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Assessing Present-Day Atmospheric Control over the Surface Mass Balance of Patagonian Icefields through Modeling

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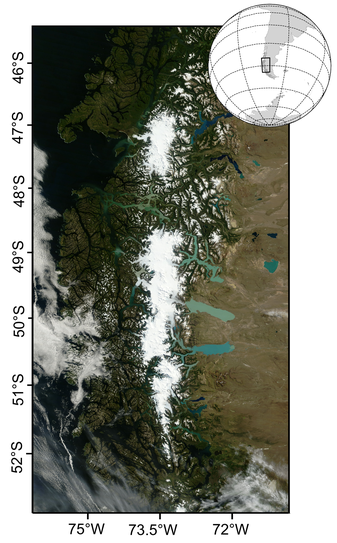
Introduction and Goals

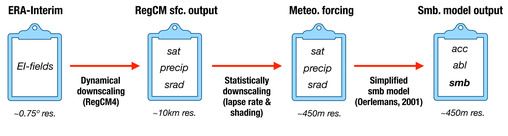
• In this study, we aim to understand the atmospheric controls for the surface mass balance (SMB) variability of the Northern and Southern Patagonian Icefields.



• The Northern and Southern Patagonian Icefields (NPI, SPI) are the largest ice bodies in the Southern Hemisphere outside Antarctica[1]. They are located in southern South America, over the Andes mountain range, and cover an area of ice of 3,953 km² and 12,514 km², respectively[2,3].

• Both icefields are drained by outlet glaciers that terminate mostly in fjords and lakes[2,4], and show a general pattern of accelerated retreat and thinning[5]. The Patagonian Icefields has been losing mass over decadal and longer timescales[6,7,8].

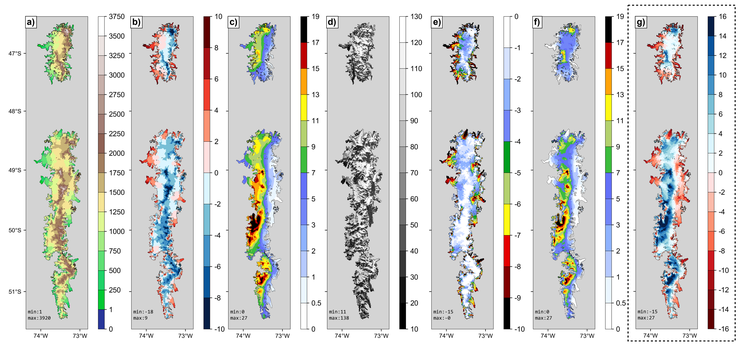
Data and Methods



• The area is characterized by a lack of temporarily and spatially dense observational data. We overcame this by modeling the present-day (1980-2015) atmospheric surface conditions for the Southern Andes[9] and then running a simplified SMB model[10] over the Patagonian Icefields extent.

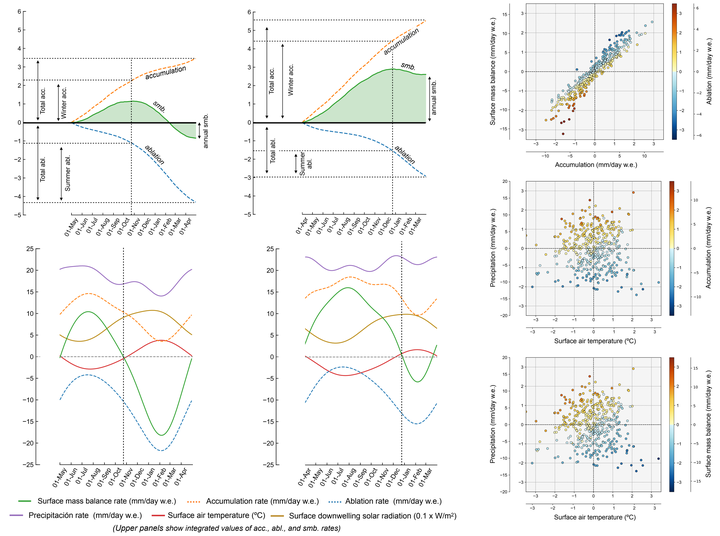
Local-Scale Control

• The mean annual (1980-2015) modeled fields including the topography show that the spatial variability of the SMB follows the thermodynamic aspects of orographically-induced atmospheric features: the altitudinal gradient of surface air temperature in first place, and the longitudinal gradient of precipitation secondly (Fig. below).



a) Topography (m) b) Surface air temperature (ºC) c) Precipitation (m/year w.e.) d) Surface downwelling solar radiation (W/m²) e) Ablation (m/year w.e.) f) Accumulation (m/year w.e.) ***g) Surface mass balance (m/year w.e.)***

• A negative (positive) annual SMB of the NPI (SPI) is mainly associated with the differences in mean annual modeled fields (left and center panel in the Fig. below). For both icefields, the intra-annual variability of the SMB follows the thermal responses of insolation variability (note the small annual-cycle of precipitation).

