Dynamics of open-cellular convection in marine CAOs

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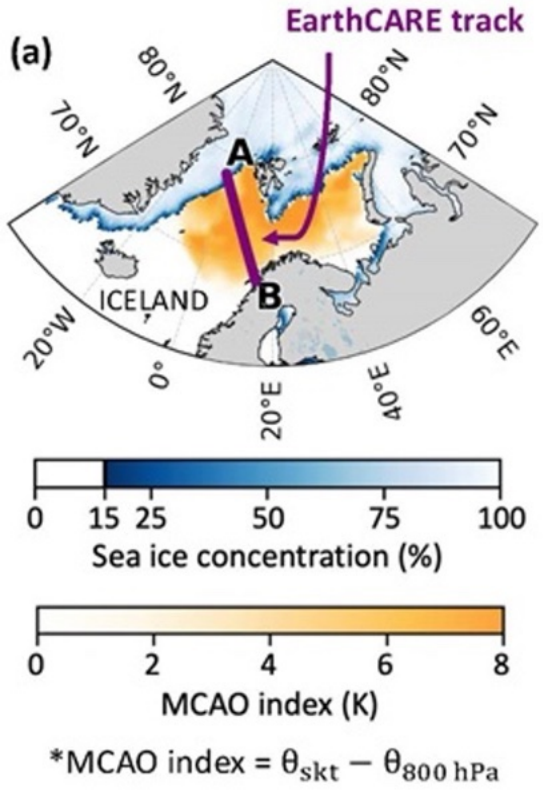
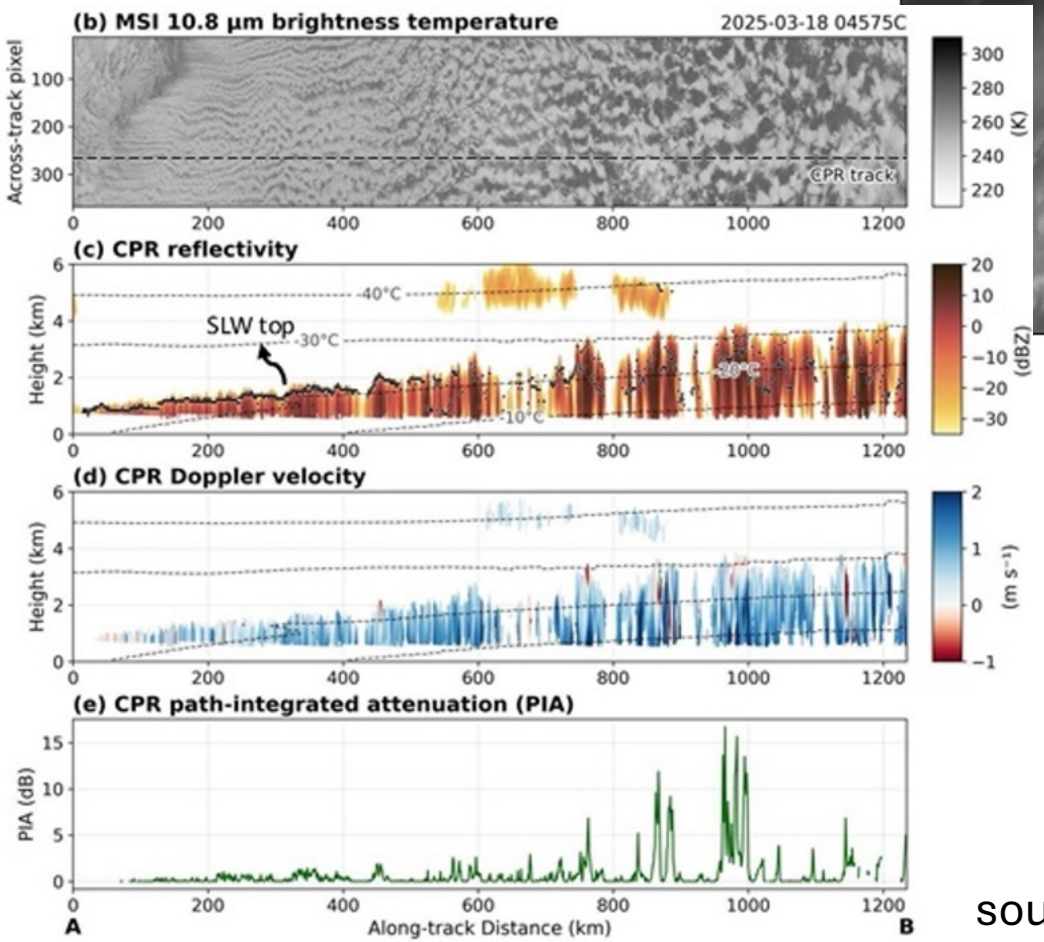
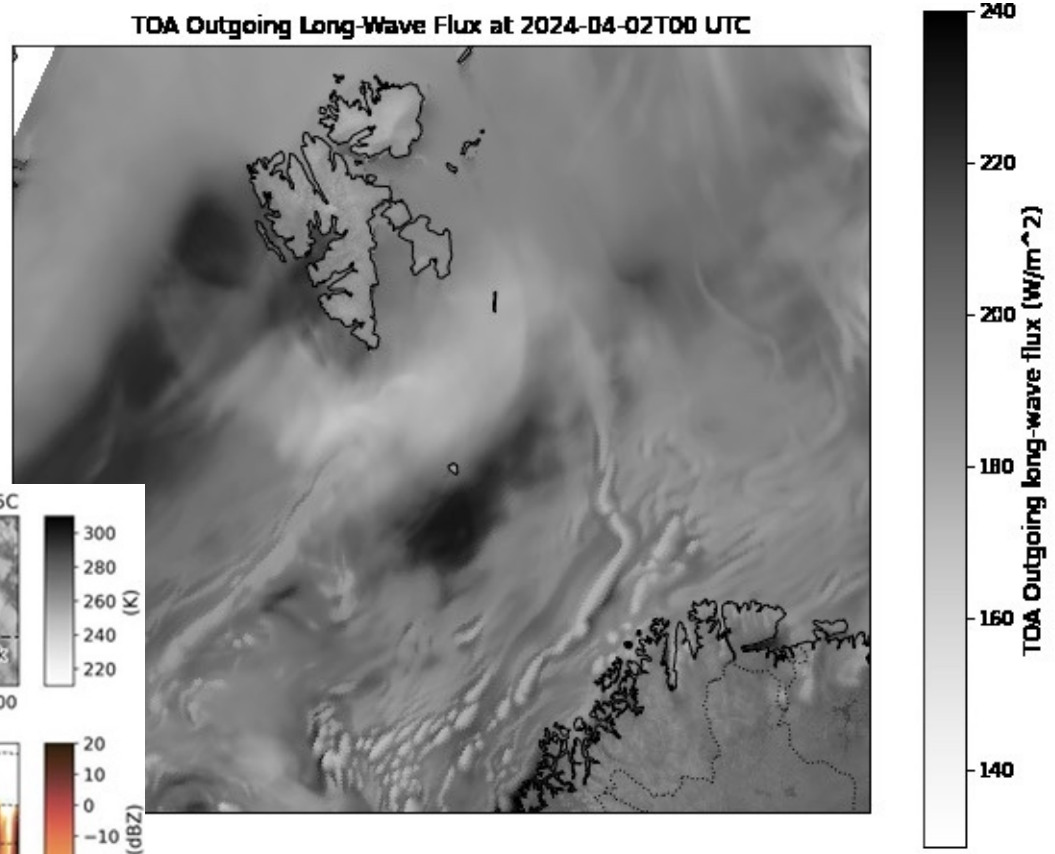
Motivation

Purpose: to investigate novel airborne radar observations of the vertical structure of marine CAO clouds, and relate this to surface fluxes, terrain, and upper-level forcing



