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Analysis of infragravity waves using Complete Ensemble Empirical Mode Decomposition (CEEMD) on microtidal and macrotidal beaches

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Infragravity waves are long waves with periods between $\sim$ 20 s and 300 s, these waves may dominate the hydrodynamics in the surf and swash zones, being the main driver of sediment transport and swash elevation (run-up).

Data of pressure sensors at different cross-shore positions and camera systems that capture the swash excursion in a micro-tidal beach (Cartagena, Colombia, Caribbean Sea) and a macro-tidal beach (Norderney, Germany, North Sea) were analyzed to study the occurrence and temporal and spatial variability of infragravity waves. We used the Complete Ensemble Empirical Mode Decomposition (CEEMD) to decompose the time series into a finite set of "intrinsic mode functions" (IMFs). This method overcomes limitations of Fourier-based methods for time series analysis (e.g. FFT and wavelet techniques) that assume linear and stationary data. CEEMD was designed to analyze non-linear and non-stationary phenomena (as those in shallow waters), identifying processes with small amplitudes and low energy hidden in the data.

A comparison with the Fourier spectrum shows the superiority of CEEMD to describe the behavior of ingragravity waves. Fourier spectra do not show infragravity energy in deeper waters; additionally, in shallow waters the energy of the spectra is spread in the infragravity band differing among sea states, therefore is not possible identifying a characteristic spectrum. On the other hand, with CEEMD the IMFs in the infragravity frequencies are observed in deeper waters, and the energy evolution cross-shore until the swash zone is shown at both beaches; furthermore, CEEMD shows the frequency clustering of the energy, allowing to see the gains or losses of energy at different frequencies.

At the micro-tidal beach (Cartagena), infragravity energy is dominant in surf and swash zones for all analyzed sea states, with dominant energy in the IMF of about 100 s of period, showing infragravity wave selection. On the contrary, at the macro-tidal beach (Norderney) the infragravity energy strongly depends on the tidal stage; infragravity energy is dominant in the swash zone during low tide while wind waves energy is dominant during high tide.