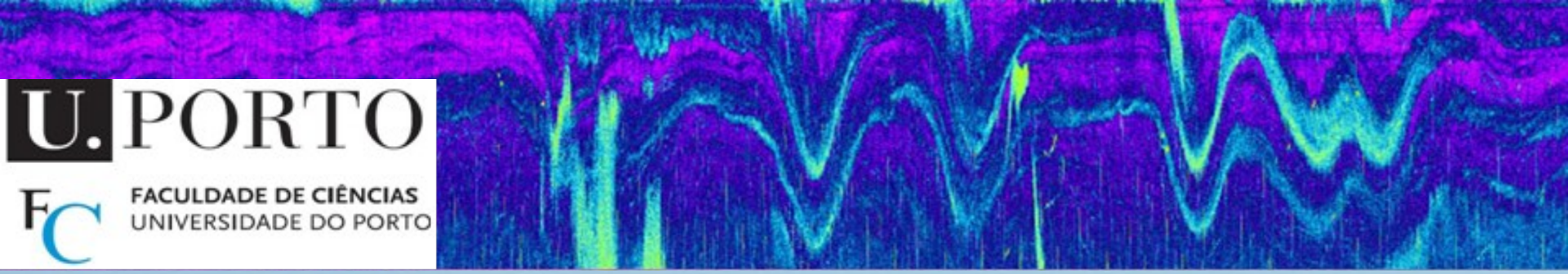

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Internal waves on the upstream side of a large sill of the Mascarene Ridge: a comprehensive view of their generation mechanisms and evolution

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NewWave : New challenges in internal wave dynamics
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Outline of this Talk

Three types (or “families”) of short-period IWs have been identified and studied in detail:

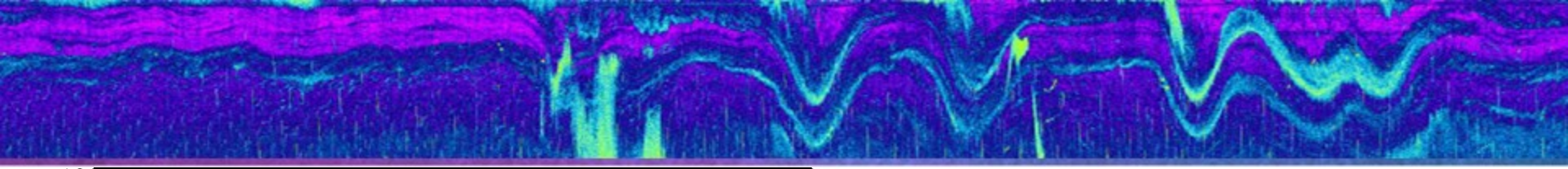
(1) Large mode-1 and mode-2 ISW- like waves that form upstream (i.e. eastwards) of the sill during relaxation of the westward tidal flow as a result of the disintegration of a multimodal baroclinic structure;

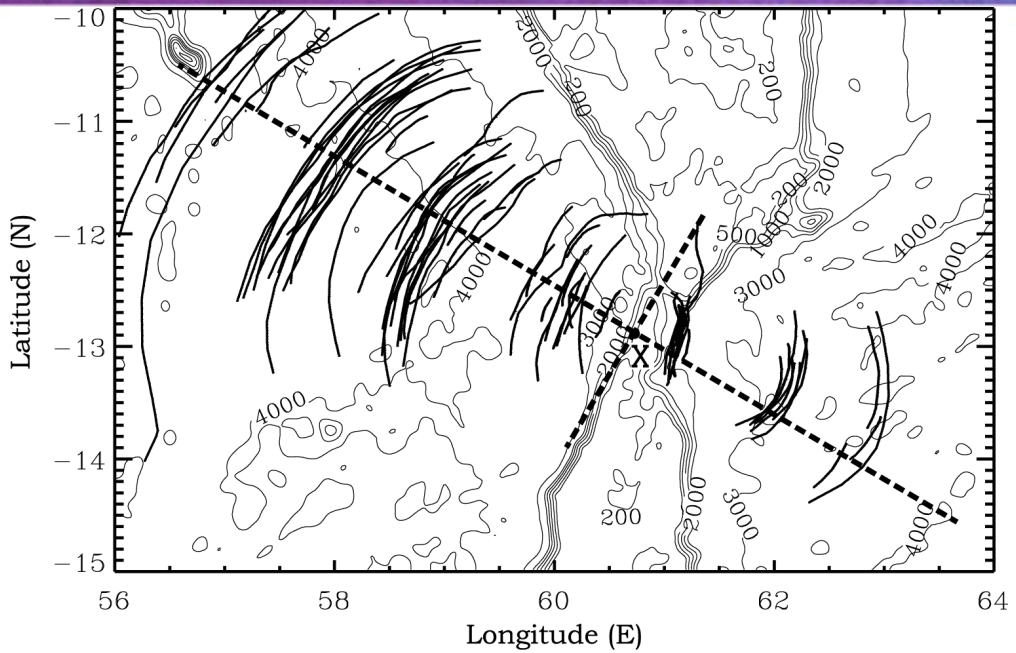
(2) Second mode IWs with trapped short-period mode-1 ISWs that form after the scattering of an IT beam with the pycnocline;

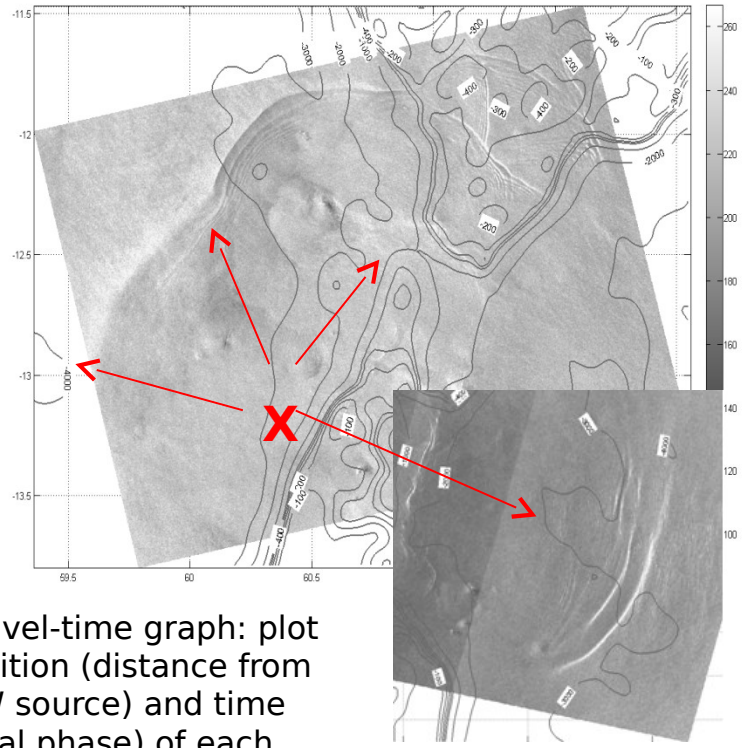
(3) Large mode-2 lee waves that form downstream of the sill and propagate upstream after the tidal flow has relaxed to subcritical conditions with respect to mode-2 waves.

Main motivation:

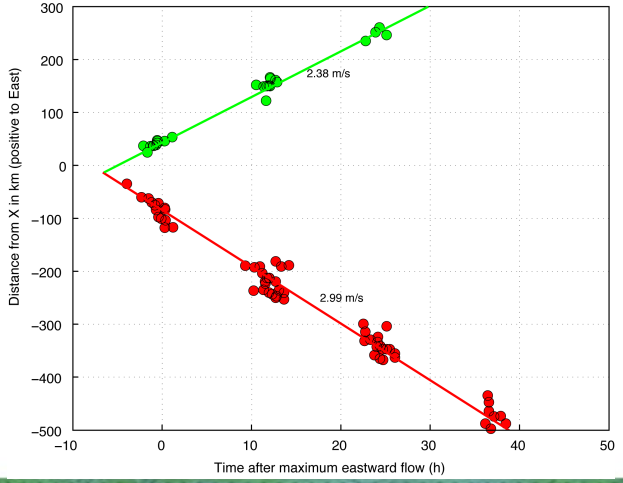
IW pressure fluxes (approximately 101 and 72kW/m east and west of the sill, respectively) are about twice as large when compared to those from the Luzon Strait in the SCS. => hence, Mascarene Ridge is the largest energetic hot spot in the ocean!







