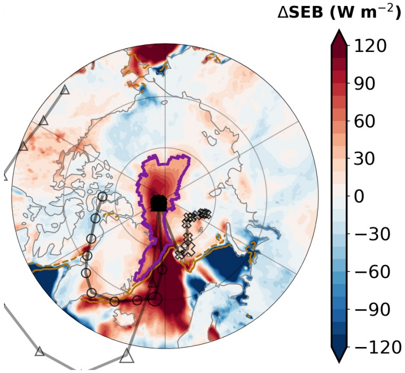


Control of extreme surface energy budget (SEB) anomalies and temperature response over sea ice in the high Arctic in winter

Sonja Murto[1,2], Lukas Papritz[3], Gabriele Messori[2,4], Heini Wernli[3], Rodrigo Caballero[1,2], Gunilla Svensson[1,2]

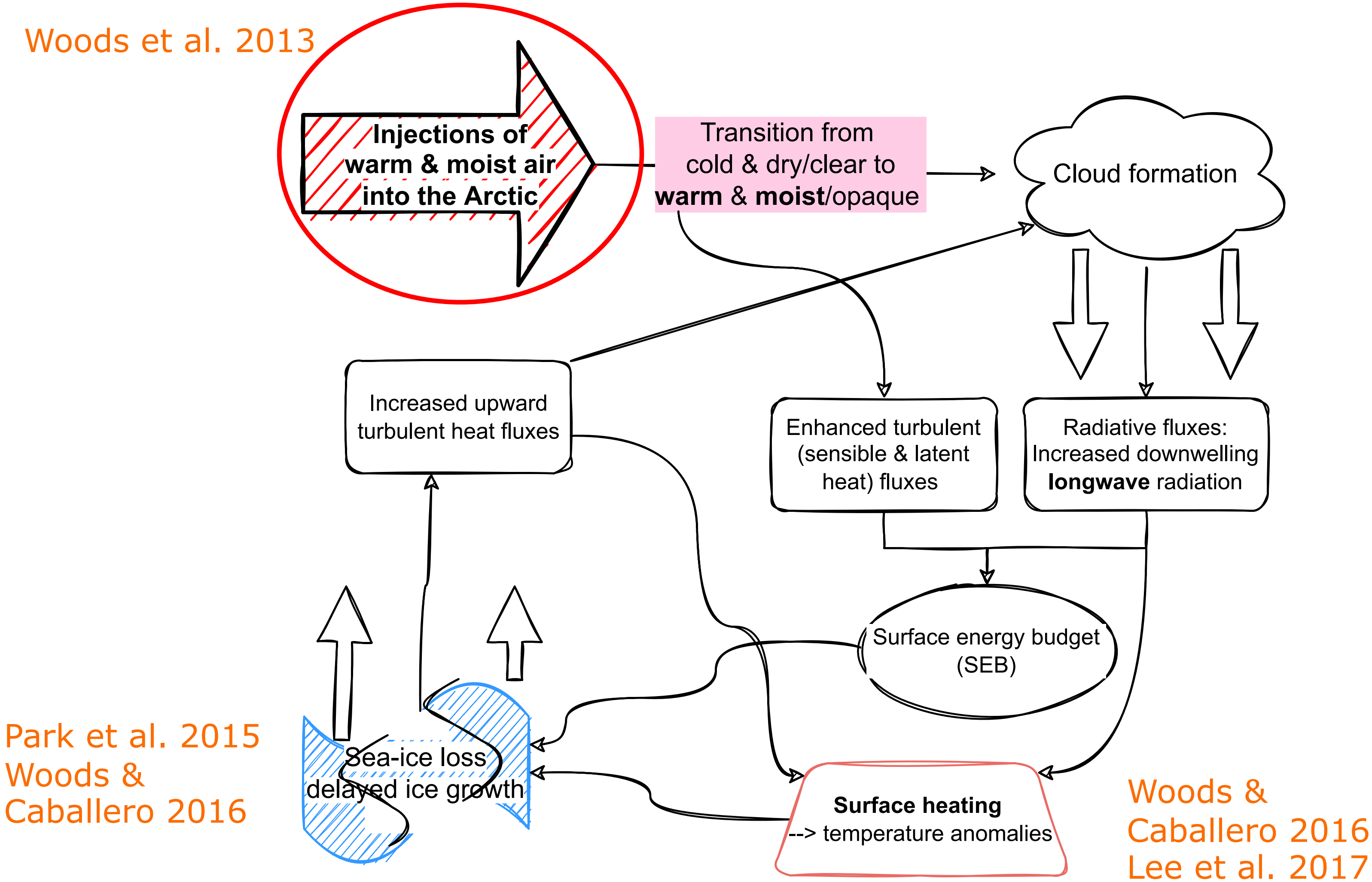
[1] *Department of Meteorology, Stockholm University, Stockholm, Sweden*

[2] *Bolin Centre for Climate Research, Stockholm University, Stockholm, Sweden*

[3] *Institute for Atmospheric and Climate Science, ETH Zürich, Zürich, Switzerland*

[4] *Department of Earth Sciences and Centre of Natural Hazards and Disaster Science, Uppsala University, Uppsala, Sweden*

Motivation – wintertime Arctic extremes



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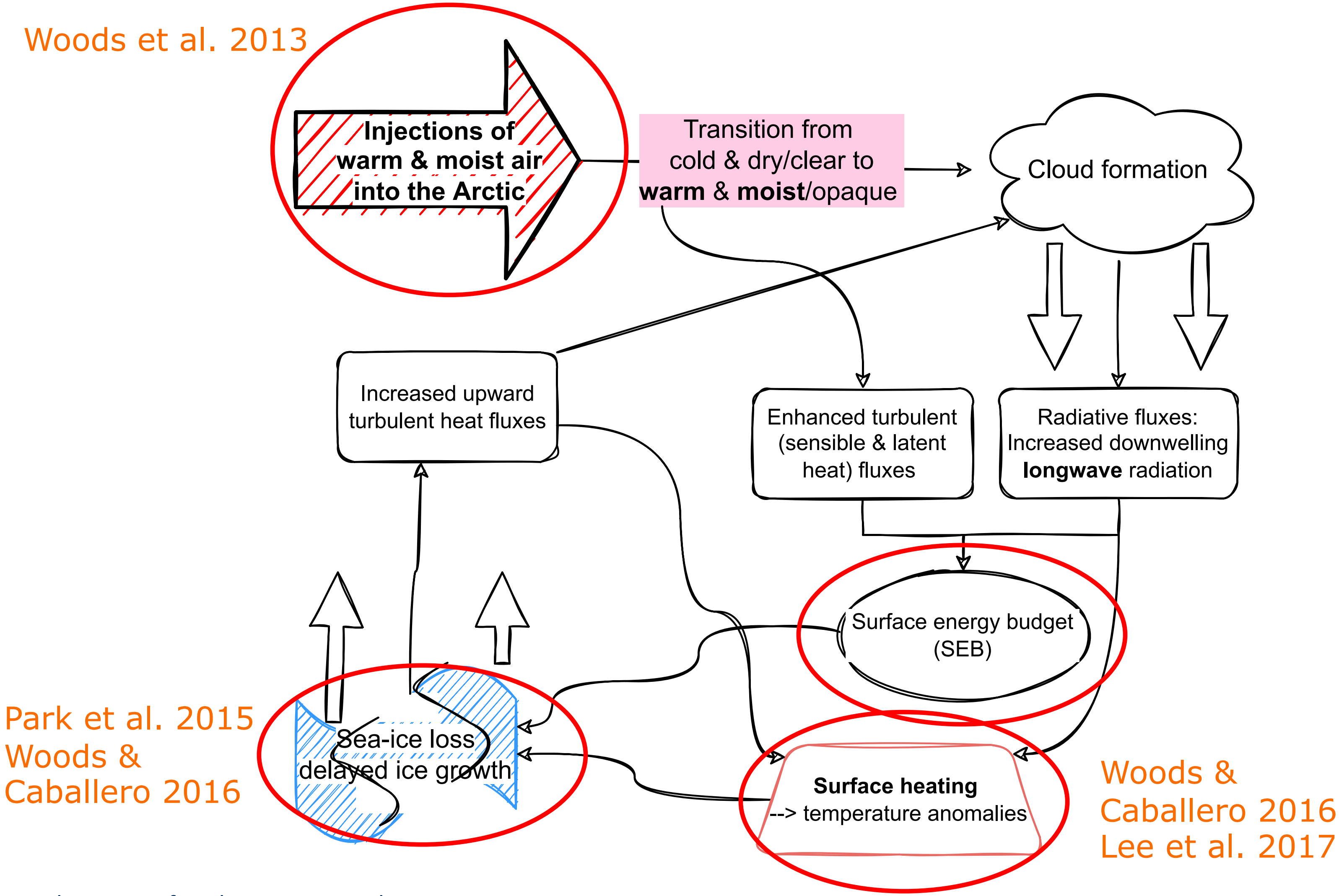

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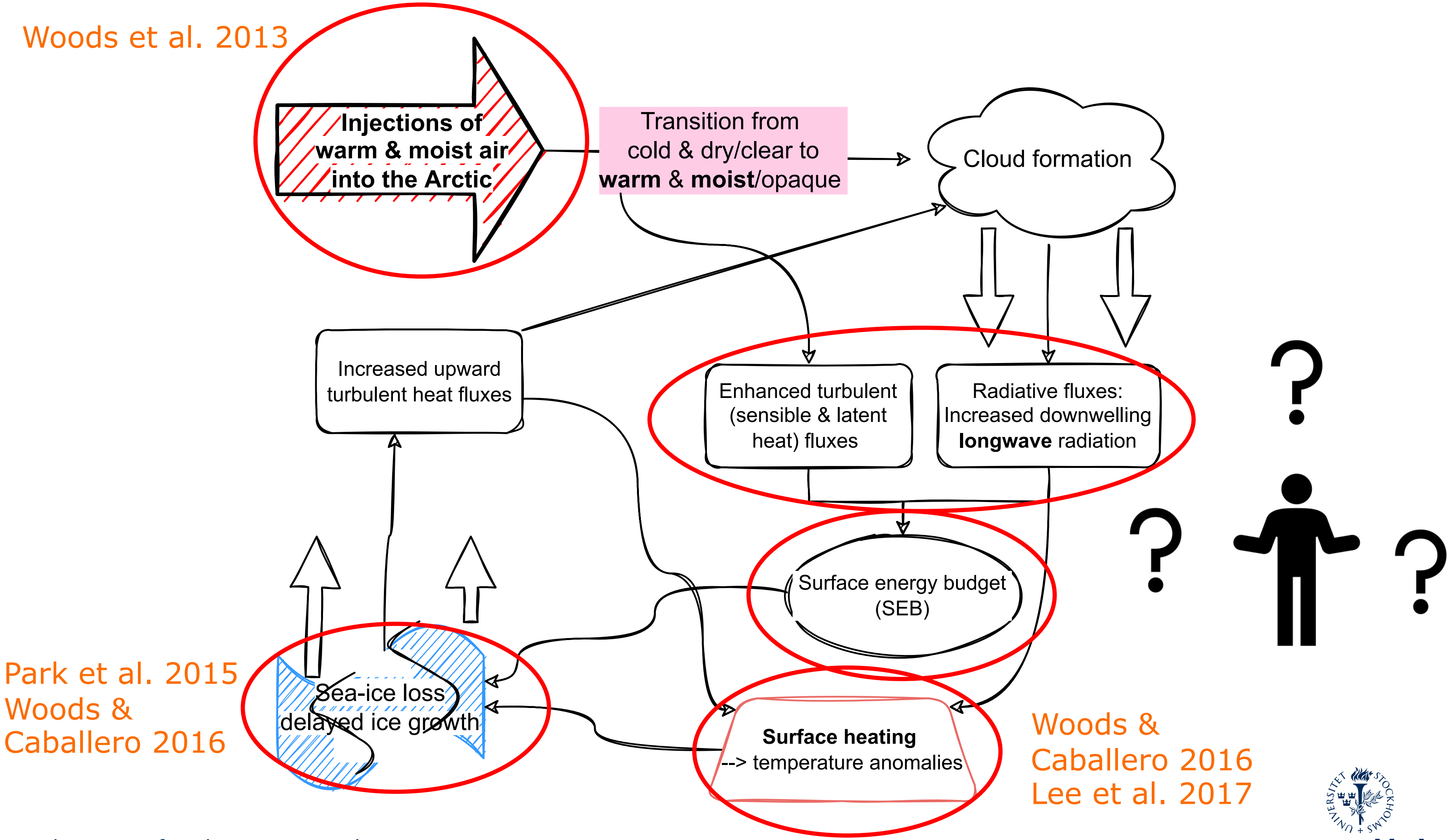
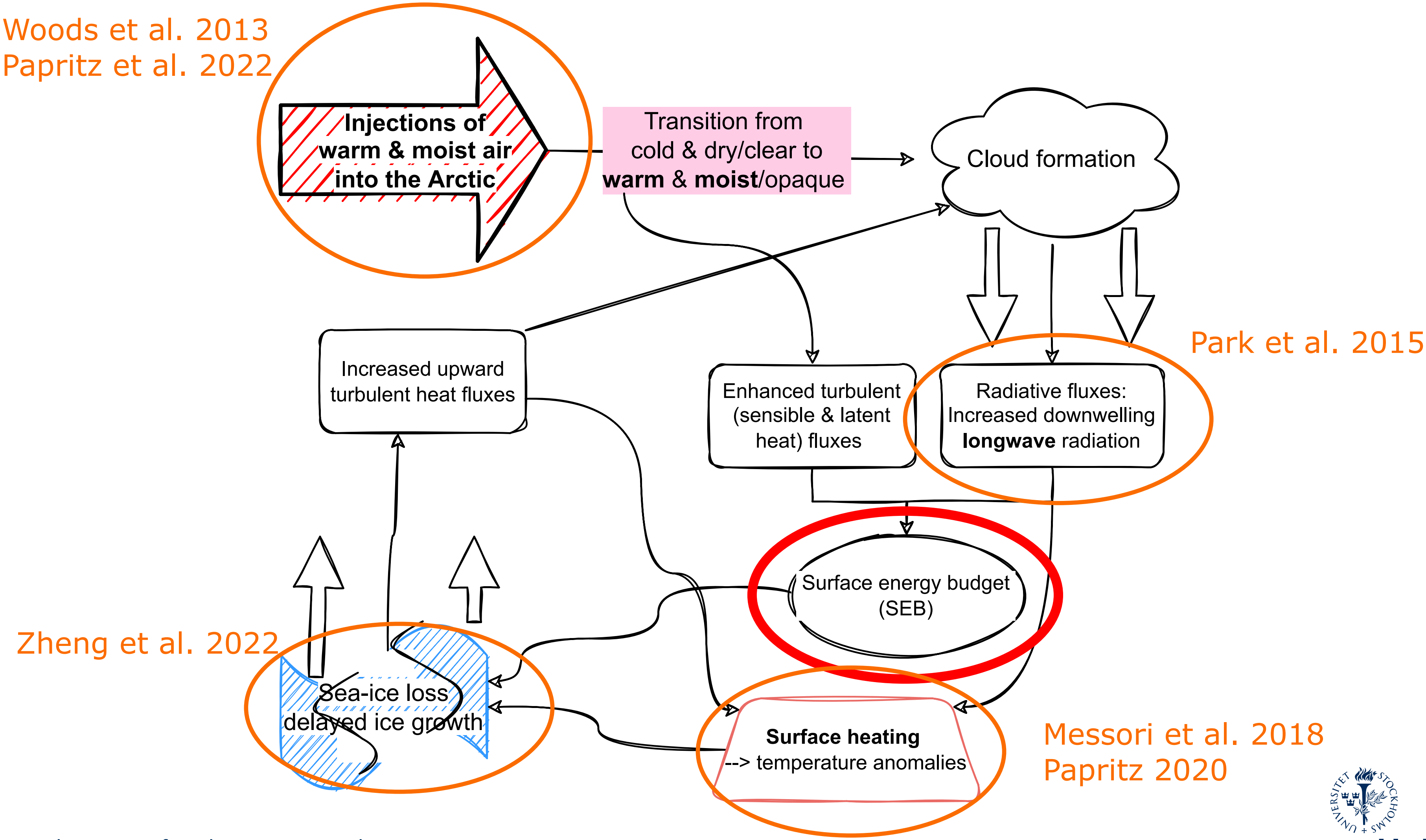


