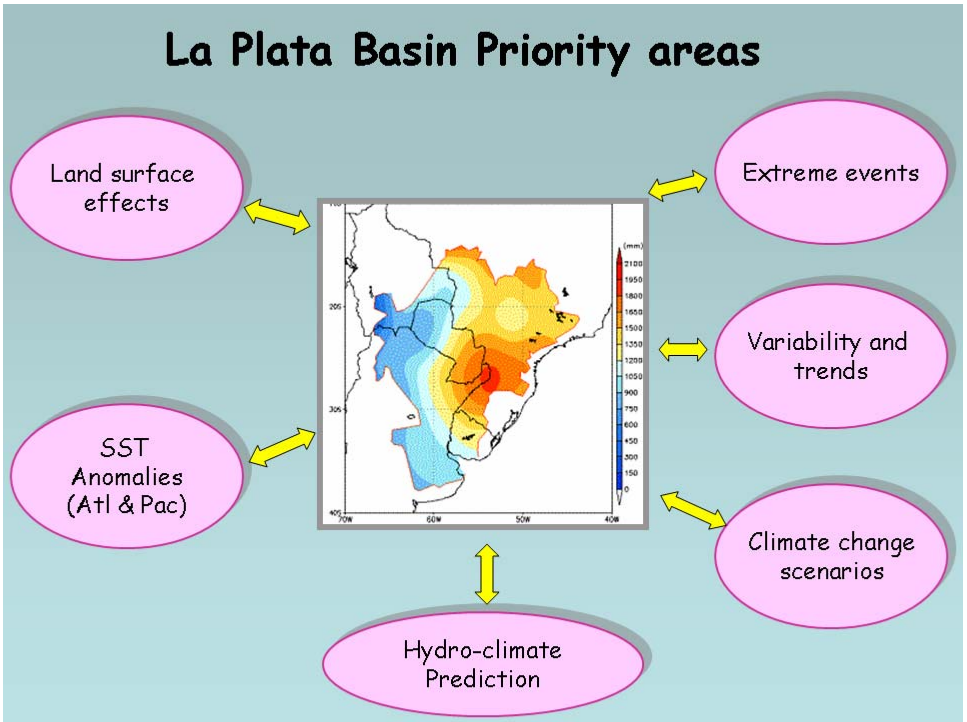
La Plata Basin (LPB) Continental Scale Experiment

Implementation Plan



Implementation Steering Group

E. Hugo Berbery (co-chair for VAMOS/CLIVAR), Maria Assunção Silva Dias (co-chair for GHP/GEWEX), Walter Baethgen, Vicente Barros, Walter Collischonn, Nicolas Failache, Dennis Lettenmaier, José Marengo, Angel Menendez, Roger Monte Domecq, Osvaldo Moraes, Carlos Morales, José Paruelo, Marcelo Seluchi, Pedro Silva Dias, Rafael Terra, Carlos Ereño (ex-officio), José Meitín (ex-officio)

This report was prepared with the contributions of the members of the LPB Implementation Steering Group, and the additional contributions of Heitor Coutinho, Nelson Luís Dias, Estebán Jobbágy, Humberto Rocha, Carolina Vera, and Steve Williams.

Draft
23 December 2005

LPB is a Continental Scale Experiments that is being coordinated jointly by GEWEX and CLIVAR, through the GEWEX Hydrometeorological Panel (GHP) and the Variability of the American Monsoons Panel (VAMOS).

Implementation Steering Group Members and Affiliations

Name	Institution	Country
E. Hugo Berbery (co-chair for VAMOS/CLIVAR)	University of Maryland (UMD)	US
Maria Assunção Silva Dias (co-chair for GHP/GEWEX)	Centro de Previsão do Tempo e Estudos Climaticos (CPTEC)	BR
Walter Baethgen	International Research Institute for Climate Prediction (IRI)	US/UY
Vicente Barros	Centro de Investigaciones del Mar y la Atmósfera/ Universidad de Buenos Aires (CIMA/UBA)	AR
Walter Collischonn	Universidade Federal de Rio Grande do Sul (UFRGS)	BR
Nicolas Failache	Universidad de la República (Uruguay)	UY
Dennis Lettenmaier	University of Washington (UW)	US
José Marengo	CPTEC	BR
Angel Menendez	Instituto Nacional del Agua (INA); UBA	AR
Roger Monte Domecq	Universidad de Asunción (UNA)	PY
Osvaldo Moraes	Universidade Federal de Santa Maria (UFSM)	BR
Carlos Morales	Universidade de São Paulo (USP)	BR
José Paruelo	UBA	AR
Marcelo Seluchi	CPTEC	BR
Pedro Silva Dias	USP	BR
Rafael Terra	Universidad de la República (Uruguay)	UY
Carlos Ereño (Ex-officio)	International CLIVAR Project Office (ICPO)	AR
José Meitín (Ex-officio)	UCAR/EOL	US

On the cover: The schematic represents the main forcings driving the hydro-climate of La Plata Basin (left), and the application areas covered in the LPB Project (right and bottom).

Executive Summary

The La Plata Basin is the fifth largest in the world and second only to the Amazon Basin in South America in terms of geographical extent. The principal sub-basins are those of the Paraná, Paraguay and Uruguay Rivers. The La Plata Basin covers parts of five countries, Argentina, Bolivia, Brazil, Paraguay and Uruguay, and is home to about 50% of their combined population, generating about 70% of their total GNP.

The countries in the basin have a history of international collaboration. Several hydropower stations have been built by bi-national agreements, and there is a commercial agreement (MERCOSUR) between four of the countries. An environmental program deals with the exchange of observations and exchange of information.

The International Program on the La Plata Basin (LPB) was endorsed by the GEWEX and CLIVAR Panels of the World Climate Research Programme; it has three major topics of interest to countries in the basin:

- What climatological and hydrological factors determine the frequency of occurrence and spatial extent of floods and droughts?
- How predictable is the regional weather and climate variability and its impact on hydrological, agricultural and social systems of the basin?
- What are the impacts of global climate change and land use change on regional weather, climate, hydrology and agriculture? Can their impacts be predicted, at least in part?

This document presents the plans for implementation of the activities that will address these questions by means of enhanced datasets resulting of monitoring of the hydroclimate of the basin and enhanced observations during a field experiment. These products will be employed for empirical, modeling and diagnostic studies to predict the future evolution of the basin.

The scientific areas that will be covered include: (a) remote effects, (b) land surface atmosphere feedbacks, land cover and land use changes, (c) extreme events, variability and trends, (d) predictability of the hydrologic system and (e) climate change scenarios and vulnerability of the basin to those changes.

The monitoring of hydro-climate variables will include an enhanced network of digital raingauges, soil moisture measurements, turbulent flux measurements with flux towers, radar products and calibration and merging of these observations with satellite products. During the field campaign, measurements of soil moisture will be estimated with remote sensing from aircraft and MCS contributions to precipitation will be further examined with a portable radar.

Modeling activities will focus on coupled land-atmosphere parameterizations, uses of distributed hydrological models, data assimilation, and finally on the production of a set of regional reanalysis developed at CPTEC. Different efforts will be initiated to

perform land data assimilation of satellite and in situ observations. Globsal and regional multi-model experiments will be routinely employed for seasonal predictability studies.

A novel aspect of this Continental Scale Experiment is the assessment of the potential effects of climate change on the basin's hydro-climate. Previous studies have shown that precipitation and river discharge have experimented important trends over large parts of the La Plata Basin in the last decades, and this has led to more frequent and severe floods. Climate change scenarios will be employed to assess the vulnerability of the region to modified conditions, and how they may impact the livelihood, economical and societal needs of the region.

Table of Contents

PART A: The International Program on the La Plata Basin (LPB)

1. La Plata Basin

1.1 Background

The La Plata Basin covers about 3.2 million km^2 (see Fig. 1). In terms of geographical extent, the basin is the fifth largest in the world and second only to the Amazon Basin in South America. The principal sub-basins are those of the Paraná, Paraguay and Uruguay Rivers. The La Plata Basin covers parts of five countries, is home to about 50% of their combined population, and generates about 70% of their total GNP. Approximately 30% of the area belongs to Argentina, 7% to Bolivia, 46% to Brazil, 13% to Paraguay and 4% to Uruguay. The basin is important in different ways for the economies of those countries. Harvests and livestock are among the region's crucial resources, rivers are natural waterways, and surface transportation has greatly increased in recent years due to the integration of regional economies. Last, but not least, several hydroelectric plants provide most of the energy consumed. The countries in the basin have a history of international collaboration. Argentina and Uruguay built Salto Grande on the Uruguay River. Brazil and Paraguay built today's largest power station in the world at Itaipú on the Paraná River. Argentina and Paraguay built Yacyretá, also a very large power station downstream from Itaipú. Besides the commercial agreement within the MERCOSUR participating countries (Argentina, Brazil, Paraguay and Uruguay), there is an environmental program that deals with the exchange of observations and exchange of information.

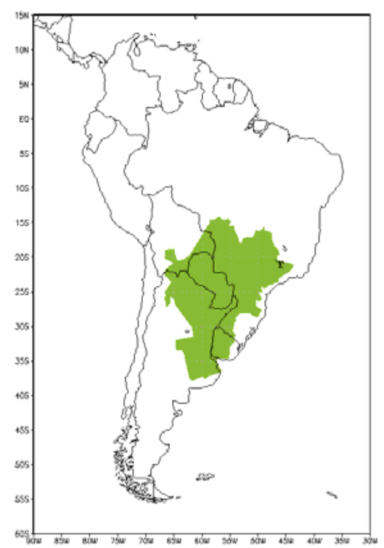


Figure 1: La Plata Basin

Within the LPB, the Guarani aquifer is one of the world's largest underground water reservoirs, with an estimated area of 1.3 million km^2, the majority beneath Brazilian territory (65%), followed by Argentina (27%), Uruguay (4%) and Paraguay (4%). The LPB and the Guarani aquifer spatially overlap and are a critical environmental link among the countries of the MERCOSUR (the Southern Cone Common Market Treaty, established in January of 1995, between Argentina Brazil, Paraguay and Uruguay).

1.2 Motivation

In 2001 the VAMOS Panel of CLIVAR/WCRP named a scientific working group with the objective of identifying and describing the main climate and hydrologic features of the La Plata Basin in South America. This group, that came to be known as "PLATIN", prepared the document **Climatology and Hydrology of the Plata Basin** (http://www.clivar.org/ publications/wg_reports/vamos/pdf_files/laplata.pdf), that identified the priority research areas that would contribute to the advancement of the relevant hydro-climate issues of the region. The document articulated the need for an international research program that targets three major topics of principal interest to countries in the basin:

- What climatological and hydrological factors determine the frequency of occurrence and spatial extent of floods and droughts?
- How predictable is the regional weather and climate variability and its impact on hydrological, agricultural and social systems of the basin?
- What are the impacts of global climate change and land use change on regional weather, climate, hydrology and agriculture? Can their impacts be predicted, at least in part?

The group also demonstrated the readiness of the region to embark on a larger project that met the requirements of a Continental Scale Experiment (CSE) as defined by the GEWEX Hydrometeorological Panel (GHP). In addition to a sound scientific plan, it is required that the activities be performed in close collaboration with operational agencies, and that there will be a free exchange of data. LPB meets several technical requirements: (a) CPTEC and IRI, both climate prediction centers, have committed cooperation with LPB. Several national and international sources provide funding for LBP research, (b) LPB includes several monitoring and experimental networks, as well as flux towers; (c) An LPB Database will be available for data storage at CPTEC and UCAR EOL, which also coordinates data management support; (d) the LPB's data policy is inspired by CEOP and used in SALLJEX. Researchers commit to the exchange of scientific information and data in conformity with the general practice of WCRP; and (e) the LPB is contributing to the evaluation of GEWEX global data products by generating in-situ data.

A recent VAMOS field experiment, the South American Low-Level Jet field campaign (SALLJEX), was planned and carried out as an early contribution to LPB activities. SALLJEX was conceived as an experiment whose achievements could contribute to the better understanding of the origins of the moisture fluxes and precipitation in the LPB. SALLJEX was performed with great success between 15 Nov 2002 and 15 Feb 2003 in Bolivia, Paraguay, central and northern Argentina, western Brazil, and Peru. SALLJEX aimed at describing many aspects of the SALLJ and was a blend of many observing systems. Scientists, collaborators, students, National Weather Service personnel and local volunteers from Argentina, Brazil, Bolivia, Paraguay, Chile, Uruguay, Peru and the USA participated in SALLJEX activities in an unprecedented way. SALLJEX was the first WCRP/CLIVAR international campaign in South America, and along with PLATIN planning demonstrated the feasibility of developing a program like LPB. The Scientific Prospectus and Implementation Plan for SALLJEX are presented in Paegle et al. (2001), and the results of the experiment and further information are available at "SALLJEX Data Management (http://www.ofps.ucar.edu/salljex/)".

The science questions of a field experiment in LPB (PLATEX) are under discussion. The main scientific issues are: (a) Strong variability of streamflows on several time scales; (b) relative contributions to variability of climate and land use change are not well known; (c) Effects of aerosols advection from biomas burning from tropical areas on precipitation are potentially large; (d) Strong contribution of Mesoscale Convective Systems (MCSs) to total precipitation; and (e) the predictability issue related to the observation system: data frequency, station location, new systems (e.g., profilers, radars, new satellite data).

1.3 Endorsements

The VAMOS/PLATIN Group made a successful contribution to the first phase of the GEF Framework Program for the La Plata Basin, producing surveys of the basin's hydroclimate, including the systems used for its prediction and monitoring. The PLATIN Group also participated in the second phase for planning the GEF full project. A structure for the discussion of future plans, including PLATIN/LPB scientists and personnel from NWS and water agencies is starting to emerge. The participation of the VAMOS/PLATIN Group in the GEF Program is unquestionably a great example of how GEWEX and CLIVAR science can be applied to solve societal needs. GEF will provide additional funding for climate monitoring, field campaigns, as well as regional database enhancement.

The GEF Framework Program (http://www.cicplata.org/marco/) generated surveys of the LPB's hydroclimate, including the systems used for its prediction and monitoring. The PLATIN-related activities in the same program are focused on the development of plans on different aspects of the LPB's hydroclimate. These plans can be an integral part of the LPB CSE's implementation plan. As part of the survey, a detailed analysis of the observational network has been compiled. Likewise, the survey of the NWP activities indicated that a large number of regional forecasting systems are now available. There are ongoing activities on the optimal combination of the available forecasts including a super-ensemble of global and regional model products, and they will be part of LPB activities as well as of the THORPEX program. The survey detected rather limited efforts on data assimilation of the conventional and remote sensing data in most of the NWS regional centers except at CPTEC. Distributed hydrological modeling is now available for several sub-basins such as the Taquari, Uruguay, Upper Paraguay. The GEF activities are in a new stage where 4 groups have been established: Group 1: Regional climate and hydrological scenarios; Group 2: Land use change and other regional processes; Group 3: Meteorological and climatological observational and prediction systems and Group 4: Hydrological observational and prediction systems. The activities related to the GEF funding in groups 3 and 4 are mostly directed to implementation of operational tools in hydrological and meteorological operational systems. Activities 1 and 2 have a stronger research component.

The relationship between LBA and LPB is very relevant for the LPB Implementation Plan. LBA is upstream of the low level jet that feeds moisture to LPB, and any changes in the Amazon climate, natural or manmade are likely to affect the climate system of LPB. The main points of LBA are: (a) focus on biosphere-atmosphere interactions in the Amazon Basin; (b) the program is fully institutionalized and there is a network of participants is functioning; (c) the participants are Amazonian countries with international partners in USA and Europe, (d) LBA is finishing Phase I and the synthesis phase is currently in operation; (e) LBA Phase II, beginning 2006, is strongly focused on the ecosystem/atmosphere/chemistry coupled models and aerosol-radiation-precipitation issues; (f) there is funding for: 14 flux towers and a network of S-band Doppler radars, radiosondes and surface weather stations maintained by the Amazon Observational System -SIPAM; (h) mostly Brazilian funding for research and maintenance of observations; (i) NASA will be funding the synthesis of Phase I, there are ongoing projects with Europe.

1.4 Anticipated benefits

The LPB program has plans for monitoring the hydroclimate of the basin, carry out a field experiment, and perform modeling studies with direct applications to data assimilation, predictability studies, and climate change scenarios. Extensive diagnostics will take advantage of observations and models. Among the expected outcomes of the program, the following are worth mentioning:

- An end-to-end coupled modeling system (including coupled atmospheric, land surface and distributed models) covering the whole LPB
- New tools for seasonal prediction
- A comprehensive observational dataset for hydro-climate studies
- A 25-yr higher resolution regional reanalysis dataset
- Climate change scenarios for hydroclimate of the LPB
- Analysis of vulnerability to Climate Change, in a form that can be reported to the policy makers
- LPB will further contribute to the enhanced integration between the research/academic community and the operational forecasting and observation centers in the area.

2. Scientific background

The document Climate and Hydrology of the La Plata Basin discussed the main areas of research that provided a basis for the current LPB Continental Scale Experiment. Here, a summary and update of the main scientific issues relevant for the Implementation Plan are presented.

2.1 Remote effects

- To what degree is the basin climatology and hydrology affected by SST anomalies?
- How is decadal variability in the tropical Atlantic SSTs linked to precipitation anomalies in the basin, particularly in the northern part (Upper Paraguay and Paraná, Upper Bermejo and Pilcomayo)?

Several studies have found links between ENSO events in the equatorial Pacific Ocean and rainfall anomalies during late austral spring-early summer and late austral fall-early winter in extratropical South America. There are significant negative correlations between rainfall and the Southern Oscillation Index (SOI) during October-November (Aceituno, 1988). Rainfall anomalies in northeastern Argentina, southeastern Brazil and Uruguay tend to be positive from November of El Niño years to February of the following years and negative from July to December of La Niña years (Ropelewski and Halpert, 1987,1989). In the same area but also in Paraguay there is a positive and significant difference in spring precipitation between El Niño and La Niña (Kiladis and Diaz, 1989).

There are also other detailed studies on the interannual response of the precipitation to the warm and cold phases of ENSO in some regions of the La Plata Basin. Precipitation correlates significantly with ENSO indexes during the austral spring in the south of Brazil (Rao and Hada, 1990; Grimm et al., 1998) with similar signals during the winter. In Uruguay and southern Brazil rainfall tends to be higher than average in El Niño years, especially during November-January, and lower than average in years with a high index phase of the Southern Oscillation (HSOI years), especially in October-December (Pisciottano et al., 1994). In addition, rainfall anomalies tend to switch signs during January and February (late austral summer) after HSOI years, but not after El Niño years. These precipitation anomalies during ENSO events are associated with atmospheric circulation anomalies. Over most of southeastern South America in spring during warm (cold) ENSO events, the subtropical jet and cyclonic activity are enhanced (weakened). During most of the warm (cold) ENSO events, the Chaco low deepens (weakens) and the moisture advection from the north increases (Grimm et al., 2000). The El Niño signals in the South American rainfall during the austral summer are more pronounced for the warm phase of the PDO than for the cold phase of the PDO (Andreoli and Kayano, 2004, 2005).

The leading empirical orthogonal function (EOF) mode of both wind components in the upper troposphere over South America during summer from the NCEP reanalysis consists of a strong, anomalous, large-scale eddy circulation over the SACZ (Robertson and Mechoso, 2000). An anomalous cyclonic (anticyclonic) eddy was found to accompany an intensified (diffuse) SACZ, with anomalous descent (ascent) to the southwest. At low levels, an intensified (weakened) SACZ was found to be associated with a weak (strong) flow east of the Andes.

Interannual variability in the January-March period appears to be largely uncorrelated with ENSO, while it exhibits strong correlations with SSTs over the southwest Atlantic (Robertson and Mechoso, 2000). However, similar SACZ circulation patterns also occur during the October–November period, at which time they are strongly teleconnected with ENSO (Cazes, et al. 2003). This marked seasonality in ENSO teleconnections is consistent with the findings of Pisciottano et al. (1994) who found the strongest ENSO influence on Uruguay rainfall to be in the spring. During the austral spring of El Niño years, the SACZ is weakened accompanied by enhanced ascent to the southwest and an intensified southward flow east of the Andes, consistent with positive rainfall anomalies over Uruguay. Doyle and Barros (2002) found that the midsummer interannual variability of the low-level tropospheric circulation and of the precipitation field in subtropical South America are associated to the SST anomalies in the western subtropical

South Atlantic Ocean. Composites corresponding to extreme SSTs in the area 20ºS-30ºS and 30ºW-50ºW show two different low-level circulation and precipitation patterns. Recent studies have identified that when the moisture transport from the Amazon region to the La Plata basin by the summertime Low Level Jet (LLJ) east of the Andes is weak/strong, the SACZ is strong/weak (Herdies et al. , 2002; Marengo et al. 2004).

During summer, increased (reduced) precipitation in southern Brazil, most of Uruguay and northeastern Argentina are likely to be associated with a weaker (stronger) SACZ, and with increased (reduced) rainfall further south in Argentina (Barros et al., 2000a). Barros et al., 2000 have also found meridional displacements of the SACZ to be important for precipitation, and that warm (cold) SST anomalies over the southwestern Atlantic (20°S - 40°S, west of 30°W) are likely to be accompanied by a southward (northward) shift of the SACZ. The precipitation field in southeastern South America is also affected in other seasons by SST anomalies in the neighboring Atlantic Ocean (Diaz et al., 1998; Barros et al 2000a).

2.2 Regional controls: Land surface-atmosphere interactions.

- *What role do soil processes play in the basin? In particular, do the large variations in the flooded area of the Pantanal impact and are themselves influenced by the variations in the region's climatology?*
- *Does water evaporated from the Pantanal wetland fall as precipitation elsewhere within the La Plata Basin? If so, how much is recycled, and where does it fall?*
- *What is the relative importance of local and remote sources of moisture in the basin? Of the water vapor that enters the basin and falls as precipitation, is any of it recycled within the la Plata basin itself? If so, how much, where from, and where does it fall?*
- *What developments and improvements in atmospheric models –in particular planetary layer formulations- are required to better represent the relationships among land surface model parameters and surface fluxes?*

There are some indications that precipitation in the region is not only teleconnected to SST anomalies in the Atlantic and Pacific oceans. Fu and Li (2004) have shown the relevance of surface conditions on the onset of the precipitation season in southern Amazonia; if surface conditions during the preceding dry season are such that more soil moisture than normal is found, then the resulting higher latent heat leads to a weaker convective inhibition providing a necessary condition for an earlier precipitation onset. Conversely, a weaker (stronger) increase of latent (sensible) heat flux during the dry season tends to delay the large scale circulation over the Amazon (Li and Fu 2004). A possible feedback between soil moisture and the monsoon activity over South America has been discussed by Grimm (2003) thus making a plausible case for the interaction between deforestation and precipitation changes through soil moisture processes. Ensemble simulations with a regional mesoscale model (Collini et al. 2006) show that the soil moisture affects not only the stability but also the intensity of the low-level jet east of the Andes, resulting changes in the precipitation magnitude over the monsoon region and affecting the northern La Plata basin. These studies are of particular importance for understanding the land cover/land use effects on the precipitation of the region, as discussed by Fu and Li (2004). Land use changes may lead to shifts in the precipitation regime that may threaten ecosystems as well as the productivity potential of the region.

2.3 Land cover/Land use changes

> - *What is the impact of land use changes associated to extended agriculture activities in the basin and in Amazonia on surface fluxes and atmospheric circulation?*
> - *What developments and improvements in hydrological models are required to better represent the relationships among model parameters and changes in soil use?*

The LPB watershed contains several key ecosystems. (1) The great Pantanal wetland, shared by Brazil, Bolivia, and Paraguay behaves as a regulator of the entire LPB hydrological system by slowing the flow of the Paraguay River's waters to the Paraná River, thus avoiding a conjunction of the maximum volume and flow rates from both rivers (Soldano 1947); (2) The highlands of both Paraguay and Paraná basins are important ecological corridors linking the Cerrados to the Pantanal; (3) The Cerrado biome covers about 2,000,000 km^2 of Central Brazil, 25% of the country's territory. It's mainly used for agriculture, producing 52% of Brazil's soybeans, 41% of the beef cattle, 34% of the rice, 26% of the maize, and 21% of the coffee (Resck 2002). The Cerrado vegetation complex is similar to the African savannahs, consisting of sparse trees of low to medium height with tortuous stems, thick bark and tough leaves, and an understory of grasses (Coutinho 1978); (4) The Chaco region, another key ecosystem, is dominated by dry woodlands and savannas, and an alluvial area formed by the sediments of the Bermejo and Pilcomayo Rivers. This region constitutes a key ecological corridor among mountains, cloud forests (Yungas rainforests), high elevation deserts (Puna), and the shallow plains of the Chaco (OAS, 1974; Bucher, 1999); (5) The Pampas is the ecosystem with the most fertile soils of the LPB, largely converted to agricultural production (Hall et al. 1992, Soriano et al. 1991); (6) Another important biome is the Atlantic Rainforest in the northeast of the LPB, characterized by intense deforestation and agricultural use. With only 7% of its original extent remaining, the Atlantic rainforest is considered to be a global biodiversity hotspot, due to the richness of its biodiversity and its high number of endangered endemic species.

