ALADIN behaviour in two cases of tropical cyclones in South-West Indian Ocean (GUILLAUME for genesis and DINA in a mature phase)

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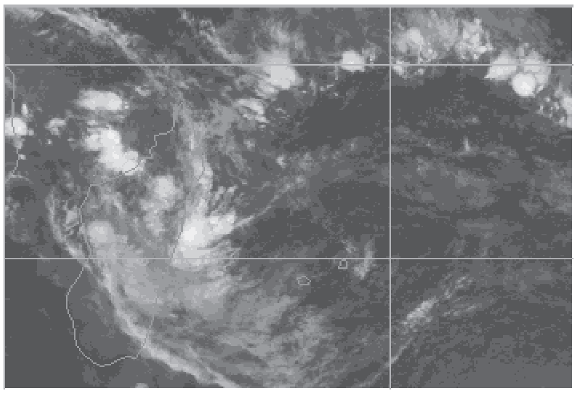
I. Introduction

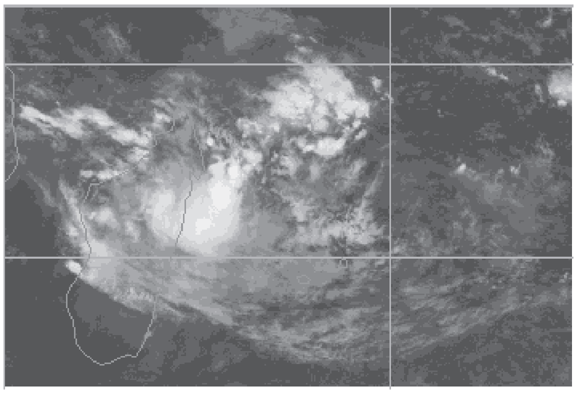
During all tropical cyclone season in South-West Indian Ocean, we have checked the quality of the tropical chain (ARPEGE-Tropiques and ALADIN), and have found that the ALADIN model with only a 33 km mesh has not improved the forecasts made by the ARPEGE-Tropiques model. In order to better test ALADIN we decided to have a close look on the impact of the mesh-size on the ability to simulate a tropical cyclone. We have then tested two cases. The first one is Guillaume in the cyclogenesis phase and the second one concern Dina in a mature case. In tropical cyclone Guillaume, with a 15 km mesh model, we have also tested the impact of the "shear-linked convection" parameterisation in addition to the CYCORA-ter operational physical package.

