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StormR: An R package to quantify and map the tropical storms and cyclones' winds characteristics

Baptiste Delaporte¹, Thomas Arsouze^{2,3¶}, Gunnar Keppel^{3,4}, Swen Jullien⁵, Christophe Menkes⁶, and Thomas Ibanez³

¹ Independent Researcher, France ² CIRAD, UMR AMAP, F-34398 Montpellier, France ³ AMAP, Univ Montpellier, CIRAD, CNRS, INRAE, IRD, Montpellier, France ⁴ UniSA STEM and Future Industries Institute, University of South Australia, GPO Box 2471, Adelaide, SA 5001, Australia ⁵ Ifremer, Univ. Brest, CNRS, IRD, Laboratoire d'Océanographie Physique et Spatiale (LOPS), IUEM, Plouzané, France ⁶ ENTROPIE, IRD, CNRS, Ifremer, Université de la Réunion, Université de la Nouvelle-Calédonie ¶ Corresponding author

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Summary

StormR is an R package allowing the easy extraction of storm track data from a provided database and the generation of surface wind fields (speed and direction) as reconstructed from storm track data and a parametric cyclone model. Then StormR allows us to compute three summary statistics (the maximum sustained wind speed, the power dissipation index, and the duration of exposure to winds reaching a given wind speed along the cyclone life span) and to plot the results. We suggest to use the IBTrACS (International Best Track Archive for Climate Stewardship) database as input ([Knapp et al., 2010, 2018](#)). This database provides a fairly comprehensive record of tropical storms and cyclones with a 3-hours temporal resolution since 1841. However any storm track data can be used as long as the mandatory fields are provided.

Storm track data can be extracted using a specified point location, a user defined spatial polygon shapefile, a country or a cyclone basin name. The main functions of the StormR package allow us to generate wind speed and direction fields as reconstructed from storm track data and a parametric cyclone model. Different models and models combinations can be chosen by the user. By default the spatial resolution is set to 2.5 min (~4.5 km at the equator), but a finer spatial resolution of 30 s (~1 km at the equator) and coarser spatial resolutions of 5 min (~9 km at the equator) or 10 min (~18.6 km at the equator) can be set. The temporal resolution is set to 1 hour by default but finer resolutions of 45 min, 30 min, or 15 min can be set.

Once wind speed is generated for each cell or specific location and each time step, StormR functions can compute summary statistics on wind speed over the lifespan of a storm. Summary statistics encompass the maximum sustained wind speed, the power dissipation index or total power dissipated by a tropical storm ([Emanuel, 1999, 2005](#)), and the duration of exposure to winds reaching defined speed thresholds. By default the duration of exposure is computed for each Saffir-Simpson Hurricane Scale threshold values for tropical cyclone categories, i.e., 33, 43, 50, 58, and 70 $m.s^{-1}$ ([Simpson, 1974](#)), but can be defined by the user.

Statement of need

Globally, an average of 86 tropical cyclones per year occurred over the past four decades ([Murakami et al., 2020](#)). These disturbances cause severe damages to ecosystems, infrastructures, and peoples ([Costanza et al., 2008](#); [Parks et al., 2021](#); [Uriarte et al., 2019](#)). Climate change has likely increased the proportion of category 3-5 tropical cyclones on the Saffir-Simpson

hurricane wind scale over the past four decades and climate scientists are predicting with high confidence that the proportion of the most intense and potentially the most destructive tropical cyclones (category 4-5) would increase by +10% even if warming is limited to 1.5°C (Intergovernmental Panel on Climate Change, 2023). StormR R package responds to the need for an easy to use tool that helps to better understand winds generated by storms and tropical cyclones in relation to potential damages.

To our knowledge two R packages are available on R CRAN: HurreconR (Boose, 2023) and hurricaneexposure (Anderson et al., 2020). As highlighted by their names, these two packages have a strong focus on the North American basin where tropical cyclones are named hurricanes. Another important limitation of those packages is that they both rely on a single model to reconstruct wind speed. The HurreconR package relies on the HURRECON model (Boose et al., 2001, 2004), a modification of the Holland (1980) model, and the hurricaneexposure package relies on the Willoughby's model (Willoughby et al., 2006). Many model exists and none of these is the best for all tropical cyclones and storms (Yan & Zhang, 2022). Compared to those packages, the StormR R package allows to reconstruct wind behaviour for tropical storms and cyclones anywhere, anytime, and this with a set of models including those used in HurreconR and hurricaneexposure packages.

Package workflow

The workflow of the stormR R package consists of four main consecutive steps:

- 1- The `defStormsDataset()` function is used to create a `stormsDataset` object from a NetCDF file, e.g., exported from a storm track database such as IBTrACS database (<https://www.ncei.noaa.gov/products/international-best-track-archive>) (Knapp et al., 2010, 2018).
- 2- The `defStormsList()` function is used to perform queries on the `stormsDataset` object and extract storms of interest based on their location and date of occurrence. The track data for these storms are then stored into a `stormsList` object. The `plotStorms()` function can be used to see the extracted data.
- 3- The `temporalBehaviour()` and `spatialBehaviour()` functions are used to compute wind speed and direction and three summary statistics: the maximum sustained wind speed, the power dissipation index, and the duration of exposure to winds reaching a given wind speed along the life span of the cyclones. The `temporalBehaviour()` function returns time series at specific point locations (list of data frames) while the `spatialBehaviour()` function returns spatial data (rasters).
- 4- The `writeRast()` and `plotBehaviour()` functions are used to export or see the final results.

