Case study of thunder and heavy rains over Mauritius in January 2013

Weather deteriorated rapidly over Mauritius in the night of Saturday the 12th January 2013. Around 21h00LT lightning was observed to the East of the island, over the sea. Violent thunderstorms and heavy showers subsequently spread over the island. The lightning was spectacular as it was occurring quite frequently. Rain subsided as from 09h00LT on the next day and improvement was as drastic as rain onset. The present report attempts to explain this thundery episode.

<u>Summary of observed and model fields explaining the thundery weather</u>

On ECMWF upper air charts of 12th January 2013 (Run 0000Z), a low was forecast to develop to the Northeast of Mauritius on the 500hPa level. In higher levels up to 200hPa the model was showing a deep trough oriented in the NW –SE direction and off the Northeastern coast of our island. The mid-tropospheric low seemed to have been cut off from a similar deep trough that was also present at 500hPa earlier. This low was seen to be embedded in a cold pool. The 1200 UTC run of the same day expected the low with its cold mid-tropspheric air to cross Mauritius from Saturday night to Sunday morning .The cooling by about 4 degrees at 500hPa brought about a change in the lapse rate and contributed towards static instability of the atmosphere .Models also expected the CAPE to reach a peak of 800 Joules/Kg at the time of crossing. Further model output of 1800UTC on the 12th, was showing convergence at 700hpa and divergence at 200hPa and vertical velocity was to be highly negative between 600 to150 hPa. Model was predicting high humidity from surface to quite high in the troposphere and even expecting saturation from 500 to 200hpa at 12 Jan @1800.

The moisture could be attributed to clouds advection which could be seen from the satellite picture at that time. The models were accurate and all these ingredients came together to produce the violent thunderstorms.

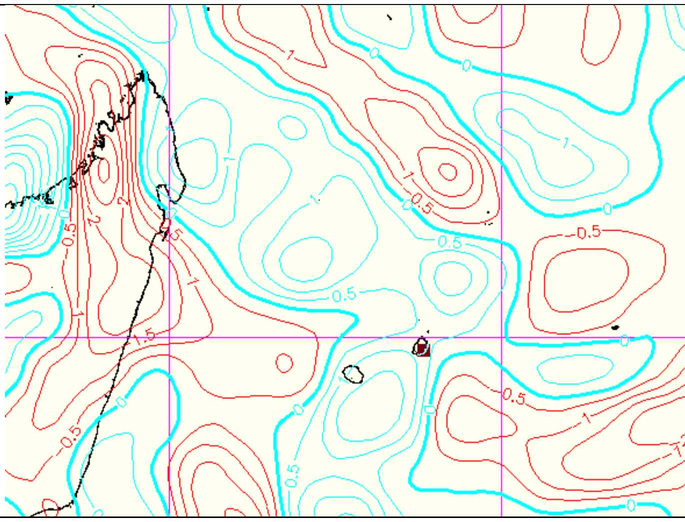
Summary of what triggered the instability

On the water vapour imagery (0.6µm) a dark roughly circular patch appeared over Mauritius. This is the location of depressed tropopause where dry stratospheric air was intruding into the tropopause directly overhead of Mauritius. This brought about advection of cyclonic vorticity aloft which was transmitted to mid-level but did not reach the ground. The cyclonic signature extends only up to 600hPa . This forcing cause drop in temperature and geopotential over the region. The instability manifested as thunder, lightning and heavy rains.

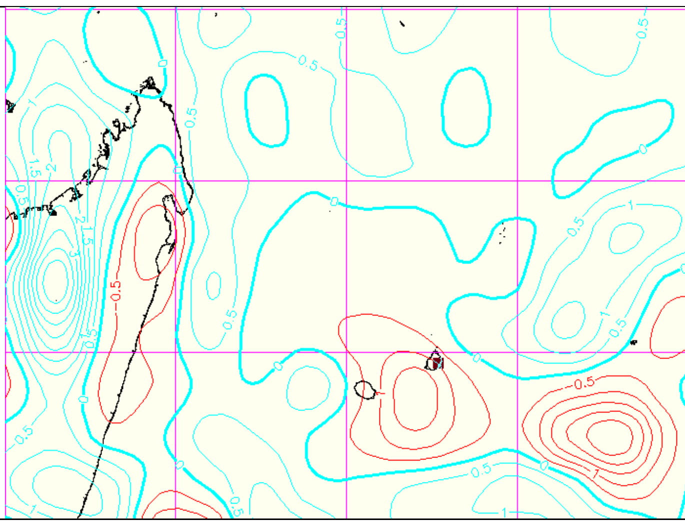
What follows is the detailed analysis of what has been explain above

Divergence field on 12 January@1800UTC

200 hPa



700 hPa



925 hPa

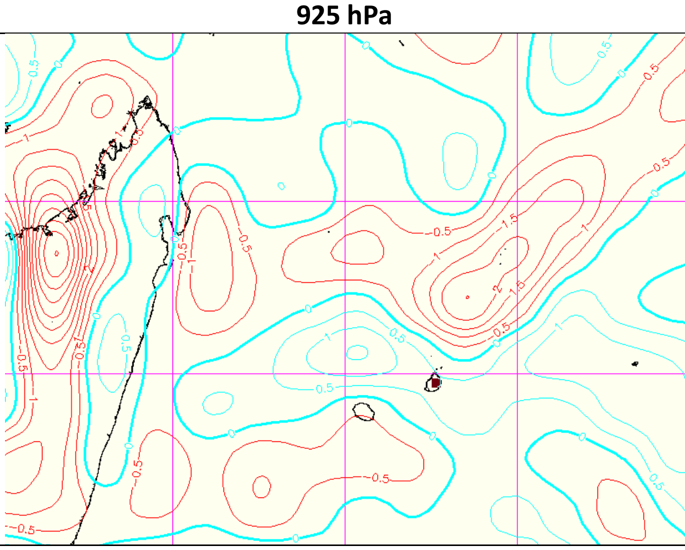
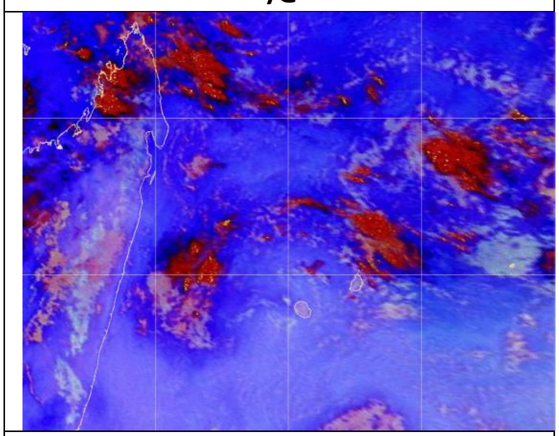


Figure 1

At 1800UTC there was divergence at 200hPa and 925hPa and convergence at 700 hPa.The strong convergence at 700 hPa corresponds in shape and location to the cloudiness appearing in the satellite pictures below (figure 2). Rising motion was favoured and became more pronounced as the cloud mass completely covered the island by 13 @ 0000UTC. Apart from being a region of strong low level convergence the cloud mass also brought moisture.

