JP2J.9 NUMERICAL MODELING OF INTENSE TROPICAL CYCLONE DINA (2002) IN THE SOUTH WEST INDIAN OCEAN USING MESO-NH MODEL

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1. INTRODUCTION

Dina was born on the 16th of January 2002 in the South West Indian Ocean. It became an intense tropical cyclone the 20th, and affected directly Mauritius and La Reunion islands on the 22nd. Material damages were estimated about hundred millions of euros. As predicted the Météo-France ground based Doppler radar made observations while the storm passed near La Réunion (55.5°E, 20.8°S), providing reflectivity and velocity data within 400 and 150 km range, respectively. The analysis of these data has revealed the kinematic structure of the storm and the possible influence of the orography on its structure and its track (Roux et *al.* 2004).

A cyclone modeling has been run for the first time in Indian Ocean with the French non-hydrostatic mesoscale numerical model Meso-Nh to simulate the cyclone Dina for 21 hours with a very high horizontal resolution of 1 km, better than actual studies: 2km for Yau et *al.* (2004); 1,33 km for Braun (2002). The model is initialized using the RDVC technique developed by Nuissier et *al.* (2005) which allows in our case to replace the ill-defined cyclone from the large-scale analysis (ECMWF) by a realistic bogus vortex derived from the ground based Doppler radar observations; following the idea of Kurihara et *al*. (1993). Results focus on the structure and propagation of the simulated storm, and the evolution of the eyewall.

Firstly we present cyclone Dina, in the second part the modeling procedure is explained and the results are then presented and discussed.

2. OUTLOOK OF CYCLONE DINA

Dina was born on the 16th of January 2002 in the middle South West Indian Ocean near Diego Garcia (76°E, 8°S). Moving south-westward and following an explosive cyclogenesis it became a tropical cyclone the 18th and then an intense tropical cyclone the 20th with surface winds of 58 m/s and wind peaks of almost 80 m/s. Starting then to weaken, it kept a stable intensity while passing at 65 km from the coasts of La Reunion island (55.5°E, 20.8°S) on the 22nd at 14h00 UTC. It changed fortunately its direction to the West when approaching the island – the orography could have influenced the dynamic of the cyclone – and its trajectory spared the island from its devastating wind peaks from the eyewall. The eyewall passed at 27 km from the coast and provocated winds of 40 to 70 m/s with heavy rains (500 to 1500 mm), cyclonic swell (6 to 9 m).(Fig. 3 (d)).

3. MODELING

3.1 The numerical model Meso-Nh

It is a French non-hydrostatic mesoscale numerical model jointly developed by Météo-France and the Laboratoire of Aerology. Simulations are run using four nested domains A, B, C, D at respectively 36, 12, 4 and 1-km horizontal resolution and corresponding respectively to 200*100, 162*162, 180*180 and 720*720- grid points(Fig. 1).

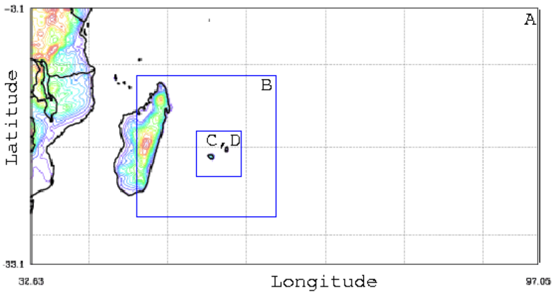

Fig. 1: 4 simulation domains

The vertical resolution of 60 levels varies between 50 m for the first level above the sea to 1 km at the top situated at 21km height.

Domains A and B use a convection parametrization (KAFR from Kain and Fritsch, 1990, 1993) whereas C and D compute explicit resolution of convection. ECMWF radiative, ISBA ground fluxes, ICE3 microphysical, TKEL turbulence (from Cuxart et *al*., 2000) and

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**Corresponding author address :* S. Jolivet, University of Reunion, Laboratoire de Physique de l'Atmosphère, Fac de Sciences, 15 avenue René Cassin - BP 7151 - 97715 Saint Denis Messageries Cedex 09 - Reunion Island - France; e-mail: samuel.jolivet@univ-reunion.fr advection of 2^{nd} space and time order –scheme are used for all the 4 domains.

The two-way grid-nesting technique is used to allow the 4 domains to exchange information. The father domain A imposes the boundary conditions to the son B which imposes boundary conditions to C. In the overlapping area the better resolution of the son “feeds” the father which recalculates its fields using this information.

