20th century climate changes in the wind waves over the Northern Hemisphere from visual data

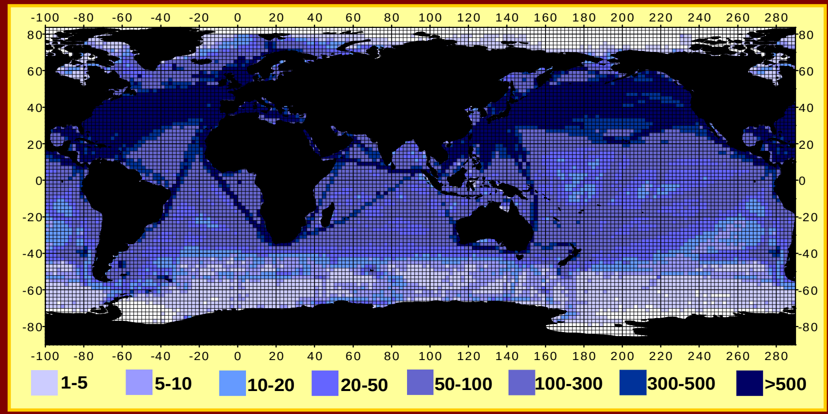
Sergey Gulev, Vika Grigorieva, Olga Zolina, Scott Woodruff

(IORAS, Moscow, MIUB, Bonn, CDC, Boulder)

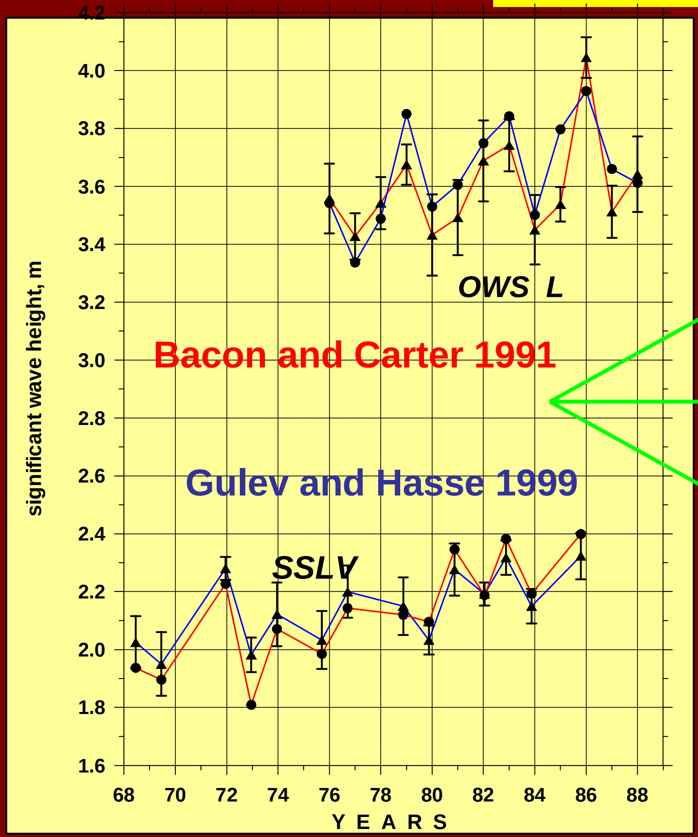
Background:

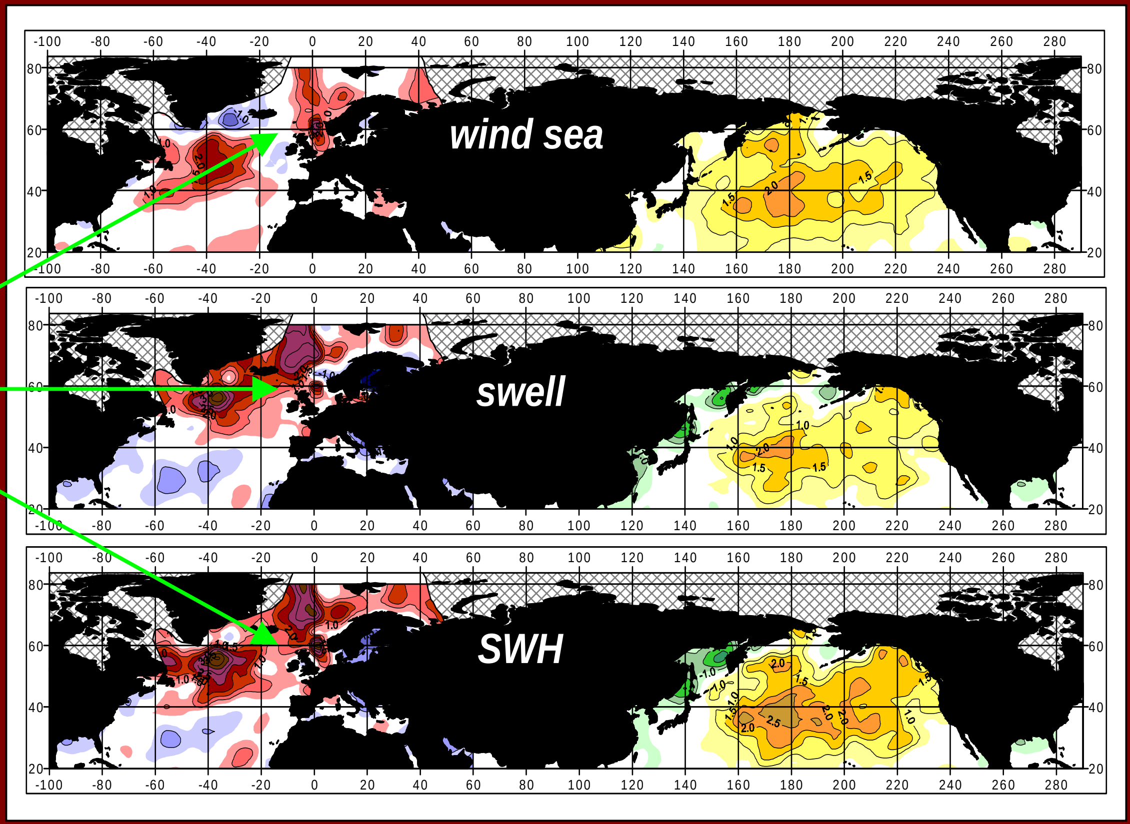
- In-situ time series: Bacon & Carter 1991, 1993 - few locations, short in time.
- Model hindacsts (Sterl et al. 1998, Wang and Swail 2002, Cardone et al. 2002) not independent from the wind.
- Altimetry (Woolf and Challenor 2002) considers significant wave height (SWH), limited in time.
- VOS collections are the only source of continuous time series of separate estimates of sea and swell, taken visually worldwide.
  The use of this information may help to identify:
  - the mechanisms driving SWH changes;
  - very long tendencies in surface roughness.

COADS-based global 2-degree climatology of ocean wave parameters [Gulev et al. 2003]: 1950-1997 (1850-1997).

