Global Trends in Wind Speed and Wave Height

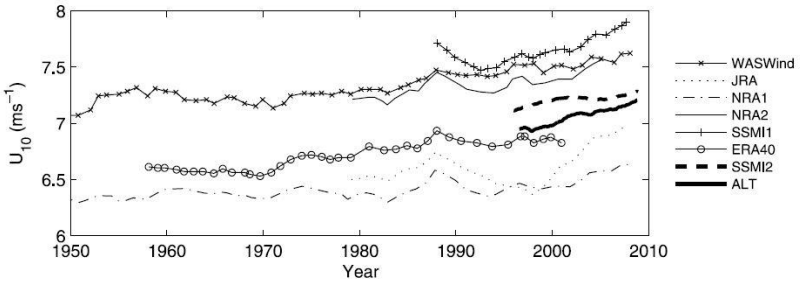
Ian Young and Agustinus Ribal

Motivation

- Evidence that over the last 30 years, there has been an increase in global values of wind speed and wave height
  - Model reanalysis
  - Satellite measurements
  - Buoy measurements

- But magnitude of these trend estimates vary significantly

- Models – updates, limitations of physics
- Satellite – multiple missions
- Buoys – replacement etc
- Trends are small!



Approach

- Build a long term multi-mission satellite database
- Calibrate all instruments consistently
- Cross validate between instruments

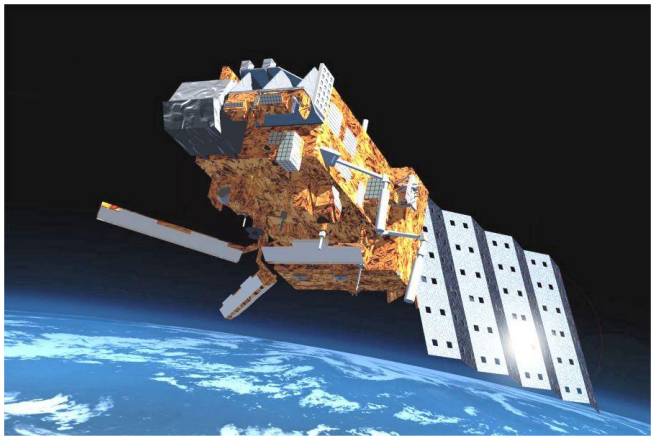
- Investigate
  - Climatology
  - Extremes
  - **Trends**

Period of data coverage

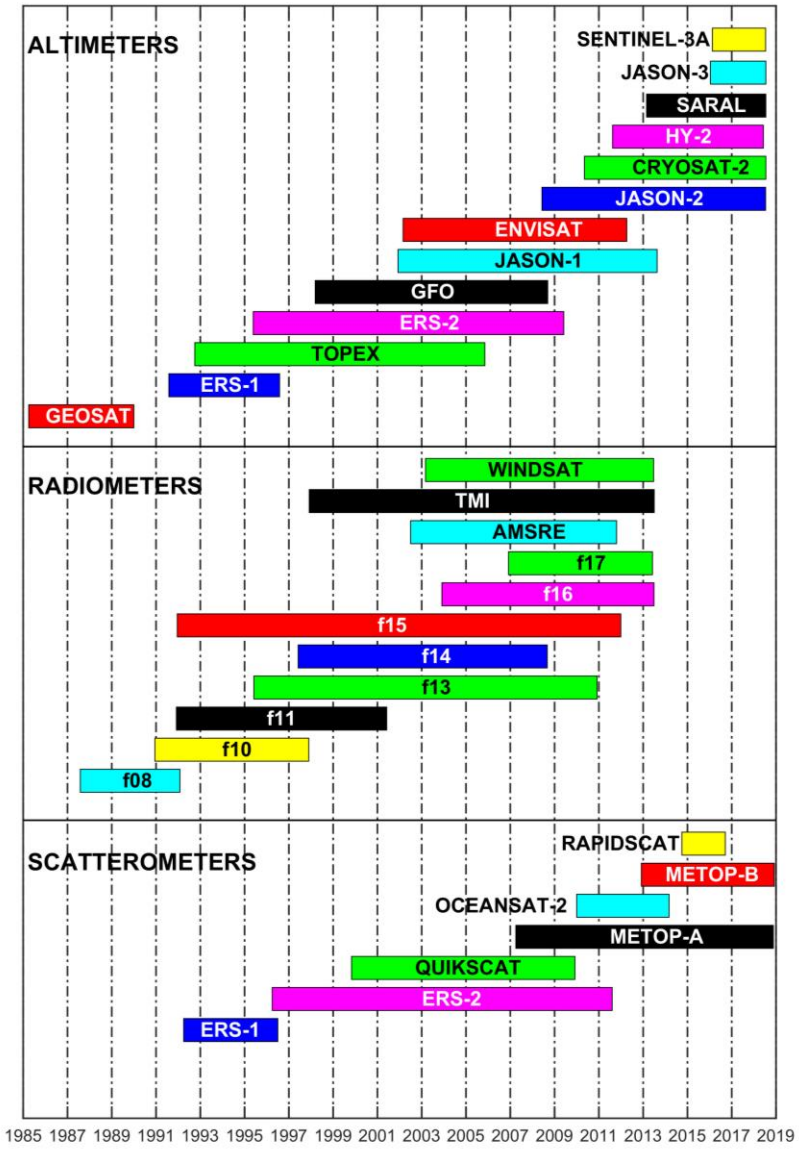
Combined dataset over 33 years

- Altimeters (H_s & U_{10})
- Radiometers (U_{10})
- Scatterometers (U_{10})