Land transformations by humans can take a diversity of forms and vary greatly in their consequences. Many of these transformations around the world have resulted in extensive soil degradation and erosion, hydrological changes, and climatic alterations (Matson et al., 1997). In addition, land use and land cover (LULC) changes are believed to contribute ~20% of the current anthropogenic CO2 emissions (Wuebbles et al. 1999) and represent the primary driving force in the loss of biological diversity (Vitousek et al. 1997). Today, there is an increased recognition that land use change is a major driver of environmental changes globally (Meyer and Turner 1994; Houghton, 1994).

A central obstacle to understanding, predicting, and assessing the interactions between human and natural systems that govern LULC change in heterogeneous landscapes is the lack of a comprehensive and integrated research framework capable of addressing the inherent complexity of the system (Vitousek et al. 1997). This complexity is evidenced by the links between spatial patterns of LULC and the function and services of ecosystems, the extent to which social and economic drivers interact with or even outweigh biophysical constraints on LULC change, and the feedback processes by which the social and environmental impacts of LULC dynamics drive further changes in the human and natural systems.

Drivers of LULC change. Biophysical and social drivers interact at multiple scales and determine patterns of LULC. Soil, topography, climate, and hydrology define the landscape and its suitability for a particular natural or human-controlled system. Other multi-scale drivers such as global markets, technological development, agricultural history, migration rates, land tenancy, external debts, legal frameworks, public policies, infra-structure, and cultural restrictions influence human behavior and their decisions regarding patterns of settlement and land use. Some of these drivers operate at particular time and space scales, while others operate across multiple scales. Disentangling these drivers is possible with spatially explicit models that track and relate the manifold drivers and the resulting LULC changes.

LULC Change Impacts. Identifying and quantifying LULC change feedback mechanisms and impacts on ecosystems and society are also critical to developing an integrative research framework. The energy and matter flows of ecosystem functioning contribute to ecosystem services on which humanity relies upon for its survival and well being: greenhouse gas regulation, water treatment, erosion control, soil quality control, and plant growth (Naeem et al 1999). Therefore, changes in ecosystem functioning lead to important alterations in ecosystem services (de Groot 1994), and these alterations in turn affect the social and ecological systems through feedback mechanisms. Impacts on ecosystem services will affect land management decisions at different hierarchical scales, from local to national. To characterize and quantify ecosystem services, and evaluate their feedbacks to the LULC drivers, is a major challenge in environmental sciences (Costanza et al. 1997; Daly 1997).

Local and regional climate processes, for example, are one of the ecosystem services closely integrated with LULC change. Pielke et al. (1997) and Stohlgren et al. (1998) showed that land use patterns have a critical influence on meso-scale atmospheric processes and hence on regional climate. Mosier et al. (1991) indicate that agricultural activity increases the release of methane ($CH4$) and nitrous oxide ($N2O$), two greenhouse gases that may have significant effects on global climate change (Sala & Paruelo 1997). Specifically determining the effect of LULC change on local and regional climate, and any feedbacks on ecosystems, requires interdisciplinary research frameworks that are difficult to foster.

Soils, while important drivers of LULC, are also major recipients of impacts derived from LULC change. Potential negative impacts of LULC change on soil quality are most directly influenced by soil erosion processes. These lead to further impacts on other ecosystem services (hydrologic and atmospheric gas regulations), as well as to socio-economic properties (net returns on agricultural inputs, rural population displacement, etc.). Soil organic matter, biological health (diversity of soil organisms and activity), and structure are early warning indicators of land degradation processes (Coutinho et al. 2003). Again, remote sensing estimates allow an integrated assessment of the magnitude and rates of soil erosion processes motivated by LULC change (Meirelles et al.2003).

From the upper Paraguay basin it can be said that original vegetation was changed to Soy bean and other crops in not more than 10% of the drainage area of rivers that form the La Plata. By contrast, 50% of the drainage area had its natural vegetation changed to pasture. Pasture should be put as the main vegetation that replaced the Brazilian cerrado.

2.4 Extreme events

- Under what circumstances the range of numerical forecast of regional, synoptic or sub-synoptic systems can be reliably extended?
-To what extent is it possible to predict the intraseasonal precipitation variability over the La Plata Basin?

La Plata Basin is particularly vulnerable to temperature and precipitation extremes. Particularly these latter phenomena affect the region's productivity, for example because of the great impact on the agriculture (due to the singular characteristics of this area, very flat and only a few meters above the sea level). In general, extreme rainfall events are caused by a wide variety of meteorological systems and almost in all time scales. Several authors (mentioned in 2.2) documented the interannual precipitation variability over broad sectors of the basin and its relationship with the phases of the ENSO. It is a verified fact that during the El Niño episodes a high probability of occurrence of floods exists on wide sectors of southern Brazil, Paraguay, eastern Argentina and Uruguay, as it happened for example during the events of 1982-83 and 1997-98.

Atmospheric blocks, which are relatively frequent over South America and also over oceanic areas near the continent, have great influence on the regional precipitation amounts (Berbery and Nuñez 1989). According to Alessandro (2003a 2003b) these systems cause strong impact on temperature and precipitation anomalies on the southern tip of the continent, with a sign and intensity that depends strongly on the relative location of these systems. As a general rule, blocking systems acting immediately to the southwest of the continent, around 70°W, have stronger influence on the thermal and precipitation regime, producing positive temperature anomalies and drastic rainfall reduction over Patagonia and, simultaneously, water excesses accompanied of relatively low temperatures on the center-south of La Plata Basin. Nevertheless, Malaka. and Núñez (1980) concluded that the major drought registered on the center of Argentina until the year 1980 owed to the action of a blocking system placed on the austral Atlantic Ocean.

Undoubtedly, the baroclinic activity and especially the passage of frontal systems, is one of the most direct causes of the sharp temperature variations and the most significant hydrometeorological events. The fronts can advance up to relatively low latitudes to the east of the Andes due to the influence that exerts this mountain range (Gan and Rao 1994, Garreaud 2000) affecting the weather and climate of the whole basin. According to Hoffmann (1971) frontal systems are responsible for about 70 % of the total precipitations on the Argentinean "Littoral" (and presumably over western Uruguay and the Brazilian State of Rio Grande do Sul). Both theoretical aspects and observational experience demonstrate that the frequency and intensity of frontal systems, as well as the magnitude and extension of temperature and rainfall extremes that they may cause, strongly depend on local and remote forcing.

During summer, frontal systems tend to become stationary over the eastern coast of South America contributing to the development of the South Atlantic Convergence Zone (SACZ), i.e., a continuous band of cloudiness that spreads from the Amazon to the Southern Atlantic Ocean lasting for several days and fostering the concentration of precipitation over the northern half of the basin. The presence of this system is highly variable and is directly responsible for a very important percentage of the total rainfall amount accumulated during the rainy season.

Extratropical cyclones that develop on the eastern coast of South America are among the baroclinic systems responsible for the occurrence of significant precipitation episodes. In particular, the "Bombs" (as the one studied by Seluchi and Saulo, 1998), whose explosive development is sometimes due to the strong influence of the latent heat release, are associated with heavy rainfall and, in some occasions, with flooding and gales. In the cases in which the low-pressure center is located over Uruguay, the irruption of intense southeasterly winds on the estuary of the Rio de la Plata may dramatically increase the water level, fostered by the funnel form of the estuary. This phenomenon, locally known as "Sudestada" (Ciappesoni and Salio, 1997), can cause important damages to the city of Buenos Aires and its suburbs. The explosive nature of these cyclones is also due to the indirect influence of Andes that delays the disturbances track from the Pacific Ocean and, hence, contributes to the additional increase of the convective potential energy on the La Plata Basin, which is later on released during the cyclogenesis process. According to Gan and Rao (1994) the development and passage of cyclonic systems is particularly frequent on the eastern coast of South America, especially during the colder half of the year, when baroclinicity moves further north and the thermal contrast between the continent and the ocean is intensified.

The Low-level Jet east of the Andes plays a critical role in the production and timing of intense precipitation, and particularly in the development of Mesocale Convective Systems (Velasco and Fritsch 1987). The flow associated with the LLJ transports moisture from the tropical Amazon to higher latitudes of South America (e.g., Berbery and Collini 2000; Gan et al. 2003; Marengo et al. 2004; Silva and Berbery 2005). The Northwestern Argentinean Low (NAL) (Lichtenstein 1980) is a component of the system of critical importance to understand the mechanisms of rainfall over the La Plata Basin. The presence of this low pressure, located almost in the geographical center of the continent, favors northerly winds over subtropical latitudes that transport heat and moist from equatorial latitudes. Saulo et al. (2004) documented the relation between the development of the NAL and the occurrence of "Chaco Low-Level Jets", (Low Level Jets that extend meridionally to the east of the Andes attaining extratropical latitudes). Even this current can be primarily the response to local scale forcing its posterior development and expansion to the south is geostrophically related to the existence, intensity and persistence of the NAL. In fact, the displacement to the south of the subtropical jet, and also the associate baroclinicity, fosters the persistence of this depression as well as the presence of the Low-Level Jet. This mechanism usually contributes to trigger squall lines and Mesoscale Convective Complexes (MCCs) (Velasco and Fritsch, 1987), two type of systems responsibly for heavy rainfall, specially during late spring and early summer.

Despite the relatively reduced horizontal and temporal scale of the NAL, the Low-Level Jet and the convective systems, some evidences exists, at least from the observational point of view, of its relationship with oscillations of larger scale. In that sense, Paegle and Mo (1997) determined two well differentiated circulation patterns over the subtropical region of South America during summer. The first one, associated with wet periods over the La Plata region, is linked to the southward displacement of the baroclinicity, the NAL and the Low-Level Jet, as well as to the suppression of the SACZ. The opposite pattern occurs when the subtropical Jet moves towards the north favoring the development of the SACZ. In these occasions high precipitation volumes accumulates on the northern half of the basin whereas further south an anticyclonic anomalous circulation inhibits precipitation.

2.5 Hydroclimatic variability and trends

What are the climatological and hydrological characterization of droughts and floods in the La Plata Basin both in time and space?

Climate variability at different timescales is often interrelated and the same modes of variability appear at very distinct frequencies. Such is the case, for instance, of the South Atlantic Convergence Zone (SACZ) – South Eastern South America (SESA) dipole. It has been shown that the strength of SACZ is inversely correlated with precipitation in SESA on interannual and interdecadal timescales (Robertson and Mechoso, 2000). The SACZ/SESA dipole is a dominant mode of variability of convective activity in the region also at the intraseasonal frequencies (Nogués-Paegle and Mo, 1997; Liebmann et al. 1999; Doyle and Barros, 2002; Díaz and Aceituno, 2003). It has been shown that SACZ variability is associated with Tropical Intraseasonal Convective Anomalies (Jones et al., 2004) and also shows interannual variations and even decadal cycles (Slingo et al., 1999).

Several studies have found significant interdecadal variability of rainfall in the basin (Krepper et al., 1989; Dai et al., 1997; Montecinos et al., 2000; Barros et al. 2000; Minetti et al., 2003). Trends have also been established in the climate of central South America especially during the austral summer (Minetti and Vargas, 1997; Liebmann et al. 2004).

The response of river streamflow to these climatic signals is of special interest since it represents a complex synthesis of precipitation, evapotranspiration and other components of the hydrological cycle in their basins, which themselves may have anthropogenic influences and extend along different climatic regions. Several studies have examined streamflow variability in the region from interannual to secular timescales (Aceituno, 1988; Mechoso and Pérez Iribarren, 1992; García and Vargas, 1996; Genta et al., 1998; Robertson and Mechoso, 2000; Berri et al. 2002 and Krepper et al., 2003). The relationships between the preferred modes of spatio-temporal variability of streamflows and those of climate, however, have received much less attention (Maheu et al. 2003).

During approximately the last century southeastern South America has experimented important changes in its precipitation regime, consequently affecting the hydrologic balance of the region, and particularly of the La Plata Basin. Changes have been observed in many other regions of the world, but South America is probably one where largest change magnitudes are found. Moreover, the trends have intensified in the last 30 to 40 years due to changes in the atmospheric circulation and likely due to land use changes. The strongest interdecadal variability in the annual cycle of precipitation occurs in regions of transition between precipitation regimes, especially in the Paraná River Basin (Rusticucci and Peñalba, 1997). In subtropical Argentina the annual precipitation also shows oscillations with periods from 7 to 10 years (Peñalba and Vargas, 1993; Minetti et al., 1982; Minetti and Vargas, 1983). On this time scale there is a close relationship between the temperature and precipitation regimes (Rusticucci and Peñalba, 1997).

Precipitation trends in Argentina have been positive since 1916, and continued to increase after the late fifties (Castañeda and Barros, 1994). This behavior is consistent with a climatic jump around the 1960's, when the southern portion of South America experienced a significant warming (Vargas et al., 1995). Precipitation increased by up to 30% between 1956 and 1991 in several localities between 20° S and 35° S east of the Andes (Castañeda and Barros, 1994). In a large part of this region, most of the increase occurred during the 1960's, and it seems to have been associated with a reduction of the meridional gradient of surface temperature, which probably caused a southward shift of the regional circulation. Another strong precipitation increase was observed during late 1970s. This correlates with an increase in the subtropical temperature of the Southern Hemisphere and a decrease of the SOI (Barros and Doyle, 1996). The positive trend in precipitation during 1956-1991 has facilitated a southward extension of the agricultural frontier in Argentina increasing available lands by the 1960s in an amount that exceeds 100,000 km2 (Barros et al, 2000b).

As a consequence of the increased precipitation in semiarid regions of Argentina, the agricultural land extent has increased, which has been beneficial for increased revenues. Changes in precipitation correspond with a doubling of changes in river discharge, so that by each 1% increase precipitation, the streamflow increases by 2% or more (see table 1, from Berbery and Barros 2002). Consequently, although semiarid regions have benefited from the increased precipitation, other regions are flooding more frequently, and in certain cases have been left permanently under water.

TABLE 1	**Rainfall rate ($m^3 s^{-1}$)**	**Stream-flow ($m^3 s^{-1}$)**	**Evap+ Infilt ($m^3 s^{-1}$)**
1998	107000	36600	70400
1999	81600	20440	61600
Difference	23 %	44 %	13 %
El Niño	76000	25250	50750
La Niña	71000	21640	49360
Difference	7 %	17 %	3 %
1951-1970	72000	19300	52700
1980-1999	83500	26000	56500
Difference	16 %	35 %	9 %

Several studies have addressed the variability of river streamflow in the La Plata Basin (e.g. Aceituno, 1988; Mechoso and Perez-Iribarren, 1992; Marengo, 1995; García and Vargas, 1998; Genta et al., 1998; García, 1999; Bischoff et al. 2000; Camilloni and Barros, 2000). The annual streamflow of the Negro, Paraguay, Paraná, and Uruguay Rivers during the period 1911-93 includes a nonlinear trend and a near-decadal component (Genta et al., 1998; Robertson and Mechoso, 1998). On the decadal time scale, high river runoff is associated with anomalously cool SSTs over the tropical North Atlantic, with the strong signal in the Paraguay and Paraná Rivers during summer. Interannual streamflow peaks with ENSO time scales were only found to be significant in the Negro and Uruguay Rivers in the southeast. Here, El Niño is associated with enhanced streamflow.

There is evidence of changes in the annual runoff cycle before and after 1983 (Camilloni and Barros, 2000). The maximum discharge changes from February (before 1880) to autumn (after 1983) in Corrientes and Posadas, together with an important increment in the mean annual discharge. These changes may be due to climate variability, river regulation by dams and/or runoff change because of changes in soil use. The climate signal is consistent with an increasing trend in the precipitation over the upper and middle Paraná basin during the fall season (Camilloni and Castañeda, 2000). River regulation by dams is a direct consequence of the annual cycle of precipitation and the overriding share of hydropower offer in the Brazilian energy matrix, which requires to save part of the waters for autumn and winter use.

2.6 Predictability of the atmospheric and surface hydrologic systems

- How predictable is the hydroclimatology variability in the La Plata Basin?
- Can the links between near-cycles found in SST and streamflow variations be used to obtain useful probabilistic prediction of river behavior?

The hydroclimatology of the La Plata River is strongly affected by ocean conditions in both adjacent oceans and rainfall and river streamflow time series show several quasi-periodicities (interannual-ENSO, interdecadal), with a major shift in precipitation and the discharge of many rivers in the late 1970s. The potential for flooding occurs at any time of the year (Berbery and Barros 2002). The largest contribution during flood episodes comes from the Paraná River. Both the Paraná and the Uruguay rivers can at least triple the mean river discharge during flood events (Berbery and Barros 2002).

In the La Plata Basin, results from a 50 year climatology 9 members ensemble of the CPTEC AGCM show that, despite the large scatter among members of the ensemble, the model captures quite well the extremes of the observed interannual rainfall variability; especially the above normal values observed in 1983 and 1998 and the drought conditions in 1989 (Marengo et al. 2003, Marengo 2005). This also has been noticed in various others AGCMs.

The SACZ connection between SST and rainfall in subtropical Argentina and Uruguay could be one of the mechanisms that relate the interannual variability of SST in the South Atlantic with precipitation in those countries. This relation was studied by Díaz et al (1998), finding the existence of an association between wet (dry) rainfall anomalies in the northern sector of Uruguay and southern Brazil and warm (cold) SST anomalies in the SACZ region and the equatorial Atlantic in the November-February period.

In terms of predictability, it is observed that regions where the remote forcing (e.g. SST anomalies in tropical oceans) is stronger exhibit relatively medium-higher predictability (e.g. Northeast Brazil, northern Amazonia, La Plata Basin) as compared to regions where the predictability is lower (west central Brazil, South American monsoon). This lower predictability seems to be related to local forcings, such as soil moisture or land surface processes. Koster *et al* (2000) showed that, for the upper Paraná, the fraction of precipitation variance explained by SST anomalies is lower than that explained by the land–atmosphere feedback.

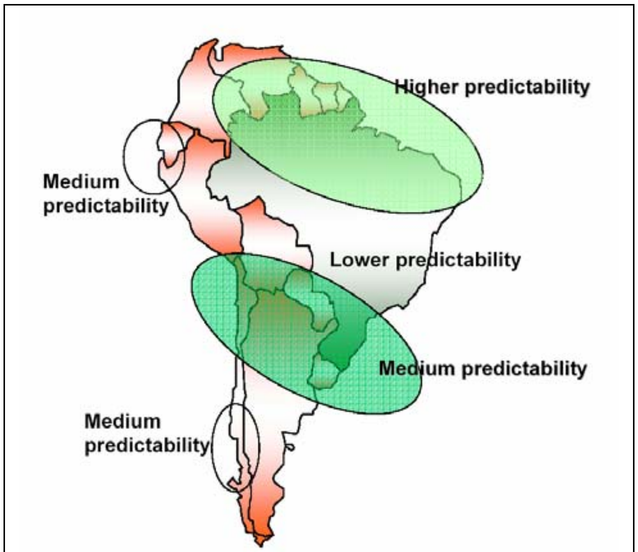


Fig 2. Scheme indicating regions with lower, medium and higher predictability at seasonal and interannual time scales (Source: J. Marengo, CPTEC/INPE).

In these regions, the precipitation variance induced by a chaotic atmospheric dynamic linked to land–atmosphere feedback is higher. In comparison, over the Amazon basin and Northeast Brazil, the fraction of precipitation induced by tropical SST variations is higher, partly explaining the relatively better predictability of the water balance components, mainly precipitation and runoff. This better predictability refers to seasonal to interannual climate prediction (Fig. 2).

It is not yet known to what extent seasonal climate predictability will change on regional scales in a scenario of global climate change; whether it will increase (in the case of increased dryness over semi arid regions) or will diminish (e.g., in the case of increased frequency of extreme events on a warmer and more humid atmosphere) as consequence of climate change, both natural and anthropogenic. In any case, the prospects of regional climate change are robust enough to justify a continuous scientific undertaking to improving the models and monitoring the environment to help society to learn to adapt to a changing climate.

2.7 Assessments of climate change scenarios on hydrologic conditions

- *The change from native forest to annual high-value crops, such as soy bean, and even more, to widespread pasture for cattle, is likely to have (a) increased annual runoff; (b) affected the magnitudes and frequency of occurrence of floods and low flows in several parts of the basin, and the change in land-use accelerated after 1970. Can the effects of land-use change on annual runoff, flood flows, and low flow duration be separated, in the flow record, from the effects of climate variations?*

Studies of climate change over particular regions of the world are particularly challenging. One strategy is to obtain different scenarios from the output of AOGCM or AGCMs simulations with various levels of concentration of GHG gases (SRES scenarios) as developed for the IPCC Third Assessment Report that are more reasonable than the current and doubled CO2 concentrations experiments produced for the IPCC Second Assessment Report. A word of caution is needed, since models still are not consistent with each other and regional precipitation is not completely well simulated for present climate. Furthermore, the simulation of rainfall extremes is still a challenging task for present climates, and the prospects of changes in hydrometeorological extremes in future warmer climates has started to be explored using model projection generated for the IPCC Fourth Assessment Report.

The observed long term climate variability in the La Plata basin shows a tendency for increases in precipitation and river runoff since the 1960's, as shown in studies by Barros and collaborators. Considering this long term variability as a base line for present climates, Marengo et al. (2005) performed some analysis of the projections of future climate change from various IPCC global models. The climate change projections are based only on the increase of concentration of greenhouse gases GHG as described by the SRES (Special Report Emission Scenarios) scenarios A2 (High emissions) and B2 (low emissions). In the La Plata Basin (Fig 3), temperatures are getting higher and rainfall tends to be above the normal as projected by all IPCC models, especially for the time slices centered in 2050 and 2080. In the same vein, Marengo (2006) shows that the apparent humidification of the La Plata basin is consistent with a drying tendency in Amazonia as simulated by 5 IPCC models. Figs 4 and 5 show the projections for rainfall and air temperature anomalies until 2100 from 5 IPCC global models. The HadCM3, the GFDL and in some degree the CCSR/NIES models shows positive rainfall anomaly trends that are more intense in the A2 scenario as compared to the B2. The rest of the models show negative rainfall anomalies. Fig. 5 shows warming in all models, particularly the HadCM3 and the CCSR/NIES, and the warming reaches up to 5C in the A2 scenario, as compared to the 3C in the B2 scenario.

For climate change scenarios for the XXI Century, new developments in dynamic vegetation schemes and coupled climate-carbon models (Cox et al. 2000, Betts el al. 2004 for the UK Hadley Centre AOGCM (HadCM3) have shown an effect named *die-back of the Amazon forest*, by which rising atmospheric CO2 is found to contribute to a 20% rainfall reduction and to more than 30% of surface temperature increases in the Amazon basin, through the physiological forcing of stomatal closure. They also show an increase in rainfall in southern Brazil-northern Argentina.

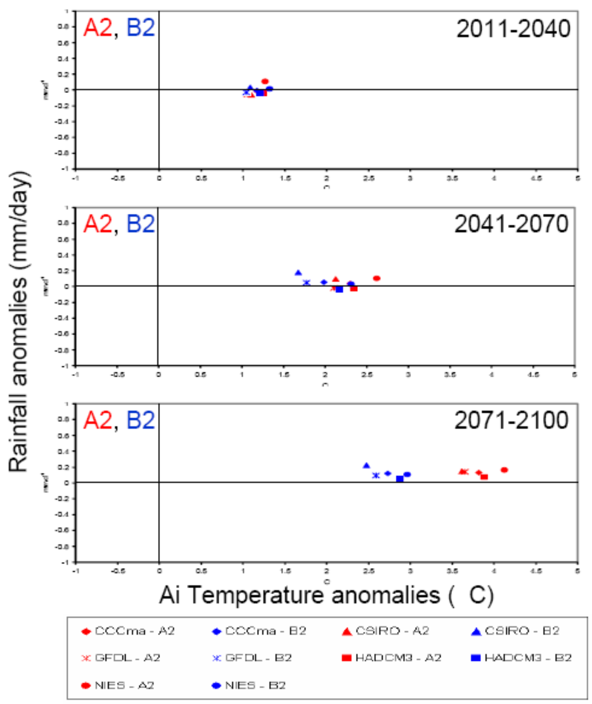


Figure 3. Scatter diagram of annual rainfall mm day $^{-1}$) and temperature(ºC) anomalies in the LPB region, in the time slices centered on 2020 (upper panel), 2050 (middle panel) and 2080 (lower panel) in relation to the 1961-90 present climate. The diagram is made considering the model projections of five IPCC AOGCMs, for the A2 (red) and B2 (blue) emission scenarios. (Marengo 2005)

The observed small negative rainfall trends in northern Amazonia, and systematic increases in rainfall and runoff in southern Amazonia and southeastern South America region since the middle 1970s (Marengo 2004, Liebmann et al. 2004, Barros and Doyle 1997) is consistent with the increase in the frequency of SALLJ events. Thus, it could be hypothesized that following Betts' results from the HadCM3 model that after the middle 2050s, the drying of the Amazon basin and the humidification of the LPB region on an extended El Niño-mode produced by this model, could perhaps be explained by changes in the regional circulation, with an increase on the SALLJ frequency and/or intensity in a global warming world. The likelihood of this scenario, however, is still an open issue. These projected changes are due only to the increase in the concentration of GHG gases. It is still uncertain if similar variations would occur in an land use land coverage scenario where the native vegetation would be replaced by agriculture development (e.. soy bean or cattle introduction) simultaneous to changes in the concentration of GHG.

