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The Brazilian National Institute of Meteorology (INMET) and its contributions to agrometeorology

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ABSTRACT

From its inception in 1909 under the Ministry of Agriculture, INMET has targeted its role as the public provider of weather, climate and related information which may help the agricultural sector to cope with the risks resulting from adverse atmospheric conditions. The Institute's contributions have evolved from gathering and offering data – initially obtained by means of meteorological gauges only, but nowadays also from satellites – to increasingly more sophisticated products. These include regular weather prediction and alerts; climate monitoring and climatological maps and data; increasingly accurate detailed numerical weather prediction; stochastic and statistical climate forecast models and seasonal forecasts. The Institute also dedicates significant efforts to developing application products, particularly for users of the agricultural sector, individual farmers and cooperatives and policy makers. Sisdagro, a decision support system for agriculture, and LATIS, a laboratory for the application of satellite image information and climate information to crop monitoring, in cooperation with CONAB, are notable examples. INMET intends to strengthen ties with other specialized institutions nationally and internationally, to amplify the range of application products and services directed to the agricultural sector and to enhance its channels of communication with final-users, to improve the usefulness of the products and services offered.

1. Introduction

1.1 A brief historical note

As the formal National Weather Service (National Meteorological Service) linked to the World Meteorological Organization, the United Nations Agency for Weather, Climate and Water, INMET was created by the Presidential Decree No. 7.672 of 18 November 1909, under the Ministry of Agriculture, Industry and Commerce, with the original name of Directory of Meteorology and Astronomy. Henrique Charles Morize, an astronomer, takes charge as its first Director.

Since then, the Institute has made special efforts to sustain a portfolio of meteorological data and products to support agricultural activities in the country. It is clearly stated in its original mission to "organize and disseminate the daily weather charts as well prediction and weather alerts to navigators and farmers". It is noteworthy that from its very beginning INMET was placed with a strong focus on agricultural research and support to agricultural practices in the country. One can notice that a contemporary newspaper published "Observatory focus: a new service started, weather forecast for agriculture" (Jornal Gazeta Noticias , Rio de Janeiro, 11 June 1917) showing the Institute strong commitment to agriculture.

One can find detailed historical facts about INMET in the publication "100 Years of Meteorology in Brazil" (OLIVEIRA, 2009) which briefly documents the Institute major achievements from 1909 to 2009. This publication, launched during the centennial celebrations on November 18th 2009 at INMET´s headquarters in Brasilia, provides a time sequence of events and achievements from 1909 up to current days of the institution, highlighting the efforts to its modernization and the provision of new products and data.

1.2 Recent contributions

Among new achievements, the Institute nowadays maintains a most technologically modern network of more than 500 automatic weather stations, an advanced Numerical Weather Prediction system, running non-hydrostatic models at 2.8 km grid spacing sustained by a rapid computational system, a large Data Bank, and seasonal climate forecast multi-model system to support agricultural practices in the whole country. Internationally, INMET exchange daily data with all the weather services worldwide and nationally with its partner organizations DHN of the Brazilian Navy and DECEA of the Aeronautical Command, ANA – the Water Agency, in addition to providing data to INPE, CEMADEN, among others.

Specifically in agriculture, collaboration with CONAB is supported by a Laboratory for Applications (LATIS), located at INMET to provide climate and remote sensing satellite data for CONAB´s twice monthly Boletim de Monitoramento Agrícola which shows estimates of major crops being grown in the country.

In addition, a comprehensive decision support system for agriculture – Sisdagro -- has been developed by INMET and is available to users at the Institute's web portal. One of the important uses of Sisdagro, at present, is to provide regular estimates of yield losses due to water deficit, in support to an insurance project for small farmers in the semi-arid region, coordinated by the Ministry of Agrarian Development (MDA).

These and other contributions of INMET to the agricultural sector are presented in sections 2 and 3. Some of them are briefly described in INMET (2015), a publication which highlights the institutional achievements in the 2009-2014 five year period.

In the international arena, INMET has been active in most World Meteorological Organization events, including technical working groups and daily exchange of data and products to all weather services around the world. The Commission for Agricultural Meteorology (CAgM) benefits from competent contribution by Brazilian researchers.

2. Weather and Climate Information in support of agrometeorology

2.1 Meteorological data

A major contribution of INMET to the agrometeorological activities in Brazil is certainly the maintenance of continuous monitoring of weather conditions by means of its modern network of meteorological stations.

At present, the Institute maintains a network of 265 conventional stations, most with more than four decades of data record, and another network with about 480 automatic stations1 that have been installed beginning in 2001, but mostly in the 2006-2010 period. Besides, INMET, in a joint effort with the Department of Airspace Control (DECEA) of Brazilian Aeronautics Command, operates 42 upper-air radiosonde stations with daily or twice daily soundings. These upper air soundings are fundamental to support daily weather prediction since they describe the three-dimensional nature of the dynamics and thermodynamics of the atmosphere.

Maps of these data gathering networks are available at INMET's Web site, at "Estações e Dados> Rede de Estações".

Most data gathered since 1961 has been put in digital format and are maintained in an Oracle Data Bank, continuously fed by upcoming new stream of data. Data before 1961 and data gaps in the period after1961 are currently being taken care in an important project that is recovering, digitalizing and properly storing over 12 million paper documents.

2.1.1 Access to data

Much of INMET's meteorological station data is currently available through its institutional web site. In the case of conventional stations, users who register at the Meteorological Data Bank for Teaching and Research (BDMEP) may download daily or monthly data for specified periods, from 1961 onwards.

Any user may also obtain data corresponding to measurements made at 0, 12 and 18 UTC time, in the case of conventional stations, and hourly measurements, in the case of automatic stations, for periods covering since the date of consultation till the previous 90 days. Data are made available at the Institute Portal in "ESTAÇÕES E DADOS > DADOS METEOROLÓGICOS> Estações Convencionais" and "ESTAÇÕES E DADOS > DADOS METEOROLÓGICOS> Estações Automáticas".

Users may also request support through "FALE CONOSCO".