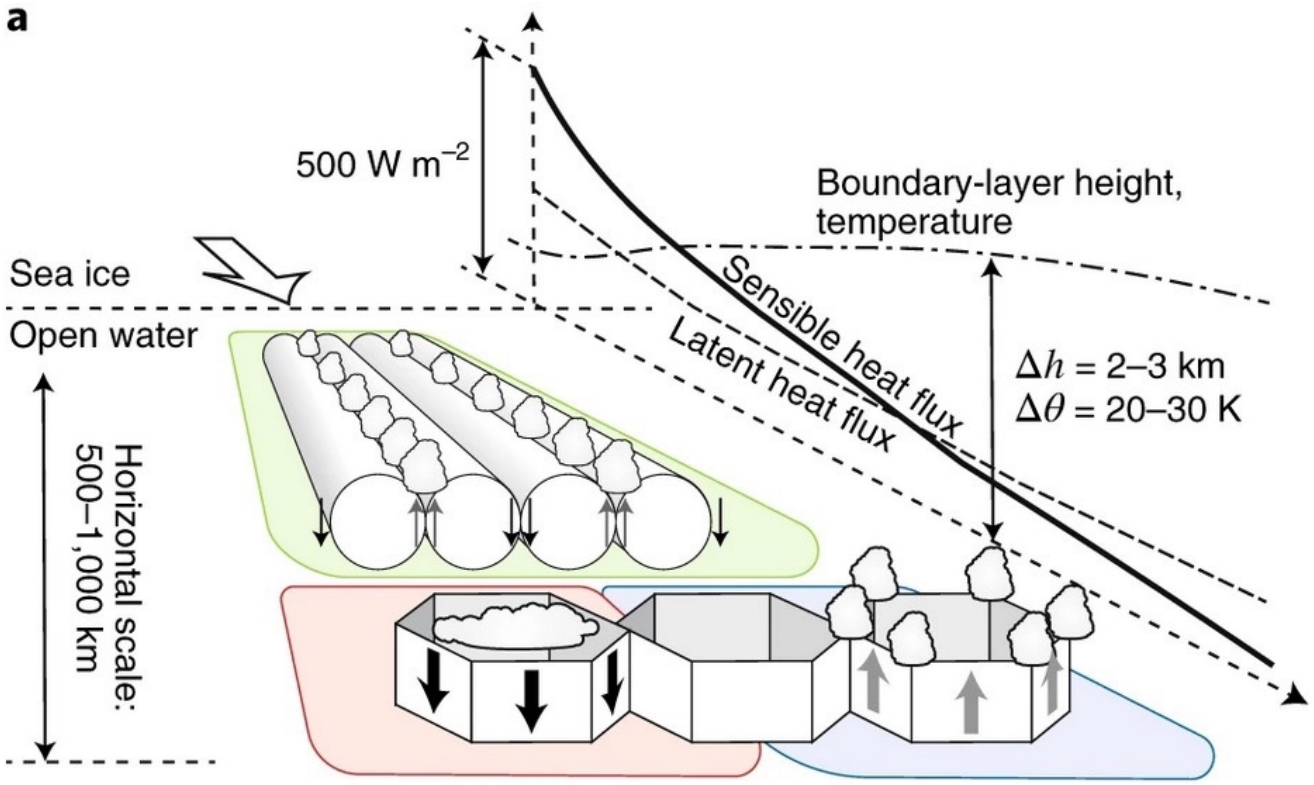




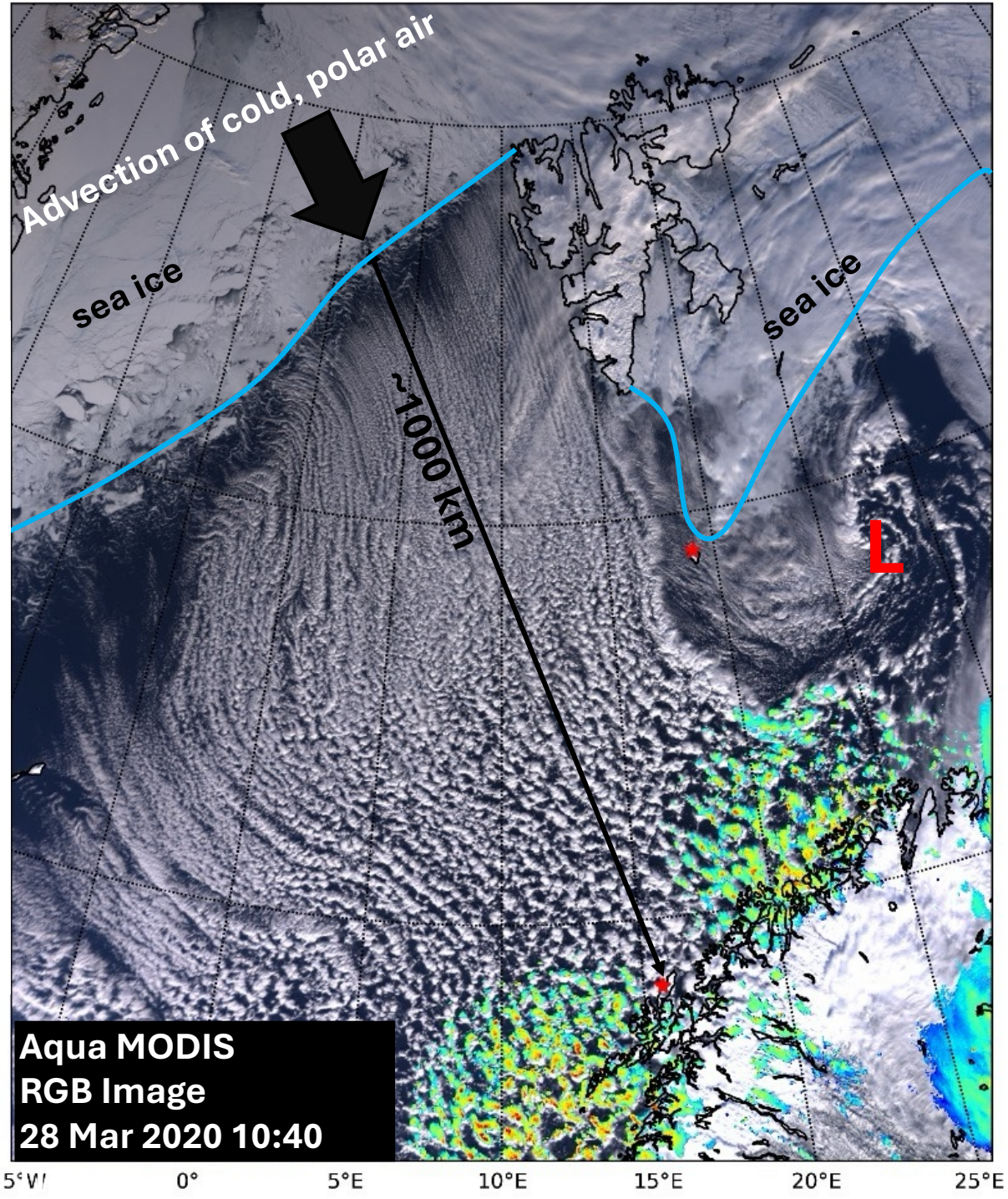
source: EarthCARE

multi-scale interactions

airmass modification in marine CAOs

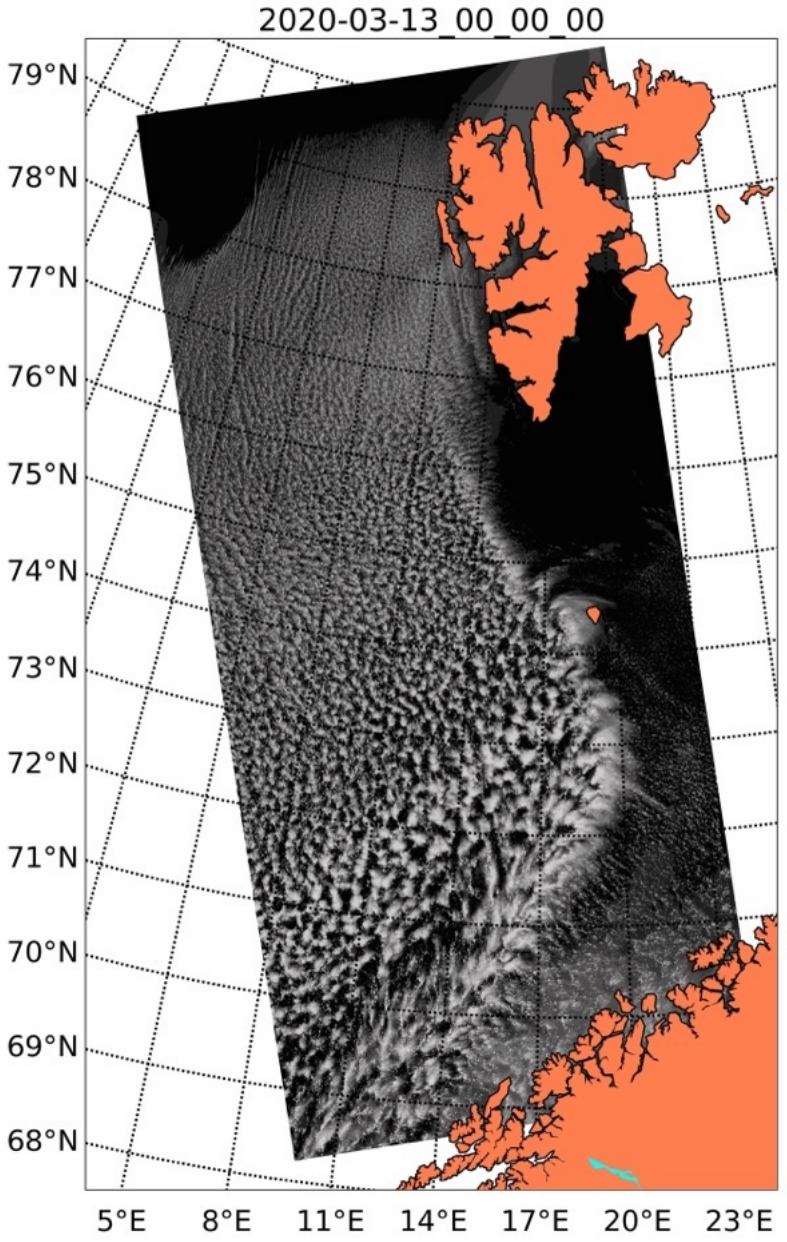


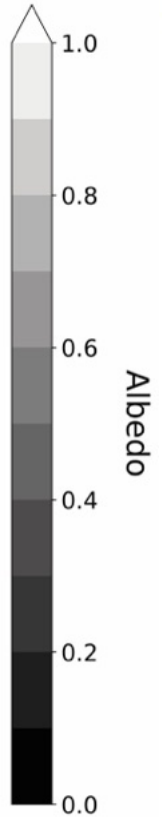