II. First case: GUILLAUME

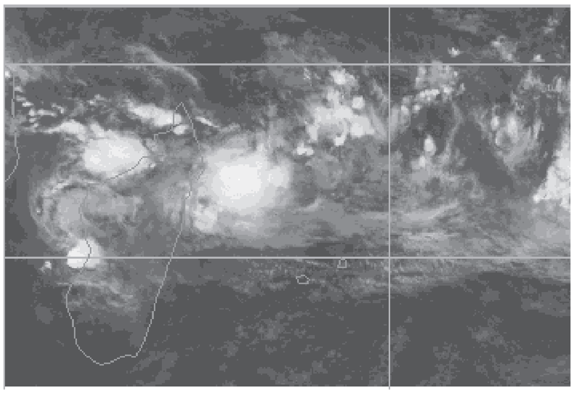
II.1 General description



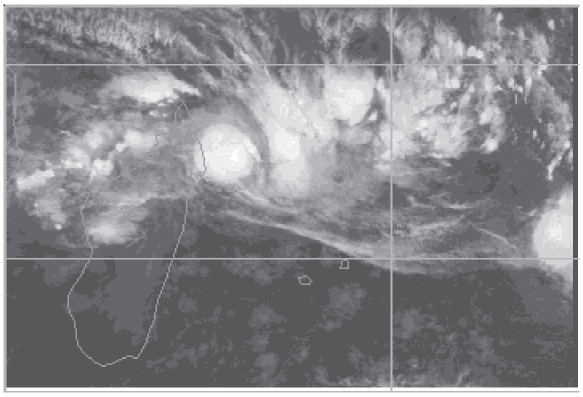
13/02/2002 at 00 UTC



14/02/2002 at 00 UTC



15/02/2002 at 00 UTC



16/02/2002 at 00 UTC

Figure 1 : Infrared images from Météosat 5

Near the East cost of Madagascar on the 13th February 2002, we notice the development of a mesoscale convective system. The intensification of the convection is noticeable during the two next days, and on 15th at 06 UTC, the tropical depression n°10 is there. It will become the tropical cyclone Guillaume. Figure 1 shows the evolution of the convection during these four days from 13th to 16th February at 00 UTC.

We have performed a 72 hours forecast from the 13th February at 00 UTC to 16th February at 00 UTC. The analysis and the boundaries conditions came from the ARPEGE-Tropiques operational analysis and forecast at the same date. No bogus was introduced in his simulation as it was only available after 15th February at 06 UTC.
In order to have a better fit to fine mesh, ALADIN with 15 km mesh is coupled with the 33 km ALADIN operational forecast that has very few differences with the ARPEGE-Tropiques one. The two experiments are called respectively Al-15 and Al-33.

2. Mesh-size impact

A/ Trajectory and intensity of the system.

On Figure 2 we show four trajectories. One is from subjective analysis from forecaster with the Dvorak method. Another one is from an objective analysis with the ICI 200 hPa temperature retrieval model. The two others are from ALADIN simulations at 15 km and 33 km.
With 33 km mesh ALADIN gives a tropical depression going very quickly to the North-West. Even if the localisation is not at the right place, with 15 km mesh the depression has a displacement that is in accordance with the ICI analysis. On satellite images the localizing the centre of the depression is very difficult with a weak system. But at the end of the forecast the trajectory given by ALADIN 15 km is not too far from the ICI objective analysis.

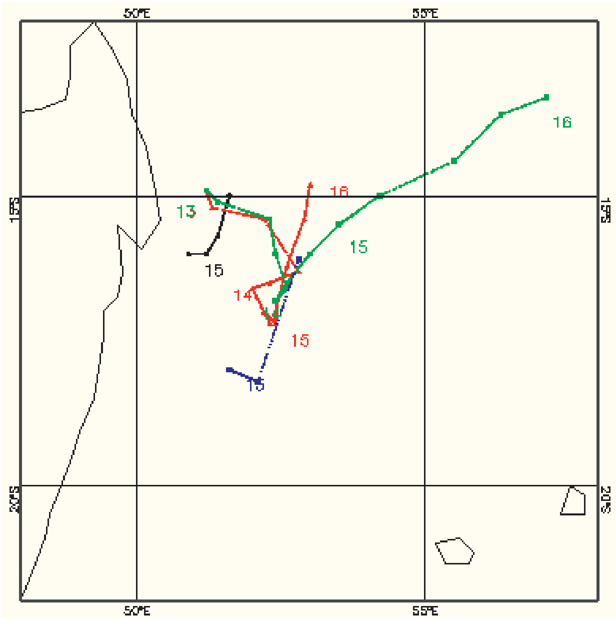


Figure 2 : Tropical depression Guillaume trajectory (red: Al-15; green: Al-33; blue: ICI objective analysis; black: forecaster subjective estimation - best track)

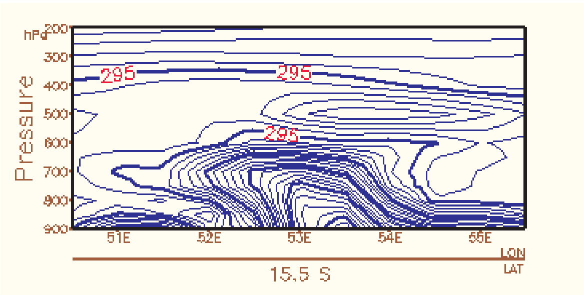
Table 1 shows the mean-sea-level pressure (mslp) at the centre of the tropical depression at all forecast ranges for both simulations (15 km and 33 km). We can compare these results with best track estimation from forecasters after 15th February at 06 UTC, as they can see a tropical disturbance in Dvorak analysis. For the 36 first hours the models do not differ that much, but after 14th at 18 UTC Al-15 begins to deepen a tropical depression with a 991 hPa low at 72 hours range, as Al-33 stays above 1000 hPa. The Dvorak mslp is 5 or 6 hPa above the Al-15 one but the tendency from 15th at 06 UTC to 16th 00 UTC is almost the same (-6 hPa for Dvorak, -7 hPa for Al-15).

