Marine storminess (1880-2012) from VOS:
Climate variability in wind wave extremes and geometry

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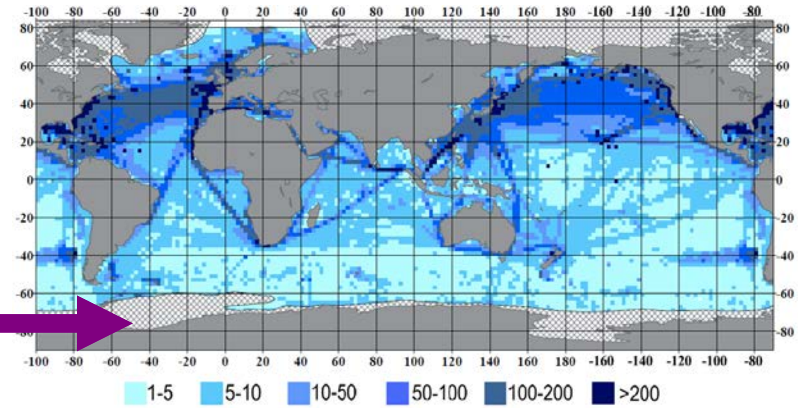
O U T L I N E:

- Visual wind wave data from VOS: the longest homogeneous records of surface roughness
- Changes in means on interdecadal to centennial scales (1880-2011)
- Changes in extreme wave height (1880-2011 and 1970-2011)
- Changes in wave geometry (1970+)
- Are the extreme waves steeper? Caveats.

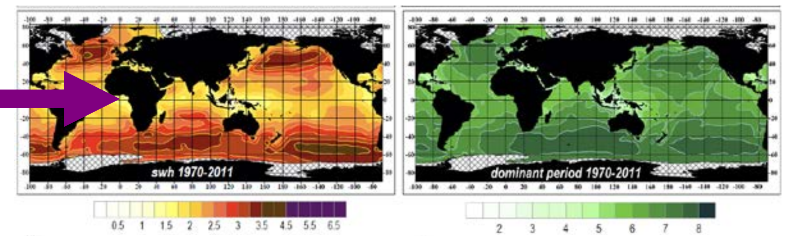
Banff, 13th International Wave Workshop - 2013

Extended outline:

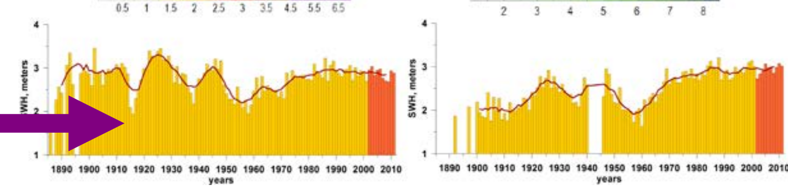
VOS visual wave reports for the period 1880 – onwards



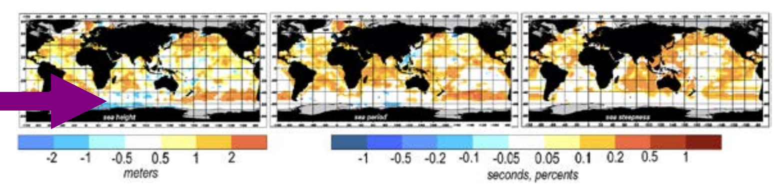
Global 2-degree climatology (1958-2011 and 1970-2011)



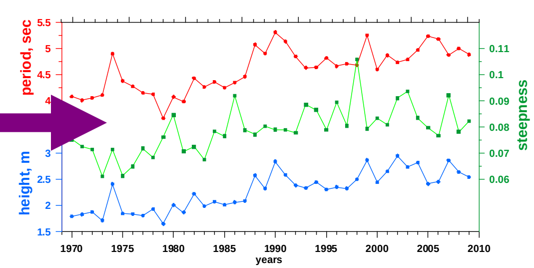
Time series: SWH (1880+), sea and swell together with periods → steepness (1970+)

