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The use of long-term satellite databases to study global wind and wave climate

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Approach

The study of global ocean wind and wave climatology can be addressed using two data sources – models or satellites

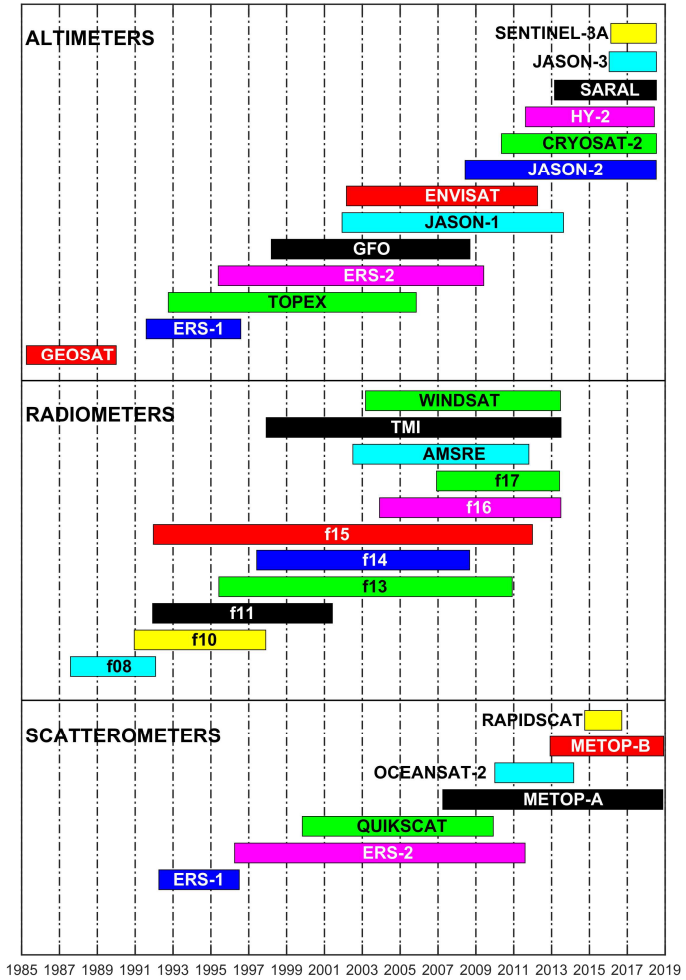
Satellites provide a measurement database but with some limitations

