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Effect of Coral Reefs on Wave Height

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For more information:

Motivation

Coral reefs act as physical barriers, influencing wave behaviour and offering natural coastal protection from extreme weather events. As climate change continues to strengthen the frequency and intensity of those events, the vulnerability of densely populated coastal regions intensifies. In concurrence, coral reefs also experience the consequences of climate change, altering their wave attenuation characteristics. Consequently, the examination of the influence of coral reefs on wave attenuation has gained paramount significance in the last two decades.
Several field and model experiments have quantified this effect, yet there is still an absence of a comprehensive global study performed with remote sensing observations .Recent advancements in satellite altimetry offer significant potential for precise and extensive observation of coral reefs' impact on wave height, particularly in coastal regions.

Data

- Significant wave height (SWH) multi-mission cross-calibrated observations from **Sea State Climate Change Initiative** version 3 (Sea State CCI).[Piollˊe et al., 2022]

- SWH estimates from fifth-generation ECMWF reanalysis **ERA5**.[Hersbach et al., 2023]

- Locations and extends of coral reefs from **Allen Coral Atlas**.[Allen Coral Atlas, 2022]

Methods

- SWH observations are categorized on ‘reef’ and ‘before reef’ values for each satellite repeat ground track through distance calculation to reef polygons.

- SWH attenuation on coral reefs is calculated by comparing SWH at the reef border to the mean SWH within the reef. This assessment spans global and regional scenarios, varying sea states and hard coral cover, to evaluate coral reefs' performance under diverse condition.

- ERA5 data is interpolated onto altimetry ground tracks using three-dimensional linear interpolation to enable direct comparison of the two datasets in the same locations.

Results

Global analysis

Statistical analysis of 18 years of SWH attenuation calculated from satellite altimetry reveals a noteworthy trend: 78.8% of observations indicate a reduction in SWH. As expected, SWH is usually higher before encountering the reef, but this finding highlights the capability of satellite altimetry to detect and quantify changes in wave characteristics resulting from the presence of coral reefs.

