GLOBAL WAVE CLIMATE TREND AND VARIABILITY ANALYSIS

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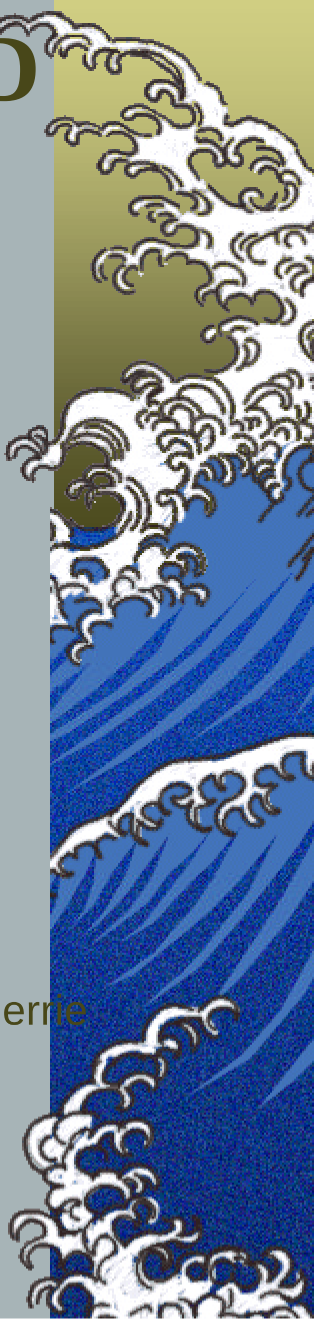


Important/motivational references:

Wang, X. L. and V. R. Swail, 2001: *J. of Climate*, **14**, 2204-2221.

Wang, X. L. and V. R. Swail, 2002: *J. of Climate*, **15**, 1020-1035.

Wang, X. L. and V. R. Swail, 2004: In: *Atmosphere Ocean Interactions*, **2**, W. Perrie (ed.)

Objectives

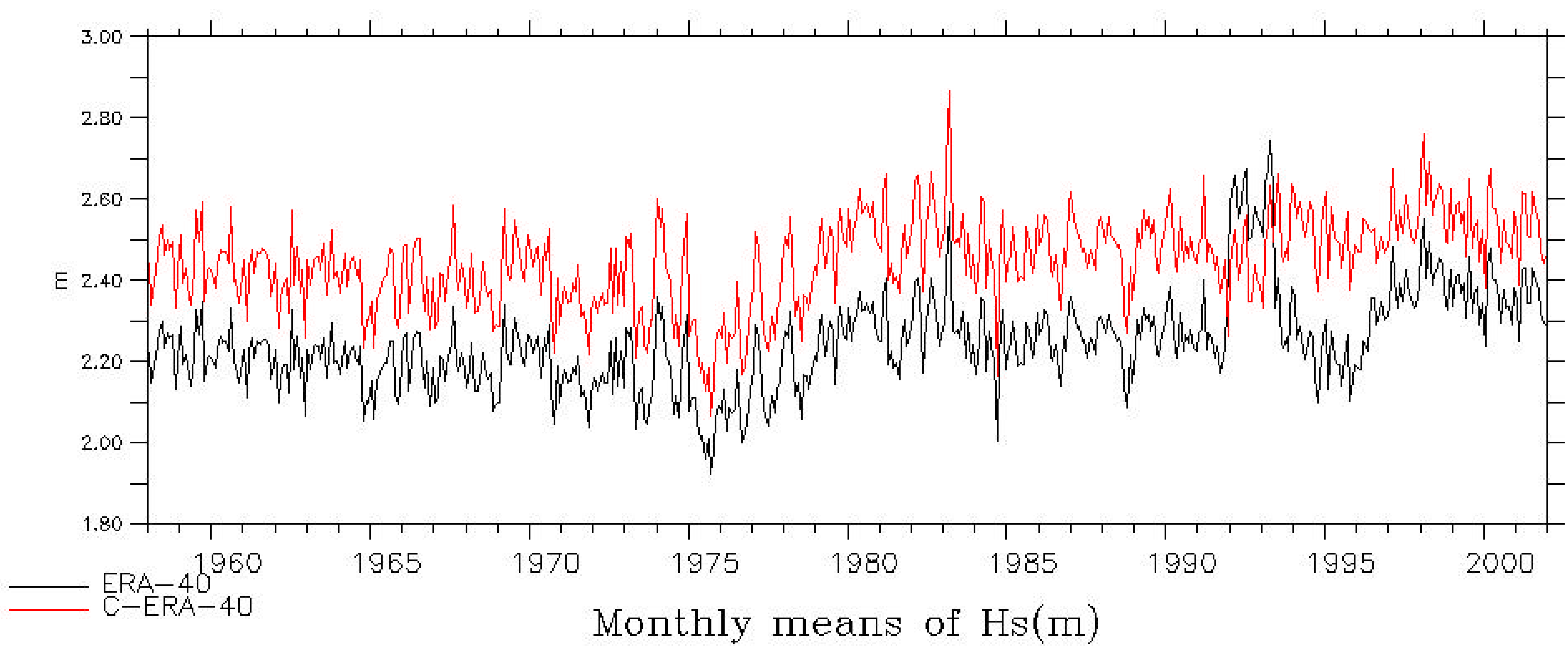
- *Inferences about global trends in seasonal means, 90^{th} and 99^{th} percentiles and extremes of significant wave height (Hs) from 1958 to 2001*
- *Inferences about their patterns of variability*
- *Compare the results with those available in the literature*

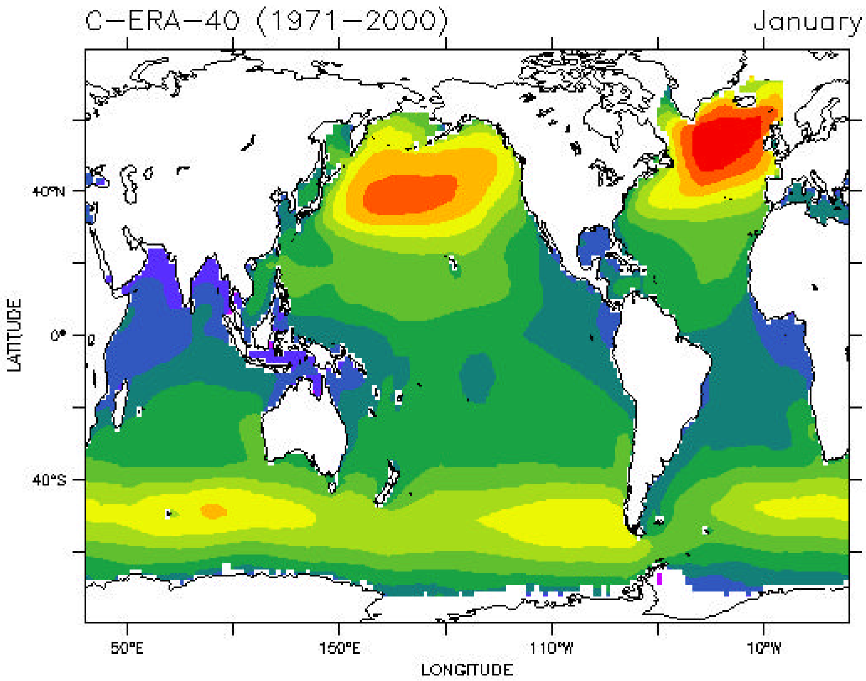
Plan of this talk

- *Description of the Hs data set used*
- *Description of main climate features*
- *Description of methodology*
- *Presentation of results*
- *Comparison with other published works*
- *Final remarks*

