Quantifying cross-scale energy transfers in numerical simulations - understanding the role of Eddy-Wave interactions.

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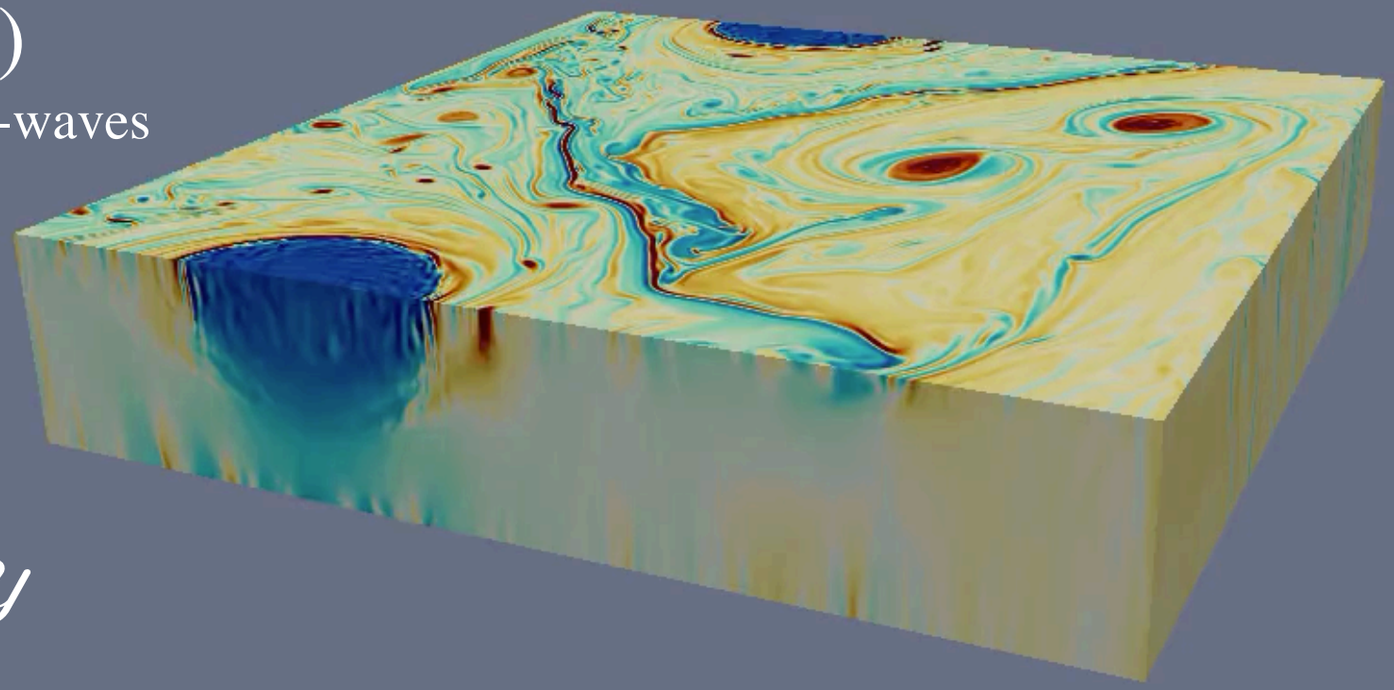
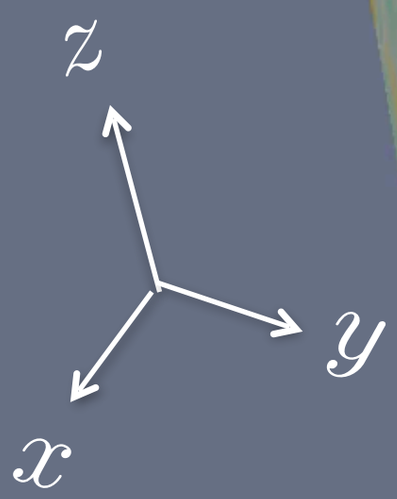
Low Frequency Forcing (LFW)