3.2 Initialization : filtering and bogussing

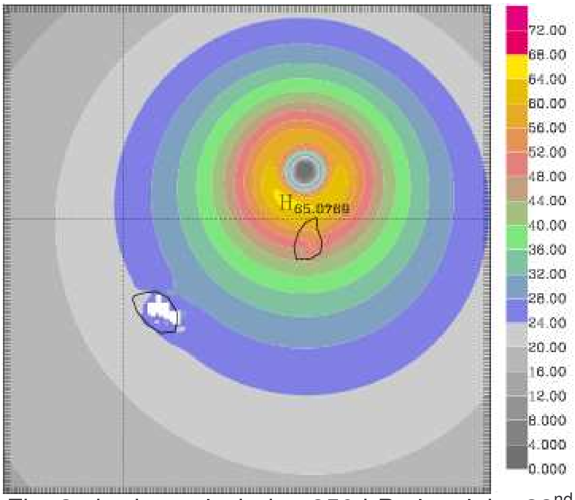

Fig. 2 : horizontal wind at 850 hPa level the 22^{nd} at 00h00 UTC after bogussing, model C

The RDVC (*Radar and Dropwindsonde Vortex Conditionning*) technique is used to initialize Meso-Nh. It consists in extracting from a large scale analysis the ill-defined cyclonic vortex to replace it by a realistic balanced vortex well situated deducted from the radar observations.

First from a large scale ECMWF field the 22/01/02 at 00h00 UTC, where Dina cyclone is not well analysed, the filtering from Kurihara *et al.* (1993, 1995) is applied. This large scale analysis is composed of a basic field and a disturbance field which are separated by using a Barnes(1983) filter. The disturbance field is composed of a non-hurricane part and a vortex part. Separating these 2 parts and coupling the basic field to the non-hurricane part gives the environmental field filtered from any vortex influence. The cyclone center and the radial extension for filtering are respectively determined by the minimum of wind and a test on the tangential wind.

Then as the Météo-France ground based Doppler radar provide reflectivity and wind dataset; a bogus vortex is parametered with the GBEVTD analysis on the radar data from 10h22 to 11h22 UTC the 22/01/02(Roux *et al.* 2004), using the technique developed by Nuissier *et al.* (2005). The bogus is a realistic vortex of 1200 km diameter and with a maximum tangential wind of 65 m/s situated at 50 km from the cyclone center (Fig. 2).

4. RESULTS

4.1 Propagation and structure

A first 36h run with the coarser 36 km horizontal resolution on domain A was computed. Then the 4 nested domains with the maximum horizontal resolution of 1km (domain D) were used for a 21h run. Fig. 3 presents Dina’s track for the run with the coarser resolution(a), for the run with 4 domains(b), the ECMWF cyclonic track(c) and the BestTrack computed by Météo-France(d).

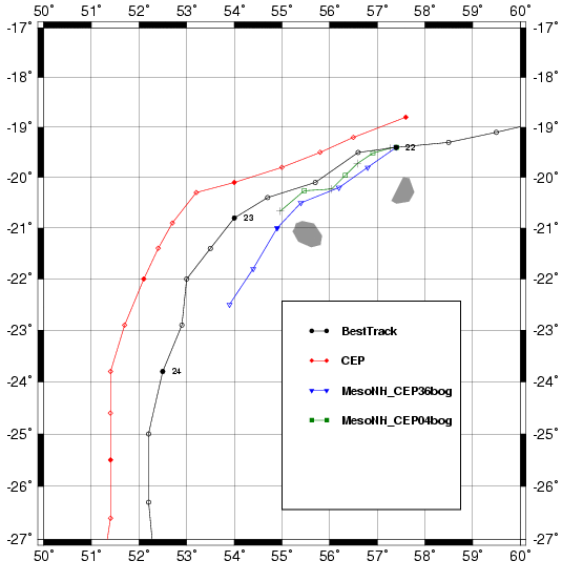

Fig. 3: Simulated tracks vs BestTrack;(a)36 km resolution in blue, (b)4 domains in green, (c)ECMWF in red and (d)BestTrack in black

Despite a slower propagation of the cyclone (caused by the spin-up of the model) compared to the BestTrack, the run with 4 domains is better than the one with 1 domain providing an improvement of the trajectory showing the benefit of the meso and small scales. The maximum difference between the BestTrack and the run with 4 domains is less than 60km. The simulated cyclone passes near the island at a distance of 35 km, closer than the observed one of 65 km. For the structure, similar characteristics are observed: RMW of 69 km maximum wind of 46.7 m/s and a minimum pressure of 941 hPa.

