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Correlation and Regression Analysis on Atlantic Tide Level Data

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SCRiM

1. Motivation

Extreme storm surges poses significant threats to life and property. Research into these surges is crucial for building and preparing critical infrastructure near the coast. A previous study (Grinsted et al., 2013) examined sea level data from NOAA and concluded that extreme surges were growing in intensity and frequency.

2. Summary

Goals:

- Re-examine the methodology of Grinsted et al. (2012) which combined observations from six different tide gauge stations.
- Develop an alternative pre-processing method and determine if there is a link between more frequent extreme storm surges and rising global temperatures.

Challenges:

- Large data sets, over 800,000 data points per station
- Accounting for overall, seasonal, and daily influences

Our Approach:

- Use harmonic regression and an ARMA model to remove the overall, seasonal, and daily trends.
- Fit a generalized extreme value distribution (GEV) to the pre-processed data and examine how the distribution changes with temperature.

Findings:

- Tide gauge stations exhibit little correlation with one another
- There is a link between rising temperatures and more frequent extreme storm surges, but it is much weaker than reported by Grinsted et al. (2013)

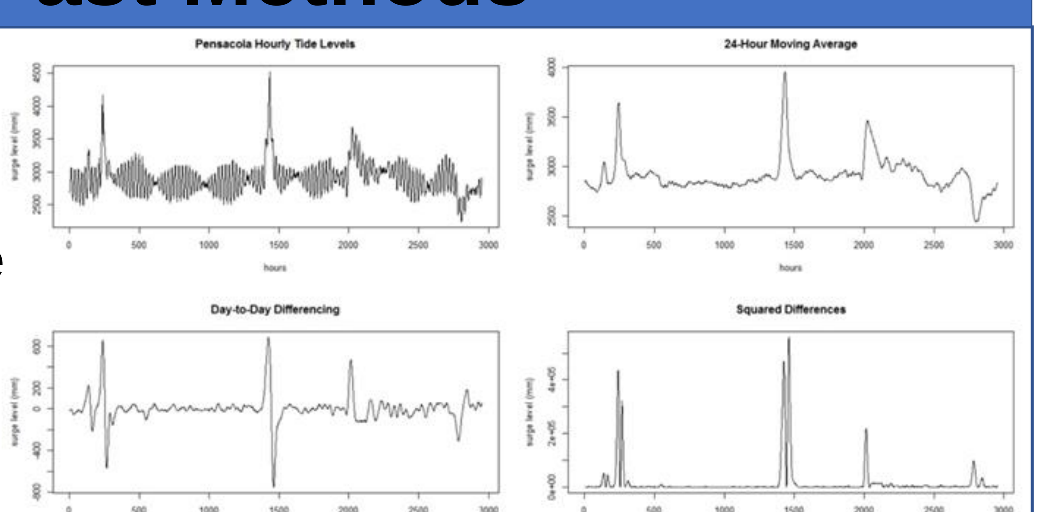
3. Data

- Tide gauge data retrieved from National Oceanic and Atmospheric Administration (NOAA)
- Focus Tide Gauge Stations:
  - Key West (FL), Charleston (SC), Atlantic City (NJ), Pensacola (FL), Galveston (TX)
  - Sea level data from 1923 to 2015

4. Past Methods

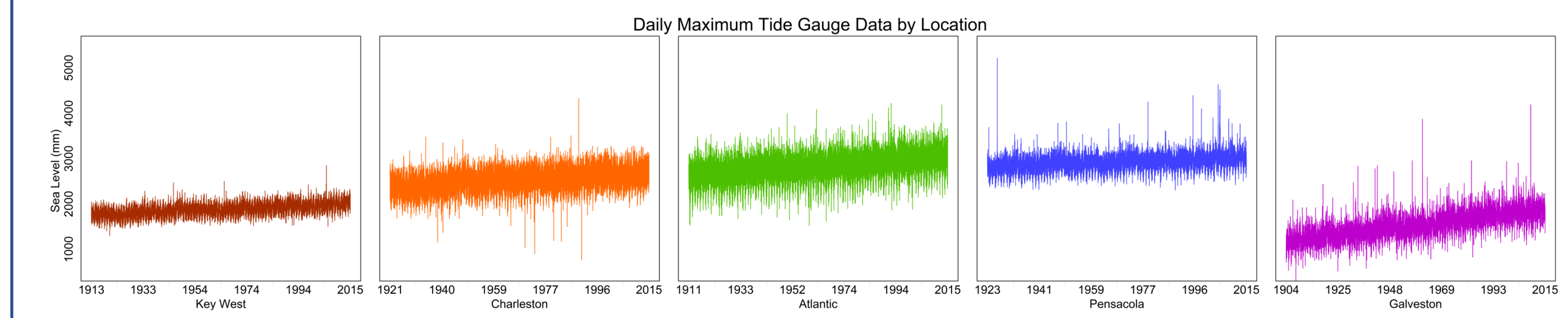
Grinsted et al. (2013):

