

Global ocean wind waves 1878-2016:



new update of the IORAS VOS-based wave products



Vika Grigorieva and Sergey Gulev

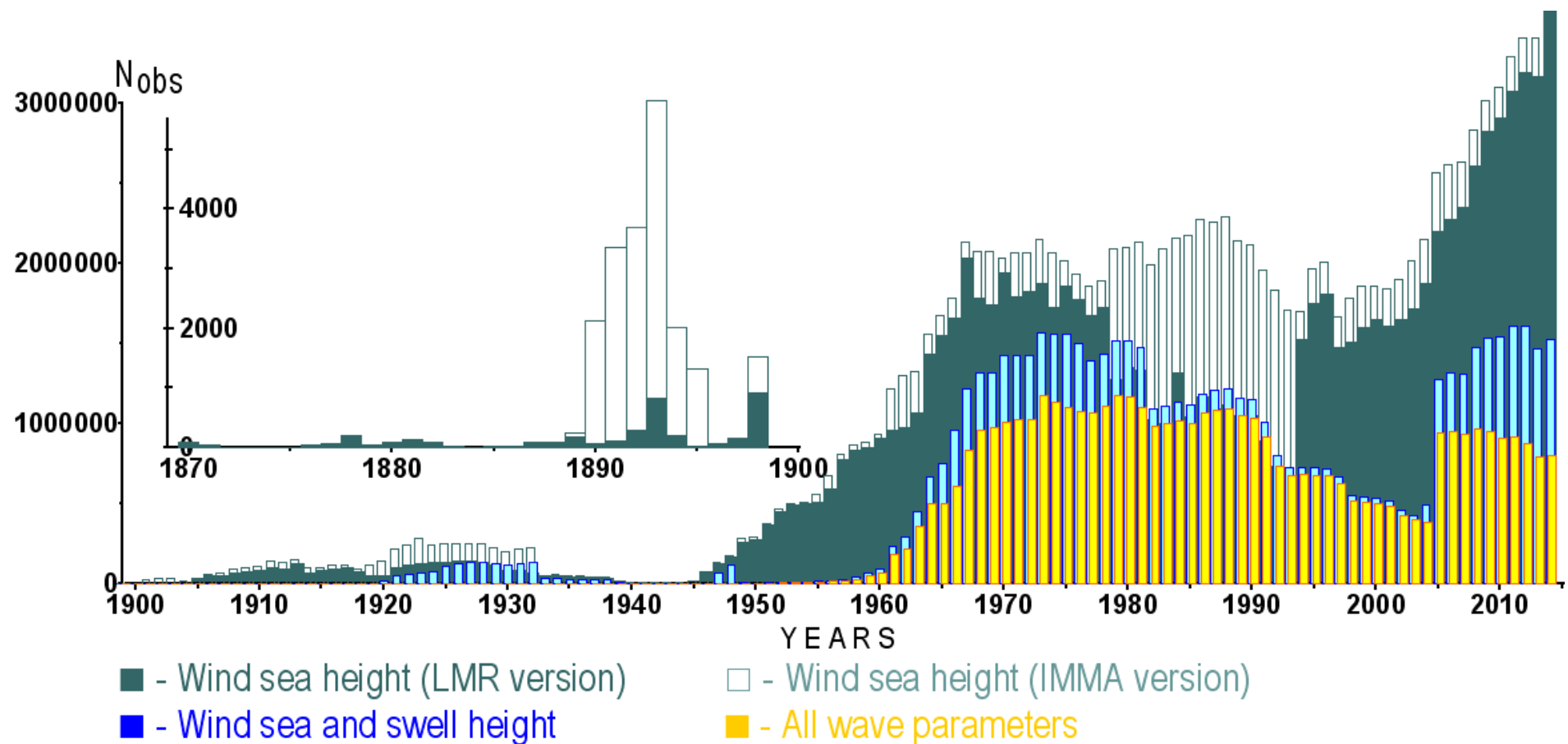
Sea Atmosphere Interaction And Climate Laboratory P. P. Shirshov Institute of Oceanology, Russia

Outline:

- IMMA-formatted ICOADS Voluntary Observing Ship (VOS) data for 1878-2016 period
- Estimation of all types of uncertainties and approaches used to minimize them
- Potential applications

Waves in VOS : (1878-2015)

- New IMMA-formatted data are available nearly operationally
- The number of wind sea height observations increased twice compared to previous release of ICOADS (LMR-formatted)
- The number of records which contain all wave parameters remains unchanged
- No cut-off on wave height after 2006 (25 m before 2006, 16 m before 1950)



Three data streams:

Parameter	Centennial (1888+)	Interdecadal-1 (1950+) [moderate complexity]	Interdecadal-2 (1970+) [superior complexity]
Wind sea height		✓	✓
Wind sea period		✓	✓
Wind sea length, steepness, age		✓	✓
Swell height			✓
Swell period			✓
Swell length, steepness, age			✓
SWH	✓		✓
Dominant period	✓		✓
SWH length, steepness, age	✓		✓

Why 3 streams?

Centennial (1888+)

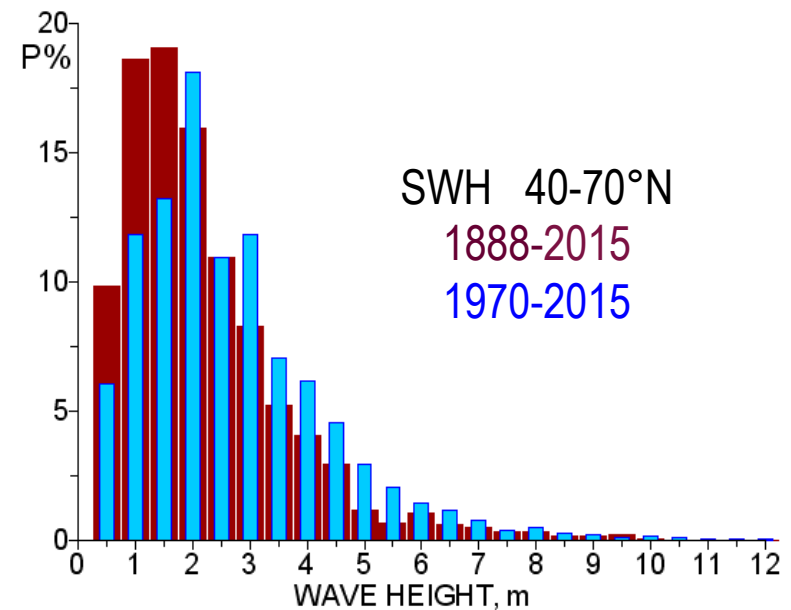
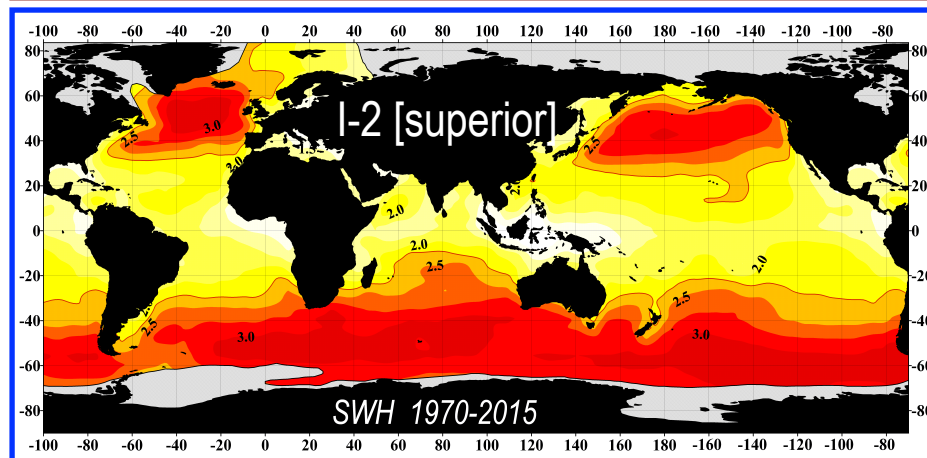
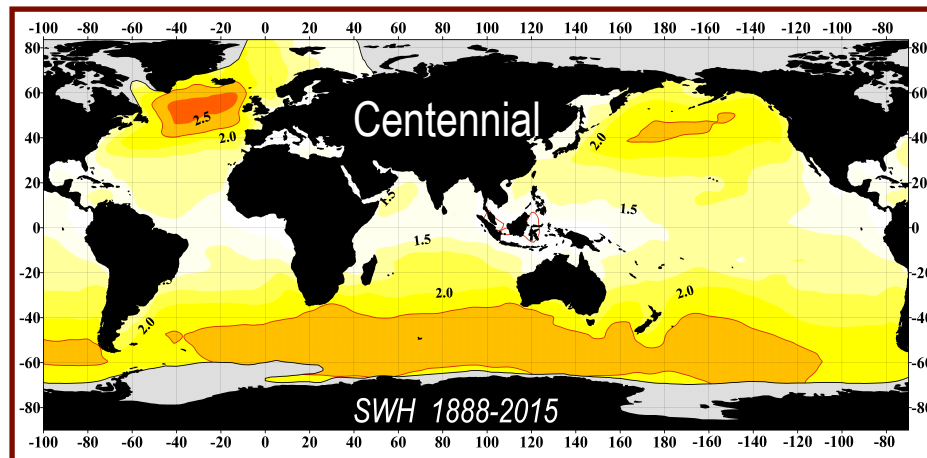
only wave height, before 1950 as reported and afterwards as a maximum of sea and swell

Interdecadal-1 (1950+)

wind sea from sea and swell observed separately,
largely dominated by wind sea reports

