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An approximately-nine-year-period variation in seismicity and crustal deformation near the Japan Trench

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It is well known that the statistical probability of earthquake occurrences changes over the course of a day due to periodic variations in the tidal stress acting on faults. However, periodicity on a decadal scale has been studied by relatively few people. It has been reported that approximated ten-year periodicity is observed globally for the seismicity of M-8-class large earthquakes. However, the mechanism underlying this periodicity has not yet been revealed. In this study, decadal-scale periodicity of earthquakes along the Japan Trench is investigated. A new finding is presented that in northeast Japan, since 1923, the probability of the occurrence of earthquakes with an M >=5 has increased approximately every nine years. This increase in probability is also evident for historic events with an M>=6 that occurred during the past one thousand years, implying the presence of a periodic stress disturbance at an appreciably regular interval. Periodicity becomes even more apparent for large earthquakes with an M>7.5 and about half of the recorded 29 events intensively occurred within two successive years on a cycle of approximately nine years. The past strain and tilt observations conducted in Japan during the 1950s through the 1970s indicate that nation-wide gradual compression was repeating every 8–10 years in the direction of relative plate motion. These compression periods are in accordance with the periods of higher seismic activity discussed above. As a first step in investigating the origin of earthquake periodicity, periods associated with lunar motion are considered. It is shown that a long-term motion primarily governed by the period of the lunar perigee is synchronised with the cyclic variation in seismicity and crustal deformation described above. Decadal changes in tidal stress, as calculated using an ordinary theory of solid Earth tide, are too small to cause periodic variations in seismicity. Therefore, the conditions by which tidal stress is sufficiently amplified to trigger an earthquake are investigated. The results show that, if assuming that a tidal force acts on a spherically asymmetric block-like upper mantle beneath the Pacific Plate, the computed phase and amplitude can explain the observations. Otherwise, it is difficult to consider direct tidal force alone as the main source of periodic variations in seismicity. Other possibilities should be considered, such as unknown interactions between the plate boundary and the ocean/atmosphere with a period of around nine years or a resonance between the period of the tidal force and a recurrence period of slow slip events in the transition zone on the plate boundary. Apart from understanding the origin, the important fact confirmed in this study is that in some areas, the occurrence of large earthquakes, if considered as a group, appears to be strongly governed by a periodic stress disturbance rather than by completely random processes. Elucidating the wide-range approximated nine-year mode helps us narrow a range in occurrence time in a probabilistic mid-term prediction of large interplate earthquakes.

Keywords: crustal deformation, earthquake cycle, seismicity, tide, subduction zone