10.1 CONTRIBUTIONS OF LBA AND GCIP TO THE WORLD CLIMATE RESEARCH PROGRAM

Richard G. Lawford
NOAA Office of Global Programs, Silver Spring, MD USA

Carlos A. Nobre
Center for Weather Forecasting and Climate Studies (CPTEC), Brazilian Space Research Institute (INPE), Cachoeira *Paulista, SP, Brazil*

1. INTRODUCTION

The Large-scale Biosphere Atmospheric Experiment in Amazonia (LBA) and the GEWEX Continental-scale International Project (GCIP) are two continental experiments in the Americas being carried out under the auspices of the World Climate Research Program's Global Energy and Water Cycle Experiment (GEWEX). GEWEX consists of two principal elements: the development of global data sets designed around specific water and energy budget parameters, and studies in different regions aimed at closing the regional water and energy budgets over different time and space scales. The closure of regional water balances over specific land areas has proven to be a very useful integrating theme for GEWEX. A total of nine large land areas form the six continental-scale experiments and affiliated projects being coordinated by the GEWEX Hydrometeorology Panel (GHP). These experiments examine climate zones stretching from South America to the northern polar latitudes and including the five major continents. The Continental Scale Experiments include the Large-Scale Biosphere Atmospheric Experiment in Amazonia (LBA) led by Brazil; the GEWEX Continental-scale International Project (GCIP) in the Mississippi River Basin led by the USA; the MacKenzie GEWEX Study (MAGS) in the Mackenzie River Basin led by Canada; the Baltic Sea Experiment (BALTEX) which includes the drainage basin for the Baltic Sea and is led by Germany; and the GEWEX Asian Monsoon Experiment (GAME) led by Japan and covering large land areas in eastern Asia from Thailand to Siberia. The CATCH initiative is a new regional study in southwest Africa being coordinated by France and Benin.

Collaborative activities between LBA and GCIP are coordinated through the GEWEX Hydrometeorology Panel (GHP) and also through the CLIVAR VAMOS Program. As a result of the GHP, LBA and GCIP are collaborating in the GEWEX Water and Energy Budget Study (WEBS), in mesoscale modeling efforts, and in the new Coordinated Enhanced Observing Period (CEOP). In addition there is excellent collaboration at the scientist level among a number of scientists contributing to both projects. The International Satellite Land Surface Climatology Project (ISLSCP) and the Biological Aspects of the Hydrologic Cycle (BAHC) program also foster linkages between LBA and GCIP. This paper provides a review of those activities where scientific collaboration is producing contributions for the World Climate Research Program. In addition, it will discuss future collaborative efforts being planned between LBA and GCIP.

2. OVERVIEW OF LBA

LBA is being carried out in the world's largest river basin. The Amazon River drains an area of 6.2 million square kilometers and carries an average of 6300 cubic kilometers of water to the ocean annually. The Amazon Basin is experiencing rapid land cover change as deforestation advances into the central part of the basin. LBA is a truly international project because the area being studied overlaps a number of national jurisdictions and the funding comes from Brazil, the United States (NASA) and the European Union.

The overall goal of LBA is to understand the climatological, ecological, biogeochemical and hydrological functioning of the Amazonia. LBA's objectives (LBA Science Planning Group, 1996) are:

1) to quantify, understand and model the physical, chemical and biological processes controlling the energy, water, carbon, trace gas, and nutrient cycles found within the Amazonia and to determine how these link to the global atmosphere;
2) to quantify, understand and model how the energy, water, carbon, trace gas and nutrient cycles respond to deforestation, agricultural practices and other land use changes, and how these responses are influenced by climate;
3) to predict the impacts of these responses to variations in climate both within and beyond the Amazonia under future scenarios of changes in land use and climate;
4) to determine the exchanges between Amazonia and the atmosphere of key greenhouse gases and species regulating the oxidizing potential of the atmosphere, and to understand the processes regulating these exchanges; and
5) to provide quantitative and qualitative information to support sustainable development and ecosystem protection policies in Amazonia in the context of both its regional and global functioning.

The broad objectives of LBA have led to a fully integrated interdisciplinary program involving hydrology, ecology, meteorology, and atmospheric chemistry. The components of the program contributing most directly to the overall GEWEX mission are its hydrology and physical climate components.

