PROJECTIONS AND SIMULATION OF WATER BALANCE IN SOUTHERN ICE FIELD, PATAGONIA, CHILE.

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1. INTRODUCTION

Climate change (CC) is an alteration of the natural state of the climate that generates disturbances in all systems, so these tend to seek new state(s) of equilibrium that can present a great deal of variability, This is why the Intergovernmental Panel on Climate Change (IPCC) has developed scenarios that aim to account for the effects of CC by representing the total radiative forcing calculated for the year 2100 and including the net effect of Greenhouse Gases (GHGs), air pollutants and land use changes (Van Vuuren et al. , 2011). Based on this, the main objectives of the study are to provide a projection and simulation of the water balance in the CHS, as well as to evaluate the processes that control and/or are responsible for the advance or retreat of glacial fronts and ice mass thinning. For this, we use General Circulation Models (GCM) coupled with climate change scenarios RCP 4.5 & 8.5.

2. STUDY AREA

The Southern Ice Field (CHS, by its acronym in spanish) is one of the largest continental ice sheets, representing a source of water for the entire globe. It extends from 40°20' S to 51°30' S, covers an area of 16,800 km2 and is formed by 49 glaciers distributed in the southern territory of Chile (85%) and in the Patagonia of the Argentine Republic (15%).

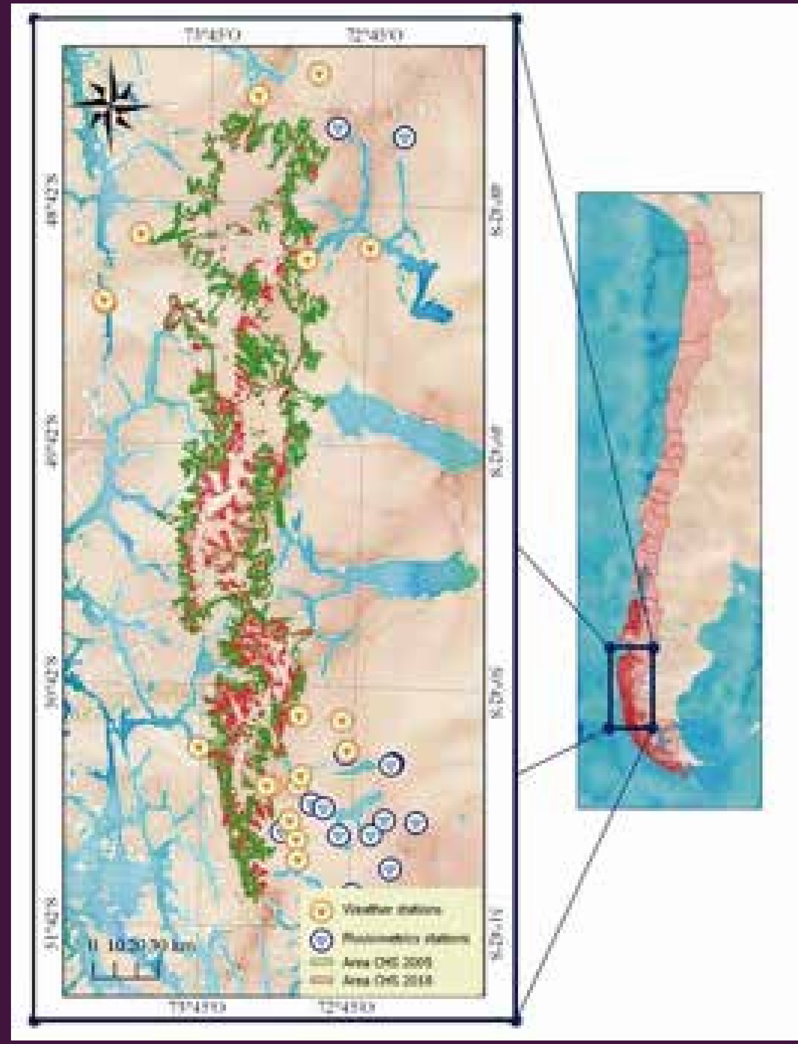

Fig. 1 Surface covered by the CHS obtained from the Landsat 5-8 satellites and analyzed in Geographic Information Systems. The green line marks the surface at the year 2005, while the red line shows the retreat of the glacier and the few mass increases at the year 2018. These effects can be associated with increases in sea level (Rivera et al., 2008), changes in evapotranspiration rates, decreased precipitation, among other effects generated by the CC.

