9D.5 NUMERICAL SIMULATION AND OBSERVATIONS IN PASSIVE MICROWAVE RADIOMETRY OF THE TROPICAL HURRICANE BRET (AUGUST 1999)

Corinne Burlaud* (1), Nicolas Viltard (1), Olivier Nuissier (2), and Frank Roux (2).
(1) Centre d'études des Environnements Terrestre et Planétaires, Vélizy, France.
(2) Laboratoire d'Aérologie, Observatoire Midi-Pyrénées, Toulouse, France.

1. INTRODUCTION

The purpose of the present study is to retrieve simplified latent heat profiles in hurricanes from spaceborne passive microwave measurements. Although, the feasibility of the technique was demonstrated and it was implemented by Yang and Smith (1999). For instance, we wanted to take a closer look at some specific problems. Among these, we focus here in the representativeness of the microphysics in the non-hydrostatic cloud-model mesoNH (Bougeault, 2000) developed in France by the "Laboratoire d'Aérologie" and "Météo-France".

The studied case is the tropical cyclone Bret (21-22-23 august 1999) before and at landfall. Series of output simulation from Meso-NH are used as an input to simulate the microwave brightness temperqtures (T_B) with a radiative transfer model at the TMI's frequencies. A sensitivity study, based on Jacobian calculation is performed to check the sensitivity of T_Bs to the water profile.

Profiles of mean Q_1 (Apparent Heating source) and Q_2 (Apparent Moisture Sink) from the formulas of Yanai (1973) qre computed on a disc centred on the hurricane's eye covering the whole domain from 0.5 to 18 km height.

2. MODEL DESCRIPTION

The simulation used here is an output of a run that begins on the 22 August 1999 at 12Z and finishes the 23 August 1999 at 06Z. The domain is represented on a regular Cartesian grid of 180 on 180 points on the horizontal (resolution: 1.6 km) and 36 levels on the vertical (resolution: 0.5km) from 0.5 to 18 km of altitude. This provides us the 3-dimensional fields of interest for the radiative transfer: wind ($m.s^{-1}$), temperature (°C), pressure (Pa), relative humidity (%), cloud liquid water ($g.m^{-3}$), rain ($g.m^{-3}$), cloud ice water ($g.m^{-3}$), snow ($g.m^{-3}$), graupel ($g.m^{-3}$), and also 2-dimensional fields: wind at 10 meter altitude and sea surface temperature.

The radiometric measurements are selectively sensitive to the integrated water content profiles and to a certain extent to the surface parameters. Between 10 and 40 GHz, the measurements are essentially sensitive to liquid precipitation, 22.235 GHz is the absorption line of the water vapor. From 35 to 150 GHz, the sensitivity to frozen hydrometeors increases with the decreasing diameter of the ice particles

The radiometer measurements simulated here are those of the TMI onboard TRMM satellite. TMI has 4 dual-polarized channels: 10.65, 19.35, 37.0 and 85.5 GHz and one vertically-only polarized channel at 21.3GHz. The resolution increases with frequencies from 63x37 km for 10.65 GHz to 7x5 km for 85.5 GHz. The radiative transfer model used here is mentioned in Kummerrow (1988, 1992). It's a one dimensional model, ″plan-parallel″ (14 layers) based on Eddington's second approximation. The particles are assumed spherical but a different drop size distribution is used for stratiform and convective rain.

* *Corresponding author address:* Corinne Burlaud, CETP, 10-12 av. de l'Europe 78140 Velizy, France; e-mail: Corinne.burlaud@cetp.ipsl.fr.

3. VARIATIONAL ANALYSIS

The variational analysis method consists in calculating the Jacobians of the radiometric measurements for variational parameters (data assimilation):

$$J_{ij} = \frac{F_i(\mu + h_j e_j) - F_i(\mu)}{h_j}, \quad (1)$$

with e, the variation and μ, the parameter.

The microwave passive radiometric measurements sensitivity to those variational parameters is evaluated for each layer. This allows us to verify the consistency of water profile retrieval from passive microwave measurement.

4. HEAT AND MOISTURE BUDGETS

To calculate the apparent heat source (Q_1) and the apparent moisture sink (Q_2) in rings centred on the hurricane's eye, we use the formulas given by Yanai (1973) :

$$Q_1(z) = \overline{\pi}\left(\overline{\vec{V}} - \vec{C}\right)\cdot\vec{\nabla}\overline{\vartheta}, \quad Q_2(z) = -\frac{L}{c_p}\left(\overline{\vec{V}} - \vec{C}\right)\cdot\vec{\nabla}\overline{q} \quad (2)$$

with π, the Exner function.

Horizontal averages are denoted by $\overline{(\;)}$. q is the specific humidity, θ, the potential temperature, $\vec{C}$, the advection velocity. Under the isotherm 0°C, L= L_V, where L_V is the latent heat of vaporization. Above the isotherm 0°C, L= L_S, where L_S is the latent heat of sublimation. The temporal evolution is assumed to be negligible compared to the advection term in our moving reference frame for this direct calculation.

