The ‘energy journey’ of a M2 tidal beam across the Tasman Sea

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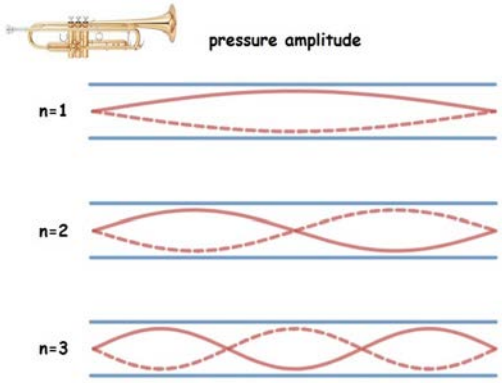
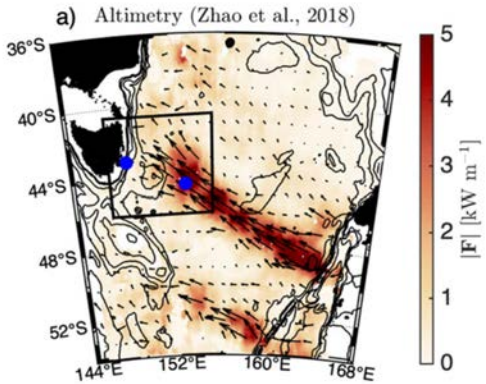
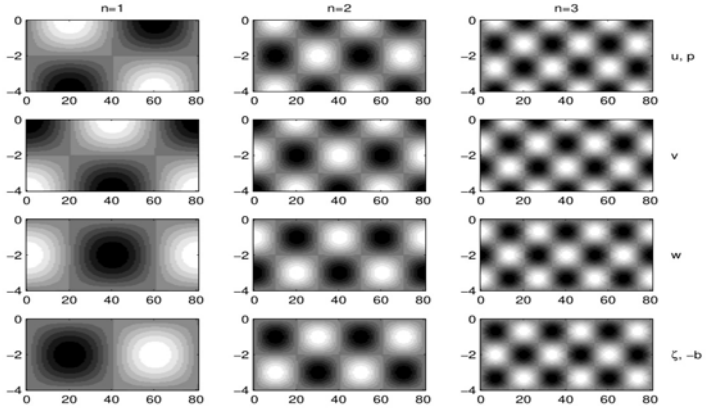
3 climate extremes ARC centre of excellence

4 Consortium for Ocean and Sea Ice Modelling Australia (COSIMA)

What are internal tidal beams?

