Statistical Reconstruction and Projection of Ocean Waves

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Outline

- Methodologies and Datasets
- Some characteristics of the observed SWH-SLP relationships
- Preliminary results on North Atlantic wave height trends over 1871-2008 (138 yr)
- Preliminary results on changes as projected in CMIP5 simulations
- Ongoing/future work

Methodologies

Statistical "downscaling" ← use an observed predictor-predictand relationship

- Conventional linear and quantile regressions → means, extremes

  (both need high resolution data for extremes)

- Extreme value (EV) model with covariates (predictors) → extremes

  Both the location and scale parameters vary with the predictors?

In order to diminish climate model biases:

- Use normalized predictor quantities in statistical downscaling

  P_t – normalized anomalies of seasonal mean SLP

  G_t – normalized anomalies of seasonal mean squared SLP gradient (geo-wind energy index)

- Use a quantile-matching algorithm to adjust (CMIP5) model simulated predictor values, so that the adjusted simulations for a baseline period share the same distribution as the corresponding observations (reanalysis data).

Datasets

1. ERA40 SLP – predictors
2. ERA40 waves (SWH) - predictand

→ observed SLP-SWH relationships

- different statistical downscaling methods

  e.g., linear regression versus Quantile regression

- different temporal resolutions, e.g., seasonal versus 6-hourly

Important - find good predictors that are also well simulated by climate models!

3. <u>Predictors</u> from 6-hourly SLP of 20CRv2, The 20th Century Reanalysis (56 runs)

   → the relationships → to reconstruct the past (1871-2008) wave climate

   - temporal homogeneity issues, homogenization - ongoing
   - basically homogeneous for the North Atlantic – focus of this presentation

4. <u>Predictors</u> from CMIP5 model simulations

   → the relationships → to project future wave climates

For extremes, scale is also varying with the covariates in a large portion of the oceans

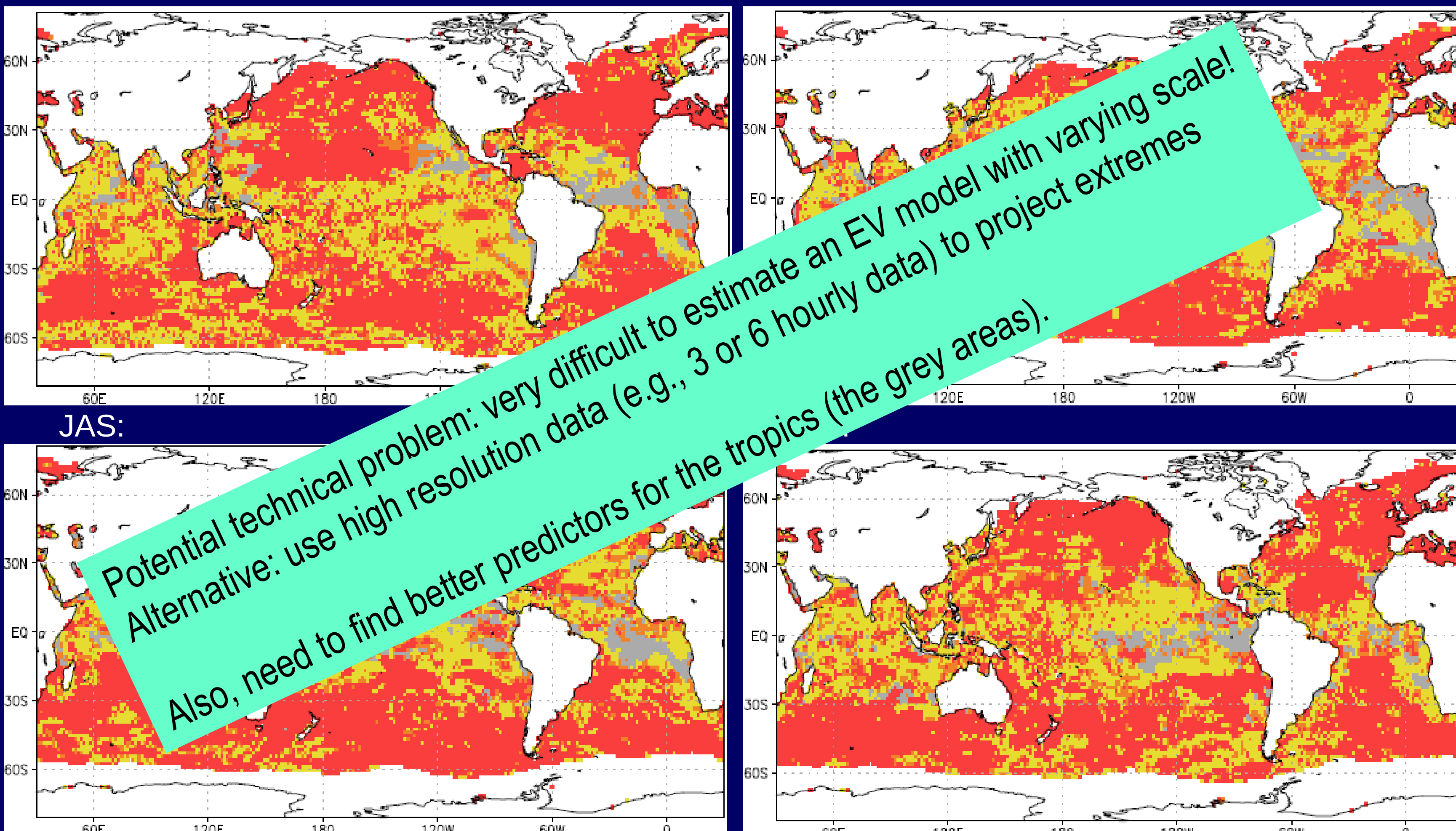
Compare EV1: <u>only location par. varies</u> with the predictors, but scale & shape are constant

with EV2: <u>both location & scale par's vary</u> with the predictors, but shape is constant

EV0: parameters are not significantly related to the predictors (EV1 is used)

JFM: AMJ:

JAS:



Potential technical problem: very difficult to estimate an EV model with varying scale!

Alternative: use high resolution data (e.g., 3 or 6 hourly data) to project extremes

Also, need to find better predictors for the tropics (the grey areas).

New: use 6-hourly data to calibrate predictand-predictors relationships

Using ERA40 { 6-hourly SLP on 2°x2° lat-lon grid
6-hourly Hs on 1.5°x1.5° lat-lon grid } for 1981-2000 (baseline period)

Will also use ERA-Interim { 6-hourly SLP on 2°x2° lat-lon grid
6-hourly Hs on 0.7°x0.7° lat-lon grid } for 1981-2000