2.2 Weather forecast

In addition to providing monitoring of the atmosphere over Brazil, INMET has evolved a lot in terms of weather prediction through numerical models. Currently, two mo-

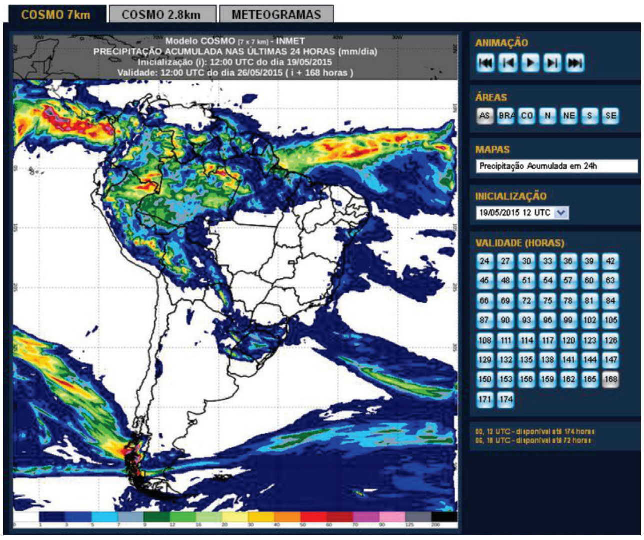

Figure 1. Example of an output of INMET's 7x7 km COSMO weather forecast model run at 12 UTC 05-19-2015 for 168 hours to predict accumulated precipitation over South America.

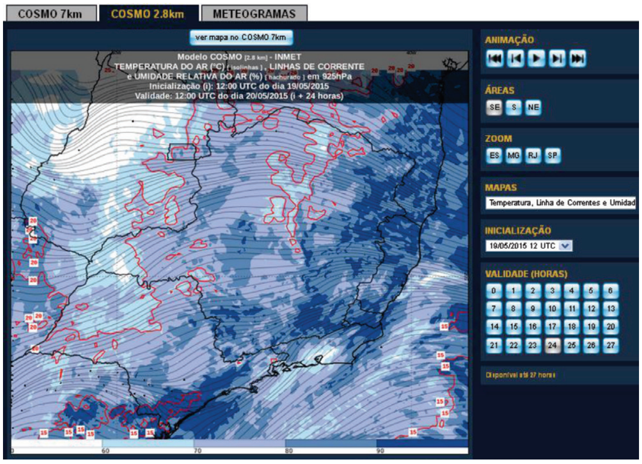

Figure 2. Example of a combined output of INMET's 2.8x2.8 7 km COSMO weather forecast model run at 12 UTC 05-19-2015 for 24 hours, showing temperature, streamlines and humidity over the southeastern area of Brazil, at 925 hPa.

dels are run ate every cycle of 6 hours. One – a hydrostatic model - with a grid spacing of 7 x 7 km and another, non-hydrostatic model, with a more refined mesh with 2.8 x 2.8 km grid. The first model have proven of very good skill up to 7 days over all South America, while the more refined 2.8 x 2.8 km model area run for up to 26 hours for specific areas of agricultural interest.

These high accuracy forecasts are thanks to a quite beneficial collaboration for the last decade with the Deutcher Wetterdienst (DWD -Germany weather service) and the European consortium of institutions responsible for developing the numerical weather prediction model COSMO (COsortium for Small-scale MOdeling).

The two models mentioned above models, run at every 6-hour cycle, are in operational routine using INMET´s supercomputer facility with a current throughput of 55 GFlops of computational speed. An adequate data storage facility is capable of handling these computational data as well as supporting the Data Bank with observational data.

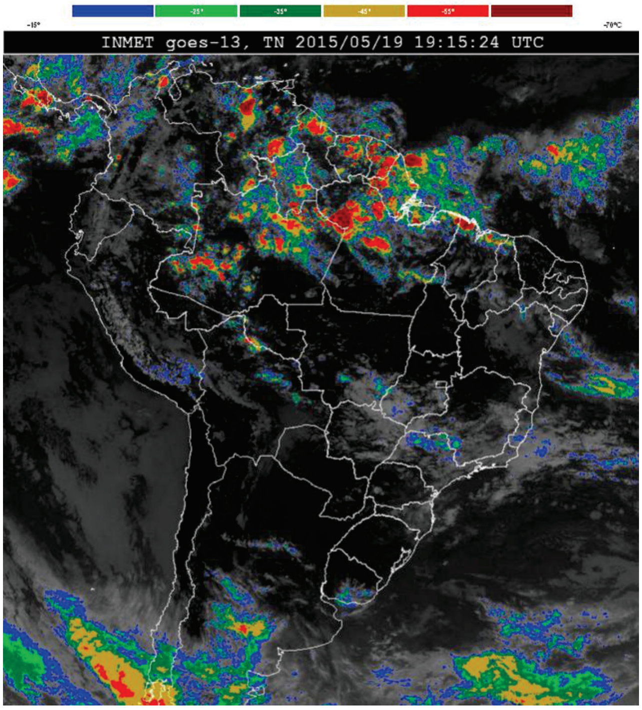

Figure 3. Enhanced cloud-top image obtained by GOES-13 NOAA satellite covering South America.

Predicted fields can be seen at INMET> TEMPO> Previsão numérica – modelo.

Figures 1 and 2 are examples of output of the 7x7 km grid and the 2.8x2.8 km grid models.

2.3 Satellite imagery products

The Institute receives satellite data and imagery from several polar-orbiting and geo-synchronous satellites. At INMET home page, in SATÉLITES > PRODUTOS DE IMAGENS DE SATÉLITES, users can access global and continental imageries as well as over selected regions and sub-regions of Brazil, in the visible and infrared spectra.

Figure 3 shows an example of the currently available products.

A modern satellite ground receiving station in x-band frequency, installed in late 2013, provides imagery for weather forecasting and special products applied to agriculture. This new system can receive and process stream data from Terra, Aqua, MetOp, NPP and FY-3 polar orbiting satellites. Several products can be made available using satellites that carry special spectrophotometers, cameras and sensors such as MODIS, used in the Aqua and Terra series. These have higher resolution (250m) and a large number (36) spectral bands that show different parts of the spectrum for multipurpose applications.

2.4 Climate monitoring products

At INMET's home page, on "CLIMA> MONITORAMENTO CLIMÁTICO", users may find a growing variety of maps that provide observed conditions of precipitation and temperature varying from one month to two year time scales.

For most products available, it is possible for the user to compare maps since 1961 up to present, as well as to select periods under specific El Niño South Oscillation (ENSO) conditions. Figure 4 illustrates the result of a search for maps on Total Precipitation Anomalies in the December-January-February season that occurred under El Niño conditions in years from 1985 up to now. To classify a given period under analysis according to the ENSO phase the application uses the information on CPC's Historical El Nino/ La Nina episodes (1950-present).

