National Oceanography Centre, Southampton
UNIVERSITY OF SOUTHAMPTON AND NATURAL ENVIRONMENT RESEARCH COUNCIL

Extreme Wave Heights from Satellites

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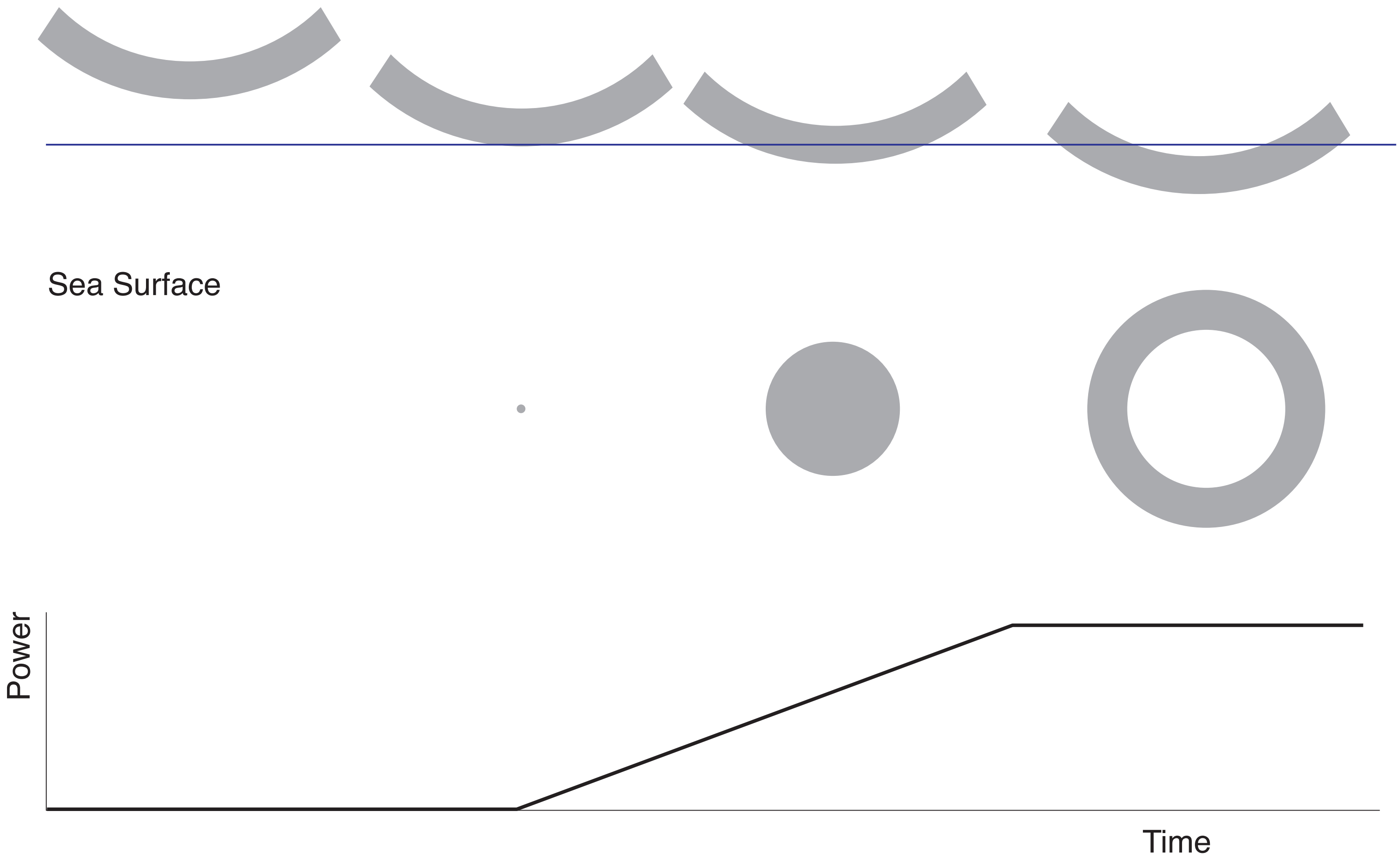
Outline