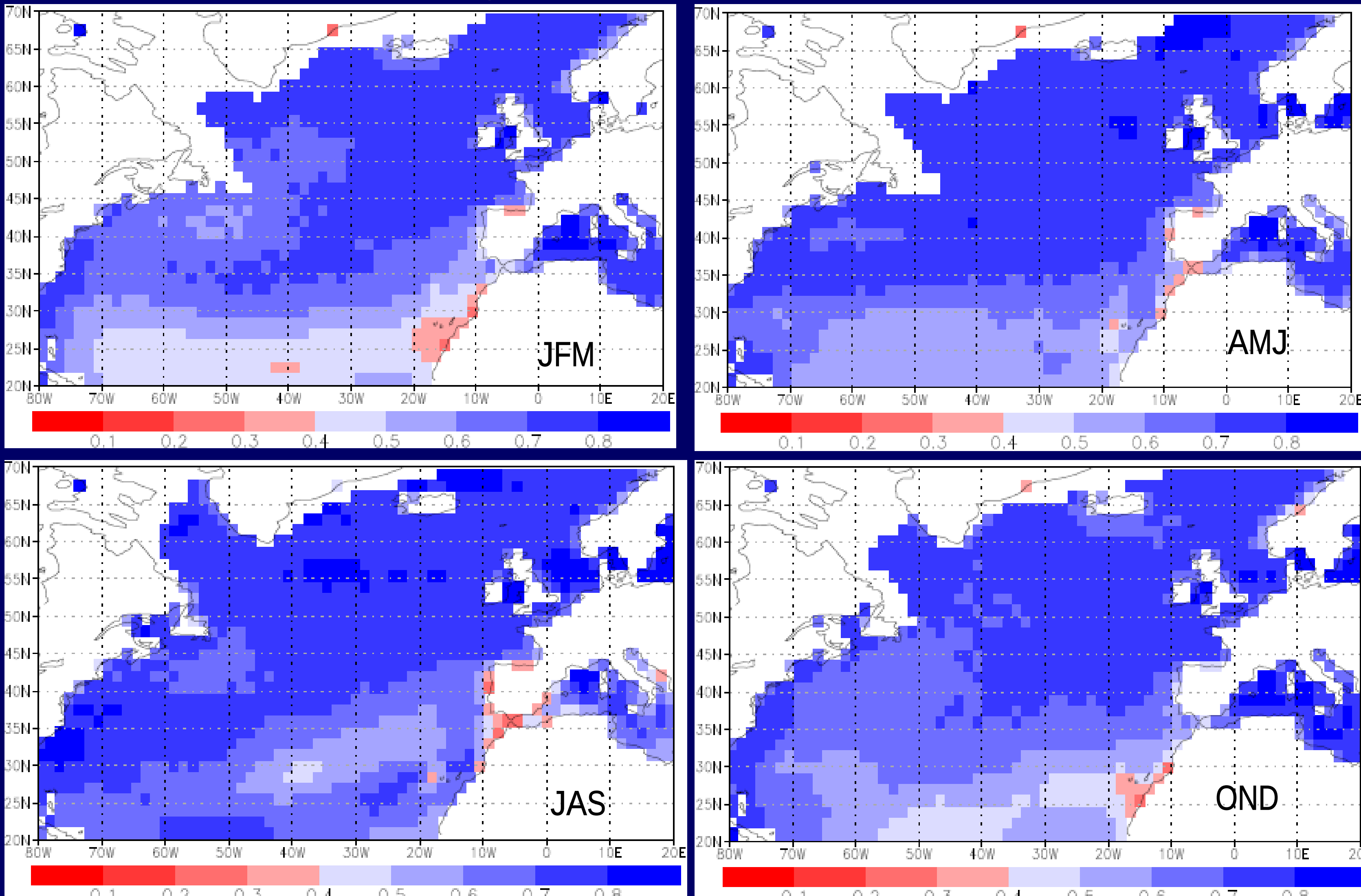
Calibrate a linear regression Ht ~ (Pt, Gt) relationship for each season separately.

Evaluate the models that are calibrated from data in a calibration period with data in an evaluation period that does not overlap with the calibration period, e.g.,

calibration: ERA40 for 1981-2000 evaluation: ERA40 for 1958-1977

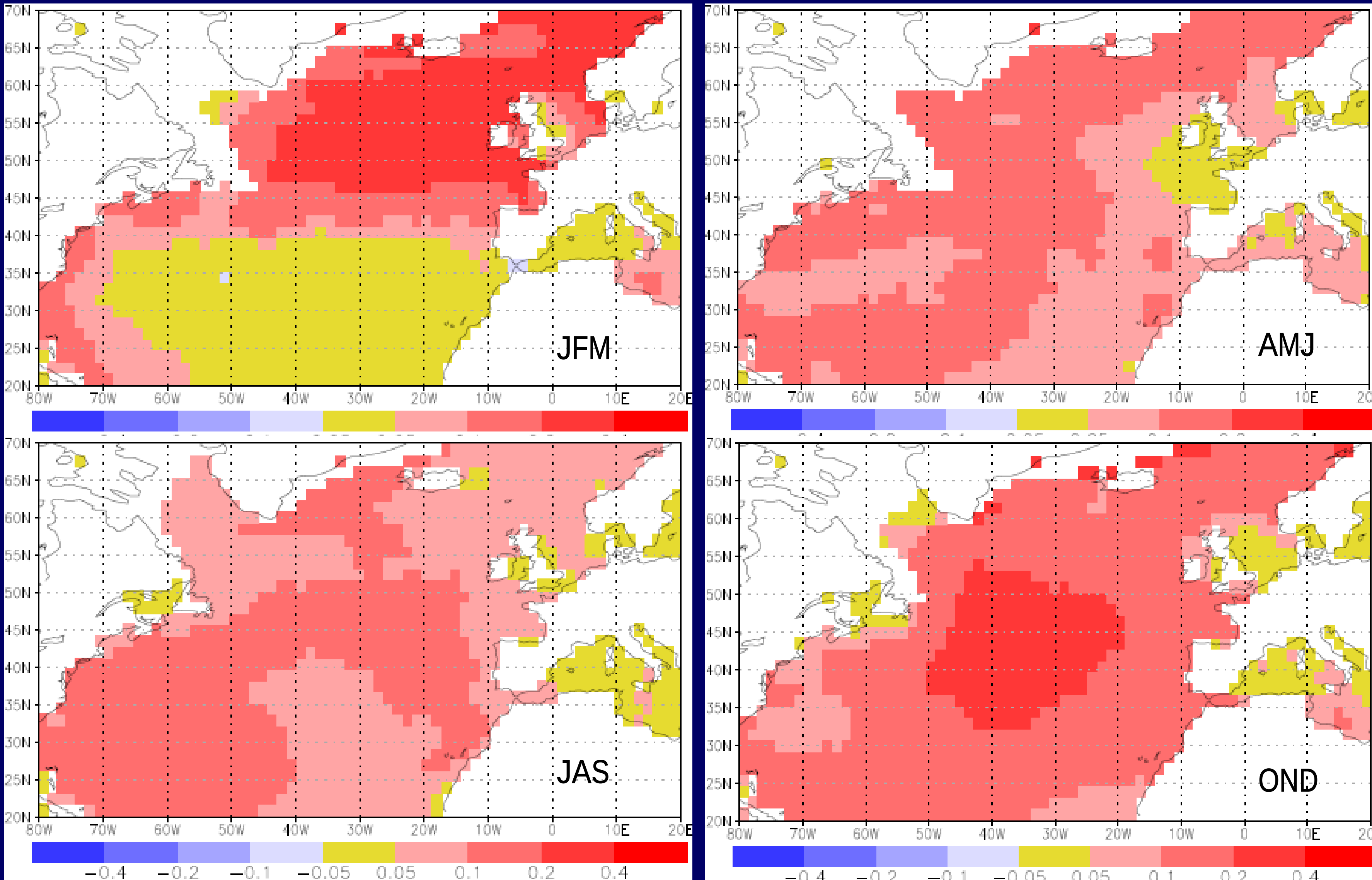
allows us to check statistical models' time-transferability

