Flying mesoscale circles at high latitudes

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HALO-SPP project:
Observing local and Remote Controls on Arctic Airmass evolution (ORCA[2])

Why do we need Arctic circles?

→ **To measure large-scale subsidence (and gradients)**

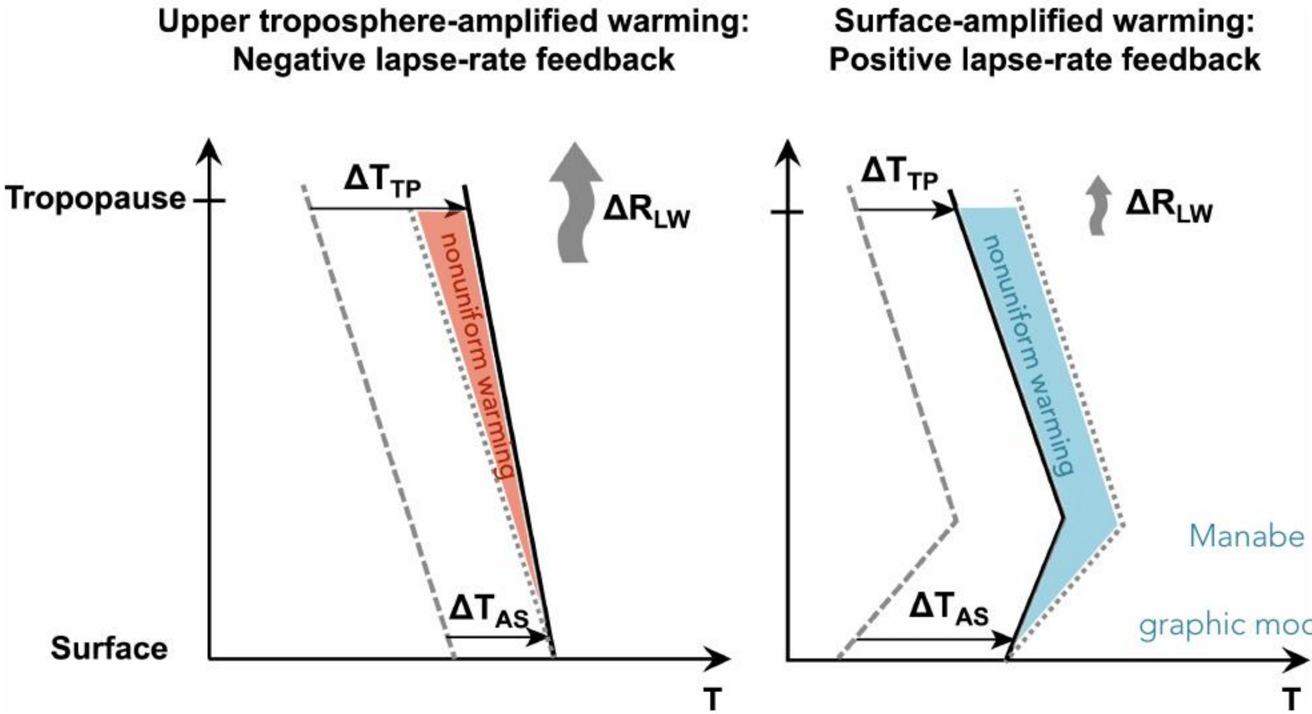
For validating reanalyses

For driving high-resolution models

For understanding the **Lapse-Rate Feedback (LRF)** at high latitudes

LAPSE RATE FEEDBACK

Radiative feedback associated with atmospheric warming that is vertically nonuniform



Manabe and Wetherald (1975)
Bintanja et al. (2012)
graphic modified from Pithan and Mauritsen (2013)

Understanding what happens at lower altitudes is crucial
Subsidence must play a role, because vertical advection acts on the lapse rate
What exactly happens at process level?

Inversions are important!