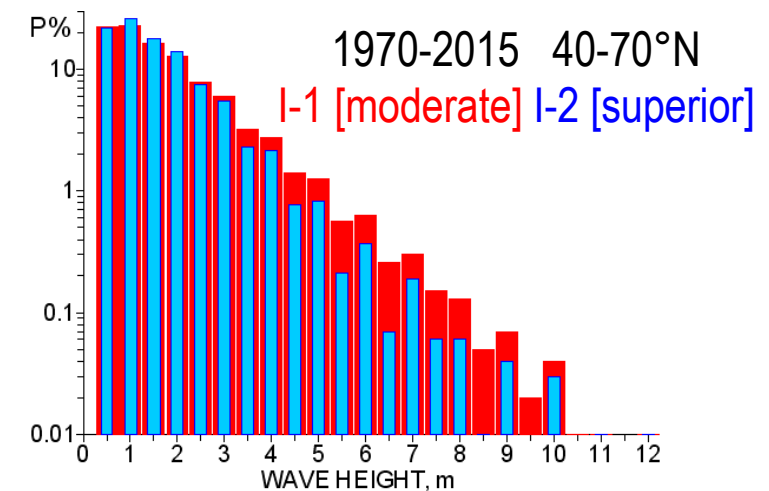
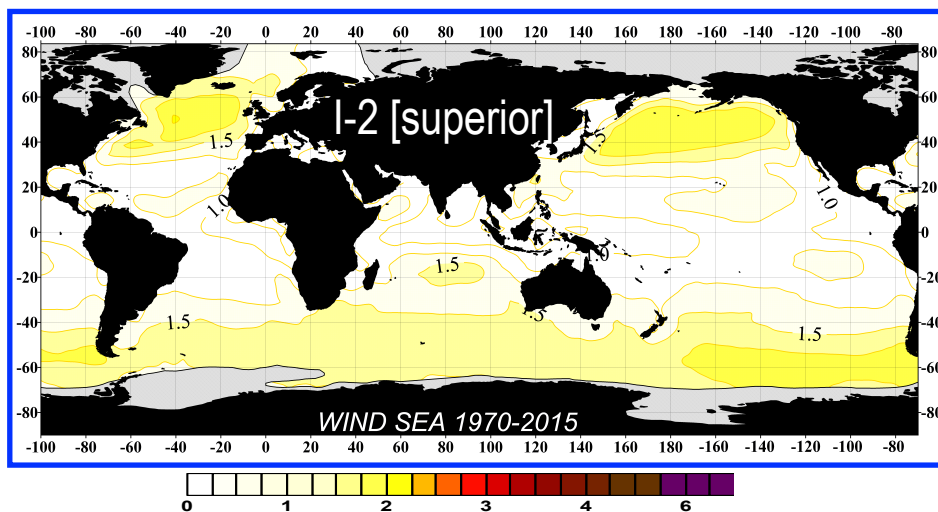
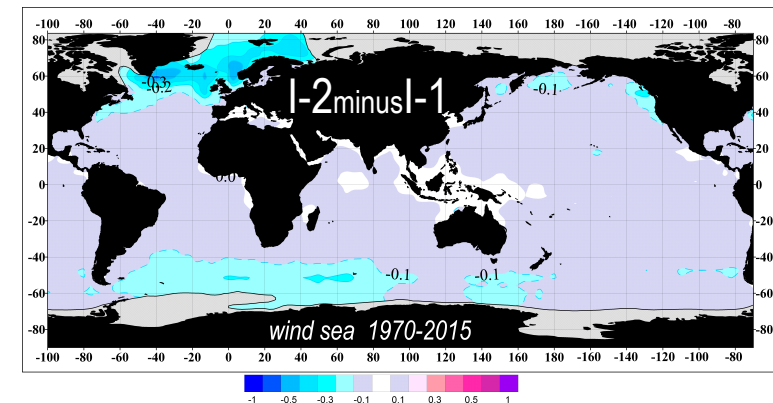
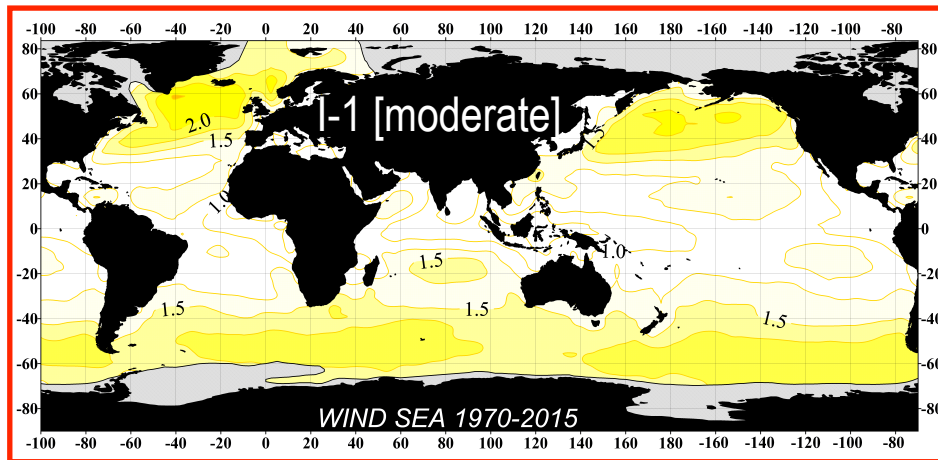
Interdecadal-2 (1970+)

separate estimates of wind sea and swell, 3 estimates of SWH

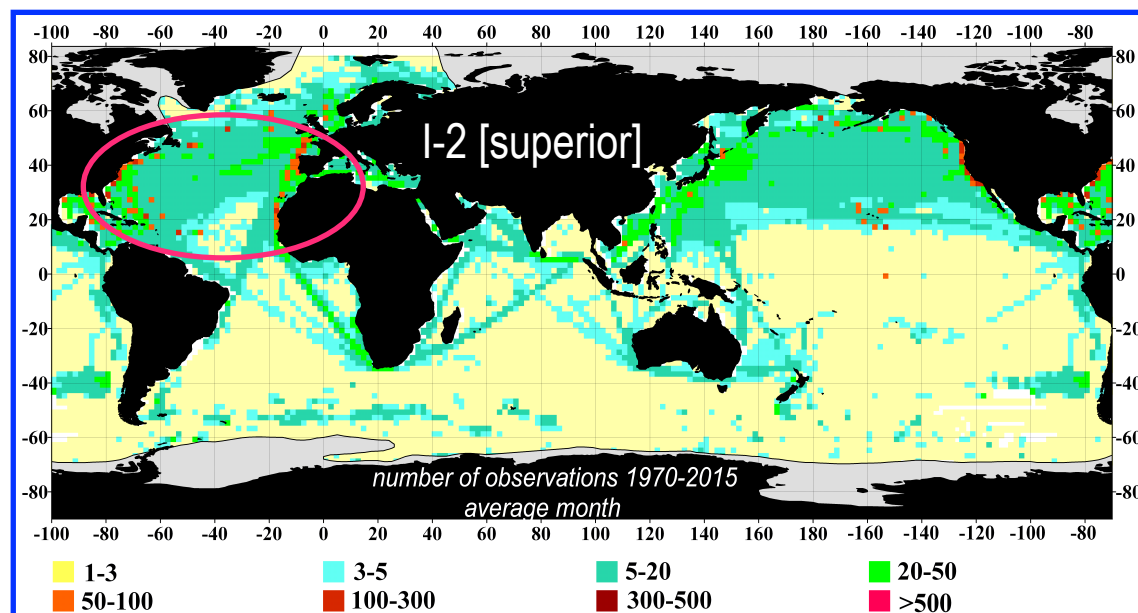
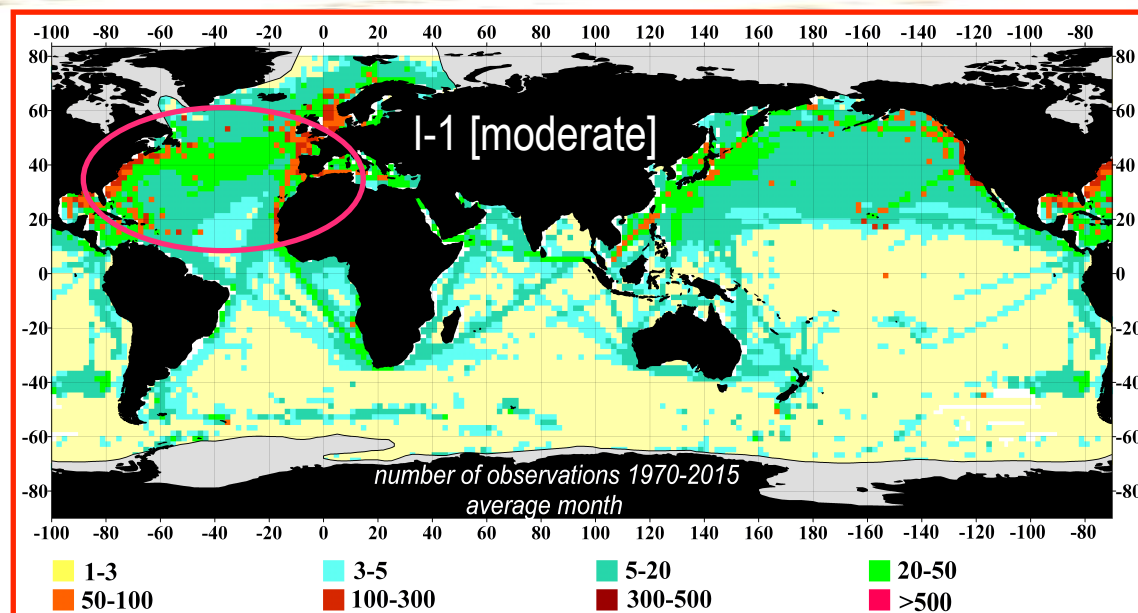


Wind sea height

Differences between **Interdecadal-1 [moderate]** wind sea and **Interdecadal-2 [superior]** are less than 10 cm almost everywhere and reach 0.5m in the North Atlantic because of two times more observations in this region

