Comparing ARM MMCR and CloudSat Measurements in the Tropical Western Pacific

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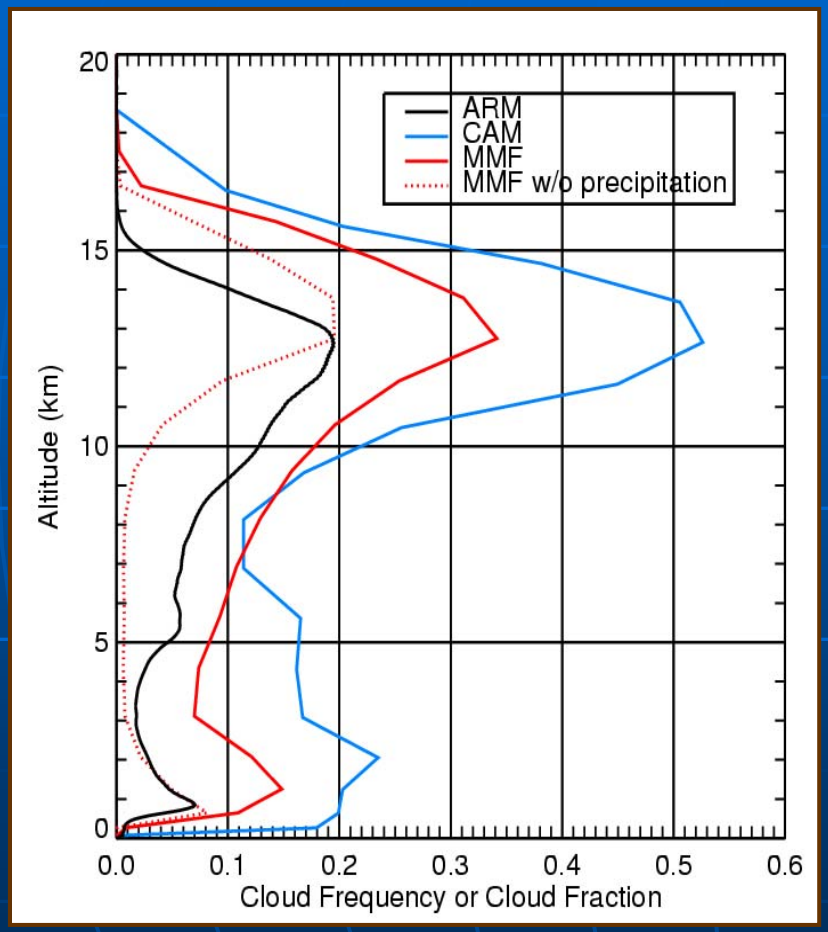
Motivation

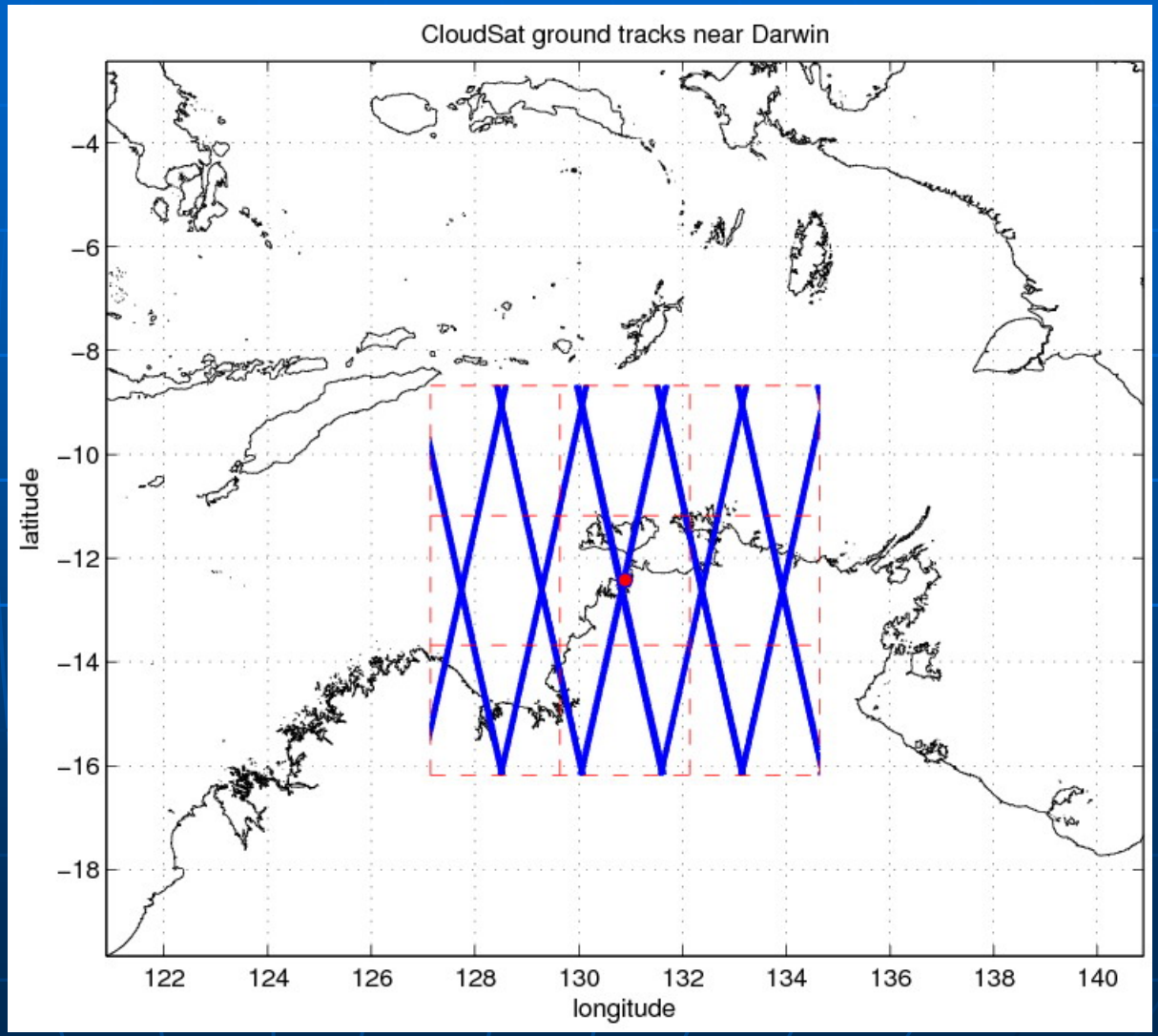


Comparison of cloud occurrence at Manus

- Are the ARM data representative of the GCM grid domain? (*or* What spatial scale do the ARM data represent?)
- Can we answer this question using CloudSat data?
- How well do MMCR and CloudSat measurements agree?