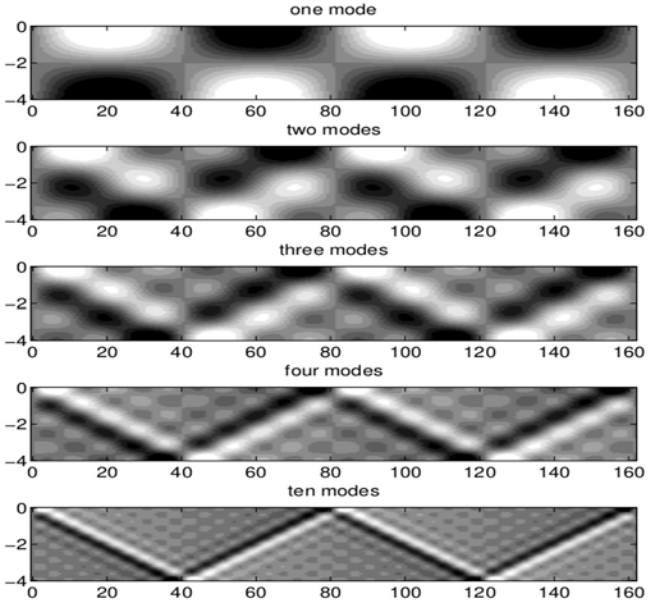






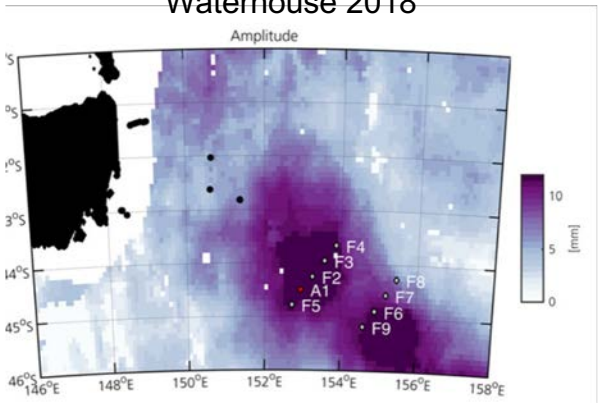
From Gerkema 2008

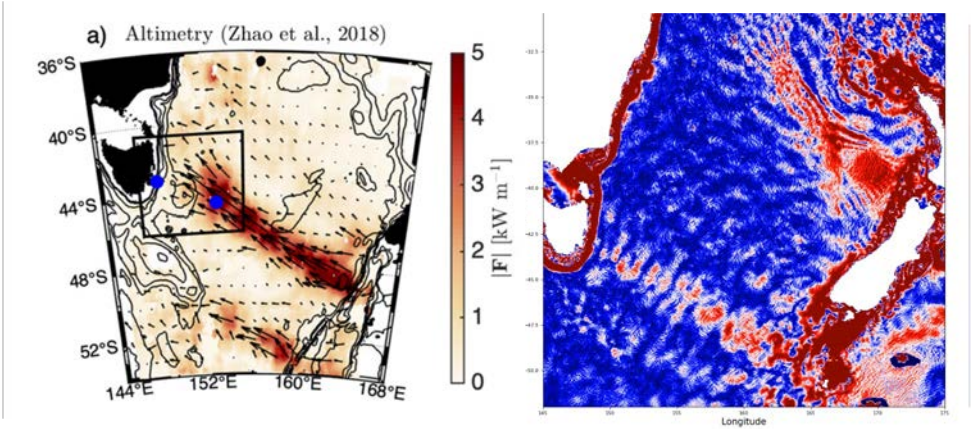
Sum them up…

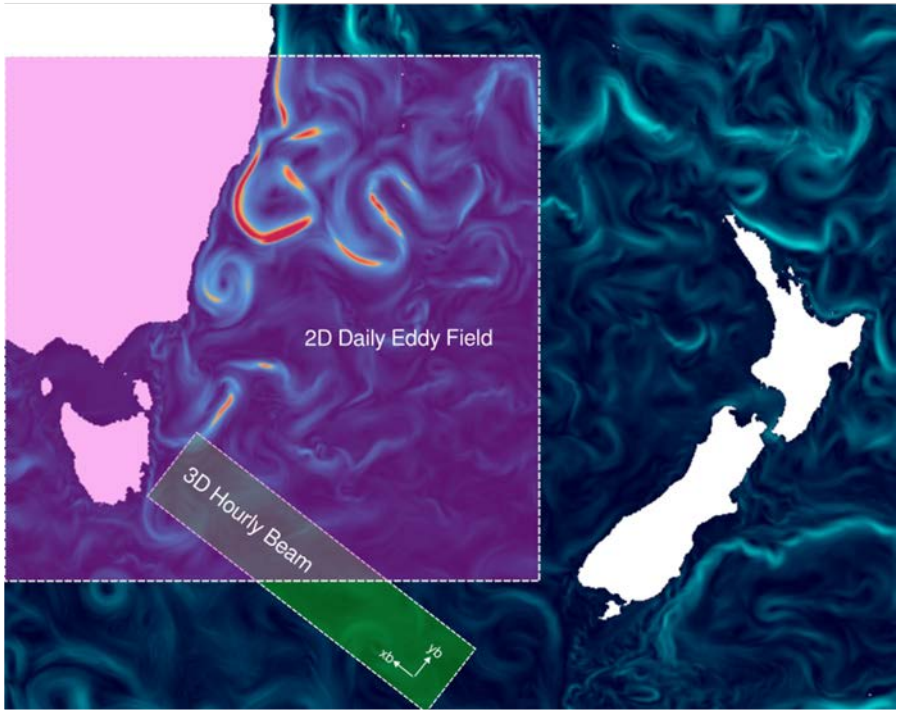


The Tasman Sea Internal Tide Beam

Waterhouse 2018



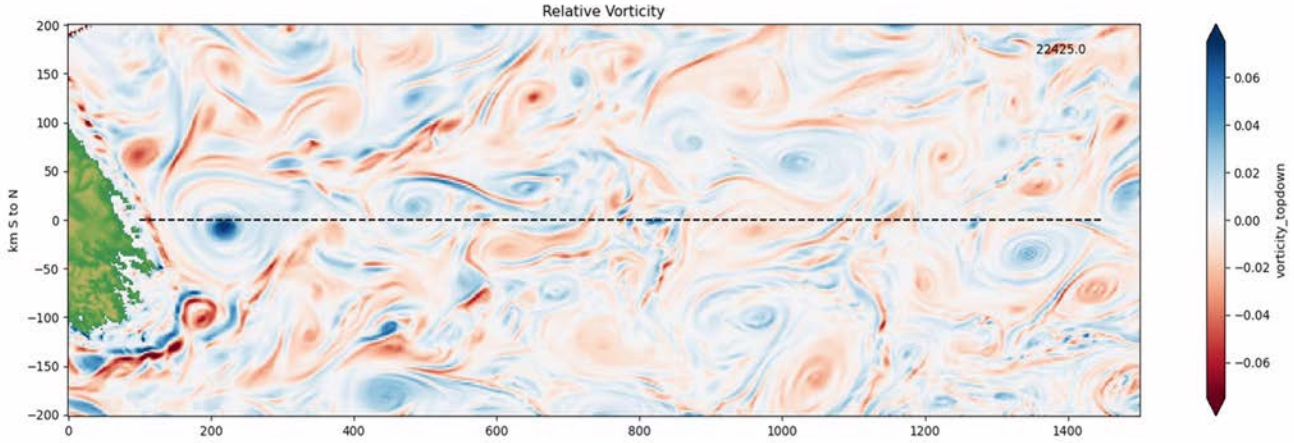




The Tasman Sea Internal Tide Beam

MOM6 regional Tasman Tide

- ERA5 surface, GLORYS Open Boundaries
- Rossby radius similar to M2 wavelength ~100-vs 200km
- Beam is dominated by M2 frequency

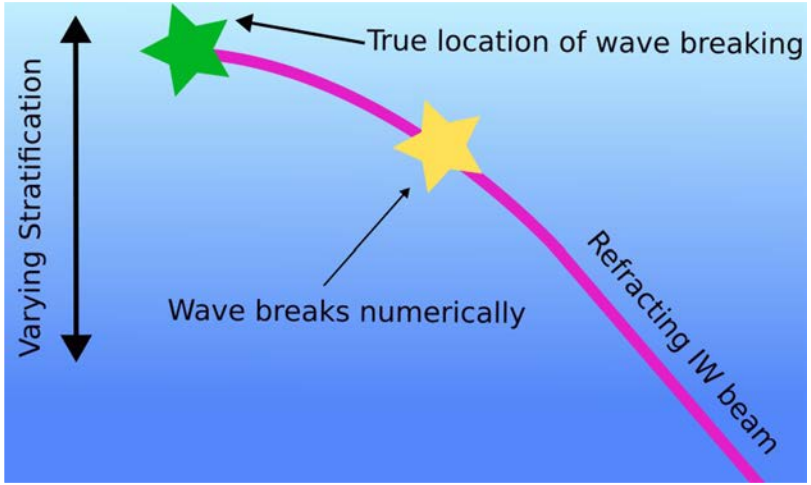


Motivation:

What happens to the IW beam energy, and does the answer depend heavily on the horizontal resolution?

- We've talked about 'eddy resolving' and 'eddy permitting' models. What about for internal waves?

- Internal waves cascade to smaller scales before dissipation can occur. Inclusion of more IW spectrum might give different energy pathways for the beam?



