Large-Scale Transport in the Arctic

Observing Meridional Transport from Aircraft

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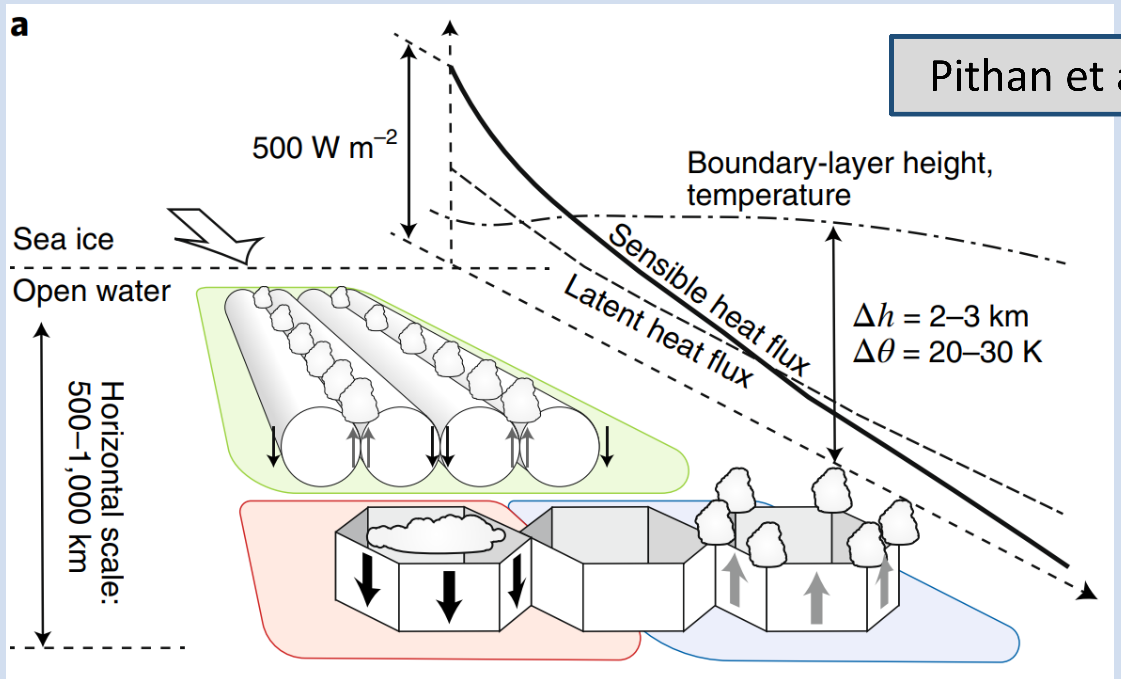
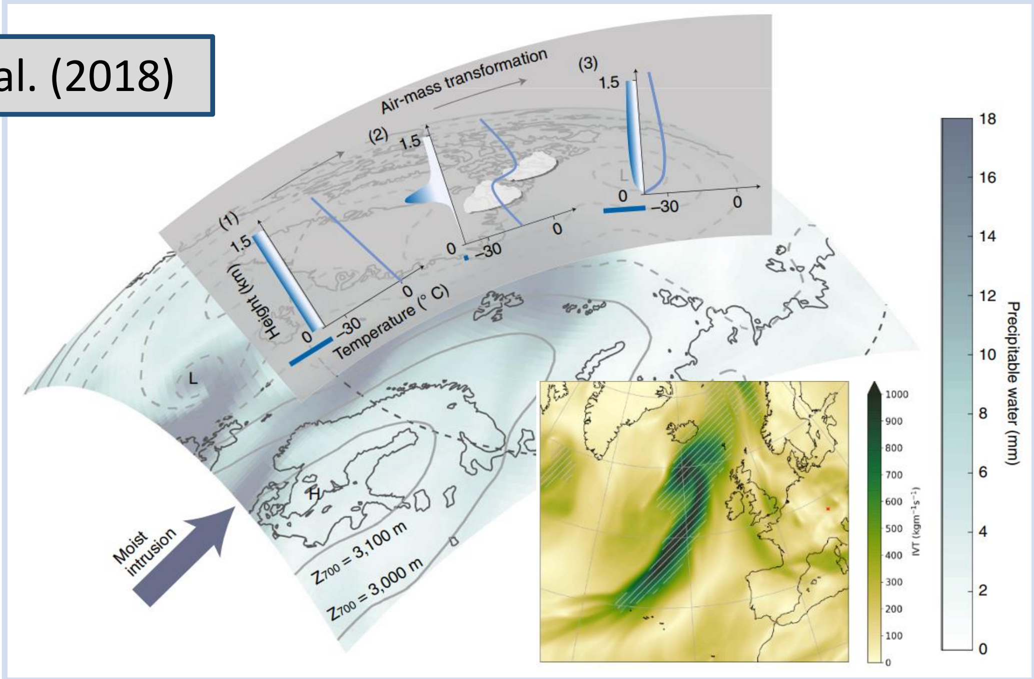
Airmass Transformation along Large-Scale Meridional Transport in the Arctic

	Cold Air Outbreaks (CAOs)	Warm Air Intrusions (WAIs) / Atmospheric Rivers (ARs)
Transport illustrations	 Pithan et al. (2018)	
Dominant Impact	generate surface fluxes of heat and moisture ➔ associated instability of the boundary layer results in shallow convection	Relevant for more ¾ of total moisture transport into the Arctic
No. of days during Dry Run	**12 days** (13 days) **stronger** (weaker) **CAOs**	**1 day** (7 days) **of stronger** (weaker) **WAIs**

What are the main scientific objectives?