Another climate monitoring product available at INMET's web site is the Agroclimatological Bulletin issued monthly and at every ten-day period. These Bulletins present a brief analysis of the climate conditions prevailing in the period as well as maps showing the behavior of the most relevant agrometeorological variables, tables with water balance values and information on extreme climate events such as frost, hail and gales that may affect agriculture.

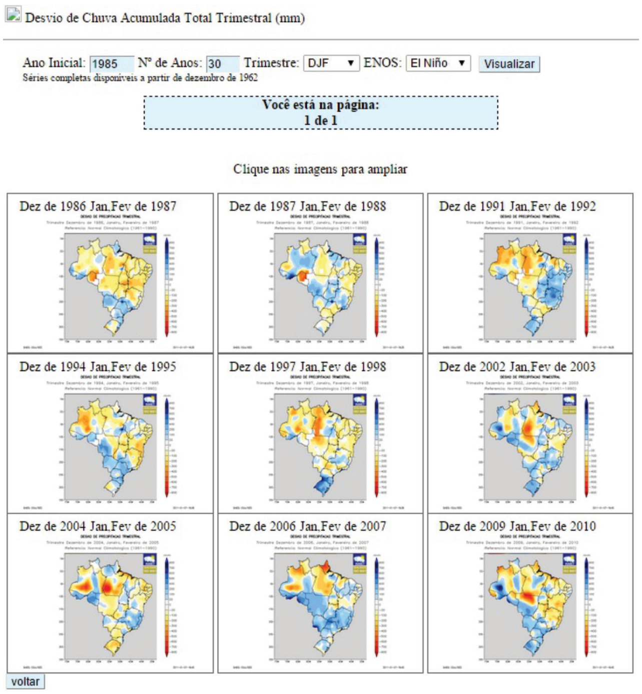

Figure 4. Comparison of Total Precipitation Anomaly for December-January- February season, which occurred under El Niño episodes from 1985-2015, obtained directly from INMET's home page at "CLIMA> MONITORAMENTO CLIMÁTICO>Desvio de Chuva Trimestral".

2.5 Climatology products

Several products of interest to agrometeorologists are available at the "CLIMA> Climatologia" section of INMET's home page, namely:

1. "Normais Climatológicas" (Climatological Normal) presents, in a user-friendly fashion, all the maps, data spreadsheets and texts included in the INMET's 2010 publication 'Brazilian Climatological Normals: 1961-1990'.

2. "Gráficos Climatológicos" (Climatological Graphics) provides graphical comparisons of the behavior of most important parameters on stations representative of the Brazilian state capitals, for both 1961-1990 and 1931-1960 climatological normals.

3. "Distribuições de Probabilidade" (Probability Distributions) provides, for a representative set of INMET's meteorological stations, climatological probability distributions of the precipitation accumulated during each of the 12 moving seasons, from December-January-February up to November-December-January. The main purpose here is to facilitate the interpretation of the seasonal climate forecast at specific locations.

4. "Faixa Normal da Precipitação Trim." (Normal range of seasonal precipitation) The standard seasonal climate forecast informs the probabilities that total precipitation observed at a given location in that season falls above, below or in the normal range. To translate this into more specific and useful information regarding a given location of interest one must know the thresholds that define the normal range. This is the information provided by this product for stations or grid points

5. "Climatologia Max e Min Temp. e Pluv." (Climatology of Maxima and Minima Temperatures and Rainfalls) informs, for a representative set of INMET's meteorological stations, complemented by grid points, the months and trimesters with maximum or minimum climatological averages of Temperature and Precipitation. The grid points correspond to the University of Delaware Air Temperature and Precipitation Monthly Gridded Data. For each chosen station, the product informs also the maximum or minimum climatological mean value of the chosen parameter in the month or trimester it occurred.

2.6 INMET's seasonal climate forecasts

Since 2006 INMET, has developed and has been continually improving a statistical climate forecasting model that has proven to show reasonable skill for many seasons and areas of the Brazilian territory where the traditional dynamic numerical models usually do not. The skill index is computed by the Pearson linear regression coefficient between time series of forecasted and observed values, from 1989 to the present, and becomes statistically significant, at a 95% confidence level for values above 0,3.

Figure 5 presents maps that show the skill of the precipitation forecast model for the seasons covering the Summer Crop period, which extends from the end of Septem-

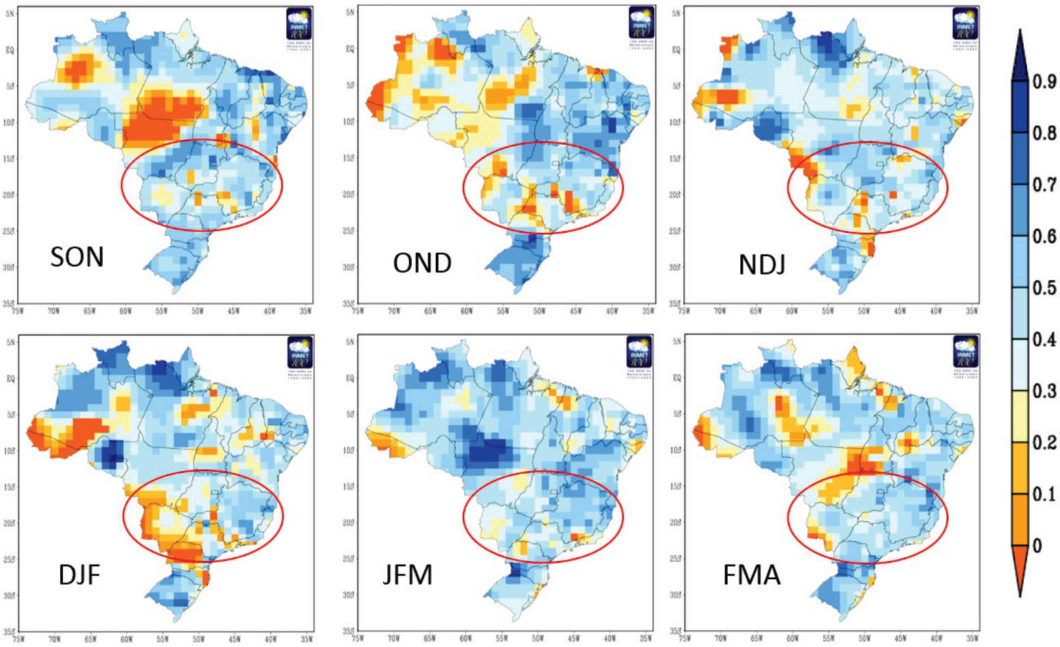

Figure 5. Skill indices of INMET's statistical seasonal precipitation forecast model for the periods covering the summer crop season in Brazil. The indices are statistically significant for areas in blue. The ellipsis highlights the southeast and center-west regions where dynamic models usually do not have skill in some of the months.

ber to the beginning of April next year.