Motivation – defining wintertime Arctic extremes



Method – identification of SEB *patches*
(=coherent areas of high ΔSEB over sea ice)

41 winters: **Nov – March**, 1979/80 – 2019/20, ERA5

Sea ice

SEB anomalies

SEB patches

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1. Include only grid-points where SIC ≥ 0.7. Exclude grid-points where SIC < 0.7 for > 30 % of days within ± 15 around the calendar day and a centred 9 year interval. → valid grid-points

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SEB anomalies

SEB patches

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2. Non-dimensional SEB anomalies ($\widetilde{\Delta SEB}$) defined from a transient climatology (SEB_{50}) and inter-quartile range (SEB_{iqr}) of the SEB at each valid grid-point:

$$\widetilde{\Delta SEB} = \frac{SEB - SEB_{50}}{SEB_{iqr}}$$

→ Within ± 15 around the calendar day and a centred 9 year interval
→ Seasonality and long-time trends removed

Sea ice

SEB anomalies

SEB patches

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3. SEB patches = spatially coherent grid-points where $\widetilde{\Delta SEB}$ > area-weighted 95th percentile of $\widetilde{\Delta SEB}$ within ± 15 around the calendar day

4. Discard patches with area < 10^5 km^2

Sea ice

SEB anomalies

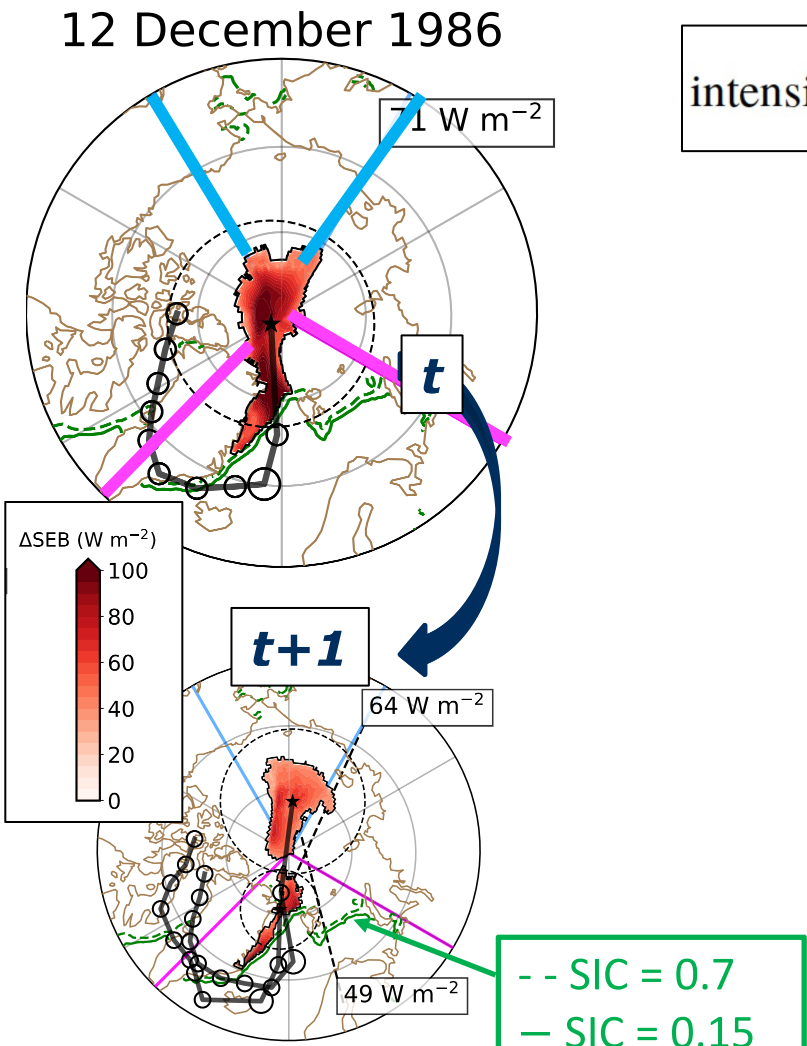
SEB patches

Method – definition of life-cycle events (LCEs)
(=temporally connected SEB patches)

Individual patches (forward and backward in time) are attributed to **intense** patches to form **multi-day LCEs**:

Amplitude × Affected area

$$\text{intensity} = \overline{\Delta\text{SEB}} \times \text{area}$$



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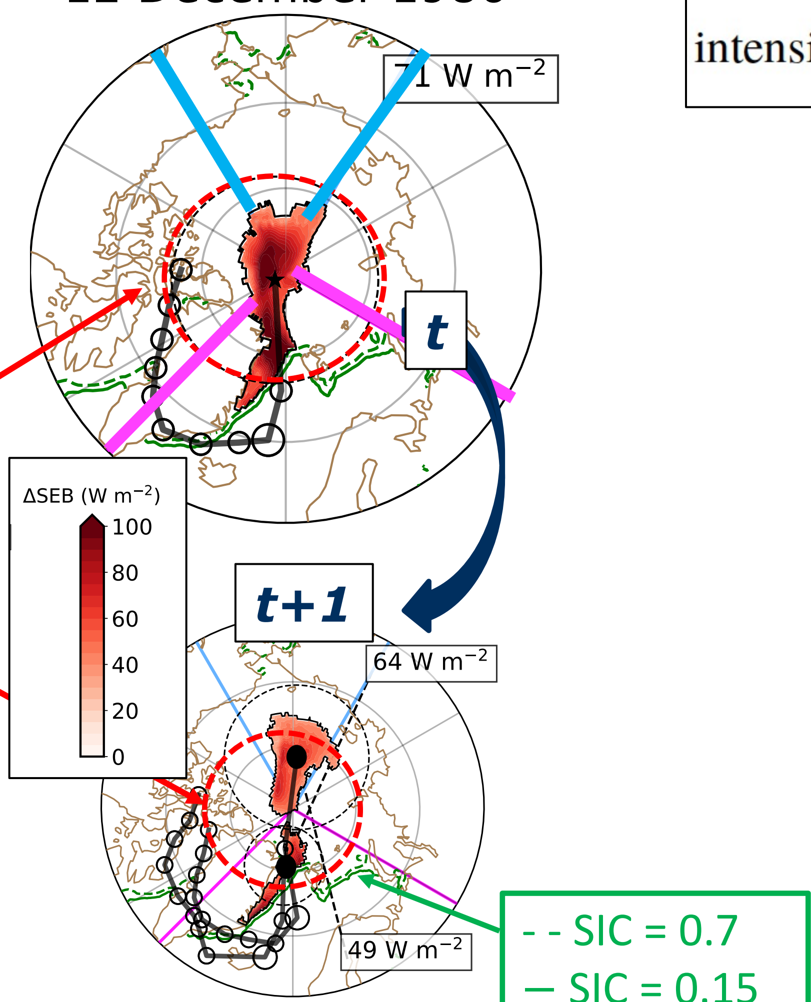

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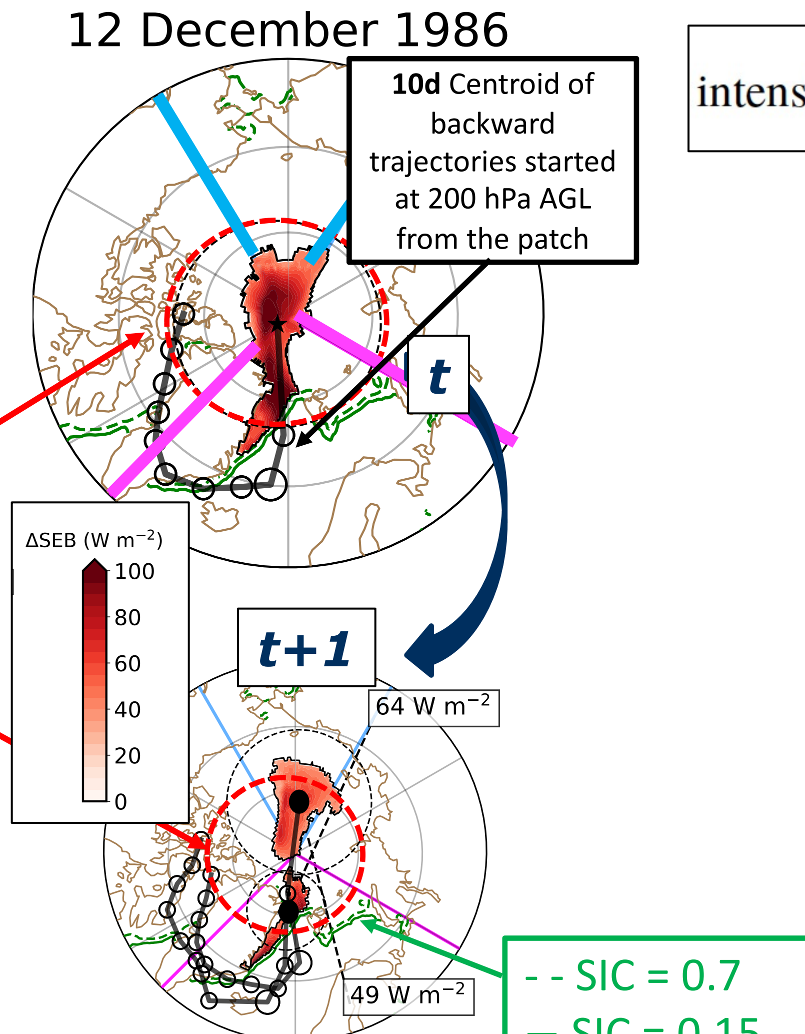

