StormR: A R package to quantify and map the behaviour of winds generated by tropical storms and cyclones in space and time

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Summary

`StormR` is an R package allowing to easily extract storm track data, to generate wind speed and direction fields, and to compute summary statistics characterising the behaviour of winds generated by tropical storms and cyclones. By default, we suggest to use the IBTrACS database [International Best Track Archive for Climate Stewardship] (https://www.ncei.noaa.gov/products/international-best-track-archive) (Knapp *et al.*, (2010), (2018)). This database provides a fairly comprehensive record of worldwide 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 to generate wind speed and direction fields as re-constructed from storm track data and a parametric cyclone model. Different models and models combination can be chose 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 spatial resolution of 45 min, 30 min, or 15 min can be set.

Once wind speed is generated for each cell 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 can cause severe damages to natural and built ecosystems. Climate change has likely increased the proportion of category 3-5 tropical cyclones on the Saffir–Simpson hurricane wind scale (Simpson 1974) over the past four decades and climate scientists are also 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 of an easy to use tool that helps to better understand and map damages and potential damages caused by winds generated by storms and tropical cyclones.

To our knowledge two R packages `HurreconR` (E. Boose 2023) and `hurricaneexposure` (Anderson et al. 2020) are available on R CRAN. 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 (E. R. Boose, Chamberlin, and Foster 2001; E. R. Boose, Serrano, and Foster 2004), a modification of the Holland (1980) model, and the `hurricaneexposure` package relies on the Willoughby's model (Willoughby, Darling, and Rahn 2006). Many model exists and none of these is the best for all tropical cyclones and storms (Yan and 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 design

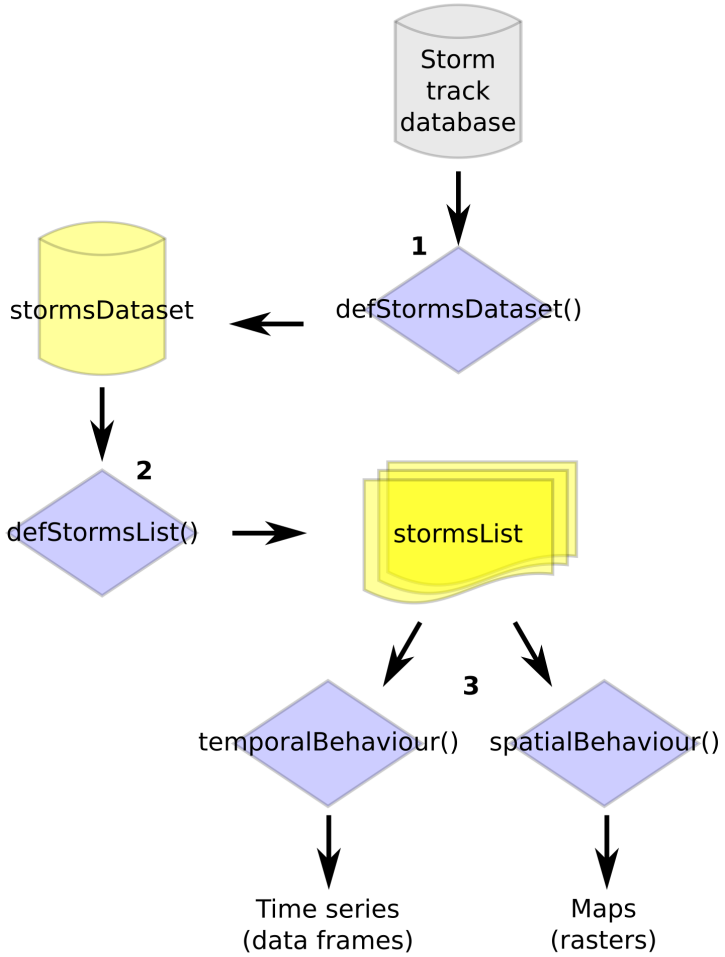

Figure 1: **Figure 1** stormR work flow

Workflow three main steps:

Storm track database, e.g., IBTrACS database (https://www.ncei.noaa.gov/products/international-best-track-archive) (Knapp *et al.*, (2010), (2018))

NetCDF format.