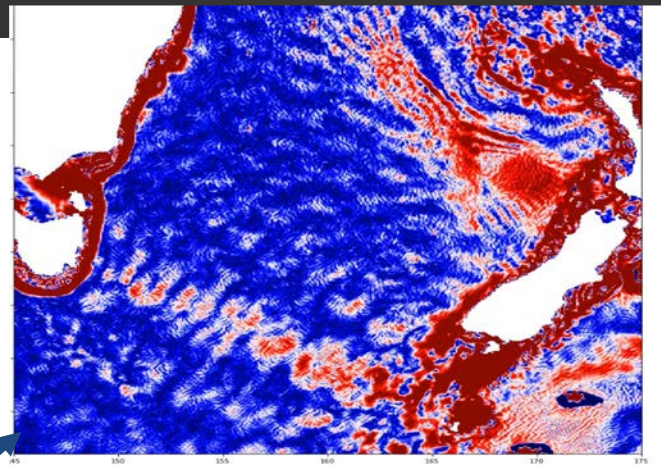
(Cartoon I drew in first year)

Motivation:

Research Questions

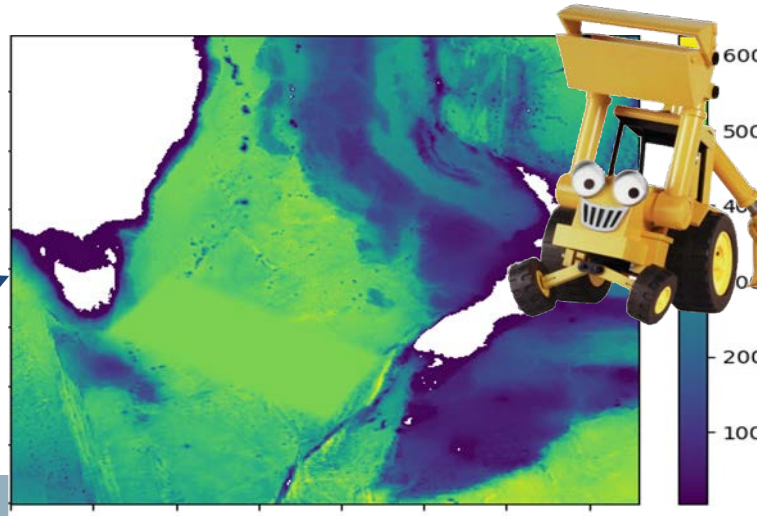
1. What portion of the energy scatters to higher modes, dissipates, or is transferred to eddies and other non waves features?

2. Does this picture change under different model resolutions



Suite of 12 models:
3 different resolutions (20,40,80th)

4 scenarios:
Everything, no tide, **quiescent flat, bathymetry**,



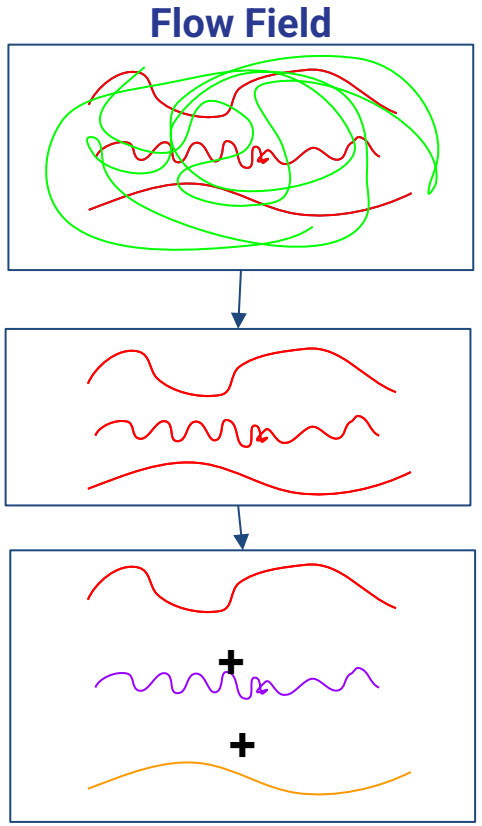
Method: Isolating our waves

1. Lagrange Filter from Shakespeare et al 2021

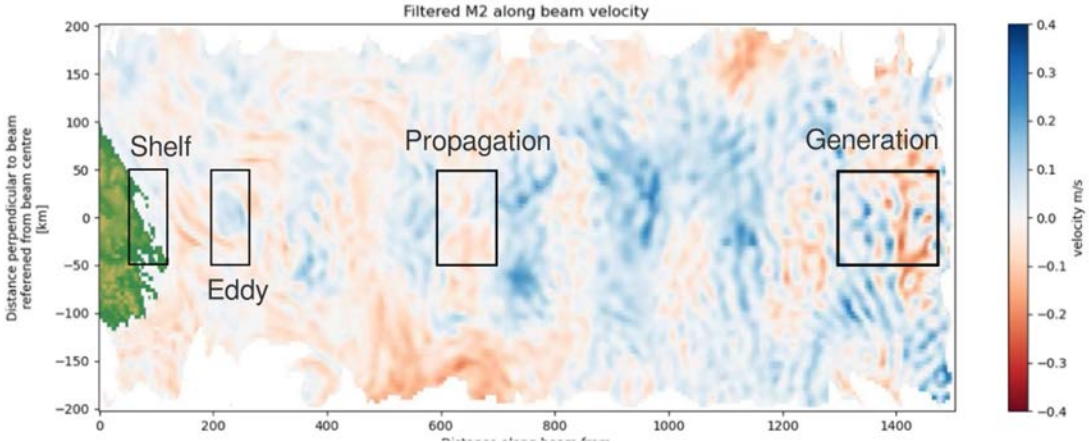
- Isolate our waves on *temporal* scales
- Enables **Cross Scale Energy Transfer calculations** via **Coarse Graining** (we'll come back to this later)

