

## **CLIMADJUST: AN OPERATIONAL SERVICE TO ADJUST BIASES IN CLIMATE PROJECTIONS**

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### **RESUMEN**

Las proyecciones climáticas de los modelos climáticos globales y regionales suelen presentar sesgos respecto a las observaciones. Habitualmente, ajustar estos sesgos es el primer paso para obtener información climática accionable, que pueda utilizarse en los estudios de impacto. Sin embargo, este proceso de ajuste de los sesgos es altamente técnico y demanda recursos especializados en términos de infraestructuras de computación y conocimientos científico-técnicos.

Climadjust (<https://climadjust.com/>) es un servicio web desarrollado con la financiación y apoyo del Servicio de Cambio Climático de Copernicus (C3S), que implementa un servicio de ajuste de sesgos fácil de usar para los usuarios. El servicio ha sido desarrollado por Predictia -empresa centrada en el desarrollo de servicios climáticos- en colaboración con el Instituto de Física de Cantabria (IFCA-CSIC-UC). Climadjust proporciona recursos escalables en la nube para obtener proyecciones climáticas ajustadas para un área de interés, para datos de CMIP y CORDEX. En este proceso, los usuarios pueden (i) cargar sus propios datos de observaciones de referencia para ajustar las proyecciones climáticas, o elegir datos provenientes de ERA5-Land o WFDE-5, (ii) elegir entre seis técnicas de ajuste de sesgo de última generación, y (iii) validar los resultados a través del marco estándar desarrollado en la acción europea COST VALUE. El resultado es un archivo netCDF validado, listo para ser utilizado por los usuarios.

En esta ponencia, presentamos algunos casos de uso sectorial que han utilizado Climadjust, en sectores como la agricultura, la hidrología y el diseño de soluciones basadas en la naturaleza.

**Palabras clave:** servicio climático, ajuste de sesgos, proyecciones climáticas, participación de usuarios.

### **ABSTRACT**

Climate projections obtained from global and regional climate models usually exhibit biases: systematic deviations from observations. Adjusting these biases is typically the first step towards obtaining actionable climate information to be used in impact

studies. However, this bias adjustment process is highly technical and resource-demanding, in terms of data and computing infrastructures, and technical knowledge. Climadjust (<https://climadjust.com/>) is a web service developed with the support of the Copernicus Climate Change Service (C3S), that implements user-friendly bias adjustment for climate projections. The service was developed by Predictia —a company with a strong focus on climate services development and climate modelling— in collaboration with the Spanish Research Council (CSIC).

Climadjust provides scalable cloud resources to compute bias-adjusted climate projections from the ensembles of CMIP and CORDEX datasets over customised areas of interest. In this process, the users are able to (i) upload their own dataset of observations to adjust the climate projections, or choose among reference datasets such as ERA5-Land or WFDE-5, (ii) choose among six state-of-the-art Bias Adjustment techniques, and (iii) validate the results through the standard framework developed in the European VALUE COST Action. The output is a validated netCDF file, ready to be used by the climate impact modellers.

This climate service is targeted at the tail end of the downstream market of climate services, and currently it has over 250 registered users. We present some sectoral use-cases that have used Climadjust, in fields such as agriculture, hydrology and the design of nature-based solutions for climate change adaptation.

**Key words:** climate service, bias adjustment, climate projections, user engagement

## **1. INTRODUCTION**

Both Global and Regional Climate Models (GCMs, RCMs) have systematic errors (biases) in their output. These biases in climate models can be caused by a range of factors (Palmer, T. N., 2011): limited spatial resolution (coarse grid sizes), simplified thermodynamic processes and physics or incomplete understanding of the global climate system. Impact models, such as hydrological models, are often very sensitive to biases in their input data, which can lead to unrealistic results.

To overcome this problem, a range of bias adjustment methods have been developed. All of these methods make use of observational (or reference) datasets, to adjust the biases of the climate models, through statistical algorithms.

