ESTIMATING EXTREME WIND WAVES FROM VOS

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OUTLINE:

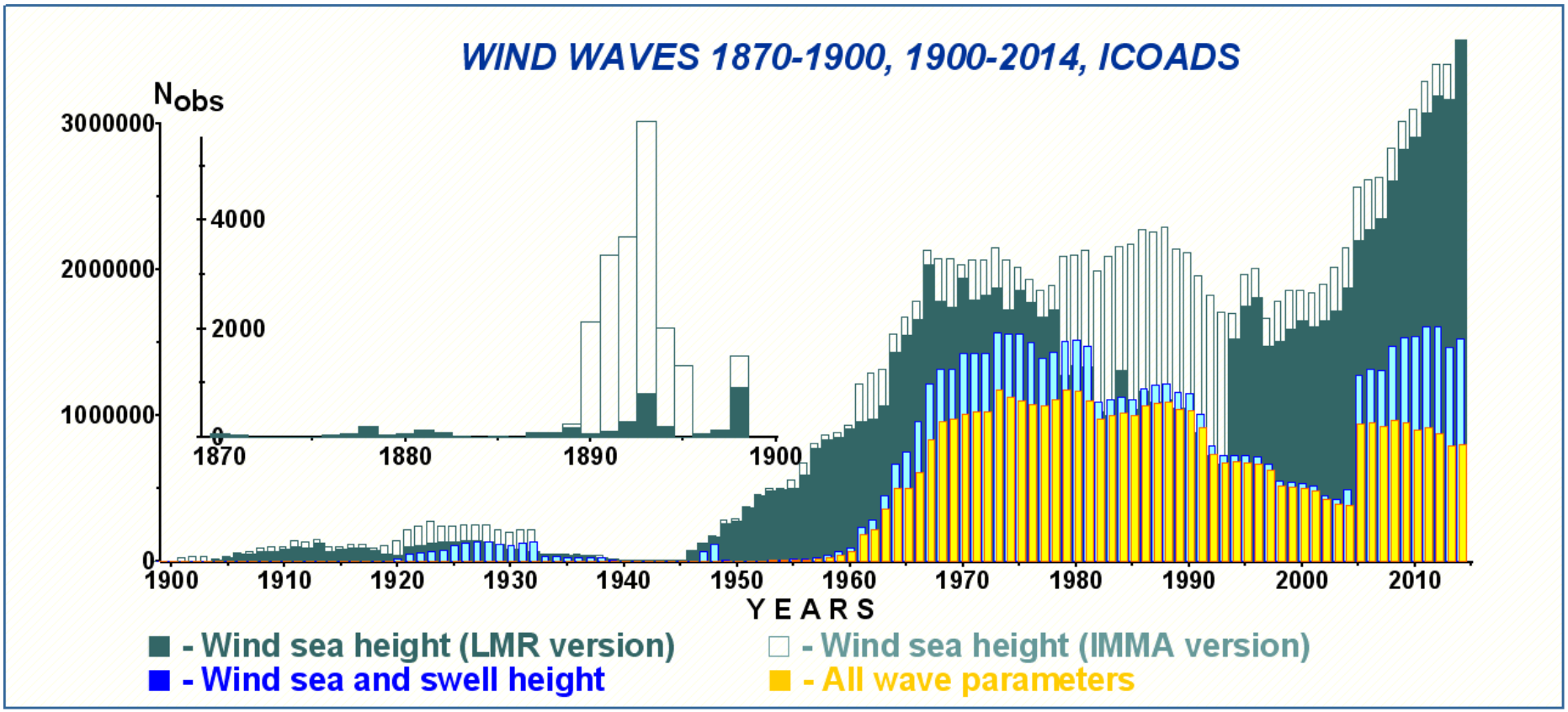
- **Voluntary Observing Ship (VOS) data – new updates**
- **Problems in the estimation of wave extremes (cut-offs, coding systems, practice of coding high waves…)**
- **Advanced quality control: using steepness and wave age**
- **HN estimates of extreme waves worldwide**

14th Wave Workshop, Nov 8-13, 2015, Florida

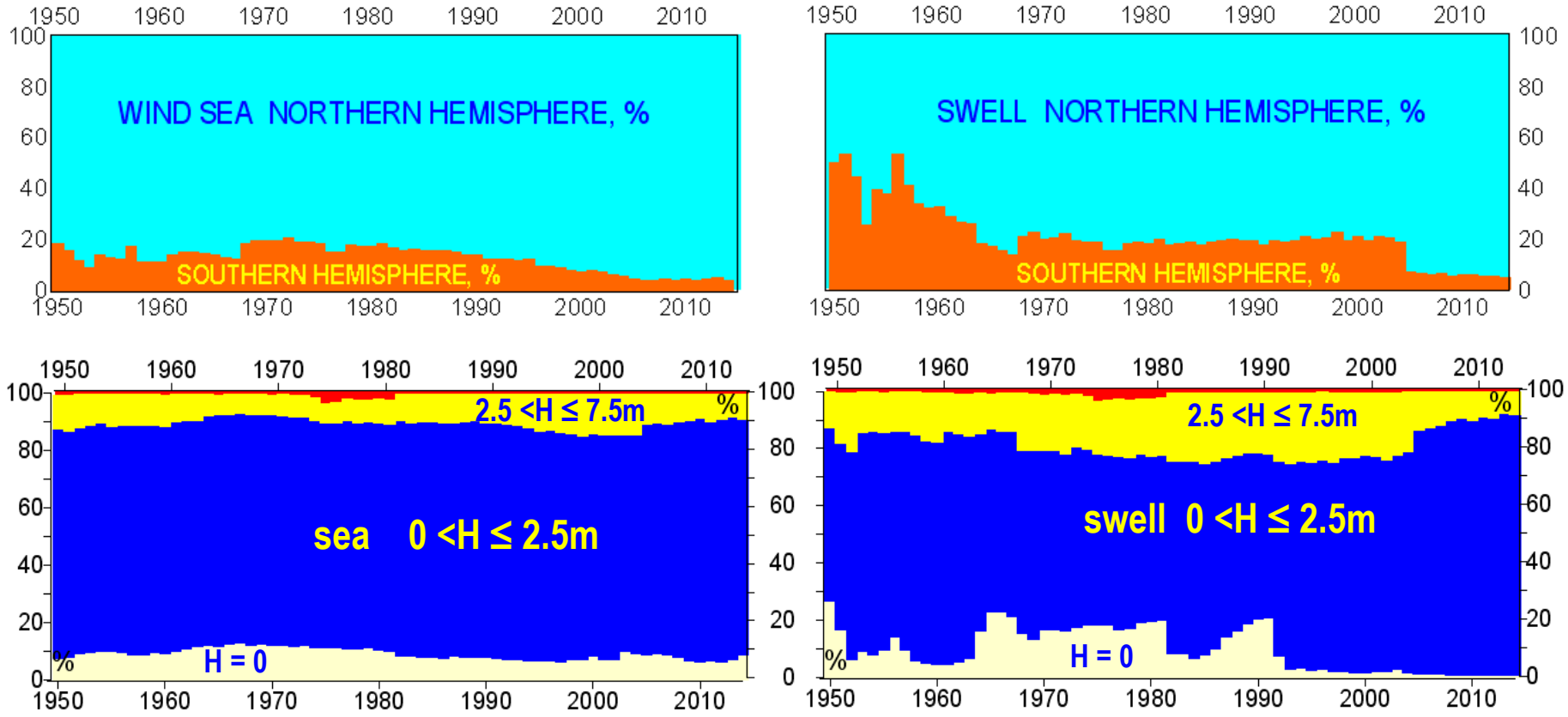
Visual wave observations from VOS: (1870-2015)

