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# The Wave Climate of the Southern Ocean

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# Motivation

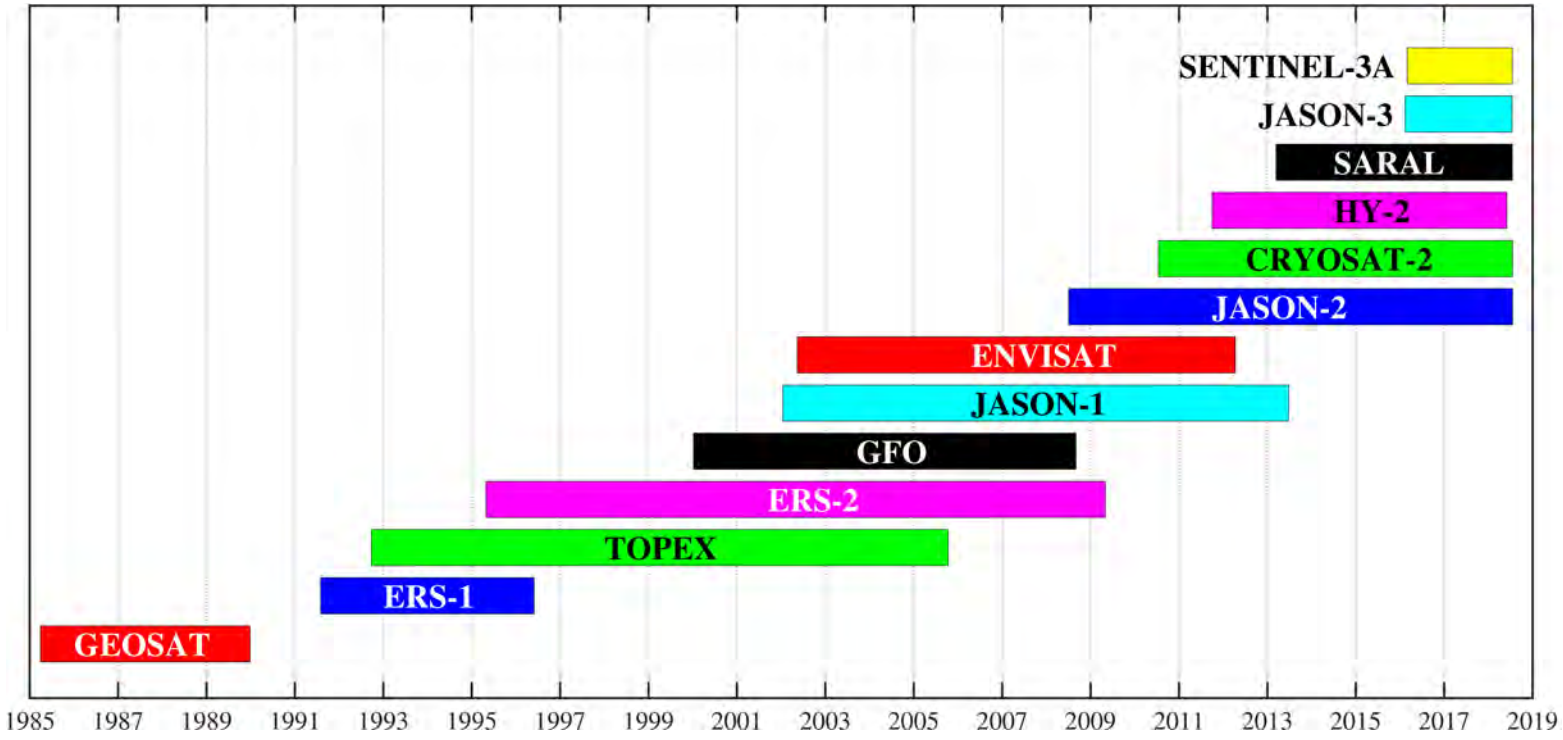
Southern Ocean Wave Climate important because:

- 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 be 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

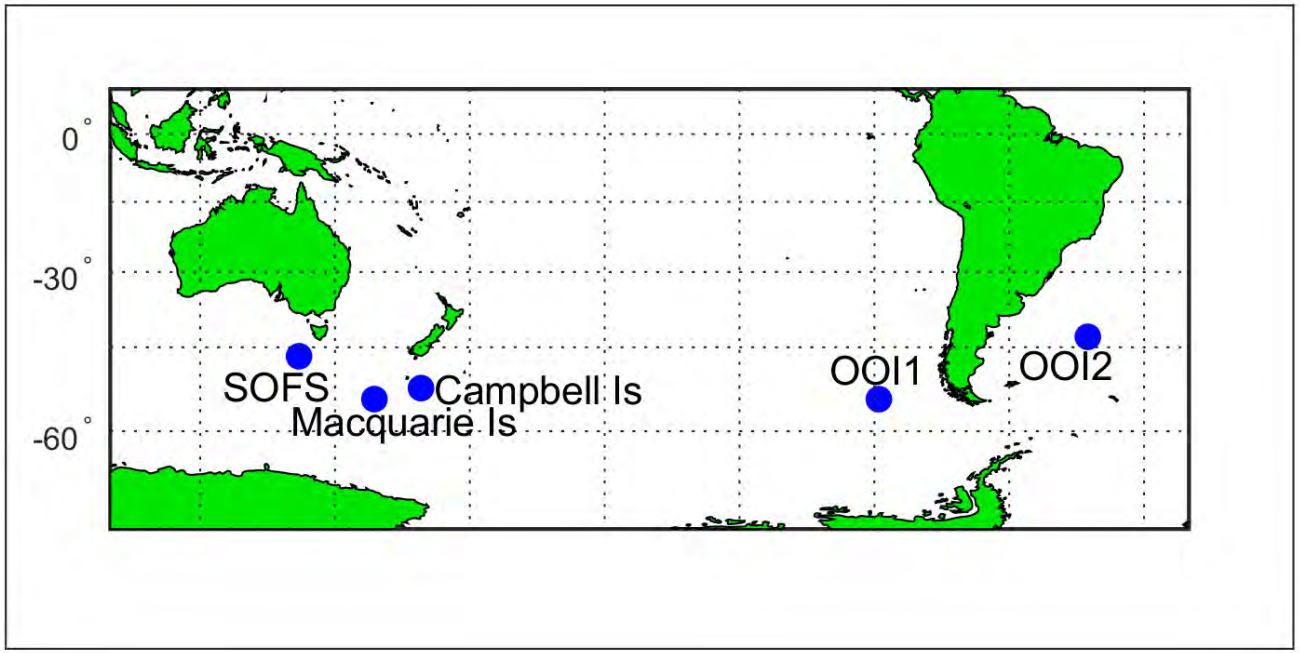
Long term (30 years) satellite datasets provide:

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



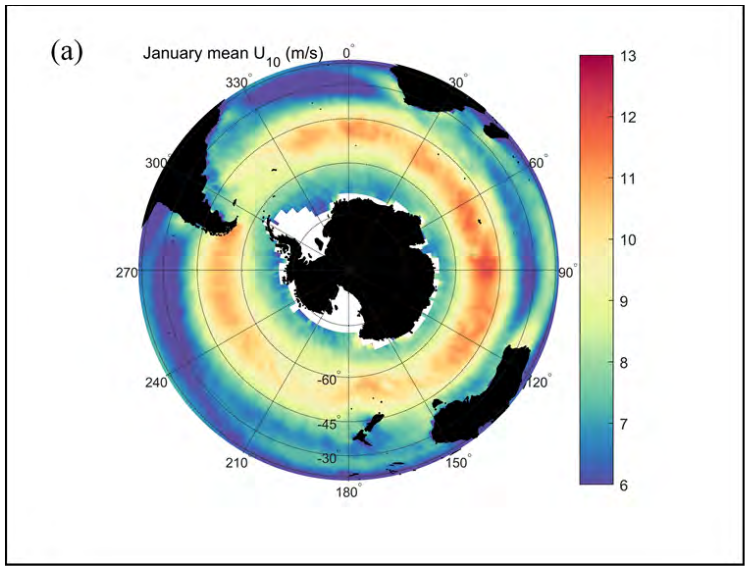

Ribal & Young, 2019, *Sci. Data*.