The waves propagate to at least 400 km to the West and more than 350 km to the East of the sill, with crest lengths that may exceed 350 km! (probably the largest in the ocean)

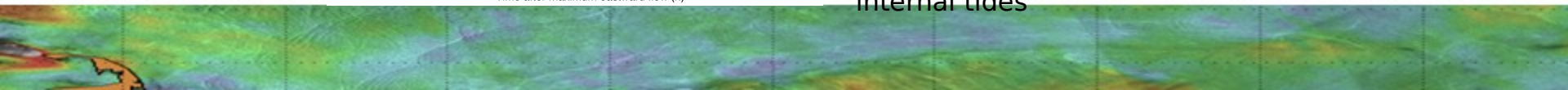


•Travel-time graph: plot position (distance from ISW source) and time (tidal phase) of each leading ISW packet detected in the SAR

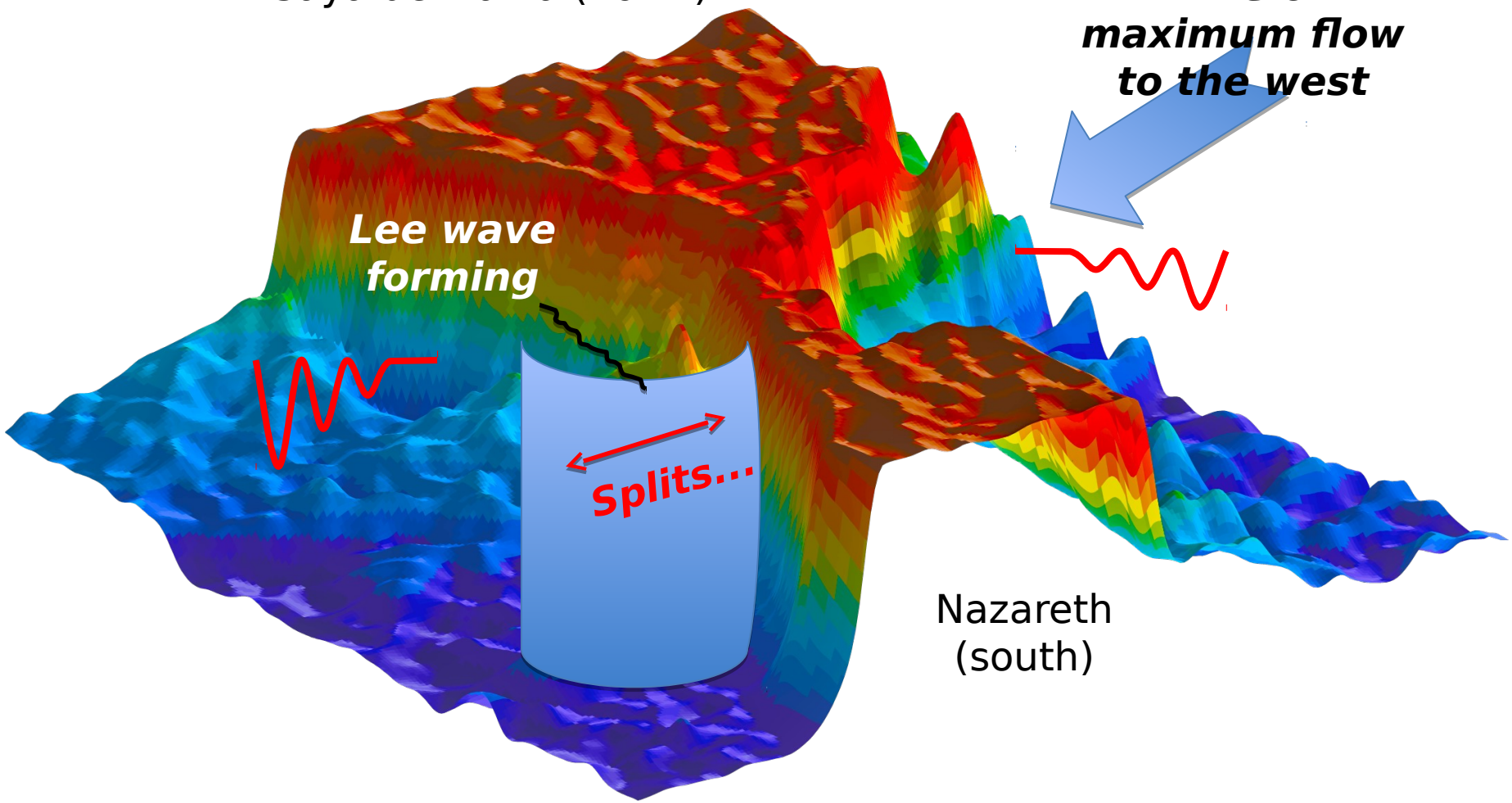
• Slopes represent ISW phase speed

• Compare favorably with linear theory

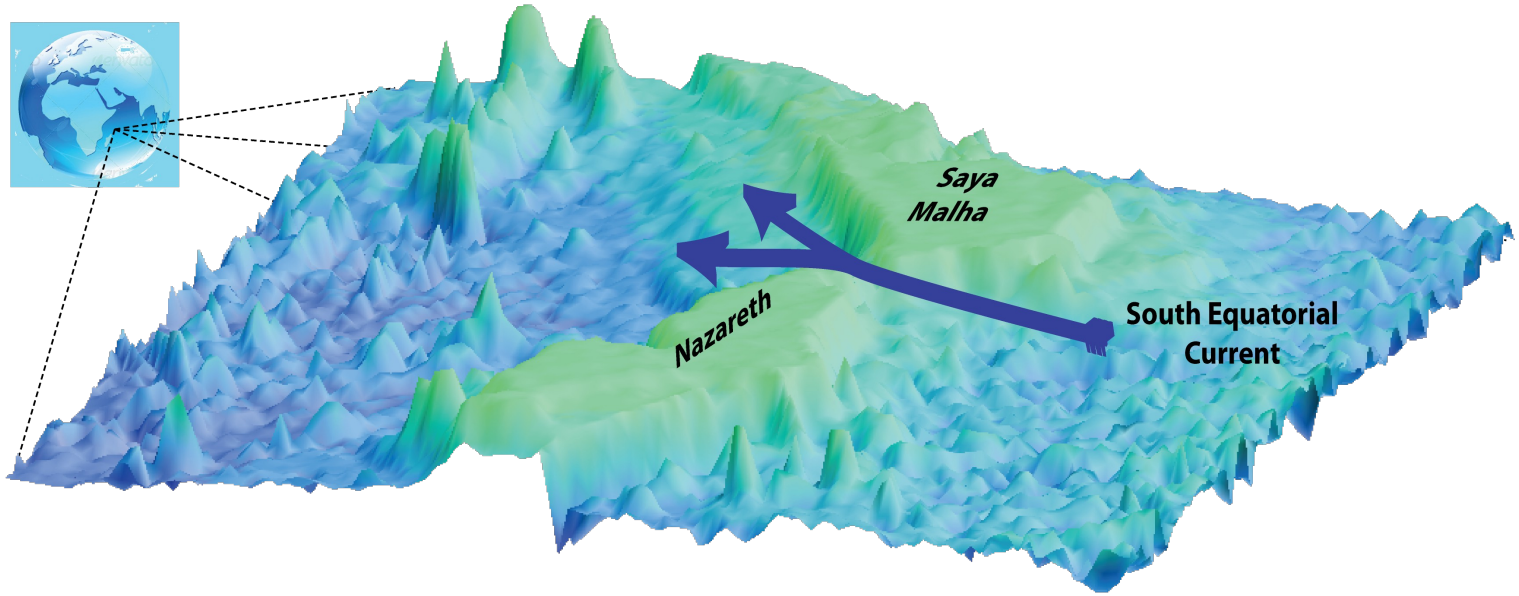
• First baroclinic mode gives the most realistic phase speeds for the deep ocean “Primary” propagating internal tides