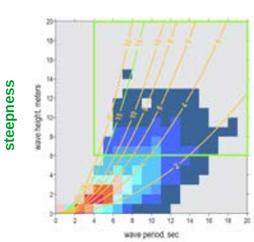


Linear trends in means and extremes for 1880-2011 and for 1970-2011



Along with the changes in heights we look also into changes in wave geometry

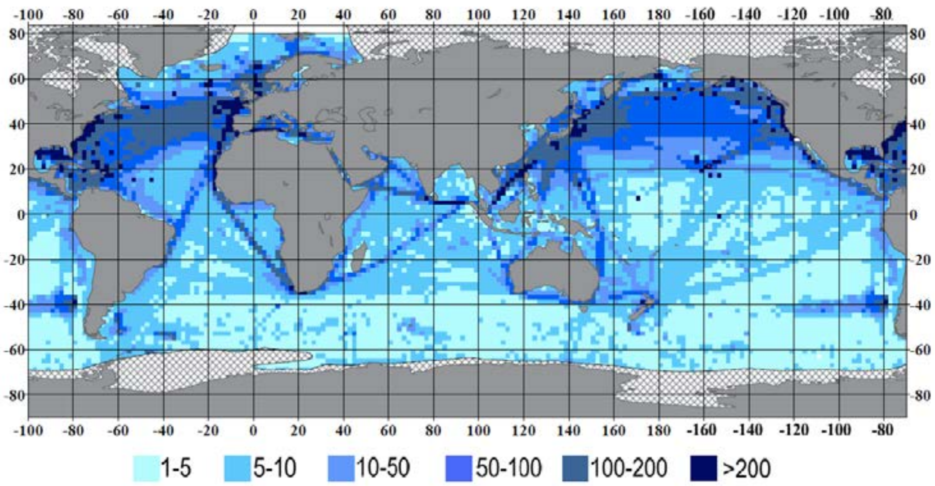


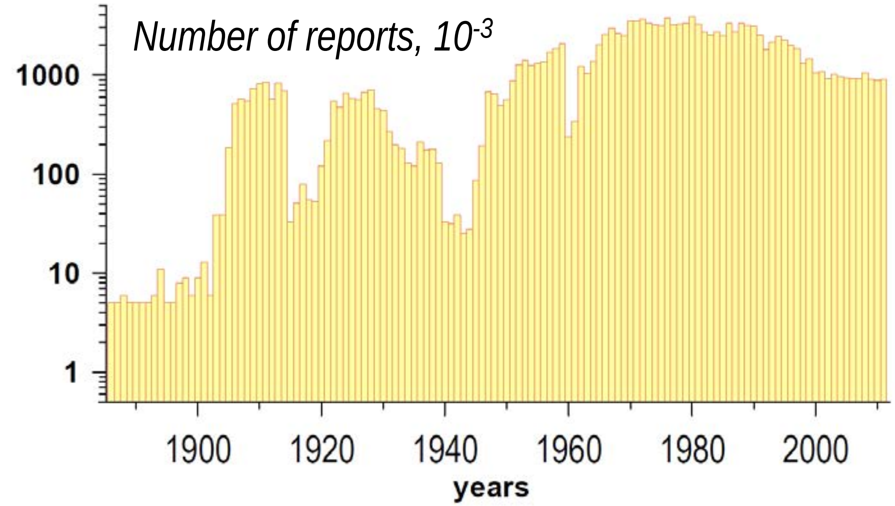


Conclusions

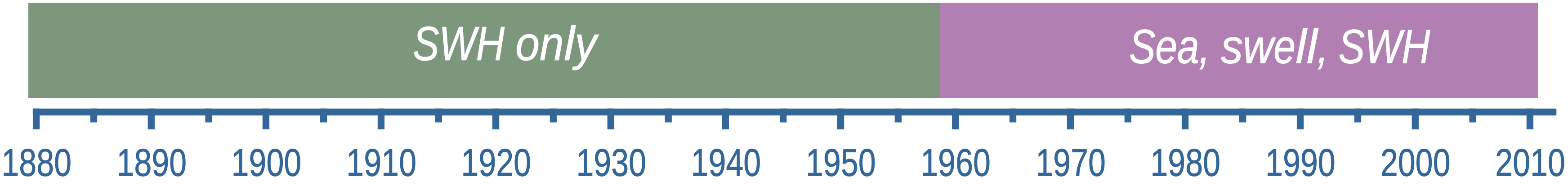
- Mean wave climate: no centennial linear trends in the NA, trends in the NP amount to 1.1 m per century, decreasing SWH during the last decade
- Extreme SWH shows evident interdecadal variability. Changes in the extreme SWH and wind sea are not correlated
- Over the last decades (1970+) there is a tendency of growing mean and extreme waves in the NA and NP midlatitudes (up to 10-20 cm/decade for means and up to 1.5-2 meters per decade for 99^{th} percentile). Mostly due to the changes before 2000s
- Changes in wind sea heights and periods, while consistent, result in positive trends in wave steepness with the largest increase of 0.006-0.008 per decade in the NH mid latitudes
- Extreme seas are generally more steep compared to the moderate seas. Reasons…..

Visual wave observations: 1856 - onwards





2 data streams: 1880-1958 and 1958-onwards



- Observational practice has never been changed
- Coding systems have been changed several times, while documented
- Assimilated in ICOADS

Table F2-3
Conversion for SP Prior to 1968

Seconds	Code	Interval
5	2	5 seconds or less
7	3	6-7 seconds
9	4	8-9 seconds
11	5	10-11 seconds
13	6	12-13 seconds
15	7	14-15 seconds
17	8	16-17 seconds
19	9	18-19 seconds
21	0	20-21 seconds
22	1	over 21 seconds
0	-	calm or period not determined

Table F2-4
Conversion for SP Beginning 1 January 1968

Seconds	Code	Interval
10	0	10 seconds
11	1	11 seconds
12	2	12 seconds
13	3	13 seconds
14	4	14 seconds or more
5	5	5 seconds or less
6	6	6 seconds
7	7	7 seconds
8	8	8 seconds
9	9	9 seconds
0	-	calm or period not determined

Changes in coding systems

Sea and swell periods are given in codes with code precisions:

1 second for sea period
2 sec for swell period.

Important change of the WMO Manual on codes has happened in 1968 (Supplement P-67).

This change affected swell periods. Incorrect conversion implies roughly doubling of swell periods.

Wave data pre-processing and corrections

1. Correction of small wave heights: code figure "01" problem
   (Gulev et al. 2003, Gulev and Grigoeiva 2009)

$$hs = 0.5 - exp(-0.658V)$$

2. Separation of sea and swell (Carter 1988, Gulev and Hasse 1999, Grigorieva and Gulev 2010)

   Wave age + 2D wind-wave PDFs with the JONSWAP curves for durations of 6 to 18 hours

3. Significant wave height (Gulev et al. 2003, Gulev and Grigoreva 2006)

$$SWH = \begin{cases} (h_w^2 + h_s^2)^{1/2}, & [dir_{sea}, dir_{swell}] \in 30^{\circ} sector \\ max[h_w, h_s], & [dir_{sea}, dir_{swell}] \notin 30^{\circ} sector \end{cases}$$

4. Correction of wave periods and derivation of the dominant period (Gulev and Hasse 1998)

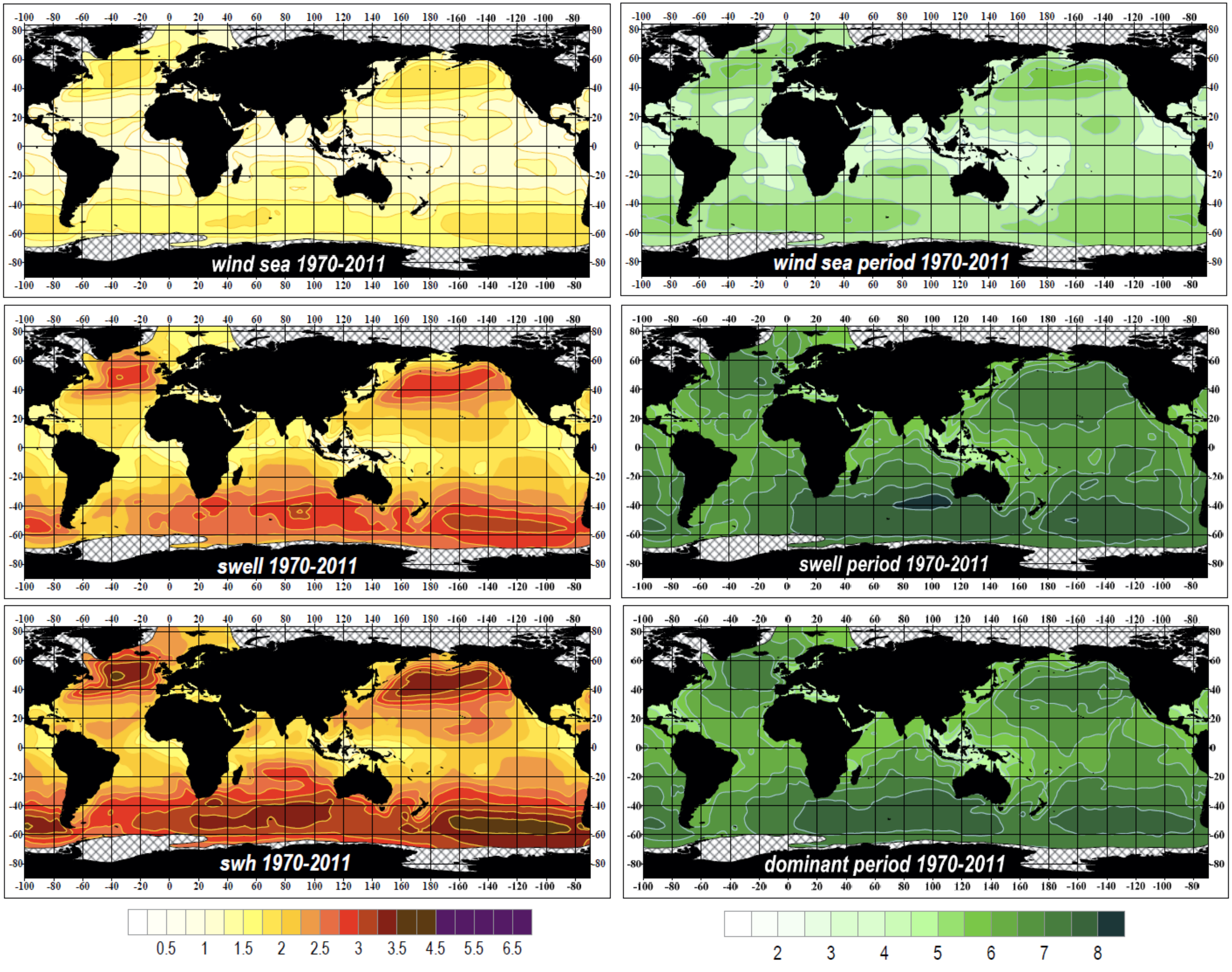
   Fitting of the 2D wave-period distributions for sea and swell

5. Uncertainty of the evaluation of the true wave direction and period from the relative direction (Grigorieva and Gulev 2004)