eddies only, no-waves

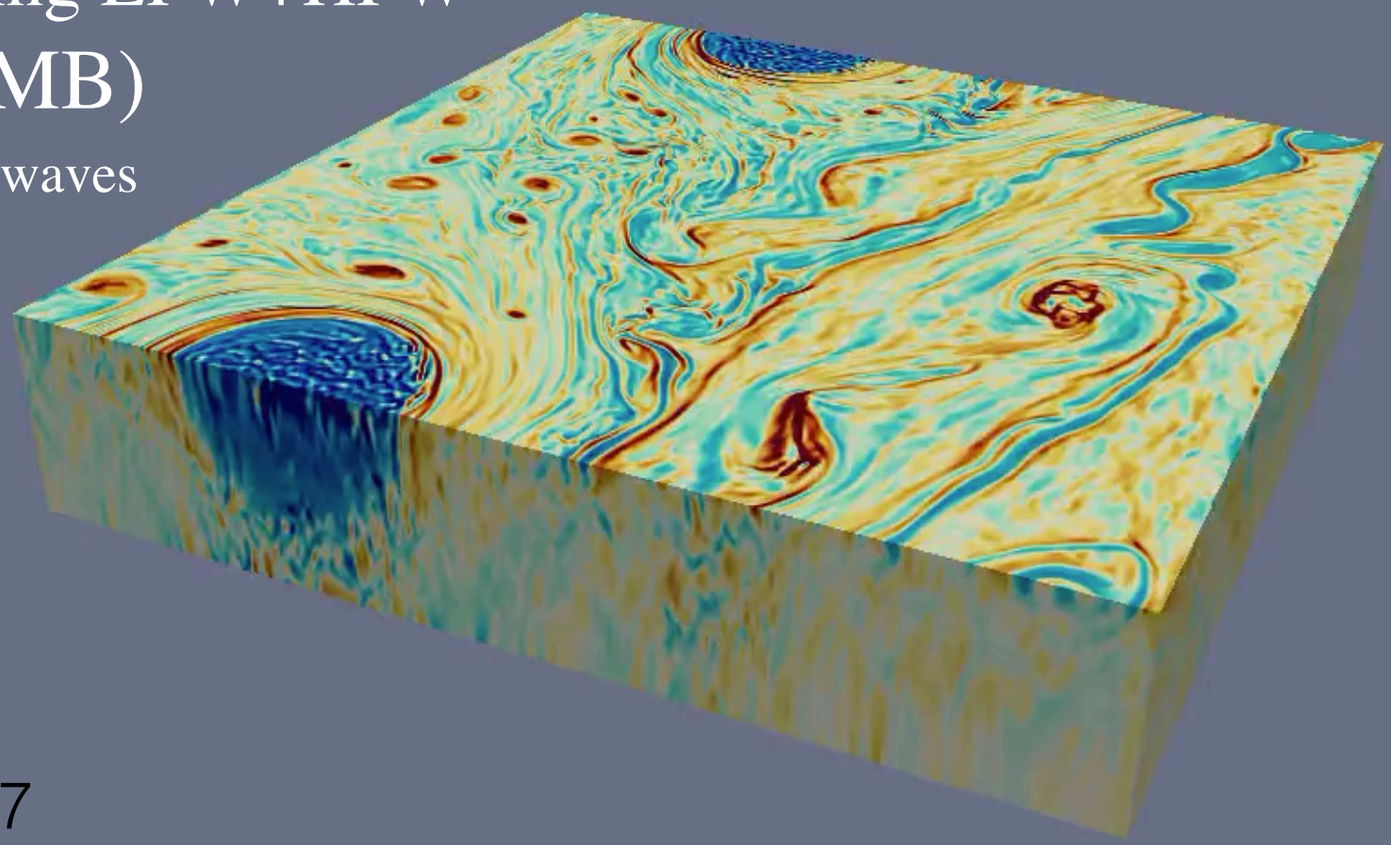




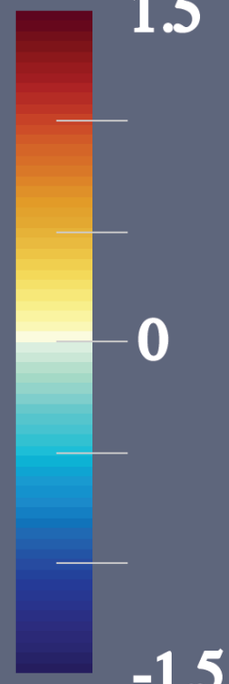
$$\zeta \equiv \frac{dv}{dx} - \frac{du}{dy}$$

Combined Forcing LFW+HFW (COMB)