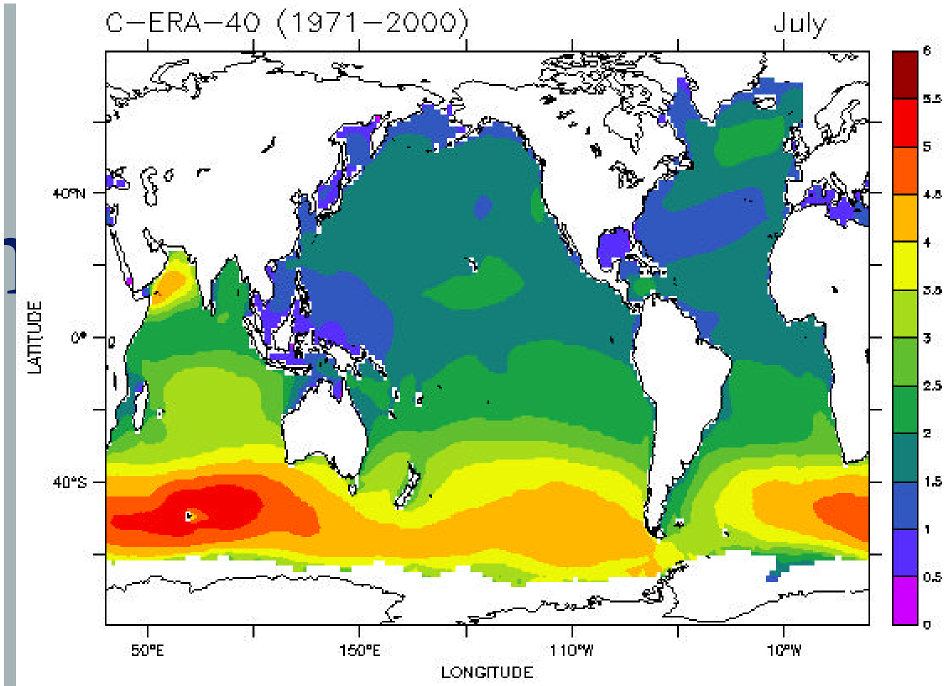
C-ERA-40

Deficiencies (underestimation of high Hs peaks and inhomogeneities) *in the ECMWF ERA-40 Hs data set motivated its correction using a non-parametric method which resulted in the C-ERA40 data set*

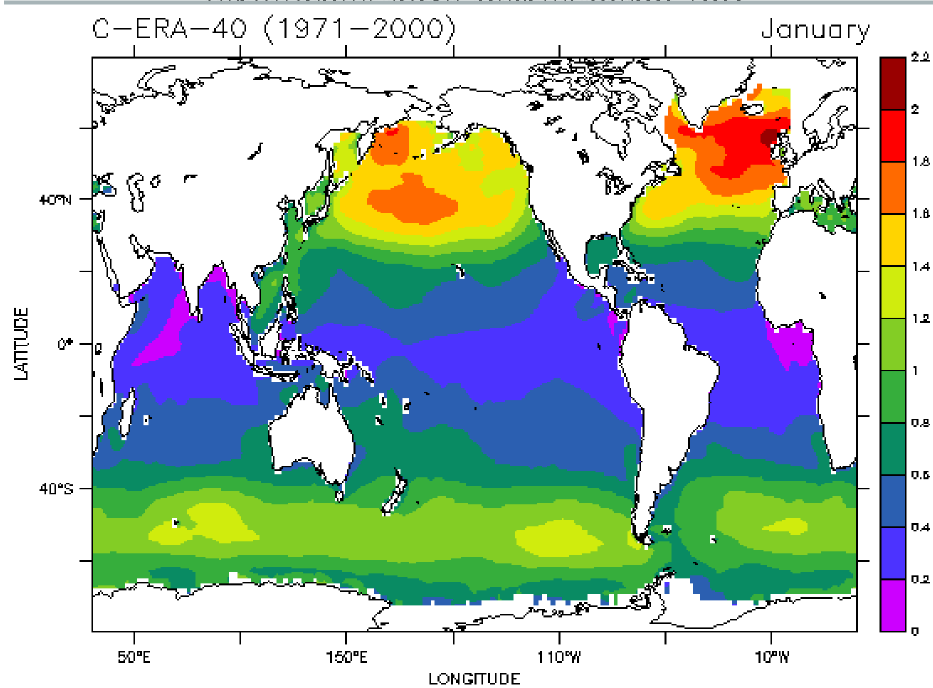




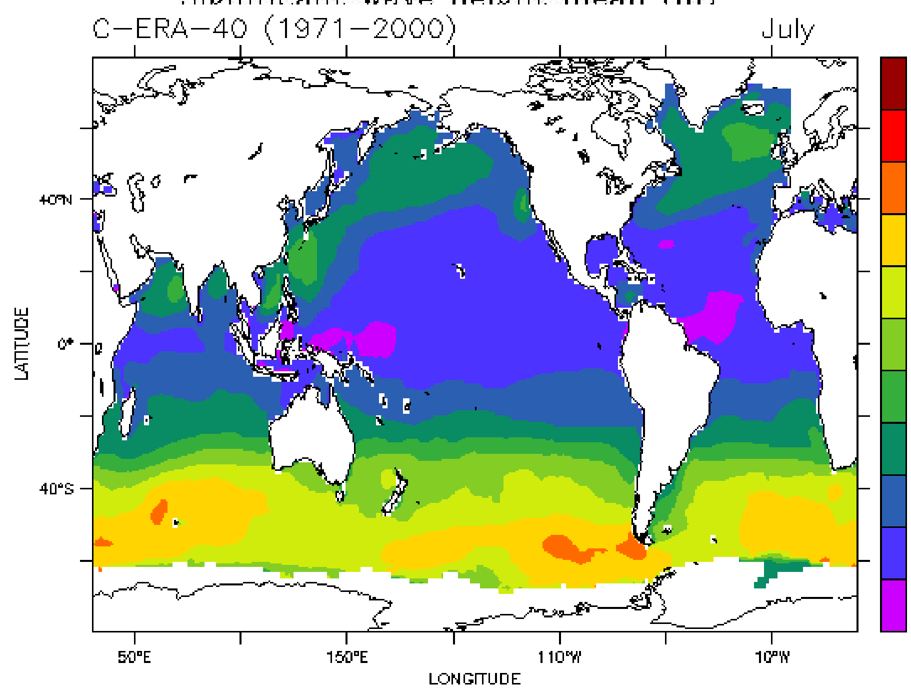
Significant wave height mean (m)



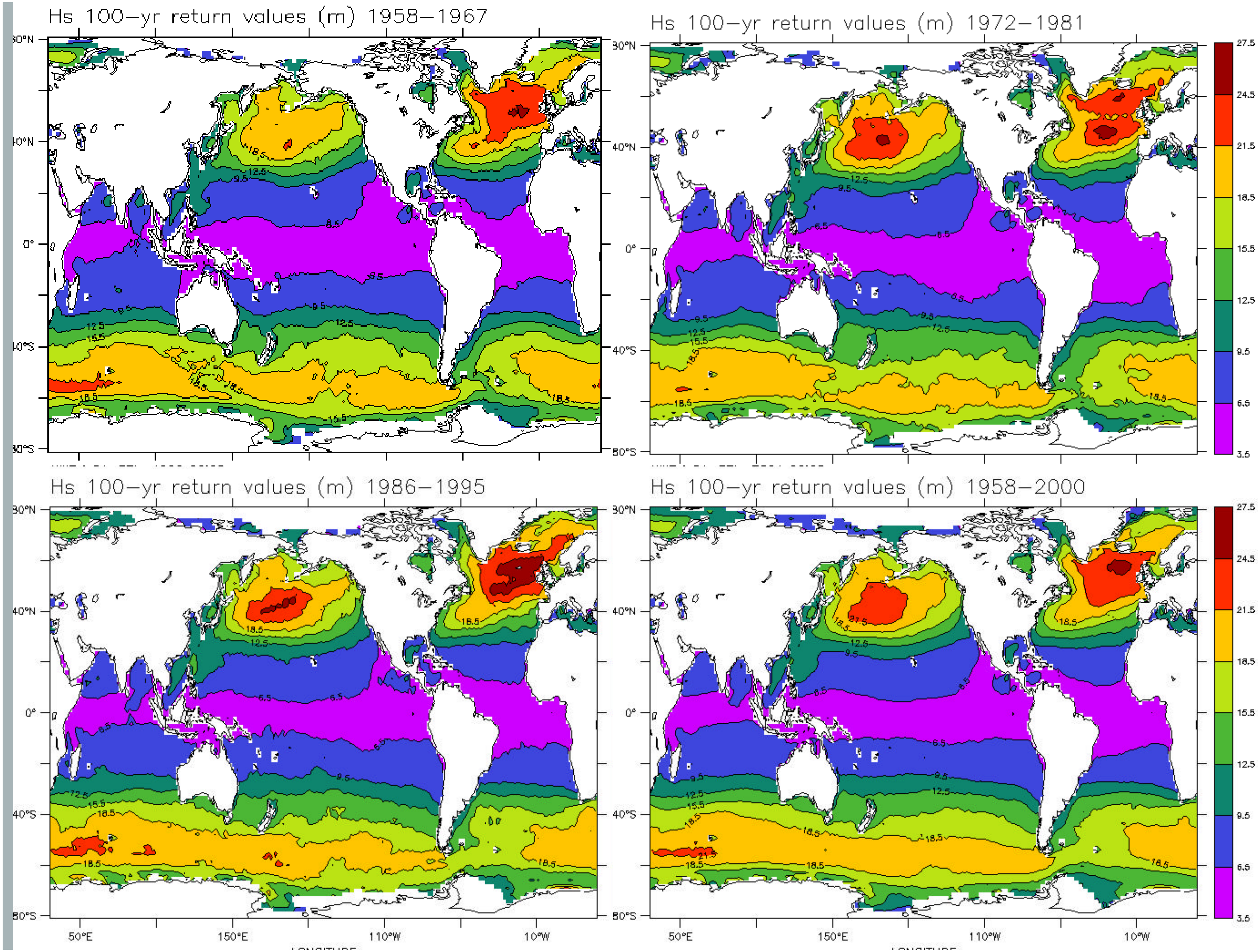
Significant wave height mean (m)

