COMMON FORM
FOR EXTRAPOLATIONS OF STORM SEVERITY
IN THE NORTH ATLANTIC ?

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ERA 20-year wave hindcast from ECMWF

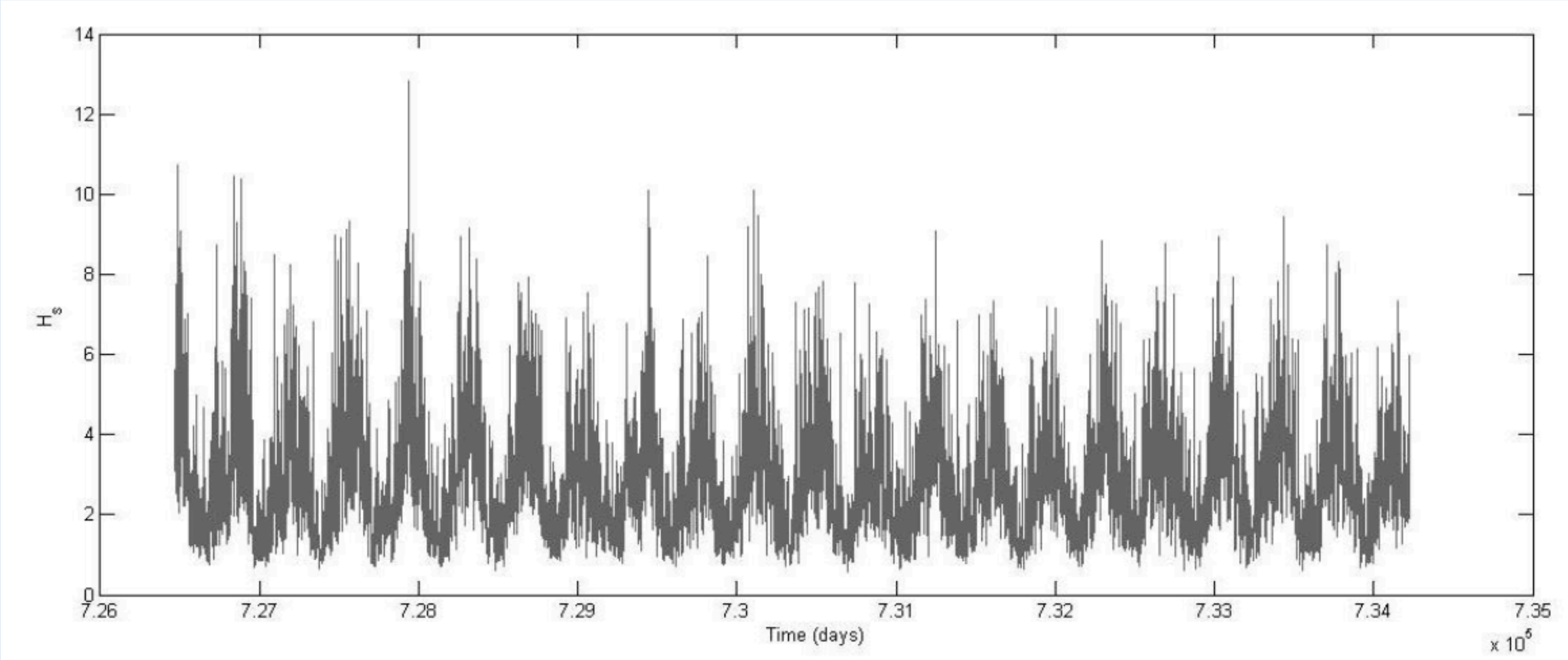
5 locations for analysis

All deep water, exposed sites

North-south traverse down eastern North Atlantic

Data downloaded
Significant wave height H_s and mean wave period T_m every 6 hours

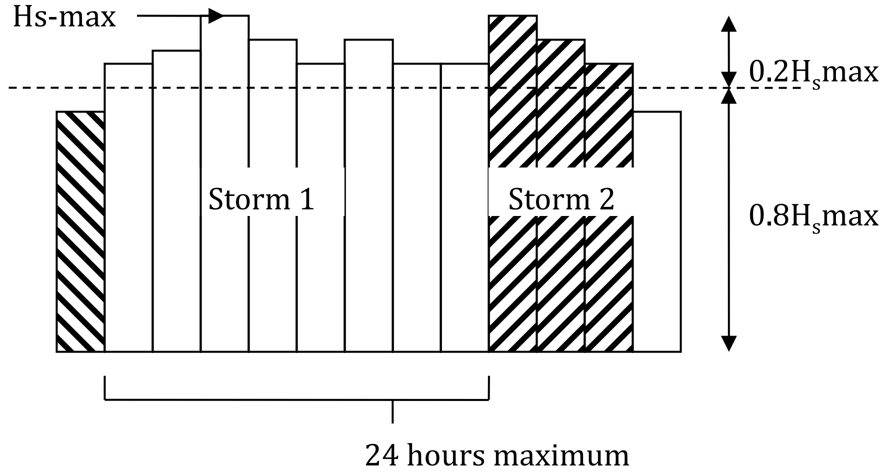
Faroes - complete 6-hourly H_s dataset



How to characterise storm-based wave severity ?

- use Peaks Over Threshold (POT) technique
- requires independent peaks : 1 number per storm
- what is a storm ?
  estimation of severity ?
- aim : robust estimate of 1 in 100-year extreme storm

Definition of a storm and storm severity

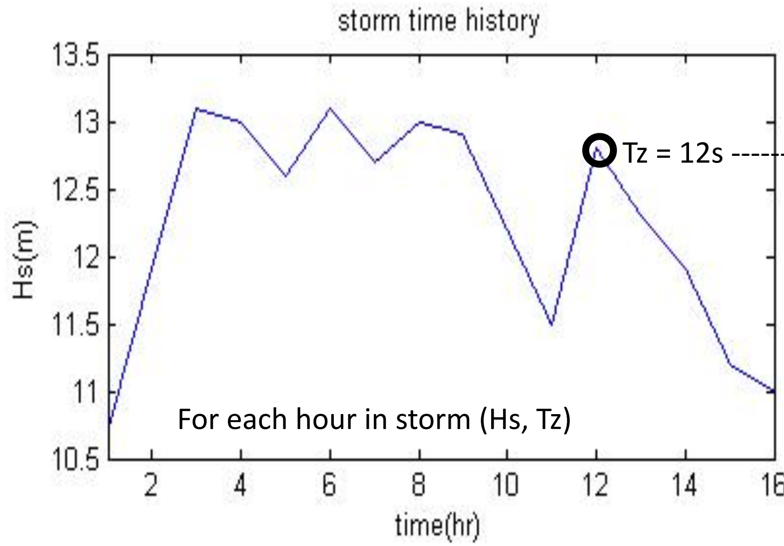


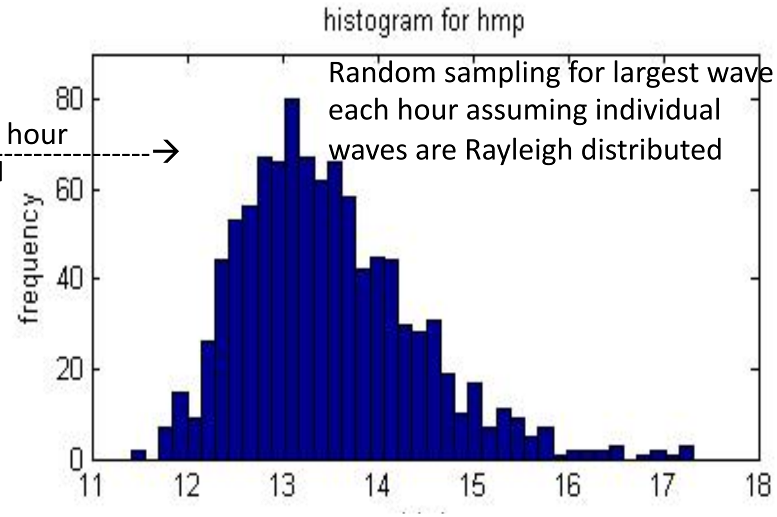
1. Identify storms in Hs record (<24hours long, Hs>0.8 Hs-max)

