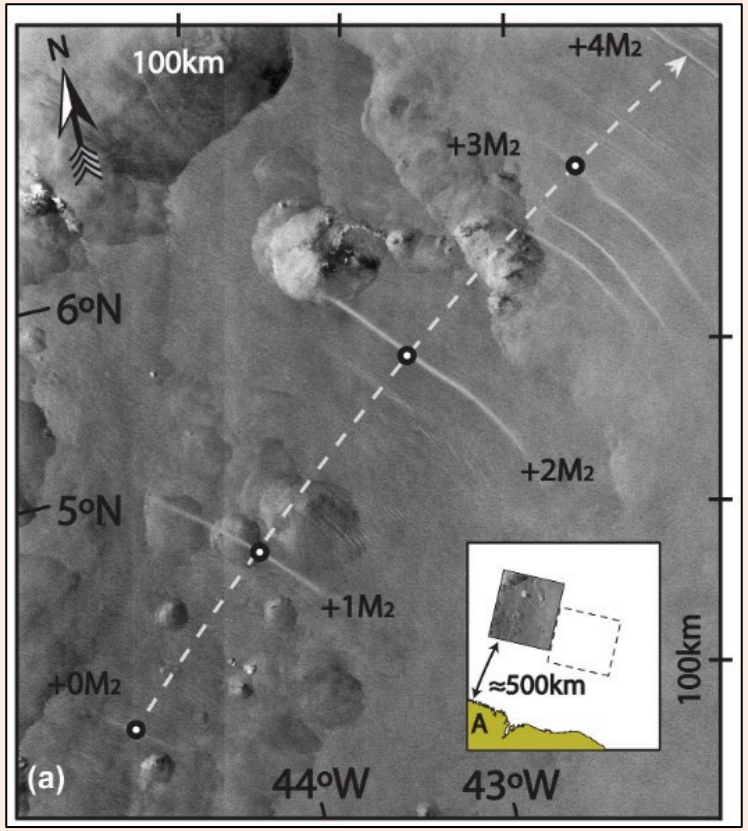
Estimating internal wave energy transfers from tidal to supertidal frequencies in a global HYCOM simulation



Tidal solitons or nonlinear internal waves with short wavelengths from Amazon shelf

Miguel Solano & Maarten Buijsman (USM)

Jay Shriver (NRL), Roy Barkan (UCLA)

Relevance and questions

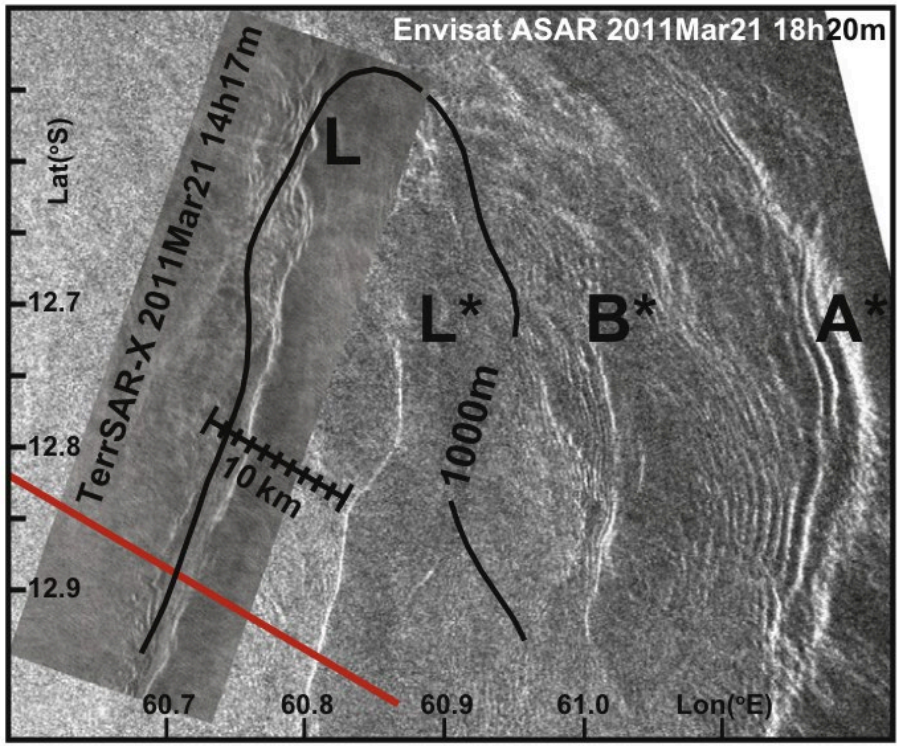
Relevance for SWOT

- Nonlinear short-wavelength internal tides (solitons) complicate the ‘detiding’ of SWOT altimetry
- Nonlinear solitons may alias linear internal tide altimetry models