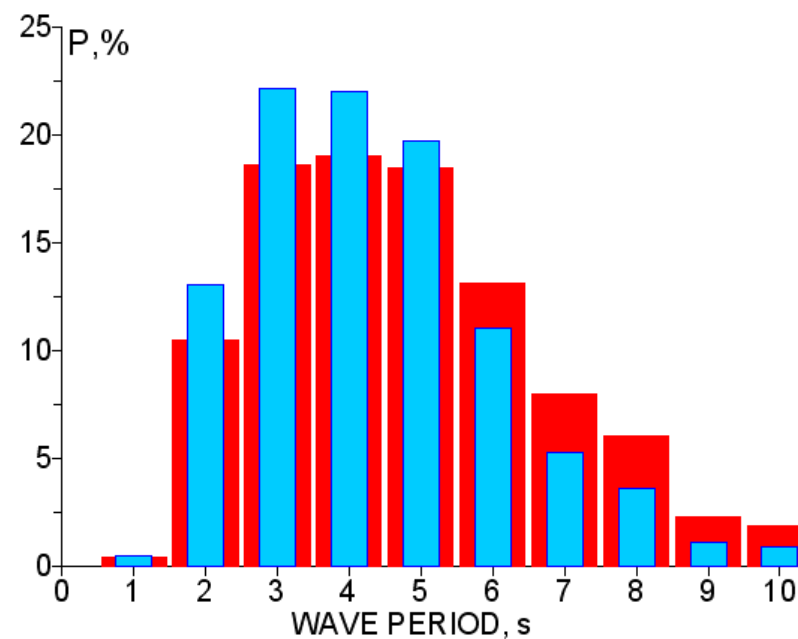
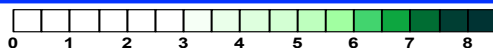
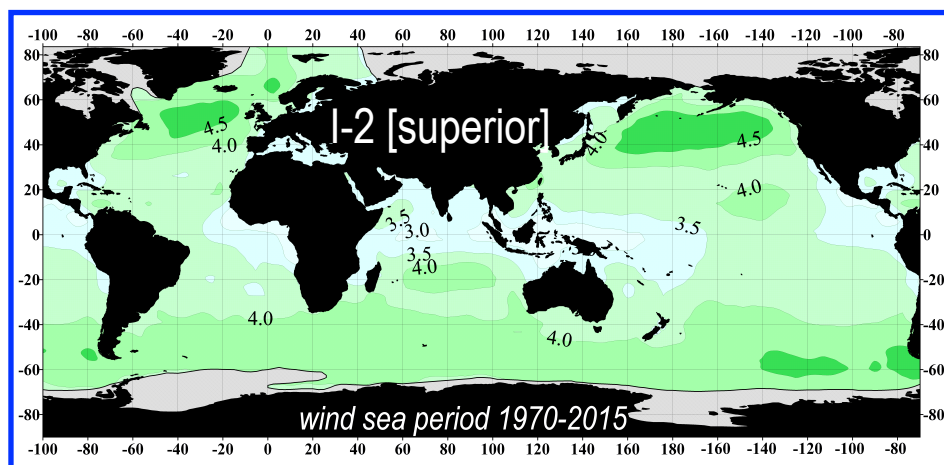
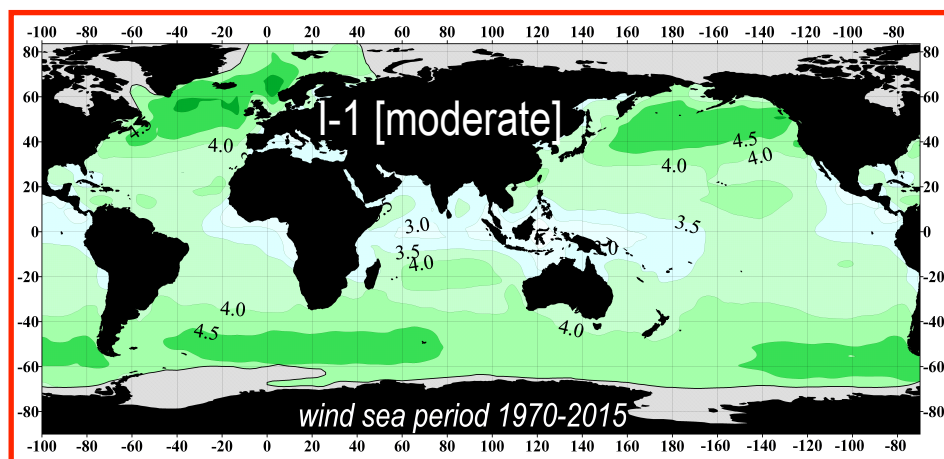


Number of observations



Wind sea period

Differences between **Interdecadal-1 [moderate]** wind sea period and **Interdecadal-2 [superior]** are less than 0.5 sec almost everywhere and reach 1 sec in the North Atlantic and in the Southern Ocean



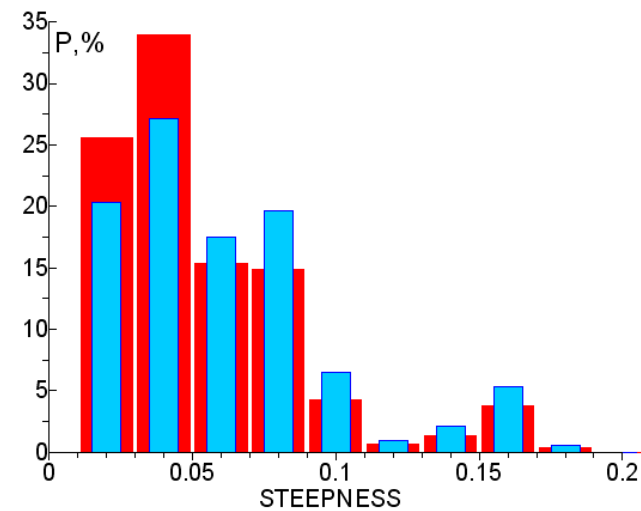
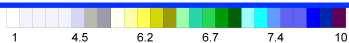
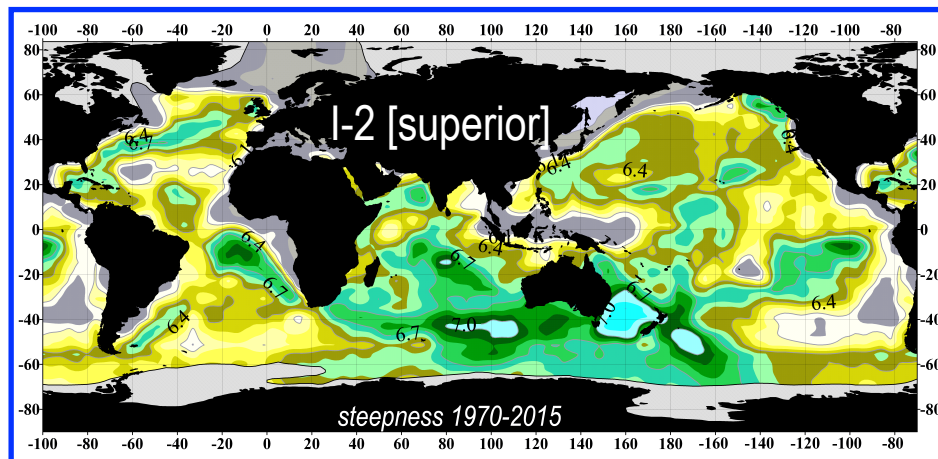
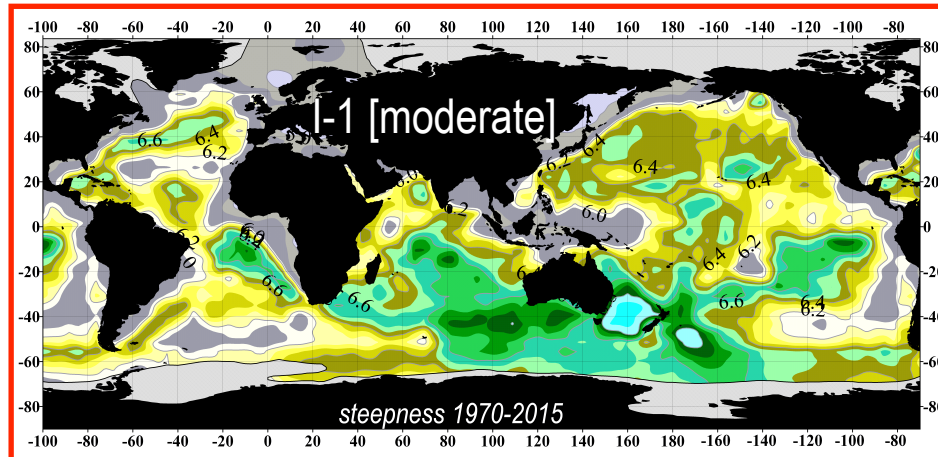
1970-2015 40-70°N

I-1 [moderate] I-2 [superior]

Wind sea steepness

Global steepness distributions are more consistent with each other but are suffering from discrete values of incoming parameters (especially unexplainable dearth of $T=7s$ and $T=9s$) :

$$\mu = 2\pi/g * H/T^2$$



1970-2015 40-70°N

I-1 [moderate] I-2 [superior]

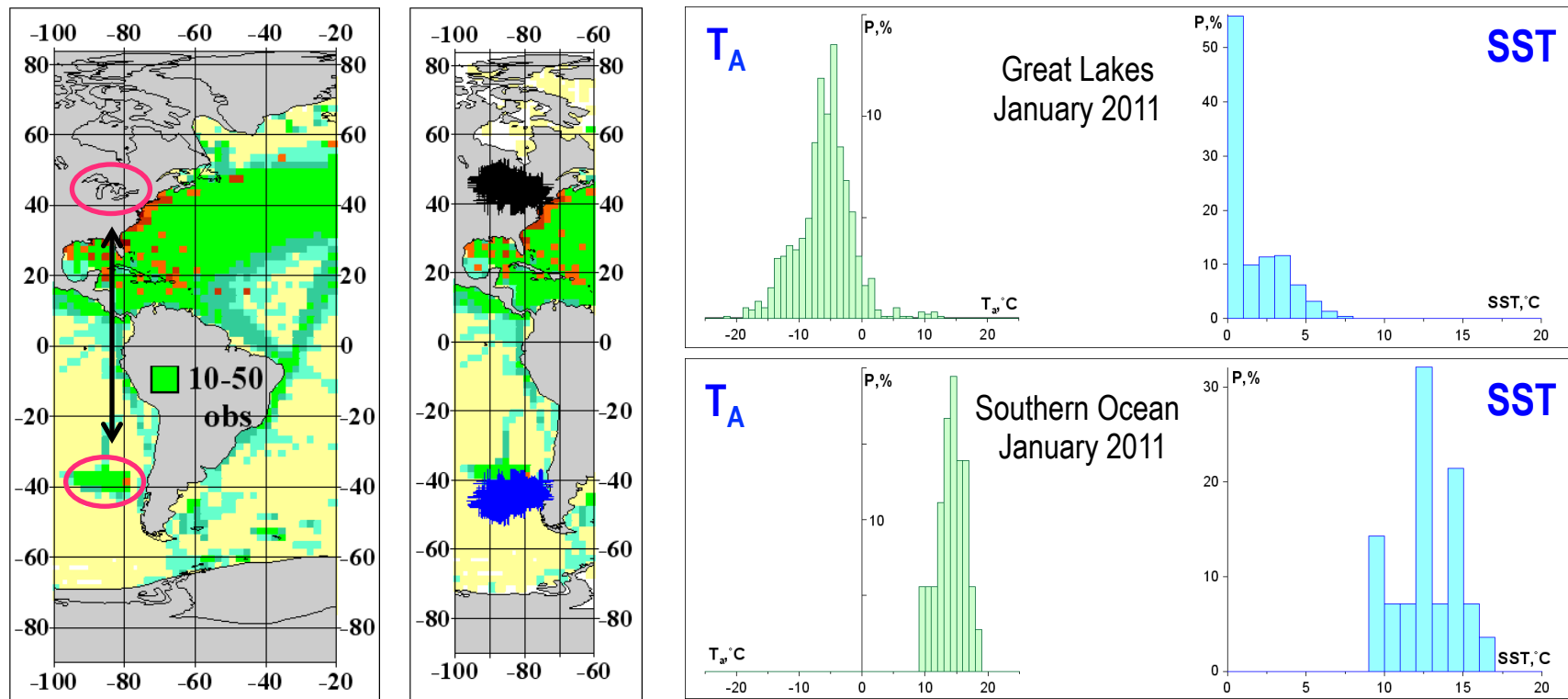
Common problems with known cures

- Unrealistic dates and mistakes in attribution of coordinates of reports («± error» North vs South, East vs West) → confuse in wave characteristics
 - Predominantly integer figures for wave height estimates (often rounded to the nearest multiple of 5)
 - Extreme waves (>25 m)
 - Different thresholds before and after 1950 and 2006
- } influence on extreme and long term estimates
-
- Wind sea and swell separation
 - Inconsistency of wave parameters (zero height with the period > 0)
 - Small wave periods («1 sec problem»)
 - Zero wave heights: calm or data missing?
- } influence on mean values
-
- What happened in 2004? → distorts the global climatology

