Progress on the Combined Radar-Radiometer Precipitation Algorithm for TRMM/GPM

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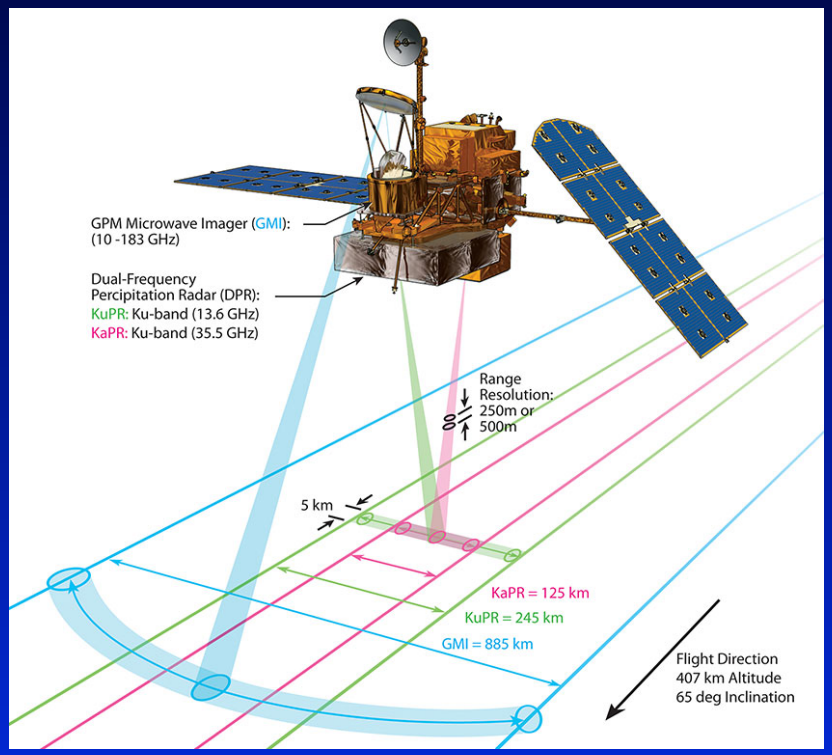
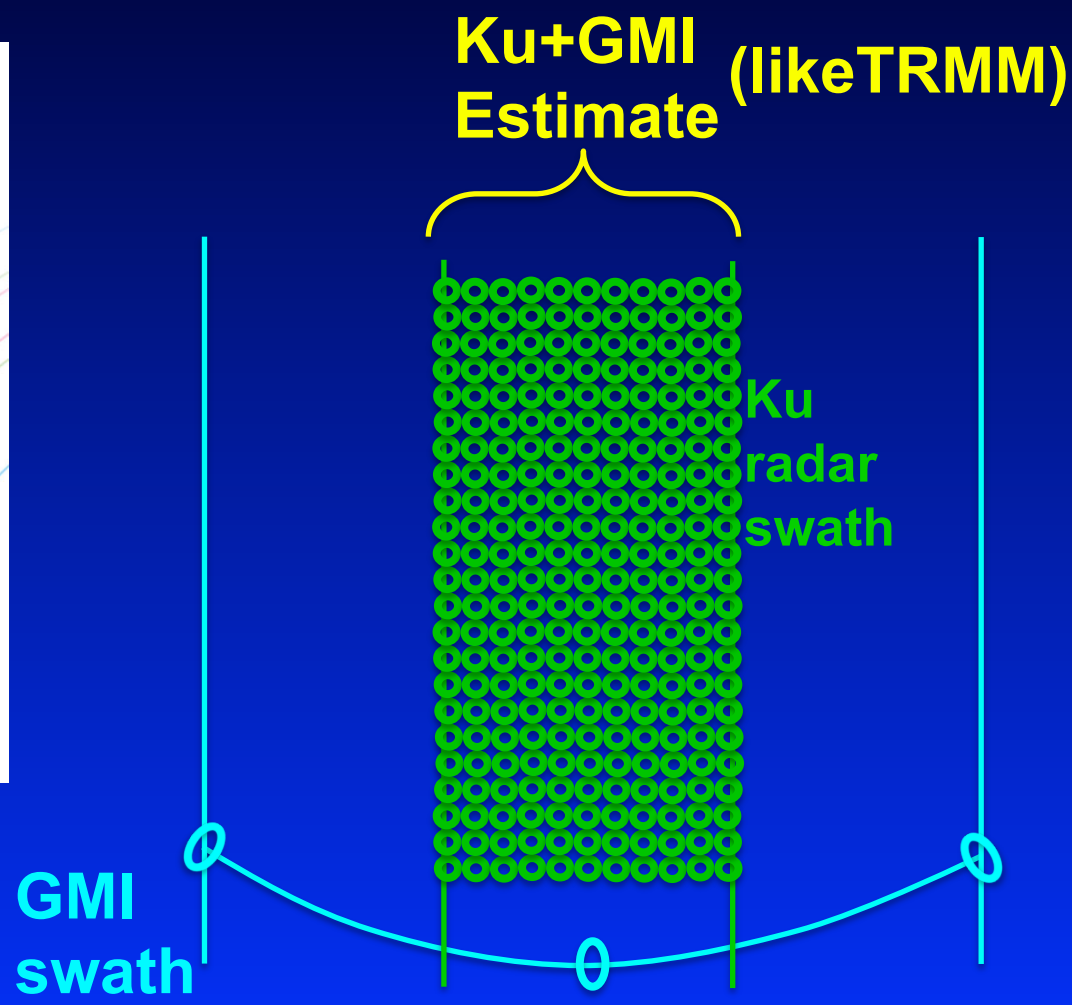
Mircea Grecu, Joe Munchak, Ziad Haddad, Kwo-Sen Kuo,
Lin Tian, Ben Johnson, and Bart Kelley
&
GPM Algorithm & GV Teams and Working Groups
&
GSFC Precipitation Processing System Personnel

rain estimates at pmm.nasa.gov (CMB)

Combined Radar-Radiometer Algorithm Input

- Dual-Frequency Precipitation Radar (DPR); Ku & Ka bands
- GPM Microwave Imager (GMI); 10 – 183 GHz.





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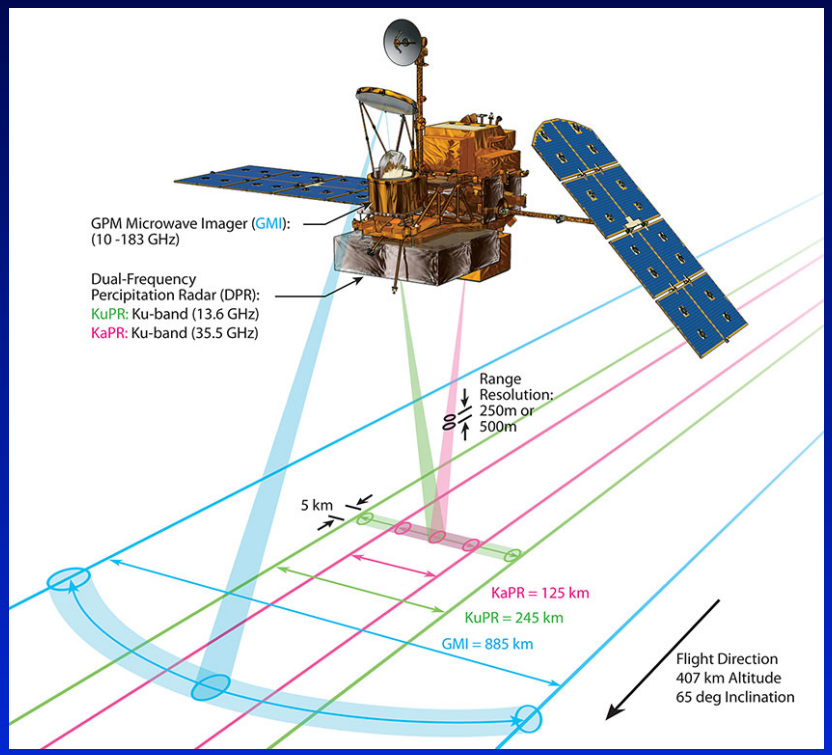
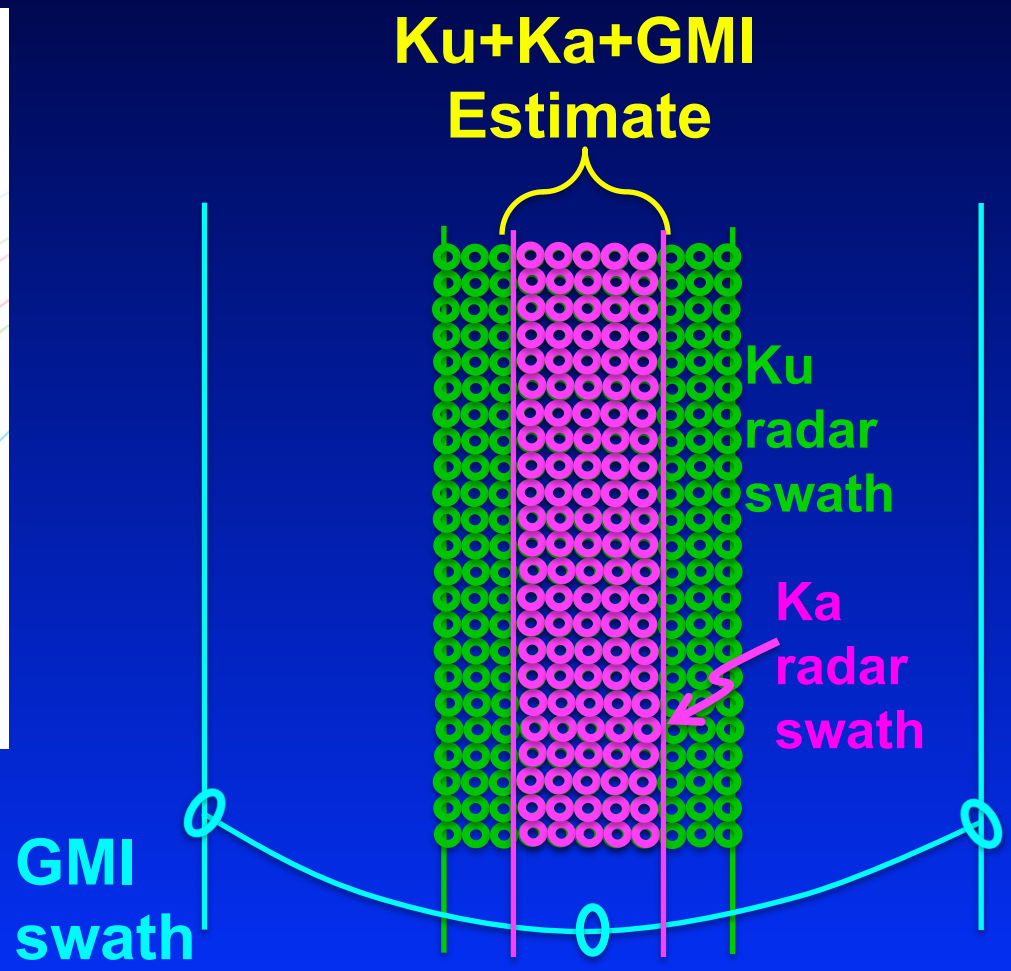




Algorithm Status

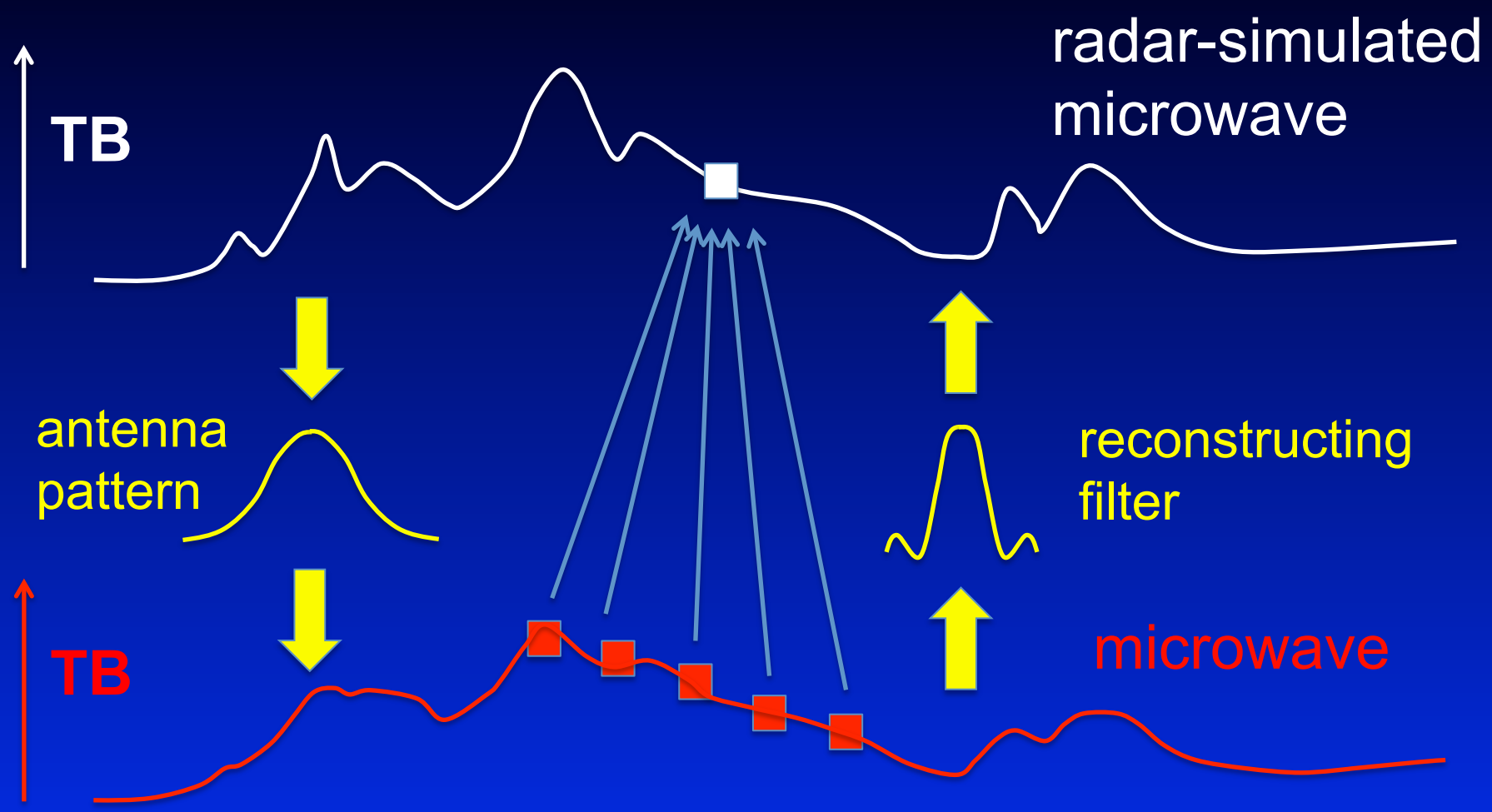
- Basic algorithm framework unchanged:
  Ensemble filtering of Z_{Ku}-constrained solutions using Z_{Ka}, $PIA_{Ku;Ka}$, and GMI TB's.

- GMI radiances are resolution-enhanced using regression-based filters.

- Hogan & Battaglia model for multiple-scattering in radar simulations is utilized where needed.

- In process, improvements in
  - surface characterization
  - impacts of non-spherical particle properties.
  - *a priori* particle size distribution properties.

