

Microwave Integrated Retrieval System (MIRS)

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Abstract: The measurements from satellite microwave imaging and sounding channels are simultaneously utilized to retrieve the profiles of atmospheric temperature, water vapor and cloud water. It is shown that the radiative transfer model including multiple scattering from clouds and precipitation can significantly improve the accuracy.

Introduction

The Advance Microwave Sounding Unit (AMSU) measurements are increasingly utilized to derive a variety of atmospheric and surface parameters such as total precipitable water, cloud liquid and ice water, as well as surface snow and sea ice concentration (Weng et al., 2003; Ferraro et al., 2005). These products are now routinely generated from the AMSU measurements at a few window channel frequencies which are insensitive to the vertical structures of atmospheric profiles (Weng et al., 2003). In particular, atmospheric parameters such as vertically integrated water vapor and cloud liquid water can be derived analytically over oceans where the surface emissivity is low and relatively uniform, and the atmospheric emission from clouds and water vapor is predominant. This study develops a microwave integrated retrieval system (MIRS) to derive the profiles of atmospheric parameters such as temperature, water vapor, and cloud hydrometeors over land and oceans by using the measurements from AMSU window and sounding channels. An advanced radiative transfer model including atmospheric and surface scattering and polarization is developed and integrated as part of the MIRS. With the microwave surface emissivity model (Weng et al., 2001), water vapor and cloud water can be retrieved over land. With the scattering radiative transfer model, the algorithm is now generally applicable under all weather conditions. A combined use of both microwave window and sounding channels makes it possible to simultaneously derive the cloud water profiles in addition to temperature and water vapor profiles. This integrated approach will lead to more robust advanced microwave products from current and future satellite microwave instruments having both imaging and sounding channels.

Retrieval Algorithm

The MIRS is composed of several key components such as advanced radiative transfer models for computing radiances and gradients of radiances (or jacobians), and a scheme of minimizing the cost function that weighs the relative contribution of background (a priori) information and satellite observations (see Fig. 1). The first guess can be obtained from several methods: numerical weather prediction model outputs, climatological data, and regression algorithms. In this study, the initial profiles of temperature, water vapor, and non-precipitating cloud liquid water are estimated from the regression algorithm using the AMSU-A measurements. In the MIRS, the cloud liquid and ice water profiles associated with precipitation are derived through the additional variational procedure by adding AMSU-B 89 and 150 GHz and using the profiles of temperature, water vapor, and cloud liquid water derived from the first variational procedure. This approach is physically sound because these two AMSU-B window channels are insensitive to the atmospheric temperature and water vapor profiles. The final step involves in a refinement to the temperature and water vapor profiles by using all AMSU-B 183 GHz water vapor sounding channels. The 183 GHz water vapor channel measurements can improve the accuracy of water vapor profiles throughout the troposphere. Note however that the second variational procedure is

only required when the scattering signatures at 89 and 150 GHz exceed the threshold as discussed in (Weng et al., 2003).

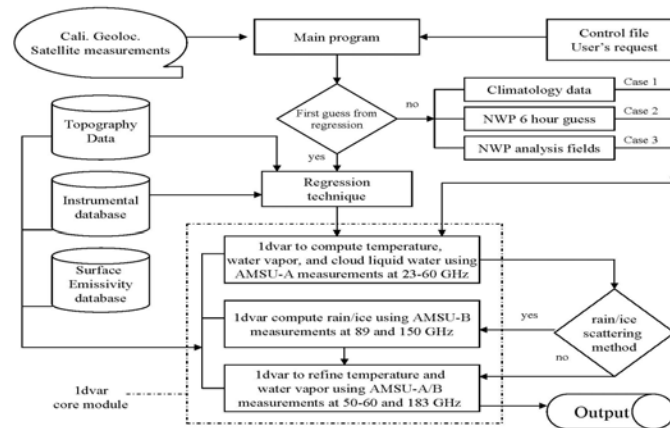


Figure 1. Flowchart of microwave integrated retrieval (MIR) algorithm. The core module describes the retrieval procedures.

An important process in MIRS is to correct the various biases from the AMSU instrument, within the forward model and the first guess. It was found that three AMSU instruments on board NOAA-15, -16 and -17 satellites all display some level of asymmetric radiances across the scan lines [1]. The causes for this asymmetry have not been fully understood. Nevertheless, an empirical algorithm was developed (Weng et al., 2003) and utilized in this study. In addition to a correction of the instrumental bias, the biases of the first guess and forward model to the truth are also corrected. When using forecast model outputs (e.g. 6 hour forecast) as a first guess, we collocate in-situ temperature and water vapor profiles observed from radiosondes with forecast model outputs, and then calculate the global mean difference between the first guess and in-situ data. The biases in the forward radiative transfer model are derived from the mean difference between measured brightness temperatures and simulated brightness temperatures that are calculated from radiosonde data.

