GPM Combined Algorithm Status

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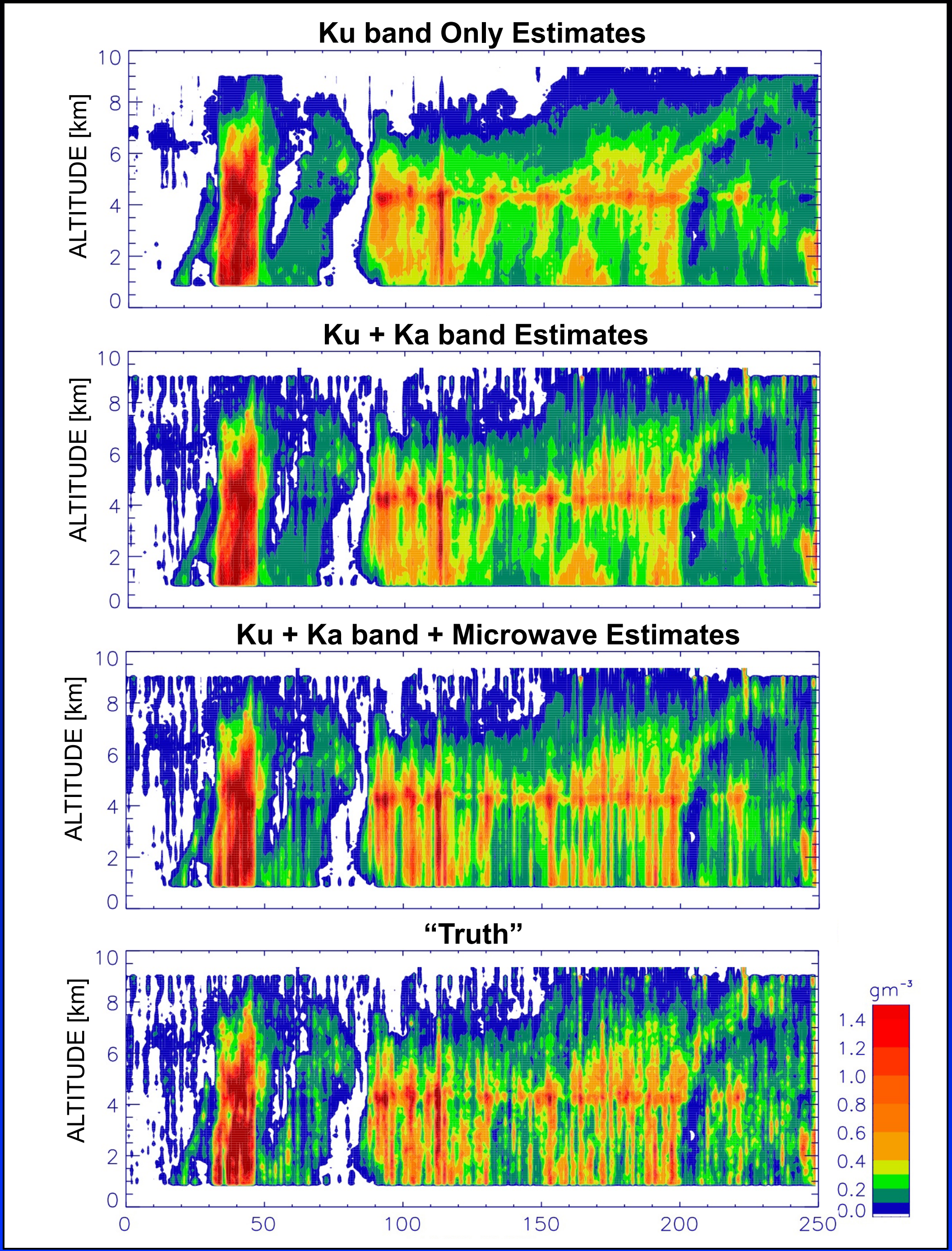
Joint Algorithm Teams
&
Working Group Contributors

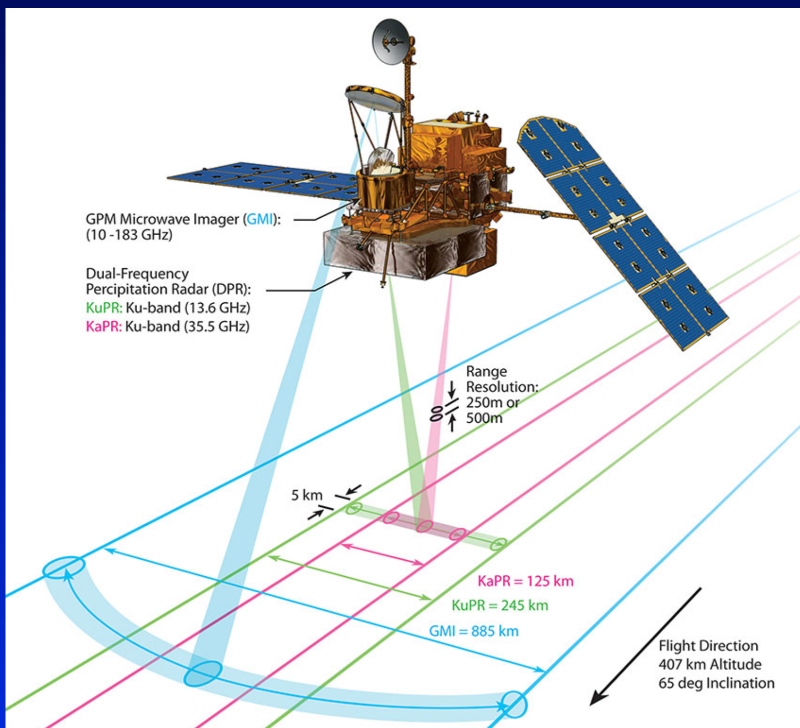
Liquid Water Content Estimates

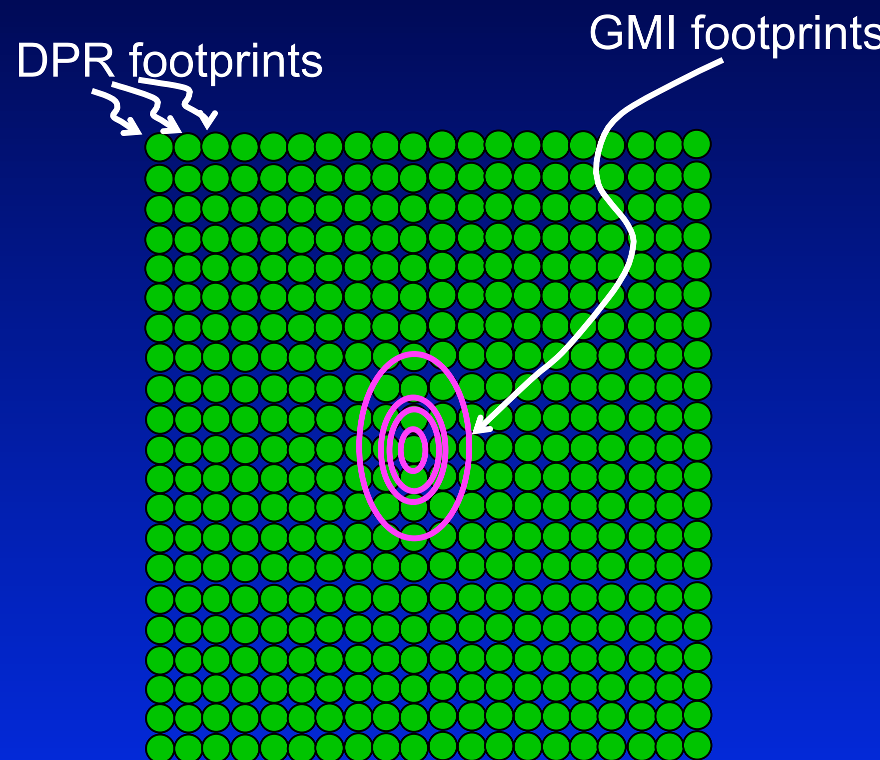
Ensemble Kalman Filter estimates of LWC using different input:



Algorithm Theoretical Basis

DPR / GMI Sampling and Resolution





DPR swath section

freq. 10.7, 18.7, 23.8, 36.5, 89.0, 165.5, 183.3±7, 183.3±3 GHz
resol. 26, 15, 12, 11, 6, 6, 6, 6 km

Algorithm Theoretical Basis - Main Progress/Activities

- new "solver" that improves consistency between radar solutions at fine resolution and lower-resolution radiometer observations.

- beta version of the satellite algorithm has been distributed to the team in Sept. 2011.

- updated databases for Bayesian estimation of "non-raining" parameters over ocean and land surfaces.

- combined team members "meet" every month to plan testing of potential modifications within existing algorithm architecture.

- <u>bottom line:</u> currently we have an algorithm that utilizes Ku + Ka + microwave over ocean and Ku + Ka over land. HF microwave won't be utilized until we understand impact.

