



Estimation of climate variability of wind wave extremes from the VOS data: using model hindcasts for validation

Sergey Gulev and Vika Grigorieva

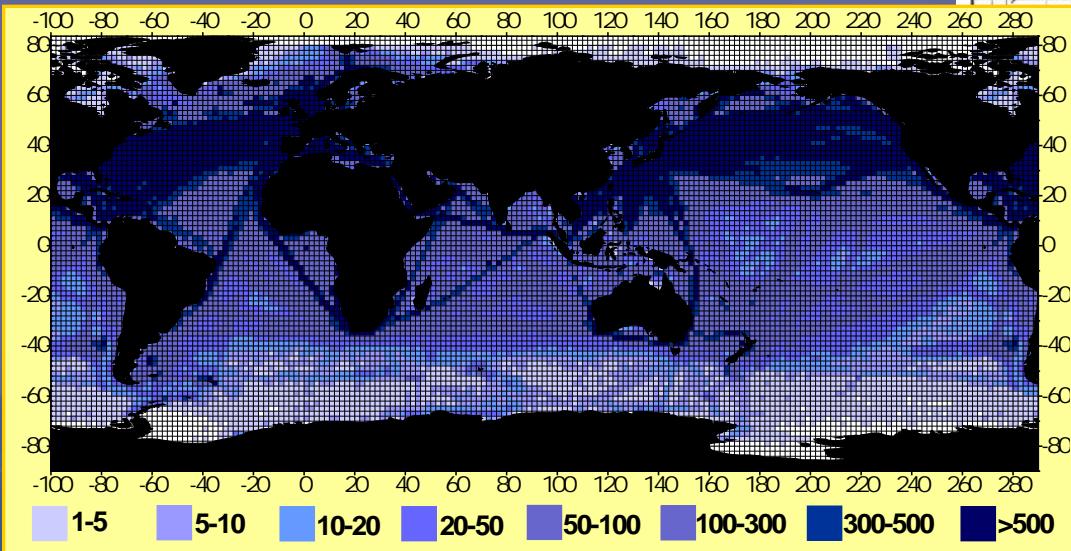
- Visual wind wave data from VOS: the longest homogeneous records of marine storminess
- Derivation of extreme waves from VOS: IVD (importance of removing of massively reported 24.5 (16) meter waves)
- EVD: Sub-sampling of WAM to derive parameter estimators for censored samples
- Using homogenized wave time series: changes in extreme wave height: Pacific vs Atlantic

Conclusions:

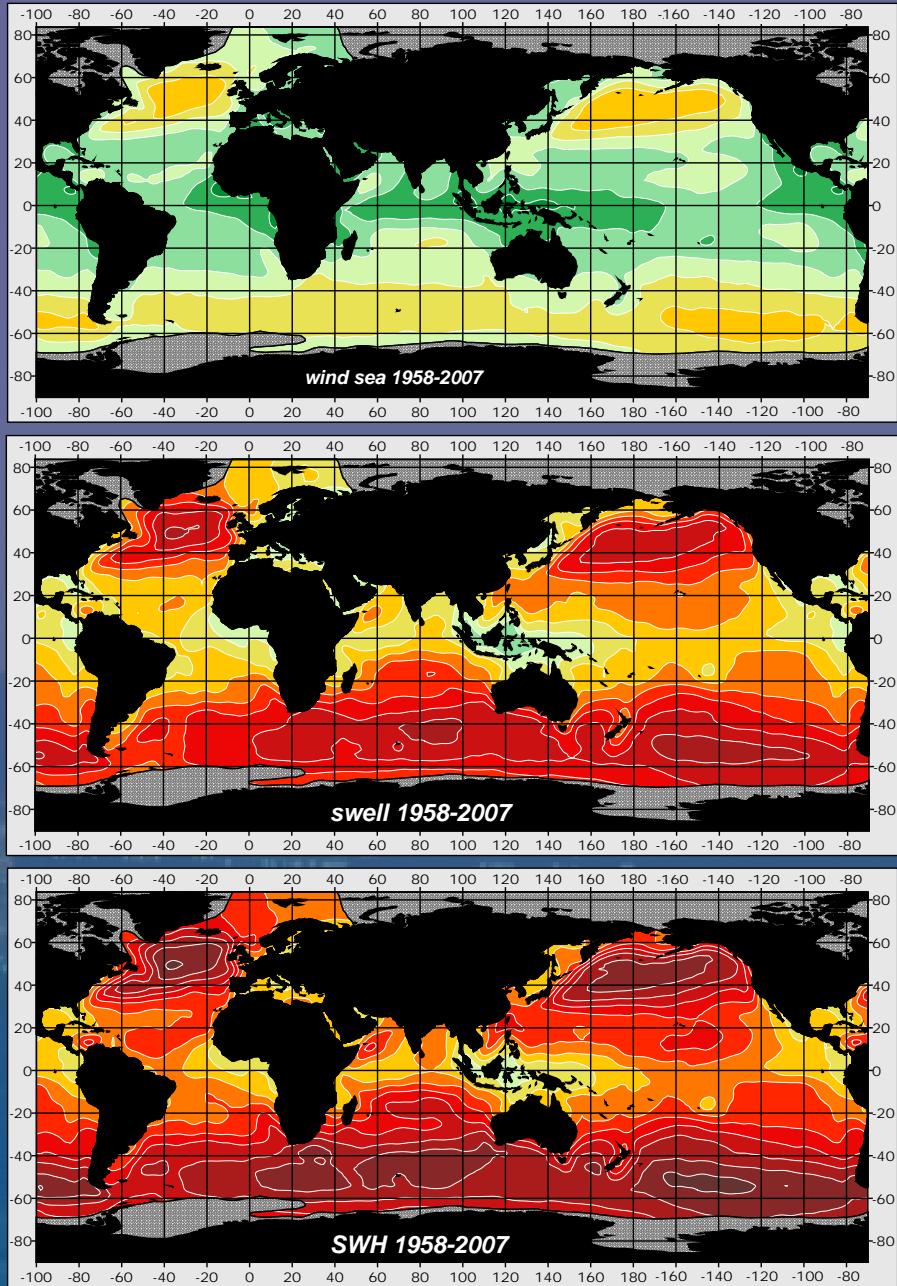
- Estimation of extreme waves from VOS can be influenced by the profound contribution of highest possible waves (need for accurate decoding)
- IVD and VOS: underestimation of extreme waves by about 25%
- EVD: Model hindcasts give a good prospect for merging the advances of VOS data and regular sampling in model waves – technique for estimation of EVD parameters from censored samples
- EVD give maxima 100-yr return value of SWH of 24-27 m in the Atlantic and 22-24 m in the Pacific (likely a bit high)
- Extreme waves revealed by VOS data show quite evident decadal variability. Decadal changes in the extreme SWH and wind sea are not correlated in the Atlantic and are closely correlated in the Pacific

Visual wave observations: 1856 - onwards

2 streams of data:
 (1856-1958) and (1958-2005)