Satellite pictures

12 January@1800UTC



13 January@0000UTC

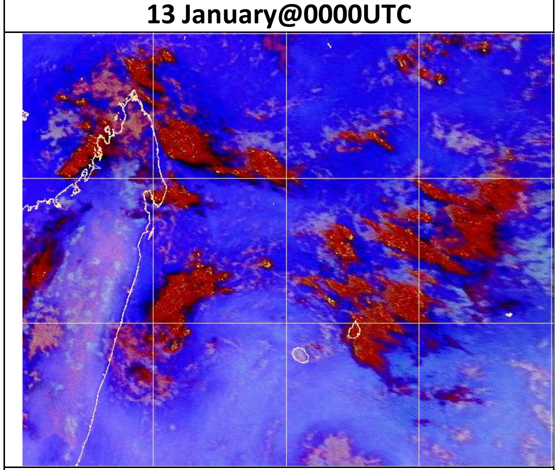


Figure 2

Streamline at the various standard levels on 12 January at 1800UTC

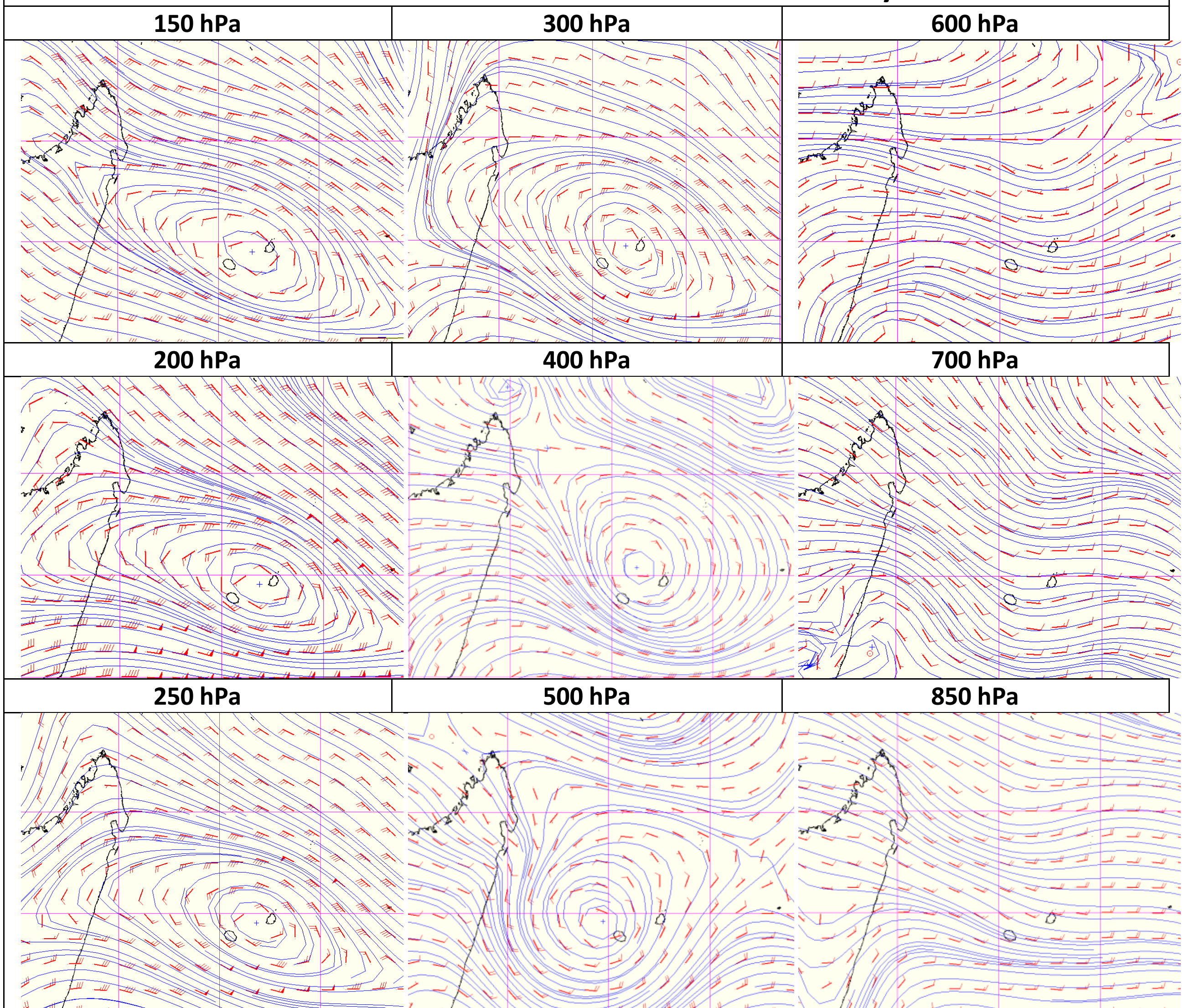


Figure 3

Referring to the table above (Figure 3), cyclonic circulation was present between 500 and 150 hPa levels. The centers of these circulations on the isobaric surfaces were vertically stacked on top of each other except between 500hPa and 400hPa where a Northeastward tilt was observed. This suggests that a deep vortex was present in the upper air over the region. The streamlines showed wind converging towards their respective circulation centers on the isobaric surfaces mentioned. This lateral mass convergence caused forced ascent of moist air from lower level within the vortex.

Figure 4 that follows confirmed that this indeed happened and the ascent was rapid and vigorous too. It ended in heavy showers and thunderstorms

