Cumulus population and microphysical properties retrieved from a synergy of scanning radar and shortwave zenith radiances over Southeast Atlantic

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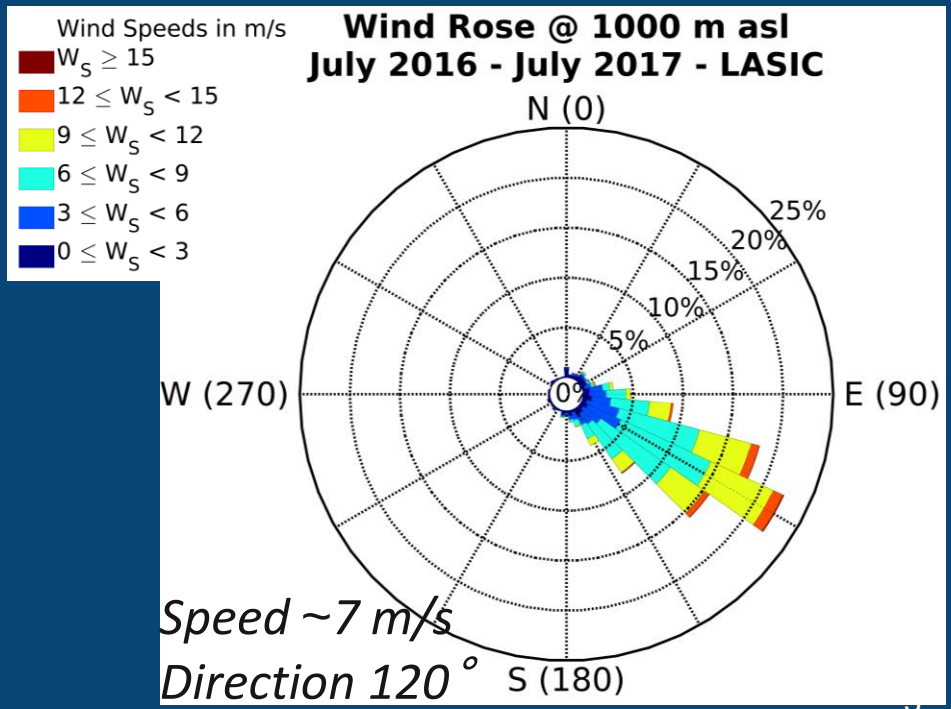
Why we observe cumulus over Southeast Atlantic

- Marine cumulus play an important role on Earth's radiation budget and affect boundary layer structure
- Cumulus population, lifetime and probability of precipitation are sensitive to shortwave-absorbing aerosol
- Representation of cumulus processes and interactions with radiation is challenging because of their high heterogeneity and their small size and cover
- 3D fields and microphysical properties could help low-cloud parametrization efforts for GCMs