Abstract Log of Ship Endurance Captain William Doane									
DATE	TIME	WAVE	SWELL	WIND	SEA STATE	WAVE	SWELL	WIND	SEA STATE
1856	1856					West	2		
1856	1856					W.N.W.	3		
1856	1856					W.E.	4		
1856	1856					W.S.W.	5		
1856	1856					W.S.E.	6		
1856	1856					W.E.	7		
1856	1856					W.N.W.	8		
1856	1856					W.S.W.	9		
1856	1856					W.S.E.	10		
1856	1856					W.E.	11		
1856	1856					W.N.W.	12		
1856	1856					W.S.W.	13		
1856	1856					W.S.E.	14		
1856	1856					W.E.	15		
1856	1856					W.N.W.	16		
1856	1856					W.S.W.	17		
1856	1856					W.S.E.	18		
1856	1856					W.E.	19		
1856	1856					W.N.W.	20		
1856	1856					W.S.W.	21		
1856	1856					W.S.E.	22		
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1856	1856					W.S.E.	26		
1856	1856					W.E.	27		
1856	1856					W.N.W.	28		
1856	1856					W.S.W.	29		
1856	1856					W.S.E.	30		
1856	1856					W.E.	31		
1856	1856					W.N.W.	32		
1856	1856					W.S.W.	33		
1856	1856					W.S.E.	34		
1856	1856					W.E.	35		
1856	1856					W.N.W.	36		
1856	1856					W.S.W.	37		
1856	1856					W.S.E.	38		
1856	1856					W.E.	39		
1856	1856					W.N.W.	40		
1856	1856					W.S.W.	41		
1856	1856					W.S.E.	42		
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1856	1856					W.S.W.	45		
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1856	1856					W.E.	47		
1856	1856					W.N.W.	48		
1856	1856					W.S.W.	49		
1856	1856					W.S.E.	50		
1856	1856					W.E.	51		
1856	1856					W.N.W.	52		
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1856	1856					W.E.	55		
1856	1856					W.N.W.	56		
1856	1856					W.S.W.	57		
1856	1856					W.S.E.	58		
1856	1856					W.E.	59		
1856	1856					W.N.W.	60		
1856	1856					W.S.W.	61		
1856	1856					W.S.E.	62		
1856	1856					W.E.	63		
1856	1856					W.N.W.	64		
1856	1856					W.S.W.	65		
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1856	1856					W.N.W.	92		
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1856	1856					W.E.	95		
1856	1856					W.N.W.	96		
1856	1856					W.S.W.	97		
1856	1856					W.S.E.	98		
1856	1856					W.E.	99		
1856	1856					W.N.W.	100		
1856	1856					W.S.W.	101		
1856	1856					W.S.E.	102		
1856	1856					W.E.	103		
1856	1856					W.N.W.	104		
1856	1856					W.S.W.	105		
1856	1856					W.S.E.	106		
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1856	1856					W.S.W.	145		
1856	1856					W.S.E.	146		
1856	1856					W.E.	147		
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1856	1856					W.S.W.	149		
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1856	1856					W.N.W.	152		
1856	1856					W.S.W.	153		
1856	1856					W.S.E.	154		
1856	1856					W.E.	155		
1856	1856					W.N.W.	156		
1856	1856					W.S.W.	157		
1856	1856					W.S.E.	158		
1856	1856					W.E.	159		
1856	1856					W.N.W.	160		
1856	1856					W.S.W.	161		
1856	1856					W.S.E.	162		
1856	1856					W.E.	163		
1856	1856					W.N.W.	164		
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1856	1856					W.E.	191		
1856	1856					W.N.W.	192		
1856	1856		</td						



1958-2007 climatology:

- small waves
- separation
- sea/swell
- SWH
- true wave direction
- day/night estimates

Estimation of wave extremes from VOS

1. Taking a maximum:

problem of the code figures 9 (12 m or 16 m) (before 1963) and 49 (24.5 meters) after 1963:

- (i) the maximum is prescribed, (ii) it is finite, (iii) it is too frequently observed (up to 0.15% of all reports)

Coding systems:

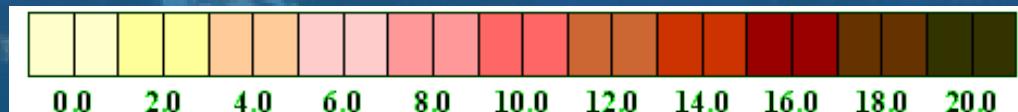
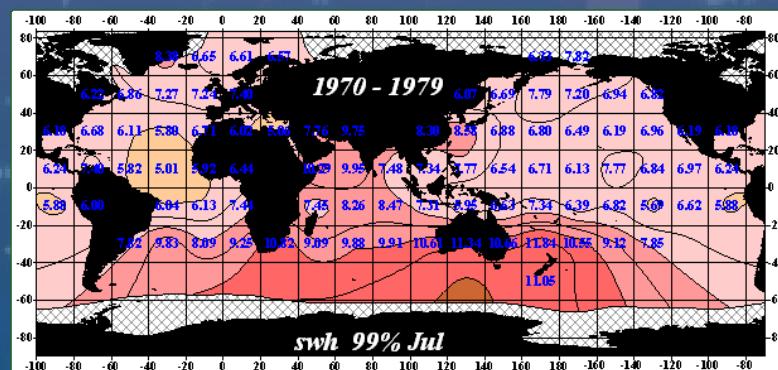
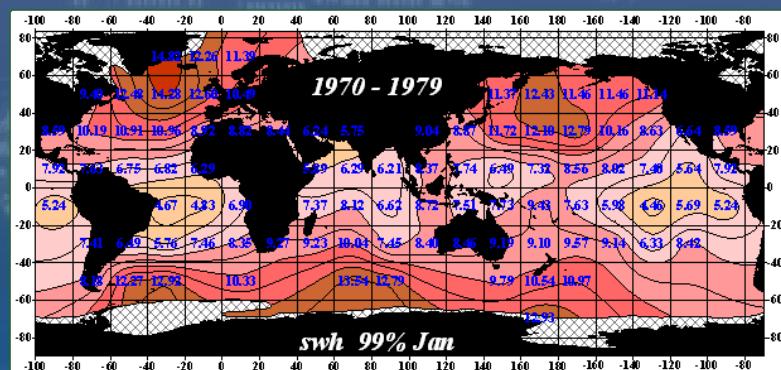
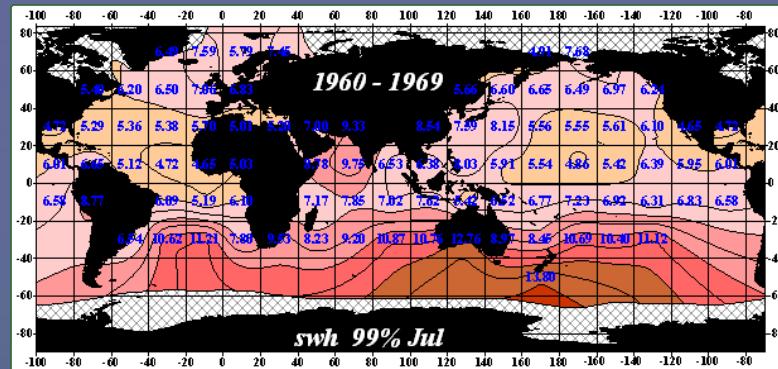
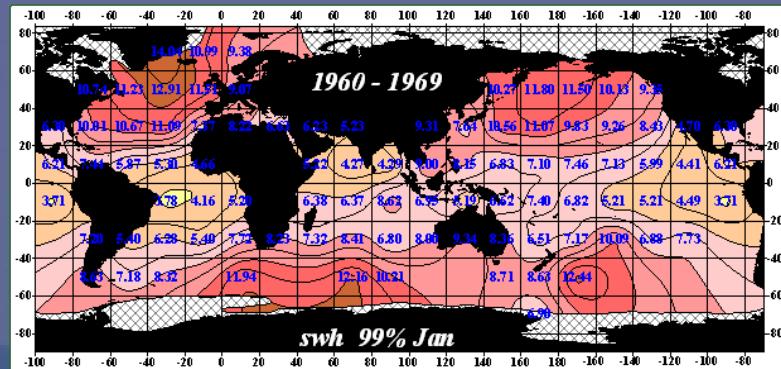
1904 (Hydrographic Office No. 1190), 1906, and 1908
(US Weather Bureau "Circular M, 2nd edition") -
descriptive

