

Reply to Reviewer 1

(original comments / our responses)

This manuscript offers a well-organized, interdisciplinary, and clearly written account of the occurrence, drivers, impacts, and projected changes in hyperdroughts in central Chile. It combines climate data, hydrological and cryospheric information, vegetation indices, social narratives, and model projections into a compelling narrative. The integration of biophysical and societal dimensions is particularly commendable. The manuscript is suitable for publication. My only suggestion is that the authors may briefly expand on the uncertainties associated with key datasets and modeling frameworks.

Reply: We thank the reviewer for her/his positive evaluation of this manuscript. It seems that assembling a large and interdisciplinary research team to address these high-impact events resulted in a well-balanced and interesting manuscript.

We greatly appreciate your suggestion on expanding on the uncertainty of key datasets, and we incorporated relevant material on this issue. To start, we added the following text in the first paragraph of section 2 (Data and methods):

“We acknowledge each dataset has some degree of uncertainty, as discussed below, stemming from errors in individual observations (e.g., McMillan et al. 2012). In most cases, however, we use monthly or annual averages that substantially abate random errors on virtue of the central limit theorem (e.g., Wilks 2011). On the other hand, the anomalies during the HDs are large, resulting in large signal-to-noise ratios to characterize these events (e.g., Chervin et al. 1974; Hosseinzadehtalaei et al. 2023)”

We commented on this issue for selected datasets. In particular:

- a. We described the type of rain gauges (mostly Hellman’s and tipping buckets). Both types are prone to wind-induced errors as large as several mm per hour when considering sub-hourly measurements (e.g., Habib et al., 2001), but keep in mind that here we use annual accumulations that effectively minimize the random errors (Villarini et al., 2008). Moreover, the use of several dozen stations along Chile and their spatial aggregation augments the confidence in this dataset to characterize year-to-year changes in the precipitation regime.
- b. We explained better the homogenization processes for the rain dataset (this was also asked by Rev. 2)
- c. We explicated that “fluviometric stations DGA measures the stage height (surface water elevation) and transforms this data into discharge using standard rating curves (e.g., Sauer 2002). Changes in the river cross section and non-uniform flow, among other factors, introduce uncertainty in the sub-daily discharge estimates (e.g., Hamilton 2008) that may result in large errors, especially during flooding events (McMillan et al. 2012)”. In the present work, however, we employed annual averages when enough daily data is available (see next) and focus on low discharge values during dry periods, when the discharge estimates are made in the range of validity of the standard rating curves.

- d. We commented on the potential bias and errors in ERA5 (with proper reference to studies elsewhere). We will also explain that we focus on anomalies (departure from long-term mean) during HDs, which at least removes bias in these products.
- e. We explained that ground water levels are measured with Dipmeters (electric Water Level Meters) that are highly accurate. Nonetheless, individual groundwater levels obtained in the observation wells may be affected by water extractions in nearby wells before or during the measurement visits. Once again, the focus on anomalies persisting over a year (or longer) and averaging several wells ensures that the signal of HDs upon ground water levels (several meters, see below) stands out against the errors present in individual observations.

All these additions, motivated by your comment, helped us to produce a more solid paper.
Thanks again!

CONTINUE.....

Reply to Reviewer 2

(original comments / our responses)

The manuscript provides a comprehensive and well-structured analysis of severe droughts in central Chile, referred to as hyperdroughts. It examines historical occurrences, recent events, and future projections, integrating climatic drivers with hydrologic, environmental, and societal impacts. Using dendroclimatology, the authors reconstruct drought occurrences over the past 600 years, revealing an increasing frequency of extreme dry spells in recent times. Projections from global circulation models indicate that drought severity in central Chile will likely intensify in the coming decades. The manuscript concludes with a compelling historical perspective, illustrating how past hyperdroughts have often acted as catalysts for significant societal and political transformations.

In my opinion, the manuscript is practically ready for publication. I only have a few comments that can be easily addressed in a minor revision.

Reply: We thank the reviewer for her/his positive evaluation of this manuscript. It seems that assembling a large and interdisciplinary research team to address these high-impact events resulted in a well-balanced and interesting manuscript. We plan to incorporate all your minor comments as follows, which helped us to clarify the text and correct some typos. Also note that we addressed the minor comments raised by the other reviewer by adding some comments/references on the uncertainties of the main datasets

L121-124: did the authors perform any procedure for homogenizing the data from different sources? To account for, e.g., the potential presence of different types of systematic errors?

Reply: Yes, the procedure includes quality control of daily precipitation data available from 1960 onward, using records from DMC, DGA, SERVIMET, and INIA. The approach follows a methodology like that described in Boisier et al. (2016). Monthly totals, computed from these datasets, were then concatenated with older (pre-1960) monthly records reported by DMC. However, no station codification existed to directly match stations across both datasets. Potential mergers were initially based on spatial proximity (locations within 10 km, due to the limited precision of older coordinates) and included station elevation data when available. The subset of stations likely to be paired was then reviewed and matched using station names and additional criteria (e.g., recognition of older stations located in landmarks such as lighthouses).

The following clarification was included in the revised manuscript version (lines 125-135, 1st paragraph of section 2.1):

“...Both data sources were merged into a single dataset, with some records from older and newer stations combined and treated as a single station. This homogenization was initially based on spatial and elevation proximity (within 10 km and 100 m of altitude), and was then refined by inspecting station names, allowing for the identification of small towns or specific locations (e.g., lighthouses).”

L136-138: did the authors double-check that individual rivers display consistent regimes before averaging out the flow series? The answer to this seems to be yes, the rivers display similar behaviors, based on Fig. 2b. I would suggest mentioning this explicitly in the text.

Reply: Yes, we checked that, and we added this text “The nine stations/basins are characterized by a nival regime with peak flow in early summer and with strong correlation when considering annual mean values (Masiokas et al., 2006)”. Also note that we are using annual mean values considering the hydrological year. (Lines 140-145)

L173-176: Before the bias correction, did the authors perform any downscaling?

Reply: No, we didn’t. We explicited this by altering the last paragraph of section 2.3: “No downscaling was applied and we simply regridded the original fields onto a 5×5 km² using the nearest neighbor. We then averaged the regridded precipitation output at grid cells in over the Chilean territory between 30-37°S to produce a 100-time series of modeled annual precipitation...”

Minor comments: Thanks for pointing them out.

L115: correct “the” in place of “their”. Corrected.

Fig. 2: the caption states that both the mean and median boxplot are shown, using solid and dashed lines. However, only one line is visible. Corrected....only shown is the median

L155-165: the word “reanalyses” is misspelled a few times as “reanalyzes” (the latter is a verb). Corrected.

L163: the acronym SST (sea surface temperature) is used here without prior definition, which is given few lines afterward. Added.

L249: “recorded” not suitable here, since the events were not recorded with any instrumentation, but “reconstructed” from dendroclimatology studies. Replaced.

Fig 3 caption (L269): panel name c) needs correction – currently it shows “b)”. Will be corrected.

L416: do you mean “per unit volume of water” instead of “per unit water”? Corrected.

Fig 10 caption (L432): correct “blue” to “red” Corrected.

L438: size of the cells (150-by-150) is not consistent with the size specified in the caption of Fig. 11 (L445). Corrected (150 is correct)

GDP values seem too small (e.g., L478, L504) Indeed.... these are low, since we are using per-capita GDP. Corrected!

Correct last-access date in the data availability statement – it currently shows last access: 20 September 2025. Corrected!