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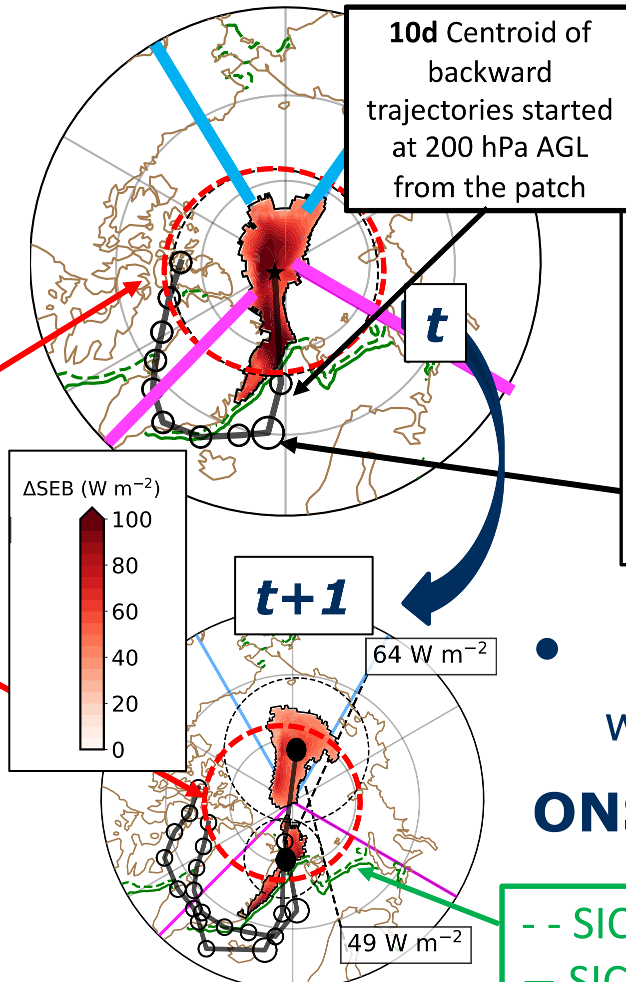
142 LCEs

12 December 1986



Amplitude × Affected area

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Sectors of air mass origin: Pacific, **Atlantic**, Canada, Siberia

- Location **2 days** prior to arrival in the peak event determines the **origin** of the LCE

- **Peak event** = SEB patch with largest **intensity**

ONSET – PEAK - DECAY

- - SIC = 0.7
— SIC = 0.15

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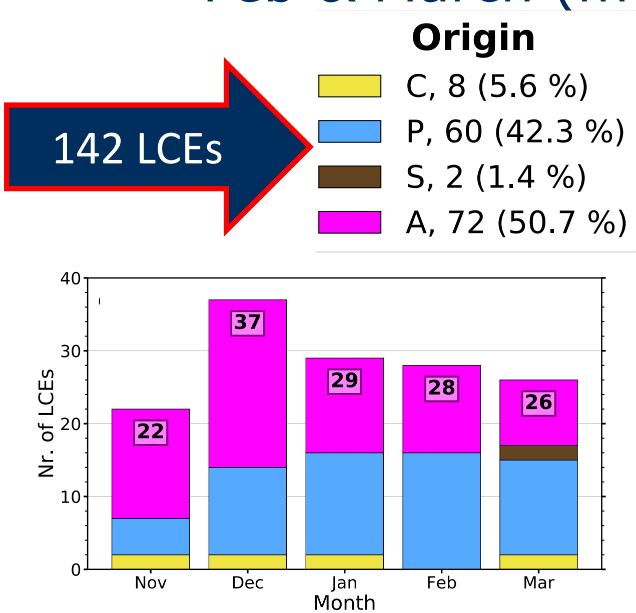
LCEs associated with vertically deep moist and warm air intrusions

- ~ 3.5 LCEs per winter season (0 – 8 LCEs)
- Duration ~ 5 days (2 – 12 days)
- Atlantic LCEs in Nov & Dec (higher North-Atlantic cyclone activity), Pacific LCEs in Feb & March (more blocks over Alaska)



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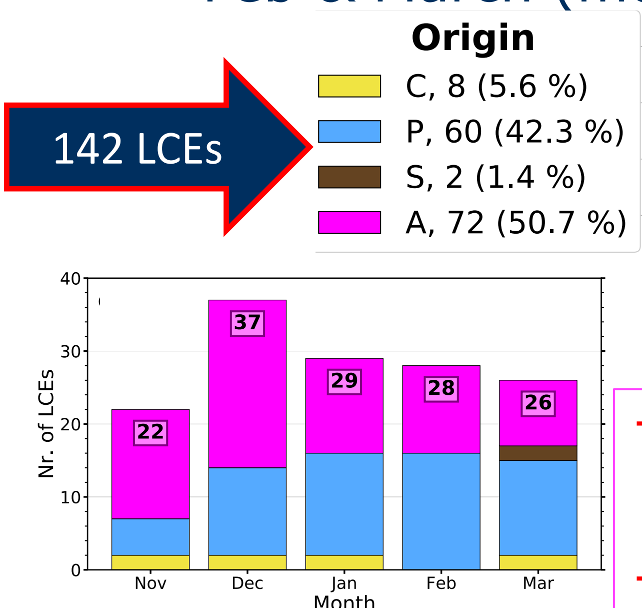

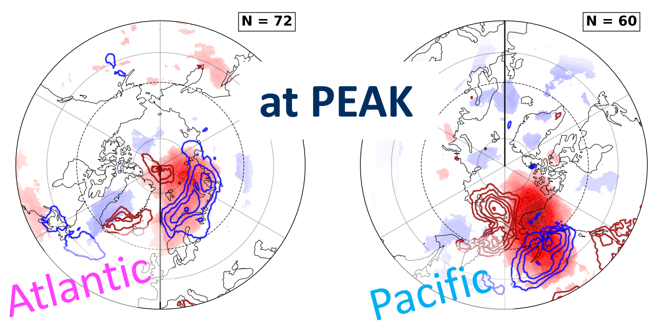

→ More cyclones in Greenland-Iceland & Central Arctic
→ More blocks in Northern Eurasia

→ More cyclones (blocks) in western (eastern) North Pacific

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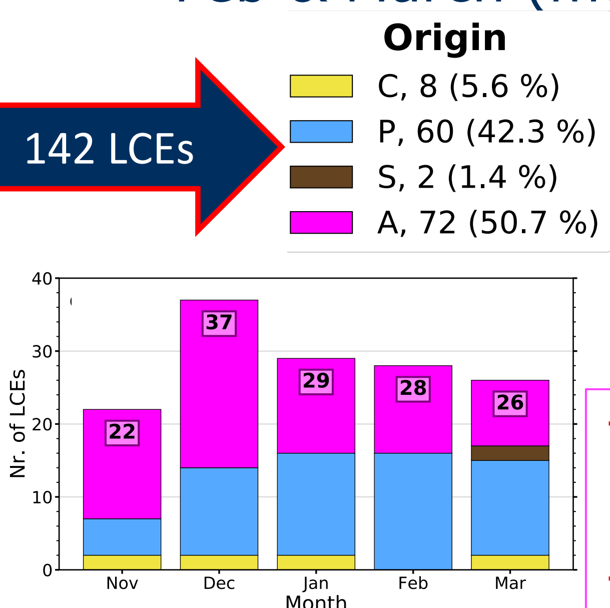

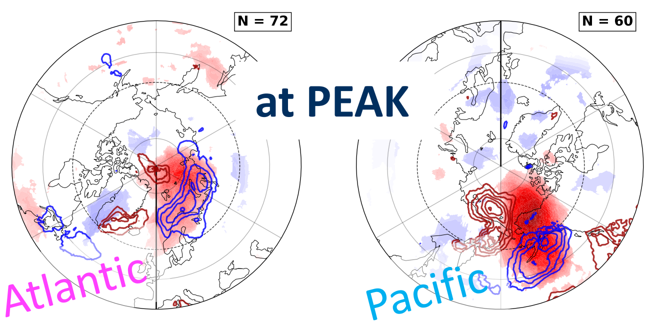

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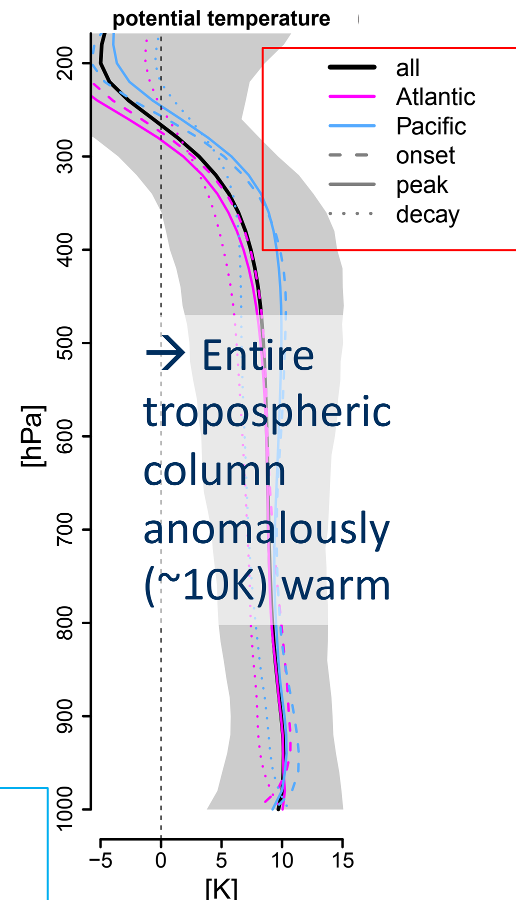
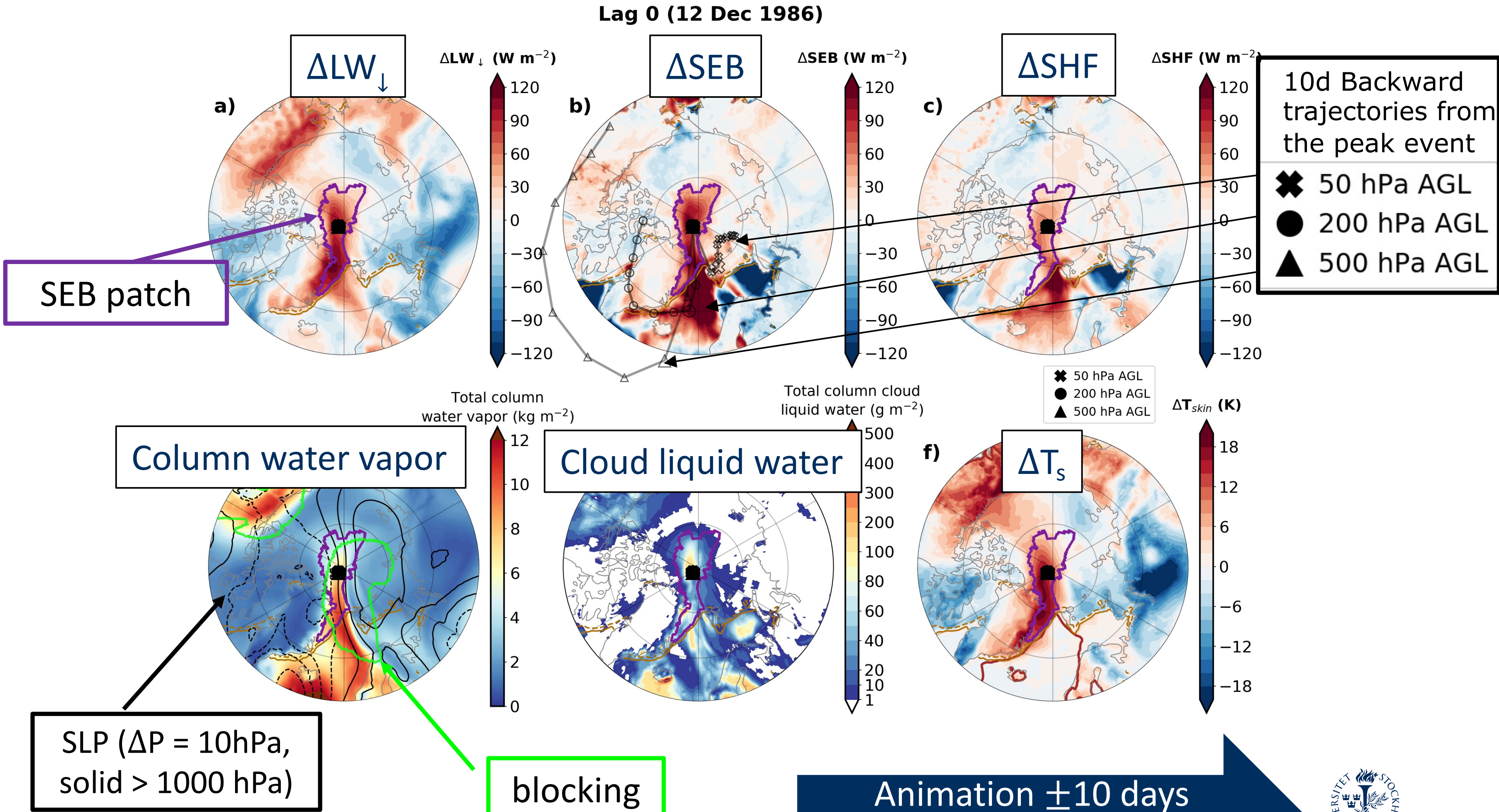