- Why are we interested in extremes from satellites?
- Waves from radar altimeters
- Extremes and altimeter data
- Classical Methods
- Bayesian Hierarchical models

Waves from satellites

- Limited coverage from buoy measurements
- Models are models
- Satellites give a direct measurement of wave conditions
- Radar altimeters and SAR’s

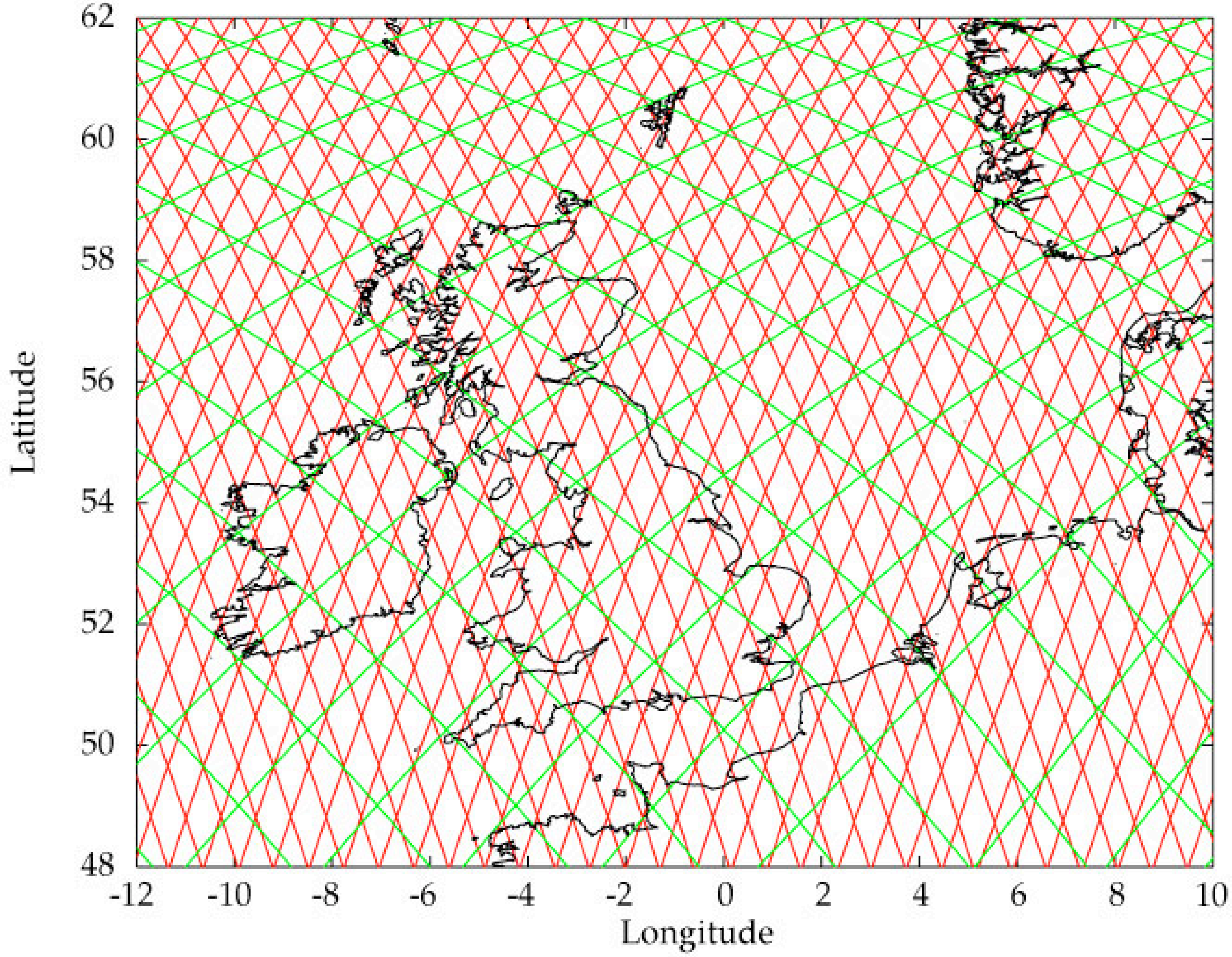
