

# living planet symposium | BONN 23–27 May 2022

TAKING THE PULSE  
OF OUR PLANET FROM SPACE



## Characterization of ice and light rain microphysics by G-band radars

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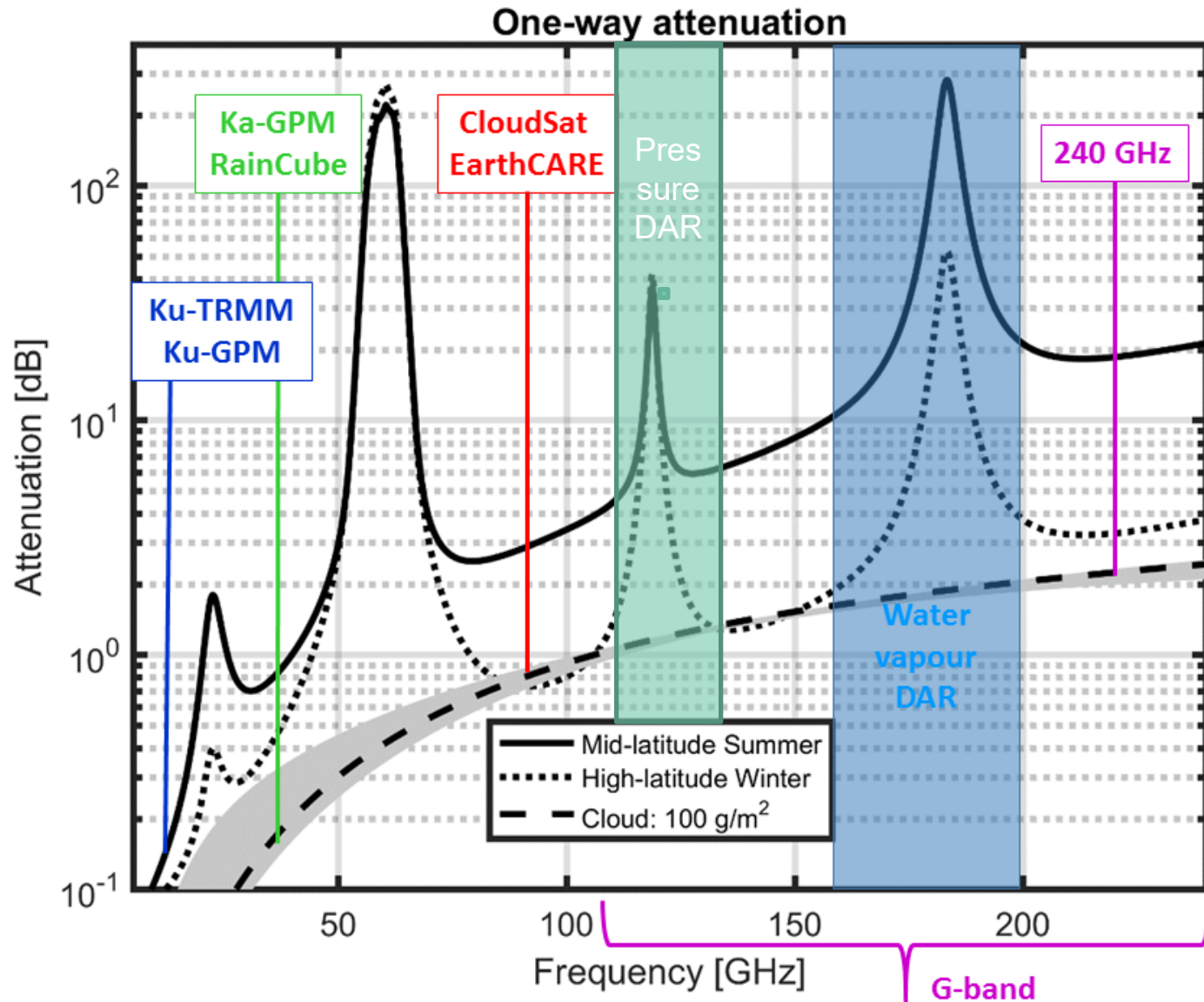
<sup>5</sup> Thomas Keating Ltd, UK