Pithan et al. (2019)

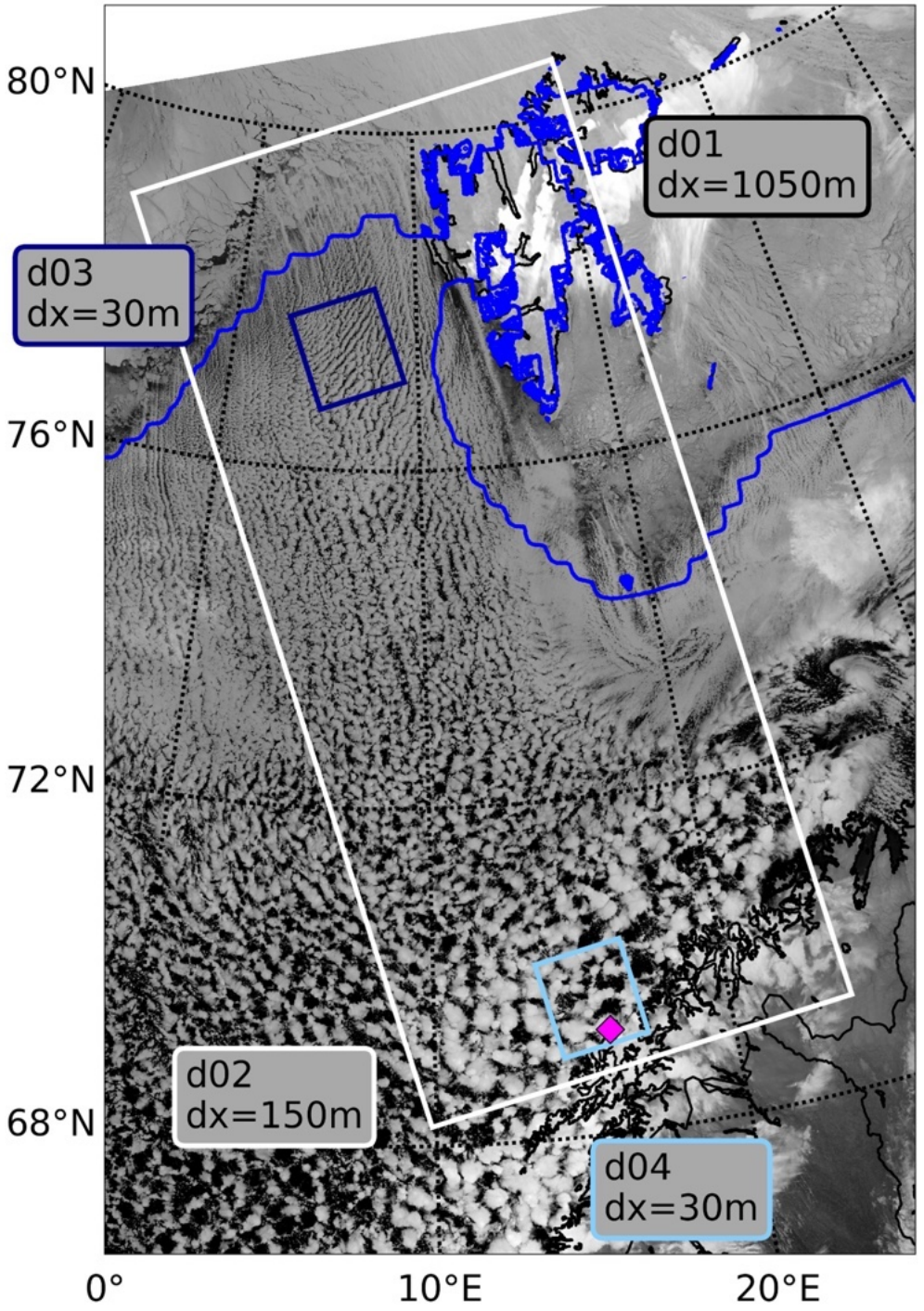


Multiscale LES modeling

linking turbulence and cloud processes with large-scale dynamics







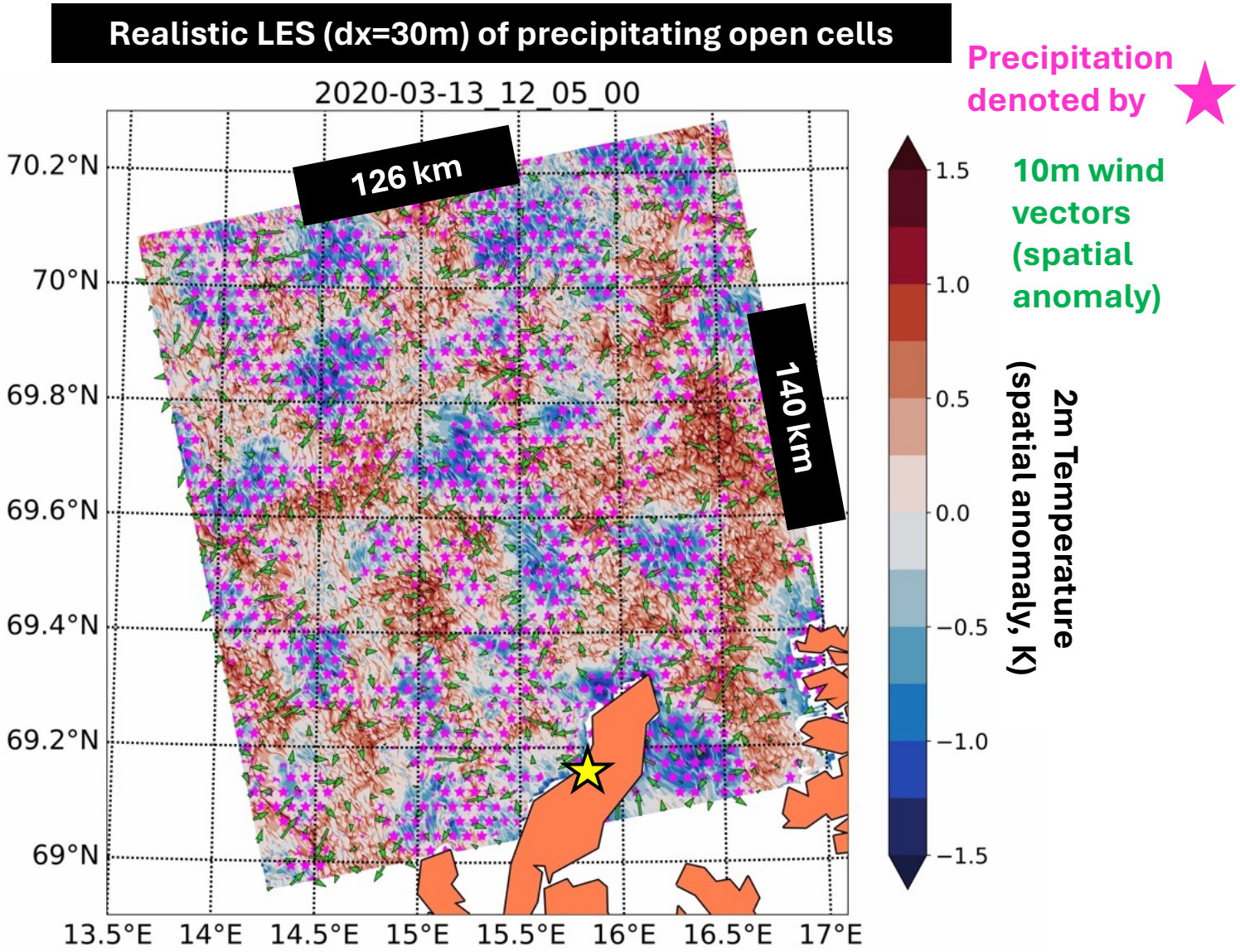
Convective cells undergo an apparent lifecycle.

