Retrieving 3D cloud microphysical properties over the Azores using scanning radar and zenith radiances

Mark Fielding

Robin Hogan, Christine Chiu and Graham Feingold

ASR Atmospheric System Research

University of Reading

Why do we need 3D observations of warm low clouds?

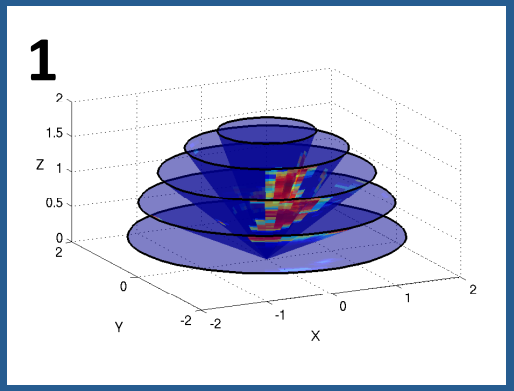
- Clouds are rarely stratiform
- 'Soda straw' view is limited
- Cloud structure affects radiative transfer
- Help provide observational constraints for realistic cloud and radiation parameterizations in global circulation models.

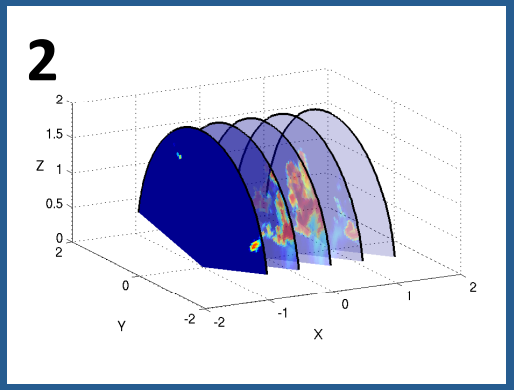
Using SACRs to observe clouds in 3D

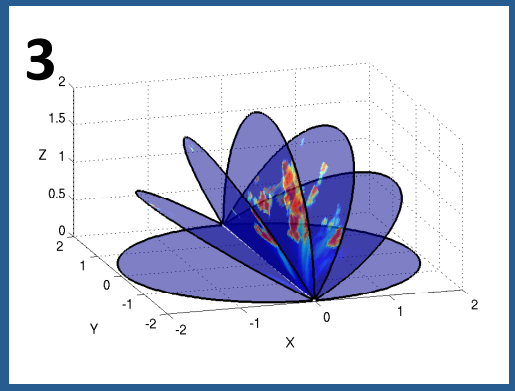
- **Problem 1:** What is the best way to scan?

Scanning cloud radar

Problem 1: Optimise scanning strategy for 3D clouds







PPI (Plan Position Indicator)

- Maximises time in BL
- Captures cloud evolution
- 'Cone of silence'

CWRHI (Cross Wind RHI)

- Frequent visits to zenith
- Minimizes sensitivity errors
- Requires frozen turbulence hypothesis