Voluntary **O**bserving **S**hip (**VOS**)

- The longest global observations taken visually by marine officers
- Separate estimates of wind sea and swell
- Code precision is 0.5m for heights and 1 sec for periods
- Assimilated in ICOADS (http://icoads.noaa.gov)
- New IMMA-formatted data 1900-2015 are used for the first time (130 million reports)
- No cut-off on wave height after 2006

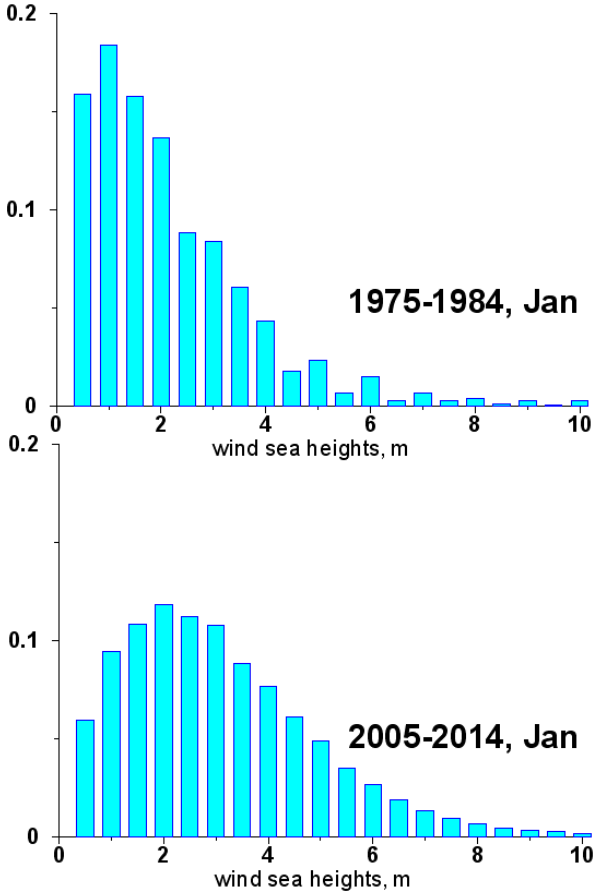


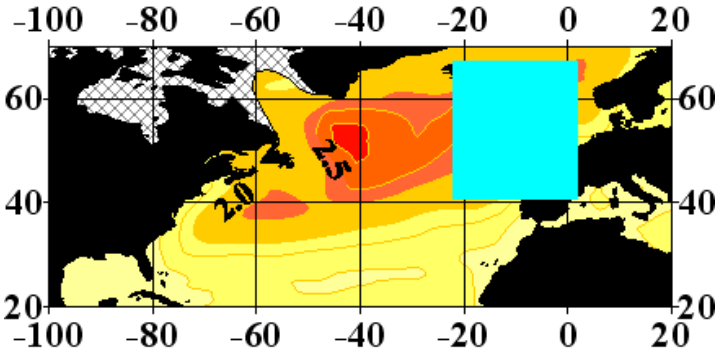
Temporal changes in wave height observations



- Significant decrease of the number of observations in the Southern Hemisphere: from 20% to 5%
- 99% of all reported wave heights are smaller than 7.5 m
- Significant (~10%) decrease of the number of reported moderate waves during the last decade

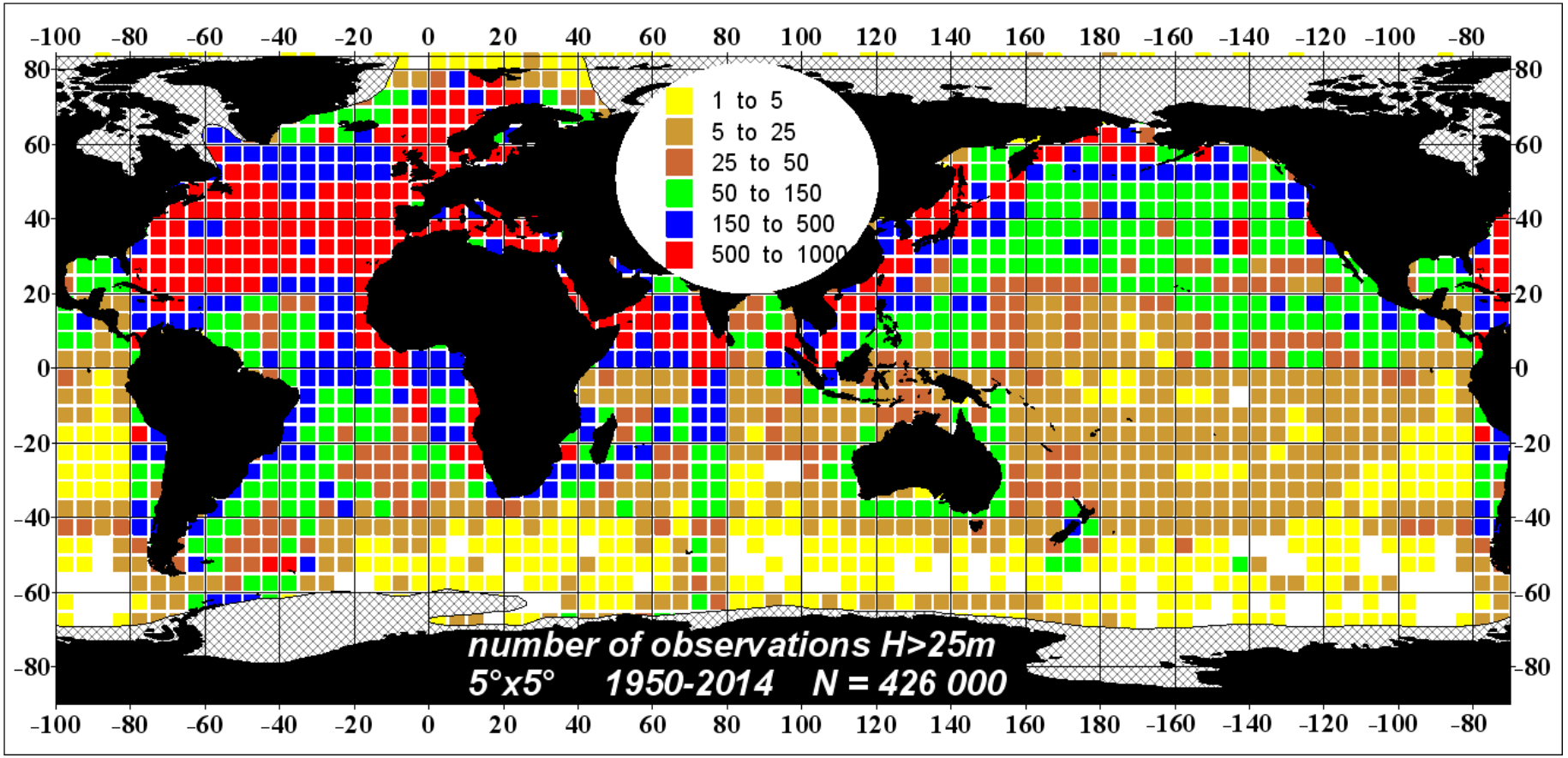
Temporal changes in wave height observations