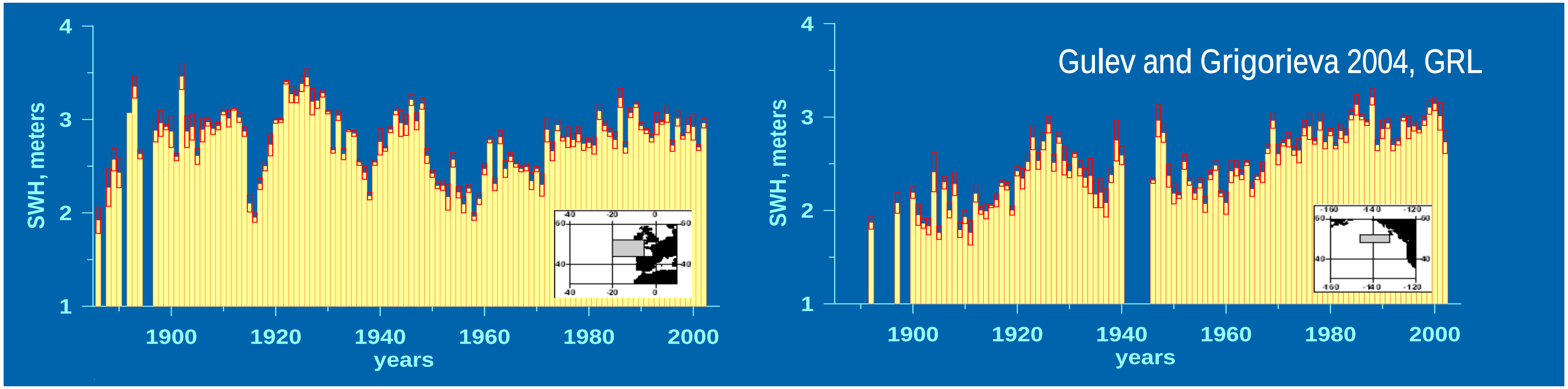
   Use of the actual ship course and velocity, wherever possible

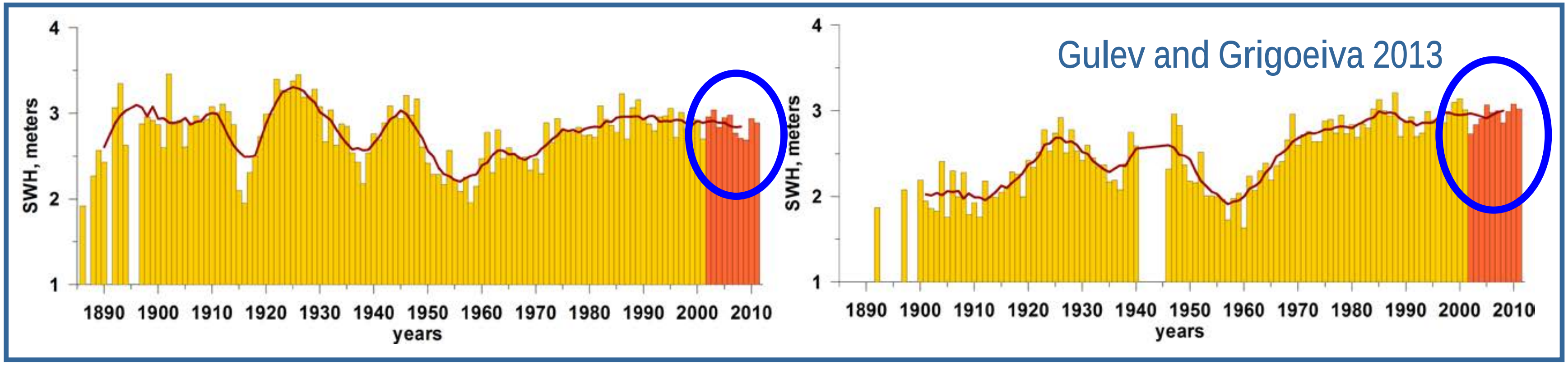
6. Day-time minus night-time biases (Gulev et al. 2003, Grigorieva and Gulev 2010)

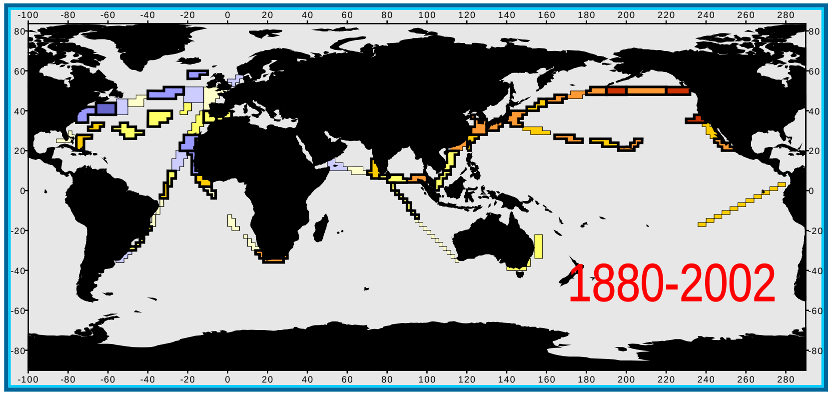
Global wave climatology (1958-2011, 1970-2011, 2x2 deg)

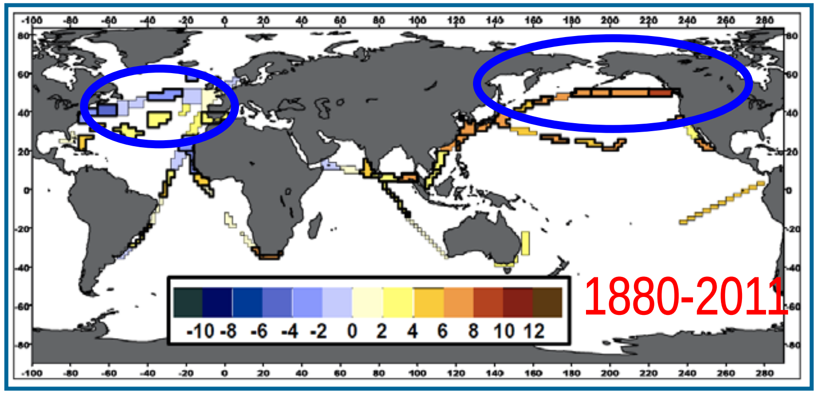


Centennial scale – means (update of G&G-2004)

