Ground-based radar remote sensing of Antarctic precipitation

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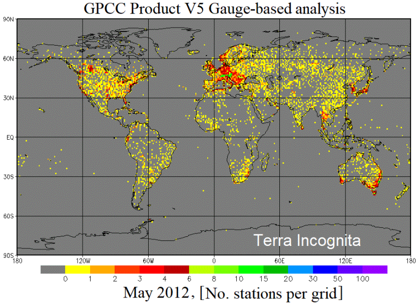
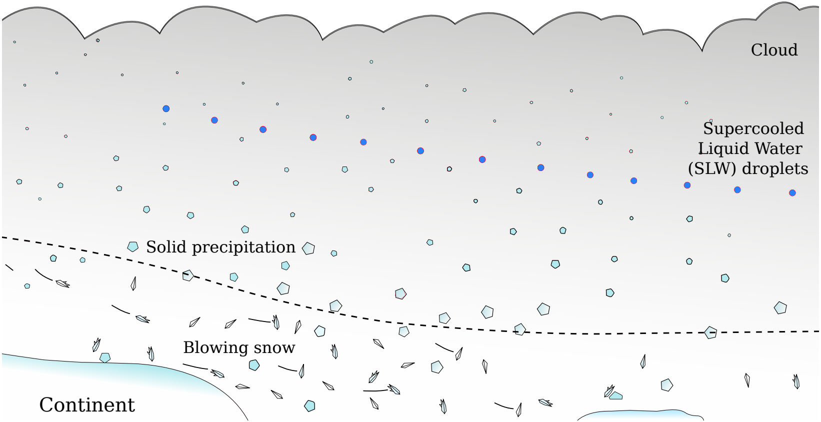
Motivation

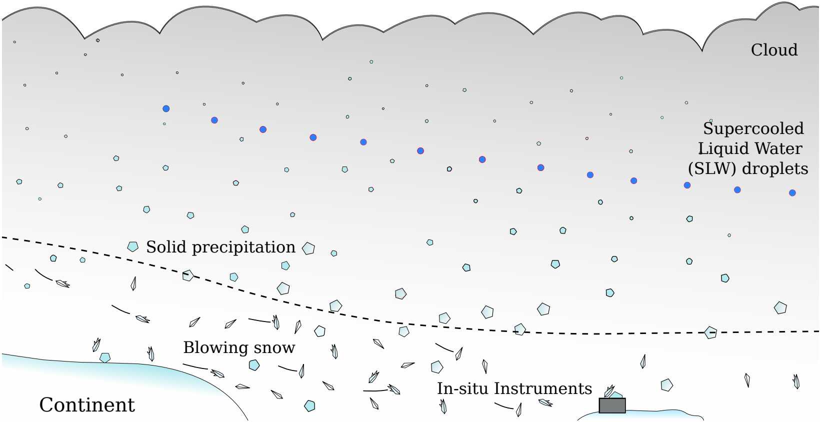
- Future evolution of precipitation remains uncertain in a changing climate
- There is a large uncertainty in models to represent current state of precipitation, specially in its solid form due to:
    - **Lack in observations** in remote areas: high-latitude and altitude regions.
    - **Uncertainties in measurements** (e.g. under catch in gauges due to wind).
- Antarctic snowfall → impact at global scale (e.g. sea level rise).
- Alpine snowfall → impact on human development (e.g. water resources).



