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# Case Study of Squall Lines Passing Over Dakar Using NOAA Sounders

**Adoum Mahamat MOUSSA[1], Bouya DIOP[2], Malick WADE[3], Abdoulaye SY[4], Abdoulaye Bouya DIOP[5], Aïchetou DIA DIOP[6], Djiby SARR[7], Abdou Karim FAROTA[8]**

[1]Laboratoire des Sciences de l'Atmosphère et des Océans/UFRSAT/Université Gaston Berger de Saint Louis.

**Abstract:** ***Squall Lines (SL) are fast and well organized mesoscale convective systems. These phenomena of primary importance have been the subject of numerous studies, mainly descriptive and dynamic. Applications made of satellite data for the study of Squall lines are mostly descriptive. The advantage of ATOVS data is that they provide a vertical view of the atmosphere by considering wavelengths. Thus we made a study of the atmosphere subjected to the passage of squall line with these data. In this study, five passages of squall lines allowed us to show the radiative signature of SLs with ATOVS data.***

**Keywords:** Squall Line, ATOVS, satellite, radiative signature, convective system

## 1. Introduction

### 1.1 Description of squall lines (SL)

Squall Lines are storm-storm disturbances improperly called tornadoes occurring in boreal summer in the Sahelian regions. They are fast and well organized convective mesoscale systems (Mathon et al., 2002). Squall Lines consist of a south-to-north alignment of cumulonimbus and move from east to west. Its width in the North-South direction is generally between 300 and 800 km, but can reach 1500 km (Adamou, 1992). They are progressively weakening as they reach the West African coast (Aspliden, 1976). It is the large-scale conditions that govern its organization (Ochei MC* and Oluleye A, 2017 ) even if favorable local conditions for the development of convection are required (Diop B., 1996). Laurent et al. (1998) estimated that Squall Lines contribute 95% of annual rainfall and account for 80% of convective cloudiness in the Sahel. In this climatic zone the human population derives most of its means of substance from agro-pastoral activities.

### 1.2 Satellite aspect of the squall lines

A SL has a sharp border at the front, preceded by a "clear sky" area (fig 1), i.e. without a cloud, while the back, which often corresponds to the eastern edge of the cluster cloudy, is difficult to define.

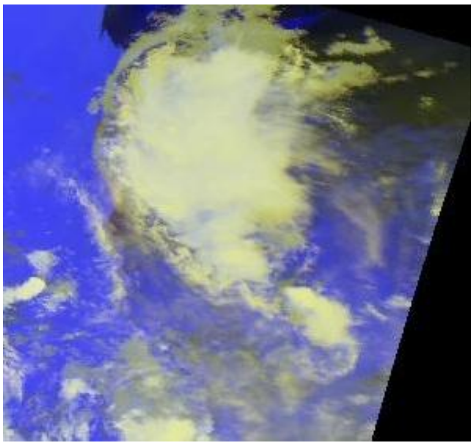

**Figure 1:** AVHRR image of the SL of July 17, 2013

This phenomenon of primary importance has been the subject of numerous studies, mainly descriptive and dynamic (Zipser 1969, House 1977, G. Tetzlaff and M. Peters 1988 ). Garba Adamou in 1992 and B. Diop in 1996 at LPAO-SF studied Squall Lines. Their trajectories, their travel speeds and their life span have been well determined in the Sahelian zone [Dhonneur, 1987; Desbois et al., 1988; D'Amato and Lebel, 1998; Gaye, A.,et al, 2005]. The works of Chong and Hauser, 1989; Houze 1993, 1997; Diop et al. , 1996, 2012 estimated the contributions of the convective part and the stratiform part (65% and 35% respectively).

Applications made of satellite data for the study of grain lines are mostly descriptive. The advantage of ATOVS data is that they make it possible to have a vertical radiative structure of the atmosphere by considering the channels of the AMSU sensors (Adoum et al, 2016). Thus, it is interesting to make a study of the atmosphere subjected to the passage of grain line with these data. We take 05 cases from the year 2013 including 02 cases before the passage, 01 cases during the passage and 02 cases after the passage of grain lines over the region of Dakar.

