Annual and Seasonal Extreme Sea Levels in the Northwest Atlantic: Hindcasts Over the Last 40 Years and Projections for the Next Century

DALHOUSIE UNIVERSITY *Inspiring Minds*

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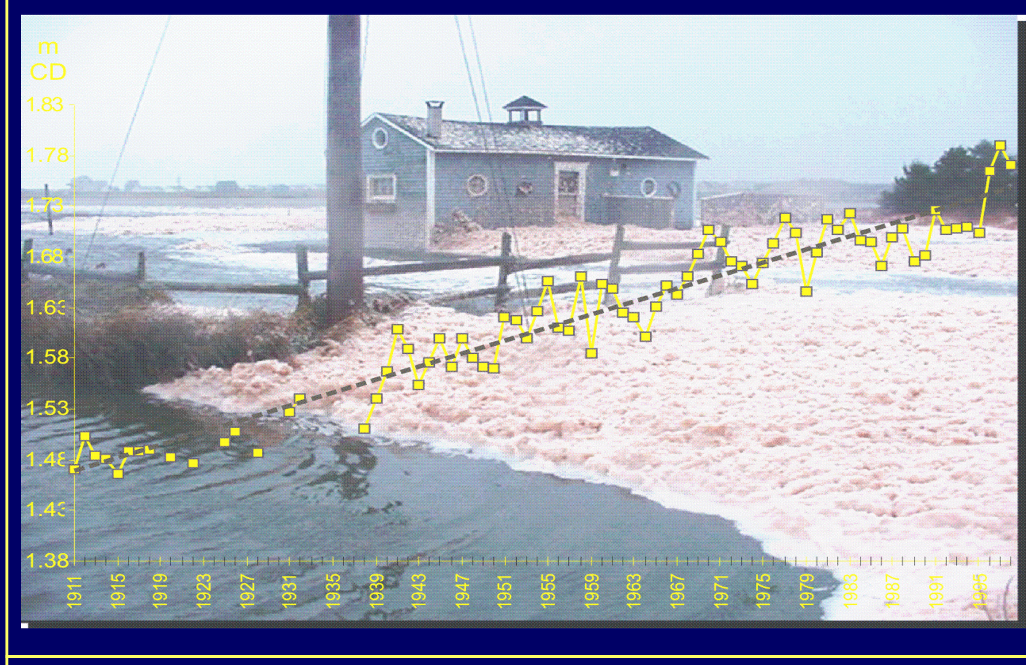
1. Why do we Care?

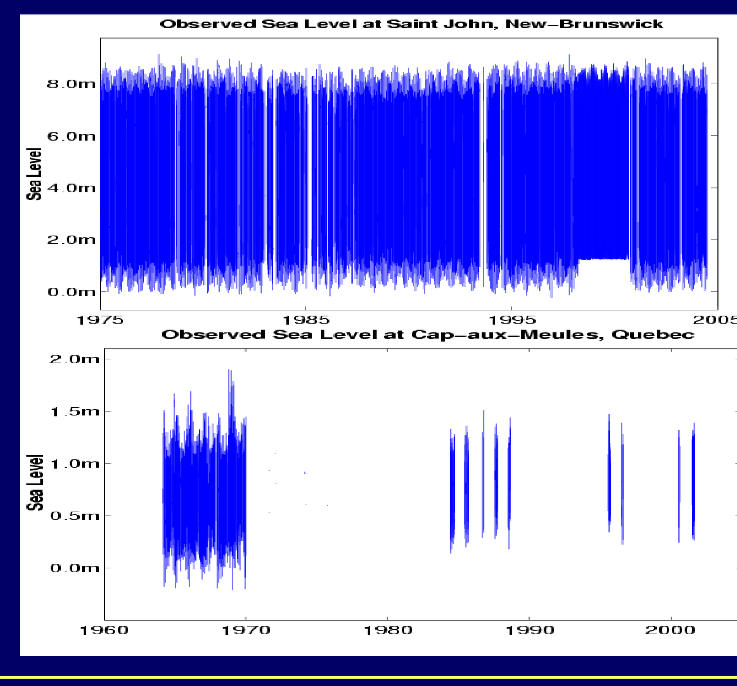


2. The Problem

Sea Level is rising and climate is changing

Insufficient and poor quality data for standard extremal analyses

→ Difficult to calculate flooding risk for past, present, and future conditions



3. Research Objectives

Can a storm surge model be used to estimate the return period of extreme sea levels?