Anomaly correlation skill scores



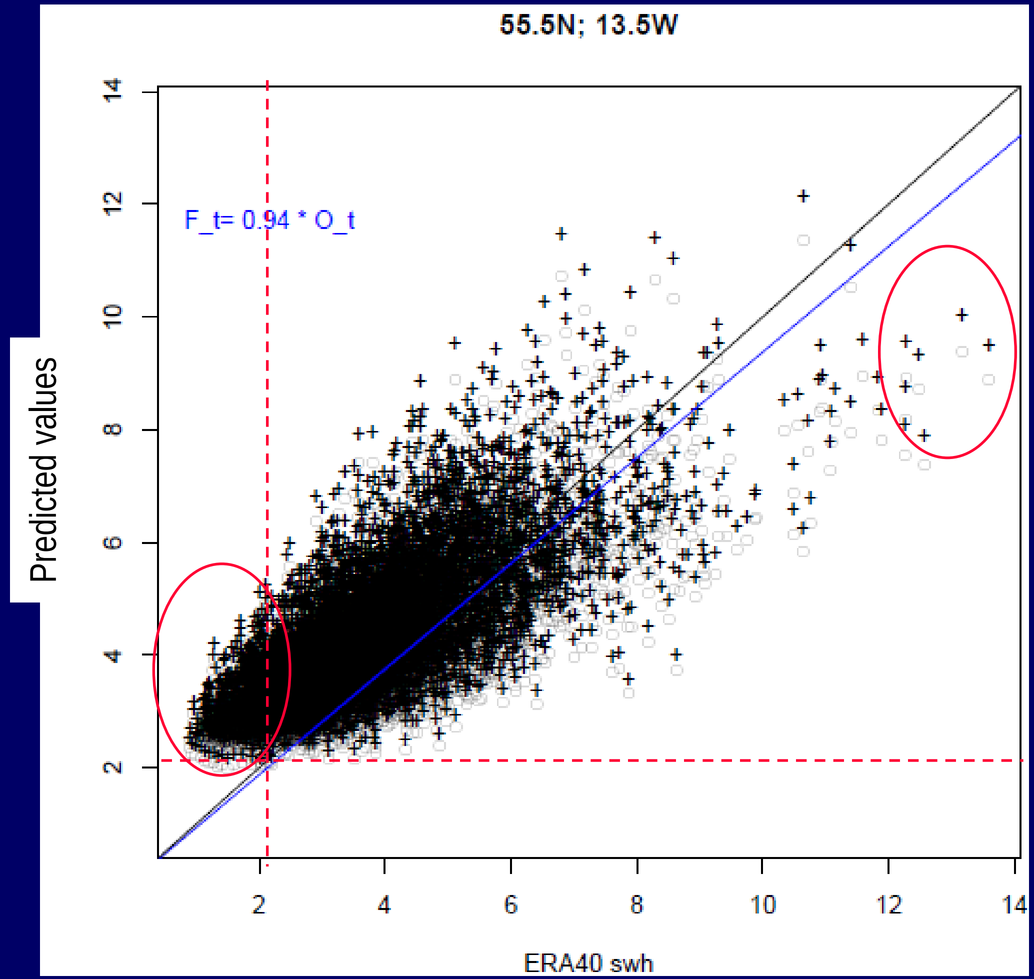
Lower skill in the lower latitudes, especially in the cold seasons (JFM, OND)

Predicted-minus-observed wave height climate (1958-1977 mean, in m)



The stat. model overestimates the wave height climate, especially in high latitudes in winter

- It overestimates mainly the low quantiles of wave heights, for example



It systematically over-predicts wave heights that are below 2 m, but under-predicts the extremes.

To improve model skill:

Will explore new models, such as quantile regression

– different predictor-predictand relationships for different quantiles

(e.g, one for the lowest 10%, one for 10-20%, …, and one for 90-100%, respectively.)

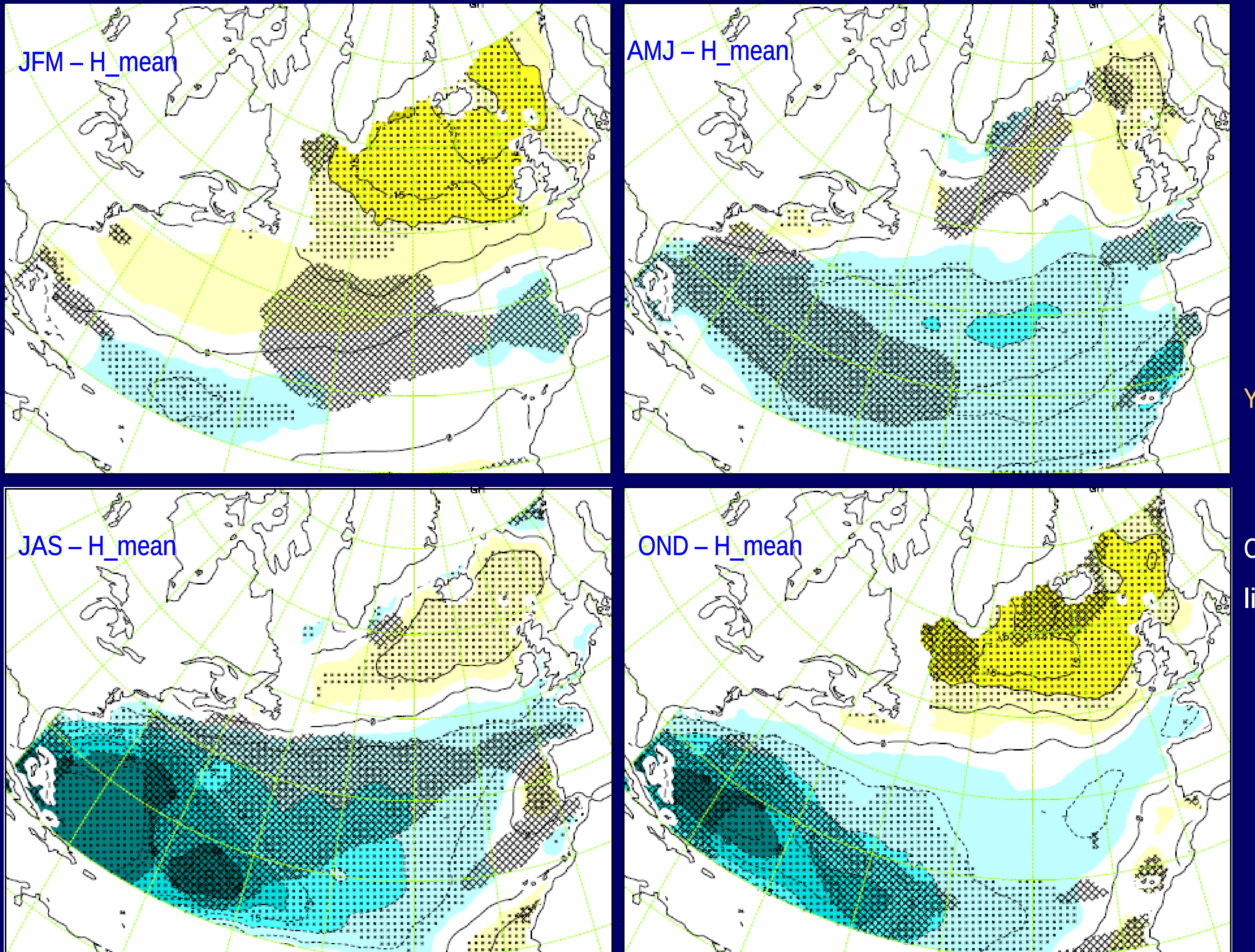
Will add a few predictors that can represent swell components.

Reconstructed 1871-2008 trends in wave heights

For now, just show trends in the North Atlantic, in which 20CR is homogeneous;

it suffers from inhomogeneity in other basins

The 1871-2008 trends in seasonal mean SWH in the North Atlantic (← 6-hourly relationships)



