A EURO-BRazilian Initiative for Improving South American Seasonal Forecasts (EUROBRISA[1])

by
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in collaboration with

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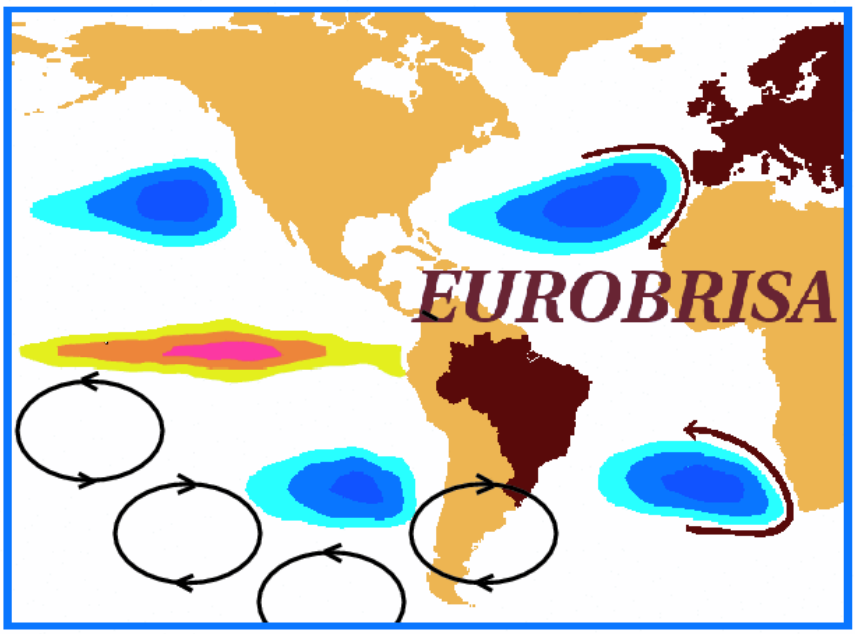

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This is a multi-institutional collaboration proposal for a project involving the Centre for Weather Prediction and Climate Studies (CPTEC - Brazil), the Brazilian National Institute of Meteorology (INMET), the University of São Paulo (USP - Brazil), the Paraná State Meteorological Institute of Technology (SIMEPAR - Brazil), the European Centre for Medium-Range and Weather Forecasts (ECMWF), the United Kingdom Met Office (Met Office), the Centre National of Recherches Météorologiques (Météo-France) and the University of Reading (UoR - United Kingdom).

[1] BRISA is the Portuguese word for breeze.

1. Introduction

This document proposes a 3-year long collaboration agreement (starting in July 2006 and finishing in June 2009) between CPTEC, INMET, USP, SIMEPAR, ECMWF, Met Office, Météo-France and UoR. This agreement will allow these eight institutions to exchange global seasonal forecast information with the aim of producing improved and well-calibrated real-time probabilistic seasonal forecasts for South America.

The South American continent is located in a region particularly benefited by El Niño-Southern Oscillation (ENSO) atmospheric teleconnections (Wallace and Gutzler 1981; Trenberth *et al.* 1998; Coelho *et al.* 1999; Coelho *et al.* 2002) in terms of seasonal predictability. Mainly because of ENSO teleconnections there is potential skill in seasonal forecasts for some regions of South America (Folland *et al.* 2001; Cavalcanti *et al.* 2002; Marengo *et al.* 2003; Moura and Hastenrath 2004; Coelho 2005; Coelho *et al.* 2005a; Coelho *et al.* 2005b). Good quality seasonal forecasts are fundamental for local governments to plan their actions in order to minimize human and economical losses that may be caused by anomalous climate events such as ENSO. In South America these forecasts are useful for civil defence, agriculture, fishery and water resources (reservoir management) planning. Brazil, the largest and most populated country of South America, produces more than 90% of its electricity with hydropower stations, which are administered by the government (http://www.ons.org.br). This emphasizes the need of good quality seasonal rainfall forecasts. The provision of improved seasonal rainfall forecasts will certainly help the Brazilian government to better plan its management actions in order to have a more efficient control of its national electricity production programme. EUROBRISA will aim to provide not only the Brazilian government but also other South American local governments with improved and well-calibrated seasonal forecasts. A pilot initiative such as EUROBRISA will certainly have positive societal impact in South America. The societal value of EUROBRISA will be demonstrated by integrated activities involving end-users of seasonal forecasts.