CloudSat Characteristics

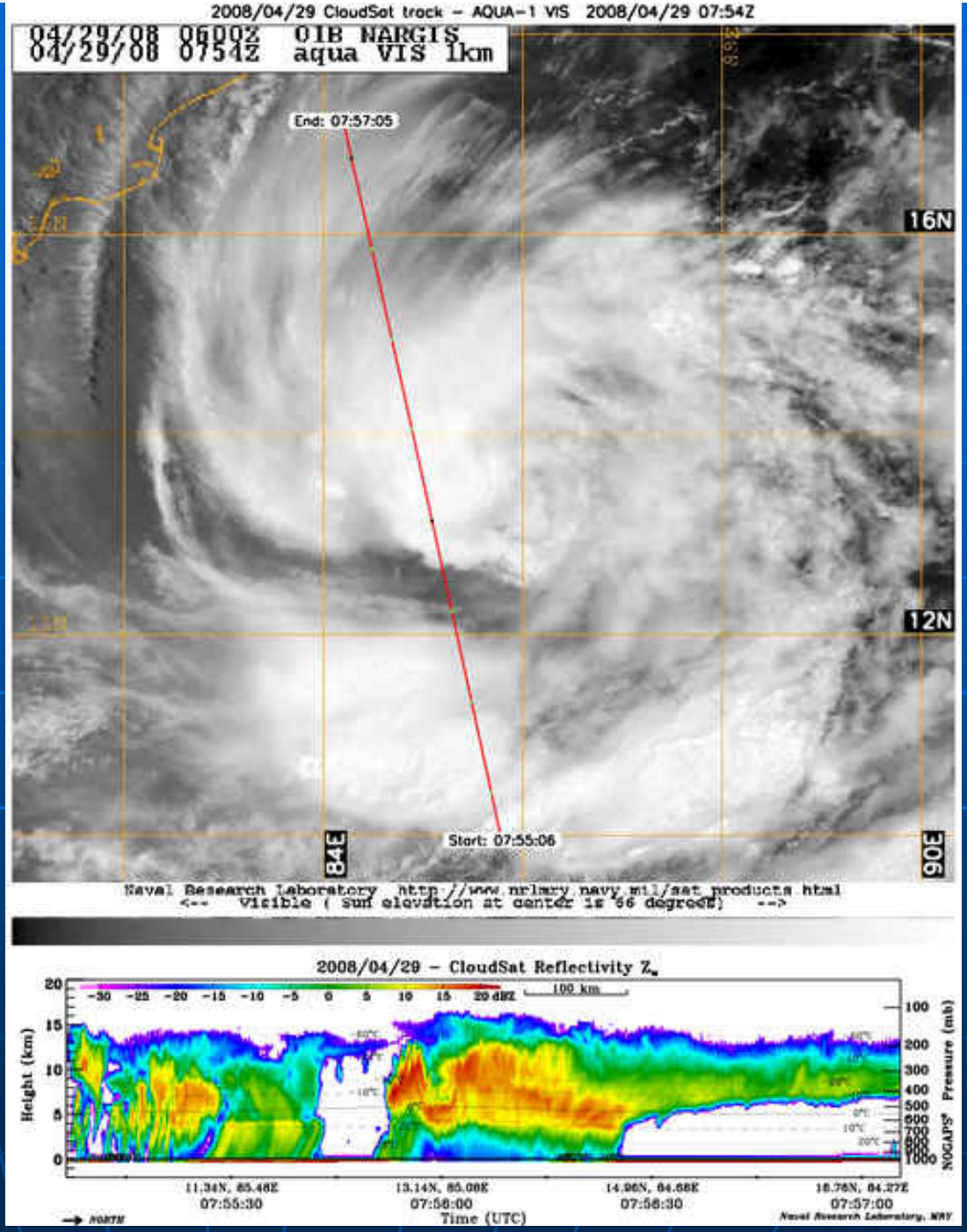
- 94 GHz cloud profiling radar
- Resolution: 1.7km × 1.4km × 480 m
- Sensitivity: -30 dBZ
- Ground track
  - Nadir viewing only
  - 14.55 orbit/day
  - Exact repeat every 16 days (233 orbits)
  - 1.55° apart at equator