Dates	Time (UTC)	Al-33 mslp (hPa)	Al-15 mslp (hPa)	Best track mslp (hPa)
2002 02 13	00:00	1007.2	1007.2	
2002 02 13	06:00	1008.3	1008.0	
2002 02 13	12:00	1006.8	1006.5	
2002 02 13	18:00	1007.5	1007.3	
2002 02 14	00:00	1007.4	1005.9	
2002 02 14	06:00	1006.5	1007.6	
2002 02 14	12:00	1004.6	1004.5	
2002 02 14	18:00	1005.6	1002.6	
2002 02 15	00:00	1004.0	999.2	
2002 02 15	06:00	1004.1	998.2	1003.0
2002 02 15	12:00	1001.6	995.1	1000.0
2002 02 15	18:00	1003.2	994.5	1000.0
2002 02 16	00:00	1001.5	991.3	997.0

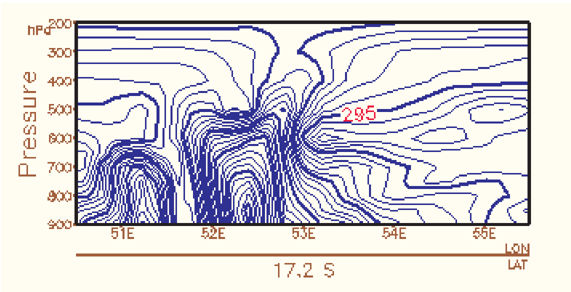
Tableau 1 : Mean sea level pressure at the centre of the tropical depression

B/ θ'*w* vertical structure of Guillaume

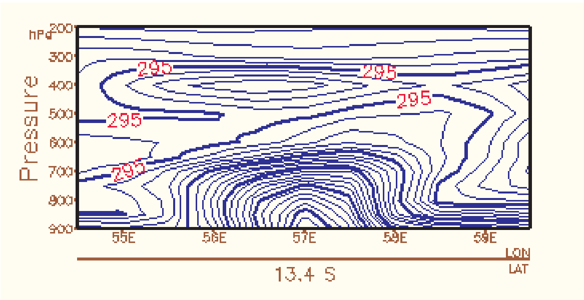
Figure 3 shows the vertical structure of the tropical depression in the 48 h- and 72 h-range forecasts for θ'*w* parameter, for both models Al-15 and Al-33. As the deepening of the system is observed after the 48 h-range forecast, it is interesting to compare the vertical structure of both models. For Al-33 the influence of the convection is localised in the low levels of the atmosphere (under 600 hPa), but with the Al-15 simulation we get a vertical structure that looks like a tropical cyclone with a vertical extension through the whole troposphere.



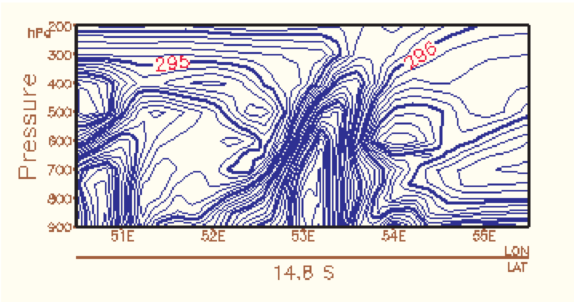
Al-33 ; 48 h forecast



Al-15 ; 48 h forecast



Al-33 ; 72 h forecast



Al-15 ; 72 h forecast

Figure 3 : Meridian vertical profiles of θ'w at the centre of the depression, for 33 km and 15 km mesh models at 48 and 72 hours forecast.