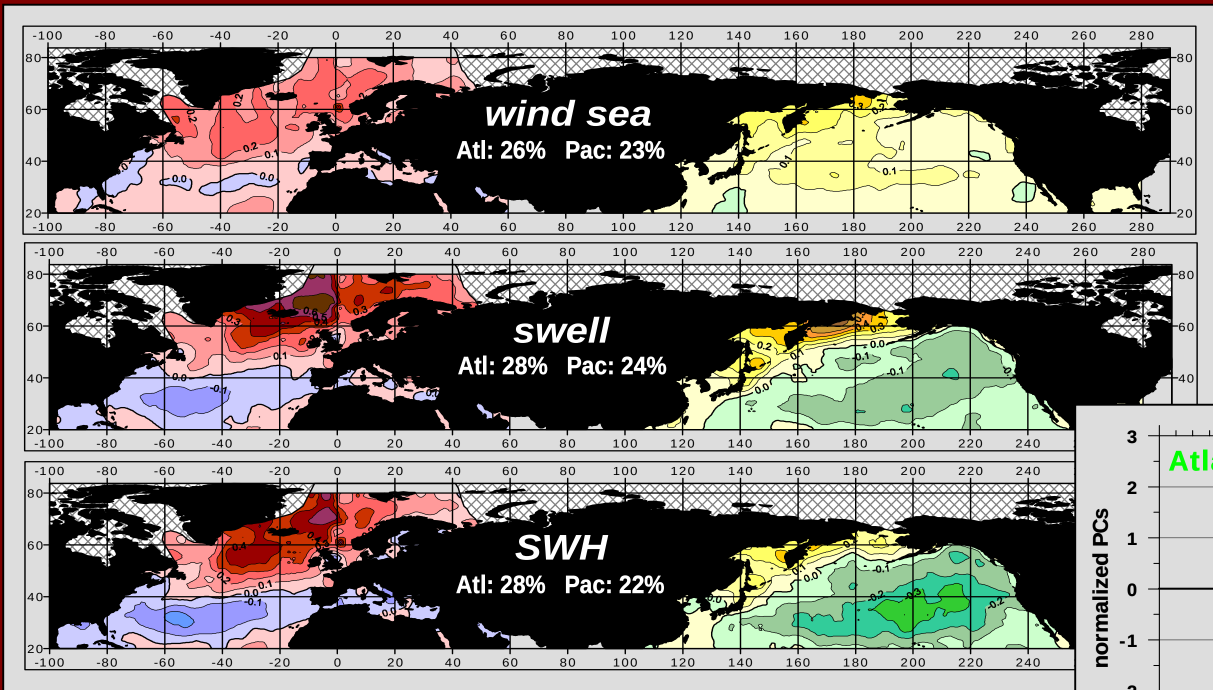


VOS waves: linear trends

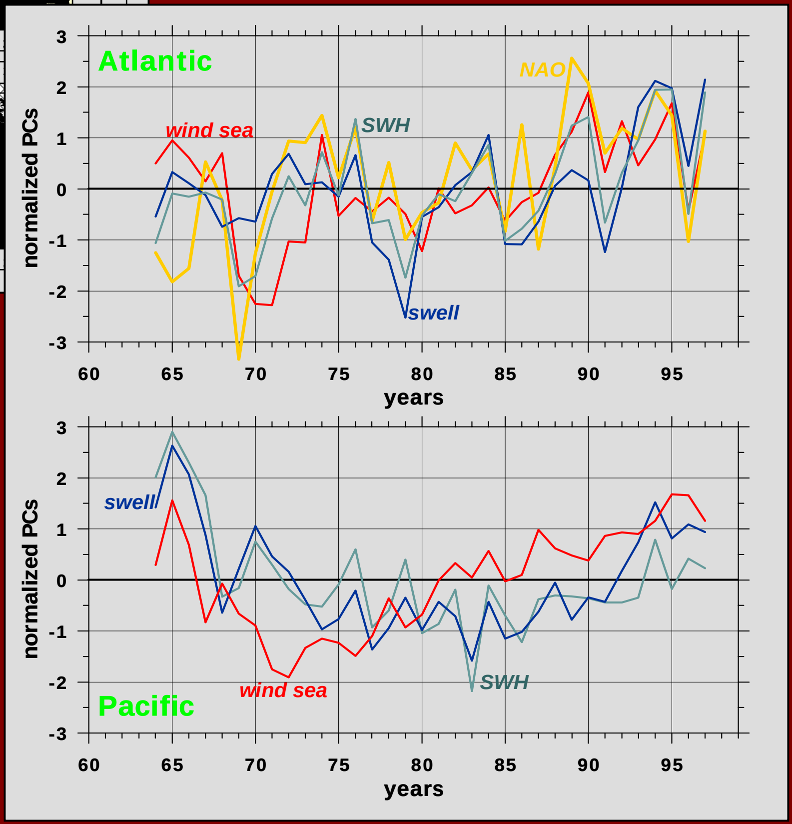




Variability of wave heights: winter (JFM) EOFs



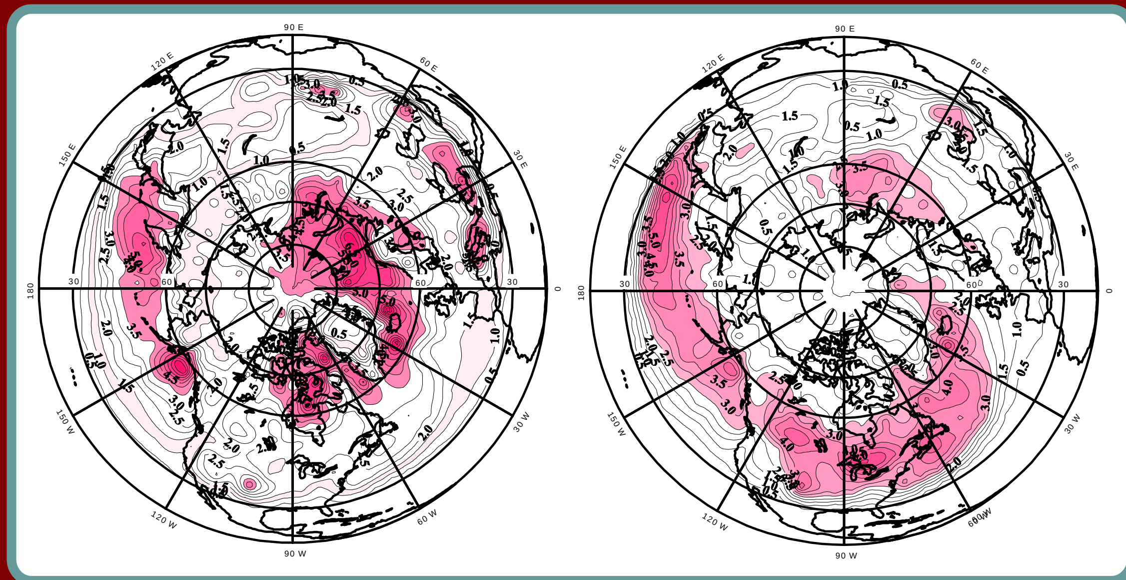
Sea and swell demonstrate different patterns of variability, especially in Pacific



Time behaviour of the leading PCs is also different for sea in comparison to swell and SWH.

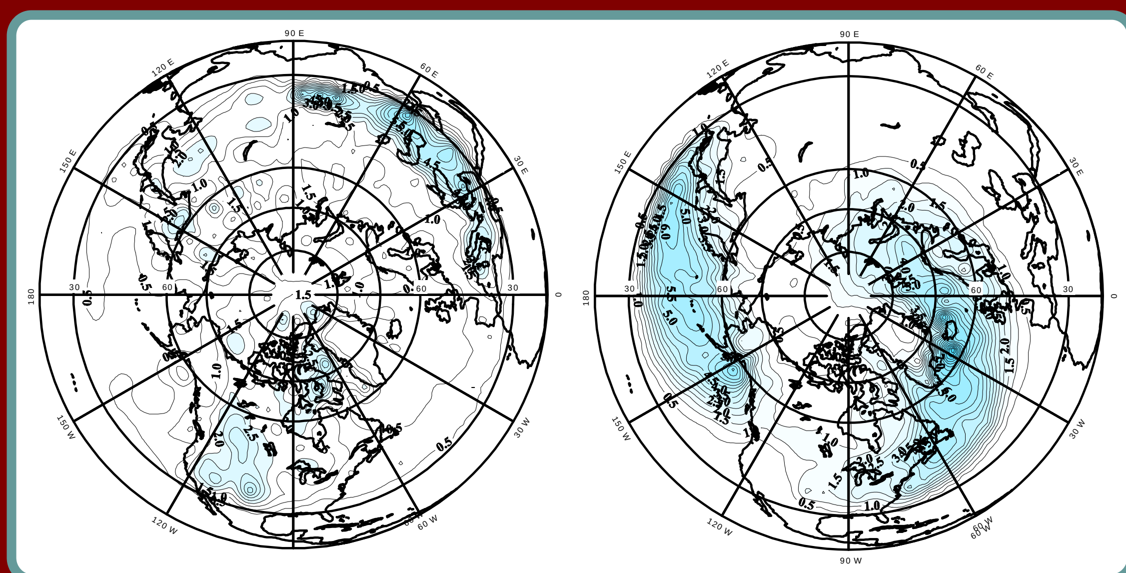
Northern Hemisphere cyclone activity 1948-2001: Zolina et al. (2001) climatology (winter – JFM)

Slowly moving (20-40 km/h)



