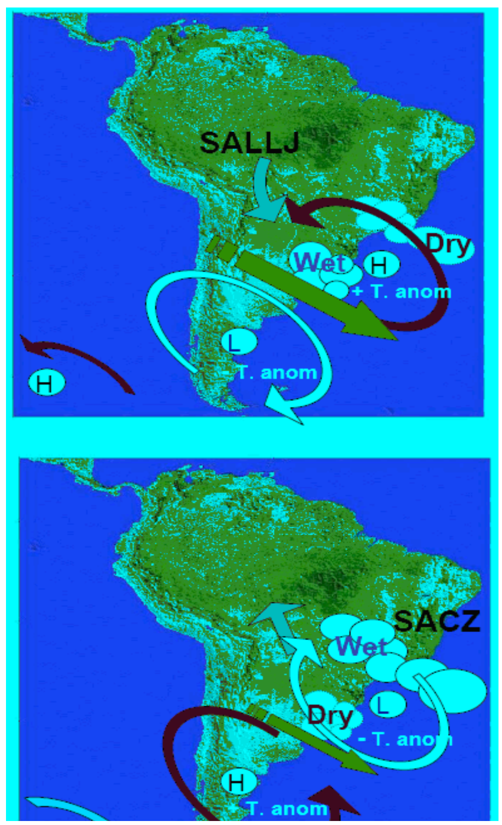
MONSOON EXPERIMENT IN SOUTH AMERICA (MESA)

Science Plan and Implementation Strategy



Prepared by the
MESA Scientific Working Group

April 2009

Cover: Typical circulation features of the SAMS accompanying wet and dry conditions over Southeastern South America and interaction between SACZ and the SALLJ (Diaz and Aceituno 2003)

MONSOON EXPERIMENT IN SOUTH AMERICA (MESA)

SCIENCE AND IMPLEMENTATION PLAN

(April 2009)

Members of the MESA Scientific Working Group

José A. Marengo	CCST/INPE, Brazil (Chair)
Tercio Ambrizzi	Universidade de São Paulo, Brazil
E. Hugo Berbery	University of Maryland, USA
Leila Vespoli de Carvalho	Universidade de São Paulo, Brazil
Alice Grimm	Universidade Federal do Paraná, Brazil
Vern Kousky	NCEP/NOAA, USA
Brant Liebmann	Climate Diagnostics Center, NOAA, USA
Ricardo Matano	Oregon State University, USA
Julia Nogues-Paegle	University of Utah, USA
Carlos Nobre	CPTEC/INPE, Brazil
Celeste Saulo	CIMA-Universidad de Buenos Aires, Argentina
Anji Seth	University of Connecticut, USA
Rafael Terra	Universidad de la República, Uruguay
Carolina Vera	CIMA-Universidad de Buenos Aires, Argentina
Ed Zipser	University of Utah, USA

Collaborators:

Paulo Nobre	CPTEC/INPE, Brazil
Maria A.F. Silva Dias	Universidade de São Paulo, Brazil

Members of the MESA Modeling and Data Assimilation Group

Iracema Cavalcanti	CPTEC/INPE, Brazil
Celeste Saulo	CIMA-Universidad de Buenos Aires, Argentina
Anji Seth	University of Connecticut, USA
Ben Kirtman	RSMAS, University of Miami USA
Vasubandhu Misra	Florida State University, USA

List of acronyms

ABRACOS	Anglo Brazilian Climate Observational Experiment
AGCM	Atmosphere General Circulation Model
AMIP	Atmospheric Model Intercomparison Program
AOGCM	Atmosphere Ocean General Circulation Model
AR4	IPCC Fourth Assessment Report
BARCA	Balanço de Agua Radiação e Carbono na Amazonia
CEOP	Coordinated Enhanced Observational Period
CIMA	Centro de Investigaciones del Mar y la Atmósfera
CIIFEN	Centro Internacional de Investigaciones sobre el Fenómeno El Niño
CLIVAR	Climate Variability and Predictability Program
CMIP	Coupled Model Intercomparison Program
CMORPH	CPC Morphing precipitation analysis technique
COLA	Center for Ocean Land and Atmosphere Studies
CPC	Climate Prediction Center (NOAA)
CPTEC	Centro de Previsão de Tempo e Estudos Climaticos
CSE	Continental Scale Field Experiment
ECMWF	European Centre for Medium Range Weather Forecast
ENSO	El Nino Southern Oscillation
GEF	Global Environmental Facility
GEWEX	Global Energy and Water Cycle Experiment
GHG	Greenhouse Gases
GHP	GEWEX Hydrometeorology Panel
GNP	Gross National Product
GPCP	Global Precipitation Climatology Project
GPCC	Global Precipitation Climatology Center
IPCC	Intergovernamental Panel on Climate Change
IAG	Instituto de Astronomia, Geofisica e Ciências Atmosfericas
INMET	Instituto Nacional de Meteorologia
IRI	International Research Institute for Climate and Society
ISO	Intraseasonal Oscillation
ISV	Intraseasonal Variability
ITCZ	Intertropical Convergence Zone
JOSS	Joint Office for Science Support
LBA	Large Scale Biosphere Atmosphere Experiment in Amazonia
LPB	La Plata River Basin Program
MCS	Mesoscale Convective System
MESA	Monsoon Experiment in South America
MJO	Madden Julian Oscillation
NAME	North American Monsoon Experiment
NAO	North Atlantic Oscillation
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Predictions
NMH	National Meteorological and Hydrological Services
NOAA	National Oceanic and Atmospheric Administration
OLR	Outgoing Longwave radiation

PACS	Pan American Climate Studies
PDO	Pacific Decadal Oscillation
PDF	Probability Density Function
PLATEX	La Plata Field Experiment
PRA	Priority Research Areas
PSA	Pacific South American Oscillation
PSAS	Physical Scheme Assimilation System
SACZ	South Atlantic Convergence Zone
SAMS	South American Monsoon System
SALLJ	South American Low Level Jet
SALLJEX	South American Low Level Jet Field Experiment
SESA	Southeastern South America
SIMEPAR	Sistema Meteorologico do Parana
SONET	Sounding Network
SSG	Science Steering Group
SST	Sea Surface Temperature
TRMM	Tropical Rainfall Mission Measurement
UCAR	University Corporation for Atmospheric Research
USP	Universidade de São Paulo
VAMOS	Variability of American Monsoon System
WGSIP	Working Group on Seasonal to Interannual Prediction
WCRP	World Climate Research Program

Executive Summary

This document constitutes the Science and Implementation plan of the Monsoon Experiment in South America (MESA). MESA is a component of the CLIVAR-VAMOS program, and its main goal is to investigate the main characteristics and variability of the South American Monsoon Systems (SAMS). The main hypothesis driving MESA is that SAMS provides a physical basis for determining the degree of predictability on short- and long timescales over the region. MESA's science agenda prioritizes research in monsoon evolution and variability that spans the diurnal, the mesoscale, the intraseasonal, the interannual and the longer time scale variabilities that is inclusive of the anthropogenic climate change. The main goal of MESA is to improve the current skills of simulating and predicting SAM at all spatio-temporal scales through improved understanding of this monsoon phenomenon. The objectives of MESA are to provide a detailed analysis of the temporal cycles of circulation and convection of the SAMS, the interaction amongst its circulation features, such as interactions between the SALLJ, ITCZ and the SACZ, and the dynamic implication of these interactions. In addition MESA has outlined to provide quantitative and qualitative estimates of the role of remote and local forcing on the SAMS that includes the role of the Andes, the land surface processes, aerosols from biomass burning, and the role of clouds .

These goals are to be accomplished by analysis of various levels of data sets, inclusive of global and regional reanalyses, local meteorological and hydrological network, remote sensing data, and output from regional and global climate models. MESA has a strong multinational scientific collaboration built from previous field experiments and international programs associated with the WCRP. In conclusion, we expect to improve the design and deployment of the observing system for monitoring and predicting the South American monsoon system that would allow for improving weather and climate models especially over the SAMS region.

Part 1: MESA Scientific Objectives

1.1 Presentation

The recent reports of the Third International Workshop on Monsoons held in 2004 (Chang et al. 2005), and of the First Pan-GEWEX monsoon workshop held in 2005 (Sperber and Yasunari 2006) have summarized the state of the art about the knowledge about monsoons worldwide. In some cases the monsoon is remarkably regular. For example, over India the interannual standard deviation of the rainfall is about 10% of the annual mean, but the perturbations are strong enough to lead to natural disasters resulting from flood or drought and the associated land-use impacts. During the course of the monsoon season there can also be strong variations in rainfall. Intraseasonal (30-60 day) variations (ISOs) influence the onset of the monsoon and give rise to protracted active (enhanced) and break (deficient) periods of rainfall. Foreknowledge of the active and break phases of the monsoon is important for crop selection, the determination of planting times and mitigation of potential flooding and short-term drought. Poor simulation of the ISO has been a pervasive problem in all scales of modeling. Though there are exceptions to this latter statement, attempts to translate "success" in simulating the ISO from one model to another have met with limited success at best. Additionally, the poor simulation of ISOs is a limiting factor for medium-range to seasonal forecasting. The success of empirical methods in forecasting intraseasonal variability indicates that there is skill to be gained through improved dynamical models.

Observational and modeling studies indicate that the diurnal cycle of radiative heating and surface fluxes over the ocean are rectified on to the intraseasonal timescale indicating that a synergistic approach to studying monsoon variability is necessary. The diurnal cycle of precipitation and clouds, which directly influence the radiative heating and surface fluxes, are also poorly represented, especially in global models. Thus, it is anticipated that improving the simulation of the diurnal cycle of precipitation and clouds in global models will contribute to an improved ability to simulate ISOs. Improved understanding and simulation of the diurnal cycle is also important since it influences low-level jets and the associated transport of moisture as well as the rainfall over regions of complex topography. Furthermore, from a physical standpoint, study and improved modeling of the monsoon is also important since the associated large-scale energy exchange due to the cycling of water vapor in the atmosphere is central to the development of the general circulation of the atmosphere.

Monsoon systems provide a framework for studies on the predictability of precipitation during the warm season, which greatly affects many human activities, including agriculture, water resource management, fire management, urban water use, etc. The life cycle and variations of the American monsoons are significantly influenced by many factors, including complex land surfaces such as major mountain chains, tropical forests and deserts, as well as climate variations in the adjacent Pacific and Atlantic Oceans.

1.1.2 Anticipated benefits and deliverables

CLIVAR studies of the Variability of the American Monsoon Systems (VAMOS) emphasize the interplay between the atmosphere, oceans and continental surfaces to improve understanding of:

- The American monsoon systems in the context of the global climate system
- The seasonal to interannual and interdecadal climate variability and predictability, and
- The impacts of anthropogenic climate change

VAMOS is organized as three integrated components that focus on different geographical regions but complement each other in scope: The North American Monsoon Experiment (NAME) is a joint CLIVAR-GEWEX Process Study aimed at determining the sources and limits of predictability of warm season precipitation over North America. The Monsoon Experiment in South America (MESA) is an internationally coordinated joint CLIVAR-GEWEX program aimed at providing:

1. a better understanding of the South American monsoon system and its variability,
2. a better understanding of the role of that system in the global water cycle,
3. improved observational data sets, and
4. improved simulation and prediction of the monsoon and regional water resources.

MESA deliverables include:

1. More comprehensive understanding of South American climate variability and predictability ;
2. Strengthened multinational scientific collaboration ;
3. Improved observing system design for monitoring and predicting the South American monsoon system;
4. Measurably improved weather and climate models that predict South American monsoon variability.

There are at least four reasons why MESA is relevant to the world:

1. In a globalized economy improving and understanding regional predictability, prediction and projection of climate becomes extremely relevant especially when a large area such as the South America is involved. A slump in the production of Soybean, corn, sugarcane production in South America as a result of climate anomalies for example, will have huge implication on the market driven economy around the world.
2. In the cause for sustainable development, building prediction systems from improved understanding for the prediction of natural calamities such as droughts, floods, heat waves at all temporal scales (from sub-seasonal to climate change scales) has a huge potential benefit to society. For the sake of world security, we can ill-afford yet another un-predicted natural calamity anywhere in the world. Modernization implores improved predictions.
3. There is growing evidence to show that improving model bias in one region has potential remote influences elsewhere. For example, there is evidence of relationship between the South American and the Indian monsoons. Similarly the SAM can be traced as part of the annual cycle of the monsoon of the Americas. Improving SAM variability may have implications on the neighboring large

subsidence (stratus) regions in the eastern Pacific which is a vexing problem for ENSO predictions.

4. The successes and failures of MESA can be related to other monsoon systems of the globe.

1.1.3 Milestones

The ultimate goal of MESA is to obtain an integrated view of the American Monsoon Systems, related inter-hemispheric connection, monsoon predictability and prediction. To accomplish this MESA has implemented a time table that contemplates the MESA milestones presented at the recent 9th VAMOS Panel in April 2006. Section 3.6 will detail the milestones by Fiscal Year. Some of these milestones have been accomplished after the SALLJEX field experiment in 2003, in the form of new developments from the observational, theoretical and modeling point of view, while others are to be accomplished after the La Plata Basin's PLATEX field experiment in 2009 (see section 6.3).

1. Better observational evidence of structure and variability of the SALLJ
2. Quantitative information of the model errors in SALLJEX
3. Evaluation of impact of SALLJEX data on analysis and forecasts using data assimilation
4. Confirmation about the ability of the models to reproduce some of the elements of the low-level circulation of the SAMS
5. Assessment of Seasonal prediction simulations in the SAMS region
6. Simulation for SALLJEX period.
7. Predictability of the SAM associated with Atlantic SST simulations.
8. Development of MESA climate indices
9. Assessment of extreme event frequency changes in the regional climate change scenarios for South America and their impact on agricultural activities.
10. Preparation of LPB science plan and LPB CSE monitoring activities.
11. Evaluate the impact of soil moisture in simulations and predictions.
12. Hydrological studies of LPB's PLATEX data

1.1.4 Endorsements and synergies

MESA has become an integral component of various large scale projects currently ongoing in South America, such as the Large Scale Biosphere Atmosphere Experiment in Amazonia (LBA) and the La Plata Basin project (LPB). There are also strong connections between MESA and the World Climate Research Programme (WCRP) Global Energy and Water Cycle Experiment (GEWEX), and the Coordinated Energy and Water Cycle Observations Project (CEOP). The CEOP Inter-Monsoon Model Study (CIMS) is concerned with inter-monsoon comparisons and interconnections; and a new focus on aerosol-monsoon water cycle interaction. MESA and CEOP-CIMS are complementary to the ocean-atmosphere approach from CLIVAR.

Through the efforts of CLIVAR and GEWEX, WCRP has played a major role in launching studies in other monsoon areas (e.g., Africa, America) as well as expanding the scope of studies in eastern Asia through the GEWEX Asian Monsoon Experiment

(GAME) and the SCMEX (South China Sea Monsoon Experiment. GAME and the other regional monsoon experiments: the North American Monsoon Experiment (NAME), the Monsoon Experiment South America (MESA), and in the La Plata Basin (LPB), and more recently the African Monsoon Multidisciplinary Analysis (AMMA); all had distinctly regional approaches to the problem. GAME finished in March 2005 and a new international program in Asia, MAHASRI (Monsoon Asian Hydro-Atmosphere Scientific Research and Prediction Initiative) has been implemented focusing on establishing scientific basis for predicting hydro-climate monsoon system with intraseasonal to seasonal time-scale, including developing warning systems for droughts and flood conditions of regional or river-basin scales. With the emergence of the Coordinated Enhanced Observing Period (*CEOP*) and the *CEOP* Inter-Monsoon Model Study (CIMS), monsoons began to be analyzed within a global framework.

The monsoon research of GEWEX and CLIVAR have made many contributions to our understanding of these phenomena both on the regional and the global scale. A decision within WCRP endorses the bi-lateral project approach between GEWEX and CLIVAR as the primary mechanism for coordinating WCRP monsoon efforts, under the name of Pan-WCRP Monsoon activities, from which MESA, as well as NAME and all the other regional monsoon panels will work together towards an implementation of coordinated monsoon activities on behalf of WCRP.

References:

Chang, C.-P., B. Wang, and N.-C. G. Lau, 2005: The Global Monsoon System: Research and Forecast, WMO/TD 1266 - TMRP 70, 542 pp. Available at http://www.wmo.int/web/arep/tmrp/REPORTS/global_monsoon_system_IMW3.pdf

Sperber, K., and Yasunari, T, 2006: The 1st Pan-WCRP Workshop on Monsoon Climate Systems: Toward Better Prediction of the Monsoons WCRP Informal Report No.2/2006 ICPO Publication Series No.103, IGPO Publication Series No.38, 48 pp.

Part 2: Scientific Rationale

The main hypothesis driving MESA is that: *The SAMS provides a physical basis for determining the degree of predictability on short- and long timescales over the region.* To accomplish this, MESA has identified some PRIORITY RESEARCH AREAS (PRA) for the better understanding and simulation of:

- PRA-1 diurnal and mesoscale processes
- PRA-2 intraseasonal variability
- PRA-3 interannual and longer time variability, including anthropogenic climate change
- PRA- 1, 2, 3 monsoon evolution and variability

MESA is directed towards a better understanding and improved simulation of:

- Diurnal cycle and seasonal evolution of the SAMS
- 3-dimensional description of the low-circulation east of the Andes.
- Mesoscale convective processes
- Role of aerosols from biomass burning due to land use change in SAMS
- Dynamics of the SA see-saw pattern
- ITCZ-SACZ interaction
- Interaction between SAMS and the stratocumulus cloud deck over the SE Pacific.
- Summertime convection and circulation over the Altiplano (Central Andes)
- Influence of MJO on SAMS
- Relative roles of internal versus forced low-frequency variability
- Relative roles of remote and local forcing (SST, land surface, topography)
- Land surface forcing – Impacts of land use change
- Global response to SAMS forcing
- Sources and limits of predictability on SAMS region

These will be accomplished by combining intensive observational monitoring data with a modeling strategy directed to simulate improvements in the depiction of SAMS characteristics and variability. The modeling strategy is explained in 3.4, but can be summarized as the following modeling issues:

- To what extent do model systematic errors affect seasonal predictability in the region?
- Why do models have deficiencies in reproducing the SACZ? Missing coupled atmospheric/ ocean and/ or biosphere/ atmosphere mechanisms in the AGCMs?
- Will seasonal predictability change as a function of land cover changes?
- Can soil moisture memory help seasonal predictions for South America? Need to improve soil moisture observations and soil moisture initialization in forecast models.
- In dealing with the complexities of orography, are higher resolution models the more robust numerical methods in steep orography and/or dowscaling?
- How to improve the Atlantic SST forcing in terms of tropical versus extratropical contributions.

- How can intraseasonal variability in the SAMS be improved in the models? Can intraseasonal oscillations be a source of short term climatic predictability?
- Can we expect that model improvements and observational techniques will improve predictability in regions such as the highly populated and economically important cities in the SAMS region?

Part 3: The MESA Program

3.1 PRAs Framework

3.1.1 The Life Cycle of the South American Monsoon System (V. Kousky)

3.1.1.1 Scientific Background

The annual cycle of precipitation, over tropical South America, features distinct wet and dry seasons between the equator and 25ºS. Many areas within that region receive more (less) than 50% (5%) of their total annual precipitation during the austral summer (winter) (Fig. 1). During the wet season an upper-tropospheric anticyclone dominates the circulation over tropical and subtropical South America, while cyclonic circulation dominates the upper-tropospheric circulation over low latitudes of the eastern South Pacific and central South Atlantic (e.g., Virji 1981; Kousky and Ropelewski 1997) (Fig. 2, top panel). Prominent low-level features (Fig. 2, bottom panel) include: 1) surface high pressure systems and anticyclonic circulation over the subtropical oceans (Pacific and Atlantic), 2) a surface low-pressure system (Chaco Low) centered over northern Argentina, and 3) a low-level northwesterly flow (low-level jet) extending from the southwestern Amazon to Paraguay and northern Argentina. Throughout the region one notes a reversal of circulation features between the lower troposphere and the upper troposphere (Fig. 2, compare bottom and top panels), which is a typical feature of the global Tropics.

The annual cycle of upper-tropospheric circulation features over South America is intimately linked to the seasonally varying horizontal temperature gradients, which arise from differential heating due to the difference in thermal capacity between land and water. During summer, temperatures over the continent become warmer than the neighboring oceanic regions. This results in a direct thermal circulation with low-level (upper-level) convergence (divergence), mid-tropospheric rising motion and precipitation over the continent, and low-level (upper-level) divergence (convergence), mid-tropospheric sinking motion and dry conditions occur over the neighboring oceanic areas (Fig. 3, left panels). These features are typical of summertime monsoons. During winter, temperatures over the continent and nearby oceanic regions are more uniform, which gives rise to a more zonally symmetric upper-tropospheric circulation pattern over the region and little or no evidence of any east-west direct thermal circulation (Fig. 3, right panels).

The development of the South American warm season Monsoon System during the austral spring is characterized by a rapid southward shift of the region of intense convection from northwestern South America to the southern Amazon Basin and Brazilian highlands (altiplano) (Fig. 4) (e.g., Kousky 1988; Horel et al. 1989; Marengo et al. 2001; Gan et al. 2004). Deep convection increases over the western Amazon Basin in September and subsequently expands southward and southeastward, reaching central Brazil in October and Southeast Brazil in November (Fig. 4). Surface (2-meter) temperatures reach their annual maximum over the southern Amazon and altiplano region in early September, just prior to the onset of the rains (Fig. 5). Transient synoptic systems at higher latitudes play an important role in modulating the southward shift in convection. Cold fronts that enter northern Argentina and southern Brazil are frequently accompanied by enhanced deep convection over the western and southern Amazon and an increase in the southward flux of moisture from lower latitudes. These cold fronts are also important in the formation, intensity and position of the South Atlantic Convergence Zone (SACZ) (e.g., Liebmann et al. 1999), which becomes established in austral spring over Southeast Brazil and the neighboring western Atlantic (e.g., Casarin and Kousky 1986; Kousky 1988) (see Fig. 4, middle column). During spring an upper-tropospheric anticyclone (Bolivian High) becomes established near 15ºS, 65ºW (Fig. 4), as the monsoon system develops mature-phase characteristics. Upper-level troughs and dry conditions are found over oceanic areas to the east and west of the Bolivian High. The deep convection over central Brazil and the Bolivian High reach their peak intensities during December-March. These features shift northward and weaken during April and May, as the summer monsoon weakens and a transition to drier conditions occurs over subtropical South America.

3.1.1.2 Scientific questions:

1) What are the leading processes controlling the seasonal evolution of the SAMS and the SACZ?

2) What is the role of transients (e.g., extratropical frontal systems) in the evolution (development and decay phases) of SAMS and in the development, position and intensity of the SACZ?

3) What is the relative role of the local versus remote forcing in driving the seasonal evolution of the SAMS and the SACZ?