3. Impact of the "shear-linked convection" scheme

We have conducted an experiment similar to Al-15 with the recent "shear-linked convection" parameterisation (F. Bouyssel et J.F. Geleyn, Newsletter 22). This experiment is called Al-15slc.

A/ Trajectory and intensity of the system.

In figure 4 we can see that the trajectories show no big differences. The difference is always less than 100 km. One can notice that the displacement speed of the tropical storm for the Al-15slc simulation is slightly higher than with the other simulation (Al-15).

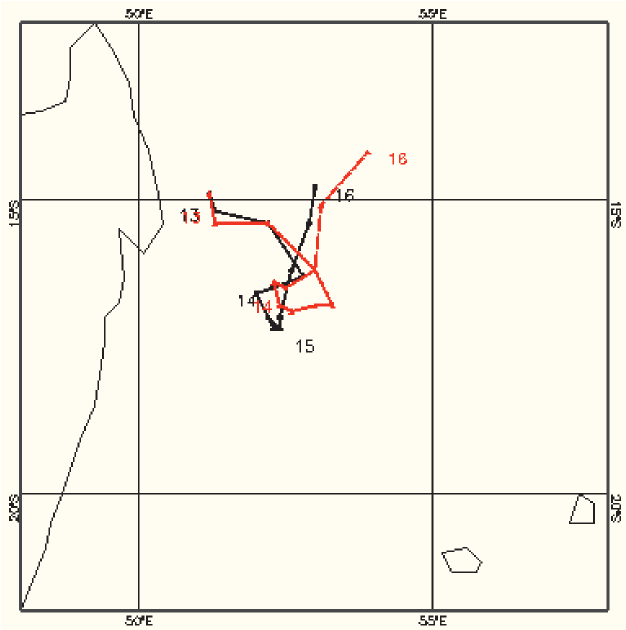


Figure 4 : *Guillaume trajectories (Black : Al-15; Red : Al-15slc)*

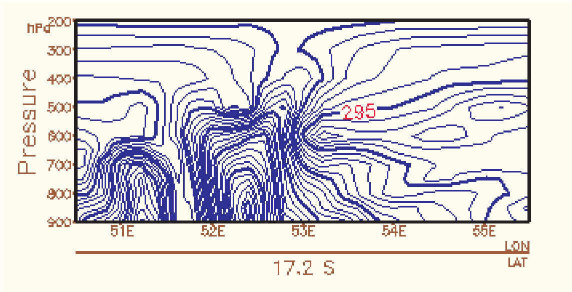
For mslp at the centre of the tropical depression, the Al-15slc values are closer to the forecaster ones than for Al-15. Table 2 shows that at 06 UTC the 15th the difference is only 2 hPa, and 1 hPa 18 hours later.

Dates	Hours (UTC)	Al-15 mslp (hPa)	Al-15slc mslp (hPa)	Best track mslp (hPa)
2002 02 13	00:00	1007.2	1007.2	
2002 02 13	06:00	1008.0	1008.0	
2002 02 13	12:00	1006.5	1006.6	
2002 02 13	18:00	1007.3	1007.7	
2002 02 14	00:00	1005.9	1008.1	
2002 02 14	06:00	1007.6	1007.1	
2002 02 14	12:00	1004.5	1003.4	
2002 02 14	18:00	1002.6	1001.1	
2002 02 15	00:00	999.2	1000.8	
2002 02 15	06:00	998.2	1001.2	1003
2002 02 15	12:00	995.1	1000.0	1000
2002 02 15	18:00	994.5	1000.0	1000
2002 02 16	00:00	991.3	996.0	997

