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Resonance of infragravity waves with ocean tides: A model

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The map of cophase lines of the M2 tide (Matsumoto et al., 2000) shows that there are many abyssal plains in the Pacific where the propagation speed of cophase line is approximately coincident with the phase velocity of infragravity waves that depends only on water depth. Such regions include the French Polynesia region and the Philippine Sea to NW Pacific region, where the long-term array observations by broadband ocean bottom seismographs have been conducted. Sugioka et al. reported (in this session) that infragravity waves in these two regions are strongly modulated by ocean tides and suggested that the modulation is a consequence of resonance of infragravity waves with ocean tides. We here present the theoretical basis for this suggestion. We take the x-axis along a conjugate line of the cophase lines of the M2 tide. Tidal height change of sea surface occurs along the x-axis in a form of sinusoidal wave with phase velocity c which is defined as the propagation speed of a cophase line. We solve using a perturbation method one-dimensional problem of shallow, linearized equation of motion for the still sea surface height H which is slightly perturbed by the tide with amplitude h and frequency f. The zeroth-order solution yields an ordinary expression of infragravity wave (amplitude A, frequency F and phase velocity C depending only on H). The solution correct to the first order of h/H adds the term expressing modulation of infragravity wave with a carrier wave with frequency f and phase velocity c. Its amplitude is expressed as AR where R is a resonance function proportional to 1/(c - C). The solution correct to the second order involves modulation of infragravity wave by a carrier wave with frequency 2f and phase velocity c, the amplitude being AR^2. Thus, infragravity wave can be resonant with ocean tide when their propagation speeds mutually coincide. Infragravity waves in open seas are probably a random superposition of those propagating in many different directions but only those propagating along the conjugate lines of cophase lines of ocean tide can be amplified by tidal coupling upon phase velocity matching. The phenomenon discovered by Sugioka et al. (in this session) bridges the forced ocean oscillations with 0.5 - 1 day in period, 20000 - 40000km in wavelength and the free ocean waves with 100 - 200s in period, 20 - 40km in wavelength.