Controlling mechanisms of fast flowing glaciers in West Antarctica

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Ice shelves play a major role in the stability of fast flowing ice streams in Antarctica, by exerting buttressing on inland ice and controlling the discharge of ice into the ocean. However, the mechanisms at work remain poorly understood and interactions between floating and grounded ice need to be better characterized in order to estimate the impact of climate change on the ice sheets. Glaciers in West Antarctica experienced significant changes over the past decades.
Pine Island Glacier, for example, has been thinning and accelerating since the 1970’s at least and its grounding line has been retreating inland at a rate of about 1 km/yr. Initiation of these changes is usually attributed to warmer ocean waters in the Amundsen Sea affecting the floating part of Pine Island. By buttressing grounded ice flow and controlling the discharge of inland ice to the ocean, the ice shelf of Pine Island plays a major role in the stability of the glacier. Thwaites Glacier features a small and heavily fractured ice shelf that provides limited back stress pressure on inland ice but is pinned on the eastern part on a prominent ridge. Contrary to Pine Island Glacier, Thwaites Glacier has maintained a consistently high velocity and negative mass balance for at least 20 years. Recent observations show a widening of its fast flowing area as well as a sustained acceleration since 2006 and a rapid retreat of its grounding line in the center of the glacier.

We use the Ice Sheet System Model (ISSM) and a three-dimensional higher-order model to simulate the evolution of the glacier for the next fifty years and assess the effect of changes in several climate forcings and model parameters, namely basal melting under the floating part, ice front position, atmospheric conditions and grounding line retreat. Simulation results show the dominant effect of basal melting and of grounding line retreat. Results also show that changes are not limited to the ice shelf and the grounding line area but propagate far inland, almost to the ice divide. We find that enhanced basal melting or grounding line retreat are each associated with a distinct pattern of ice thinning and acceleration. We compare the simulation results with remote sensing observations of velocity changes and grounding line evolution to elucidate which forcing is more likely to have caused the recent changes observed on these glaciers.

This work was performed at the California Institute of Technology's Jet Propulsion Laboratory and the University of California Irvine under a contract with the National Aeronautics and Space Administration, Cryospheric Sciences and Modeling, Analysis and Prediction Programs