Jet Propulsion Laboratory
California Institute of Technology

A MAGIC error budget of CloudSat warm marine rain

Peter Kalmus[1,2] and Matt Lebsock[1]

[1]Jet Propulsion Laboratory and California Institute of Technology

[2]University of California, Los Angeles

Outline

We use MAGIC campaign data to correct errors in CloudSat warm rain.

- We focus on errors in 2C-RAIN-PROFILE product below cloud base.
- These errors originate from the evaporation model's parameterization.
- We perform an empirical correction from MAGIC W-band radar.
- We explore generalizability of the correction.

CloudSat 2C-RAIN-PROFILE product

CloudSat provided first global estimates of light rain from warm marine clouds.

CloudSat's Cloud Profiling Radar (CPR) has sensitivity of -30 dBZ.

This allows it to see light rain.

2C-RAIN-PROFILE product uses an optimal estimation retrieval.[1]

2C-RAIN-PROFILE includes physics appropriate for warm marine rain.

- modified drop size distribution
- parameterization of cloud water attenuation
- evaporation modeled below lowest detectable radar range bin (~720 m)

1 Lebsock and L'Ecuyer (2011), "The retrieval of warm rain from CloudSat"

The 2C-RAIN-PROFILE evaporation model

Reflectivity as function of height for falling drizzle?

Drops evaporate differentially as they fall.

Larger drops have higher terminal velocity.

Model[1] (assumes still air) :

$$Z(d) = Z_{\mathrm{CB}} \exp(-qk(d/\bar{r}^{2.5})^{1.5})$$

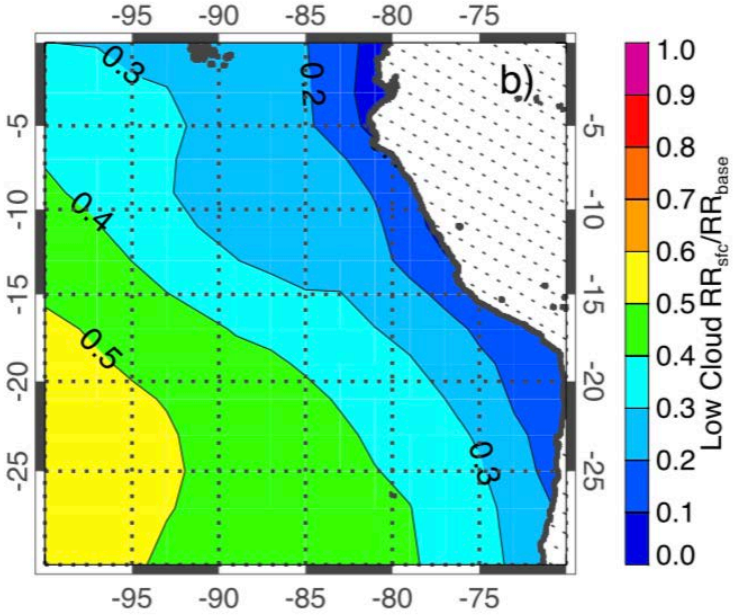
d: distance below cloud base

rbar: mean drop size at cloud base

Constants tuned for stratocumulus drizzle:

q=0.75 (models evaporative Z-R change)

k = 320 $um^{3.75}$ $m^{-1.5}$ (RH gradient, DSD)



SE Pacific: fraction of low cloud rain evaporating en route to surface[2]

1 Comstock et al. 2004, “Reflectivity and rain rate in and below drizzling stratocumulus.”

2 Rapp et al. 2013, “Low cloud precipitation climatology in the southeastern Pacific marine stratocumulus region using CloudSat.”

MAGIC campaign

ARM instrumentation on container ship:

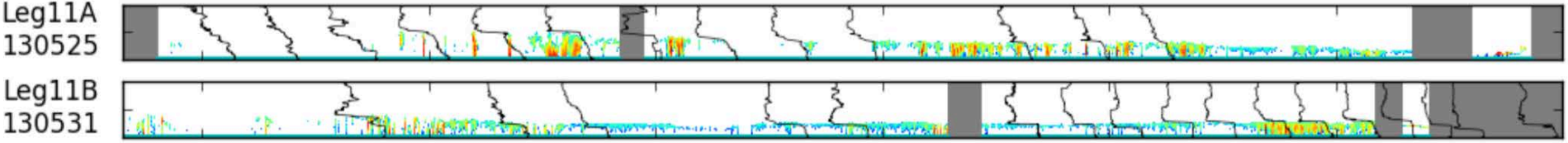
23 round trips between Hawaii and Los Angeles

