L'évolution des événements extrêmes du niveau de la mer

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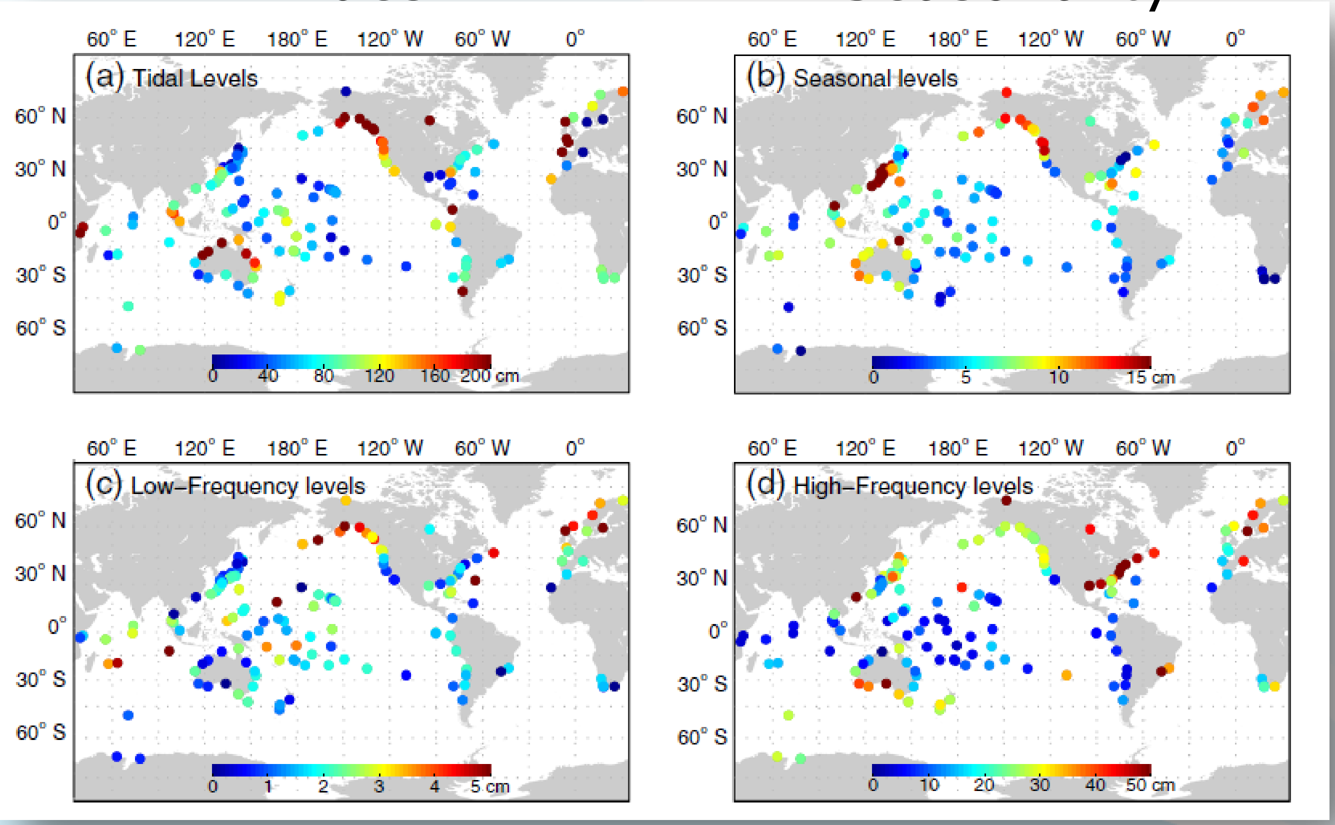
Motivation

Contributions to extreme sea levels

Tides

Seasonality



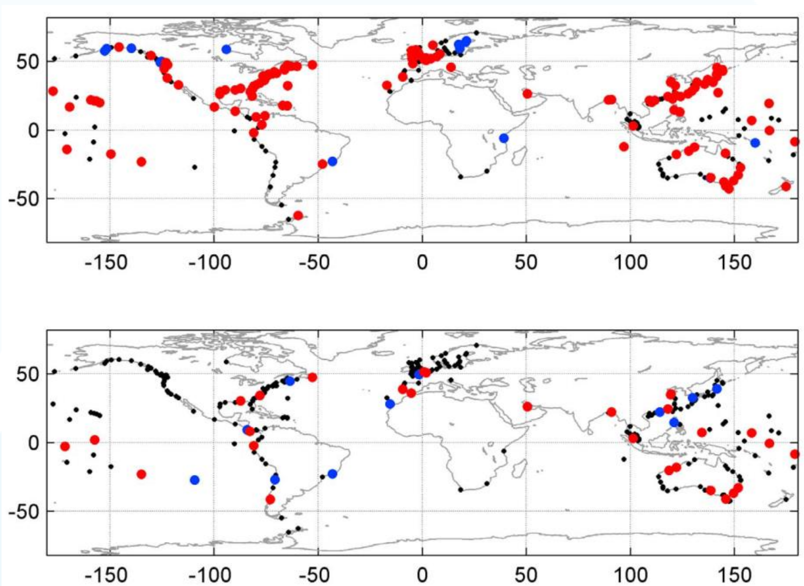
Mean sea level

Merrifield et al (2013)