## 2. Case Study of Grain Lines with ATOVS Sounders

### 2.1 Methodology

The analysis of the daily climate observation data made it possible to note all the Squall Lines having passed over Dakar for the year 2013. The SLs recorded are 11, but as the ATOVS data used correspond to the punctual hours of 12: 00 and 00: 00, the selected cases are based on these hours. Depending on the proximity of the time of passage of the grain lines and the ATOVS data collected, five (05) cases were selected. A case of passage of the SL at the reference time, two (02) cases of data taken before the passage and two (02) cases after the passage of SL. The following table 1 details the dates and times of the data taken as well as those of passage of the SL

**Table 1:** Characterization of the cases used in the study

| Days and hours of passage of SL | Days and times for obtaining the ATOVS data considered | Offset between passage time SL and satellite |
|---|---|---|
| September 27th at 22:00 | September 28th at 00:00 | 02 hours after |
| September 19th at 06 : 00 am | 19 September 19th à 12 : 00 | 06 hours after |
| 07September 07th at noon | 07 Augus at noon (12 : 00) | Passage |
| September 17th at 2 : 00 pm | 17 Septembe at 12 : 00 | 02 hours before |
| 30 Augus à 4: 00 pm | 30 August at 12 : 00 | 04 hours before |

The study consisted in making an analysis of anomalies of the gloss temperature values compared to the summer average. Considering the microwave and infrared data and for each of the five (05) cases, this study makes it possible to note the variational magnitude of the temperature values of brigthness of each channel.

### 2.2 Summer Average

The summer average consisting of the months of July, August and September is carried out with microwave (AMSU-A and MHS) and infrared (HIRS) data at 12:00 UT and 00:00 UT. Figure 2 shows that considering the microwave data, the vertical atmospheric signature is almost the same at noon and midnight. On the figure 2 and figure 3 Moy 12hr is the average at 12 hours, and Moy 00kr is the average at noon

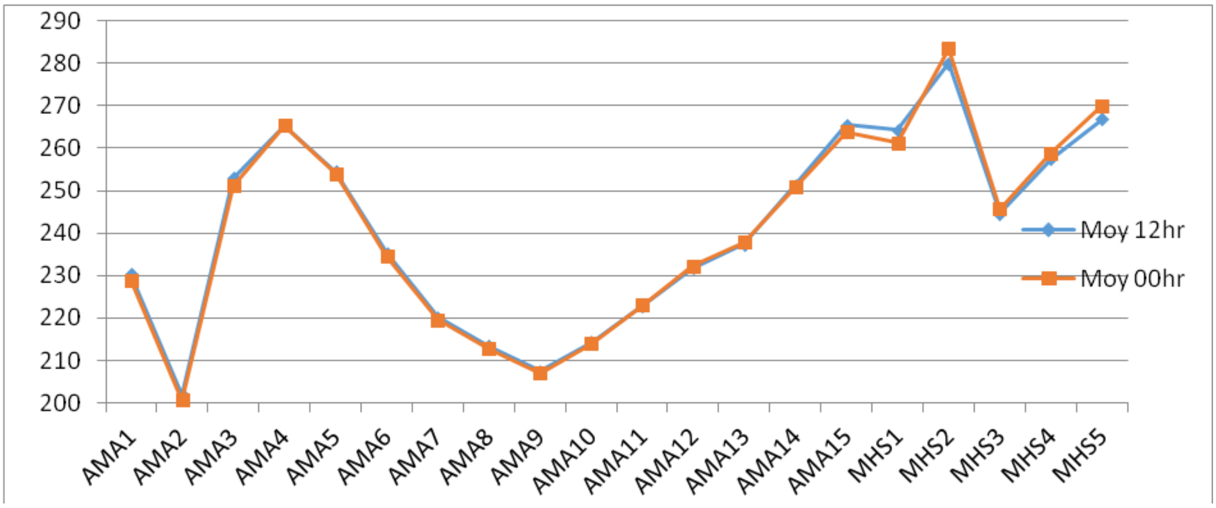


**Figure 2:** Summer average of the microwave data at 12:00 and at 00:00. On the ordinate, we have the brightness temperatures in K, in abscissa the AMUS-A and MHS channels (AMAi = AMSUAi, i = 1 at 15; MHSi, i = 1 to 5)

Similarly for infrared data, night and daytime averages are nearly identical for all channels. Except for surface channels 18 and 19, the average gloss temperature values at noon are higher than midnight.

