The Wave Climate of the Southern Ocean

Ian Young and Qingxiang Liu

THE UNIVERSITY OF MELBOURNE

Motivation

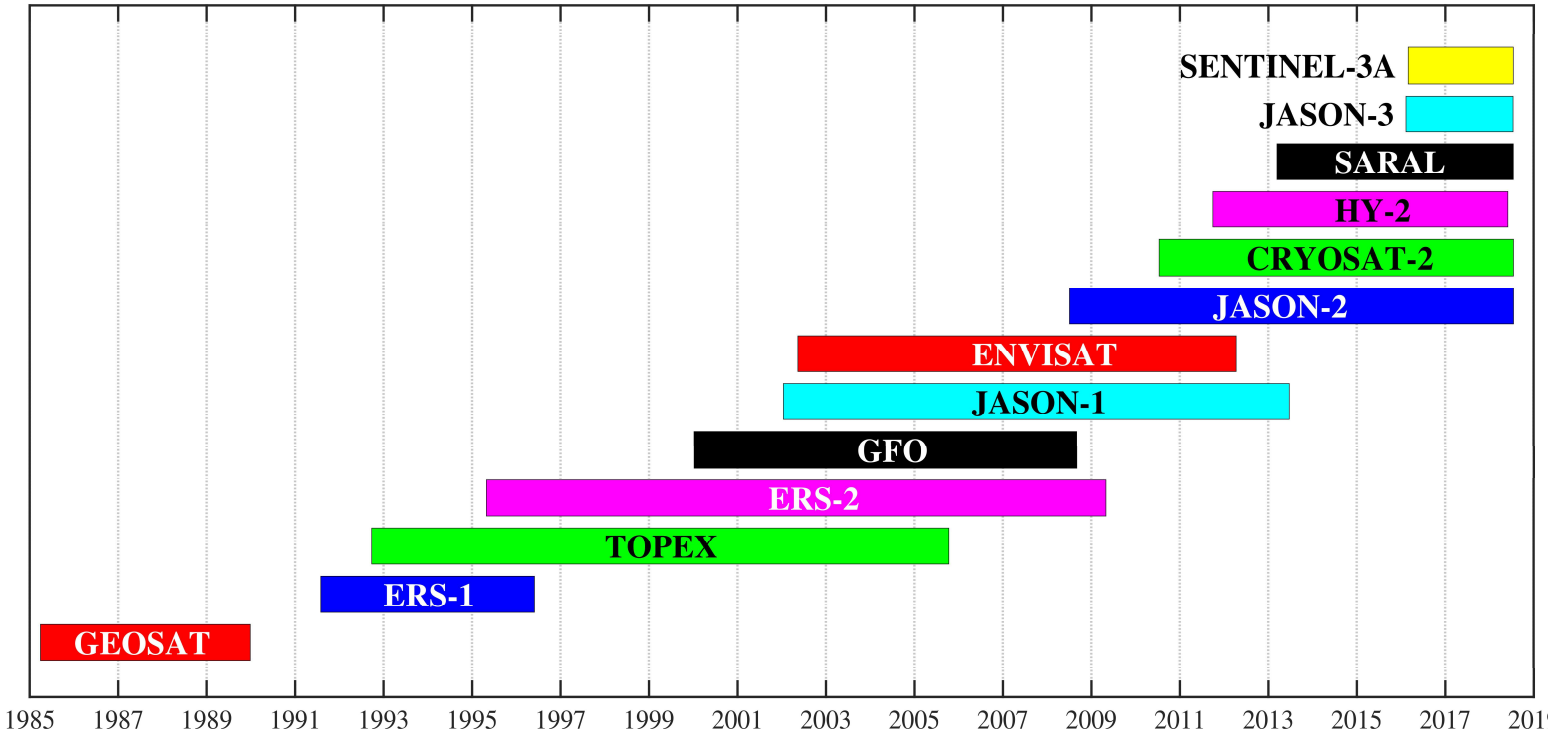
Southern Ocean Wave Climate important because:

- Southern Ocean dominates swell in Indian, Pacific and South Atlantic
- Evidence that Southern Ocean Wave Climate increasing – may continue in the future
- With SLR, wave setup will become more important. Changes to Southern Ocean wave climate will impact on beach stability for many countries
- Impacts of sea ice breakup
- A unique environment with extremely long fetch conditions

Satellite dataset

Long term (30 years) satellite datasets provide:

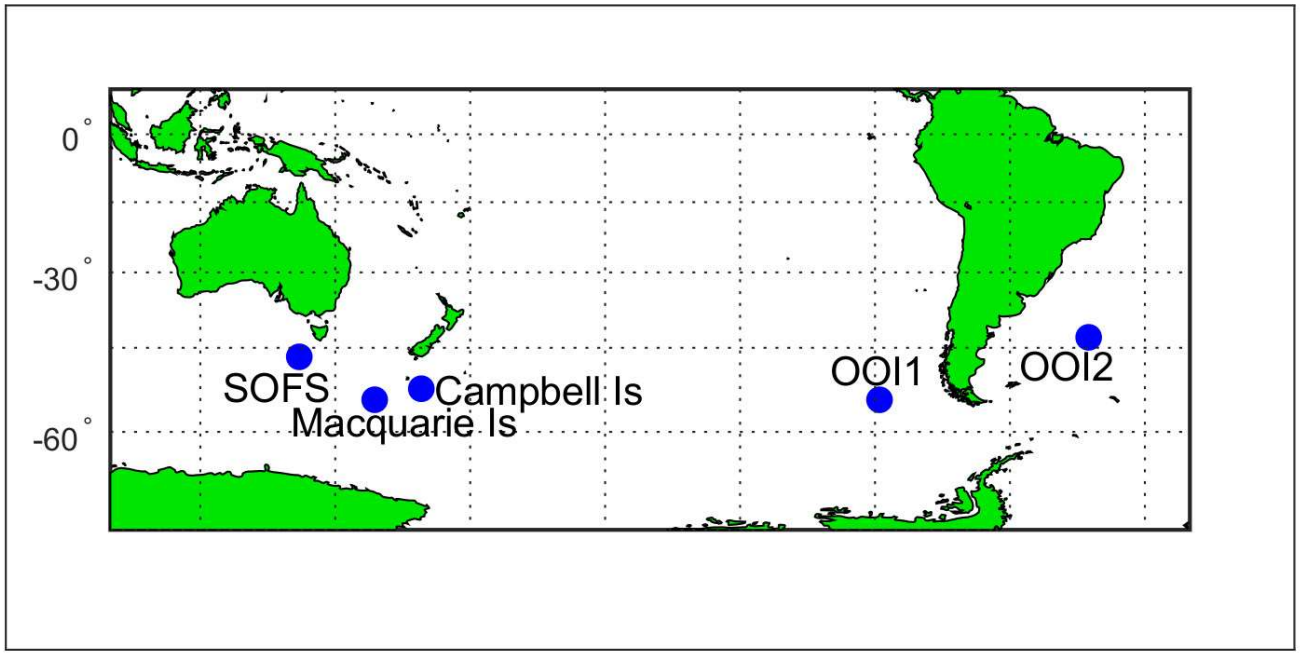
- Seasonal variation in monthly wind speed and wave height
- Extreme value estimates of H_s and U_{10}
- Trends in H_s and U_{10}