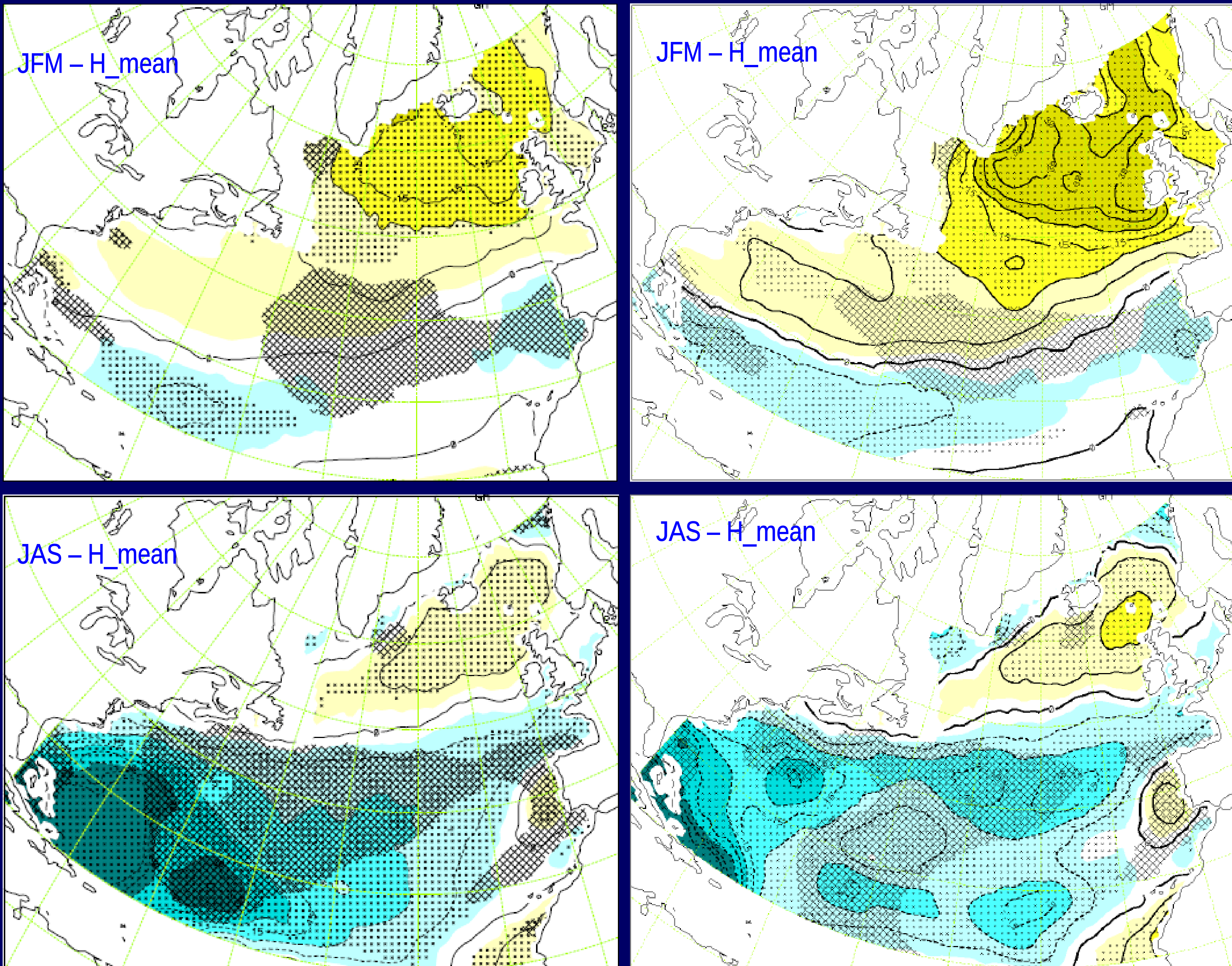
Yellow: ↑

Cyan: ↓

Contours: linear trends

Crosses: location of significant (at least 5%) linear trends   grid-hatching: locations of significant quadratic trends

Trends from 6-hourly relationships | Trends from seasonal relationships



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Contours:

linear trends

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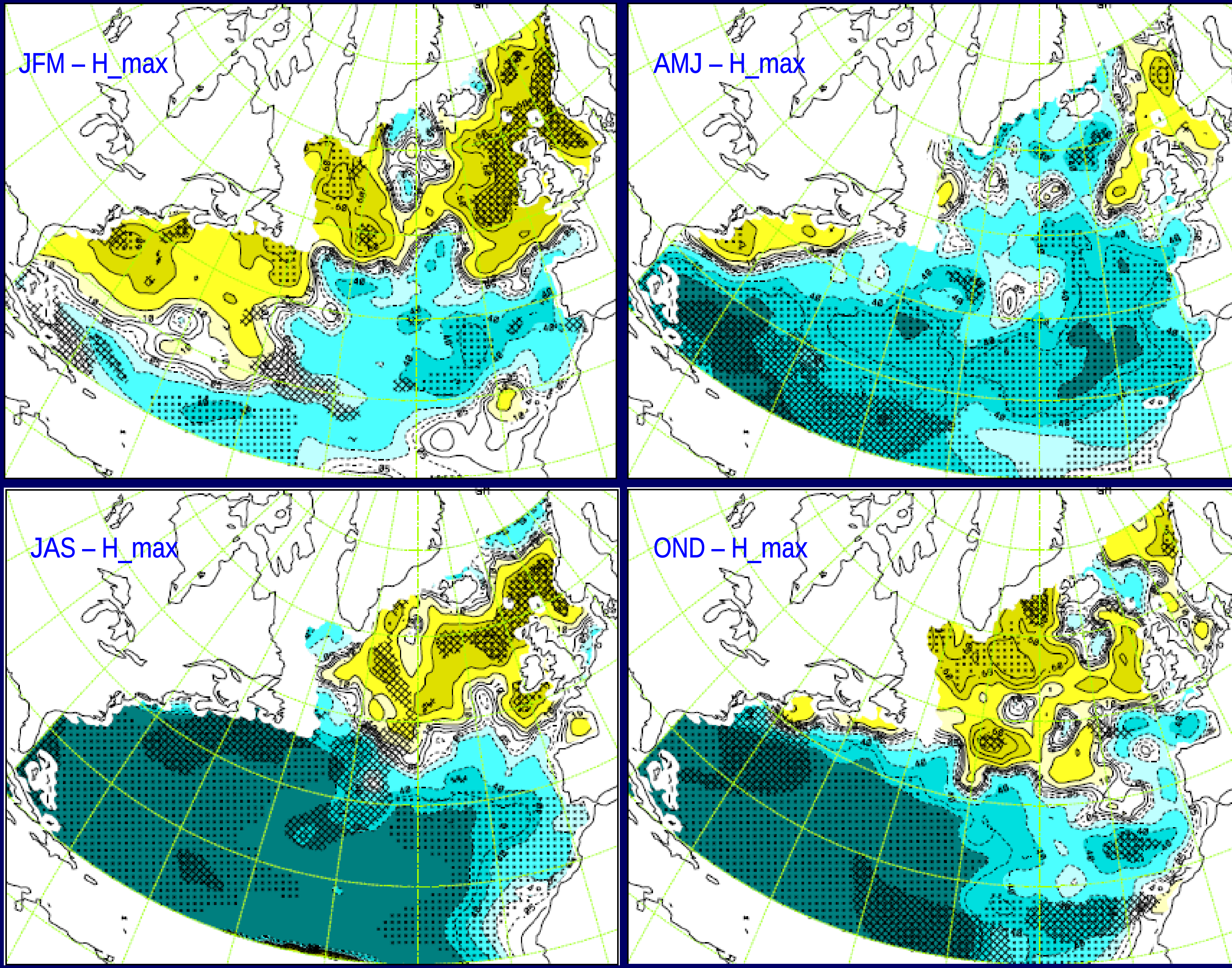
The 1871-2008 trends in seasonal max SWH in the North Atlantic (← 6-hourly relationships)



