Assimilation of all-weather GMI and ATMS observations into HWRF

Isaac Moradi[1,2] Frank Evans[3], William McCarty[2], Frank Marks[4]
1. ESSIC, University of Maryland, 2. GMAO/GSFC/NASA, 3. U. of Colorado, 4. AOML/NOAA

98th AMS Annual Meeting 7–11 January 2018
Austin Convention Center | 500 East Cesar Chavez | Austin, TX.

January 11, 2018

Lack of reliable RT inputs and parameters

GMAO
Global Modeling & Assimilation Office

The relation between the observations (O) and the forward operator (H) can be expressed as: $O = H(\vec{x}, \vec{p_b}, \vec{p_s}) + \epsilon$
$\vec{x}$ control vector, $\vec{p_b}$ parameters such as shape and size distribution of hydrometers, $\vec{p_s}$ indicates the scattering parameters (e.g., phase function)

- $H(\vec{x})$ is the mean signature as it is the mean value of the model variables within grid-box; H is a non-linear thus $\overline{H(\vec{x})} \neq H(\bar{\vec{x}})$.
- The NWP models tend not to make a close first guess for cloud parameters or clouds are often displaced in the NWP simulations.
- $\vec{p_s}$ are neither provided by the model nor fully measurable in thus are estimated from limited in-situ and aircraft measurements.
- Operational RT models that use a simplified RT framework, such as spherical hydrometeors, which is not appropriate at higher microwave frequencies where ice scattering is important.
- DA systems assume Gaussian error statistics, examined using the departures, but in the case of cloudy radiances the departures are likely to be non-Gaussian.

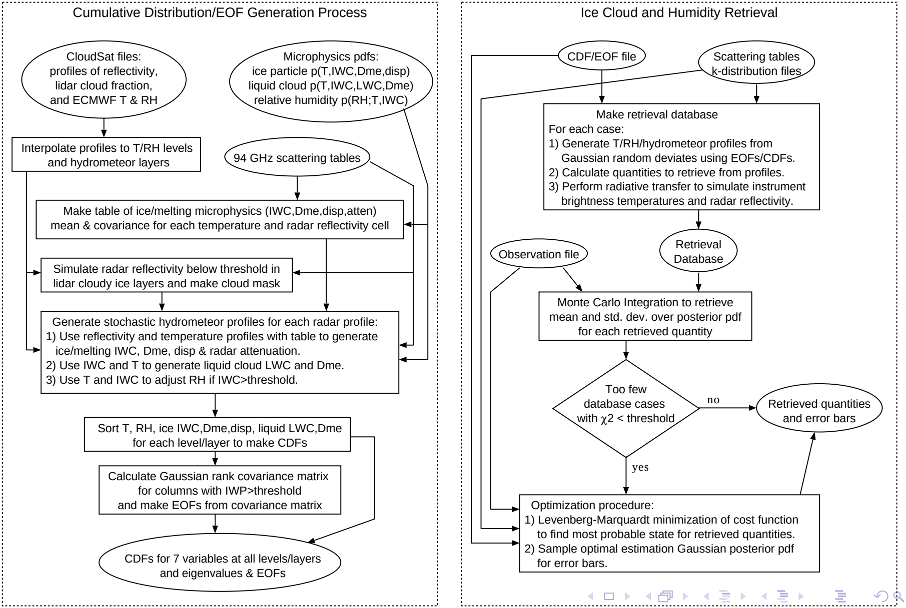
GMAO
Global Modeling & Assimilation Office

The BMCI technique can be summarized in three steps:

- generation of a retrieval database of atmospheric state and cloud variables using a-priori information. The database should also include extreme cases as the extrapolation is not allowed.
- the atmospheric state and cloud variables are fed into the RT model to generate the synthetic observations. In addition to the state variables such as temperature, water vapor, and cloud profiles, cloud microphysics and parameterization such as particles' shape and size distribution are also utilized as input.
- real measurements along with the generated database are given to the retrieval package, then the retrieval package will select the cases which are close to the real measurements and integrate them according to the Bayes' theorem to give the estimate of the mean and uncertainty of the state and cloud variables.