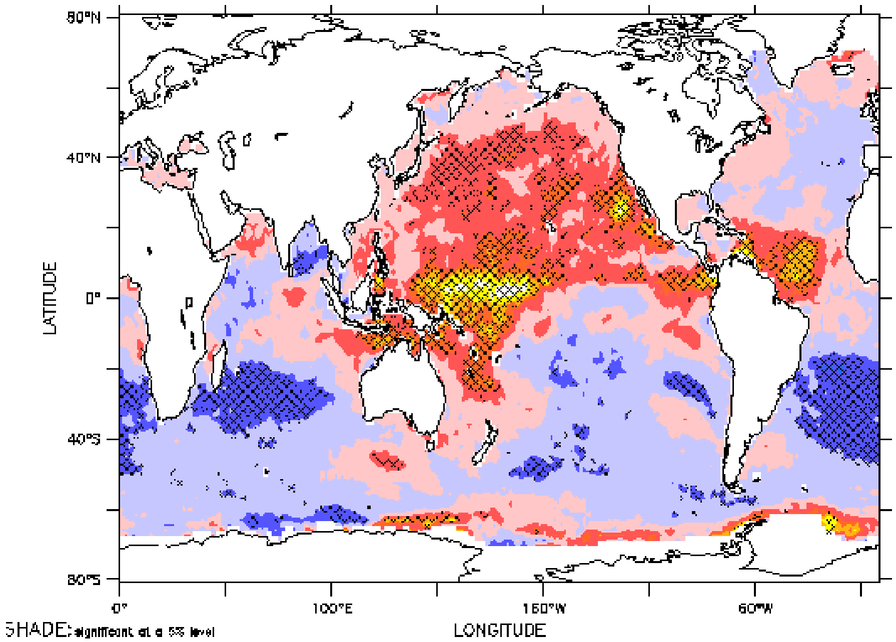


Significant wave height standard deviation (m)

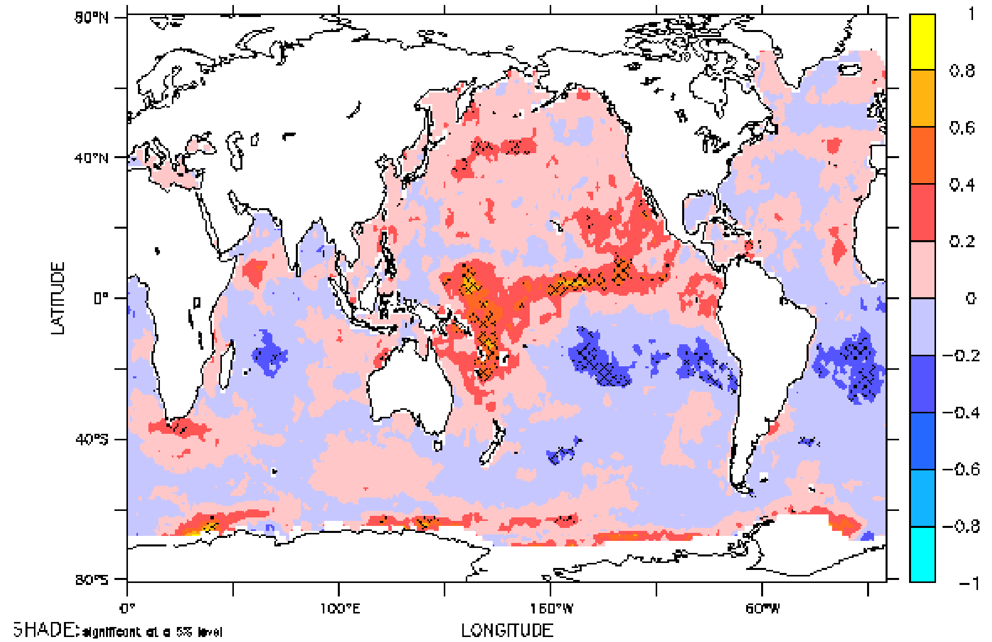


Significant wave height standard deviation (m)

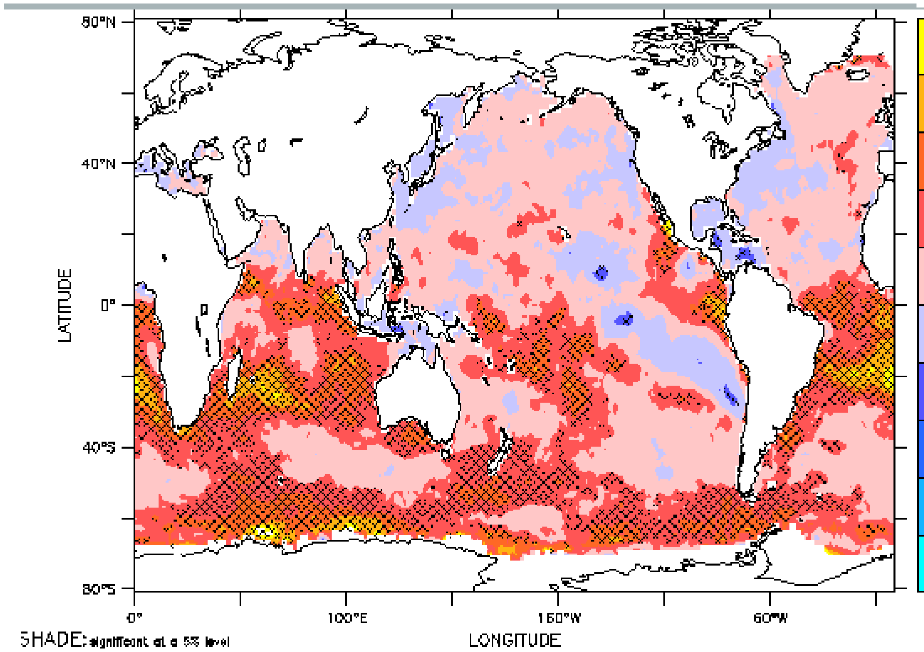

Hs 100−yr return values (m) 1958−1967
Hs 100−yr return values (m) 1972−1981
Hs 100−yr return values (m) 1986−1995
Hs 100−yr return values (m) 1958−2000
80°N
40°N
0°
40°S
80°S
50°E
150°E
110°W
10°W
27.5
24.5
21.5
18.5
15.5
12.5
9.5
6.5
3.5