Cyclone Nargis in the Bay of Bengal before landfall in Myanmar

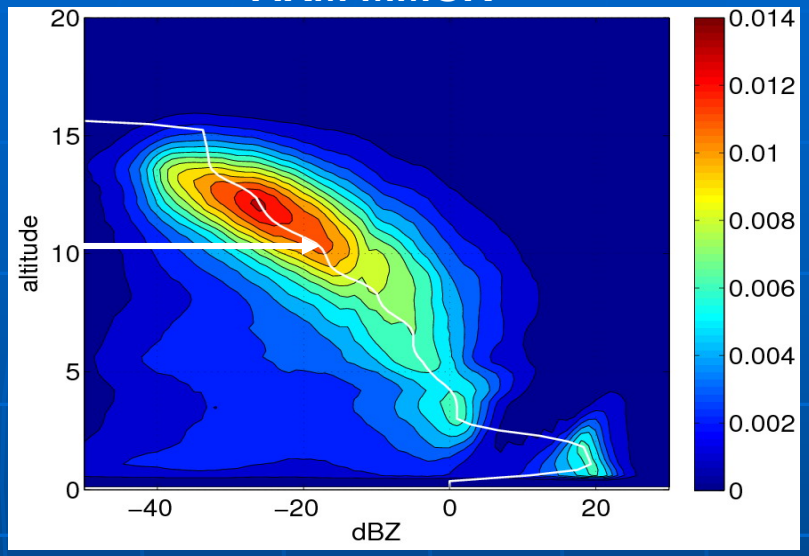
MODIS image

CloudSat curtain along red line

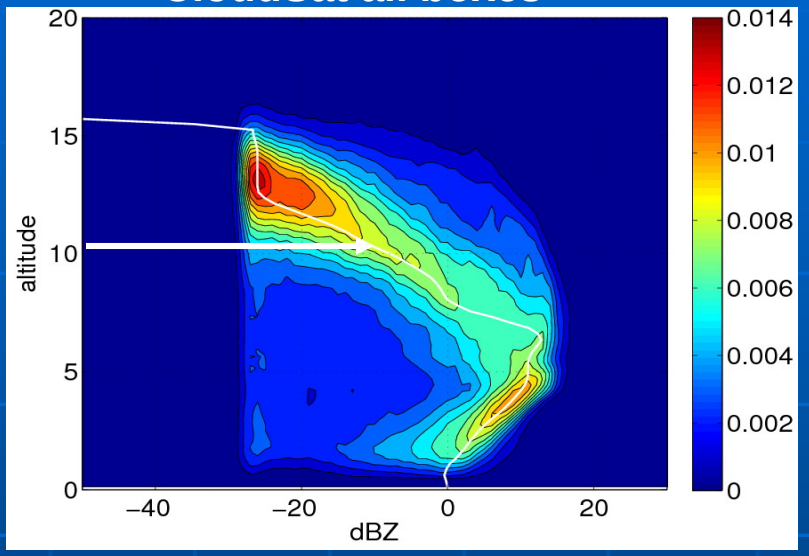


Issue #1: Different frequencies and views

ARM MMCR



CloudSat all boxes

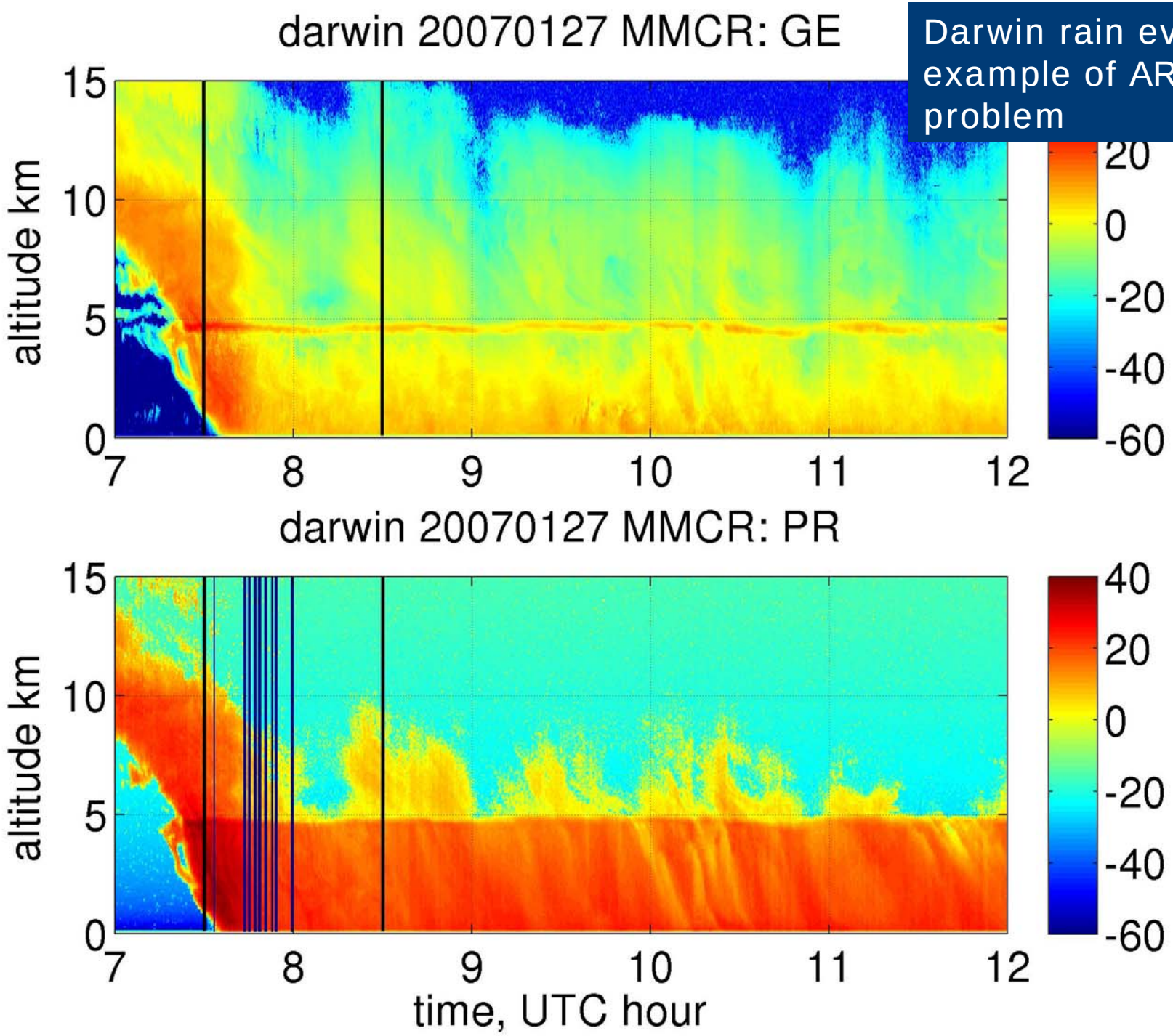


- All Darwin data for 5 months (rainy season 2006-07)
- Above melt level
  - Similar shapes but MMCR ~10 dBZ less
  - MMCR attenuated by precipitation
- Below melting level:
  - CloudSat reflectivity values increase with height due to attenuation
  - MMCR has a discontinuity at ~3 km (20 dBZ => 0 dBZ) due to ARSCL analysis problem

Issue #2: ARM MMCR data problems

- MMCR operates in 4 modes; ARSCL is best estimate of 4 modes
- Manus MMCR
  - Gradually loses transmitted power from 120 W to 10 W
  - **10 dB** offset in reflectivity
  - Can't use data until problem solved
- Nauru MMCR
  - Very few reports of reflectivity exceeding 20 dBZ in rain
  - Now understand problem: MMCR precip mode not working and General mode used in ARSCL
  - Are now analyzing Nauru data
- Darwin MMCR
  - Uncertain about quality of precip mode data
  - ARSCL not incorporating precip mode data correctly
  - Can work around by eliminating precip profiles