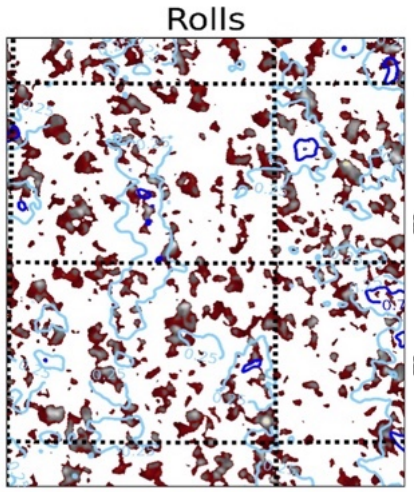
They produce clearings in their collapsing stage.

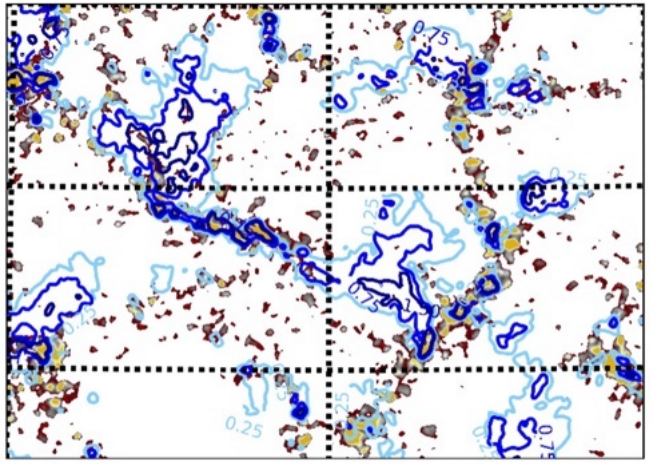
Snow sublimation and downward θ_e transport produces cold pools.

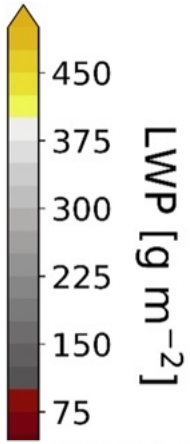
These cold pools are divergent.

Convergent areas are warm anomalies driving new convection.