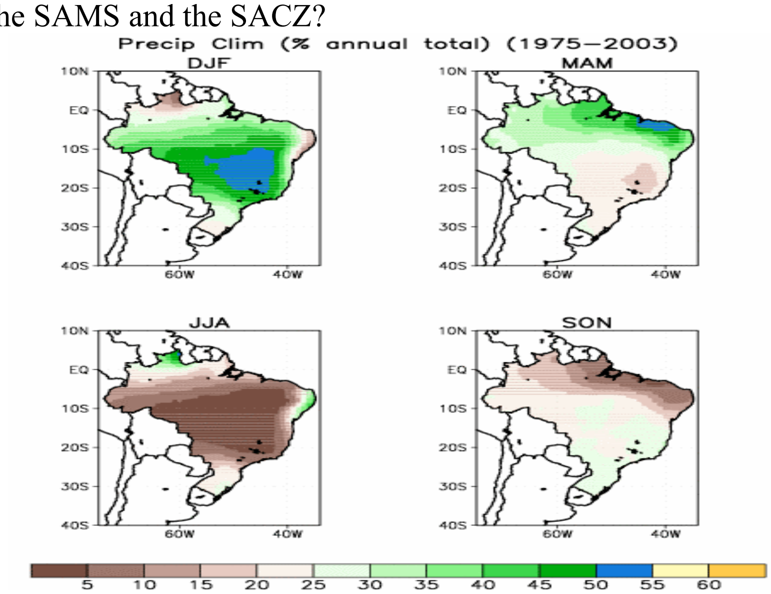


Figure 1. Percent of mean (1975-2003) annual precipitation for each season. Data are derived from gridded daily precipitation analyses available from the Climate Prediction Center.

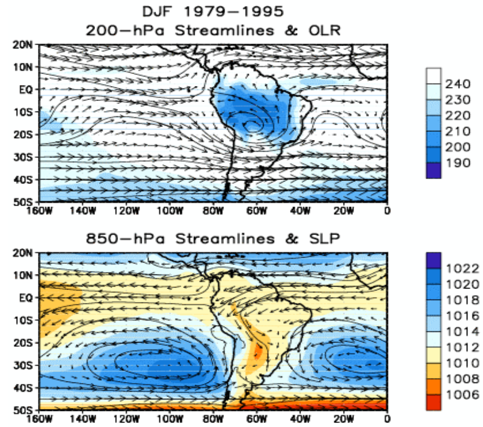


Figure 2. Mean (1979-1995) 200-hPa vector wind/ streamlines and outgoing longwave radiation (OLR) (top) and 850-hPa vector wind/ streamlines and sea level pressure (SLP) (bottom). Units are W m^{-2} for OLR and hPa for SLP. Circulation data are derived from the NCEP/ NCAR CDAS-Reanalysis data archive.

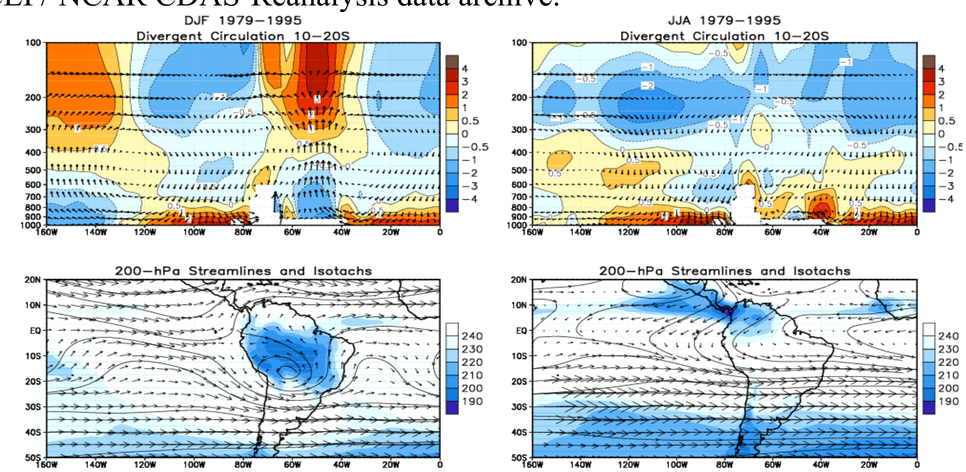


Figure 3. Vertical-longitude cross-section of the mean (1979-1995) divergent circulation (vectors) for the latitude band 10º-20ºS (top panels) and mean (1979-1995) 200-hPa vector wind/ streamlines and OLR (bottom panels) for December-February (left panels) and June-August (right panels). Units are 10^{-6} s^{-1} for divergence (contours and shading in top panels) and W m^{-2} for OLR (shading in bottom panels).

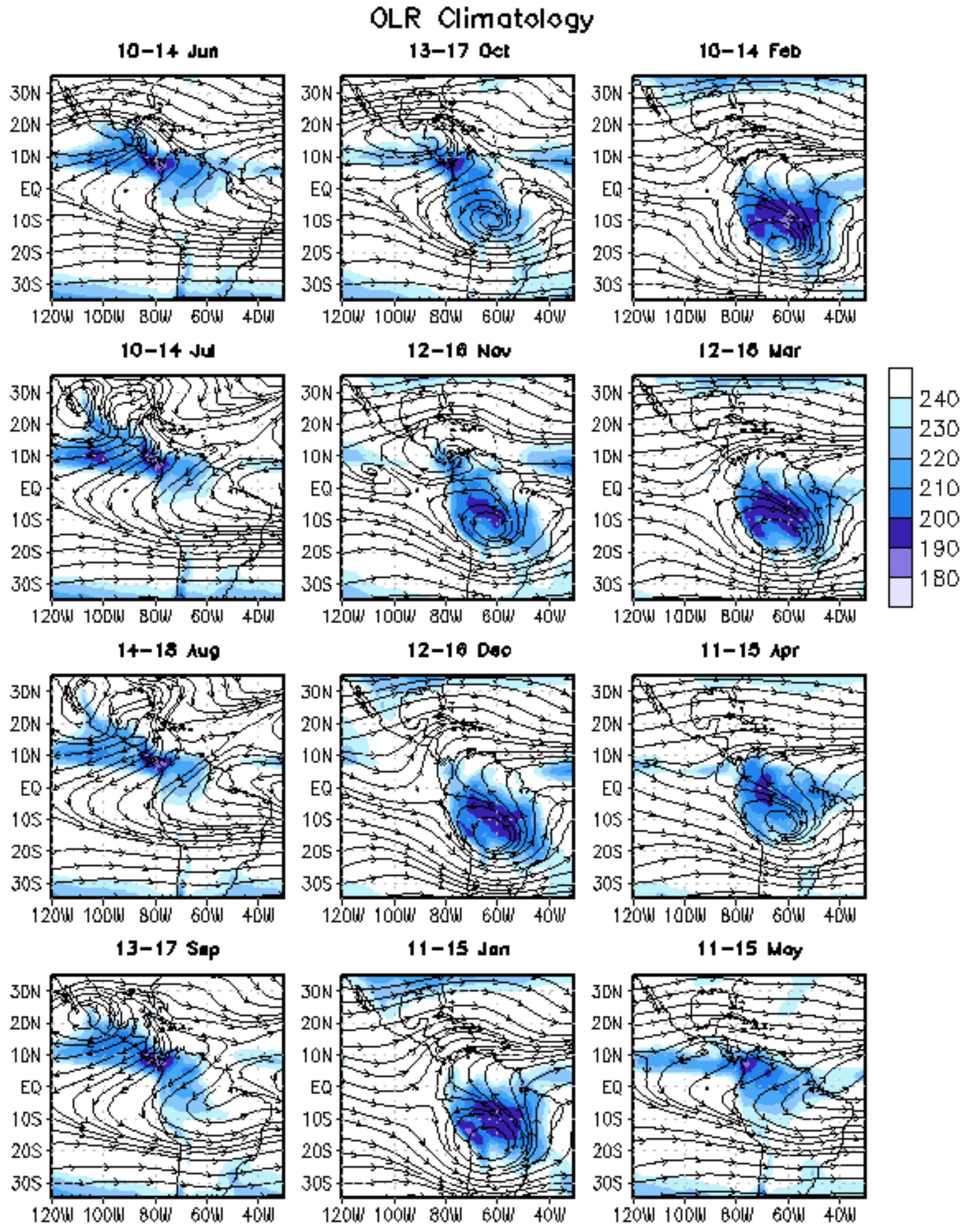


Figure 4. Mean (1979-1995) seasonal cycle of OLR and 200-hPa streamlines. Units for OLR are W m^{-2}. Low values of OLR indicate cold cloud tops (deep convection) in the Tropics.

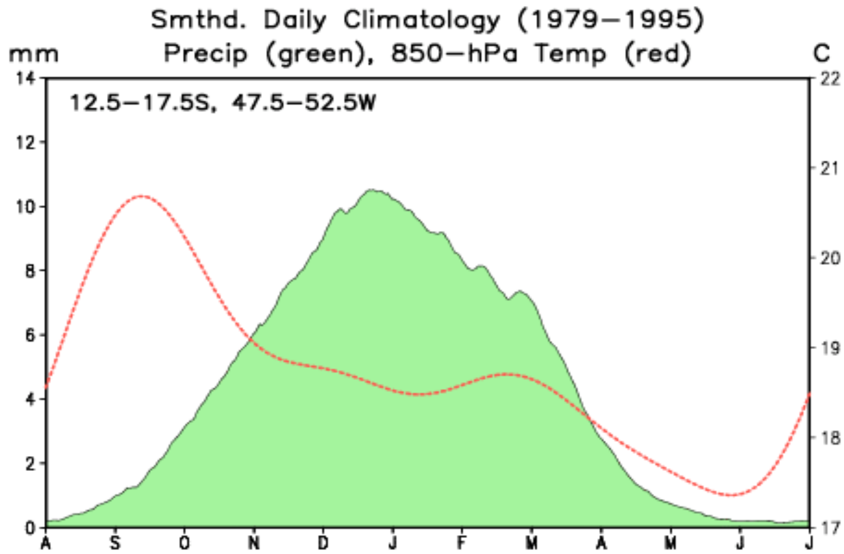


Figure 5. Mean (1979-1995) daily precipitation (mm) for central Brazil (12.5º-17.5ºS, 47.5º-52.5ºW (shaded in green), 850-hPa temperature (degrees C, red curve, top panel), and 850-hPa zonal wind (mm s^{-1}, red curve, bottom panel).

References:

Casarin, D. P. and V. E. Kousky, 1986: Anomalias de precipitação no sul do Brasil e variações na circulação atmosférica (Precipitation anomalies over Southern Brazil and variations in the atmospheric circulation). *Rev. Bras. Meteor.*, **1,** 217-231.

Gan, M. A., V. E. Kousky, and C. F. Ropelewski, 2004: The South America monsoon circulation and its relationship to rainfall over west-central Brazil. *J. Climate*, **17**, 47-66.

Horel, J. D., A. N. Hahmann, and J. E. Geisler, 1989: An investigation of the annual cycle of convective activity over the tropical Americas. *J. Climate*, **2**, 1388-1403.

Kousky, V. E., and C. F. Ropelewski, 1997: The tropospheric seasonally varying mean climate over the western hemisphere (1979-1995). NCEP/Climate Prediction Center ATLAS, No. 3, Washington, 135pp.

Liebmann, B., G. N. Kiladis, J. A. 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.

Marengo J. A., B. Liebmann, V. E. Kousky, N. P. Filizola, and I. C. Wainer, 2001: Onset and end of the rainy season in the Brazilian Amazon basin. *J. Climate*, **14**, 833-852.

Virji, H., 1981: A preliminary study of summertime tropospheric circulation patterns over South America estimated from cloud winds. *Mon. Wea. Rev.,* **109**, 599-610.

3.1.2 **Diurnal and mesoscale variability** (C. Saulo, E. Zipser, R. Terra)

3.1.2.1 Scientific background

The diurnal cycle is a dominant feature in South America as in every other monsoon system. However, there are a number of characteristics unique to the SAMS case. The very wide and wet continental land mass over the equatorial region sustains a diurnal regime of convection that is quite distinct to that over drier land but still very well defined and controlled by the land surface characteristics. The large magnitude of the Amazon and Central Brazil heat sources during the Southern Hemisphere summer drives significant responses in the vertical circulation in adjoining regions as shown by Silva Dias et al. 1987 and Figueroa et al. 1999). The nighttime peak of precipitation in northern Argentina, northwestern South America, along the Atlantic ITCZ and off the coast of southeastern Brazil along the SACZ may be controlled by the very strong late afternoon and early evening peak of the convective activity over the tropical sector of the continent and/or may be modified by the nocturnal peak in the SALLJ (Nicolini and Saulo 2006), which in turn feeds most of the MCSs observed during the warm season (Salio et al., 2007)

There are clear features that drive most of the diurnal oscillations over SAMS region: the SALLJ, the orographic effect and land-sea breezes and wet areas, which in conjunction with the solar cycle are responsible for the observed diurnal cycle of convection. The interaction between these features and precipitation are enormous challenges to the understanding and, consequently, the prediction, of the SAMS.

Numerical analysis and modeling of rainfall variability in the SAMS are limited by the capability of the models to simulate the physics of the rain-producing weather systems.

The diurnal pulse of convection over the wet Amazonian region has proven a challenge for the parameterization of cumulus convection in numerical climate models. The daily amplitude in soil temperature is small, unlike over drier land, but not negligible as is usually the case over the ocean.

The appropriate representation of land-surface and Planetary Boundary Layer turbulence processes are key to the correct simulation of shallow cumulus activity and the daily transition to deep penetrative convection. Current convective parameterizations do not quite reproduce the observed diurnal cycle over the Amazon. This can have serious consequences in the regional climate since the strong diurnal pulse over this large region are thought to condition other large-scale components of the SAMS system like the SACZ (Figueroa et al. 1995) or the subsidence regime over the Eastern Pacific (Bretherton et al., 2004). Diurnal variability is dominant over mesoscale phenomena in the Central Amazon although westward moving squall lines initiated near the Atlantic coastline are known to develop (e.g., Kousky 1980; Garreaud and Wallace 1997; Janowiak et al. 2005). It has also been suggested that deforestation patterns may induce mesoscale circulations that can affect convective triggering (Avissar et al. 2002).

One strong limitation to document mesoscale circulations that may exhibit a diurnal oscillation is the lack of observations with adequate temporal and spatial resolution. The LBA campaign has been helpful over the Amazon region to provide insight on this issue On the other hand SALLJEX (Vera et al. 2006) has provided a unique opportunity to illustrate the characteristics of the diurnal cycle of the SALLJ. Nicolini et al. (2004) using pibals and radiosonde data at various sites, confirm that the

wind hodographs reveal an oscillation consistent with PBL-related processes (i.e. diurnal cycle of friction and differential heating over sloping terrain) though the oscillation does not show a regular cycle. A nighttime maximum of wind speeds has also been verified.
The nature of the diurnal cycle is quite different in subtropical South America, where the role of mesoscale convective systems (MCSs) becomes dominant, at least from a precipitation point of view. Zipser et al. (2006) point out that we need to simulate not only average rainfall and its seasonal and diurnal distribution, but in addition, to distinguish the nature of the convective storms that produce the rainfall.

There are major, systematic, regional differences in the structure, intensity, and diurnal cycle of rainfall systems. The La Plata Basin (LPB) in SESA is particularly dominated by large and intense mesoscale convective systems (MCSs). In contrast, the rainfall in the Amazon Basin comes partly from smaller MCSs and partly from frequent showers and thunderstorms.

Nesbitt and Zipser (2003) show that regional rainfall over subtropical South America for MCS precipitation features exhibits a sharp maximum by 07 local time, while this maximum shifts to 15 local time for precipitation features without ice scattering. Looking at the diurnal cycle of the cold-cloud shield associated with a set of MCSs identified during two warm seasons, Nieto Ferreira et al (2003) find a single broad maximum that occurs between the nighttime and the early morning hours.

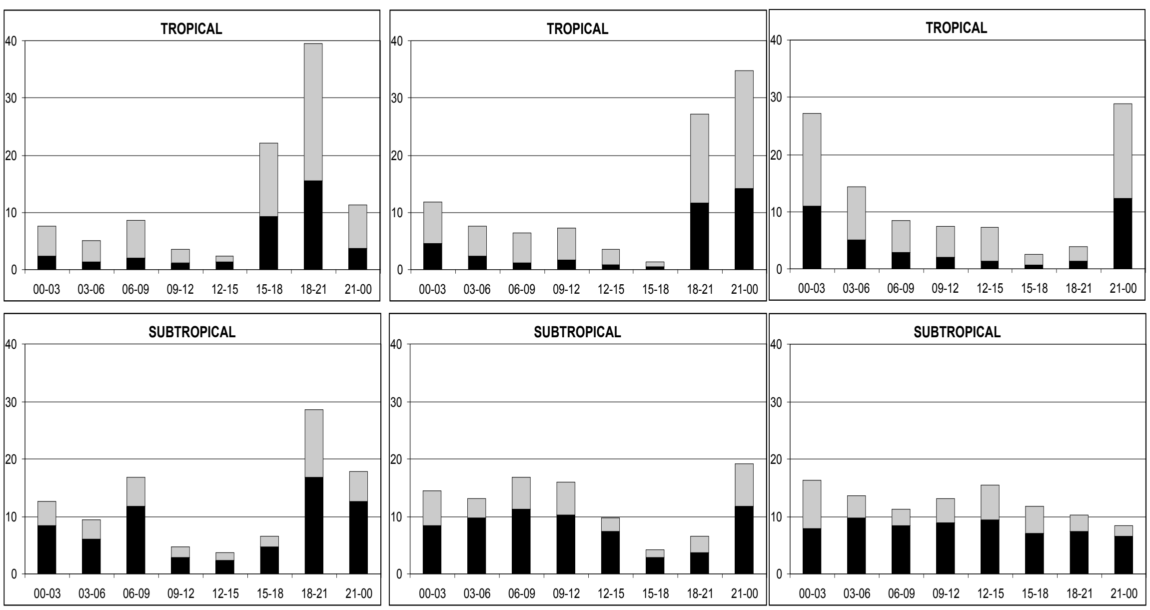


Figure 6: Frequency distributions in percent of MCSs for SALLJ (dark gray) and NOSALLJ (light gray) samples of (left) initiation, (middle) maximum extent, and (right) dissipation time in UTC. (from Salio et al., 2007)

Many authors suggested that this nocturnal maximum in precipitation over Southeastern South America (SESA) could be related to the low level jet (Berbery and Collini, 2000, Nicolini et al., 2002, Salio et al., 2002 among others) and to the valley circulation in the Paraguay/Paraná river. Salio et al. (2007) using TRMM data, showed that the MCSs that have a nocturnal – early morning maximum (0130UTC- 1030UTC) – fig. 6- are co-located with the exit region of strong low level jet episodes. Figure 7 shows the regional variability in the diurnal cycle of precipitation resulting from the composite of strong low level jet events (Chaco Low-level jets, CJE).

Abrupt changes in the diurnal cycle of convection also occur in the west-east direction and over relatively small distances. An example of significant changes in the diurnal cycle of convection over the Altiplano has recently been shown by Falvey and Garreaud (2004). A distinctive climatic feature of the Altiplano is the vigorous afternoon convection between December and March, that contributes more than 90% of the annual precipitation (Aceituno, 1997). Recent analysis of equivalent black body temperature (*Tbb*) from GOES data during SALLJEX period (Falvey and Garreaud 2004), suggests that this maximum convective activity may not be related to the same synoptic regime at different areas over the Altiplano: the behavior documented in a large area including the western and southern Altiplano (Garreaud 1999) seems to be different to the convection regime that appears to operate in the northeastern Altiplano (Lake Titicaca basin and mountains to the north).

The aforementioned issues clearly indicate not only the relevance of the diurnal cycle for a better understanding of the SAMS, but also the necessity of an assessment of its impact with a detailed spatial resolution, so as to capture the important changes in regimes.

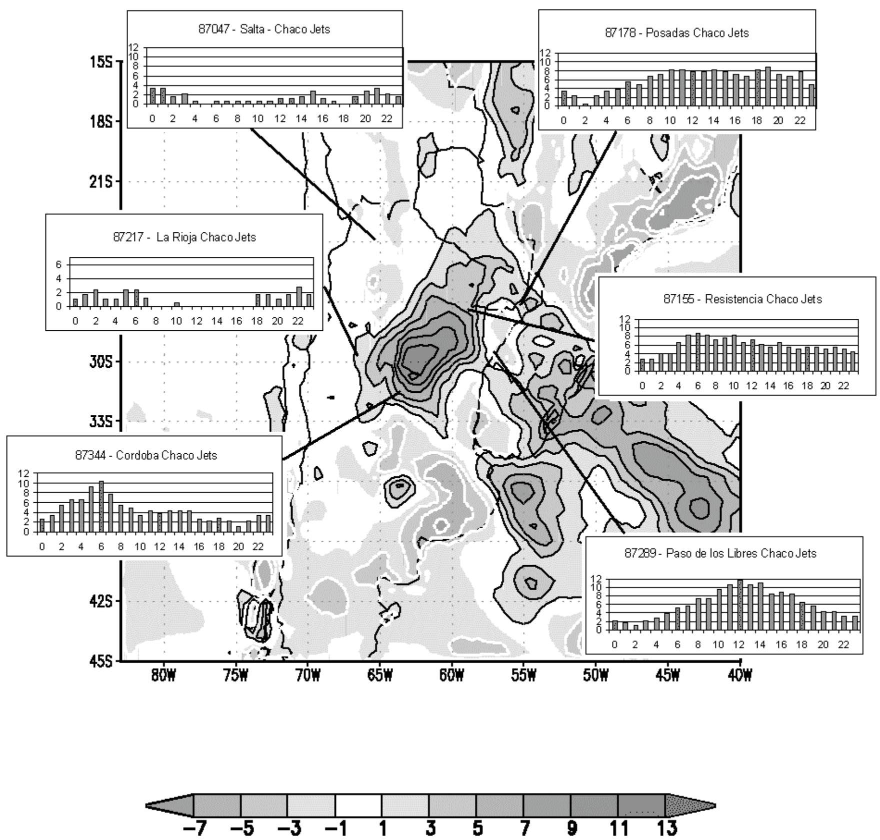


Figure 7: Nighttime (0600–1200 UTC) minus daytime (1800–0000 UTC) Eta/CPTEC model mean precipitation (mm day $^{-1}$) during the 1997–1998 warm season. Diagrams show the hourly frequency of occurrence of convection – per season – during CJE at selected stations, derived from the hourly weather report (from Nicolini and Saulo, 2006)

3.1.2.2 Scientific objectives

The main objective is to identify and quantify the diurnal cycle of precipitation associated with the main precipitation regimes documented over SAMS

3.1.2.3 Science questions:

In order to make progress in some key issues related to the diurnal cycle and mesoscale variability over SAMS, it is suggested to address the following specific questions

1) Which are the main processes underlying the identified diurnal cycles in different areas of the SAMS?

2) Is the e physics of rainfall processes in different portions of the SAMS relevant for the diurnal variability?

3) To what extent and through which mechanisms does soil hydrology affect the diurnal cycle?

4) How does the diurnal cycle relate to the lower-frequency variability and the mean of the SAMS and therefore to seasonal and longer predictability?

3.1.2.4 Actions

In order to accomplish the specific questions raised, the following are the recommended activities:

-Collection of high resolution (both spatial and temporal) precipitation and convection data sets. While the latter are available, the variety of techniques and algorithms used, make comparisons difficult. On the other hand, although there are sparse precipitation observations, there are increasing amounts of derived-precipitation data (proxies for precipitation) that need to be validated.

-Comparison of various rainfall estimation algorithms so that biases in the proxies are identified

-Use of models to analyze the main processes driving the observed diurnal cycle. Resolution is crucial for the ability to simulate MCSs. Very high resolution (i.e., 3 km grid size or smaller) experiments are needed to get a better picture of the organizational characteristics of MCS.

With regard to regional/weather/climate models and their ability to capture the diurnal cycle, the following recommendations arise:

- *The diurnal cycle is a basic climatic feature* in the consideration of all other scales (i.e. resonance with intraseasonal). A correct value for the annual mean may sometimes be obtained for the wrong reasons. The current status of the diurnal cycle in existing models should be documented through a small diagnostic project, with runs already available, and then perform new runs. (WGCIP can help on that.)
- The simulation of MCS necessarily requires a firm understanding of the close interaction between parameterized convective fluxes, including the momentum ones, and mesoscale circulations that are explicitly resolved by the model's dynamics. Basic research is needed to address this issue and determine the resolution required to successfully simulate the relevant dynamics. This effort has to be accompanied by observational studies that could improve our understanding of MCSs and provide the observational and reanalyses datasets required to guide the modeling work.

