6B.6 EVALUATION OF SATELLITE-BASED LATENT HEATING PROFILE ESTIMATION METHODS

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1. INTRODUCTION

In recent years, methods for estimating atmospheric latent heating vertical structure from both passive and active microwave remote sensing have matured to the point where quantitative evaluation of these methods is the next logical step. Two approaches for heating algorithm evaluation are considered: First, application of heating algorithms to synthetic data, based upon cloud-resolving model simulations, can be used to test the internal consistency of heating estimates in the absence of systematic errors in physical assumptions. Second, comparisons of satellite-retrieved vertical heating structures to independent ground-based estimates, such as rawinsonde-derived analyses of heating, provide an additional test. The two approaches are complementary, since systematic errors in heating indicated by the second approach may be confirmed by the first.

In this study, two latent heating estimation algorithms are evaluated. Both algorithms are based upon the Bayesian estimation method described in Kummerow et al. (1996) and Olson et al. (1996, 1999), but they differ in the type of satellite remote sensing data utilized. The first algorithm yields estimates of latent heating based upon multichannel passive microwave radiometer observations, while the second incorporates (combined) measurements from both passive microwave radiometer and spaceborne radar. Latent heating estimates from these algorithms are compared to rawinsonde budget estimates of heating. In addition, since the combined algorithm estimates are expected to have better precision due to the additional radar information, the radiometer heating estimates are also compared to the combined algorithm estimates, which serve as a reference.

2. DATA AND METHODS

The TMI is a 5-frequency, passive microwave radiometer with dual-polarization channels at 10.65, 19.35, 37.0, and 85.5 GHz, and a vertical-polarization channel at 21.3 GHz. Specifications of the TMI may be found in Kummerow et al. (1998). The lower-frequency channels are primarily sensitive to the vertical path-integral of liquid precipitation in the atmosphere. The channels become increasingly sensitive to the vertical path-integral of ice-phase precipitation as the channel frequency increases, while the range of sensitivity to rain decreases. At 85.5 GHz, measured radiances are essentially insensitive to variations in rain path for path-integrals greater than about 1 kg m^{-2}, but radiances can decrease by 10's of ^oK for modest increases in the path-integrals of snow or graupel. Due to these sensitivities, the TMI has a crude precipitation profiling capability, which is somewhat compromised by the loss of horizontal resolution at the lower frequencies. The sampling resolution of the TMI is about 14 km along-track and 5 km cross-track.

The PR is a single-frequency weather radar operating at 13.8 GHz. It scans cross-track only ±17^o from nadir, and therefore each radar beam samples a nearly vertical column in the atmosphere, at 0.25 km vertical resolution. The along- and cross-track sampling by the PR is about 4.5 km. Both the TMI and PR are part of the Tropical Rainfall Measuring Mission (TRMM) observatory that was launched in November, 1997; see Simpson et al. (1988).

The TMI and combined TMI-PR Bayesian estimation methods for estimating latent heating rates are supported by a diverse set of cloud resolving model (CRM) simulations that serve as a kind of "look-up" table. For each footprint-sized area in each CRM simulation, forward radiative calculations are performed to simulate both the upwelling microwave radiances that TMI would observe as well as the radar reflectivities PR would detect. These footprint simulations establish the relationship between TMI/PR radiances/reflectivities and the precipitation/latent heating vertical profiles in the footprints. For a given set of TMI or combined TMI-PR observations, the CRM database is scanned to find those simulated footprints that are radiatively consistent with the observations. The precipitation/latent heating profiles of the radiatively consistent footprints are composited to yield the estimated precipitation/latent heating profiles.

3. EVALUATION

The TMI latent heating algorithm was applied to all observations within the South China Sea Monsoon Experiment (SCSMEX) Northern Enhanced Sounding Array (NESA) polygon during the period 15 May to 20 June 1998. During this period, estimates of average surface rainfall rate and vertical Q_1 (apparent heat source; see Yanai et al. 1973) profiles within the NESA polygon were derived from the SCSMEX/GAME sounding network and GAME Reanalysis by Johnson and Ciesielski (2002).

