A CONSISTENT DESCRIPTION OF THE SPATIAL DISTRIBUTION OF WIND GENERATED WAVES WITHIN HURRICANES

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Background

20 years of investigation from:

- Insitu buoys
- Numerical modelling
- Satellite observations
- Advances in understanding of wind-wave physics

Comprehensive and consistent understanding of:

- Spatial distribution of wave height and peak wave period
- Spectral shape
- Directional properties
- Physics at play in tropical cyclones

Wind field

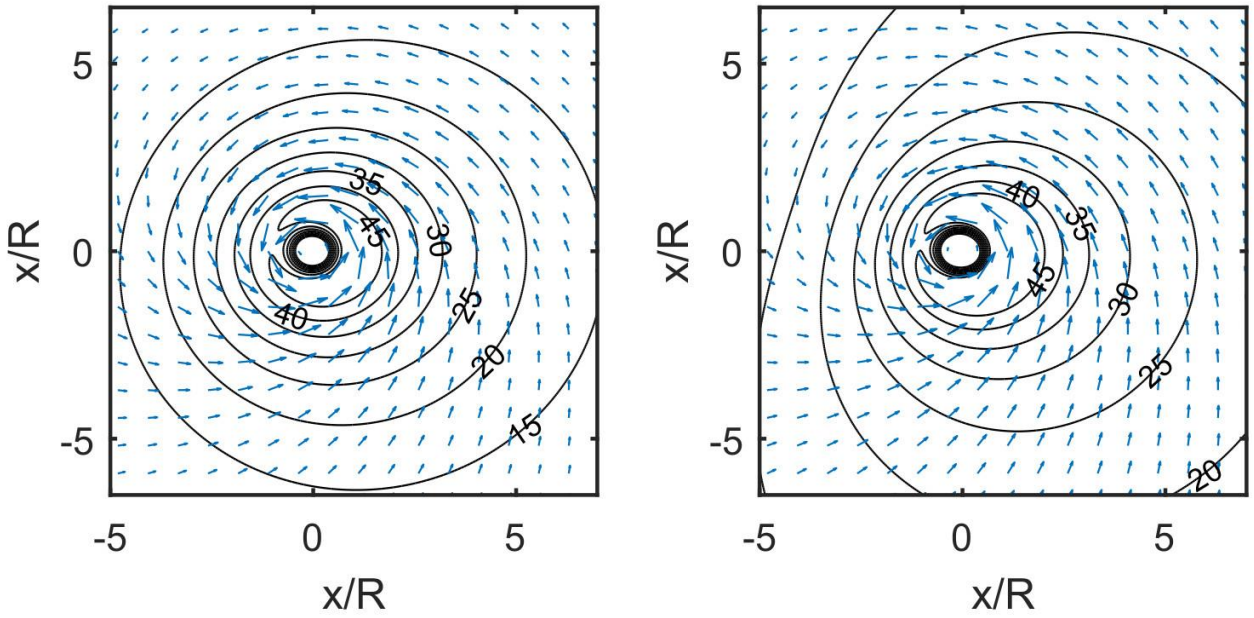
Can be described by a Holland vortex

p_0 - central pressure

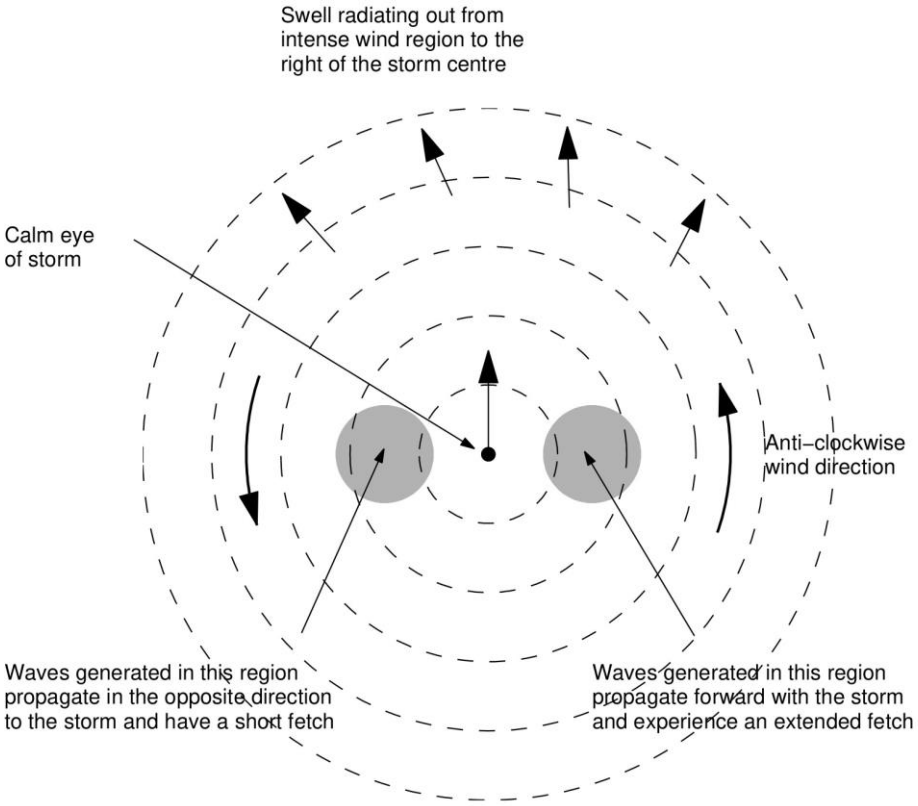
$V_{\max}$ - max wind velocity

V_{fm} - velocity of forward mvmt.