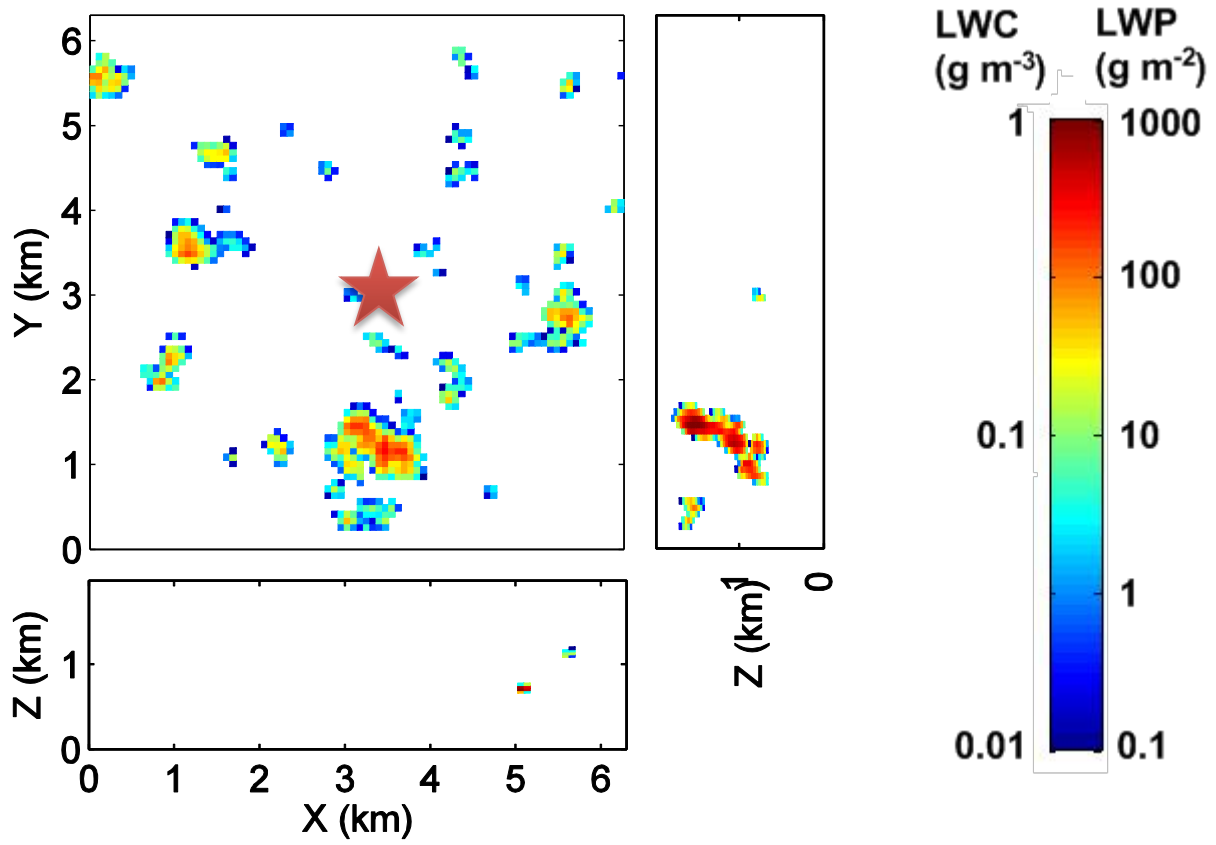
Sydney Opera House (SOHO)

- Best of both?
- Use in low wind conditions?

Fielding et al. 2013 (*JGR*)

Problem 1: Optimise scanning strategy for 3D clouds

Radar sensitivity gives greatest error in reconstructions