Overarching goal: **Understanding air mass transformations along the pathways of large-scale meridional transports**

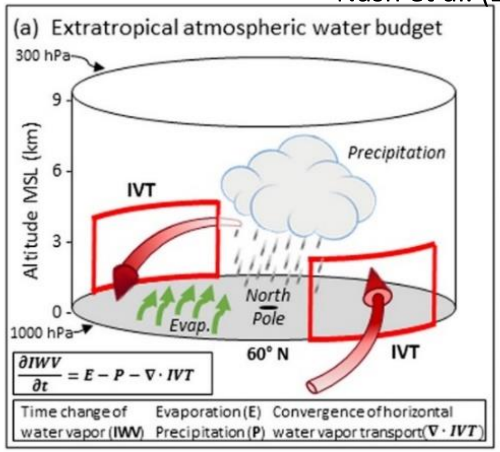
- Q1: Can we close the **moisture budget** of meridional transport phenomena?
- Q2: How large is the **precipitation efficiency** in WAIs/ARs & how does the **precipitation modulate the lifetime** and size of a moist intrusion?
- Q3: How is the **surface energy budget** affected along the transport pathway and by changes in surface type (open-sea & ice)?
- Q4: How is the quasi-lagrangian evolution of the boundary layer and cloud formation affected by the surface conditions along CAOs?

Q1: Aircraft-based closure of moisture budget

Analysing the **moisture budget** in corridors along **large-scale transports** is key to understand the **spatio-temporal airmass evolution** and their **precipitation efficiency**

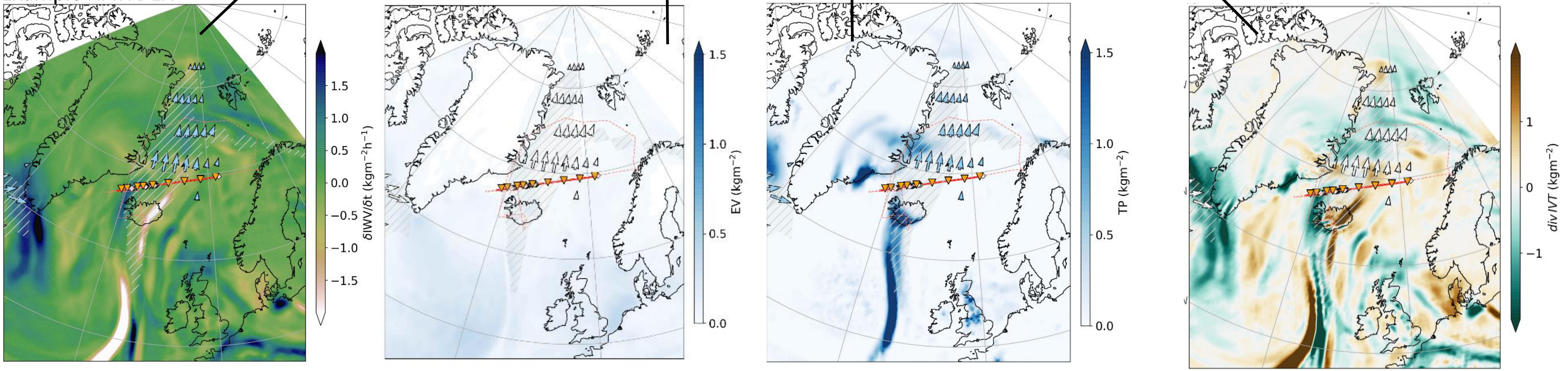
→ accuracy in **budget components** essential

Nash et al. (2018)



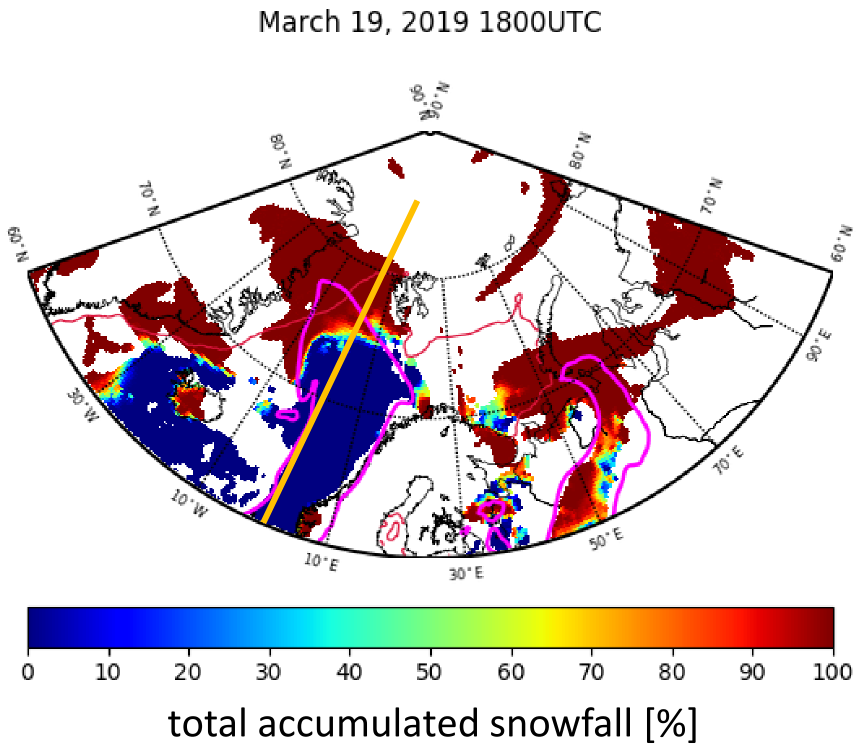
$$\underbrace{\frac{\delta IWV}{\delta t}}_{\text{Temporal change of water vapour load}} = \underbrace{E}_{\text{evaporation}} - \underbrace{P}_{\text{precipitation}} + \underbrace{\nabla IVT}_{\text{water vapour transport convergence}}$$