Investigate

- Climatology
- Extremes
- Trends

Period of data coverage

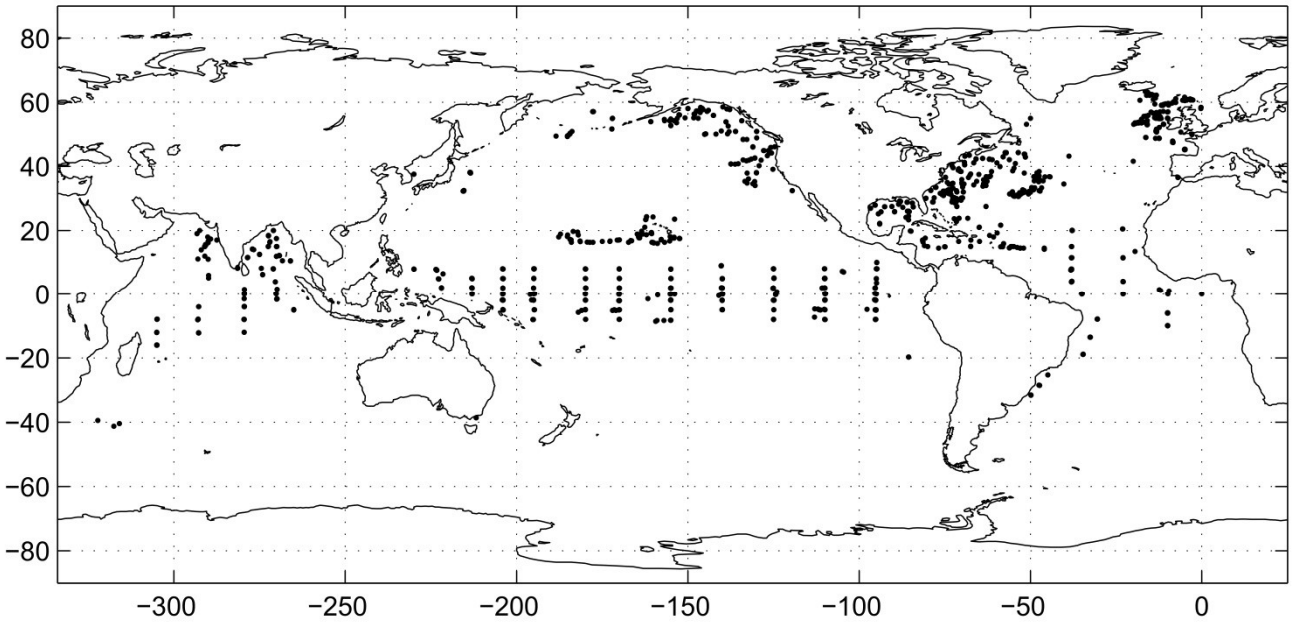
Combined dataset of 33 years duration



Insitu calibration buoys

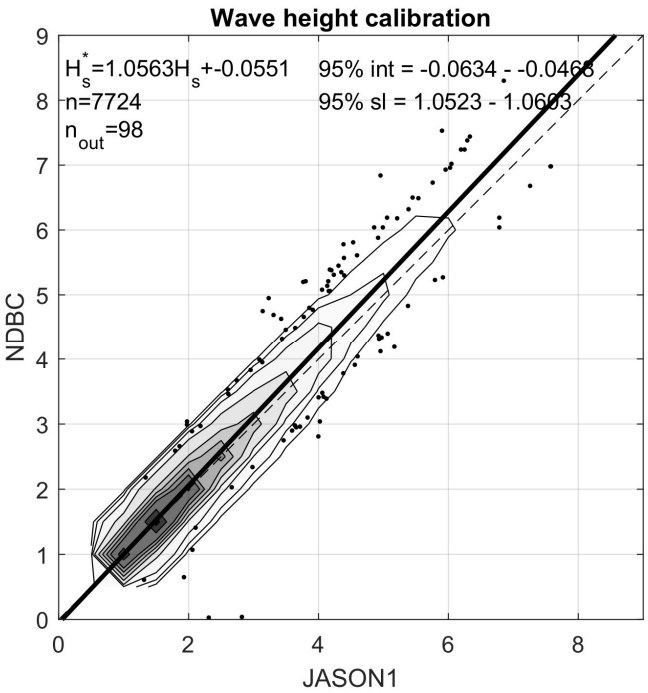
Two data sets

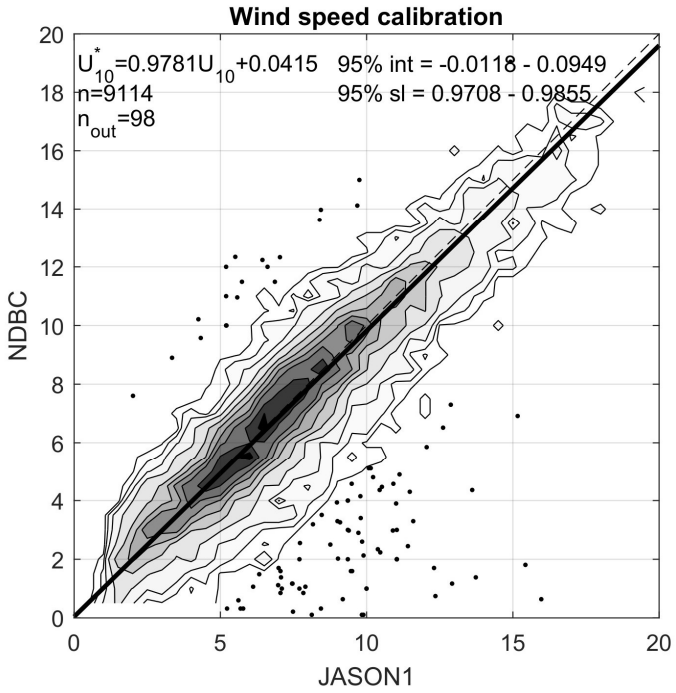
- NDBC
- ECMWF composite data



Altimeter calibration

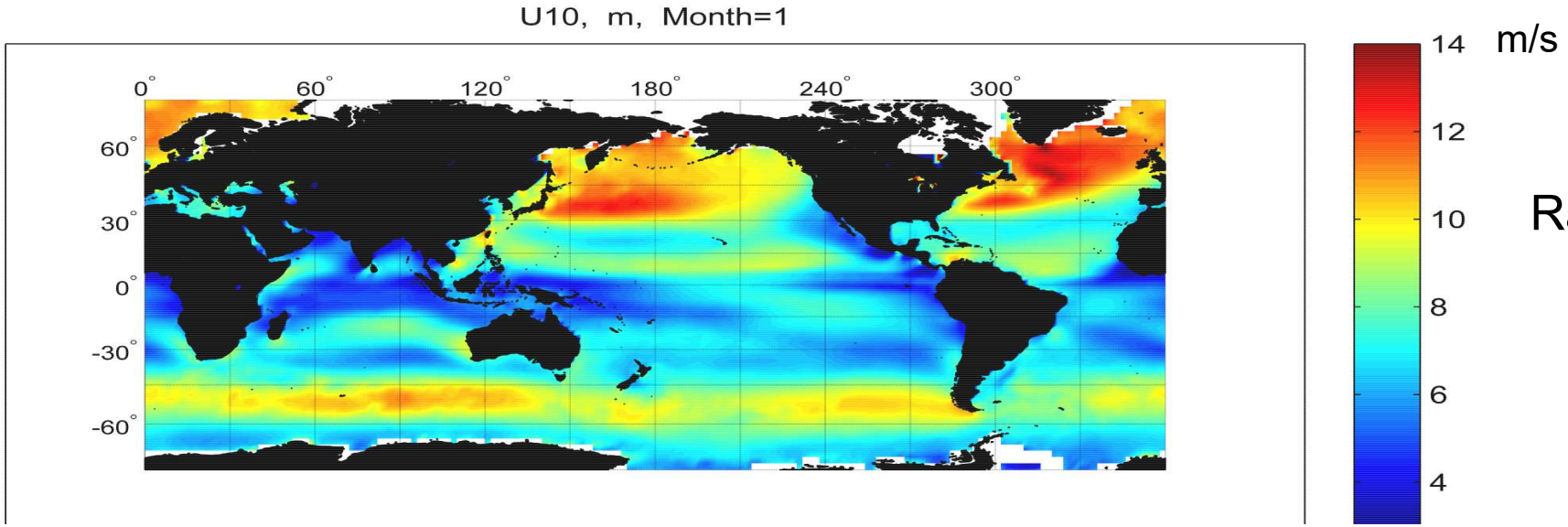
Matchups – 50km and 30 mins.



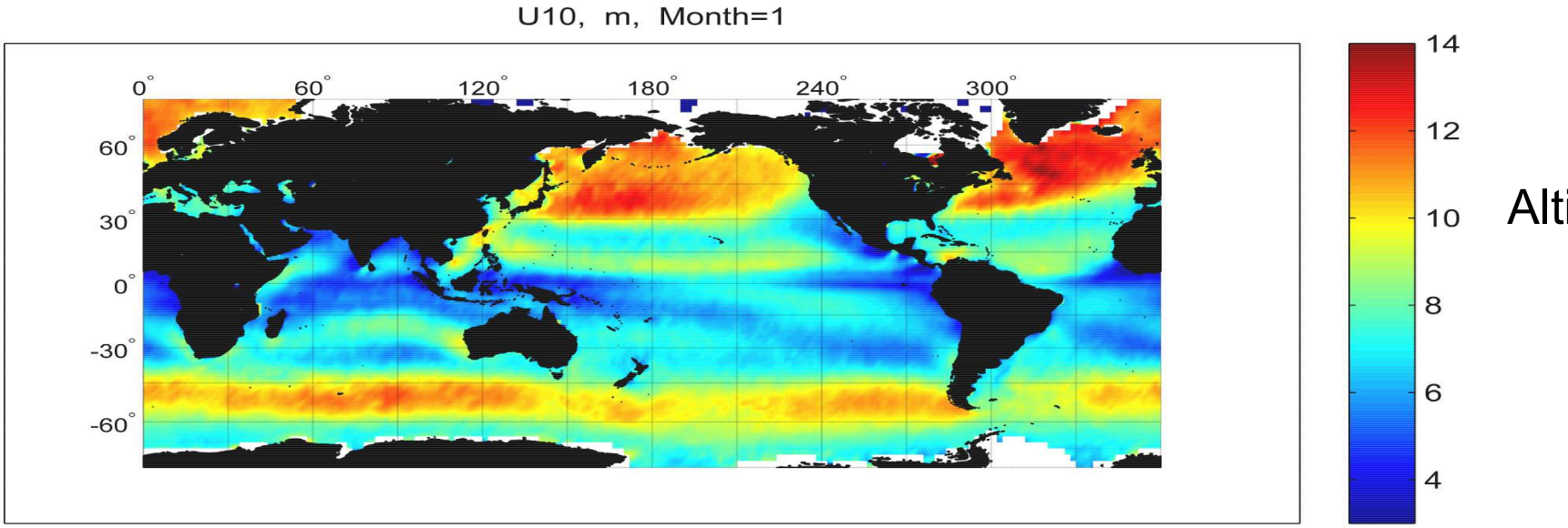


Greater scatter for wind speed

Global climatology – January U_{10} Monthly means

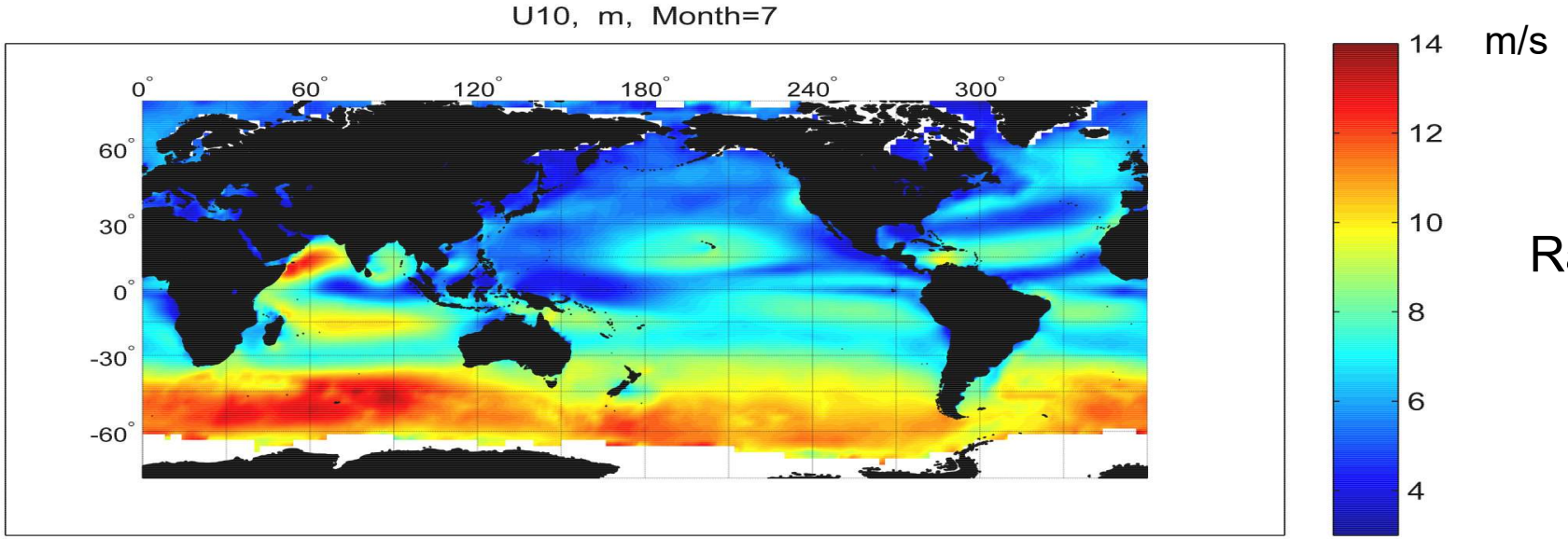


Rad.