While these bias adjustment techniques are commonly used among the climate modelling community, it is not always the case for the climate impact assessment community (Zscheischler, 2019). There are several barriers for the implementation of bias adjustment techniques that explain this gap in use of Bias Adjustment techniques:

- Awareness: there's a lack of awareness among the impact community of the need to adjust the biases from the outputs.
- Technical: Managing large climate datasets requires access to computing infrastructure, handling specialised packages (e.g. Climate4R, xarray) as well as handling information in specific formats that are not widely used outside the climate modelling community (e.g. netCDF).
- Knowledge: developing sound climate analysis requires specialised personnel that is not always easy to find or hire.

To lower some of these access barriers, the Copernicus Climate Change Service funded Climadjust (climadjust.com): a web service to apply bias adjustment to climate datasets. This communication presents the service as well as several use cases, to showcase the potential and different uses for bias adjusted climate projections.

## 2. METHODS

### 2.1. Climadjust architecture

As a web service, Climadjust architecture was designed with two objectives in mind: stability of service and scalability. The service runs on the cloud, on a commercial service that allows the deployment of Virtual Machines on-the-go, scaling up according to the users' demands. On the architecture specified in Figure 1, three elements are key to Climadjust:

- **Computing engine:** coded in Python and including Climate4R, the R package used to perform the bias adjustment.
- **Data Sources:** the data included in the platform comes from trusted sources such as Copernicus Climate Data Store or ESGF. In addition, it allows the users to upload their own reference datasets.
- **Storage System:** the data is stored in commercial cloud storages, such as Google Cloud. The data is mirrored on two different storage services, to have a backup service in case of unavailability of the main storage service.

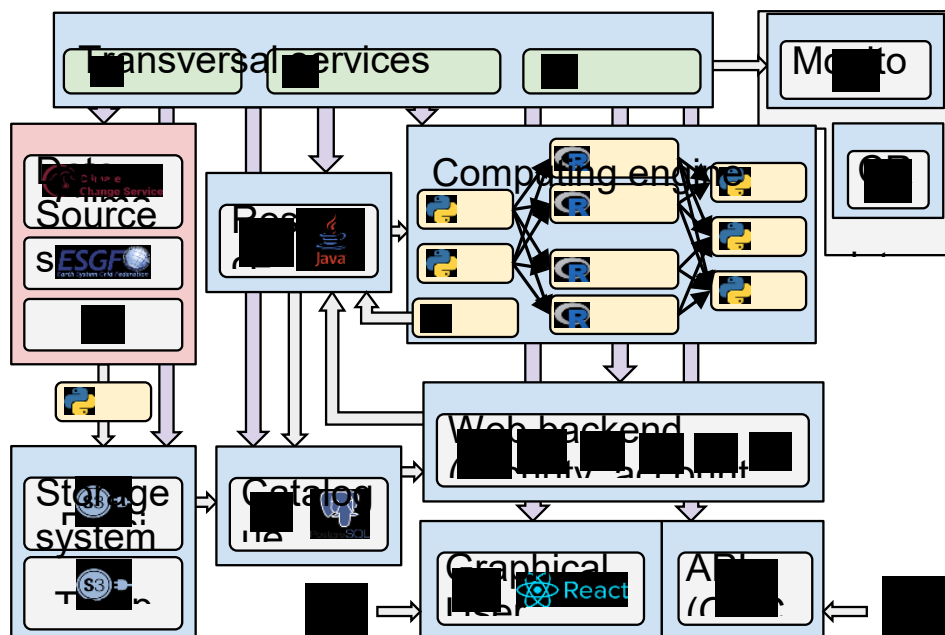


Fig. 1: Architecture of Climadjust

### 2.2. Climate4R: an R-package to manage climate data

At the core of Climadjust architecture lies Climate4R: a bundle of R packages for transparent climate data access, post-processing (including data collocation and bias adjustment/downscaling) and visualisation. The package is developed, maintained

and updated by the Santander Meteorology Group. Climadjust makes use of the 6 state-of-the-art, bias adjustment methods in this package. These methods were selected among a wide range of bias adjustment methods, due to they are used by the IPCC on the AR6, specifically on the WGI report. The user can select one of these methods and fine-tune it by adjusting some specific parameters (e.g. fit distribution, wet threshold)

### 2.3 Storage & Scalability

Climadjust provides access to climate data, both for climate projections as well as reference datasets. Overall, this represents 22 TBs of climate information, stored in two cloud services. This duplication of storage is necessary to provide a more stable service, by providing a main storage and a back-up. The storage providers are commercial cloud providers (Scaleway, Google Cloud). The publicly available datasets in Climadjust are listed in the table below.

