Seasonal Climate Forecasts to Aid Decision Making in Brazil

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INTRODUCTION
Brazil’s Center for Weather Forecasting and Climate Studies (CPTEC) produces climate forecasts that predict rainfall and temperature anomalies for Brazil on a seasonal scale. CPTEC conducts seasonal climate research and operational forecast efforts, while also coordinating its work with collaborating institutions and technicians. Its seasonal forecasts are created using the outputs from several global climate models, which are both generated in-house and from other climate centers in the world. The raw output models are combined and discussed among scientists and users during monthly climate outlook forums. The main products generated are probability maps for seasonal rainfall distributions, with terciles of above-normal/normal/below-normal categories.

One of the major innovations put into practice throughout the development of CPTEC’s seasonal climate forecasting service was the continued engagement with state bureaus of meteorology. This engagement was centered on the monthly seasonal outlook forums, which were held in each state each month, from October to August of every year. Each state bureau was responsible for running the forum once a year, providing meteorologists and hydrologists in each state a platform for capacity building. Most importantly, the forums brought a wide range user groups together on a monthly basis, including farmers, state secretariats, civil defense officials, and the media. Forums became a regular and expected annual event in each state, bringing prestige to local meteorologists and acting as a major media event for local newspapers, radio, and television stations.

The monthly seasonal outlook forums still happen today, but to a much lesser degree and with uncertain results. This is in part due to CPTEC’s decision to pull back in leadership over the years, and in part to the absence of permanent technical bodies in the state bureaus. It is likely that the previous strength of the forums was due mostly to the synergy between the scientists and technicians, and less to the institutional framework at that time, although the changing institutional framework certainly played a large role in the decline as well.

SOCIOECONOMIC BACKGROUND
Seasonal climate forecasts have a wide range of applications in Brazil, since rainfall anomalies have consequences on a number of different socioeconomic sectors and the generation of hydroelectricity. Forecasts can help decision makers to anticipate yields of corn and beans for rain-fed subsistence agriculture in the Northeast; rainfall forecasts are also relevant for dam management, especially with regards to tradeoffs between electricity generation and the drinkable water supply for cities.

TARGET AUDIENCE
The target audience for this service is mostly the Brazilian federal and state secretaries of agriculture and water resources. Examples of users include the National Operator of the Electric Energy Sector (ONS), NGOs that advise on agricultural activities over the semi-arid northeast, the cities and states civil defense, and the sugar cane producer associations, as well as individual small and large farmers. Users are identified as they approach the forecast producers (CPTEC) and the state bureaus of meteorology. Both local and national media normally cover the monthly outlook forums, but forecast reports only reach the press and television when major anomalies of either floods or droughts are highly probable.

CLIMATE AND CONTEXTUAL INFORMATION
Drought relief is a major issue in Northeast Brazil, and the government has focused a lot of attention and resources on managing the water supply: digging water wells, restoring dams, and distributing drinkable water with water tank trucks. Flooding and landslides are other problems that have enormous impacts on society, but are less relevant for the purposes of this study because the seasonal climate forecasts have been less effective in confronting them. This is because the meteorological events that cause city floods and landslides are synoptic-scale phenomena, which are seldom captured by current methods and models of seasonal climate prediction.

The seasonal forecasts are based on global climate models outputs, regional model outputs, and global atmospheric and oceanic diagnostic fields (i.e. observations in a gridded format). The National Centers for Environmental Prediction (NCEP) provides the global diagnostic fields, while the National Meteorological Institute and the state bureaus of meteorology provide national rainfall and temperature data. Oceanic data is provided by the multinational Prediction and Research Moored Array in the Atlantic (PIRATA) and global forecast products are provided by Brazil’s Center for Weather Forecasting and Climate Studies/National Institute for Space Research (CPTEC/INPE), MeteoFrance, the UK Meteorological Office (UKMO), the European Centre for Medium-Range Weather Forecasts (ECMWF), and the International Research Institute for Climate and Society (IRI).

Information is accessed through the websites of all the providers mentioned above and via File Transfer Protocol (FTP). The users of climate information in Brazil can reach the CPTEC’s net products through its website, as well as through the website of the state bureaus of meteorology. There is no direct cost to obtaining the diagnostic and prognostic fields used to generate the CPTEC seasonal climate forecasts.