Adapted from *Fielding et al.* 2013 (*JGR*)

Using SACRs to observe clouds in 3D

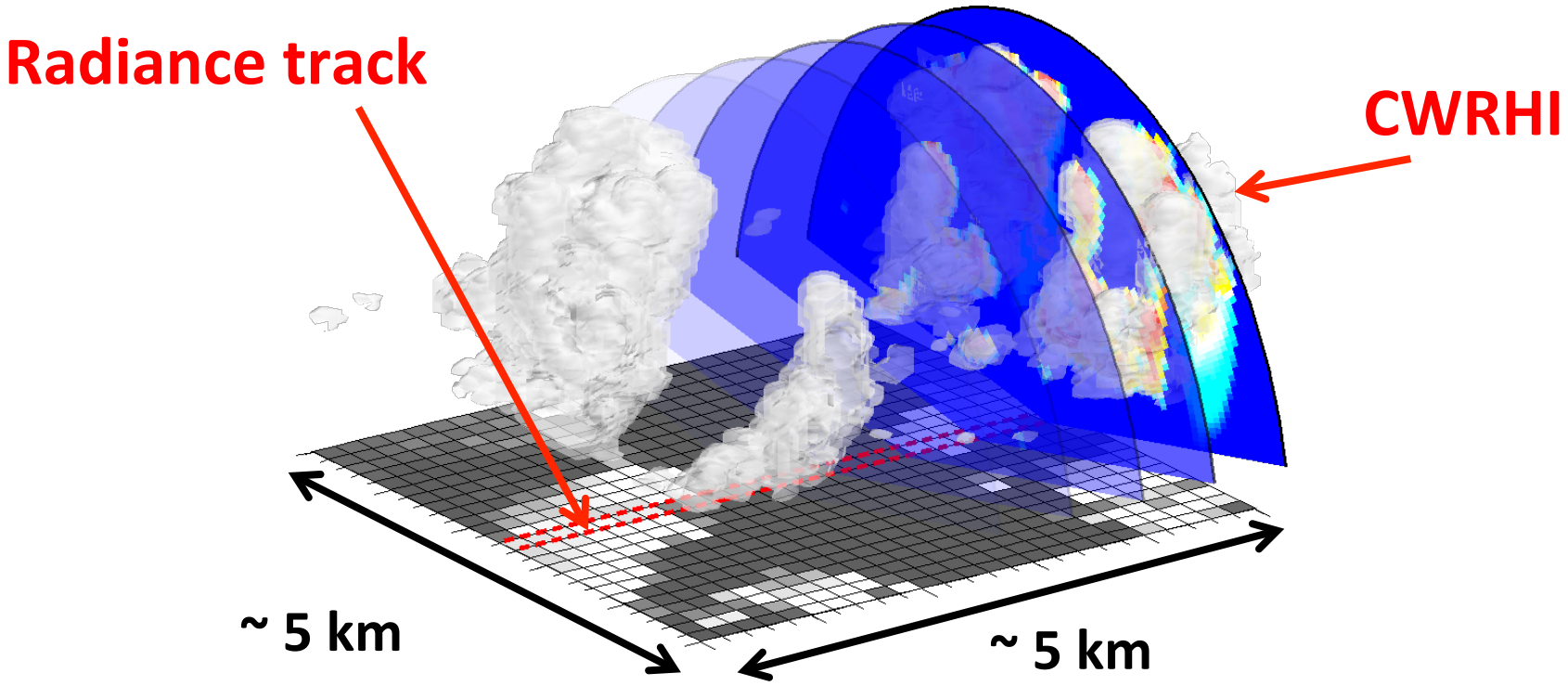
- **Problem 1:** What is the best way to scan?
- **Solution:** Use CWRHI for cloud field snapshot

