Geophysical Research Abstracts
Vol. 15, EGU2013-5187, 2013
EGU General Assembly 2013

Blue ice areas formed by an interplay between ice velocity and SMB

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Blue ice areas (BIAs) cover around 1% of the East Antarctic ice sheet and are visual evidence of long-term ablation. However, the physical processes that drive the presence of these BIAs are poorly understood. Here, we combine high-resolution (5.5 km) maps of surface mass balance (SMB) and firn layer characteristics of East Antarctica, produced with the regional atmospheric climate model $RACMO_2$, and knowledge of ice velocities, to describe the interplay between ice dynamics and SMB on the formation of blue ice. We show that blue ice typically forms in areas with small ablation such as in coastal Dronning Maud Land. In these regions, more snow is sublimated and/or eroded than is accumulated. Due to the locally low ice velocities (< 1 m/year), the entire firn layer is removed before the ice is transported away to locations with positive SMB. This erosion is a very slow process: typically, it takes $\sim$10000 years before the ice is exposed at the surface. An exception is found on multiple glaciers in Transantarctic Mountains, such as Byrd Glacier. Here, ice velocities are high ($\sim$1 km/year), but due to extremely high wind speeds that occur in the narrow glacial valley, strong drifting snow sublimation and erosion quickly erode the firn layer. With a firn layer model the erosion of an existing firn layer upstream of a BIA, and the subsequent downstream build-up of the firn layer downstream of the BIA, is simulated to assess the sensitivity of these BIAs for positive feedback mechanisms. BIAs have a lower albedo, leading to higher near-surface temperatures and corresponding higher sublimation amounts. Also, a BIA surface is smoother, making it less prone for precipitating snow to stick to the surface. These mechanisms make a BIA to some extent self-sustaining.