# 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 strati 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]

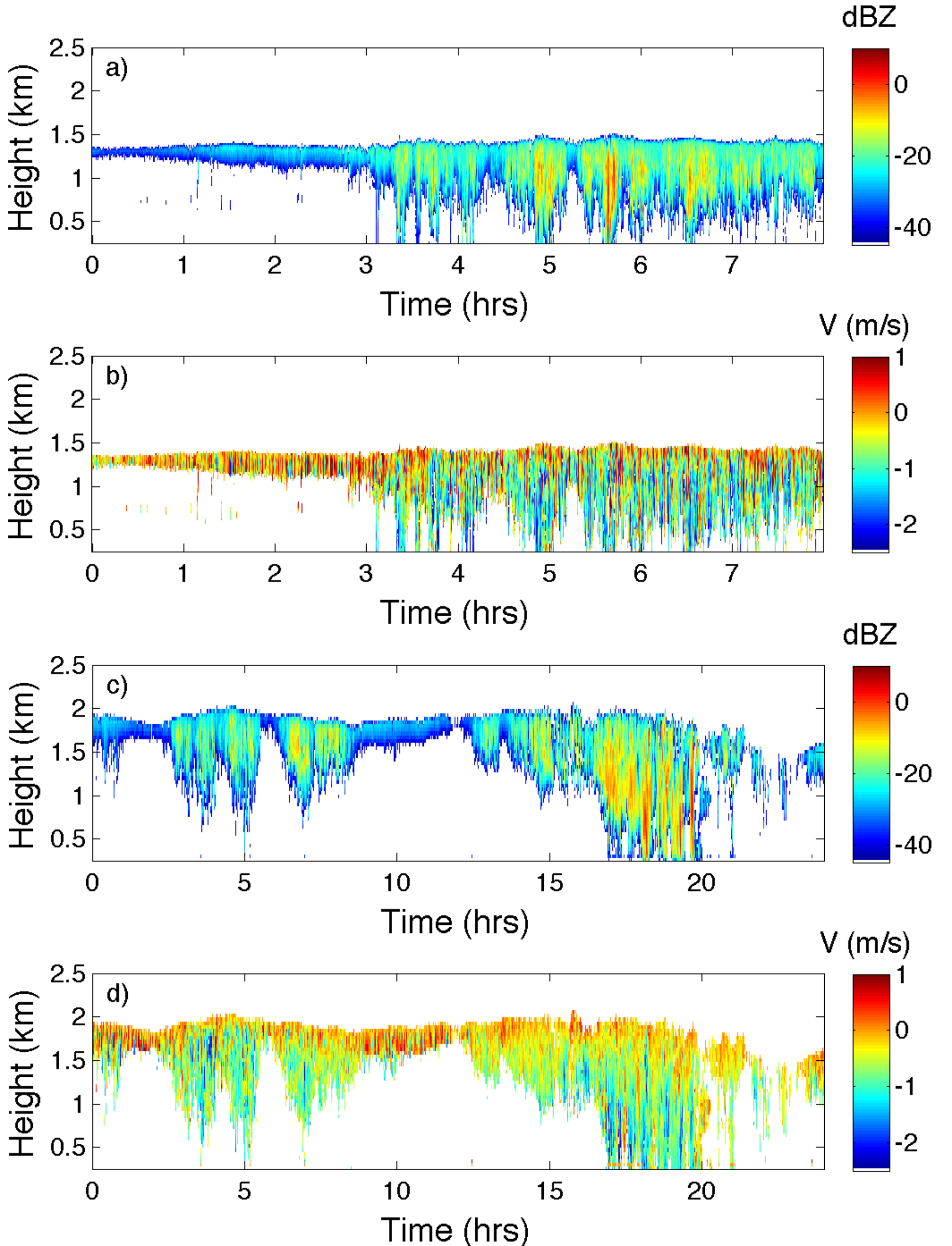
3) Illingworth et al., 2015. 4) Tanelli et al., 2008. 5) Tanelli et al., 2004. 6) Battaglia and Kollias, 2015

