MINISTRY OF MINES AND ENERGY – MME

NATIONAL ELECTRIC SYSTEM OPERATOR - ONS

META PROJECT

Technical Assistance Project for the Energy and Mineral Sectors

WORLD BANK

INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT – IBRD

Loan: **9074 - BR**

Term of reference for Subproject 23-3 of the STEP Acquisition Plan – Consultancy-3

Studies of consecutive years of extreme events: major floods and droughts and related phenomena focusing on recent years. Meteorological characterization, precursor and subsequent formation mechanisms, analogues identification techniques and application to present conditions.

October/2023

SUMMARY

REFERENCE TERM - TDR

Studies of consecutive years of extreme events: major floods and droughts and related phenomena focusing on recent years. Meteorological characterization, precursor and subsequent formation mechanisms, analogues identification techniques and application to present conditions.

1. CONTEXT

The National Electric System Operator (ONS) is the body responsible for coordinating and controlling the operation of electrical energy generation and transmission facilities in the Brazilian National Interconnected System (SIN) and for planning the operation of the country's isolated systems. As part of efforts to promote the development and technical training of the Brazilian energy sector, the ONS is part of the second stage of the project of Technical Assistance for the Energy and Mineral Sectors, also referred to as the META II Project. One of the projects supported by the META II Project is Subproject 23, which seeks to make a study to identify the causality of changes in flow rate regimes and in the major meteorological variables of interest for the SIN operation. The SIN is made up of four subsystems in the South, Southeast/Midwest, Northeast and most of the North regions, which present a diversity of climate regimes.

According to ONS data, 72% of the average energy produced in Brazil in 2022 came from hydroelectric plants, even with the growing share of photovoltaic and wind generation, which, together, corresponded to 15% of the SIN generation. As the SIN operation is linked to the weather conditions, and in particular to the precipitation volume over the river basins, the planning and scheduling of the electroenergy operation, as well as the expansion planning, depend on the forecast/generation of inflow scenarios for all of the SIN's hydroelectric developments, from the first operational week to horizons of five to ten years ahead. Therefore, understanding the causes associated with any change in climatic conditions is of the utmost importance, since systematic inaccuracies in flow rate forecasting can increase energy costs or jeopardize proper SIN planning.

Within the scope of project META II, the Joint Venture (JV) formed between companies PSR and CLIMATEMPO was contracted to coordinate Subproject 23. Table 1 shows the group of products provided for in this subproject. **Consultancy-1** (JV) is in charge of the execution of Products in Grouping 1 (Products 1, 2, 3, 4 and 12). The Product in Grouping 3 (Product 6), which is the scope of this TdR, will be performed by **Consultancy-3**. Product 6 will be a requirement for Product 8, to be performed by **Consultancy-5**.

Table 1 – Bidding procedures for Subproject 23 of the ONS, considering that the bidding procedure of Consultancy-3, which is the scope of this TdR, are the Activities and Products of Grouping 3.

Grouping	Product	Activity	Bidding Procedure
1	----------	**COORDINATION**	**Consultancy-1 (Coordinator Joint Venture PSR and CLIMATEMPO)**
	Product-1	**Literature Review**	
	Product-2	**Collection and Analysis of meteorological data with long observation periods in the SIN**	
	Product-3	**Collection and Analysis of Data from Coupled Precipitation Forecast Models, Other Meteorological Variables and soil use (considering series obtained per paleoclimate)**	
	Product-4	**Preliminary assessment of weather variability/change in available meteorological and hydrological series**	
2	**Product-5**	**Diagnosis/assessment of Regionalization of a Precipitation Forecast Model and Other Meteorological Variables**	**Consultancy-2 (Bidding Procedure in progress)**
3	**Product-6**	Studies of consecutive years of extreme events: major floods and droughts and related phenomena focusing on recent years. Meteorological characterization, precursor and subsequent formation mechanisms, analogues identification techniques and application to present conditions.	**Consultancy-3 (Purpose of this TdR)**
4	**Product-7**	**Paleoclimatology Studies**	**Consultancy-4 (future bidding procedure)**
	Product-8	**Definition of More Representative Climate Indices for the Oceans/Atmosphere**	**Consultancy-4 (future bidding procedure)**
	Product-9	**Study of Possible Causes and Possible Predictability of Change/Maintenance of Climate Indices and their**	**Consultancy-4 (future bidding procedure)**

		Effects on Flow Rates and Meteorological Variables	
	Product-10	**Analysis of Climate Variables and Correlation structures which can be Incorporated into SIN Operation and Expansion Planning Models.**	**Consultancy-4(future bidding procedure)**
5	**Product-11**	**Methodology for Estimating Monthly Hydrological and Meteorological scenarios Using Climate Information**	**Consultancy-5(future bidding procedure)**
1	**Product-12**	**Final Report of the Subproject**	**Consultancy-1 (Coordinator Joint Venture PSR and CLIMATEMPO)**