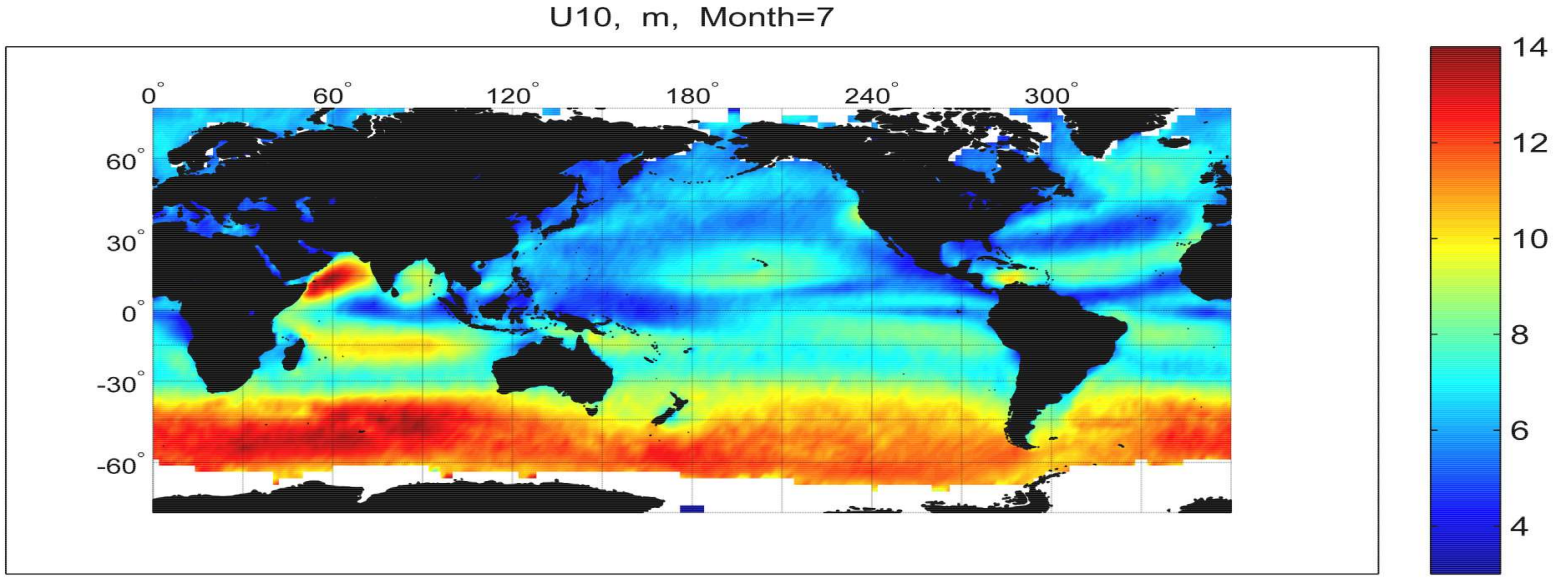


Altimeter

Global climatology – July U_{10} Monthly means

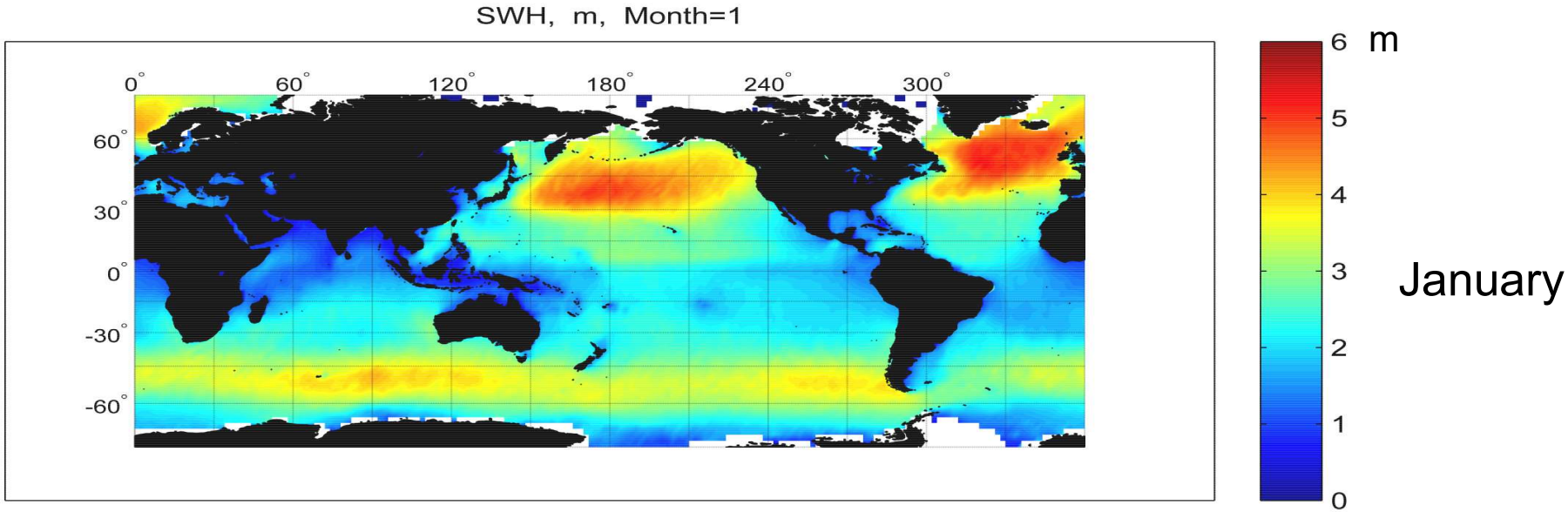


Rad.

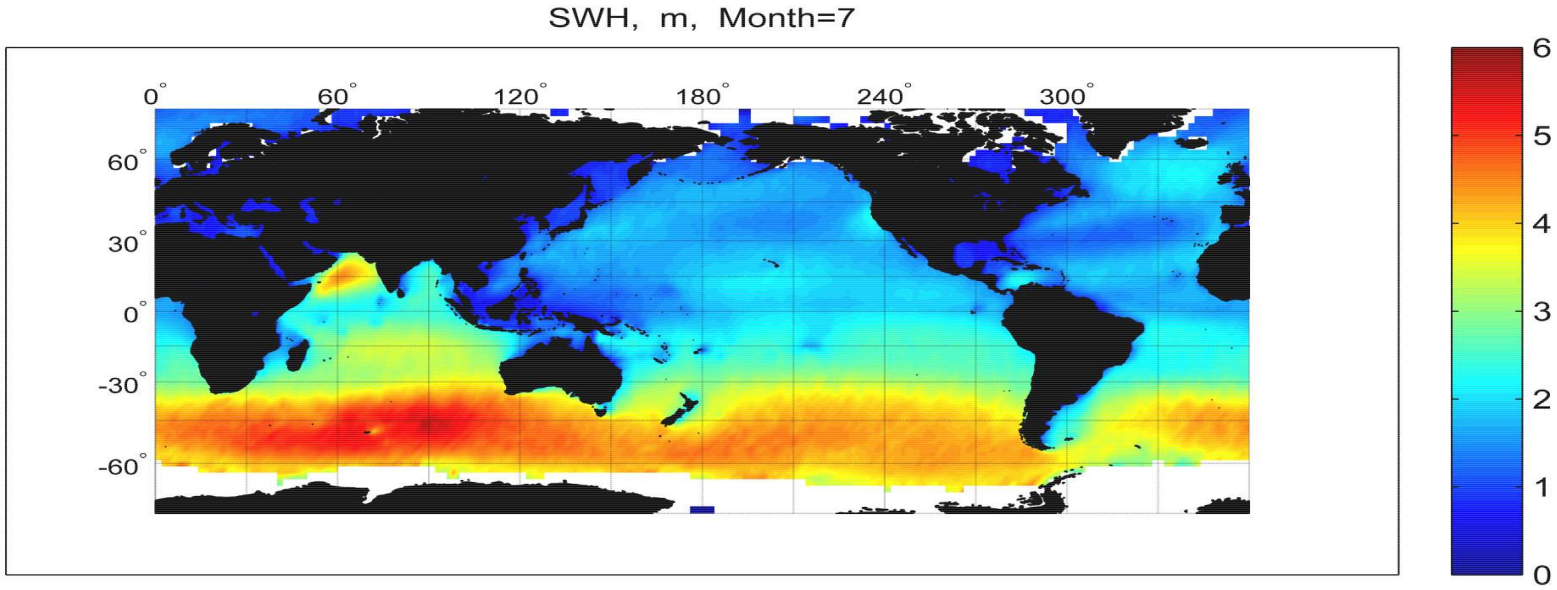


Altimeter

Global climatology – Hs Mean monthly - altimeter



January



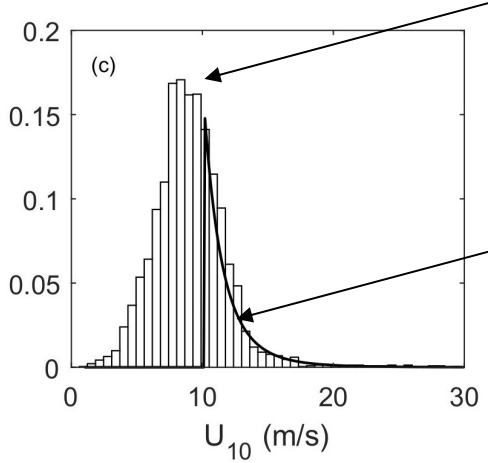
July

Extreme value analysis

- Determine probability distribution function (PDF) of wind speed and wave height
- Fit an extreme value distribution to the upper percentiles
- Peaks over threshold and Generalized Pareto distribution
- Extrapolate to extreme value level