1 http://clima1.cptec.inpe.br/
The main products generated by CPTEC are generally not tailored for specific users. The seasonal forecasts are provided as is, without much tailoring to the specific application or demand. However, some seasonal forecast products, such as the probability distribution of occurrence of above-normal or below-normal rainfall over a specific hydrographic basin, are occasionally generated specifically for the energy and agricultural sectors. In this case, they are tailored by meteorologists and hydrologists hired by the interested party.

Seasonal climate information is used in decision making in many sectors throughout Brazil. For example, in the agricultural sector in the Northeast, the information is used to inform seed distribution. A higher probability of a normal seasonal rainfall period induces the government to anticipate seed distribution and finance earlier soil preparation. On the other hand, a prediction of below-average rainfall influences decision-makers to either halt the distribution of seeds, which generates downstream social consequences of great magnitude, or to assist farmers with emergency irrigation facilities later on.

In the energy sector, the information is used to regulate the volume of water in the reservoirs needed for hydroelectric power plants. An outlook of below-average rainfall also leads decision-makers to retain a larger volume of water in the reservoir, whereas if normal to above average rainfall is predicted, the water reservoirs are used to regulate the river flow, avoiding flooding conditions in cities downstream.

Federal government programs are particularly interested in information regarding the seasonal forecasts and the projected anomalies. This is largely due to the severe social consequences of drought in the semi-arid northeast, which requires a great deal of federal funds for social programs and infrastructure construction such as small dams. For instance, the 2012 severe drought led the Federal Government to devote R$2.7 billion (~US$1.4 Billion) to support the region. Because drought is so often a problem in the region, television, radio, and newspapers there are always working to provide information on the current rainfall conditions, and forecasts.

IMPLEMENTATION

PROCESSES AND MECHANISMS

STAKEHOLDER AND ISSUE IDENTIFICATION

The primary stakeholders who use the CPTEC seasonal climate information service are federal and state governments, and electric energy companies. These users include the state secretaries of agriculture, the banking system, and the operator of the national electric system, with the civil defense of both federal and state governments being the most important.

State governments were identified by their varying needs to address drought, taking into account regional issues, like their need to support families that depend on rain-fed subsistence agriculture, or the large soybean producers in the Central-West region. Drought has particularly large socio-economic implications for the country because agriculture is such an important part of Brazil’s economy. Currently, Brazil is the third-largest exporter of agricultural goods worldwide. In the energy sector, drought and nationwide blackouts forced the hydroelectric companies to focus their attention on seasonal climate outlooks produced by CPTEC.

The production of these forecasts is supported by multiple data-producing institutions, which are long-term collaborators with CPTEC. These include PIRATA, Brazil’s Center for Weather Forecasting and Climate Studies/National Institute for Space Research (CPTEC/INPE), MetéoFrance, UKMO, ECMWF, and IRI.

STAKEHOLDER INVOLVEMENT

The scientific discussion that accompanies the generation of the “consensus forecast” results in a two-page report, which is then made available to the public through CPTEC’s web page. Also, the state bureaus of meteorology generate bulletins with both monitoring and forecasting information, which are then provided to stakeholders.

Technicians from the interested parties – mainly the energy sector and the agricultural departments – also participate in the consensus forecast activity, during which outlooks are produced according to the global monitoring data published by the Climate Prediction Center (CPC) at the United States National Oceanic and Atmospheric Administration’s (NOAA), the prognostic fields generated by CPTEC’s own models, as well as a dozen other global models available from IRI and various European centers. This gathering of experienced climatologists involves discussion about the several information sources available and provides an opportunity to learn about the technical jargon, limitations, and uncertainties of the publicized seasonal outlooks/forecast products. Unfortunately, there are no specific educational materials aimed at providing the needed education on the terms and concepts used during the meetings.

The Internet is used to access all data and model products used to generate the seasonal climate consensus forecast. Synthesis products and forecast text and maps are also distributed online.

FUNDING MECHANISMS

The seasonal forecast outlook forums and their model runs are funded solely by the Brazilian government through the Ministry of Science, Technology and Innovation. The government understands the importance of investing in forecasts, which help it to anticipate extreme climate events rather than spend money later on relief efforts. The private sector investments in specific products are less significant, and mostly aimed at individual needs. For instance, the television companies may pay for a specialist to work in tandem with CPTEC’s forecast meteorologists in order to customize the forecast information used by the television network.

In terms of equipment, reasonably secure funds have available for the acquisition of supercomputer infrastructure for CPTEC, which costs around US$20 million every four years. These investments made for supercomputer upgrades average US$5 million each year, while investments made in the PIRATA network of buoys over the tropical Atlantic are of the order of US$1 million each year; the expansion of the national network of meteorological stations costs approximately another half a million US dollars per year.