The first stage of this subproject performed by **Consultancy-1** (JV) was the extensive literature review on the latest results of the impacts of natural weather variabilities, climate changes in Brazil and changes in land use in the SIN river basins (Product 1 on Table 1). Furthermore, the implementation of this subproject includes the collection and analysis of hydrometeorological databases with long periods of observation in the SIN, which is Product 2. This product encompasses data from hydrometeorological stations, satellites and reanalysis of several different meteorological variables, such as precipitation, temperature, wind, sea surface temperature, among others, as shown in Annex I. The subproject also includes the collection and analysis of data from coupled precipitation forecast models, other meteorological variables and soil use (including series obtained per paleoclimate), which forms Product 3 (Annex II). Finally, Product 4 includes the preliminary assessment of climate variability/change in the available meteorological and hydrological series.

The instrumental data has been reviewed and shows a change in the hydrological cycle in river basins located in the eastern portion of Brazil, with a tendency of reduction of precipitation and the number of consecutive rainy days (e.g. BEZERRA et al., 2019; HAGHTALAB et al., 2020; ÁVILA-DIAZ et al. 2020; SHIMIZU; ANOCHI; KAYANO, 2022). This tendency also shows in the series of SIN natural flow rates over the last 20 years, which point to a significant reduction in inflows in the river basins of rivers São Francisco, Doce, Mucuri, Jequitinhonha, Paraguaçu and Parnaíba, and also in the headwater basins of rivers Tocantins, Grande and Paranaíba. On the other hand, studies have shown a strengthening of the hydrological cycle in parts of the Amazon basin since the 1970s (GLOOR et al., 2013; ESPINOZA et al., 2019; HAGHTALAB et al., 2020), as well as an increase in inflows in the basins of the South and Midwest regions, and in the state of São Paulo.

A recent study to detect possible forcings of changes in precipitation performed with numerical simulations of the Detection and Attribution Model Intercomparison Project (DAMIP), which make up the sixth stage of the Coupled Model Intercomparison Project

(CMIP6), suggested that these tendencies may be associated with the natural variability of the weather system and/or with the increase in the concentration of greenhouse gases and aerosols (SHIMIZU; ANOCHI; KAYANO, 2022). Furthermore, the changes in rainfall regimes may also be related to variations in sea surface temperatures (SSTs) in the Pacific Ocean on intra-seasonal (Madden-Julian Oscillation, MJO), inter-annual (El Niño Southern Oscillation, ENSO) and decadal (Pacific Decadal Oscillation, PTO) scales, to the strengthening of the Walker circulation (BARICHIVICH et al., 2018; SHIMIZU; ANOCHI; KAYANO, 2022), to the SST in the Tropical Atlantic (GLOOR et al. 2013), and to the influence of the Atlantic Multidecadal Oscillation (AMO, KAYANO et al., 2016; JONES; CARVALHO, 2018).

The detection of extreme climatic events and the associated phenomenology is of special importance for understanding the meteorological phenomena that influence precipitation and other meteorological variables in Brazil on different time scales and, consequently, the regime of precipitation and flow rates in river basins with hydroelectric facilities which are part of the SIN. These events may be studied by calculating several indicators of climatic extremes, including those listed in Annex III. These indicators are calculated from data on temperature, precipitation, wind speed, humidity, among others, and provide information on the magnitude, frequency and duration of such extreme events. Thus, through a database validated for Brazil, it becomes possible to study extreme climate events such as the 2021 water crisis, and to identify the climatic causes and phenomena that preceded and followed such events.

This brief contextualization shows the importance of studying extreme climatic events and the associated phenomenology, in order to show possible ways of adapting/mitigating future water crises, optimizing and making SIN planning more predictable from a climatic point of view.

2. JUSTIFICATION

The study of extreme events (major floods and droughts) and the associated phenomenology can provide greater understanding on the causes of changes in precipitation and flow rate regimes in the river basins which are part of the SIN, in order to assist the adaptation and mitigation in scenarios of water scarcity. The knowledge of the phenomena associated with climate variability in each region of the SIN and on what the future behavior of precipitation patterns and other variables may be over a 5-to-10-year horizon will help improve planning for the Brazilian electricity sector.

3. PURPOSE

The purpose of **Consultancy-3** is to perform a study of consecutive years of extreme events, including major floods and droughts, in addition to the associated phenomenology in the main regions of interest to the SIN, by using Products 1, 2, 3 and 4, and other databases that **Consultancy-3** deems necessary and to which they have access.

Specific purposes are: i) Analysis of extreme indicators and identification of associated meteorological phenomena; ii) Development of a method for classifying and identifying situations similar to extreme events based on historical data.

4. SCOPE

In the specific case of this TdR, which addresses the contracting of **Consultancy-3**, they expect to obtain Product 6 in Table 2 below.

5. EXPECTED RESULTS & PRODUCTS

During the contracting period, the product specified in Table 2 must be provided.

Table 2 – Product to be provided by Consultancy-3.

