PROSUR

Pilot Project on Floods in the Paraná-Plata basin: Impacts and Climate forcing

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CONTENTS

1. General context

1.1 Background

The Plata river basin stretches over 3 millions Km² and has a streamflow of more than 20.000 m³ /s. Its main tributary, the Paraná River, contribute with about 80 % of the streamflow and more than 90 % of the surface. For this reason, this Project refers to the Plata basin as the Paraná-Plata basin (Fig 1).

The Paraná River starts at the junction of the Paranaiba and Grande Rivers, north of 20°S. the main tributaries in Brazilian territory are the Paranapanema and the Iguazú in a region of predominantly rapid runoff (Fig 1) In this region the Paraná and its tributaries are very regulated by numerous dams, most of them built after 1980. Close before Corrientes receives the Paraguay River, and from this location on flows in a plain with a very small slope until its outlet at the Plata. Until Corrientes the river is known as Upper Paraná, and from this location until Santa Fe as Middle Paraná. Downstream of Santa Fe, the lower Paraná has two or more branches in some sectors and develop a delta before ending at the Plata. Discharges downstream of Corrientes only increase in a small proportion because the contribution of tributaries is relatively small. According to the different climate forcings it is convenient to distinguish three sectors in the Upper Paraná basin; the northern, upstream of Jupiá and including the Paranaiba and Grande basins; the central between Jupiá and the junction with the Iguazú River; and the southern between this point and the junction with the Paraguay River. The Middle and Lower Paraná have low coasts, especially in its right margin that are flooded when the river has large discharges.

The Iguazú River has a relatively small basin, but flowing in a terrain with strong slope, has sometimes large and rapid discharges that contribute to floods downstream in the Paraná.

The Paraguay River begins north of the Pantanal, a huge wetland of 140.000 Km2, a plain region with small runoff (Fig 2). After the Pantanal outlet, the river flows in a gentle plain and its low coasts facilitate the flooding in a fringe of about 10 to 15 km wide, both in the Paraguayan and in the Argentine territory. The sector between the Pantanal and the junction with the Apa River, is known as the Upper Paraguay, and from this point up to Asunción as the Middle Paraguay.

The Uruguay is the only great river of the Plata basin that is not tributary of the Paraná (Fig 1). Although, it has a larger basin than the Iguazú, shares its feature of having large and rapid discharges originated in one or two synoptic events.

1.2 Floods

Floods are the type of catastrophe that causes greater damages in the Paraná-Plata basin. There are different types of floods with different spatial and time scales forced from diverse climate or weather forcings. If we consider the spatial scale as an indicator of different types, they range from very local events caused by a convective storm, to the overflow of the large rivers of the Paraná-Plata Basin. In an intermediate situation, mesoconvective systems or intense extratropical cyclones at times causes the flood of extended plain areas region and /or the overflow of smaller rivers. Another frequent type of flood is the overflow of the Plata over its Argentine margin because of the pilling of water by the action of strong southeasterly winds known as locally as ¨sudestadas¨. They are caused by certain synoptic situations including cyclogenesis to the north of the Rio de la Plata.

Of all the ample spectrum of floods in the Paraná-Plata basin, the Pilot Project focuses on those caused by the overflow of the greatest tributaries of the Plata, namely the Paraná, the Paraguay and Uruguay rivers for the reasons discussed in the next paragraphs

There were some previous indications that these floods were related to large- scale climate events, as for instance the El Niño (EN) (Aceituno 1988 and other authors). Because of the dimensions of these river basins, these floods are caused obviously by large-scale atmospheric processes that last for several months (Fig. 3). This figure shows that both, the Paraná and Uruguay daily discharges of 1997-1998 were modulated by the same forcing, EN event, but in the case of the Uruguay River, the impact of higher frequency events at the synoptic scale was superimposed on the lower frequency variability (Camilloni and Caffera 2003). In the case of the Paraguay River, its annual peaks are correlated more than 0.9 with the mean annual discharges indicating that peaks are part of waves that take at least several months (Barros et al 2003). Therefore, the major discharges in the Paraná and Paraguay rivers can be studied from records of monthly averages that are easily available.

The knowledge of the large-scale climate processes in southeastern South America was important and rapidly evolving at the time this Project started. The study of major discharges of the greatest Plata tributaries was a cross cutting issue of various aspects of the hydrology of the basin and of central subjects of PROSUR, like the role of the large-scale sea surface temperature (SST) in the variability of the southeastern South America and the tropical – extratropical interactions

Most of the damage caused by the floods of the great rivers in the Plata-Paraná basin is in the urban sectors. This is a result of the complex human interaction with the environment in which is not absent the lack of planning and poverty. Indeed, the more vulnerable population to floods is the most impoverished that occupy precarious settlements in frequently flooded areas. Developing a characterization of the features of the major floods and of their climate forcing, as it was done in the Project will help to the improvement of the early alarm systems.