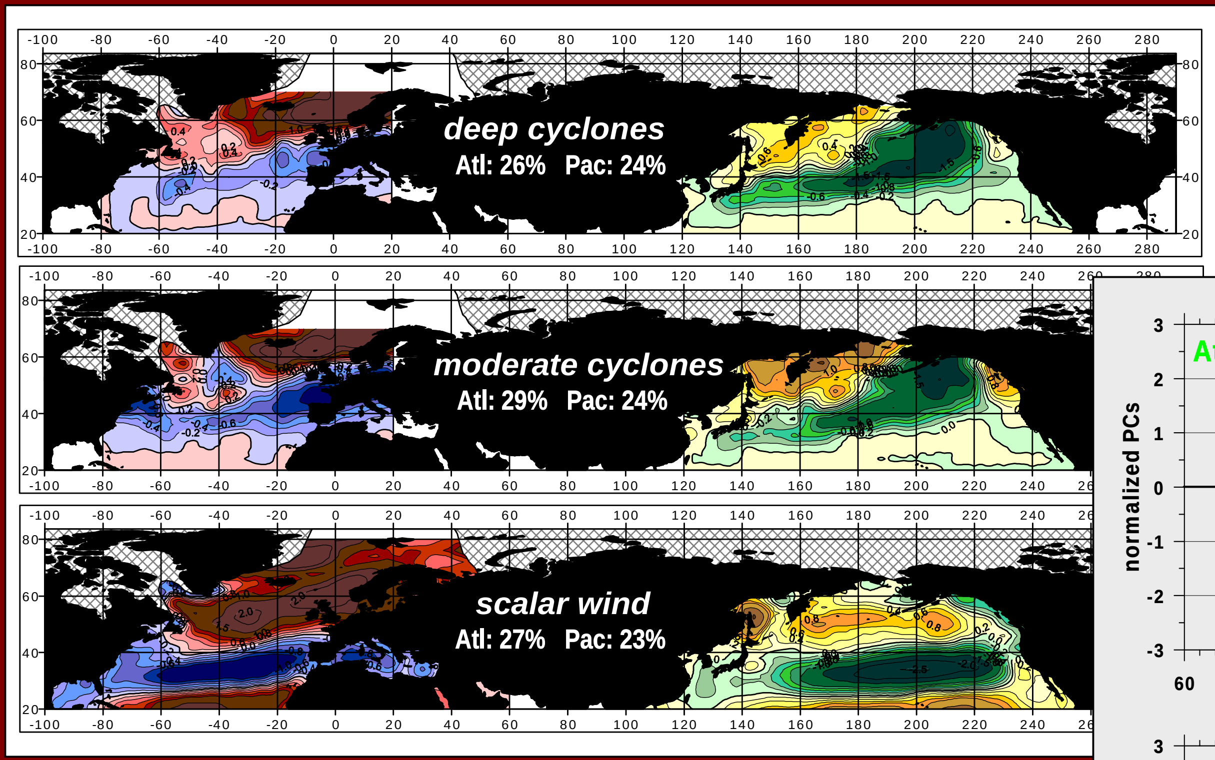
Rapidly moving (40-60 km/h)

Shallow (>1000 hPa)

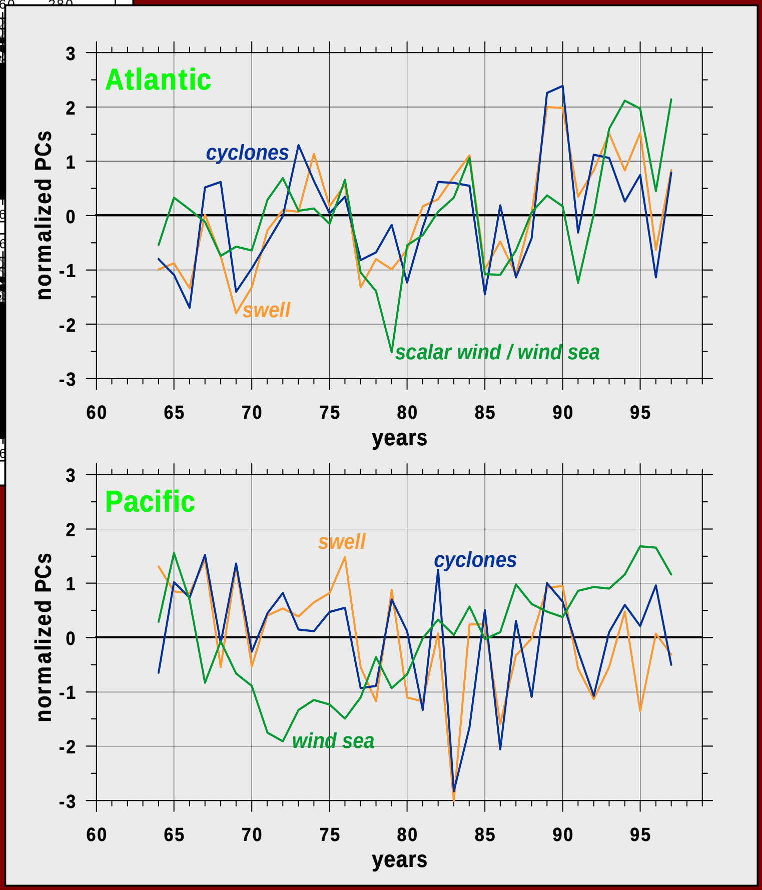


Intense (<980 hPa)