Presented on Fig. 4 and Fig. 5 respectively a vertical section of θe (K) and a vertical section of horizontal wind intensity (m/s) .The eye appears clearly with the eyewall tilted from the bottom to the top.

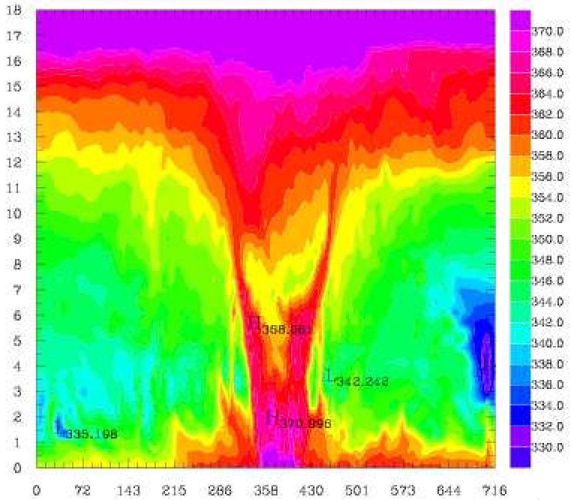

Fig. 4 : vertical N-S section of θe(K) the 22nd at 15hUTC, model C

Low level radial convergence is contained in the first kilometers whereas divergence is situated at 12 kilometers high. Classical wind profile can be seen: wind attenuation with the altitude and the augmentation of the radius. The maximum winds are in the low levels where accumulation of θe occurs because of humidification and heating by surface fluxes. Vertical transport is also shown with the updraft in the eyewall on the contrary of downdraft in the inner part of the eyewall corresponding to fall of stratospheric air; and large scale subsidence away from the eye. Dry warm core appears between 6 and 9 km.

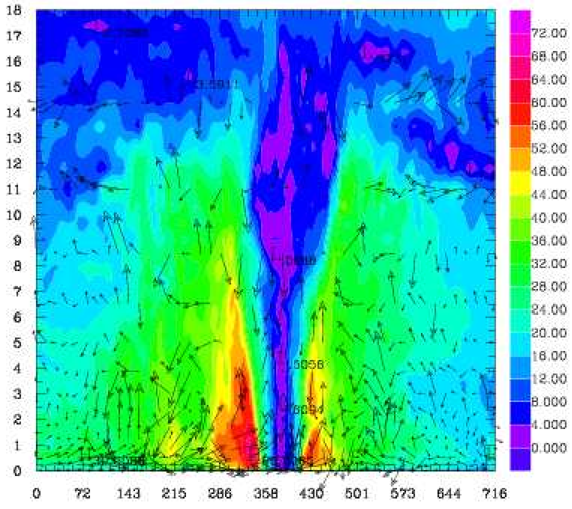

Fig. 5: vertical N-S section of horizontal wind intensity(m/s) and vertical motion the 22nd at 15hUTC, model C

4.2 Eye evolution

An elliptic structure(axes of 80 and 55 km) of the eye moving clockwise(cyclonic rotation) with a period of 110 min appears clearly on Fig. 6 corresponding to horizontal wind intensity at 850 hPa level the 22nd from 12h30 UTC to 13h30 UTC computed on the domain C at the 4 km horizontal resolution. It is similar to the observations with an elliptical shape of 70 and 50 km axis. It characterizes an