The Original Reference Manual of 1917 - 0-9 scale in feet
1925 US instructions (Circular M, 4th edition): a 0-9 scale is
used

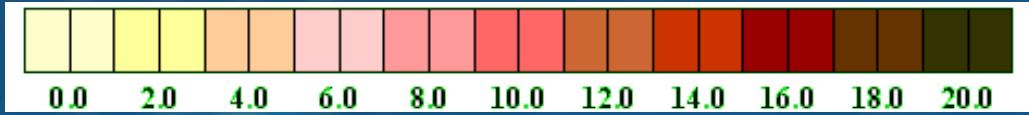
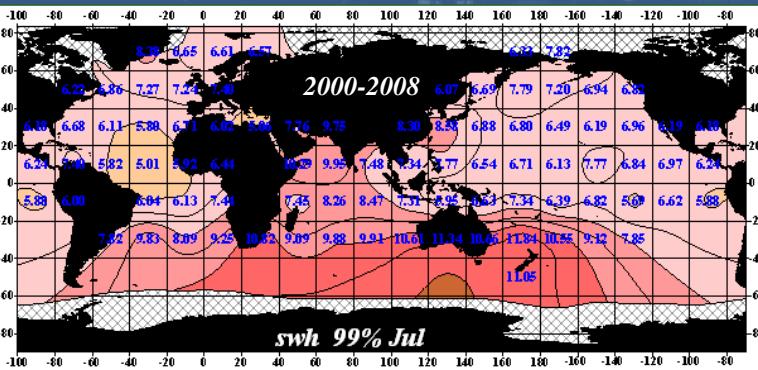
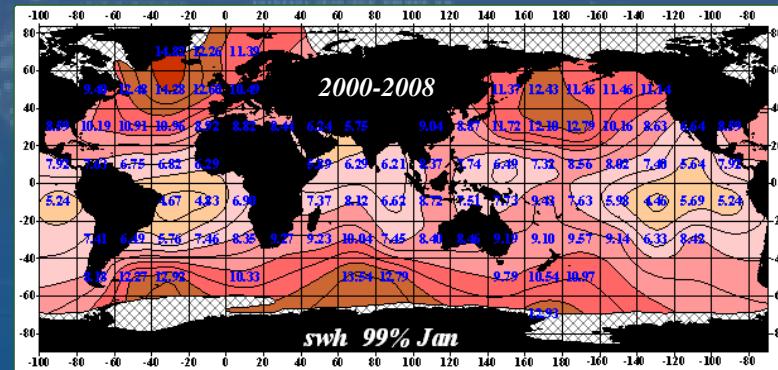
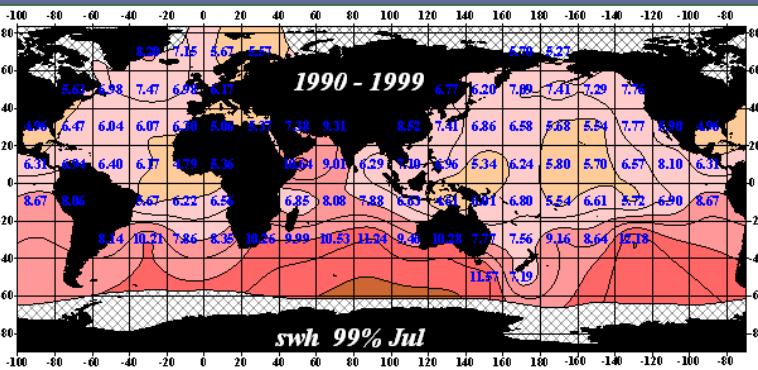
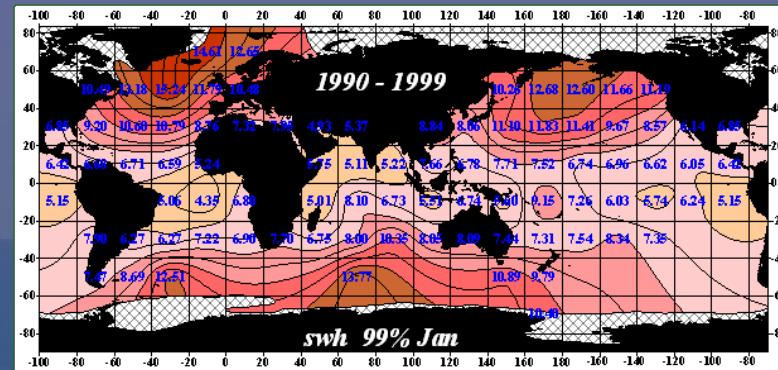
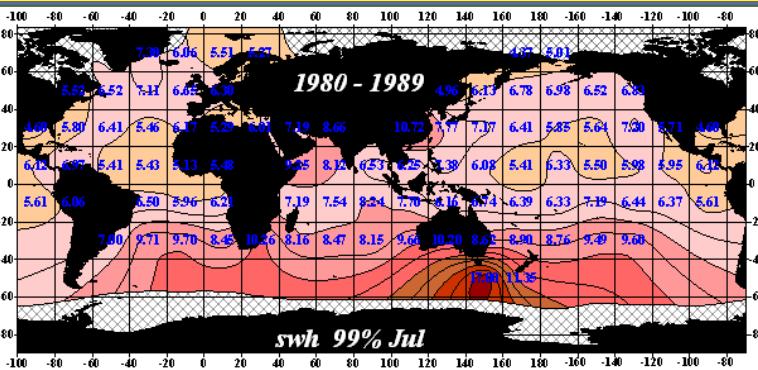
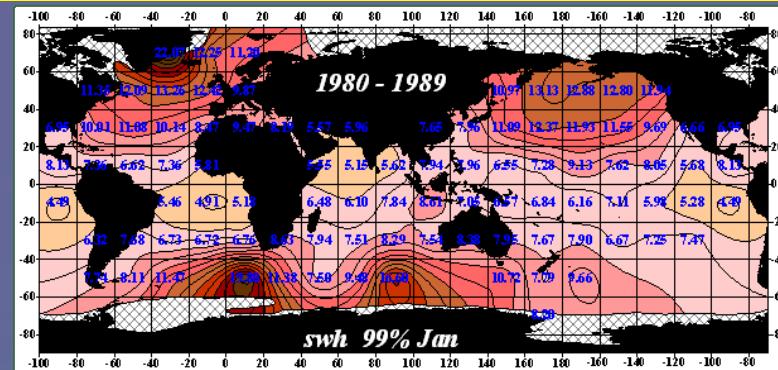
1963 WMO Manual on codes: 1-49 (0.5 meter increments)