3. OBSERVATIONS

This study considers three analysis periods. In the historical period (T1: 1970-2005) we used records from fluviometric and meteorological stations (Fig. 1). For the near (T: 2006-2050) and far (T3: 2051-2100) future projections, we use statistical downscaling results from the GCMs.

4. METHODOLGY

GCM

- CSIRO - MK 3.6
- MPI - ESM

STATISTICAL DOWNSCALING

Spatial: inverse to the distance between meteorological stations and JCG pixels.

Temporal: annual contrast of hydrological records and GCM simulations.

EVALUATION & PROJECTIONS

Evaluation of the balance in the historical period in the near and distant futureand projections.

WATER BALANCE

1) $B_{gl} = P_{gl} - L_{gl}$ (Rivera et al 2008)

2) $PET = \left(16 \cdot \left(\frac{10 \cdot t}{1}\right)^3\right) \cdot \frac{D_{days}}{30} \cdot \frac{H_{sun}}{12}$ (Thornthwaite 1948)

3) $R = P - \frac{P}{\left(1 - (P/PET)^2\right)^{0,5}}$ (Turc & Pike 1964)

4) $\Delta S = P - R - PET$

Where: Bgl (mm): water balance, Pgl (mm): precipitation over the glacial area & Lgl (mm): relation between generated flow and glacial area (Qgl/Sgl). Then, PET (mm) is evapotranspiration, t (°C): average monthly temperature, I: annual caloric index (It is the sum of 12 monthly indexes i. [i= (t/5) ^1,514]), a: complex function of I ([a=6,7· 10 ^(-3)·I^3-7,7 ·10 ^(-5)·I^2+0.0179·I+0.4923]), ndays: number of days in the month & Hsun: maximum number of hours of sunshine (depends on month and latitude). Finally, R (mm): runoff & P (mm): precipitation.

