ESA-JAXA Pre-Launch EarthCARE Science and Validation Workshop

13 – 17 November 2023 | ESA-ESRIN, Frascati (Rome), Italy

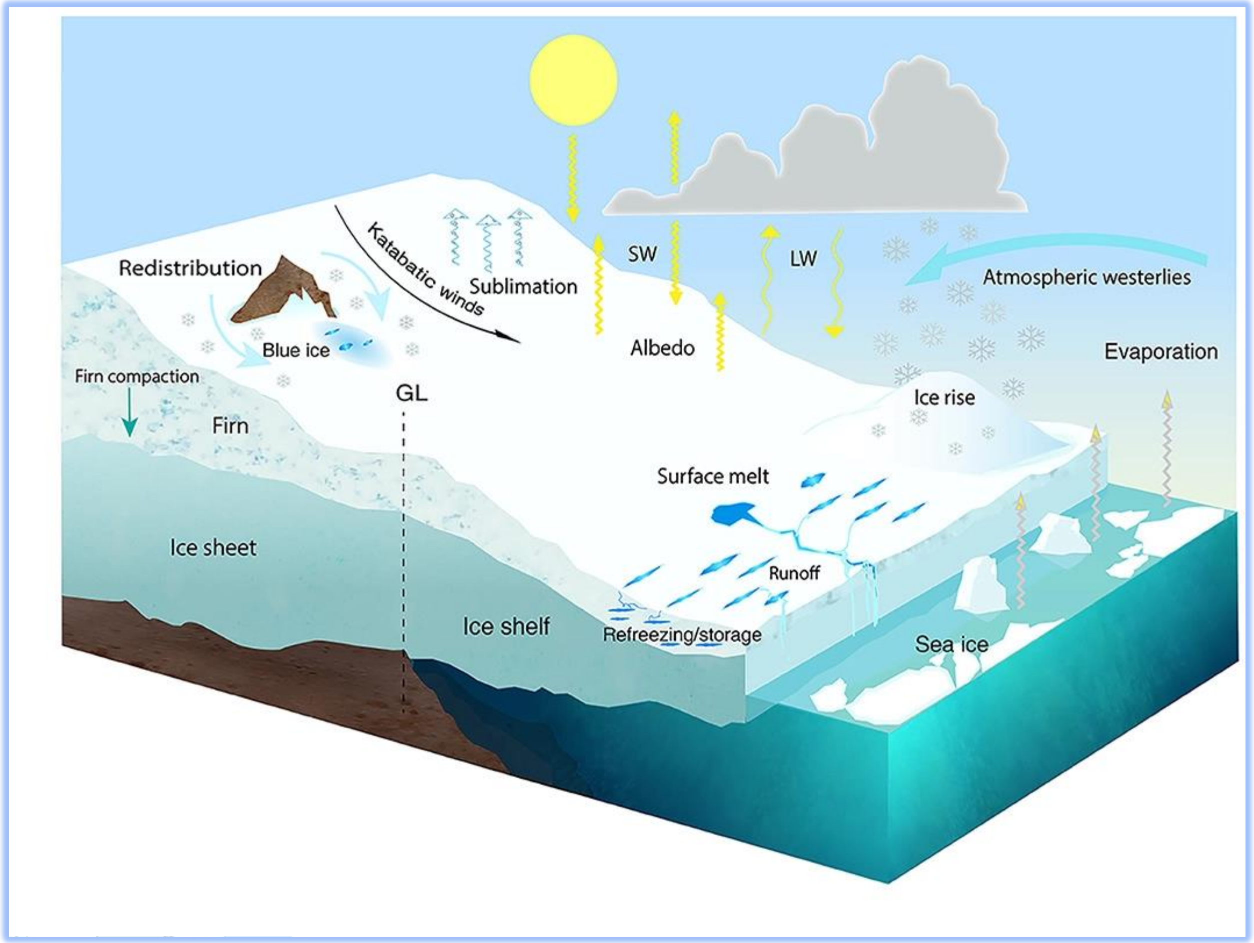
K2W, a methodology for evaluating spaceborne W-band Doppler radar using Micro Rain Radar and disdrometer: results from an Italian station in Antarctica

A. Bracci [1], K. Sato [2], L. Baldini [1], F. Porcù [3], H. Okamoto [2]

[1] Institute of Atmospheric Sciences and Climate (CNR-ISAC), Rome, Italy
[2] Research Institute for Applied Mechanics, Kyushu University, Fukuoka, Japan
[3] Department of Physics and Astronomy, University of Bologna, Bologna, Italy

Rationale

Importance of Antarctic precipitation



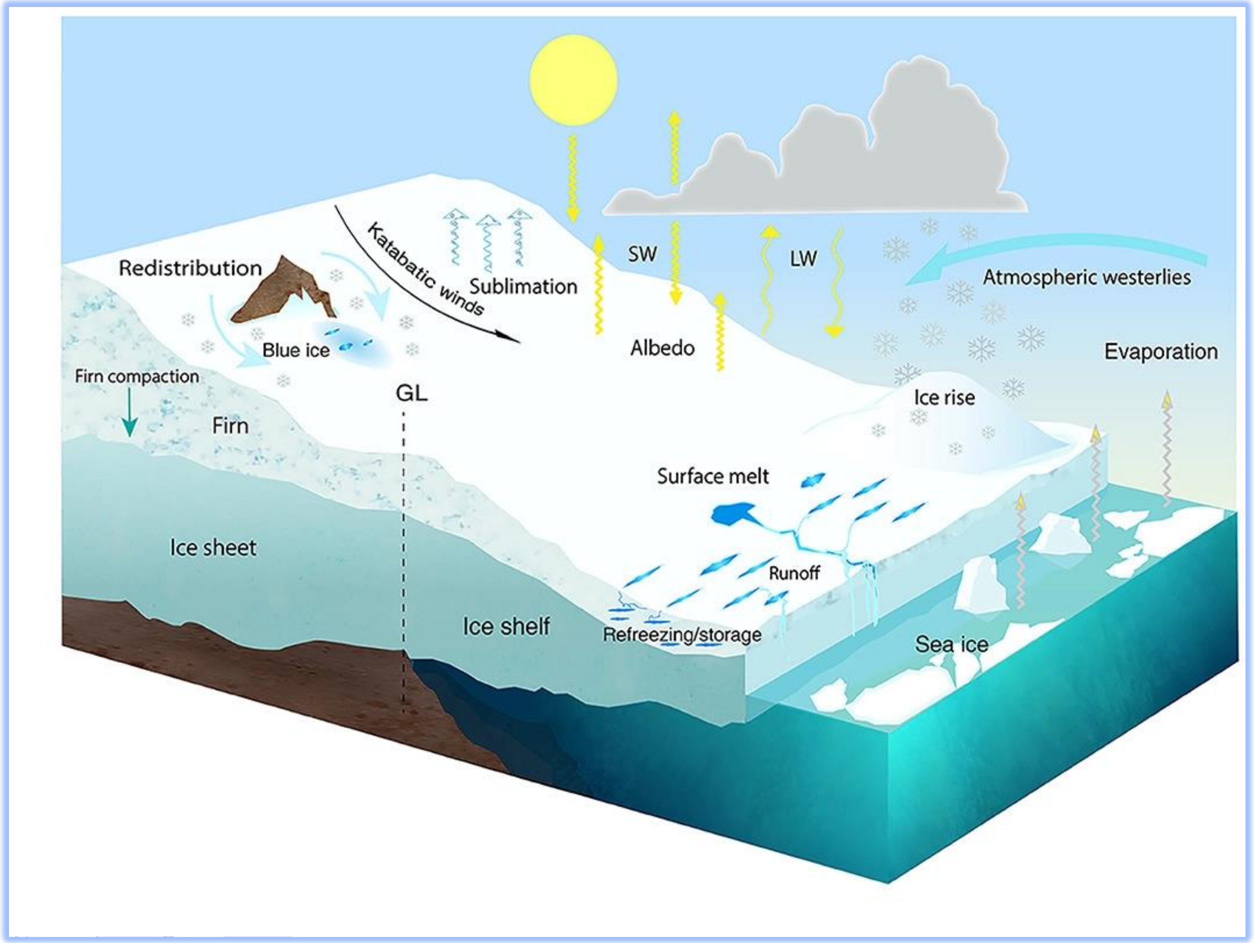
Observing and Modeling Ice Sheet Surface Mass Balance
(10.1029/2018RG000622)

Rationale

Importance of Antarctic precipitation

↓

Surface Mass Balance of Antarctic Ice Sheet (AIS)



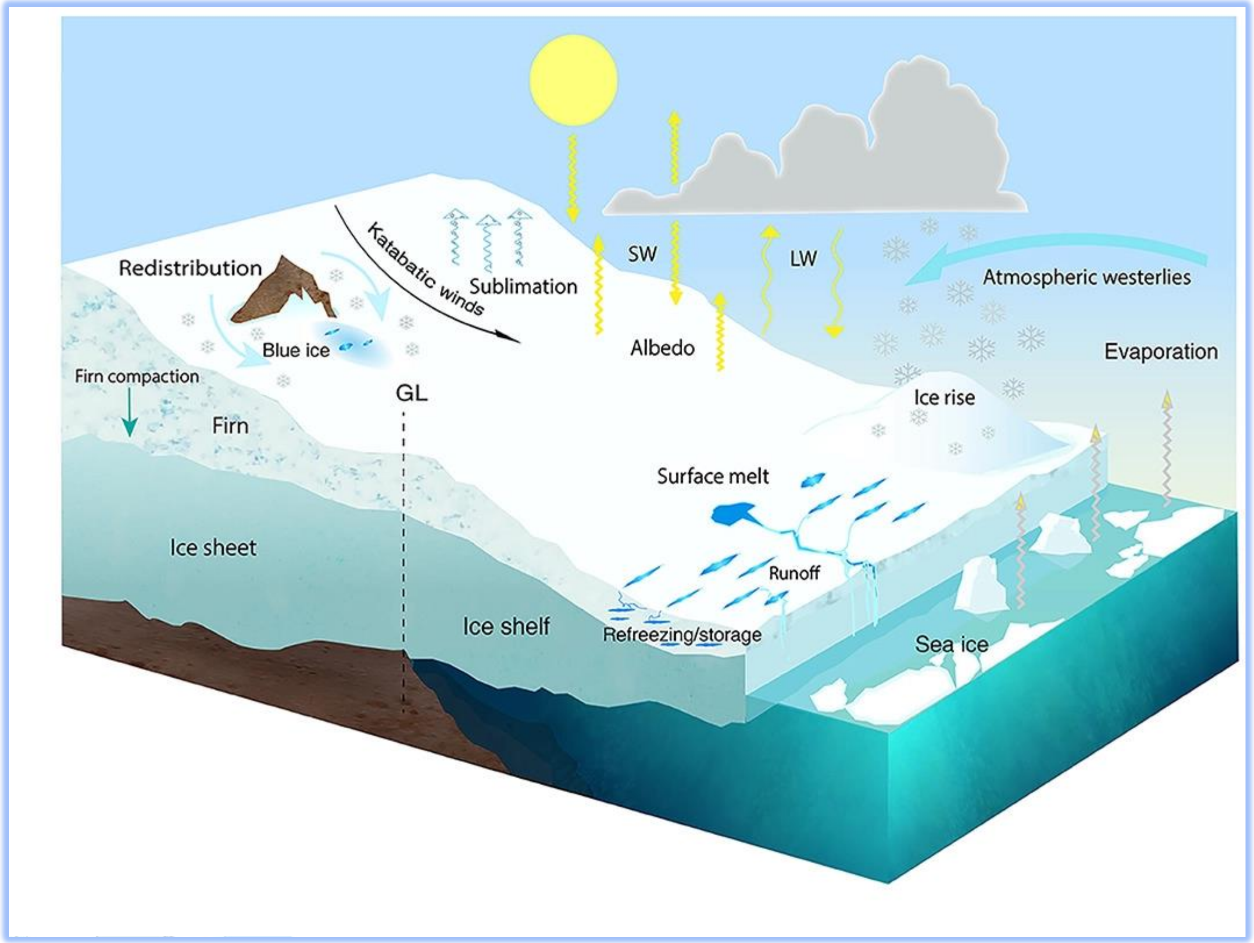
Observing and Modeling Ice Sheet Surface Mass Balance (10.1029/2018RG000622)

Rationale

Importance of Antarctic precipitation

Surface Mass Balance of Antarctic Ice Sheet (AIS)

- During precipitation and deposition mass accumulates at the surface
- Snowfall is the primary input of mass for the AIS and its variability and change have an impact on the ice sheet mass balance



Observing and Modeling Ice Sheet Surface Mass Balance (10.1029/2018RG000622)

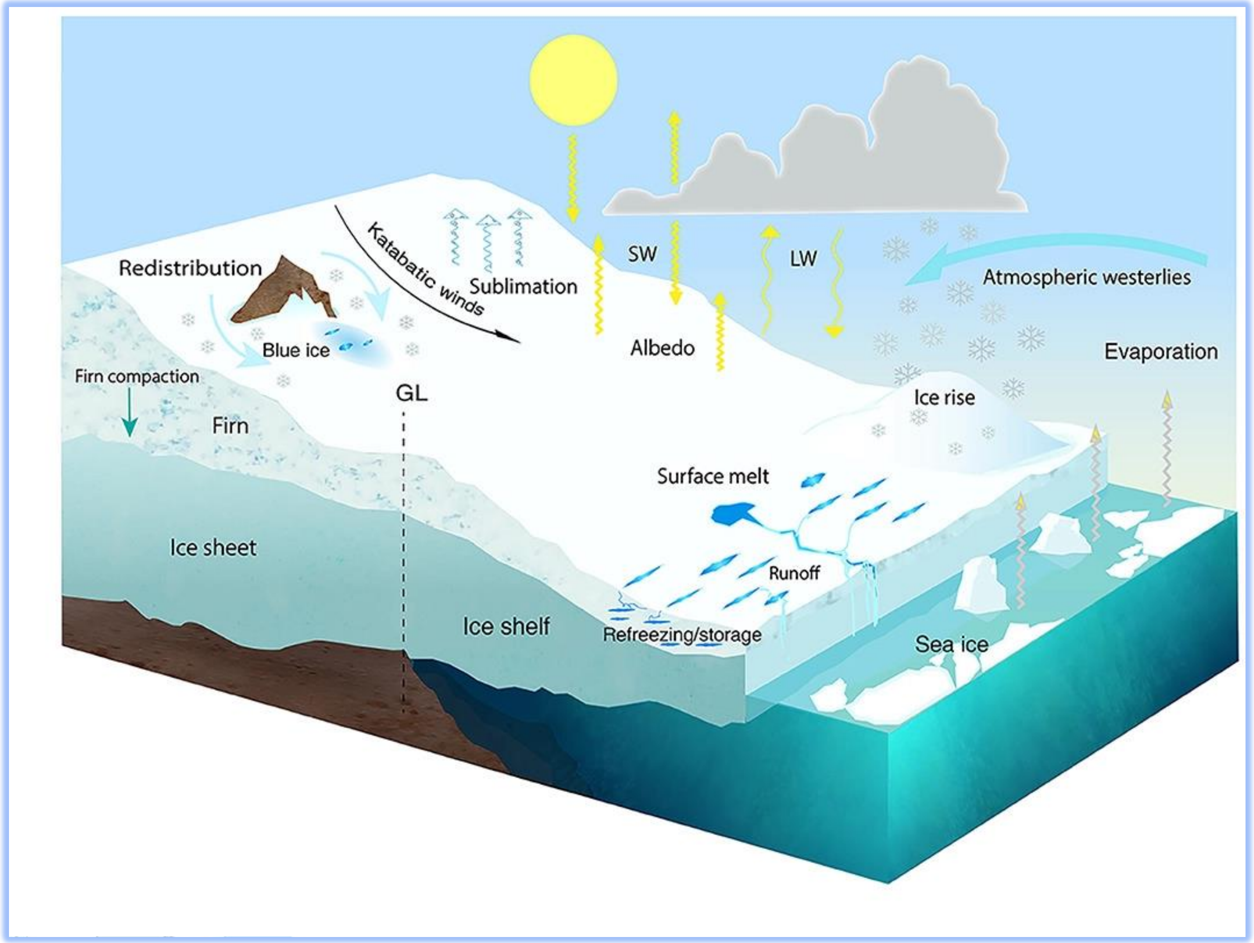
Rationale

Importance of Antarctic precipitation

Surface Mass Balance of Antarctic Ice Sheet (AIS)

- During precipitation and deposition mass accumulates at the surface
- Snowfall is the primary input of mass for the AIS and its variability and change have an impact on the ice sheet mass balance

Impact on global sea level



Observing and Modeling Ice Sheet Surface Mass Balance (10.1029/2018RG000622)

Rationale

What do we know about Antarctic precipitation?

Rationale

What do we know about Antarctic precipitation?

Unfortunately, not much

Rationale

What do we know about Antarctic precipitation?