R - radius to maximum winds



Spatial Distribution of Waves

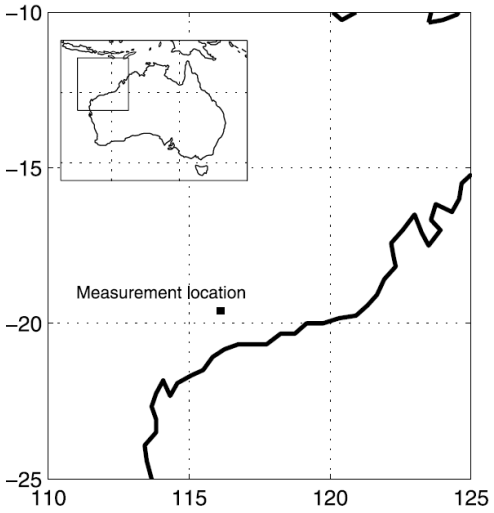


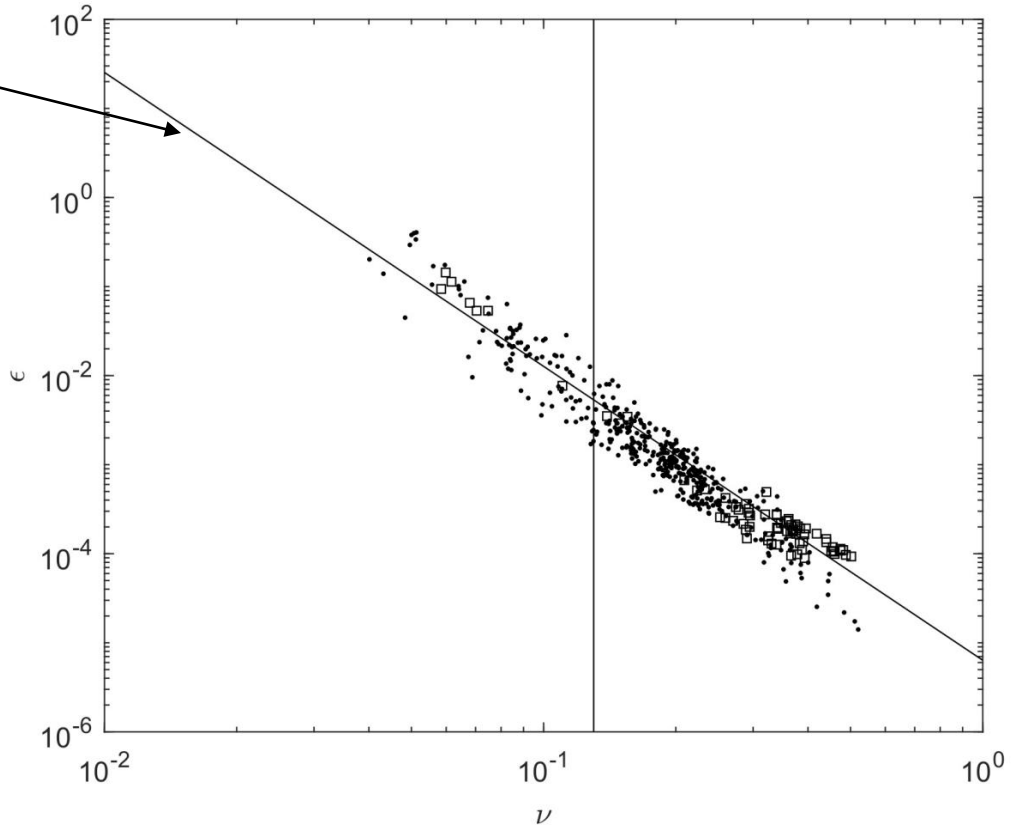
- SAR aircraft observations (King and Shemdin)
- Extended fetch

Energy – peak frequency relationship

Insitu tropical cyclone observations of non-d energy vs non-d frequency
Almost identical to fetch-limited results!

