Geophysical Research Abstracts
Vol. 13, EGU2011-7917, 2011
EGU General Assembly 2011

Calving glacier dynamics controlled by subglacial water pressure close to ice overburden pressure in Glaciar Perito Moreno, Patagonia

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Calving glaciers flow faster than land terminating glaciers, particularly because the basal flow processes are enhanced by high water pressure generated by the proglacial water body. It is urgently needed to understand the role of water pressure in the calving glacier dynamics because glacier acceleration takes a key role in rapid retreat of calving glaciers in Alaska and Patagonia, as well as outlet glaciers in Greenland and Antarctic ice sheets. Nevertheless, subglacial water pressure measurements are very scarce in calving glaciers and the lack of field data poses limitation to numerical ice flow models.

More than 80% of major glaciers in Patagonia terminate in lakes and the ocean. Despite the importance of these calving glaciers for the evolution of the Patagonia Icefields, studies on glacier dynamics are very few and subglacial observations have never been carried out in the region. To investigate the role of subglacial water pressure in the dynamics of calving glaciers, we drilled through Glaciar Perito Moreno, a fast flowing (400–800 m a^{-1}) fresh water calving glacier in the Southern Patagonia Icefield. This was the first attempt of hot water drilling in Patagonia.

The drilling was performed from February to March 2010 at about 5 km from the terminus, where the glacier is 510 m thick and the bed is 330 m below the proglacial lake level. We drilled two boreholes to the bed and installed pressure sensors to measure water levels in the boreholes. Ice surface speed was measured with GPS by surveying poles installed on the glacier surface every hour. The water levels and flow speed were measured from 5 to 14 March and 25 February to 2 April 2010, respectively.

The borehole water level was at about 440 m above the bed, oscillating in a diurnal manner within a range of $\pm$15 m. This observation indicated that the subglacial water pressure was 91–98% of the ice overburden pressure. Ice flow speed showed clear diurnal variations and correlated with air temperature over the 5 weeks measurement period (r=0.77). A comparison of the flow speed and borehole measurements revealed that 40% changes in the flow speed were driven by only 6% subglacial water pressure variations.

These data imply that the ice speed was controlled by the relatively small pressure variations generated by melt water input to the bed. The speed was very sensitive to the pressure change, probably because the water pressure was consistently close to the ice overburden pressure. According to these observations, accurate treatment of subglacial water pressure and inclusion of a pressure dependent basal flow law are very important to predict future evolution of calving glaciers with numerical glacier models.