# 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

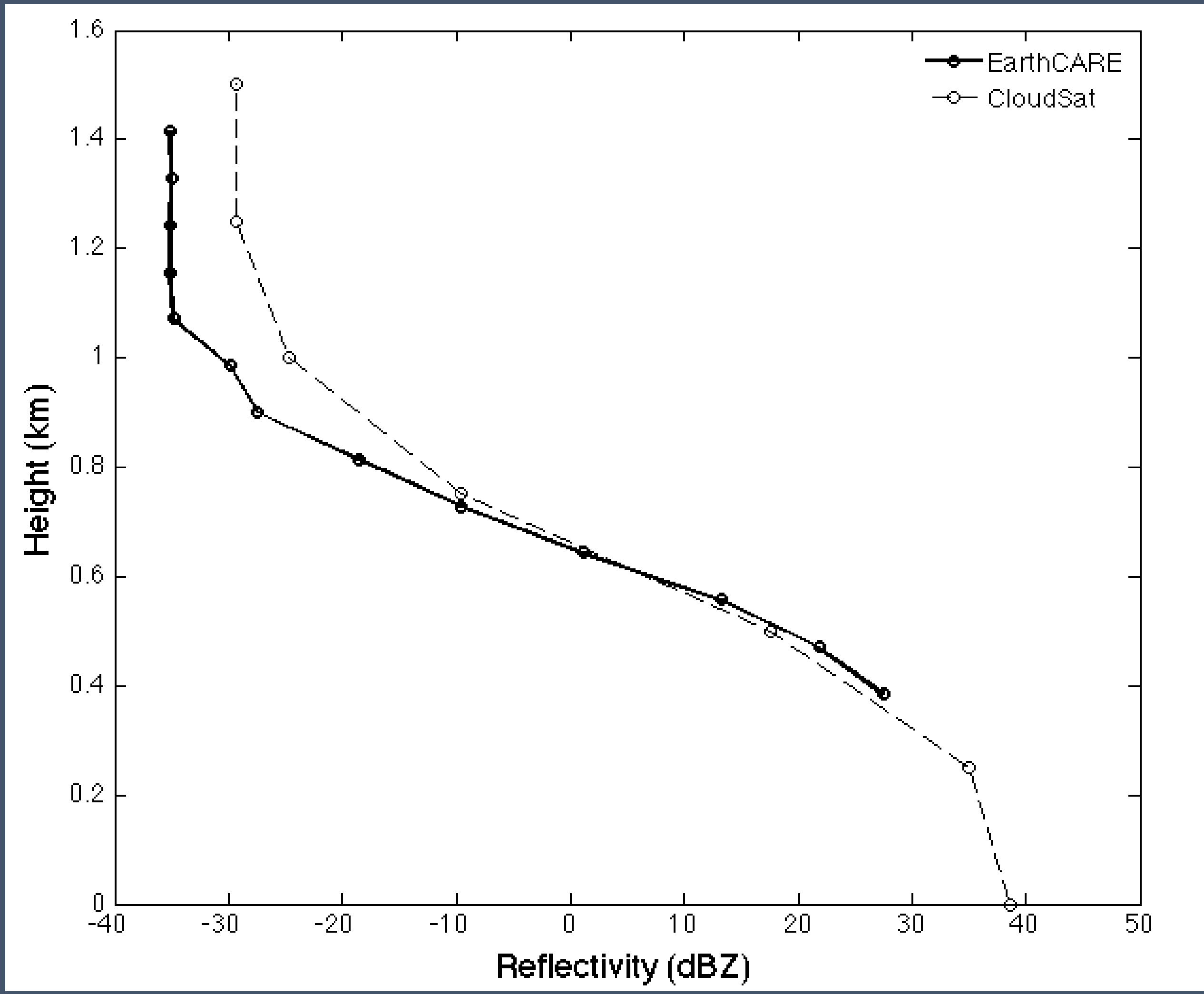
# Input data

- 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

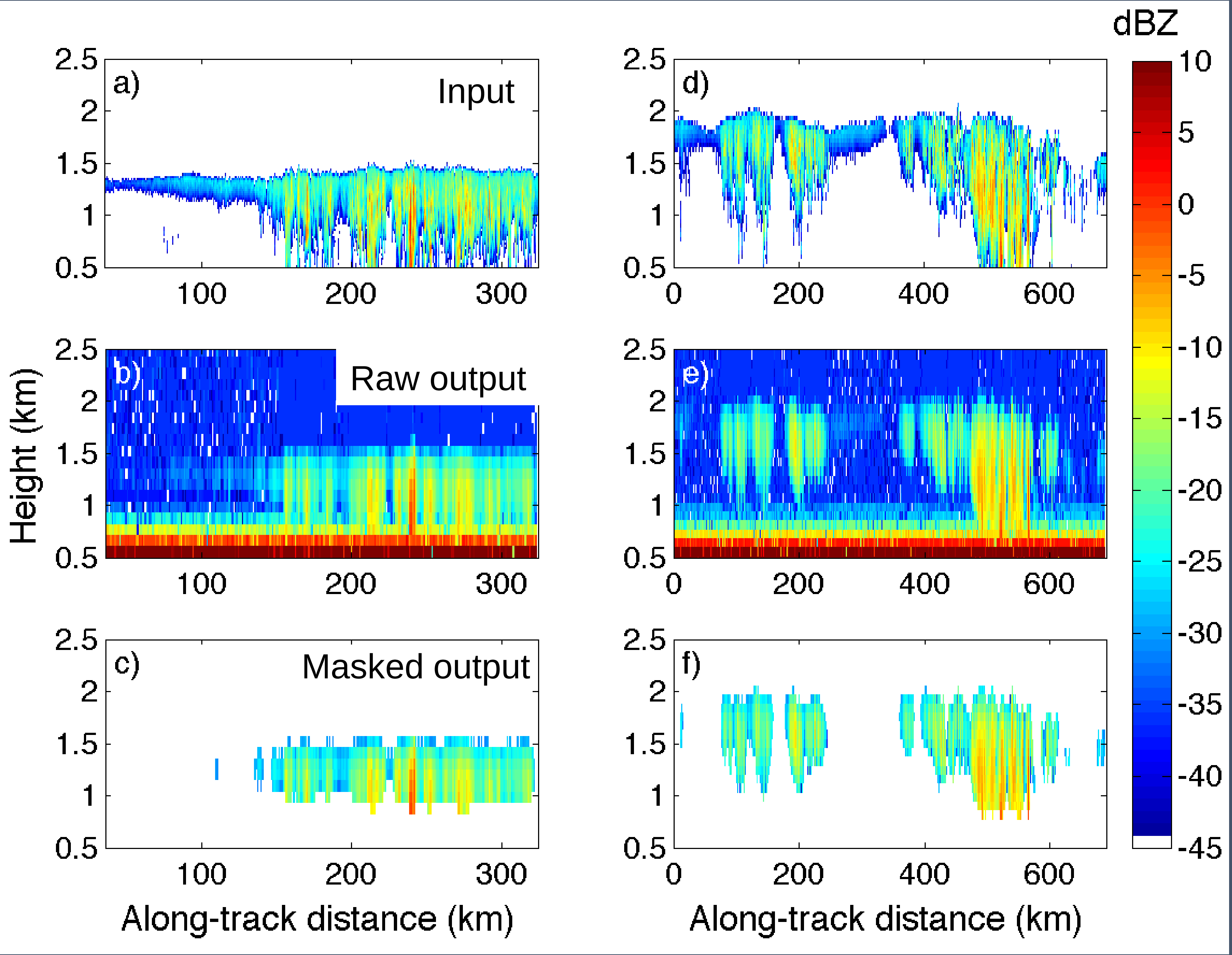