Donelan et al (1985)
(fetch-limited)

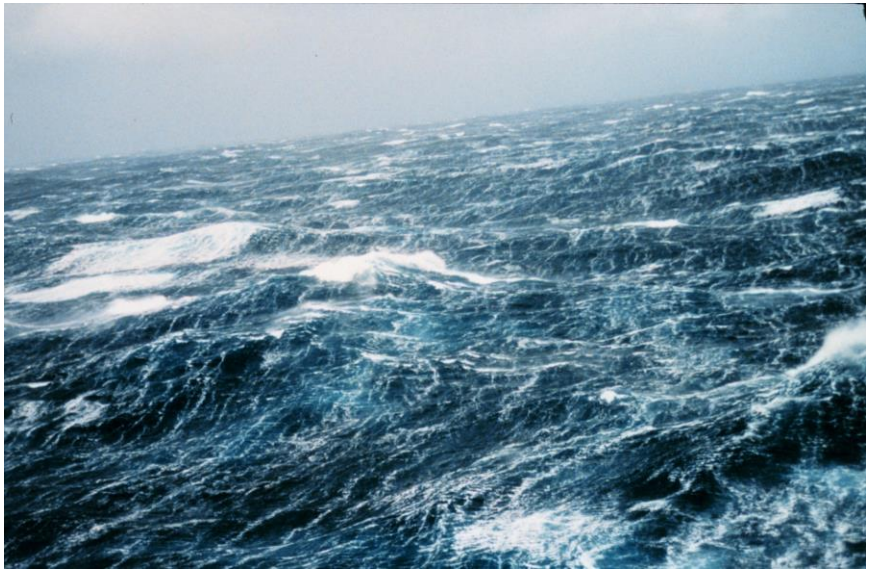




Energy – peak frequency relationship

The fact that the energy – frequency relationship is the same as for fetch-limited growth suggests:

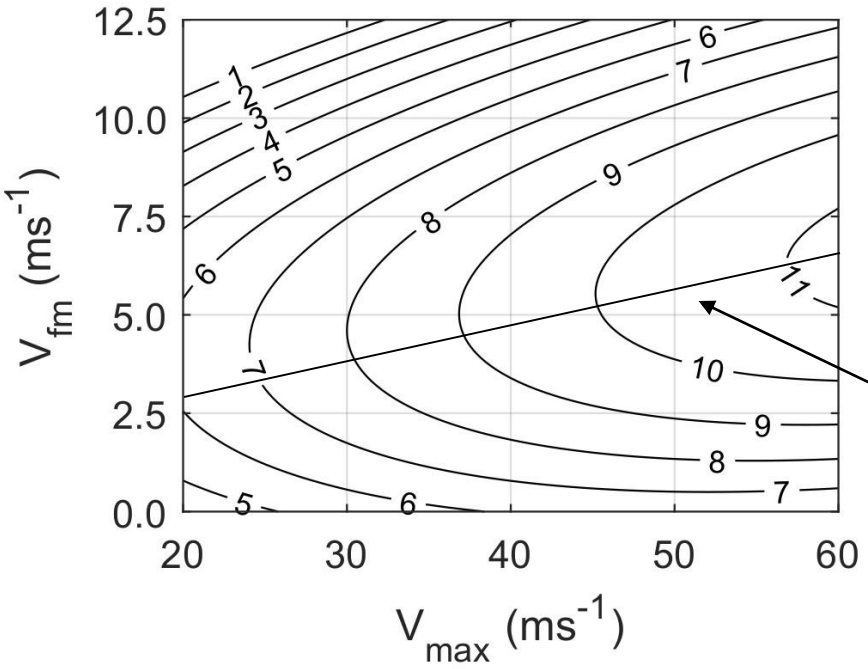
- Non-d scaling can be used, as for fetch-limited (JONSWAP)
- Nonlinear processes probably dominate



Investigate distributions with model runs

Young (1988) explored the $V_{fm}, V_{\max}$ parameter space with a numerical model.