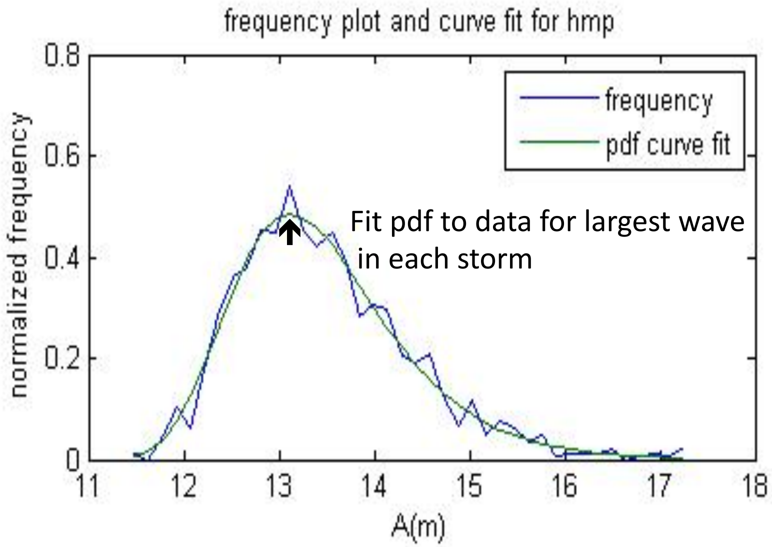
2. Choose a single parameter to capture storm strength *and* duration
   Assume individual wave heights each hour are Rayleigh distributed

3. **H_{mp} – most probable maximum wave height for each *storm***

   - first introduced by Tromans and Vanderschuren 1995, OTC7683







Example from buoy 46035 (Bering Straits)

H_{mp} = most probable maximum individual wave height

- captures both severity of storm (H_s values *and* duration)

In the 11th workshop in Halifax (Taylor, Barker, Bishop and Eatock Taylor),
we compared fits to Norwegian (Haltenbanken off Trondheim) and Pacific buoy data using

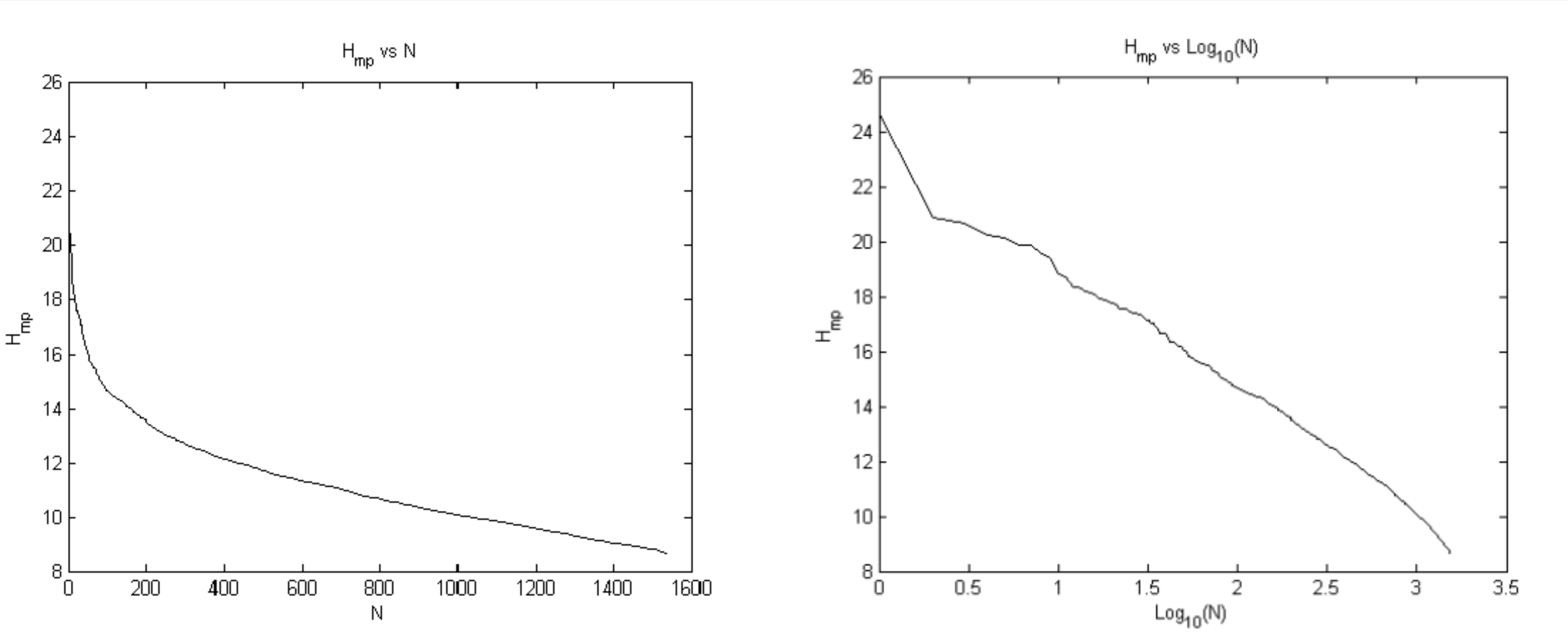
Order statistics - (N, N-th largest H_{mp})

2 fitting forms
– both examples of 'thin exponential-type tails' in extreme value theory

$Log_{10}\, N = a + b\, H_{mp} + c\, H_{mp}^{2}$ - quadratic scaling

$= A + B\, H_{mp}^{C}$ - simple power law

Here we concentrate on the power law form
- this is motivated by the form of the data



Faroes data : Order statistics - (N, N-th largest H_{mp})

Taking Log N helps, but curve is slightly convex

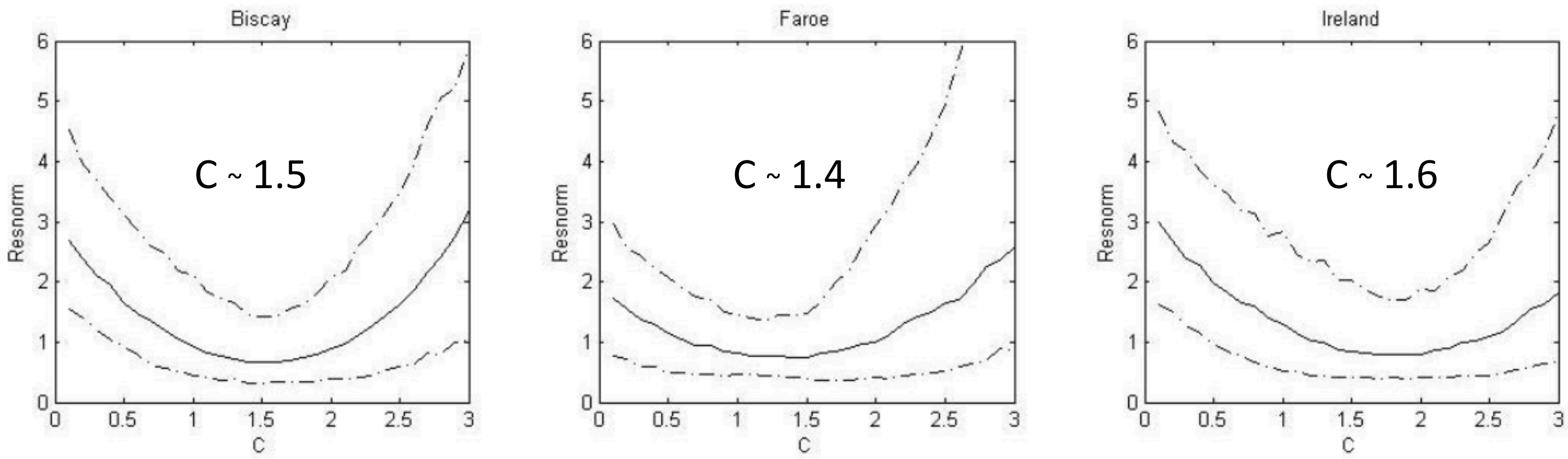
So 3 –parameter fit Log N = A + B H_{mp}^{C}

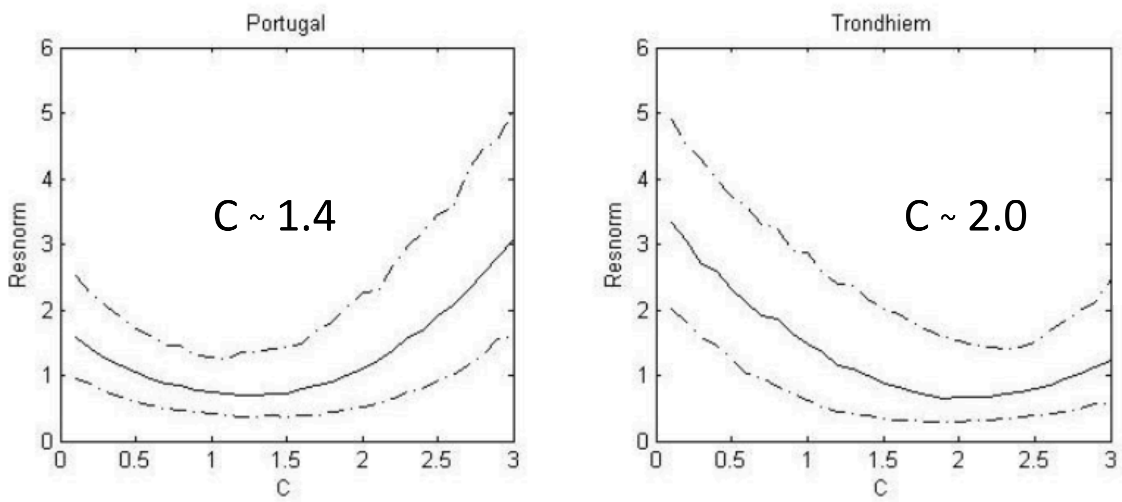
Desirable features of extreme value predictions