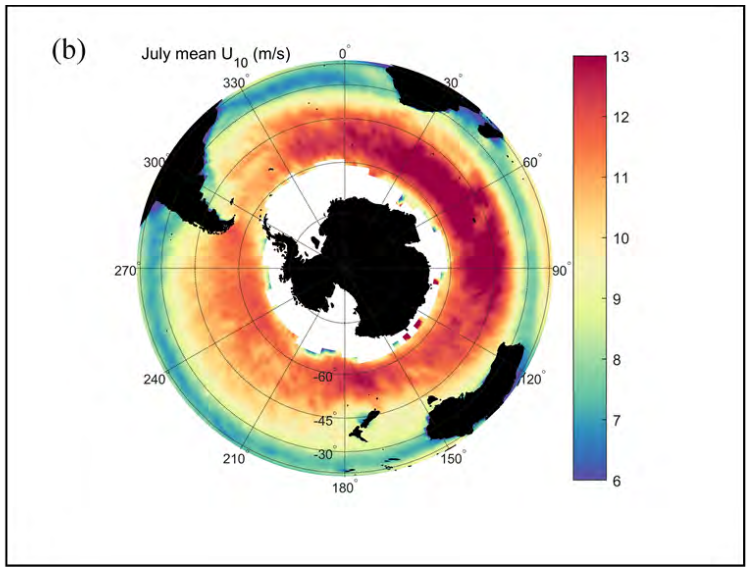
# Buoy dataset

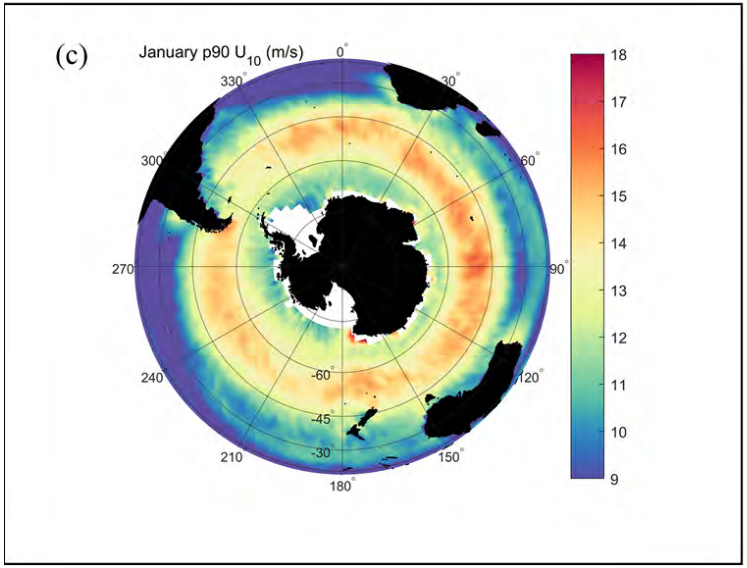


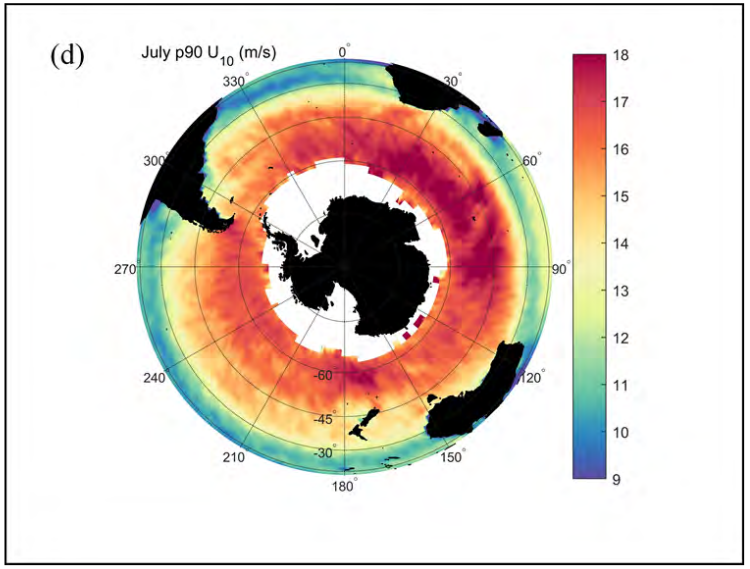

# Wind speed climatology

## Young & Donelan, 2018




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

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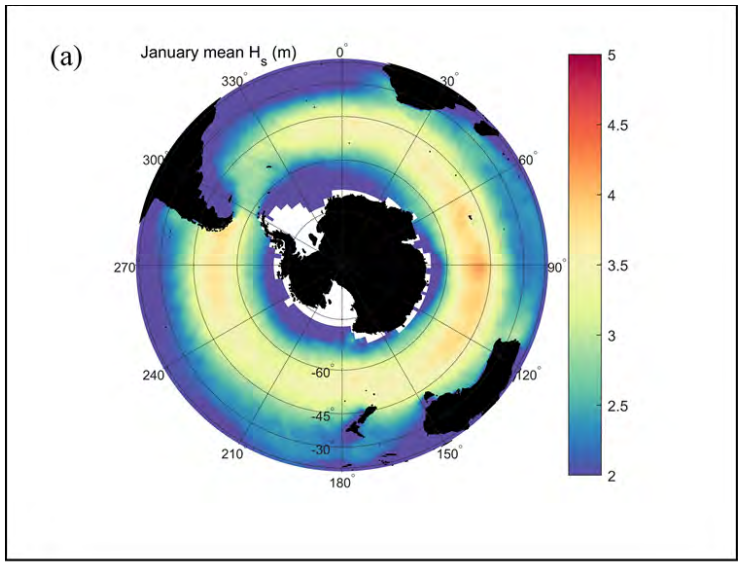
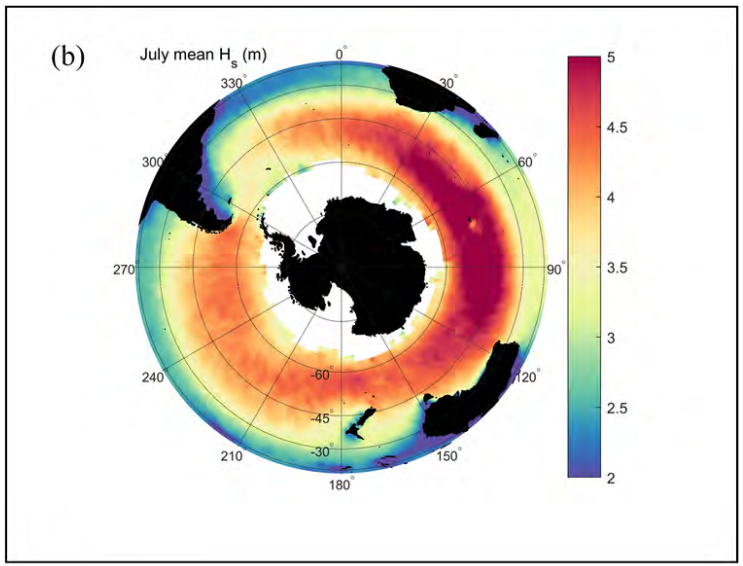
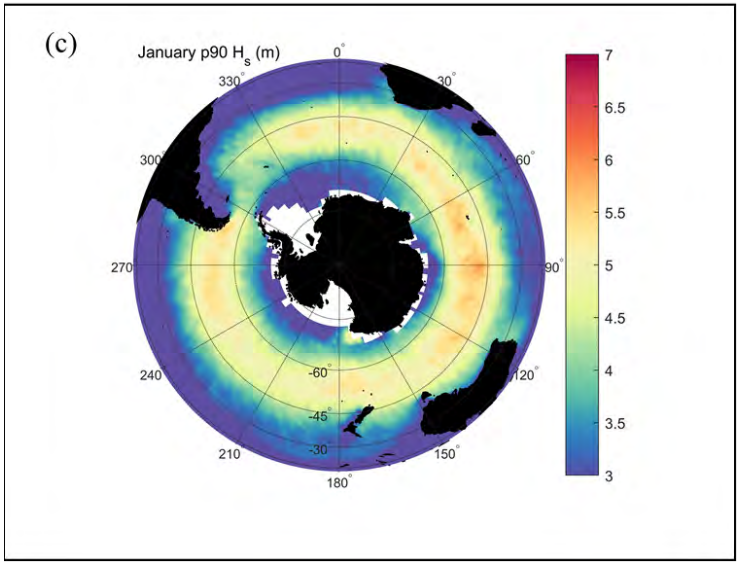
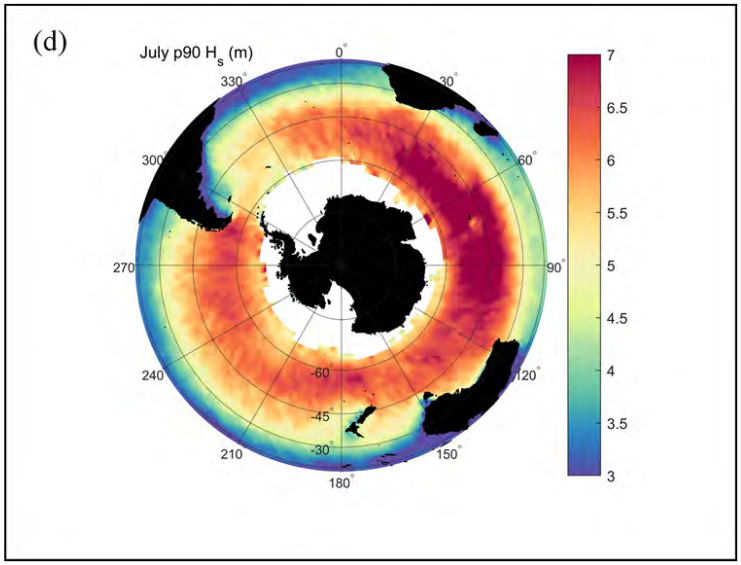
# Significant wave height climatology

