P7.16 STOCHASTIC CLOUD CLEARING OF HYPERSPECTRAL RADIANCES OBSERVED BY THE ATMOSPHERIC INFRARED SOUNDER (AIRS) ON THE AQUA SATELLITE

Choongyeun Cho * and David H. Staelin
Massachusetts Institute of Technology, Research Laboratory of Electronics
Cambridge, Massachusetts

1. ABSTRACT

This paper presents a stochastic approach to estimating cloud perturbations of hyperspectral radiances observed by the Atmospheric InfraRed Sounder (AIRS) on the National Aeronautics and Space Administration (NASA) Aqua satellite, launched in May 2002. The proposed cloud-clearing algorithm estimates the effects of clouds on AIRS radiances based on 294 infrared radiances from AIRS and 5 microwave channels from the Advanced Microwave Sounding Unit (AMSU), and then compensates these radiances for the cloud effects. Each cloud-cleared radiance spectrum corresponds to a ~50-km cell for which the infrared spectra of 9 independent sub-cells with ~15-km resolution are examined. The nine sub-cells are arranged in a 3x3 array. Each 50-km estimate is based on spectra from two or more 15-km sub-cells. The proposed stochastic cloud-clearing algorithms and alternatives will be compared.

2. INTRODUCTION

2.1 Cloud Clearing

In order to retrieve accurate atmospheric temperature or water vapor profiles from infrared data obtained from satellites, detection and compensation of possible cloud contamination within the field of view is required. Cloudy infrared radiances are difficult to use in retrieval or radiance assimilation schemes since they do not generally provide accurate information on the thermodynamic state of the atmosphere below the cloud. Therefore if clouds cover a portion of the FOV of an infrared radiometer, an accurate treatment of the effects of clouds on the observed IR radiances is critical to obtaining accurate soundings. The proposed algorithm takes infrared and microwave brightness temperatures and provides estimates of the cloud-cleared infrared radiances.

2.2 AIRS/AMSU/HSB Sounding Suite

AIRS observes 2378 spectral channels in the range 3.7 to 15 microns wavelength, and AMSU/Humidity Sounder for Brazil (HSB) observes 19 microwave channels at frequencies from ~23.8 to 190 GHz with comparable spatial resolution. AIRS is the first hyperspectral infrared radiometer designed to support the operational requirements for medium-range weather forecasting of the National Ocean and Atmospheric Administration's National Centers for Environmental Prediction (NCEP) and other numerical weather forecasting centers. AIRS, together with the AMSU and HSB microwave radiometers, will achieve global retrieval accuracy of better than 1 K in the lower troposphere under clear and partly cloudy conditions. (Aumann, 2003)

3. CLOUD-CLEARING ALGORITHM

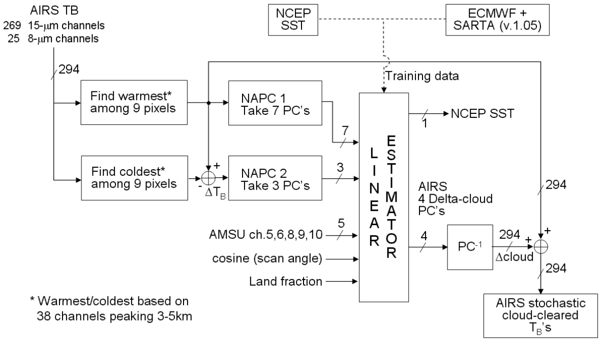

Figure 1. Block diagram of the stochastic cloud-clearing algorithm

Figure 1 illustrates the structure of the proposed statistical cloud-clearing algorithm. In this exercise we used 294 15- and 8-micron channels. Principal Component Analysis (PCA) is widely used to reduce the number of inputs to a linear estimator in order to stabilize the estimator and reduce the noise in the input. Noise-Adjusted Principal Components (NAPC) are known as a linear transformation which maximizes the signal-to-noise ratio of the given input vectors (Green, 1988). The algorithm uses linear regression that estimates the 4 NAPC scores of the cloud perturbations in brightness temperature relative to the warmest pixel in a 3x3 array. Since a single AIRS footprint, called golfball, covers 9 AMSU footprints, the warmest and coldest pixels among nine AIRS pixels are chosen based on the average brightness temperature over 38 channels for which the peak altitudes of the weighting function range from 3 to 5 km. The inputs to the regression are: 7 NAPC scores for the warmest of nine pixels; 3 NAPC's for the difference between the warmest and the coldest pixels; AMSU channels 5, 6, 7, 9, 10; cosine of scan angle; and land fraction.