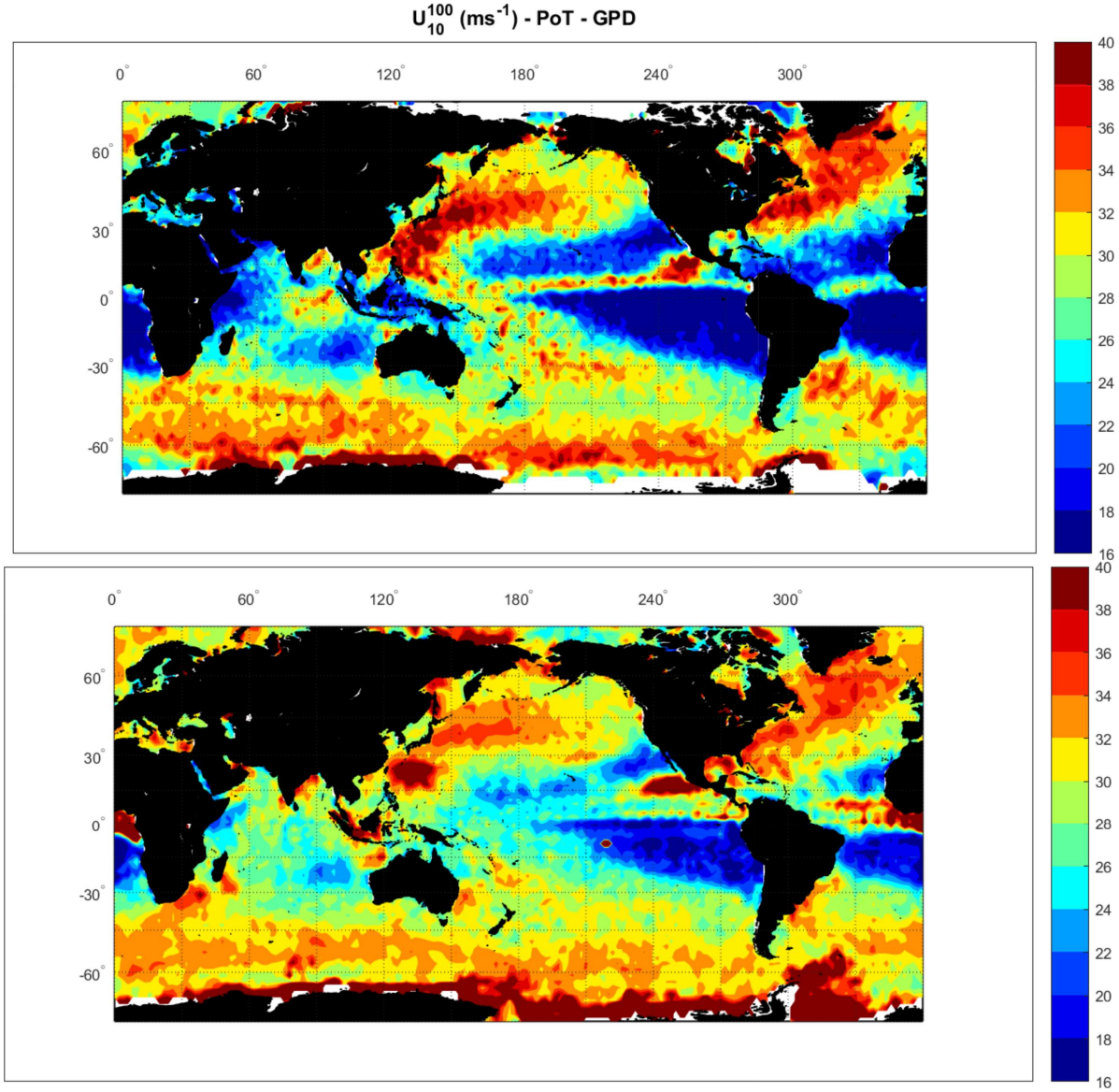
  e.g. 1in 100 years

Observed PDF



Generalized Pareto Distribution
To give 100 year estimates

Altimeter/Scatterometer – U_{10} – PoT (GPD)