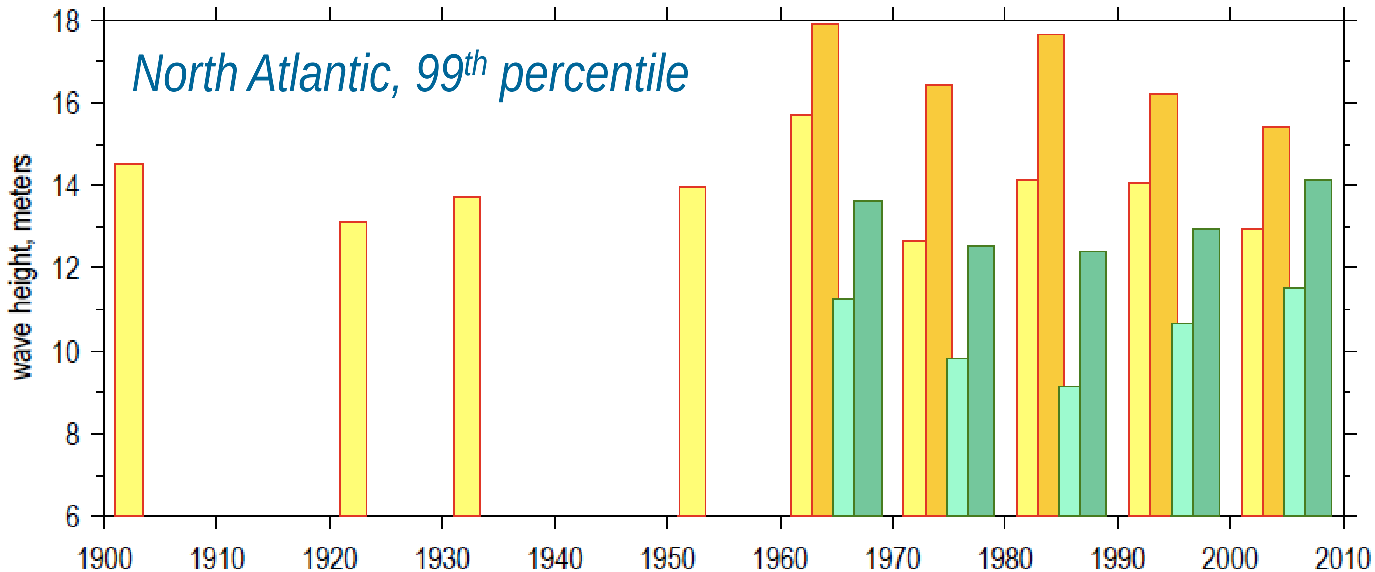


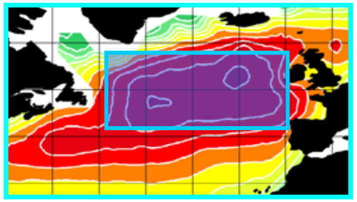


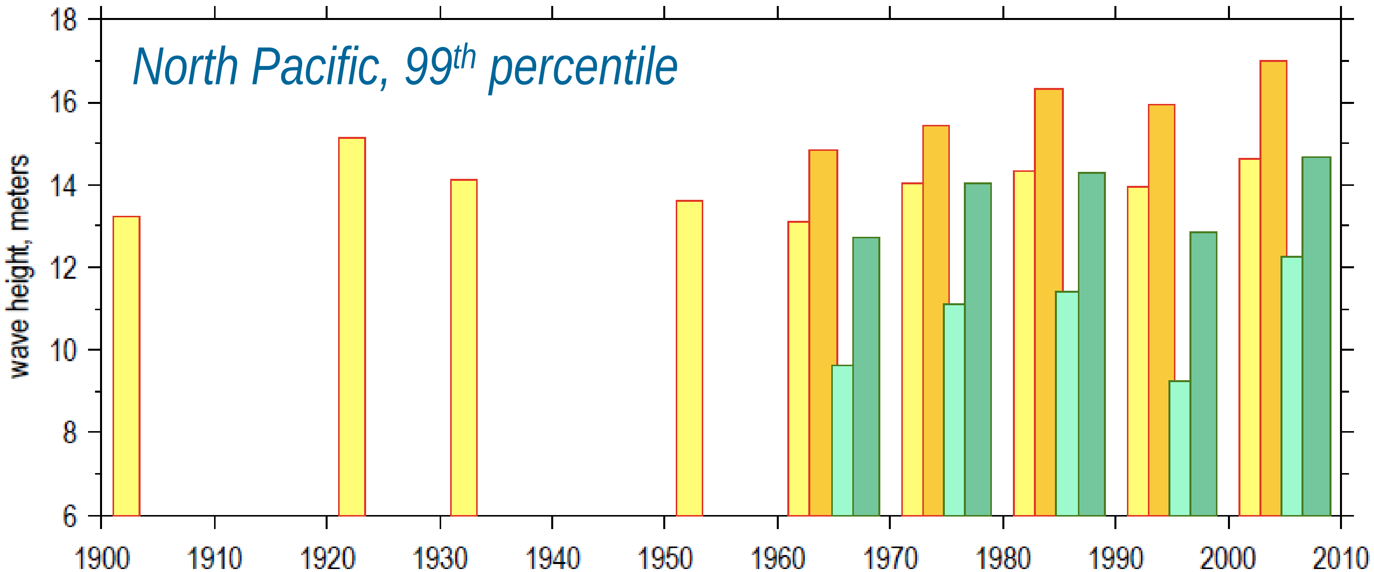


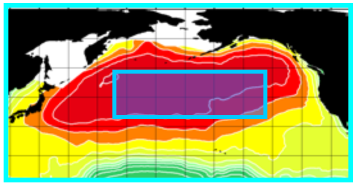


Centennial estimates of extreme in wind sea and SWH



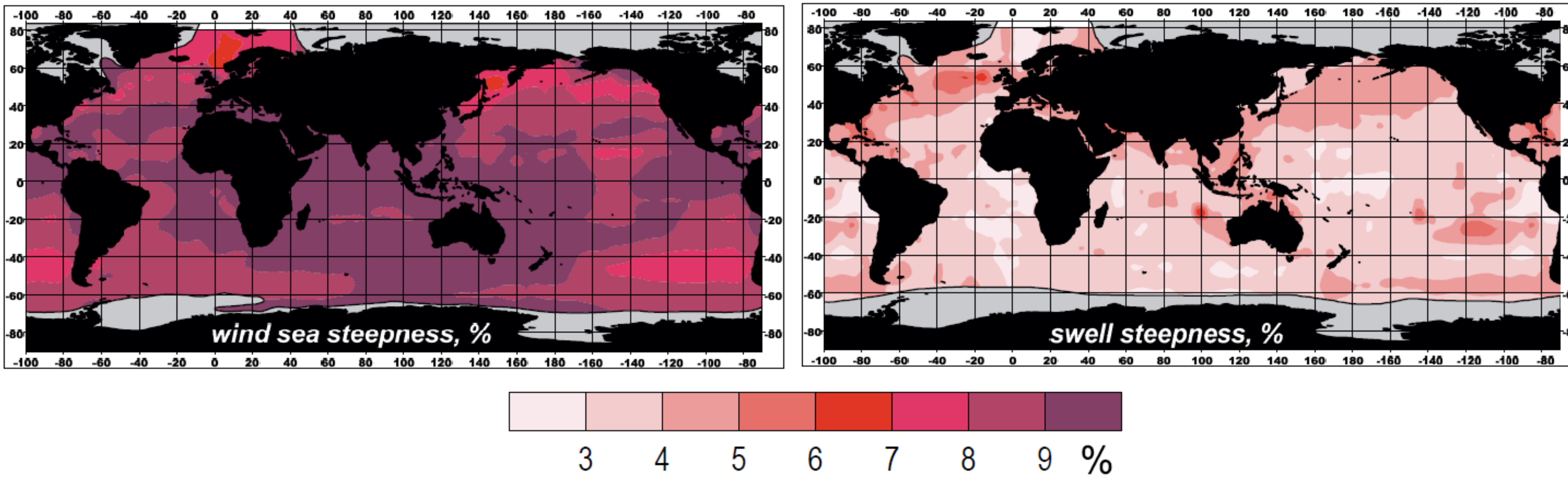




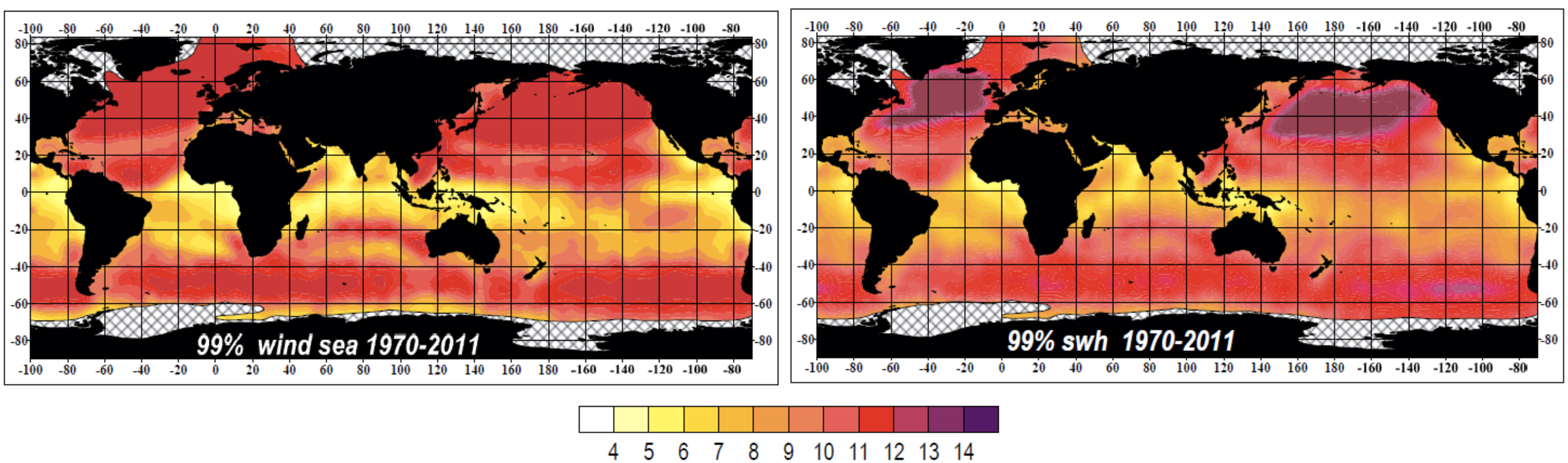


SWH, IVD