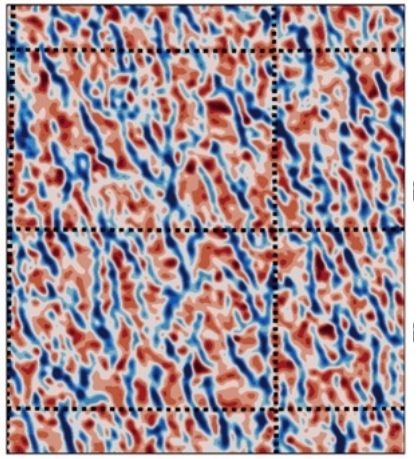


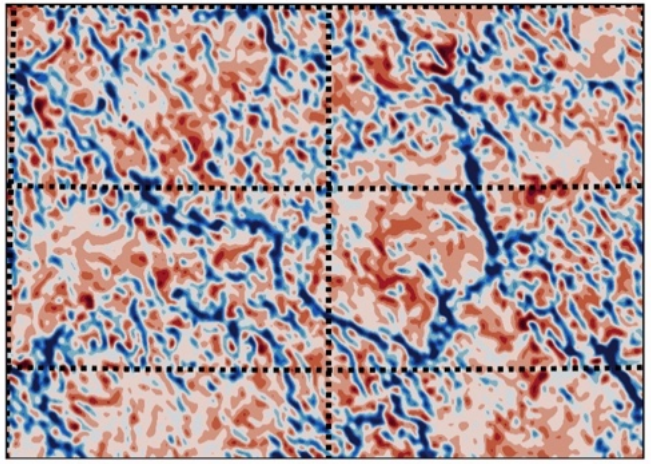


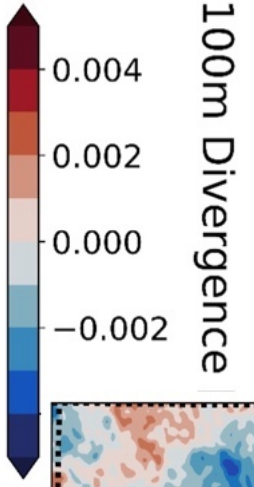
20 km

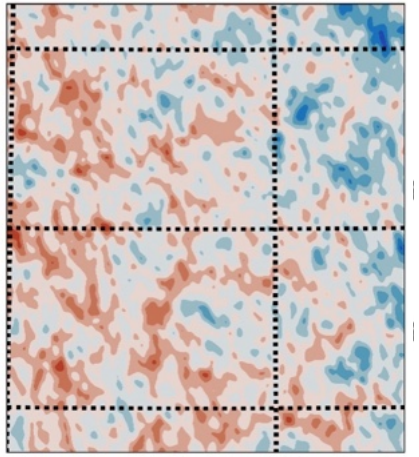
open cell region

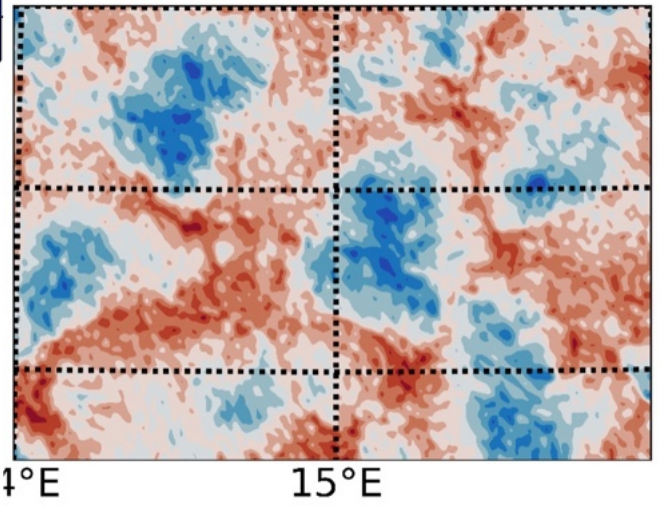
IWC at 1 km

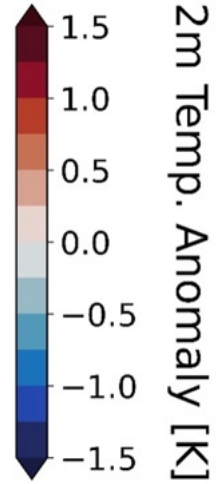












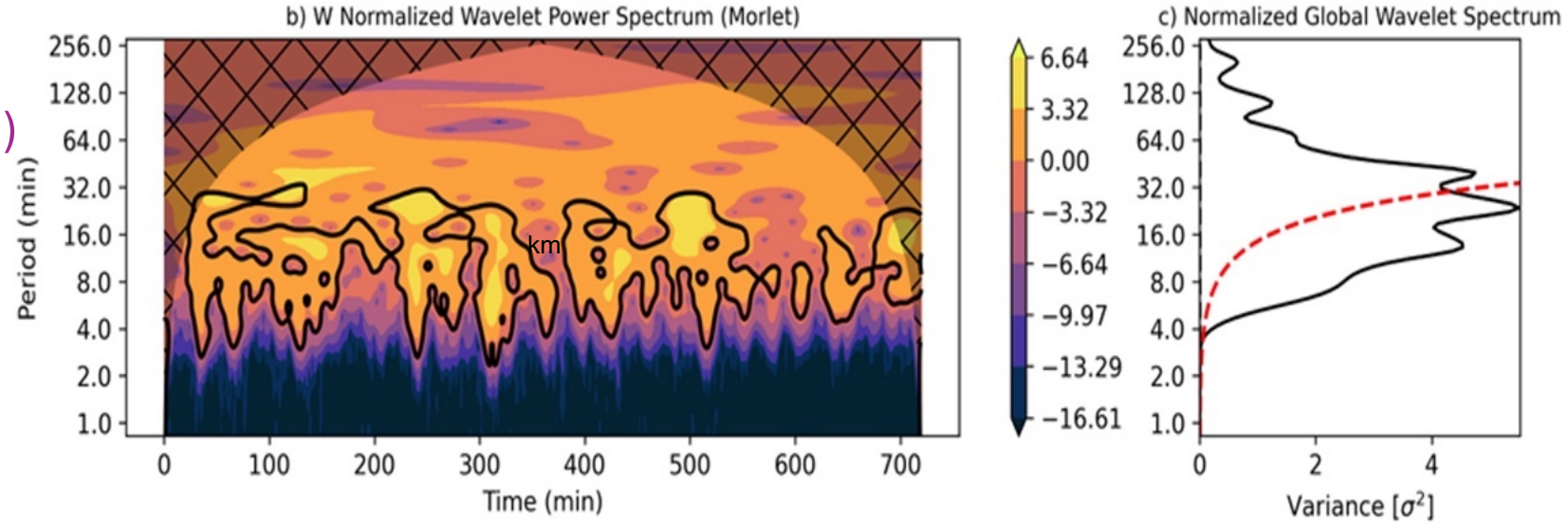
rolls

Open-cell region

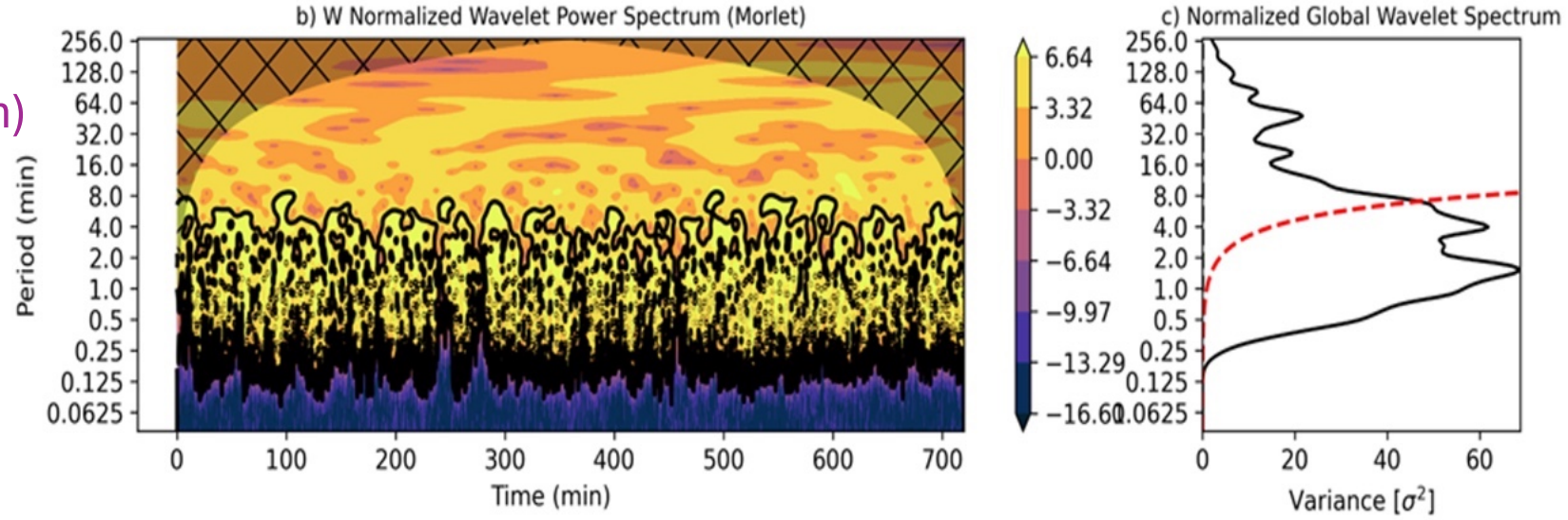
continuous wavelet transform of *w* at ~115 m AGL

KE spectrum depends on grid resolution

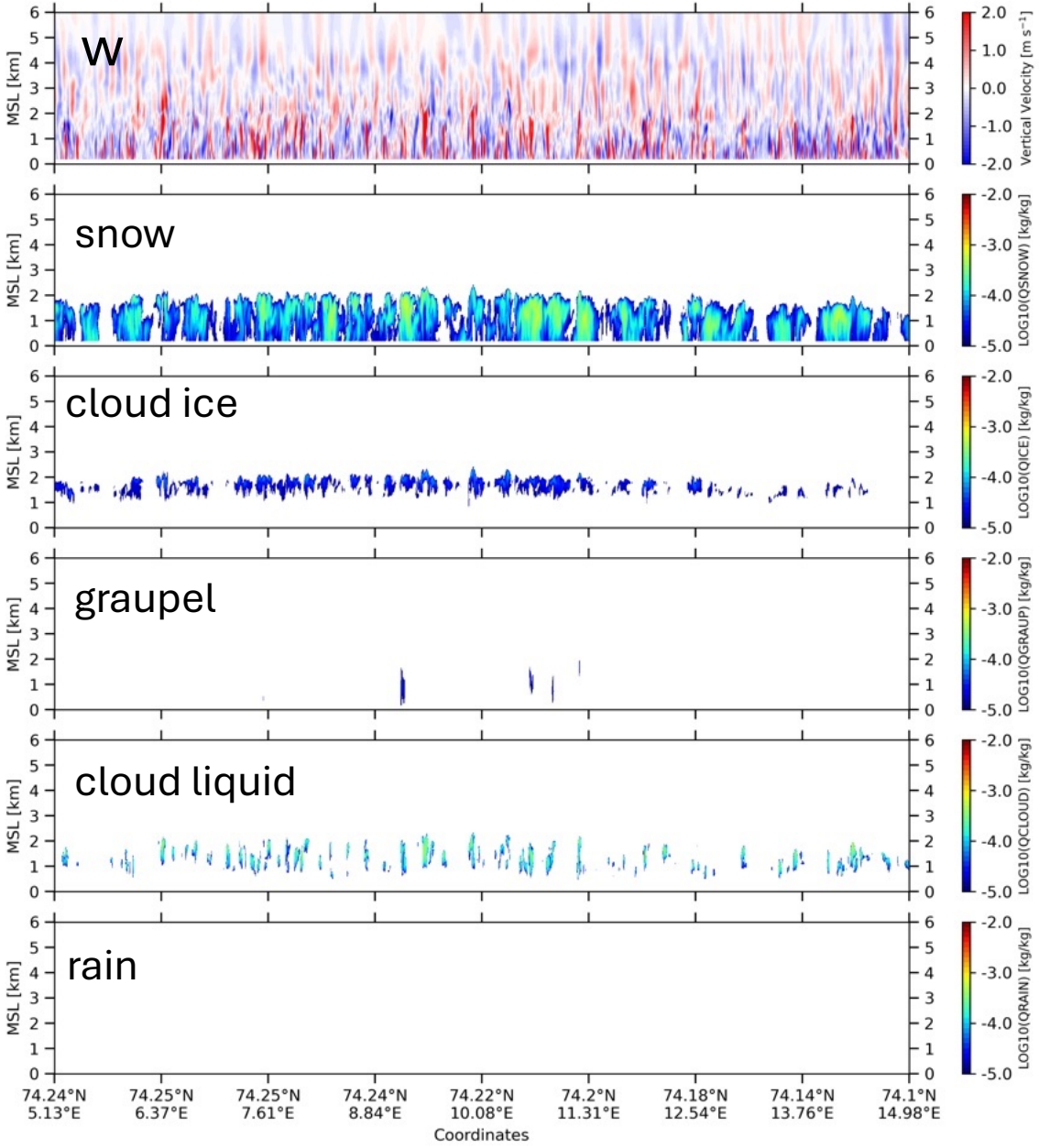
d01 (1050 m):
dominant scale ~4-32 min (~4-20 km)