Interannual variability of cyclone frequency and scalar wind 1st EOFs

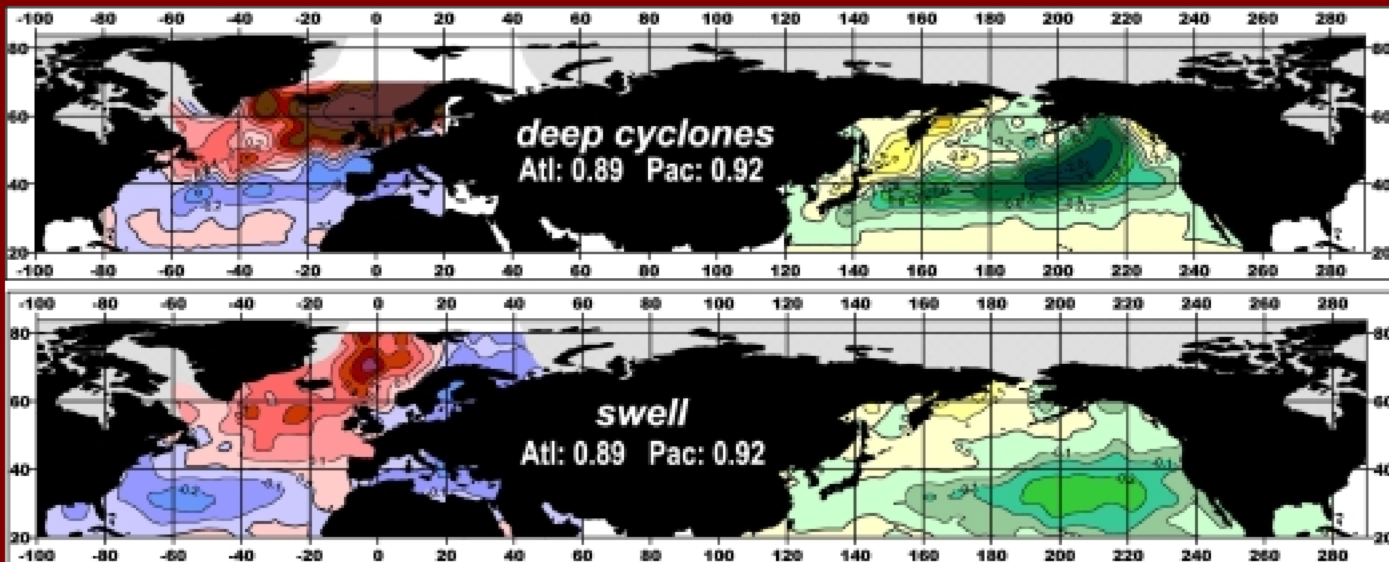


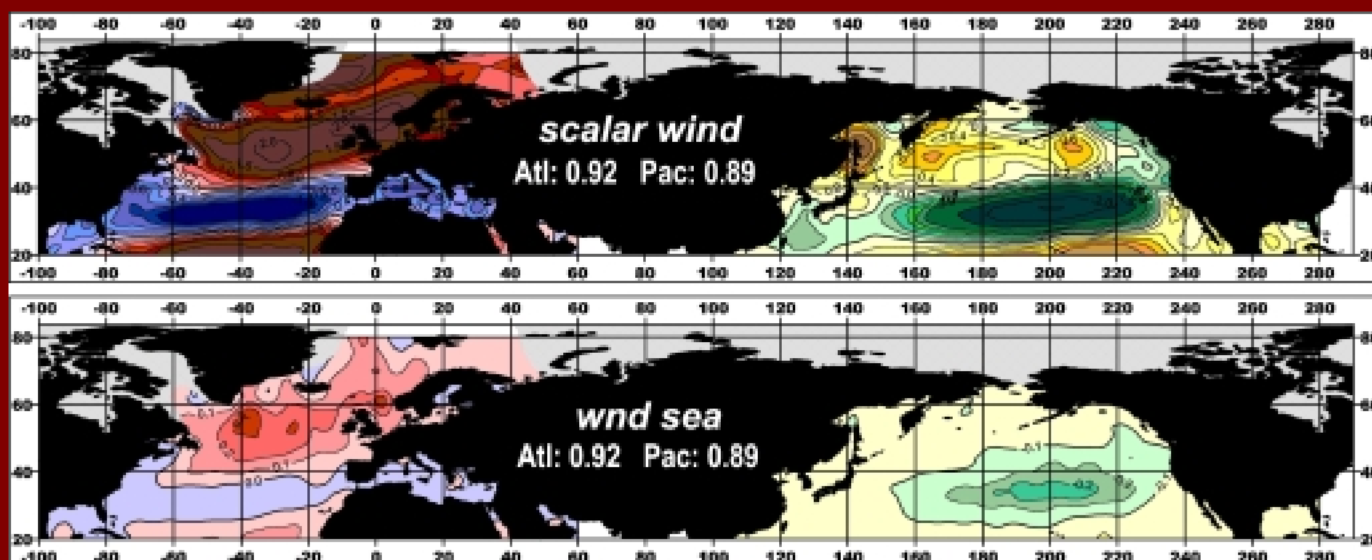
1st EOFs



Normalized PCs

Canonical patterns

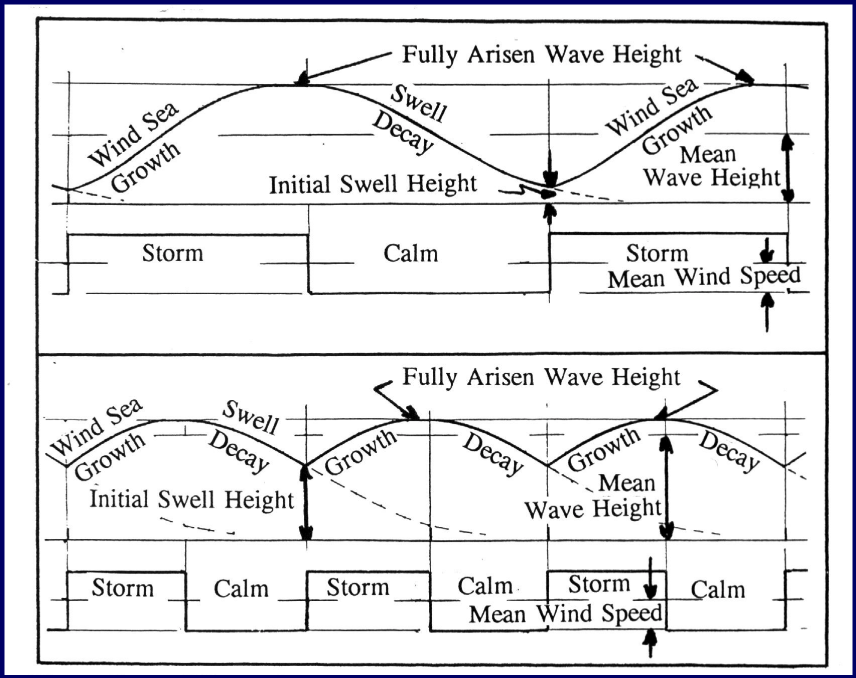


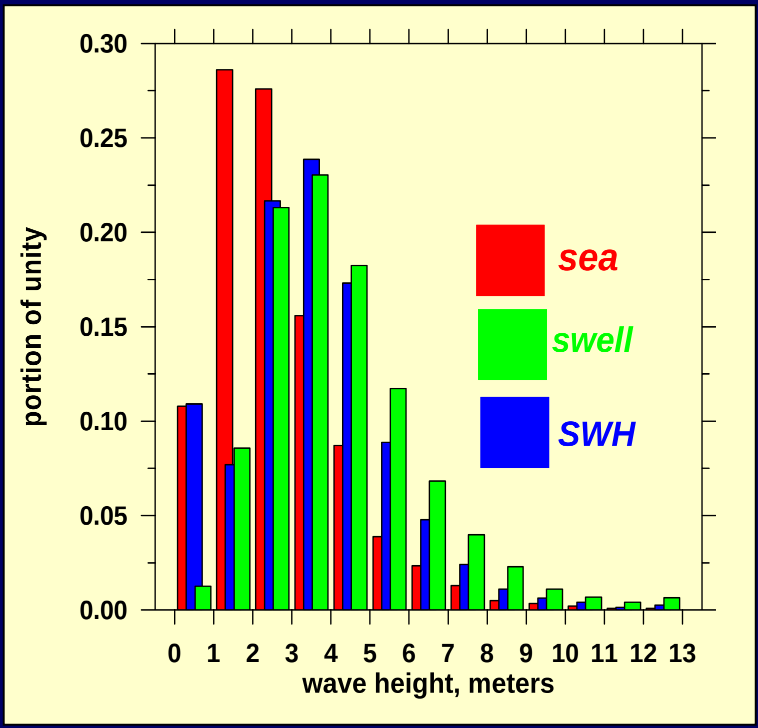


How can swell change differently from wind sea and scalar wind?

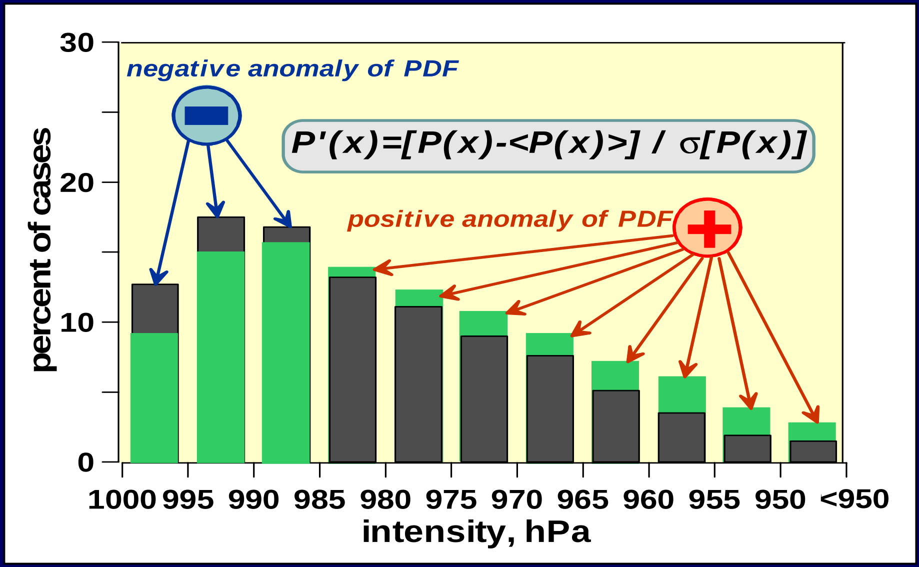
A hypothetical mechanism of Hogben (1995): the role of not fully decayed swell.

Bauer et al. (1999): no manifestation of this mechanisms in the WAM run with doubled frequency of the wind forcing.