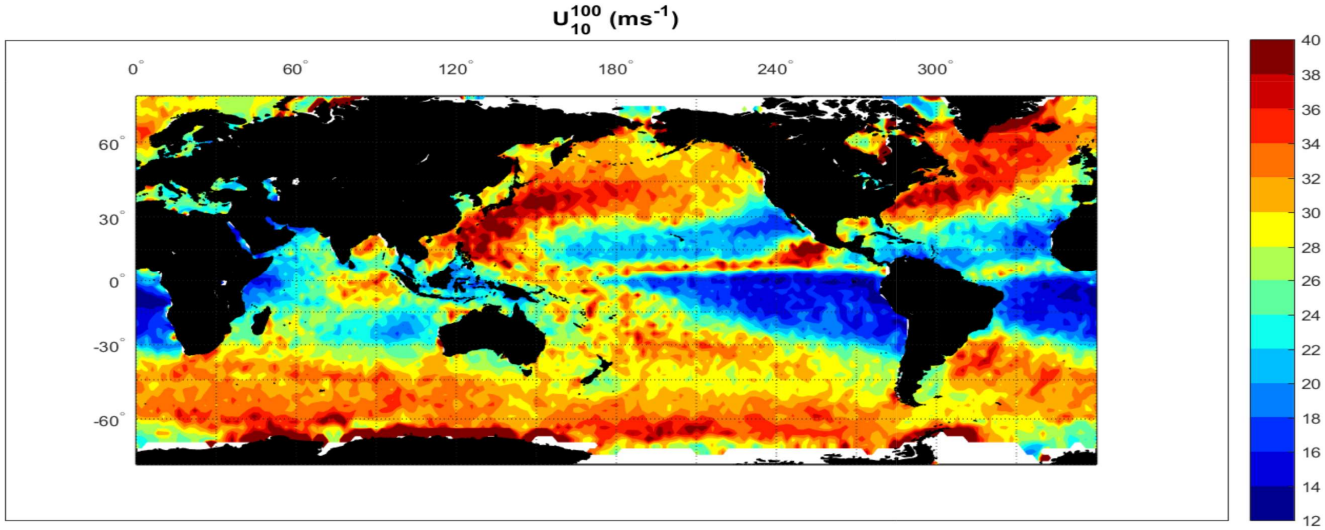


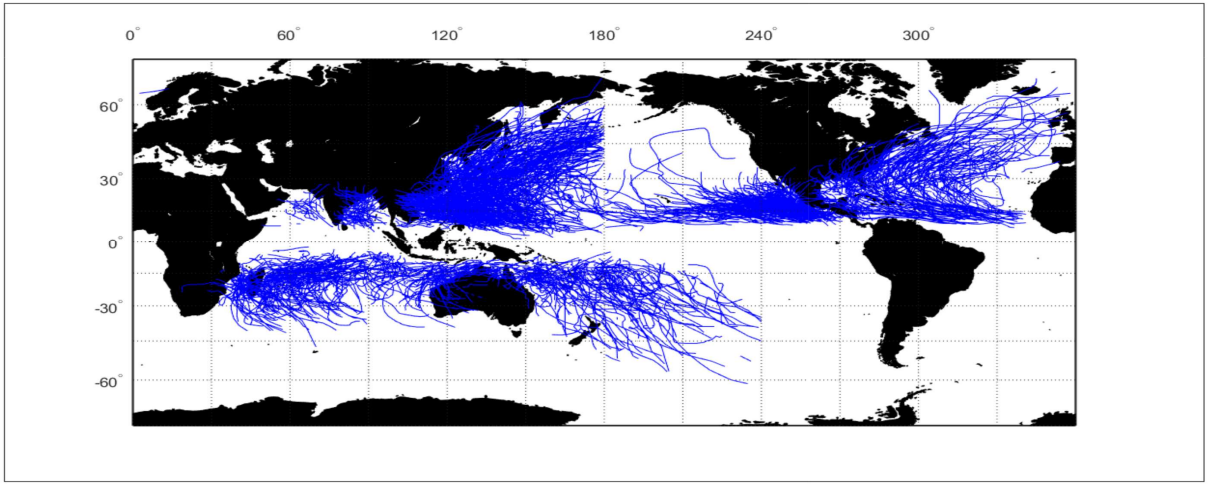
Altimeter

Scatterometer

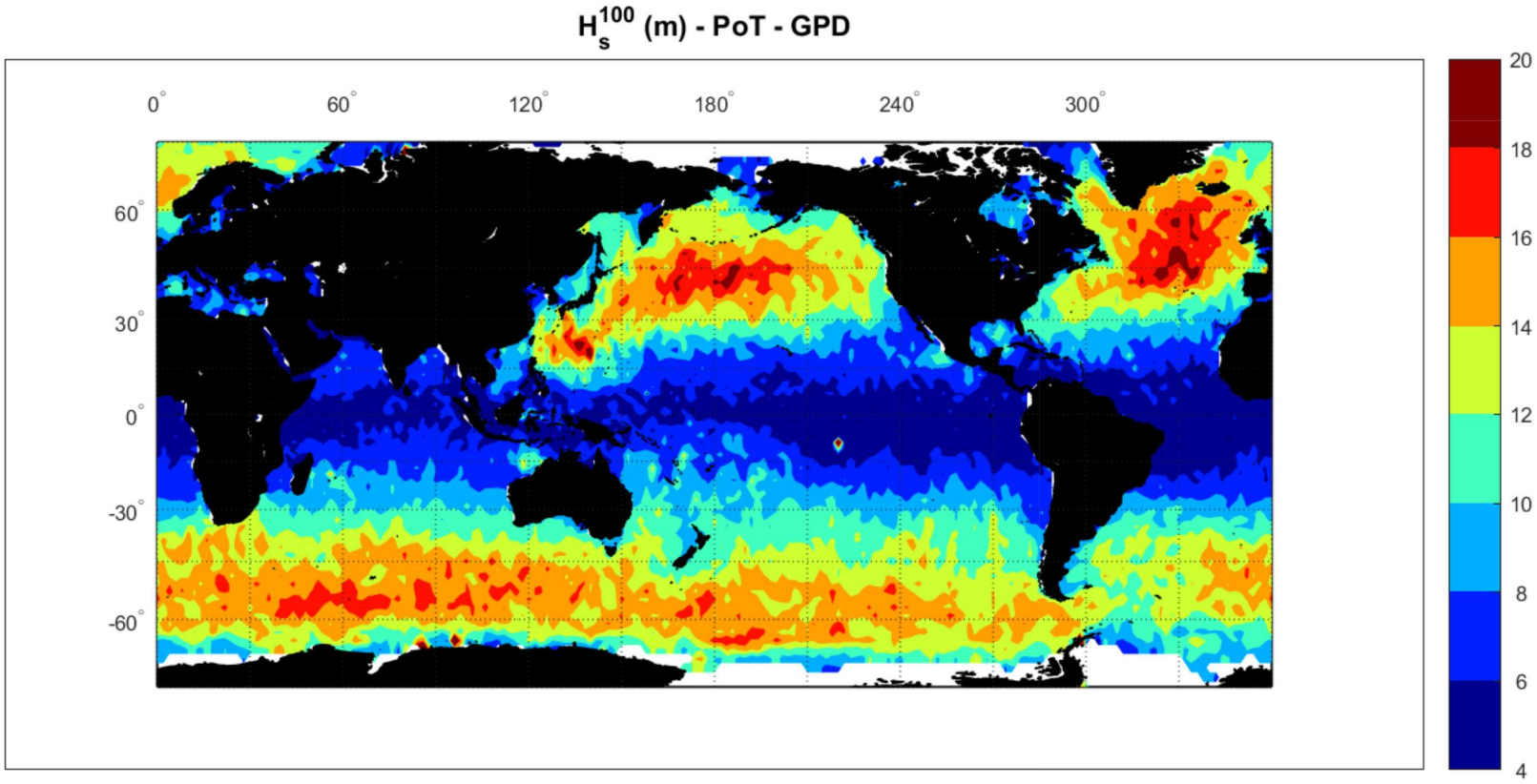
Takbash et al., 2019

Tropical Cyclone Tracks





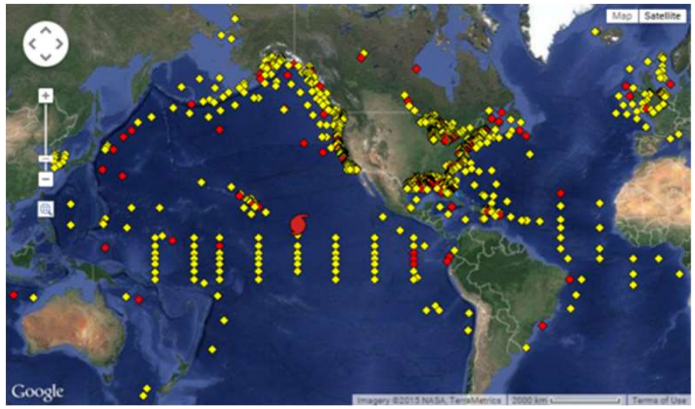
Altimeter – H_s - PoT (GPD)



Takbash et al., 2019

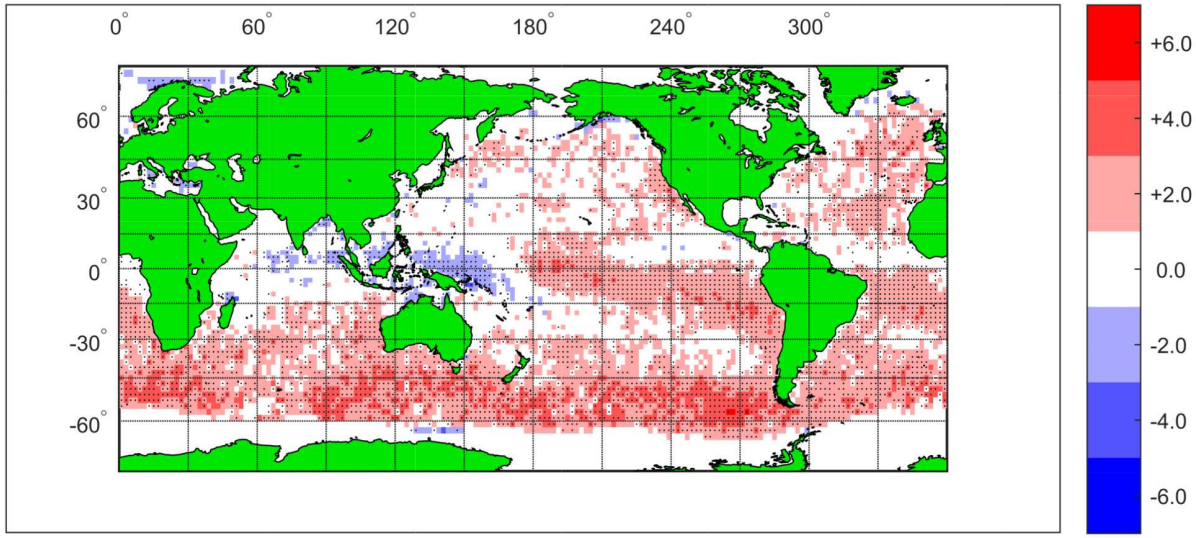
Data for trends

- Altimeter, radiometer, scatterometer
  - Calibrated against buoys
  - Validated against independent buoys
  - Discontinuities and drift removed
  - High wind speed/wave height checked and corrected
  - Corrected for boundary layer stability
    (climatological correction)
    Young & Donelan, 2018