Sept. 2012 to Oct. 2013

Upward looking W-band radar

- servo-stabilized
- 5 Hz sampling rate
- vertical reflectivity profiles begin 128 m above surface

One round trip from campaign (W-band radar boundary layer slices, 0 to 4km)



Hawaii

Los Angeles

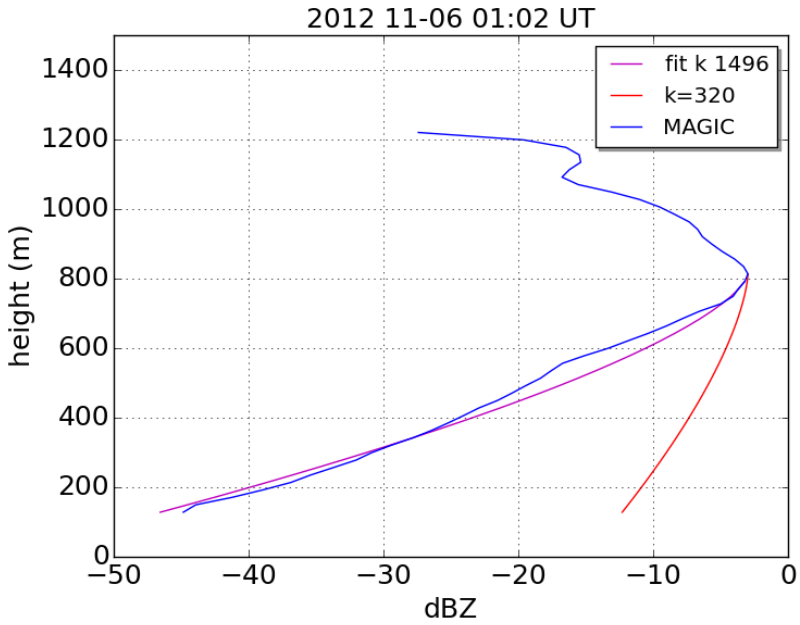
Comparing model to MAGIC radar

Create ~2 km MAGIC averages

- Remove background from reflectivity profiles
- Average 5 Hz profiles over 10 minutes
- Cut profiles with refl(h=720 m) < -15 dBZ

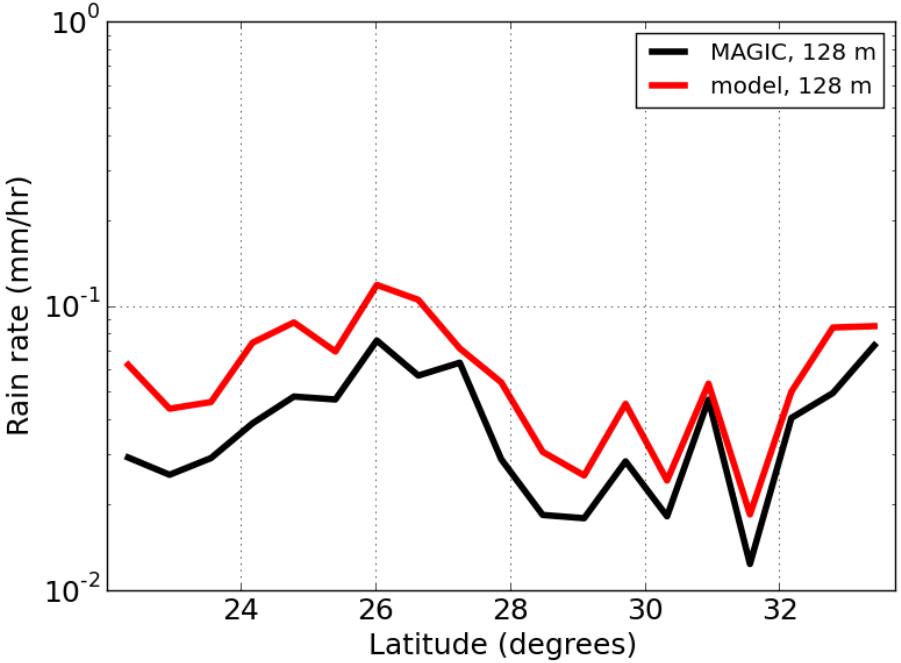
Create model profiles

- rbar estimated from lookup table
- using k = 320 $\mu m^{3.75}\ m^{-1.5}$ (red curve)
- using k estimated from least-squares fit to MAGIC (purple curve)