↓

Unfortunately, not much

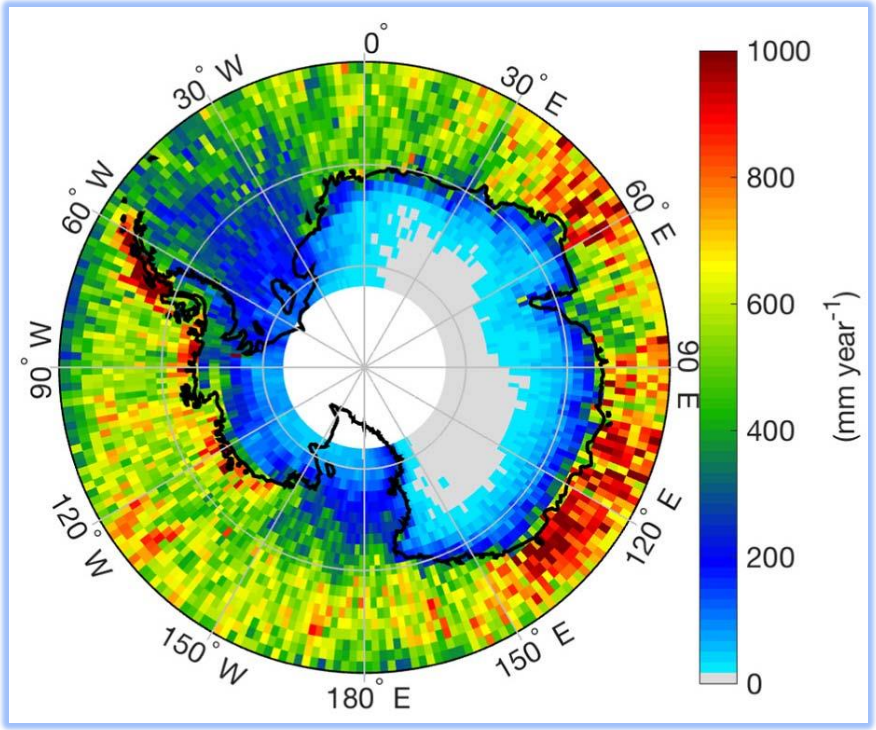
- Ground-based observations of precipitation are sparse over Antarctica, due also to complex logistical operations, extreme climatic conditions, difficult accessibility and instrument maintenance

Rationale

What do we know about Antarctic precipitation?

Unfortunately, not much

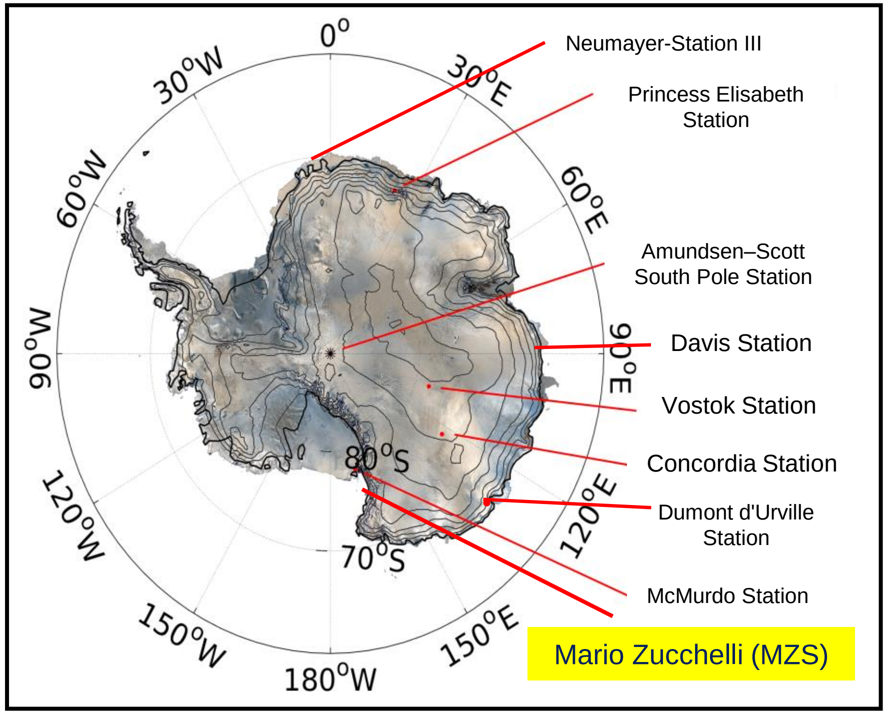
- Ground-based observations of precipitation are sparse over Antarctica, due also to complex logistical operations, extreme climatic conditions, difficult accessibility and instrument maintenance
- Precipitation estimations over the Continent rely on numerical model and satellite measurements
- Both need ground observations for validating and improving precipitation parameterizations and for minimizing the impact of intrinsic limitations of the measurement techniques



CloudSat: Mean annual snowfall over Antarctica (Milani et al., 2018)

Rationale

Availability of ground-based radar profilers for validation purposes

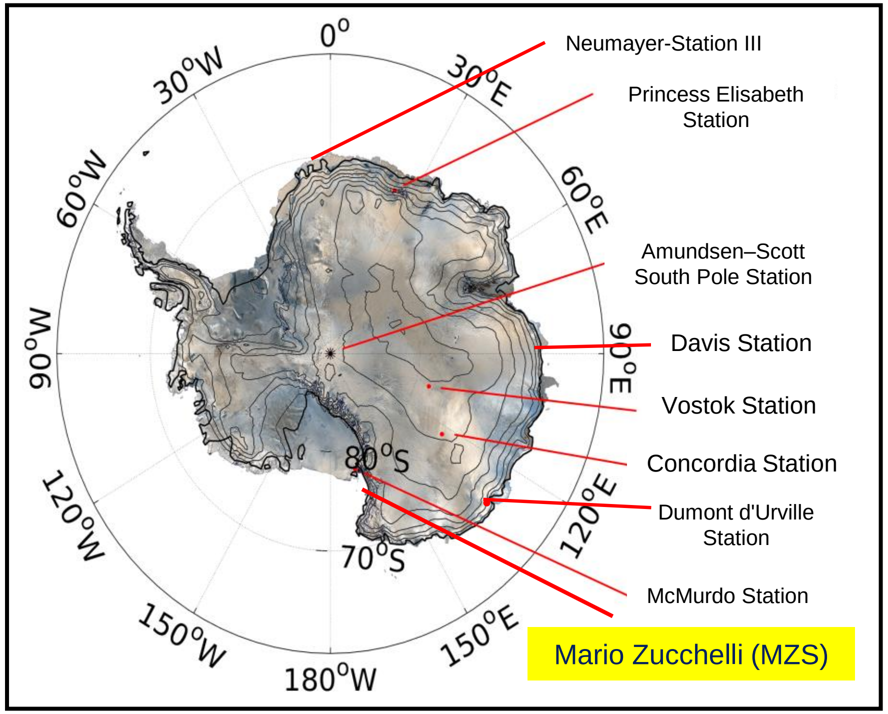


Research stations (precipitation monitoring)

Rationale

Availability of ground-based radar profilers for validation purposes

- W-band radars:
  - Mc-Murdo (Lubin, 2020) T
  - Davis (Alexander, 2023) T



Research stations (precipitation monitoring)

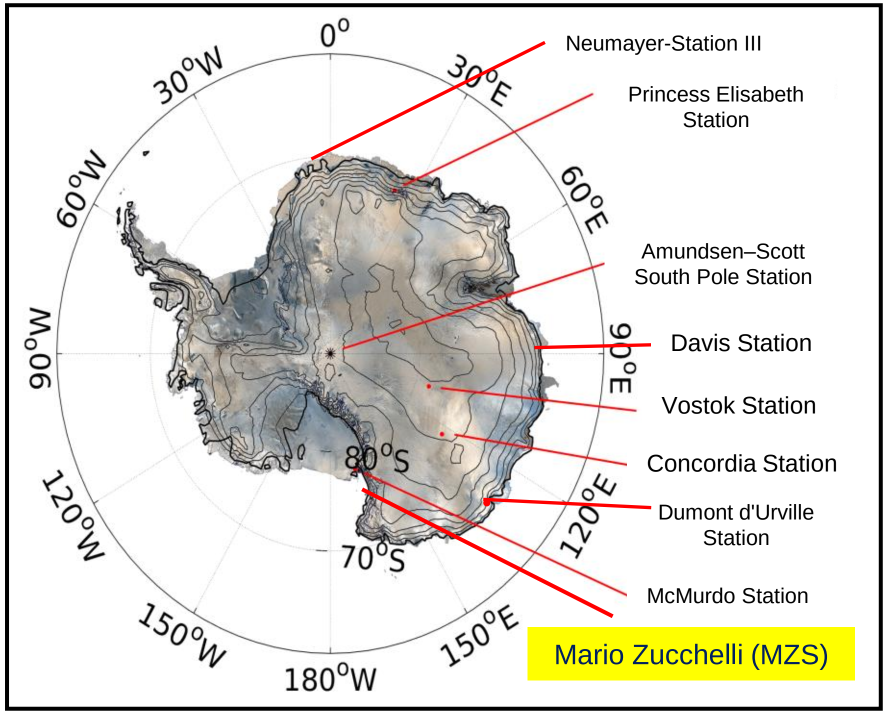
T=temporary; F= fixed; P=planned

Rationale

Availability of ground-based radar profilers for validation purposes

- W-band radars:
  - Mc-Murdo (Lubin, 2020) T
  - Davis (Alexander, 2023) T

- Ka-band radars:
  - Mc-Murdo (Lubin, 2020) T
  - Neumayer III (Radenz, 2023) **F**



Research stations (precipitation monitoring)

T=temporary; F= fixed; P=planned

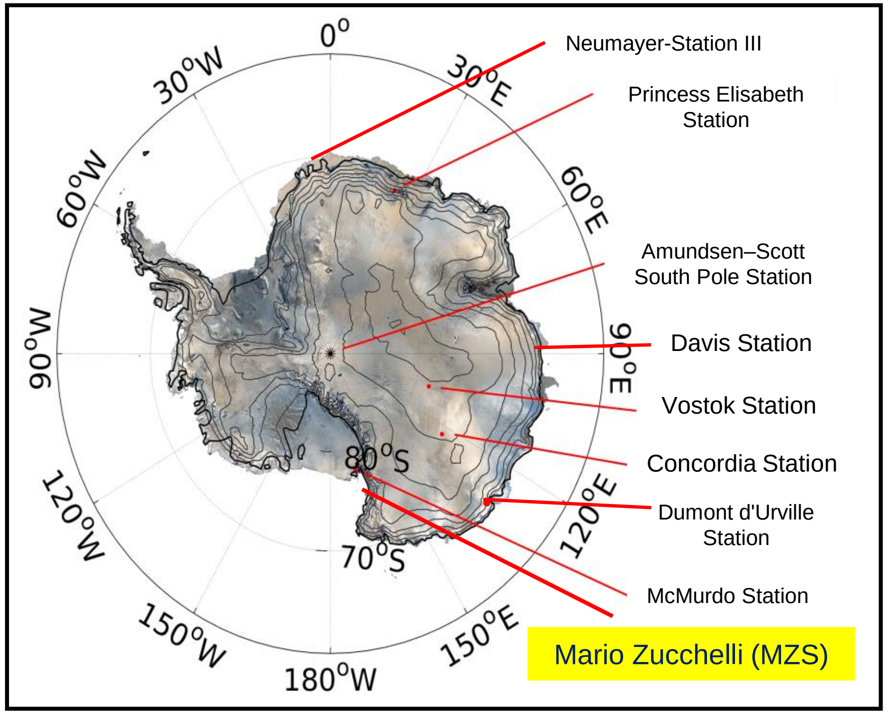
Rationale

Availability of ground-based radar profilers for validation purposes

- W-band radars:
  - Mc-Murdo (Lubin, 2020) T
  - Davis (Alexander, 2023) T

- Ka-band radars:
  - Mc-Murdo (Lubin, 2020) T
  - Neumayer III (Radenz, 2023) **F**

- K-band radars:
  - 4 @ Princess Elisabeth (Gorodetskaya, 2015; Ferrone, 2023) **F** T T T
  - 1 @ Dumont D'Urville (Grazioli, 2017) **F**
  - 2 @ Mario Zucchelli (Scarchilli, 2020; Bracci, 2022) **F F**
  - 1 @ Concordia (Di Natale, 2022) **F**
  - 1 @ Vernadsky (Pishniak, 2022) **F**
  - 1 @ Davis (Alexander,2023) **F**
  - 1 @ Marambio P



Research stations (precipitation monitoring)

T=temporary; F= fixed; P=planned

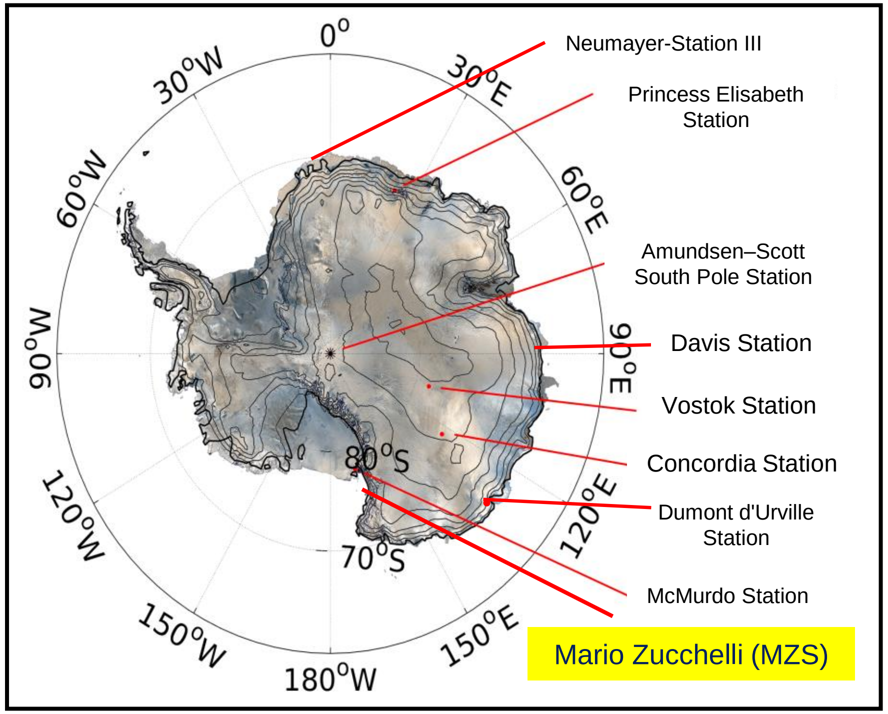
Rationale

Availability of ground-based radar profilers for validation purposes

- W-band radars:
  - Mc-Murdo (Lubin, 2020) T
  - Davis (Alexander, 2023) T

- Ka-band radars:
  - Mc-Murdo (Lubin, 2020) T
  - Neumayer III (Radenz, 2023) **F**

- K-band radars:
  - 4 @ Princess Elisabeth (Gorodetskaya, 2015; Ferrone, 2023) **F** T T T ✓
  - 1 @ Dumont D'Urville (Grazioli, 2017) **F** ✓
  - 2 @ Mario Zucchelli (Scarchilli, 2020; Bracci, 2022) **F F** ✓
  - 1 @ Concordia (Di Natale, 2022) **F** ✓
  - 1 @ Vernadsky (Pishniak, 2022) **F**
  - 1 @ Davis (Alexander,2023) **F** ✓
  - 1 @ Marambio P



Research stations (precipitation monitoring)

T=temporary; F= fixed; P=planned

Simulation of Doppler spectra at W-band using K-band Doppler Spectra

Simulation of Doppler spectra at W-band using K-band Doppler Spectra

- Metek - **MRR** is a K-band profiling Doppler radar, typically used in vertical pointing mode to derive Doppler spectra in 64 bins over 32 vertical range bins. Set with 35 m as vertical resolution -> range probed: 105-1050 m a.g.l.

- OTT - **Parsivel** is an optical laser disdrometer that measures the sizes and fall velocities of the hydrometeors (binned in 32 × 32 diameter/speed classes)

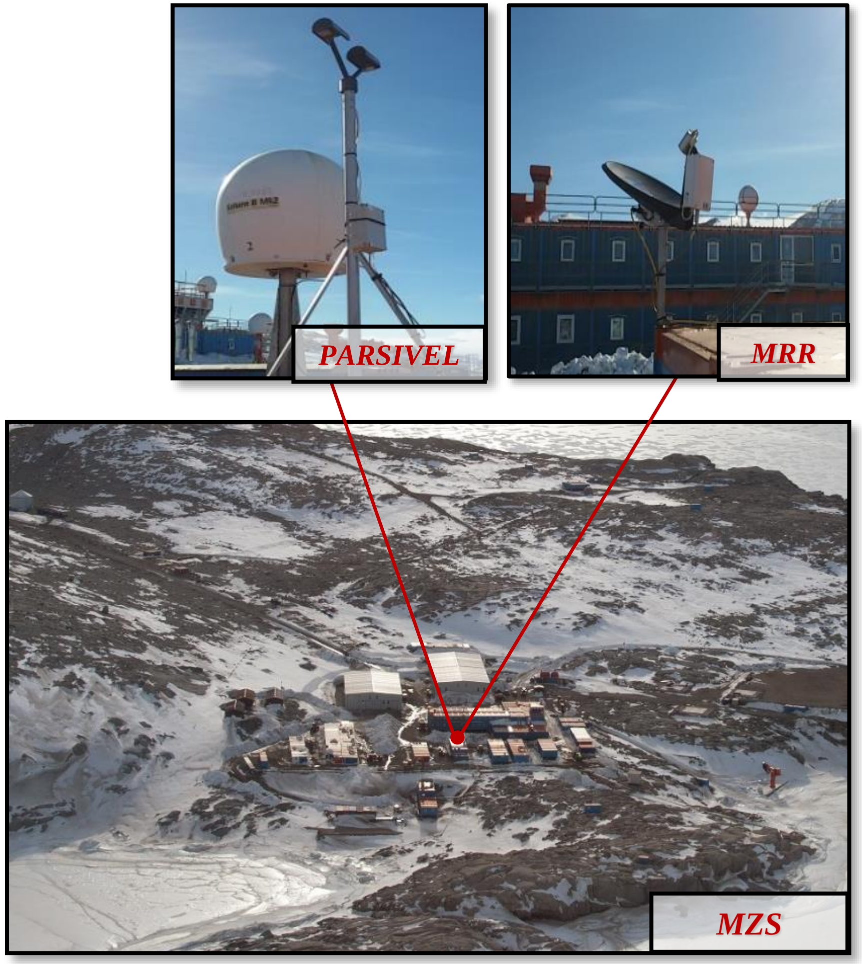
K2W methodology

Simulation of Doppler spectra at W-band using K-band Doppler Spectra

- Metek - **MRR** is a K-band profiling Doppler radar, typically used in vertical pointing mode to derive Doppler spectra in 64 bins over 32 vertical range bins. Set with 35 m as vertical resolution -> range probed: 105-1050 m a.g.l.

