Improving Internal Wave Drag Parametrisations

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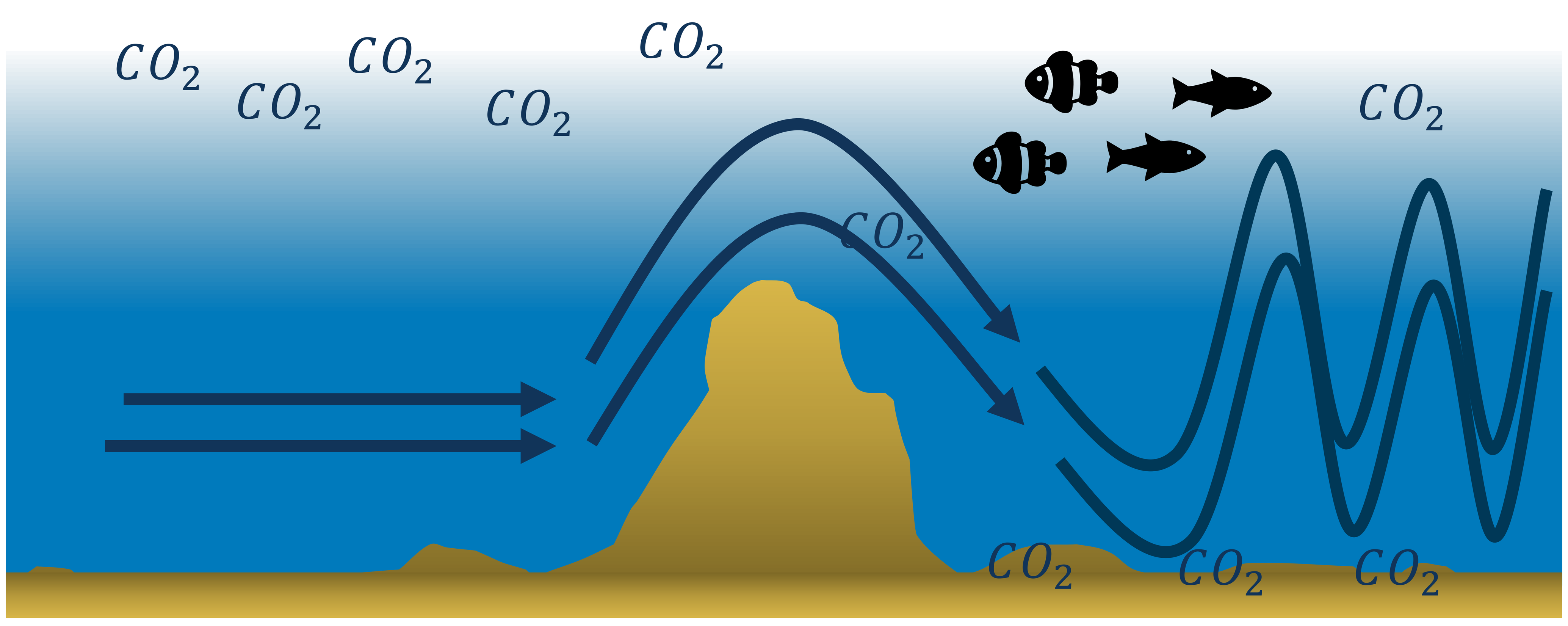
What are Internal Waves?

Internal waves are waves beneath the ocean's surface caused by disturbances such as strong winds or ocean currents flowing over rough topography.

These waves drive ocean mixing, transferring nutrients from the ocean floor to aquatic life and helping to sequester carbon from the surface.