How an altimeter works



Altimeter waves

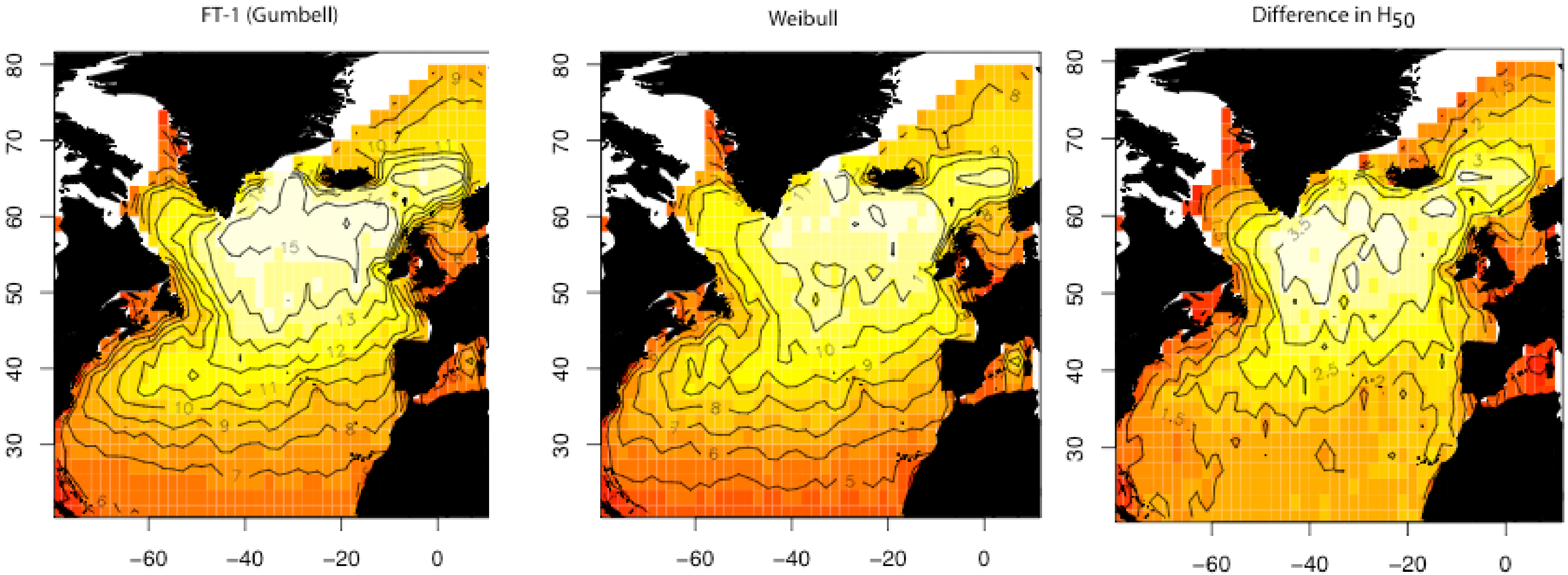
- Direct measurement of significant wave height

  (Can also measure wave period)
- Accuracy comparable (or better than) buoys
- Calibration of instruments needed to produce a consistent data set between instruments
- Only measures directly below the satellite