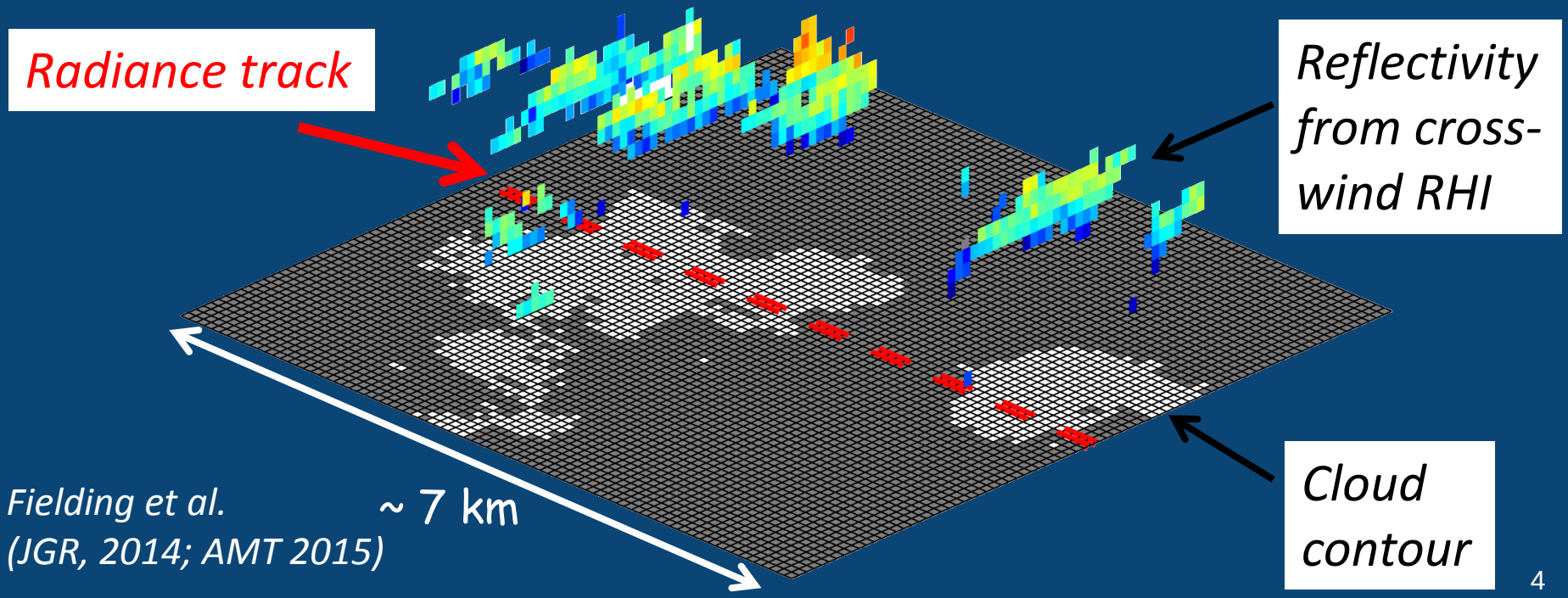
Data used in the study

- ARM Mobile Facility LASIC deployment (July 2016 – October 2017)
- Airport site (76 m)
  - *Ceilometer and radiosonde*
- ARM main site (341 m)
  - *Ka-band cloud radars, shortwave radiometers*
  - *Scanning for 13 min every hour (mid July – end Sept 2017)*



Ensemble Cloud Retrieval (ENCORE)

- Combine scanning cloud radar and zenith radiances
- Include 3D radiative transfer as a forward model
- Use the Iterative Ensemble Kalman Filter as an optimal estimation framework
- Tested for St, Sc and Cu over Azores, Pacific and West Africa

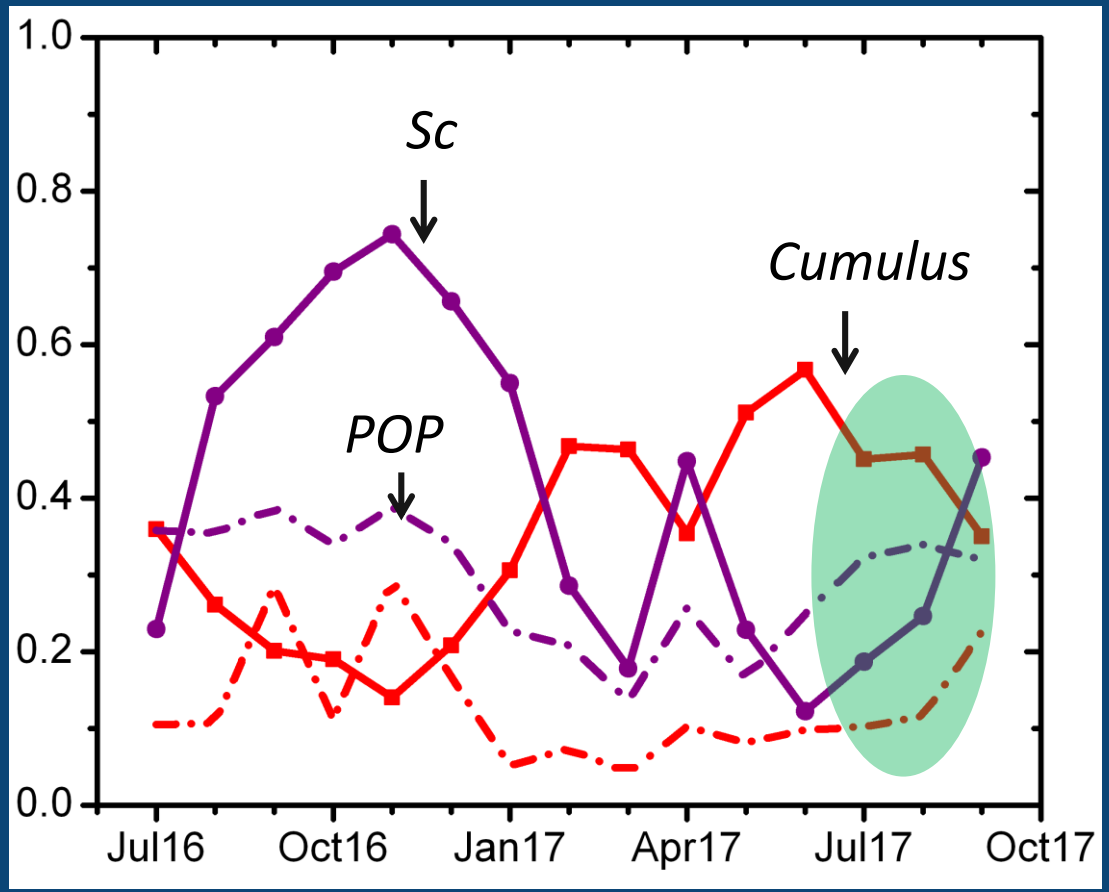


Fielding et al.
(JGR, 2014; AMT 2015)