This document seeks to extend the existing collaboration agreement signed in early 2003 by the directors of CPTEC and ECMWF that covers technical and scientific cooperation between these two institutions. CPTEC and INMET are the two institutions responsible for producing and issuing seasonal forecasts for Brazil and South America. The University of São Paulo will conduct theoretical and observational predictability studies and develop empirical forecasting systems to be compared with the deterministic methods (Cardoso and Silva Dias 2004; 2005 and Raupp and Silva Dias 2005a; 2005b). The University of São Paulo will also produce dynamical regional downscaled predictions using initial conditions of CPTEC, ECMWF, Met Office and Météo-France global coupled model seasonal forecast systems. SIMEPAR[2] is a non-profit governmental organization that provides meteorological, environmental and climate information as well as climate and weather forecasts for the State of Paraná, in the south of Brazil. SIMEPAR will conduct diagnostic studies of extreme hydrologic events and investigate their connections with large-scale coupled ocean-atmospheric patterns. SIMEPAR will also develop a forecasting system for seasonal streamflow using calibrated forecasts produced by EUROBRISA. The University of Reading will provide expert advice on forecast

[2] Further information about SIMEPAR are available at http://www.simepar.br

calibration, combination and verification. The responsibilities of the eight involved institutions are listed below:

ECMWF, Met Office and Météo-France:

- Provide hindcasts and real-time global seasonal forecasts of their coupled seasonal forecast systems, which compose the operational European multi-model system hosted at ECMWF, to CPTEC and INMET via MARS[3], provided that appropriate access to MARS is granted to CPTEC and INMET

CPTEC and INMET:

- Post-process the forecasts provided by the European multi-model system in order to produce well-calibrated combined probabilistic seasonal forecasts for South America (i.e. combined predictions using only multi-model coupled forecasts and also using both empirical and multi-model coupled forecasts)
- Evaluate the skill of forecasts produced by the European multi-model system (both before calibration and after post-processing) and provide feedback to ECMWF, Met Office and Météo-France to help future model developments/improvements
- Produce global seasonal forecasts with CPTEC coupled system composed by the atmospheric CPTEC/COLA[4] model and the oceanic MOM3[5] model, using NCEP atmospheric initial conditions and its own oceanic initial conditions
- Stimulate the use of well-calibrated combined seasonal forecasts in governmental application activities (e.g. electricity generation and agriculture)

University of São Paulo:

- Conduct theoretical and observational predictability studies
- Evaluate the skill of forecasts based on metrics associated to models abilities to reproduce teleconnection patterns
- Develop empirical forecasting systems
- Produce regional downscaled climate forecasts for the southeast region of Brazil (with emphasis over São Paulo State) using the Regional Climate Model version 3 (RegCM3)[6]

SIMEPAR:

- Conduct diagnostic studies of extreme hydrologic events (rainfall and streamflow) for the Brazilian northeastern, southeastern, midwestern, and southern hydrographic basins
- Conduct diagnostic studies of teleconnection patterns associated with extreme hydrologic events (large-scale floods and droughts)
- Develop a seasonal streamflow forecasting system that uses EUROBRISA seasonal rainfall forecasts as inputs for large-scale hydrologic models

[3] ECMWF's Meteorological Archival and Retrieval System (MARS).
[4] CPTEC atmospheric general circulation model, originally derived from the National Centers for Environmental Prediction (NCEP) model by the Center for Ocean-Land-Atmosphere Studies (COLA).
[5] Geophysical Fluid Dynamics Laboratory Modular Ocean Model version 3 (MOM3), Princeton, USA.
[6] The Abdus Salam Internatinoal Centre for Theoretical Physics (ICTP) regional climate model.

University of Reading:

- Provide expert advice on forecast calibration, combination and verification.