The LBA research strategy relies upon the measurement of key parameters in selected areas over long periods (3 to 5 years) and intensive observing periods to supplement these measurements. In addition, model development and case studies allow an assessment of the large-scale effects of deforestation. Finally the project will develop methodologies to translate these results into forms that are useful for policy makers concerned with sustainable development.

3. OVERVIEW OF GCIP

The GCIP initiative in the Mississippi River Basin considers a smaller geographical domain than LBA that is primarily in the USA with a small northward extension into Canada. The Mississippi River drains 3.2 million square kilometers of agricultural and forested land and carries an average 570 cubic kilometers to the Gulf of Mexico annually. This flow frequently includes high sediment loads and large concentrations of nitrates. These nitrates lead to a depletion of oxygen in the receiving waters in the Gulf of Mexico and during the summer frequently generate a large "hypoxia" area in the Gulf where no fish are present.

The strategic mission for GCIP is "to demonstrate the ability to predict changes in water resources on time scales up to seasonal and interannual as part of a climate prediction system." An underlying principle of GCIP's observational activities has involved exploiting the extensive conventional measurements in the basin to the maximum extent possible. However, for some land surface modeling requirements GCIP has had to install additional regional soil moisture measurement sites and flux towers.

To achieve its mission GCIP has established five working objectives (NRC, 1998), namely:

1) to determine and explain the annual, interannual and spatial variability of water and energy cycles in the Mississippi River Basin;
2) to develop and evaluate coupled hydrologic-atmospheric models at resolutions appropriate to large-scale continental basins;
3) to develop and evaluate atmospheric, land and coupled data assimilation schemes that incorporate both remote and in-situ observations;
4) to improve the utility of hydrologic predictions for water resource management up to seasonal and interannual time scales; and
5) to provide access to GCIP in-situ, remote sensing and model data sets for use in GCIP and as benchmarks for model evaluation.

4. COMMON LBA/ GCIP RESEARCH AREAS

4.1 Mesoscale Modeling

LBA and GCIP have used common regional models to explore land atmosphere interactions. In particular, the RAMS (Regional Atmospheric Modeling System) model has been used to assess the importance of surface heterogeneity for mesoscale circulations. While some studies of flux estimates have shown that scaling up by aggregation techniques to scales appropriate for climate models does not have a significant effect on overall fluxes, observational evidence is now supporting the RAMS model results that show patchy areas with length scales in excess of 10 km are capable of generating their own mesoscale circulations. While this has implications for the Great Plains of the USA where variations in spatial patterns in vegetation cover can change on a seasonal basis, the effects are even more dramatic over the Amazon where patterned changes in the landscape occur due to the relatively organized fashion in which deforestation occurs as a result of roads being built in an area.

Another common modeling activity between LBA and GCIP involves the use of the Eta model. The Center for Weather Forecasting and Climate Studies (CPTEC) runs the Eta model with a SSiB land surface model interface. This model provides regional forecasts throughout the area and the results have also been used for water balance studies. Through the National Centers for Environmental Prediction (NCEP), the GCIP project has been relying upon the Eta model with the NOAH Land Surface Scheme to provide data assimilation products for water and energy budget studies in the Mississippi River Basin. The results from these models have shown that improvements are needed in the parameterization schemes for both the Amazon and Mississippi River Basins. In particular, the Eta model has difficulty simulating precipitation over the Amazon Basin, possibly because of the complexities of vegetation-atmosphere interactions. Difficulties in simulating precipitation also occur over the USA although these differences appear to be more manageable and arise from different causes.

4.2 Water and Energy Budget Studies

As a first step to predicting changes in water budget components the GEWEX Hydrometeorology Panel has initiated a Water and Energy Budget Study (WEBS). The objectives of this effort are:

1) to document water and energy budget components over the Continental Scale Experiment areas and their variability in space and time;
2) to describe the processes that control the variability in these water budgets;
3) to determine to what degree the water and energy budget of each CSE can be closed; and
4) to provide data that will be useful in model development for predicting changes in water budget components.

