Relation between long-term slow slip events and correlation between tidal triggering effect and deep low-frequency earthquakes in Bungo Channel: Part 2

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Long-term slow slip events (LSSEs) have occurred with the interval of 5-6 years beneath the Bungo Channel [e.g., Kobayashi, 2017, EPS]. Deep low-frequency tremors and earthquakes (LFEs) have synchronized with the LSSEs and have activated [Hirose et al., 2010, Science]. It is pointed out that tremors have high tidal correlation [Ide, 2010, Nature; Ide & Tanaka, 2014, GRL]. There is no study that investigated long-term changes of the tidal correlation of LFEs.
On the other hand, the correlation between regular seismicity and tide also have been investigated energetically, and then there is a report that the tidal correlation became higher before the large earthquake around the focal region and became lower after the mainshock [e.g., Tanaka et al., 2012, GRL]. In addition, it is also pointed out that a leading period of high tidal correlation corresponded with the magnitude of a following earthquake.
Accordingly, we investigated temporal changes of tidal correlation of LFEs before and after LSSEs beneath the Bungo Channel on the analogy of tidal correlation of background seismicity before and after large earthquakes.
We extracted LFEs from the earthquake catalog unified by Japan Meteorological Agency (JMA) that occurred beneath the Bungo Channel from 2000 to March 21, 2018. Accuracy of locations of LFEs is lower than that of regular earthquakes. Note that hypocenter determination method for LFE by JMA changed since March 22, 2018, and then detection level also changed at the border. Taking int consideration that the change is not suitable in order to investigate long-term changes of tidal correlation of LFEs, we selected LFEs data.
It is necessary to set fault parameters in order to estimate the theoretical below-ground tidal response. Because our study area was narrow area with 15 km square, we set one fault plane (strike angle 237°, dip angle 16°, and rake angle 103°) taking into consideration the plate configuration [Hirose et al., 2008, JGR] and MT solutions of deep very LFEs [Ide & Yabe, 2014, GRL]. In addition, we set hypocenters of LFEs to the common location (longitude 132.254°, latitude 33.142°, and depth 32 km). We used only occurrence times of LFEs determined by the JMA.
We summed temporal variations of the solid and oceanic tide loading effects for six independent components of the strain tensor, as estimated at the hypocenter of each event. Then we converted them to temporal variations of volumetric strain (ΔV) at the hypocenter, and shear stress ($\Delta\tau$), normal stress ($\Delta\sigma$), and the Coulomb failure function (ΔCFF) on the assumed fault plane. In the ΔCFF calculation, we assumed values of 0.1, 0.4, and 0.7 for the apparent friction coefficient μ'. In the case of ΔV and $\Delta\sigma$, we defined expansion/dilatation as positive and contraction/compression as negative; consequently, positive $\Delta\sigma$ values promote fault slip. We also defined $\Delta\tau$ and ΔCFF as positive when they promote fault slip. Using the time series of tidal stress (strain) levels, we assigned phase angles of −180° and 180° to the minimum tidal stress (strain) levels before and after an event, respectively, and 0° to the maximum tidal stress (strain) that occurred between these two minima. The phase angle at the earthquake occurrence time was estimated by linear interpolation in the time interval between −180º and 0° or between 0° and 180°. The possible occurrence of LFEs at certain tidal phase angles was evaluated using the *p* value, as

calculated by Schuster [1897].
We found that LFEs tended to occur near a tidal phase angle of 0° for $\Delta\tau$ (when the tidal force promoted fault slip). This result indicates extremely low μ' and high pore pressure, being consistent with the existence of fluid inferred from the seismic velocity structure [Hirose et al., 2008]. LSSEs occurred three times (in 2003-2004, 2009-2011, and 2014) during the study period. Temporal changes of *p* value showed to tend to become lower before the LSSEs and become higher after ones (Tidal correlation tended to become higher before the LSSEs and become lower after ones). This result is similar to temporal changes of *p* value for background seismicity before and after large earthquakes. Accordingly, temporal tidal correlation of LFEs indicates to be affected by stress perturbation associated with LSSEs. Note that *p* value at March in 2018 falls to a level just before past LSSEs.

Keywords: Earth tide, Schuster's p value, Low frequency event, Long-term slow slip event, Bungo Channel