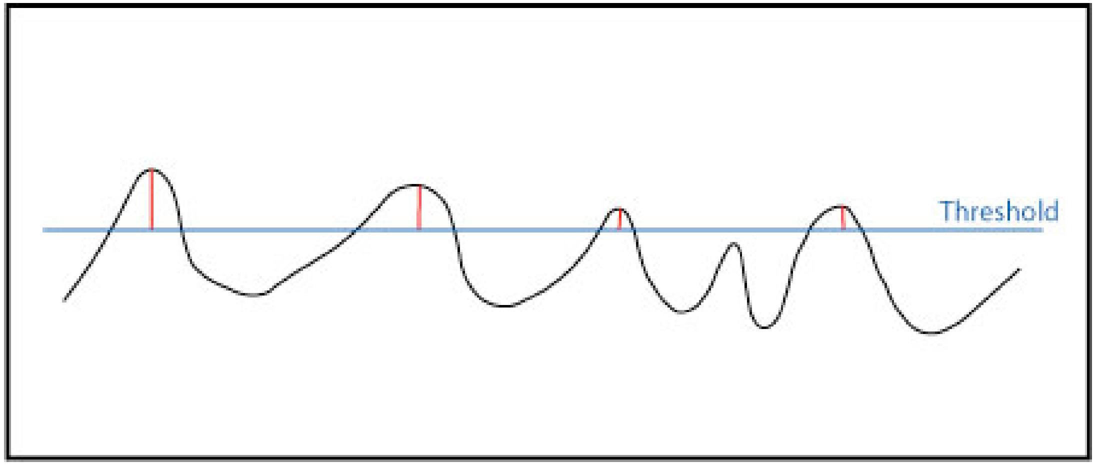

62
60
58
56
54
52
50
48
Latitude
-12
-10
-8
-6
-4
-2
0
2
4
6
8
10
Longitude

Data

- TOPEX and ERS-1/2 data from 1992 -2004 from the NOC GAPS database
- Data calibrated to US data buoy network
- (Also processed data from the TUD RADS database - similar results - not presented here)



- Different distributions give very different answers.



1. Choose a high threshold (u)
2. Take all exceedences above that threshold
3. Fit a GPD distribution

$$P(X < x | x > \mu) = 1 - [1 + \frac{\eta . x}{\sigma}]^{-\frac{1}{\eta}}$$

POT for altimeter data

- Altimeter data do not record the biggest exceedences at a point
- But the distribution of any exceedence = probability of the largest
- The temporal sampling is poor
- Undersampling will lead to an underestimate of the extremes by about 10-15% (Robinson and Tawn, 2000)

