3D cloud reconstructions from scanning radar simulations for shortwave radiation closure

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Fielding et al. (submitted, JGR) and further info
http://www.met.reading.ac.uk/~rj021286

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.

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.

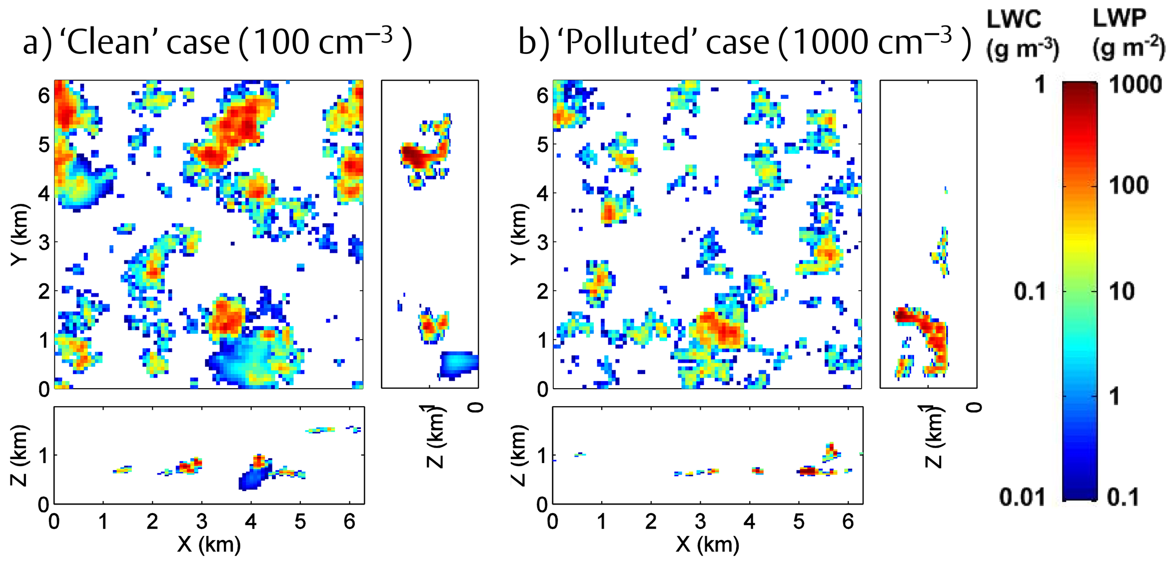

Figure 2. a) 'Clean' case with initial aerosol number concentration N_a=100cm^{-3}; middle, liquid water path (LWP g m^{-2}); right and bottom show liquid water content (LWC g m^{-3}) profiles for X=3.1 km and Y=3.1 km respectively. (b) same but for 'Polluted' case with N_a=1000cm^{-3}.