SWH, POT+EVD
sea, IVD
sea, POT+EVD

1970+: Wave steepness - climatology

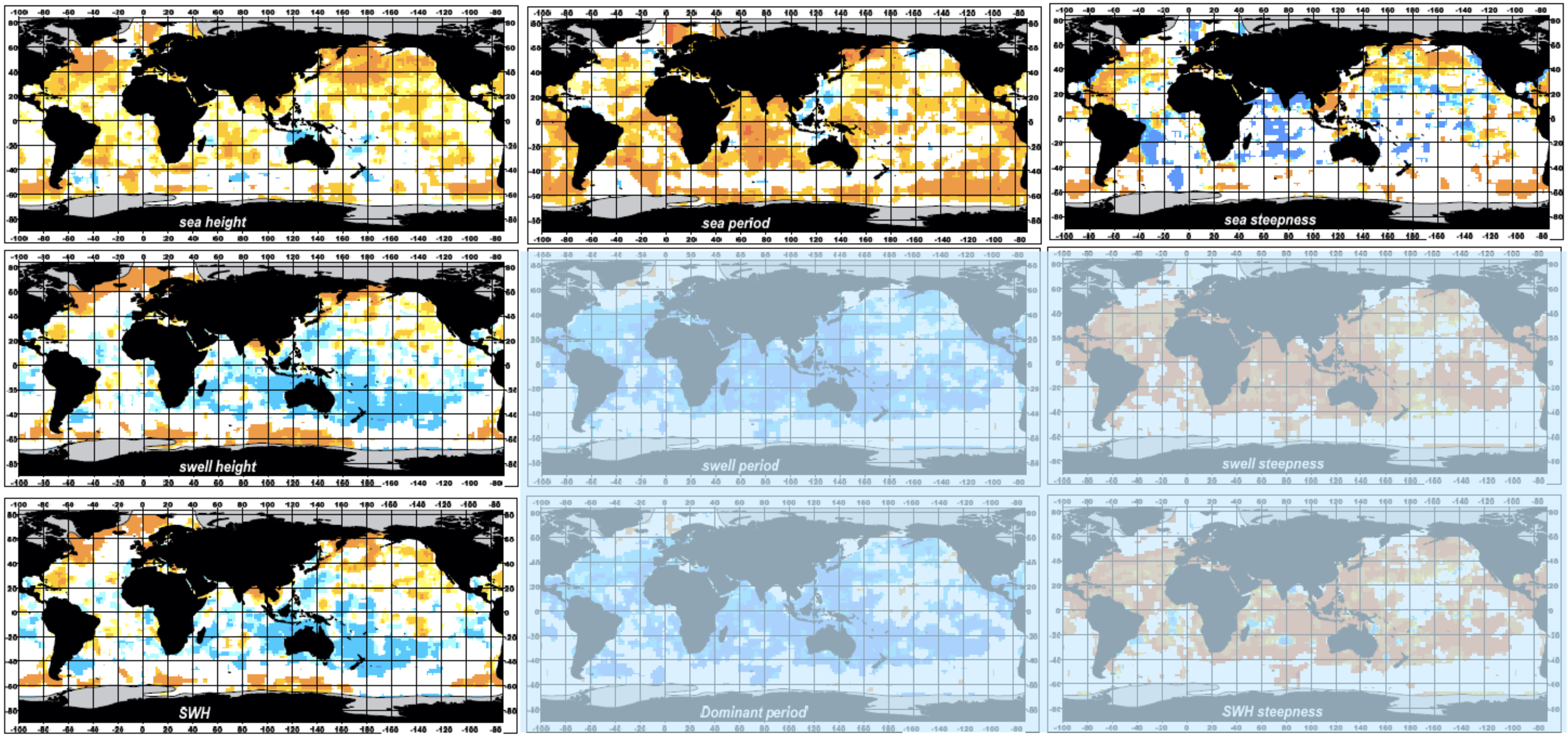


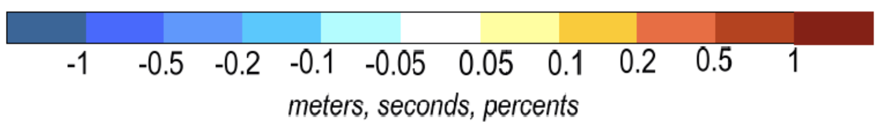
Extreme waves – wind sea and SWH



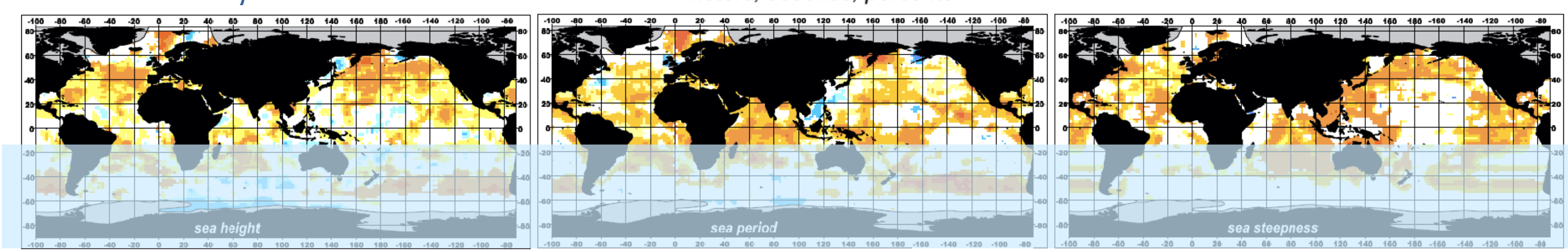
means

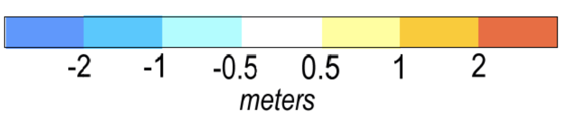
Linear trends, 1979-2011, units per decade