1. 3 Use of water

The Paraná-Plata basin produces most of the agriculture output of the MERCOSUR with a grain production of more than 100 Millions of Tons a year. Therefore, regional agriculture output is not only the alimentary base of the four countries of the region, but a considerable share of their export trade. In this region, meteorological information is very important for in the decision making process in the production, trade, transport de grains. Thus, it is important to develop information directly relevant to agriculture as for instance the water content of soil, which is not present in the usual meteorological reports, except in Brazil where the CPETEC provides this service.

2. *Objectives*

2.1 Floods

The objective of the Pilot Project was characterize the major discharges of the large tributaries of the Paraná – Plata basin from the point of view of its hydrology and its climate forcing as well as of their socio-economic impacts.

After the initiation of a Pilot Project on Human dimensions related to the Plata basin floods, the objective of the Pilot Project were reduced to the hydrological and climate aspects. The focus was on describing the hydrological features of the major discharges in magnitude, source region and seasonality, as well as in their climate or synoptic forcings.

2.2 Water content in soil

The intention was to develop capacity building for the development of an experimental operative system on water content in soil estimated from meteorological information

3. Work Team

3.1 Co-Pi and associates

PI: Vicente Barros (Universidad de Buenos Aires (UBA))

Contributions by Co-Pi and associates as follows:

Hydrological cycle
Ernesto H. Berbery (University of Maryland) and Vicente Barros (UBA)

Characterization of floods:
Uruguay River
Mario Caffera (Universidad.de la República) and Inés Camilloni (CIMA and UBA)

Paraná River
Inés Camilloni (CIMA and UBA) and Vicente Barros (UBA)

Paraguay River

Genaro Coronel, Lucas Chamorro (Universidad. de Asunción), Julián Baez (Meteorological Service of Parguay) and Vicente Barros (UBA)

Predictability
Iracema Cavalcanti (Centro de Prediccion do Tempo e o Clima (CPTEC))
Pedro L. da Silva Dias (Universidad statal de San Pablo (USPE))

Low frequency analysis
Walter Vargas (UBA)

Water availability in soil
Xavier Tomasella (CPTEC), Moira Doyle (UBA) and Ernesto H. Berbery (University of. Maryland)

3.2 Basic papers

Results are described in the following papers

Camilloni, I. and V. Barros 2000: The Paraná River Response to El Niño 1982-83 and 1997-98 events. *J. Hidrometeorology.* **1**, 412-430.

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

Vargas W., Minetti J. and A. Poblete 2002: Low-frequency oscillations in climatic and hydrological variables in southern South America's tropical-subtropical regions. *Theor. Appl. Climatol*. **72**, 29-40

Tucci, C., R. Clarke, W. Collischon, and P.L. da Silva Dias 2002: Long term flow based on Climate and Hydrological modeling: Uruguay River basin

Camilloni, I. and V. Barros 2003a: Extreme discharge events in the Paraná River and their climate forcing. *J. Hidrology.* **278**, 94-106.

Camilloni, I. and R. Caffera 2003: The largest floods in the Uruguay river and their climate forcing. Submitted to the *J. Hydrometeorology.*

Camilloni, I. and V. Barros 2003b: La temperatura del Atlántico sur y la diferencia de caudales del río Paraná durante los eventos El Niño 1982-83 y 1997-98. Submitted to the *Revista Brasileira de Meteorology.*

Barros, V., L. Chamorro, G. Coronel and J. Baez 2003: The major discharge events in the Paraguay River. Submitted to the *J. Hydrometeorology*.

Iracema

A synthesis of the results of these papers are presented in the next section, since in many cases some sentences and paragraphs were literally taken from them, they are indicated at the beginning of each section.