Scanning cloud radar

- **Problem 2:** SACR provides cloud structure, but droplet size/LWC not constrained
- **Solution:** Synergy with zenith spectral radiances

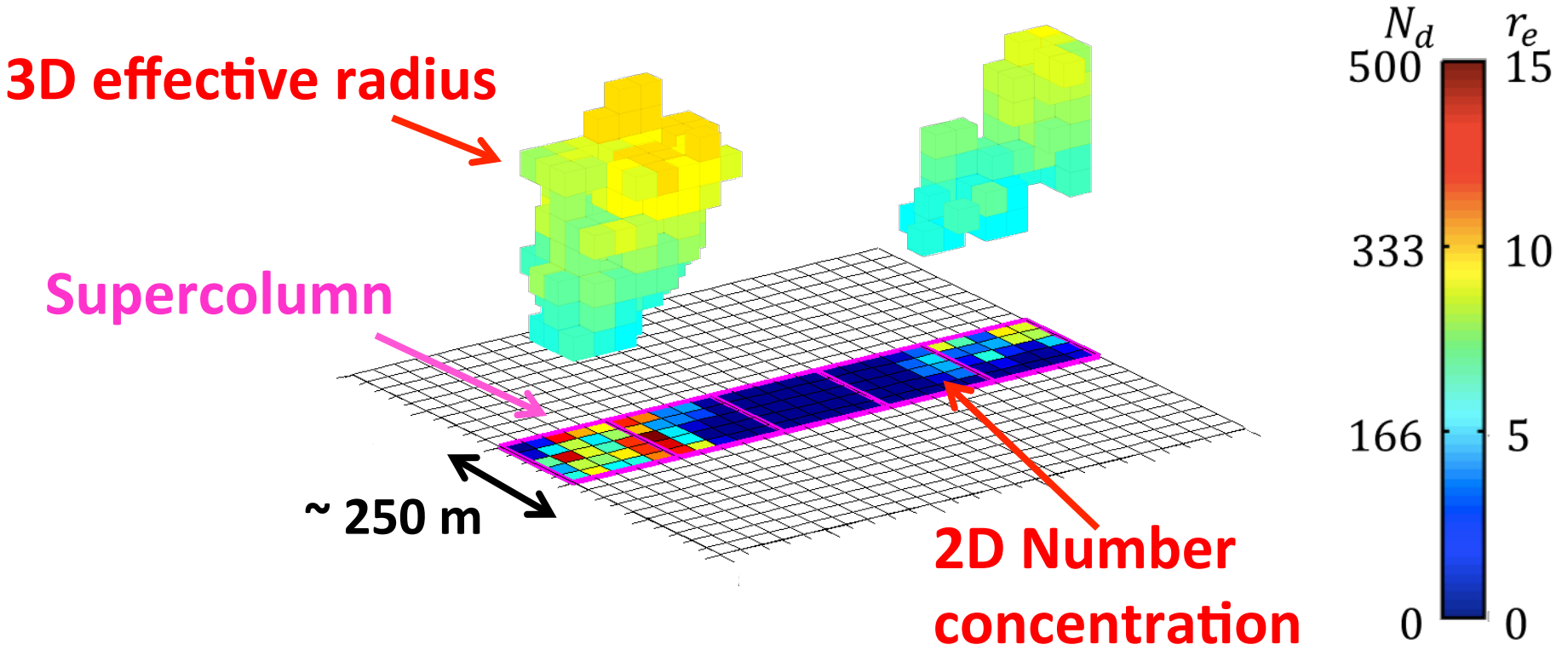
Spectroradiometer

3D ENCORE (ENsemble ClOud REtrieval) Method



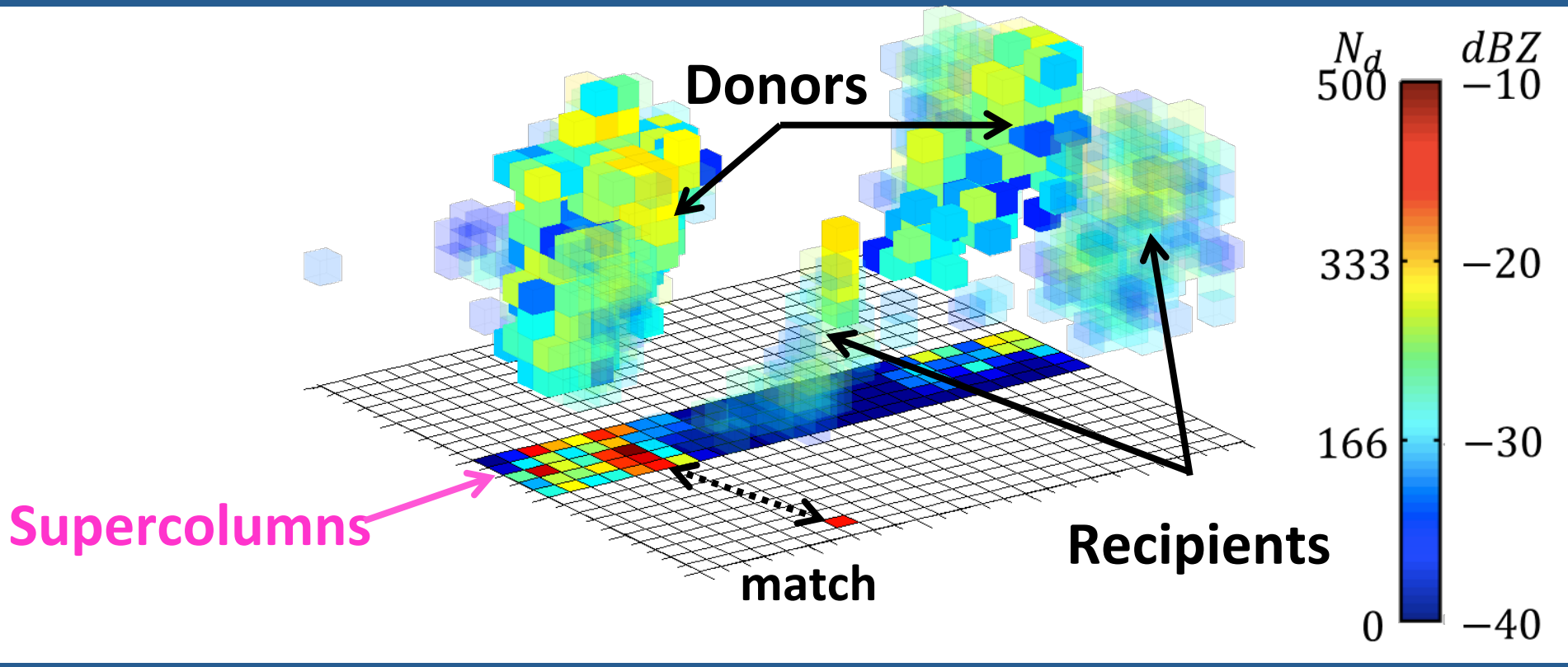
- Zenith radiances mainly constrained by overhead cloud properties -> two step approach

Method – Step 1 (Retrieve within ‘Supercolumn’)