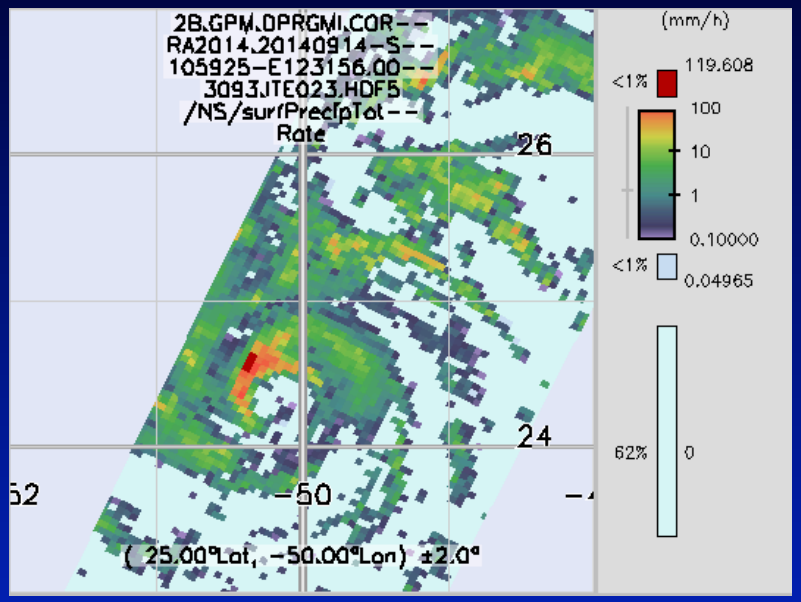
Resolution-Enhancement of GMI Radiances



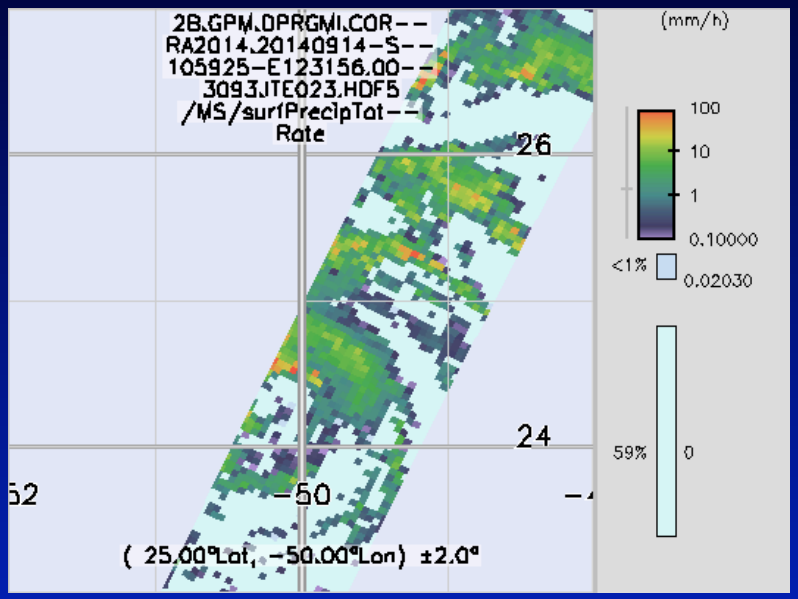
Mircea Grecu

Precip. Estimates from Hurricane Edouard

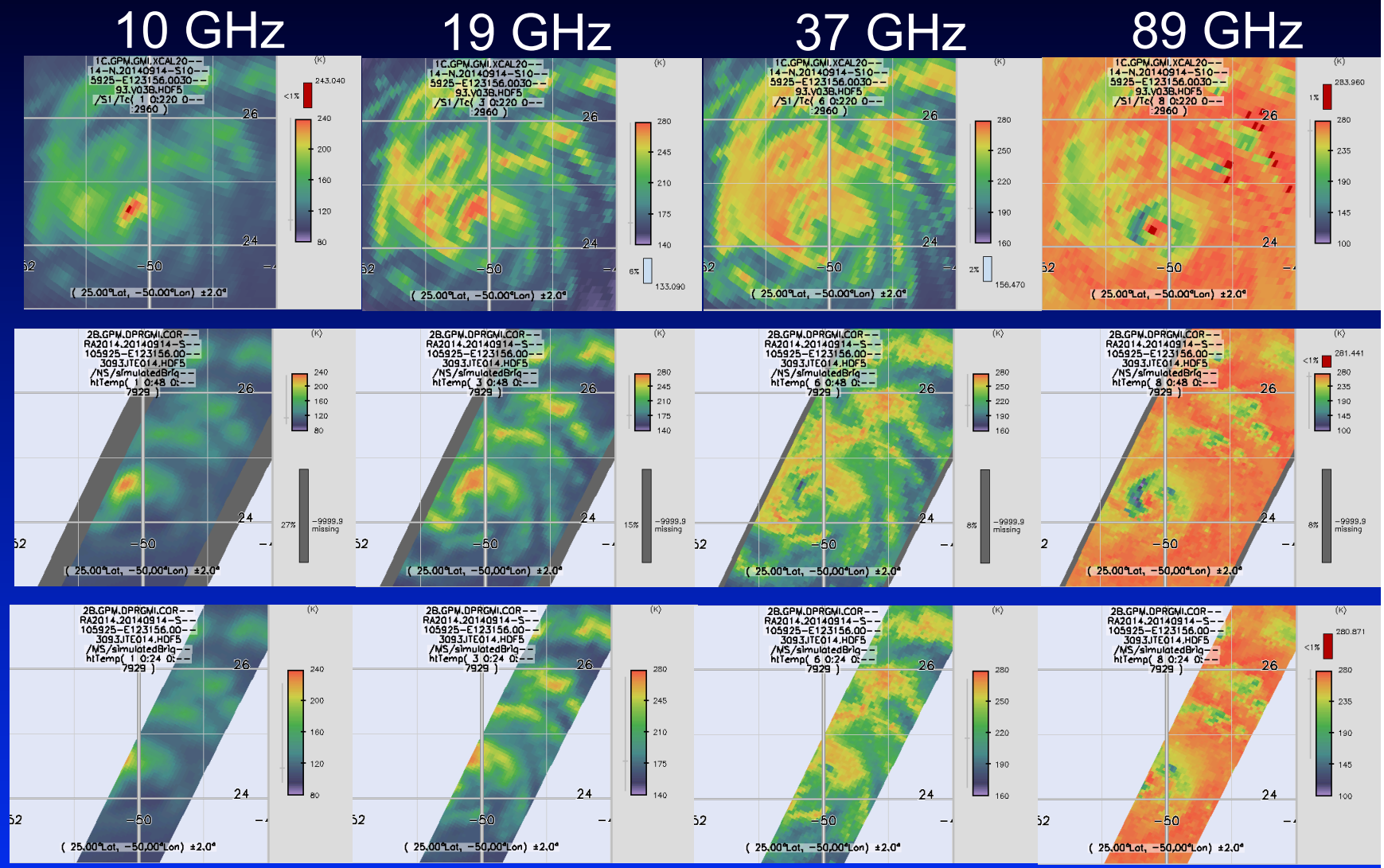
Ku+GMI Rain Rate



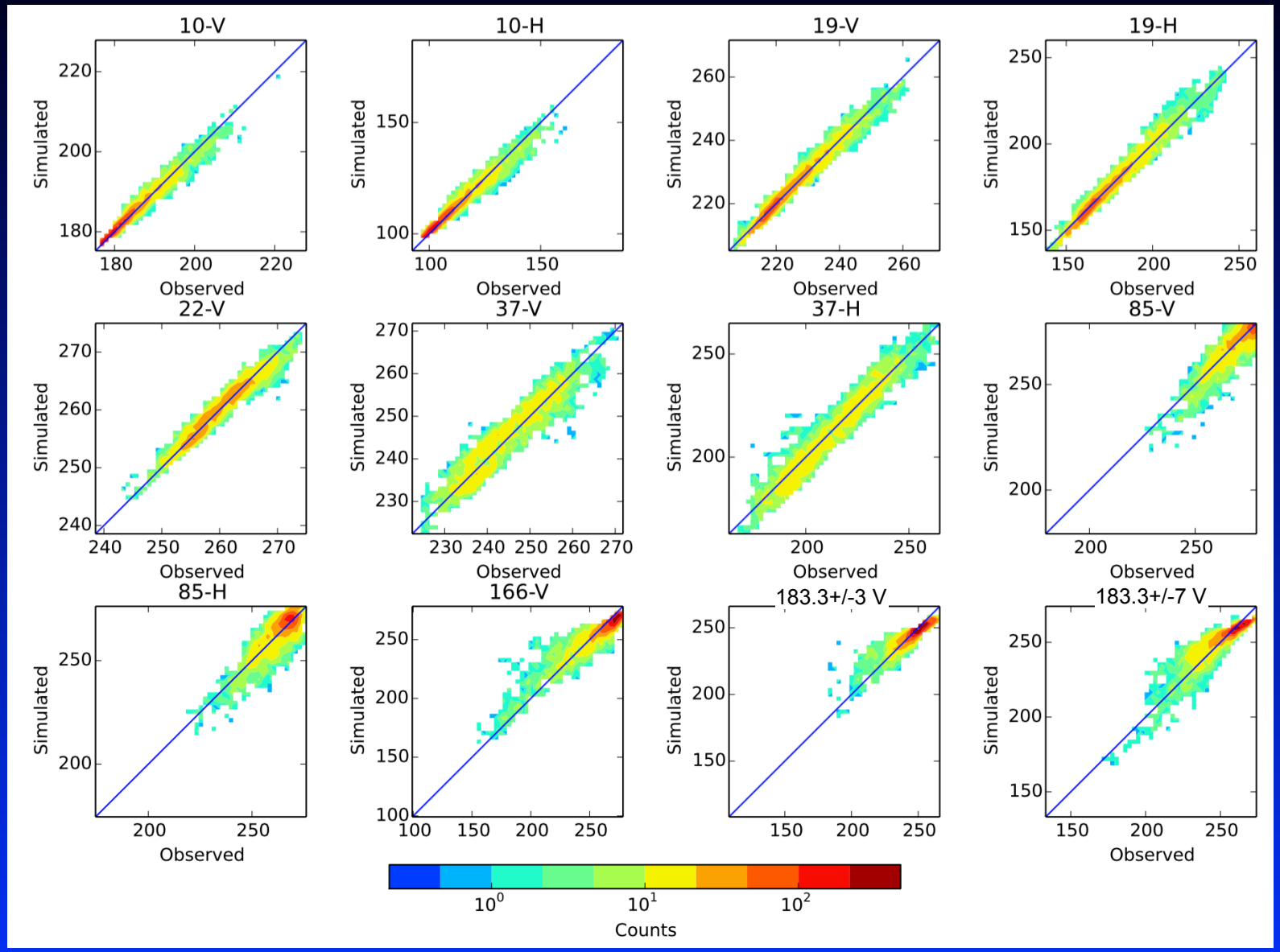
Ku+Ka+GMI Rain Rate



TB Simulations from Hurricane Edouard

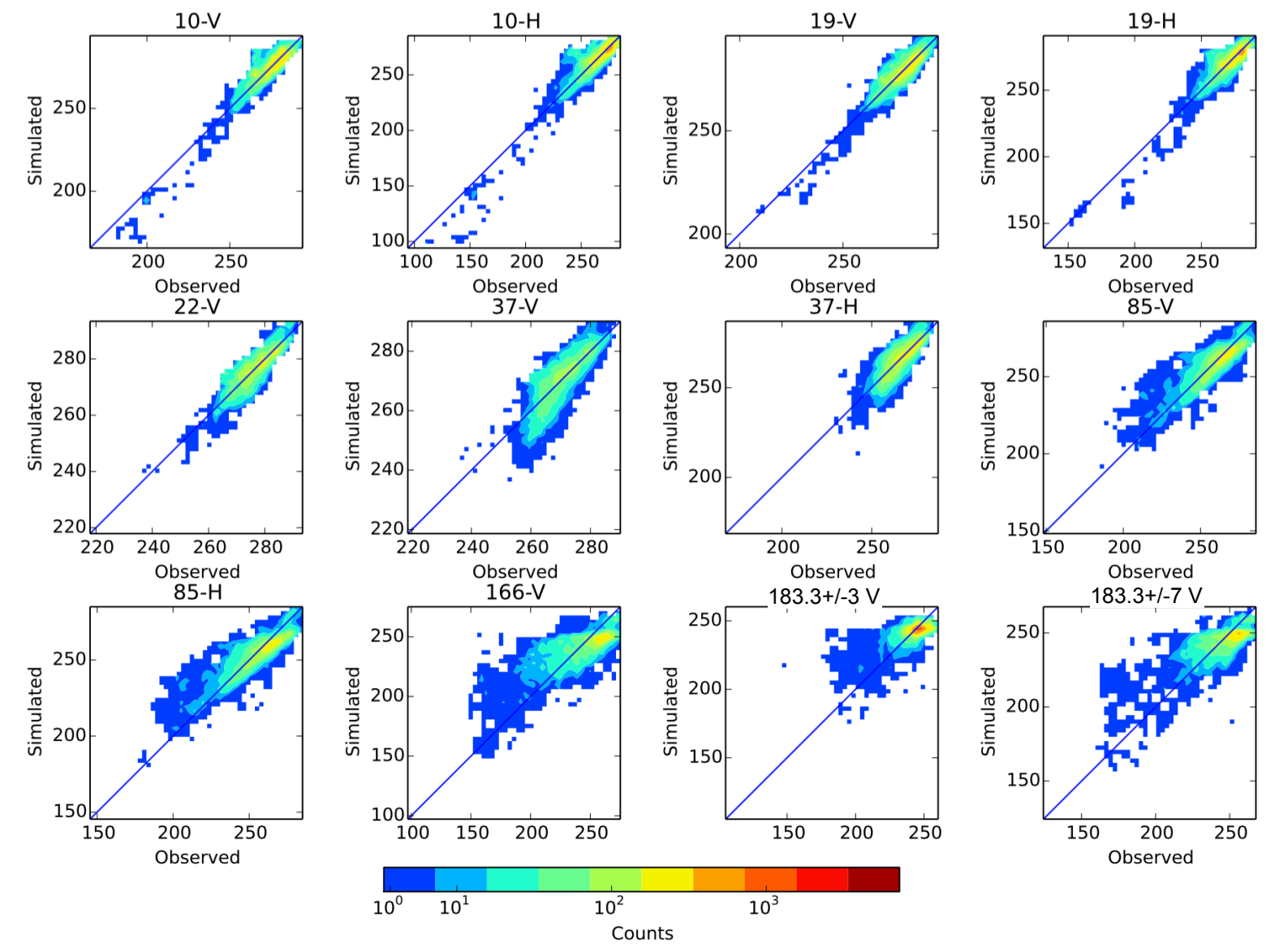


TB Simulations vs. Observations over Ocean



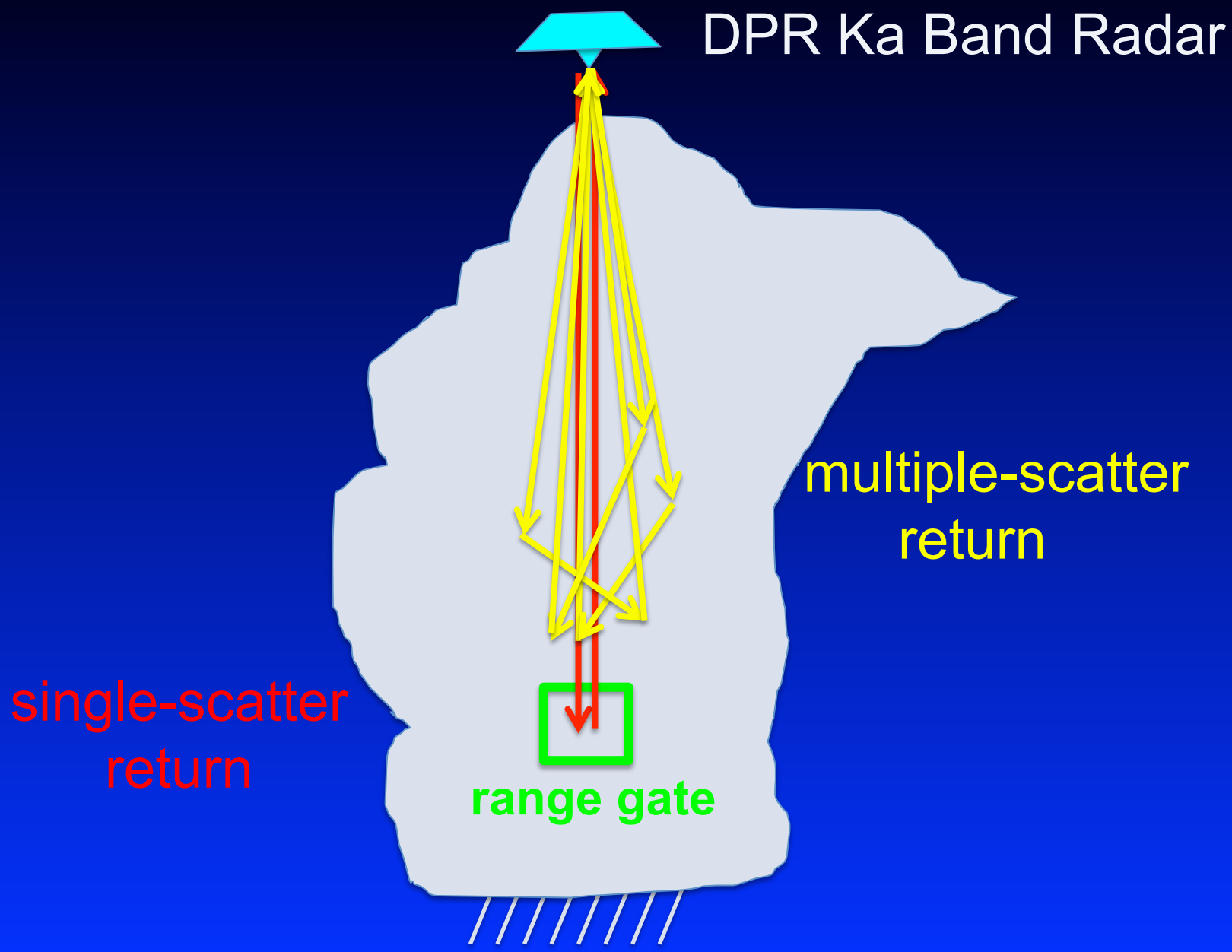
from Mircea Grecu

TB Simulations vs. Observations over Land

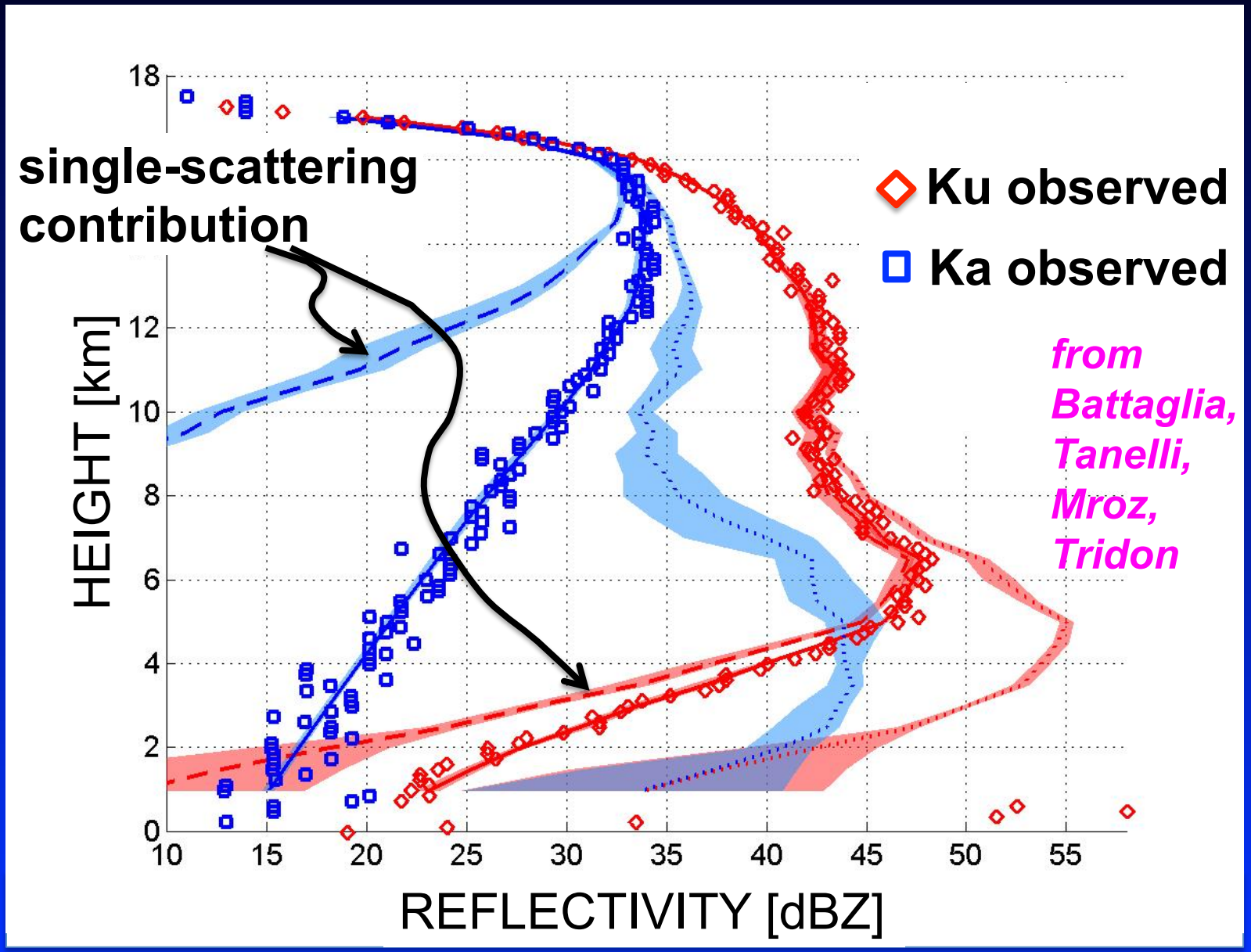


from Mircea Grecu

Impact of Multiple Scattering



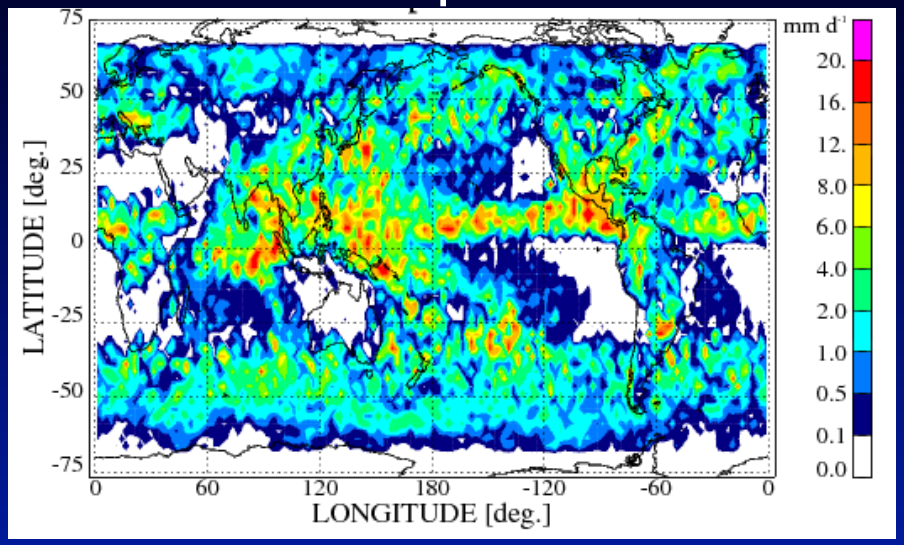
Observed and Modeled DPR Reflectivities



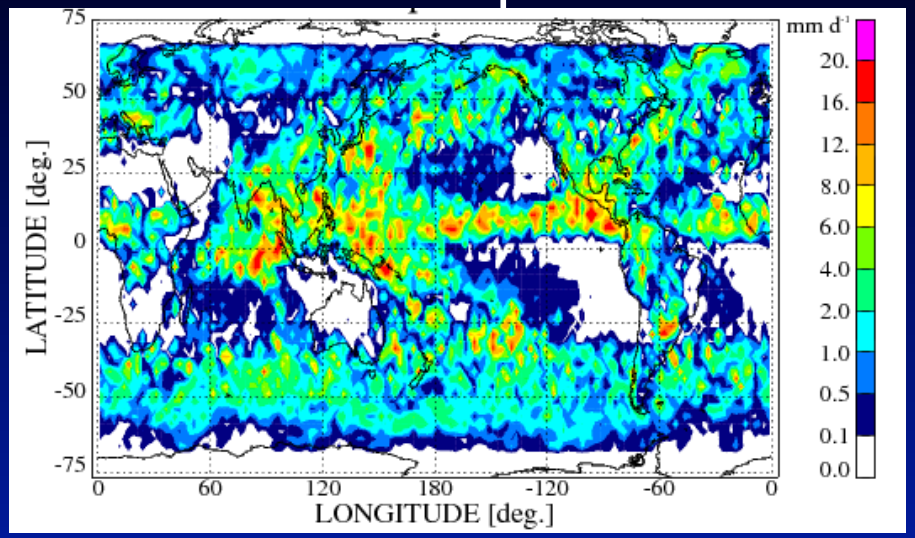
Comparison of GPM Mean Precip. vs. GPCP

Dave Bolvin

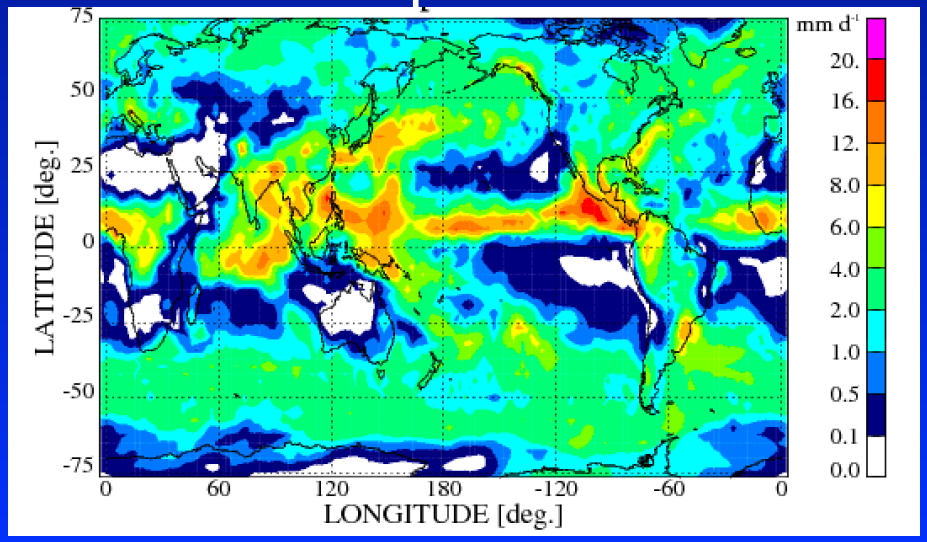
Ku+GMI Sep 2014 Mean



