Tsunami source models of Tokachi-oki earthquakes in 17th to 21st centuries

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In the source region of the 2003 Tokachi-oki earthquake (M 8.0), great earthquakes have previously occurred in 1952 (M 8.2) and 1843 (M 8). Larger tsunamis have been inferred in the 17th century and earlier from coastal tsunami deposits (Nanayama et al., 2000; Hirakawa et al., 2000). Here we summarize tsunami source models for these great earthquakes by comparing observed run-up heights and inundation distance inferred from deposits with the results of tsunami numerical computation.

The 2003 Tokachi-oki earthquake produced maximum 4 m tsunamis along the Tokachi coast. Seismological analyses (e.g., Yamanaka and Kikuchi, 2003) indicate a re-rupture of the 1952 earthquake. The tsunami run-up measurements, on the other hand, indicate a height distribution different from that of the 1952 tsunami (Tanioka et al., 2004). If we assume that the tsunami source coincides with the aftershock area and is a 100 km x 10 km fault at the depth of 30-60 km, then the average slip is estimated as about 5 m to reproduce the observed runup heights.

The 1952 Tokachi-oki earthquake produced maximum tsunami runup heights of 3-6 m around Akkeshi bay. Hirata et al. (2003) showed from tsunami waveform inversion that the fault slip was distributed at 15-60 km depth off Tokachi and 10-34 km depth off Akkeshi Bay. We confirmed that the latter slip is needed to explain the large runup heights and severe damage around Akkeshi and Kiritappu. If we approximate the Hirata et al. model by a single fault plane (200 km x 100 km), then the average slip of 3 m explains the observed runup heights.

The 1843 earthquake also produced 4-5 m tsunami around Akkeshi bay. Hatori (1984) concluded that the 1843 source was the same as the 1952 source, based on the observations that tsunami height distribution has a peak around Akkeshi and the distributions along the Sanriku coast are similar. In order to reproduce the large tsunami heights around Akkeshi bay, fault slip off Akkeshi is also needed.

Tsunami deposits can be traced 1 - 4 km from the coast, much further inland than the inundation limits of 19-21st century tsunamis (Nanayama et al., 2000; Hirawaka et al., 2000), and on beach terrace of 6.5 -18 m high (Hirakawa et al., 2000). Such unusual tsunamis have recurred at about 500 year interval, much longer than the 20th century earthquakes, with the most recent one in the 17th century. Nanayama et al. (2003) proposed that multi-segment interplate earthquakes (300 km long, 17-51 km deep and average slip of 5 m) can explain the long tsunami inundation. The details of tsunami deposits indicate that the most recent (17th) deposit is thicker and longer inundation in Tokachi, while the penultimate event (around 13th century) was thicker and longer inundation in Kiritappu and to the east. The unusually long (4km) inundation and more than 10 m run-up in Toakchi need more than 10 m slip on the fault.