→ Entire tropospheric column anomalously (~10K) warm

Case study – Atlantic event LCE 44 (5days) at peak

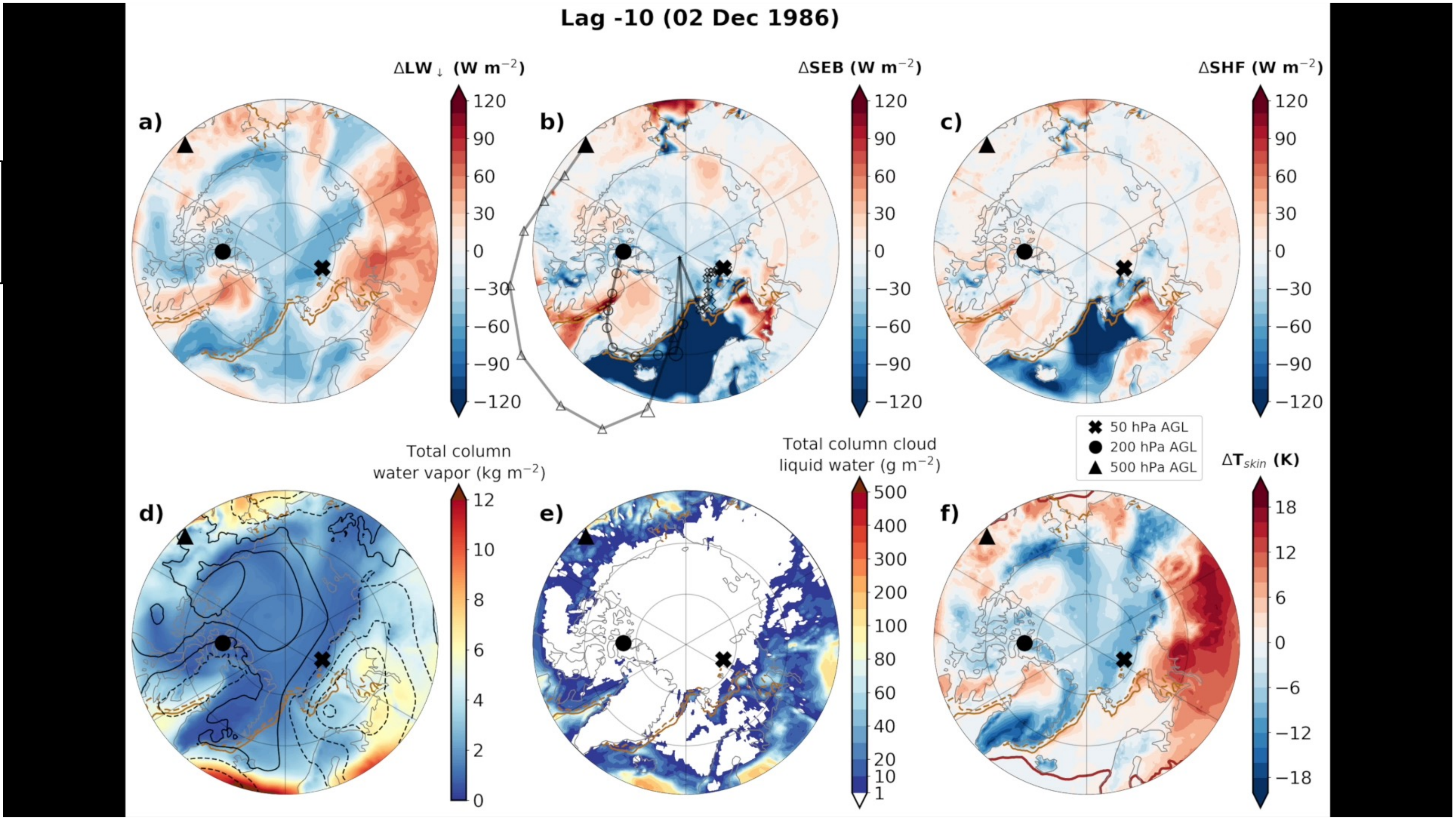


Animation ±10 days around the peak event

LCE 44 (peak 12 December 1986)

✖ 50 hPa AGL
● 200 hPa AGL
▲ 500 hPa AGL

ΔSEB terms



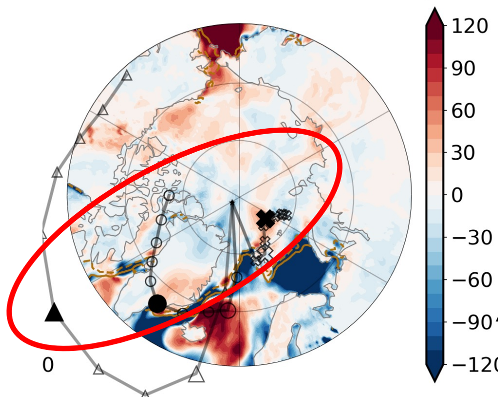
Moisture, clouds

ΔT_s

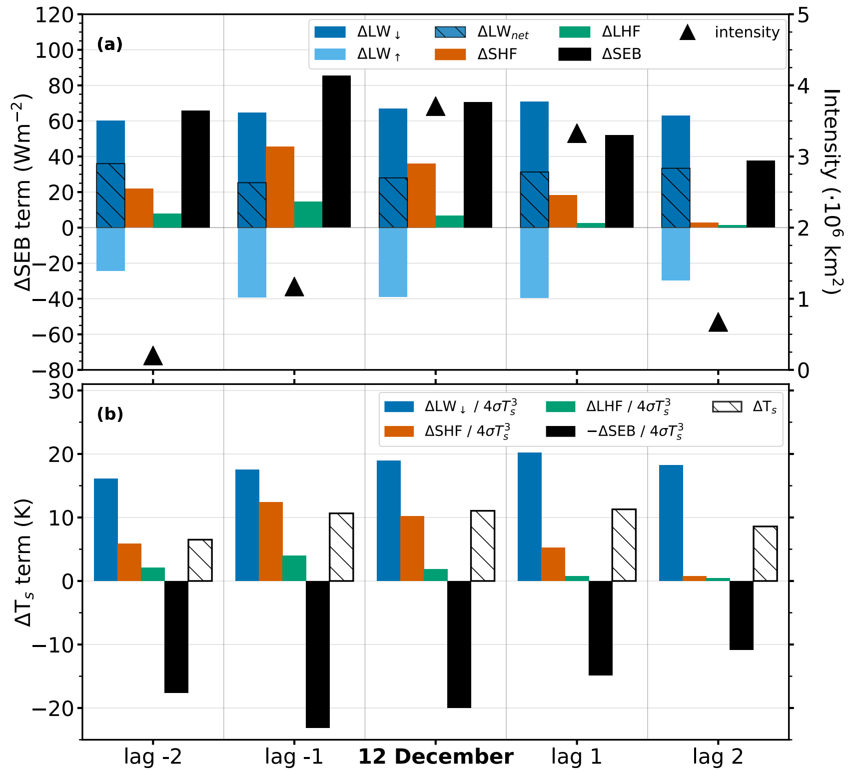
Case study – Atlantic event LCE 44

Lag -5 (07 Dec 1986)

before



Spatially-averaged terms



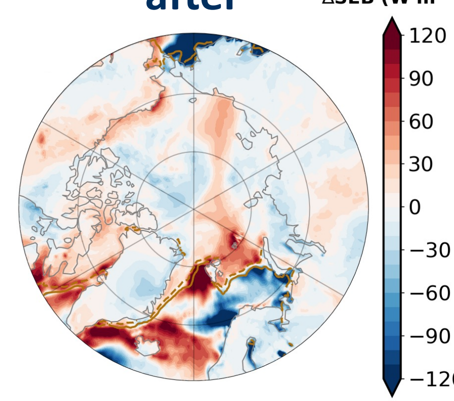
ONSET – PEAK – DECAY

↓

largest **intensity**

Lag 5 (17 Dec 1986)

after



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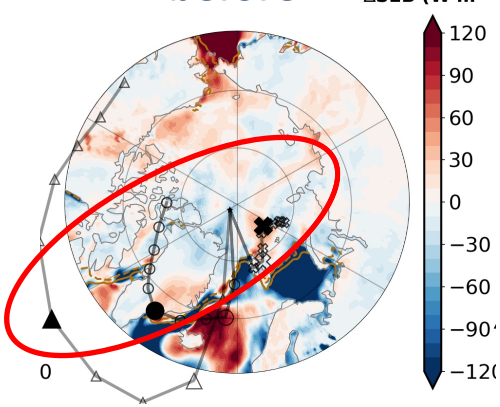
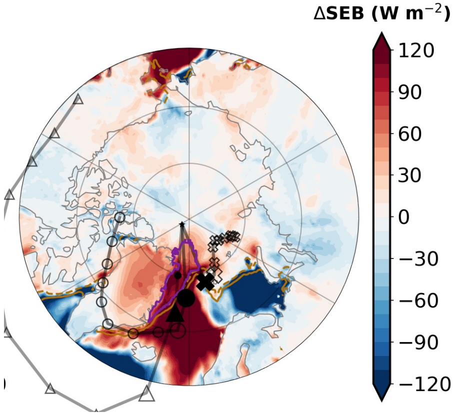


Lag -1 (11 Dec 1986)



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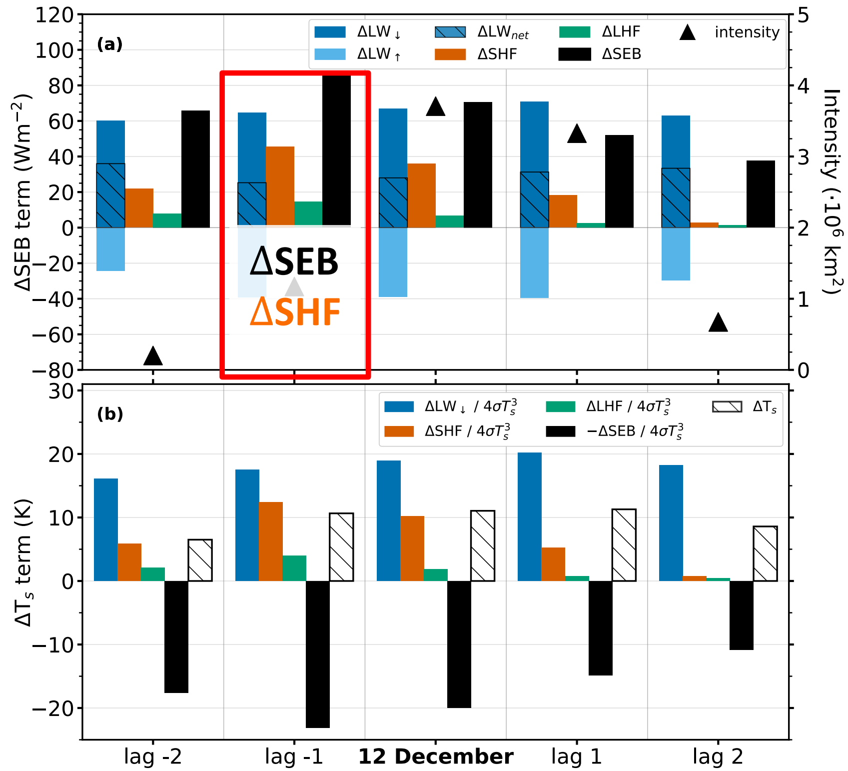

ONSET – PEAK – DECAY

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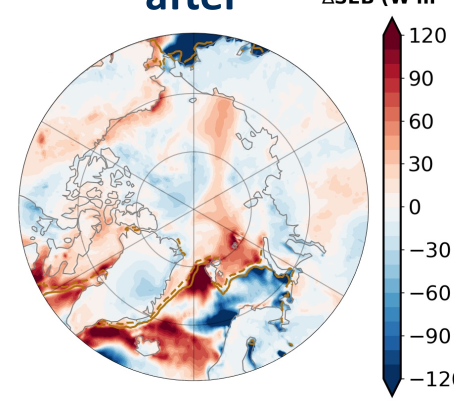

✖ 50 hPa AGL
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Case study – Atlantic event LCE 44

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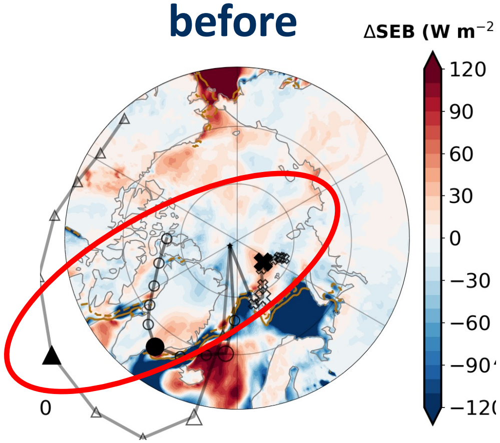

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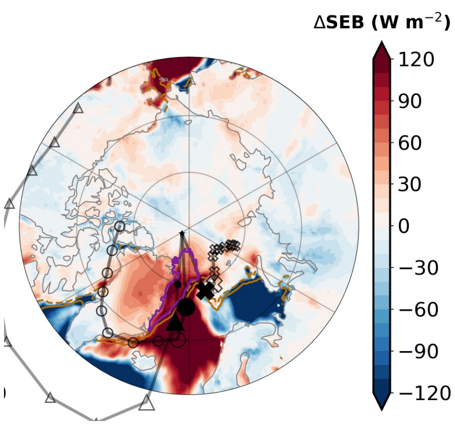