Products	Description
Product 6	Study report on extreme events (major floods and droughts, heat/cold waves, among others) and associated phenomenology in the regions of interest to the SIN (Brazilian territory, river basins, South America) observed from the 1970s onwards, including at least: ● Description of the state of the art of studies on the occurrence of extreme events and associated phenomena, including methodologies used to identify them, emphasizing the applicability of different methodologies taking into account the variable and time scale used to define the event. ● Definition of indicators to be calculated, with selection of extreme events (dry/rainy periods, heat/cold waves, among others) for large Brazilian regions or basins ● Meteorological characterization* of extreme events (major floods and droughts, heat/cold waves, among others) considering at least the major flood events of 1979 (São Francisco) and 1982/1983 (Paraná river basin) and major droughts: 2000/2001 (Southeast), 2014-2021 (Northeast and Southeast). ● Development of a method for identifying similar events ● Final Report

Product 6 will be provided through 4 monthly partial reports and a final report, in accordance with Table 3.

Table 3 – Delivery route for Product 6: requirements and type

Product (code)	**Requirement**	**Type**
Partial Report-1 (6.RP1)	-	Technical report
Partial Report-2 (6.RP2)	6.RP1	
Partial Report-3 (6.RP3)	6.RP2	
Partial Report-4 (6.RP4)	6.RP3	
Final Report (6.RF)	6.RP4	

6. SCOPE OF WORK AND PROJECT BOUNDARIES

The activities that the contractor must perform for providing Product 6 are listed below. For the listed activities, the database of subproject 23 (Products 2 and 3) will be provided to **Consultancy-3**. The entire structure of such a database is described in Annex IV.

Product 6 - Study of extreme events and associated phenomena

- Based on the knowledge presented in the technical bid, the consultant must deepen the description of the state of the art on the occurrence of extreme events and associated phenomena in the regions of interest to the SIN (Brazilian territory, river basins, South America).
    - Summary of the main studies performed on the topic, including the works of Coelho et al. (2012), Cavalcanti et al. (2017), Marengo et al. (2017), Shimizu, Ambrizzi and Liebmann (2017), among others.
    - Inclusion of studies and description of methodologies for calculating indicators of extreme events, emphasizing their applicability, taking into account the variable and time scale used to define the event.

- Analysis of indicators of climate extremes and associated phenomena.
    - Selection of the most appropriate databases for indicators of climate extremes in the SIN regions based on the criteria of time period (long or short time series), spatial resolution and type of data (station, satellite, reanalysis).
    - Definition of indicators to be calculated, with selection of extreme events (dry/rainy periods, heat/cold waves, among others) minimally defined for large Brazilian basins in the case of precipitation/flow rate and for Brazilian regions in the case of other variables focused on monthly to seasonal scales
    - Presentation of a table with the events selected using the defined indicator(s)
    - *Meteorological characterization of selected events:
        1. Identification of favorable/unfavorable low-frequency climate factors, considering different climate scales (e.g., decadal, seasonal, monthly) using climate indices (e.g., PDO, AMO, MEI, ONI, TNA, TSA, MJO, IOD, etc.) and analysis of atmospheric circulation and associated anomalies based on the analysis/reanalysis products and variables shown in Product-2
        2. Comparison of the results obtained in item 1 with the characteristics of atmospheric circulation from years whose relevant indices show a behavior which is similar to those of the events selected and identified in 1
        3. Synoptic analysis during the peak and/or main event identified in 1, with characterization of the main sources of low-frequency variability and the influence of these events on meteorological systems such as the South American monsoon, frontal systems, South Atlantic Convergence Zone (SACZ), South Atlantic subtropical high, low-level jet, among others.
        4. Identification of precursor formation mechanisms on seasonal/monthly and synoptic scales using analyzes/variables which are relevant to such time scales
        5. Identification of subsequent formation mechanisms on seasonal/monthly and synoptic scales using analyzes/variables which are relevant to such time scales

- Development of a method for identifying similar events (analogues)
    - Definition of a methodology for identifying similar events, including analysis of recurrence time, frequency and intensity of extremes.
    - Analysis of composites of similar events and associated phenomenology
    - Application of a conceptual model (e.g., stochastic models, neural network, AI, etc.) to test the method of identifying similar events in an independent database.

- Preparation of the Final Report containing the assessment and the inter-relationship of all information and results obtained, as well as the conclusions and general recommendations associated with them.

7. DEADLINE/SCHEDULE

The deadline for the consultancy and delivering the product, described in item 5, is within 150 days. Table 1 below shows the products provided for **Consultancy-3**, their durations and estimated percentage of the amount to be paid for each product provided.

Table 1 – Products provided for Consultancy-3, durations and estimated percentage.

