UNIVERSITÄT LEIPZIG

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DFG

PROM SPP 2115

Project overview:

CHARACTERIZATION OF OROGRAPHY-INFLUENCED RIMING AND SECONDARY ICE PRODUCTION AND THEIR EFFECTS ON PRECIPITATION RATES USING RADAR POLARIMETRY AND DOPPLER SPECTRA (CORSIPP)

SPP-PROM Meeting, July 18, 2023

Anton Kötsche, Veronika Ettrichrätz

PI: H. Kalesse-Los, M. Maahn

GENERAL QUESTION

What processes affect snowfall formation and snowfall rates in orographically influenced terrain and what are their external drivers?

Why?:

Research Gap:

- Only sparse observations at remote mountaineous regions
- Which processes dominate, what is their impact on precipitation rates
- External drivers in complex terrain is poorly understood

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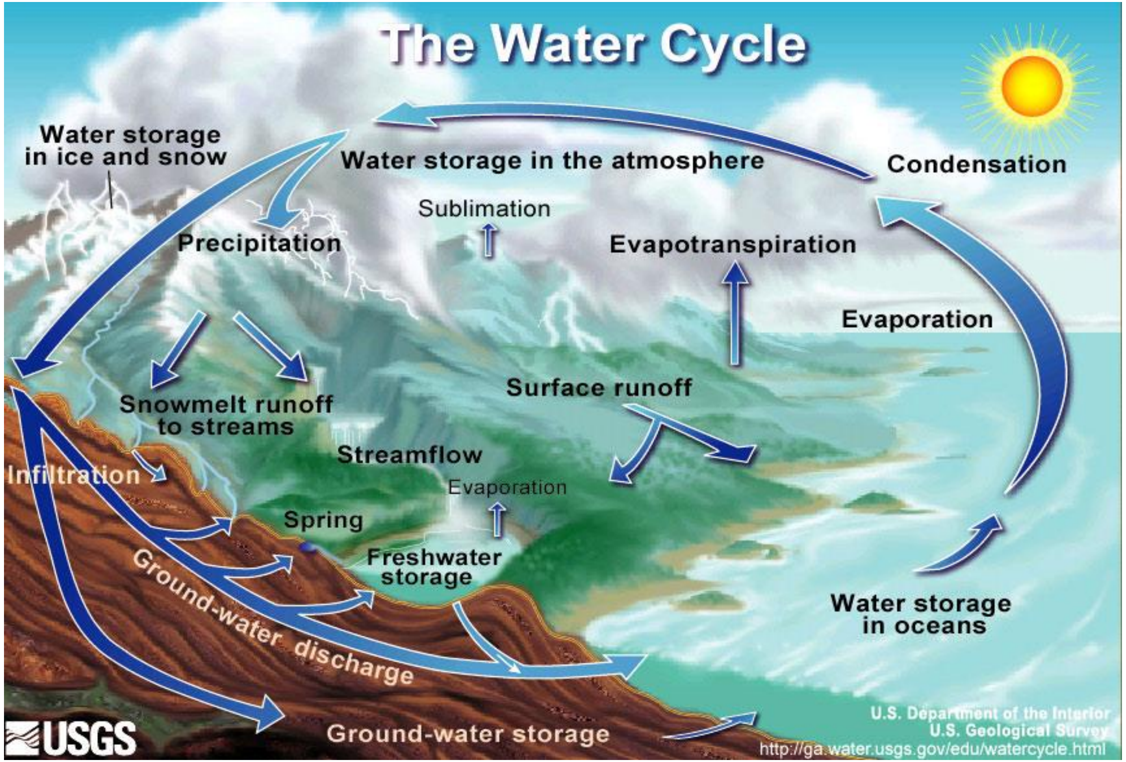
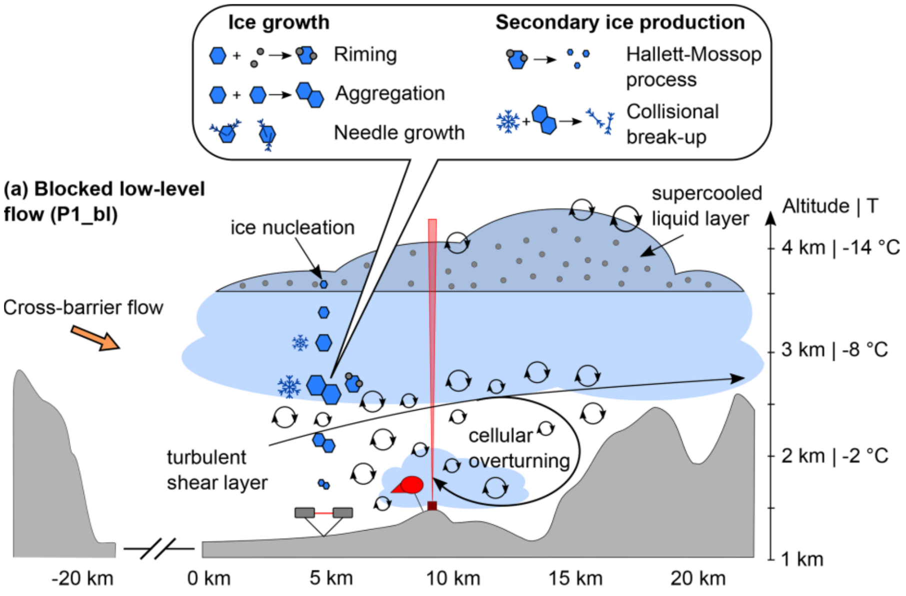


By John M. Even / USGS - USGS - http://ga.water.usgs.gov/edu/watercycleprint.html (English Wikipedia, original upload 27 April 2005 by Brian0918 en:Image:Water cycle.png), Public Domain, https://commons.wikimedia.org/w/index.php?curid=313135

OROGRAPHIC INFLUENCE

- Enhanced turbulence due to strong vertical wind shear between blocked valley and cross-barrier flow aloft → **Increase in SIP and riming, enhancement in orographic precipitation** (e.g., Medina et al., 2005; Ramelli et al., 2021)
- In-valley circulation leads to the production of local updrafts, acceleration of aggregation, ice-ice collision and riming (e.g., Yano et al., 2016)
- Enhance orographic precipitation through the seeder–feeder mechanism (e.g.,Bergeron, 1965)
- Influence of blowing snow on ice production



(Ramelli et al., 2021)

THE CORSIPP CAMPAIGN (NOV 15, 2022 – JUNE 6, 2023)

PROM SPP 2115

94 GHz W-Band Cloud Radar LIMRAD94

Court: Ben Schmatz

In-Situ Snowfall Camera VISSS

Court: Isabelle Steinke

Heike Kalesse-Los (PI), Maximilian Maahn (PI), Veronika Ettrichrätz (Postdoc), Anton Kötsche (PhD Student)

Court: Isabelle Steinke

Winters deepest snowpack: 246 cm on March 22

Total snowfall this winter: 916 cm

Court: Ben Schmatz

ARM* SAIL** AND NOAA SPLASH***

https://www.arm.gov/research/campaigns/amf2021sail

- September 2021 to June 2023
- Insights into how Upper Colorado River watersheds interacts with the atmosphere
- Measured quantities: precipitation, clouds, aerosols, wind, energy, temperature, humidity

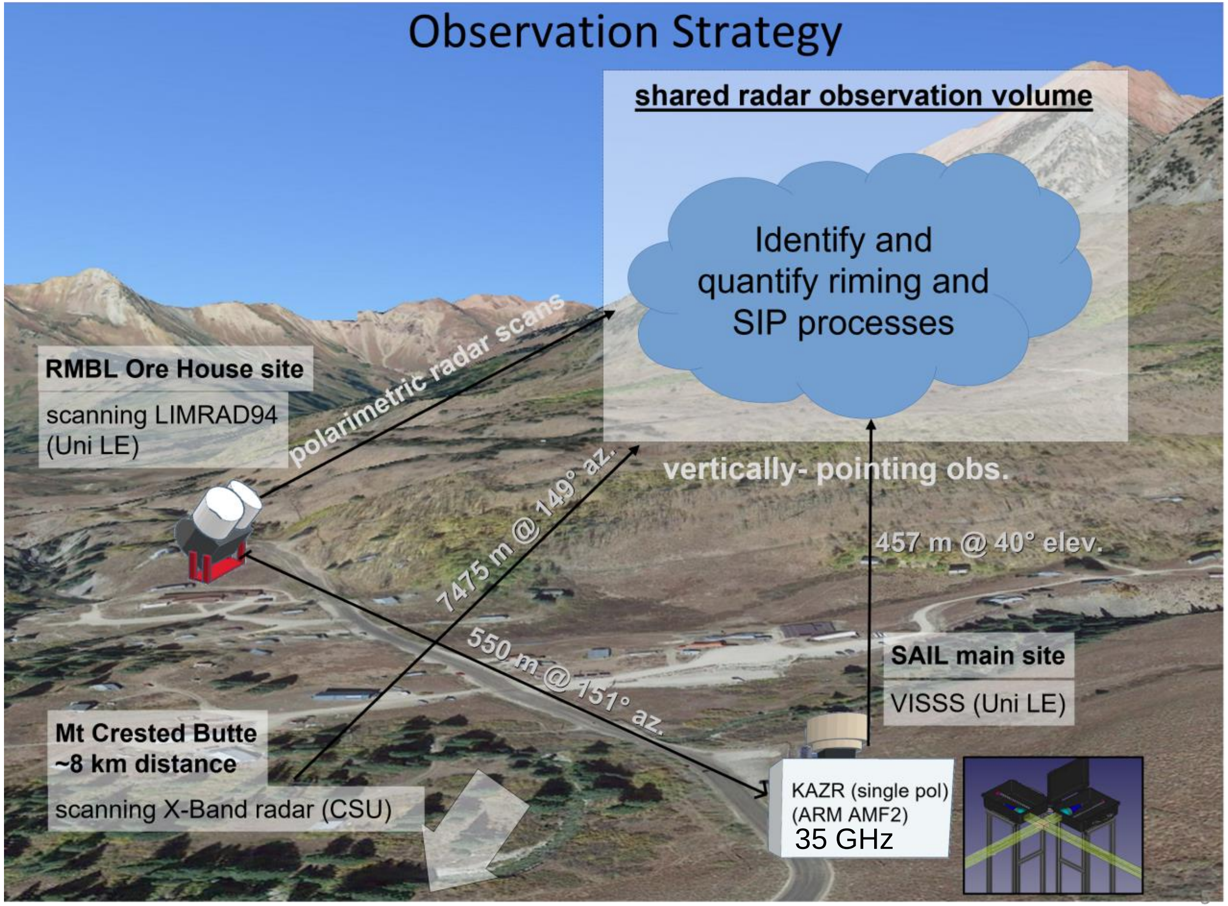
Court: Heike Kalesse-Los

* Atmospheric Radiation Measurement
** Surface Atmosphere Integrated Field Laboratory
*** Study of Precipitation, the Lower Atmosphere and Surface for Hydrometeorology