Occurrence of cloud type and precipitation

- Use radar obs. for cloud type classification *[Rémillard et al,2012]*

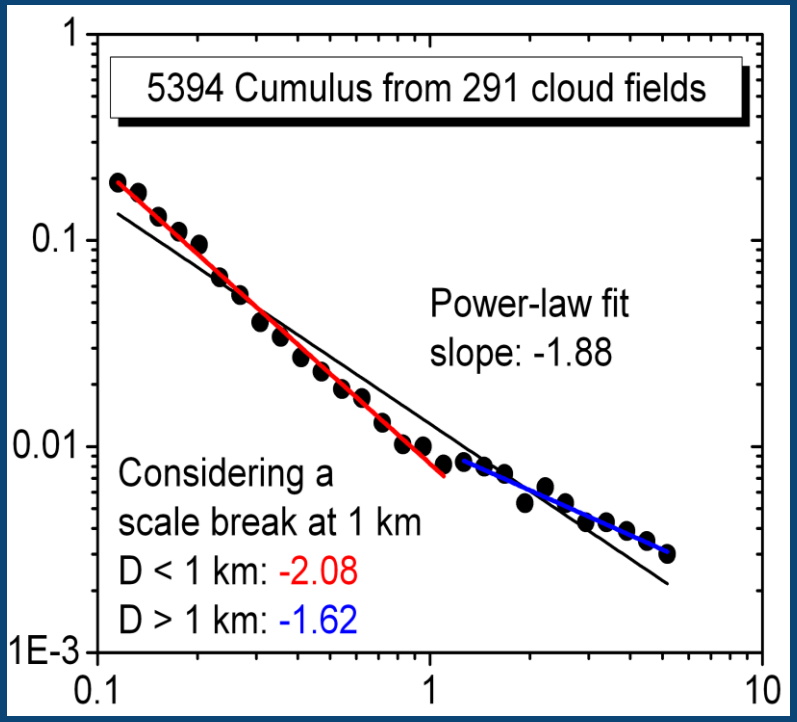
Occurrence



- Cumulus occurs more often in February to July
- Define possibility of precipitation (POP) = # of rainy / # of cloudy
- POP for cumulus is about 5 -30 %

Cumulus size distribution and organization from scanning (3D) obs. for two-month data

Normalized frequency

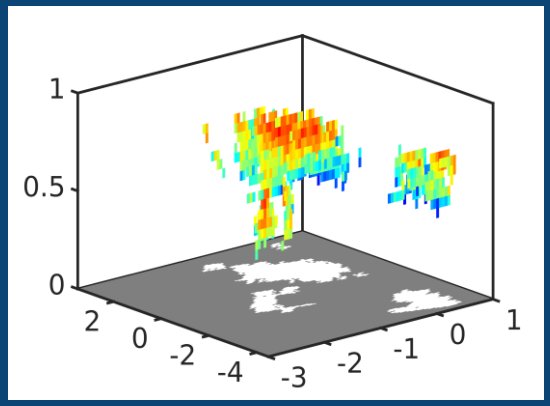


Cloud diameter (km)