## 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.*

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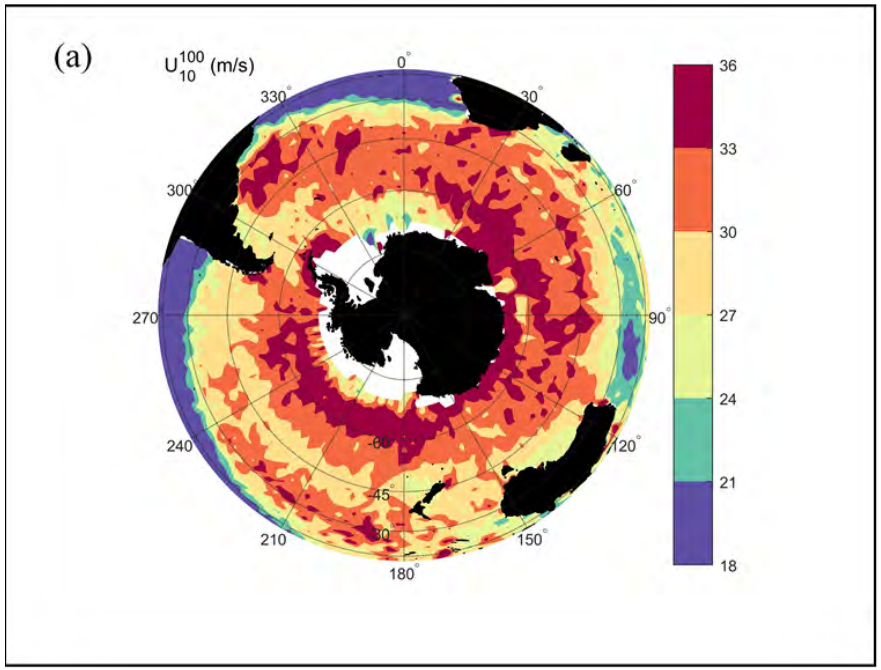
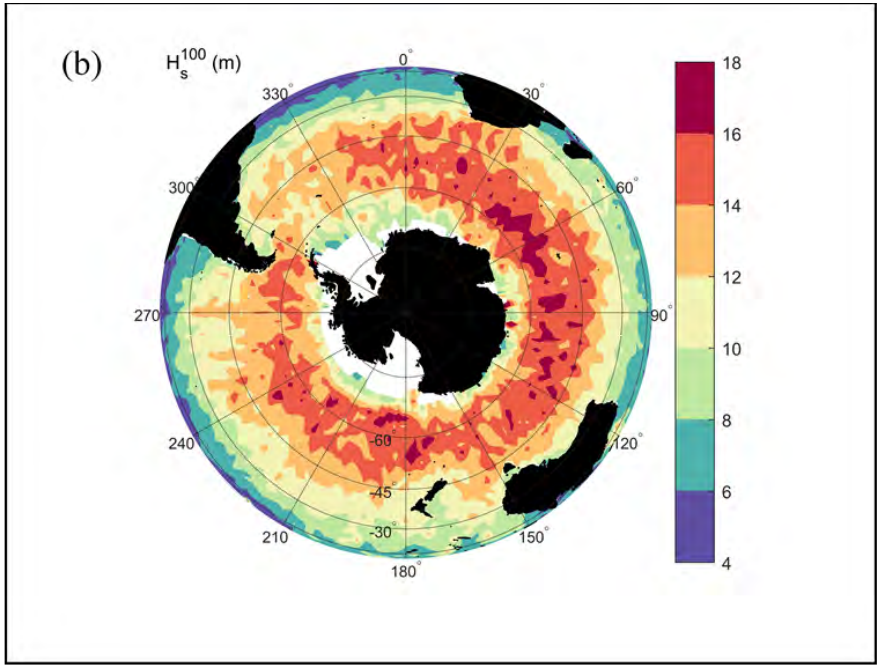
# 100-year return period wind speed and significant wave height