Algorithm Theoretical Basis

<u>Environment Module</u>

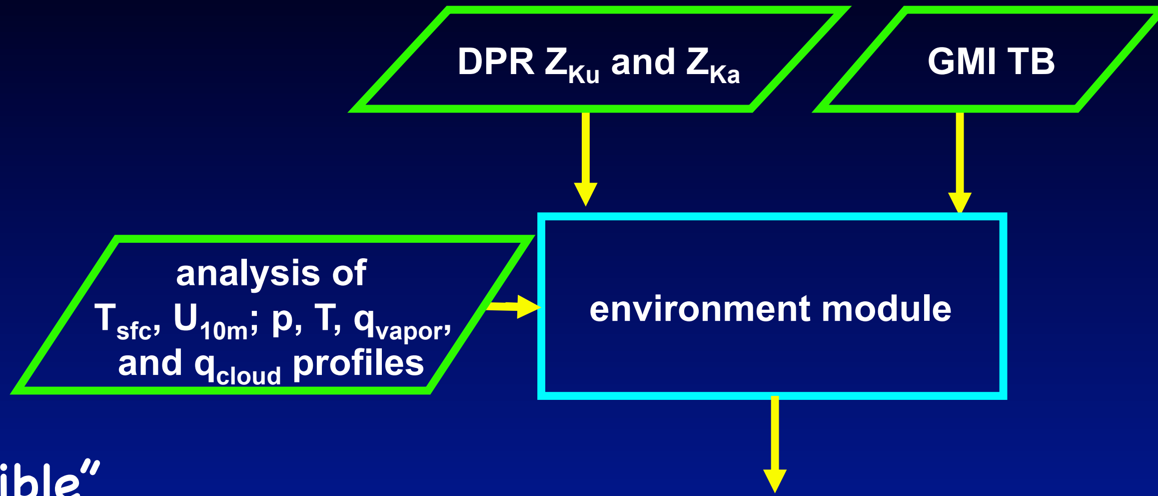
- geographic lookup.

- interpolate TB to DPR locations.

- use TB to find “rain possible” regions.

- retrieve environmental parameters T_s, TPW, CLWP, U_{10m} (emissivity EOF weight; land) outside of “rain possible” regions.

- interpolate environmental parameters into “rain possible” regions.



Output is field of environmental parameters over swath at DPR resolution.

Algorithm Theoretical Basis

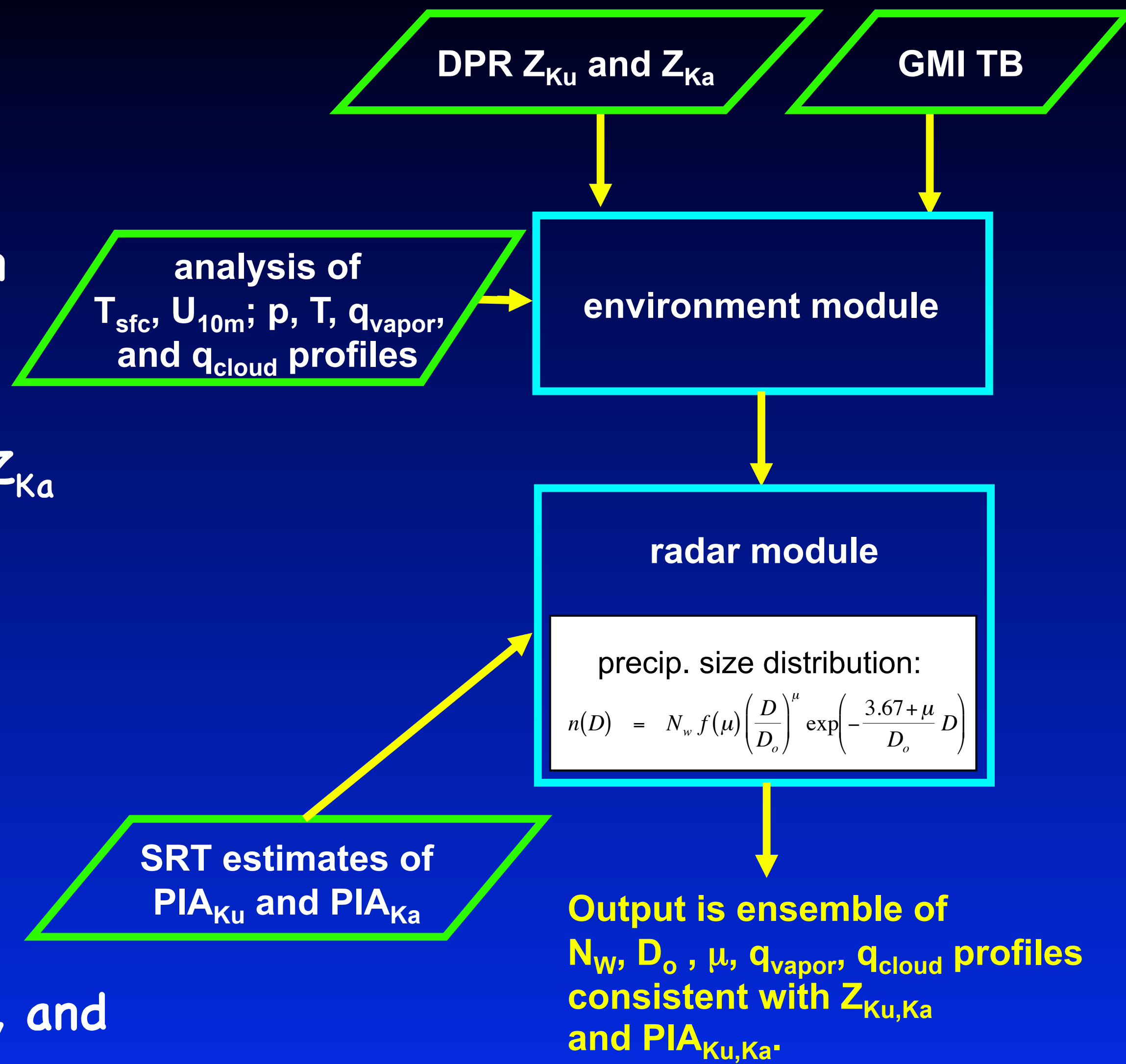
Radar Module

- generate ensembles of initial q_{vapor}, q_{cloud}, and N_w profiles at DPR precipitation locations.

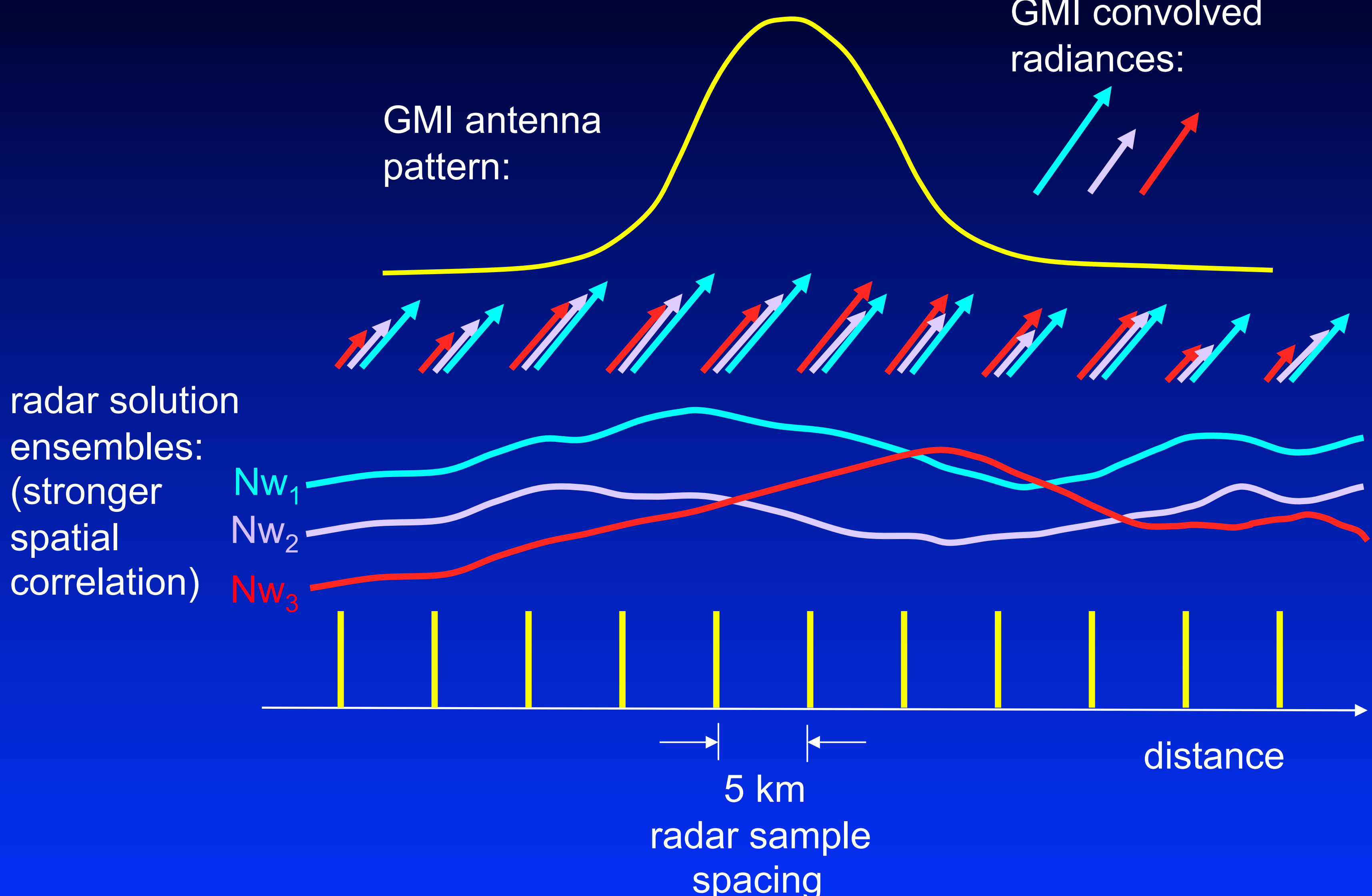
- attenuation-correct Z_{Ku}, Z_{Ka} for water vapor & cloud.