Surges

Motivation

Changes in extremes



Trends in 99th percentiles of sea level (top) and reduced to their annual median (bottom)

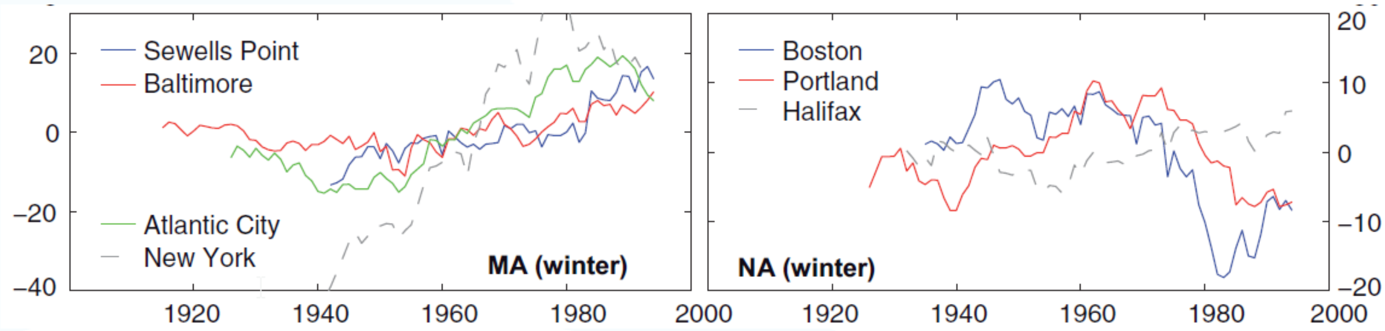
Menéndez and Woodworth (2010)

"there is low confidence of any trend or long term change in tropical or extratropic storm frequency or intensity"

IPCC AR5

Increase in extreme sea levels are mostly the result of rise in mean sea level

How to detect changes/trends in extreme sea levels?



Changes in 100-years return levels at tide gauge stations

Wahl and Chambers (2015)

- Parametric (adjusting a distribution with temporally changing parameters)
- Non-parametric (e.g. using time windows and adjust a distribution)
- All rely in Maximum Likelihood Estimations… which does **not always converge**

Outline

Sea level data set and data processing

Methodology: state space models for extreme occurrence and for extreme intensitity

Changes in extreme intensities

Changes in extreme occurrences

Large scale coherency

Conclusions

Sea level data set and processing

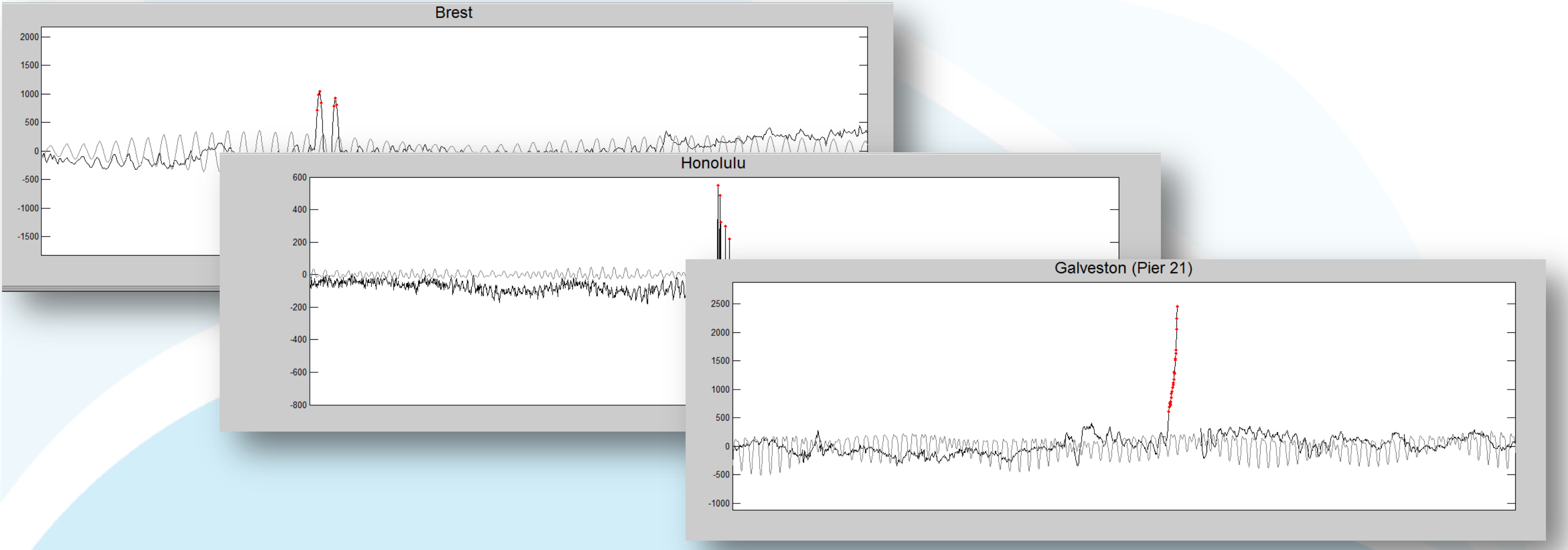
675 stations (GESLA+UHSLC)