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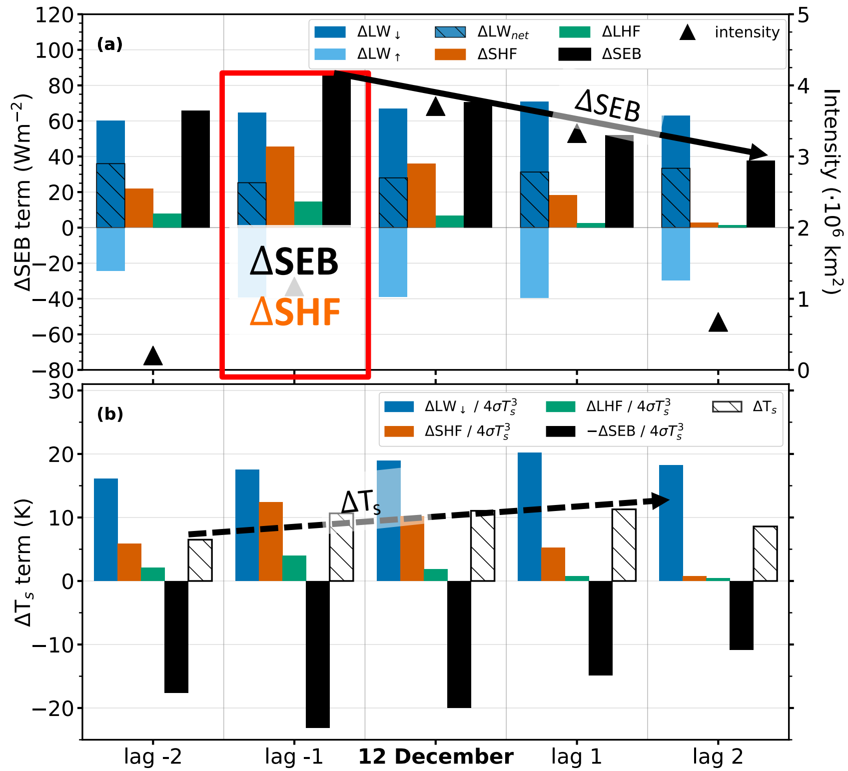

ONSET – PEAK – DECAY

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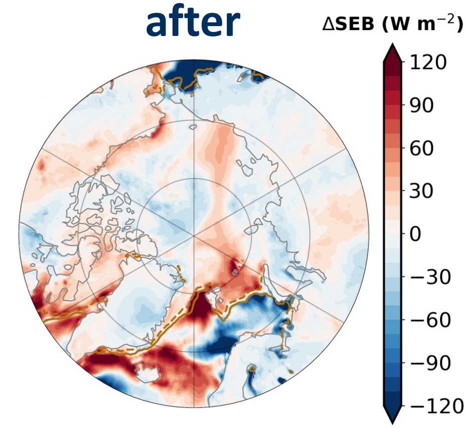

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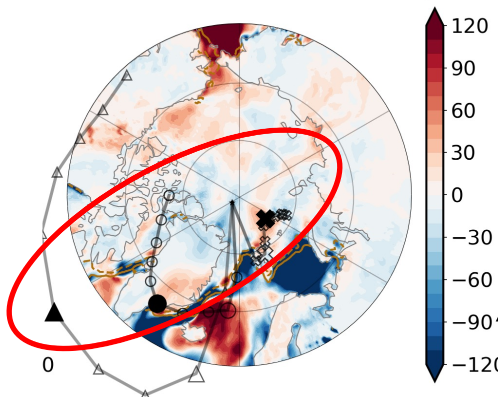

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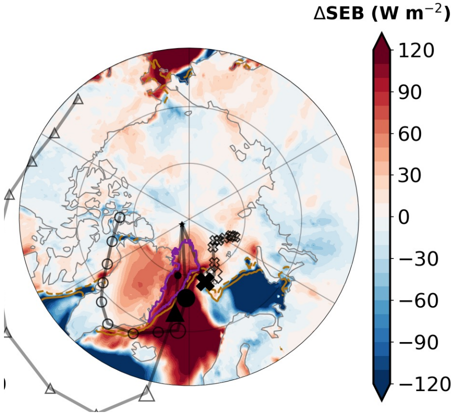

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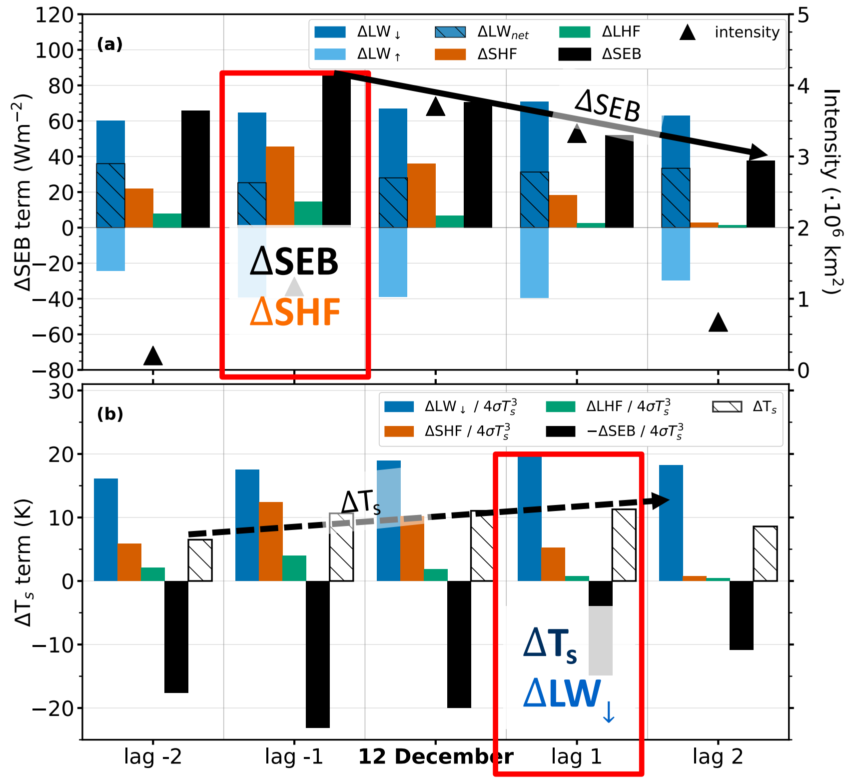
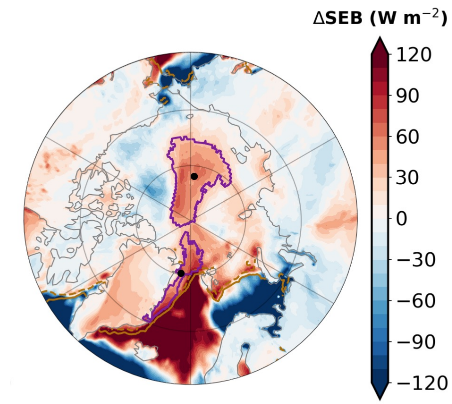


ONSET – PEAK – DECAY

↓

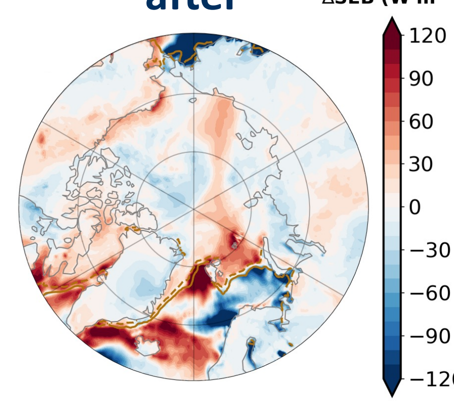
largest **intensity**

Lag 1 (13 Dec 1986)

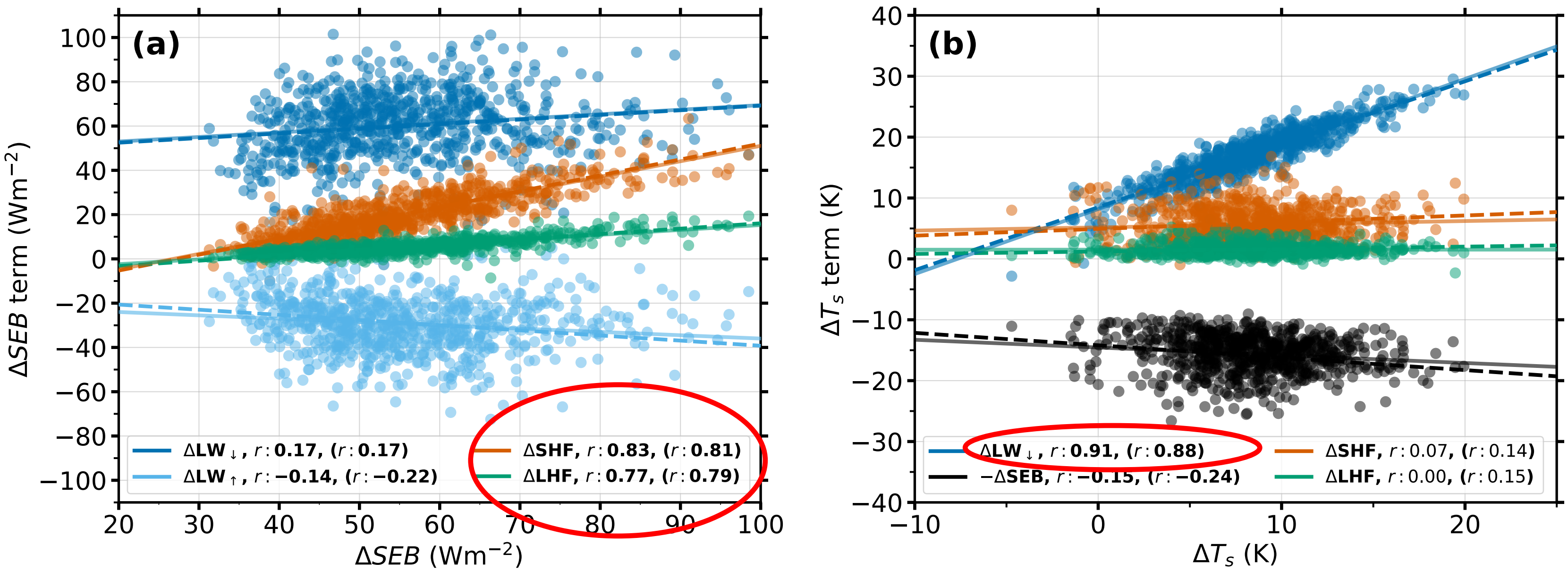


Lag 5 (17 Dec 1986)

after



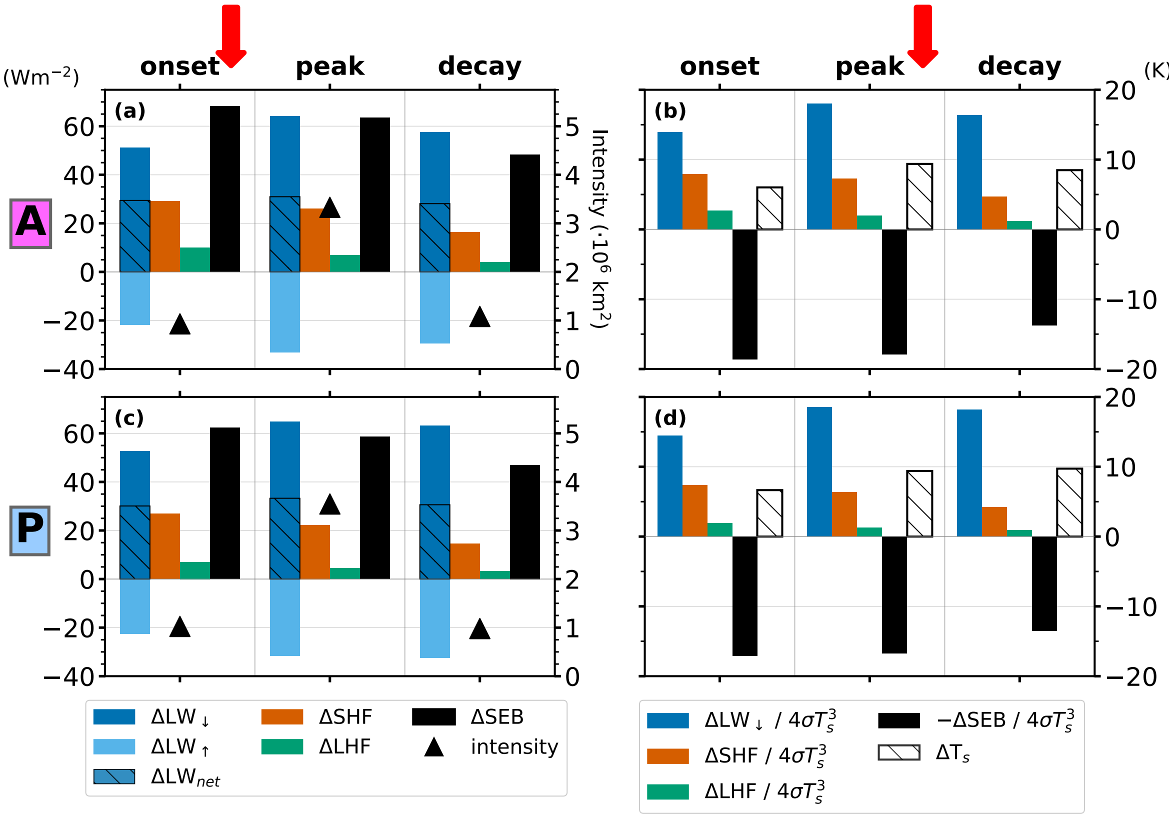
Scatterplots between ΔSEB (left) and ΔT_s (right) and their components – correlation analysis