2. Vertical Modal decomposition (after temporal filter)

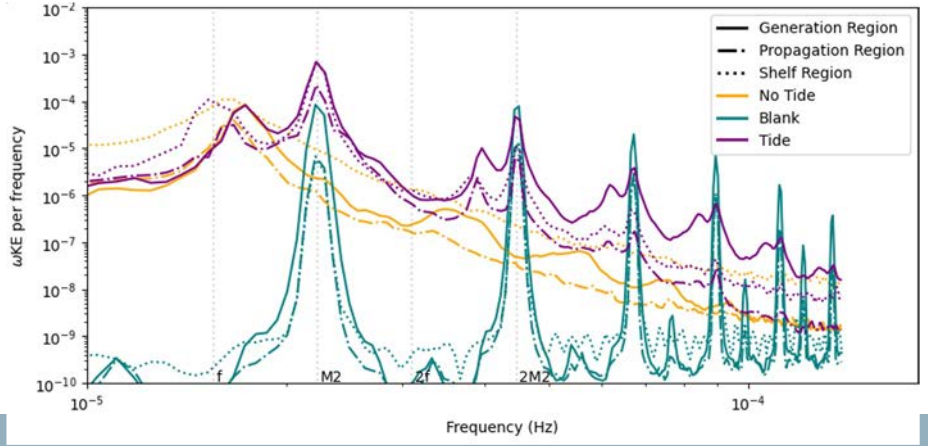
- Splits things up into the *spatial* scales
- Informed by the dispersion relation of the waves themselves
- **Quite fiddly to get right!** Ask if you want to use some code



Method 1: Temporal Filter



Kinetic Energy along the beam

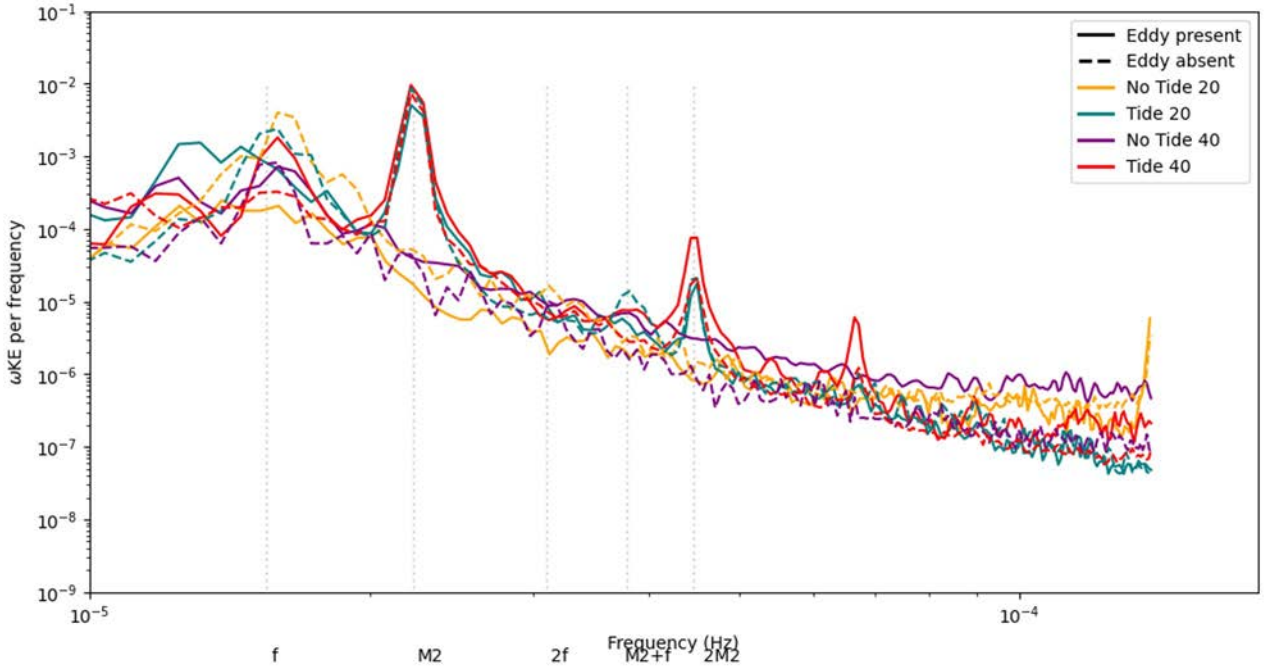


This tells us that there are some differences between our experiments, and spatially

But doesn't tell us **why**

Method 1: Temporal Filter

Lagrange Filtered Kinetic Energy: eddy vs no eddy



No real difference!

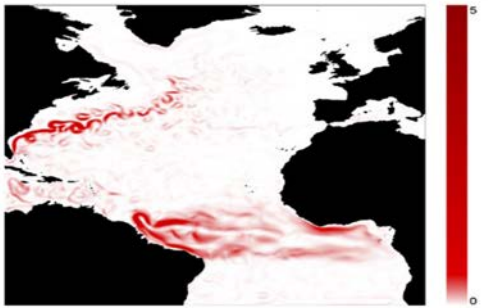
Method 1: Coarse Graining

- Using the **empirical** framework from Aluie, Barkan and others

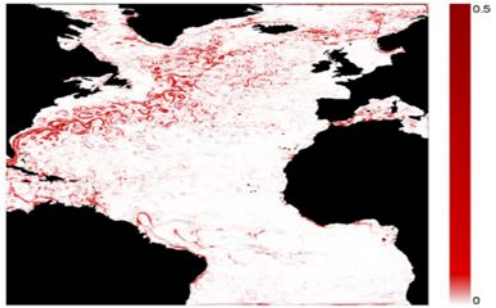
- Effectively recovers a quantity similar to *reynolds stress* between your scales, which becomes **energy** in the flux form of the momentum equation

$$\frac{\partial}{\partial t}\rho_0 \frac{|\overline{\mathbf{u}}_\ell|^2}{2} + \nabla \cdot \mathbf{J}_\ell^{\text{transport}} = -\Pi_\ell - \rho_0 \nu |\nabla \overline{\mathbf{u}}_\ell|^2 + \overline{\rho}_\ell g \cdot \overline{\mathbf{u}}_\ell$$