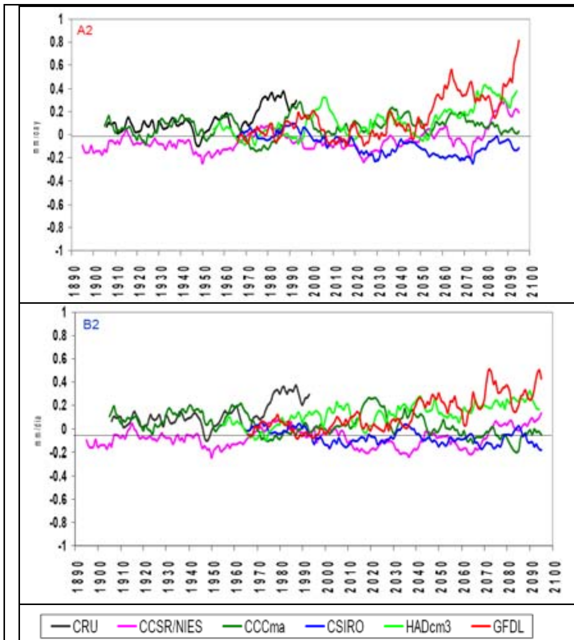


Figure 4. Time series of annual rainfall anomalies for the La Plata Basin as projected by five IPCC global models. Each color represent a model (lower panel), and the anomalies (in mm/day) are in relation to the 1961-90 mean. Observations (CRU-Climate Research Unit) are shown by the black line.

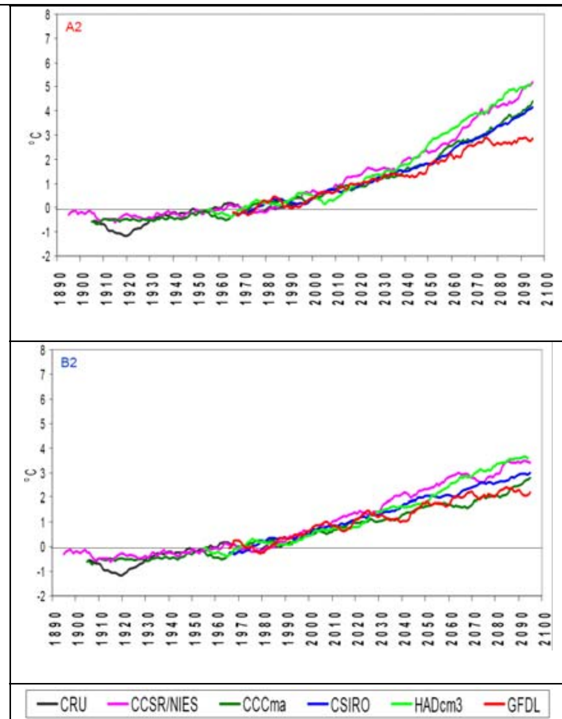


Figure 5. Time series of annual temperature anomalies for the La Plata Basin as projected by five IPCC global models. Each color represent a model (lower panel), and the anomalies (in °C) are in relation to the 1961-90 mean. Observations (CRU-Climate Research Unit) are shown by the black line. (Marengo 2005)

Figs. 4-5 show projections for climate change on the long term for the La Plata Basin, but they do not provide information on how climate extremes will behave on a warmer world. A recent study by Tebaldi et al (2005) analyzes the projections of some climate extremes using eight IPCC models. The indices were defined by Vincent et al (2005), Haylock et al (2005) and Alexander et al (2005). The projections for some climate extremes for 2080-2099, basically indicate a warm climate, with some differences in the regional distribution as well on the scenario. Some of the rainfall indices suggest an increase in the frequency and intensity in rainfall extremes in the LPB. For the LPB region, there is an increase in the extreme rainfall indices R10 and R95P, as well as in the consecutive dry days and maximum precipitation accumulated in 5 days. However, all these changes do not show statistical significance. The warm nights and heat waves indices show statistically positive significant trends, where the HWI can reach up to 3-4ºC.

PART B: Current status of research and applications

3. Survey of observational datasets

3.1 Surface datasets

The most important recent improvement in topographic data availability came from the SRTM (Shuttle Radar Topography Mission). Topographic data obtained from space is now freely available from CGIAR-CSI (2005), with spatial resolution of nearly 90 m, and typical errors of 10 m or less. The quality of this dataset is comparable to the 1:50,000 scale maps, and probably better than the 1:100,000 scale maps that are the only available topographic data in most of the upper Paraguay basin, except for extremely flat areas. The SRTM dataset is certainly much better than the GTOPO30 dataset which is sometimes used in large scale hydrological models and regional atmospheric models.

Digital Elevation Models derived from the SRTM set are being used for hydrologic modeling in the Upper Paraguay, including parts of Bolivia, Paraguay and Brazil, and in many parts of the Upper Paraná basin (Allasia et al., 2005).

Vegetation maps. Atmospheric models, even regional ones, employ a relatively coarse resolution surface parameters. The same is true for soil types and other associates characteristics. Recently, a high resolution (1km) data set of vegetation types was developed (Eva et al. 2004). The development of high resolution maps of surface conditions is one of LPB’s objectives.

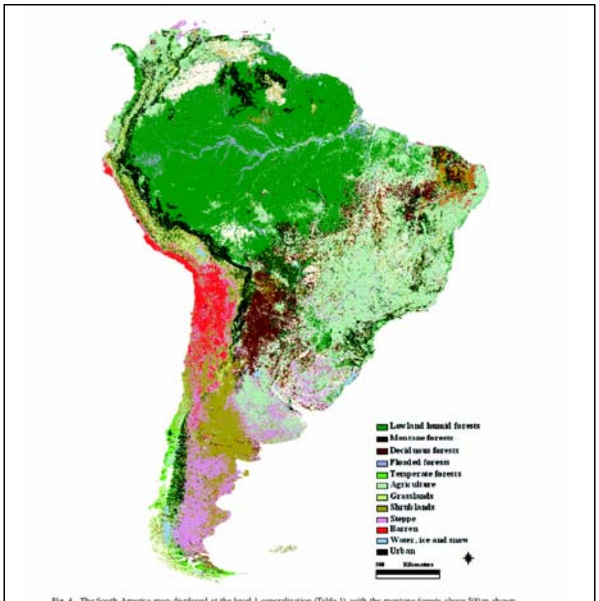


Fig 6. Vegetation map (Eva et al. 2004)

The soil units of Uruguay are mapped in scale 1:1.000.000 (Dirección de Suelos y Aguas del MGAP, 1976), and are available in shapefile format.. Each unit has associated a value of water maximum capacity of retention (Molfino, 2001).

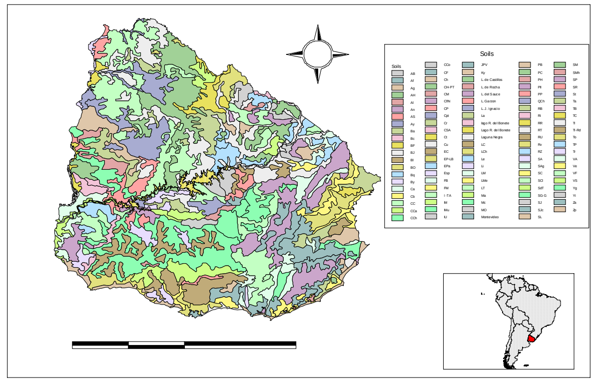


Fig. 7 Soil units of Uruguay mapped in scale 1:1.000.000.

Digital Elevation Model. Uruguay has a geoidal digital elevation model developed from level curves in scale 1:50.000. This level curves belongs to the Servicio Geografico Militar and are 10 meters spaced. This digital elevation model has been compared to the SRTM model showing satisfactory results. The model belongs to the Ministerio de Transportes y Obras Publicas (www.clearinghouse.gub.uy).

3.2 In-situ measurements

Different surface networks have been examined during the Survey performed for the “Proyecto Cuenca del Plata” with funding from the Global Environmental Fund (GEF), and are summarized in the figure below. Fig. 8a presents the surface stations that are part of the WMO network; Fig. 8b shows raingauge stations that belong to public and private organizations in Argentina, Paraguay and Uruguay.

Panel c in Fig. 8 shows additional surface stations in belonging to different organizations: In purple, stations belong to the Argentine National Institute of Agricultural Technology (INTA); in green stations of the Argentine Water Resources Secretary; in red, from the Brazilian National Water Agency and Paraguay’s Ministry of Agriculture. Lastly, light blue dots represent stations belonging to INMET- INPE - SIMEPAR in Brazil.

The Brazilian Water Resources Agency (Agencia Nacional da Agua) maintains a raingauge network with daily observations, and a databank of the historical collected data. The data is freely available through the web at www.ana.gov.br. In the region of the headwaters of the Parana River in Brazil, there can be found locations with the highest raingauge density within Brazil, along the Tiete and Grande rivers. Contrasting to this region, the Pantanal region shows very low raingauge density, with only one gauge per 3000 km^2, which is only higher than in the Amazon.

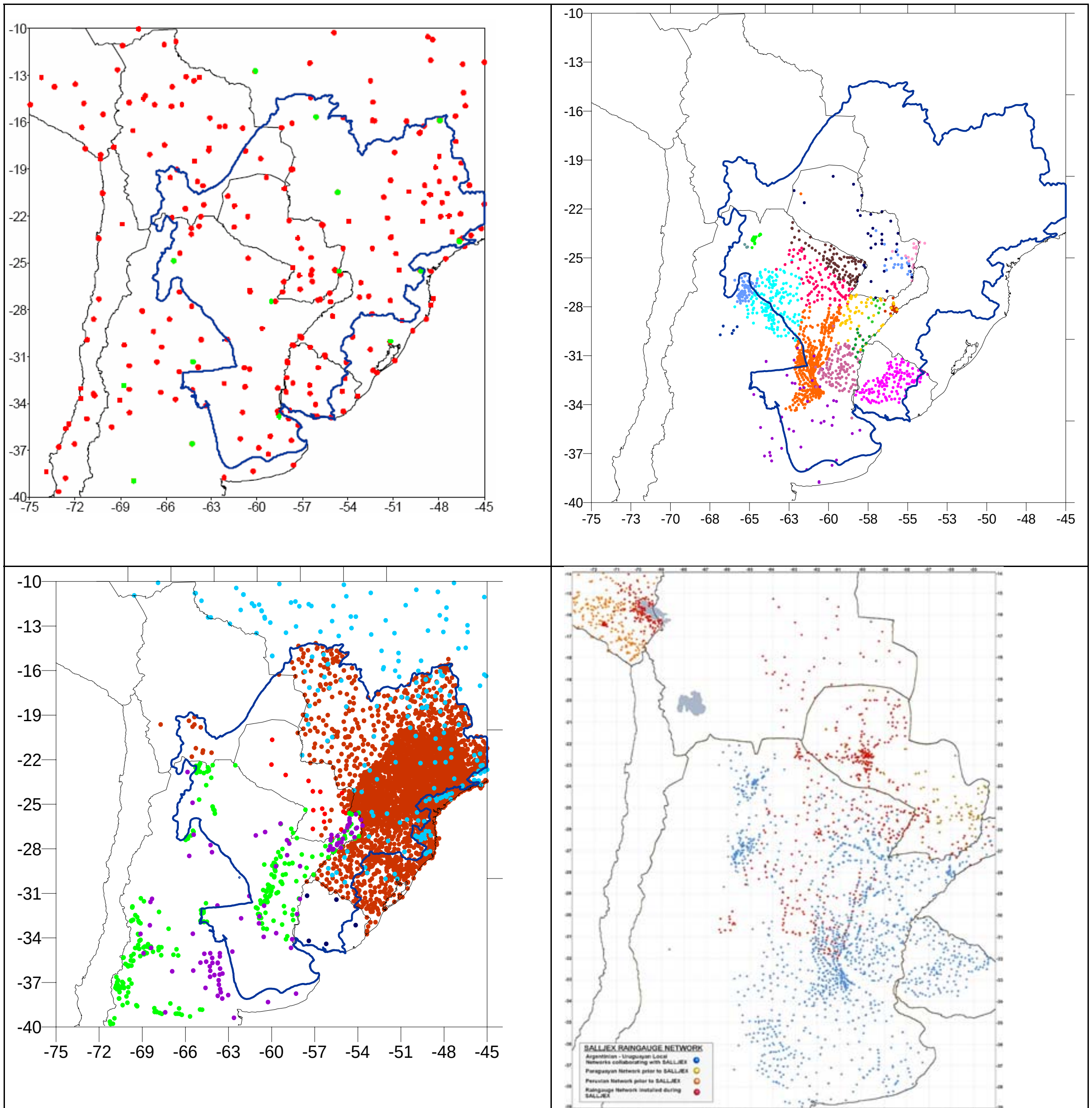


Figure 8: (a) Surface and radiosonde stations (red and green respectively) that are part of the WMO World Weather Watch Programme; (b), (c) other state, federal and privately funded networks available; (d) raingauge distribution during SALLJEX

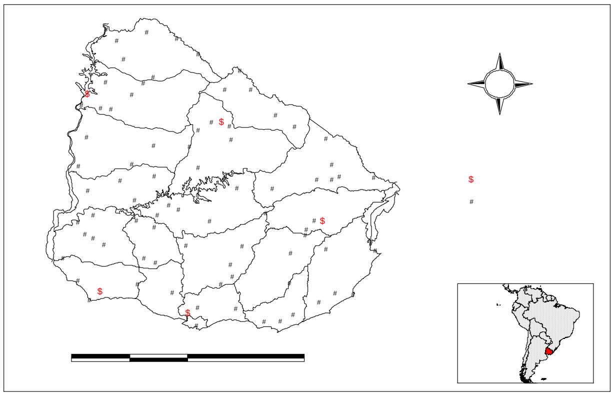


Figura 9. Estaciones meteorológicas y pluviómetros operados por INIA y DNM.

Uruguay's Dirección Nacional de Meteorología (DNM) has a raingauge and meteorological network The web site for this document will include the complete list of stations as well as the periods that they cover. However, availability of these data may be limited as most are not in digital format. See www.meteorologia.com.uy

Uruguay has 5 complete meteorological stations managed by the Instituto Nacional de Investigaciones Agropecuarias (INIA), which have daily values since 1970, all available from their web site www.inia.org.uy

3.3 Hydrologic Observations

Besides the raingauges, the Brazilian Water Resources Agency (Agencia Nacional da Agua) is also responsible for most of the streamflow observation sites in Brazil. Again in this case there is a strong contrast between the relatively well covered region of the Brazilian part of the Parana and the poorly covered region of the Paraguay. Observations are daily and the databank of historical collected data is also freely available through the web at www.hidroweb.ana.gov.br.

The Parana River and its tributaries show a high number of dams and reservoirs which affect the hydrological regime and thus change the natural relation between rainfall and discharge. Therefore most analysis of streamflow time series are done for "naturalized" streamflow series, which were developed by organizations dealing with hydroelectric energy production, such as ONS (Operador Sistema Elétrico Interligado Nacional – Operator of the National Linked Electric System) and ANEEL (Agencia Nacional de Energia Elétrica – National Electric Energy Agency), and are not as easily available as streamflow gauge time series. The "naturalized" streamflow time series begin in 1931 and end in 2001, and were calculated based on water budget of reservoirs and

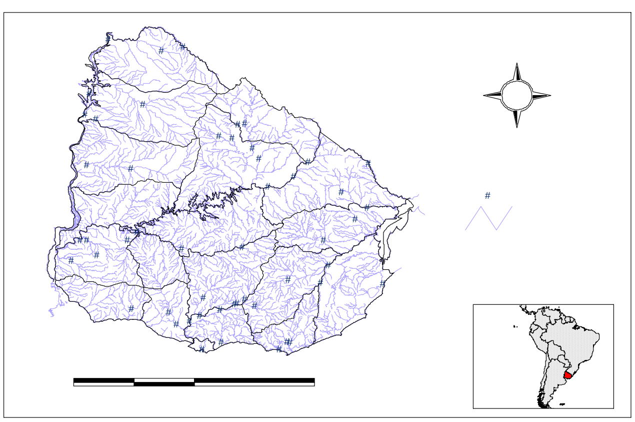


Figure 10. DNH.Hydrometric stations

stream gauge time series. Consumptive use of water and direct evaporation from reservoirs is taken into account, and added to the observed streamflow and water budgets. Due to several uncertainties in the methodology used to generate the natural streamflow these data should be used with care when looking for trends, patterns changes and cycles.

Two streamflow measuring networks are available in Uruguay, manager by the Dirección Nacional de Hidrografía (DNH) (www.dnh.gub.uy). In the Negro River Basin, Usinas Termoeléctricas del Estado (UTE) has an additional network for its three dams

Networks in Paraguay are handled by three Organizations: Administración Nacional de Navegacion y Puertos (ANNP), Centro Multiuso de Monitoreo Ambiental e Hidrologico (CMMAH) and Itaipu Bi-national.

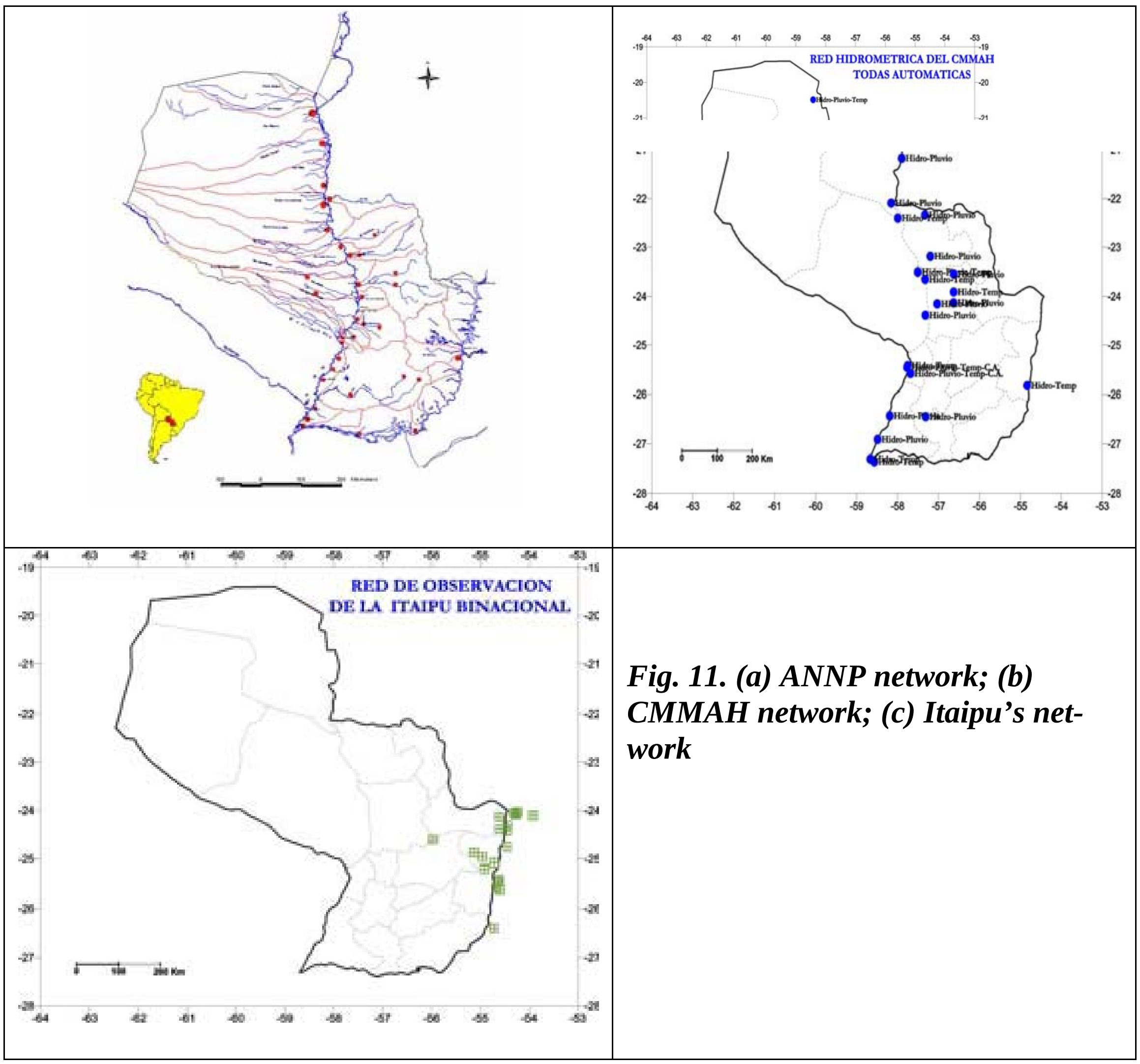


Fig. 11. (a) ANNP network; (b) CMMAH network; (c) Itaipu's network

The Paraguayan Agency ANNP has a total of 48 conventional gauging stations; 24 over the Paraguay River, 8 over the Parana River, and 17 on other tributaries of the Paraguay River. The CMMAH has 22 automated hydrometric stations at the locations shown in the map. Finally, Itaipu Bi-national has a total of six stations (4 automated) all over the Parana River or its tributaries.

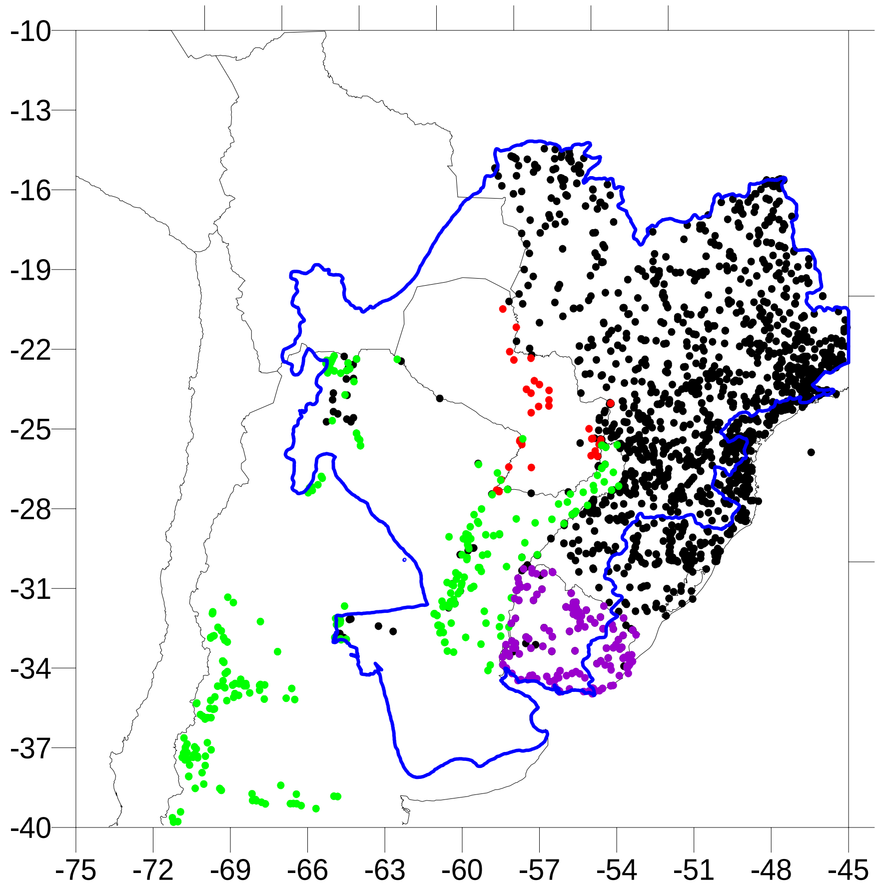


Figure 12. Summary of the hydrologic networks of Argentina, Brazil, Paraguay and Uruguay.