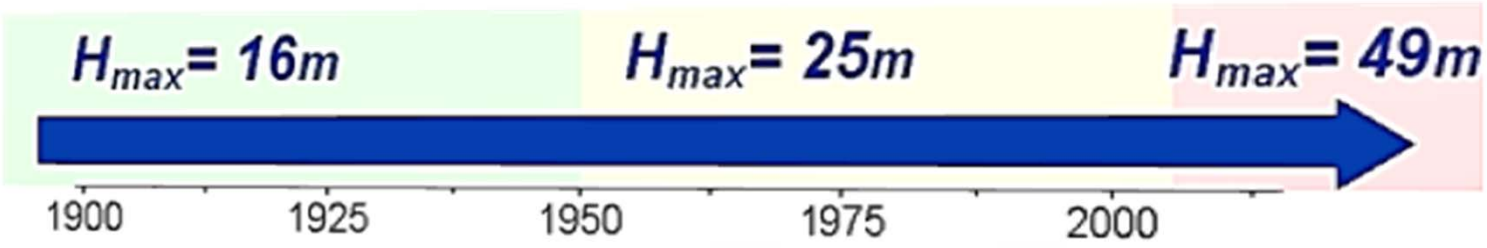


- Significant changes in regional wave height probability distributions towards higher occurrence of high waves

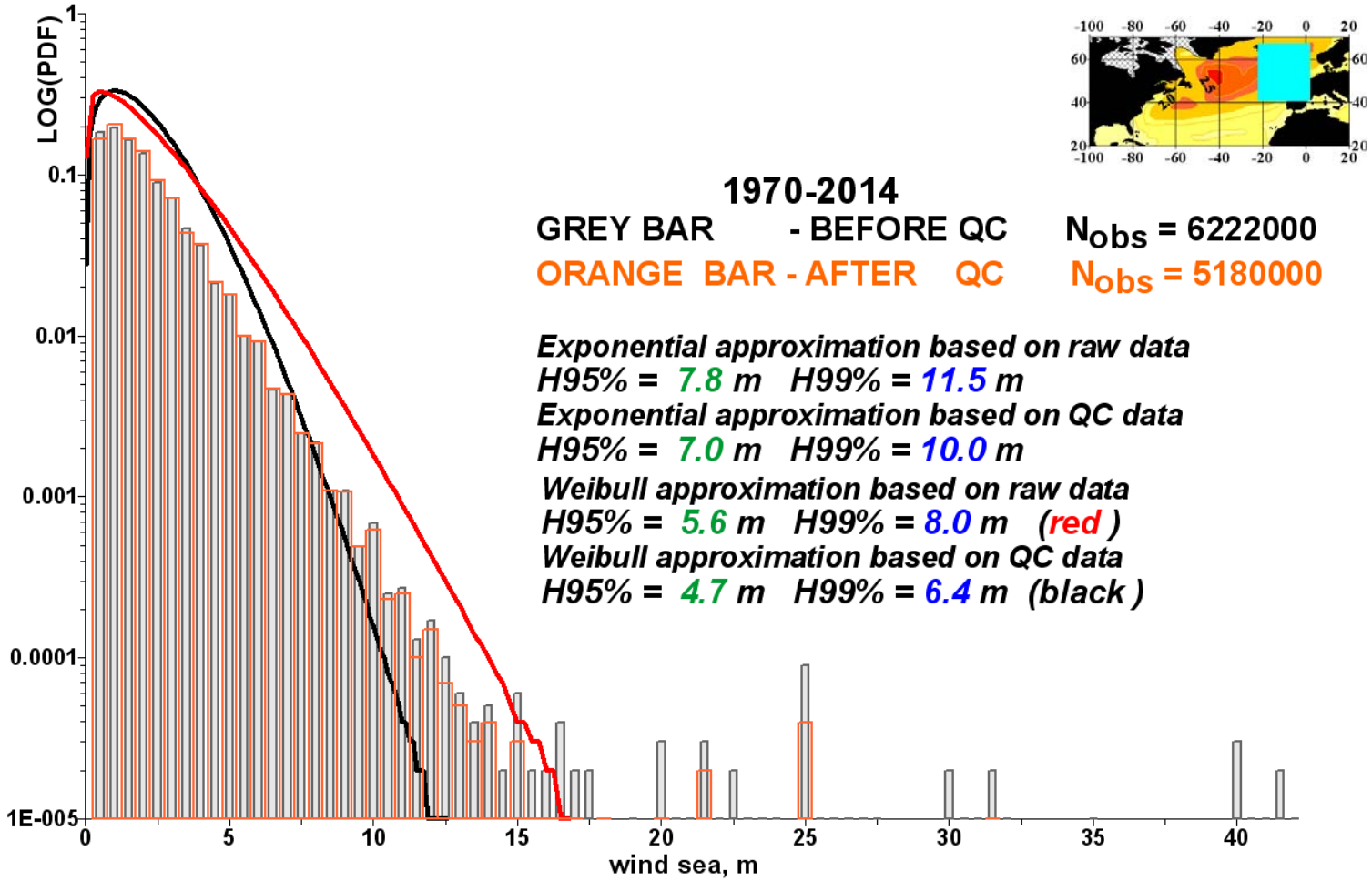
Estimation of extreme waves



Number of observation with wind sea heights > 25m is 0.3% from all reports which contain this parameter



Estimation of extreme waves



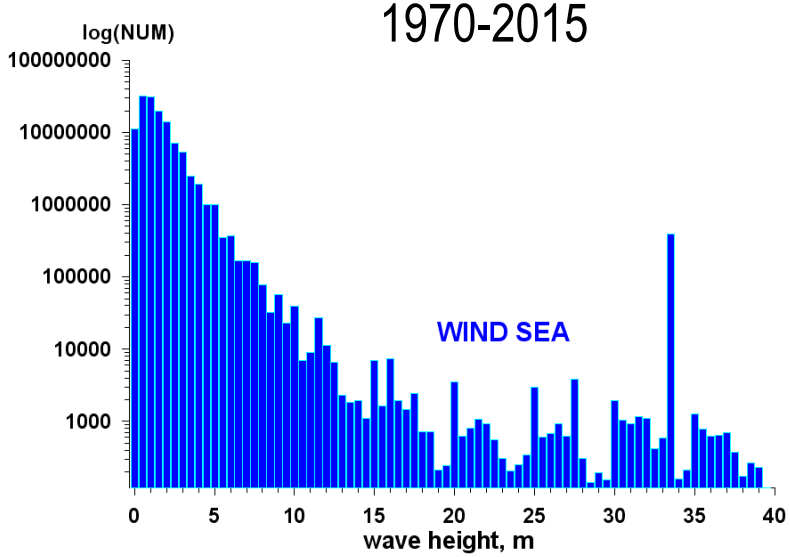
- Two data sets (before and after the QC) → up to 2m difference in wave extremes
- Two methods (exp vs Weibull) → up to 3m difference in estimates of extreme waves