Noting JONSWAP type scaling, defined an equivalent fetch

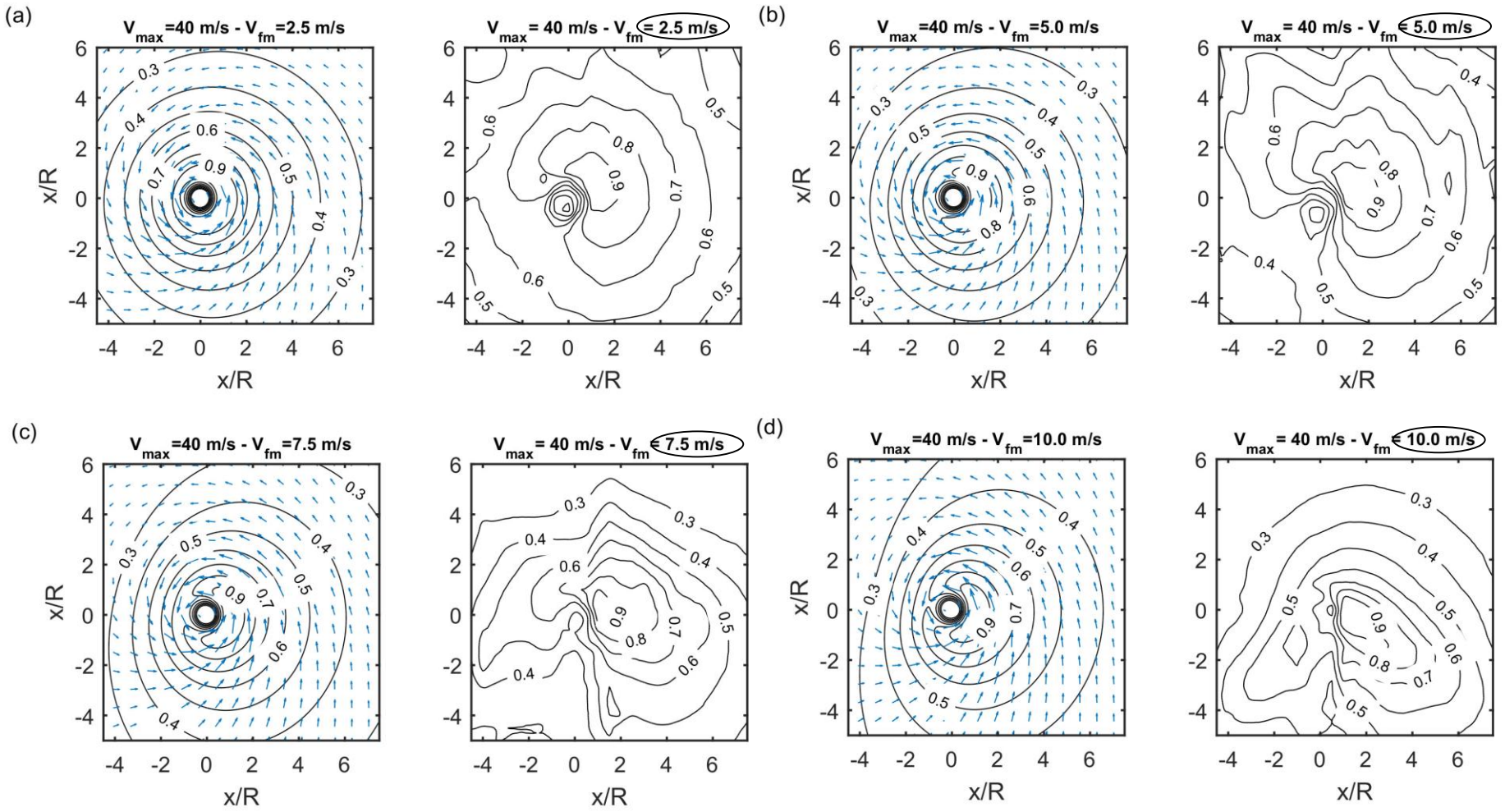


Extended fetch model

- With equivalent fetch defined, the max H_s in the storm follows from JONSWAP relationship

$$\frac{gH_s^{\max}}{V_{\max}^2} = 0.0016\left(\frac{gx}{V_{\max}^2}\right)^{0.5}$$

Extended fetch model – spatial distribution

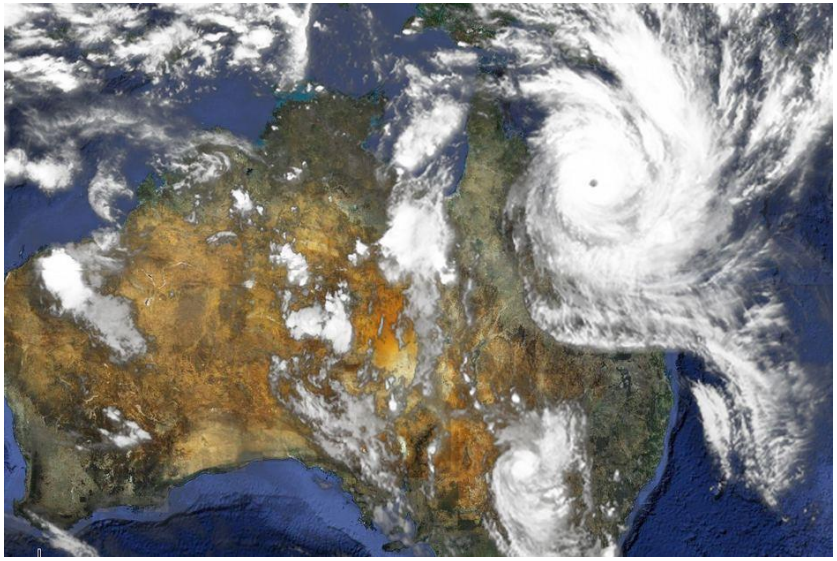


- Spatial distribution H_s greater than U_{10}
- H_s distribution changes with V_{max} and V_{fm}