Vertical velocity field

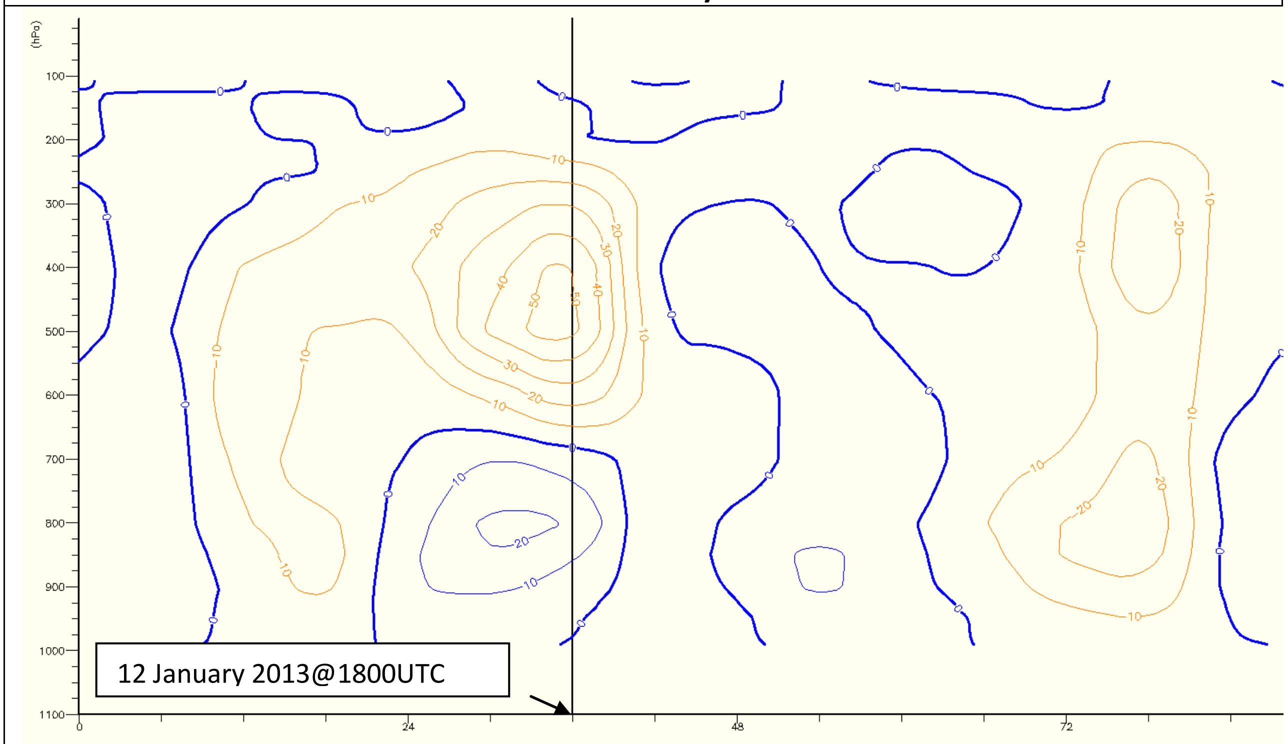


Figure 4

Metgram of 500 hPa temperature

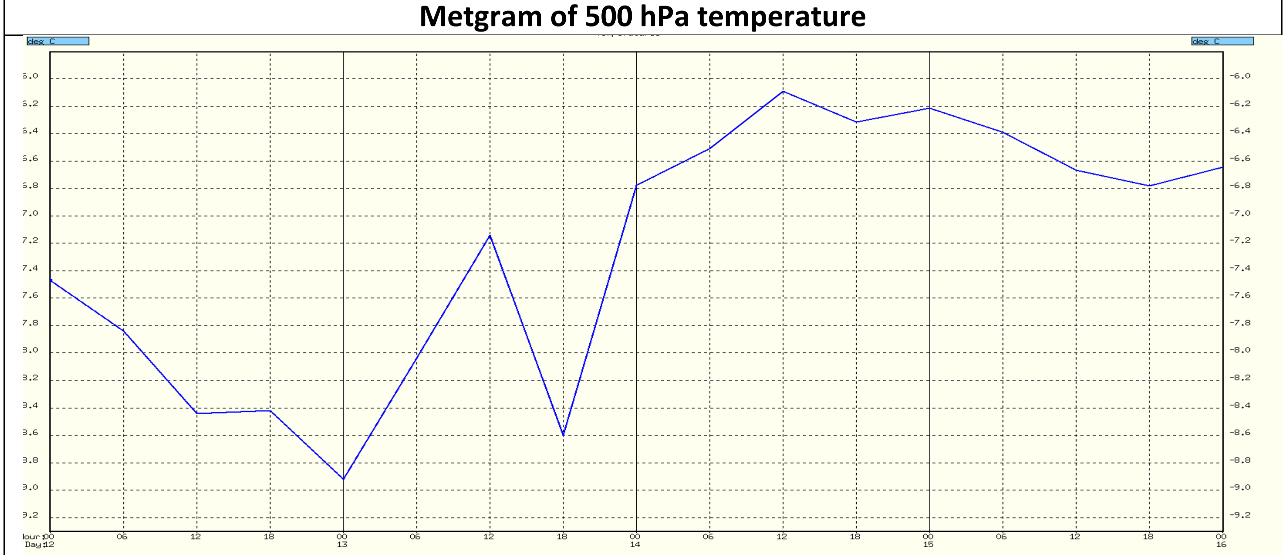


Figure 5

The metgram show a constant drop of temperature at 500 hPa to reach a minimum on 12th January at 1800UTC.The lapse rate was steepening which contributed toward increase in static instability.