The success of this effort is beneficial to ECMWF, Met Office, Météo-France, CPTEC, INMET, USP and SIMEPAR:

Benefits to ECMWF, Met Office and Météo-France:

- ECMWF, Met Office and Météo-France will gain increased international visibility by providing coupled multi-model seasonal forecasts for non-profitable governmental use in developing countries of South America
- ECMWF, Met Office and Météo-France will have the skill of their global multi-model combined and calibrated (i.e. post-processed) forecasts evaluated by CPTEC and INMET. By evaluating the skill of ECMWF, Met Office and Météo-France multi-model combined and calibrated forecasts and feeding skill information back to these three institutions, CPTEC and INMET will be contributing to future model developments and improvements at ECMWF, Met Office and Météo-France

Benefits to CPTEC and INMET:

- CPTEC and INMET will be able to use the best available coupled multi-model seasonal forecast system for issuing real-time seasonal forecast for South America
- CPTEC and INMET will be able to use the diagnostic potential of USP for analysing model performance

Benefits to USP:

- USP will have access to coupled model seasonal forecasts, which will improve the scope of monthly climate discussions regularly conducted at the Department of Atmospheric Sciences at USP with participation of undergraduate and graduate students
- USP and INMET are currently promoting strong interactions and the co-participation in this project will strengthen on-going collaborations
- USP will be able to use initial conditions from four global coupled model seasonal forecast systems for performing dynamical regional downscaling

Benefits to SIMEPAR:

- SIMEPAR will be able to use the best available coupled multi-model seasonal forecast system for issuing forecasts for the southern region of Brazil, and providing climate guidance for agricultural and water resource activities
- SIMEPAR will be able to assess and compare the skill of streamflow forecasts produced using EUROBRISA calibrated forecasts with the skill of the operational statistical hydroclimatic forecast system currently used for all basins where hydroelectricity is generated
- SIMEPAR will be able to improve its reservoir management capability through the integration of EUROBRISA forecasts with large-scale hydrologic models

2. Methodology

The methodology for the calibration and combination of forecasts has been developed during the PhD of Caio Coelho (Coelho 2005; Coelho *et al.* 2005a and 2005b; Stephenson *et al.* 2005) in the Department of Meteorology of the University of Reading under supervision of Dr. David B. Stephenson and Dr. Francisco J. Doblas-Reyes, in collaboration with Dr. Magdalena Balmaseda. This development used seasonal hindcasts of three DEMETER[7] coupled models (ECMWF, Met Office and Météo-France), which compose the real-time multi-model seasonal forecast system at ECMWF. This method also allows the combination of empirical and coupled model seasonal forecasts (Coelho *et al.* 2003 and Coelho *et al.* 2004). Coelho 2005 has developed an empirical (statistical) model that uses Pacific and Atlantic sea surface temperatures as predictors for South American rainfall. This empirical model will also be used in EUROBRISA.

3. Researchers involved/responsibilities in the project

Caio Coelho (FAPESP/CPTEC):

- Retrieve multi-model forecasts from MARS
- Skill evaluation of the European multi-model system to provide periodical feedback to ECMWF
- Implementation and further development of the multi-model forecast calibration and combination procedure at CPTEC
- Develop a multi-model calibration and combination procedure for users' applications

Iracema Cavalcanti and Luciano Pezzi (CPTEC)

- Produce global hindcasts and real-time seasonal forecasts with CPTEC coupled forecasting system
- Produce bias-corrected CPTEC coupled model forecasts
- Skill evaluation of CPTEC coupled model forecasts
- Investigate physical mechanisms operating in regions of low seasonal predictability in order to improve seasonal forecast skill over these regions

Reinaldo Silveira (INMET)

- Retrieve CPTEC coupled model forecasts from CPTEC's archiving system
- Retrieve multi-model forecasts from MARS
- Skill evaluation of the multi-model system composed by CPTEC, ECMWF, Météo-France and Met Office coupled models
- Perform research on the use of EUROBRISA forecasts in agricultural activities over selected regions of Brazil

Tércio Ambrizzi (USP)

- Theoretical and observational studies on ENSO atmospheric teleconnections and seasonal predictability
- Produce downscaled seasonal predictions for the southeast region of Brazil using RegCM3

[7] EU-funded project Development of a European Multimodel Ensemble system for seasonal to inTERannual prediction (DEMETER)

Pedro Dias (USP)