eddies + waves

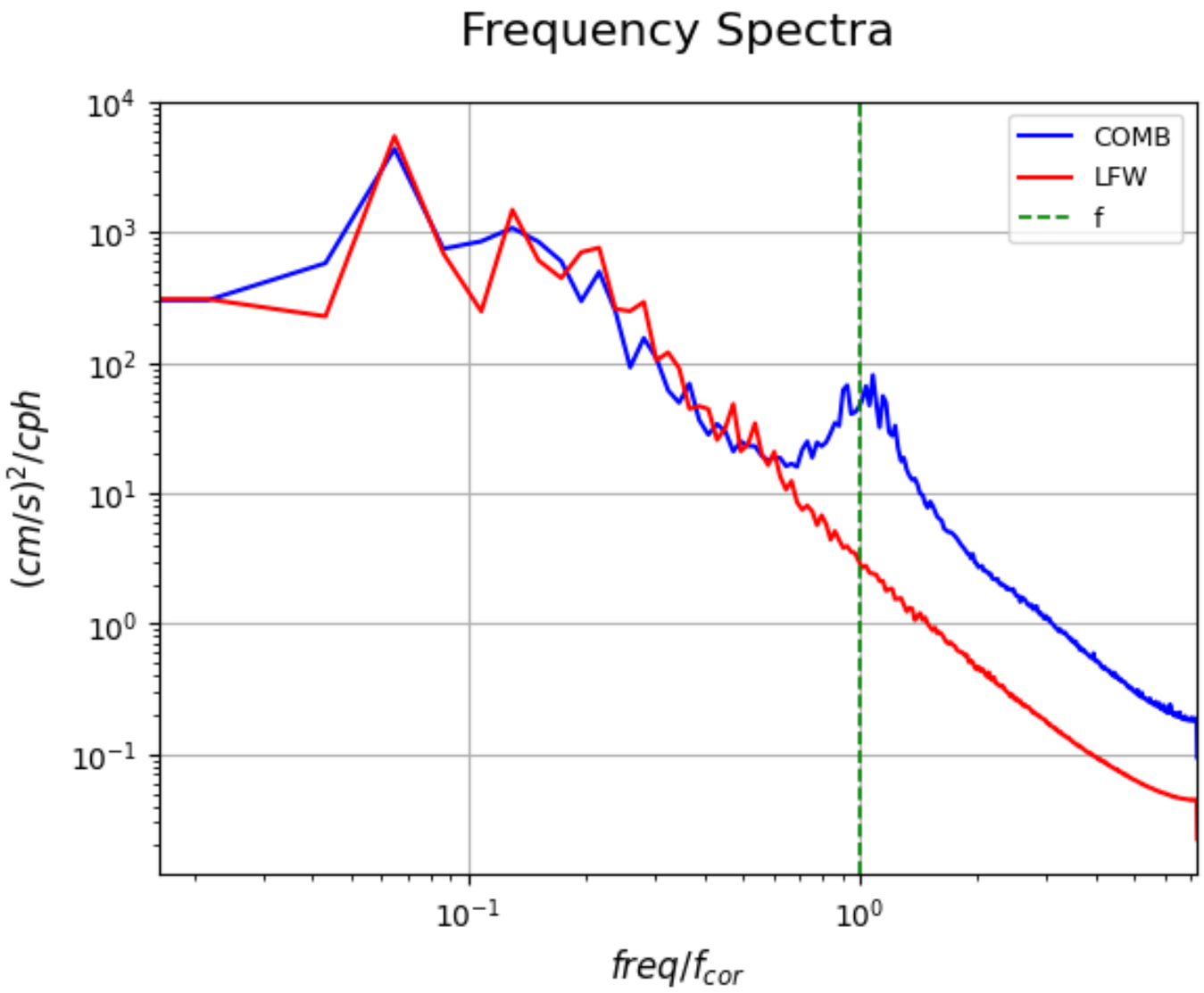


$$Ro = \frac{\zeta}{f}$$



Barkan et al. 2017

NIW in the COMB solution



- NI energy in the COMB solution
- Higher frequencies in COMB solution

Methodology - Spectral Fluxes Decomposition

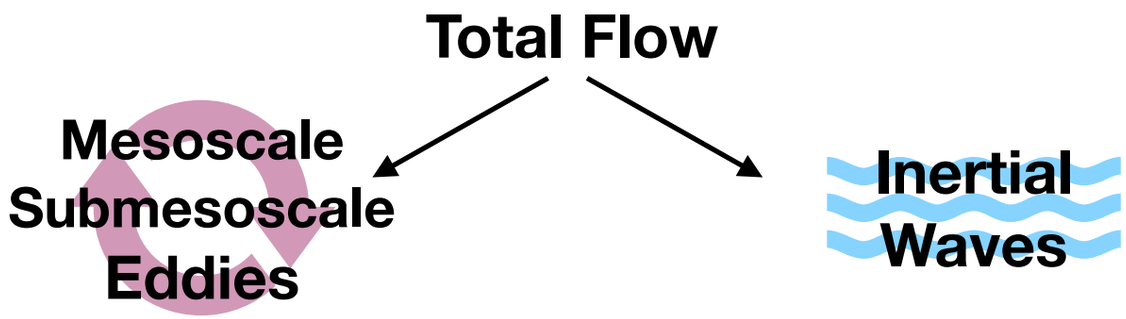
Definition:

$$\Pi(k) \equiv -\frac{\partial}{\partial t}\int_0^{|\boldsymbol{k}'|=k} E(\boldsymbol{k}')d\boldsymbol{k}' = \int_0^{|\boldsymbol{k}'|=k} \mathscr{R}\{\widetilde{\boldsymbol{u}}_{k'} \cdot [\widetilde{(\boldsymbol{u}\cdot\nabla)\boldsymbol{u}}]^*_{k'}\}\, d\boldsymbol{k}'$$

Interpretation:

FORWARD CASCADE $\Pi(k) > 0$ INVERSE CASCADE $\Pi(k) < 0$

Decomposition:



Helmholtz Decomposition

Temporal Filters	Divergent	Rotational
High freq. (<16hr)	IW	-
Low freq. (>24hr)	Submesoscale Current	Mesoscale Balanced Eddies

substitute $\mathbf{u} = \mathbf{u}^E + \mathbf{u}^W$ into the definition above, we get 8 terms:

$$\Pi(k) = \Pi^{Www} + \Pi^{Eee} + \Pi^{Wew}/\Pi^{Wwe} + Residuals$$

Π^{Www}: wave-wave Interaction

Π^{Eee}: eddy-eddy interaction

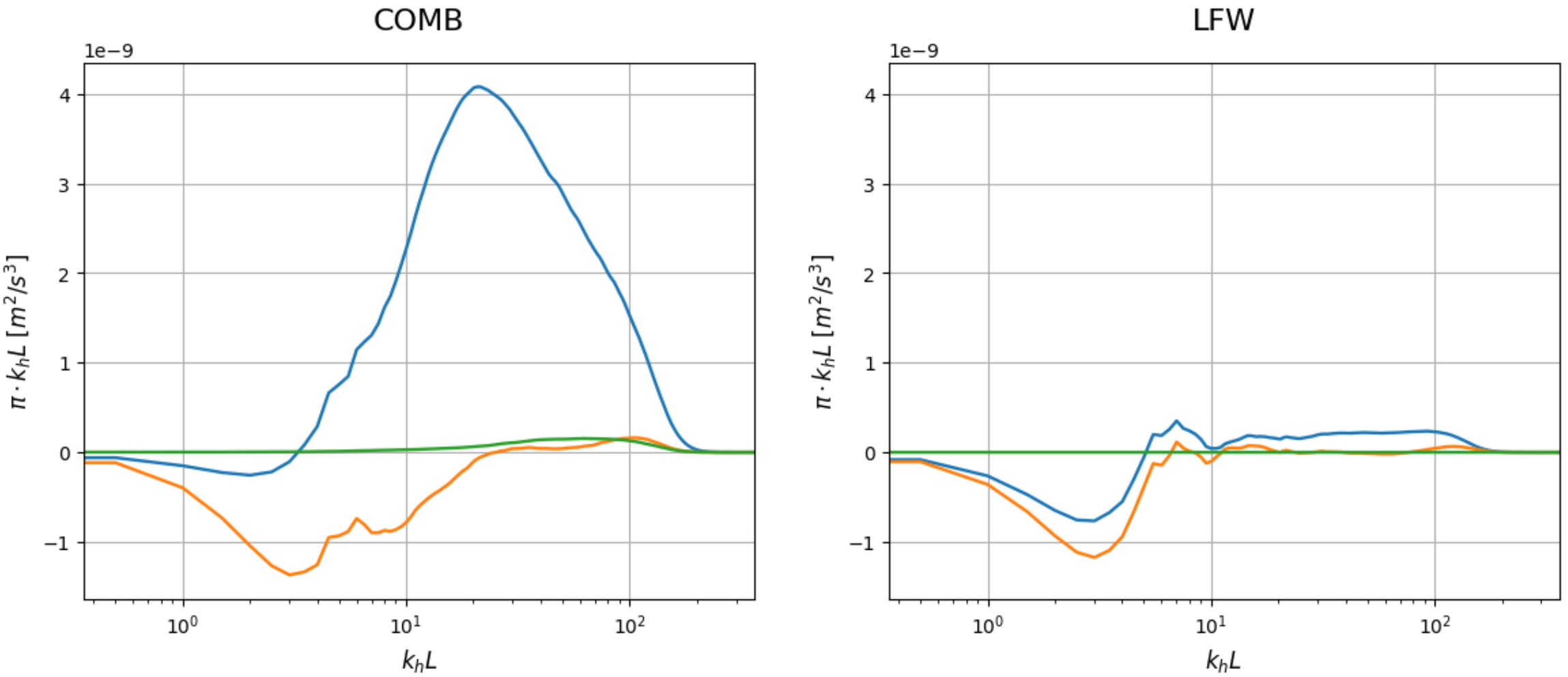
Π^{Wew}/Π^{Wwe}: wave scattering

Stimulated Forward Cascade Π^{Eee}

Rotational Low Frequency —> Geostrophic Eddies

Divergent Low Frequency —> *Submesoscale Currents

Low Frequency (Rot+Div) —> Geostrophic Eddies **and** Submesoscale Currents



- Only geostrophic eddies - inverse cascade.
- COMB - energy cascade shifts from inverse cascade to forward cascade.

➡ *Interactions between the Geostrophic Eddies and the Submesoscale Currents, in the presence of IW, cause a transfer to smaller scales.*