Darwin rain event – example of ARSCL problem



Rain event at Darwin – ARSCL merged product

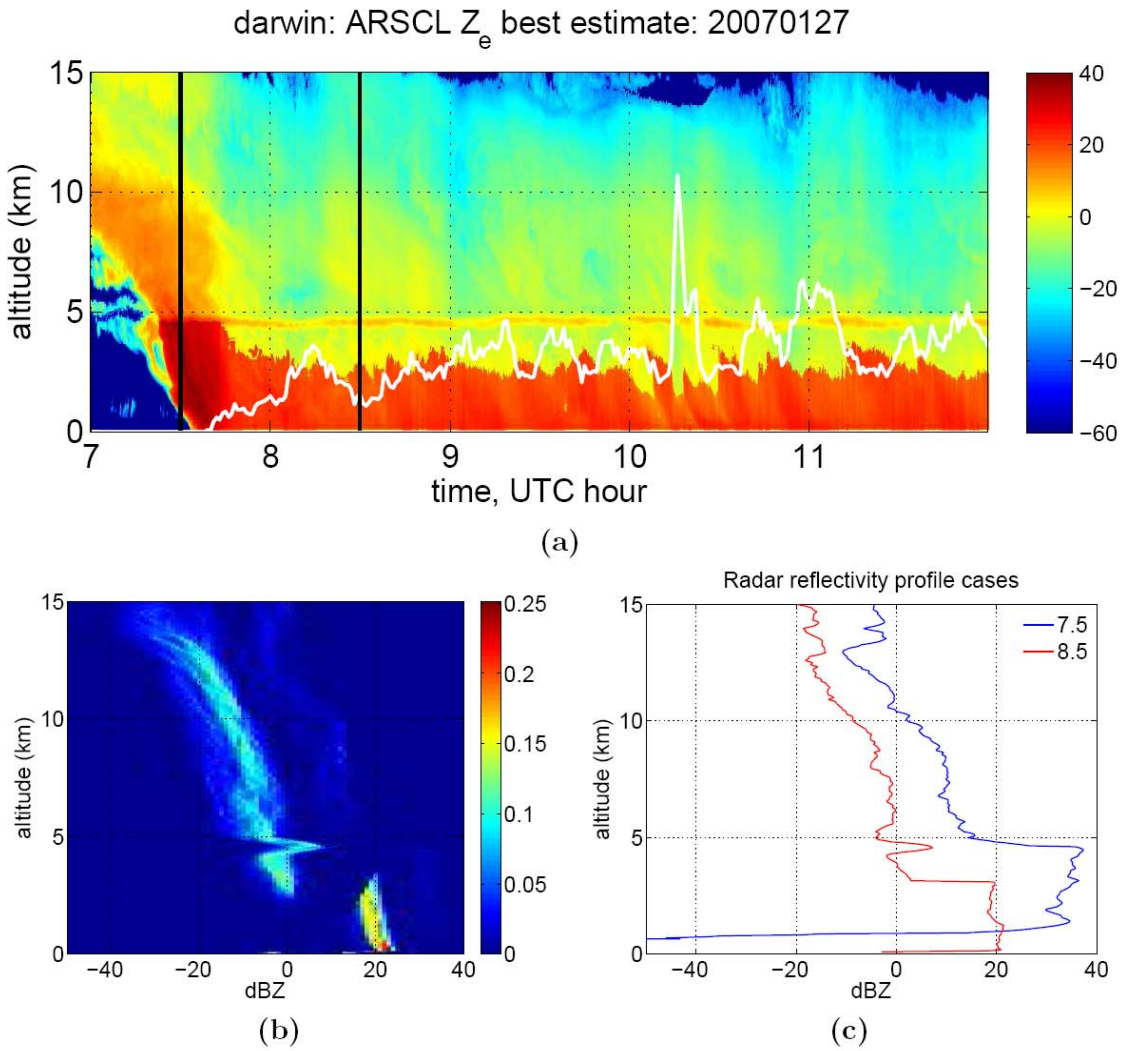
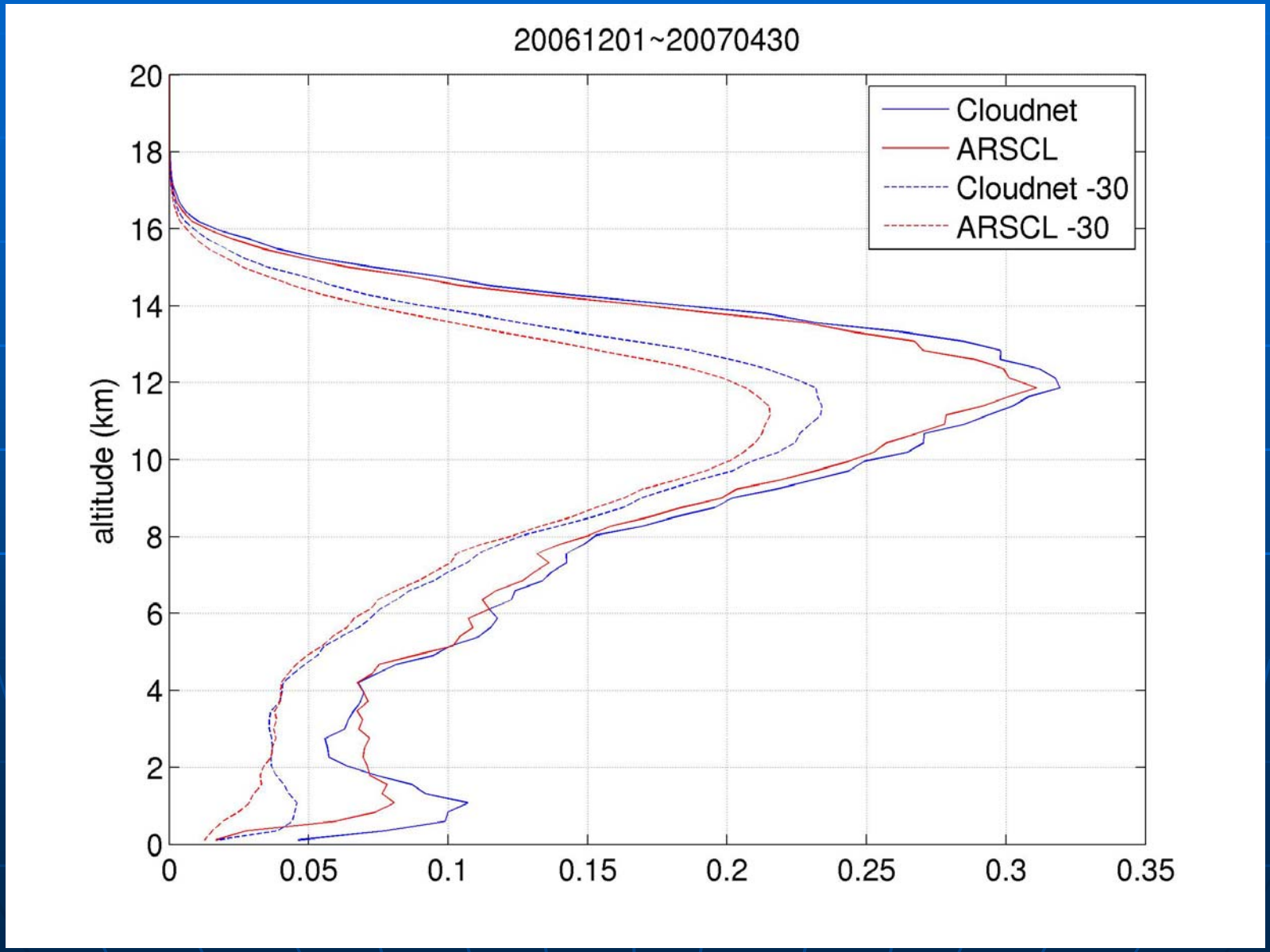


Figure 3.2: (a) Part of ARM MMCR observations on Jan. 27, 2007 at Darwin. The two vertical black lines shows where the two cases in (c) are drawn. The white line is the precipitation rate with unit of mm/hr. (b)The joint histogram for this period. (c)Two radar profiles at 730UTC and 830UTC.

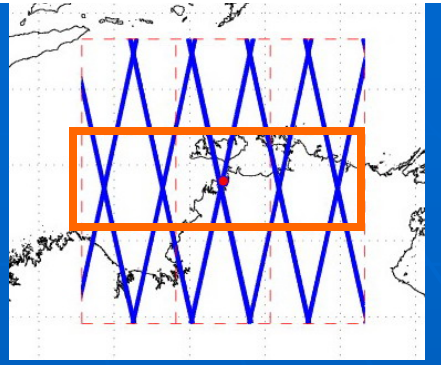
Issue #3: Data availability

- CloudSat available since 2006
- Darwin rainy season: December to April
- ARSCL (cloud mask) only available for 2006-07 season
- CloudNet (cloud mask radar processing by group at U of Reading) available for both 2006-07 and 2007-08
- Little difference between CloudNet and ARSCL for **“no precip”** data
- Will use the two interchangeably for our work
- NOTE: ARSCL 2007-08 has just become available and we will process this

ARSCL / CloudNet Comparison – no precip



Issue #4: Sampling uncertainty



- CloudSat samples along each ground track about 24 times/year
- 2.5° box contains, on average, 3 ground tracks: 72 transects/year
- Darwin, because of its precise location, experiences only about 30 transects in 5 months of wet season
- Each transect is an "independent" observation, but each pixel in a transect is not