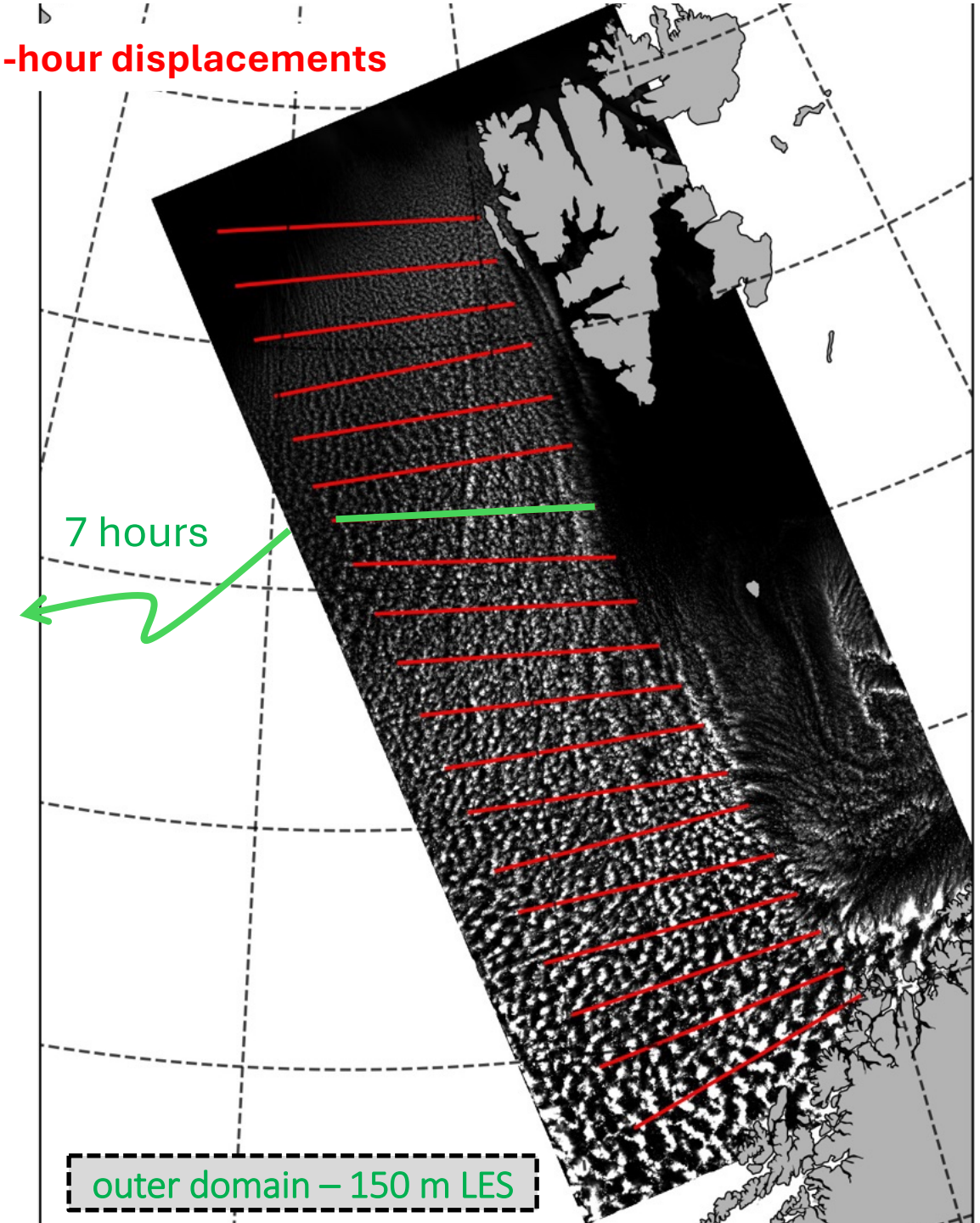


d04 (30 m):
dominant scale ~0.5-6 min (~0.3-4 km)