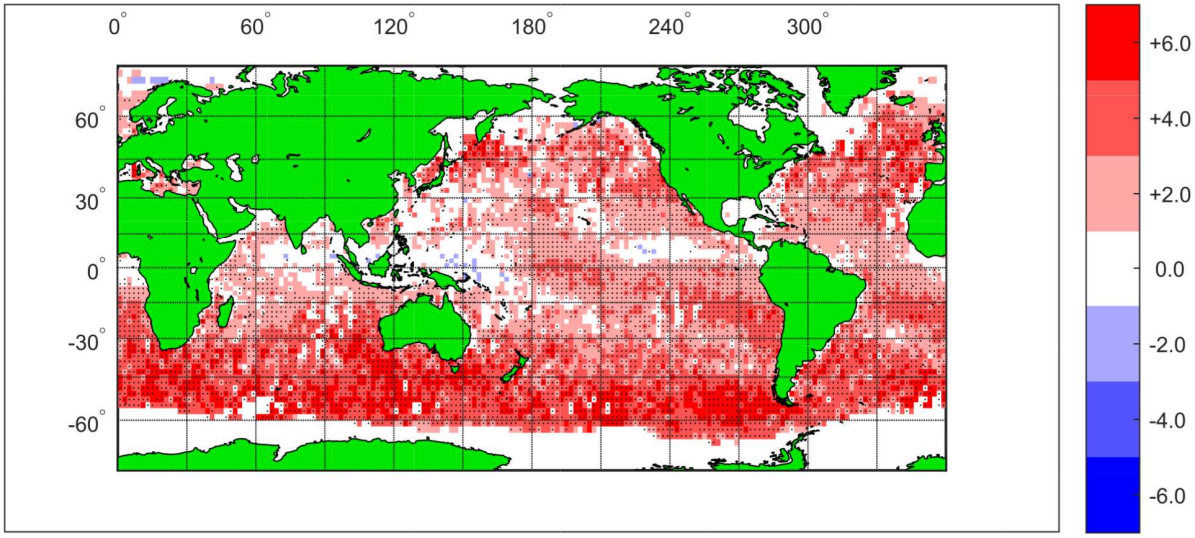


Wind speed U_{10} trends

Altimeter U_{10} mean trend (1985 - 2018) [cm/s/yr]



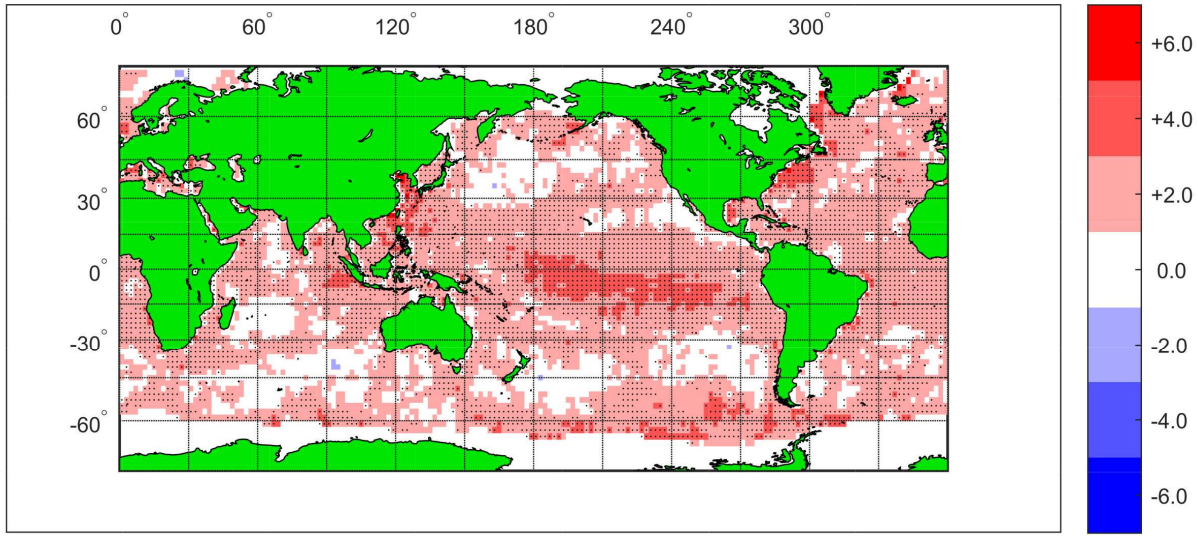
Altimeter U_{10} p90 trend (1985 - 2018) [cm/s/yr]



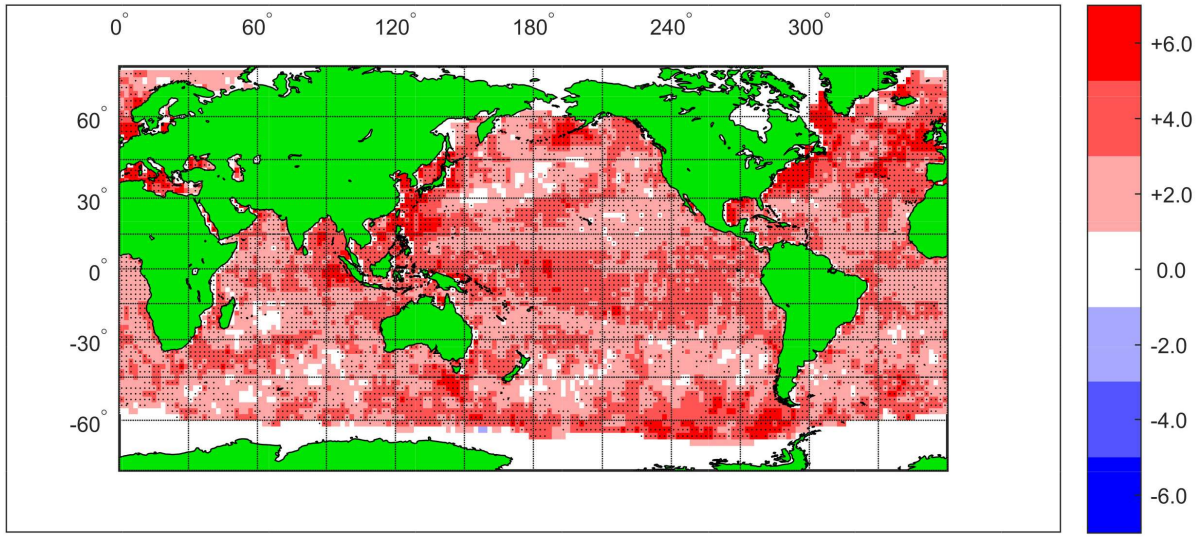
Young & Ribal, 2019

Wind speed U_{10} trends

Scatterometer U_{10} mean trend (1992 - 2018) [cm/s/yr]



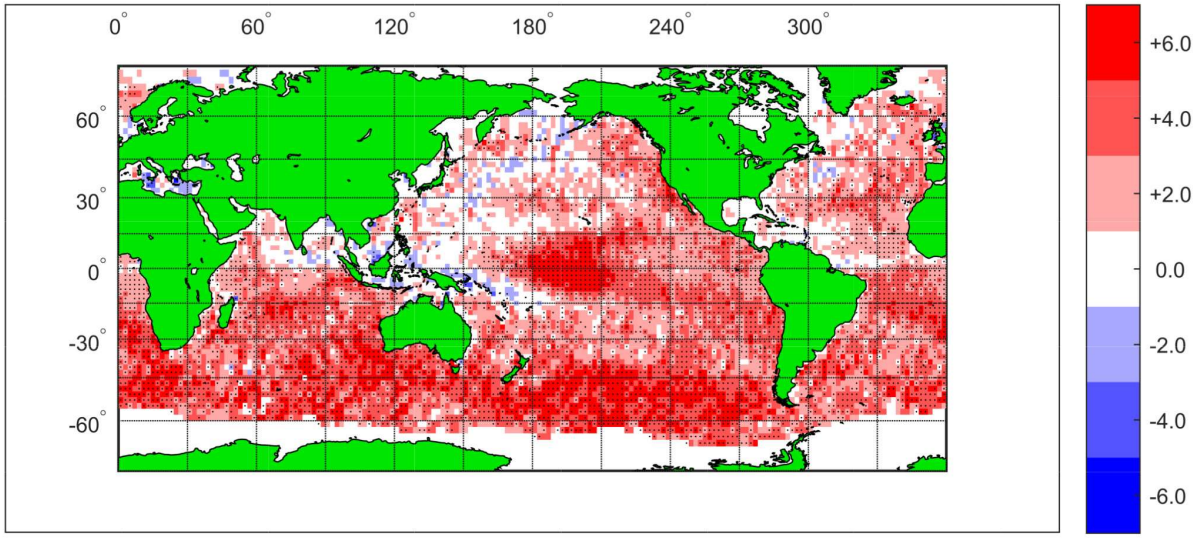
Scatterometer U_{10} p90 trend (1992 - 2018) [cm/s/yr]



