FAPESP São Paulo School on Advanced Studies

2011 School on Global Climate Modeling

Summary Report

Ubatuba, Brazil, 3-14 October 2011

FAPESP Research Program on Global Climate Change – PFPMCG

Brazilian Program for Climate Change Research – Rede CLIMA

National Institute for Science & Technology for Climate Change – INCT-MC

National Institute for Space Research – INPE

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FAPESP's 2011 São Paulo School on Advanced Studies

17 January 2013

Cover Photograph: picturing students and lecturers of

2011 FAPESP's São Paulo Summer School on Global Climate Modeling

October 3-14, 2011, Ubatuba, São Paulo, Brazil

INTRODUCTION

The São Paulo School on Global Climate Modeling (SPSGCM) was an initiative of the National Institute for Space Research's (INPE) Center for Earth System Science (CCST), sponsored by FAPESP's Research Program on Global Climate Change (PFPMCG), through the São Paulo School of Advanced Studies program.

The Summer School initiative was motivated by the great challenge of constructing a state of the art global Earth System Model, fruit of South-South cooperation among India, Brazil, and South Africa—the IBSA Program. The seed for the construction of an IBSA-Earth System Model (ESM) was launched during the IBSA-Ocean meeting in Goa, India, in March 2009, following the Brazilian initiative to start its own ocean-atmosphere-biosphere global coupled model. The first IBSA-ESM workshop then followed suit in October 2010, hosted by INPE in São José dos Campos, Brazil. The strategy adopted during this inaugural workshop was to focus on the land-ocean, land-atmosphere, and ocean-atmosphere interfaces, through the modular component models and coupling strategies contributed by the expert teams from the participating nations. The 2011 SPSGCM in Brazil was the next step, with lecturers and students from the IBSA countries, as well as the United States, Germany, Uruguay and Chile. In the sequence, the upcoming IBSA-ESM Summer Schools shall focus on the land-atmosphere and the ocean-atmosphere couplings. The forthcoming Schools are expected to happen in India and South Africa, before taking place in Brazil again.

The goal of the 2011 IBSA-ESM Summer School was to attract bright young scientists from South America, South Africa, and India to discuss modeling aspects of the climate system, with focus on *the effects of river discharge on ocean circulation and climate*. The Summer School was held in Ubatuba, SP, from October 3 to 14, 2011, and consisted of lectures, hands-on modeling work and discussions. 24 students, 6 research assistants and 7 lecturers attended the School, from India, South Africa, Uruguay, Chile, United States, Germany, and Brazil.

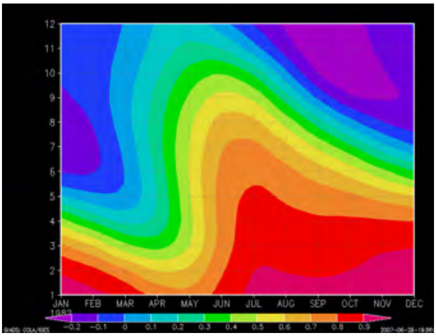
In the modeling laboratory work done during the School, students were exposed to techniques and concepts ranging from shell scripting language to the mechanics of the coupled ocean-atmosphere model, also learning the details of the continental scale hydrological model used during the School. In total, students did 24 experiments with the hydrological model at their local workstations provided by the School, as well as over 100 runs of INPE's ocean-atmosphere-land coupled model remotely at INPE's CRAY XT6 supercomputer, in Cachoeira Paulista, SP.

Each student ran his/her own hydrology modeling experiment with varying land use scenarios and model parameters for the Amazon Basin, generating Amazon River discharges, which were then used as input of the coupled ocean-atmosphere model runs. The results of the coupled model simulations were comprised by varying river discharges, and then contrasted with two control runs: with and without seasonal river discharges. These were used to gauge the varying effects of river discharges on global ocean surface salinity and temperature. Among the results, discussed among students and lecturers, was the significant role of the Amazon and Congo River discharges to altering both sea surface salinity and temperature on a basin scale.

Among the many achievements of the SPSGCM, one is still to be sought: the continued joint research and publication on the subjects covered during the Summer School, once students, as well as lecturers are back to their home stitutions.

The São Paulo School on Global Climate Modeling web address is: http://spsgcm.ccst.inpe.br/, where its full report can be accessed.

Dr. Paulo Nobre, from INPE, Brazil, opened the School with an introductory talk on the objectives and scientific challenges the Summer School was going to present. Among them were the questions of how we can contribute to better the understanding and modeling of the world's climate; and of where predictability comes from. According to Dr. Nobre, the objectives of the School were therefore twofold: to promote the discussion of leading edge problems of climate modeling, in particular regarding land-ocean coupling; and to foster the establishment of an India-Brazil-South Africa network of young climate researchers to develop the IBSA-Earth System Model. The challenge thus was the establishment of a collaborative network across the Atlantic and Indian Oceans, to engage both young and senior scientists to continue to cooperate on the research topics brought forth during the Summer School.

