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Climate change estimates of South American riverflow through statistical downscaling

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Water availability in South America presents a considerable uncertainty across several time scales. This notion is a serious problem for various applications, such as agriculture and hydroelectric energy. Multi-decadal regional climate model projections are assimilated into a linear statistical model in order to produce an ensemble of downscaled riverflows in the La Plata Basin and in southern-central Chile. The statistical model uses atmospheric circulation fields (geopotential heights at the 200 hPa level) as predictors in a perfect prognosis approach.

The conformal-cubic atmospheric model (CCAM; McGregor, 2005) has been configured for a number of applications including multi-decadal projections and high-resolution reanalysis (Engelbrecht et al 2011). A 30-year period of 0.5° resolution 6-hourly data from 1979 to 2008 were produced by providing the CCAM at 6-hourly intervals with NCEP reanalysis data. Seasonal (3-month) averages of this CCAM-based reanalysis data set were subsequently calculated and used here as predictors for perfect prognosis statistical downscaling (Maraun et al 2010). The predictors are the CCAM reanalysis 200 hPa geopotential height fields. The perfect prognosis equations are created through principal component regression (PCR) and the predictor domain is the area between the equator and 70°S, and between 160°W and the Greenwich Meridian. The predictands in the perfect prognosis equations are seasonal flows for four rivers in subtropical South America, namely the Uruguay and Negro rivers in the La Plata Basin, and Biobio and Itata rivers in southern-central Chile.

The gauge points locations are: 31°9'S and 58°W for the Uruguay River; 32°48'S and 56°25'W for the Negro River; 37°42'S and 71°54'W for the Itata River, and 37°9'S and 72°4'W for the Biobio River. Rainfall distribution is fairly uniform during the year and the minimum run-off arises from high summer evapotranspiration. However, the characteristic intermediate-seasons double peak of the precipitation annual cycle shows up in the Uruguay River streamflow, with a maximum in austral spring. The maximum flows for the Negro River is reached in winter. It is worth noting that monthly dispersion of streamflow is substantial for both rivers, giving rise to a considerable amount of uncertainty in the flows. Biobio and Itata rivers also present their maximum streamflow during winter and follow the precipitation annual cycle in that region.

CCAM multi-decadal simulations of regional climate at the same horizontal resolution as the CCAM-reanalysis set were performed by forcing the CCAM with the bias-corrected sea-surface temperature (SST) and sea-ice output of a number of different coupled global climate models used in AR4 of the IPCC (CSIRO, GFDL20, GFDL21, MIROC, MPI and UKMO). All six of these projections were for the A2 SRES emission scenario.