# Simulator

- 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



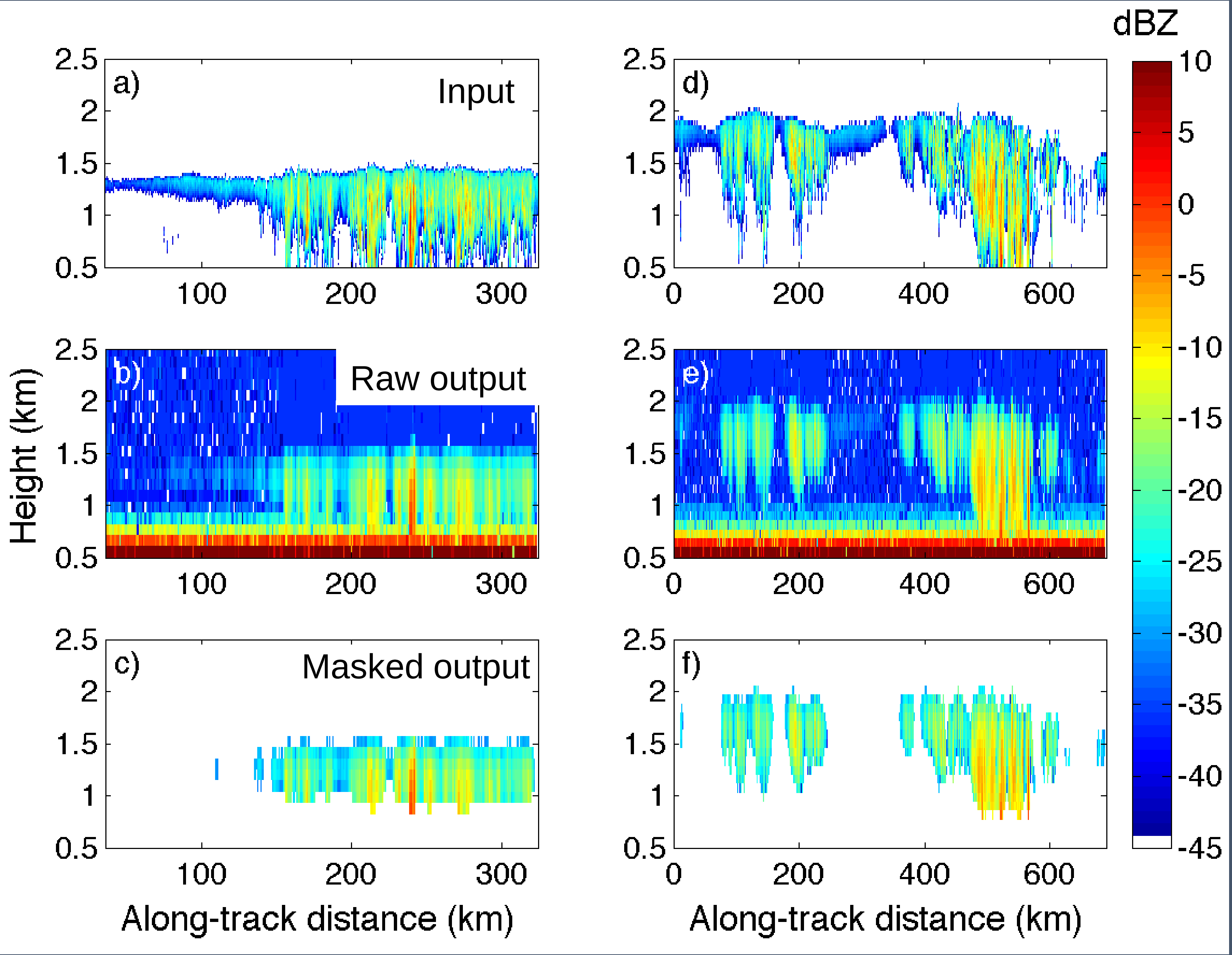
# Results



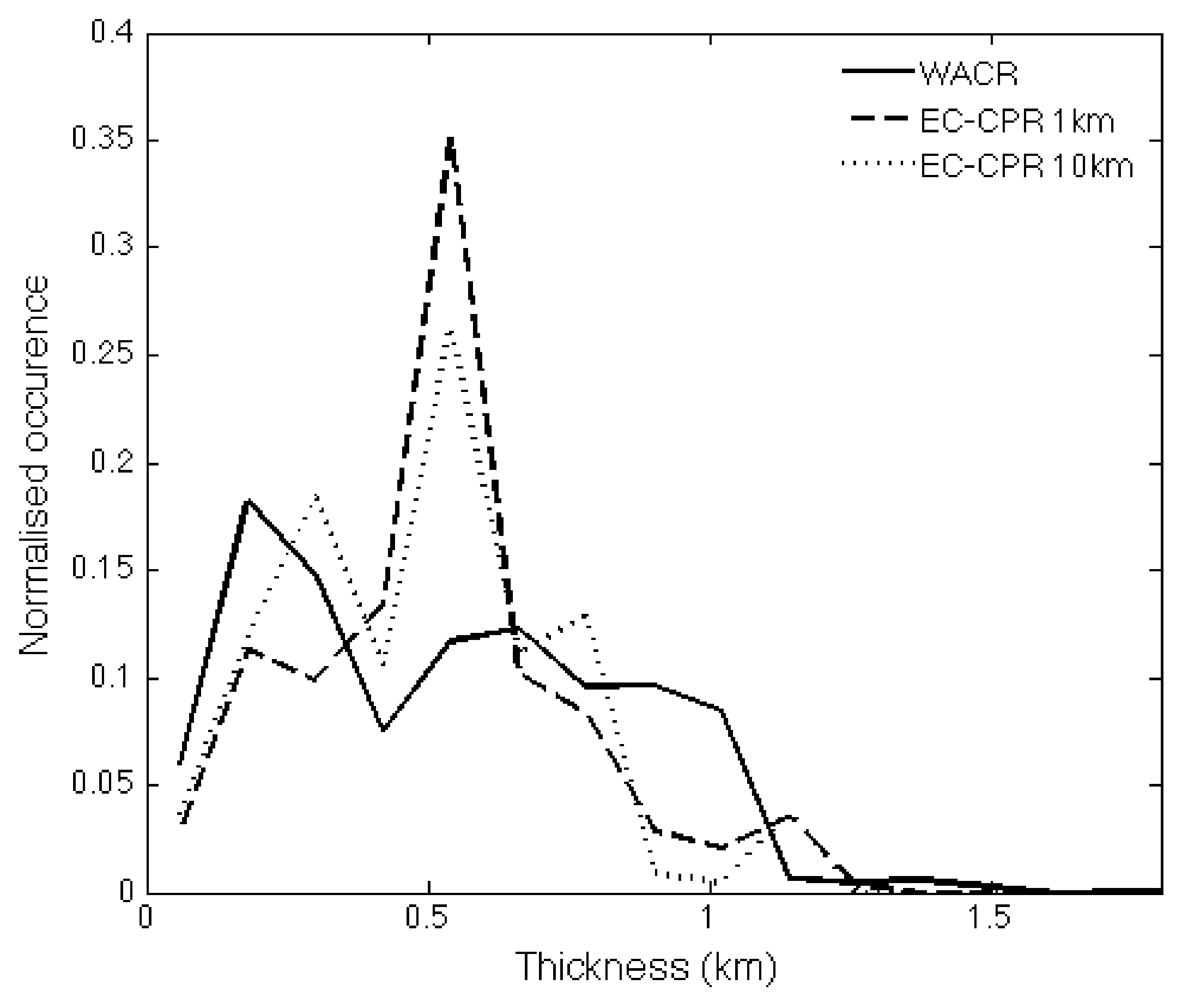
dBZ
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
a)
Input
b)
Raw output
c)
Masked output
d)
e)
f)
Height (km)
2.5
2
1.5
1
0.5
100
200
300
0
200
400
600
Along-track distance (km)
Along-track distance (km)