5. RESULTS AND DISCUSSION

Fig. 1 represents the Q_1 and Q_2 budgets calculated for both runs: 22nd at 18 UTC and 23rd at 06 UTC on a disc of 140 km radius (about the whole domain). For Q_2, two peaks at 2 km and at 6 km altitude are present on the 22nd and at 3 km and at 6 km for the 23rd. For Q_1, one peak at 5km is also present for both simulations. On the other hand, between 10 and 18 km, a temporal decrease is observed in Q_1 profiles.

On fig. 2, sensitivity to ice precipitation (snow and graupel) for each channel is shown. The data used are those of the 22nd at 18 UTC. The 10 GHz exhibits negligible sensitivity to ice. The sensitivity to ice increases with frequency. The 19 and 21 GHz are usually weakly sensitive to ice but the dramatic amount of ice produced by the model induces undue scattering effects. The sensitivity peak of snow (around 10-14 km) is above the graupel one (around 6-8 km) because of the density difference.

The present set up of the radiative transfer model allows 14 levels with only 4 levels between 6 and 18 km. In order to improve our results and the ice representativeness, additional layers will be added.

A simplified latent heat profile can probably be retrieved from measured T_Bs if the hydrometeors profile is properly retrieved. This study, in its present stage, shows the sensitivity of the T_Bs to the profiles of the different species of hydrometeors on the one hand and the correlation between the Q_1 and Q_2 profiles and the system evolution on the other hand.

Acknowledgements. We wish to deeply thank the Goddard DAAC and TSDIS for providing us with the TRMM data. We thanks too E. Moreau (ECMWF, Rieding), C. Klapisz (CETP).

References

Bougeault P. and P. Mascart, 2000: The Meso-NH atmospheric Simulation System Scientific documentation. Météo France, CNRS.

Chevallier F., J. F. Mahfouf, 2001: Evaluation of the Jacobians of Infrared Radiation Models for Models for Variational Data Assimilation. *J. of Applied Meteorology*, **40**, 1445-1461

Kummerrow, C. 1992: On the Accuracy of the Eddington Approximation for Radiative Transfer in the Microwave Frequencies. *J. Geophys. Res.,* **98**, 2757-2765.

Kummerrow, C and J. A. Weinman, 1988: Determining Microwave Brightness Temperatures from Precipitating Horizontally Finite and Vertically Structured Clouds. *J. Geophys. Res.,* **93-D4**, 3720-3728.

Yanai, M., Esbensen S. and J.-H. Chu, 1973: Determination of Bulk Properties of Tropical Cloud Clusters from Large-Scale Heat and Moisture Budgets. *J. Atmos. Sc.*, **30**, 611-627.

Yang S., E. A. Smith, 1999: Four-dimensional structure of monthly latent heating retrieval derived from SSM/I satellite measurements. *J. Climate*, 12, 1016-1037

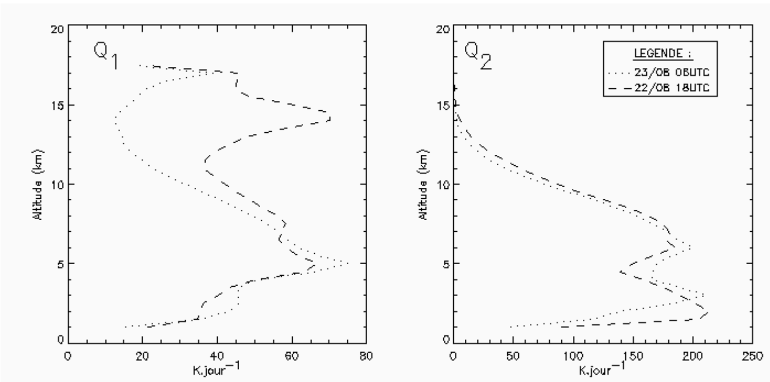

FIG. 1. Profiles of Q1 and Q2 in a disc of 140km centred at hurricane's eye.

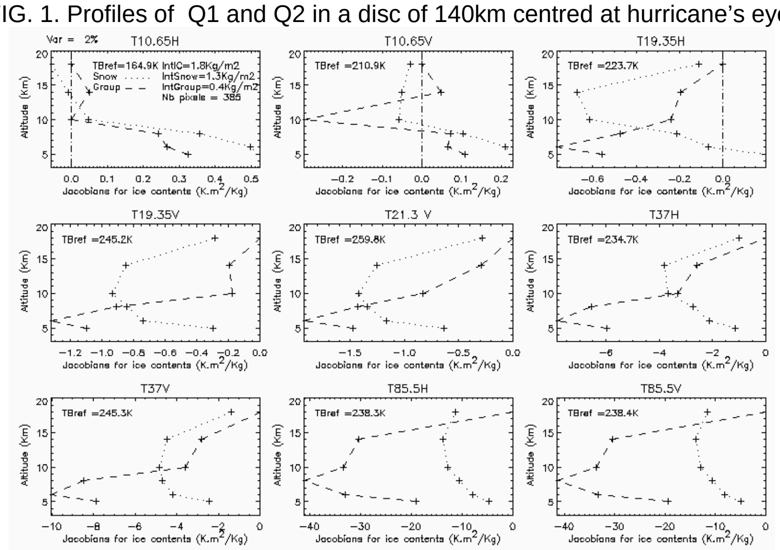

FIG. 2. Jacobians of ice precipitation for each channel for the output of 22/08 at 18UTC.