Development of a regional-specific guidelines to enable operational production of objective seasonal forecasts in South America subregions - Western Coast of South America Climate Outlook Forum (WCSACOF) and Southeast South America Climate Outlook Forum (SSACOF)

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Executive Summary

This specific guidance document presents the current status and regional-specific guidelines to maintain, co-develop and enable operational production of objective seasonal and intraseasonal forecasts in South America, including the regions covered by the Western Coast of South America Climate Outlook Forum (WCSACOF) and Southeast South America Climate Outlook Forum (SSACOF).

The document is organised as follows. After providing some background, Part I introduces the basic societal and physical context, including a brief discussion on the role of natural climate variability and climate change for precipitation and temperature in South America. Then, Part II presents the current status of seasonal and intraseasonal products, while Part III discusses limitations, needs, gaps identified and related key tailored recommendations. Part IV summarises these recommendations framing them in terms of (a) continental, regional and sub-regional coordination and synergies, (b) operational processes regarding data and methodological improvements, (c) capacity building and trainings, (d) communication and user support and feedback mechanisms, and (e) documentation requirements.

After analysing the available products and the semi-structured interviews conducted to regional expects at the Regional Climate Centres, some of the most relevant tailored recommendations to maintain and enhance operational seasonal and intraseasonal forecasts in South America include **keeping a regional technical and strategic coordination**, via the WMO Regional Office and the RCCs, **the co-development of a funding roadmap** to guarantee continuity of products, as well of a **multi-year tailored regional research and development agenda.**

The document also presents recommendations regarding the **co-development of new operational products while maintaining and enhancing the ones already in existence**, including observational datasets; forecast

quality assessments; forecasts of additional variables; provision of measures of uncertainty; furthering the understanding of key modes of variability and their interactions with the anthropogenic climate change signal; the co-development of physically-consistent and demand-driven predictions across timescales for all possible thresholds of interest (i.e. provision of forecast in flexible format); and the use of multiple calibration and downscaling methods, including Machine Learning.

Other suggestions include taking advantage of international and regional schools and trainings; holding joint cross-pollination workshops between the two Regional Climate Centres and their related National Meteorological and Hydrological Services; implement frequent feedback mechanisms for users; take advantage of present and future AI technologies to help communicate information and services to decision makers; and to co-develop a set of guidance and protocols to guarantee a minimum quality of the provided products.

Background

The Climate Services Information System (CSIS) serves as the operational core of the Global Framework for Climate Services (GFCS). Its primary function is to routinely produce, archive, analyse, model, exchange, and process climate-related information, encompassing past, present, and future data. CSIS operates on a three-tiered structure comprising global, regional, and national levels. At the regional level, the system is supported by World Meteorological Organisation (WMO) designated Regional Climate Centres (RCCs). These RCCs serve as centres of excellence, enhancing the capacity of WMO Members within each region to deliver high-quality climate services. They provide vital regional climate information, including data analysis, monitoring, prediction, and projection, thereby supporting National Meteorological and Hydrological Services (NMHSs) in generating and delivering up-to-date climate products and services.

Strengthening the CSIS Regional component (CSIS-R) will enable the associated country-level delivery of priority services and will be conducted through RCCs. RCCs and NMHSs, through Regional Climate Outlook Forums (RCOFs), provide climate predictions in climatologically homogeneous regions, and assess the likely implications of the outlooks on the most pertinent socio-economic sectors for the regions. RCOFs have been in operation in most sub-regions worldwide for decades now, and provide a unique platform for strengthening the operationalisation of the CSIS on regional and sub-regional scales.

Recently, the Seventy-Second session of the World Meteorological Organisation (WMO) Executive Council (EC-72) has promoted the operationalisation of objective seasonal forecasts and tailored products on sub-regional scales with country-level service delivery, transitioning from currently subjective and consensus-based seasonal outlooks practices of RCOFs, into traceable and reproducible objective seasonal predictions – based on multi-model ensembles from dynamical climate models. Additionally, EC-72 promotes a) the shift from tercile-based probability forecasts to other probability-based formats that address the requirements of specific applications, b) the digitalisation of these outlooks and forecasts, c) the standardisation of the verification and the skill assessment as an evaluation method for forecasts, and d) the reduction of manual activities in the preparation of the forecast through their operationalisation. To facilitate this process, WMO has developed a Guidance on *Operational Practices for Objective Seasonal Forecasting* (WMO-No. 1246, or WMO, 2020), outlining key steps:

1. Implement a Traceable and Well-Documented Procedure: Establish systematic forecasting processes, including model selection, bias correction, calibration, and statistical downscaling, to ensure traceability and rigorous verification.

2. Utilize Dynamical Climate Models: Use multi-model ensembles to enhance forecast robustness and reliability.

3. Maintain High-Quality Observational Databases: Develop and maintain comprehensive datasets with sufficient historical depth and spatial resolution for verification, calibration, and bias correction.

4. Identify and Monitor Climate Variability Drivers: Track key climate drivers, assess their representation in models, and evaluate their predictive skill.

5. Verify Forecasts According to Established Standards: Conduct regular performance assessments, archive past forecasts, and refine methodologies through post-season evaluations.

6. Communicate Forecasts Clearly: Disseminate seasonal forecasts using clear, non-technical language. Emphasize their probabilistic nature and inherent uncertainties to manage user expectations effectively.

7. Engage with Users and Stakeholders: Establish mechanisms for user feedback and actively involve stakeholders in the co-production of tailored forecast products. This collaboration ensures that forecasts meet user needs and enhances their practical application.

Using *Guidance on Operational Practices for Objective Seasonal Forecasting* as a reference – alongside global examples of similar guidances and a survey to RCCs to assess the current status of operational practices for the production and dissemination of regional climate forecasts - the SSA contractor will develop regional-specific guidelines for the implementation of objective seasonal forecasts. These guidelines will focus on the Western Coast of South America Climate Outlook Forum (WCSACOF) and the Southeast of South America Climate Outlook Forum (SSACOF) sub-regions The objective is to enhance forecast production and dissemination by addressing infrastructural, institutional, procedural, and human resource requirements, ultimately supporting informed decision-making across various sectors.

The overall purpose and scope of the region-specific guidance document for the two South America subregions - Western Coast of South America Climate Outlook Forum (WCSACOF) and Southeast South America Climate Outlook Forum (SSACOF) can be found below and a more detailed version is described in the following *outline*:

- Society and physical context of South America
- Current status of the seasonal and intraseasonal forecasts of the RCOFs, including data, methods and services and products, feedback process and mechanism, mobilized resources and collaborative networks
- Analysis of limitations, needs and gaps with respect of the implementation of the objective Seasonal Forecast;
- Recommendations for the RCOF process and capacity development of the national experts within the region.

To prepare this report, the authors conducted a series of semi-structured interviews to key experts belonging to both Regional Climate Centres in South America, along with a literature review of key documents and reports -most of them available online at the Regional Climate Centres or National Met Services websites, or were directly provided by these institutions-, exhaustive exploration of the RCC's websites, and the authors own experience of almost two decades working with institutions in the region.

Part I. Societal and Physical Context

South America: The continent and its people

South America has a total area of about 17,814,000 km², or roughly one-eighth of the land surface of Earth. South America's geologic structure consists of two dissymmetric parts. In the larger, eastern portion are found a number of stable shields forming highland regions, separated by large basins (including the vast Amazon basin). The western portion is occupied almost entirely by the Andes Mountains. The Andes—formed as the South American Plate drifted westward and forced the oceanic plate to the west under it—constitute a gigantic backbone along the entire Pacific coast of the continent. The basins east of the Andes and between the eastern highlands have been filled with large quantities of sediment washed down by the continent's great rivers and their tributaries.

South America is bordered by Central America and the Caribbean Sea to the northwest, the Atlantic Ocean to the east and north and the Pacific Ocean to the west. It includes a total of 12 sovereign states (Colombia, Venezuela, Suriname, Guyana, Ecuador, Brazil, Peru, Bolivia, Uruguay, Paraguay, Chile and Argentina). The subcontinent has an estimated 2024 population of 435,611,750 people[1], a population density of approximately 24 per km² and an overall population growth rate of over 1% per year. South America is known for its racial and ethnic diversity. Based on the recent data, about 40 million people in Latin America are indigenous and about 130 million are afro-descendants[2].

Economically, the region presents a combination of different realities with a combination of high-income countries, emerging economies, and nations struggling with poverty and instability. Countries like Brazil, Argentina, Chile, and Colombia are considered emerging markets, characterized by rapid industrialization, a growing middle class, and increasing foreign investment. South America is rich in natural resources, and many of its countries depend heavily on the export of raw materials (oil, minerals, agricultural products). This

[1] https://population.un.org/wpp/
[2] https://perla.princeton.edu/

dependence makes them vulnerable to global price changes. For example, Venezuela's economy is heavily reliant on oil, while Chile is known for its copper exports. Argentina, Brazil, and Peru are also major agricultural exporters.

The political reality in South America varies significantly depending on the country of interest. Whilst there are countries with well-established democracies, there are also examples of severe political instability and economic crises, impacting inflation, the investor confidence and the general business climate in the region.

Socio economic snapshot

Despite the current GDP (current prices) of the region reaching 4.23 thousand billions, the region has made relative progress in terms of poverty reduction (Figure 1). The population living in poverty decreased about 10 pp since the 2000s, but those living in extreme poverty have remained constant for the past two decades (https://statistics.cepal.org/portal/cepalstat/dashboard.html?theme=1&lang=es, visited in December 2024). This improvement also benefited indigenous people. The percentage of indigenous households living in poverty declined in Peru and Bolivia, while the proportion living in extreme poverty was reduced in Peru, Bolivia, Brazil, Chile and Ecuador. The wage gap was reduced in urban Bolivia and Peru, though big differences remain in rural areas and within indigenous households, if considered by gender. Primary education has reached most indigenous latitudes. However, education is still a pending subject, especially for afro-descendants. On average, their literacy rate is half of that for the region (Freire et al. 2016).

The economic shocks caused by the COVID-19 pandemic and fluctuating commodity prices have set back some of these gains (Maloney et al. 2024). This inequality is seen not only in income but also in access to education, healthcare, and basic services. Poverty afflicts 43 percent of the indigenous population in the region, which is more than twice the proportion of non-indigenous people. Additionally, 24 percent of all indigenous people live in extreme poverty, which is 2.7 times higher than the proportion of non-indigenous people living in extreme poverty (Freire et al. 2016). Indigenous

People and afro-descendents often lack formal recognition over their lands, territories and natural resources. They are often the last to receive public investments in basic services and infrastructure and face multiple barriers to fully participate in the formal economy, access to justice, and participate in political processes and decision making.

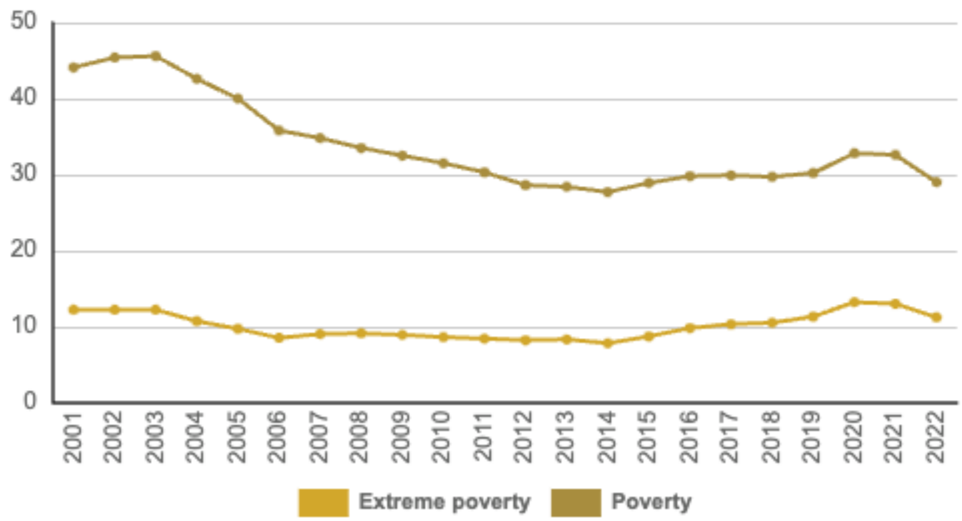

Figure 1. Population living in poverty and extreme poverty (percentage) in Latin America. Source: CEPAL.