One-dimensional spectrum

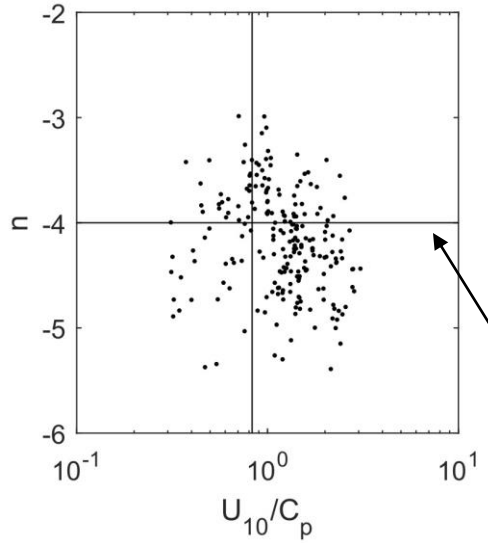
- Insitu buoy observations from NW coast of Australia
- Spectra within 8*R* of storm centre unimodal
- Try JONSWAP type fit to data

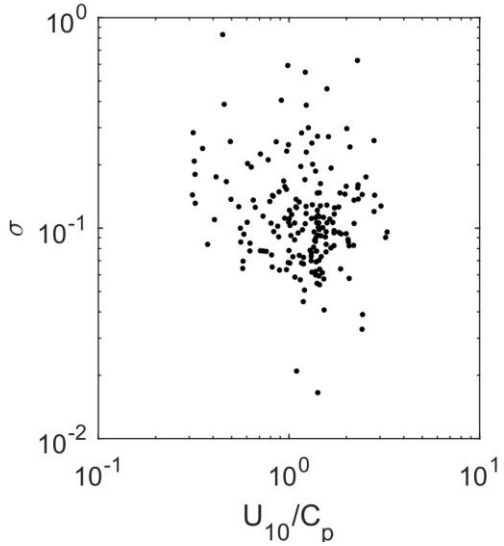
$$F(f) = \beta g^2 (2\pi)^{-4} f_p^{-(5+n)} f^n \exp\left[\frac{n}{4}\left(\frac{f}{f_p}\right)^{-4}\right] \cdot \gamma^{\exp\left[\frac{-(f-f_p)^2}{2\sigma^2 f_p^2}\right]}$$



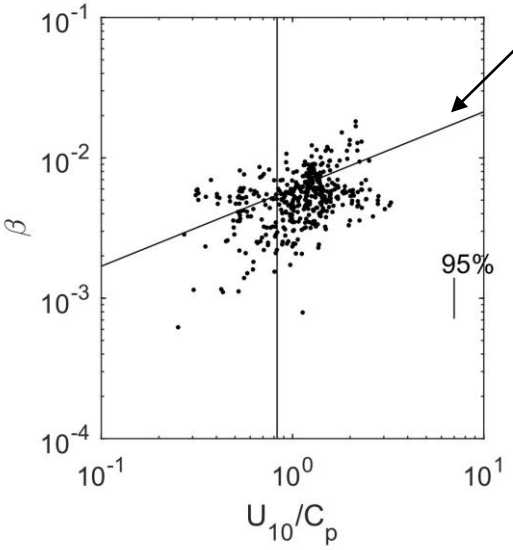
(Generalized Donelan et al, 1985)