- OTT - **Parsivel** is an optical laser disdrometer that measures the sizes and fall velocities of the hydrometeors (binned in 32 × 32 diameter/speed classes)

- MRR and Parsivel have been installed since December 2016 at Mario Zucchelli Station (**MZS**) in the framework of the project "Antarctic Precipitation Properties" (APP) of the Italian National Antarctic Research Program (PNRA)



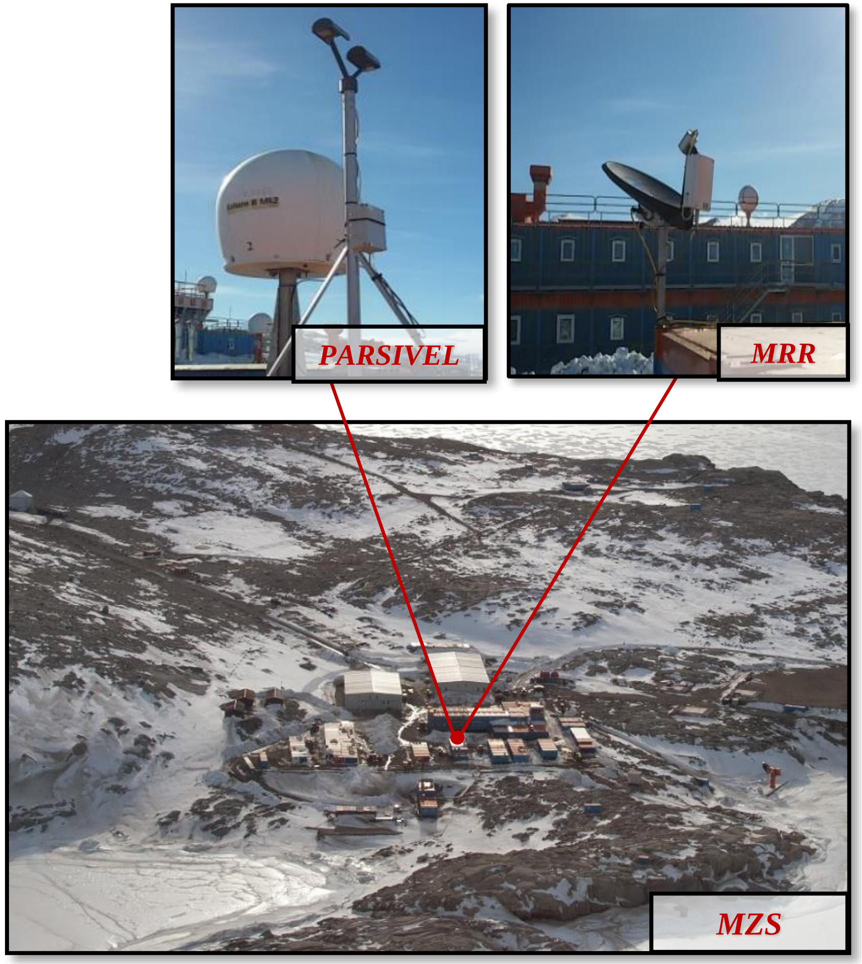
Simulation of Doppler spectra at W-band using K-band Doppler Spectra

- Metek - **MRR** is a K-band profiling Doppler radar, typically used in vertical pointing mode to derive Doppler spectra in 64 bins over 32 vertical range bins. Set with 35 m as vertical resolution -> range probed: 105-1050 m a.g.l.

- OTT - **Parsivel** is an optical laser disdrometer that measures the sizes and fall velocities of the hydrometeors (binned in 32 × 32 diameter/speed classes)

- MRR and Parsivel have been installed since December 2016 at Mario Zucchelli Station (**MZS**) in the framework of the project "Antarctic Precipitation Properties" (APP) of the Italian National Antarctic Research Program (PNRA)

- Extensive DDA **database of single-scattering properties** of simulated pristine crystals and aggregate particles (Kuo, JAMC-2016) was selected, being the most comprehensive database including the K-band and W-band simulations. We considered aggregate particles during CloudSat overpass based on habit classification (Bracci, RS-2021)



K2W methodology

Simulation of Doppler spectra at W-band using K-band Doppler Spectra

Simulation of Doppler spectra at W-band using K-band Doppler Spectra

I. Spectral reflectivity density with respect to Doppler velocity: $\eta_v(v_s, \mathrm{R}) = \frac{\eta(\mathrm{s}, \mathrm{R})}{\Delta \mathrm{v}}$

K2W methodology

Simulation of Doppler spectra at W-band using K-band Doppler Spectra

I. Spectral reflectivity density with respect to Doppler velocity:

$$\eta_v(v_s, \mathrm{R}) = \frac{\eta(\mathrm{s}, \mathrm{R})}{\Delta \mathrm{v}}$$

II. Particle size distribution is obtained by:

   I. Expressing spectral reflectivity density with respect to particle diameter

   II. Dividing by backscattering cross-section

$$\eta_\mathrm{D}(\mathrm{D}) = \eta_v(\mathrm{v}) \frac{\partial v}{\partial \mathrm{D}}$$

$$\mathrm{N}(\mathrm{D}) = \frac{\eta_D(\mathrm{D})}{\mathrm{C}_{bk}(\mathrm{D})}$$

K2W methodology

Simulation of Doppler spectra at W-band using K-band Doppler Spectra

I. Spectral reflectivity density with respect to Doppler velocity:

$$\eta_v(v_s, \mathrm{R}) = \frac{\eta(\mathrm{s}, \mathrm{R})}{\Delta \mathrm{v}}$$

II. Particle size distribution is obtained by:

  I. Expressing spectral reflectivity density with respect to particle diameter

  II. Dividing by backscattering cross-section

$$\eta_{\mathrm{D}}(\mathrm{D}) = \eta_v(\mathrm{v}) \frac{\partial v}{\partial \mathrm{D}}$$

$$\mathrm{N}(\mathrm{D}) = \frac{\eta_D(\mathrm{D})}{\mathrm{C}_{bk}(\mathrm{D})}$$

MRR Retrieval (Peters, 2002)

K2W methodology

Simulation of Doppler spectra at W-band using K-band Doppler Spectra

I. Spectral reflectivity density with respect to Doppler velocity:

$$\eta_v(v_s, \mathrm{R}) = \frac{\eta(\mathrm{s}, \mathrm{R})}{\Delta \mathrm{v}}$$

II. Particle size distribution is obtained by:

   I. Expressing spectral reflectivity density with respect to particle diameter

$$\eta_{\mathrm{D}}(\mathrm{D}) = \eta_v(\mathrm{v}) \frac{\partial v}{\partial \mathrm{D}}$$

   II. Dividing by backscattering cross-section

$$\mathrm{N}(\mathrm{D}) = \frac{\eta_D(\mathrm{D})}{\mathrm{C}_{bk}(\mathrm{D})}$$

MRR Retrieval (Peters, 2002)

III. Making explicit the frequency dependencies:

$$\mathrm{N}(\mathrm{D}) = \frac{\eta_{D,K}(\mathrm{D})}{\mathrm{C}_{bk,K}(\mathrm{D})}$$ as well as $$\mathrm{N}(\mathrm{D}) = \frac{\eta_{D,W}(\mathrm{D})}{\mathrm{C}_{bk,W}(\mathrm{D})}$$ considering same snow habit

K2W methodology

Simulation of Doppler spectra at W-band using K-band Doppler Spectra

I. Spectral reflectivity density with respect to Doppler velocity:

$$\eta_v(v_s, \mathrm{R}) = \frac{\eta(\mathrm{s}, \mathrm{R})}{\Delta \mathrm{v}}$$

II. Particle size distribution is obtained by:

   I. Expressing spectral reflectivity density with respect to particle diameter

   II. Dividing by backscattering cross-section

$$\eta_{\mathrm{D}}(\mathrm{D}) = \eta_v(\mathrm{v}) \frac{\partial v}{\partial \mathrm{D}}$$

$$\mathrm{N}(\mathrm{D}) = \frac{\eta_D(\mathrm{D})}{\mathrm{C}_{bk}(\mathrm{D})}$$

MRR Retrieval (Peters, 2002)

III. Making explicit the frequency dependencies:

$$\mathrm{N}(\mathrm{D}) = \frac{\eta_{D,K}(\mathrm{D})}{\mathrm{C}_{bk,K}(\mathrm{D})}$$ as well as $$\mathrm{N}(\mathrm{D}) = \frac{\eta_{D,W}(\mathrm{D})}{\mathrm{C}_{bk,W}(\mathrm{D})}$$ considering same snow habit

IV. Going backwards:

$$\eta_{v,W}(v) = \eta_{v,K}(v) \frac{\mathrm{C}_{bk,W}(D)}{\mathrm{C}_{bk,K}(\mathrm{D})}$$

K2W methodology

Simulation of Doppler spectra at W-band using K-band Doppler Spectra

I. Spectral reflectivity density with respect to Doppler velocity:

$$\eta_v(v_s, R) = \frac{\eta(s, R)}{\Delta v}$$

II. Particle size distribution is obtained by:

  I. Expressing spectral reflectivity density with respect to particle diameter

  II. Dividing by backscattering cross-section

$$\eta_D(D) = \eta_v(v)\frac{\partial v}{\partial D}$$

$$N(D) = \frac{\eta_D(D)}{C_{bk}(D)}$$

MRR Retrieval (Peters, 2002)

III. Making explicit the frequency dependencies:

$$N(D) = \frac{\eta_{D,K}(D)}{C_{bk,K}(D)}$$ as well as $$N(D) = \frac{\eta_{D,W}(D)}{C_{bk,W}(D)}$$ considering same snow habit

IV. Going backwards:

$$\eta_{v,W}(v) = \eta_{v,K}(v)\frac{C_{bk,W}(D)}{C_{bk,K}(D)}$$

$$\eta_{v,W}(v_s) = \eta_{v,K}(v_s)\frac{C_{bk,W}(v = g(D))}{C_{bk,K}(v = g(D))}$$

Simulation of Doppler spectra at W-band using K-band Doppler Spectra

I. Spectral reflectivity density with respect to Doppler velocity:

$$\eta_v(v_s, R) = \frac{\eta(s, R)}{\Delta v}$$

II. Particle size distribution is obtained by:

   I. Expressing spectral reflectivity density with respect to particle diameter

   II. Dividing by backscattering cross-section

$$\eta_D(D) = \eta_v(v)\frac{\partial v}{\partial D}$$

$$N(D) = \frac{\eta_D(D)}{C_{bk}(D)}$$

MRR Retrieval (Peters, 2002)

III. Making explicit the frequency dependencies:

$$N(D) = \frac{\eta_{D,K}(D)}{C_{bk,K}(D)}$$ as well as $$N(D) = \frac{\eta_{D,W}(D)}{C_{bk,W}(D)}$$ considering same snow habit

IV. Going backwards:

$$\eta_{v,W}(v) = \eta_{v,K}(v)\frac{C_{bk,W}(D)}{C_{bk,K}(D)}$$

$$\eta_{v,W}(v_s) = \eta_{v,K}(v_s)\frac{C_{bk,W}(v = g(D))}{C_{bk,K}(v = g(D))}$$

→ $Z_{e,W}$, $V_{D,W}$

K2W methodology

Simulation of Doppler spectra at W-band using K-band Doppler Spectra

I. Spectral reflectivity density with respect to Doppler velocity:

$$\eta_v(v_s, \mathrm{R}) = \frac{\eta(\mathrm{s}, \mathrm{R})}{\Delta \mathrm{v}}$$

II. Particle size distribution is obtained by:

  I. Expressing spectral reflectivity density with respect to particle diameter

  II. Dividing by backscattering cross-section

$$\eta_\mathrm{D}(\mathrm{D}) = \eta_v(\mathrm{v}) \frac{\partial v}{\partial \mathrm{D}}$$

$$\mathrm{N}(\mathrm{D}) = \frac{\eta_D(\mathrm{D})}{\mathrm{C}_{bk}(\mathrm{D})}$$

MRR Retrieval (Peters, 2002)

III. Making explicit the frequency dependencies:

$$\mathrm{N}(\mathrm{D}) = \frac{\eta_{D,K}(\mathrm{D})}{\mathrm{C}_{bk,K}(\mathrm{D})}$$ as well as $$\mathrm{N}(\mathrm{D}) = \frac{\eta_{D,W}(\mathrm{D})}{\mathrm{C}_{bk,W}(\mathrm{D})}$$ considering same snow habit

IV. Going backwards:

$$\eta_{v,W}(v) = \eta_{v,K}(v) \frac{\mathrm{C}_{bk,W}(D)}{\mathrm{C}_{bk,K}(\mathrm{D})}$$

$$\eta_{v,W}(v_s) = \eta_{v,K}(v_s) \frac{\mathrm{C}_{bk,W}(v = g(D))}{\mathrm{C}_{bk,K}(v = g(D))}$$

→ $Z_{e,W}$, $V_{D,W}$

K2W

Results

DATA @MZS

Consistency test

Nov 2019 – Feb 2020

CloudSat overpass

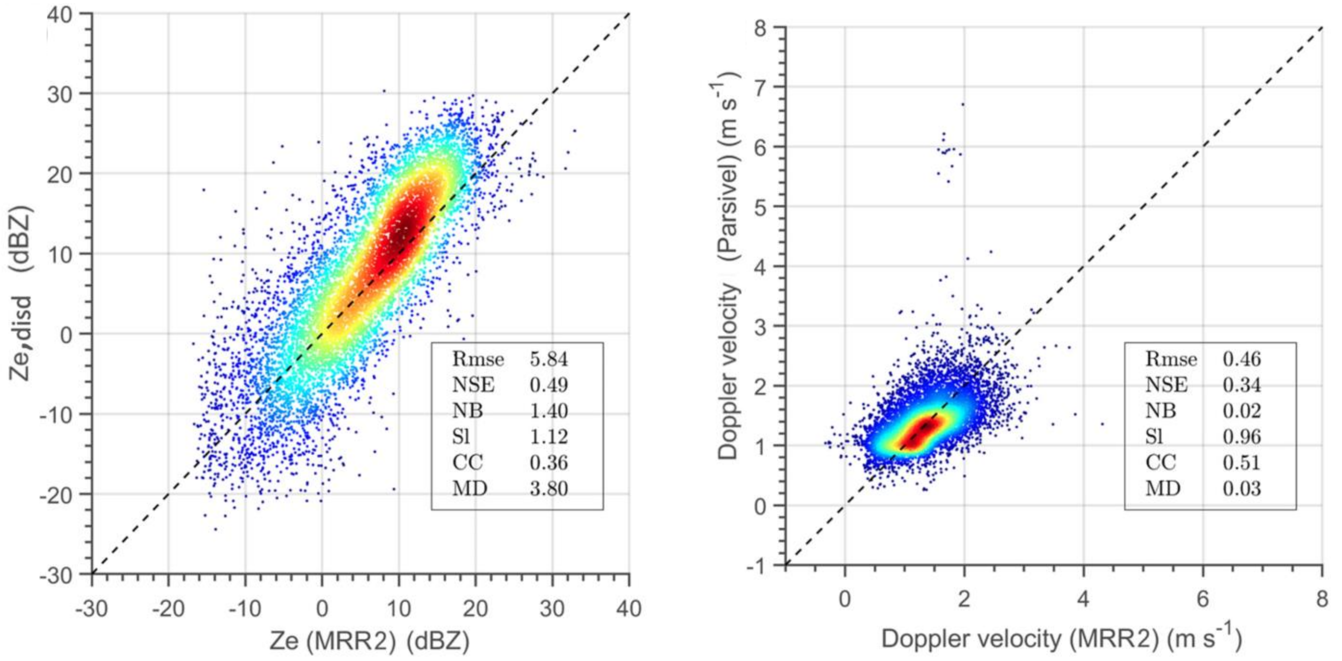
4 December 2018

Results

- Consistency test
  - Dataset of >9000 min of solid precipitation collected by MRR and disdrometer

