Bioextremes: an open-source tool to accelerate remote sensing studies on extreme weather events and ecosystem stability

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New space-borne sensors such as laser scanners and imaging spectrometers will allow researchers to understand the relationship between biodiversity, ecosystem response, and extreme weather events (EWE) at macroscales. To accelerate cutting-edge remote-sensing-based studies on ecosystem resistance and resilience (a.k.a. ecosystem stability) and decision-making on adaptive management, we are developing the Bioextremes open-source tool. Here, we present our pilot study for the Atlantic basin mangroves, historically affected by droughts and hurricanes.

Bioextremes tool

Our Python tool allows users to download and extract metrics from large amounts of NASA's Global Ecosystem Dynamics Investigation (GEDI) laser scanner and ERA-5 reanalysis climate datasets, as well as to analyze the relationships between historical EWE and vegetation structural and functional metrics from landscape to global scales. We developed an efficient code to download pieces of GEDI from NASA Earth Data that correspond to our areas of interest only, as well as subset the metadata and integrate metrics of interest for each 25-m-resolution footprint. The EWE metrics calculation admits varying climate variables, time windows, and extremeness thresholds and is transferable across ecosystems.

Methods

Using NCAR Research Data Archive API, we downloaded 0.25-degree-resolution ERA-5 climate datasets from 1979 to 2018. We calculated the normals and extreme weather dimension metrics of rainfall (mean total precipitation rate) and wind speed (10m wind gust), such as intensity (1), duration (2), frequency (3), and time since the last event (4). We also downloaded, filtered, and integrated GEDI metrics that correspond to forest height (RH98) and vertical profile metrics such as Plant Area Index (PAI) and Foliage Height Diversity (FHD). We extracted the median values of each GEDI metric within each ERA-5 pixel and fitted quantile regressions to visualize the effect of EWE metrics on vegetation structural metrics per percentile.

Results

Our preliminary results showed that extreme wind and drought affect mangrove structural and functional diversity in the Atlantic Basin. While extreme wind demonstrated to have a higher impact on the upper quartile of structural metrics (**Fig. 1B and 1C**), drought doesn't show the same pattern. Mangrove diversity displayed effects from all wind metrics. Only the frequency of droughts showed a stronger relationship with mangrove structure (**Fig. 1E and 1F**).

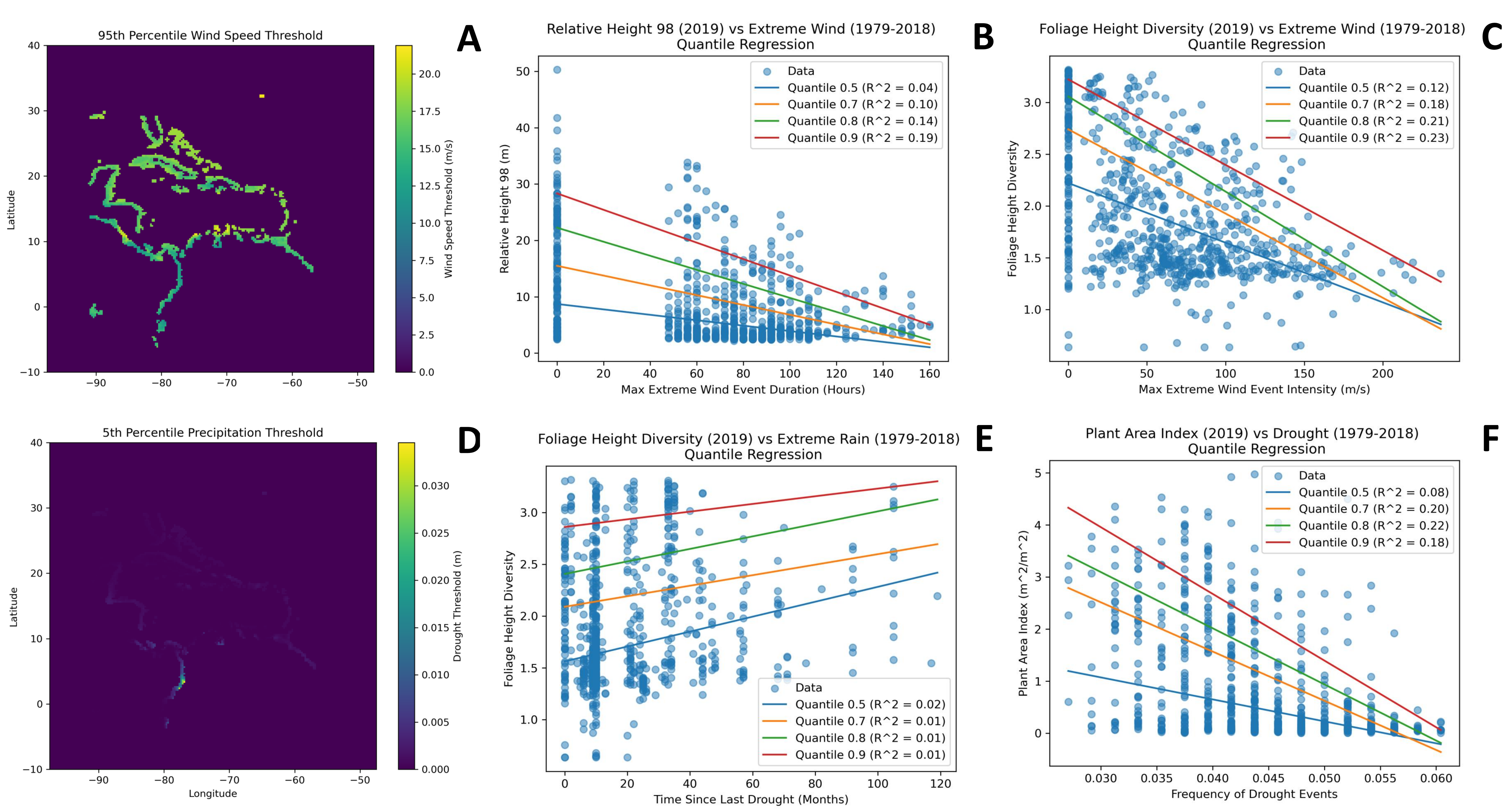

Figure 1. A) 95th percentile of wind speed threshold; B) Relative height and extreme wind duration regression; C) Foliage height diversity and extreme wind intensity regression; D) 5th percentile of precipitation threshold; E) Foliage height diversity and time since the last drought regression; F) Plant area index and frequency of drought regression. All regressions showed a p-value < 0.005.

Next steps

The next steps of our open-source software development are to advance the integration of different EWE metrics over time (1), expand the analysis to mangroves worldwide (2), and extract ecosystem functional metrics, such as richness, evenness, and divergence, from 30-m-resolution DESIS imaging spectroscopy over focal areas (3).

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