ICE WATER PATH STUDY USING PASSIVE MICROWAVE SENSORS DURING THE CLOUD LIFE CYCLE

Ramon Campos Braga[1] and Daniel Alejandro Vila[1,2]

1 e 2- Divisão de Satélites e Sistemas Ambientais - DSA/CPTEC/INPE
2- Cooperative Institute for Climate and Satellites – CICS/ESSIC/UMD

ABSTRACT

This research focuses on the possible relationship between ice water path (*IWP*) retrievals using satellites and the life cycle stage of convective clouds and its possible application on satellite-based rain rate retrievals. In the first part of this work, it is analyzed the relationship between *IWP* and cloud area expansion rate using 235K isotherm. The *IWP* is retrieved using the Microwave Surface and Precipitation Products System (MSPPS), which use high frequency channels (89 and 150 GHZ) from AMSU-B and MHS sensors (NOAA 16-19), while the cloud expansion rate analysis was calculated using FORTRACC algorithm, which makes possible identify and track the evolution of mesoscale convective systems from thermal infrared images (10.7µm) on board geostationary satellites. In a second step, it was analyzed the relation between clouds convective fraction and rain rates (using radar data) and the cloud life cycle. Two regions with different precipitation patterns were selected for this study: São José dos Campos region (23.2ºS, 45.95ºW) and the Fortaleza region (5.06ºS, 39.26ºW) at the Brazilian southeastern and northeastern regions respectively. In the first region, it was found that, during the selected period, 84% of precipitant clouds has ice in their structure, while in Fortaleza region only a half of precipitant clouds has ice. The results of this research shows that, while convective systems are intensifying (area is expanding and temperature is decaying), larger *IWP* values tends to be observed. Larger rain rates and convective fraction is also measured for radar retrievals when convection is in the early stage compared with mature systems.

1. INTRODUCTION

Ice clouds play a significant role in the atmospheric radiation budget and has strong influence on weather and climate forecasts (Rossow and Schiffer, 1991 and 1999). For clouds with ice in their structure, different methods have been adopted for estimate ice water path (*IWP*). In thin ice clouds, like cirrus, the *IWP* retrieval is made with accuracy using IR information, while for thick ice clouds the microwave information has better accuracy (Vivekanandan, 1991; Weng and Grody, 2000; Sun and Weng, 2012).

Cloud convection studies in the tropical region show the use of thermal infrared channel (10.8 um) in the structure and radiative characteristics of these clouds, while other studies offer a climatology of cloud life cycle in convective systems over Americas (Machado et al.,1993 and 1998) . Wang et al. (1997) found that the use of water vapor absorption channels (183GHz) on passive microwave sensors could give cloud convection information.

In this way the main objective of this research was study the relation between *IWP*, cloud evolution, on its life cycle, and the possible application of this information in rain rate estimation using microwave sensors on board polar and equatorial satellites.

2. REGIONS OF STUDY

Two regions were selected for this study: São José dos Campos (23.2°S, 45.95ºW) and Fortaleza (5.06°S, 39.26ºW, see location at Figure 2.1). The first region is affected mainly by orographic precipitation and by the South Atlantic Convergence Zone, while in the second region precipitation is caused by oceanic systems, generally warm clouds, and by the Intertropical Convergence Zone. The period used was the rain season of 2012 for both regions.

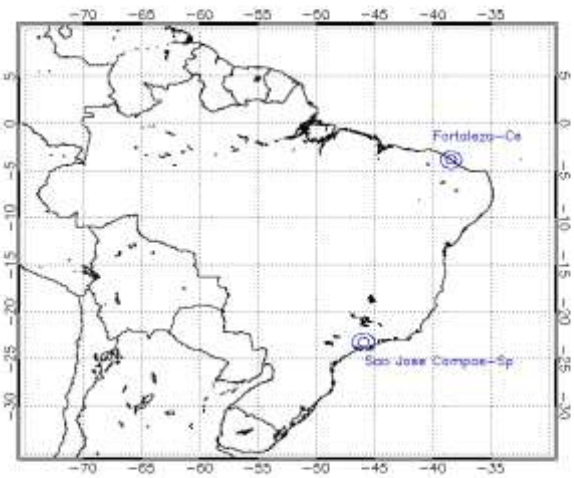

Figure 2.1 Areas covered by radars in São José dos Campos and Fortaleza.