M-PACE case 2
Morrison et al. (QJRMS, 2009)

Delicate structures featuring sharp jumps

Possibly multiple inversions in a profile

Climate sensitivity has been linked to the representation of inversions (Block et al, 2019; Lauer et al, 2020)

Subsidence strongly interacts with these inversions, acting as a remote control on the evolution of associated mixed-phase cloud layers (Neggers et al., 2019)

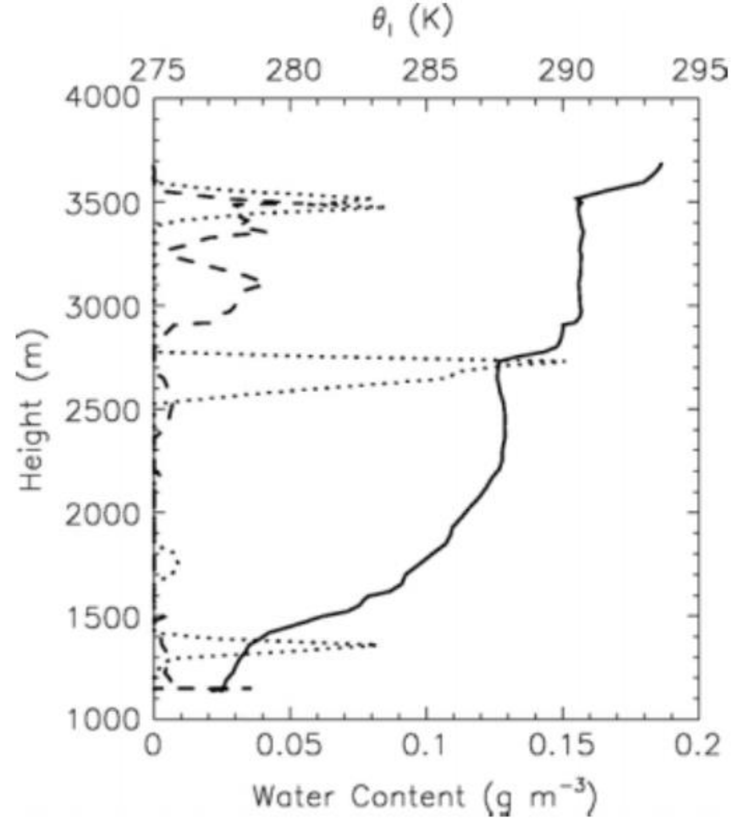


Figure 3. Example of an aircraft profile of liquid water potential temperature, θ_l (solid), liquid water content (dotted), ice water content (dashed), observed during an ascent spiral at about 1917 UTC on 6 October.

Relevant questions for HALO-$(AC)^3$

So subsidence is important for Arctic Amplification

But can we trust large-scale divergence derived from reanalyses?

Can the circle method work at high latitudes too?

Brief update on ongoing work towards answering these questions:

- OSSE: Calculate divergence from virtual dropsondes launched in ERA5 fields
- The ACTIVATE field campaign