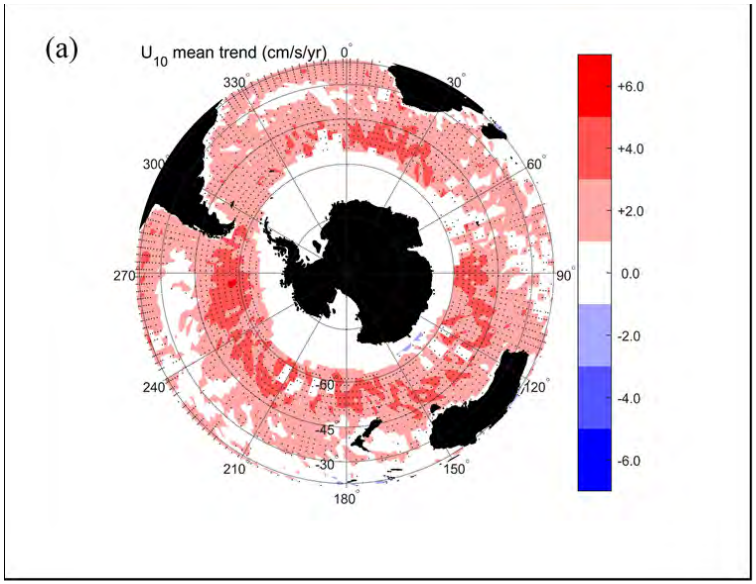


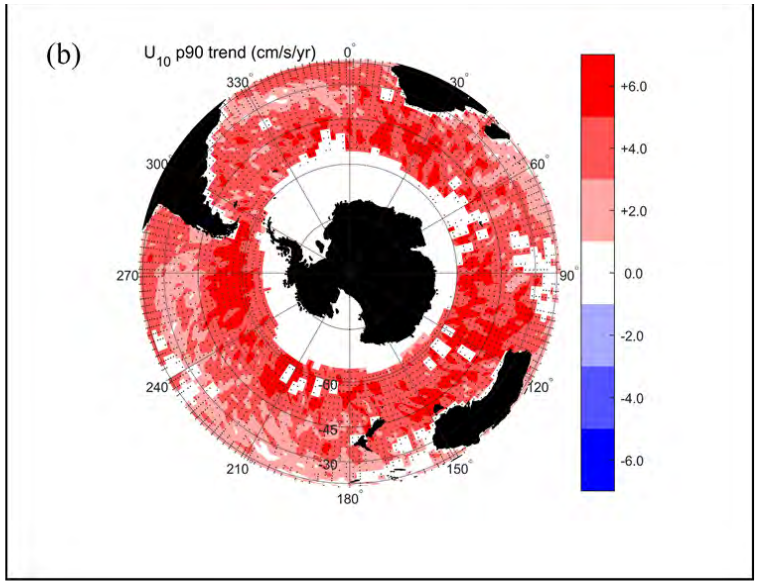



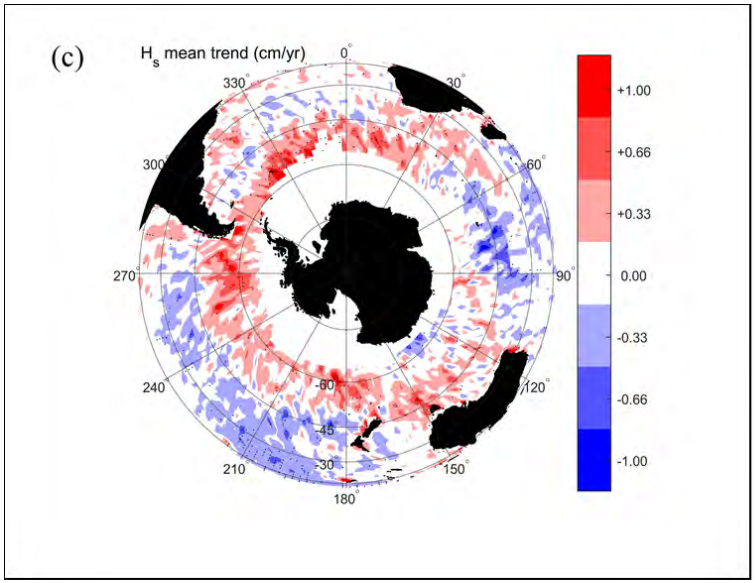

Takbash et al., 2018, *J. Clim.*

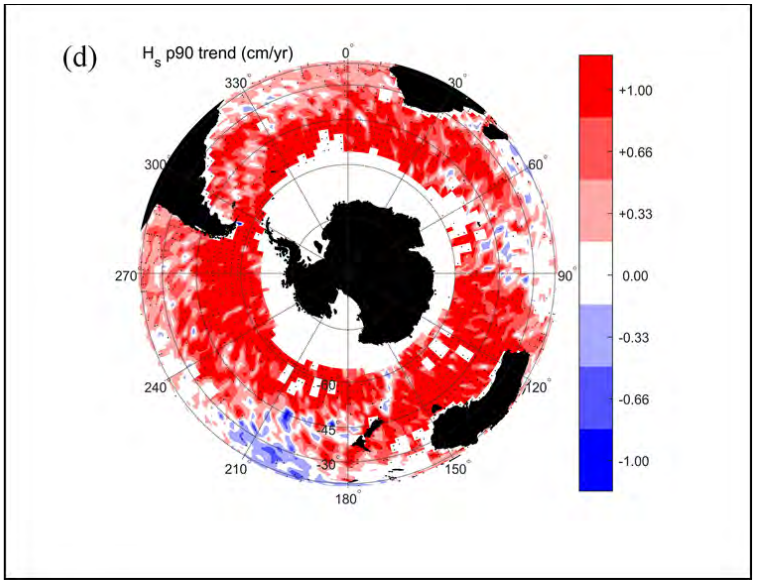
# Trends in mean and 90th percentiles

Young & Ribal, 2019, Science



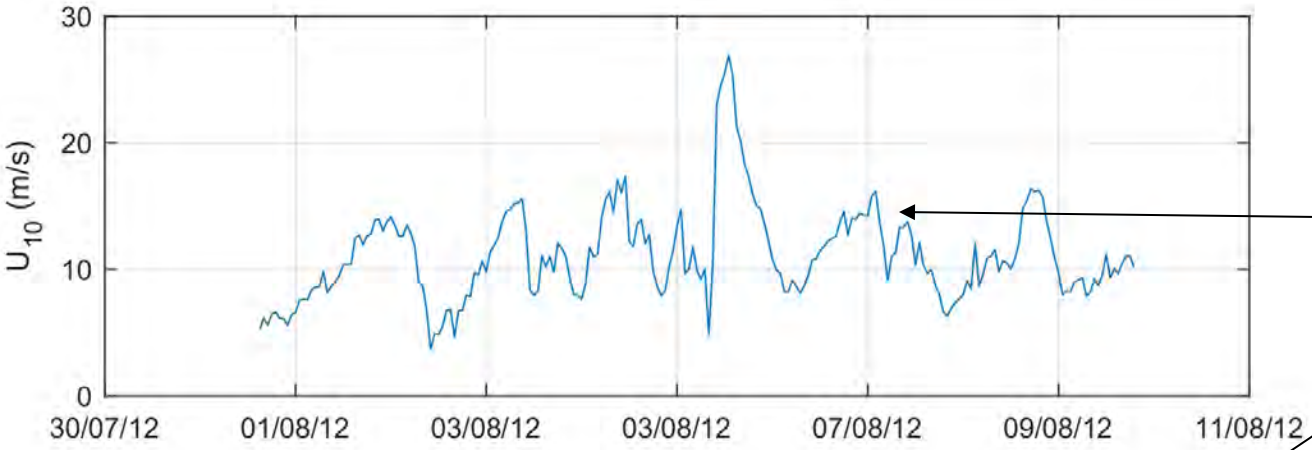



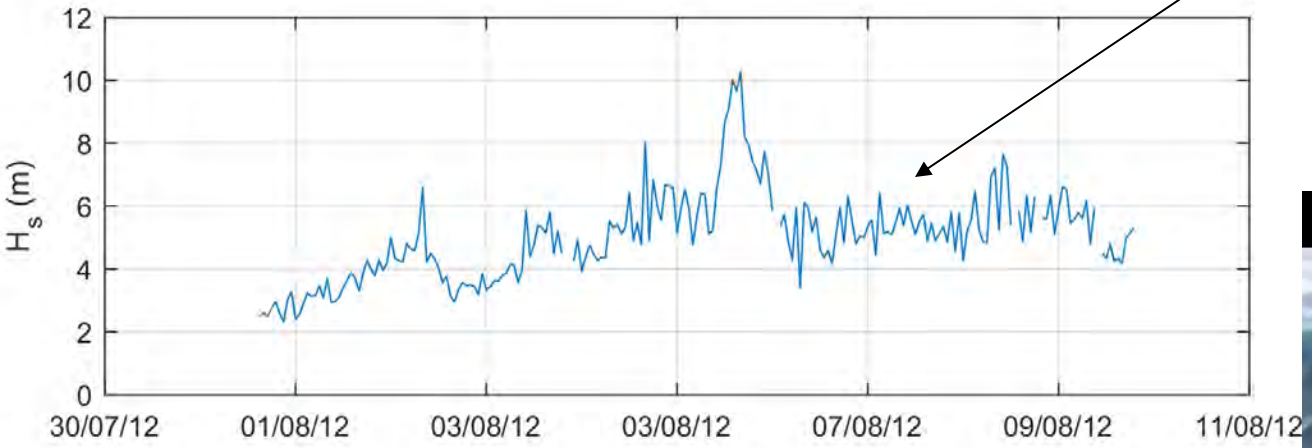