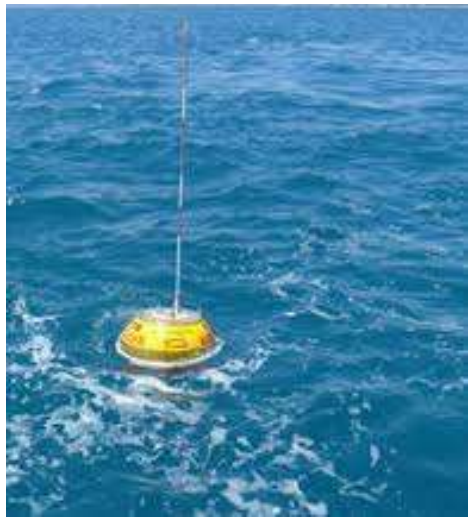


Ribal & Young, 2019, *Sci. Data*.

THE UNIVERSITY OF MELBOURNE

Buoy dataset

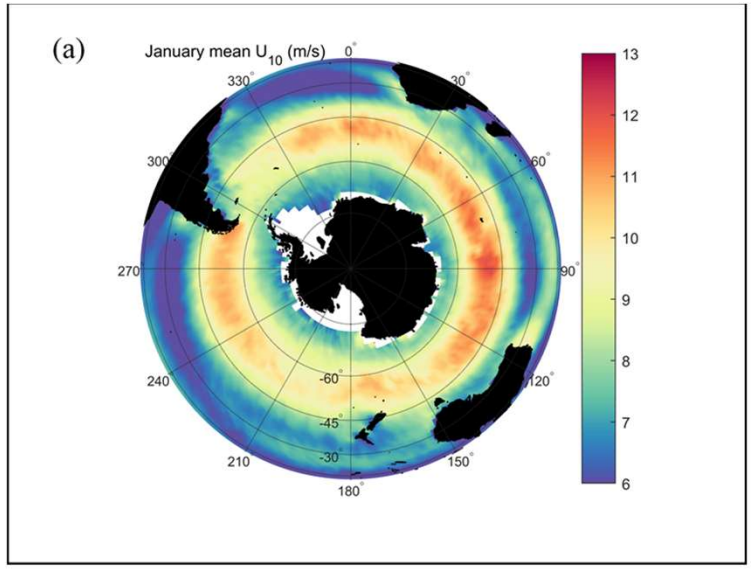


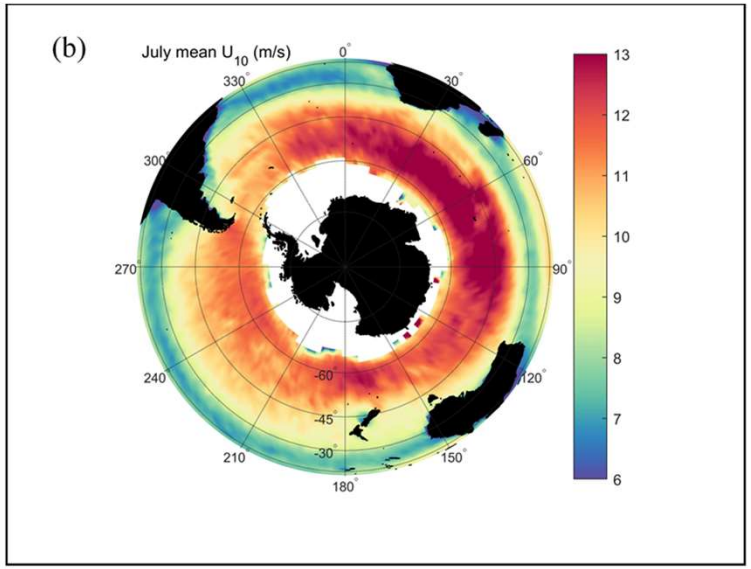


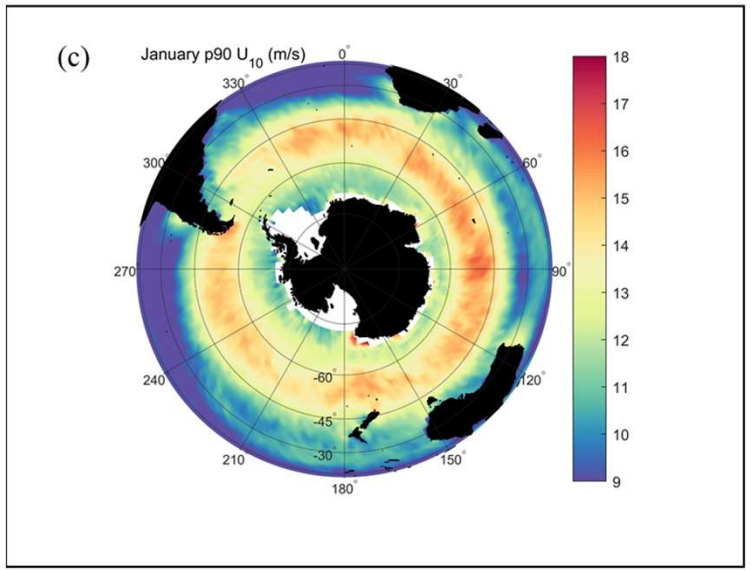