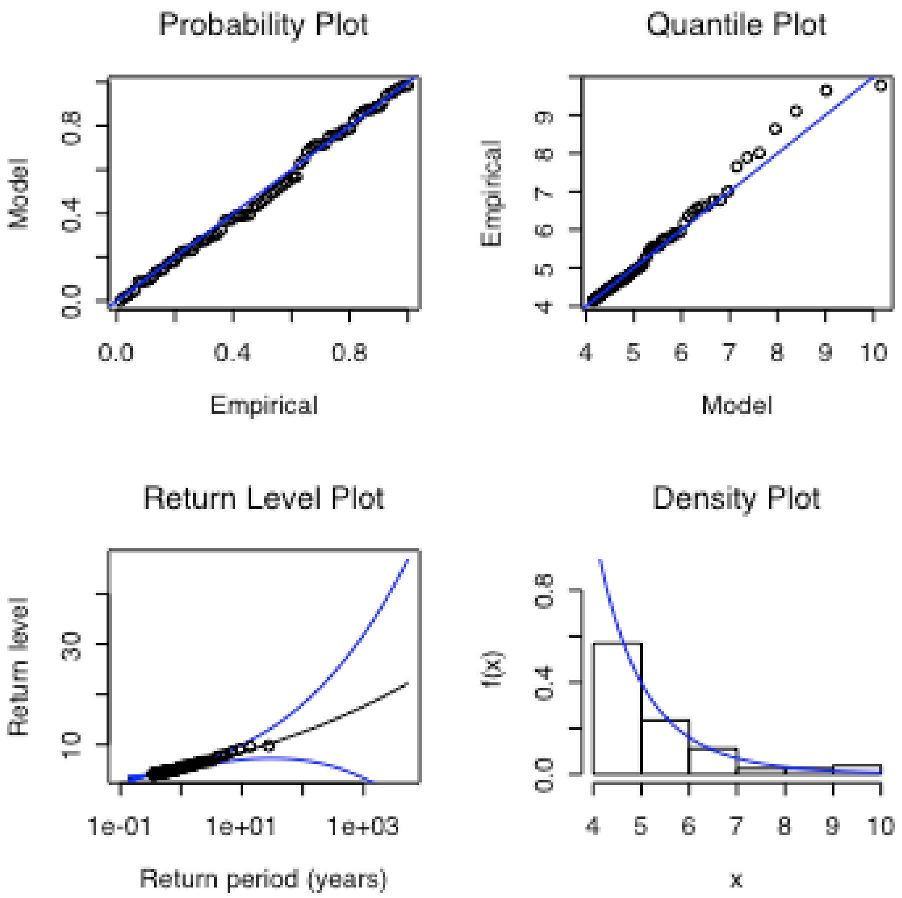
Altimeter Processing

- For each 2° square in the North Atlantic take each altimeter pass across the square.
- Replace each pass by its median (declustering)

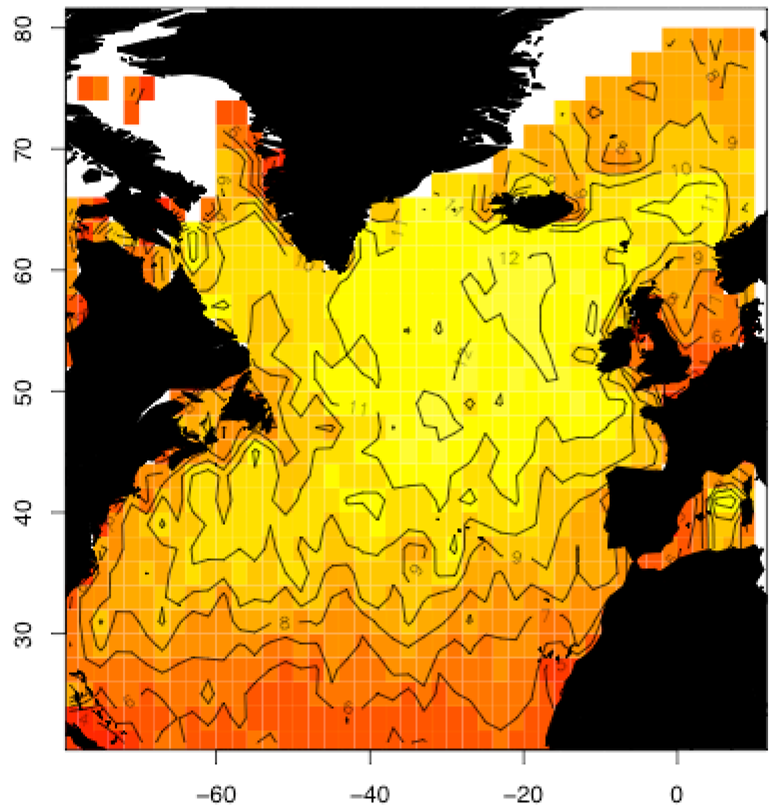
Setting the Threshold

- With *in situ* data we set the threshold by hand - start high and lower the threshold until nothing changes
- We cannot do that so we set the threshold to the 90th quantile i.e 10% of the data are exceedences

An Example Fit



50-year Return Value



Max value = 14.9m

Non-stationarity

- So far we have assumed that the wave climate is stationary i.e. that the statistics of exceedences are the same throughout the year
- This is not true - storms are bigger in the winter