Estimation of wave extremes from VOS

2. Excluding all code figures “49” and apply initial value distribution method

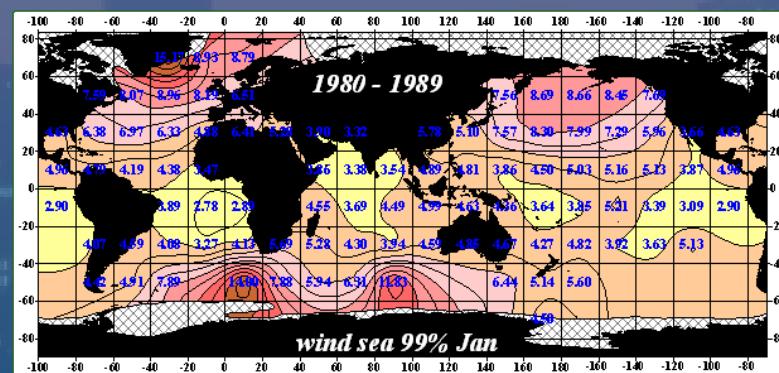
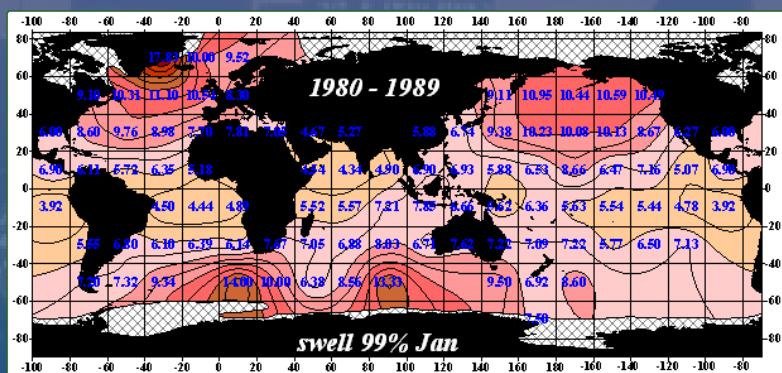
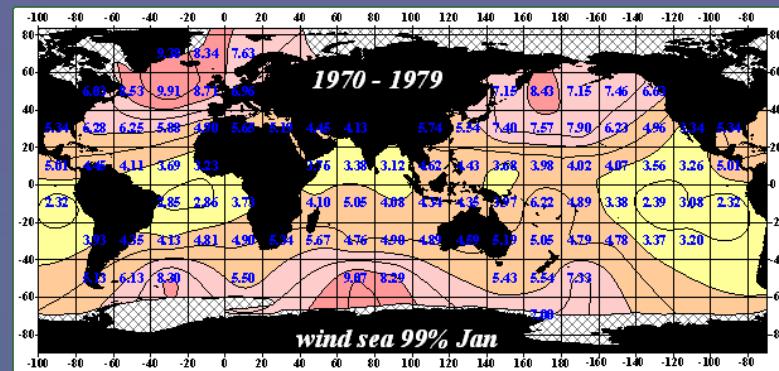
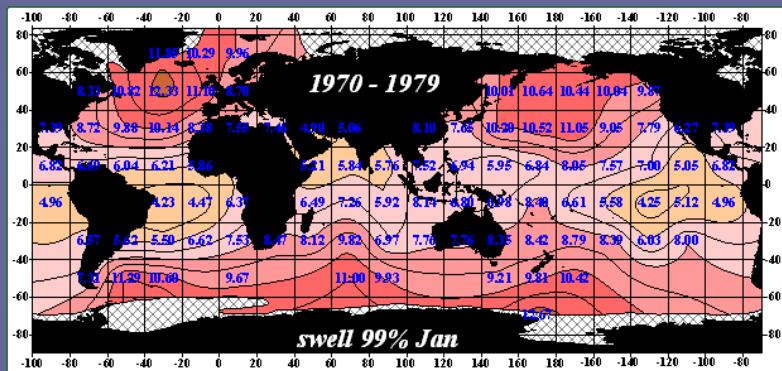


Estimation of wave extremes from VOS: IVDM

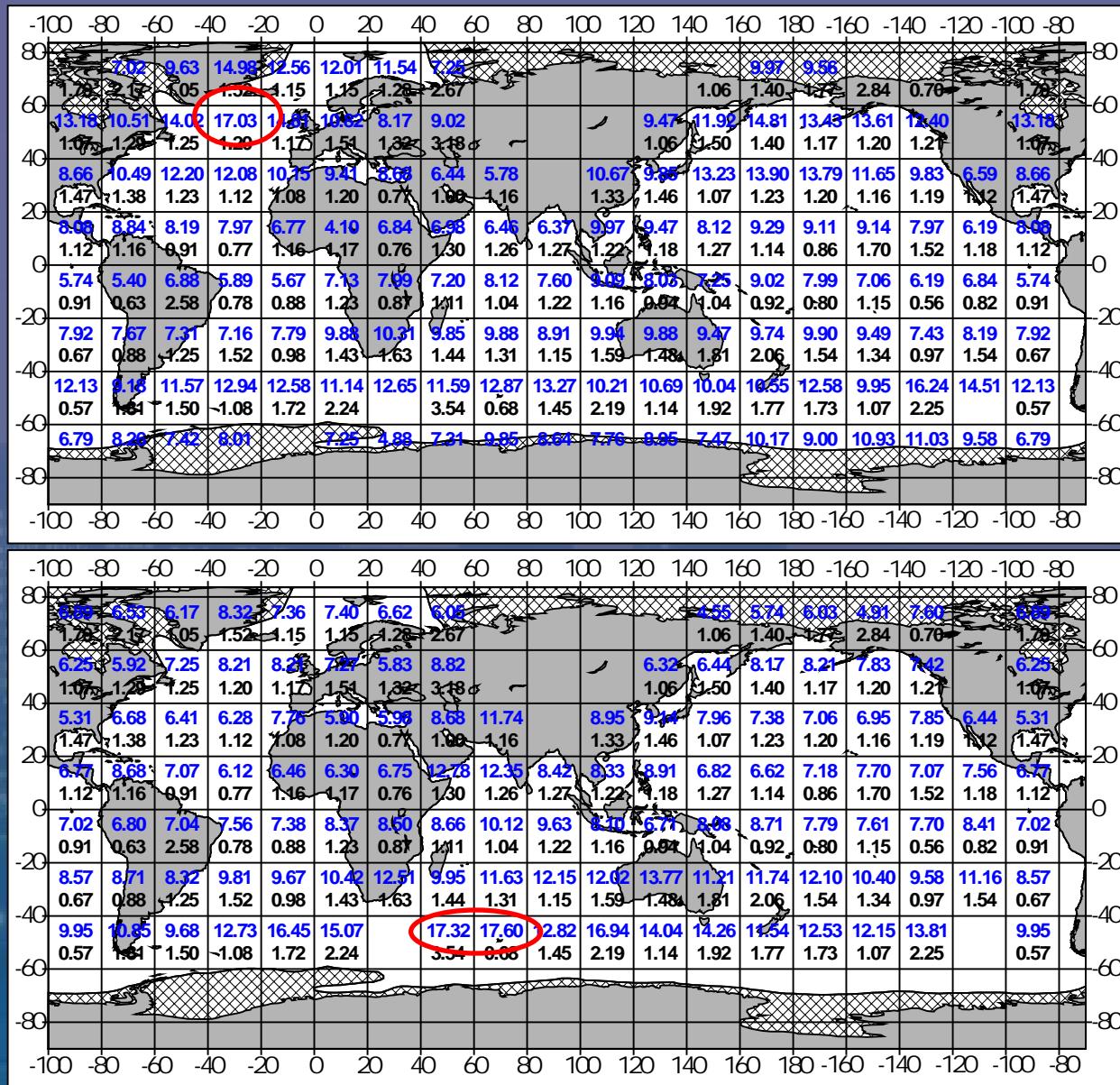


Estimation of wave extremes from VOS:

IVD – sea and swell extremes



VOS 100-yr returns: IVDM



VOS data and POT: problems of application

VOS data may not necessarily report the highest exceedances =>

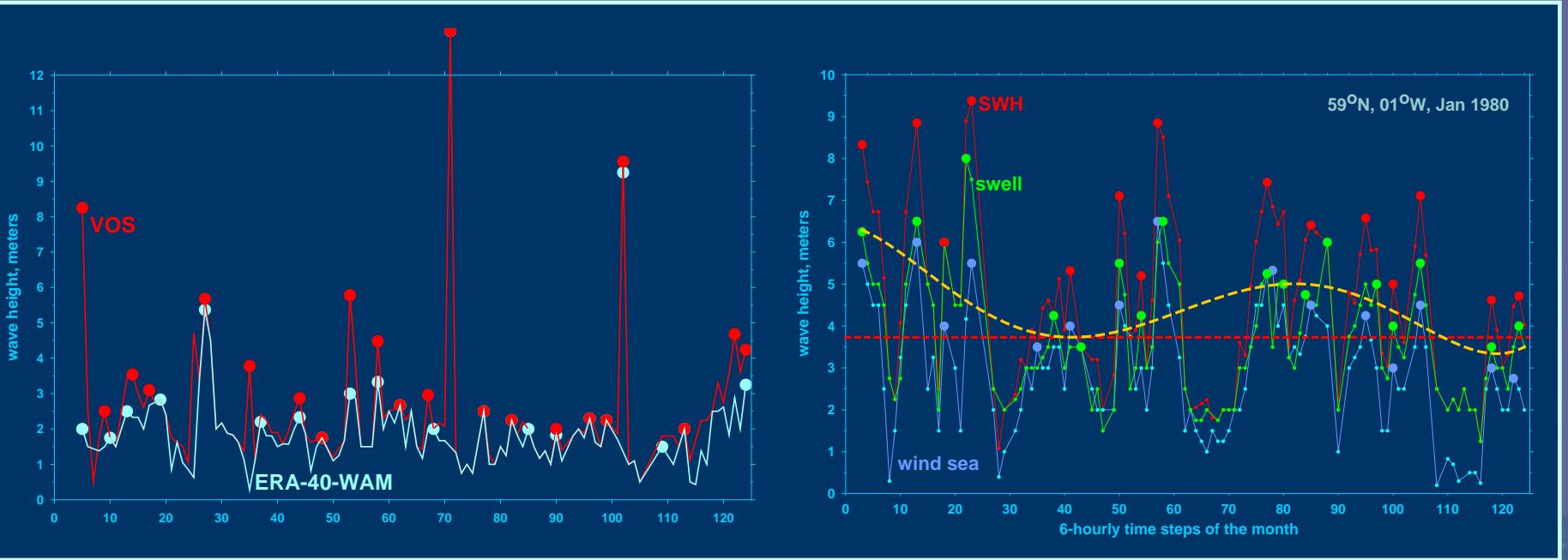
but the distribution of any exceedance = probability of the largest

VOS data are influenced by sampling uncertainty =>

Undersampling results potentially in underestimation of extremes



- Use WAM hindcast (1958-2002) to simulate VOS sampling density
- Estimate EVD from the original and sub-sampled WAM
- Build up the transfer function for EVD based on full sample
- Define threshold using storm durations estimates and moving 40-day period
- different EVDs are fitted to the storm peak values (medians of them if several reports are available for 2-degree cell)



EVD: $P(x) = -(\alpha \cdot \beta) \cdot \exp(\beta x) \cdot \exp[-\alpha \cdot \exp(\beta x)], \quad \alpha > 0, \beta < 0$

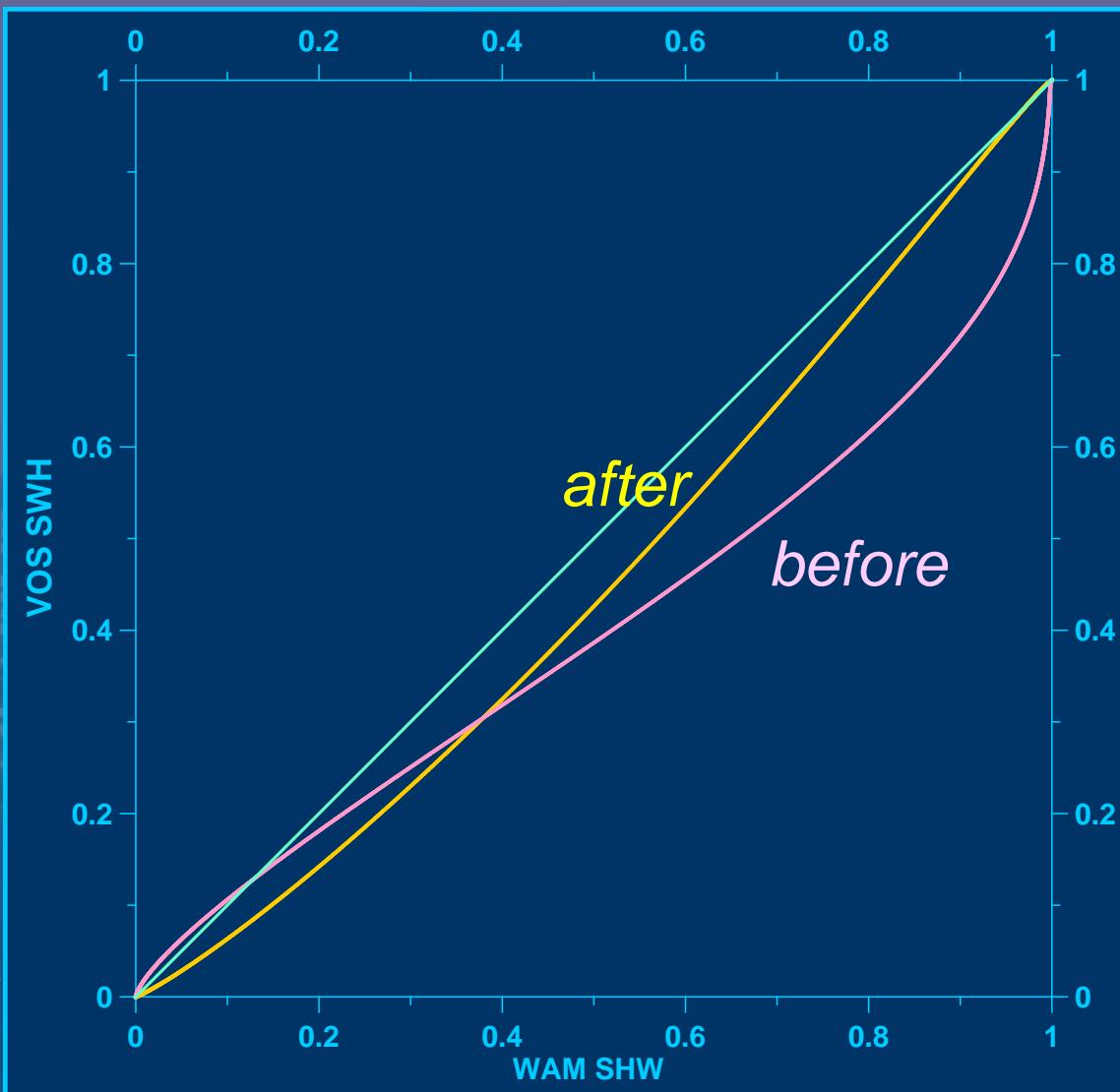
$$\frac{n}{\beta} + \sum_{i=1}^n x_i - n \sqrt[n]{\sum_{i=1}^n e^{\beta x_i}} \cdot \sum_{i=1}^n x_i e^{\beta x_i} = 0; \quad \alpha = n \sqrt[n]{\sum_{i=1}^n e^{\beta x_i}}$$