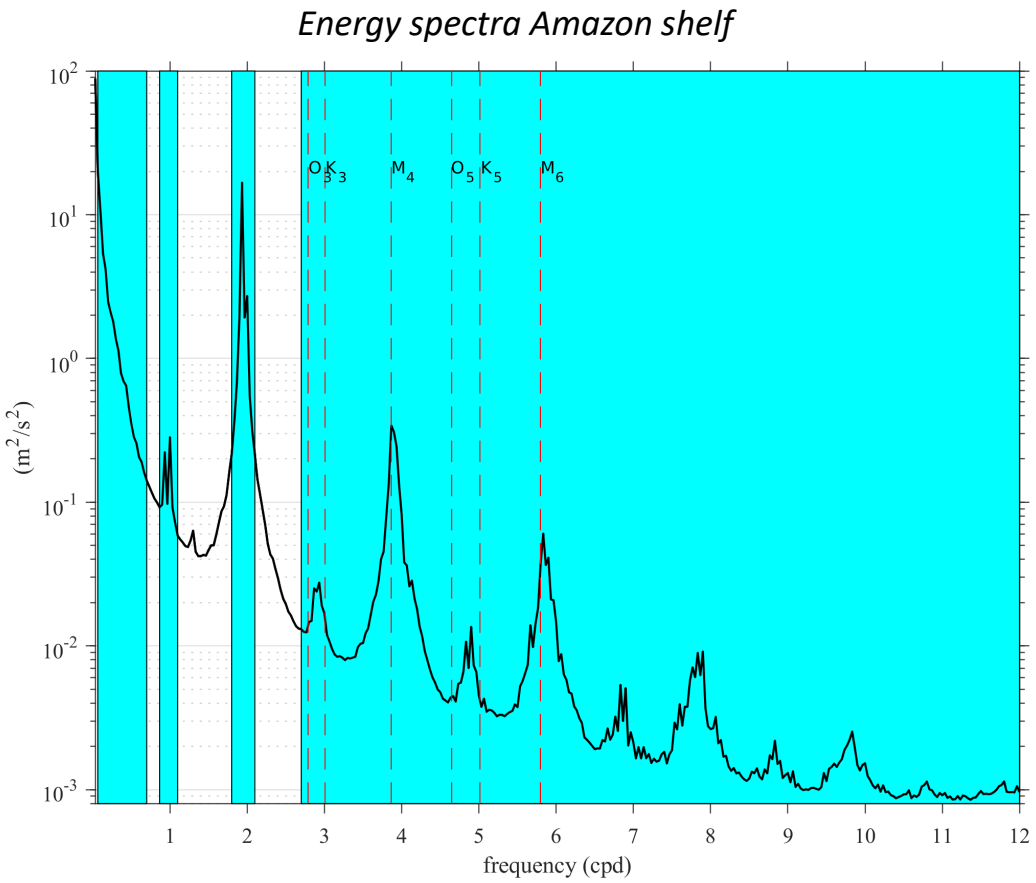
Research questions

1. What is the energy content in the nonlinear internal tides in a global HYCOM simulation?
2. How much are the energy transfers from the linear to the nonlinear internal tides?

Tidal solitons from Mascarene Ridge



Methods



HYCOM

- $1/25°$ horizontal resolution, 41 vertical levels
- 3 hr winds + tides (M_2, S_2, N_2, K_1, O_1)
- No data assimilation

Analysis

- Analyze hourly 3D fields for 30 days of September 2016 and May/June 2019
- Band-pass for semidiurnal (**D2**) and diurnal (**D1**) bands
- Capture the supertidal band (**HH**) via a high-pass
- Conduct baroclinic energy analysis between $\pm 25°$