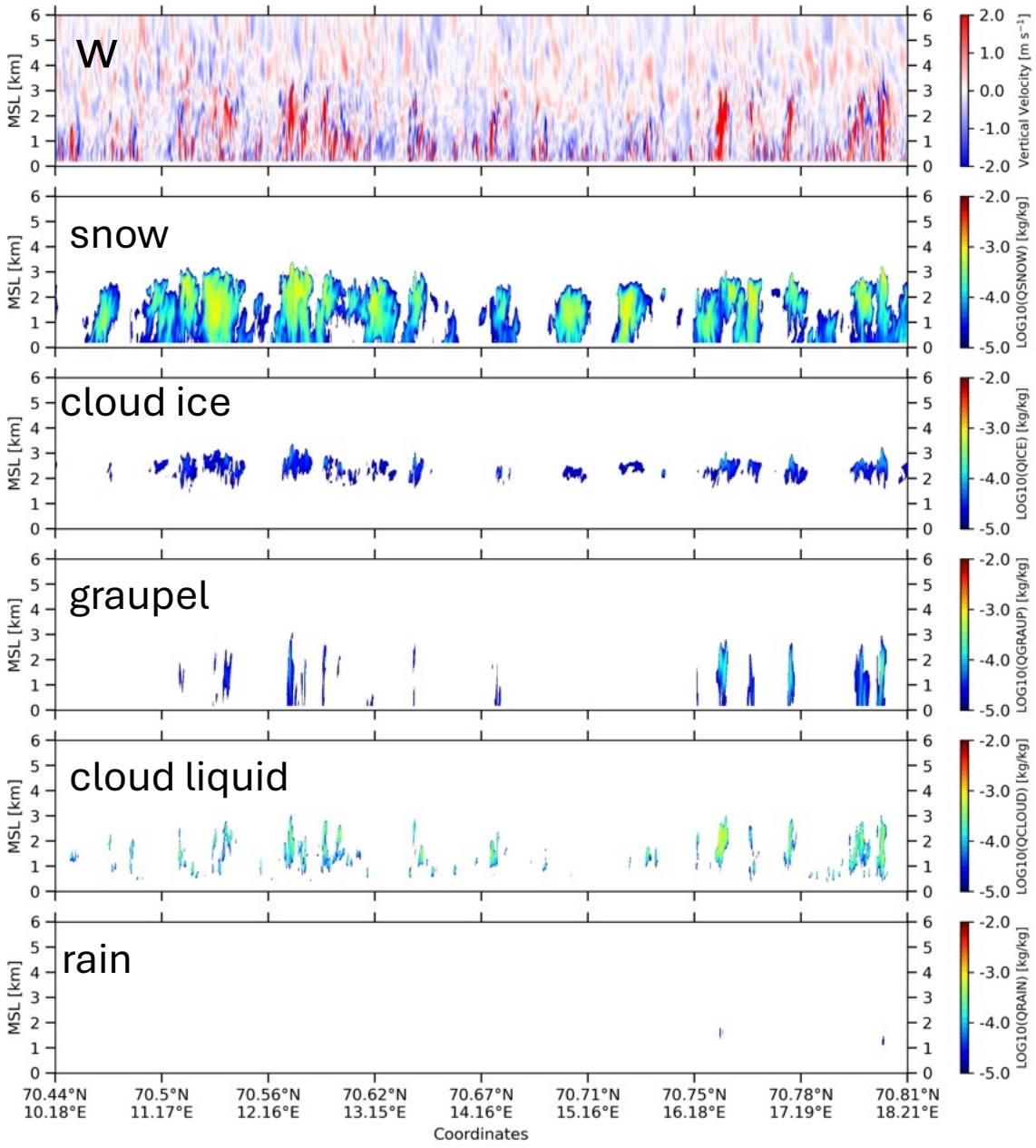


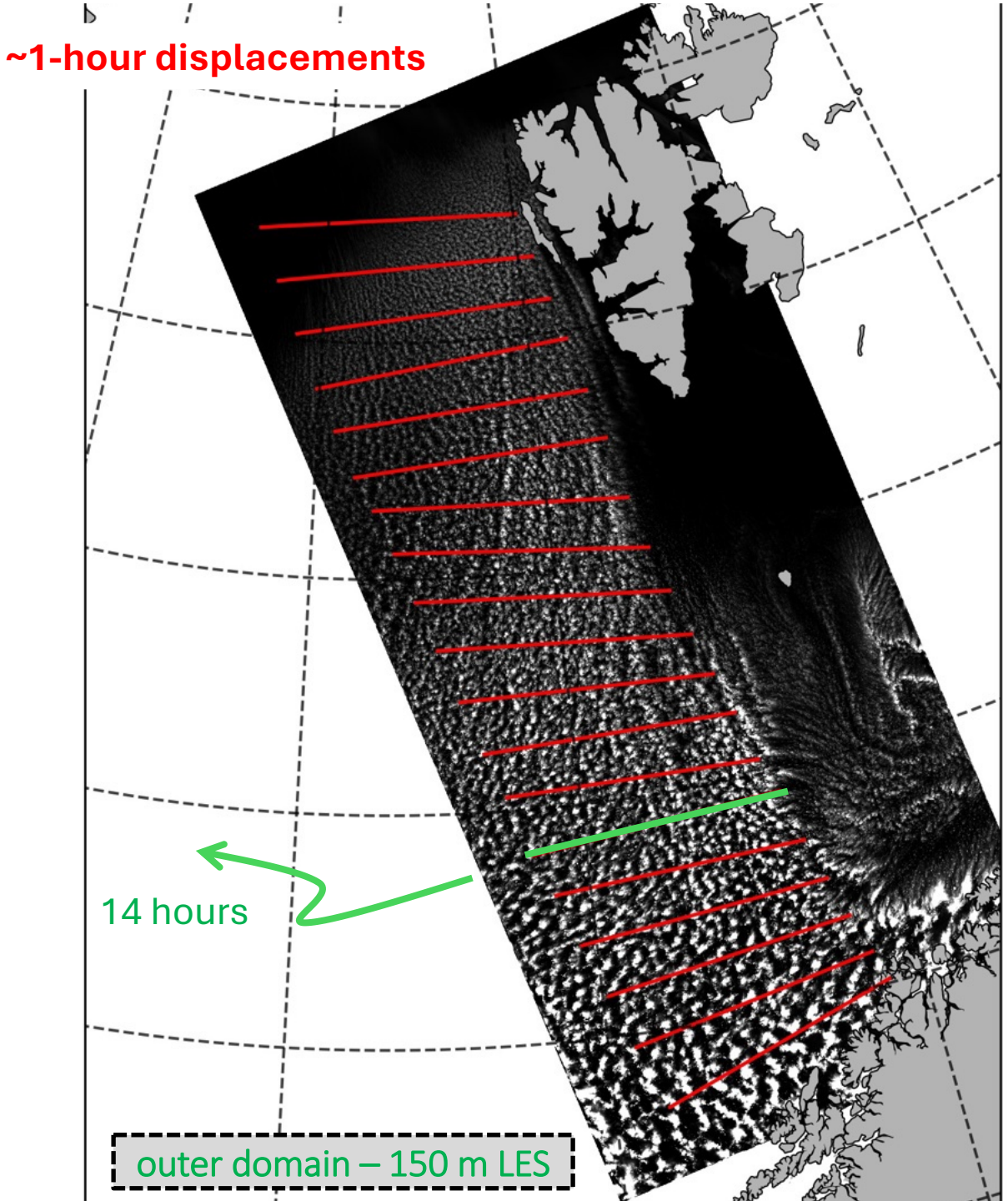
Lagrangian LES analysis: across-roll spectral analysis





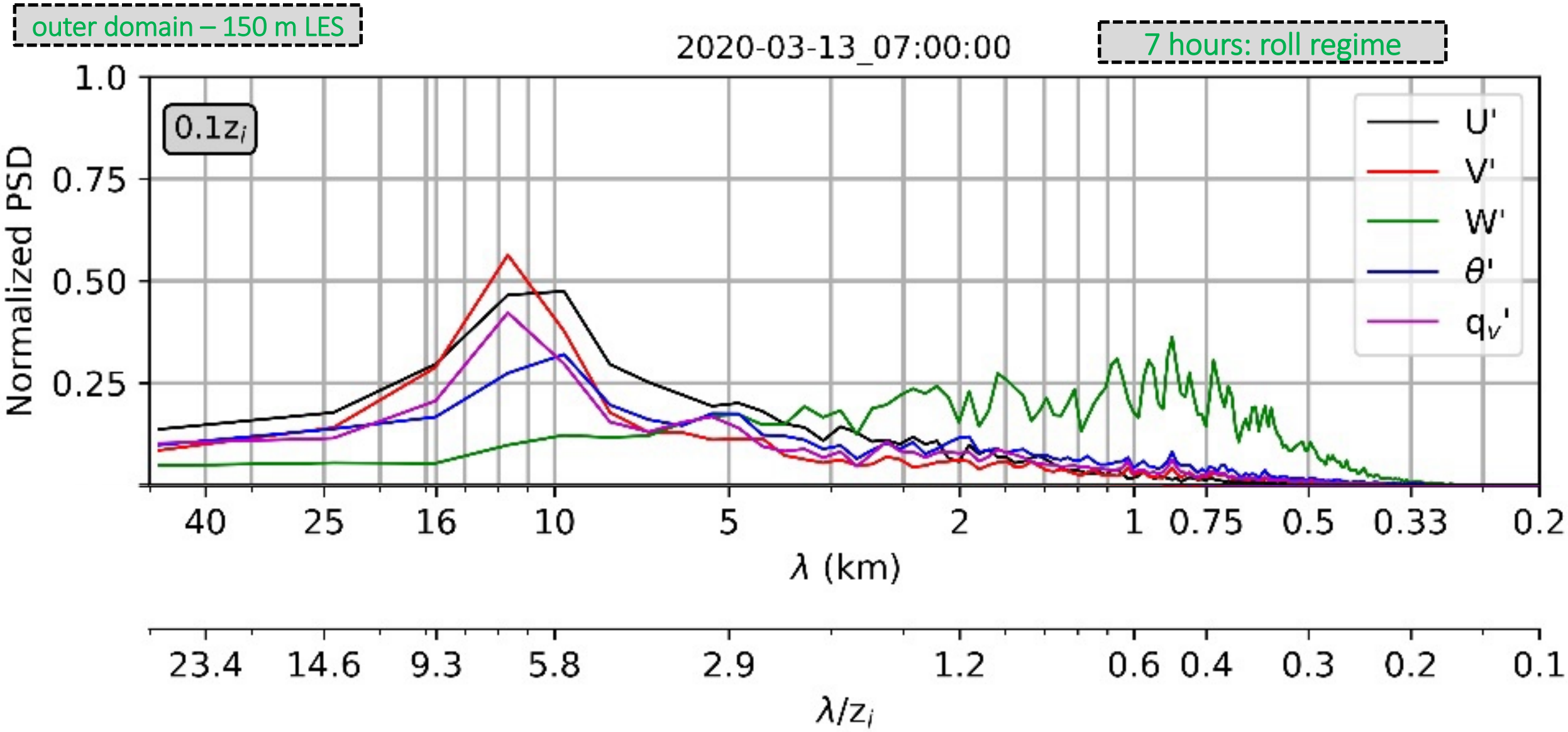
Lagrangian LES analysis: across-roll spectral analysis





Lagrangian LES analysis: across-roll normalized PSD

PSDs for each variable are normalized by maximum value across all heights and times
(6 h period, Δt=10min)