- 31 satellites
- 4 billion observations of H_s & U_{10}



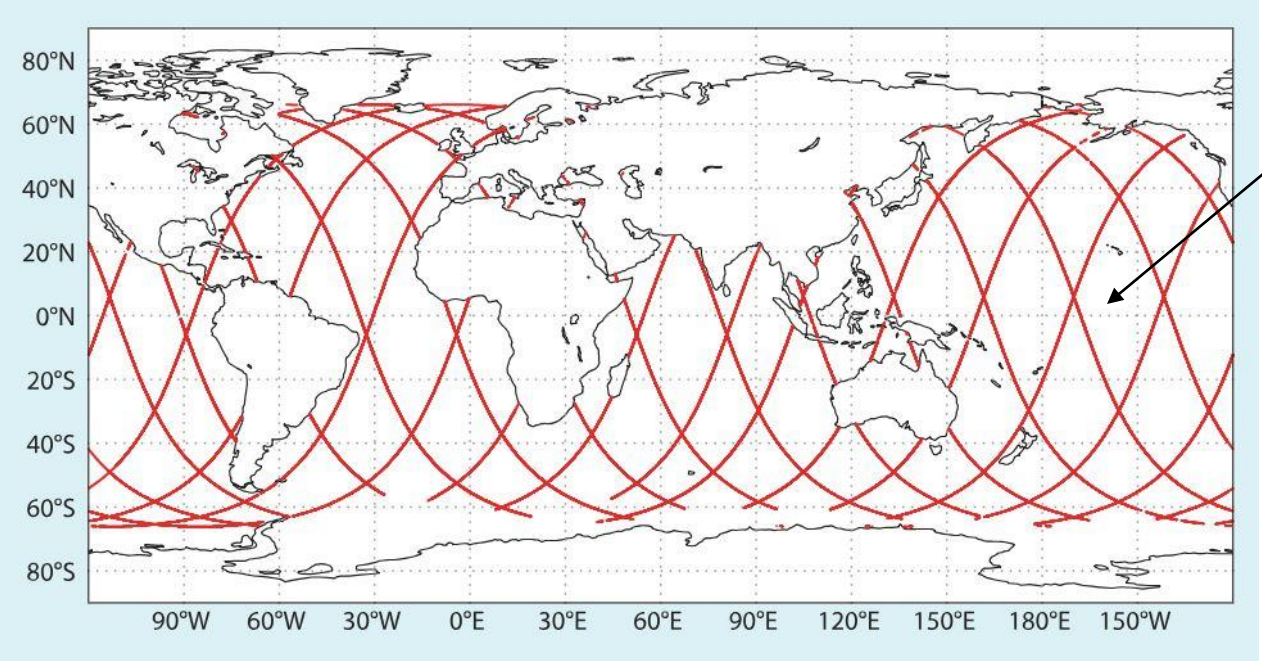
METOP-A



Ribal & Young, 2019, *Sci. Data*.

Satellite data coverage (1-day)

Satellite Data Coverage – Altimeter (JASON-3)

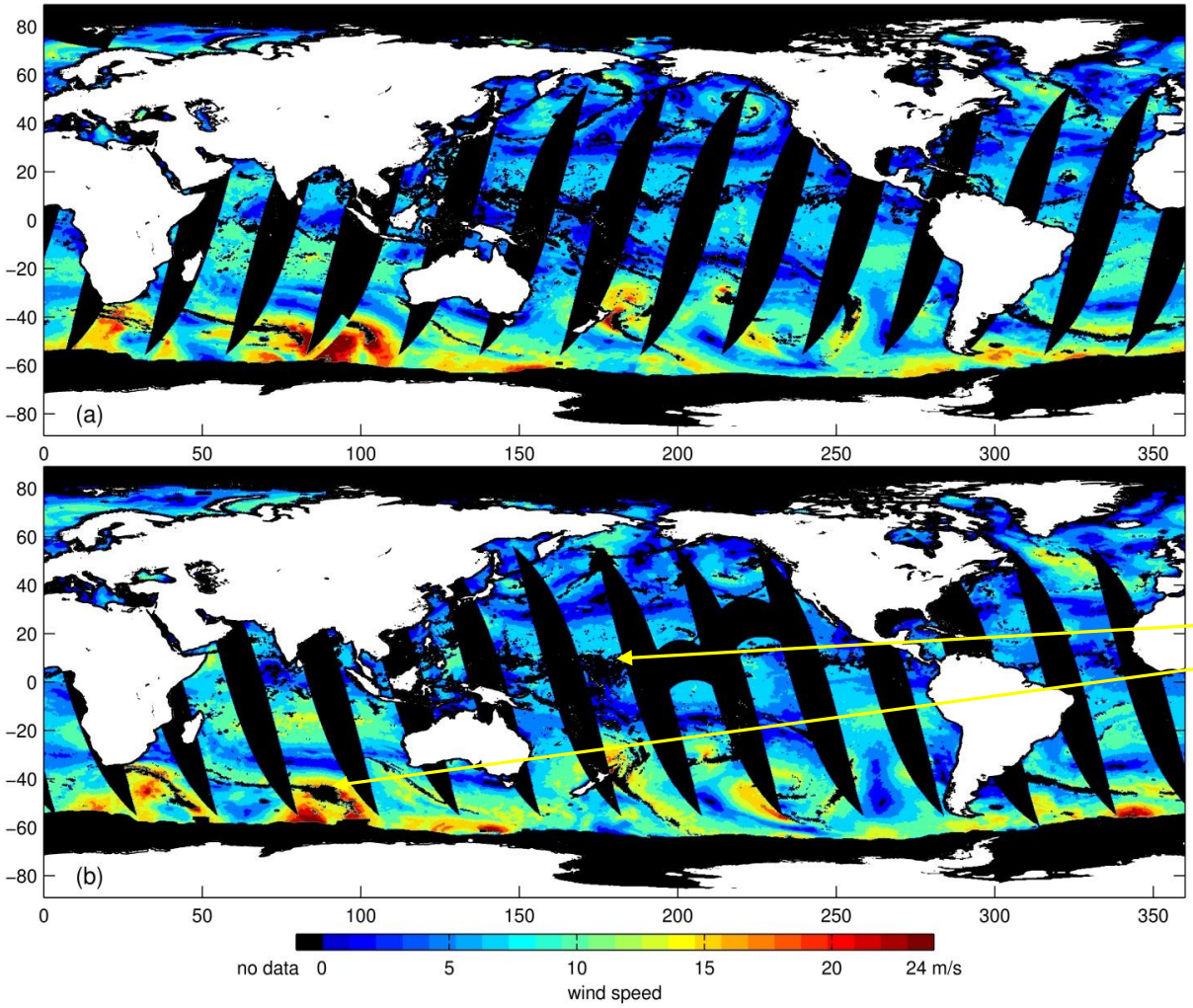


Poor cross-track resolution

JASON-3

Satellite data coverage (1-day)