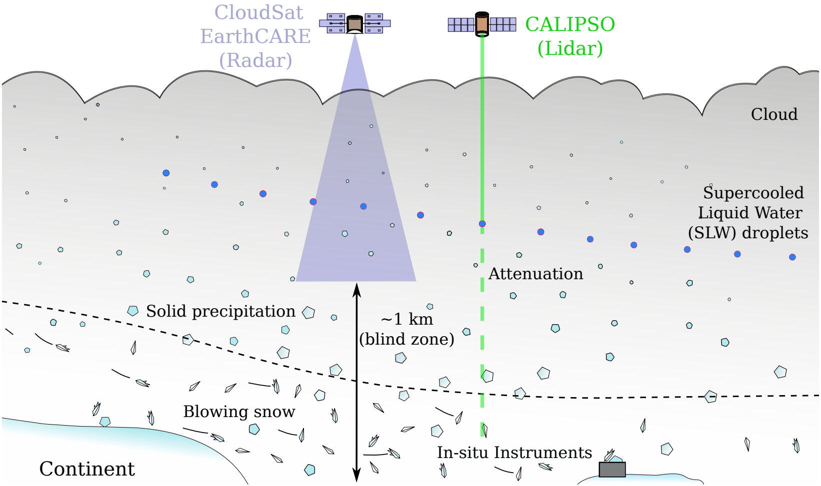
Antarctic context



Antarctic context



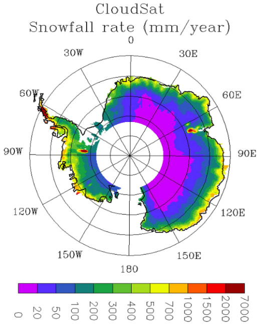
Antarctic context



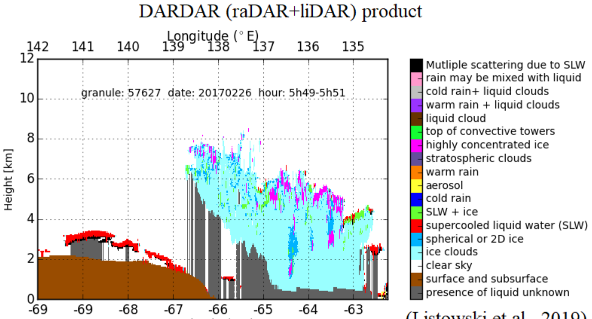
Remote sensing from space

Observations from space

- Allow the study of spatial and vertical **structure of precipitation** and **mixed-phase clouds**
- **Limitations**: Lack of observations for validation, low temporal resolution, limited observations near the surface

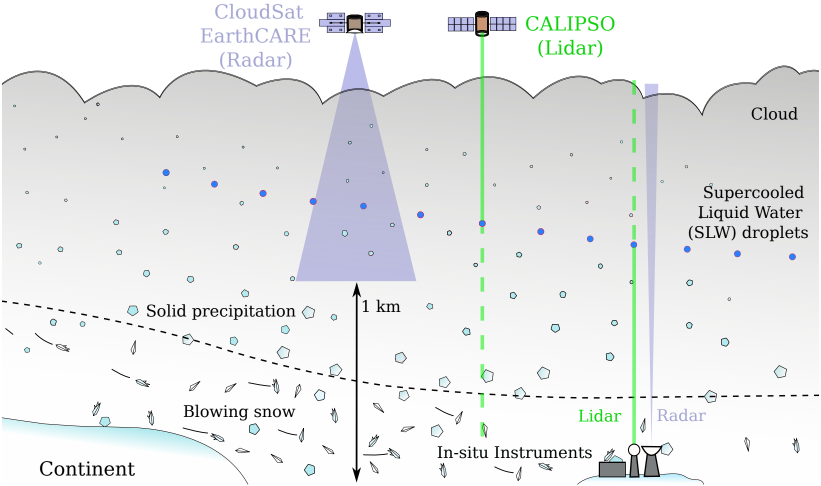


Mean annual snowfall rate (Palerme et al., 2014)



(Listowski et al., 2019)

Remote sensing from surface



Research objective

Objective: Vertical structure of precipitation

To characterize the **vertical structure of the precipitation** in two contrasted but important regions of the cryosphere, Antarctica and the Alps, in the low troposphere using ground-based radars.

Plan

- **Instruments and Datasets**
- **Vertical structure of precipitation using radars**
- **General conclusions and perspectives**

Plan

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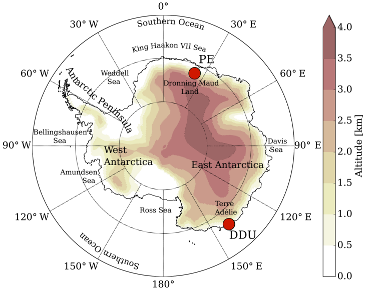
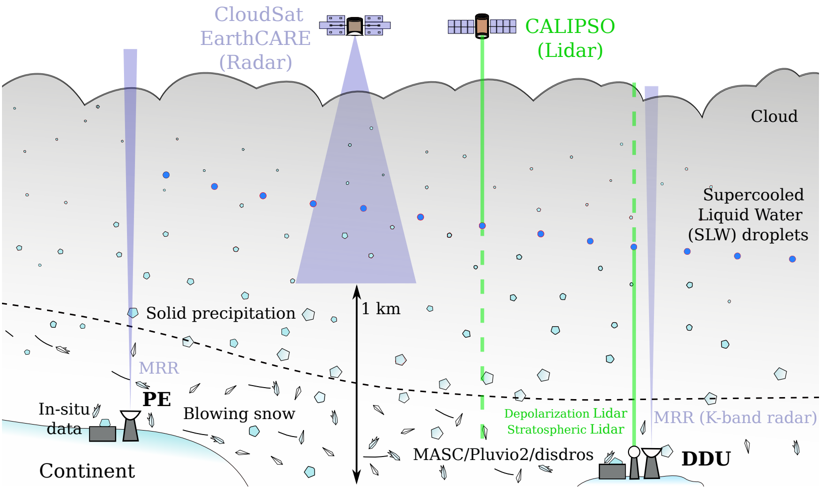
- General conclusions and perspectives