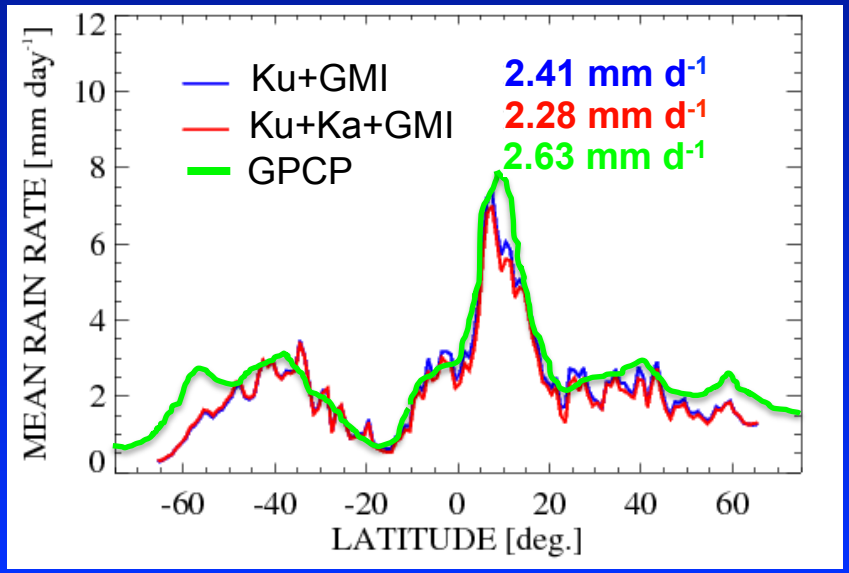
Ku+Ka+GMI Sep 2014 Mean



GPCP Sep 2014 Mean

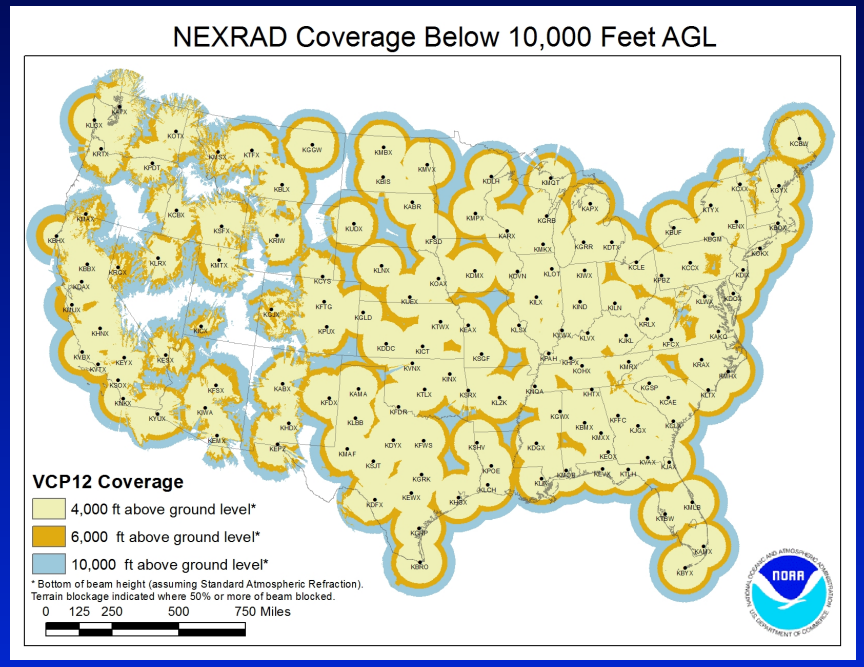


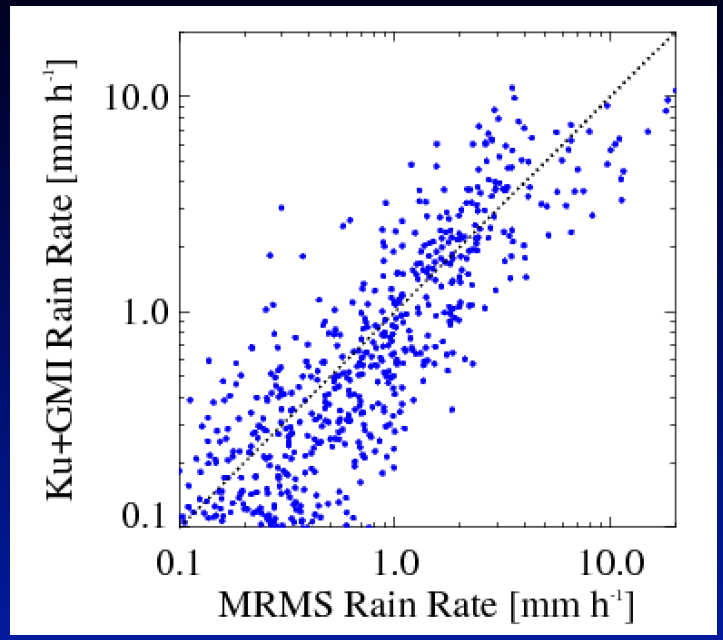
Zonal Means

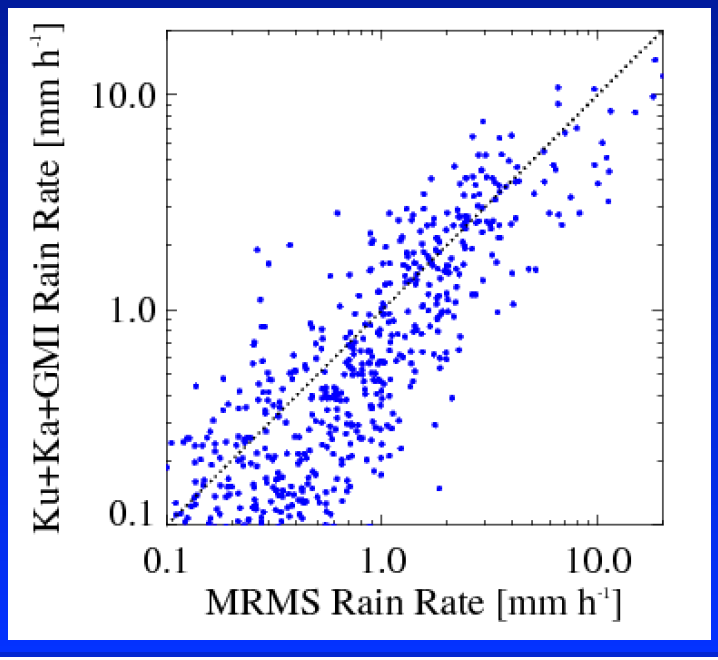


Ground Radar Comparisons for Sep 2014

MRMS are gage-calibrated NEXRAD rain rates







Pierre Kirstetter, Bart Kelley, Chris Kidd

Concluding Remarks

- Combined algorithm V4 should be ready for release 1 month after radar L2 algorithm stabilizes.

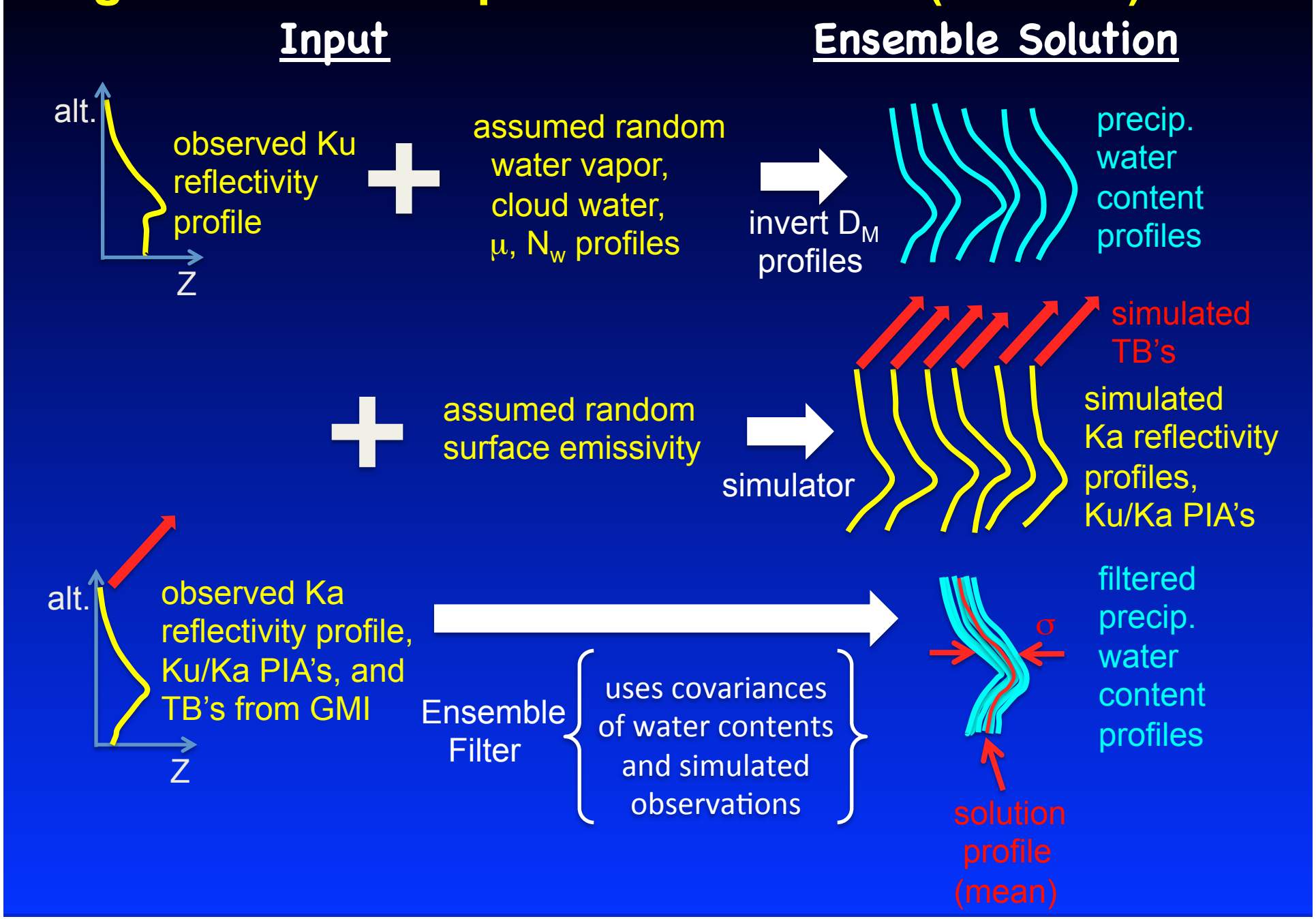
- Will work with radiometer team to produce empirical databases.

- Extend validation.

- Improved physical and statistical parameterizations are still key objectives:
  - sub footprint-scale precip variability.
  - radar multiple-scattering effects.
  - *A priori* PSD assumptions; PSD representation.
  - impacts of non-spherical particles.
  - surface characterization.