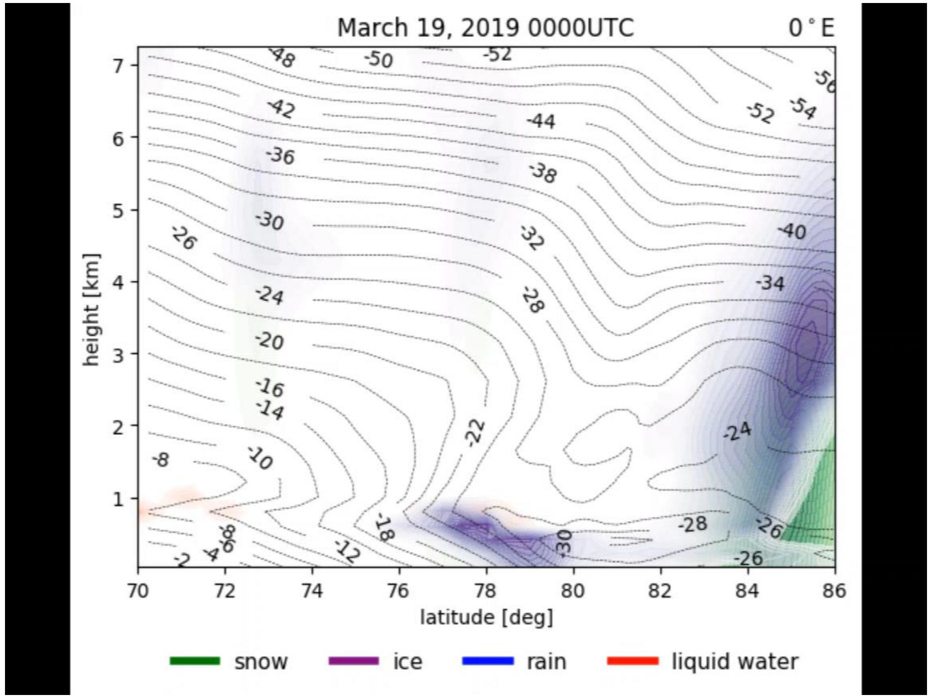
Example NAWDEX



Q2: Precipitation **Characteristics**

- How large is the **precipitation efficiency** in WAIs/ARs & how does the **precipitation modulate the lifetime and size** of a moist intrusion?
- How resilient is the liquid cloud layer along the pathway?