Antarctica stations

- Dumont d'Urville (DDU): Antarctic coast, strong katabatic winds.
- Princess Elisabeth (PE): Inland (173 km and 1392 m a.s.l), colder and dryer, less strong katabatic winds.



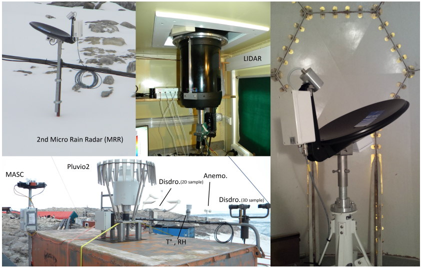
Strategy of observation in Antarctica



Strategy of observation in Antarctica

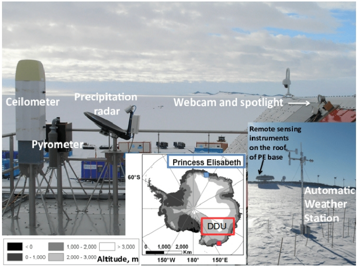
- Remote sensing: **MRR**, depolarization lidar (at DDU), Radio Sounding.
- In-situ sensors: Snow gauge, disdrometers, temperature, relative humidity, particle cameras.

Dumont d'Urville station (41 m a.s.l.)



Radar reflectivity Z_e, vertical vel. W and spectral width σ collected since Nov 2015.

Princess Elisabeth station (1392 m a.s.l.)



Same data collected since 2010, mostly in summer and autumn.

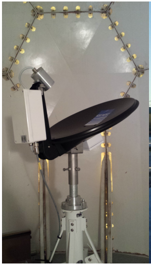
Plan

- Instruments and Datasets
- **Vertical structure of precipitation using radars**
- General conclusions and perspectives

The vertical structure of precipitation in East Antarctica and the Alps derived from micro rain radars

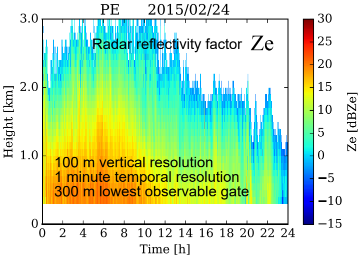
Motivation

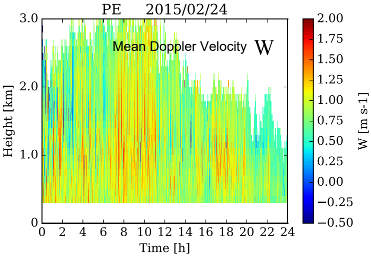
- Evolution of the vertical profile of precipitation is fundamental to understand surface precipitation, and evaluate satellite and numerical products.

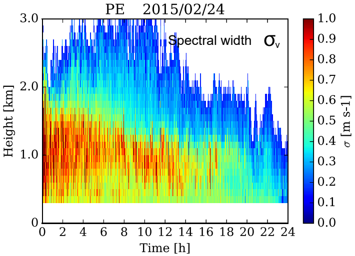



Example of MRR data

- Data collected at PE on 24 Feb 2015.
- Processed using IMProToo from Maahn and Kollias (2012).