References

Aceituno, P., 1997: Climate elements of the South American Altiplano. Rev. Geofis., 44, 37-55.

Avissar, R., Silva Dias, P. L.; Silva Dias, M. A. F.; Nobre, C. The Large-Scale Biosphere-Atmosphere Experiment in Amazonia (LBA): Insights and future research needs. J. Geophys. Res. 107, D20, LBA, pp. 54.1-54.6 , 2002.

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

Bretherton, C. S., T. Uttal, C. W. Fairall, S. Yuter, R. Weller, D. Baumgardner, K. Comstock, R. Wood, and G. Raga, 2004: The EPIC 2001 stratocumulus study. Bull. Amer. Meteor. Soc., 85, 967-977.

Falvey, M., and R. Garreaud, 2004: Variability of Moisture and Convection over the Central Andes during SALLJEX. CLIVAR-Exchanges, 9, 11-13.

Figueroa, S., P. Satyamurti, and P. L. Silva Dias, 1995: Simulation of the summer circulation over the South America region with an eta coordinate model. J. Atmos. Sci., 52, 1573-1584.

Garreaud, R. D., 1999: Multi scale analysis of the summertime precipitation over the Central Andes. Mon. Wea. Rev., 127, 901 – 921.

Garreaud, R. D., and J. M. Wallace, 1997: The diurnal march of convective cloudiness over the Americas. Mon. Wea. Rev., 125, 3157-3171.

Janowiak, J. E., V. E. Kousky, and R. J. Joyce, 2005: Diurnal cycle of precipitation determined from the CMORPH high spatial and temporal resolution global precipitation analyses. *J. Geophys. Res*., **110**, D23105, doi:10.1029/2005JD006156.

Kousky, V. E., 1980: Diurnal rainfall variations in Northeast Brazil. *Mon. Wea. Rev*., **108**, 488-498.

Misra, V., 2005: Simulation of the intraseasonal variance of the south American summer monsoon. Mon. Wea. Rev., 133 (3), 663-676.

Nesbitt, S. W., and E. Zipser, 2003. The diurnal cycle of rainfall and convective intensity according to three years of TRMM measurements. J. of Climate, 16, 1456-1475.

Nicolini, M., Salio, P., Ulke, G., Marengo, J., Douglas, M., Paegle, J. and Zipser, E., 2004: South American Low Level Jet Diurnal cycle and Three Dimensional Structure. CLIVAR-Exchanges, 9, 6-8.

Nicolini, M., A. C. Saulo, J. C. Torres, and P. Salio (2002) Strong South America low-level jet events characterization during warm season and implications for enhanced

precipitation. Meteorologica Special Issue on South American Monsoon Systems, 27, Nº1-2, 59-69.
Nieto Ferreira R, Rickenbach TM, Herdies DL, Carvalho LM (2003) Variability of South American convective cloud systems and tropospheric circulation during January–March 1998 and 1999. Mon Wea Rev 131: 961–973
Salio, P., M. Nicolini, and A. C. Saulo (2002), Chaco low-level jet events characterization during the austral summer season, J. Geophys. Res., 107(0), 32-1 32-17, doi:10.1029/2001JD001315.
Salio, P., M. Nicolini, and E.J.Zipser, (2007) Mesoscale convective systems over southeast South America and their relationship with the South American Low- Level Jet. Mon. Wea. Rev., in press.
Nicolini, M. and A. C. Saulo, 2006: Modeled Chaco low-level jets and related precipitation patterns during the 1997-1998 warm season. Met. and Atmos. Phys., 94, 1-4, 129-143. (DOI: 10.1007/s00703-006-0186-7)
Silva Dias, P. L., J. P. Bonatti and V. E. Kousky, l987: Diurnally forced tropical tropospheric circulation over South America. Mon. Wea. Rev.,115,1465-1478.
Vera, C.; J. Baez; M. Douglas; C. B. Emmanuel; J. Marengo; J. Meitin; M. Nicolini; J. Nogues-Paegle; J. Paegle; O. Penalba; P. Salio; C. Saulo; M. A. Silva Dias; P. Silva Dias; and E. Zipser, 2006. The South American Low-Level Jet Experiment (SALLJEX). Bull. Am. Met. Soc , Vol. 87, No. 1, pp. 63–77
Zipser, E.J., D.J.Cecil, C.Liu, S.W.Nesbitt, and D.P.Yorty, 2006: Where are the most intense thunderstorms on earth? Bull. Amer. Meteor. Soc., 87, 1057-1071
Salio, P., M. Nicolini, and A. C. Saulo (2002), Chaco low-level jet events characterization during the austral summer season, J. Geophys. Res., 107(0), 32-1 32-17, doi:10.1029/2001JD001315.
Salio, P., M. Nicolini, and E.J.Zipser, (2007) Mesoscale convective systems over southeast South America and their relationship with the South American Low- Level Jet. Mon. Wea. Rev., in press.
Silva Dias, P. L., J. P. Bonatti and V. E. Kousky, l987: Diurnally forced tropical tropospheric circulation over South America. Mon. Wea. Rev.,115,1465-1478.
Vera, C.; J. Baez; M. Douglas; C. B. Emmanuel; J. Marengo; J. Meitin; M. Nicolini; J. Nogues-Paegle; J. Paegle; O. Penalba; P. Salio; C. Saulo; M. A. Silva Dias; P. Silva Dias; and E. Zipser, 2006. The South American Low-Level Jet Experiment (SALLJEX). Bull. Amer. Meteor. Soc, 87, 63-77.
Zipser, E., Salio, P., and M. Nicolini, 2004: Mesoscale Convective Systems activity during SALLJEX and the relationship with SALLJ. CLIVAR-Exchanges, 9, 14-16.

3.1.3 Intraseasonal variability (L. Carvalho, J. N.. Paegle, C. Jones, V. Misra)- Udpated April 2009

3.1.3.1 Scientific background

Precipitation in South America exhibits variations in a wide range of space and time scales. Convection in the Amazon Basin is characterized by pronounced diurnal and seasonal changes while intraseasonal (10-90 days) oscillations (ISO) are more pronounced over eastern South America (Grimm et al. 2005). It has been noted that ISO modulates active and break periods in the South American Monsoon system (SAMS) (e.g. Jones and Carvalho 2002). Furthermore, subseasonal variations are known to result from the propagation of midlatitude disturbances into the region (Nogués-Paegle and Mo 1997; Liebmann et al. 1999). At periods between 30 and 60 days, the Madden-Julian Oscillation (MJO) modulates precipitation in the South Atlantic Convergence Zone (SACZ) (Casarin and Kousky 1986; Nogués-Paegle and Mo 1997; Nogués-Paegle et al. 2000; Carvalho et al. 2004). Teleconnection studies have indicated that 30-60 day variability over the SACZ region can be forced by Rossby wave propagation linked to MJO events in the Pacific Ocean (Grimm and Silva Dias 1995).

The importance of subseasonal variability in the range of 10-30 days along the SACZ has also been demonstrated (Liebmann et al. 1999). The influential nature of ISO has been identified in the skills of medium-range weather forecasts in the Pan-American sector (Nogués-Paegle et al. 1998; Jones and Schemm 2000) and in the occurrence of extreme precipitation events (Carvalho et al. 2004; Liebmann et al. 2004; Jones et al. 2004). The relationship between the diurnal variability and the ISV is discussed in 3.1.2. Although significant advances in the understanding of ISO have been made, a number of issues related to ISO and their importance in the South America climate remain to be investigated.

It is shown that there is a diurnal rectification of the ISV over the SAMS region. A control regional climate model nested into a GCM showed barely any intraseasonal variance over SAMS. The results from this regional model integration, basically amplified the bias of the GCM, one of which was weak ISV variability. We then did anomaly nested integrations with the same GCM, wherein the climatology is prescribed by the NCEP-NCAR reanalysis while the anomalies are obtained from the GCM for all the nested variables. In Fig. 1 we compare the intraseasonal variance from NOAA OLR (Liebmann and Smith 1996), NCEP-NCAR reanalysis, (COLA) GCM integration, control regional climate model integration (nested into the COLA GCM) and the anomaly nested integrations. Considerable improvement in the anomaly nested regional climate integrations are observed. This improvement was traced to diurnal rectification of the large-scale field. In replacing the climatology of the nested variables of the GCM (nesting interval was 6 hours) with the reanalysis climatology computed for every 6 hour interval separately, the large-scale diurnal cycle was rectified. It is shown that in the anomaly nested integrations that there is vacillation of the intraseasonal variation at the diurnal scales.

3.1.3.2 Scientific Questions:

1) How do ISO affect predictability in SAMS from the synoptic to the seasonal time scales?.

2) What are the underlying processes (local and remotely forced) associated with different time scales of ISO?.

3) What are the relationships between ISO and extreme weather events?

Other science questions are also to be considered:

- Are current descriptions of the ISO over South America accurate?.
- How well are local and remote forcings known and specified in model simulations?
- Do GCM models have realistic intraseasonal oscillations? Which models perform better? Is the skill of seasonal forecasts dependent on the strength of the ISO?
- Is the predictability and signal of the ISO dependent on initial conditions? What ensemble methodologies succeed in measuring signal/noise ratio for simulation of ISO time scales?
- How important is it to reproduce the diurnal cycle in SA for simulations of the ISO?
- How does the ISO over South America affect regions outside South America?
- What is the evidence for inter-annual and longer modulations of the ISO over South-America?
- How does ISO modify regional circulation patterns in South America?
- How predictable is the influence of the ISO on the occurrence of extreme weather events?

3.1.3.3 Actions:

I) Observational studies:

i) to evaluate existing gridded and field data (e.g. SALLJEX) to obtain measures of analysis fit to observations, intercomparison of existing and future reanalysis with and without field data to obtain best analyses to study IS variability;
ii) to describe remote and local forcings as well as the internal dynamics of ISO. Easy access to vegetation cover data, as well as other measured quantities of fluxes (including carbon) from towers, better cloud climatologies, precipitation estimates from space (CMORPH) radar, gages and other data from remote platforms (including the extent of the Antarctic ice) would help accelerate progress in this topic. This can be accomplished by establishing electronic pointers to such data sets.

II) Diagnostic analyses related to:

i) complex scale interactions that modulate intraseasonal variations from diurnal through inter-annual and decadal, and from mesoscale systems through planetary scale and inter-hemispheric interactions;
ii) local versus remote forcing through observational studies that include special surface data and simplified numerical (and theoretical) models;

iii) remote contributions to the SA ISO from the tropics and extra-tropics;
iv) dependence of model skill on the ISO;
v) evaluation of climate and extended numerical forecasts, and
vi) the need to develop a "conceptual model" of the ISO and its manifestation over SA.

III) Simulation strategies

i) there is a recognition that ISO evolve on a time varying basic state and this offers opportunities and challenges in developing weather and climate numerical models. Dependence of SAMS onset on initial conditions that contain IS signals needs to be captured in numerical simulations.
ii) Ensemble techniques based on initial states that span different phases of the ISO may not be suitable and optional methods should be considered. There was general agreement that simulation of the ISO over SA requires coupled models to properly simulate the ocean-air interaction in the SACZ, sophisticated regional models with adequate land-air interactions to downscale the signal over the highly complex surface conditions of SA, and a modeling approach that allows for local processes to feedback in the large scale circulation.
iii) Extended numerical integrations (from CPTEC and four different model runs) are available and could be diagnosed to examine the veracity of ISO simulations. Extended operational weather forecasts (up to 30 days) are available from CPTEC and other global forecasting centers. These operational runs should be made available in digital form for further analysis of their ability to hold significant ISO. The model runs could be placed in data archive that can be easily accessed (such as the UCAR data portal or the NCEP NOMAD archive)

IV) Simulations and model experiments

i) extended simulations with coupled and uncoupled general circulation models participating in the IPCC Fourth Assessment Report AR4 are available for the present climate (IPCC 20C3M) and future climate scenarios. These model runs can used to assess which GCM's best simulate the mean climate and intraseasonal variability in South America.
ii) the potential role of the rectification of the diurnal variability into the instraseasonal time scale should be further pursued with simplified and fully complex models.

References

Carvalho, L. M. V., C. Jones, B. Liebmann, 2004: The South Atlantic Convergence Zone: intensity, form, persistence, relationships with intraseasonal to interannual activity and extreme rainfall. *J. Climate*, **17**, 88-108.

Casarin, D. P., and V. E. Kously 1986: Anomalias de precipitacão no sul do Brasil e veriacões na circulacões atmosférica. *Rev. Bras. Meteor.,* **1**, 83-90.

Grimm, A. M., e P. L. Silva Dias, 1995: Analysis of tropical-extratropical interactions with influence functions of a barotropic model. *Journal of the Atmospheric Sciences*, **52**, 3538-3555.

________, C. Vera, and R. Mechoso, 2005: The South American Monsoon System. Chang, C.-P., B. Wang, and N.-C. G. Lau, Eds. *The Global Monsoon System: Research and Forecast*, WMO/TD 1266 - TMRP 70, 542 pp. Available at http://www.wmo.int/web/arep/tmrp/REPORTS/global_monsoon_system_IMW3.pdf

Jones, C., and L. M. V. de Carvalho, 2002: Active and break phases in the South American Monsoon System. *J. Climate*, **15**, 905-914.

________, D. E. Waliser, K. M. Lau, and W. Stern, 2004: Global occurrences of extreme precipitation events and the Madden-Julian Oscillation: observations and predictability. *J. Climate*, **17**, 4575-4589.

Liebmann, B., G. N. Kiladis, J. A. Marengo, T. Ambrizzi, J. D. Glick, 1999: Sub monthly convective variability over South America and the South Atlantic Convergence Zone. *J. Climate,* **12**, 1877-1891.

__________ G. N. Kiladis, C. S. Vera, A. C. Saulo, and L. M. V. Carvalho, 2004: Subseasonal variations of rainfall in South America in the vicinity of the low-level jet east of the Andes and comparison to those in the South Atlantic convergence zone. *J. Climate,* **17,** 3829–3842.

Misra, Vasubandhu, 2005: On the simulation of the intraseasonal variance of the South American summer Monsoon. Mon. Wea. Rev., 133, 663-676.

____________ and M. Kanamitsu, 2004: Anomaly Nesting: A methodology to dowscale seasonal climate climate simulations from an AGCM. J. Climate, 17, 3249-3262.

_____________, P. A. Dirmeyer, B. P. Kirtman, H.-M. Juang and M. Kanamitsu, 2002:Regional Simulation of Interannual Variability over South America. J Geophys. Res., 107, 8036, 10.1029/2001JD900216.

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

__________, K. Mo, and J. Paegle, 1998: Predictability of the NCEP–NCAR reanalysis model during austral summer. *Mon. Wea. Rev.,* **126,** 3135–3152.

_________, L.A. Byerle, and K.C. Mo, 2000: Intraseasonal modulation of South American summer rainfall. *Mon. Wea. Rev.,* **128,** 837–850.

Zipser, E.J., D.J.Cecil, C.Liu, S.W.Nesbitt, and D.P.Yorty, 2006: Where are the most intense thunderstorms on earth? Bull. Amer. Meteor. Soc., 87, 1057-1071

3.1.4 Interannual and Interdecadal Variability (A. Grimm, B. Liebmann, T. Ambrizzi)

3.1.4.1 Scientific Background

ENSO is the main source of interannual variability in South America (SA). The first mode of interannual variability of annual total precipitation over SA is associated with ENSO. This mode shows negative (positive) rainfall anomalies during warm (cold) ENSO events in northern SA, and positive (negative) anomalies over southeastern SA (south Brazil, southeast Paraguay, northeast Argentina, and Uruguay) (Grimm and Zilli 2006). Modes associated with ENSO also are among the first when seasonal rainfall is considered during the monsoon season (Zhou and Lau 2001; Nogués-Paegle and Mo 2002; Grimm and Zilli 2006). The second mode of annual precipitation variability, however, is not connected with ENSO, and features a center of variability over central-east Brazil, slightly north of the climatological position of the South Atlantic Convergence Zone (SACZ), with opposite variations of weaker magnitude in northern and southern SA. This is also the leading mode during the monsoon season (Grimm and Zilli 2006).

In spring (SON), the first mode is associated with ENSO and shows a dipole-like pattern, with centers of equal magnitude over southeastern South America (especially southern Brazil) and central-east Brazil (slightly north of the SACZ), extending into the northern part of the continent. The second mode shows a center of variability near, but slightly south of the climatological SACZ, and also is connected with sea surface temperatures (SSTs) in the Pacific Ocean. In summer, a dipole-like pattern similar to the first mode of spring, but not associated with ENSO, shows up as the first mode of variability, with a stronger center in central-east Brazil. The second mode of summer precipitation is connected with ENSO and, as the first, also shows a center over central-east Brazil, but with no significant variations of opposite sign over southern Brazil (as shown in Grimm, 2003, 2004). Modes similar to the first and second summer modes were also obtained with a different set of reconstructed data by Nogués-Paegle and Mo (2002), Variability similar to that described by the first summer mode has been described by Robertson and Mechoso (2000) and Doyle and Barros (2002).

Analyses of South American precipitation have also shown that there are modes of interdecadal variability, in connection with regional or global non-ENSO SST and atmospheric variations, such as the Pacific Decadal Oscillation (PDO) and the North Atlantic Oscillation (NAO) (e.g., Robertson and Mechoso 2000; Zhou and Lau 2001; Nogués-Paegle and Mo 2002; Vargas et al. 2002; Grimm and Canestraro 2003a, b). The first mode of interdecadal variability of annual totals of precipitation shows a change of phase in the mid 1970’s, when there is a change of phase in the NAO and PDO. The main contribution to this mode comes from autumn/winter rainfall (Grimm and Canestraro 2003a). Other studies have shown a substantial increase in southern/southeastern Brazil rainfall after the 1970’s (e.g., Liebmann et al. 2004), as well as in the river discharges in the Paraná/La Plata Basin (Garcia and Vargas 1998; Genta et al. 1998). Even the spatial patterns of intraseasonal variability of rainfall undergo interdecadal modulation (Ferraz and Grimm 2004), as does the ENSO impact on precipitation (Grimm and Ferraz 2002). Marengo (2004) found changes in the decadal variability of rainfall in both northern and southern Amazonia, with the northern region being more sensitive to drought during strong ENSO events. Northern Amazonia shows slight negative rainfall trends, while southern Amazonia, the SAMS area and Southeastern South America (SESA) exhibit positive rainfall trends, consistent with increased streamflow during the later half of the 20^{th} as reported above particularly in SESA. These studies show that Amazonia and Southern South America feature opposite changes, as the South American monsoon features shifted southwards, also in association with changes in ENSO and the 1976–1977 climate shift. The interdecadal oscillations also affect predictability and the skill of climate mod els (Grimm et al. 2006).

Although ENSO is a primary source of interannual variability, there are indications that the summer peak in ENSO-related anomalies ~~in peak summer are~~ is not exclusively remotely forced. It can originate from regional processes of land-surface/atmosphere interactions, involving anomalies of soil moisture, temperature, circulation and precipitation, including also topographic effects (Grimm 2003, 2004; Grimm et al. 2006). Also non-ENSO related variability in summer, such as that associated with the first summer mode, seems to have a significant contribution from regional processes. Although remote influences on this mode, like those suggested by Grimm and Silva Dias (1995) are possible, regional processes appear to be of equal importance.

Although there are consistent impacts associated with ENSO events, there is significant inter-event variability in association with differences in the position and intensity of SST anomalies in the tropical center-east Pacific (Coelho et al 2002; Silva and Ambrizzi 2006; Ambrizzi et al. 2004; Drumond and Ambrizzi 2006) and subtropical South Pacific (Barros and Silvestri 2002), which produce different patterns of atmospheric teleconnections (Vera et al. 2004; Magaña and Ambrizzi 2005). Besides the influence of the ENSO-related SST anomalies, there are other connections between SAMS precipitation and SST anomalies, although it is not always easy to separate cause and effect. For instance, enhanced (suppressed) precipitation in the SACZ is related with colder (warmer) SST in southwestern subtropical Atlantic, near the SACZ (Robertson and Mechoso 2000, Doyle and Barros 2002). Grimm (2003) showed that January rainfall in Central-East Brazil is positively correlated with November SST in the oceanic SACZ, off the southeast coast of Brazil, and negatively correlated with January SST in the same region. Anomalies of precipitation and circulation in the region, such as those associated with El Niño events in November, favor increased shortwave radiation and set up warm SST anomalies. On the other hand, enhanced convection and rainfall in January lead to negative SST anomalies. Although these relationships indicate atmospheric control over the ocean in this region, one might speculate that warmer SST in November helps trigger the regional circulation anomalies that lead to enhanced precipitation in January. There are possible feedback mechanisms between SST and the atmosphere in the SACZ (Robertson et al. 2003; Chaves and Nobre 2004; Drumond and Ambrizzi 2005).

3.1.4.2 Scientific questions

Work on understanding seasonal to longer time scale variability has focused primarily on understanding the influence of SSTs on temperature and precipitation anomalies, although the role of land surface-atmosphere processes in setting up consistent anomalies has been explored in some studies (Grimm 2003, 2004; Grimm 2006). The El Niño / La Nina signal in the equatorial Pacific has been well-documented, although the exact mechanisms by which anomalies are produced are not yet entirely clear, and possibly include land surface-atmosphere interactions. The role of the tropical Atlantic has also been examined, but until recently the emphasis has been on its influence on northeast Brazil precipitation (e.g., Nogués-Paegle and Mo 2002). With other studies of late indicating an influence by the subtropical Pacific and possibly the subtropical Atlantic, it is clear that all the proximate oceans must be considered, and in combination, to achieve the maximum possible predictability. While some decadal scale trends in precipitation and temperatures have been observed, the dynamical causes of these trends have, for the most part, yet to be determined.

The basic objectives are to understand and improve prediction of the monsoon system. In order to achieve these objectives, the following questions must be addressed:

1) How does the interannual to interdecadal variability influence the SAMS evolution?
2) How do land surface processes and biomass burning affect variability?
3) Is there an active role of SST in the western subtropical Atlantic in setting up the precipitation variability in central-east Brazil or near the SACZ that allows prognostic application?
4) How do the leading patterns of SST and large scale circulation in interannual and interdecadal time scales (atmospheric/oceanic) influence the South America monsoon variability?
5) How does the interannual and interdecadal variability affect the frequency of daily extreme events?

3.4.1.3 Actions

In order to accomplish these objectives, it is at a minimum necessary to accomplish the following:

1) Improve access to historical precipitation and temperature records. At present, there is reasonable coverage over many parts of South America for about 30 years. While this is marginally adequate to address issues of large-scale interannual variability, this coverage is inadequate to address issues of regional scale variability and long term trends. There is still very little cooperation between agencies and countries to achieve the optimal product by which to valid numerical simulations and conduct observational studies.
2) Develop soil moisture data sets. Recent studies have indicated an important influence by variations of soil moisture in the determination of precipitation and temperature variability. While specialized data sets (e.g., ABRACOS) exist, they only cover one small and specific region. There is presently no large-scale spatial information available for any time scale approaching interannual, let alone decadal. Prospects for obtaining direct historical records are dim, so the hope is some combination of satellite and hydrological modeling can eventually yield a research tool that would be immensely valuable for improving land-surface models.
3) Enhance modeling and diagnostic studies to refine the relationships between SST and precipitation/temperature variability, in order to improve prognostic relationships, especially in central-east Brazil. Enhance observations in western subtropical South Atlantic.
4) Investigate the relationship between NAO and PDO and SAMS. Although there is some work relating tropical north Atlantic anomalous SST and the rainy season over Northeast Brazil through the modification of the ITCZ

position, particularly during the austral autumn season, it is still not clear how the impact is during summer. Statistical data analysis using observational data and global – regional numerical modeling are important to test some hypotheses.