https://www.google.de/maps

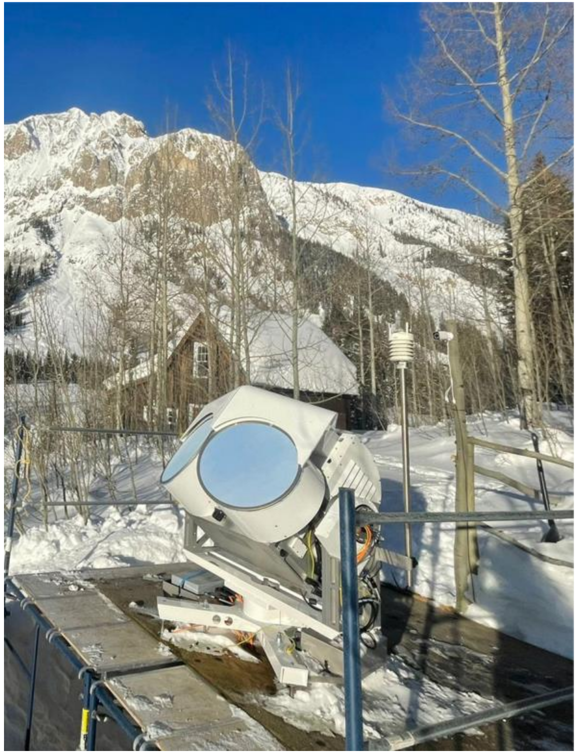
Loc: Gothic (CO) at Rocky Mountains Biological Laboratory (RMBL)

Alt: 3000m ASL



Observation Strategy
shared radar observation volume
Identify and quantify riming and SIP processes
RMBL Ore House site
scanning LIMRAD94 (Uni LE)
polarimetric radar scans
7475 m @ 149° az.
vertically- pointing obs.
457 m @ 40° elev.
550 m @ 151° az.
SAIL main site
VISSS (Uni LE)
Mt Crested Butte
~8 km distance
scanning X-Band radar (CSU)
KAZR (single pol)
(ARM AMF2)
35 GHz

UNI LEIPZIG RPG CLOUD DOPPLER 94 GHZ RADAR (LIMRAD94)



Court: Ben Schmatz

- Dual polarisation, simultaneous-transmission-simultaneous-reception (STSR) mode radar
- Reflectivity, ZDR, PhiDP, KDP, ρhv
- 94 GHz (λ=3.19 mm)
- First observations with prototype cold temperature scanner
- Observations either in constant elevation (40deg) or in scanning mode

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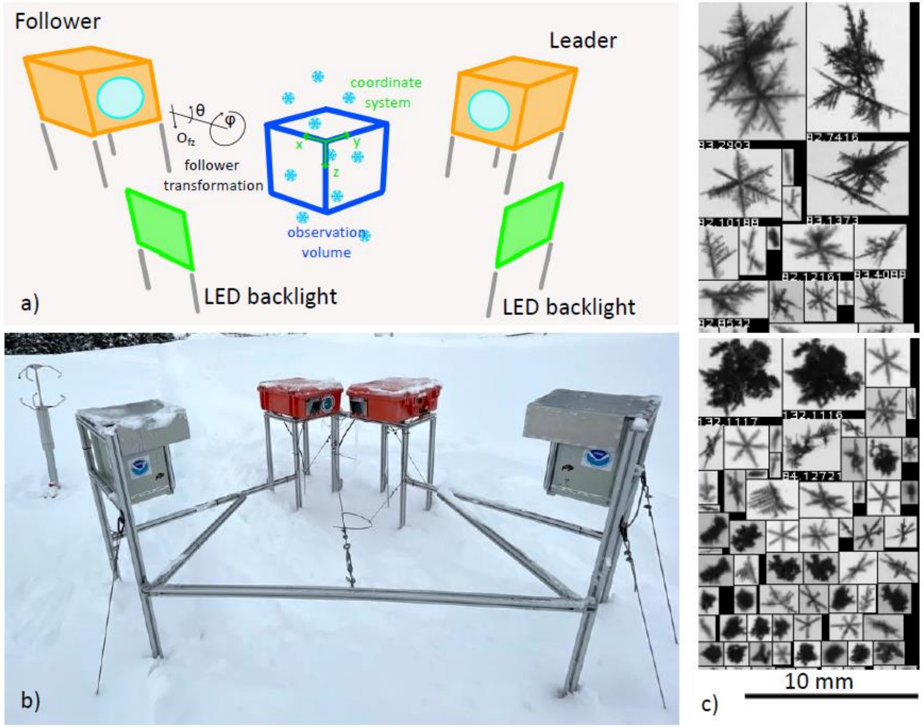
VIDEO IN SITU SNOWFALL SENSOR (VISSS)

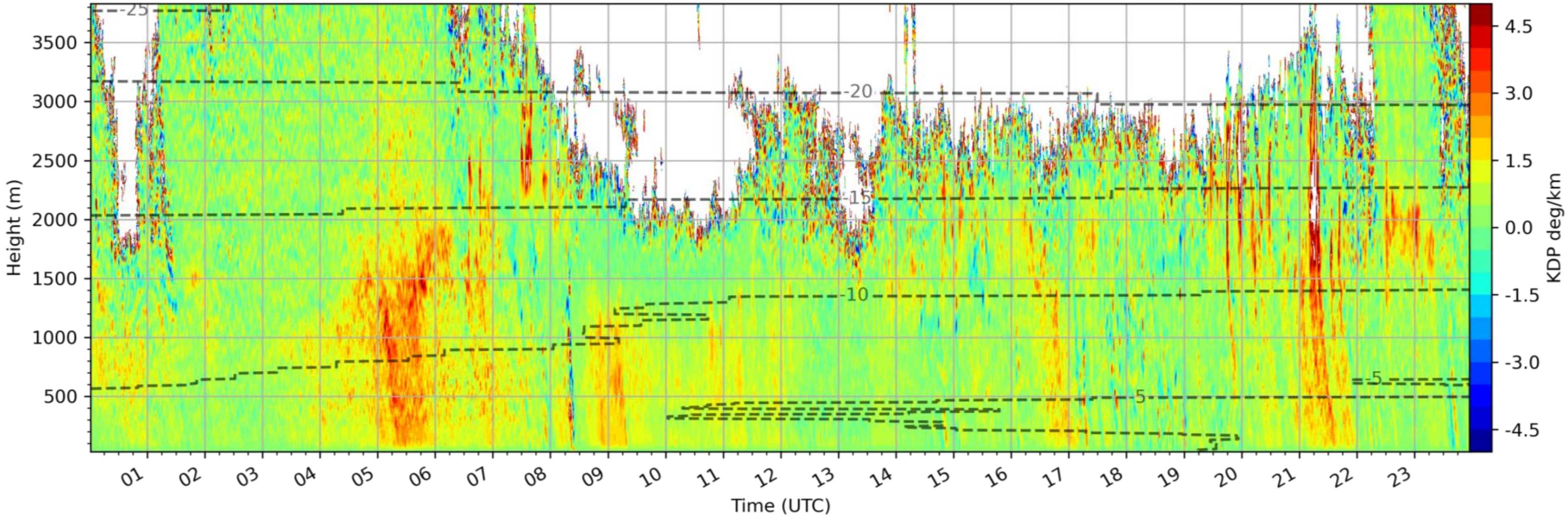


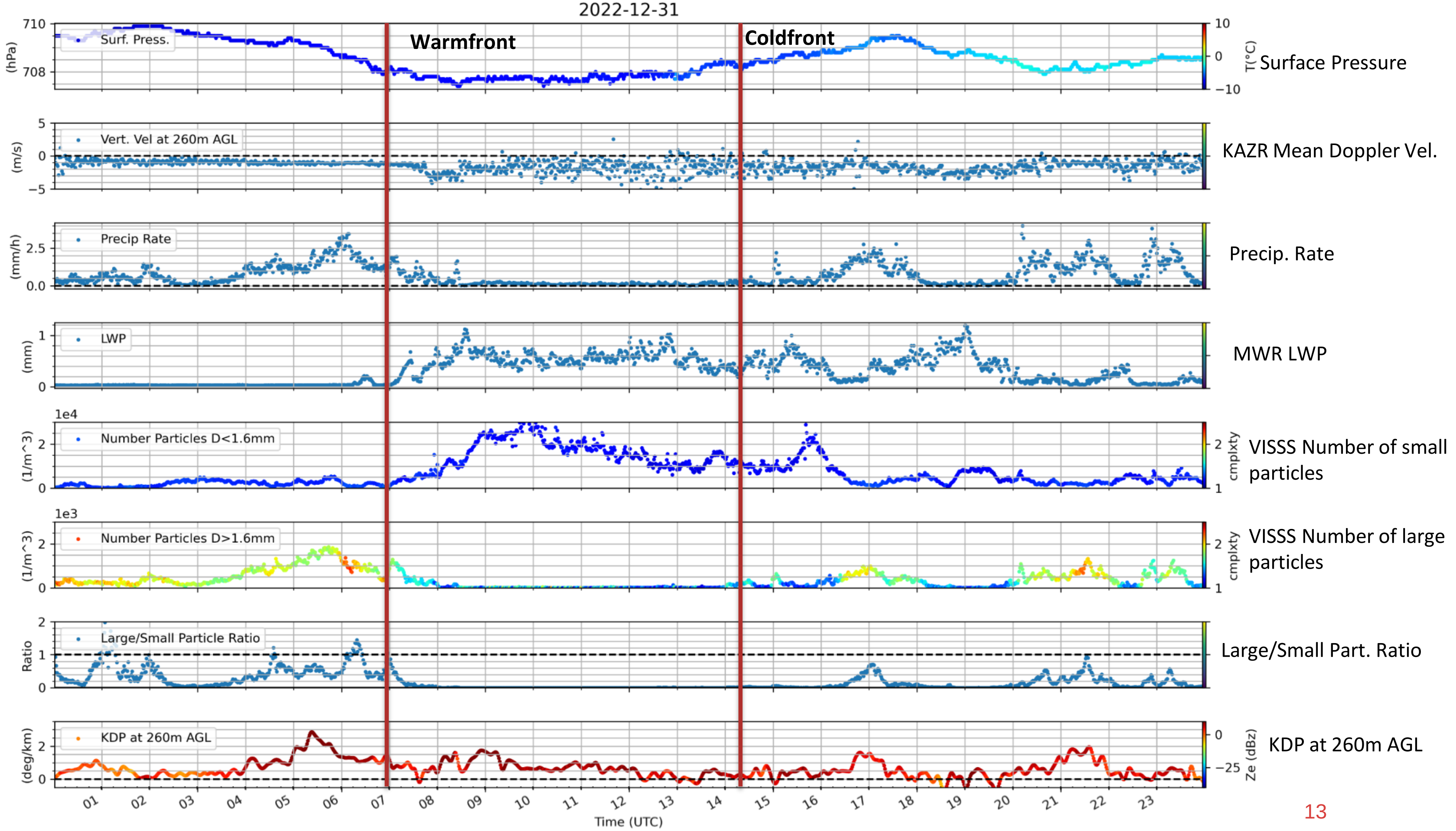
(Maahn et al., 2023)

