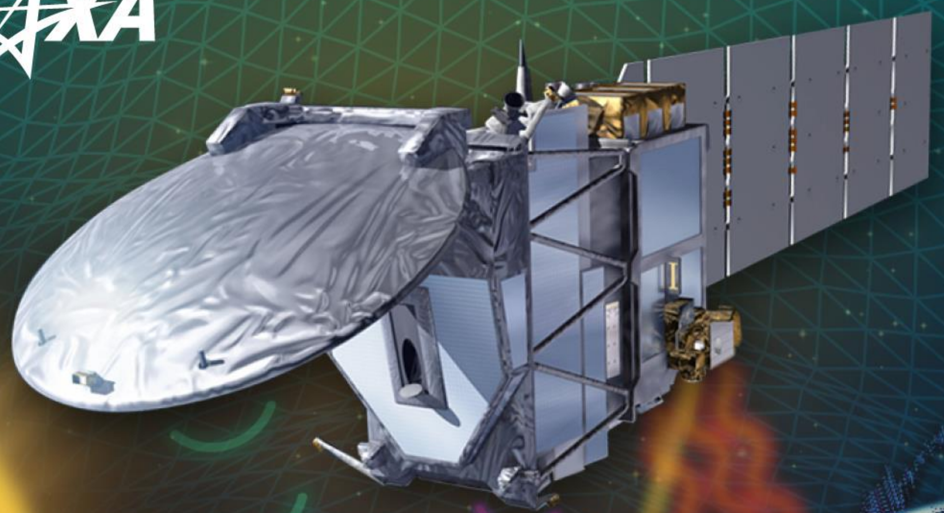
ESA-JAXA Pre-Launch EarthCARE Science and Validation Workshop
13 – 17 November 2023 | ESA-ESRIN, Frascati (Rome), Italy



On the utility of the EarthCARE CPR Doppler observations for evaluating the representation of convective dynamics in regional and global high-resolution models

Pavlos Kollias[1,2], Bernat Puigdomenech Treserras[2], Zhuocan Xu[1], Alessandro Battaglia[3,4], Kamil Mroz[4]

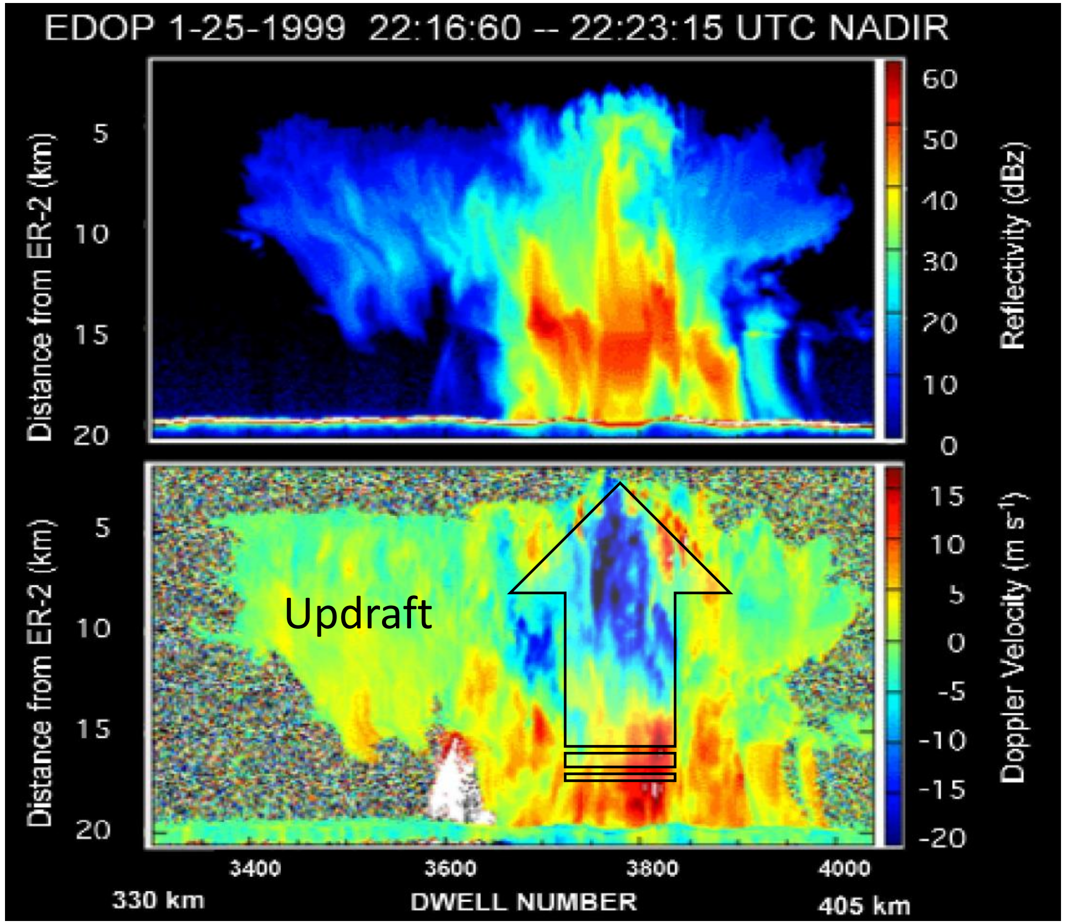
1. Stony Brook University, USA, 2. McGill University, Canada, 3. Politechico di Torino, Italy, 4. University of Leicester, UK

Introduction

The Doppler capability of the CPR is expected to provide the first ever global observations of convective motions in shallow and deep convection. Here, two topics are discussed:

Quality of the CPR Doppler velocity measurements in shallow and deep convection

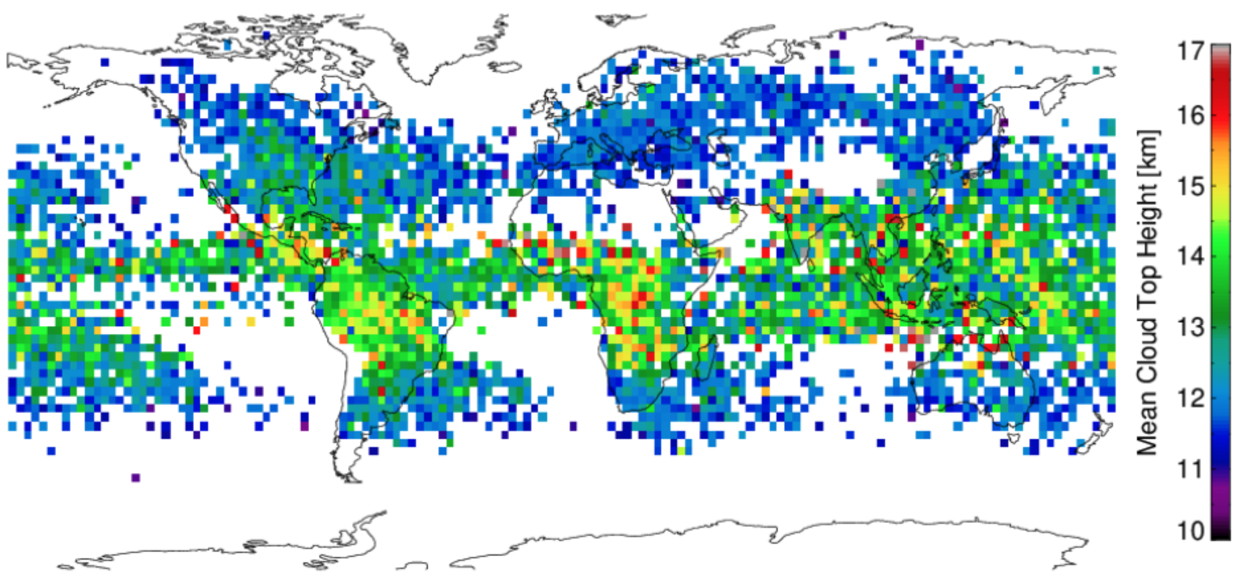
Methodologies for bridging the CPR observations with high resolution numerical models.