3.4 Remote sensing

CPTEC has a Division of Satellite Applications (http://satelite.cptec.inpe.br) that provides several products for monitoring and nowcasting. They are: (a) Cloud classification, (b) Vegetation Index, (c) Electrical discharges, (d) Ultraviolet index, (e) Fog, (f) Precipitation, (g) Biomass burning spots, (h) Solar and terrestrial radiation, (i) Mesoscale Convective Systems, (j) TOVS and ATOVS soundings, (k) Brightness temperature, (l) Sea Surface Temperature, (m) Tropospheric winds, and (n) MODIS products

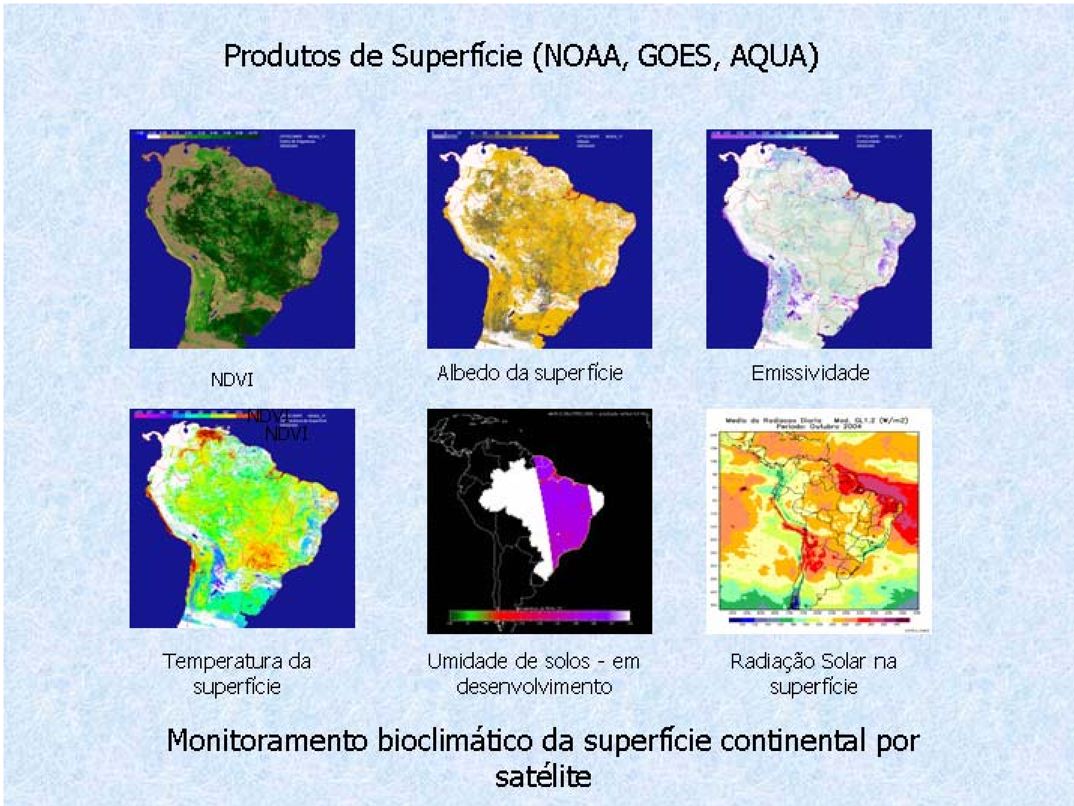


Figure 13.

Precipitation estimated by the TRMM group of sensors can be very useful to force hydrological models in regions where observational networks are to sparse. Experiments in the São Francisco River basin, which is the northeast neighbor of the Parana Basin, and in the Tapajos river basin, which is to the north of the Upper Paraguay, showed good results of simulated streamflow, when using daily rainfall data from TRMM (Collischonn et al., 2005).

3.5 Radars

Currently Brazil has 23 weather radars that are associated with federal and state agencies and universities. The “Sistema de Proteção da Amazônia” (SIPAM) – “Sistema de Vigilância da Amazônia” (SIVAM) are federal agencies that are responsible for the protection and surveillance of the Amazon region. These agencies control 23 S-Band Doppler weather radars that were manufactured by Enterprise Electronics Corp. (EEC). These radars use the MURAN/Colibri-II software of GAMIC for radar control, data processing and visualization. The SIPAM/SIVAM has also a rainfall mosaic of the Amazon region, but it is not released to the public yet. The SIVAM radars are installed over the Amazon region.

The “Departamento de Controle do Espaço Aéreo” (DECEA) is a federal agency that controls the Brazilian air-space, and operates 6 S-Band Doppler weather radars that were manufactured by a Brazilian company named TECSAT. These radars use the MURAN/Colibri-II software of GAMIC for radar control, data processing and visualization. The radars are installed in southern and southeastern part of Brazil, i.e., Gama (Brasilia), São Roque (São Paulo), Morro da Igreja (Santa Catarina), Canguçu and Santiago (Rio Grande do Sul).

The "Instituto de Pesquisas Meteorológicas" (IPMet) of the "Universidade Estadual de São Paulo" (UNESP) is a meteorological research institute that has 2 S-Band Doppler weather radar that were manufactured by EEC. These radars use the IRIS software of SIGMET Inc for radar control, data processing and visualization. The IPMet radars are installed in Bauru and Presidente Prudente in the State of São Paulo.

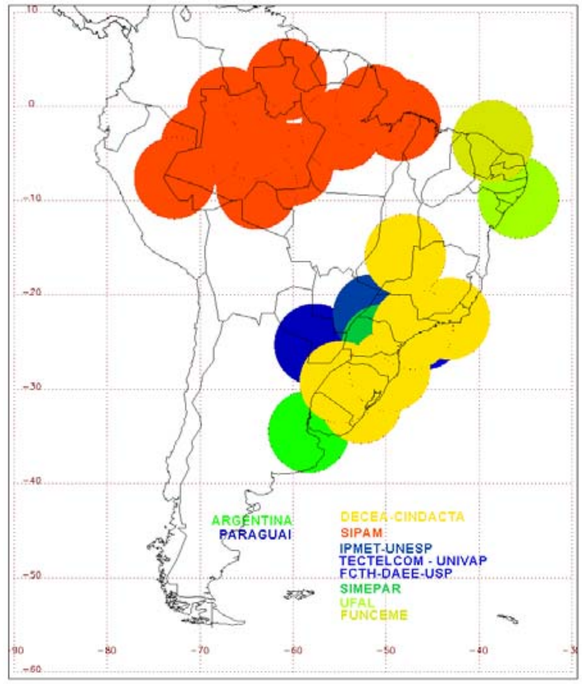


Figure 14.

The "Sistema de Meteorologia do Estado do Paraná" (SIMEPAR) is a state meteorological institute that has one S-Band Doppler weather radar that was manufactured by EEC. This radar uses the EDGE software of EEC for radar control, data processing and visualization. The SIMEPAR radar is installed in Teixera Soares in the State of Paraná.

The TECSAT and "Universidade Vale Paraibana" (UNIVAP) are private companies that operate one S-Band Doppler weather radar that were manufactured by TECSAT. This radar uses the MURAN and Colibri-II software of GAMIC for radar control, data processing and visualization. The TECSAT radar is installed in São José dos Campos in the State of São Paulo.

The "Centro Tecnológico de Hidraulica" (CTH) of the 'Universidade de São Paulo" (USP) is a state agency responsible for water resources management of São Paulo state, and it has one S-Band weather radar manufacture by McGill University. This radar uses McGill software of GAMIC for radar control, data processing and visualization. The CTH radar is installed in Salesópolis in the State of São Paulo.

The "Fundação Cearense de Meteorologia" (FUNCEME) is a state agency responsible for the water resources and meteorological management of the Ceara State, and it has one X-Band weather radar that was manufactured by EEC. This radar uses the RADSYS software of EEC for radar control, data processing and visualization. The FUNCEME radar is installed in Fortaleza in the State of Ceará.

The “Sistema de Radar Meteorológico de Alagoas” (SIRMAL) is agency associated with the “Universidade Federal de Alagoas” (UFAl). This instituted has one C-Band Doppler radar that was manufactured by EEC, and it uses a software developed by the University of Paul Sabatier – France for radar control, data processing and visualization. The SIRMAL radar is installed in Maceió in the State of Alagoas

According to a scientific collaboration established in 2005, INPE and USP began to integrate the weather radars of DECEA, IPMet, TECSAT/UNIVAP, and in the following months to come a rainfall mosaic will be posted in realtime to the general community. [A benchmark can be checked at: http://satelite.cptec.inpe.br/htmldocs/precipitacao/novo/precipitacao_radar.shtml].

All the radars except the SIPAM/SIVAM and FUNCEME store the volume scan continuously. In general, the radars have two modes, one with surveillance (240-400 km, up to 3 elevations) and volumetric scan (150-240 km, up to 15 elevations).

3.6 Soil moisture measurements and estimates

Brazil has an extensive network of soil moisture measurements, with several of them within La Plata basin. The sensors are located at depths of 10 cm, 20 cm, and 40 cm. However, work is needed in calibrating the sensors, a task that is expected to be developed within LPB.

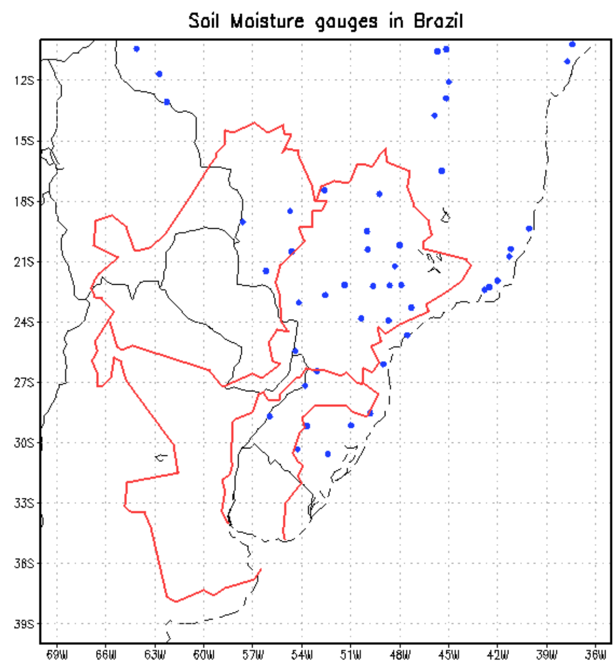


Figure 15

Soil moisture measurements in Uruguay. There have been many short term field campaigns measuring soil moisture for agriculture related studies at Instituto Nacional de Investigación Agropecuaria (INIA) and Facultad de Agronomía (FA-UdelaR) during the 80's and 90's, but they were intermittent, show variable frequencies in sampling and do not extend to the present. However, there are two other campaigns that started in 2001 and 2004, respectively, that are still active and constitute the longest continued operating moisture monitoring in the country. In all cases seasonal measurements are taken with neutron probes up to a depth of 1.2 to 1.3 m. Both sites are aimed at identifying the impact of afforestation on hydrology so they are located at pine and eucalyptus plantations as well as control catchments where land use is mainly pasture with livestock grazing. Sites are located at Bella Unión (Rivera) and at the Tacuarembó river basin (Tacuarembó), see map.

Figure 16. Operating long-term soil moisture monitoring sites in Uruguay.

Soil moisture is also measured at several locations in Argentina; they are usually managed by the Argentine National Institute of Agricultural Technology (INTA), and, as in the case of Brazil. The sensors need calibration.

3.7 Flux towers

The main purpose of the micrometeorological flux tower is to provide a characterization of the exchange of energy, water and mass between the surface and the atmosphere at the different ecosystems. Such information is crucial to weather and climatic forescast models, in the sense that the almost entirety of these properties enter the atmospheric system through the surface. Incorrect description of the energy, mass and water surface fluxes may lead to appreciable inaccuracies in the numerical model outputs.

The surface flux observations are also very important for research purposes. The exchange of CO_2 between the surface and the atmosphere at such an important and large ecosystem will help to understand the problem of Carbon budget, which is an open question facing the scientific community. Furthermore, the energy budget has never been explicitly determined in similar surface types, leading to a lack of proper knowledge of the physical processes controlling temperature and humidity in the region.

Measurements of latent and sensible heat fluxes will be very helpful in the development of a common representation of surface hydrology in hydrological models and regional atmospheric models. Results of hydrological models should be compared in terms of latent heat flux for the most widespread land use and vegetation types in the basin, as long as with streamflow, as is usually done. The aim is to develop hydrological models that are able to generate reasonable streamflow time series, but for the correct reasons.

Three towers are available in Argentina, towards the southern portion of the La Plata Basin. One of these towers (37º 45' S, 58º 18' W) has been employed previously for campaigns measuring fluxes over different types of crops. The second tower is located over grassland in Santa Fe Province, and the third one (under development) is located over a forest region. The latter two towers belong to the Terrestrial and Environmental Research, Observation and Monitoring Center (CIOMTA) [www.ciomta.com.ar]. CIOMTA provides data from its tower and a network of automated stations on its web site. LPB is considering this tower as a candidate to be a reference site for the Coordinated Enhanced Observing Period (CEOP).

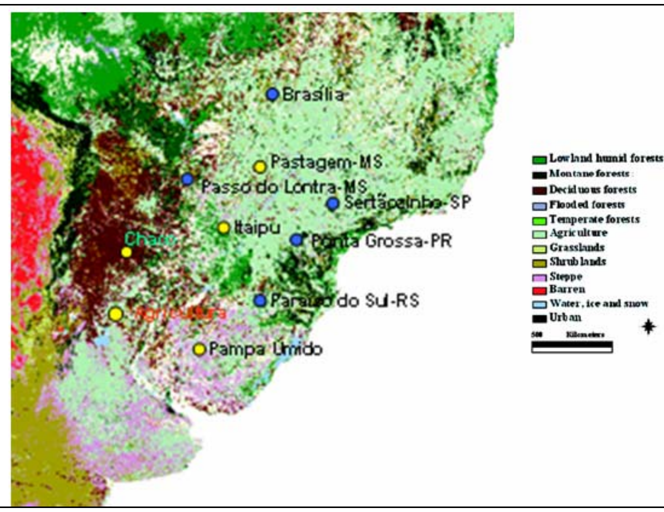


Figura 17 - Rede de medidas de fluxos à superfície. Azul: rede existente. Amarelo: estações propostas.

Brazil has several flux towers in the Brazilian sector of La Plata basin. They are: over the periodically flooded savannah of the Pantanal in the Paraguay River (managed by UFMS and CPTEC-INPE); over the cerrado *senso strictu*, in the Parana River near Brasilia (managed by Prof. Heloísa Miranda, UNB); over *manchas de cerrado*, sugar cane crops, and eucalyptus trees, the three in Sao Paulo State (Tiete River) managed by Prof. Humberto Rocha, IAG-USP; over soy crops in the Paranapanema river basin, Parana State, managed by Prof. Nelson Dias, UFPR and Simepar; and finally over rice crops in Santa Maria in Rio Grande do Sul State, managed by Prof. Osvaldo Moraes, UFSM.

Experimental sites at Sao Paulo State. Three experimental sites are currently under operation, in the state of São Paulo, Brazil, over three different ecosystems, namely the Cerrado restrito (woodland savannah), sugar-cane and eucaliptus, respectively. The measured variables at the sites are provided as 30 min averages, recorded electronically, and are as following:

i) surface-atmosphere fluxes of energy, water and $CO2$ (with the eddy covariance method);

ii) climatological variables with automatic weather station: air temperature, humidity, wind speed, precipitation, global solar and PAR radiation (incident and reflected), net radiation, soil heat flux (REBS);

iii) hidrometeorological variables: soil moisture 2 m profile (10 levels); hydrological discharge (automatic stream-gauge station with water level recorder) in catchments varying from 4 to 7 km^2; water table level at 10 – 90 m wells at a few locations over all catchments.

A brief description of the sites (see Fig. 18) is given next.

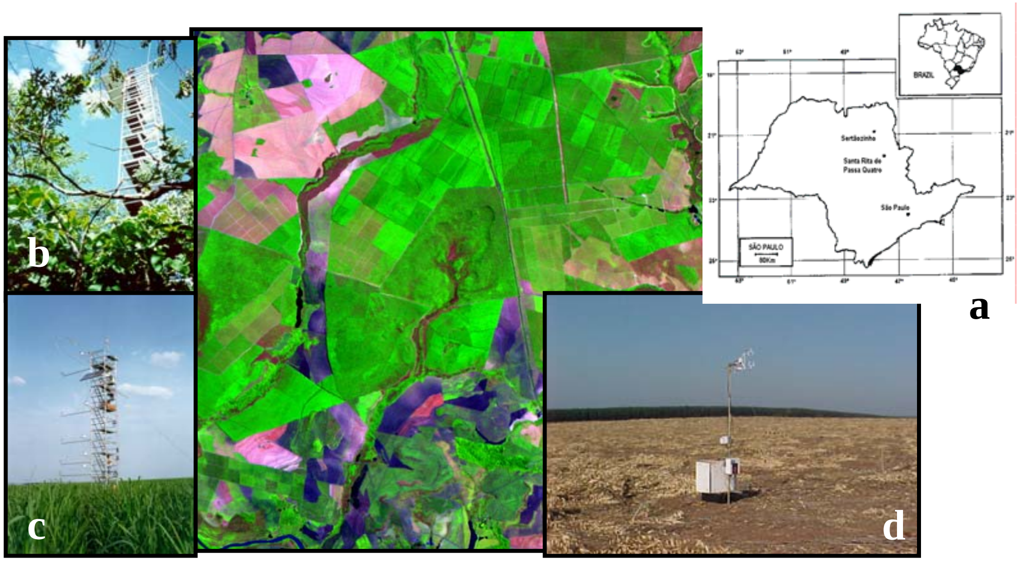


Figure 18. The three experimental sites in (a) the state of São Paulo (top right corner), Santa Rita do Passa Quatro city, over (b) Cerrado restrito, (c) sugar cane, and (d) eucalyptus (previously harvested).

(i) Cerrado restrito: called Gleba Pé de Gigante (Parque Estadual de Vassununga, Instituto Florestal/Santa Rita do Passa Quatro city, state of São Paulo), a 1060 ha reserve park, 695 m altitude. The micrometeorological tower is at (21^{o}37’ S, 47^{o}38’ W)

(ii) Eucaliptus: an eucaliptus plantation, 7-yr cycle, harvested in Jul/2004, in Cara Preta farm, Santa Rita do Passa Quatro city, with the micrometeorological tower at (21^{o}35’ S, 47^{o}36’ W) and 690 m altitude.

(iii) Sugar cane: plantation in the Usina Santa Rita farm, one-year cycle, with the micrometeorological tower at (21º38’S, 47º47’W, 552 m altitude).

a

Sites in the Parana State

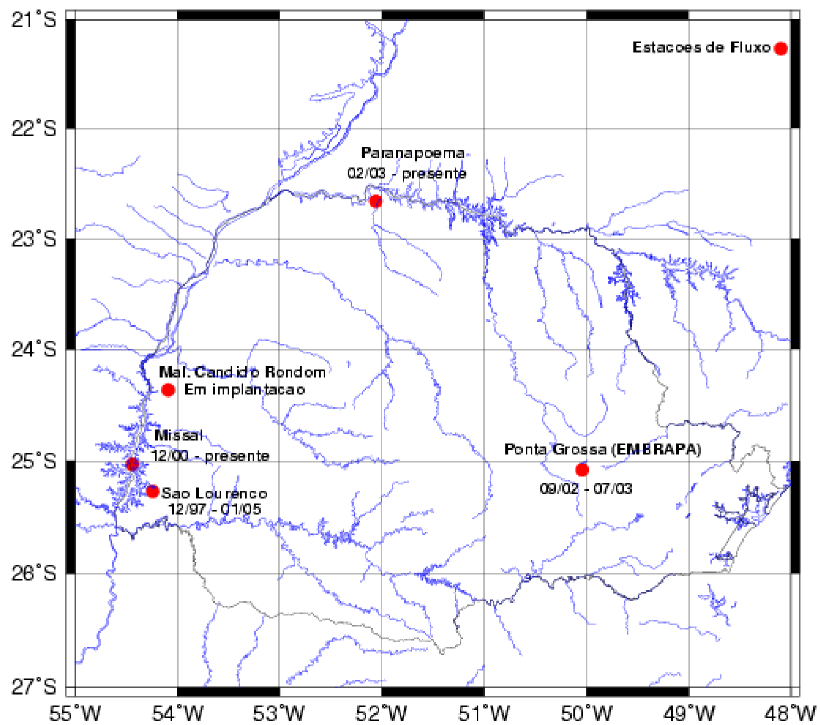


Figure 19. Flux stations in Parana State

All our ground stations work with the following configuration:

- *Sonic anemometer* - *Young 81000*, measuring u, v, w, theta_v (virtual temperature) at 10 Hz, at 10 m above ground level.
- *Campbell CS500 hygrometer and a Campbell FWTC3 thermopar* protected by a ventilated plastic tube measuring air temperature Tc, relative humidity y and the thermopar fluctuation of air temperature Te, at 10 Hz.
- In a few stations a second set of *CS500*, naturally ventilated, at 2 m, is being installed for comparison with official weather stations.
- Rainfall, solar radiation incident and reflected, and the net radiation are also measured.
- In the soil the heat flux in 2 or 3 levels (at the depth of 2, 20 and 40 cm) and 2 or 3 soil temperatures Ts and volumetric soil moisture Ws is measured using TDR´s (Campbell CS615)
- At the Itaipu and Furnas lakes there are no soil sensors but instead a buoy measures the water surface temperature.

The set of resulting measurements produces the turbulent fluxes of momentum, sensible heat H, virtual sensible heat Hv and latent heat LE at every 30 minutes or 1 hour intervals. This set also produces the average horizontal velocity, average temperature and relative humidity at each 30 minutes or 1 hour intervals, at 10 m.

4. Modeling capabilities

4.1 Atmospheric Models

Weather forecasts are normally divided according to the following time-scales: (a) up to 12 hours – very short term, or *nowcasting*; (b) short-term, from 12 to 48 hours; (c) medium term, up to 10/15 days, and (d) long-term or intra-seasonal, from 10 to 60 days. Climate forecasts are generally given at the seasonal time-scale (i.e., up to 4 or 6 months). Numerical weather forecasting models are classified as global, regional and local, depending on the domain and resolution.

A fundamental problem in atmospheric modeling is the need for representing processes with spatial scales smaller than those explicitly resolved by the discretized equations. The representation of the unresolved scales in atmospheric modeling is known as parameterization. A typical example of an atmospheric phenomenon that is generally treated in term of a parameterization is moist convection. Convective clouds play an important role in the heat, moisture and momentum balance of the atmosphere (besides being important mechanisms for vertical transfer of aerosols and gases that, in turn, affect other atmospheric processes, mostly related to radiative transfer).

In particular, in the South American case, it is of particular relevance the numerical restrictions posed by the presence of very steep orography in the Andes region and along the eastern boundaries of the La Plata Basin. The La Plata Basin precipitation is very much dominated by relatively small-scale convective complexes (Velasco and Fritsch 1987), with spatial scales of the order of a few hundred km, which require sophisticated parameterizations.

a. Weather forecasts

The forecasting models need initial conditions that are based on the observational system that is basically maintained by the national weather services and complemented with remote sensing products. The weather services generally provide meteorological conditions at regularly distributed time intervals but the spatial coverage is very irregular, in particular over South America where there are significant data void regions, such as in the northwestern and northern portions of the La Plata Basin.

Remote sensing products are available from polar orbital satellites (or equatorial) and geostationary satellites. Polar orbital satellites produce information of data swaths twice a day over the same area while the geostationary satellites have the capability for generating high frequency information but generally at 30 min intervals. Most of the geostationary satellite information in the La Plata Basin comes from US satellites (the GOES series). However, some information can be obtained from the European satellites although their angle of vision is rather poor for regional applications (they are stationed over Africa). The initial condition of the forecasting models is based on the so-called four dimensional data assimilation system (4DDA), which is currently defined as the process for defining the state of the atmosphere in the structured grid of the numerical model based on data collected in a non-uniform grid in space and time. The 4DDA system allows the evaluation of state variables not directly observed, to propagate information from data rich to data poor areas and it constitutes an important component of the quality control system (Rood et al. 1994).

In general, global models produce weather forecasts with horizontal resolution of the order of several tens to a few hundreds km over the global domain. The regional models have resolution of the order of a few tens of km over limited areas, in general of continental scale. Local models have horizontal resolution of a few km to a few tens of km, generally over very limited areas such as a water basin. Regional and local model need boundary conditions that have to be provided throughout the time integration. In general, boundary conditions for regional models are provided by global models, while local models generally rely of the regional models' products. Regional and local models are expected to give a better representation of the smaller scale structure of the atmosphere. Their use is based on the assumption that the state of the atmosphere is strongly influenced by the ability to represent smaller scales of the atmospheric motion and by the characteristics of the lower boundary condition, which is provided by the physiographical characteristics of the surface (topography, vegetation types, coastal shape, land/water distribution).

Global forecasting centers regularly distribute numerical forecasts in the medium time scale, which are available at the National Weather Services via the Global Telecommunication System (GTS); some products are also available through INTERNET. The weather forecasting products from global centers generally used in the La Plata basin countries are: the National Centers for Environmental Prediction - NCEP (USA), available at the site www.ncep.noaa.gov, (b) the European Center for Medium Range Weather Forecasts - ECMWF (an European consortium focused on the medium range to seasonal forecasts) available at www.ecmwf.int and (c) the United Kingdom Meteorological Office (UKMET), available at www.meto.gov.uk.