THE UNIVERSITY OF MELBOURNE

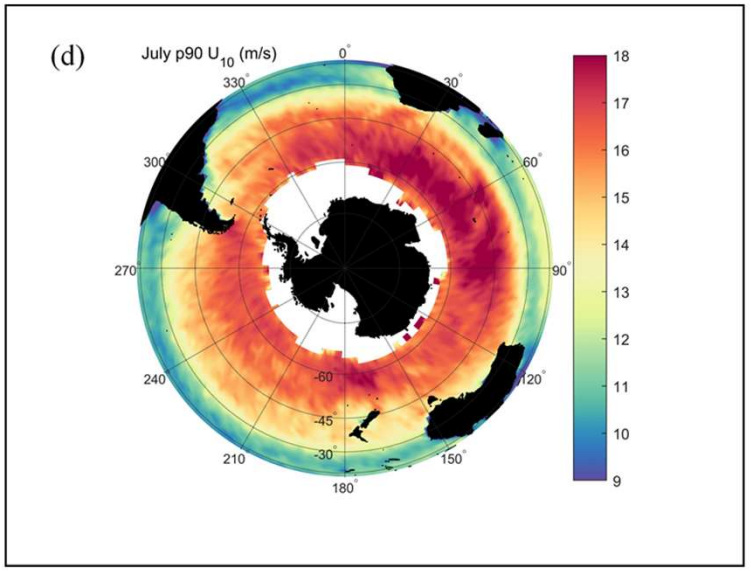
Wind speed climatology

Young & Donelan, 2018







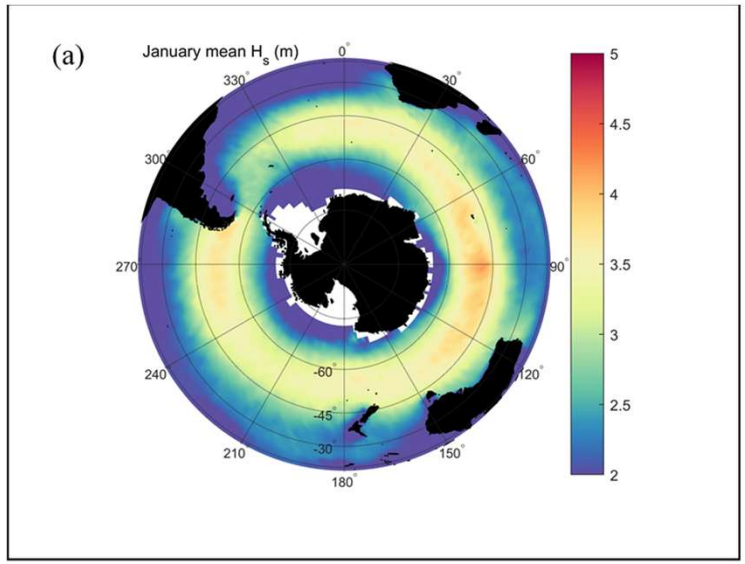


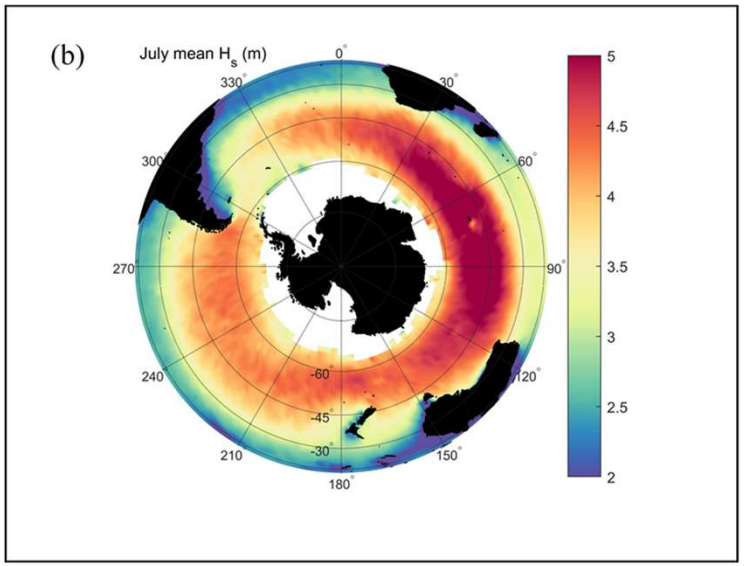
Young & Donelan, 2018, *Rem. Sens. Env.*