L>50 yrs and 70% completeness

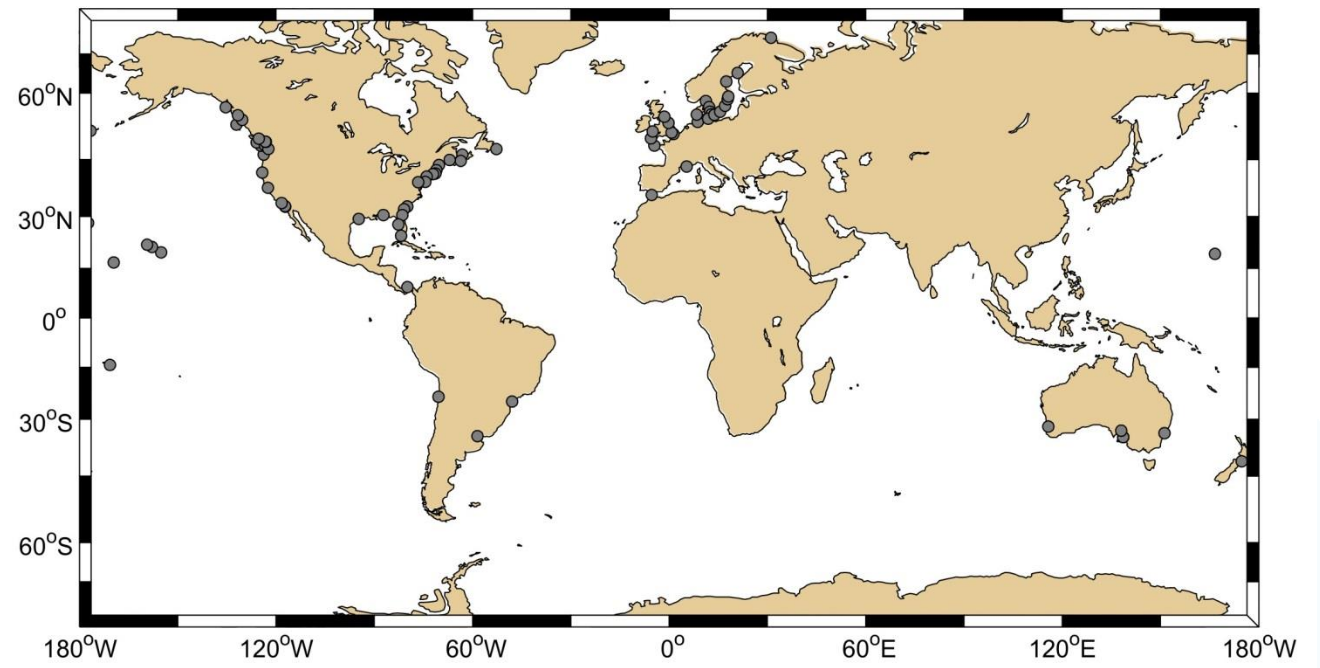
~123 stations

Removal of tides, seasonal cycle and MSL

Visual quality control



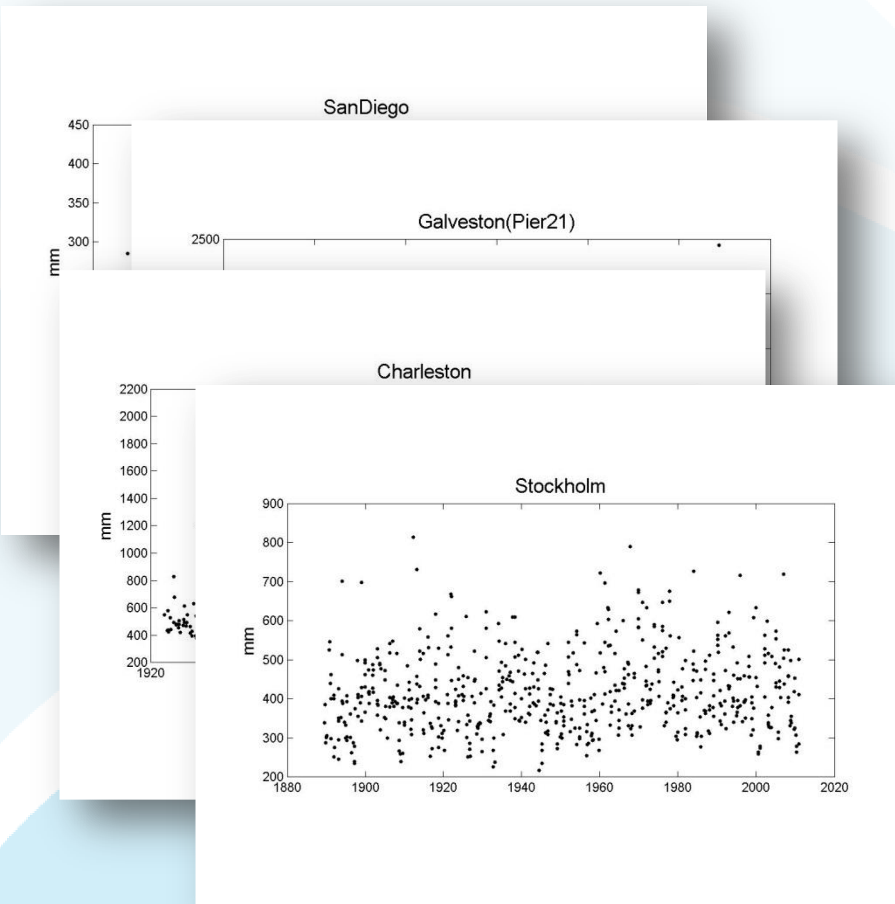
Sea level data set and processing



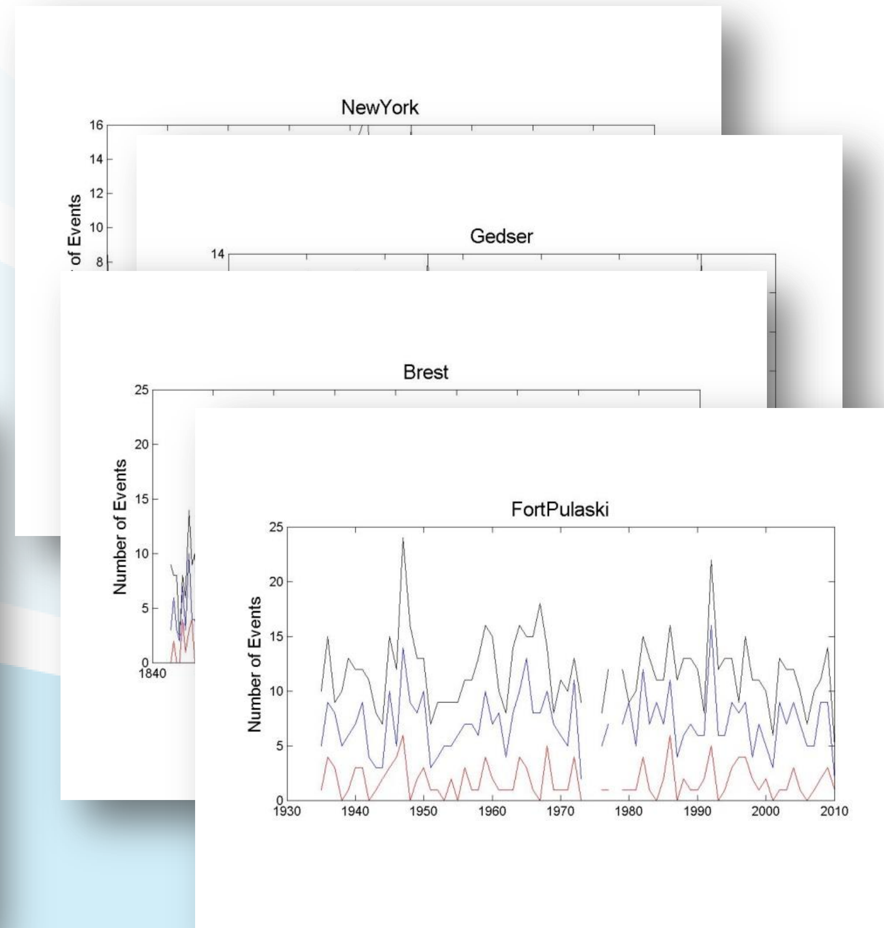
77 tide gauge stations unevenly distributed

Sea level data set and processing

Intensity of extremes (5 events per year)



Frequency of extremes (events exceeding the 99th, 99.5th and 99.9th percentiles)



Methodology: state space approach

Sequence of observations from time 1 to N $\{Y_1, Y_2, \ldots, Y_N\}$

Sequence of unobserved (hidden) states $\{X_1, X_2, \ldots, X_N\}$

State Equation $X_{t+1} = G_t(X_t) + \omega, \quad \omega \sim \mathcal{N}_d(0, W_t)$

Observation Equation $Y_t = F_t(X_t) + \upsilon, \quad \upsilon \sim \mathcal{N}_m(0, V_t)$