full sample

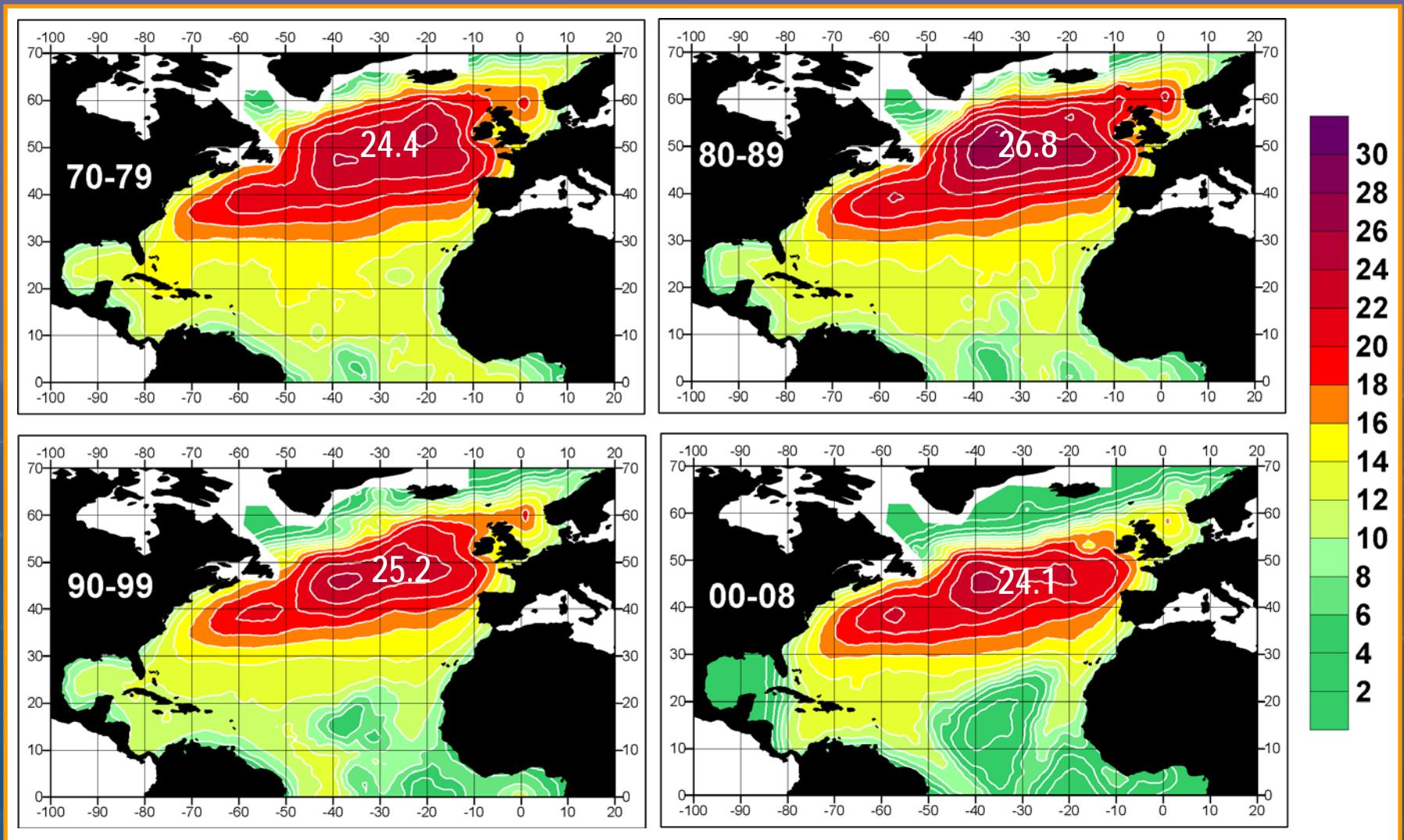
$$\frac{n}{\alpha} = n_1 + \sum_{i=n_1+1}^n \exp(-\beta x_i), \quad -\frac{n}{\beta} - \frac{n_1}{\beta} (C + \ln \alpha) + \sum_{i=1}^n x_i = \frac{2}{\alpha^2 \beta} \left(\frac{3}{2} - C - \ln \alpha \right) + \sum_{i=n_1+1}^n x_i \exp(-\beta x_i)$$

censored sample

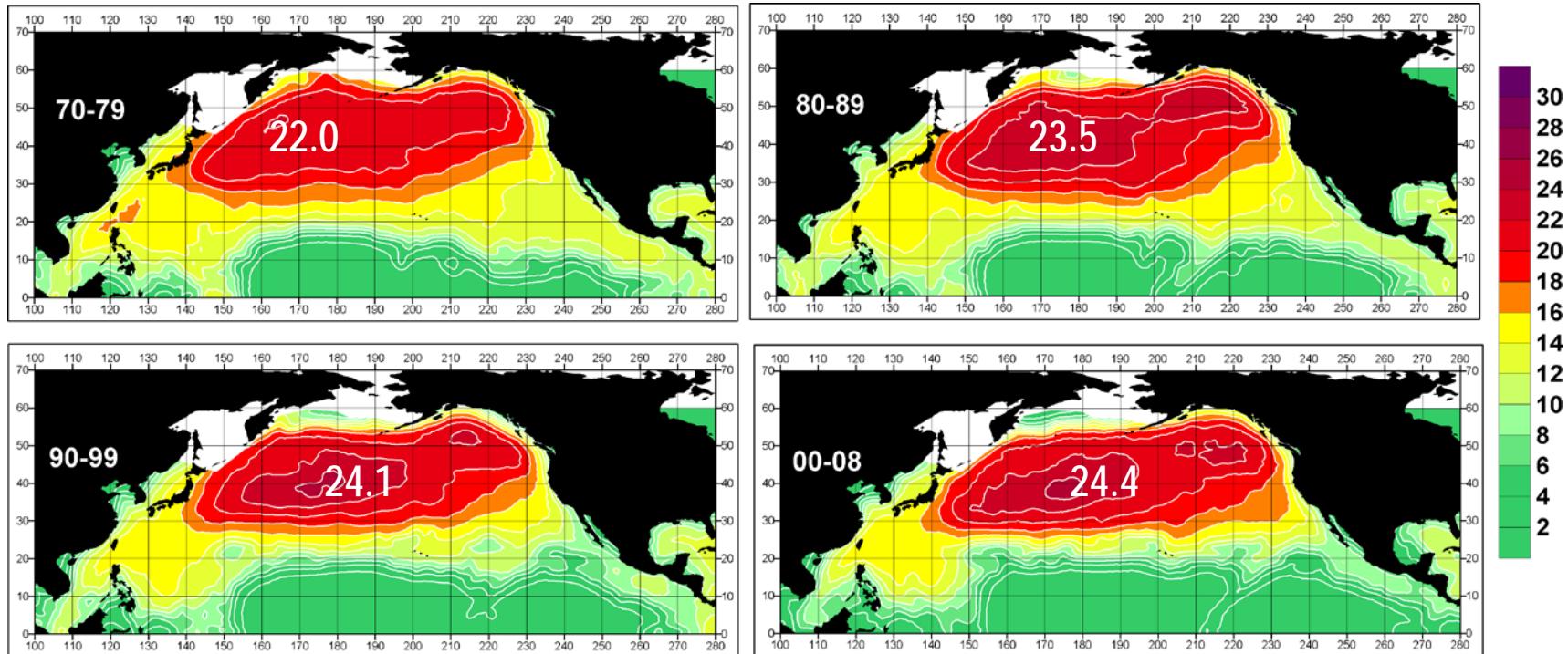
VOS vs WAM hindcast: how the inconsistencies were improved by courtesy of the adaptation of EVD to the censored sample