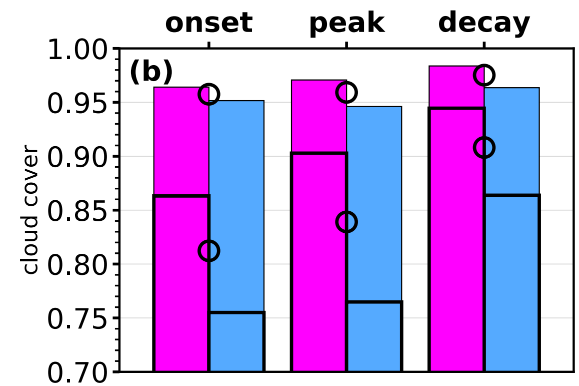


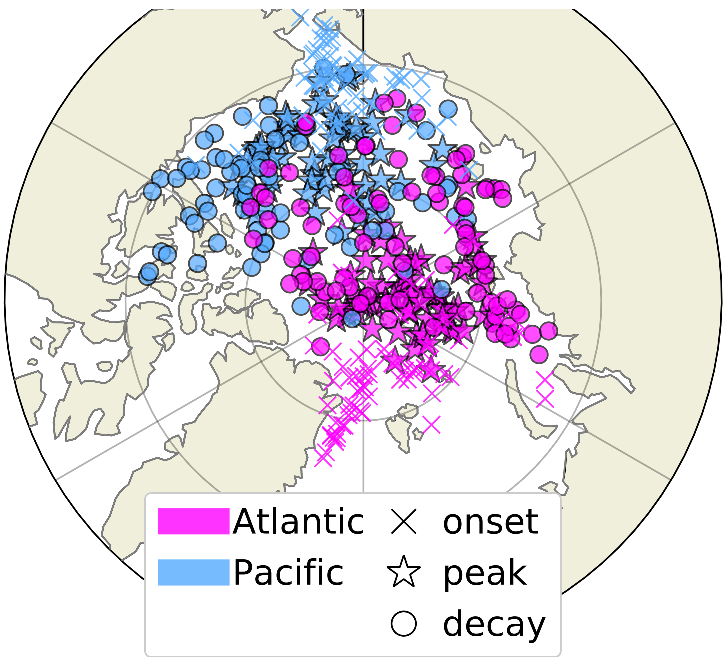
→ Variations in **ΔSEB** linked to variations in **ΔSHF** (and **ΔLHF**), only partly contributed by **ΔLW**$_\downarrow$

→ Variations in **ΔT_s** reflect variations in **ΔLW**$_\downarrow$

Time evolution & LCE pathways







→ **ΔSEB** peaks earlier than **ΔT$_s$** (strong ΔSEB ⇏ strong ΔT$_s$?)

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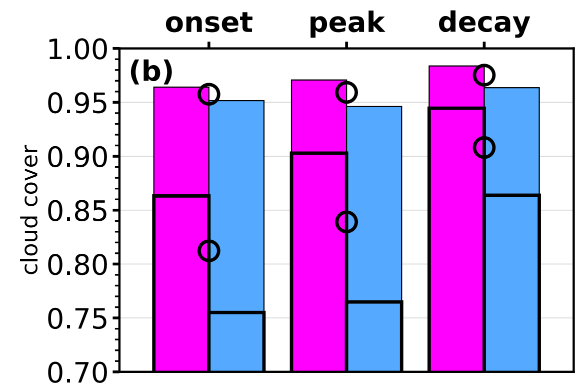

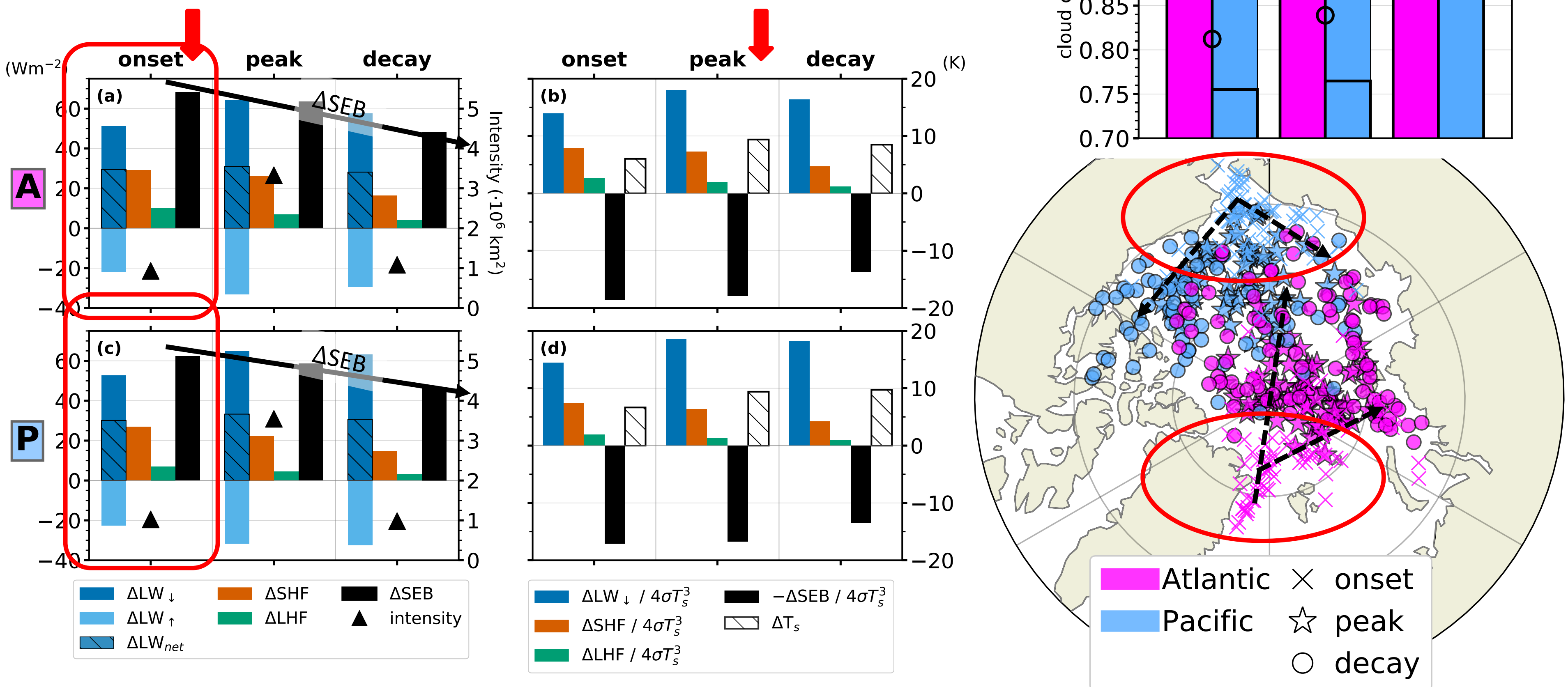

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→ **ΔSHF** and **ΔLHF** strongest at onset (largest **ΔSEB**) at the ice edge, weakening when moving into the Arctic interior

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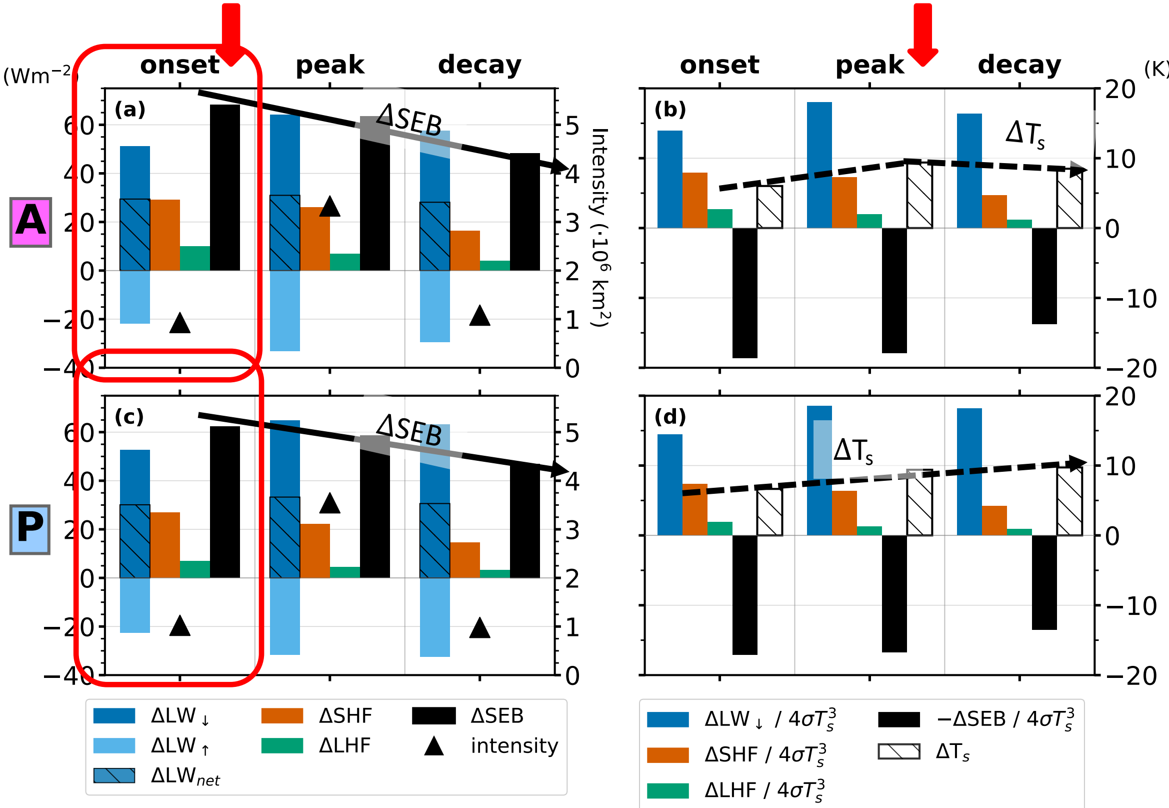

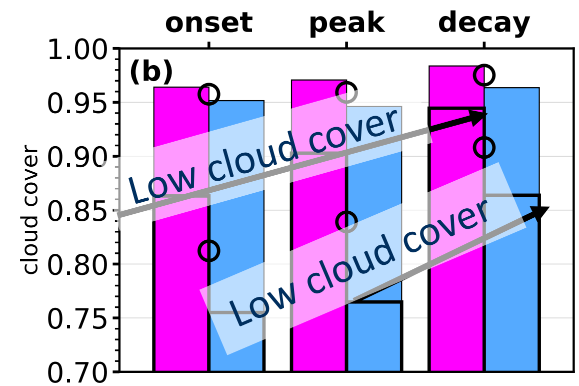

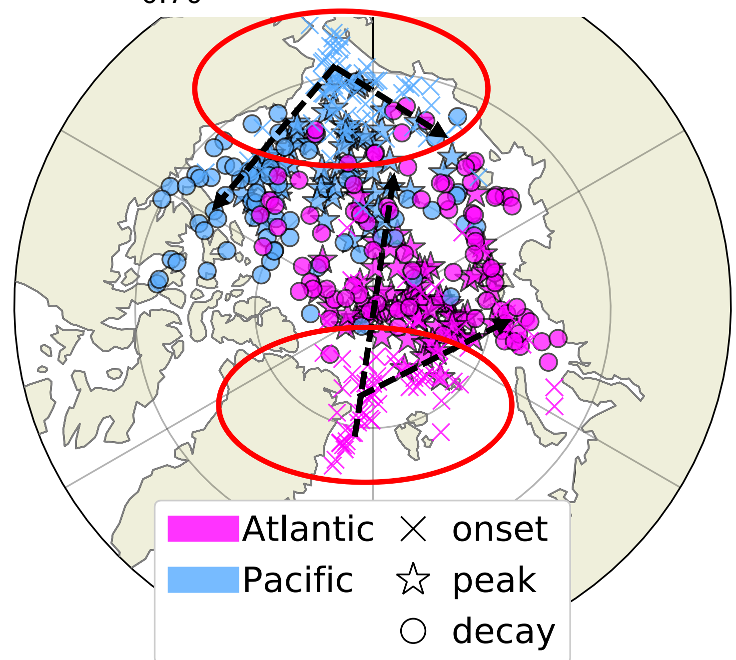

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→ **ΔLW$_{net}$** constant through LCEs (**ΔLW$_\uparrow$** compensates for **ΔLW$_\downarrow$**)

→ **ΔT$_s$** tracks **ΔLW$_\downarrow$**, strongest at peak, increased low cloud cover