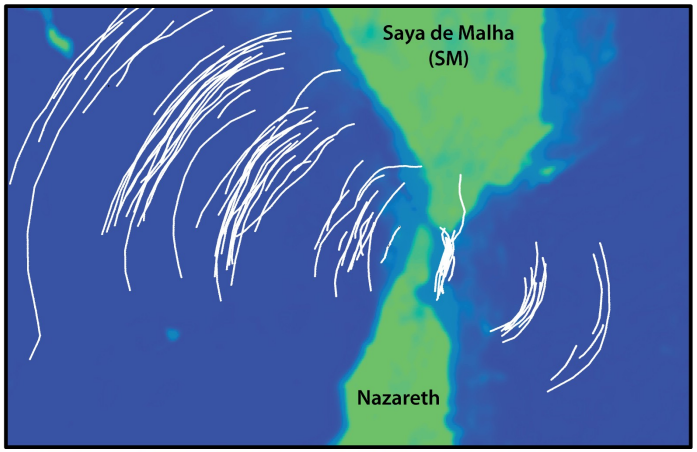


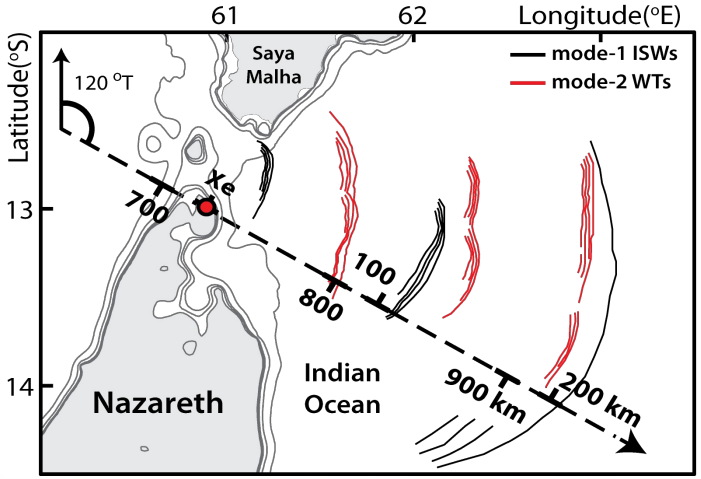
Lee wave splitting mechanism



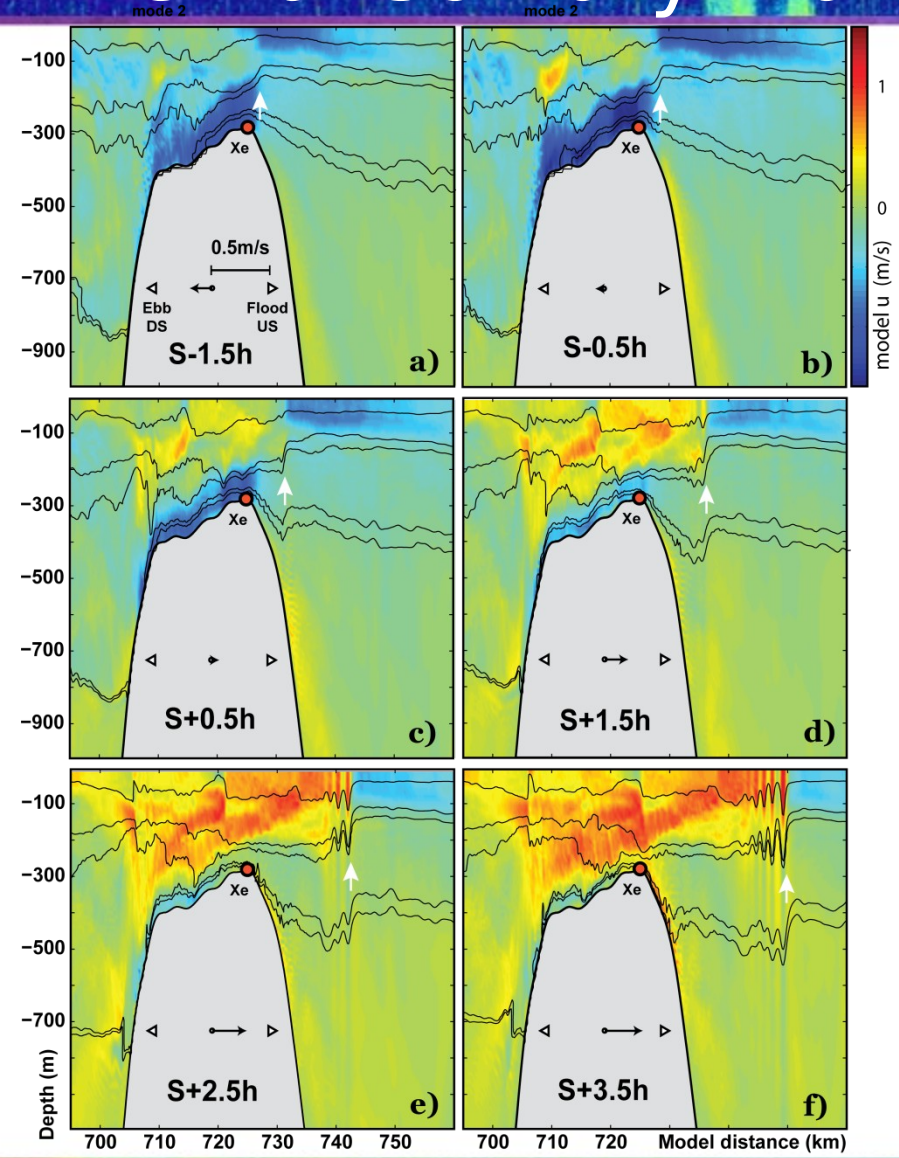
ISWs at the Mascarene ridge of the Indian Ocean