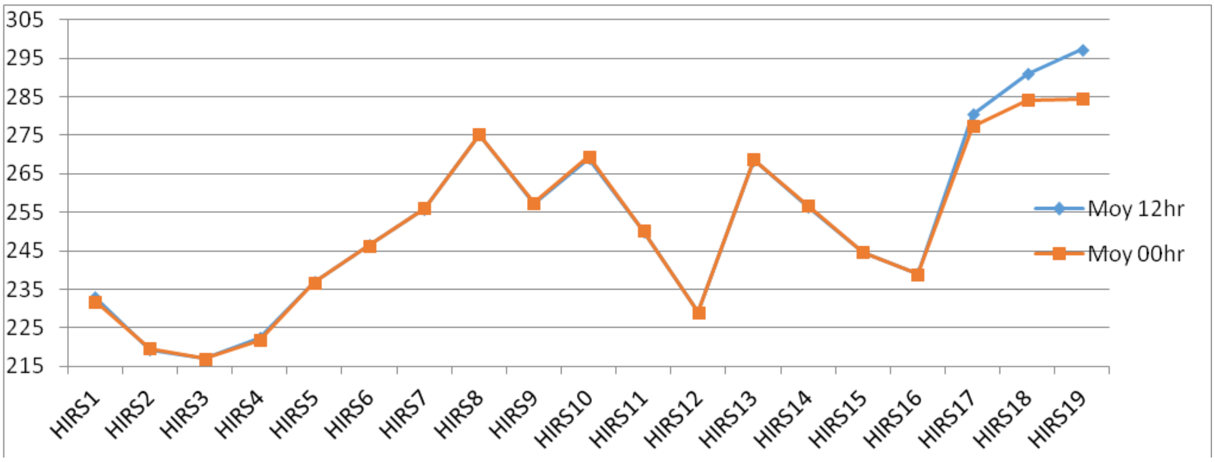


**Figure 3**: Summer average of infrared data at 12: 00 and 00: 00. On the ordinate we have the brightness temperatures in K, on the abscissa the HIRS channels (HIRSi, i = 1 to 19)

### 2.3 Microwave data

As indicated in the table, the majority of the AMSU-A channels are sensitive to oxygen () therefore used especially for the sounding of temperature. The frequencies of the AMSU-A channels 1, 2, 3 and 4 as well as all the MHS channels are sensitive to the water vapor molecules (), thus used for the sounding of the specific humidity. The MHS sensor is an evolution of the sounder AMSU-B with three identical channels out of the five (05). The AMSU-B water vapor channels have unique advantages, such as high sensitivity to ice particles (Burns et al., 1997, Wang et al., 1997, Bennartz and Bauer, 2003), and impact. negligible soil surface and low-lying liquid water clouds in the middle troposphere. Figure 4 shows the variations of the channels for the five cases compared to the summer average. On the figure 4 an the figure 5, 2hr ap is the courbe two hours after the passage of SL, 6hr is the courbe, six hours after the passage of SL. On the same figure 4, 2hr av and 4hr av are the two hours et four hours before the passage of the SL.