Internal Tides (IT): sources and sinks

Time-mean and depth-integrated energy balance

Tidal (D1+D2) $C = \nabla \cdot F + \Pi_\tau + A + D$

Supertidal (HH) $C + \Pi_\tau = \nabla \cdot F + A + D$

C topographic barotropic to baroclinic energy conversion

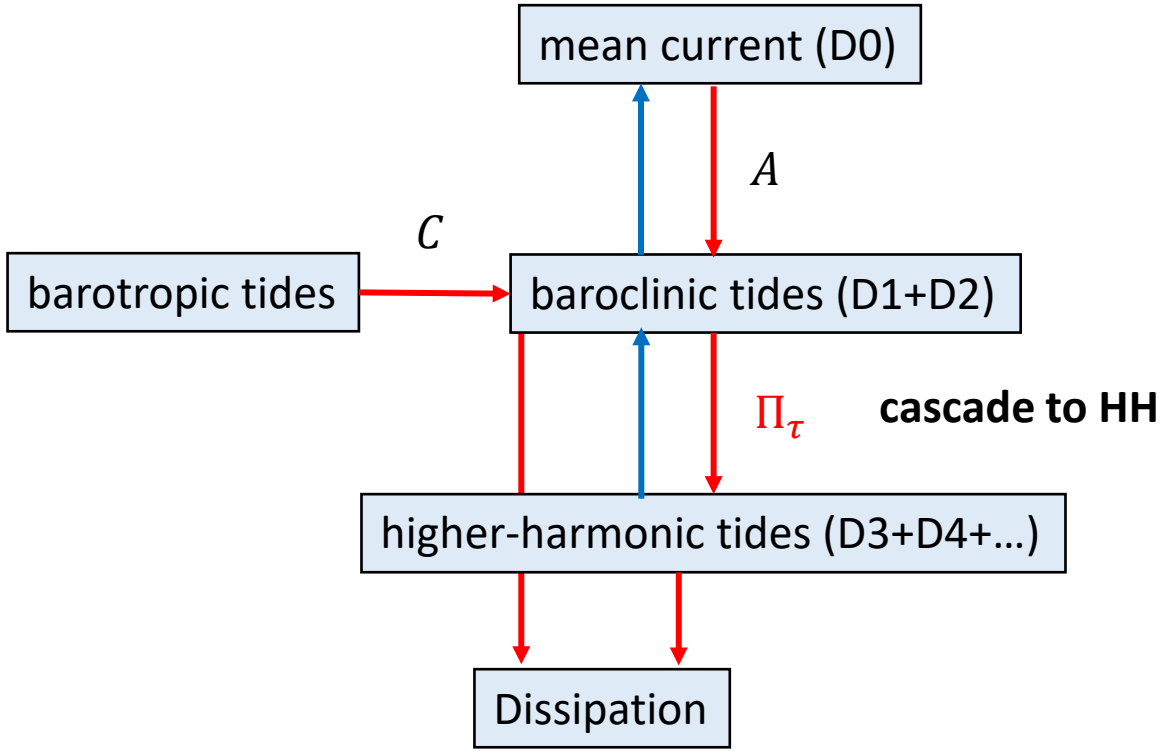
F barocline energy flux

A mean flow advection and mean flow shear/buoyancy production

D dissipation

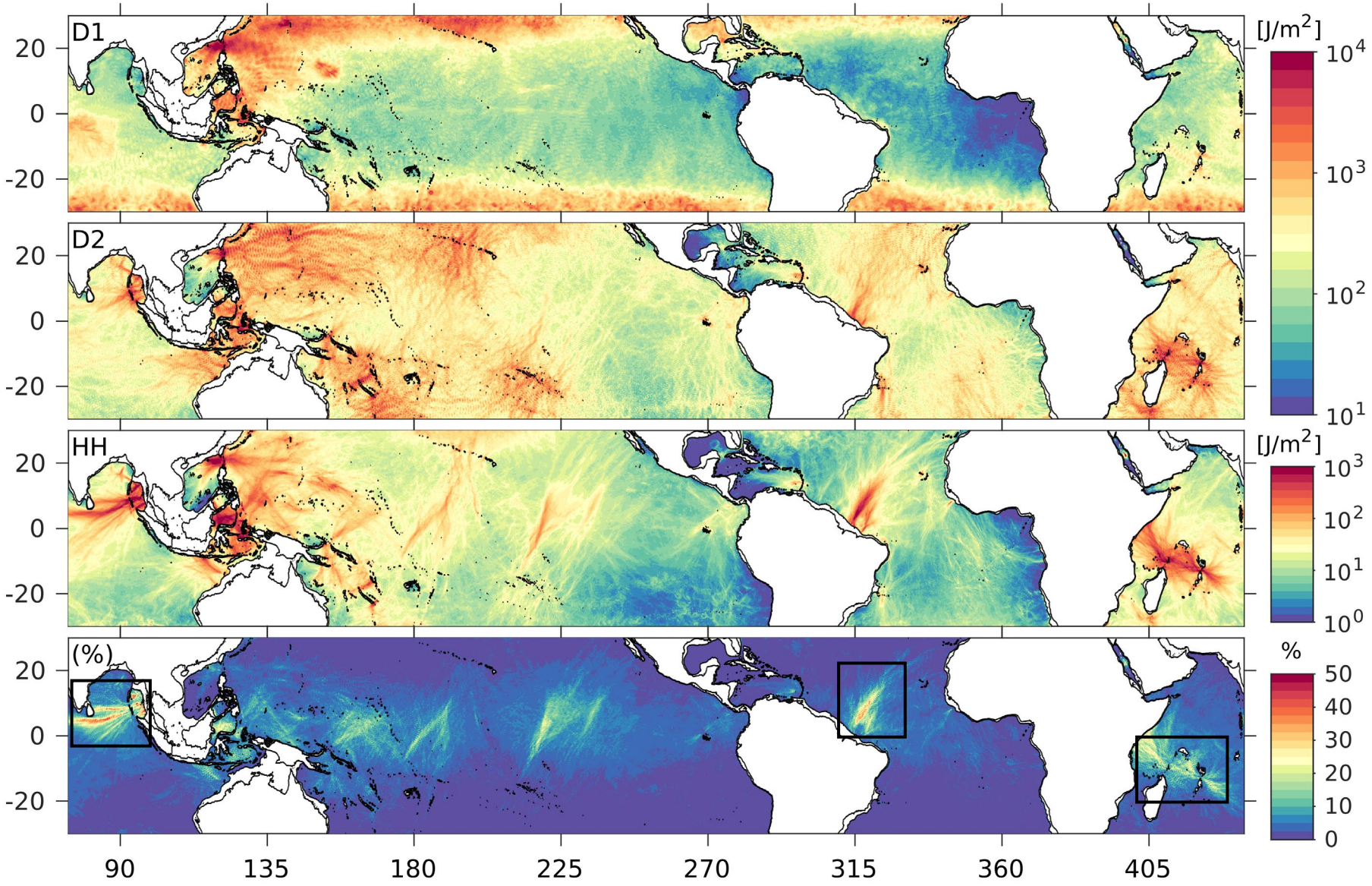
Π_τ $-\int \rho_0 \left(\overline{u_i u_j} - \overline{u_i}\,\overline{u_j}\right) \frac{\partial \overline{u_j}}{\partial x_j}\, \mathrm{d}z$ $\tau = 9hr$

energy transfer associated with nonlinear wave-wave interactions (coarse-grained Kinetic Energy, *Eyink and Aluie, 2009; Barkan et al 2021*)



Kinetic Energy per frequency band

- Supertidal energy (HH) coincides with the strong stratification in the equatorial region
- HH energy is present at sites with strong D2 tides (Bay of Bengal, Amazon Shelf, Mascarene ridge)
- HH energy constitutes up to 20-40% of total (D1+D2+HH)

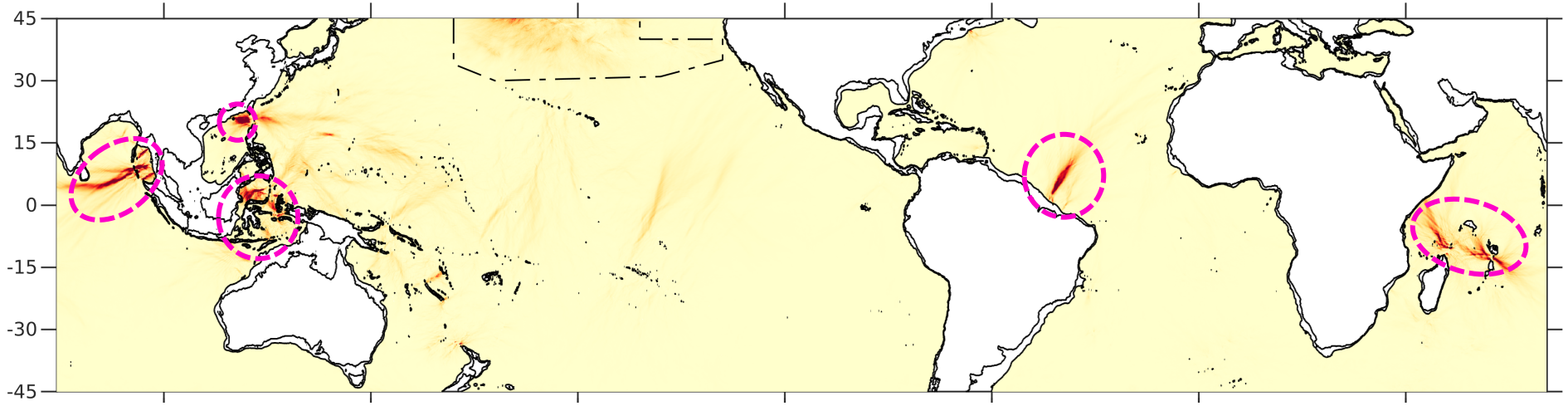


Nonlinear Internal Waves (NLIW)