Temperature and Geopotential fields at 500 hPa on 12 January 2013 @ 1800UTC

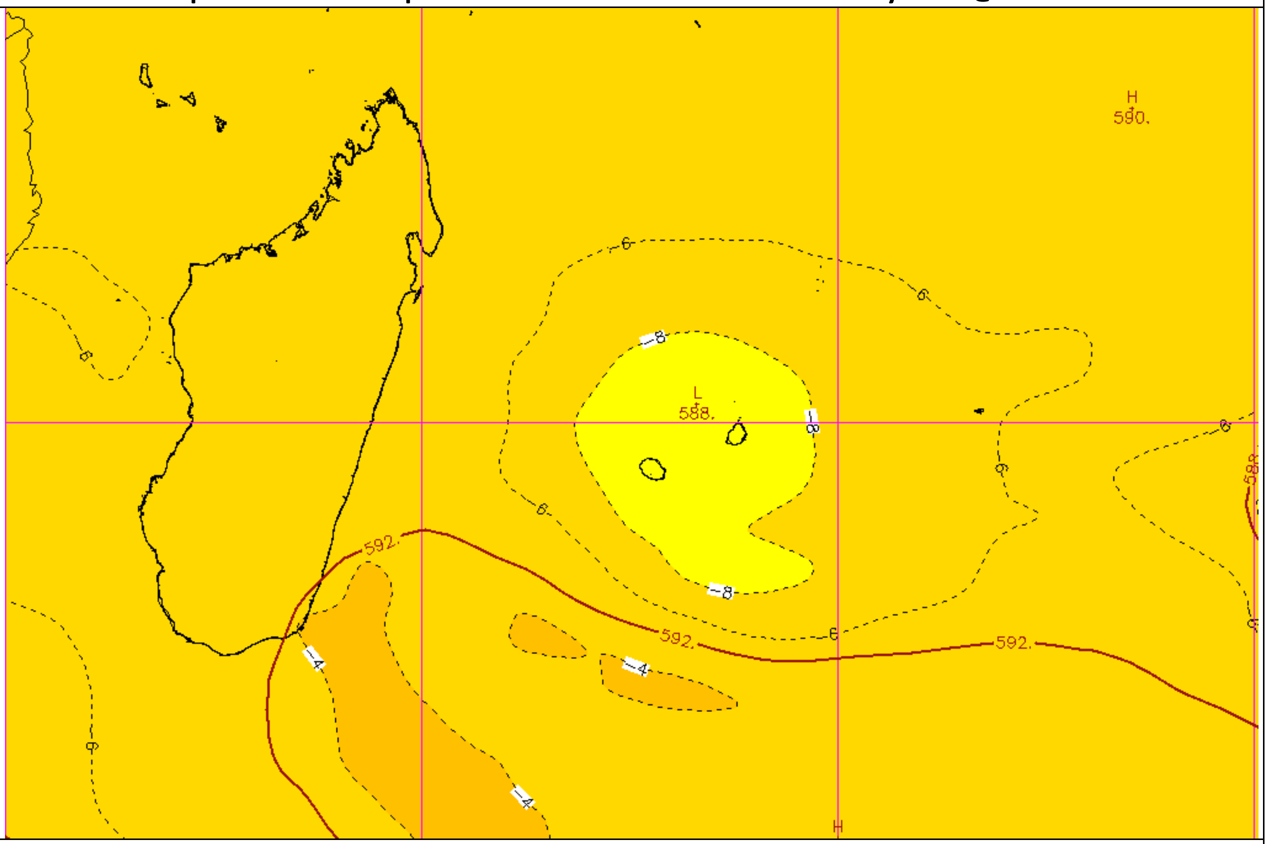


Figure 6

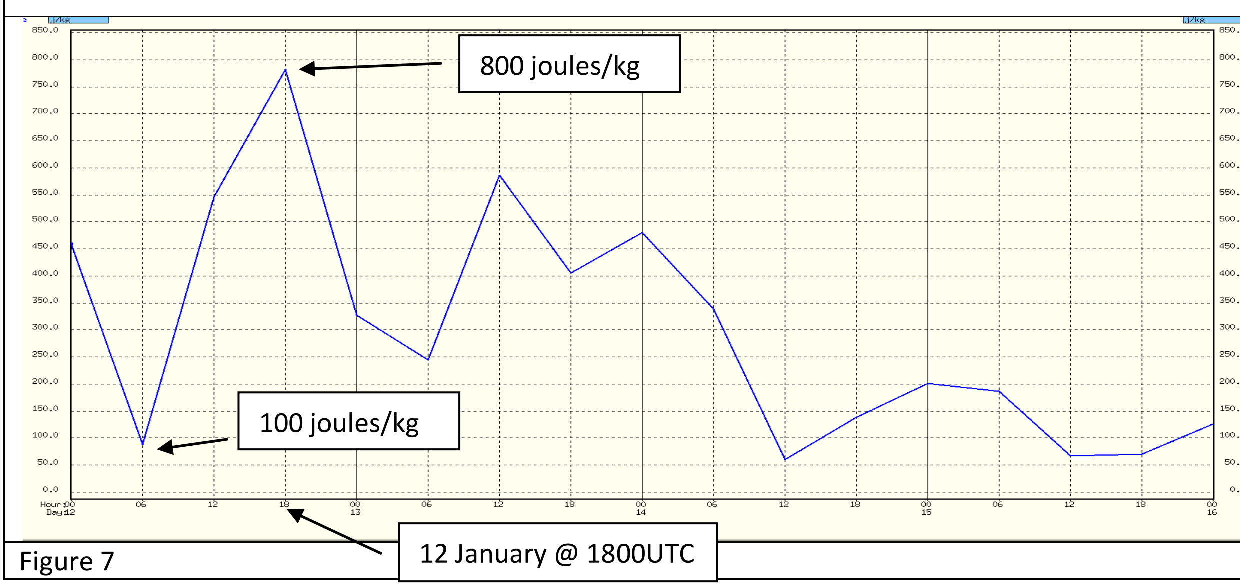


Figure 7

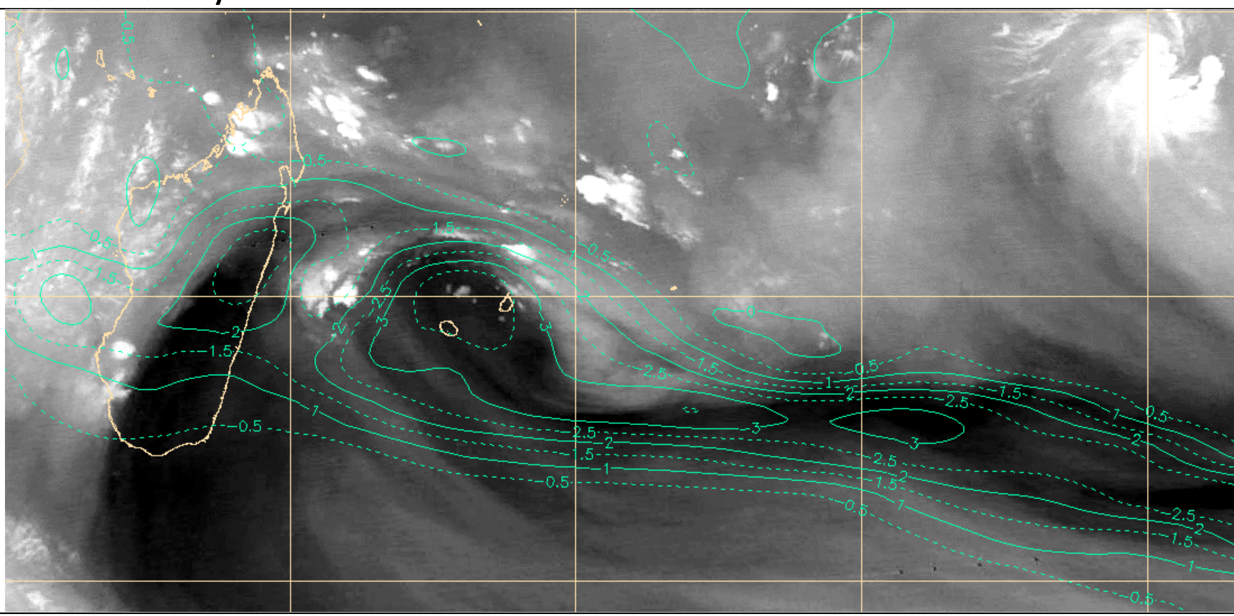
From figures 6 and 7, there was a cold pool and a geopotential low on the 500 hPa .The CAPE shoot up to 800 joules/kg .All contributed in creating instability on that thundery night.

What created the instability?

The answer is obtained by analyzing the water vapour imageries of 12 January 2013 of 1800UTC that are displayed below.

Water vapour imagery of 12 January 2013 @ 1800UTC with isentropic potential vorticity and temperature at 200 hPa superposed

