Rainfall sensitivity analyses for the HSB sounder during Dry-to-Wet/AMC/LBA field campaign

W. F. A. Lima (1) , L. A. T. Machado (1), C. A. Morales (2), N. Viltard (3) and C. Angelis (1)

(1) **Centro de Previsão de Tempo e Estudos Climáticos – CPTEC/INPE**
(2) **Instituto de Astronomia, Geofísico e Ciências Atmosféricas - Universidade de São Paulo-IAG/USP**
(3) Centre d'Etudes des Environnements Terrestre et Planétaires, France.
wagner@cptec.inpe.br | machado@cptec.inpe.br | morales@model.iag.usp | angelis@cptec.inpe.br

ABSTRACT

This work examines the sensitivity of the different channels of the HSB (Humidity Sensor for Brazil), on board the AQUA satellite, for the purpose of retrieving surface rainfall over land. The analysis is carried out in two steps: a) Theoretical study performed using two radiative transfer models, RTTOV and the so called Eddington method; and b) Correlation between coincident measurements of HSB brightness temperatures and radar rainfall estimates during the DRY-To-WET/AMC/LBA field campaign held in the Amazon region during September and October of 2002. Theoretical results indicate the sensitivity of the HSB to water vapor content and cloud liquid water in the precipitation estimation. Theoretical and experimental analyses show that the channels 150 and 183 ± 7 GHz are more adapted to estimate precipitation than 183 ± 1 and 183 ± 3 GHz. The simulations analyses show clearly a hierarchy in physical effects that determine the brightness temperature of these channels. The rain and ice scattering dominate over the absorption of liquid water and the liquid water absorption effect dominates over the absorption of water vapor. The results show that the 150 and 183 ± 7 channels are more sensitive to the variation of liquid water and ice than the 183 ± 1 and 3 channels. For the precipitation estimation using these channels, it was found that it is best adapted to the low precipitation rate situations, since the brightness temperature is rapidly saturated in the presence of high intense precipitation. A case study to estimate precipitation using the radar data has shown that it is possible to adjust a curve that relates the precipitation rate to the brightness temperature of the 150 GHz channel with a good level of accuracy for low precipitation rates.

In 2002 the Earth Observing System program launched the polar orbiting satellite AQUA, which carried the HSB sensor. This humidity sounder was developed to get information on: water vapor content, precipitation, and vertical profiles of temperature and humidity under clear and cloudy sky conditions (this inference is done in conjunction with the AMSU-A and AIRS instruments also carried by the AQUA satellite). The HSB sensor has four passive microwave channels, sensitive to vertical polarization with a spatial resolution of 13.5 km at nadir (Lambrigtsen and Calheiros, 2003), Table 1.

TABLE 1 – Technical characteristics of the HSB channels

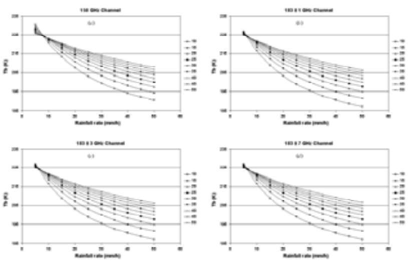
HSB Channels			
Channel s	Central Frequency (GHz)	Band Width (GHz)	Weighting Function Maximum (HPa)
1	150 ± 0.9	2 x 1	Near surface
2	183,31 ± 1	2 x 0,5	400
3	183,31 ± 3	2 x 1	600
4	183,31 ± 7	2 x 2	750

➢ Dry-to-Wet/AMC/LBA field campaign

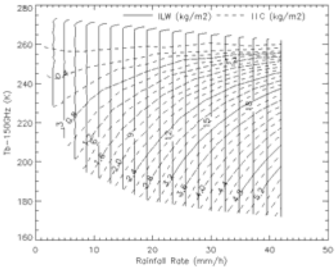
The LBA experiment (Avissar et al, 2002) came about through an international multidisciplinary research initiative led by Brazil. The purpose was to gain an understanding of the Amazon region in climatological, ecological, biochemical and hydrological terms, and its interactions with the global system. The experiment also sought to understand how the changes in land use affects these aspects and what the implications are of these changes for the biological, chemical and physical sustainability of the Amazon region. in 2002, in the period from the 15th September to 31st October, a second measuring campaign, the RaCCI/LBA, took place during the dry-to-wet transition season in the same region (Silva Dias et al, 2003).

In our analyses, we used the HSB data from the 2nd September to 30th October 2002 over the south western Amazon. The over passing times were at 06:00 and 18:00 UTC. Relative humidity and temperature profiles used in this study for sensitivity tests were obtained from tropical standard atmosphere (McClatchey et al. 1971), figure 2. Radiosondes collected 6 times per day at the Guajará-Mirim (10,8ºS ; 65,38ºW), Ouro Preto d'Oeste (10,75ºS ; 62,36ºW) sites. The rainfall estimations are validated using radar measurements performed by the Brazilian TECTELCOM radar installed in the center of the Rondônia State (10,90ºS ; 62,42ºW).