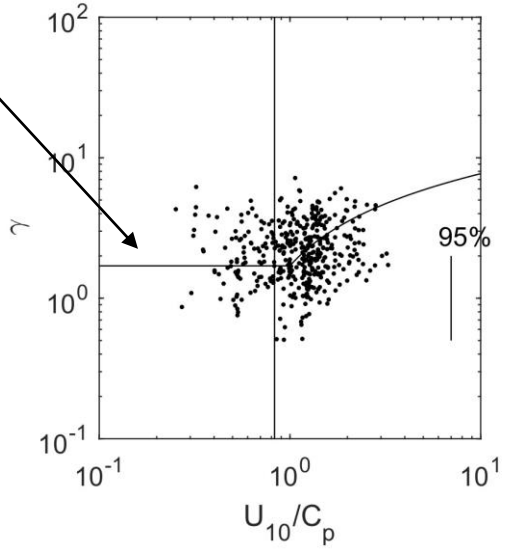
One-dimensional spectrum





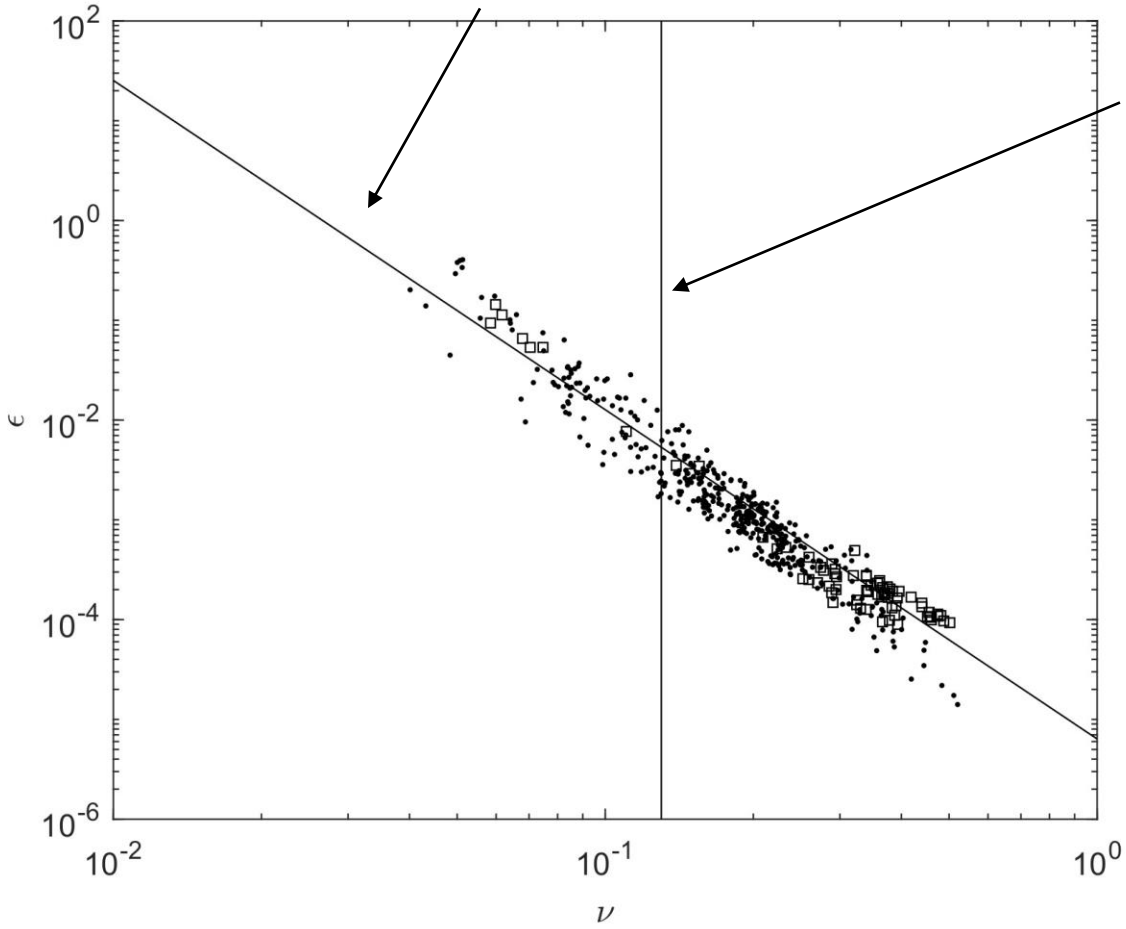
Fetch-limited results





One-dimensional spectrum

Fetch-limited results



Fully developed limit

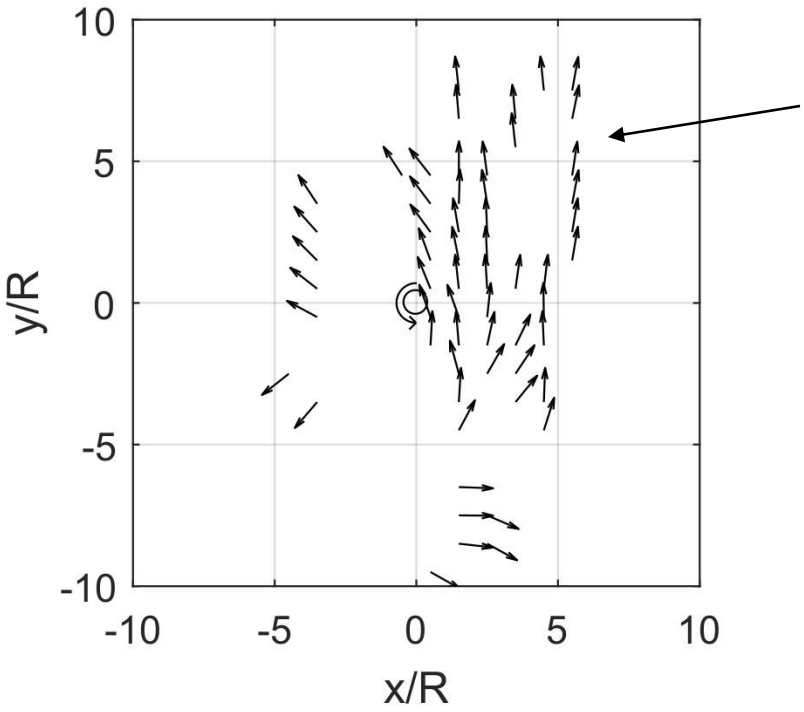
Active physics

Why do tropical cyclone waves look and scale like fetch-limited waves?

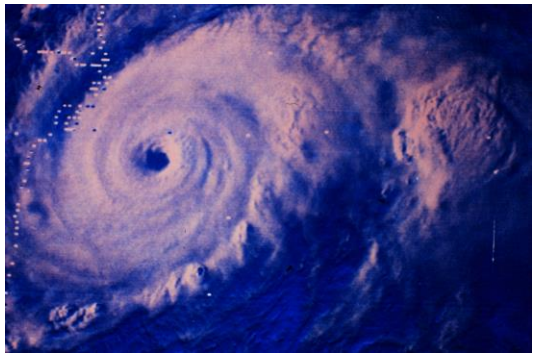
- Non-linear source terms dominate
- Even follow fetch-limited scaling in regions where no atmospheric input, means that nonlinear terms must be dominant
- i.e. Zakharov view of the world!