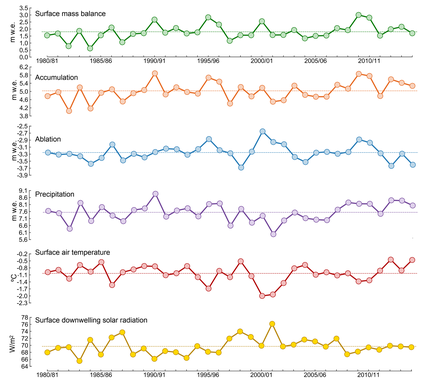


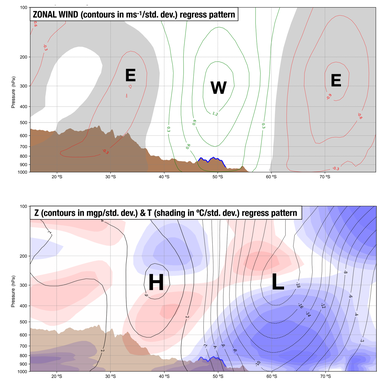
• Monthly SMB and accumulation anomalies are highly correlated (r=0.95) for the Patagonian Icefields (Fig. above, right panel). The monthly SMB variability is well explained by the temperature and precipitation variability. On the other hand, temperature and precipitation fields are poorly correlated (r=0.04) and the fraction of variance explained by precipitation is more than 3 times that of temperature.

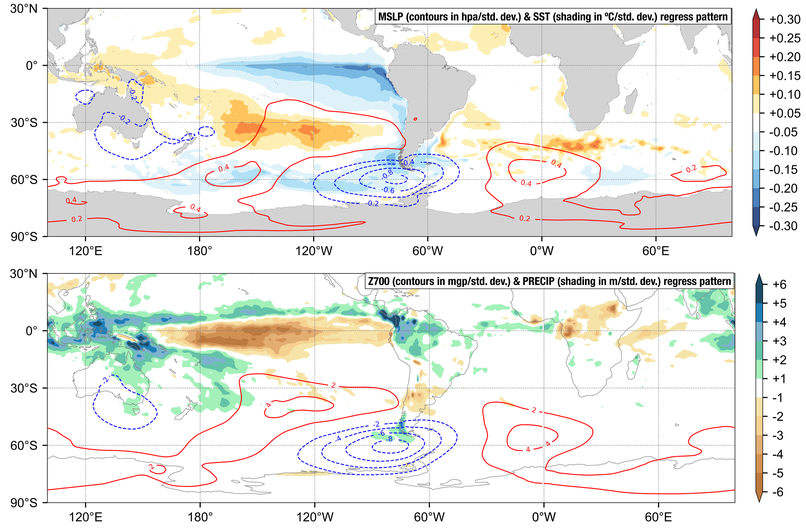
Large-Scale Control

• Interannual SMB variability and trend follow closely that of accumulation, which resembles that of precipitation (Fig. on the right, left panel).

• Vertical cross-sections (at 80ºW) of regression patterns of the annual SMB series onto zonal wind, geopotential height and temperature fields, show that years of higher (lower) than normal SMB features a strengthening (lowering) of the westerly winds impinging Patagonia. The geopotential height (Z) and temperature (T) anomalies are typically of a thermal wind balance (Fig. on the right, right panel).







• (Fig. on the left) Regression patterns of the annual SMB series onto mean sea level pressure (MSLP), geopotential height at 700 hPa (Z700), sea surface temperature (SST) and precipitation (PRECIP) fields.

• Years of higher than normal SMB feature anomalous low pressure center located near the Bellingshausen Sea. This low pressure center promotes a cyclonic circulation that intensifies the geostrophic wind impinging Patagonia.

• The above conditions are accompanied by lower than normal SST and higher than normal PRECIP in the Pacific ocean near Patagonia. A remarkable equatorial pattern of anomalies, distinctive of ENSO-like phenomena appears. No signal of the Southern Annular Mode was found.

Conclusions

• The *spatial variability* of the SMB is controlled by the orographically-induced patterns of surface air temperature, in first place, and precipitation, secondly. The *intra-annual variability* of the SMB follows the thermal responses of insolation variability.

• The *inter-annual variability* of the SMB is controlled mainly by the precipitation variability over the Patagonian Icefields. Years of relatively high (low) SMB are associated with low (high) pressure anomalies near the Bellingshausen Sea, causing an anomalous cyclonic (anticyclonic) circulation that enhances (reduces) the westerlies impinging Patagonia and thus, the orographic precipitation.

• Regarding the *leading modes of variability affecting the Southern Hemisphere*, La Niña-like (El Niño-like) conditions favor (disfavor) the SMB, while the Southern Annular Mode seems to have no impact on it. According to the projections for the XXI-century (equatorial SST warming), the Patagonian Icefields could face increasingly adverse conditions in terms of the SMB.

References and Acknowledgments:

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