Potential vorticity



Temperature

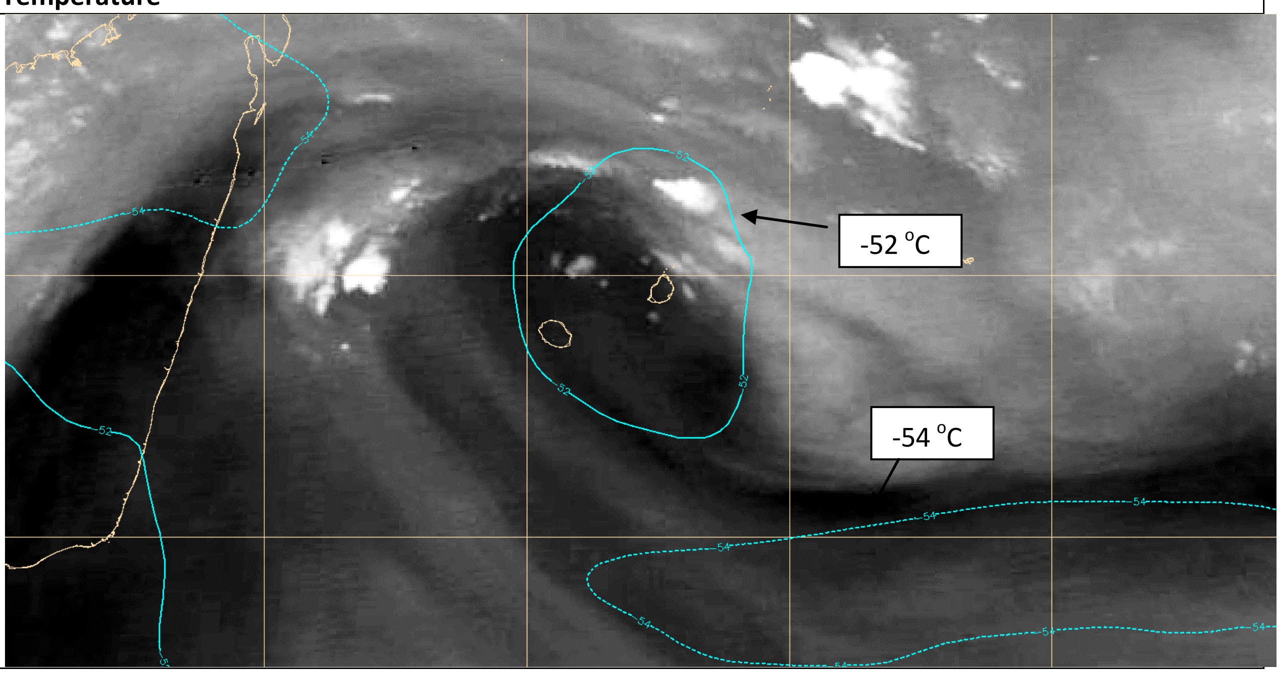
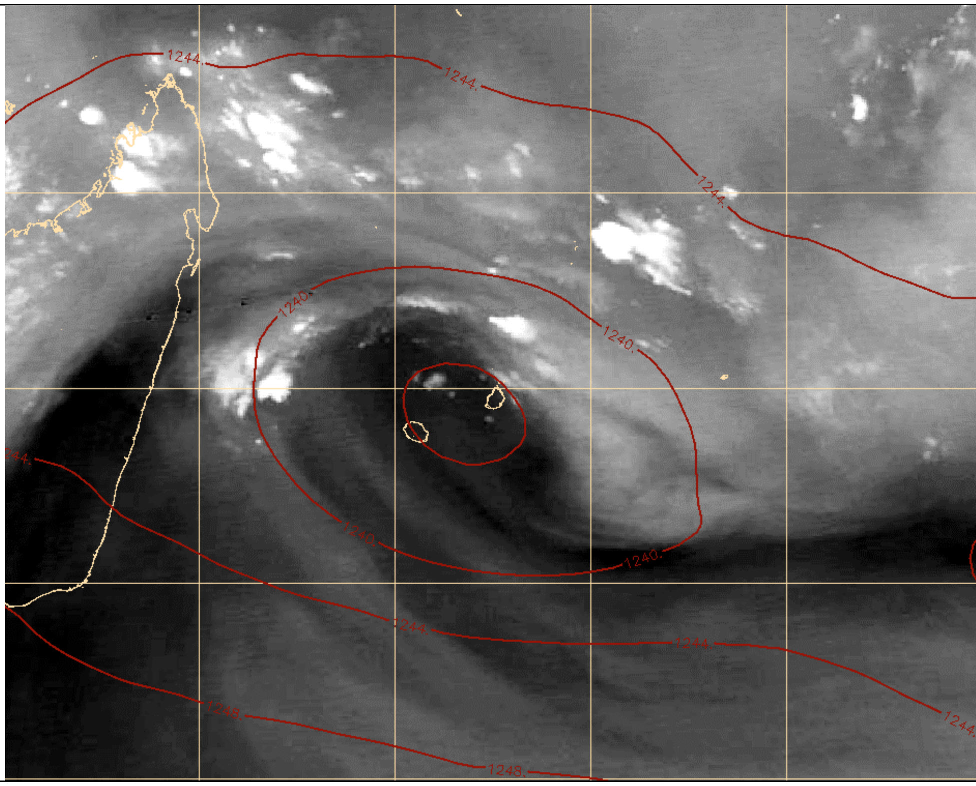


Figure 8

Water vapour imagery of 12 January 2013 @ 1800UTC with Geopotential height and Wind at 200 hPa superimposed



