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Deliverable D3.2

[Toolbox]

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1. OVERVIEW OF THE CSTOOLS PACKAGE

The toolbox developed in MEDSCOPE provides tools to exploit dynamical seasonal forecasts in order to provide information relevant to stakeholders. Although the tools are primarily thought/designed for seasonal forecasts, they can also be used for sub-seasonal or decadal forecasts. Written in the open source programming language *R*, **CSTools** is now publicly available on the [CRAN repository](#). The package contains approximately 50 functions, which can be divided in five broad categories: downscaling, verification, correction, plotting and basic functions.

Basic Functions

1. **CST_Load** - retrieves and aggregates forecast data from local file systems or from remote OPeNDAP servers and arranges it in a CSTools object. Can interpolate if necessary.
2. **CST_Anomaly** - computes anomalies relative to a climatology along selected dimension with or without cross-validation
3. **CST_SaveExp** - save CSTools objects of class 's2dv_cube' containing experiment data in NetCDF format. Useful to save data that have been post-processed with CSTools functions.
4. **CST_SplitDims** - splits a dimension in two.
5. **s2dv_cube** - this function creates a 's2dv_cube' object
6. **as.s2dv_cube** - converts data loaded using start*R* package or s2dverification load function into a 's2dv_cube' object.
7. **CST_MergeDims** - merges two dimensions into one.

Downscaling

1. **CST_Analogs** - performs a downscaling using Analogs.
2. **CST_RainFARM** - stochastic precipitation downscaling function based on the RainFarm methodology.
3. **CST_RFSlope** - computes spatial spectral slopes from a CSTools object to be used for RainFARM.
4. **CST_RFWeights** - computes climatological weights for RainFARM stochastic precipitation downscaling.
5. **CST_RFTemp** - downscales surface temperature using lapse-rate or a delta-bias correction compared to fine-scale climatology.
6. **CST_AdamontAnalogs** finds analogous data in the reference dataset to experiment data based on weather types

7. **CST_AdamontQQCorr** computes quantile-quantile correction of forecast data considering weather types
8. **CST_AnalogsPredictors** AEMET Downscaling method for Precipitation and maximum and minimum temperature based on analogs and considering synoptic situations and significant predictors.

Verification

1. **CST_MultivarRMSE** - calculates the RMSE from multiple variables.
2. **CST_MultiMetric** - calculates anomaly correlation coefficient, root mean square error, or the root mean square error skill score of individual models and multi-models mean.
3. **CST_MultiEOF** - performs EOF analysis over multiple variables.
4. **CST_EnsClustering** - performs clustering on members/start dates and returns a number of scenarios, with representative members for each of them.

Correction

1. **CST_BiasCorrection** - applies a simple bias adjustment technique
2. **CST_Calibration** - applies four types of member-by-member bias correction.
3. **CST_QuantileMapping** - provides a quantile mapping adjustment between a hindcast and observation.
4. **CST_BEI_Weighting** - computes the normalized weights for each member of the forecast using the probability density functions.
5. **BEI_PDFBest** - computes a probability density function from two probability density functions.
6. **CST_CategoricalEnsCombination** - converts a multi-model ensemble forecast into a categorical forecast by giving the probability for each category.
7. **CST_WeatherRegimes** - computes the weather regimes from a cluster analysis.
8. **CST_RegimesAssign** - performs the matching between a field of anomalies and a set of maps used as a reference.

Plotting

1. **PlotMostLikelyQuantileMap** - plot maps of most likely quantiles.
2. **PlotForecastPDF** - plots the probability distribution function of several ensemble forecasts.
3. **PlotCombinedMap** - plots multiple variables in a single map with the cylindrical equidistant latitude and longitude projection.
4. **PlotTriangles4Categories** - converts any 3-d numerical array to a grid of coloured

triangles. 5. **PlotPDFsOLE** - plots two probability density gaussian functions and their optimal linear combination.

The package also includes the description of each individual function through the typical R [documentation](#). An overview of the package is also available in a poster format [here](#). Guidelines on how to use the software and how to analyze climate data are also provided in the shape of vignettes, instructive tutorials demonstrating practical uses of the software with the discussion of the interpretation of the results. There are currently 10 vignettes:

- Downscaling precipitation with [RainFARM](#)
- Downscaling with [Analog](#)s
- Evaluate [multi-model scores](#)
- [Multi variable RMSE](#) computation
- [Weather Regimes](#)
- [Ensemble Clustering](#)
- Plotting with [PlotForecastPDE](#)
- Obtaining the [Best Estimate Index](#)
- Compute and visualize [Most Likely Terciles](#)
- [Data Storage and Retrieval](#) considerations

2. INSTALLATION

The publicly released version of CSTools can be installed from CRAN by simply typing the following in an R session:

```
> install.packages("CSTools")
```

and can be used by simply loading the package as follow:

```
> library(CSTools)
```