

TC ACTIVITY ON SWIO BASIN / CLIMATE CHANGE

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WMO RA-I Training course 2023



Climatology and observed trends

- RSMC data base
- Reanalysis activities
- Statistic and trends

Climate projections

- Global Climate Models
- Regional models for the SWIO

TC activity future evolution

- TC activity within the climate simulation
- Results and key messages



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Climatology and observed trends : RSMC best-track data base

Best-track data base maintained by RSMC La Réunion

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- First data : season 1847-1848 (mainly track information until 1960)
- > Partial information on intensity starts in the early 60s (begining of satellite observation)
- More detailed information on the intensity from 1976-1977 season
- Fairly homogeneous data from 1982-1983 season but still some need to improve the homogeneity especially for intensity







Climatology and observed trends : Reanalysis activity

- Ongoing reanalysis work for more than 10 years
- Based on Hursat satellite image archive (season 1978-1979 to 1997-1998)
- Best-tracking activity in order to review all parameters describing cyclone's track, intensity (min pressure and max wind) and structure (strong wind extensions).

Ref. period 41 seasons 1982-1983 → 2022-2023	Tropical storms- cyclones > 33kt	Tropical cyclones > 63kt	Intense tropical cyclones > 89kt	Very intense tropical cyclones > 115kt
Before reanalysis	402 (9,8)	208 (5,1)	121 (3,0)	17 (0,5)
After partial reanalysis	401 (9,8)	208 (5,1)	137 (3,3)	28 (0,7)

	Tropical storms- cyclones > 33kt	Tropical cyclones > 63kt	Intense tropical cyclones > 89kt	Very intense tropical cyclones > 115kt
41 seasons 1982-1983 → 2022- 2023	9,8	5,1	3,3	0,7
Last 10 seasons 2013-2014 → 2022- 2023	10,4	5,8	3,7	1

Climatology and observed trends : Statistics and trends

Nb of Tropical Storm (TS) and Tropical Cyclone (TC)



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Possible increase of the number of TS and TC over 42 years but need for **further reanalysis work**

Possible increase of the conversion rate from TS to TC over 42 years



¢ RÉPUBLIQUE **Climatology and observed trends : Statistics and trends** FRANCAIŠE METEO FRANCE

Nb of Intense Tropical Cyclone (ITC) and Very Intense Tropical Cyclone (VITC)



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No significative trend for Intense and Very Intense Tropical Cyclones over 42 years.



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Poleward migration of LMI for very intense tropical cyclones : statistically unsignificant





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Global projections within the IPCC framework



To quantify how the climate might evolve under such socialeconomic scenarios, climate modeling centers ran their respective numerical models to feed a dataset named CMIP6 (Coupled Model Intercomparison Project - Phase 6). The IPCC AR6 report uses this set of global climate simulations to analyze past climate trends and project into the future.

For example: for the SSP3-7.0 scenario (in red on the graph on the right), the global average temperature could rise by almost 4.5°C on average by the end of the century, compared with the 1850-1900 reference period, with an uncertainty range of +/- 1°C due to numerical modelling.

- Definition of different « Shared Socioeconomic Pathways, SSP » combined with « Representative Concentration Pathways, RCP » to characterize the future evolution of Green House Gases responsible for global warming :
 - SSP1-2.6 (RCP 4.5), optimistic scenario: strong reductions in GHG emissions (international effort); net zero in 2080 (COP21 Paris Agreement aiming to limit global warming to below +2°C in 2100).
 - **SSP2-4.5** (RCP 4.5), intermediate scenario: continuation of current emissions until 2050; decrease thereafter.
 - **SSP5-8.5** (RCP 8.5), pessimistic scenario: high emissions; doubling by 2050; tripling by 2100; continuing demographic and economic growth; heavy dependence on fossil fuels.





Global Climate Models



Atmosphere : air

- **Hydrosphere** : water (oceans, rivers and lakes)
- **Lithosphere** : land (continental surfaces)
- **Biosphere** : plant cover
- **Cryosphere** : ice (snow cover, frozen ground, sea ice, icebergs and glaciers)

- Climate models simulate the interactions between the components of the climate system using numerical methods
- Climate models are composed of different sub-models, each one representing one component of the system
- These sub-models interact together through couplers that simulate heat, momentum and mass fluxes





Global Climate Models : CMIP6 experiment

(b) Change in global surface temperature (annual average) as **observed** and simulated using human & natural and only natural factors (both 1850–2020)







- More than 30 GCMs implemented by climate modeling groups spreaded all over the world
- Global CMIP6 interactive atlas :

https://interactive-atlas.ipcc.ch/



20*5

Global Climate Models : CMIP6 experiment

Anomalies de précipitations (%) à l'horizon 2080 période de référence 1981-2010

SSP585 - Trimestre AMJ - moyenne 22 modèles CMIP6



-50-45-40-35-30-25-20-15-10-5 0 5 10 15 20 25 30 35 40 45 50



Some regional evolution information available

But

Too low resolution (> 100km) to assess changes at local scale (especially for small Islands) and to represent Tropical Cyclones



Regional climate models

- To obtain regional-scale climate information from CMIP6 simulations on the globe, we apply "downscaling" techniques, both dynamic and statistical.
- \geq More precise quantification of the impact of global warming on precipitation and temperature on Reunion Island by the end of the century, as well as the evolution of cyclonic activity in our ocean basin.