<sup>6</sup> Stony Brook University, US

<sup>7</sup> University of Reading, UK

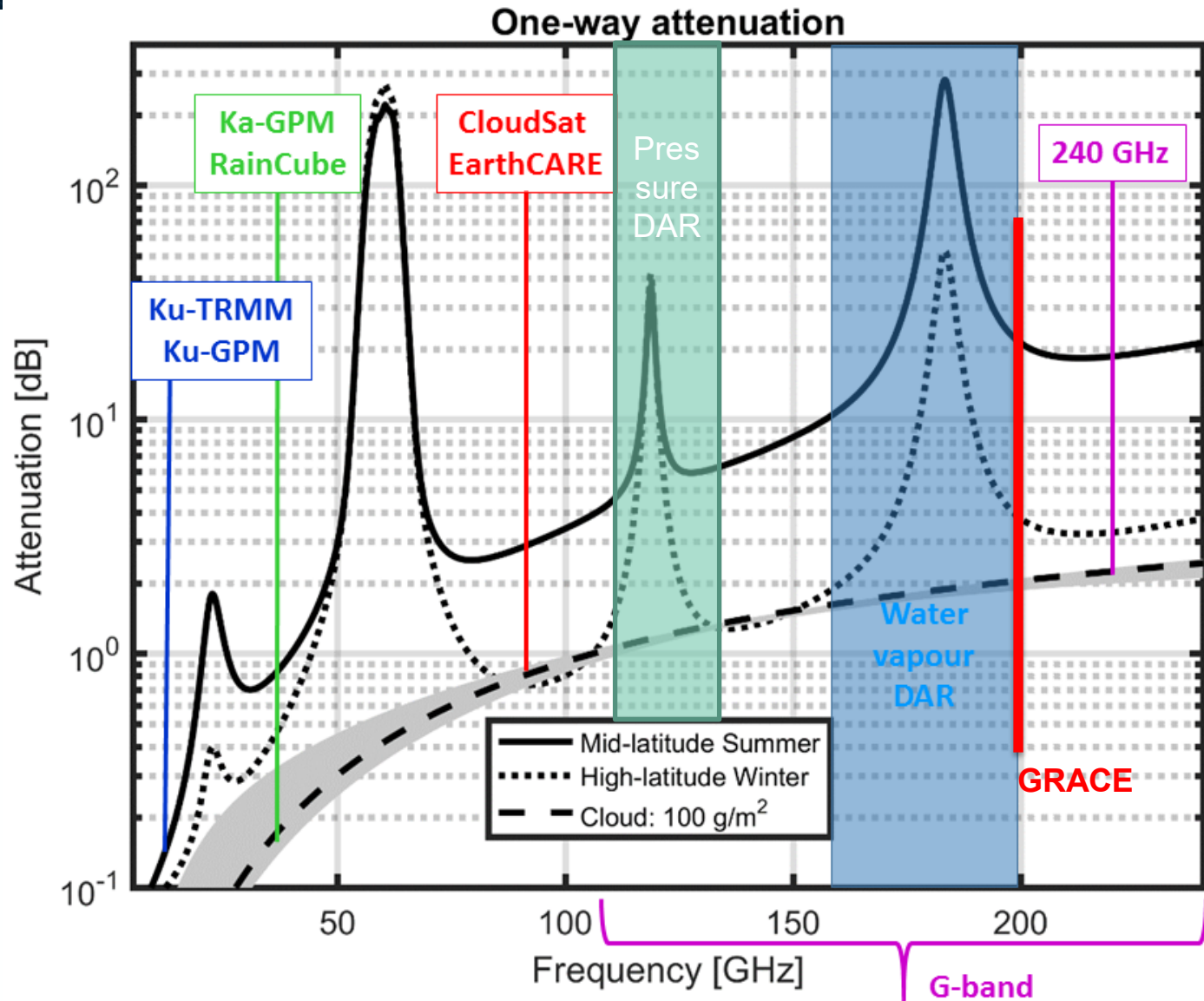
<sup>8</sup> Caltech JPL, US

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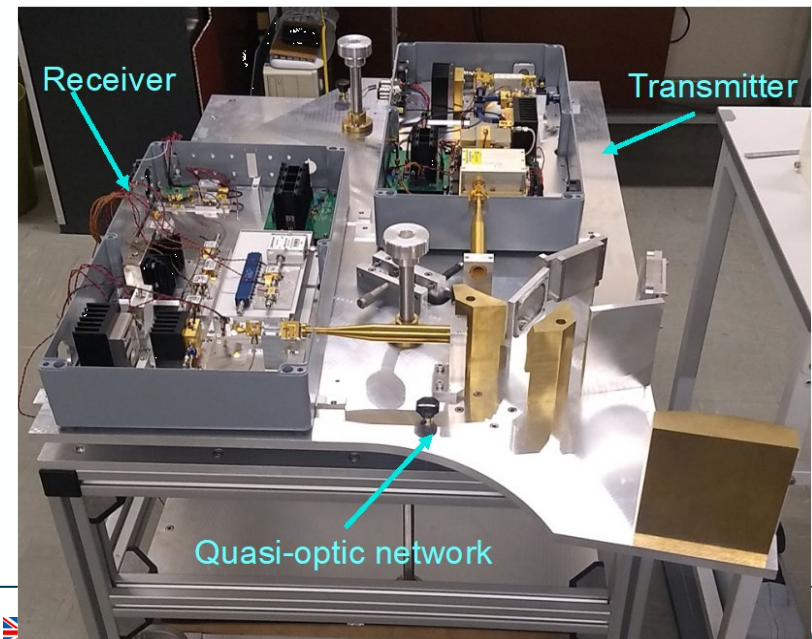
- Cloud radars at 140–215 GHz more than 30 years ago! (Nemarich et al., 1988; Mead et al., 1989; Wallace, 1988)
- Notional studies (Lhermitte 1989, Hogan and Illingworth 1999, Battaglia et al., 2014).

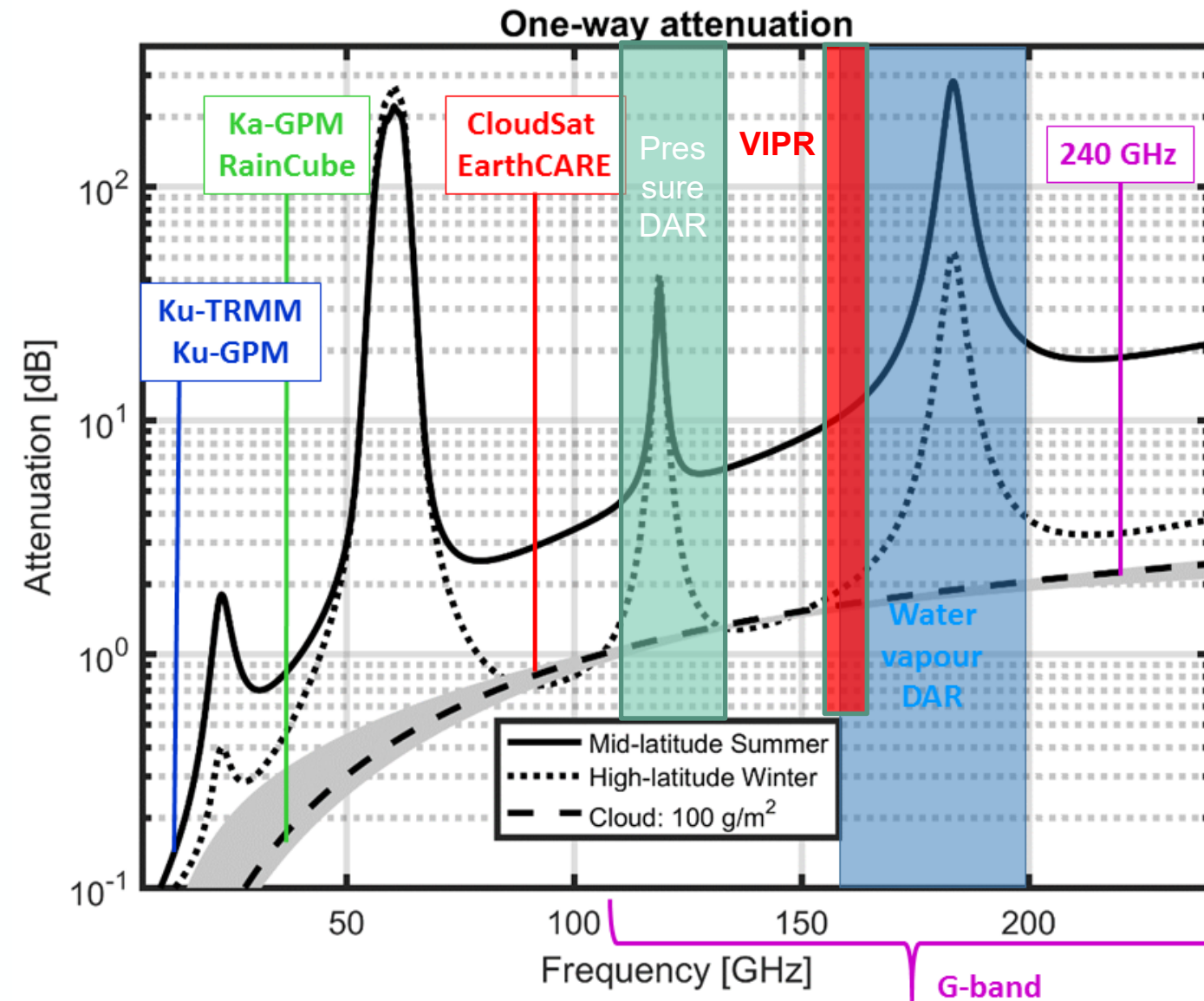
**Game changer:** mm- and sub-mm solid state power devices and low noise amplifiers have recently enabled higher frequency radar capable of achieving sensitivities good enough for cloud studies.



