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# Remote sensing observations of ocean wave sources of microseisms and microbaroms

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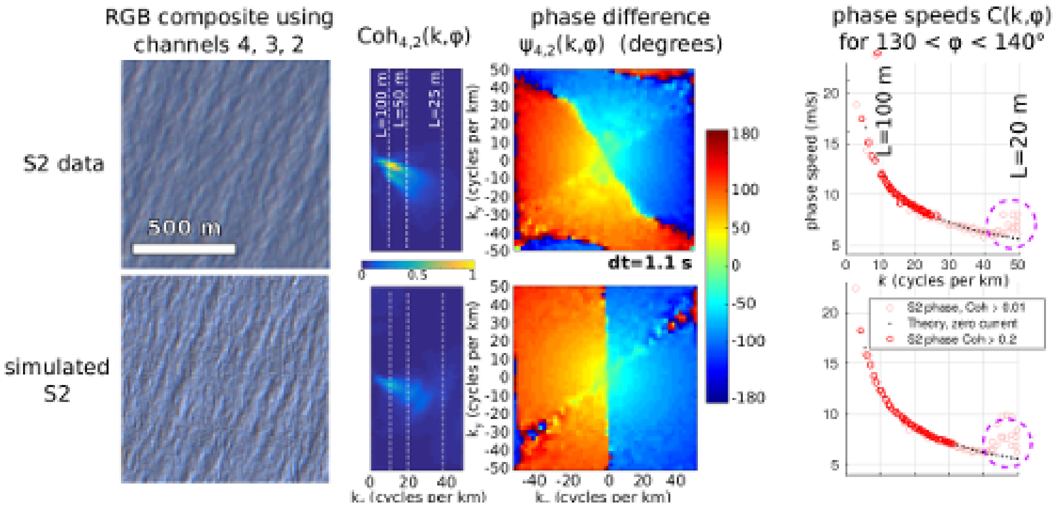
Microseisms in the dominant double-frequency band, around 5 s period and their ubiquitous presence makes them an interesting signal for exploring the solid Earth and associated natural hazards (e.g. Olivier et al. 2019).  These microseisms are generated by opposing ocean waves of equal frequencies (Hasselmann 1963) that generally arise within the locally generated sea state at high frequencies (class I, Ardhuin et al. 2011), due to coastal reflection (class II) or when swell from a distant storm collides with another wave system, which generally corresponds to the strongest microseism sources (class III). Improving on solid Earth knowledge and natural hazard monitoring can benefit from a better quantitative knowledge of these sources. Similar applications to the study of the stratosphere can use atmospheric infrasound that are generated by the same opposing ocean waves, the microbaroms (Brekhovskikh et al. 1973, De Carlo et al. 2020). So far, very few direct measurements of wave properties have been able to quantify the presence of waves in opposite directions, and the magnitude of microseism sources has relied on numerical simulations. Here we use sun glitter measurements from the Copernicus-Sentinel 2 satellites, as processed in the SARONG project (http://www.sarong.global/). We show that the presence of opposing waves gives a strong anomaly in the phase of co-spectra of optical images from Sentinel 2 (S2). When using only 2 time-lagged images this feature generally limits the possibility to measure surface currents from waves shorter than about 25 m, that always have a significant energy in opposing directions (class I microseism sources).




Caption: Processing from Sentinel 2 Level-1c images to phase speeds. Top: data from Copernicus Sentinel 2 on 29 April 2016 off California (See Figs. 3-9 in Kudryavtsev et al. 2017). Bottom: simulated S2 data based on in situ wave spectrum determined from directional moments using the Maximum Entropy Method. The phase speed anomalies, highlighted with the dashed magenta circle near the Nyquist wavelength L = 20 m, disappear when no energy propagates in opposing directions.

The same also happens for longer components when strong (class III) microseism sources are present. However this signature is also an opportunity to directly measure the sources of microseisms and quantify the energy in opposing directions using 2 or more different time lags (Ardhuin et al., in 2021). Given its coastal coverage, we find that S2 is particularly well suited for estimating reflection coefficients of waves off the coast, which is a major source of uncertainty for microseism and microbarom source modelling.

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