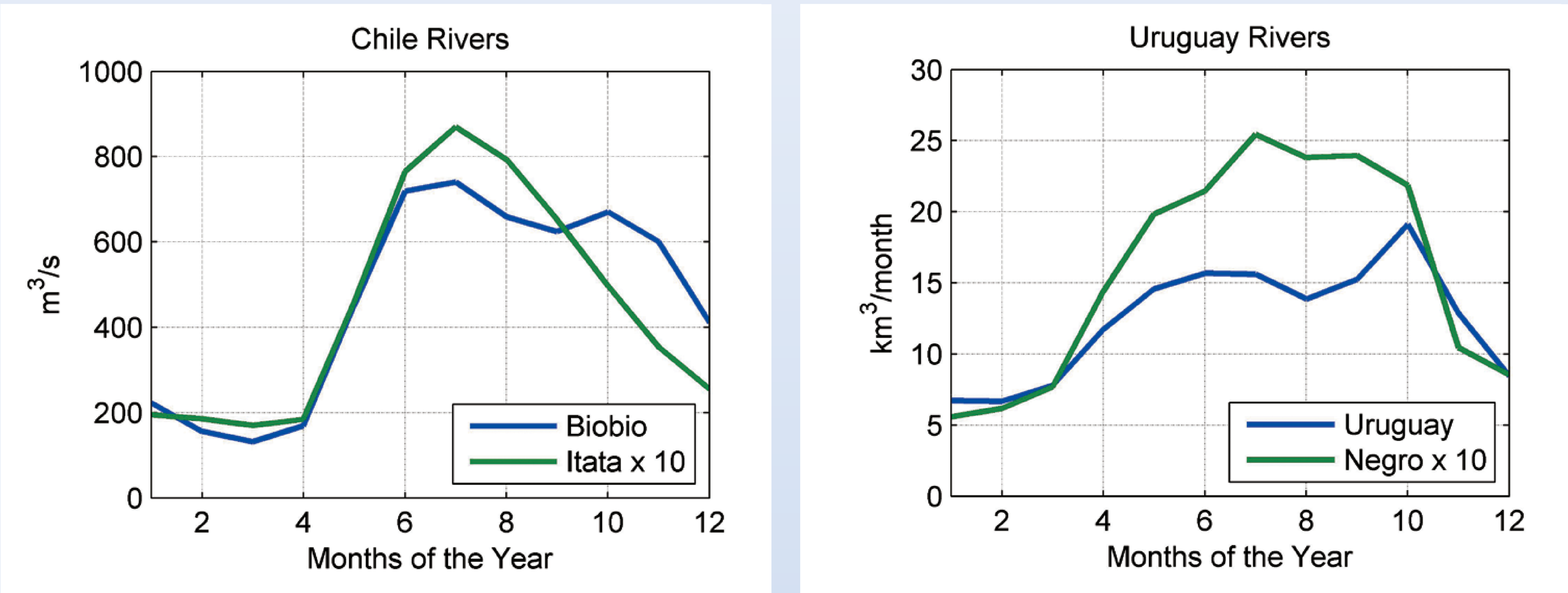

Figure 1. Seasonal cycle of flows in the four rivers of subtropical South America considered here.

Figure 1 shows the annual cycles of monthly flows for each of the four rivers. The seasons considered are SON for the Uruguay River, and JJA for Negro, Biobio and Itata rivers. The PCR perfect prognosis equations are subsequently used to simulate seasonal flows over 90 years from 1961 to 2050 and for each of the six CCAM-AR4 projections in order to produce an ensemble of statistically post-processed projections. The statistically modelled flows averaged over the 30-year period from 1961 to 1990 are compared with observed flows over the same period in order to calculate an estimate of the bias of each of the six projections. Bias adjustments are subsequently applied over the entire 90-year period and for each simulation.