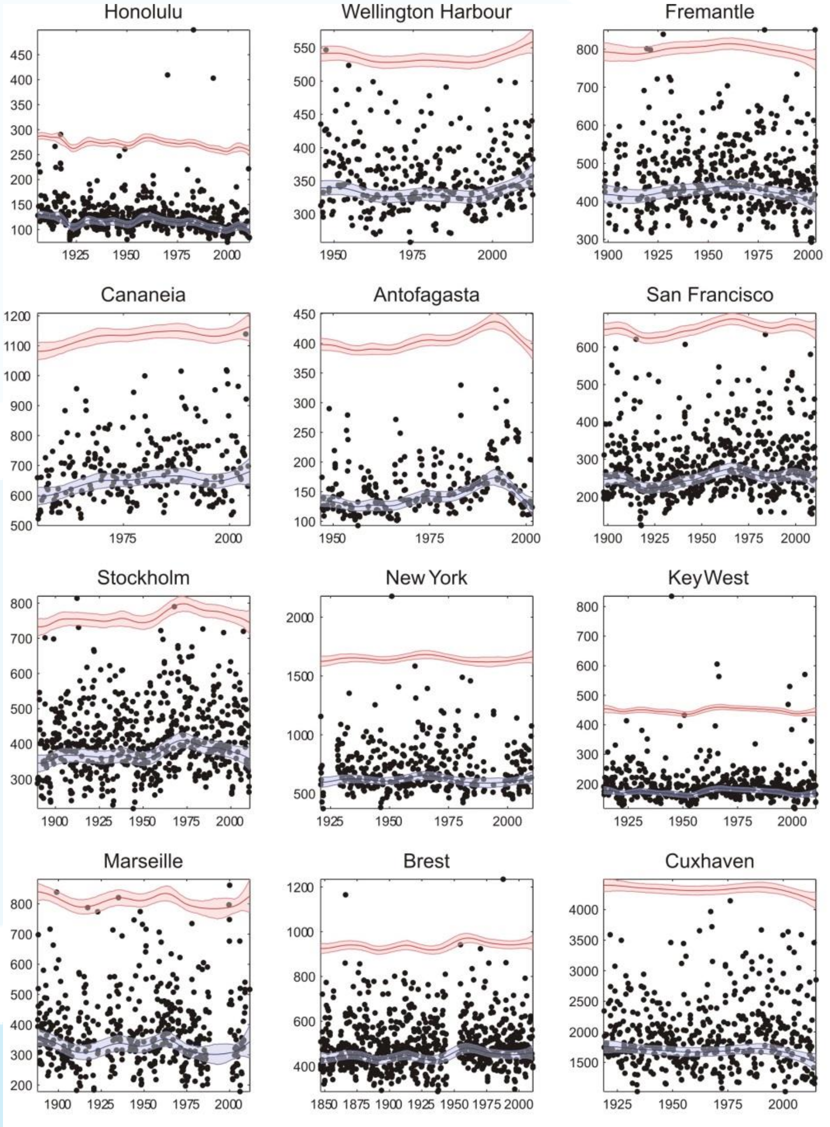
$p(X_t | y_{1:N})$

Methodology: state space approach

Advantages

- No assumptions are made regarding the temporal variability of the observations
- Uneven data sampling and gaps in the time series are allowed