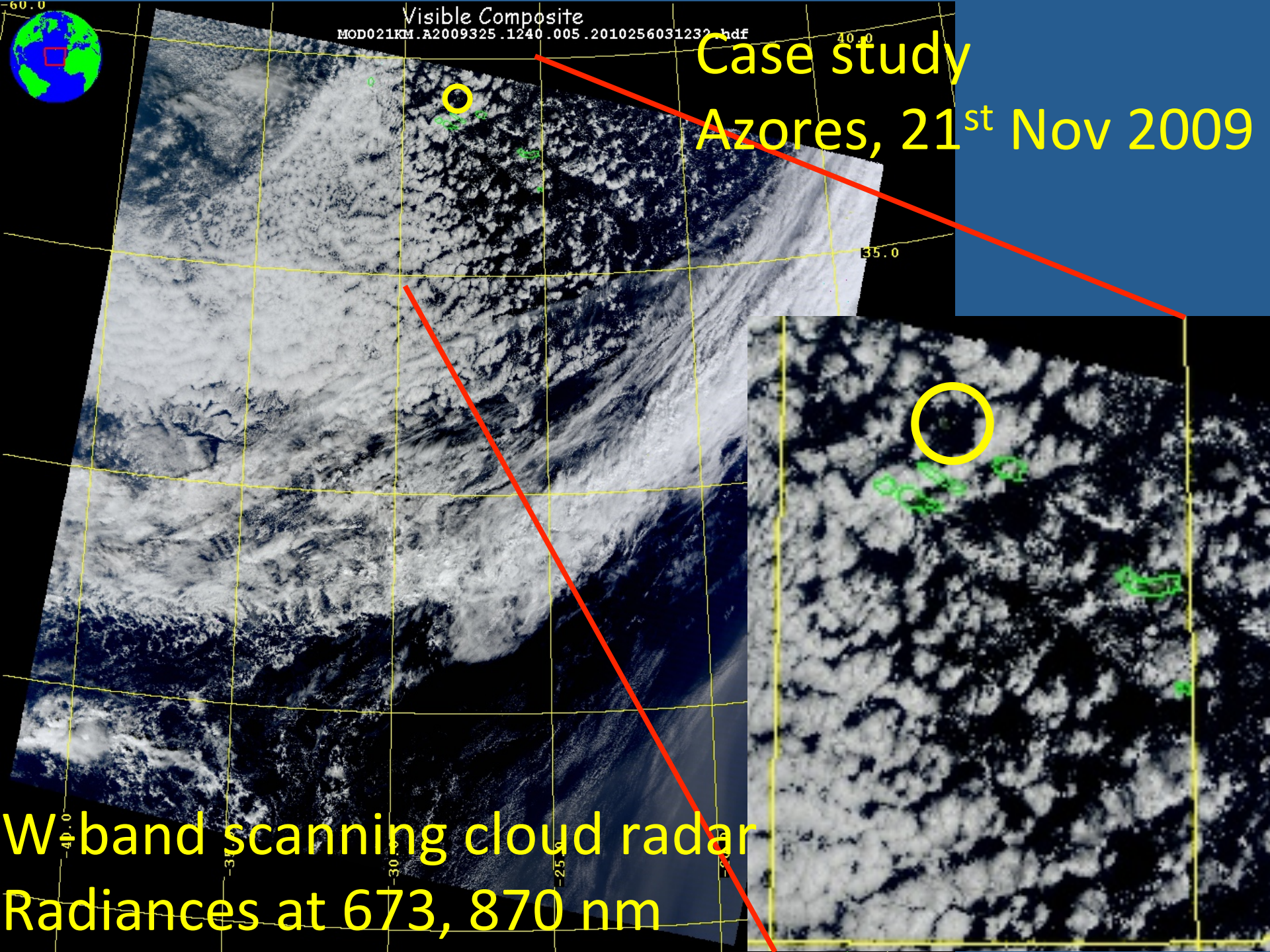


- Use iterative Ensemble Kalman Filter as an optimal estimation framework to retrieve cloud properties – full error statistics
- Use 3D radiative transfer as a radiance forward model
- Assume monomodal lognormal droplet distribution

Method – Step 2 (Reflectivity matching)



- Similar to *Barker et al.* 2011, match columns of radar reflectivity outside the supercolumn (recipients) to columns inside supercolumn (donors).
- Assign donor column's number concentration to recipient column.


Visible Composite
MOD021KM.A2009325.1240.005.2010256031232.hdf
Case study
Azores, 21st Nov 2009
W-band scanning cloud radar
Radiances at 673, 870 nm

Example (1) SCu

Effective radius

Radiance track

LWP

Z (km)

Y (km)