Yet despite government commitment, funding for the work does not always come easily. The biggest financial challenging is the assembly and maintenance of stable civil servants staffs in both federal and state institutions. Other investments in human resources are limited by the number of qualified scientists and technicians available nationwide. Similar challenges have presented themselves in the effort to scale up the production of forecasts.
The government established the state bureaus of meteorology and water resources in an attempt to scale up the forecast producing service, from 1992 to 2006. The program showed great potential and was highly successful for more than a decade, but ultimately could not be sustained at its original scale, as the initial federal investments dwindled and were not replaced by enough local state government resources. Currently, only some of these state bureaus of meteorology are still operational, doing both weather and seasonal climate forecasting, with widely varying degrees of sophistication. Over time, there has been a tendency to strengthen federal institutions to replace the services previously done by the state bureaus.

**MANAGEMENT AND DECISION MAKING**

CPTEC/INPE is the lead institution involved with the management of the seasonal outlook forums; it is responsible for publishing the consensus reports online for access by end-users. Project management is also shared with the National Institute of Meteorology (INMET) and the state bureaus of meteorology.

The decisions concerning the seasonal climate consensus forecast used to be made according to the physical basis for the specific situation. However, over time a number of factors led some of the most experienced climatologists to other endeavors, leaving the work done by a group of less experienced fellows. Such changes have influenced the seasonal climate outlook, eroding part of its value.

**EVALUATION**

CPTEC is responsible for evaluations, which are made based on objective criteria for the model outputs. Meanwhile, the subjective consensus forecasts are seldom rigorously evaluated. This is a portion of the system that hurts the perception of value that seasonal climate outlooks might have. The lack of an objective measure of seasonal forecast skill is one of the largest barriers to the information being better utilized. User feedback regarding changing forecast technique is also lacking.

**INFLUENCING ADAPTAION**

Seasonal climate forecasting has been used by government agencies to adapt to changes in regional climate in numerous occasions. For example, during the 1998 drought, forecasting information was used to guide the installation of a potable water supply in the city of Fortaleza. The seasonal forecast clearly predicted a serious drought throughout the region and proved itself to be true. Based on this information, a water supply forecast was made, projecting that the drought would result in the complete collapse of water supply to the city. The government then decided to go ahead with the construction of the planned channel, which it completed in record time, avoiding the collapse of Fortaleza’s water supply.

Another example took place in 2002-2003, when CPTEC climate information was used daily by government officials and decision-makers in the energy sector to manage hydroelectricity shortage that resulted from the drought in southeastern Brazil. In this case, which provides an early example of today’s concept of seamless prediction system, both weather forecasts and seasonal climate forecasts were used in tandem to manage the water reservoir levels. The more expensive thermo-electric power plants were used to provide the more energy to the grid.

**CAPACITIES**

**EXISTING CAPACITIES**

CPTEC’s seasonal climate outlook team has evolved over time. The group began in 1984 as a small team of young scientists at INPE, producing conceptual predictions for the rainy season in Northeast Brazil. Slowly, their efforts expand to include a larger and more experienced scientific team with access to a state-of-the-art supercomputer system and an array of sophisticated prognostic tools.

The level of expertise in user organizations varies widely. In general, state bureaus of agriculture are dependent on external support to interpret the seasonal climate outlook information. Meanwhile, the energy sector hires technicians specifically to assemble their own “ensemble prediction” system, which is based on CPTEC’s monthly climate outlook information.

**CAPACITY GAPS**

Throughout the development of CPTEC’s seasonal climate prediction practices and products, establishing partner relationships was a challenge. As the products became more popular among user groups, competition among producers became an obstacle. This challenge has been overcome, however, and institutions that used to compete are partners today. Such partnerships came into place as a mutual recognition of the benefits of sharing data and expert knowledge among their scientists and technicians.

Another serious challenge has been the lack of steady funding to support the constantly expanding need for accurate monitoring and prediction information. Additionally, improvement to the service has stagnated over the years, in part due to the understated need to assemble and maintain trained teams of civil servants both at CPTEC and the state bureaus of meteorology.

As mentioned earlier, another missing capacity is the lack of specific educational materials aimed at providing the needed education on the terms and concepts used during the climate outlook meetings.