4. Results

4.1 Hydrology

Taken from Berbery and Barros (2002) and Barros, Chamorro, Coronel and Baez (2003)

Discharge of La Plata River has small amplitude in its annual cycle, due to the different precipitation regimes present throughout the year. The maximum tends to occur in late austral summer and autumn, as a result of the more dominant effect of summertime precipitation. The minimum occurs during spring and early summer. The annual cycle of river discharge in each of the subbasins is determined by the different precipitation regimes. The Upper Paraná River is most influenced by the summer monsoon regime, thus the river has a maximum discharge in late summer The annual cycle of the Paraguay River discharge presents a maximum in early winter, resulting from both the slowly runoff of the Pantanal summer precipitation and the excess of precipitation over evaporation in the Upper and Middle basin during autumn. The mean Paraguay River discharge diminishes from June to February, in winter because of the scant precipitation, and in spring and summer because of the large evaporation. Consequently, after the junction with the Paraguay River, the Paraná presents a smoother annual cycle. The annual cycle of precipitation over the Uruguay River basin has two maxima, one in late autumn and the second one in spring and, consistently, the river discharge is largest in winter and spring. Thus the apportion of the Paraná and Uruguay with different phases in their annual cycles contributes to smooth out the annual cycle of the Plata discharge

La Plata River largest discharges for a given month, occurs at any time of the year, with a peak during austral winter. The largest contribution during major episodes comes from the Paraná River. Taken individually, both the Paraná and the Uruguay rivers can at least triple the mean river discharge during flood events, while the Paraguay does not show peaks as extreme. In each tributary, the minimum river discharges do not depict much dispersion, but notably the Uruguay River is the most affected since minima can be about one order of magnitude smaller than the mean values for any month of the year. Only the Paraguay River has a similar situation during spring.

The annual cycle of the Plata Basin is well related to the water vapor flux from continental low latitudes. Contrary to what happens in North America, the low-level jet is present all the year

(Fig.4) and in particular over the Uruguay River is related to more frequent major discharges than in summer (Camilloni and Caffera 2003). The wintertime maximum of moisture flux has a somewhat different structure, with the core located at a higher elevation than that during the warm season (850 hPa vs. 925 hPa) (Fig. 5); still, the total supply of moisture to the basin during winter and summer remains at about the same magnitude. Other import aspect is the change of location of the maximum of moisture flux with season. In winter is found eastward of its summer position (Fig 4). Therefore, this contributes to the different precipitation regime at this flux outlet that at in the west is more monsoon-like than in the east.

Interannual and longer time variability of discharges reveal a high vulnerability of the region to increased precipitation. There are evidence that changes in precipitation are amplified in the streamflow signal (Table 1). The ratio between streamflow and basin-averaged precipitation changes is a little more than two, that is, for every one percent change in precipitation there was a little more than two percent change in streamflow. This sensitivity was reasonably stable whether calculated over two consecutive years (1998 and 1999) over interannual changes (El Niño/La Niña composites) or decades (1951-70 vs.1980-99). Collinshonn et al (2001) also reported this feature at decadal scale and they related it to the use of soil change (Tucci and Clarke 1998). However, since it was also valid for consecutive years, which had little change in the use of soil, it seems that is an intrinsic feature of the hydrological system. Within the present context of Climate Change, this feature may have important consequences in the basin hydrology as relatively modest variations in the mean precipitation might lead to important variations in the river discharges. Hence, the understanding of the relative contribution of the change of the use of soil and of the natural conditions of the system to this amplification factor remains as an important scientific and practical issue

4.2 Floods

4.2.1 Paraná River

Taken form Camilloni and Barros (2000, 2003a and 2003b) and from Barros, Chamorro, Coronel and Baez (2003)

Huge monthly discharges were registered in many occasions at the gauging station in Corrientes, where the Middle Paraná begins. The 16 major monthly anomalies discharges ranged from more than 15,000 m^3/s to 38,300 m^3/s, which added to the mean values that according to the season range from 12,500 m3/s to 21,000 m^3/s, constitute enormous streamflows, Table 2. Although in the average, the contribution of the central and southern Upper basin is only about 40% of this streamflow, the major discharges in Corrientes usually originated in these basins, especially in the central one. The contribution of the Paraguay River to the major discharge anomalies in Corrientes enhances the Upper Paraná contribution, but in a relative small proportion. On the other hand, the contribution of the northern Upper Paraná to the major discharge anomalies in Corrientes is not only generally small -less than 25 %- but in some cases even negative. Of course, most of the greatest anomalies in the northern Upper Paraná discharges were carried over downstream, but in most of the cases their magnitude was reduced as they progressed downstream. It can be concluded that the major anomalous discharges in the Middle and Lower

Paraná originated in precipitation anomalies over the southern and central Upper Paraná basins with some extension over the Paraguay basin and little or no extension over the northern Upper Paraná basin. Thus, the northern part of the Paraná basin, the most affected by the South Atlantic convergence zone (SACZ), despite its significant contribution to the mean discharge of the Paraná River, is not relevant in the case of the largest discharges

Regarding the seasonal characterization, the major discharge anomalies in Corrientes occurred at any time of the year, but with more frequency in autumn and spring and only on a few occasions in summer and winter. Their seasonal frequency does not follow the annual cycle of the streamflow or of the rainfall over the corresponding upstream basin, since both present a summer maximum, Table 2.