## Window frequencies → Ice and light rain microphysics

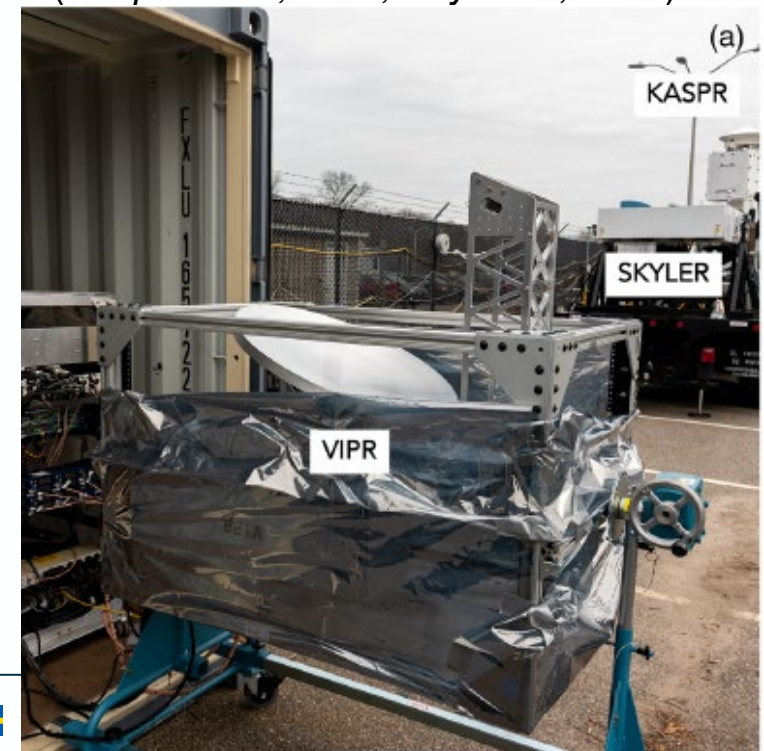
The UK-CEOI G-band Radar for Cloud Experiment (**GRACE**) (partners involved: RAL Space, STFC Rutherford Appleton Laboratory with Thomas Keating Ltd., University of Leicester & University of St Andrews) has developed a prototype ground-based, zenith looking 200 GHz Doppler cloud radar.





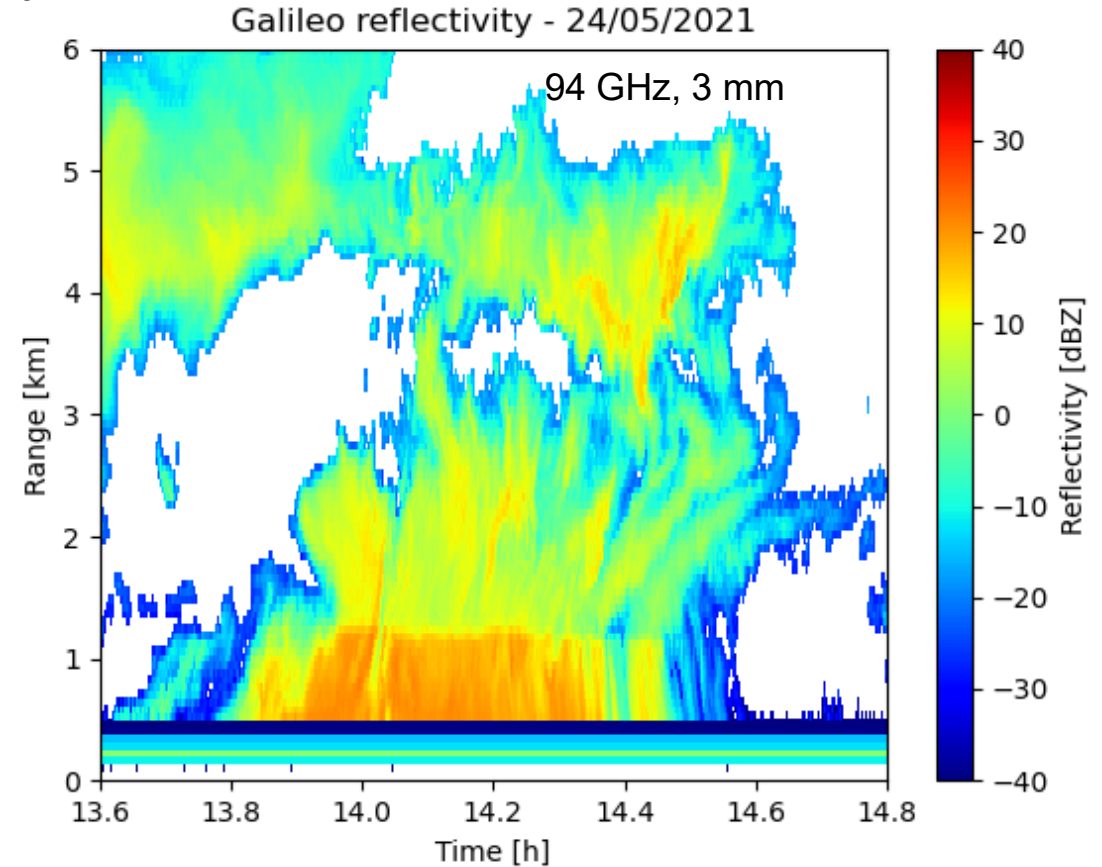
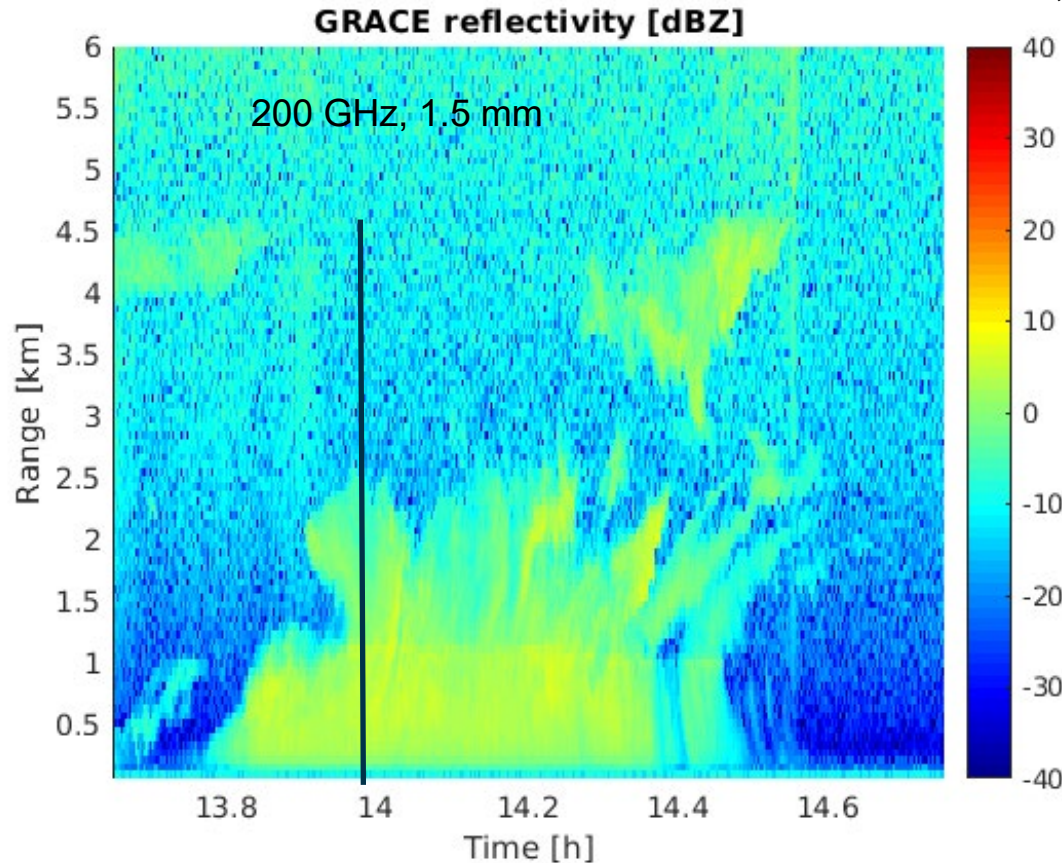
## Absorption band freq → water vapour profiling in the 183 band

The JPL Vapor In-cloud Profiling Radar (**VIPR**) demonstrated the possibility of operating a radar system in differential absorption mode with tones within the 183 GHz water vapour absorption band (*Cooper et al., 2018, Roy et al., 2018*).