Satellite Data Coverage – Radiometer/Scatterometer

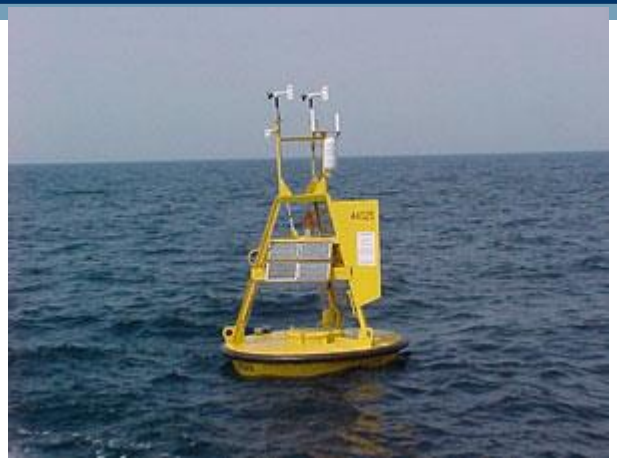


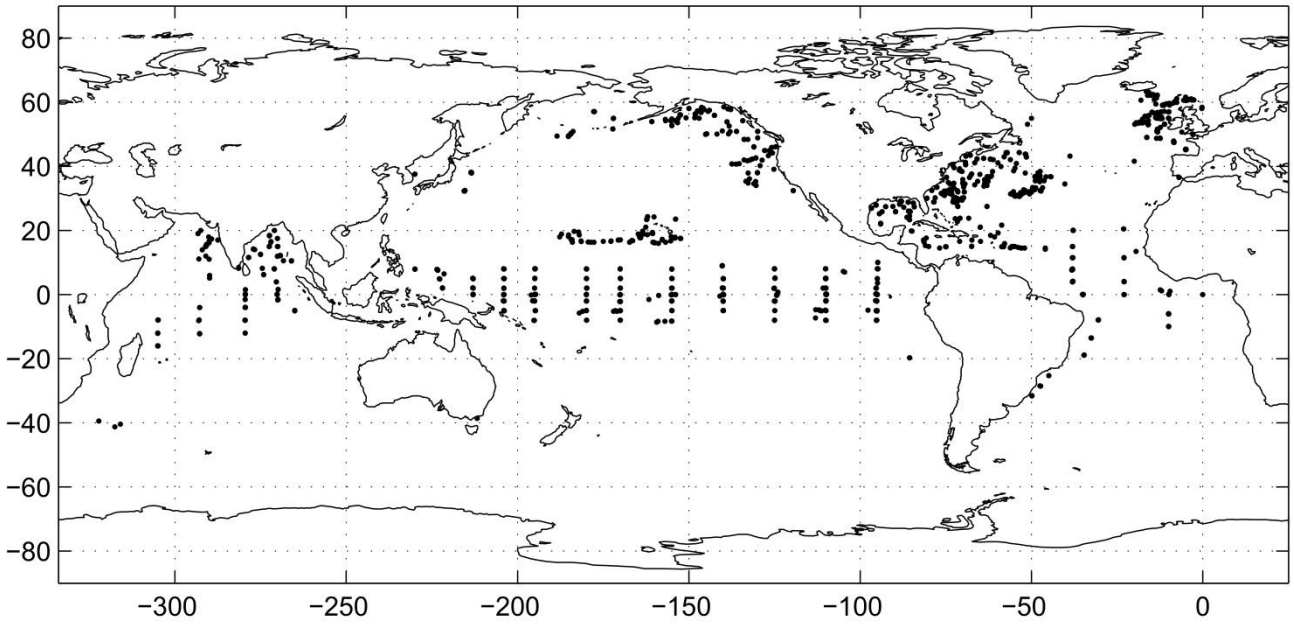
Data “holes” under rain for radiometers

Insitu calibration buoys

Two data sets

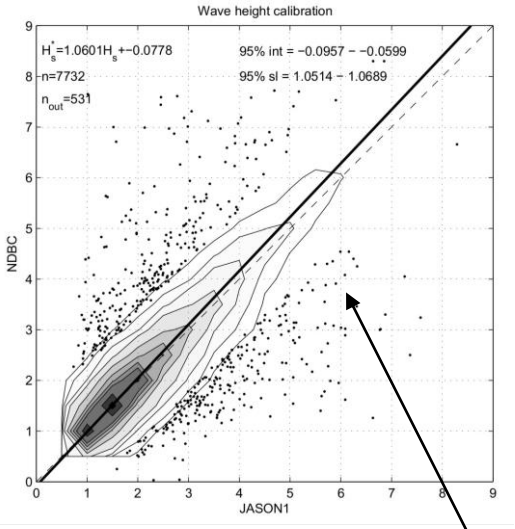
- NDBC
- ECMWF composite data



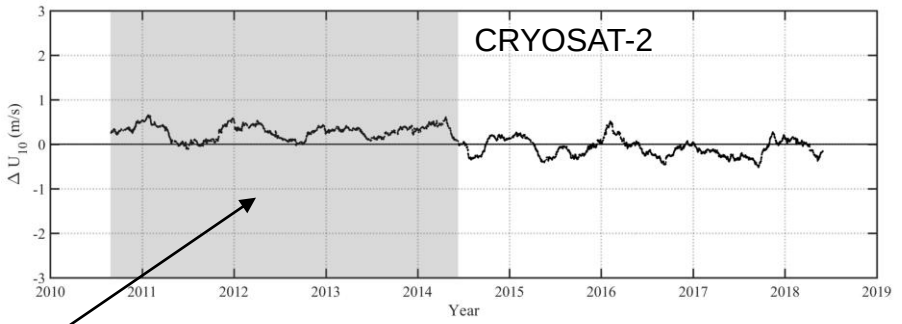


Calibration and validation

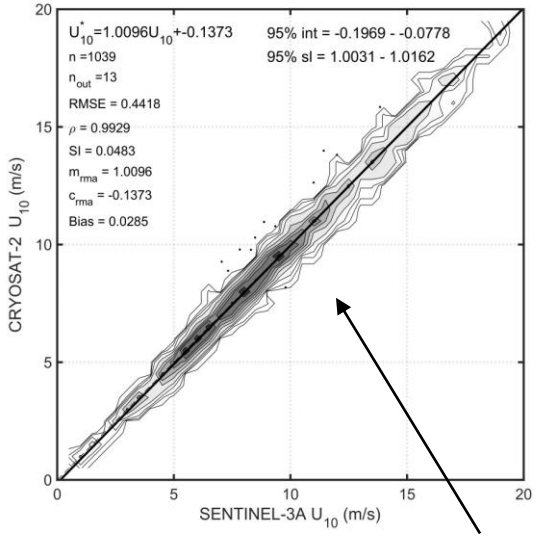
Matchups – 50km and 30 mins.