Results

The effects of cloud and precipitation scattering on the temperature retrievals are readily demonstrated by comparing the results from a scattering radiative transfer model to those from the emission-based model. In Figure 2(a), the magnitude of the cold temperature anomaly at 850 hPa derived from the scattering model is more agreeable with other results (Hawkins and Rubsam, 1964; Zhu et al., 2002) than that from the emission-based in Figure 2(b). Because of the scattering of liquid phase hydrometeors, the microwave brightness temperatures at sounding channels are strongly depressed. If this scattering effect would not be properly taken into account in the retrieval process, the physical temperatures at 850 hPa would have been forced to the colder values which become highly non-physical (see Fig. 2(b)). Using the scattering model, the retrieved structure of cooling at 850 hPa is smooth and the anomaly in a magnitude of 3-5°K is more realistic according to Hawkins and Rubsam (1964).

The quality of the temperature distribution at 200 hPa has been also improved significantly using the scattering model. Note that the temperature at the center is about 10 degrees warmer than that of its environment (see Fig. 2c) and is favorably comparable to other early observations [5]. It is also interesting to see that the retrieved temperature from the emission-based model (Fig. 2d) is generally warmer than that from the scattering model (Fig. 2c). This is because the ice cloud

whose scattering is neglected in the retrievals would behave more like an absorber, attenuate warm radiation from the lower troposphere and re-emit with their own colder temperatures. The algorithm can only enforce warmer temperatures in the upper troposphere because the AMSU observed brightness temperatures are generally higher than those predicted by the emission-based model.

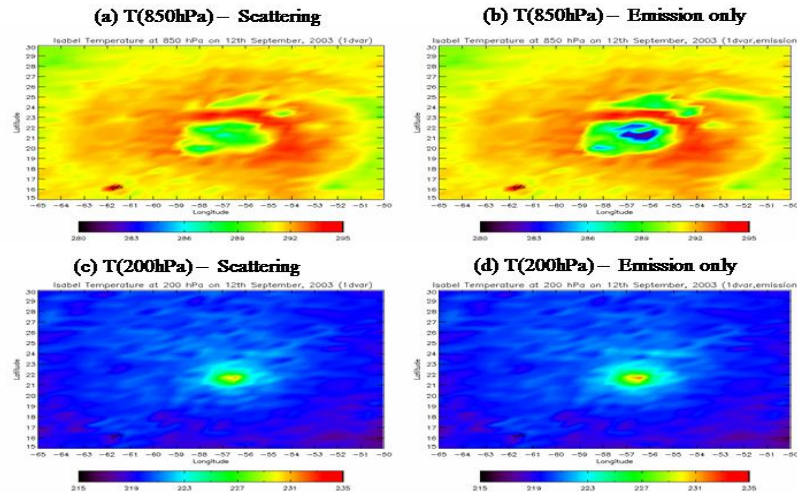


Figure 2. Retrieved atmospheric temperature at 850 hPa through (a) scattering radiative transfer model, and (b) emission radiative transfer model ; and the retrieved atmospheric temperature at 200 hPa through (c) scattering radiative transfer model and (d) emission radiative transfer model, for Hurricane Isabel on 12th September, 2003.

Conclusions

This study presented a microwave integrated retrieval system (MIRS) for profiling atmospheric temperature, water vapor and cloud water. Scattering effects from clouds and precipitation are taken into account. Using an emission-based radiative transfer model, the retrieved temperatures tend to be colder at lower altitudes and warmer at high altitudes. With a full scattering radiative transfer model, the quality of the retrieved temperature profiles can be significantly improved, and the retrievals agree well with coincident dropsonde's measurements.

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Reference

- Ferraro, R. R., F. Weng, N. C. Grody, L. Zhao, M. Huan, C. Kongoli, P., Pellegrino, S. Qiu and C. Dean, NOAA Operational Hydrological Products Derived from the Advanced Microwave Sounding Unit (AMSU), *IEEE Trans. Geosci. & Remote Sensing*, **43**, 1036-1049.
- Hawkins, H. F., and D. T. Rubsam, 1968: Hurricane Hilda, 1964. II. Structure and budgets of the hurricane on October 1, 1964, *Mon. Wea. Rev.*, **96**, 617-636.
- Liu, Q. and F. Weng, 2004: One-dimensional variation retrieval algorithm for temperature, water vapor and cloud profiles from Advanced Microwave Sounding Unit (AMSU). *IEEE Trans. Geosci. & Remote Sensing*, **43**, 1078-1095.
- Weng, F., L. Zhao, R. Ferraro, G. Poe, X. Li, and N. Grody, 2003: Advanced Microwave Sounding

- Unit Cloud and Precipitation Algorithms, *Radio Sci.*, **38**, 8086-8096.
- Weng, F., B. Yan, and N. C. Grody, 2001: A microwave land emissivity model, *J. Geophys. Res.*, **106**, 20,115 – 20,123.
- Zhu, T., D. Zhang, and F. Weng, 2002: Impact of the advanced microwave sounding unit measurements on hurricane prediction, *Mon. Wea. Rev.*, **130**, 2416-2432.