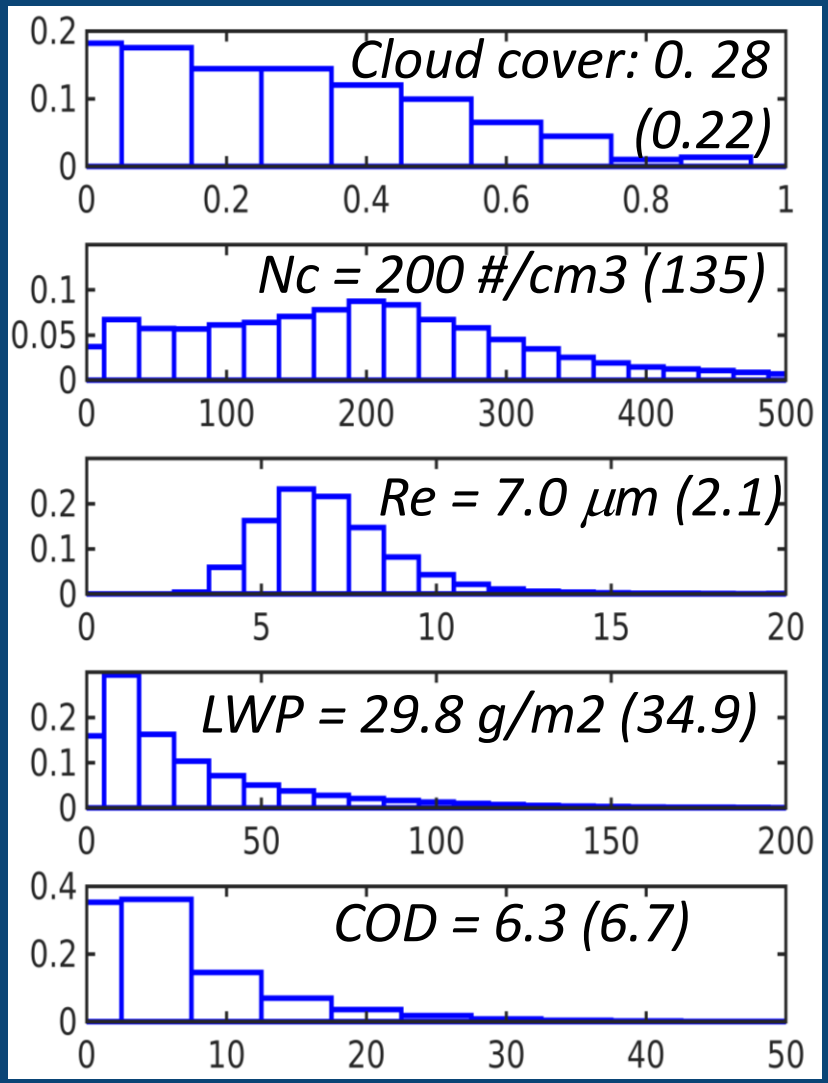
- Cloud size distribution and organization are related to cloud cover and albedo, precipitation, 3D LW radiative effect
- Reconstructed cloud fields follows a power-law relationship, with a scale-break at 1km. Slope smaller than RICO
- Peak in nearest neighbor distance at 400m, more than RICO

