Spatial Grids for Hurricane Climate Research

A Meteorologist-turned-Geographer's Perspective

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Acknowledgement: Thomas H. Jagger & Robert E. Hodges

Take Home Points

- Here I introduce a new spatial framework for studying hurricane climate change.
- I show hexagons are efficient at covering hurricane tracks.
- They provide a scaffolding for combining hurricane attribute data and spatial climate data.
- Hurricane seasons having similar tracks can be assessed and grouped.
- Regional cyclone frequency and intensity variations can be mapped.

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- Geographically-weighted regression of cyclone intensity on SST is performed using the hexagons.
- Results confirm the importance of warm oceans to cyclone intensity, especially over regions where the heat content is largest.
- Greatest mismatch between observed and predicted intensity occurs near land.
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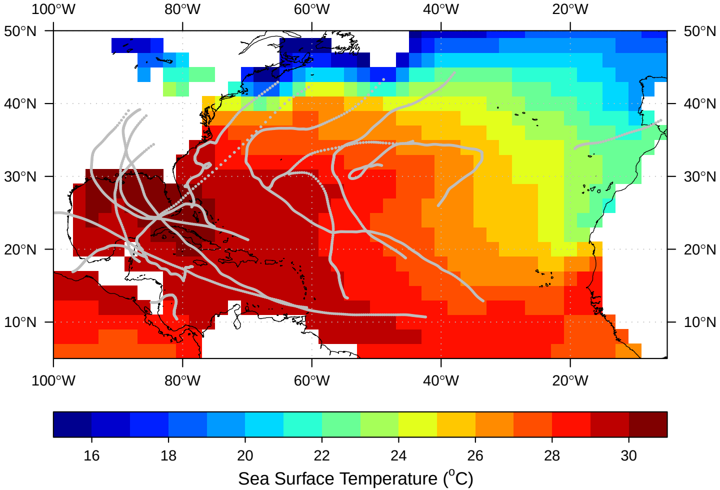
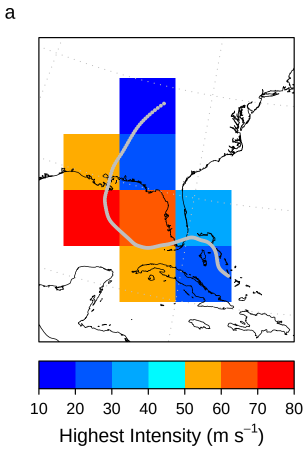
Problem: Storm tracks don't match climate data



Solution: Tracks as grids; New problem: Efficiency



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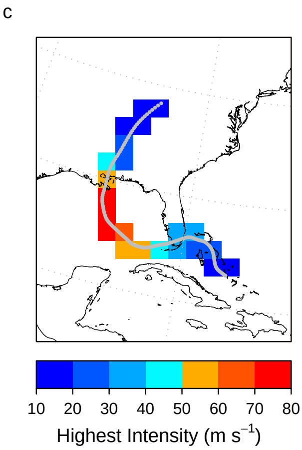
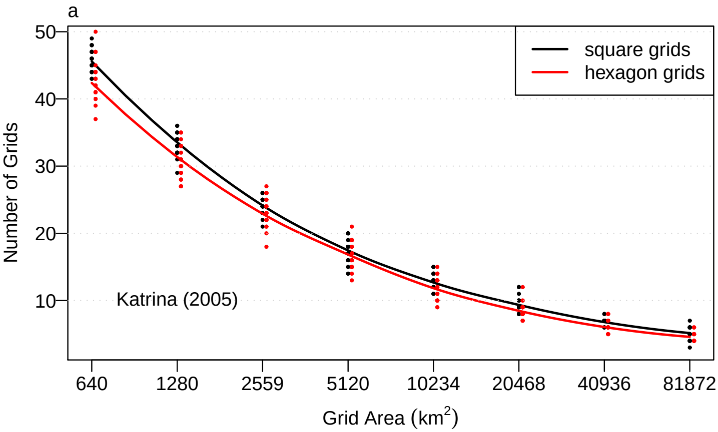