OSSE for PASCAL

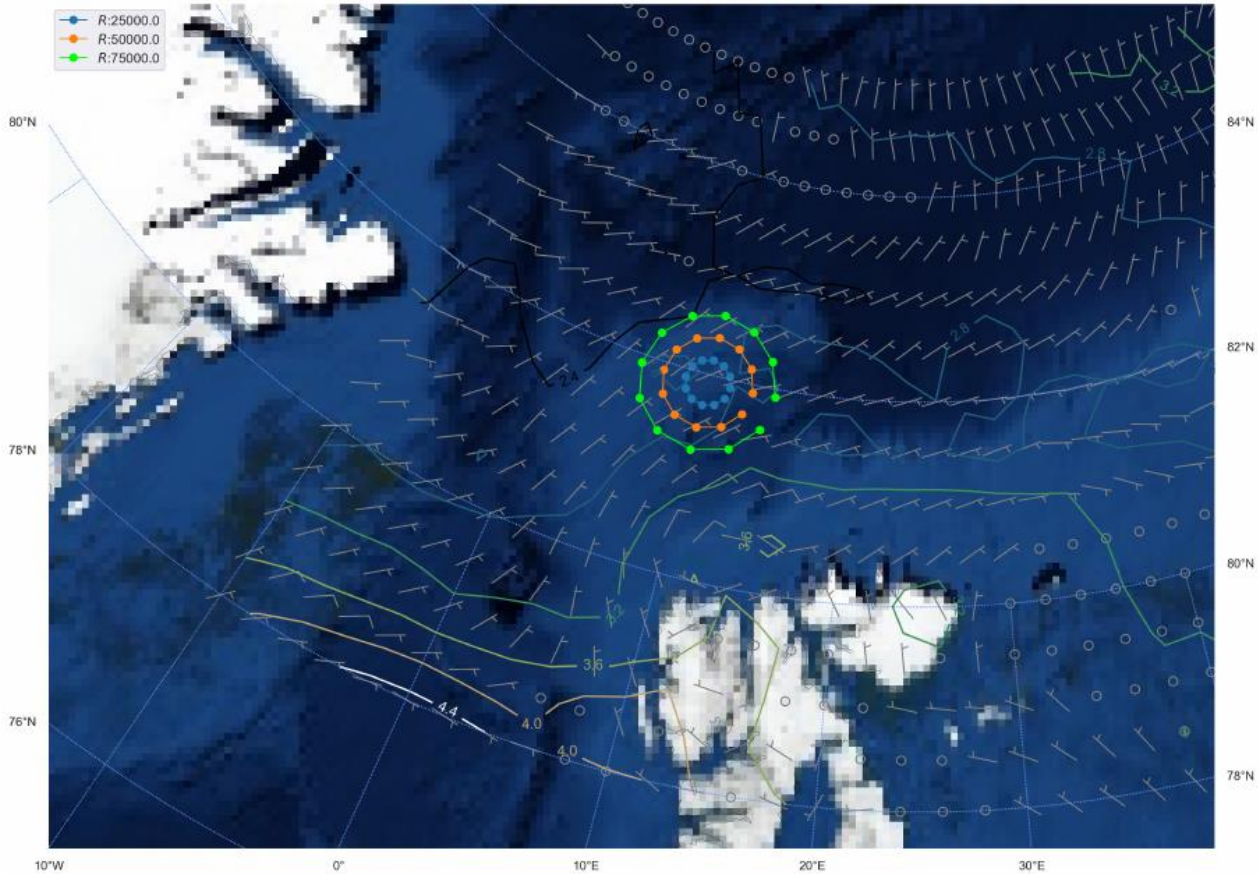


Figure 1: Barb plot of the low level flow in the Svalbard region at 16:45 on 7 June 2017, based on ECMWF IFS data. The water vapor specific humidity is contoured [g/kg]. The dark blue, orange and green lines indicate the circle patterns for circle C02 with a radius of 25, 50 and 75 km, respectively. Each dot represents a virtual dropsonde launch. The circles are centered around the RV Polarstern location. Sea ice is not shown in this image.