Both LBA and GCIP have undertaken research to address the water budget issues although databases for historic studies are much more extensive in the GCIP area. However, even in the Mississippi River Basin, it is clear that the conventional networks do not provide the space and time resolution required to accurately close the water budget. For example, radiosonde launchings separated by 12-hour intervals do not provide sufficient time resolution

to resolve moisture flux convergence over the basin. Some of the features of the water cycle in the Amazon and Mississippi River Basins that have been documented by these studies are:

1) the importance of ENSO events in both basins. However, the effects are more dramatic in the Amazonia where a change in the Walker circulation associated with an ENSO event shifts the location of precipitation maxima. In the Mississippi River Basin the ENSO influence of precipitation is weaker and is generally limited to winter months;
2) strong North-South gradients in annual precipitation exist across the Amazon Basin, particularly between 74W and 62W and between 56W and 50W. Also, the North-South gradient reverses at approx. 58W. In the Mississippi River basin the strong gradients in precipitation occur in the East-West direction;
3) significant diurnal variability occurs in precipitation patterns in both basins. However, the diurnal variability in the Mississippi River Basin appears to be more strongly linked to a nocturnal low level jet that transports moisture into the central USA;
4) seasonal precipitation patterns over the Amazonia indicate that precipitation maxima tend to shift spatially with season although the maximum near the Andes mountains is quite persistent. On the other hand the precipitation maxima in Northeast Brazil appear to be confined to the December to May period. Clearly, the movement of the ITCZ through the region has a dramatic effect on seasonal precipitation patterns. The Mississippi Basin is not dominated by such a large-scale feature and the seasonal signal is strongly continental (summer maximum, winter minimum), particularly in the western regions; and
5) the discharge from the Amazon River shows strong interannually variability although this variability is not as strong as the seasonal variability. The Amazon River peak flows generally occur in June or July. In the Mississippi River Basin where snow melt is often a contributor to spring discharge, the peak flows can occur as early as March or as late as June. Again interannual variability is large and in years of extremes such as 1988 (drought) and 1993 (flood) it can exceed the magnitude of the annual cycle.

4.3 *Coordinated Enhanced Observing Period*

The Coordinated Enhanced Observing Period is a GEWEX initiative that is moving from the planning stage to implementation in the coming year. The CEOP objective of most relevance to GCIP and LBA is "to demonstrate added skill in predictions up to seasonal for water resources applications using improved land-hydrology models." (GHP <draft>, 1999). To achieve this objective both projects will extend and enhance their special observing periods and contribute data from reference sites within the areas of interest. Data sets from the Southern Great Plains Cloud and Radiation Testbed (CART) in the GCIP area will constitute one of the foundational reference data sets for CEOP. Model transferability studies between the Mississippi River Basin and the Saskatchewan River Basin in Canada and the Rio del Plata in Argentina are also being considered as contributions to CEOP.

5. FUTURE DIRECTIONS FOR LBA AND GCIP COLLABORATION

The links between LBA and GCIP are expected to strengthen over the next three years as a result of the collaborative activities described above. In addition, the following activities are expected to be jointly addressed in both programs:

1) role of low-level jets and monsoonal circulations: both the Amazon and Mississippi River Basins have large moisture influxes from the surrounding oceans. While the relative contributions of these areas are quite well known, the mechanisms and controls for the movement of this moisture are not as well known. More research is needed to document the role of these processes in regional water budgets;
2) predictability: the existence and time decay of memory and predictability associated with a number of physical processes such as vegetation and soil moisture need to be explored and understood. Where memory and predictability are significant, techniques will be developed for incorporating this understanding into prediction systems; and
3) model transferability studies: as part of the process of developing more generalized land surface schemes, models developed in one area will be tested in other areas. Although some related work is being done in both regions with the RAMS and Eta models, more rigorous model transferability studies designed to assess the robustness of process representations, parameterization algorithms and calibrations are needed.

6. SUMMARY

Both LBA and GCIP have benefited from their collaboration through the GEWEX Hydrometeorology Panel. The involvement of these CSEs in more demanding GEWEX projects such as the Water and Energy Budget Studies and the Coordinated Enhanced Observing Period will strengthen these linkages and provide new opportunities for technology transfer.

7. REFERENCES

GEWEX Hydrometeorology Panel CEOP Working Group, 1999: Draft Science and Implementation Plan for a Coordinated Enhanced Observing Period (CEOP), Silver Spring, MD.

LBA Science Planning Group, 1996: The Large Scale Biosphere-Atmosphere Experiment In Amazonia: Concise Experimental Plan, LBA Project Office, 41 pp.

National Research Council, 1998: Global Energy and Water Cycle Experiment (GEWEX) Continental-scale International Project: A Review of Progress and Opportunities, Washington, DC, 93 pp.