Motivation

- Accurate representation of clouds and their radiative impact is essential for robust climate change predictions.
- To improve cloud formulations, we must move away from the ‘soda-straw’ view to a new three-dimensional (3D) paradigm.
- The new Ka/W-Band ARM scanning radars provide a unique opportunity to make this jump.

Radiative transfer scheme

- Surface downwelling fluxes are calculated using the Spherical Harmonics Discrete Ordinates Method (SHDOM) in full 3D mode.
- Reconstructions have a resolution of 75 m in the horizontal and 30 m in the vertical.
- All calculations in this poster are monochromatic at 870 nm, use a solar zenith angle of 45° and 950 W m⁻² µm⁻¹ direct beam.

Scan strategies

- Each scan mode takes 5 min to complete.
- We use ~37.5 dBZ at 1 km as a ‘realistic’ radar sensitivity.

Modelled cumulus cloud fields

- Snapshots taken from a LES model with bin microphysics using Rain In Cumulus over Ocean (RICO) forcing.
- ‘Clean’ and ‘Polluted’ cloud fields allow us to test for a range of droplet sizes, cloud size and cloud fraction.
- ‘Clean’ case has larger droplet sizes and some drizzle, whereas ‘Polluted’ case has smaller clouds and sharper cloud edges.

Realistic radar sensitivity reduces apparent cloud sizes

Polluted case gives largest errors

- Smaller droplets make clouds more difficult to detect
- CWRHI minimises errors due to radar sensitivity

Polluted case with infinite sensitivity 'Polluted' reconstruction; middle, liquid water path (LWP g m⁻³) right and bottom show liquid water content (LWC g m⁻³) profiles for X=3.3 km and Y=0.3 km respectively. (b) same but for ‘Polluted’ case with Ny=1000 cm⁻².

Figure 2. a) ‘Clean’ case with initial aerosol number concentration Na=1000 cm⁻³ middle, liquid water path (LWP g m⁻³) right and bottom show liquid water content (LWC g m⁻³) profiles for X=3.3 km and Y=0.3 km respectively. (b) same but for ‘Polluted’ case with Ny=1000 cm⁻².

Figure 3. a) PPI with infinite sensitivity ‘Polluted’ reconstruction; middle, liquid water path (LWP g m⁻³) right and bottom show liquid water content (LWC g m⁻³) profiles for X=3.3 km and Y=0.3 km respectively. (b) same but with realistic sensitivity. (c) and (d) show the difference in the downwelling flux with the reconstruction used in (a) and (b) respectively.

A. Missed cloud edges cause areas of increased surface radiation underneath them.
B. Missed cloud edges cause a decrease in diffuse flux to the rest of the domain.

Conclusions

- The best scan strategy for cumulus clouds is PPI or CWRHI.
- If droplet sizes are small, CWRHI performs best.
- Errors suggest a broken-cloud radiation closure experiment is possible.

Droplet size unconstrained in drizzle

- Using a Z=a*LW² retrieval is not appropriate; need a better retrieval or restrict analysis to drizzle-free clouds.
- Large underestimates in domain averaged flux of 4-6%

Sampling errors are relatively small

- Bias due to the reconstruction algorithm is less than 1%
- Square-root interpolation superior to linear interpolation

Figure 4. Surface flux errors in reconstructions from different scan strategies using realistic radar sensitivity.

Table 1. Summary of errors in surface downwelling flux (W m⁻² µm⁻¹) introduced by various sources for the clean and polluted case, based on the PPI scan mode. Brackets are a difference in error due to sampling / reconstruction only.

<table>
<thead>
<tr>
<th>Source of error</th>
<th>Clean</th>
<th></th>
<th>Polluted</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bias</td>
<td>RMSE</td>
<td>Bias</td>
<td>RMSE</td>
</tr>
<tr>
<td>Sampling / Reconstruction</td>
<td>-0.6</td>
<td>65.8</td>
<td>+3.4</td>
<td>91.1</td>
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<tr>
<td>Realistic radar sensitivity</td>
<td>+7 (-8)</td>
<td>86 (21)</td>
<td>+20 (+16)</td>
<td>155 (64)</td>
</tr>
<tr>
<td>Frozen turbulence</td>
<td>-2 (-1)</td>
<td>105 (39)</td>
<td>+3 (0)</td>
<td>111 (20)</td>
</tr>
<tr>
<td>Imperfect LWc retrieval</td>
<td>-20 (-19)</td>
<td>172 (106)</td>
<td>+3 (0)</td>
<td>97 (6)</td>
</tr>
</tbody>
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