There is a clear relationship between the phases of the ENSO and the major discharge anomalies in the Middle and Lower Paraná. About two thirds of the major discharge anomalies in Corrientes (Table 2) and of the major anomalous contributions of the central Upper Paraná occurred during EN events (Table 3). In addition, none of the major anomalies occurred during LN phase. This contrasts with the weak correlation between the Southern Oscillation index and discharges in Corrientes (Aceituno 1988), indicating that the major discharge anomalies were more related to El Niño phase than to the rest of these anomalies.

The major discharge anomalies in Corrientes and major discharge contributions of the central and southern Upper Paraná that were related to El Niño occurred either in spring (0) or in autumn +, accompanying the seasonal variation of El Niño precipitation signal in eastern subtropical South America (Table 2). During the recorded period, the top discharges of the Paraná River at Corrientes occurred in the autumn +. In all of these events, El Niño SST anomaly in El Niño 3 region persisted until this season. Also, whenever El Niño 3 SST anomalies continued until the autumn +, there was an important positive discharge anomaly at Corrientes, greater than 10,000 m^3/s.

To understand the autumn+ climate forcing, figure 6 shows the composite precipitation anomaly of these events for the March-May months. There is an important positive anomaly of more than 80 mm/month centered in the Alto Paraná basin that affects also the eastern part of the Upper and Middle Paraguay basins. The SST corresponding to the autumn + (not shown) presents the well-known pattern of EN, with warmer than usual temperatures at the eastern equatorial Pacific Ocean, and large positive anomalies off the coast of South America. Consistent with the persistence of positive anomalies in the equatorial Pacific, in the upper troposphere (Fig 7) there is a pair of anticyclone anomaly circulation over the central and eastern Pacific straddling from the equator in each hemisphere. Over South America, there is a strong cyclonic circulation anomaly. Its position with respect to the anticyclonic anomaly suggests the propagation of a stationary Rossby wave-like train induced by the equatorial source of EN (Mo 2000). This anomaly circulation enhance the cyclonic vorticity advection over the Upper and Middle Paraguay and the central and southern Upper Paraná basins and the subtropical jet, which favors the cyclogenesis and mesoscale convective systems, two important mechanisms for the development of large rainfalls in the region.. It can be concluded that during the autumn +, the circulation anomaly field is consistent with the strong positive precipitation anomalies observed.

During the spring (0), although the streamflow contributions from the central and southern Upper Paraná to the discharge anomalies of the Paraná River did not reach the top magnitudes of the autumn +, they were also very important and with few exceptions consistently positive. As in the case of autumn +, the largest anomalies in the composite rainfall for the spring 0 occurred near the triple border between Paraguay, Brazil and Argentina, but with the maximum centered a 300 km to the south with respect to the autumn + (Fig. 8). This anomaly field is consistent with the increase the cyclonic vorticity advection in the upper troposphere (Barros and Silvestri 2002) and the enhancement of the subtropical jet over South America (Grimm et al 2000)

The remaining third of the major discharge contributions from the central Upper Paraná took place during the austral spring or the austral summer of neutral periods. During the three summer months with a major discharge contribution from the upper Middle Paraná, there were positive anomalies along the Pacific coast of South American from the Equator to 30°S, as well as predominant positive anomalies in the subtropical Atlantic west of 20°W. These features were consistent with the correlation pattern between January-February SSTs and the discharge contributions from the upper Middle Paraná.

The extraordinary EN 1982-83 event was accompanied by the greatest monthly discharge registered in Corrientes and by a persistent anomalous high streamflow that went on from July 1982 to December 1983. Five out of the 15 major discharge anomalies in Corrientes occurred during this period. Although, the combination of different factors could have contributed to these peaks, the exceptional magnitude of these anomalies and particularly their spatial extension and persistency for a year and a half, require a better understanding.

During 1997-98 the strong EN, comparable in intensity to the 1982-83 event, but discharges in the Paraná River were not as considerable. The greatest differences in discharge were in the early winter + and in summer. The first is consistent with the earlier end of the event in 1998. During summer the differences were originated in the important precipitation anomalies during November and January. In November, there are not indications that the precipitation differences were caused by the Atlantic SST and are very likely related to the different SST pattern in the central subtropical South Pacific (Barros y Silvestri 2002). During January 1983 there was a strong positive SST anomalies in the Atlantic to the north of the SACZ mean location and an equally strong negative anomalies to the south of it, except near the coast. This pattern is highly correlated with positive anomalies in convection and precipitation over the central and northern Upper Paraná and Upper Paraguay basin, as happens in January1983 (Doyle and Barros 2002). On the contrary in January 1998, the SST pattern was completely different. Thus the large difference in streamflow between both events was in the northern and central Upper Paraná contribution.