1. Independent of choice of threshold
2. Universal form, no sign of upper limit, consistent with theory of extreme value statistics
3. Unbiased and robust prediction

	Number of Storms	
Area	H_s min = 5	H_s min = 4
Biscay	487	1086
Faroe	1043	
Ireland	1723	
Portugal	488	1252
Trondheim	387	948

Choose to fit up to 500 storms (~25 per year, 2 per week in winter for ERA data)





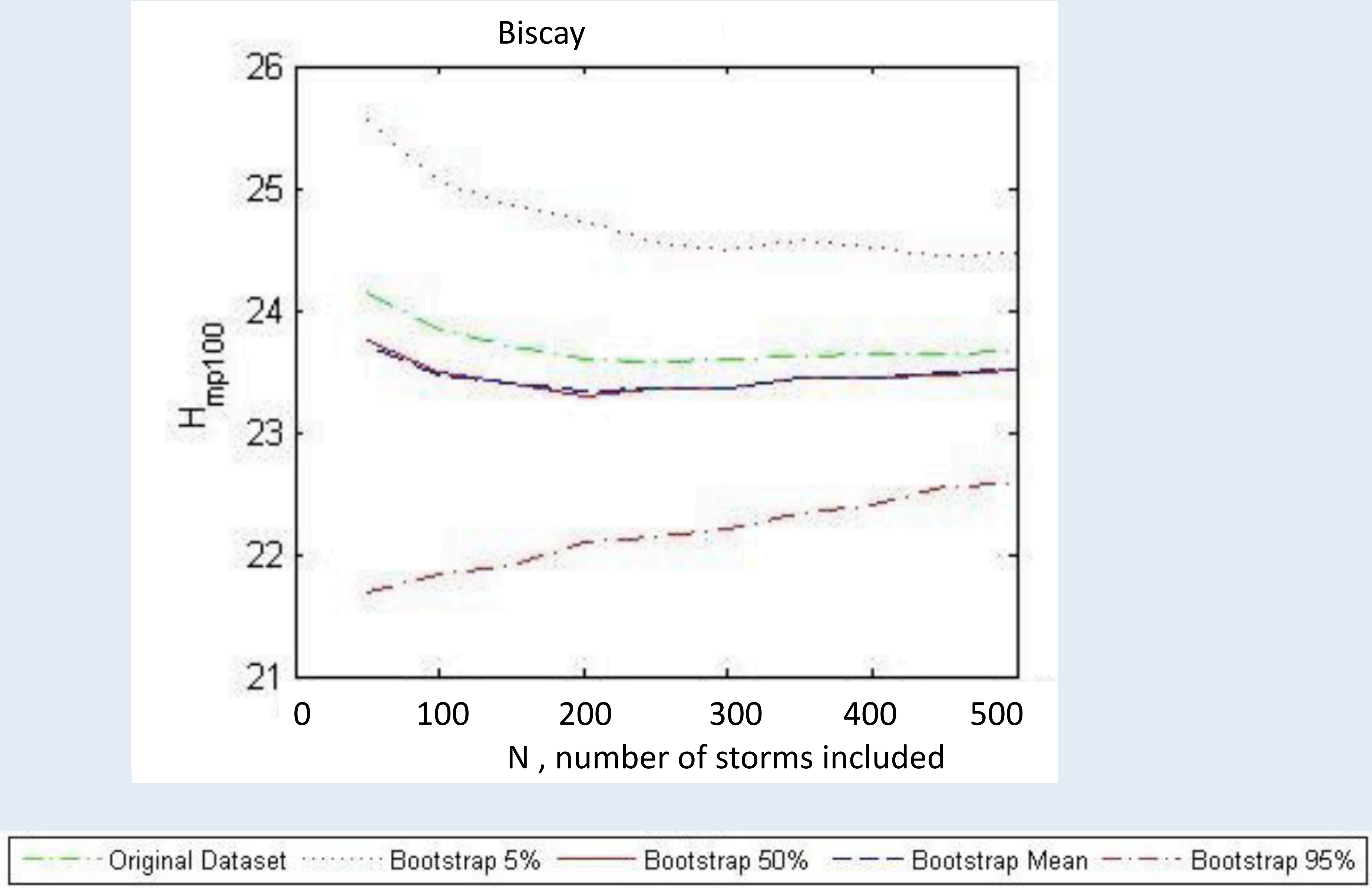
Goodness of fit

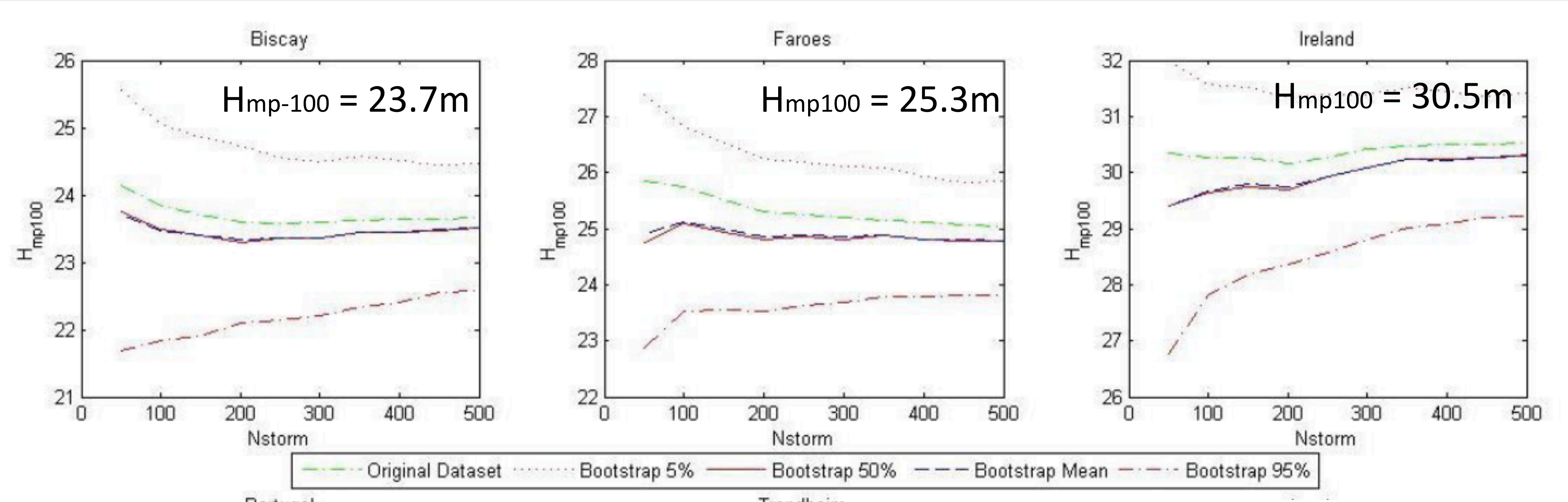
$$resnorm = \left[\sum_{i=0}^{N_{max}} \left[H_{mpi} - \left[\frac{1}{B} \{ log_{10} N_i - A \} \right]^{1/c} \right]^2 \right]^{1/2}$$

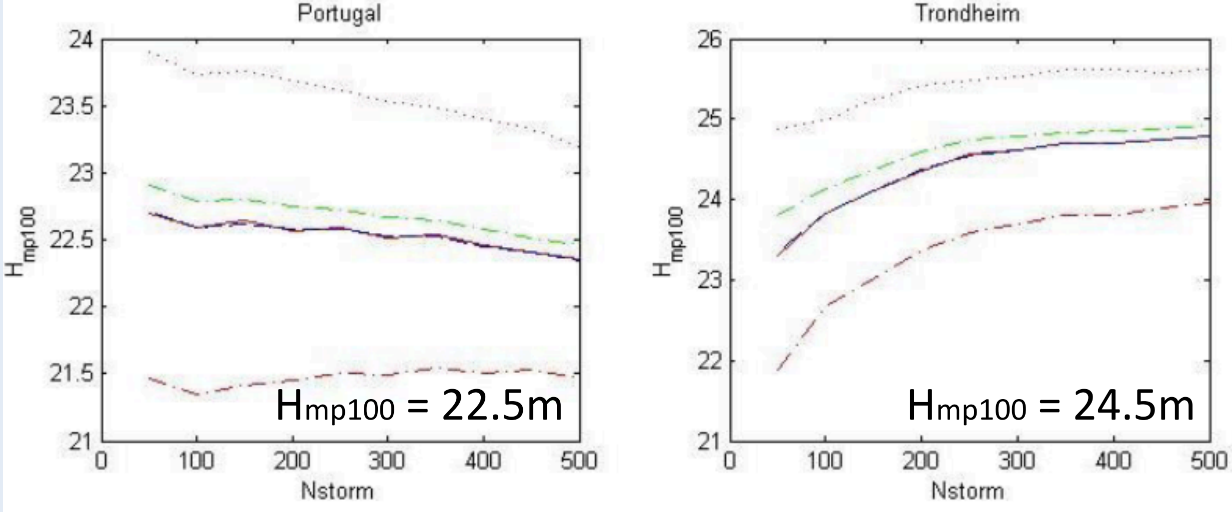
-fits to 500 storms

Bootstrapped mean and 5- 95% estimates of the constant C in Log N = A + B H_{mp}^{C}

