# MAPPING ICE SLABS IN ANTARCTIC ICE SHELVES USING ENHANCED-RESOLUTION L- AND C-BAND RADAR BACKSCATTER IMAGE TIME SERIES

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## ABSTRACT

Enhanced-resolution radar backscatter (σ°) image time series (2015) generated using observations collected by the short-lived (83 days) quad-polarization L-band radar (in scatterometer-mode) aboard the NASA Soil Moisture Active Passive (SMAP) mission and the vertically-polarized C-band Advanced SCATterometer (ASCAT) aboard the EUMETSAT Meteorological Operational (MetOp) satellite mission are exploited to map embedded ice structures -- including continuous meters-thick ice slabs, single or stacked sequences of thinner ice layers, and relatively sparse networks of ice pipes and lenses -- within the firn column of the percolation facies of Antarctic ice shelves (Figure 1). Combined, these satellite-derived parameters provide a continent-wide approximation of firn air depletion, which has implications for identifying ice shelves that are potentially vulnerable to supraglacial lake or firn aquifer formation, meltwater-induced hydrofracture, and collapse and disintegration from space. Distinctive spatial trends in L- and C-band σ° signatures identified via principal component analysis (PCA) are used to develop a multi-frequency polarimetric algorithm that is calibrated using firn cores, snow pits, and ground penetrating radar (GPR) transects (Figure 2). Algorithm results are partially validated using airborne ice-penetrating radar surveys (Figure 3) and optical and synthetic aperture radar (SAR) satellite imagery.

Ice slabs (~230,000 km2) are primarily mapped in the Antarctica Peninsula and in East Antarctica and preferentially form near ice shelf grounding zones extending from faster-flowing tributary glaciers. Scattered locations are also mapped in West Antarctica. Expansive ice slabs are mapped on the Scar Inlet, southern Larsen C, Larsen D, central George VI, northern Wilkins, Bach, Stange, southern Abbot, Shackleton, West, Amery, and Roi Baudouin ice shelves. On the Larsen C and D, Wilkins, and Abbot ice shelves, ice slabs overlay firn aquifers that have continuously existed within the deeper firn column for decades. Ice layers ~210,000 km2 and ice pipes and lenses ~330,000 km2 are mapped over the remainder of the percolation facies ~770,000 km2 which covers ~50% of the total ice shelf extent. We attribute ice slab formation to enhanced surface melting driven by katabatic and foehn wind flow channeled downslope by the local topography. Heavy rainfall, extensive ice layering during sequential years, and brine infiltration within the firn column may precondition ice shelves for accelerated ice slab formation an[...] in ext[...]