How are return periods likely to change over the next century?

Can the results be presented in a form useful to communities?

4. Surge Model

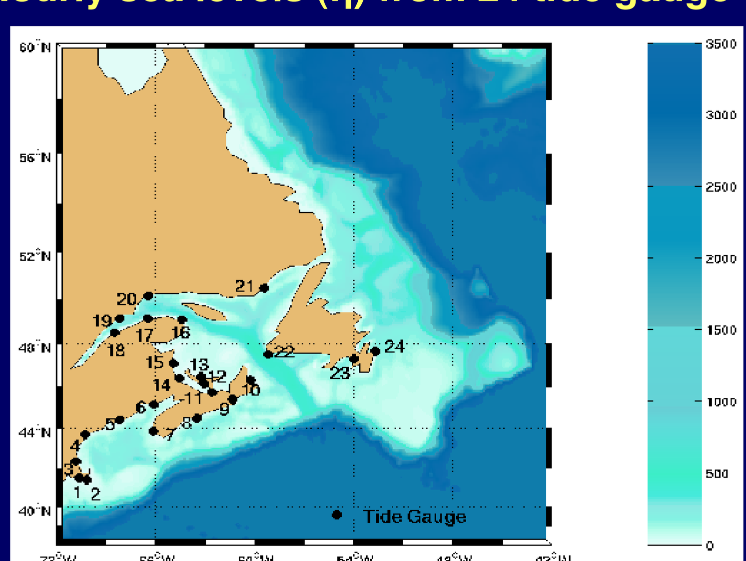
2D, barotropic, nonlinear, based on POM
42-72W, 38-60N
1/12 degree horizontal resolution
Forced with AES40 surface winds and inferred air pressure (6 hourly, horizontal resolution is ~60 km, Swail *et al.*, 2000)

Hindcast Period and Output

40 year hindcast, 1960-1999
Hourly maps of sea level (η_S) due to atmospheric forcing

Observations used for Validation

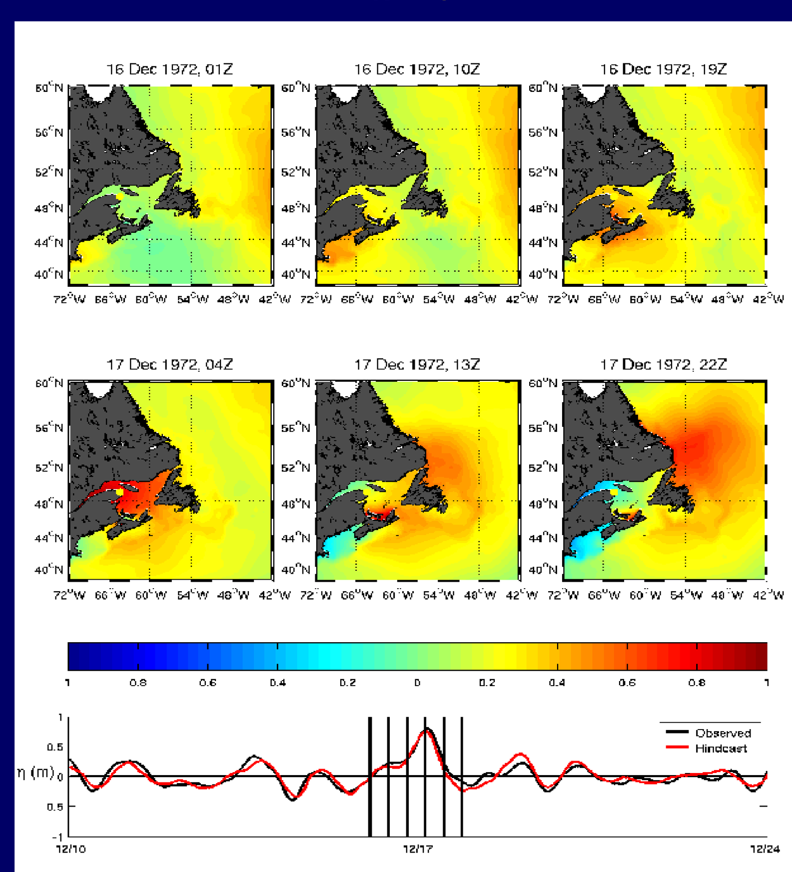
Hourly sea levels (η) from 24 tide gauge