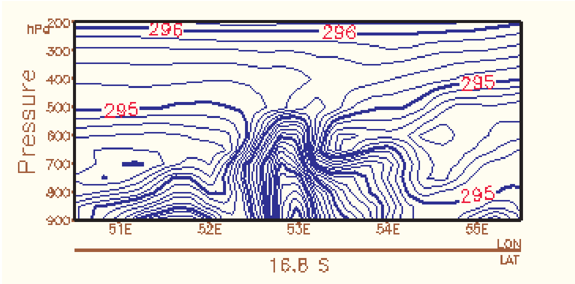
Tableau 2 : *Mslp at the centre of the tropical depression*

B/ θ'*w* vertical structure of Guillaume

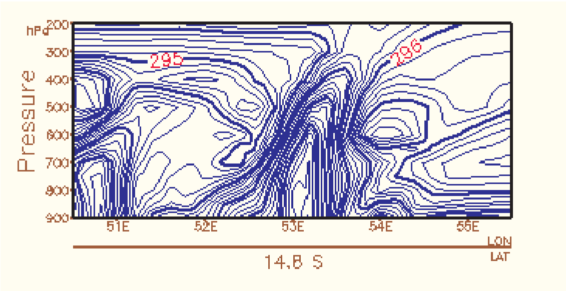
There are no big differences between the two simulations. The only one come from Al-15 that gives a centre for the tropical cyclone a bit warmer (1 or 2 K) than Al-15slc. This remark is in agreement with the less deep depression in Al-15slc than in Al-15



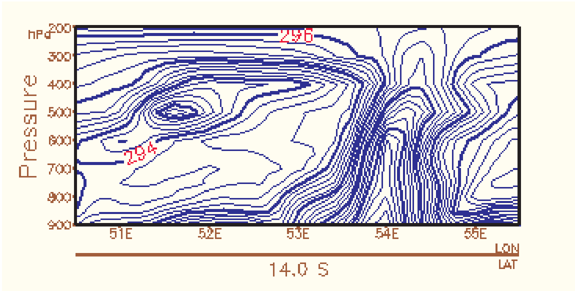
Al-15 ; 48 h forecast



Al-15slc ; 48 h forecast



Al-15 ; 72 h forecast

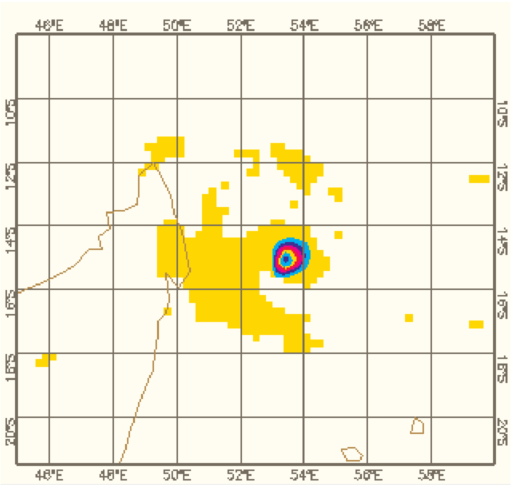


Al-15slc ; 72 h forecast

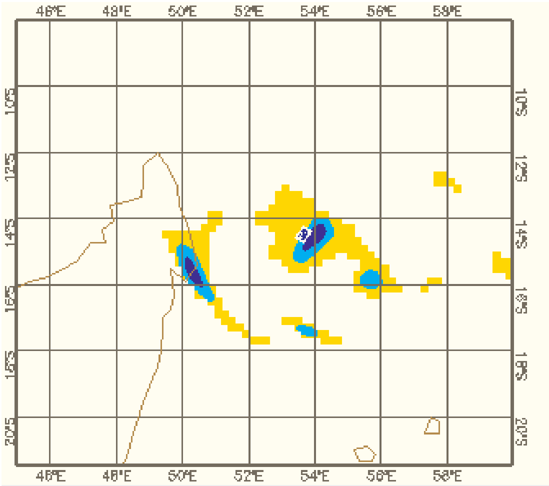
<u>Figure 5</u> : Meridian vertical profiles of θ'w at the centre of the depression for 15 km mesh models with (right column) and without (left column) shear-linked convection parameterisation at 48 and 72 hours forecast