Artefacts

- Unrealistic dates
 - 1855-1949
 - 1893-1949
 - 1950-2016

31 days almost in every month
each year is leap year
problems are fixed
- Wrong attribution of S/N and E/W coordinates of reports

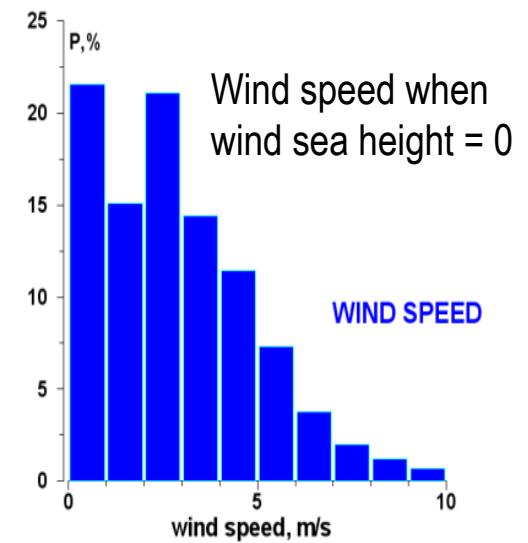
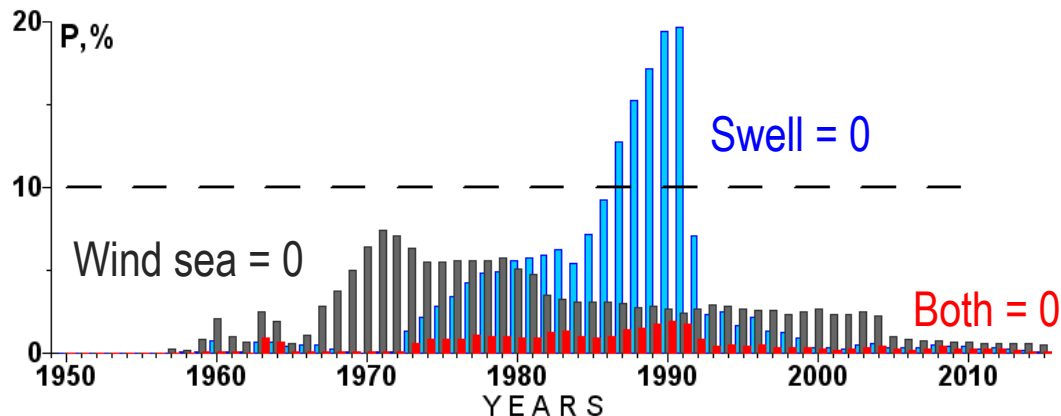
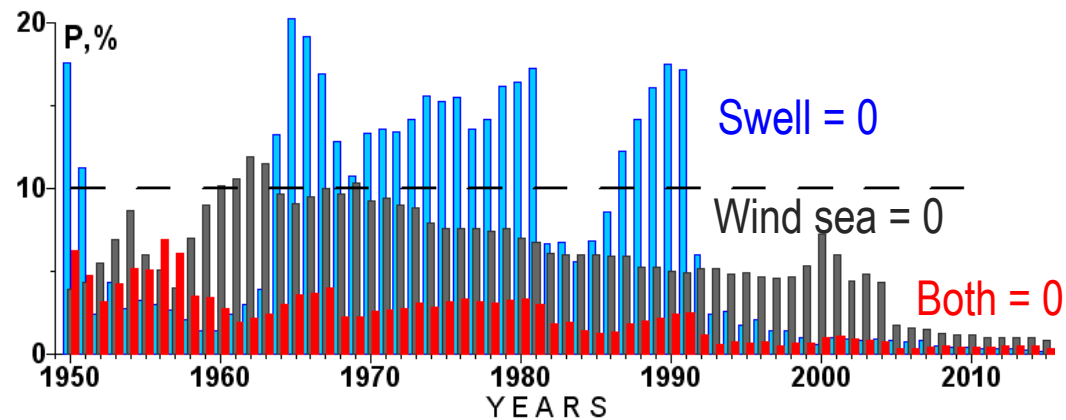


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Zero wave heights: calm or data missing

Most observations are located in the areas dominated by wind sea with a little occurrence of swell (likely NH)

Beaufort scale, buoy and satellite wind-wave analysis allow zero wind waves (or less than 0.5m) when wind speed is less than 5 m/s



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Wave heights and periods

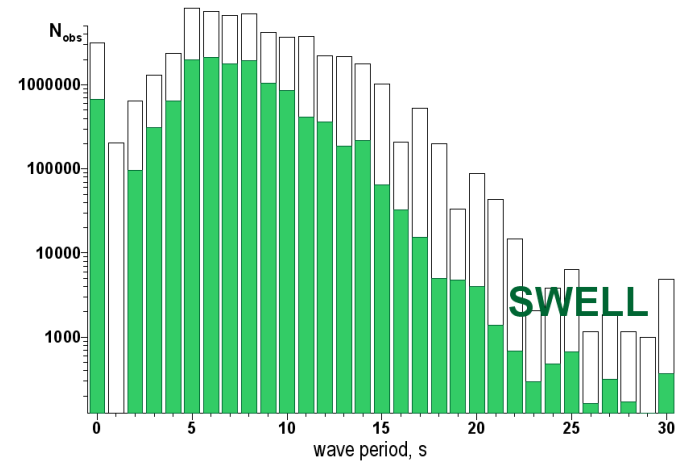
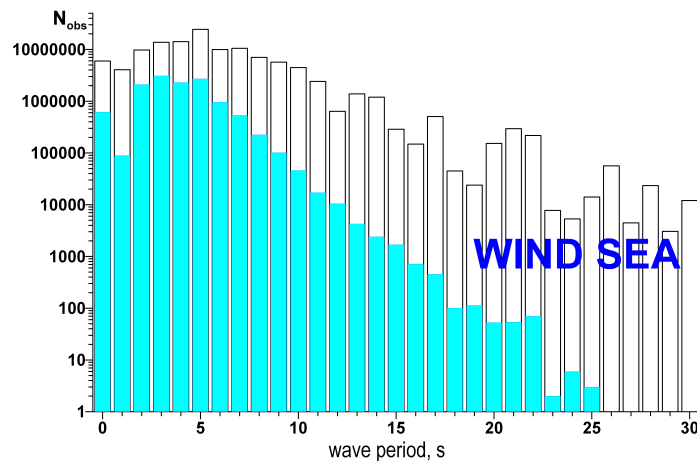
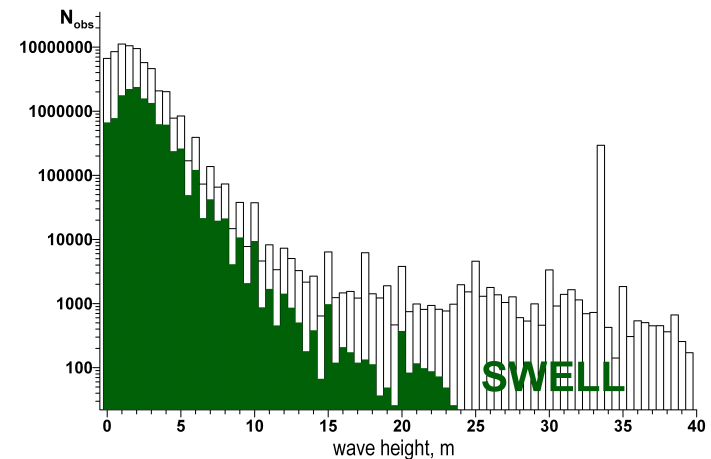
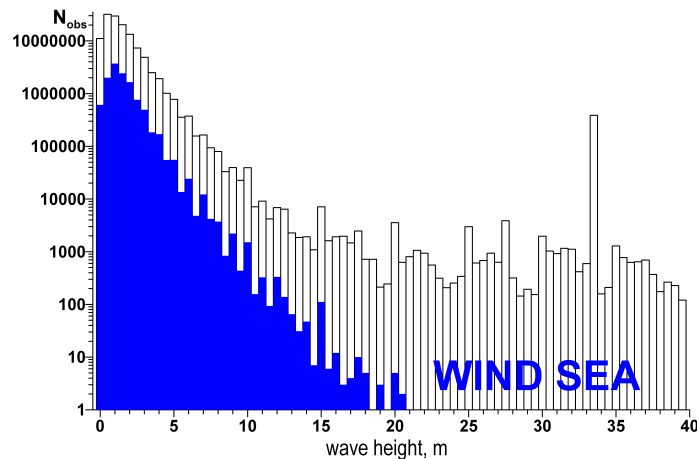
After all QC procedures – from 700 000 reports (27%, 1970) to 550 000 (2%, 2015)

Open questions: $H=11.5\text{m}$ – the real value or not converted feet? ($11.5\text{ Ft} = 3.5\text{ m}$)