5) Define climate indices for MESA and appropriate metrics for classification of the ENSO events from the point of view of the impact in the S. American region, and the potential impact of the metrics on the analysis on long term series in order to explore the longer time variability. Again observational data analysis and numerical modeling are important to analyze this topic.

References

Ambrizzi, T., Souza E.B., and Pulwarty R.S., 2004: The Hadley and Walker regional circulation and associated ENSO impacts on South American seasonal rainfall. *The Hadley Circulation: Present, Past and Future*. H.F. Diaz and R. S. Bradley Eds., Kluwer Academic Publishers, Dordrecht, 203-235.

Barros, V. R., and G. E. Silvestri, 2002: The relation between sea surface temperature at the subtropical South-Central Pacific and precipitation in Southeastern South America. *J. Climate*, **15**, 251–267.

Chaves, R. R., and P. Nobre, 2004: Interactions between sea surface temperature over the South Atlantic Ocean and the South Atlantic Convergence Zone. Geophysical Research Letters, v. 31, n. 3, L0320410.1029/2003GL018647.

Coelho, C. A. S., C. B. Uvo, and T. Ambrizzi, 2002: Exploring the impacts of the tropical Pacific SST on the precipitation patterns over South América during ENSO periods. Theoretical and Applied Climatology, 71, 185-197.

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.

Drumond, A.R.M., and Ambrizzi, T. (2005): The role of SST on the South American atmospheric circulation during the January, February and March 2001. Climate Dynamics, v. 24:781-791.

_____, and Ambrizzi, T. (2006): Inter-ENSO variability and its influence over the South American monsoon system. Advances in Geosciences, v.**6:**167-171.

Ferraz, S. E. T., and A. M. Grimm, 2004: Intraseasonal variability in Summer: modulation by the interdecadal variability. Proceedings of the 13th Brazilian Meteorological Congress, Fortaleza, Brazil, Brazilian Meteorological Society.

García, N.O. and W.M. Vargas, 1998: The temporal climatic variability in the 'Río de la Plata' basin displayed by the river discharges. *Climatic Change,* **38**, 359–379.

Genta, J. L., G. Perez-Iribarren, and C. R. Mechoso, 1998: A recent increasing trend in the streamflow of rivers in southeastern South America. *Journal of Climate*, **11,** 2858–2862.

Grimm, A. M, and P. L. Silva Dias, 1995: Analysis of tropical–extratropical interactions with influence functions of a barotropic model. *J. Atmos. Sci*., **52**, 3538–3555.

_____, and S. E. T. Ferraz, 2002: Interdecadal variations of the relationship between ENSO and precipitation over Brazil. Proceedings of the 12th Brazilian Meteorological Congress, Foz do Iguaçu, Brazil, Brazilian Meteorological Society.

_____, and C. D. Canestraro, 2003a: Seasonality of the interdecadal variability in Southeastern South America. Preprints 7th International Conference on Southern

Hemisphere Meteorology and Oceanography, Wellington, Nova Zelândia, American Meteorological Society.
_____, and C. D. Canestraro, 2003b: Interdecadal oscillations in southeastern South America and their relationship with sea surface temperature. *Abstracts,* International Symposium on Climate Change (ISCC), Beijing, China, 166.
_____, 2003: The El Niño impact on the summer monsoon in Brazil: regional processes versus remote influences. *J. Climate*, **16**, 263–280.
_____, 2004: How do La Niña events disturb the summer monsoon system in Brazil? *Climate Dynamics,* **22***,* n. 2-3, 123-138.
_____, A. K. Sahai, and C. F. Ropelewski, 2006: Interdecadal Variations in AGCM Simulation Skills. ***Journal of Climate,*** **19**, 3406–3419.
_____, J. Pal, and F. Giorgi, 2006: Connection between Spring Conditions and Peak Summer Monsoon Rainfall in South America: Role of Soil Moisture, Surface Temperature, and Topography in Eastern Brazil. *Submitted to J. Climate..*
_____, and M. T. Zilli, 2006: Interannual variability of summer rainfall in South America: large-scale influences and the role of antecedent conditions in spring. *(In preparation).*
Liebmann, B., C. Vera, L. M.V. Carvalho, I. A. Camilloni, M. Hoerling, D. Allured, V. Barros, J. Baez, and M. Bidegain, 2004: An observed trend in Central South American precipitation. *J. Climate*, **17**, 4357-4367.
Magaña, V. & Ambrizzi, T. (2005): Dynamics of subtropical vertical motions over the Americas during El Niño boreal winters. Atmosfera, v.: 18(4): 211-235.
Marengo, J.A., 2004: Interdecadal and long term rainfall variability in the Amazon basin. *Theoretical and Applied Climatology,* **78**, 79-96.
Nogués-Paegle, J., and K. Mo, 2002: Linkages between summer rainfall variability over South America and sea surface temperature anomalies. *J. Climate*, **15**, 1389–1407.
Obregon G, Nobre CA (2003) A climate shift in mid-1970’s in Northwest Amazonia and Southern Brazil. In Proceedings of the 7th International Conference on Southern Hemisphere Meteorology and Oceanography. Wellington, New Zealand, Ed. By American Meteorological Society, Boston, Massachusetts. pp 88-89.
Robertson, A. W., and C. R. Mechoso, 2000: Interannual and interdecadal variability of the South Atlantic Convergence Zone. *Mon. Wea. Rev*., **128**, 2947-2957.
_____, J. D. Farrara, and C. R. Mechoso, 2003: Simulations of the atmospheric response to South Atlantic sea surface temperature anomalies. *J. Climate*, **16**, 2540-2551.
Silva, G.A.M. & Ambrizzi, T. (2006): Inter-El Niño variability and its impact on the South American low level jet east of the Andes during austral summer – Two case studies. *Advances in Geosciences*, V.**6:**283-287.
Vargas, W. M., J. L. Minetti, and A. G. Poblete, 2002: Low-frequency oscillations in climatic and hidrologic variables in southern South America’s tropical-subtropical region. *Theor. Appl. Climatol*., **72**, 29-40.
Vera, C. S., G. Silvestri, V. Barros, and A. Carril, 2004: Differences in El Niño response over the Southern Hemisphere. *J. Climate*, **17**, 1741-1753.
Zhou, J., and W. K.–M. Lau, 2001: Principal modes of interannual and decadal variability of summer rainfall over South America, *Int. J Climatol*., **21**, 1623-1644.

3.1.5 Long-term variability and climate change (J. Marengo, R. Terra, C. Nobre)

Scientific background

The current understanding of long term climate variability in the monsoon regions remains as one of considerable uncertainty with respect to circulation and precipitation. Chase et al (2003) and Wang and Ding (2006) examined changes in several indices of four major tropical monsoonal circulations outside SAMS for the period 1950-2003 and found a consistent picture of significantly diminished monsoonal circulation. On the other hand, rainfall in the SAMS region seems to exhibit a long term positive trend (Section. 3.1.4). For the SAMS, few studies have documented long-term variability that could be attributed to natural climate variability, as linked to interannual (El Nino) or decadal (El Nino-like or tropical Atlantic related) forcings (See Section. 3.1.4). These changes could possibly be explained by natural climate variability. However, to date few attribution studies have linked the PDO variability to the increase of concentration of greenhouse gases (Shiogama et al 2005), and simulations suggest that the observed variability includes an unusually large trend relative to the natural variation, and that the anthropogenic forcing causes the large trend.

Broad regions in southeast South America and southern Amazonia have been experiencing significant changes in land surface characteristics over the last 30 years due to intensive deforestation and land-use changesTropical deforestation in the Amazon has been found to affect sea surface temperatures in nearby Ocean locations, further amplifying teleconnections (Avissar and Worth, 2005; Feddema, 2005; Neelin and Su, 2005; Voldoire and Royer, 2004). However, studies also indicate that there are significantly different responses to similar land use changes in other tropical regions and that responses are typically linked to dry season conditions (Voldoire and Royer 2004; Feddema et al, 2005). Simulations of Amazonian deforestation typically show a strong climate response, both locally and in mid-latitude areas, especially North America and central Asia (Feddema et al, 2005, Marengo 2006). However tropical land cover change in Africa and southeast Asia appear to have weaker local impacts in large part due to influences of the Asian and African monsoon circulation systems (Voldoire and Royer, 2004; Mabuchi et al., 2005a,b). This has not been well investigated in the SAMS region.

As global warming will lead to faster warming over land than over the oceans, the continental-scale land-sea thermal contrast will become larger in summer and become smaller in winter. Based on this, a simple idea is that the summer monsoon will be stronger and the winter monsoon will be weaker in the future than the present. However, model results are not as straightforward as this simple consideration (Tanaka et al. 2005) as they showed a weakening of these tropical circulations by the late 21st century compared to the late 20th century.

The analysis of the climate change projections for the IPCC SRESA1B scenario made by Vera et al. (2006) show a substantial agreement among IPCC-AR4 models in precipitation changes for the period 2070-2099 relative to 1970-1999, mainly characterized by an increase of summer precipitation over the northern Andes and southeastern South America, while over the Amazon-SACZ, results are mixed. This is confirmed by Boulanger et al (2006a, b), and Cavalcanti et al (2006) who used the SRES A2, B2 and A1B scenarios and nearly similar future time slice. Downscaling experiments on climate change scenarios in South America have also shown a reduction of rainfall in Amazonia as well as an small increase in rainfall in SESA during 2071-2100 for the

SRES A2 and B2 scenarios (Marengo and Ambrizzi 2006, Nuñez at al. 2006). On the interannual variability, Grimm and Natori (2006) analyze summer monsoon rainy season in South America and its relationship with SST as simulated for the SRES A2 scenario, and conclude that the relationship between ENSO events and precipitation variability in SESA weakens for the A2 scenario, especially in spring, which is presently the season with strongest ENSO-related impact. The SAMS is strongly influenced by ENSO (Lau and Zhou, 2003; Grimm 2003, 2004), and thus future changes in ENSO will induce complementary changes in the region.

Climate change scenarios for the XXI Century proposed by Cox et al. (2000) and Betts el al. (2004), including new developments in dynamic vegetation schemes and coupled climate-carbon models, have shown a *die-back of the Amazon forest*. This effect is due to the increase in atmospheric CO_2 that leads to a 20% rainfall reduction and to a 30% increase of surface temperature in the Amazon basin. These future scenarios also show an increase in rainfall in SESA after the year 2050, all of which seems to be consistent with an increase in the frequency of low level jet events. This would favour an increase of extreme rainfall events in SESA and SAMS as suggested by Tebaldi et al. (2006) for the IPCC AR4 A1B scenario. The intense/ more frequent rainfall events would be associated with the accelerated low level jet east of the Andes. The likelihood of this scenario, however, is still an open issue.

The recently released IPCC AR4 (IPCC 2007) shows an increase of precipitation is projected in the Austral-Asian and African monsoons during he warm season in global warming scenarios. The monsoonal precipitation in the North American monsoon is projected to decrease in association with increasing precipitation over the eastern equatorial Pacific through Walker circulation and local Hadley circulation changes. Moreover, the uncertain role of aerosols in general, and carbon aerosols in particular, complicates the nature of future projections of monsoon precipitation, particularly in the Asia and the SAMS. New evidence, relevant to climate change, indicates that increased loading of aerosols may have strong impacts on monsoon evolution through changes in local heating of the atmosphere and land surface (Menon et al., 2002) Anthropogenic variations such as the increase in the concentration of GHG global or changes in land use have become apparent in the SAMS region. However, associated circulation and rainfall changes and cause and effect relations remain unclear. Loading of atmospheric aerosols affects regional climate and its future changes. If the direct effect of the aerosol increase is considered, surface temperatures will not get as warm because the aerosols reflect solar radiation. For this reason, land-sea temperature contrast becomes smaller than in the case without the direct aerosol effect, and the summer monsoon becomes weaker.

Recently, Voldoire (2006) studied the impact on atmospheric climate of future land-use changes relative to the increase in greenhouse gas (GHG) concentrations is assessed in time-slice simulations with the ARPEGE-Climate atmospheric general circulation model (AGCM) for the IPCC SRES B2 scenario. The impact of realistically changing land-cover is clearly of second order as compared to the impact of changing GHGs concentrations. Fig. 8 shows that the relative impact of vegetation change to GHG concentration increase is of the order of 10% for a B2 scenario, and can reach 30% over localized tropical regions. However the. conclusions of this study is thus limited to the mean climate point of view because ocean feedbacks may also be important to understand the climate response to vegetation changes over some specific regions. In the Amazon region, the impact of vegetation changes could be more important on inter-annual variability than on the mean climate, and land cover conversions could affect the sensitivity to GHGs when considering extremes

Therefore, there are numerous sources of uncertainty on global and regional climate change projections in the SAMS as in any other region of the planet. Land use/cover change is an important forcing that is inherently regional in scope. The other major component of uncertainty is the responses and feedbacks of the climate system to emissions as represented in climate models. These uncertainties are related to the model representation of the conversion of the emissions into concentrations of radiatively active species (i.e., via atmospheric chemistry and carbon-cycle models) and the subsequent response of the physical climate system. In turn, the latter uncertainties result from the representation of resolved processes (e.g., moisture advection), the parameterizations of sub-grid-scale processes (e.g., clouds, precipitation), feedback mechanisms on the global and regional scale (e.g., changes in land-use/cover affecting the atmosphere, the role of aerosols on the rainy season in Amazonia) and so on. The long-term variations of models´ skill represent an additional source of uncertainty, and indicate that the regional reliability of long climate model runs may depend on the time slice in which the output of the model is analyzed (Grimm et al. 2006).

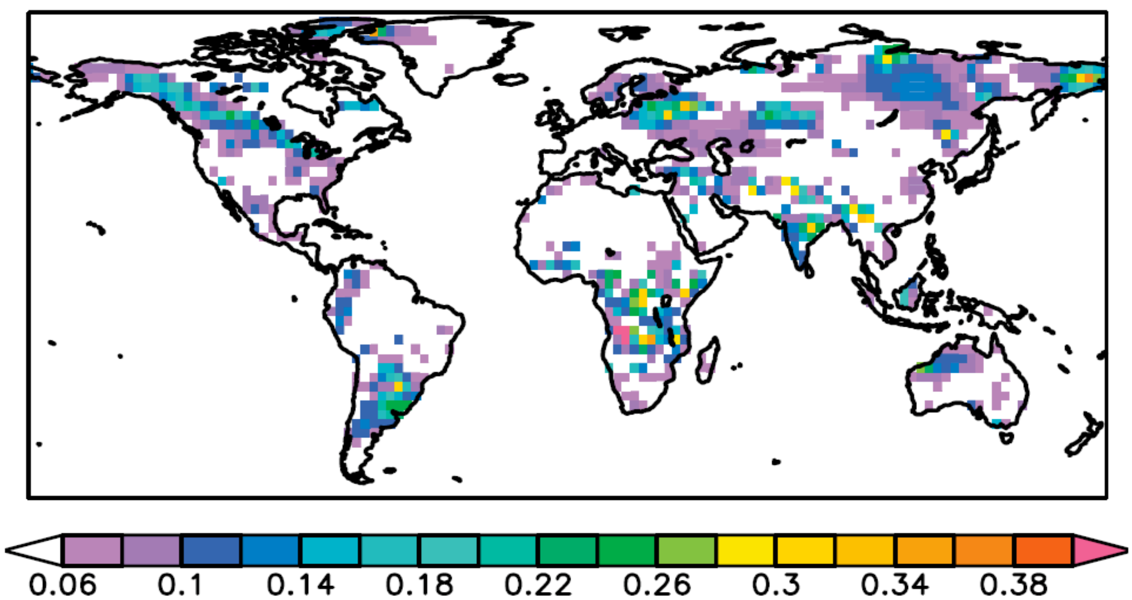


Fig. 8. Ratio of the magnitude of the near surface temperature response to land cover change over the magnitude of the response to GHGs concentrations increase, for the B2 scenarios (Voldoire 2006)

Scientific objectives

The main objectives of this component are:

-To describe the major characteristics describing the spatial distribution of observed trends in the SAMS precipitation, including interdecadal variability .
-To understand to what extent long-term variability in SAMS is potentially attributed to global warming

-To assess the expected impact of anthropogenic climate change on the functioning of the SAMS for mean, extremes and variability at various time scales
-To assess the impacts of climate change on the frequency of climate extremes, including droughts, floods, heat and cold waves;
-To assess impacts of climate change in the SAMS region and their consequences in society as well as to assess its vulnerability.
-To assess the impact of climate change due to land use changes and GHG concentration increase in teleconnections patterns that control weather and climate in the SAMS region.
-To asses the impact of climate change on the natural ecosystem functioning in the SAMS region, that may lead to agricultural zoning

Science questions

In order to achieve these goals, the following scientific questions must be addressed:

1. What are the patterns and magnitude of SST increase in the oceans surrounding the South American continent under climate change scenarios?
2. To what extent will the seasonal cycle of SAMS change under climate change scenarios?
3. How will the low-level moisture transport in the SAMS change for different time and space scales?
4. How will SAMS seasonal to interannual climate predictability change in future climate scenarios (GHG increase and land use changes)?
5. How will rainfall and temperature extremes and hydrological extremes (frequency and intensity) in the SAMS region behave under future climate change scenarios?
6. What will be the risk of extremes in future climate and how these will impact society?

Actions:

To accomplish the goals and to address the scientific questions, the following actions are proposed in the context of the MESA Science and Implementation Plan:

1. Analyses of long term climate simulations for the XX Century (IPCC AR4 20C3M) to asses uncertainties in simulated trends in mean and extremes for the SAMS region
2. Analyses of long term climate simulations for the XXI Century (using IPCC AR4) to assess projections in mean and extremes for the SAMS region
3. Implementation of modeling activities in the SAMS region including experiments on land-use change and GHG forcing individually and combined in order to assess regional feedbacks on the intensity and variability of SAMS. These simulations should also account for the impact of aerosols from Amazon biomass burning
4. Regional downscaling of present time and future climate change scenarios for the SAMS using regional models that account for increase in GHG and aerosol concentrations
5. Modeling simulation of extremes under climate change scenarios.
6. Development of indices that would help in the vulnerability assessment to climate variability and change in the SAMS region.

References

Avissar, R., and D. Werth, 2005: Global Hydroclimatological Teleconnections Resulting from Tropical Deforestation. Journal of Hydrometeorologyeor. 6, 134-145.

Betts, R., P.M. Cox, M. Collins, P.P. Arris, C. Huntingford, and C.D. Jones, 2004: The role of ecosystem-atmosphere interactions in simulated Amazonian precipitation decrease and forest die back under global climate warming. *Theoretical and Applied Climatology,* **78**, 157-166.

Boulanger, J.-P., Fernando Martinez and Enrique C. Segura,2006a: Projection of future climate change conditions using IPCC simulations, neural networks and bayesian statistics.Part 1: Temperature mean state and seasonal cycle in South America, Climate Dynamics, 27, 233-259, DOI 10.1007/s00382-006-0134-8.

Boulanger, J.-P., Fernando Martinez and Enrique C. Segura, 2006b: Projection of future climate change conditions using IPCC simulations, neural networksand Bayesian statistics.Part 2: Precipitation mean state and seasonal cycle in South America, Climate Dynamics, In Press.

Cavalcanti, I. F, Camilloni, In, Ambrizzi, T., 2006 : Escenarios Climaticos Regionales. Chapter 13 in *El Cambio Climatico en la Cuenca del Plata*. V. Barros, R. Clarke, P. Silva Dias. Eds. Buenos Aires, CONICET 2006. 232 pp.

Chase, T. N., J. A. Knaff, P.A. Pielke Sr., and E. Kalnay, 2003: Changes in global monsoon circulation since 1950. *Natural Hazards*, **29**, 229–254.

Cox, P.D., R.A. Betts, C.D. Jones, S.A. Spall, and I.J. Totterdell, 2000: Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model. *Nature*, **408**:184-187.

Feddema J.J., K.W. Oleson, G.B. Bonan, L.O. Mearns, W.M. Washington, G.A Meehl, D. Nychka, 2005b. A comparison of a GCM response to historical anthropogenic land cover change and model sensitivity to uncertainty in present-day land cover representations, Climate Dynamics, 25, 581-609. DOI: 10.1007/s00382-005-0038-z

Grimm, A. M., A. K. Sahai, and C. F. Ropelewski, 2006: Interdecadal Variations in AGCM Simulation Skills. *Journal of Climate,* 19, 3406–3419.

Grimm, A. M., 2003: The El Niño impact on the summer monsoon in Brazil: regional processes versus remote influences. *J. Climate*, **16**, 263–280.

_____, 2004: How do La Niña events disturb the summer monsoon system in Brazil? *Climate Dynamics,* **22**, n. 2-3, 123-138.

_____, A. K. Sahai, and C. F. Ropelewski, 2006: Interdecadal Variations in AGCM Simulation Skills. *Journal of Climate,* **19**, 3406–3419.

_____, and A. A. Natori (2006), Climate change and interannual variability of precipitation in South America, *Geophys. Res. Lett.*, **33**, L19706, doi:10.1029/2006GL026821.

Lau, K.M. and Zhou, J., 2003: Responses of the South American Summer Monsoon climate system to ENSO during 1997–99. *Int. J. Climatol.* , **23**, 529–539.

Mabuchi, K, Y. Sato and H. Kida. 2005: Climatic Impact of Vegetation Change in the Asian Tropical Region. Part I: Case of the Northern Hemisphere Summer. Journal of Climate: Vol. 18, No. 3, pp. 410–428.

Mabuchi, K, Y. Sato and H. Kida. 2005: Climatic Impact of Vegetation Change in the Asian Tropical Region. Part II: Case of the Northern Hemisphere Winter and Impact on the Extratropical Circulation. Journal of Climate: Vol. 18, No. 3, pp. 429–446.

Marengo, J., T. Ambrizzi, 2006: Use of regional climate models in impacts assessments and adaptations studies from continental to regional and local scales. The CREAS (Regional Climate Change Scenarios for South America) initiative in South America. Proceedings of 8 ICSHMO, Foz do Iguaçu, Brazil, April 24-28, 2006, p. 291-296.

Menon, S., et al., 2002: Climate effects of black carbon aerosols in China and India , *Science*, **297**, 2250– 14 2253.

Neelin, J.D. and H. Su. 2005: Moist Teleconnection Mechanisms for the Tropical South American and Atlantic Sector. Journal of Climate: Vol. 18, No. 18, pp. 3928–3950.

Nuñez, M., Solman, S. Cabre, M. 2006: Mean climate and annual cycle in a regional climate change experiment over Southern South A II: Climate change scenarios (2081-2090). Proceedings of 8 ICSHMO, Foz do Iguaçu, Brazil, April 24-28, 2006, p. 326-331.

Shiogama, H, M. Watanabe, M. Kimoto, T. Nozawa, 2005: Anthropogenic and Natural Forcing Impacts on the Pacific Decadal Oscillation during the Second Half of the 20th Century, Submitted to *Geophysical Research Letters*

Tanaka, H. L., Ishizaki, N., N. Nohara, 2005: Intercomparison of the Intensities and Trends of Hadley, Walker and Monsoon Circulations in the Global Warming Predictions. Submitted, SOLA, 2005.