- obtain generalized Hitschfeld-Bordan solution for D_o, using Z_{Ku}, for each ensemble member.

- simulate Z_{Ka}, PIA_{Ku}, PIA_{Ka}, and Ensemble Kalman Filter q_{vapor}, q_{cloud}, N_w profile ensembles using observed Z_{Ka}, PIA_{Ku}, PIA_{Ka}.



Algorithm Theoretical Basis



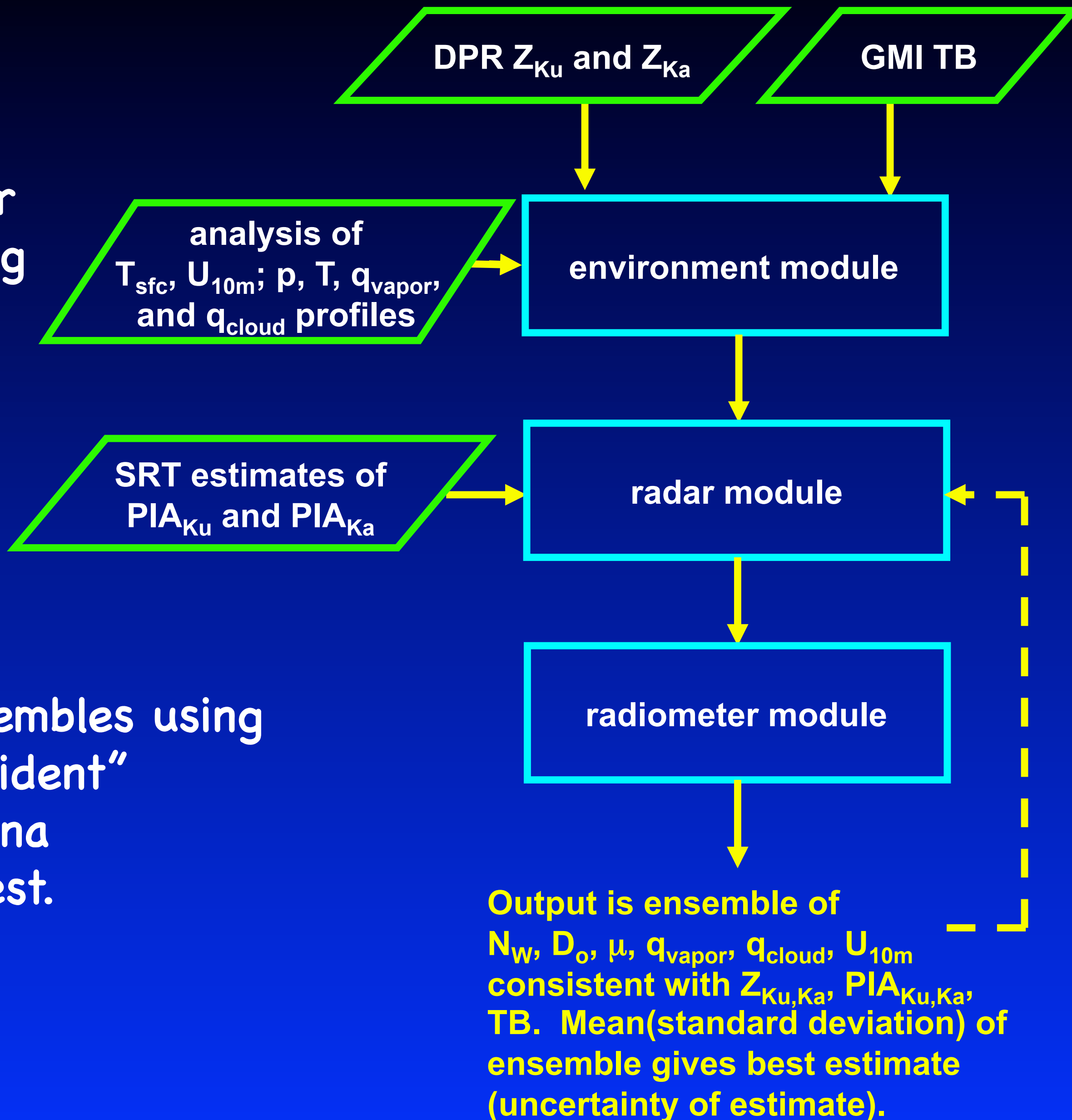
Algorithm Theoretical Basis

Radiometer Module

- simulate upwelling TB for each ensemble member profile at each precipitating DPR footprint location.

- convolve simulated TB to simulate lower-resolution GMI TB.

- Ensemble Kalman Filter q_{vapor}, q_{cloud}, N_w profile ensembles using GMI TB, but only at "coincident" DPR location, where antenna pattern response is greatest.



Test Plan Outline

Sensitivity Studies (ongoing)

- Data: airborne or TRMM Z_{Ku} retrieval -> synthetic Z_{Ka}, PIA's, TB's

- Tests: basic algorithm mechanics.
  sensitivity to input data.
  sensitivity to *a priori* assumptions.
  sensitivity to particle scattering assumptions.
  sensitivity to land surface characterization.
  sensitivity to phase transition, environmental data.

Physics Studies (beginning)

- Data: airborne Ku, Ka, PIA's, TB's, *in situ* microphysics;
  e.g., MC3E data.

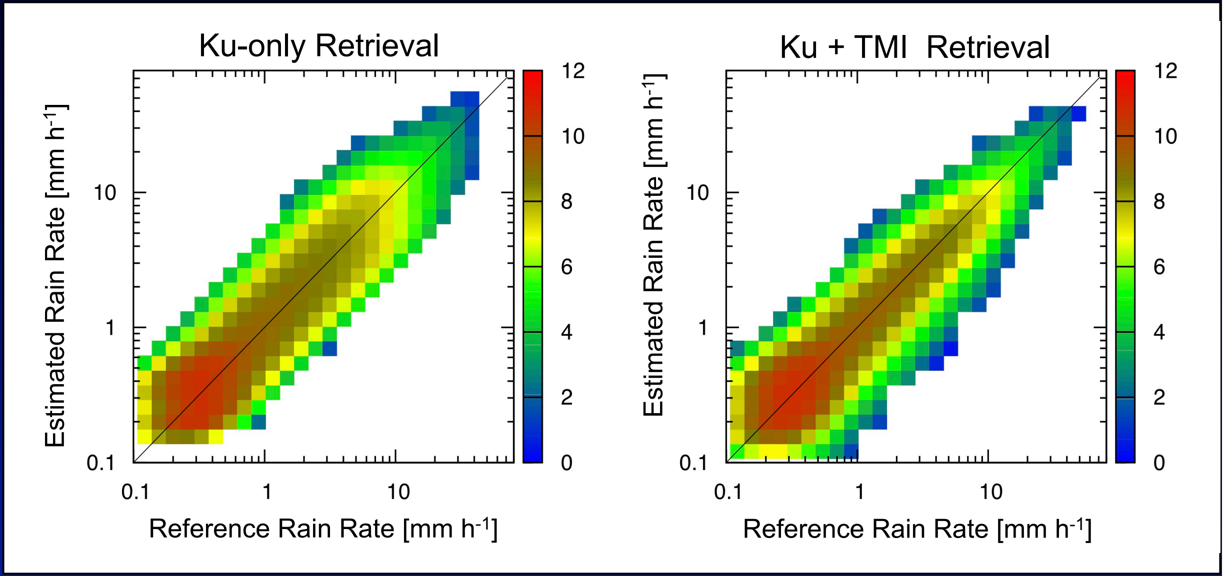
- Tests: e.g., test consistency of physical models with simultaneous
  observations using algorithm framework;
  following Liao et al. (2005).
  e.g., test *in situ*-derived Z vs. observed Z.