The ellipses in red indicate the southeast and center--west regions, which are important for agriculture, but where dynamic models usually do not exhibits forecast skill.

The INMET's precipitation climate forecast model is the ensemble of three models: two stochastic models, based on models ARIMA and Holt-Winters (HOLT, 1957; WINTERS, 1960; BOX e JENKINS, 1976) and one statistical model utilizing canonic correlation analysis (CCA). In the CCA, INMET's model makes use of three predicting variables, namely: Sea Surface Temperature, Geopotential Height at 500 hPA, and Vertical Velocity at 850 hPA. For more details, see Lucio et al. (2010).

INMET' seasonal climate forecast for both precipitation and mean temperature are available at CLIMA> PREVISÃO CLIMÁTICA> Previsão sazonal do INMET. Besides maps with the forecasted mean values and tercile probabilities, other complementary information such climatology and verification area also presented.

Figure 6 illustrates results of the forecast for the season January-February-March 2015.

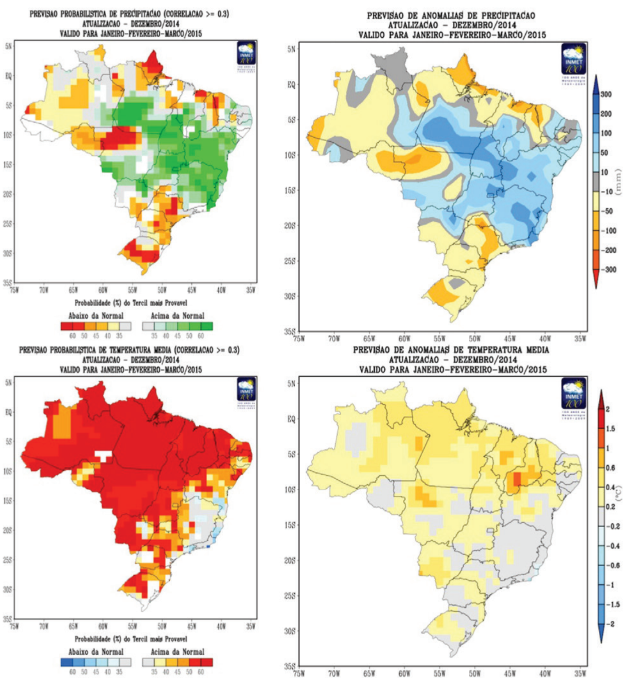

Figure 6. Forecast outputs of the INMET seasonal forecast statistical model for JFM 2015. Maps in the left show the probabilistic forecast, in terms of the probability of the most likely tercile, for Precipitation (up) and Mean Temperature (bottom). Maps in the right show the anomalies of the forecasted mean of Total Precipitation (up) and Mean Temperature (bottom).

2.7 Forecasted probability distribution

Besides the standard forecast in terms of tercile probabilities, for points of the map corresponding to stations used by the INMET model, one can obtain the forecast in terms of quantiles as well of cumulative distribution and

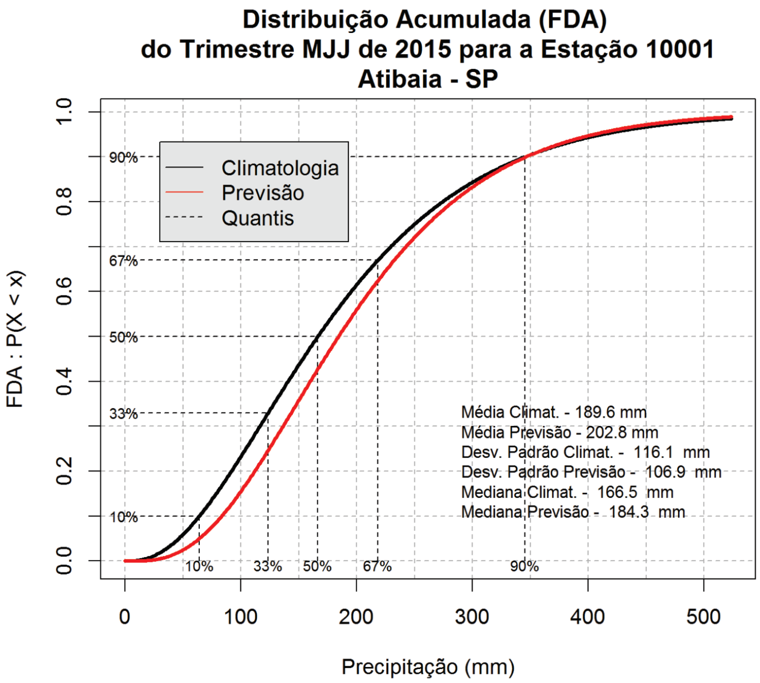

Figure 7. Cumulative Distribution Function of Total Precipitation for JFM-2015 at Atibaia, SP, as forecasted by INMET's statistical seasonal forecast model.

probability density functions. See CLIMA> PREVISÃO CLIMÁTICA> Distribuições de probabilidade previstas.

Figure 7 shows the Cumulative Distribution Function (CDF) and Probability Density Function (PDF) forecasted for the station at Atibaia, SP, in the JFM 2015 season.

3. Support to decision making in agriculture

3.1 Laboratory for application of satellite image technology

LATIS, the Laboratory for Application of Satellite Image Technology, is a cooperation initiative between INMET and CONAB – the Food Supply National Company, under the Ministry of Agriculture of Brazil. It functions within INMET's headquarters, where specialists from CONAB and INMET make use of satellite remote sensing and climate information in support of CONAB's crop production estimate activities.

One of the regular products of LATIS is the Agricultural Monitoring Bulletin, produced and made available twice a month at CONAB´s web page.

3.2 Support to low income farmer insurance

Since 2010 INMET has been supporting a division of the Ministry of Agrarian Development (MDA) responsible for the administration of the "Garantia Safra" Insurance. This is a federal government program designed to help small farmers in the Brazilian semi-arid region to cope with adverse climate conditions in the event of severe crop losses resulting from adverse climate conditions, usually due to water deficit.