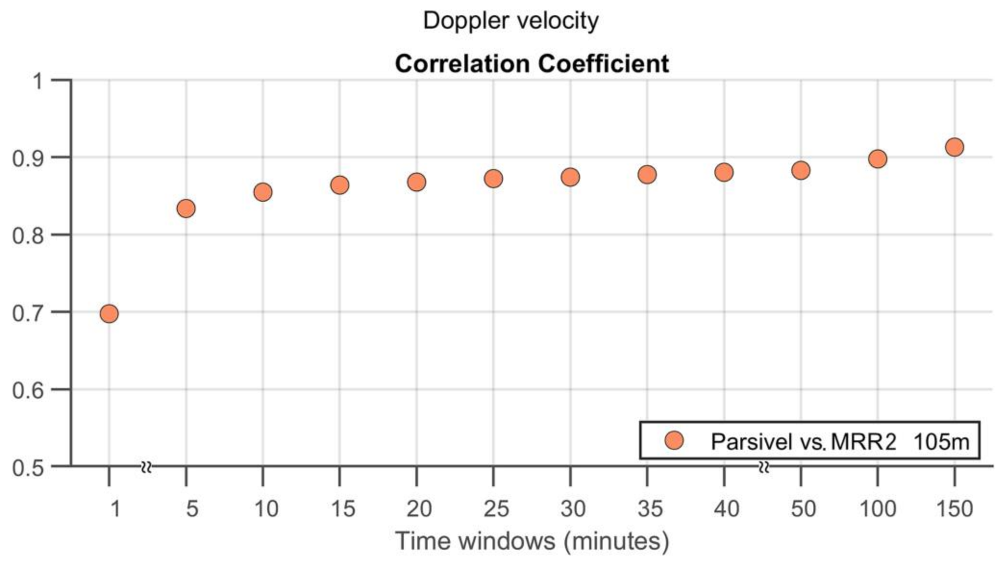
Results

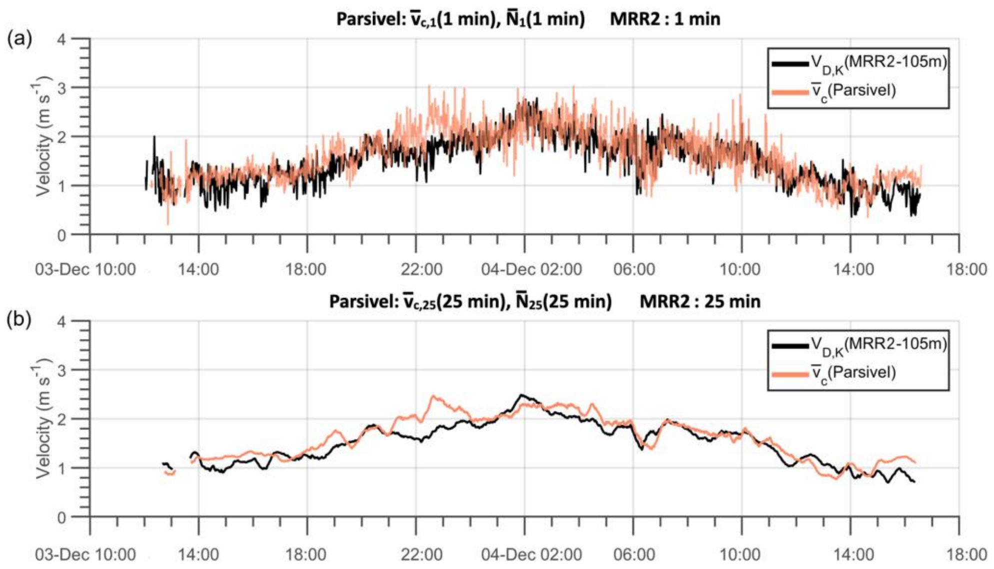
- Consistency test
  - Dataset of >9000 min of solid precipitation collected by MRR and disdrometer
  - Agree for most frequent reflectivity values (~10 dBZ) and Doppler velocities (1-min time resol.)



Results

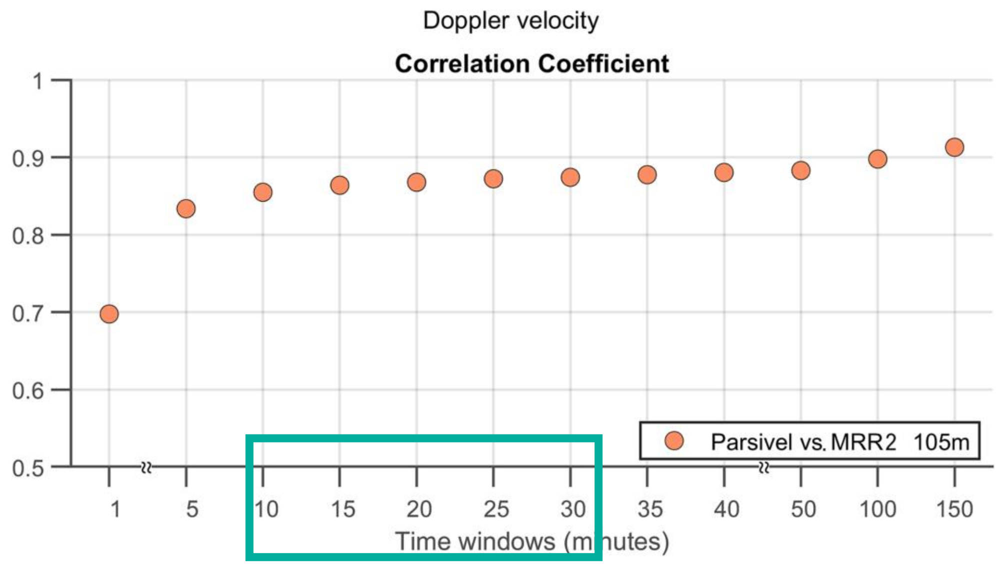
- Consistency test
  - Dataset of >9000 min of solid precipitation collected by MRR and disdrometer
  - Agree for most frequent reflectivity values (~10 dBZ) and Doppler velocities (1-min time resol.)
  - Set trade-off for averaging time required for the most reliable correspondence

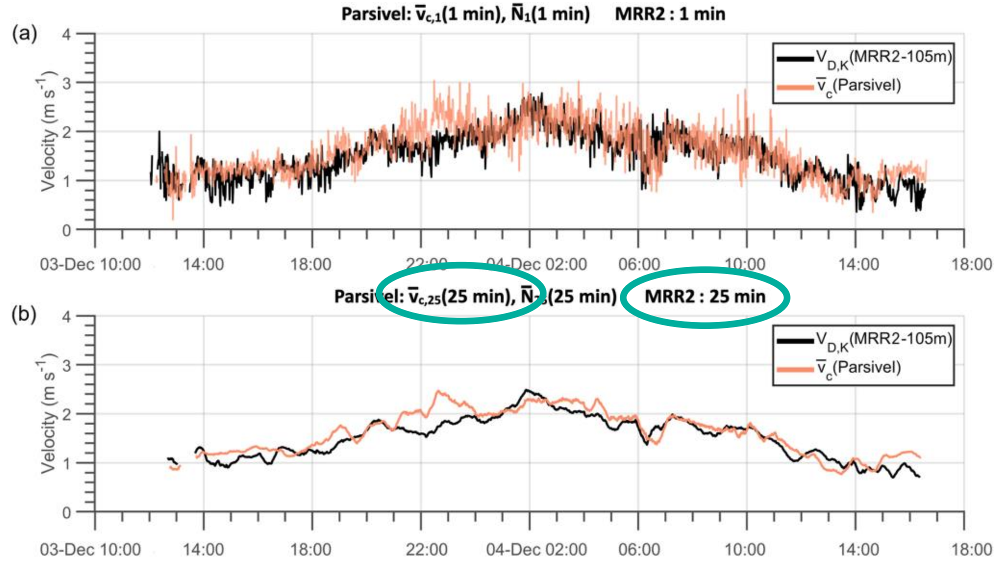




Results

- Consistency test
  - Dataset of >9000 min of solid precipitation collected by MRR and disdrometer
  - Agree for most frequent reflectivity values (~10 dBZ) and Doppler velocities (1-min time resol.)
  - Set trade-off for averaging time required for the most reliable correspondence





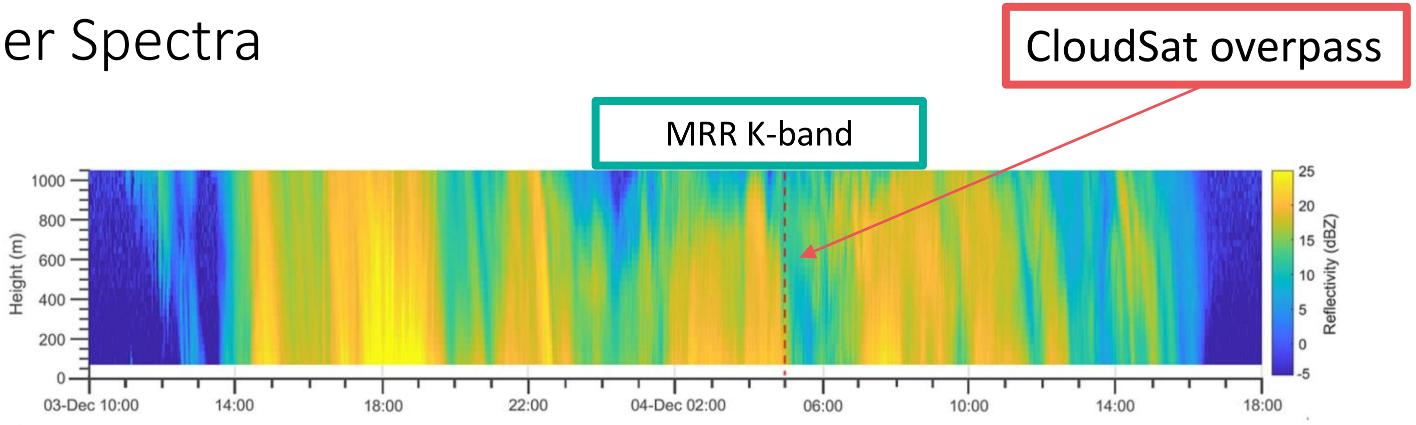
Results

- K2W: Simulation of W-band Doppler Spectra

Results

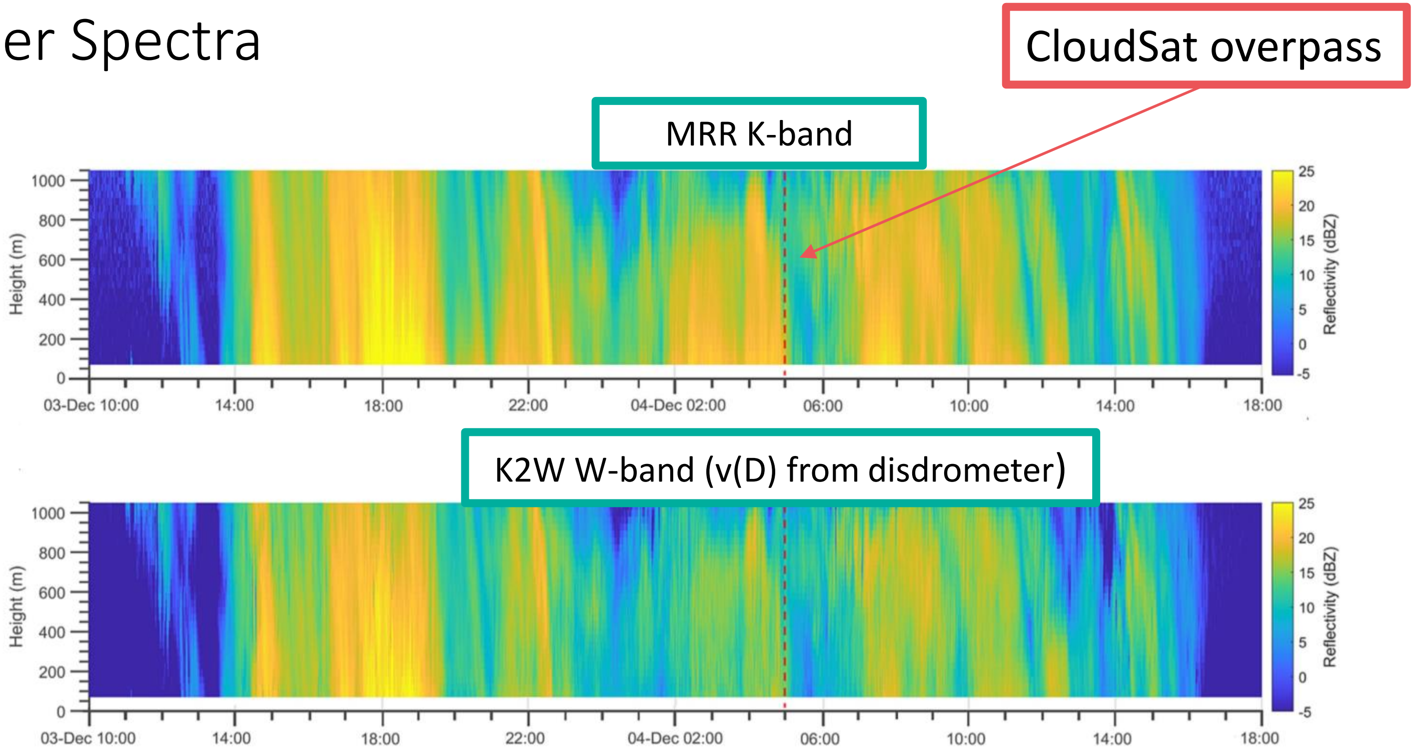
- K2W: Simulation of W-band Doppler Spectra

  - Radar Reflectivity time series



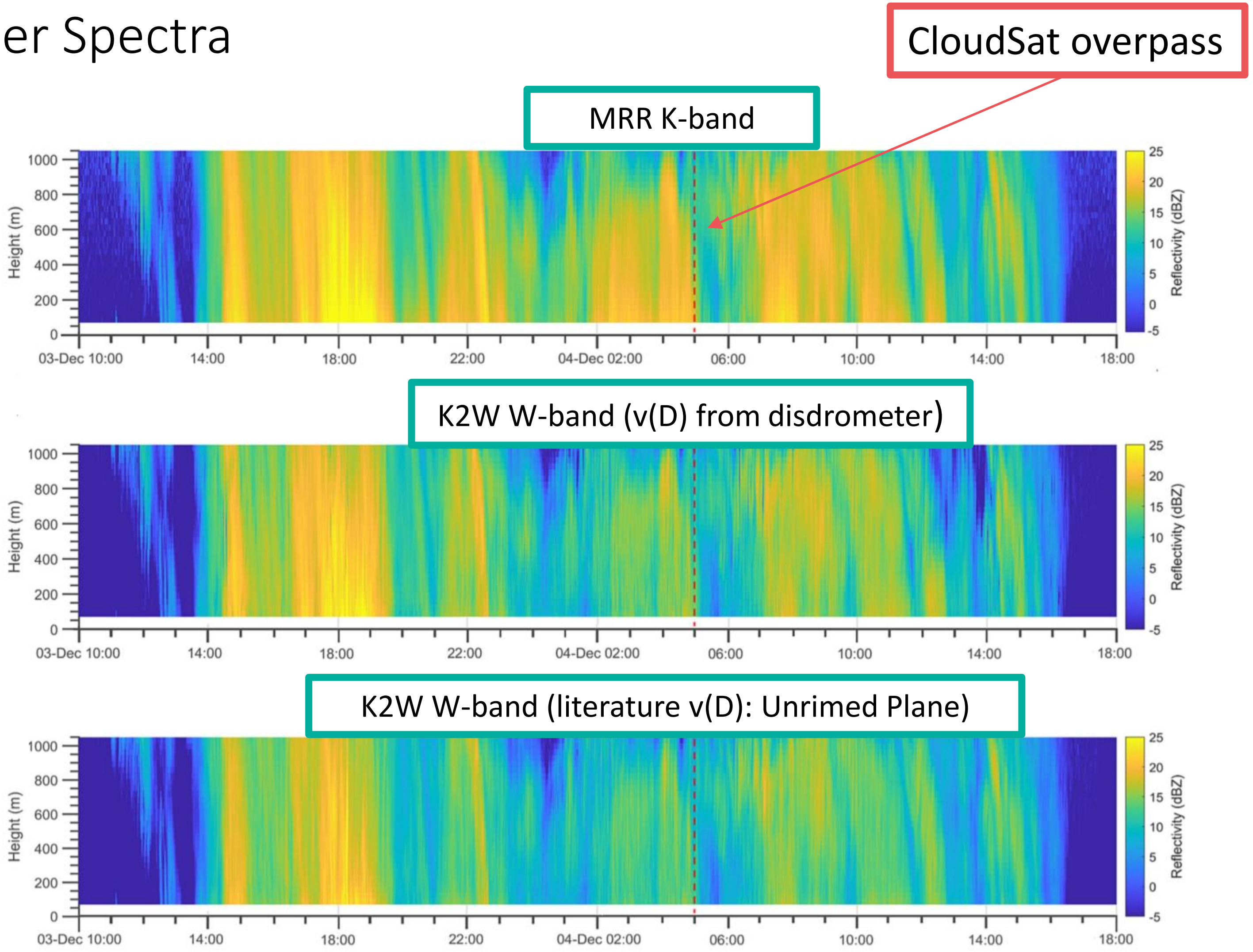
Results

- K2W: Simulation of W-band Doppler Spectra
  - Radar Reflectivity time series
    - W-band values lower than K-band



