

FINAL REPORT PROGRAM LEFE

LEFE IMAGO & GMMC	Sea Turtles for Ocean Research and Monitoring – Preliminary phase (Pre-STORM)	Years 2020 – 2022
<p>PI: Olivier Bousquet - olivier.bousquet@meteo.fr Laboratoire de l'Atmosphère et des Cyclones (UMR8105) Main participating Institutions : MERCATOR-Ocean (FR), IFREMER (FR), CEDTM/KELONIA (FR), Inria (FR), TAAF (FR), SIF (SEY), Nelson Mandela University (RSA), CTV (MOZ), Sydney Marine Institute (AUS), ADSEI/PNM (COM)</p>		<p>Contribution to (international projects): <i>ReNovRisk Cyclones and Climate Change</i> (2017-2021, EU) <i>STORM-IO</i> (2021-2023, EU)</p> <p>Other (national) funding sources: STORM-SAT (CNES/TOSCA, from 2020 on)</p>
<p>Context: Sea turtle-borne oceanographic measurements have been conducted in the Southwest Indian Ocean (SWIO) since January 2019 to assess the relevance of biologging observations for monitoring and modelling tropical ocean properties, and further understanding the ecology of all sea turtle species living in this area.</p> <p>Objectives / scientific questions: Investigate the relationship between cyclonic activity and the properties of the oceanic mixed layer in the SWIO basin, and estimate the potential of these observations to evaluate the performance of both ocean models and Earth observation satellites in this region.</p> <p>Main results: The Sea Turtle for Ocean Research and Monitoring (STORM) research program started in January 2019 through a feasibility study conducted within the framework of the International “ReNovRisk Cyclone” project (funding by INTERREG-V Indian Ocean 2014-2020). As the first results obtained from Reunion Island were extremely encouraging, the project team decided to expand these research activities by seeking funding from other research organizations. In 2020, the “PreSTORM” project was funded by the CNRS, under the programme LEFE IDAO/ GMMC, quickly followed by the TOSCA project “STORM-SAT” (CNES/TOSCA). In June 2021, a large-scale international project, “STORM-IO” was eventually funded by EU under the frame of the INTERREG-V Indian Ocean program to extend these activities to the entire SWIO.</p> <p>As of January 2023, more than 100 animals of various species (loggerhead, leatherback, green, hawksbill and Olive Ridley) have been equipped with Argos or GPS Platform Terminal Transmitters (PTD) from 6 marine reserves in the Indian Ocean area: Reunion Island (40), Aldabra (Seychelles, 10), iSimangaliso (South Africa, 20), Moheli National Park (Comoros, 12), Europa and Tromelin islands (TAAF, 20). In addition to provide accurate position and depth data at high space-time resolution (200 m, 5 minutes), all tags also provided surface and in-depth temperature measurements and, for some of them, salinity (15) and fluorescence (10) data, over periods ranging from a few weeks to 20 months (Figure 1).</p> <p>Observations collected during STORM have been used for many oceanographic and marine ecology research applications {e.g., climatology of the tropical Indian Ocean and evaluation of satellite observations and ocean model forecast outputs (Bousquet et al. 2020, Barthe et al. 2021), fine-scale oceanographic process studies (Bousquet et al. 2021), ecology of sea turtles living in the SWIO area (Laforges et al. 2023, Monsinjon et al. 2023, Niviere et al. 2023)}. However, one of the most original aspects of the STORM program lies in the study of atmospheric interactions in the vicinity of tropical cyclones developing in the SWIO basin. Since 2019, a dozen sea turtles have been trapped in (or in the immediate vicinity of) tropical cyclones, allowing to collect precious and unique information on the evolution of the storms during their cyclogenesis or intensification phases (Figure 2). In this regard, another particularly promising application of STORM consists in assimilating these observations in the regional ocean model NEMO Indian-Ocean to improve ocean and coupled ocean-atmosphere model forecasts in cyclonic conditions (ongoing work).</p> <p>This program, by far the most ambitious and original of its kind ever conducted in this part of the world, now involves about 25 research institutions worldwide and has been established as one of the key assets of AniBOS (animal Borne Ocean Sensors), the new marine animal observation subnetwork of the Global Ocean Observing Programme (GOOS).</p>		