Vera, C., G. Silvestri, B. Liebmann, and P. Gonzalez (2006): Climate change scenarios for seasonal precipitation in South America from IPCC AR4 models. Geophys. Res. Lett., 33, L13707, doi:10.1029/2006GL025759.

Voldoire, A., and Royer J. F. 2004: Tropical; deforestation and Climate Variability. *Climate Dynamics*, **22**, 857-8

Voldoire, A. 2006: Quantifying the impact of future land-use changes against increases in GHG concentrations, Geophys. Res. Lett., 33, L04701, doi:10.1029/2005GL024354.

3.2 MESA Modeling and Data Assimilation (I. F.A.Cavalcanti, A. Seth, C. Saulo, B. Kirtman, V. Misra, P. Nobre)

3.2.1 Scientific Background

The most prominent climatological signatures of the South American Monsoon System (SAMS) are reasonably well simulated by AGCMs. The modeled Bolivian High, Atlantic trough, South Atlantic Convergence Zone (SACZ), subtropical Atlantic High, and Intertropical Convergence zone (ITCZ) are all located near their observed position, and with the correct magnitude (e.g.,Cavalcanti et al. 2002; Gates et al. 1999; Johns et al. 1997; Cavalcanti and Marengo 2003 and others). These features are also evident in regional simulations (Seth et al. 2006; Rauscher et al. 2007).

Although the large scale features of the South American Monsoon are reasonably well simulated, the precipitation tends to be underestimated in the Amazon Region (Cavalcanti et al. 2002; Brankovic and Molteni 1997; Hurrell et al. 1998; Stern and Miyakoda 1995). In addition, some models also show an overestimation in the southern part of the SACZ. Other systematic errors over South America are excessive precipitation over Andes Mountains in summer and a deficit of precipitation over southern/southeastern South America. AGCM simulations considering regional features over South America are reported in Marengo et al (2003). In that study, the well defined annual cycle of precipitation in the tropical areas of South America is simulated, but with different magnitudes than the observations. Other studies report an improvement in the representation of precipitation and circulation patterns when a downscaling approach is adopted (Misra 2002, Misra et al 2003, Rojas and Seth 2003, De Sales and Xue 2006).

The simulated interannual variability shows good predictability in most models in eastern Amazonia and northern South America, as well as in the Northeast region, which show high positive anomaly correlations and convergence among ensemble members. However, model skill tends to be very low for central and southeastern areas of the monsoon system. In these areas there is large dispersion among ensemble members, which reduces confidence in the results. In fact, several two tier AGCM experiments (e.g. Marengo et al., 2003) show negative correlations between observed and simulated summer rainfall anomalies over the South Atlantic Convergence Zone (SACZ) area on interannual time scales. One aspect of particular interest in this regard is the importance of ocean-atmosphere feedbacks among SST-cloud-solar radiation, as suggested in the work of Chaves and Nobre (2004). The importance of ocean-atmosphere feedbacks over the SW tropical Atlantic for the SACZ dynamics was also highlighted by coupled ocean-atmosphere modeling studies of Campos et al. (2005).

The main atmospheric characteristics related to the LLJ, which are seen in the reanalysis, have been simulated by both global and regional models (Cavalcanti et al. 2002b; Berbery and Collini 2000; Saulo et al. 2000). The variety of mechanisms forcing the low level wind current from tropical to extratropical latitudes are represented by a regional model (Saulo et al. 2004) and also provides a useful depiction of the diurnal cycle of precipitation associated with strong LLJ events (Nicolini and Saulo 2006). The interaction between tropical and extratropical regions over South America, through the Low Level Jet (LLJ) has been also identified in climatological simulations with an AGCM (Rodriguez and Cavalcanti 2006).

The Amazonia region acts as a source of humidity and latent heat for the SAMS, through the large amount of evapotranspiration and generation of convective clouds. Deforestation in the region can affect the energy balance and the atmospheric circulation over South America, as seen in several model experiments (Nobre et al. 1991; Roberts et al. 2003). The Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA) has developed in the last years, a large amount of studies on several scientific issues related to physical, biochemical, hydrological and climate mechanisms in the region (http://lba.cptec.inpe.br/lba/). The related studies can be linked to those of the SAMS mechanisms. Several field campaigns have provided data observation that could be used in the modeling experiments of SAMS.

Land-Atmosphere exchanges and the role of several variables in the physical processes are important issues to consider in climate experiments over the monsoon region. Changes in soil moisture and vegetation in modeling experiments can indicate changes in precipitation, temperature and atmospheric circulation (de Gonçalves et al, 2006a; Brankovic et al, 2006). The impact on South America precipitation, of a regional model soil moisture initialization was discussed by de Gonçalvez et al (2006b). The soil moisture initialization was generated by SALDAS (South American Land Date Assimilation System). Other implementations of estimated soil moisture initialization have been conducted at CPTEC with both regional and global models (Gevaerd and Freitas, 2006).

Another important issue is the influence of aerosols released by biomass burning in tropical South America. They can affect the radiation and energy budget and should be considered in modeling simulations. Monitoring of biomass burning over tropical South America using a regional model shows that the pollutants are transported southward by the mean flow and can affect areas of southeast (Freitas et al. 2004).

The model results for short range forecasting are very dependent on the observed initial conditions. In the SALLJ region there are few observations that are used operationally in the integrations. During SALLJEX, additional observations were made and used in an assimilation scheme (PSAS) to provide a new dataset (Cavalcanti and Herdies 2004). Another effort on data assimilation during SALLJEX has been reported by Herdies et al. 2007, using essentially the same analysis system as the NCEP-GDAS. This work shows that low level wind intensity is underestimated without the ingestion of SALLJEX observations. Additional satellite data is expected to be used in assimilation schemes to further improve the model results.

Clearly, there are several modeling/data assimilation issues that arise not only from the above mentioned research, but also from the other scientific questions introduced along this document. It is expected that MESA modeling component will perform as a cross-cutting activity among all these issues.

3.2.2 Modeling Objectives:

The MESA modeling objectives are organized by modeling strategy (assessment and hypothesis testing), and by specific modeling activities (methodological improvements, data assimilation, and parameterization development) and are designed to achieve MESA Scientific objectives which span spatial and temporal scales associated with the South American Monsoon System. As such, MESA modeling objectives include:

- *Model Assessment*

- Verify the ability of models to simulate and predict features of the SAMS

- Identify model deficiencies

- *Model Development*

- Improve the seasonal prediction and weather forecasting over South America
- Stimulate the development of physical parameterizations
- Stimulate the implementation of data assimilation

- *Hypothesis Testing*

- Evaluation of scientific hypotheses to meet MESA science objectives, in several time-scales.

Appropriate simulation of the diurnal cycle of convection is critical for the production of user relevant prediction information including subseasonal climate statistics such as extreme temperatures and rainfall. Errors in the simulation of the diurnal cycle can lead to biases in the annual cycle, in the regional response to global SST forcing, and in local response to anthropogenic climate forcing. Thus, careful examination of the diurnal cycle of convection and related surface fluxes and hydrology in a number of climate models is an important task for MESA. A range of models should be examined including models used for short-term weather forecasts and those employed for seasonal prediction and climate change studies. Specific studies related to diurnal cycle are mentioned in section 3.1.2. Considerations of specific metrics will have implications for the extension of monitoring networks (e.g., radar or automatic stations for the provision of PDFs). SALLJEX field observations and satellite-derived products (e.g., TRMM and CMORPH) are critically important sources of verification data for evaluating the simulated diurnal cycle.

It has been shown that on intra-seasonal timescales, local land surface feedbacks can be important and may be associated with some predictability. Also, ocean-atmosphere feedbacks seem to be an integral part of SACZ interannual variability. Thus in addition to remote forcing of ISV (Intraseasonal variability e.g., MJO and PSA), it is important to examine local land and ocean surface feedbacks. Both regional and global models can be used to test such hypotheses. For example, can an IS signal seen in surface flux tower data be replicated by coupled atmos-land models? What is the role of ocean-atmos coupling to explain the observed ISV over land? Does local variability have global effects? Can we use regional models to understand IS fluctuations in surface data and improve the model simulation? By moving beyond the mean to examining higher order statistics in the models our understanding of existing problems and potential for improvement will be expanded. These issues should be examined in a number of models (including simple models) with analysis performed in a probabilistic manner. Some questions of ISV in model simulations are mentioned in section 3.1.3.

MESA modeling interest on interannual timescales begins with the simulation of ENSO teleconnections in South America. While many models perform well in the region of Northeast Brazil, when forced with observed SST, the predictability of tropical Atlantic SST is poor, and fundamentally, the two-tier approach (prescribing SST in an atmospheric model) is flawed due to resulting inconsistencies in oceanic surface fluxes. This seems to be especially important for the correct simulation of the SACZ variability. Thus it is recognized that coupled ocean-atmosphere models are the appropriate tools for seasonal prediction (and climate change) studies, though much evaluation and improvement is needed for these models, including transient activity, horizontal and vertical resolution, and evaluation of derived variables. In particular, most coupled ocean-atmosphere models currently available present severe deficiencies with regard of the correct simulation of basic oceanographic basin scale thermodynamic features over the equatorial oceans. This is the case of the climatological eastward shoaling of the thermocline, which the coupled models fail to represent over the equatorial Atlantic. Other aspect of relevance regarding SST-surface fluxes-rainfall interactions affecting SAMS variability is the determination to what extent SST variability over the tropical Atlantic is a surface flux driven phenomena and the ability of the current coupled models to predict it.

Finally, and crucially important, is the issue of developing clear metrics for the evaluation of the models on inter-annual time scales. How is the onset of the monsoon to be defined? Is monitoring needed of moisture flux, or other elements of the surface water balance? Are there other metrics, which are more appropriate for the South American monsoon system? Other questions related to interannual variability are mentioned in section 3.1.4.

On decadal and centennial time scales, long term trends provide a critical background state upon which interannual variability is manifested. Thus examination of trends and projections of future climate scenarios are important not only for planning but also for understanding the context of present day variability. There exist numerous global model and multi-model data repositories for present day (historical: CMIP, AMIP) climate integrations and future scenarios (IPCC), which are available in standardized data formats. These global models should be examined in detail for the South American region (and its influence globally). Analysis of these model data will provide a baseline that would guide directions of further model development and experimentation. Other questions and actions are mentioned in section 3.1.5.

3.2.3. MESA modeling strategy

Modeling experiments have shown some deficiencies in correctly simulate features that are crucial for the hydrological cycle of the SAMS. Besides, other features of the SAMS need to be evaluated. Therefore MESA modeling strategy will include both Model Assessment and Hypothesis Testing.

The model assessments should include

(1) the diurnal cycle in both regional and global models
(2) the annual cycle
(3) intra-seasonal variability
(4) interannual variability
(5) decadal variability (IPCC AR4 models)
(6) 20th century observed climate trends (IPCC AR4 20C3M model runs)
(7) simulation and predictability during SALLJEX,
(8) simulation of extremes.

The hypothesis testing should include but may not be limited to

(1) Synergy between SALLJ and MCS
(2) Mechanism for the NW Argentina heat low
(3) Sensitivity to soil moisture
(4) Sensitivity to ice cover in Antarctica
(5) Coupled simulation in the region of the SACZ
(6) Local and remote (global) influence of SAMS
(7) Sensitivity to the diurnal cycle of surface heat fluxes over land and oceans
(8) Sensitivity to IC and BC perturbations for ensemble predictions

In the context of the MESA working group work plan, it is recommended that a task force be assembled with researchers dealing with ocean-atmosphere-biosphere coupled modeling, to draw a combined modeling and observational effort toward addressing the systematic errors present in current coupled models. In particular, it must be kept in mind that the tropical Atlantic Ocean has substantial differences with respect to the tropical Pacific; as to avoid the temptation of applying "ENSO-like" thought process to studying the Atlantic climate variability. For instance, coupled modes of variability over the tropical Atlantic are likely to be more strongly affected by monsoonal atmospheric flow induced by the neighboring land masses than the Pacific does. Also, and possibly the most challenging aspect of SST simulation and prediction over the tropical Atlantic, is the correct definition and possible separation between "signal" and "noise" both magnitude and phenomena-wise.

A few topics for discussion are:

1. How to properly initialize coupled o-a models over the tropical Atlantic (are current data quantity/quality stream enough? Should area coverage of PIRATA-type data be enlarged, e.g. over the equatorial and extra-equatorial tropical Atlantic?);

2. What should be done to minimize the warm SST bias over the eastern equatorial Atlantic: is it due to excessive short radiation linked to cloud-parameterization problem; or an ocean circulation deficiency linked to the EUC; or both?

3. How important are spatial/vertical GCM resolutions to improve coupled forecasts over the Atlantic? Is there space for nested regional atmospheric modeling there?

4. In the signal/noise arena, and the correct simulation of intraseasonal atmosphere and ocean variability, what the importance of correct diurnal cycles of precipitation, surface temperature, and winds on both atmosphere and ocean model components?

5. Looking into larger time-scale phenomena, the inclusion of carbon cycle into the coupled model through codes of dynamical vegetation (both over the continent and the oceans) seems to be essential;

6. While the needed model development is slowly worked out (for which a CMIP is a need), ensemble of coupled models (both stochastic and CGCMs) may represent a useful tool to improve SSTA forecast skill.

3.2.4. MESA scientific inquiry

Based on the modeling strategy proposed above, and also considering the modeling experience developed during SALLJEX, we propose the following as important science questions for MESA:

- What are the features of SAMS that are and are not well simulated/predicted on diurnal, intra-seasonal, annual, and interannual timescales?
- What is the importance of high frequency “weather noise” to trigger seasonal variations of SAMS?
- What are the features of SAMS life cycle and extreme precipitation reproduced by both uncoupled and coupled ocean-ice-atmosphere-land models?
- Are there consistent errors among models, which can be attributed to specific formulations of physical parameterization?
- How can intraseasonal variability in the SAMS be improved in the models?
- Can soil moisture memory help for seasonal predictions for South America?
- How to improve the treatment of orography in order to better simulate the effect of Andes Cordillera?
- What is the role of Atlantic SST forcing? What is the difference between tropical versus extratropical influences?
- What are the roles of local versus remote forcings?
- How is the diurnal cycle represented in the models?
- How to improve predictability considering simulation/prediction of teleconnection patterns that affect SAMS?
- How does the data assimilation improve the SAMS features?
- What are the future scenarios for the SAMS, considering climate change?
- What are the SAMS changes considering the Amazonia deforestation?
- What is the effect of aerosol from biomass burning on SAMS?
- What is the effect of change in ice covering in Antarctica on SAMS?
- Will a combination of models (super ensemble) provide greater predictability? What combination techniques should be used?

Some of these questions are addressed also in other sections related with each timescale and are enhanced here.

3.2.5 Activities for MESA Modeling

MESA should encourage people within the modeling community to design experiments that help to answer the science questions. A list of experiments are suggested:

1. Short period integrations of Global and Regional models with outputs at each hour to analyze the diurnal cycle. The integrations can also be used to the following developments:

- Calibration of complex models using Amazonia updated vegetation data sets;
- Model validation using data from field experiments of GEWEX and CLIVAR.

2. Use of coupled ocean-atmos-land model simulation datasets (global and regional) to analyze the monsoon lifecycle, interannual and intraseasonal variability. The following points can be addressed:

- Identification of monsoon life-cycle based on metrics (precipitation, OLR, wind field, moisture flux);
- Implementation of indices and metric for assessments of model performance;
- Influence of regional features on monsoon life-cycle (soil moisture from the previous season, evapotranspiration, atmospheric moisture flux, Low Level Jet behavior, MCS occurrences, SST-solar radiation-precipitation feedbacks on coupled models);
- Influence of synoptic systems (frontal systems, upper level cyclonic vortex) on the monsoon onset;
- The use of operational products and seasonal forecasts to investigate predictability of the SAMS.

3. Model experiments to explore specific cases of SAMS and extreme events in nearby Amazonia and La Plata basin.

- Study of severe episodes of floods and droughts, such as Paraná river flood in 1982-1983, Argentina 2003-2004 drought, the drought in Amazonia in 2005, Southeastern and Central Brazil drought in 2001, Southern Brazil flood in 1982;
- Study of the intense SALLJ event in January (18 and 21) 2003 and the intense MCS systems developed in northern Argentina during SALLJEX field campaign;
- Work in synergy with CLARIS for modeling of extremes using reanalyses and regional models, with application of the above indicated extremes.

4. Sensitivity experiments

- Sensitivity to soil moisture: The climatological soil moisture field, usually considered in the models, can be replaced by estimated real time soil moisture obtained from hydrological models. These can be validated from data collected in various sites from field experiments such as ABRACOS or LBA;
- Sensitivity to deforestation and land use changes: Experiments of deforestation and land use changes due to agricultural expansion are being conducted at INPE-CPTEC, with its coupled ocean-atmos-land and atmos-land GCMs, and at CIMA/DCAO UBA. Results of these experiments or from any other from different modeling center can be analyzed to assess the impact on the SAMS characteristics and variability;
- Sensitivity to SST initial and boundary conditions: Experiments perturbing SST anomalies over the tropical oceans on coupled ocean-atmos and uncoupled models can be done in order to assess the degree of nonlinearity of SAMS intraseasonal to interannual variability.

6. Experiments with data assimilation

- The impact of assimilating the SALLJEX data can be assessed comparing with a control reanalysis, and also through forecast results that can be performed using the reanalysis data as initial conditions;
- Other activities can be: sensitivity tests including data from one station at each time; and use of Regional PSAS with Eta Model, considering the boundary conditions from the CPTEC/COLA AGCM reanalysis (including SALLJEX dataset or data from any other future field experiments such as BARCA-LBA and LPB-PLATEX);

- Explore the impact of the assimilation of higher resolution satellite data available over South America;
- Verify the impact of the assimilation of rainfall estimates on the quality of the analysis and on forecast skill;
- Verify the impact of ocean data assimilation in the Atlantic and Pacific Oceans on extended range forecasts and on seasonal prediction.
- Verify the impact of land surface assimilation data from SALDAS.

3.2.6. Models' outputs arquive:

1. Model simulations available at CPTEC, IRI, NCEP, CIMA, NOAA Climate Test Bed, COLA and DGH/UCH.
2. IPCC AR4 model simulations.
3. CPTEC's AGCM and CGCM monthly outputs for ensemble forecast runs (1982-2001).
4. NCEP/NCAR reanalysis
5. ERA40 reanalysis
6. CPTEC Eta reanalyses (2000-2005)

3.2.7. Data sets archuive:

1. SALLJEX data (at the VAMOS data site at NCAR/EOL)
2. LBA data archive…
3. PIRATA (Tropical Atlantic oceanic and atmospheric hourly data from moored array of ATLAS buoys) (at www.pmel.noaa.gov): 1998 – present.
4. INPE's network of automatic data collection platforms: three hourly surface meteorological data (at www.cptec.inpe.br), 1994 – present.

We expect that model output from new experiments shall be archived at CPTEC (for this there is a need for funding of additional disk space) and at the VAMOS MESA data archive at NCAR/EOL. A possibility of distributed data centers (USP-IAG, CIMA) to archive some components of the data is also an option.

References

Berbery EH, Collini EA, 2000: Springtime precipitation and water vapor flux over Southeastern South America. *Mon Wea Rev*, **128**, 1328–1346.

Brankovic, C., F. Molteni, 1997: Sensitivity of the ECMWF model northern winter climate to model formulation. *Clim. Dyn*., **13**, 75-101.

Cavalcanti, IFA, J.A.Marengo, P.Satyamurty, C.A Nobre, I. Trosnikov, J.P Bonatti, A O. Manzi, T. Tarasova, L.P. Pezzi, C. D'Almeida, G. Sampaio, C.C. Castro, M. B. Sanches, H.Camargo, 2002. Global climatological features in a simulation using CPTEC/COLA AGCM. *J.Climate,* **15***, 2965-2988.*

Cavalcanti, IFA, CA Souza, VE Kousky, 2002b. The low level jet east of Andes in the NCEP/NCAR reanalyses and CPTEC/COLA AGCM simulations. VAMOS/CLIVAR WCRP Conference on South American low level jet. Sta Cruz de la Sierra, Bolivia, Feb. 2002. at: *http://www-cima.at.fcen.uba.ar/sallj_conf_extabs.html*.

Cavalcanti, IFA; JA Marengo, 2003. "Typical features of the South America monsoon system and relations with the low level jet and South Atlantic Convergence Zone in a climate simulation". *International Conference on Southern Hemisphere Meteorology and Oceanography,* 24-28 march 2003, Wellington, New Zealand.

Cavalcanti, IFA; D.Herdies, 2004. Data assimilation study using SALLJEX data. *CLIVAR Exchanges*, 29.

Cavalcanti, IFA; M Mendonça; S.Nilo; P.R.Fernandez; D.Herdies, E. Oliveira, 2004. Experimentos com mudanças na parametrização de convecção nos modelos de circulação global atmosférico CPTEC/COLA e regional Eta e com mudanças de CO2 no MCGA. *XIII Congresso Brasileiro de Meteorologia*, Fortaleza, Out. 2004.

De Goncalves, L. G. G., W. J. Shuttleworth, E. J. Burke, P. Houser, D. L. Toll, M. Rodell, and K. Arsenault, 2006a. Toward a South America Land Data Assimilation System: Aspects of land surface model spin-up using the Simplified Simple Biosphere, *J. Geophys. Res.*, *111*, D17110, doi:10.1029/2005JD006297.

De Goncalves, L. G. G., W. J. Shuttleworth, B. Nijssen, E. J. Burke, J. A. Marengo, S. C. Chou, P. Houser, and D. L. Toll, 2006b, Evaluation of model-derived and remotely sensed precipitation products for continental South America, *J. Geophys. Res.*, *111*, D16113, doi:10.1029/2005JD006276.

De Sales, F., and Y. Xue, 2006. Investigation of seasonal prediction of the South American regional climate using the nested model system, *J. Geophys. Res.*, 111, D20107, doi:10.1029/2005JD006989.

Freitas, S.R.; Longo, K. M.; Silva Dias, M. A.F.; Silva Dias, P. L.; Chatfield, R.; Prins, E.; Artaxo, P.; Recuero, F. 2004. Monitoring the transport of biomass burning emissions in South America. *Environmental Fluid Mechanics*, 5(1): 135-167, DOI: 10.1007/s10652-005-0243-7.

Gevaerd,R; S.Freitas, 2006. Estimativa operacional de umidade do solo para iniciação de modelos de previsão numérica da atmosfera. Revista Brasileira de Meteorologia, Volume Especial da LBA (www.cptec.inpe.br/ brams/papers/soilmoisture_Gevaerd&Freitas_RBMET2006.pdf)

Herdies, DL, VE Kousky, W. Ebisuzaki, 2007. The Impact of High-Resolution SALLJEX Data on NCEP Global Analyses" J.Climate (submitted)

Hurrell, J.W., J.J. Hack, B.A. Boville, D.L. Willianson, J.T. Kiehl, 1998: The dynamical simulation of the NCAR Community Climate Model version 3 (CCM3). *J. Clim*. **11**,1207-1236.

Johns, T.C., R.E. Carnell, J.F. Crossley, J.M. Gregory, J.B. Mitchell, C.A. Senior, S.B. Tett, R.A. Wood, 1997: The second Hadley Centre coupled ocean-atmosphere GCM: model description, spinup and validation. *Clim. Dyn*. **13**, 103-134.