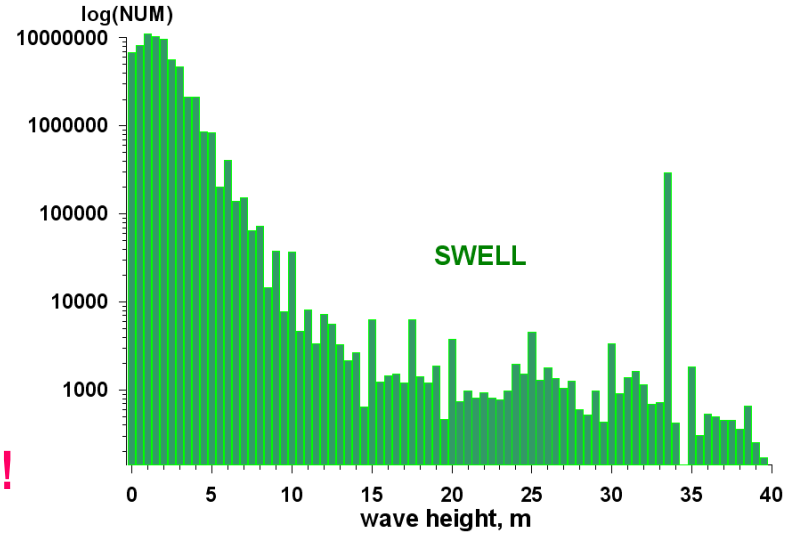
6 Problems of VOS wave data

- Predominantly integer figures for wave height estimates (often rounded to the nearest multiple of 5)
- Extreme waves (>25 m) and 33.5 m – “33” instead of “3” or missing value?
- Unrealistic dates and mistakes in attribution of coordinates of reports («± error» North vs South, East vs West)
- Inconsistency of wave parameters (zero height with the period > 0)
- Different thresholds before and after 1950
- Zero wave heights: calm or data missing?

ADVANCED QUALITY CONTROL IS REQUIRED!

Wave heights
1970-2015

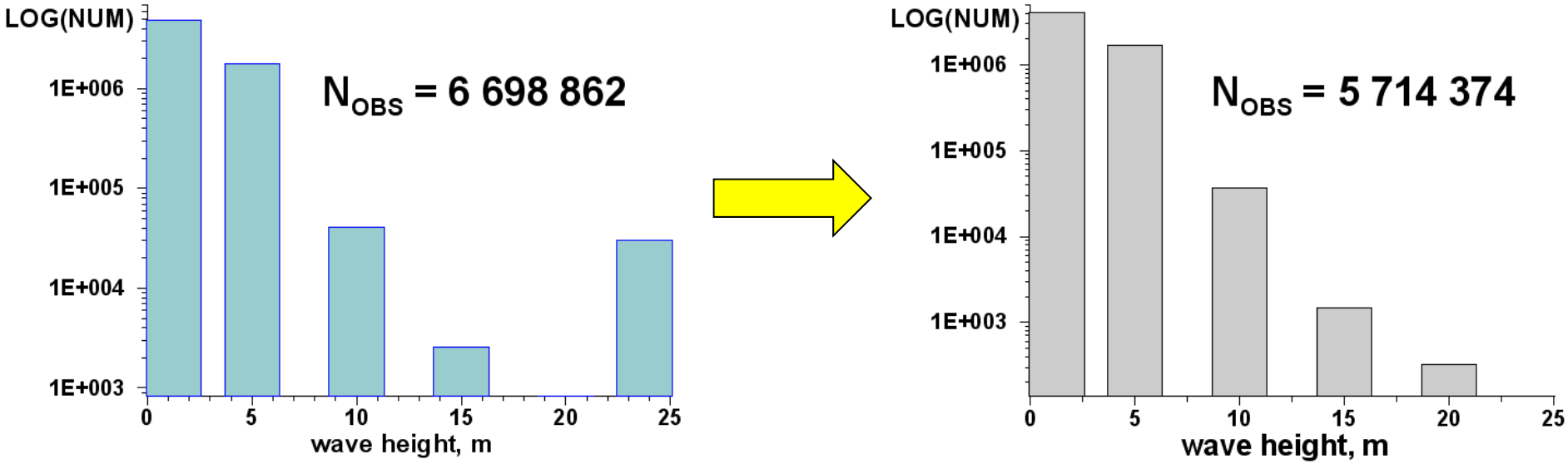




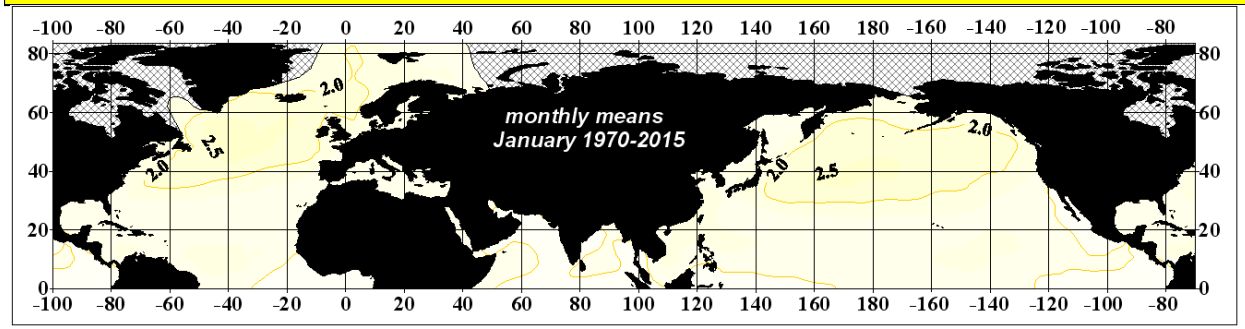
Minimization of uncertainties

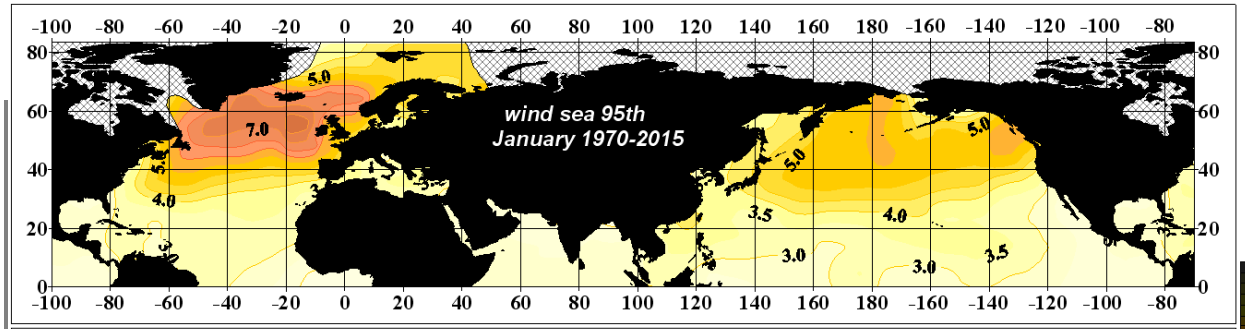
- Northern Hemisphere oceans, 1970-2015s
- Use large bins instead of 0.5m step in the original distributions
- Quality Control:
  - reports contain all wind sea characteristics
  - artefacts were excluded
  - H=0m and H≥25m were eliminated
  - waves with T=1s were excluded
  - steepness control ($\delta = \frac{2\pi}{g} * \frac{H}{T^2}$ <0.2)
  - wave age control ($a = \frac{c_p}{v_{ef}}$, $c_p = \frac{gT}{2\pi}$, $a \leq 1.2$)