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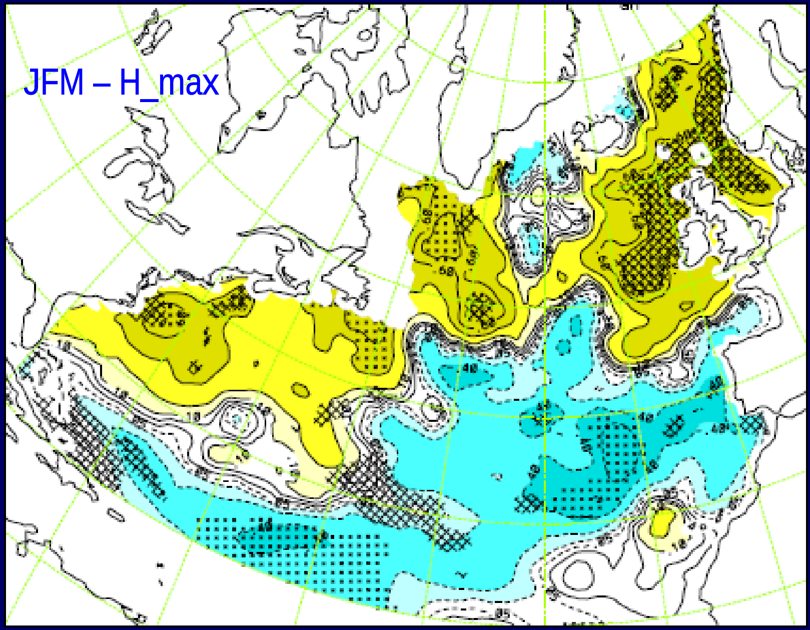
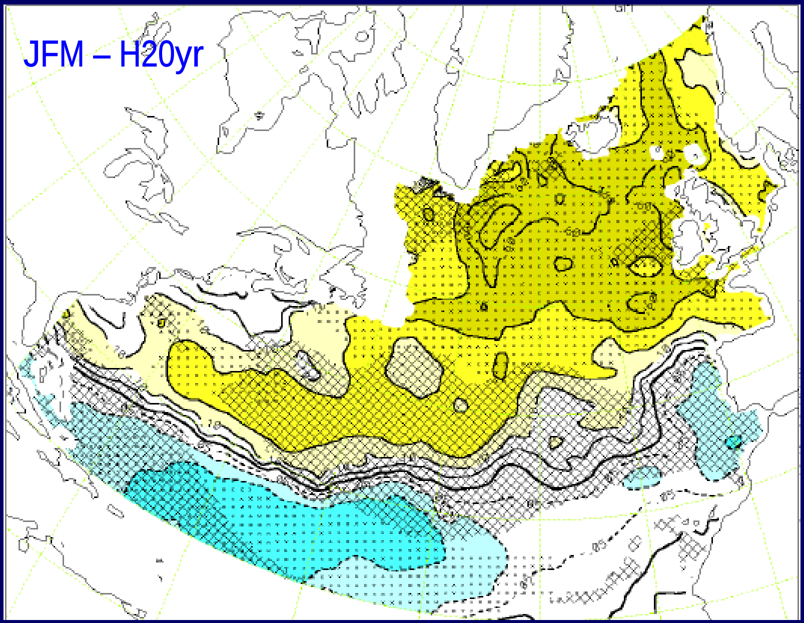
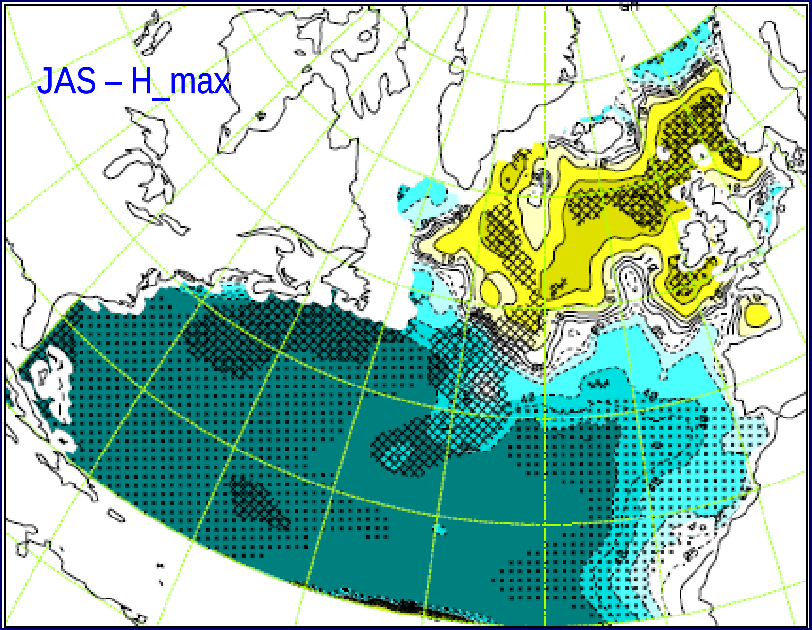
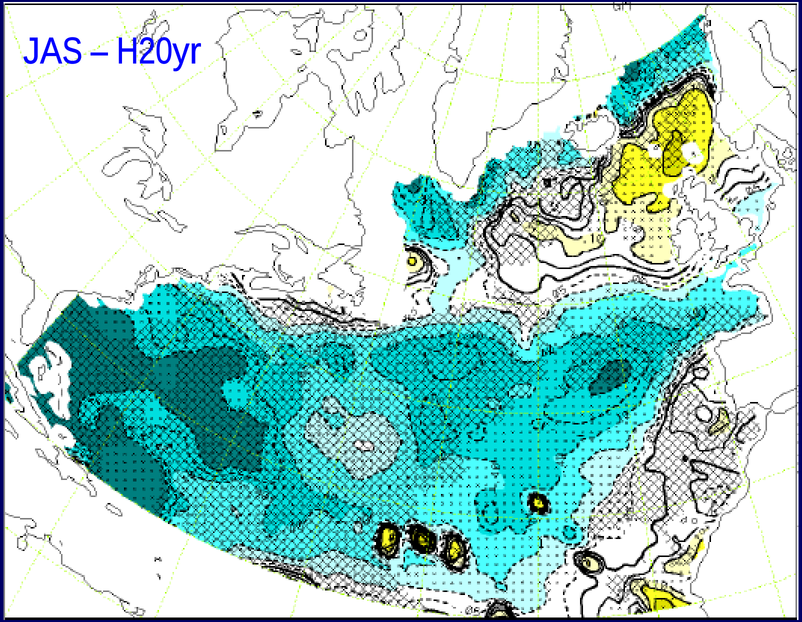
Trends from 6-hourly relationships

