ABSTRACT

Microwave radiometers have wide application in atmospheric remote sensing and provide essential inputs to numerical weather-prediction models. But the applications of these space-borne, multispectral measurements from multiple sensors are often plagued with the problem of nonuniform spatial resolution caused by the limited size of satellite instrument antenna and the frequency dependent microwave emission from the earth-atmosphere system. This mismatch in resolution becomes a critical issue when observations from multiple sources are combined to retrieve geophysical parameters. To address this issue, much effort has been made to develop remapping algorithms that can effectively unify the field of view (FOV) of measurements from various sources.

This study compares the performance of two remapping algorithms that have been widely adopted in the operational ATMS data pre-processing. One is Backus-Gilbert inversion (BGI) method, implemented in ATMS Resampling Algorithm to produce ATMS brightness temperature at each Cross-track Infrared Sounder (CrIS) FOV. The other is the Filter algorithm, applied in ATOVS and AVHRR Pre-processing Package (AAPP) to remap ATMS data to AMSU-like FOV. The two algorithms are compared both in the simulated and actual ATMS data.

ATMS Remapping Algorithms

BGI Algorithm

BGI algorithm remaps the data in the spatial domain.  It finds a set of optimal coefficients $a_{ij}$, for constructing a new observation $T_{original}^{remap}$ with an expected FOV as a linear combination of adjacent original observations $T_{original}^{adj}$.  

$$ T_{original}^{remap} = \sum_{i,j=0}^{N} a_{ij} T_{original}^{adj} $$

The coefficients are obtained by minimizing the following objective function:

$$ Q = Q_{0} + \psi \sum \omega_{i,j} a_{ij} T_{original}^{adj} - Q_{0}^{filter} \sum \omega_{i,j} a_{ij} $$

$$ \omega_{i,j}^{\text{original}} = \omega_{i,j}^{\text{filter}} $$

$\psi$: scale factor set to be 6.001

$\psi$: noise tuning factor, determined by imposing the constraint $\sum_{i=1}^{N} \sum_{j=1}^{N} \omega_{i,j} T_{original}^{adj} = \psi$.

Filter Algorithm

Filter Algorithm is established based on the convolution theorem. It is regarded as the convolution of Tb with antenna gain function in spatial domain, which is equivalent to the multiplication of them in frequency domain. This algorithm manipulates the beam width in frequency domain:

$$ T_{original}(f) = \text{FFT Transform} \rightarrow F_{original}(F) \rightarrow \text{FFT Inverse Transform} \rightarrow T_{original}(f) $$

$$ T_{filter}(f) = \text{Minimize} F_{filter}(F) $$

$MTF_{filter}$ and $MTF_{original}$ are the Fourier transform of the original/target antenna pattern. Note that for image enhancement, a cutoff parameter is added to suppress the amplified noise.

Evaluation by Actual ATMS Datasets

Having examined simulated images, we now consider using actual data to compare the performance of BGI and Filter algorithm. Both algorithms are applied to ATMS observations around west coast of Africa at UTC300 May 26, 2019.

Evaluation by Simulated Datasets

To compare the performance of these two remapping algorithms and evaluate the noise characteristic of the remapped data, the model-simulated observations are generated by integrating the product of Tb and the ATMS PSF. The Tb field is simulated by Community Radiative Transfer Model (CRTM) from the geophysical field provided by Global Forecast System (GFS). The case of hurricane Dorian near South Florida at 1800 UTC August 31, 2019 is used in this study.

Summary

A comparison of two different methods, BGI and Filter algorithm, for remapping the ATMS observations from FOV with 5.2° and 2.2° beamwidth in a AMSU-A like FOV with 3.3° beamwidth has been presented. The conclusions drawn from the experiments with the simulated and actual ATMS datasets are consistent:

- Resolution Enhancement:
  - Both algorithms improve the resolution to some extent.
  - BGI increases the noise by 0.5 K while Filter algorithm maintains the original noise level.
  - Filter algorithm generates bias as large as 2.3 K at high beam angles.

- Resolution Degradation:
  - BGI can perfectly remap the observations while Filter algorithm shows obvious bias around coastlines.
  - Both algorithms reduce the noise from 0.4 K to 0.1 K.

References