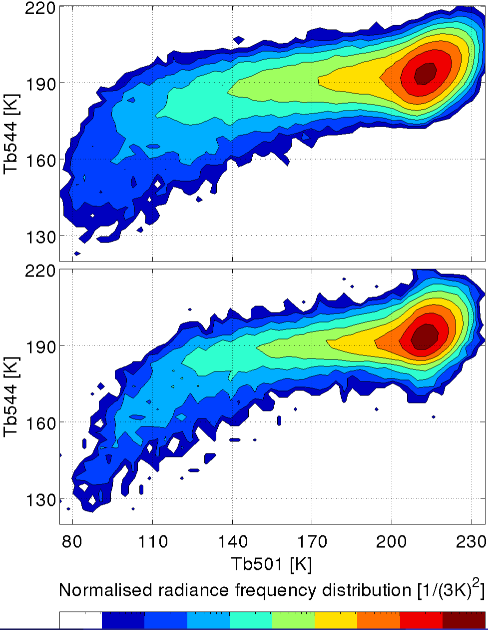
Proposed Approach

GMAO
Global Modeling & Assimilation Office

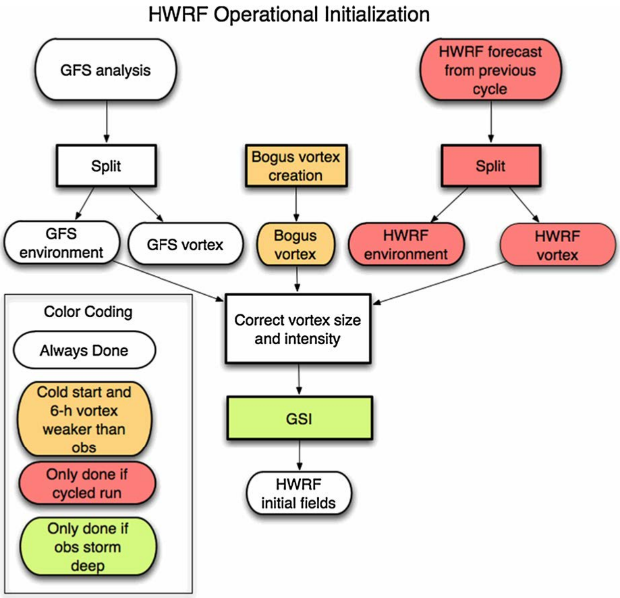


Proposed Approach

GMAO
Global Modeling & Assimilation Office



Proposed Approach



Hurricane Sandy CloudSat overpassed it on October 27, 2012

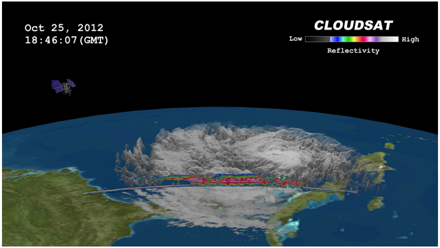
Hurricane Iselle CloudSat overpassed the hurricane on August 4, 2014

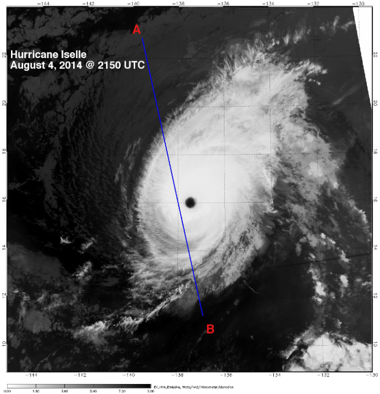
Hurricane Amanda CloudSat overpassed Hurricane Amanda on May 25, 2014

Hurricane Joaquin In an early stage of the formation of Hurricane Joaquin, on September 29, 2015, CloudSat passed over the center of the hurricane in the Caribbean.

Image credit:

`cloudsat.atmos.colostate.edu`





Improvments to the BMCI Retrieval

We have made a significant progress on enhancing the BMCI retrieval system and adding new functionalities to the code. Some of the major enhancements to the code are as follows:

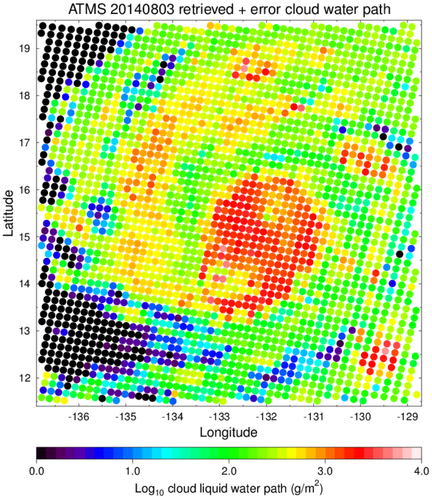
- Adding temperature profile retrieval capability
- Computing ice particle scattering properties at new frequencies using DDA/ADDA, and generated new scattering tables
- Implementing the FASTEM microwave ocean surface emissivity model, both forward and adjoint, in 1D retrieval code
- adding retrieving the ocean skin temperature and near surface wind speed
- Modifying the original CloudSat reflectivity profile based CDF/EOF program to also use GPM Dual-frequency Precipitation Radar (DPR) reflectivity profiles when CloudSat reflectivity is too attenuated