Scan strategies

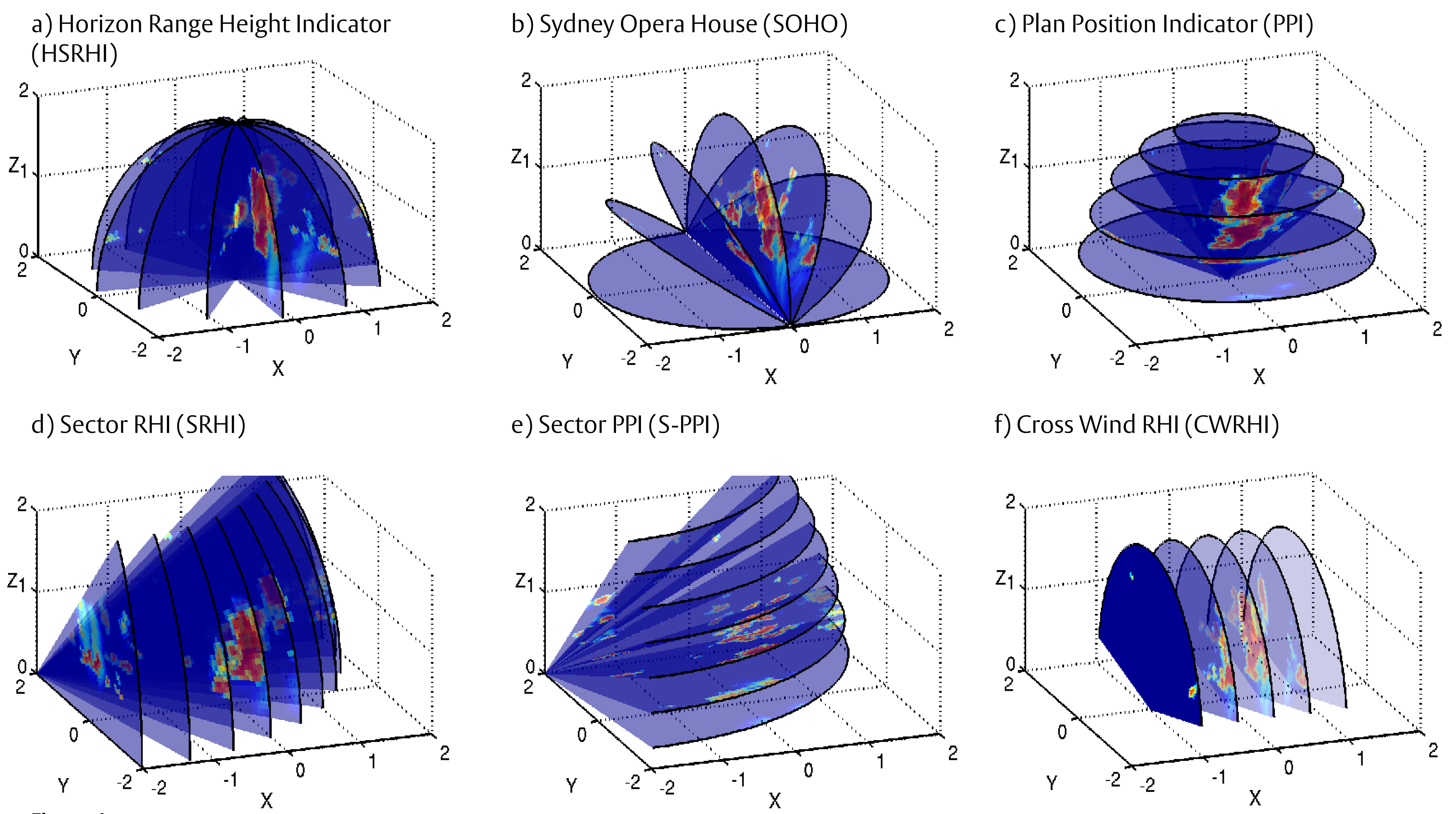

Figure 1.

- Each scan mode takes 5 min to complete.
- We use −37.5 dBZ at 1 km as a 'realistic' radar sensitivity.
- We use a single snapshot of the modelled cloud field and assume Taylor's frozen turbulence hypothesis, with clouds advecting across the domain at a constant wind speed.
- Errors due to attenuation and beamwidth are neglected