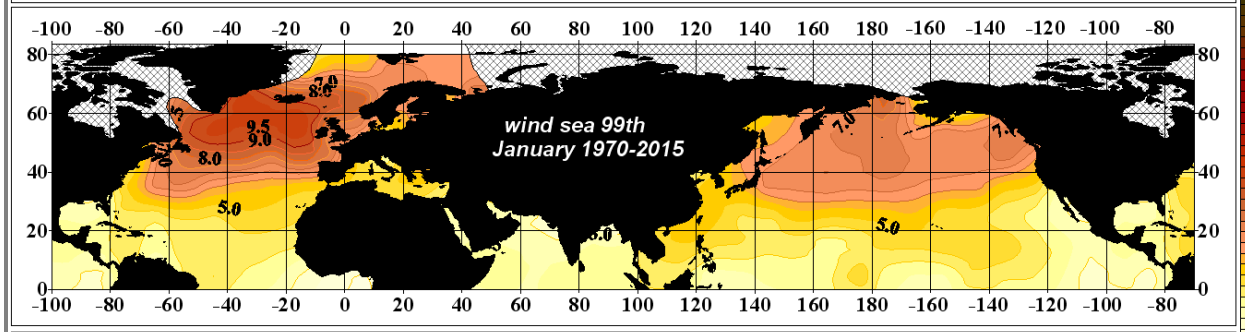
NORTHERN HEMISPHERE - IMMA DATA JANUARY 1970-2015 - WIND SEA HEIGHTS

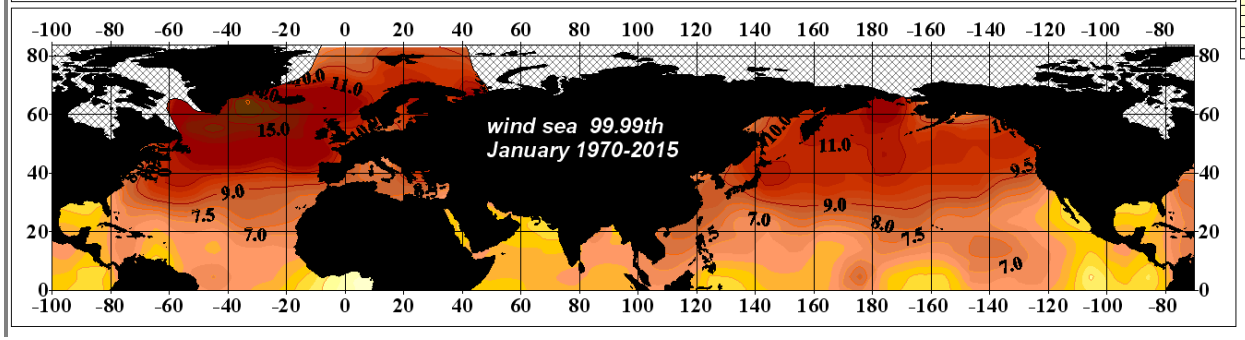


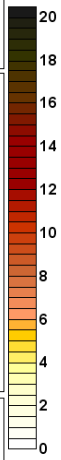
Northern Hemisphere extremes 1970-2015











- 10°x10° boxes
- January 1970-2015
- QC has been applied
- Weibull approximation

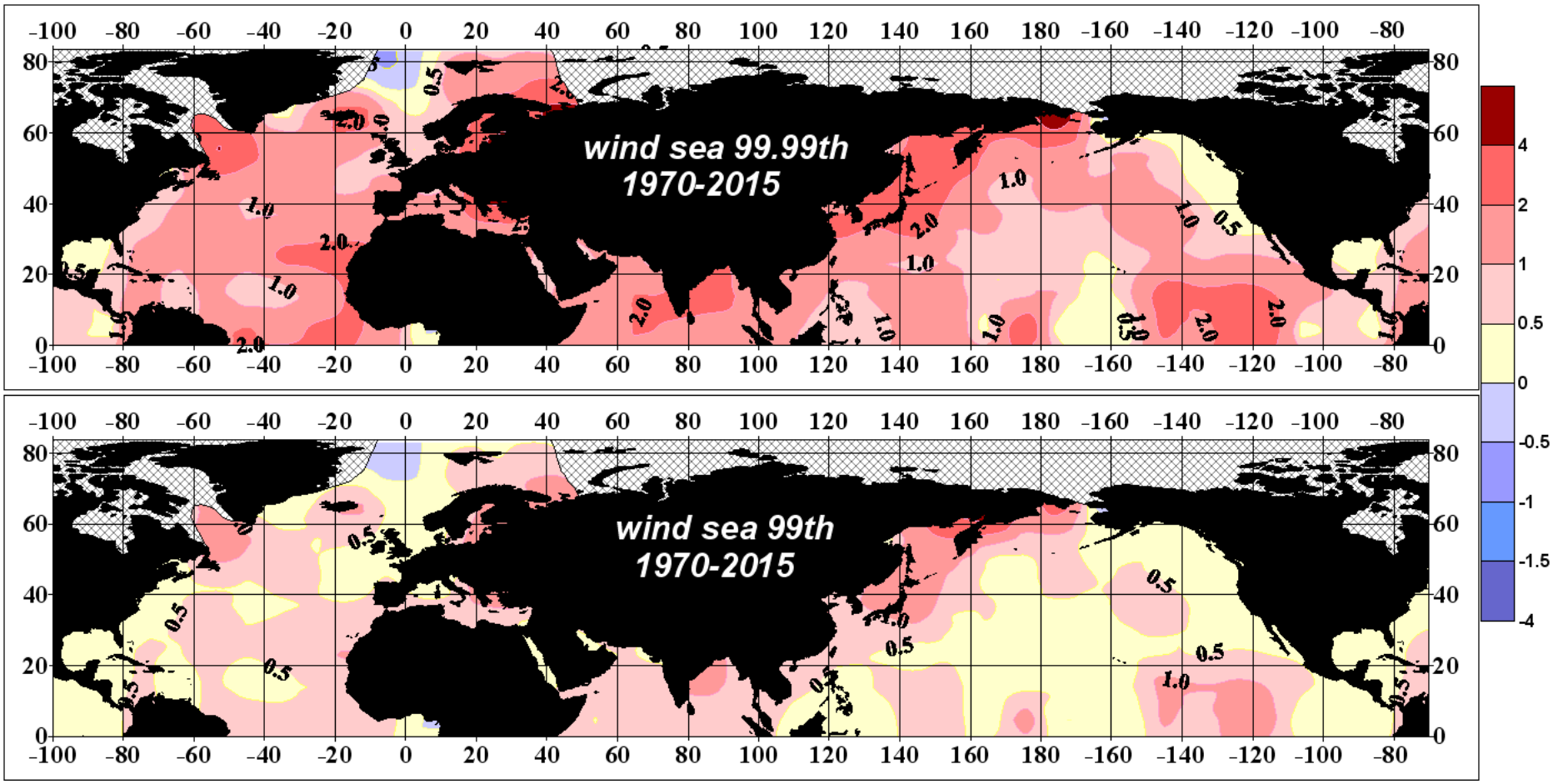
- North Atlantic winter extremes are higher than in the North Pacific