Testing - Application to Simulated TRMM Data

TMI simulated from Ku

Ku-only 5% bias; 35% rms

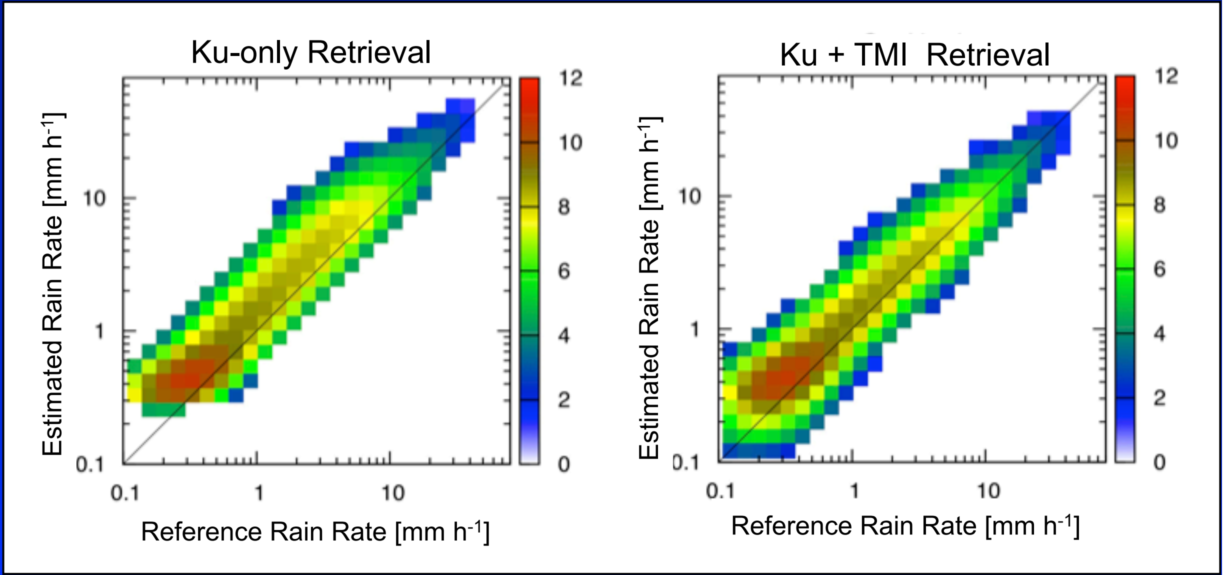
Ku+TMI -2% bias; 15% rms



w/positive bias in initial N_w

Ku-only 43% bias; 41% rms

Ku+TMI 18% bias; 14% rms



Test Plan Outline

Pre-Launch "Validation" Studies (beginning winter 2012)

- Data: TRMM Observations

  CRM-generated GPM Observations
  (e.g., tropical MCS, midlatitude squall line, synoptic-scale snow, lake effect snow, high-latitude shallow stratiform).

  } -> PPS GPM formats

- Tests: compatibility with PPS
  fitting of physical model to data.
  retrieved parameters within realistic ranges?
  is attenuation correction of Z data reasonable?
  how well are rain rates and DSD's estimated?
  (data sensitivity, e.g. Ku vs. Ku + Ka, ancillary data source.
  state sensitivity, e.g. land vs. ocean, high vs. low latitude.)

- TRMM Validation: Primary Validation Sites (Kwajalein, Melbourne)
  GPM Validation Network (VN Z's and NMQ rain rates)

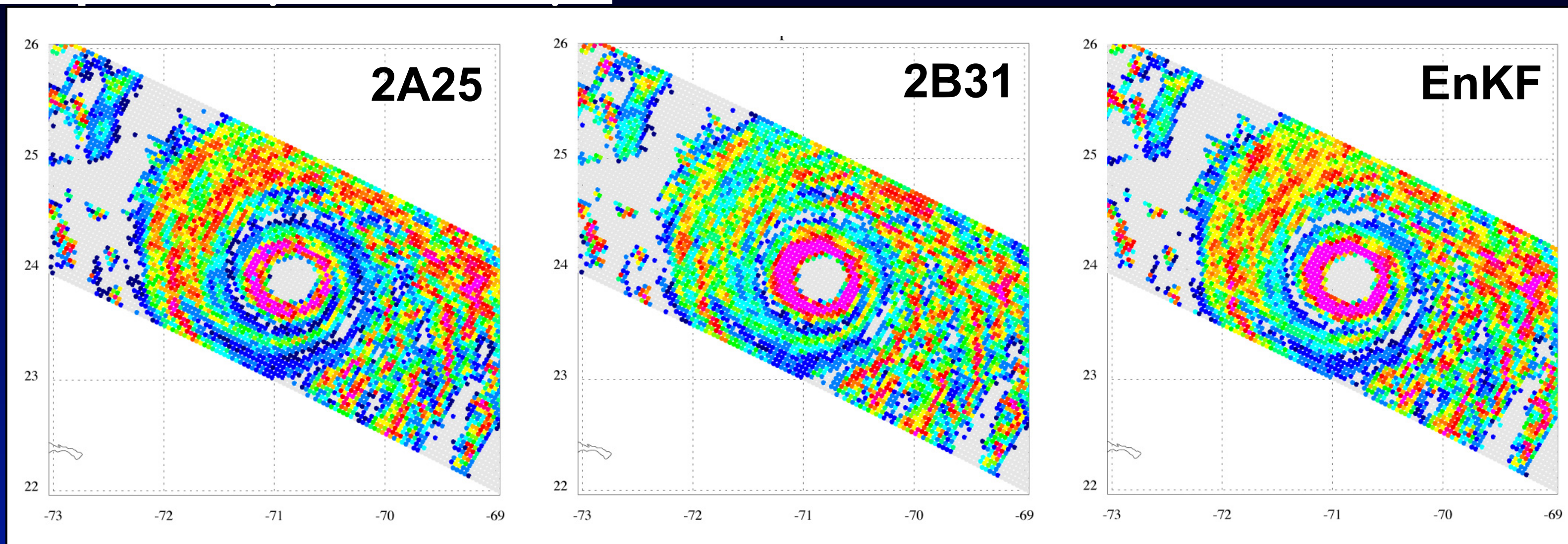
Post-Launch Validation Studies (beginning 2014)

- **Data:** GPM Z_{Ku}, Z_{Ka}, PIA's, TB's.

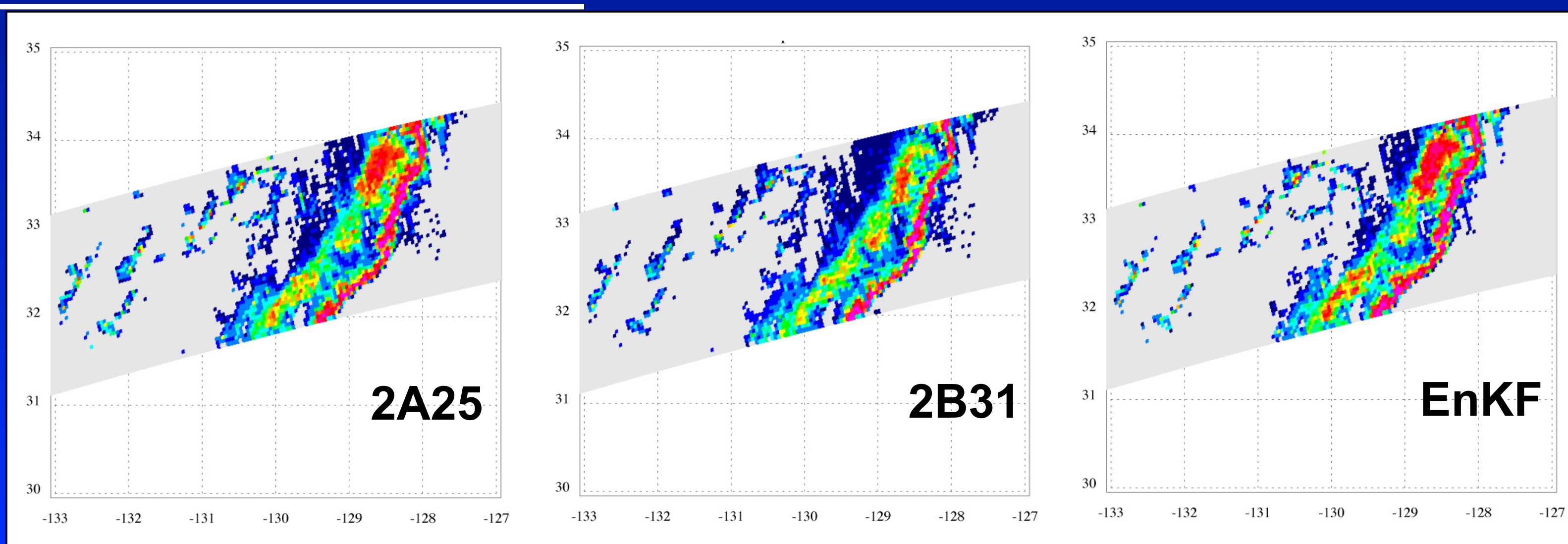
- **Tests/Validation: see above; extend to GV in other regimes.**

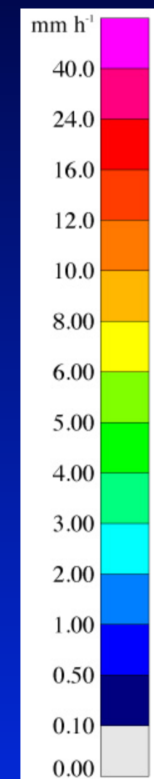
Testing - Application to TRMM Data

Tropical Cyclone Floyd



Pacific Winter Storm





Baseline Code for Nov. 2011

- Will include all modules/datasets outlined in this talk.