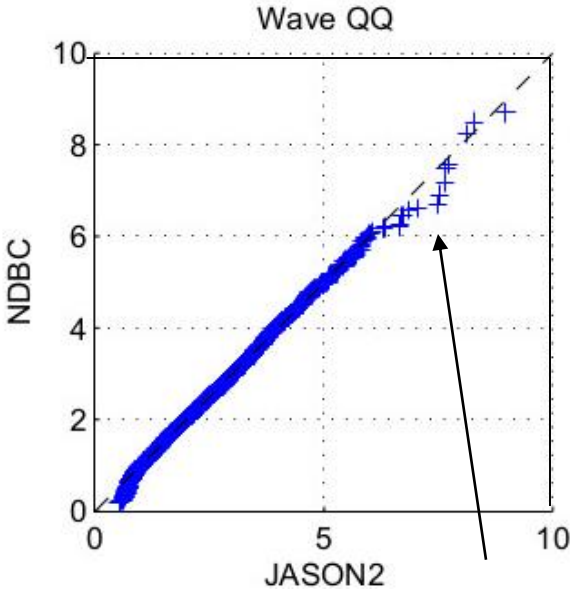
Calibrate against buoys



Consistency over time



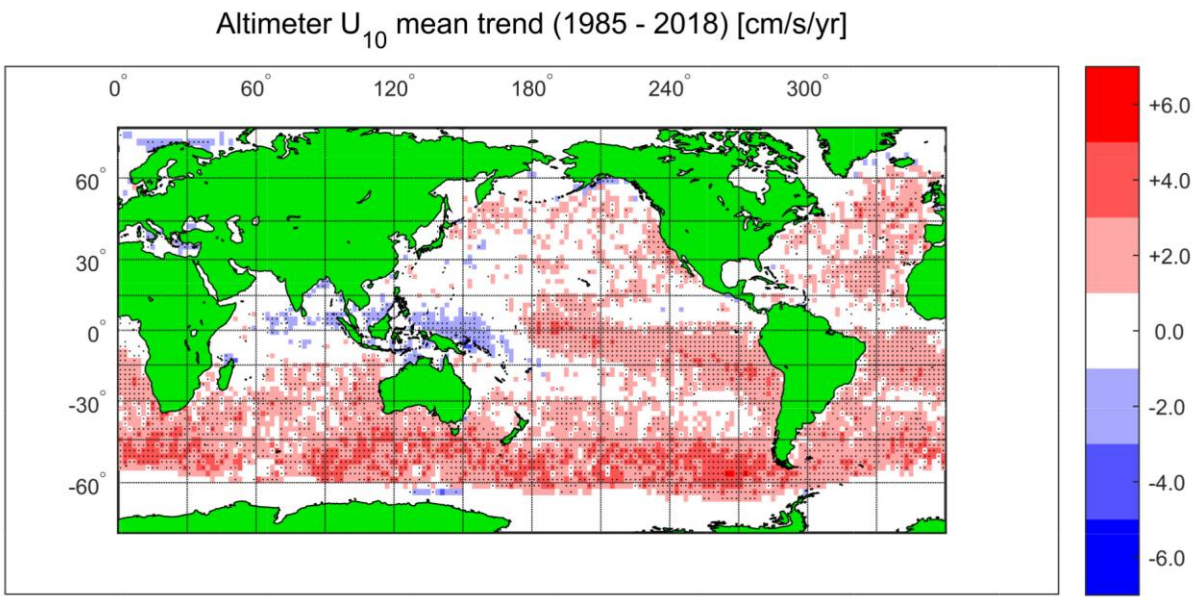
Cross-validate between missions



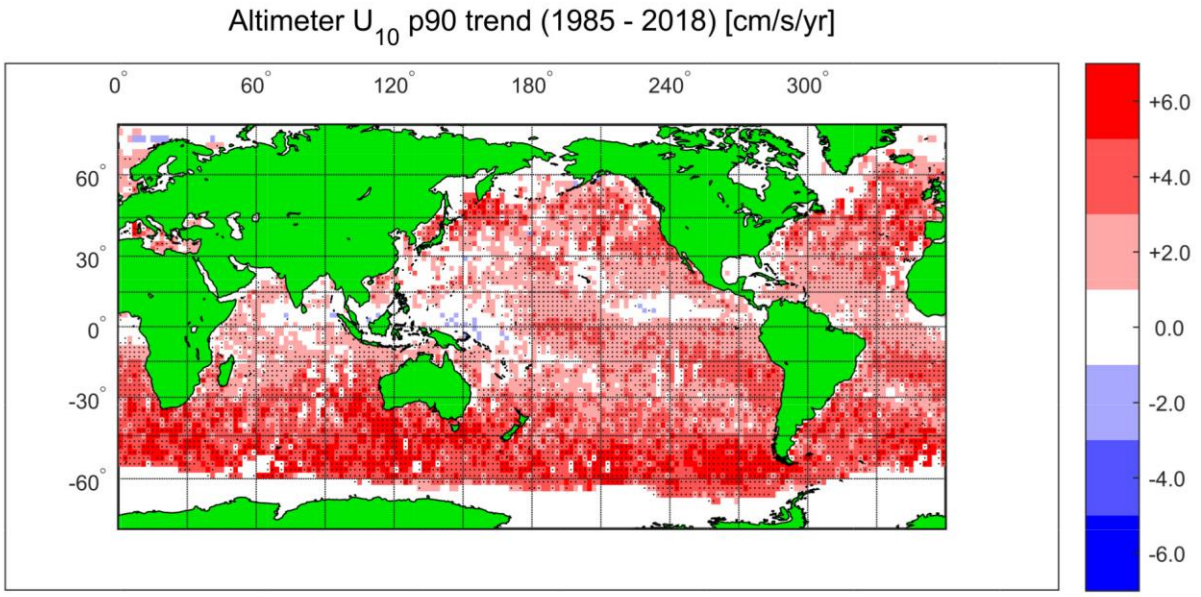
Extreme performance

Young et al., 2017, *JTech*; Ribal & Young, 2019, *Sci. Data*.