5. Surge Validation

Tides (η_T) calculated using t_tide (Pawlowicz *et al.*, 2002)
$\mathcal{L}\eta_R=\mathcal{L}(\eta-\eta_T)$, $\mathcal{L}$ → Low pass filter designed to remove energy at frequencies below 12h (the Nyquest frequency)

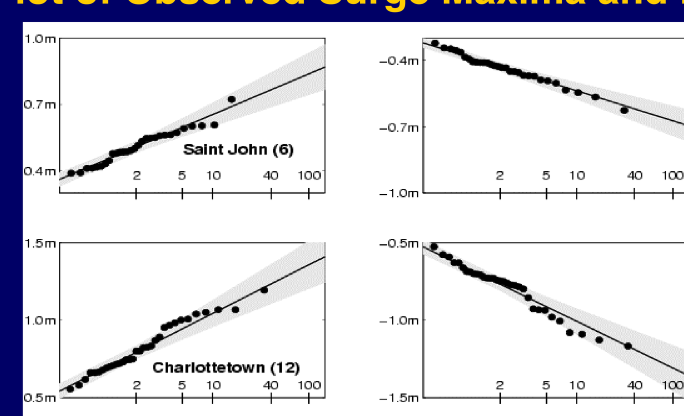
Typical rms of ($\mathcal{L}\eta_R-\eta_S$) is 8 cm



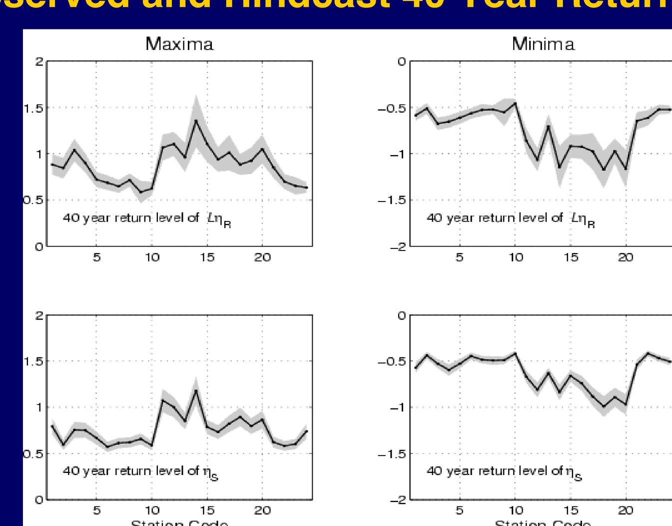
6. Type I Extremal Analysis

$\Pr(M_n > \eta_c)=1-\exp\{-\exp[-(\eta_c-a_n)/b_n]\}$
M_n denotes Annual Maxima
η_c denotes Critical Sea Levels
a_n, b_n are the Location and Scale Parameters