5. RESULTS

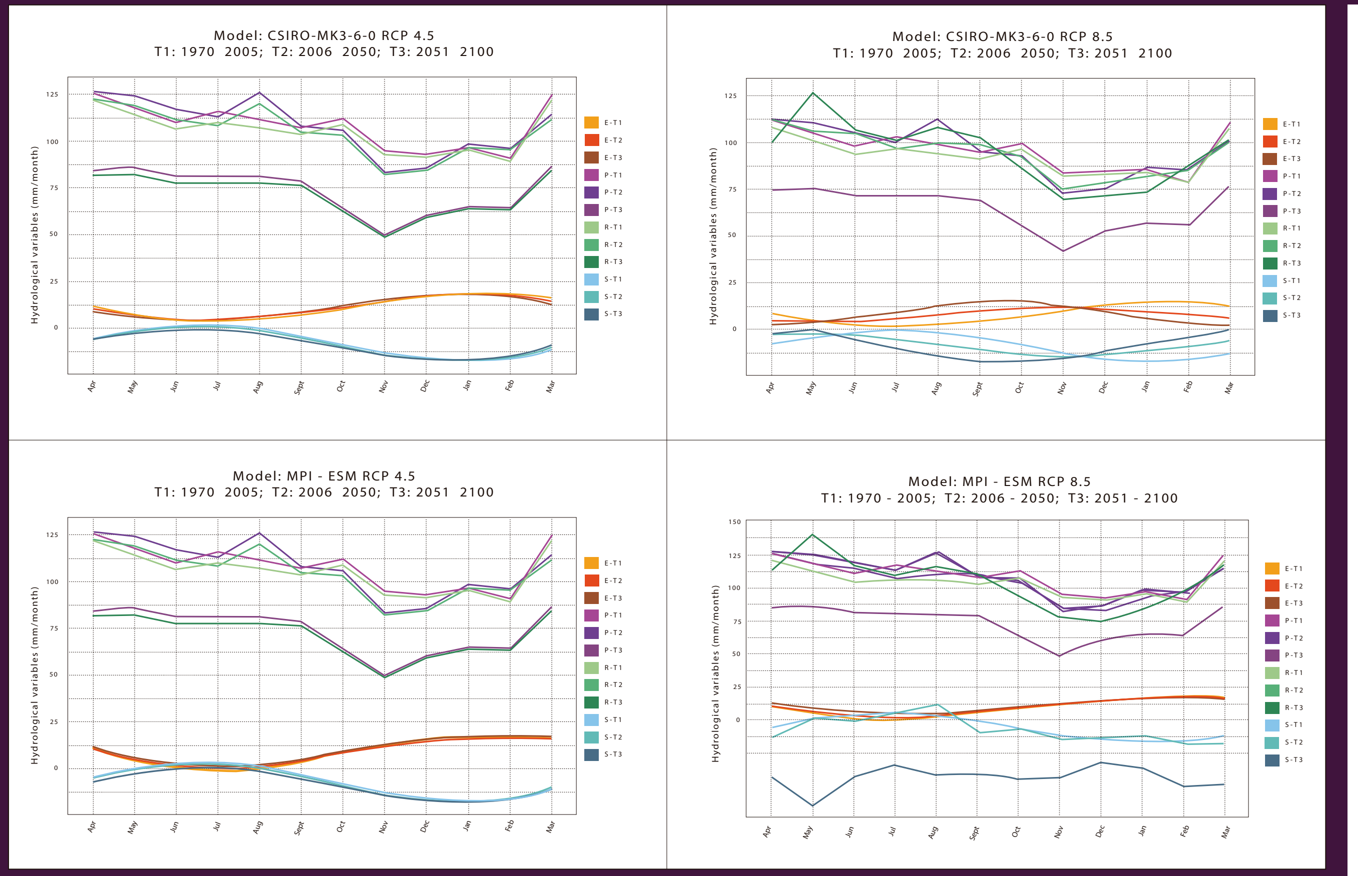

Fig. 2 Variation of hydrometeorological variables in T1, T2 and T3. Precipitation (P) and runoff (R) in CHS present similar levels, while potential evapotranspiration (PET) is 20% of precipitation. Consequently, monthly storages (S) tend to be negative, where water release peaks are in the summer season (dec-mar).

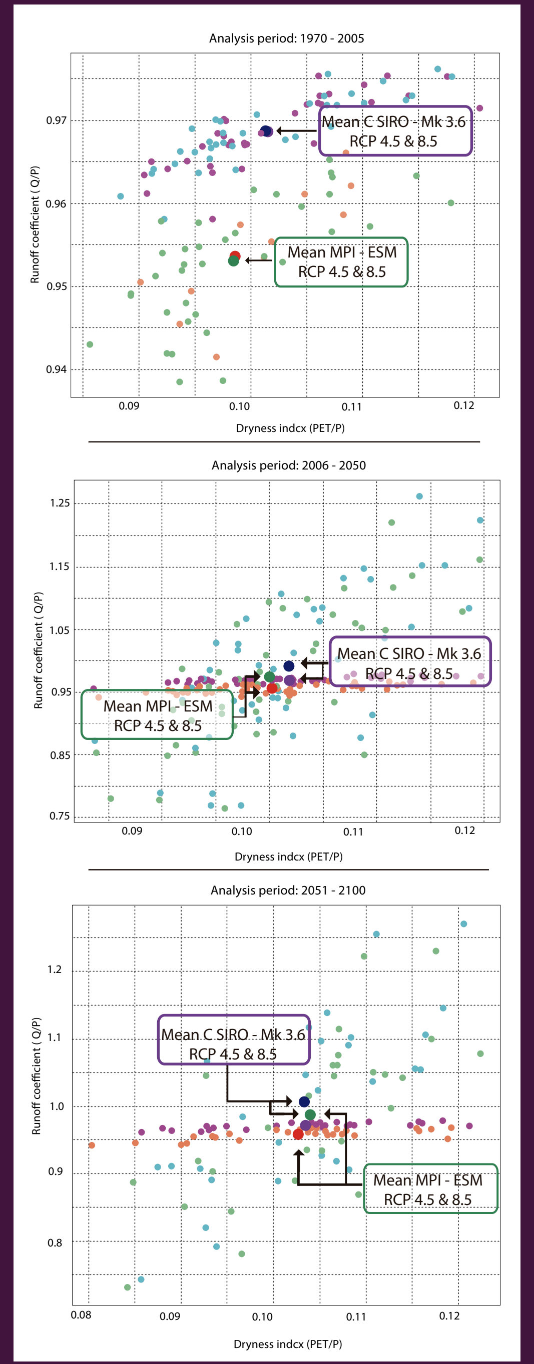

Fig. 3 Annual values of the aridity index and run-off coefficient. The average values of T1, T2 and T3 (larger circles) under the CSIRO-Mk3-6-0 model (light blue and purple points) reveal more unfavourable results compared to the MPI-ESM model (orange and green points).