Wind speed trends - Altimeter

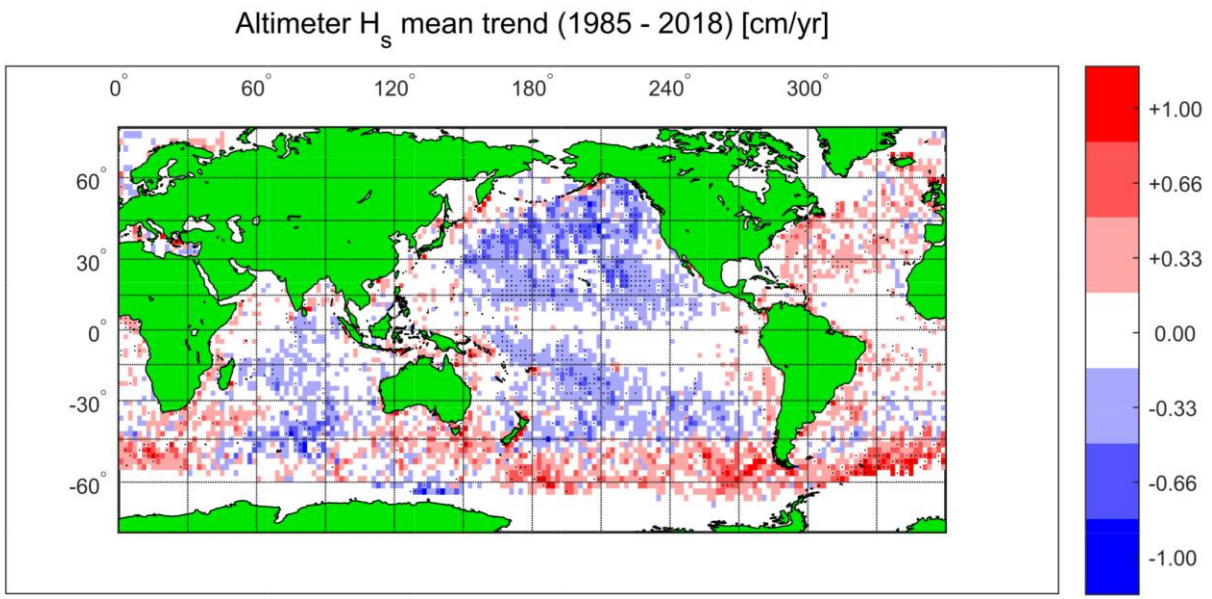


Mean

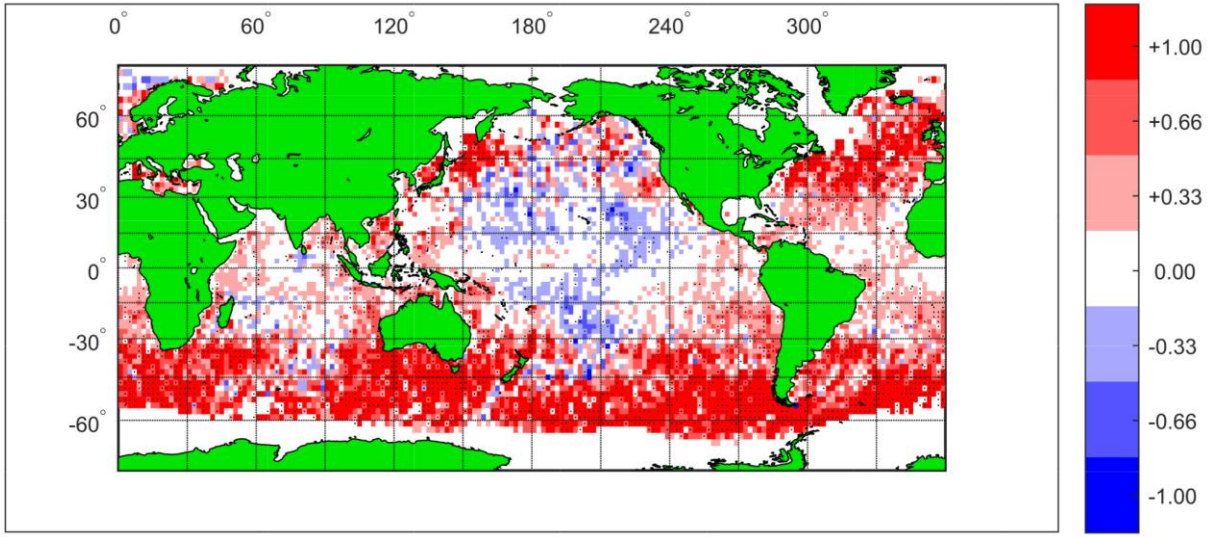


90th percentile

Significant wave height trend - Altimeter



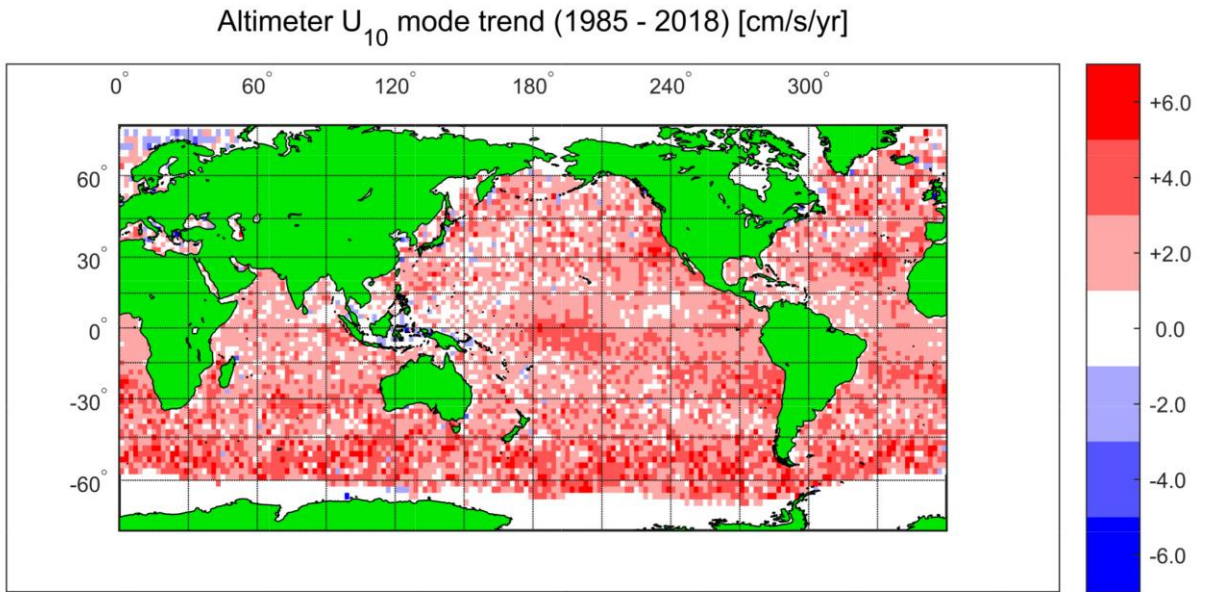
Mean



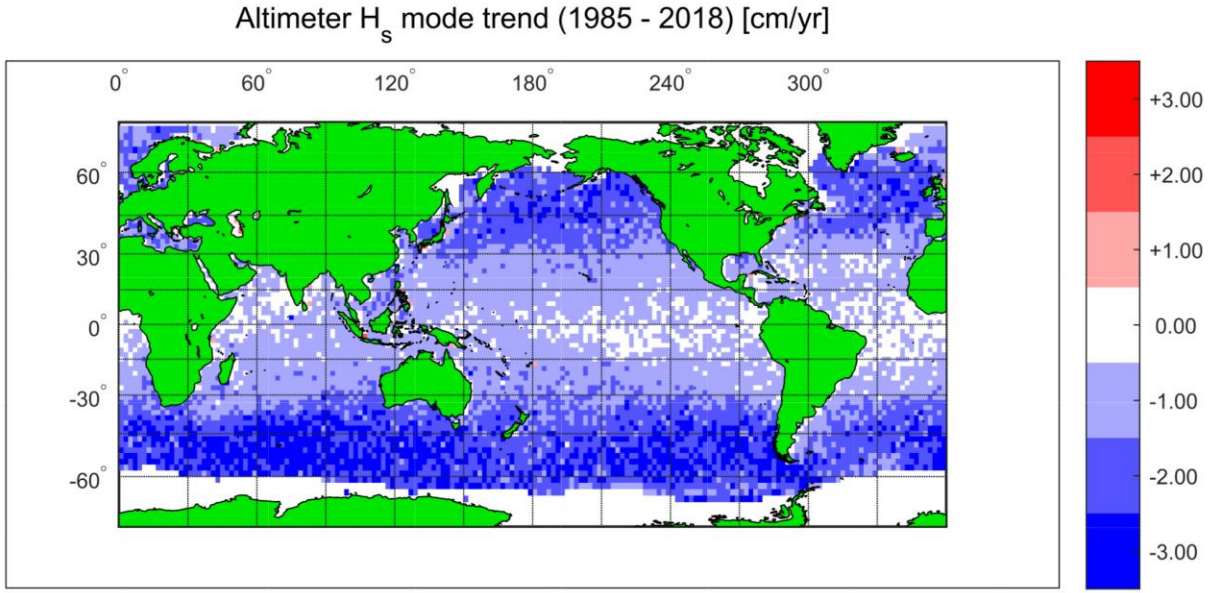
90th percentile

Why is the wind speed trend larger than the wave height trend? For fully-developed conditions $H_s \sim U_{10}^2$