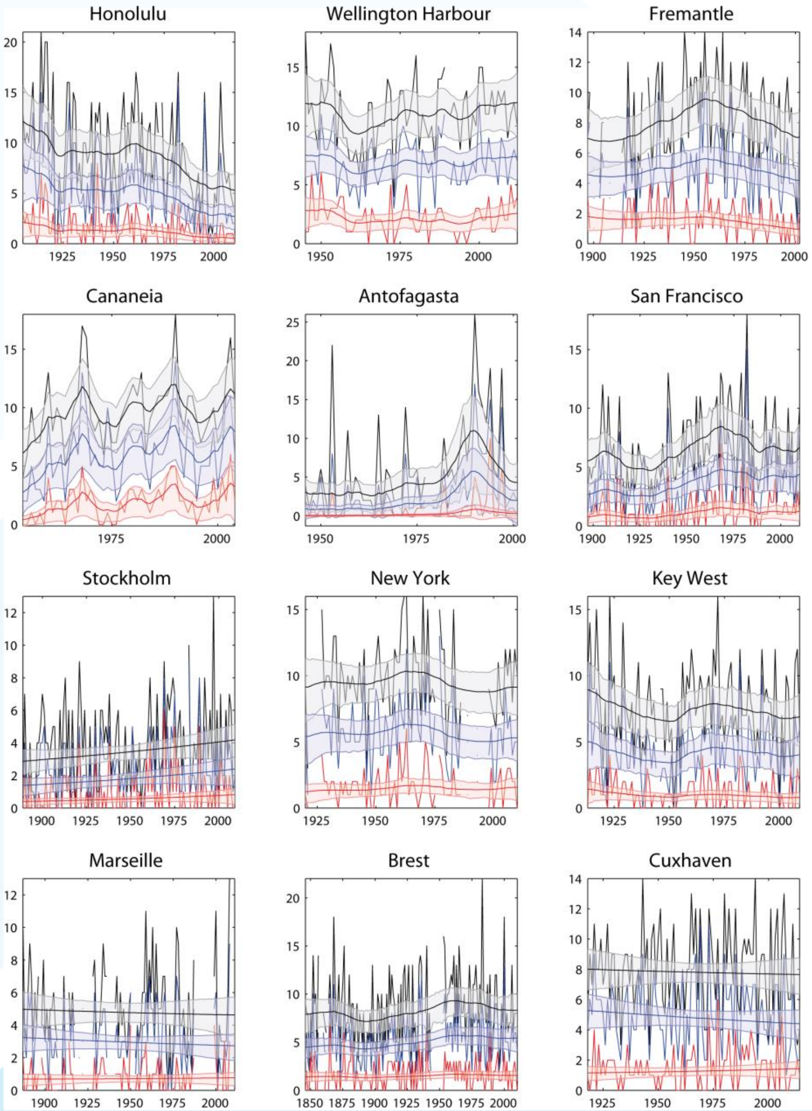
Changes in extreme intensity



...for selected sites

Extreme sea levels and time varying location parameter and return level

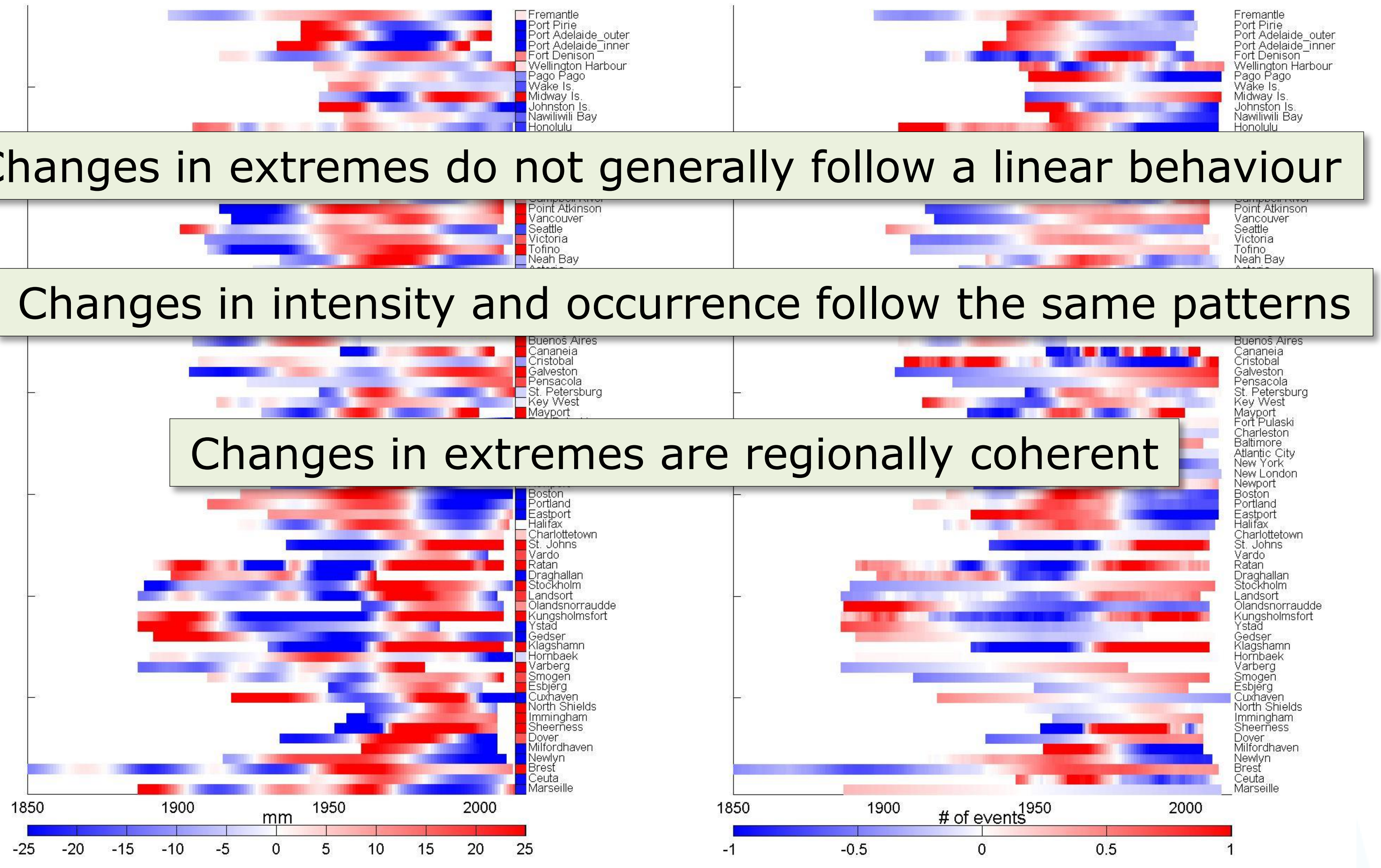
Changes in extreme occurrence



…for selected sites

99th percentile
99,5th percentile
99,9th percentile

Large scale coherency

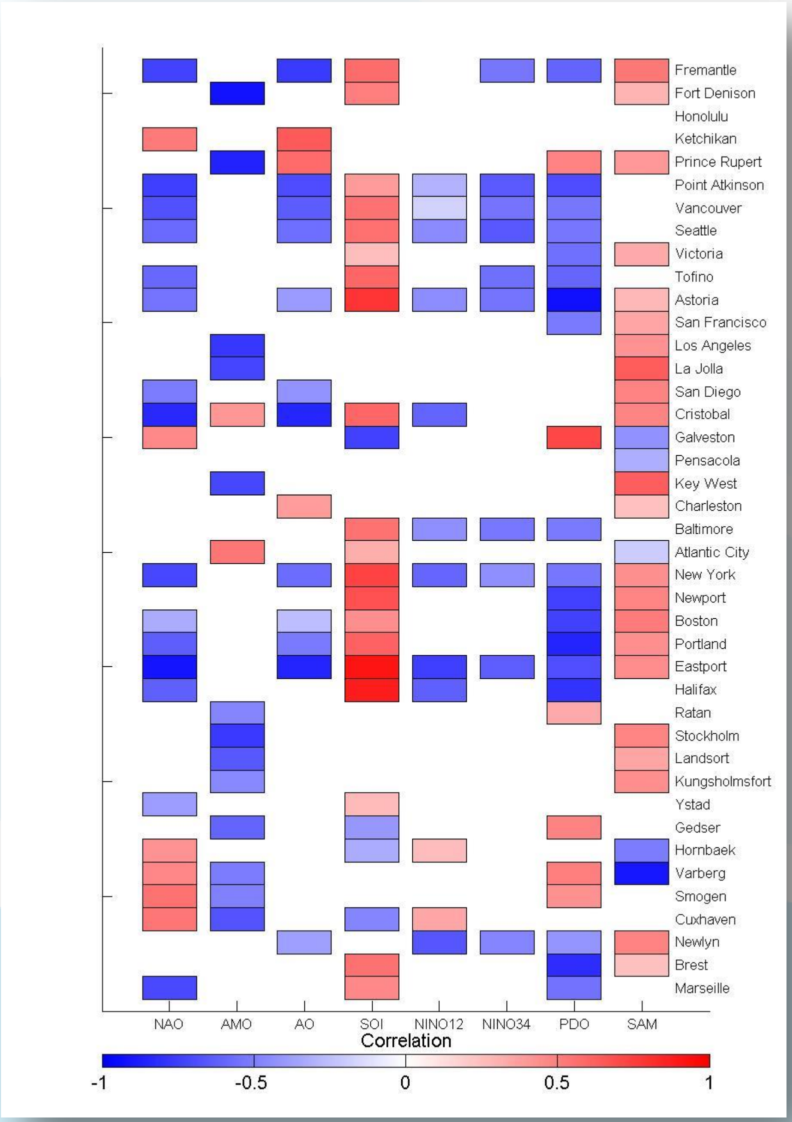


Changes in extremes do not generally follow a linear behaviour

Changes in intensity and occurrence follow the same patterns

Changes in extremes are regionally coherent

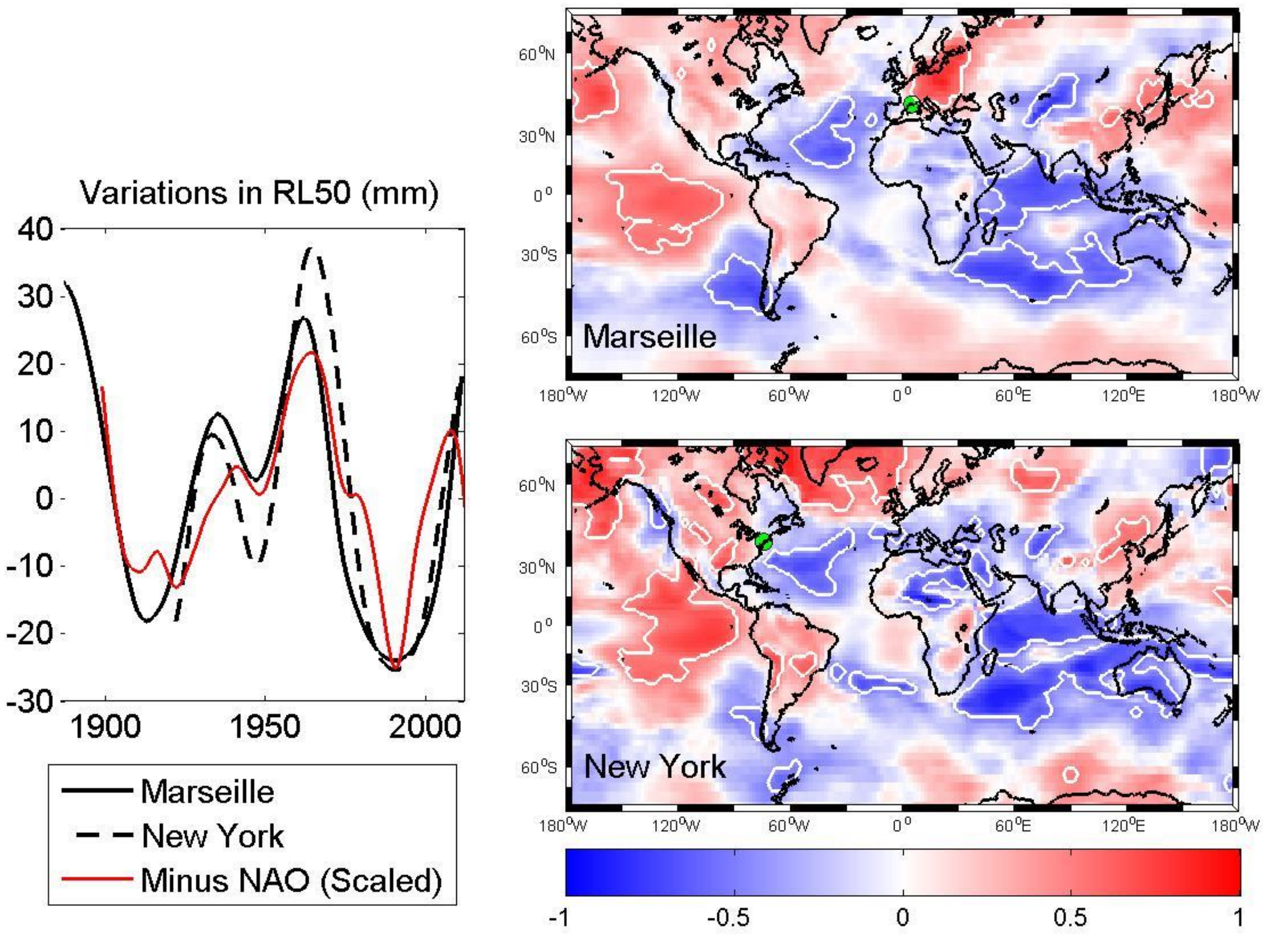
Large scale climate drivers



Correlations between climate indices and 50-years return levels

Large scale climate drivers

Sea level extremes in Marseille and New York and their relationship with the NAO



Conclusions

- A careful and detailed quality control is important for any extreme sea level study.
- Long term changes in extremes (and uncertainties) are robustly estimated using SSM, even when time series are uneven and gappy.
- Changes in extreme intensity and frequency at decadal time scales vary accordingly.
- Changes in extremes at decadal time scales are geographically consistent, suggesting a relationship with large scale climate drivers.

All the details can be found at:
Marcos et al. (2015) Long-term variations in global sea level extremes. JGR-Oceans

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JGR

Journal of Geophysical Research: Oceans

RESEARCH ARTICLE
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Key Points:
- A state space approach is used to estimate changes in sea level extremes
- Intensity and frequency of extreme sea levels vary coherently at most sites
- Changes in extremes unrelated to mean sea level are regionally consistent

Supporting Information:
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- Figure S1
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- Figure S3
- Figure S4
- Figure S5
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Long-term variations in global sea level extremes