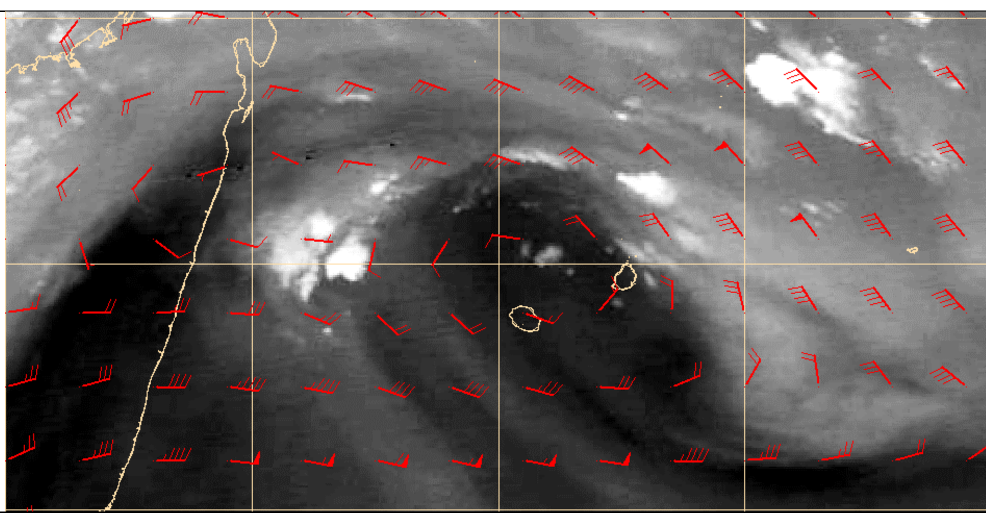


Figure 9

Pink is relative humidity and brown is isentropic potential vorticity

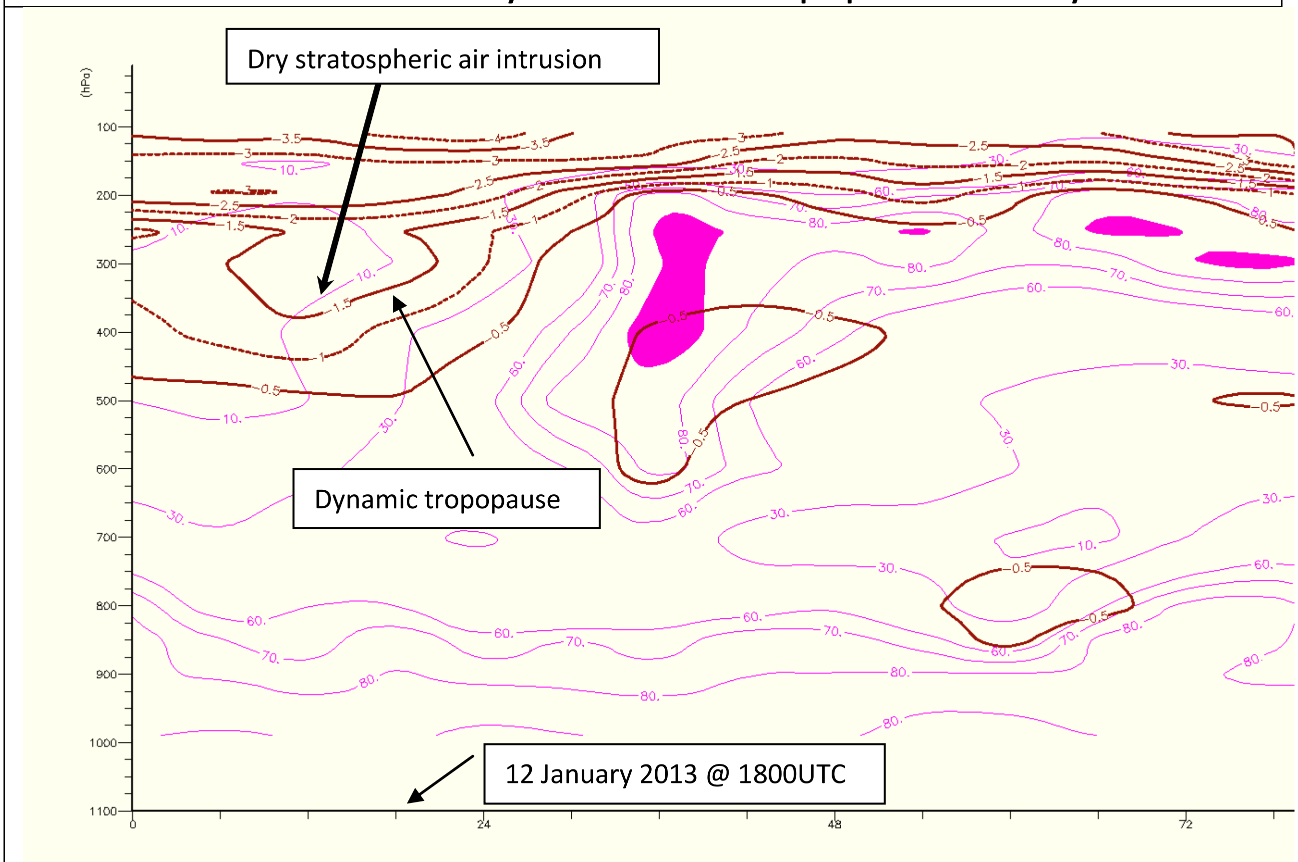
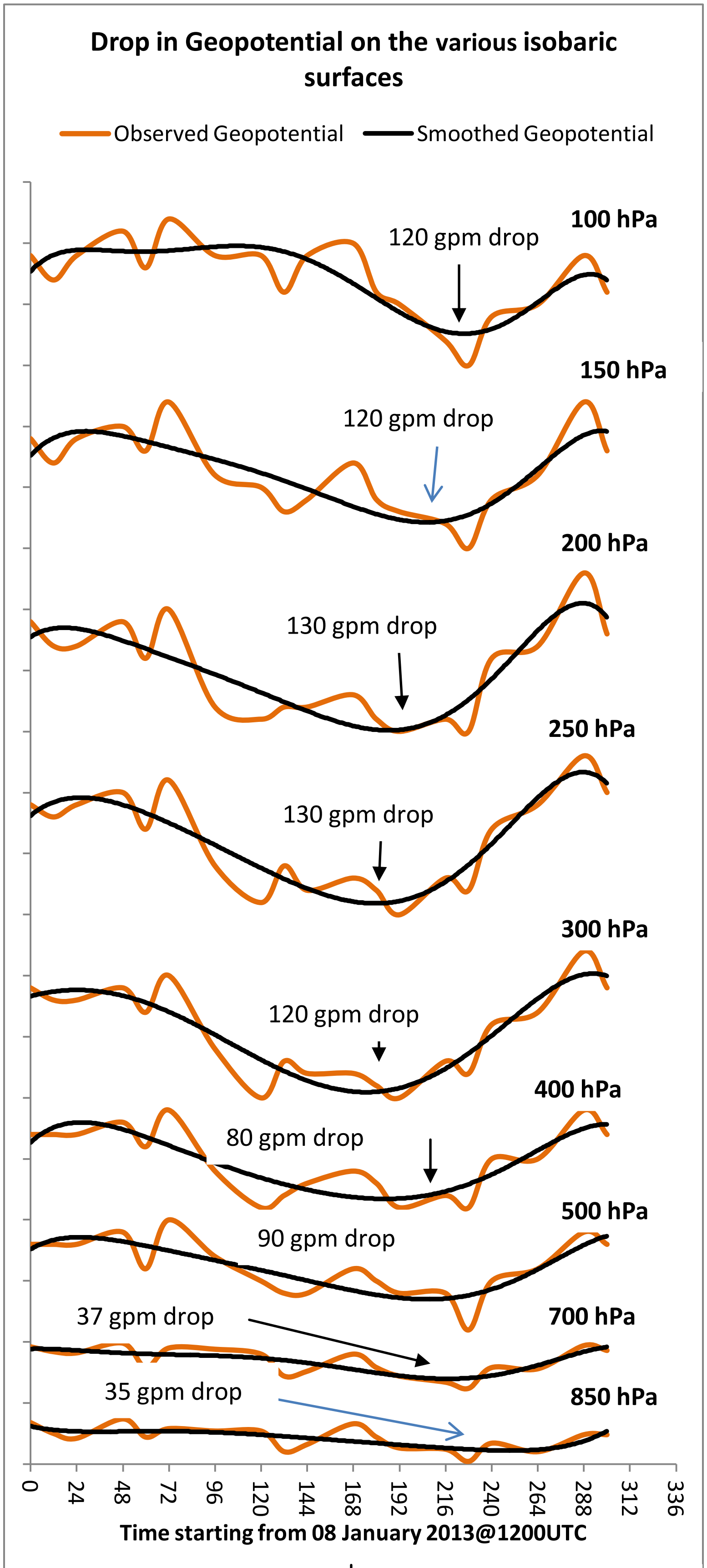