4.2.2 Paraguay River

Taken from Barros, Chamorro, Coronel and Baez (2003)

Most of the peaks of the major discharges at Asunción took place between May and July, in phase with the maximum of the annual cycle (Table 4). However, although the peaks of the top discharge anomalies also occurred in the May to July period, other major anomalies peaked at almost every time of the year (Table 5).

The major discharges of the Paraguay River originated in the Upper and Middle Paraguay basin, and the occurrence or not of the major discharges in the Paraguay River were not dependent on the Pantanal water storage. Not only the discharge anomalies of the Pantanal did not contribute substantially to the respective anomalies in Asunción discharges, but also they were not even appreciable correlated with the contribution to the Paraguay River discharge from the Upper and Middle basins

About two thirds of the major discharge anomalies at Asunción occurred during EN months, and although in a few cases, this could have been a fortuitous coincidence, there is little probability that the observed rate of major discharges during EN phase could happen by chance. EN signal was more unambiguous in the five cases that occurred during the autumn + as they rank between the top peak discharges. The composite of these cases shows a tropospheric wave train from the equatorial Pacific that enhances the subtropical jet and the cyclonic vorticity advection over the eastern Paraguay River basin (Fig. 7). Consistent with this anomaly circulation pattern, the precipitation pattern had a positive anomaly of more than 80 mm/month centered in the Alto Paraná basin that extends over the eastern part of the Upper and Middle Paraguay basins (Fig. 6).

Despite of the clear EN signal, about a third of the major peak anomalies were no related to the ENSO phase as they occurred indistinctly during LN or the neutral phases. Of these cases, the five that occurred during wintertime share common circulation and precipitation features. The average fields from April to August of all these cases had an almost barotropic tropospheric pattern at high latitudes with a very deep cyclonic anomaly between 120° and 160° W and an anticyclonic anomaly centered at the southern tip of South America (Fig 9). This pattern is indicative of frequent blocking conditions in the circulation over southern South America, which favors the deviation of the frontal and cyclonic perturbations entering into the continent more to the north. The respective precipitation anomalies reflect these conditions with positive anomalies for the five months period over almost the whole Paraguay River basin. These anomalies while not very important in absolute value, represent, however a precipitation considerably exceeding the mean evaporation of these months.

4.2.3 Uruguay River

Taken form Camilloni and Caffera (2003)

The number of extreme events occurred at the Salto Grande gauging station at the daily scale during the warm semester (October to March) are the same than during the cold season (April to September). However, the highest river levels are mostly observed during the cold semester (Table 6). Floods registered during the warm season are due to intense rainfall in the upper basin particularly in the period 12 to 9 days before the flooding date (Fig. 10), consequently the hydrological forecast of these events is possible many days in advance. The largest discharges occurring during the cold semester are mostly due to the large rainfall registered over and upstream from Salto Grande in two separate periods, 12 to 9 and 4 to 1 days before the flooding date (Fig 10), and therefore the hydrological prediction should necessarily depend on an appropriated weather forecast.

Almost half of the largest discharge events of the Uruguay River at Salto Grande could be related to enhanced precipitation due to moisture flux convergence in the South American low level jet (SALLJ) region. The frequency of occurrence of SALLJ during the 12 days before the flooding date of the cold season extreme events is slightly larger than during the warm semester (Table 7). This result shows the relevance of the cold season SALLJ in the contribution to moisture transport and atmospheric convection and also indicates a departure from the behavior of the North American LLJ that is only present and exhibits large moisture fluxes during the warm season (Berbery and Barros 2002).

The hydrological response to ENSO is evident as most of the largest monthly discharge events of the Uruguay River at Paso de Los Libres gauging station occurred during the El Niño phase. Nevertheless, the analysis of the individual extreme discharge events on daily basis show that these floods last between 3 and 10 days and consequently it is necessary to study their synoptic forcing.