3. DATABASE

Satellite data

In this research it was used the Microwave Surface and Precipitation Products System (MSPPS) (Ferraro et al. 2005) for *IWP* retrievals, which uses information from high frequency channels (89GHz and 150GHz) of AMSU-B and MHS (NOAA 16-19), using only pixels with viewing angle lower than 30º (+/-). The information of life cycle it was used from operational FORTRACC algorithm (Vila et al. 2008), which uses information from GOES-12 (channel 4) for identify and track convective clouds with brightness temperature lower than 235K.

Radar data

The radar information was from X-band radar dual polarization used in CHUVA-GLM project at Vale do Paraiba experiment, while for Fortaleza region it was used a S-band radar (only horizontal polarization) from FUNCEME organization. The radar information were used for retrieval the Constant Altitude Plan Position (CAPPI) at 2 and 3 Km. The relation that convert reflectivity in rain rate were:

$$Z = \begin{cases} Z < 35 \;\; e \;\; Kdp \leq 0.3 & Z = 200 \, RRx^{1.6} \\ Z \geq 35 \;\; e \;\; Kdp > 0.3 & RRx = 19.63 \, | K_{dp} |^{0.823} \end{cases}$$, Bringi et al. (2007),

for São José dos Campos and:

$$\boxed{Z = 301,76 \, RRx^{1.52}}$$

, Albrecht et al. (2012),

for Fortaleza.

4. METHODOLOGY

The data analysis was developed in 2 steps. In the first step, NOAA 16-19 passages were selected for São José dos Campos (SJC) and Fortaleza (FOR) radar areas in the proposed period, considering maximum time interval of 2 minutes between the radar and satellite information. The maximum time for threshold for FORTRACC information is 7 minutes.

After this screening process, a cloud classification technique (convective or stratiform) is applied using radar reflectivity data (Steiner et al., 1995). Based on this classification the convective fraction was analyzed inside AMSU-B/MHS pixel. The life cycle was obtained from FORTRACC output. Three life cycle stages was considered: 1) Intensifying: when system's area is growing and the minimum brightness temperature (TB_{min}) is decreasing, 2) Dissipating: when system's area variation is zero or negative or TB_{min} is rising, e 3) Not Identified: when FORTRACC do not identify the system and *IWP* is greater than zero (according with MSPPS).

In a second step, it was calculated statistical parameters of *IWP* and effective diameter of ice particles (De), from MSPPS, in function of convective fraction and cloud life cycle. The Figures 4.1 a-d shows the variables analyzed for an event at 08-01-2012 for a convective system over SJC (indicated by a red arrow in Figure 4.1-c) which was in intensifying stage according to FORTRACC.