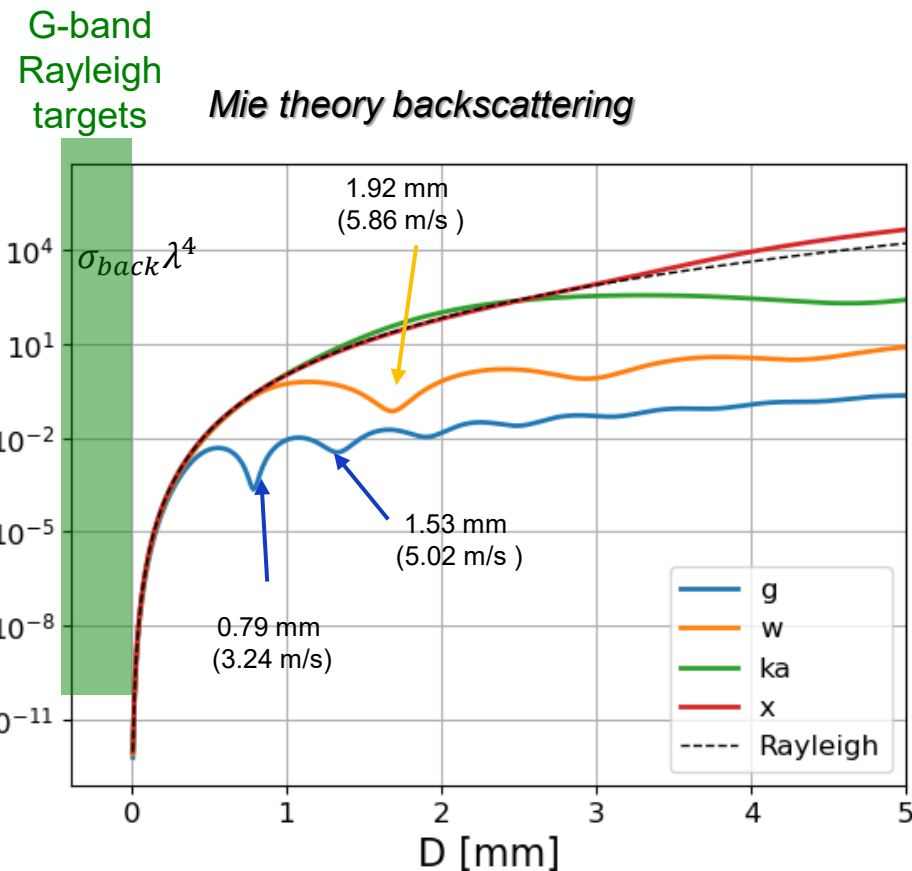
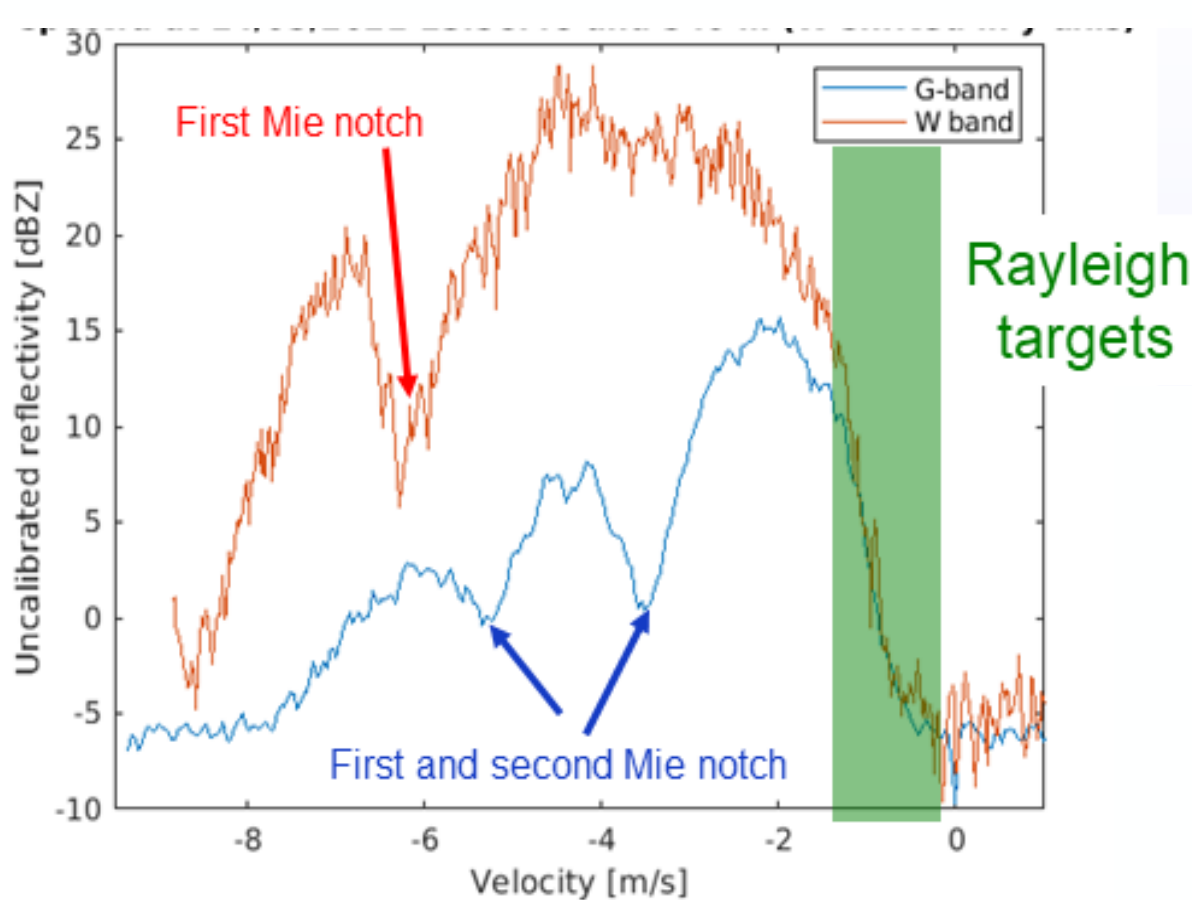
# Watershed moment: first light of a G-band Doppler system in Chilbolton

Courier et al., GRL 2021



- Rain event on May 24<sup>th</sup>, freezing level at around 1 km (UK “summer” atmosphere conditions).
- GRACE reduced reflectivity results from attenuation and non-Rayleigh effects (which will provide the additional information for microphysical characterization).