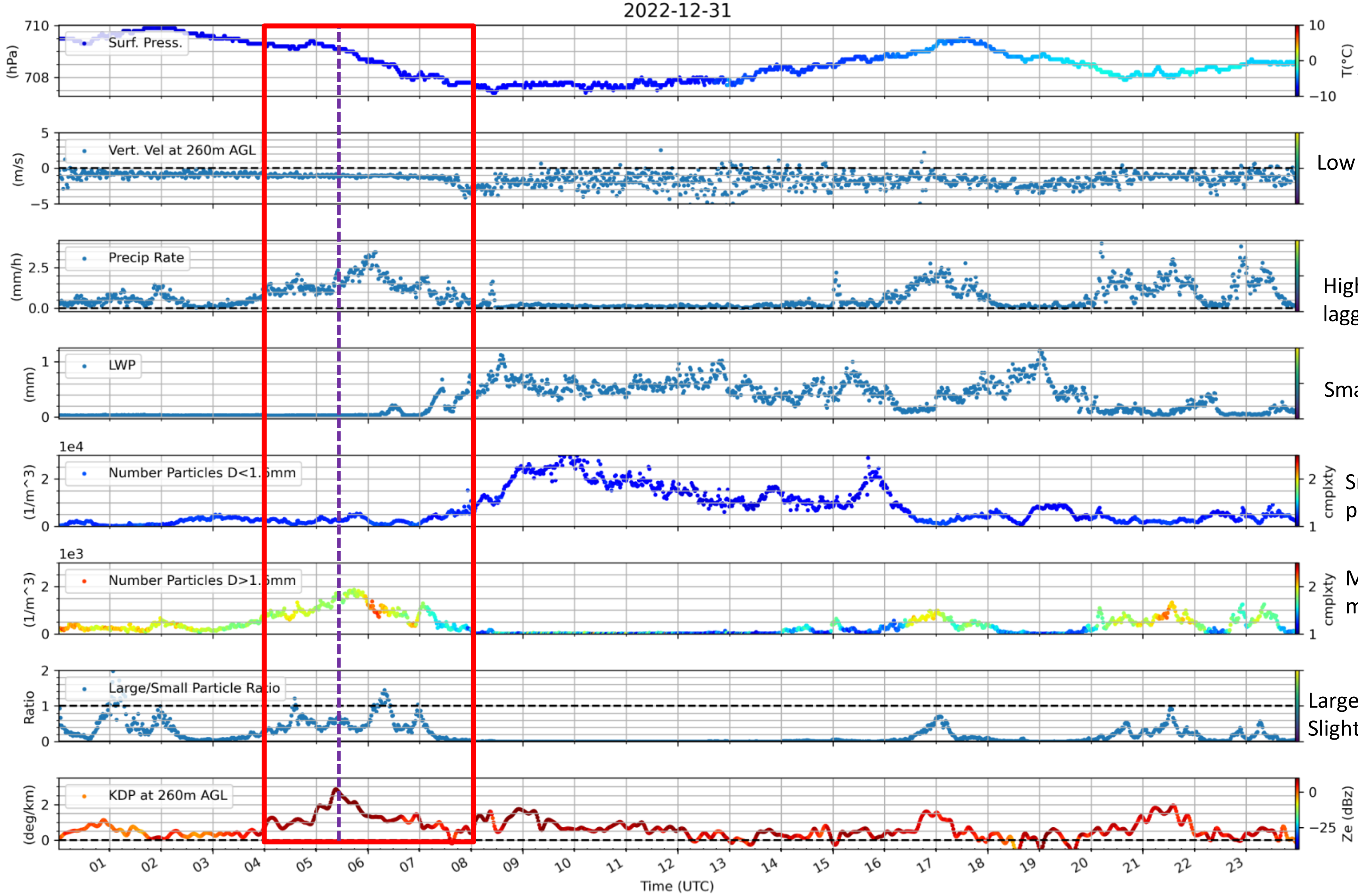
- Two camera systems
- Size, Number, Shape, Complexity

- Framerate: 250 Hz
- Measurement volume: approx. 8 x 8 x 6 cm
- Minimum detection size: 200 µm

KDP 2022-12-31




2022-12-31
Warmfront
Coldfront
Surf. Press.
Surface Pressure
KAZR Mean Doppler Vel.
Vert. Vel at 260m AGL
Precip Rate
Precip. Rate
LWP
MWR LWP
Number Particles D<1.6mm
VISSS Number of small particles
Number Particles D>1.6mm
VISSS Number of large particles
Large/Small Particle Ratio
Large/Small Part. Ratio
KDP at 260m AGL
KDP at 260m AGL
Time (UTC)



