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Internal tides on the Australian North-West Shelf: from generation to breaking

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The combination of strong tidal forcing and year-round density stratification generates an energetic, tidally generated internal wave climate on the Australian North West Shelf (NWS). The NWS has a large and growing oil and gas industry, employing both shore-based and offshore floating technology, as well as a unique marine environment. The region thus faces the twin challenges of industrial development and marine management, in turn, requiring a sound understanding of the physical oceanography and the impact of internal wave-driven processes, in particular.

Previous work (eg Holloway, 2001; van Gastel et al, 2009; Rayson et al, 2012) has shown the spatial variability of the internal tide over the NWS and also identified regions where highly nonlinear internal waves can be found. Generation regions are found on near critical slope regions and identifying both the location and describing the mean and turbulent flow fields near-bottom is of importance in the design of the sea-floor pipelines carrying gas hydrates throughout the region. Direct field measurements (Bluteau et al 2011, 2013) have shown these internal tide generation regions are characterized by strong bore-like surges up and down the slope, in turn generating strong near bottom overturning events with near-bottom turbulent diffusivities ranging up to $10^{-4}\ m^2 s^{-1}$ in bottom boundary layers of thickness of order $25\,m$. Nevertheless, comparison of circulation models with observations have shown the models do a good job of describing the generation of the internal tide and the description of the overall energetics because the generation process is predominantly linear.

It is more challenging to accurately describe the subsequent nonlinear evolution of the internal tide, and there are a number of locations on the NWS where this evolution into strongly nonlinear waves occurs. Guided by previous three dimensional modeling work and observational work at the internal tide generation region, we use the nonlinear and nonhydrostatic model SUNTANS (Fringer et al, 2006) to model the internal tide evolution in a two-dimensional transect in the Pilbara region of the NWS, a transect known to exhibit strongly nonlinear waves. In the modeling we use the criteria suggested by Vitousek and Fringer (2011). The results (Fringer et al, 2013) show the nonlinear events are strongly linked to tidal amplitude and vary with the seasonal variation of the density stratification, in particular the deepening of the surface mixed layer during winter cooling. However, prediction of extremes, such as the location and intensity of bottom currents, are extremely sensitive to the phasing between the barotropic tides and the arrival of nonlinear internal wave packets.

For waves propagating inshore, there is also considerable interest in the shoaling phase of the internal tide in shallow waters. Motivated by observations such as those on the NWS, recent laboratory experiments (Sutherland et al, 2013) in a two-layer fluid have shown that the Iribarren number concept introduced by Boegman et al (2005) can be generalized to describe the shoaling of internal tides where the waves are of such large amplitude they cannot be described by Korteweg-de Vries theory.

The dynamics can be broken down into collapsing, plunging, surging and non-breaking waves, and for breaking waves simple predictions can be made to describe the effects of topographic slope, incident wave amplitude and width. These predictions seem consistent with recent field observations. These observations also show evidence of significant sediment transport and mixing during this shoaling phase, and it remains to be seen how well these can be described by numerical models and what are the requirements in terms of both model resolution and description of the turbulence fields needed to describe this final phase of the internal tide.

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