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Investigation of Antarctic Ice Melt Variations Using Gravity Data and Its Relationship with Climate Change

Giovanna Reis (Universidade de São Paulo), Renata Constantino (Universidade de São Paulo), Tércio Ambrizzi (Universidade de São Paulo)

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Abstract

Climate change has intensified extreme weather events, including storms, heatwaves, and heavy rainfall, with profound socioeconomic consequences. The 2024 floods in Rio Grande do Sul (which affected 90% of the state) exemplify this trend, driven by ENSO (El Niño-Southern Oscillation) and atmospheric blocking events that stalled cold fronts. These blocking systems – persistent high-pressure zones with displaced airflow – operate differently in each hemisphere: orographic forcing drives them in the North, while thermal forcing dominates the dynamics in the South. Antarctica plays a crucial role in the climate system, with the sea ice edge positioned in a sensitive region south of the baroclinic zone, capable of modulating atmospheric patterns from the surface to the mid-troposphere. Its variability is closely linked to the Antarctic Oscillation (AAO), the dominant mode of climate variability in the Southern Hemisphere, which controls sea ice expansion or retreat through its positive phase (intense winds expanding ice) or negative phase (heat transport causing localized melting). This project (2025–2026) will analyze gravity data from the GRACE/GRACE-FO missions to relate Antarctic ice mass changes to AAO patterns. By combining geophysics, atmospheric sciences, and oceanography, it aims to improve extreme weather prediction by deciphering Antarctic-global climate connections.

Method

The methodology integrates three main stages to investigate Antarctic ice mass variations and their climate connections. First, a spatial analysis will be conducted through linear regression between Bouguer anomalies and filtered topography, using the Airy isostatic model as reference. This stage will apply moving 2°×2° windows (with 75% overlap) to map regression parameters (slope, intercept, correlation coefficient) and identify residuals that may indicate density heterogeneities associated with ice excess or deficit. All analyses will use equivalent topography for standardization across continental, oceanic, and glacial regions. In the second phase, monthly data from GRACE/GRACE-FO missions (2002-present) will be analyzed to quantify temporal mass variations in identified anomalous regions, enabling detection of seasonal and long-term trends. Finally, the research will investigate potential climate teleconnections through statistical (Pearson) correlations between ice mass change time series and two climate indicators: South Atlantic sea surface temperature (SST) and the Antarctic Oscillation Index (AAO). This multidisciplinary approach combining geophysics, remote sensing, and climatology aims to elucidate the mechanisms linking Antarctic ice variability to global climate patterns.

Expected Results

It is expected that, through a linear regression analysis between the gravity Bouguer anomaly and topography over the Antarctic continent, it will be possible to identify anomalous regions indicative of mass loss associated with ice melt. Since these results reflect only the mass loss, a temporal analysis of gravity field variations may help to determine the specific periods during which such mass loss occurred. This approach aims not only to identify these periods, but also to assess whether they are correlated with the Antarctic Oscillation (AAO) climate variability index and with sea surface temperature anomalies in the South Atlantic Ocean.