Product	Quantity	Duration	Value of the agreement
6.RP1	1	1 month	15%
6.RP2	1	1 month	15%
6.RP3	1	1 month	15%
6.RP4	1	1 month	15%
6.RF	1	1 month	40%

8. TEAM QUALIFICATION AND SPECIFICATION

8.1 Key Team

This qualification and specification (Table 2) addresses the minimum key team to be part of **Consultancy-3** to fulfill the services contracted in Subproject 23, according to the activities provided for in Item-6. Key team professionals will be assessed based on the evidence presented in their CVs. The know-how and experience required for key team positions must be evidenced through professional performance, scientific articles, participation in research and R&D projects, and program patents. It should be emphasized that the evidence presented must be linked to the services/subjects that are the purpose of this subproject.

Table 2 – Key Team Profile of Consultancy-3

Qty	Station	Training	Required Experience	Duties
01	Coordinator	Higher education in Engineering/Mathematics /Physics/Meteorology, with a postgraduate	Minimum of ten (10) years in studies and research in the area; and experience in	General coordination of the project. Execution of product 6

		degree in areas related to the agreement purpose (hydrology/climatology/ meteorology/statistics) Fluency in English	coordinating and supervising research projects linked to the analysis of extreme events and statistical methods	
01	Technical leader	Higher education in Engineering/Mathematics /Physics/Meteorology/statistics with a postgraduate degree in areas related to the agreement purpose. Fluency in English	Minimum of ten (10) years in studies and research linked to the analysis of extreme events and statistical methods	Definition of technical teams and proposed schedule. Coordinate studies and issue opinions and technical reports, follow up and analyze the planned product. Execution of product 6
02	Executors	Higher education in Engineering/Mathematics /Physics/Meteorology/Computer Science/Statistics.	Minimum of five (05) years in studies and research in the area of interest to the study.	Execution of product 6

8.2 Support team

Consultancy-3 may define, at their discretion, the make-up of the support team to support the performance of activities of Product 6. The support team is a team of professionals provided by the consultant to perform part of the services together with the key team, as per this TdR. Therefore, the size of the support team must be described in the technical bid.

8.3 Required Consultant Profile

For this subproject, the contractor must be experienced in the following requirements:

(i) studies and/or projects and/or research on the occurrence of extreme events (major floods and droughts, heat/cold waves, among others), analysis and meteorological characterization of associated phenomena;
(ii) studies and/or projects and/or research on indicators of climate extremes and associated meteorological phenomena;
(iii) studies and/or projects and/or research on methods for identifying similar events
(iv) studies and/or projects and/or research in conceptual modeling, statistics, in addition to knowledge in artificial intelligence and machine learning techniques

In order to prove the aforementioned requirements, the consultant must present, in their technical bid, only the latest services (last 10 years) which are somewhat associated with the requirements and services requested in this TdR. It should be emphasized that the services presented must only be provided by the consultant as a company, not by their experts, either working privately or for other companies.

9. FORM OF PRESENTATION OF PRODUCTS

The products shall be provided in Portuguese, in the form of a report, electronically, according to the following format:

- Compositions: MS Word® 2013 or later version, with delivery of the file in ".doc"/".docx" format;
- Spreadsheets, Charts and Tables: MS Excel 2013 or later version;
- Pictures in general: JPG, GIF, BMP, TIFF or PNG;
- Presentations: MS PowerPoint 2013 or later version;
- Database: in accordance with the structure and specifications established in Annex-IV.
- Products in the form of Reports must display the appropriate logos, to be inserted in the following order: ONS, META Project, World Bank and MME/Federal Government. A template file will be provided to the contractor in ".doc"/".docx" format.

Any electronic spreadsheets developed must be provided unlocked with no editing restrictions.

In addition to said logos, the following information must be informed in the product/report: Research/Product/Work performed with funds from Loan Agreement No. 9074-BR, formalized between the Federative Republic of Brazil and the International Bank for Reconstruction and Development - IBRD, on July 21st, 2021.

10. PAYMENT METHODS

The estimated percentage of the total value of the Agreement, for each product, is provided in item 7 herein. Payment methods, as well as deadlines for delivery and approval of the product will be linked to the Contract Draft, an instrument which is part of the Invitation to Bid.

11. SUPERVISION

The Technical Supervisory Committee (TSC) for the activities provided for in this TdR will be formed by at least three full members and three alternates, linked to the ONS and to JV PSR-Climatempo. The JV PSR-Climatempo and the ONS shall be responsible for the following duties for the activities provided for in this TdR:

JV PSR-Climatempo:

- Management of information, basic data and supplies to be provided for Consultancy-3;
- Analysis and assessment of data and products received from Consultancy-2;

- Arrangement for workshops/meetings with preparation of records along with Consultancy-3;
- Issuance of technical opinions relating to studies and products received from Consultancy-3.

ONS:

- General supervision of the terms of the agreement to be established with Consultancy-3;
- Supervision of activities and interaction between JV PSR-Climatempo and Consultancy-3;
- Assessment and final acceptance of products received from Consultancy-3.

The beginning of the works, as well as the presentation of the products provided for herein must be preceded by a meeting with the TSC for general guidance on the process and monitoring by Consultancy-3.

During the performance of Consultancy-3 activities, meetings shall be held for follow-up and direction.