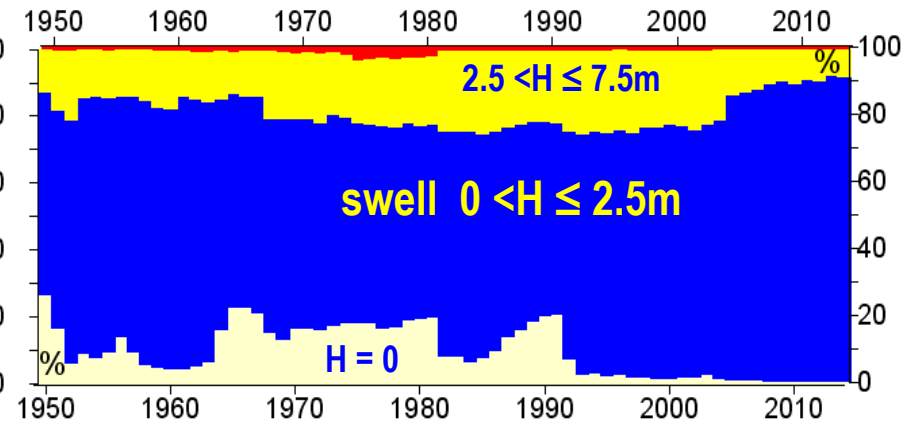
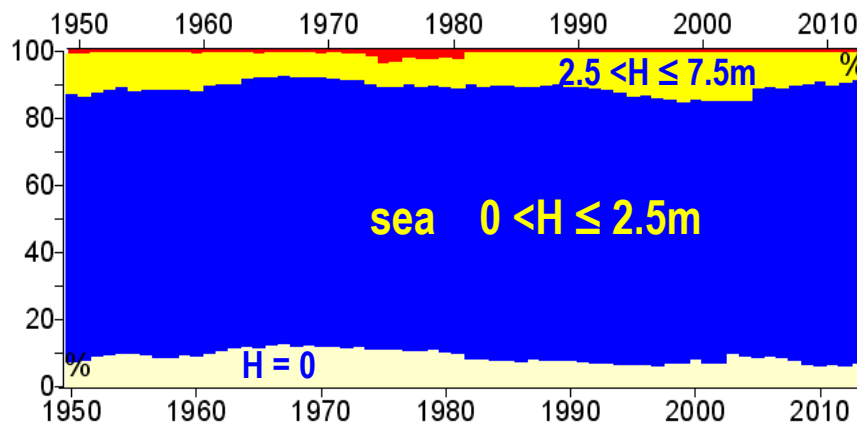
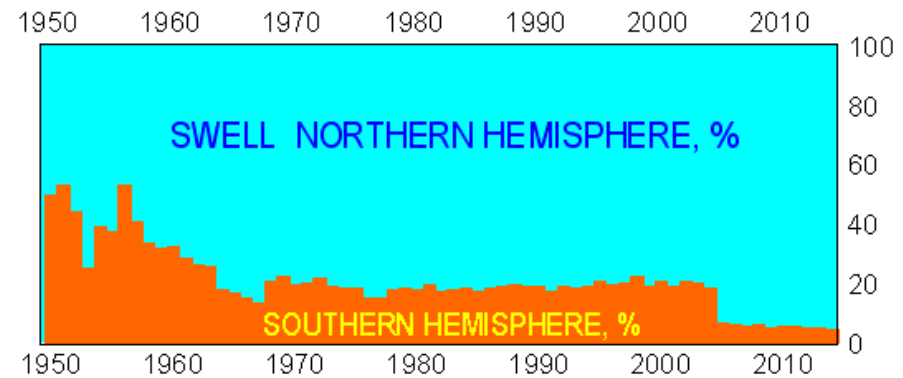
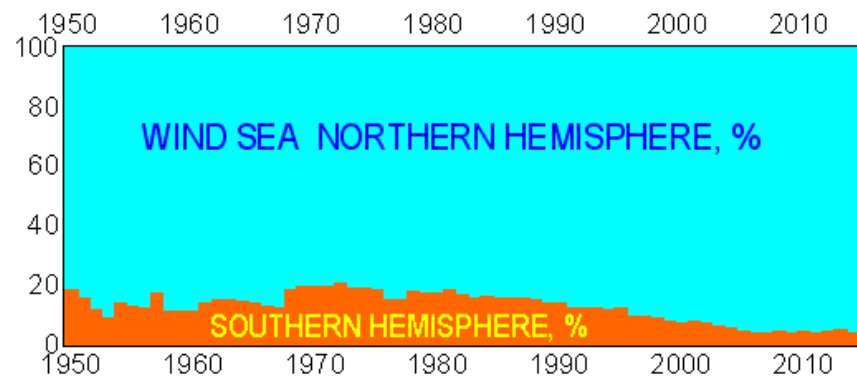
$H=33.5\text{m}$ – ?

1950-1959 – no swell higher than 10 m

1968-1979 – swell periods range within 5-15 sec



What happened in 2004?



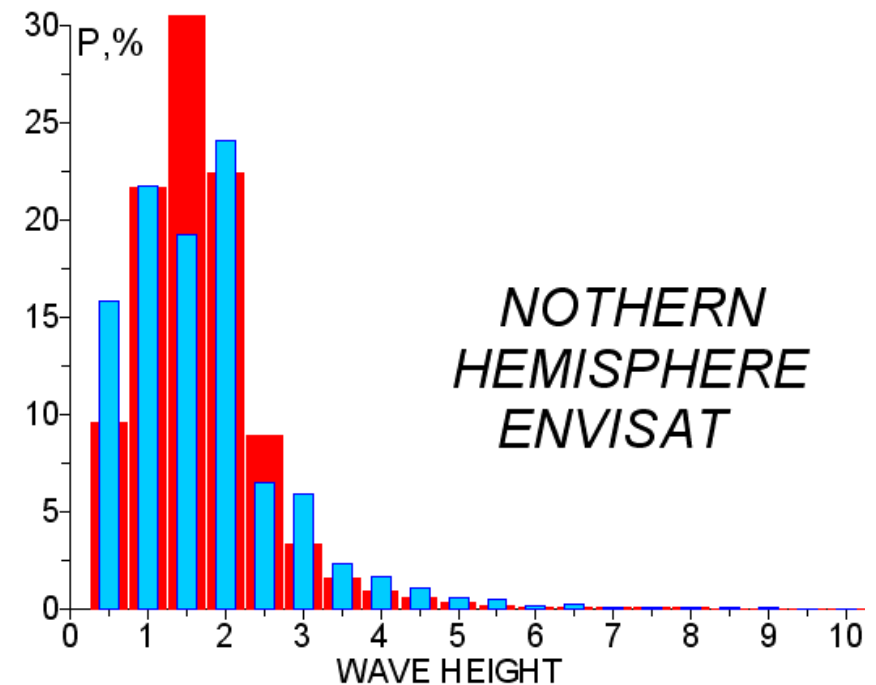
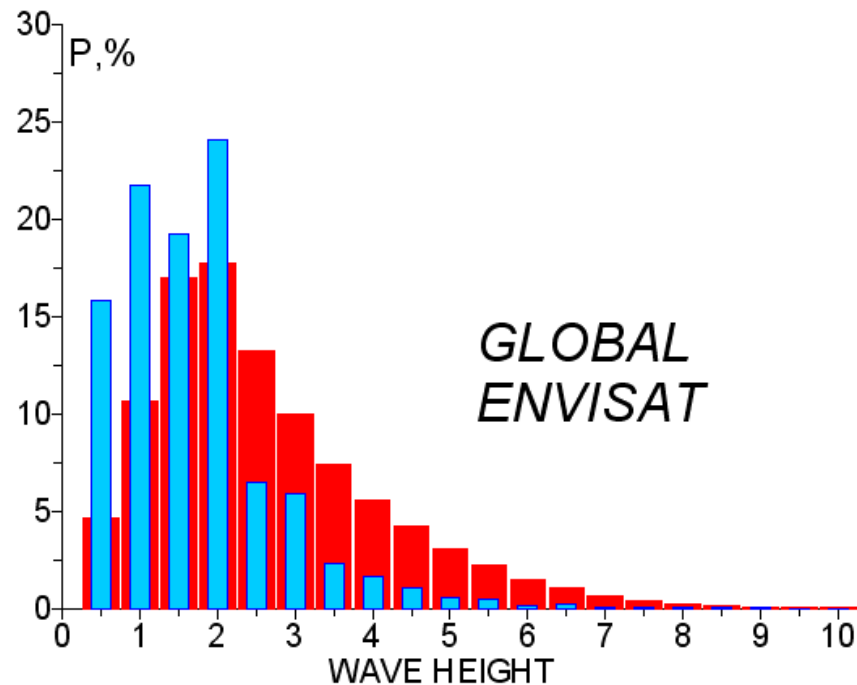
- Significant decrease of the number of observations in the Southern Hemisphere: from 20% to 5%
- 99% of all reported wave heights are smaller than 7.5 m
- Significant (~10%) decrease of the number of reported moderate waves during the last decade

And how it influences SHW distribution shape

RED – ENVISAT

BLUE – VOS

2005-2011 July



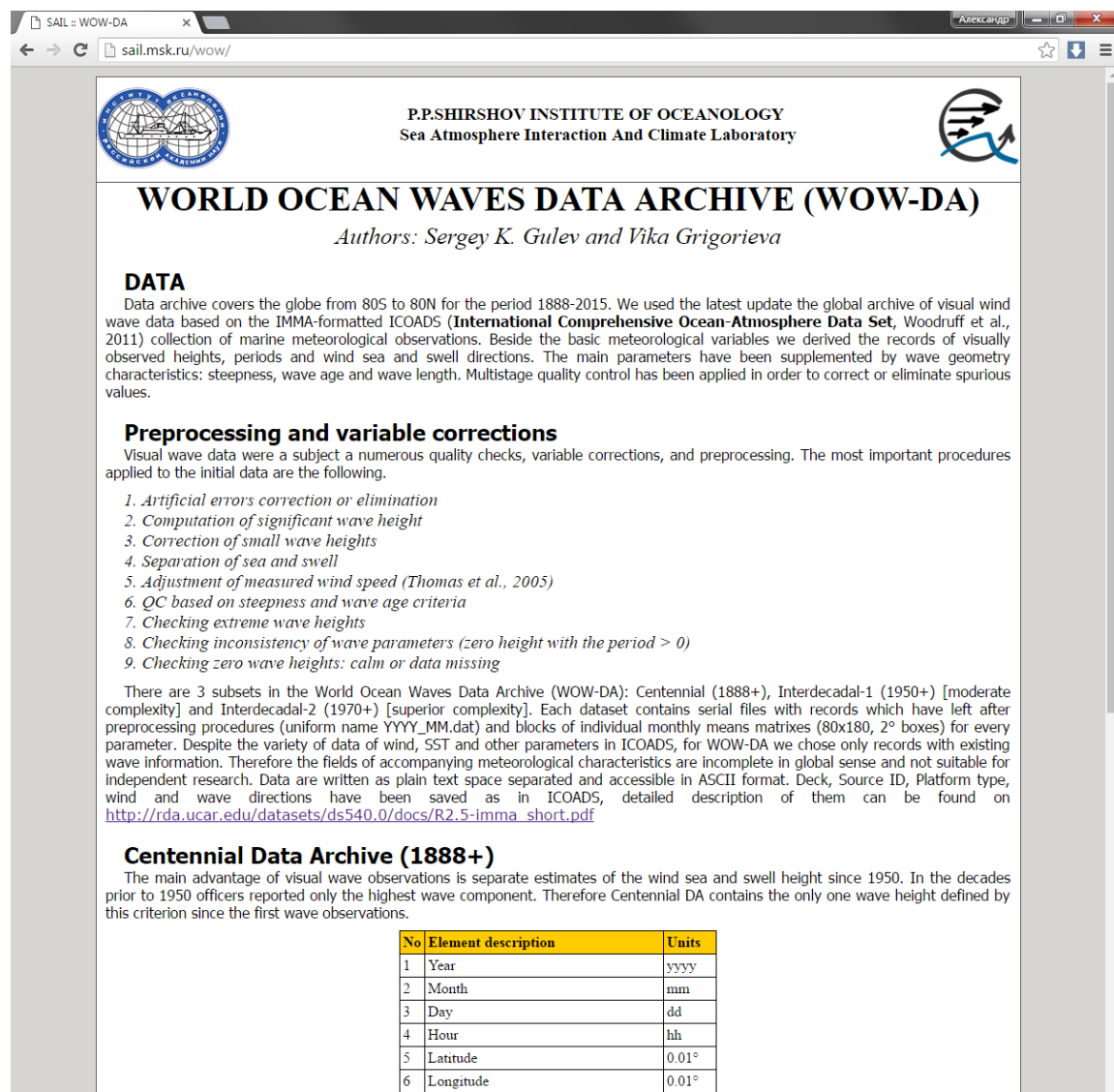
PDFs of SWH derived for the NH from Envisat are matching well the global PDFs from VOS