Figure 10

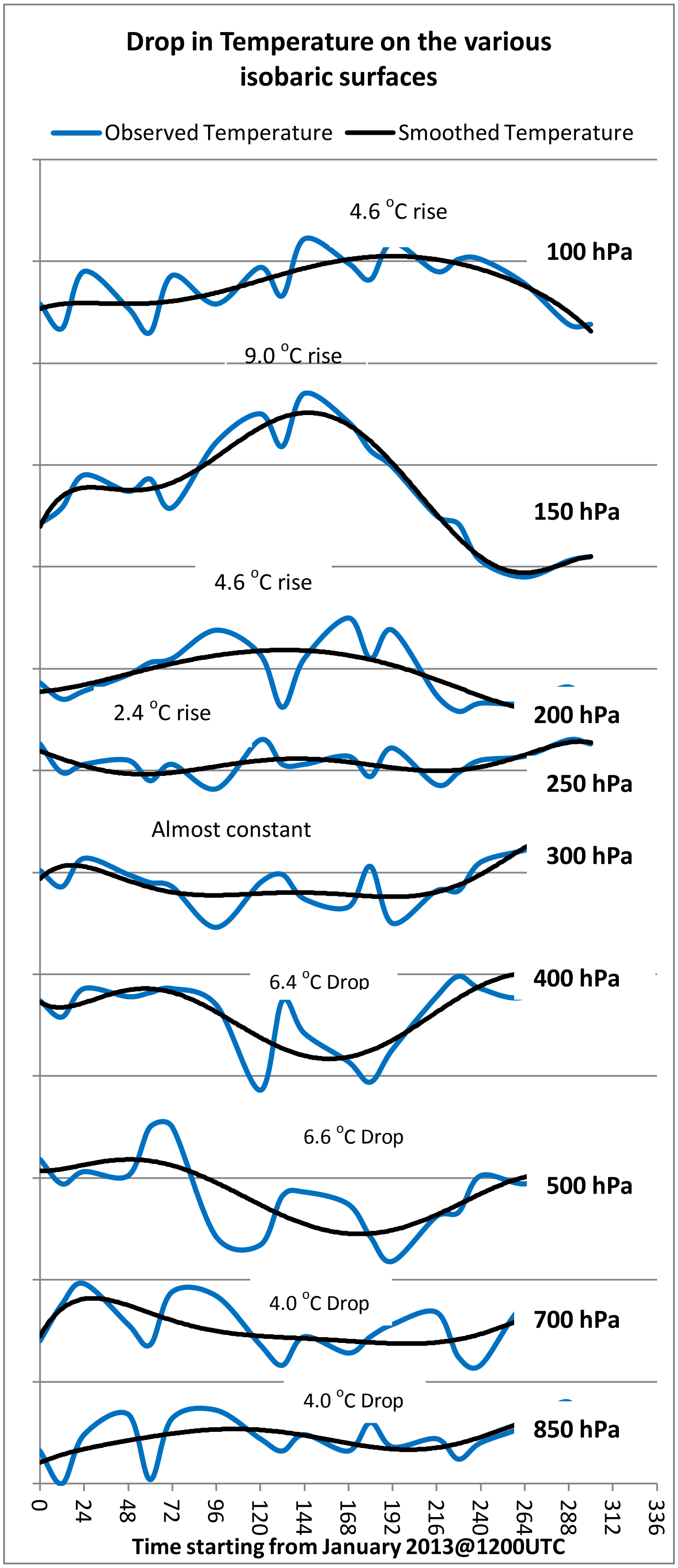
Figures 8 and 9 revealed a very important phenomenon which took placed on the 12th @ 1800UTC.The dark patch over the area indicates very dry stratospheric air which has intruded aloft. The isentropic potential vorticity which was greater than 3.5 PVU was without doubt stratospheric air (tropospheric air has PVU less than 1.5 and the dynamic tropopause has a PVU of 1.5 PVU). The temperature isotherm is higher by 2 degrees compared to the immediate surroundings, which is interpreted as relatively warmer stratospheric air that has dug downward. Further the geopotential has also lowered at 200 hPa and a marked cyclonic circulation has been established there. All these analysis proved unanimously that stratospheric air was intruding into the troposphere at that time. Moreover figure 10 revealed that numerical models have predicted this stratospheric air intrusion to occur 24 hours before it actually happened.

This single element could explain the adverse weather. Stratospheric air very rich in cyclonic potential vorticity imposed clockwise circulation from 150hPa downward to 500hPa. The dynamic tropopause is also depressed and this lowering of geopotential was transmitted downward. That caused readjustment in the geostrophic thermal wind and a drop in temperature on the isobaric surface which is well represented on the 500hPa level.

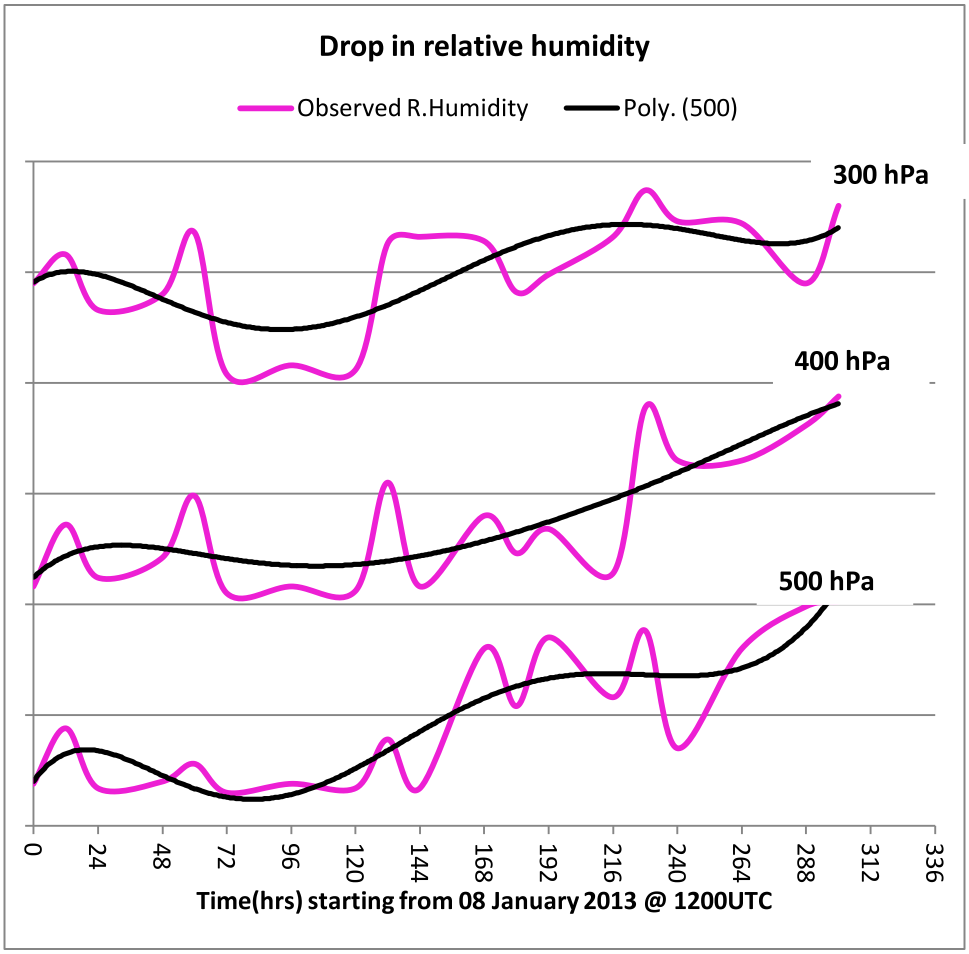
Validation of the Numerical model forecast with measured upper air data



The change in the air mass overlying Mauritius and Reunion was monitored to detect any major trends in temperature, Relative Humidity and geopotential on the standard isobaric surfaces with time.TEMP from Mauritius and Reunion was arranged in chronological order and temperature, Relative Humidity and geopotential plotted .The curve obtained was smoothed by fitting the data to a polynomial of degree six to highlight the significant trends. Note that a drop in geopotential is observed which is more consequent in higher levels. The graph represent the airmass over a location off the two sister islands in the direction of movement of the weather system and is also what prevailed over Mauritius on 12 January 2013 @ 1800UTC



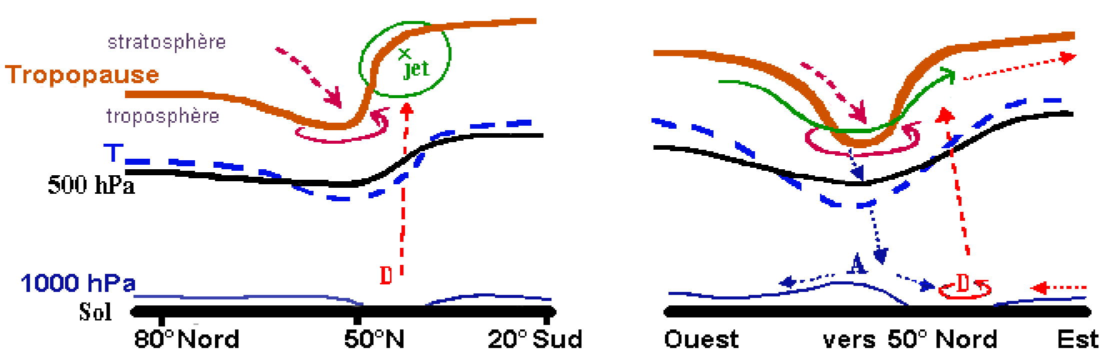
The temperature is showing a decreasing trend in lower level and warming at higher levels. The temperature rise above 250 hPa may be due to intrusion of warm stratospheric air couple with adiabatic compression causing additional warming. Drop in temperature below 300 hPa may have occurred in response to the upper level disturbance.

