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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, 2005, 1999) 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 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.

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.

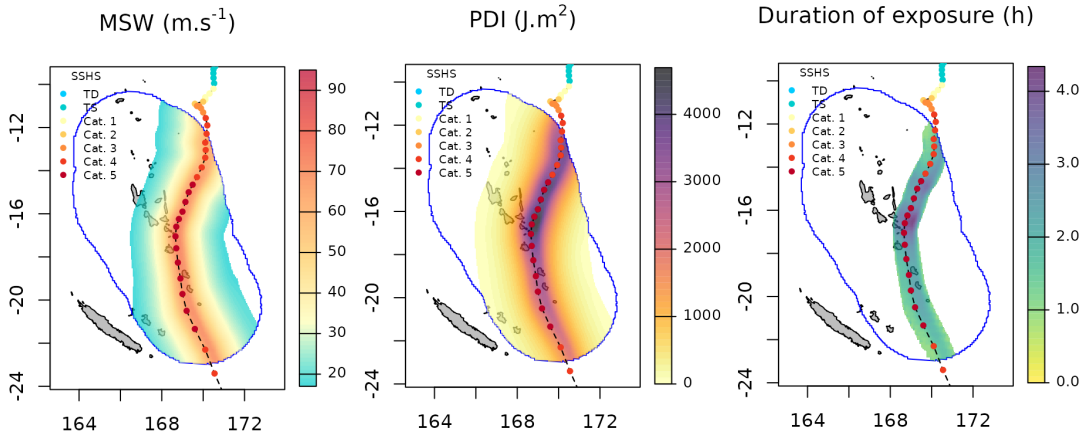

Figure 1 Maximum Sustained Wind, Power Dissipation Index and Duration of Exposure to wind stronger than 58 $m.s^{-1}$ for the tropical cyclone Pam (2015) in Vanuatu.

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References

Anderson, B., Yan, M., Ferreri, J., Crosson, W., Al-Hamdan, M., Schumacher, A., & Eddelbuettel, D. (2020). *hurricaneexposure: Explore and map county-level hurricane exposure in the united states*. https://cran.r-project.org/package=hurricaneexposure

Boose, E. (2023). *HurreconR: Models hurricane wind speed, wind direction, and wind damage*. https://CRAN.R-project.org/package=HurreconR

Boose, E. R., Chamberlin, K. E., & Foster, D. R. (2001). Landscape and Regional Impacts of Hurricanes in New England. *Ecological Monographs*, *71*(1), 27–48. https://doi.org/10.1890/0012-9615(2001)071%5B0027:LARIOH%5D2.0.CO;2

Boose, E. R., Serrano, M. I., & Foster, D. R. (2004). Landscape and Regional Impacts of Hurricanes in Puerto Rico. *Ecological Monographs*, *74*(2), 335–352. https://doi.org/10.1890/02-4057

Emanuel, K. A. (2005). Increasing destructiveness of tropical cyclones over the past 30 years. *Nature*, *436*(7051), 686–688. https://doi.org/10.1038/nature03906

Emanuel, K. A. (1999). The power of a hurricane: An example of reckless driving on the information superhighway. *Weather*, *54*(4), 107–108. https://doi.org/10.1002/j.1477-8696.1999.tb06435.x

Holland, G. J. (1980). An Analytic Model of the Wind and Pressure Profiles in Hurricanes. *Monthly Weather Review*, *108*(8), 1212–1218. https://doi.org/10.1175/1520-0493(1980)108%3C1212:AAMOTW%3E2.0.CO;2

Intergovernmental Panel on Climate Change (Ed.). (2023). Technical Summary. In *Climate Change 2021 – The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 35–144). Cambridge University Press. https://doi.org/10.1017/9781009157896.002

Knapp, K. R., Diamond, H. J., Kossin, J. P., Kruk, M. C., & Schreck, C. J. I. (2018). *International Best Track Archive for Climate Stewardship (IBTrACS) Project, Version 4*. https://doi.org/https://doi.org/10.25921/82ty-9e16

Knapp, K. R., Kruk, M. C., Levinson, D. H., Diamond, H. J., & Neumann, C. J. (2010). The International Best Track Archive for Climate Stewardship (IBTrACS): Unifying Tropical Cyclone Data. *Bulletin of the American Meteorological Society*, *91*(3), 363–376. https://doi.org/10.1175/2009BAMS2755.1

Murakami, H., Delworth, T. L., Cooke, W. F., Zhao, M., Xiang, B., & Hsu, P.-C. (2020). Detected climatic change in global distribution of tropical cyclones. *Proceedings of the National Academy of Sciences*, *117*(20), 10706–10714. https://doi.org/10.1073/pnas.1922500117

Simpson, R. H. (1974). The Hurricane Disaster—Potential Scale. *Weatherwise*. https://www.tandfonline.com/doi/abs/10.1080/00431672.1974.9931702

Willoughby, H. E., Darling, R. W. R., & Rahn, M. E. (2006). Parametric Representation of the Primary Hurricane Vortex. Part II: A New Family of Sectionally Continuous Profiles. *Monthly Weather Review*, *134*(4), 1102–1120. https://doi.org/10.1175/MWR3106.1

Yan, D., & Zhang, T. (2022). Research progress on tropical cyclone parametric wind field models and their application. *Regional Studies in Marine Science*, *51*, 102207. https://doi.org/10.1016/j.rsma.2022.102207