

# A CONCEPTUAL STUDY OF INFRA-GRAVITY DRIVEN CROSS-SHORE TRANSPORT

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## INTRODUCTION

Infra-Gravity (IG) waves, characterized by periods exceeding typical wind-generated gravity waves have received increasing attention in the study of coastal dynamics. IG waves in the surf zone explain the well known surf beats and are connected to various other nearshore and coastal processes such as rip currents, run-up/overtopping, as well as beach and dune erosion (Munk, 1949; Russel 1993; Roeber & Bricker, 2015; Bertin et al., 2018)

The creation of IG waves is due to a secondary generation mechanism, distinct from the wind forcing which drives gravity-wave creation. IG waves can be categorized into two principal types: bound waves, phase-locked to deep-ocean wave groups, and free IG waves, generated in the surf zone. Bound IG waves exhibit a well established behavior where ocean waves conventionally appear in groups, carrying long-period oscillations of the mean water level. (Longuet-Higgins & Stewart, 1962). Once released in shallow water, they become free to propagate with their own celerity, a process which often occurs near the break point. (Symonds, 1982; Baldock et al., 2012)

Empirical evidence reveals IG waves' substantial impact on nearshore phenomena, spanning river plume oscillations, cross-shore particle transport and sediment movement (Flores et al., 2022; Bjørnstad et al., 2021; Mendes et al., 2020). Despite the observational evidence correlating IG wave periods with cross-shore transport, a comprehensive theoretical understanding of this connection has remained elusive. The present work aims to provide a firm explanation of how IG waves drive oscillatory cross-shore movement. Employing analytical, linear, and numerical modeling, we try to discern the fundamental mechanism through which IG waves propel cross-shore currents. We will provide the theoretical underpinning of why IG waves dominate nearshore particle transport, explaining empirical observations with a clear kinematic framework to illuminate the subtle yet consequential role of IG waves in nearshore dynamics and in shaping coastal landscapes.

## ANALYTICAL INSIGHTS

Attention is directed towards the kinematic characteristics of IG waves, highlighting their substantial influence despite modest amplitudes. For linear monochromatic waves it is possible to find the path lines of fluid particles in closed form. We show that waves with long periods provide significantly larger particle excursions than waves of equal amplitude, but in the ordinary gravity band of the spectrum. To provide an example of an arbitrary sea state, we use a standard JONSWAP spectrum with a small IG component added by hand. After spectral de-

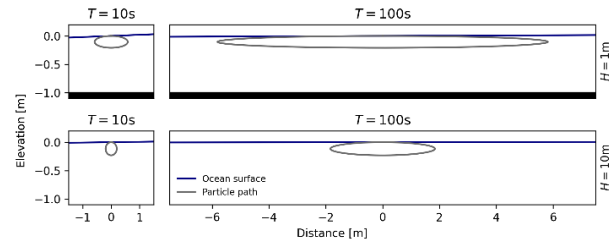


Figure 1 - Pathlines for fluid particles for one period of a monochromatic wave. Left panels: a 10-second wave with amplitude for depth  $H=1\text{m}$  and  $H=10\text{m}$ . Right: a 100-second wave with the same amplitude and for the same two depths. It is apparent that the infra-gravity wave induces a much larger extent of horizontal movement.

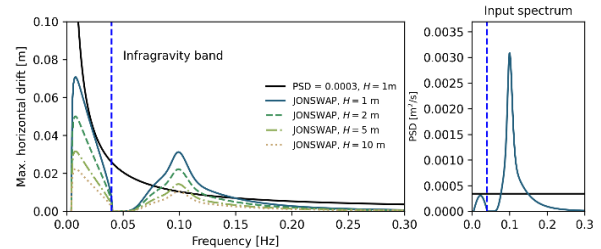


Figure 2 - Horizontal extend of particle transport based on analytical solutions of the movement of the particle in a surface wave of a single frequency. The black curve in the left panel shows the horizontal movement associated with different wave components with equal amplitude  $a=0.025\text{m}$ . The remaining curves show the maximum horizontal transport due to linear waves with amplitudes chosen from a JONSWAP spectrum with  $H_s = 0.1\text{m}$  and  $T_m=10\text{s}$ , with an added infra-gravity component with 10% of the peak energy, and with varying depths.

trending, it can be observed that the IG component clearly dominates the cross-shore transport.

## PARTICLE MODELLING

Building on observed phenomena, we employ both linear wave theory and the numerical nearshore wave model BOSZ (Roeber et al., 2010) to understand the dynamics of IG waves. The objective is to establish a robust connection between the presence of IG waves and the observed substantial cross-shore motion while waves of various periods and amplitudes interact with the particles and each other. We demonstrate for both the linear and non-linear model the IG-band dominates the horizontal excursions. In the non-linear model we review situations in which IG-waves are generated show how in a beach environment the importance of IG-waves grows the closer the waves get to the shore.

## RESULTS

We emphasize the importance of IG waves on particle motion in a shore-normal transect. The research demonstrates a direct link between the presence of IG waves and primary cross-shore fluid particle movement. This conclusion is drawn from a nuanced analysis considering both linear and nonlinear cases, providing a comprehensive understanding of how even minute IG waves can cause substantial back-and-forth motions in the fluid. The results contribute to the theoretical underpinning of IG wave dynamics, shedding light on their fundamental role in nearshore processes. Practical implications for coastal engineering are highlighted, emphasizing the potential of IG waves to influence sediment transport, circulation patterns, and other critical aspects of coastal dynamics.

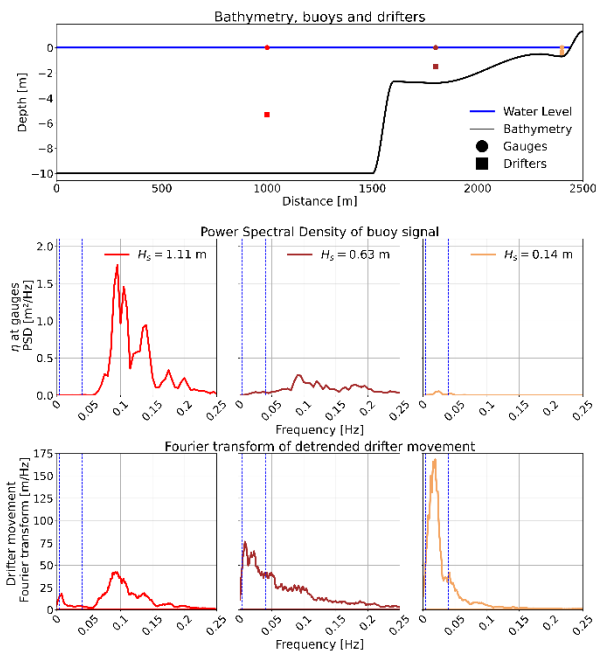


Figure 3 - Numerical results for particle tracer movements. Row 1: Bathymetry and locations. Row 2: PSD of the wave elevation at the gauges. Row 3: PSD of the movement of the particles after the Stokes drift has been removed.

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