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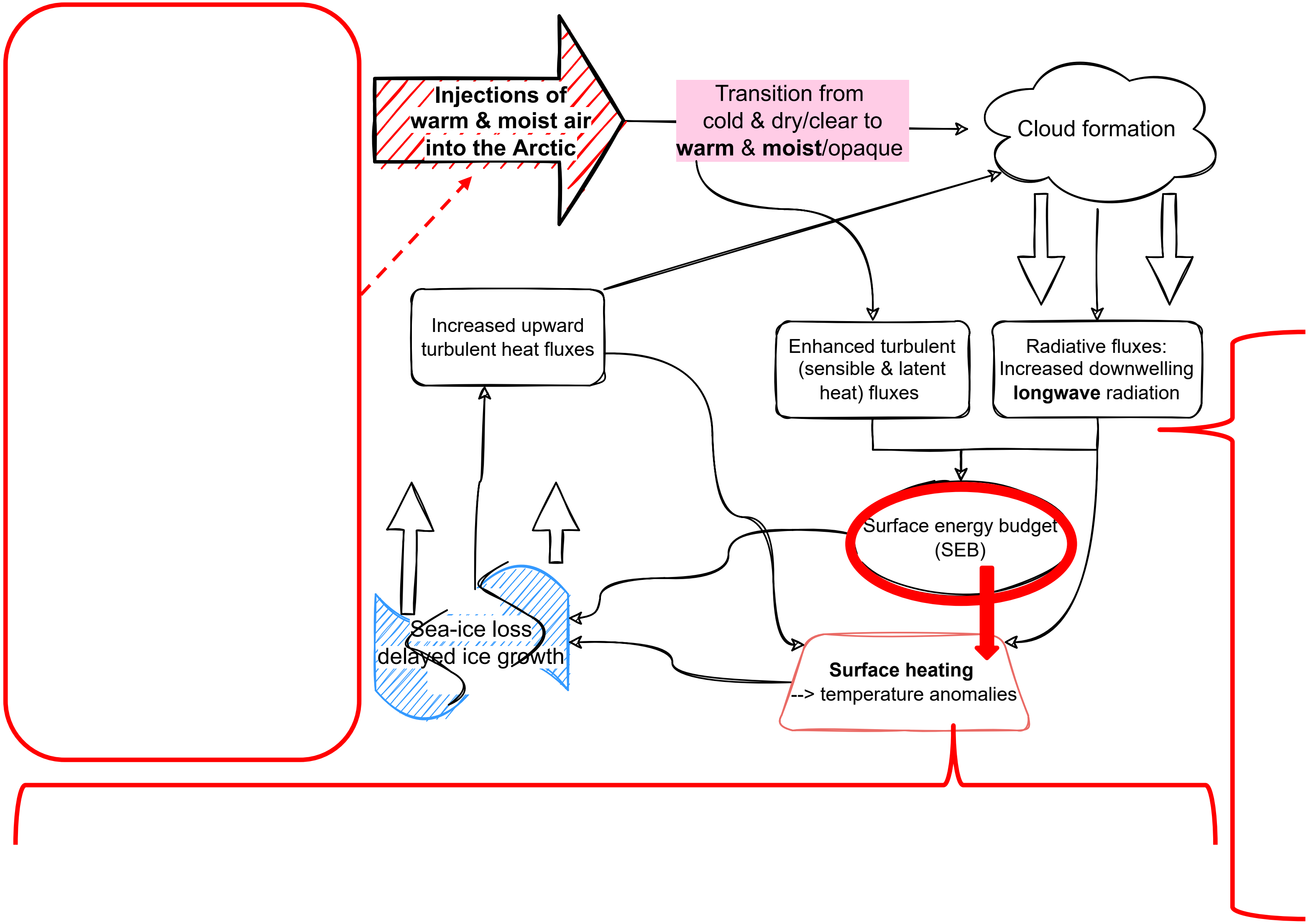
Summary



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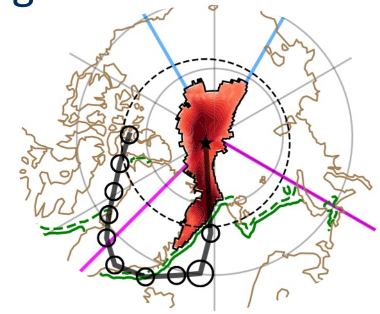
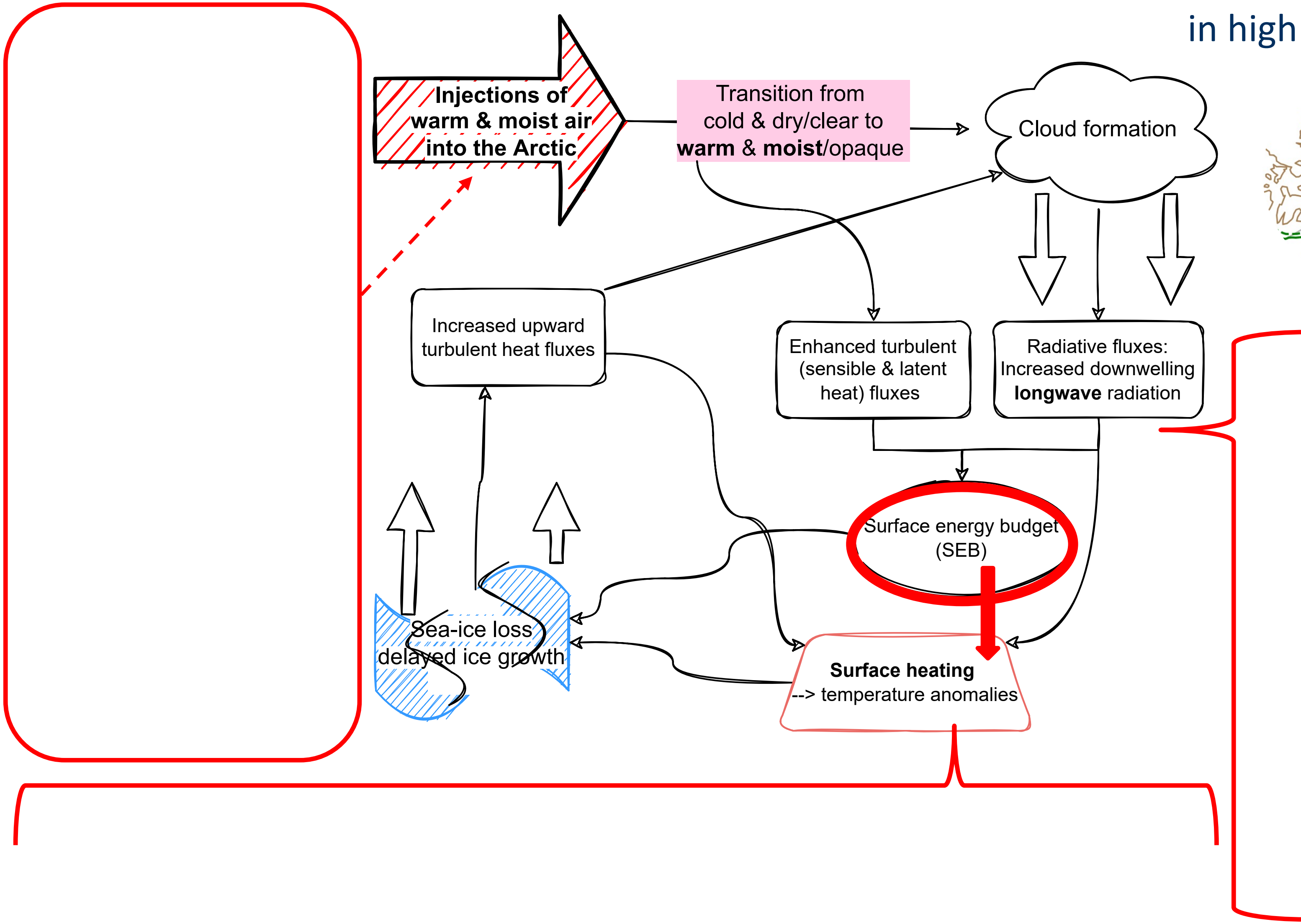
Summary

Extreme positive **SEB** anomaly life-cycle events in high Arctic in winter





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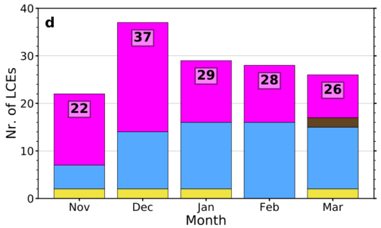
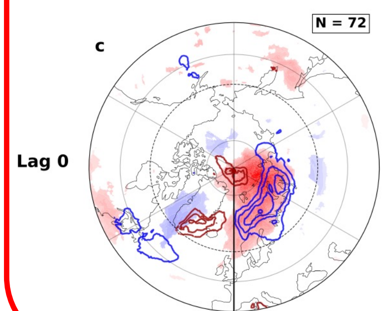
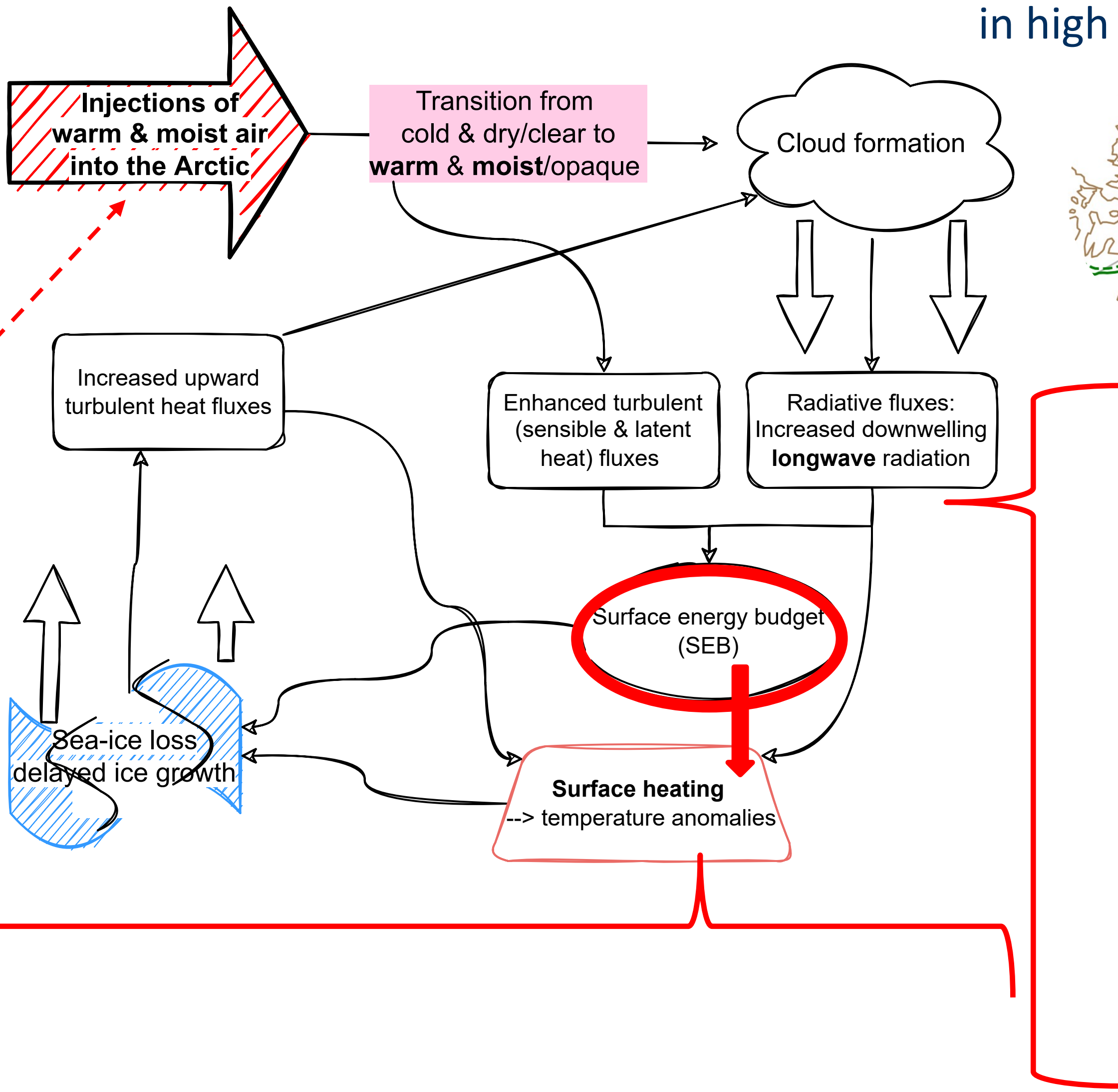
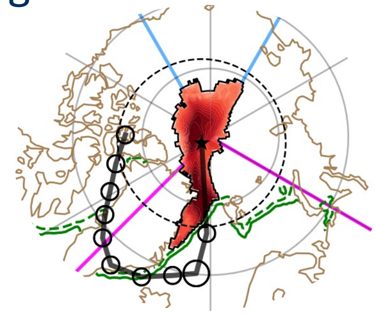


- Majority of LCEs associated with inflow from **Atlantic** or **Pacific** sectors







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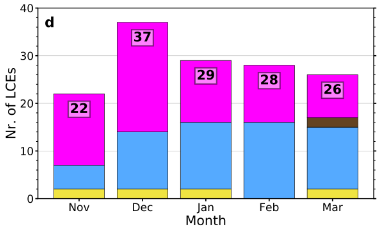