4.3 Predictability

Taken from I. Cavalcanti IRACEMA: Some reference aside from Mar del Plat workshop? and Tucci, Clarke, Collischonn, and Silva Dias 2002

A procedure for predicting seasonal discharge in the Rio Uruguay basin lying in Brazilian territory was described by Tucci et al (2002). Sequences of predicted 24 hours daily rainfall, produced by the global climate model of CPTEC, were used as input to a rainfall-runoff model for the drainage basins. Simulated forecasts of Uruguay River discharge were made for the period 1995-2001 and were compared both with observed streamflow and with monthly mean or median flows obtained from the discharge record. The global climate model underestimated rainfall over almost all the basin, particularly in winter. However, it reproduced .the inter-annual variability in regional rainfall relatively well. Therefore, a statistical correction permitted to adjust rainfall with acceptable results. The corrected rainfall was transformed to flow by the hydrologic model, to forecast the Uruguay basin discharge. These forecasts resulted better than forecasts based on historic mean or median flows by 37 % for monthly flows, and by 54 % for three-monthly flows (Fig 11). This result indicates that there is a potential predictability on this basin, and that the CPTEC model correctly captures part of the interannual rainfall variability.

Therefore, the CPTEC model permits an appreciable improvement over Climatology in the Uruguay basin when its outcomes are combined with a hydrological model if its systematic errors are eliminated. However, its general good results on the Paraná basin, the CPETEC model fails to forecast a few cases associated to cold fronts (Fig 12). In this case, the precipitation anomaly was is the result of an ensemble of 11 (IRACEMA VERIFY) forecasts, some of which, indeed, capture the basic features of the maximum precipitation over southeastern South America (Fig.13). This seems to indicate that in certain occasions predominate unpredictable conditions.

4.4 Low frequency

Taken from Vargas, Minetti and Poblete 2002

Fig 14 shows the correspondence in low frequency between an EN index, the discharge at Corrientes that gathers the runoff of the Upper and Middle Paraná and the Paraguay basins and rainfall in one station of northwestern Argentina The figure seems to indicate that rainfall over the Paraná basin has a low frequency variability that is a feature of a larger regions of South America

4.5 Water availability in soil

Since 1998, CPTEC produce experimental soil water estimation for assessing critical areas of the Brazilian Northeast semi-arid. The purpose of this effort is to provide guidance for mitigation actions.

The model integrates meteorological and pedological information, incorporating climate and soil variability at a regional scale. It is based on a simple bucket that uses rainfall and potential evaporation as input variables. Meteorological data (from the synoptic network) are used to calculate potential evaporation. Potential transpiration is estimated using Penman-Monteith equation, according to FAO methodology (Tomasella et al 2000).

In mid 2001, an effort to apply and validate the model for Sourthern Brazil and Argentina begun under PROSUR. Because soil data was available for Buenos Aires province, the region was selected as a pilot area for model application.

Model parameters were derived from pedological data (soil surveys), using pedo-transfer functions. Pedo-transfer functions are statistical techniques for estimating the parameter of an analytical retention curve or the soil moisture at a specific potential from basic soil data. Knowing the soil water retention for each horizon of every soil profile, parameters such wilting point, field capacity, etc can be derived. Those parameters can be integrated along the profile to the root depth. Point information from soil profiles can be extended using interpolation techniques, incorporating (or not) grouping defined by soil maps.

In the pilot phase, soil water storage was estimated on a daily basis for a period 1970-1990. Meterological data came form the National Weather Service of Argentina and several sources in Brazil.

5. Capacity building

During the Project, the following training activities funded by PROSUR permitted the development of human resources.

Moira Doyle from UBA was trained in CPETEC in the use of the water balance model of soil under the direction of Xavier Tomasella.

Moira Doyle finished her Doctoral degree at the University of Buenos Aires funded by a IAI – PROSUR fellowship

José Luis Cabrera from the University of Asunción was trained in UBA during a short visit in the use of software for meteorological use (GRADS)

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6. Connections with other projects

CO-PIs participating in the Pilot Project undertake other initiatives in related subjects. In most of the cases, their participation in PROSUR helped to mature these joint initiatives:

- The program of Strategic Projects of the University of. Buenos Aires, starting in 2001 funded a limited number of projects (less than ten). The Project on Climate Change and Floods is one of them. The principal investigator is V. Barros and one of the CO-PIs is W. Vargas.
- The Project of START- TWAS : Assessment of impacts and adaptation to climate change in multiple regions and sectors (AIACC) funded a Project with CO-PIs of PROSUR. Is the AIACC Project ¨ The impact of global change on the coastal areas of the Rio de la Plata: Sea level rise and meteorological effects ¨. The Principal investigator is V. Barros and W. Vargas, R. Caffera and M. Bidegain participate as CO-PIs.
- A proposal for preparing a Technical Report entitled ¨ Trends in the hydrologic cycle of the Plata basin: Raising awareness and new tools for water management ¨ was submitted to the IAI SGPII. In this initiative participate all the PROSUR CO-PIs participating in the Pilot Project, namely Silva Diaz, R. Caffera, I. Cavalcanti, V. Barros, W. Vargas and G. Coronel. Other researchers related to the Pilot project also participate. They are I. Camilloni, J. Baez and L. Chamorro.
- PROSUR decided to start a Project on human dimensions with focus on the social and economic aspects of floods in the Paraná-Plata basin. This initiative made a proposal to the IAI SGPII.