- Max winter value for 99.99th percentile is 16.9m – North Western part of the Atlantic Ocean

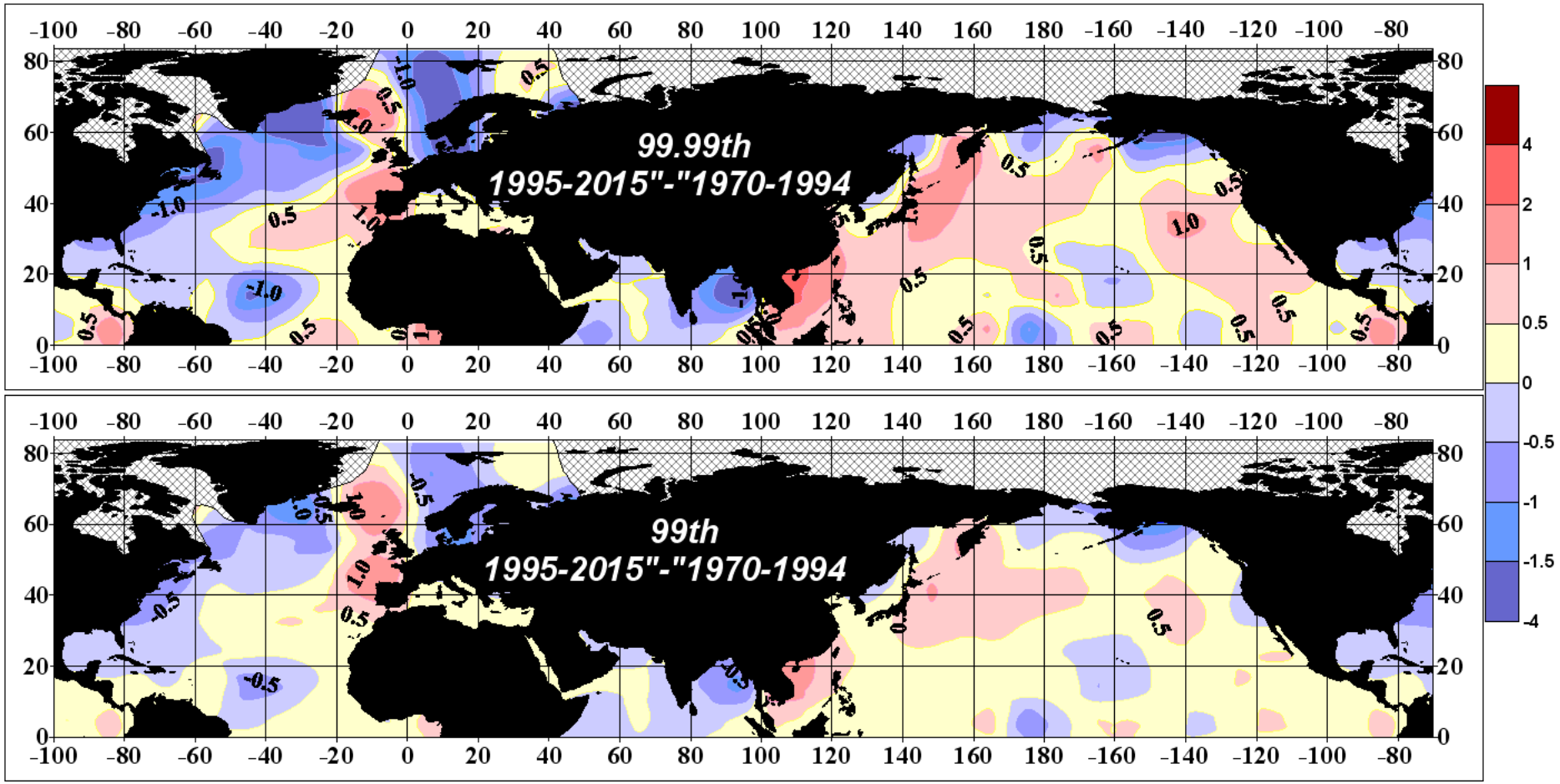
- Max summer extremes are observed in the Indian Ocean 99th = 11m

Differences due to Quality Control

Raw data extremes are higher than the ones after QC - up to 2m in some regions.
99th percentile differences are of about 0.5 m everywhere except PO (up to 1.5m)

