An Algorithm for Estimating Precipitation Using Combined Radar-Radiometer Observations from GPM

Mircea Grecu, Lin Tian, Bill Olson, and Simone Tanelli
&
GPM Radar and Combined Algorithm Teams
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**Dual-wavelength Precipitation Radar (DPR)**

freq: 13.6 GHz (Ku) and 35.5 GHz (Ka)

**GPM Microwave Imager (GMI)**

freq: 10.7, 18.7, 23.8, 36.5, 89.0, 165.5, 183±8, and 183±3 GHz

new GPM channels in cyan.
DPR/GMI Sampling and Resolution

DPR footprints

GMI footprints

DPR swath section

freq. 10.7, 18.7, 23.8, 36.5, 89.0, 165.5, 183.3±8, 183.3±3 GHz
resol. 26, 15, 12, 11, 6, 6, 6, 6 km
Algorithm Development Considerations

- Dual-wavelength radar will be used to estimate two parameters of the precipitation size distribution, if possible.

- Radiometer data will provide addnl. information regarding the environment (cloud water, water vapor) to further constrain estimates.

- Output to include uncertainties of precipitation estimates.

- Design should be modular, robust, computationally-efficient.
Ensemble Kalman Filtering Approach

- Assume a priori ensemble, $x_i$, of desired parameter, $x$. 

$X_i$
Ensemble Kalman Filtering Approach

- Assume \textit{a priori} ensemble, $x_i$, of desired parameter, $x$.

- Use forward model $y = f(x)$ to simulate observable $y_i$ for each $x_i$. 
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- Update $x_i$ using $y_{obs}$ and covariance $\sigma_{xy}$ of $x_i$ and $y_i$:

$$x_i' = x_i + \frac{\sigma_{xy}}{(\sigma_{yy} + \sigma_{noise}^2)} \cdot (y_{obs} - y_i)$$
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- Take mean of $x_i$ (solution) and standard deviation of $x_i$ (uncertainty).
Precip. size distribution:

\[ n(D) = N_w f(\mu) \left( \frac{D}{D_o} \right)^n \exp \left( -\frac{3.67 + \mu}{D_o} D \right) \]
Algorithm Architecture

- Analysis of p, T, q, and CLW profiles
- DPR Z_{Ku} and Z_{Ka}

- Initial ensemble of q, CLW profiles; calc. atten. at Ku, Ka

- Recursively ensemble filter \textit{a priori} N_{W,D_o} using Z_{Ku,Ka}

- Ensemble filter N_{W,D_o} profiles using PIA_{Ku,Ka}

- SRT estimates of PIA_{Ku} and PIA_{Ka}

- Analysis of T_{sfc}, emissivities (U_{10})

- Save estimates and uncertainties

- Ensemble filter N_{W,D_o}, q, CLW profiles and emissivities using deconvolved TB_{GMI}

- Use DPR-resolution to constrain GMI TB deconvolution

- Simulate TB_{GMI} ensembles at DPR resolution

- Assign T_{sfc}, emissivity ensemble to DPR-derived profile ensembles

- Output is ensemble of N_{W,D_o}, q, CLW profiles and emissivities consistent with Z_{Ku,Ka}, PIA_{Ku,Ka}, and deconvolved GMI TB’s.
Assume $q$, CLW, $\mu$, $N_w$ profiles for each Ku-band profile; estimate $D_o$ profile.

Create “true” precip. size distributions:

Simulate $Z_{Ka}$, $\text{PIA}_{Ku/Ka}$

and

TB at 10, 19, 37, 85 GHz, given $T_{sfc}$, and $U_{10}$ (surface emissivity)
Liquid Water Content Estimates

Ensemble Kalman Filter estimates of LWC using different input:

- Ku band Only Estimates
- Ku + Ka band Estimates
- Ku + Ka band + Microwave Estimates
- “Truth”
Summary of Synthetic Data Test

LWC estimates

Bias (% of mean):    -15.1%                                       -5.2%                                    -1.3%
RMSE (% of $\sigma$):  55%                                       45%                                    35%
Corr. Coef.                  .78                                          .85                                    .91
Synopsis

• “1-D” algorithm ready. Ensemble Kalman approach produces reasonable estimates & improvement with radiometer channels.

• Current work is on GMI deconvolution step, and construction of a priori ensembles to constrain estimated parameters.

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

• Full satellite algorithm testing to start mid-2011.