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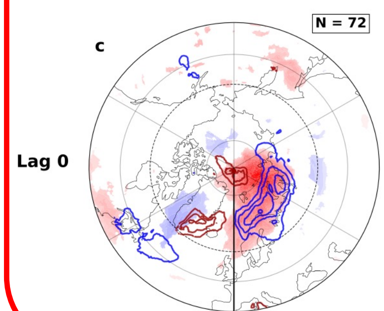
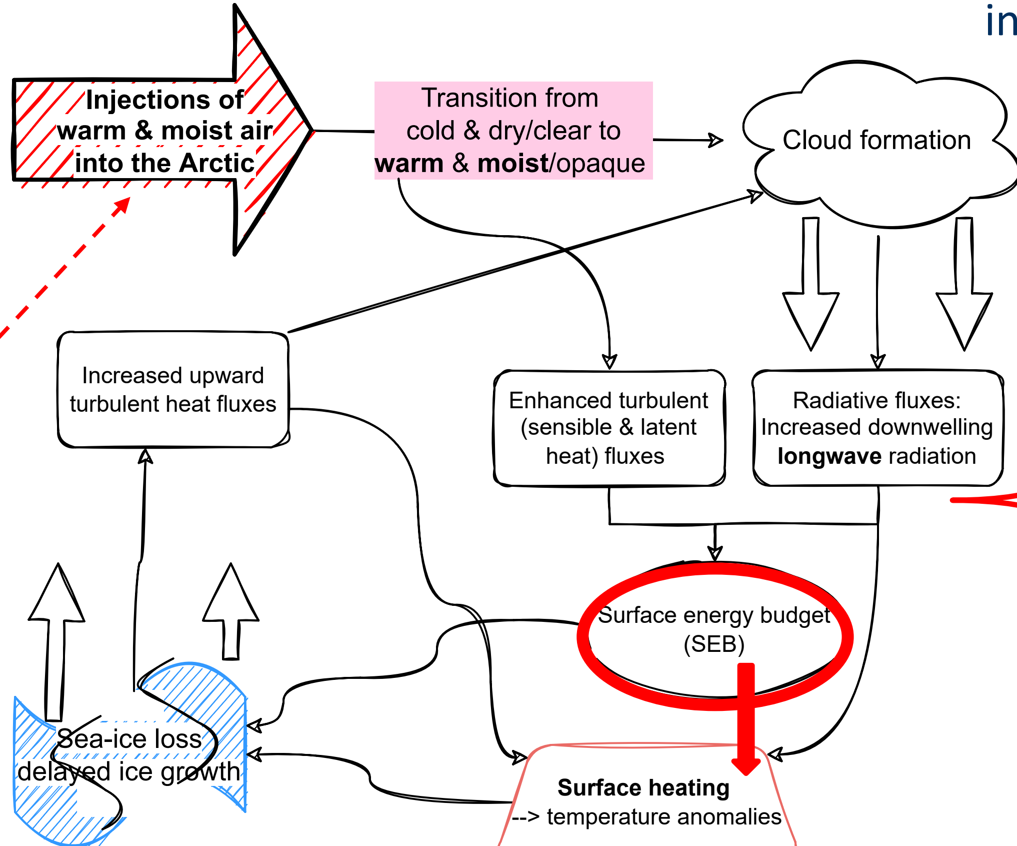
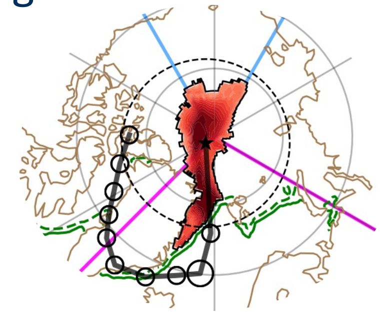
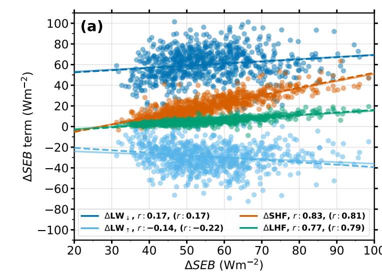






→ **ΔSEB** linked to **ΔSHF** (and **ΔLHF**), partly linked to $\Delta \mathbf{LW}_{\downarrow}$

→ $\Delta \mathbf{T_s}$ reflects variations in $\Delta \mathbf{LW}_{\downarrow}$



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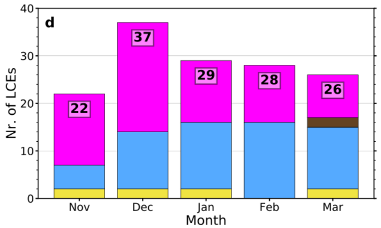
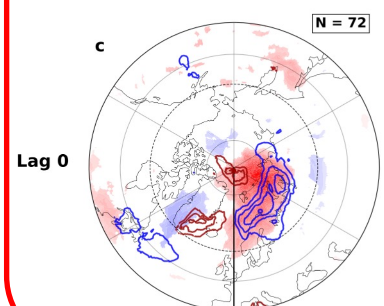
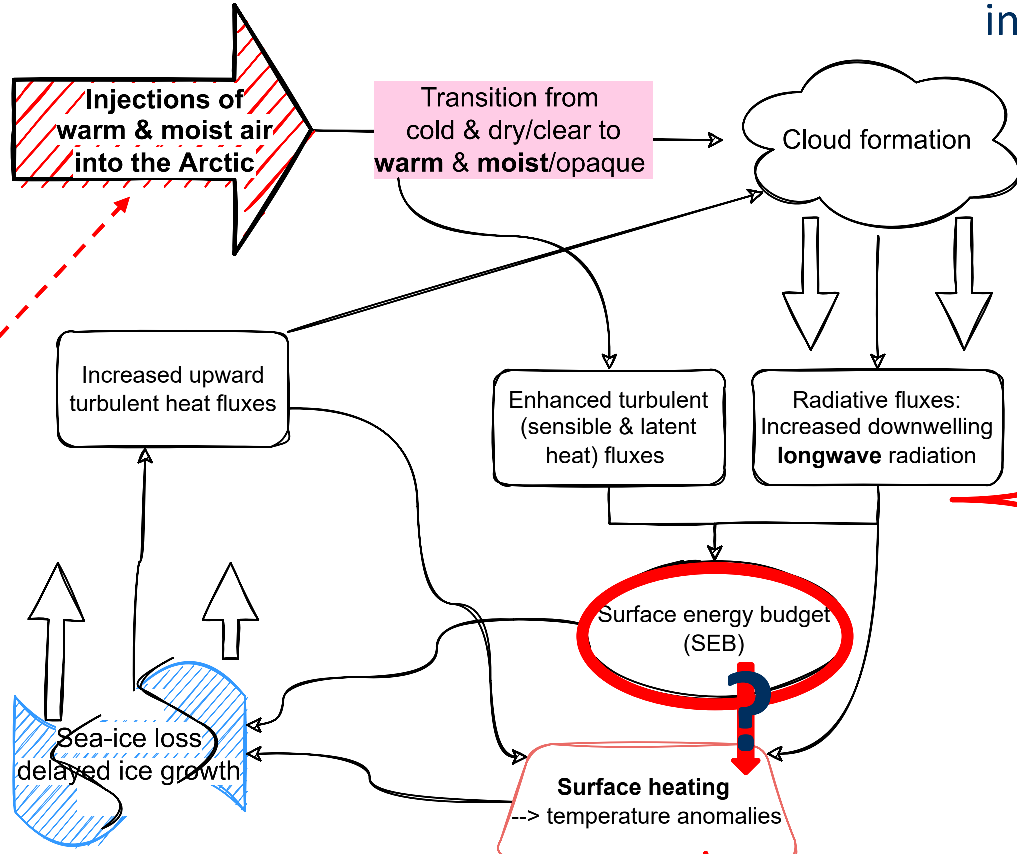
Summary

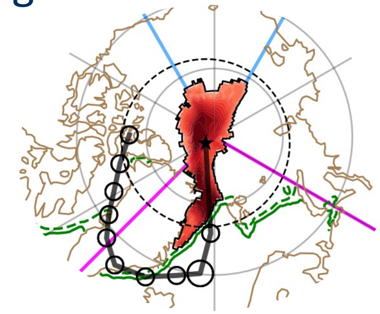
Extreme positive **SEB** anomaly life-cycle events in high Arctic in winter



- Majority of LCEs associated with inflow from **Atlantic** or **Pacific** sectors







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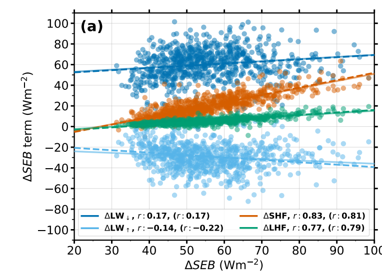

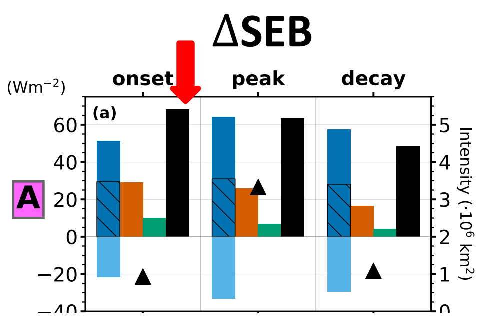

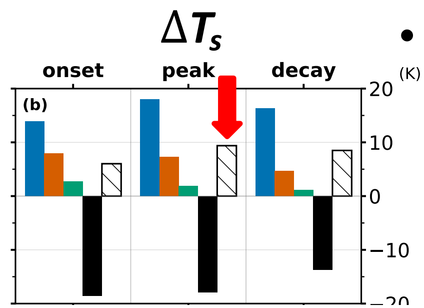

- **ΔSEB** → ΔT_s, peak in ΔSEB preceding strongest surface temperature anomaly

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Thank you for Listening!
Questions?

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Photo taken north of Greenland during SAS-expedition with Icebreaker Oden in summer 2021

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Wintertime Arctic extremes events defined by positive SEB anomalies (ΔSEB) over sea-ice

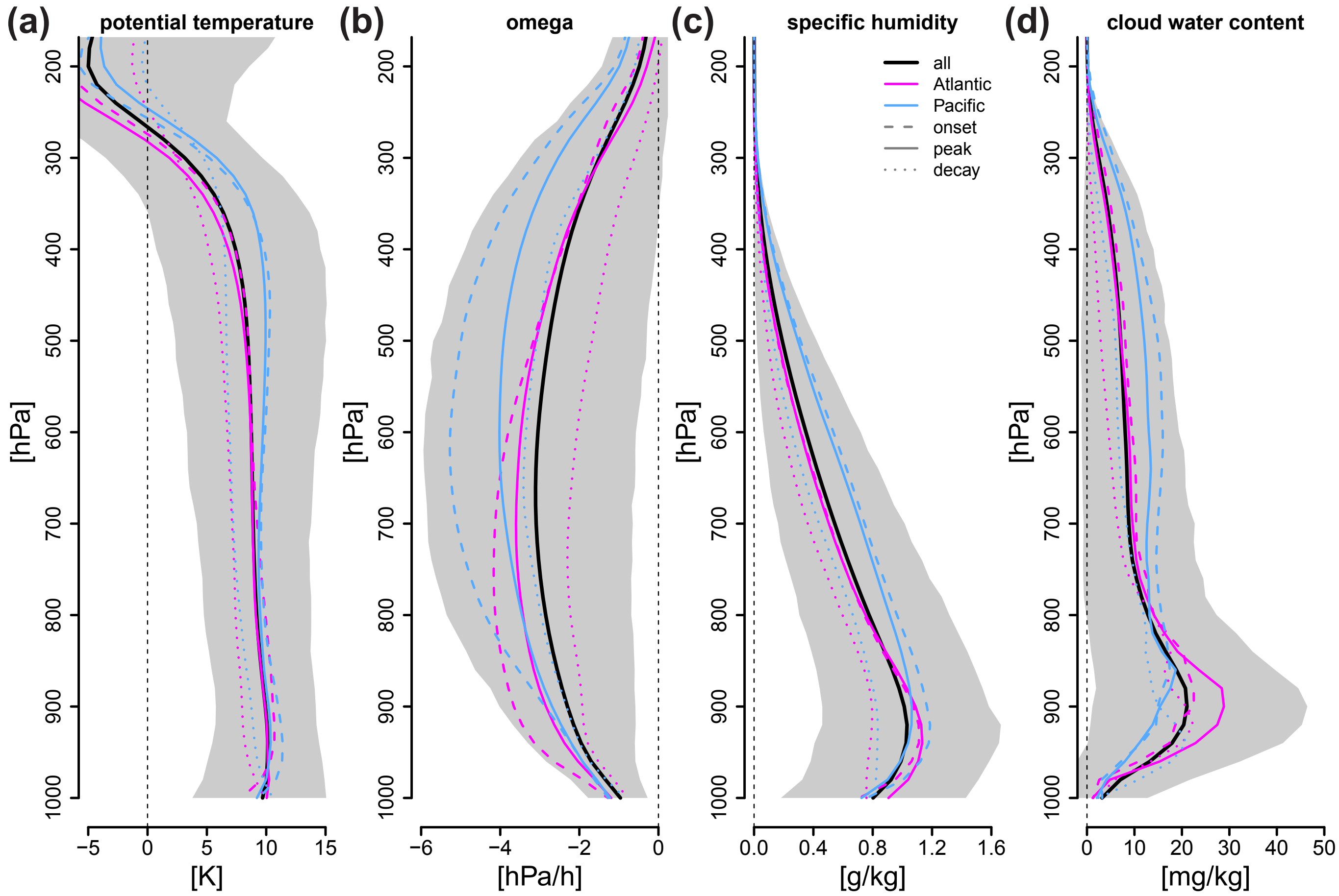
- 41 winters: Nov – March, 1979/80 – 2019/20, ERA5 reanalysis data
- Positive ΔSEB = net energy flux to the surface by turbulent and radiative fluxes, which need to be balanced by energy flux out of the surface to the surfaced below (ice/ocean) → thus imposing local sub-surface warming and delay of sea-ice growth or ice melt

$$-\Delta C = \Delta \mathbf{SEB} = \Delta LW_{\downarrow} - \Delta LW_{\uparrow} + \Delta SHF + \Delta LHF$$

- $\Delta \mathbf{T_s}$ can be approximated from changes in SEB terms by $LW_{\uparrow}$ ($=\epsilon\sigma T_s{}^4$, following Lesins et al. 2012; Lee et al. 2017):

$$\Delta T_s = \frac{\Delta LW_{\downarrow} + \Delta SW_{net} + \Delta SHF + \Delta LHF + \Delta C}{4\epsilon\sigma T_s^3}$$

Vertical anomalies



Patches with anomalously low / high ΔSEB