The Performance of the EarthCARE Cloud Profiling Radar in Marine Stratiform Clouds

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Background

• Marine stratiform clouds play a critical role in Earth’s climate, due to large horizontal coverage, high albedo [1], and regulating effect on marine boundary layer [2]

• Evaluation of marine stratiform clouds in climate models require large scale observational datasets – challenging to conduct from ground-based platforms

• Spaceborne observations offer global coverage and thus are key for monitoring properties of marine clouds

1) Hartman et al., 1992. 2) Stephens et al., 2003
EarthCARE

• Earth Clouds, Aerosols and Radiation Explorer (EarthCARE) Cloud Profiling Radar (EC-CPR):
  • First spaceborne radar with Doppler capability
  • 94 GHz, 2.5 m antenna
  • Improved vertical sampling rate (100 m) and sensitivity (-36 dBZ) compared to CloudSat (240 m and -30 dBZ [4])

• Space-based observations of marine stratus are challenging
  • Receiver noise and surface echoes mask weak cloud and drizzle signals
  • Velocity estimation affected by aliasing, non-uniform beam filling [5], and antenna mispointing [6]

3) Illingworth et al., 2015. 4) Tanelli et al., 2008. 5) Tanelli et al., 2004. 6) Battaglia and Kollias, 2015
Aims

• Here, we investigate how well the EC-CPR captures marine stratiform properties: cloud fraction, boundaries, reflectivity, and Doppler velocity

• EC-CPR simulator produces EC-CPR observations from ground-based radar input data

• Simulated and “true” data are then compared to identify uncertainties and biases
Input data

• Data from ARM Mobile Facility deployments at Graciosa Island, Azores (GRW), and in MAGIC campaign are used as input to simulator

• Observations made from W-band ARM Cloud Radar (WACR) and Marine-WACR (M-WACR)
  • 95 GHz
  • 42 m (GRW) and 21 m (MAGIC) vertical resolution
  • 2 s (GRW) and 0.2 s (MAGIC) integration times
Simulator

- Simulator is as used in Kollias et al. (2014)
- EC-CPR effects added to input data
  - Antenna pattern and range-weighting function
  - Doppler bias due to satellite motion
  - Surface echo
  - Receiver noise (-21 dBZ)
- Velocity corrected for NUBF effects
- V, Z estimates integrated horizontally to reduce effect of noise
Results
Results

- Average cloud fractions over >100 hrs of observations:
  - Lidar: 94 %
  - WACR: 91 %
  - EC-CPR: 49 %, 51 %, 67 %, 75 % (500 m, 1 km, 5 km, 10 km integrations)

- Simulated and true cloud top:
  - RMSD: 73 m
  - Mean difference: 16 m
Impact of sampling volume and surface echo
Impact of sampling volume and surface echo

Limited detection and stretching of thin clouds by EC-CPR shifts cloud peak upwards.

Surface echo masks deep drizzle, shifts drizzle peak down.

The WACR distribution shows two peaks – cloud and drizzle.
Impact of sampling volume and surface echo
Doppler velocity

- RMSD at 1 km and 5 km integrations for SNR>1

- GRW case:
  - 1 km integration: 0.94 ms\(^{-1}\) (1.28 ms\(^{-1}\))
  - 5 km integration: 0.47 ms\(^{-1}\) (0.57 ms\(^{-1}\))

- MAGIC case:
  - 1 km integration: 1.20 ms\(^{-1}\) (1.48 ms\(^{-1}\))
  - 5 km integration: 0.68 ms\(^{-1}\) (0.79 ms\(^{-1}\))
Summary

- Marine stratiform clouds are an important target for the EarthCARE-CPR, yet weak reflectivity and low altitude make them challenging also.
- EC-CPR marine stratus cloud observations are simulated using real cloud scenes.
- EC-CPR detects around 50% of marine stratus observed by ground-based radar at 500 m sampling, rising to around 90% for 10 km sampling.
- Presence of surface echo severely restricts observations below 800 – 900 m.
- Uncertainties of approx. 1 ms$^{-1}$ in Doppler velocity at 1 km integration.
- 5 km integration required to reduce error to approx. 0.5 ms$^{-1}$. 
Questions?
References


References


Feature mask

- Feature mask algorithm distinguishes true signals from those due to noise
- Composed of binary mask, surface identification, and along-track smoothing filter
- Mask is array of same size as reflectivity field – value of 1 (significant signal) or 0 (noise)
- Binary mask:
  - Noise level calculated in each vertical profile according to Hildebrand and Sekhon (1974)
  - If $P > P_N + 3\sigma_N$, mask is set to 1
- Effect of surface returns removed by comparison with clear sky case
- Along-track smoothing filter reduces false positives and false negatives
## CloudSat-CPR

<table>
<thead>
<tr>
<th>Parameter</th>
<th>EC-CPR</th>
<th>CS-CPR</th>
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<tbody>
<tr>
<td>Frequency (GHz)</td>
<td>94</td>
<td>94</td>
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<tr>
<td>Antenna diameter (m)</td>
<td>2.5</td>
<td>1.85</td>
</tr>
<tr>
<td>Altitude (km)</td>
<td>400</td>
<td>700</td>
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<tr>
<td>Range resolution (m)</td>
<td>500</td>
<td>500</td>
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<tr>
<td>Vertical sampling rate (m)</td>
<td>100</td>
<td>250</td>
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<tr>
<td>Horizontal sampling rate (km)</td>
<td>0.5 – 10</td>
<td>1.1</td>
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<tr>
<td>Sensitivity (dBZ)</td>
<td>-36 (10km integration)</td>
<td>-30</td>
</tr>
<tr>
<td>Beamwidth (degrees)</td>
<td>0.095</td>
<td>0.12</td>
</tr>
<tr>
<td>PRF (kHz)</td>
<td>6.1 – 7.5</td>
<td>3.7 – 4.3</td>
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