Hexagons: More efficient at covering tracks



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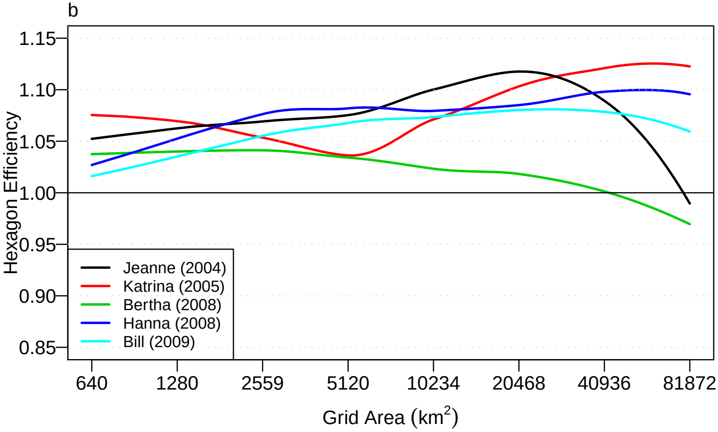
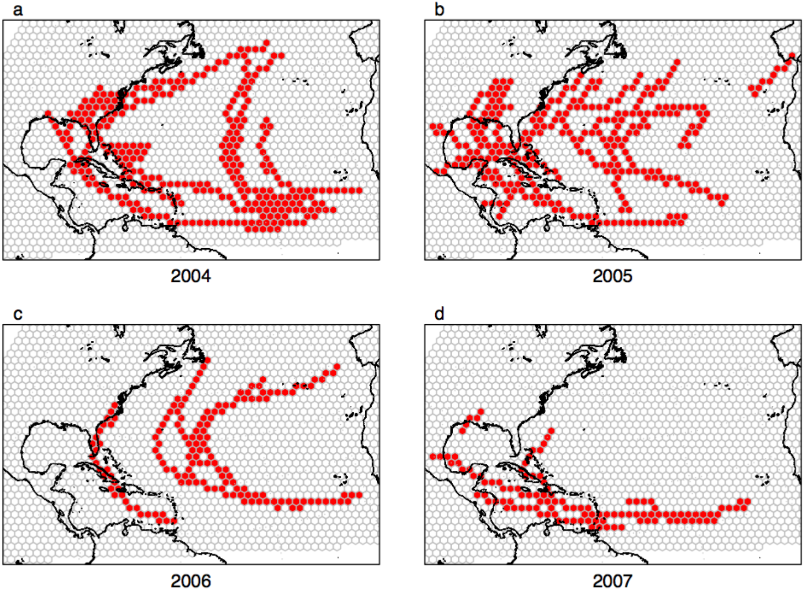
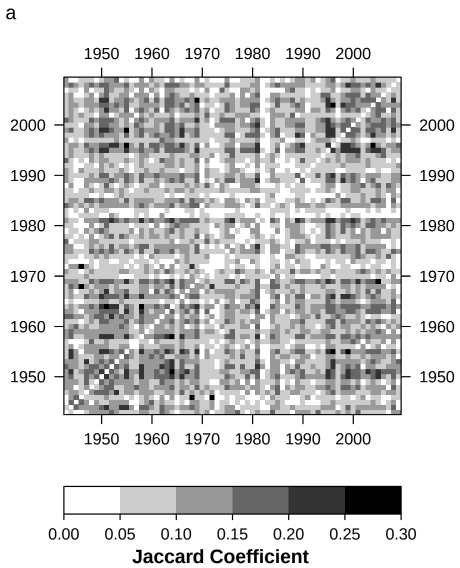


Analogue seasons



How well do they match?