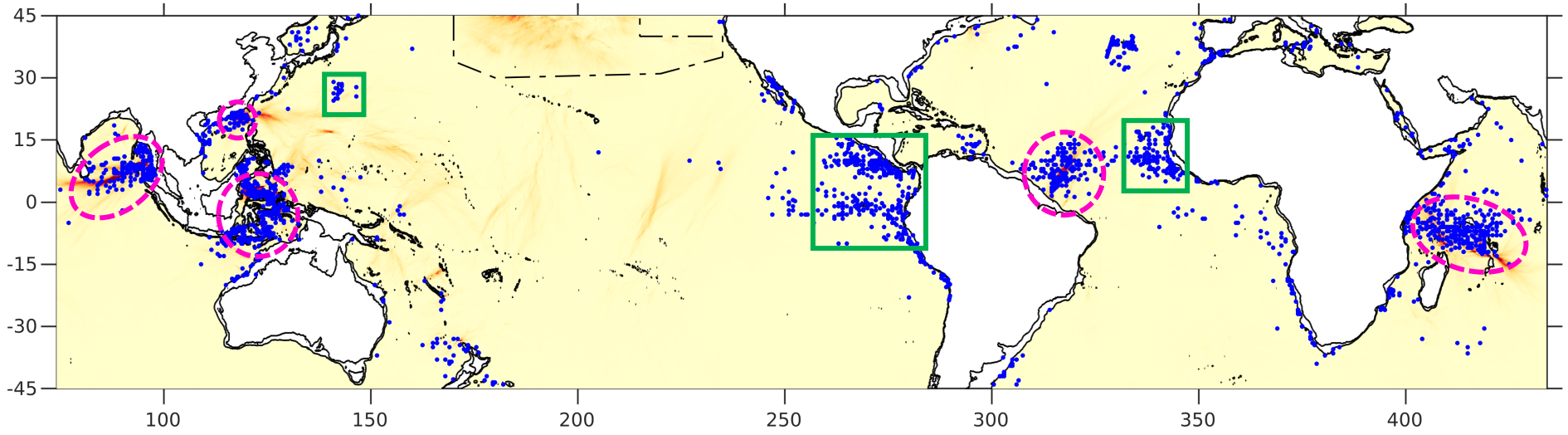
- Ellipses:
  strong HH fluxes
  (> 3 kW/m) coincide
  with observations of
  NLIW (solitons)

- Boxes:
  - Are these NLIW of
  *non*tidal origin?
  - Tidal generation sites
  are not well resolved?

Supertidal (HH) pressure flux in HYCOM



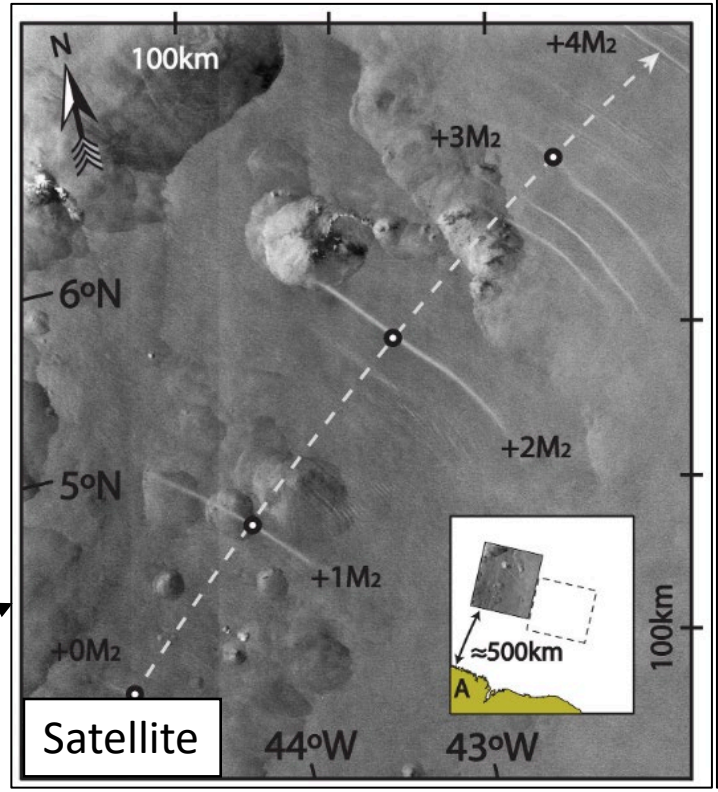
Location of NLIW observed in 250m resolution satellite imagery (Jackson et al. 2012)