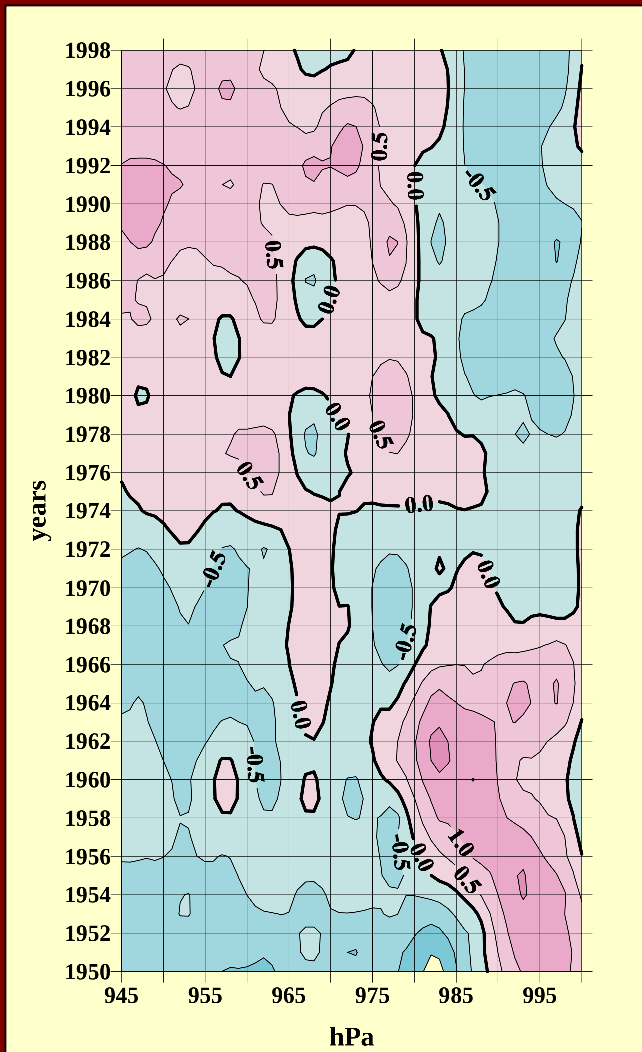


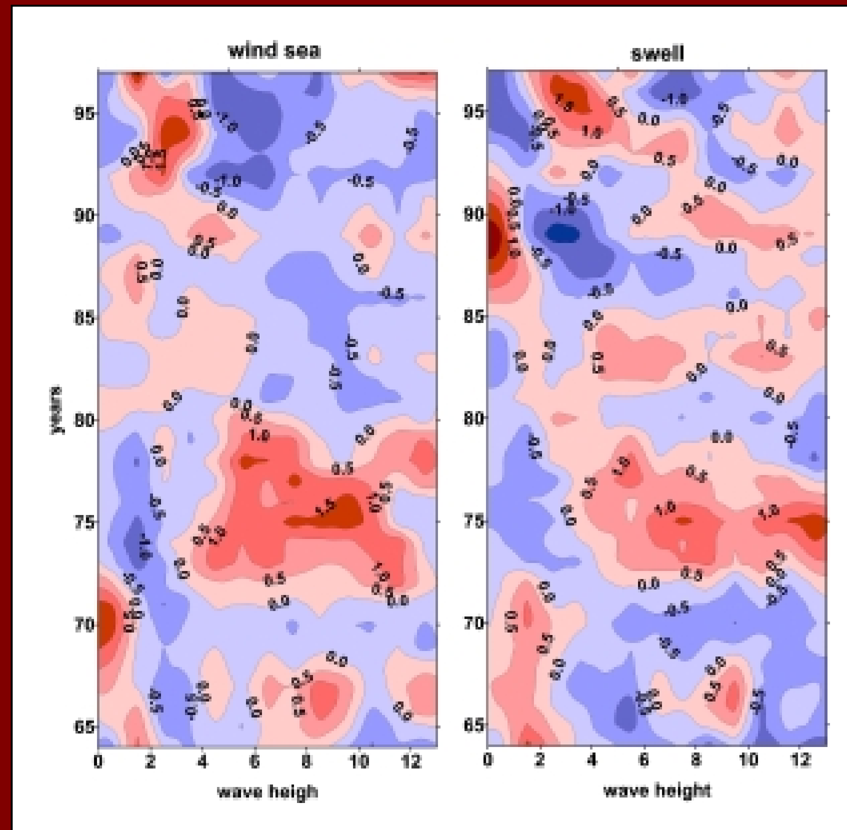


Evaluation of occurrence anomalies

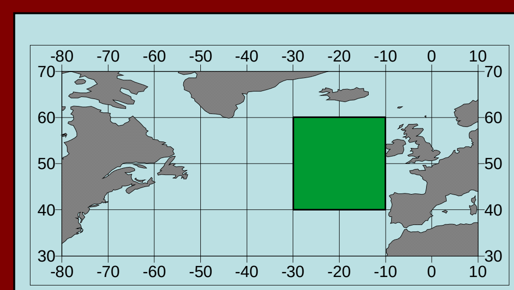


Changes in statistical properties of sea, swell, SWH and cyclone intensity

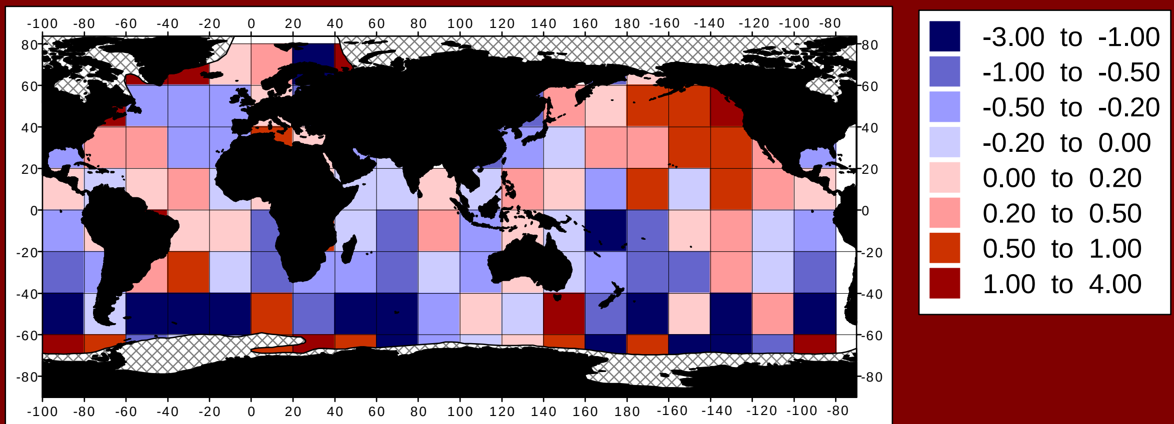




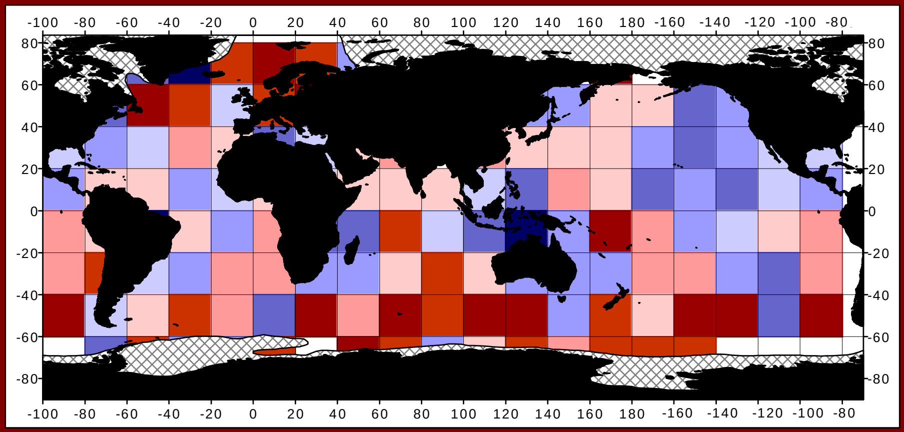
Cyclone frequency: NE Atlantic



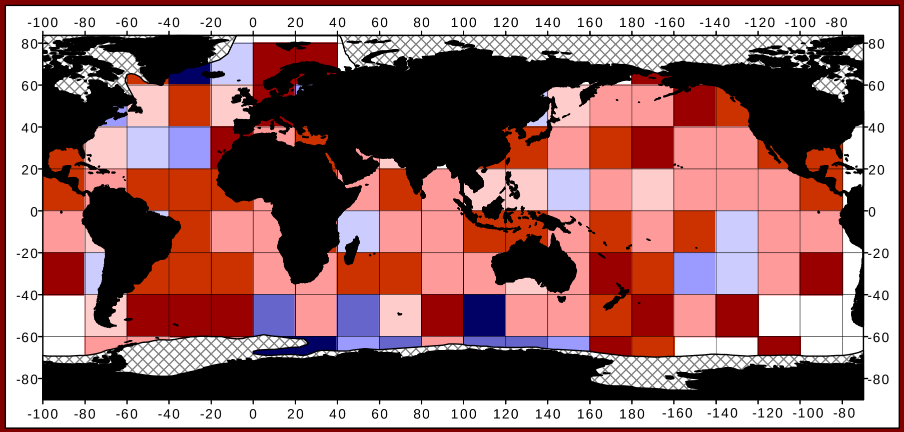
Changes in extreme wave heights: 100-yr returns