**CHALLENGES MEETING USERS NEEDS**

Keeping up with growing expectations has been challenging. As seasonal forecasts became more widely used, they have proved their value in preventing financial losses due to unexpected drought or floods. However, due to the high-stakes involved in using climate information for this purpose, predications that turn out to be inaccurate are increasingly met with anger and frustration, particularly among user groups that are not as familiar with climate forecasting.

For example, in 1989 – before regular seasonal predictions were broadly available – only the state of Ceará used them. The pre-season oceanic conditions that year were characteristic of very wet years over the Northeast, but the rainy season didn’t start until mid-March, leading some northeastern states to declare an emergency drought in early March. When the rainy season did turn out to be very wet, the same states declared emergency flooding conditions. Ceará State’s pioneering use of seasonal climate forecasting allowed it to manage both extreme drought and flooding conditions in a controlled way, and was praised by neighboring states and the federal government.
Another example occurred in 1993, prior to a very strong ENSO episode over the Pacific, which resulted in one of the driest years on record in Northeast. Despite the fact that the seasonal forecast had already indicated the possibility of extreme drought, the managers in charge of the Ceará State Bureau of Meteorology chose not to take that forecast into consideration, informing the government and other users that it was likely to be “near normal” year. The drought was severe and many lost their savings. While a great deal of experience was gained in the years since 1993, in 2012 a similar thing happened. In this occasion, however, CPTEC and the state bureaus of meteorology chose not to take the majority of model outputs indicating below normal total seasonal rainfall conditions into consideration. As a result, with the installation of the severe drought over the region, the Federal Government destined emergency funds of the order of US$1.4 Billion as relief funds.

LOOKING TOWARD THE FUTURE

GOALS
CPTEC aims to revive the outlook forums and establish itself as a leading center, thereby bringing the scientific expertise developed over the years back to the podium and encouraging conversation among users and providers of climate information.

PROJECT EXPANSION
A new generation of climate prediction tools developed at CPTEC is being put in use for operational product generation. This will expand the range of prognostic information for the seasonal to decadal scale prediction, including intra-seasonal climate variability, marine ice extension, and the earth system carbon fluxes.

Scaling the program up, making more accurate, customized climate information products available is a need. It requires a comprehensive coordination effort on the part of CPTEC and other institutions. It also requires an articulated framework for producing weekly updates of the seasonal forecasts, a pool of climatologists from the state bureaus working at CPTEC on a rotational basis, and regional models tuned for each of the nation’s regions, generating customized products for different regions and stakeholders.

LESSONS LEARNED
The success or failure throughout CPTEC’s experience with seasonal climate forums depended upon the availability of its team of experts, and the proximity of the team to the user audience. Dissemination of seasonal climate information showed to be a science by itself, as the jargons and concepts widely used by climatologists to communicate climate information to society are seldom understood. General audiences often misinterpret the very concept of probabilistic forecast into three categories.

For instance, predicting below-average rainfall as the most probable tercile over the Northeast encounters involuntary resistance even among meteorologists in the region. Communication between providers and users is critical on all levels: from meteorologists to the state bureaus, the energy sector, state governments, and farmers.

THE WAY FORWARD
CPTEC has amassed a very large supercomputer and the capacity to develop its own climate prediction tools. Brazil’s Federal Government is investing billions of dollars to build a sustainable scientific and technological growth in the country. The Science Without Borders program is one such venue, which is sending waves of doctoral students abroad and attracting young postdocs to work in the country, as well as senior scientists from other countries to interact with Brazilian scientists in universities and research institutes. The transient lack of leadership experienced by CPTEC was a hard lesson learned, which shall make the center more resilient and in charge of its leading role to providing state of the art climate information to society in the future.
**PRINCIPLES OF THE GFCS**

All of the principles listed below apply to the climate services developed by CPTEC.

**Principle 1:** All countries will benefit, but priority shall go to building the capacity of climate-vulnerable developing countries.

**Principle 2:** The primary goal of the Framework will be to ensure greater availability of, access to, and use of climate services for all countries.

**Principle 3:** Framework activities will address three geographic domains; global, regional and national.

**Principle 4:** Operational climate services will be the core element of the Framework.

**Principle 5:** Climate information is primarily an international public good provided by governments, which will have a central role in its management through the Framework.

**Principle 6:** The Framework will promote the free and open exchange of climate-relevant observational data while respecting national and international data policies.

**Principle 7:** The role of the Framework will be to facilitate and strengthen, not to duplicate.

**Principle 8:** The Framework will be built through user – provider partnerships that include all stakeholders.