12. AVAILABLE SUPPLIES AND ELEMENTS

In order to prepare this bidding procedure, the ONS shall provide, through JV PSR-Climatempo, the Products 1, 2, 3 and 4 previously detailed in item 1 and in annexes I and II.

13. TRAINING NEEDS

Considering the type of products expected (reports), there is no need for any training.

14. WORLD BANK ENVIRONMENTAL AND SOCIAL FRAMEWORK

All activities supported by the project, including studies to propose policies and regulations, must be analyzed in accordance with the World Bank's Environmental and Social Standards, which establish guidelines for identifying, assessing, mitigating and managing potential risks and impacts associated with projects funded by the Bank.

The adoption of the Environmental and Social Standards aims to support borrowers in adopting international best practices related to environmental and social sustainability, fulfilling their national and international environmental and social obligations, as well as increasing non-discrimination, transparency, participation, accountability, governance and improvement of projects' sustainable development outcomes through ongoing stakeholder engagement. In addition to the World Bank Environmental and Social Framework, the World Bank Group's Environmental Health and Safety Guidelines (IFC-EHSGs) shall be complied with, including specific guidelines for the mineral, power, and oil and gas industries.

The preparation of the work should consider the World Bank's Environmental and Social Framework, which became effective on October 1st, 2018, assessing potential social and environmental impacts of subprojects, whenever necessary. The most relevant standard for the concerned Subproject 23 is Environmental and Social Standard 2 - Working Conditions and Workforce of the team that will perform the studies.

15. INSTITUTIONAL AND ORGANIZATIONAL ARRANGEMENTS

Subproject 23 shall be managed by organizational structures linked to the Brazilian Ministry of Mines and Energy (MME) and to the Brazilian National Electric System Operator (ONS), as determined by the Operational Manual for the Project – MOP, available online at the MME website (www.mme.gov.br).

At the MME, the project will be managed by the Project Management Committee (CGP) and the Central Project Management Unit (UGP/C).

At the ONS, it will be managed by the Sectorial Project Management Unit (UGP/S), as per Figure 1~~Figure 1~~.

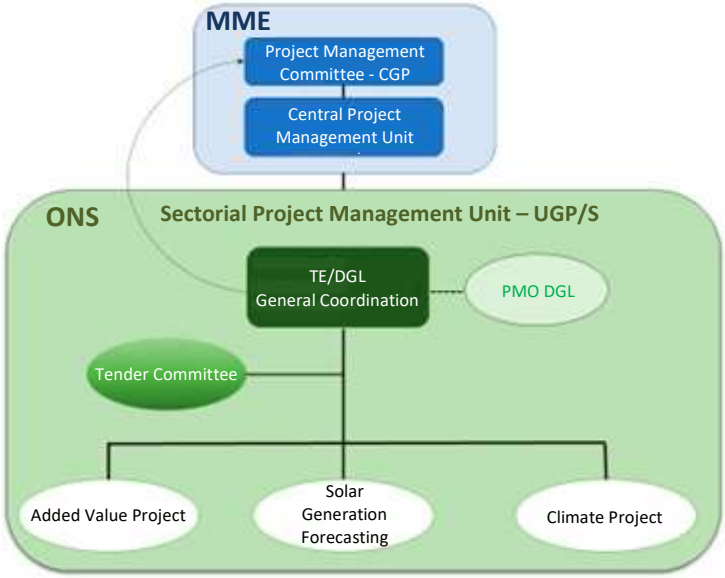

Figure 1 Functional structure of ONS' Sectorial Project Management Unit – UGP/S

Table 1 UGP/S Formation in ONS

UGP/S	Managements
General Coordination	Strategic Transformation Executive Management
DGL Projects Office	Strategic Transformation Executive Management
Tender Committee	Financial Executive Management
	Legal Executive Management
	Water Resources and Meteorology Management

	Methodology and Energy Model Management
	Calculation, Analysis and Operation Costs Executive Management
	Supply Executive Management
Climate Project(*)	Water Resources and Meteorology Management

(*) Climate Project is the short name for Subproject 23 within the ONS

16. LIST OF REIMBURSABLE EXPENSES

Reimbursable activities will not be necessary with regard to the contracting of Consultancy-3 in Subproject 23.

17. LEGAL PROHIBITION

The contractor may not directly or indirectly hire, in any capacity, active servants of the Federal, State, Federal District or Municipal Government or employees of its subsidiaries and controlled companies, within the scope of international technical cooperation projects. Art. 7 of Decree 5,151 from 07/22/2004.

18. Technicians in Charge

Name: Paulo Diniz de Oliveira

Agency: Water Resources and Meteorology Management – Operating Board

Signature:

19. Approval:

Name: Maria Cândida Abib Lima

Position: Executive Operation Schedule Manager

Signature:

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ANNEX I - Product 2 hydrometeorological databases

Tables I.1 and I.2 show the hydrometeorological data that make up Product 2. (Note: The availability of the data listed shall depend on an internal assessment and finalization of Product 2).