- Output will be vertical precipitation profile PSD parameters at 250 m resolution, rain rates, and their uncertainties; cloud liquid, water vapor profiles, p, T, surface T & emissivities.

- Ku + microwave (full Ku swath) and Ku + Ka + microwave products.

- Software essentially complete; primarily need:
  - inclusion of PSD parameters estimates, etc.
  - integration of over-land non-raining parameter estimator.
  - tests of PPS compatibility.

At Launch Code for Nov. 2012

- Include GMI high-frequency data, if positive impact.
- Select inter-variable and spatial auto-correlation constraints.
- Select particle scattering tables.
- Partitioning of land surface databases.
- Test compatibility with DPR L2 PRE, VER, CSF, and SRT inputs.
- Test of full satellite algorithm, including TRMM and CRM-generated synthetic data.
- Perform final tests of PPS compatibility.

Synopsis

- Baseline algorithm, ATBD, for PPS will be produced this month (Nov. 2011).

- On track to deliver At-Launch algorithm by Nov. 2012.

- Primary activity in 2012 will be the testing of algorithm options within the basic algorithm architecture that has been established.

- To optimize impact of new GPM channels, need to ensure physics & *a priori* assumptions are realistic. FC data & 1-D testing.

- Final TRMM and synthetic data tests, over a range of environments and storm types, will determine consistency with Level 1 science requirements.

- Will maintain required compatibility with PPS computing environment.

Extras

Test Data Synthesized from Airborne Precipitation Radar-2 (APR-2) Observations

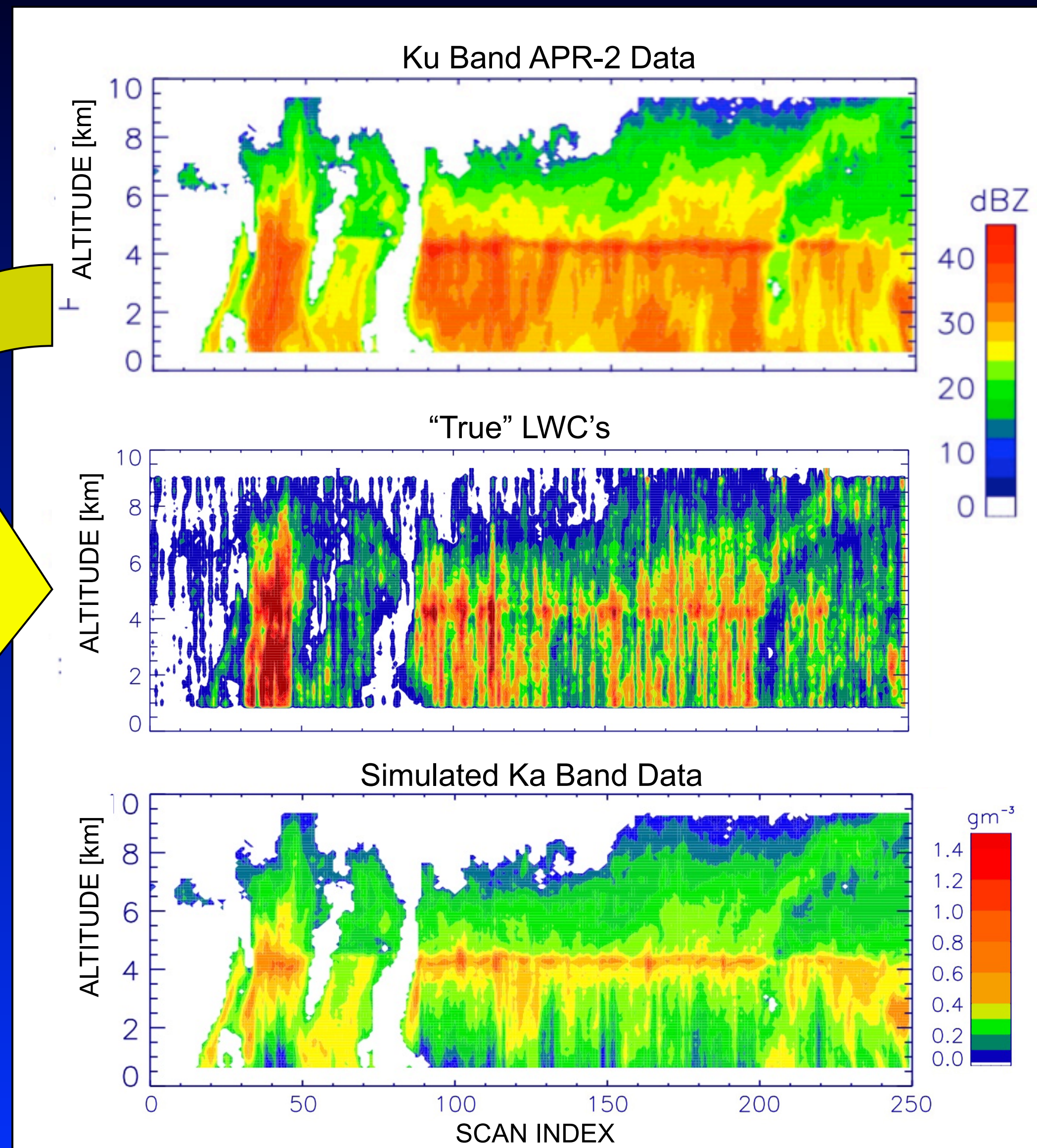
Assume q, CLW, μ, N_w profiles for each Ku-band profile; estimate D_o profile.

Create "true" precip. size distributions:

Simulate Z_{Ka}, $PIA_{Ku/Ka}$,

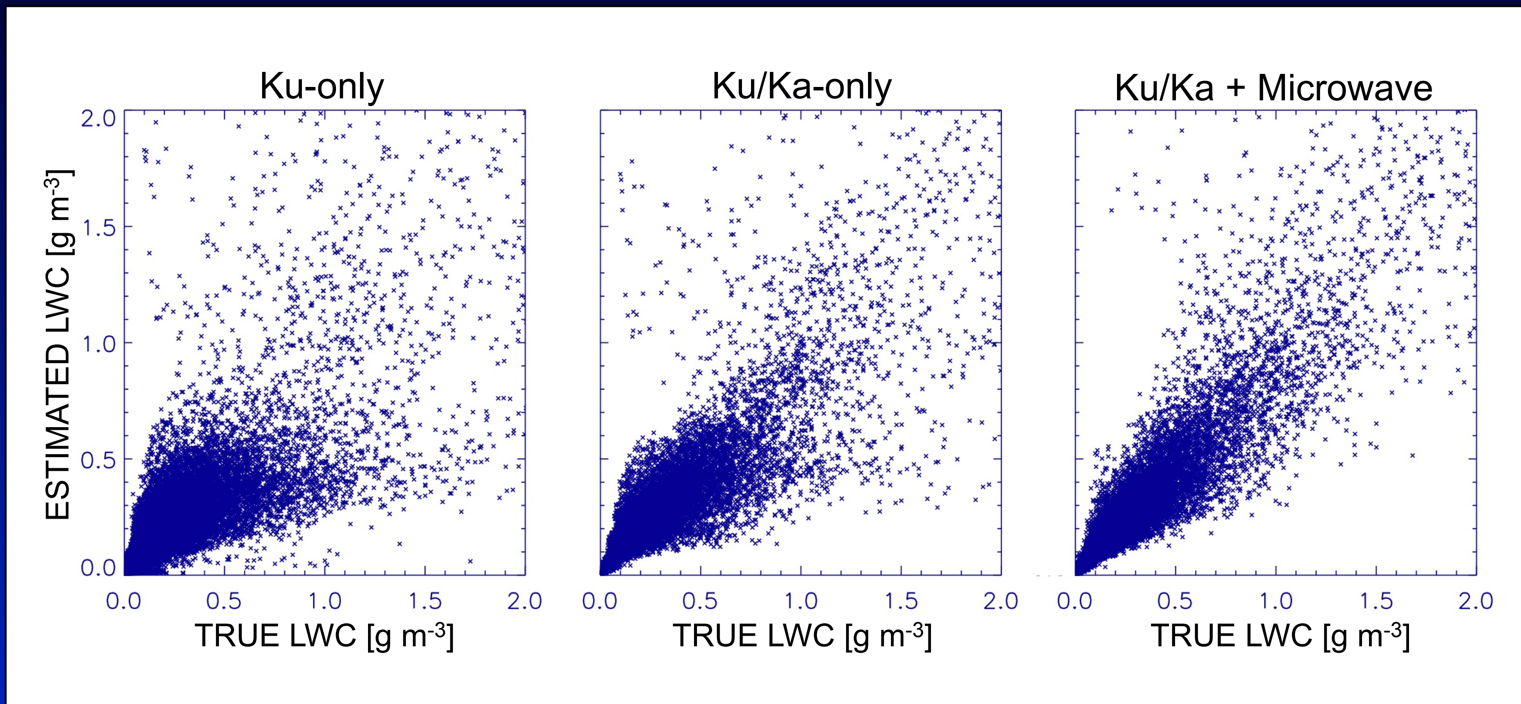
and

TB at 10, 19, 37, 85 GHz, given T_{sfc}, and U_{10} (surface emissivity)



Summary of Synthetic Data Test

LWC estimates



Bias (% of mean):	**-15.1%**	**-5.2%**	**-1.3%**
RMSE (% of σ):	**55%**	**45%**	**35%**
Corr. Coef.	**.78**	**.85**	**.91**

At-Launch Code for Nov. 2012

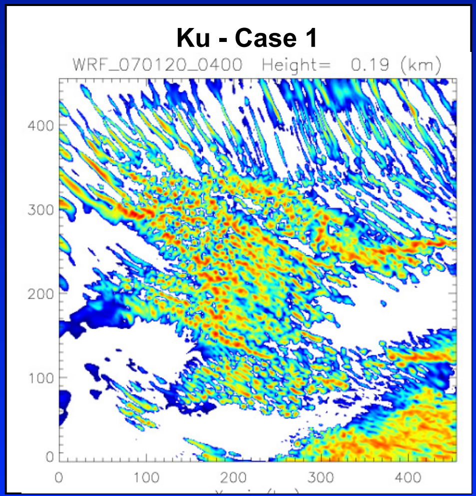
- Satellite Algorithm Verification

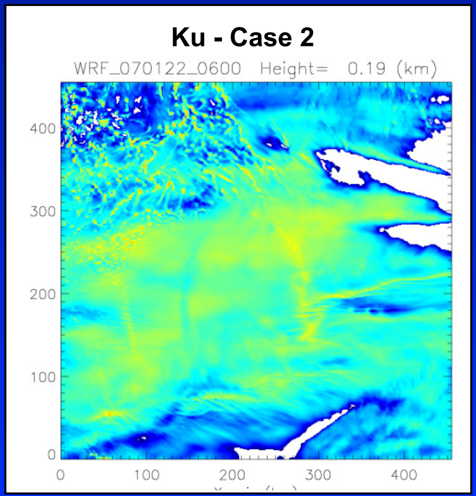
Matsui/Kim GPM Radar/Radiometer Simulator
-need to add radiometer simulator component

Cloud-Resolving Model Simulations covering a range of environmental forcing situations over a range of latitudes, land and ocean, have been identified to run.

Tropics:
- Hurricane/Typhoon
- SCSMEX
- KWAJEX
- LBA

Mid-/Higher-Latitude:
- PRESTORM
- MC3E
- Wakasa Bay
- N. California
- C3VP
- LPVEx