Comparing model to MAGIC radar

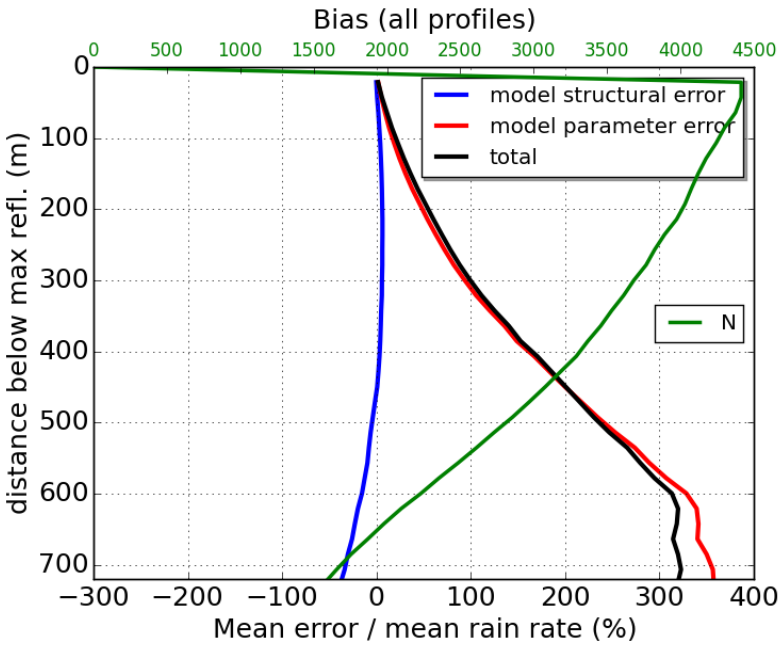
the evaporation model overestimates conditional rain rate in MAGIC region

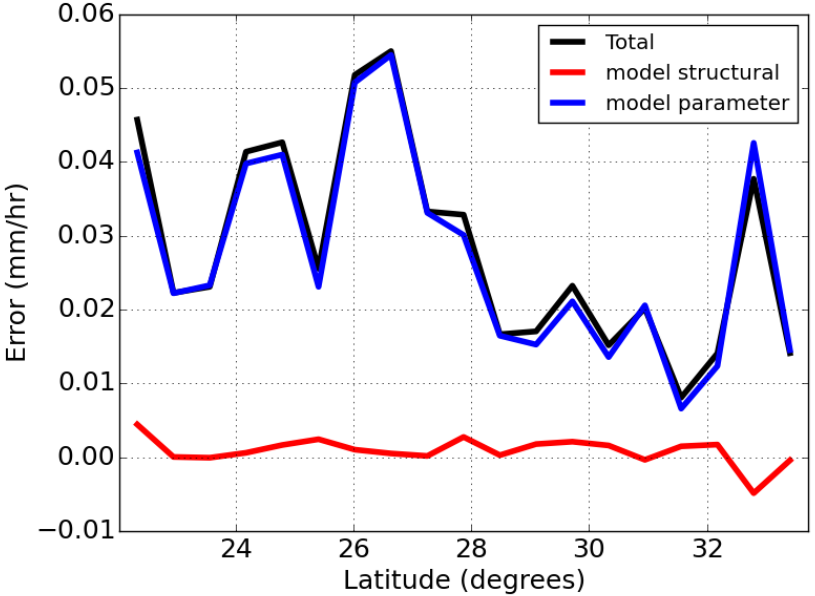


Comparing model to MAGIC radar

Error in model parameters (k, rbar) dominate.

This may indicate incorrect DSD assumptions.