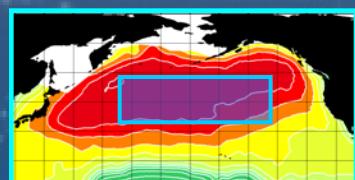
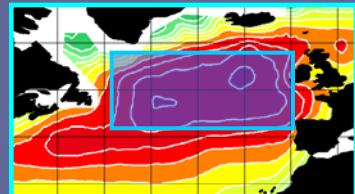
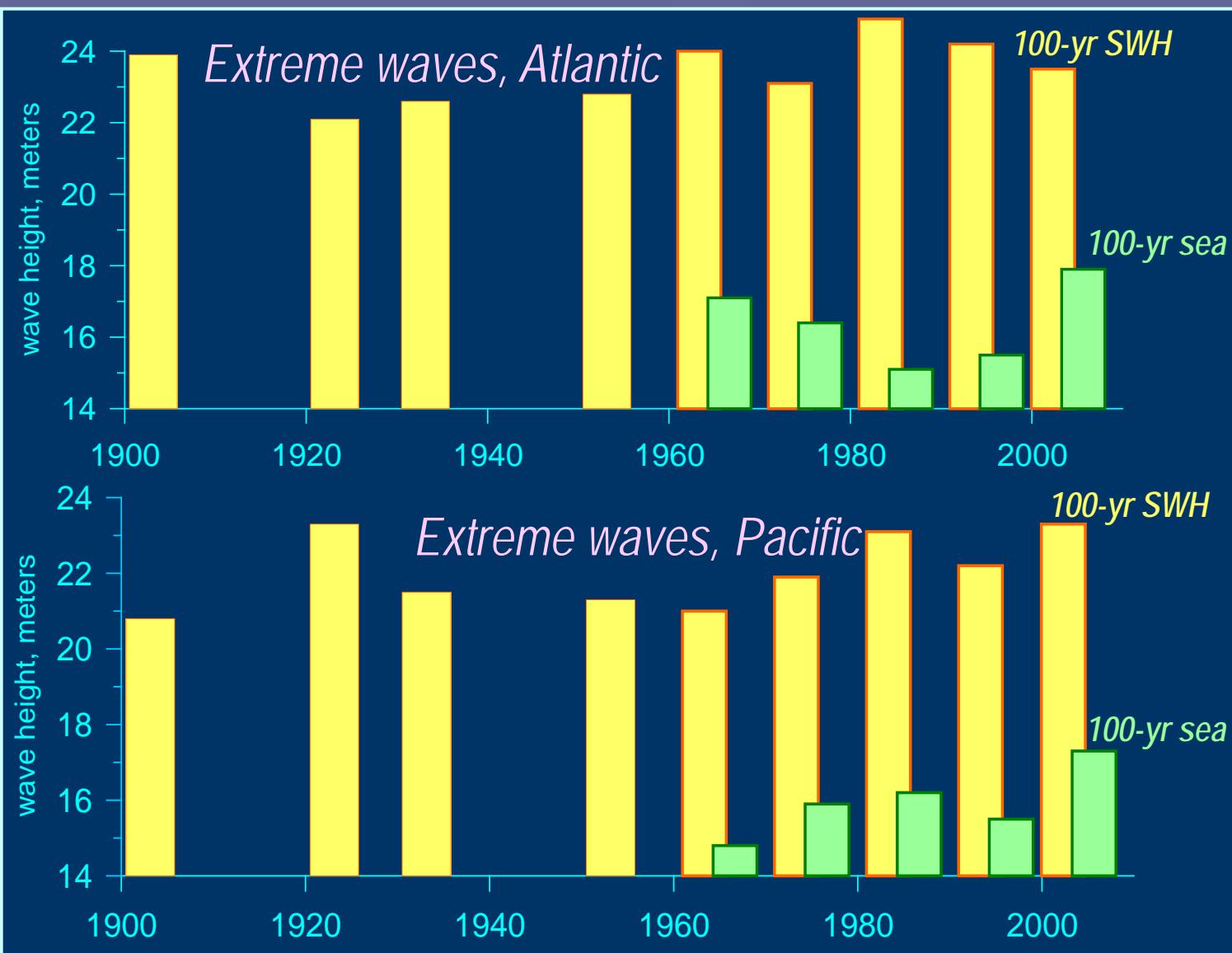
100-year return SWH for different decades



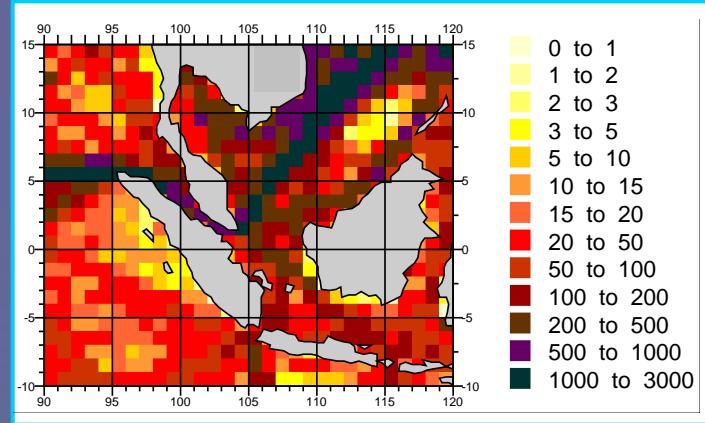
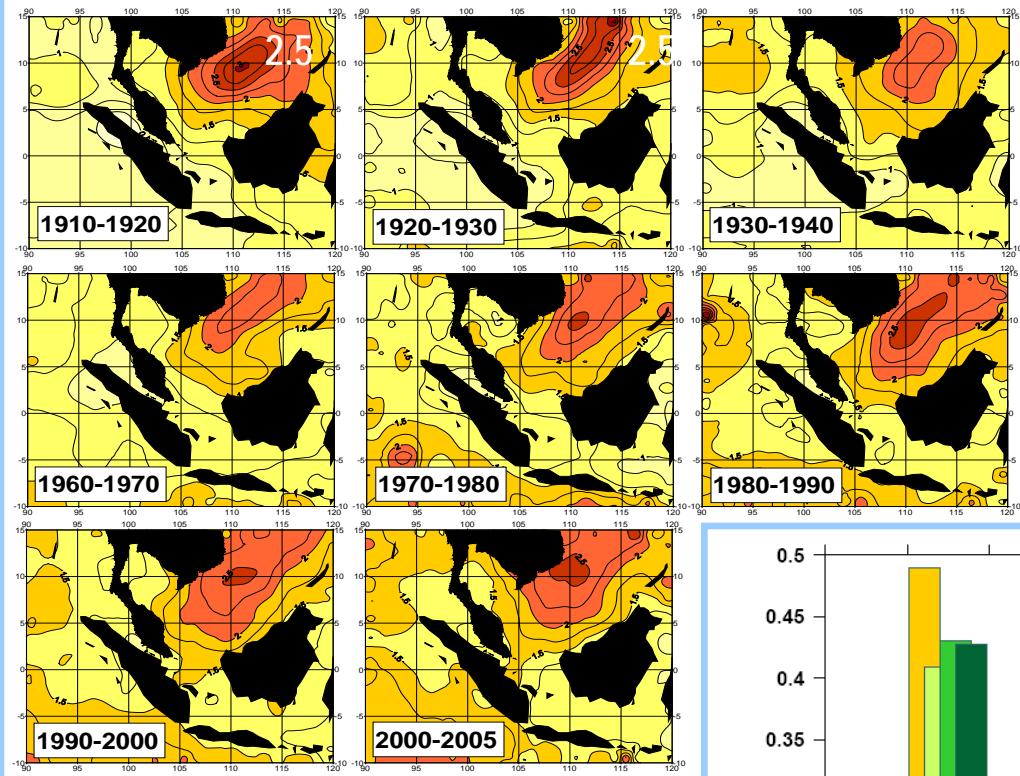
100-year return SWH for different decades