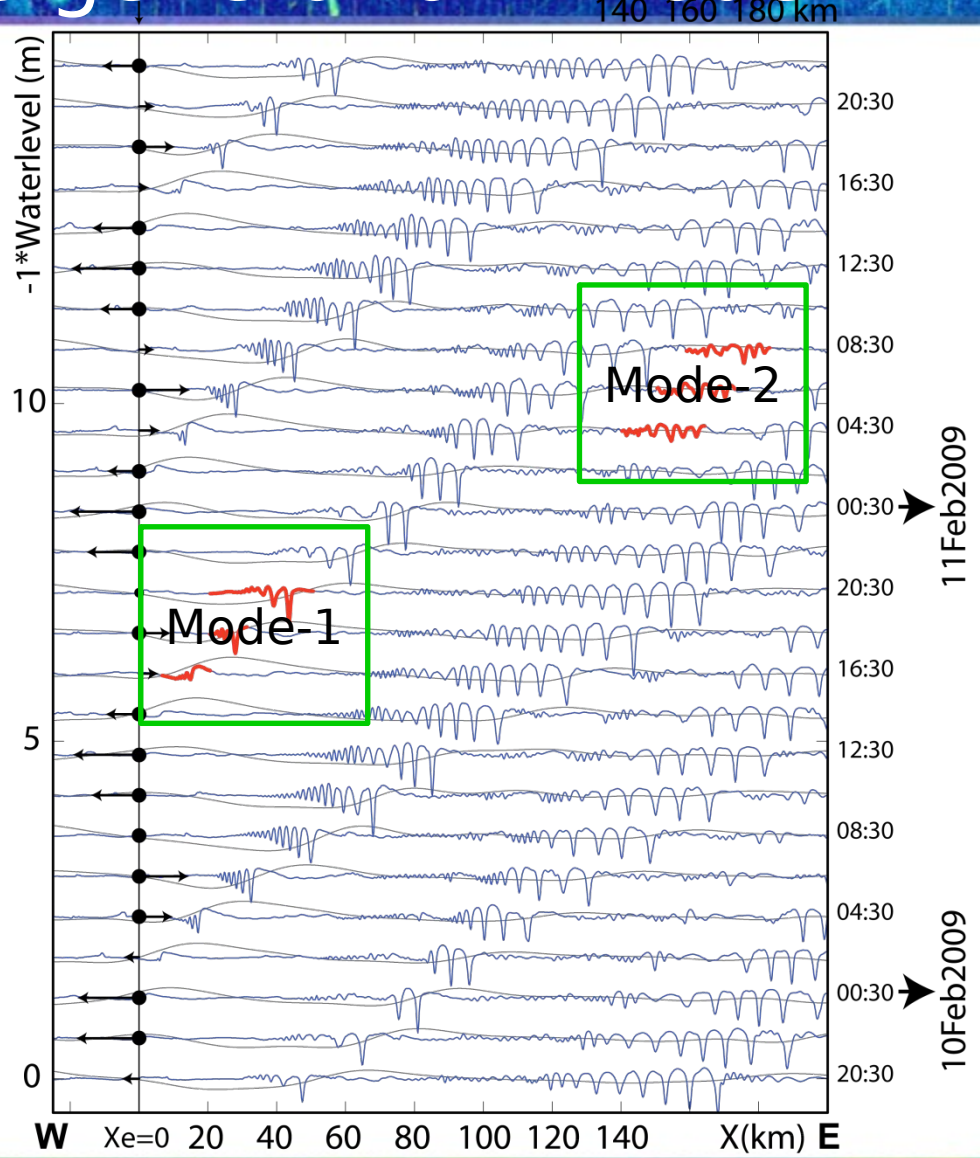






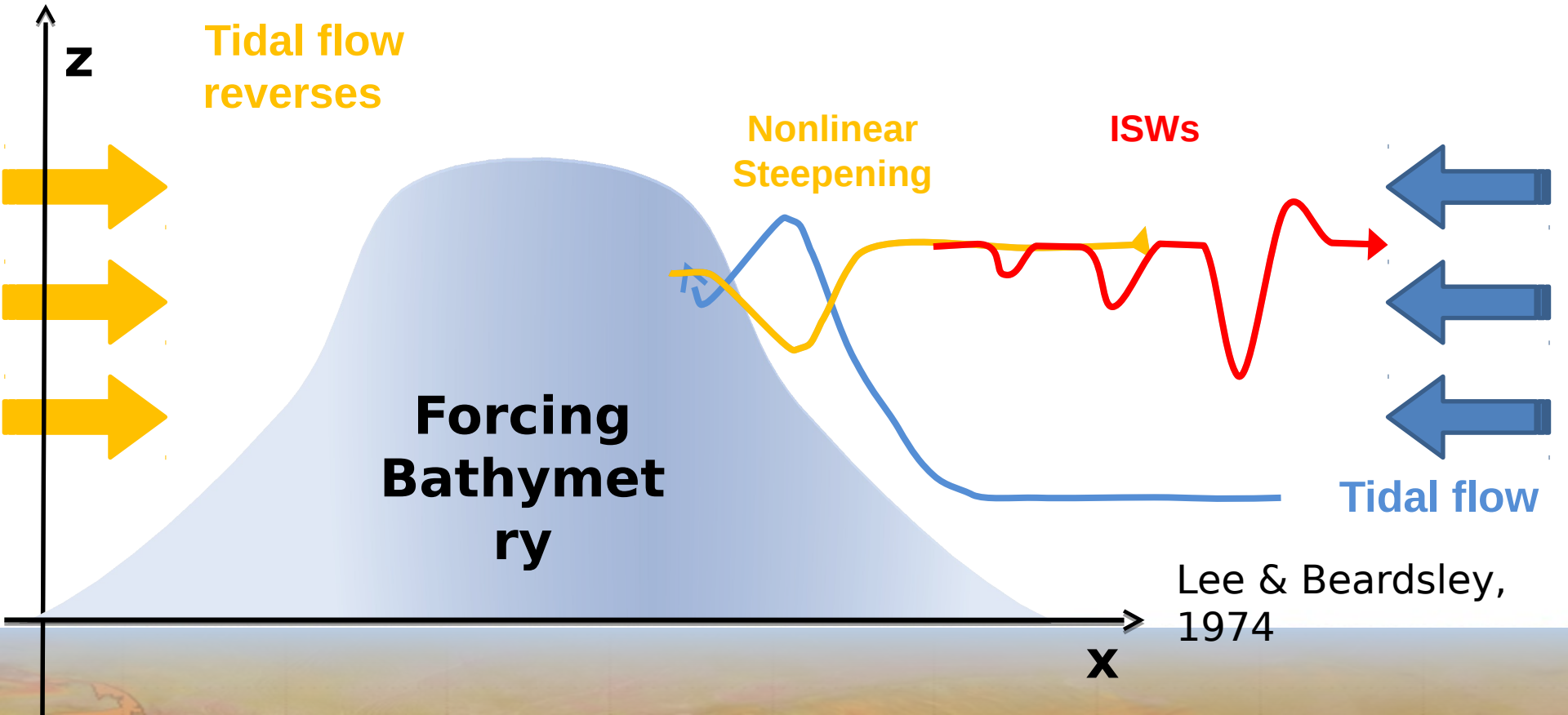
Internal Solitary Wave generation: mode-1



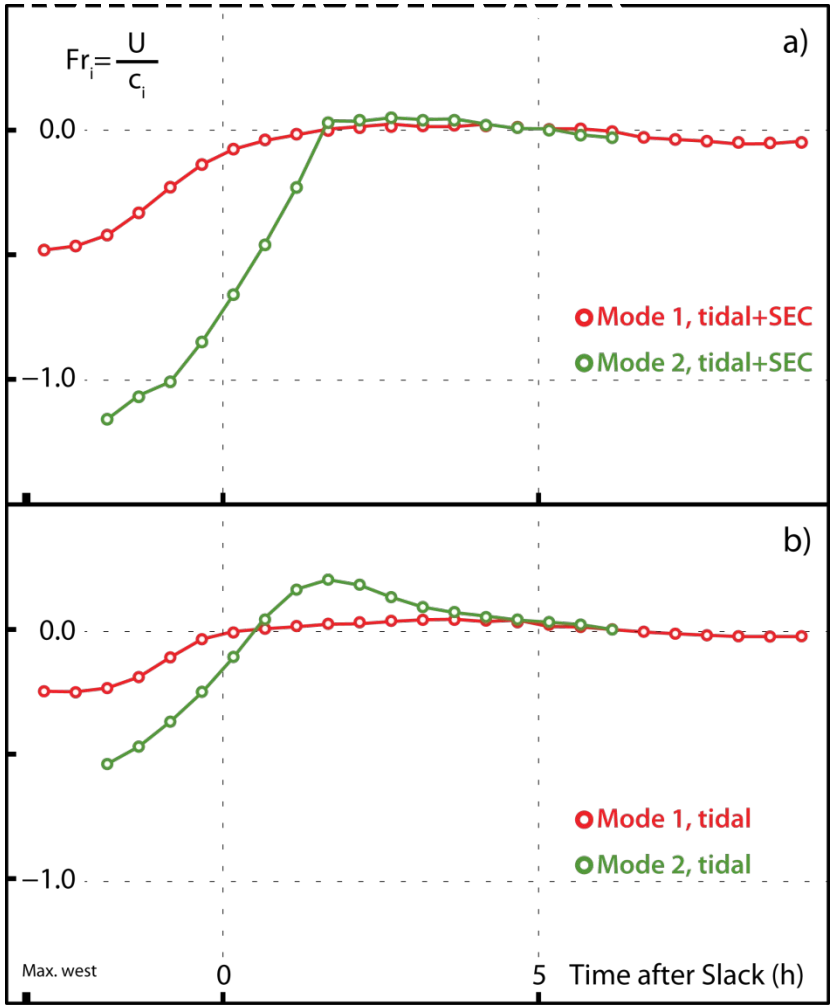


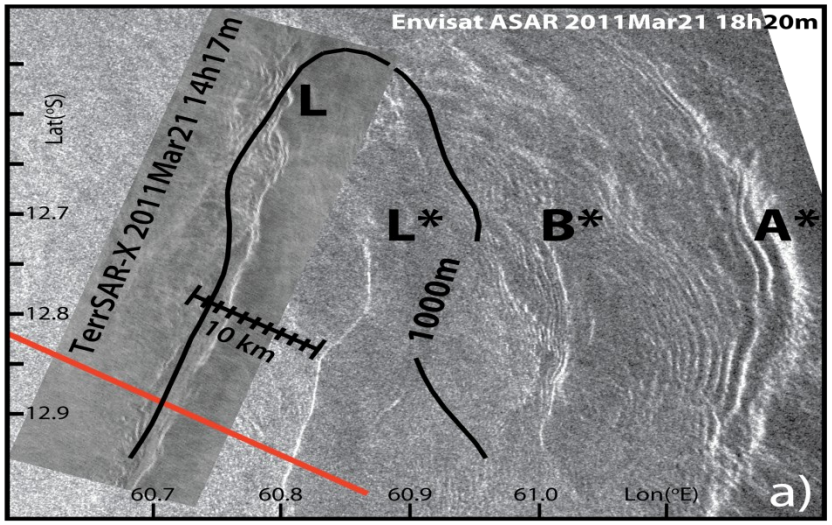
Internal tide Release Mechanism Schematics (Buijsman et al., 2010)