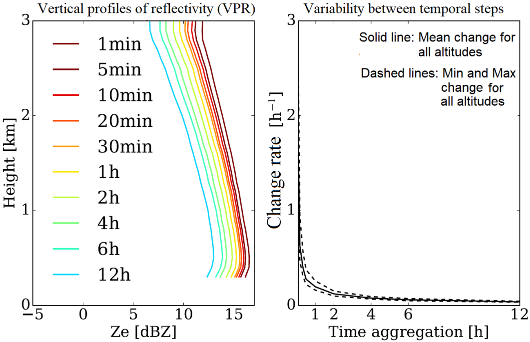


Temporal integration

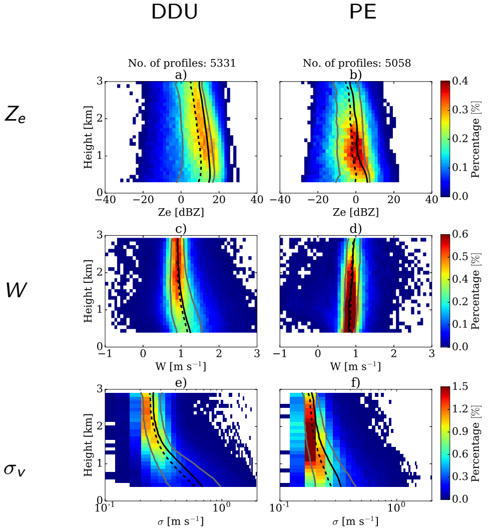
At what temporal resolution should we analyze the MRR data?

- Too high: influence of precip. advection on vertical profile.
- Too low: too much smoothing + not enough values to get robust statistics.

1h seems a reasonable trade-off!



Case of Antarctica: DDU and PE, East Antarctica

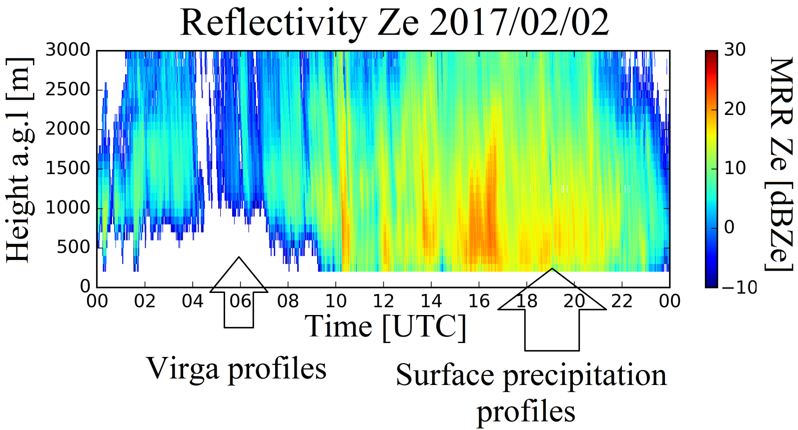


Solid lines: Mean profiles
Dashed lines: Median profiles
Grey lines : 20 and 80% quantiles.

- Z_e at DDU > PE. Diff. type, size and density of particles, intensity, etc.
- Vertical velocity in lowest 1 km at DDU > PE. Changes in density and shape of particles.
- Spectral width (turbulence, diff. crystal types) in lowest 1 km DDU > PE.

Surface precipitation and virga events

Virga correspond to profiles with no signal at lowest level (300 m agl).



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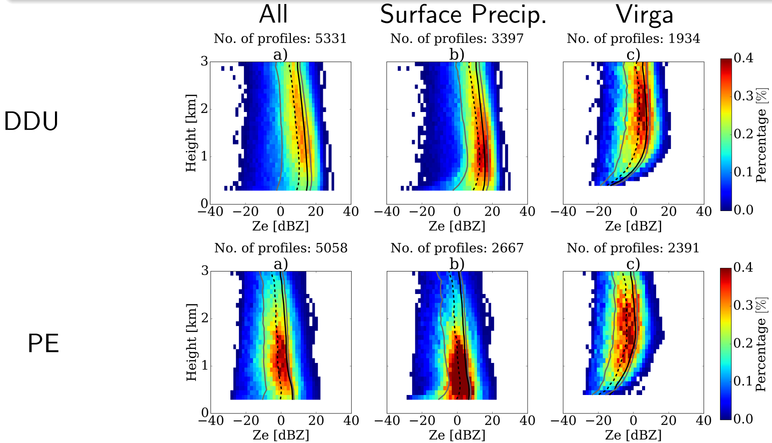
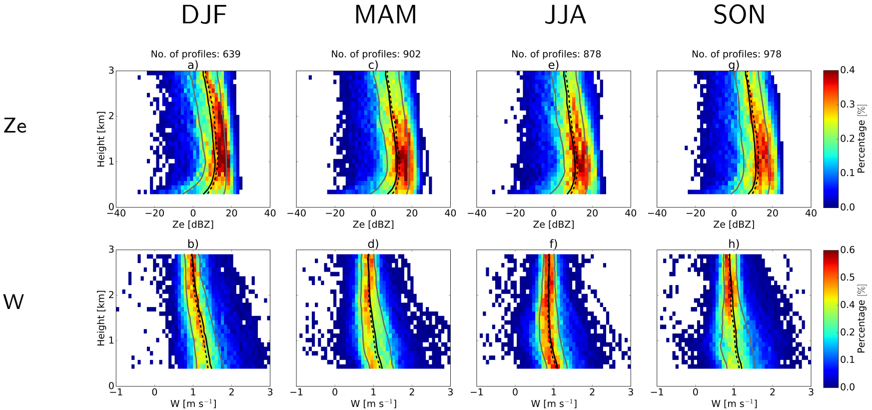