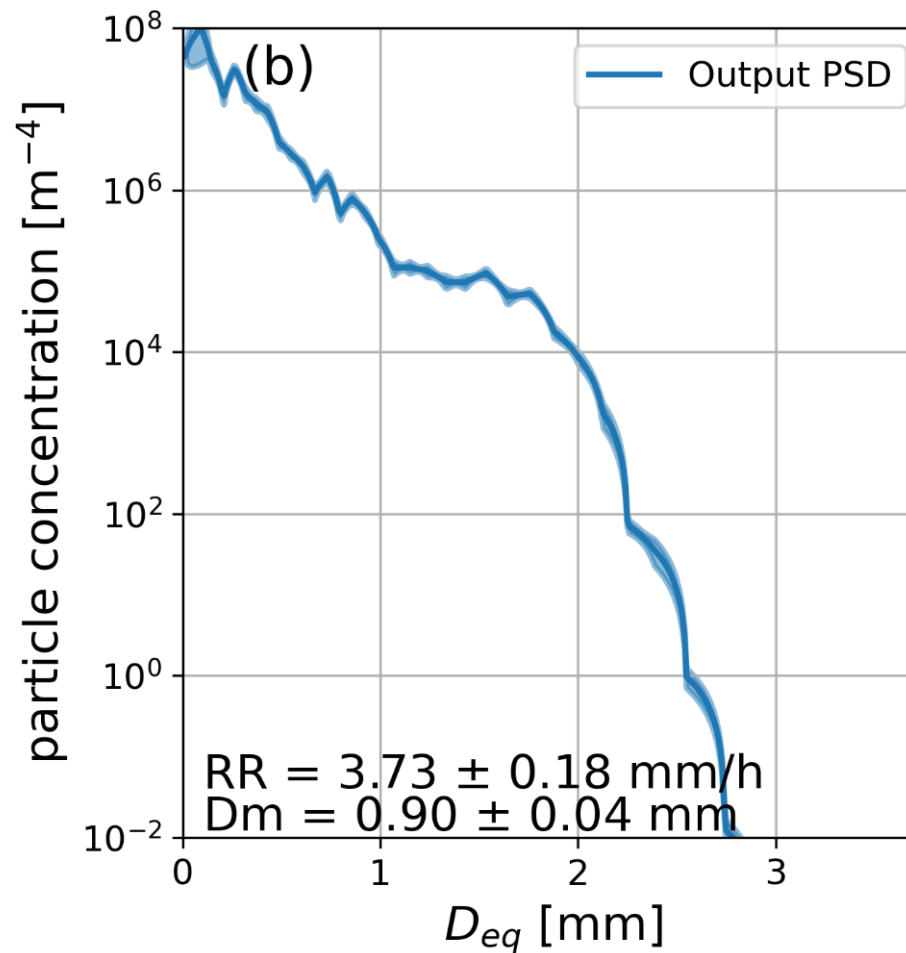
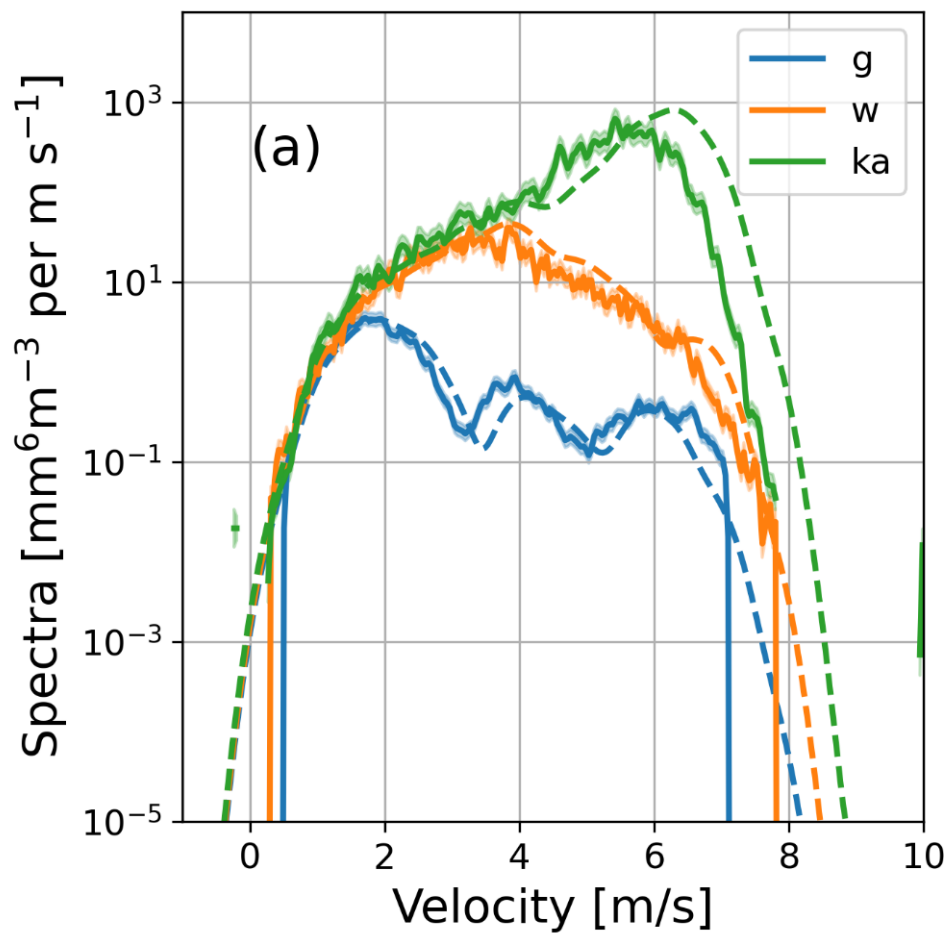
# First-ever Doppler spectra at G-band



Doppler spectra in rain present peaks and valleys → raindrops are non Rayleigh targets at 200 GHz → specific sizes produce constructive or destructive interference of the backscattering cross sections → “Mie notches”

The decrease in backscattered power with respect to lower frequency can be used to size particles