- Implementation of empirical forecasting based on Kalman filters and wavelet analysis
- Theoretical investigation of non-linear interaction among atmospheric waves and effect on predictability
- Use evaluation metrics of seasonal forecast based on models abilities to reproduce amplitude and time evolution of teleconnection patterns

David Anderson and Timothy Stockdale (ECMWF):

- Produce global hindcasts and real-time seasonal forecasts with ECMWF coupled forecasting system

Magdalena Balmaseda and Francisco Doblas-Reyes (ECMWF):

- Further development of the multi-model forecast calibration and combination procedure
- Develop a multi-model calibration and combination procedure for users' applications

Richard Graham (Met Office)

- Produce global hindcasts and real-time seasonal forecasts with Met Office coupled forecasting system
- Provide expert advice on the Met Office empirical and dynamical prediction system for northern Brazil
- Provide expert advice on developments of forecast products for applications in hydroelectric power generation

Michel Déqué (Météo-France)

- Produce global hindcasts and real-time seasonal forecasts with Météo-France coupled forecasting system

David Stephenson (University of Reading):

- Further development of the multi-model forecast calibration and combination procedure
- Provide expert advice on forecast verification
- Develop a multi-model calibration and combination procedure for users' applications

Alexandre Guetter (SIMEPAR):

- Perform diagnostic studies of extreme hydrologic events for the Brazilian northeastern, southeastern, midwestern, and southern hydrographic basins, linking these events to large-scale teleconnection patterns
- Develop and calibrate large-scale hydrologic models that use EUROBRISA rainfall forecasts as inputs for yielding seasonal streamflow forecasts
- Assess the utility of EUROBRISA forecasts for water resources management and hydropower production planning on macro-scale hydrographic basins, taking into account the technological requirements (e.g. seasonal climate model predictions, observational hydrologic datasets, and hydrologic models), and institutional constraints (e.g. the role of the national electricity generation

operator system, role of hydropower agents, and procedures to validate new technologies for operational use)

- Provide expert advice on shaping climate forecast products for hydropower generation and reservoir management safety

4. Work plan

Period	Activities
July 2006 to June 2007	• CPTEC, INMET and ECMWF set up a data file transference system to transfer multi-model hindcasts and real-time forecasts from the operational system at ECMWF to CPTEC and INMET • CPTEC starts producing hindcasts and real-time global coupled model forecasts with its own model • CPTEC produces bias-corrected global coupled model forecasts with its own model • CPTEC performs analysis of the skill of its own global coupled forecasting system • CPTEC and INMET start performing calibration and combination of South American multi-model forecasts • CPTEC and INMET perform preliminary analysis of the skill of the coupled multi-model forecasting system over South America • CPTEC and INMET provide feedback to ECMWF, Met Office and Météo-France on the performance of the multi-model forecasting system while predicting South America climate • USP and CPTEC conduct observational studies on seasonal predictability • USP and CPTEC implement new metrics for evaluating seasonal forecasts based on the reproducibility of teleconnection patterns • USP, CPTEC and INMET develop and start to implement empirical seasonal prediction schemes based on standard regression methods. USP also begins to develop Kalman Filter and wavelet schemes • USP implements a dynamical regional downscaling system that uses initial conditions provided by CPTEC, ECMWF, Met Office and Météo-France global coupled models • SIMEPAR conducts diagnostic studies of extreme hydrologic events (rainfall and streamflow) for the Brazilian northeastern, southeastern, midwestern, and southern hydrographic basins • SIMEPAR conducts diagnostic studies of teleconnection patterns related to extreme hydrologic events (large-scale floods and droughts)