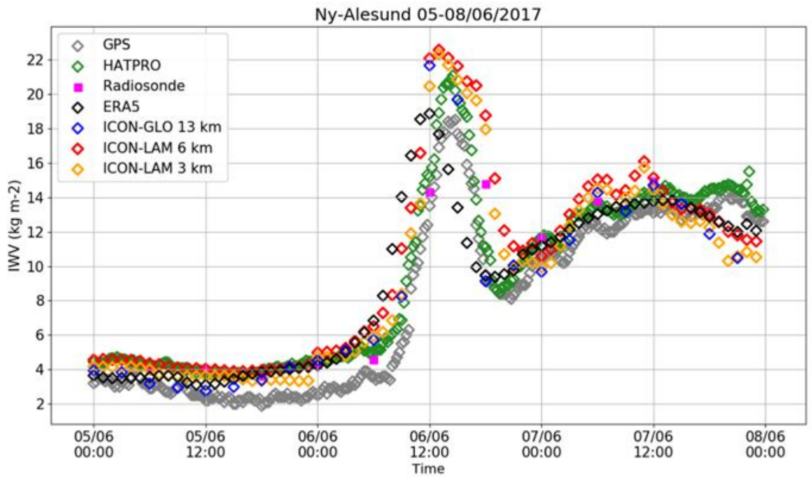


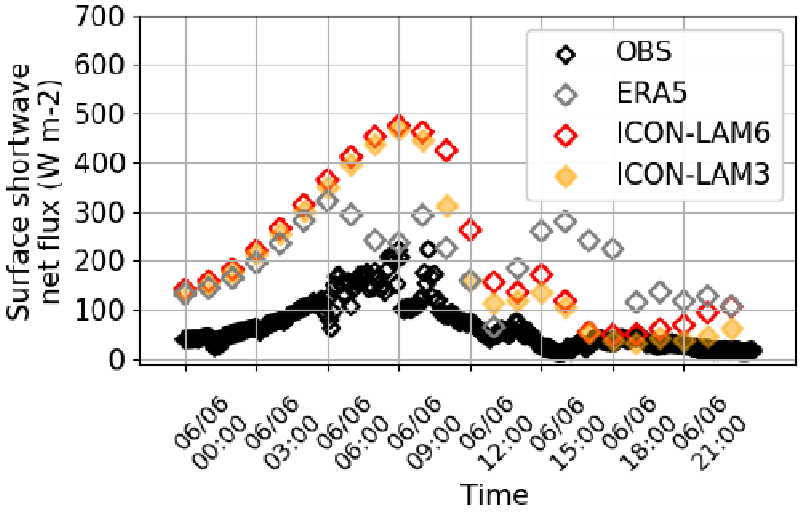


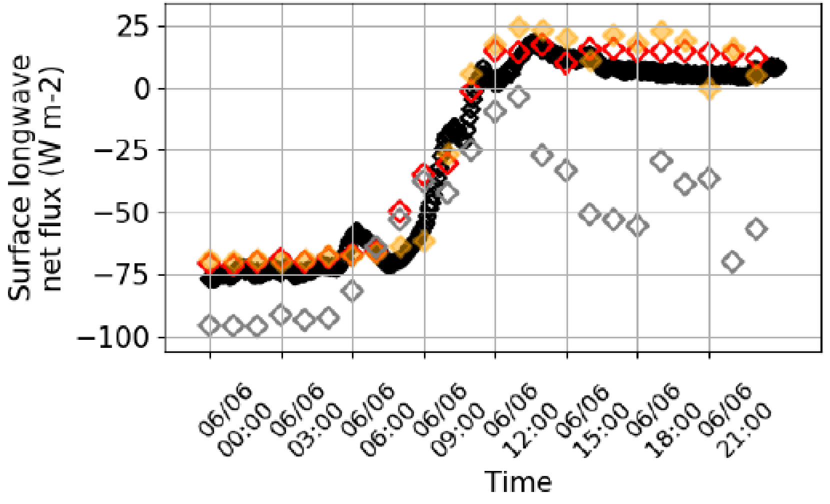
Q3: Surface Energy Budget

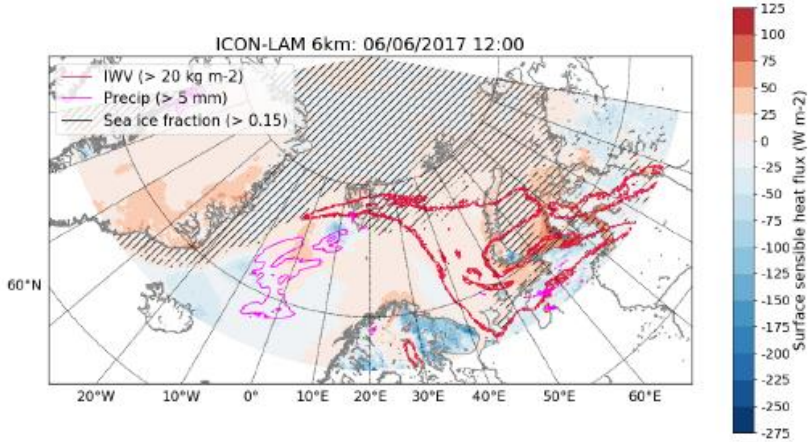
How is the **surface energy budget** affected along the transport pathway and by changes in surface type (open-sea & ice)?

