A Close Look at a Severe Mesoscale Convective System Surrounding the Air France 447 Crash

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Background

- On 1 June 2009, the Air France (AF) flight number 447 crashed in the tropical Atlantic Ocean between 02:00 and 02:15 UTC.
- An analysis of the severe Mesoscale Convective System (MCS) surrounding the AF 447 flight could provide some insights.
- No study, to our knowledge, has looked at the degree of severity of the cloud top features associated with this specific MCS.
- Although we do not engage in any discussion concerning the causes of the AF 447 crash, we will present results that highlight the severeness of the MCS when the accident occurred.

Flight path

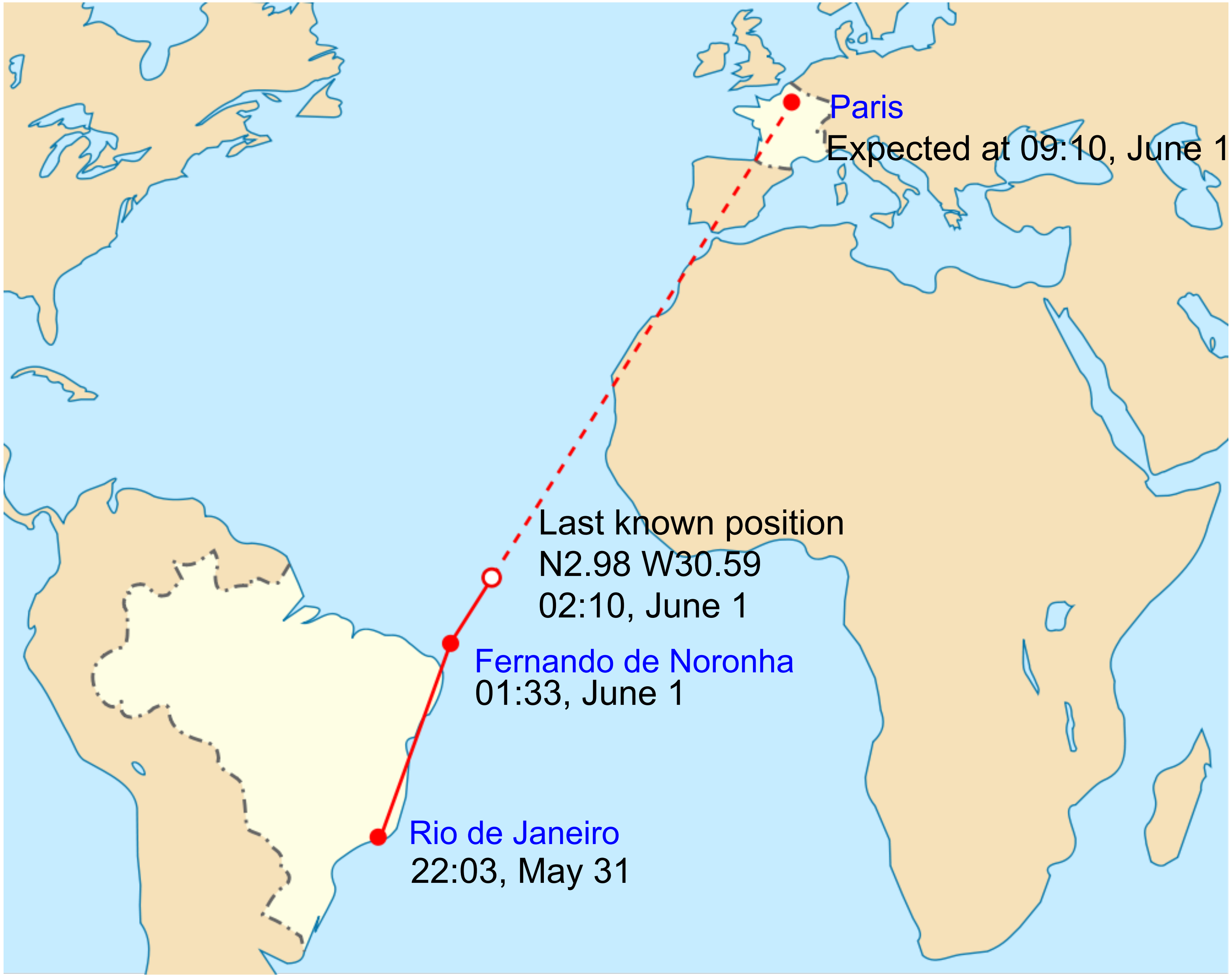


Fig. source: Wikipedia (2011) "Air France Flight 447"