INMET's Development and Research division (CDP) has developed a model that estimates the yield losses occurring in each municipality since plantation dates, assuming they follow a given distribution along the planting calendar defined by "Garantia Safra" for the specific region. The crop growth component of the model was based on Allen et al. (1998) and it has been shown to be quite useful whenever it predicts losses above the 50% threshold (MONTEIRO et al., 2010). With the implementation of Sisdagro (next section), the crop growth simulation has been performed by the routines imbedded in the system.

Figure 8 shows maps that constitute one example of the output generated for "Garantia Safra".

3.3 Sisdagro – a decision support system for agriculture and livestock

Sisdagro, a Decision Support System in Agriculture, is being developed by the National Institute of Meteorology - INMET in order to support users of the agricultural sector in their planning decisions and agricultural management. Its target audience is made up of rural extension and agricultural technicians, producers with some substantial training in agronomy and government managers responsible for running public policies aimed at agricultural sector.

In its first phase, already available at INMET's web page at AGROMETEOROLOGIA> SISDAGRO, the system offers tools for monitoring the conditions prevailing until

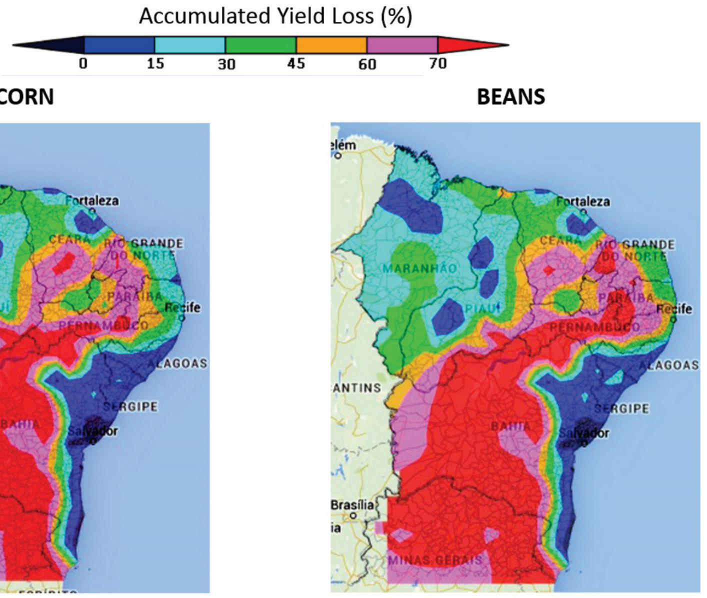

Figure 8. Example of maps generated by INMET to support MDA in the management of "Garantia Safra" Program. They show the accumulated yield losses simulation for corn and beans as of May-12-2015, for the Brazilian semi-arid region.

the date of consultation, as well as conditions forecasted for the next few days. In general, these tools make use of meteorological information recorded by the network of INMET's stations, as well as data obtained from INMET's numerical weather prediction models for temperature, precipitation, relative humidity, wind speed and direction and solar radiation.

Currently, there are three classes of applications: Water Balance, Vegetation Index and Livestock Thermal Comfort. In the case of Vegetation Index, the system uses data obtained from satellite images.

In a second phase, already under development, Sisdagro will incorporate tools based on climatology, which would allow the user, for instance, to search for favorable planting dates. Another important tool envisaged to be included will allow foreseeing estimates of the crop future behavior, taking into account seasonal climate forecasts.

The system was developed as part of a technical cooperation among INMET, Instituto Tecnológico SIMEPAR and Instituto Agronômico do Paraná - IAPAR, under the umbrella of a Technical Cooperation Agreement with the Inter-American Institute for Cooperation on Agriculture - IICA. The project has benefited from recommendations made by experts in Agrometeorology from EMBRAPA, ABC Foundation and ESALQ, and was based on a product developed earlier for INMET by researchers from the Viçosa Federal University.

3.3.1. Water balance products

In the "Water Balance" section, Sisdagro currently offers "Crop Water Balance and Yield Estimation", "Sequential Water Balance", and three categories of "Water Balance Maps", namely: Daily Maps, Maps of Accumulated Values within a user-defined Period and Maps of Average Values for a user-defined Period.

3.3.1.1 Reference points

The Crop and the Sequential Water Balances calculations are performed for reference points chosen by the user among three available possibilities in the neighborhood of the locale of interest: Conventional Meteorological Stations, Automatic Meteorological Stations or "Virtual Stations", which correspond to one degree grid spacing points to which the system associates values obtained from INMET's numerical weather prediction model2.

To facilitate the user choice of a convenient reference point, Sisdagro offers an auxiliary map that uses OpenLayers and Geoserver technologies. This tool is illustrated in Figure 9.

3.3.1.2 Crop water balance and yield estimation

For a chosen reference point, the user may get a simulation of a given crop, chosen from a list of most important temporary crops cultivated in Brazil, as a function of its date of emergence and type of soil.

The main objective of the simulation is to estimate the Relative Yield Loss due to Water Deficit affecting the plant since the emergence up to the date of simulation or the end of the growth cycle (harvest), whichever comes first. As by-products, the systems offers information, both in graphical and table formats, for the main variables needed for water balance computation, such as Soil Water Stora-

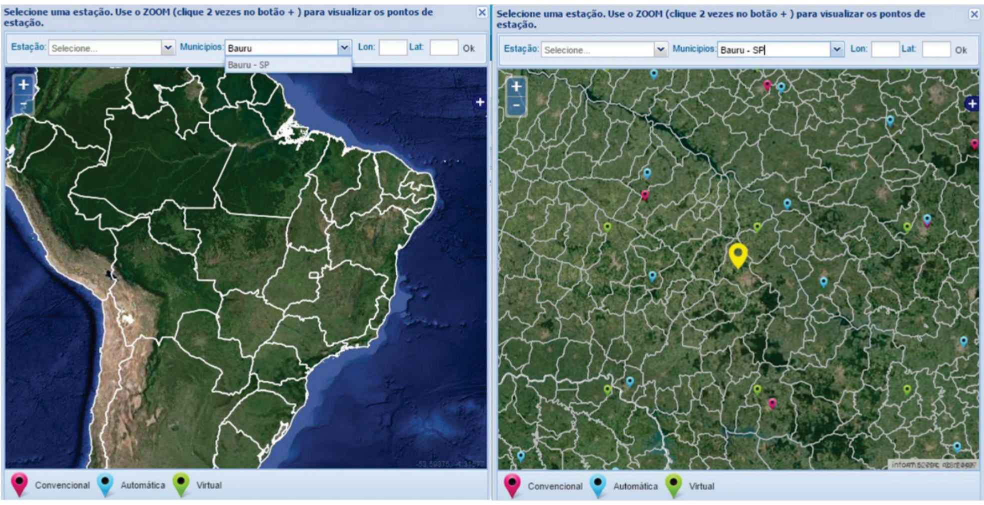

Figure 9. Use of Sisdagro's auxiliary map to choose a reference point. In the left, the user enters the name of the locale of interest (Bauru). The right map exhibits a zoom to geographical center of the chosen place (yellow balloon), showing balloons that represent stations in the neighborhood that may be selected as the reference point.