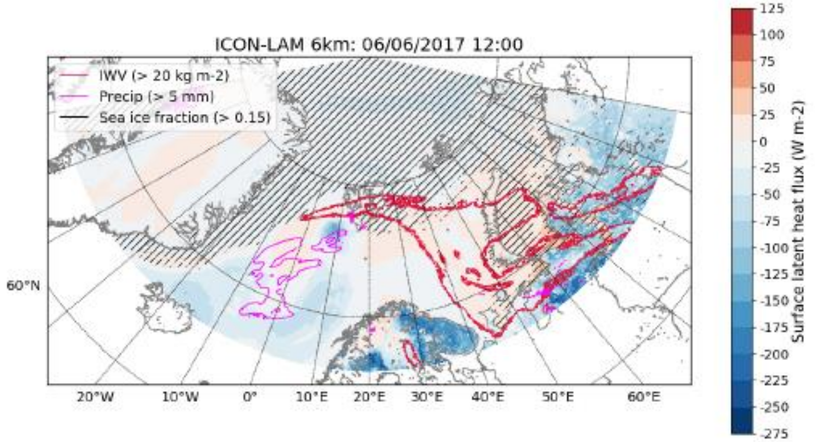
Ny-Alesund 06/06/2017







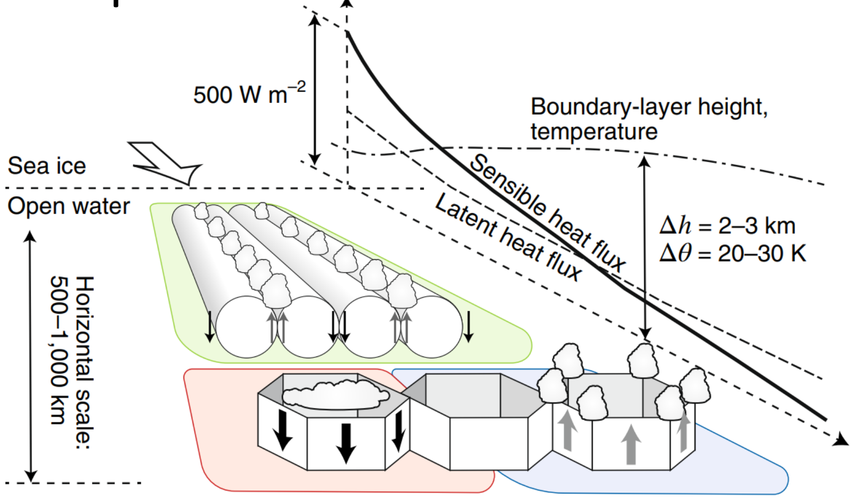


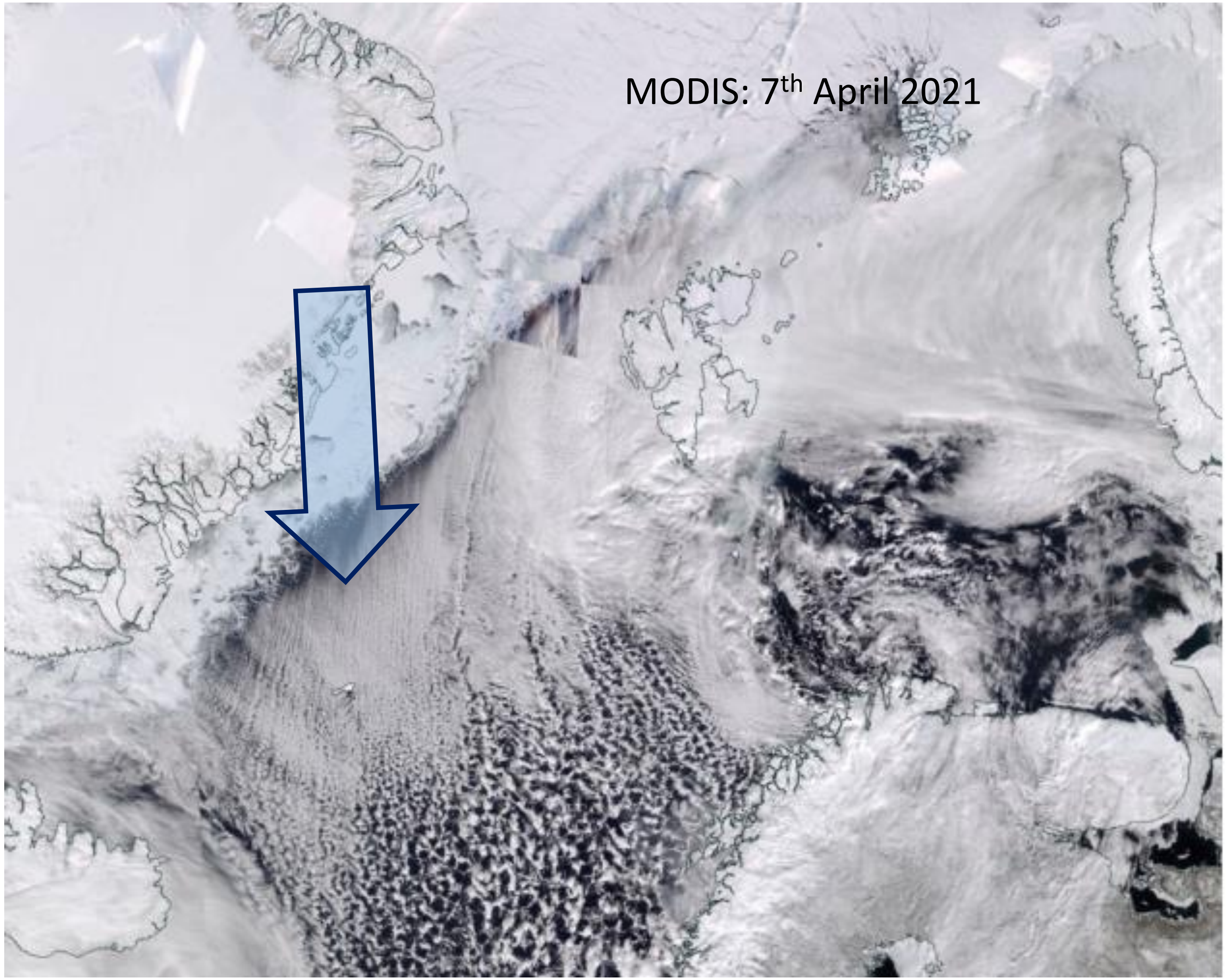


Bresson et al. 2021

Q4: Quasi-Lagrangian Airmass Evolution in CAOs

- How is the **quasi-lagrangian evolution** of the **boundary layer** and **cloud formation** affected by changing **surface conditions**?
- To what extent do **cloud streets** precipitate?
- How do CAOs trigger the **cyclogenesis of polar lows**?





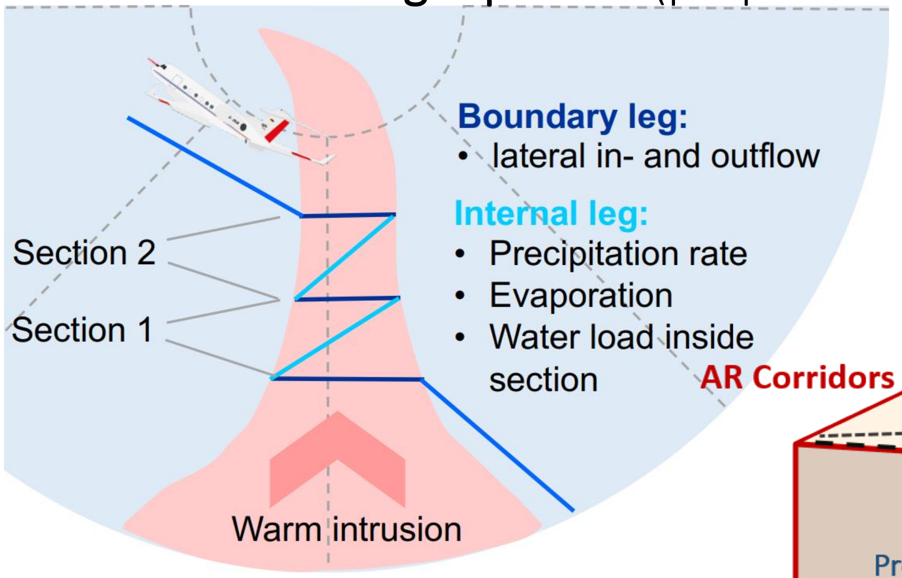
Required Measurement Performance

Are **specific flight patterns** necessary?