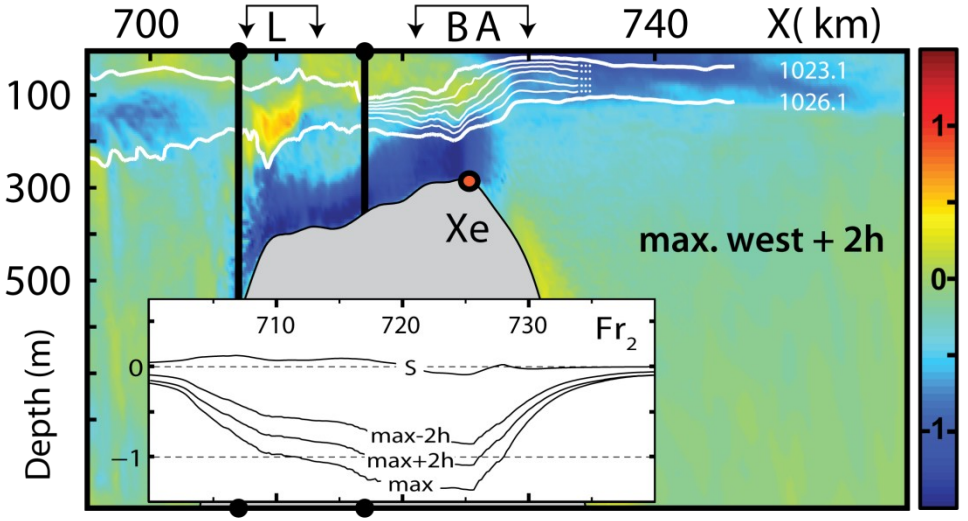
Generation of ISWs eventually occurs as nonlinear steepening and dispersion balance.



Internal Solitary Wave generation:

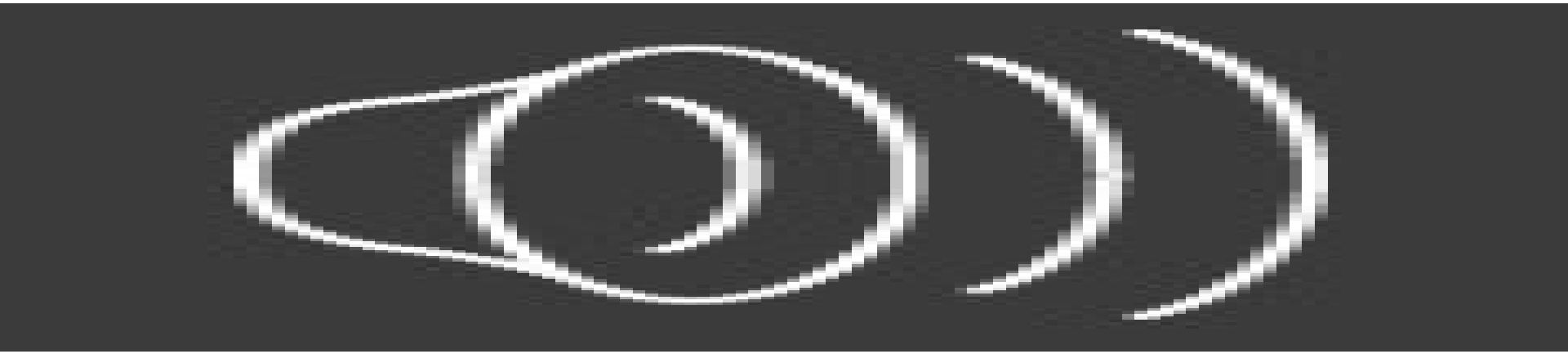




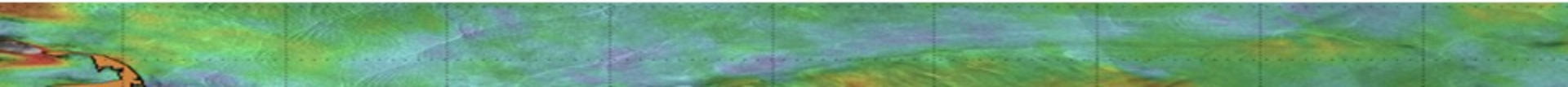


Internal Solitary Wave

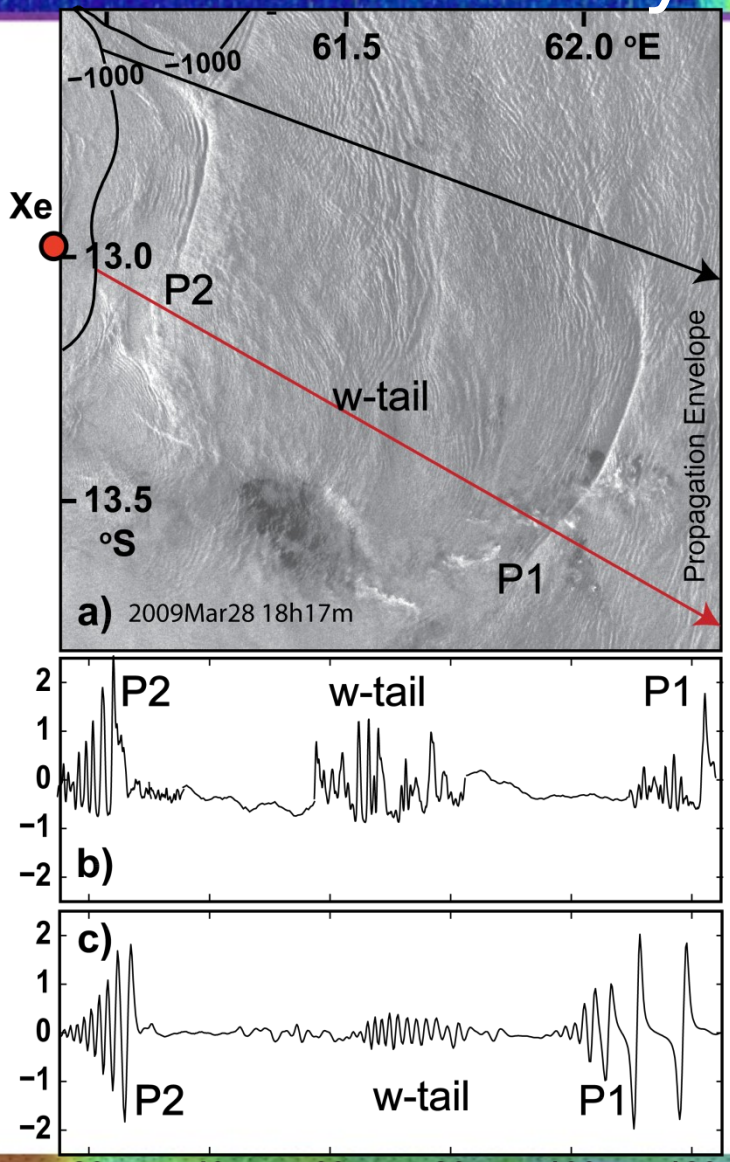
MITgcm nonhydrostatic, fully nonlinear



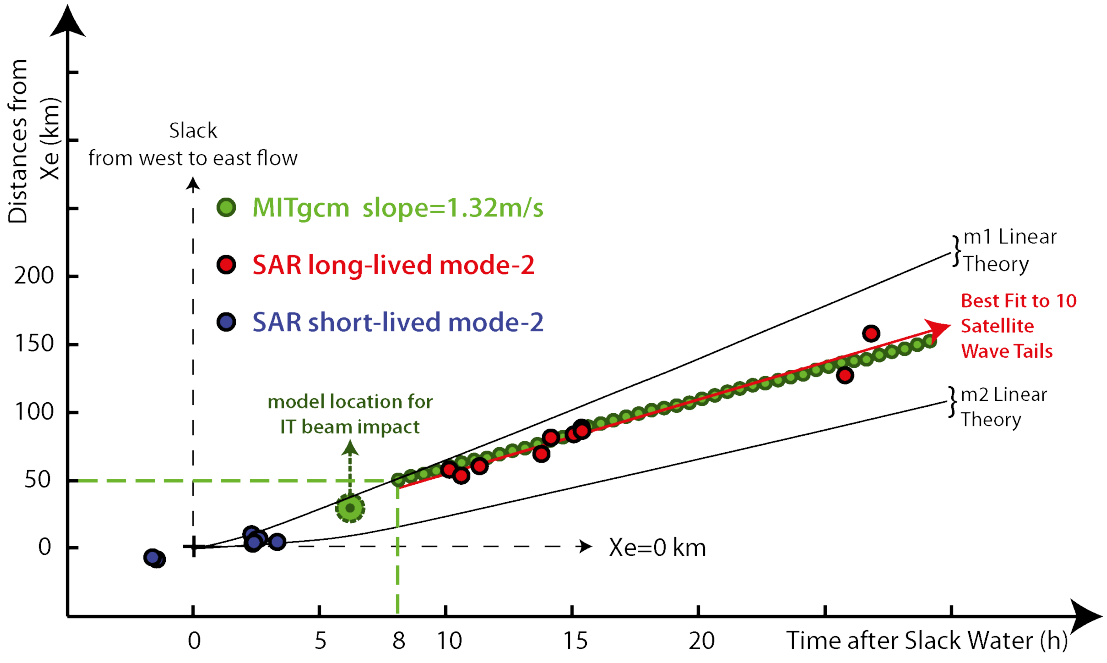
da Silva et al. (2015)