4 out of 5 locations have C ~ 1.5, only Trondheim is significantly different with C ~ 2


Biscay
26
25
24
23
22
21
H_{mp100}
0
100
200
300
400
500
N , number of storms included
Original Dataset
Bootstrap 5%
Bootstrap 50%
Bootstrap Mean
Bootstrap 95%



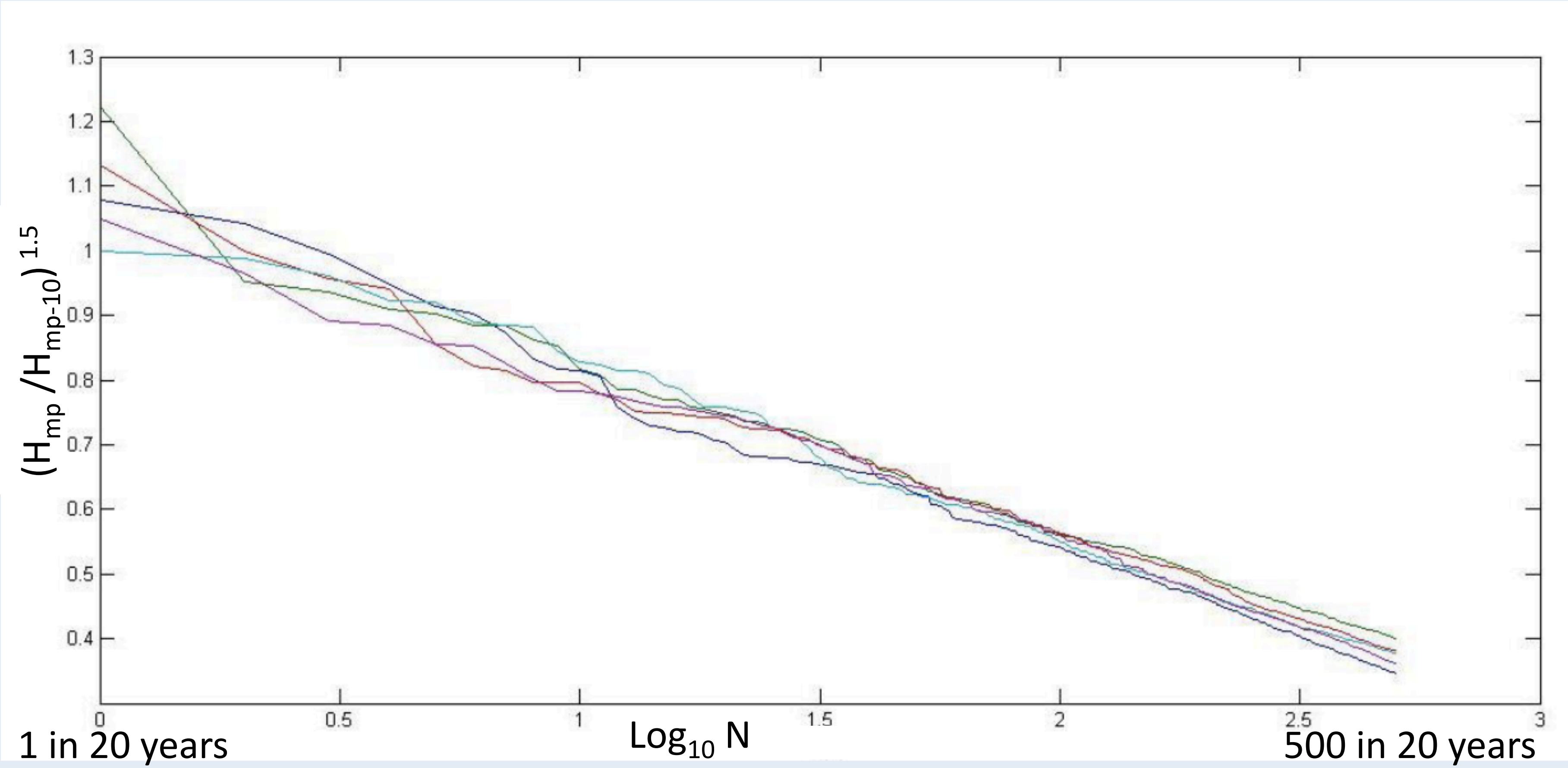


Comments:

Slight bias original data fit vs. bootstrap
Bootstrapped 50% same as mean,
CI close to symmetric

Only Trondheim has significant threshold sensitivity

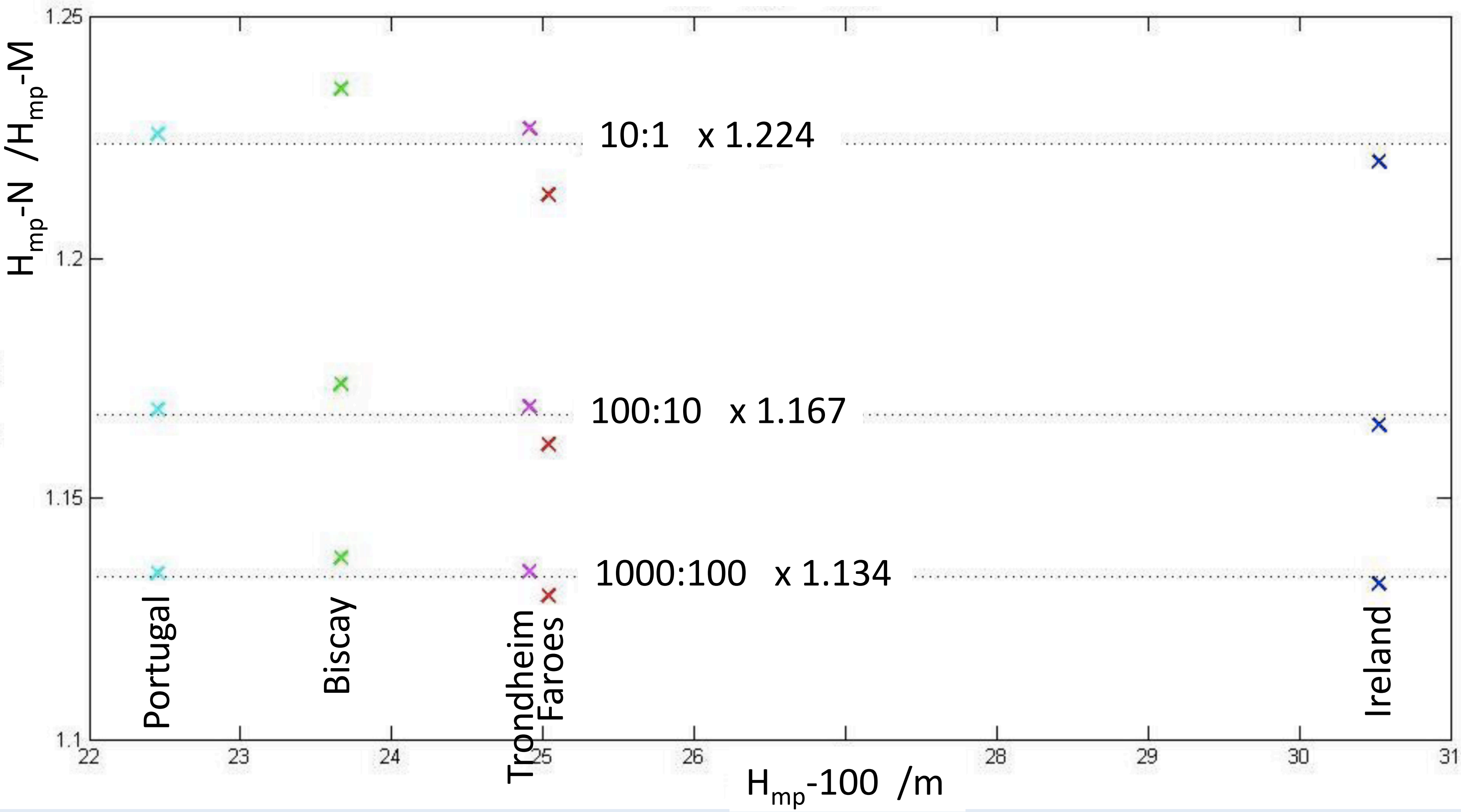
100-year estimate vs. number of storms (Nstorm) in 20-year record



Possible collapse of order statistics to single form ?