Table I.1 - Hydrometeorological data obtained from stations.

Source	Variable	Time scale
ONS	Flow rate	daily and monthly
INMET	Precipitation, temperature, wind direction and speed, solar radiation, relative humidity	daily and monthly
ANA	Precipitation and flow rate	daily and monthly
CEMADEN	Precipitation	daily and monthly

Table I.2 - Data obtained from satellites, analyzes and reanalyzes.

Name	Type	Area and starting year	Variable
CHIRPS	Satellite estimation	Latitude: 50°S - 50°N Longitude: 0° - 360° 1981	Precipitation
CMORPH	Satellite estimation	Global, 1998	Precipitation
MERGE	Satellite estimation	Latitude: 85°W-27°W Longitude: 57°S-13°N 2000	Precipitation
MSWEP	Satellite estimation	Global, 1979	Precipitation
ERA-5	Reanalysis	Global, 1940	Temperature (2m and pressure levels), wind (10m, 100m and pressure levels), pressure (surface and sea level), solar and longwave radiation, sea surface temperature, precipitation, precipitable water, geopotential at pressure levels, relative and specific humidity at pressure levels, vertical speed at pressure levels
GPCC	Reanalysis	Global, 1951	Precipitation
ERSSTv5	Reanalysis	Global, 1854	Sea surface temperature
HadISST2	Reanalysis	Global, 1850	Sea surface temperature
DOISST2.1	Reanalysis	Global, 1981	Sea surface temperature

META
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ANNEX II - Databases of coupled sub-seasonal and seasonal forecast models of Product 3

Tables II.1 and II.2 show forecast data on the sub-seasonal and seasonal scales that make up Product 3, respectively. (Note: The availability of the data listed shall depend on an internal assessment and finalization of Product 3).

Table II.1 - Sub-seasonal forecast models.

Model	Time range (days)	Resolution	Hindcast Period	Forecast Period	Coupled Ocean	Coupled Sea Ice
ECMWF - version CY48R1	0-46	Tco639/ 319L91	1995-2021	2015-2022	Yes	No
NCEP - CFSv2	0-44	T126L64	1999-2010	2015-2022	Yes	Yes

Table II.2 - Seasonal forecast models.

Model	Time range (months)	Resolution	Hindcast Period	Forecast Period	Coupled Ocean	Coupled Ice
ECMWF - version SEAS5	7 months (13 months)	T319	1981-2016	2017-2022	Yes	Yes
GFS - CFSv2	9 months	T126	1982-2010	2011-2022	Yes	Yes

ANNEX III - Indicators of climate extremes

Table III.1 shows the main indicators of climate extremes.

Table III.1 - Indicators of climate extremes.

Index	Definition	Unit
Weekly climate indices		
TXx	Weekly Maximum of Maximum Temperature	°C
TNx	Weekly Maximum of Minimum Temperature	°C
TXn	Weekly Minimum of Maximum Temperature	°C
TNn	Weekly Minimum of Minimum Temperature	°C
WD	Number of Rainy Days in the Week	days
Rx1day	Maximum Weekly Rainfall in 1 Day	mm
R20	Number of Days in the Week with Accumulated Total > 20 mm	days
R20tot	Total Accumulated Weekly Rainfall > 20 mm	mm
Monthly and seasonal climate indices		
CWD	Number of consecutive rainy days	days
CDD	Number of consecutive dry days	days
Rx5day	Maximum rainfall in 5 days	mm
WSDI	Number of days with at least 6 consecutive days with TX>90p	days
CSDI	Number of days with at least 6 consecutive days with TN<10p	days

ANNEX IV - Data engineering pipeline

This document is the definition of the data storage infrastructure to be provided for developing the activities. For this purpose, a Desktop as a Service shall be contracted. The chosen technology was designed to meet some requirements, namely:

- Flexible;
- Storage of different file types;
- Availability of data refinement;
- Viewing not restricted to any technology.

The technological platform of the products shall follow the layered architecture pattern, especially separated into data and integration. The data layer is responsible for collecting data from different sources (stations, weather models, satellite data, environmental data) and sharing it in a standard format for the platform's internal processing. The integration of data and its proper storage to meet product demands takes place in the integration layer. This component of the platform also acts in a centralized manner to allow access to data, seeking to ensure traceability, resilience and access scalability. This layered architecture also ensures a separation of responsibilities, which supports not only the traceability of access to information, but also the handling of errors, delivery (deployment) of new features or refinement of existing ones.

It should be emphasized that all of these technologies have been widely adopted and used in the market in general, which ensures the long-term continuity and maintenance of the platform.