Trends from seasonal relationships









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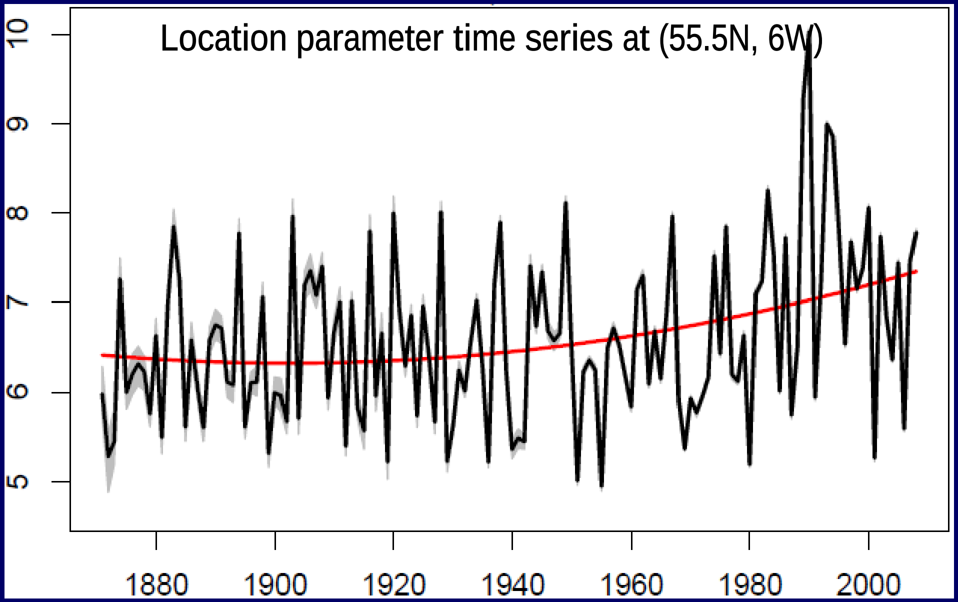
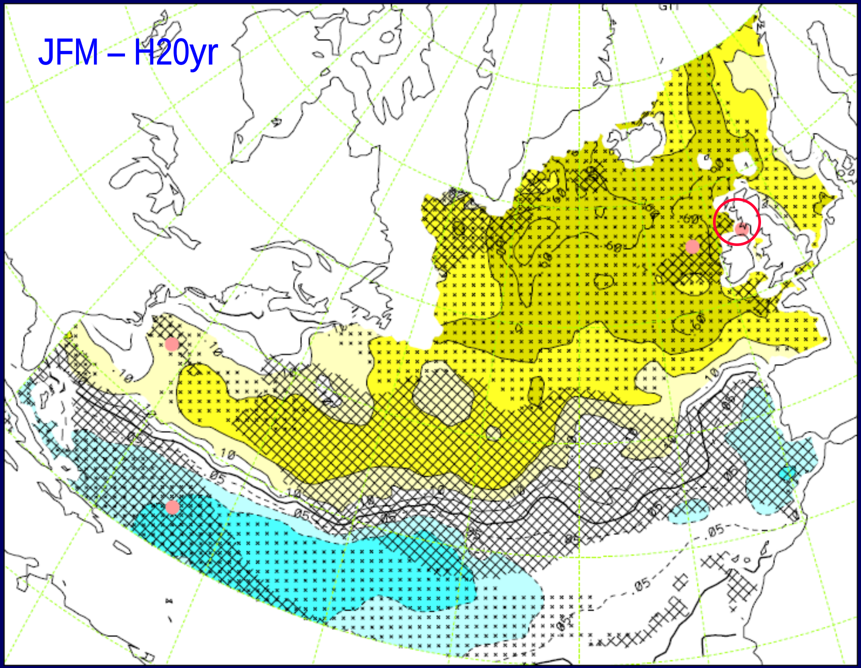
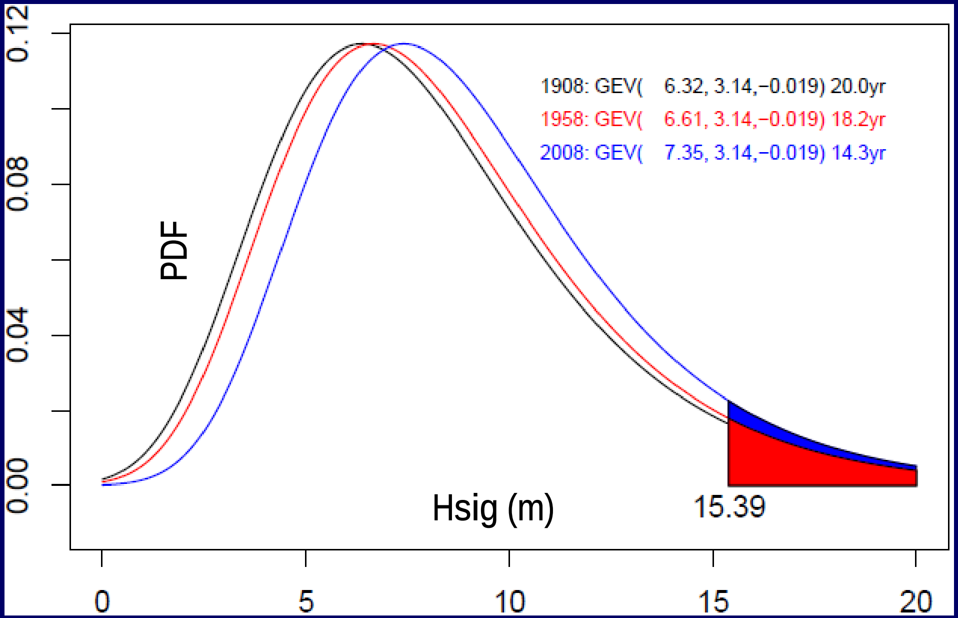
Examples of changes in the distribution of JFM seasonal maximal significant wave heights

(from seasonal GEV relationships)





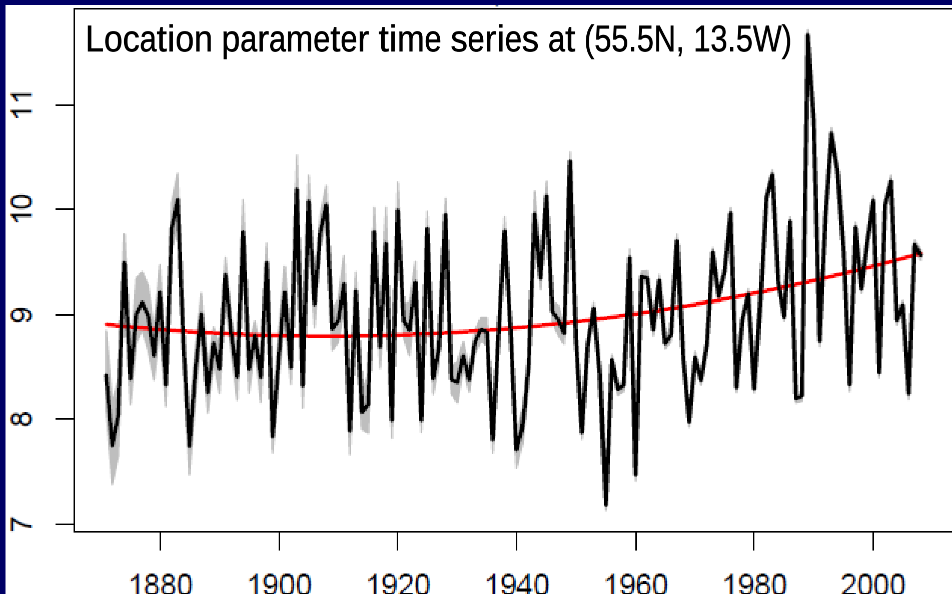


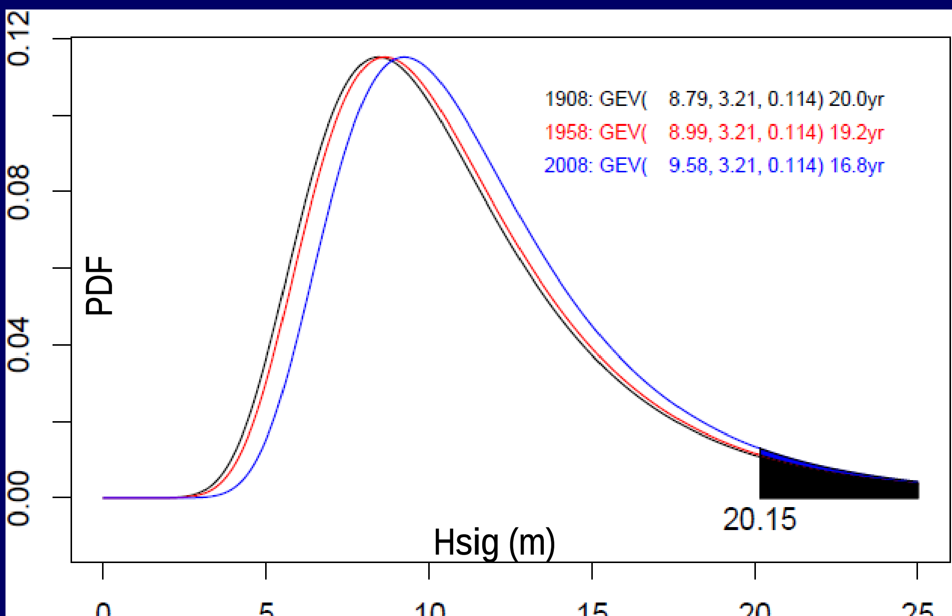
A 20-yr event has become a 14-yr event during the past century.