5-95% bootstrap confidence bands for each are 2x as wide as differences between individual distributions

Return periods in years, N:M - H_{mp} ratio



Scaling – effect of changing return period – universal ?

With $\text{Log } N = A + B\, H_{mp}^{\,C}$

It becomes possible to use recurrence relations
to extrapolate to long return periods

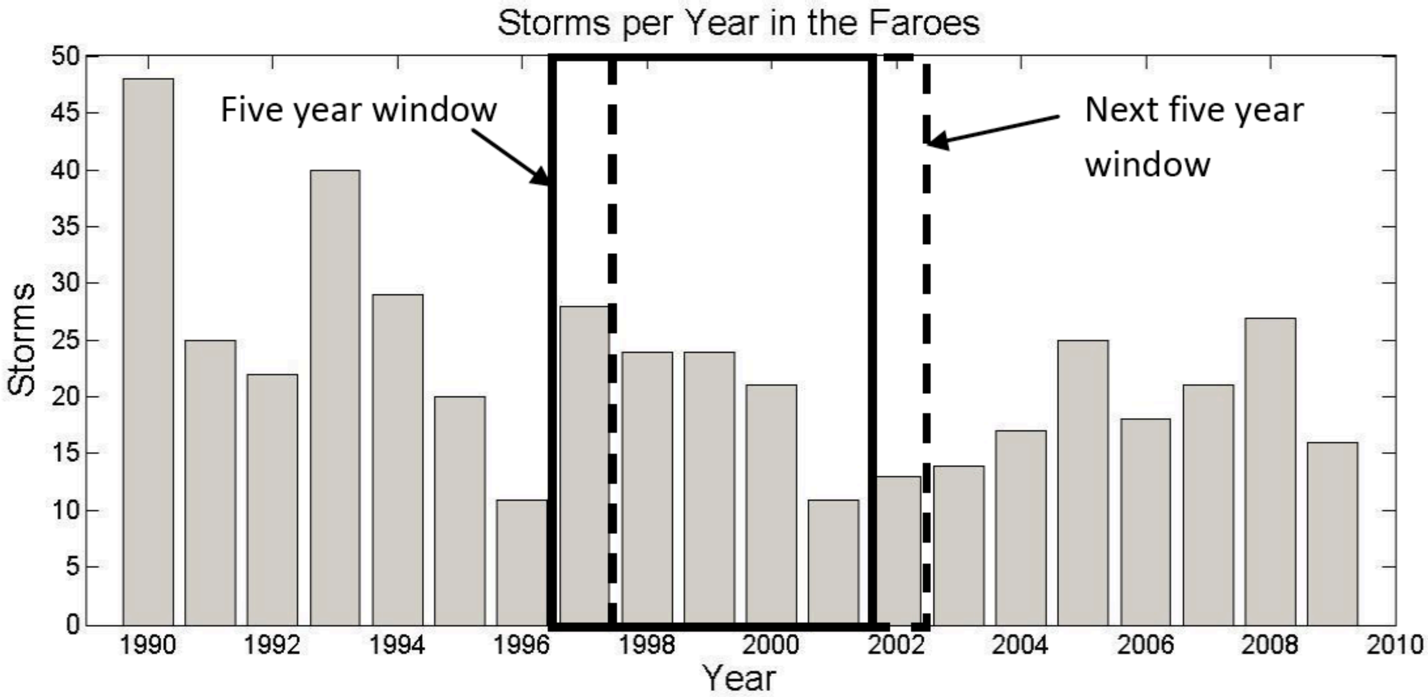
So with estimates for the 1-year $H_{mp\text{-}1}$
and the 10-year $H_{mp\text{-}10}$

$$(H_{mp\text{-}100})^C = 2\,(H_{mp\text{-}10})^C - (H_{mp\text{-}1})^C \qquad \text{etc.}$$

Apparently robust approach to estimating
long return period storm severity
based on several decades of wave data

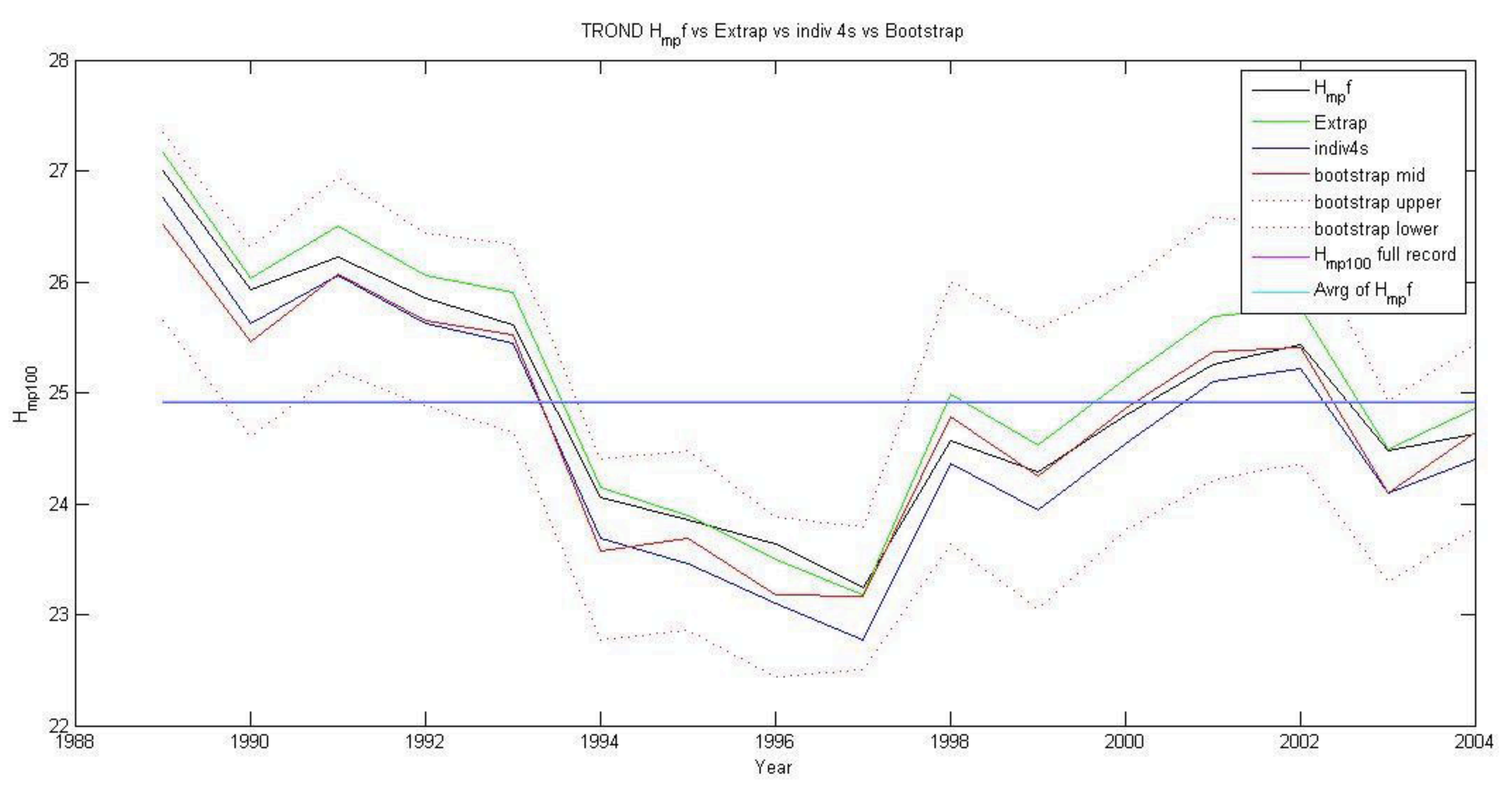
Wave climate VARIATION over 20-year hindcast