 \rightarrow For dynamic downscaling, the French Regional Climate Model ALADIN was run at 12 km resolution over a large part of the south-western Indian Ocean. The domain covers most inhabited areas from the coast of Mozambique (33°E) to 74°E, as well as the main tropical cyclogenesis zone [2°S - 28°S].

@ 150 km

m

Relief MODELE GLOBAL CNRM-ESM2-1

14/21

ALADIN-CLIMAT-V6 12km SWIC itude relief Madagascar max : 2011 44°E 46°E 48°E 50°E

7 (m



Regional climate models : more realistic representation of Tropical Cyclones

CNRM-ESM2



ARPEGE-150 km : SLP (2012-02-10 at 18 UTC) / min Pmer : 990 hPa



ALADIN



ALA-12km [ARP-150 km] : SLP (2012-02-10 at 18 UTC) / min Pmer : 889 hPa





Projet RenovRisk-Cyclones : funded by Région Réunion (Interreg V), coordination LACy

ARPEGE-climat v6 model (streched grid, pole centered over the Indian Ocean) implemented by CNRM (F. Chauvin)

15 km resulution over SWIO basin ; SST prescrites (CMIP5,corrigées QQ))



Climat présent : 1965 – 2014

Climat futur : 2046-2094 scénario RCP8.5





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Regional climate models :

How is the TC activity reproduced (from a climatological point of vue) ?



ALADIN : proportion of Intense Tropical Cyclone too hight (tendancy to over-intensify)

 \rightarrow Strong bias in the intensity of Tropical Cyclones

ARPEGE and ALADIN : Main Development Area shifted towards the south-east

 \rightarrow Spatial bias

Trajectoires P625SIOT359srP1 (1980-2013)



Trajectoires SWIO12_CNRM_ESM2_1_HIST (1980-2013)



Regional climate models :

How is the TC activity reproduced (from a climatological point of vue)?



ALADIN-v6-SWIO12NBTTCT : 4,0NBCT : 3,6 (90 %)NBCTI : 2,9 (72 %)NBCTTI : 2,4 (60 %)

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Référence BT-CMRSNBTTCT : 9,8NBCT : 5,1 (52 %)NBCTI : 3,3 (34 %)NBCTTI : 0,7 (7 %)

PDF VMAX : BT-CMRS (black) - P625SIOT359srP1 (blue)VMAX en m/s

ARPEGE-v6-T359str NBTTCT : 9,3 NBCT : 4,0 (43 %) NPCTL : 2 6 (29 %)

 NBCTI
 : 2,6 (28 %)

 NBCTTI
 : 1,6 (17 %)

Over representation, in proportion, of intense or very intense TCs in ALADIN simulation

Distribution of systems ok but still too high rate of very intense.

Need to calibrate the data from both simulations in order to better fit with the observed distribution of the different TC categories



Results and publications

Recent past (historical period)	Future period (second half of the century)
ARPEGE-v6-T359str – Calibrated 1966-2013 NBTTCT : 10,2 NBCT : 5,2 (51 %) NBCTI : 2,3 (22 %) (20,1°S) NBCTTI : 0,45 (4,5 %) (19,6°S)	ARPEGE-v6-T359str – Calibrated 2046-2093 RCP8.5 NBTTCT : 6,9 NBCT : 4,7 (68 %) NBCTI : 3,1 (45 %) (20,9°S) NBCTTI : 0,52 (7,5 %) (22,4°S)
ALADIN-v6-SWIO12 – Calibrated 1981-2014 NBTTCT : 3,9 NBCT : 2,0 (51 %) NBCTI : 0,9 (23 %) NBCTTI : 0,23 (5,1 %)	ALADIN-v6-SWIO12 – Calibrated 2046-2093 SSP585 NBTTCT : 2,1 NBCT : 1,2 (57 %) NBCTI : 0,65 (31 %) NBCTTI : 0,25 (11,9%)

Julien Cattiaux, Fabrice Chauvin, Olivier Bousquet, Sylvie Malardel, Chia-Lun Tsai. Projected changes in the Sout hern Indian Ocean cyclone activity assessed from high-resolution experiments and CMIP5 models. Journal of Cli mate, American Meteorological Society, Society, 2020, 33 (12), pp.4975 -4991. 10.1175/jcli-d-19-0591.1. hal-025 16828

Leroux M.-D., Bonnardot F., Somot S., Alias A., Kotomangazafy S., A.-O. Ridhoine, P. Veerabadren, V. Amélie. Building Resilience Over The Southwest Indian Ocean: From CMIP6 Downscaling Towards Climate Services For Vulnerable Islands. 2023. In prep.for submission to Meteorology



Key messages for SWIO basin

Recent passed

- No observed significative trend
- Suspected southward extension of the LMI mean latitude

Future

- Possible decrease of the total number of tropical systems (tropical storms and cyclones all together, around 20 % reduction)
- Expected slight increase of the frequency of intense and very intense tropical cylones (strong increase of their proportion)
- Simulations suggest an increase of the maximum lifetime intensity (LMI)
- Pursuit of the poleward extension of the LMI area
- Expected increase of rainfall associated with tropical cyclones