Method

- Multispectral data of Spinning Enhanced Visible and Infrared Imager (SEVIRI) onboard Meteosat-9 based on detection of overshooting tops
- Two SEVIRI water vapor (WV) band images (6.2 μm and 7.3 μm) and the SEVIRI thermal infrared (IR) band images (10.8 μm) provided information about the structure and the microphysics of the MCS cloudiness
- While the Meteosat-9 (Meteosat Second Generation, MSG) measurements do not directly provide information on vertical motions, we focus on the combination of water vapor and infrared window channels to depict overshooting tops at these MCS's as proxies for convective intensity.
- We define the convective overshooting tops as a region in which an air parcel absorbed the upwelling cold radiation from the cloud top. This is to be associated with the deepest convective clouds reaching the stratospheric temperature, as a proxy for convective intensity
- WV–IR differences larger than +3.0 ^{o}C are associated with deep convective clouds (overshooting clouds) that have a large amount of ice and strong updrafts

Overshooting tops

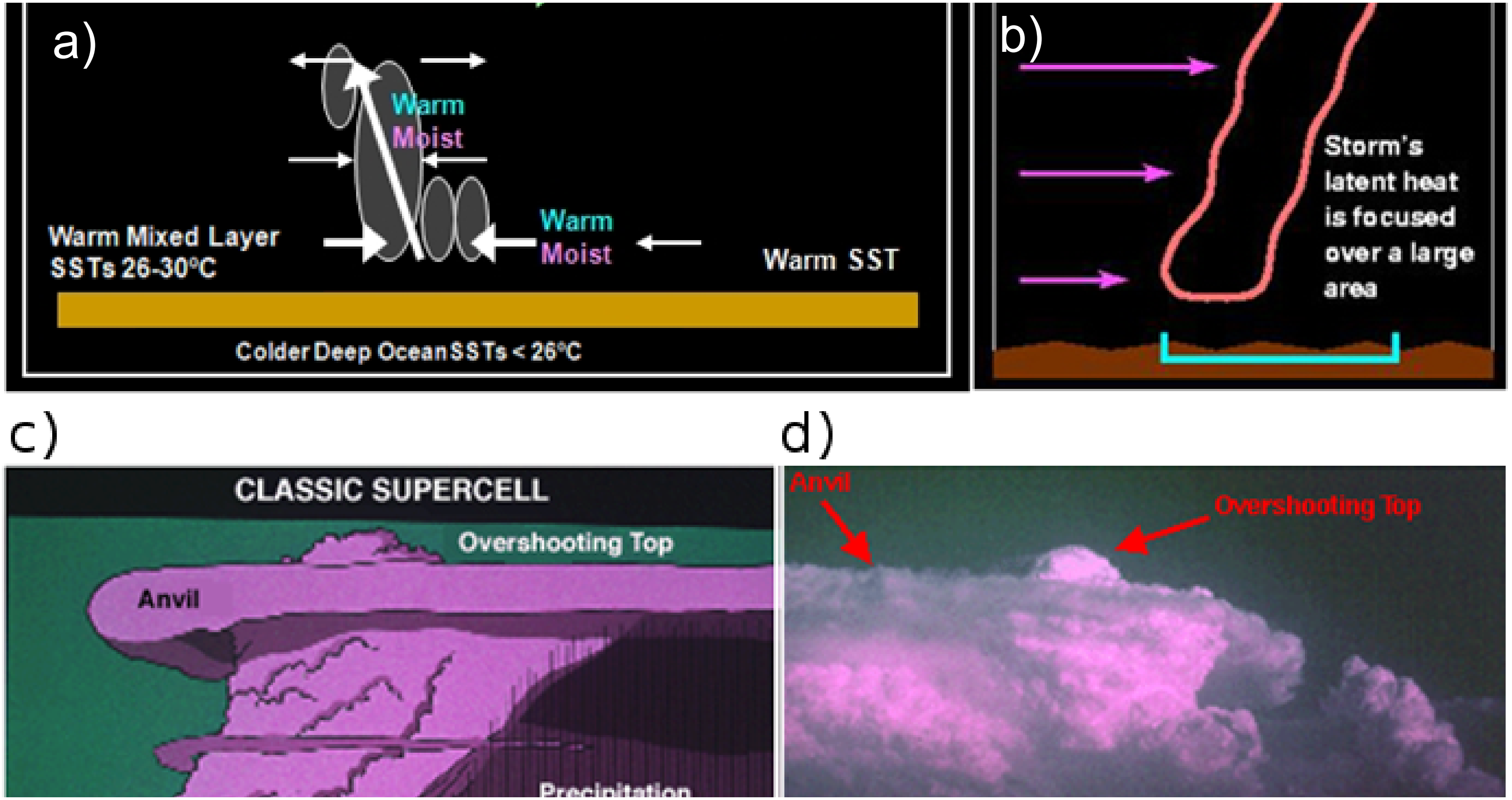
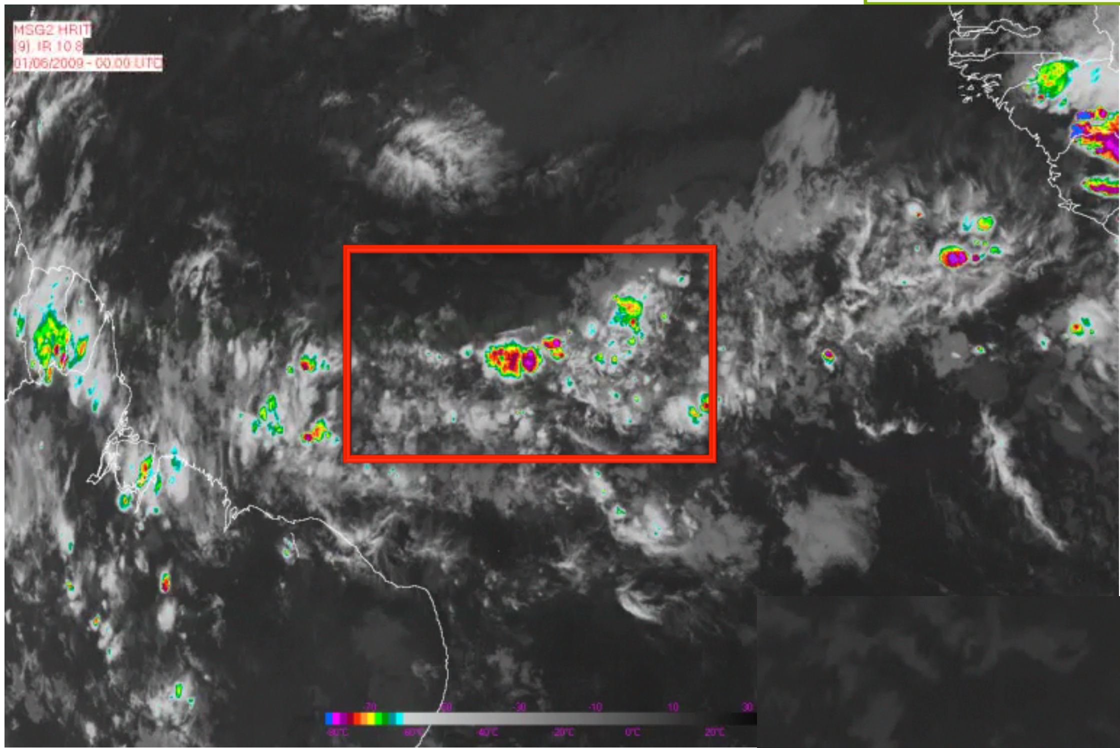


