Analysis of the impacts of EC-Earth Global Circulation Model in the RCP45 climate change scenario on maximum daily streamflow quantiles at global scale

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Introduction

Climate changes can have an impact on various components of hydrological cycle. From a risk assessment point of view it is certainly interesting understanding how extreme streamflow values can change as a consequence of climate variability. In order to do this the outputs of a climate model (EC-EARTH) that accounts for a standard climate scenario were used to feed a hydrological model and to generate 140 years (1960-2100) of continuous streamflow simulations in a large number of stations that cover all the world. These time series were then post-processed in order to evaluate how annual daily maximum streamflow quantiles change because of climate scenarios. The analysis highlights that in many cases there is an increment or a decrease of the quantiles for fixed return periods, but only in a reduced number of situations these variation lay out of the confidence intervals of the quantiles estimated in current climate. The analysis was carried out on over 5000 stations distributed in all continents and spanned the period 1960-2100 according to the climate scenario RCP45.

Datasets and methodology

EC-Earth: global circulation model long period simulation (*Timestep:* 3 hours, *Spatial resolution:* 1.125°, *Coverage:* global (Longitude: 0 - 360° , Latitude: -90 - +90°)) , corrected with CRU TS 3.1 monthly mean temperatures (Climatic Research Unit, time-series datasets with a spatial resolution of 0.5 deg, available from 1901 to 2012) and CHIRPS rainfall (Climate Hazards Group InfraRed Precipitation with Station data, global rainfall dataset. CHIRPS incorporates 0.05 deg resolution satellite imagery with in-situ station data to create pentadal gridded rainfall time series for trend analysis and seasonal drought monitoring).

RivDIS: The Global River Discharge Database (RivDIS v1.1) Water Systems Analysis Group. Complex Systems Research Center. Institute for the Study of Earth, Oceans and Space. University of New Hampshire (available at http://www.rivdis.sr.unh.edu/ or alternatively at http://www.sage.wisc.edu/riverdata/). About 2700 hydrometer stations are available with at least 15 years of data, un-homogeneous spatial distribution over the world.

CONTINUUM: *Continuum* is a continuous distributed hydrological model that strongly relies on a morphological approach. It is designed to be implemented in different contexts with a special focus on data scarce environments. All the main hydrological phenomena are modeled in a distributed way.
The basin is represented using a regular square mesh based on Digital Elevation Model (DEM), the flow directions are identified on the basis of the directions of maximum slope derived by the DEM. The drainage network is represented distinguishing between hillslope and channeled flow. Infiltration and subsurface flow are described using a semi-empirical, but quite detailed, methodology based on a modification of Horton algorithm and focuses especially onto exploiting land use information and climatology to set the infiltration parameters. The energy balance is based on the "force restore equation" which balances forcing and restoring terms, with explicit soil surface temperature prognostic computation. Vegetation interception and water table flow have been also schematized. In this application the model has been implemented at 0.083 deg of spatial resolution and 3 hours of time resolution.

Results

HC = Historial Climate
NF = Near Future Climate
FF = Far Future Climate

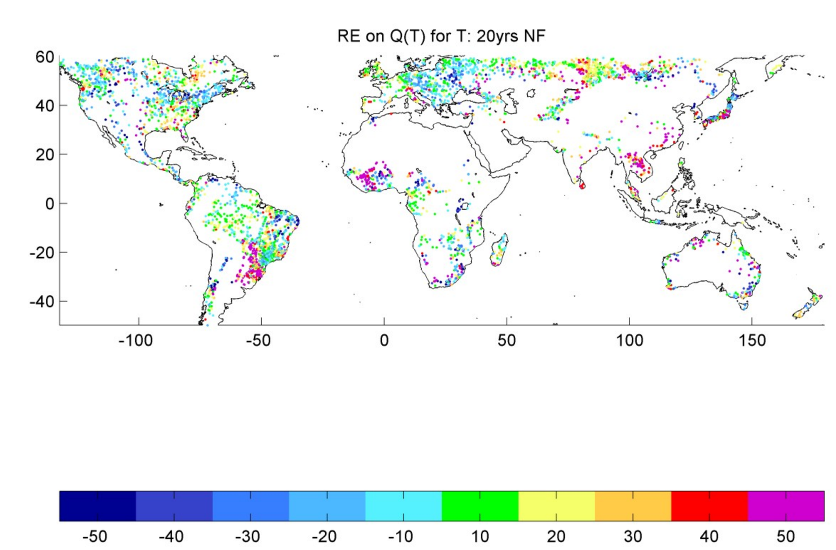

Figure 3: Relative Error (%) of the Quantiles with T=20 yrs. Near Future reference period.