# Results

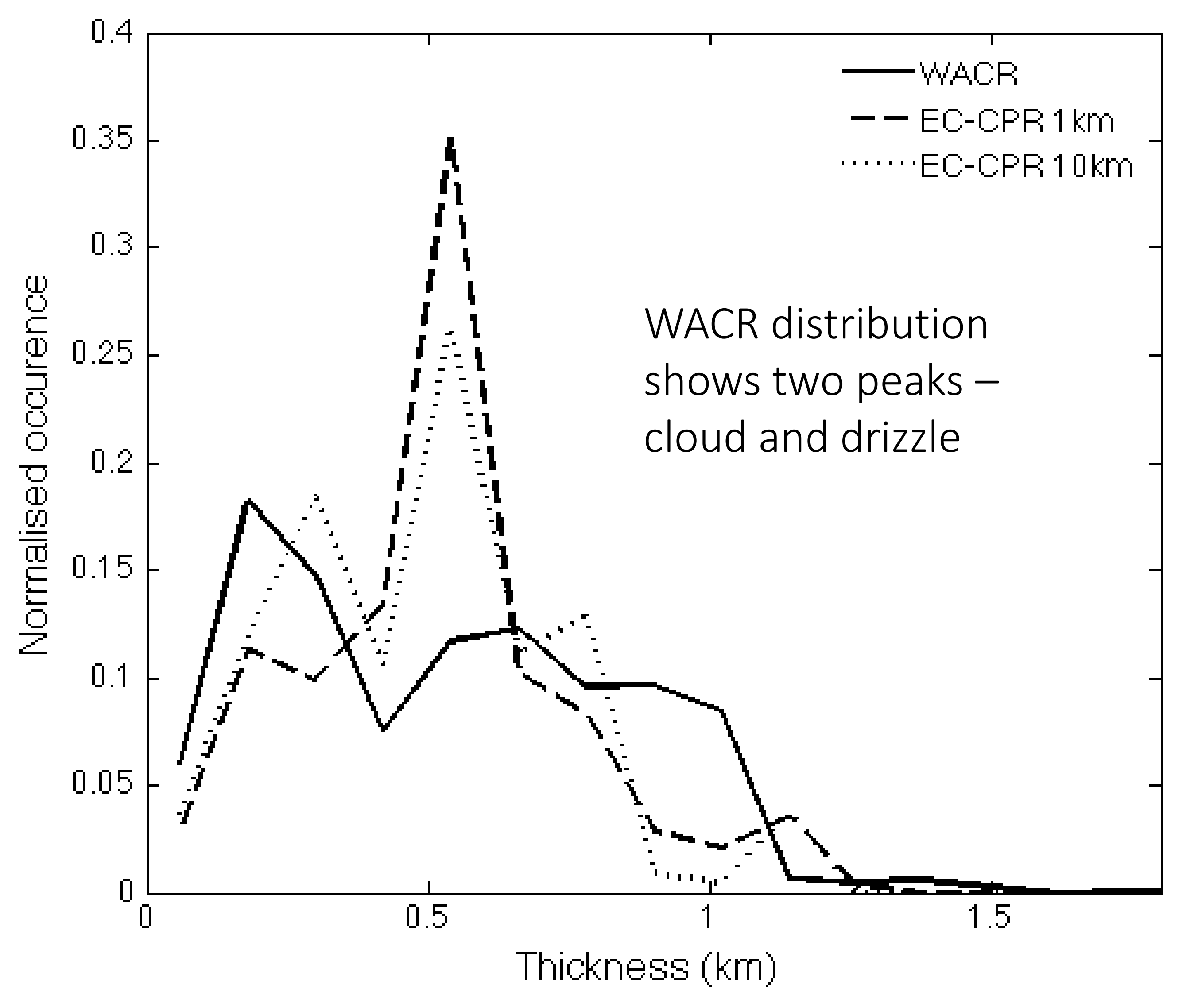
- Average cloud fractions over >100 hrs of observations
  - Lidar: 94 %
  - WACR: 91 %
  - EC-CPR: 49 %, 51 %, 67 %, 75 % (500 m, 1 km, 5 km, 10 km integrations)
- Simulated and true cloud top:
  - RMSD: 73 m
  - Mean difference: 16 m