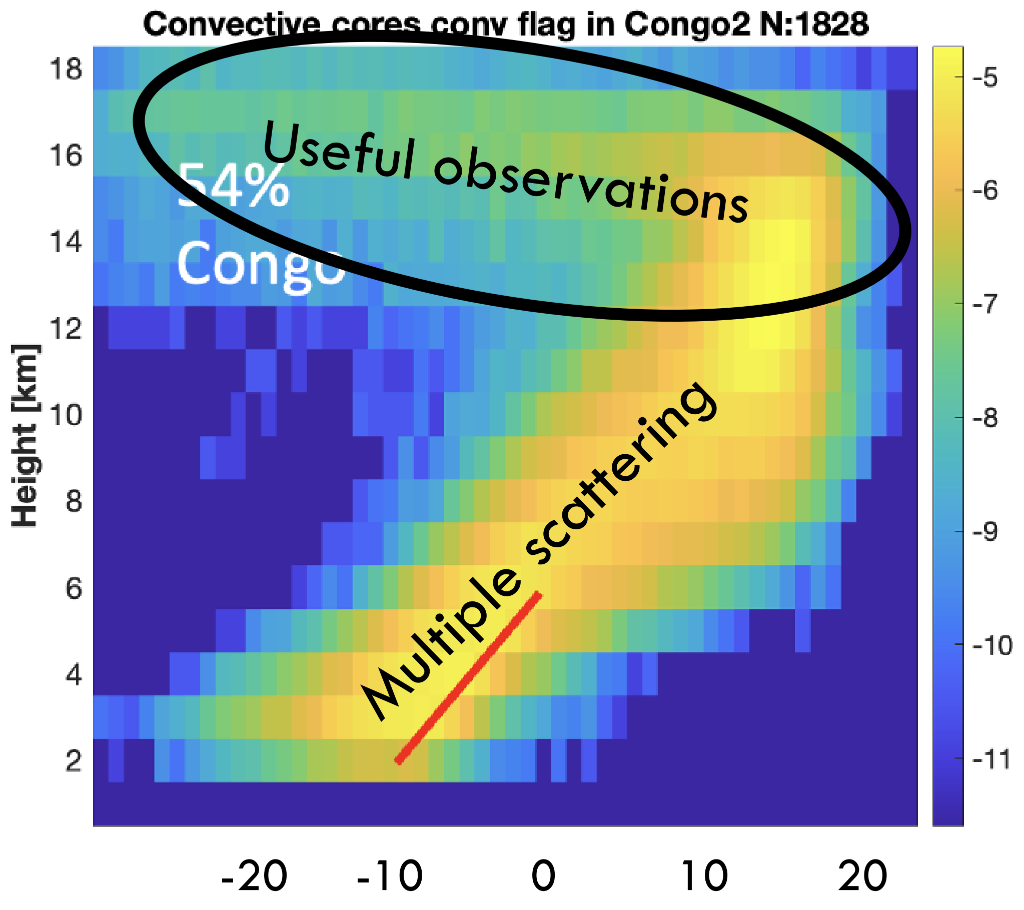


courtesy of G. Heymsfield, NASA GSFC

CloudSat: Convective Cores Climatology

CloudSat CPR Cloud top height (km)

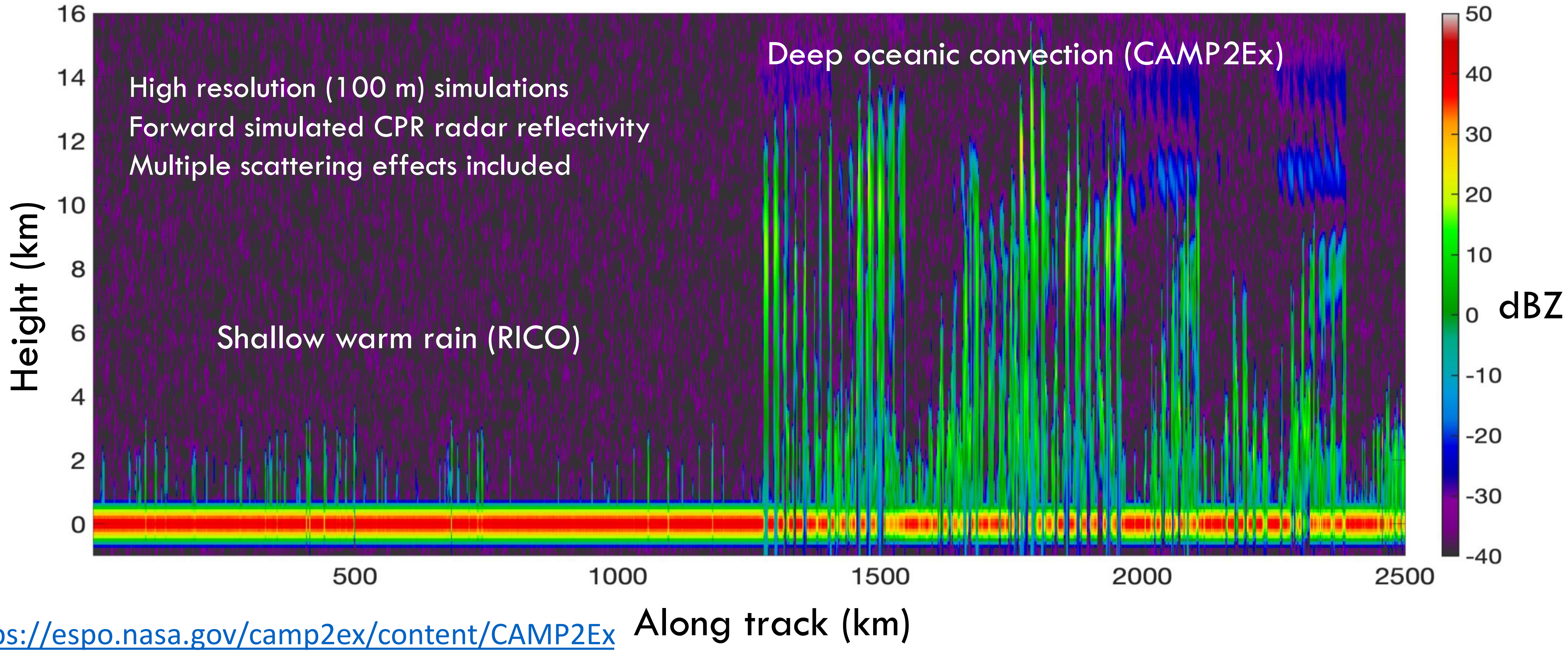




Using a new methodology to identify deep convective cores (Xu et al., 2023)

Limited sampling

Use end-to-end OSSEs in convective clouds

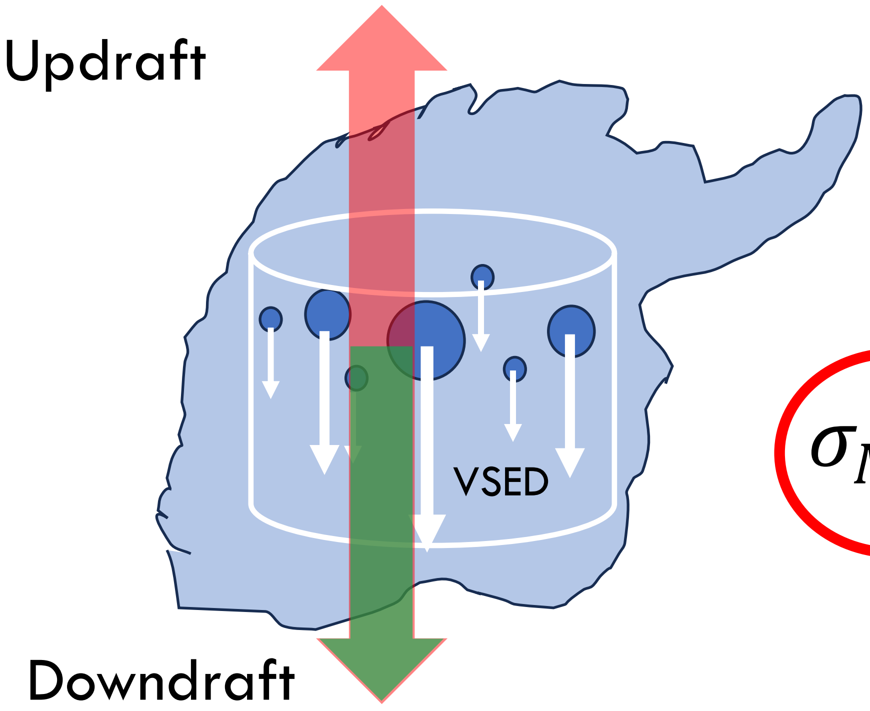


https://espo.nasa.gov/camp2ex/content/CAMP2Ex
https://www.eol.ucar.edu/field_projects/rico

Spaceborne Doppler velocity

$$MDV = VAM + VSED$$

Vertical Air Motion (VAM)