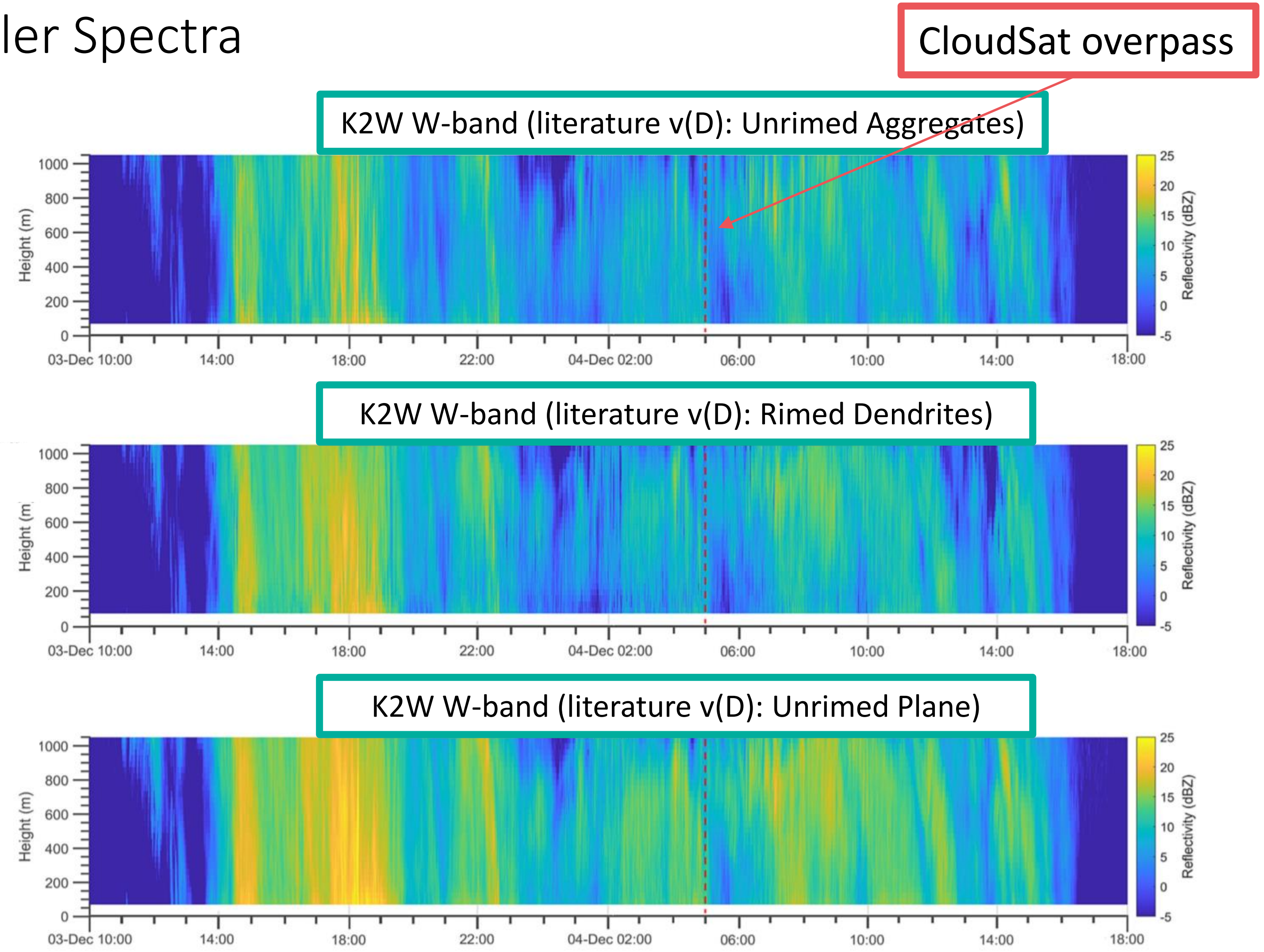
Results

- K2W: Simulation of W-band Doppler Spectra
  - Radar Reflectivity time series
    - W-band values lower than K-band
    - Impact of v(D) relationship used in K2W



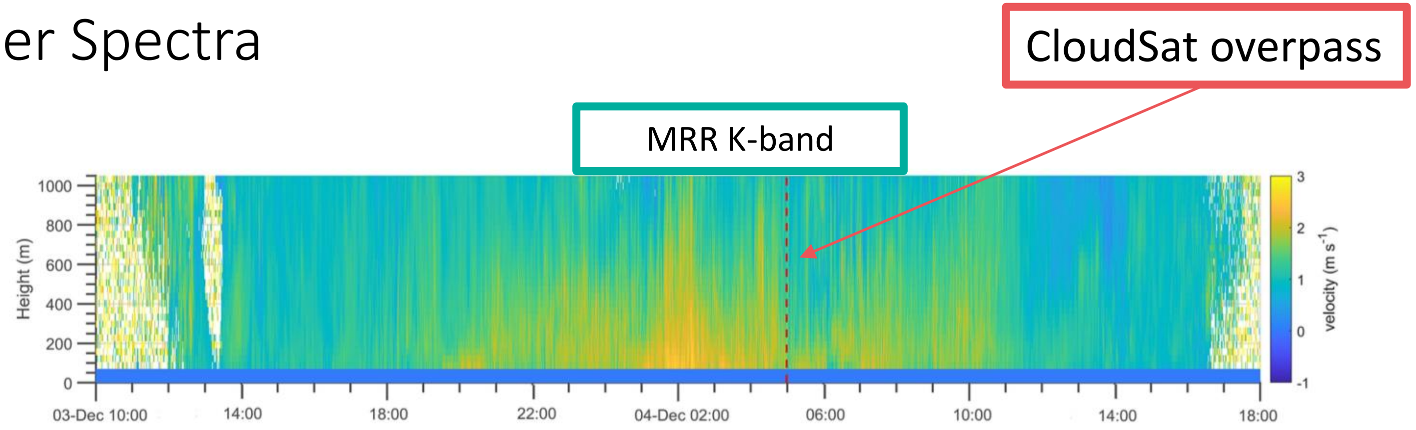
Results

- K2W: Simulation of W-band Doppler Spectra
  - Radar Reflectivity time series
    - W-band values lower than K-band
    - Impact of v(D) relationship used in K2W



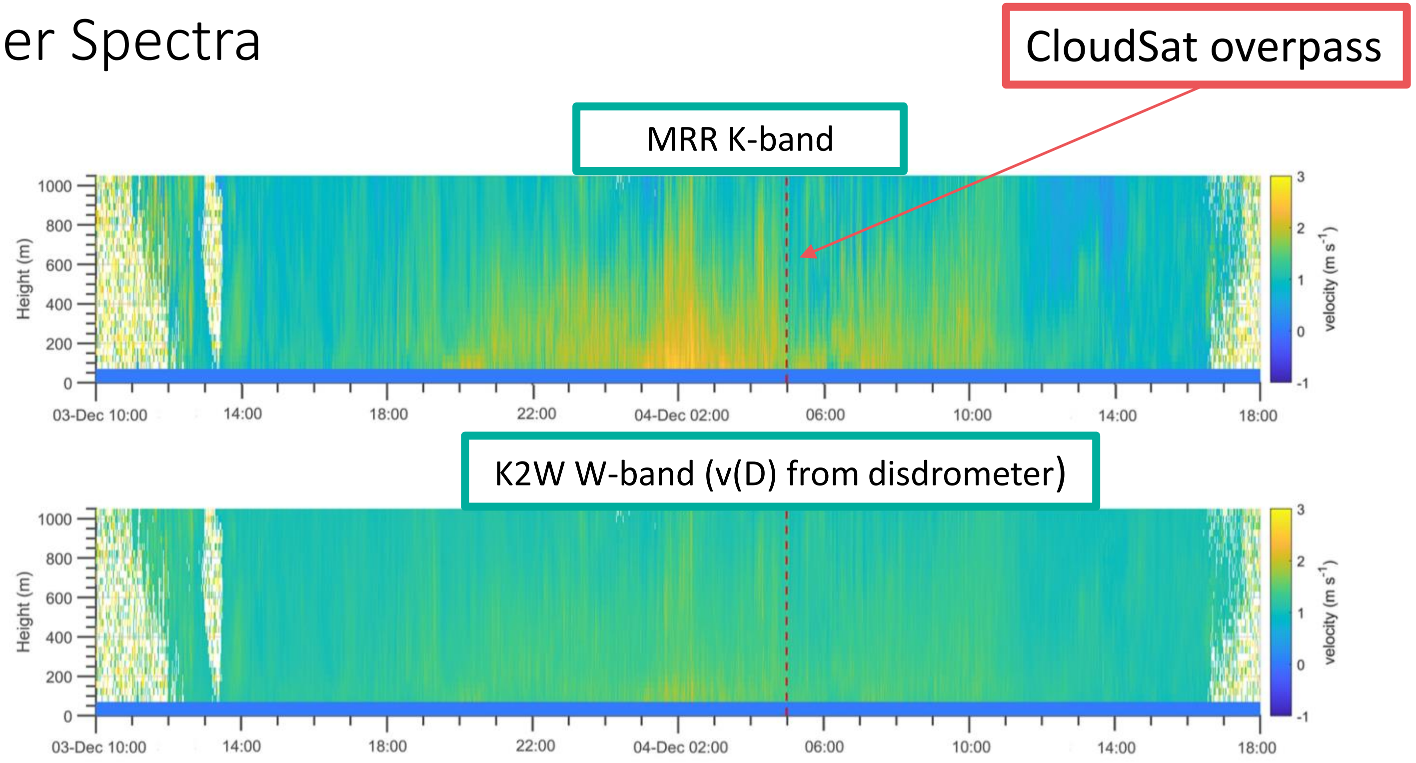
Results

- K2W: Simulation of W-band Doppler Spectra
  - Radar Reflectivity time series
    - W-band values lower than K-band
    - Impact of v(D) relationship used in K2W
  - Doppler Velocity time series



Results

- K2W: Simulation of W-band Doppler Spectra
  - Radar Reflectivity time series
    - W-band values lower than K-band
    - Impact of v(D) relationship used in K2W
  - Doppler Velocity time series
    - Similar values for velocity <1.5ms^{-1}
    - $V_{d,K} > V_{d,W}$ for v > 1.5 ms^{-1}

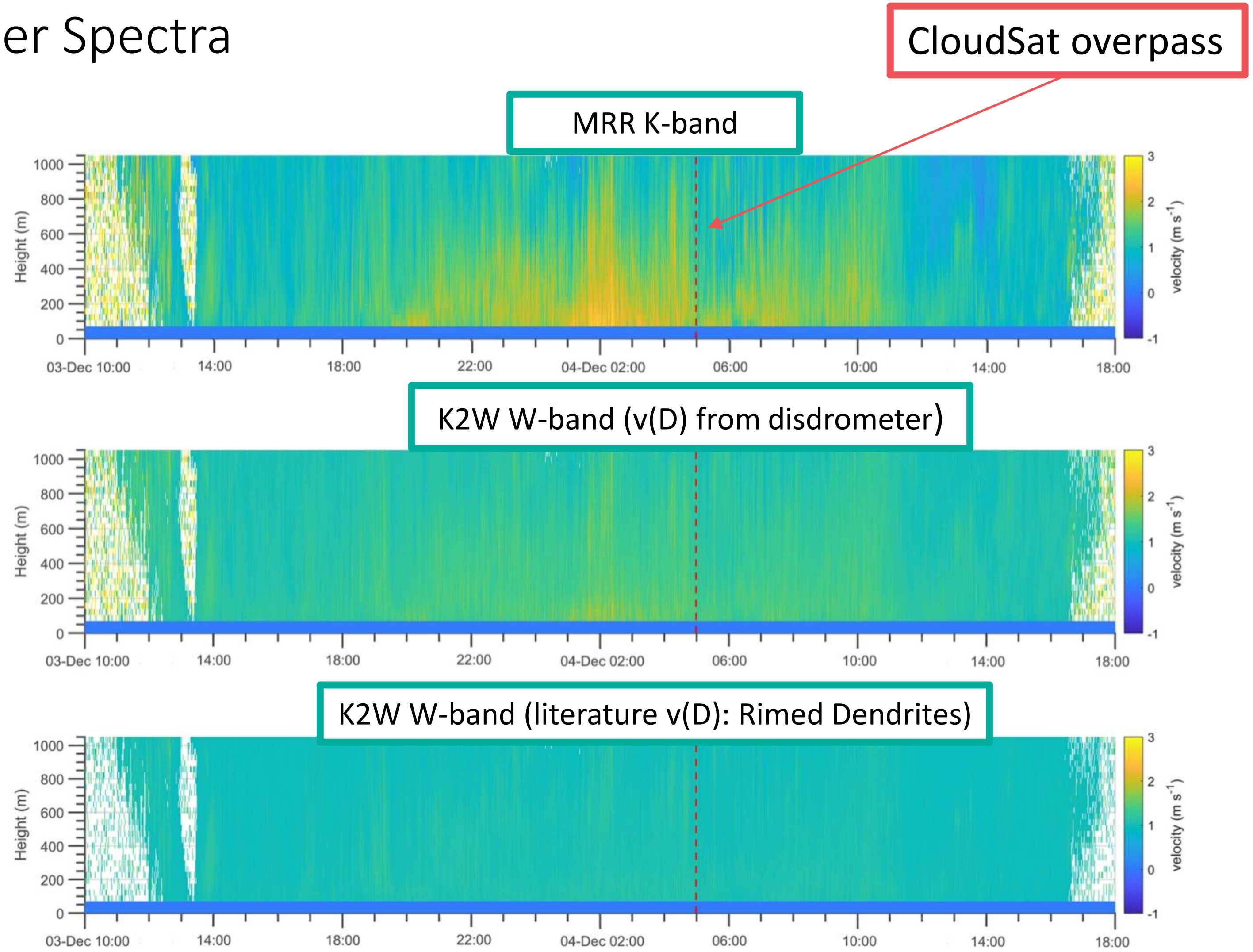


Results

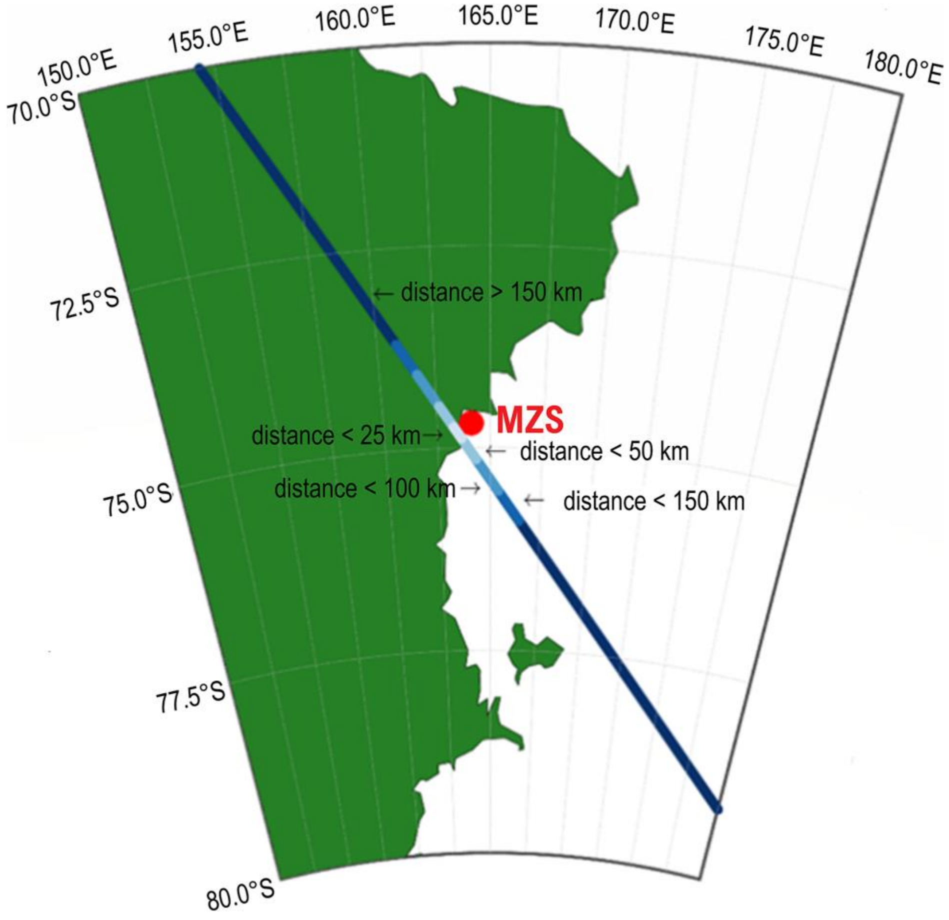
- K2W: Simulation of W-band Doppler Spectra

  - Radar Reflectivity time series
    - W-band values lower than K-band
    - Impact of v(D) relationship used in K2W

  - Doppler Velocity time series
    - Similar values for velocity <1.5ms^{-1}
    - $V_{d,K} > V_{d,W}$ for v > 1.5 ms^{-1}
    - Large differences using literature v(D)

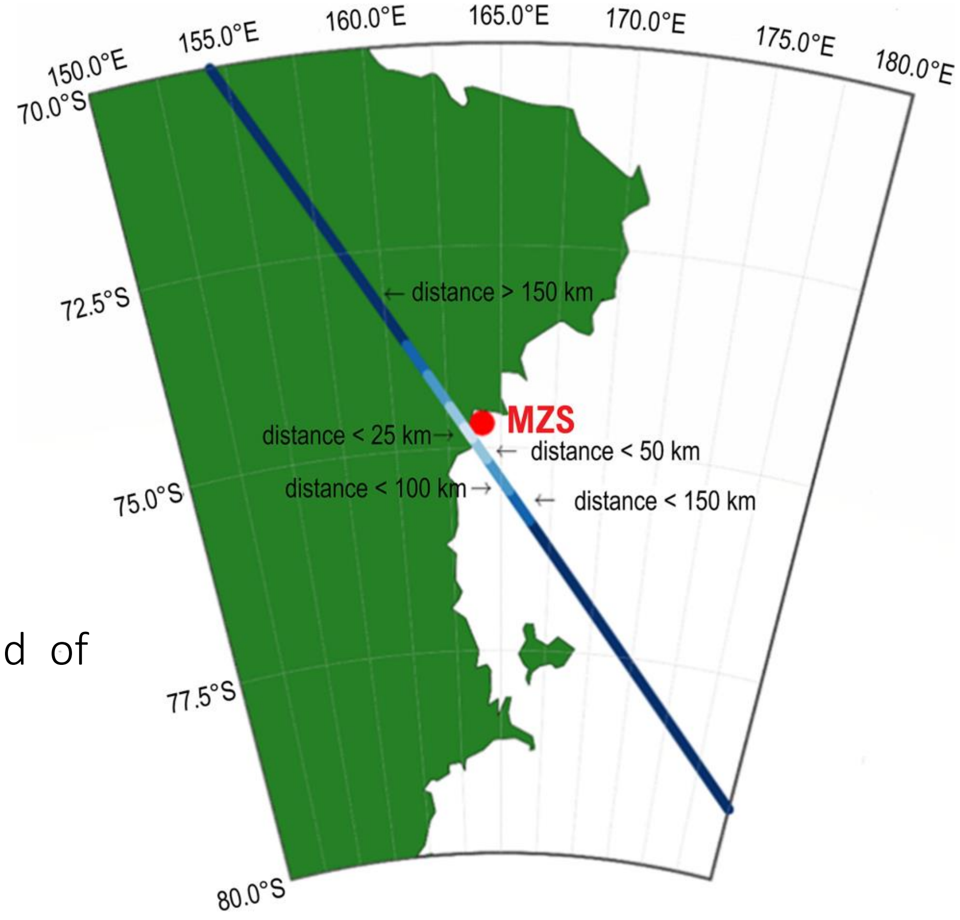


Results: Comparison CloudSat-K2W profiles



Results: Comparison CloudSat-K2W profiles

- Comparison CloudSat-K2W profiles
  - Overpass: 5:00 UTC on 4 December 2018
  - **Minimum distance from MZS: 22.9 km**
  - **Lowest CloudSat range gates** (720, 960 m a.s.l)
  - **8 MRR range gates averaged to match CS vertical resolution**
  - 15 ms^{-1} horizontal wind speed at the ground -> moving speed of precipitating system (first approximation)