The NCEP products are derived from a global model with horizontal resolution on the order of 80km, similar to the resolution of the UKMET. The ECMWF digital products are restricted to the European community and, except for a low-resolution product available through GTS (2.5 degree resolution in latitude and longitude), the available products are in graphical format. The NCEP products are available in digital form either through GTS and/or INTERNET at resolutions of 1.0 degree and 2.5 degree over the globe. Typically, two forecasts are available every day, based on initial times at 00 and 12 GMT, and the information is provided every 6 hours (12 hours after a certain number of days). The NCEP forecast are available up to 15 days. Ensemble forecasting (i.e., forecast based on slightly different initial conditions, which are prescribed in order to estimate the uncertainty of the forecasts) are also available from NCEP in real time and digital formats up to 15 days. The UKMET forecasts (7 days) are available in digital form at the lower resolution through GTS and in graphical form in their homepage.

It is important to point out that the ECMWF is considered as the center that produces the highest quality forecasts and atmospheric analysis from the global view perspective. In the last couple of years the ECMWF forecast skill in the Southern Hemisphere has equaled the Northern Hemisphere scores in view of significant improvement in their data assimilation system, which makes efficient use of the remote sensing products that are now available mostly in the USA and for public access in almost real time (however, data files size restricts its transfer through internet).

ECMWF and NCEP experience clearly indicates that the introduction of new, more sophisticated, techniques for data assimilation are responsible for the improvement of the quality of the operational weather forecasts. Their experience suggests that nearly 50% of the improvement is associated to the evolution of the data assimilation system and the other 50% due to model improvements (Reynolds et al. 1994).

b. Ensemble weather forecasting

Prediction of weather patterns is difficult if not impossible depending on how far into the future the prediction is attempted. The difficulties are due to the atmosphere's chaotic nature. A system is chaotic if small differences in an initial condition ultimately compound and grow to produce large differences at a later time (Lorenz 1963). Lorenz calculated that even with a perfect atmospheric model, the average limit of predictability on planetary scales is about two weeks.

One way to maximize the performance of numerical forecasts is to use the technique of forecasting by ensembles. This consists of specifying a set of possible initial states, all of which are slightly different, and then integrating the numerical model starting from each initial state separately, thus giving a set of forecasts. Ensemble forecasting is based on theoretical studies showing that the mean of the ensemble has better accuracy than individual elements of the ensemble, if the initial conditions are representative of the initial probability distribution of the basic field (Leith 1974).

Global forecasting centers such as NCEP and ECMWF run ensemble global forecasts up to about 15 days in advance. ECMWF has a special product up to 30 days but not available for non-European countries. The NCEP results are available in graphical format through their homepage. Digital products are restricted to the Northern Hemisphere. Ensemble forecasting products are quite useful not only because the mean forecast is better, in a statistical sense, than any of the members, but in view of the fact that the ensemble statistics provides a measure of the uncertainty of the forecast, an information that the users can introduce in the their decision tree.

The only center to process ensemble forecasts based on perturbations of the initial condition in South America is CPTEC. In this case, 15 forecasts up to 12 days (15 days very shortly) are generated using small perturbations of initial conditions. The products are provided to the users in the CPTEC homepage (www.cptec.inpe.br) in the form of the so-called “spaghetti diagram,” probability of occurrence of precipitation in different thresholds and meteograms (time series of selected atmospheric variables) during the forecasting period.

The large number of regional forecasts currently available, in association with the products available from several global forecasting centers, suggests the use of multi-model regional ensemble forecasting in an integrated consortium among all regional institutions.

c. Seasonal climate forecasts

Climate forecasts are made using statistical methods or by means of complex dynamic models run on high-performance computers or by combination of dynamical model and statistical downscaling. The statistical approach, used at many centers, is very useful in many situations, but does not work well in atypical conditions.

The atmospheric models used for climate are essentially the same as the ones used for weather forecasting. However, they generally have lower resolution due to the computational cost of considerably longer runs. It is well recognized that seasonal forecasts are highly dependent on sea surface temperature (SST) anomalies and that these are frequently rather persistent on the time scale of a few months. Thus, there are two main types of dynamical climate prediction models: (a) coupled atmosphere/ocean models and (b) atmospheric models forced by prescribed SST anomalies. The coupled atmosphere/ocean models have been recently introduced in the more advanced operational centers but most centers still run the uncoupled version, forced by persistence of the SST anomalies or predicted SST anomalies provided by either simplified ocean models or statistical models.

Some foreign climate forecast centers provide products for South America, covering the La Plata Basin such as NCEP, ECMWF. The International Research Institute for Climate Prediction (IRI, http://iri.columbia.edu/pred) provides numerical predictions on the seasonal time-scale based on several model from USA and European Institutions. Since 1995, CPTEC/INPE is the only meteorological center in Latin America that issues operational, numerical climate forecasts in digital form, with lead-time of 5 months (http://www.cptec.inpe.br/products/indexp.html). However, the CPTEC forecasts, like those of other world centers, have low spatial resolution and do not give regional details (resolution about 180km).

The SST anomalies exert an important control on the precipitation in a large portion of the La Plata Basin through the El Niño/La Niña phenomena and South Atlantic anomalies (Grimm et al., 1998). In the oceans, CPTEC uses two methods for incorporating SST data into the atmospheric model during the period of integration: (a) as persistent anomalies in SST in all the oceans; and (b) as the SST predicted by the National Centers for Environmental Prediction - NCEP in the Equatorial Pacific and SST as predicted by a statistical model (SIMOC) for the Tropical Atlantic [Pezzi et al., 2001]. In areas other than the Atlantic and Pacific tropical areas, and in the Indian and other oceans, the SST is given by assuming that the anomaly observed at the beginning of the integration period persists throughout. The two procedures are important for testing the influence of SST anomalies, which have a significant impact on climate anomalies observed in other parts of the globe.

CPTEC model also produces seasonal ensemble forecasts. Between 20 and 30 forecasts are calculated, every month, for the following six months, beginning from different initial conditions (days from *i*=1 to *i*=20 or 30). These can be used to estimate the degree of predictability (i.e., reliability) of numerical predictions. Dynamical forecasts are available every month at the homepage www.cptec.inpe.br as the average for 3 months up to 5 months in advance. Monthly data are only available as time series for selected areas.

Statistical forecasts for portions of the La Plata Basin are also provided by CPTEC based on the correlation between precipitation and SST anomalies in the Pacific and Atlantic Oceans. The forecast is issued on 3-month averages with up to 6-month lead time (e.g., in June the following forecasts are available: Jul/Aug/Sep/, Aug/Sep/Oct/ and Sep/Oct/Nov, Oct/Nov/Dec).

The forecasts provided by CPTEC are provided in the form of probabilities that the precipitation or temperature will be in the lowest one-third of the climatological distribution, the middle one-third, or the highest one-third. The forecasts are a distillation of information from a number of inputs, the most important being the predictions of several dynamical atmospheric models that respond to the expected patterns in sea surface temperature (SST). The forecasts of the individual prediction models themselves are also shown each month.

Both statistical and dynamical tools are available to downscale the low-resolution climate forecasts from global models. Statistical downscaling require the determination of statistical relations between the historical record of the local variable to be predicted and some larger scale atmospheric feature that can be appropriately simulated by a global model. Dynamical downscaling consists on the nesting of a higher resolution numerical model within the global climate model to simulate the regional features. It is a scientifically and computationally challenging tasks to be performed operationally and CPTEC is just beginning to operationally produce seasonal dynamical downscaling using the ETA model with 40 km resolution over South America. Statistical downscaling of the global models is not yet operationally produced for South America.

Recent applications of atmospheric ensemble forecasting to hydrological models in the La Plata Basin have been attempted with substantial success, as described in session 3.1.2.

d. Modeling Climate Change Scenarios

The numerical models required for modeling climate change scenarios caused by (a) the effect of global warming associated with the impact of increasing concentration of greenhouse gases, (b) the effect of land use change, (c) the effect of changes in the aerosol and other trace gases in the atmosphere, (d) the impact on the regional hydrology, are, in general, of two categories:

- highly simplified, conceptual models of the climate system,

- dynamic atmospheric models, coupled with the ocean and biosphere.

The numerical models are either of global domain or regional. In the last case, as in numerical weather forecasting, the models need boundary conditions, which are generally provided by the global models.

Recent results on the effect of land use change, particularly associated with deforestion, have suggested different trajectories of the precipitation reduction as a function of deforestations (Avissar et al. 2002). Avissar et al. (2002) suggest three different patterns, among many possible speculated options. One option suggests an increase in precipitation as a result of partial deforestation maybe due to the mesoscale circulations triggered by the deforestation as in Silva Dias et al. (2002b).

Strong differences in the seasonality of runoff and streamflow are also expected to be found in the La Plata Basin region. In the La Plata mouth, the seasonal signature of runoff is extremely damped, and is only modestly higher in the months following the precipitation peak. However, the upper portion of the basin goes through a very marked seasonal cycle. Thus, modeling of the climate/hydrological characteristics of the region under changing global forcing associated with the increase of the greenhouse gases or changes in land use, require rather sophisticated modeling capabilities. The climate changes, especially in precipitation, may be attributed in considerable part to the characteristics of the land surface forcing. Some of the differences, especially in the seasonality and temporal variability of runoff, are due to specific topographic, geological, and vegetation catchment-characteristics.

Considering the high computation cost of global simulations, downscaling of global model scenarios constitute a modern toll for studying the effects of global change. Several studies were identified in Brazil and Argentina on these issues, mostly at CIMA/UBA and CPTEC/INPE. Process studies, primarily related to land use change and the role of aerosols produced by biomass burning have also been identified in the region, primarily in Brazil at the University of São Paulo (Freitas et al. 2004). CPTEC current computation power is partially compromised with modeling studies on the regional effects of global change.

4.2 Distributed Hydrological Models

Recent developments in a number of fields make it now possible to use models which, although more complex than ARMA models, are more realistic physically. In particular, the Distributed Hydrological Models outlined below are available for use. Computational developments, both in hardware and software, now enable complex rainfall-runoff models to be calibrated and used to calculate confidence intervals of future forecasts.

At present, the range of modeling tools available for flow forecasting, based on knowledge of the physical processes relating runoff to rainfall, is greatly extended:

- Distributed hydrological models that are based on the physical principle of conservation of matter, maintaining the balance between rainfall, runoff, evaporation and infiltration;
- These distributed hydrological models can include spatial information about land use obtained by remote sensing (by satellite or from radar and other instruments aboard aircraft), as well as information on variability in terrain and topography within a drainage basin;
- These distributed hydrological models can be used to model large drainage basins, and can now be calibrated relatively rapidly (taking several hours, instead of the milliseconds needed to calibrate an ARMA model; but this difference is not important when forecasts are made for the coming weeks and months).

In a large scale distributed hydrological model, a drainage basin is typically subdivided into elements of area, with vegetation and land use within each element of area categorized into one or more classes, the number of vegetation and land use types being at the choice of the user (Collischonn, 2001; Collischonn and Tucci, 2001). To reduce de number of computations, the Grouped Response Unit (GRU) (Kouwen et al., 1993; Pietroniro and Soulis, 2003) approach is normally adopted for large basins. The GRU approach consists of grouping all areas with a similar combination of soil and land cover, such that a grid square will contain a limited number of distinct GRUs. Surface water budget is computed for each GRU, and runoff generated from the different GRUs in the cell are then summed together and routed to the stream and river systems. This kind of approach has been used by several large scale hydrological models, such as VIC, applied in several large north American basins (Wood et al., 1992; Liang et al., 1994; Nijssem et al., 1997), WATFLOOD, applied in the Mackenzie GEWEX Study (Soulis et al., 2004) and MGB-IPH (Collischonn; 2001; Collischonn and Tucci, 2005), described shortly below.

Parameter values for hydrological models can be hardly known a priori, as shown recently by Lohmann et al. (2004). The usual approach in the case of distributed models of large basins is to relate parameter values to readily obtainable information, such as land use and vegetation classes, or soil types. However, unlike regional atmospheric models, hydrological models are seldom used without parameter calibration. Calibration of such models can use a criterion of fit in the form of a multi-objective function, minimized by manual iterations or using automatic optimization methods based on evolution algorithms (Sorooshian et al., 1993; Collischonn and Tucci 2003; Gupta et al., 1998; Boyle et al., 2000; Vrugt et al., 2003). Multi-objective methods will be even more important as data from flux measurement towers become available, leading to a problem of which data should be given more confidence: latent heat fluxes for different land use and vegetation, measured by flux towers at spatially restricted spots, or streamflow, as an integrator of the hydrological processes occurring over the whole basin.

The ***MGB-IPH model***, developed by the Instituto de Pesquisas Hidráulicas (IPH) of the Federal University of Rio Grande do Sul in Brazil (Collischonn, 2001), has been used successfully in various sub-basins of the La Plata. The MGB-IPH model uses information from satellite images, digital elevation models and digitized maps of land use, vegetation cover, relief and soils. The model uses a daily or hourly time step, and is similar to the LARSIM [Bremicker, 1998] and VIC-2L [Wood et al., 1992; Liang et al., 1994; Nijssen et al., 1997] models. Soil water balance is computed independently for each GRU of each cell, considering only one soil layer. The model has components representing canopy interception, evapotranspiration, infiltration, surface runoff, subsurface flow, baseflow and soil water storage. Evapotranspiration from the soil, vegetation and the canopy to the atmosphere is estimated through the Penman–Monteith equation as described by Wigmosta et al. (1994).

River networks are derived from Digital Elevation Models (Reed, 2003; Paz et al., 2005) and streamflow is propagated through the river network using the Muskingum–Cunge method with hourly time steps, according to the stream reach length and slope. Within each cell the flow is propagated using three linear reservoirs (baseflow, subsurface flow and surface flow).

The model is calibrated using rainfall and meteorological data from gauging stations within the basin. Values are interpolated spatially and at each time step, to give an estimate at the center of each grid cell. Some parameters, such as Leaf Area Index and canopy resistance, are not used in calibration, but are given seasonally-varying values taken from the literature.

Several applications of the MGB-IPH model are ongoing now, or were recently ended, as can be seen in the picture below, which shows the basins where the model was applied in South America.

Use of MGB-IPH model was successfully combined with forecasts of seasonal rainfall forecasts from a global circulation model (Marengo et al., 2003), in the Rio Uruguay basin up to Iraí, in Brazil (drainage area of nearly 60.000 km^2). The forecasts extended for three months ahead, and performed better than forecasts given by statistical models of various types (Tucci et al., 2003).

The MGB-IPH model is also being used in an ongoing project, sponsored by ONS (Operador do Sistema Elétrico Interligado Nacional – Operator of the National Linked Electric System), in which reservoir inflow forecasts for leading times up to 12 days are being tested for two sub-basins of the Parana, based on rainfall forecasts from the CPTEC regional model ETA, described in 5.1. The two sub-basins are: 1) part of the Parana basin between Porto Primavera and Itaipu dams (150000 km^2), and 2) the Paranaíba basin between Itumbiara and São Simão dams (75000 km^2). Results of this tests are very encouraging, particularly for the Paranaíba river, located more to the north of the basin.

The upper Paraguay River basin, from its headwaters in Brazil and Bolivia to the confluence with the Apa River, between Brazil and Paraguay, was also simulated using the MGB-IPH model. This region poses a real challenge to hydrological simulation, due to the immense area that is flooded during the summer and due to diverging drainage patterns, which give rise to unknown paths followed by the water that drains from the circulating highlands. In addition large parts of the basin to the west, in Bolivia and Paraguay, which are in the Chaco region, are endhorreic (not connected to any river), draining to brackish ponds that are formed only during the rainy season (Tucci et al., 2005).

A preliminary analysis of the combined effect of precipitation variability and land use change was performed using the MGB-IPH model for the Taquari basin (27000 km^2), which is a tributary of the Paraguay river (Collischonn, 2001). This basin underwent major vegetation change during the 70's and 80's, at the same that the whole region recovered itself from a decade of lower than-normal-precipitation. At mid 90's pasture was the most important vegetation in the basin, covering half of it, while another 10% of the original cerrado vegetation was converted to crop fields, mainly soya and cotton. According to the preliminary results presented by Collischonn (2001) streamflow changed from 200 mm $year^{-1}$ during years 1969 to 1970 to 500 $mm.year^{-1}$ during years 1979-1984, and precipitation changes were responsible for 70% of this increase, while land use accounted for the rest. These results can only be considered as preliminary because the differences in evapotranspiration between the original cerrado vegetation and the now widespread pasture were never validated by latent heat flux measurements.

Figure 20: Basins where the MGB-IPH model is being applied (adapted from Allasia et al., 2005).

Application of this hydrological model is now starting in the Rio Grande watershed, which is the most important tributary of the Paraná in Brazil (the Paraná is formed by the confluence of the Rio Paranaíba and the Rio Grande. This basin is where the most important regulation reservoirs are located, and where good streamflow forecasts based on rainfall forecasts in the range of a few days to 12 months would be most useful. This research is sponsored by Brazilian institutions FINEP, CNPq and CTHIDRO, and is a cooperative work between IPH/UFRGS, CPTEC/INPE and IAG/USP (Silveira, 2005).

Results obtained for the Sao Francisco basin (near but not in LPB) show that streamflow results using TRMM fields are comparable to results using raingauge data. Similar tests could be performed readily for the La Plata basin, or for sub-basins inside the La Plata region, although the TRMM estimates are known to be better for convective rainfall, which is prevalent in the northern parts of the basin, than for frontal rainfall, which is common to the south.

Use of Collischonn's model was successfully combined with forecasts of daily rainfall calculated from a global circulation model, in the Rio Uruguay basin. The forecasts extended for three months ahead, and performed better than forecasts given by statistical models of various types. The same model (but without rainfall forecasts from an atmospheric model) was used to model the sub-basin of the Rio Taquarí in the Pantanal, and the Rio Taquarí-Anta in the State of Rio Grande do Sul.

Distributed models are driven by the occurrence and magnitude of rain falling throughout a period of time, and varying spatially. Clearly, in the case of basins with long response times, use of observed rainfall is likely to result in flow forecasts which are more accurate than forecasts from statistical models that do not use this information, once the distributed models are appropriately calibrated. However, in basins with short response times (of the order of days, for example) it becomes essential to use estimates of the evolution of rainfall through time, based on meteorological forecasts.

Distributed hydrological models require detailed information on the physical characteristics of the land surface, which are coupled to a component describing interactions between soil, plant and atmosphere (SVAT - ***S****oil* ***V****egetation* ***A****tmosphere* ***T****ransfer models*). As shown below, meteorological models describe the exchange of energy between atmosphere and surface by means of SVAT models. However, the SVAT components of hydrological and atmospheric models differ in the way they describe physical processes.

The initialization of distributed hydrological models is also more complex than in the case of stochastic models (for which the initial condition is just the flow observed in the immediate past). They also require boundary conditions to be specified which are often given by remote sensing (type of vegetation and its condition, as specified for example by its leaf area index –LAI-) or by *in situ* analyses of soil physical characteristics at different depths.

SVATs used in hydrological models, even in the more recent distributed hydrological models, are quite simpler than SVATs used in regional atmospheric models. For example, the number of vertical layers in which the soil is divided is usually much smaller in hydrological models SVATS than in atmospheric models SVATs. These simplifications lead to a more parsimonious representation of the soil water processes, in which the physical meaning of parameter values is somewhat reduced, but in which the calibration process turns out to be easier. During the calibration process of hydrological models SVATs large attention is given to results of runoff, which are compared at points where observed streamflow series exist.

SVATs used in atmospheric models are usually not calibrated. A priori known parameter values are used, or local measurements of latent and sensible heat fluxes, and soil temperature and moisture are taken to set the parameter values.

As a result of these different approaches, SVATs of hydrological models perform better in reproducing runoff, while SVATs of atmospheric models obtain better results for local fluxes of water vapor and heat. Despite its lack of physical meaning, parameter values of hydrological SVATs calibrated using streamflow data from gauging stations reflect regional features.

One could say that hydrological models have good results when integrated over large areas for the wrong reasons, i.e. a sum of locally doubtful results is able to generate regionally reasonable results, while atmospheric models SVATs are a collection of good reasons that result in a rather poor performance when integrated over larger areas. Therefore the coupling of hydrological and atmospheric modeling needs a move to more similarity in both kinds of models.

HIDRO URFING Model (IMFIA). The HIDRO URFING model (Silveira (1998), Silveira (1998) & Genta (1992)), is a sub basins aggregated model developed for the Río Negro. The hydrological module is a simplification of the Sacramento Model, and the propagation in the channels is very similar to the Muskingum method. The model is manual calibrated. Actually is not in use, and after his develop never was used to any objective like hydroelectric or water resources management by any institutions involucrate (UTE and DNH).

Monthly water balance models (IMFIA) were applied by DNH in 16 gauged basins. The models were calibrated by direct search methods. The parameters of the models are regionalized using the capacity of water retention of the soils. Actually the same models are calibrated by genetic algorithms with multi objective functions. The models are:

- Temez (Temez, 1977) (IMFIA-DNH, 2002), proposed for estimate the monthly runoff in no gauged basins with small dams for rice irrigation.
- abcd (Fernandez, 2000) (IMFIA-DNH-PHI-UNESCO, 2002), used to evaluate the components of the hydrological cycle in Uruguayan's basins.

The **Variable Infiltration Capacity (VIC) model** [Liang et al., 1994, 1996] is a grid-based land surface scheme which parameterizes the dominant hydrometeorological processes taking place at the land surface-atmosphere interface. The model was designed both for inclusion in GCMs as a land-atmosphere transfer scheme, and for use as a standalone macroscale hydrologic model. The model solves both surface energy flux and water balances over a grid mesh. The model is characterized by a mosaic representation of land surface cover and a subgrid parameterization for infiltration, which accounts for subgrid scale heterogeneities in land surface hydrologic processes. The soil column is comprised of three soil layers, which allows the representation of the rapid dynamics of soil moisture movement during storm events and the slower deep inter-storm response in the bottom layer. The VIC model uses the variable infiltration curve [Zhao et al., 1980] to account for the spatial heterogeneity of runoff generation. It assumes that surface runoff from the upper two soil layers is generated by those areas for which precipitation, when added to soil moisture storage at the end of the previous time step, exceeds the storage capacity of the soil.The formulation of subsurface runoff follows the Arno model conceptualization [Todini, 1996].

The VIC model has been implemented over the entire La Plata basin at a resolution of 0.125 degree for purposes of simulating the land surface water balance of the major La Plata tributaries. The modeled water balance has been evaluated with streamflow records from the three major subbasins of La Plata: the Parana, Paraguay, and Uruguay Rivers.

The VIC forcing data sets, which consist of daily time-series of precipitation, maximum temperature, minimum temperature, and wind speed from 1979 through 1999, were developed at 0.125 ° (total 18641 grid cells). Daily precipitation and temperature were gridded from NCAR and GDCN (Global Daily Climatology Network) station data, and wind speed was downscaled from the NCEP/NCAR reanalysis. The Uruguay and Parana rivers have good station coverage for precipitation, while coverage in the Paraguay River and the lower Parana basins is sparse. Temperature stations are sparse for the entire basin, although our concern with temperature station density is less than for precipitation because of its longer spatial correlation length.

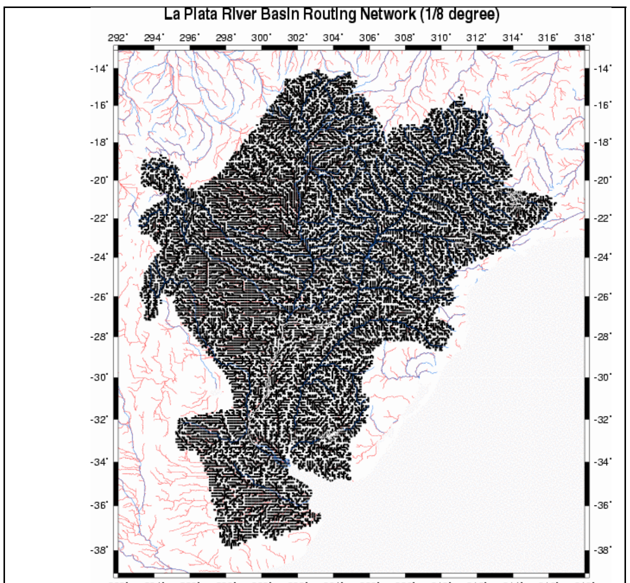


Figure 21. Digital River Networks for the La Plata Drainage Basins at the 0.125 ° Resolution

A 0.125° ×0.125° river network was developed over the entire La Plata basin (Figure 21) based on the USGS 30 arc-second digital elevation model of the world (GTOP30) (available from http://edcdaac.usgs.gov/gtopo30.asp). This network is the basis for a routing scheme which takes daily VIC surface and subsurface runoff as input to obtain model simulated streamflows at the outlets of the major river basins.