Mode trends H_s and U_{10} - Altimeter

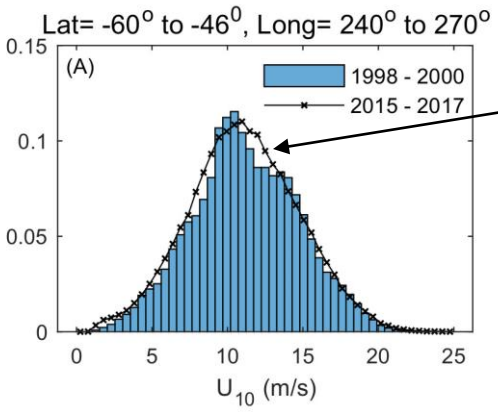


U_{10} mode
- like mean

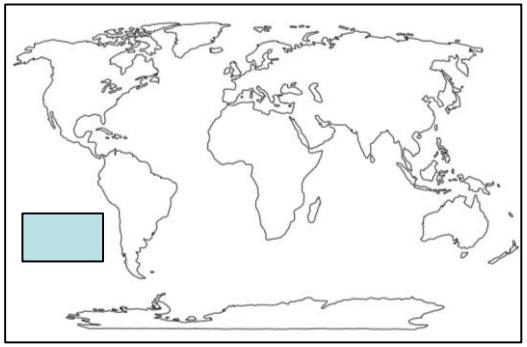


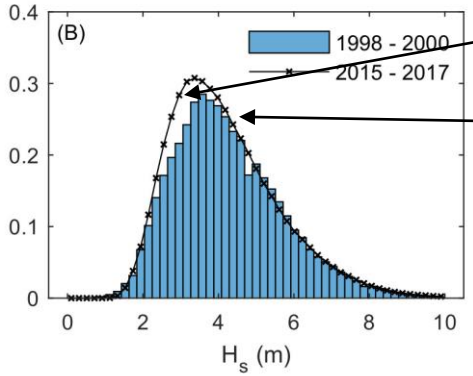
H_s mode
- very different to mean!

Changes in PDFs - Altimeter



Broadening of U_{10} PDF





Responds to broadening of U_{10} PDF

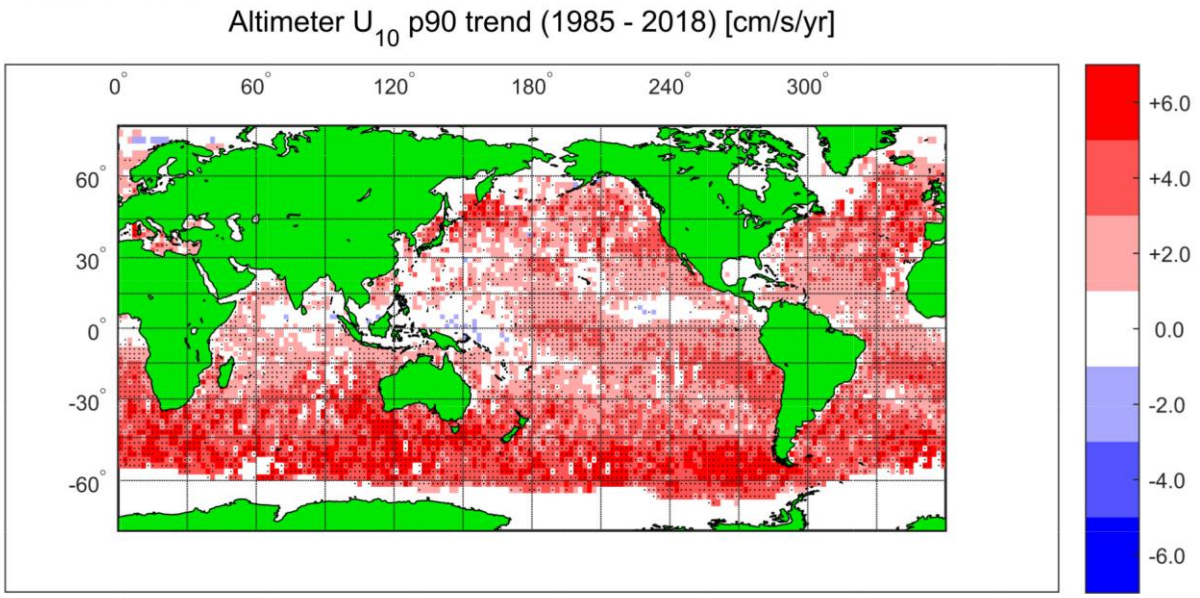
No response to broadening of U_{10} PDF

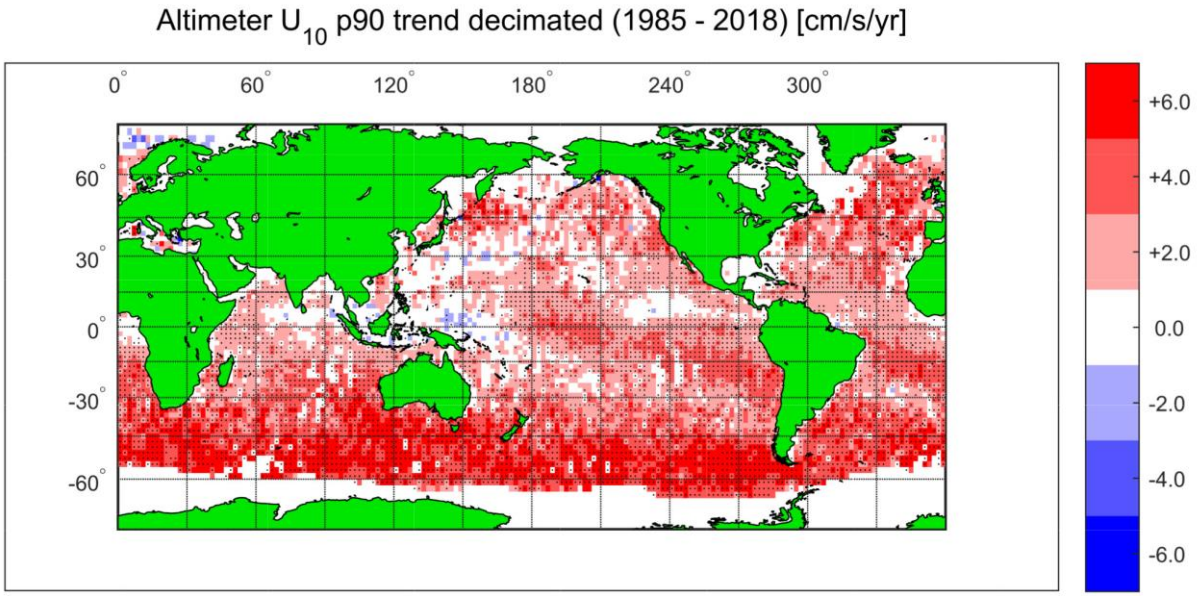
Speculate that the wind duration is not sufficient

Time required to reach full development

U_{10} (m/s)	t (hrs)
5	9
10	17
15	26

How robust are altimeter 90th percentile trends?