C/ Rain band structures

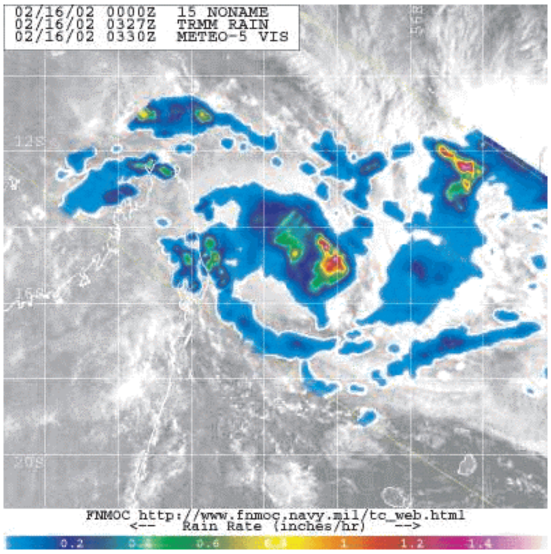
We have compared the structure of the precipitation forecasts by both models with the reality, as seen through TRMM satellite. In order to compare these two kinds of data we had to focus our study on 72 h-range forecasts with a 6 h cumulative rain quantity.



a)



b)



c)

Figure 6 :a) Total rain in 6 hours for Al-15 72 hours forecast ; b) Total rain in 6 hours for Al-15slc 72 hours forecast c) TRMM rain from microwaves 16/02/2002 at 03:27UTC

The results are very different. With Al-15 (figure 6a), one can notice a circular pattern for the intense precipitation zone. This area is surrounded by a large flat one, with small rain (< 15 mm in 6 hours). With the shear-linked convection parameterisation (figure 6b), one can notice many rain cores, but with a smaller intensity. The Al-15slc simulation has a similar shape as that shown by satellite data (figure 6c).

III. Second case: DINA

To achieve the study on the impact of mesh-size, we decided to conduct another study but with a mature tropical cyclone. Dina at 00 UTC the 22nd January 2002 was a good case. As it has been done for Guillaume we have studied the impact of a smaller mesh (15 km against 33 km) on Dina's trajectory and deepening. As we had also data from TRMM, we have decided to study the structure of rain bands.

1. General description

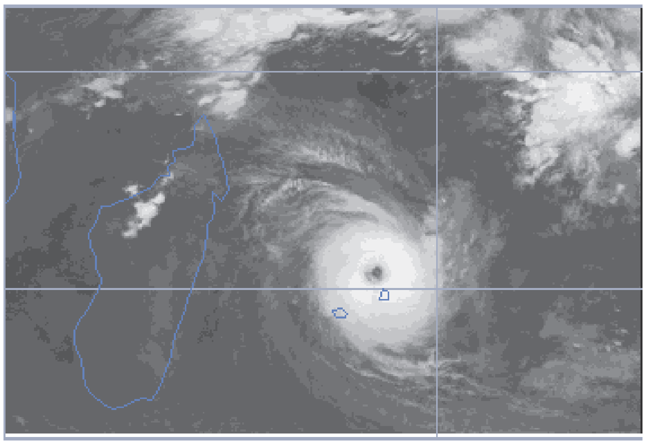
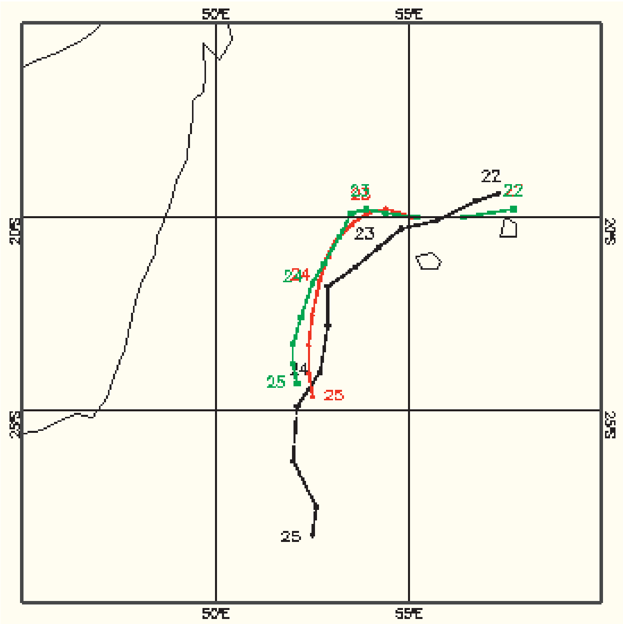