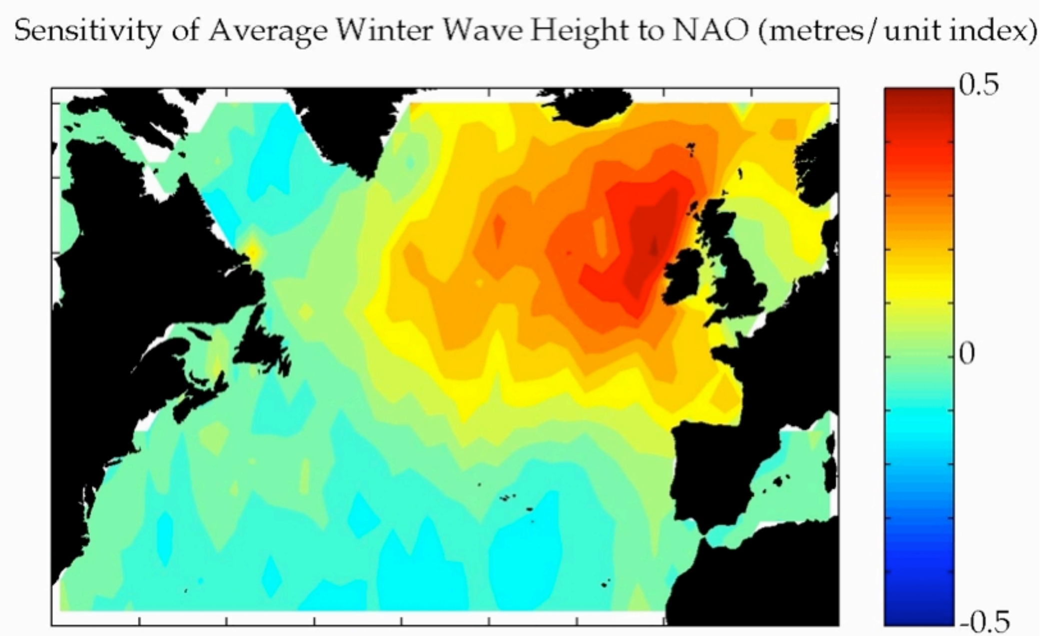
Variable Threshold

- Use a different threshold value every month
- We can check whether this more complex model is ‘better’ (likelihood ratio test)
- It is significantly better everywhere

The North Atlantic Oscillation

- We know that the NAO affects mean wave height

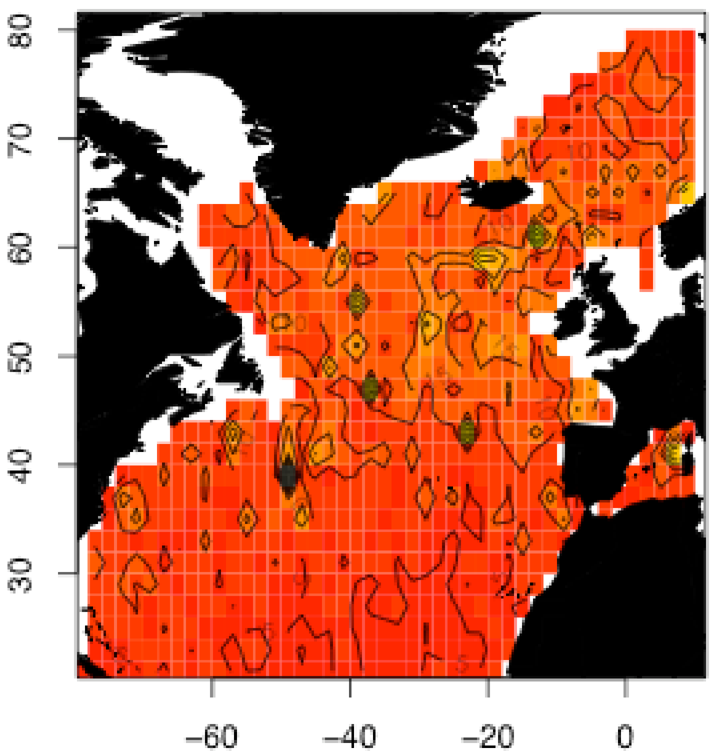
- Does it also affect the extremes?

