6B.5 LATENT HEATING RETRIEVAL FROMM TRMM OBSERVATIONS USING A SIMPLIFIED THERMODYNAMIC MODEL

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1. INTRODUCTION

Knowledge regarding the spatial and temporal distribution of heating in the Tropics is required for various applications. These applications range from long-term climate prediction to storm-scale diagnostics and forecasting. A comprehensive discussion may be found in Olson et al. (1999). The large spectrum of applications justified the development of algorithms for latent heating estimation from observations provided by space borne instruments. Examples of such algorithms are those derived by Olson et al. (1999) for passive microwave observations, Tao et al. (1993), and Yang and Smith (1999) for both passive and active microwave observations. Olson et al. (1999) algorithm is based on a Bayesian procedure that assigns, for a given set of observations, probabilities to a set of latent heating profiles derived from cloud model simulations. Tao et al. (1993) use only the surface precipitation, a convective-stratiform classification, and a set of normalized latent-heating profiles (derived also from cloud model simulations), while Yang and Smith (1993) assume a steady-state and use hydrometeor conservation equations to estimate the latent heating. Given the lack of information regarding the dynamics of the observed precipitation, only approximate algorithms may be derived, and, as apparent from the above description, various approaches are possible.

In this study, we investigate a hybrid, computationally more demanding,approach that may yield results superior to those from the existing algorithms. The approach is based on a system of simplified hydro- and thermodynamic equations that are integrated in time until a steady state is achieved. A statistical procedure is used for the system initialization. Thus, the formulation extends two of the existing algorithms. The approach, which is devised to use observations from the precipitation radar (PR) onboard the Tropical Rainfall Measuring Mission (TRMM), is evaluated using synthetic data derived from cloud model simulations.

2. FORMULATION

In the absence of a time sequence of observations a steady state-solution consistent with the conservation of momentum and energy laws is sought. Assuming that the hydrometeor latent heating is known and omitting the diffusion terms for simplicity, the hydrodynamic evolution of the observed system is described by the momentum, thermodynamic and continuity equations:

$$\frac{D\mathbf{v}}{dt} = -\frac{\nabla p}{\rho} \quad (1)$$

$$\frac{D\rho}{dt} = -\rho\nabla\cdot\mathbf{v} \quad (2)$$

$$\frac{D\theta}{dt} = Q \quad (3)$$

where Q is the latent heating and the other variables have the traditional meaning.

The latent heating estimation algorithm uses Eqs (1)-(3) iteratively. The velocity, pressure, temperature and density fields are set using large-scale observations. The initial Q is estimated from observed reflectivity profiles through a Bayesian procedure and Eqs. (1)-(3) are integrated until a steady state is reached. Then, using the observed reflectivity fields and the predicted velocities, a procedure similar to that of Chong and Hauser (1990) is used to update Q. The cycle of predicting **v** and θ from Q, and updating Q based on **v,** is repeated several times.

3. RESULTS

The algorithm is evaluated using synthetic observations derived from cloud resolving model simulations. In this study, a simulation of Hurricane Bonnie (19-30 August, 1998) performed using the PSU/NCAR MM5 model is employed. The physical variables produced by the numerical model are used to generate radar reflectivity data with the TRMM PR characteristics (frequency, and spatial resolution). Then a Bayesian latent heating estimation procedure, similar to that of that of Olson et al. (1999), but extended to work with radar observations, is developed and used to provide the initial estimates of Q in Eq. (3). Eqs. (1) — (3) are solved iteratively as described in the previous section.

Presented in Figure 1 are the actual and Bayesian-estimated azimuthally-averaged hydrometeor latent heating as a function of range from the eye. One may note a fairly good agreement between the actual and the retrieved latent heating. Similar agreement (not shown) is obtained for the vertical velocities. The estimates from the iterative algorithm appear to be about 10% (in terms of root mean squared error of Q normalized by the standard deviation of Q) more accurate than the initial Bayesian estimates, i.e. the initial Q that is specified in Eq. (3).