Figure 7 : Infrared Météosat 5 Image; DINA 22/01/2002 at 00 UTC

On 16th January 2002 Dina appears in the middle of the Indian Ocean. After an explosive genesis Dina is a tropical cyclone only 48 hours later. Its maximum intensity (915 hPa) is reached on 20th January 2002. Two days later it is at the north of Mauritius island, and goes straight to Reunion island. We have decided to conduct the 72 hours forecast experiments at this date of intense activity of the tropical cyclone Dina, as shown on figure 7.

2. Trajectory and intensity of the system

As for Guillaume the two experiments are named Al-33 and Al-15. On figure 8 one can notice that the two experiments are not so different. The trajectories are exactly the same till the 48 hours forecasts and the gap between them is less than 100 km at 72 h range. The 24 hours delay of the Al-33 simulation is still here in the Al-15 one. It is due to the westward trajectory during the first day of simulation, and a too slow meridional speed of the simulated tropical cyclone.



<u>Figure 8</u> : Dina Trajectory (green: Al-15; red : Al-33; black : best-track from forecaster

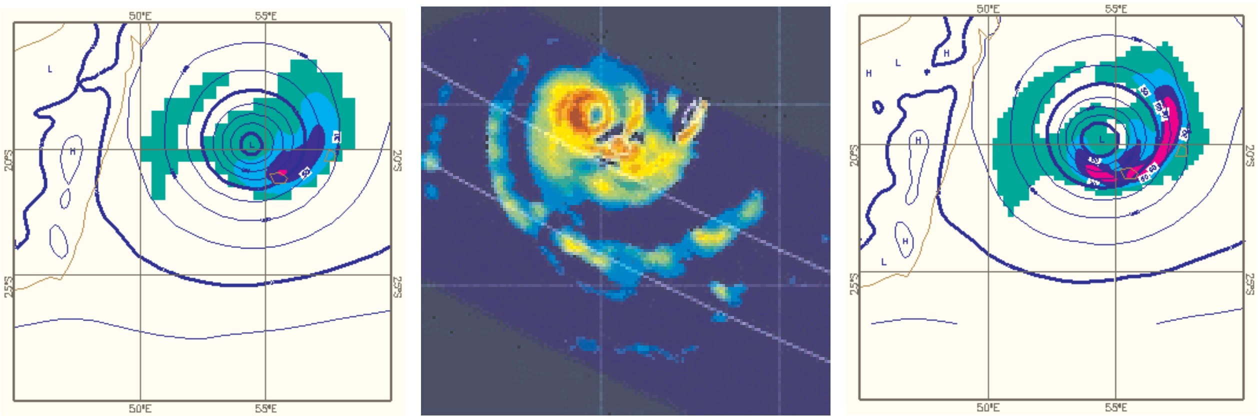
For the pressure field structure the 15 km simulation gives a bigger horizontal gradient than the 33 km one.
Table 3 shows the evolution of the mean sea level pressure at the centre of the tropical cyclone. The minimum of pressure is reached in Al-33 after 36 h forecast, but only after 72 h forecast in Al-15. Both simulations are not very realistic, as the observed minimum is at the beginning of the period.