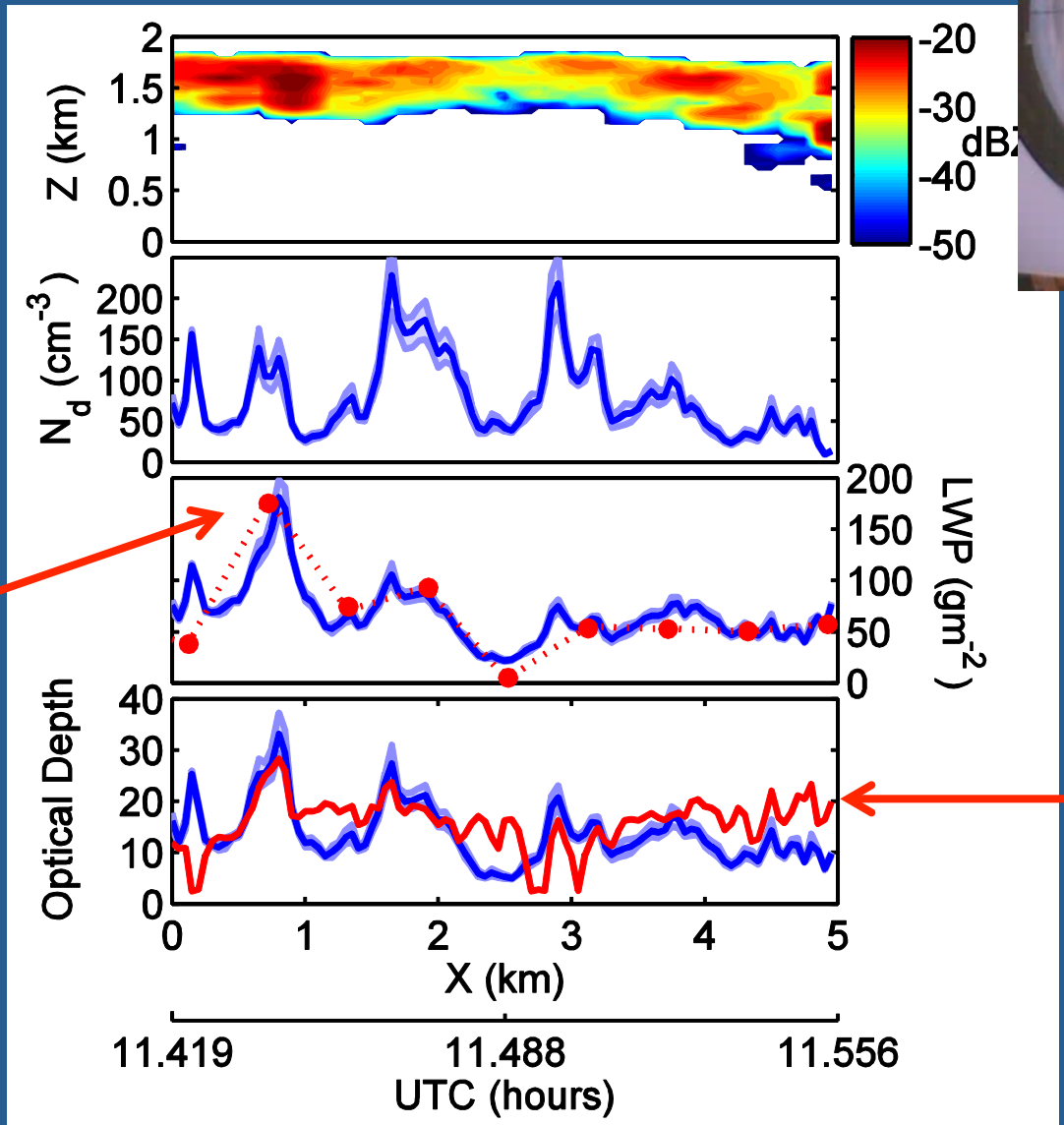
X (km)

Effective radius (μm)

LWP (g m^{-2})