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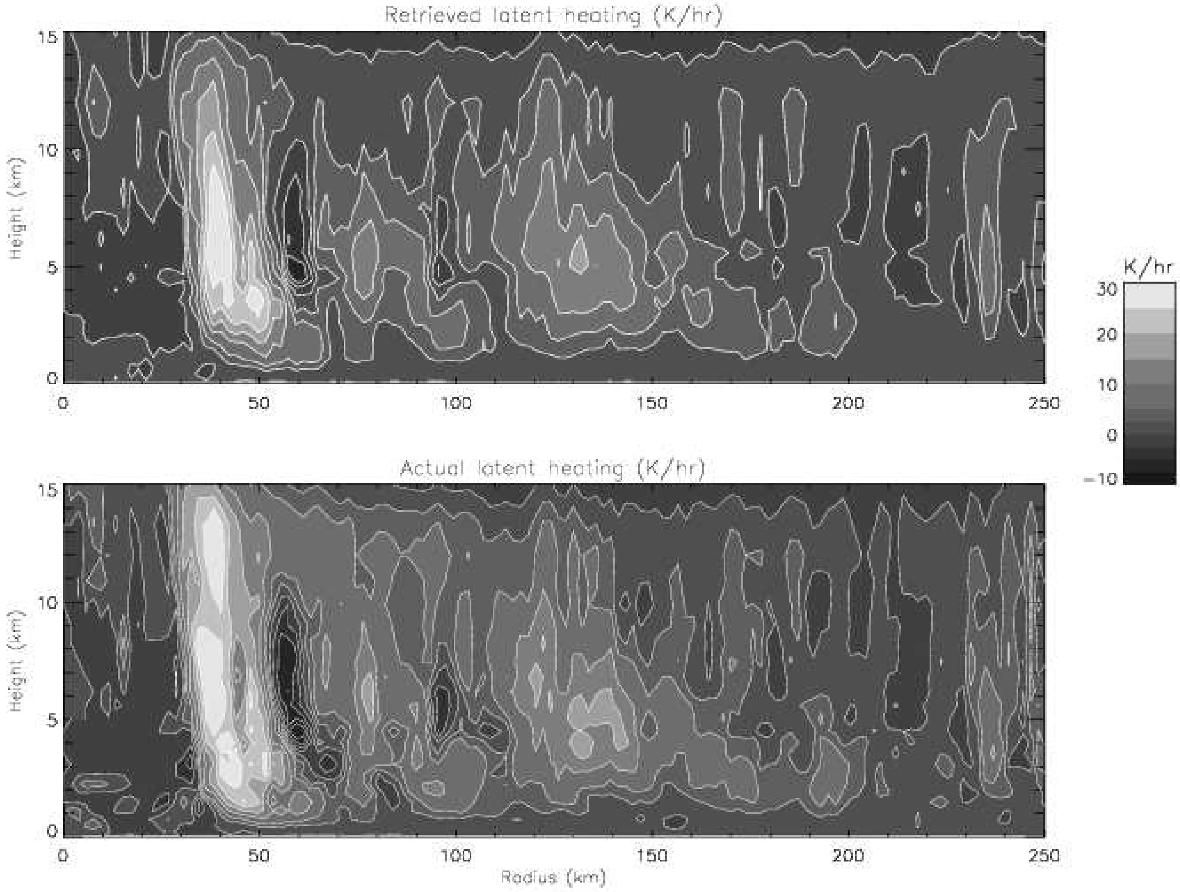

Fig. 1. Actual and retrieved azimuthally averaged latent heating as a function of range

Future studies need to be conducted to investigate whether this improvement translates to real life applications when the microphysical scheme of Chong and Hauser (1990) may not be able to accurately characterize the actual processes. Ground radar sequential observations and dual Doppler (or 4-D variational) retrievals will be used to address this issue. Also, it should be mentioned that the formulation presented in this study is computationally intensive and not appropriate for operational application. Nevertheless, if the results from the approach presented herein prove to be superior to those from the Bayesian approach in real-life situations as well, one may use these results to improve the Bayesian approach. One of the deficiencies of the Bayesian approach is that while performing satisfactorily in the cloud resolving model realm, it may produce unrealistic results in practice due to poor representation of real life cloud and precipitation distributions by the model. The iterative approach presented in this study is an attempt to reconcile the numerical modeling with actual observations and is likely to produce better relationships between observed reflectivity profiles and hydrometeor latent heating profiles.

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References

Chong, M., and D. Hauser, 1990: A Tropical Squall Line Observed during the COPT 81 Experiment in West Africa. Part III: Heat and Moisture Budgets. *Mon. Wea. Rev.*, **118**, 1696—1706.

Olson, W. S., C. D. Kummerow, Y. Hong, and W. K. Tao, 1999: Atmospheric Latent Heating Distributions in the Tropics Derived from Satellite Passive Microwave Radiometer Measurements. . *J. Appl. Meteorol.*, **38**, 633—664.

Tao, W. K., S. Lang, J. Simpson, and R. Adler, 1993: Retrieval algorithms for estimating the vertical profiles of latent heat release: Their applications for TRMM. *J. Meteor. Soc. Japan*., **71**, 685—700.

Yang, S., and E. A. Smith, 1999: Moisture budget analysis of TOGA COARE area using SSM/I retrieved latent heating and large scale Q2 estimates. *J. Atmos. Oceanic Technol*., **16**, 633—655.