Geophysical Research Abstracts
Vol. 19, EGU2017-1231, 2017
EGU General Assembly 2017

Precursor slope distress leading up to the 2010 Mount Meager landslide, British Columbia

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Volcanoes are highly prone to landslides, in part due to erosion of the flanks by glaciers and streams. Mount Meager (British Columbia, Canada) is a glacier-clad volcano that is one of the most landslide-prone areas in Canada, due in part to glacial erosion. In 2010, the south flank of the volcano failed catastrophically, generating one of the largest ($\sim$50 x 10^6 m ^{3}) landslides in Canadian history. We document the evolution of the edifice up to the time of this failure using an archive of historic aerial photographs spanning the period from 1948 to 2006. Oblique digital photos taken after the landslide yielded information on the geology and internal structure of the volcano. All photos were processed with Structure from Motion (SfM) photogrammetry. We used the SfM products to produce pre-and post-failure geomorphic maps that document glacier and edifice changes. The maps show that a glacier below the 2010 landslide source area re-advanced in the 1980s, then rapidly retreated up to the present. Our photographic reconstruction documents 60 years of progressive development of tension cracks, bulging, and precursor failures (1998, 2009) at the toe of the 2010 failure zone. The final 2010 collapse was conditioned by glacial debuttressing and triggered by hot summer weather accompanied by ice and snow melt. Meltwater increased porewater pressures in fragmented and fractured material at the base of the 2010 failure zone, causing it to mobilize, which in turn triggered several secondary failures controlled by lithology and faults. The landslide retrogressed from the base of the slope to near the peak of Mount Meager and involved basement rock and the overlying volcanic sequence. Elsewhere on the flanks of Mount Meager, large fractures have developed in recently deglaciated areas, conditioning these slopes for collapse and debris avalanches. Potential failures in these areas have larger volumes than the 2010 landslide. Atmospheric warming over the next several decades will cause further loss of snow and glacier ice, and induce additional slope instability. Satellite- and ground-based monitoring of these slopes might provide advanced warning of future landslides and could be used to reduce risk in regions downstream of the volcano.