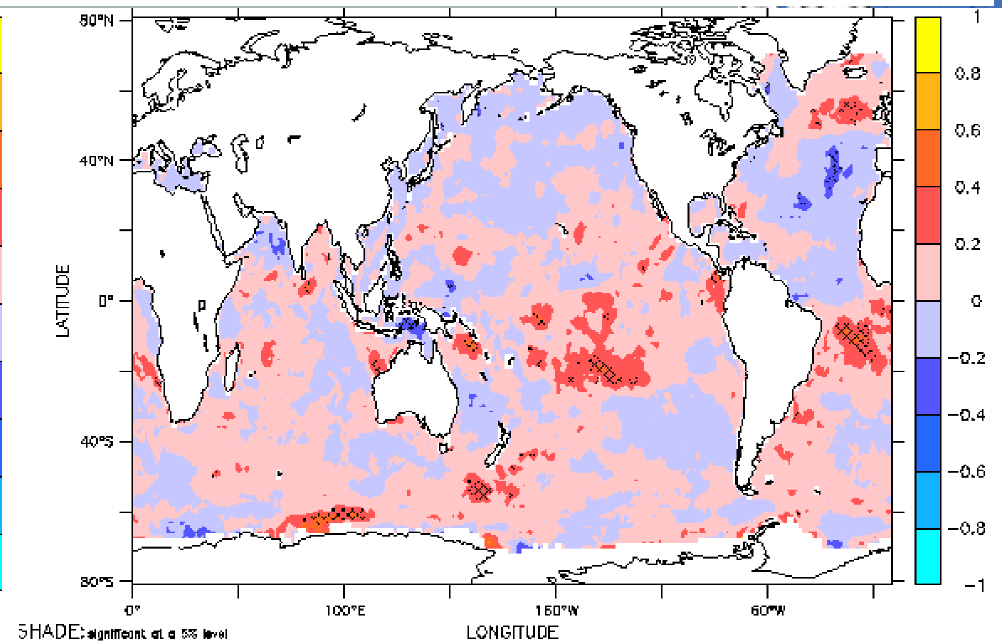
[LAMBDA(72−81)−LAMBDA(58−67)]/LAMBDA(58−67)



[ALPHA(72−81)−ALPHA(58−67)]/ALPHA(58−67)



[LAMBDA(86−95)−LAMBDA(72−81)]/LAMBDA(72−81)



[ALPHA(86−95)−ALPHA(72−81)]/ALPHA(72−81)

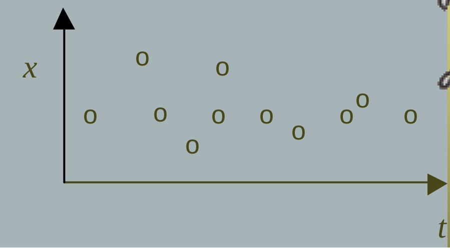
Methodology

Trend analysis in means and percentiles: *the Mann-Kendall non-parametric test was used to identify significant trends at a 5% level; the trend estimator is based on Kendall's rank correlation.*

Trend analysis in the extremes: *The non-homogeneous Poisson process was used to estimate trends and the likelihood ratio to infer their significance.*

Variability analysis: *Standard EOF analysis was used.*

Non-stationary extension of POT/GPD



$C = \{(t, x) : x > u(t), 0 \le t \le T\}$

Non-homogeneous Poisson process

$$l(t,x) = \frac{1}{s(t)}\left(1 + x(t)\frac{x - m(t)}{s(t)}\right)_+^{-\frac{1}{x(t)}-1} \quad \text{for } (t,x) \in C$$

$$r(A) = \int_A l(t,x)\,dt\,dx$$

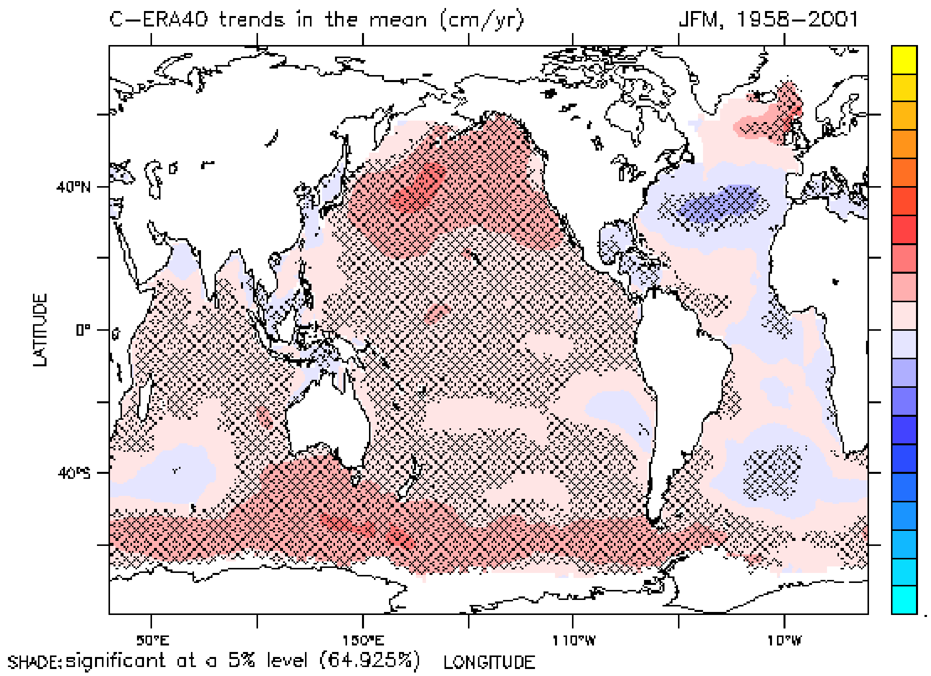
$$m(t) = a + bt \qquad s(t) = s \qquad x(t) = x$$

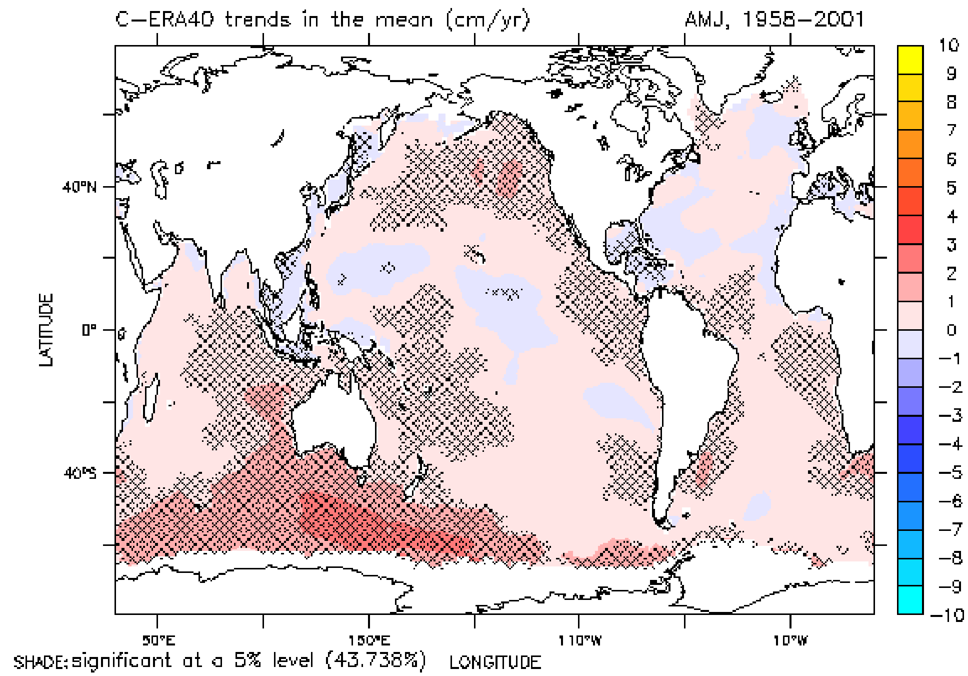
m-year return value

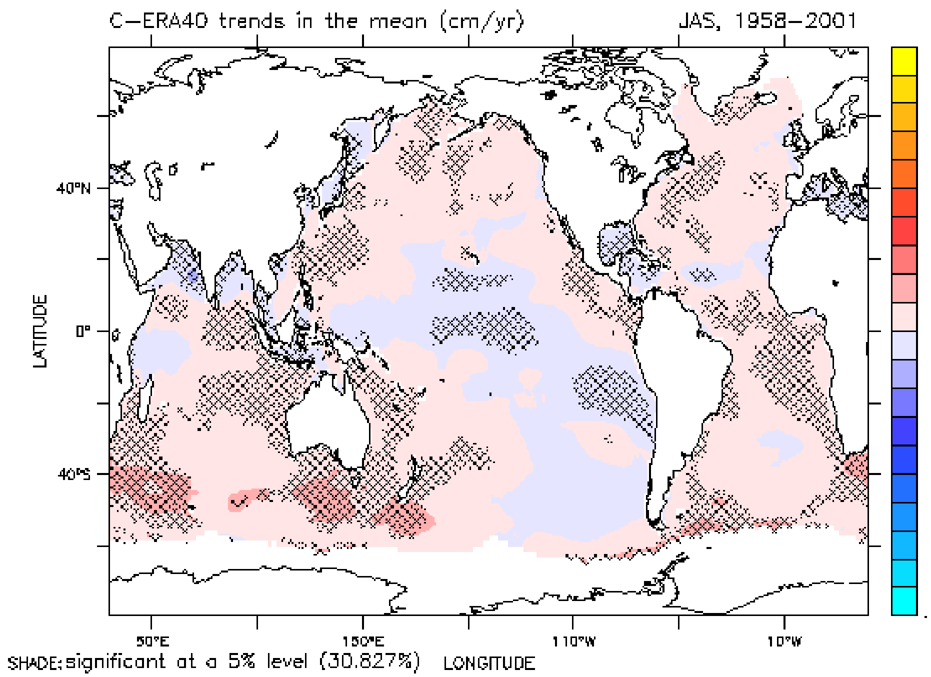
$$\int_0^m \left(1 + x(t)\frac{x_m - m(t)}{s(t)}\right)^{-\frac{1}{x(t)}} dt = 1$$