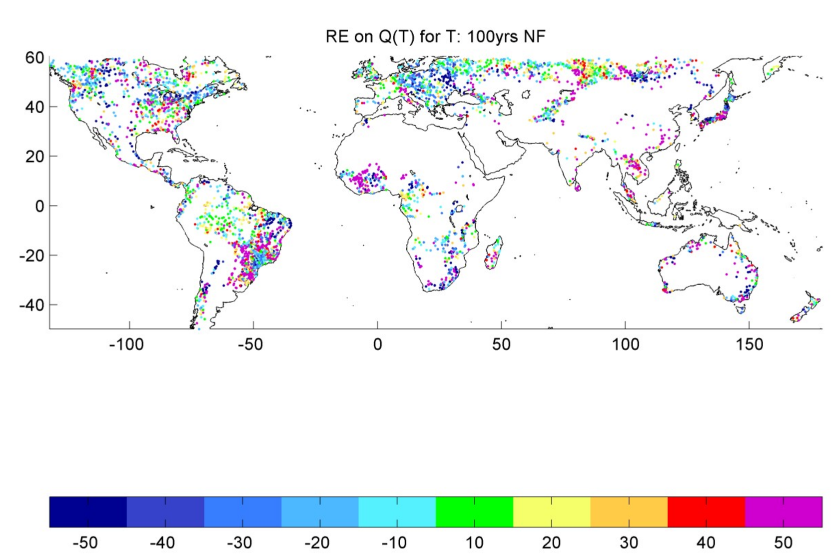

Figure 4: Relative Error (%) of the Quantiles with T=100 yrs. Near Future reference period.

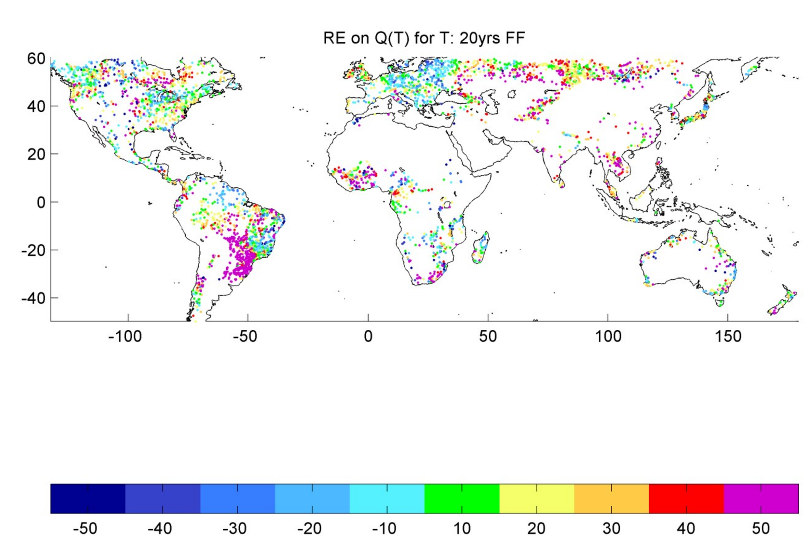

Figure 5: Relative Error (%) of the Quantiles with T=20 yrs. Far Future reference period.