1- Use the `defStormsDataset()` function to create a `stormsDataset` object

2- Use the `defStormsList()` to extract storm track data for storms of interest selected using location and time of occurrence listed into `stormsList` object

3- Use the `temporalBehaviour()` and `spatialBehaviour()` functions to

The `spatialBehaviour()` function allows computing wind speed and direction for each cell of a regular grid (i.e., a raster) for a given tropical cyclone or set of tropical cyclones. The `product="Profiles"` argument allows producing 2D wind fields during the lifespan of the cyclone at a temporal resolution of up to 15 minutes. The `spatialBehaviour()` function also allows to compute three associated summary statistics: the maximum sustained wind speed (`product="MSW"`), the power dissipation index (`product="PDI"`) and the duration of exposure to winds reaching defined speed thresholds along the life span of the cyclones (`product="Exposure"`).

Example

A `test_dataset` is provided with the `StormR` package. This test data set comprises the track data of nine storms that occurred near Vanuatu and New Caledonia between 2015-2016 and 2020-2021, respectively. Figure 1 shows how the `spatialBehaviour()` function can compute different products (i.e., "MSW", "PDI", "Exposure") for the tropical cyclone Pam (2015) near Vanuatu.

Acknowledgements

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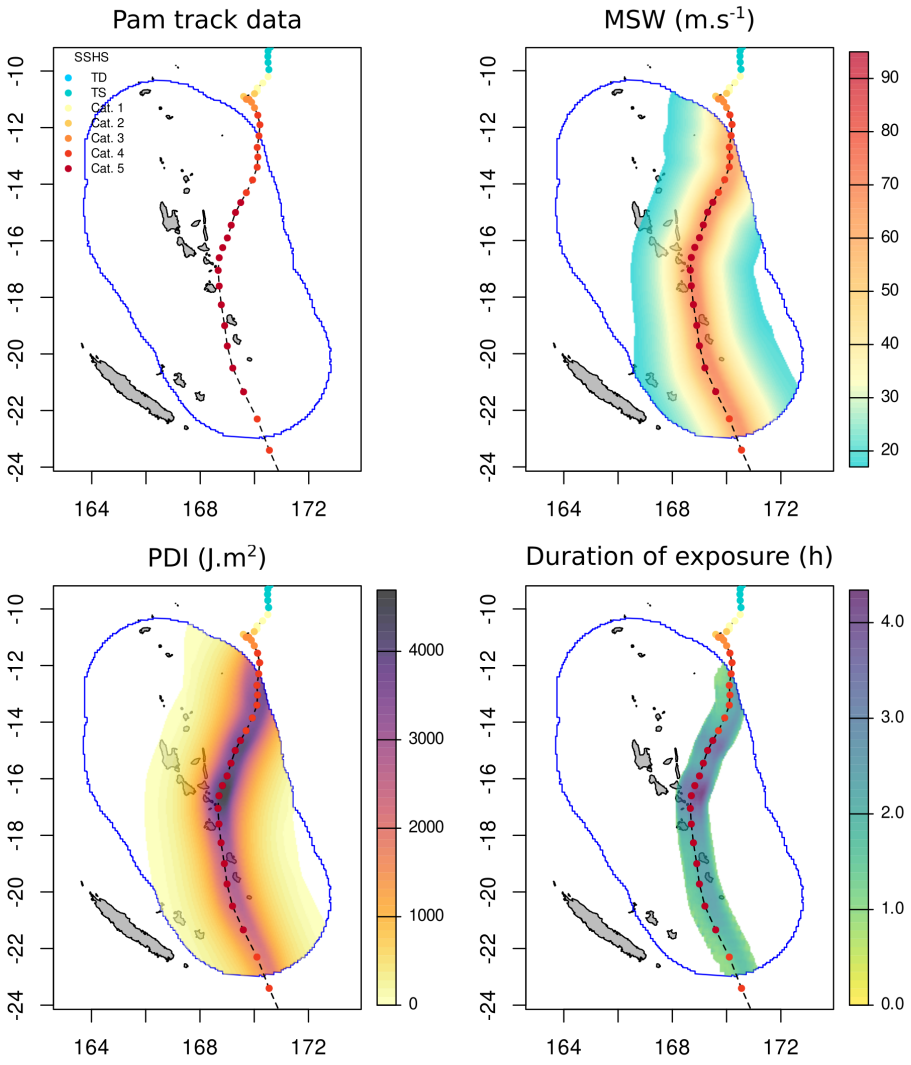

Figure 2: **Figure 2** Maximum Sustained Wind, Power Dissipation Index and Duration of Exposure to wind stronger than 58 $m.s^{-1}$ for the tropical cyclone Pam (2015) in Vanuatu

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