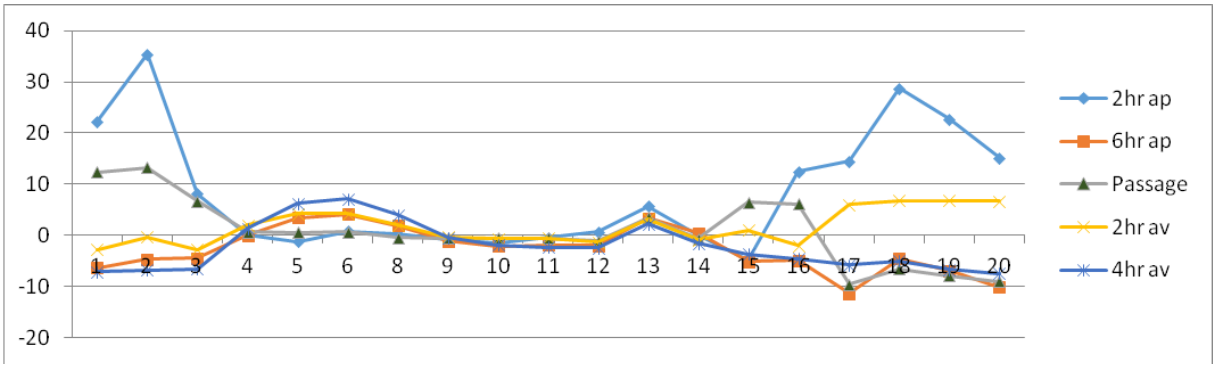


**Figure 4:** Difference between the microwave brightness temperatures of the cases considered compared to the summer average. On the abscissa, the microwave channels on the ordinate show the brightness temperature shifts

In order to discriminate the channels of greater variations according to the atmospheric situation, we will perform a channel analysis sensitive to oxygen molecules and channels sensitive to water vapor.

### 2.4 Before the passage

***Channels sensitive to water vapor***

Four hours before the SL passage, the brightness temperature data of the different channels are much lower than the summer average except for channel 4. Two hours before the passage of the SL, the brightness temperatures are substantially equal to that of the summer average, except for the altitude channels 17, 18, 19 and 20. For these channels, there is a significant increase in the brightness temperature compared to the summer average.

***Oxygen-sensitive channels***

The brightness temperature data of the oxygen-sensitive channels are generally close to the summer average four hours before the passage of the SL. An increase of about 7 ° K is observed at channels 5, 6 and 8 covering the 750-150 hPa layer. Similarly, two hours before the passage, these channels have a slight increase compared to the average. The brightness temperatures are generally close to those of the summer average for the remaining channels.

### 2.5 During the passage

At the passage of the SL, the brightness temperature values for the surface channels (1, 2, 3, 15, and 16) show that there is a marked increase compared to the summer average. The channels 4, 17, 18, 19 and 20 covering the 950-500 hPa layer have a drop in brightness temperature compared to the summer average. The remaining channels sensitive to O2 molecules do not show much variation from the summer mean.

### 2.6 After the passage

***Channels sensitive to water vapor***

Two hours after the passage of the SL, apart from channel 15, the channels sensitive to water vapor show a sharp increase in the brightness temperature compared to those of the summer average, with a peak of + 35.4K for channel 2. Six hours after the SL has passed, the brightness temperature data are lower than the average, except for channel 4.

***Oxygen-sensitive channels***

Two hours and six hours after passing the SL, the channels used for the sounding of the temperature have lower gloss temperature data than the summer average. In addition, the channels 5, 6, 8 and 13 exhibit gloss temperature data slightly above the summer average.

### 2.7 Infrared data

Squall Lines are deep convective systems and the infrared signal fades strongly through the clouds. Thus the infrared signals of the HIRS sounder channels can hardly reach the atmospheric layers near the surface. However these data used in coordination with the microwave data may be a supplement improving the results of the study of the atmosphere at the passage of the grain lines. Figure 5 shows the fluctuations of the brightness temperature values of the HIRS channels (1 to 19) for the different cases.



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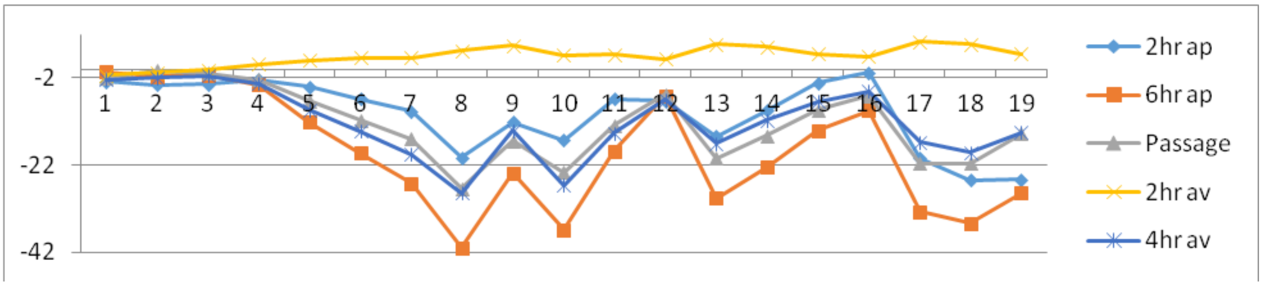