OSSE for PASCAL

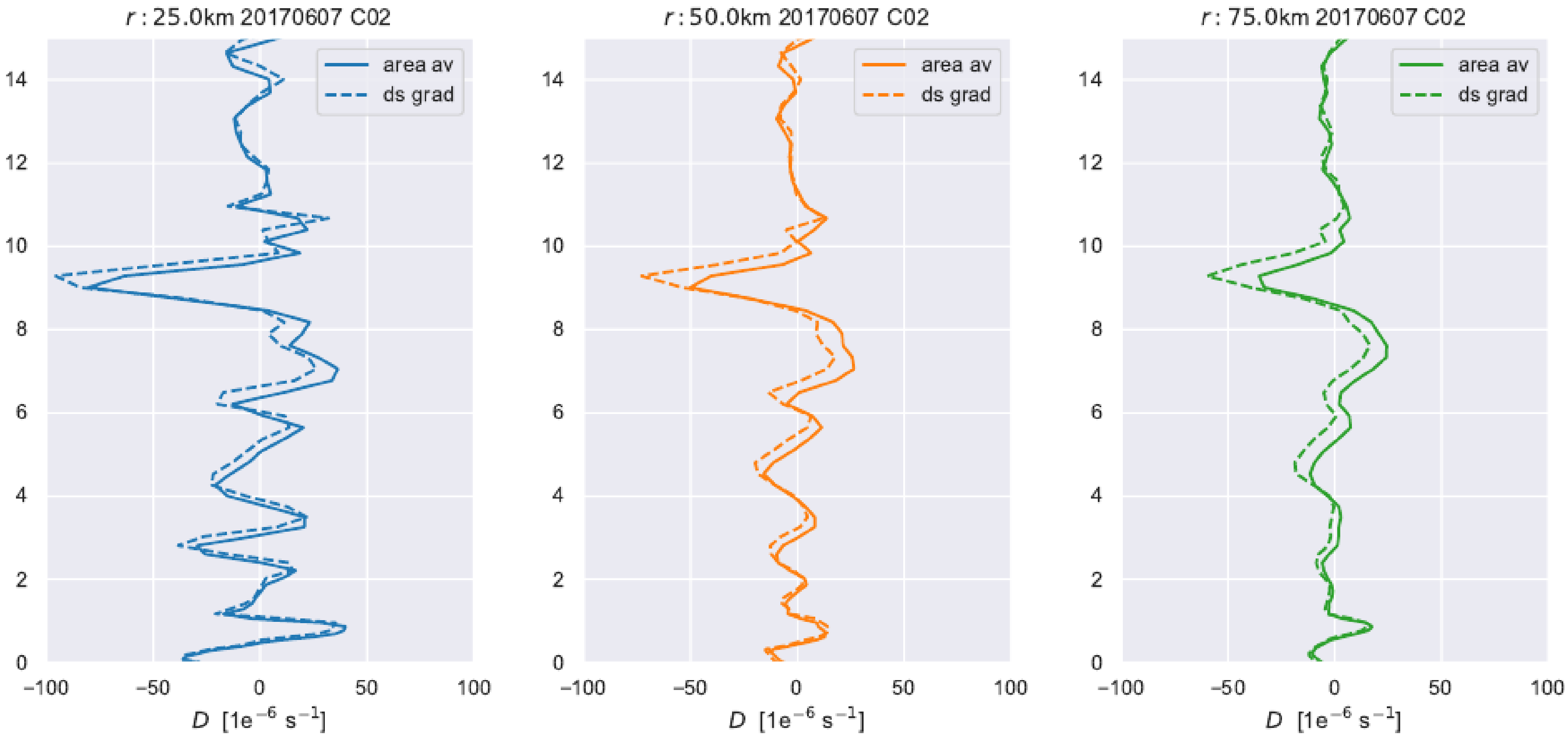


Figure 4: Profiles of reconstructed divergence (dashed) and true area-averaged divergence (solid) in circle C02 for three circle sizes. Left: $r = 25$ km. Middle: $r = 50$ km. Right: $r = 75$ km.