Winter 100-yr SWH difference between the best estimates from 1980s and 1970s

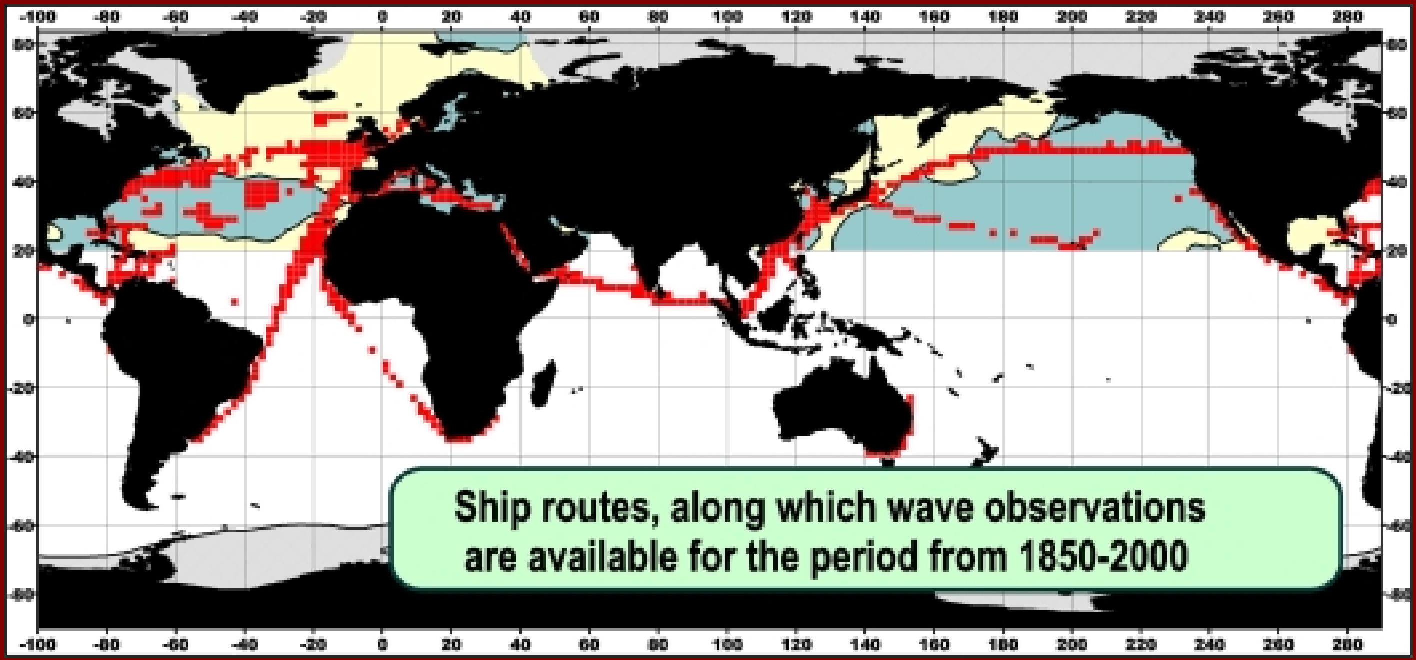


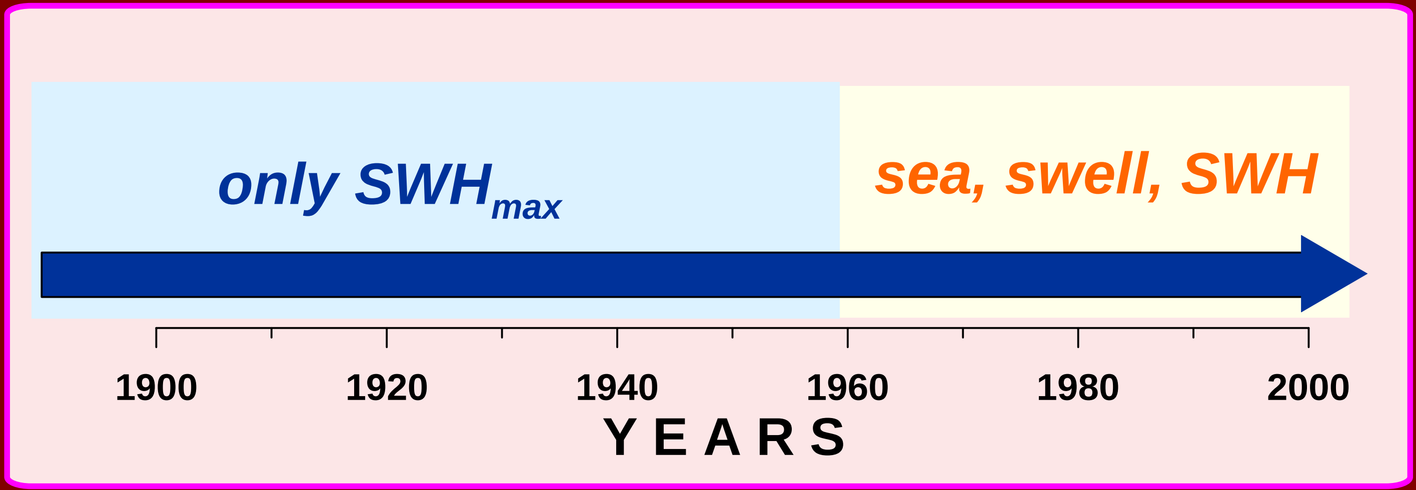
Winter 100-yr SWH difference between the best estimates from 1990s and 1980s



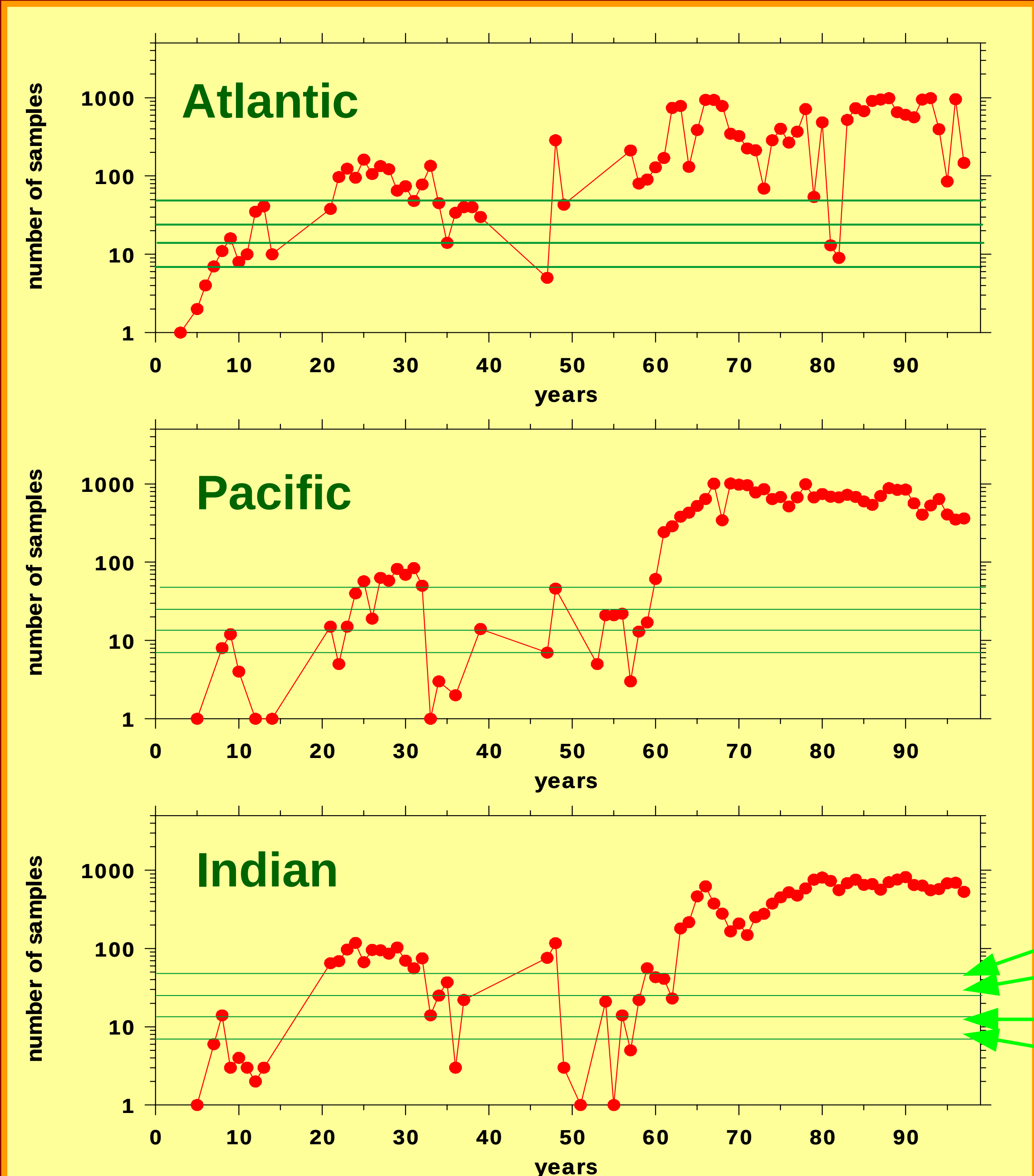
Winter 100-yr SWH difference between the best estimates from 1990s and 1960s

Very long-term changes





Homogenezation of sampling in 100-yr series



Sub-sampling of VOS wave reports along the ship route for fixed number of observations

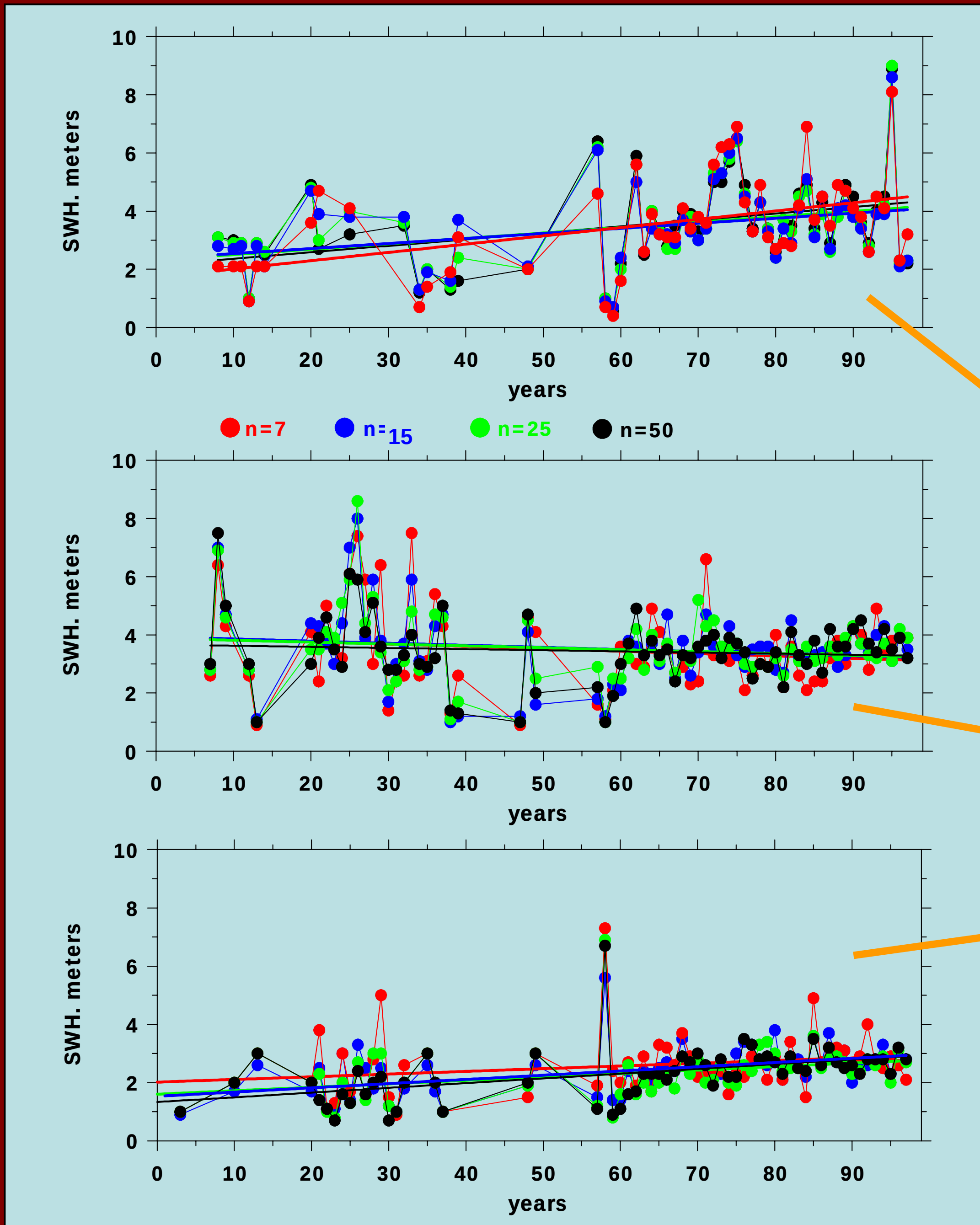
Per month per 2°x 2° box:

50 samples

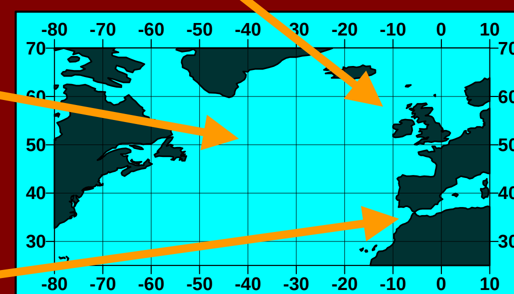
25 samples

15 samples

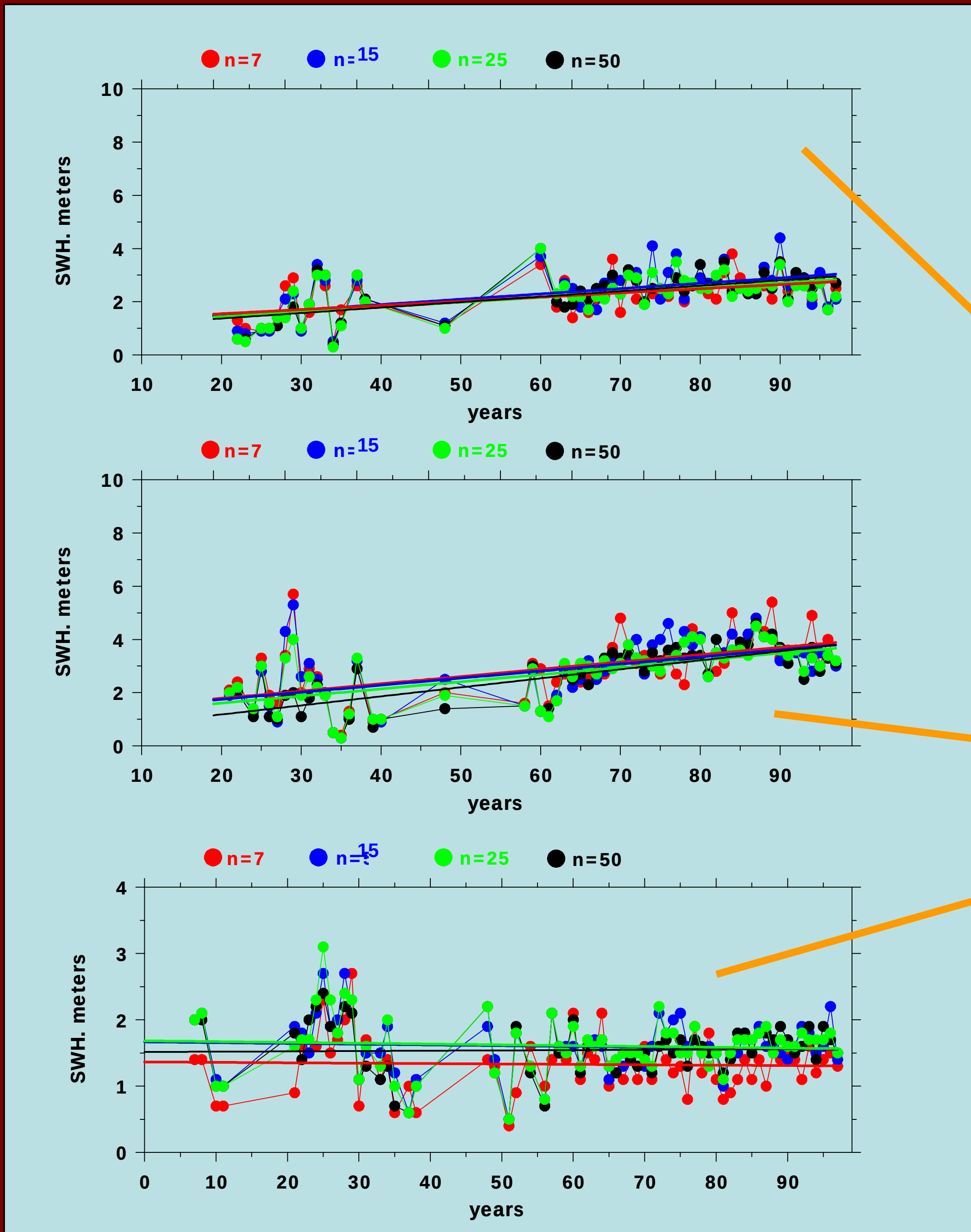
7 samples



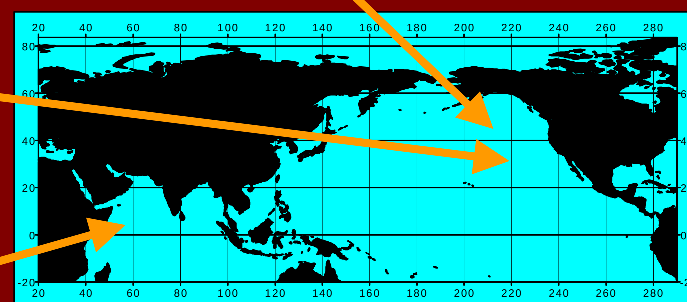
Very long-term changes: consistency of tendencies for different sampling density



North Atlantic



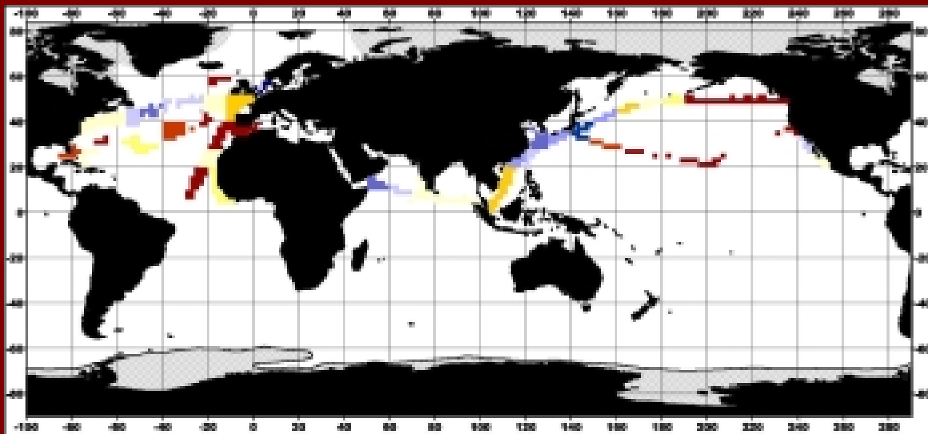
Very long-term changes: consistency of tendencies for different sampling density