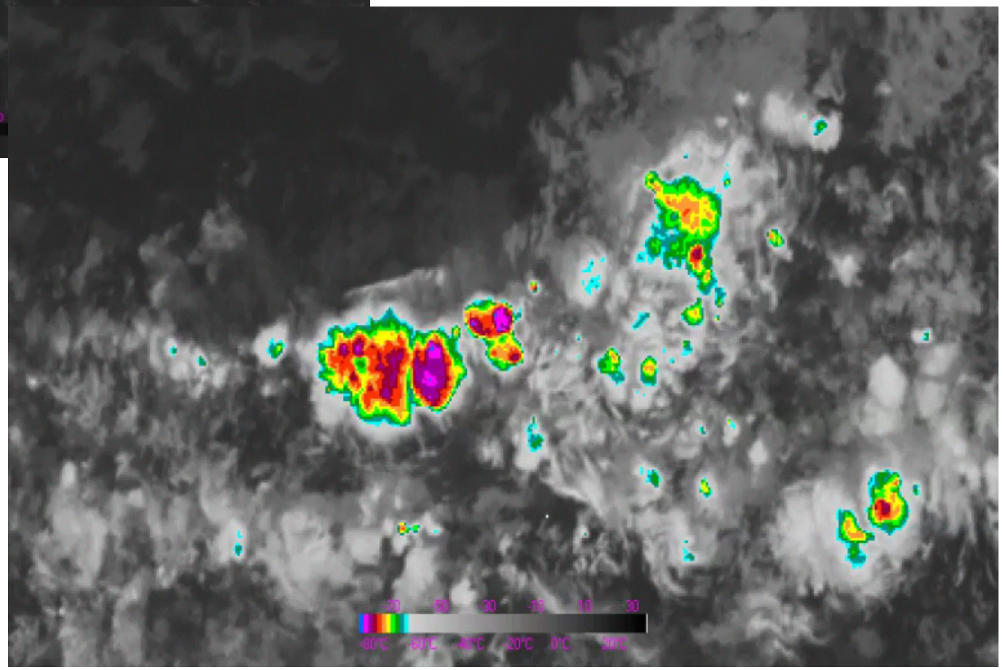
Figure 1 - Wet phase is characterized by an "envelope" of deep convection composed of numerous higher frequency "events" (e.g., equatorial waves) that propagate both east and west through the envelope (a). An increase in vertical wind shear can tilt the Cb, spreading the warm core column over a larger area. (b). Severe thunderstorms usually extend all the way to the tropopause (c) and can be seen in the photo as storms producing overshooting tops (d).

Results

- Analysis of the difference between the water vapor and the infrared brightness temperature reveals unique details on the severity of the MCS formed in a line west-east across the flight path
- Several overshooting tops cooling below -80 ^{o}C were found in our analysis. These were associated with a severe MCS cloud cluster on the route of the flight.
- A striking feature is that this cloud cluster resulted from the merging of four smaller clusters with cloud top temperature that reached -81^{o}C – this cloud structure could potentially be responsible for the extremeness of the MCS.