OSSE for PASCAL

Four different time-points,
three circles each

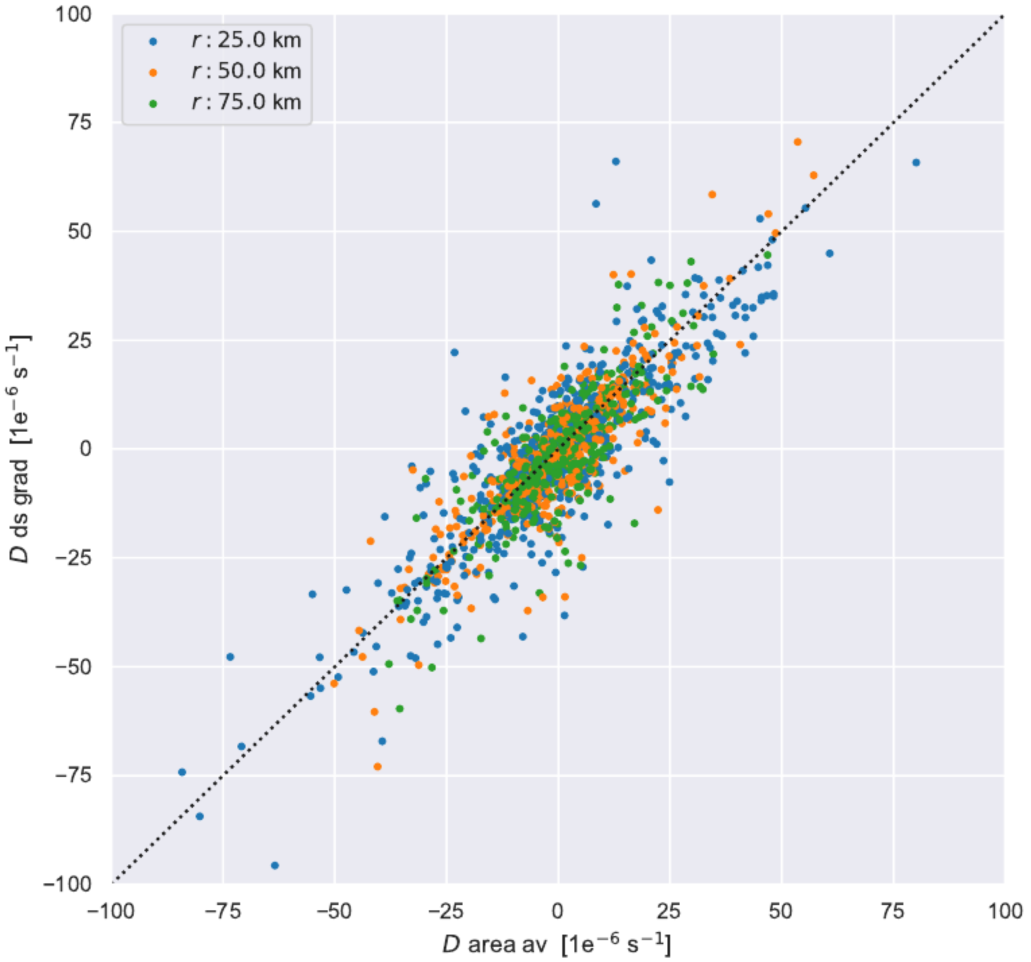


Figure 5: Scatterplot of area-averaged true divergence (abscissa) versus the divergence obtained with the gradient-based method using virtual dropsonde profiles of u and v (ordinate). Color indicates the circle radius. Four circles on 7 June 2017 are included, each coinciding with a RV Polarstern radiosonde released at a 6-hourly interval.

Circles during ACTIVATE

150 flights over the NW Atlantic with two platforms (Falcon & King Air) between 2020-2022

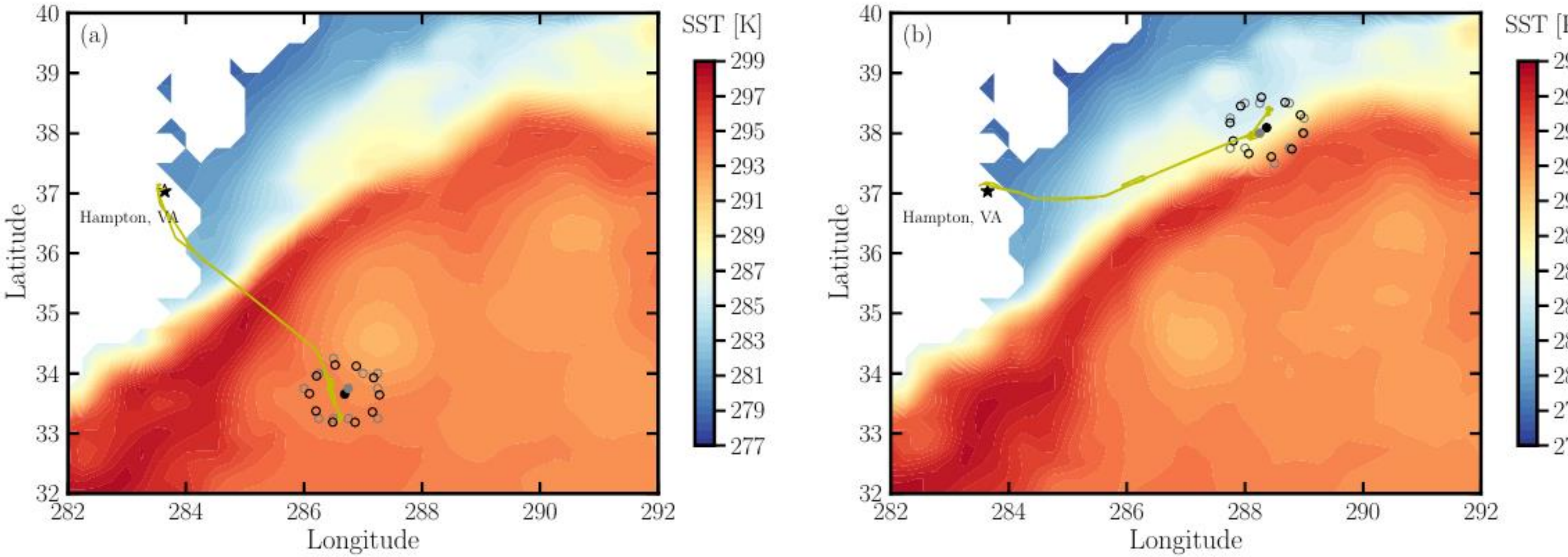


FIG. 1. Location of dropsondes for the (a): February 28 case and (b): March 1 case. Black open symbols are the location of dropsondes at the surface and the gray ones are mapped locations from the ERA5 reanalysis data. Solid dots represent the center of the dropsonde circle. The contour map shows ERA5 SST in the measurement region. Black stars represent the location of Hampton, VA on this map. The yellow curve shows the flight path.