Scale > L

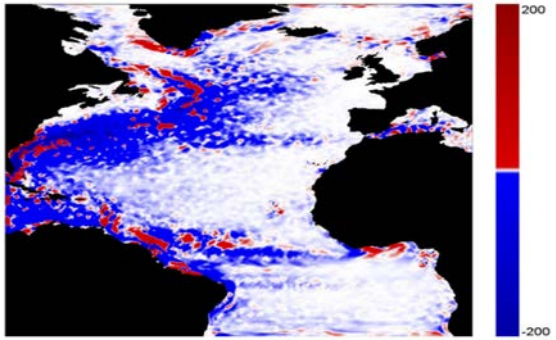


Scale <= L



From Aluie et al. 2018

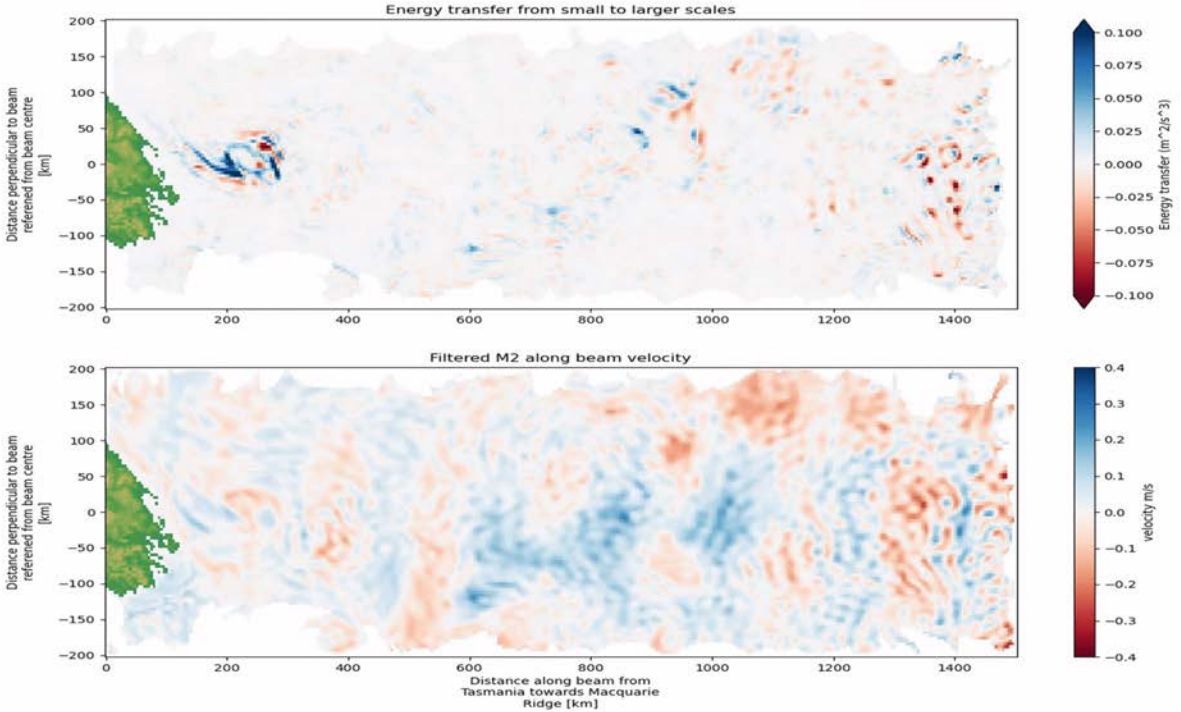
Energy transfer between scales



Method 1: Coarse Graining

Temporal Cross Scale Energy Transfer: Waves to Eddies

Using a filter Lagrange filter at 1.2f



Method 1: Coarse Graining

Temporal Cross Scale Energy Transfer: Waves to Eddies

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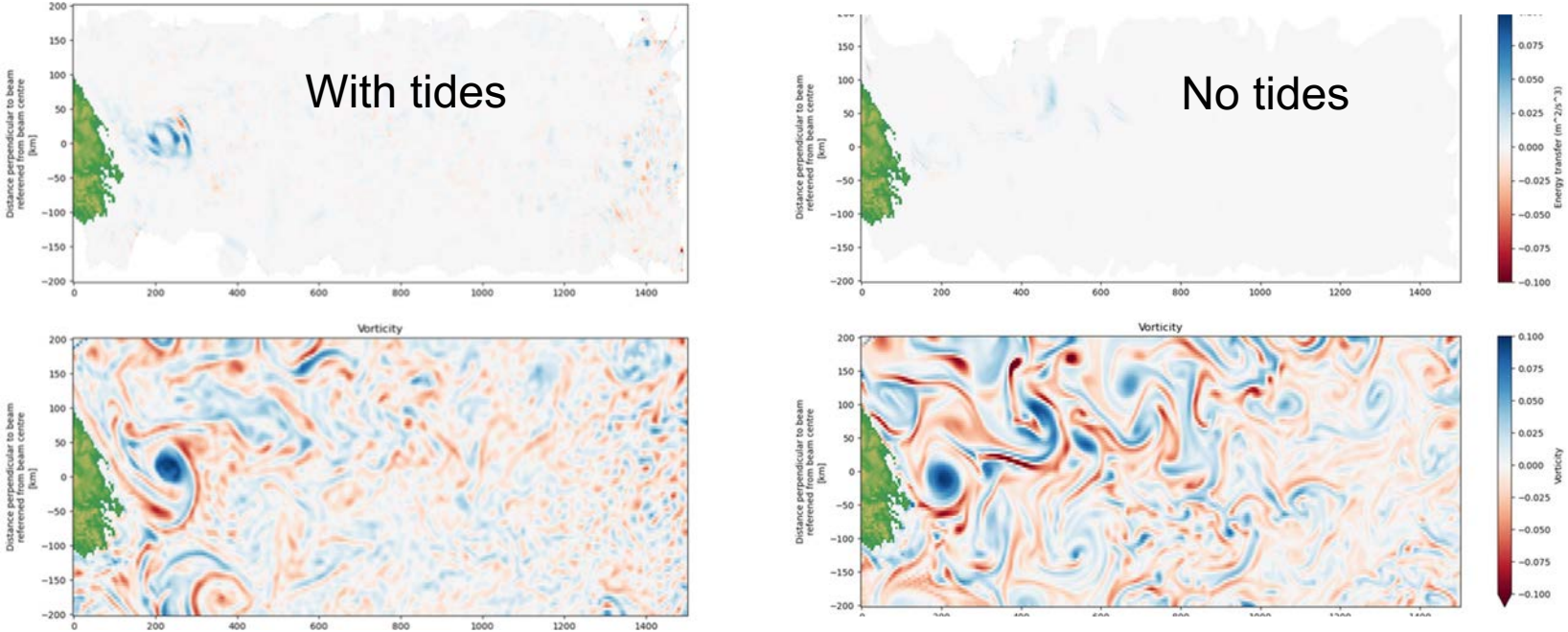