Reference datasets in Climadjust	Climate models in Climadjust
ERA5-Land	CMIP5
WFDE5 CRU	CMIP6
WFDE5 CRU + GPCC	EURO-CORDEX
Iberia01	Other CORDEX domains (on demand)

*Table 1: Datasets publicly available in the service*

All of the data available in Climadjust comes from trusted and reliable sources: Copernicus Climate Data Store and Earth System Grid Federation.

### 2.4. Graphical Interface & guided process

To target directly one of the access barriers (the technical one), the service can be operated entirely using a web interface that guides the process of setting up a bias adjustment experiment in 7 simple steps. The interface and the visual identity for Climadjust were designed by Mubien, a design agency specialised in corporate identities and UX (User Experience).

### 2.5. API Access

In addition, a non-dismissable portion of the user base has ample technical background, being accustomed to code regularly. Therefore, Climadjust can be accessed as well through API. This was deemed necessary to reach those users, mainly consultancy companies, that already have a data pipeline in place and need to integrate external services.

### 2.6. Validation metrics for bias adjustment: VALUE: COST Action ES1102

One of the key steps in the climate data journey is the validation of the post-processed data. To follow a standardised approach towards validation, Climadjust provides the user with the validation metrics defined by the COST Action VALUE, that took place between 2012 and 2015, and established a validation standard for downscaling and bias adjustment methods.

## **2.7. Gathering a user base & User Research**

Climadjust as a SaaS service was fully operational within 6 months after the start of the project. One full year was dedicated to gathering a user base for Climadjust and user engagement. This provided a user base of over 250 registered users and delivered over 40 user interviews. The information gathered in these interviews informed a user needs database, that informed different improvements during the lifetime of the project, and will inform future developments of the tool. In addition, these contacts with users served to clarify the details of specific use cases that use Climadjust as their climate data provider. Three of these use cases are explained in more detail below.

### **1. Use-case 1: IHCantabria**

IHCantabria is a research centre focusing on hydrology research and climate change impacts. They oversee, manage and coordinate multiple research projects on a national and international dimension. As such, several of their research projects (e.g. ALICE, DRYvER), needed high resolution climate projections of several climate indicators. They used Climadjust to produce a final dataset that can be used across projects.

### **2. Use-case 2: Yale University**

In the context of a master's thesis involving soil carbon and nitrogen dynamics, the Yale Institute for Biospheric Studies needed climate change projections actionable at a local level. The projections were needed for 4 different locations around the world: Kenya, Argentina, inner Mongolia and northern Colorado.

### **3. Use-case 3: Wine sector**

To directly target end-users on a very specific sector, the Climadjust communication strategy involved developing its own use cases showcasing the potential uses for the service. One of the most sensitive economic sectors to climate change in Spain are wineries and vineyards. To target this sector, the team computed the future evolution of a specific agroclimatic index (i.e. the Winkler index) for the Rioja Designation of Origin.

## **3. RESULTS**

Climadjust currently has 278 registered users, spanning across different sectors, as shown in the graph below.