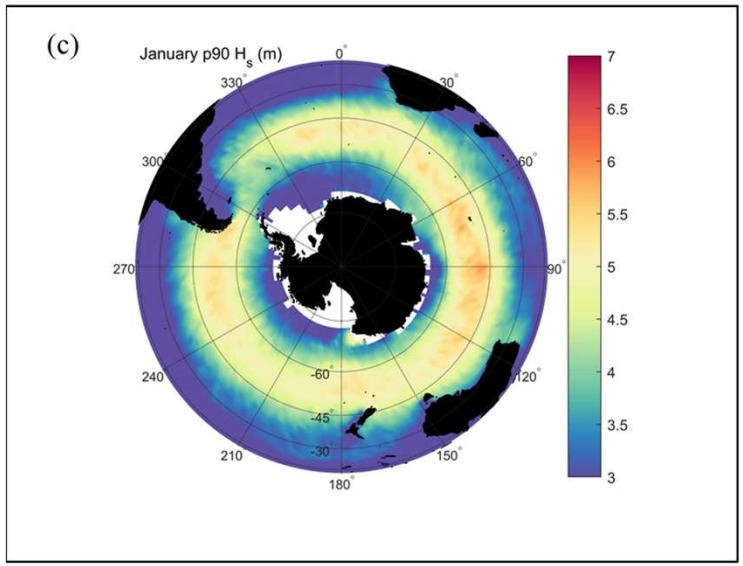
THE UNIVERSITY OF MELBOURNE

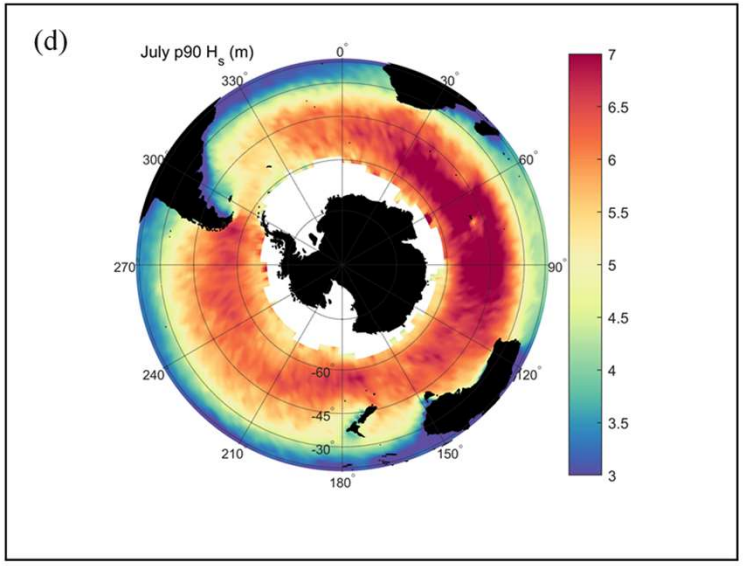
Significant wave height climatology

Young & Donelan, 2018









Young & Donelan, 2018, *Rem. Sens. Env.*

Extreme value analysis

Peak over threshold analysis with threshold set at 90th percentile
Fit Generalized Pareto distribution

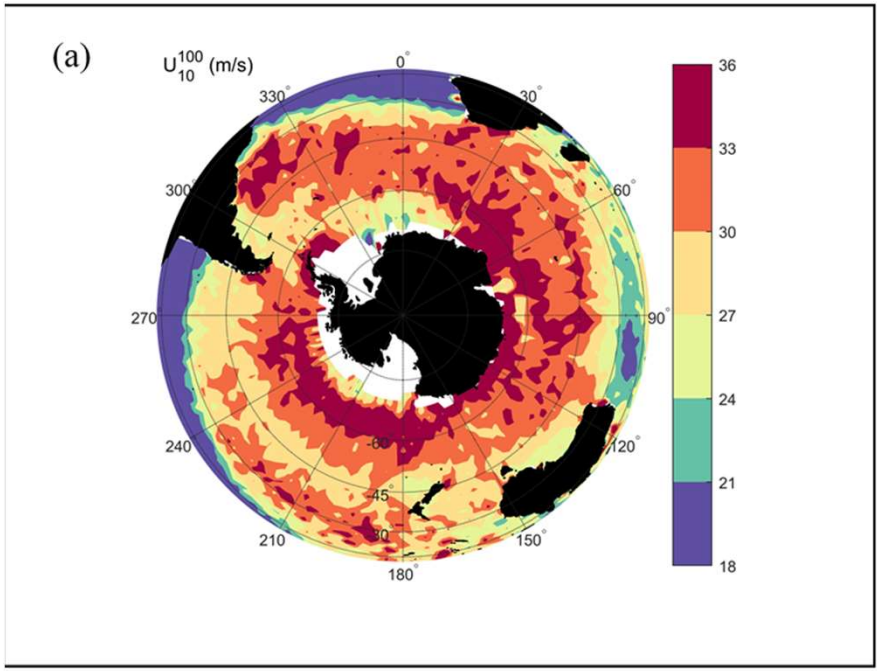
$$F(x) = 1 - \left[1 + k \left(\frac{x - A}{B} \right)^{-1/k} \right]$$

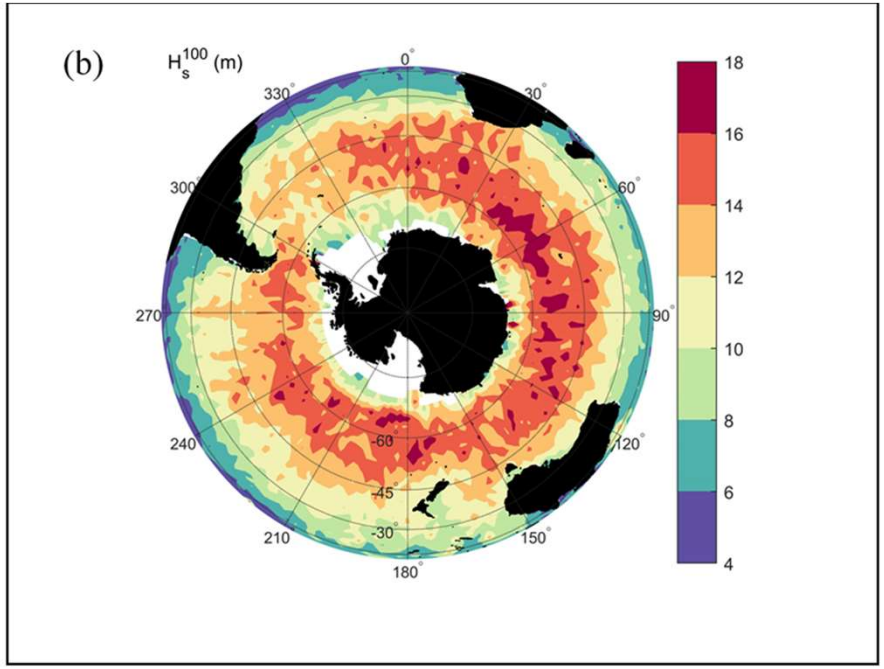
x – wind speed or significant wave height
k – shape parameter
B – scale parameter
A - threshold