**Figure 5:** Differences in infrared brightness temperatures of the cases considered compared to the summer average. (The values 1 to 19 are the HIRS channels). On the ordinate the differences in K; the cases of SL are: 2 hours before the passage of SL, 4 hours before the passage of SL, the passage of SL, 2 hours after the passage of SL, 6 hours after the passage of SL

Overall, all the observations show temperatures of glosses lower than the average of summer except for the case 02 hours before the passage of SL. The channels with a greater variation in gloss temperature values are: 7, 8, 9, 10, 11, 13, 14, 17, 18 and 19. Channels 1, 2, 3 and 4 which are sensitive to C covering the 400-10 hPa layer of the atmosphere do not show enough fluctuations compared to the summer average for the different cases considered.

### 2.8 Discussions

This study allowed us to detect that the data of the microwave channels 1, 2, 3 and 15 of the AMSU-A sensor, as well as those of all the MHS channels have a large variation of values for an atmosphere subjected to the passage of grain line.

Yann Delhenger and Bouya Diop (2003) studied a grain line in Dakar on October 27, 2001, using data from the AMSU-B sounder. They found that at the time of passage of the grain line the temperature of channel 1 AMSU-B (16 in Figure 4.4) has a maximum, while all other channels have a minimum. Figure 4.4 confirms these results, thus for the channels 17, 18, 19 and 20 the case of the passage of the grain line has the lowest brightness temperature value compared to other cases. Similarly, the channel 16 has a high value during the passage of the grain line.

Using data from the AMSU-B sonar and the Goddard Cumulus global model, Gang Hong et al. (2005) studied a simulated tropical ocean grain line as input to a radiative transfer model. They agree with us that all canals are influenced by deep convective clouds and their thick cirrus flowing outward. Likewise, all channels are generally sensitive to variations in the glacial content of hydrometeors at levels greater than 7 km.

AMSU-B channels at 89, 150 and 183.3 ± 7 GHz are highly sensitive to variations in liquid water content at levels greater than 5 km. The sensitivity suggests that it should be possible to estimate the properties of frozen hydrometeors at levels greater than 7 km for deep tropical convection systems using the channels around 183 GHz (channels 18, 19 and 20).
Two hours before the passage of the grain line, the brightness temperature data of all the channels have similar values, which may have potential for making short-term forecasts of the passage of the grain lines.

## Conclusion

The average summer of the months of July, August and September 2013 is carried out with microwave (AMSU-A and MHS) and infrared (HIRS) data at 12:00 UT and 00:00 UT separately. The comparison of microwave averages at noon and midnight showed that the vertical atmospheric signature is almost the same for all channels. There is still a slight difference in gloss temperature for the channels MHS1 and MHS5. Similarly for infrared data, night and daytime averages are nearly identical for all channels. Except for surface channels 18 and 19 whose mean values of gloss temperature at noon are higher than those of midnight. From the study of grain lines with microwave data we have obtained radiative signatures.

The comparison of the microwave brightness temperature data of the 05 cases considered (2 cases of data of the situations before the passage of grain lines, 01 cases of ATOVS data taken during the passage of a line of seeds and 02 cases of data after the passage of the grain lines, it was possible to evaluate the difference of the brightness temperature of each channel with respect to the summer average.

The microwave channel data 1,2,3 and 15 of the AMSU-A sensor, as well as those of all the MHS channels have a large variation in brightness temperature values for an atmosphere subjected to grain line passage. These channels can provide indicators for the study or forecast of these stormy phenomena. Study of grain lines with infrared data.

With the infrared data, all the observations show gloss temperatures lower than the summer average except for the case 02 hours before the passage of the SL. The channels with a greater variation in brightness temperature values are as follows: 7, 8, 9, 10, 11, 13, 14, 17, 18 and 19. The channels 1, 2, 3 and 4, which are furthermore sensitive to the $CO_2$ molecules covering the 400 -10 hPa layer do not show enough fluctuations by

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