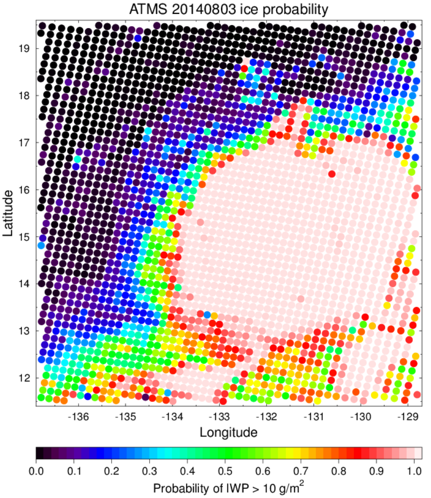
Improvments to the BMCI Retrieval

- Analyzing in situ warm cloud and rain microphysical data from the Hurricane Research Division (HRD) and generating stochastic profiles of warm liquid cloud profiles
- Adding ERA-Interim profiles of stratospheric temperature and water vapor matched to CloudSat times and locations to complement the CloudSat ECMWF-AUX profiles (which only reach 24 km).
- Modifying the CDF-EOF algorithm to allow for clear layers using a hydrometeor masking procedure for ice, rain, and liquid cloud
- Modifying the 1D Bayesian retrieval program to input the new CDF-EOF a priori file and generate consistent profiles of temperature, relative humidity, and ice particle, raindrop, and cloud droplet size distribution parameters to use in the Bayesian profile retrievals.

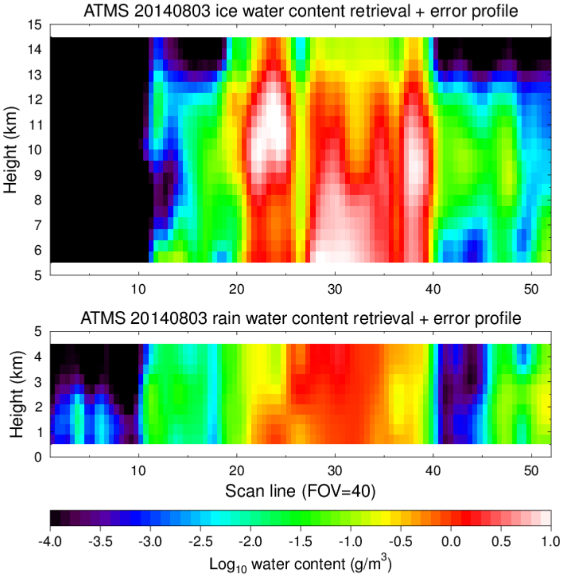
BMCI Retrievals

GMAO
Global Modeling & Assimilation Office

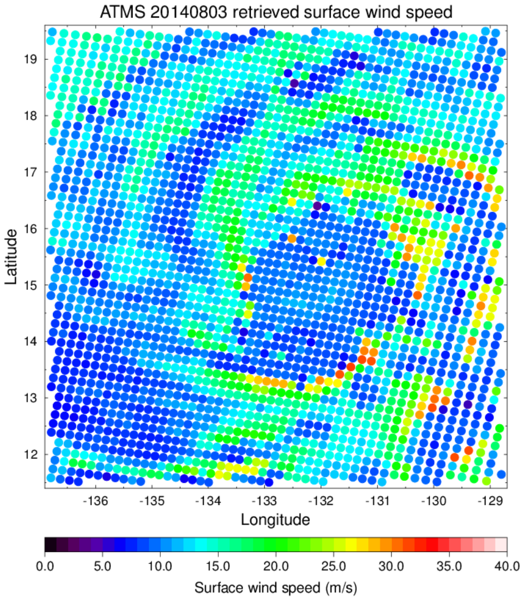




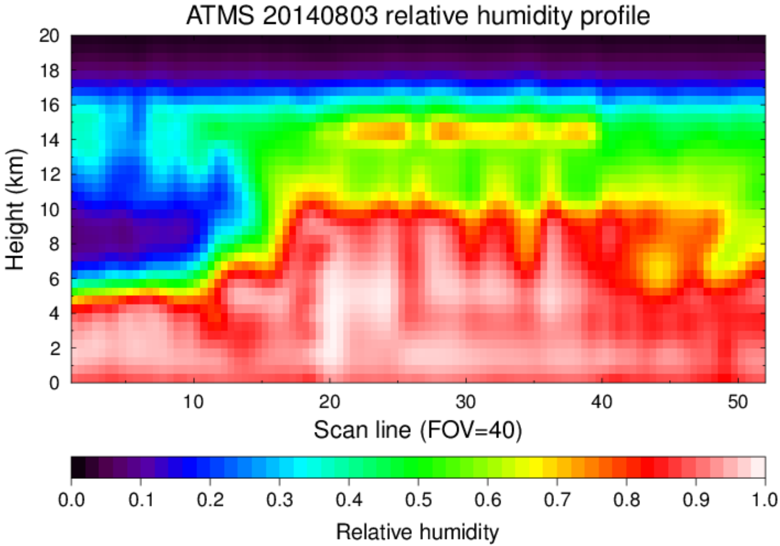
BMCI Retrievals



BMCI Retrievals



BMCI Retrievals



Conclusions

- Variational data assimilation schemes cannot properly assimilate satellite radiances in the rainband of tropical cyclones due to inaccuracy in RT scattering parameters as well as inaccuracy in the first guess provided by NWP models
- A new technique is proposed that does not depend on the minimization of the cost function.
- Preliminary results from BMCI technique are encouraging but requires extensive validation, though validation itself is challenging
- These retrieved profiles are valuable for both analyzing the structure of the hurricanes as well as to provide more accurate initial conditions for the NWP models

Thank you for your attention!