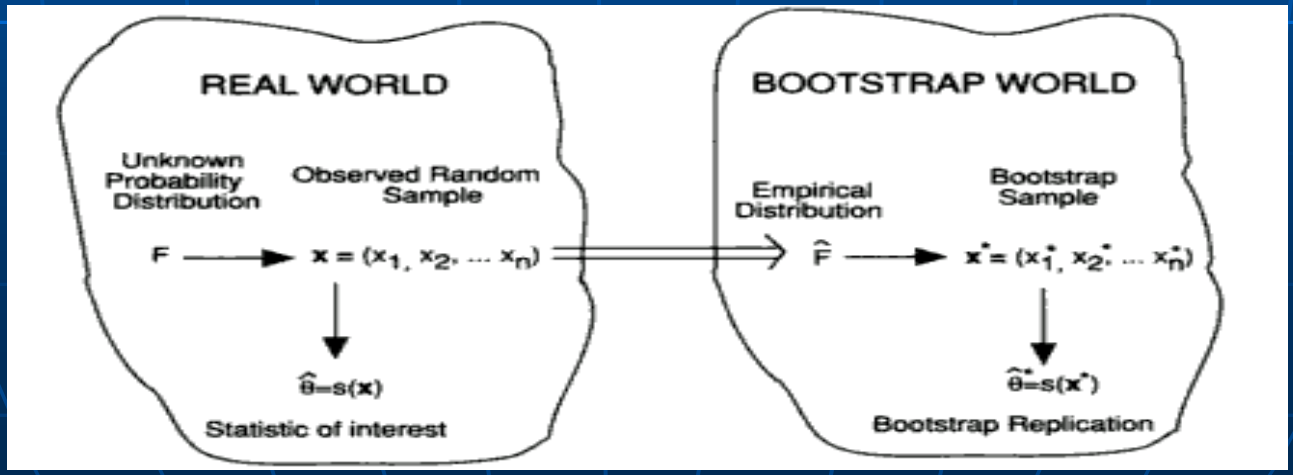
Large uncertainties in CloudSat observed statistics are expected at the scale of any 2.5° box

Number of CloudSat transects with more than 50 profiles, total number of profiles and "rain" profiles ratio in the nine CloudSat 2.5° × 2.5° boxes.

Box position	NW	North	NE	West	Center	East	SW	South	SE
No. of transects	27	35	27	37	16	36	27	35	27
No. of profiles	6009	8871	6380	9582	4144	8956	6681	8577	6690
"Rain" profiles ratio	0.122	0.091	0.127	0.129	0.243	0.161	0.111	0.147	0.126

Issue #4: CloudSat Autocorrelation Bootstrap method

- Provides an estimate of confidence limits for data with unknown statistical distribution
- Simulate the sampling process by resampling observed data
- Calculate replications of the statistic of interest
- Use the bootstrap resampling uncertainty to estimate the sampling uncertainty
- “Moving block” bootstrap (Wilks, 1997) used to capture autocorrelation in observations

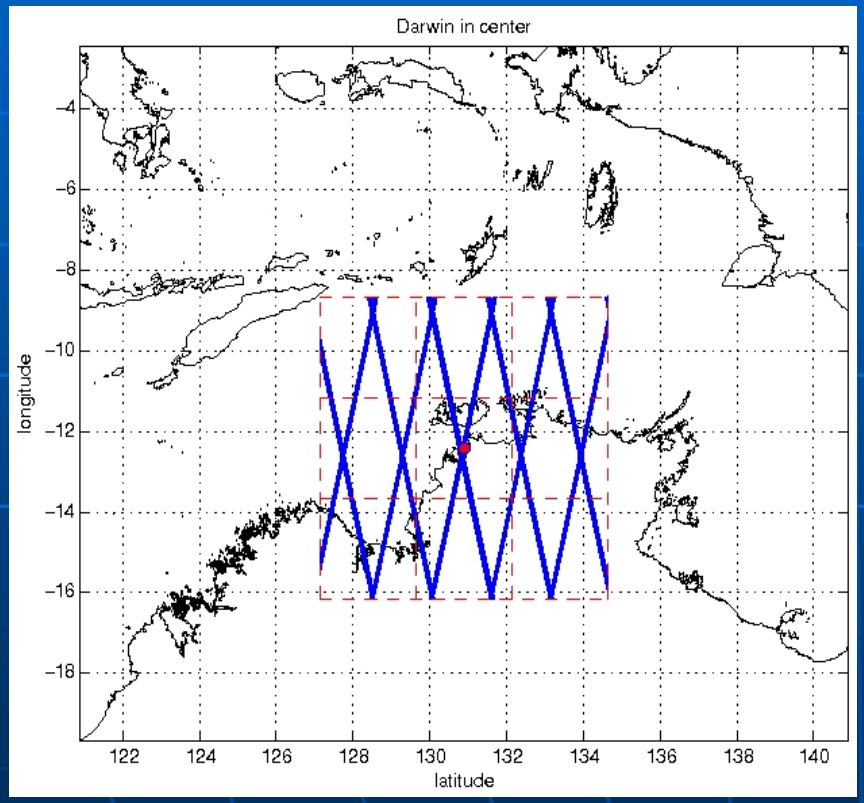


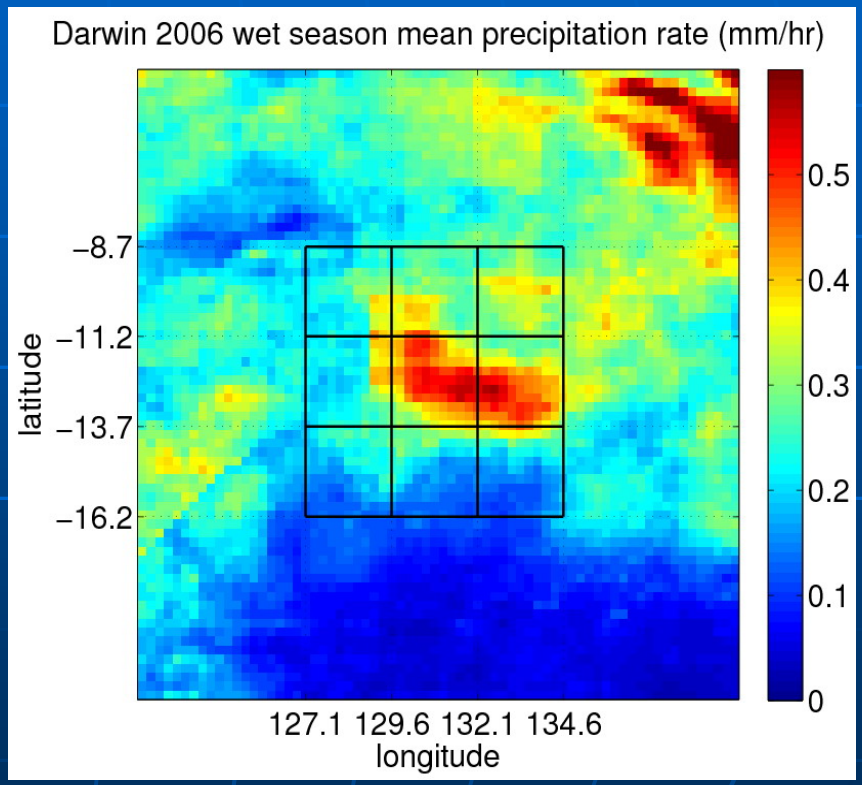
(*Efron and Tibshirani, 1993*)