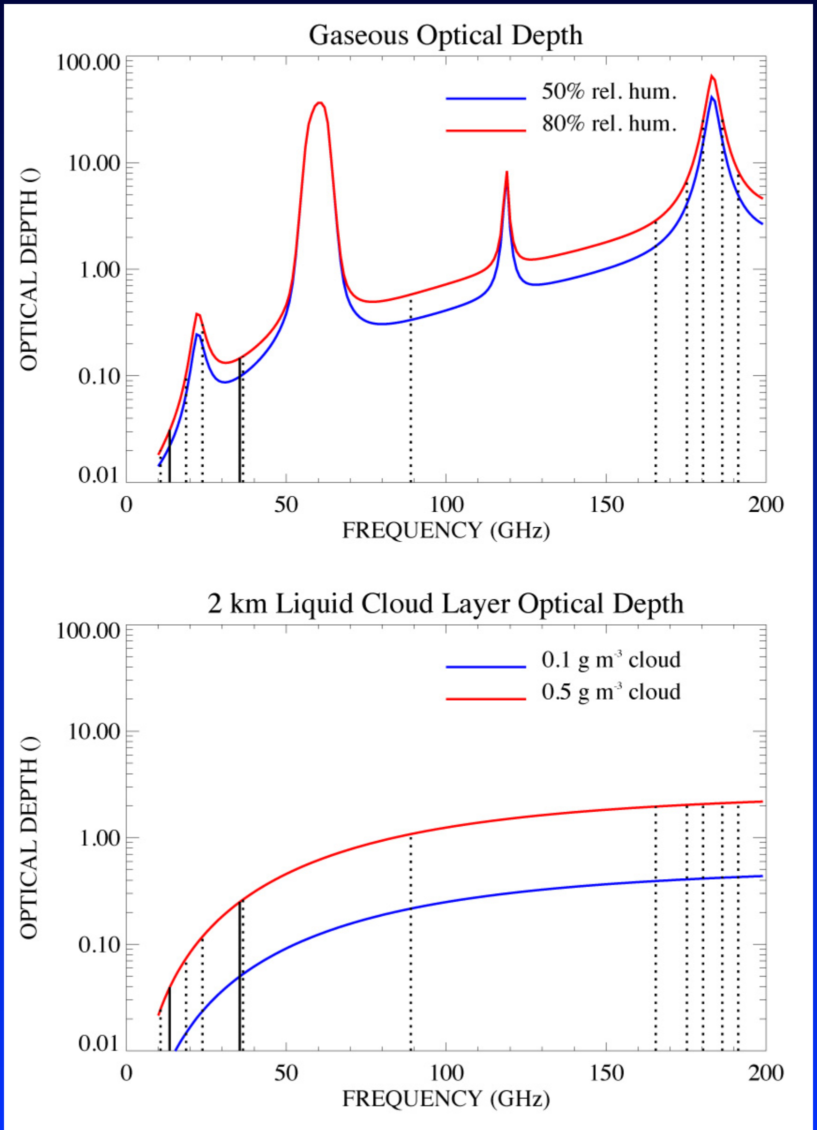




from Toshi Matsui

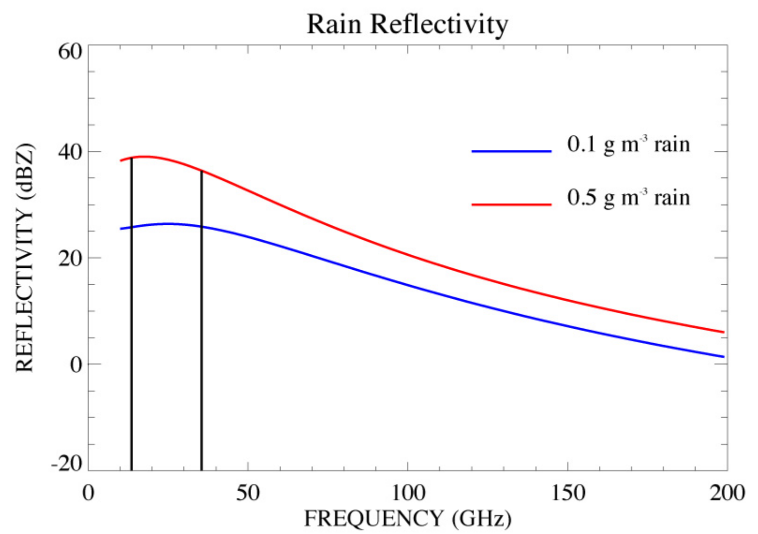
Physics of DPR/GMI Channels

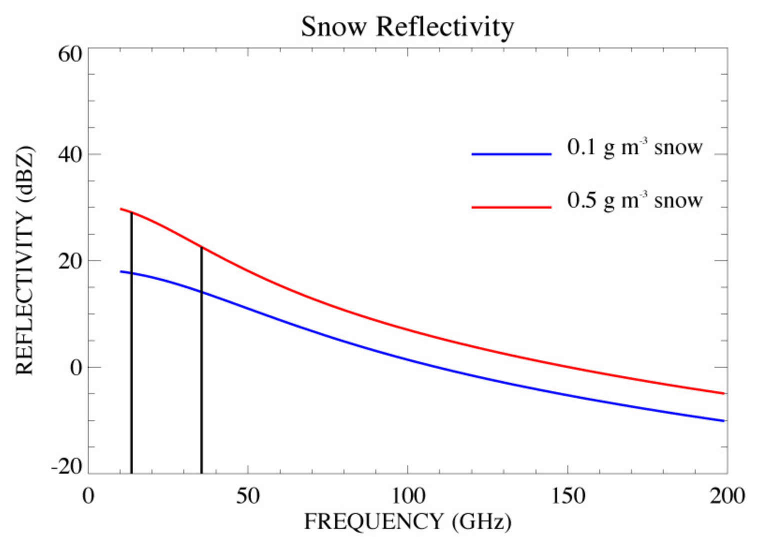
Gaseous and Cloud Absorption



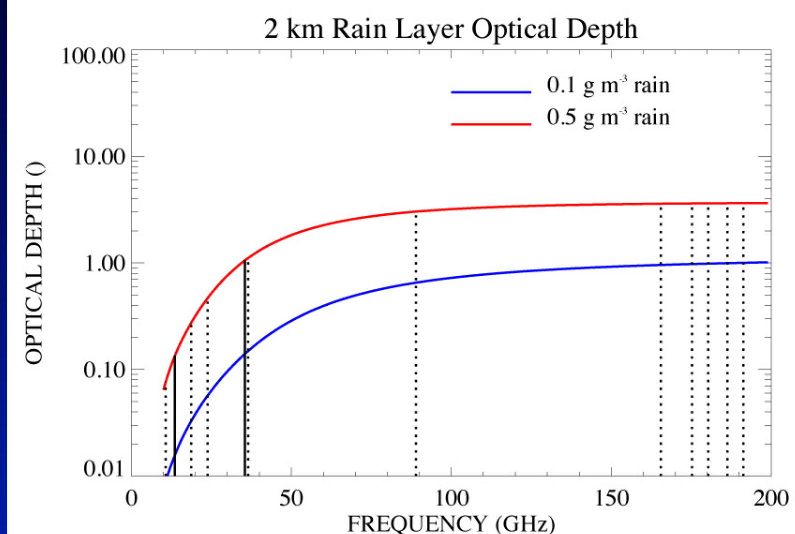
Physics of DPR/GMI Channels

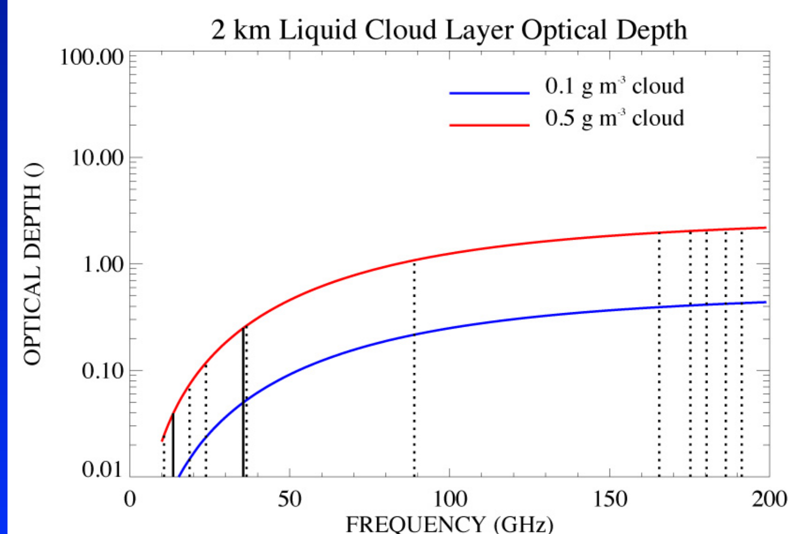
Reflectivities



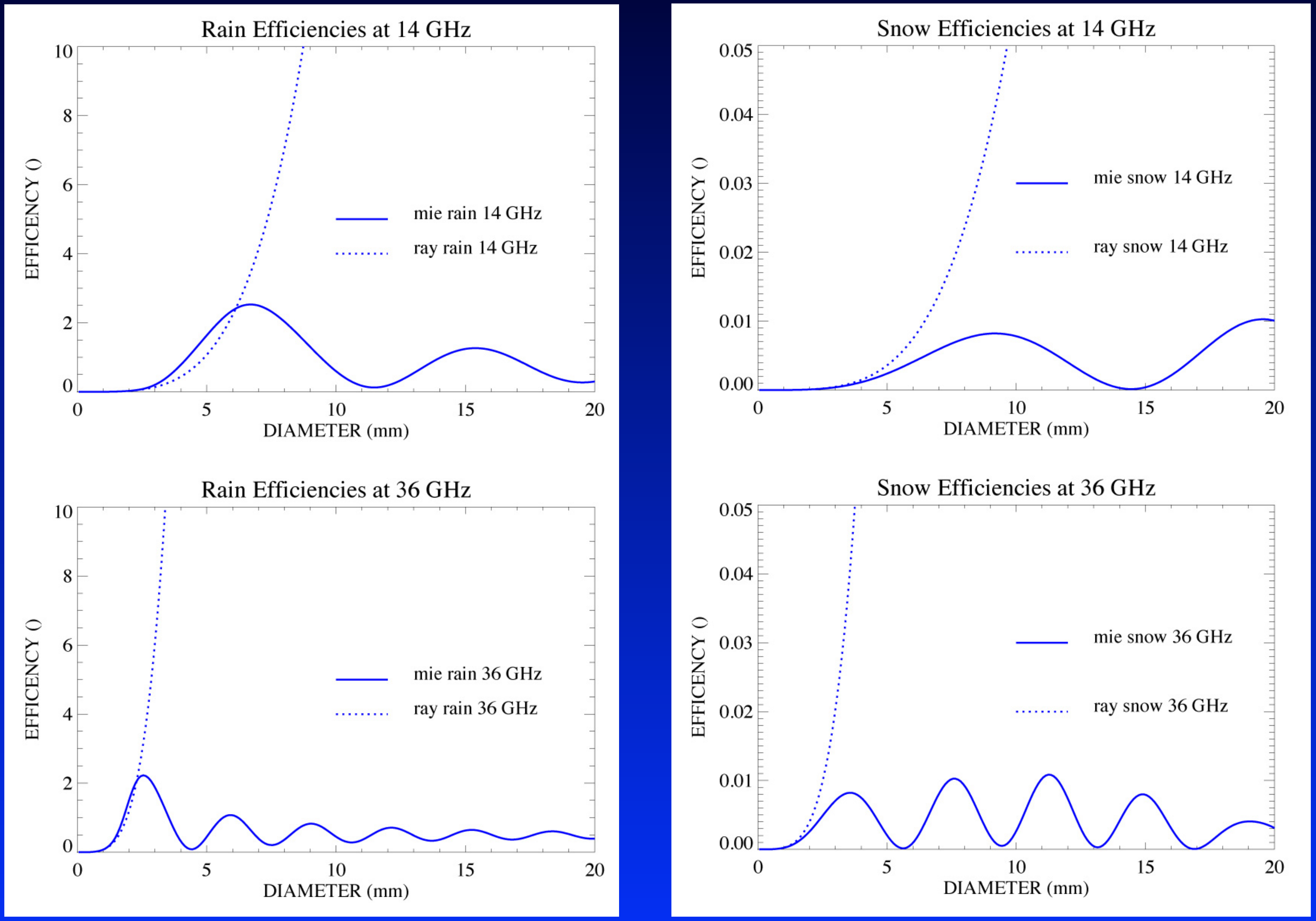


Attenuation

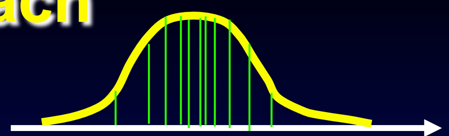




Rain/Snow Backscatter Efficiencies



Ensemble Kalman Filtering Approach



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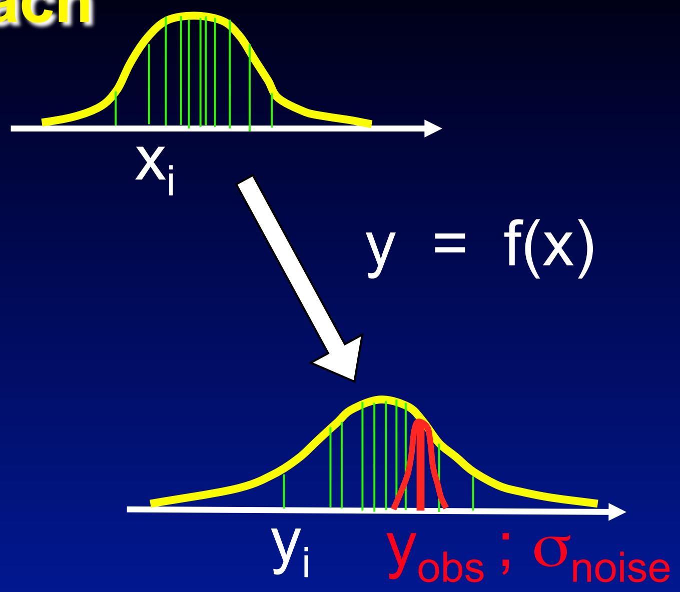