Nicolini, M. and A. C. Saulo, 2006: Modeled Chaco low-level jets and related precipitation patterns during the 1997-1998 warm season. Met. and Atmos. Phy., **94**, 129-143. (DOI: 10.1007/s00703-006-0186-7)

Marengo, J.A.; I..FA. Cavalcanti; P.Satyamurty, I. Troniskov; C.A. Nobre; J.P. Bonatti; H.Camargo; G.Sampaio; M.B. Sanches; A.O. Manzi; C.C. Castro; C.DÁlmeida; L.P. Pezzi; L. Candido, 2003: Assessment of regional seasonal rainfall predictability using the CPTEC/COLA atmospheric GCM. *Clim. Dyn*., **21**, 459-475.

Misra, V., 2002. Regional simulation of interannual variability over South America, *J. of Geophys. Res*., 107, 3.1- 3.16.

Misra, V., P. A. Dirmeyer, and B. P. Kirtman, 2003. Dynamic downscaling of seasonal simulations over South America, J. Climate, 16, 103-117.

Nobre, C.A., P.J. Sellers, J. Shukla, 1991. Amazonian deforestation and regional climate change. *J.Clim*., 4, 957-988.

Rauscher, S., A. Seth, B. Liebmann, J.-H. Qian, and S. Camargo, 2006: Subseasonal statistics from a regional model climatology for South America: Rainy season onset, dry and wet spells, *Monthly Weather Review,* in press.

Rodrigues, D.A., IFA Cavalcanti, 2006: Simulations of the Hydrologic Cycle over Southern South America using the CPTEC/COLA AGCM. *J. of Hydrometeor*, **7**, 916– 936.

Saulo, A. C., M. Nicolini, S. C. Chou, 2000: Model characterization of the South American low-level flow during the 1997-98 spring-summer season, *Clim. Dyn.*, **16**, 867-881.

Roberts, D.A., M.Keller, J.V.Soares, 2003. Studies of land-use and biophysical properties of vegetation in the Large Scale Biosphere Atmosphere experiment in Amazonia. *Remote Sensing of Environment*, 87, 377-388.

Rojas, M., and A. Seth, 2003. Simulation and sensitivity in a nested modeling system for South America, Part II: GCM boundary forcing, *J. Climate*, 16, 2454-2471

Saulo, C., M. E. Seluchi and M. Nicolini, 2004: A Case Study of a Chaco Low-Level Jet Event. *Monthly Weather Review*: Vol. 132, No. 11, pp. 2669–2683.

Saulo, C., J. Ruiz and Y. García Skabar, 2007. Synergism between the low level jet and organized convection at its exit region, 45pp.. *Mon. Wea. Rev.* (in press). Seth, A., S. Rauscher, S. Camargo, J.-H. Qian, and J. Pal, 2006: RegCM regional climatologies for South America using reanalysis and ECHAM model global driving fields. *Climate Dynamics*, DOI 10.1007/s00382-006-0191-z.

Stern, W., and K. Miyakoda, 1995: Feasibility of seasonal forecasts inferred from multiple GCM simulations. *J. Clim*., **8**, 1071-1085.

3.3 MESA and the South Atlantic (R. Matano, P. Nobre and C. Vera)

3.3.1 Scientific Background

During the last few decades there has been a growing body of evidence that the South Atlantic SSTs influence the South American climate from intra-seasonal to inter-annual time scales. It is, for example, recognized that SST patterns in the southwestern Atlantic and the tropical Atlantic affect rainfall over the La Plata basin and Northeast Brazil. The role that the SACZ plays in South American climate, as well as its variability and change, has been extensively addressed in the previous sections. It has been identified as a source of variability on intraseasonal and interannual timescales influencing central South America and also remote regions as the North Atlantic Ocean. Recent model experiments, performed by Chaves and Nobre (2004), show a consistent air-sea coupling associated with the SACZ variability, although the lack of continuous observations of both ocean and atmospheric conditions over the southwestern Atlantic has limited the understanding of such interaction on an observational basis. There is also evidence that the South Atlantic itself is affected, to varying degrees, by global phenomena such as ENSO, the Antarctic Circumpolar Waver or the Southern Hemisphere Annular Mode (SAM), although it remains largely undetermined whether the South Atlantic influences these climate modes.

In order to understand the influence of the South Atlantic circulation on the regional climate, it is necessary to identify first the mechanisms that control SST variability. Recent observational study using data from the PIRATA array suggests that off-equatorial SST variability over the tropical Atlantic is due primarily to 1-D fluxes of solar and latent heat with the atmosphere (Foltz et al., 2003). However, the South Atlantic SSTs are not just a passive response to solar and atmospheric forcing but are also greatly influenced by the oceanic thermocline circulation. This influence is evident in the spatial structure of the leading modes of SST variability (Palastanga et al., 2002). The first EOF mode, for example, is characterized by a slanted dipole whose lobes are separated by a region of large SST gradients. This region has been associated with the northeastward flow South Equatorial Current (Venegas et al., 1997). The close connection between oceanic circulation and SST variability is reinforced by the fact that the dominant period of this EOF is of the same order of magnitude as the period corresponding to the oceanic adjustment at mid-latitudes (i.e., decades). The second SST mode also evidences strong influences from the oceanic circulation. This particular mode has maxima in the middle of the basin and over the regions with the largest mesoscale variability in the South Atlantic: the Brazil/Malvinas Confluence and the Cape Basin region. The relation between this mode and the mesoscale variability of the South Atlantic is also reflected in the fact that this is the only leading mode that exhibits a significant spectral peak on intra-annual time scales. Observations also indicate a close correspondence between the first two leading modes of SST and SSH (sea surface height) variability. This correspondence suggests that the SST variations represented by these modes correspond to variations in the thermocline circulation (i.e., the SSTs are not just a mixed layer process). The third EOF mode, which has the largest correlation with ENSO (Sterl and Hazeleger, 2003), displays linkages between global and regional climate variability. Thus, observations indicate that the South Atlantic's SST structure is strongly influenced by the oceanic circulation and the South Atlantic's interocean exchanges.

3.3.2 Objectives

In spite of the strong evidence on the linkages between the South Atlantic SSTs and climate variations over South America our understanding of the coupling between the oceanic circulation and climate variability has been hindered by the scarcity of dedicated observational and modeling studies. To stimulate further research in these matters MESA recommends prioritizing the following questions:

3.3.3 Science Questions

i) What are the relative contributions of remote and local influences on the determination of the South Atlantic SST anomalies? What is the ocean's role in creating SST anomalies? What is the relative importance of the thermocline variability and the mixed layer variability?

ii) What are the physical mechanisms that cause the SST variability on interdecadal, interannual, and intraseasonal timescales in the South Atlantic? What are the feedbacks among surface heat fluxes, winds, heat content and SSTs that contribute to the low-frequency SST variability? What are the contributions of high frequency-eddy resolving time-space scales to modulate low-frequency SST variability?

iii) What are the mechanisms driving ENSO signals in the South Atlantic and how do they impact on South America and Africa? How do the subseasonal variations of circulation and SST in the southwestern subtropical Atlantic, associated with ENSO, interact with each other?

iv) What are the effect of the Southern hemisphere Annular Mode (SAM) on the South Atlantic's SSTs?

v) Are the decadal-multidecadal signals seen in the South Atlantic a regional mode or part of a near-global signal and how do they relate with the interdecadal variability observed in the South American climate?

vi) Does the South Atlantic influence global modes of climate variability? (e.g. ENSO, NAO, SAM, etc).

vii) Do SST changes in the Brazil/Malvinas Confluence influence the regional climate?

viii) What are the mechanisms by which the South Atlantic's variability influences the SACZ and ITCZ variability?

3.3.4 Actions

To address the above questions it is necessary to advance our understanding of the role of the South Atlantic SSTs on the regional climate as well as the role of the oceanic circulation on the generation of the SST anomalies. The first item could be partially addressed with the observational and modeling studies produced by MESA.To understand the role of the oceanic circulation on the generation of SST anomalies we need to improve our understanding of the South Atlantic circulation and its connection to the neighboring basins. To address these necessities we need augment and extend the existing oceanic observational systems and foster the development of new modeling activities .

The lack of continuous observations of both ocean and atmospheric conditions over the southwestern Atlantic has limited the understanding of the air-sea interaction in the SACZ region on observational basis. It is therefore expected that an ocean-atmosphere observing system over the southwestern Atlantic will help validate and improve climate models, and provide data required for prediction purposes and for climate variability and climate change monitoring.

Currently only the tropical Atlantic is being monitored as part of the Pilot Research Moored Array in the Tropical Atlantic (PIRATA). However, the PIRATA backbone and its southwest extension, which was moored by Brazil in September 2005 and has sent real time daily data (surface winds, solar radiation, precipitation, air temperature and humidity, and upper ocean T-S readings) ever since, are located north of the region of high precipitation associated with the SACZ (see Figure 1). Thus, it is proposed to deploy an additional ATLAS type buoy in the western subtropical South Atlantic in the region of maximum rainfall associated with the SACZ. The new site will complement the PIRATA southwestern extension and provide the much needed information necessary to better understand the role of sea-air interactions and vertical mixing at the base of the ocean mixed layer. Given that there are no time series observations in the subtropical South Atlantic, to some degree the proposed observations should be viewed as exploratory.

Additionally, it is proposed that a set of oceanographic field campaigns be planned to generate a high quality and high density data set of both ocean and atmospheric variables (associated with the SACZ life-cycle) over the SW Atlantic. Such campaigns shall complement the fixed-buoy measurements provided by the ATLAS systems already in place as part of the PIRATA SWE array and the additional ATLAS buoy proposed at 30°S, 40°W. The combined set of simultaneous land-based and ocean-based atmospheric and oceanic observations shall be used in modeling studies to initialize both CGCM and AGCM models, as well as to validate the models' results. Variables to be measured are four times daily: vertical profiles of atmospheric temperature, humidity, wind velocity, and barometric pressure; vertical profiles of upper ocean (up to 500 m depth) temperature, salinity, and dissolved oxygen; and ten minutes interval: surface measurements of solar radiation, air temperature and humidity, rainfall, wind velocity, pressure, and sea surface temperature. Ship mounted ADCP measurements shall be done continuously during the cruises, with hourly vertical profiles. Figures 3 and 4 exemplify two types of data to be obtained from the oceanographic cruises proposed. Figure 3 shows a SW-NE cross section of temperature vertical profile of the upper 500 meters of the ocean and the lower 1000 meters of the atmosphere obtained during the PIRATA SWE-I oceanographic cruise in September 2005. It reveals a thicker atmospheric planetary boundary layer over a layer of warmer waters. Figure 4 shows ocean velocities at 25-75 m depth along track the PIRATA SWE-I cruise, revealing the presence of strong eddy activity over the region. When taken systematically over a period of time, such data sets shall become invaluable to initialize and validate coupled ocean-atmosphere modeling studies over the region. Twin model experiments with/without ocean-atmos data assimilation shall be run, to gauge the relative importance of atmospheric state over land/ocean to initialize atmospheric and coupled models to simulate and forecast SAMS variability.

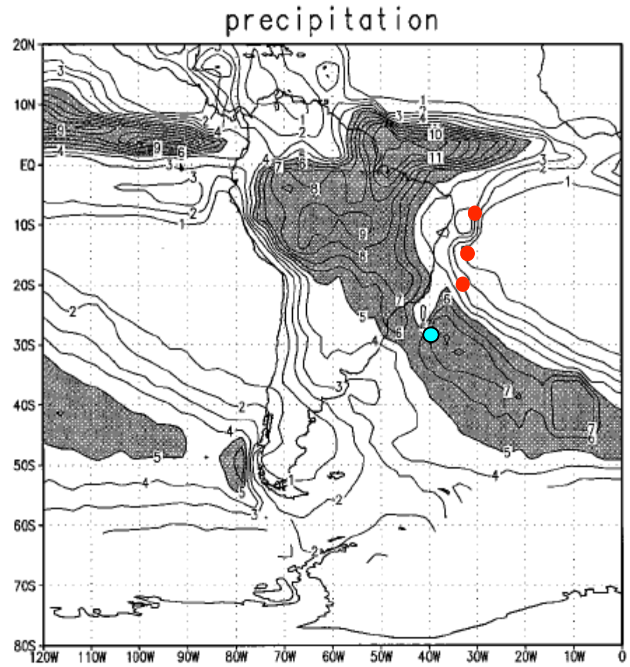


Figure 1: Monthly mean total precipitation averaged from December through March 1979–93, contoured every 1 mm (from Nogués-Paegle and Mo, 1997). The red dots indicate the locations of the Pirata Southwestern Extension and the light blue dot marks the location of the proposed site.

The site is located approximately at 28°S – 43°W, east of the core of the Brazil Current (see Figure 2). Historical hydrographic data reveals that the sea surface temperature at this location varies between 19 and 26°C, and the mixed layer depth increases from ~20 m in January to ~150 m in August. Though the region is recognized as important for the regional continental climate, there is no knowledge on the interannual variability and on how these changes are related to the ocean circulation.

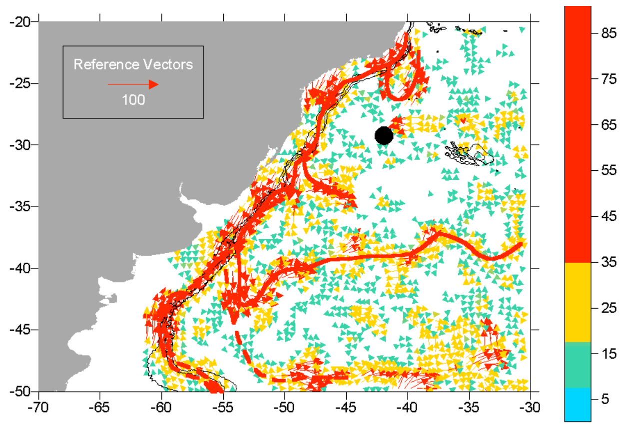


Figure 2: Surface current velocity field derived from 10 years of surface drifter observations. The black dot indicates the location of the proposed observing site.

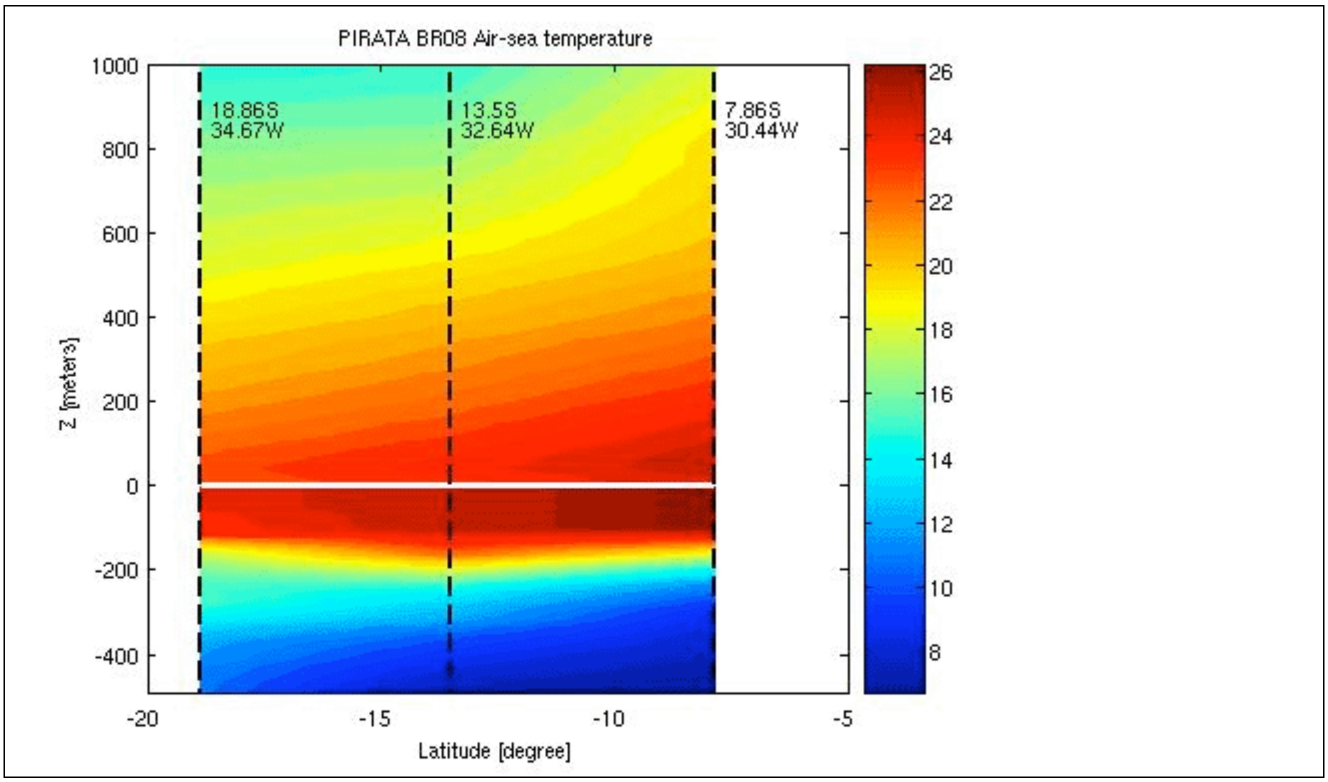


Figure 3 – Along-track temperature vertical profiles for both ocean depths and atmosphere heights during the PIRATA SWE-I inauguration mooring cruise in August 2005. Source: (Nobre et al., 2007)

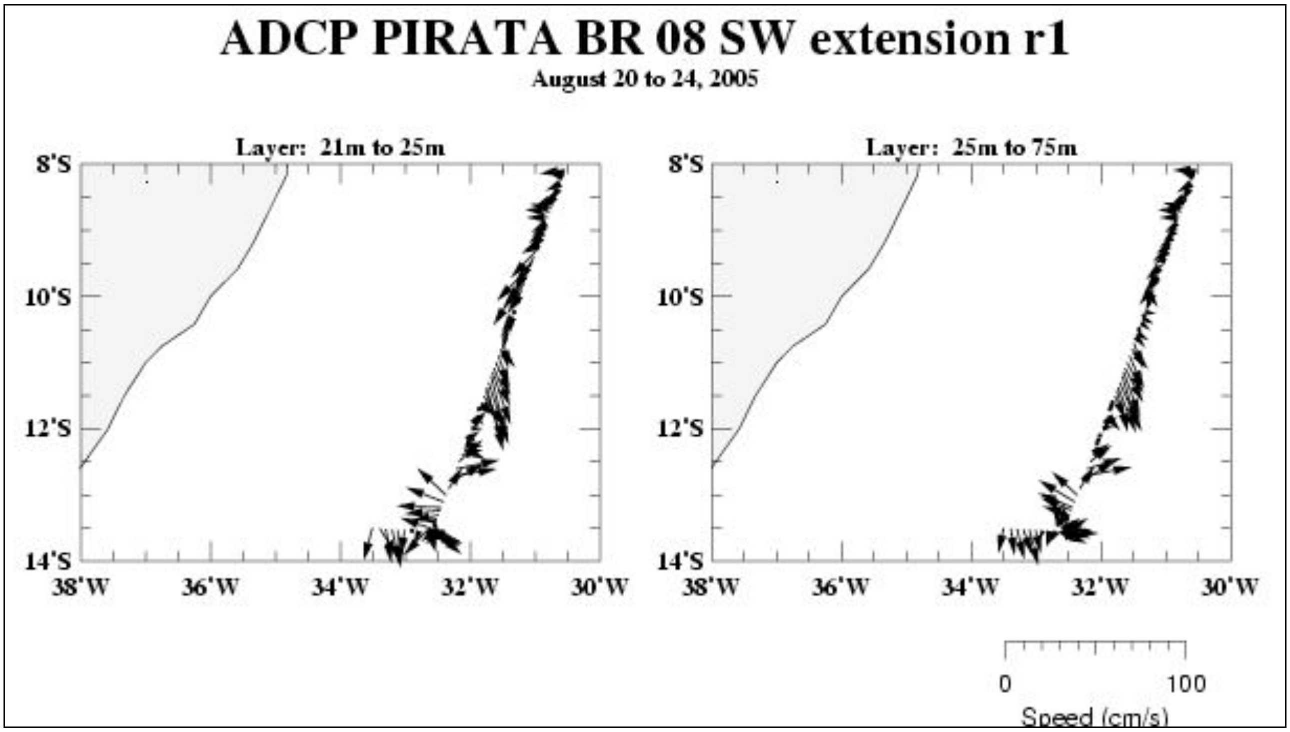


Figure 4 – Along-track horizontal velocities at 25-75 m depth during the PIRATA SWE-I inauguration mooring cruise in August 2005. Courtesy of Domingos Urbano Neto.

References

Chaves, R. R., and P. Nobre, 2004: Interactions between the South Atlantic Ocean and the atmospheric circulation over South America. *Geophys. Res. Lett.,* **31,** doi:10.1029/2003GL018647.

Foltz, G. R., S. A. Grodsky, J. A. Carton, and M. J. McPhaden, 2003: Seasonal mixed layer heat budget of the tropical Atlantic Ocean. *J. G. R - Oceans,* 3146-.

Nobre, P., E. Campos, J. Servain, and M. Araujo, 2007: The PIRATA South-West extension: scientific motivation, realization and perspective. *Bull. Amer.Meteor. Soc.,* submitted.

Nogués-Paegle, J., and K. C. Mo, 1997: Alternating Wet and Dry Conditions over South America during Summer. *Monthly Weather Review,* **125,** 279-291.

Palastanga, V., C. S. Vera, and A. R. Piola, 2002: On the leading modes of sea surface temperature variability in the South Atlantic Ocean. *Exchanges,* **25,**

Sterl, A., and W. Hazeleger, 2003: Coupled variability and air-sea interaction in the South Atlantic Ocean. *Clim. Dynamics,* **21,** 559-571.

Venegas, S. A., L. A. Mysak, and D. N. Straub, 1997: Atmosphere -ocean coupled variability in the south Atlantic. *Journal of Climate,* **10,** 2904-2920.

3.4 Unified view of the American monsoon systems (C. Vera)

As CLIVAR research on the American monsoon systems evolves, a unified view of the climatic processes modulating continental warm season precipitation is beginning to emerge. VAMOS has made significant progress in our understanding of the American monsoon systems, in large part because of the complementary objectives of the North American Monsoon Experiment (NAME) and the Monsoon Experiment South America (MESA) programs (see Part I). Recent advances include new insights into moisture transport processes, description of the structure and variability of low level jets, and resolution of the diurnal cycle of precipitation in the core monsoon regions (Vera et al. 2006). NAME and MESA are also driving major efforts in model development and hydrologic applications.

3.5 Project structure and Timeline

The ultimate goal of MESA is to obtain an integrated view of the American Monsoon Systems, related inter-hemispheric connection, monsoon predictability and prediction. To accomplish this MESA has implemented a time table that contemplates the MESA milestones presented at the recent 10th VAMOS Panel in March 2007 are (organized by Fiscal Year FY):

- FY04:

- Quantitative information of the model errors in SALLJEX
- Evaluation of impact of SALLJEX data on analysis and forecasts
- Confirmation about the ability of the models to reproduce some of the elements of the low-level circulation of the SAMS

- FY05:

- SALLJEX Data Assimilation.
- Assessment of the IPCC-AR4 simulations in the SAMS region

- FY06:

- Assessment of extreme event frequency changes in the regional climate change scenarios for South America and their impact on agricultural activities.
- Assessment of Seasonal prediction simulations in the SAMS region
- Seasonal simulation of SALLJEX season.
- Predictability of the SAM associated with Atlantic SST simulations.

