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Bedload parting in western Torres Strait, northern Australia

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ABSTRACT

This paper presents a new style of bedload parting from western Torres Strait, northern Australia. Outputs from a hydrodynamic model identified an axis of bedload parting centred on the western Torres Strait islands (~142°15′E). This bedload parting is similar to others documented from mixed tidal regimes as it is driven dominantly by the O1, K1 and M2 tidal constituents. However, parting is aided by overtides on the eastern, mixed semidiurnal side of the strait. Bedload parting is also strongly impacted by wind-driven currents. Wind-driven currents during the trade wind season lead to the average estimates of bedload transport to be directed west, through the strait, over the 8 year model duration. As a result, east and west directed bedload parting is only active during the monsoon season when the influence of wind-driven circulation is negligible. A simulation of bedload transport using a range of sediment grain sizes indicated that sediments with a grainsize greater than ~2 mm were transported in a direction consistent with tidally driven bedload parting, as opposed to residual wind-driven flow.

1. Introduction

Bedload partings occur at the heads of individual, oppositely-directed bedload transport pathways and are therefore important for understanding the dispersal of sediments on tidally dominated continental shelves (Belderson and Stride, 1966). Harris et al. (1995) describe bedload partings as regions of divergent bedload transport occurring in zones of maximum bed stress related to either: (1) flow acceleration at amphidromic points or (2) flow acceleration induced by local constrictions due to coastal geometry. Belderson and Stride (1966) described an idealised sequence of bedforms associated with decreasing current velocity from a bedload parting consisting of scoured bedrock, sand ribbons, sand waves and sand banks, and lastly a smooth bed composed of fine grained deposits. Sediment supply and current velocity determine whether this entire bedform sequence is present. Furthermore, this sequence of bedforms generally reflects increasing sediment availability towards the down-drift end of the pathway.

Bedload parting is commonly described in regions with a semi-diurnal tidal regime such as the western European shelf, the White Sea (Russia), Cape Cod/Georges Bank (USA), and Moreton Bay (Australia) (Belderson et al., 1978; Kenyon et al., 1981; Harris, 1988a; Harris et al., 1995). In semi-diurnal tidal regimes, tidal asymmetry is explained by inequalities between the maximum ebb and flood tidal currents that occur in response to the 'interference' between the principal astronomical constituents and overtides (Aubrey and Speer, 1985). In the North Sea, interactions between the M2 semi-diurnal tidal currents and the M4 harmonic are the most important to bedload transport; locations of maximum bottom stress due to these interactions closely match regions of bedload parting (Pingree and Griffiths, 1979). The dominance of ebb or flood tide bedload transport in semi-diurnal regimes is controlled by the phase angle between the M2 and M4 tidal constituents (Aubrey and Speer, 1985; Friedrichs and Aubrey, 1988). Tidal velocity asymmetry is not limited to semi-diurnal tidal regimes and can also be attributed to the interactions of the O1/K1/M2, O1/K1/M2/S2, or P1/K1/S2 tidal constituents in diurnal and mixed, mainly diurnal regimes (Ranasinghe and Pattiaratchi, 2000; Hoitink et al., 2003; van Maren et al., 2004; O'Callaghan et al., 2010; Song et al., 2011). The transport of sediment in response tidal asymmetry has also been shown to be complex in tropical environments, where the trade winds can create significant seasonal wind-driven currents. Modelling from the Singapore Strait indicated that fine sediment fractions were sensitive to residual wind-driven flows, while the transport of coarser sediment fractions were directed by tidal asymmetry (van Maren and Gerritsen, 2012).

The Torres Strait region of northern Australia is a tropical, mixed tidal environment, strongly influenced by seasonal wind-driven currents (Wolanski et al., 1988; Harris, 1989; Saint-Cast, 2008). Harris (1988b) inferred the presence of bedload partings in Torres Strait using a limited range of data sets (sediment samples, sidescan sonar, and aerial photography). However, the hydrodynamic character of the region is known to be complex and the

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forces driving bedload transport and dune dynamics have remained poorly understood.

The aim of this paper is to use hydrodynamic and bedload transport modelling and sediment sample analyses to investigate a bedload transport divergence in western Torres Strait. To obtain a detailed understanding of the key drivers of bedload transport in the region a range of simulations are implemented, specifically:

(1) Bedload transport calculations are made using different temporal subsets of data to understand seasonal variations in bedload transport.
(2) Tide-only simulations incorporating specific subsets of tidal constituents are used to understand what tidal mechanism are driving bedload parting.
(3) Bedload transport based on hypothetical sediment grainsizes are used to determine if comparatively 'coarse' and 'fine' sediments have similar or different transport pathways within Torres Strait.

Interpretations of model results are supported by sediment sample data which further indicate areas of scour (co-located with a divergence in bedload transport) and distal fine sediment deposits. Implications of the model outputs to sediment transport are discussed.