The Problem

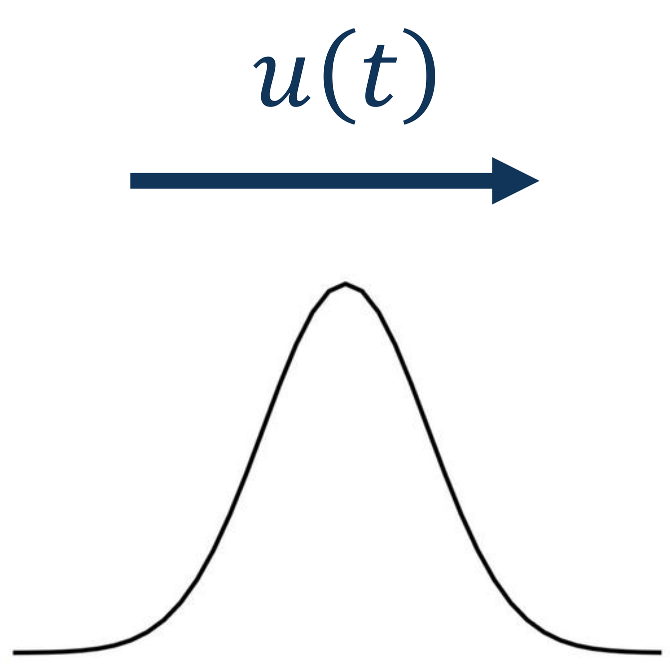
Modelling internal waves in ocean models requires very fine grid spacings of less than 1 km^2.

For a global model, this is too computationally intensive, so we must find simpler formulae (parametrisations) that approximate the effects of internal waves.

Our Approach

For simplicity, we focus on internal waves generated by an isolated hill in 2 dimensions.

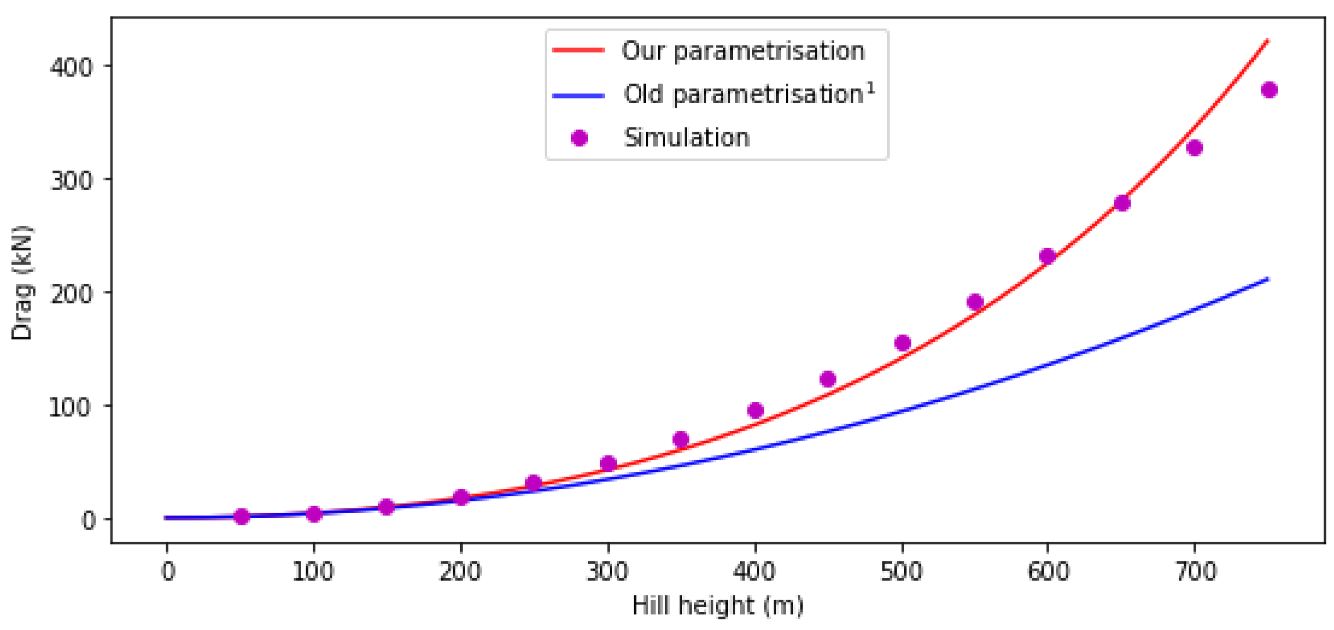
We developed formulae for the drag force in 3 cases --- a purely tidal flow, a constant (mean) flow, and a combined (tidal + mean) flow. Each formula was then tested against hundreds of small-scale computer models.



Case 1: Tidal Flow

$u(t) = u_{tide} \cos(\omega t)$

Under a tidal forcing, the current is periodic. In this case, we use a drag formula that extends existing parametrisations to large hill heights. For most cases, our formula is very accurate but does not account for wave-surface interactions.