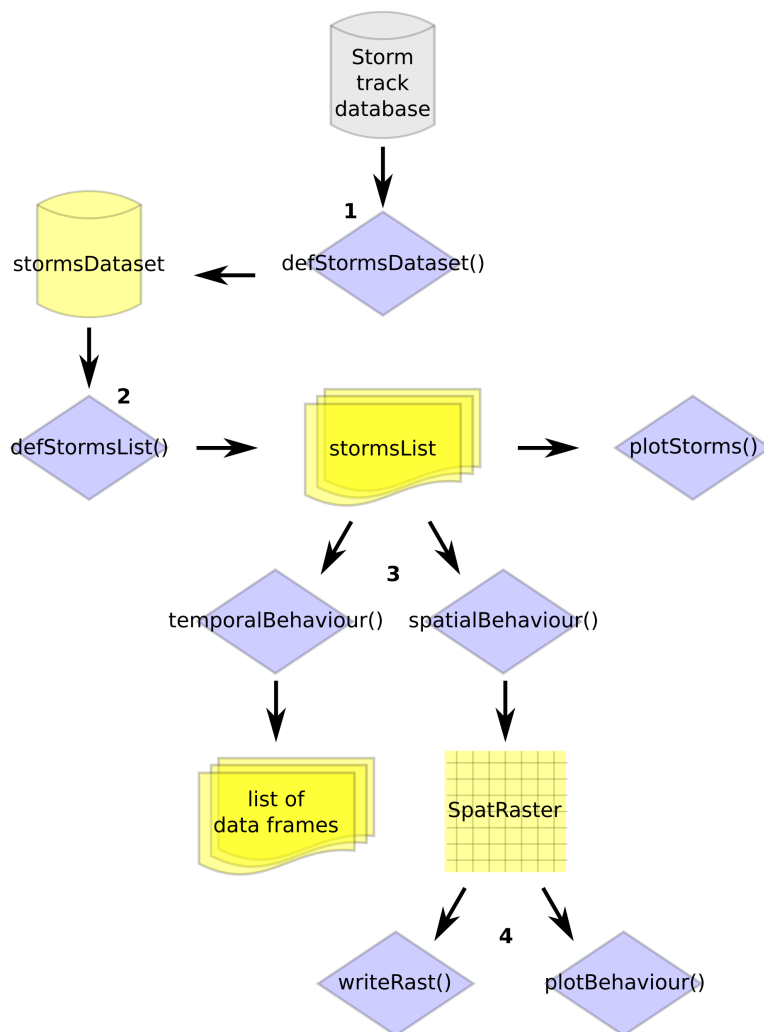


Figure 1: Simplified workflow and main functions of the stormR R package. External storm track database in grey, main functions in blue, and R objects created by the stormR functions in yellow.

Example

A test_dataset is provided with the StormR package. This test data set is comprised of the track data of nine storms that occurred near Vanuatu and New Caledonia between 2015-2016 and 2020-2021, respectively. Figure 2 shows how the spatialBehaviour() function can compute different products for the tropical cyclone Pam (2015) near Vanuatu.

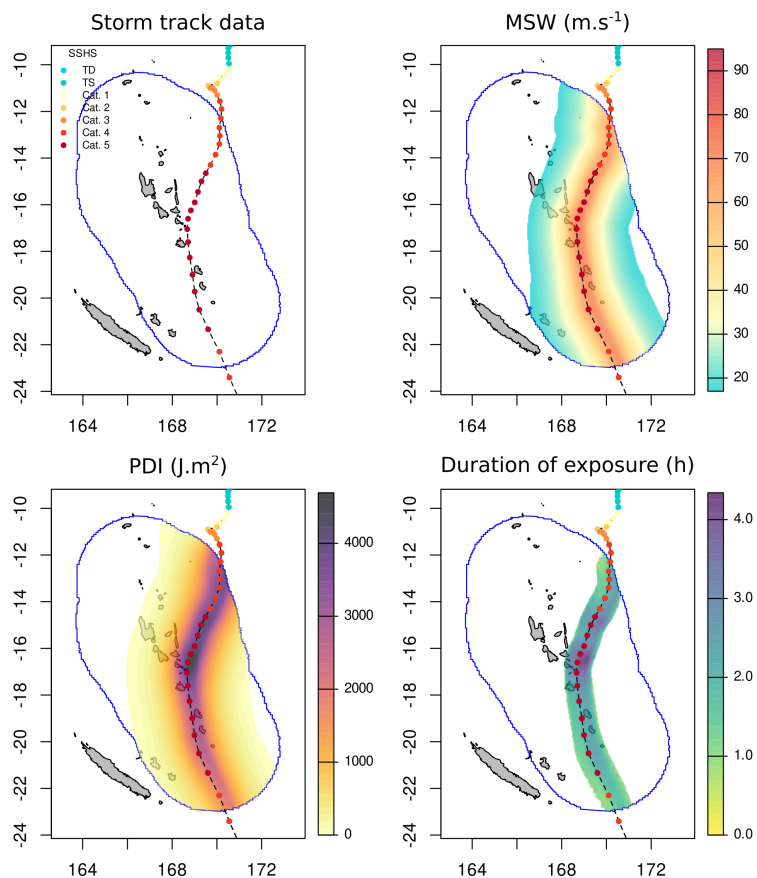


Figure 2: Example of outputs for the tropical cyclone Pam (2015) nearby Vanuatu with default settings. Storm track data (SSHS=Saffir-Simpson Hurricane Scale, TD=tropical depression, TS=tropical storm), maximum sustained wind (MSW), power dissipation index (PDI), and duration of exposure to wind stronger than 58 m.s^{-1} . Plots were generated with the `plotStorms()` and `plotBehaviour()` functions as shown in the [spatialBehaviour](#) article.

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