July 2007 to June 2008	• CPTEC and INMET implement operationally a multi-model seasonal forecasting system for South America • CPTEC, ECMWF and the University of Reading conduct further developments of the multi-model calibration and combination procedure with the aim of improving the quality of the forecasts • CPTEC tests the new developments of the multi-model calibration and combination procedure and evaluates the skill of global forecasts obtained with the newly developed procedure • CPTEC and INMET provide feedback to ECMWF, Met Office and Météo-France on the performance of the multi-model forecasting system while predicting the global climate using the newly developed procedure • USP conducts theoretical studies on seasonal predictability and proceeds on the development of Kalman Filter and wavelet based empirical schemes • USP, CPTEC and INMET evaluate the performance of empirical against deterministic schemes • USP evaluates the performance of regional downscaled predictions for the southeast region of Brazil • SIMEPAR develops and calibrates large-scale hydrologic models for assimilating EUROBRISA seasonal rainfall forecasts and producing experimental seasonal streamflow forecasts • Publication of articles on the work up to this date
July 2008 to June 2009	• CPTEC, with inputs from ECMWF and the University of Reading, develops a the multi-model calibration and combination procedure for user applications in South America (e.g. electricity production and agriculture) • CPTEC and INMET test the developments of the multi-model calibration and combination procedure for user applications and evaluate the skill of forecasts obtained with this procedure • USP implements an empirical forecasting system based on Kalman filters and wavelet analysis • SIMEPAR, CPTEC and INMET assess the impacts of the use of EUROBRISA multi-model forecasts for water resources and hydropower applications • CPTEC and INMET provide feedback to ECMWF, Met Office and Météo-France on the performance of the multi-model forecasting system while producing South American user applications forecasts • Publication of articles on the user applications work

5. Final considerations

The proposed collaboration between ECMWF, Met Office, Météo-France, CPTEC, INMET, USP and SIMEPAR is beneficial to all institutions. ECMWF, Met Office and Météo-France will gain international visibility and also receive feedback on the performance of their coupled multi-model seasonal forecast system (before and after calibration and combination) in predicting the global climate. It is worth noticing, however, that this project is focused in South America, a region where ECMWF and Météo-France seasonal forecasts are not usually diagnosed and verified in detail. Therefore, this initiative provides a good opportunity for evaluating the ability of European models in simulating the South American climate. CPTEC will produce its own coupled model seasonal forecasts, using an independent coupled model from all those available in Europe, and also gain additional forecast information from three different European coupled models to produce well-calibrated combined forecasts for South America. INMET is an official national meteorological institution recognised by the World Meteorological Organization (WMO) for issuing climate predictions. INMET and CPTEC currently conduct monthly meetings with the aim of producing a joint report that contains the forecasts of the climate conditions in Brazil for the following three months. This monthly report is made available in the websites of both INMET and CPTEC (http://www.inmet.gov.br and http://www.cptec.inpe.br). An initiative such as EUROBRISA will certainly help both INMET and CPTEC issue better quality seasonal forecasts for Brazil. SIMEPAR will be able to use EUROBRISA forecasts for producing improved streamflow seasonal forecasts. EUROBRISA combined and calibrated seasonal forecasts will also be useful as an additional source of information for producing probabilistic climate predictions for South America during regional climate outlook fora, which are regularly sponsored by WMO, with routinely participation of climate researches of CPTEC and INMET. The use of EUROBRISA forecasts in these fora will give additional international recognition to all patterns of the EUROBRISA initiative. The experience acquired and all scientific advances achieved in EUROBRISA will contribute to improving seasonal forecasts not only in South America but also in other regions of the globe. This proposal strengthens the relationship between operational centres and the academic community. USP has traditionally been actively involved in cooperation with CPTEC and the University of Reading has been collaborating with ECMWF. EUROBRISA will reinforce these collaborations.

Currently, South American seasonal forecasts are produced at CPTEC using an atmospheric general circulation model (CPTEC/COLA) forced with forecast and observed (or persisted) sea surface temperatures (SSTs). Forecast Atlantic SSTs are obtained from an empirical model (SIMOC[8]) and forecast Pacific SSTs are obtained from the NCEP coupled model. This Euro-Brazilian initiative of producing combined and calibrated coupled multi-model forecasts will substantially improve the current operational South American seasonal forecasting system at CPTEC. The International Research Institute for Climate Predictions (IRI) also regularly produces seasonal forecasts for South America using a multi-model ensemble system composed of three different atmospheric general circulation models forced with observed and forecast SSTs. EUROBRISA aims to keep close relations with seasonal forecast experts from IRI in order to exchange ideas/experiences and identify common problems in the

[8] Statistical Oceanic Modelling System (SIMOC)

multi-model forecasting system used at IRI as well as in the EUROBRISA coupled multi-model forecasting system. Initial contacts with IRI scientists have already been made in order to achieve this goal in the future. The director of INMET (Dr. Antonio D. Moura) is the former director of IRI, and will stimulate interactions between climate researchers of these two institutions. Additionally, the principal investigator of this initiative (Caio Coelho) is now involved in the European Commission's 6th Framework ENSEMBLES project[9]. This project allows external institutions to become affiliated members. Caio Coelho and David Stephenson aim to include CPTEC as an external affiliated institution to ENSEMBLES in order to continue their collaboration work with other partners of this project. Such international cooperation is expected to benefit all research institutions involved in this process.