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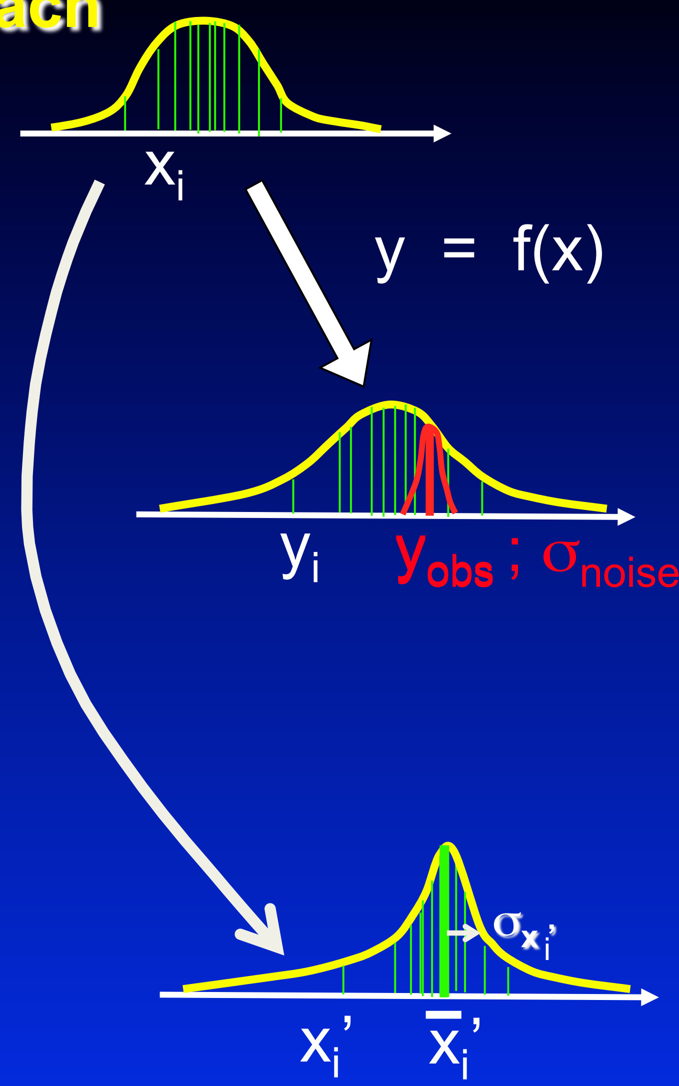
- Update $\mathbf{x}_i$ using $\mathbf{y}_{obs}$ and covariance σ_{xy} of $\mathbf{x}_i$ and $\mathbf{y}_i$:

$$x_i' = x_i + \sigma_{xy} / (\sigma_{yy} + \sigma^2_{noise}) \cdot (y_{obs} - y_i)$$

- take mean of x_i (solution) and standard deviation of x_i (uncertainty).



Ensemble Kalman Filtering Approach

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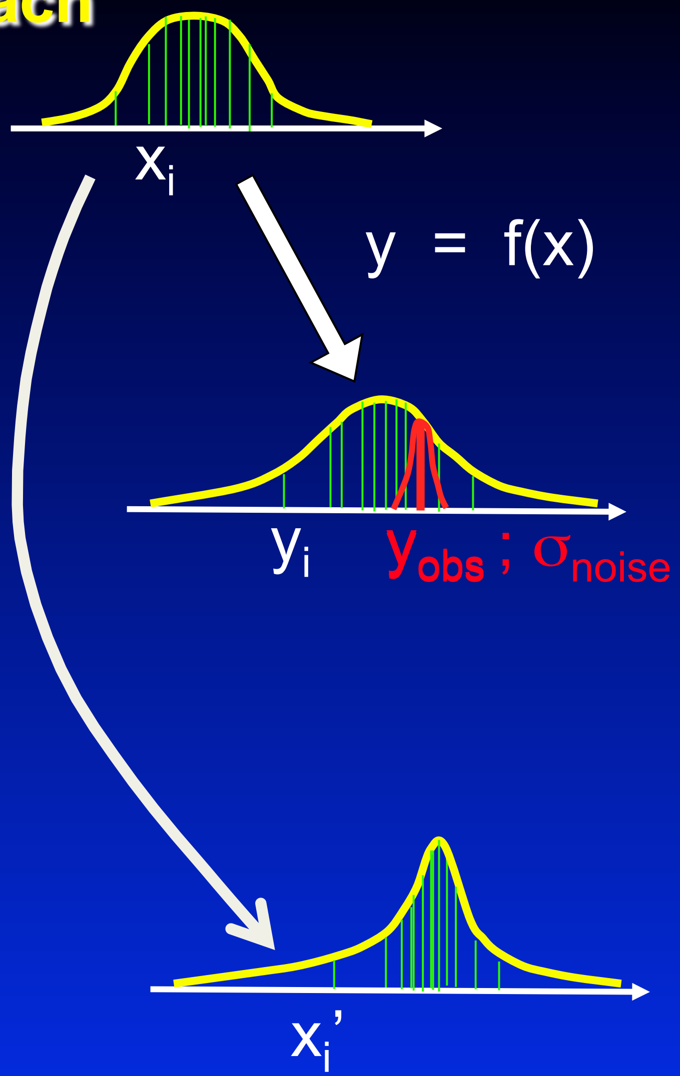

Simple Examples

- Take a simple 1D example:

$y_{obs} = 4$, with noise $\sigma_{noise} = 0.5$

& try to fit model $y(x) = x^2$

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$y_{obs} = 4$, with noise $\sigma_{noise} = 0.5$

& try to fit model $y(x) = x^2$

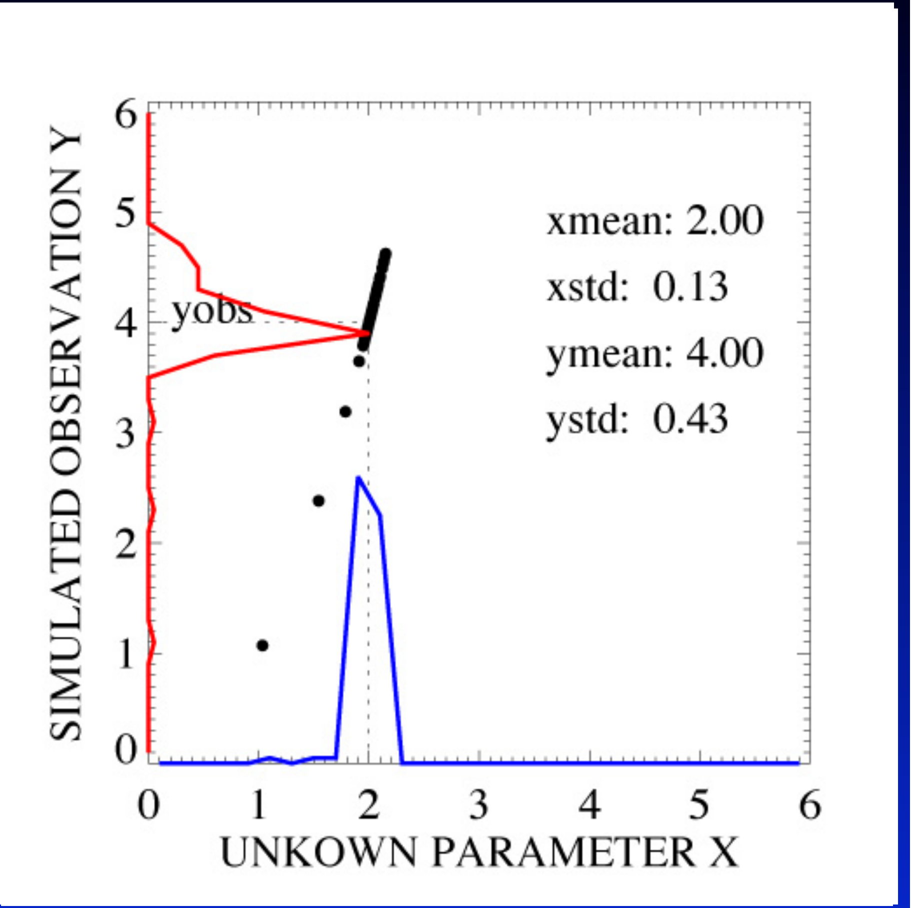
Ensemble Filtering approach:

update *a priori* distribution, x_i, using

$y_i = y(x_i)$ and then

$x_i' - x_i = \sigma_{xy} / (\sigma_{yy} + \sigma^2_{noise})$

$\bullet \; (y_{obs} - y_i)$



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} .