Figure 22 shows mean monthly streamflow for the three major subbasins in the La Plata. The VIC model does a very good job in reproducing the observed streamflow over the Uruguay River mainly because of the good coverage of precipitation stations and less human activities in the region. The simulated seasonal variations also show consistence with the observations at Jupia (representing upstream of the Parana River) and the Iguazu River. There are several hydroelectric plants over the Parana River, including the world's largest to date, Itaipu reservoir (the green triangle in Figure 22). The reservoir regulations lead to smaller ranges in annual discharge cycles, with a reduction in the austral summer peaks and an increase in the winter flows. The simulated streamflow at Posadas (downstream of the Itaipu reservoir) shows a higher summer peak and lower winter flow than the observations main due to the lack of reservoir representation in the VIC model. About 100,000 km^2 of upstream of the Paraguay basin are covered by a vast swamp called the Pantanal, the largest wetland in the world. Streamflow at Puerto Bermejo shows a maximum during the austral winter although the precipitation peaks during the summer. The

VIC model doesn't capture this delay between the streamflow at Puerto Bermejo and the austral summer rainfall in the upper Paraguay basin. There is currently a lake and wetlands model in the VIC. We are now working on improving the lake mode in the VIC to represent the water processes in the Pantanal.

The preliminary evaluations indicate that the VIC model performs very well over the Uruguay and Parana River. However the VIC model can not capture the timing of the observed streamflow at the Paraguay River because of the existence of Pantanal. Further work will focus on:

1. Collecting more precipitation information over the Paraguay and the lower basin of the Parana River, and employing some other data sets for diagnostic analysis (e.g, ERA-40 precipitation).
2. Using methods like those reported by Haddeland et al (2005) to construct simple models of the effects of reservoirs on river discharge.
3. Improving and updating the lake/wetlands model in the VIC to represent the water processes in the Pantanal.

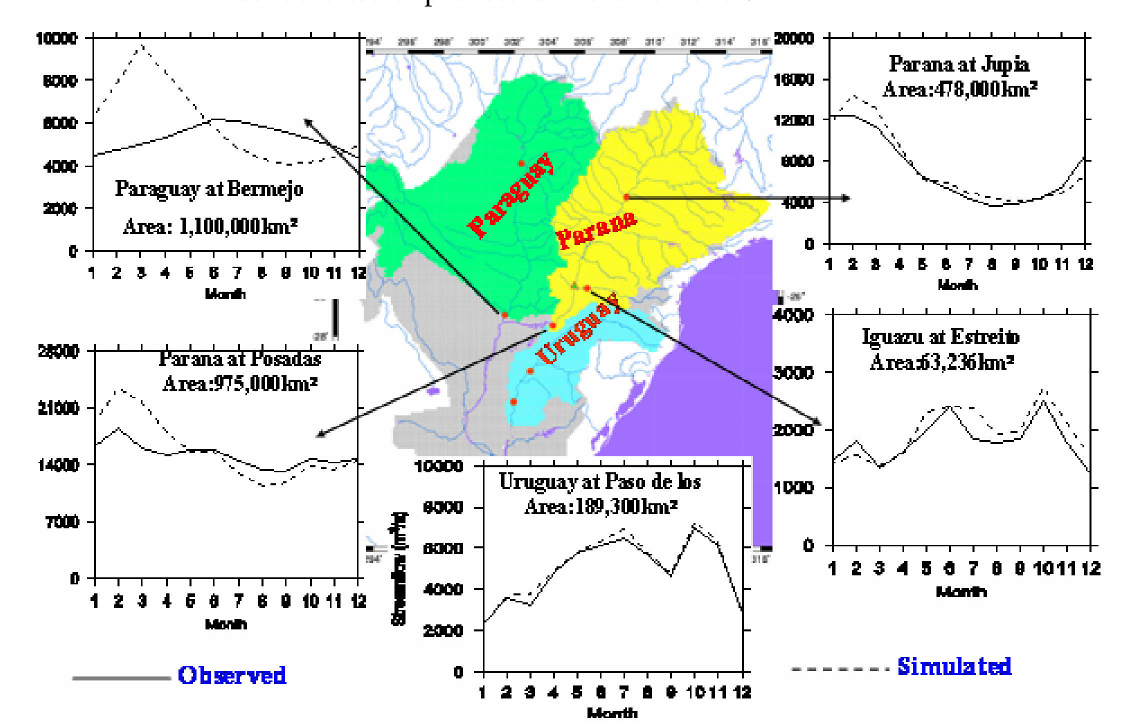


Figure 22. Mean monthly streamflow simulations for the three major subbasins in the La Plata (1979-1999).

4.3 Regional Institutions

Numerical weather forecasts are regularly conducted in Brazil and Argentina at the weather services. Regional numerical weather forecasts are produced by several research labs and universities as described in the next section.

a. CPTEC

Weather forecasts in Brazil advanced greatly with the introduction of numerical forecasting by the Center for Weather Forecasting and Climate Studies (CPTEC), linked to the Institute for Space Research - INPE, which began to operate regularly in 1995. CPTEC will act as a primary link between LPB and operational institutions.

CPTEC issues forecasts calculated on high-performance computers with parallel and vector architecture. Forecasts, whether digital or graphical, are available twice daily, starting from 0000 and 1200 GMT (http://www.cptec.inpe.br). CPTEC operates two basic models for weather forecasts: (a) a global spectral model which runs at a resolution on the order of 80km with 28 vertical level, producing 15-day forecasts and (b) a regional model with 20 km resolution and 38 vertical levels, based on the NCEP regional model ETA over a large domain which covers the entire S. American continent and adjacent areas. The regional model forecasts are for the next 7 days and the boundary conditions are provided by the global model.

On special periods, CPTEC also runs the ETA model at higher resolution (order of 10km) but over limited areas. CPTEC runs a data assimilation system which is based on the PSAS system which allows for the use of conventional meteorological data, remote sensing products (such as temperature and moisture soundings, wind vectors derived from satellite information at a few vertical levels and surface winds derived from microwave sensors). CPTEC also runs a forecasting cycle for the global model is on initial conditions provided by NCEP, which is transferred via Internet. CPTEC runs an ensemble forecast with 100 km resolution twice per day with 15 members based on perturbation of the initial conditions. The new addition to the CPTEC models is an environmental model run at 40 km resolution including the emissions by biomass burning and by large urban areas and providing the prediction of aerosol concentration, carbon monoxide and carbon dioxide for South America for 72 hours in advance.

The regional forecasting system requires more limited data, essentially over the South American Continent and adjacent areas and the data flow in this case is more satisfactory. Nevertheless, the initial condition provided by NCEP produces a better forecasting skill and a more complete data flow is required to achieve more independence in the operational procedure. Geostationary satellite data availability for data assimilation is also somewhat limited during periods when the scanner operation is limited to North America (during severe weather events). In this situation, satellite information is available over South America only at 3 hr intervals. Given than modern 4DDA systems are able to assimilate data at any time, the satellite data loss may have a significant impact in the forecast quality.

Seasonal forecasting is part of the operational suite of CPTEC. The same global model used for weather forecasting but at lower resolution (approximately 200km) runs 7 months forecast. The first two months are forced with observed sea surface temperatures (SST). From this point on, either predicted SST from NCEP in the Pacific Ocean and a statistical prediction of the SST anomalies in the tropical Atlantic (based on a CPTEC model) or a persistence of SST anomalies are used up to the end of the integration. Marengo et al. (2003) describes the seasonal forecasting operational system at CPTEC, and Nobre et al (2005) discusses the strategy developed by the International Research Institute of Climate Prediction - IRI consortium of seasonal forecasting products. In view of the high seasonal forecasting skill that is achieved by the CPTEC forecasting system, it is under discussion the possible acceptance of the CPTEC AGCM into the modeling suite for seasonal climate prediction at CPTEC.

Products are available at the homepage www.cptec.inpe.br, with free access by the users. Numerical products tailored to meteorologists are also available, as well as some products for agriculture and water resources users.

The CPTEC computer system is based on a NEC SX-6 computer with 12 nodes of 8 processors each, totaling 96 processors with peak performance on the order of 768 Gflops. The computer system is within the 10 highest world meteorological centers in computer power. The CPTEC models have undergone significant improvement in the last 8 years in view of the close relationship between research development and operational activities. CPTEC research and operational staff is on the order of 300 people and the model development is also based on cooperation with other research and academic institutions in Brazil, Argentina and the USA.

b. The National Institute of Meteorology in Brazil

The "Instituto Nacional de Meteorologia" (INMET) runs a regional model that was installed by the German Weather Service (DWD) under a World Meteorological Organization (WMO) agreement in 1999. It runs at a horizontal resolution of 25 km, 30 vertical levels in a grid of approximately 310 by 310 points covering a domain over the S. American continent and adjacent areas. The model forecasts of up to 60 hours are available twice a day, based on the 00 and 12 GMT initial conditions which are transferred from the DWD center via INTERNET. No data assimilation system is operationally used, although the numerical forecasting system has the capability of modifying the initial condition which is provided by the DWD global model in view of the observed conventional data available in the South American region. Model development is basically dependent on the interaction with DWD but the local staff is able to maintain the operational suite.

A large number of products based on the numerical forecasts, tailored for meteorologists, is available at the homepage (www.inmet.gov.br) on a regular basis.

c. The Argentine National Weather Service

The Argentine Weather Service numerical products are based on the ETA model, which is a finite difference model with a vertical grid which represents mountains as steps (the so-called step orography). The current domain covers the area from 14^o to 65^o S and from 30^o to 90^o W and forecasts are run twice a day based on the lateral boundary conditions provided by the NCEP global models. No data assimilation system is available to modify the NCEP initial condition based on the regionally available data. Forecasts are available up to 120 hr with horizontal resolution on the order of 25 km over the limited domain with 38 vertical levels. Model development is based on the international community of the ETA model users.

The homepage of the Argentine National Weather service (www.meteofa.mil.ar) contains several products based on the numerical forecasts, including a special product with relevant information at the La Plata River delta.

d. Other regional forecasting products available in the La Plata Basin

Numerical weather forecasts on a regional basis and in some cases local domains are also available in the La Plata Basin produced by several research and academic institutions. In some cases, these activities are done in collaboration with Universities and Forecast Centers from outside the region. A few selected research/academic institutions run atmospheric forecast models in the basin on a regular basis, with products available at their respective homepages:

- Department of Atmospheric Sciences of the Institute of Astronomy, Geophysics and Atmospheric Sciences of the University of São Paulo – Laboratory of Meteorology Applied to Regional Atmospheric Systems (MASTER) – www.master.iag.usp.br
- Ocean and Atmosphere Research Center of the University of Buenos Aires (CIMA-UBA): www.prono.cima.fcen.uba.ar
- Department of Atmospheric and Oceanic Science, University of Maryland, USA, www.atmos.umd.edu/~berbery/etasam; www.atmos.umd.edu/~berbery/wrf

These institutions run on a regular basis, in general twice a day, atmospheric numerical forecasting models with horizontal resolution of the order of a few tens of km, over periods of 48 up to 120 hr, in general based on initial and boundary conditions provided by the NCEP or CPTEC global models. In general, no data assimilation system is used to generate the initial conditions, and this will be one of the objectives of LPB.

Several others can be seen in the homepage: http://tucupi.cptec.inpe.br/comparacao/ as part of a model comparison project.

PART C: Implementation of LPB CSE

The main objective of the implementation plan is "*to determine surface states and variables at scales adequate for regional modeling with the purpose of improving the predictability of the precipitation and river discharge of the La Plata basin and its main sub-basins*"

5. Data rescue efforts

The surveys prepared under Framework Program have identified Flux Towers, soil moisture measuring locations, in addition to many regional raingauge networks, and radar products that have been archived in many institutions. The availability of these data could be extremely important if an agreement can be reached for their distribution to the scientific community.

A second aspect to be considered within LPB activities is the conversion of many archives to digital format. Historical data are available at many centers, but they are in hard copy formats.

6. Hydro-climatic monitoring activities

The monitoring system will have three basic elements: (a) a network for monitoring the diurnal cycle of precipitation; (b) a flux tower that includes CO_2 fluxes; and (c) a wind profiler. The climate monitoring will take place during the duration of LPB although it is expected that it will continue afterwards with support of local institutions.

Rainfall is a crucial variable for measuring the state of the hydro-climate system; and it is as important in data assimilation systems for weather forecasting. Dense coverage of a large region is costly, mainly due to the high frequency data transmission and to maintenance activities. In this context there is a need for alternative ways to estimate the temporal and spatial distributions of precipitation. Thus the plan for LPB will be to establish a monitoring system that in addition to raingauges, employs satellite estimates, radar information where available, and lightning information. These measurements will be combined to produce precipitation estimates that have the coverage and resolution needed for hydrological purposes.

6.1 A supersite

The LPB Implementation Steering Group believes that particular effort should be dedicated to constructing a supersite that could eventually outlast the Field Experiment. With the support of the Global Environmental Fund (GEF) a region near the Argentina-Paraguay-Brazil boundaries will be selected to establish a raingauge Meso-network; the central site will have soil moisture measurements, a rawindsonde, a wind profiler, radiation measurements, and estimates of turbulent fluxes (Flux Tower). The feasibility of having a radar nearby is currently being explored.

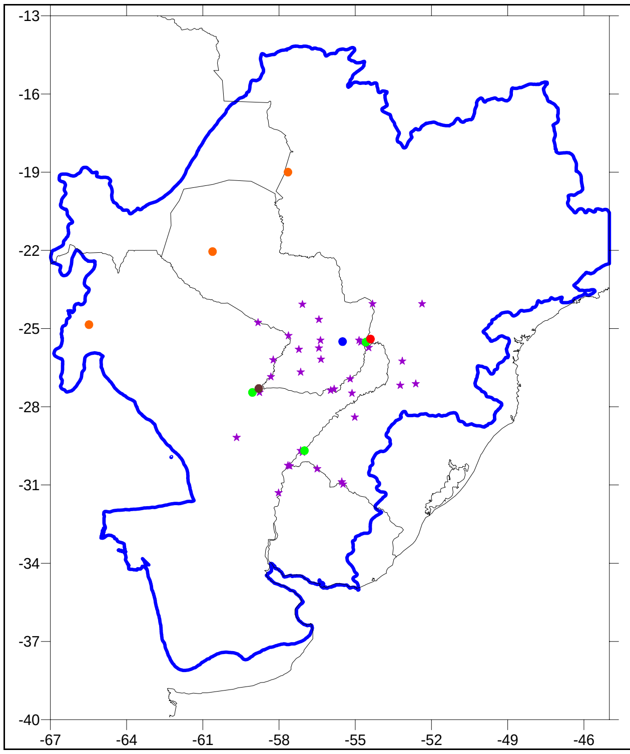


Figure 23: Tentative location of the supersite: Purple dots represent the meteorological network, the dark blue dot is the location of the Flux Tower, green dots represent rawindsonde locations (1st option), and red dots represent rawinsonde locations (2nd option). The light blue dot is the location of the Doppler radar.

6.2 Digital raingauges

A Doppler radar (S band) is needed in order to investigate the MCSs, monitor severe events, and estimate the diurnal cycle of precipitation. So far there is none in operating conditions over the pilot region, although one is being installed in Asunción, Paraguay. Plans are being considered for the installation of a portable radar near Foz do Iguassu, with support of GEF funding. In either case, a network of digital raingauges with high temporal resolution will be complementing the radar. The raingauge information will be employed for radar calibration, adjust satellite estimates of precipitation and other activities like data assimilation.

The proposed GEF funded activity plans on installing a network of about 27 raingauges with two possible configurations. The first option is for the case where a radar is installed weither in Asunción or Foz do Iguassu. In this case, 15 raingauges will be installed within the range of the radar, and 12 spread in other meteorological stations within the pilot region. The second option is in the case that a radar is not installed in time .In this case the 27 raingauges may be evenly spread over the pilot region, following the tentative locations suggested in Fig. 23.

Raingauges will be “tipping bucket gauges” with a 0.1mm resolution and a 1% precision up to 50 mm/hr. The instruments will have a datalogger with a storage capacity that will let them work up to 4 months. The datalogger should have a storage capacity of at least 1000 mm. The expenses will include a calibration kit for field operations, and a GPS system.

6.3 In-situ soil moisture measurements

6.4 Flux Towers

In addition to the existing flux towers, it is planned the addition of another one (see location in Fig. 23), complemented with soil moisture sensors. The site will be chosen in a forest location not affected by human activities, near the boundary of Brazil/Paraguay/Argentina. Brazilian scientists are planning the installation of towers to have a more uniform coverage of the Upper Parana basin. Regions being considered are over grassland, over the typical Chaco vegetation, and near the lake formed by the Itaipu dam.

For the purpose of the present project, it is highly desirable to have observations of the surface exchange on each of the relevant ecosystems that comprise the La Plata Basin. In this sense, we believe the Pampa plainlands should be considered as the priority, since it is one of the most important and largest in South America, which has not been continually monitored by similar type of observations in any previous long-term observational study. Other ecosystems of relevance are the arid region towards the northern portion of the Basin, the wetlands of Pantanal and agroecosystems.

The hardware and software of the tower will be compatible with similar equipments already installed in Brazil and Argentina (see section 3.7)

6.5 Wind profiler

A wind profiler radar that will measure continuously winds up to three or four km will be located near Resistencia, Argentina. Training and operations will likely be handled by the Argentine National Weather Service.

7. Field Experiment (PLATEX)

The objective of this section is to plan, implement, and carry out a comprehensive field experiment with a focus on land surface atmosphere interactions that will lead to improvements of both atmospheric and hydrologic models. Operational hydrological and meteorological data are clearly not sufficient for validation of complex models for water management applications.

Special data sets are required in order to calibrate, validate and test distributed hydrological models in operational environments. In particular, we propose that pilot studies should be undertaken in which flow forecasts obtained from different distributed hydrological models are compared with existing ARMA models. Atmospheric models also require more substantial validation against specially obtained data. An example is the uncertainty in estimating precipitation efficiency in the precipitating systems in northern Argentina, Paraguay, Southern Brazil and Uruguay (Mohr and Zipser, 1996).

The Field Experiment (a) will provide a set of intensive observations for the diagnosis and forecasting of MCSs and other precipitation events; (b) will give a quantitative measure of the impact of additional datasets on weather forecasts for the basin; (c) training of weather services employees in data assimilation and new forecast techniques, including sharing information and developing shared activities among the services.

Data sampling during PLATEX will have the specific aim of developing a database that will enable a better diagnosis of the MCSs, developing better parameterizations, particularly those related to the land surface-atmosphere energy exchanges, and ultimately improving the hydro-climate predictability of the region.

The Field Campaign will last about four months, during spring/early summer, and will include the enhancement, of surface and atmospheric observations by means of conventional and non-conventional equipment, and particularly taking advantage of an S Band Doppler radar.

7.1 Doppler radar measurements

A radar in the pilot region is a critical component for the studies of MCSs and the diurnal cycle of precipitation. Therefore if no operational radar (Asuncion, Paraguay) is available, a portable radar will be temporarily installed during the field campaign. Potential sites are either Foz do Iguassu (Brazil) or Puerto Iguazu (Argentina). The radar estimates will be complemented with the network of raingauges already discussed in section 6.2. Training of personnel at the National Institute of Meteorology (Brazil) and at the Argentine National Weather Services will precede the operational activities.

7.2 Aircraft soil moisture measurements

7.3 Flux towers

7.4 Upper air observations

The objective will be to reduce the uncertainties in estimating the diurnal cycle of the moisture and heat fluxes over a upper air data sparse region (upstream of the main area of precipitation). Four times daily ((00Z, 06Z, 12Z, 18Z) observations will be performed in Uruguayana (Brazil), Foz do Iguassu (Brazil), and Resistencia (Argentina). Depending on funding, those observations will be complemented with three other sites also measuring four times daily, in Salta (Argentina), Mariscal Estigarribia (Paraguay) and Corumba (Brazil). All these sites belong to the respective countries weather services.

7.5 Operations Center

Operations during the field campaign will be coordinated from CPTEC. CPTEC is the only forecast center in South America that has the capability of performing extensive data assimilation experiments and numerical forecasting from regional to global scales. CPTEC will be the communications center among all the measuring stations, and will collect and store and process daily the observations received. It will also provide the basin infrastructure for the teams working at the Field Campaign center of operations. Both original and processed data will be transmitted to other centers (SMN (Arg), UBA, UNA, UCAR/EOL, etc) for further use and archiving.

8. Data management

8.1 Archives locations

The development and maintenance of a comprehensive and accurate data archive is a critical step in meeting the scientific objectives of LPB. The overall guiding philosophy for the LPB data management is to make the completed data set available to the world scientific community as soon as possible following the Field Phase in order to better incorporate land surface-atmosphere-ocean data for improved simulations and predictions with coupled models.

The LPB data will be available to the scientific community through a number of designated distributed LPB Data Archive Centers (DACs) coordinated by the UCAR/Earth Observing Laboratory (EOL). These EOL activities fall into two major areas: (1) development and implementation of an on-line field catalog to provide in_field support and project summaries/updates for the Principal Investigators (PIs) and insure optimum data collection; and (2) establishment of a coordinated distributed archive system and providing data access/support of both research and operational data sets for the LPB PIs and the world scientific community. EOL will make arrangements to ensure that “orphan” data sets (i.e. smaller regional and local networks) will be archived and made available through the LPB archive. The EOL may also quality control and reformat selected operational data sets (e.g. atmospheric soundings or surface data) prior to access by the community as well as prepare special products or composited data sets.

8.2 Data Management Policy

The following data protocol and management issues were discussed and agreed to by the LPB Science Working Group. This data management strategy (i.e. protocol, schedule, data submission, and distribution) form the basis of the LPB data management policy discussed in this chapter and expanded in subsequent sections of this document.

LPB data will be provided from a variety of field activities lead by researchers and group of researchers, which have already received specific funding to support their activities. Henceforth, these will be referred to as data providers or LPB participants. The archiving of LPB data set will be done into one of the distributed LPB Data Archive centers (PDA).

Performing high-quality measurements during the planned LPB period, carrying out quality and error checking procedures, and submitting data and related documentation to the PDA will require substantial financial and logistical efforts of the data providers. The necessary support for these activities originates from a variety of international, national and institutional sources. This policy was approved at the LPB coordination meeting.

8.3 Data Categories

In order to set up data release guidelines which balance the interests of both data users and data providers; it was considered useful to divide LPB data into the following two categories:

> **Category 1: Standard data**. (e.g. operative rawinsondes, surface standard meteorology) Low or common exploitation value, measurement technology common, generally well understood little or no problems with data interpretation.
>
> **Category 2: Enhanced or Experimental data**. (e.g. LPB rawinsondes, pibal balloon and aircraft data, radar data) High exploitation value, measurement technology sophisticated and/or of experimental nature, contacts to data providers recommended for correct interpretation of data, high efforts necessary to maintain continuous measurements and high quality of data. These data will be taken for specific research purposes and maintained by a specific research group and/or the station or instrument PI.

8.4 Data release and dissemination guidelines

Release of Data in Compliance with WMO Resolution 40 (CG-XII) and WMO Resolution 25 (CG-XIII). LPB was initiated by VAMOS/CLIVAR/WCRP, whose co-sponsor is WMO, as an international project. It is thus appropriate that any policy for release and dissemination of LPB data should principally comply with the WMO policy, practice and guidelines for the exchange of meteorological, hydrological, and related data and products, as embodied in Resolution 40 of the Twelfth WMO Congress 1995 (CG-XII), and Resolution 25 of the Thirteenth WMO Congress 1999 (CG-XIII); that is, *free and unrestricted exchange of essential data and products.*

The no-restriction principle shall in particular mean that no financial implications are involved for the LPB data exchange. LPB data files available through one of the PDA shall be offered free of charge to the data users.

No Commercial Use or Exploitation. It is understood that all LPB data shall be delivered to users only for scientific studies designed to meet LPB-WCRP objectives. Commercial use and exploitation by either the data users nor the PDA is prohibited, unless specific permission has been obtained from the LPB investigators concerned in writing.

No Data Transfer to Third Parties. One restriction, which will be imposed on all data users, concerns the re-export or transfer of the original data (as received from the archive) to a third party. Such restriction shall apply to all categories of LPB data, and is in the best interests of both the LPB investigators and the potential users.

Unrestricted copying of the original data by multiple, independent users may lead to errors in the data and loss of identity of its LPB-PDA origin and is strictly prohibited.

PDA will offer LPB data files to potential data users through electronic means, (e.g. the Internet) or other designated media (e.g. CD ROMs). The PDA shall install technical means to keep protocol on all data transfers to data users thus maintaining a catalogue of all data users, and the data files they have obtained.

Timing for Release of LPB Data from PDA. The timing issue clearly involves some conflicting aspects. The data user will obviously be interested in obtaining data as soon as possible after the time of measurement. The data providers, as well as the PDA, will wish to ensure the highest attainable quality of the data. The latter will generally be time consuming, particularly in view of the shortage of manpower in many cases.