JOSE y BIDEGAIN. Please add other initiatives

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TABLES

	Rainfall rate[1] over La Plata Basin (m^3	Streamflow ($m^3\ s^{-1}$)	Evaporation + Infiltration ($m^3\ s^-$
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 %

Table 1: Amplification of the climate signal. [1]For lack of available precipitation records north 20° S during the 1951-1970 period, rainfall rates over La Plata basin for this and for the 1980-1999 period were calculated only for the area south of this latitude.

Date and ENSO phase	Corrientes	Jupiá	Upper Middle Paraná contribution	Lower Middle Paraná contribution	Middle Paraná contribution	Puerto Bermejo
Jun 1983 Autumn (+)	38335	8505 (5360)	18058 (13331)	6121	24179	5635
Jun 1992 Autumn (+)	26787	470 (2502)	10530 (13301)	11322	21852	4449
D Dec 1982 Summer N	26131	4380 (2273)	9427 (9528)	7584	17011	4633
Mar 1983 Autumn (+)	24231	8368 (13224)	8756 (3648)	3763	12519	3354
Jun 1905 Autumn (+)	24153	N/A (N/A)	N/A (N/A)	N/A	N/A	N/A
May 1998 Autumn (+)	22999	380 (-994)	9421 (16284)	8631	18052	4559(*)
Oct 1998 Spring neutral	21006	794 (-434)	15206 (12250)	970	16176	4077(*)

Oct 1983 Spring neutral	20451	5914 (5359)	6363 (6968)	5980	12343	2235
Jul 1982 Winter (0)	18809	2907 (3664)	9154 (2939)	3566	12720	3145
Feb 1997 Summer neutral	17657	874 (7432)	12817 (-2023)	2204	15021	1776
Sep 1989 Spring neutral	16698	990 (1090)	8509 (4490)	3823	12332	3370
Sep 1990 Spring neutral	16410	869 (710)	7935 (5177)	5658	13593	1941
Jan 1912 Summer N	15946	N/A (N/A)	N/A (N/A)	N/A	N/A	N/A
Nov 1997 Spring (0)	15595	1072 (309)	9814 (9190)	1619	11433	3102
Jan 1966 Summer N	15424	3271 (2376)	2624 (3754)	6504	9128	3023
Sep 1957 Spring (0)	15033	1347 (877)	10331 (8449)	1327	11658	2022

Table 2. Major discharge anomalies (m^3/s) at Corrientes and the corresponding discharge anomalies at Jupiá and Puerto Bermejo and anomaly contribution to discharges (m^3/s) of the upper Middle, lower Middle and Middle Paraná. Previous month discharge or contribution anomaly is indicated in brackets. Summer N, stands for El Niño periods.

Date and ENSO phase	Upper Middle Paraná contribution	Jupiá	(Itaipú+Salto Caxias)
Jun 1983 Autumn (+)	18058	8505	26563
Apr 1998 Autumn (+)	16284	-994	15290
Oct 1998 Spring neutral	15206	794	16000
May 1992 Autumn (+)	13301	2502	15803
Feb 1997 Summer neutral	12817	874	13691
Jan 1995 Summer N	11473	-1344	10129
Oct 1935 Spring neutral	11176	1419	12595
Jan 1990 Summer neutral	10797	3901	14698
Sep 1957 Spring neutral	10331	1347	11678
May 1987 Autumn (+)	10180	1408	11581
Nov 1997 Spring (0)	9814	1072	10886
Oct 1972 Spring (0)	9592	2637	12229
Nov 1982 Spring (0)	9528	2273	11801
Jul 1982 Autumn (+)	9154	2907	12061
Mar 1983 Autumn (+)	8756	8368	17124
Sep 1989 Spring neutral	8509	990	9499
Sep 1990 Spring neutral	7935	869	8804
Oct 1993 Spring (0)	7850	924	8774

Table 3. As in Table 2, but for the major contributions to discharge anomalies (m^3/s) of the upper Middle Paraná and the corresponding discharge anomalies (m^3/s) at Jupiá and discharge contribution anomalies at (Itaipú + Salto Caixas).

