Geophysical Research Abstracts
Vol. 14, EGU2012-11535, 2012
EGU General Assembly 2012

Low frequency noise generated by ocean waves: a consistent theory from surface gravity waves to seismic Rayleigh and waves.

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Both oceanic observations, even in very deep water, and seismic observations, anywhere on Earth, contain low frequency noise that can be related to ocean waves. Most of the recorded noise has been explained by a nonlinear wave-wave interaction mecanism. This noise can take the form of surface gravity (Herbers and Guza 1994), acoustic (Lloyd 1981) or seismic waves (Longuet-Higgins 1950), that can be free to propagate outside of their generation area, or forced to follow their forcing wave groups. All previous theoretical work on seismic waves has been related to Rayleigh modes, while acoustic studies have only considered an ocean of infinite depth. Here we show how all types of waves: seismic waves (including Rayleigh and body waves), acoustic waves in the ocean, and surface gravity waves can be produced and estimated from directional wave spectra, using one single theory. This theory gives the known and well-verified gravity wave
result, derived for incompressible motions, when taking the limit of short wave numbers. This consistent approach makes it possible to reconcile noise measurements at sea with land-based seismic data, as illustrated with
data acquired in 2010 in the the southern Indian Ocean. In particular, this new dataset shows very well the presence of at least the first 4 vertical modes in a water layer of 4500 m over a uniform solid half-space, as expected from the theory by Stoneley (1926). Based on this understanding, it is possible to validate the noise sources predicted by a numerical wave model (Ardhuin et al. 2011, Schimmel et al. 2011) using locally forced gravity modes, measured with pressure sensors at depths from 10 to 300 m (Herbers and Guza 1994).
Because seismic waves are caused by this same noise source, but now integrated spatially, this better knowledge of the source can be used to focus on uncertainties in the noise propagation and attenuation. In particular, there is a clear evidence from seismic stations on land, that the seismic attenuation must vary spatially.