Type I Plot of Observed Surge Maxima and Minima

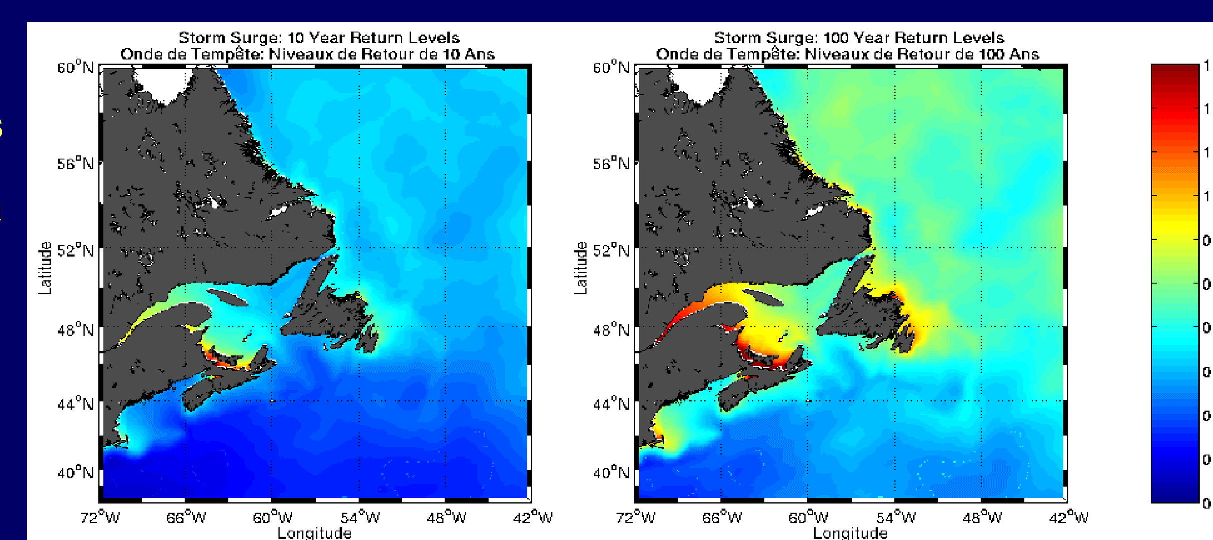


Observed and Hindcast 40 Year Return Levels

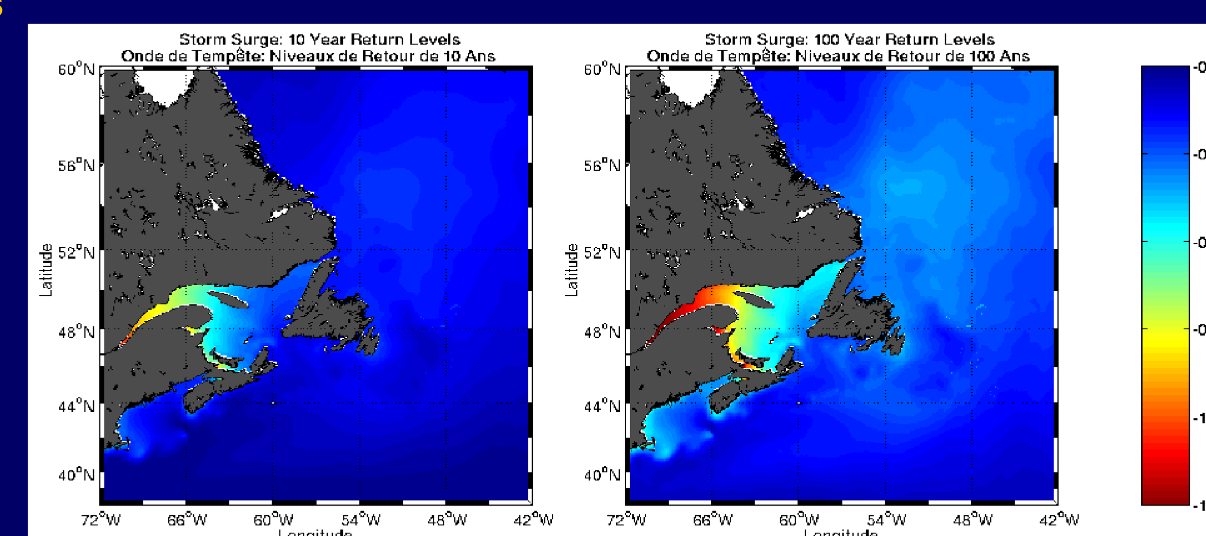


7. Return Level Maps

Surge Maxima



Surge Minima



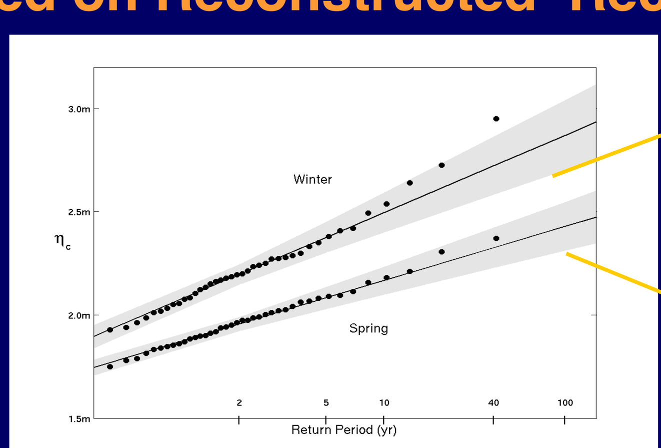
8. Reconstruction of Total Sea Level Records From Short Records

