

Answer to Report #1 (Submitted on 30 Apr 2022) by Anonymous referee #2

For final publication, the manuscript should be accepted as is

Suggestions for revision or reasons for rejection (will be published if the paper is accepted for final publication)

I am satisfied with the responses to my comments. I just wonder if the considerable dimensions of the new Table 1 do not lead the authors to consider inserting it in the Appendix. I would do so, leaving some more synthetic information in Table 1.

Thanks for the comment. Yes, we considered inserting it as an appendix. However, since Table 1 seemed relevant for both referees, we had originally decided to keep it as part of the main manuscript. Given this comment and a comment from Referee #3 on the readability of the manuscript, we have followed this suggestion and moved the current version to the appendix and synthesized Table 1 as follows:

Table 1. Summary of the functions and methods by category included in CSTools. Prefix “CST_” refers to functions working on a specific object class called “s2dv_cube”. Asterisk indicates functions that are used in vignettes (see Appendix B for a detailed table).

Retrieval and transformation	CST_Load*, CST_Anomaly*, CST_SaveExp, CST_MergeDims, CST_SplitDims, as.s2dv_cube, s2dv_cube
Classification	CST_MultiEOF, CST_WeatherRegimes*, CST_RegimesAssign*, CST_CategoricalEnsCombination, CST_EnsClustering*
Downscaling	CST_Analogs*, CST_RainFarm*, CST_RFTemp, CST_AdamontAnalog, CST_AnalogsPredictors
Correction	CST_BEI_Weighting*, CST_BiasCorrection, CST_Calibration, CST_QuantileMapping, CST_DynBiasCorrection
Assessment	CST_MultiMetric*, CST_MultivarRMSE*
Visualization	PlotCombinedMap*, PlotForecastPDF*, PlotMostLikelyQuantileMap*, PlotPDFsOLE, PlotTriangles4Categories*

Answer to Report #2 (Submitted on 12 May 2022) by Referee #3, Matteo De Felice

accepted subject to minor revisions

Suggestions for revision or reasons for rejection (will be published if the paper is accepted for final publication)

This paper describes an impressive software package in terms of features. Given the complexity and the number of features provided by the package, the paper results a bit long and hard to follow. In general, I would suggest the authors to shorten the paper possibly:

- Reducing section 2.1, especially the first half
- Keeping only one use case and moving the other two to the supplementary

1. Reducing Section 2.1

We suspect the reviewer means Section 2.2.1 and not 2.1, since Section 2.1 is only 3 paragraphs long and describes the data structure of the package (which is essential in our opinion).

On the other hand, based on this comment and a similar comment from the other referee, we have reduced Table 1 and moved the current version to an appendix. Furthermore, the first paragraph in Section 2.2.1 has been removed.

2. Moving the use cases

We would like to keep all three use cases in the main document if possible. CStools already has a GitLab project and a CRAN repository where a reference manual documents all available functions. Rather than documenting the toolbox, the main purpose of this manuscript is to showcase the potential usability of CStools in a climate service context. Therefore, we consider that keeping just one use case in the main manuscript would lead readers to underestimate its flexibility.

Here, some additional comments:

- The authors mention EUROSIP in the first paragraph but it has been taken over by the C3S Multi-model system (see <https://www.ecmwf.int/en/about/media-centre/news/2019/c3s-multi-model-seasonal-forecasting-system-takes-over-eurosip>). I would suggest mention this one.

Changed.

- After the list of the categories at the beginning of Section 1.2, I would specify which ones are covered by CStools

All the items of the list are covered by CStools, except for the first one. The subsequent paragraph after the list of categories (beginning of Section 1.2) has been modified to:

“The primary aim of CStools is therefore to make post-processing methods (i.e. **correction methods for forecast calibration, classification methods for multi-model forecast**

combination or scenario selection, downscaling methods, and visualization tools) available in one coherent framework in order to facilitate analysis or the post-processing of data such that might be required by an impact model. Because additional steps are required, CStools also includes functions for **data retrieval and formatting as well as skill assessment** in order to facilitate the use of the toolbox.”

- The authors write "CStools, on the other hand, targets scientists interested in providing a climate product to some final users" but this sentence is unclear, what are exactly the differences between CStools and other tools that make it more suitable for "final users"?

The underlined sentence was added: “The main purpose of these different packages is the facilitation of research. CStools, on the other hand, targets scientists interested in providing a climate product to some final users. This is done by allowing the creation of complete post-processing chains, from data retrieval to the creation of high-quality datasets to feed impact models or tailored forecast visualization products.”

- The authors state that CStools is compatible with other packages, this point should be better explained.

CStools functions operate on data array objects. The array class is the same class used by other packages such as s2dverification, SpecsVerification, easyVerification and startR. Furthermore, CStools is also compatible with CSIndicators as the latter accepts s2dv_cube objects as inputs directly. If a package operates on a different class of objects (e.g. data.frame), some transformations will be required, thus breaking the compatibility. The following sentence has been adjusted:

“The CStools development guidelines have been designed to maximise compatibility with other libraries such as s2dverification, s2dv, SpecsVerification, easyVerification and startR, all of them designed to operate fundamentally with the same array class. Furthermore, CStools is also compatible with CSIndicators (Pérez-Zanón et al., 2021) as the latter accepts “s2dv_cube” objects as inputs.”