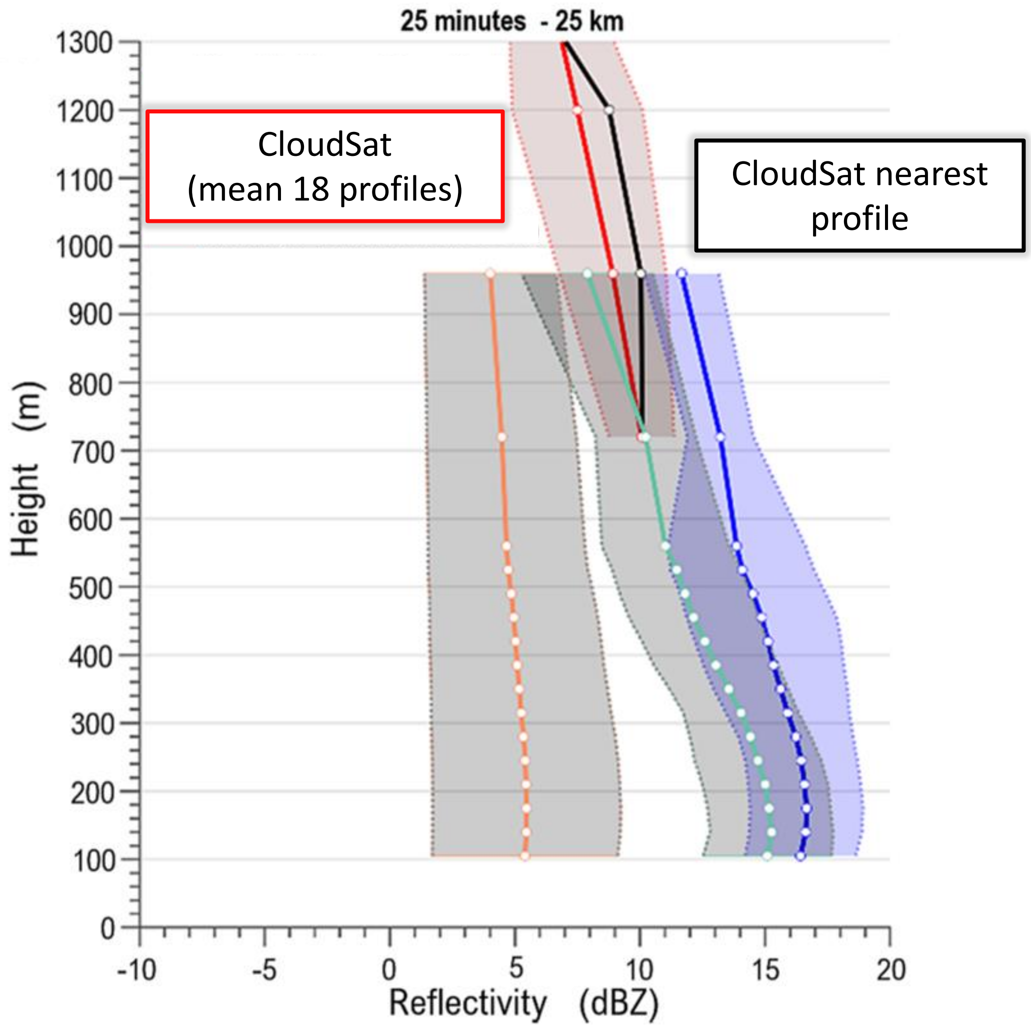


Results: Comparison CloudSat-K2W profiles

Radar Reflectivity

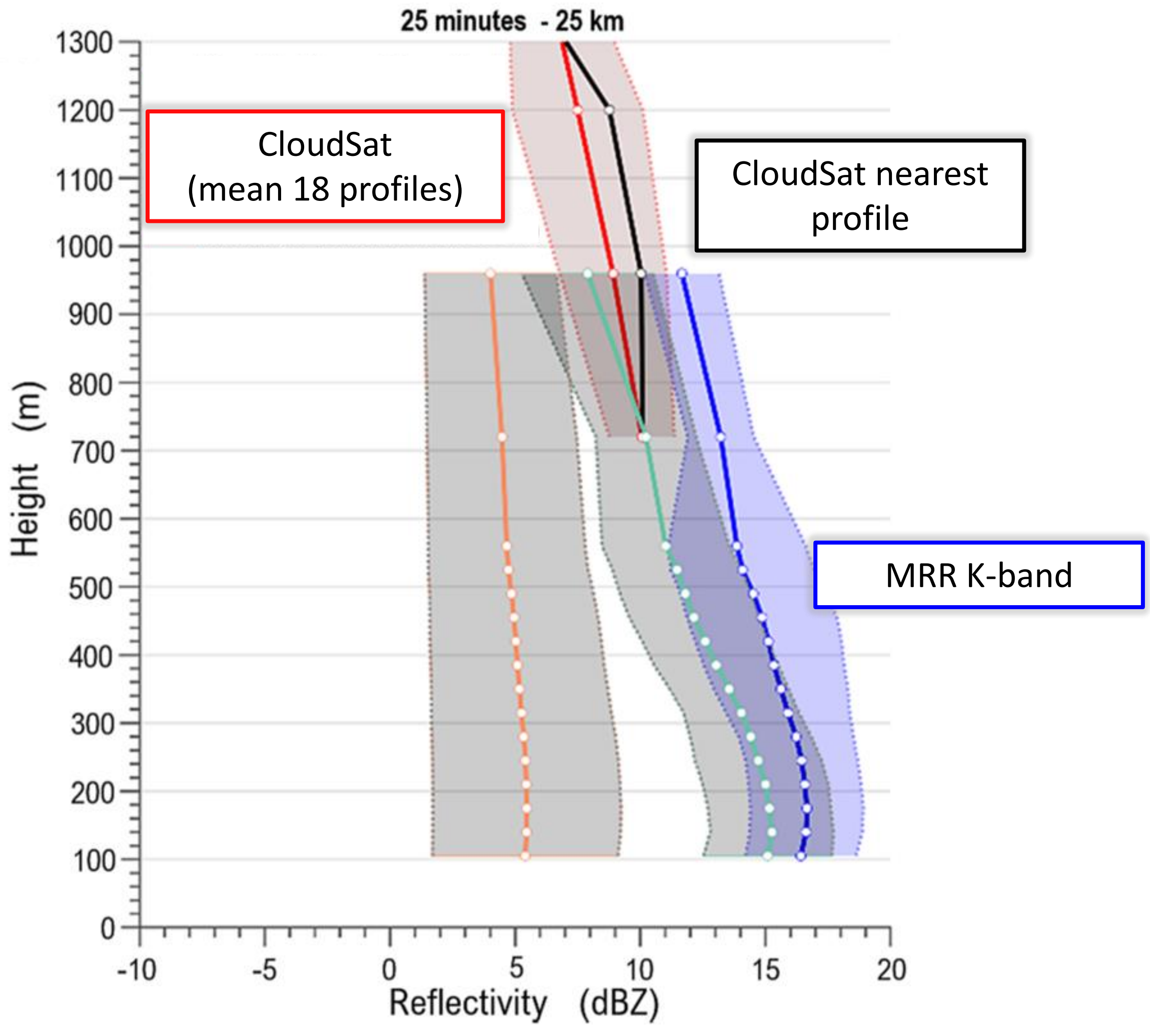
Results: Comparison CloudSat-K2W profiles

Radar Reflectivity



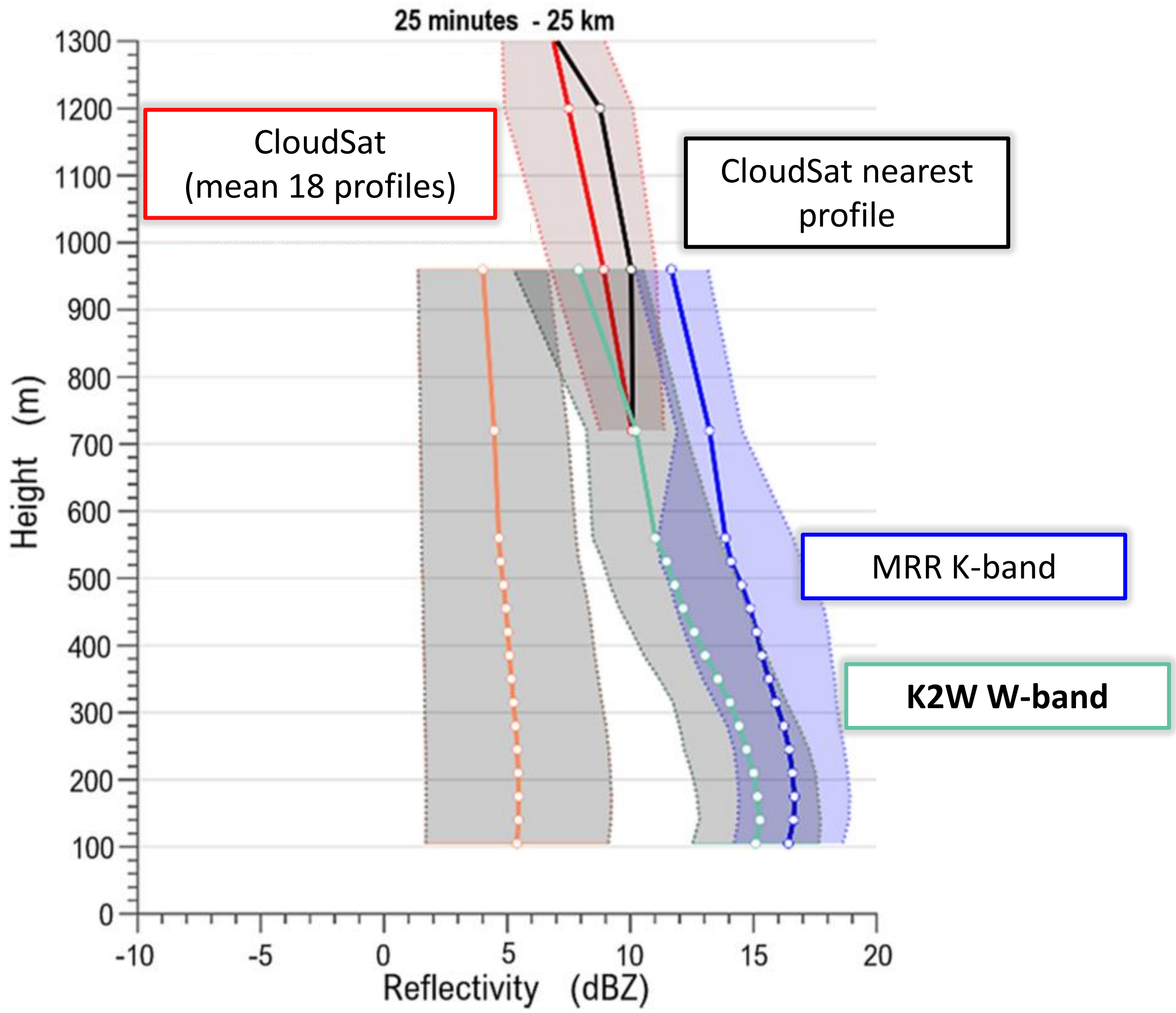
Results: Comparison CloudSat-K2W profiles

Radar Reflectivity



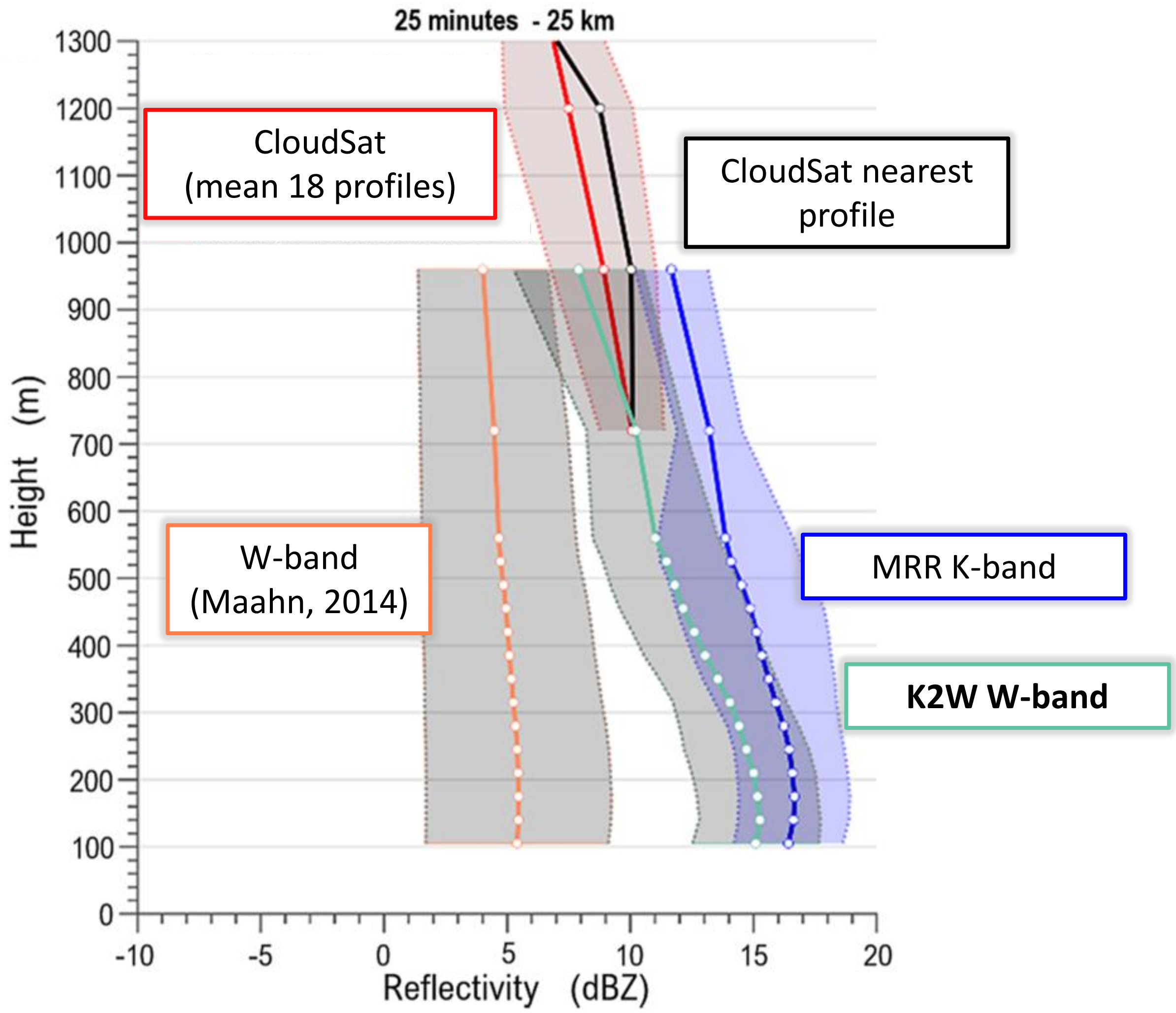
Results: Comparison CloudSat-K2W profiles