On the monetary front, independent central banks in Brazil, Chile, Colombia, and Peru continue to cut rates, and others are following. Regional inflation, excluding Argentina and the República Bolivariana de Venezuela, stands at 3.5 percent, compared to 5.7 percent in the OECD in January 2024. Most South American countries, inflationary expectations remain anchored and central bank targets are expected to be achieved in 2024. The successful fight against inflation partially reflects external factors—fuel and food prices have fallen—but core inflation has also begun to fall, further signalling deeper rooted progress (Maloney et al., 2024).

On the financial front, higher interest rates have led to debt distress for households and firms, and non-performing loans increased but are subsiding (Maloney et al., 2024). This debt service shock is taking place against a backdrop of an almost doubling of consumer credit as a percentage of GDP in many countries over the past 20 years. Despite solid macroeconomic management in the region, prospects for growth remain low, not only because of global conditions, but also because of long unaddressed structural issues. Regional growth remains constrained by low capital accumulation and low productivity growth over the longer term. Further, despite the enthusiasm for nearshoring, foreign direct investment (FDI) remains below levels of 12 years ago in real terms and greenfield investment announcements continue to fall. Further, the big investments driving a recent upturn in FDI have occurred mainly in natural resource sectors, while manufacturing investment continues to decrease (Maloney et al., 2024b).

Climate and health

Over the last 30 years, South America has experienced drastic changes in its epidemiological profile, with an increase in the burden of non- communicable diseases (NCDs) and improvements in communicable diseases (CDs) along with health problems associated with poor maternal, new-born, and child health (MNCH). Nowadays, South America has a triple burden of diseases. While NCDs represent the largest percentage of death and disease, high rates of CDs, MNCH complications still persist. Many CDs and MNCH are easily preventable, but they persist in the region due to low income, lack of access to healthcare, low quality of health services, and poor water, sanitation infrastructure and hygiene practices (Bancalari et al., 2023). South America has made considerable progress in preventable diseases, yet, undernourishment continues to be a significant problem despite improvements. New challenges emerge on the opposite side of the nutritional spectrum: mother and child overweight (Bancalari et al., 2023).

NCDs represent a large and growing burden. While in 1990 around half of the healthy life lost was due to NCDs, in 2019 the burden increased to almost 80%, closer to the level of high -income countries in North America, Europe, and East Asia. By 2019, the burden of disease in the region is led by cardiovascular diseases, neoplasms, and diabetes, while in 1990 it was led by maternal and neonatal disorders, cardiovascular diseases, respiratory infections and tuberculosis, in this order. The burden on NCDs varies across and within countries in LAC, and it is driven by behavioural risk factors associated with nutritional practices, lifestyle (i.e. sedentarism), as well as ethnic/racial and demographic composition (Webber et al. 2012).

Background climate drivers: natural climate variability and climate change in South America

Climate varies at multiple timescales, and its impacts are the result of the independent action of certain climate drivers (e.g. modes of variability), the interactions between climate drivers, or a combination of the above. Typical climate drivers impacting South America are the El Niño-Southern Oscillation (ENSO; e.g. Zebiak et al., 2014), the Atlantic Meridional Mode (AMM; Foltz and McPhaden, 2010), the Madden-Julian Oscillation (MJO; e.g. Wheeler and Hendon, 2004), the South Atlantic Convergence Zone (SACZ; e.g., Carvalho et al., 2004), the South Atlantic Dipole (SAD; Nnamchi et al., 2011; Doss-Gollin et al., 2018) and the regional Seasonal-Intra-Seasonal Pattern (Alvarez et al., 2014; Vera et al., 2017), the Southern Annular Model (SAM; Marshall, 2003), the Pacific Decadal Oscillation (PDO; Zhang et al., 1997) and anthropogenic climate change, to just mention a few.

Given a particular location, a climate variable -such as surface temperature or precipitation- can be separated or decomposed in terms of its long-term (climate change) signal, the inter-decadal natural, and inter-annual (and shorter timescales) variability signals, for example as shown in Figure 2, following the methodology described by Greene et al (2011), Muñoz et al. (2016b) and Thomson et al. (2018). The timescale decomposition shows that the inter-annual timescale is the one explaining most of the total variance for precipitation (regions in purple in Figure 2c) and surface temperature in most of the southern cone of South America (Figure 2f), and that the climate change signal explains little of the precipitation variance is South America (Figure 2a), but it explains about 50-70% of the total variance of surface temperature in a large section of the continent (see the large diagonal region in red, orange and light purple tones in Figure 2d). A similar analysis can be conducted for the inter-decadal signals, exhibiting an important “hotspot” for surface temperature in southern Peru, northwestern Bolivia and the far western Brazil (Figure 2e). Overall, this type of analysis underscores the importance of understanding the different impacts of climate change and natural climate variability in different climate variables and timescales.

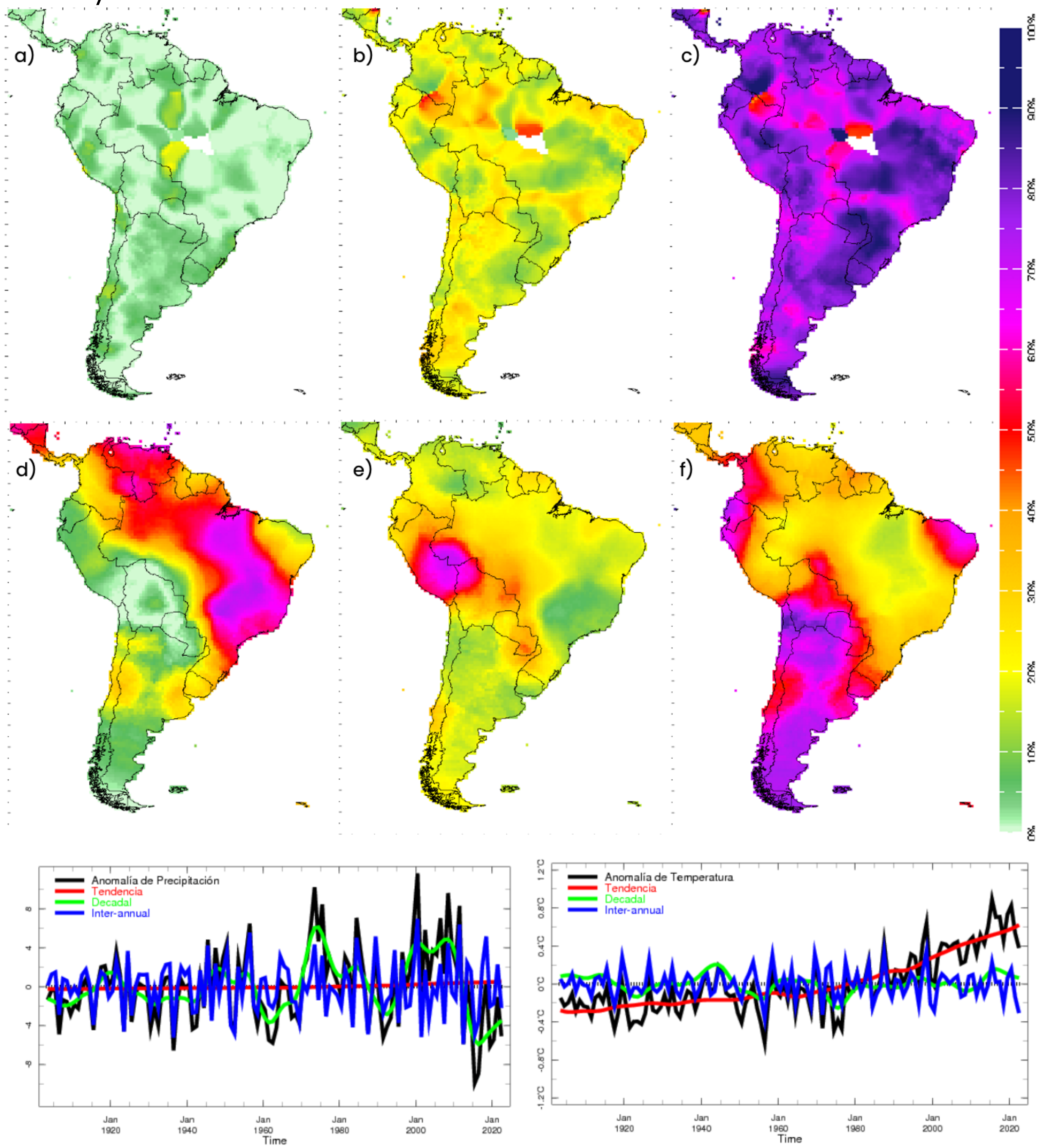

Figure 2. Timescale decomposition of observed annual precipitation (a-c) and surface temperature (d-f) over South America. Colours indicate the explained variance of the particular timescale under consideration with respect to the total observed variance (see colorbar). The lower panels show the spatially-averaged annual precipitation (left) and surface temperature (right) time series for the same domain shown in the upper panels. In the lower panels, the black line corresponds to the original time series, red to the long-term tendency, green to the inter-decadal signal, and blue to the inter-annual variability one.

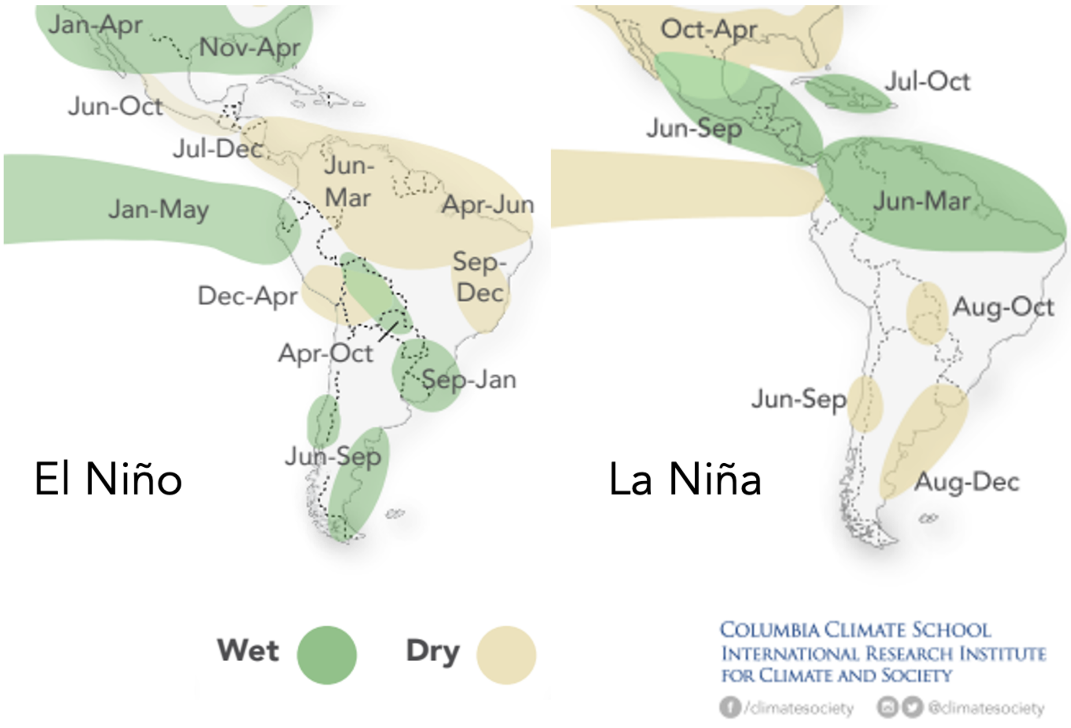

Figure 3. Typical rainfall anomalies of El Niño (left panel) and La Niña (right panel). Source: Adapted from the original version by The International Research Institute for Climate and Society (IRI). Columbia University's Climate School.