Maximum likelihood estimation

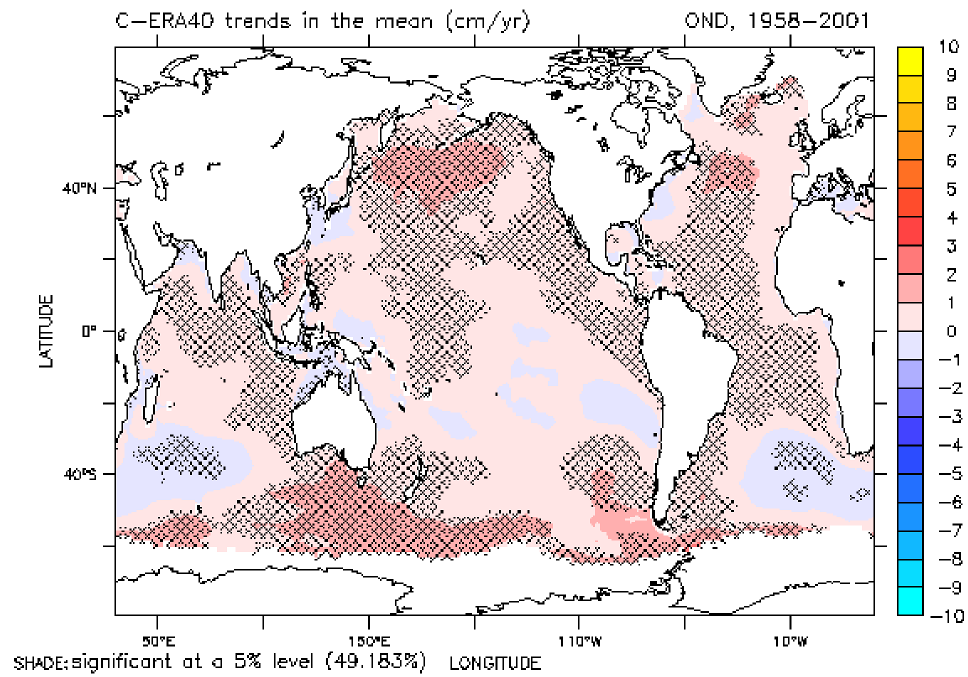
$$L = \exp\left\{-\int_C \lambda(t,x)\,dt\,dx\right\} \prod_{i,j} \lambda(t_{i,j}, x(i,j)).$$



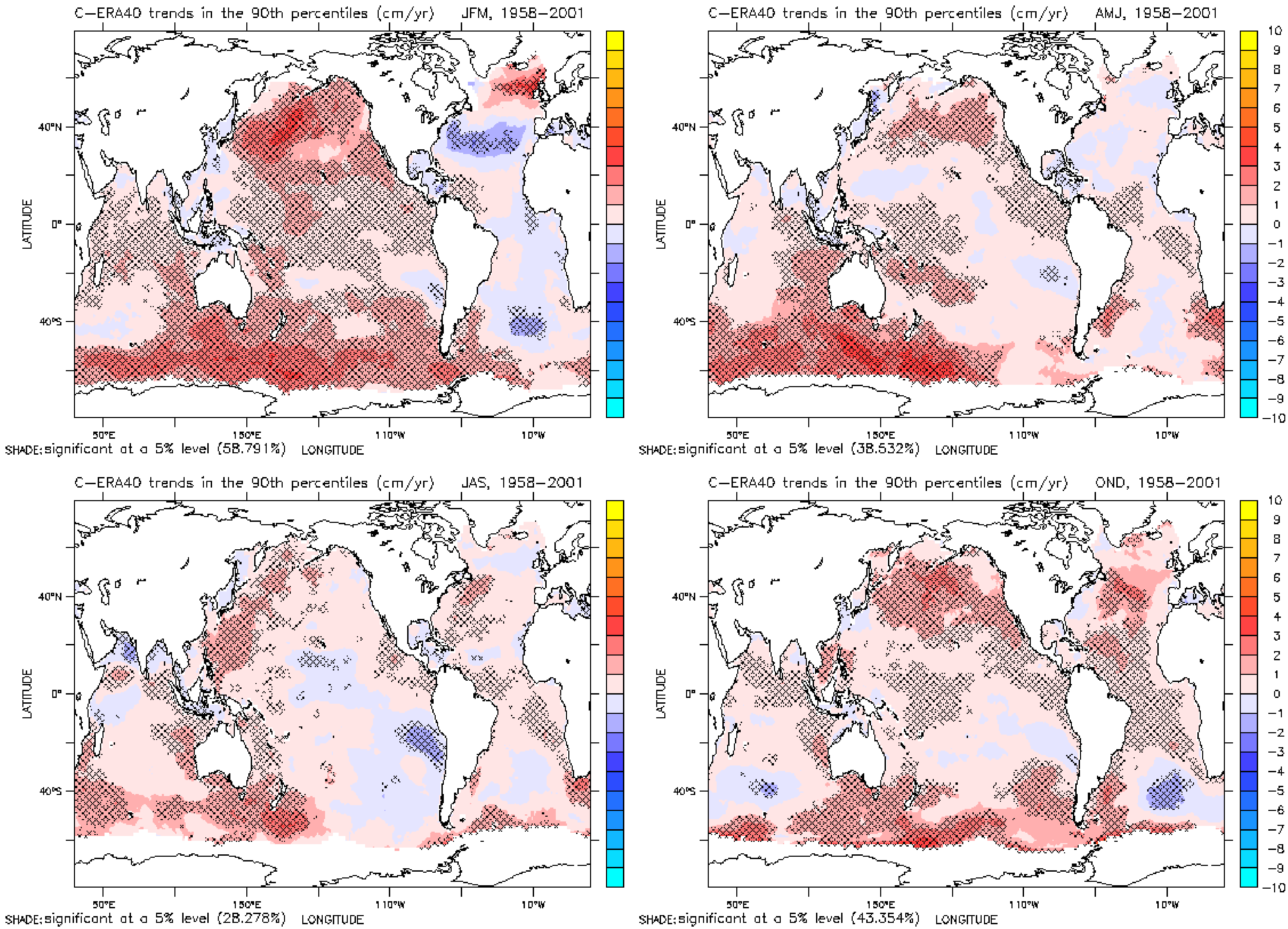




Hs trend in the JAS mean (cm/yr)