Although CPTEC and INMET will receive global seasonal forecasts from ECMWF, Met Office and Météo-France, CPTEC and INMET will only issue real-time multi-model combined and calibrated forecasts for South America. Note that this does not restrict CPTEC from issuing global real-time seasonal forecasts produced by its own coupled model. Seasonal forecast information of regions other than South America (e.g. over the Pacific and Atlantic sectors) are important and useful for improving the skill of forecasts over the South American continent. The planned methodology allows the use of forecast information of these remote regions in order to improve South American seasonal forecasts.

EUROBRISA will research and develop trial real-time forecast products for non-profitable governmental use only. The delivery of EUROBRISA forecast products for commercial use by private companies, with the aim of having financial gain, will require separate agreements with the ECMWF committee on data policy and council. EUROBRISA forecasts will contain the logo of the five contributing institutions (CPTEC, INMET, ECMWF, Met Office and Météo-France) plus USP's logo for downscaled forecasts. This will give international visibility to all institutions involved in this initiative. Combined and calibrated South American multi-model forecasts will be useful for a number of governmental applications such as water resource management for electricity production and agriculture. This will demonstrate the societal value of EUROBRISA by integration with seasonal forecast end-users. Preliminary studies suggest that combined and calibrated multi-model forecasts are useful for local downscaling of rainfall and river flow anomalies for some regions of South America (Coelho et al 2005c).

EUROBRISA will provide forecasts for governments institutions for use for example in reservoir management and electricity power forecasting. These activities will be conducted with the help and expertise of Dr. Alexandre Guetter from SIMEPAR. SIMEPAR is a meteorological governmental institution that works with governmental hydropower stations in Brazil with the aim of providing weather and climate information for electricity production and forecasting. Currently SIMEPAR provides to the government of Paraná State experimental seasonal streamflow forecasts for the large basins of the Brazilian hydropower system. The current streamflow forecasting system is based on an empirical (statistical) model that uses observed natural streamflow (estimated from reservoir operational data, with the effect of reservoir

[9] Project full title: ENSEMBLE-based Predictions of Climate Changes and their Impacts (http://www.ensembles-eu.org)

storage and operation removed), monthly observed SSTs and some climate indices as predictors. The skill of this forecasts is being evaluated since June 2004 and encouraging scores are being obtained. The inclusion of SSTs and climate indices has provided a large improvement over the standard empirical model based solely on streamflow autocorrelation, which is being used operationally to plan the joint operation of the Brazilian hydropower system. It is expected that the availability of EUROBRISA multi-model seasonal forecasts, in association with the development of large scale hydrologic models, will significantly enhance the skill of streamflow forecasts.

Dr. Tércio Ambrizzi and Dr. Pedro L. S. Dias from the University of São Paulo will conduct theoretical and observational investigations on South American seasonal predictability. Dr. Ambrizzi will also produce regional downscaled seasonal predictions for the southeast region of Brazil. Dr. Ambrizzi and Dr. Dias are experts in dynamical meteorology and will substantially contribute for the understanding of climate variability and predictability physical processes over South America.

The University of Reading will play an important role in this project, through the involvement of Dr. David B. Stephenson. Dr. Stephenson is an expert in statistical climatology and forecast quality assessment (verification) and, with the additional seasonal forecast expertise of Dr. Magdalena Balmaseda and Dr. Francisco J. Doblas-Reyes from ECMWF, will contribute for further improvements on the multi-model forecast calibration and combination procedure developed during the PhD of Caio Coelho. This will allow CPTEC and INMET to provide better quality probabilistic seasonal forecasts for South America.

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