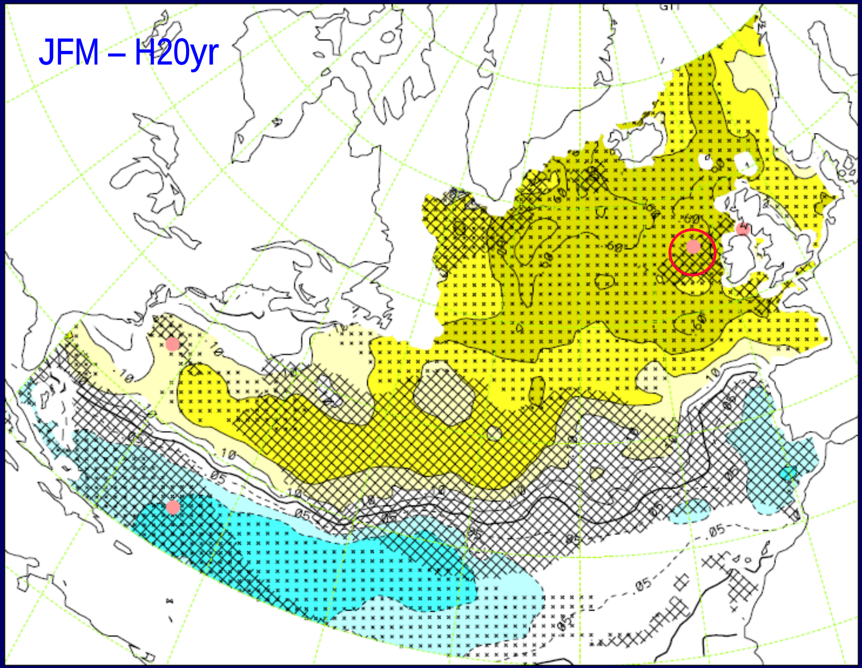
The increase is mainly in the last 30 years.

Examples of changes in the distribution of JFM seasonal maximal significant wave heights

(from seasonal GEV relationships)





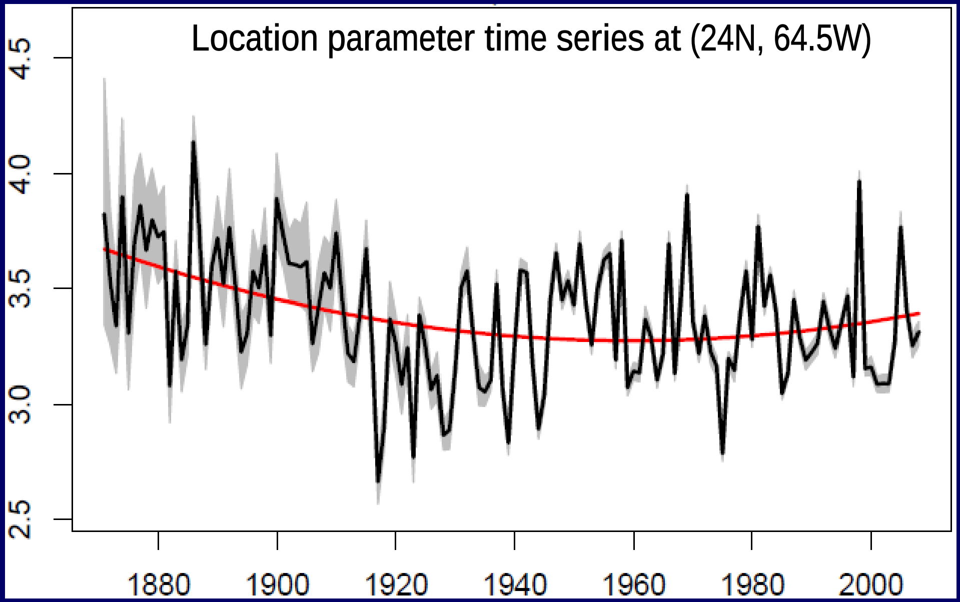


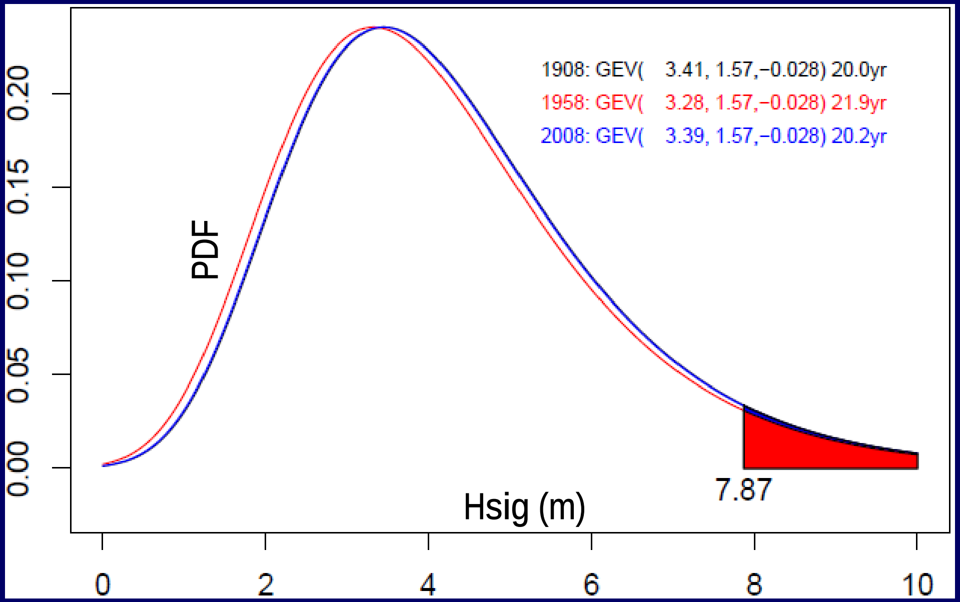
A 20-yr event has become a 17-yr event during the past century.

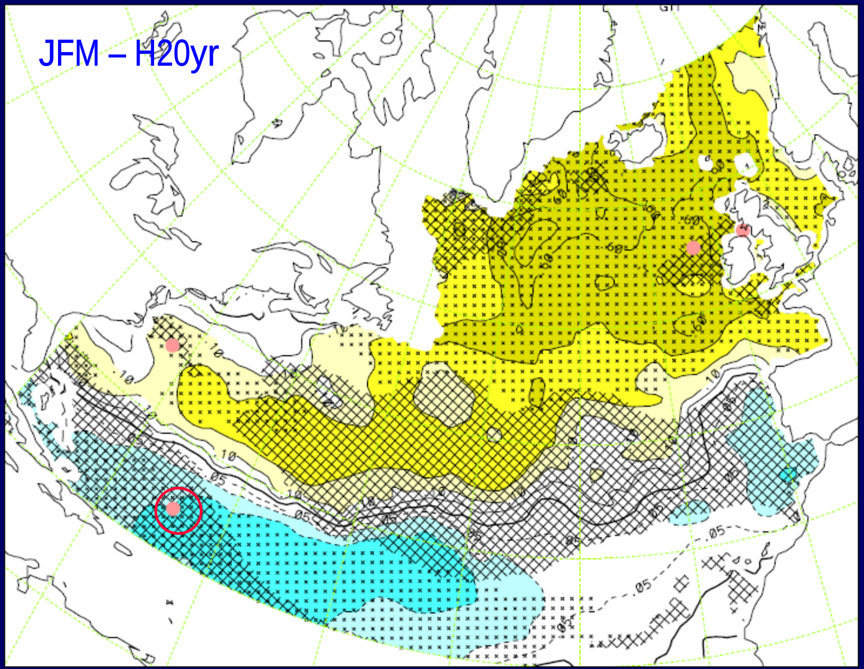
The increase is mainly in the last 30 years.