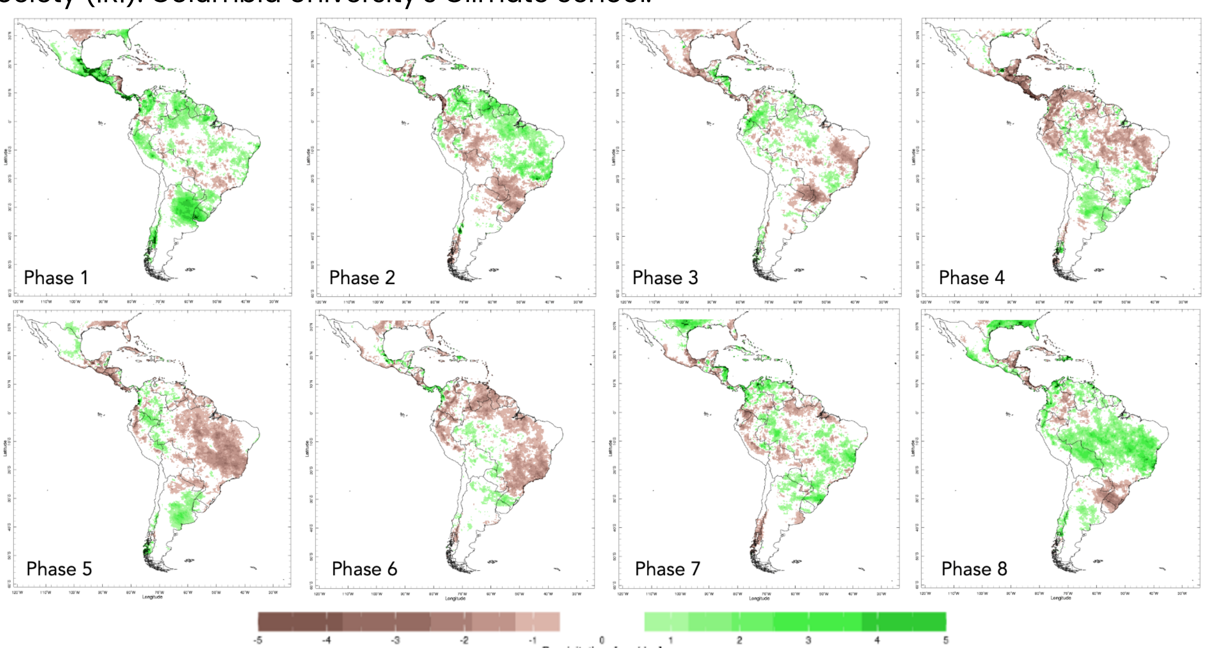

Figure 4. Typical rainfall anomalies related to the Madden-Julian Oscillation's phases in Oct-Nov (1991-2020 normal). Source: the authors, using the IRI Data Library.

As mentioned, multiple climate drivers control the climate of South America, two of the most important ones (although not at all the only ones) are ENSO and the MJO. Although there are multiple “flavours” of ENSO, it typically tends to impact rainfall (wet/dry) anomalies during different seasons as shown in Figure 3. Similarly, an active MJO tends to control rainfall anomalies in different locations depending on its phase and magnitude, exhibiting a strong seasonality (Figure 4 shows typical rainfall anomalies related to each MJO phase for Oct-Nov; other months and seasons show a different set of patterns).

Part II. Current Status on Seasonal and Intraseasonal Predictions

This section discusses the joint present status of the different activities coordinated by the Regional Climate Centres in South America, regarding seasonal and –to the extent they are already implemented or available– intraseasonal predictions.

Regional Climate Centres and Climate Outlook Fora

South America has two Regional Climate Centres (RCCs), each supporting a regional Climate Outlook Forum (COF) to enhance climate services and decision-making across the continent.

The Regional Climate Centre for Southern South America (RCC-Southern South America) is a collaborative initiative aimed at enhancing climate services for the region, primarily focused on improving climate prediction, monitoring, and the capacity to respond to climate-related hazards. The RCC-Southern South America was created in demonstration phase in 2014 and formally approved by the WMO in 2017, by the need for better regional climate services to address climate variability and change in the region, particularly for agriculture, water resources, and disaster risk reduction. The RCC-South America was established as part of a broader global initiative under the World Meteorological Organisation for countries in Southern South America including Argentina, Brazil, Bolivia, Chile, Paraguay, and Uruguay. The overall network's goal is to strengthen the capacity of countries in the region to manage climate risks and improve the use of climate data for decision-making in sectors such as agriculture, water management, energy, and disaster preparedness.

Southern South America faces significant challenges due to climate variability, including droughts, floods, and temperature extremes. These events can have serious consequences for agriculture (a vital sector in the region), food security, water availability, and human health. The RCC-Southern South America was created to provide more accurate, timely, and localized climate

predictions and assessments to help mitigate these risks. One of the central elements of the RCC-South America is the emphasis on regional collaboration. Countries within the region share data and knowledge to improve their collective capacity to predict and respond to climate events. This includes sharing meteorological data, forecasts, and climate models that are specifically tailored to the conditions and needs of Southern South America.
The centre works closely with national meteorological and hydrological services to integrate local knowledge with global climate models.

The RCC-Southern South America provides a range of climate-related products and services, including seasonal climate forecasts and specialized reports on climate trends and hazards. These services support policy-makers, scientists, and sectors like agriculture and water management by giving them access to accurate and regionally specific climate data, helping them prepare for extreme weather events.

One of the present duties of the RCC-SSA is to help coordinate the efforts related to the regional Climate Outlook Forum. **The Southeast South America Climate Outlook Forum (SSACOF)** started in 1998. Initially, it covered Argentina, Brazil, Paraguay and Uruguay, and later expanded to include Bolivia and Chile, covering the domain of the CRC-SAS. The focus of the SSA-COF is on rainfall and temperature variability. Similar to other COFs, the SSACOF produces seasonal climate outlooks to inform stakeholders in agriculture, water management, flood control, and energy production. The COF emphasizes the need to provide high-quality climate data for disaster risk management, particularly to reduce the impact of severe floods or droughts. It also aims to foster cross-border cooperation to help countries in this region deal with climate extremes. The COF produces seasonal forecasts focusing on rainfall patterns, mean temperature, with special attention to drought events and integrates outlooks that incorporate both climate models and observational data.

The Regional Climate Centre for Western South America (RCC-WSA) is a collaborative regional initiative aimed at improving climate services and enhancing resilience to climate variability and change in the western part of South America, which includes countries like Colombia, Ecuador, Peru, Bolivia, and parts of Chile. It was initiated in 2015 and it is part of a broader effort under the World Meteorological Organization (WMO) to strengthen regional climate centres across the globe.

The RCC-Western South America was established to address the specific climate-related challenges faced by countries in the Western Andes and Pacific coastal regions. These countries are highly vulnerable to climate extremes such as droughts, floods, and El Niño and La Niña events, which significantly impact agriculture, water resources, and disaster risk. The primary goal of the centre is to improve climate predictions, provide early warnings, and offer tailored climate information for decision-making, particularly in sectors such as agriculture, water management, and disaster preparedness.

The RCC-Western South America operates through collaboration between national meteorological and hydrological services, research institutions, and regional organizations. The network facilitates the sharing of climate data, models, and forecasts, enabling countries in the region to work together in addressing common climate challenges. By pooling resources and knowledge, the RCC ensures that countries benefit from more accurate, region-specific climate information, which is essential for managing climate risks and planning adaptation strategies.

The RCC-Western South America provides various products and services, including seasonal climate forecasts, early warning systems, and climate impact assessments. These tools are used by governments, businesses, and communities to make informed decisions about water use, crop management, and disaster response. The centre also focuses on capacity building—training meteorologists, decision-makers, and local communities in the use of climate information to better prepare for extreme events.

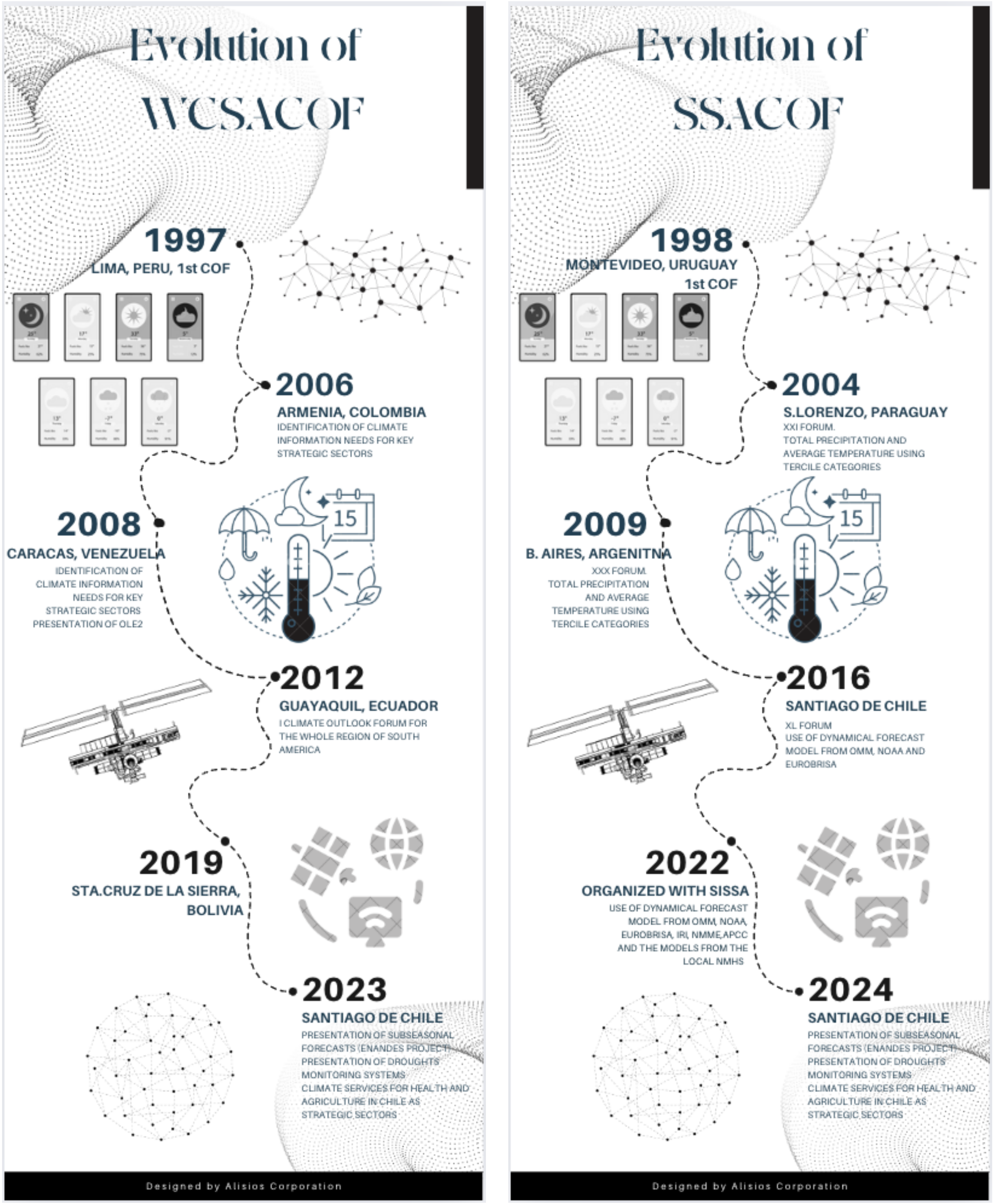

Figure 5. A pictorial representation of the evolution in time of the Climate Outlook Fora (COFs) in South America. Source: the authors and Alisios Corporation.