Young & Ribal, 2019, *Science*

# Southern Ocean Buoy Data - SOFS



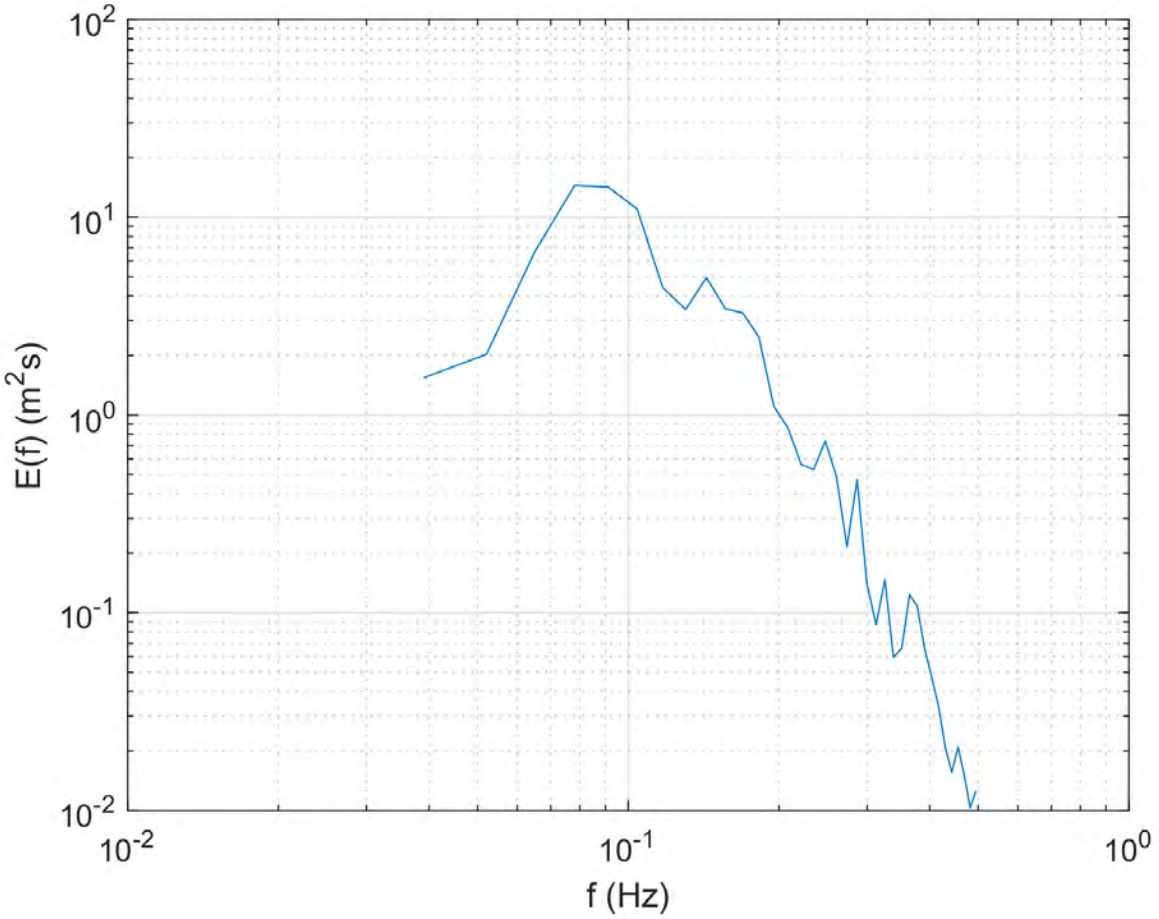




Weak connection to local wind except at extremes

# Southern Ocean Buoy Data - SOFS

Waves do not look like swell

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

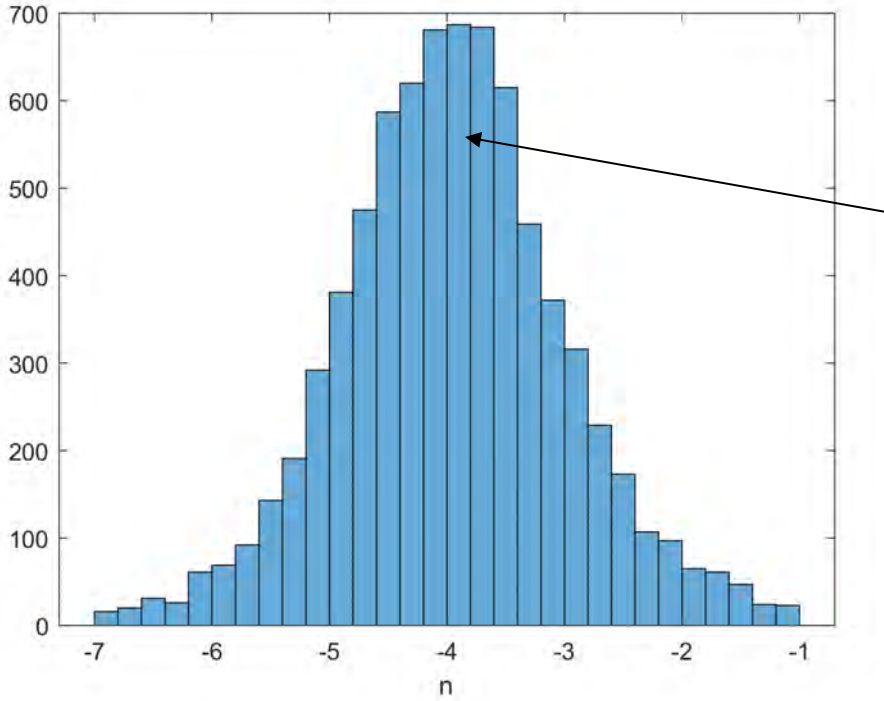