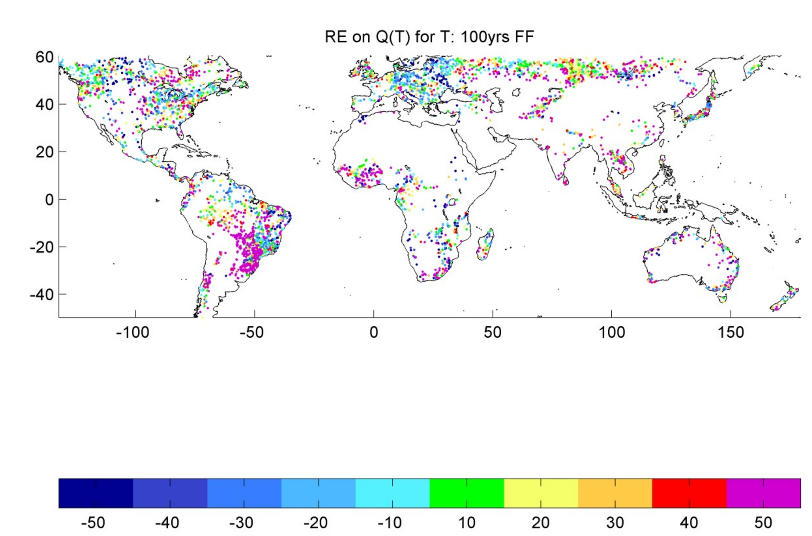

Figure 6: Relative Error (%) of the Quantiles with T=100 yrs. Far Future reference period.

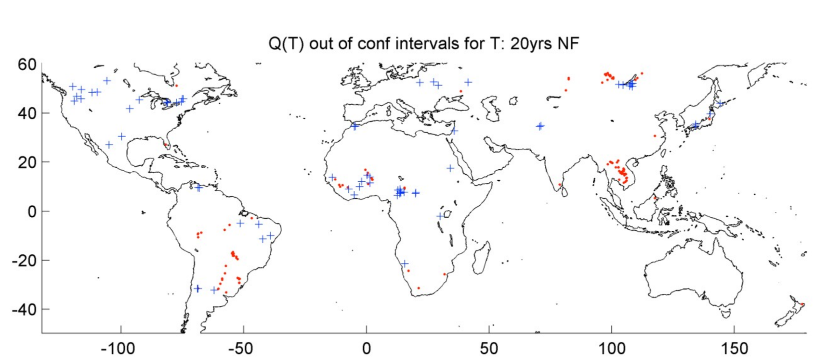

Figure 7: Sections where the quantiles with T=20 yrs in NF are out of the confidence intervals of HC quantiles. Red points NF quantiles out of upper confidence interval, blue crosses NF quantiles out of lower confidence interval.

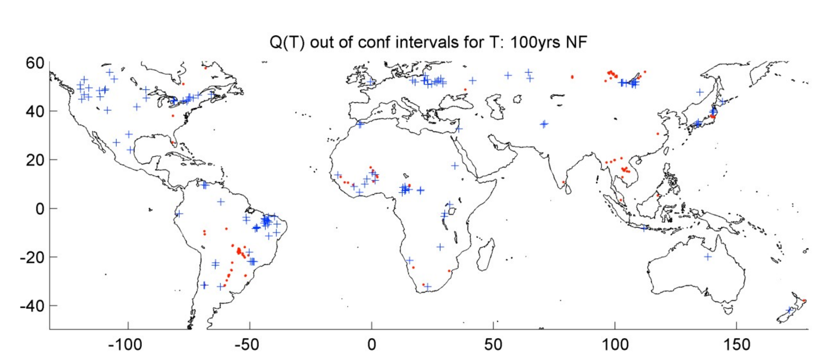

Figure 8: Sections where the quantiles with T=100 yrs in NF are out of the confidence intervals of HC quantiles. Red points NF quantiles out of upper confidence interval, blue crosses NF quantiles out of lower confidence interval.

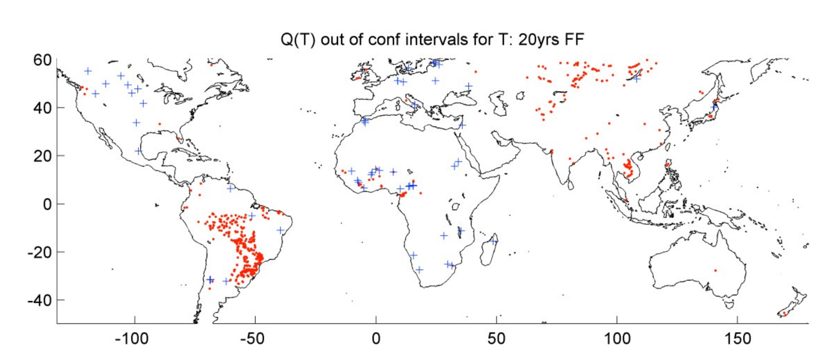

Figure 9: Sections where the quantiles with T=100 yrs in FF are out of the confidence intervals of HC quantiles. Red points NF quantiles out of upper confidence interval, blue crosses FF quantiles out of lower confidence interval.

