Storm Clustering in the Mediterranean Sea

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OUTLINE

- Motivation for Storm Analysis
- Data Set
- Storm clustering identification technique
- Analysis for single location
- Basin scale trends
MOTIVATION

Occurrence of different coastal storms in a short time has been studied in the context of storm driven erosion of beaches and dunes. Storms occurring in quick succession may result in greater beach erosion than the cumulated erosion induced by single storm of higher return periods.

Vousdoukas et al., 2012; Coco et al., 2014; Splinter et al., 2014; Karunarathna et al., 2014; Dissanayake et al., 2015
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2 storms cluster
3 storms cluster
x single storm

Karunarathna et al., 2014
MOTIVATION
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Repetition Time/Recovery Time
Coco et al., 2014

Dissanayake et al., 2015
MOTIVATION

ICODEP - Impact of Changes in the Foreshore on coastal Defence Performance

The overall dynamics of the beach depends both on the energy level of the storm sequence and on the position of individual storm in the group.

Large Wave Flume, GWK
There is a fast and automatized procedure to identify storm clusters?

Coco et al., 2014

Analysis of wave storms sequences

Karunaratna et al., 2014
THE MEDITERRANEAN SEA, DATA SET

The analysis has been carried out in the Mediterranean Sea (microtidal)

We employed two data set

- Buoy measures – Rete Ondametrica Nazionale (RON)

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<th>Station Name</th>
<th>From</th>
<th>To</th>
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</table>
THE MEDITERRANEAN SEA, DATA SET

The analysis has been carried out in the Mediterranean Sea (microtidal)

We employed two data set

- Wave hindcast 1979-2016 @ 0.1° in lon-lat and 1 hr time res
Hindcast validation vs wave buoys (Mentaschi et al., 2015)
STORM CLUSTERING IDENTIFICATION TECHNIQUE

The occurrence of time clustering of wave storms is carried out through an analysis of wave storms sequences.

Sequences of natural events such as earthquakes, rainfall, wildfires, can be seen as realizations of stochastic point processes.

Here time series of sea states are considered.

Sequence of storms are be extracted from a time series of sea states (POT, different percentiles).
STORM CLUSTERING IDENTIFICATION TECHNIQUE

Sequence of storms are be extracted from a time series of sea states (POT, different percentiles) – Point Process

[Map and graph showing storm clustering in the Mediterranean Sea]
STORM CLUSTERING IDENTIFICATION TECHNIQUE

Point processes are studied by defining equally spaced time windows of duration $\tau$ and counting the events in each window. The result is a sequence of counts $N_k$ ($k = 1,...,M$, where $M$ is the number of time windows)

$$AF(\tau) = \frac{\left\langle \left[ N_{k+1}(\tau) - N_k(\tau) \right]^2 \right\rangle}{2 \left\langle N_k(\tau) \right\rangle}$$

A point process is called fractal when a number of the relevant statistics shows scaling with related scaling exponent.

$$AF(\tau) = 1 + \left( \frac{\tau}{\tau_1} \right)^\alpha$$

A Poissonian Process

$$\alpha \sim 0 \rightarrow AF \sim 1$$

Non-Poissonian Process

$$\alpha > 0 \rightarrow AF > 1$$

(Non-Homogeneous Poisson Process)
STORM CLUSTERING IDENTIFICATION TECHNIQUE

$$AF(\tau) = 1 + \left(\frac{\tau}{\tau_1}\right)^{\alpha}$$

fractal onset time that marks the lower limit for significant scaling

Different ranges of $\tau$ can reveal different time scaling (clustering) of the same process through different slopes of $AF$ due to different kind of forcing

Cyclic (Non-Homogeneous) Poisson processes can show $AF>1$ for time scale associated to cyclic components (Serinaldi & Kilsby, 2013)

It is necessary to identify and separate the timescales at which clustering occurs from those at which the point process is Poissonian

To this end it is necessary to compare the $AF$ pattern found in the wave time series with that of a process of known properties
STORM CLUSTERING, BUOYS VS HINDCAST

Ponza

Mazara

Allan Factor

τ [days]
STORM CLUSTERING VS SIMULATED N-H POINT PROCESS

It is necessary to identify and separate the timescales at which clustering occurs from those at which the point process is Poissonian.

To this end it is necessary to compare the AF pattern found in the wave time series with that of a process of known properties.

The rate function of the simulated Non-Homogeneous Poisson process is generated as a sum of sinusoidal components with amplitudes, periods and phases obtained from the Fourier analysis of the reference signal.
STORM CLUSTERING IN THE MED SEA
STORM CLUSTERING IN THE MED SEA

Seasonal Cycles

Departure from the Poisson regimes

No Clustering
STORM CLUSTERING IN THE MED SEA

Slope $\alpha$ for $0.5 < T < 3$ days

15th International Workshop on Wave Hindcasting and Forecasting & 6th Coastal Hazard Symposium

Storm Clustering in the Mediterranean Sea

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STORM CLUSTERING IN THE MED SEA

Slope $\alpha$ for $0.5 < T < 10$ days
STORM CLUSTERING IN THE MED SEA
CONCLUSIONS

Presence of a departure from the Poisson distribution for time scales shorter than $\tau < 1200$ hours (50 days)

For $\tau > 50$ days the arrival of storms is dominated by seasonal and inter-seasonal oscillations (cyclic Poisson process)

Persistence of cyclonic events explains the behavior at smaller scales. Clustering at scales of days indicates that meteorological conditions favor the occurrence of multiple events in few days

Where these persistent conditions do not occur, the arrival of storms is well described as a cyclic-Poisson process

$AF$ values do not allow to draw conclusions on whether this deviation from a Poisson distribution is large or small for the phenomenon at hand, as there is no comparison with other basins
THANK YOU FOR YOU ATTENTION!