The Western Coast of South America Climate Outlook Forum (WCSACOF), presently led by CIIFEN (International Centre for the Research of El Niño Phenomenon in English) as the Regional Climate Centre, focuses on the Western coastal region of South America, which includes Bolivia, Chile, Colombia, Ecuador, Peru and Venezuela. Since 1997, the National Meteorological Services of the region have produced climate outlooks which provide seasonal climate forecasts for precipitation and temperature. These Outlook Fora advice for sectors like agriculture, energy, water resources management and disaster preparedness for the mentioned region. More recently, through the ENANDES project, CIIFEN also provides subseasonal climate information for the region (ENANDES, 2024). The WCSACOF also focuses on improving early warning systems for extreme events such as El Niño-related droughts or flooding along the coast, and there is an emphasis on improving collaboration between countries in the region to share data, forecasts, and best practices for climate resilience.

A pictorial representation of the time evolution of the SSACOF and WCSACOF is presented in Figure 5.

Regional and National Services and Products

Both the RCC-SSA and the RCC-WSA report a wide diversity of products and services in their respective websites (see Figures 6 and 7, respectively). These products and services involve observational and forecast datasets, but also analysis and discussions, training material and research and development. Although the main focus of his report involves the existing operational seasonal forecasts in South America, a list of the general products and services is included for contextual purposes.

Among the RCC-SSA's products and services the site lists (Figure 6)

- observed rainfall and temperature maps, using *in situ* and satellite data,
- El Niño and La Niña products,
- climate indices (including extremes and trends),
- a climate atlas with the normal temperatures and rainfall for different reference periods, at monthly, seasonal and annual timescales,

- drought monitor and forecast,
- temperature and rainfall climate forecasts (including seasonal and intraseasonal timescales),
- regional and local vegetation indices; values and anomalies (NDVI and EVI),

Figure 6. Landing site (by Dec 2024) of the RCC-SSA, listing some of its products and services. Source: https://www.crc-sas.org/en/

- analyses of forecasts and information on past and coming Climate Outlook Fora (COFs),
- training materials,
- information on projects.

Figure 7. Landing site (by Dec 2024) of the RCC-WSA, listing some of its products and services. Source: https://crc-osa.ciifen.org/

In the case of the RCC-WSA, the listed (Figure 7) products and services include

- climate monitoring,
- El Niño and La Niña products,
- temperature and rainfall climate forecasts (next-season and next-month timescales, presented as absolute values and anomalies),
- drought monitor,
- climate projections,
- climate database,
- analyses of forecasts and information on past and coming Climate Outlook Fora (COFs),
- training materials,
- information on projects.

The above two lists have been written on purpose in such a way that the similarities are clearly visible. As can be seen, the two South American RCCs offer very similar products and services, the differences answer to the more regional and local demands the decision makers and National Meteorological and Hydrological Services present to their RCCs.

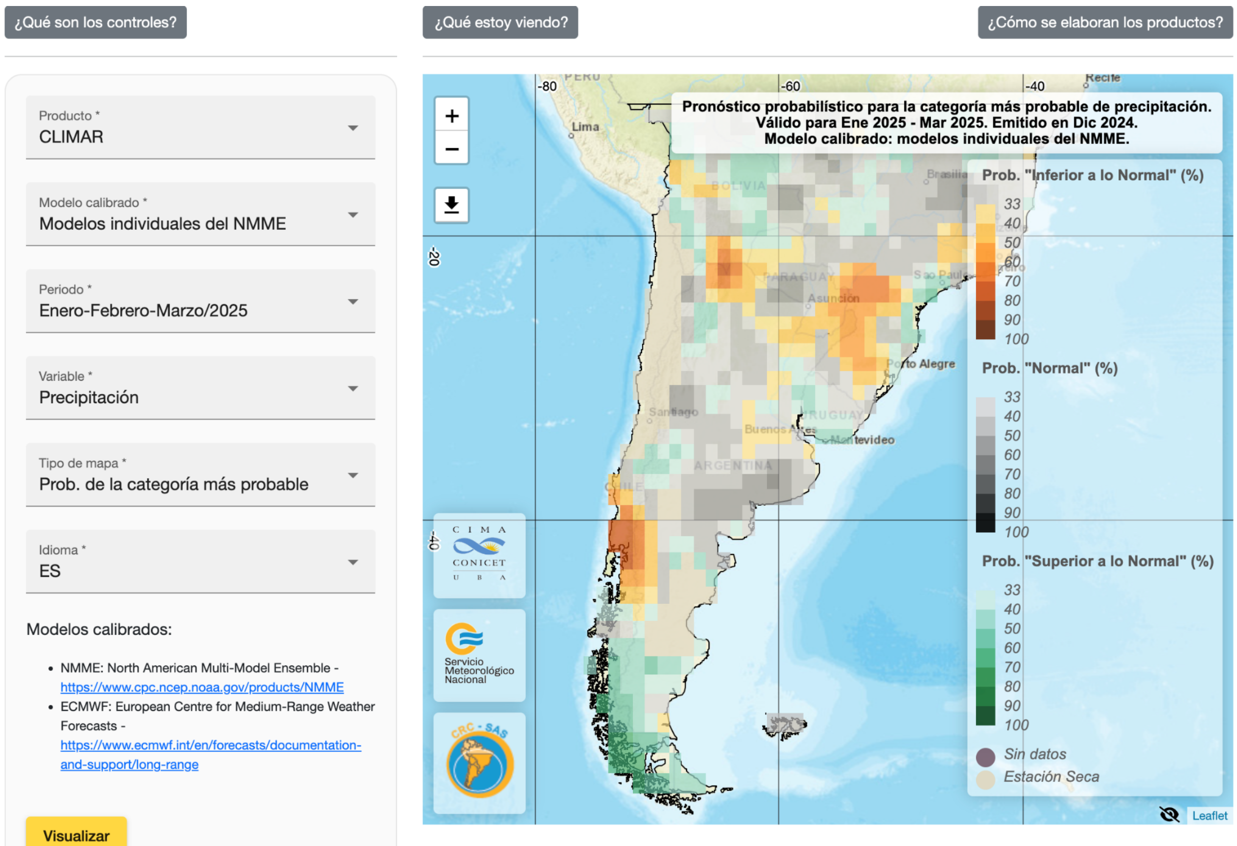

Figure 8. CLIMAR: Probabilistic, multi-model, tercile-based precipitation seasonal forecasts, provided by the RCC-SSA. Source: https://www.crc-sas.org/en/

Focusing now on the actual *forecast* products and services, presently both RCCs report in the interviews conducted that presently their main prediction products are **seasonal** accumulated precipitation and mean 2-meter temperature forecasts, presented as probabilistic maps for the corresponding above-normal, normal, or below normal categories for each variable, and publicly available via the respective RCCs' websites and "Boletines Estacionales" (seasonal bulletins), which include an analysis of the forecasts and often targeted recommendations. In addition to the tercile-based categories, the RCC-SSA also provides as part of their SISSA project[3] forecasts of exceeding the 66th and 80th percentiles, as well as for not exceeding the 20th and 33rd percentiles. Figure 8 and 9 show examples for the RCC-SSA and the RCC-WSA, respectively.

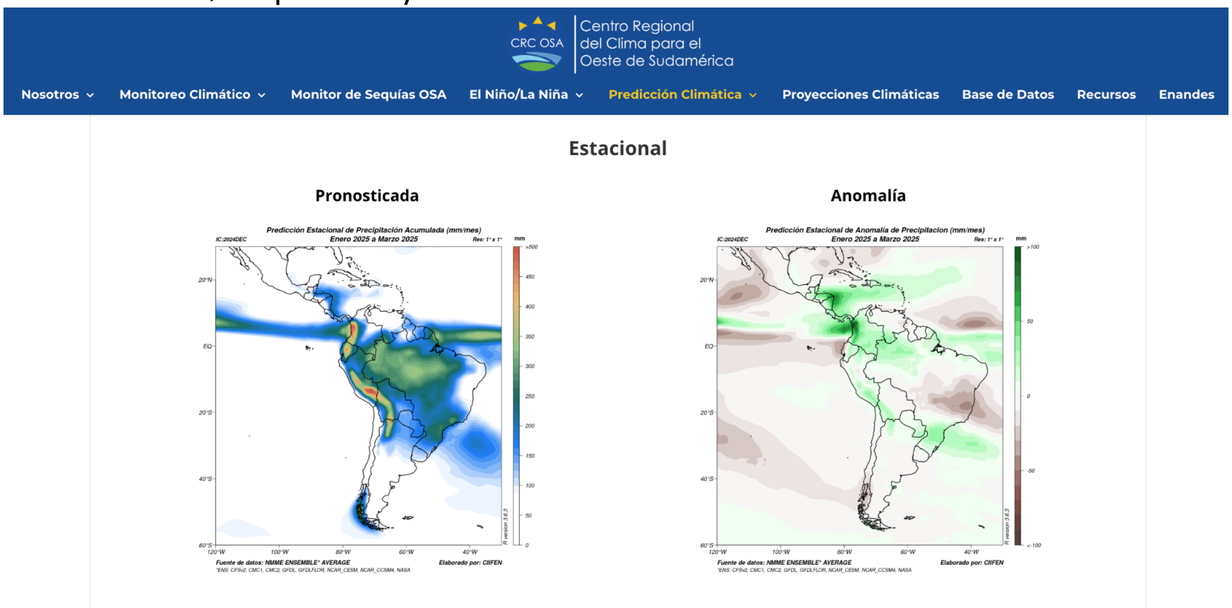

Figure 9. Multi-model seasonal precipitation forecast for total rainfall (in mm; left panel) and as anomalies (in mm, right panel) for the site (by Dec 2024) provided by the RCC-WSA. Source: https://crc-osa.ciifen.org/

These RCCs forecast products are not the official country forecasts –each country delivers its own forecast via its website, social media, bulletins and workshops– although are often used as a reference for the country forecasts.

Regarding **intraseasonal** (also known as "subseasonal") forecasts, the RCC-SSA produces and publishes calibrated fortnightly (corresponding to what the forecast community commonly refers to like a joint "week 1+2") forecasts of accumulated precipitation and droughts (characterised by the Standardised Precipitation Index, SPI); this RCC also reports the production of calibrated intraseasonal precipitation hindcasts for the 2010-2019 period. These forecasts, as well as forecast evaluation maps, are available at the RCC-SSA website: https://sissa.crc-sas.org/pronosticos-de-lluvia-y-sequia/pronostico-de-

[3] The SISSA project is the Information System for Droughts in Southern South America, providing tools and information to governments, NGOs, private institutions and individuals about droughts and its impacts. More info: https://sissa.crc-sas.org/que-es-sissa/acerca-del-sissa/

sequia-a-15-dias-chirps-gefs/ . An example for a calibrated, fortnight accumulated rainfall intraseasonal forecast is presented in Figure 10.