$$\eta=\eta_T+\eta_S+\eta_{R'}$$

sea level=tide+surge hindcast+error

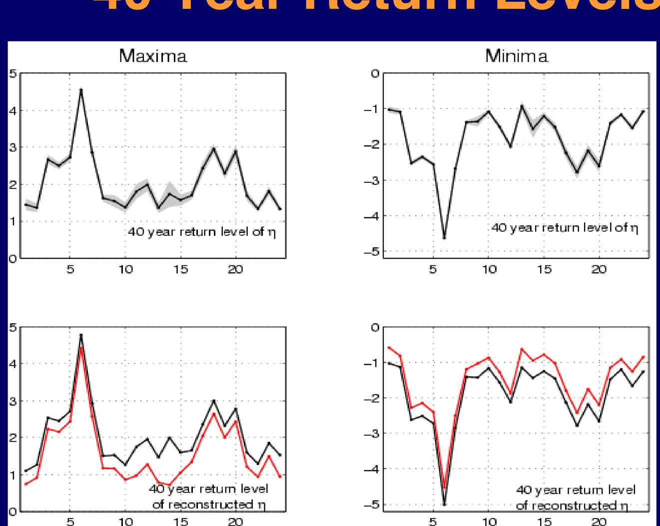
1. Calculate Tide and Error using short observation records
2. Use 1 year of observations to predict Tides
3. Use other years/seasons to calculate the Error
4. Randomly sample from short Error record to obtain 40 year error record
5. Combine Error, Surge Hindcast, and Tidal Prediction to get Total Sea Levels for 40 years or 40 seasons.

9. Shediac (14) Seasonal Return Periods based on Reconstructed Records



In 25 years, Spring Return Levels will resemble Winter Return Levels due to Sea Level Rise