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Abstract Decadal to multidecadal variations in sea level extremes unrelated to mean sea level changes have been investigated using long tide gauge records distributed worldwide. A state space approach has been applied that provides robust solutions and uncertainties of the time evolving characteristics of extremes, allowing for data gaps and uneven sampling, both common features of historical sea level time series. Two different models have been formulated for the intensity and for the occurrence of extreme sea level events and have been applied independently to each tide gauge record. Our results reveal two key findings: first, the intensity and the frequency of occurrence of extreme sea levels unrelated to mean sea level vary coherently on decadal scales in most of the sites examined (63 out of 77) and, second, extreme sea level changes are regionally consistent, thus pointing toward a common large-scale forcing. This variability of extremes associated with climate drivers should be considered in the framework of climate change studies.

1. Introduction

Extreme sea levels resulting from the combined effects of mean sea level (MSL), tidal oscillations, and storm surges are a serious potential threat for coastal environments and assets. Changing climatic and topographic conditions may alter one or more of these contributions to extreme sea levels, thus leading to increased or decreased coastal vulnerability at the seaside. MSL varies in a wide range of spatiotemporal scales due to ocean warming/cooling, water redistribution, and water mass variations associated with changes in the land ice volume and in land hydrology. There is scientific consensus on the rise of MSL since the beginning of the twentieth century [*Church and White*, 2011; *Jevrejeva et al.*, 2008; *Hay et al.*, 2015] at both global and regional scales, as a consequence of an increased ocean warming and enhanced land-based ice melting. In some regions, the increase in MSL may induce significant changes in tidal ranges as well [*Arns et al.