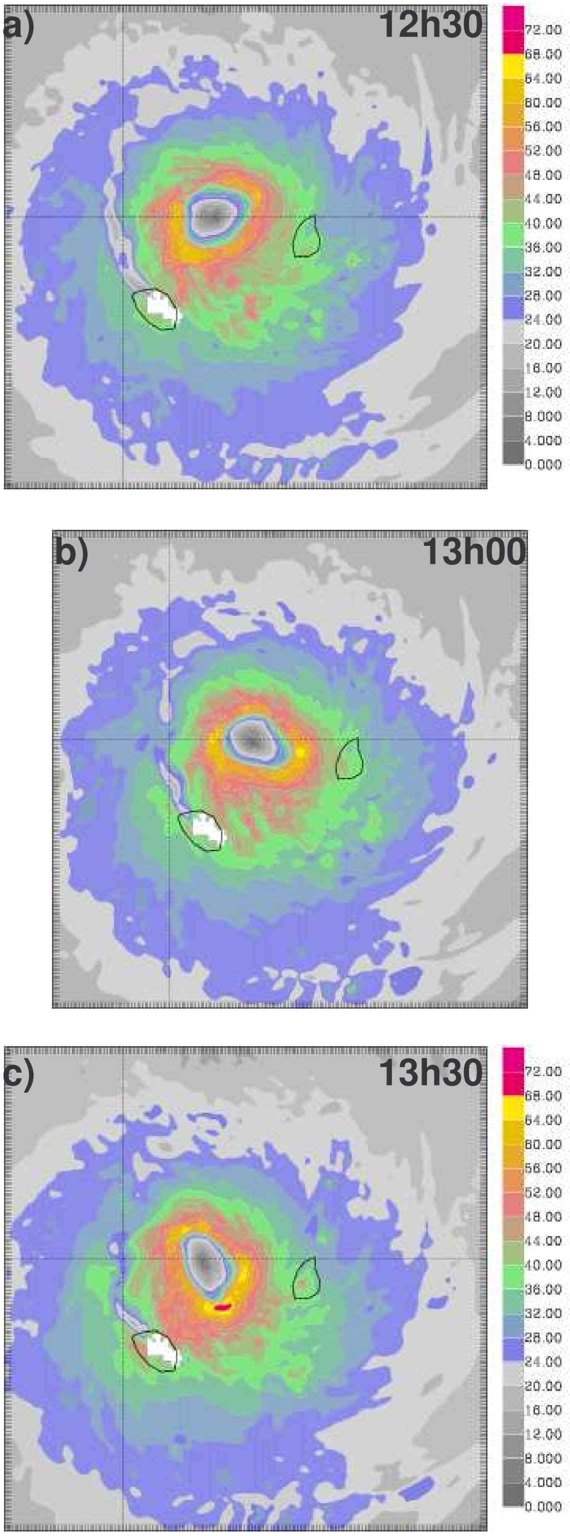

Fig. 6 : horizontal wind intensity at 850 hPa level the 22nd at a)12h30, b)13h00 and c)13h30 UTC

asymmetric structure of cyclone. At 1 km resolution cyclonic mesovorticies in the inner edge of the eyewall and polygonal shape of the eye can be seen (Kossin and Schubert, 2003; Nuissier et *al.*, 2005) . From recent studies Rossby waves are suggested to play a role in this type of structure (Wang, 2002 ; Nuissier et *al.*, 2005).

Approaching La Reunion island, its orography influences the structure of the eye. Indeed the polygonal structure of the eye is enhanced as the cyclone interacts with the orography (Fig. 7 and Fig. 8). Light rains also appear in the inner center of the eye similar to observations.

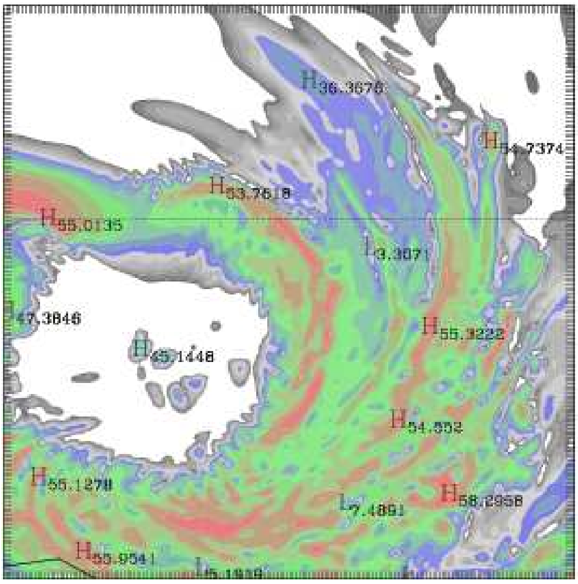

Fig. 7 :radar reflectivity at z=1 km the 22nd at 17h10 UTC(dBZ)