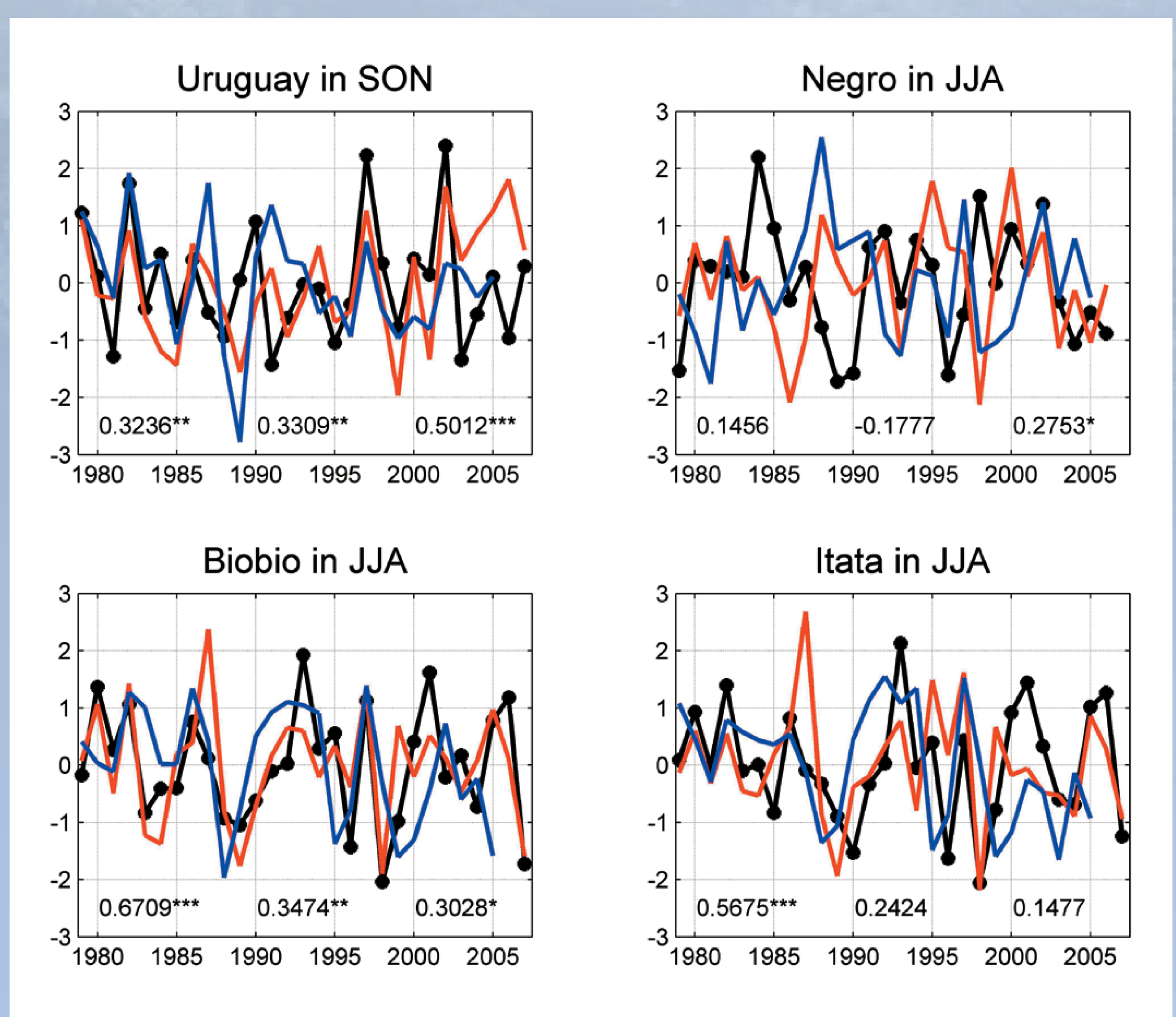

Figure 2. Cross-validated (5-year-out) perfect prognosis (red), MOS (blue) and observed (black) seasonal flows. Spearman rank correlations are shown (see text) [*** significance at 99%, ** significance at 95%, * significance at 90%]

Figure 2 shows the 5-year-out cross-validation results obtained by using seasonal 200 hPa geopotential heights of the CCAM reanalysis as predictors of the respective flows, and by using AMIP-style CCAM height simulations as predictors through model output statistics (MOS). The former is indicative of the strength of the perfect prognosis PCR equations, and the latter is indicative of the CCAM's ability to correctly respond to SST forcing (a notion worth testing since the regional model projections are *also* a consequence of SST forcing). Spearman rank correlation values are presented (left: using CCAM reanalysis as predictor; middle: using CCAM AMIP as predictor; right: rank correlation between the two downscalings).