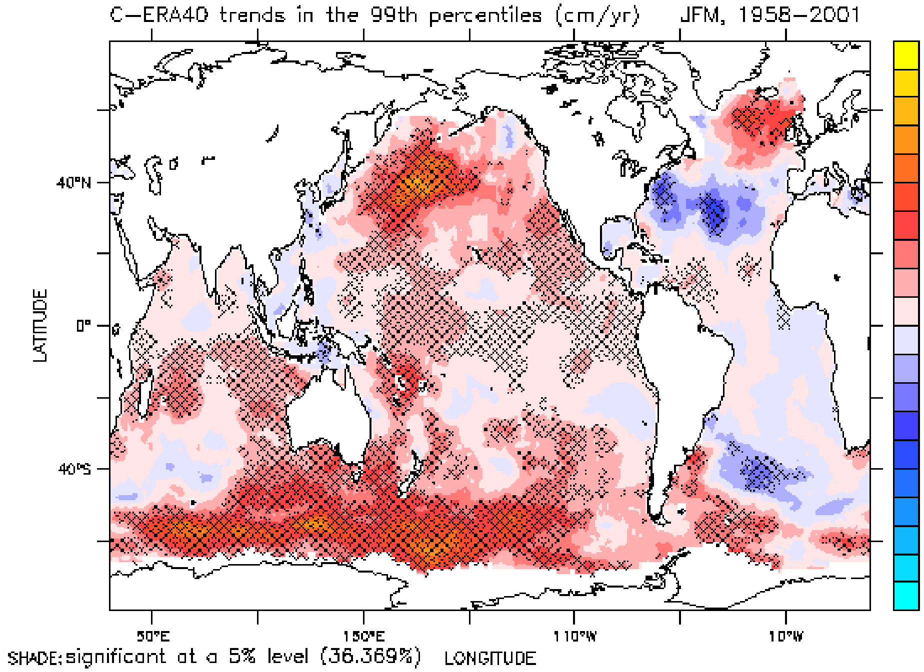


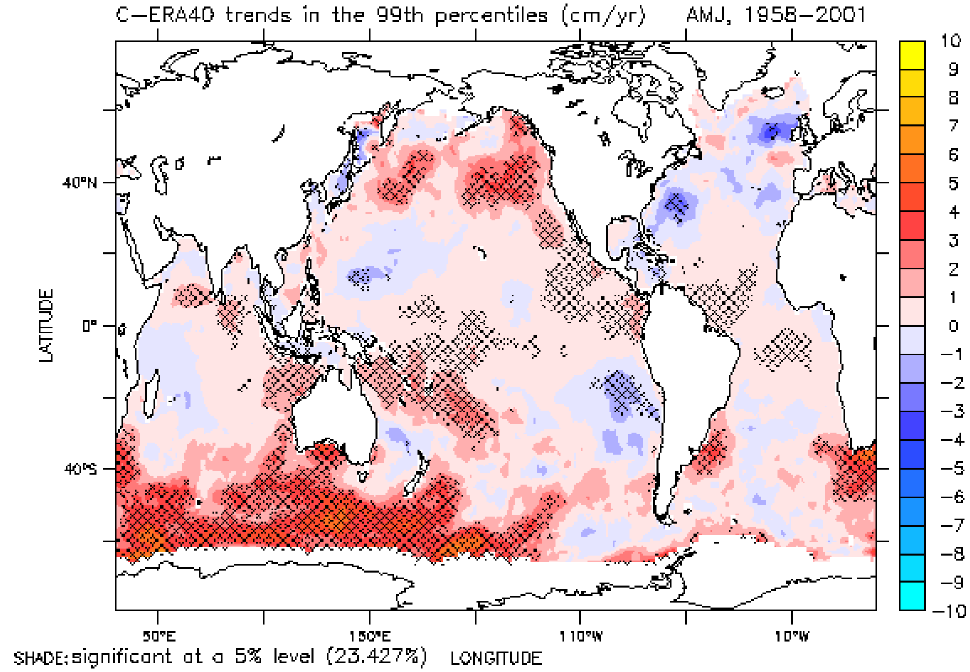
Hs trend in the OND mean (cm/yr)

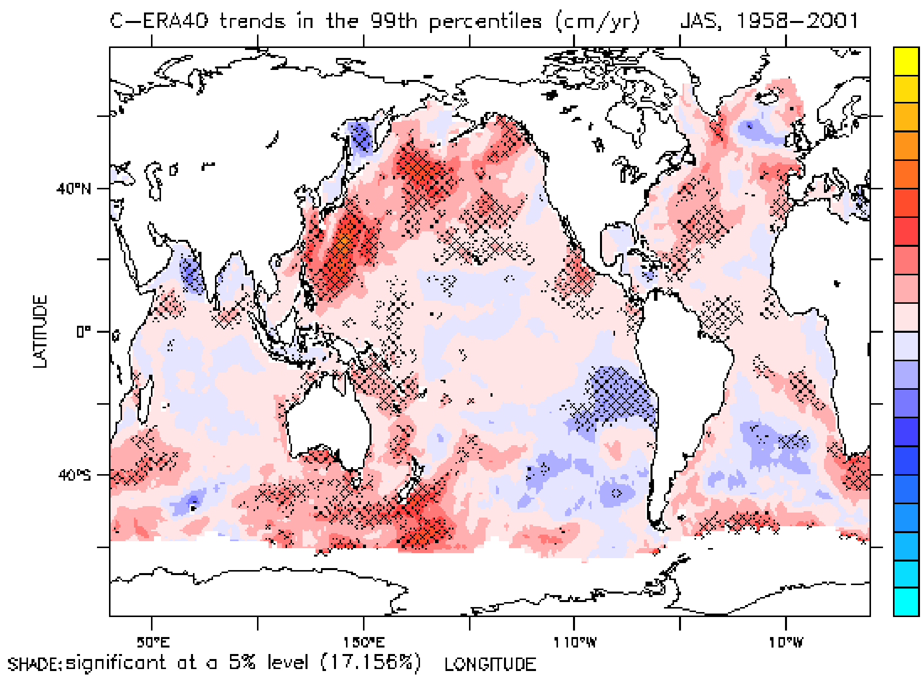


Hs trend in the JAS 90th percentiles (cm/yr)

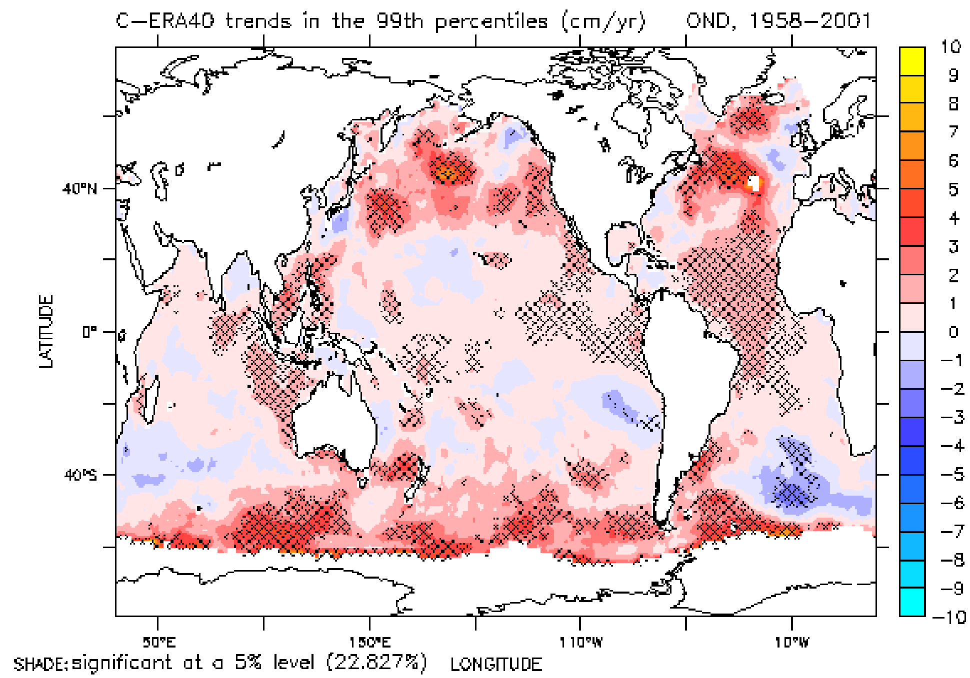
Hs trend in the OND 90th percentiles (cm/yr)