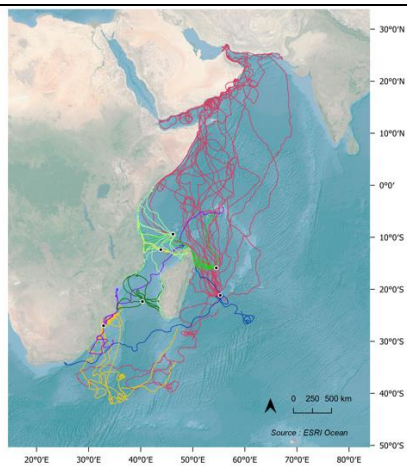
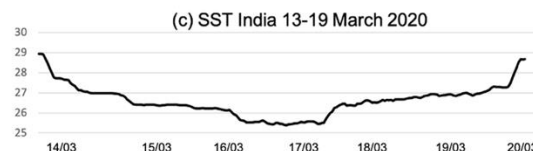
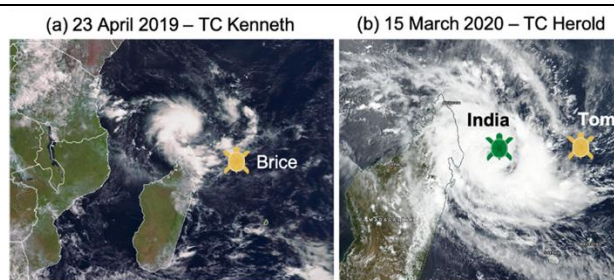


Figure 1



(c) SST India 13-19 March 2020

Figure 2

Figure 1: Tracks of the 102 sea turtles equipped under the STORM program since January 2019 (as of December 2022).

Figure 2: Examples of sea turtles (ST) trapped in tropical cyclones (TC) during STORM. Satellite images of (a) TC KENNETH on 15 April 2019 and (b) TC HEROLD on 15 March 2020. Sea turtle symbols show the location of ST “Brice” during the cyclogenesis of TC KENNETH (left panel) and of STs “India” and “Tom” during the intensification phase of TC HEROLD (right panel). (c) Evolution of sea surface temperature ($^{\circ}\text{C}$) in the immediate vicinity of TC HEROLD, as measured by ST “India” between 14 and 20 March 2020 within the area ($51.93\text{--}52.62^{\circ}\text{E}$; $13.9\text{--}14.67^{\circ}\text{S}$). From Bousquet et al. (2021).

Future of the project: STORM is still being supported by CNES under the frame of the TOSCA program. A new large scale international and multidisciplinary project aiming at extending STORM activities to other emblematic marine species of the SWIO should soon be submitted to ANR under the frame of the new research program [SIOMPA](#) (which has been designed by the PI during his secondment to Expertise France in South Africa).

Number of publications, communications and theses

Six published or submitted articles in peer-reviewed journals and five currently in preparation, including an overview paper; Six communications in international conferences; Numerous communications in various medias (e.g., TF1, Euronews, France TV, newspapers and magazines...).

- Bousquet, O. ; Dalleau, M. ; Bocquet, M. et al. (2020): Sea Turtles for Ocean Research and Monitoring: Overview and Initial Results of the STORM Project in the Southwest Indian Ocean. *Front. Mar. Sci.* 7:594080. <https://doi.org/10.3389/fmars.2020.594080>
- Bousquet, O. ; Barruol, G. ; Cordier, E. et al. (2021). Impact of Tropical Cyclones on Inhabited Areas of the SWIO Basin at Present and Future Horizons. Part 1: Overview and Observing Component of the Research Project RENOVRIK CYCLONE. *Atmosphere* 2021, 12, 544. <https://doi.org/10.3390/atmos12050544>
- Laforges, A. ; Gaspar, P. ; Barat, A. et al. (2023): Uncovering loggerhead (*Caretta caretta*) navigation strategy in the open ocean through the consideration of their diving behaviour. Submitted to the *Journal of Royal Society Interface*.
- Monsinjon, J. ; Laforge, A. ; Gaspar, P. ; Barat, A. ; Bousquet, O. ; et al. (2023). Intra-species variability in migratory movement of hawksbill turtles in South-West Indian Ocean. Submitted to the *Journal of Royal Society Interface*.
- Niviere, M.; Ballorain, K.; Bourgea, J. et al. (2023). Intra-species variability in migratory movement of hawksbill turtles in South-West Indian Ocean. Submitted to *Biological Conservation*
- Bousquet, O.; Ciccione, S.; Nel, R.; Fletcher-Dogley, F. et al. (2023). Do sea turtles equipped with environmental satellite tags behave like Argo drifters? Summary of four years of observations collected during the Sea Turtle for Ocean Research and Monitoring (STORM) research programme. In preparation for *Front. Mar. Sci.*

Data availability

All STORM data are currently available from a ftp server accessible from the STORM program website at <http://www.storm.re>, but will be soon relocated to a more perennial server.