- Virga are frequent (36% at DDU, 47% at PE) + diff. vertical structure.

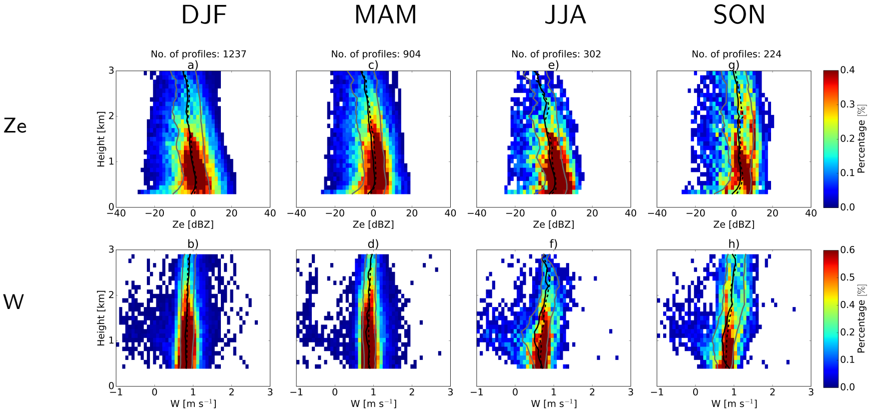
→ Precip and virga should be analyzed separately.

Seasonal + precipitation only analysis - DDU



- Z_e: similar general shape for all seasons with larger vertical extent in summer + low-level sublimation due to katabatic winds.
- W: differences due to microphysics (aggregation/riming)?
- σ: no seasonal influence (not shown).

Seasonal + precipitation only analysis - PE



- Z_e: similar behavior to DDU, with lower vertical extent.
- W: no lower level increase in $V \rightarrow$ diff. microphysics than at DDU?
- Possible sampling effects because of limited data in winter and spring.

Plan

- Instruments and Datasets
- Classification of cloud and precipitation using lidar (Objective 1)
- Vertical structure of precipitation using radars (Objective 2)
- **General conclusions and perspectives**

Conclusions and perspectives

Conclusions

- Clouds and precipitation were studied using lidar combined with MRR, to detect and classify the particles.
- Differences of **Doppler moments are consistent with local climatology**: relative warmer and moister at DDU so profiles corresponding to deeper and more intense precipitation.
- Possible influence of different dominant microphysical processes.
- **Frequent occurrence of virga in Antarctica** (36 (DDU) and 47% (PE) of all profiles).
- These studies provide information to improve the interpretation of the numerical models and to validate satellite data

Conclusions and perspectives

Perspectives

- Expand the analysis to other stations with MRR and/or lidar data.
- Information from MRR will be useful to **validate and calibrate new satellite mission** as the case of EarthCARE.


Merci beaucoup pour votre attention !
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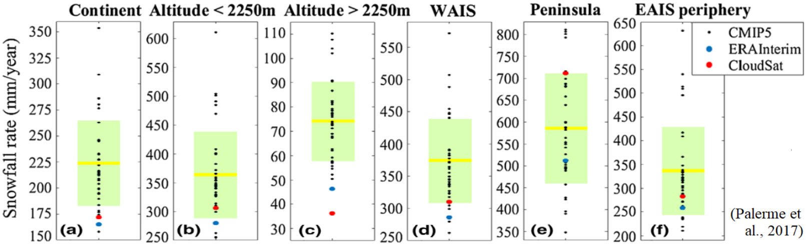
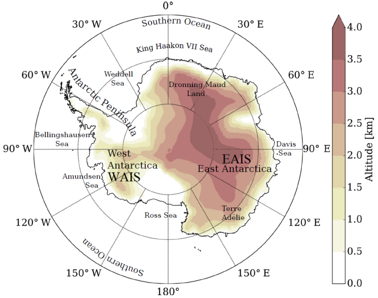
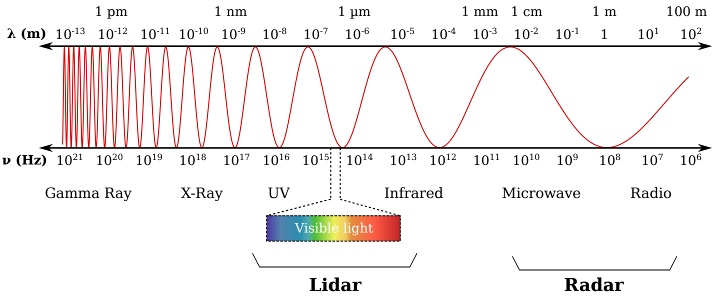
Antarctic context