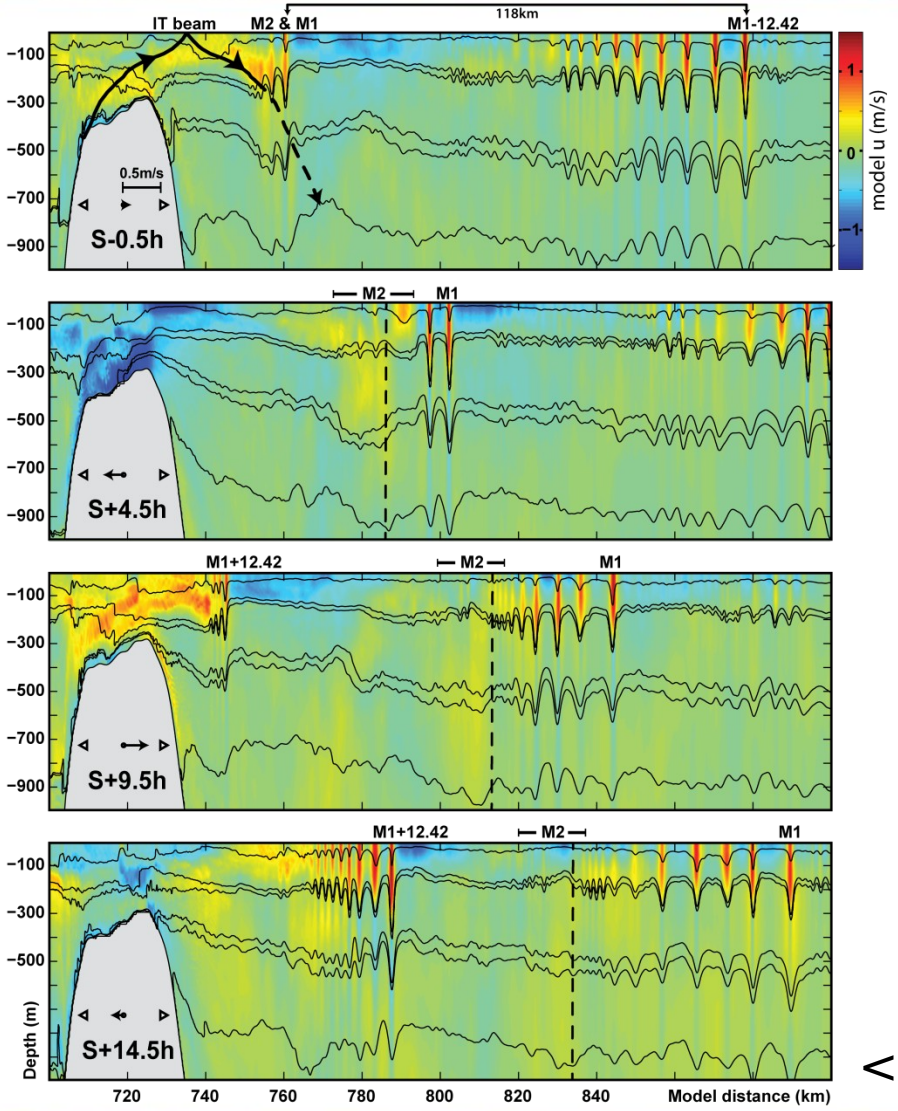
Internal Solitary Wave generation: mode-2