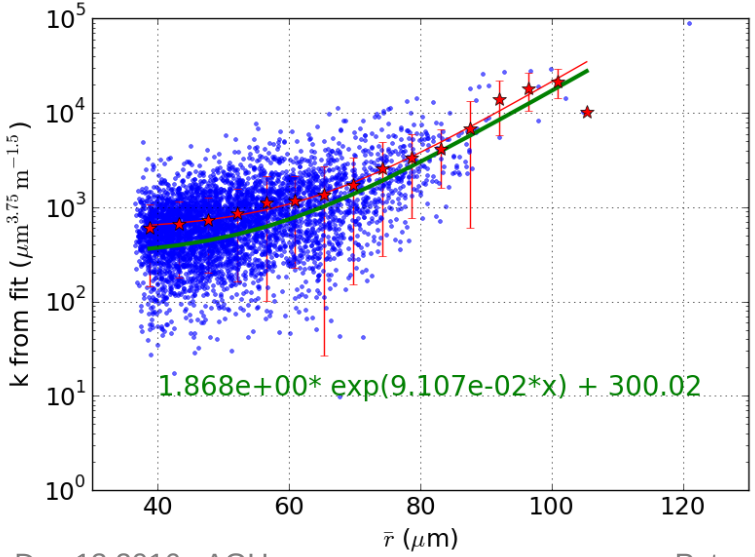
Bias-correction

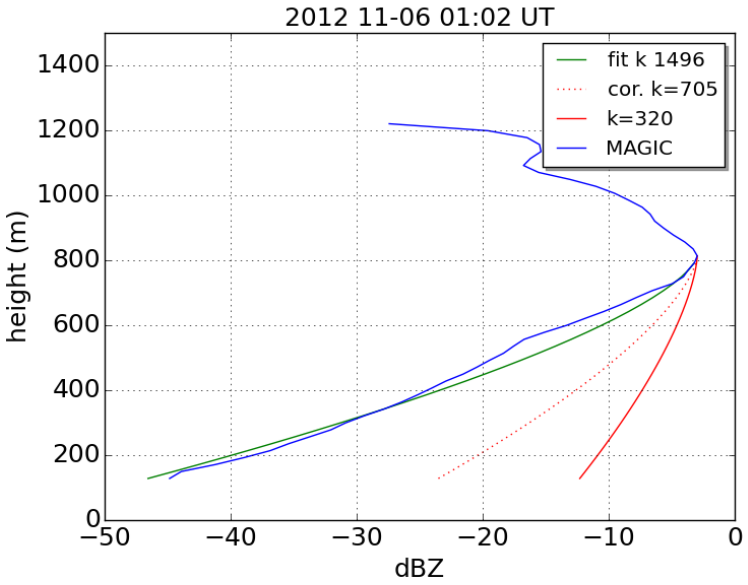
We estimate the mean absolute bias at 128 m.

We minimize this by fitting the k-parameter:

$$k = A \exp(B*rbar) + C$$

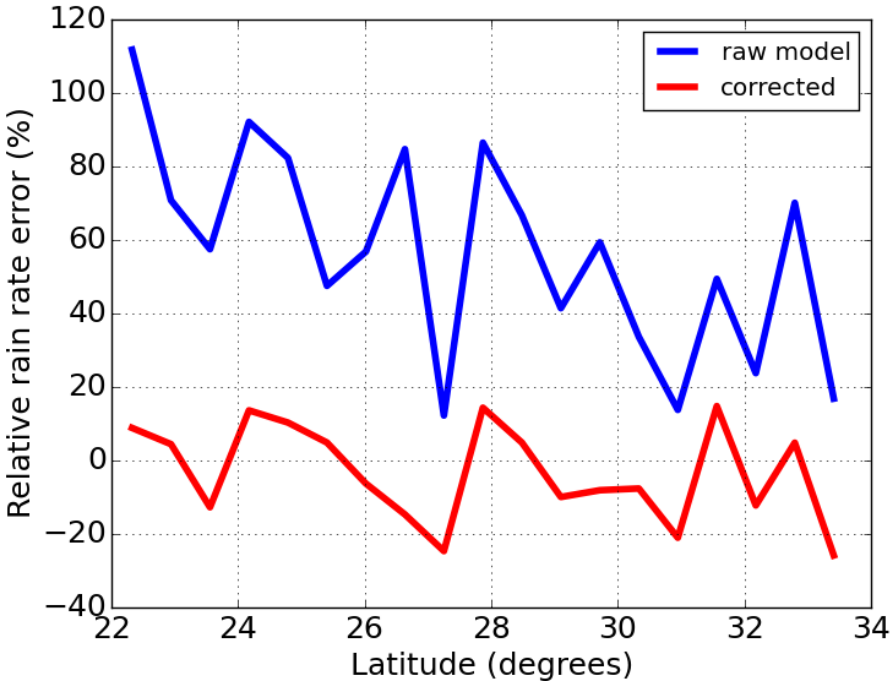
We then use this function to adjust k.





Improvement in near-surface rain rate (MAGIC region)

By design, the correction zeros out the bias in near-surface rain rate.