# Triple Frequency Optimal Estimation of drop size distribution

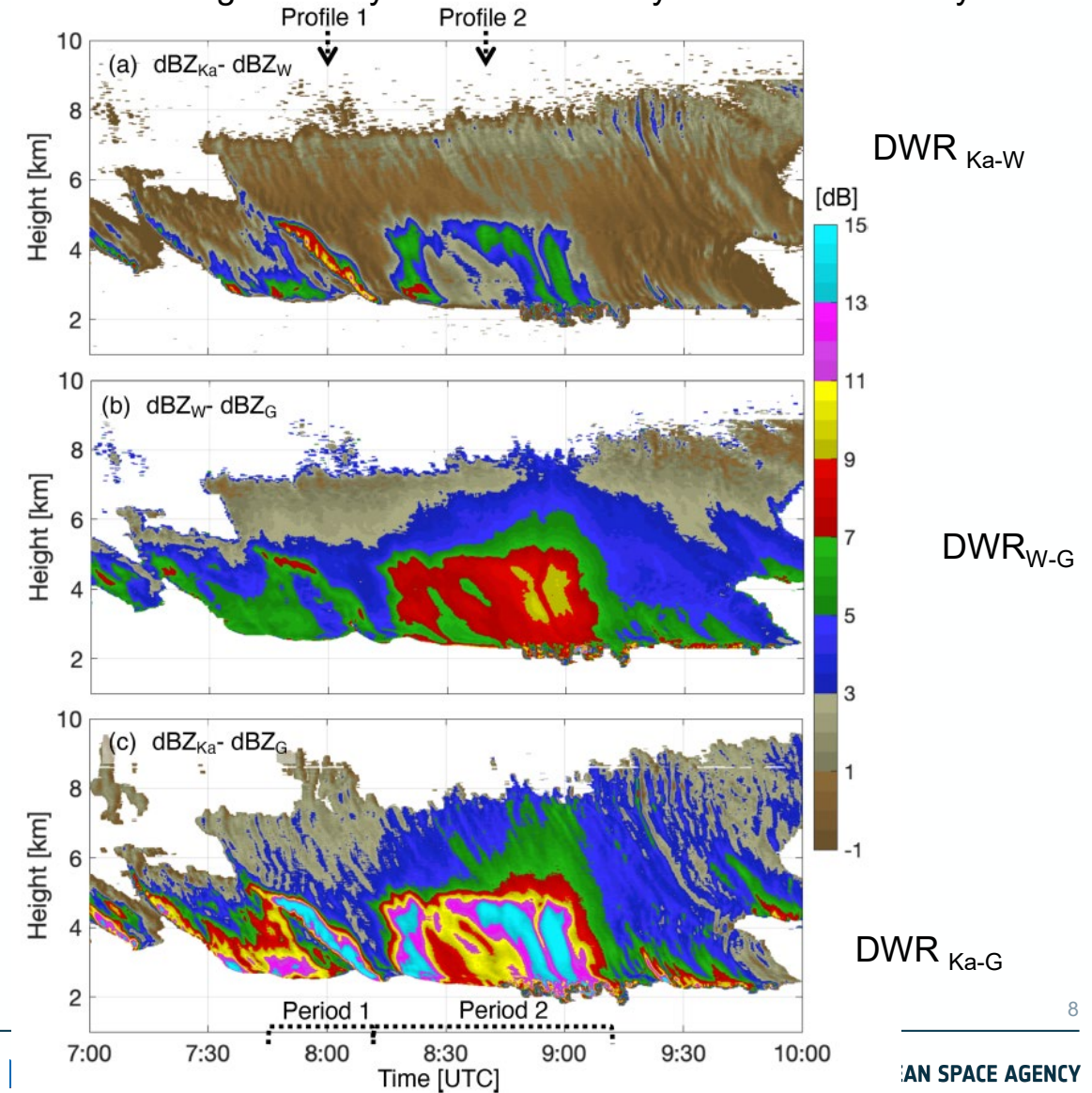
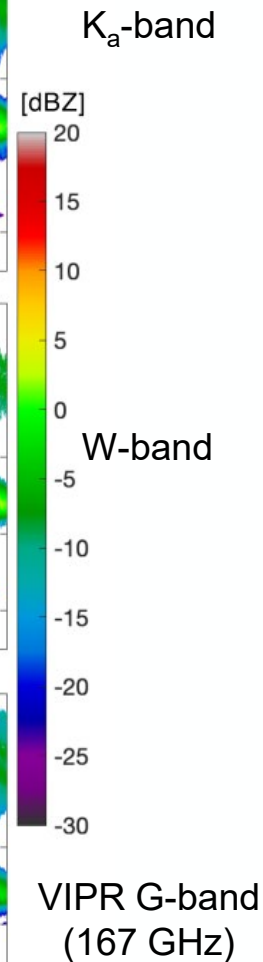
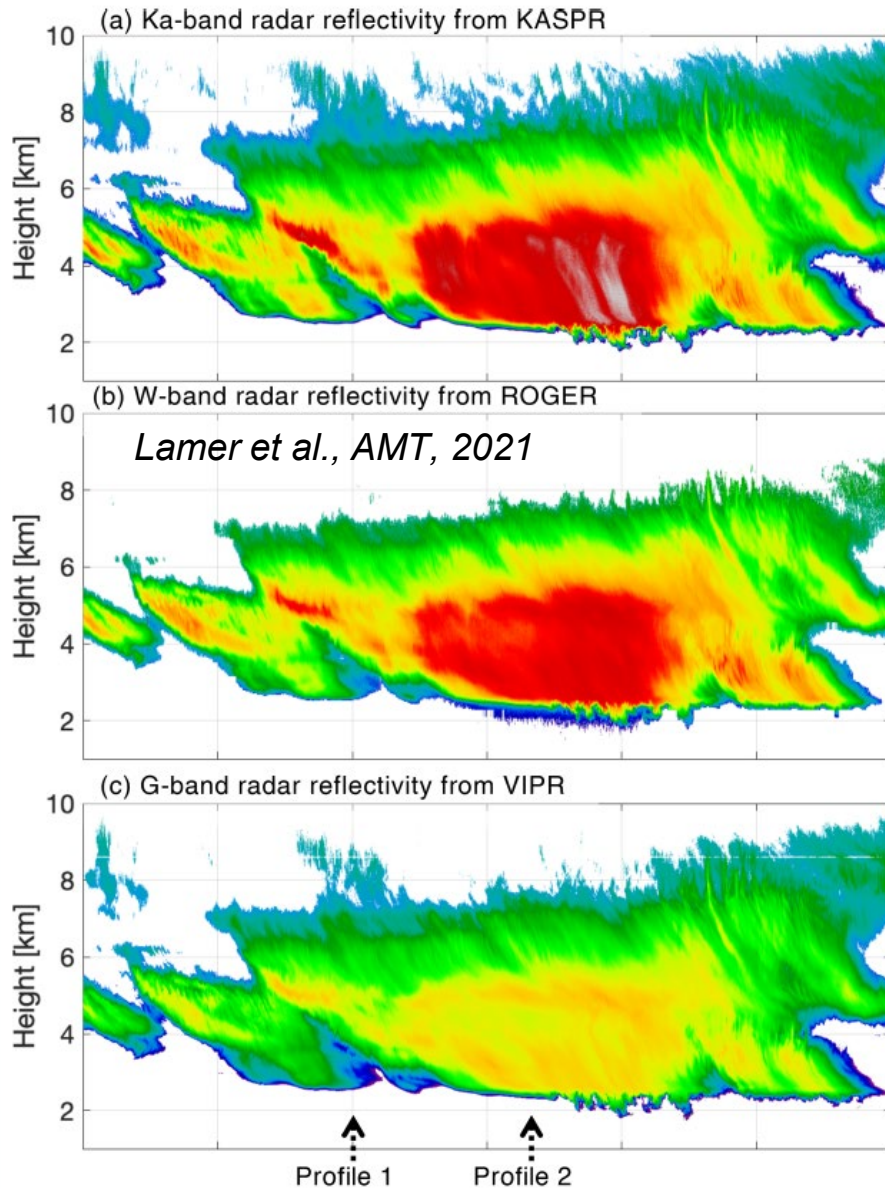


Solid lines in left plot show observed spectra aligned at the Rayleigh region (W-band has been calibrated)

Dashed lines show spectra forward modelled using retrieved PSD.