ge, Water Deficit, Water Surplus, Potential Evapotranspiration (PET), Crop Evapotranspiration (CET), Actual Crop Evapotranspiration (ACET), Precipitation and Temperature. In Sisdagro, PET is estimated by the method of Penman-Monteith (FAO-56, 1998), CET is computed as PET times as a crop coefficient Kc which depends the crop and on the stage of growth of the plant (days after emergence). ACET results from the water balance computation and represents a depletion of CET whenever the water available in the soil is not enough for the crop evapotranspiration to be fully realized.

The computation of the crop water balance follow the principles proposed by Thornthwaite & Mather (1955) and the values of Kc were adapted from those in Doorenbos & Kassam (1979). The Relative Cumulative Yield Loss estimation is also computed according to the principles established by Doorenbos & Kassam (1979), which relate the relative yield decrease to the relative evapotranspiration deficit.

Figure 10 depicts a screen showing an example of simulation performed by Sisdagro. The chosen reference point was INMET's conventional meteorological station in Campo Grande, MS, the crop was soybean with a cycle of 150 days, the emergence date was December 15, 2014 and the soil texture was "medium". The suggested Available Water Capacity (AWC or CAD, in Portuguese) is 40 mm (a value the user may adjust). The main output of the simulation is a graph with two curves representing, respectively, the estimated relative yield evolution and the relative yield loss due to water deficit, from the emergence to the simulation date.

The system also offers several other output options, such as the graph of Water Stored in the Ground versus Daily Precipitation observed during the simulation defined above, shown in Figure 11. Besides, Sisdagro shows on-line a table with the daily computation of the Water Balance e Productivity, which the user may also download in the form of an Excel spreadsheet.

3.3.1.3 Sequential water balance and maps

Sequential Water Balance calculation is quite similar to the crop water balance described above, except that it is performed for a standard soil coverage, such as grass, and its evolution for a given reference point is shown in Sisdagro for a 90-day period up the simulation date chosen by the user.

Maps of Soil Water Storage (ARM), Actual Evapotranspiration (ETR), Water Deficit (DEF), Water Surplus (EXC), Potential Evapotranspiration (ETP), Precipitation (P), Mean Temperature (Tm), Maximum Daily Temperature (Tmax) and Minimum Daily Temperature (Tmin) are generated by combining information of all reference points available through a Cressman interpolation scheme, performed by the software GrADS3 . There are maps for days, presently starting from 01/01/2011, and periods – from a chosen starting date to a chosen final date. Maps for periods may be of accumulated values, when it makes sense, or of daily means.

Figure 12 shows two examples of maps for the 2014-2015 summer crop period, from 10-1-2014 to 04-30-2015. The first is for Water Deficit Accumulated in the period (in mm), and the second is for the average Soil Water Storage in the period (as a percentage of the Available Water Capacity).

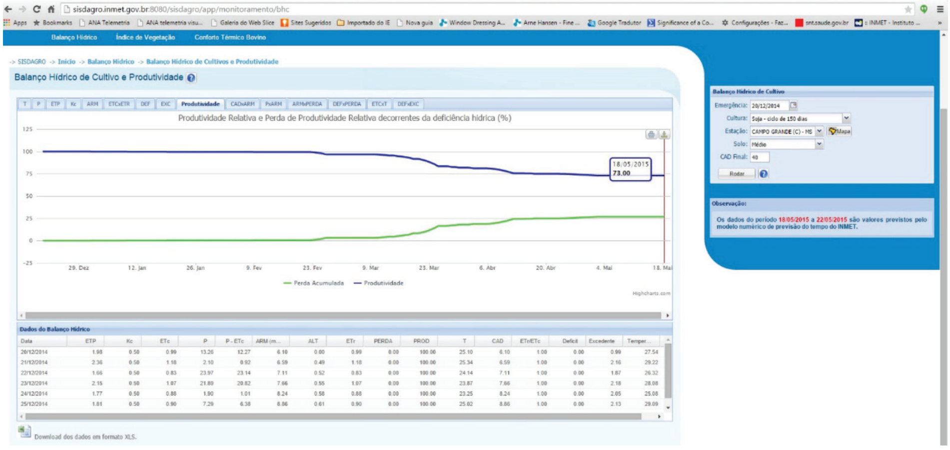

Figure 10. Example of a simulation performed by Sisdagro for a 150-day-cycle soybean plantation with emergence on 12/20/2014, in medium-texture soil, in Campo Grande (MS). The graph shows the estimated relative yield evolution and the relative yield loss due to water deficit.

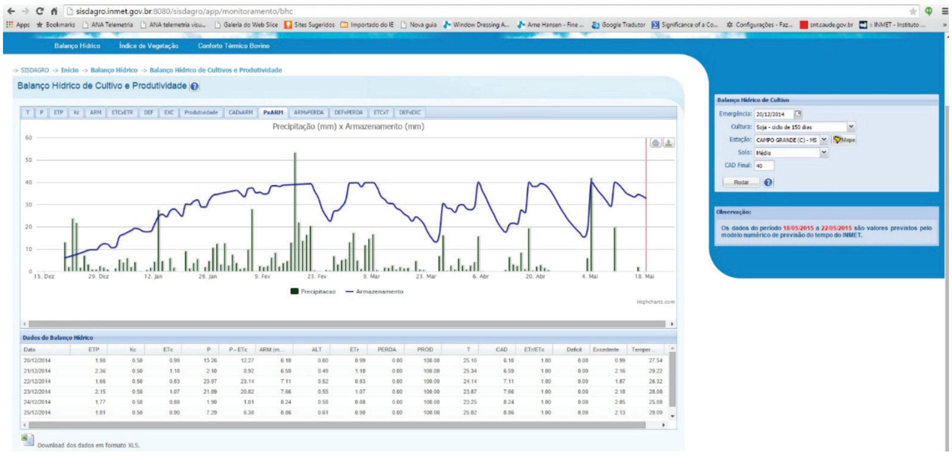

Figure 11. Example of complementary information offered by Sisdagro in a Crop Water Balance and Yield simulation. The graph shows the Precipitation and Soil Water Storage in Campo Grande (MS), from 12-20-2014 to 5-18-2015. The other simulation parameters are the same of Figure 3.3.1.3.