Example (1) SCu

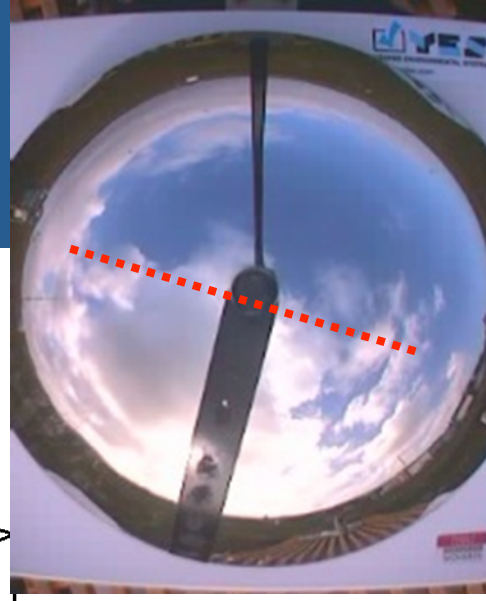
Radiance track

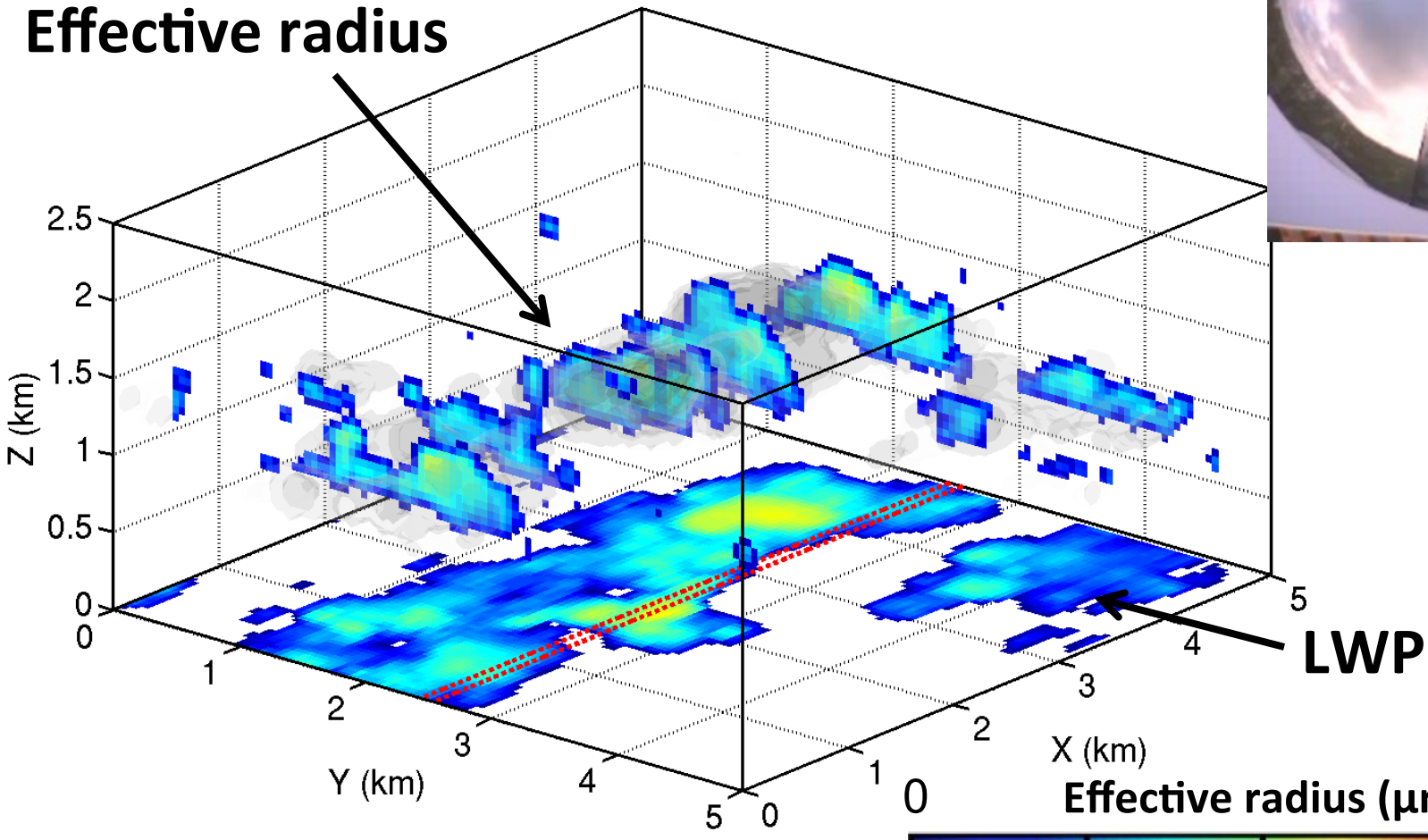


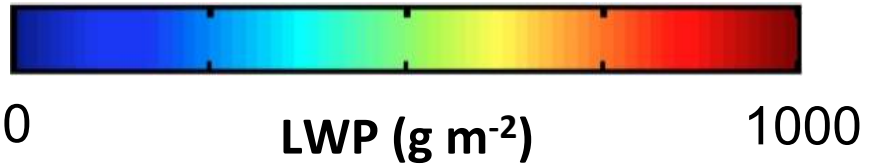
Microwave radiometer retrieval RMSD ~20 g m^{-2}