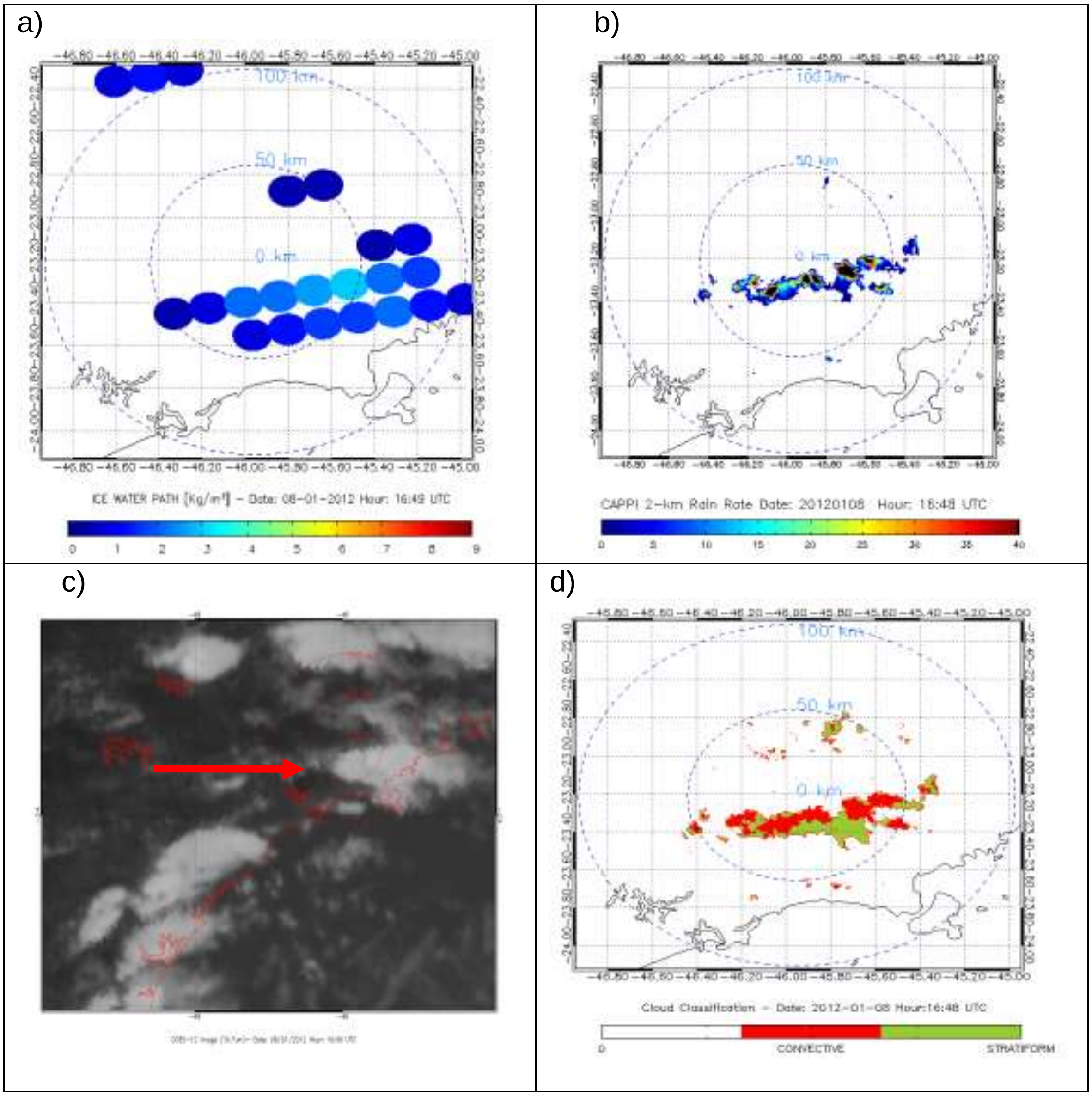

Figure 4.1 a) Ice Water Path in Kg/m², b) X-band radar rain rate, c) GOES-12 image (10,7 µm) for the precipitant event at 08-01-2012 and d) convective and stratiform cloud classification. The red arrow indicate the event on figure c).

5. RESULTS AND DISCUSSIONS

The Figure 5.1 shows a frequency histogram for pixels identified, or not, by FORTRACC over SJC region. For identified pixels, in 23% the clouds where in intensification stage, while in 21% the clouds where in dissipating stage. For those cases where FORTRACC could not identify any MCS (according to the threshold used int this study), 40% had ice (according with MSPPS), and in 16% where from warm precipitant clouds. Therefore, 84% of precipitant clouds at SJC area are cold while 16% has only liquid water in it's structure. For clouds with ice in their structure, 54% was identified by FORTRACC. The others 46% were not identified due to retrieval's characteristics from operational FORTRACC version. In this case, the tracking occurs in clouds with cloud top brightness temperature under 235K and minimum area of 90 GOES-12 pixels (1440 Km^2).