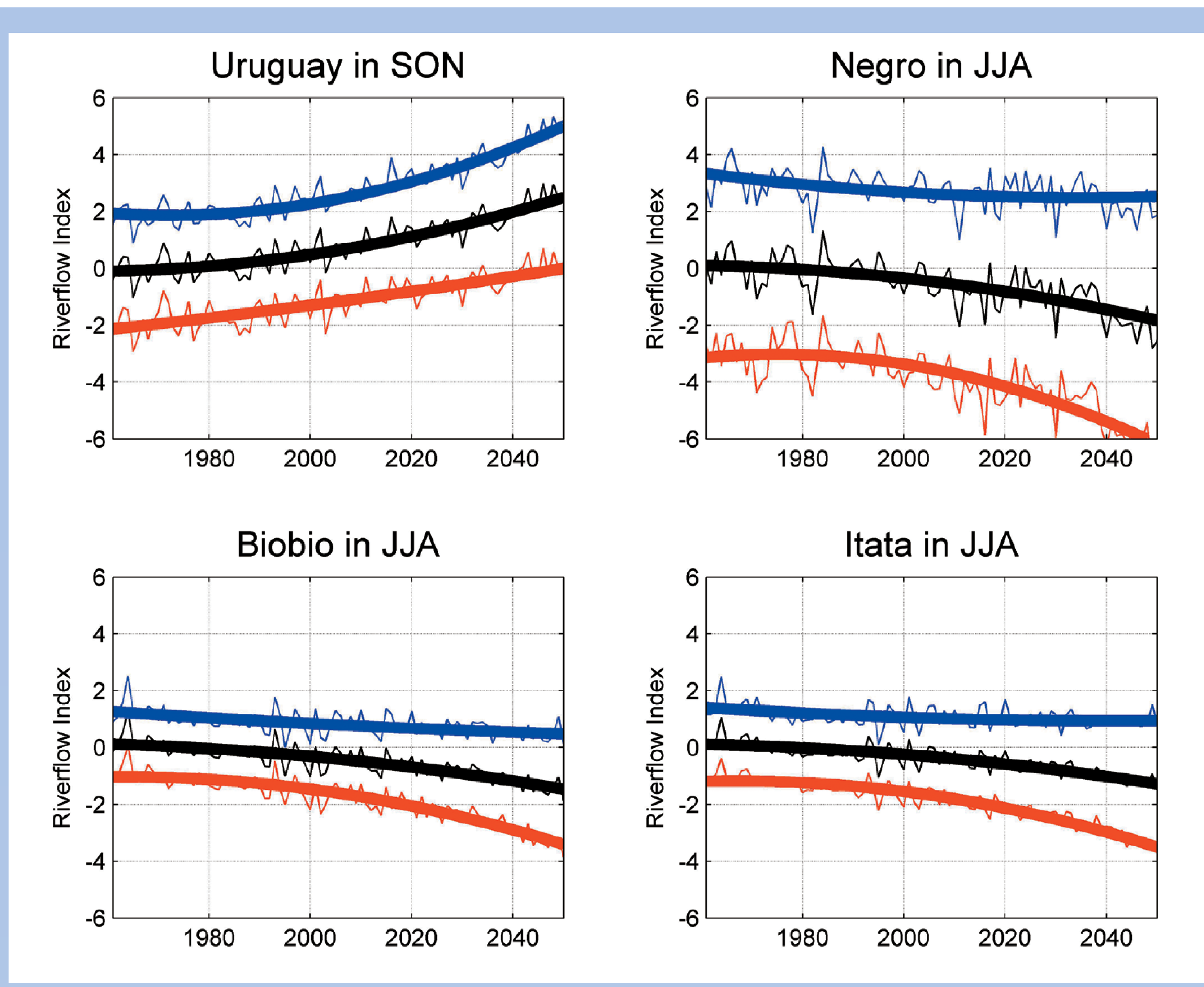

Figure 3. Ensemble mean downscaled flows (bias-adjusted) for the four rivers, along with 1-standard deviation confidence limits. Simulations for each year and for fitted polynomials are presented.

The bias-adjusted flow projections for the four rivers, along with one standard deviation confidence limits, are shown in Figure 3. The downscaled projections show an *increase* in the Uruguay River flows (during austral spring) towards the middle of this century, while *decreases* in the flows are projected for the remaining rivers (during austral winter). Take note of the larger uncertainties in the Negro River projections – possibly attributed to the weakness of the perfect prognosis and MOS equations as reflected in the low Spearman correlations found.

CONCLUSIONS

The development of a simple statistical downscaling procedure to objectively simulate seasonal flows in some rivers in subtropical South America over multiple decades was presented here. First the present-day linear relationships between modelled 200 hPa geopotential heights and some of the observed flows was found to be significant, which suggested reliable projections of a future climate if these relationship remain robust. The subsequent downscaling to seasonal flows over multiple decades showed increased flows during austral spring in the Uruguay River, but decreased flows in the Negro, Biobio and Itata rivers during austral winter. Notwithstanding the assumptions made with statistical downscaling and the demonstrated limited level of linear relationships between atmospheric circulation and seasonal flows, the projections presented may at least be able to provide some guidance to policy makers responsible for action plans to mitigate and adapt changes in river flows as a consequence of climate change.

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