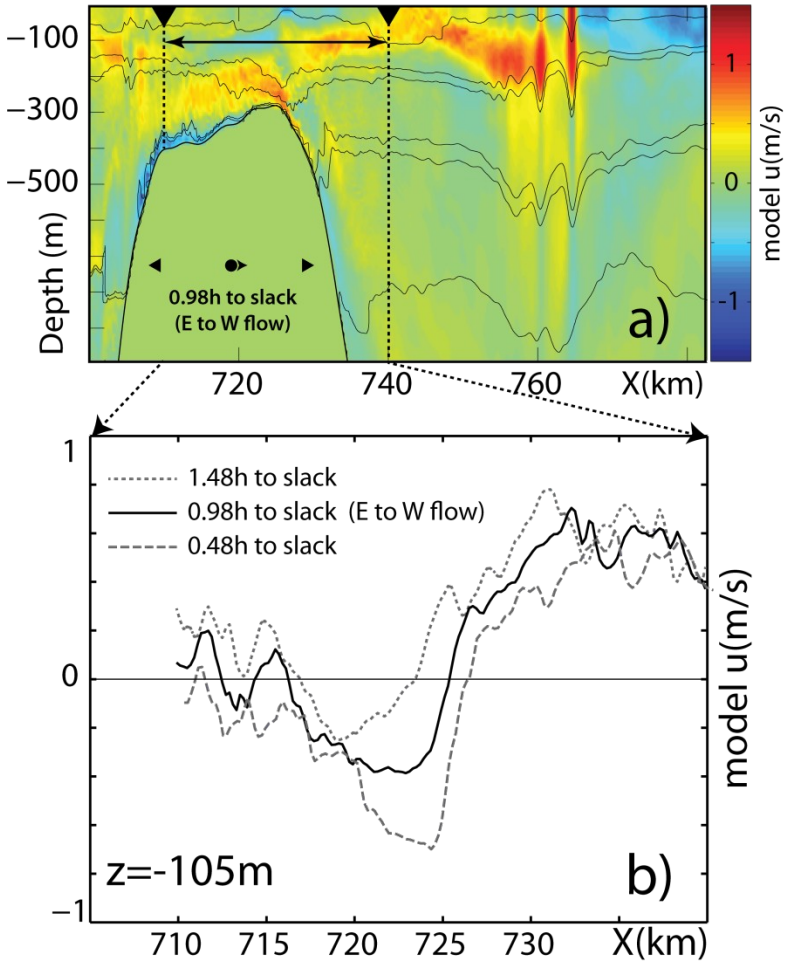


Generation of Mode-2 ISWs



Internal Solitary Wave generation: mode-2



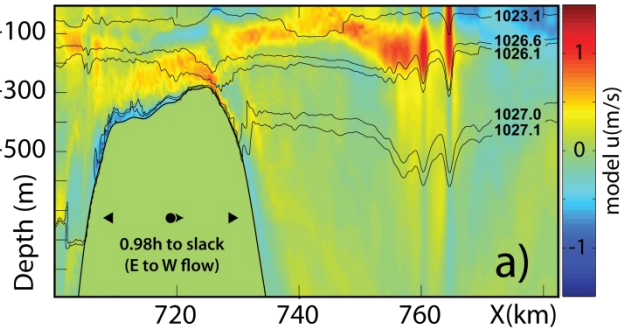


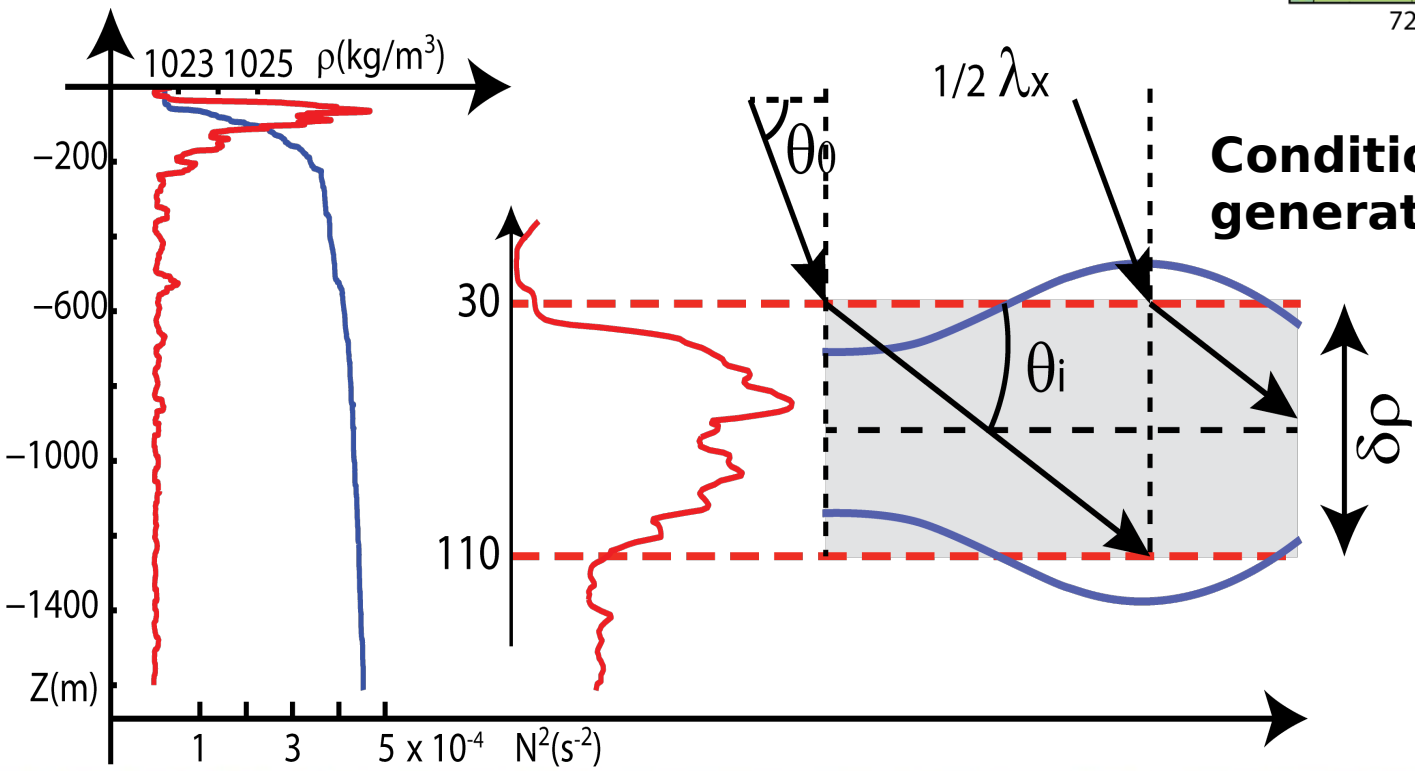
<= total period of 15 h.

Internal Solitary Wave generation: mode-2

Bragg-like resonance condition (Grisouard et al., 2011) based on simple geometric arguments

$$s = \pm\left(\frac{\omega^2 - f^2}{N^2 - \omega^2}\right)^{\frac{1}{2}}$$

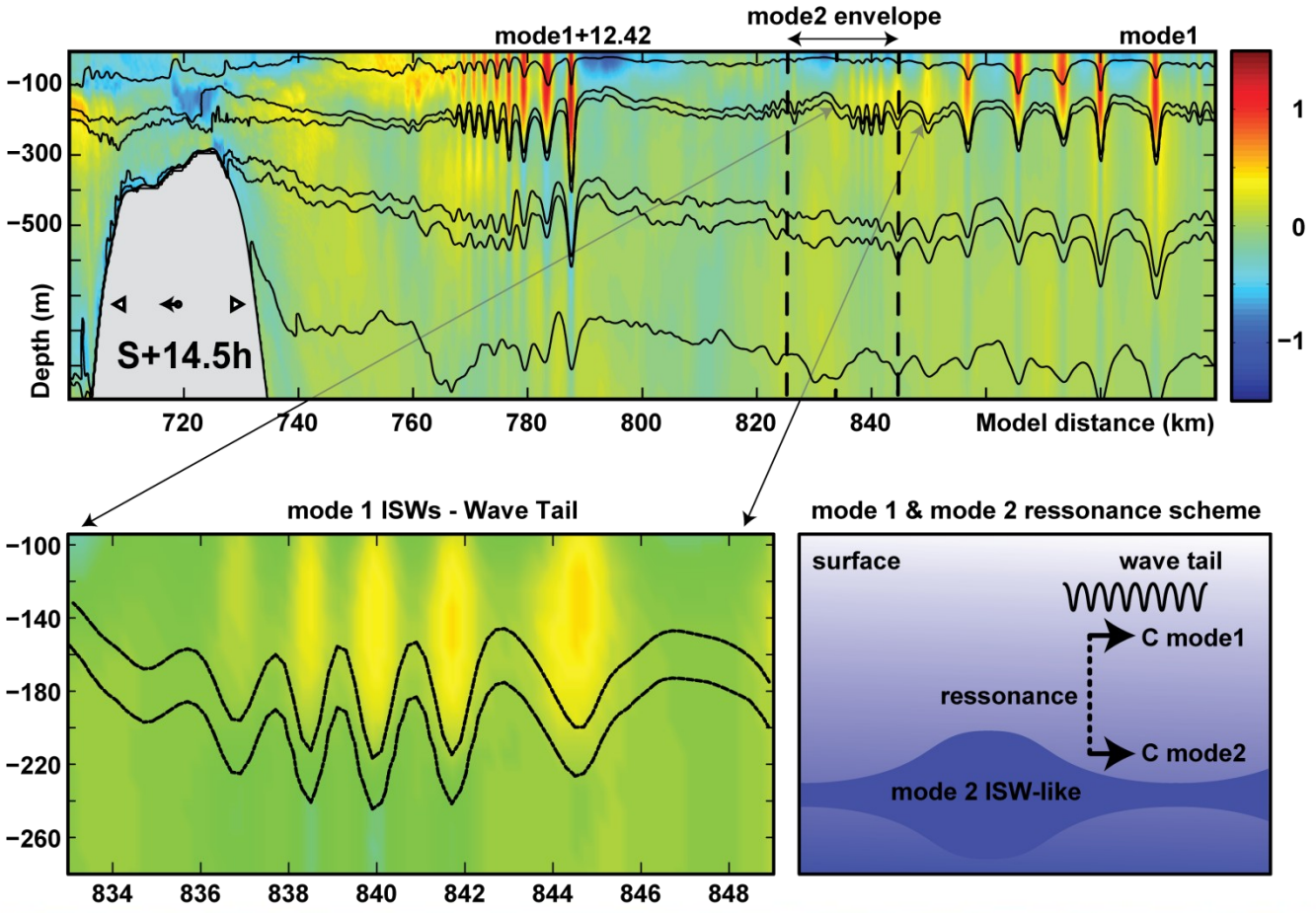




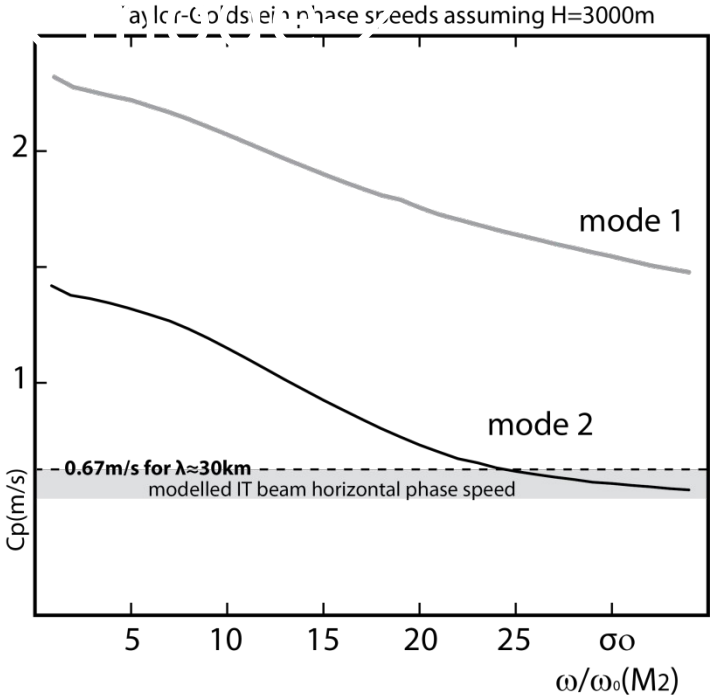
Condition for mode-2 generation:

The horizontal wavelength of the wave beam λ_x must be twice as large as the (integrated) path of an IW characteristic between the boundaries of the pycnocline