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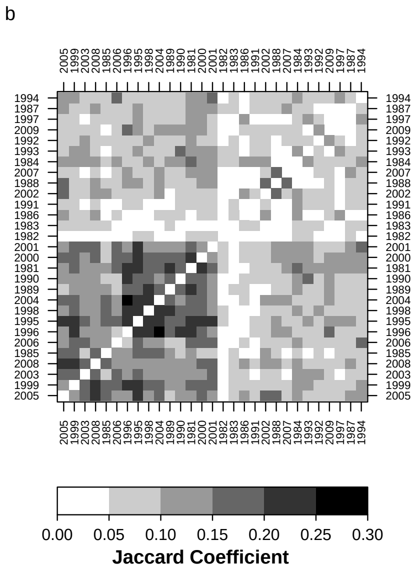
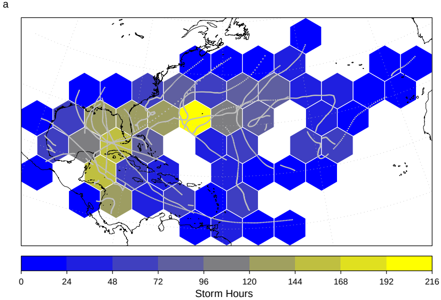


Hurricane frequency and intensity

a



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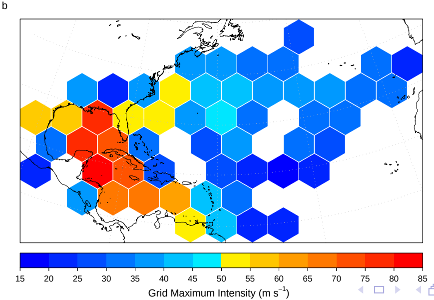
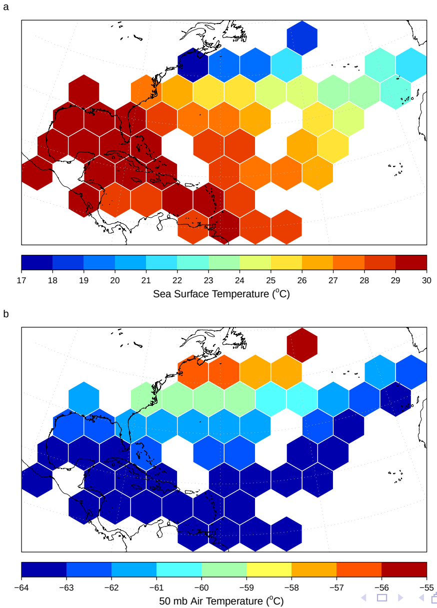
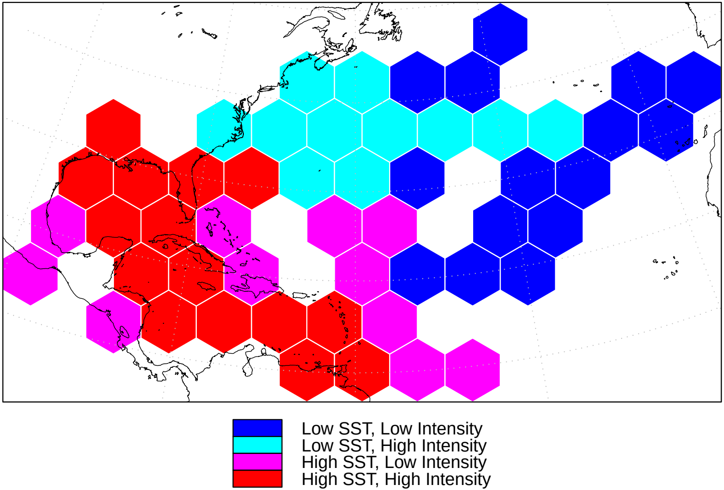


