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Marine natural hazards in coastal zone: observations, analysis and modelling (Plinius Medal Lecture)

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Giant surface waves approaching the coast frequently cause extensive coastal flooding, destruction of coastal constructions and loss of lives. Such waves can be generated by various phenomena: strong storms and cyclones, underwater earthquakes, high-speed ferries, aerial and submarine landslides. The most famous examples of such events are the catastrophic tsunami in the Indian Ocean, which occurred on 26 December 2004 and hurricane Katrina (28 August 2005) in the Atlantic Ocean. The huge storm in the Baltic Sea on 9 January 2005, which produced unexpectedly long waves in many areas of the Baltic Sea and the influence of unusually high surge created by long waves from high-speed ferries, should also be mentioned as examples of regional marine natural hazards connected with extensive runup of certain types of waves.

The processes of wave shoaling and runup for all these different marine natural hazards (tsunami, coastal freak waves, ship waves) are studied based on rigorous solutions of nonlinear shallow-water theory. The key and novel results presented here are: i) parameterization of basic formulas for extreme runup characteristics for bell-shape waves, showing that they weakly depend on the initial wave shape, which is usually unknown in real sea conditions; ii) runup analysis of periodic asymmetric waves with a steep front, as such waves are penetrating inland over large distances and with larger velocities than symmetric waves; iii) statistical analysis of irregular wave runup demonstrating that wave nonlinearity nearshore does not influence on the probability distribution of the velocity of the moving shoreline and its moments, and influences on the vertical displacement of the moving shoreline (runup). Wave runup on convex beaches and in narrow bays, which allow abnormal wave amplification is also discussed.

Described analytical results are used for explanation of observed extreme runup of tsunami, freak (sneaker) waves and ship waves on different coasts along different bottom profiles.