Examples of changes in the distribution of JFM seasonal maximal significant wave heights

(from seasonal GEV relationships)





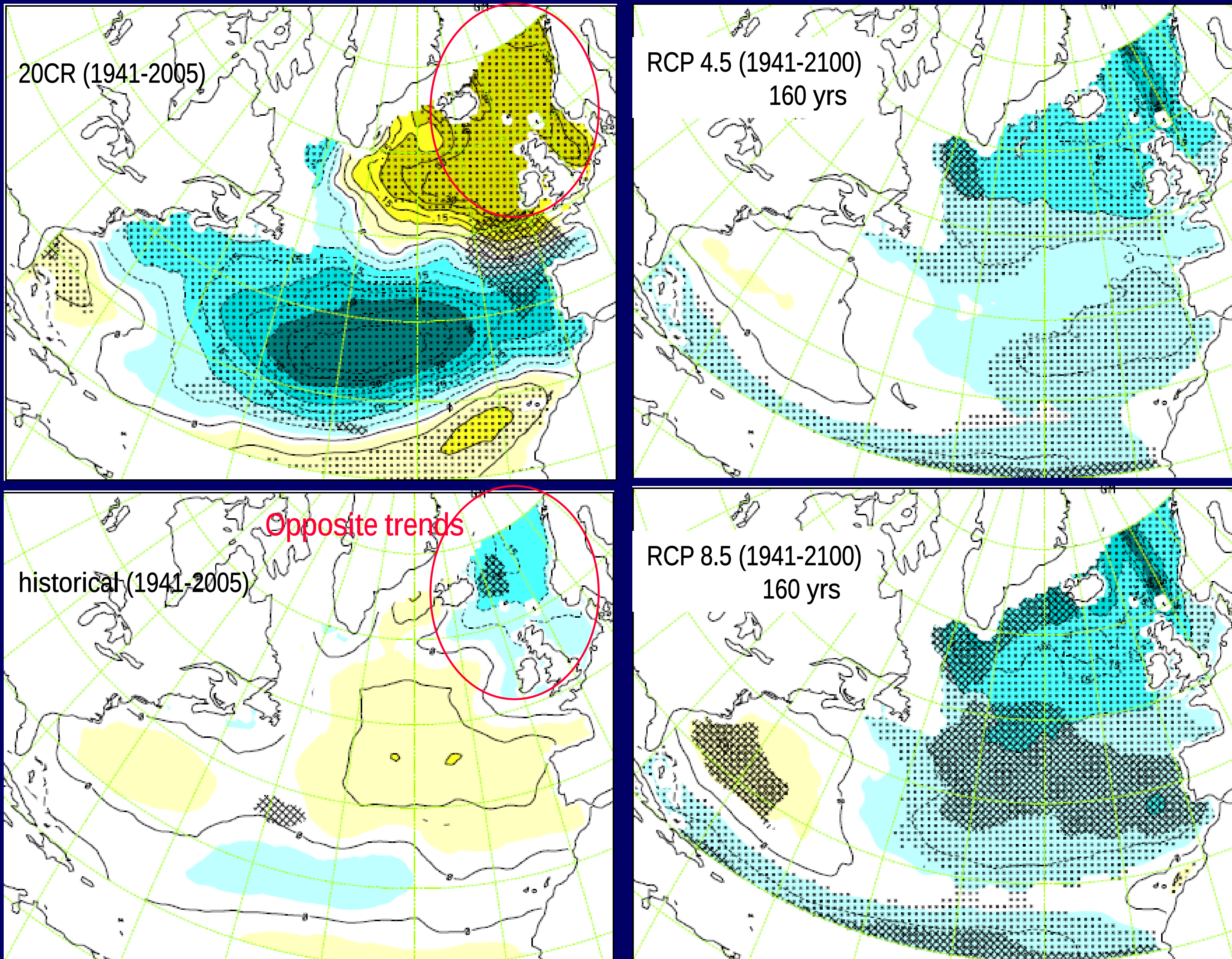


There seems to be a significant decrease in the early decades but no trend since early 20C.

Trends in wave heights as downscaled from the CanESM2 simulations

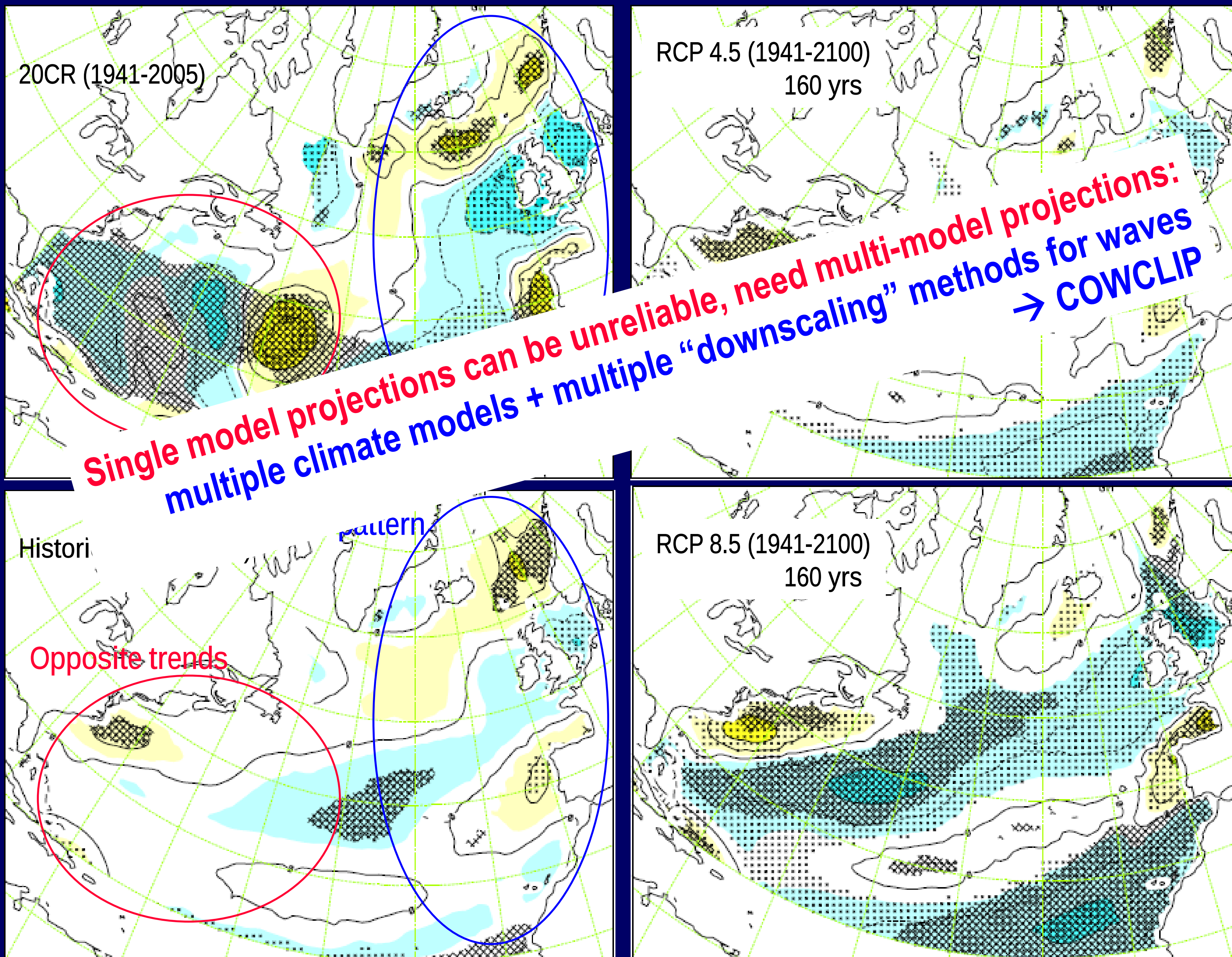
- historical simulations for 1941-2005 (5 ensemble members)
- RCP 2.6 simulations for 2006-2100 (95 yrs)
- RCP 4.5 simulations for 2006-2100 (95 yrs)
- RCP 8.5 simulations for 2006-2100 (95 yrs)

CanESM2 simulated trends in JFM mean wave heights



Crosses: location of significant (at least 5%) linear trends grid-hatching: locations of significant quadratic trends

CanESM2 simulated trends in JAS mean wave heights



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Ongoing/future work

- Develop, apply, and evaluate different statistical downscaling methods - ongoing

- Reconstruct the 1871-2008 global wave climate using the 20CRv2 SLP - ongoing

- Characterize global wave climate trends over the 138-year period since 1871, with temporal homogeneity assessment

- Conduct statistical projections of global wave climate using CMIP5 simulations

- Analyze the COWCliP wave projections to characterize climate change signal and various uncertainty associated with wave climate change projections

Thank you very much!