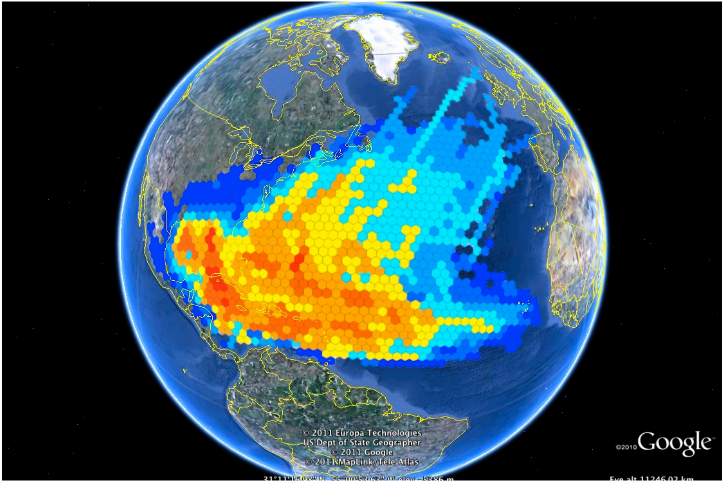
Sea surface & upper air temperatures



Grouped by SST and Intensity



Fly in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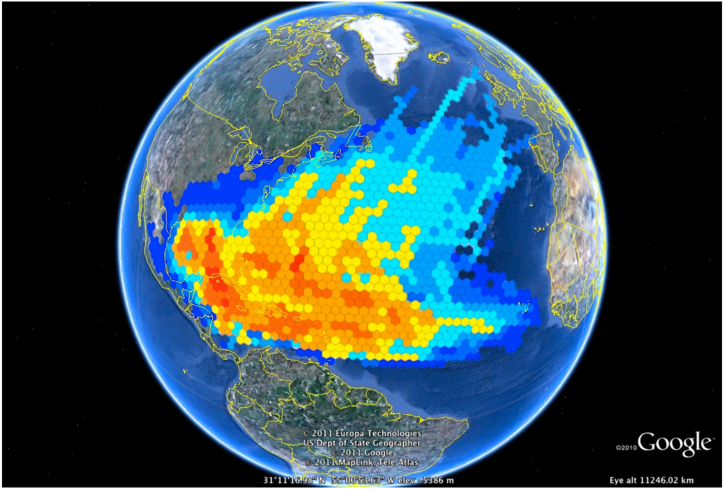

Moran's I

$$I = \frac{n}{s}\frac{y^T W y}{y^T y}$$

- n is the number of hexagons
- y is the vector of cyclone intensities one for each hexagon [deviations from the overall mean]
- W is a weights matrix indicating which hexagons are neighbors
- s is the sum over all the weights, and
- subscript T is the vector transpose operator

Spatial autocorrelation: Moran's I

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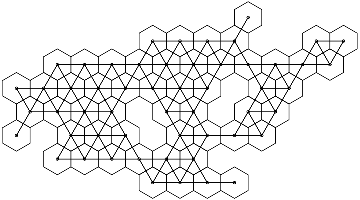
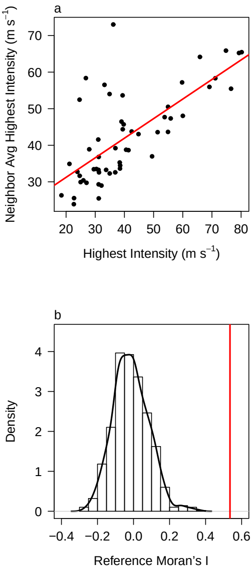
Spatial autocorrelation: Statistical significance





Ordinary least-squares regression

$$y = X\beta + \varepsilon$$

- β is a vector of regression coefficients
- $\varepsilon \sim N(0, \sigma^2)$ is a vector of independent and identically distributed residuals with variance σ^2

Maximum likelihood estimate for β

$$\hat{\beta} = (X^T X)^{-1} X^T y$$

Ordinary vs geographically-weighted regression

Geographically-weighted regression

$$y = X\beta(g) + \varepsilon$$

where g is a vector of hexagon locations

Maximum likelihood estimate for $\beta(g)$

$$\hat{\beta}(g) = (X^T W X)^{-1} X^T W y$$

where W is a weights matrix given by

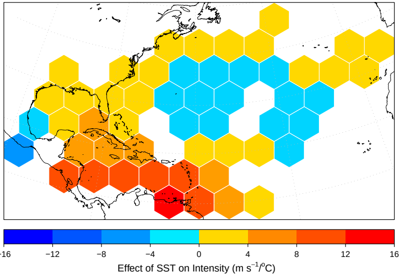
Weights matrix

$$W = \exp(-D^2/h^2)$$

where D is a matrix of pairwise distances between the hexagons and h is the bandwidth.

