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

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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

1. **PPI (Plan Position Indicator)**
   - Maximises time in BL
   - Captures cloud evolution
   - ‘Cone of silence’

2. **CWRHI (Cross Wind RHI)**
   - Frequent visits to zenith
   - Minimizes sensitivity errors
   - Requires frozen turbulence hypothesis

3. **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
Using SACRs to observe clouds in 3D

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

- **Problem 2**: SACR provides cloud structure, but droplet size/LWC not constrained
  - **Solution**: Synergy with zenith spectral radiances
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.
Case study
Azores, 21st Nov 2009

W-band scanning cloud radar
Radiances at 673, 870 nm
Example (1) SCu

Effective radius

Radiance track

LWP

Effective radius (μm)

LWP (g m⁻²)
Example (1) SCu

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

Radiance track

2NFOV radiance-only retrieval
RMSD ~6
Example (2) - Cu

Effective radius
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