- Daily max of squared day-to-day differences
- Removed annual cycle by division
- Combined records from 6 stations into one surge index

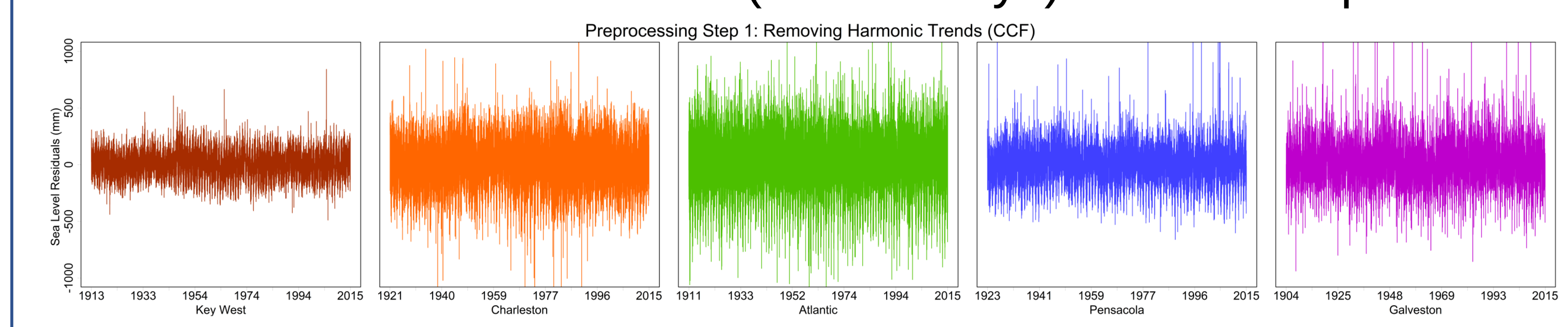


5. Pre-processing Methods

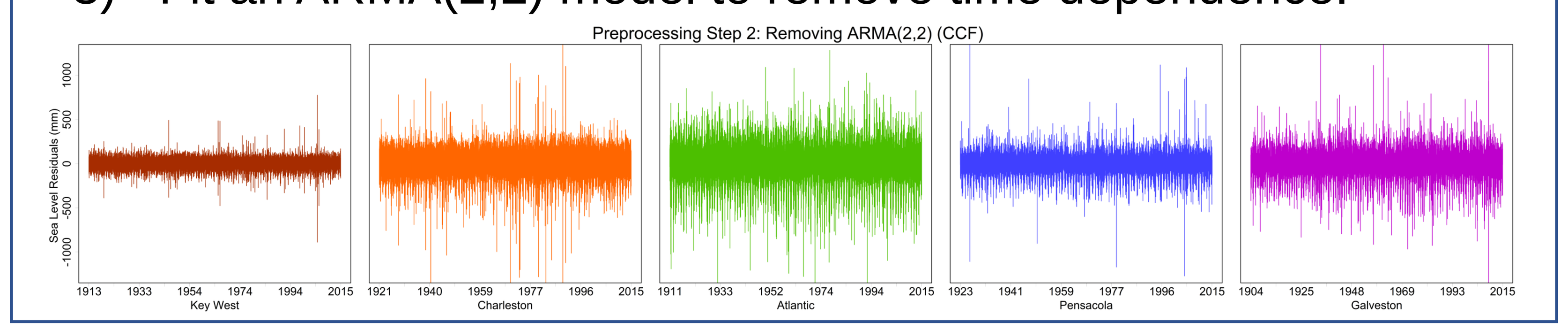
Detrending/Removing Seasonality:



1) Fast Fourier Transformation (FFT) to decompose time series into fundamental frequencies.
2) A harmonic regression with 7 pairs of sines and cosines was used to remove seasonality. Periods used were:
   - A yearly period (365.25 days)
   - Synodic lunar month (29.55.. days) and its half period
   - Sidereal lunar month (27.32.. days) and its half period
   - Anomalistic lunar month (27.55.. days) and its half period