Radar Reflectivity



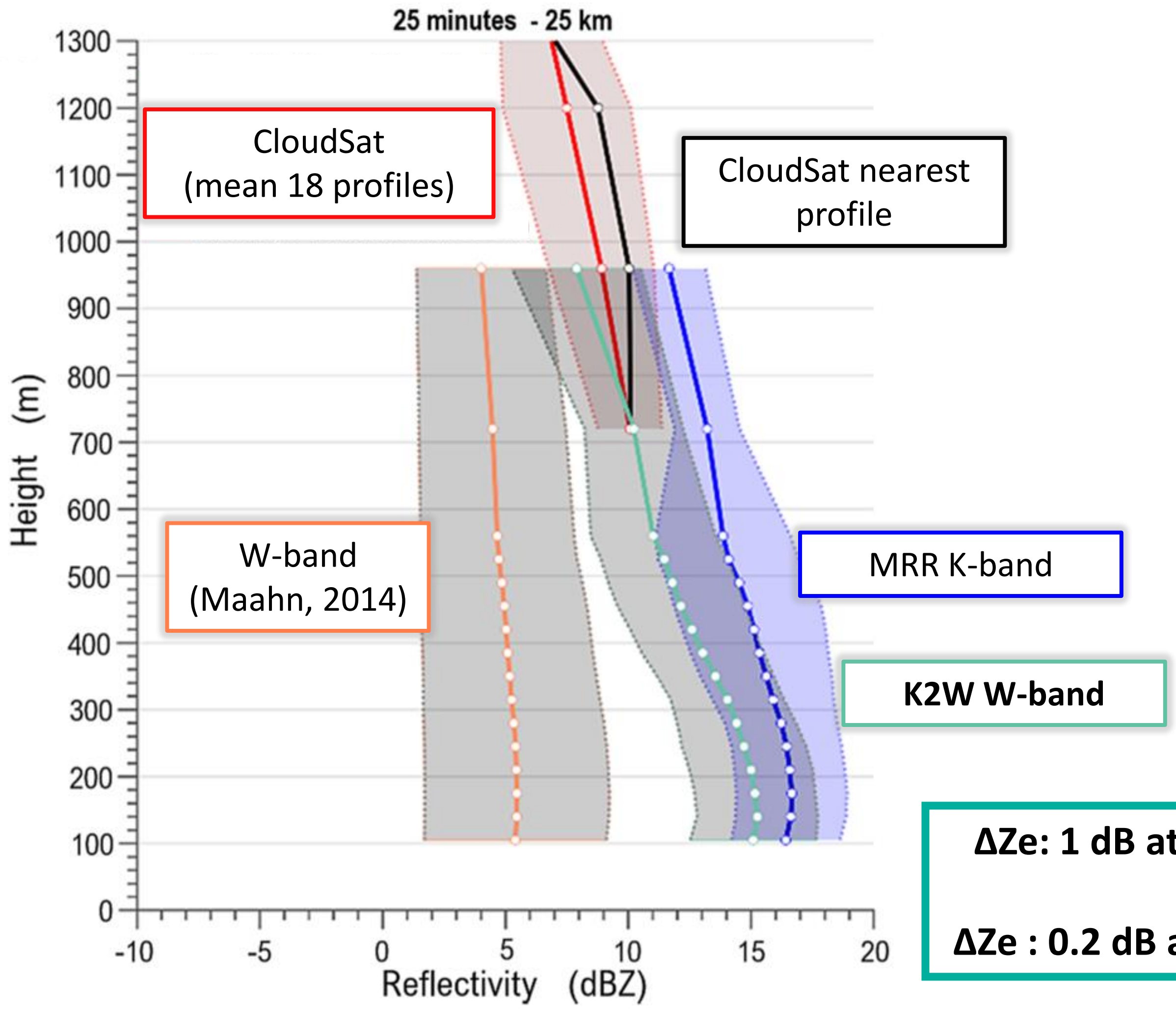
Results: Comparison CloudSat-K2W profiles