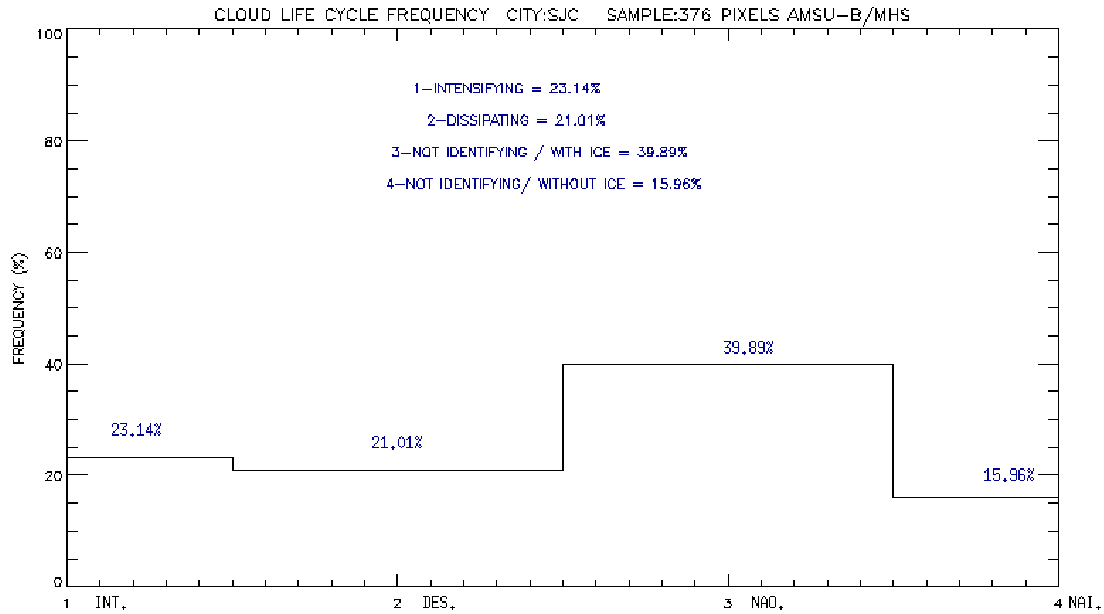

Figure 5.1- Frequency histogram for AMSU-B/MHS pixels from NOAA 16-19 passages over São José dos Campos. 1-4 indicates the observed class by FORTRACC: 1- Intensifying, 2- Dissipating, 3- Not Identifying by FORTRACC and cloud with ice and 4- Warm precipitant clouds.

The Figure 5.2-a show 'Box & Whisker' plot of a *IWP* in function of life cycle over SJC area. The central box is the interquartil extent (Q3-Q1), and the central line is the sample's median. The maximum and minimum values and outliers are presented too. When clouds are in intensification (INT) process, the *IWP* scatter diagram is displaced towards larger values than in dissipating (DES) process. A less scatter graph with lower medium value is observed in ice clouds not identified by FORTRACC (NAO).The same behavior is verified for rain rates estimated by radar data (Figure 5.2-b), which present the medium rain rate in at least 60% of radar pixels overlapping with a NOAA pixel. For warm clouds (NAI) the rain rate is lower than the stages mentioned previously. The *De* doesn't have large variation in function of cloud life cycle (Figure 5.2-c). However, for systems in DES and NAO process the *De* distribution tends to have, in average, higher values, even for lower *IWP*. This result suggests that for DES stage the ice particles are mixed with water and air, which cause the density decreasing and the ice size rise, even when *IWP* is low. Clouds in INT stage has a larger *De* scatter, this due to ice formation process being in initial stage. The cloud convective fraction observed by radar in NOAA pixels, also with minimum overlapping of 60% is presented at Figure 5.2-d. It shows that convective fraction is similar to *IWP* distribution, with larger convective fraction in clouds at INT than DES and smaller when clouds have little or no ice content.