Directional spectra

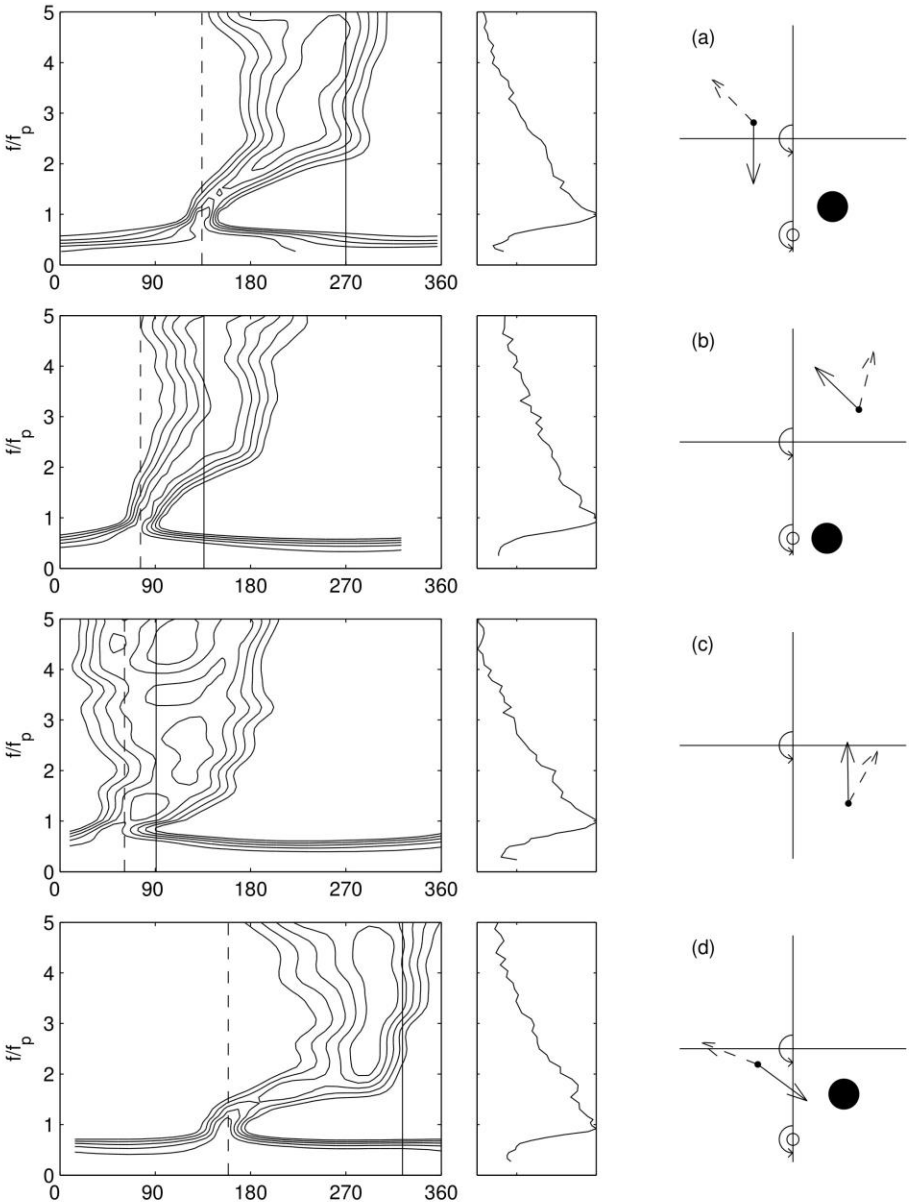
Young (2006) composite of Aust NW Shelf data



As observed by King and Shemdin (1978) and Hwang et al (2016)