4. RESULTS

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* *Corresponding author address*: Choongyeun Cho, 77 Massachusetts Ave., Room 26-345, Cambridge, MA 02139; e-mail: cycho@mit.edu

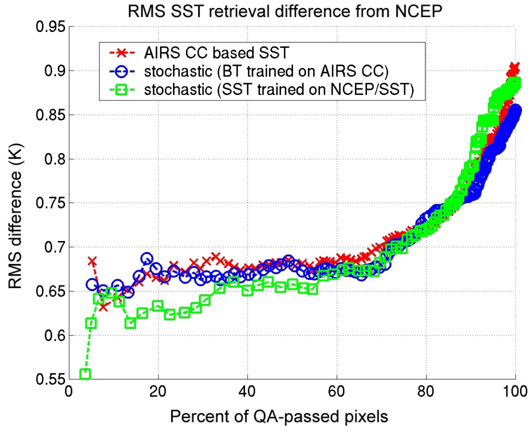

Figure 2. SST retrieval difference

For sea surface temperature (SST) retrievals, 1755 and 1365 golfballs collected on January 3, April 9, July 14 in 2003 were used for the training and testing respectively. All the data are located in ocean between 40 North and 40 South in latitude. Only one third of the golfballs close to nadir are used. Furthermore, about 29% of all pixels which passed quality assurance test are used for training and testing. Figure 2 shows RMS differences with respect to the NCEP SST for three different approaches to retrieving SST. Horizontal axis is percentage of QA-passed pixels, and pixels are rank-ordered using cloud-cleared minus observed radiance for an 8-micron window channel. First, SST is calculated by AIRS version 3.5.0 cloud-cleared radiances, denoted as the red curve. Second, the stochastic cloud-clearing algorithm trained with AIRS cloud-cleared radiance yields the blue curve, using the same SST-retrieval calculation with 2 window-channel radiances. It follows the AIRS result. Third, SST is directly estimated by the stochastic cloud-clearing algorithm, which is trained with NCEP SST. This scheme bypassed the estimation of cloud-cleared radiances, thus outperforming the first two.

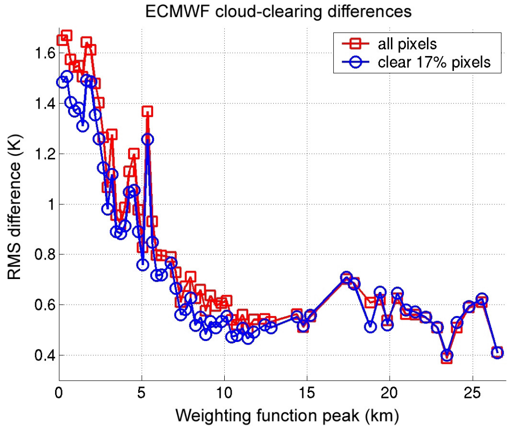

Figure 3. Cloud-clearing differences with respect to ECMWF cloud-cleared radiance

Global ECMWF numerical prediction data on August 21, September 3, and October 12 in 2003 are used to simulate cloud-cleared radiance via the SARTA v1.05 radiative transfer forward model. For this experiment also, only daytime oceanic data between 40 North and South are used. 499 golfballs each are used for training and testing. Clear pixels are defined as those having cloud-cleared-minus-observed radiances less than 1 K, which yields about 17% of the all pixels. Figure 3 shows cloud-clearing differences vs. weighting function peak of the channels used for analysis. ECMWF cloud-clearing radiances are used as ground truth. For this experiment no quality-assurance screening was done. RMS difference is below 1 K above 3 km.

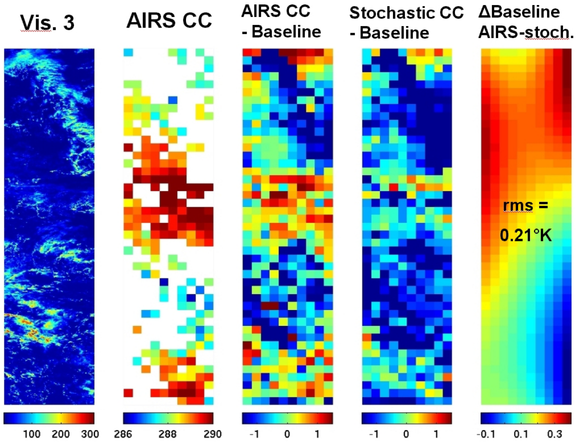

Figure 4. Images for granule #92, 4/9/03

The first image in Figure 4 is AIRS visible channel 3. The second image is AIRS v3.5.0 cloud-cleared brightness temperature for a window channel at 1219 cm^{-1}. The pixels which failed quality assurance due to clouds are shown as white. The third image is AIRS cloud-cleared brightness temperature minus baseline, where the baseline is defined as the 2D 3rd-order polynomial fit to the QA-pass pixels. The fourth image is the stochastic cloud-cleared brightness temperature minus its baseline. The residual image using the stochastic cloud-clearing algorithm exhibits very little white noise. The last image shows the difference between the AIRS baseline and stochastic baseline on an expanded scale. The two algorithms give nearly identical results with an RMS difference of ~0.21 K.

5. FUTURE WORK

Although these preliminary cloud-clearing results are encouraging, more can be done. The reduction of instrument noise is one of the major future tasks. For example, the noise in the warmest pixel which is added to the estimated cloud correction can be spatially and spectrally filtered.

The cloud-clearing algorithms in this paper used one third of the fields of view close to nadir because given inputs to the linear estimator are sensitive to scan angle and the current cloud-clearing estimator does not adequately handle the nonlinearities which scan angle causes. Thus, further study and amelioration of scan angle effects are another area for future improvements.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

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