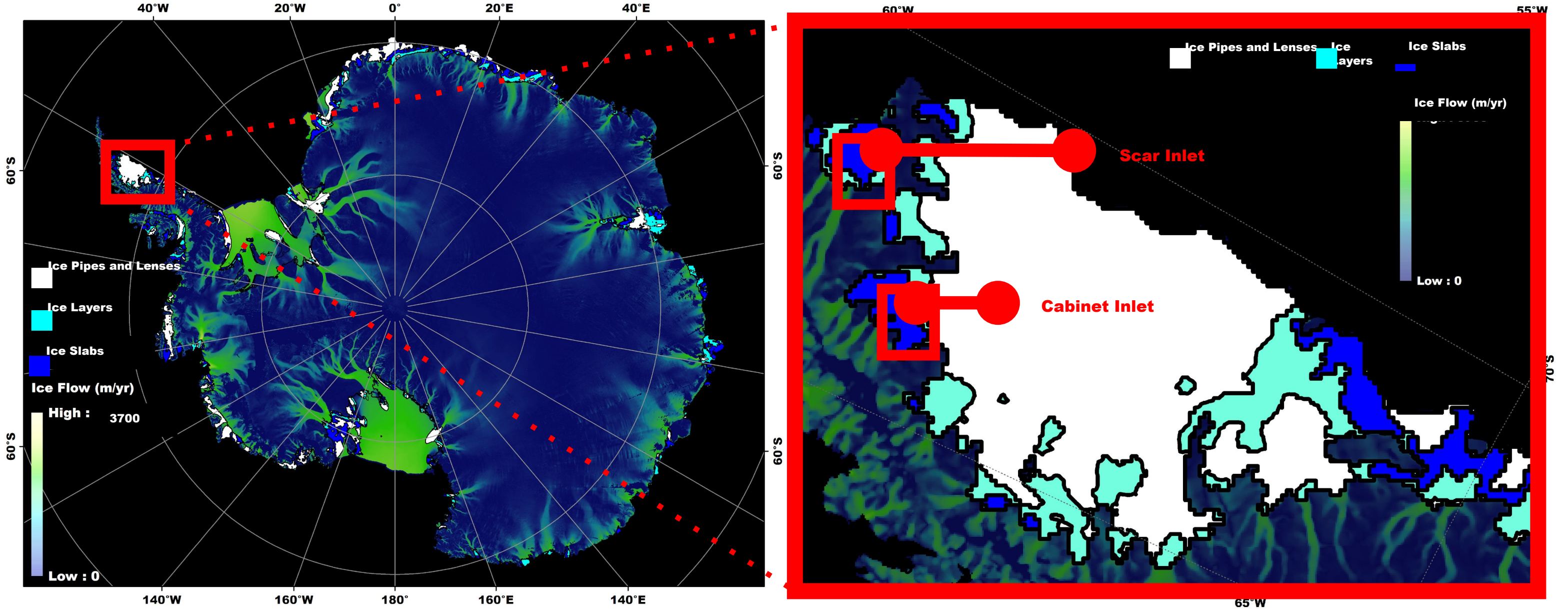


**FIGURE 1. Mapping of Ice Slabs, Ice Layers, and Ice Pipes and Lenses using L- and C-band Radar Backscatter (2015)**

Enhanced-resolution mapping generated using coincident σ° observations collected by the quad-polarization L-band radar (in scatterometer-mode) aboard the NASA SMAP satellite mission and the vertically polarized C-band ASCAT scatterometer aboard the EUMETSAT satellite mission over **(left)** Antarctica and **(right)** the Larsen C Ice Shelf. Airborne ice-penetrating radar surveys over the Cabinet and Scar inlets (red boxes) in the right image are shown in **Figure 3**. The black lines are the 2013-2014 MODIS MOA grounding lines and ice extent. The blue and green colored shading are ice f[...]

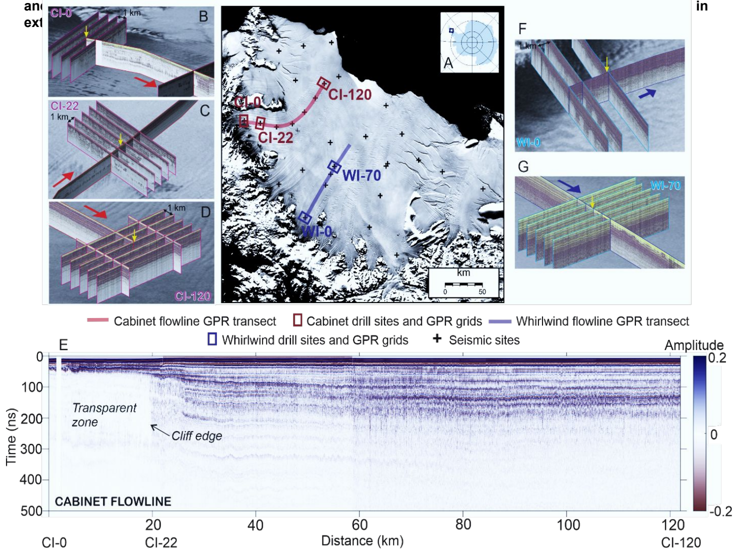


**FIGURE 2. Ground Penetrating Radar (GPR) Transects**

**(A)** Location map of Larsen C Ice Shelf on 2013-2014 MODIS Mosaic of Antarctic (MOA) image. The location map shows GPR, seismic and weather station sites. Boreholes were drilled at CI-0, CI-22, CI-120, WI-0 and WI-70. **(B-D)** Cabinet Inlet flowline dense GPR grids. **(E)** GPR transect along the Cabinet Inlet flowline. **(F-G)** Whirlwind Inlet flowline dense GPR grids. Yellow arrows **(B-G)** indicate respective drill site locations, and red **(B-D)** and blue **(F-G)** arrows respectively indicate ice flow directions in Cabinet and Whirlwind inlets.

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**Rapid formation of low-permeability ice slabs in Antarctic ice shelves.**

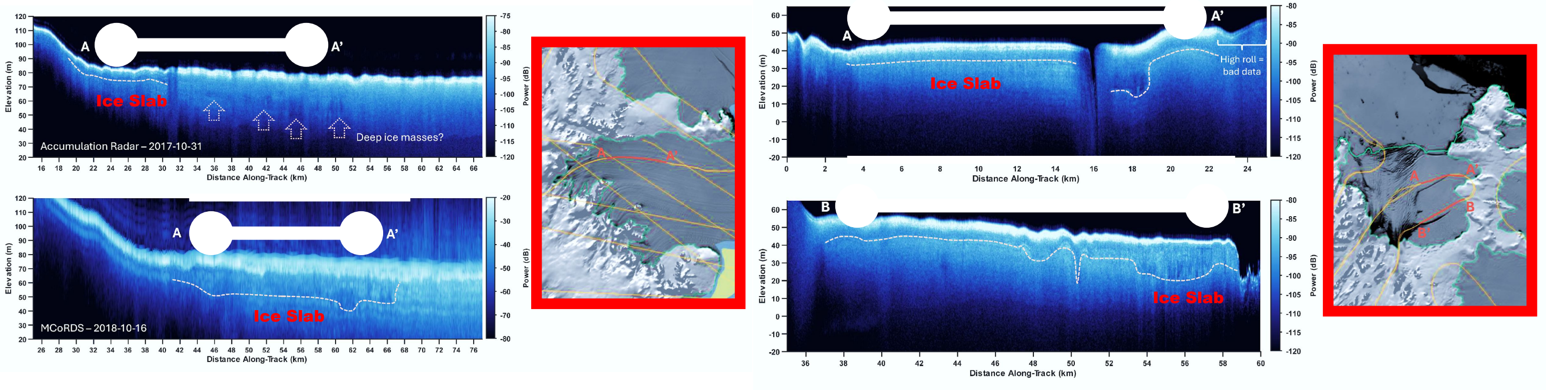


**FIGURE 3. Airborne Ice-Penetrating Radar Surveys over the Cabinet and Scar Inlets**

Airborne ice-penetrating radar surveys (Accumulation Radar and MCoRDS system) over ice slabs on **(left)** Cabinet and **(right)** Scar inlets. Yellow lines are flight lines overlaid the 2013-2014 MODIS MOA. The teal lines are the 2013-2014 MODIS MOA grounding lines and ice extent.