Summary
We propose a novel Bayesian Monte Carlo Integration (BMCI) technique to retrieve the profiles of temperature, water vapor, and cloud liquid/ice water content from microwave cloudy measurements in the presence of tropical cyclones (TCs). These retrievals then can either be directly used by meteorologists to analyze the structure of TCs or be assimilated to provide accurate initial conditions for the NWP models. The technique is applied to the data from the Advanced Technology Microwave Sounder (ATMS) onboard Suomi National Polar-orbiting Partnership (NPP) and Global Precipitation Measurement (GPM) Microwave Imager (GMI).

The BMCI Technique
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.

Starting from Bayes’ theorem:

$$P_{\text{posterior}}(x|y) = \frac{P(y|x)p(x)}{P(y)} = \text{Posterior} \times \text{Prior} \times \text{Marginal Likelihood}$$

ending with...

$$\hat{x} = \frac{\sum w_i \hat{y}_i}{\sum w_i} \quad w_i = \exp \left( -\frac{1}{2} \chi^2 \right)$$

$$\chi^2 = \sum_{j=1}^{M} \frac{(y_j - H_j(x))^2}{\sigma_j^2}$$

$\sigma$ is the noise in the measurements.

Data Assimilation
Hurricane Maria: 20170917 0000z - 20170930 1800z

- TCvital Obs
- FP-CTRL
- FP+Both
- FP+ATMS-Thin
- ConvOnly

Minimum sea-level pressure in the GEOS analysis for Hurricane Maria.

Vertical cross section of wind magnitude in meters per second (top shaded) and temperature anomaly in Kelvin (top contours) as well as 850 hPa wind speed (bottom shaded) and sea surface pressure in hPa (bottom contours). The depicts for the cycle 21z, September 22, 2017.

Reference: Moradi et al., MWR 2020: https://doi.org/10.1175/MWR-D-19-0341.1