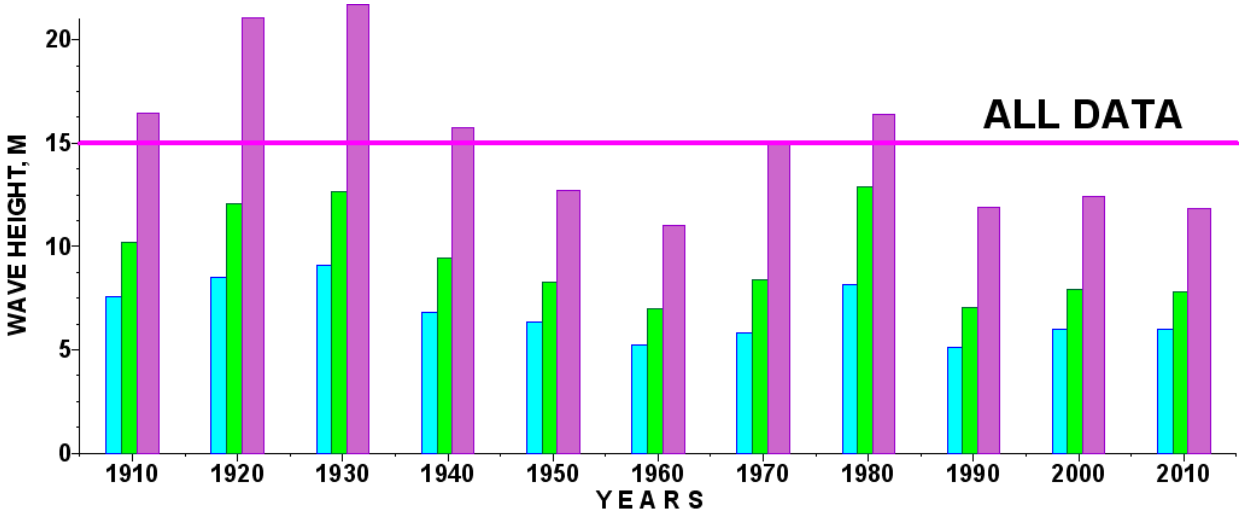


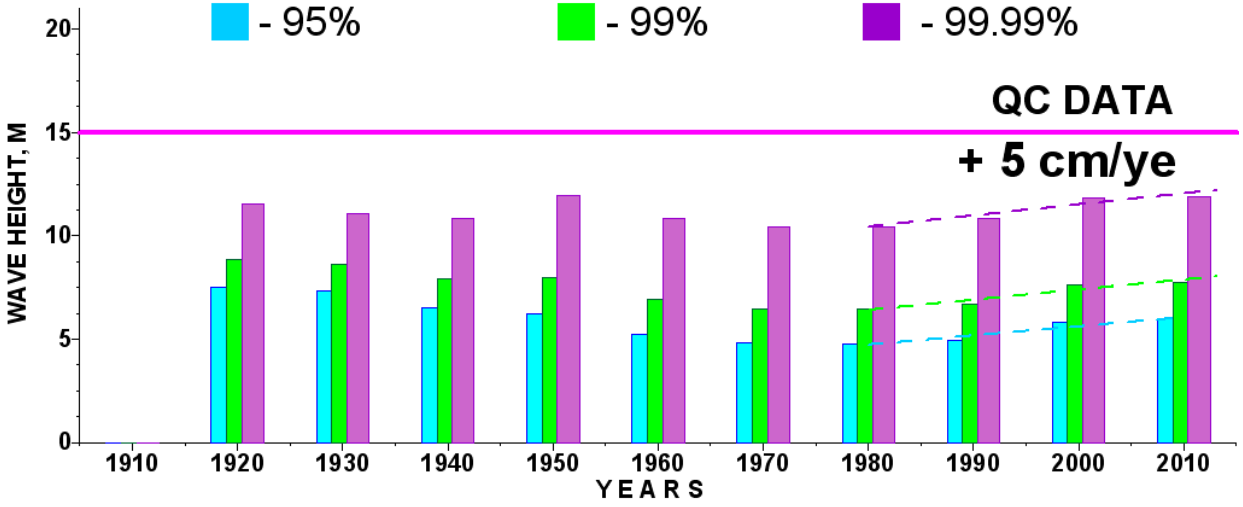
Interdecadal differences: 1995-2015 minus 1970-1994

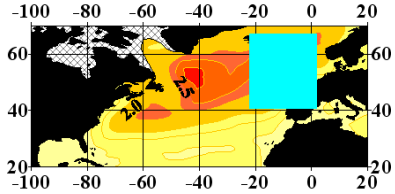


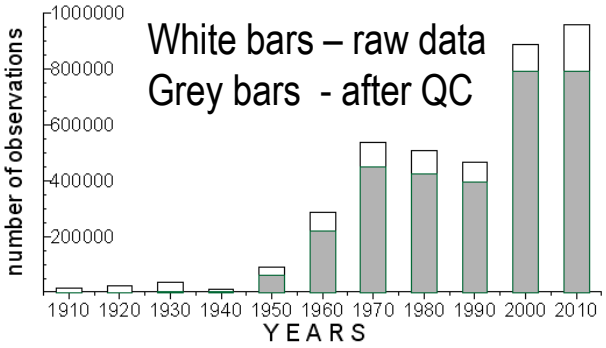
99th and 99.99th percentile extremes have increased along the East coast of the AO and along the West coast of the PO. Note an evident upward signal in the South China Sea.

Decadal extremes 1900-2015









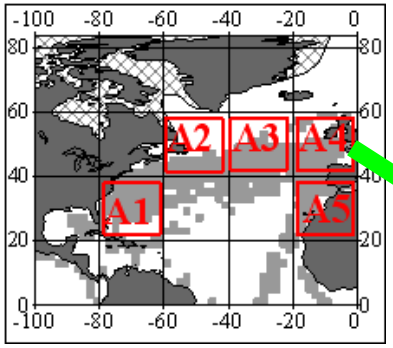
Winter season:
1905-2015

Extremes show a slight increase of ~ 5 cm/year

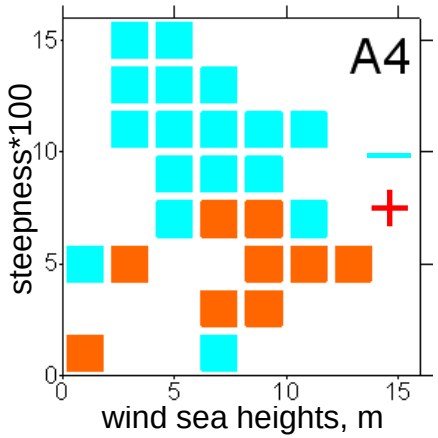
(~ 6 cm/year for January)