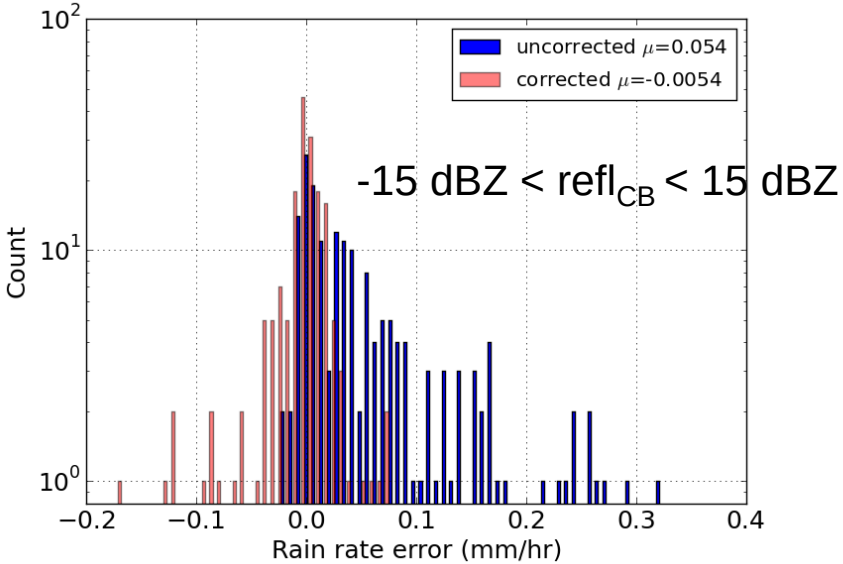


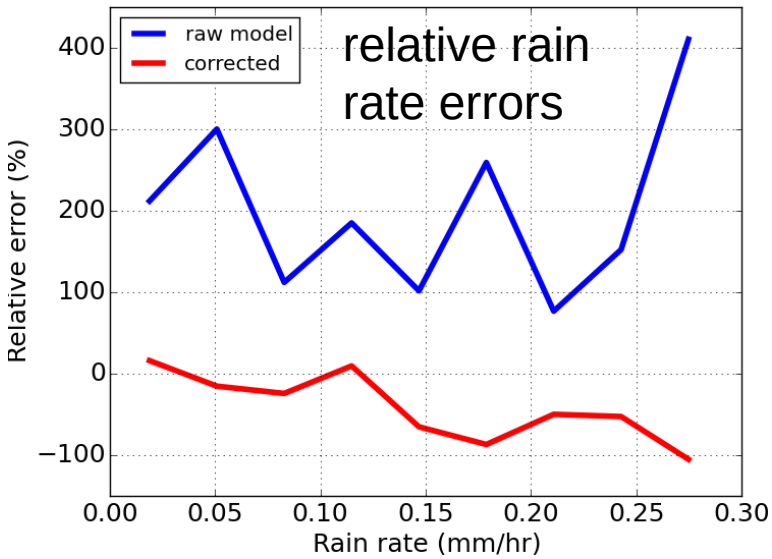
Improvement in Southeast subtropical Pacific

VOCALS campaign, W-band radar off the coast of Chile W-band, flew on C130

MAGIC-trained correction decreases near-surface rain rate bias

by 10x for light rain ($refl_{CB}$ < 15 dBZ) and by 4x for rain with $refl_{CB}$ > 15 dBZ