100-year storm severity H_{mp}-100 estimated using 5-year sliding window



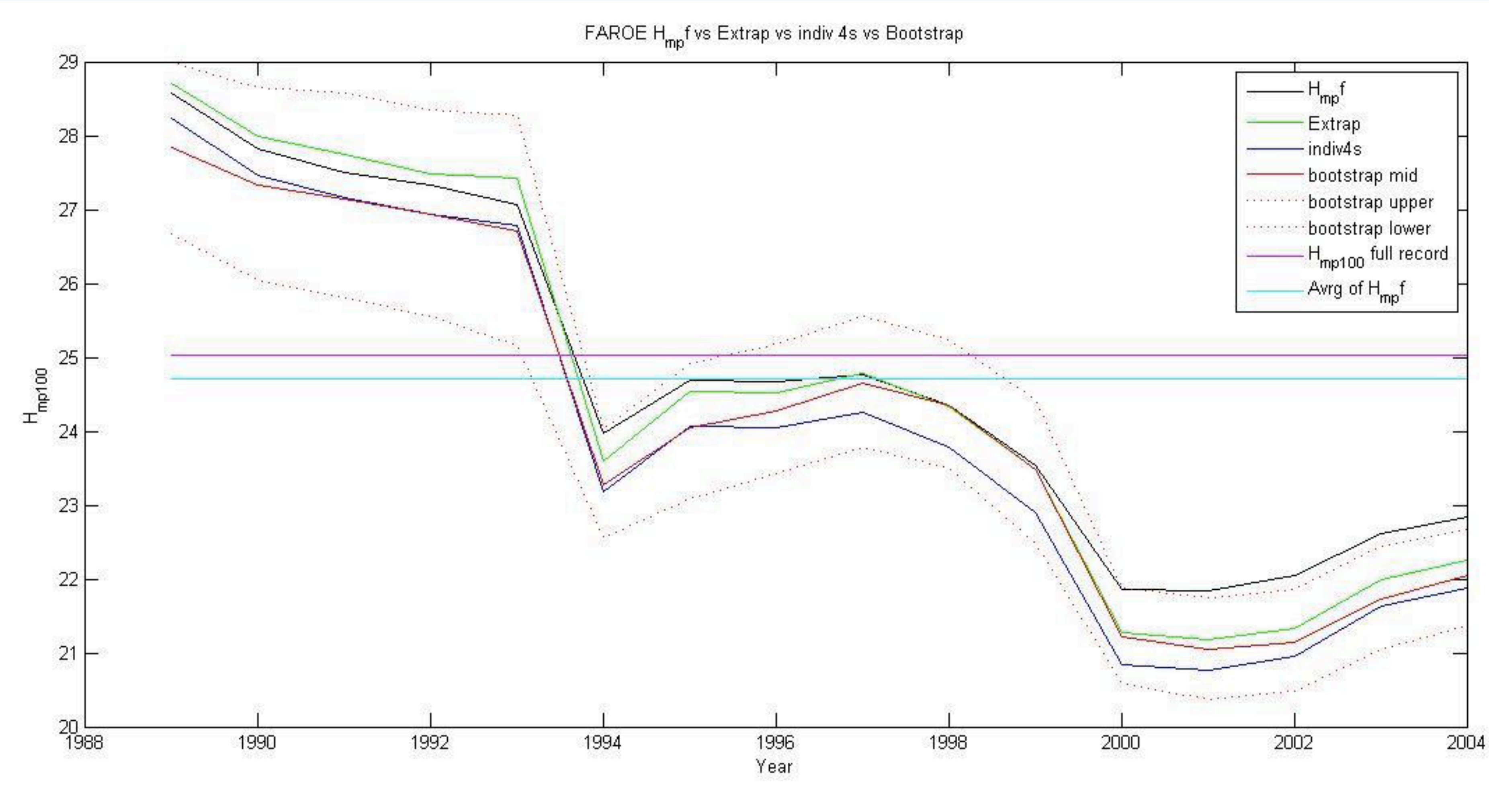
Recall that based on whole dataset we have $\frac{H_{mp100}}{H_{mp5}} = 1.2332$

Retain C=1.5, making sliding window and whole dataset fits consistent



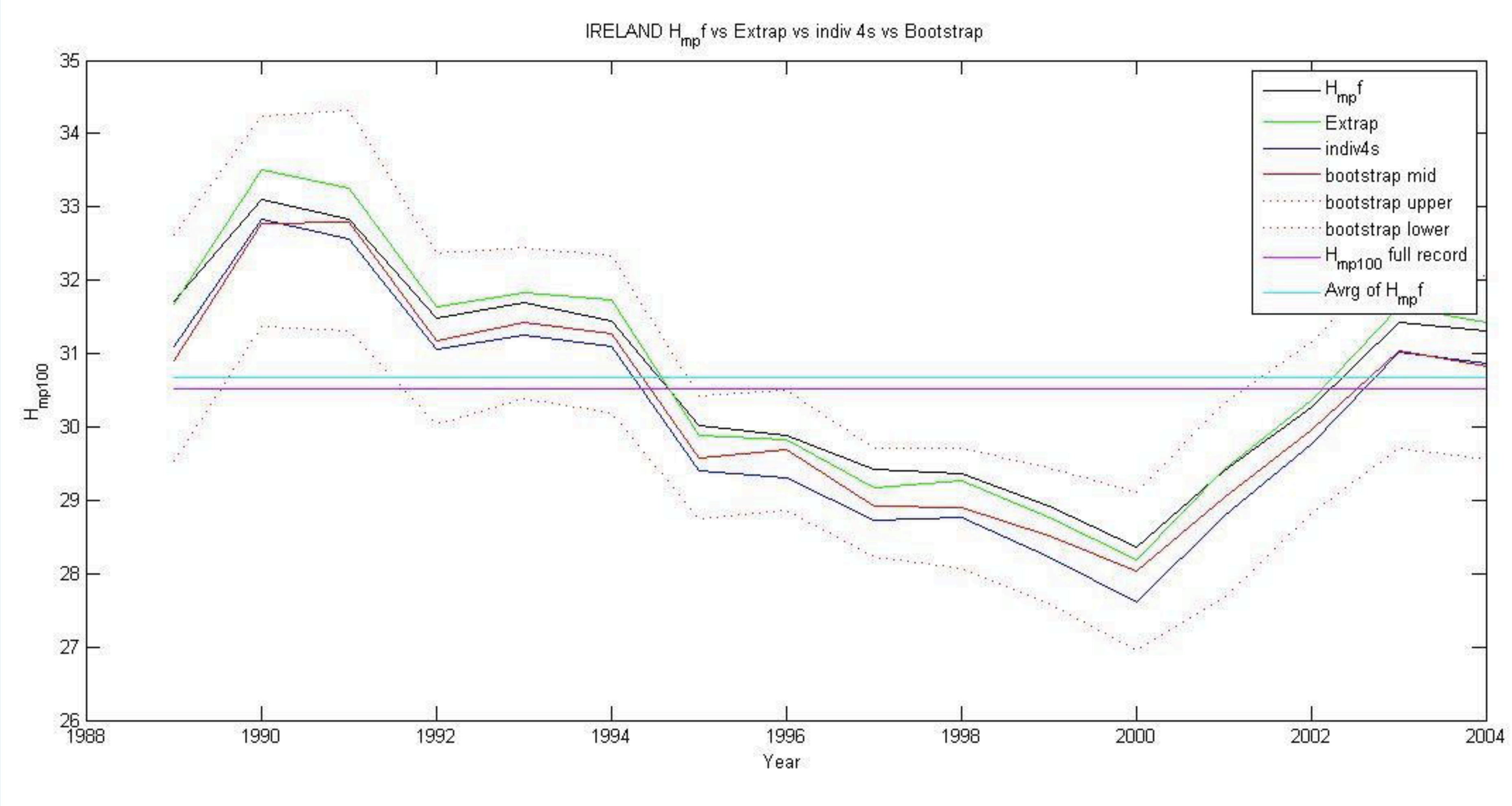
Trondheim : total variation ~ 4m (16%)