Some results

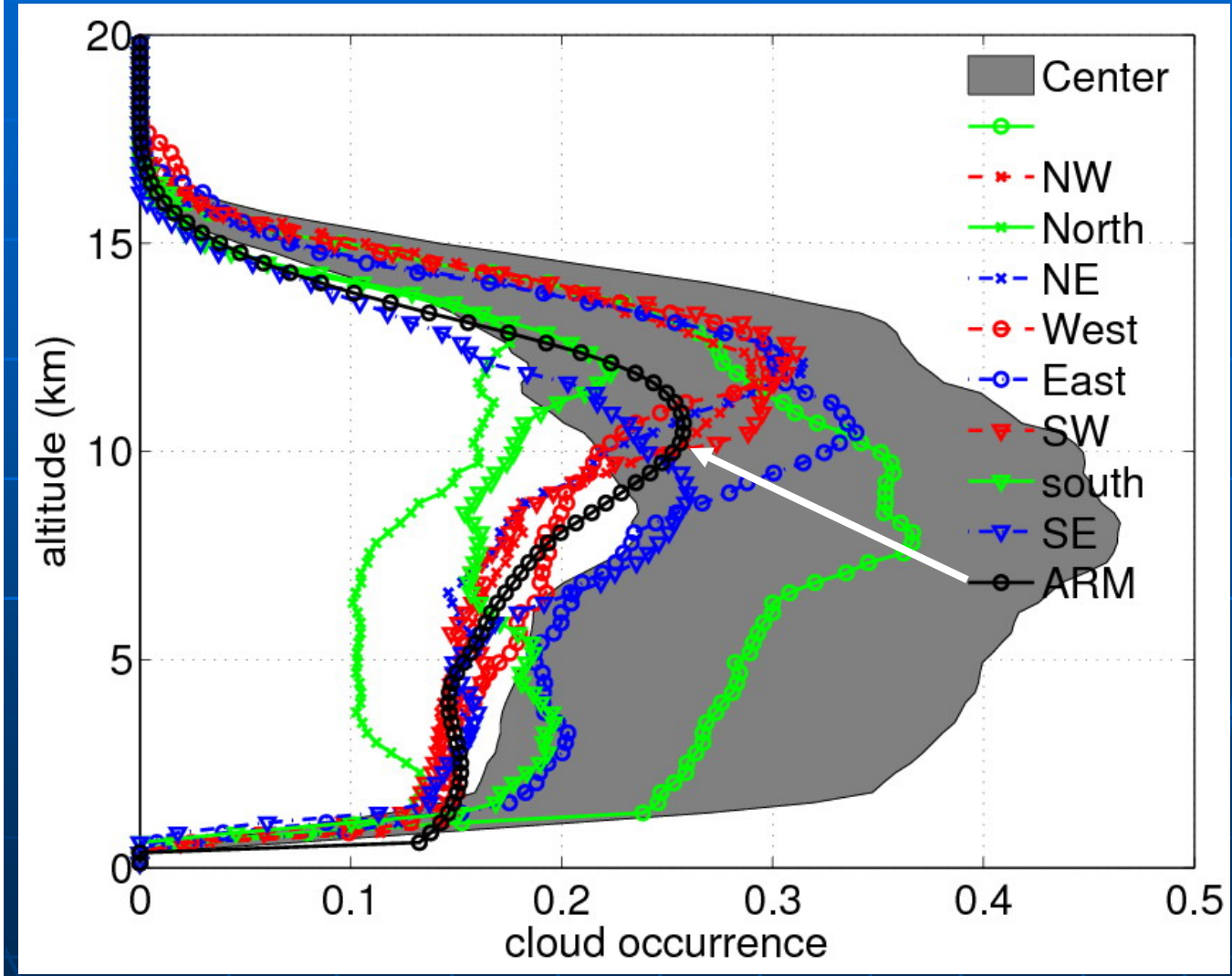
Finally!

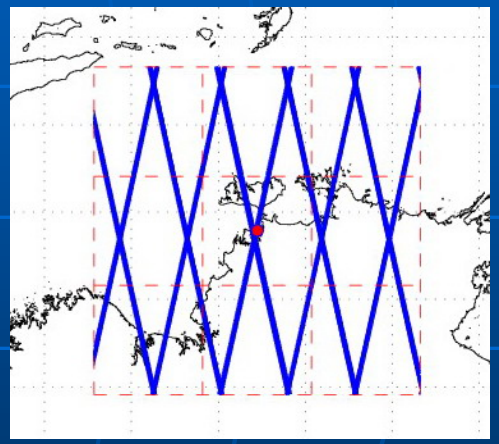
Spatial variability of rain (TRMM)





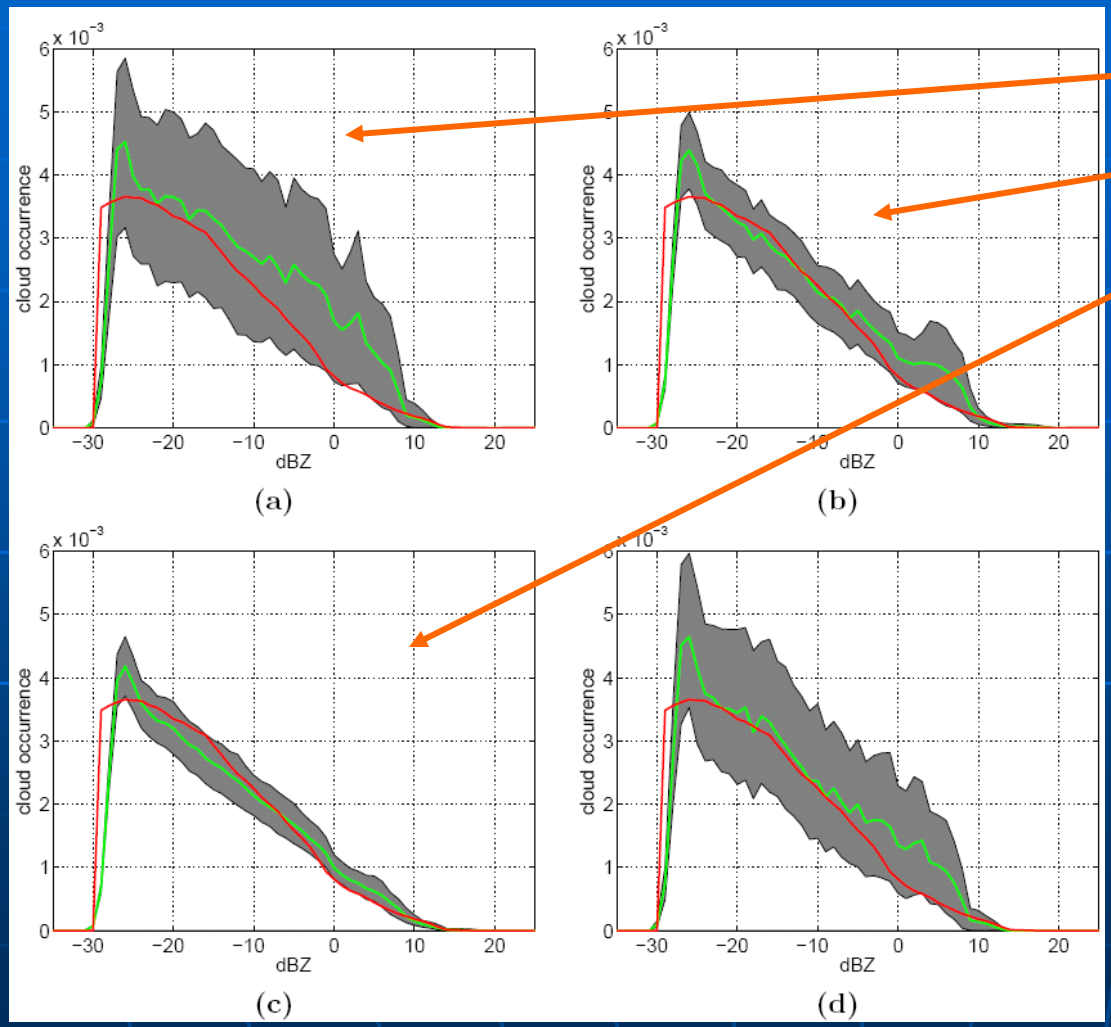
Cloud occurrence in CloudSat boxes





Analysis includes precip profiles

Spatial scale (all vertical levels, no precip)