At Warm Front

Low variability in MDV

High Precip Rate, peak laggs the KDP peak

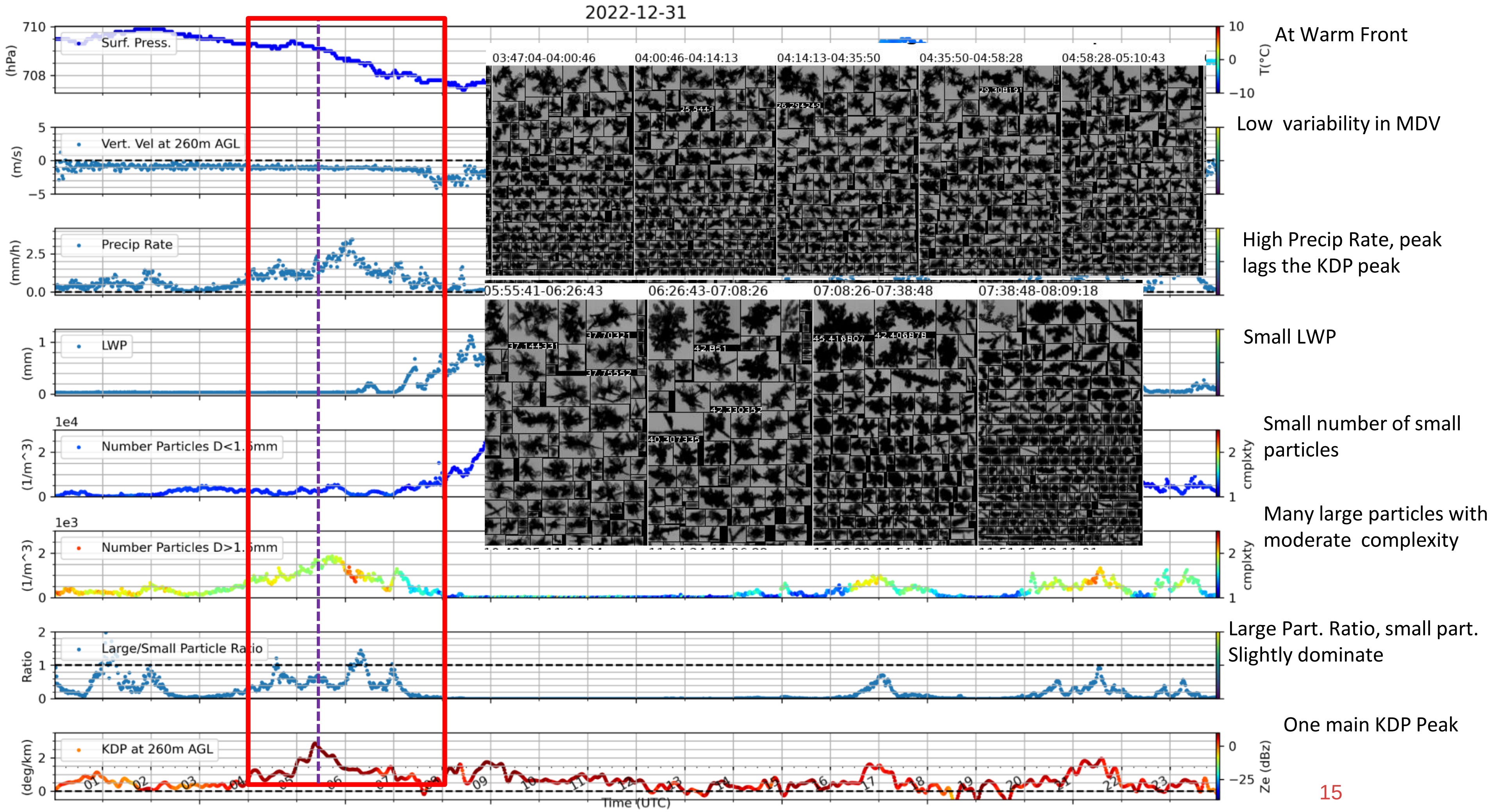
Small LWP

Small number of small particles

Many large particles with moderate complexity

Large Part. Ratio, small part. Slightly dominate

One main KDP Peak


2022-12-31
Surf. Press.
Vert. Vel at 260m AGL
Precip Rate
LWP
Number Particles D<1.5mm
Number Particles D>1.5mm
Large/Small Particle Ratio
KDP at 260m AGL
Time (UTC)
03:47:04-04:00:46
04:00:46-04:14:13
04:14:13-04:35:50
04:35:50-04:58:28
04:58:28-05:10:43
05:55:41-06:26:43
06:26:43-07:08:26
07:08:26-07:38:48
07:38:48-08:09:18
At Warm Front
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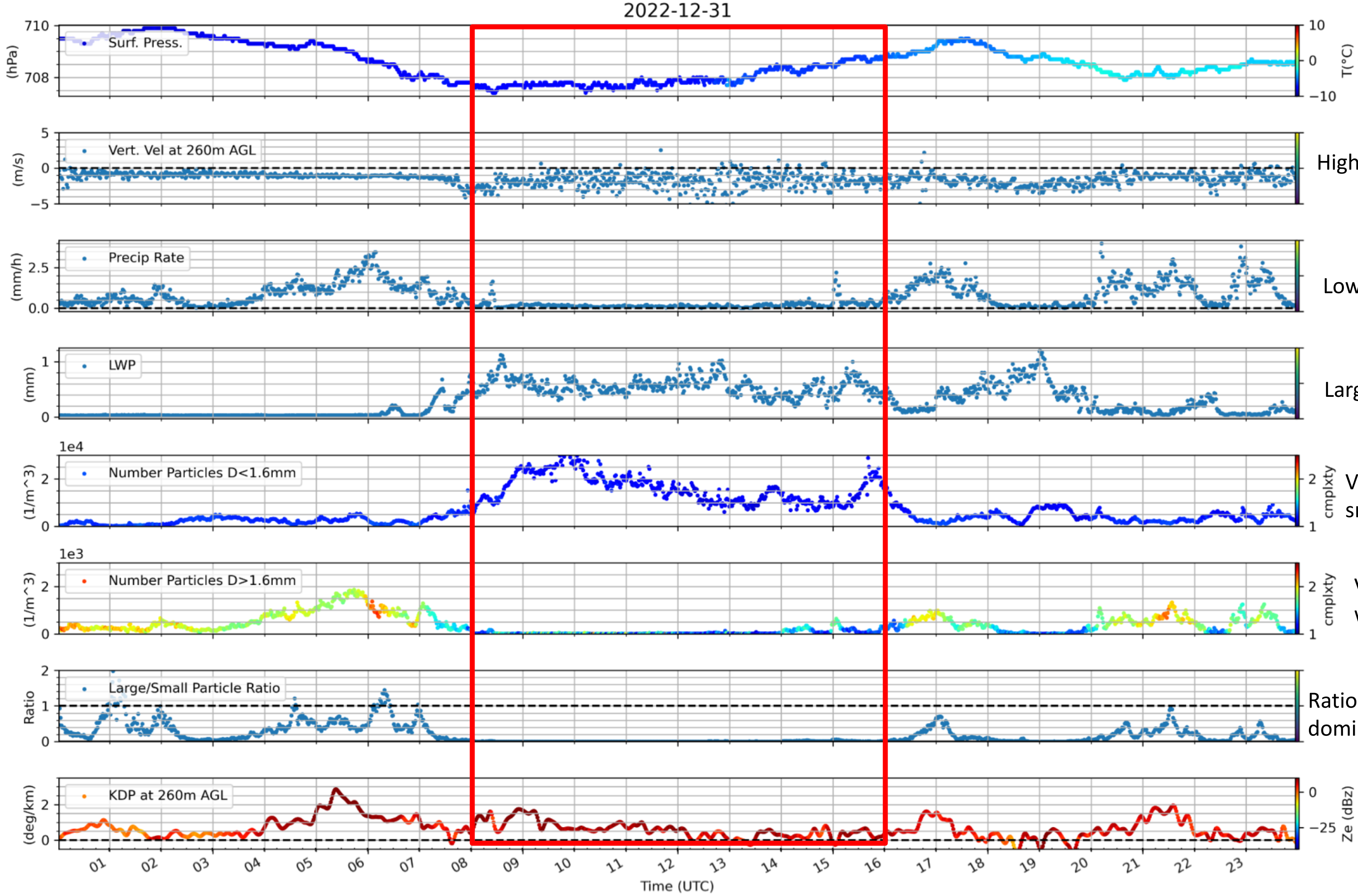