2 x width of bootstrap 5-95% bands



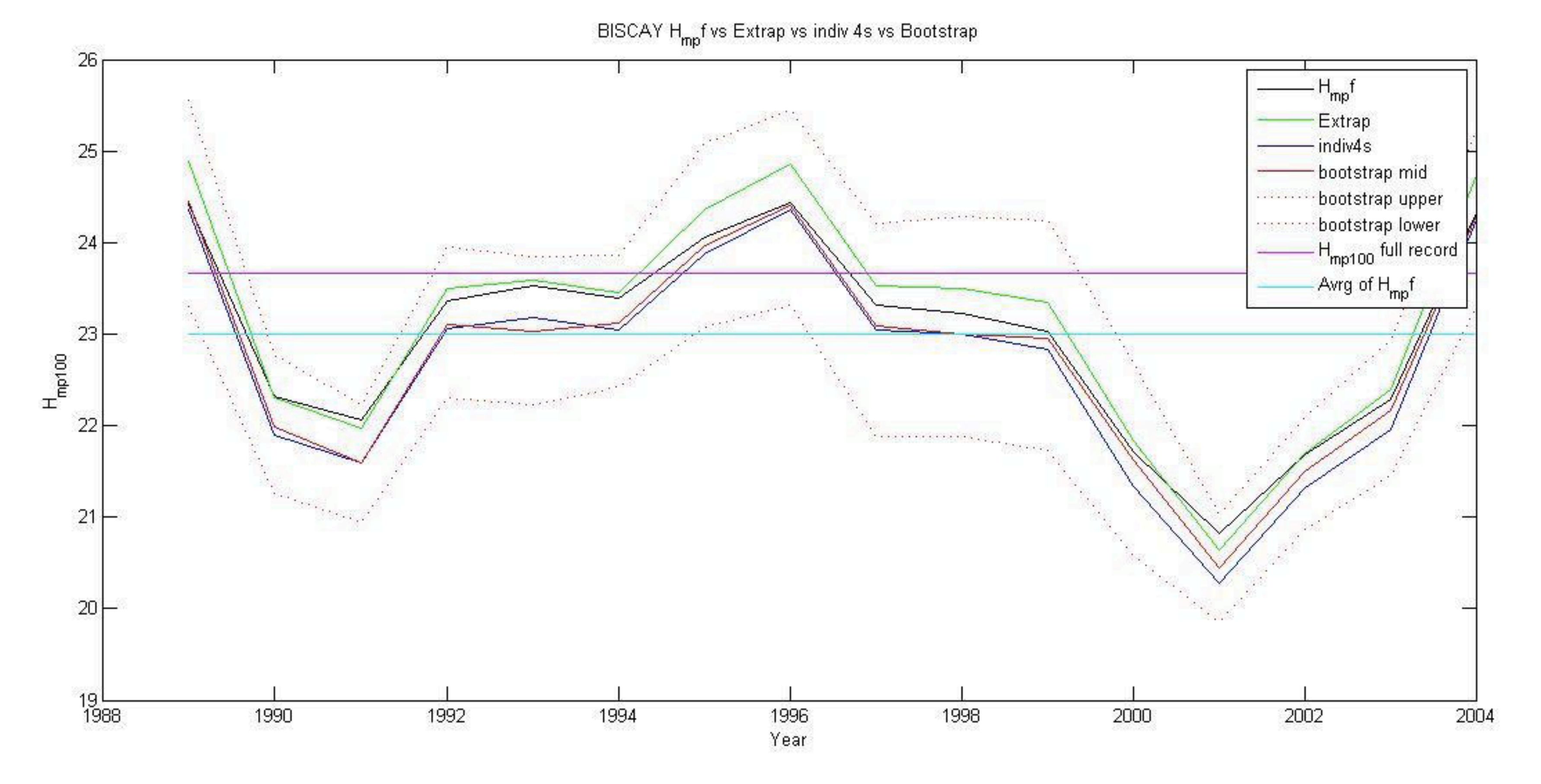
Faroes : total variation ~ 7m (30%)

>2 x width of bootstrap 5-95% bands



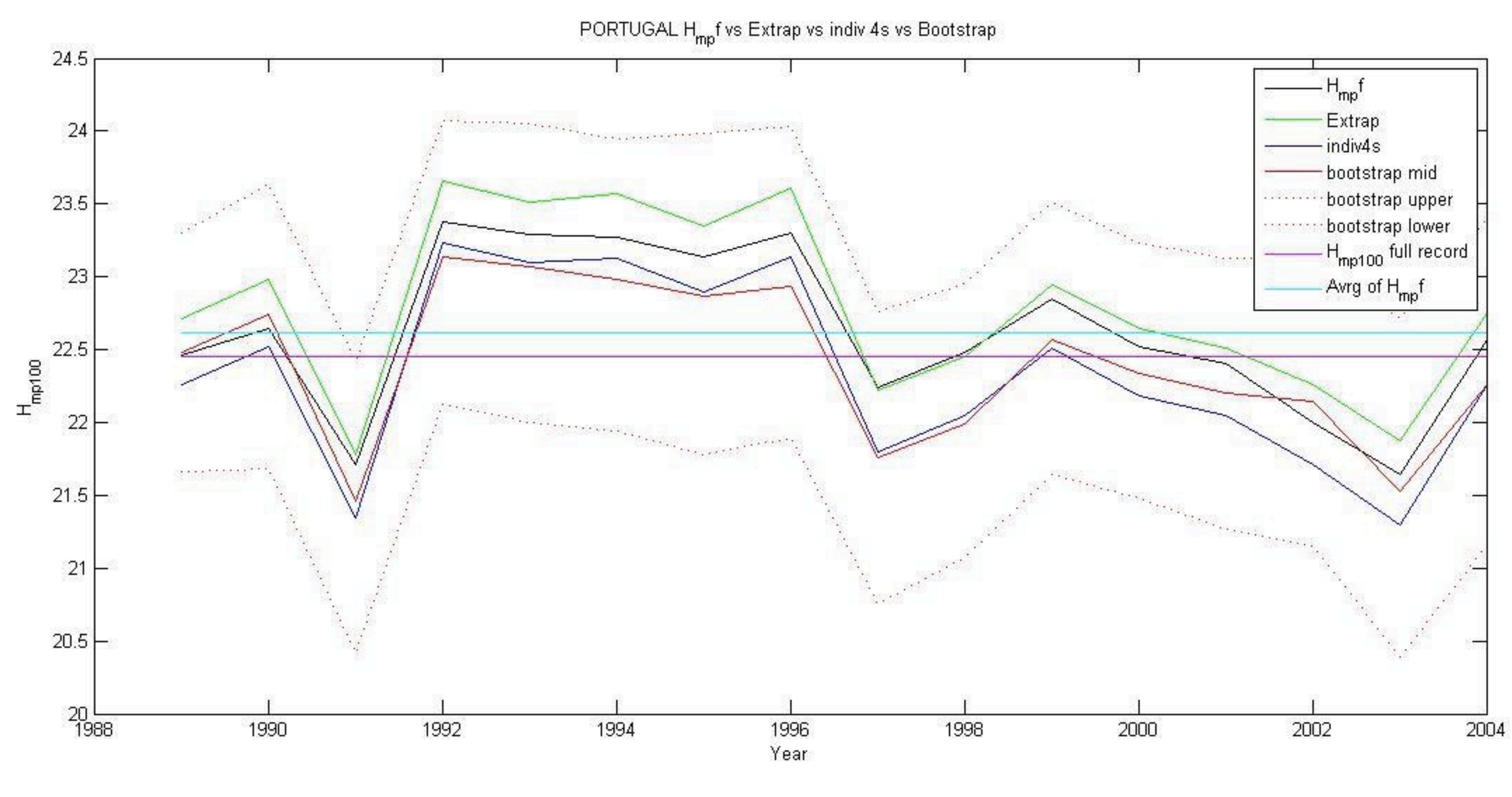
Ireland : total variation ~ 5m (16%)

1.5 x width of bootstrap 5-95% bands



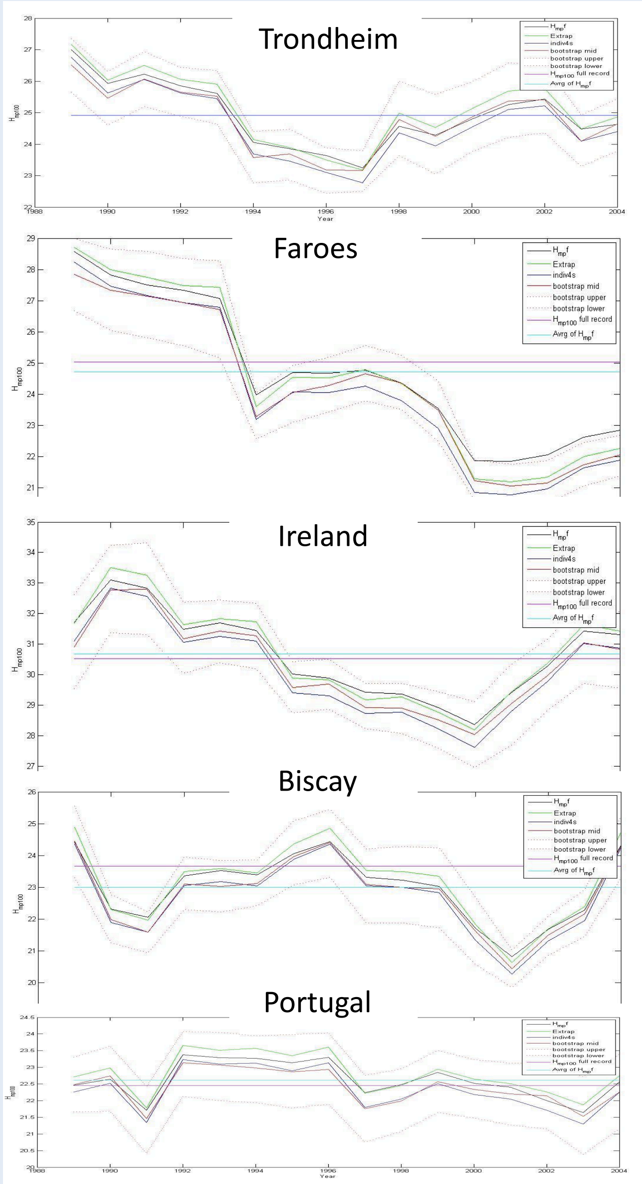
Biscay : total variation ~ 4m (17%)

