El Niño Southern Oscillation (ENSO) – induced hydrological anomalies in central Chile

Authors: R. van Dongen, D. Scherler, D. Wendi, E. Deal, L. Mao, N. Marwan, C. Meir

1.- General comment

In my opinion this manuscript does not add significant new information to the well documented knowledge of ENSO impacts on rainfall, surface temperature and river discharge regimes in central Chile. In addition to this, many errors and deficiencies in the presentation, some of them quite basic, led me to conclude that in its present version this paper does not reach the minimum standard of quality needed for publication.

2.- Specific comments

2.1.- Lines 185 – 186: Data selection: "…*we selected stations based on data availability during the chosen time period (1961 – 2009), requiring a record length of at least 10 years".* 178 catchments listed in Table S1 were selected based on this and other requirements.

Observation:

Considering the main purpose of the study, which is to characterize hydrological anomalies during El Niño and La Niña events, a minimum record length of 10 years is too small to achieve this goal with results that are statistically significant. Furthermore, the list of 178 stations in Table S1 includes 20 stations with record lengths below 10 years during the time period selected for the analysis (1961 – 2009), with some of them as short as 3 years (stations 6000003, 7317003, 7317005, 8117006, 8312001, 8313000, 8372002, 10100006, 10122003, 10327001, 10351001, 10401001, 10405002, 10431000, 10432003, 10503001, 10514001, 10520001, 10523002).

2.2.- Lines 201 – 202: Classification of river catchments: "*… we classified the river catchments into Andean (high elevation) or coastal region (low elevation) river catchments*"

Observation:

This classification is quite arbitrary and ignores the main characteristic of topography of central Chile from around 33°S to 40°S, dominated by the Andes cordillera on the east where, on the average, precipitation occurs as snowfall during winter in areas above 3.000 m above sea level and by the central valley and a coastal range where precipitation occurs mostly as rainfall. Thus, just a few of the so-called coastal stations corresponds to low-level coastal basins where precipitation always occurs as rainfall. In most of the stations identified as coastal, located in the middle or lower part of Andean basins, the ENSO impact on river discharge is a mixture of a simultaneous impact on rainfall during the rainy season and a delayed impact on snow melting in the high Andes during summer.

Furthermore, there are a large degree of redundancy among some of the selected hydrological time series, corresponding to measurements of the same river at different elevation within its basin (for example stations 8123001, 8124001, 8124002, 8133001, 8135002 of the Itata river; stations 8307002, 8312000, 8312001, 8317001, 8319001, 8334001 of the river Bio Bio). In these cases, differences between records at different elevation in the basin could prove more useful to separate the ENSO impact on river discharge in the Andes and in the central valley.

Station Rio Hurtado en Entrada Embalse Recoleta (N° 4506002), with mean elevation of 2264.4 m, is classified as “Coastal Region”, which is clearly a mistake.

2.3.- Line 208 – 214: Filling missing data in daily hydrological records

Observations:

A more clear explanation is needed of the method that was used, particularly regarding the determination of the “tolerable gap lengths” for each station. Presumably gap lengths were shorter than 10 days, as all months containing data gaps longer that 10 days were removed, as indicated in line 210.

Regarding In the example presented in Fig. S2 it is unclear which stations are considered in this figure. There is a reference to 516 river discharge stations across Chile (line 176). From these 516 stations 178 of them were selected for further analysis (line 184), based on several requirements, but it is not mentioned how many stations were initially considered for the region of the study (29° - 42°S). I suppose these are the nearly 320 stations included in Fig. S2

2.4.- References to previous studies

Observations:

The manuscript includes a large number of references to previous investigations about ENSO-related climate (rainfall and temperature) and hydrological anomalies in central Chile and also about the physical mechanisms involved. But some statements regarding those references are wrong or incomplete:

Lines 143 – 145: *“… El Niño conditions develops from pressure differences above the Pacific ocean that weaken or reverse the equatorial trade wind, pushing warm sea surface waters from the Western Pacific ocean toward the coast of South America*”. This statement ignores the weakening of the equatorial upwelling and the reduced difference in the sea level along the equatorial Pacific as major factors for the positive sea surface temperature anomalies during El Niño episodes.

Lines 146 – 147: “*Due to the anomalously warm sea surface temperature near the coast of South America, this state is also termed as the warm phase of an ENSO event*”. This is incorrect. El Niño is identified as the warm phase of ENSO in association with the positive sea surface temperature anomalies that occur during El Niño episodes along the central and eastern equatorial Pacific.

Lines 151 – 152: “*During El Niño phases the SPH intensity weaken, which results in the blocking of storm tracks across the Admunsen-Bellinghausen Sea and the intensification of the westerlies at mid-latitudes…*”. The weakening of the SPH is not the cause of the establishment of a blocking high pressure system over the Admunsen-Bellinghausen Sea during El Niño episode. This is part of a teleconnection pattern triggered by the enhanced atmospheric convection in the central Pacific. Furthermore, the weakening of the SPH in subtropical latitudes combined with the blocking high pressure system in the south explain a weakening of the westerlies at mid-latitudes

Lines 159 – 160: “*When ENSO condition prevail, either El Niño or La Niña, the SPH changes its intensity in the summer season*”. This statement is meaningless. In fact throughout the entire year

El Niño episodes are associated with a weaker than normal SPH while the opposite occurs during La Niña events.