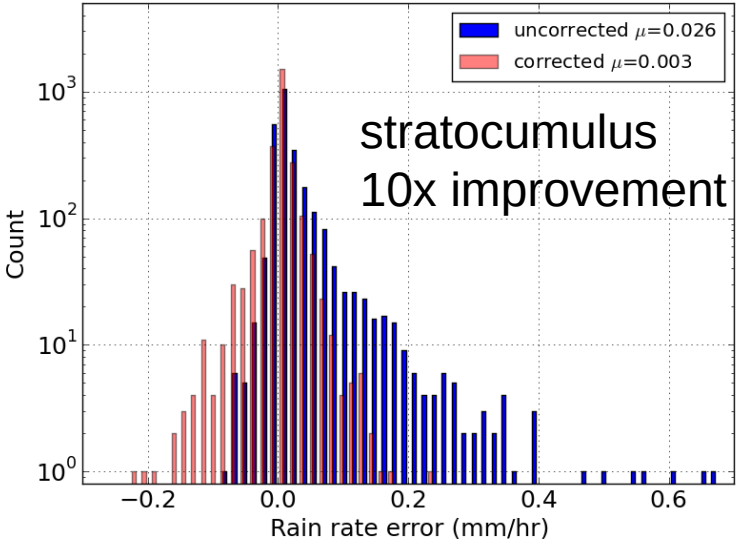


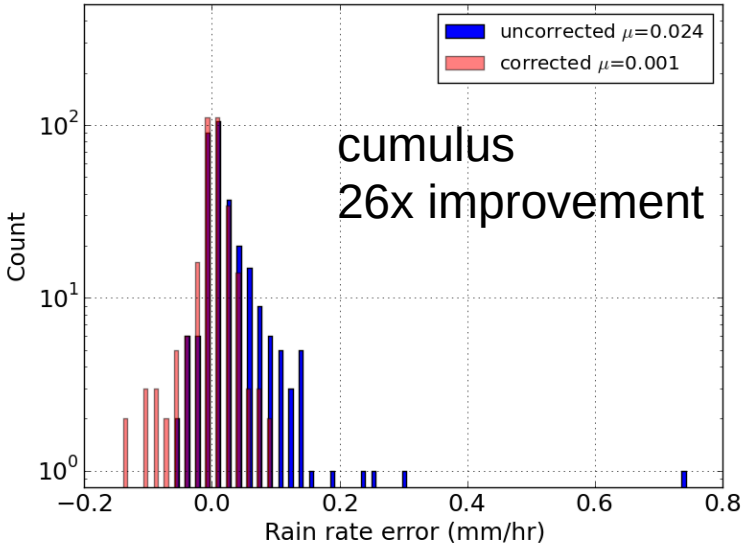
Improvement across cumulus and stratocumulus regimes

We use MAGIC ceilometer to divide profiles into two cloud regimes.

Both regimes show a large improvement, indicating correction is agnostic.

Histograms of near-surface conditional rain rate, before and after correction:





Conclusions

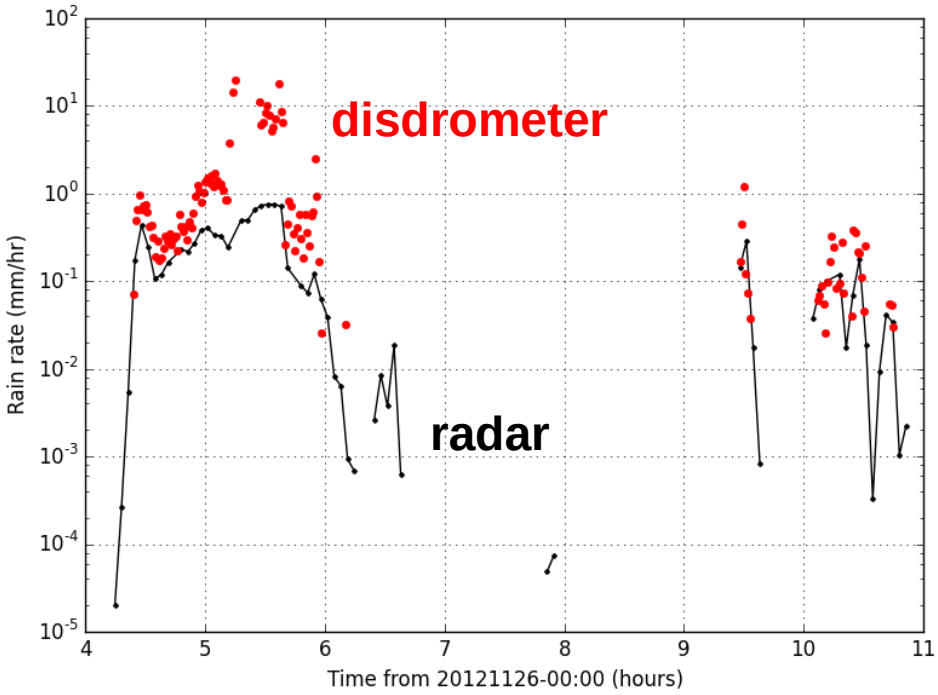
Empirical bias correction significantly reduces error in CloudSat light marine rain.

- by an order of magnitude in Southeast subtropical Pacific

We will process these corrections in **CloudSat 2C-RAIN-PROFILE R05**.

- available in late 2017

Backup Slides

Disdrometer comparison to radar

MAGIC disdrometer estimates commonly exceed radar estimates by over an order of magnitude.