In addition, the data providers may have for good reasons an interest to exploit the respective data, or part of it, for his/her own scientific interest, or for another funded project or experiment, before these data are made openly available to a larger community.

Ideally, data should be ready for general release after some specific period following its acquisition, during which the exchange process between the data provider, the PDA and also the other data providers, including quality control and assurance, will have been completed. **Six months** has been considered as the appropriate length for this data turn-around period.

All data taken for LPB, shall be categorized into standard (category 1) and enhanced or experimental (category 2) data. See section 2.1.1 above for definition of these categories. Standard data shall be freely open to the science community after the basic turn-around period of six months. Enhanced or experimental data shall be freely open to the science community after a prolonged turn-around period of **15 months** at maximum.

Each data providers will be responsible to divide data provided to the LPB- PDA into the mentioned category scheme (Section 2.1.1). In cases of conflict, it is the data provider who decides on the category of specific data at the respective site.

It shall be possible in special cases for a potential data user to establish direct contact to a data provider in order to agree on exceptions (i.e. shortenings of the turn-around period) to these rules for specific data or data periods. It is suggested that these communications shall be performed with co-ordination of the PDA.

Acknowledgement and Citation. Whenever LPB data distributed by PDA are being used for publication of scientific results, the data's origin must be acknowledged and referenced. A minimum requirement is to reference LPB and the PDA. If only data from one specific source of LPB data (or a limited number of them) has been used, additional acknowledgement to the data provider and its (their) institutions or organizations shall be given.

Maintaining continuous, high-quality measurements, performing quality and error checking procedures, and submitting data and related documentation to the PDA will require substantial financial and logistical efforts of the LPB investigators.

The PDA shall make proper reference to all data providers and, if required, to their funding sources.

Co-Authorship for Principal Investigators (PIs). Co-authorship of LPB participants on published papers making extensive use of LPB data is justifiable and highly recommended, in particular, if a PI has responded to questions raised about the data's quality and/or suitability for the specific study in question, or has been involved in directly contributing to the paper in other ways. It is highly recommended that any data user should contact the responsible PI and ask him/her if he/she wants to become co- author, or if an acknowledgement (see section 2.5) would be sufficient. If co-authorship is requested, the PI and the data user should establish a basis for collaboration. A PI in this context means the responsible site or instrument scientist or any person (student, collaborator) that he/she may suggest.

Data users of LPB data are encouraged to establish direct contact with PIs and LPB investigators for the purpose of complete interpretation and analysis of data for publication purposes. This is in particular recommended for category 2 data.

LPB Publication Library. Whenever LPB data distributed by PDA are being used for publication of scientific results, the author(s) shall sent a copy of the respective publication, preferably in electronic form, to the LPB Project Office in order to build up a LPB publication library. The Project Office will maintain this library and will make it public, for example via the LPB website, for a continuous monitoring of the LPB data applications and LPB's achievements in general.

8.5 Data Management Functional Description and Strategy

The general approach to data management support for LPB is summarized in a data flow diagram (see Fig. 1). It is important that the LPB data management strategy be responsive to the needs of the investigators, assuring that data are accurate and disseminated in a timely fashion. It is also important that the investigators know what is expected of them in this process. A time line of critical dates in the sequence of LPB data management tasks are included in Fig. 2. After a description of the Data Archive Center (Section 3.1), each step in the LPB data management process is discussed in more detail.

8.6 Data Archive Center

The LPB data will be available to the scientific community through a designated LPB Data Archive Center located at UCAR/EOL, Boulder, Colorado, USA. All data sets collected for LPB will be available through the existing interactive EOL Data Management System (CODIAC). CODIAC offers scientists access to research and operational data. It provides the means to identify data sets of interest, facilities to view data and associated metadata, and the ability to automatically obtain data via internet file transfer or magnetic media. The user may *browse data* to preview selected data sets prior to retrieval. Data displays include time series plots for surface parameters, thermodynamic diagrams for soundings, and GIF images for model analysis products and satellite imagery. CODIAC users can *directly retrieve data.* They can download data via Internet directly to their workstation or personal computer or request delivery of data on magnetic media. Data may be selected by time or location and can be converted to one of several formats before delivery. CODIAC automatically includes associated documentation concerning the data itself, processing steps, and quality control procedures.

9. Modeling activities

9.1 Development of hydrologic distributed models

The development of hydrologic distributed models has many advantages for the basin as follow:

- *Better understand the physical behavior of the basin rainfall – runoff relationship, contribution of the basin on the surface and groundwater flow; impact of soil use; rainfall distributions, among others;*
- *Improve the lead time forecast in many river sections of the basin taking into account the integration effects of the basin;*
- *Improve the long term forecast and the climate variability prediction on the flow from the climate models.*

In the basin there are a few models applied in sub-basins of La Plata Basin but a distributed model integrated for the total basin will be an important tool in planning and forecast the hydrological behavior together with the climate and meteorological conditions as inputs for the water management.

There are several challenges in the development of an integrated La Plata Basin distributed hydrological model capable of addressing the goals above.

Firstly the model will need to be able to cope with hydrological complex regions, such as the Pantanal, the endhorreic regions of the Chaco, and the floodplains of the Parana, in Argentina. Secondly it should consider several major reservoirs, located in the headwaters of the Parana within Brazil. It should also be applied with only minor calibration, or with parameters that could be related to readily obtainable data (topography, land use, vegetation cover, soil types).

Regions with large diversity of hydrological regimes will need to be represented in the model. This is the case of regions of flat highlands, or plateaus, known in Brazil as "chapadas" where streamflow is dominated by groundwater flux, and where surface runoff is almost absent, although annual rainfall exceeds 1500 mm, in contrast to watersheds dominated by surface runoff.

To serve as a tool to analyze the effects of climatic variability and land use changes over the basin the hydrological model need to be verified against observed latent heat fluxes in several points of the basin, at locations where the soil types and vegetation covers are representative of widespread or typical situations. One should include at least two latent and sensible heat flux towers in two typical cerrado regions: one representative of a groundwater dominated region ("chapadas") and another representative of a mixed groundwater and surface runoff situation in a more hilly region. Results of this towers should be compared to measurements taken in locations with similar soil types and topography but where vegetation cover was changed from the original cerrado to soya or cotton (in the "chapadas") and to pasture (in a hilly region).

Field information of the river channels in the lower Paraguay and Parana reaches are also needed. River cross sections and flood plain width and storage capacity along the lower reaches of these rivers are also needed.

The objective should be to have data and models that cover all sub-basins in the LPB at scales of use for water resource and environmental management. Complement with statistical and/or dynamical downscaling is necessary in order to fulfill the operational requirement for the management of water resources at the smaller sub-basins.

9.2 Coupled models development

The development of fully coupled model is necessary in view of the complexities of the physical systems associated with the highly interactive nature of the interaction between the atmosphere, hydrosphere and the biosphere. These complex models are needed for the complete analysis of the impacts of climate change due to global warming and due to land use. Of particular interest in the La Plata Basin is the potential effect of climate change due to the intensive use of biomass burning during the dry season. Another important effect which requires the use of coupled atmosphere/hydrological models is the fact that very large flooding areas are produced in heavy rainfall events, leading to a possible feedback between the atmosphere and surface processes (such as in the case of the Pantanal region). The intense cyclogenesis off the coast of southeastern South America and its potential interaction with oceanic processes, as well as the control exerted by the SST anomalies in the development of climatic anomalies in the region also support the need for more extensive use of coupled atmospheric/oceanic models.

Development of coupled atmospheric-hydrologic models will be accomplished in well identifiable steps. The first step is to implement the SVATs used in atmospheric models in the structure of an hydrological model and force them with observed rainfall and surface temperature, incoming short wave radiation, wind speed, humidity and pressure data. Calculated runoff can then be compared to observed streamflow at gauging stations, in order to analyze SVAT results integrated over large areas. The second step is the identification of shortcomings of the SVAT performance, and identifying the reasons for poor performance. At the same time evaporation calculated by distributed hydrological models will be compared to latent heat fluxes at the locations where measurement towers were installed. The next step will be analyze these results and identify shortcomings of the hydrological models SVATs. A final step will be to propose common SVATs that can be used both in hydrological and atmospheric models, with a flexible, user settable, complexity, and taking into account the spatial variability that cannot be entirely represented by the models spatial resolution (subgrid variability). After these steps the new common hydrologic-atmospheric SVATs will be tested as the land module of atmospheric models.

In summary, the following types of coupled modes have to be implemented in order to improve forecasts in the La Plata Basin and to understand the potential impact of climate change in the water resources management:

- *Development of atmospheric-hydrologic coupled models*
- *Development of atmosphere-ocean coupled models*
- *Development of atmosphere-biosphere coupled models*

9.3 Data Assimilation Effort

The experience of the major world forecasting centers as well as of the advanced regional forecasting systems is that substantial improvement of the quality of the numerical forecasts actually comes from our capability to assimilate data leading to the improvement of the initial conditions of the forecast models (meteorological, hydrological and air quality). This concept is clearly valid for weather forecasting. For seasonal forecasting, data assimilation becomes particularly important for the coupled atmosphere/ocean models and for surface data assimilation which described the soil and vegetation state. The overview of the operational forecasting system currently used in the La Plata Basin clearly indicates that most of the operational institutions do not run a data assimilation system. CPTEC is only institution which is experimenting with an atmospheric data assimilation system but the basic forecast is still based on NCEP products. In addition, there is a wealth of land data from remote sensing applications that need to be used in hydrological and atmospheric forecasting. Thus, there is clear need to improve the understanding of the land-surface linkages and to:

- *Adapt and develop land surface models addressing specifically for La Plata basin characteristics.*

- *Improve and implement land data assimilation systems;*
- *Implement atmosphere and land data assimilation systems in an integrated fashion;*
- *To produce remote sensing products adequate for assimilation*
- *Retrospective regional mesoscale reanalyses*
- *Routinely develop Quantitative Precipitation Forecast (QPF) products for the whole basin at scales that can be useful for water management.*

The next to last item follows a current trend in hydrometeorological studies that recognizes the need for diagnostic analysis that can only be performed with a meteorological data set with high resolution (of the order of 20-40km). The reanalysis of the available data with a modern data assimilation system provides time series which do not suffer from the influence of the impact of changes in the model physics and data assimilation procedures. Such a data set is fundamental for observational studies.

Substantial effort is necessary to achieve more autonomy in the numerical forecasts applicable to the La Plata Basin, with a coordinated effort among leading groups and integration with specialists in data assimilation from other sciences, particularly in Applied Mathematics and Engineering.

9.4 Ensemble forecasting

Uncertainty in initial conditions and the non-linear character of the atmospheric and hydrological coupling, tied to the model imperfections clearly suggests the use of model ensemble forecasting or multi-model ensembles of forecasts. Experience in other basins as well as preliminary work in the La Plata Basin indicates that there is already plenty of atmospheric models available in the area and that a better forecast could be obtained from the statistical treatment of the individual results. Ensemble forecasting with the CPTEC model is already publicly available as well as results from other global centers.

Data assimilation and ensemble forecasting are closely related. Data assimilation and ensemble forecasting should also be seen from the perspective of the coupled hydrological/atmospheric models. It is recommended that this problem be viewed as an operational issue and therefore highly integrated with the operational weather and climate forecast centers.

9.5 Coordination among forecasting institutions

This report recognizes the need of concerted efforts among operational and research institutions in order to achieve best efficiency during the activities and to reach out to a larger community. Focus will be given to the following aspects:

- *Enhance the coordination among regional institutions involved in modeling*
- *Define and apply model performance metrics to measure skill of hydrologic and atmospheric forecasts*

- Promote and establish a mechanism for multi institution ensembles
- Give priority to training and favor exchanges between operational institutions
- Develop institutional mechanisms for cooperation, with a particular emphasis in activities with direct relation to societal needs

10. Predictability and climate change assessments

10.1 Land cover/Land use

- Identification and assessment of major LULC drivers, and development of a LPB geographic information system incorporating information from regional databases and local study areas;
- Multi-temporal description of the spatial heterogeneity in land cover and land use;
- Analysis of the links between an increase in agricultural lands in the LPB and changes in the dynamics of net primary productivity and evapotranspiration at both landscape and regional scales;
- Analysis of regional climate interactions with LULC patterns;
- Analysis of the hydrologic dynamics related to projected LULC change

Environmental Drivers (climate, soils). Most of the climate data is already held by the participating institutions. Complementary data, freely available, will be obtained from the national meteorological offices of the LPB countries (monthly precipitation, temperature, radiation, and evapotranspiration) and from global climatic databases (e.g. Global Historical Climatology Network, or the Global Precipitation Climatology Centre). Our goal is to compile data for the longest period possible (>30 years). For soil data we will use and make compatible soil databases already available from state agricultural agencies, such as SAGPYA (Argentinean Secretary of State for Agriculture, Cattle, Fisheries and Food), INTA (National Institute of Agricultural Technology, Argentina), EMBRAPA (Brazilian Agricultural Research Enterprise), and INIA (National Institute of Agricultural Research, Uruguay). From these institutions' soil inventory databases we will consider the following parameters: organic carbon content, salinity, alkalinity, texture, depth, and drainage type.

The databases will be compiled in each country. Project investigators will generate common legends and make all the variables compatible across political boundaries. Data will be stored in the already established data base of the Variability of the American Monsoons Systems (VAMOS) program, part of the World Climate Research Program's Climate Variability and Predictability program. This data base is supported by funds from the National Oceanographic and Atmospheric Administration Office of Global Programs and will be made available to this proposed project at no charge.

Five study areas will be selected across the main environmental gradients of the LPB which encompass the political and social heterogeneity of the area. Even though covering the heterogeneity of the basin will be the main criteria for selecting the study areas, practical considerations dictate that the project include areas where members of the team or their associates are currently carrying on field research. Table 1 presents the list of the selected study areas. Because an important and common activity to be performed in every study area is to generate detailed descriptions of the LULC patterns, each area is defined by its Landsat scene extent. These scenes are largely already in use by the respective institutions involved, and if necessary more scenes can freely be acquired from the Global Land Cover Facility at the University of Maryland (http://glcf.umiacs.umd.edu).

A detailed description of LULC patterns in the study areas based on the Landsat TM and ETM imagery will be performed. The Landsat images will be classified into discrete classes and miscellaneous units following protocols developed by Guerschman et al. (2003). The classification will be initially based on the seasonal dynamics of the Normalized Difference Vegetation Index (NDVI) and complemented by the albedo and surface temperatures, both derived from the spectral indices that capture the quantity and the seasonality of ANPP (Paruelo and Lauenroth 1998). At least three images per growing season (November to March) will be used for the pilot areas dominated by agricultural crops, and two images per year (dry and rainy seasons), for the areas dominated by pastures. Field work and interviews with local stakeholders will be used to evaluate and verify the LULC classifications obtained. An object-oriented image analysis based on context information (texture, neighborhood, distance, shape, etc.), will be conducted, and a state transition diagram representing the possibilities of LULC changes will be developed to increase the accuracy and level of automation of LULC classification (Pakzad et al., 2003). We will use several study areas that include international borders to represent "pseudo experiments", where the same environmental conditions are present but different social, political, cultural and economic conditions may influence LULC changes.

Table 1. Summary description of LPB study areas

Pilot area	**Host Countries**	**Coordinates Path/Row UL / LR**	**Mean Temp (oC)**	**Mean rainfall mm (Jul/Jan)**	**Major LULC**	**Biome(s)**
SW Buenos Aires	Argentina	226/086 (-36° 31' 37";-61° 54' 27"/-38° 25' 30";-60° 19' 32")	15	800	Winter Crops Pastures	Grasslands
Colón Paysandú	Argentina Uruguay	225/082 (-30 °47´59";-58° 42´14"/-32°41´12";-57°12´32")	17	1200	Implanted Forest Summer Crops	Savanas
Río Quaray	Brazil Uruguay	224/081 (-29° 21' 54";-56° 46' 11"/-31° 14' 59";-55° 17' 36")	19	1400	Rangelands Rice	Grasslands
Río Apa – SW Miranda	Brazil / Paraguay	225-226-227/075 (-20° 54' 36";-58° 05' 24"/-22° 30' 36";-55° 46' 12")	21	1500	Rangelands Soybean	Pantanal / Cerrado / Rain Forest
Río Taquarí	Brazil	225-224/72;225-224/73 (17° 03' 36";-55° 15' 04"/-19° 55' 56";-53° 01' 04")	21	1800	Rangelands Soybean	Pantanal / Cerrado /

Coarse resolution satellite data will be used for regional scale analysis, including the Argentine satellite SAC-C and the US AVHRR/NOAA series satellites (Large Area Coverage and Pathfinder AVHRR Land) (James and Kalluri 1994). These data is already rectified, standardized, and in use by the project participants. The descriptions of LULC obtained at the pilot area level (the Landsat level) will be aggregated up to the regional level (the SAC-C and AVHRR level). Based on the detailed description of LULC patterns from Landsat imagery classification, a fusion procedure will be applied and deconstruction of a SAC-C or AVHRR/NOAA pixel will be possible from the application of a mixture model (Paruelo et al submitted). This procedure will allow the generation of temporal profiles of reflectance, vegetation index, temperature, and evapotranspiration for the different LULC types. From the actual profiles observed from AVHRR imagery at a spatial resolution of 8x8 km and by inverting the mixture model, we will derive the proportion of the different LULC types. In the case of the regional description based on AVHRR data, LULC will be characterized based on the proportion of different land cover types. We will also incorporate existing LULC data from the national agricultural ministries and departments within each of the LPB countries. From this information, we will derive for each county the proportion of croplands.

Analysis of the links between increase in agricultural lands in LPB and changes in the dynamics of net primary productivity and evapotranspiration at both landscape and regional scales. A hierarchical approach using different satellite sensors (Landsat TM, SAC-C, MODIS, and AVHRR-NOAA) will be applied to describe the spatial and temporal heterogeneity of ecosystem variables directly related to exchanges of energy and matter (ecosystem functioning). We have selected a set of variables theoretically and empirically connected to the spectral data provided by satellite sensors, including the seasonal dynamics of the NDVI, NPP, the surface albedo (Liang 2000), and the surface temperature (Ouaidrari et al. 2002). NDVI is a linear estimator of the amount of photosynthetically active radiation intercepted by the canopy (Sellers et al. 1992) and hence, of primary production (Running et al. 2000). Seasonal dynamics of evapotranspiration, another key aspect of ecosystem functioning, will be determined from climate data and the seasonal patterns of the NDVI.

Analysis of regional climate variations related to projected LULC pattern scenarios. Climate change scenarios for the LPB will be used to drive the model of LULC changes that will be developed by the project. Concerning the feedbacks, we will use a climate modeling system that can incorporate large perturbations in the climate external to the LPB. The modeling system will be used to contrast simulations in which the feedbacks with the LULC model will be allowed or suppressed.

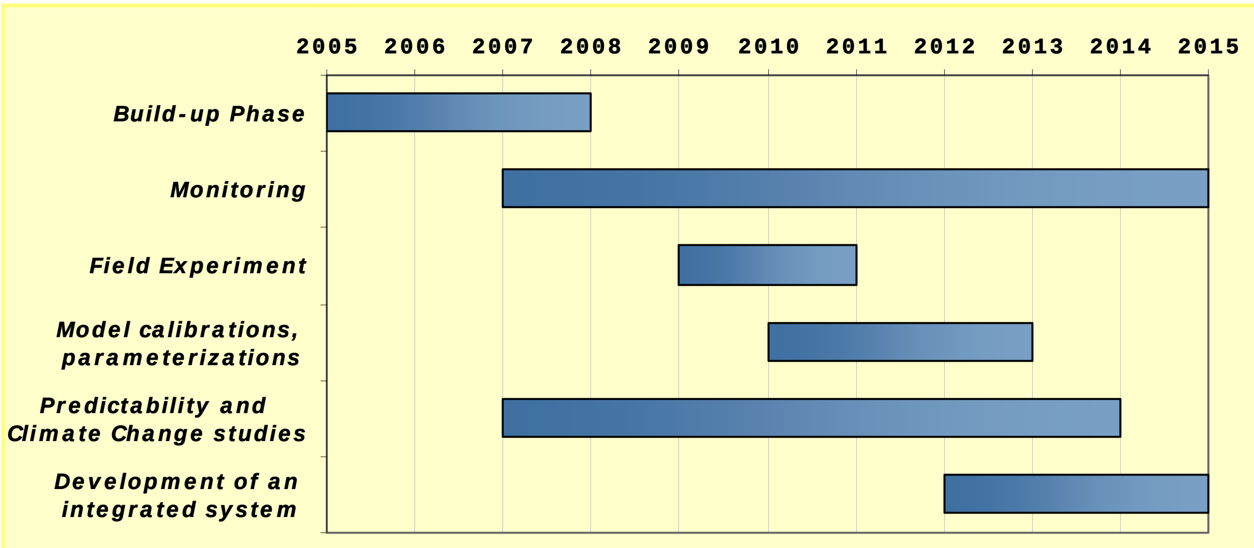
To generate climate scenarios, the outputs of the models participating in assessments produced by the Intergovernmental Panel on Climate Change (IPCC) will be used. The IPCC runs consist of control simulations that are representative of the present-day or pre-industrial times, and of equilibrium and transient-response simulations in which the atmospheric composition is changed either instantaneously or following a prescribed evolution. Outputs of the simulations are available at the IPCC Data Distribution Center and from participating modeling groups. In this case our task will be to select extreme cases of climate change over South America and prepare the data for input to the model of LULC change.

10.2 Climate change scenarios and regional downscaling

<SCIENCE STUDIES THAT ARE GOING TO BE INITIATED?>

11. LPB Timeline (2005-2015)

Build-up phase (2005-2008)
Monitoring: 2006/2007 →
Field Experiment: 2008-2010 (buildup phase 2006-2008)
Model calibrations, parameterization issues (2009-2012)
Analysis and diagnostics (2006-2012)
Development of an integrated system (2012-2015)



It is envisioned that to achieve the objectives set for LPB, a broader structure will be needed. Managed by an *LPB International Program Office*, working groups need to be established for the more important activities. Working Groups will be needed at least for (a) Observing Systems, (b) Data management, (c) Hydrological and Meteorological Models Development, (d) Predictability and Climate Change Scenarios, and (e) Societal and Economic Applications.

12. LPB Legacy

12.1 Links to International Programs

LPB is strongly linked and reliant on the activities that will be developed with GEF funds through the Framework Program of the Coordinating Intergovernmental Committee (CIC) for the countries in La Plata Basin (http://www.cicplata.org/).

LPB will maintain strong ties with the GEWEX Hydrometeorological Panel (http://ecpc.ucsd.edu/projects/ghp/) and other Continental Scale Experiments. GHP represents a unique opportunity for LPB to present its science questions and findings to a community of world experts in similar subjects.

Specific observations during the monitoring and field campaign activities will be contributed to the Coordinated Enhanced Observing Period (CEOP) (http://www.ceop.net). LPB will offer the products of at least two flux towers (one in the southern portion of the basin, while the other will be in the subtropical sector) as reference sites for CEOP.

LPB modeling activities will be harmonized with the VAMOS Monsoon Experiment for South America (MESA) group.

Coordination with LBA (http://lba.cptec.inpe.br/lba/) will also be sought given the links between the two continental scale experiments (see section 1.3).

Ongoing activities in regional research programs like PROSUR and CLARIS are also expected to become important joint activities with LPB.

12.2 Links to Weather Services

Operational weather services are going to provide critical support to LPB, and in turn LPB's research will be closely coordinated those services. The primary link will be with CPTEC, which will act as operations center during the field campaign, and will provide numerical and data collection support throughout the duration of the project. Other services, like the Argentine National Weather Service will provide support during the enhanced activities of the field campaign.

The International Research Institute for Climate and Society (IRI) has the mission to enhance society's capability to understand, anticipate and manage the impacts of seasonal climate fluctuations, in order to improve human welfare and the environment, especially in developing countries. Collaborations with IRI are viewed as a means of transferring LPB science to the society and stakeholders.

12.3 Dissemination

a. LPB Brochure to be distributed during build-up phase as a motivation to expand the rain gauge observation network. Links to GLOBE?
b. Special issues of international journal with scientific results (after field experiment) and at the end of the project.
c. LPB Monogram for High School education.

12.4 Final Products

a. Datasets 30-year land surface variables fields at least at 1/8° (LDAS); 25-year regional reanalyses
b. Integral coupled system for hydrological prediction
c. Regional capacity building

References

Aceituno, P., 1988: On the functioning of the Southern Oscillation in the South American Sector. *Mon. Wea. Rev*., **116**, 505-524.

Alessandro A.P., 2003a: Blocking action situations in the South of South América during the 1990s. Meteorologica, 28, 23-38.

Alessandro A.P., 2003b: The influencie of Blocking event in the So on temperature and precipitation in Argentina during the 1990s. Meteorologica, 28, 39-52.