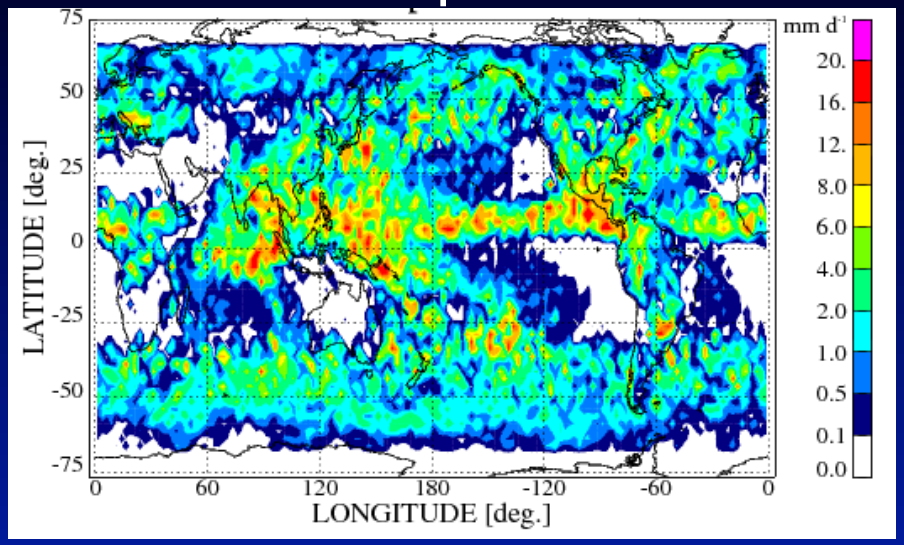
Extras

Algorithm "Concept" --- Ensemble (Kalman) Filter

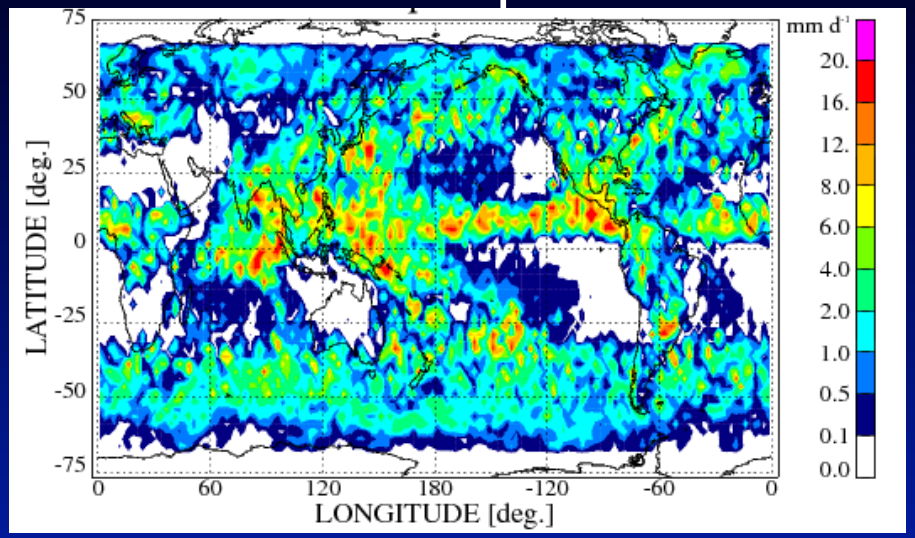


Comparison of GPM Mean Precip. Estimates

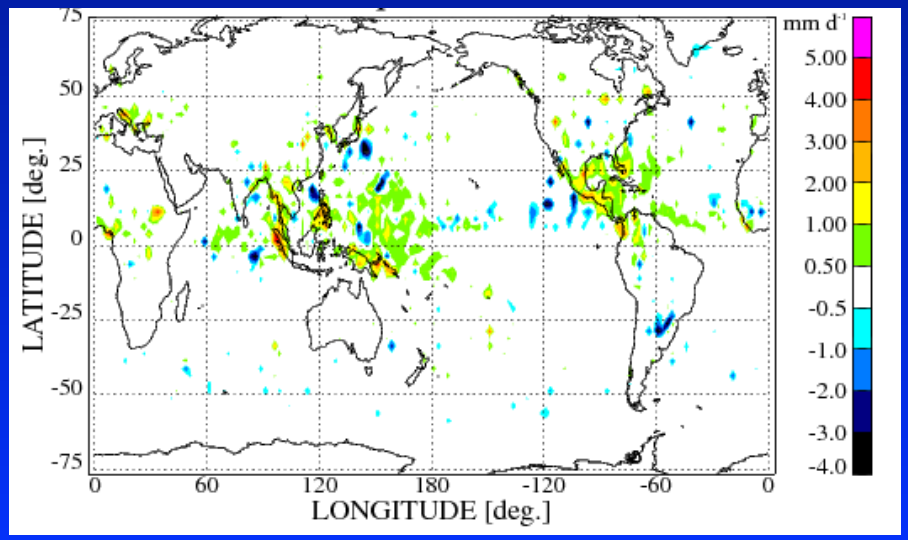
Ku+GMI Sep 2014 Mean



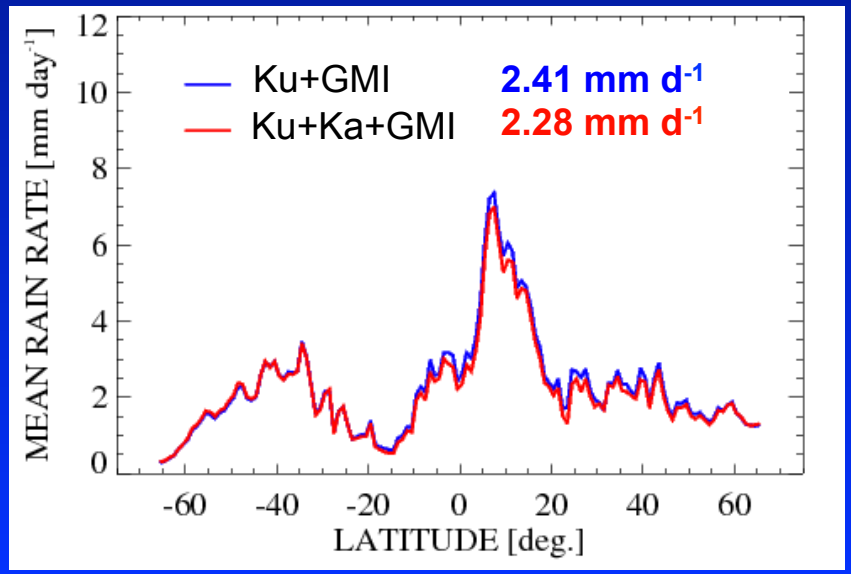
Ku+Ka+GMI Sep 2014 Mean



Ku+GMI minus Ku+Ka+GMI



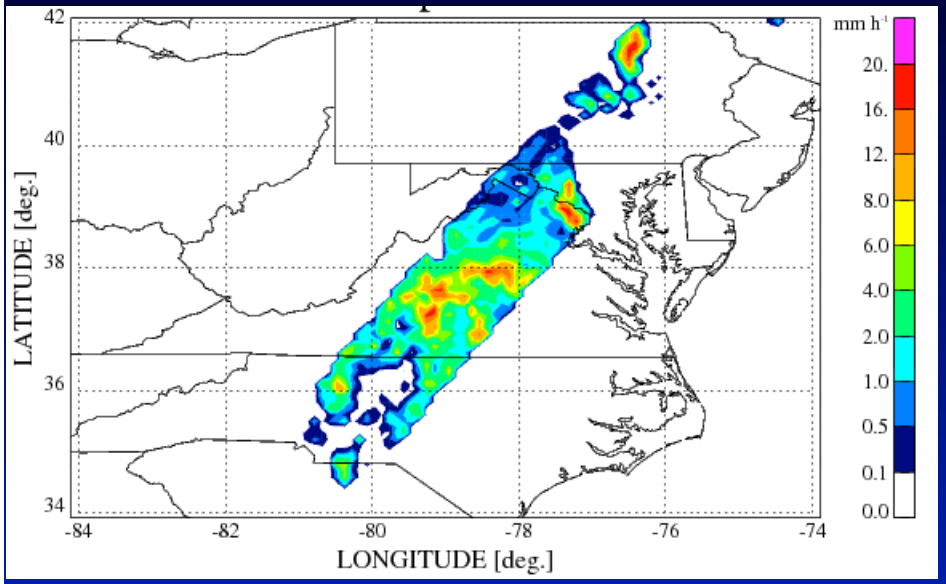
Zonal Means



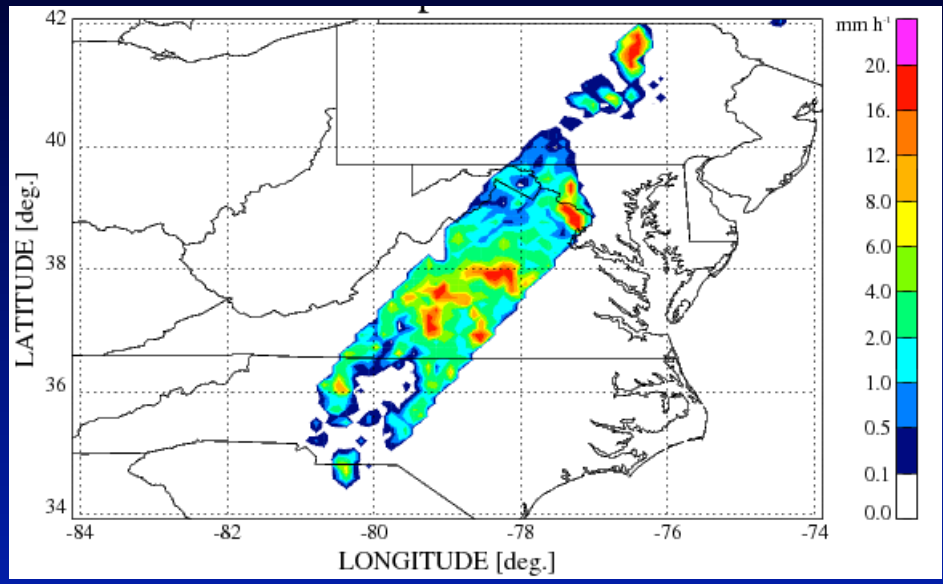
Early Ground Validation Studies

GPM vs. MRMS Radar Product; 16 May, 0.1 deg.

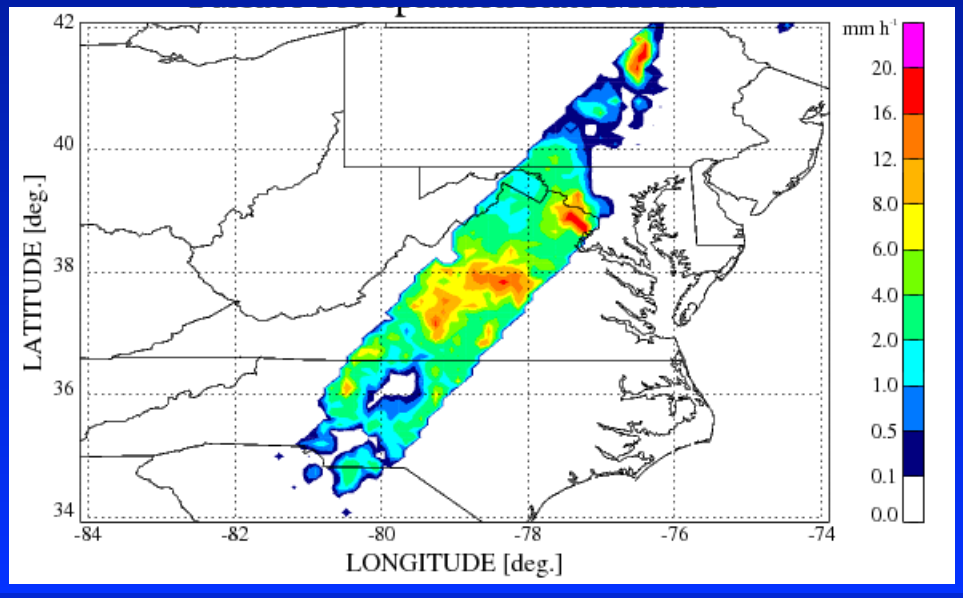
Ku+GMI Surface Rain Rate



Ku+Ka+GMI Surface Rain Rate



MRMS Surface Rain Rate

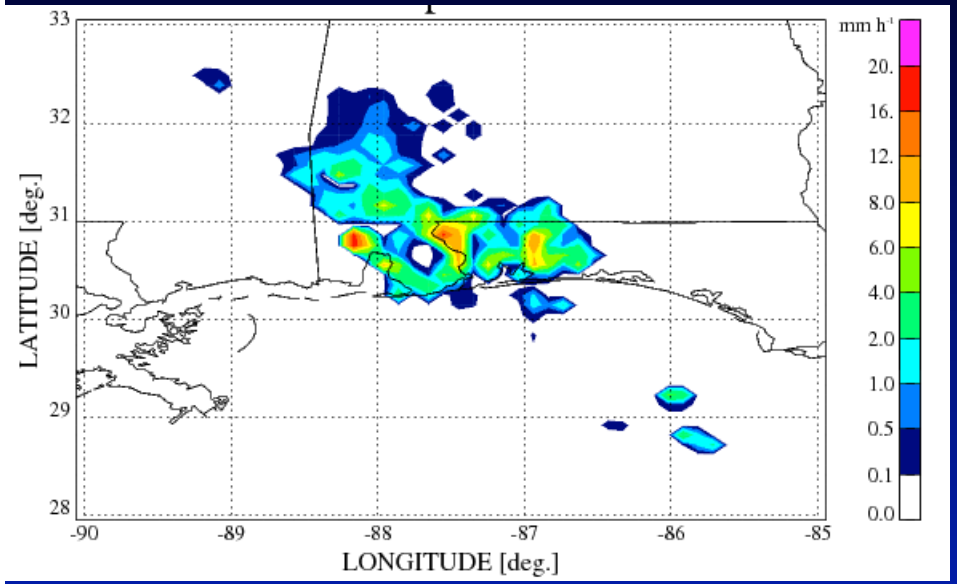


collocated MRMS from Pierre Kirstetter

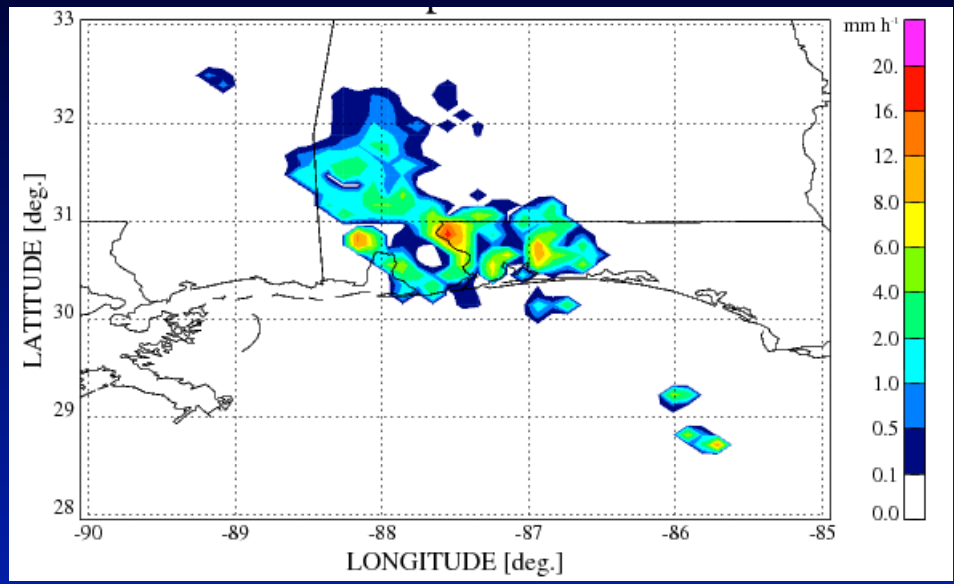
Early Ground Validation Studies

GPM vs. MRMS Radar Product; 29 May, 0.1 deg.

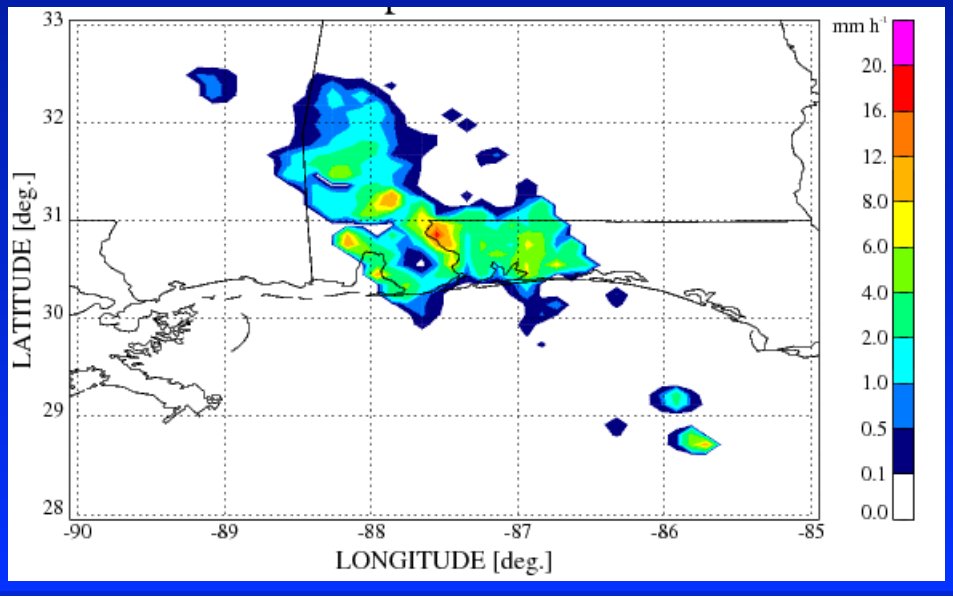
Ku+GMI Surface Rain Rate



Ku+Ka+GMI Surface Rain Rate



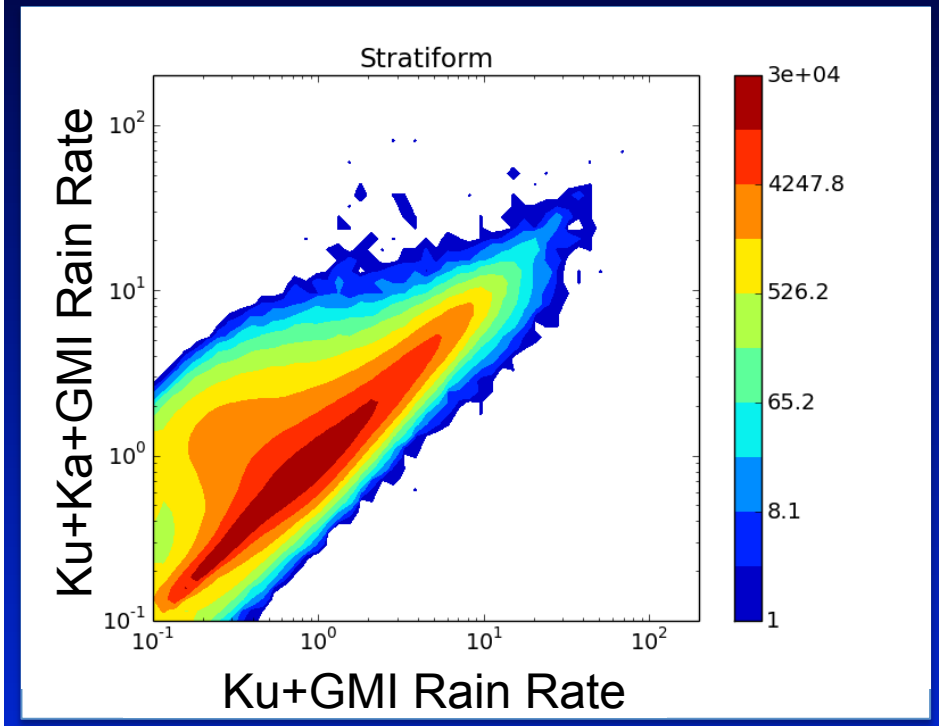
MRMS Surface Rain Rate



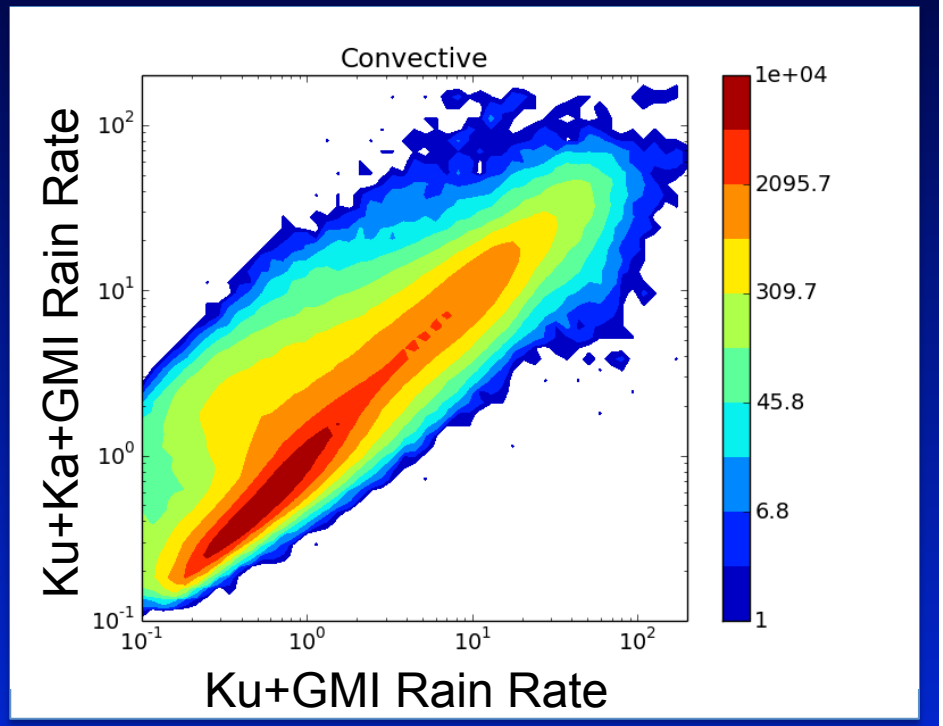
collocated MRMS from Pierre Kirstetter

Estimated Rain from Ku+GMI vs. Ku+Ka+GMI

Stratiform Precipitation



Convective Precipitation



Overview

- Basic algorithm framework:
  Ensemble filtering of Z_{Ku}-constrained solutions using Z_{Ka}, $PIA_{Ku;Ka}$, and GMI TB's.