Animation





Zoom in

Figure 2

28 °C SST and lapse rate of about 4 °C/km (between 150 and 100 hPa),

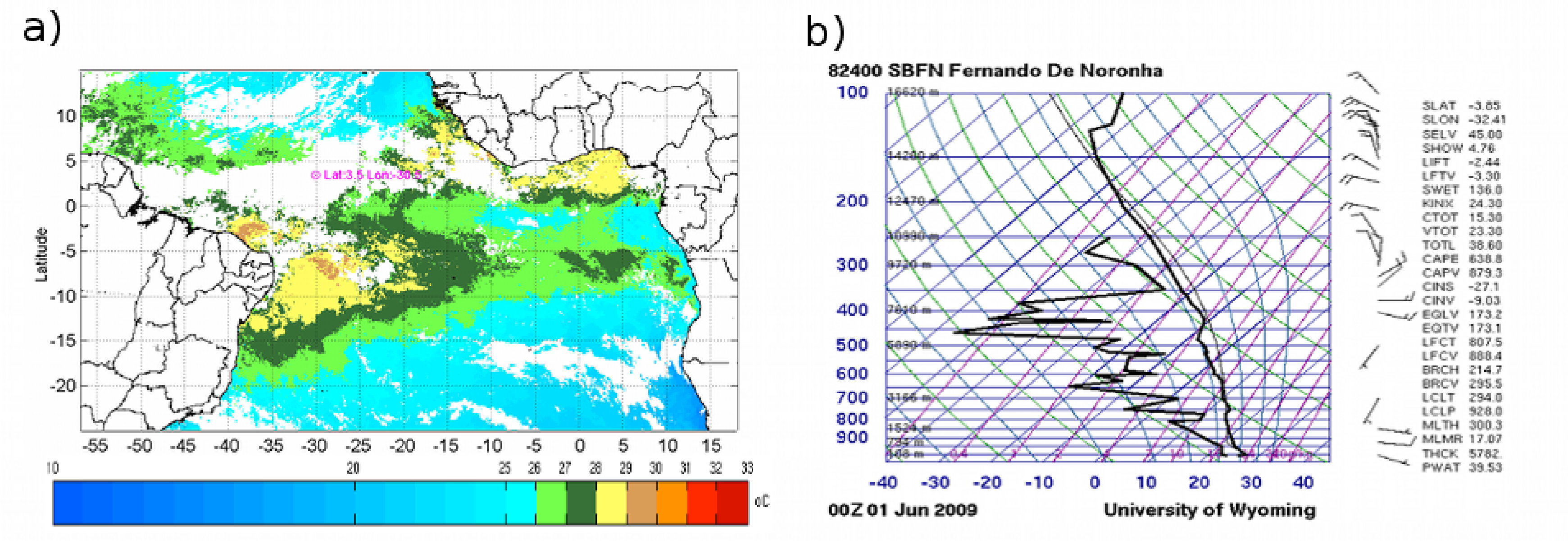
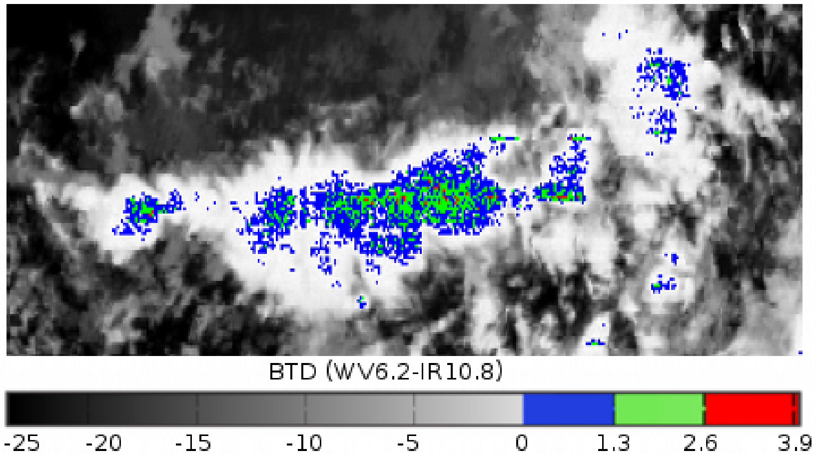


Figure 2 - Sea Surface Temperature (SST) image displayed on 01 June 2009 at 00:00 UTC and the position (3.5º S; 30.5º W) where the AF 447 made its last transmission (a). 82400 SBFN Fernando de Noronha sounding valid at 0000 UTC on 01 June 2009 (b)

Figure 2 – cont.

c)

d)