Warmsektor

High variability in MDV

Low Precip Rate

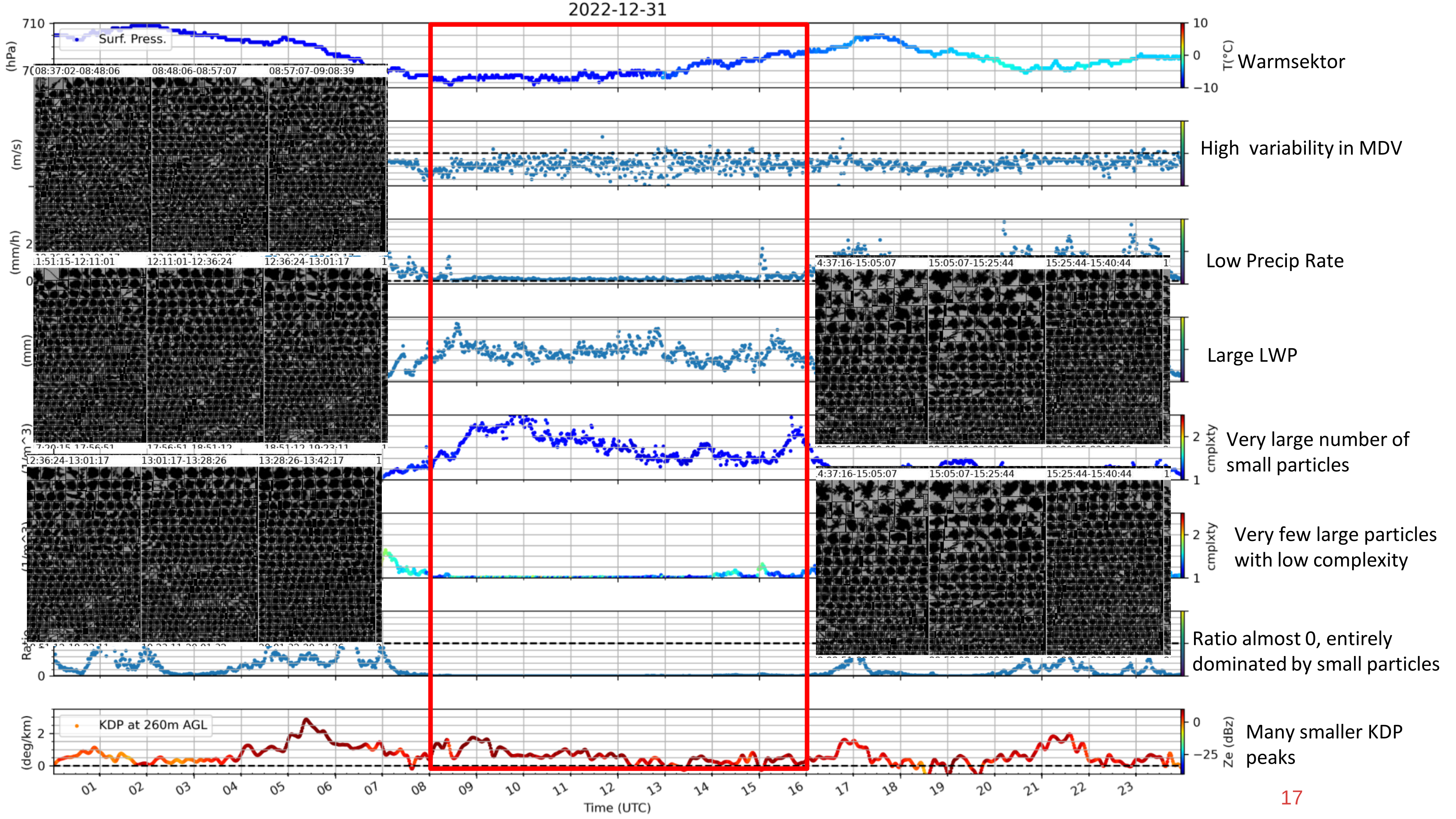
Large LWP

Very large number of small particles

Very few large particles with low complexity

Ratio almost 0, entirely dominated by small particles

Many smaller KDP peaks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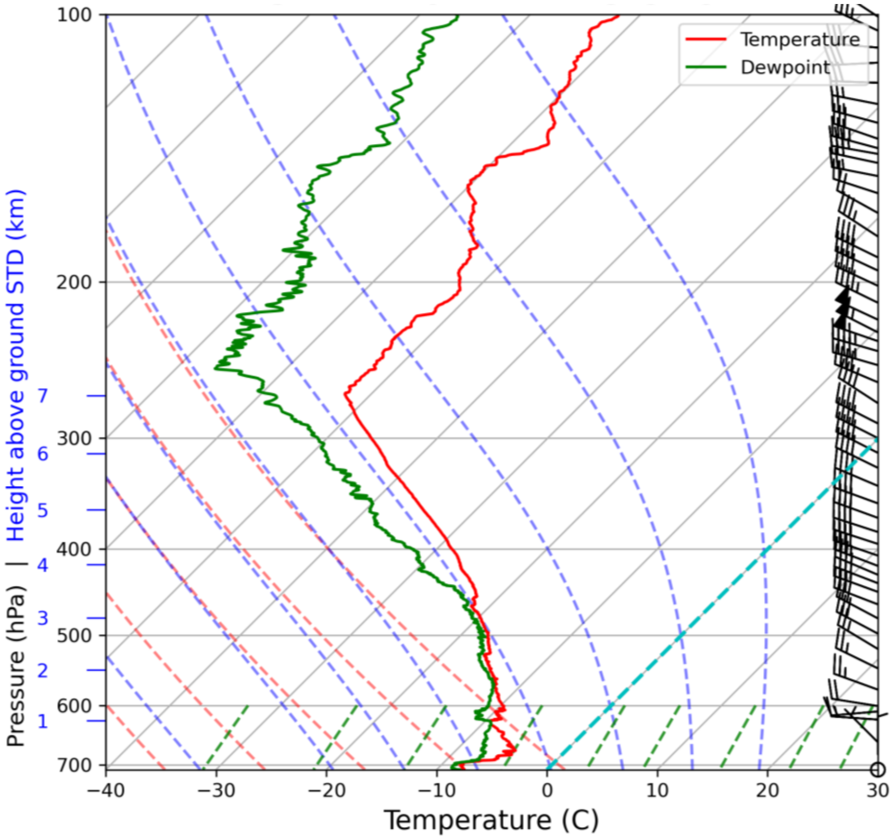
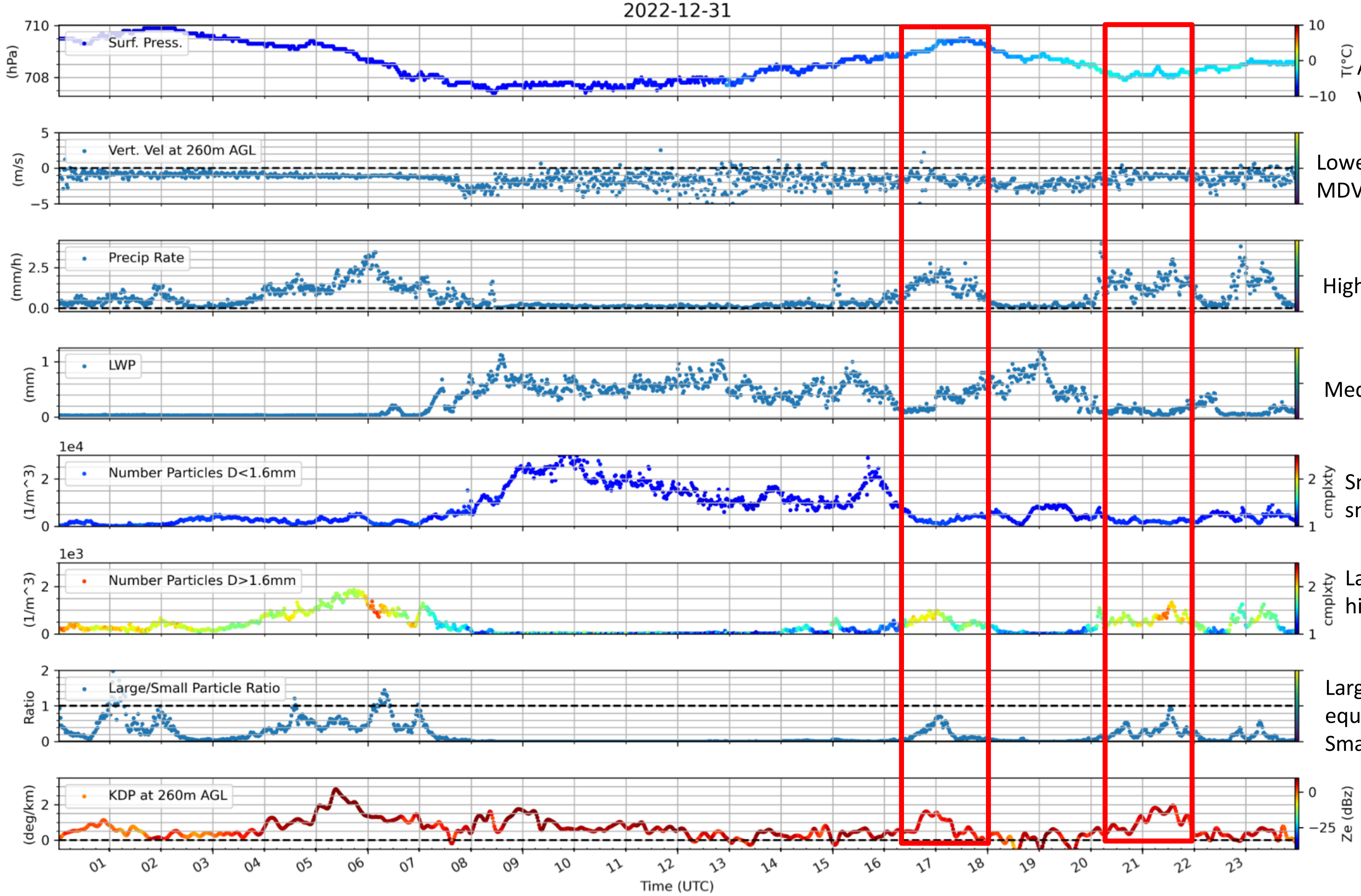
Ratio almost 0, entirely dominated by small particles
KDP at 260m AGL
Many smaller KDP peaks
Time (UTC)

2022-12-31 RADIOSONDE IN GRAUPEL ENVIRONMENT





After Cold Front / New warm front?

Lower variability in MDV

High Precip Rate

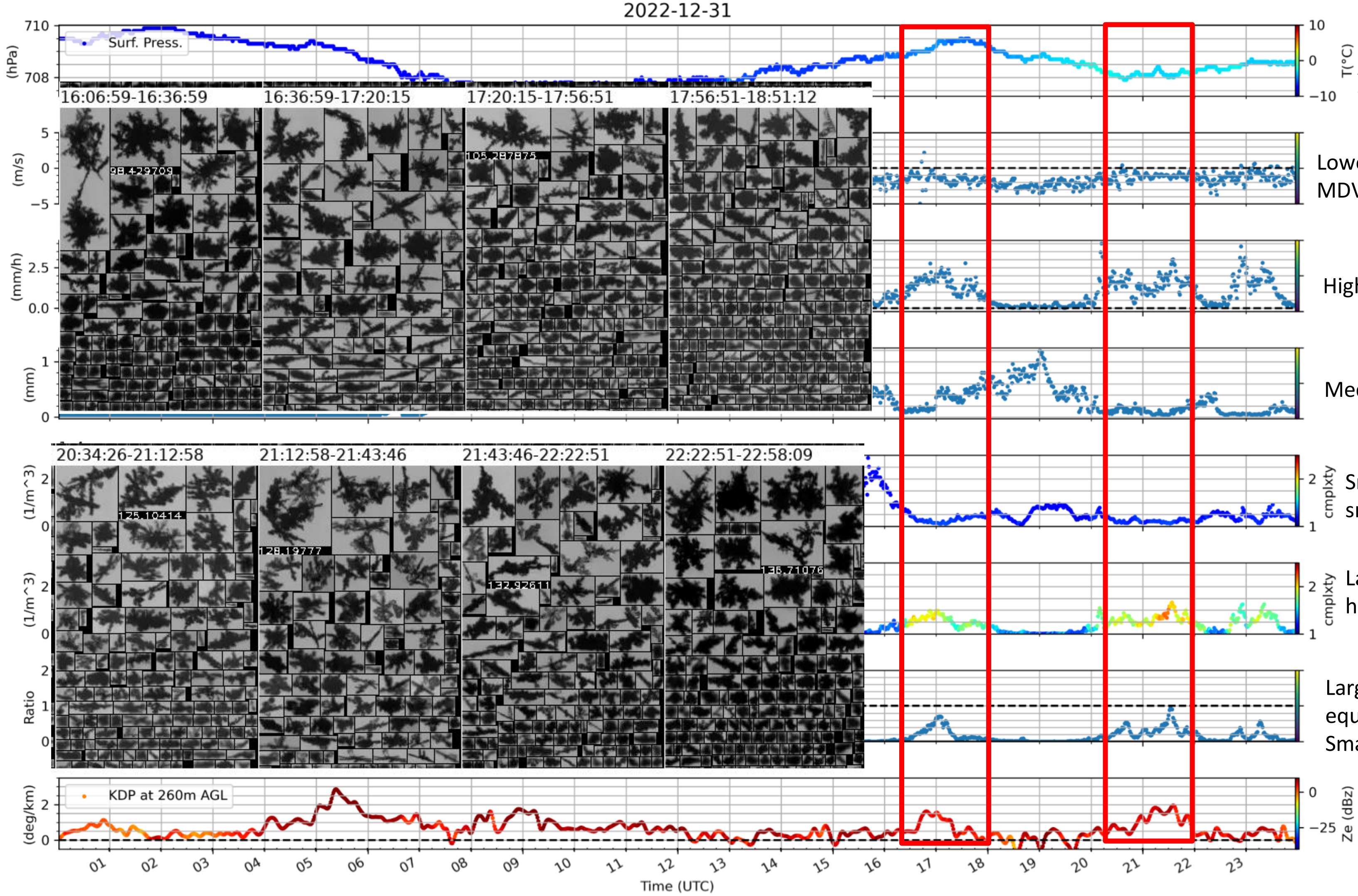
Medium LWP

Smaller number of small particles

Large particles with high complexity

Large Part. Ratio, almost equal number of Large and Small

Larger KDP Peaks



After Cold Front / New warm front?

Lower variability in MDV

High Precip Rate

Medium LWP

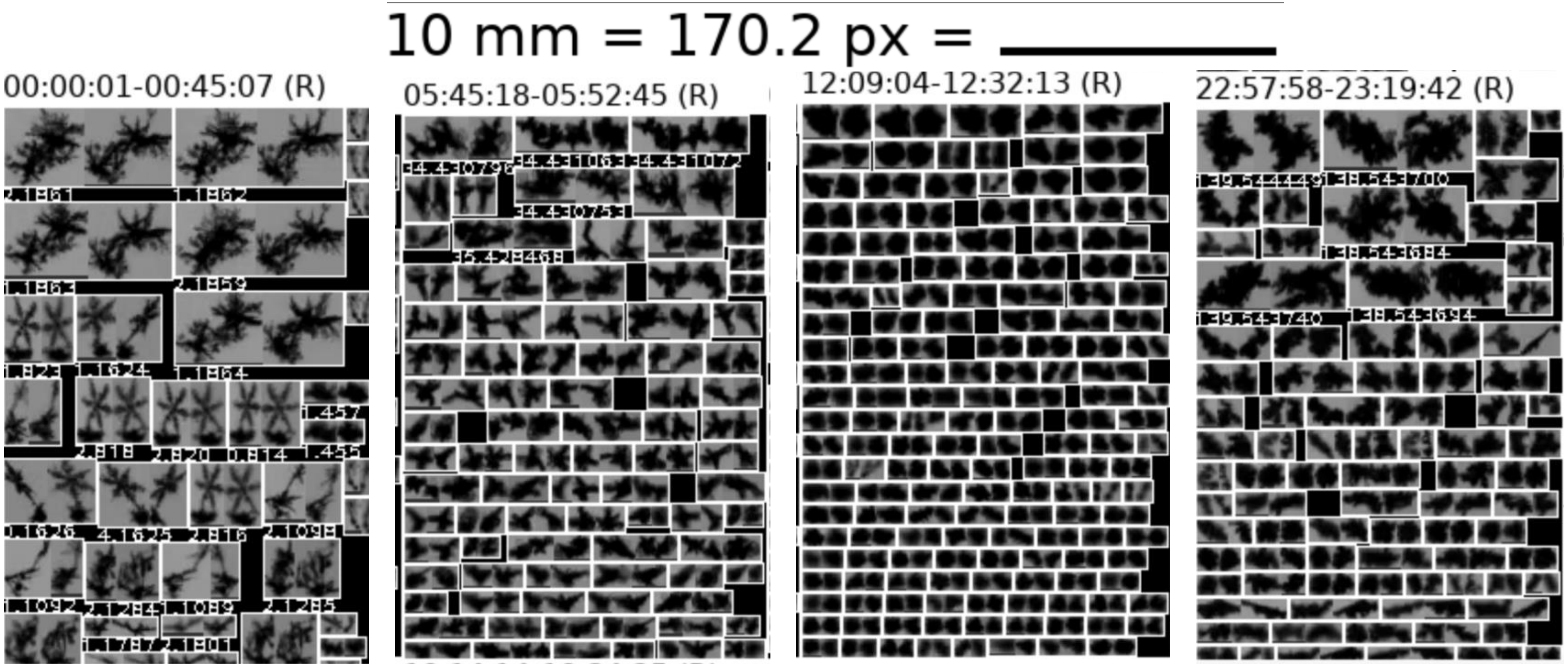
Smaller number of small particles

Large particles with high complexity

Large Part. Ratio, almost equal number of Large and Small

Larger KDP Peaks

2022-12-31 DENDRITES, ROSETTES, GRAUPEL, & AGGREGATES



QUANTITATIVE MEASURES OF RIMING IN TWO DIFFERENT WAYS

normalized rime mass M, unrimed: M=0, fully rimed: M=1

combined method:

via optimized estimation, with reflectivity (ZE) from Radar and PSD from in-situ, and simulated reflectivity from PAMTRA with PSD input from VISSS

In-situ method:

Riming changes shape to more spherical particles

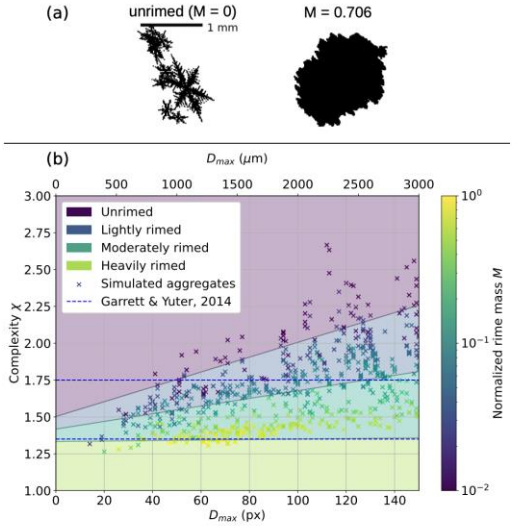
Complexity **χ**: Perimeter/(2√(**π***Area)) Gergely et al. (2017)

Sphere: **χ**=1

Not size independent, larger particles have larger **χ**

Relation between **χ** and M by Maherndl et al. 2023

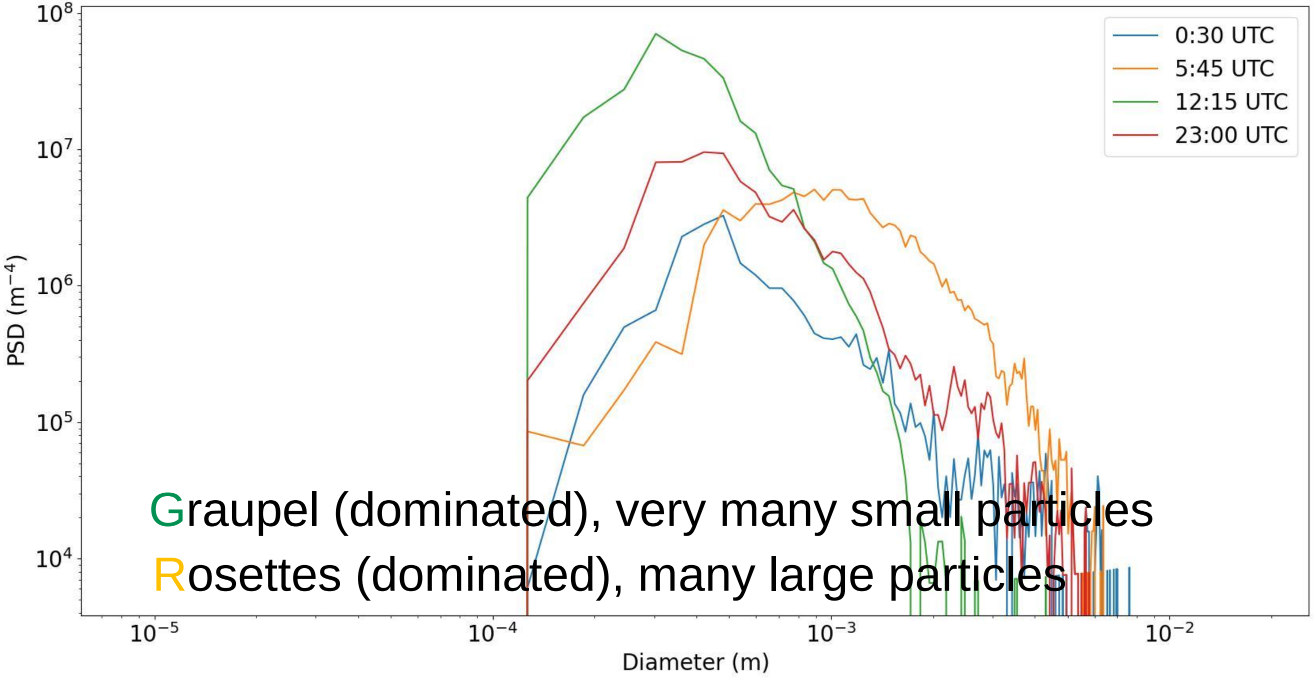
Relations and PAMTRA calculations for rosettes



Maherndl et al. 2023

PARTICLE SIZE DISTRIBUTIONS 2022-12-31BY VISSS

How many particles are on average in observation volume?