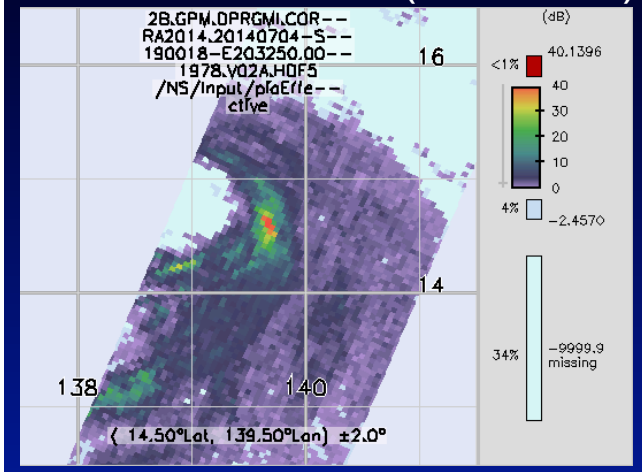
★ Sub-footprint-scale variability modeled using extended ensembles.

★ Simple Ka multiple-scattering parameterization.

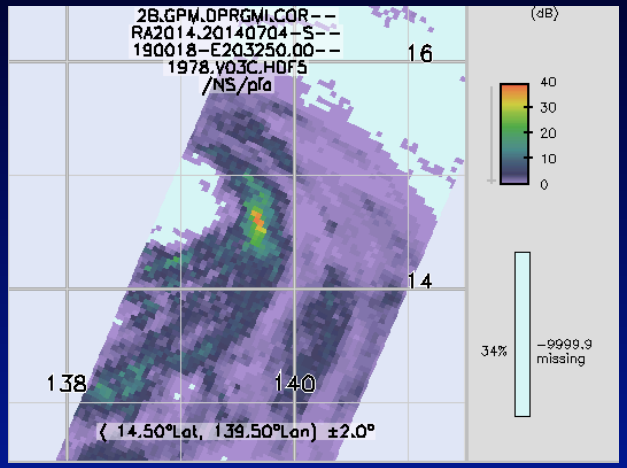
★ Preliminary evaluation of estimates.

Typhoon Neoguri on 4 July 2014, Fitting of Data

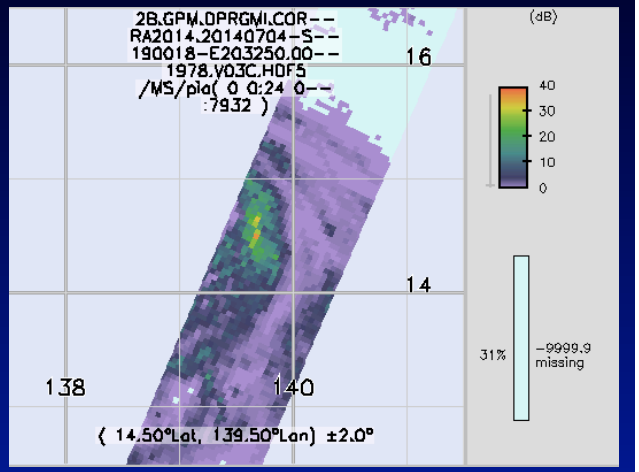
Observed Ku PIA (from SRT)



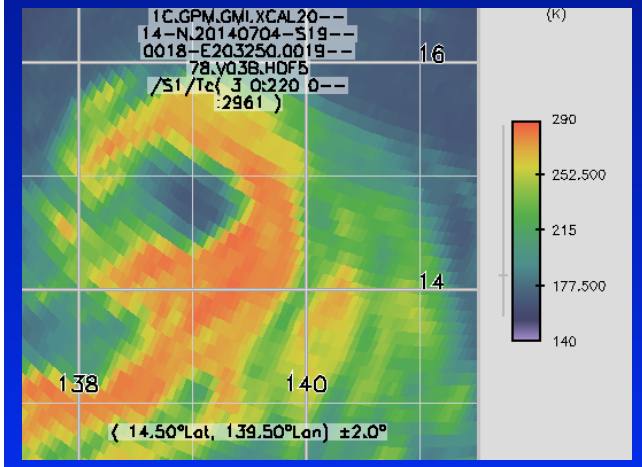
Ku+GMI Est. Ku PIA



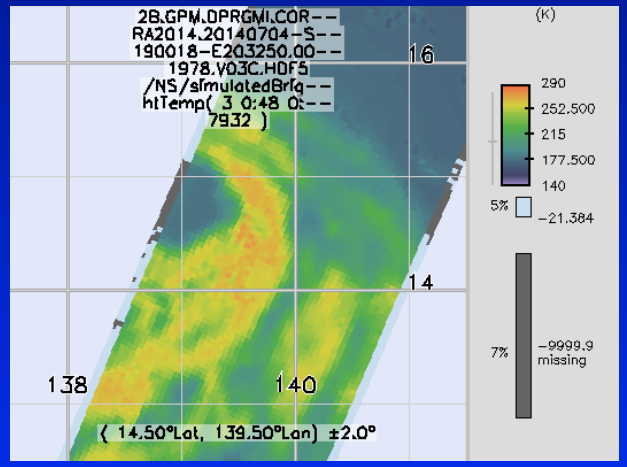
Ku+Ka+GMI Est. Ku PIA



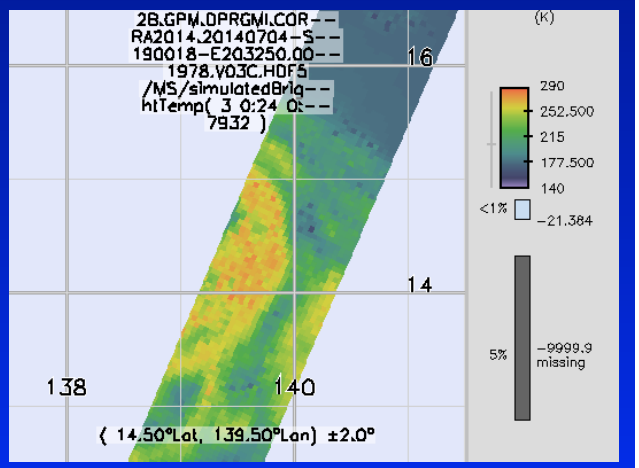
Observed 19 GHz TB



Ku+GMI Est. 19 GHz TB

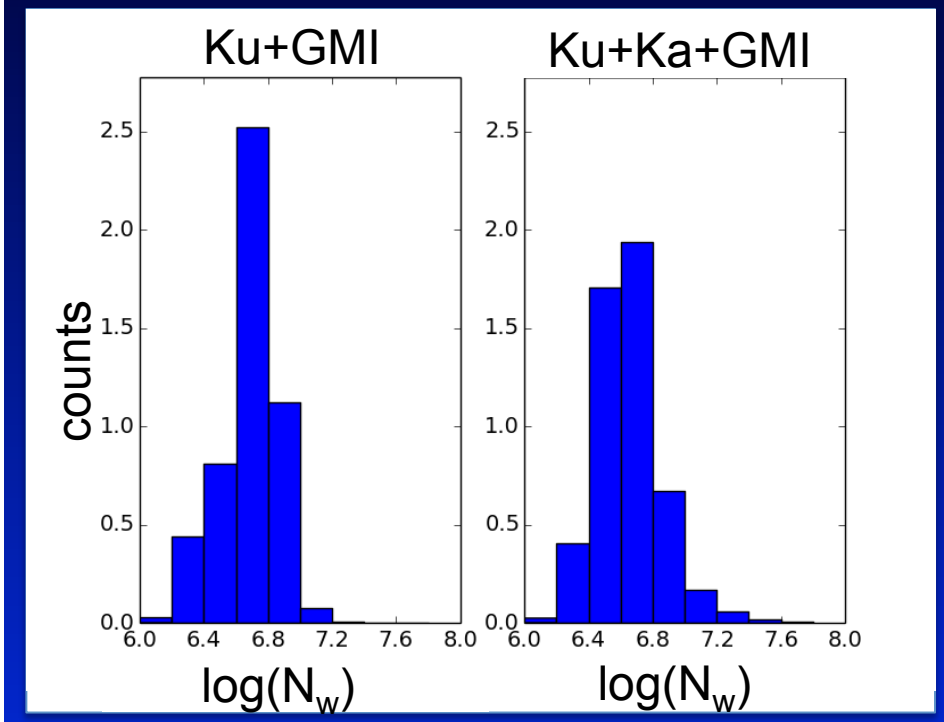


Ku+Ka+GMI Est. 19 GHz TB

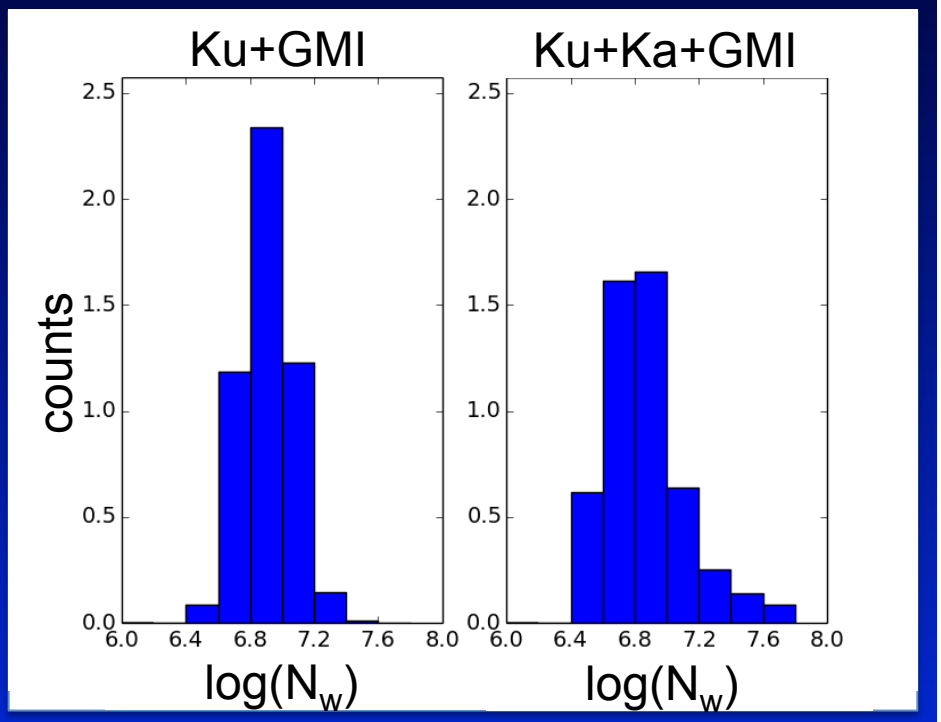


Estimated N_w from Ku+GMI vs. Ku+Ka+GMI

Stratiform Precipitation



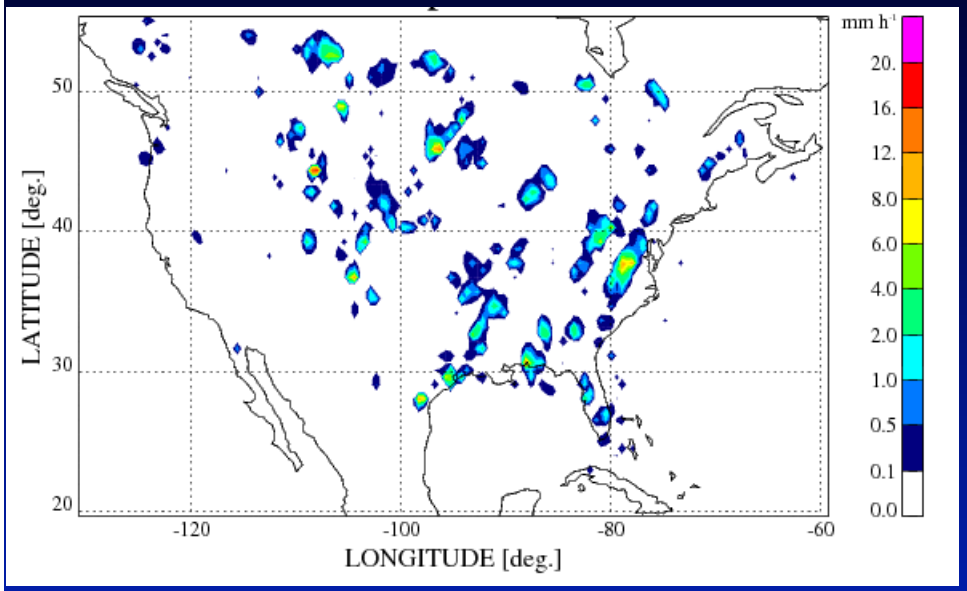
Convective Precipitation



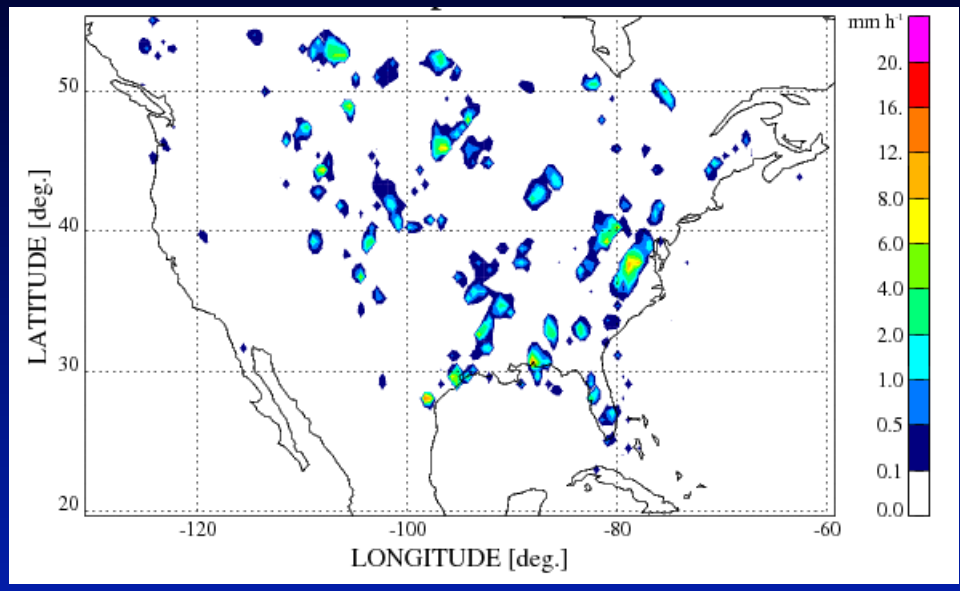
Beginning Ground Validation Studies

GPM vs. MRMS Radar Product; 16-31 May; 0.5 deg.