Takbash et al., 2018, *J. Clim.*

THE UNIVERSITY OF MELBOURNE

100-year return period wind speed and significant wave height



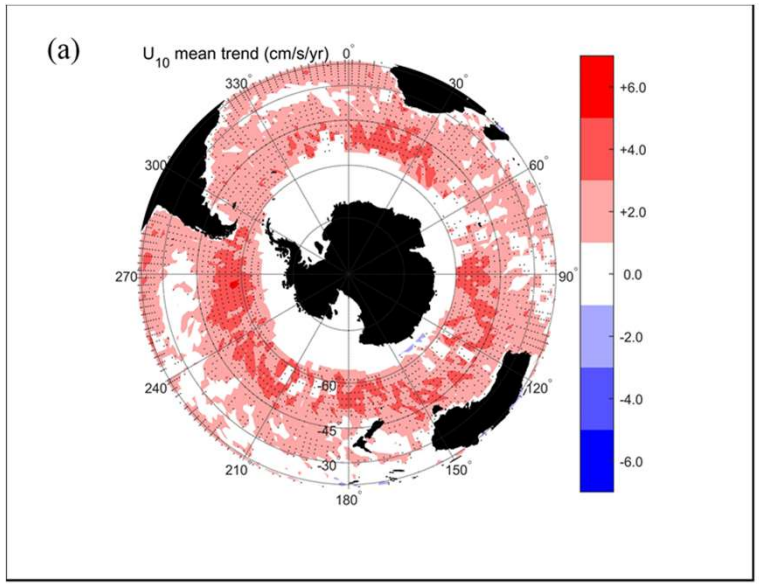


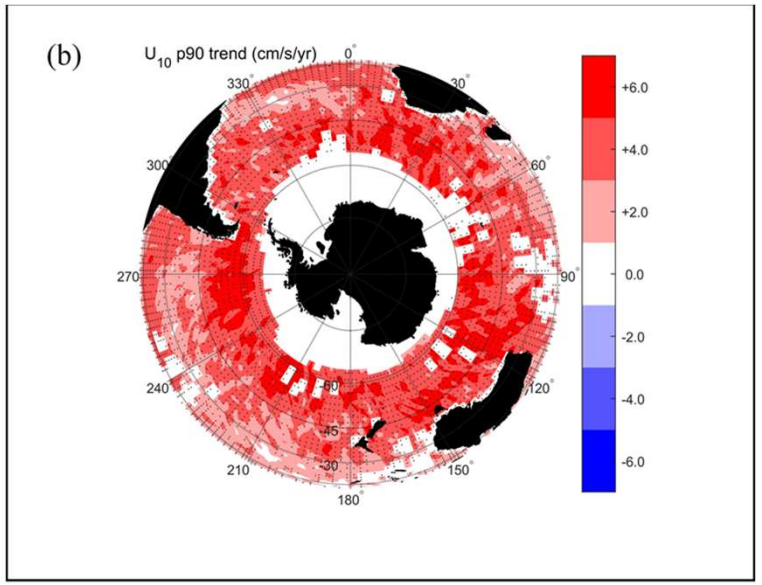
Takbash et al., 2018, *J. Clim.*

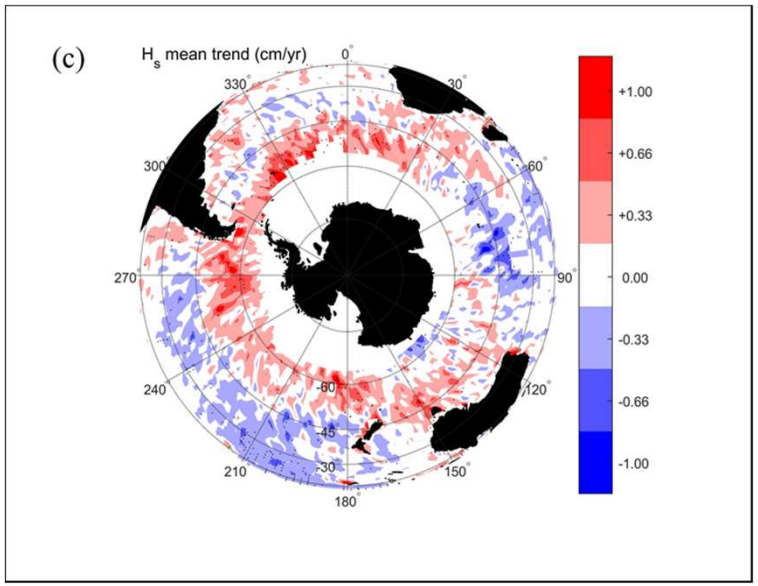
THE UNIVERSITY OF MELBOURNE

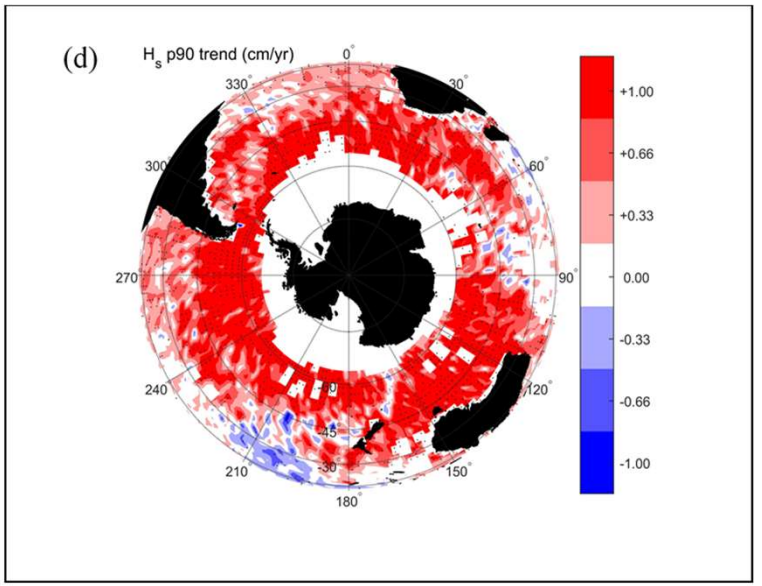
Trends in mean and 90th percentiles

Young & Ribal, 2019, Science







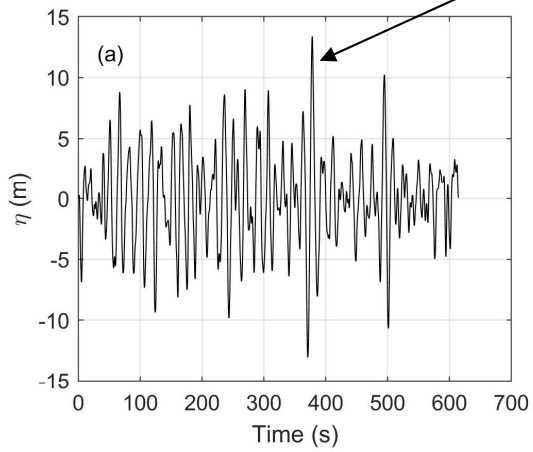


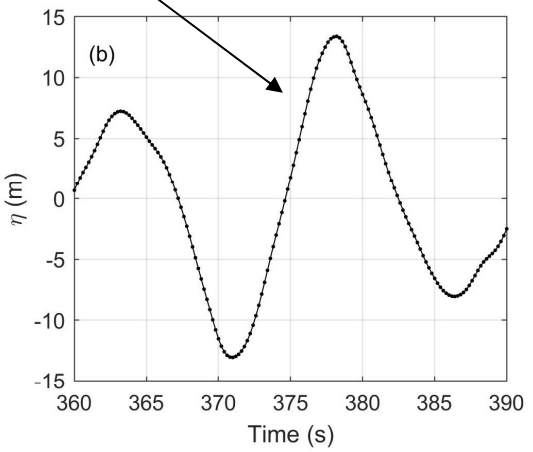
Young & Ribal, 2019, *Science*

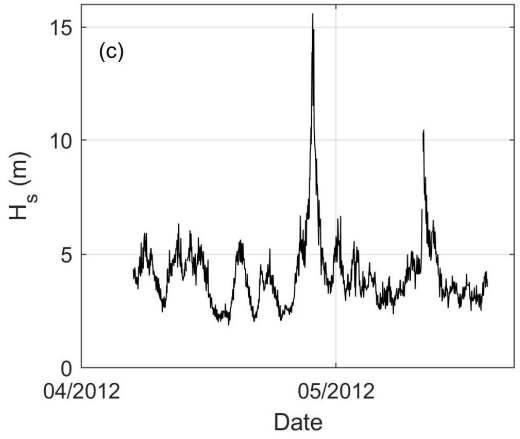
Southern Ocean Buoy Data - SOFS

The wave climate can be extreme

Example of a crest to trough wave height of 26m with H_s=15m