Geographically-weighted regression: Results

a



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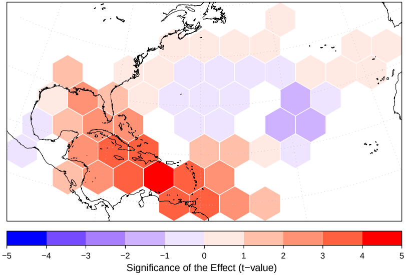
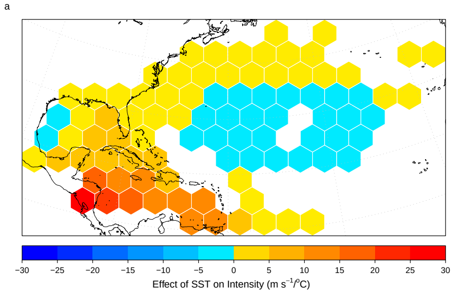
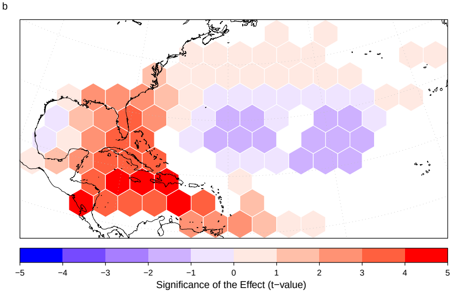
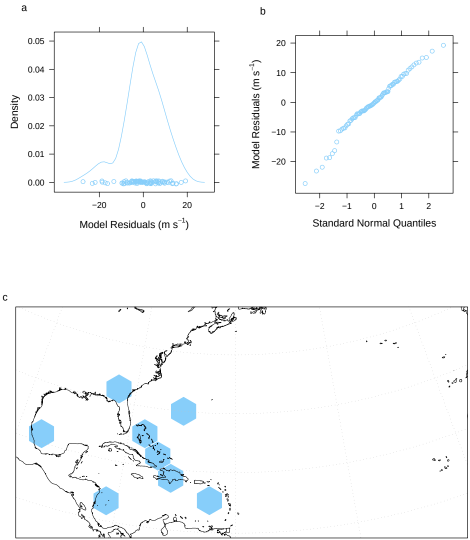


Geographically-weighted regression: Does scale matter?



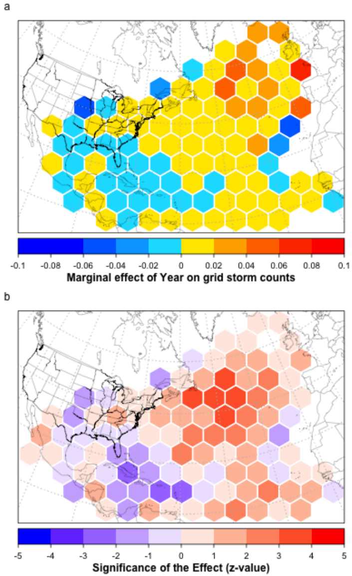


Geographically-weighted regression: Residuals

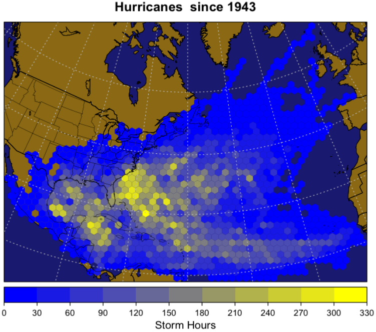


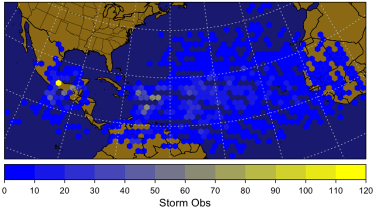
Grids Where Model Over Predicts Intensity By More Than 10 m s^{-1}

Local Poisson regression: Trends in hurricane frequencies



Observed vs modeled (CMIP3) tropical cyclones





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