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Export of Ice-Cavity Water from Pine Island Ice Shelf, West Antarctica

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Stability of the West Antarctic Ice Sheet is sensitive to changes in melting at the bottom of floating ice shelves that form the seaward extensions of Antarctic glaciers flowing into the ocean. Not least because observations in the cavities beneath ice shelves are difficult, heat fluxes and melt rates have been inferred from oceanographic measurements obtained near the ice edge (calving fronts). Here, we report on a set of hydrographic and velocity data collected in early 2009 near the calving front of the Amundsen Sea's fast-moving and (until recently) accelerating Pine Island Glacier and its associated ice shelf. CTD profiles collected along the southern half of the meridionally-trending ice front show clear evidence for export of ice-cavity water. That water was carried in the upper ocean along the ice front by a southward current that is possibly related to a striking clockwise gyre that dominated the (summertime) upper-ocean circulation in Pine Island Bay. Signatures of ice-cavity water appear unrelated to current direction along most of the ice front, suggesting that cross-frontal exchange is dominated by temporal variability. However, repeated hydrographic and velocity measurements in a small "ice cove" at the southern end of the calving front show a persistent strong (mean velocity peaking near 0.5 ms^{-1}) outflow of ice-cavity water in the upper 500 m. While surface features (boils) suggested upwelling from deep below the ice shelf, vertical velocity measurements reveal 1) that the mean upwelling within the confines of the cove was too weak to feed the observed outflow, and 2) that large high-frequency internal waves dominated the vertical motion of water inside the cove. These observations indicate that water exchange between the Pine Island Ice Shelf cavity and the Amundsen sea is strongly asymmetric with weak broad inflow at depth and concentrated surface-intensified outflow of melt-laden deep water at the southern edge of the calving front. The lack of significant mean upward motion within the cove strongly suggests that the upwelling takes place within the highly fractured ice along the southern shear margin of the ice shelf. If so, the upwelling water is likely to contribute to both the volume of apparent "basal" melting and to the weakness of that shear margin.