Alexander, L. V., and coauthors, 2005: Global observed changes in daily climate extremes of temperature and precipitation, Submitted to J. Geophys Res.

Allasia, D., B. Silva, W. Collischonn, and C. Tucci (2005), Use of large basin simulation model MGB-IPH in Brazil, paper presented at Symposium S7.6 (New distributed modeling approaches and methods for testing models against observations), VII IAHS Scientific Assembly, Foz do Iguaçu (PR), Brazil, April.

Andreoli, R. V., and M. T. Kayano, 2004: Multi-scale variability of the sea surface temperature in the Tropical Atlantic. *J. Geophys. Res*., **109**, C05009, doi: 10.1029/2003JC002220.

Andreoli, R. V., and M. T. Kayano, 2005: ENSO-related rainfall anomalies in South America and associated circulation features during warm and cold Pacific decadal oscillation regimes. *Int. J. Climatol*., (accepted)

Barros, V. R.; Doyle M.; 1997: Interannual variability of Precipitation in Southern South America. *Fifth International Conference on Southern Hemisphere Meteorology and Oceanography, Pretoria, South Africa, MAS, 228-229.*

Barros, V. R., M. E: Castañeda and M. E. Doyle, 2000: Recent precipitation trends in Southern South America east of the Andes: An indication of climatic variability. In: *Southern Hemisphere Paleo- and Neoclimates. Key Sites, Methods, Data and Models*. P.P Smolka and W. Volkheimer (Eds.). Springer Verlag, Berlin, 187–206.

Berbery, E. H., and M. N. Núñez, 1989: An observational and numerical study of blocking episodes near South America. *J. Climate*, **2**, 1352-1361.

Berbery, E. H., and E. A. Collini, 2000: Springtime precipitation and water vapor flux over subtropical South America. *Mon. Wea. Rev*.**,128**, 1328-1346.

Berbery, E. H., and V. R. Barros, 2002: The hydrologic cycle of the La Plata basin in South America. *J. Hydrometeor*., **3**, 630-645.

Berri, G. S., M. A. Ghietto and N. O. García, 2002: The influence of ENSO in the flows of the Upper Paraná River of South America over the past 100 years. *J. Hydrometeorology*, **3**, 57–65.

Betts, R., Cox, P., Collins, M., Harris, P., Huntingford, C., and Jones, P. (2004) The role of ecosystem-atmosphere interactions in simulated Amazonian precipitation decrease and forest dieback under global change warming. Theoretical and Applied Climatology, 78, 157-175

Boyle, D. P.; Gupta, H. V.; Sorooshian, S. 2000 Toward improved calibration of hydrologic models: Combining the strenghts of manual and automatic methods. Water Resources Research Vol. 36, No. 12 pp. 3663-3674.

Bremicker, M. 1998 Aufbau eines Wasserhaushaltsmodells für das Weser und das Ostsee Einzugsgebiet als Baustein eines Atmosphären-Hydrologie-Modells. Dissertation zur erlangung des Doktorgrades der Geowissenschaftlicher Fakultät del Albert-Ludwigs-Universität. Freiburg. Juli.

Cazes-Boezio GH., A.W. Robertson, C. R. Mechoso, 2003: Seasonal dependence of ENSO teleconnections over South America and relations with precipitation in Uruguay. *J. Climate*, 16, 1159-1176.

CGIAR-CSI (2005), Void-filled seamless SRTM data V1 - 2004, International Centre for Tropical Agriculture (CIAT), The CGIAR Consortium for Spatial Information, http://srtm.csi.cgiar.org.

Ciappesoni, H. H., Salio P., 1987: Pronóstico de Sudestada en el Río de la Plata, Meteorologica, 22, 71-86.

Collini, E. A., E. H. Berbery, V. R. Barros, 2006: Soil moisture effects in the onset and development of the South American monsoon precipitation. To be submitted to *Mon. Wea. Rev*.

Collischonn, B.; Collischonn, W.; Silva, B. C.; Tucci, C. E. M. 2005 Hydrologic simulation of the São Francisco river basin using precipitation data from the TRMM satellite. XVI Simpósio Brasileiro de Recursos Hidricos, November (in Portuguese)

Collischonn, B.; Collischonn, W.; Silva, B. C.; Tucci, C. E. M. 2005 Hydrologic simulation of the São Francisco river basin using precipitation data from the TRMM satellite. XVI Simpósio Brasileiro de Recursos Hidricos, November (in Portuguese)

Collischonn, W.; Tucci, C. E. M. 2005 Use of a large-scale distributed hydrologic model for streamflow estimates of an ungaged basin. Anais VII IAHS Scientific Assembly. Foz do Iguaçu.

Collischonn, W.; Haas, R.; Andreolli, I.; Tucci, C. E. M. 2005 Forecasting river Uruguay flow using rainfall forecasts from a regional weather-prediction model. Journal of Hydrology Vol. 305 pp. 87-98.

Collischonn, W.; Tucci, C. E. M. 2003 Multi-objective calibration of a hydrologic model. Revista Brasileira de Recursos Hídricos V. 8, N. 3 27-40 (in Portuguese).

Collischonn, W.; Tucci, C. E. M., 2001. Hydrologic simulation of large basins (in Portuguese) Revista Brasileira de Recursos Hídricos. Vol. 6 No. 1.

Collischonn, W. 2001. Hydrologic simulation of large basins (in Portuguese) PhD Dissertation. IPH UFRGS.

Cox PM, Betts RA, Jones CD, Spall SA, Totterdell IJ, (2000) Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model. Nature 408:184-187.

Dai, A., I. Y. Fung, and A. D. Del Genio, 1997: Surface observed global precipitation variations during 1900-88. *J. Climate*, **10**, 2943-2962.

Díaz, A. and P. Aceituno, 2003: Atmospheric Circulation Anomalies during episodes of enhanced and reduced convective cloudiness over Uruguay. *J. Climate*, **16**, 3171-3185.

Dirmeyer, P.A. and Tan, L. (2001). A multi-decadal gridded meteorological and land surface data set over South America. COLA Technical Report, COLA, Calverton, USA.

Doyle, M. E., and V. R. Barros, 2002: Midsummer low-level circulation and precipitation in subtropical South America and related sea surface temperature anomalies in the South Atlantic. *J. Climate*, **15,** 3394–3410.

Fernandez W., R.M. Vogel, & A. Sankarasubramanian. “Regional Calibration of a Watershed Model” Hydrological Sciences-Journal-des Sciences Hydrologiques, 45(5) (2000), 689-707.

Gan M.A, Rao B.B., 1994: The influence of the Andes Cordillera on Transient disturbances, *Mon. Wea. Rev*. 122, , 1141-1157.
García N. O. and W. M. Vargas; 1996: The spatial variability of runoff and precipitation in the Rio de la Plata basin. *J. Hydrol. Sci*., **41**, 279-299.
Garreaud R. 2000: Cold air incursions over Subtropical South America: Mean structure and dynamics. Mon. Wea. Rev. 128, 2544-2559.
Genta, J. L., Pérez Iribarren, G. and Mechoso, C. R., 1998: A recent increasing trend in the streamflow of rivers in Southeastem South America. *J. Climate*, **11**, 2858-2862.
Genta, J.L., Charbonnier F. y Failache N., "Modelo regional de balance hídrico mensual para cuencas no aforadas en Uruguay" IV Congreso Internacional de Ingeniería Agrícola, 2001, Universidad de Concepción, Chillán, Chile.
Genta, J.L., Anido, C. & Silveira, L. 1992 Aplicación del Modelo HIDRO URFING a la Cuenca del Río Tacuarembó. AIIH: Memorias del XV Congreso Latinoamericano de Hidráulica. Cartagena, Colombia.
Grimm, A. M. 2003: The El Nino impact on the summer monsoon in Brazil: Regional processes versus remote influences *J. Climate* **16**, 263-280.
Grimm AM, Barros VR and Doyle ME. 2000: Climate variability in southern South America associated with El Niño and La Niña events. *Journal of Climate*, 13, 35-58.
Grimm AM, Ferraz SET and Gomes J. 1998: Precipitation anomalies in southern Brazil associated with El Niño and La Niña events. *Journal of Climate*, 11, 2863-2880.
Gupta, H. V.; Sorooshian, S.; Yapo, P. O. 1998 Toward improved calibration of hydrologic models: Multiple and noncommensurable measures of information. Water Resources Research, Vol. 34 No. 4 pp. 751-763.
Haddeland, I., Lettenmaier D.P., Skaugen, T., 2005: Effects of irrigation on the water and energy balances of the Colorado and Mekong river basins, Journal of Hydrology (in press).
Haylock M. R., and coauthors, 2005: Trends in total and extreme South American rainfall 1960-2000 and links with sea surface temperature. *Submitted Journal of Climate.*
Herdies, D. L., A. Da Silva, M. A. Silva Dias, and R. Nieto-Ferreira, 2002: Moisture budget of the bimodal pattern of the summer circulation over South America. J. Geophys. Res., 107, 42/1-42/10.
Hoffmann J., 1971: Frentes, Masas de Aire y Precipitaciones en el Norte Argentino. Meteorológica, 130-149.
IMFIA-DNH-PHI-UNESCO (2002). Balances Hídricos Superficiales del Uruguay. http://unesco.org.uy/phi/act1a.htm.
IMFIA-DNH, 2002: Directivas de Diseño Hidrológico e Hidráulico de Pequeñas Presas, en proceso de publicación por DNH-MTOP.
Jones, C., L. M. V. Carvalho, R. W. Higgins, D. E. Waliser and J.-K. E. Schemm, 2004: Climatology of Tropical Intraseasonal Convective Anomalies: 1979–2002**.** *J. Climate*, **17**, 523–539.
Kiladis, G. N., and H. F. Diaz, 1989: Global climatic anomalies associated with extremes in the Southern Oscillation. J. Climate, 2, 1069-1090.
Kistler, R., Kalnay, E., Collins, W. (2001). "The NCEP/NCAR 50-year reanalysis: monthly means CD-ROM and documentation". Bulletin of the American Meteorological Society, v. 82 (2), pp. 247-268.

Koster, R., M. J. Suarez, and M. Heister, 2000: Variance and predictability of precipitation at seasonal-to-interannual timescales. *J. Hydromet.*, **1,** 26-46.

Kowen, N., E. D. Soulis, A. Pietroniro, J. Donald, and R. A. Harrington (1993), Grouped response units for distributed hydrologic modeling, J. of Water Resourc. Plann. and Manag., 119(3), 289-305.

Krepper, C. M., B. Scian, and J. Pierini, 1989: Time and space variability of rainfall in central-east Argentina. *J. Climate*, **2**, 39-47.

Krepper C. M., García N. O. and P. D. Jones, 2003: Interannual variability in the Uruguay River basin. *Int. J. of Climatology*, **23**, 103-115.

Liang, X.; Lettenmaier, D. P.; Wood, E. F.; Burges, S. J. 1994 A simple hydrologically based model of land surface water and energy fluxes for general circulation models. Journal of Geophysical Research, Vol. 99, No. D7, pp. 14415-14428.

Liang, X., E. F. Wood, and D. P. Lettenmaier, 1996: Surface soil moisture parameterization of the VIC-2L model: Evaluation and modifications, Global Planet. Change, 13, 195– 206.

Lichtenstein, 1980: La Depresión del Noroeste Argentino, PhD. Dissertation, Buenos Aires University.

Liebmann, B, Vera, C, L. Carvalho, Camilloni, I, Hoerling, M.P., Allured, D. Barros, V., Baez, J., Bidegain, M, 2004: An Observed Trend in Central South American Precipitation. Accepted. J Climate

Liebmann, B., G. Kiladis, J. Marengo, T. Ambrizzi, and J. D. Glick, 1999: Submonthly convective variability over South America and the South Atlantic convergence zone. *J. Climate*, **12**, 1877–1891.

Lohman, D.; Mitchell, K. E.; Houser, P. R.; Wood, E. F.; Schaake, J. C.; Robock, A.; Cosgrove, B. A.; Sheffield, J.; Duan, Q.; Luo, L.; Higgins, R. W.; Pinker, R. T.; Tarpley, J. D. 2004 Streamflow and water balance intercomparisons of four land surface models in the North American Land Data Assimilation System project. Journal of Geophysical Research, vol. 109 D07S91.

Maheu C., A. Cazenave and C. R. Mechoso, 2003: Water level fluctuations in the Plata Basin (South America) from Topex/Poseidon satellite altimetry. *Geophys. Res. Letters*, **30**, 1143.

Malaka, I. Nuñez, S. 1980: Aspectos sinópticos de la sequía que afectó a la República Argentina en el año 1962. Goacta, 10(2) 1-21.

Marengo, J.A. (2004) Interdecadal variability and trends of rainfall across the Amazon basin. Theoretical and Applied Climatology. 78, 79-96

Marengo, J. A 2005 Caracterização do clima no Século XX e Cenários Climáticos no Brasil e na América do Sul para o Século XXI derivados dos Modelos Globais de Clima do IPCC. Relatório No. 1. Ministério Do Meio Ambiente - Mma Secretaria De Biodiversidade E Florestas - Sbf Diretoria De Conservação Da Biodiversidade – DCBio. PROBIO. Cacheira Paulista, 2005. 158 pp.

Marengo, J. A., and coauthors, 2003: Ensemble simulation of regional rainfall features in the CPTEC/COLA atmospheric GCM. Skill and Predictability assessment and applications to climate predictions. *Climate Dynamics*, **21,** 459-475.

Marengo, J, W. Soares, C. Saulo, M. Nicolini 2004: Climatology of the LLJ east of the Andes as derived from the NCEP reanalyses. *Journal of Climate, 17, 2261-2280.*

Marengo, J., Cavalcanti, Ifa, Satyamurty, P., Nobre, C. A., Bonatti, J. P., Manzi, A., Trosnikov, I. Sampaio, G., Camargo, H., Sanches, M. B., Cunningham, C.A.C., D'almeida, C., Pezzi, L. P., 2003: Ensemble simulation of regional rainfall features in the CPTEC/COLA atmos-pheric GCM. Skill and Predictability assessment and applications to climate predictions. Climate Dynamics.

Mechoso, C. R. And G. Pérez Iribarren, 1992: Streamflow in southeastem South America and the Southem Oscillation. *J. Climate*, **5**, 1535-1539.

MGAP, Dirección de Suelos y Aguas (1976). "Carta de Reconocimiento de Suelos del Uruguay a escala 1:1.000.000".

Minetti, J. L., W. M. Vargas, A. G. Poblete, L. R. Acuna, and G. Casagrande, 2003: Nonlinear trends and low frequency oscillations in annual precipitation over Argentina and Chile, 1931-1999. *Atmosfera*, **16**, 119-135.

Molfino J.H., Califra A (2001). "Agua Disponible de las Tierras del Uruguay", División de Suelos y Aguas, Ministerio de Ganadería Agricultura y Pesca, Uruguay.

Montecinos, A., R. Garreaud y P. Aceituno, 2000: Interdecadal Rainfall Variability in Subtropical South America and its Relationship with Tropical Pacific SST. Sixth Int. Conf. on S. H.. Meteorology and Oceanography, 3-7 April, 2000. Santiago – Chile, AMS.

Nijssem, B; Lettenmaier, D. P.; Liang, X.; Wetzel, S. W.; Wood, E. F. 1997 Streamflow simulation for continental-scale river basins. Water Resources Research, Vol. 33 No. 4 pp. 711-724, April.

Nogués-Paegle, J., and K. C. Mo, 1997: Alternating wet and dry conditions over South America during summer. *Mon. Wea. Rev.*, **125**, 279–291.

Paegle J., Mo K., 1997: Alternating Wet and Dry Conditions over South America during Summer, MWR, 125, 279-291.

Paz, A. R.; Collischonn, W.; Silveira, A. L. L. 2005 Improvements in large scale drainage networks derived from digital elevation models. Water Resources Research, (submitted).

Pietroniro, A.; Soulis, E. D. 2003 A hydrology modelling framework for the Mackenzie GEWEX Program. Hydrological Processes, 17: 673-676.

Robertson, A. W., and C. R. Mechoso, 2000: Interannual and interdecadal variability of the South Atlantic convergence zone. *Mon. Wea. Rev.*, **128**, 2947-2957.

Slingo J. M., D. P. Rowell, K. R. Sperber and F. Nortley, 1999: On the predictability of the interannual behaviour of the Madden-Julian Oscillation and its relationship with El Niño. *Q. J. R. Meteorol. Soc.*, **125,** 583-609.

Rao, V. B., Hada, K., 1990: Characteristics of rainfall over Brasil. Annual variations and connectiosn with the Southern Oscillation. Theor. Appl. Climatolt.42, 81-91.

Reed, S. M. (2003), Deriving flow directions for coarse-resolution (1-4 km) gridded hydrologic modeling, Water Resourc. Res., 39(9), 1238, doi:10.1029/2003WR001989.

Ribeiro Neto, A.; Collischonn, W.; Vieira da Silva, R. C.; Tucci, C. E. M. 2005 Hydrological modelling in Amazonia - use of the MGB-IPH model and alternative data base. IAHS Publications (to appear).

Robertson, A. W., and C. R. Mechoso, 2000: Interannual and Interdecadal Variability of the South Atlantic Convergence Zone. *Mon. Wea. Rev.*, **128,** 2947-2957.

Ropelewski CF and Halpert MS. 1987: Global and Regional Scale Precipitation Patterns Associated with the El-Niño Southern Oscillation. *Monthly Weather Review*, 115, 1606-1626.

Ropelewski CF and Halpert MS. 1989: Precipitation Patterns Associated with the High Index Phase of the Southern Oscillation. *Journal of Climate*, 2, 268-284.

Saulo, A,C., Seluchi, M.E., Nicolini, M., 2004: A Case Study of Low Level Jet Event, Aceptado en Mon. Wea. Rev. **132**, 2669-2683 .

Seluchi M.E., A. C. Saulo, 1998: Possible mechanisms yielding an explosive coastal cyclogenesis over South America: experiments using a Limited Area Model. *Australian Meteorological Magazine*, **47,** 309-320.

Silva, B. 2005 Streamflow forecasts in the Sao Francisco basin based on weather and climate forecasts. PhD Dissertation. IPH UFRGS (in Portuguese).

Silva, V. B. S., and E. H. Berbery, 2005: Intense rainfall events affecting the La Plata basin. *J. Hydrometeor.*, in press.

Silveira, L., 1998: Hydrological Modelling of Natural Grasslands with Small Slopes in Temperate Zones. Doctoral thesis. Division of Hydraulic Engineering. Department of Civil and Environmental Engineering. Royal Institute of Technology, Stockholm, Sweden. ISRN KTH/AMI/PHD 1022-SE.

Silveira, L., 2000: Large scale basins with small to negligible slopes. Part II: Hydrological Modelling. Nordic Hydrology - An International Journal. Vol. 31(1), 27-40.

Silveira, A. L. L. 2005 Inflow forecasts for hydroelectric reservoirs – module 1. Preliminary Report. IPH/UFRGS CPTEC/INPE, IAG/USP (in Portuguese).

Sorooshian, S.; Gupta, H. V.; Bastidas, L. A. 1998 Calibration of hydrologic models using multi-objectives and visualization techniques. Final Report EAR 9418147. Dep. Hydrology and Water Resources, University of Arizona 78p.

Soulis, E. D.; Kowen, N.; Pietroniro, A.; Seglenieks, F. R.; Snelgrove, K. R.; Pellerin, P.; Shaw, D. W.; Martz, L. W. 2004 A framework for hydrological modeling in MAGS. In Spence, C.; Pomeroy, J. W.; Pietroniro, A. Prediction in ungauged basins: Approaches for Canada's cold regions. CWRA – CSHS. 218pp.

Tebaldi, C., Hayhoe, K., Arblaster, J., Meehl, G., 2005: Going to the extremes An intercomparison of model-simulated historical and future changes in extreme events. Submitted to Geophys Res Letters.

Temez, J. R. "Modelo matemático de transformación precipitación-aportación", ASINEL, 1977.

Todini, E., 1996: The ARNO rainfall-runoff model, J. Hydrol., 175, 339–382.

Tucci, C.E.M. , Clarke, R.T., Collishonn, W. Dias, Pedro L.S., Sampaio & Gilvan, 2003, Long Term Flow Forecast based on Climate and Hydrological Modeling: Uruguay river basin, Water Resources Research, 39: 1181-1191

Tucci, C. E. M.; Collischonn, W.; Allasia, D.; Bravo, J. M.; Collischonn, B. 2005 Hydrological simulation model in the upper Paraguay basin – Final Report. ANA-GEF-UNEP-OAS.

Velasco I. Fritsch J. M., 1987: Mesoscale convective complexes in the Américas, J. Geoph. Res, 92, 9591-9613.

Vincent L., and coauthors, 2005: Observed Trends in Indices of Daily Temperature Extremes In South America, 1960-2002. *Submitted Journal of Climate*.

Vrugt., J. A.; Gupta, H. V.; Bastidas, L. A.; Bouten, W.; Sorooshian, S. 2003 Effective and efficient algorithm for multiobjective optimization of hydrologic models. Water Resources Research vol. 39 n. 8.

Wigmosta, M. S.; Vail, L. W.; Lettenmaier, D. P. 1994 A distributed hydrology-vegetation model for complex terrain. Water Resources Research Vol 30 No. 6 pp. 1665-1679.

Wood, E. F., D. P. Lettenmaier, and V. G. Zartarian (1992), A land surface hydrology parameterization with subgrid variability for general circulation models, J. of Geophys. Res., 97(D3), 2717-2728.

Yapo, P. O.; Gupta, H. V.; Sorooshian, S. 1998 Multi-objective global optimization for hydrologic models. Journal of Hydrology, Vol. 204 pp. 83-97.

Zhao, R. J., Y. L. Zhang, L. R. Fang, X. R. Liu, and Q. S. Zhang (1980), The Xinanjiang model, in Hydrological Forecasting Proceedings, Oxford Symposium, IASH Publ., 129, 351–356.

Acronyms

4DDA	Four Dimensional Data Assimilation
ADAS	Advanced Data Analysis System
ARMA	Auto-Regressive Moving Average
ARPS	Advanced Regional Prediction System
ADAS	Advanced Data Assimilation System
BRAMS	Brazilian RAMS
CAPE	Convective Available Potential Energy
CAPS	Center for Analysis and Prediction of Storms
CATO	Centro de Modelagem do Sistema Atmosfera-Terra-Oceano
CHBN	Marine Meteorological Service of the Center of Hydrography of the Brazilian Navy
CIMA	Centro de Investigaciones del Mar y la Atmósfera
CPRM	Companhia de Pesquisa de Recursos Minerais
CPTEC	Centro de Previsão de Tempo e Estudos Climáticos
DMH	Dirección de Meteorología e Hidrología (Paraguay)
DWD	German Weather Service
ECMWF	European Centre for Medium-Range Weather Forecasts
ENSO	El Niño / Southern Oscillation
FSU	Florida State University
GCM	General Circulation Model
GFDL	Geophysical Fluid Dynamics Laboratory
GMT	Greenwich Mean Time
GOES	Geostationary Satellite
GTS	Global Telecommunication System
INMET	Instituto Nacional de Meteorología (Brasil)
INPE	Instituto Nacional de Pesquisas Espaciais
IPCC	Intergovernamental Panel on Climate Change
IPH	Instituto de Pesquisas Hidráulicas
IRI	International Research Institute for Climate Prediction
LAHM	Limited Area Federal Hydrometeorological Institute-Belgrade University Model
LAI	Leaf Area Index
LNCC	Laboratório Nacional de Computação Científica
LPM/UFRJ	Laboratório de Prognósticos em Mesoescala/UFRJ
MASTER/USP	Meteorologia Aplicada a Sistemas de Tempo Regionais / USP
MM5	Mesoscale Model 5
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NWS	National Weather Services
OACGCM	Ocean Atmophere Coupled General Circulation Model
PREVIVAZ	Previsão de Vazão
PSAS	Physical-space Statistical Analysis System
PSU	Pennsylvannia Sate University
QPF	Quantitative Precipitation Forecast
RAMS	Regional Atmospheric Modeling System

SIMEPAR	Sistema Meteorológico do Paraná
SIMOC	Sistema de Modelagem Estadística dos Oceanos
SSARR	Streamflow Synthesis and Reservoir Regulation
SST	Sea Surface Temperature
SVAT	Soil Vegetation Atmosphere Transfer models
UBA	Universidad de Buenos Aires
UFRGS	Universidade Federal do Rio Grande do Sul
UFRJ	Universidade Federal do Rio do Janeiro
UFSC	Universidade Federal de Santa Catarina
UKMET	United Kingdom Meteorological Office
UMD	University of Maryland
USP	Universidade de São Paulo
UTE	Administración nacional de Usinas y Transmiciones Eléctricas
VIC	Variable Infiltration Capacity
WMO	World Meteorological Organization
WRF	Weather Research and Forecasting Model