- ➡ World Ocean Waves (WOW) Digital Atlas
- ➡ Global wave climatology ($2^{\circ} \times 2^{\circ}$)
- ➡ Regional climatologies ($1^{\circ} \times 1^{\circ}$ or smaller)
- ➡ Long term changes
- ➡ Extreme waves
- ➡ Testing of wave theories
- ➡ Rogue waves
- ➡ Satellite and model verification
- ➡ Combined climatology

World Ocean Waves (WOW) from VOS data:

<http://www.sail.msk.ru/wow>

Easy access, easy use, multistage QC and continues data stream for all wave parameters



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WORLD OCEAN WAVES DATA ARCHIVE (WOW-DA)

Authors: Sergey K. Gulev and Vika Grigorieva

DATA

Data archive covers the globe from 80S to 80N for the period 1888-2015. We used the latest update the global archive of visual wind wave data based on the IMMA-formatted ICOADS (**I**nternational **C**omprehensive **O**cean-**A**tmosphere **D**ata **S**et, Woodruff et al., 2011) collection of marine meteorological observations. Beside the basic meteorological variables we derived the records of visually observed heights, periods and wind sea and swell directions. The main parameters have been supplemented by wave geometry characteristics: steepness, wave age and wave length. Multistage quality control has been applied in order to correct or eliminate spurious values.

Preprocessing and variable corrections

Visual wave data were a subject a numerous quality checks, variable corrections, and preprocessing. The most important procedures applied to the initial data are the following.

1. *Artificial errors correction or elimination*
2. *Computation of significant wave height*
3. *Correction of small wave heights*
4. *Separation of sea and swell*
5. *Adjustment of measured wind speed (Thomas et al., 2005)*
6. *QC based on steepness and wave age criteria*
7. *Checking extreme wave heights*
8. *Checking inconsistency of wave parameters (zero height with the period > 0)*
9. *Checking zero wave heights: calm or data missing*

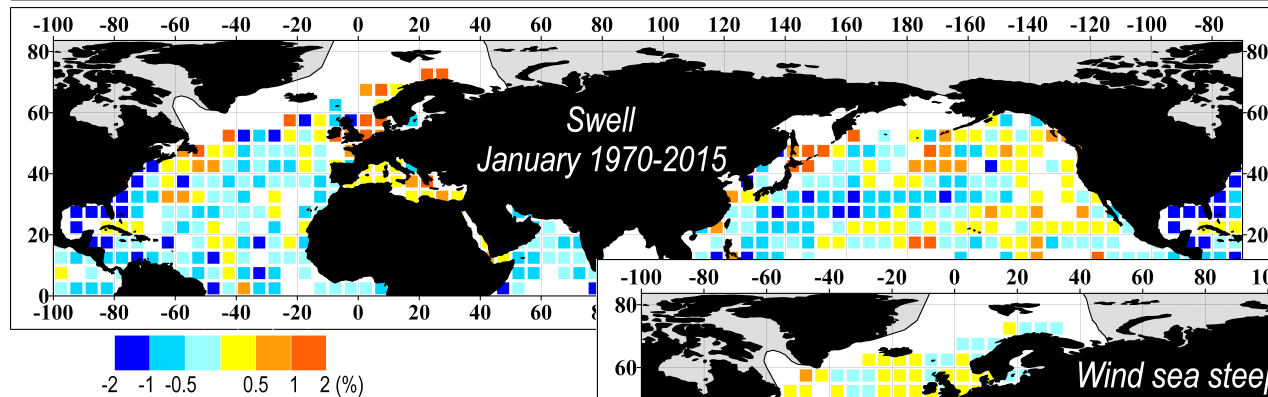
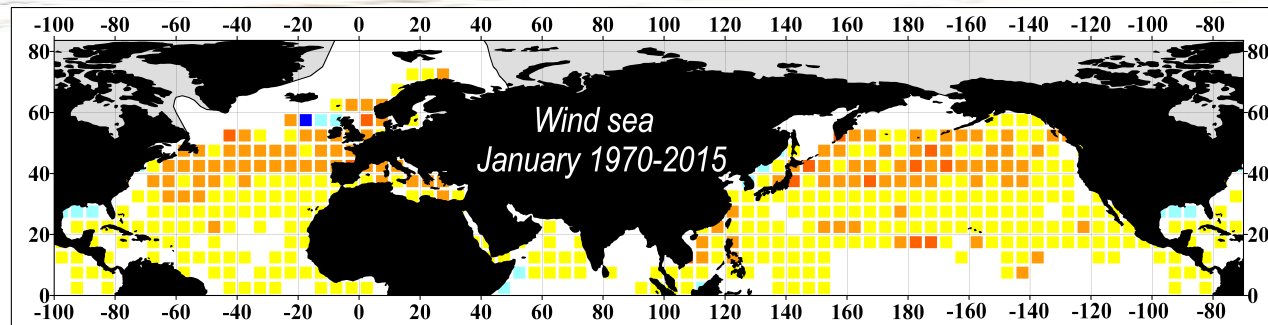
There are 3 subsets in the World Ocean Waves Data Archive (WOW-DA): Centennial (1888+), Interdecadal-1 (1950+) [moderate complexity] and Interdecadal-2 (1970+) [superior complexity]. Each dataset contains serial files with records which have left after preprocessing procedures (uniform name YYYY_MM.dat) and blocks of individual monthly means matrixes (80x180, 2° boxes) for every parameter. Despite the variety of data of wind, SST and other parameters in ICOADS, for WOW-DA we chose only records with existing wave information. Therefore the fields of accompanying meteorological characteristics are incomplete in global sense and not suitable for independent research. Data are written as plain text space separated and accessible in ASCII format. Deck, Source ID, Platform type, wind and wave directions have been saved as in ICOADS, detailed description of them can be found on http://rda.ucar.edu/datasets/ds540.0/docs/R2.5-imma_short.pdf

Centennial Data Archive (1888+)

The main advantage of visual wave observations is separate estimates of the wind sea and swell height since 1950. In the decades prior to 1950 officers reported only the highest wave component. Therefore Centennial DA contains the only one wave height defined by this criterion since the first wave observations.

No	Element description	Units
1	Year	yyyy
2	Month	mm
3	Day	dd
4	Hour	hh
5	Latitude	0.01°
6	Longitude	0.01°

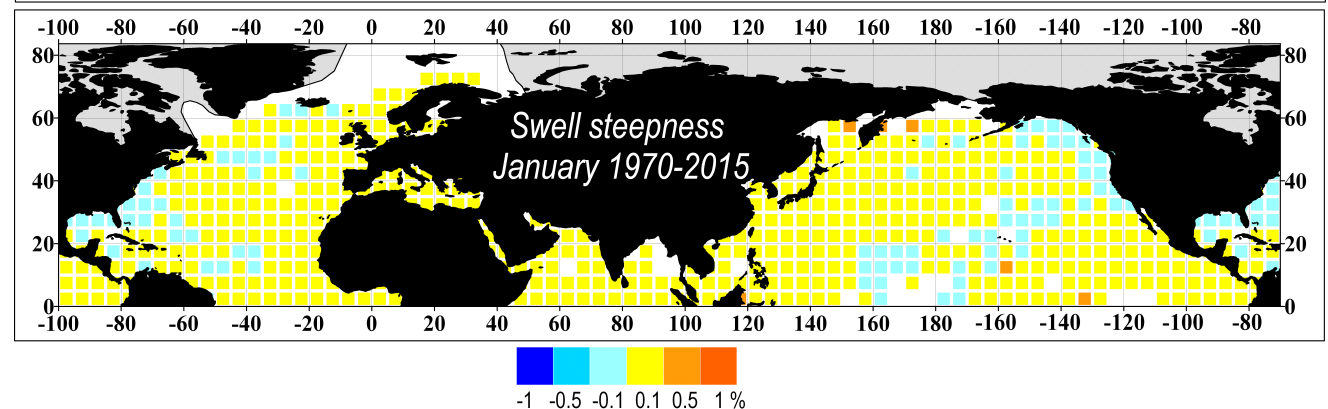
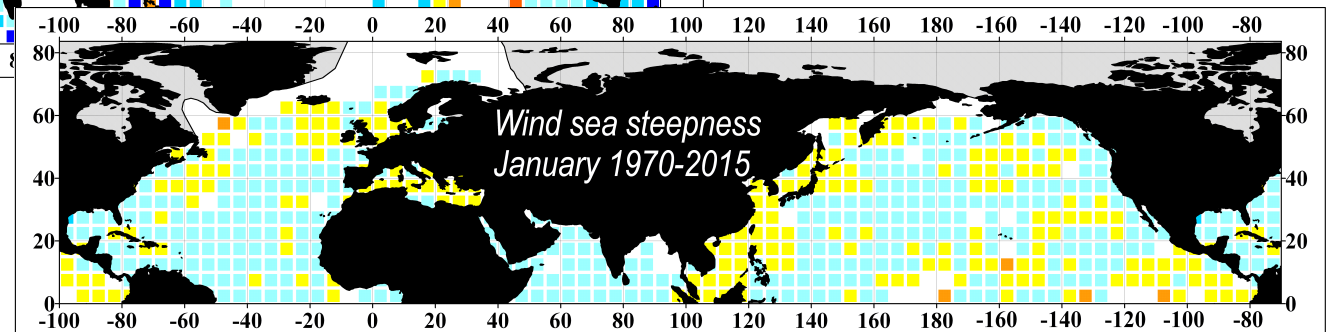
Long term trends