Li et al., preprint, https://arxiv.org/abs/2107.06193

Circles during ACTIVATE

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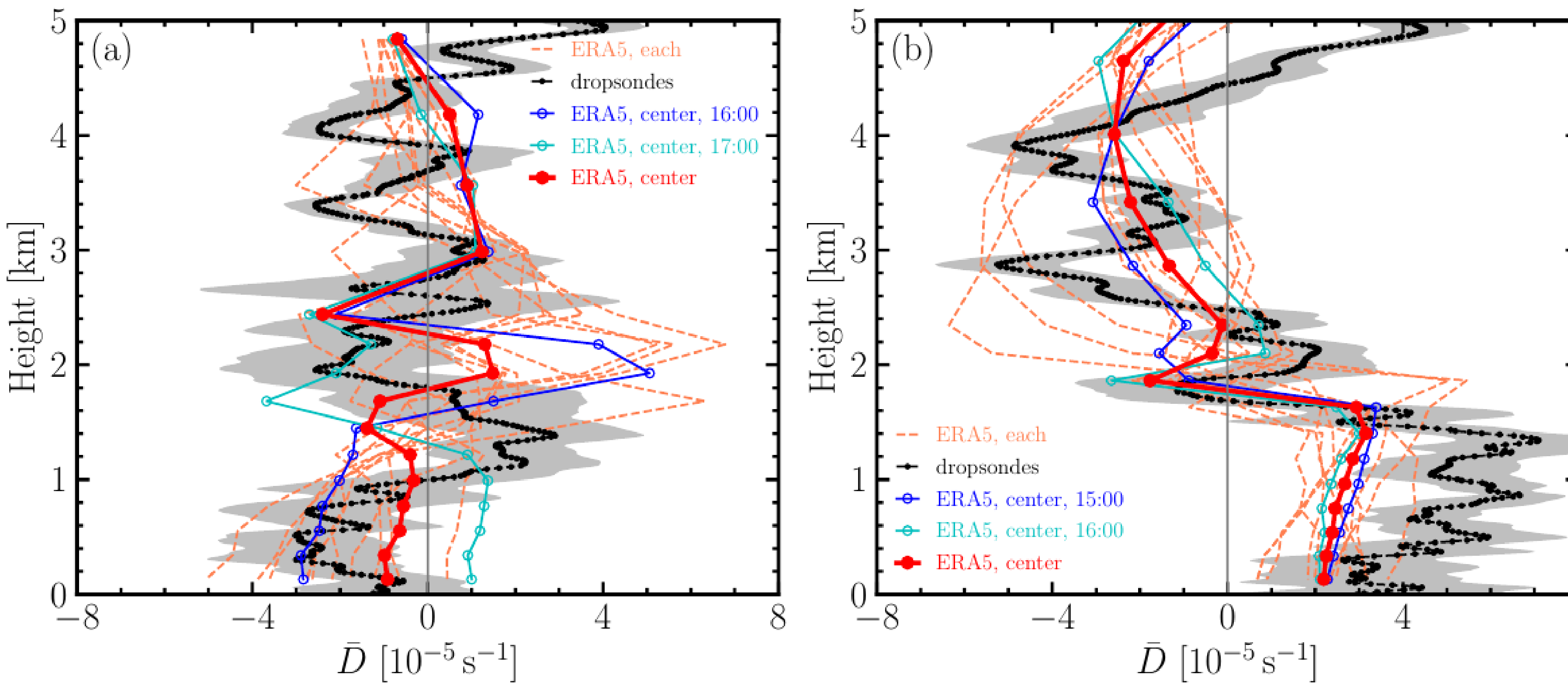


FIG. 3. Comparison of $\bar{D}$ profiles estimated from dropsonde measurements with the one from ERA5 reanalysis data for the (a): February 28 case and (b): March 1 case. Black dotted lines represent $\bar{D}$ estimated from 10 dropsondes with $\pm\sigma_\epsilon$ uncertainty (gray shaded area). Blue lines represent ERA5-$\bar{D}$ profiles at 16:00 UTC for the February 28 case and 17:00 UTC for the March 1 case at the center of dropsondes. Cyan lines represent ERA5-$\bar{D}$ profiles at 17:00 UTC for the February 28 case and 16:00 UTC for the March 1 case at the center of dropsondes. Red solid-dotted lines represent $\bar{D}$ from ERA5 reanalysis data averaged during the measurement time (between blue lines and cyan lines). The dashed coral-colored lines represent ERA5 reanalysis data at the location of individual dropsondes averaged during the measurement time for each case.