➢ Brightness Temperature Simulations



Simulation of brightness temperature as a function of rainfall rate and integrated liquid water using IWV equal 50 kg/m2. (a) channel 150 GHz; (b) 183 ± 1 GHz; (c) 183 ± 3 GHz; and (d) 183 ± 7 GHz. The curves correspond to ILW values from 10 to 50 kg/m2

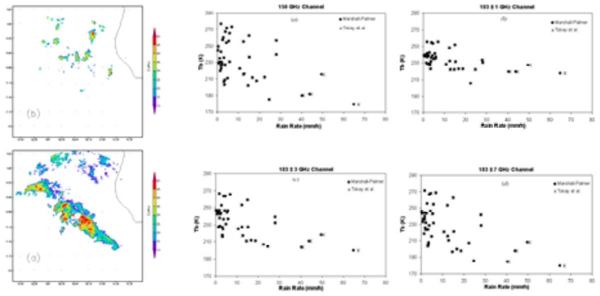


Simulation of 150 GHz brightness temperature as a function of rainfall rate for different values of integrated liquid water (*ILW*) and integrated ice content (*IIC*). Continuous lines indicate the integrated liquid water content, while the dashed lines present the integrated ice content. The *ILW* varies from 0-20 kg/m2 and *IIC* varies from 0 to 6 kg/m2.

➢ Rainfall estimation using the HSB channels.

Since we want to relate Tb with rainfall rate, we transform the radar reflectivity (Z) values measured at the 2 km height CAPPIs into rainfall rate (R) using the Z-R relationship established by Marshall and Gunn (1952) and Tokay et al. (2002), equations (1) and (2) respectively.

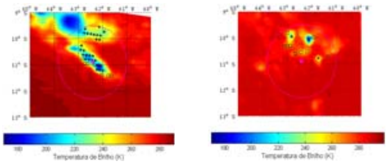
$$Z = 200\,R^{1.6} \qquad (1) \qquad\qquad Z = 240.894\,R^{1.543} \qquad (2)$$



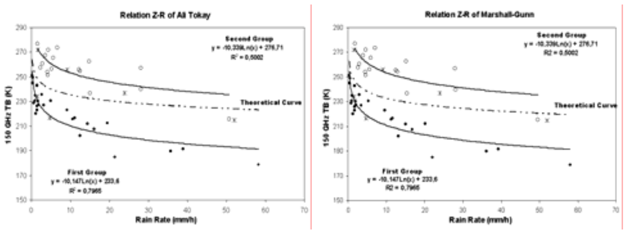
The figures above Radar reflectivity fields (dBZ) for CAPPIs of 3km height on: (a) 27 September 2002 at 05:30 GMT; and (b) 20 October 2002 at 17:50 GMT. Scatter diagram between brightness temperature and precipitation rate at 2km altitude for the channels: (a) 150 GHz; (b) 183±1 GHz; (c) 183±3 GHz; and (d) 183±7GHz from the HSB sensor. The precipitation rates were obtained from equations (1) and (2).

➢ Dispersion of the data

The dispersion observed in the previous figures can be related to the following factors: viewing angle, spatial variability of the pixels and cloud edges. Those factors are listed in the figure below.



➢ Curve of Adjustment for estimate of the Rainfall



This work analysed the application of microwave channels in the atmospheric window (150 GHz) and in the water vapour absorption band (183 GHz) present in the HSB sensor to estimate precipitation over land. Based on the results obtained theoretically and empirically, it is concluded that the HSB channels respond satisfactorily to the variability of liquid water and to the precipitation rate, mainly in the 150GHz channel. In order to eliminate possible errors in estimating precipitation careful analysis of pixel characteristics is important in terms of: the homogeneity of the rain, the viewing angle of the satellite and the cloud border effects.

REFERÊNCIA

Avissar, R., Silva Dias, P. L., Silva Dias, M. A. F. and Nobre, C., 2002: The Large-Scale Biosphere-Atmosphere Experiment in Amazonia (LBA): Insights and future research needs. **Journal of Geophysical Research**, 107 (D20): pp. 54.1-54.6.

Lambrigtsen, B. H. and Calheiros, R. V., 2003: The Humidity Sounder for Brazil – An international partnership. **IEEE Transactions on Geoscience and Remote Sensing**, 41, pp. 352-361

Marshall, J.S. and Gunn, K. L. S., 1952: Measurement of Snow Parameters by Radar. **Journal of Meteorology**, 9, pp. 322-327.

Silva Dias, M. A., Fisch, G., Fattori, A. P., Silva Dias, P. L., Machado, L. A. T., Morales, C. R, et al., 2003: Radiation, Cloud, and Climate Interactions in SW Amazon during the DRY-TO-WET Transition Season/LBA. **Geophysical Research Abstracts**, 5, pp. 13683-13683.

Tokay, A., Krueger, A., Krajewski, W. F., and Pereira Filho, A. J., 2002: Measurements of drop size distribution in southwestern Amazon Basin. **Journal of Geophysical Research**, 107(D20), pp. LBA 19-1 to LBA 19-15, 2002.