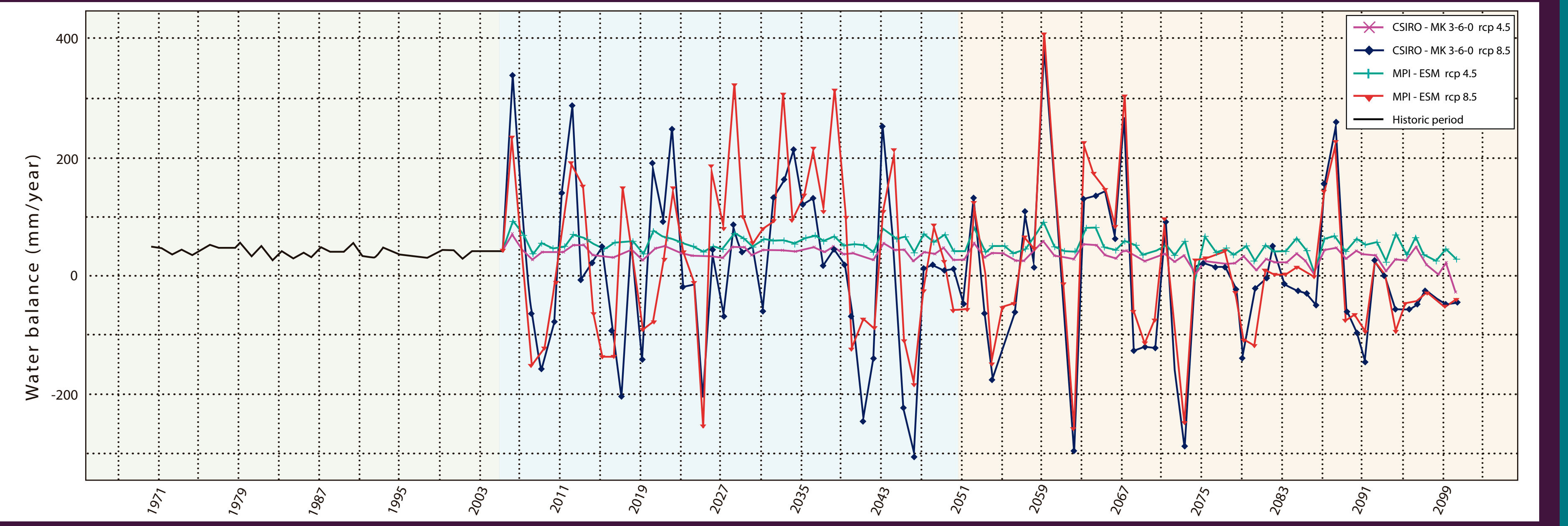

Fig. 4 The water balance evaluation (T1) is shown in black. The green and purple lines are the projections and simulations of the RCP 4.5 scenario, these follow the historical trend in T2 and T3, presenting slight decreases in the latter. The blue and red lines respond to RCP scenario 8.5 and indicate clear increases in the series means over time.

6. CONCLUSIONS

Both models, when evaluated in the previously mentioned scenarios, indicate that the CHS present an emptying to a greater or lesser degree according to the scenario, for which reason, the ice mass that makes up the CHS will follow the behavior it has experienced up to now and will continue to detach itself.

The values of the runoff coefficient range between [0.75 - 1], values higher than 1 are due to the uncertainty in the climate projections, due to the fact that different GCM and RCP scenarios were applied, in addition, the methodology applied has uncertainty in its structure (downscaling methods and estimated variables).

Finally, both models indicate a 30% deficit in precipitation by 2050, with gradual decreases over the years. Which are likely to induce decreased glacial mass balances across the study domain.

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