Dates	Hours (UTC)	Al-33 mslp (hPa)	Al-15 mslp (hPa)	Best track mslp (hPa)
2002 01 22	00:00	979.3	979.3	935
2002 01 22	06:00	980.4	980.2	930
2002 01 22	12:00	976.9	976.5	930
2002 01 22	18:00	974.4	973.2	930
2002 01 23	00:00	969.4	970.2	930
2002 01 23	06:00	966.7	969.7	940
2002 01 23	12:00	964.5	967.0	950
2002 01 23	18:00	965.6	965.9	955
2002 01 24	00:00	966.7	964.1	960
2002 01 24	06:00	967.1	963.7	966
2002 01 24	12:00	967.3	958.4	972
2002 01 24	18:00	967.9	955.8	975
2002 01 25	00:00	967.3	953.7	985

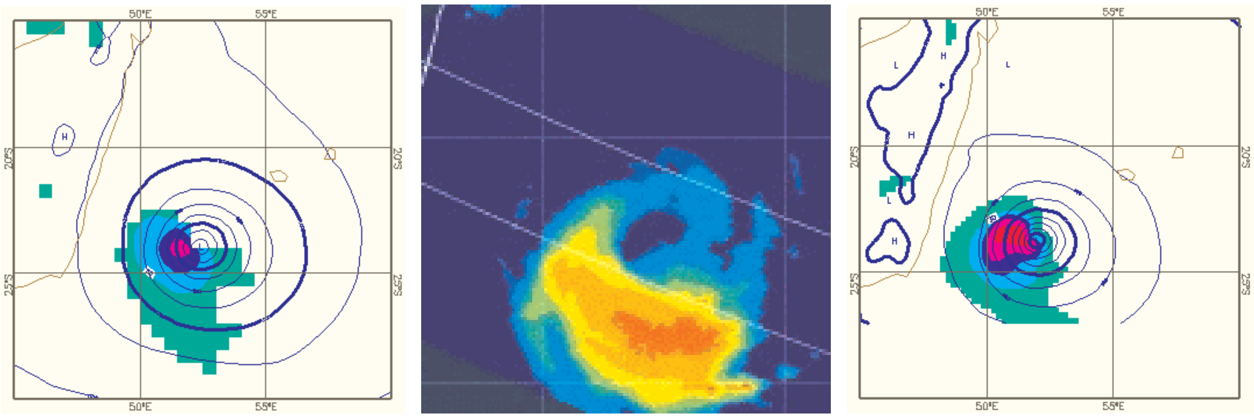
<u>Tableau 3 :</u> MSLP at the centre of the tropical depression

3. Rain band structures

In this part we want to have an objective estimation of rain band structures with two swaths of TRMM over Dina.
The TRMM data are available on 22/01/2002 at 00:21 UTC and 24/01/2002 at 16:38 UTC. We can notice on figure 9 that both numerical simulations with ALADIN succeed in reproducing rain band structures around Dina's centre. The localisation of high intense precipitation is in good agreement with TRMM observations.



Al-33 ; cumulative rain 12-18 h — TRMM 22/01/2002 at 16:52 UTC — Al-15 ; cumulative rain 12-18 h



Al-33 ; cumulative rain 60-66 h — TRMM 24/01/2002 at 16:38 UTC — Al-15 ; cumulative rain 60-66 h

<u>Figure 9</u> : cumulative rain on 6 hours as seen by ALADIN and by microwaves imager from TRMM.

IV. Conclusions

By these studies on two different cases we have shown that mesh size is very sensitive for tropical cyclone simulations, especially for cyclogenesis. With a 33 km mesh, ALADIN is not able to create the tropical depression Guillaume, as it is possible with a 15 km mesh model. But for a mature tropical cyclone as Dina, a finer mesh is not very useful, for the track forecast, and even worth for intensity forecast.
The impact of shear-linked convection parameterisation scheme on GUILLAUME cyclogenesis gives very encouraging results. This scheme tends to reduce rain and give a less deep depression than in the simulation without it. The rain bands are also more realistic in comparison with real data.

Some more simulations are now under test, as we have a 20 km mesh model ALADIN with shear-linked convection parameterisation operating daily over western south Indian Ocean.