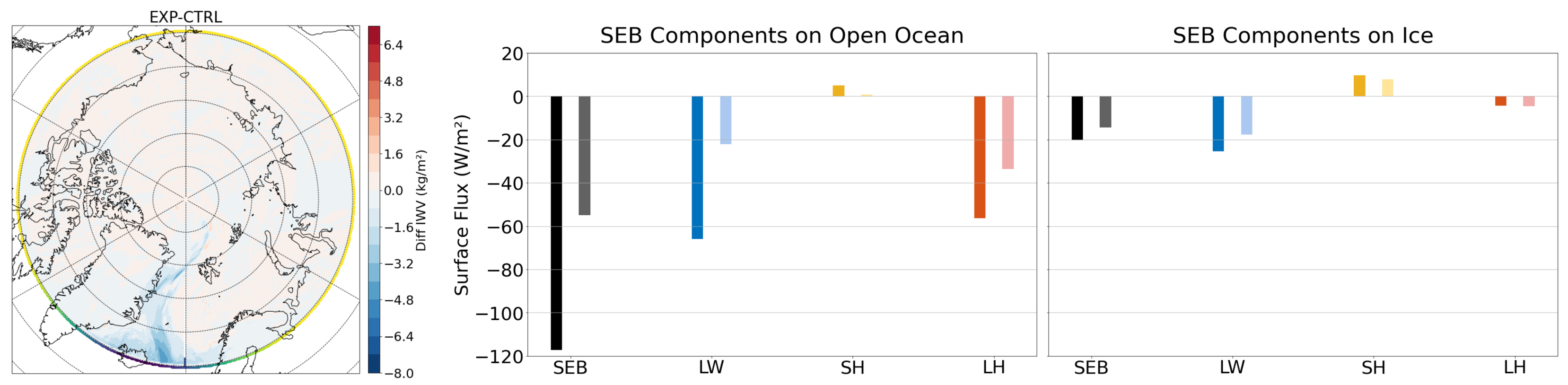


***Fig. 3:** Results of sensitivity run with reduced moisture inflow. Difference in IWV between experiment (EXP) and control run (CTRL) on 2019-11-16, 12 UTC (**left**): Colored ring at the borders show area and strength of reduction, yellow=no change, dark blue = max change of -40% inflow.*

*Average of SEB and its component for experiment (dark colors) and control run (light colors), as in figure 2, for grid points with open ocean (**center**) and with sea ice (**right**).*

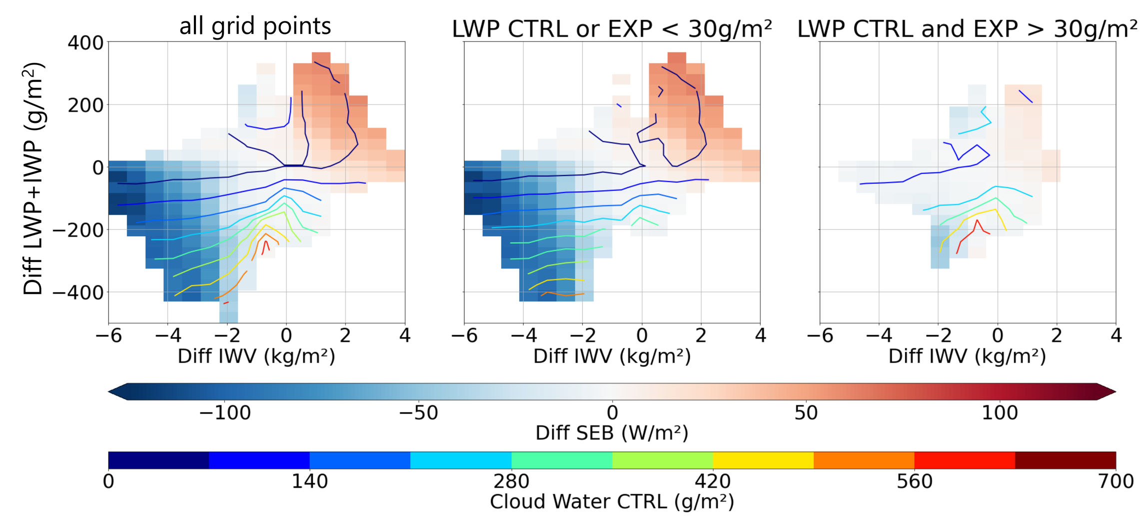


***Fig. 4:** Averages of differences (EXP-CTRL, including both experimental runs) in SEB, sorted by difference in IWV and sum of LWP and IWP (**left**), for subset of grid points where EXP or CTRL run show optically thin liquid-bearing clouds (center) and for grid points were both CTRL and EXP run show optically thick liquid-bearing clouds (**right**). Contour lines show the average of cloud water content of the control run in the respective bin. For threshold between optically thin and thick liquid-bearing clouds, an LWP of 30g/m² is used, according to the findings of Shupe and Intrieri [9].*

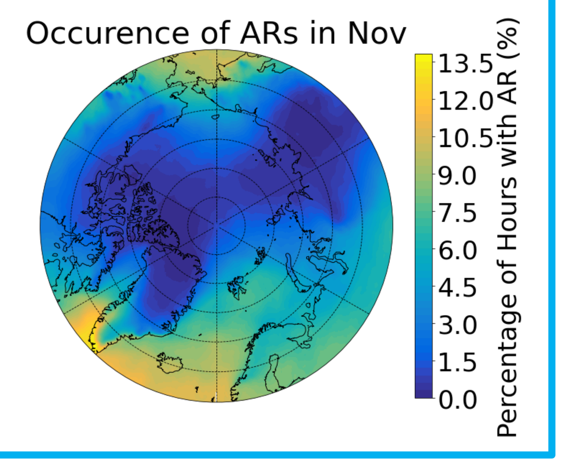
6. Conclusions

- Event shows **a less negative SEB (i.e. less energy loss) over ocean** and even a change from negative to **positive SEB over sea ice**.
- **Reducing the AR strength (moisture) causes a reduced impact on SEB,** especially due to **less downward longwave radiation**.
- The sensitivity study suggests for this case: While the presence of a cloud is important, the **change in the SEB during the event seems to be more sensitive to changes in IWV than in cloud water**.

7. Outlook

Climatological examination of ARs regarding their impact on the SEB:

- Seasonal & regional differences
- Extreme events
- Connection to circulation patterns
- Dependence on sea ice cover and thickness
- Categorization in wet & windy ARs



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