The TMI estimates of average surface rain rate and vertical Q_1-Q_R (apparent heat source less radiative heating) profiles in the polygon are compared to the

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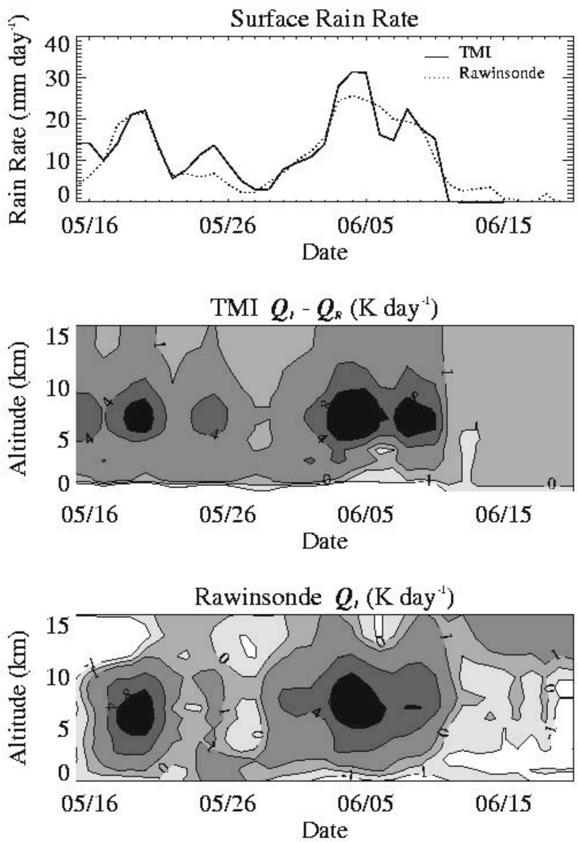

Fig. 1. Time series of surface rain rate, Q_1–Q_R from TMI, and Q_1 from rawinsonde analyses, over the NESA of SCSMEX from 15 May to 20 June, 1998. Heating contours are –1, 0, 1, 4, and 8 K day^{-1}

sounding estimates in Fig. 1. A 3-day running mean filter was applied to all time series data in the figure. First, note that the time series of rain rate from the TMI algorithm and rawinsonde analyses are in fairly good agreement, in spite of differences in temporal sampling by the instruments involved (The TMI typically observed part of the NESA during 1-2 overpasses per day, while the maximum sounding frequency was 4 per day.). The correspondence of the TMI Q_1-Q_R and rawinsonde Q_1 time series is also reasonable, considering the fact that radiative cooling generally lowers Q_1 relative to Q_1-Q_R. The effect of radiative cooling is particularly apparent in less active periods, such as 27-28 May and after 15 June 1998.

After accounting for differences in estimated rain rates, the mean heating profiles from TMI and rawinsonde analyses (Fig. 2) appear similar. However, excesses of heating at high altitudes and cooling near the surface in the TMI estimates are artifacts arising from insufficient information in the radiometer data.

Additional tests of the precipitation/latent heating algorithms will be presented at the conference.

Acknowledgments: The authors wish to thank Richard Johnson and Paul Ciesielski, who kindly provided their SCSMEX rawinsonde analyses for this study. The authors also thank Scott Braun, Christine Chiu, Brad Ferrier, Dan Johnson, Chris Kummerow, Steve Lang, Grant Petty, and Yansen Wang for their contributions and advice. This research was supported by the TRMM Science Program.

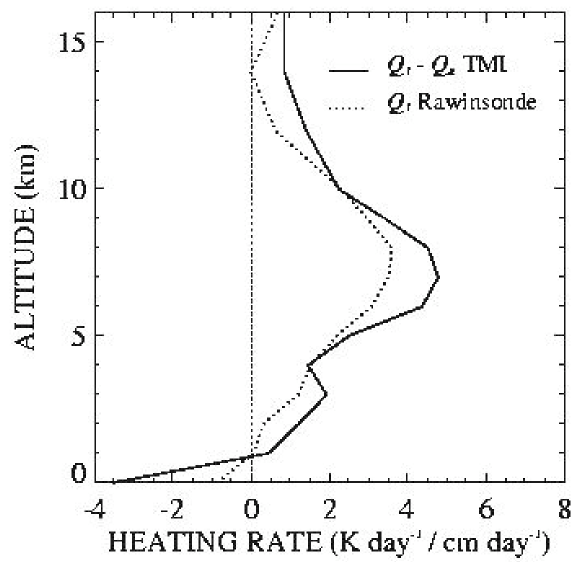

Fig. 2. Rainrate-normalized mean profiles of heating from TMI and rawinsonde analyses over the NESA of SCSMEX for the period 15 May – 20 June 1998.

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