$$\sigma_{VAM} = \sqrt{\sigma_{MDV}^2 + \sigma_{SED}^2}$$

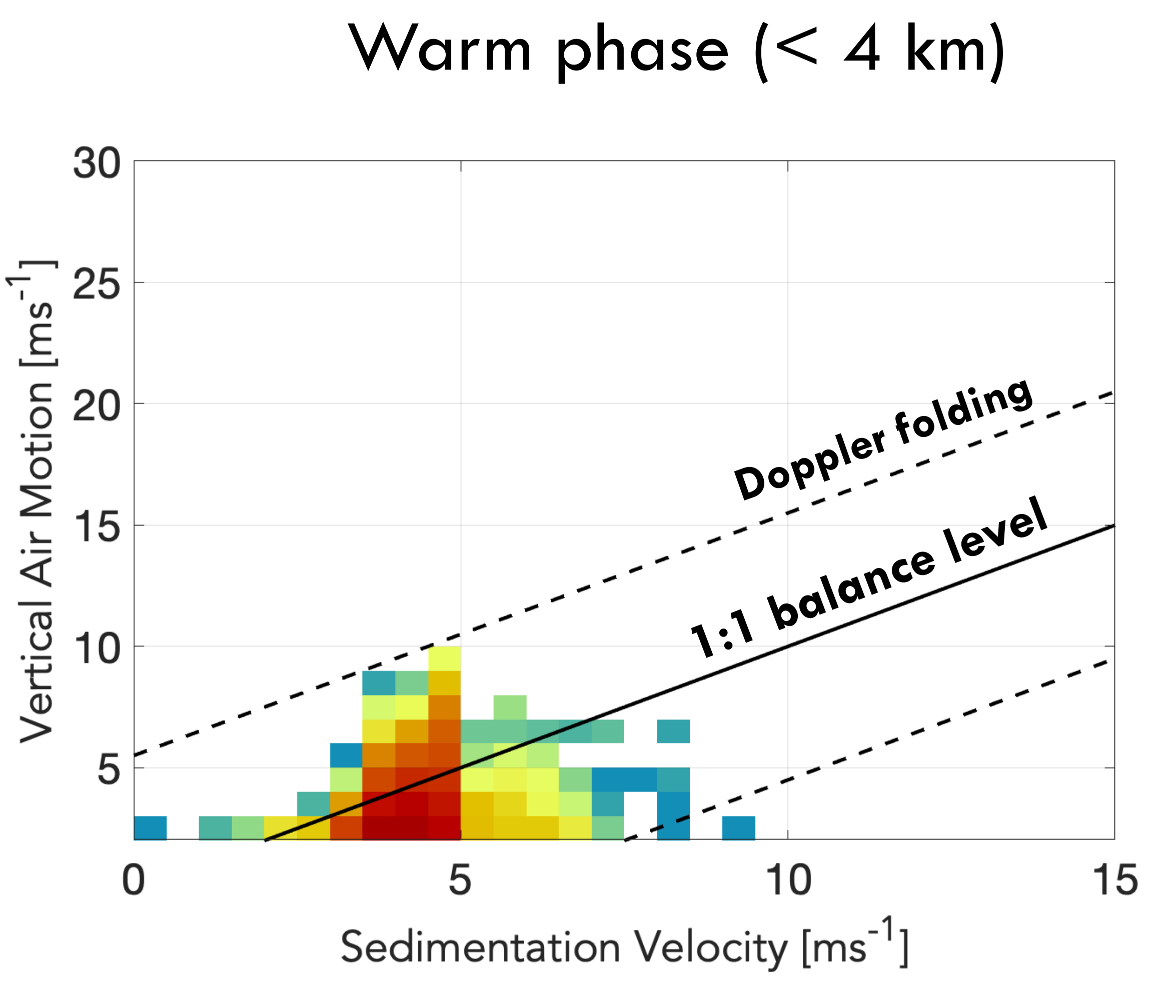
How well can we measure the Doppler velocity ?

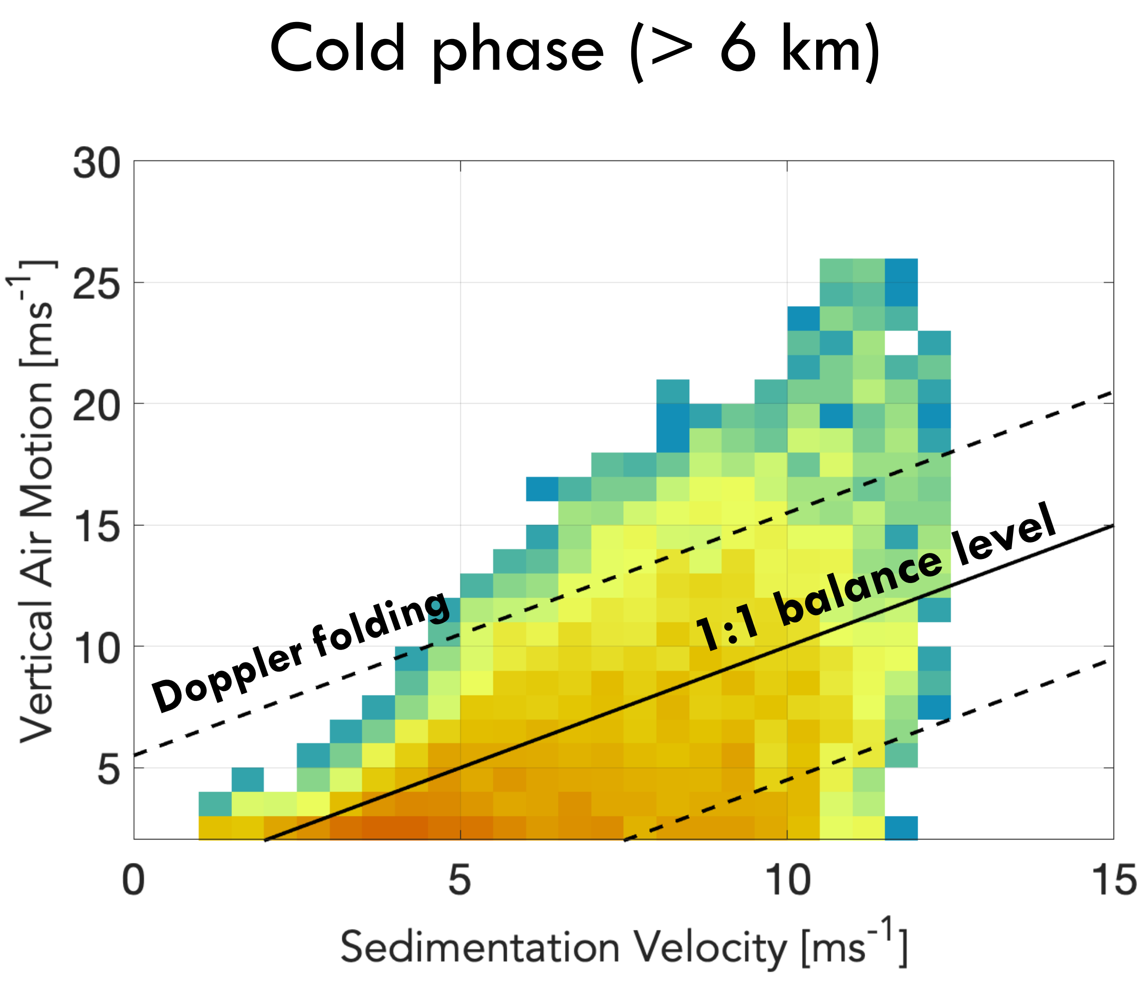
How well do we know the hydrometeor sedimentation velocity (VSED)?