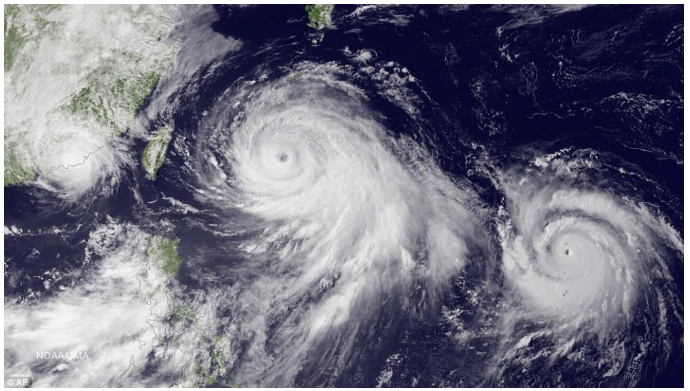


Directional spectra



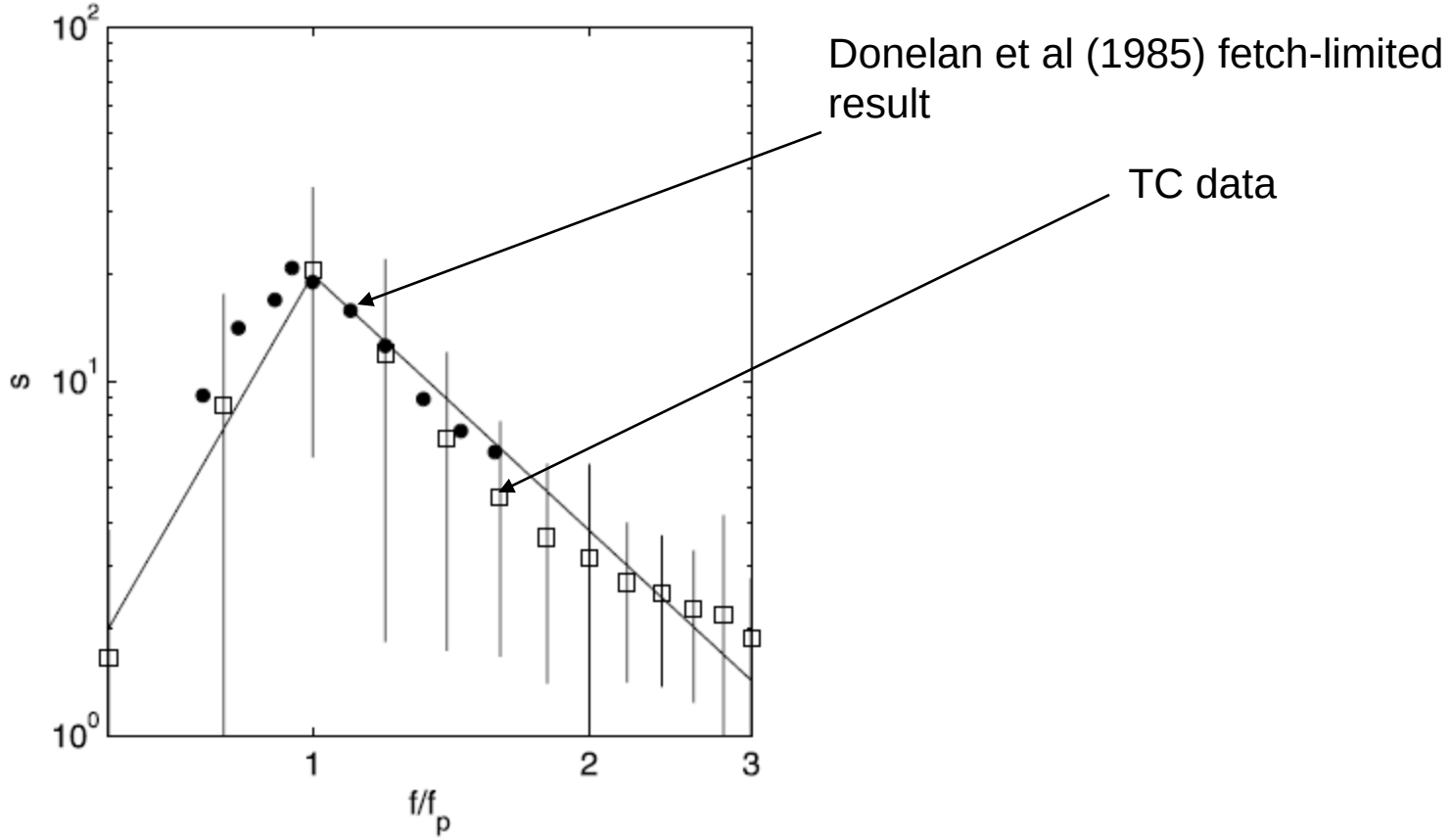
Directional spectra skewed

One-d spectra unimodal and JONSWAP-like



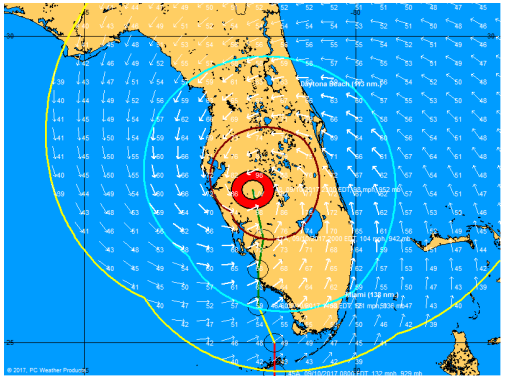
Directional spreading

Despite directional skewing, spreading again follows fetch-limited relationships



Summary

- Extended fetch model captures basic role of V_{fm} and V_{max} in defining fetch
- Works because of dominant role of non-linear terms
- Model fully defines spatial distribution and spectral shape
- Needs to be updated with runs from a better numerical model (underway)



Young, 2017, *Atmosphere*

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