Users classified by sector - March 2022

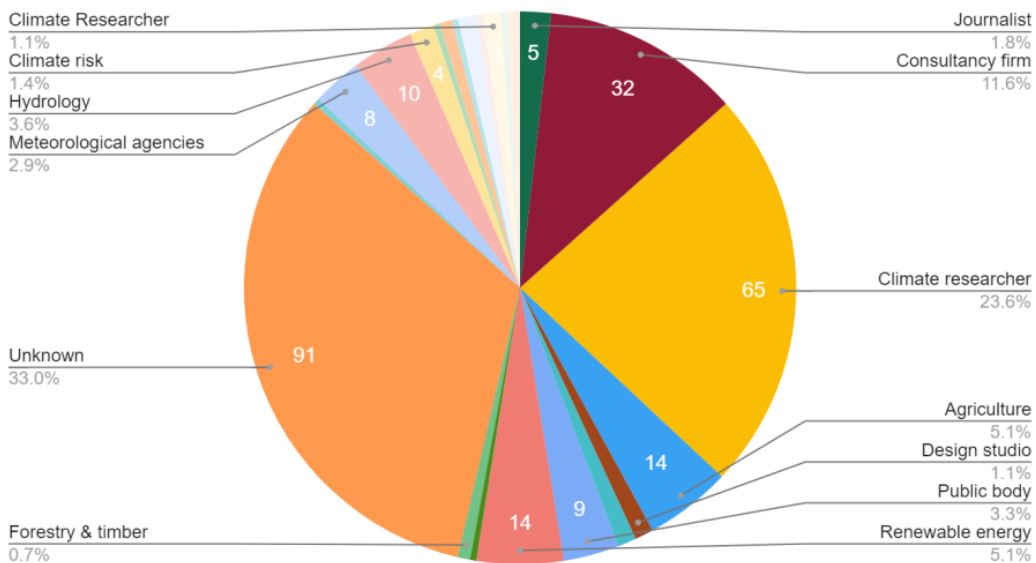


Fig. 2: Typology of users, classified by sector

As expected, a representative percentage of users (23.6%) are climate researchers, since bias adjustment is a very specific post processing technique. However, the communication actions brought users from different backgrounds on board. The more important categories are consultancy firms (11.6%), agriculture (5.1%), and renewable energy (5.1%). In addition, a third of the users couldn't be tied to a specific sector, since their registration email was not institutional (gmail, yahoo and other personal mail services).

**1. Use-case 1: IHCantabria**

Using Climadjust, the IHCantabria was able to produce climate datasets covering several regions in Northern Spain (Galicia, Asturias, Cantabria, Euskadi, with 1 Km spatial resolution. The adjusted data are calculated under two different climate change scenarios, RCP 4.5-8.5, and correspond to over 20 different variables and derived indexes. Overall, 1 TB of final data was produced.

**2. Use-case 2: Yale University**

In this case, the five climate models from CMIP6 were considered. The selection of the models followed the recommendations of ISIMIP (ISIMIP3, 2022), so the variability of climate models is well represented. The Bias Adjustment method used was ISIMIP3, and the reference data were provided by the University of Yale.

**3. Use-case 3: Wine sector**

The Winkler index was calculated using the bias adjusted temperatures obtained from Climadjust. For that, the reference dataset was Iberia01 (Herrera, 2019), and the bias adjustment technique chosen was ISIMIP3. The climate models to adjust were the full ensemble of EURO-CORDEX regional models provided by Copernicus Climate Data Store (C3S, 2019)

The bias adjusted data reproduce the historical records, as well as the results provided by other studies (Fundación Biodiversidad, 2019). These preliminary results were presented and well received in sectoral platforms, such as the Spanish Technological Wine Platform.

#### **4. DISCUSSION**

The service has been well received by the climate research community: the number of user uptake is significant, with over 250 users, and the information received by climate researchers in the User Research interview is positive. For users working in climate change impacts, the situation is slightly different: while they see the value in Climadjust, as it simplifies the process of getting actionable climate projections, they still face different barriers. This community is not monolithic in their needs, but multifaceted. Some users have a need to convert netCDF files to other formats such as CSV; others need to go beyond daily resolution, to have hourly resolution; and others need structured reports or more complex climate indices for their field. This set of varying needs is consistent with the literature on user engagement in climate services. To tackle such needs, Climadjust needs to evolve to implement new features: format conversion, visualisation of the data produced, tailored reports...

#### **ACKNOWLEDGEMENTS**

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