$$\sigma_{MDV} = \sqrt{\sigma_B^2 + \sigma_{NUBF}^2 + \sigma_P^2}$$

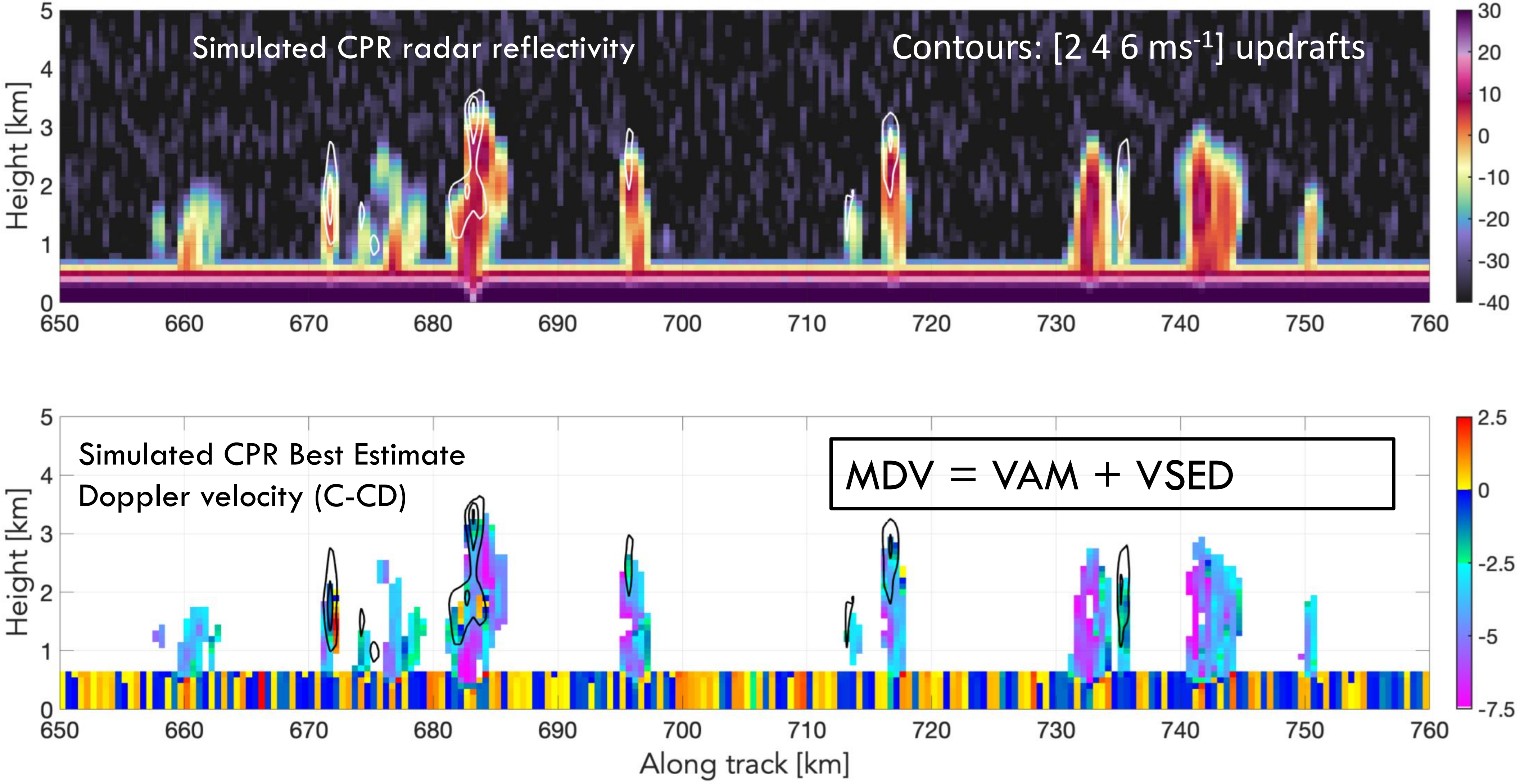
~ 1 ms^{-1} ? ~ 0.15 ms^{-1}

Relationship between VAM and VSED

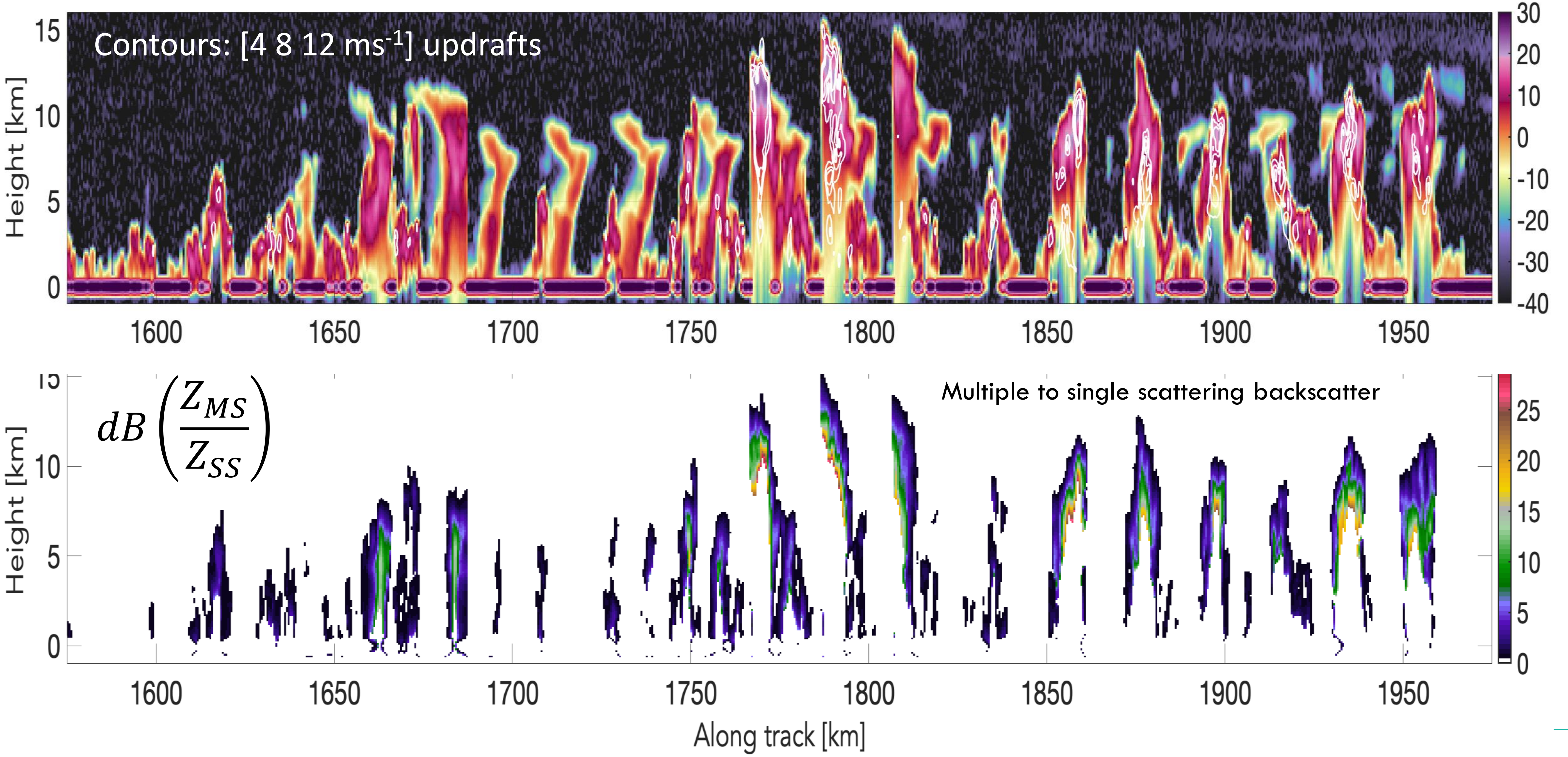




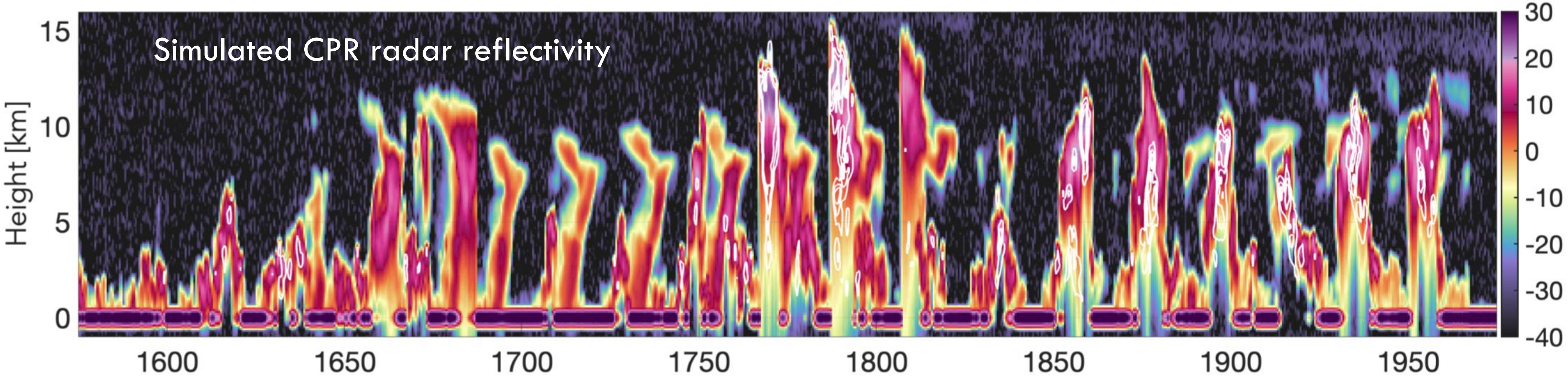
Shallow Convection (RICO)

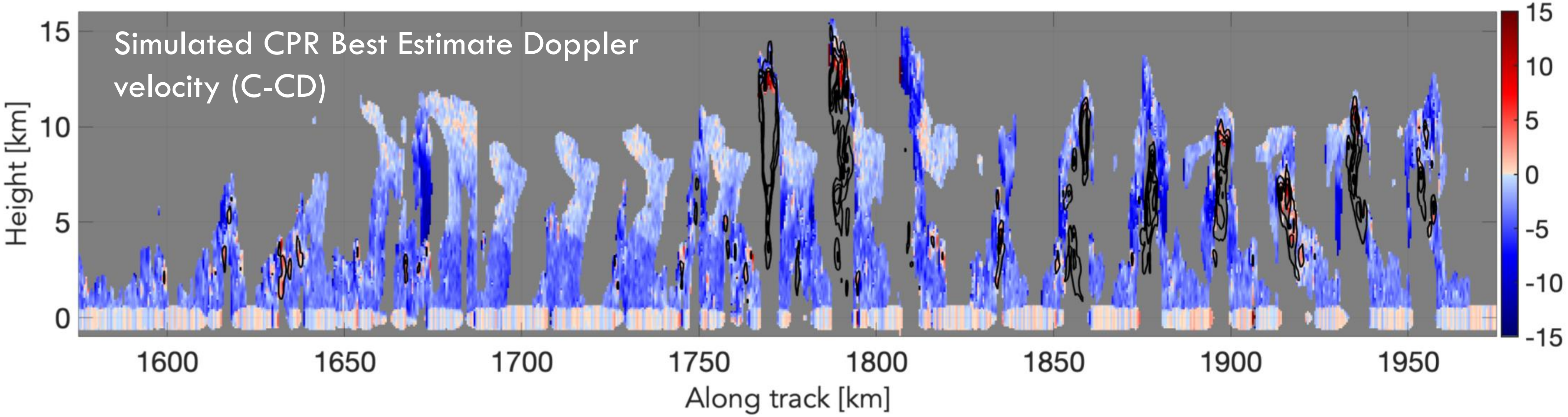


Deep Convection (CAMP2Ex)