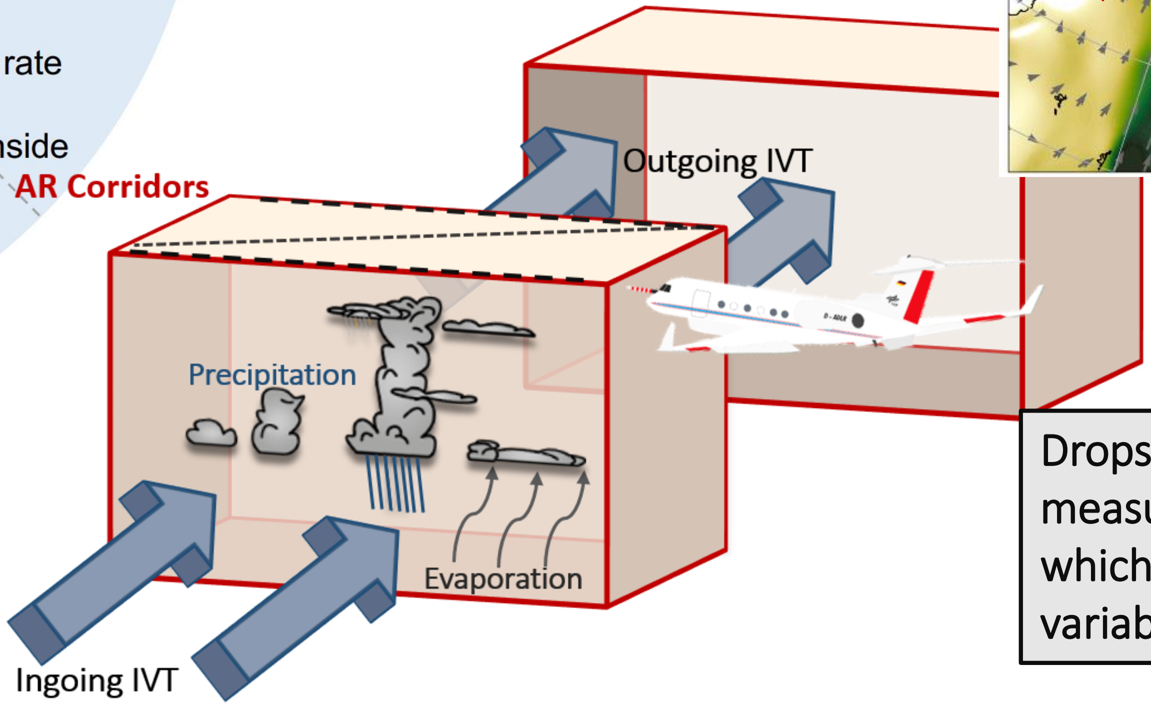
Meridional transport undergoes dominantly oriented flows

→ flight pattern should be adapted accordingly:

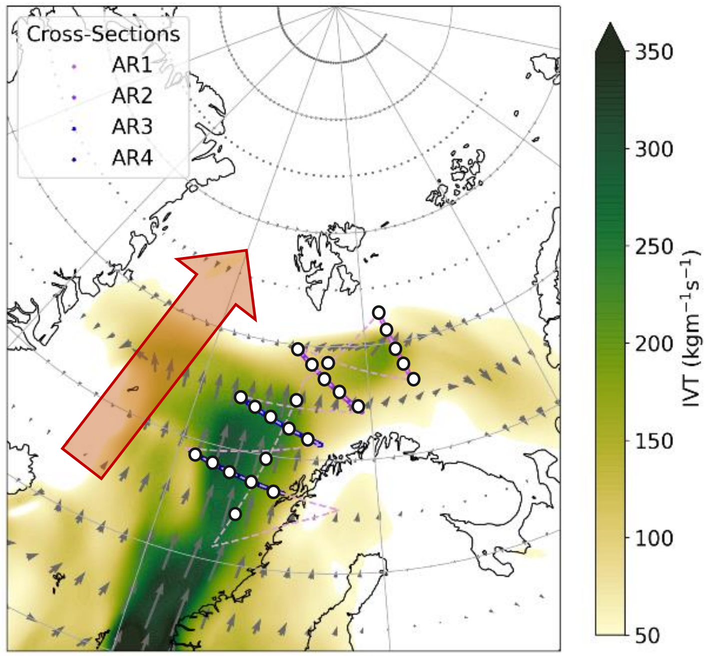
HALO saw-tooth flight pattern (perpendicular and diagonal to the flow)