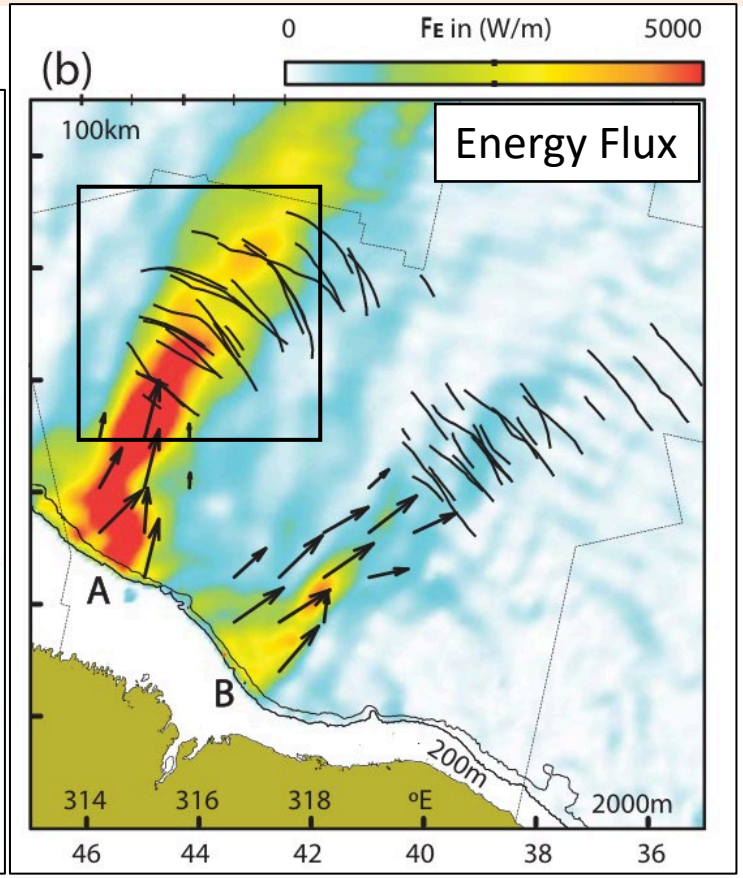


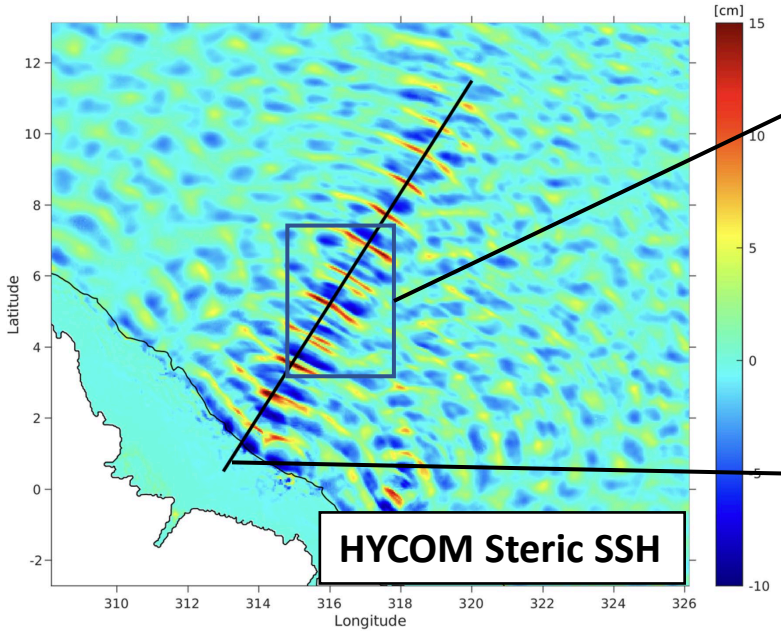
Internal tides at the Amazon Shelf

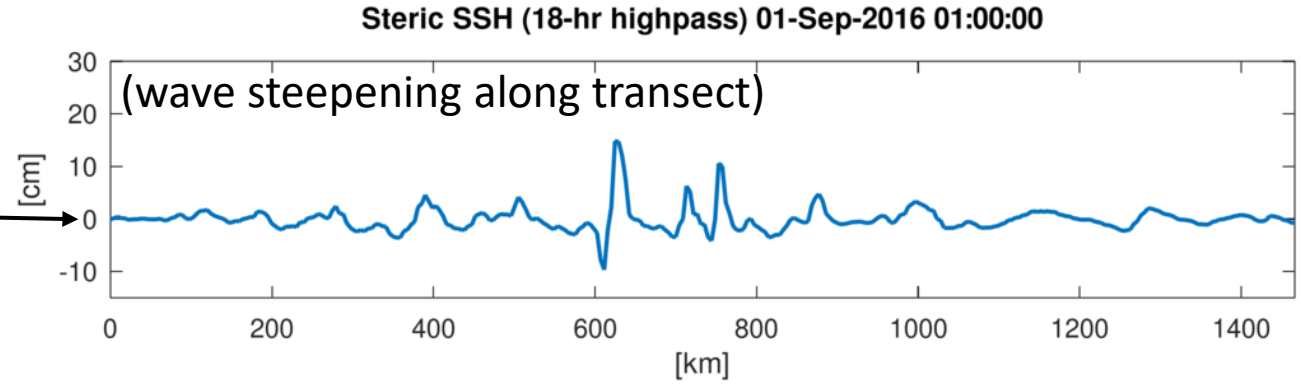
- Strong internal tides evolve into short and sharp crested solitons due to nonlinear dispersion (wave steepening)
- Observations coincide with strong D1+D2 fluxes

Magalhaes et al. (2016)