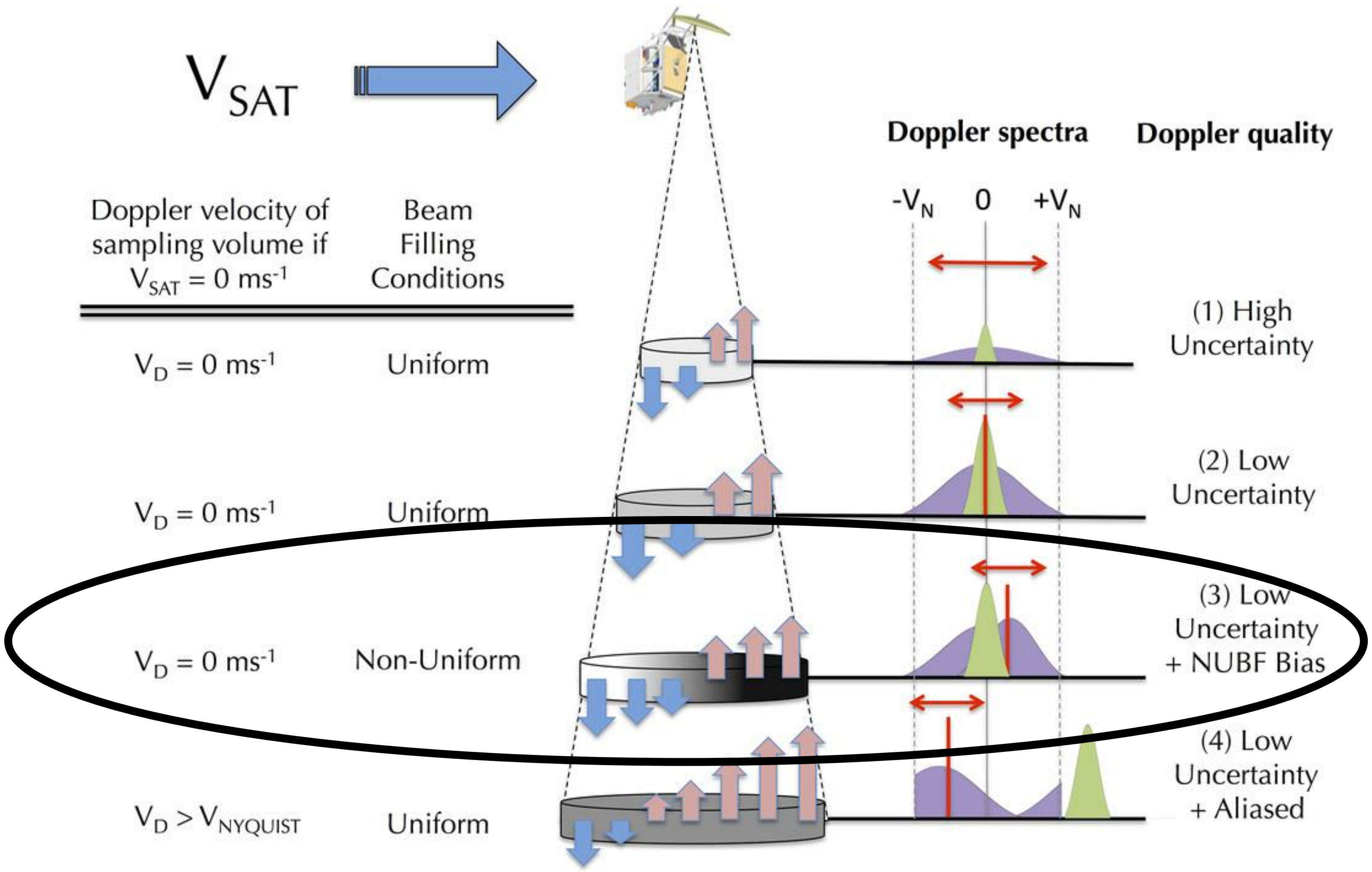


Attenuation (MS) limits CPR penentration





NUBF Doppler velocity bias

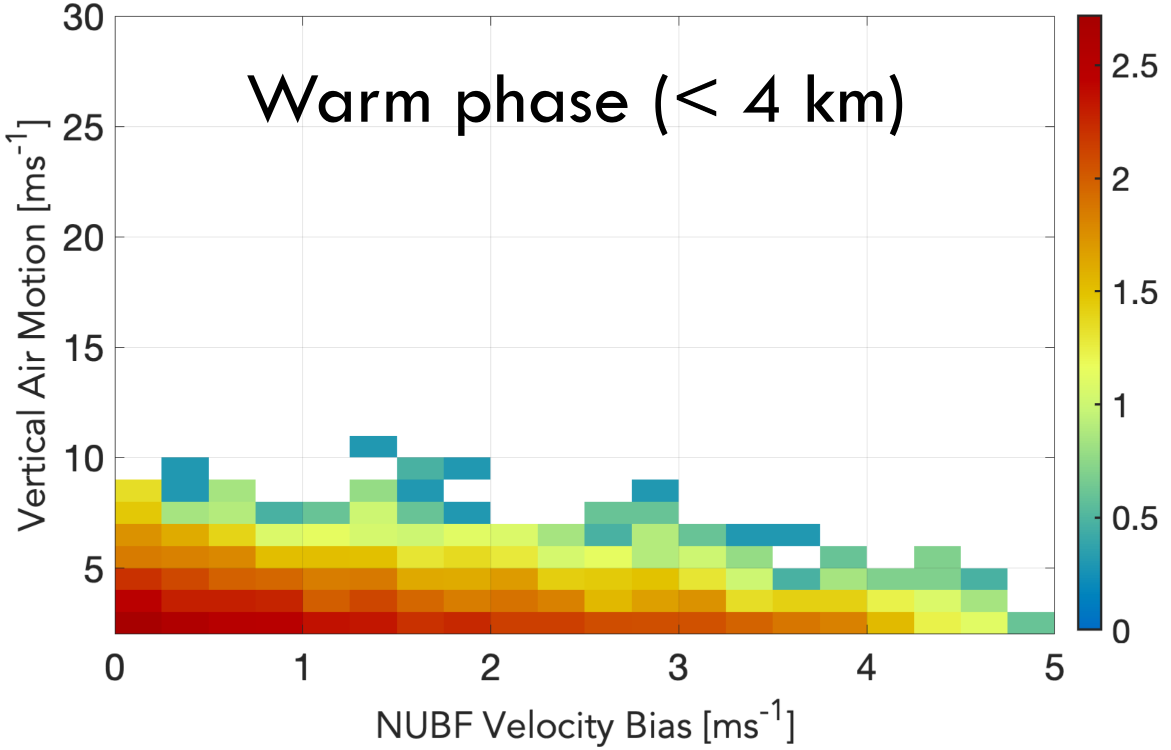


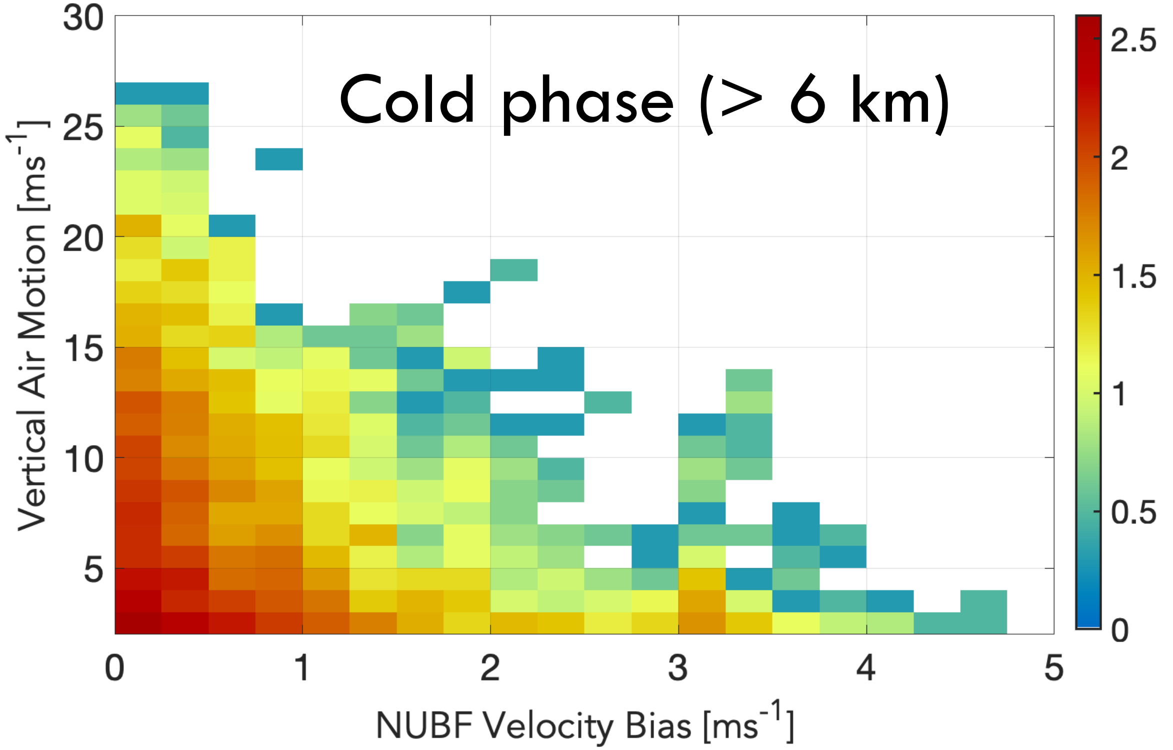
Non-Uniform Beam Filling (NUBF) conditions within the CPR sampling volume combined with the apparent Doppler velocity introduced by the satellite motion can result to Doppler velocity biases