Regional normalized occurrence anomalies

$$P'(x) = \frac{P(x) - \overline{P(x)}}{\sigma[P(x)]}$$

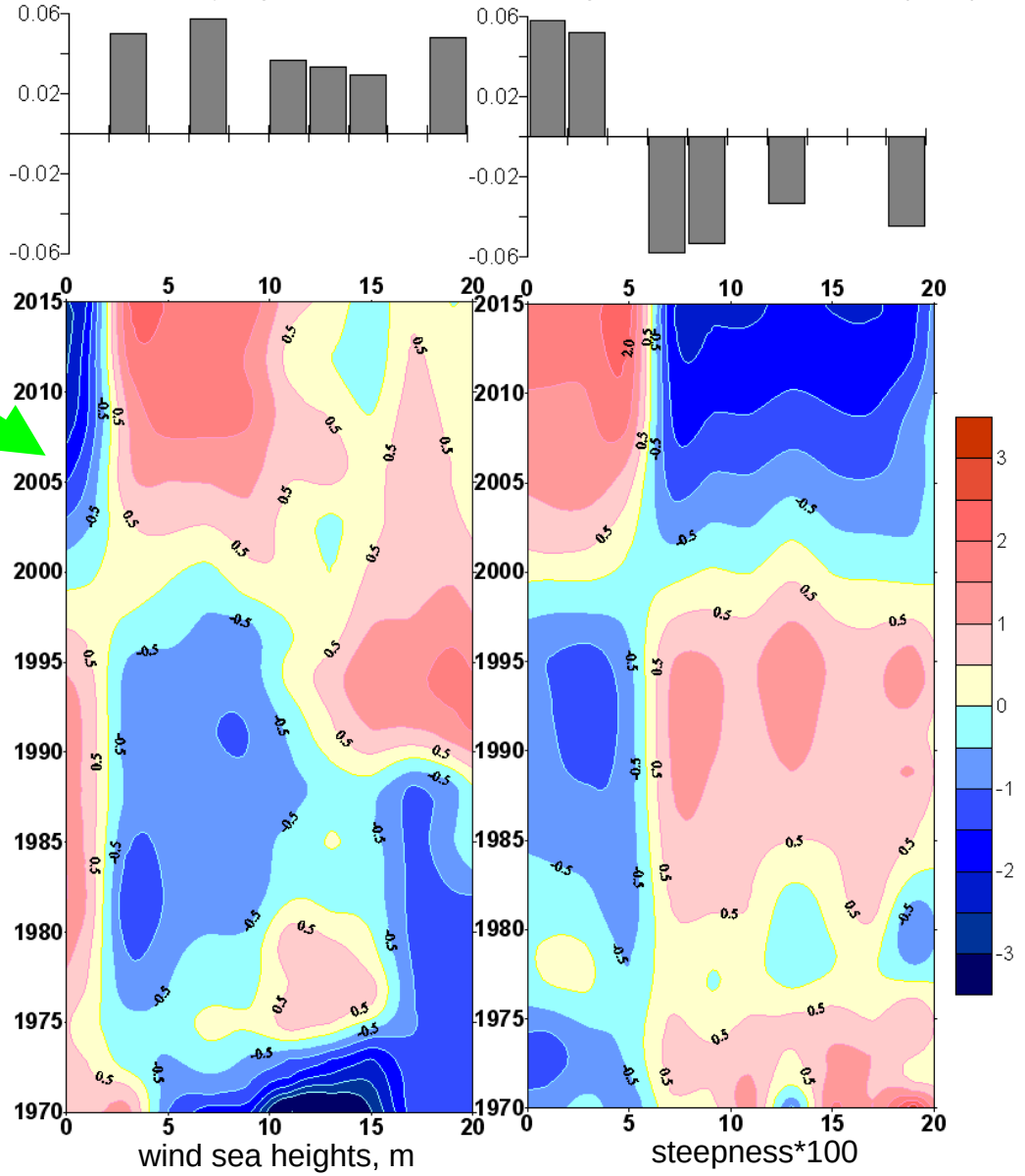


- East Atlantic – occurrence of high waves increases on expense of small waves, simultaneously occurrence of steep waves decreases



Trends in 2D normalized occurrence anomalies
January 1970-2015

Statistically significant trends according to the Student's t-test (95%)



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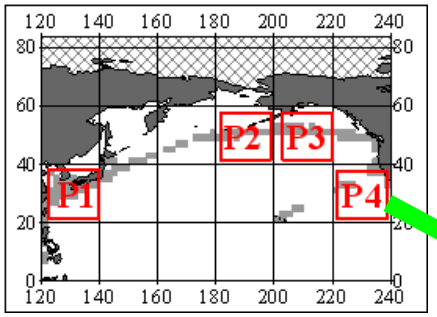
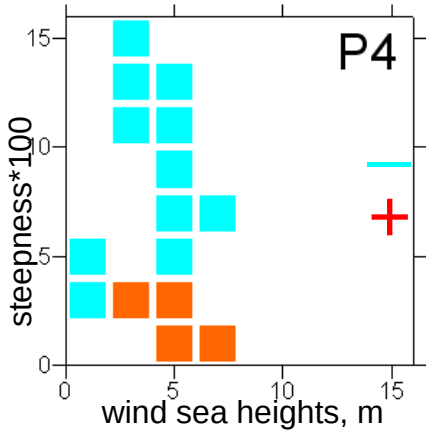


- East Pacific – occurrence of extreme waves tends to grow, less waves with high steepness and more waves with low steepness



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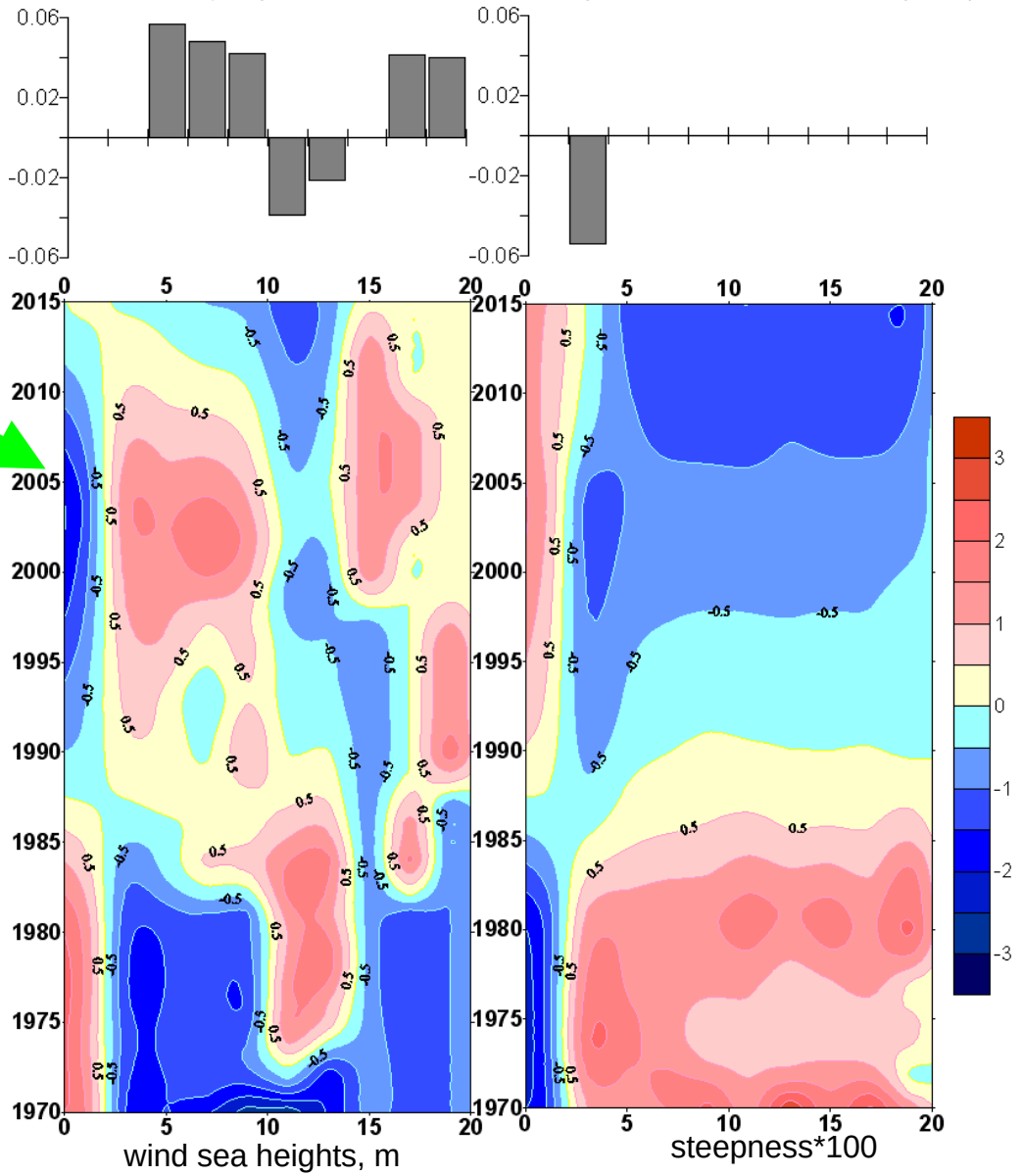

Conclusions

- Newly updated VOS data base has been used for estimation of extreme wave heights
- Major identified biases are associated with the coding system changes, different cut-offs for different periods and observational practices applied for high waves
- Advanced multistage quality control system was developed
- There is an evident west-east Atlantic pattern in the interdecadal variability of extreme waves and a pattern of growing waves extremes in the western Pacific. Decadal estimates of extreme waves in the NA show a secular growth of about 5 cm per year in the Eastern Atlantic
- Analysis of long-term evolution of occurrence anomalies shows an inconsistency with anticipated changes in the wave steepness (at least for the Pacific Ocean)