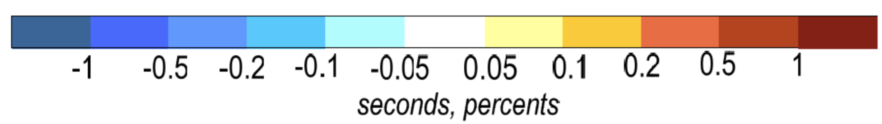




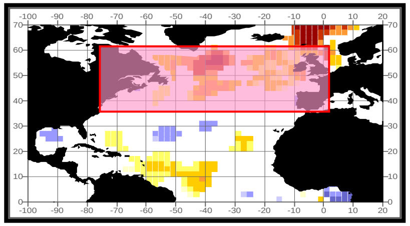
Extremes, 99%

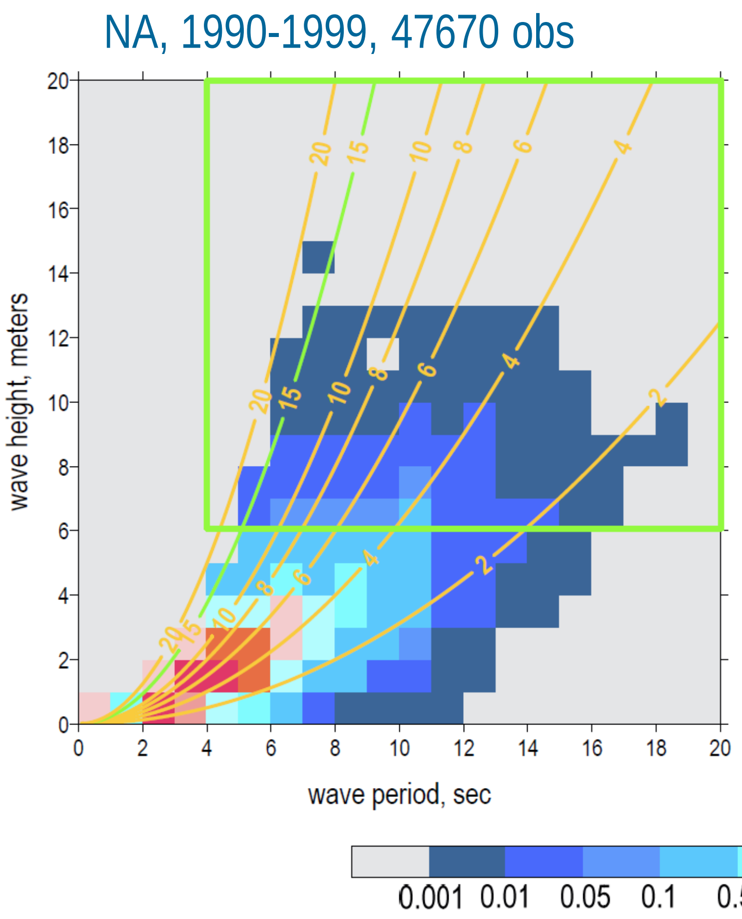


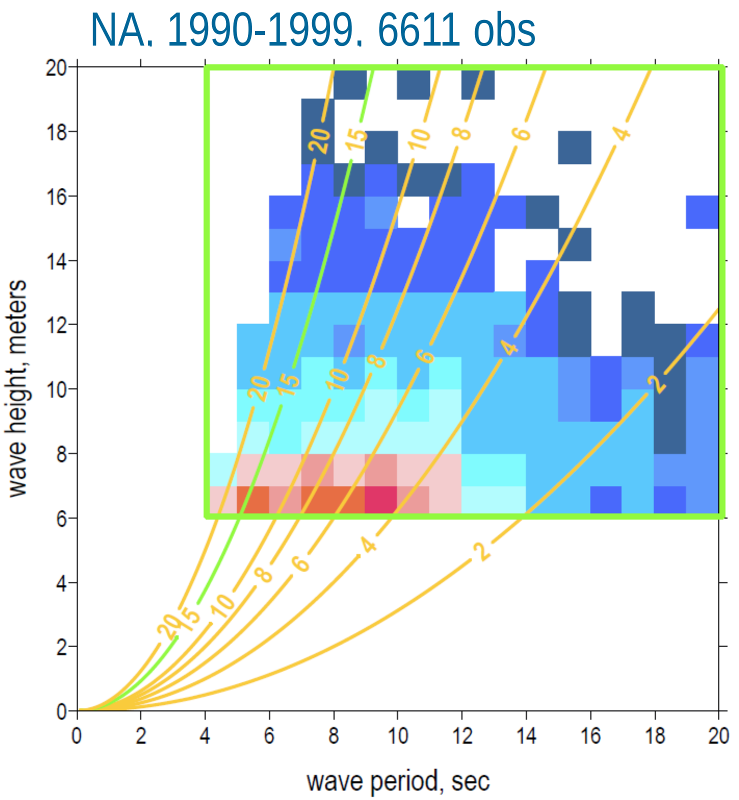




Are the extreme waves steeper?