Kollias et al., 2014; 2022
Sy et al., 2014; 2023
Illingworth et al., 2015

NUBF Doppler velocity bias

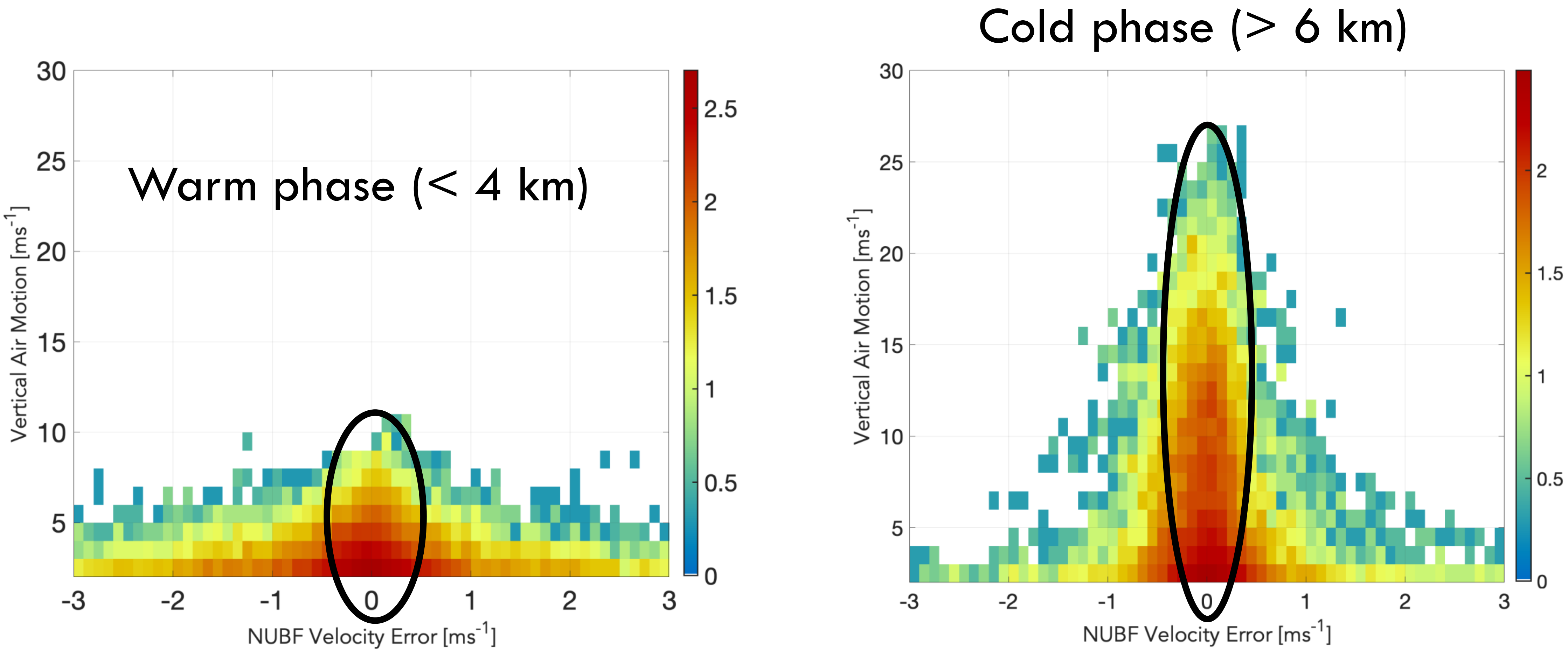
Strong NUBF velocity biases are observed in shallow convection. This reflects the relationship between the size of the convective cores in shallow and deep convection and the CPR footprint (~800 m).



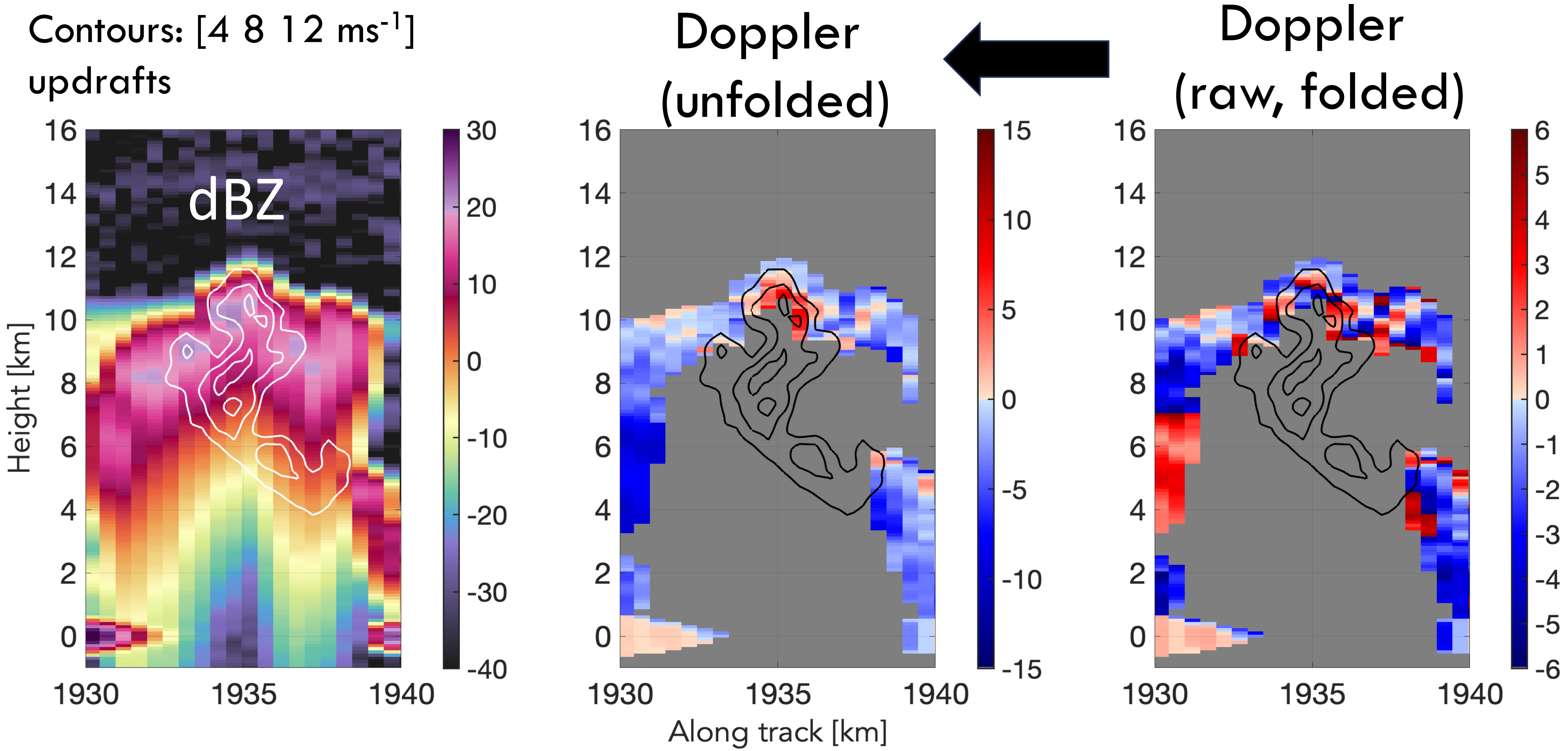


NUBF Doppler velocity residual error

After the NUBF correction is applied, the mean residual error is on average 0.3-0.4 ms^{-1}