This structure shall remain under the responsibility of Climatempo for 34 months. It should be emphasized that, from the second half of 2023, new companies (referred to herein as consultants) shall be contracted to keep performing the works. At this stage, Climatempo shall only act as a supervisor of the works, as well as being responsible for the maintenance/supervision of the cloud service. New consultants must bear the costs of:

- Downloading data for performing studies in their own environment;
- The inclusion of new data in the database or data lake following the previously described standards.
- The creation of new EC2 for development.
- At the end of the service, the closure of the EC2 and the transfer of the database by Deployment in the Contracting Party's environment will be requested.
- A brief description of the assembled infrastructure can be seen below.

Cloud Environment

AWS (Amazon Web Service) was chosen to be the cloud service for this project.

Managing access permissions

Amazon Virtual Private Cloud (Amazon VPC) lets you launch AWS's features in a virtual network.

Servers will be accessed via SSH on private or Public IP with default port 22. The console will be accessed by creating users in IAM with the necessary permissions.

The database must be accessed via CLI (Command Line Interface) or via PGadmin (if the database is Postgres or Aurora) with IP/DNS and standard port, in the case of data in S3, access can be via console or using AWS CLI (AWS Command Line Interface).

Data Layer

AWS S3 or Amazon Simple Storage Service is a site where we can store objects. S3 Standard Storage with a capacity of 32 Tb per month shall be contracted for this project. It should be emphasized that AWS Aurora will be used as the data source.

The data to be stored are:

i. Daily and monthly flow rate data from the hydroelectric plants of the SIN: noticed database from natural flow rates at daily and monthly time frequencies of all hydroelectric plants belonging to the SIN. Such data will be acquired from the public database provided by the Brazilian National Operator for the Electricity System (ONS) and the Energy Research Company (EPE).

ii. Observational data from conventional and automatic stations: Observational data from conventional and automatic stations will be collected from the primary official public sources in Brazil that comprise the territorial domain of the SIN. Data of variables for precipitation, wind direction and speed, air temperature at 2 meters, relative humidity and solar radiation on the surface will be collected by the meteorological stations of the Brazilian National Institute of Meteorology (INMET), both conventional and automatic, daily and monthly. For the precipitation variable, other official observation sources will be used to make up the observational set that will serve as the supply for the studies resulting from this one. Such sources refer to the rainfall stations of the Brazilian National Water Agency (ANA), the National Center for Natural Disaster Monitoring and Warnings (CEMADEN) and the ONS itself.

iii. Grid point data, analyses, reanalyzes, data estimated per satellites, proxies and synthetic series: Climate Hazards Group Infra-Red Precipitation with Station – CHIRPS; Climate Prediction Center (CPC Morphing Technique (MORPH), database referred to as CMORPH; MERGE from the Center for Weather Forecasting and Climate Studies (CPTEC) of the Brazilian National Institute for Space Research (INPE); Multi Source Weighted-Ensemble Precipitation – MSWEP; ERA5 from the European Centre for Medium-Range Weather Forecasts (ECMWF); CFSv2 from the National Centers for Environmental Prediction (NCEP); and Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA2), from the National Aeronautics and Space Administration (NASA) of the Global Modeling and Assimilation Office (GMAO).

iv. Data from operational models for forecasting precipitation, air temperature at 2 meters, wind strength and solar radiation incident on the surface:
   - Sub-seasonal forecast Models: ECMWF 0–46 Tco639/ 319L91 3–4 Days 1995–2021 2015-2022; and NCEP 0–44 T126L64 Daily 1999–2010 2015–2022.

- Seasonal forecast Models: ECMWF (version SEA5); and CFSv2.
- Series of climate indicators.

v. Paleoclimate model data:
- Paleoclimate models: PMIP4.

vi. Georeferenced data:
- Land coverage;
- Digital elevation model;
- Pedology; and
- Others.

Hydrometeorological station data is stored in Aurora (pre-described items i and ii). It will provide information on source, id, latitude, longitude, altitude, variable and figures. All information will be stored in UTC time. It should be emphasized that two structures will be created in it: one for raw data and another one for processed data. A database drawing can be seen in Figure IV.1.