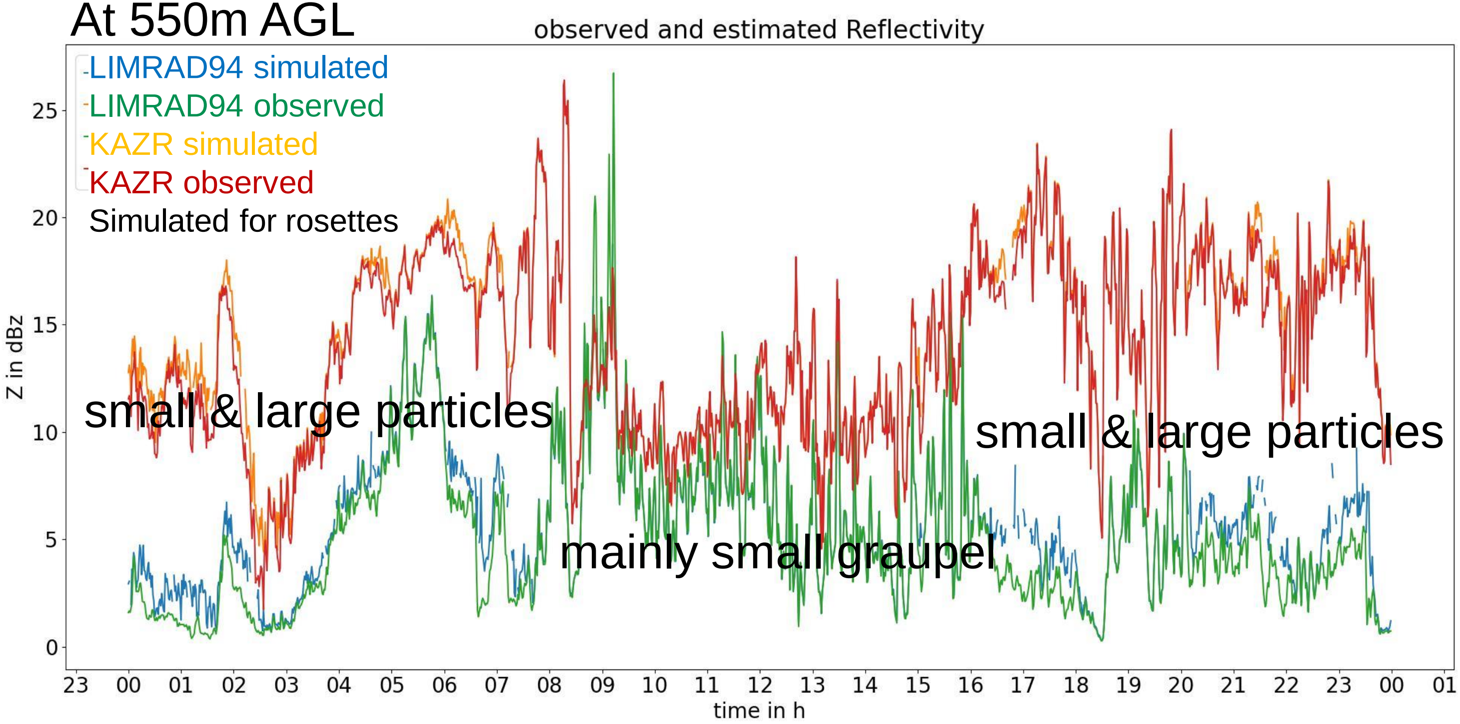


Graupel (dominated), very many small particles

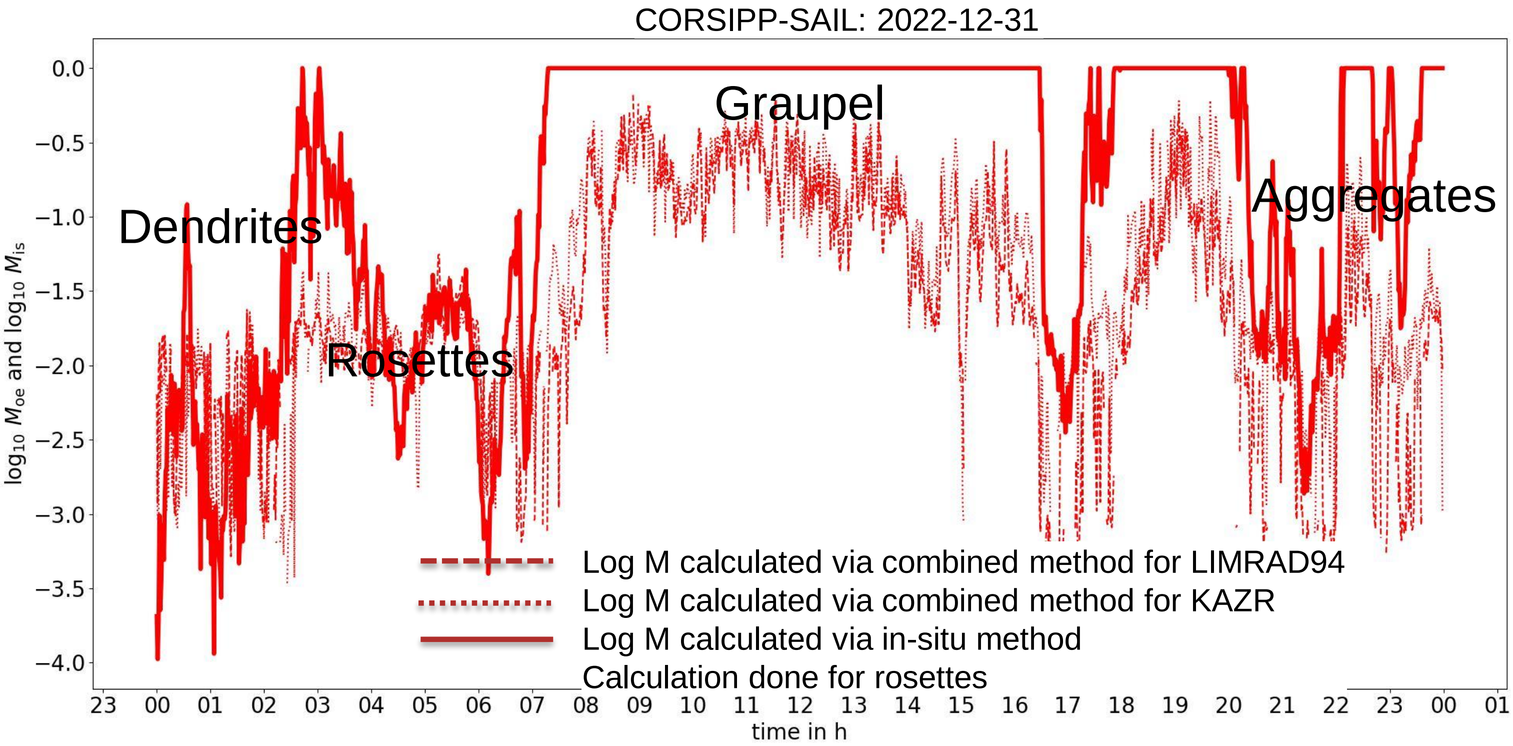
Rosettes (dominated), many large particles

OBSERVED & SIMULATED REFLECTIVITY 2022-12-31

At 550m AGL

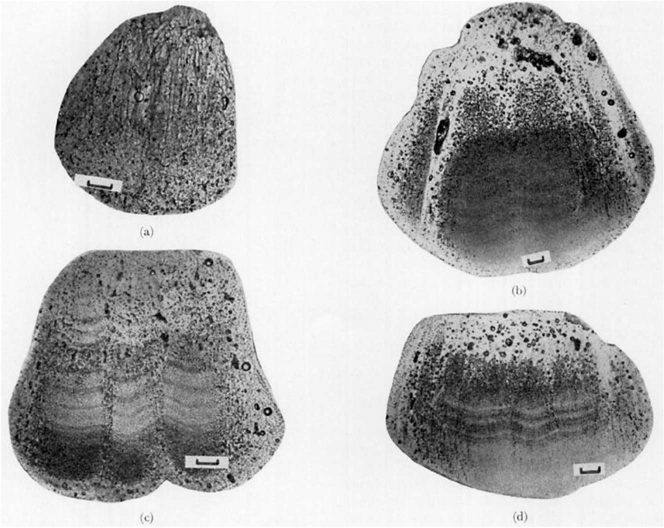


NORMALIZED RIME MASS M (LOG), UNRIMED: NEG, FULLY RIMED: 0



CONICAL GRAUPEL

- Graupel is devided into three main shapes: Hexagonal, Lump, Conical
- The growth mechanism for conical graupel is the least understood
- Certain conditions seem to promote the growth of conical graupel
- If these conditions are met, conical graupel growths the fastest becomes important for precipitation formation (Knight and Knight, 1972)



Conical Graupel (Knight and Knight, 1972)

FORMATION MECHANISM SUGGESTED BY KNIGHT AND KNIGHT (1972)

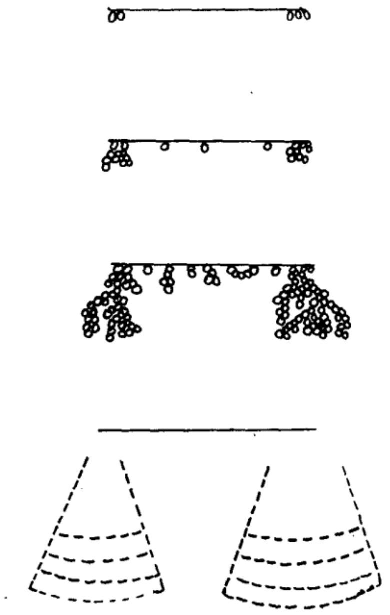
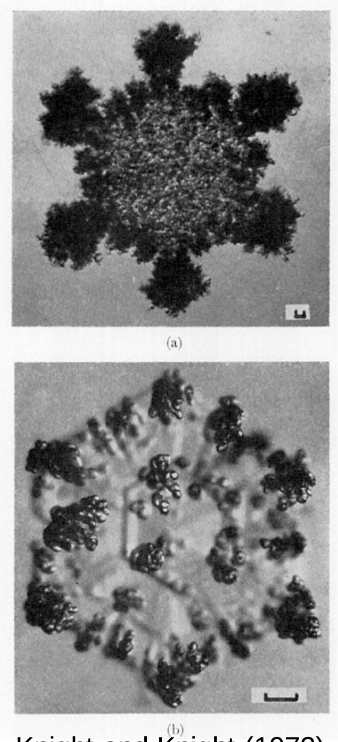


Fig. 5. Diagram showing the suggested mode of origin of conical graupel.

Knight and Knight (1972)

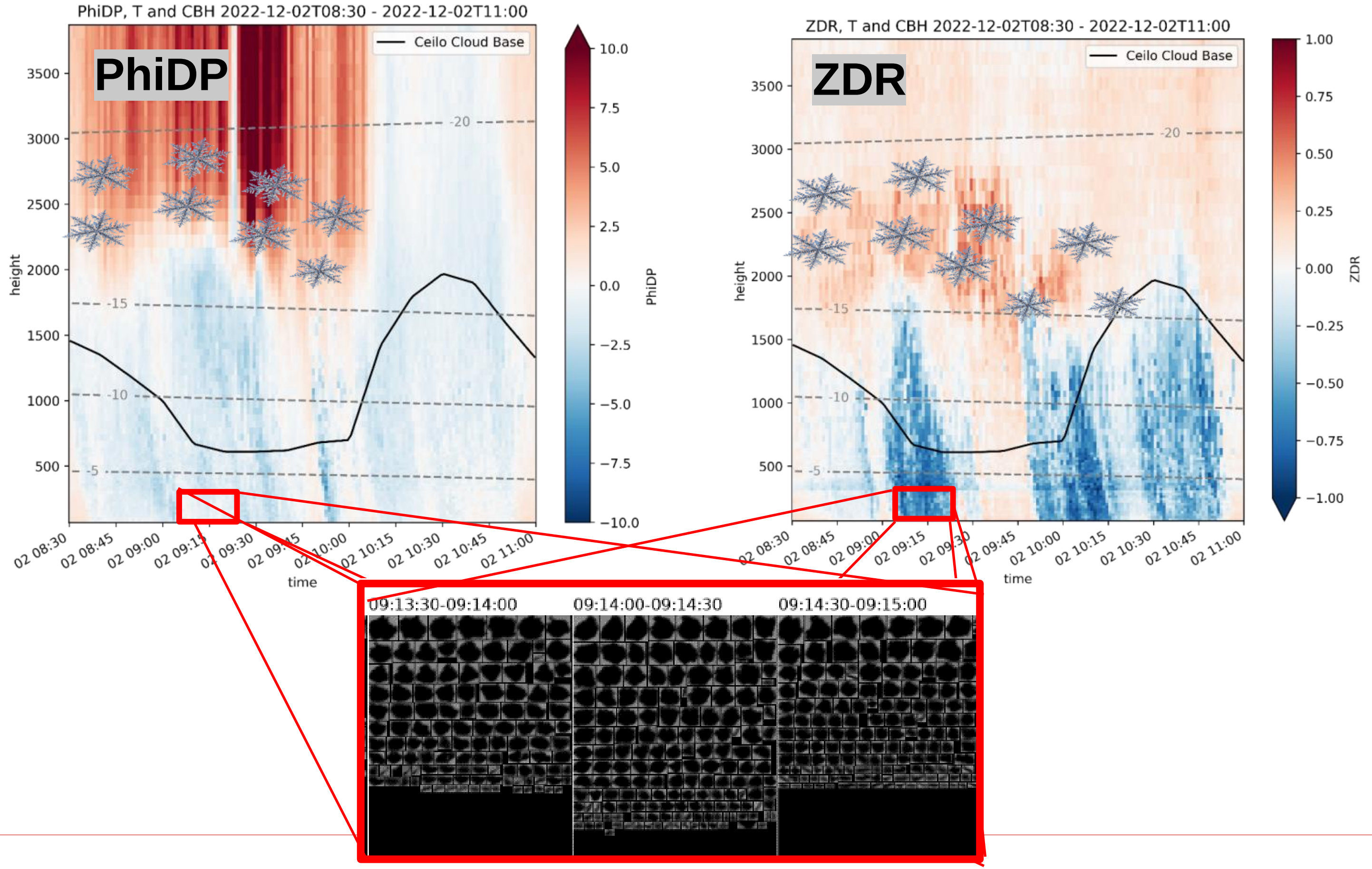
- Dendrite starts riming on the outer edges
- Rime builds up into the wind
- Cones start to form
- Cones break of from the dendrite and grow further or aggregate