Doppler velocity unfolding

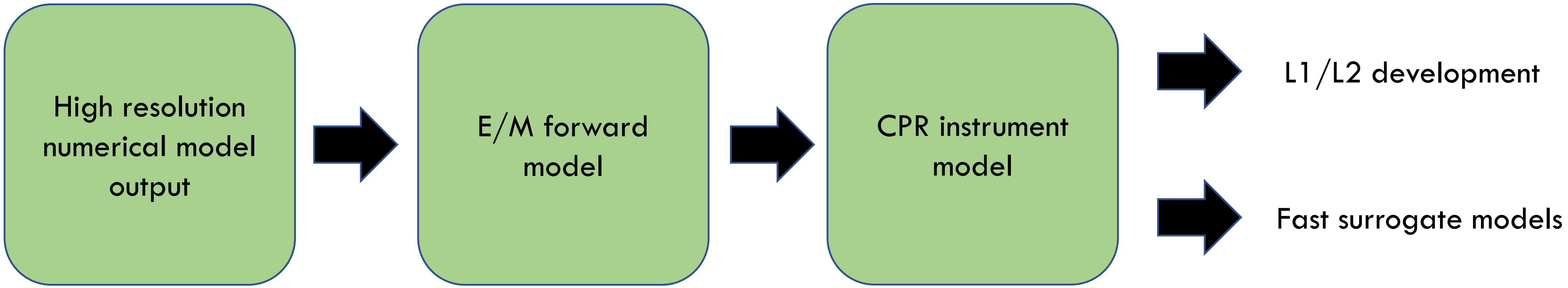


Quick emulators for numerical models

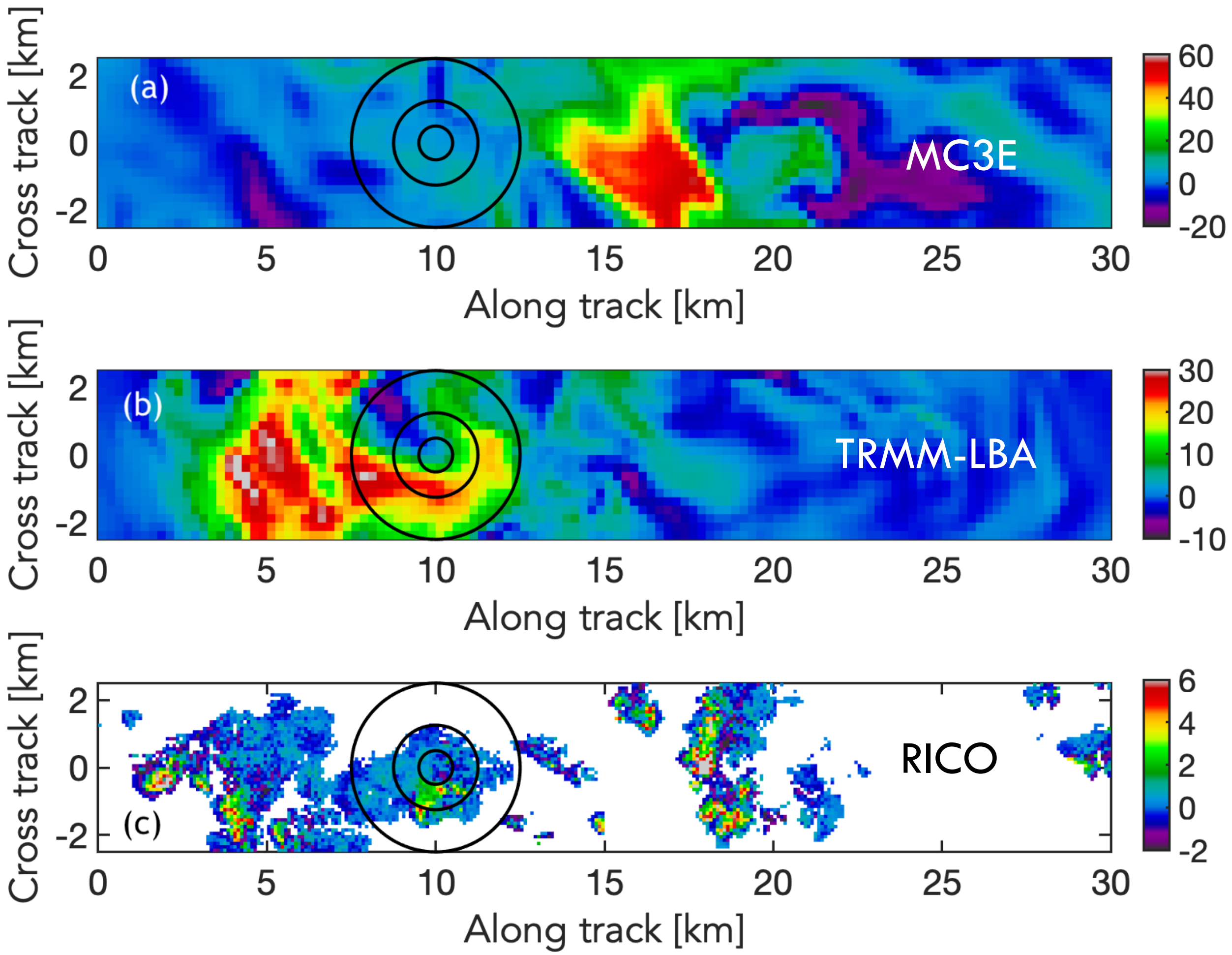
The state-of-the-art EarthCARE CPR forward simulator can be used for:

L2 algorithm development and testing

Develop fast CPR surrogate forward models for high resolution numerical models for an apples-to-apples comparison with CPR observations



Non-uniform Beam Filling



Horizontal cross-section showing vertical air motion (V_{AIR} in ms^{-1}; positive indicates upward motion) from three different model simulations: (A) MC3E at 12 km height, (B) TRMM-LBA at 10 km height, and (C) RICO at 1 km height. Overlaid circles represent the 5, 2.5 and 1 km instantaneous field of view (IFOV).

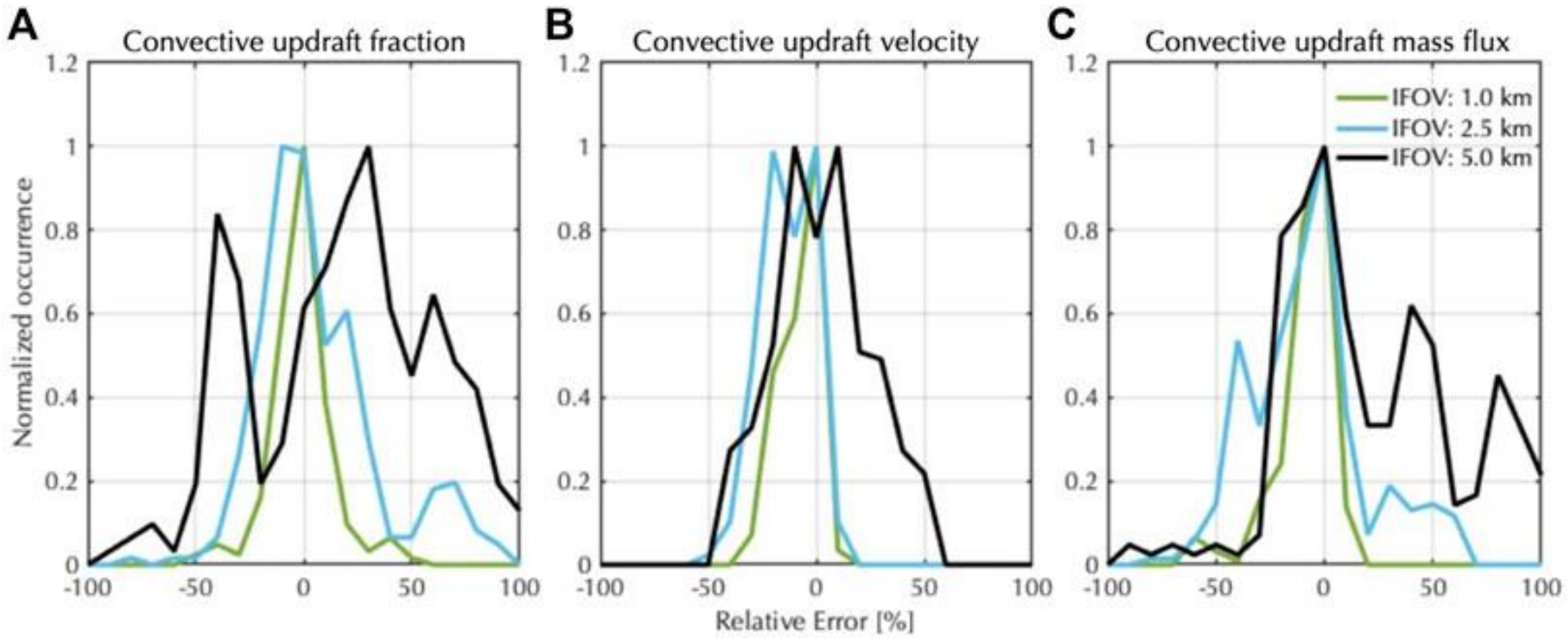
NUBF is a source of Doppler velocity bias for the EarthCARE CPR.

NUBF is a spatial filter that should be considered in model – CPR intercomparisons

Kollias et al., 2022: Mind the Gap – Part 3
https://doi.org/10.3389/frsen.2022.860284

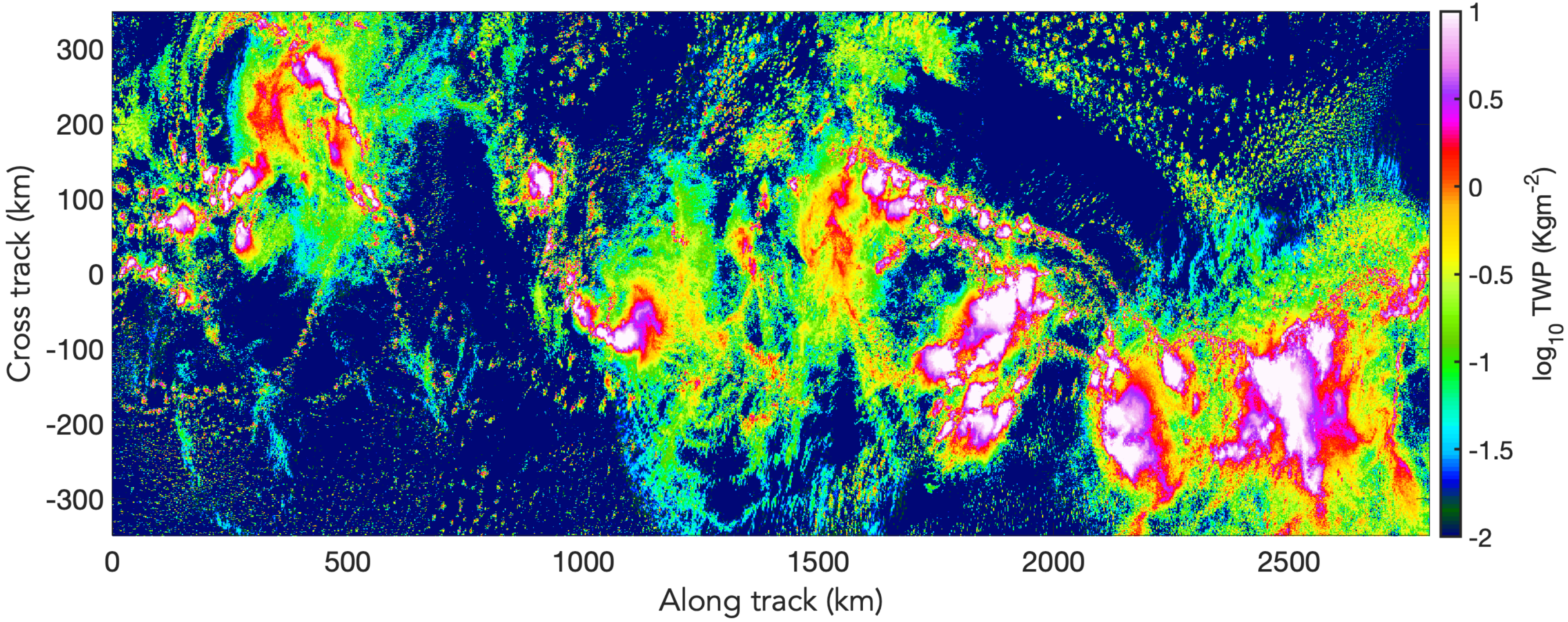
Impact of the satellite footprint on convective updraft properties