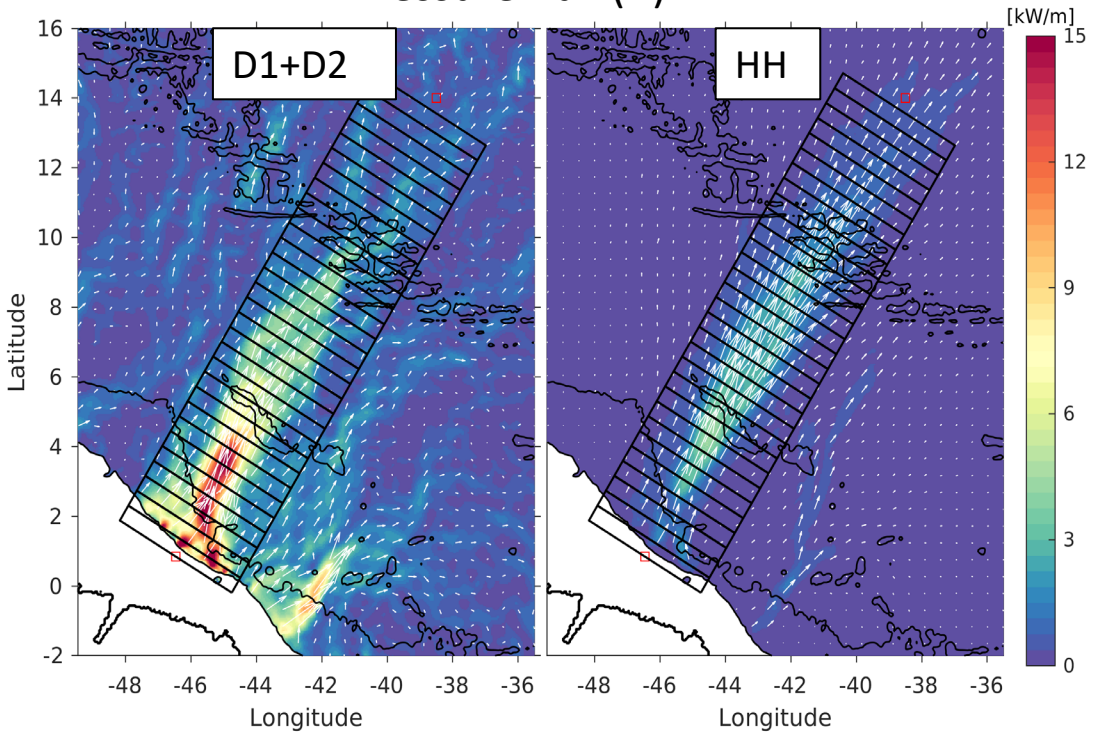




D1+D2 ⇒ HH nonlinear energy transfers

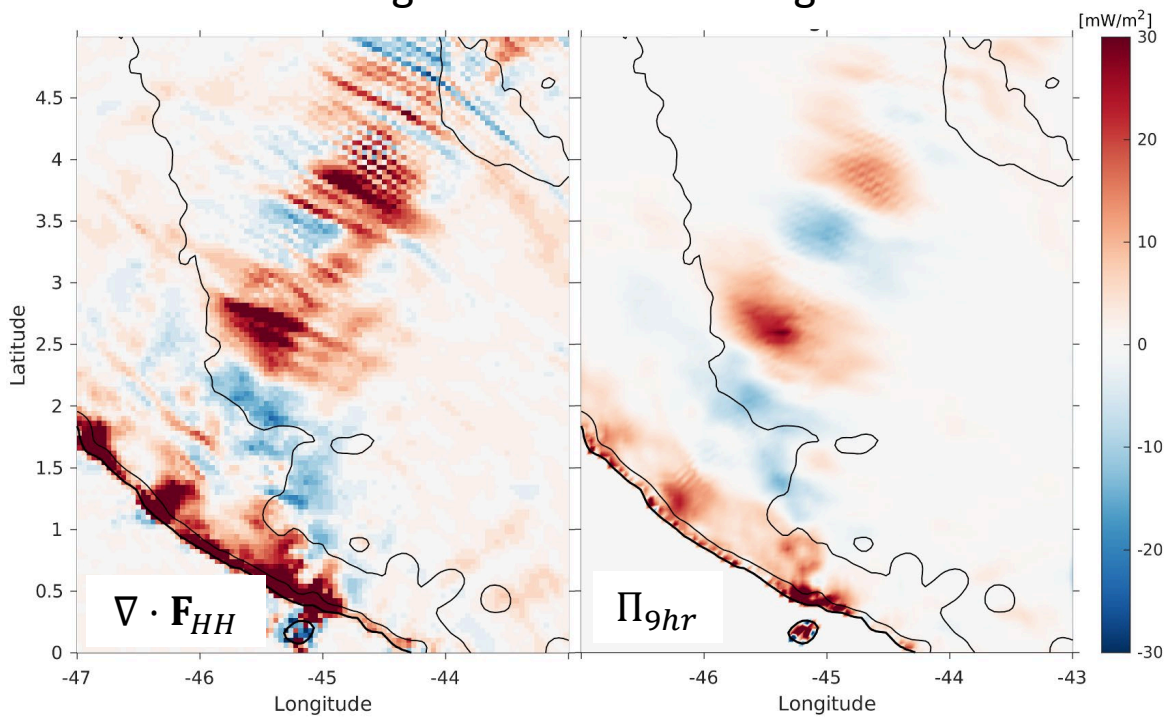
THE UNIVERSITY OF SOUTHERN MISSISSIPPI

Pressure flux ($\mathbf{F}$)