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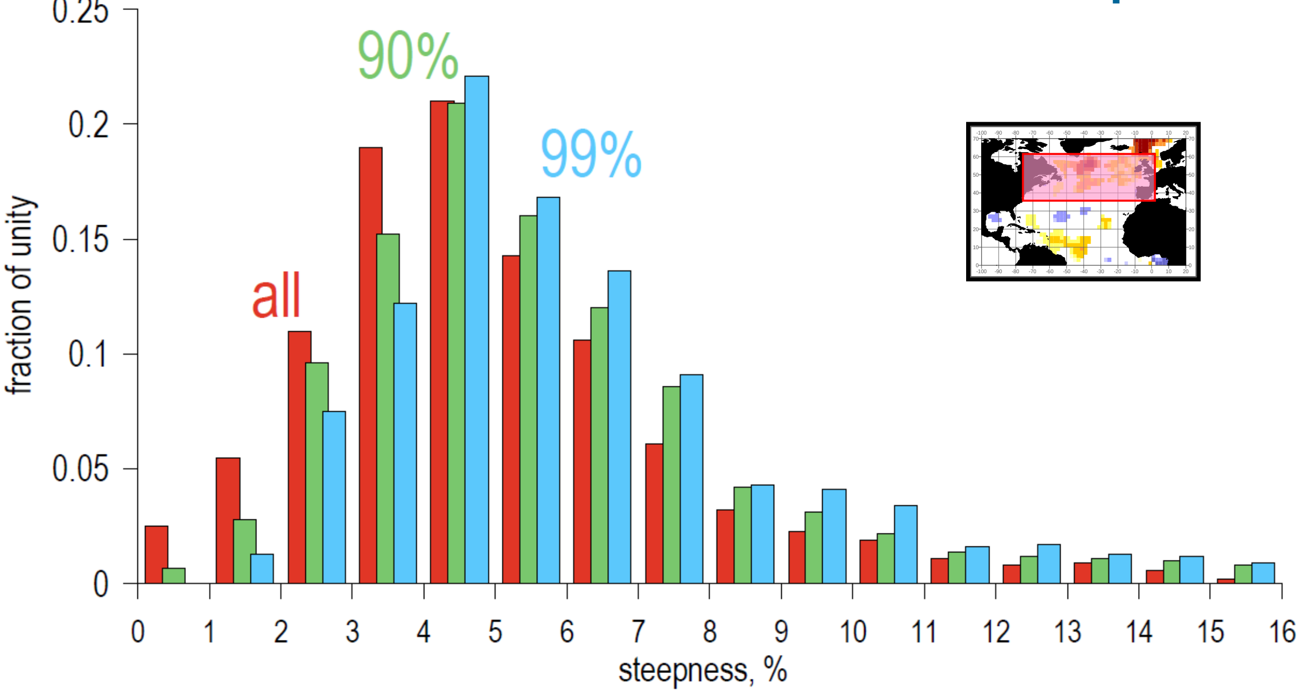
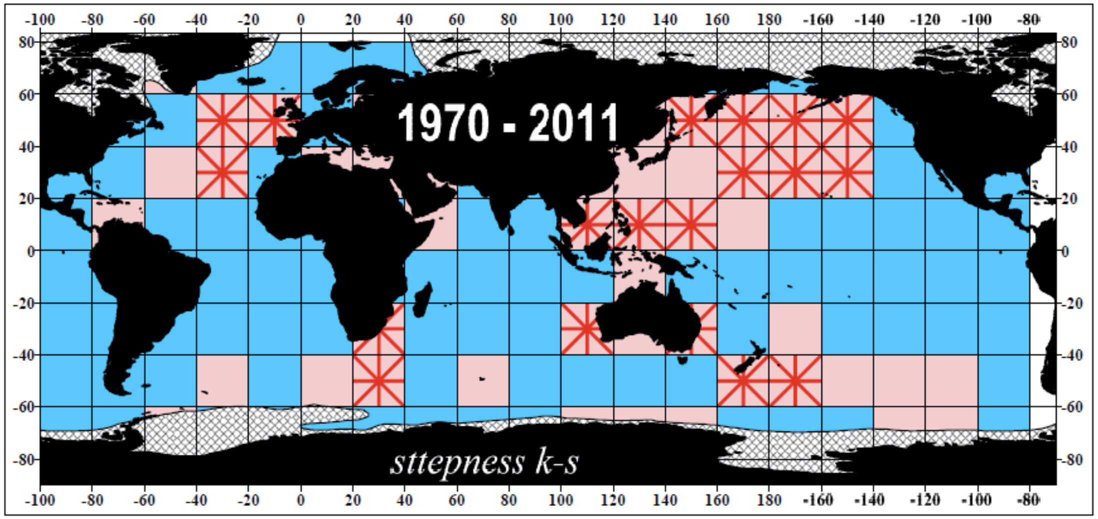
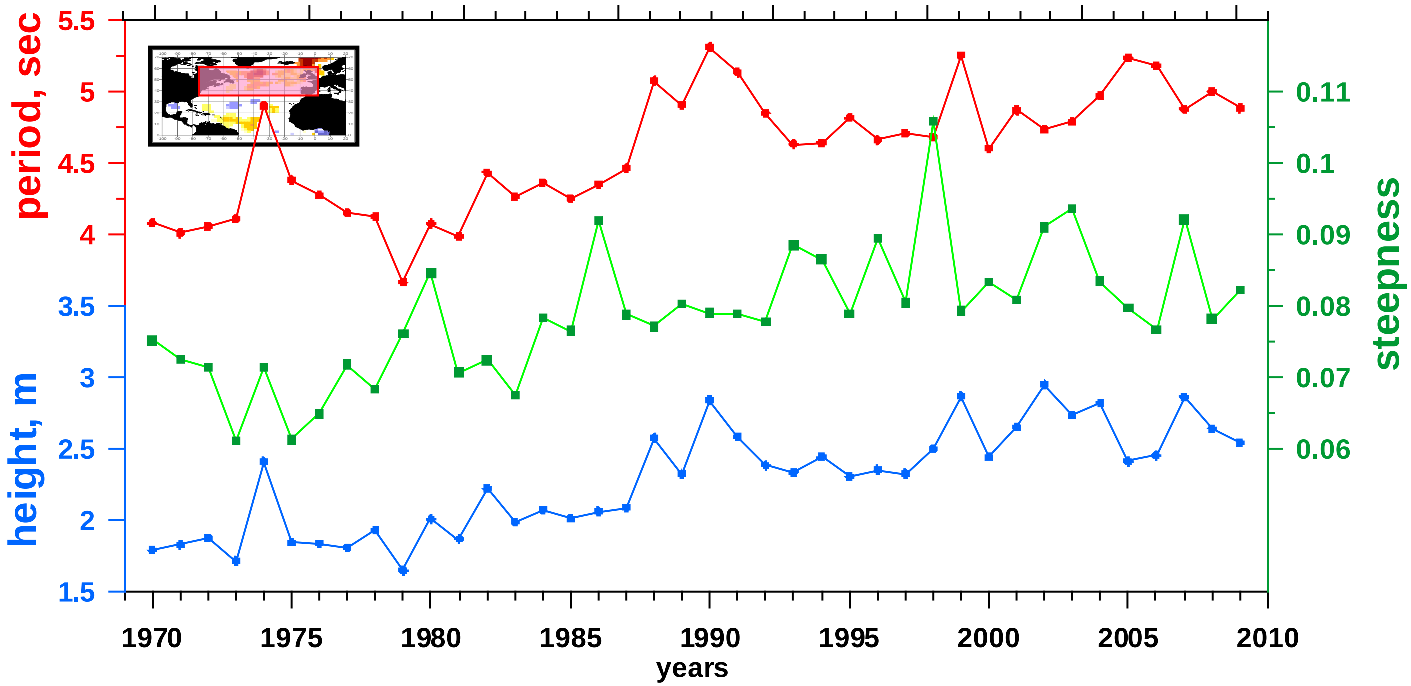
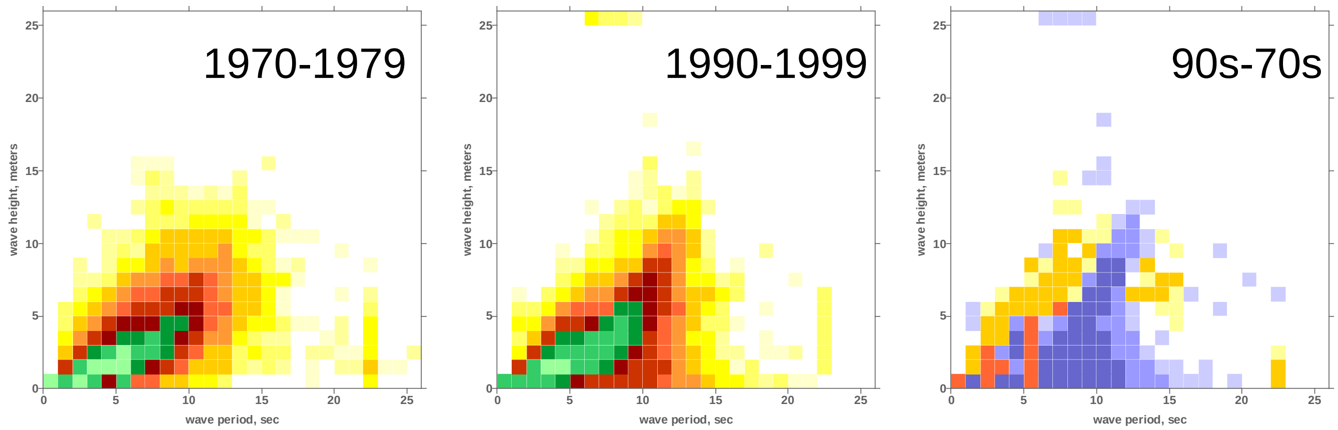




The distributions (all vs 90%) are significantly different

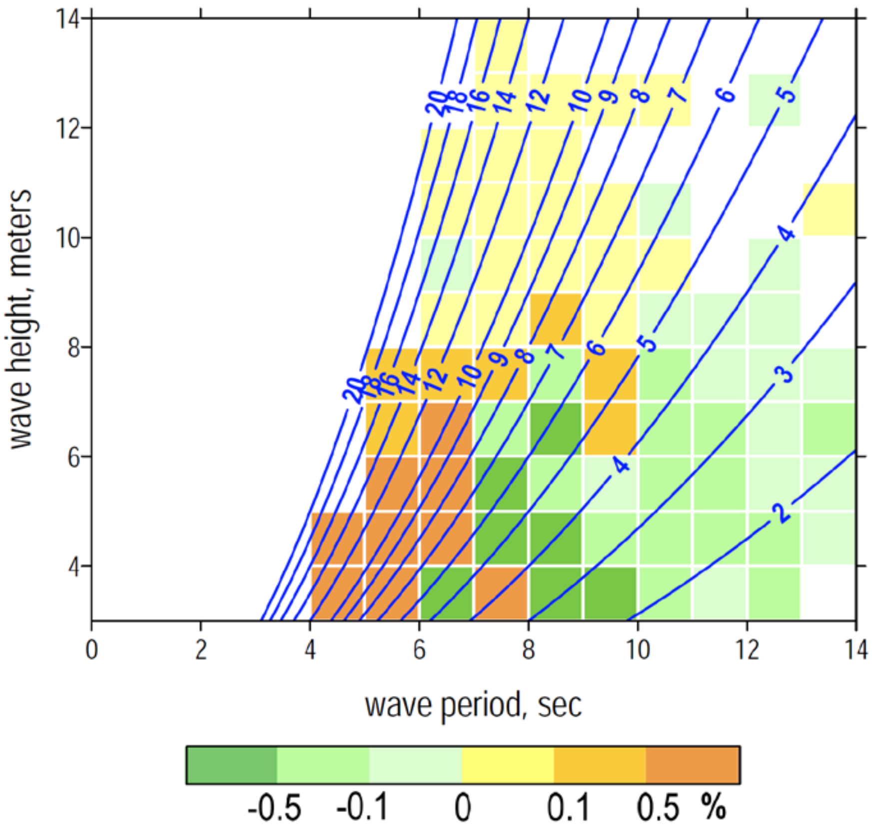
Whether changes in wind sea and period are coordinated?