Rank	Year	Month	ENSO phase	Duration	Discharge (10^3 m^3/s)

					Asunción	Asunción-Ladario	Ladario
1	1905	Jun	Niño (autumn +)	Mar-Sep	11.0	9.1	1.9
2	1983	Jun	Niño (autumn +)	Mar- Aug	10.7	8.1	2.5
3	1992	Jun	Niño (autumn +)	May-Jul	9.7	7.3	2.3
4	1988	Jul	Niña	Jun-Aug	8.6	6.0	2.6
5	1982	Jul	Niño	Jul-Oct	8.4	6.2	2.2
6	1919	Jun	Niño (autumn +)	Jun	8.3	7.1	1.1
7	1931	Jun	Niña	May-Jun	7.9	5.4	2.5
8	1979	Jun	Neutral	May-Aug	7.5	4.9	2.7
9	1998	May	Niño (autumn +)	May	7.4	6.4	1.0
10	1913	May	Niño	May-Jun	7.2	3.8	3.3
11	1983	Jan	Niño	Dec-Jan	7.1	6.0	1.2
12	1912	Jan	Niño	Dec-Jan	7.1	6.3	0.7
13	1985	Jun	Niña	May-Aug	7.0	4.2	2.8
14	1980	Jul	Neutral	Jul	6-5	4-2	2.3
15	1997	Dec	Niño	Dec	6-4	5.7	0.7
16	1965	Jun	Niño	Jun	6.4	5.2	1.2

Table 4: The major discharge peaks ordered according to Asunción discharges (1904-1998). Duration refers to the period with monthly discharges exceeding 6230 m³/s. Autumn + indicates the autumn of the year following the year of El Niño onset. Values in Ladario were taken a month before the monthly peak in Asunción.

Rank	Year	Month	ENSO phase	Duration	Discharge anomalies (10³ m³/s)		
					Asunción-Ladario	Asuncion	Ladario
1	1905	Jun	Niño (autumn +)	Dec-Dec	6.7	6.8	0.1
2	1983	Jun	Niño (autumn +)	Dec-Aug	5.8	6.5	0.7
3	1992	Jun	Niño (autumn +)	May-Jun	5.1	5.5	0.4
4	1919	Jun	Niño (autumn +)	Jun-Jul	4.8	4.1	-0.7
5	1912	Jan	Niño	Dec-Jan	4.5	4.4	-0.1
6	1982	Aug	Niño	Aug-Nov	4.4	4.9	0.5
7	1998	May	Niño (autumn +)	Mar-May	4.2	3.5	-0.7
8	1988	Jul	Niña	Jul-Sep	3.9	4.7	0.8
9	1931	Jun	Niña	Jun	3.1	3.7	0.6
10	1979	Sep	Neutral	Jul-Sep	3.0	3.3	0.3
11	1995	Feb	Niño	Feb	2.9	2.9	0
12	1908	Mar	Niña	Mar	2.9	2.5	-0.3
13	1920	Dec	Neutral	Nov-Dec	2.9	3.4	0.5
14	1965	Jun	Niño	Jun	2.9	2.2	-0.7
15	1956	May	Niña	May	2.8	2.2	-0.7
16	1989	Oct	Neutral	Sep-Oct	2.5	3.1	0.6
17	1980	Aug	Neutral	Aug	2.4	2.7	0.3

Table 5: As in Table 4, except that cases are ranked according to the anomalies of the discharge differences between Asunción minus Ladario. Only cases with this anomaly exceeding 2,400 m³/s, twice the standard deviation of the 1950/1990 period, was included. Duration refers to the period with the anomaly persisting over this value. Ladario discharges taken as in table 2

Date	Height (m)
16 April 1959	20.18
25 July 1983	17.85
16 April 1986	17.71
7 June 1992	17.71
19 June 1972	17.16
8 May 1983	16.91
10 January 1998	16.70
8 September 1972	16.43
26 April 1998	16.26
20 October 1997	16.01
17 November 1982	16.01
25 April 1987	15.91
13 November 1997	15.76
9 March 1998	15.59
18 October 1979	15.46
13 February 1998	15.33
9 November 1979	15.04
30 October 1954	14.63

Table 6. Greatest Uruguay River daily levels at Salto Grande during 1950-2000.

	Period before the flooding date		
	-12 to -9 days	**-8 to -5 days**	**-4 to -1 days**
Warm season events	41.7	33.3	47.2
Cold season events	50.0	22.2	55.6

Table 7. Relative frequency (%) of occurrence of SALLJ for three four-day periods before the flooding dates indicated in Table 1.