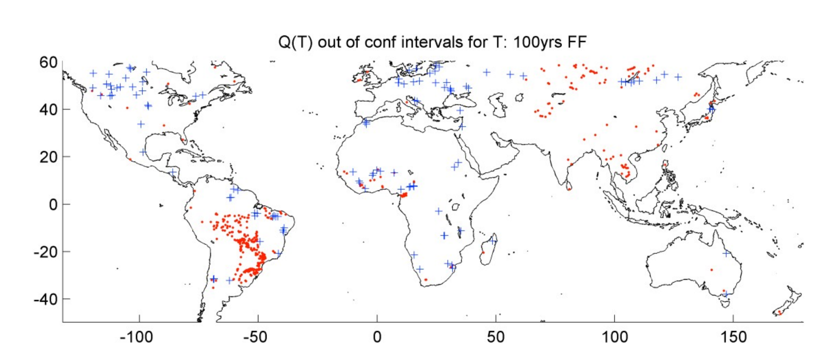

Figure 10: Sections where the quantiles with T=100 yrs in FF are out of the confidence intervals of HC quantiles. Red points NF quantiles out of upper confidence interval, blue crosses FF quantiles out of lower confidence interval.

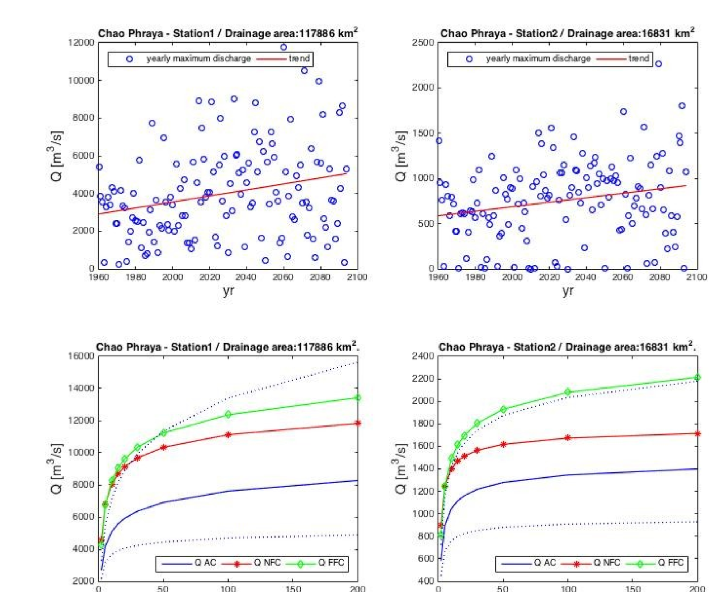

Figure 1: Chao Phraya river. On top left and right panels the linear regression of the AMDS time series for the two reference stations are reported. On bottom left and right panel the quantiles curves for Current Climate, Near Future, and Far Future periods are reported together with the confidence intervals of HC.