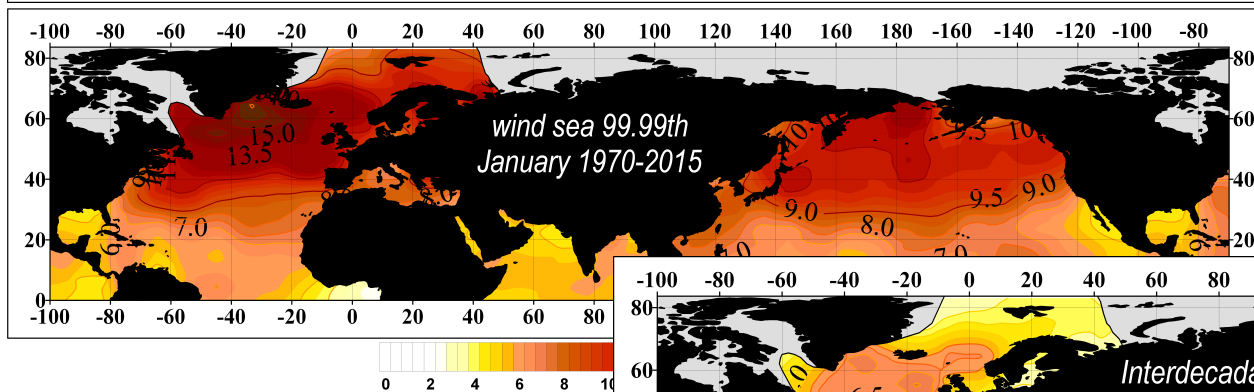
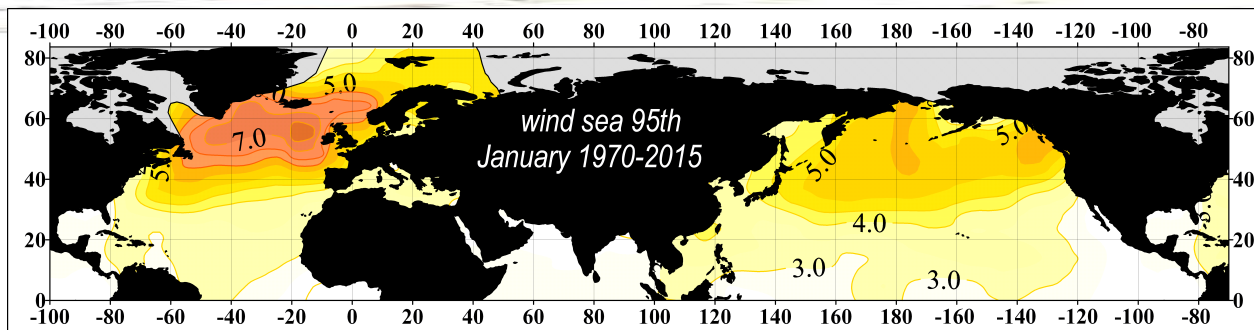
Wind sea are growing of about 0.1-0.4 cm/year in the Northern Hemisphere oceans but swell is slightly decreasing (-0.1-0.6 cm/year)

0.05 significance level
Student's t-test

Wind sea are becoming less steep and higher while swell is becoming steeper but lower

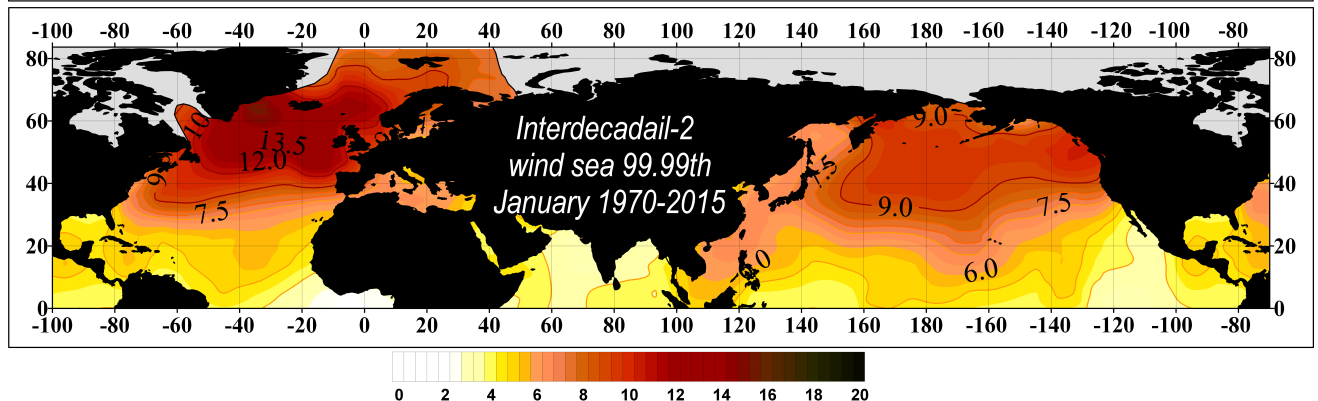
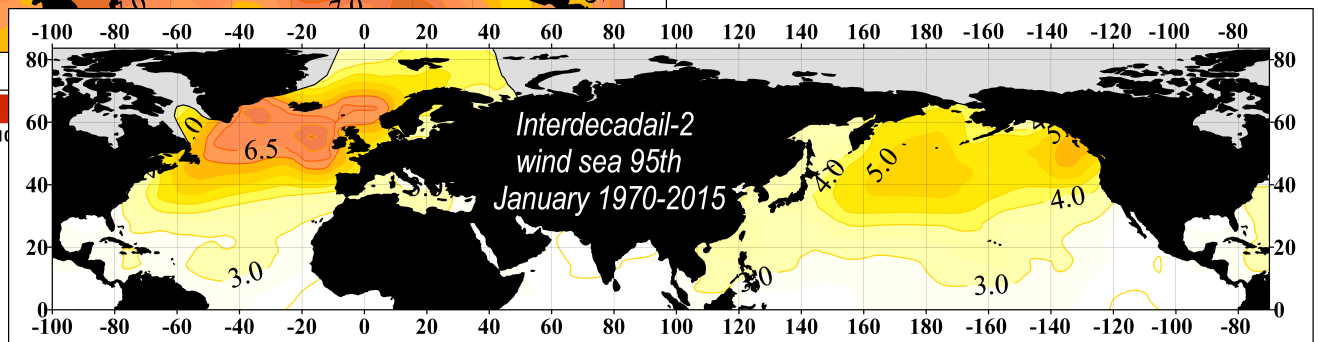


Extreme waves 1970-2015

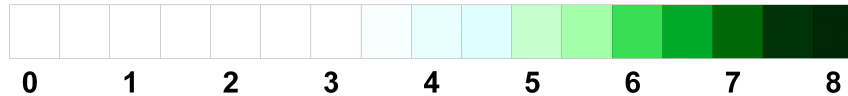
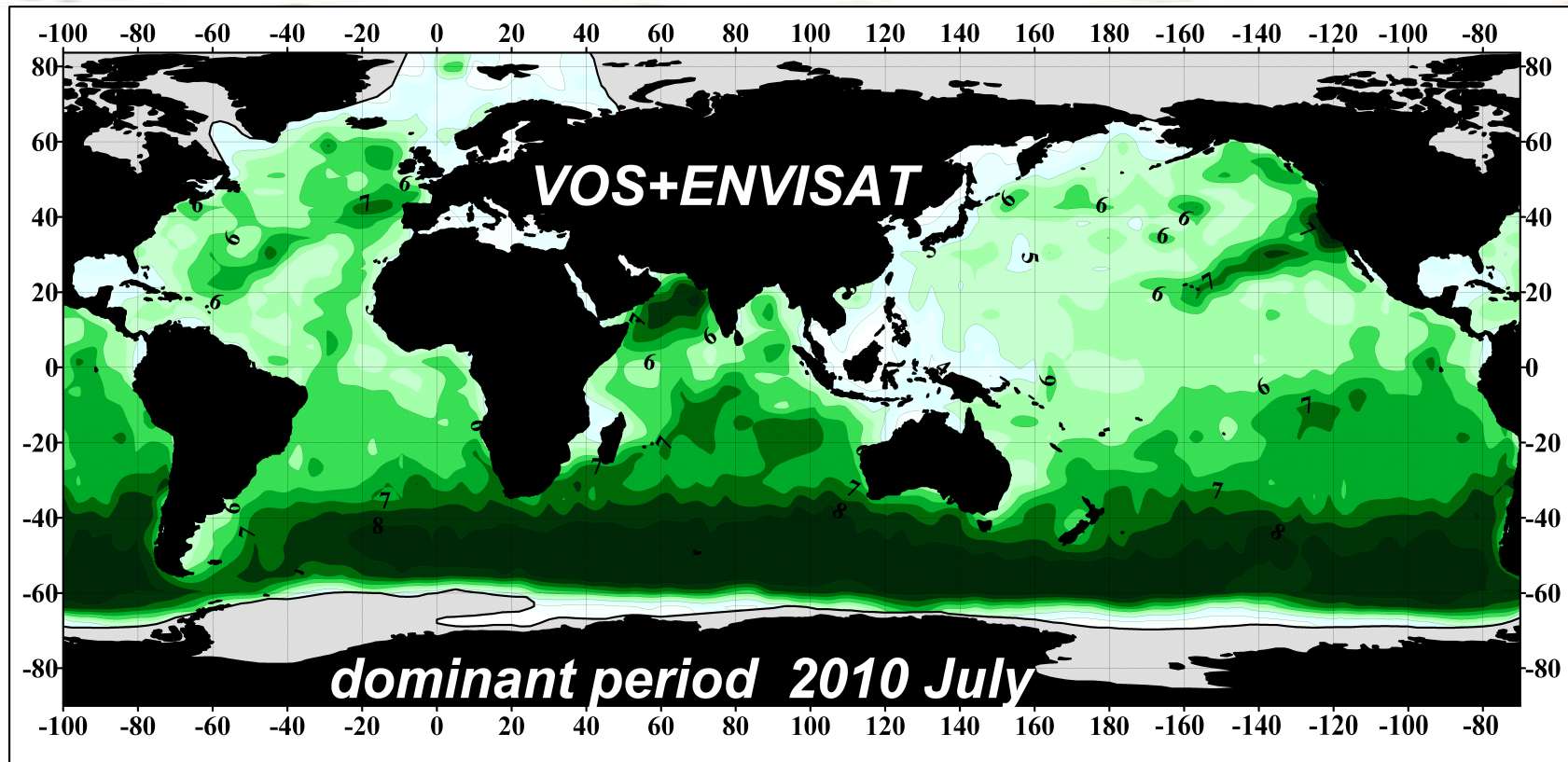