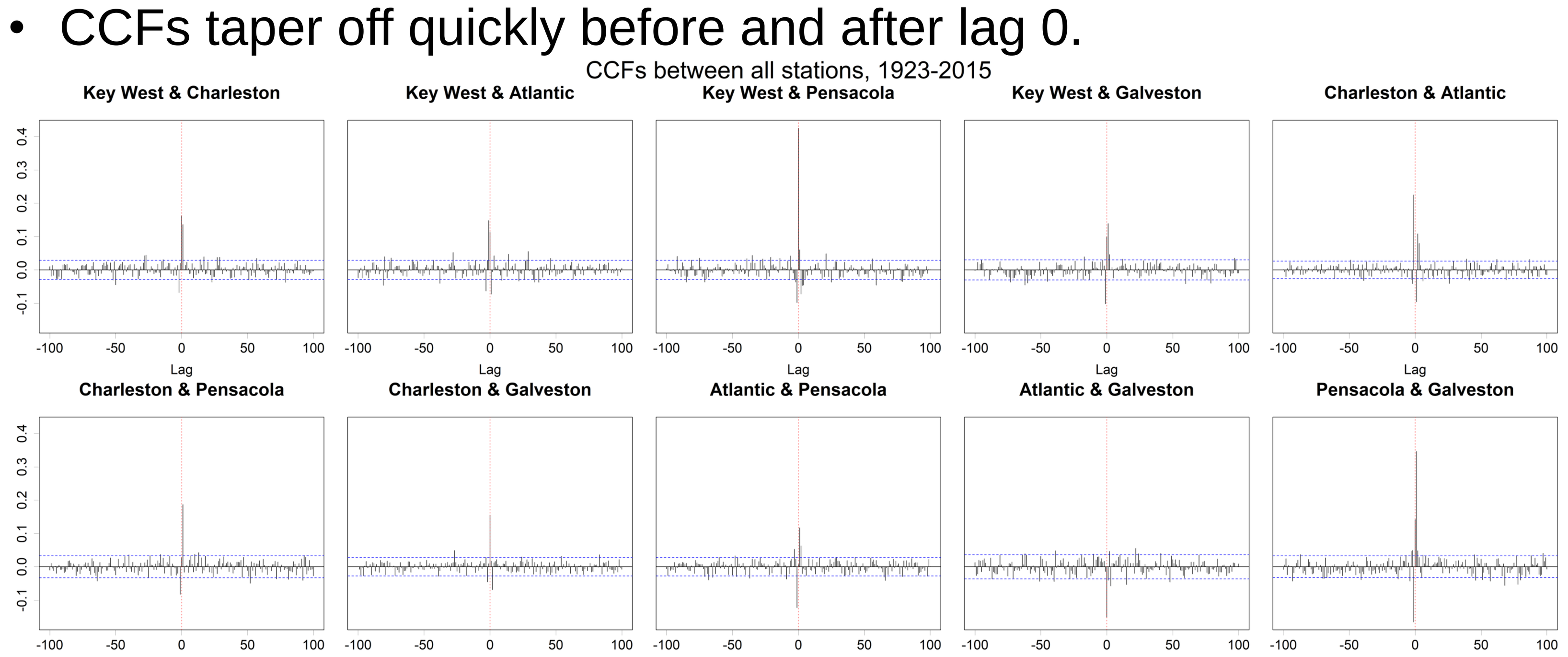
3) Fit an ARMA(2,2) model to remove time dependence.



6. Results

Cross-Correlation Function:

- CCF is a measure of similarity between two series, as a function of lags of one relative to another.
- Strong Correlation between nearby tide gauge stations (~500 mi) at lag 0, maximum of Key West and Pensacola (FL) with 0.42.
- Moderate negative correlation at lag 0 with distant tide gauge locations (~1350 mi), maximum of -0.16 with Galveston (TX) and Atlantic City (NJ).
- CCFs taper off quickly before and after lag 0.