$$\frac{\delta IWV}{\delta t} = E - P + \nabla IVT$$



HALO-(AC)³
Dry Run

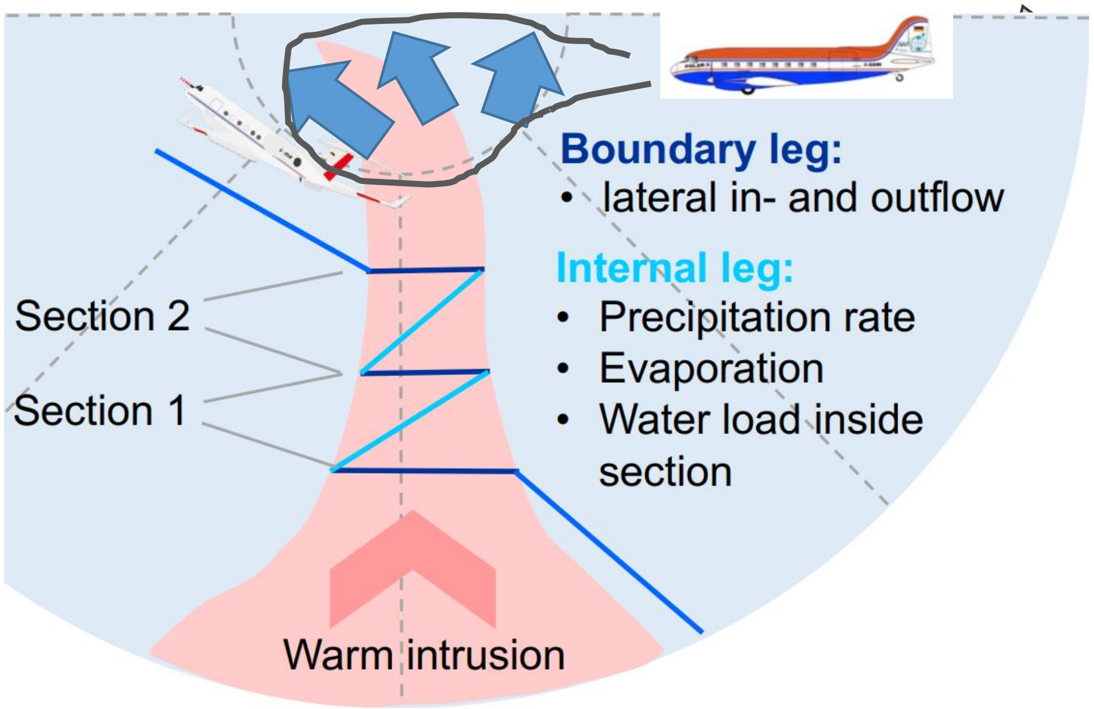


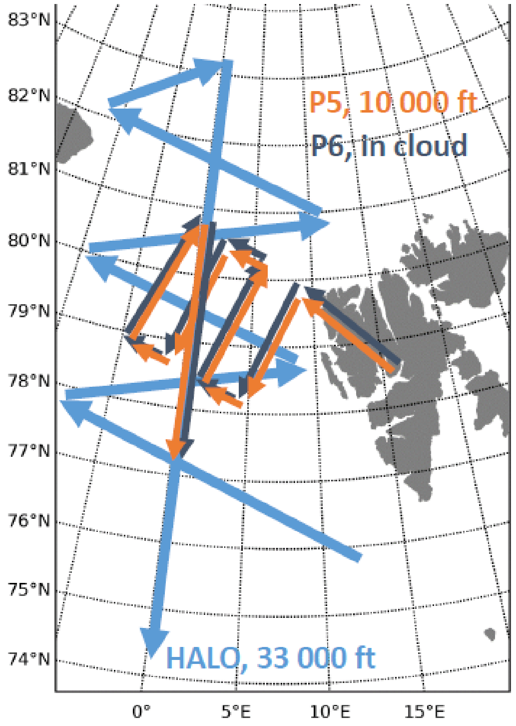
Dropsondes are our single measure of vertical wind profiles which undergo substantial variability across boundary legs

Required Measurement Performance

Are **coordinated flight activities** (HALO/P5/P6) necessary?

- strongly recommended when we want to go into small-scale details
- **HALO is the preferred aircraft for remote-sensing of large-scale transports (long-range)**, but Polar 5&6 can add complementary information of conditions in other AR regions or external of the AR (e.g. if entrainment is significant?).
- Combo pattern reveal more insights in internal legs **(higher resolution)** by **cloud microphysics/ surface fluxes.**

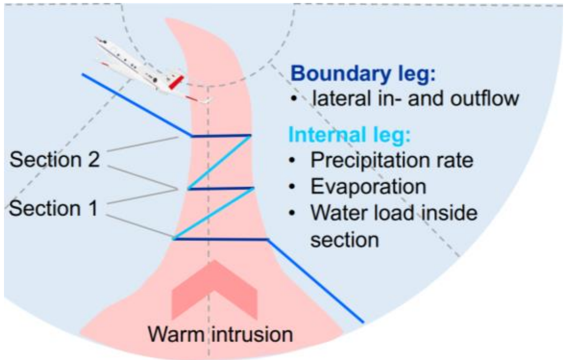




Combo Platter

Required Measurement Performance

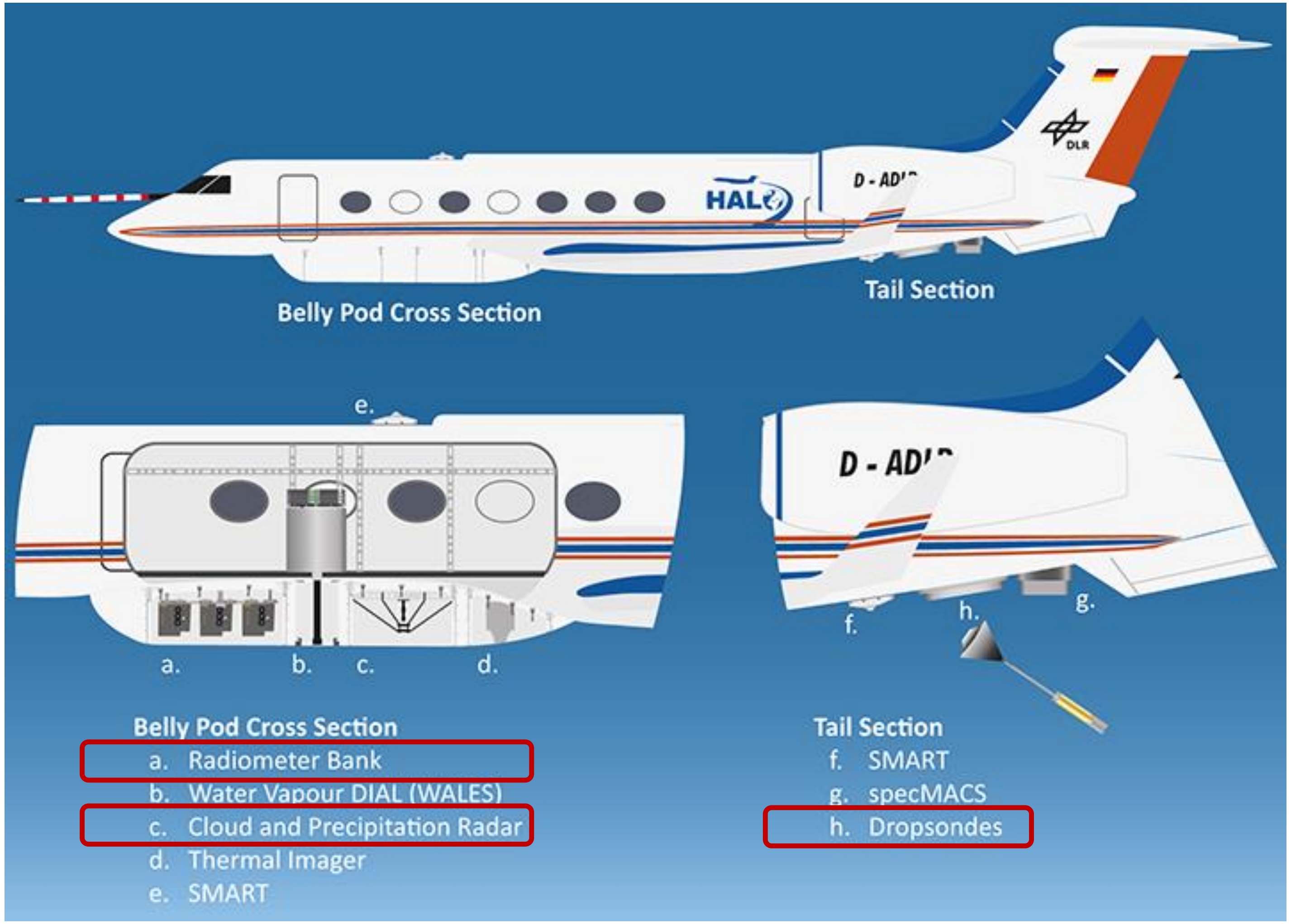
Which **measurement systems** are required?