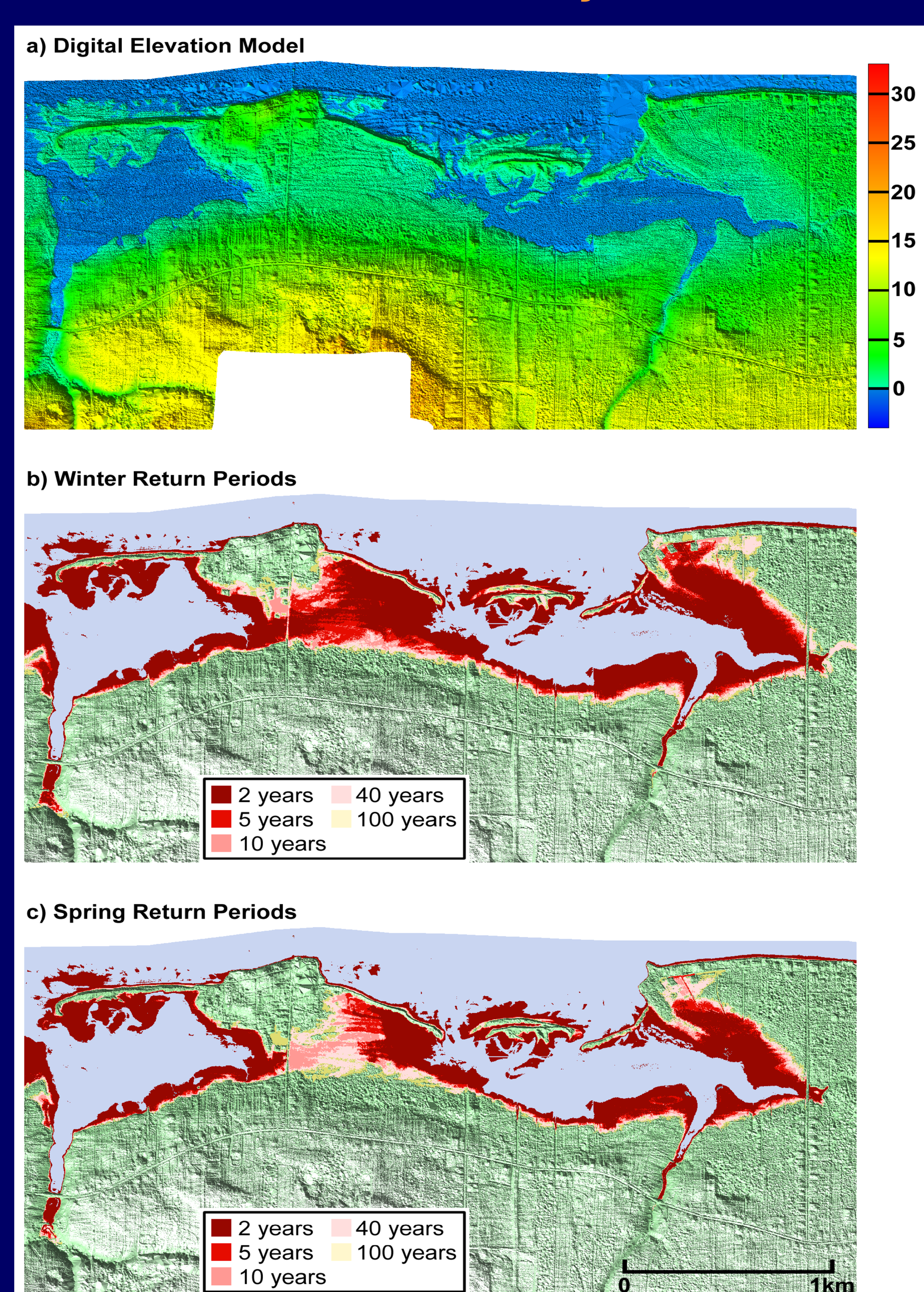
10. Observed and Reconstructed 40 Year Return Levels



Red line is maximum tidal contribution

Observed and Reconstructed 40 year Levels (black lines) are within 10 cm

11. Downscaling Extremal Analyses to the Community Level



12. Evaluating the impact of Sea Level Rise and Changes in Storminess at Halifax

Including:

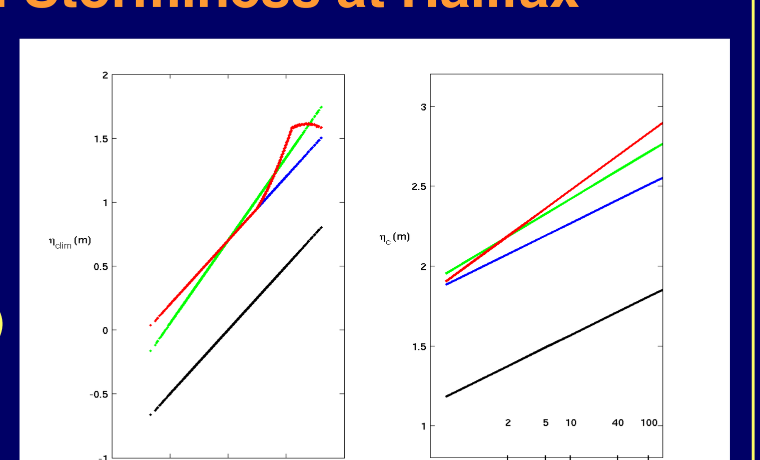
1)Sea Level Rise (SLR)

→ η_{clim}=SLR+η_{pres}

2) Changes in storminess (α)