→ **Effective SIP Mechanism**

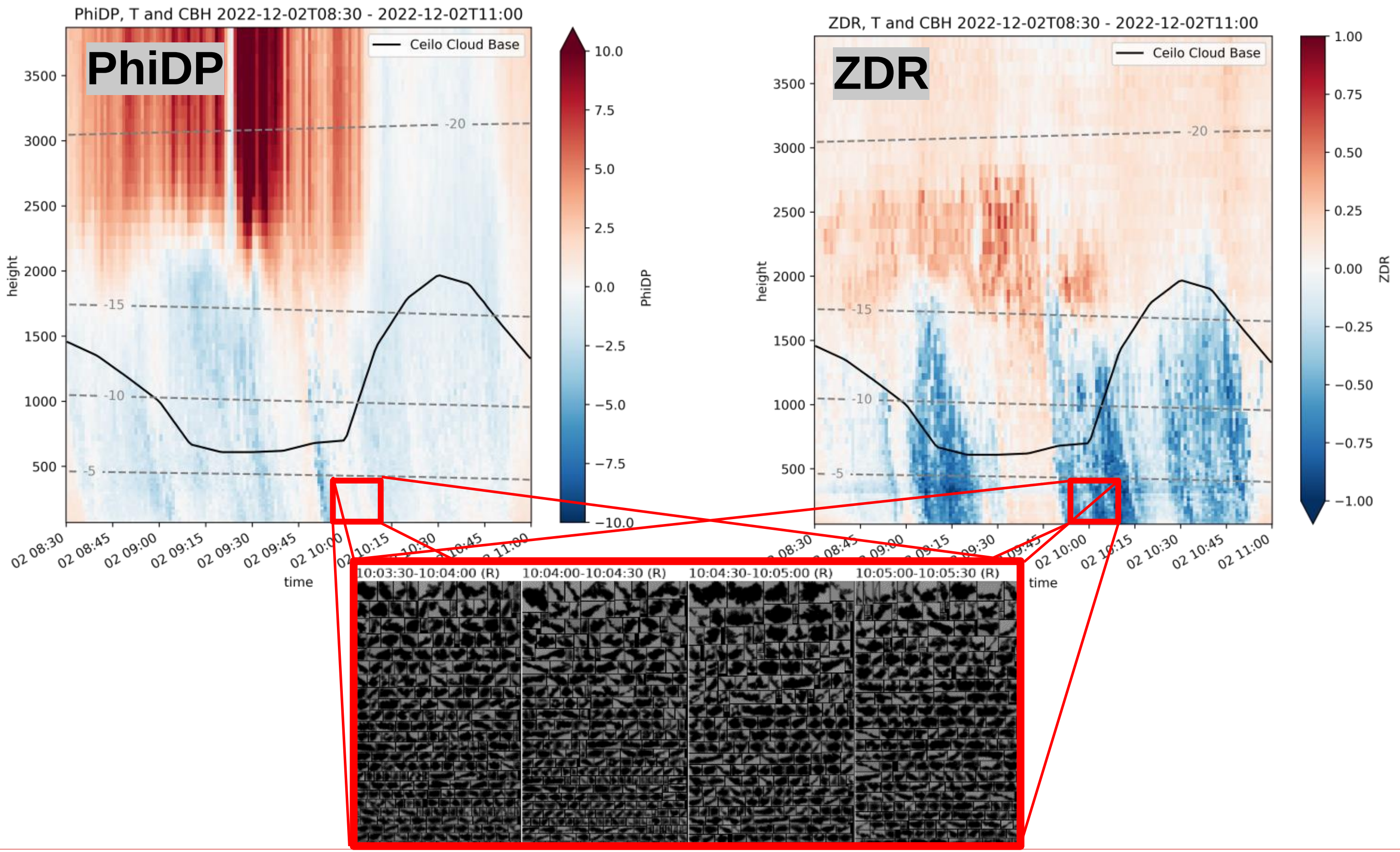


Knight and Knight (1972)

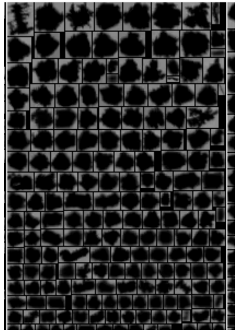
2022-12-02 CASE STUDY

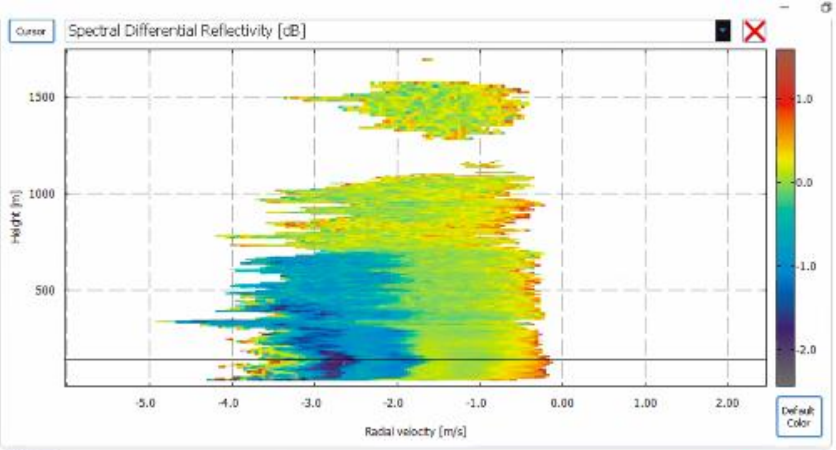


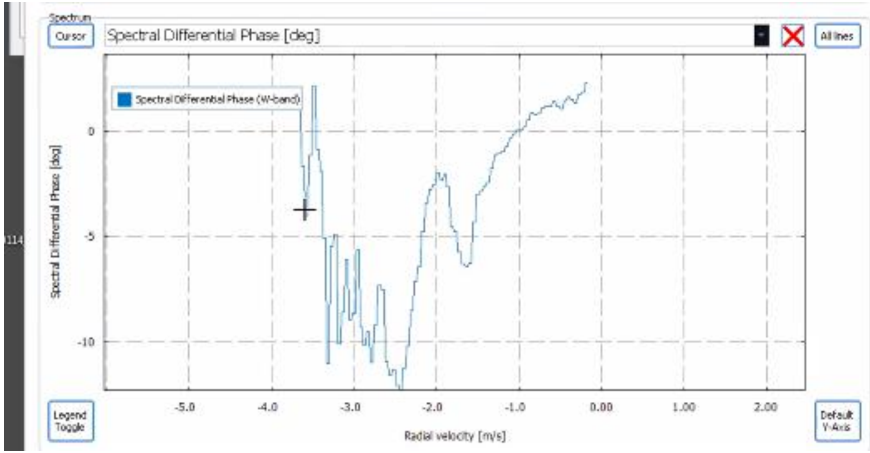
2022-12-02 CASE STUDY

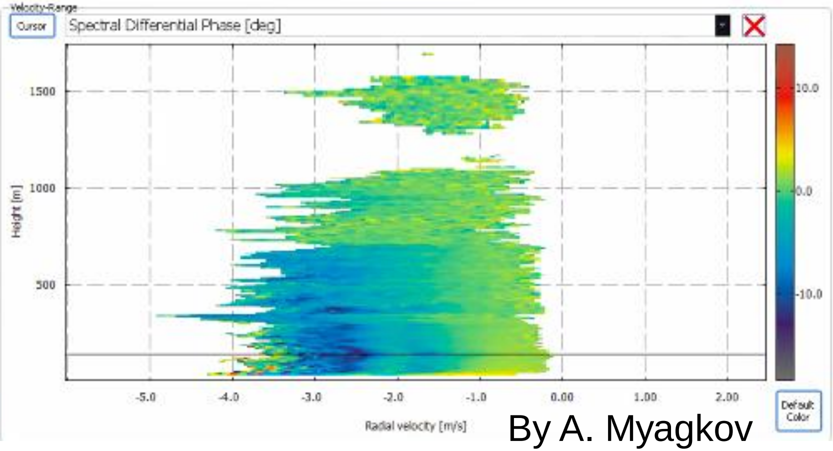


SPECTRAL OSCILLATIONS IN CONICAL GRAUPEL? 2022-12-05



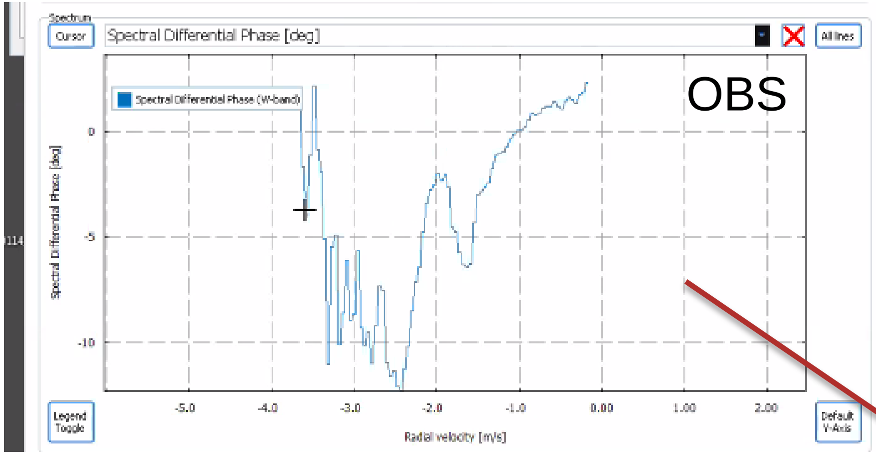


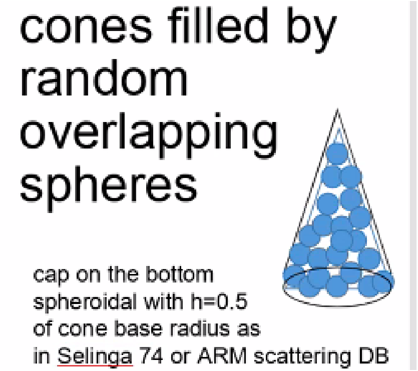




By A. Myagkov

SCATTERING SIMULATIONS BY DAVIDE ORI





- First simulations are able to repoduce the oscillations

deg

Eqiuv. Diameter (mm)

By D. Ori

SUMMARY AND OUTLOOK

- We see clear differences in the polarization variables for different ice habits
- Good agreement between the two applied riming retrieval methods
- Observations of “rare” particles (conical graupel)

-> Develop/apply precipitation rate retrieval
-> Determine external drivers
-> Include polarimetric parameters to PAMTRA
-> Estimate polarimetric scattering properties
-> Quantify riming and SIP processes

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First Results | CORSIPP