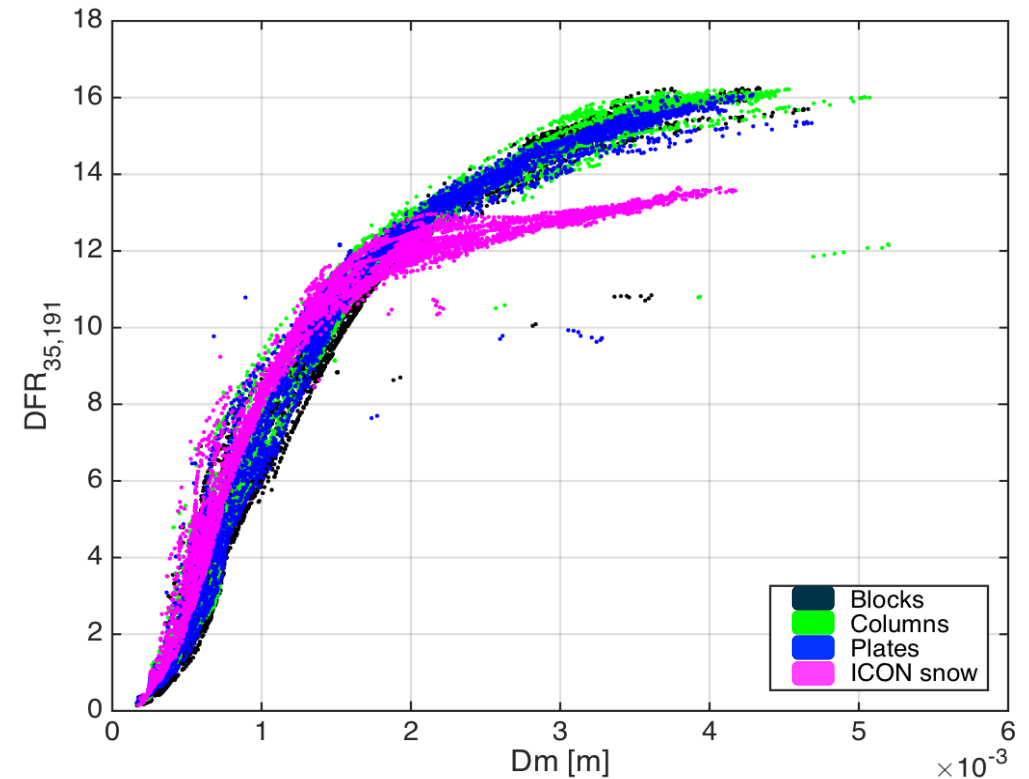
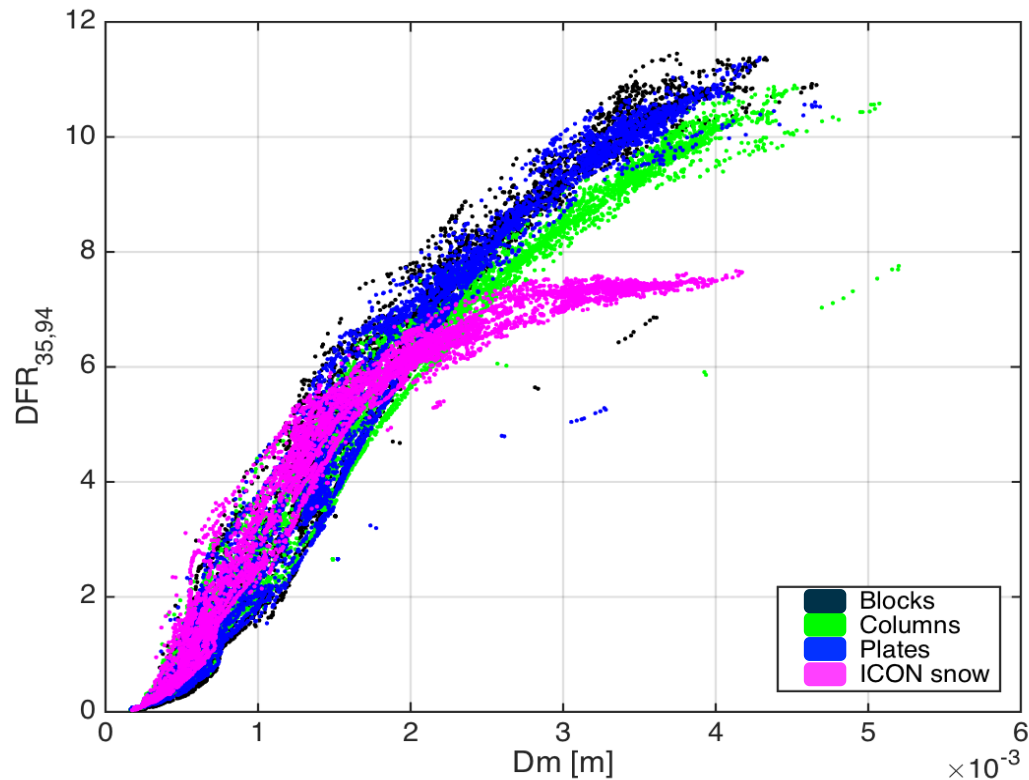
# First multi-frequency G-band radar observations of ice clouds

Two days of data collected during February 2020 at the StonyBrook Radar facility





- PSDs measured in-situ from 2D-S and HVPS on FAAM aircraft during PICASSO campaign (case 13/02/2018)
- Particle models from ARTS scattering database (Ekelund et al., 2020: ARTS Microwave Single Scattering Properties Database (1.1.0) [Data set]. Zenodo. <https://doi.org/10.5281/zenodo.4646605>)

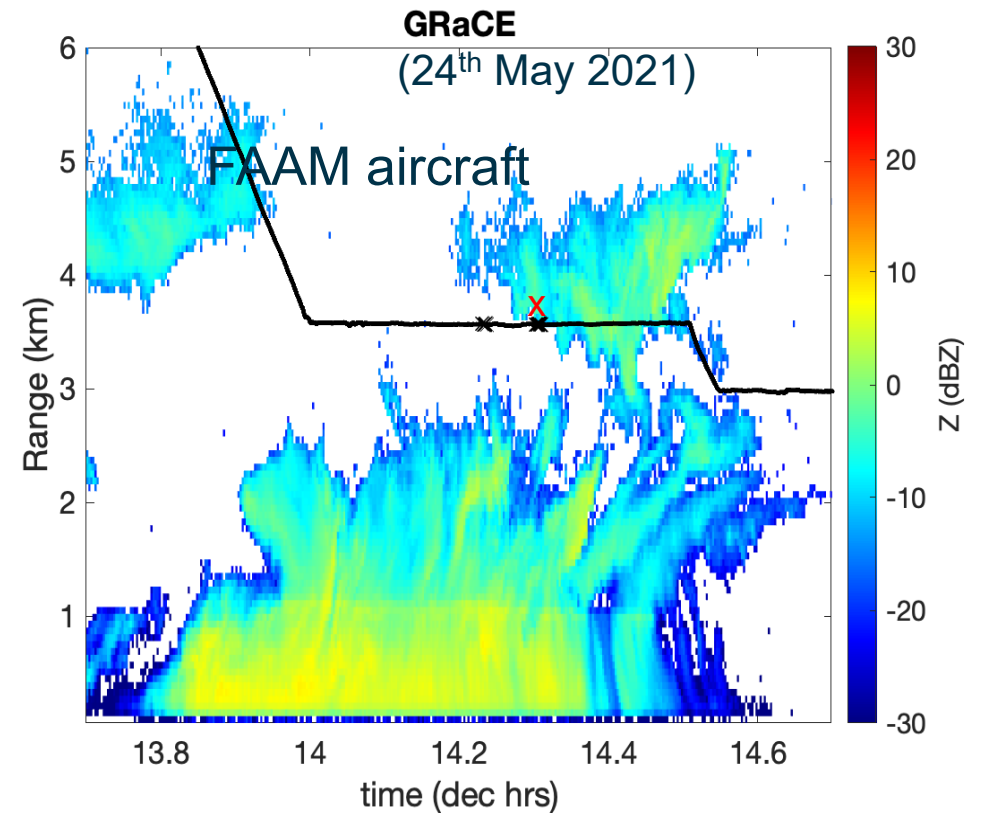


Larger DWRs → G band has potential for quantitative retrievals of smaller size crystals compared to those achievable by using longer wavelengths