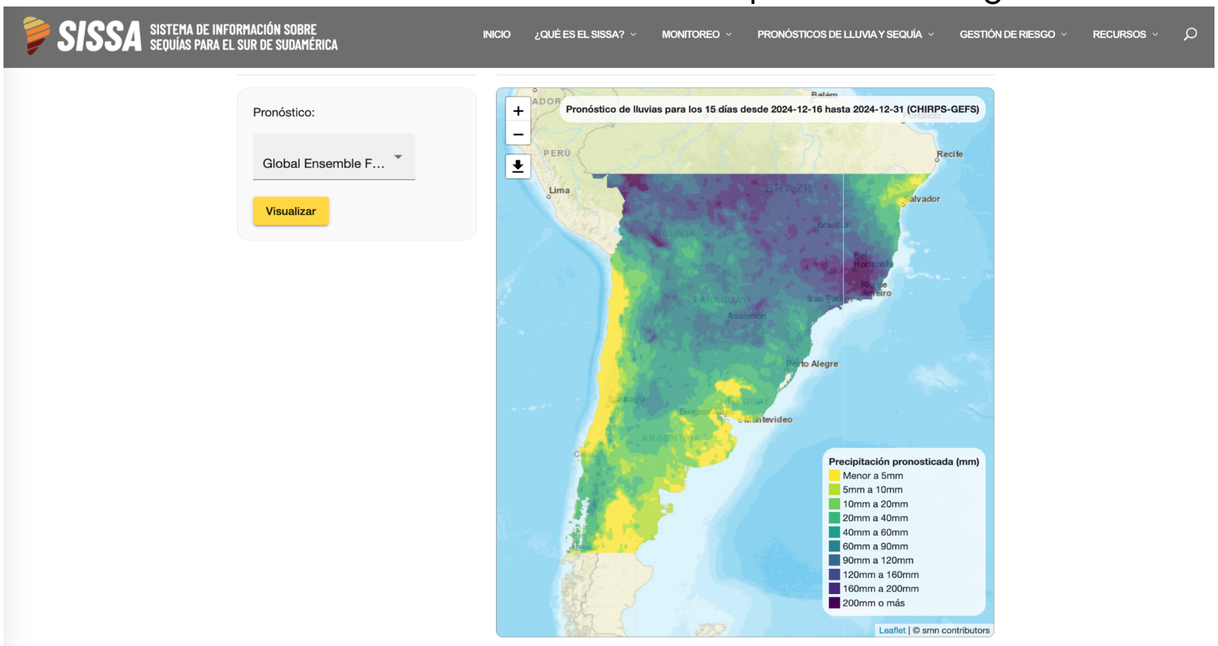

Figure 10. Intraseasonal fortnight precipitation forecast, provided by the RCC-SSA. Source: https://sissa.crc-sas.org/

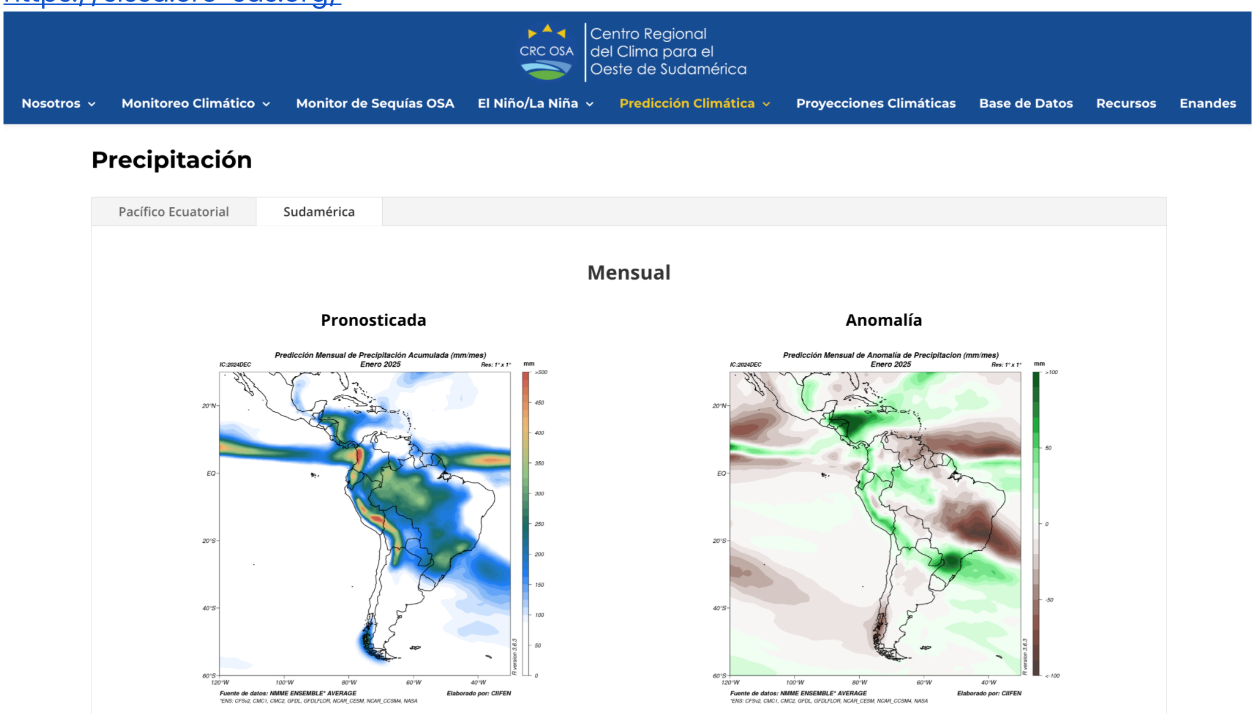

Figure 11. Intraseasonal fortnight precipitation forecast, provided by the RCC-SSA. Source: https://crc-osa.ciifen.org/

The RCC-WSA offers next-month forecasts for both precipitation and temperature (as absolute values and anomalies) in its website (Figure 11). Although by definition these are **intraseasonal** forecasts because of the monthly target, they are produced using an ensemble of the North American Multi-Model Ensemble (NMME) models, which are -except for the case of the CFSv2 model- executed with a seasonal forecast configuration.

Nonetheless, recent progress has been made in the WSA region regarding the intraseasonal forecasts (Figure 12) using a calibration and ensemble of internationally-available intraseasonal model output via the WMO-implemented ENANDES[4] project: operational intraseasonal forecasts for accumulated weekly precipitation were co-designed, implemented and have been continuously available since 2023 (ENANDES, 2024) for Colombia, Ecuador, Peru, Chile and most of Bolivia and Venezuela. These forecasts are publicly available via the International Research Institute for Climate and Society (IRI) Data Library in this link: https://iridl.ldeo.columbia.edu/maproom/ENANDES/precip_flex_subx_weekly.html .

As discussed in detail in ENANDES (2024) and in the service website, these intraseasonal forecasts are presented in different ways, including actual forecast values in mm with the corresponding uncertainty envelope (as the inter-quantile range, IQR), probability of exceeding the median, tercile-based probabilities, and the use of the entire probability density function.

[4] The WMO-led ENANDES project aims to increase the resilience and adaptive capacity to climate variability and change of highly vulnerable communities living in the Andes. More info: https://wmo.int/activities/projects/project-portfolio/enhancing-adaptive-capacity-of-andean-communities-through-climate-services-enandes

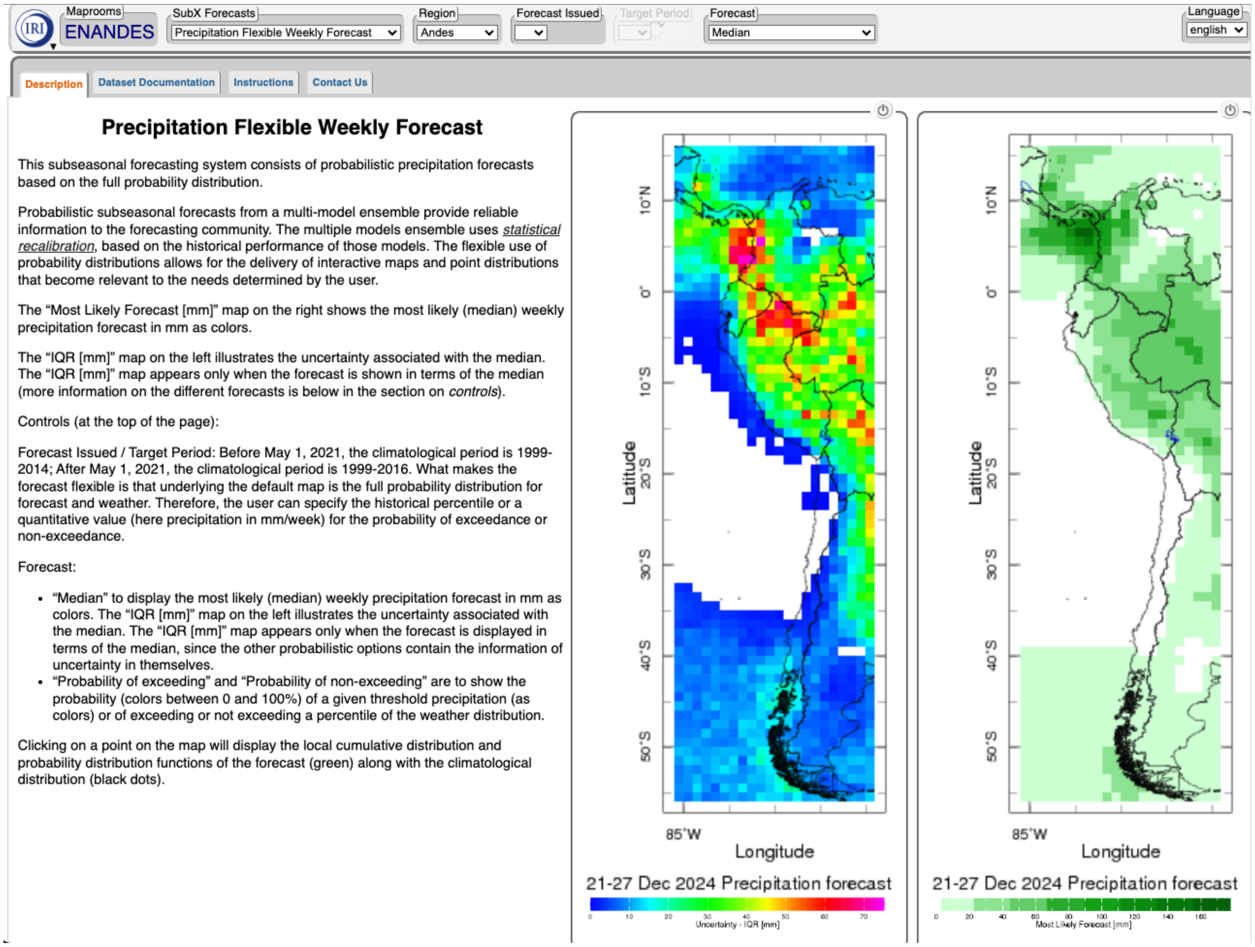

Figure 12. Intraseasonal, calibrated, multi-model weekly precipitation forecast, provided by the RCC-SSA. Source: https://iridl.ldeo.columbia.edu/maproom/ENANDES/

In terms of other types of products and services, the RCC-SSA offers, for example, monitoring and analysis of two different vegetation indices, the NDVI and EVI (Figure 13). The RCC-WSA reports that a new repository is being developed for their region, with the goal of offering the National Meteorological and Hydrological Institutes easy access to different gridded datasets that can be used for different purposes.

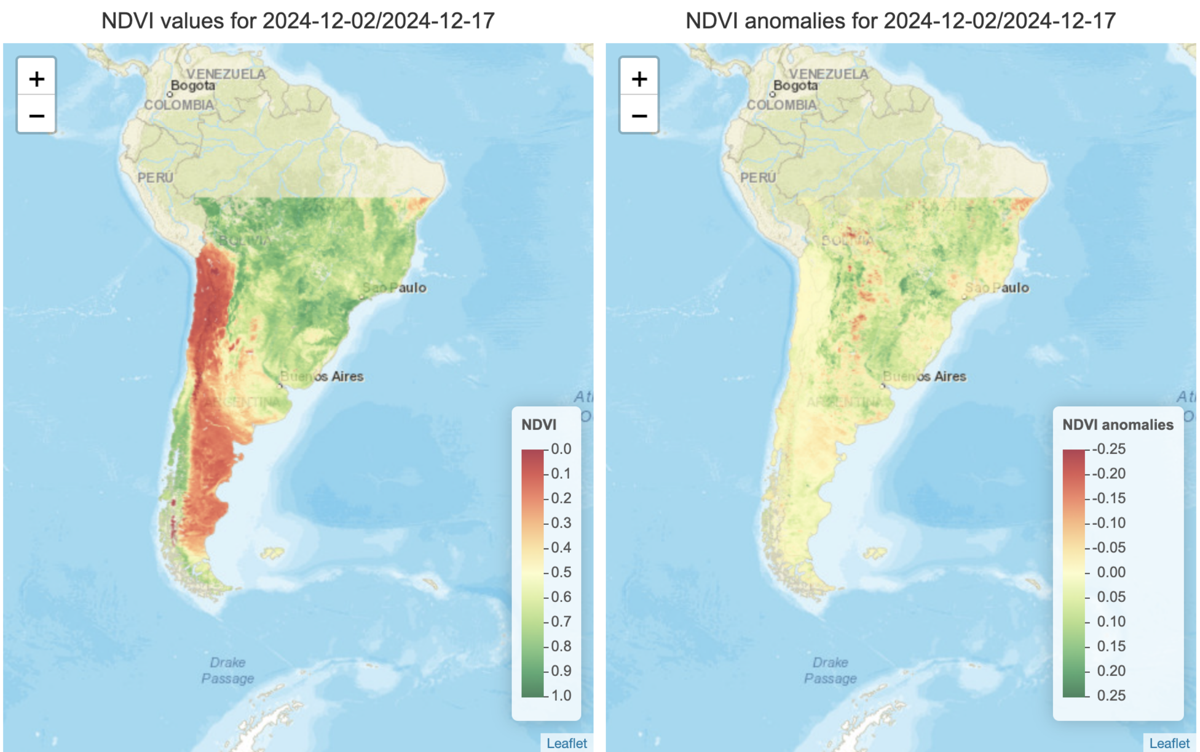

Figure 13. Monitoring of NDVI values and anomalies, provided by the RCC-SSA. Source: https://www.crc-sas.org/en/aplicaciones.php

Data and Availability

This subsection presents a summary (Table 1) of the sources of the data used to produce the forecasts. These forecasts are made available via the RCCs', the National Met Services' or the IRI Data Library's websites.