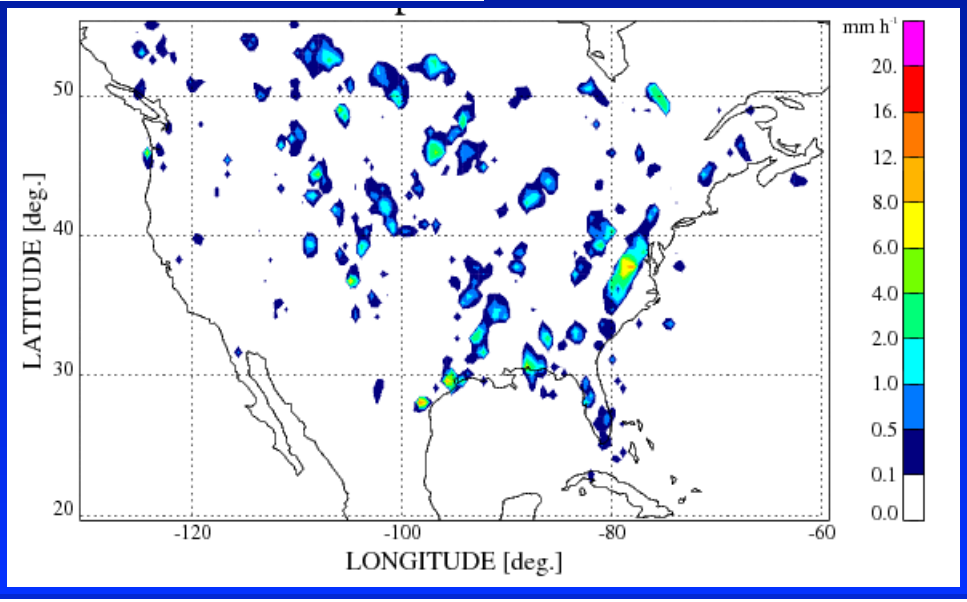
Ku+GMI Surface Rain Rate



Ku+Ka+GMI Surface Rain Rate



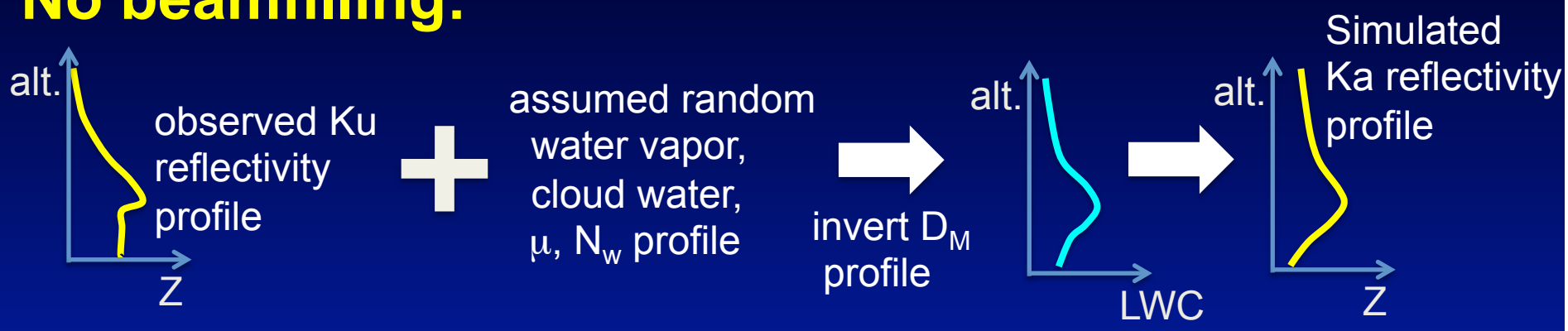
MRMS Surface Rain Rate



collocated MRMS from Pierre Kirstetter

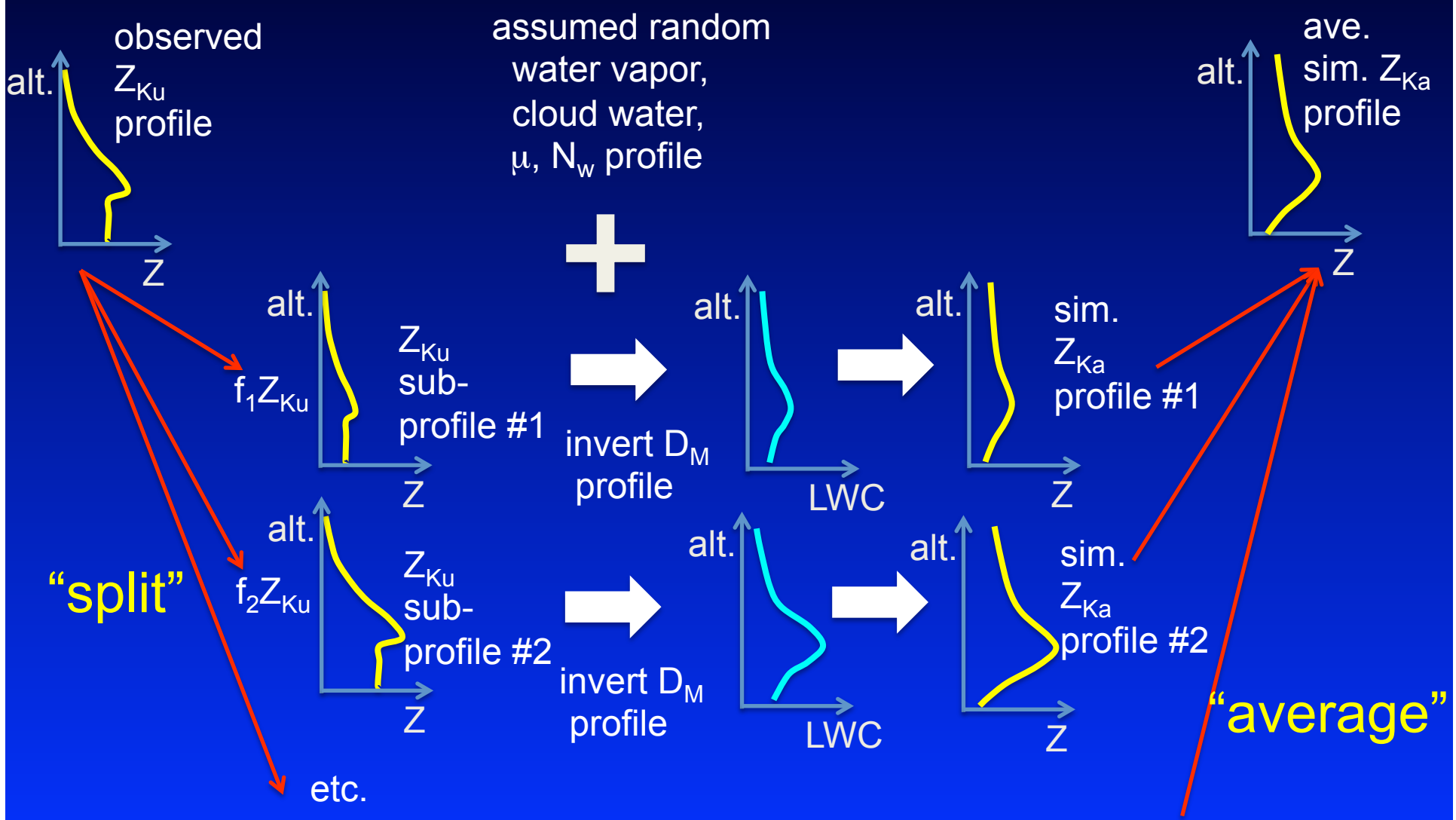
"Downscaling" to Represent Beamfilling

No beamfilling:



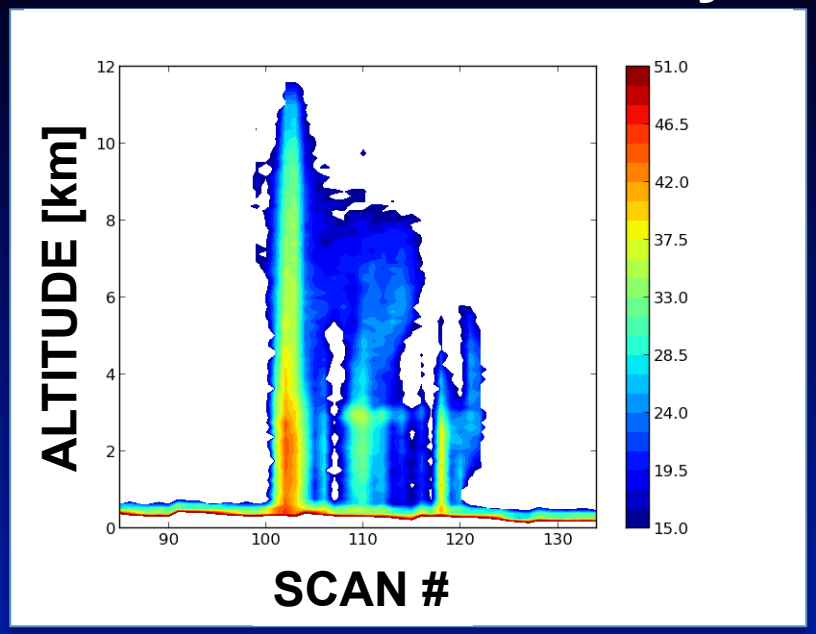
"Downscaling" to Represent Beamfilling

With beamfilling:

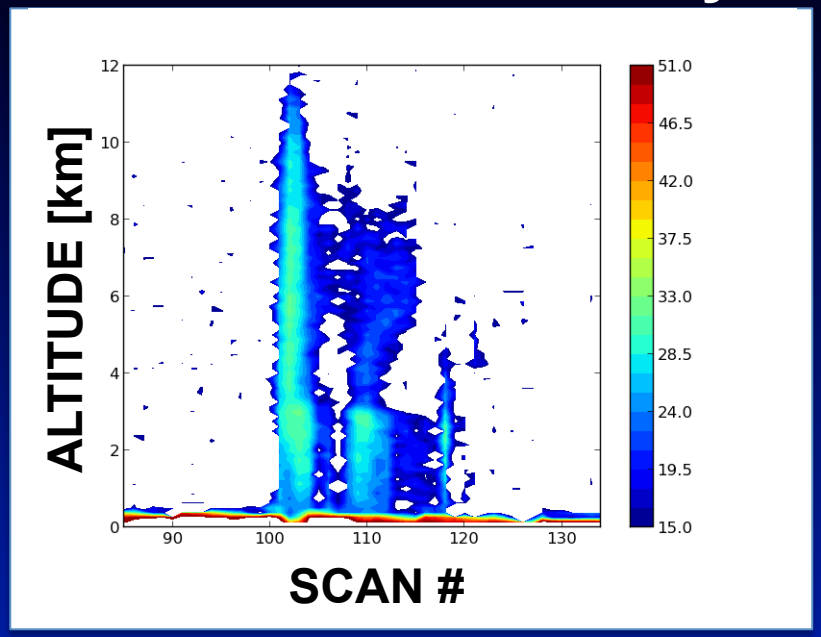


Multiple Scattering Effects

Ku-Band Reflectivity



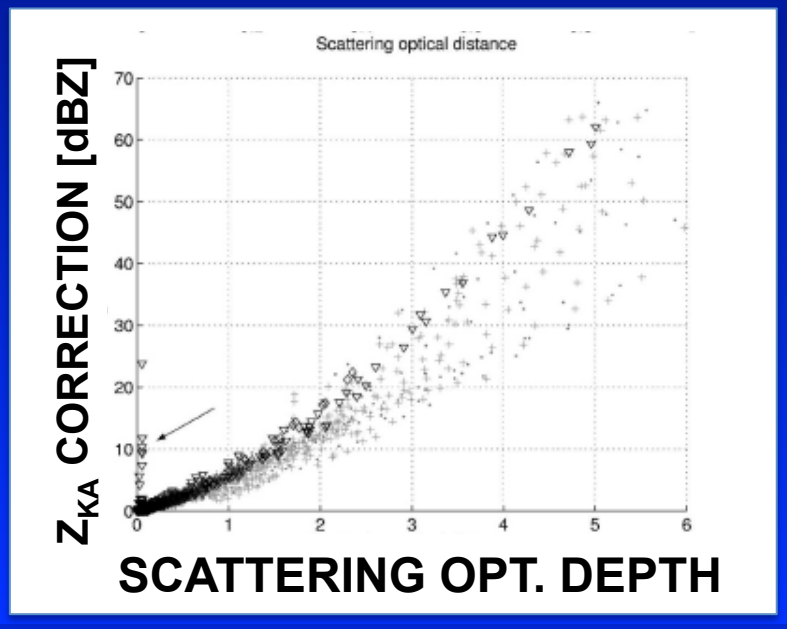
Ka-Band Reflectivity



Z_{KA} Correction:

from

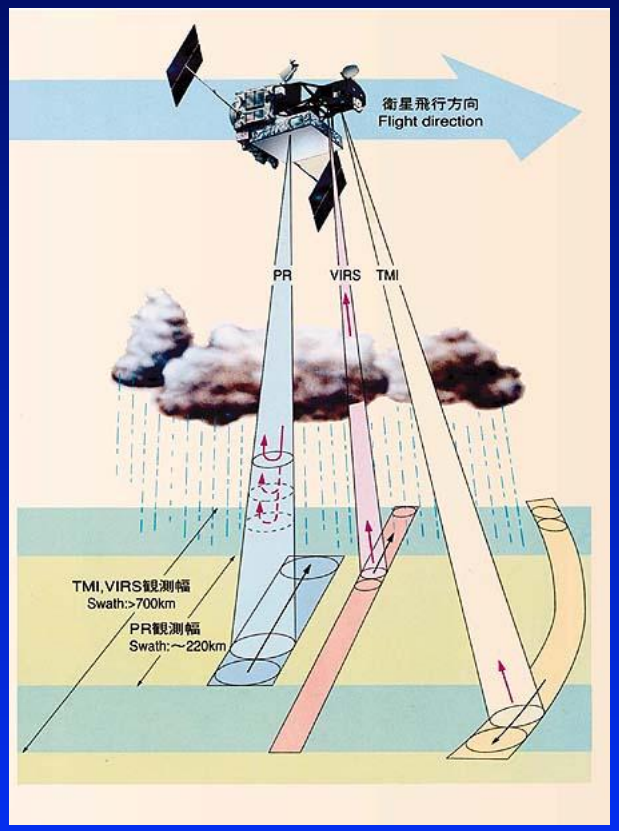
Battaglia et al. (JAMC, 2006b)



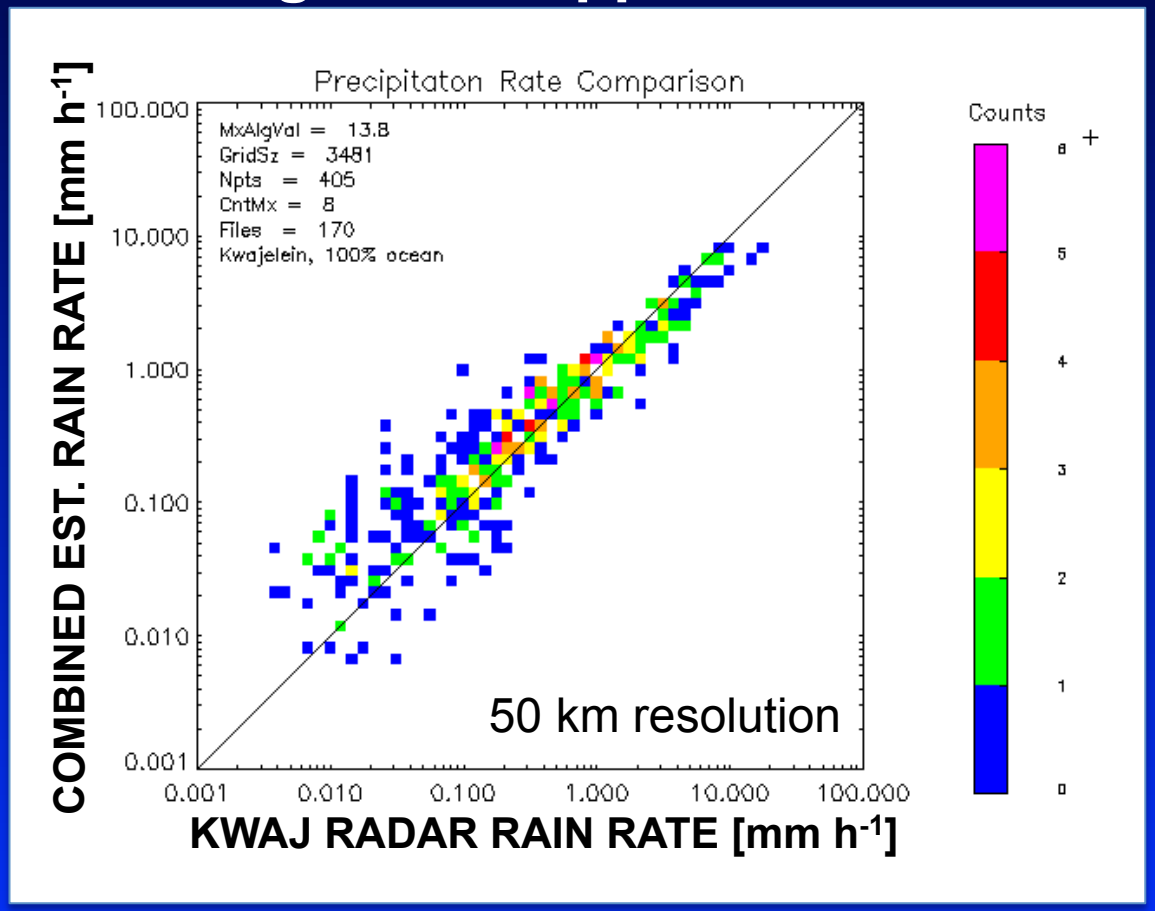
Algorithm Testing (Pre-Launch)

Want < 50% error for 50 km res. estimates at 1 mm h^{-1}
< 25% error for 50 km res. estimates at 10 mm h^{-1}

TRMM: Ku radar + TMI radiometer

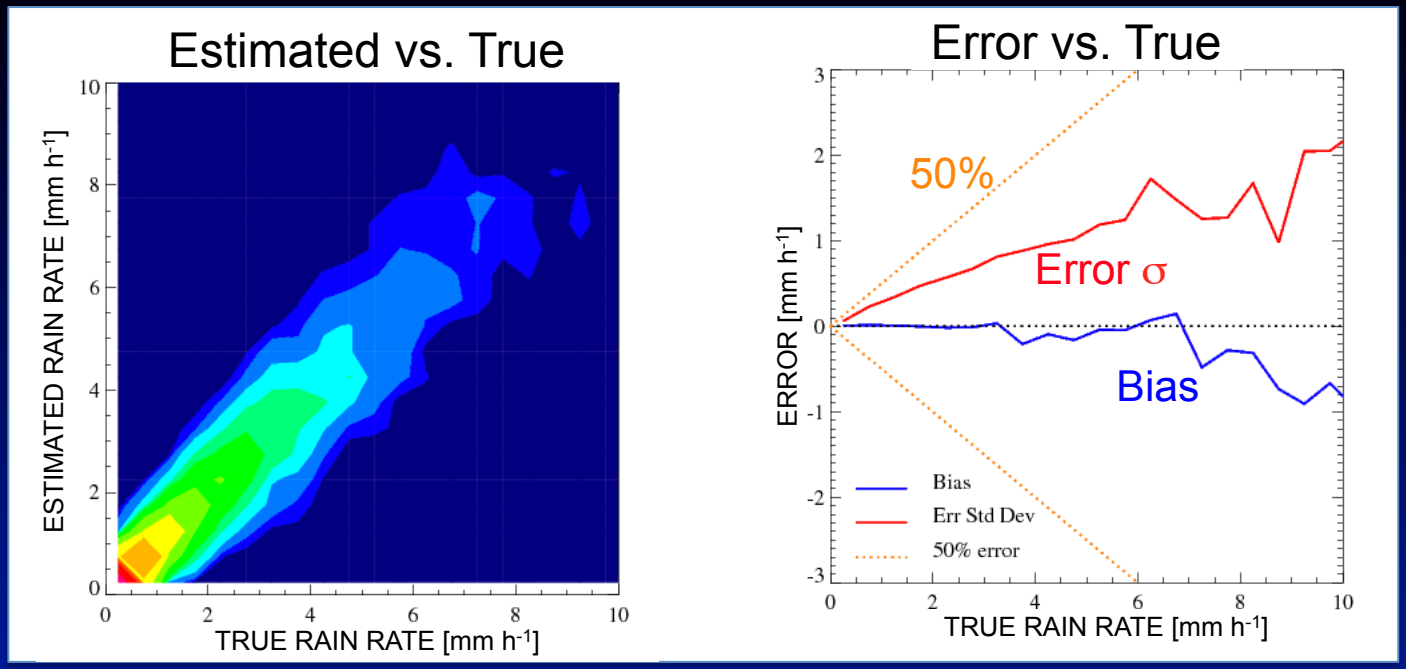


GPM Algorithm Applied to Ku+TMI

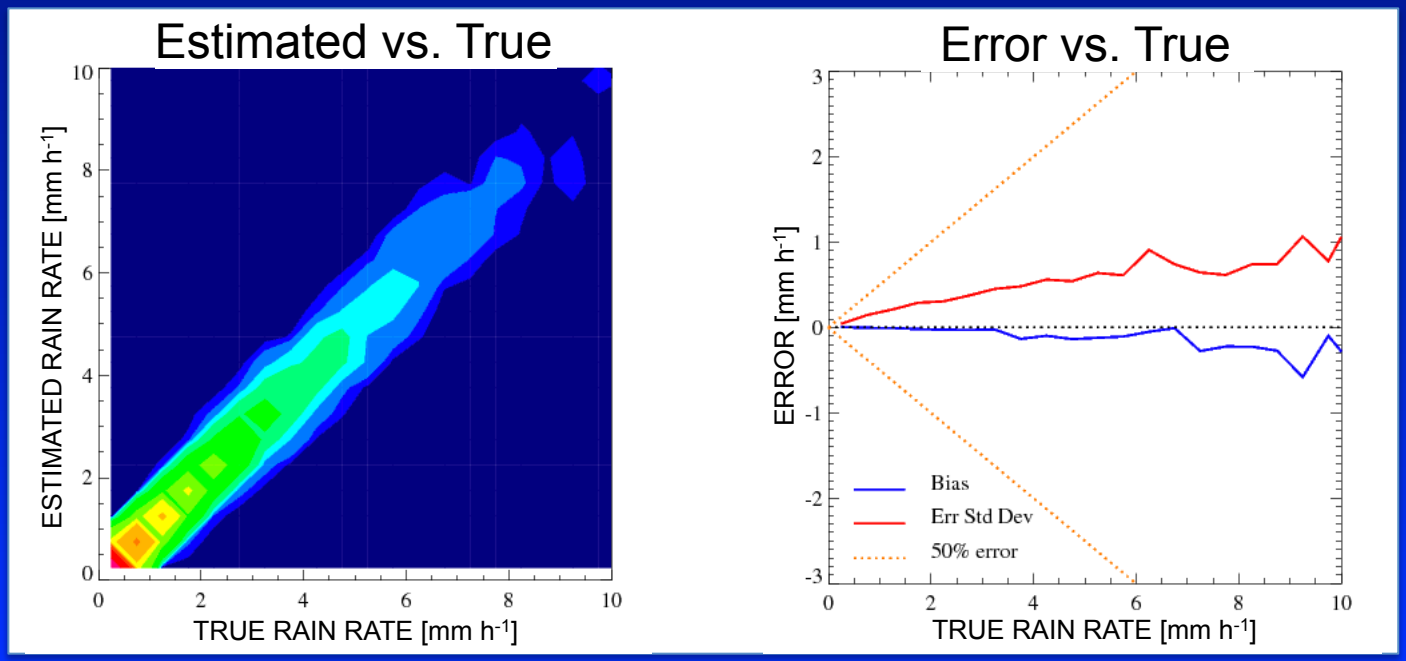


Synthetic Ocean Data; Statistics at 50 km Resolution

"TRMM" Estimates (Ku radar + Microwave)