2.5.- **Comparison between CR2MET and WorldClim V2.1 rainfall data sets** (lines 233 – 235)

Observation:

It is mentioned that compared to the CR2MET data set, the WorldClim v2.1 data set was found to overestimate precipitation during the rainy season from April to September (lines 234 – 235). What it is shown in Fig. S4 is just the opposite, with MMP CR2MET values exceeding by a factor larger than 2.0 the MMP WorldClim values. This is recognized in line 241. Furthermore no information is given regarding the regional characteristics of the bias of these rainfall estimations when compared with rainfall measured at meteorological stations. Apparently it is considered that the accuracy of the CR2MET data set is acceptable everywhere.

2.6.- **Comparison between CPC and CR2MET mean monthly surface temperature data** sets (lines 236 – 240)

Observation:

The comparison is made in Fig. S5 at a monthly scale considering all stations in the semi-arid, mediterranean and humid-temperate regions. This figure shows the existence of large differences between the two data sets, with the CPC estimations underestimating the CR2Met ones by values as large as -10.0 °C at individual stations. Fig. S5 also shows that the difference is larger at stations in the Andes, so the large difference of -5.95°C that is documented year-round in line 240 for the semi-arid region is explained by the fact that most of the stations considered for this regions are in the Andes (Fig. S1H)

2.7.- Adoption of the WorldClim v2.1 rainfall and the CPC surface temperature data sets

Observation:

In spite of the fact that the WorldClim v2.1 rainfall and the CPC surface temperature data underestimate the supposedly closer to reality CR2MET data, in some stations by a large amount, the World Clim and CPC data sets were chosen in the study. This decision is not questionable if the interannual variability in the two data sets of temperature and rainfall is similar, but this is not verified in the article.

2.8.- **Period used for the analysis**

Observation:

The chosen time period for the analysis is 1961-2009. According to this, it is strange that some results are presented for the period 1950 – 2010 (Fig. 2b,c and Figs. S6 and S7). This discrepancy led to the error in lines 268 - 269 where in reference to Fig. S6 it is mentioned that over the 1961-2009 time period, non-ENSO periods are relatively evenly distributed.

2.9.- **Differences in temperature, rainfall and river discharge during El Niño and La Niña episodes with respect to neutral ENSO conditions** (Figs. 4 and 6).

Observations:

Figures 4 and 6 summarize the differences in rainfall, temperature and river discharge when El Niño and La Niña conditions prevail in the central Pacific, with respect to values observed during neutral ENSO conditions (wrongly named in the article as non-ENSO conditions), at the annual and seasonal time scales for each station (left panels); considering all stations all together (panels in column A); for stations in the Andes and those labeled as "coastal region" (panels in column B), and at a regional scale considering all the stations within the semi-arid, mediterranean and humid-temperate regions (panels in column C). I have several observations regarding the way the results are presented:

a) In my judgement, the most serious deficiency in this article is the lack of a rigorous assessment of the statistical significance of the differences that are presented. So, it is impossible to discriminate which of the differences presented in Figs. 4 and 6 as well in Tables S3 and S5 may have occurred by chance or were determined by the occurrence of El Niño or La Niña episodes.
b) Mean river discharge differences with respect to neutral ENSO conditions at individual stations during El Niño and La Niña episodes are not comparable between them, even at nearby stations, due to the different record length of the time series (see Fig. 2c).
c) The methodology used to calculate rainfall differences during the summer season is useless for the semi-arid and most of the mediterranean region, where it does not rain during this season.
d) Differences in temperature expressed as percentage during El Niño and La Niña episodes with respect to neutral ENSO conditions is not standard and hard to interpret in physical terms (¿how many °C correspond to the maximum value of +253.24% indicated in Table S3 for the T_{95} in the semi-arid region ?)
e) Differences at the seasonal scale of river discharge do not consider its seasonal delay in the response associated to snow melting during the spring and summer. In fact, regarding ENSO impacts on river discharges, particularly in the semi-arid and mediterranean regions, the maximum values in the annual cycle occurring during summer (DJF) are mostly conditioned by the ENSO state during the previous rainy season in winter. So, for these two regions at least the impacts of El Niño on river discharge in summer, when it is reached the maximum in the annual cycle, should be calculated with a delay of 6 months considering the occurrence of El Niño conditions during the previous winter.
f) Usefulness of results presented in column A of Figs. 4 and 5 are doubtful as they ignore the latitudinal and altitudinal differences in the ENSO impacts on temperature, rainfall and river discharge.
g) Results presented in panels of column B ignore the uneven relative distribution of "Andes" and "CR" stations in the three latitudinal regions. In particular, in the semi-arid zone most of the station are Andean, while in the humid-temperate zone most of the stations are classified as "coastal", as shown in Fig. 2.