Empirically, it looks like we have net energy from internal wave to eddies!

Method 2: Modal Decomposition

- Assume **flat bathymetry** and **slowly varying N** in x,y
- Assume linear wave decomposition i.e

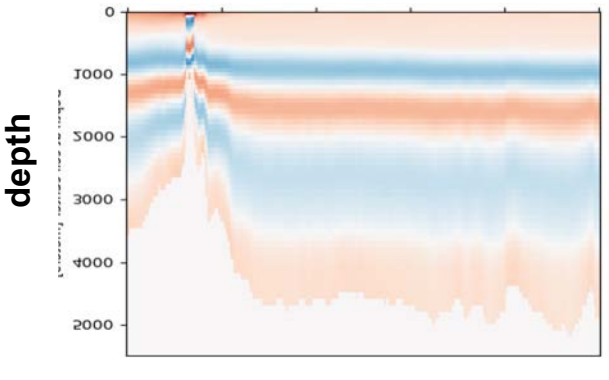
$$w(x,y,z,t) = W(z)e^{i(xk_1+yk_2-\omega t)}$$

- Solve the ODE for every point in space to get the vertical eigenfunctions W for each mode. W(0) = W(H) = 0

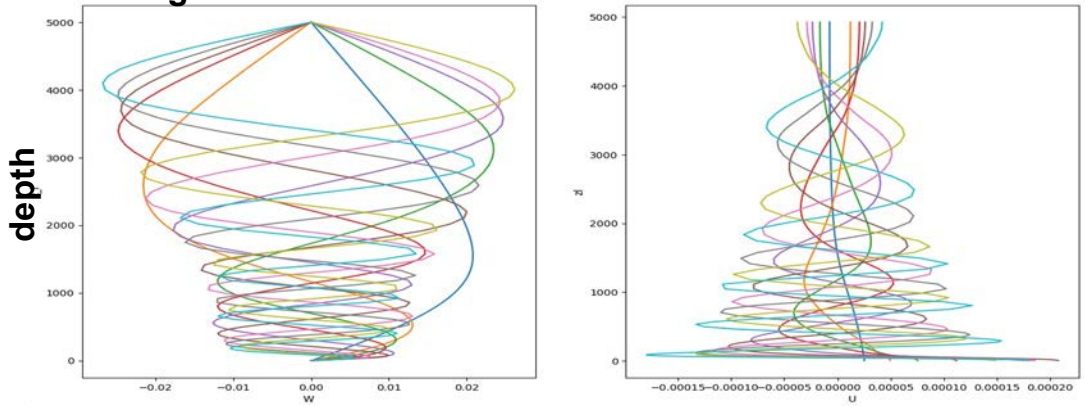
$$\partial_{zz}W(z) + k_n^2\left(\frac{N(z)^2}{\omega^2 - f^2}\right)W(z) = 0$$

- Project velocities on to eigenfunctions (next slide)