Microphysical properties from ENCORE3D

291 retrieved non-precipitating Cumulus fields

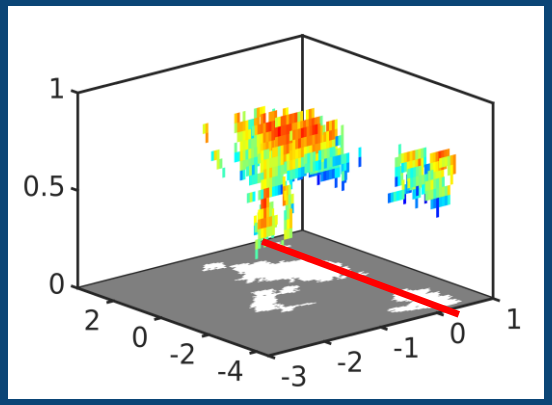


Statistics over 43 days

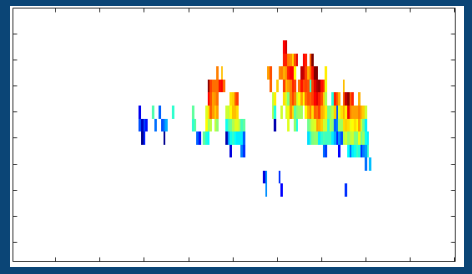


Address sampling and 3D effects on retrievals

291 retrieved non-precipitating Cumulus fields



Slice



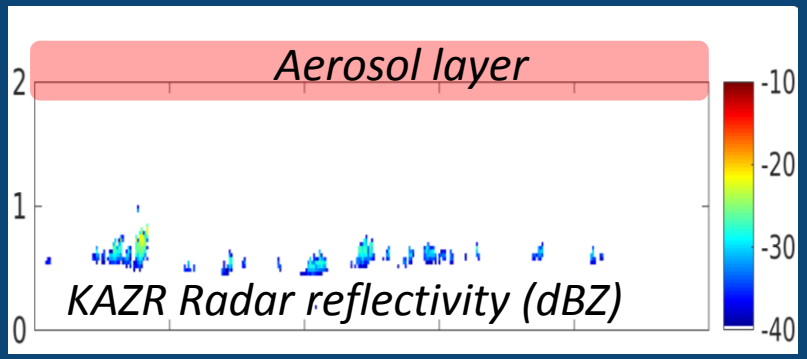
Sampling effect

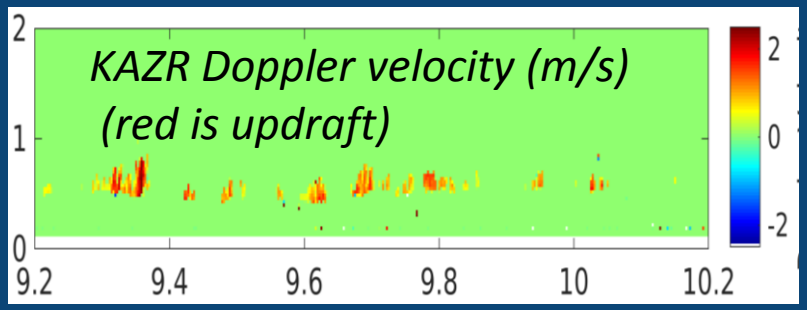
Run 1D RT model

3D effects

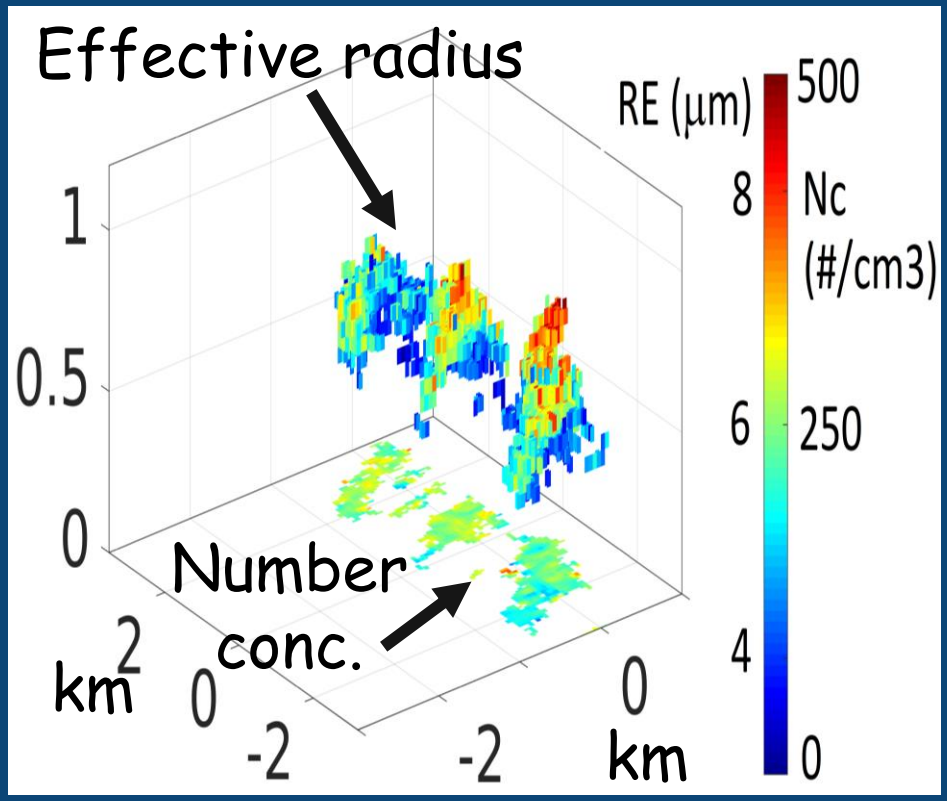
- Sampling effect: Limited impact on retrieved quantities (<5%) but cloud fraction is higher by 70%
- Neglecting the 3D effects cause an underestimation of effective radius (10%) and overestimation of number concentration (20%)
- 3D retrievals can close radiation to 10% vs. 70% for 1D

Microphysical properties from synergistic obs. on 24 July 2017





Height (km)



Summary

- **291 cumulus scenes retrieved from scanning cloud radar observations were analyzed.**
- **The cloud population of these 3D reconstructed fields follows a power-law relationship, with a scale-break at 1km, as found in 2D satellite images, but with opposite pattern.**
- **Cumulus sizes are generally small with small liquid water path (75% got less than 35 g/m2). Droplet effective radii (mean value ~7 μm) are also slightly smaller than those from RICO and Nauru.**
- **Preliminary study shows that our 3D retrieval can close radiation to ~10%, while retrieval from 1D-view leads to ~70% errors, compared to MFRSR.**