*Capet et al. 2008

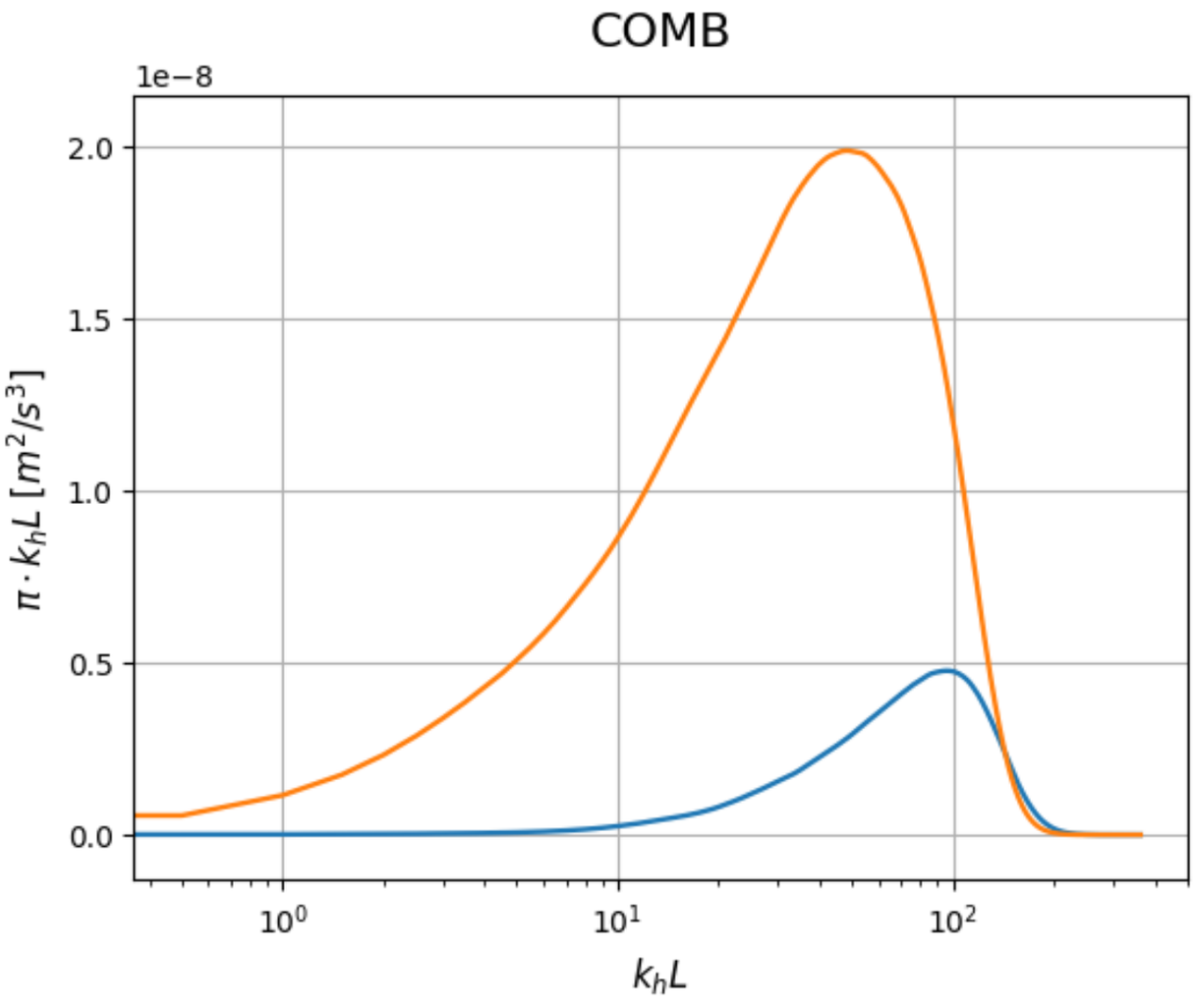
The significance of Wave scattering

E = Rotational Low Frequency —> Geostrophic Eddies

W = Divergent High Frequency —> Inertial Waves

Π^{Www}

Π^{Wew}/Π^{Wwe}



- ✦ The wave-scattering term has higher energy forward cascade than the wave-wave interactions.
- ➡ *wave-scattering by the balanced flow is significant mechanism in wave dynamics.*

Conclusions

- Wave scattering by the balanced flow is a significant mechanism in wave energy transfers.

- The externally forced IW stimulated the forward cascade of the eddies, by enhancing interactions between the geostrophic eddies and the submesoscale currents.