# Impact of sampling volume and surface echo



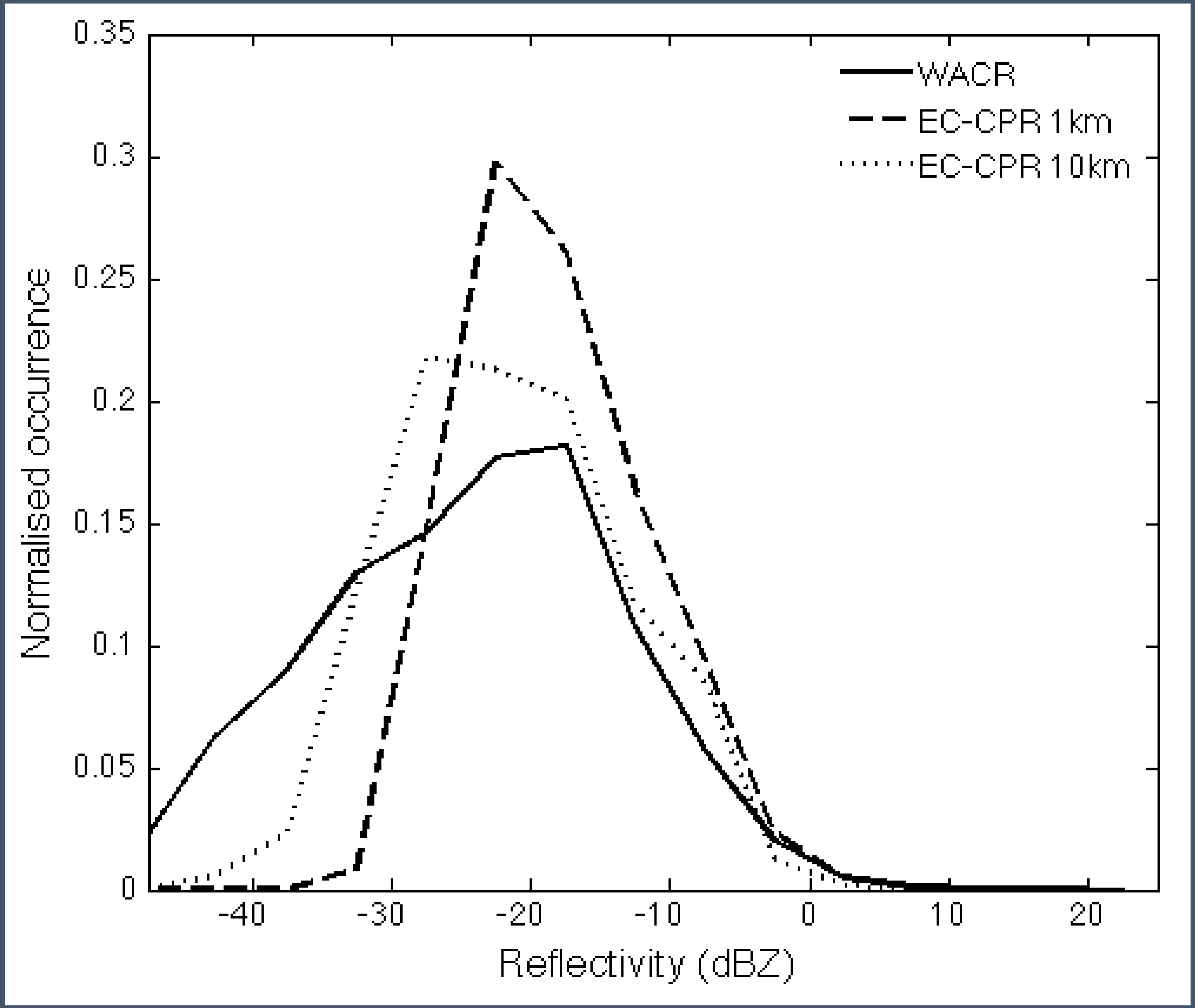
# Impact of sampling volume and surface echo