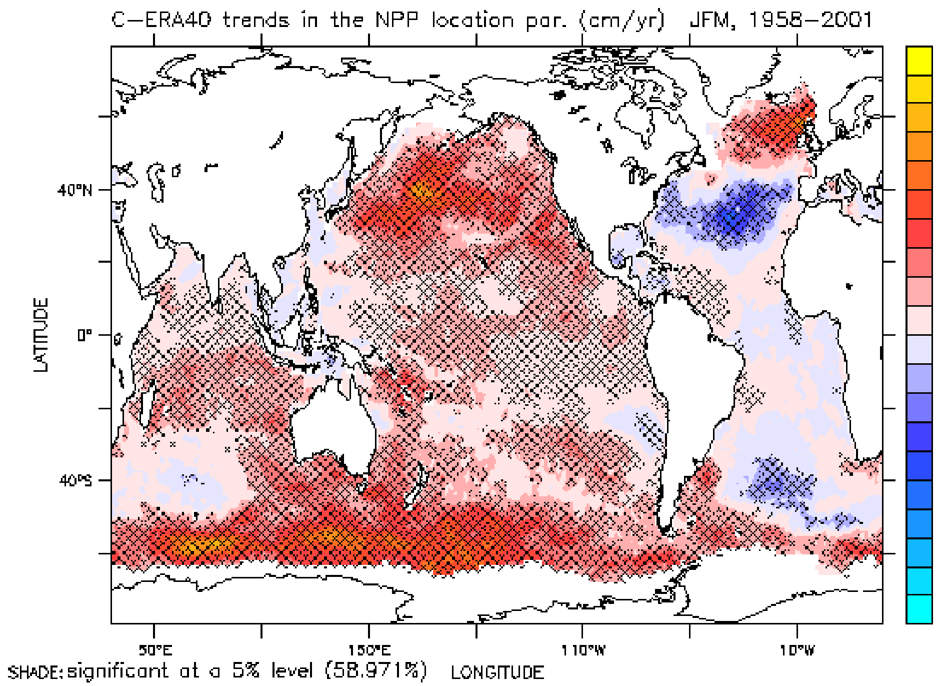


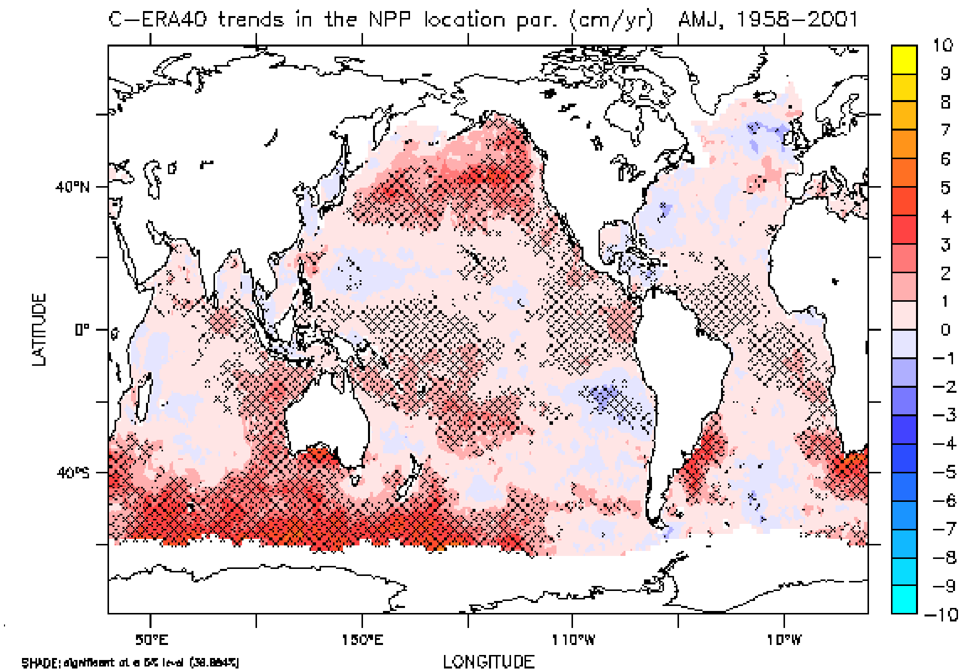


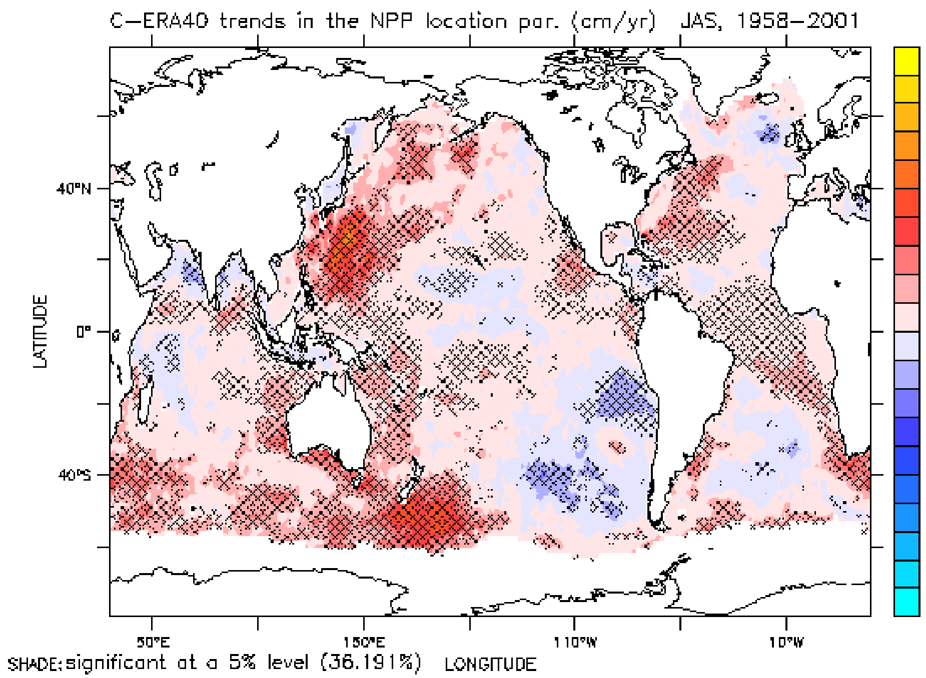
Hs trend in the JAS 99th percentiles (cm/yr)



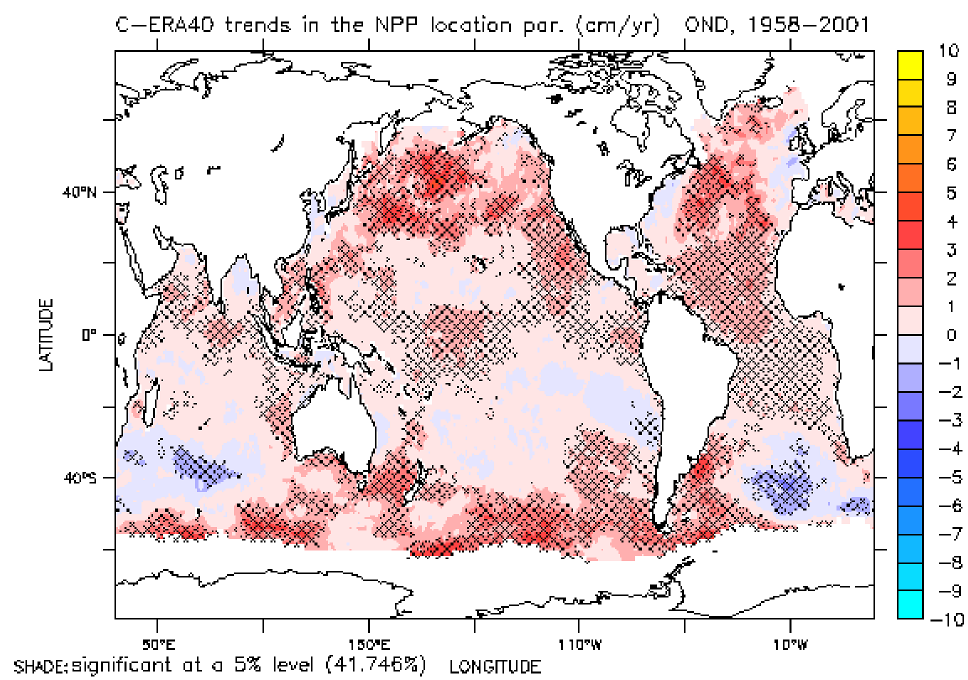
Hs trend in the OND 99th percentiles (cm/yr)







Hs trend in the JAS NPP location par. (cm/yr)