Normalized distribution of the relative error $\frac{model-radar}{model} \cdot 100\%$



(A) convective updraft fraction, (B) mean convective updraft velocity, and (C) convective updraft mass flux. Results are shown for three different instantaneous radar field of views close to that of radar 1 (1.0 km; green), radar 5 (2.5 km; cyan), radar 4 (5.0 km; black).

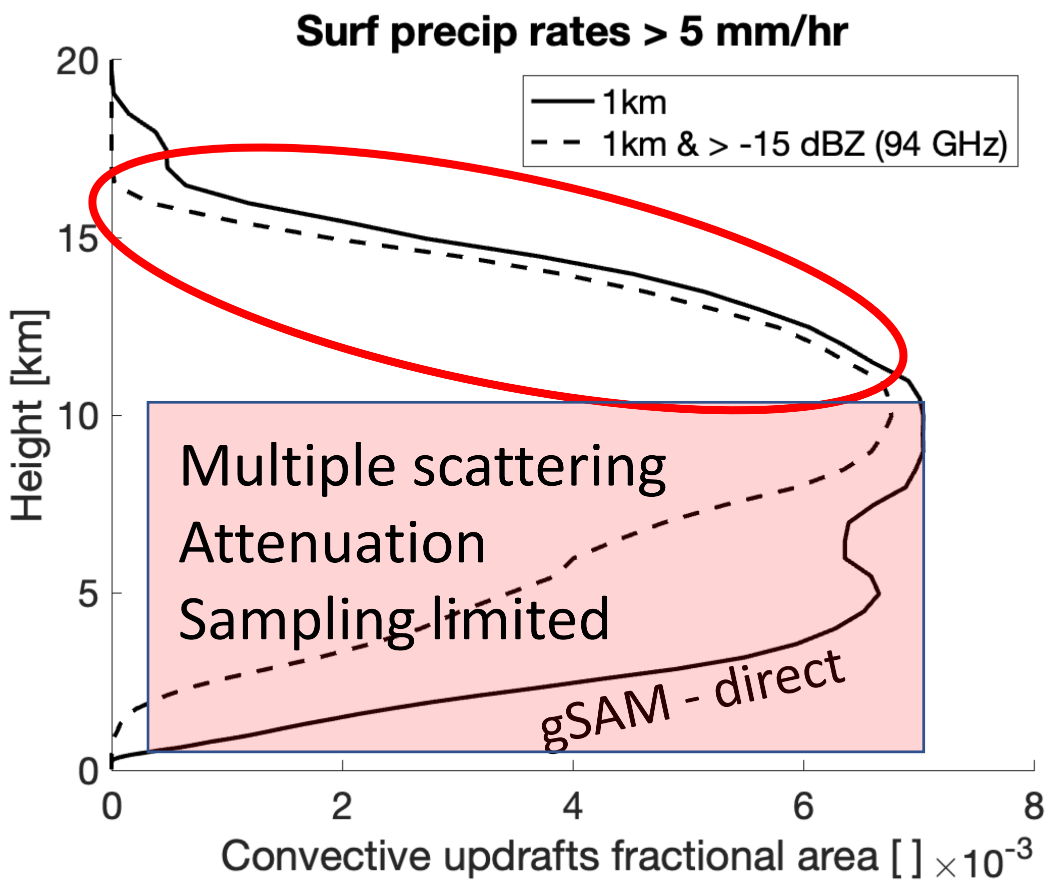
Representativeness of the CPR observations

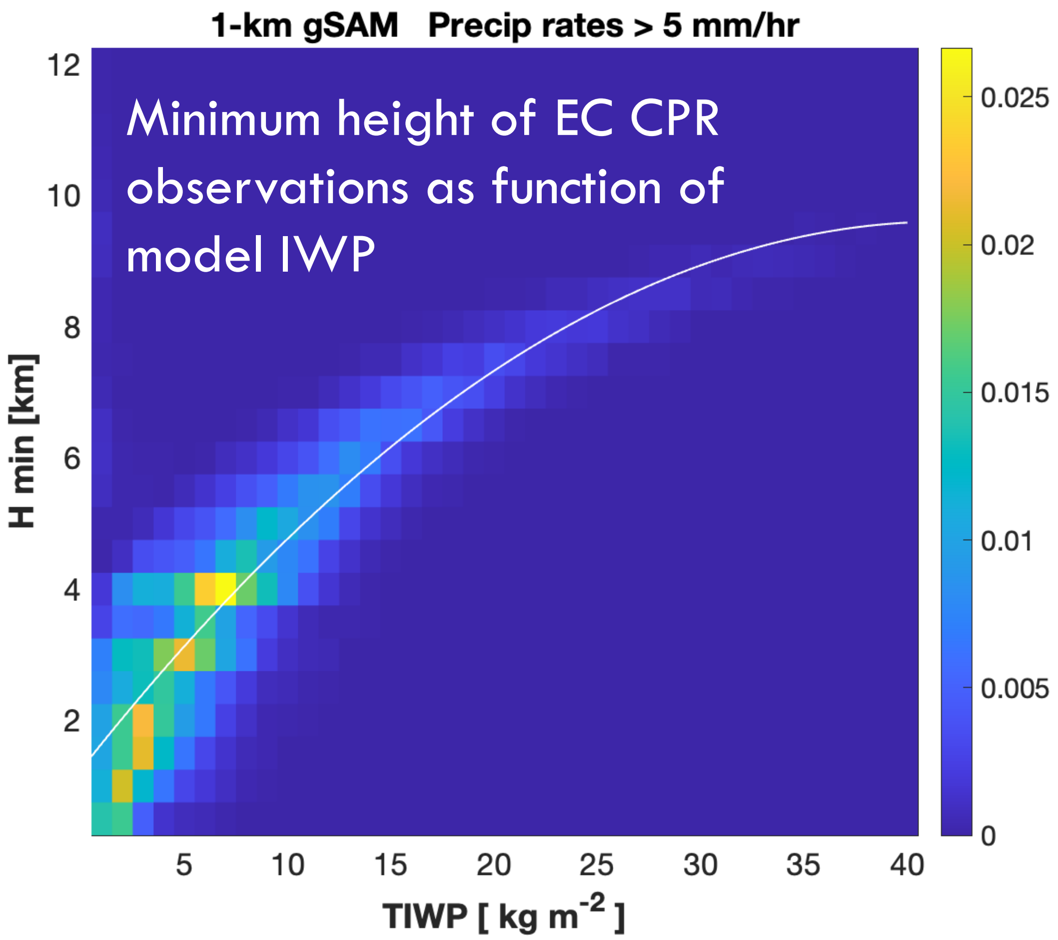


gSAM 1 km simulation
Started from ERA5 and boundaries are nudged to ERA5
4.6S - 18.6N, lon: 174.00E - 221E

9.5% of columns with $V_{max} > 2ms^{-1}$
1.4% of columns with $V_{max} > 5ms^{-1}$
23% of columns with $WP > 0.25\ kgm^{-2}$

EarthCARE CPR fast emulator for GSRMs





Summary

In shallow convection, the CPR excellent resolution (footprint) and sensitivity are expected to resolve shallow and weak updrafts. The challenge is to decompose the VSED and VAM contributions to the observed CPR Doppler velocity.

In deep convection, attenuation (MS) limits the penetration depth of the CPR observations. Yet, unique, global observations of convective motions in the upper (3-4) km of deep convective clouds are expected. The challenge is to perform Doppler velocity unfolding.

NUBF is not a source of concern for the quality of the CPR Doppler velocities in deep convection. The expected uncertainty in the retrieved convective vertical air motion is 1.5 - 2.0 ms^{-1} in shallow convection and 2.0 – 3.0 ms^{-1} in deep convection.

Fast CPR emulators for GSRMs and high resolution regional models should account for the penetration depth in deep convection (i.e., parameterize as a function of IWP) and the sample size of CPR convective motions.