*, 2015; *Mawdsley et al.*, 2015]. Conversely, long-term changes in storm surges, which are associated with changes in the intensity, occurrence, and paths of storms and low-pressure systems, are more unclear [e.g., *Von Storch*, 2014; *Dangendorf et al.*, 2014]. Indeed, the IPCC AR5 [*Church et al.*, 2013] establishes only "low confidence" in the long-term trends for these phenomena.

The uncertainty in long-term variability of sea level extremes is partly due to the inherent definition of an extreme as a rare event; the number of extreme events is small (typically a few every year), and this hinders our ability to compute robust statistics on their temporal distribution. Also, remarkable is the scarcity of high-frequency sea level observations, especially when long time series are concerned. The relatively low number of such long records is a constraint for the study of the spatial distribution of changes in extreme events. Nevertheless, long and good quality sea level time series with high-frequency (hourly) sampling do exist and have been explored in earlier works. Global studies have been carried out, for example, by *Menéndez and Woodworth* [2010] who investigated changes in extremes in recent decades using more than 250 tide gauge records, and *Merrifield et al.* [2013] who used 145 good quality stations longer than 10 years to estimate the contributing factors to high waters. Many other works have a more regional or even local focus, mostly because of the geographical variability of extreme sea levels, especially when they are considered in combination with MSL and tides, and sometimes also due to the availability of particular series of data. Examples of recent regional studies are *Marcos et al.* [2009] in Southern Europe; *Thompson et al.* [2013], *Ezer and Atkinson* [2014], and *Wahl and Chambers* [2015] along the U.S. coasts; *McInnes et al.* [2009]

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