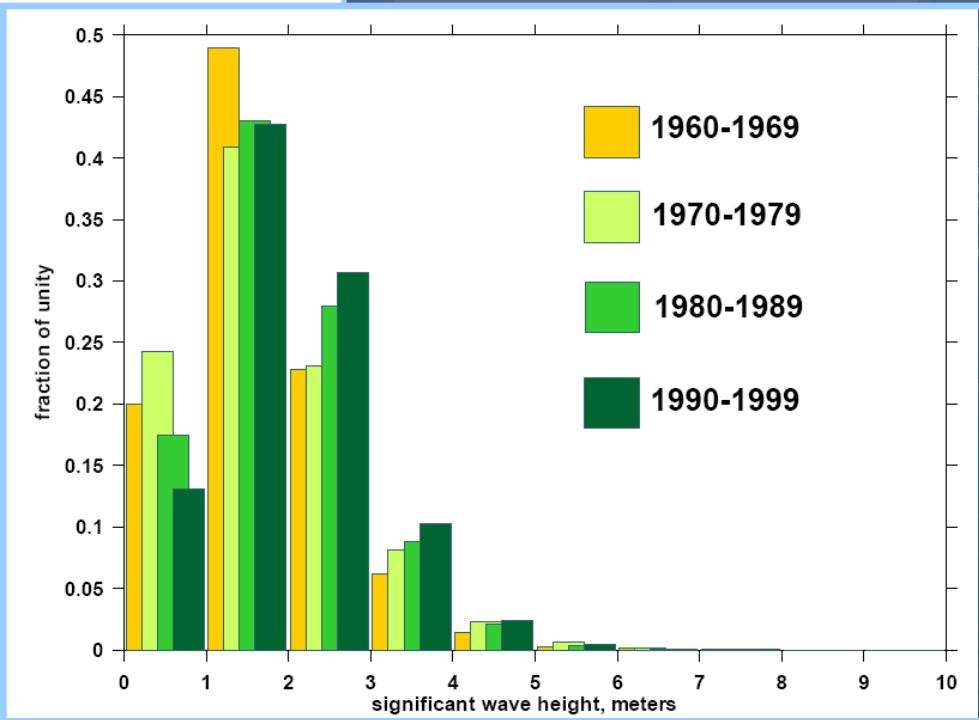
Decadal changes in 100-yr return values of SWH. averaged over NA and NP mid latitudes



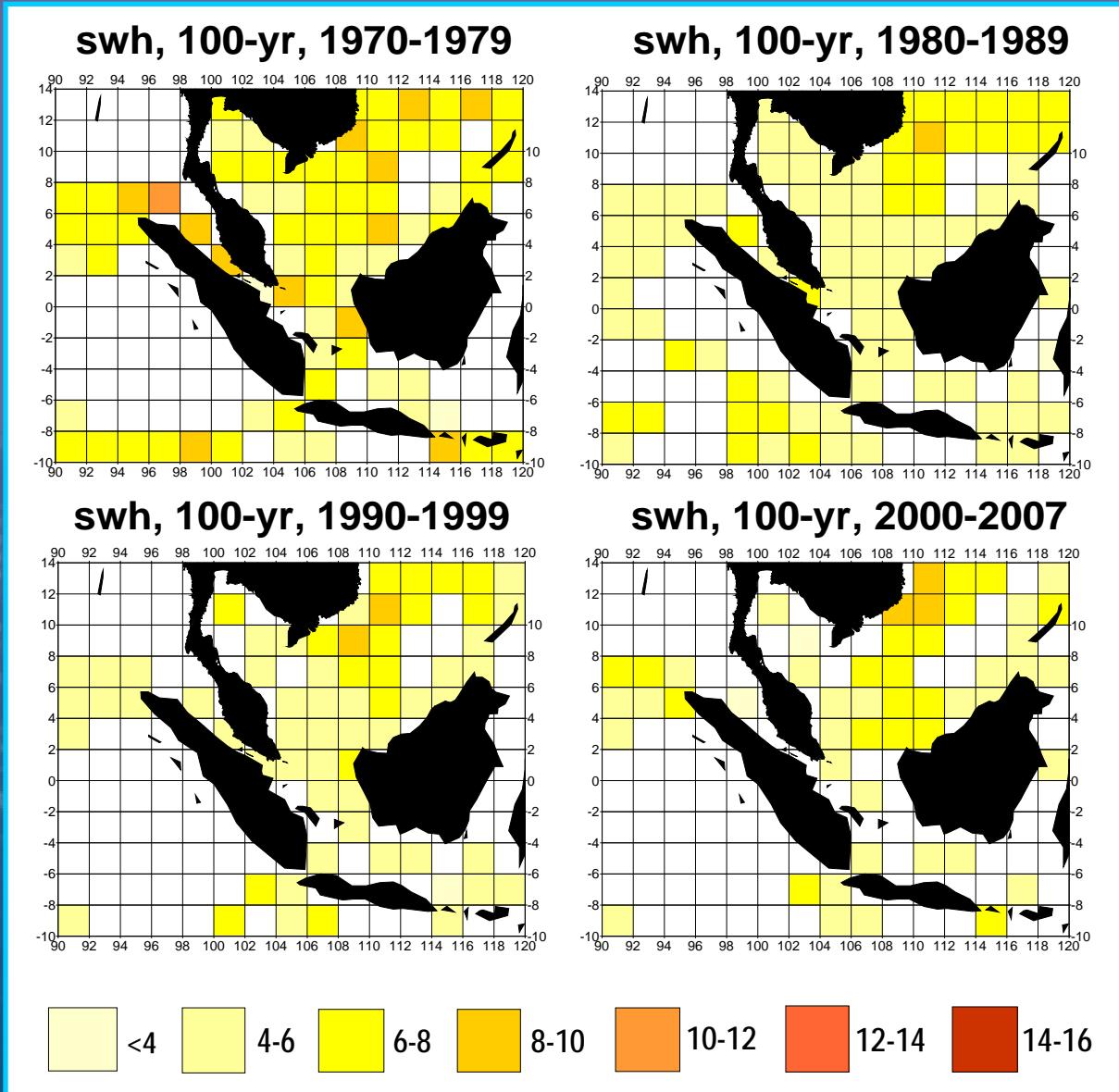
Best sampled ship route in the world: 1910-2005



**Interdecadal
changes in
probability
distributions
of SWH**



Extreme SWH for 1970-2007



Conclusions:

- Estimation of extreme waves from VOS can be influenced by the profound contribution of highest possible waves (need for accurate decoding)
- IVD and VOS: underestimation of extreme waves by about 25%
- EVD: Model hindcasts give a good prospect for merging the advances of VOS data and regular sampling in model waves – technique for estimation of EVD parameters from censored samples
- EVD give maxima 100-yr return value of SWH of 24-27 m in the Atlantic and 22-24 m in the Pacific (likely a bit high)
- Extreme waves revealed by VOS data show quite evident decadal variability. Decadal changes in the extreme SWH and wind sea are not correlated in the Atlantic and are closely correlated in the Pacific