# Southern Ocean Buoy Data - SOFS

## Spectral form

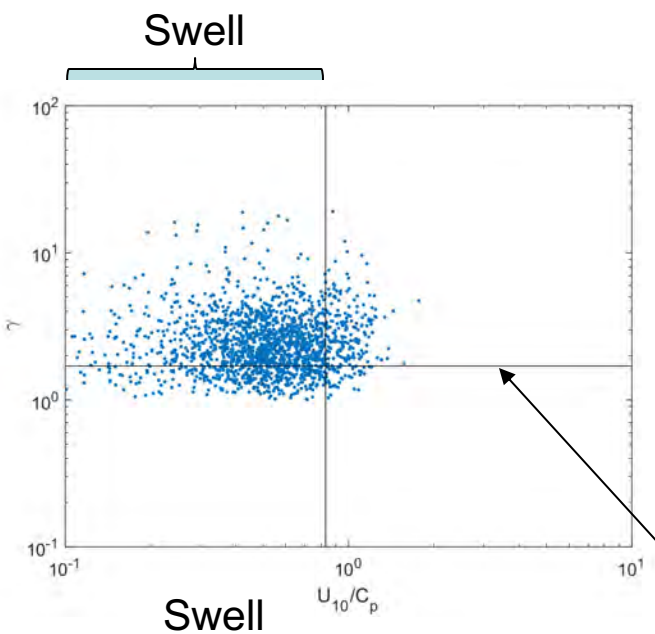
$$F(f) = \beta g^2 (2\pi)^{-4} f_p^{-(5+n)} f^n \exp\left[\frac{n}{4}\left(\frac{f}{f_p}\right)^{-4}\right] \cdot \gamma^{\exp\left[\frac{-(f-f_p)^2}{2\sigma^2 f_p^2}\right]}$$

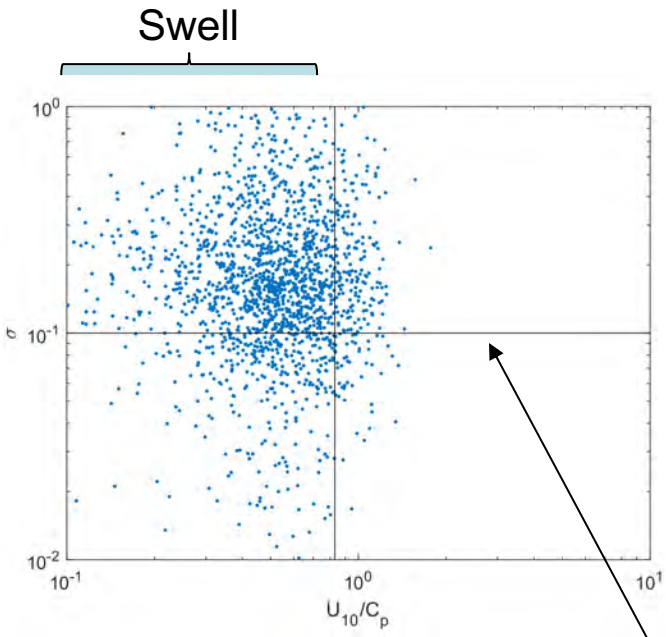
(Generalized Donelan et al, 1985)