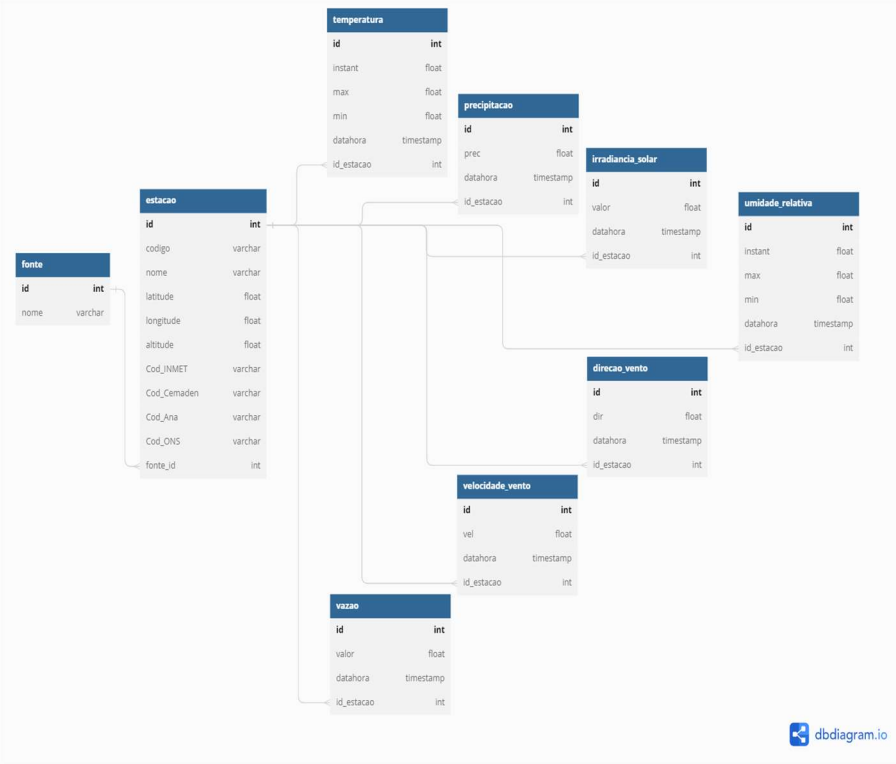

Figure IV.1 - Relationship of entities - ONS Climate Project.

All of the other project data (models, reanalysis, satellite, environmental and others) are stored in S3. The files will be separated by type (satellite, reanalysis, environmental, models), source (ECMWF, NCEP, INPE and others), period (historical, time, sub-seasonal, seasonal and paleoclimate), time scale (year, month, day, hour, minute).

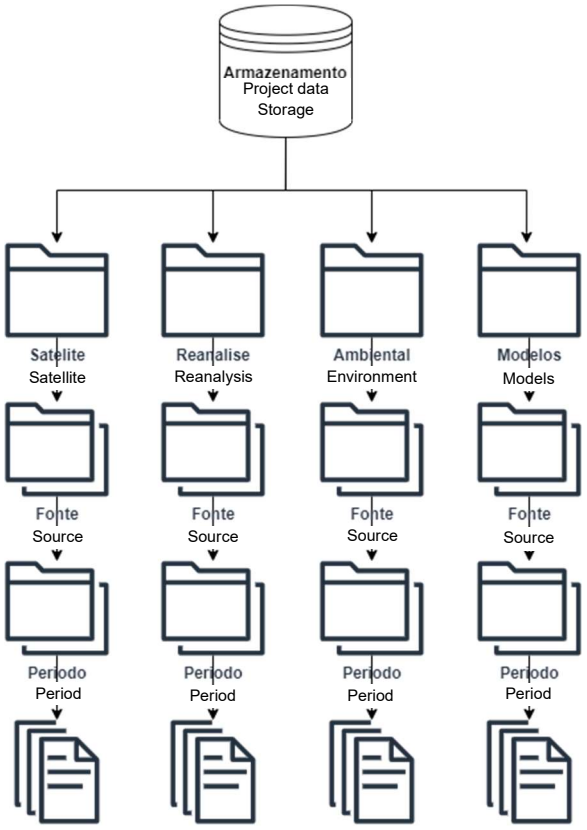

Figure IV.2 - Data storage.

Integration layer

Amazon Elastic Compute Cloud (Amazon EC2) is a Web-based service that provides safe, scalable cloud-based computing power. EC2 offers many options that allow the creation and execution of virtually any application. A machine will be created in it for project development, where:

- Leasing: shared instances;
- Operating System: Linux;
- Workload consistent with the number of instances: 1;
- Advanced EC2 instance: m7g.4xlarge (Family: m7g | 16vCPU | 64 GiB Memory);
- Pricing strategy: use on demand – 214 hours/month;
- Storage capacity: 1 TB.

In this environment, researchers will perform all of the activities required to deliver Product 2 - Analysis of meteorological data with long periods of observation in the SIN, Product 3 - Analysis of Data from Coupled Precipitation Forecasting Models, Other Meteorological Variables and soil use (considering series obtained by Paleoclimate) and 4 - Preliminary assessment of climate variability/change in available meteorological and hydrological series.

All scripts created will be developed in Python language. The justification for its adoption, compared to all other valid alternatives, such as R, is the expectation of wide application of different machine learning architectures, and that Python has consolidated itself as the main development language with greater support for this type of application. Among the most important frameworks to be applied in development, PyTorch will be adopted. Still in relation to the main frameworks applied in development, given the expectation that the models will have to continually process large volumes of input data, the Polars framework will be adopted for IO activities, data processing and DataFrame handling in general, as it has considerable performance gains and better memory management compared to more classic Python alternatives, such as Pandas.

Tools

In order to view the data, the following will be used: Climate Data Operators (CDO), which represents a set of statistical and arithmetic commands which are useful for processing meteorological data in GRIB and NetCDF formats; Quantum GIS (QGIS), which is a free, open-source program used to process geospatial data; and an picture (charts and tables) viewer; Python 3 to run scripts; Python's own frameworks (E.g.: PyQT5 and Tkinter).