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

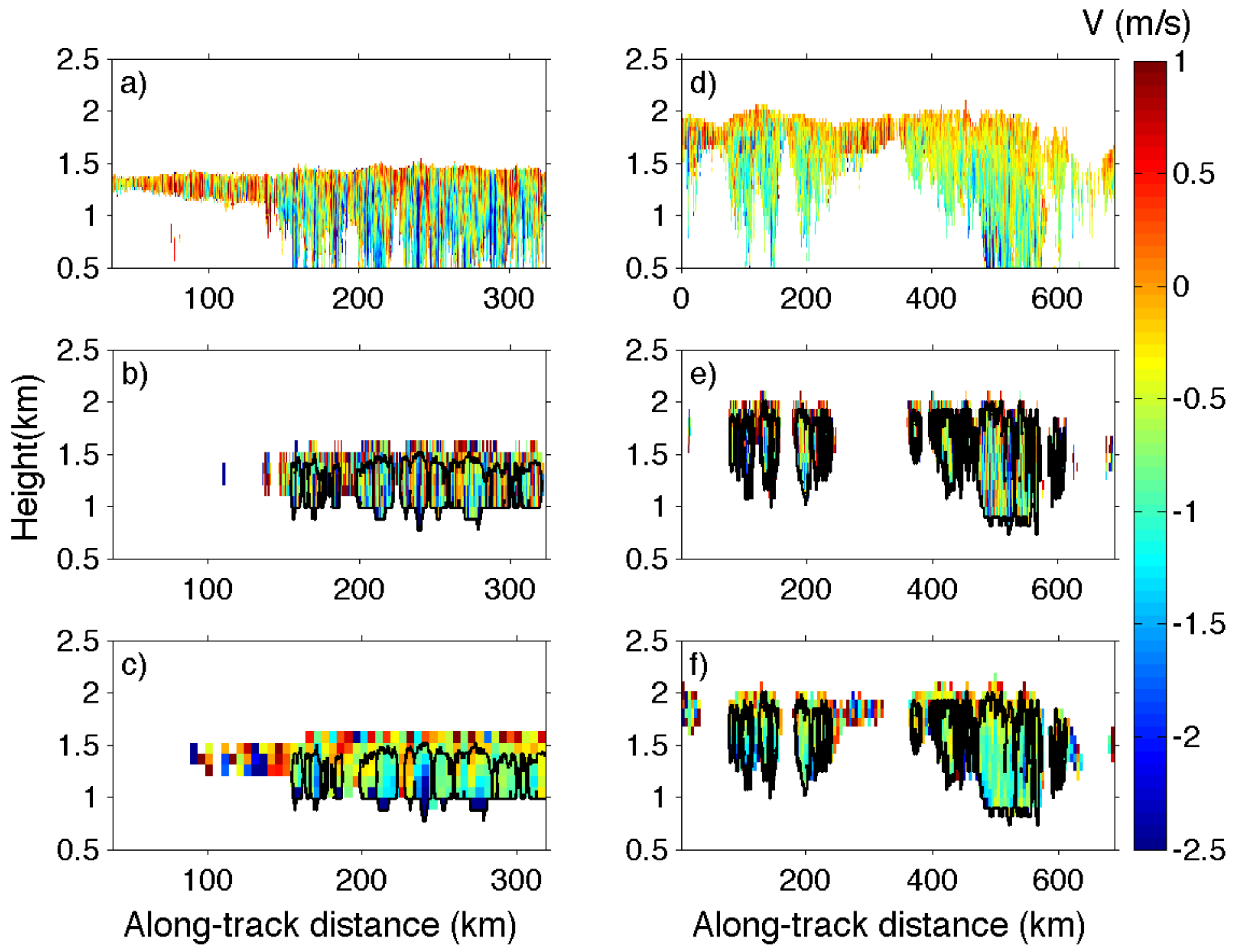
Surface echo masks deep drizzle, shifts drizzle peak down