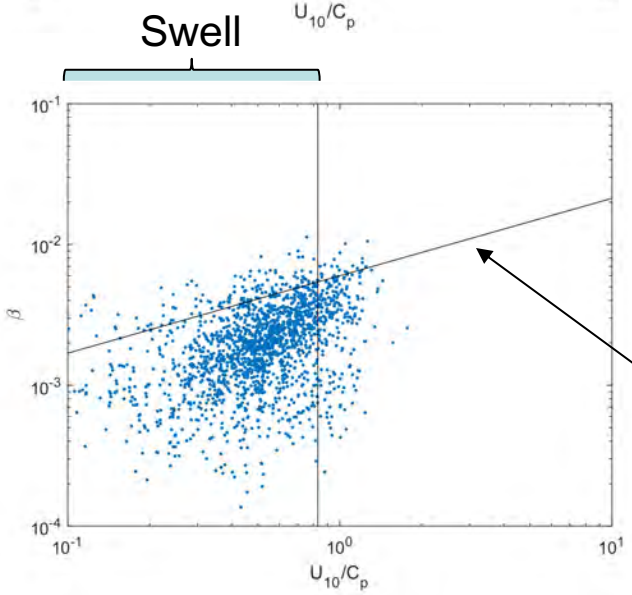



$f^{-4}$ high f decay

# Southern Ocean Buoy Data - SOFS




Donelan fully developed value

Average fetch-limited value

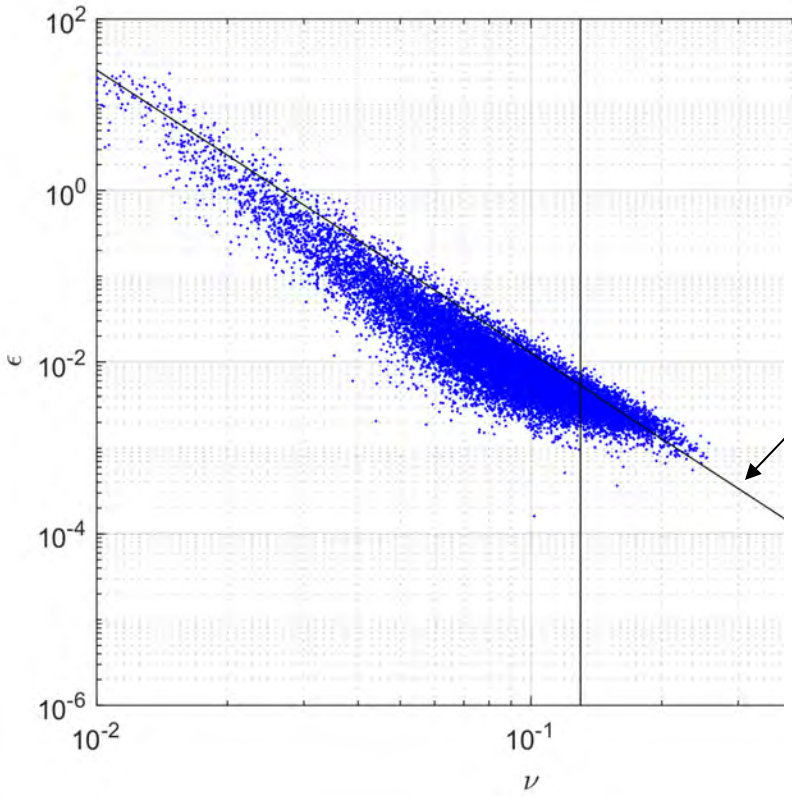
Donelan fetch-limited relation

**These look like fetch-limited waves!**

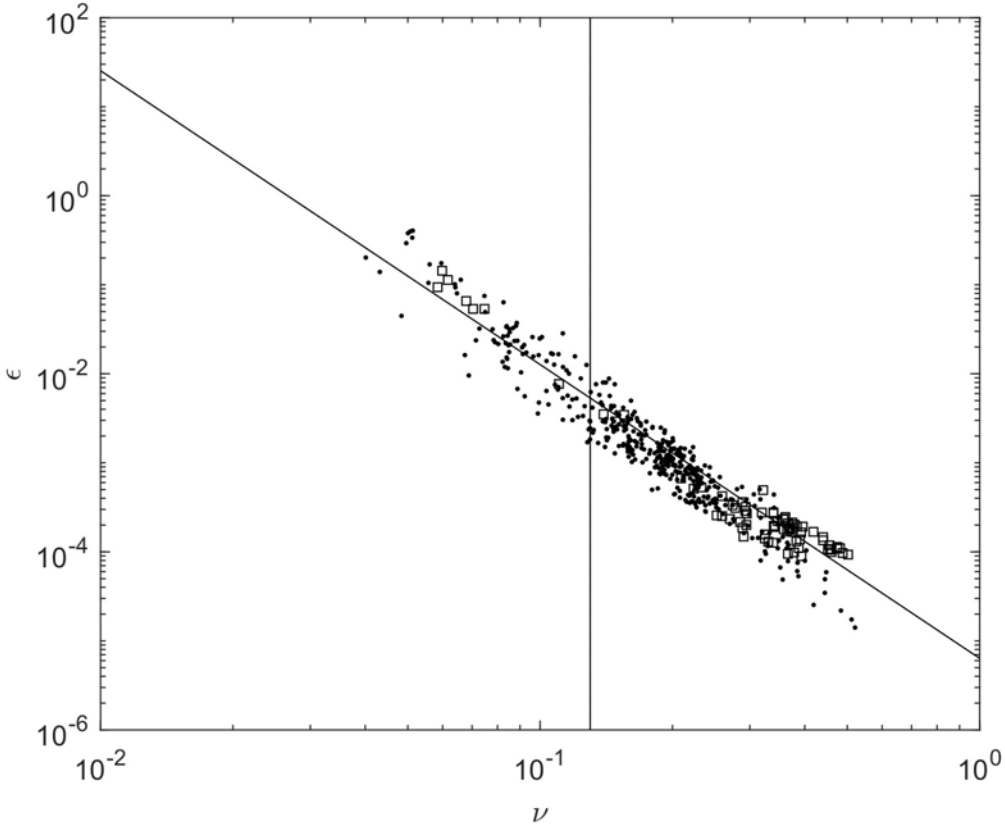
# Southern Ocean Buoy Data - SOFS

Swell

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

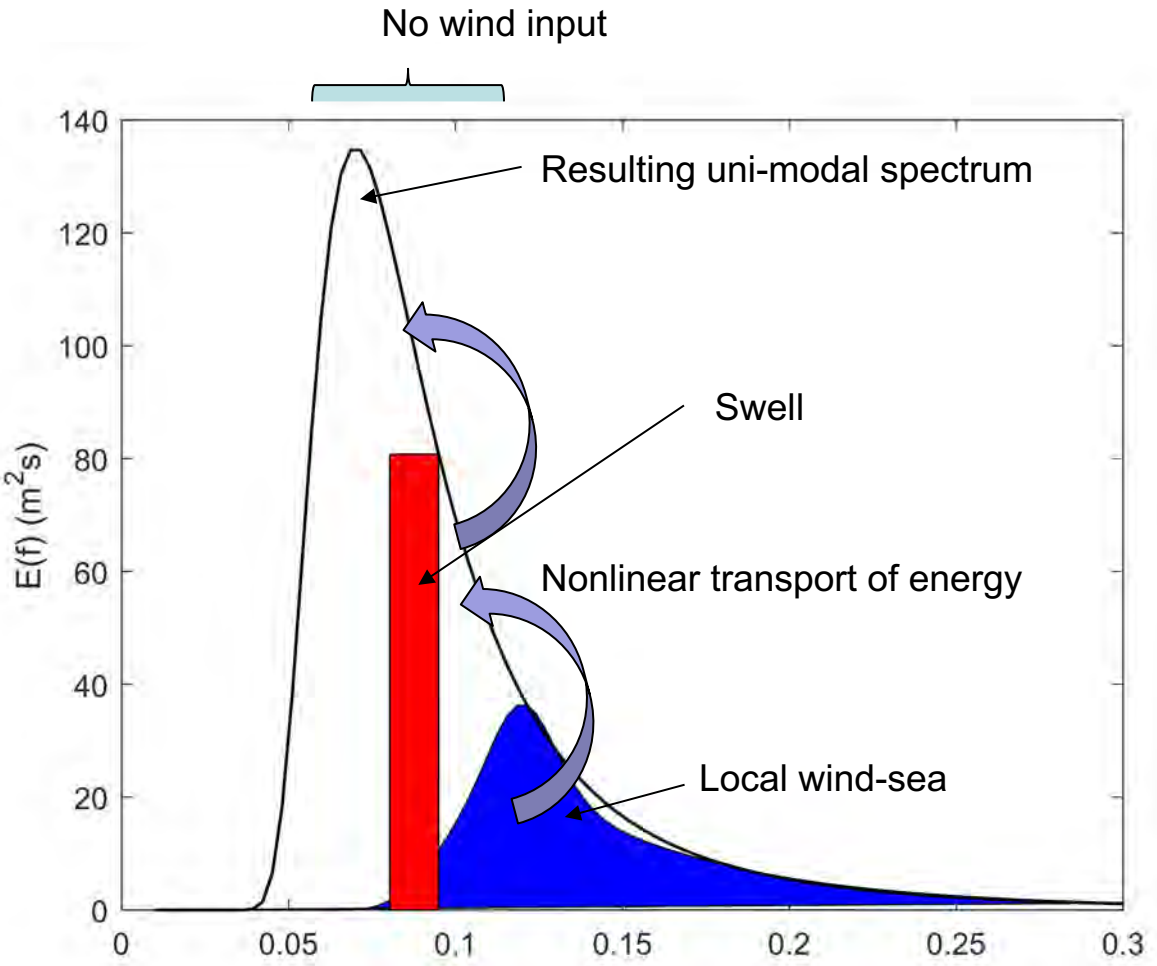



Donelan fetch-limited relation




Seen this before with hurricane waves

# Southern Ocean energy balance




# Conclusions

Unique combined dataset to investigate Southern Ocean Waves

- Critical to future global wave climate
- Critical to coastal stability
- Important insights to wave evolution
- Need to understand energy balance in these over-developed situations

- Not swell as we know it!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