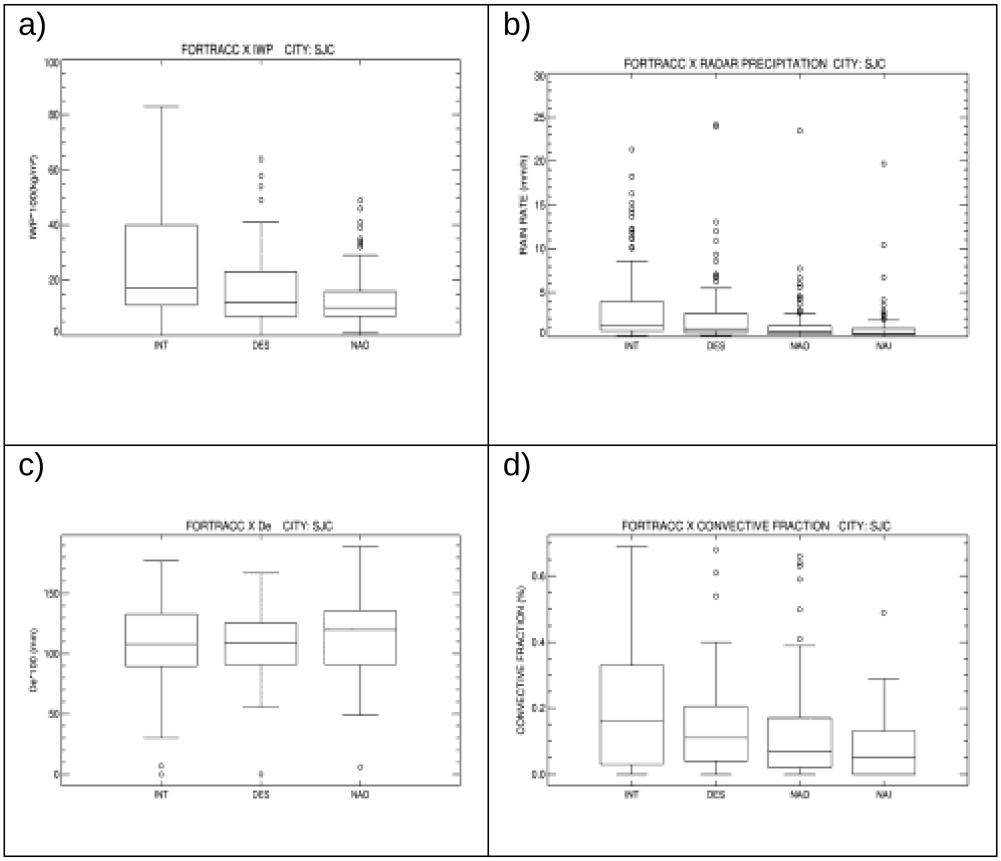

Figure 5.2- Scatter diagram for *IWP* (a), RRx (b), De (c) and convective fraction (%Convective; d) in function of cloud life cycle.

For Fortaleza region (FOR) the sample was smaller than in SJC, with only 277 pixels. In this case, only 21% of pixels (55) were possible to identify the life cycle information using operational FORTRACC. The small amount of identified pixels doesn't make possible robust *IWP*, De and rain rate analysis during the cloud life cycle. However it's possible observe ice in precipitant pixels (not identified by FORTRACC) in 31% of sample; while 48% of precipitant pixels doesn't has ice in clouds according with MSPPS (Figure 5.3).

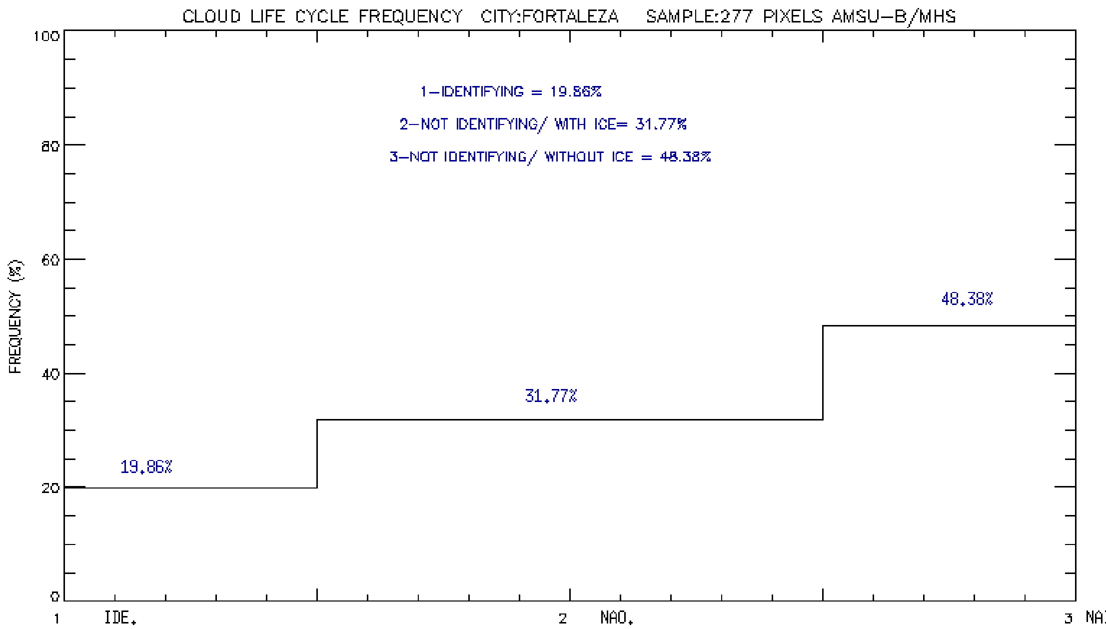

Figure 5.3- Frequency histogram of AMSU-B/MHS pixels from NOAA 16-19 passages over Fortaleza region. 1-3 indicates the observed class by FORTRACC: 1- Identifying by FORTRACC, 2- Not Identifying by FORTRACC and cloud with ice and 3- Warm precipitant clouds.