# 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:
  - 1km 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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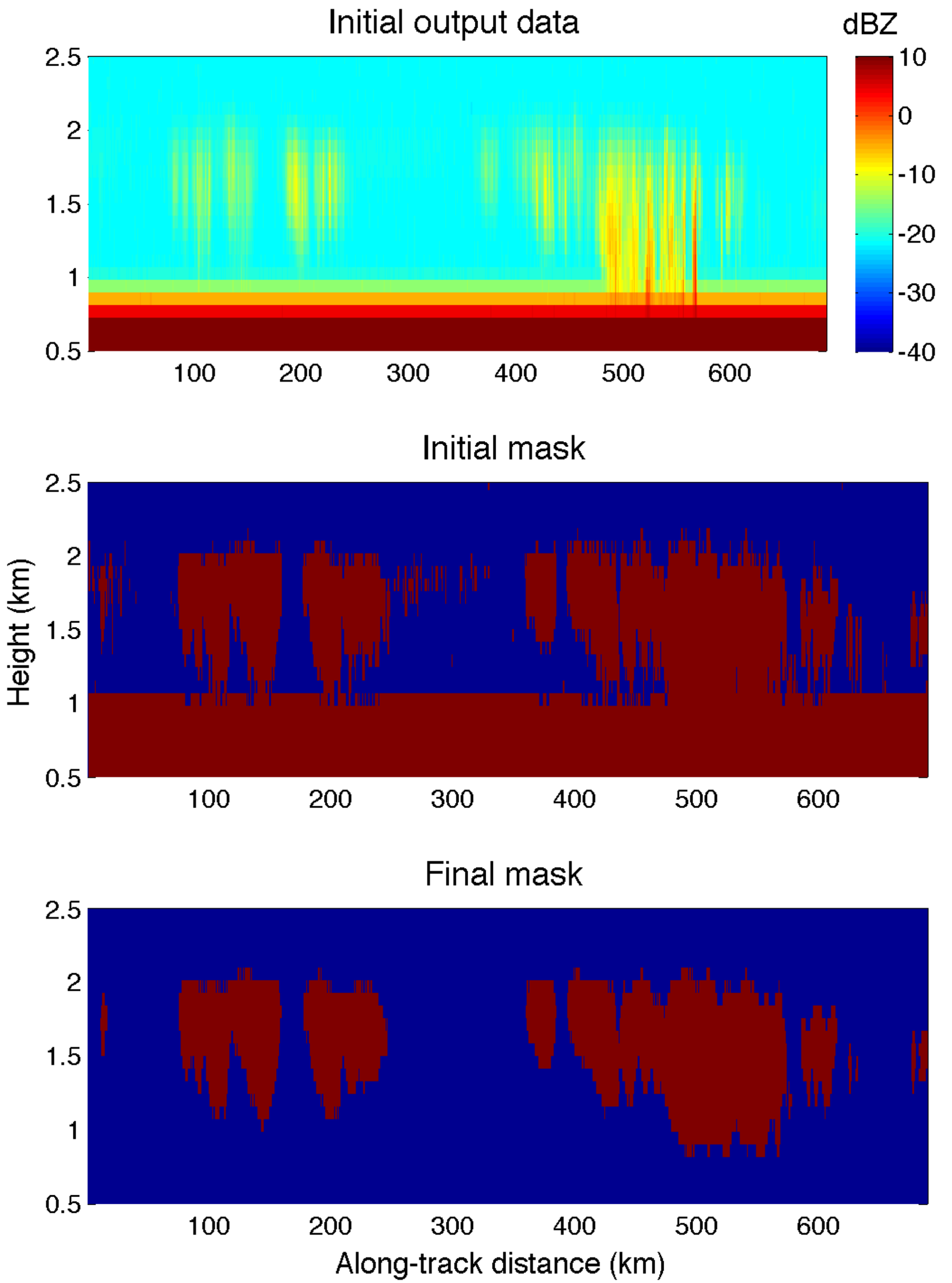
# Feature mask

- 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

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