Southern Ocean Buoy Data - SOFS

Spectral form

- Initially fit a simple spectral form to data

$$F(f) = \beta g^2 (2\pi)^{-4} f_p^{-(5+n)} f^n \exp\left[\frac{n}{4}\left(\frac{f}{f_p}\right)^{-4}\right] \cdot \gamma^{\exp\left[\frac{-(f-f_p)^2}{2\sigma^2 f_p^2}\right]}$$

(Generalized Donelan et al, 1985)

Southern Ocean Buoy Data – 1D Spectra

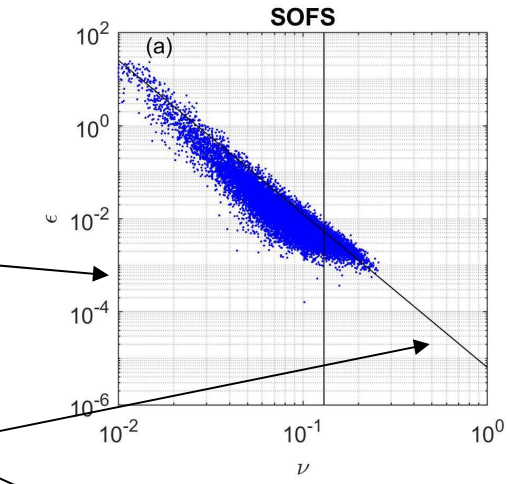
Swell

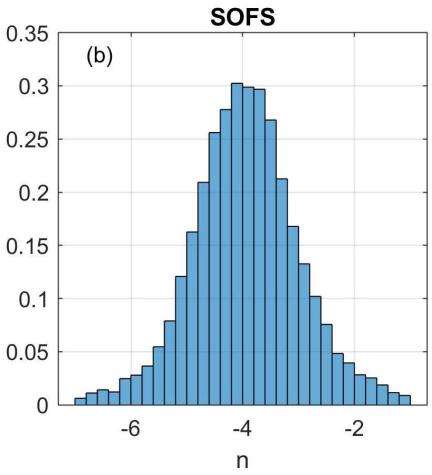
These look like fetch-limited waves!

Waves do not look like swell

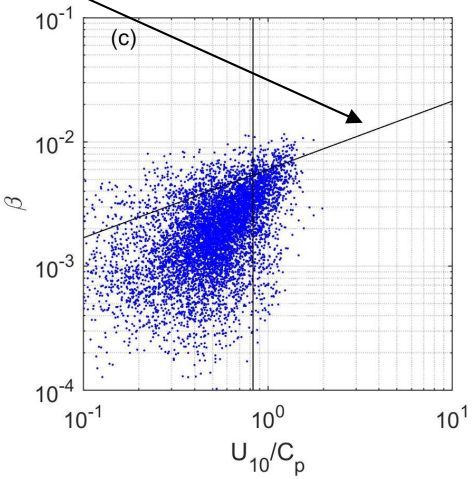
- Unimodal
- f^{-n} high f decay

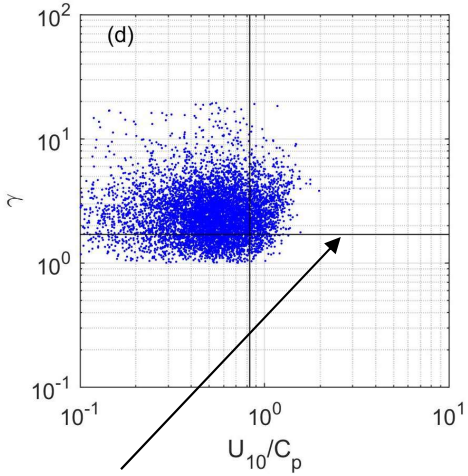
$$\varepsilon = g^2 E_{Tot} / U_{10}^4 \quad \nu = f_p U_{10} / g$$