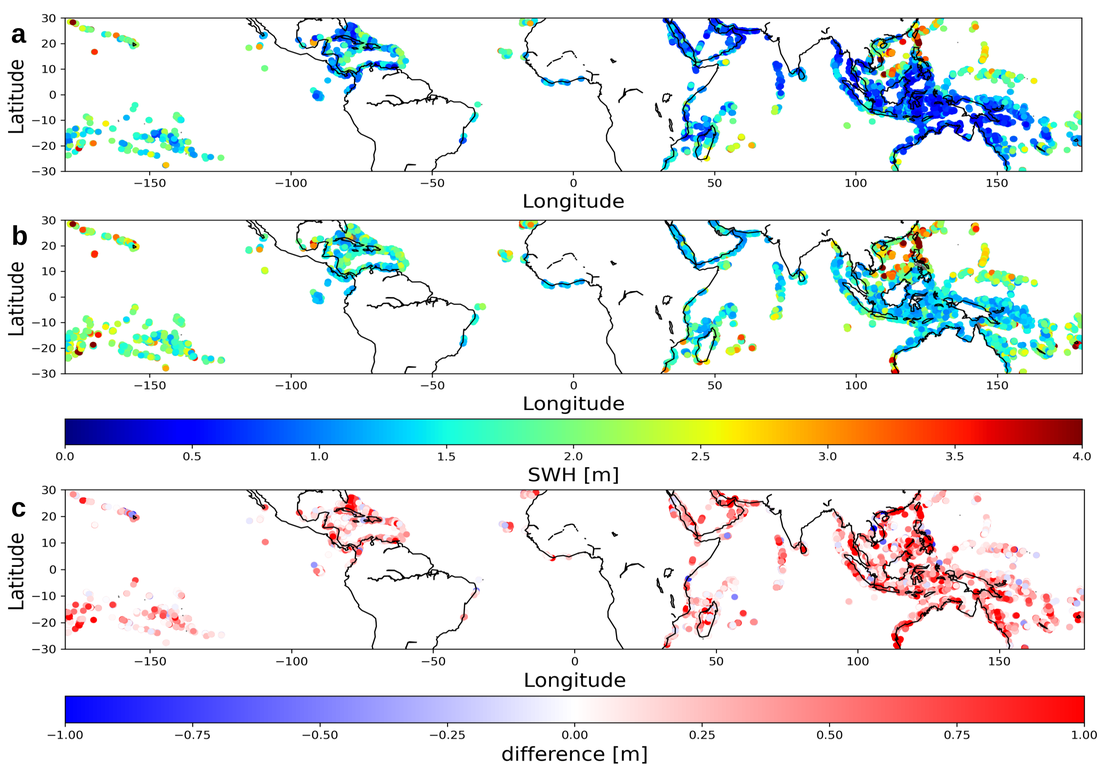

Figure 1. Map of mean SWH on coral reefs (a), before reefs (b) and their differences (c)computed from Sea State CCI dataset for years from 2002 to 2020.

Dataset comparison

The results of the comparative analysis of satellite altimetry and ERA5 interpolated on satellite tracks revealed a remarkable agreement between the two datasets, yielding a correlation coefficient of 0.724. Furthermore, the central tendencies, variability, and distributions characterizing the computed SWH attenuations consistently aligned between the two datasets.

Calculation	Sea State CCI v3	ERA5 on a grid	ERA5 on satellite tracks
Mean SWH attenuation [m]	0.48	0.24	0.37
Standard deviation [m]	0.46	0.34	0.44
Positive differences [%]	78.8	79.6	81.2

Table 1. Mean attenuation, standard deviation and percentage of positive differences computed from 18 years of data for all datasets.

SWH attenuation for different sea states

As the sea state increases, the likelihood and the amount of wave height attenuation also rise. Notably, for the highest sea states, waves lose on average 50% of their height while travelling across a coral reef. The significant reduction in SWH for higher sea states is evident in the analysis of both datasets.

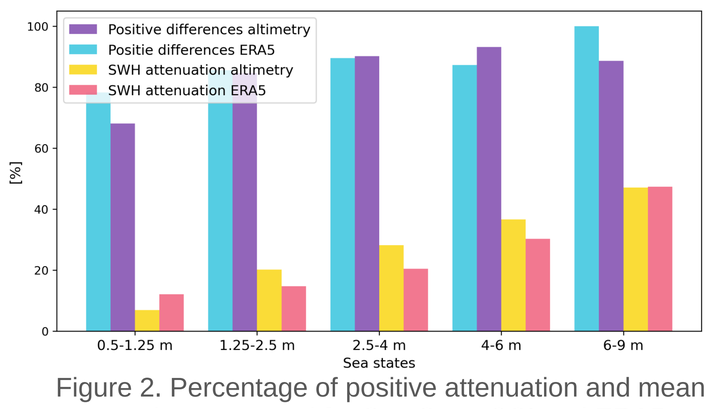

Figure 2. Percentage of positive attenuation and mean attenuation computed for Sea State CCI and ERA5 interpolated on satellite tracks.

Influence of structural complexity of coral reefs

After the strong El Niño events in 1997-98 and 2015-16, coral reefs experienced substantial loss of their hard coral cover, leading to alterations in their wave attenuation ability. Mean SWH attenuation was computed for different regions using the Sea State CCI dataset (Tab 2). The results indicate a noticeable decline in observed positive attenuations across most regions, with the worst outcomes recorded in 2018, a year characterized by the lowest global percentage of hard coral cover.

Region	Mean Attenuation 2018 [%]	Mean Attenuation 2009 [%]	Mean Attenuation 2002 [%]
East Asian Seas	31.6	35.8	33.0
Pacific region	27.3	26.7	25.7
Australian	30.2	32.4	30.5
Caribbean	27.9	29.9	28.1
West Indian Ocean	24.4	25.1	24.8
Red Sea	31.3	35.3	34.6
South Asia	22.4	26.9	21.9
East Tropical Pacific	27.5	29.2	28.2

Table 2. Mean SWH attenuation on coral reefs computed for eight significant regions for years with different coral structural complexity.

Summary and outlook

- Satellite altimetry shows high degree of agreement with ERA5 interpolated on satellite tracks.
- About 80% of observations show a decrease in SWH as the wave travels over coral reef.
- Improving altimetry retracking algorithms and high spatial resolution enable a more detailed examination of coral reefs' impact on wave characteristics compared to the modeled data.
- Global coverage and long record of altimetry observations allows for global and regional analysis of coral reefs’ influence on wave characteristics, taking into account various initial conditions.

References
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