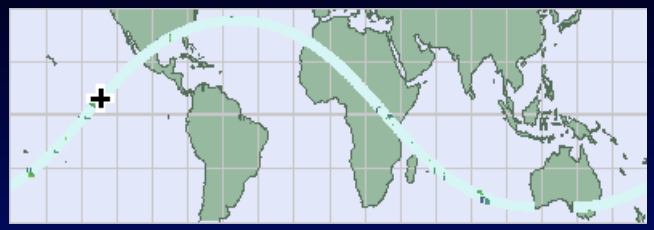


"GPM" Estimates (Ku+Ka radar + Microwave)



Comparison of TRMM and GPM Rain Estimates

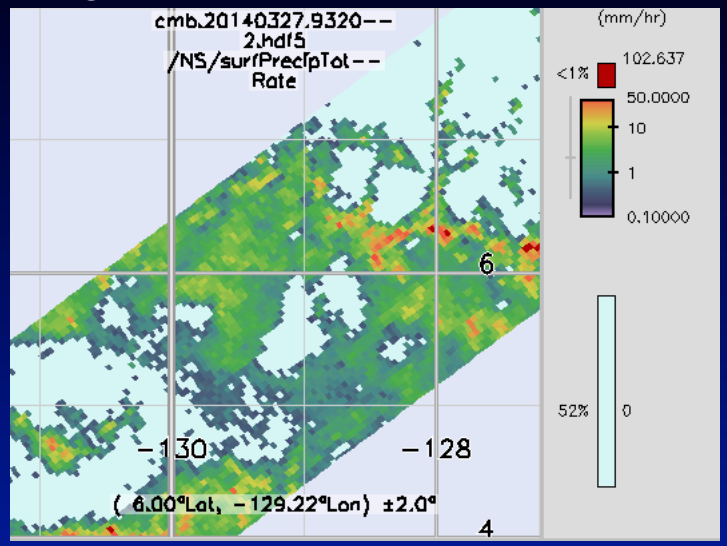
TRMM Orbit #93202



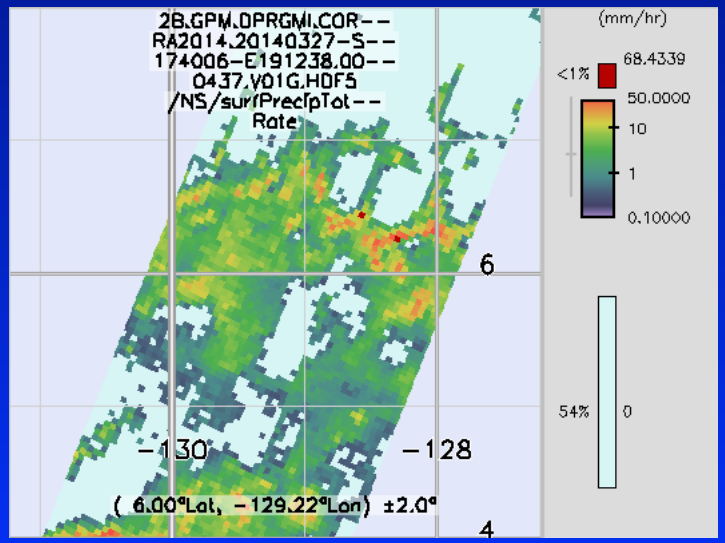
GPM Orbit #437

cross-over ~30 s apart

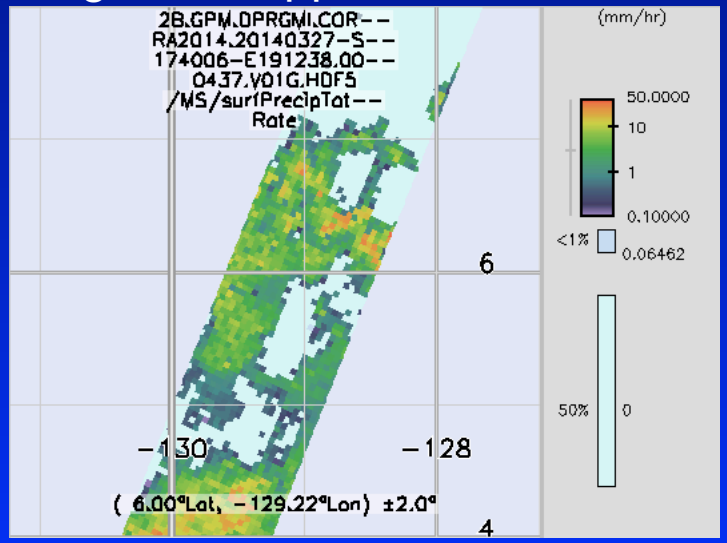
GPM Algorithm Applied to TRMM Ku+TMI



GPM Algorithm Applied to GPM Ku+GMI

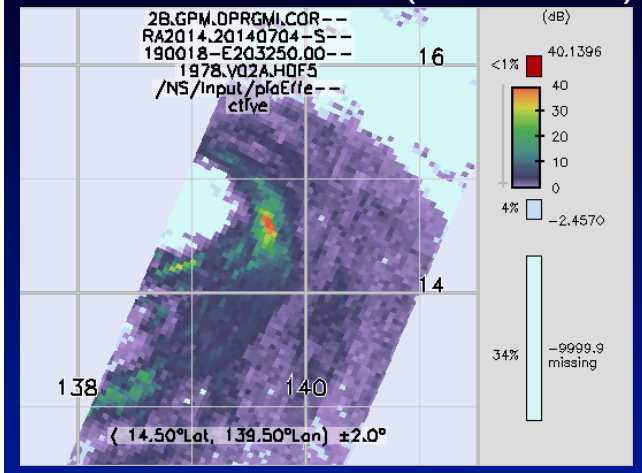


GPM Algorithm Applied to GPM Ku+Ka+GMI

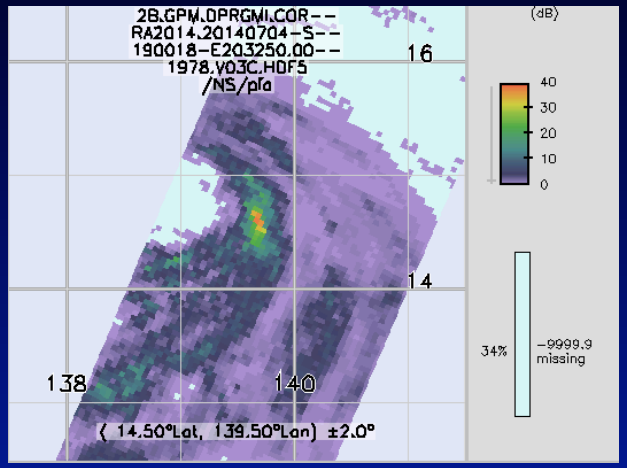


Typhoon Neoguri on 4 July 2014, Fitting of Data

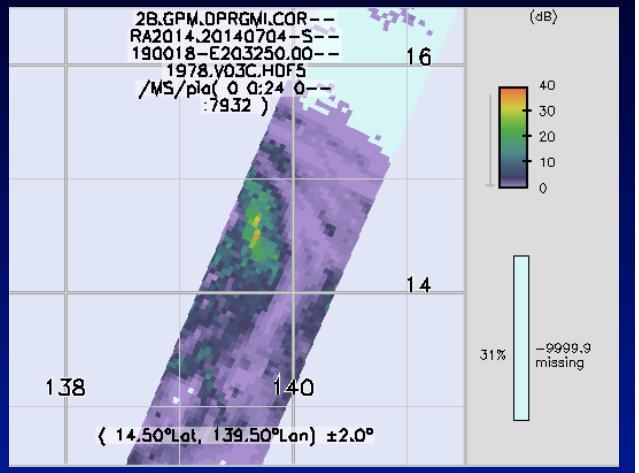
Observed Ku PIA (from SRT)



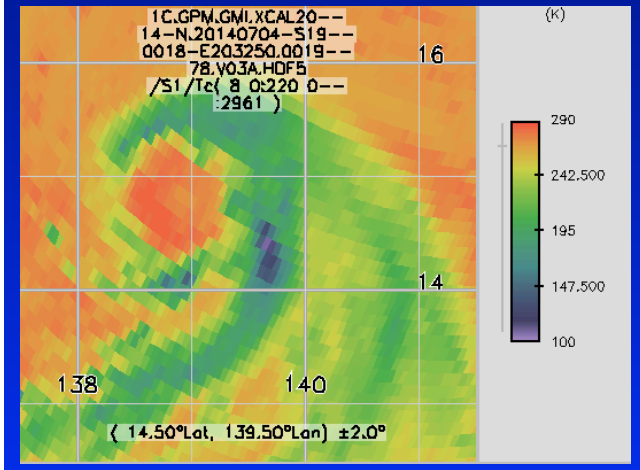
Ku+GMI Est. Ku PIA



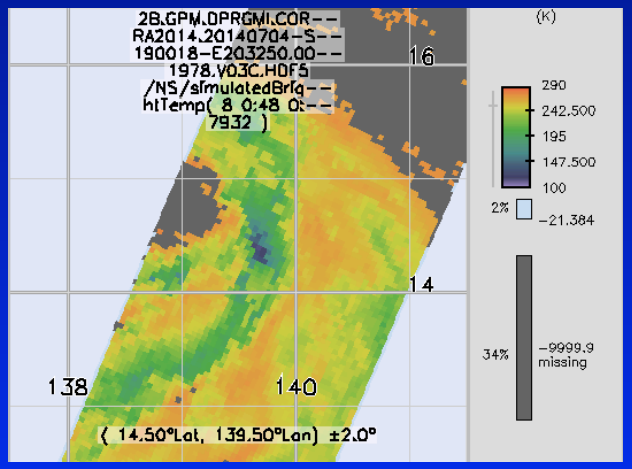
Ku+Ka+GMI Est. Ku PIA



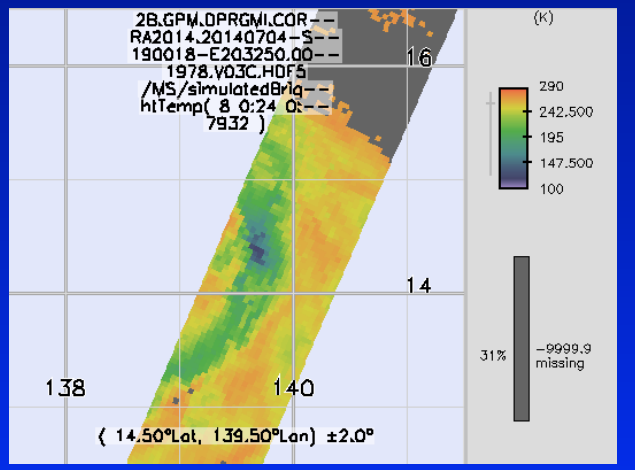
Observed 89 GHz TB



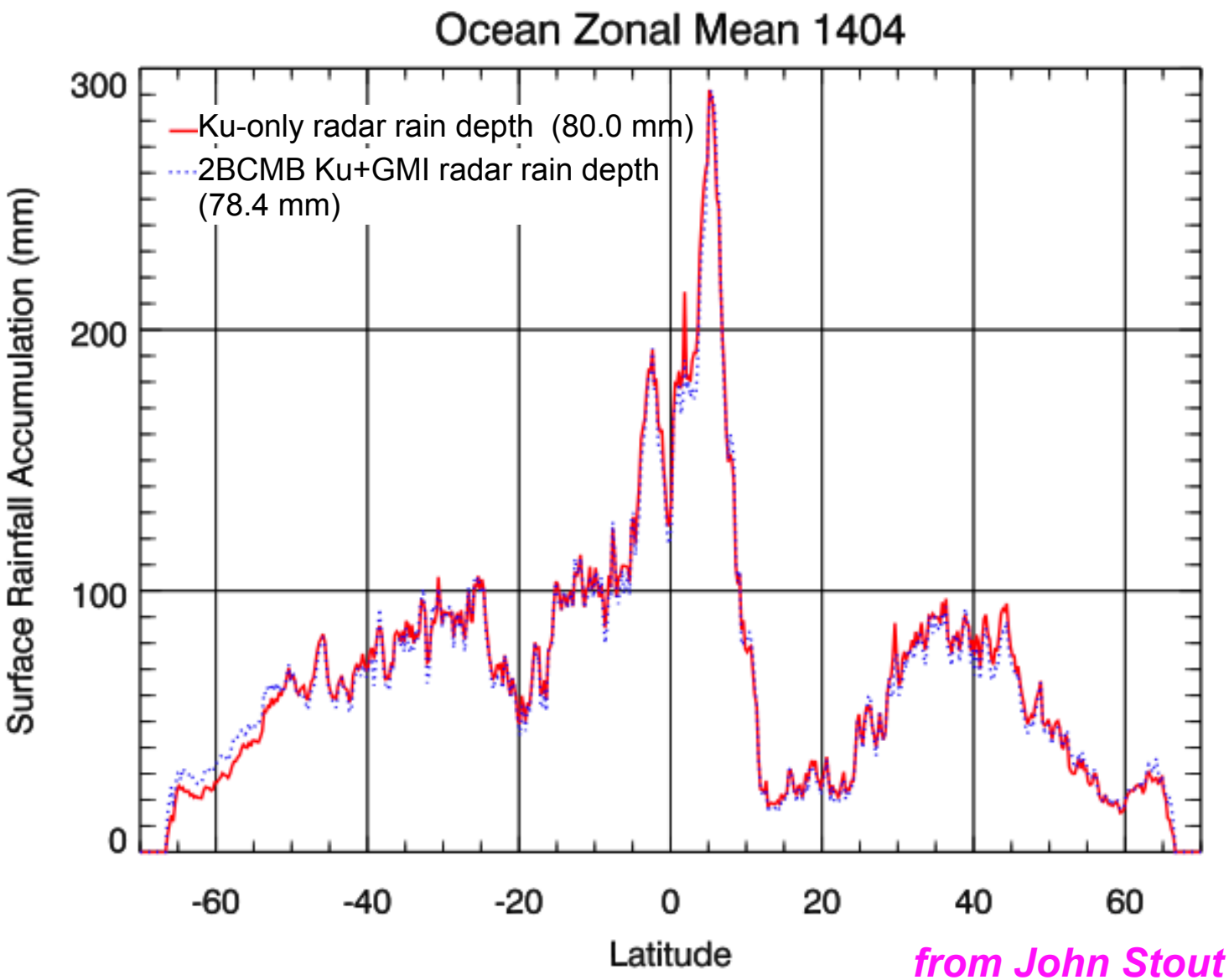
Ku+GMI Est. 89 GHz TB



Ku+Ka+GMI Est. 89 GHz TB



Monthly Zonal Mean Estimates for April 2014



from John Stout

Algorithm Theoretical Basis

Generalized Hitschfeld-Bordan Method (applied to Ku-band data only)

- original Hitschfeld-Bordan fast, but reqs. $k = \alpha Z^{\beta}$.

$$Z(r) = \frac{Z_{Ku}(r)}{\left[1 - q\int_0^r \alpha(s) Z_{Ku}^{\beta}(s)\, ds\right]^{1/\beta}}, \quad q \equiv 0.2\,\beta \ln(10)$$

- iterative techniques typically slow.

- alternative interative procedure, assuming $N_o(r)$ and approximate *approximate β from k-Z* relation:

$$Z(r) = \frac{Z_{Ku}(r)}{\left[1 - q\int_0^r Z_{Ku}^{\beta}(s) \frac{k(Z(s))}{Z^{\beta}(s)}\, ds\right]^{1/\beta}}$$

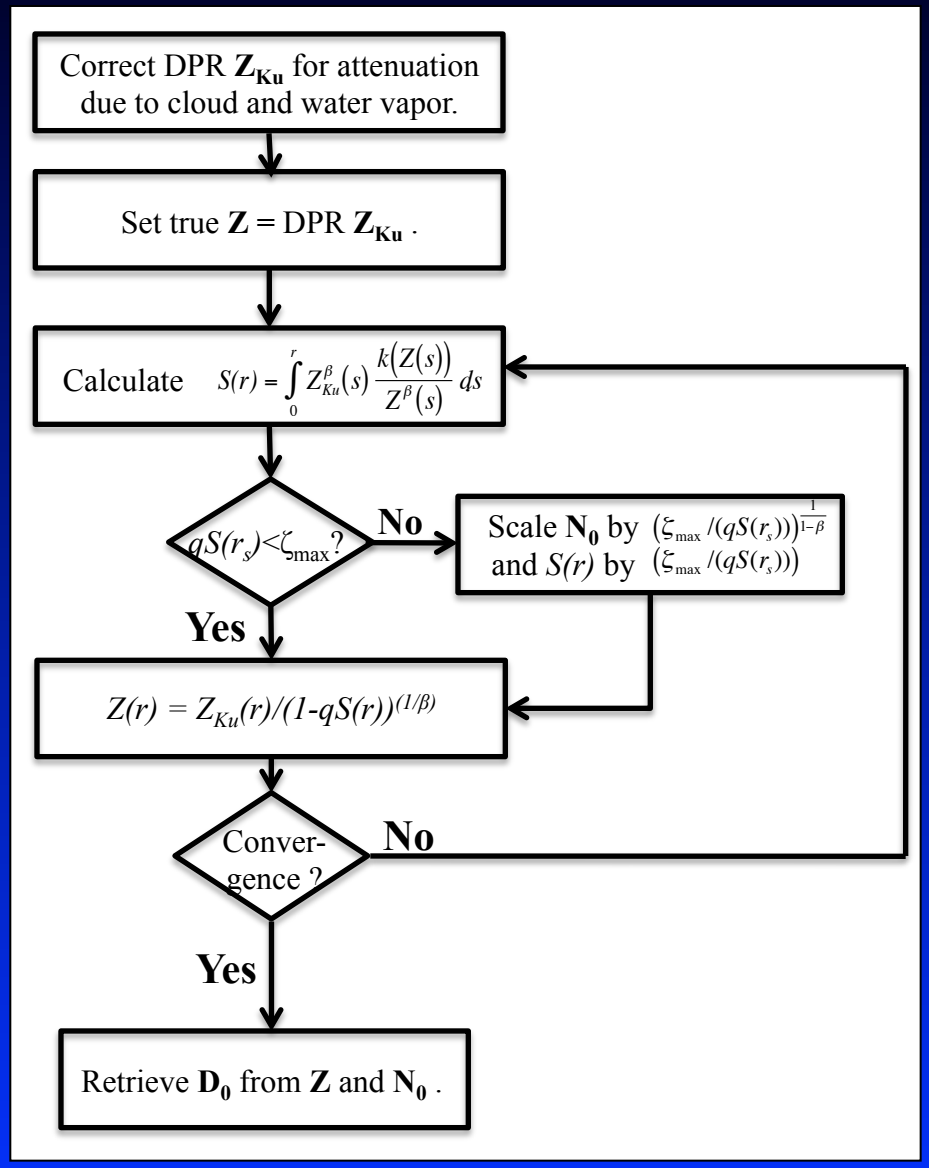
Algorithm Theoretical Basis

Generalized Hitschfeld-Bordan Method

- procedure is fast because iterative equation is a close approx. to H-B solution.