- FY07:

- Development of MESA climate indices
- Final version of the MESA Science and Implementation Plan
- Regional downscaling of IPCC-AR4 simulations

- FY08:

- Evaluate the impact of soil moisture in simulations and predictions.
- Regional downscaling of IPCC-AR4 simulations
- Studies on impacts and vulnerability of SAMS to climate change
- Metrics for climate simulations and projections

- FY08:
- Update of the Science and Implementation Plan (Ongoing)
- Studies on impacts and vulnerability of SAMS to climate change
- Studies on climate variability on decadal time scales
- Modeling of ISO

Some barriers that have been identified in the development of research related to MESA, and they may affect the progress of MESA:

• The decay of the observational network needs to be reversed, with the network expanded into regions where observations are scant.
• Raise the profile of model and parameterization development. This calls for a sustained funding commitment from agencies.
• Lack of adequate computer facilities for the sensitivity testing to understand complex processes and their feedbacks. Testing the spatial resolution and temporal resolution and physics dependencies should be considered a grand challenge problem to the modeling community in terms of scientific effort and computing.

Part 4: MESA Field Component

At this time MESA is not considering the realization of field campaign, and it will take advantage of other past and future experiments, like the South American Low-level Jet Experiment (SALLJEX) that took place during the summer of 2002-2003. However, a field experiment ANDEX is proposed by 2009 or 2009, that is planed inside MESA, and that may be relevant to the planned GEWEX LPB PLATEX for the same time frame (See Section 6.3)

4.1 SALLJEX Field Experiment (Updated April 2009)

4.1.1 Introduction

The South American Low Level Jet Experiment (SALLJEX) was a field experiment carried out in western-central South America during the 2002-2003 rainy season as part of the South American low-level jet (SALLJ) program. The SALLJ, a component of the CLIVAR/VAMOS program, is an internationally coordinated effort to contribute to the understanding of the role of the SALLJ in moisture and energy exchange between the tropics and extratropics as well as related aspects of the regional hydrology and climate variability. One of the goals of SALLJEX is to reduce the uncertainty in estimating the daily (and longer time scale) characteristics of the tropospheric flow over a large region of South America that is currently lacking a sufficiently dense sounding network. Accurate atmospheric estimates are needed to quantify the variability of the LLJ over different spatial and temporal scales, as well as to describe the spatial variability of the diurnal cycle of the lower- and middle-tropospheric wind field.

The SALLJEX Field Campaign took place between November 2002 and February 2003. For this purpose a dense raingauge network was deployed as well as a provisional upper air observation network which included 16 new pilot balloon stations in Peru, Bolivia, Paraguay, Argentina and Brazil. Most of these upper air stations operated twice daily, and some of them were set as provisional radiosonde sites. NOAA-P3 Airplane flights were also carried out during low level jet and other specific events during the months of January and February 2003. A large data set was obtained from this field campaign with purposes centered on a better understanding of the spatial and vertical structure of the low level jet and the relationship between this system and the large mesoscale convective systems that generate during the austral summer over eastern Bolivia, Paraguay and northern Argentina

The full description of the MESA activities with SALLJEX data have been provided in the ALLS science Plan (Paegle at al 2000), and have been successfully summarized by Vera et al. (2006).

4.1.2 Scientific questions

The main scientific question addressed by SALLJEX is:

What is the role of the LLJ on the moisture transport from the Amazon to the La Plata basins?

More specific science questions include:

1) How is the synoptic variability of the LLJ?, What is the role of the synoptic forcing associated with upper-level westerly flow?, Is the Chaco Low important in the modulation of the LLJ?, What is the role of the heat source associated to latent heat release versus sensible heat on the Bolivian Altiplano and in Amazônia/West Central Brazil?

2) What is the spatial structure and time variability from diurnal to intrasasonal time scales?, What is the role of the of the LLJ in the intraseasonal variability of precipitation along the ZCAS?, What is the role of the LLJ in the dynamics of the Mesoscale Convective Complexes over the La Plata Basin?, What is the dependence of the diurnal cycle of in the Andean Region to the east of the Andes in relation to the LLJ?

3) How is the interuannual variability of the LLJ?, What is the dependence of the LLJ in relation to SST anomalies in the Pacific and Atlantic?

4) Do the atmospheric models reproduce adequately the spatial and temporal structure of the LLJ at different time and space scales? Is there any difference in the representation of the LLJ in terms of the vertical and horizontals discretization of the numerical models?

5) What is the coupling between the occurrences or not of LLJ episodes and rainfall in the Andean region, east of the Andes, and southern Brazil-northern Argentina?

6) What satellite based techniques and monitoring describe adequately the spatial structure and temporal variability of the LLJ?

The extension and upgrading of the current observational network during the experiment allowed for better and more frequent surface and upper-air directed towards an improved understanding of the LLJ, based on a combination of observation and monitoring of circulation and fluxes associated to the LLJ, complemented by regional and global models. One objective of SALLJEX was to determine the relationship between fluctuations in the SALLJ and precipitation over the region. To do this a dense rain gauge network was considered desirable. Additional rainfall observations were also considered to be important for providing ground truth estimates to help determine the accuracy of satellite-rainfall estimates over the region, as well as for comparison with various numerical simulations of rainfall.

A complete description of SALLJEX appears in Vera et al (2006). An upper-air network, including radiosonde and pilot balloon sites, was established during SALLJEX to reduce the upper-air observational gaps existing in the region. The network included pilot balloon sites previously established by PACS-SONET (information available online at www.nssl.noaa. gov/projects/pacs) that were already operating in the region. The BOP of the network extended from 15 November 2002 to 15 February 2003 and consisted of one RAOBS at 0600 UTC and two PAOBSs at 0600 and 2100 UTC. Within the BOP, an SOP took place between 6 January and 15 February 2003. RAOBS were launched twice daily (0600 and 2100 UTC), while PAOBS were made 4-times daily in Argentina, Bolivia, and Paraguay. In Brazil, four RAOBS were made each day at SALLJEX sites. IOPs had a higher observational frequency with three or four RAOBSs and/or eight pilot balloon observations per day at selected sites along the LLJ axis. Knowledge of detailed horizontal variations in the LLJ structure is important for the validation of fine mesoscale model simulations of the jet, especially along the topographic gradient immediately east of the Andes. The inherent uncertainties associated with larger-scale analyses (such as the NCEP reanalysis) also mandate such observations to identify possible systematic errors of the analyzed horizontal moisture fluxes. In this context, the flight missions of the Lockheed WP-3D Orion aircraft owned by NOAA (P-3) were an essential component of SALLJEX in providing a detailed representation of the mesoscale structure of the LLJ east of the Andes and useful information for the study of the NAL, MCSs, and their relationship with SALLJ. The NOAA P-3 is one of the two world's premier research aircrafts, and it participated in a wide variety of national and international meteorological, oceanographic, and environmental research programs in addition to its widely known use in hurricane research and reconnaissance. It is equipped with an unprecedented variety of scientific instrumentation, radars, and recording systems for both in situ and remote sensing measurements of the atmosphere, the Earth, and its environment. Further information about the NOAA P-3 is available online at www.aoc.noaa.gov/aircraft_lockheed.htm.

Multinational field experiments require a variety of complex arrangements that must be made from months to years in advance, and in particular, the operation of the NOAA P-3 required the necessary flight permits to execute research flights in support of SALLJEX scientific objectives. Consequently, permits were secured for flights over Bolivia, Paraguay, Argentina, and Chile. The NOAA P-3 base of operations was also chosen to be based in Santa Cruz de la Sierra, carrying out its research missions from Viru Viru International Airport.

NOAA P-3 deployment went as planned, with 13 research missions flown between 11 January and 8 February, for a total of 99 research. Fortuitously, the weather during the aircraft program allowed for most of the planned flights to be carried out. There were only minor deviations from the planned allocation of flights to the various objectives, as forced by the weather. In addition to eight flights for the LLJ structure, there was one complete MCS mission and two partial MCS missions—one southerly (cold front) jet, one northwestern Argentina low mission, and one mission to the east Pacific, which also sampled an undisturbed day on the Altiplano, covering similar tracks about 5 h apart. The majority of the LLJ flights were carried out in a "porpoising" mode, which involved almost continuously ascending and descending between 300 m and about 3000 m AGL, occasionally as high as 4000–5000 m. This mode was designed for mapping out essential features of the horizontal and vertical structure of the LLJ.

References:

Vera, C.; J. Baez; M. Douglas; C. B. Emmanuel; J. Marengo; J. Meitin; M. Nicolini; J. Nogues-Paegle; J. Paegle; O. Penalba; P. Salio; C. Saulo; M. A. Silva Dias; P. Silva Dias; and E. Zipser, 2006: THE SOUTH AMERICAN LOW-LEVEL JET EXPERIMENT (SALLJEX), Bull Am. Met Soc. 87, 53-72.

Nogues-Paegle, J.,J. Paegle, M. Nicolini, C. Vera, J. Marengo, R.Garreaud, J. Shuttleworth, C. R. Mechoso, H. Berbery (2000): American Low Level jets.A Scientific Prospectus and Implementation Plan. May 2000. Available from www.met.utah.edu/jnpaegle/research/ALLS.html

4.2 ANDEX (R. Garreaud, ….)

4.2.1 Presentation

Between 14°S and 22°S the Andes divides into an eastern and a western part, forming a high altitude (~4000 m ASL) basin known as the Altiplano. Climatologically, the Altiplano is situated between the hyper-arid Pacific coastal desert to the west and the moist continental lowlands to the east. Its semi-arid climate is punctuated by a distinctive summer-time rainy period between December and March, when 60%-90% of the annual rainfall occurs during intense afternoon thunderstorms (Garreaud et al., 2003). The annual rainfall is between 200 mm and 1000 mm, decreasing both from north to south and from east to west (Vuille and Keimig, 2004).

The summertime rainfall over the Altiplano has importance in its own, because it is the only source of water for this semi-arid region and thus its variability has important socio-economic impacts on the agriculturally based societies of the region (UNESCO, 2003). The Altiplano is also of great interest in paleo-climataology, as archives drawn from its lakes and glaciers provide some of South America's most valuable records of climate change (e.g., Baker et al, 2001, Vuille et al, 1998, Thompson et al., 2003). On a more broad context, the convective activity over the Altiplano is an integral part of the South American Monsoon system, that interact with the low-level jet east of the Andes, the main area of convection over the central part of the continent, and probably with the deck of low-level clouds over the eastern Pacific.

A conceptual model linking the large-scale circulation, ABL moisture and convective activity (Falvey and Garreaud 2005), has been largely defined on the basis of a few observations near the western rim of the Altiplano and coarse-resolution gridded data (e.g. Reanalysis), and assumed to be applicable to the entire plateau. However, recent climatological studies indicate that, at least over inter-annual time scales, the Altiplano exhibits distinct zones of largely uncorrelated variability (Vuille 1999, Vuille and Keimig 2004), implying that precipitation processes may differ considerably throughout the Altiplano. Examination of the spatial structure of moisture and precipitation over the Altiplano and surrounding areas has been hampered by the lack of station data in this region.

Thus, there is a strong need of in-situ observation over the Altiplano and the Andean slopes in order to advance our knowledge about the climate and weather of the Altiplano. In this short document we give a preliminary description of a field experiment, named ANDEX, focused in this region and oriented to answer the questions presented in the next section.

4.2.2. Key scientific questions

• Up to what extent is the morphology of the rainfall and convective cloudiness field over the Altiplano determined by the complex topography of this region?

• How reliable are the satellite rainfall estimate over the Altiplano?

• Are the current cumulus parameterizations (used in regional models) capable of simulating the convective activity that develops over the Altiplano?

• Which are the thermodynamic features of the Atmospheric Boundary Layer (ABL) and the free troposphere over the Altiplano? How these features vary in time (for instance between wet and dry periods) and space (for instance in a north-south transect)?

• At which levels (in the free troposphere) take place the maximum moisture transport from the interior of the continent toward the Altiplano?

• How significant is the near-surface moisture transport over the eastern slope of the Andes (regional transport) for the water vapour budget over the Altiplano? Is this

transport concentrated in deep Andean valleys? How this transport is modulated by the intensity of the LLJ?
• How the regional moisture transport is modulated by the middle- and upper-level flow? In particular, what happen with the regional, upslope moisture transport under episodes of westerly flow aloft?

4.2.3 Experimental design

The Altiplano Field Experiment (ANDEX) will provide a set of intensive meteorological observation during 40-50 days at the height of the austral summer (e.g., January/February), including radiosonde, aircraft, satellite and surface-based platforms. A pictorial overview of the different platforms (including those available) is shown in Fig. 4.1. The main components of ANDEX are describe next.

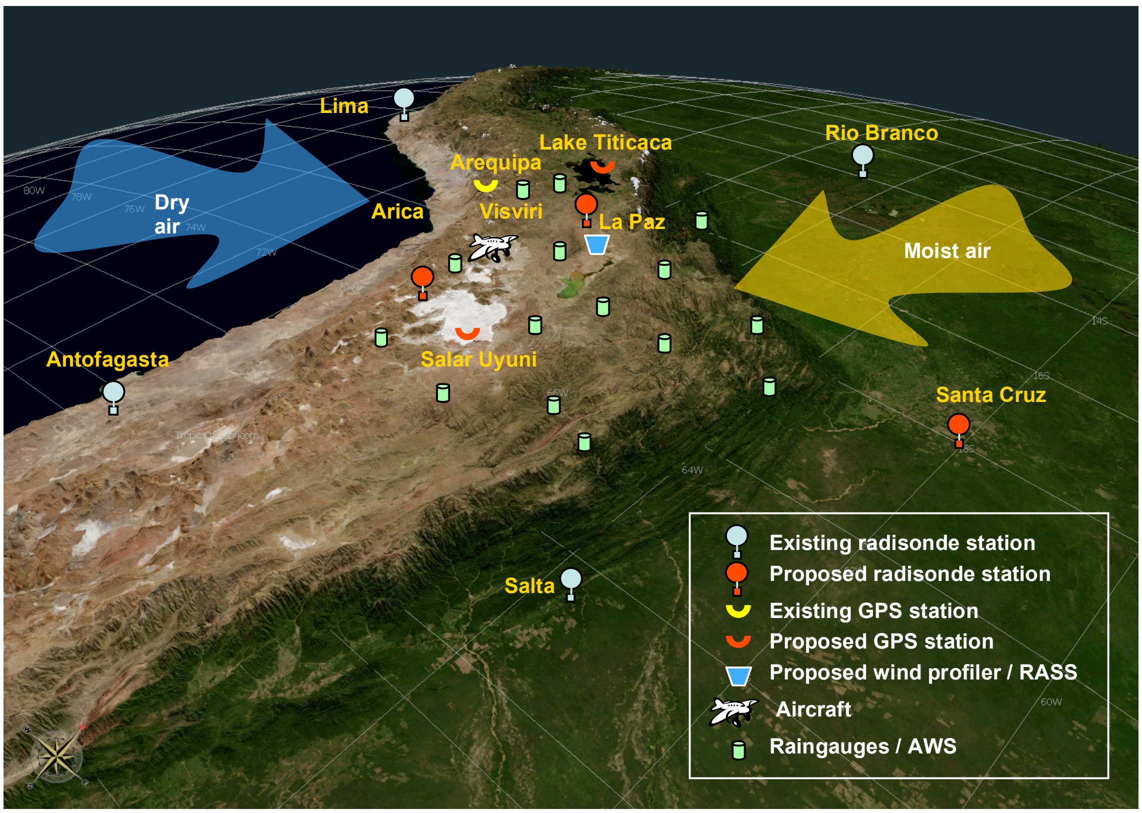


Figure 4.1: Our dream of ANDEX

Vertical profile measurements

A key to understand the meteorological processes over the Altiplano is to obtain upper-air data, with enough temporal resolution as to describe the day-to-day variability of the circulation and thermodynamic properties over this region. Unfortunately, there is no upper-air data over the Altiplano, but for a few radiosonde observations in a small field campaign back in 1994 (Garreaud 1999) and pilot balloon data during SALLJEX (Vera et al. 2006). Thus, we propose the following observations during ANDEX:

• Once or twice daily standard radiosonde observations over the northeast (moist) and southwest (dry) sides of the Altiplano. Suitable locations are La Paz or Juliaca (near Lake Titicaca) and Visviri or Charaña (near the Bolivia-Chile border). Once daily radiosonde observations at Santa Cruz de la Sierra (Bolivia) are also relevant. These proposed radiosonde observations during ANDEX will be complemented with the existing radiosonde stations at Antofagasta (Chile), Lima (Perú), Rio Branco (Brazil) and Salta (Argentina) operated by the respective national weather services, this providing an unprecedented, complete description of the large-scale circulation over the central Andes and the adjacent low-lands.
• A wind profiler (with RASS) station at La Paz, with a vertical resolution of 3 km (or higher), to measure wind and temperature continuously and with high temporal resolution, will allow us to characterize the diurnal cycle of the low-level circulations over the eastern rim of the Altiplano.
• Two Global Positioning System (GPS) receivers, one near Lake Titicaca and other near Salar Uyuni, will be deployed during ANDEX to obtain precipitable water (PW) in these two contrasting sites of the Altiplano. These two stations will be complemented with the site already operating at Arequipa (Falvey and Garreaud 2005). These integrated measurements of tropospheric moisture (GPS-PW) can be obtained in a near-continuous fashion with temporal resolution of 30 min or higher.

Precipitation, weather and convection measurements

How much rain falls over the Altiplano? Currently no ones know, because in-situ data is very sparse over the Plateau and the surrounding mountains and satellite derived estimates have not been validated over this region. To quantify the precipitation we propose:

• A dense network of low-cost raingauges over the Altiplano to obtain daily totals over as much points as possible. These instruments can be placed in town and villages, and will be operated by trained collaborators.
• A less dense network of automatic weather stations (AWS) with a 30 min measurement interval. The AWS will include a tipping bucket raingauges (or similar instrument), and sensors for air temperature, relative humidity and wind. Both the low-cost raingauge network and higher-cost AWS network could stay in operation several months before and after ANDEX.
• Aircraft measurements, including S Band Doppler radar. A number of flights (number and flight plans to be defined) will produce unprecedented data as to describe the structure and organization of the convection over the Altiplano.

References

Garreaud, R. D, 1999: Multi-scale analysis of the summertime precipitation over the Central Andes. Mon. Wea. Rev., 127, 901-921

Garreaud, R., Aceituno, P., 2001: Interannual rainfall variability over the South American Altiplano. J. Clim., 14, 2779 - 2789

Garreaud R. D., M. Vuille, A. C. Clement, 2003: The climate of the Altiplano: observed current conditions and mechanisms of past changes. Palaeoclimatol, 194,5-22.

Hardy, D.R., Vuille, M., Braun, C., Keimig, F., Bradley, R.S., 1998: Annual and daily meteorological cycles at high altitude on a tropical mountain. Bull. Amer. Meteor. Soc., 79 (9), 1899-1913.

UNESCO (United Nations Educational, Scientific and Cultural Organizations), 2003: Lake Titicaca basin, Bolivia and Peru, Pilot case studies, a focus on real-world examples. First World Water Development Report.

Vuille, M., 1999: Atmospheric circulation over the Bolivian Altiplano during DRY and WET periods and extreme phases of the Southern Oscillation. Int. J. Climatol., 19, 1579-1600.

Vuille, M., Bradley, R. S., Keimig, F., 2000: Interannual climate variability in the Central Andes and its relation to tropical Pacific and Atlantic forcing. J. Geophys. Res., 105,12,447-12,460.

Part 5: Dataset development and Data Management

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

MESA data will be available to the scientific community through a number of distributed Data Archive Centers (DACs) coordinated by the NCAR's Earth Observing Laboratory (EOL) and Brazil's Centro de Previsão de Tempo e Estudos Climáticos (CPTEC). The EOL activities fall into two major areas: (1) establishment of a coordinated distributed archive system and providing data access/support of both research and operational data sets for MESA investigators and the world scientific community. (2) EOL and CPTEC will make arrangements to ensure that "orphan" data sets (i.e. smaller regional and local networks) will be archived and made available through the MESA archives. 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.

5.1 Data Policy

As MESA is a program within the CLIVAR Variability of the American Monsoon Systems (VAMOS) program, the VAMOS data protocol is based on the World Meteorological Organization (WMO) Resolution 40 (adopted by the XII Congress on 26 October 1995) and Resolution 25 (Cg-XIII, adopted by the 13th Congress in May 1999) for the exchange of meteorological and hydrological data and products to be adopted and practiced by each of the VAMOS data modules and affiliated Data Archive Centers:

"As a fundamental principle of the World Meteorological Organization (WMO), and in consonance with the expanding requirements for its scientific and technical expertise, the WMO commits itself to broadening and enhancing the free and unrestricted international exchange of meteorological and related data and products"; As well as, *"adopts a stand of committing to broadening and enhancing, whenever possible, the free and unrestricted international exchange of hydrological data and products, in consonance with the requirements for WMO's scientific and technical programmes."*

In general, users will have free and open access to all the VAMOS datasets subject to procedures in place at the various distributed data centers involved (see Data Access). Further details on data set compilation and attribution are provided (see Data Compilation).

5.2 Data Access

The MESA Program will take advantage of the capabilities at several of the existing data centers to implement a distributed data management system, much like the framework of other VAMOS activities. This system will provide single-point access for search and order of MESA-related data from data centers operated by different agencies (and countries) with the capability to transfer small data sets electronically from the data center to the user. VAMOS began collecting information on datasets and added data services (access) capability as each project matures and data requirements become better defined. The existing system has the capability to implement a Data Portal concept for data services using the World Wide Web (WWW) as a method of data access coordinated through NCAR's Earth Observing Laboratory (EOL) Metadata Database and Cyberinfrastructure (EMDAC). The EMDAC WWW page is located directly at http://data.eol.ucar.edu/ and also accessible via the VAMOS Data Information Server. The data server contains general information on the data activities on-going in VAMOS, links to related programs and field projects, and data access to known archive centers.

The data sets residing at NCAR / EOL will be archived and distributed through the existing Interactive Data Management System (CODIAC) as requested by the MESA Science Working Group. 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. The user may *browse data* to preview selected data sets prior to retrieval. Data displays include time series plots for surface parameters, skew-T/log-P diagrams for soundings, and GIF images for model analysis 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.

5.3 Data Compilation

The costs for data management, including data reproduction costs, will be kept to a minimum, primarily through use of existing data centers. The costs incurred for the initial compilation of information on MESA data is supported by NOAA's Climate Program Office under the Climate Prediction Program for the Americas (CPPA). Costs for data sets that are compiled for general use by investigators involved in MESA will also be borne by the CPPA. The incremental costs for preparing data sets designed to individual specifications will, in general, be borne by the user making the request for the data. For purposes such as resource planning and the assignment of costs, there are three types of compiled data sets, referred to as standard, custom, and as requested.

A standard data set is one whose specifications are agreed to before the data collection period starts so that standing orders can be provided to the data centers. The specifications will be agreed to at the project level on a year-by-year basis. The primary purpose of the standard data sets is to give wide distribution, especially internationally, to specific MESA data so as to encourage MESA relevant analysis, research, and modeling studies.

A custom data set is one that is either distributed from or compiled at a central location and will be made easily accessible for a group research effort. Applications of custom data sets include validation or intercomparison of algorithms, energy and water budget studies, and model evaluation studies. The primary purpose of the custom data sets is to facilitate "group" research efforts on MESA relevant topics. The specifications for custom data sets will be agreed to by MESA steering group.

5.4 MESA Data Management Committee

Because of the complex nature of the data management issues involved, MESA is encouraged to establish a Data Management Committee (DMC) to address a number of data-related issues and activities and help define data requirements to accomplish the MESA scientific objectives. The terms of reference of the DMC are to:

- coordinate with the MESA scientific community to define the needs for MESA data

- Design a distributed data management system to provide access to existing data sets

- Prepare a data management plan describing the MESA data strategy and implementation

- Review and recommend augmentation of existing VAMOS data sets to include the continental-scale region required of MESA

- Recommend assembly and oversee the production of new data sets as needed to achieve the MESA objectives

- Collection of data to ensure a permanent archive upon completion of the program

- Coordinate and collaborate with other VAMOS field projects/programs

The DMC would be composed of members representing various MESA scientific interests and data sources/types participating in MESA.