Mode-2 Internal Waves



Internal Solitary Wave resonance: mode-1

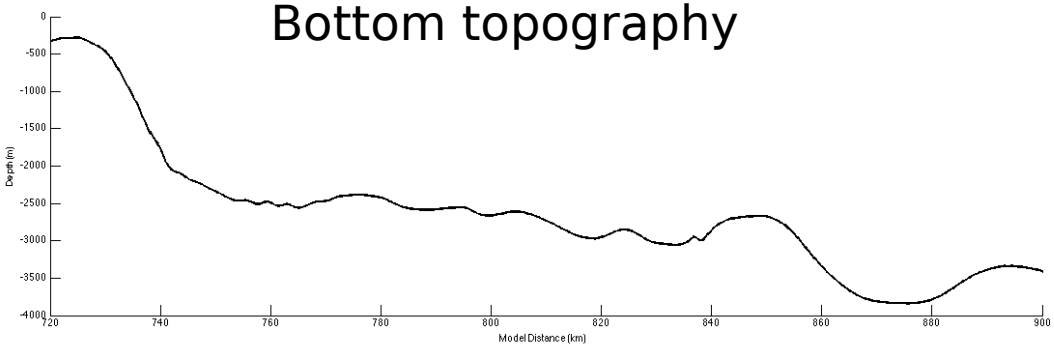


1
2
Non-hydrostatic

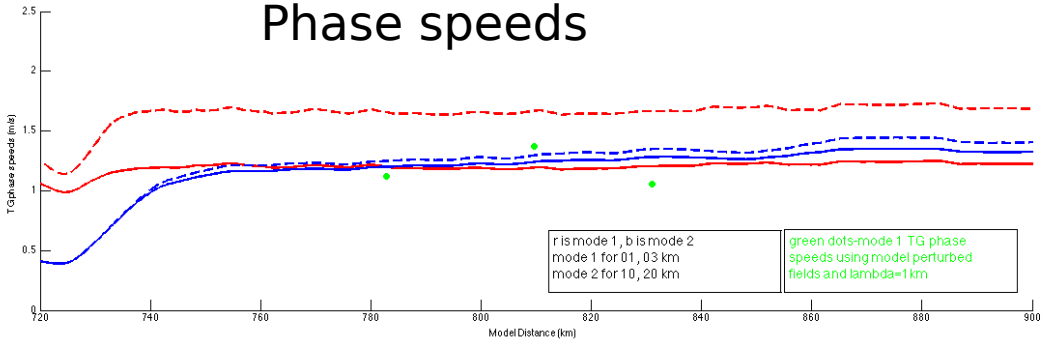
1
2
Hydrostatic

Comparison between mode-1 and mode-2 linear phase speeds along the ISW trajectories (variable bathymetry).

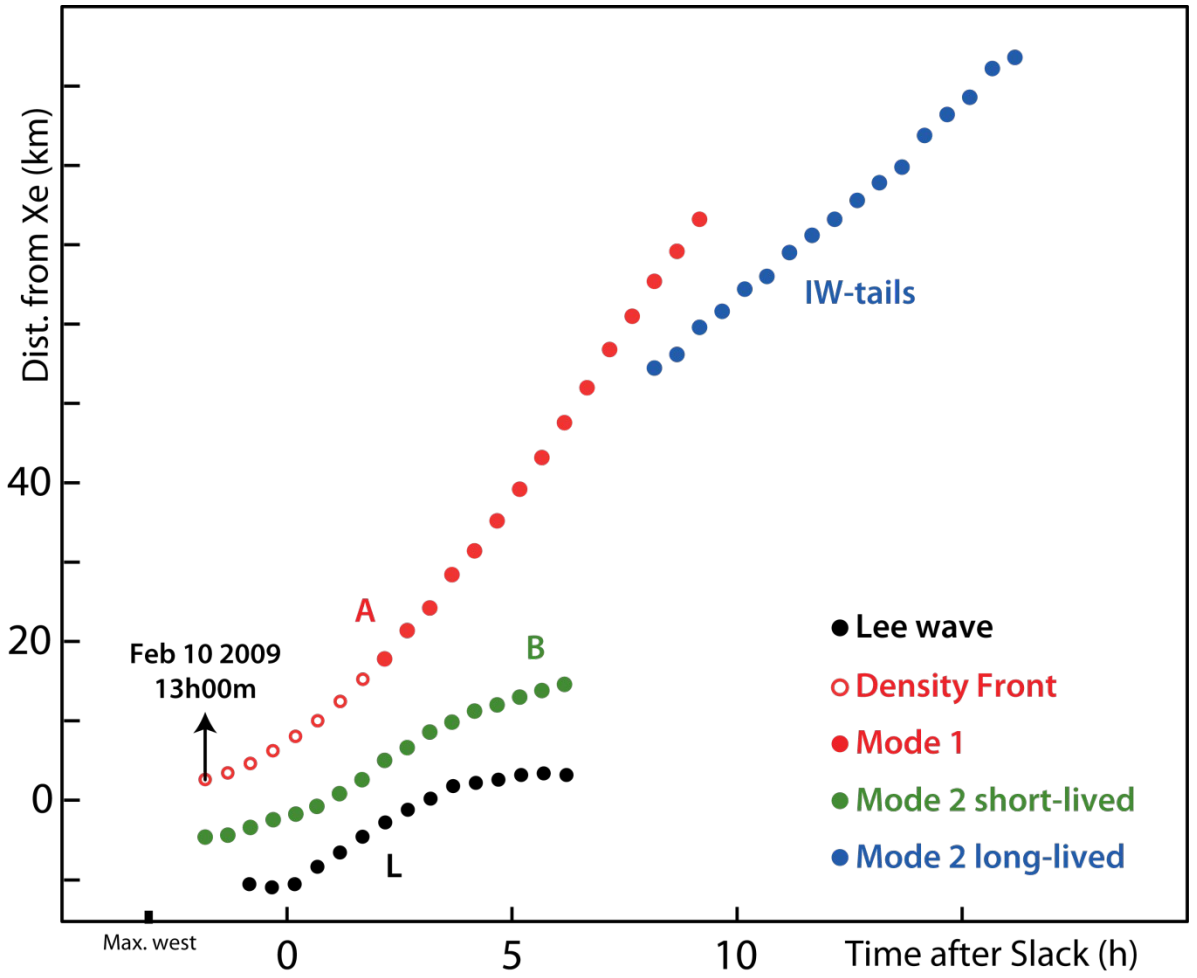
Bottom topography



Phase speeds



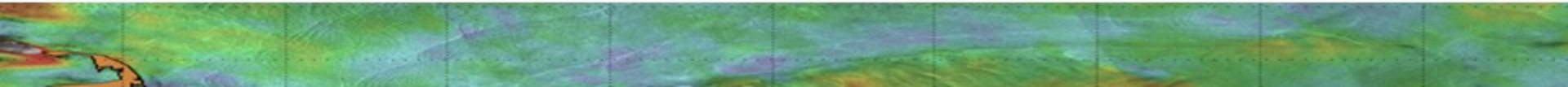
Internal Solitary Wave generation: all

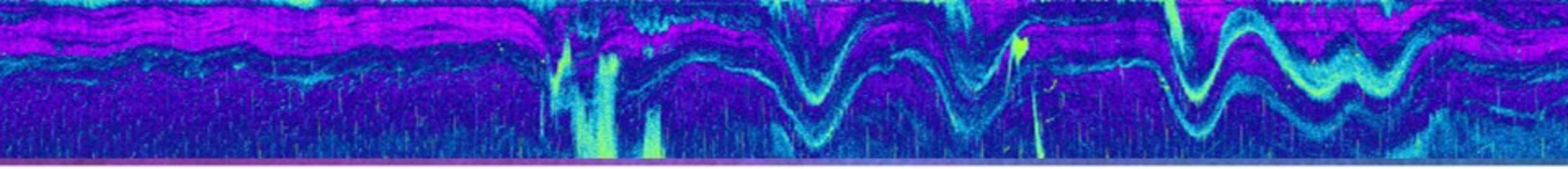


ISWs at the Mascarene ridge of the Indian Ocean

Conclusions

- “Primary” mode-1 ISWs generate upstream from the sill (internal tide release mechanism)
- Large mode-2 lee wave generates short-lived solitary waves (over the sill)
- Long-lived mode-2 nonlinear IWs (and short-period mode-1 ISWs) are consistent with “Thermocline beam scattering” generation mechanism





Thank you!

Band of breaking surface waves associated with internal waves in the South China Sea
(curtesy of Guozhen Zha)