Young & Ribal, 2019

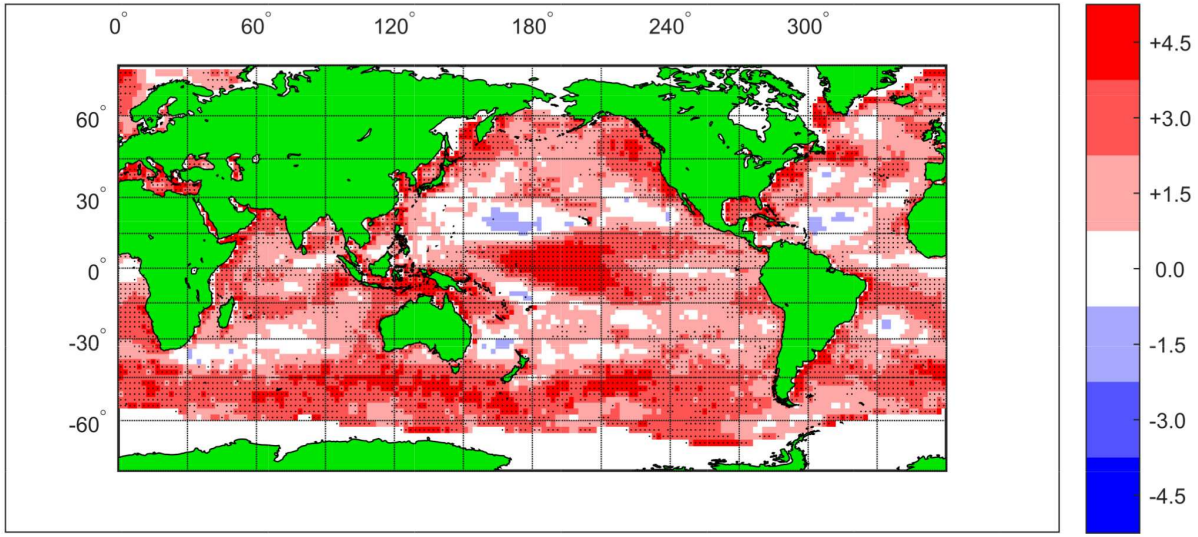
Altimeter and Radiometer Comparison

Altimeter U_{10} mean trend (1985 - 2008) [cm/s/yr]



Magnitude and distribution of trends comparable between completely different instruments

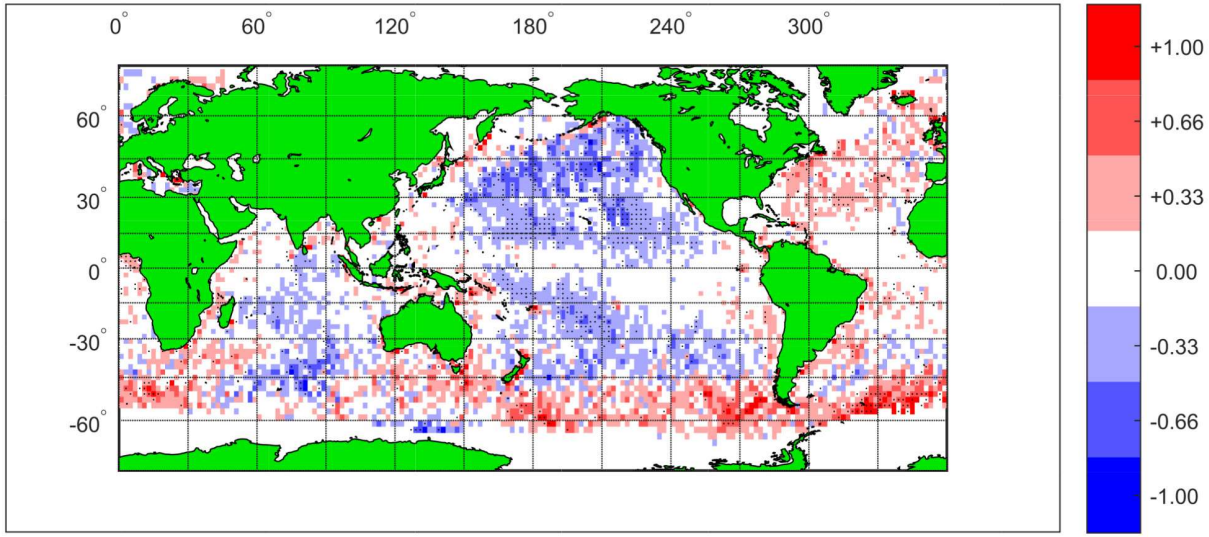
Radiometer U_{10} mean trend (1985 - 2008) [cm/s/yr]



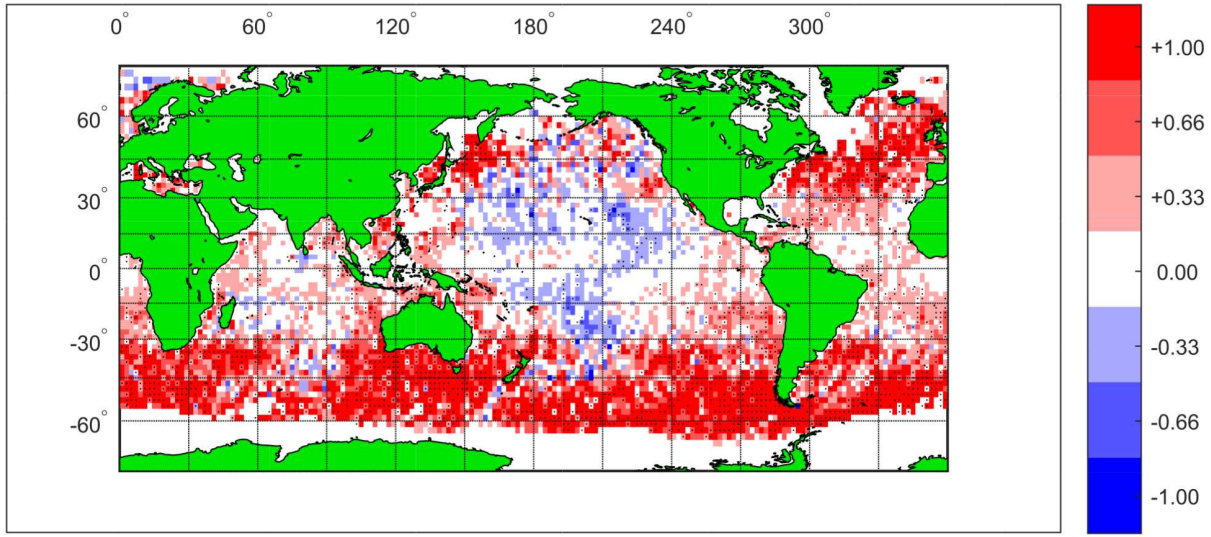
Young & Ribal, 2019

Wave Height H_S trends

Altimeter H_s mean trend (1985 - 2018) [cm/yr]



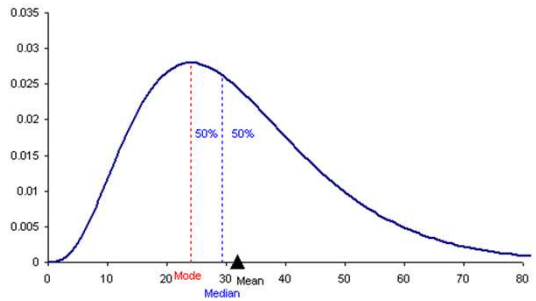
Altimeter H_s p90 trend (1985 - 2018) [cm/yr]