	RCC-SSA	RCC-WSA
Source	IRI Data Library, Copernicus Data Store	IRI Data Library, National Met Services
Observations	**Seasonal**: CPC-CMAP-URD and CHIRPS (precipitation) **Intraseasonal:** CHIRPS-GEFS (precipitation)	**Seasonal**: local station data for nationally-produced seasonal forecasts (precipitation, CPT) **Intraseasonal:** CPC-Unified (precipitation, ENANDES system)
	Seasonal: GHCN-CAMS and ERA5-Land (temperature)	**Seasonal**: local station data for nationally-produced seasonal forecasts (temperature, CPT)
Models	**Seasonal:** All NMME models and System 5 (IFS-ECMWF) **Intraseasonal**: GEFS	**Seasonal:** All NMME models and System 5 (IFS-ECMWF) **Intraseasonal**: NMME (monthly) and the SubX Consortium (SubC; weekly)
Forecast Frequency	**Seasonal:** Monthly **Intraseasonal**: daily	**Seasonal:** Monthly **Intraseasonal**: Fridays
Target	**Seasonal:** next season **Intraseasonal**: next fortnight	**Seasonal:** next season **Intraseasonal**: next month, next 4 weeks
Format	**Seasonal:** tercile-based probabilities, and exceedance and non-exceedance probabilities for certain thresholds. **Intraseasonal**: values	**Seasonal:** values and anomalies **Intraseasonal**: values and anomalies (monthly), values, anomalies, (non)exceedance and full

	(mm)	PDF (flexible format)

Table 1. Summary of the sources of observations, model forecasts, forecast target and format.

Typical Methods Used

This subsection summarises typical methods used by each RCC (Table 2), including, when conducted, calibration and verification of forecasts.

	RCC-SSA	RCC-WSA
Climatological Reference	1991-2020 (**seasonal**) 1981-2010 (**intraseasonal**)	1991-2020
Calibration Models and Tools	**Seasonal**: **CLIMAR** (ensemble regression) and IRI's **CPT** (using CCA). None for **intraseasonal**	**Seasonal**: no calibration in the regional products (**CPT** in national ones). **Intraseasonal**: none in the monthly forecasts, and **ELR** for weekly forecasts
Cross-validation Approach	Leave-one-out cross-validation for **seasonal**. None for **intraseasonal**	None for **seasonal**. Three-leave-out for the **intraseasonal** weekly forecasts
Downscaling Approach	In **CPT** only, as a by-product of the CCA approach (**seasonal**). None for **intraseasonal**	None in the regional products, **seasonal** or **intraseasonal**. National products (using **CPT**) are downscaled as a by-product of the calibration
Model Weighting and Ensemble	**CLIMAR:** weights are a function of correlation between hindcasts and observations.	Unweighted average of NMME models for the regional products for the **seasonal and monthly**

Approach	**CPT:** equal weighting after CCA calibration None for **intraseasonal**	products. **Intraseasonal**: unweighted average of SubC models.
Predictive Skill Assessment Approach	Metrics include HSS, RPSS, BSS, reliability and ROC diagrams. Details in Osman et al (2021) and publicly available reports	None conducted by the RCC. Metrics include Pearson correlation, RMSE, MAE and ROC, computed by the NMHS.

Table 2. Summary of the sources of observations, model forecasts, forecast target and format.

Communication and user support and feedback mechanisms

Both the RCCs and the NMHSs in South America have a significant presence in different social media channels, which allows for the interaction with their community of practice (CoP) and their community of interest (CoI). The selection of these social media channels slightly differs per institution. Whilst, the Regional Climate Centre Network for Southern South America is available through Facebook, X, LinkedIn and Youtube, the Regional Climate Centre for Western South America can be contacted through Facebook, X, Instagram, LinkedIn and Youtube. The NMHS in the region also offer a different variety of social media to engage with but overall, X and Facebook are the most common ones (see Annex 1). In recent years, following the social trend, NMHS have been moving towards video-based channels and platforms like Youtube or Instagram.

However, it is unclear the frequency of the feedback between the RCCs with their CoP and CoI. All institutions, including the RCCs and the NMHS, also offer an email address for users to contact them with queries. But, as per December 2024, none of the NMHSs nor the RCCs has a FAQ section. It is difficult to assess the tools and mechanisms to implement the feedback from users, their CoP or their CoI.

Mobilised resources and collaborations

Both RCCs report key collaborations and joint work with the NMHS, which catalyse the core of the co-development of climate services. In addition, in the case of the RCC-SSA, collaborations with academic institutions such as the Centro de Investigaciones del Mar y la Atmósfera (CIMA, https://www.cima.fcen.uba.ar/) at the Buenos Aires University continuously help advance different aspects of the work.

Besides economic support from local sources, both RCCs receive key support from different projects funded by a diversity of international sources. During the semi-structured interviews conducted by the authors, the RCC-SSA personnel mentioned CLIMAX (e.g. Osman et al., 2021) as an essential project supporting the CLIMAR seasonal forecast system, and SISSA for the intraseasonal precipitation forecasts. In turn, the RCC-WSA reports key support from ENANDES and Euroclima (https://www.euroclima.org/en/).

Documentation (guidelines, protocols) available

Regarding objective seasonal forecasts, it is very important that both South American RCCs already routinely reference and use the WMO's *Operational Practices for Objective Seasonal Forecasting* (WMO No-1246; WMO, 2020). The fact that they are already following this comprehensive guidance implies that there is a common minimum set of recommendations and requirements accepted, implemented or being implemented by both RCCs.

In addition, it also sets the stage for a similar set of recommendations and requirements for the intraseasonal timescales, as the soon-to-be-published WMO's Guidance on *Operational Practices for Objective Subseasonal Forecasting* (expected to be published in 2025) largely draws from the seasonal guidance document, expanding the approaches as needed by the intraseasonal timescale.

The RCC-SSA has a variety of technical reports available to download on its website. They cover the following topics:

1. Design of the daily climate data quality control process in the RCC-SSA in Spanish (2013).
2. Approach for the harmonization of a regional network of climate series at a daily resolution in Spanish (2013).
3. Description of the quality control for daily climate data implemented by the RCC-SSA in Spanish (2014).
4. Towards a Drought Information System for South America. A Strategic Plan to implement a Drought Information System (DIS) for South America in English (2018).
5. Description of indexes for the monitoring of meteorological drought implemented by the RCC-SSA in Spanish (last update in 2020).
6. Description of the daily climate database and the quality control implemented by the RCC-SSA in Spanish (last update in 2023).

In addition to these, the RCC-SSA also provides the link to some guidelines developed by WMO on climatological, hydrological and agricultural meteorological practices. And a guideline on analysis of extremes in a changing climate in support of informed decisions for adaptation.

The RCC-WSA offers in its website links to guidelines developed by WMO on climatological and hydrological I and II practices, as well as the WMO online library. It also provides the link to a policy brief on Climate Change and Biodiversity in the Tropical Andes (in Spanish) published by the Inter-American Institute for Global Change Research in 2015 and a chapter focused on local risk management of the book *Risk Management - Current Issues and Challenges* with techniques, case studies, good practices and guidelines for WMO Members (Martinez et al., 2012).

The RCC-WSA also offers links to several online training courses with:

- Trainings in meteorology, hydrology and associated sciences developed by WMO.
- Teaching and Training Resources for the Geoscience Community, developed by UCAR, both in Spanish and English.

- Virtual Institute for Satellite Integration Training, developed by NOAA-NESDIS Cooperative Institutes for atmospheric tele-detection, in English and updated regularly.
- Severe Thunderstorm Forecasting Course, published by the Cooperative Institute for Research in the Atmosphere, Colorado State University. The course is taught in English and updated regularly.
- Other courses available at the website of the Cooperative Institute for Research in the Atmosphere.

Part III. Limitations, Needs and Gaps in the implementation of objective seasonal and intraseasonal predictions

This section discusses gaps and limitations co-identified with the RCCs, specifically focused on -although not confined to- the advancement of objective seasonal and intraseasonal forecasts. The section is organised in terms of subsections summarising the various dimensions of the identified needs, which can be considered interrelated and structured by an overall need for maintaining and additional co-developing of climate services for the region, as described in the following subsection. Concrete recommendations regarding these gaps are suggested, also summarised in the Part IV of this Guidance Document.

Need for cross-timescale climate services co-development

The South American RCCs, and the NMHS before them, have clearly identified multiple demands from decision makers regarding the need for provision of a variety of climate services at multiple timescales, in particular at seasonal and intraseasonal ones. This demand is consistent with the one identified in other regions of the world: decision makers tend to do a better job when having actionable climate information at multiple timescales (Goddard, 2016), even if their main focus is one particular scale, such as seasonal or intraseasonal.

To illustrate the need with one example, consider the case of the agricultural sector. Even when it is not the goal of the RCC-SSA to directly deal the farmer federations, this is an example to illustrate the importance of supporting the NMHS to produce forecasts across timescales. Depending on the crop, the ag sector tends to require both past information (typical behaviour over different types of years –e.g. La Niña versus El Niño years) and forecasts of accumulated precipitation, minimum, mean and maximum temperatures, and a variety of extremes at seasonal timescales; but it is also important to know at intraseasonal timescales *how* the precipitation is going to be distributed (e.g. onset, duration, frequency of rainy or dry days, weekly amounts, demise), *when* certain temperature thresholds are going to be exceeded (or not), *when and how* critical extreme events might impact the crop, etc.

Other types of related climate information are also needed at longer timescales, involving what is referred to today as the annual, interannual, decadal, interdecadal and climate change timescales. Indeed, even if the farmer federation's main focus is this season and year, understanding that this season and year is part of a broader climate landscape such as a multi-year drought, or part of an unusually cooler decade, all superimposed over the global warming long-term signal, helps decision makers to produce better, more holistic strategies and plans than if they were to consider only the season (or year) ahead.

Assuming the present services are maintained (the end of some projects can impact the continuity of some of the present services offered), the lack of robust and operational climate services covering additional timescales is, hence, considered an important identified gap. It is clear the South American RCCs are working as much as they can -given the limited economic, human and time resources typically available in the region- to resolve this limitation, but the gap exists and support is needed from national governments and international institutions, including WMO, to advance the co-development of climate services across timescales, which is not necessarily the same as co-development of new services at additional timescales.