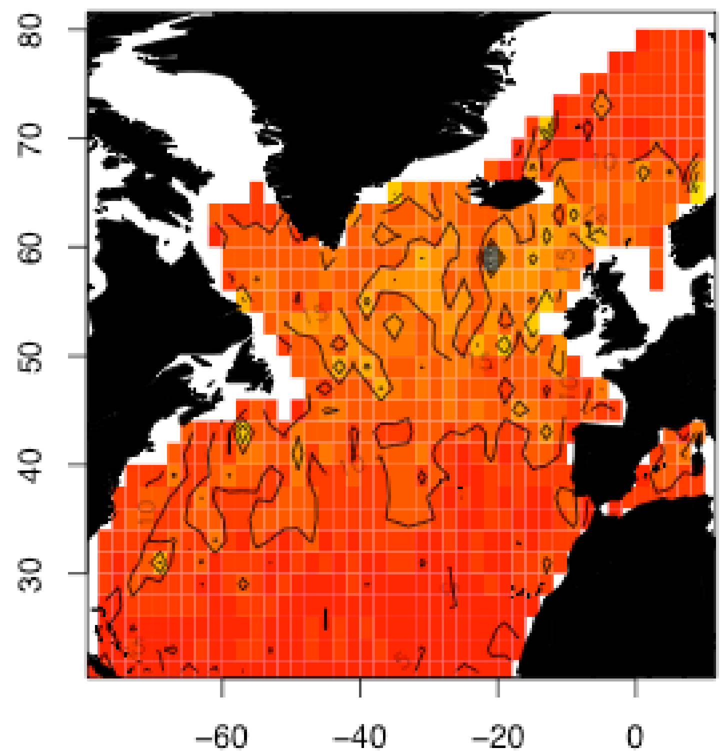


Adding monthly values of the NAO to the scale parameter does little to improve the fit.

If we add an interaction term - a different response to the NAO each month we get better results

These plots show a low (left) and high (right) NAO January H_{50}





Interim Conclusions

- We have found an NAO response,but it is noisy.
  - Perhaps we need to use the winter rather than monthly NAO
  - Or vary the shape parameter
  - Or we may need more data

Spatial Models for Extremes

- So far we have assumed that the extremes in each 2° square are independent of the extremes in the squares around it.
- This is clearly not true
- Two ways to approach this
  - Use a continuous model in space (similar to kriging or optimal interpolation)
  - Treat each 2° square separately but build in some correlation structure between them
- For computational reasons we are investigating the latter