2. Study area

Torres Strait is a shallow seaway in northern Australia, about 150 km in width (from north to south) separating the Cape York Peninsula (northern Australia) from Papua New Guinea (Fig. 1). The strait is a shallow ridge of basement rock with a complex topography due to numerous islands, channels, reefs, and sand banks. The region is typically less than 25 m deep, however, the strait is at its shallowest along the axis of the western Torres Strait islands (~142°15′E) where depths are rarely greater than 15 m. A north/south bathymetric profile along the axis of Torres Strait islands (Fig. 1) shows that the southern section is characterised by numerous continental islands and reefs with channels in between (particularly between Prince of Wales Island and Mabiuag Island), whereas the northern section of the profile is characterised by a broad flat plain with few islands. The only islands in the northern area are Turnagain and Boigu, which are mud islands rather than continental rock (Torres Strait NRM Reference Group, 2005). The 12 m bathymetry contour illustrates how the dissected reef and channel morphology of the western Torres Strait islands becomes a broad, flat plain north of Mabiuag Island.

Torres Strait experiences two distinct seasons. The trade wind season lasts for ~7 months (May–November) and is characterised by relatively low rainfall and strong south-easterly winds. The monsoon season lasts for ~5 months (December–April) and is characterised by relatively high rainfall and weaker north-westerly winds.

Torres Strait has a complex tidal regime. Semi-diurnal tides propagate into the strait from the Coral Sea in the east and diurnal tides propagate from the Gulf of Carpentaria in the south–west. However, only 30% of the tidal wave energy approaching from the east or west is transmitted through the strait due to friction and attenuation of the tidal waves by the complex bathymetry (Wolanski et al., 1988). Saint-Cast (2008) indicated that a boundary between diurnal (western) and semi-diurnal (eastern) regimes is

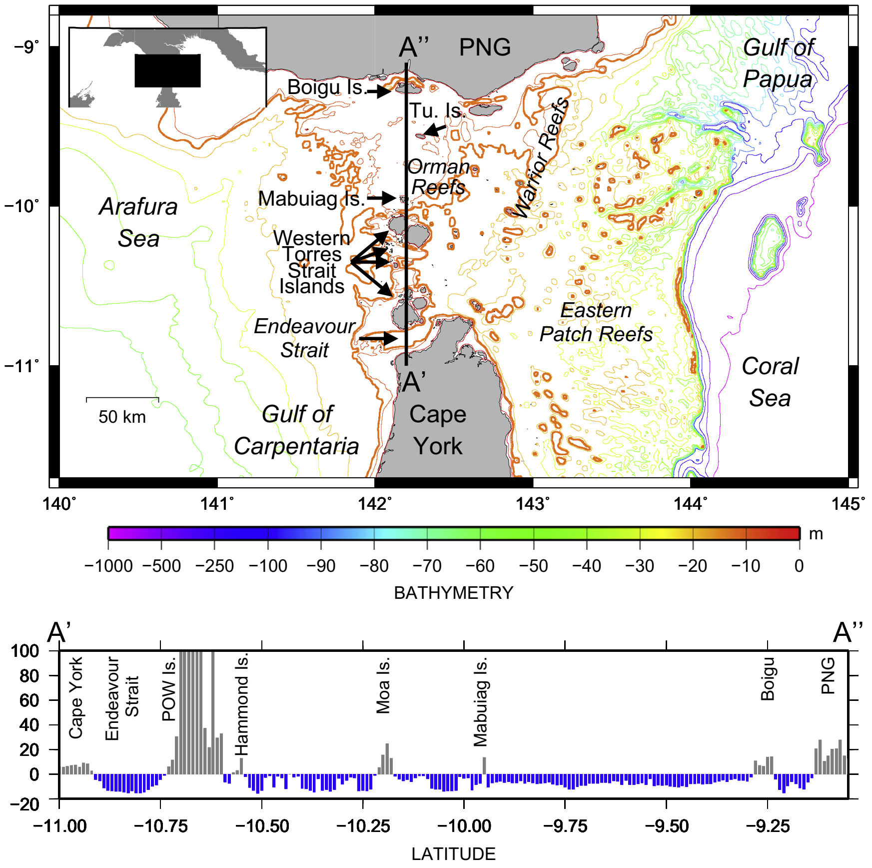

Fig. 1. Bathymetry of the Torres Strait region showing the 12 m contour in bold, which highlights the separation of western Torres Strait into a southern region characterised by islands, reefs and channels and a northern region that is a broad, flat plain. A topographic cross-section taken through Torres Strait from south to north (A′ and A″ respectively) is shown to highlight the change in morphology (Prince of Wales is abbreviated to POW, Turnagain to Tu, and Papua New Guinea to PNG).