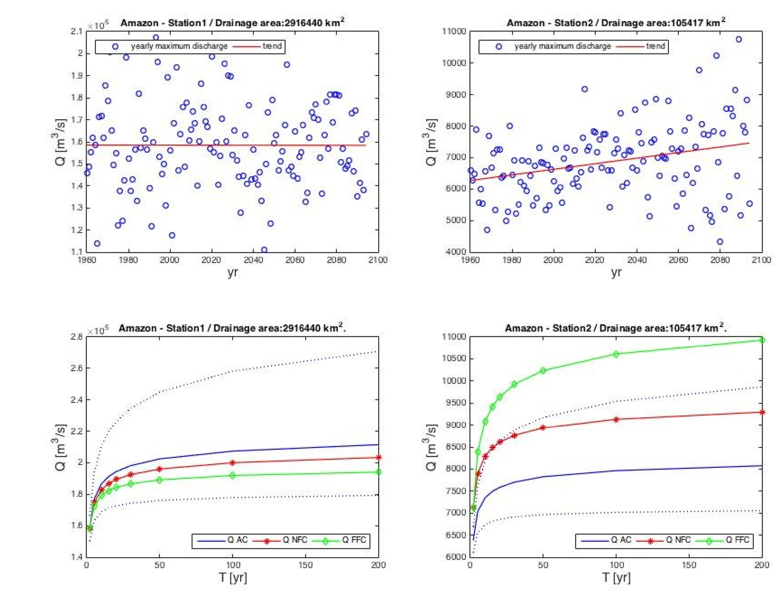

Figure 2 Amazon river. On top left and right panels the linear regression of the AMDS time series for the two reference stations are reported. On bottom left and right panel the quantiles curves for Current Climate, Near Future, and Far Future periods are reported together with the confidence intervals of HC.

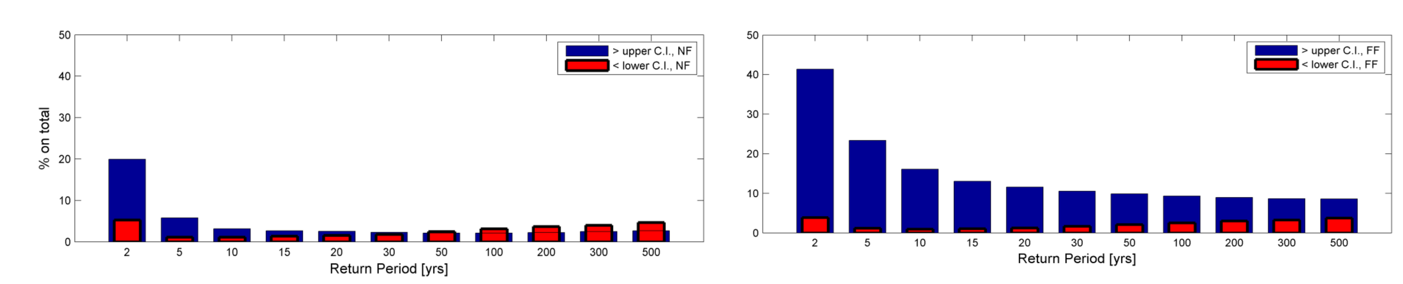

Figure 11: Percentage of sections where quantiles are out of confidence intervals in HC as a function of return period for NF and FF. Upper C.I. means that Q(T) is larger than upper bound of confidence interval in HC, lower C.I. means that Q(T) is smaller than lower bound of confidence interval in HC

Conclusions

The analysis has been conducted comparing the statistical analysis in current climate (1960-2012) with those conducted considering two future periods: near future (2010-2060) and far future (2044-2094). The study allowed to estimate the differences of quantiles estimated considering the different periods and evaluate the possible impact of RCP4.5 climate scenario on the extreme streamflow values at global scale.
The results highlight that in different regions of the world there is a different impact of the climate change RCP4.5 scenario in terms of extreme streamflow values, in some cases there is an increasing in some others a decreasing of the quantiles, while in some cases they change negligibly.
The Confidence Intervals analysis allowed to individuate those cases where the changes in quantiles should not be due to statistical uncertainty. This approach on one side pointed out that the changes in Q(T) are in many cases inside the statistical uncertainty, on the other side showed that there are some areas in the world (for example Canada, Thailand and some areas of South America) where changes in Q(T) are more probable and consistent. Furthermore different results are obtained for NF and FF periods; in FF a larger number of sections show quantiles estimation out of confidence intervals of HC in respect of NF, moreover in FF there is a larger tendency to an increasing of quantiles contrary to what happen in NF. It is clearly evident that the NF and FF scenarios in terms of streamflow are strongly driven by the GCM model and by the RCP scenario that was considered; even in the theoretical case that we produce a system that can perfectly calculate the effects in terms of streamflow due to the meteo-climate forecast, the results could be totally wrong if the climate scenario will result to be unrealistic.