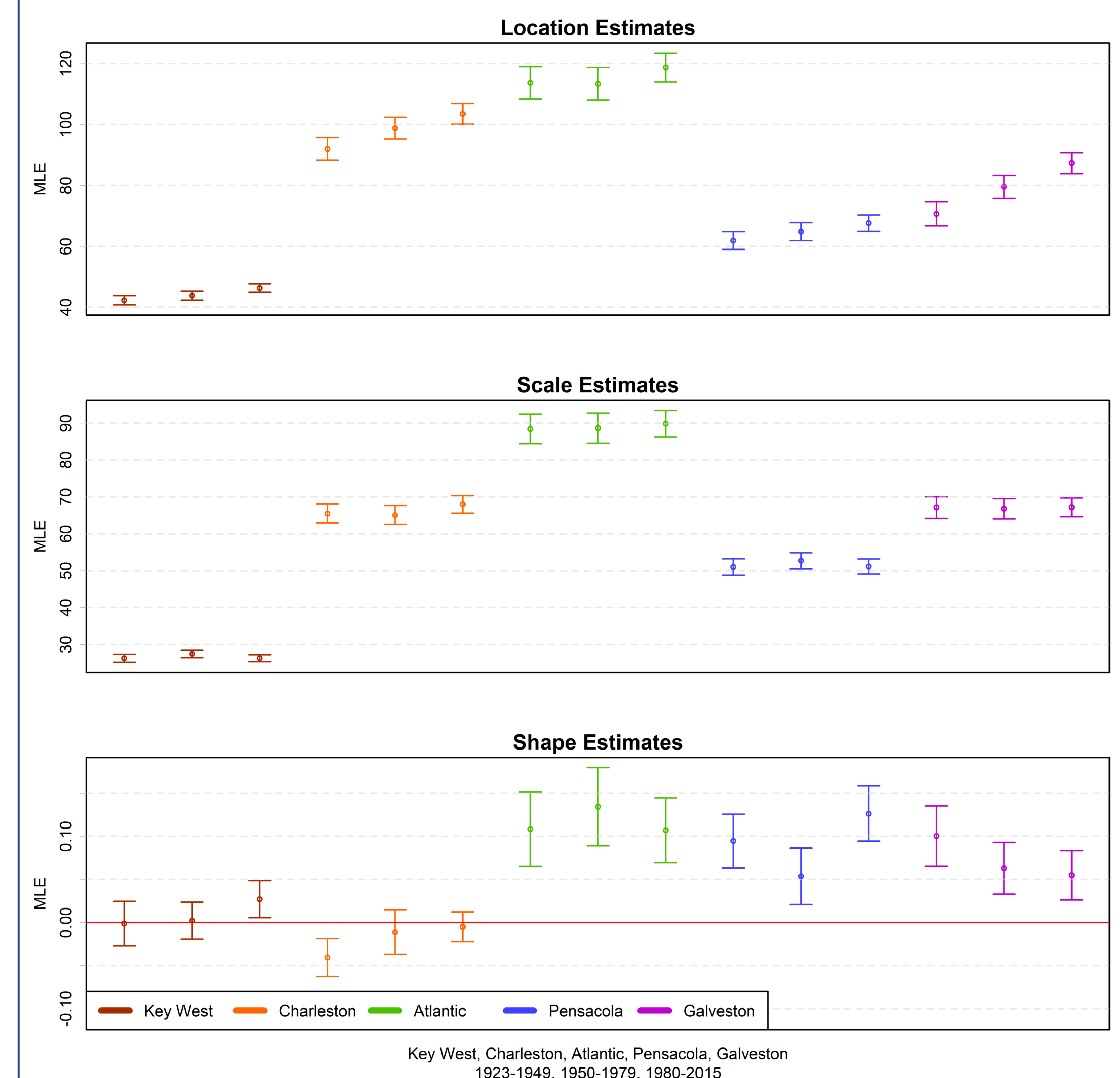
7. Results

Generalized Extreme Value Distribution:

- Location parameters changes with respect to rising temperatures.
- Scale and Shape parameters did not change with respect to temperature.

PDF:

$$f(x;\mu,\sigma,\xi) = \frac{1}{\sigma}\left[1+\xi\left(\frac{x-\mu}{\sigma}\right)\right]^{(-1/\xi)-1} \exp\left\{-\left[1+\xi\left(\frac{x-\mu}{\sigma}\right)\right]^{-1/\xi}\right\}$$



8. Conclusions and Future Work

Spatial Dependence:

- Tide gauge stations closer in proximity showed a strong correlation to one another while distant stations did not.
- Stations are not similar, so combining them (Grinsted et al., 2013) is not recommended.

Non-Stationary GEV:

- GEV analysis shows a strong increase in the location parameter over time, with no overlap in the 95% CI in four of five tide gauge locations

Future Work:

- Implement estimates for missing stretches of data

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