Donelan fetch-limited relation



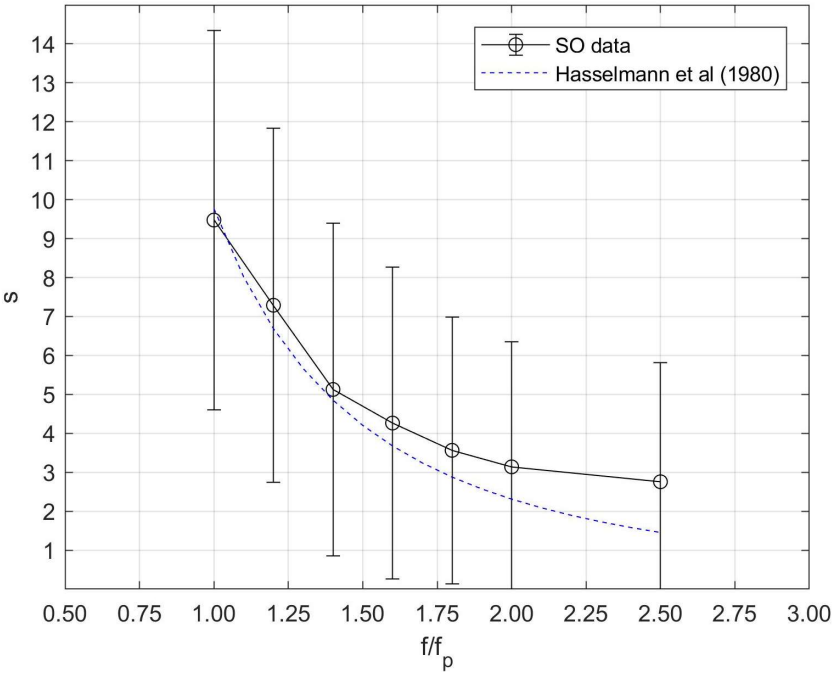


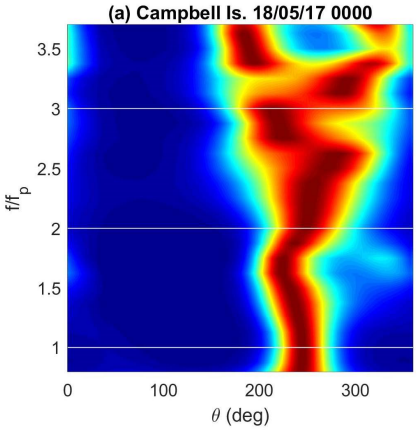
Donelan fully developed value

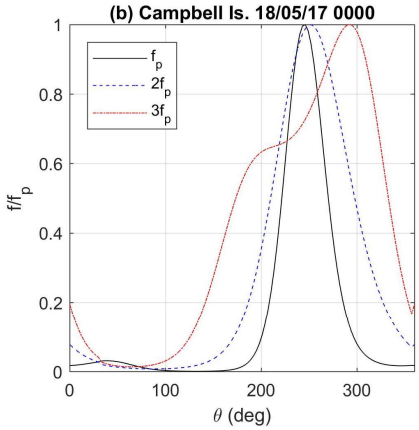
Southern Ocean Buoy Data – Directional spectra

The directional spectra also look like fetch-limited waves

$$\cos^{2s}\theta/2$$

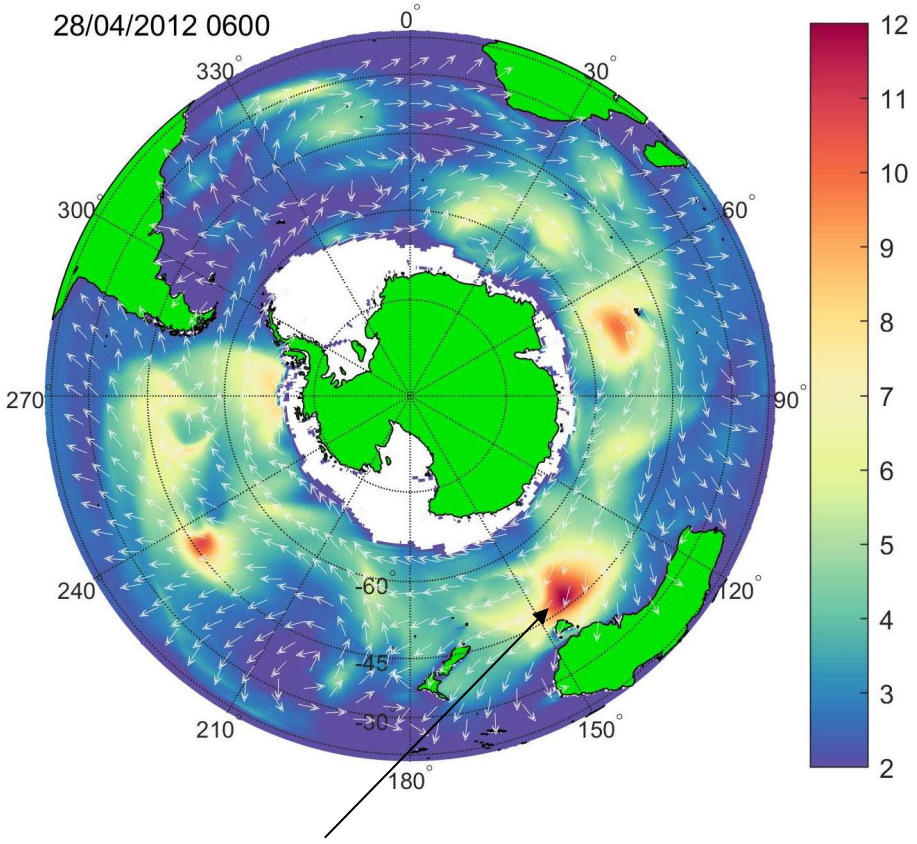






Model results to understand source term balance

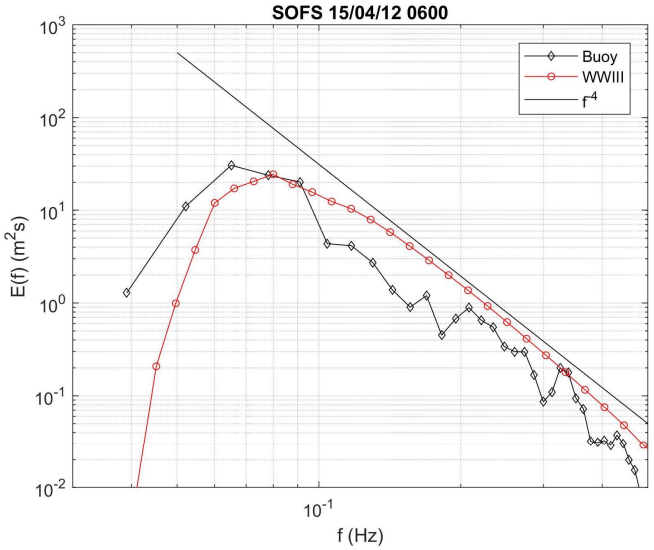
WavewatchIII with ST6 physics
Model periods for which we have insitu data