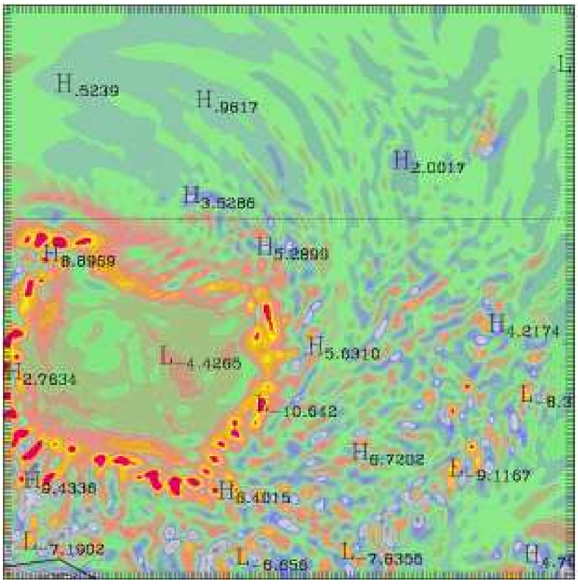

Fig. 8 :relative vorticity at z=1 km the 22nd at 17h10 UTC($10^{-3}.s^{-1}$)

5. CONCLUSION

The French non-hydrostatic mesoscale numerical model Meso-Nh was used with a very high horizontal resolution of 1 km to study the case of Dina (2002) in a new region of investigation: the Indian Ocean. This simulation was initialized using the RDVC method but this time with a ground based, in place of an airborne, Doppler radar situated in La Réunion. This initialization method provided a realistic balanced vortex similar to reality. Compared to the large scale prediction (ECMWF) the simulated track was improved. The simulation of meso and small scales still benefit to the resullts. The dynamic and thermodynamic structures are similar to observations and special features such as the rotating elliptical eyewall observed by the radar appear. The Domain D with the 1 km horizontal resolution provides very interesting characteristics similar to former numerical studies and observations, like the polygonal shape and its evolution near the island. This information is now examined and will be presented in a next study especially the interaction of the orography with the inner-core.

References :

BARNES, G. M., ZIPSER, E. J., JORGENSEN, D. and MARKS, F., 1983: Mesoscale and Convective Structure of a Hurricane Rainband. *J. Atmos. Sci.*, **40-9**, 2125–2137.

BRAUN, S. A., 2002: A cloud-resolving simulation of hurricane Bob (1991): storm structure and eyewall buoyancy. *Month. Wea. Rev.*, **130**, 1573-1592.

CUXART, H., BOUGEAULT, PH. and REDELSPERGER, J. L., 2000: A turbulence scheme allowing for mesoscale and large-eddy simulations. *Quart. J. Roy. Meteor. Soc.*, **126**, 1-30.

KAIN, J. S. and FRITSCH J. M., 1990: A one-dimentional entraining/detraining plume model and its application in convective parametrizations. *J. Atmos. Sci.*, **47**, 2784-2802.

KAIN, J. S. and FRITSCH J. M., 1993: Convective parametrization for mesoscale models: the Kain-Fritsch scheme. *Meteor. Monogr.*, **46**, 165-170.

KOSSIN, J. P. and SCHUBERT, W. H., 1993: Mesovortices in Hurricane Isabel. *Bull. Amer. Meteor. Soc.*

KURIHARA, Y., BENDER, M. A. and ROSS, R. J., 1993: An Initialization Scheme of Hurricane Models by Vortex Specification. *Month. Wea. Rev.*, **121-7**, 2030–2045.

KURIHARA, Y., BENDER, M. A., TULEYA, R. E. and ROSS, R. J., 1995: Improvements in the

GFDL Hurricane Prediction System. *Month. Wea. Rev.*, **123-9**, 2791–2801.

NUISSIER, O., R.F. ROGERS and F. ROUX, 2005: A numerical simulation of Hurricane Bret on 22-23 August 1999 initialized with airborne Doppler radar and dropsonde data. *Quart. J. Roy. Meteor. Soc.*, **131**, 155-194.

ROUX, F., F. CHANE-MING, A. LASSERRE-BIGORRY and O. NUISSIER, 2004: Structure and evolution of intense tropical cyclone Dina on 22 January 2002: GB-EVTD analysis of single Doppler radar observations. *J. Atmos. Oceanic Technol.*, **21**, 1501-1518.

WANG, Y., 2002: Vortex Rossby Waves in a Numerically Simulated Tropical Cyclone. Part II: The Role in Tropical Cyclone Structure and Intensity Changes. *J. Atmos. Sci.*, **59-7**, 1239–1262.

YAU, M. K., LIU, Y., ZHANG, D. L. and CHEN, Y., 2004: A Multiscale Numerical study of Hurricane Andrew (1992).Part VI: Small-Scale Inner-core Structures and Wind Streaks. *Month. Wea. Rev.*, **132**, 1410-1433.