2NFOV radiance-only retrieval RMSD ~6

Example (2) - Cu



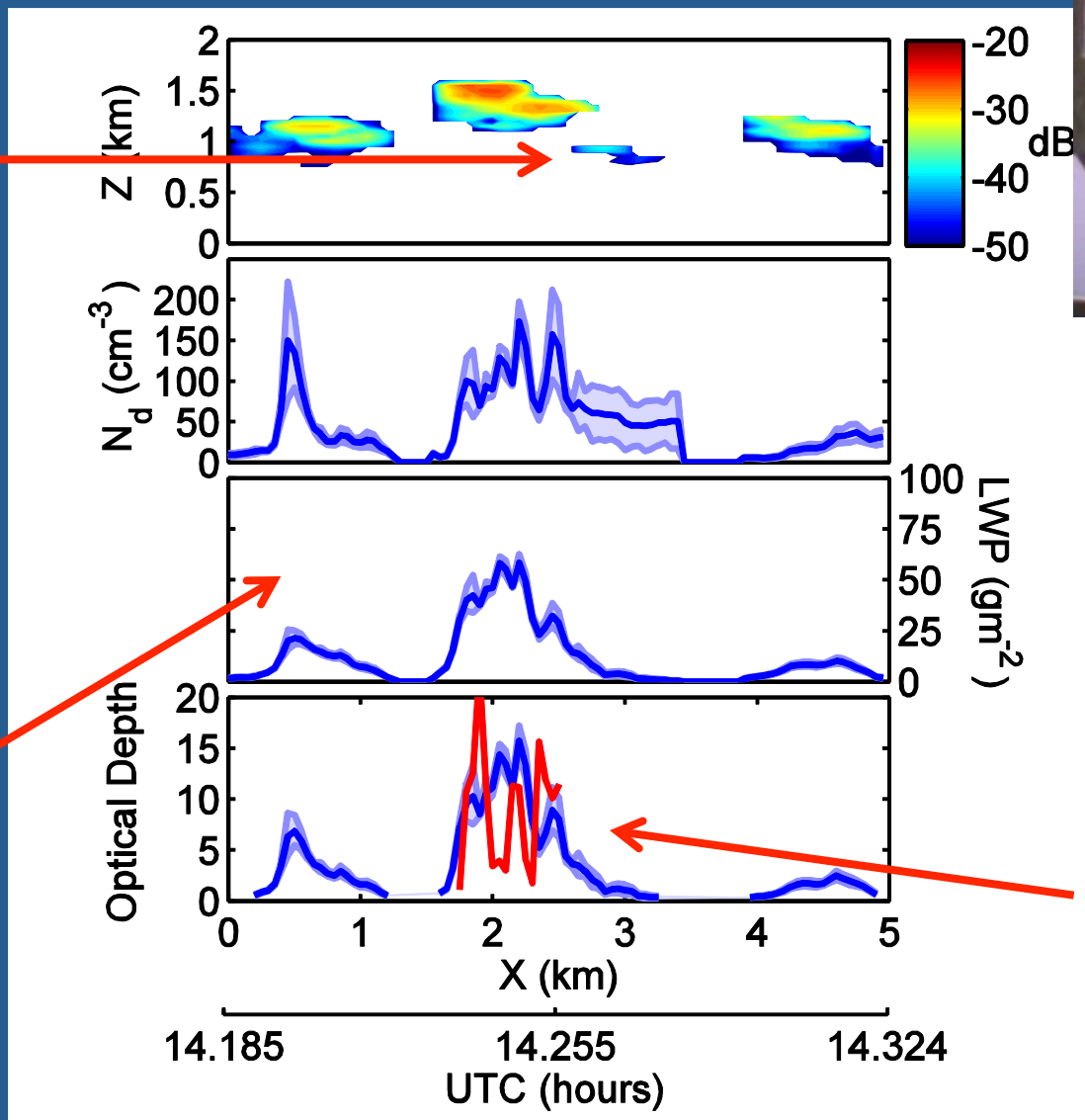

Effective radius
LWP
Z (km)
Y (km)
X (km)
0
0.5
1
1.5
2
2.5
0
1
2
3
4
5


0
Effective radius (µm)
20
0
LWP (g m-2)
1000

Example (2) - Cu

Limit of radar sensitivity

Microwave radiometer retrieval is negative



2NFOV retrieval only physical for larger Cu clouds

Summary

- New method to provide 3D cloud fields in overcast and broken-cloud – key step to understand 3D effects
- Verified using LES shallow cumulus (see poster)
- Good agreement with independent LWP in stratocumulus case
- Flexible ensemble optimal estimation framework