- In Line 192 some 'common guidelines' are mentioned: does it mean that they published specifications/requirements to follow to implement - for example - another input data format or another post-processing method?

The common guidelines, which are in the supplementary material, is a document that explains the most relevant aspects to consider when adding a new function to CStools: avoid duplication of methods already included in other software tools without justification, data formats and examples. We have added a reference to the supplementary material in the main text (2nd paragraph of Section 2).

- What is exactly the repository of CStools? The repository at <https://earth.bsc.es/gitlab/external/cstools> says that is the repository of the MEDSCOPE project.

Thanks for pointing this outdated file in the repository. Yes, this is the CStools repository. The README file has been updated to clarify this point and to include the reference to this manuscript, the link to the CRAN repository and some other relevant information.

- I would add a paragraph in section 2.1 giving some more details on the possibility to do lazy and distribute calculations using startR, that is a very important topic for climate scientists

We feel adding explanations on how to distribute calculations using startR would be lengthy and detract from the main point of that section. However, we agree that distribute computing is a very important issue, so instead we have added the following sentence pointing to the startR gitlab repository where one can find an example of a CStools calibration method integrated in a startR workflow:

“An example on how to use a CStools function in a startR workflow can be found in its GitLab repository (<https://earth.bsc.es/gitlab/es/startR>).“

- The fourth column in the Table 1 is a bit confusing, what is its meaning? For 's2dverification' I assume that its functions are directly called into CStools code, but what about the rows with empty values ('-')? What's the difference between '-' and 'adaptation to CStools'?

To improve the readability of the main manuscript, table 1 has been moved to Appendix B and substituted in the main text by a synthetic table:

Table 1. Summary of the functions and methods by category included in CStools. Prefix “CST_” refers to functions working on a specific object class called “s2dv_cube”. Asterisk indicates functions that are used in vignettes (see Appendix B for a detailed table).

Retrieval and transformation	CST_Load*, CST_Anomaly*, CST_SaveExp, CST_MergeDims, CST_SplitDims, as.s2dv_cube, s2dv_cube
Classification	CST_MultiEOF, CST_WeatherRegimes*, CST_RegimesAssign*, CST_CategoricalEnsCombination, CST_EnsClustering*
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Correction	CST_BEI_Weighting*, CST_BiasCorrection, CST_Calibration, CST_QuantileMapping, CST_DynBiasCorrection
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Visualization

PlotCombinedMap*, PlotForecastPDF*, PlotMostLikelyQuantileMap*, PlotPDFsOLE, PlotTriangles4Categories*

The fourth column of the table (now in Appendix B), aims to distinguish methods that are novel software developments included in CSTools from functions that are wrappers from other packages and existing software codes that have been adapted or re-coded to be included in CSTools. The original title of this column, 'Original code version', has been changed to 'Original development?'. The following possible expressions are used to fill the column:

- Yes: meaning that the function is a novel development
- Adaptation to CSTools: a version of the method is already available as a software function or software code but has been included in CSTools following the development guidelines. This is the case, for example, of the RainFARM downscaling method that exists as standalone Julia and R packages but has been adapted here to be part of CSTools.

The table has been reviewed and all the cells are now filled.

- Are the specifications of s2dv_cube described? Would it be possible for someone to create a function generating s2dv_cube objects that can be used straightly into CSTools?

Yes, the detailed description of the s2dv_cube is included in the supplementary material.

There is already a function generating s2dv_cube objects called 's2dv_cube' (see 2nd paragraph of Section 2.2.1).

- I would suggest removing the 'single but powerful' at the beginning of Line 280, I understand the enthusiasm but it seems a bit an exaggeration.

The expression has been removed.

- Does the function CST_MultiEOFs deal with ensembles (i.e. working directly with the members without using the ensemble mean)? How?

The CST_MultiEOF function works on multiple variables (e.g. geopotential at different levels, geopotential and temperature etc.). Typically it is applied separately to timeseries of individual ensemble members and not to the ensemble mean (applying it to the ensemble mean would also suppress a large fraction of the variability). In the present implementation it is applied to a series of fields in time (considering together both the forecast time and the starting dates), producing separate sets of EOFs and PCs for each other ensemble dimension. So if an ensemble of experiments with different starting dates and forecast times is provided for analysis, the result will be EOFs and PCs computed separately for each ensemble member.

The description in the manuscript has been adjusted as follows:

“The CST_MultiEOF function allows conducting Empirical Orthogonal Functions (EOF) analysis simultaneously over multiple variables for either each ensemble member or all the ensemble members concatenated altogether (i.e., it can be applied to each one of the ensemble members separately or to the whole ensemble).”

In general, I think the paper is relevant and well-done but, however, before publication I think it should be simplified to improve the readability, especially for non-climate scientists.

Thanks for your feedback. We really appreciate the time you dedicated to help us improve the readability.