The impact of baroclinity on tidal ranges in the North Sea

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Tidal range is one of significant contributors of coastal inundation. Therefore, it is very important to investigate the dynamics of tidal range variations over different time scales. The baroclinity has the potential to modulate surface tides through ocean stratification on seasonal scale. In order to better understand the impact of ocean stratification on tidal ranges in the North Sea, the numerical simulations were carried out in baroclinic and barotropic modes covering the period from 1948 to 2014, using the regional 3D hydrodynamic prognostic Hamburg Shelf Ocean Model (HAMSOM). In the barotropic mode, the river forcing was also included, which only increases the local sea level without any influence on the density. The tidal range difference between baroclinic and barotropic modes in winter (less stratification) and summer (strong stratification) are compared at 22 tide-gauge stations, where the simulated sea surface elevations agree well with observations from 1950 to 2014. The statistical analysis generally shows that the difference at 19 stations (86% of total stations) in summer is much larger than that in winter during more than 32 years (50% of the analysis period). This suggests that the stratification decouples the surface and bottom layers weakening the damping effects of bottom friction, which is visible even at the coastal tide-gauge stations, where the ocean water is well-mixed. Obviously, the signal induced by stratification is propagated by the tidal Kelvin wave through the North Sea. Additionally, the spatial distribution of tidal range differences indicate that the amphidromic points in the North Sea moved westward in the baroclinic mode. Regarding the seasonal mean sea level at the stations, the results show that the coastal sea level could be increased by baroclinity itself, since the river runoff freshens the coastal water in the baroclinic mode, and thus the local sea level increases due to steric effect. Consequently, the increased sea level could further weaken the damping effect. However, this is a relatively minor impact on the tidal range.