Realistic radar sensitivity reduces apparent cloud sizes

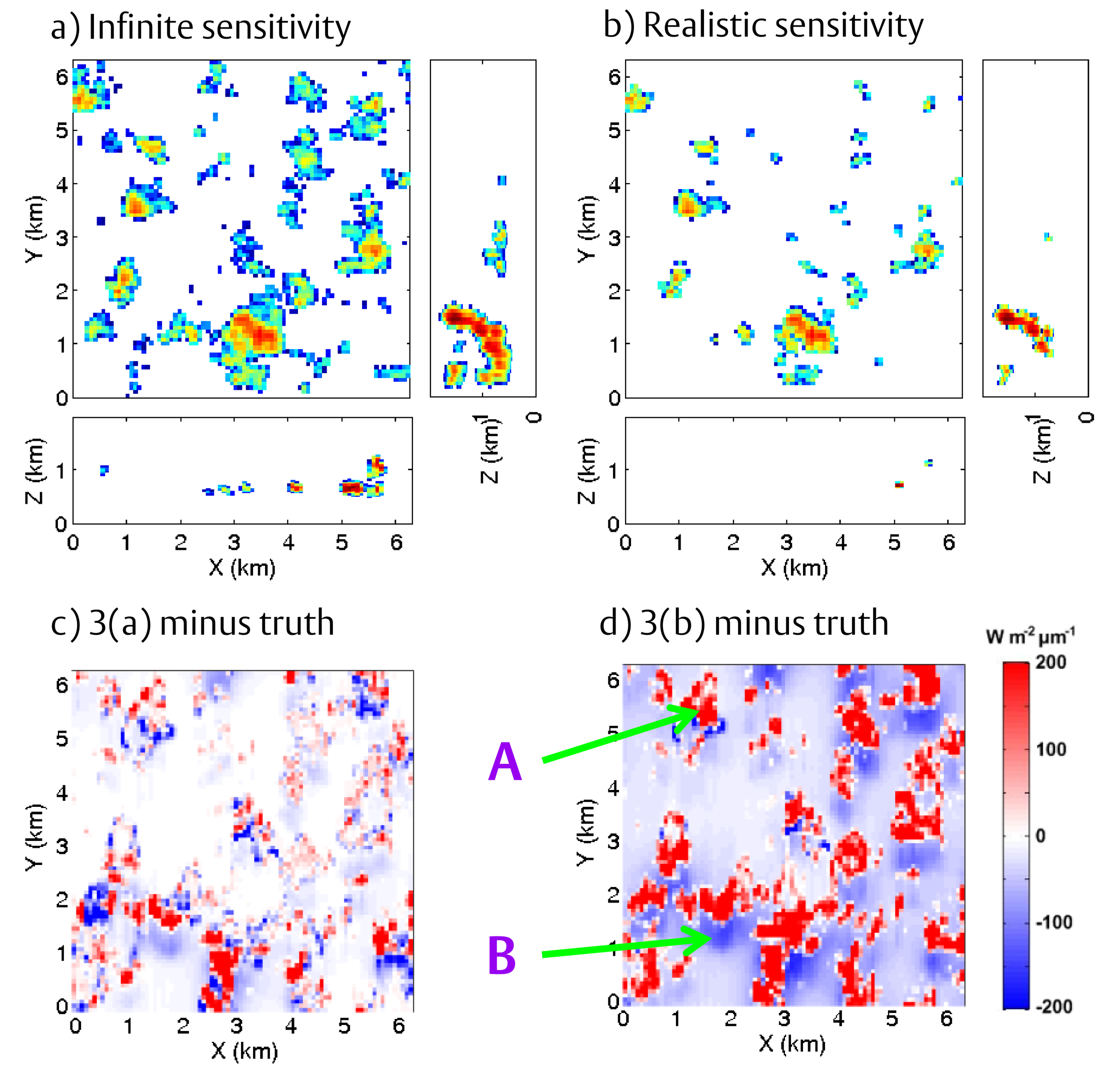

Figure 3. a) PPI with infinite sensitivity 'Polluted' reconstruction; middle, liquid water path (LWP g m^{-2}); right and bottom show liquid water content (LWC g m^{-3}) profiles for X=3.1 km and Y=3.1 km respectively, see Fig 2 for colour scale. (b) same but with realistic sensitivity. (c) and (d) show 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.