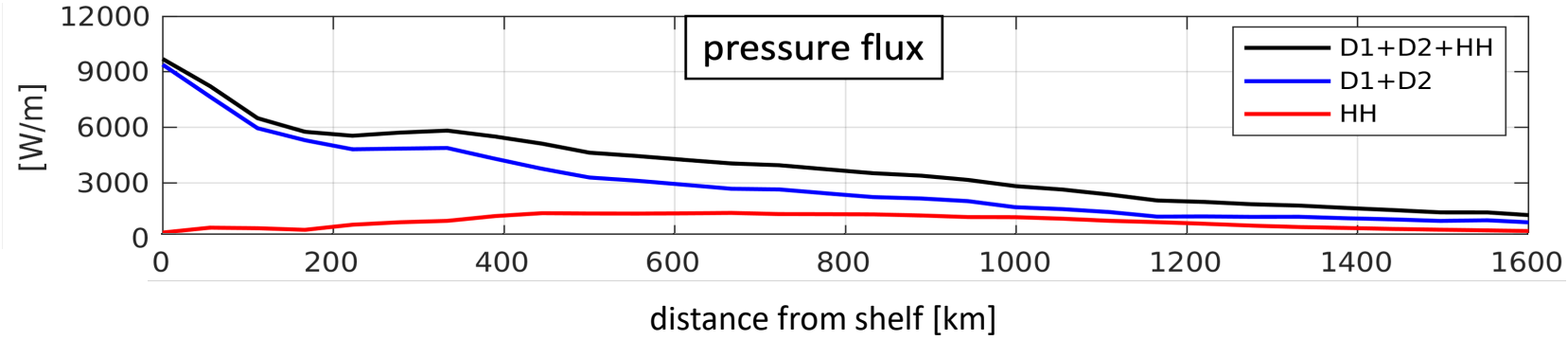
HH flux divergence

coarse-grained KE



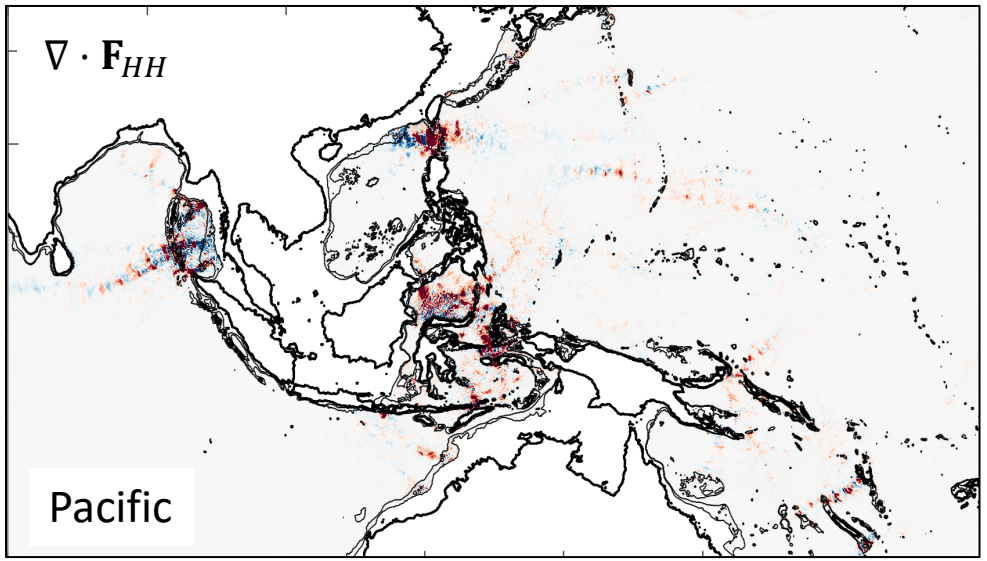
forward (D1+D2⇒HH)

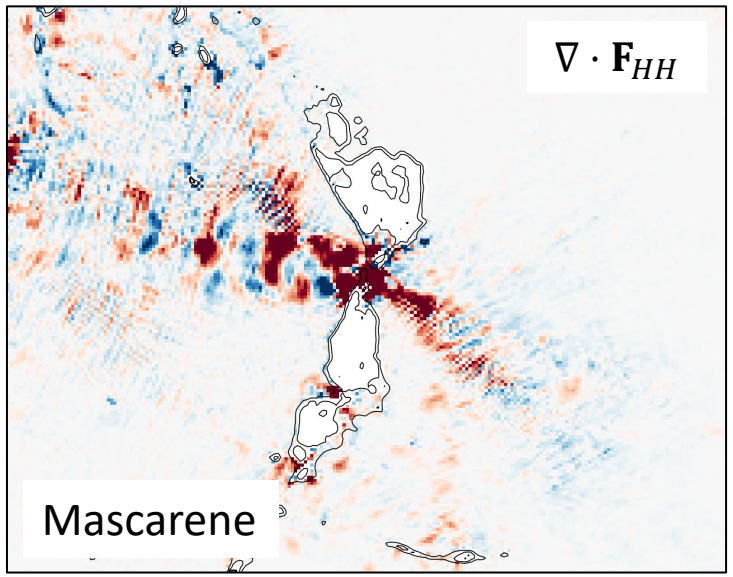
inverse (D1+D2⇐HH)

