P5.38

RETRIEVAL OF ATMOSPHERIC INVERSIONS USING GEOSTATIONARY HIGH-SPECTRAL-RESOLUTION SOUNDER RADIANCE INFORMATION

Jun Li
Cooperative Institute for Meteorological Satellite Studies (CIMSS)
University of Wisconsin-Madison

Timothy J. Schmit
NOAA/NESDIS, Office of Research and Applications, Advanced Satellite Products Team (ASPT)

Hung-Lung Huang, and Harold M. Woolf
Cooperative Institute for Meteorological Satellite Studies (CIMSS)
University of Wisconsin-Madison, Madison, WI

1. INTRODUCTION

The era of high-spectral-resolution radiance measurements from the geostationary perspective is approaching. The first instrument to usher in this new era is the experimental Geosynchronous Imaging Fourier Transform Spectrometer (GIFTS), which is to be followed by an operational Advanced Sounder Baseline (ABS). The advanced sounders will have thousands of channels with widths on the order of single wavenumbers, while the current GOES Sounder (Menzel and Purdom, 1994) has only 18 bands with widths on the order of tens of wavenumbers. High-spectral-resolution sounder measurements from geostationary orbit will allow for monitoring the evolution of temperature and moisture inversions in clear skies. The current GOES sounder radiance measurements are, in general, not able to depict atmospheric inversion structure because of their lower spectral-resolution. Being able to characterize inversions is important for many reasons, including the detection of severe weather potential and possible fog formation, numerical model initialization, and sounding retrieval. High-spectral-resolution sounder radiances, as well as current GOES sounder radiances, will be simulated, with instrument noise included, for a number of radiosonde profiles with varying inversion strengths. A physical retrieval algorithm will be employed to retrieve temperature and moisture profiles with both sounders. The retrievals will be compared to the true profiles that were used to create the radiances in order to determine the strength of an inversion that can be retrieved from both current and the next-generation geostationary radiances.

Corresponding author address: Jun Li, Space Science and Engineering Center, Uiniversity of Wisconsin-Madison, 1225 West Dayton Street, Madison, WI 53706; e-mail: JunL@ssec.wisc.edu

2. RETRIEVAL SIMULATIONS

A fast and accurate transmittance models called Pressure Layer Optical Depth (PLOD) or Pressure layer Fast Algorithm for Atmospheric Transmittances (PFAAST) (Hannon et al. 1996) is used for the Advanced Baseline Sounder (ABS) or Cross-track Infrared Sounder (CrIS) (Bloom, 2001) simulations. The calculations are made at 101 pressure levels (0.01–105 kPa) and take into account the satellite zenith angle, absorption by well-mixed gases (including nitrogen, oxygen, and carbon dioxide), water vapor (including the water vapor continuum), and ozone.

A two-step algorithm, a Principle Component Regression (PCR; Huang and Antonelli 2001) followed by a non-linear physical retrieval method (Li and Huang 1999; Li et al. 2000), will be adopted for retrieval of atmospheric temperature and moisture profiles from ABS or CrIS simulated radiances which are added with the instrument noise. The regression retrieval serves as the first guess (or background) in the physical retrieval. PCR uses the projections of the predictor variables (brightness temperature) onto a subset of principle components. Once a first guess is obtained from a numerical model forecast or generated from the regression technique described above, a non-linear iterative procedure is applied to the radiative transfer equation to further improve the profiles. Approximately half of the channels (optimal channels) are used in the physical retrieval procedure.

A data set containing more than 6000 global radiosonde profiles between 65S and 65N latitude is used for ABS retrieval simulation. 90% of the profiles are used for training - to create the regression coefficients, while the remaining 10% of the profiles are used to test the retrieval performance. The radiative transfer calculations of the ABS spectral band radiances are performed for each profile from the training data set to provide a temperature-moisture-ozone profile/ABS radiance pair for use in the statistical regression analysis. The ABS instrument noise is added into the calculated spectral band radiances. The eigenvector or Empirical Orthogonal Function (EOF) regression equation is then generated based on these calculated radiances and the matching atmospheric profiles. To complete the regression retrieval, the regression equation can be applied to the ABS independent radiances to obtain the estimated atmospheric profile retrieval, the regression retrieval is further updated with the nonlinear physical retrieval procedure. Comparison between the true and retrieved profiles gives the accuracy of retrieval performance.

3. RESULTS

Figure 1 shows an example of CrIS brightness temperature spectra and GOES band brightness temperatures (lower panel) calculated from profile with low level temperature inversion. The ABS Technical Requirement Document (TRD) noise (upper panel) is included in the CrIS radiances, while the GOES-8 spec noise is added in the GOES radiances. It can be see that the temperature inversion signal is well depicted by the CrIS spectra, while it is smoothed by the GOES brightness temperatures due to the low spectral resolution of the current GOES sounder. Figure 2 shows the true atmospheric temperature profile used in the simulation, the CrIS and GOES retrieved temperature profiles. Since CrIS spectra is able to well reflect the atmospheric inversion signal, significant improvement of CrIS low level temperature retrieval over the GOES sounder retrieval is found.