Boundary leg:
- Dropsondes (GPS-based) → q, v, T, CAO index
- Radiometer (Microwave Bank) → q, T

Internal leg:
- Radar (Ka-Band Doppler Radar)→ Precipitation, Melting Layer
- Radiometer → Hydrometeor-Retrieval, q, T
- Dropsondes → q, T

Other devices:
- WALES (Water-Vapour Lidar) → Hydrometeors, q, Cloudnet Target Algorithm
- specMACS (Hyperspectral Imager) → Cloud-Ice, Curtain representativeness
- Thermal Imager, SMART → Radiative Fluxes



What is expected from the modeling side?

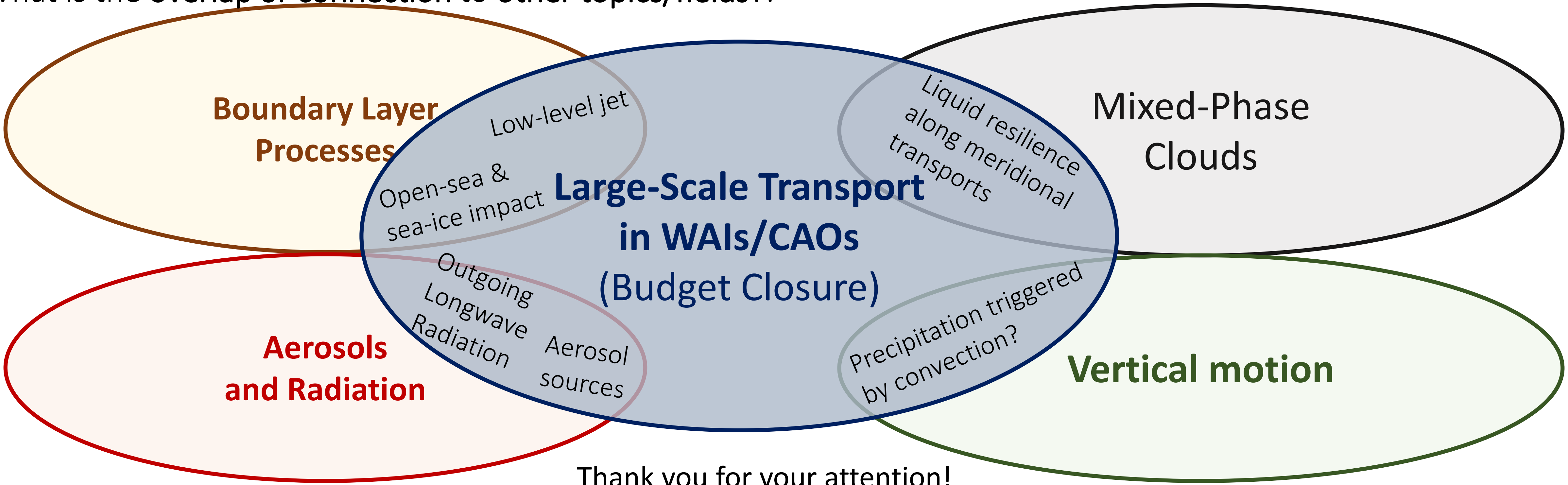
- What is the **position** of the WAI/AR/CAO?
  - NWP with high spatial resolution (<10 km),
  - output of phenomena indicators (IVT,CAO-Index)
- How does the transport act in the boundary layer?
  - Processes of AR/CAOs dominate in BL, high vertical resolution
- How will the **track** of AR/WAI/CAO look and where does it originate?
  - Forecast time steps (<= 1h) and trajectories (LAGRANTO)
- How fast propagates the air mass?
  - requirements from above
- How could HALO fly?
  - easy access of synthetic flight tracks, transport indicators in MSS Tool

Budget closure will be applied in model simulations as well in order to reveal & compare uncertainties in observations and simulations

Conclusions

- Objective: Understanding **arctic air mass evolution in large scale transports**, by **sampling air masses several times** along their track and **close budgets** (moisture/energy)
- Method: **HALO saw-tooth flight pattern**, complemented by Polar aircraft observing small-scale structures
- **Dropsondes are our single device that can quantify winds**

What is the **overlap or connection** to **other topics/fields**?:



Thank you for your attention!