Radar Reflectivity



Results: Comparison CloudSat-K2W profiles

Radar Reflectivity

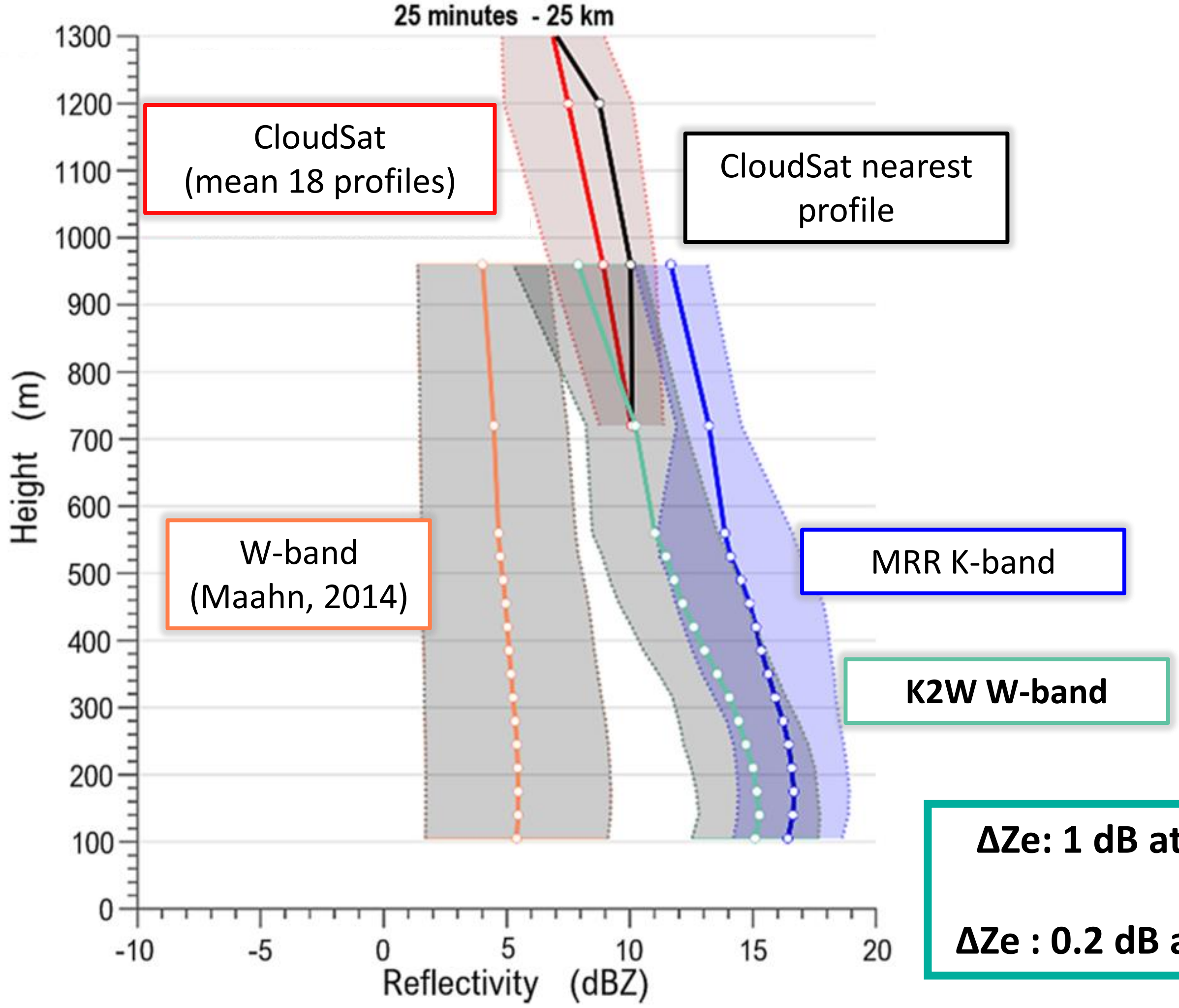


ΔZe: 1 dB at 960 m

ΔZe : 0.2 dB at 720 m

Results: Comparison CloudSat-K2W profiles

Radar Reflectivity



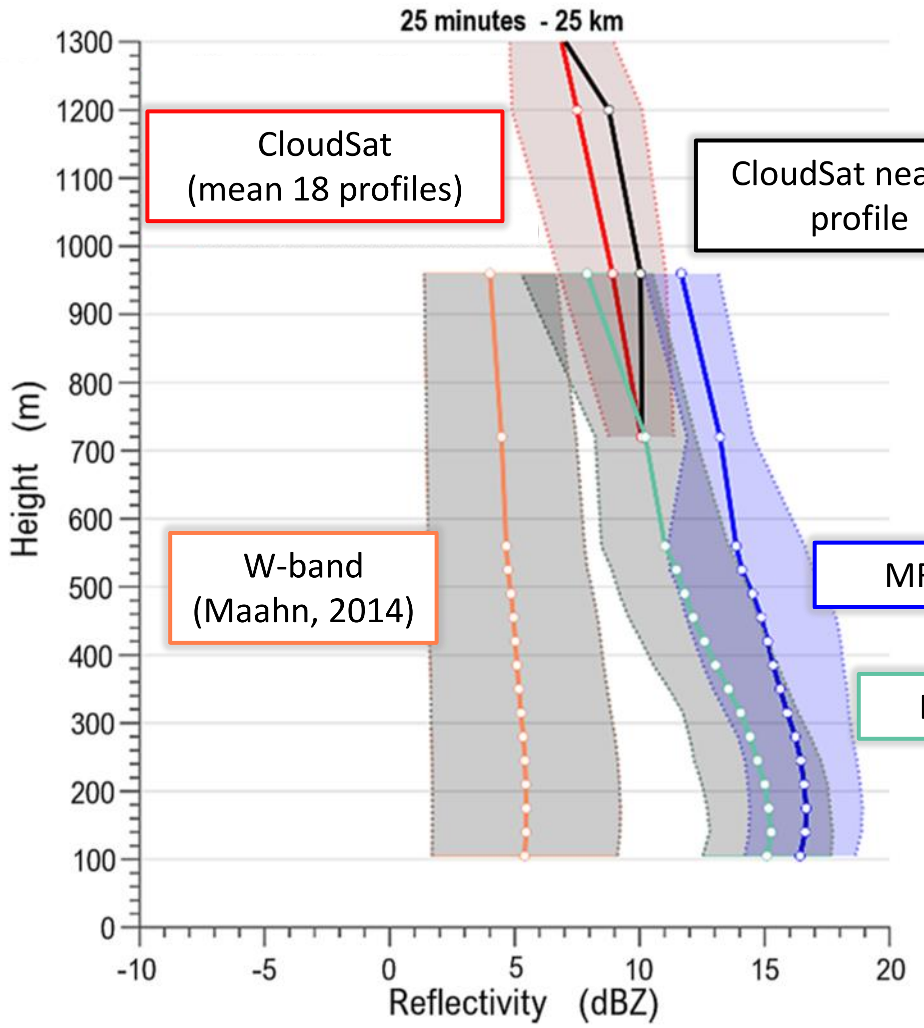
ΔZe: 1 dB at 960 m

ΔZe : 0.2 dB at 720 m

Doppler Velocity

Results: Comparison CloudSat-K2W profiles

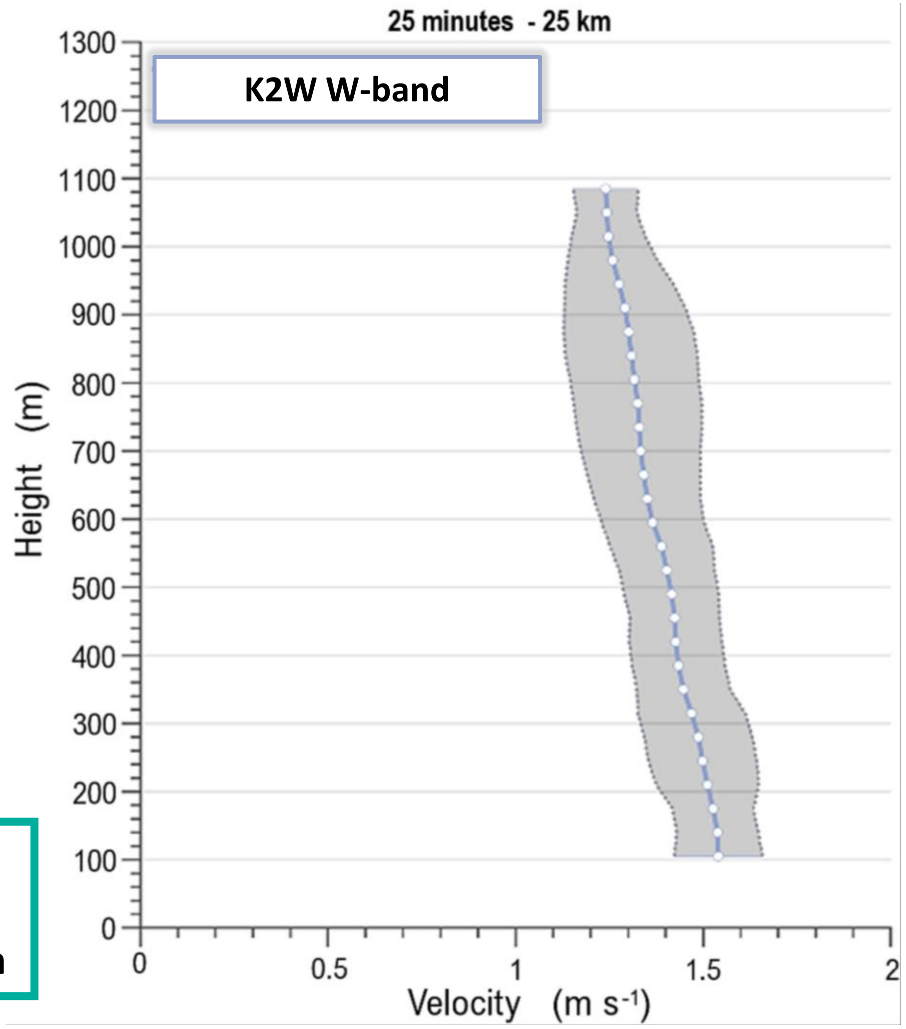
Radar Reflectivity



ΔZe: 1 dB at 960 m

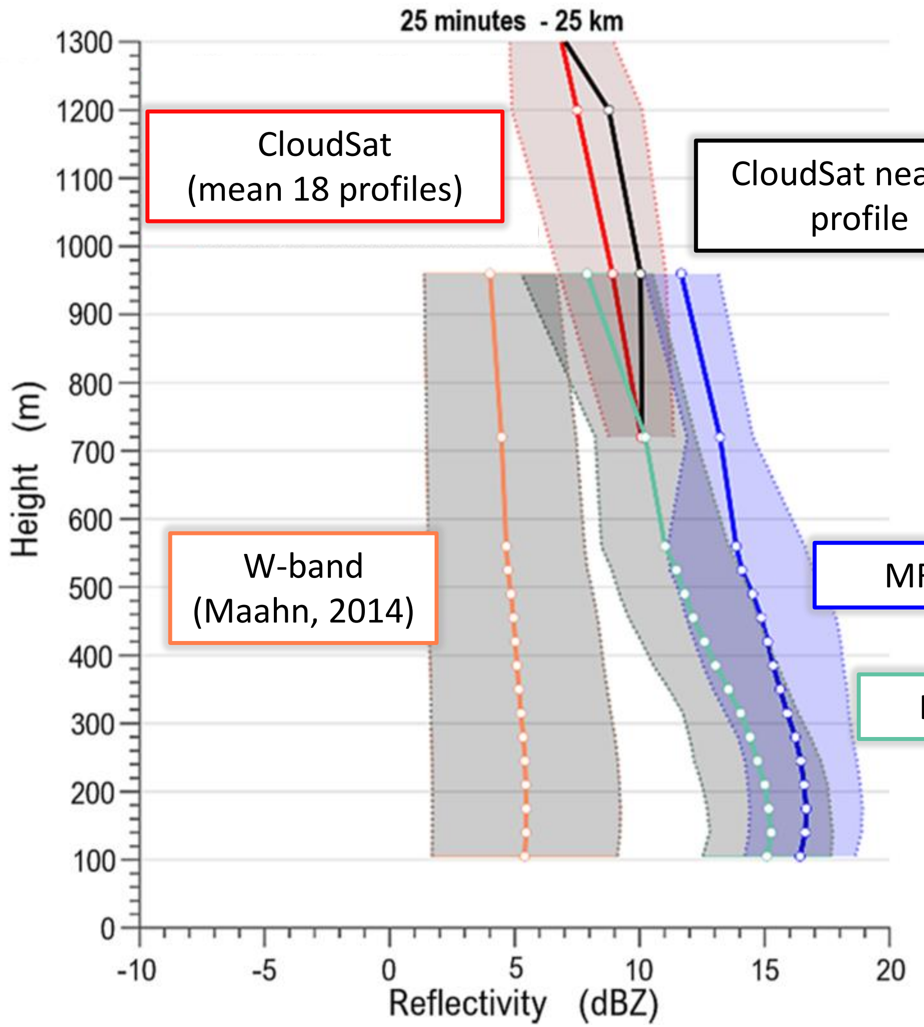
ΔZe : 0.2 dB at 720 m

Doppler Velocity



Results: Comparison CloudSat-K2W profiles

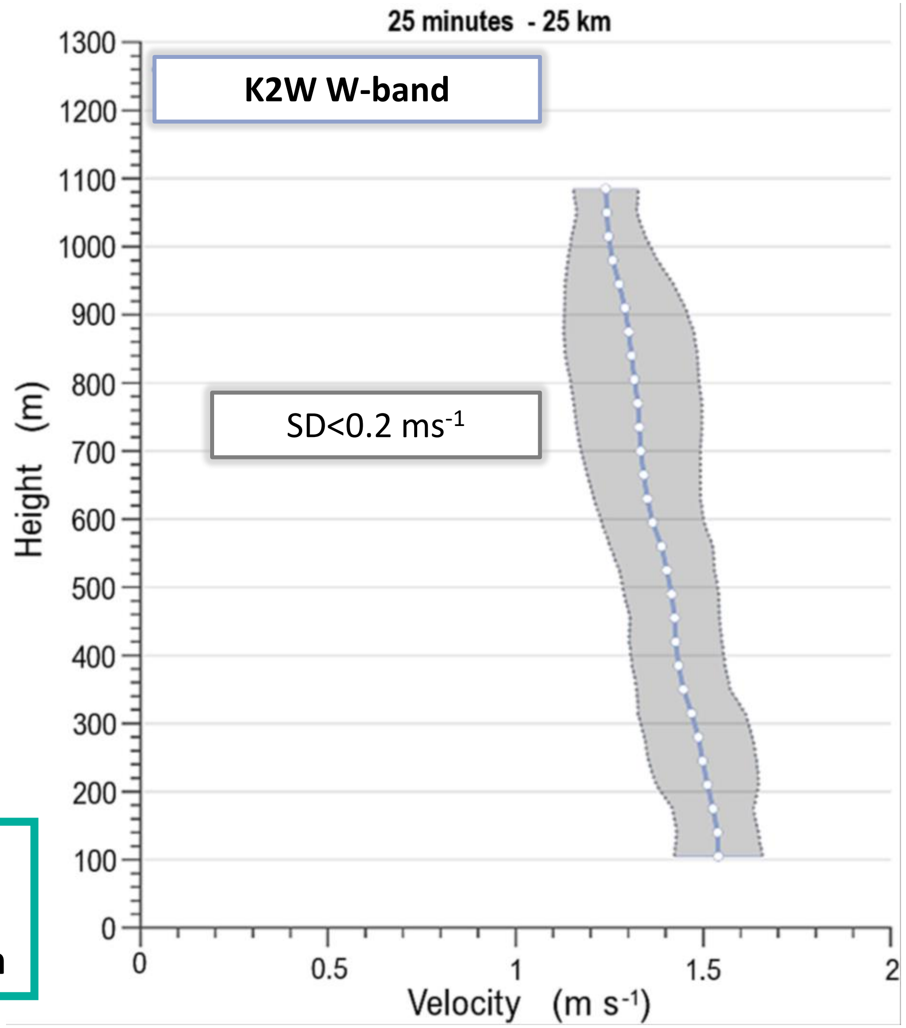
Radar Reflectivity



ΔZe: 1 dB at 960 m

ΔZe : 0.2 dB at 720 m

Doppler Velocity

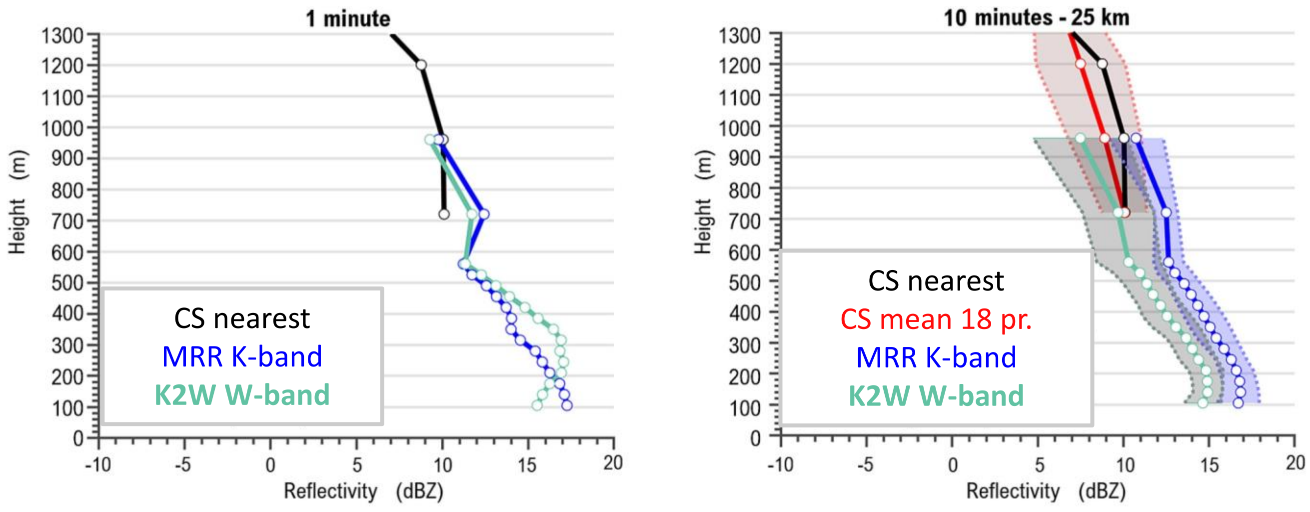


Results: Comparison CloudSat-K2W profiles

- Radar Reflectivity (sensitivity analysis)
  - Change time window and distance from MZS to consider spatial variability of precipitation during CloudSat overpass

Results: Comparison CloudSat-K2W profiles

- Radar Reflectivity (sensitivity analysis)
  - Change time window and distance from MZS to consider spatial variability of precipitation during CloudSat overpass



Narrowing

- 1-min: K2W fails to convert
- 10-min: ΔZe>1.4dB

Results: Comparison CloudSat-K2W profiles

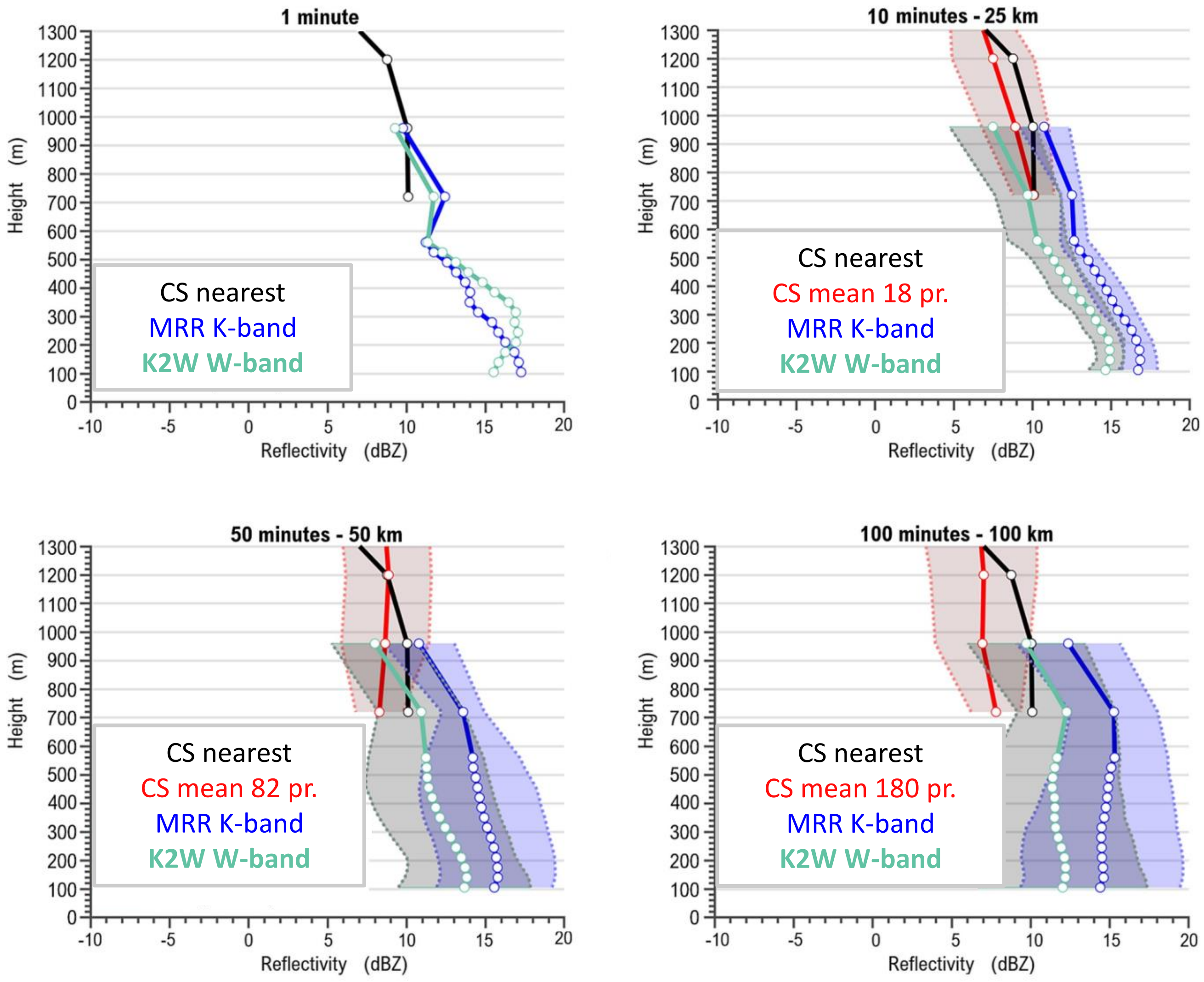
- Radar Reflectivity (sensitivity analysis)
  - Change time window and distance from MZS to consider spatial variability of precipitation during CloudSat overpass

Narrowing

- 1-min: K2W fails to convert
- 10-min: ΔZe>1.4dB

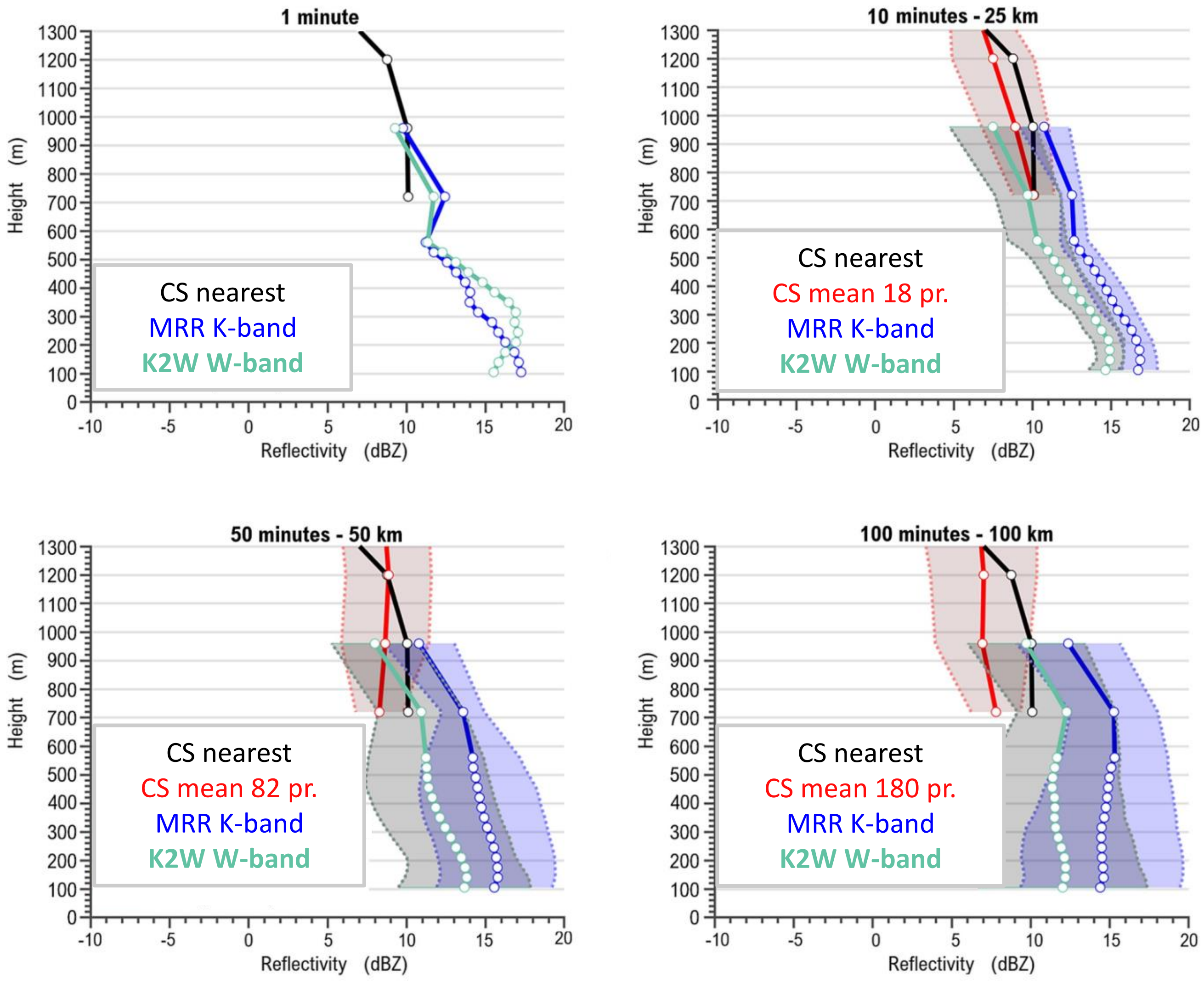
Widening

- Profiles start to be quite distinct
- Led to worsening of corresponde



Results: Comparison CloudSat-K2W profiles

- Radar Reflectivity (sensitivity analysis)
  - Change time window and distance from MZS to consider spatial variability of precipitation during CloudSat overpass



Narrowing

- 1-min: K2W fails to convert
- 10-min: ΔZe>1.4dB

Widening

- Profiles start to be quite distinct
- Led to worsening of corresponde

Best correspondence for 25-min time averaging

Good agreement for 10-30 min time averaging < CPR calibration error (2dB)

Conclusions

- Satellites are the major source of information about precipitation in Antarctica -> development of a reliable validation strategy for the satellite measurements is in high demand

- K2W methodology combines MRR Doppler spectra and disdrometer data to simulate 94 GHz reflectivity and Doppler measurements

- K2W was assessed using CloudSat overpass over MZS for a typical snowfall event:
  - **K2W reproduces** CloudSat Z_e profile with 0.2 dB mean difference at the lowest radar range bin and 0.5 dB difference on average below 1 km altitude
  - **K2W simulates** the Z_e profile within the CloudSat blind zones. This unattenuated W-band profile can be used to evaluate spaceborne W-band radar retrievals
  - **K2W simulates** the W-band Doppler velocity below 1 km altitude that will be observed by EarthCARE

Conclusions

- Satellites are the major source of information about precipitation in Antarctica -> development of a reliable validation strategy for the satellite measurements is in high demand

- K2W methodology combines MRR Doppler spectra and disdrometer data to simulate 94 GHz reflectivity and Doppler measurements

- K2W was assessed using CloudSat overpass over MZS for a typical snowfall event:
  - **K2W reproduces** CloudSat Z_e profile with 0.2 dB mean difference at the lowest radar range bin and 0.5 dB difference on average below 1 km altitude
  - **K2W simulates** the Z_e profile within the CloudSat blind zones. This unattenuated W-band profile can be used to evaluate spaceborne W-band radar retrievals
  - **K2W simulates** the W-band Doppler velocity below 1 km altitude that will be observed by EarthCARE

- More details about K2W methodology can be found in:

ELSEVIER
Remote Sensing of Environment
Volume 294, 15 August 2023, 113630

Development of a methodology for evaluating spaceborne W-band Doppler radar by combined use of Micro Rain Radar and a disdrometer in Antarctica

Alessandro Bracci [a,b], Kaori Sato [c], Luca Baldini [a], Federico Porcù [b], Hajime Okamoto [c]

Outlooks

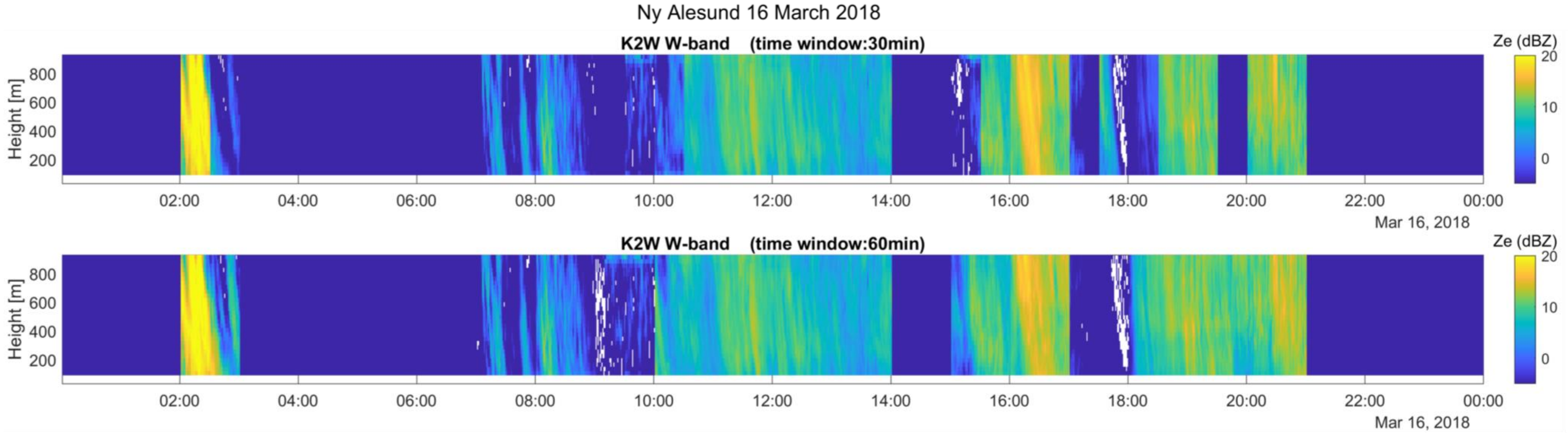
- Pairs of MRR-disdrometer are available in many ground observation sites worldwide and in most of the research stations in Antarctica -> K2W method has a wide application

Data from Ebell, Zenodo-2020

Outlooks

- Pairs of MRR-disdrometer are available in many ground observation sites worldwide and in most of the research stations in Antarctica -> K2W method has a wide application

- New tests of K2W methodology:
  - Ny-Ålesund (Svalbard): Solid precipitation with a collocated ground-based MRR, disdrometer and W-band radar
  - L' Aquila (Italy): Liquid/solid precipitation with a collocated ground-based MRR, disdrometer and W-band radar (take a look at the poster by Montopoli et al.)



Data from Ebell, Zenodo-2020

Thanks for your attention!

a.bracci@isac.cnr.it