Precipitation uncertainty

- Large discrepancy between models.
- Similar results CloudSat and ERA-interim. Problems with orographic precipitation for coarse resolution.



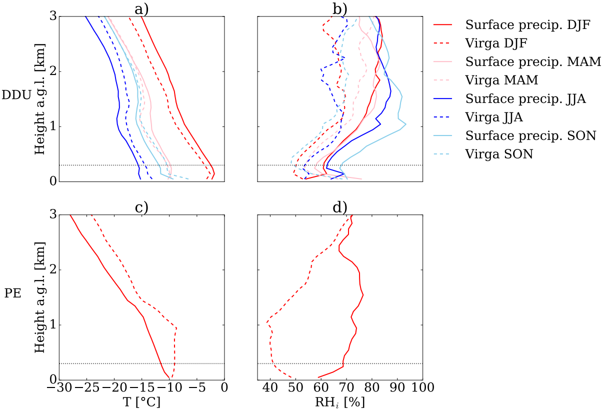


Radar bands	Frequency	Uses
S	2–4 GHz	Long range weather observations
C	4–8 GHz	Weather observations
X	8–12 GHz	Weather observations
K	18–27 GHz	Rain and snowfall
W	75–110 GHz	Cloud and precipitation

Virga events and radio soundings

Verifying virga events using radio soundings

- Co-located RS and precipitation events. Only summer RS at PE).
- Low relative humidity (RH_i) with respect to the ice during virga events.



Snow/rainfall classification vs. disdrometer outputs

- Snow/rainfall Classification was evaluated with an independent classification derived from disdrometer data
- Comparison shows agreement between both classifications

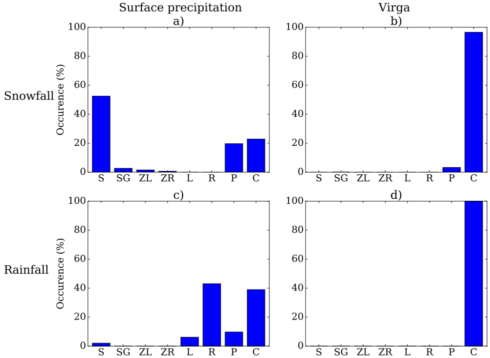
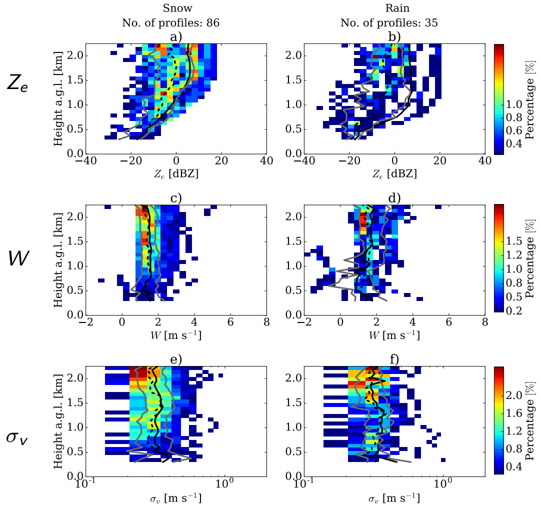


Table 1: PWS100 NWS output codes.

Name	Code
No precipitation	C
Precipitation	P
Drizzle	L
Freezing drizzle	ZL
Rain	R
Freezing rain	ZR
Snow	S
Ice pellets	IP
Snow grains	SG
Ice crystals	IC
Hail	A

Vertical distributions for virga events



- Significant decrease of Z_e toward the surface (both)
- narrowed values of W
- lower values of σ_v