Part 6: Programmatic Context

6.1 Project infrastructure

…

6.2 Education and Training

…

6.3 GEWEX The La Plata Basin (LPB) Regional Hydroclimate Project (H. Berbery, M. A. Silva Dias)

6.3.1 Background

The La Plata Basin covers about 3.2 million km^2 (see Fig. 6.1). 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 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.

Fig. 6.1 The La Plata Basin domain

The hydroclimate system of the La Plata basin presents several challenges that have become apparent along the years; from vulnerability to floods and droughts to efficiency of hydropower production. CLIVAR and GEWEX recognized the uniqueness of these components, and first formed a study group, known as *Platin* that now is called LPB with the desire of identifying the main issues that need to be addressed in the basin.

6.3.2 Science questions

The main LPB hydroclimatic issues can be summarized in the following questions:

i) What climatological and hydrological factors determine the frequency of occurrence and spatial extent of floods and droughts?

ii) How predictable is the regional weather and climate variability and its impact on hydrological, agricultural and social systems of the basin?

iii) What are the impacts of global climate change and land use change on regional weather, climate, hydrology and agriculture? To what extent can their impacts be predicted?

The LPB science plan was approved by CLIVAR and GEWEX and in the GHP meeting in September 2002 the La Plata basin program was proposed as a GEWEX CSE experiment. After some interaction with the LPB science committee, the GEWEX SSG approved the proposal in January 2004. LPB became a GEWEX CSE and as such there are several technical requirements that have to be satisfied: (a) CPTEC and IRI, both NWP and climate prediction centers, have committed cooperation with LPB. Several national and international sources are expected to provide funding for LBP research, (b) LPB includes monitoring and experimental activities (e.g. PACS SONET, SALLJEX), as well as flux tower measurements; (c) a database will be available for data storage at CPTEC and mirrored at 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 (e) the LPB is contributing to the evaluation of GEWEX global data products by generating in-situ data.

The LPB implementation plan envisions two main activities, monitoring of hydroclimate variables and a field experiment to develop a set of unique data that will (a) help understand the land surface-atmosphere processes that may lead to persistent events, and (b) to calibrate and improve parameterizations in regional and global models employed for forecasting and prediction up to seasons. This plan is available at *www.eol.ucar.edu/projects/lpb.*

The MESA interdisciplinary group will work together with research and operational centers to find the most efficient ways of addressing the activities to be developed, in collaboration with LPB PLATEX.

LPB has now two web sites: (a) the operational site at *CPTEC - http://www.cptec.inpe.br/LPB* – and (b) the Earth Observing Laboratory-University Corporation for Atmospheric Research EOL-UCAR) *http://www.eol.ucar.edu/projects/lpb/.* The CPTEC site is the LPB is intended to contain updated information of weather and climate forecasts, available data and links to the related activities. The EOL/UCAR web site will act as a front page from where activities, links etc will be accessed.

6.3.3 Strategy

The monitoring system of LPB CSE will have three basic elements: (a) a network for monitoring the diurnal cycle of precipitation; (b) a flux tower that includes CO2 fluxes; and (c) a wind profiler. The feasibility of having radar nearby is currently being explored and a network of digital raingauges with high temporal resolution will be complementing the radar.

It is expected that the GEF Framework Program for the La Plata Basin (http://www.cicplata.org/marco/) will partially support the monitoring activities and the field campaign of the LPB CSE. The GEF Framework Program generated surveys of the LPB's hydroclimate, including the systems used for its prediction and monitoring. 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. The survey of the Numerical Weather Prediction activities indicated that a large number of regional forecasting systems are now available (based on several regional models such as the ETA, WRF, MM5, ARPS, RAMS and the LAHM). There are ongoing activities on the optimal combination of the available forecasts (including the global models and ensemble forecasting with global models. The survey detected rather limited efforts on data assimilation of the conventional and remote sensing data in most of the NMH regional centers except at CPTEC. Distributed hydrological modeling is now available for several sub-basins such as the Taquari, Uruguay, upper Paraguay and the Pantanal will be included next.

The GEF/LPB activities are now focused on the generation of the implementation plan and 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 GEF implementation plan is planned for June 2005. 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.

6.3.4 The LPB Field Experiment: PLATEX (M.A. Silva Dias, H. Berbery)

In complement to the monitoring activities, a comprehensive field experiment with a focus on land surface atmosphere interactions (PLATEX) as part of the LPB observational strategy is being planned that will lead to improvements of both atmospheric and hydrologic models. Within the framework of these questions the LPB experiment – PLATEX - was thought as an auxiliary research tool where specific aspects, and specific scientific questions, can be addressed.

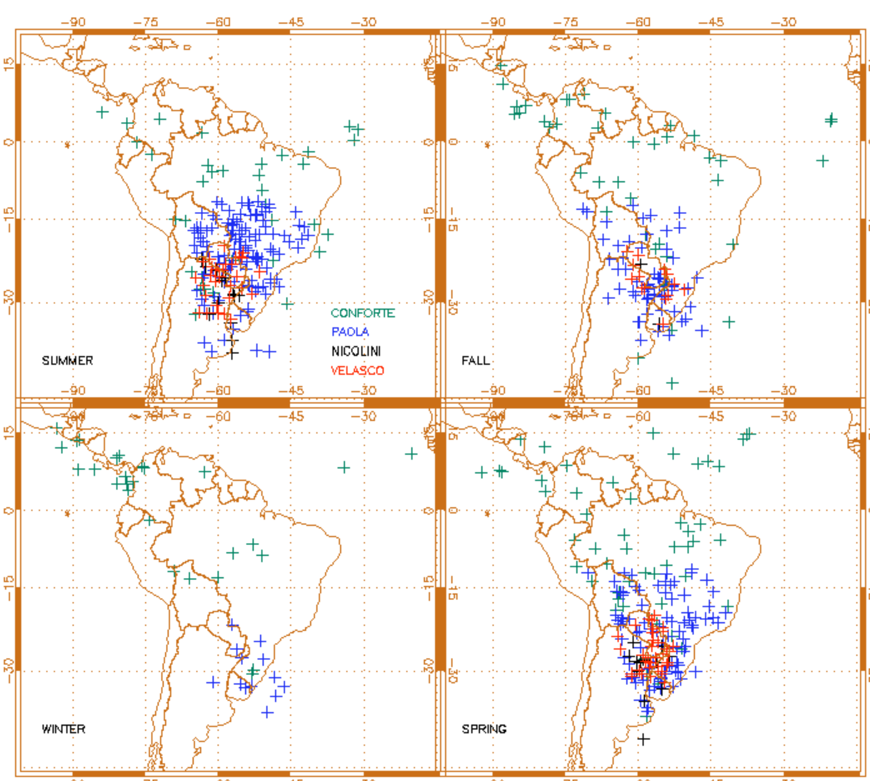


Figure 6.2. Mesoscale Convective Systems in South America

Vera et al (2006) describe the SALLJEX – South American Low Level Jet Experiment that had a focus on the relationship between the low level jet east of the Andes but also studied the simultaneous occurrence of Mesoscale Convective Systems - MCS.

The MCS are systems with a lifetime between 6 and 12 hours, in general, and with well-defined seasonality as may be seen in Fig. 6.2. Spring, Summer and Fall seasons are the preferred period of the year for these systems which have low predictability and large impact on water resources in the LPB.

Spring time has another peculiarity: it is the time of the year with major biomass burning in Central Brazil, with regional transports of aerosol and trace gases over the LPB as may be seen in Fig.6.3.

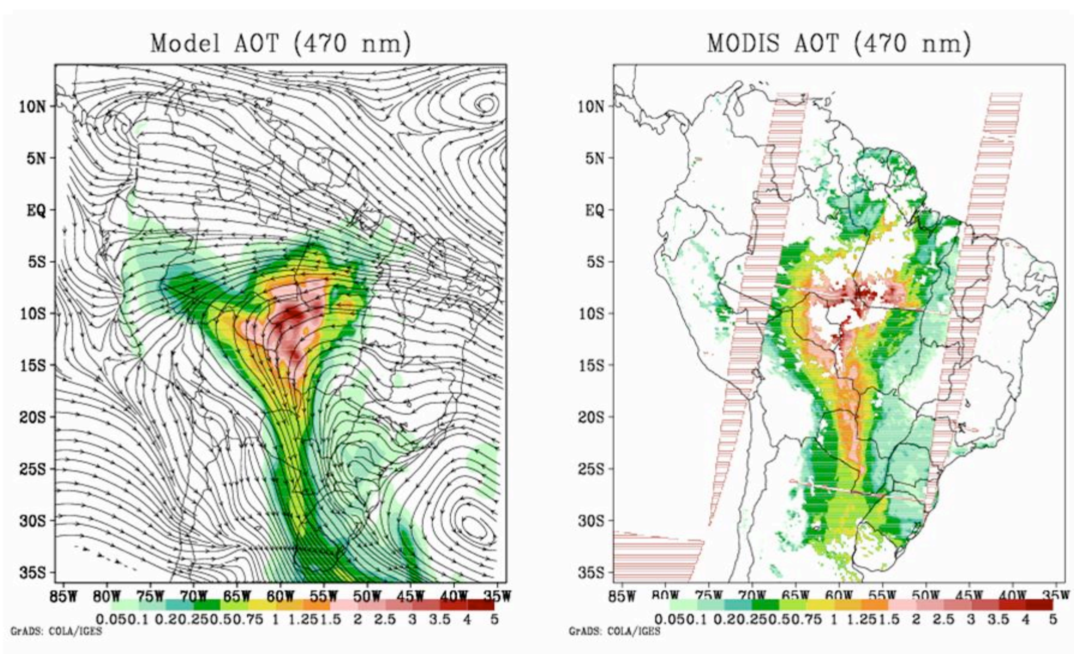


Figure 6.3 Numerical simulation and validation with MODIS of aerosol optical thickness. Freitas et al (2005)

The combination of vigorous convection with a large input of aerosol at variable heights poses the scenario for a quite complex interaction between radiation, cloud microphysics and the thermal structure of the atmosphere. The combined result represents a potentially large impact in the surface climate, precipitation and temperature. The sole impact of aerosol on radiation (shading effect) has been modeled by Longo et al (2005) and the effect is quite impressive as may be seen in Fig. 6.4

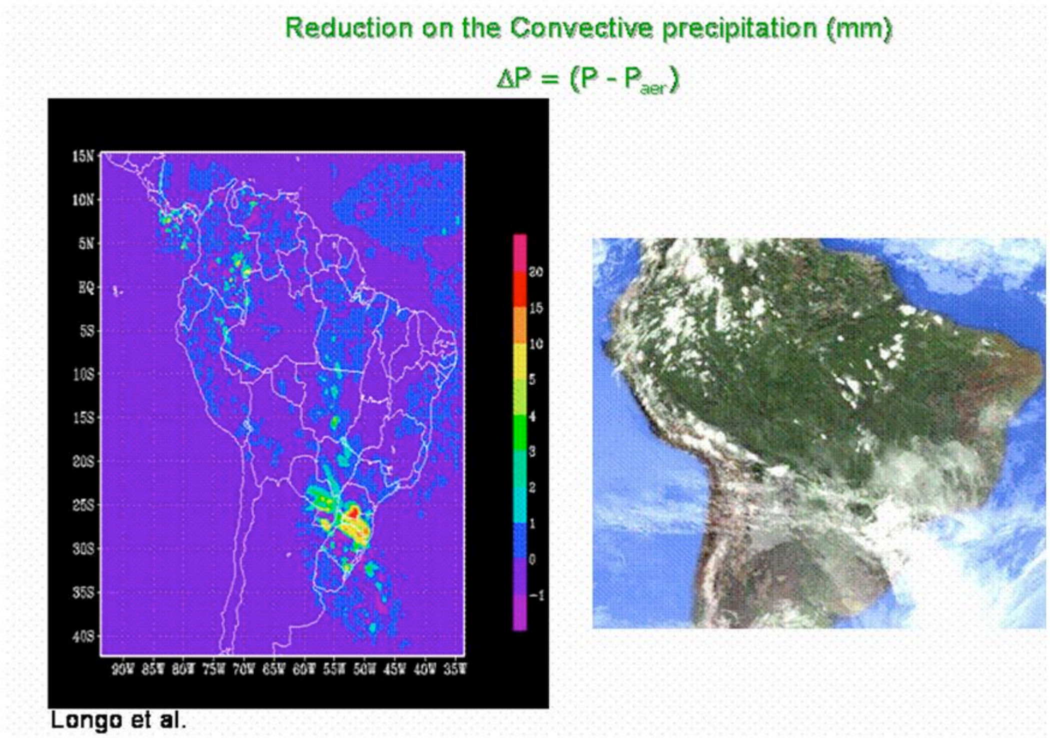


Figure 6.4.The figure on the left shows the difference in convective precipitation between two experiments without and with the aerosol-radiation interaction for the situation on the right, showing the corresponding satellite images. Red colors (positive values) indicated reduction in accumulated precipitation.

Understanding the processes involved is non trivial, mainly because the cloud microphysics impact is highly non linear. It is expected that predictability of weather systems, and quantitative rainfall prediction, are affected. Progress in scientific understanding requires special measurements, and thus the main motivation for a field campaign.

a. Scientific objectives

The **PLATEX** has as main scientific questions:

- *What is the role of biomass burning products in the evolution of MCS in the LPB?*
  - *What are the typical cloud microphysical processes involved in local convection, mesoscale convective systems and cold fronts? How aerosol contributes to the cloud processes in each case?*
  - *What is the typical MCS for the three different types of low level jet: CJE NCJE and LLJA*

- What is the impact of advected aerosol on the surface heat and moisture budgets?
- What is the radiative effect in the MCS life cycle?
- What are the constraints on MCS predictability?
- How is the typical microphysical structure of the convective clouds and how predictable is this microphysics structure?
- What are the rain volumes associated with the MCS in the LPB? Is the rain volume affected by biomass burning?

In parallel, there are several questions with respect to process understanding that require long term measurements. This can be achieved by a permanent three-dimensional super site. Besides an operacional monitoring of rainfall and aerosol to help with the research towards the PLATEX questions, there is another set more related to the establishment of a **LPB Super Site**. These are:

- *What is the role of land use and land cover change on the rainfall patterns in the LPB?*
    - *Is the surface condition as defined by land use, important for the convective development?*
    - *How are the surface fluxes of sensible and latent heat affected by agricultural practices?*
    - *How important is the large scale forcing vs local condition?*
    - *What is the relative importance of baroclinic conditions, aerosol input, land change, in the production of rainfall?*
    - *How predictable are floods in the LPB?*

b. Experimental Design

The LPB is covered by a network of surface and upper air instrumentation that is unparalleled in spatial distribution in South America. There are however gaps in temporal coverage due to different problems, the most common being budget limitations in the several countries involved.

The operational surface and upper air network may be seen in Figure 6.5.

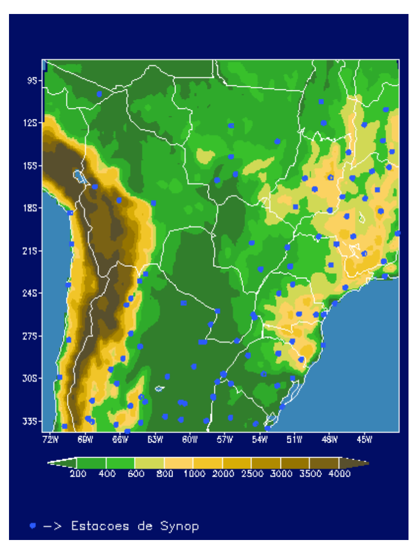


Figure 6.5. Operational upper air network on the left. Upper and lower panels on the right show the Metar and Synop- surface network of meteorological stations.

The operational radar network may be seen in Figure 6.6.

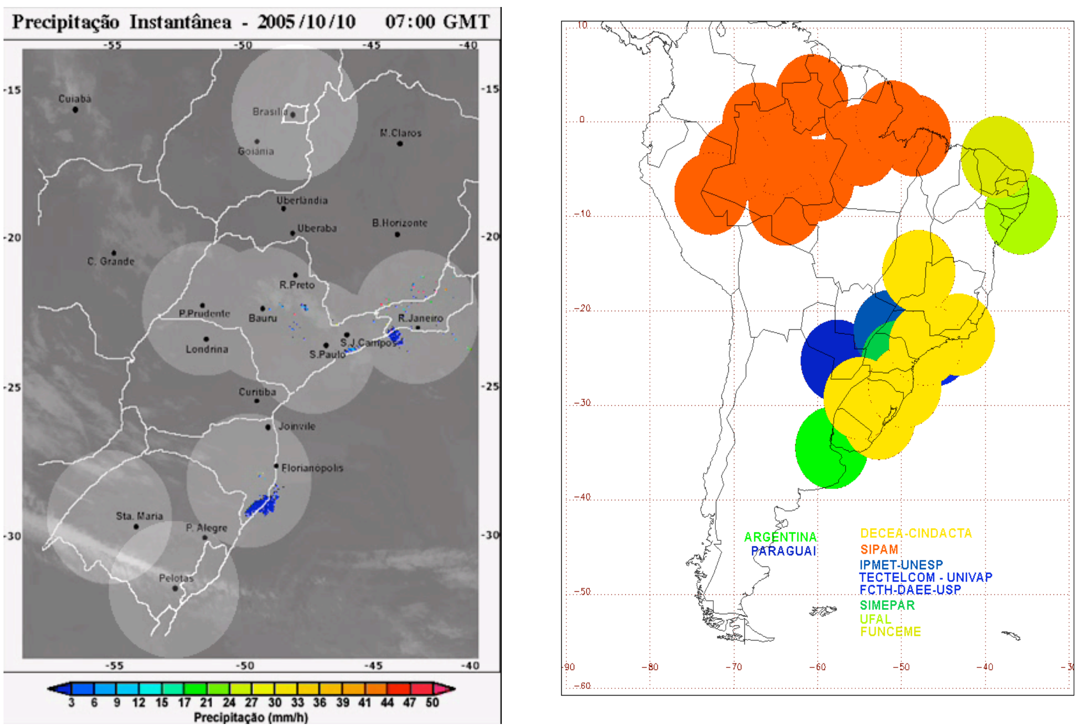


Figure 6.6. On the left the meteorological radar coverage in Southern Brazil. On the right the same for So. America.

c. PLATEX extra observations

The SALLJEX as described by Vera et al (2006) incremented the upper air network through extra radiosonde stations and pibal ballon stations. A Similar approach is proposed for PLATEX.

Dual Pol Doppler radar from NCAR – SPOL and XPOL from University of São Paulo to be installed in Foz do Iguaçu

Another portable S-Doppler Radar from TECSAT, as long we can get some funding for them

Assuncion Paraguay has a S-Doppler Radar that works on IRIS, which it will be helpful.

Argentina – The Air force of Argentina controls 2 S-Doppler radars from EEC that can provide information as well.

d. The LPB Super Site

Establish Foz do Iguaçu as the main site, so Paraguay, Argentina and Brazil have common measurements.

Weather Radar: provide 3D – Doppler measurements
Ground Radiometers: Provide microwave radiometry measurements
Aerosols: Particle counters and CCN counters, aeronet sun photometer, aerosol lidar.

e. Lightning Network:

Since we are measuring MCS activity, lightning information can be an indicative of MCS strength, since it is related to updrafts, water and ice content, and hydrometeors distributions. Later, very few campaigns focused on an intercomparison between different lightning networks to establish the real detection efficiency among the different instruments. Therefore, this campaign can provide a unique opportunity to establish this kind of validation and at the same time, provide 3D information of the lightning activity. Based on this concept, we can begin an interaction with atmospheric electricity community to participate in PLATEX. The following instruments and networks should operate near Foz do Iguaçu as the main central stations:

- RINDAT – The Brazilian Lightning Detection Network has several antennas installed in Rio Grande do Sul, Paraná, Santa Catarina and Mato-Grosso, which can provide information about cloud-to-ground activity.
- SIDDEM – The Santa Catarina Lightning Detection Network operates a lightning systems that can provide total lightning information, i.e., cloud-cloud, intra-cloud and cloud-to-ground over Santa Catarina
- ZEUS – This VLF system is expanding the network to incorporate 2 more receivers in Brazil, which will enhance the lightning monitoring over the entire South America. One important point is that if we submit a proposal do NSF or NASA, we can receive another receivers to support this campaign, or move the existing receivers from Africa to here.
- WWLLN – This is another VLF system that measures CG over the entire globe. We can contact the PI at University of Washington at Seattle to provide the measurements;
- LDAR – VHF system that measures total lightning activity in a 100 km area. The MSFC and University of Texas have such systems that can be installed during the campaign. Also, Vaisalla has interested in testing this system in Brazil.
- Field Mills, Dr. Earle Williams and Dr. Osmar Pinto have several antennas that measure the vertical electrical field that can be used to track the lightning activity.

Research balloon (people from Toulouse who participated in the AMMA project)

The LPB Science and Implementation Plan, along with meeting presentations and other information, is available at http://www.eol.ucar.edu/projects/lpb/ . Observations and other operational information will be available at http://www.cptec.inpe.br/LPB

6.4 Link with other programs

-A Europe-South America Network for Climate Change Assessment and Impact Studies-CLARIS-LPB (updated April 2009)

The CLARIS LPB Project aims at predicting the regional climate change impacts on La Plata Basin (LPB) in South America, and at designing adaptation strategies for land-use, agriculture, rural development, hydropower production, river transportation, water resources and ecological systems in wetlands. In order to reach such a goal, the project has been built on the following four major thrusts:

1-Improving the description and understanding of decadal climate variability is of prime importance for short-term regional climate change projections (2010-2040).

2-Second, A sound approach requires an ensemble of coordinated regional climate scenarios in order to quantify the amplitude and sources of uncertainties in LPB future climate at two time horizons: 2010-2040 for adaptation strategies and 2070-2100 for assessment of long-range impacts. Such coordination will allow to critically improve the prediction capacity of climate change and its impacts in the region.

3-Adaptation strategies to regional scenarios of climate change impacts require a multi-disciplinary approach where all the regional components (climate, hydrology, land use, land cover, agriculture and deforestation) are addressed in a collaborative way. Feedbacks between the regional climate groups and the land use and hydrology groups will ensure to draw a first-order feedback of future land use and hydrology scenarios onto the future regional climate change.

4-Stakeholders must be integrated in the design of adaptation strategies, ensuring their dissemination to public, private and governmental policy-makers.

5- Finally, in continuity with the FP6 CLARIS Project, our project will put a special emphasis in forming young scientists in European institutes and in strengthening the collaborations between European and South American partners.

The project is coordinated with the objectives of LPB, an international project on La Plata Basin that has been endorsed by the CLIVAR and GEWEX Panels.

The project is a partnership of European and South American institutions, among them CPTEC, CIMA-UBA, University of Chile, among others.

-The EUROBRISA Project

The goal of this project is to improve seasonal forecasts in S. America:
a region where there is seasonal forecast skill and useful value. The project aims to:

- Strengthen collaboration and promote exchange of expertise and information between European and S. American seasonal forecasters

- Produce improved well-calibrated real-time probabilistic seasonal forecasts for South America
- Develop real-time forecast products for non-profitable governmental use (e.g. reservoir management, hydropower production, and agriculture)

This project represents a partnership between CPTEC, INMET, ECMWF, UK Met Office, Meteo France, Universidade Federal de Parana, SIMEPAR, University of Reading, Universidade de Sao Paulo, CIIFEN and the IRI.