Polluted case gives largest errors

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

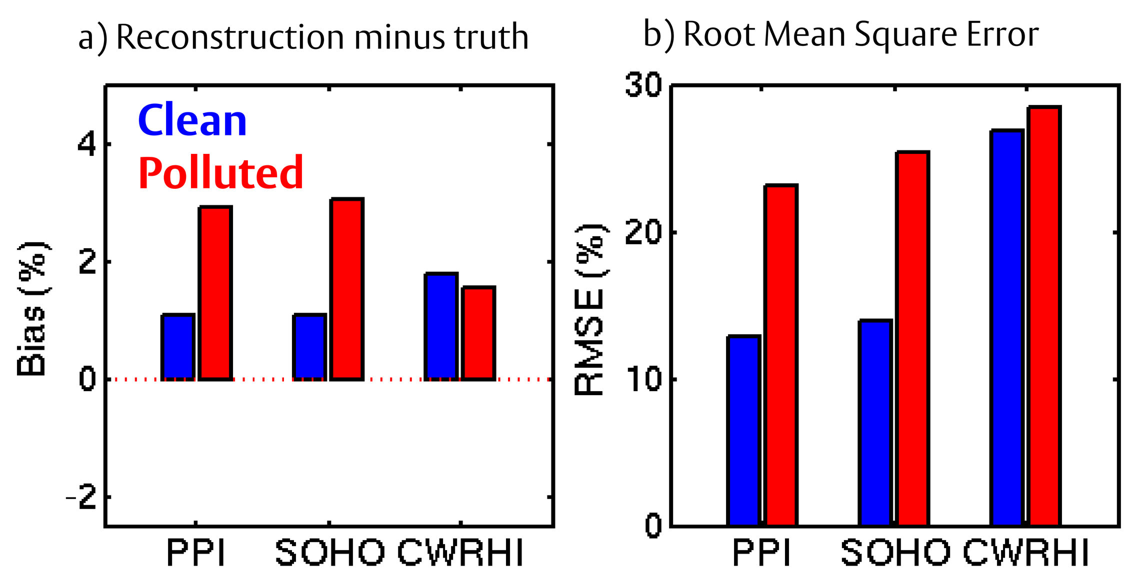

Figure 4. Surface flux errors in reconstructions from different scan strategies using realistic radar sensitivity.

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

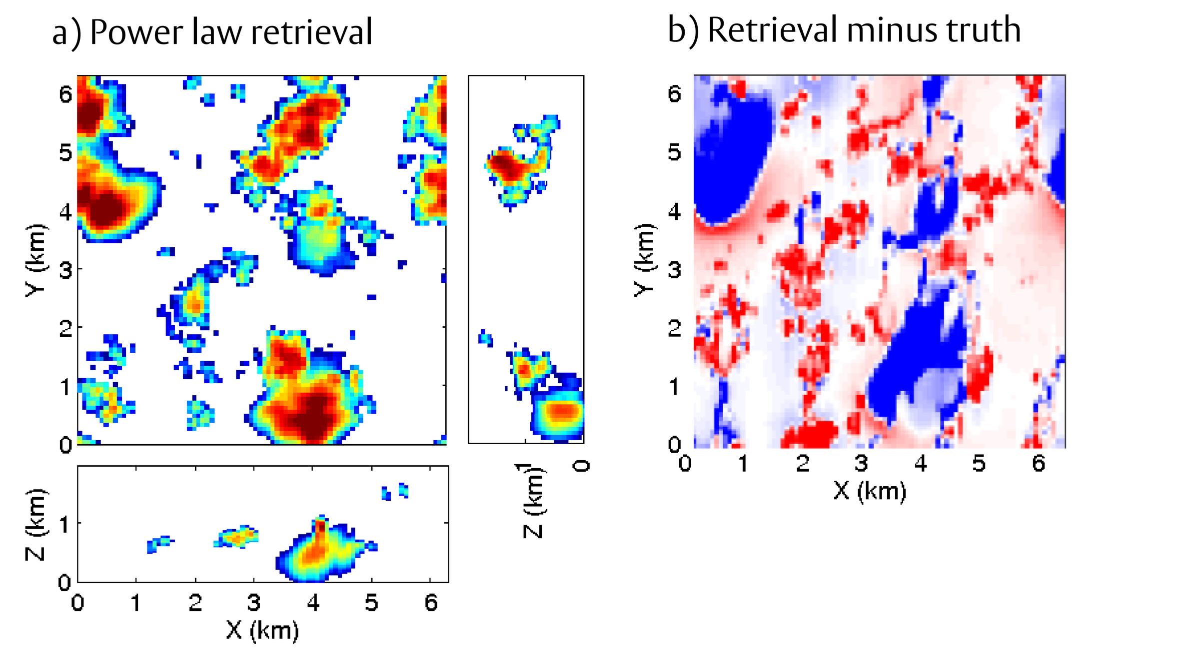

Figure 5. Effect of using power-law retrieval in drizzle. a) PPI infinite sensitivity 'Clean' reconstruction using power-law retrieval. b) difference in surface dowelling flux with a) and truth. See Fig 2 and 3 for colour scales.

Sampling errors are relatively small

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

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 difference from error due to sampling / reconstruction only .

Source of error	Clean		Polluted	
	Bias	RMSE	Bias	RMSE
Sampling / Reconstruction	−0.6 (–)	65.8 (–)	+3.4 (–)	91.1 (–)
Realistic radar sensitivity	+7 (+8)	86 (21)	+20 (+16)	155 (64)
Frozen turbulence	−2 (−1)	105 (39)	+3 (0)	111 (20)
Imperfect LWC retrieval	−20 (−19)	172 (106)	+3 (0)	97 (6)