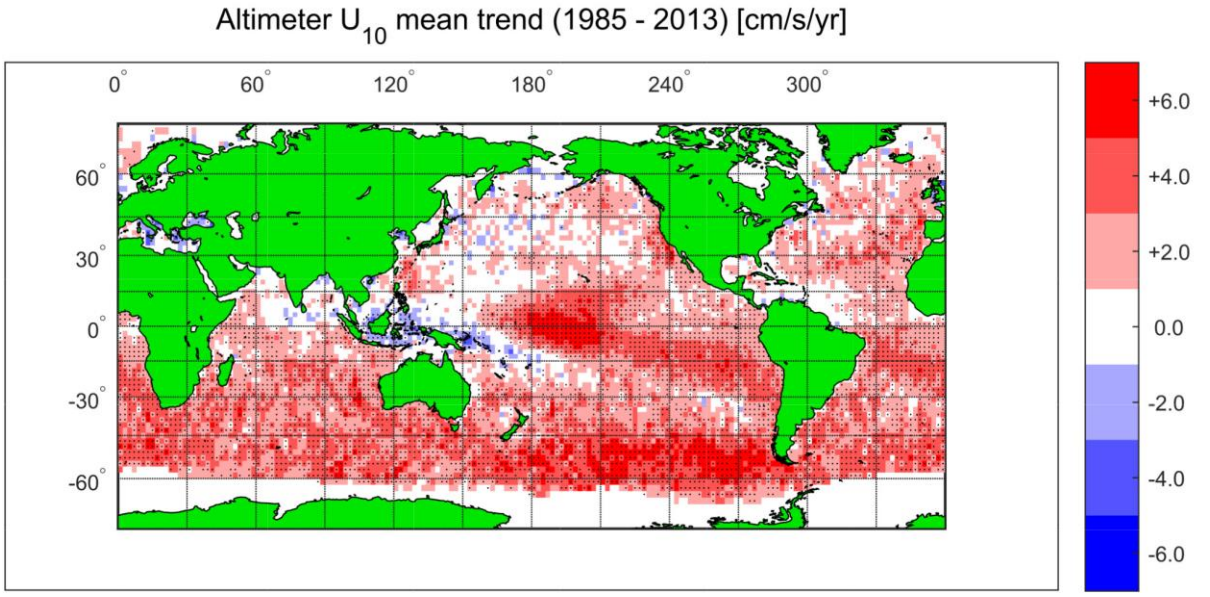




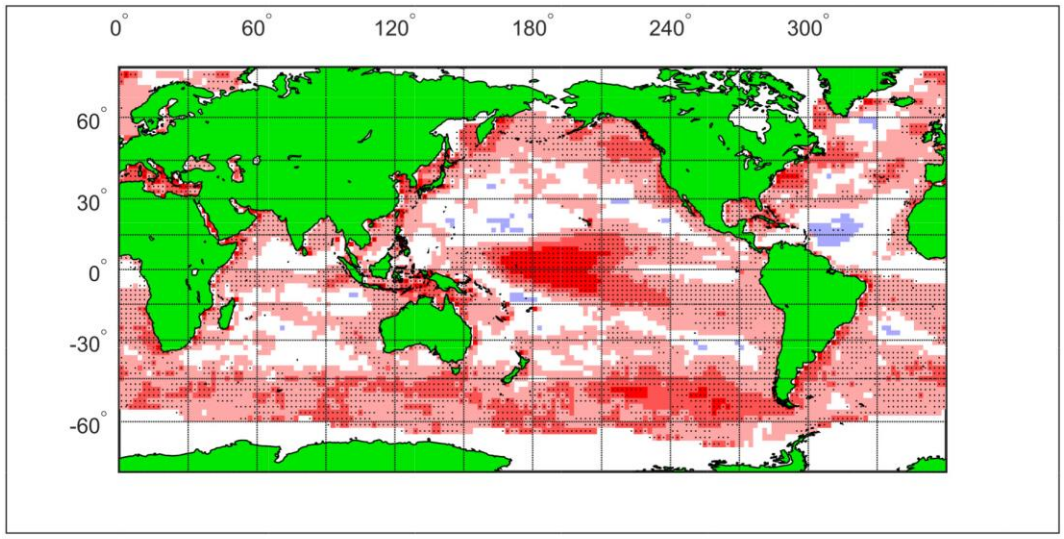
Trend from monthly 90th percentiles

Trend with satellites removed to give approx. constant density with time

Compare with radiometer mean U_{10} trend

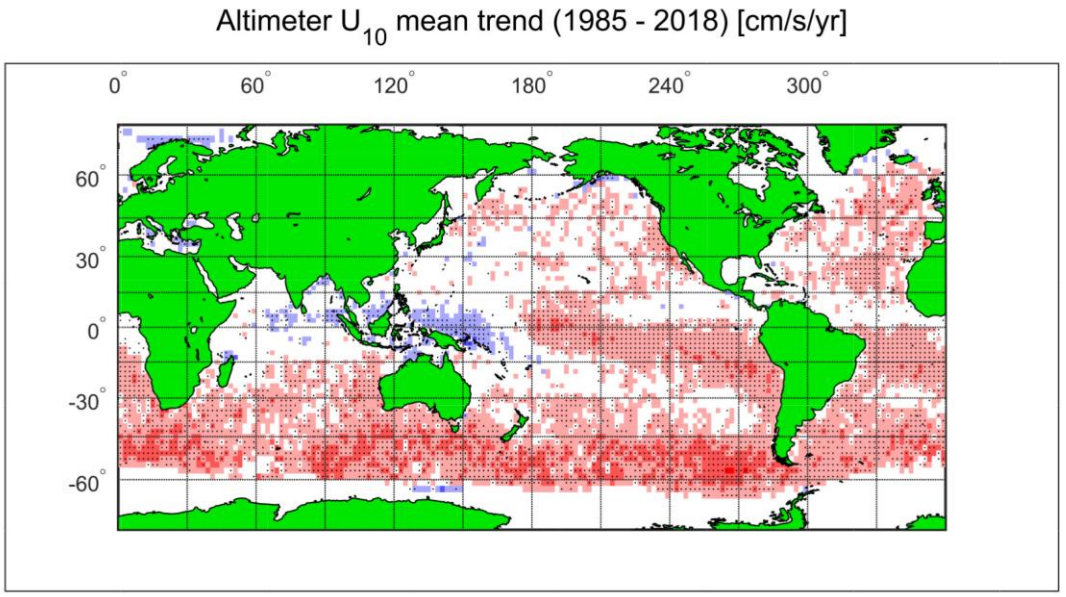


Altimeter

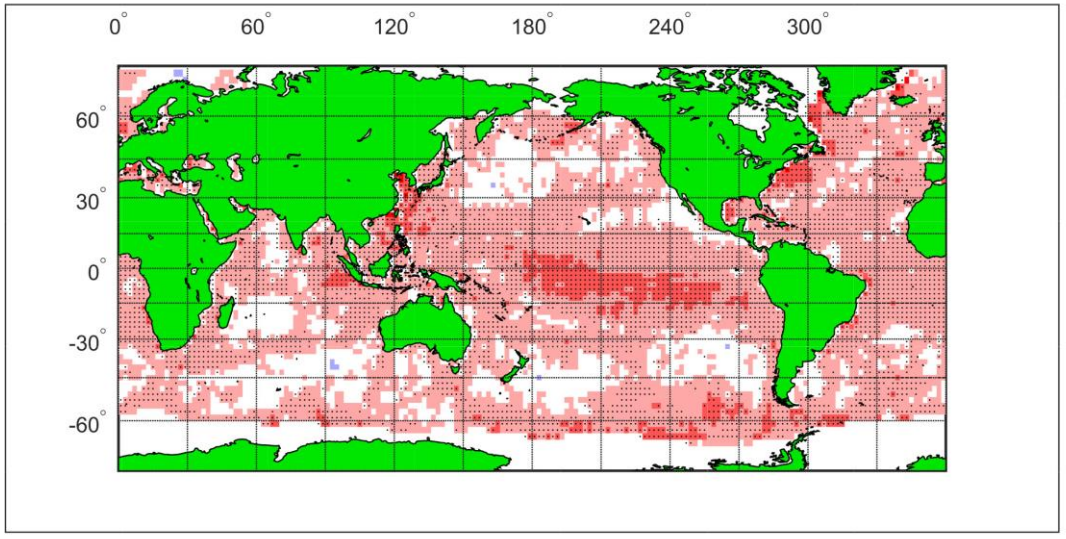


Radiometer

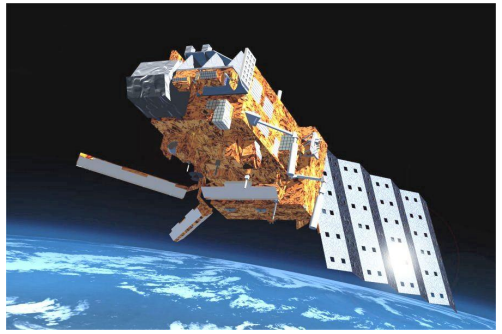
Compare with scatterometer mean U_{10} trend



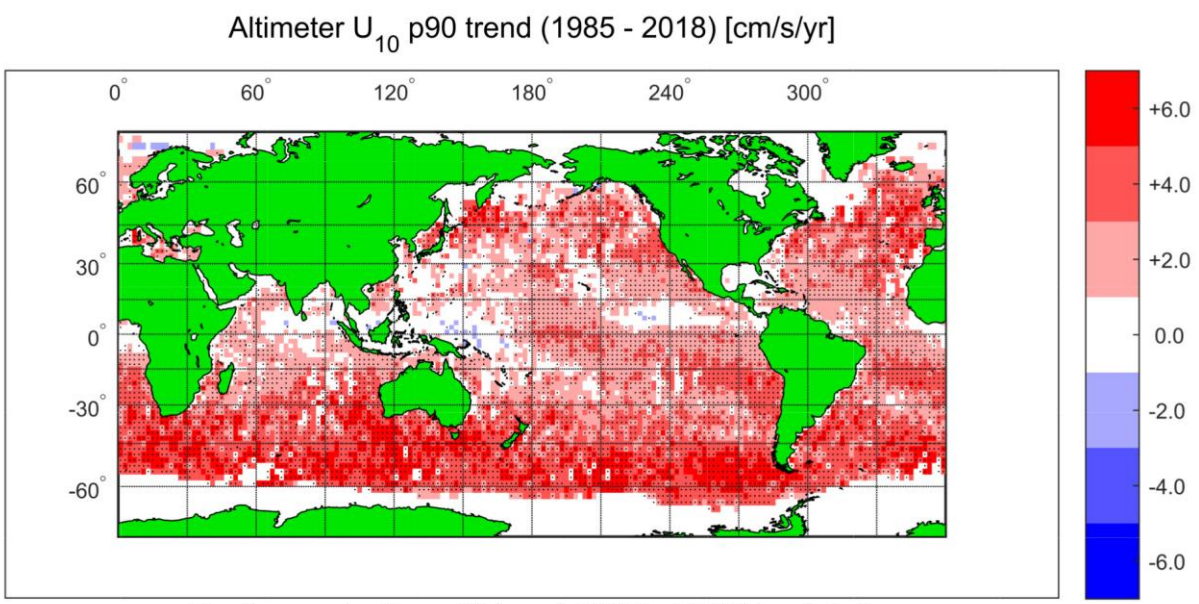
Altimeter



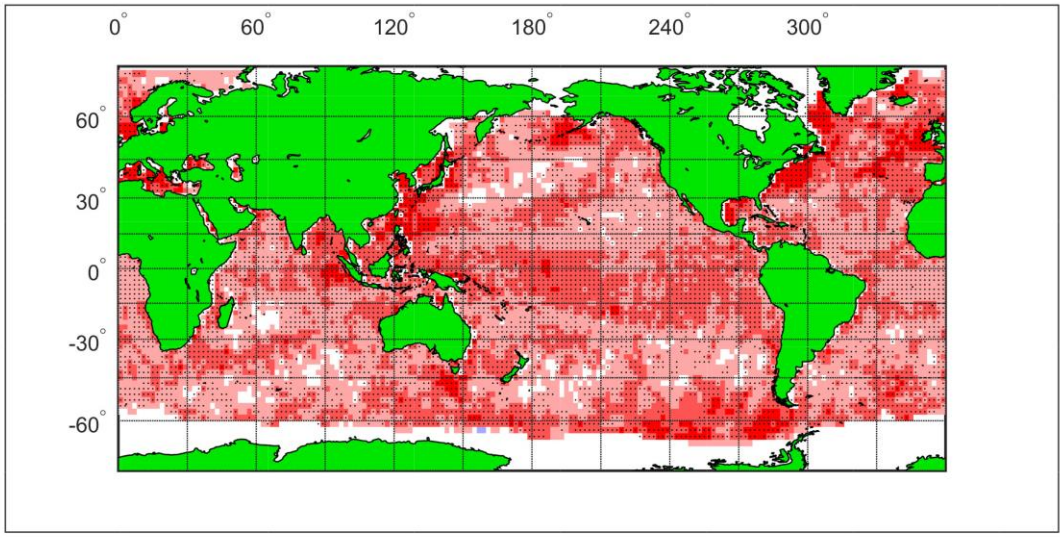
Scatterometer



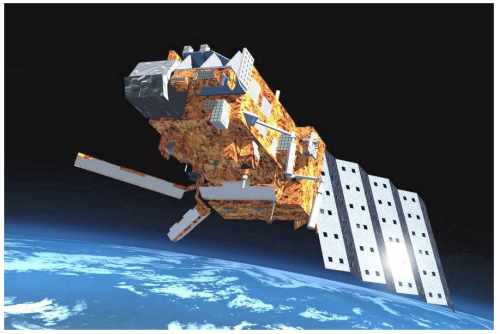
Compare with scatterometer 90th percentile U_{10} trend



Altimeter



Scatterometer



Conclusions

Over the last 33 years:

- Extreme winds in the Southern Ocean have increased by approx. 1.5m/s (5cm/s/yr) or 8%.
- Extreme waves in the Southern Ocean have increased by approx. 30cm (1cm/yr) or 5%.
- Extreme winds have also increased in the equatorial Pacific and Atlantic and in the North Atlantic (0.6 m/s or 2 cm/s/yr).
- Smaller increases in mean values
- Wave trend is smaller than wind trend. Probably due to changes in duration of winds.
- Results confirmed across three platforms – altimeter, radiometer, scatterometer

JASON-2

SSMI-f15

QUIKSCAT

Young & Ribal, 2019, *Science*

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