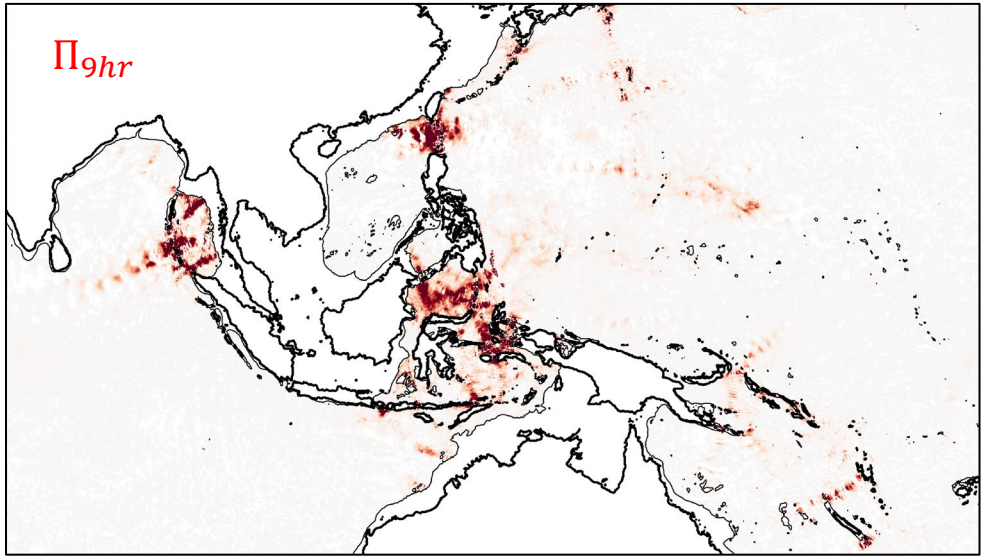


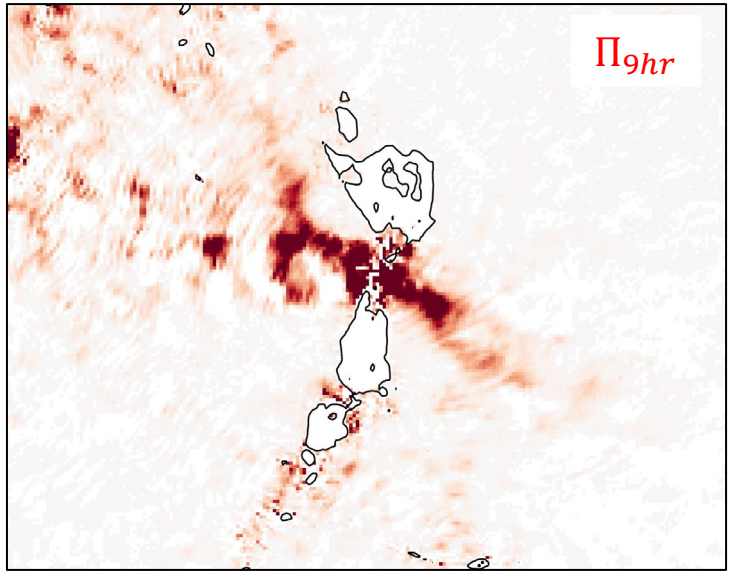
- The D1+D2 flux decay is due to dissipation and energy transfer to HH (Π_{9hr})
- Patterns of HH flux divergence agree with Π_{9hr}

D1+D2 ⇒ HH nonlinear energy transfers





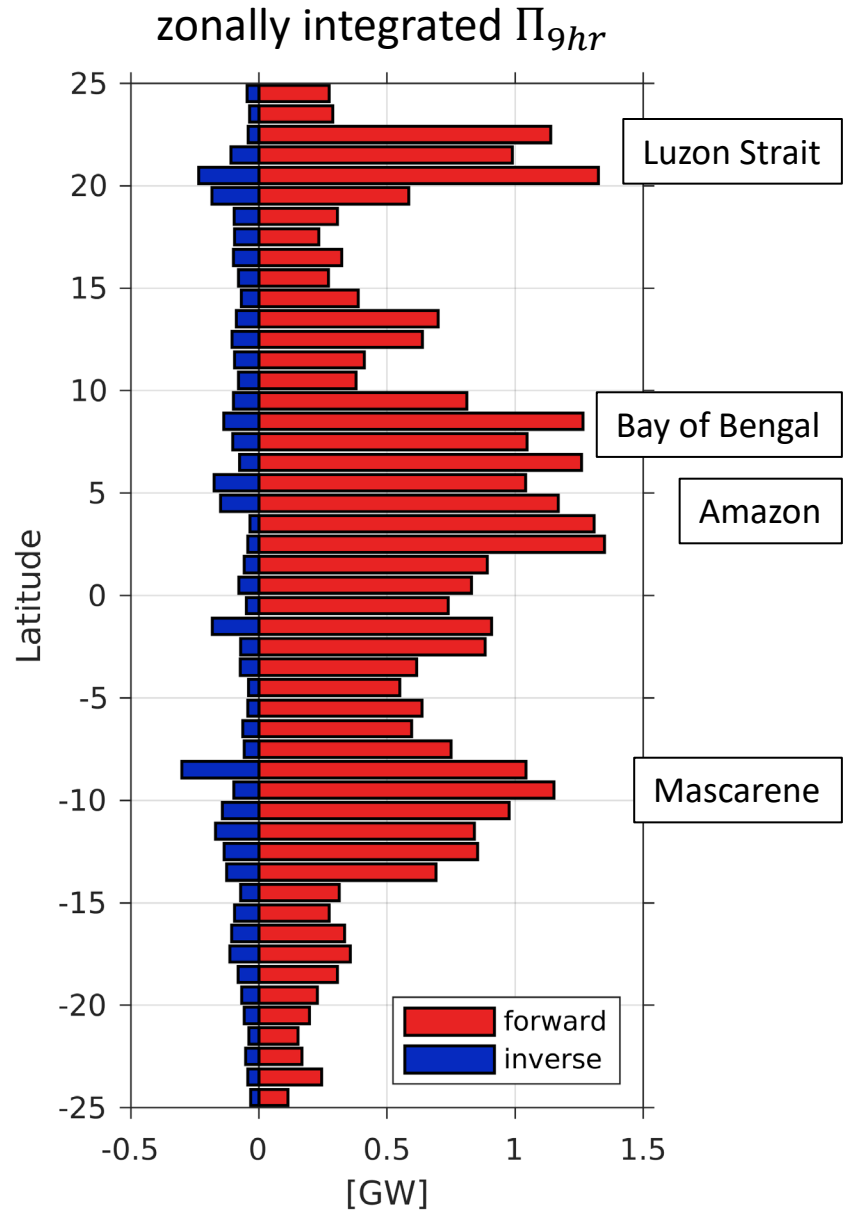




- The magnitudes and spatial patterns of $\nabla \cdot \mathbf{F}_{HH}$ agree with Π_{9hr}
- The 'banding' requires further explanation

Summary

- At strong internal tide generation sites, super tidal energy constitutes up to 40% of the total internal tide energy in the tropics
- Areas with high supertidal energy in HYCOM coincide with observations of nonlinear internal waves
- Internal tides loose energy through wave-wave interactions in a forward cascade, transferring a net 40GW to HH within $\pm 25°$
- At current horizontal grid resolution (~ 4 km), these numbers may not be accurate, as solitary waves are not well resolved



IT at the East Mascarene Ridge

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

Solitary Waves at Mascarene Ridge (da Silva et al. 2015)