1.5 x width of bootstrap 5-95% bands



Portugal : total variation ~ 2m (9%)
width of bootstrap 5-95% bands

Time →



Same vertical scales for H_{mp-100}

Variation of 100-year H_{mp} predictions based on 5-year sliding windows

Some gross similarities in time

Trondheim / Faroes / Ireland

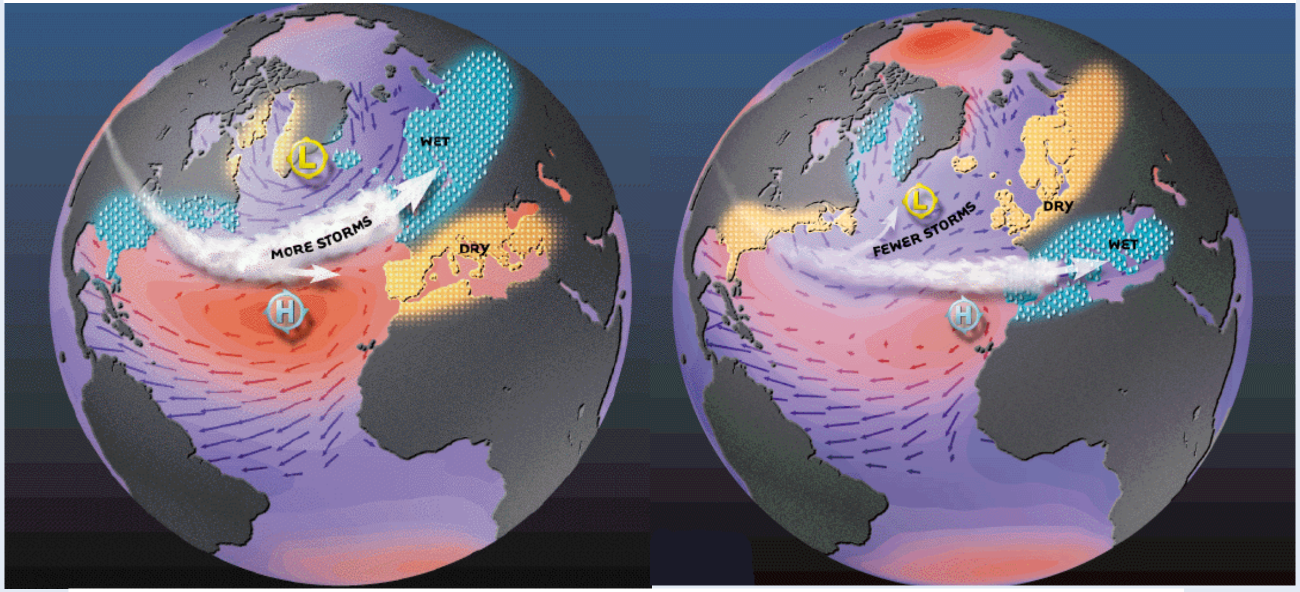
Biscay / Portugal

Largest variation for Faroes,
smallest variation for Portugal

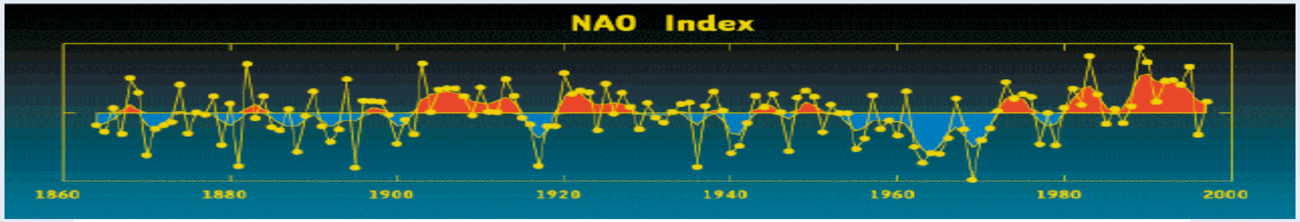
NORTH ATLANTIC OSCILLATION

+ve phase
N. European winter: mild + stormy
+ northerly storm tracks

-ve phase
: cold and dry
+ tracks more southerly



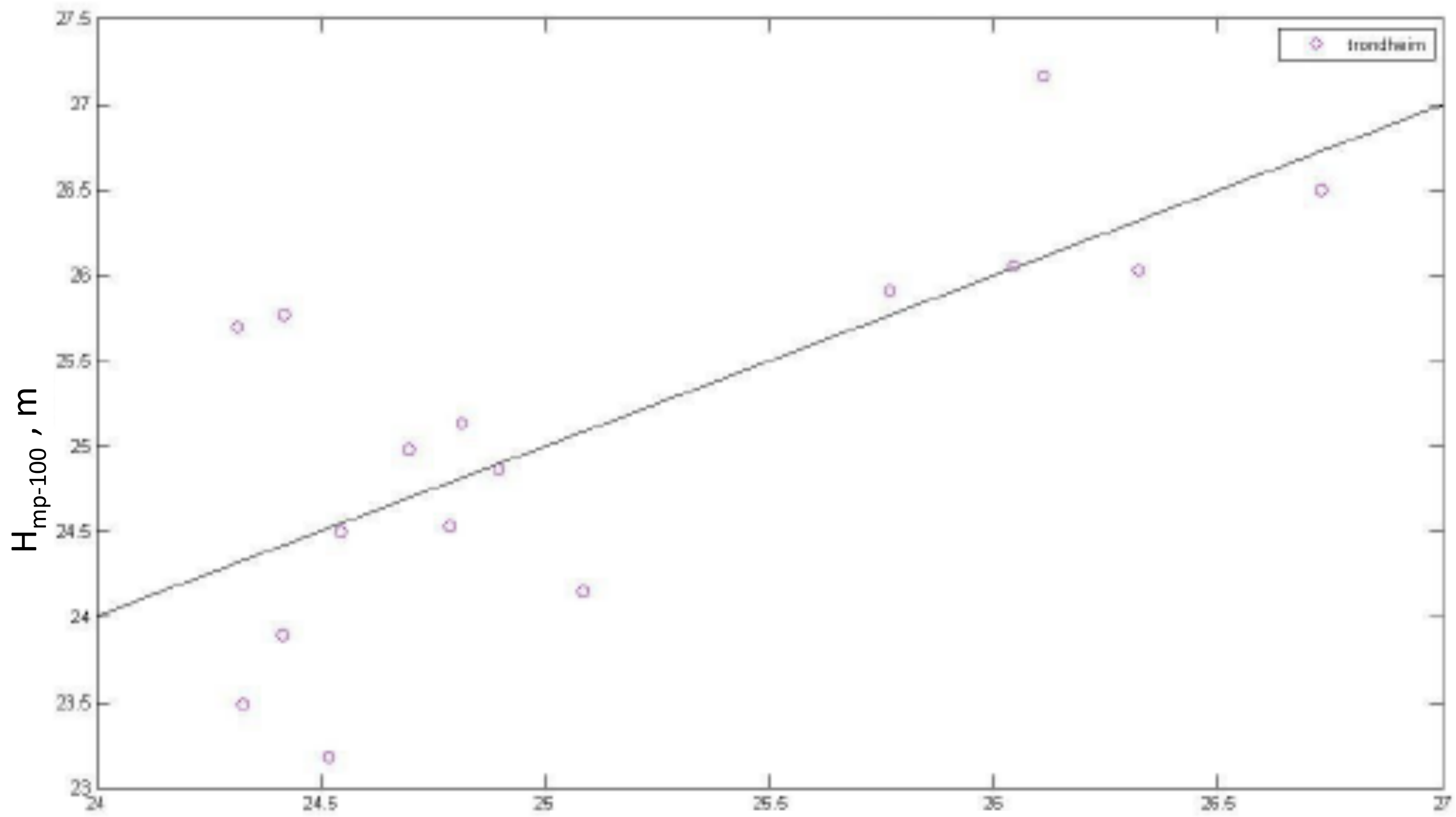
NAO defined as average pressure difference Gibraltar-Iceland in winter



NAO defined as average pressure difference Iceland-Gibraltar

Is this teleconnection correlated with variation in North Atlantic storm severity ?

http://www.ldeo.columbia.edu/res/pi/NAO/



NAO correlation for H_{mp-100} ,m

Trondheim 100-year storm correlated against winter NAO value over 20 years
- maybe explains 50% of variability

Fit to 5-year sliding window 100-year prediction $H_{mp-100} = 3.33 * NAO + 23.8$
- but not really large enough NAO variation

Conclusions

Robust method for estimating long return period storm severity
for deep water, exposed sites in eastern North Atlantic

Common exponential-type distribution in $(\text{wave height})^{1.5}$
- except for Trondheim – too far north, towards edge of storm tracks?

For northern points, more 5-year variability

Most severe location : west of Ireland, most variable : Faroes
Least severe and least variable : Portugal

Some correlation with NAO in the north,
but 20 years data not long enough for firm conclusions on variability of wave climate