Next steps

Prepare for the campaign, and make some decisions:

We learned quite a lot from the dry run:

- We can do circles in the Fram Strait with HALO flying from Kiruna

Discussion points:

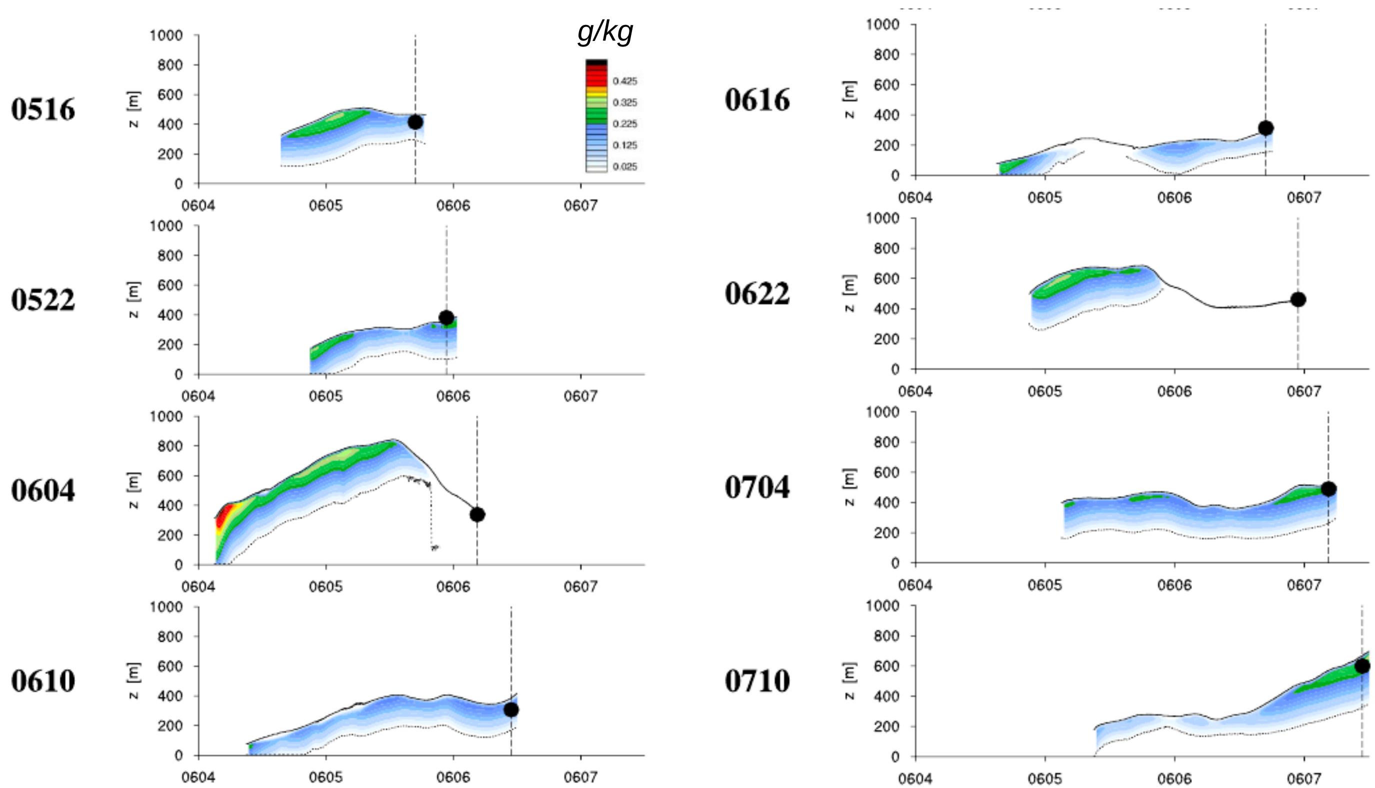
- How many circles can we do? (dropsonde number)
- When are circles appropriate? (conditions/science questions)
- How best to combine circles with other flight patterns?
- Should we still consider doing two circles? (clockwise & counterclockwise)
- Who will use circle data?

Practical points:

- Dropsonde logistics
- Launch training?