- note procedure avoids instability by rescaling $N_o(r)$, if needed.

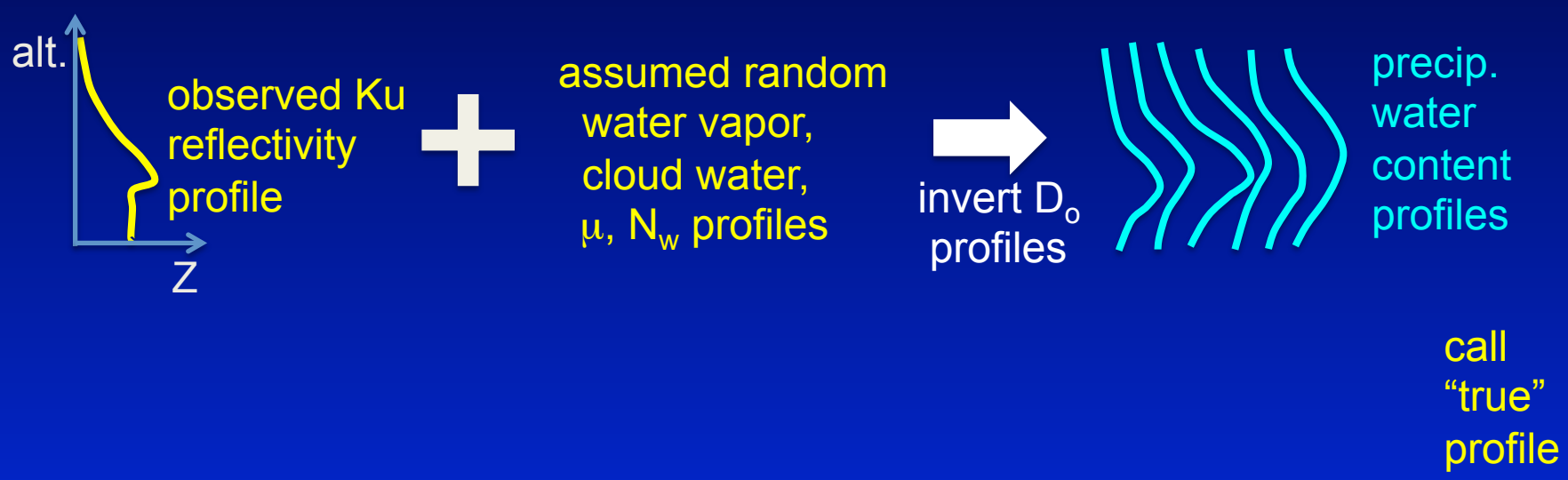
- yields $D_o(r)$, given $N_o(r)$, μ, and Z_{Ku} .



Test Plan Outline

(2) "Internal" Synthetic Retrieval Tests

Data: use **TRMM PR** to synthesize DPR & GMI observations.

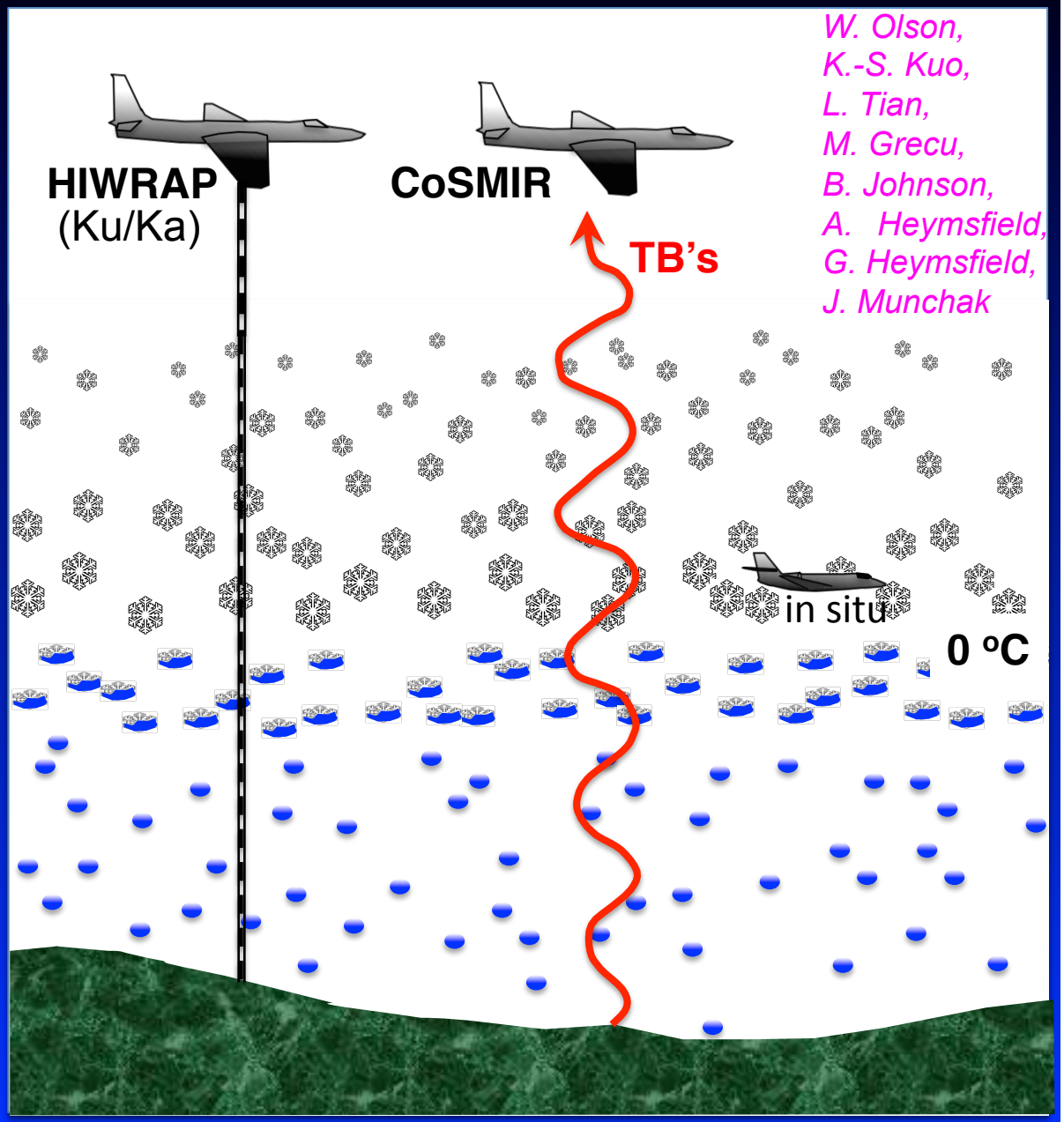


Tests: e.g., sensitivity to sensor/environment information, *a priori* assumptions.

Evaluating Snow Physics Using HIWRAP and CoSMIR in MC3E

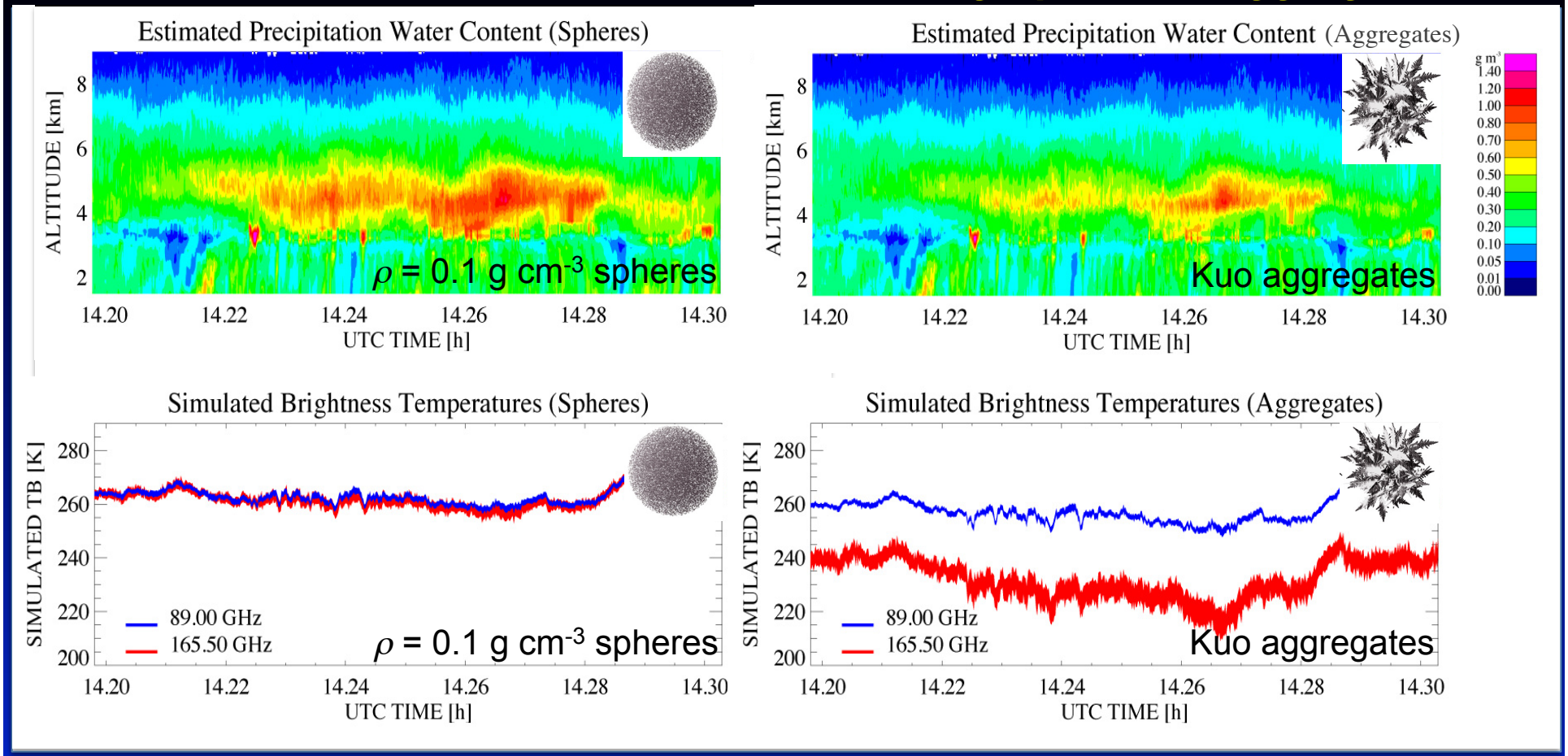
- Assign scattering model.
- Retrieve precip profile (PSD's) using HIWRAP.
- Compute consistent microwave scattering properties in profile.
- Simulate upwelling brightness temperatures at 89, 165.5 GHz.
- Compare to CoSMIR obs.

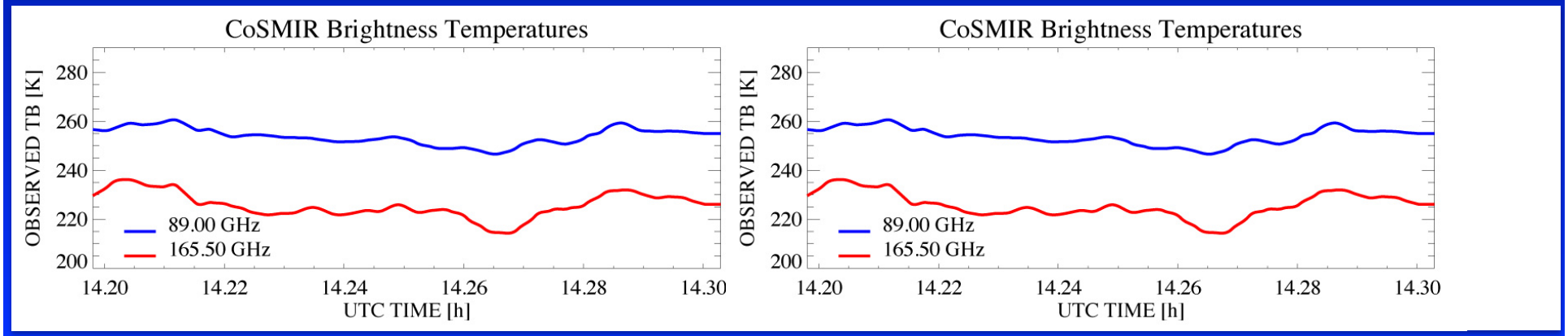
Note: brightness temps aren't sensitive to variations of surface emission and liquid precip if light rain is present => scattering signatures discriminate snow particle models.



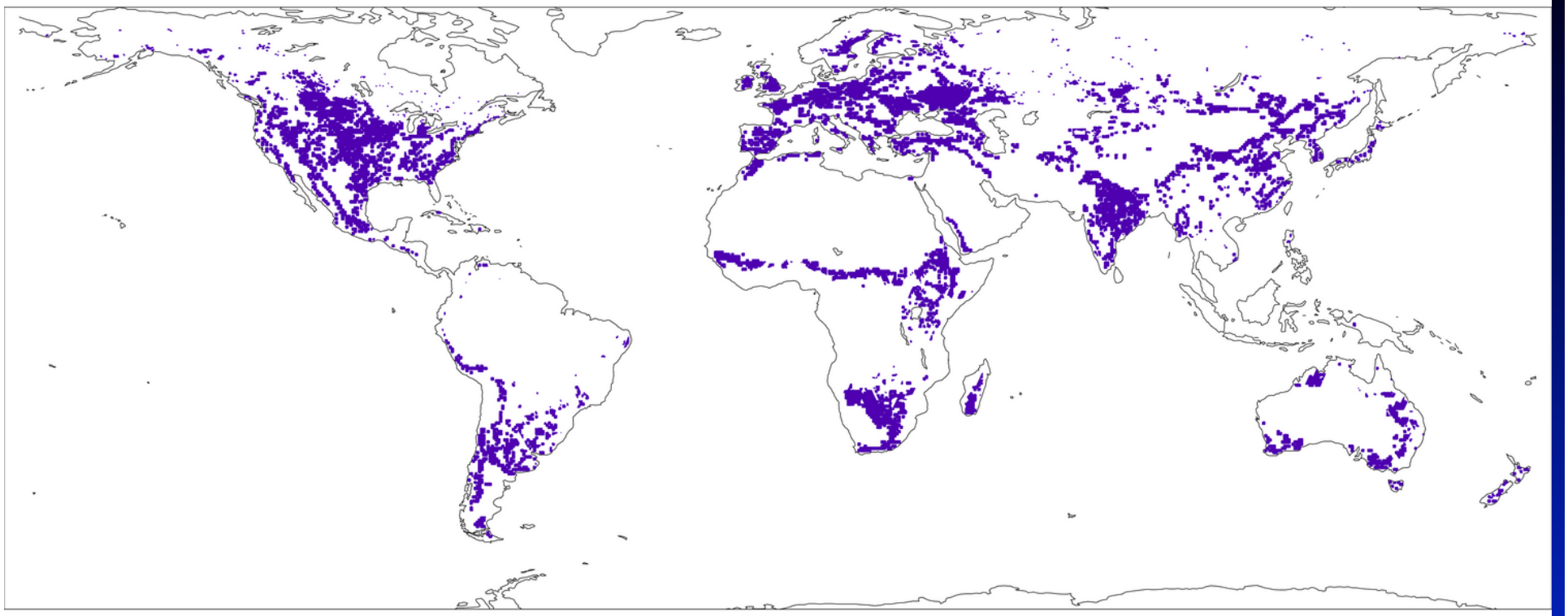
W. Olson,
K.-S. Kuo,
L. Tian,
M. Grecu,
B. Johnson,
A. Heymsfield,
G. Heymsfield,
J. Munchak

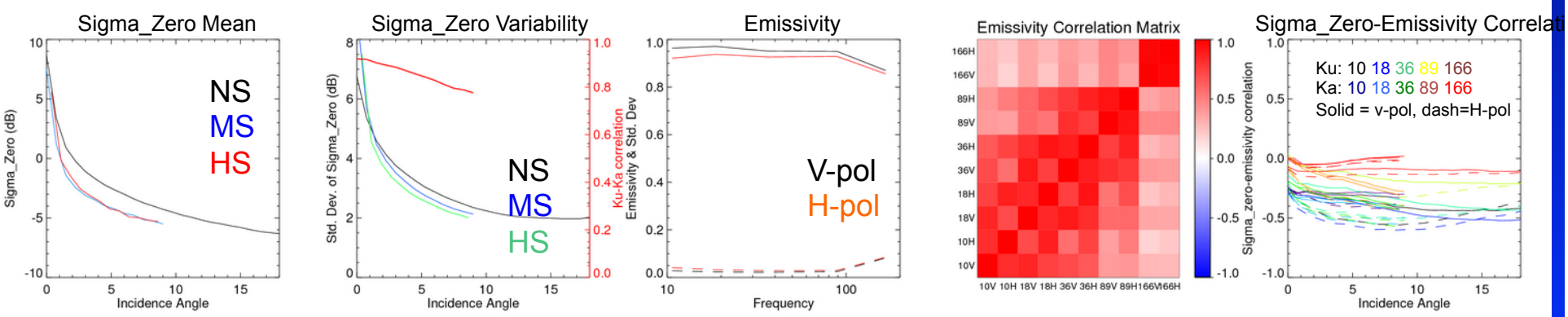
Radar Retrieval and Simulation of TB's Using Spherical/Aggregate Ice





Surface Type 4





from Joe Munchak