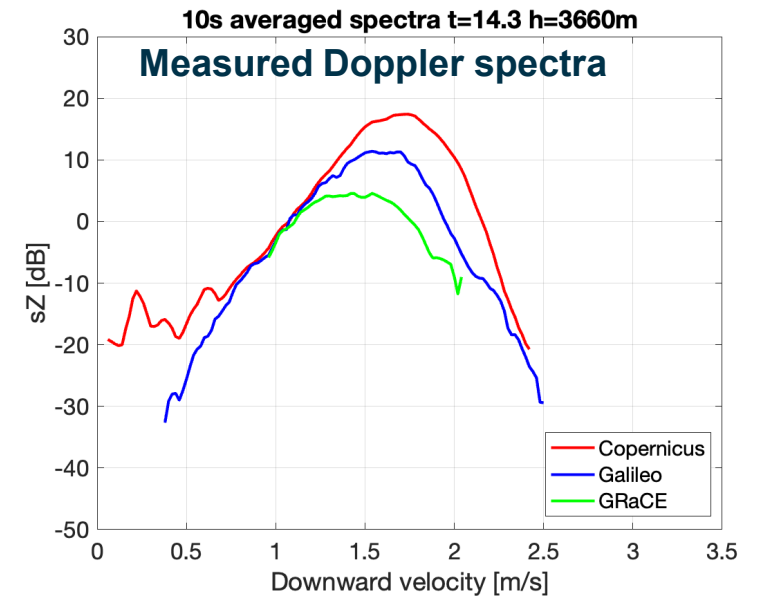
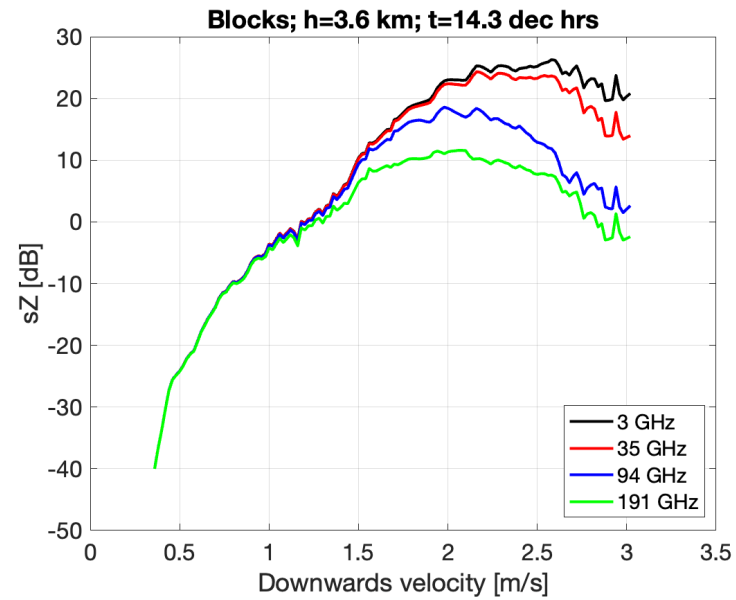
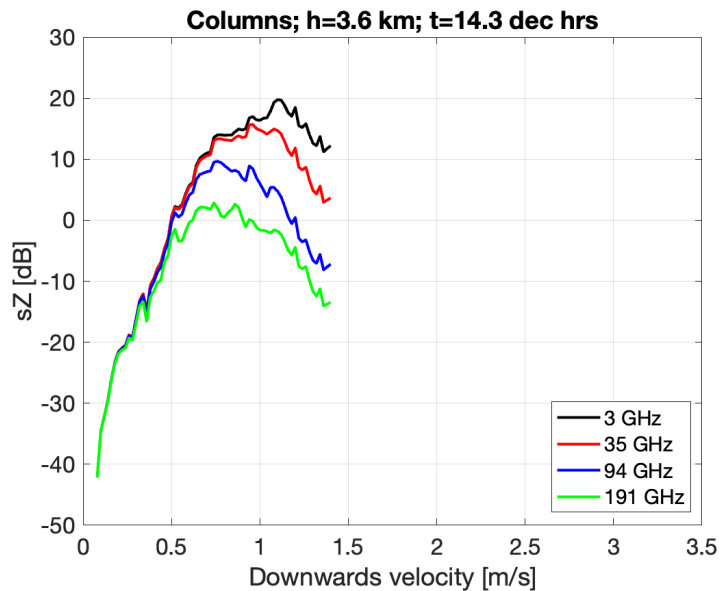
Significant attenuation expected as well at G-band, particularly with riming → testbed for PMW scattering properties

# Doppler spectra in ice

Trying to select scattering and fall-speed velocity models that better fit measurements

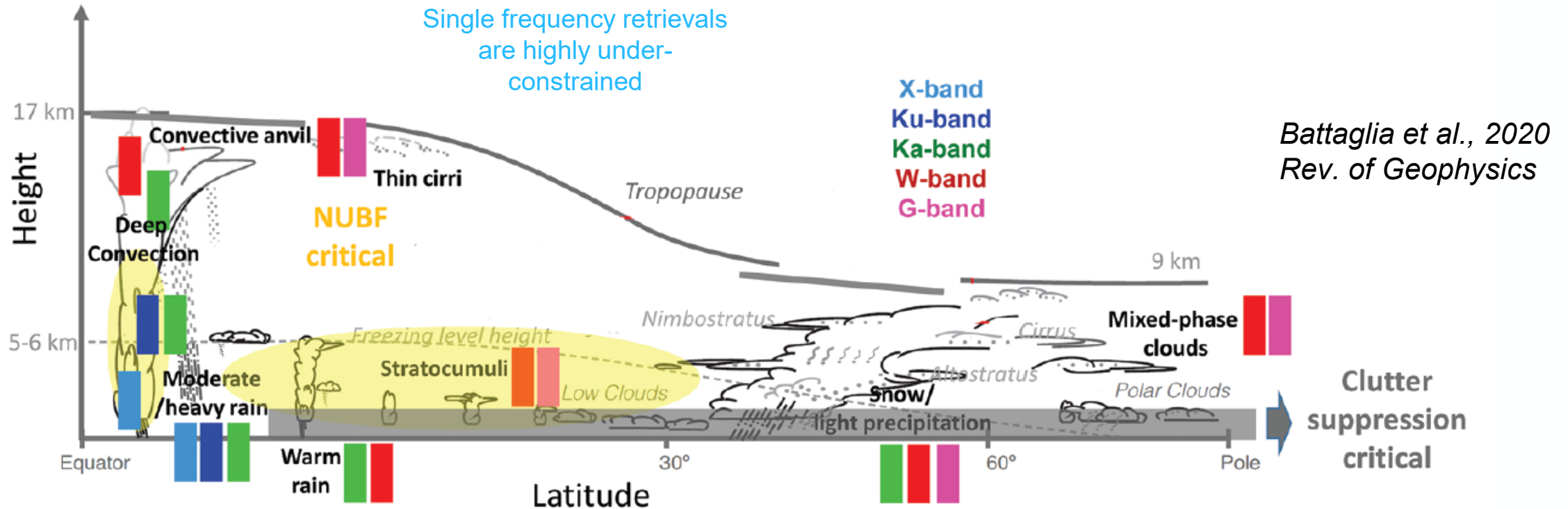


## Simulated Doppler spectra at different frequencies using in-situ PSD



# Science case for cloud&precipitation radar observations

**Problem:** limited understanding of cloud feedbacks is the major source of **uncertainty in climate sensitivity** (from 1.5 up to 4.5°C) → better characterization of cloud&precipitation vertical structure and microphysics needed



**Solution:** combination of multi-frequency (Doppler) radars with frequencies ranging from 10 to above 200 GHz allows characterizing from heavy precipitation particles to small-size ice crystals. Inclusion of G-band highly beneficial in three areas: **boundary layer clouds, cirrus and mid-level ice clouds and precipitating snow.**

- Progress in G-band technology is driving sensitivities to levels appropriate for cloud studies → **G-band cloud radars** are now a **reality**.
- **First ground-based demonstrators** now acquiring measurements, with airborne demonstrators under constructions.
- DAR systems in the G-band hampered by ITU restrictions

A G-band system could be flown **in constellation/formation with other cloud radars** (e.g. those to be deployed in the ESA-JAXA EarthCARE or the polar component of the NASA AOS mission) **and/or with passive microwave high frequency systems** (AWS, ICI) → SCOUTS mission seem the best opportunity (open for collaboration with industrial partners keen to develop such a system).

G-band spectra for a light rain event  
Chilbolton 2/3/2022