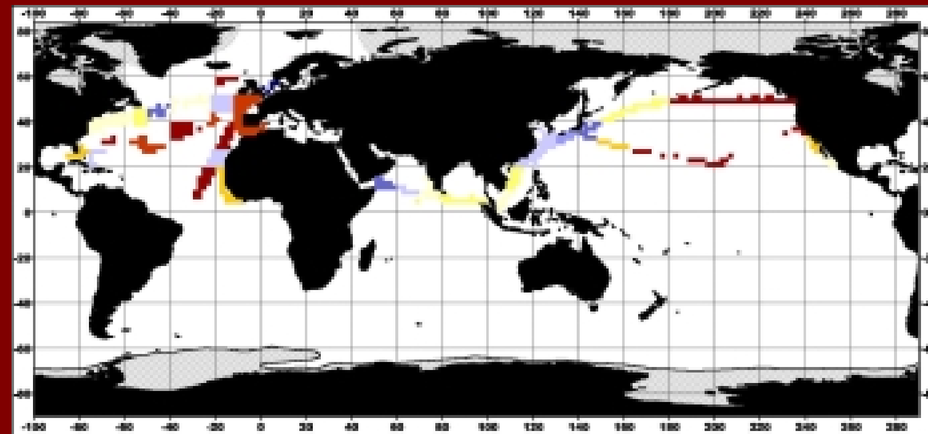
North Pacific and Indian

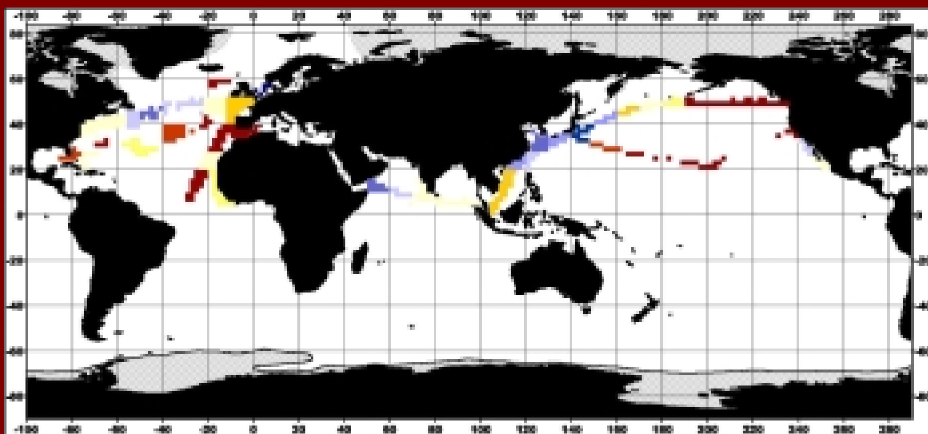
Very long-term changes: linear trends

N=7

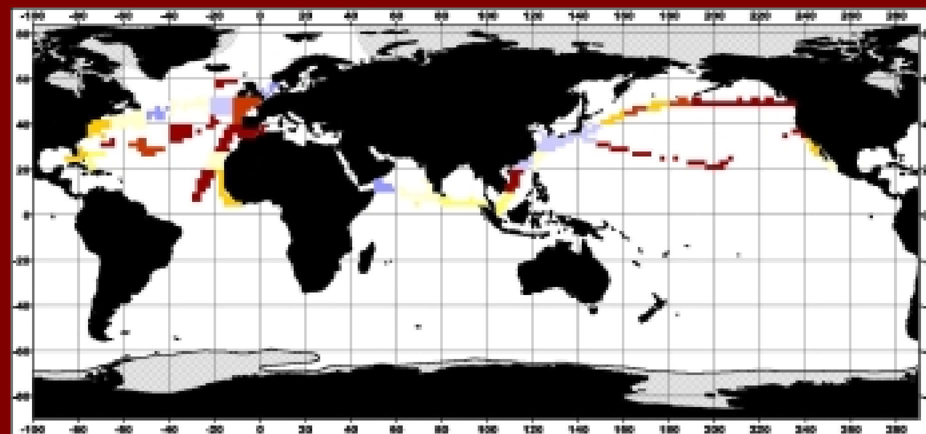


N=15



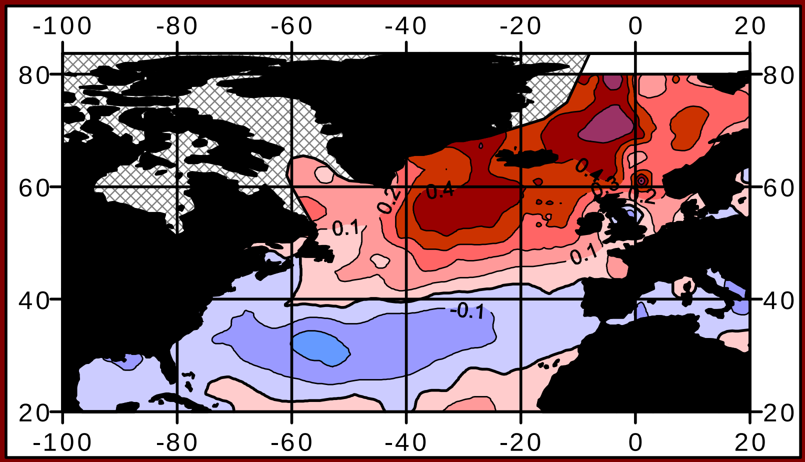


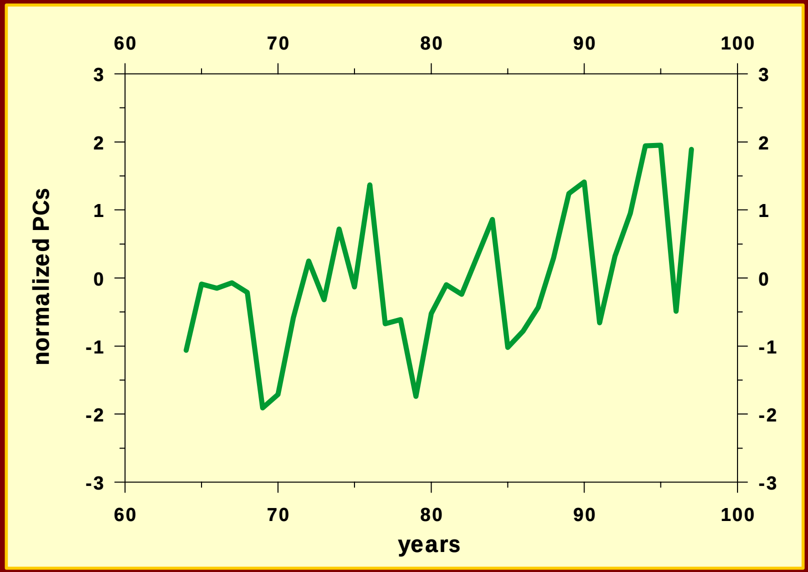
N=25

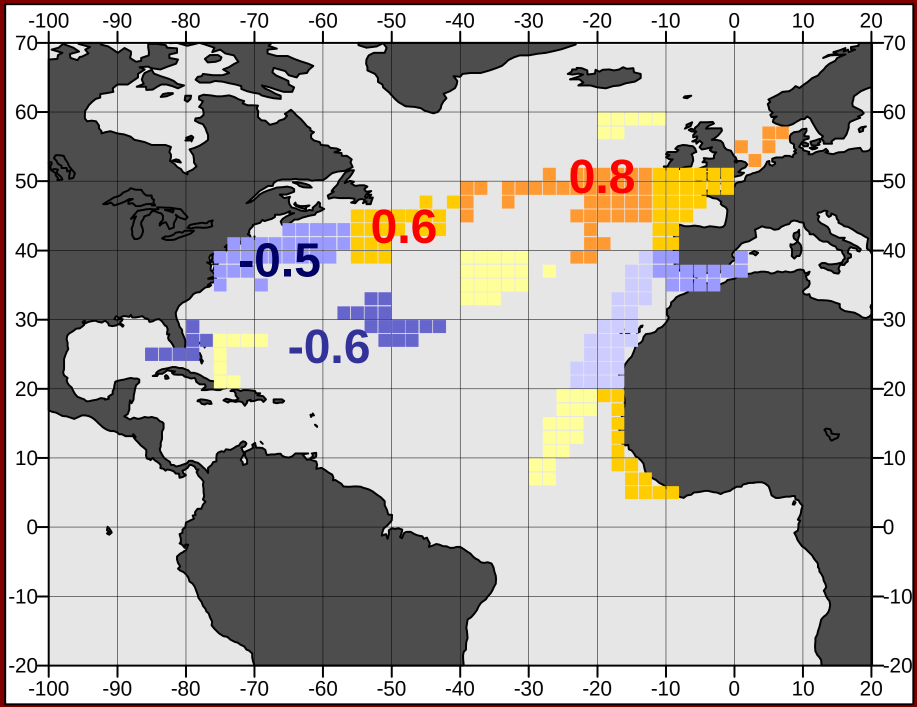


N=50

Consistency for the period 1958-1997: winter projection







Conclusions:

- *Visual wave observations provide reliable information about long-term interannual variability of surface roughness and allow for the separate analysis of sea and swell changes.*
- *Wind sea and swell demonstrate different variability patterns in the Northern Hemisphere oceans*.
- *Wind sea is primarily driven by the local wind, while swell is influenced to a higher degree by forcing frequency (cyclone activity) than forcing magnitude, providing changes in SWH.*
- *Extreme wave statistics (100-yr returns) may experience considerable changes when estimated from different decades. Overall, they grow up by about 0.5-1m over 40-year period.*
- *Visual wave data allow for the analysis of centennial-scale variability of ocean wind wave characteristics: linear trends in the North Atlantic and North Pacific may amount to 1.6 m per century.*