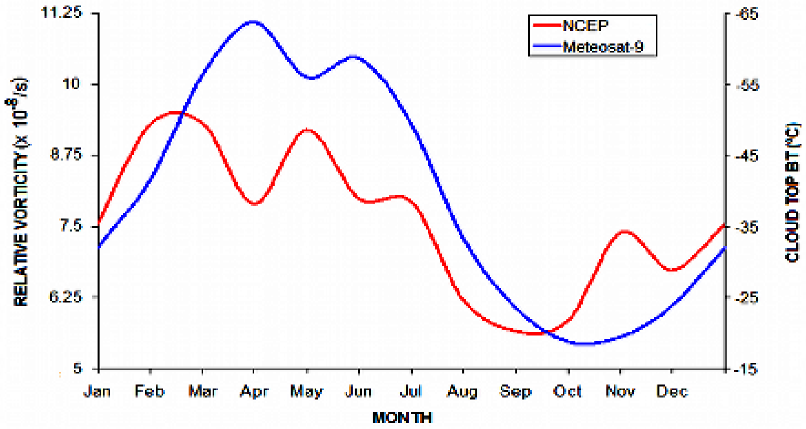


Figure 2 (cont.) - The geographical distributions of cloud top pixels with BTD (WV6.2 – IR10.8) > 0 from the water vapor minus infrared differential image (c). Spatially averaged, the 3y-mean seasonal cycle calculated over 2006-2009 for both the 700 hPa relative vorticity (red curve) in the (30°W –15°E, 5°N –5°S) region and the cloud top (IR 10.8 µm) brightness temperatures (blue curve) in the (2º N –4º N, 25º W –35º W) region (d).

Figure 3

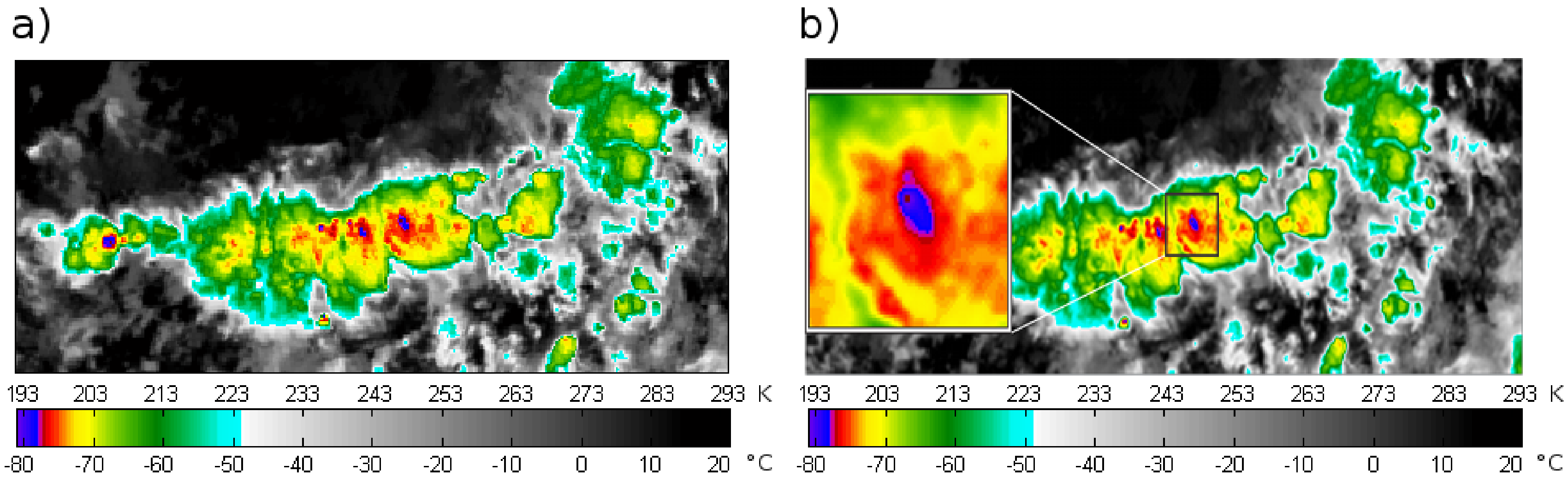


Figure 3 - Cloud-top features seen in the enhanced SEVIRI IR10.8 band image over 1º N to 5º N latitude and 25º W to 37º W longitude on 01 June 2009 02:00 UTC (a). Zoomed in view of the IR10.8 band image for deep convective burts with cloud tops colder than -81 ºC (blue color) (b).