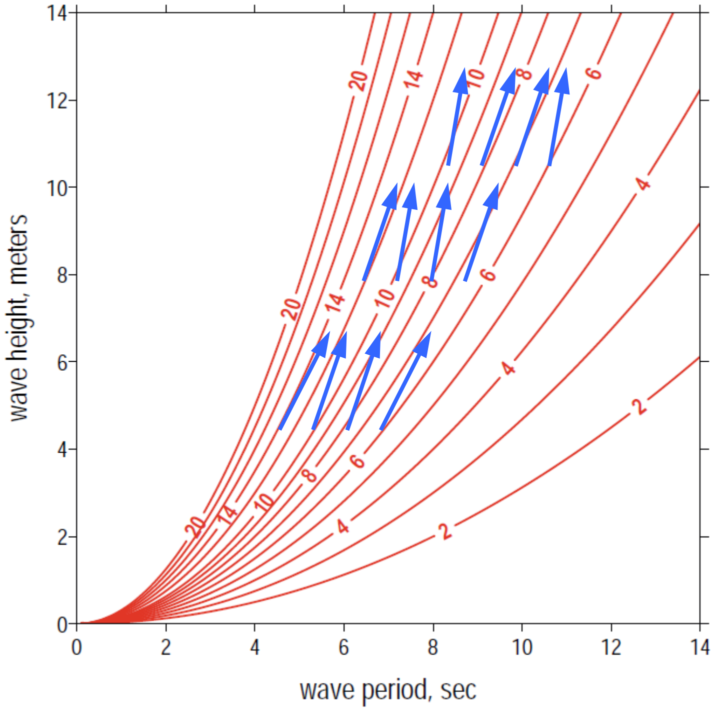




Changes in the steepness of high and extreme waves

2000s minus 1970s





Extreme waves are steeper – why?

Observational practice uncertainty

When observing 10 waves and estimating period, it is more likely that the "missed" wave will occur in the parcel of small or moderate waves than in the parcel of high waves → should result in longer period (smaller steepness) of small and moderate waves

Mates tend to overestimate high waves → should result for higher steepness of high waves

Young swells are frequently counted as seas → should result in smaller steepness of small waves

Otherwise….

Physical mechanisms?

Conclusions

- Mean wave climate: no centennial linear trends in the NA, trends in the NP amount to 1.1 m per century, decreasing SWH during the last decade
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Estimation of extreme waves from VOS – 3 problems

How to apply GEV (or any other extreme distribution) to irregularly sampled data) →

model hindcast proxy is needed for the first guest of storm durations

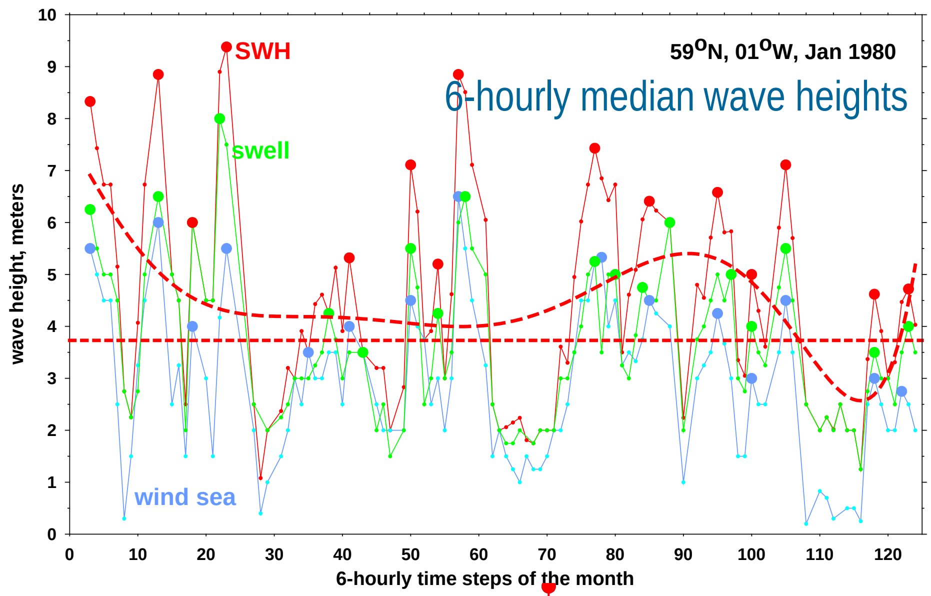
VOS data may not necessarily report the highest exceedances →

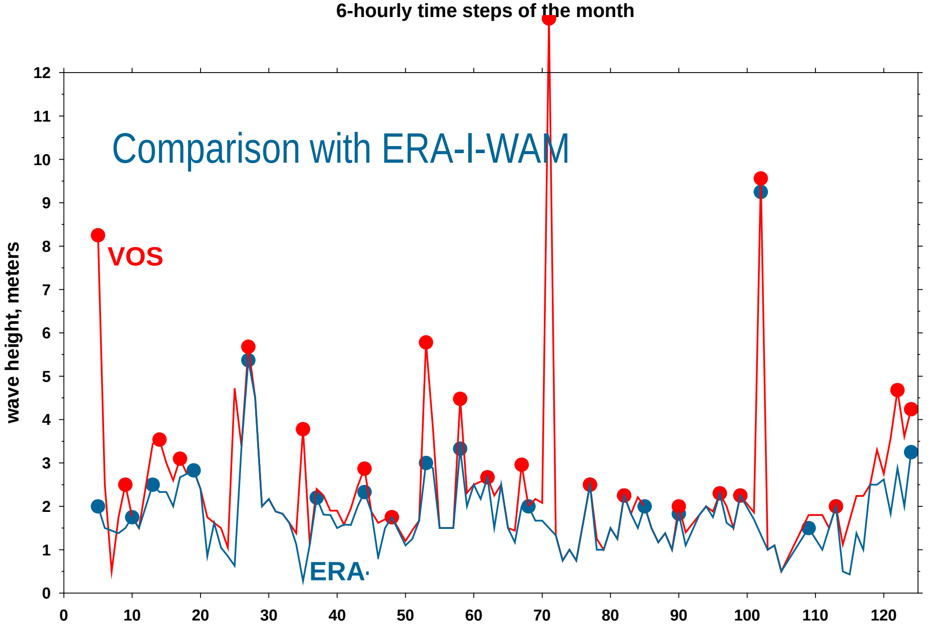
but the distribution of any exceedance = probability of the largest

VOS data are influenced by sampling uncertainty →

Undersampling results potentially in underestimation of extremes

Application of extreme distributions to VOS data





- For more than twelve 6-hourly snapshots per months only
- Threshold is variable, set to 75% - 93% percentile
- Storm duration is also variable and is parameterized by the Lanczos filter with parameters being determined from the ERA-I hindcast
- durations for individual months & medians for each snapshot
- EVD is fitted to the storm peak values