Lagrangian LES analysis: Temporal evolution of across-roll normalized PSD

outer domain – 150 m LES

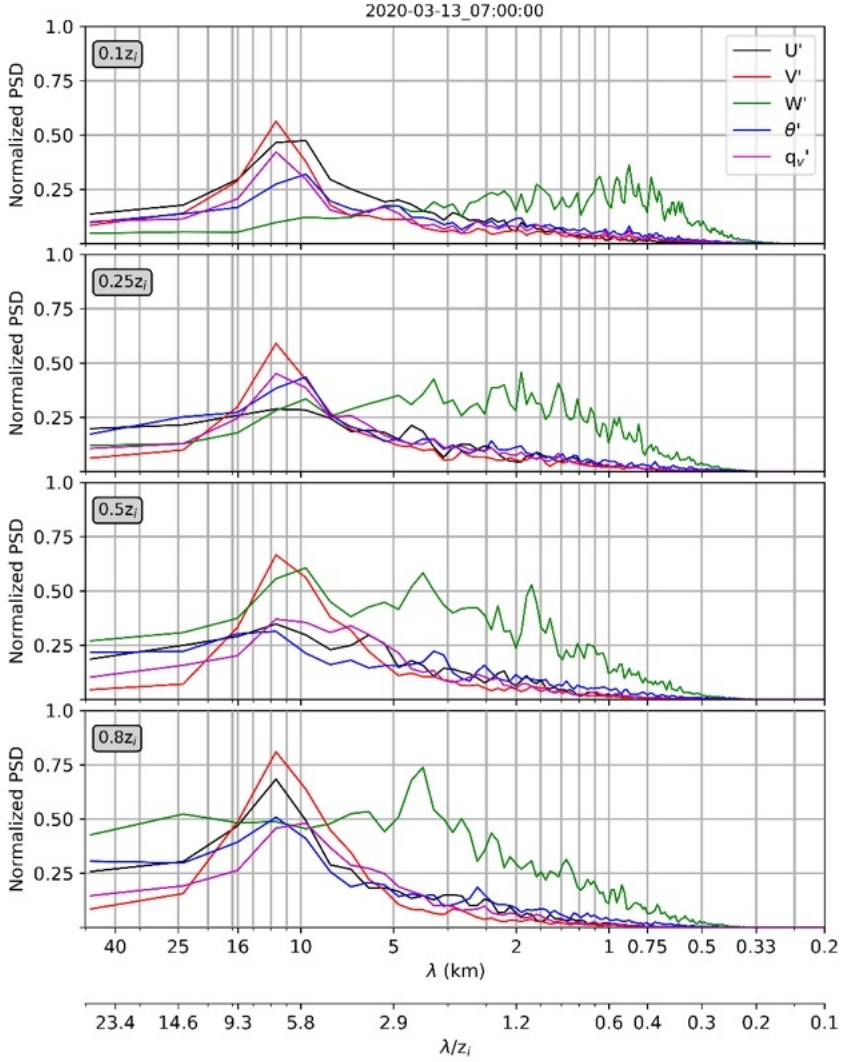
height

time

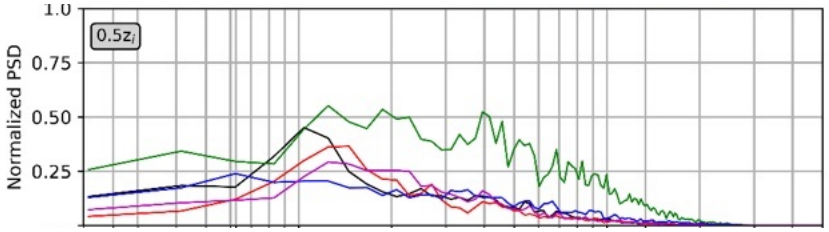
Key Takeaways:

- w’ is clear outlier: most energy-containing structures characterized by sizes much smaller than the wind/thermodynamic fields, esp. at low levels
- Increase in energy over time due to organization of coherent structures
- Transfer of energy from relatively smaller scales to larger scales

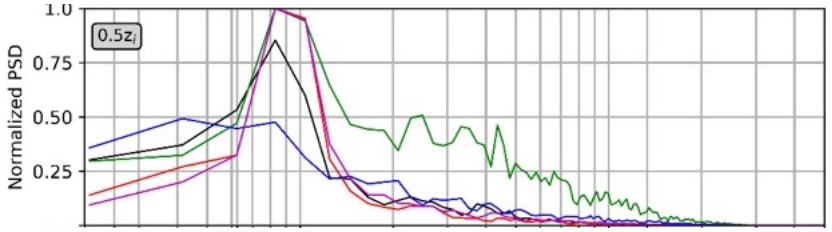
07 UTC - rolls



04 UTC - rolls



14 UTC – open cells



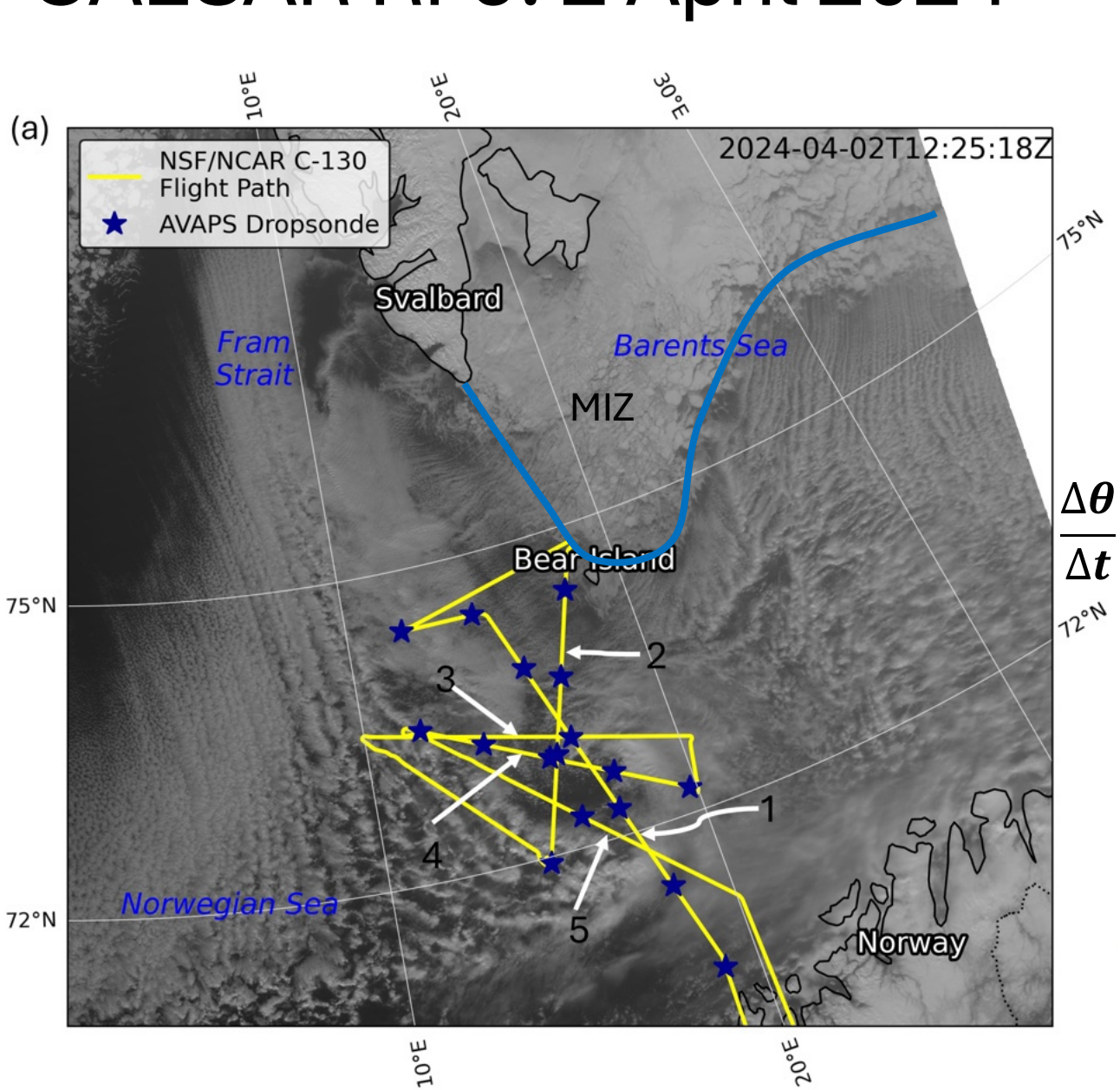
*Note: PSDs for each variable are normalized by maximum value across all heights and times (6 h period, Δt=10min)

CAESAR

profiling radars, lidars, and passive microwave radiometer
on the NSF/NCAR C-130
22 Feb-7 April 2024, from Kiruna Sweden

CAESAR RF9: 2 April 2024

18 hr kinematic back-trajectories ending at 1000 mb



$$\frac{\Delta\theta}{\Delta t} \sim \frac{12K}{18hr}$$

$$\nabla\theta \sim \frac{6K}{200\ km}$$