Identification of interacting climate drivers at global, regional and sub-regional scales

In order to advance the co-development of prediction services across timescales, a need discussed in the previous subsection, it is essential to further the understanding and identification of key climate drivers, their interactions, physical mechanisms and impacts over the regions. It is clear that a lot is already understood about the mechanisms and impacts of climate modes of variability such as El Niño-Southern Oscillation, the South Atlantic Convergence Zone, the Southern Annular Mode, etc. (see also discussion in Part I), but far less is known about the particular impacts of these and other drivers, including the MJO, in combination with each other. Although some work has been carried out in this direction (e.g. Muñoz et al., 2015, 2016a; Doss-Gollin et al., 2018), there is still a lot to be understood about how these cross-timescale interactions can (nonlinearly) amplify or attenuate climate impacts at global, regional and sub-regional scales.

Since prediction models are far from perfect and still cannot capture well the independent modes of variability –and much less some of the key cross-timescale interactions discussed in the previous paragraph–, it is not safe to assume at the moment that state-of-the-art climate models adequately deal with these processes and can be always reliably be used to produce accurate predictions. Further studies using a combination of physically-based and statistical models, including the so-called Artificial Intelligence (or more appropriately Machine Learning) models, as part of a regional research agenda supervised by the RCCs is needed, and will benefit from further collaborations with national, regional and international academic and research institutions.

Predictive skill assessment and verification

Another gap identified is the public availability of predictive skill assessments in ways easy to understand and visualise by decision makers using the forecast products, such as metrics and plots shown for different regions or locations, predictive skill maps, and forecast maps showing only skilful locations by use of a skill-based masking, with the possibility of defining "skill" in different ways (i.e. by choosing different metrics). This information should be available for each *initialisation and target time, variable, timescale and location*, preferably automatically updated and accessible via the RCC's websites.

The public availability of this type of products related to skill assessment is essential as it adds value and conveys transparency and reproducibility to the forecast maps and products being presently provided by the RCCs. The availability of public reports and peer-reviewed papers is indeed an excellent first step, but decision makers often complain about the difficulties involved in clearly and quickly being able to visualise and understand the quality of the forecasts being provided.

It is important to also be able to clearly offer to decision makers information on what skill metric to use depending on the question being asked (or, formally, the forecast attributes of interest).

Finally, given the increased demand on cross-timescale predictions -as discussed previously in this section– a cross-timescale skill assessment approach is urgently needed, and at the moment it is largely non-existent, not only in South America but worldwide.

Downscaled and tailored climate information, data and methods

Both RCCs are already conducting statistical downscaling as a byproduct of the pattern-based calibration performed with IRI's Climate Predictability Tool. As several past studies have shown, downscaling indeed increases the spatial resolution, but does not necessarily increase predictive skill, in particular it does not necessarily increase the signal-to-noise ratio (the signal is not only increased when conducting downscaling, the noise can also be increased and at a faster rate than the signal, hence producing high-resolution products that are not necessarily more skilful than the low-resolution ones).

Since downscaling is conducted as part of the pattern-based calibration approach, the products produced by CPT tend to have higher skill than the original raw model output. An identified gap is that the downscaling-via-calibration should also be explored with other or additional variables than the actual one being predicted; e.g. for precipitation, the CCA is conducted using model's precipitation or sea-surface temperatures, but other related physical fields controlling precipitation, such as moisture advection, or geopotential height anomalies. Since the use of Machine Learning approaches is becoming more and more common, it is encouraged to explore the use of *explainable* (e.g. Barnes et al., 2022) Machine Learning methods for downscaling (and also calibration).

In addition to the excellent work already being conducted by both RCCs in South America for –in the case of the RCC-WSA– mean precipitation and temperatures, and –in the case of the RCC-SSA– tercile-based and threshold-specific exceedance and non-exceedance probabilistic precipitation forecasts, another limitation identified is related to the lack of a more flexible prediction system. Decision makers tend to act on different triggers, usually related to one or more thresholds of the variables of interest; although the NMHS are the ones in charge of the interactions with decision makers and end users, the NMHS often require methodological and coordination support. To illustrate the need for a flexible (i.e. multi-threshold) prediction approach, consider the case of a farmer who can buy a relatively expensive seed if the seasonal rainfall forecast is expected to exceed -say- 120 mm in its location, or buy the usual seed if it does not exceed 100 mm. In multiple locations, it is not infrequent that both thresholds (120 and 100 mm) are part of the above-normal category. This is a missing opportunity for RCCs to support NMHS in their interactions and regarding related requests from such decision makers.

A solution is the implementation of forecasts systems for the different variables of interest that consider the entire probability density function, something known as “forecasts in flexible format”, and directly recommended in the WMO Guidance Document for Operational Seasonal Forecasts (WMO, 2020). CPT has had this functionality implemented for more than a decade now, and it is part of IRI’s NextGen approach (Muñoz et al., 2020; Campos, Cabello, Muñoz, 2025), but presently just Colombia’s and Chile’s NMHS have implemented such flexible formats at seasonal timescales, and the RCC-WSA along with Chile, Peru and Colombia’s NMHS have it implemented at the intraseasonal timescale (e.g. Figure 12). Both RCCs and their related NHMS can benefit from such implementation at regional level, which should also consider forecasts of extremes defined via multiple thresholds.

Another limitation mentioned during the RCC’s interviews conducted by the authors is that there is a demand for additional variables, beyond mean temperature and precipitation. Not only minimum and maximum temperatures will be beneficial –as mentioned in the previous paragraph, forecasts should be produced for all possible thresholds, for example by forecasting the entire PDF; fields such as winds, the Standardised Precipitation Index, the Standardise Precipitation-Evaporation Index, and soil moisture were all mentioned in the interviews as needed by decision makers.

Related also to tailoring of variables, implementing the forecasts in terms of odds and relative odds in addition to the more traditional probabilistic formats tend to be very beneficial, due to the wide variety of decision makers and needs. It is a relatively trivial calculation given the already available probabilistic forecasts produced by the RCC-SSA. In the case of the RCC-WSA, it would be beneficial to also present the seasonal forecasts in these formats, in addition to the absolute values and anomalies. In fact, in the case of the RCC-WSA it is essential to include an uncertainty envelope to their seasonal and monthly forecasts, for example by presenting maps with the inter-quantile range (using 20th and 80th percentiles, for example) for each variable. The RCC-SSA can also trivially present their forecasts as values and anomalies and their respective uncertainty envelopes. The authors are very aware that this is not a traditional approach, but a technical argument can be discussed with the interested readers to show the benefits of having both formats (probabilistic and non-probabilistic), and the fact that they actually convey the same information in different ways, often something needed -again- due to the diversity of decision makers.

Regarding the sources of datasets used to produce the different products and services, both RCCs can benefit from implementing –whenever possible– a backup system to download the data. For example, since both RCCs mention that they use the IRI Data Library to routinely download key datasets, but those datasets are also provided by other sources, it can be wise to implement programming scripts to download the datasets from the additional sources in case there are any issues with the primary one.

Communication and user support and feedback mechanisms

The analysis conducted shows that both RCCs are already doing an excellent job in terms of internal (e.g. with the NHMS) and external (e.g. with governments, media, etc) communications, via their websites, social media and especially their respective COFs. Perhaps, as suggested earlier in this document, clearly communicating forecast predictive skill via interactive tools such as online maps or by masking the maps using different predictive skill metrics, can help better support decision makers in furthering their understanding of forecast quality.

Regarding feedback mechanisms, an existing gap is that there is presently no formal, objective and continuous feedback mechanism available at any South American RCC, only informal and occasional ones (for example, during the COFs). This is essential to assess the value of the products, how well are understood, analyse the evolution of concrete demands, and identify ways to improve products and services.

Sustainability, resources and collaborations

Long-term sustainability for the present and future products and services is essential, and –as reported by both RCCs during the interviews– is seriously endangered by lack of enough trained personnel, computational resources, and maintaining strong collaborations. Most of these elements can be supported by continuous funding from a variety of sources, involving both the public and private sectors.

Need for documentation (guidelines, protocols)

As presented in Part II of this document, both RCCs have done an extraordinary job developing guidelines and protocols for a wide variety of topics. After reviewing potential gaps regarding documentation, a first suggestion is to check Chapter 4 of the WMO Guidance Document for Operational Seasonal Forecasts (WMO, 2020), which clearly outlines recommended essential tasks and hence the existence of related guidance and protocols.

In addition, new documentation should be produced describing the innovations and respective methods that will be implemented to deal with the region-specific limitations and gaps presented in Part III of this document. See recommendations in the next section for more details.

Part IV. Recommendations and tailored guidance

This part of the guidance includes a list of targeted recommendations, mostly a summary of the more detailed discussion of gaps and needs presented in Part III, and some directly suggested during the different interactions with both RCCs. For the sake of simplicity, the list of recommendations is organised in terms of different key "dimensions" for tailored guidance, although several of them permeate multiple of these dimensions.

Continental, regional and sub-regional coordination and synergies

1. The RCC-WSA underscored the importance of the **WMO Regional Office** in maintaining **both technical, strategic and political coordination**, at continental, regional and sub-regional level. It is recommended to keep the excellent work conducted by the WMO Regional Office, and to strengthen it as needed. The needs for strengthening can be updated periodically by consensus with the RCCs and NMHSs.
2. The RCCs' and NMHS's new (and some present) climate services development and maintenance depend on funding availability, which is not trivial to find and tend to be "intermittent". A more formal **funding roadmap** that avoids funding gaps must be established, with mechanisms to keep it **updated and flexible** enough to divert money to emergent issues, after guaranteeing annual continuity of the core regional and sub-regional services. It is recommended that this funding roadmap involves both the public and the private sectors.
3. It is essential to maintain the **inter-RCC and inter-NMHS coordination** and the establishment of a multi-year, tailored **continental/regional agenda** involving methods, good practices, funding opportunities and forecasters exchange of experiences, taking full advantage of virtual platforms. Perhaps it is possible, and even economically efficient, to hold a joint WCSA-SSA COF every two years to boost the exchange of experiences and discuss the continental exchange agenda.

Operational processes regarding data and methodological improvements

The following recommendations reinforce the ones already indicated in the Guidance on Operational Practices for Objective Seasonal Forecasting (WMO, 2020).

1. To **maintain updated, homogenised and quality-controlled observational datasets**, both at local (i.e. station) level and also as gridded datasets. For the gridded datasets and also to complete missing values in the station data, consider different approaches involving merging calibrated satellite and reanalysis products, or the use of internationally available gridded observational products such as CHIRPS, CPC Unified, etc.
2. To **support the operationalisation and continuous update and publication** (e.g. in the NMHSs' websites) of the **forecast quality** of the national and regional prediction systems at seasonal and intraseasonal timescales. The forecast quality should follow the WMO's Guidance on Verification of Operational Seasonal Climate Forecasts (WMO, 2018); although this document targets seasonal forecasts, the approaches discussed are general and can be also used at the intraseasonal timescale), and it is important that multiple metrics are used, considering various forecast attributes. The forecast skill should be saved for future comparison purposes, such as for analysis of how the skill has increased over time.
3. To **explore the feasibility and develop forecasts for additional variables**, considering approaches that predict the entire probability density function, as suggested by WMO's Guidance on Operational Practices for Objective Seasonal Forecasting (WMO, 2020). Examples of such new variables of particular interest to decision makers and hence the NMHSs that the RCCs support are rainfall characteristics beyond total rainfall, such as frequency of rainy or dry days, onset, duration and demise of the rainy season(s); other tailored variables, always informed by the demand of information, can be -for example- frequency of days exceeding (or not exceeding) particular thresholds of interest to users, the Standardised Precipitation-Evaporation Index, soil moisture, etc.

