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Decadal- to centennial-scale fluctuations of East Asian winter monsoon intensity over the last millennium recorded in coastal dune sediment, Japan Sea

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The southern coast of Japan Sea exhibits many dune fields formed by winter northwesterly wind, which is driven by East Asian winter monsoon that blows from the Siberian High developed around Mongolia and Lake Baikal to western Pacific. The coast is almost perpendicular to the northwesterly, causing longitudinal and transverse dune ridges to develop nearshore. These dune fields have been activated intermittently with some inactive periods marked by organic sand layers during the Holocene. We applied a detailed stratigraphic analysis that combines ground-penetrating radar (GPR) and optically-stimulated luminescence (OSL) dating to two transverse dune ridges on the Tottori coast, southern central Japan Sea. This combination allowed us to establish a thorough chronostratigraphy of dune deposits as optical dating is applied to subsurface sediment sampled in accordance with continuous GPR profiles, and we found patterns of aeolian process affected by decadal- to centennial-scale fluctuations in winter monsoon intensity over the last 1000 years. OSL dating showed concordant results with radar stratigraphy and topographic changes since AD 1932 revealed by maps, suggesting it works well for the Tottori dune sand. Two OSL ages showed that the dune deposition occurred in 11th century AD, but no age was obtained from the 12th to late 15th centuries, suggesting the dune was inactive during this period. Remarkable reactivation of the dune occurred in the late 15th century, and has periodically continued until present. The dune is generally dominated by landward migration, but the outer dune ridge shows a clear seaward accretion during the 18th century. This seaward migration reflects a decrease in wind capacity, which restricted sand transport nearshore. The 18th century showed a decline in winter monsoon revealed by Chinese historical documents, which is associated with higher winter temperature and lower frequency of thunder and aeolian dust fall. In contrast, two remarkable events of landward dune sand accretion occurred in AD 1580–1640 and around AD 1840, respectively, corresponding to periods of increased dust fall in China, which suggest enhanced winter monsoon. These suggest that the Tottori dune has evolved in relation to the winter monsoon intensity. The dune reactivation over the last several centuries is generally correlated with intensified winter monsoon, and is probably related to the beginning of the Little Ice Age, during which many European coastal and inland dune fields were activated due to increased storminess. The dune reactivation and associated increased aeolian sand transport were reported from historical documents and sediment record for other coastal dune fields along Japan Sea, and thus are considered as widespread phenomena, which led to the need for coastal afforestation since the 17th century.