Raw data extremes

Interdecadal-2 extremes



VOS + ALTIMETRY climatology



$$T = \pi \sqrt{\frac{H_s}{\mu g}}$$

$$\mu \approx 0.596 \left| \nabla_p H_s \right|^{1/5}$$

$\nabla_p H_s$ – directional derivative

2° boxes

$$SWH_{VOS} + \mu_{alt} \rightarrow T$$

Conclusions

- Global Wind Wave Climatology and associated digital grids have been developed. Climatology includes all wave parameters as well as characteristics of wave geometry. 3 streams:
 - Centennial (1888+)
 - Interdecadal-1 (1950+)
 - Interdecadal-2 (1970+)
- Data access: <http://www.sail.msk.ru/WOW>
- Significant wave height demonstrates downward trends in the NH during the last 46 years (1970+) primarily due to changes in swell, wind sea height is growing over the same period
- Some potential of blending VOS data with satellite measurements for a proper representation of wave periods has been demonstrated

Special thanks

Steve Worley, NCAR

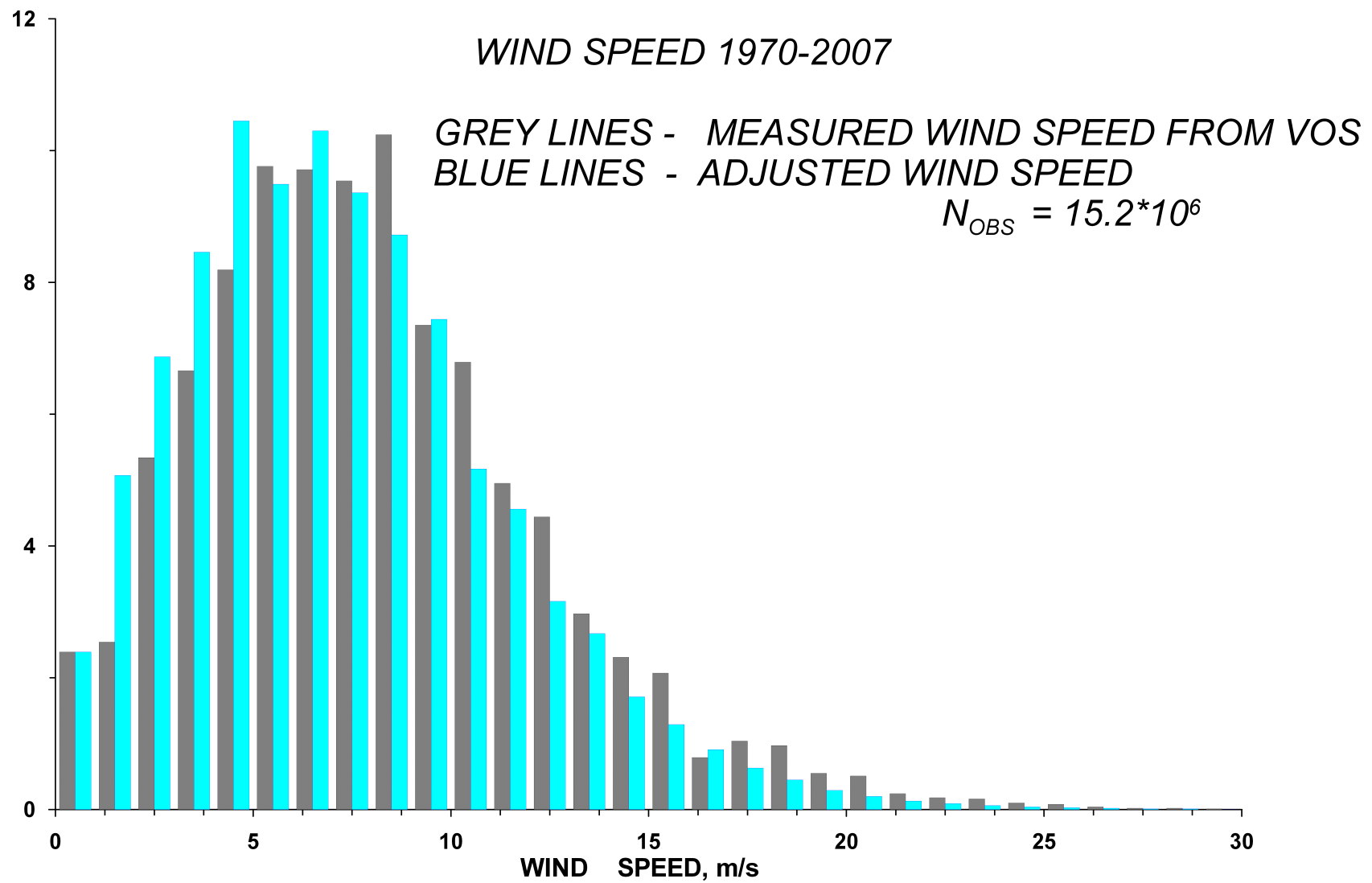
Scott Woodruff, NOAA

Eric Freeman, NOAA

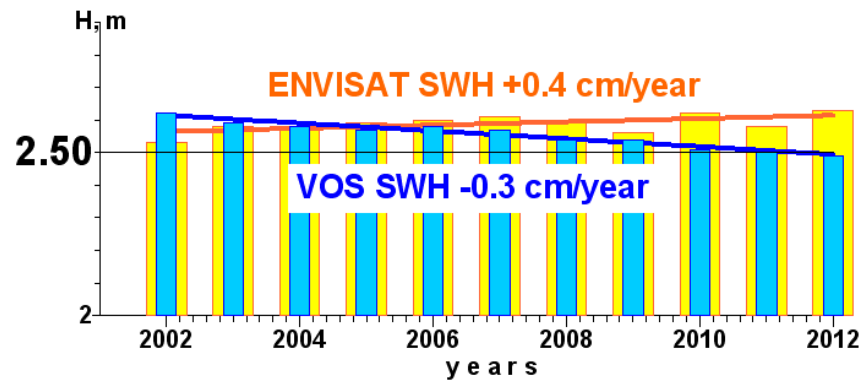
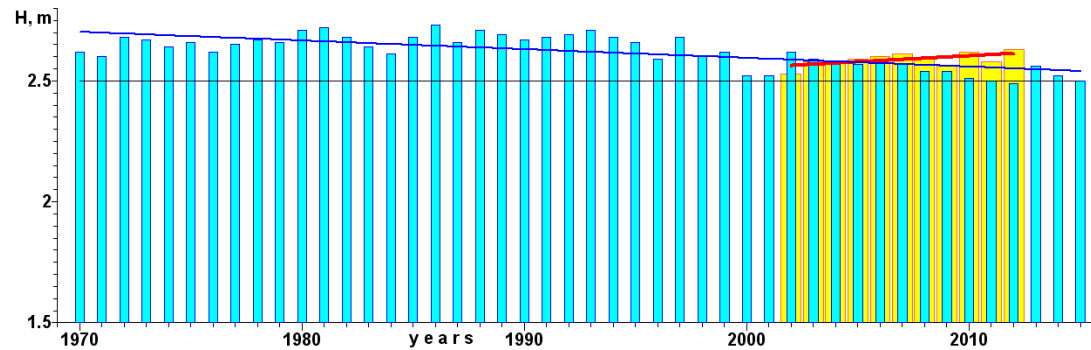
for many years of reliable feedback
in ICOADS data provision

Cabo da Roca

Wind



The average of human being

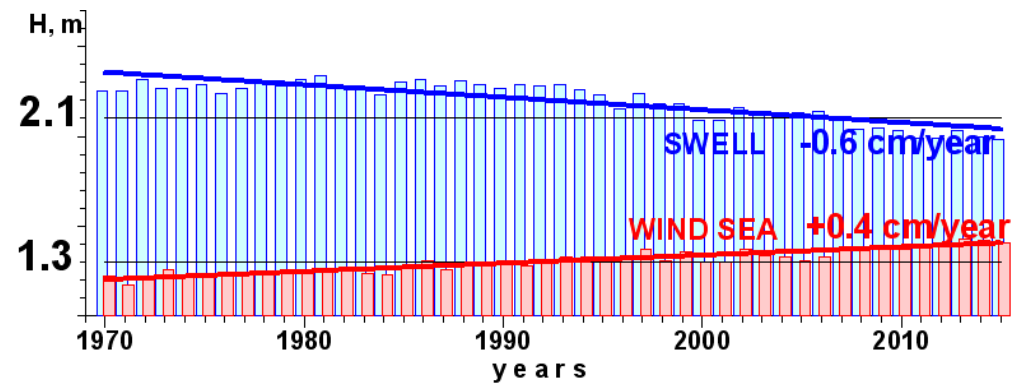


● Blue bars - VOS SWH

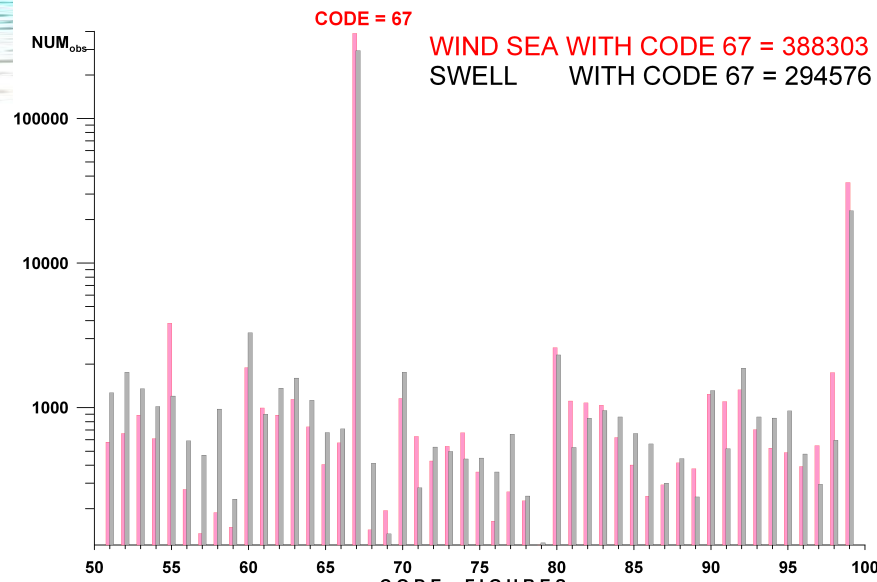
$$SWH1 = (\overline{h_w^2} + \overline{h_s^2})^{1/2}$$

● Yellow bars

SWH – Envisat 2002-2012



IMMA DATA 1900-2014



33.5