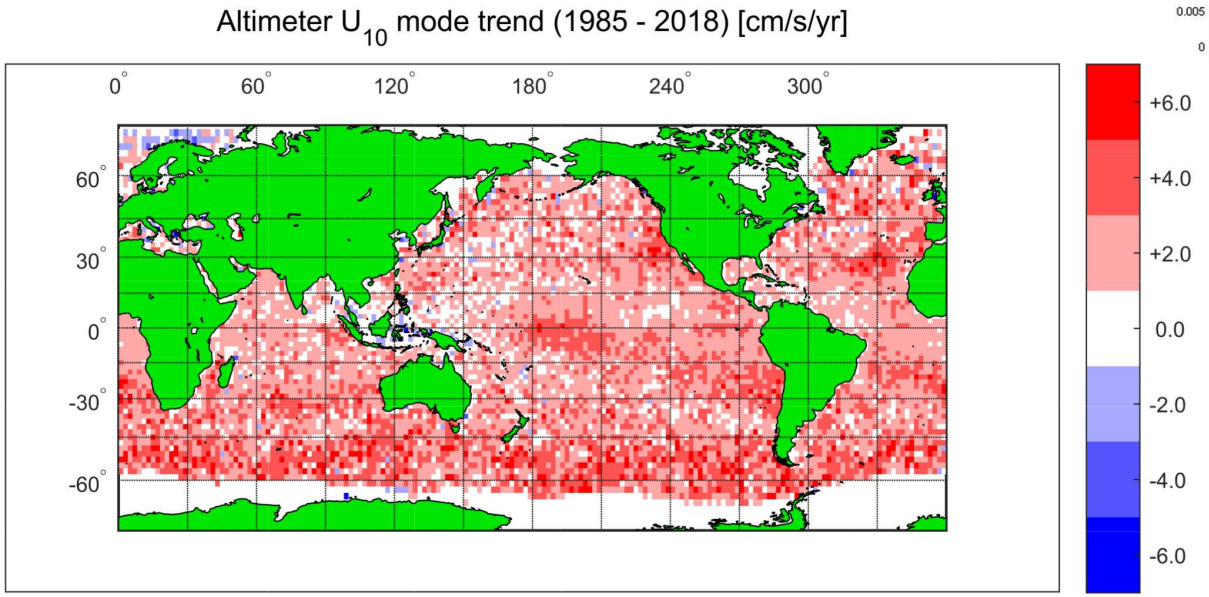
Young & Ribal, 2019

Trends wind vs waves

- Stronger trends in U_{10} than H_s
- This is counter-intuitive, as for "fully developed" conditions $H_s \propto U_{10}^2$
- Therefore, might expect stronger trend for H_s
- Perhaps not "fully developed"
- Trend on mode of distribution, rather than mean



Similar to mean
More noisy
Nothing unusual



Young & Ribal, 2019

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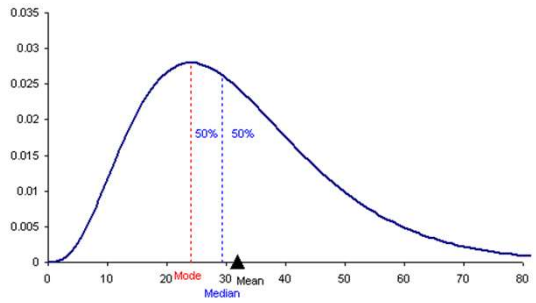
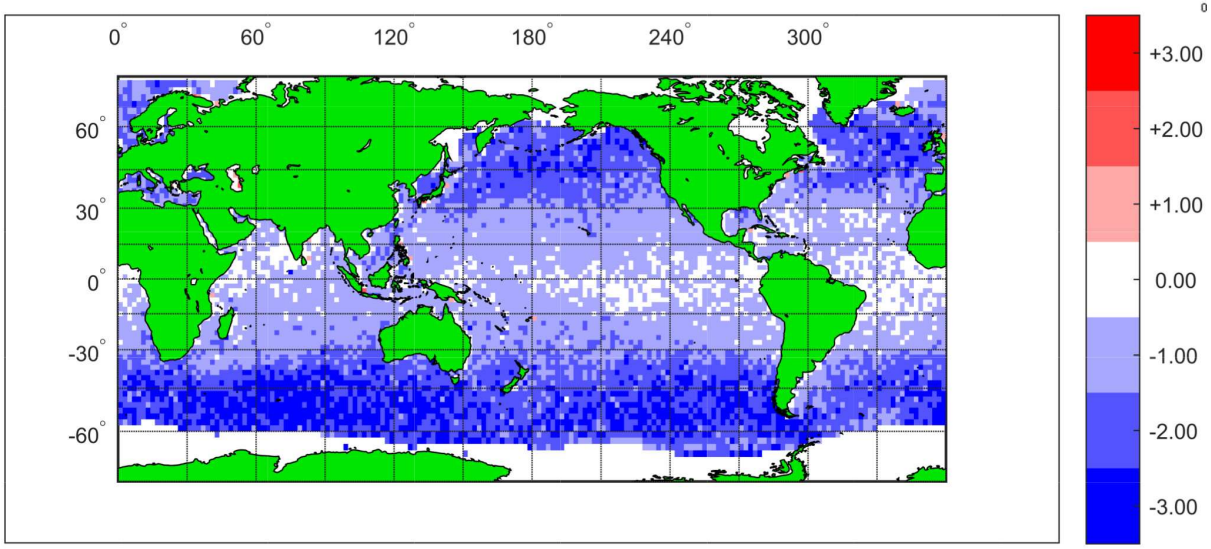


Altimeter H_s mode trend (1985 - 2018) [cm/yr]



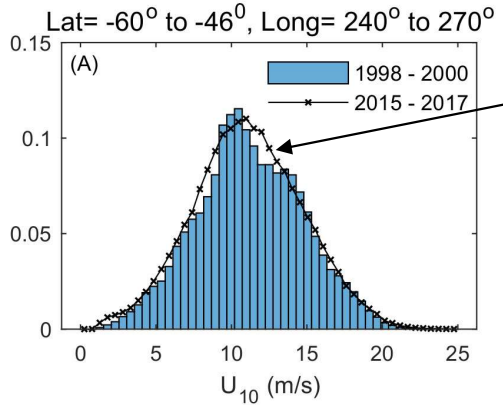
Strong negative trend

Young & Ribal, 2019

Changes in wind speed and wave height PDFs

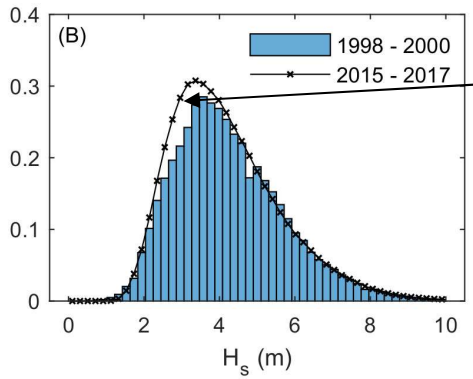
- Consider how PDFs of wind speed and wave height have changed over time

Wind speed



Wind speed PDF has broadened
Mean has increased
Mode has increased

Wave height



Wave height PDF
Mode has decreased
Mean hardly changed

Young & Ribal, 2019

Changes in wind speed and wave height PDFs

Winds generate waves, so why does the wave height PDF behave so differently to the wind speed?

To generate waves far from land, need:

- Wind speed
- Wind duration

May have a wind increase but if the wind duration decreases may have no increase in wave height (or even a decrease)

As we have a broadening of the wind speed PDF, the strengthening winds may not have sufficient time to generate increased waves

U_{10} (m/s)	t (hrs)
5	8.5
7.5	12.7
10.0	16.7
12.5	21.2
15.0	25.5
17.5	29.7

Time to generate smaller waves

Insufficient time to generate larger waves

Summary/Conclusions

- Climatology consistent between all instruments
- Differences in wind speed due to atmospheric stability

- Consistent extreme value analysis results for altimeter and scatterometer wind speeds – altimeter does not appear to excessively under-sample extremes
- Radiometer unusable for extreme value analysis due to fair weather bias

- Reasonably consistent trends for wind speed across all three instruments
- Weaker trends in wave height than wind speed may be due to changes in duration of strong winds
- Consistency of trend results indicate that altimeters not significantly impacted by changing sampling density with more satellites in orbit in recent years

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