Comparison of the Remapping Algorithms for Advanced Technology Microwave Sounder (ATMS)

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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 efforts have been paid 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 via both 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 Ta^{target} with an expected FOV as a linear combination of adjacent original observations $Ta_{ij}^{original}$:

$$Ta^{target} = \sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij}\, Ta_{ij}^{original}$$

The coefficients are abtained by minimizing the following objective function:

$$Q = Q_0 \cos\gamma + e^2 w \sin\gamma$$

$$Q_0 = \int \left(\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij}\, G_{ij}^{original} - G^{target}\right)^2 dA$$

$$e^2 = \Delta T_{rms}{}^2 \sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij}^2$$

$G^{original}$ / G^{target}: original/target gain functions

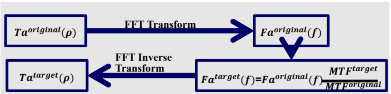
ΔT_{rms}: observation noise

w: scale factor set to be 0.001

γ: noise tuning factor, determined by imposing the constraint $\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij}=1$

❑ Filter Algorithm

Filter Algorithm is established based on the convolution theorem. Ta 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:

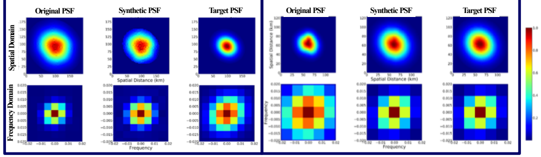


$MTF^{original}$/ MTF^{target} are the Fourier transform of the original/target antenna pattern. Note that for image enhancement, a cutoff parameter is added to suppress the amplified noise.

Reconstructed Point Spread Function (PSF)

BGI Enhancement from Ch.1 with 3dB beam width of 5.2 ° to 3.3 °

BGI Degradation from Ch.3 with 3dB beam width of 2.2 ° to 3.3 °

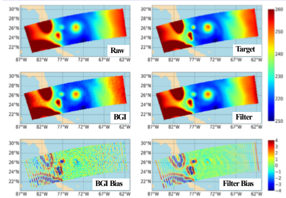


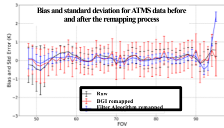
- BGI enhancement shows some improvement in the synthetic PSF. Compared to the original one, the synthesized PSF contains more high frequency components which is closer to the target one.
- BGI degradation shows that the synthetic PSF perfectly matches the target PSF.
- For Filter algorithm, the antenna pattern is not projected to earth surface and thus no reconstructed PSF is provided.

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.

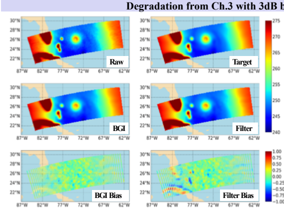
Enhancement from Ch.1 with 3dB beam width of 5.2 ° to 3.3 °

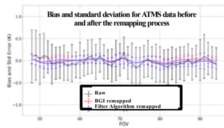




- Both algorithms produce some resolution improvement, but fail to capture the sharp change in Ta around coastlines.
- Noise level is amplified by BGI while well maintained by the Filter algorithm because of the using of the cutoff parameter.
- The data remapped by Filter algorithm show large bias towards the end of the scan, due to the fact that the change in the relative geometry of PSF over scan is not considered.

Degradation from Ch.3 with 3dB beam width of 2.2 ° to 3.3 °





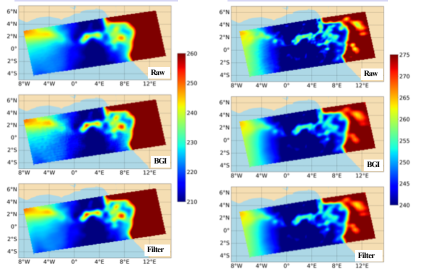
- The observations remapped by BGI approximate the "truth" very well.
- The observations remapped by the Filter algorithm still have large bias around coastlines.
- The channel noise is significantly reduced by both algorithms.

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 UTC1300 May 26, 2019.

Enhancement from Ch.1 with 3dB beam width of 5.2 ° to 3.3 °

Degradation from Ch.3 with 3dB beam width of 2.2 ° to 3.3 °



- For resolution enhancement, both algorithms strengthen the cumulus centers and the coastlines. The noise level of the remapped data is amplified by BGI and reduced by Filter algorithm. Compared to BGI, Filter algorithm produces positive bias around the left corner of the image.
- For resolution reduction, both algorithms blur the cumulus centers and the coastlines. The noise level is suppressed to a large extent.

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 to 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 maintain the original noise level.
  - Filter algorithm generates bias as large as 2.3 K at high scan 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

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