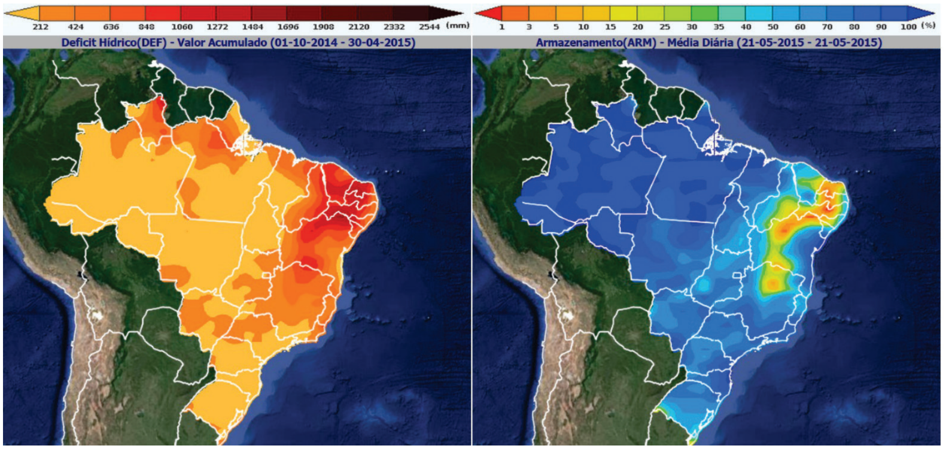

Figure 12. Accumulated Water Deficit (left) and Daily Average Soil Water Storage (right) corresponding to the Brazilian summer-crop season 2014-2015 (October to April).

3.3.2 Vegetation index

For any point chosen by the user with the help of an auxiliary map, Sisdagro currently offers the possibility of comparing curves of NDVI (Normalized Difference Vegetation Index) from years 2005 to 2015. The NDVI values presently used come from NASA's MODIS sensor installed in satellite TERRA.

Figure 13 depicts a screen of Sisdagro with the NDVI curves corresponding to years 2015, 2014 and 2013 for a point in the state of Paraná. To pick the point of interest, one can make use of a Google Maps image, which is able to suggest possible plantation areas.

It is interesting to observe, in the picture, the sudden drops in the NDVI curves at the beginning of February 2013, and by the end of February 2015. One possible interpretation for those is the harvesting, which in 2015 would have taken place almost a month later than in 2013.

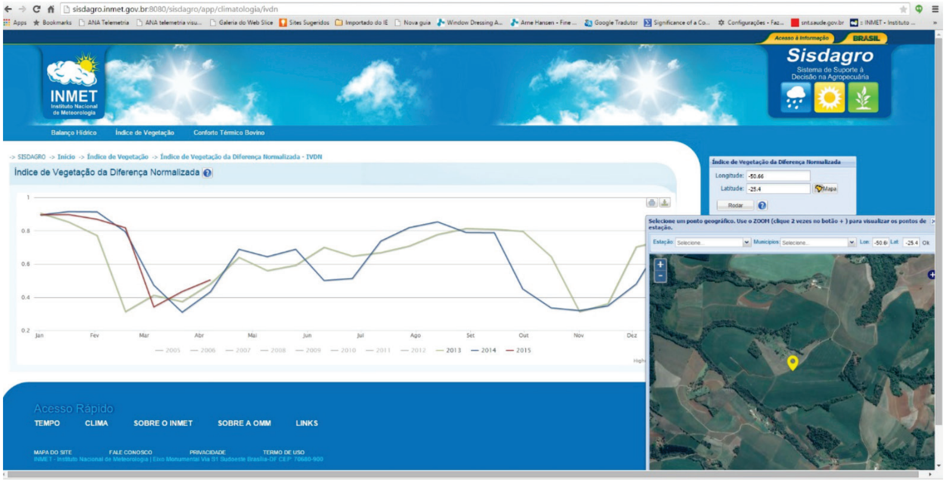

Figure 13. Example showing the use of the NDVI tool in Sisdagro. The point to be analyzed was chosen with the help of the auxiliary map shown in the right bottom corner of the picture, which uses Google Maps.

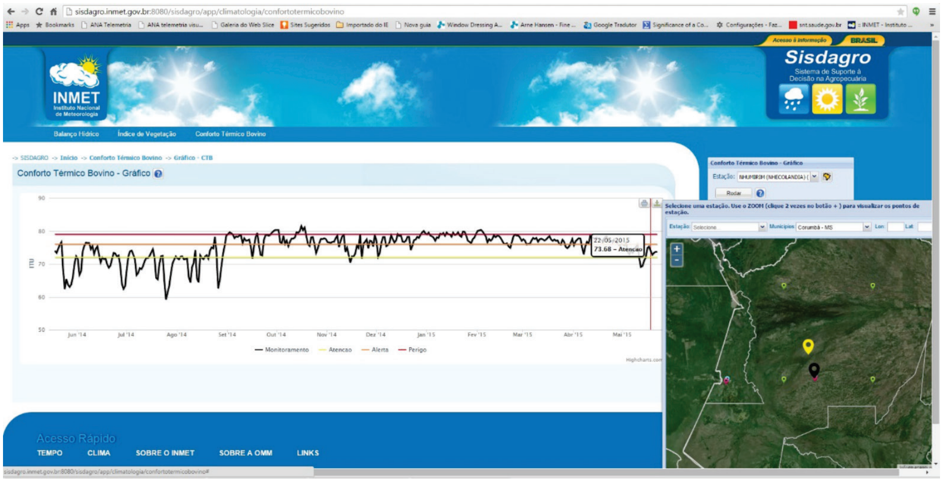

Figure 14. Graphics of Bovine Thermal Comfort for the nearest point of reference to Corumbá, MS, obtained on 5-18-2015. It covers a one-year period and extends until 5-22-2015.