A Bayesian hierarchical model

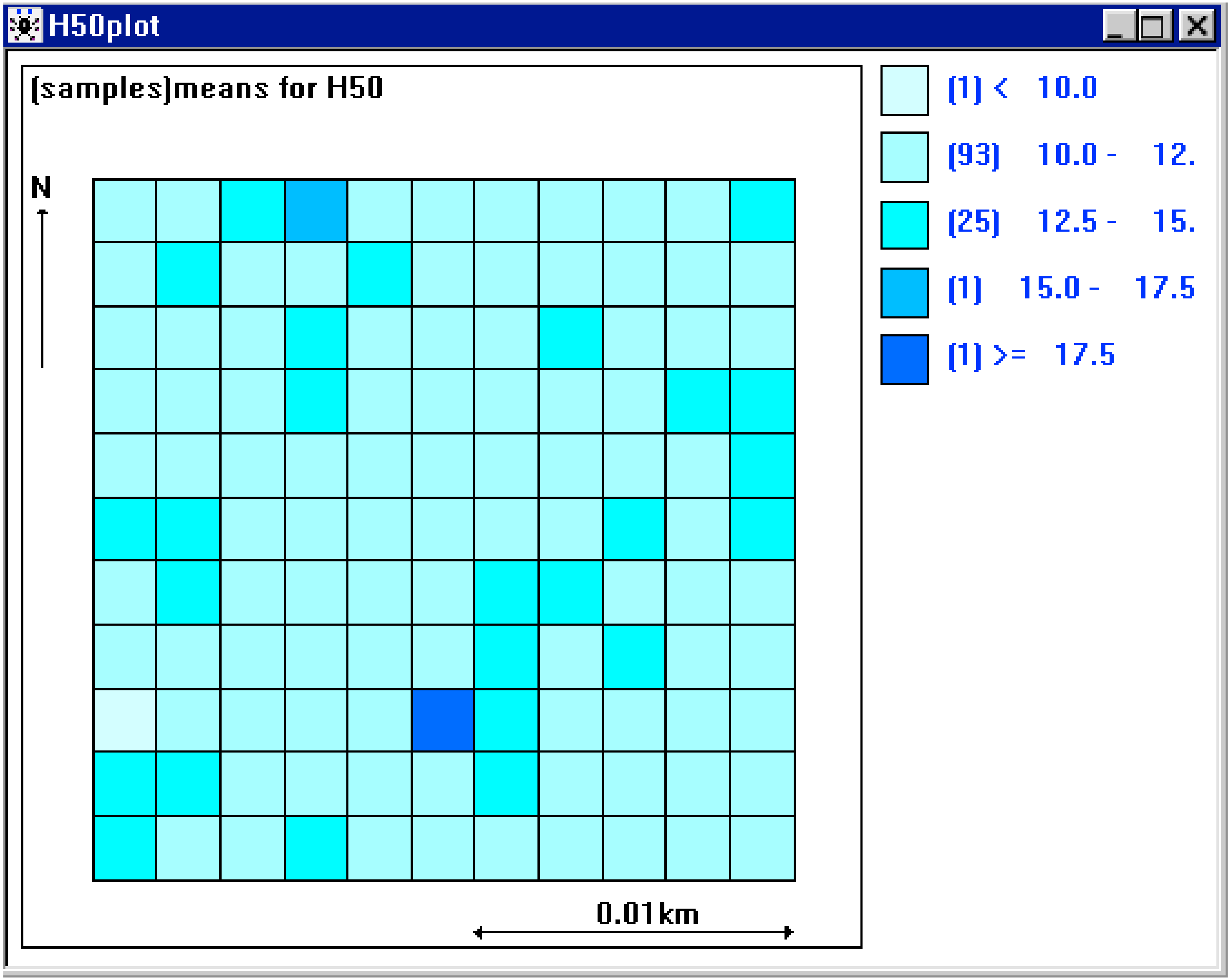
- Conditional on the values of the parameters in each 2° square the exceedences are given by a GPD
- The parameters are either fixed (u) or have priors attached to them.
- The calculations are done in WinBUGS
- square are a weighted average of the parameters in adjacent squares.
- Computations still underway

Conditionally Autoregressive Model

- For a spatial model we make the prior for σ, say, follow a 'conditional autoregressive' (CAR) model.
- Essentially this means that prior for σ in one square is a weighted average of the prior values in adjacent squares.
- Bermudez, Mendes, Pereira and Turkman (2008)

Non Spatial

- Use 11x11 square for test purposes
- 12-22°N 24-34°W
- 20 largest values in each square
- Threshold = 21st
- Gamma Prior on s
- Normal Prior on eta
- Run Gibbs sampler for 1000 iterations to burn in


H50plot
(samples)means for H50
N
0.01km
(1) < 10.0
(93) 10.0 - 12.
(25) 12.5 - 15.
(1) 15.0 - 17.5
(1) >= 17.5

Spatial

- CAR prior on s
- constant eta?
- CAR on eta

Things to do

- Get it working!
- Larger area; better choice of data
- Proper priors
- Covariates - NAO etc