6. CONCLUSIONS

The present study had the objective of observe the *IWP* in function of cloud life cycle over São José dos Campos (SJC) and Fortaleza (FOR) regions during the rainy season. The results showed that different precipitation patterns. In SJC the rain pattern is caused by ice clouds, while in FOR only a half of clouds has ice in their structure, according with MSPPS. When clouds are in intensification process is observed larger *IWP*, rain rate and convective fraction than in dissipation stage. Future works will be developed for improve the rain rate estimated by MSPPS using the life cycle information. Furthermore, comparative studies with other precipitation estimates using satellite data will be done.

REFERENCES

ALBRECHT, R; COSTA, I. ; MORALES, C.; SAKURAGI, J; MACHADO, L.; TOKAY, A.. Raindrop size distribution and rainfall characteristics from CHUVA Field experiments. **International Precipitation Working Group-IPWG**, São José dos Campos, 2012

BRINGI, V.N.; THURAI, M.; HANNESEN R.(eds.). Hydrometeor classification at S, C and X-bands. In: ______. **Dual-polarization weather radar handbook**. 2. ed.. , 2007. 163 p. Gematronik Handbook first published in August 2005.

FERRARO,R.; WENG, F.; GRODY, N.; ZHAO, L.; HUAN, M; LONGOLI, C; PELLEGRINO, P.;

QIU, S; DEAN, C.. “NOAA OPERATIONAL HYDROLOGICAL PRODUCTS DERIVED FROM THE ADVANCED MICROWAVE SOUNDING UNIT (AMSU)”, **IEEE Transactions Geoscience Remote Sensing**, v.43, p.1036-1049. 2005.

MACHADO, L. A. T., ROSSOW, W. B.. Structural characteristics and radiative properties of tropical cloud clusters. **Monthly Weather Review**, v. 121, n. 12, p. 3234-3260, 1993.

MACHADO, L. A. T., ROSSOW, W. B.; GUEDES, R. L.; WALKER, A. W.. Life cycle variations of mesoscale convective systems over the Americas. **Monthly Weather Review**, v. 126, p. 1630-1654, 1998.

ROSSOW, W. B.; SCHIFFER R. A.. ISCCP cloud data products **Bulletin of the American Meteorological Society**, v.72, p.2–20. 1991.

ROSSOW, W. B.; SCHIFFER R. A.. Advances in understanding clouds from ISCCP. **Bulletin of the American Meteorological Society**, v.80, p.2261–2288. 1999.

STEINER M.; HOUZE R. A. JR.; YUTER S. R.: Climatological characterization of three-dimensional storm structure from operational radar and rain gauge data. **Journal of Applied Meteorology**., v.34, p.1978–2007. 1995.

SUN N.; WENG F.. Retrieval of Ice Water Path from Special Sensor Microwave Imager/Sounder (SSMIS). **Journal Applied Meteorology Climatology**, v.51, p.366-379. 2012.

VILA D.A.; MACHADO L. A. T.; LAURENT H.; VELASCO I.. Forecast and Tracking the Evolution of Cloud Clusters (ForTraCC) Using Satellite Infrared Imagery: Methodology and Validation. **Weather Forecasting**, v.23, p.233-245. 2008.

VIVEKANANDAN J.; TURK J.; BRINGI V. N.. Ice Water Path Estimation and Characterization Using Passive Microwave Radiometry. **Journal of Applied Meteorology**, v.30, p.1407-1421. 1991.

WANG J.R.; ZHAN J.; PACETTE P.. “Storm-associated microwave radiometric signatures in the frequency range of 90-220 GHz”, **Journal of Atmospheric and Oceanic Technology**, v.14, p.13-31. 1997.

WENG F.; GRODY N. C.. Retrieval of ice cloud parameters using microwave imaging radiometer. **Journal of the Atmospheric Sciences**, v.57, p.1069-1081. 2000.