3.3.3 Bovine thermal comfort

For a chosen point of reference, Sisdagro offers a graphic with the Temperature-Humidity Index (THI) and its possible stress impact on bovine conditions. The THI calculation in Sisdagro is done as a function of the dry bulb and the dew point temperatures, as proposed in the literature (BUFFINGTON et al., 1981; KLOSOWSKI et al., 2002). The association between ranges of the THI values and management alerts also follows the literature (ROSENBERG et al., 1983; HAHN, 1985): "Normal" for THI bellow 72; "ATTENTION" for ITU between 72 and 76; "ALERT", between 76 and 79; "DANGER", between 79 and 84; and "EMERGENCY, ABOVE 84. The graphic covers a 12-month period and extends five days into the future make use of the weather forecast model information.

Figure 14 illustrates the use of the bovine stress tool for Corumbá (MS) in 5-18-2015. It shows that for periods such as the end of September-2014, the middle of October, and middle February-2015 the condition of "DANGER" was verified. For the coming days (5-18-2015 to 5-22-2015), the index is expected to stay in the condition of "ATTENTION".

Sisdagro also maps of the THI for days specified by the user.

4. Other contributions to agrometeorology

4.1 Special technical publications

In recent years INMET has made available a few but quite relevant special technical publications that certainly contribute to the works of agrometeorologists in Brazil.

The book "Agrometeorologia dos Cultivos: o fator meteorológico na produção agrícola" (Agrometeorology of Crops: the meteorological factor in agricultural production) (MONTEIRO, 2009) resulted from a very successful project conceived by a consultant specialist working for INMET at the time.

This book is structured in chapters following a thematic structure, with original contributions from 105 researchers from 37 Brazilian federal and state research centers, institutes and universities. It brings together a broad base of information on 32 of the main crops of Brazilian agriculture and their relationship with meteorological conditions. Each chapter is dedicated to as specific crop and divided in three parts: a) main characteristics of the crop and its phenology; b) agrometeorological yield constraints; and c) adverse events.

The book quickly became a reference in Agrometeorology courses and its first edition was sold out rapidly. Arrangements are on the way for an electronic version.

"Normais climatológicas do Brasil:1961-1990" (Brazilian climatological normals: 1961-1990) (INMET, 2010) is a 465-page glossy hardcover publication, which displays the corresponding climatological normal values for the period 1961-1990, recalculated for 394 conventional weather stations of the INMET network. It includes 29 tables with averages for 29 meteorological parameters, as well maps of monthly and annual averages for 22 of these parameters. In addition to the standard parameters usually included in the normals, several others, considered of interest for agrometeorological studies, are included, such as: accumulated precipitation over ten-day periods, number of wet days in each month and in the year, number of periods with 3, 5, 10 or more consecutive dry days. The book (Atlas) is no longer available in printed version, but its full content is made available at INMET's home page on CLIMA>CLIMATOLOGIA> Normais Climatológicas.

4.2 Brazilian participation in the agrometeorological works of WMO

Brazil has a large number of well-qualified agrometeorology researchers based in several Brazilian universities and research centers throughout the country.

In July 2010 Brazil hosted the WMO World Agrometeorological Congress in Belo Horizonte. INMET and several federal and state (Minas Gerais) supporting institutions made this a possible excellent international event, as recognized in the statement in the Opening Ceremony remarks made by the Secretary General of WMO.

Currently, many scientists from the Brazilian agrometeorological community participate in high level technical committees and working groups of CAgM (WMO Commission for Agrometeorology), including its Management Group, responsible for carrying out the implementation of policies and technical recommendations of WMO.

As an example, Dr. Orivaldo Brunini from IAC – the Agronomical Institute of Campinas – with colleagues from several research institutions and the Brazilian Agrometeorological Society (SBAgro) have formed a research coalition to further advance the research agenda.

5. Final considerations

INMET, from its inception in 1909 under the Ministry of Agriculture, is conscious of the importance of the meteorological factoswhich impact agriculture. Thus, the Institute is fully aware of the importance of its contribution to minimize the effects of adverse climate conditions in the agricultural sector. The Institute's strategic plan for the 2015-2024 horizon (INMET, 2015) emphasizes this vision. For instance, it establishes as one of its strategic objectives "to offer products and high quality services, continuously enhanced, that meet the real needs of users", highlighting the directive of "prioritizing the provision of products and services to support the country's agricultural sector".

To achieve these goals, INMET is committed to strengthening cooperation ties with institutions dedicated to the agricultural sector, such as CONAB and Embrapa, under the Ministry of Agriculture, and several others in the country in order to enhance and amplify initiatives such as the ones described before in section 3.

The Institute clearly recognizes it is essential that the products and services offered meet the real needs and expectations of the user community. For such, it plans to intensify exchanges with end-users and welcomes comments and suggestions towards innovation and research leading to improvement of current products and services or the development of new ones.

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O Instituto Nacional de Meteorologia do Brasil (INMET) e suas contribuições para a agrometeorologia

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RESUMO

Desde a sua criação, em 1909, no âmbito do Ministério da Agricultura, o INMET tem consciência de seu papel de provedor público de informações relacionadas a tempo, clima e áreas afins que possam ajudar o sector agrícola a fazer face aos riscos resultantes de condições atmosféricas adversas. As contribuições do Instituto desde a coleta e divulgação de dados – inicialmente obtidos apenas por meio de estações meteorológicas, mas atualmente também a partir de satélites – até produtos cada vez mais sofisticados. Estes abrangem previsões do tempo e alertas meteorológicos convencionais; mapas e dados de monitoramento do clima e climatologia; previsões numéricas de tempo detalhadas e cada vez mais precisas; modelos de previsão climática estocásticos e estatísticos, e previsões sazonais. O Instituto também dedica esforços significativos para o desenvolvimento de produtos de aplicação, especialmente para usuários do setor agrícola, de agricultores individuais e cooperativas a formuladores de políticas governamentais. O Sisdagro, um sistema de apoio à decisão para a agricultura, e o LATIS, um laboratório para a aplicação de informações de imagens de satélite e informações climáticas no monitoramento de safras, em cooperação com a CONAB, são exemplos notáveis. O INMET pretende reforçar os laços com outras instituições especializadas, nacionais e internacionais, para ampliar a gama de produtos de aplicação e serviços voltados para o setor agrícola e para melhorar seus canais de comunicação com os usuários finais, objetivando tornar mais úteis os produtos e serviços que oferece.

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