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Focusing of N-waves: A Possible Mechanism for Amplified Run-up

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The initial free-surface displacement generated by a submarine earthquake has a dipolar nature, which is computed analytically by Okada's solution [1] and is finite crested. The resulting leading long wave has an N-wave shape as noted by Tadepalli & Synolakis [2, 3]. Here, we present a simple analytical solution of the linear shallow-water wave equations over a constant depth to study the propagation of a finite strip source. We show the existence of focusing points of dipolar initial displacements, i.e. points where wave amplification may be observed, due to the directional focusing of three waves, namely a positive wave from the center of elevation part and two positive waves from the sides of depression. N-wave focusing is not restricted to linear non-dispersive wave theory, but can also be observed using nonlinear shallow-water wave theory and dispersive theory. The location of the focusing point depends on the strip length. The focusing mechanism is an inherent property of the initial waveform and thus is not caused by bathymetric lenses, which can have a significant combined effect on the evolution of earthquake-generated tsunamis. Using the 1998 Papua New Guinea, 2006 Java and 2011 Japan tsunamis as examples, we discuss the geophysical implications of the focusing and how this can be related to abnormal high run-up values observed during these events, which were insufficiently explained so far.

[1] Okada, Y. 1985 Surface deformation due to shear and tensile faults in a half-space. Bull. Seism. Soc. Am. 75, 1135–1154.

[2] Tadepalli, S. & Synolakis, C. E. 1994 The run-up of N-waves on sloping beaches. Proc. R. Soc. Lond. A 445, 99–112.

[3] Tadepalli, S. & Synolakis, C. E. 1996 Model for the leading waves of tsunamis. Phys. Rev. Lett. 77, 2141–2144.