4. To **always include at least one measure of uncertainty**, either in terms of probabilistic forecasts, odds (or relative odds, depending of what is needed) or, when the demand requires actual values rather than probabilities or odds, include an uncertainty envelope, such as the inter-quartile range for the 80th and 20th percentiles, as it was -for example-done in the case of the WMO-led ENANDES project.
5. To **further advance the understanding of how global, continental, regional and more local climate drivers control and impact predictive skill of the climate variables of interest** to decision makers, NMHSs and hence RCCs. Beyond the need of better understanding the different "flavours" of ENSO and the more local impacts of the MJO, there are several other climate modes of variability at seasonal and intraseasonal timescales that, regionally or locally, can exhibit a more important role in controlling key variables. Hence, it is recommended to implement a regionally-defined research agenda informed by both researchers and operational forecasters, considering global and regional climate modes of variability, and their interactions at the same and across timescales (cross-timescale interference mechanisms and analysis), and also regarding interactions with the anthropogenic climate change signal.
6. To **develop a research and implementation agenda to produce and provide physically-consistent forecasts across timescales**, preferably **forecasts in flexible format** (i.e. prediction of the entire probability density function). The provision of the forecasts in flexible format is already recommended by the WMO Guidance on Operational Practices for Objective Seasonal Forecasting (WMO, 2020), but the best ways to "bridge" predictions across timescales is still a hot topic of research by the global climate scientific community and deserves close attention in the region. It is recommended to explore a variety of methods, including explainable Machine Learning ones.
7. To **explore the technical adequacy and demand's befitting** (how fit-for-purpose it is) of **different calibration and downscaling methods**, including Machine Learning ones.
8. Regarding **data-related policies**, it is recommended to make the data publicly available; indeed, these policies depend on the actual regulations and policies implemented by each NMHS and national governments, but it is recommended as much as possible to transition

whenever possible to such a "data as a public good" approach. In addition, all forecast products should be directly hosted by the NMHS or the RCCs, not by external institutions (e.g. the intraseasonal prediction system co-developed by the ENANDES project should be mainly executed by computing servers located in the region). Regarding the sources of datasets used to produce the different products and services, both RCCs can benefit from implementing –whenever possible– a shared backup system to download common data.

Capacity building and trainings

Due to the lack of enough human resources with the required training, building regional and national local capacities was identified as a key need.

1. To continuously identify relevant academic programmes in Latin America **to strengthen regional expertise and catalyse knowledge transfer**.
2. To **take advantage of annual international and regional schools and trainings** happening both in person and virtual, such as those organised by the WMO Global Campus Initiative, the World Climate Research Programme (WCRP), the International Centre for Theoretical Physics (ICTP), and similar other institutes.
3. To **hold at least one joint cross-pollination (online) workshop** among the NMHS and relevant universities and research centres related to both RCCs, to exchange knowledge, experiences and good practices (see #3 in the coordination and synergies subsection).

Communication and user support and feedback mechanisms

1. To **implement a formal and frequent set of feedback mechanisms for users to evaluate the information, tools and services provided by the**

NMHSs and RCCs. The nature and frequency of such feedback mechanisms (e.g. seasonally-conducted semistructured interviews, online surveys, workshops) needs to be defined by each institutions depending on the type of product. Such feedback should be then **used as soon as possible to improve the information**, tools and services provided.

2. To **clearly communicate forecast predictive skill** via interactive tools such as online maps or by masking the maps using different predictive skill metrics.
3. To **strengthen the Help Desks** already operating in the different institutes, or create them as needed.
4. To **take advantage of present and future AI technologies to help communicate** information and services to decision makers.

Documentation (guidelines, protocols) recommended

1. To **continuously update the documentation on the approaches and methods** used to conduct the different operational tasks.
2. To **co-develop a set of guidance and protocols to guarantee a minimum quality** of the products being developed. The minimum quality depends on the products and the demand, and hence these documents are expected to provide broad guidance and not a set of "one size fits all" standards, which is probably impossible to achieve in most tailored products.
3. To **include** in the RCCs, NMHS and COF websites, as needed, **a set of Frequently Asked Questions** (FAQ).
4. To take advantage of the collection of learning resources available by several institutes, such as those provided by the WMO Global Campus.

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Annex

Table with products and services of the NMHS in South America as found in the respective websites in December 2024. This is not intended to be an exhaustive list and has not been approved by any NMHS or RCC. It is presented as a guide for some of the multiple products offered by the NMHS.

	INAMHI	INAMEH	IDEAM	INAMHI	DMC	SMN	SENAMHI	DMH
	Perú	**Venezuela**	**Colombia**	**Ecuador**	**Chile**	**Argentina**	**Bolivia**	**Paraguay**
Early warning (2-3 days) Bulletins	High temperature Wild fires		Same day EWS (wildfires, landslides and hydrological alerts). 24h forecast for precipitation 3 days bulletin for precipitation		For the energy sector and the agriculture sector, several variables	Variables: storm, precipitation, snow-storms, wind, zonda wind, fog, dust, smoke, volcanic ashes and wildfire index 3days lead time and short term warnings	Variables: storm, precipitation, snow-storms, winds and atmospheric conditions for fires 3 days lead time	no/unclear

Nowcasting (next 24h)	yes	yes	yes	yes	yes with a particular section for turistic towns, mounting pass Los Libertadores and borders crossing areas	UV Solar Index, Antartic forecast (includes maritime forecast)		
Hydrological warning (same day)	yes		yes	yes		No		
Weather Forecast	Infographic bulletins per region covering different variables (temperature, precipitation, fog, wind)		Precipitation Solar radiation Temperatures Cloudiness Wind speed ET Ozono	Infographic bulletins per region covering different variables (temperature, precipitation, fog, wind)	Infographic bulletins per region covering different variables (temperature, precipitation, fog, wind)	Precipitation Temperature Winds Wind direction	Precipitation Temperature Winds Wind direction	Precipitation Temperature Winds Wind direction
Numerical prediction at	**Every 3h and 6h**		**Every 6h and 12h**	**Every 3h, 6h and 24h**		**Every 6h**		

national and regional level	Precipitation Temperature Humidity Winds at 10m Winds at 150 hPa Winds at 200 hPa Winds at 300 hPa Winds at 400 hPa Winds at 500 hPa Winds at 700 hPa Winds at 850 hPa Winds at 1000hPa		Precipitation Temperature Winds at surface level Winds at 200 hPa Winds at 500 hPa Winds at 700 hPa Winds at 850 hPa Cloudiness Temperature at 2m Relative humidity GFS (every 6h) WRF Colombia every 12h	Precipitation temperature, humidity, winds at 10m, winds at 150hPa, winds at 200hPa, winds at 300hPa, winds at 400hPa, winds at 500hPa, winds at 700hPa, winds at 850hPa, winds at 1000hPa	WRF with observations from DMC. WRF atmospheric	Precipitation Temperature Winds Cloudiness Regional info for De la Plata River (temp. and precip.) Ensembles: Low resolution (7 days, 50km) and high resolution (2days 4km) Waves (high and period). 4 days forecast and retro analysis Storm waves. 4 days forecast for De la Plata River and its platform.		WRF Accumulated precipitation every 1h,3h,6h Temperature at 2 meters Max Cape Winds and humidity at 200 hPa Winds at 300 hPa Winds at 400 hPa Winds at 500 hPa Winds at 700 hPa Winds at 850 hPa Wind speed and direction Geopotential and vorticity at 400hPa Geopotential and vorticity at 500hPa Geopotential and vorticity at 700hPa Convection inhibition index

Subseasonal forecast	ENANDES (not publicly available in their website, but https://shorturl.at/PPNJA)				ENANDES. Also included in the monthly seasonal forecast (recorded and available in youtube)	Precipitation (accumulated and anomalies) Temperature (mean and anomalies) 2 weeks in advance		Precipitation (accumulated and anomalies) Temperature (anomalies) 1 month in advance

Seasonal forecast	Variable of interest: precipitation total mm/month for the next 3 months and anomalies Domain: national and regions Bulletins	Bulletin with seasonal information on temperature and precipitation. Last update form February 2024 (as seen on December 2024). Monthly summary of model ensembles for precipitation and temperature. Last update form November 2023 (as seen on December 2024). Historical climatological data per month and state for precipitation and temperature	Monthly forecasts for precipitation, wind and temperature. Seasonal forecast for precipitation (NextGen) linked to IRI DL. CFSv2-WRF and Jaziku (link not working)	Bulletin with monthly seasonal information on precipitation.	Monthly seasonal forecast for temperature (anomalies, max, min), heat waves, and precipitation, SST, winds, MJO, ASO, international forecasts. Available on the website and youtube.	Variables of interest: probabilistic precipitation (a/n/b) and temperature Domain: national and regions Bulletins	Variables of interest: observation of previous month (total mm and temperatures max, med and min) probabilistic precipitation (a/b/n) and temperature seasonal (total season and monthly) Domain: national and regions Bulletins	Probabilistic forecast for precipitation and temperature from IRI
Projections or simulations					yes			

El Niño	Total monthly accumulated precipitation at national level (TIF)	Probabilities of ENOS phases. Last update form February 2024 (as seen on December 2024).	ZCIT	Monthly accumulated precipitation Monthly precipitation anomalies Seasonal accumulated precipitation Seasonal precipitation anomalies	El Niño/La Niña intensity forecast. Available with the seasonal forecast (recorded and available on the DMC website and youtube)	Monthly bulletins from April 2019 and monitoring system	Monthly monitoring included in the seasonal forecast	
	Monthly precipitation anomalies vs average El Niño years (TIF)		Typical ENOS					
	Total quarterly accumulated precipitation at national level (TIF)		Monthly precipitation CHIRPS precipitation					
	Quarterly precipitation anomalies vs average El Niño years (TIF)		Monthly wind					

Meteorological annual books	Starting in 1994	Monthly precipitation anomalies from December 2020 to May 2021		Meteorological (since 1994) and hydrological (since 1993)	Since 1872 (although more consistence since 1900s)				
Other services	Hydrometeorological station viewer app	Monitoring system of the main rivers	Monthly agroclimatic bulletins MTAs bulletins	Hydrometeorological station viewer app	UV index forecast per region Aeronautical meteorology (turbulence due to ice, montain range turbulences, commercial aviation, general aviation, forecast for airfields, gliding, 7days forecasts, runaway visual range, etc.)	Ag sector: Regional weather forecast (4 days), daily, dekadal and monthly agro meteorological monitoring, monitoring of vegetative cover, ground and water. Aeronautical services Volcanic Ash Advisory Center Maritime sector Hydrological (per basin) and energy sector (regions with temp lower than 10C and higher than 26C	Agroclimatic monthly and dekadal bulletins	Hydrological levels of rivers (historical data and daily forecasts), well level updated hourly, and water level forecast for the next 2 months Ag services with historical data since 1987 (including water levels, soil information and crop information)

	Drought monitoring system app: Based on SPI, STI, SSMI,SVHI,SPEI	Monthly hydrological bulletin of the Orinoco and Apure rivers	Monthly Climate and health bulletins (last update July 2024)	Drought monitoring system	Services for the energy sector, agrometeorology, solar radiation, CC, heatwaves, cold spells,			
	Repository (Meteoglow) Satellite data for precipitation Weather forecasts for precipitation, temperature,relative humidity and wind speed GOES monitoring (cloud and moisture; fire temperature	Short term (3 weeks) forecasts of hydrological conditions of the main rivers	Drought bulletin ENANDES bulletin ENOS bulletin Air quality bulletin	Meteoglow applications Satellite data for precipitation Weather forecasts for precipitation, temperature,relative humidity and wind speed GOES monitoring (cloud and moisture; fire temperature	Monthly data of humidity, temperature, precipitation, winds, pression, weather stations and metadata, satellite information, droughts, AMDAR reports,			
					Air quality (Ozone forecasts, WRF Chem, and time series per station)			

Free data download	yes	no	yes	yes	yes	yes	Prior request	free for the ag sector
IG, X, facebook , other social media channels	X and Fb	X, FB, IG and youtube	X, FB, IG and youtube	X, FB, LinkedIn and youtube	X, Fb, IG, youtube and flicker	X, FB, youtube, iG,	X,FB, Youtube	X, FB
Telegram/ whatsapp	no/unclear	no/unclear	no/unclear	no/unclear	no/unclear	Whatsapp	Whatsapp	no/unclear