How subsidence controls Arctic inversions

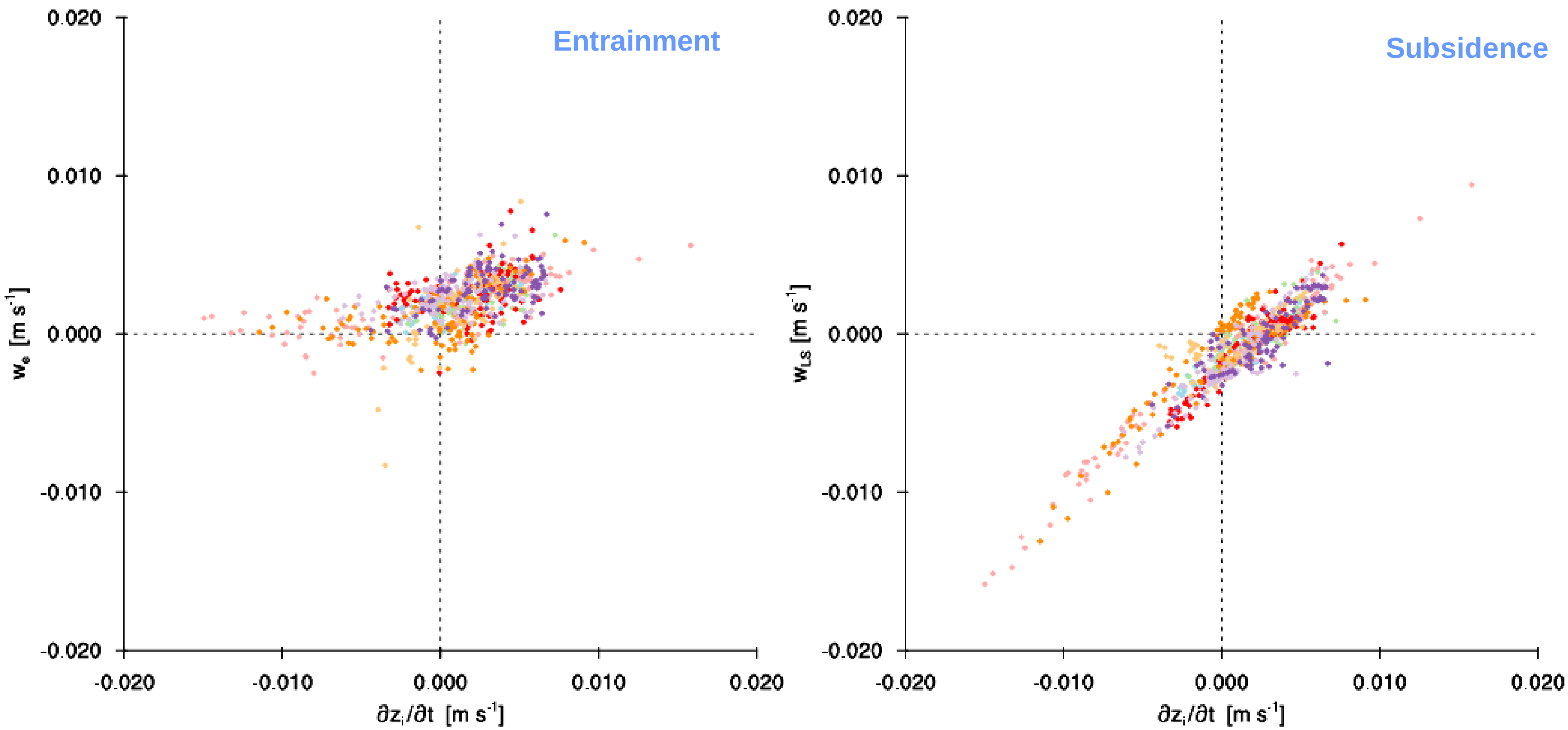
Cloud liquid water in Lagrangian LES for 8 observed air masses during PASCAL:



Neggers et al. (JAMES, 2019)

Bjorn’s mixed layer budget comes to mind, without mass flux: $$\frac{\partial z_i}{\partial t} = w_\mathrm{e} + w_\mathrm{LS}$$

We found that subsidence acts as a strong control on ML deepening:



Liquid water is needed to keep entrainment going. If clouds are pushed below their LCL, break up can occur. The subsidence-entrainment balance might explain the observed persistence of mixed phase clouds in the Arctic (*Morrison et al, Nature, 2012*)