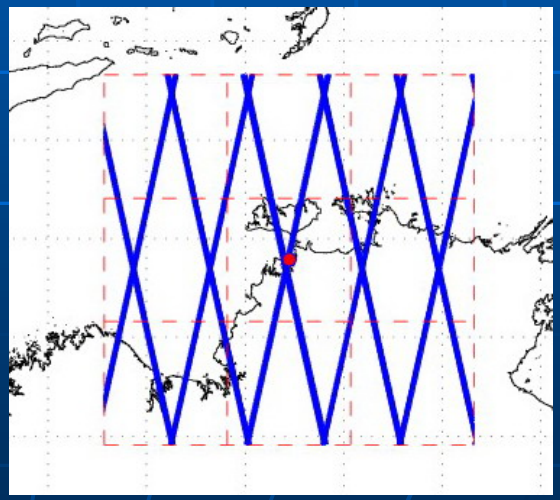


(a) 2.5° box

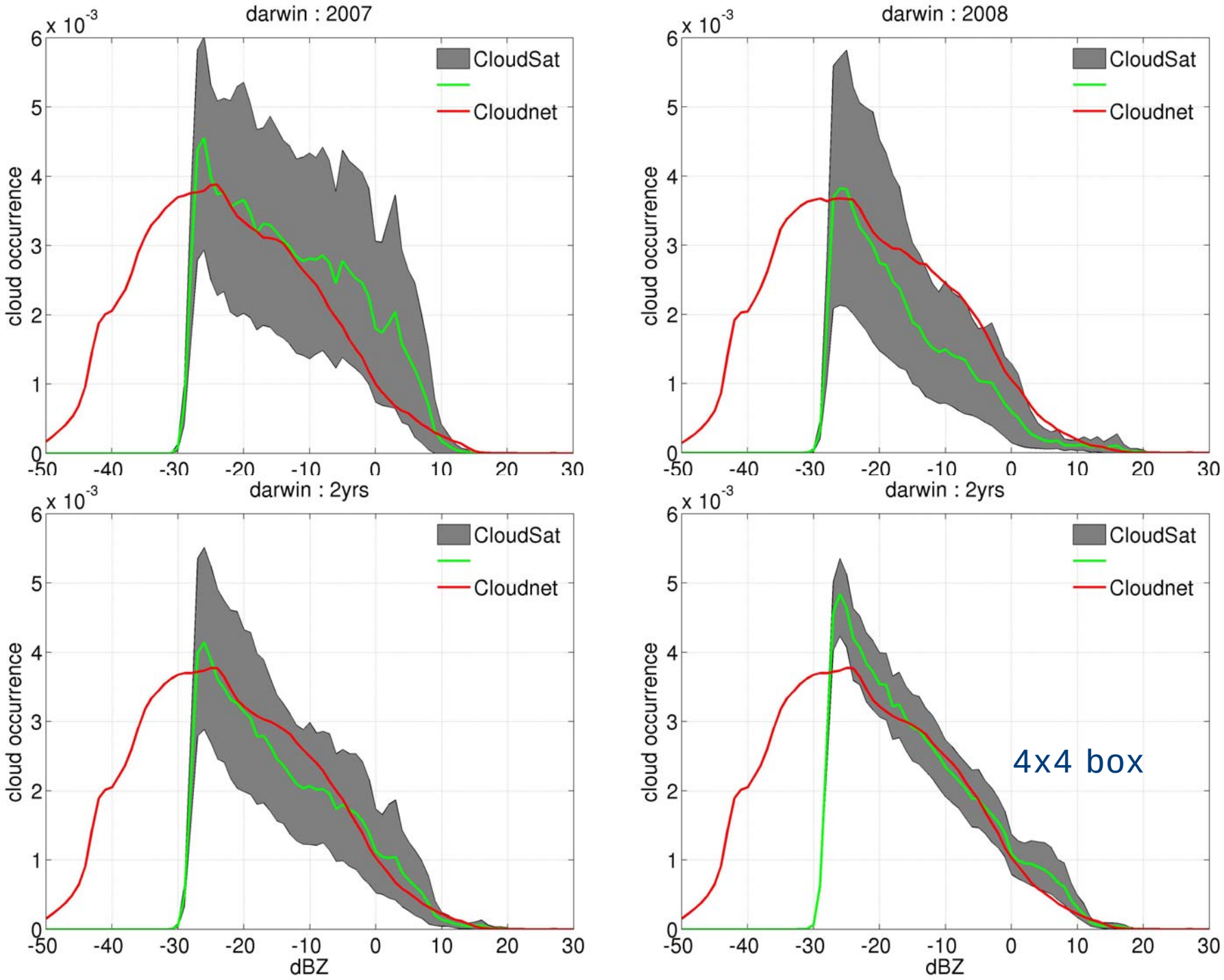
(b) 4.0° box

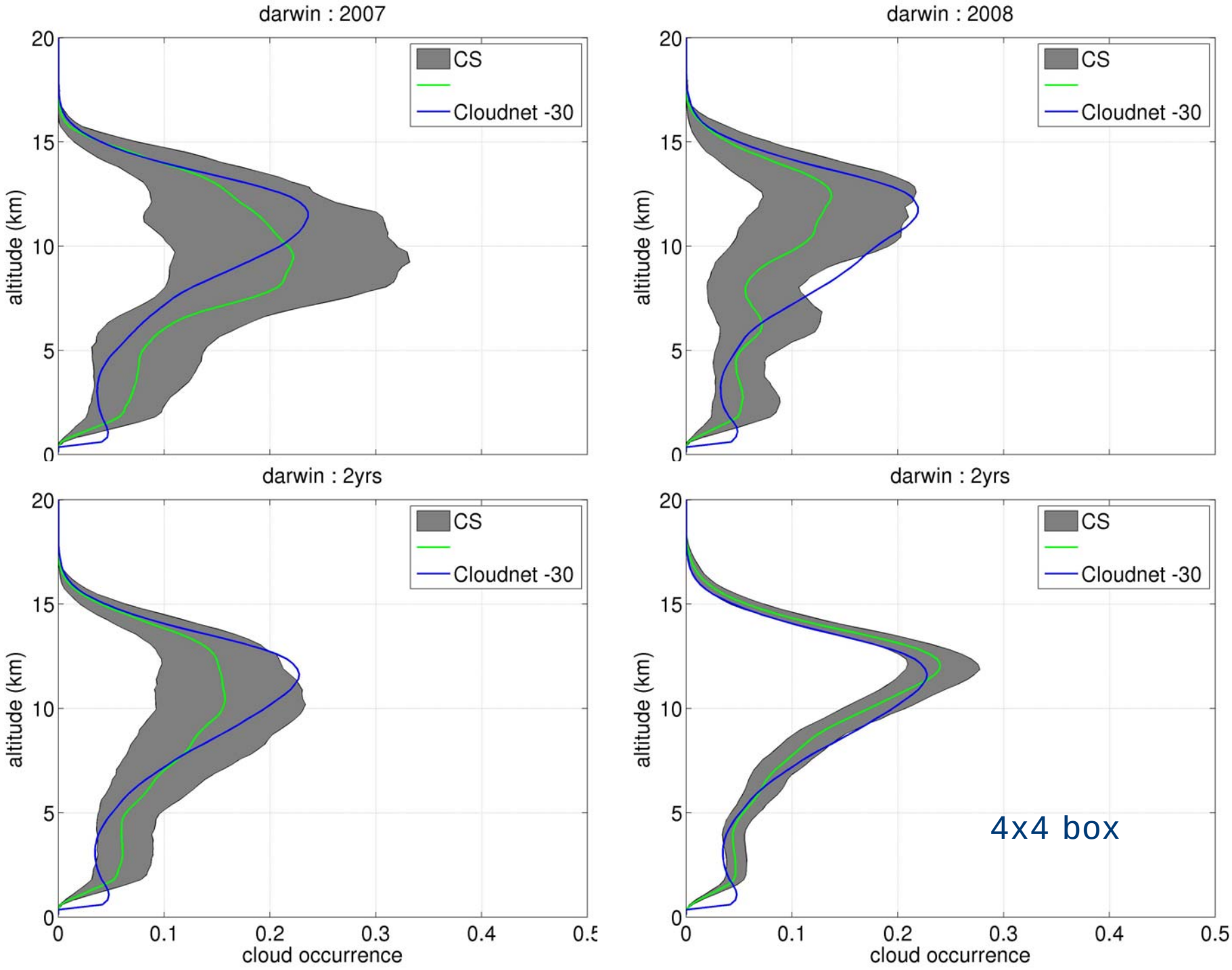
(c) 7.5° box

(d) 2.5° box shifted north



ARSCL **CloudSat**


darwin : 2007
darwin : 2008
darwin : 2yrs
darwin : 2yrs
x 10^-3
cloud occurrence
CloudSat
Cloudnet
dBZ
4x4 box


darwin : 2007
darwin : 2008
darwin : 2yrs
darwin : 2yrs
CS
Cloudnet -30
altitude (km)
cloud occurrence
0
5
10
15
20
0.1
0.2
0.3
0.4
0.5
4x4 box

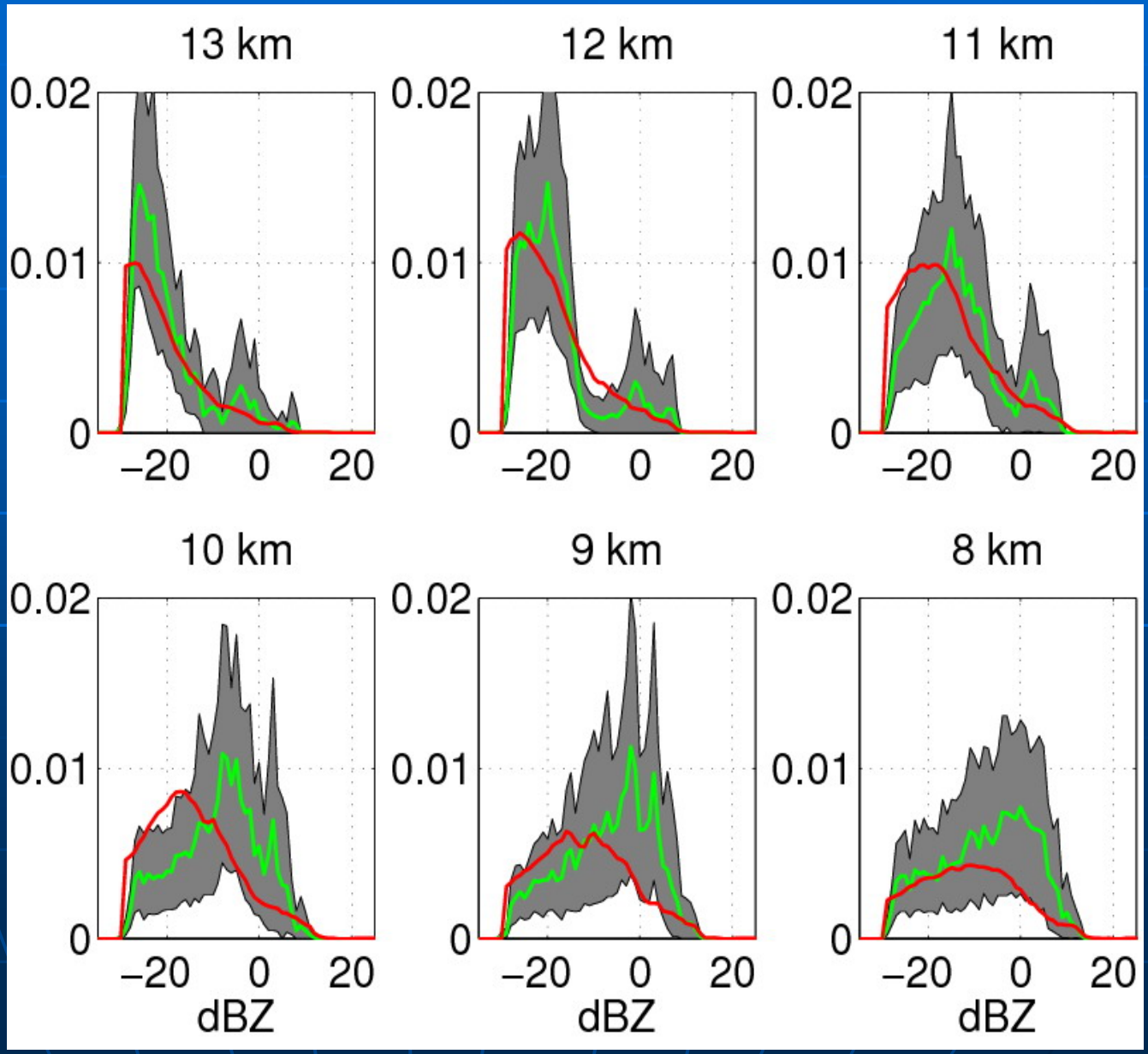
Comparison at vertical levels

ARSCL

CloudSat

2.5 degree box

No precip



Conclusions

- Radar comparisons based on “no precip” analysis (removes 13-15% of total number of profiles)
- CloudSat and MMCR distributions are **similar** but not **identical** (under “no precip” conditions)
- Aggregating vertically or horizontally improves similarity – does this make physical sense for larger horizontal scale?
- CloudSat sampling mode implies:
  - Sum over multiple years => lose interannual variability
  - Sum over larger horizontal areas => lose local variability
- MMCR appears to be a reliable sample on scales of a few hundred kilometers over a few months
  - May be reliable over shorter time scales but can’t tell from CloudSat due to sampling


Thank you for your attention!