→ η_{clim}=SLR+$\alpha\eta_{pres}$

Then $\eta=\eta_T+\eta_{clim}+\eta_{R'}$



13. Trends in Surge Maxima and Pressure Minima?

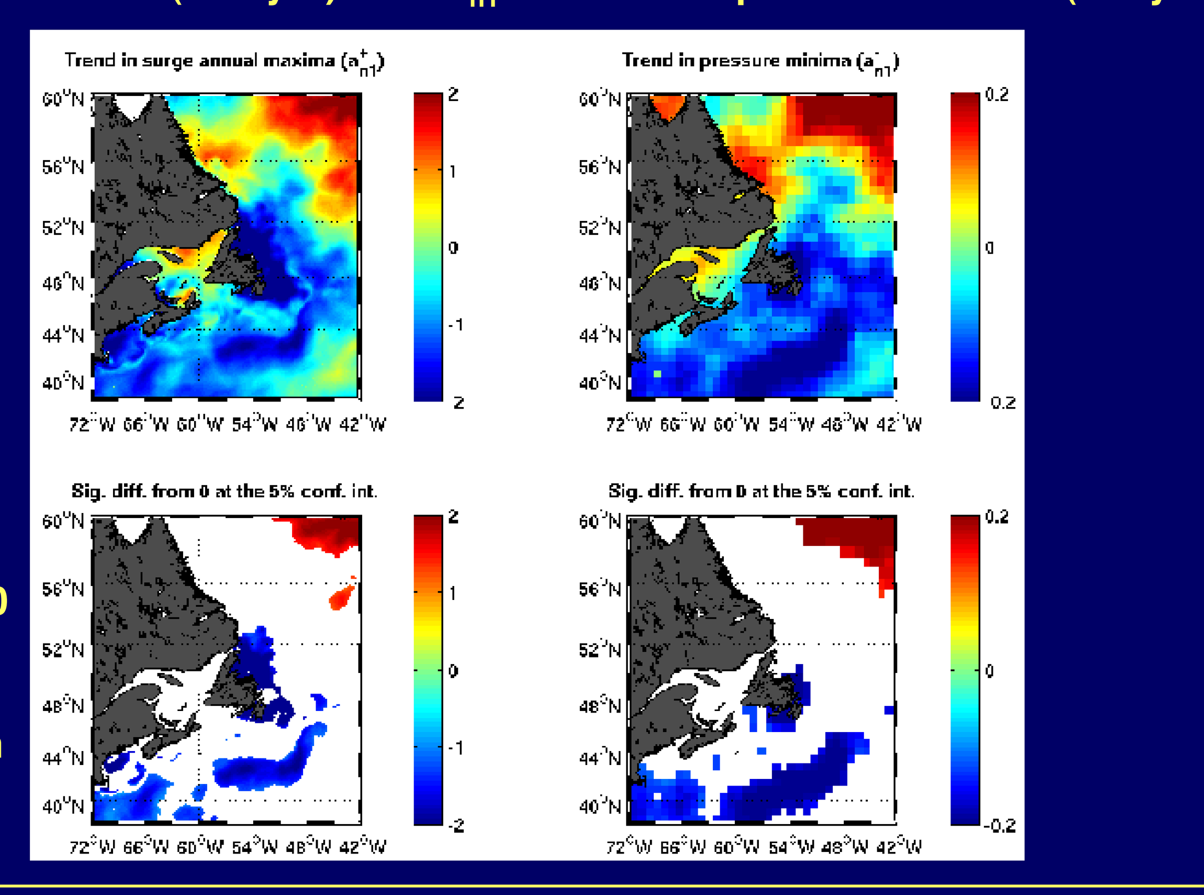
Allow for trends in a_n → let $a_n=a_{n0}+a_{n1}t$

a^+_{n1}→ trends in surge maxima (mm yr^{-1})

a^-_{n1} → trends in pressure minima (mb yr^{-1})

Negative values →extremes are becoming less extreme

Majority of trends are not significantly different from 0 at the 5% significance level but taken together they indicate a slight decrease in extreme positive surges



14. Summary

- Return levels of 40 year extreme surges and extreme sea levels in the NW Atlantic have been reproduced to within 10 cm and mapped using a storm surge model
- Changes in the extremes, over the next century, are most sensitive to sea level rise and more frequent mid-range surges
- Digital Elevation Models are useful for downscaling the statistics of extreme sea levels (by the draping of return periods) and facilitating public outreach
- Baroclinicity (seasonal variations in density structure) and tide-surge interactions are important and affect sea levels by as much as 15 and 10 cm respectively (not shown)

References

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