Spatial variation of eigenfunction

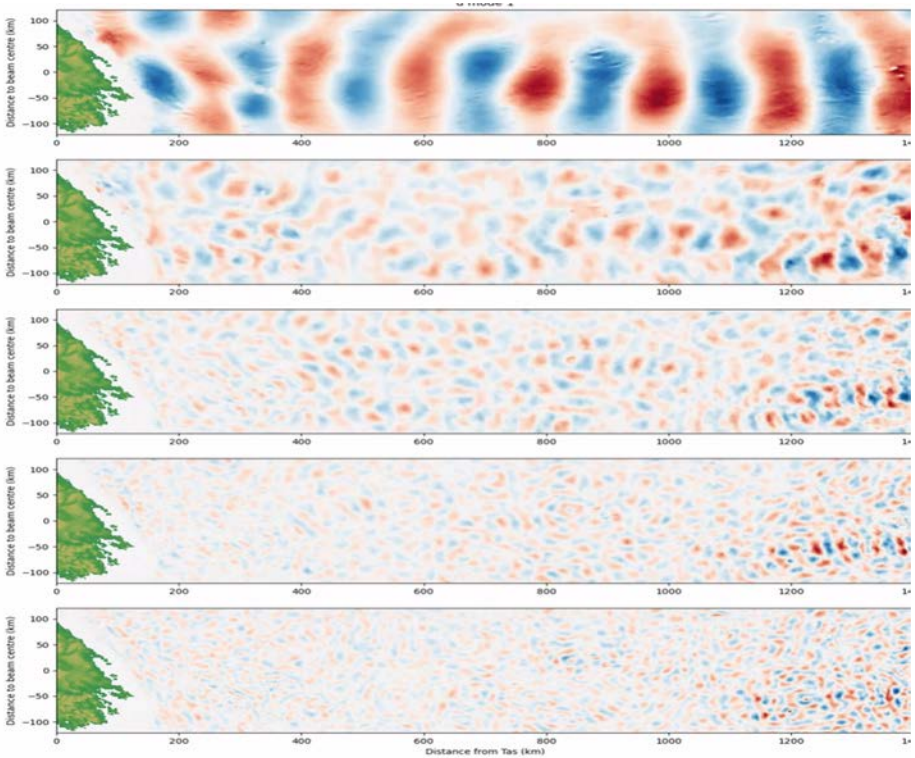


Eigenfunctions for Vertical and Horizontal velocities

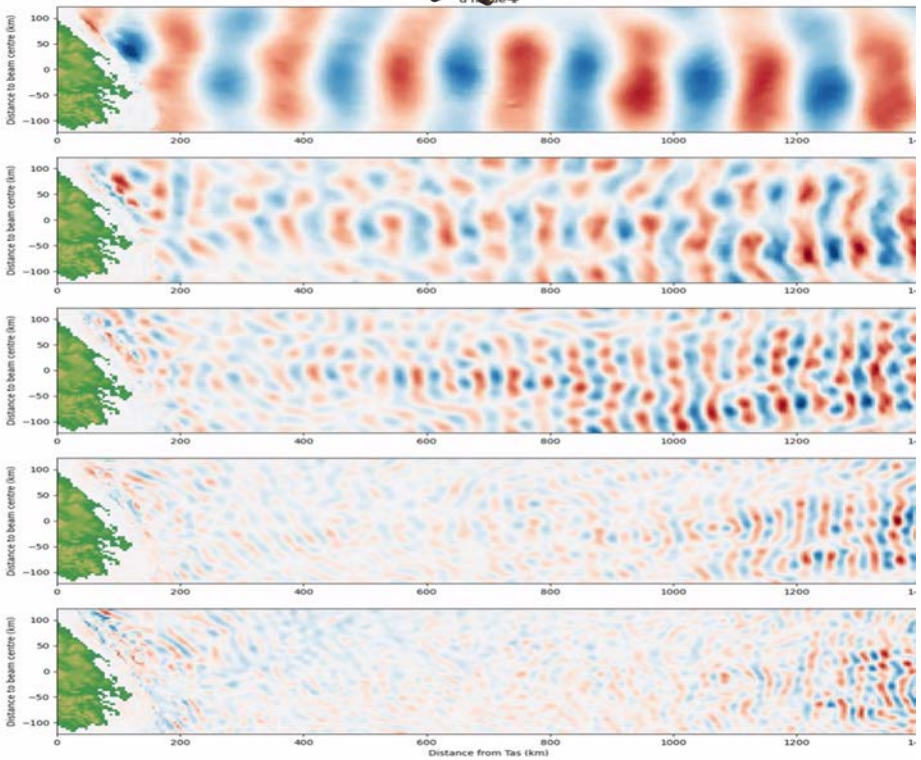


Method 2: Modal Decomposition

Realistic Topography

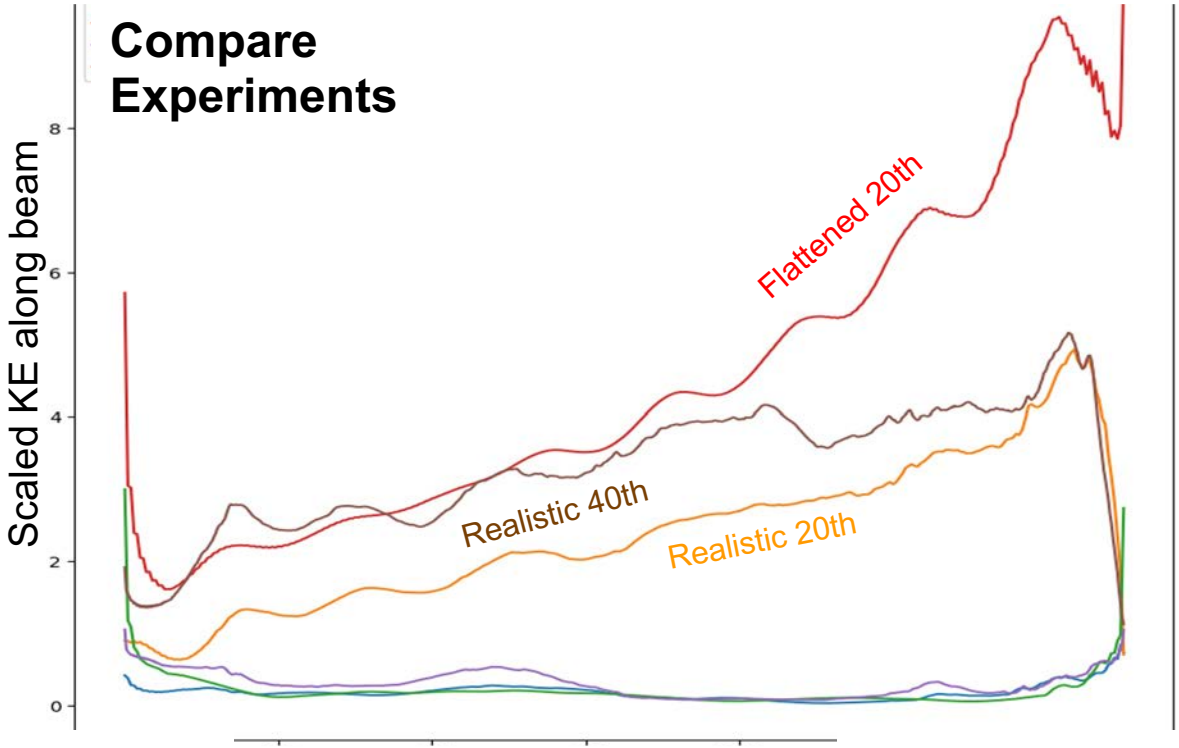


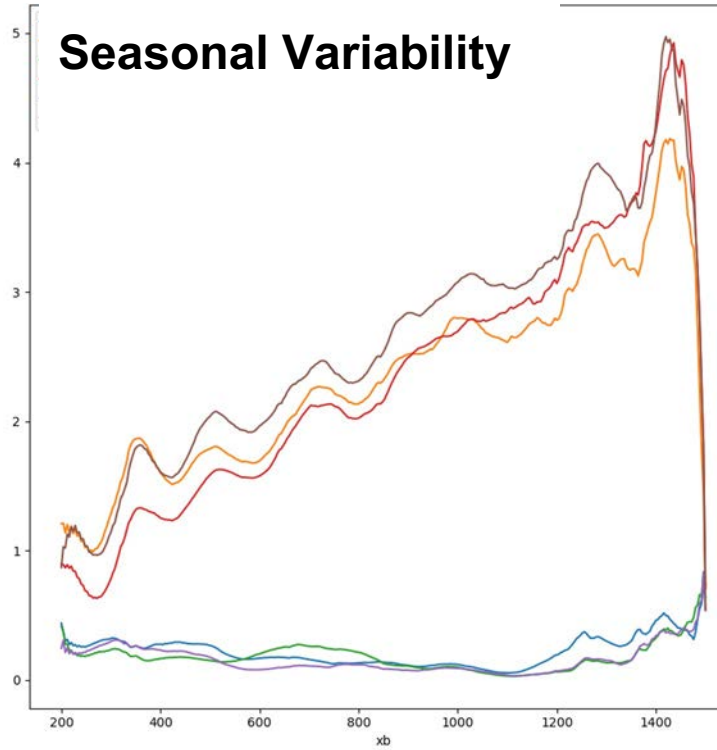
Flattened



Method 2: Modal Decomposition

Directionally Filtered Kinetic Energy

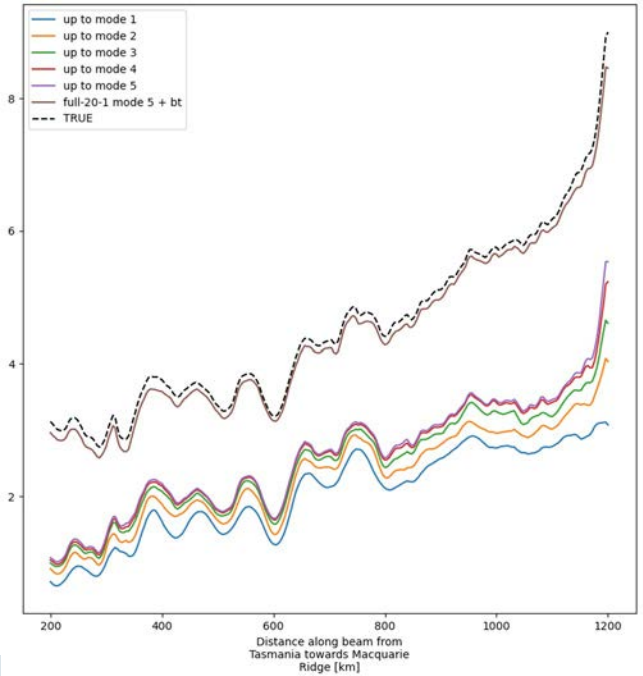




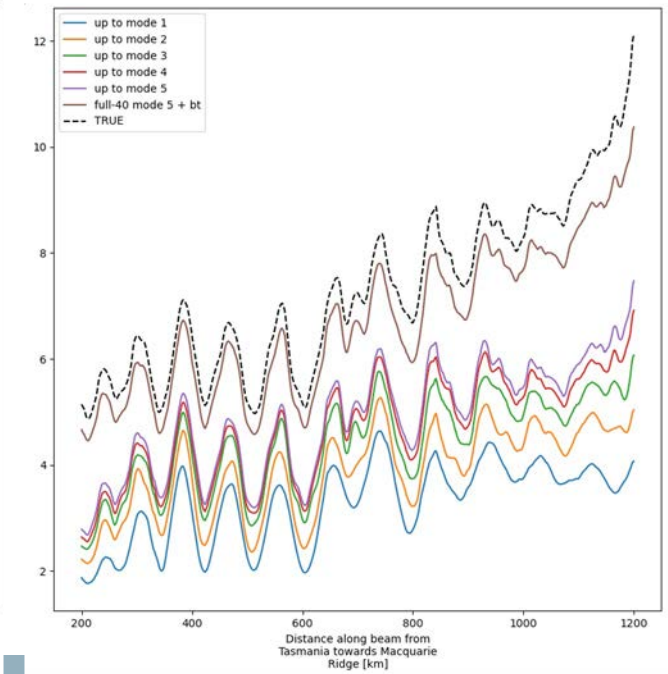
Method 2: Modal Decomposition

KE decomposition by vertical mode

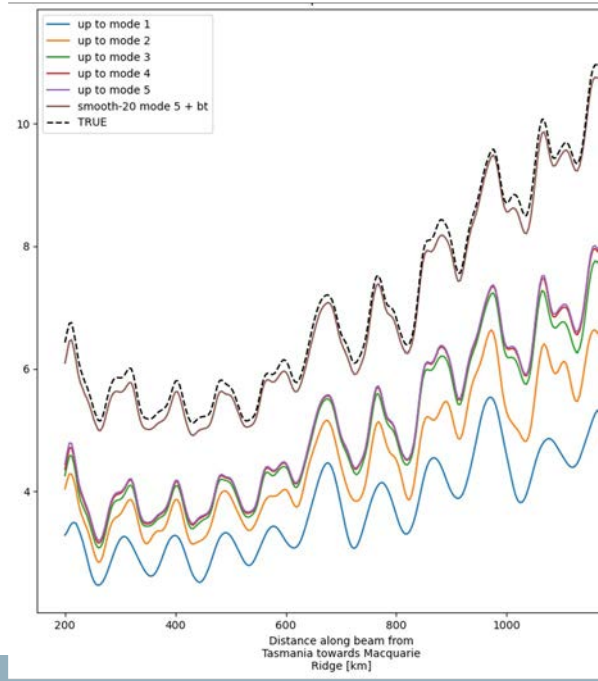
Realistic 20th



Realistic 40th



Flattened 20th



Next Steps:

1. **Temporal analysis**: Quantify the M2 kinetic energy, dissipation and cross scale transfer across our different experiments. Are eddy interactions significant?

2. **Modal Decomposition:** Analyse the way the modal structure changes. Is this affected by eddies or topography?

1. Compare the energy pathways under different resolutions

This is very much a work in progress!!

We'd be very grateful for suggestions, ideas or feedback

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https://github.com/**ashjbarnes/tasman-tides**