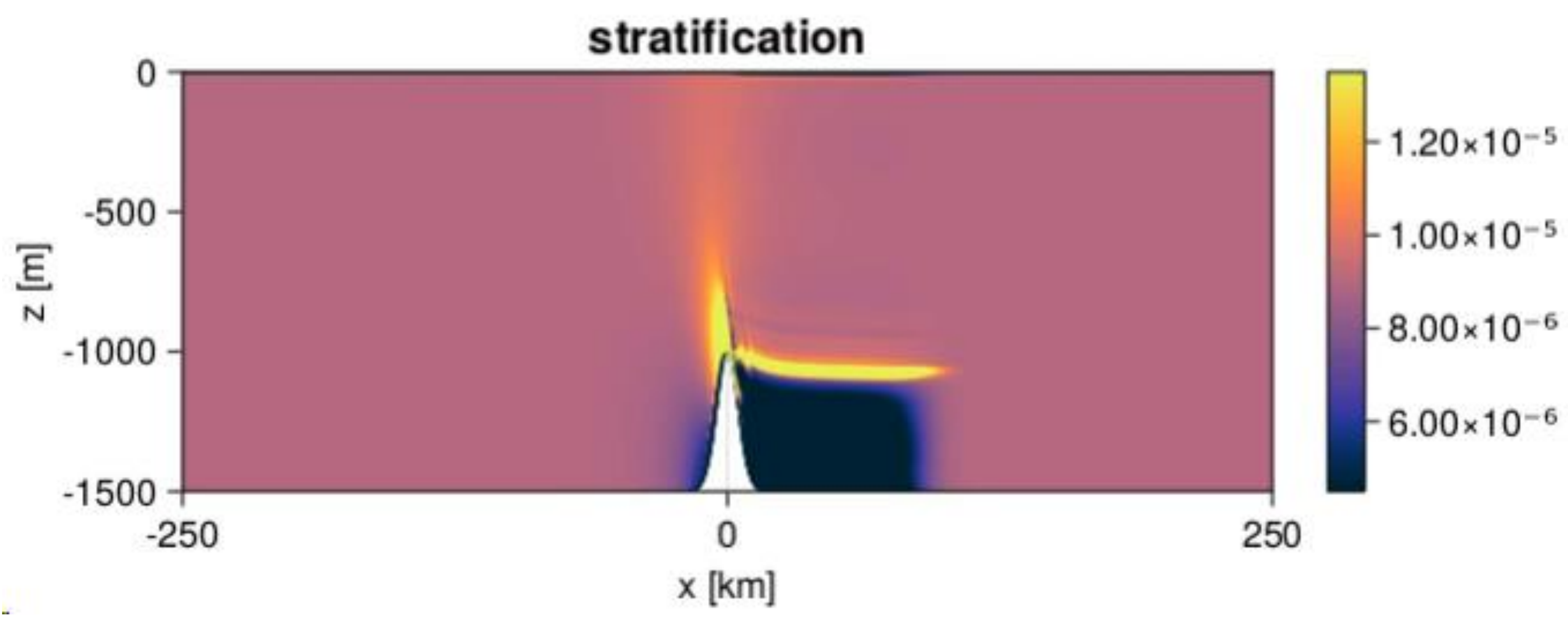
For these simulations, the ocean depth was set to 1500 m.

[1]Shakespeare, C., Arbic, B., & Hogg, A. (2021). *The impact of abyssal hill roughness on the benthic tide.* Journal of Advances in Modeling Earth Systems

Case 2: Mean Flow

$u(t) = u_0 = constant$

Under a constant forcing, a modification of our tidal drag formula is only accurate near the equator. For larger latitudes, wave formation is inhibited by the Coriolis force. This leads to intense mixing downstream which is difficult to parametrise. It is unclear whether this mixing is reduced in 3-dimensions.



Here, stratification is proportional to the density gradient, meaning the darker regions are more mixed.

Case 3: Combined Flow

Combining cases 1 and 2 produces a current of the form $u(t) = u_0 + u_{tide} \cos \omega t$. Near the equator, the drag force is easily parametrised as the addition of the drag forces from the tidal and mean cases. However, away from the equator, the tidal component of the drag becomes significantly damped whereas the mean component stays the same. We attribute this to the different stratification profiles in the tidal and mixed cases.

Tidal case   Mixed case