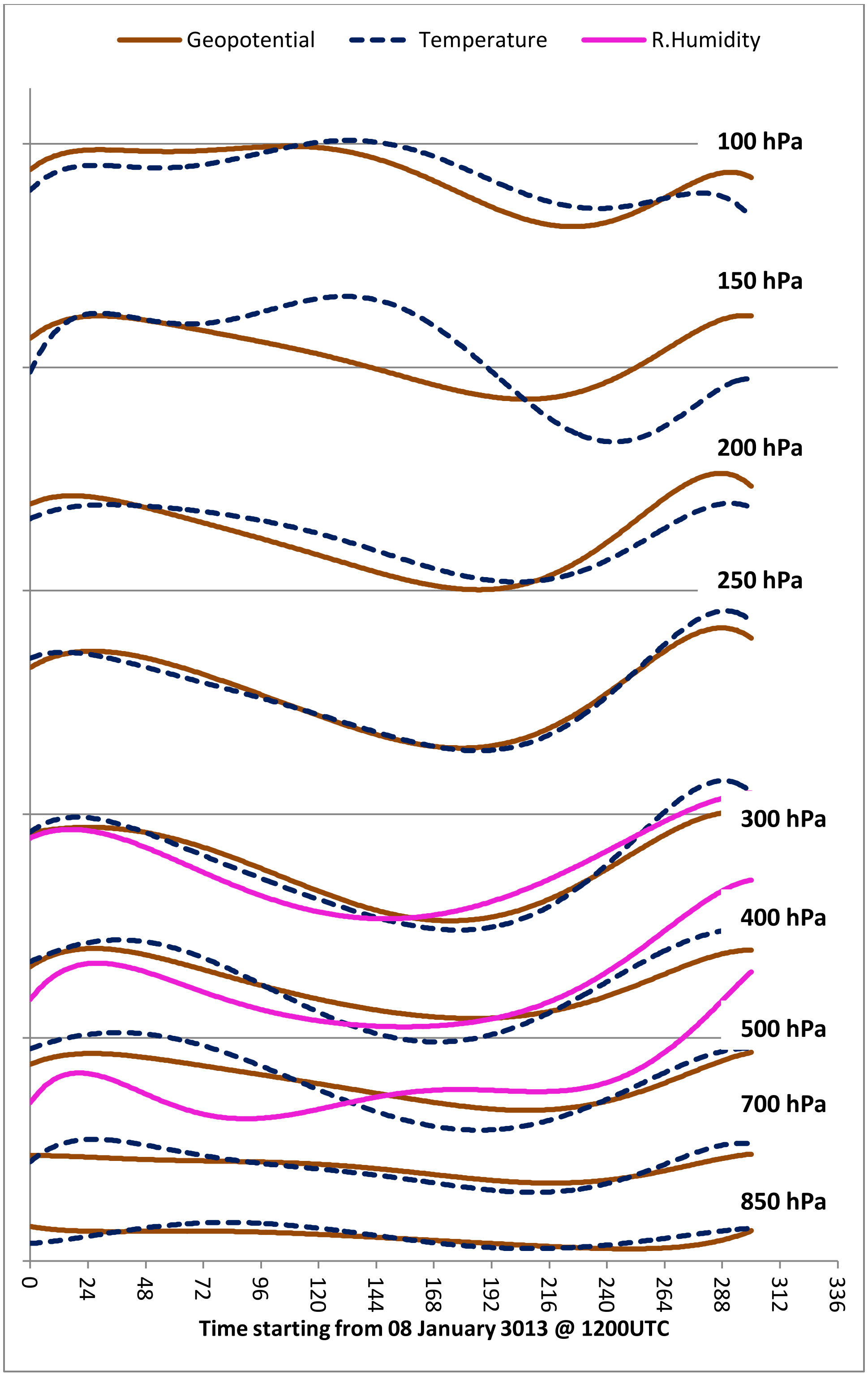


There is a marked drop in relative humidity between 11 to 13 January 2013.this too can be attributed to stratospheric air intrusion which is very dry.

When the three fields are superposed it is seen that the fluctuation is nearly in phase. This support the claim that stratospheric air has brought about the variation in these fields. Note the resemblance with the conceptual model below

<u>Glimpse of the conceptual model (extracted from Mr. P.Santurette lecture)</u>





Geopotential
Temperature
R.Humidity
100 hPa
150 hPa
200 hPa
250 hPa
300 hPa
400 hPa
500 hPa
700 hPa
850 hPa
0
24
48
72
96
120
144
168
192
216
240
264
288
312
336
Time starting from 08 January 3013 @ 1200UTC

Comments on our forecast

While verifying the different meteorological parameters from surface up to the 500hPa, the severity of the weather could not be foreseen in time on Saturday afternoon. The MSLP was around 1015-1018hPa and the dew-point was around 22 to 23^{o}C at Plaisance. In summer, a dew point of 22 to 23 is not considered that moist. Previously, on Friday night around 2200 hours, there were thundery activities to the offshore on the South of the island which could be heard and seen in the region of Quatre-Bornes. That was an indication that the atmosphere was being destabilized. Nevertheless, after some showers on Friday night, Saturday was rather partly cloudy with few passing showers over the high grounds. The more severe weather started in the night. The airmass over our region did not undergo any major changes yet the weather on Saturday night had severe thunderstorms. To investigate further into what caused the severe weather, we had to extend our analysis higher up in the atmosphere even to the lower limit of the stratosphere. After reanalyzing using the conceptual model the cause became clear.

Though Numerical model was depicting the passage of a cold low at 500 hPa and a simultaneous crossing of a trough at 200hPa, the two systems were considered independent. This is especially because they seem to be moving in opposite directions. The 500 hPa low was seen to be retrograding as it was moving towards the West. The cooling with consequent drop in geopotential was also considered not to be linked with these two Lows until the use of the conceptual model showed later, they were all consequences of the same cause. Rapid improvement in weather occurs because most of the instability was confined within the upper air vortex which was moving .The latter cause subsidence in its wake immediately after its transit over our area (figure 4).

Conclusion

This study highlighted that numerical models have become more accurate nowadays and should be given more consideration when elaborating forecast than used as mere guidance. Correct interpretation using the appropriate conceptual models is also essentials when dealing with models.