Figure 3 is the 1km vertical resolution temperature RMS (left panel) and 2km vertical resolution water vapor mixing ratio RMS (right panel) from the 605 independent profile retrievals with EOF regression physical procedures. There is substantial improvement of physical retrieval procedure over the EOF regression procedure for the boundary layer temperatures, while the accuracy of moisture retrievals is significantly improved from the physical procedure over the EOF regression procedure (2 ~ 5% improvement for atmospheric water vapor mixing ratio). Figure 4 shows the residual RMS from the EOF regression first guess profiles, the physical retrieval profiles, along with instrument noise (NEDT RMS). It can be seen that the EOF regression first guess fits the radiances very well (the residual is close to the instrument noise) in the longwave CO_2 region, this is due to the fact that CO_2 absorption region's radiances are more linear to atmospheric temperature profile since there is only CO_2 absorption in that region. For the longwave window region and the midwave water vapor region, the radiances are highly nonlinear to the water vapor mixing ratio. The regression first guess is not able to fit the observed radiances, while the nonlinear physical approach can reduce the first guess residual to the noise level in those spectral regions.

4. CONCLUSIONS

Retrievals from simulated CrIS radiances with the ABS TRD noise indicates that

(1) Nonlinear physical retrieval procedure improves eigenvector regression derived first guess profile, especially for atmospheric moisture profile;
(2) Simulations from CrIS radiances demonstrates that the next GOES advanced sounder (ABS) meets the NWS requirement for atmospheric profile products (1K of temperature for 1km vertical resolution and 15% of

water vapor mixing ratio for 2km vertical resolution);

(3) The ABS is able to depict the atmospheric temperature inversion structure on which the current GOES sounder has limited information.

5. REFERENCES

Bloom, H. J., 2001: The Cross-track Infrared Sounder (CrIS): A sensor for operational meteorological remote sensing, Technical Digest of Optical Remote Sensing of the Atmosphere, 74-76, February 5-8, 2001, Coeur d'Alene, Idado.

Hannon, S., L. L. Strow, and W. W. McMillan, 1996: Atmospheric infrared fast transmittance models: A comparison of two approaches. *Proceedings of SPIE*, 2830, 94-105.

Huang, H. L., and Antonelli, 2001: Application of principal component analysis to high-resolution infrared measurement compression and retrieval, *J. Appl. Meteor*. 40, 365-388.

Li, J., and H. L. Huang, 1999: Retrieval of atmospheric profiles from satellite sounder measurements using the discrepancy principle. *Appl. Optics*, 38, 916-923.

Li, J., W. Wolf, W. P. Menzel, W. Zhang, H.-L. Huang, and T. H. Achtor, 2000: Global soundings of the atmosphere from ATOVS measurements: the algorithm and validation. *J. Appl. Meteor*. 39, 1248 - 1268.

Menzel, W. P., and J. F. W. Purdom, 1994: Introducing GOES-I: The first of a new generation of geostationary operational environmental satellites. *Bull. Amer. Meteor. Soc.*, **75**, 757-781.

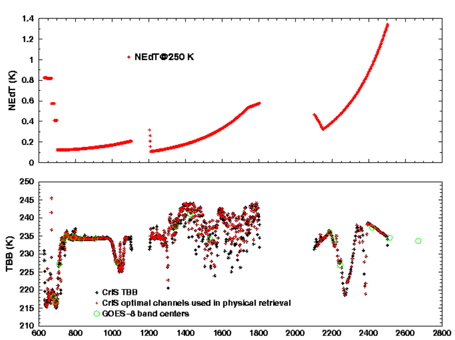

Figure 1, CrIS brightness temperature spectra and GOES band brightness temperatures (lower panel) calculated from profile with low level temperature inversion. The ABS TRD noise (upper panel) is included in the CrIS radiances, while the GOES-8 spec noise is added in the GOES radiances.

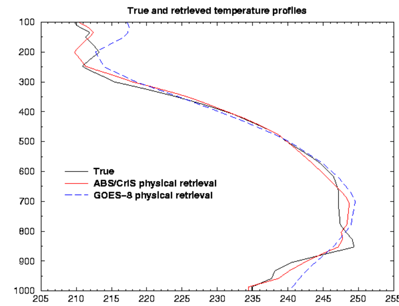

Figure 2, the true atmospheric temperature profile used in the simulation, along with the CrIS and GOES retrieved temperature profiles.

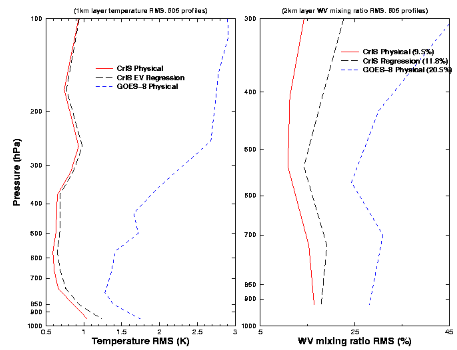

Figure 3, 1km vertical resolution temperature RMS (left panel) and 2km vertical resolution water vapor mixing ratio RMS (right panel) with EOF regression physical procedures (CrIS and GOES).

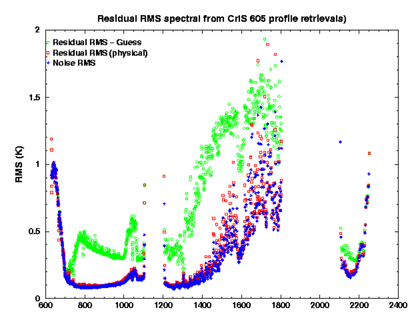

Figure 4, the CrIS residual RMS from the EOF regression first guess profiles, the physical retrieval profiles, along with instrument noise (NEDT RMS).