Figure 3 – cont.

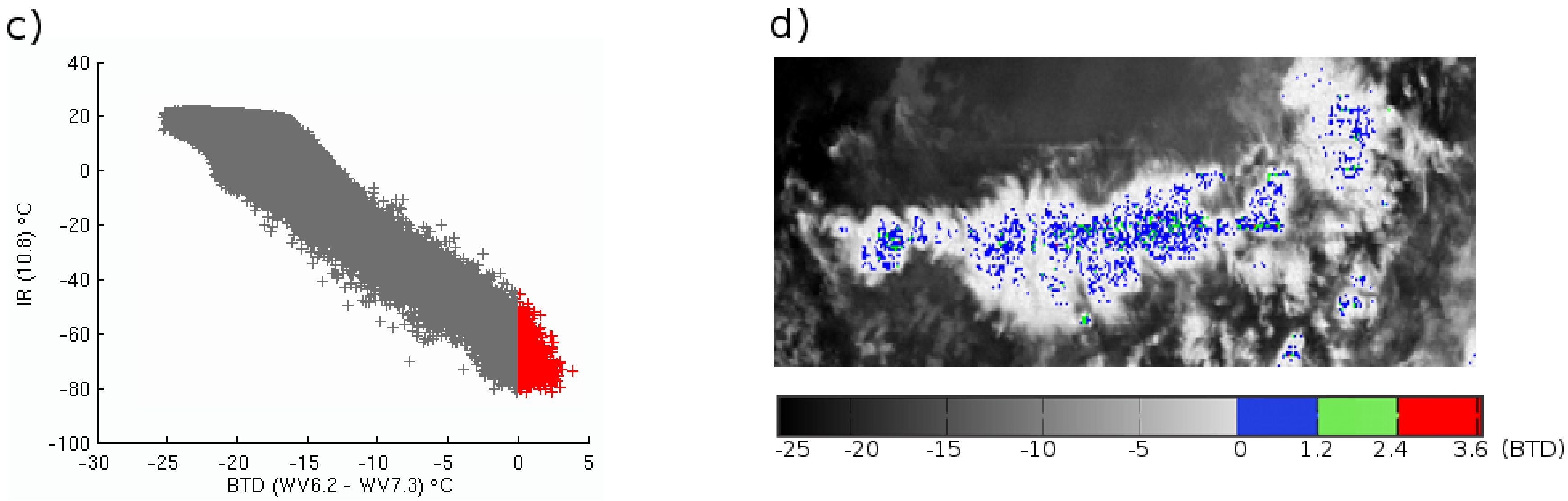


Figure 3 (cont.) - The scatterplots of the BT (IR10.8 pixels) against BTD (WV6.2-WV7.3 pixels) extracted for all pixels over the 1º N to 5º N latitude and 25º W to 37º W longitude (c). The geographical distributions of cloud top pixels with BTD (WV6.2 – WV7.3) > 0 from the water vapor differential image (d).

Conclusion

- The spatial changes of the positive differences between the WV and IR images of Meteosat-9 suggest how extreme the different cold cloud tops are in the TMCS tracked on 1 June 2009. Maximum differences reach values higher than + 3ºC in the coldest top, where tempereatures were about -81 °C. These tops are therefore identified as convective overshooting tops.
- The synoptic conditions at the closest point to Fernando de Noronha (Brazil), 28 °C SST in combination with a lapse rate of about 4 °C/km (between 150 and 100 hPa), could contribute as a moisture source to the extremeness of this TMCS.
- There is evidence that spatial changes in 700 hPa relative vorticity (not shown) at mean daily scale based on the period 2006–2009, in large part associated with the spatial changes of very cold IR brightness temperatures, can significantly impact deep moist convection through African-easterly-wave activity in the region where the accident occurred.
- The results suggest that AEW activity did exert an influence on convective overshooting tops in the TMCS tracked on 1 June 2009.

Thank you!

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