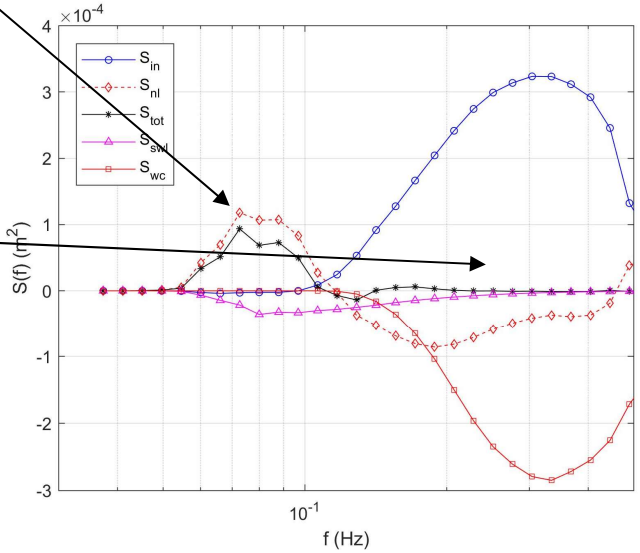
When 26m wave recorded

Source tern Balance

- No wind input at peak
- Balance of S_{nl}, S_{wc} & S_{swl}

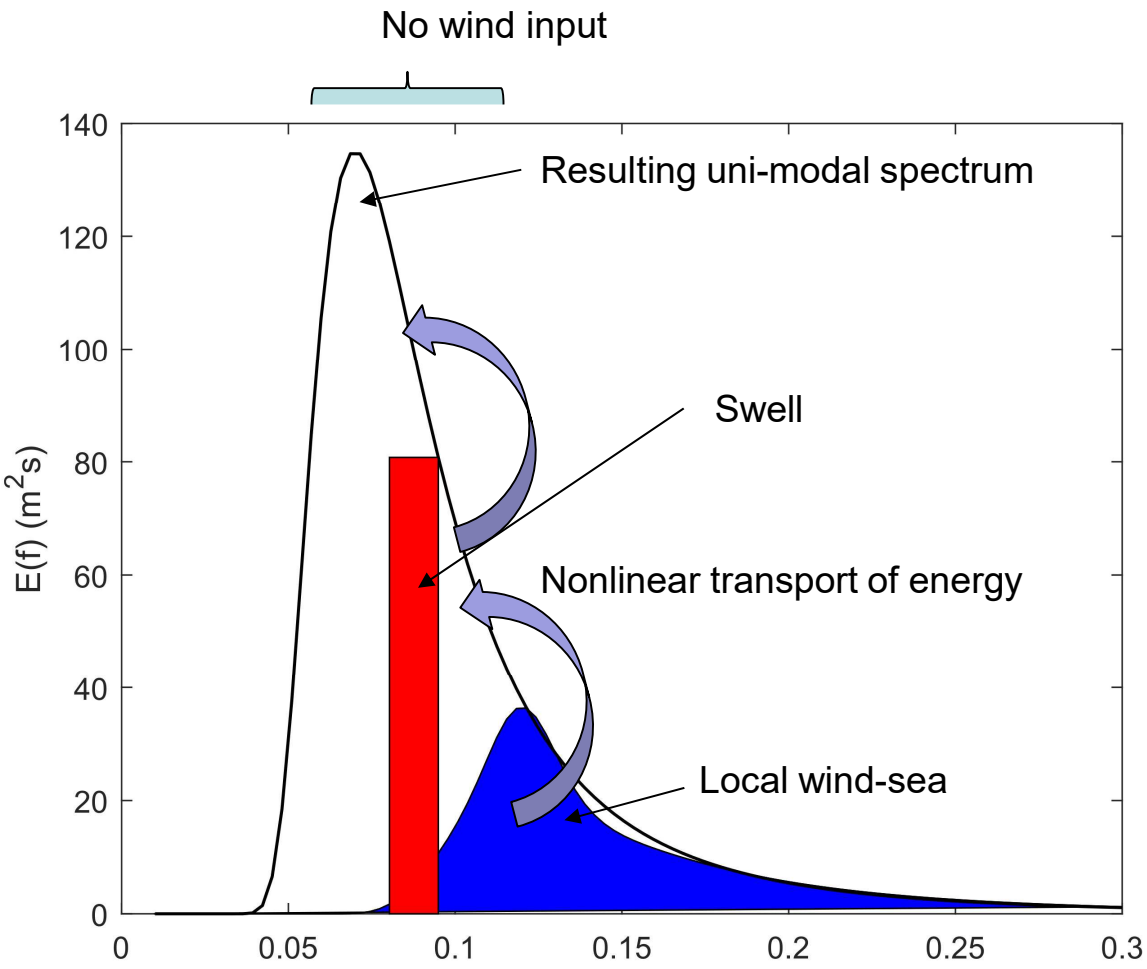


- Balance of S_{in}, S_{wc} & S_{nl}
- f^{-4} tail as for fetch-limited



THE UNIVERSITY OF MELBOURNE

Southern Ocean energy balance



THE UNIVERSITY OF MELBOURNE

Conclusions

Unique combined dataset to investigate Southern Ocean Waves

- Critical to future global wave climate
- Critical to sea level rise
- Important insights to wave evolution
- Need to understand energy balance in these over-developed situations

- Not swell as we know it!

THE UNIVERSITY OF
MELBOURNE