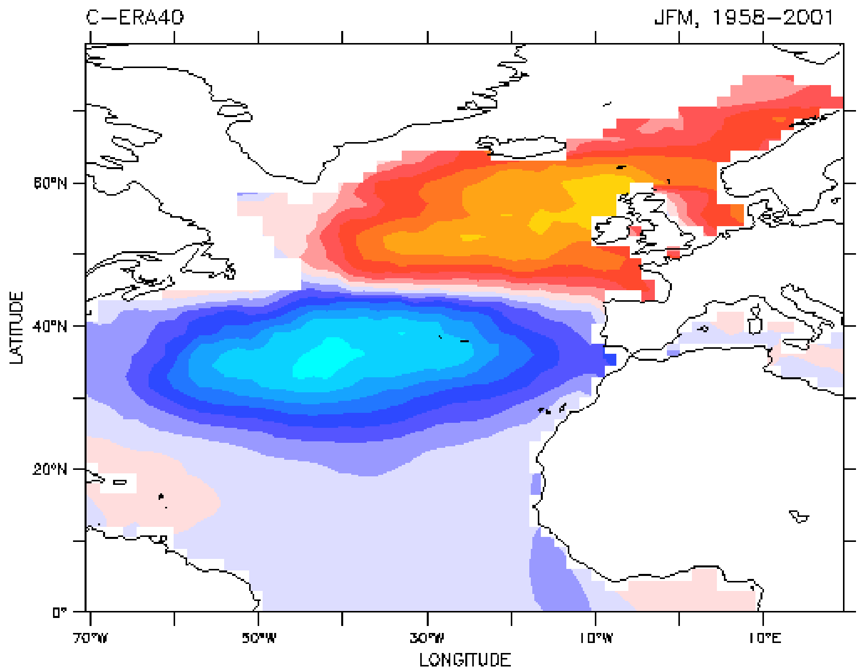
Hs trend in the OND NPP location par. (cm/yr)

Trends in the literature

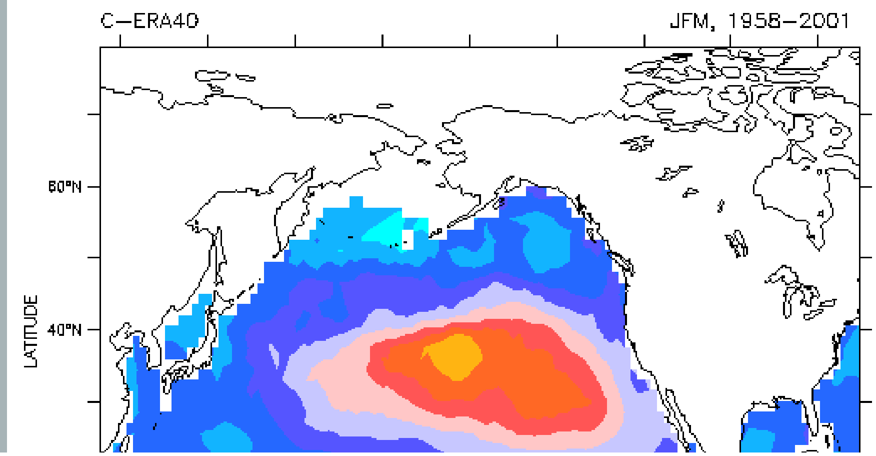
Study	Location	Variable	Period	Trend (cm/yr)
Carter and Draper (1998)	Seven Stones light vessel	Annual means	1962-1985	3.4
Bacon and Carter (1991)	Seven Stones light vessel	Annual means	1962-1985	2.2
Wang and Swail (2002)	Grid points around SSLV	Annual means	1962-1985	0.05-0.21*
C-ERA40	Grid points around SSLV	Annual means	1962-1985	-0.04-0.18*
Bouws et al. (1996)	Box 1 (50°-55°N, 50°-40°W)	Annual 50th percentiles	1961-1987	2.3
Wang and Swail (2002)	Box 1 (50°-55°N, 50°-40°W)	Annual 50th percentiles	1961-1987	-1.0-0.1*
C-ERA40	Box 1 (50°-55°N, 50°-40°W)	Annual 50th percentiles	1961-1987	-0.3-0.4*
Bouws et al. (1996)	Box 2 (50°-55°N, 20°-10°W)	Annual 50th percentiles	1961-1987	2.7
Günther et al. (1998)	Box 2 (50°-55°N, 20°-10°W)	Annual 50th percentiles	1961-1987	1.0
Wang and Swail (2002)	Box 2 (50°-55°N, 20°-10°W)	Annual 50th percentiles	1961-1987	-1.0-0.1*
C-ERA40	Box 2 (50°-55°N, 20°-10°W)	Annual 50th percentiles	1961-1987	-0.3-0.6*

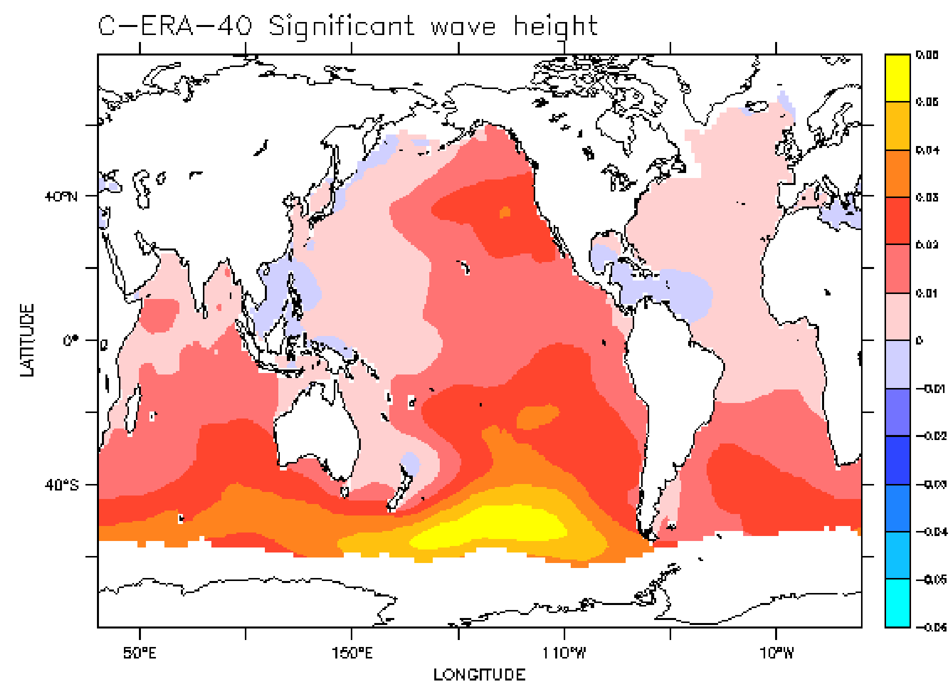
Study	Location	Variable	Period	Trend (cm/yr)
Günther et al. (1998)			1955-1994	0.25-0.75
Wang and Swail (2002)	Northeast Atlantic	Annual means	1958-1997	0.5-2.5
C-ERA40			1958-1997	0.6–1
Günther et al. (1998)			1955-1994	2-3
Wang and Swail (2002)	Northeast Atlantic	Annual 90th percentiles	1958-1997	1-3
C-ERA40			1958-1997	2-3
Günther et al. (1998)			1955-1994	3-4
Wang and Swail (2002)	Northeast Atlantic	Annual 99th percentiles	1958-1997	2-6
C-ERA40			1958-1997	2-4
Günther et al. (1998)			1955-1994	7-10
Wang and Swail (2002)	Northeast Atlantic	Annual maxima	1958-1997	4-7.6
C-ERA40			1958-1997	4-6.7
Sterl et al (1998)	North Atlantic	January mean	1979-1993	12
C-ERA40				15
Sterl et al (1998)	South Africa	July mean	1979-1993	7
C-ERA40				7.4
Gower et al. (2002)		Monthly mean		2.1
Allan and Komar (2000)	NDBC-NOAA Buoy 46005	Annual mean		2.7
Anderson et al. (2001)		3 hourly		1
C-ERA40		Annual mean		1

Variability



EOF1 of winter 99th percentiles (29.445%)





1st EOF eigen vectores (explains 15.221%)

The coefficients are highly correlated with the global mean

Final remarks

•Ss high trends in the CNP and the NEA (winter and fall) and SO (all year round).

•Trends of up to 2.6, 5.1, 8.6 are to be expected in the means, 90^{th} and 99^{th} percentiles, respectively.

•Trends of up to 8 cm/yr in the scale par., % of global oceans where trends are ss varies seasonally between 36 and 59%.

•Variability modes correlated to known climate indexes.

•Trend estimates have magnitudes lower than those given by studies based on observations. The spatial structure of the trends is very similar to those of estimates based on wave model results.

Caveats: Data only for deep waters and tropical cyclones are not resolved.

Global wave climate atlas based on ERA-40/C-ERA-40 wave and wind data is available at www.knmi.nl/waveatlas