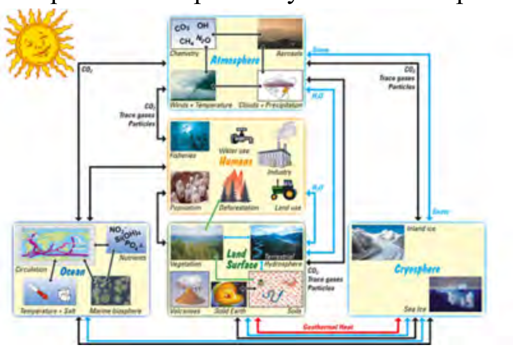


At the end of his introductory remarks, Dr. Nobre stated that the Summer School was a Brazilian initiative, co-sponsored by FAPESP, Rede CLIMA, and INCT-MC, aiming at bringing South American, South African and Indian researchers together to develop an across-the-oceans Global Climate Model; addressing both small and large questions relevant to Southern Hemisphere climate, not addressed by other models. In time, Dr. Nobre mentioned that the idea of the Summer School among Indian, South African, and Brazilian Ph. D. students emerged from a conversation he had with Prof. George Philander, in South Africa, in 2009.

Dr. Guy Brasseur, from the Climate Services Center, Germany, presented a comprehensive overview of the climate system, from basic physical fundaments of the climate science to advanced topics of climate modeling and societal impacts. He approached two great challenges faced by the scientific community regarding weather and climate: the numerical weather prediction, and climate change.

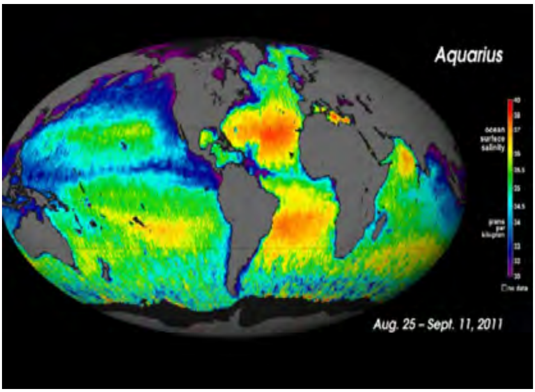
Explaining the several components of the climate system, and their interconnections, Dr. Guy highlighted the challenge of climate modeling due to the multiple feedbacks interlinking the system.

In sequence, by pointing to century old remarks by famous physicists and mathematicians and the sequence of exploratory work developed along the centuries about climate sciences, Dr. Brasseur demonstrated that humanity faces an unprecedented challenge to live in a changing planet. His remarks also brought the attention of the students to the need of understanding the role of societies as both agents and subjects of climate change. After the lecture, Dr. Brasseur handed a set of questions concerning climate change and climate modeling, which were subject to group discussions and early evening presentations by the groups. On the second day of the School, Prof. Brasseur covered mathematical aspects of: differential partial equations solving techniques used to integrate the equations of motion forward in time; adaptive grids; and computational stability issues.



Dr. Jim Carton, Dean of the Department of Atmospheric Sciences of the University of Maryland at College Park (UMCP), USA, delivered his lecture live from his office in College Park, MD, via high speed internet connection with the Summer School.

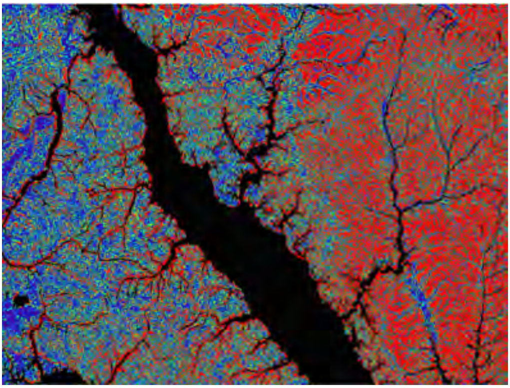
Dr. Carton's lecture covered several aspects of the hydrological cycle over the oceans, discussing the effect of fresh water on ocean dynamics and thermodynamics. Dr. Carton went at length to show the impacts of the hydrological cycle of the salinity field over the oceans. He showed both observational and modeling evidence of the freshening of northern latitudes of the Atlantic Ocean and its impacts on climate. The global coverage of surface ocean salinity, obtained by NASA's Aquarius satellite, illustrated well the advances on global ocean observations techniques, which will ultimately help improve global ocean models' accuracy and reliability.



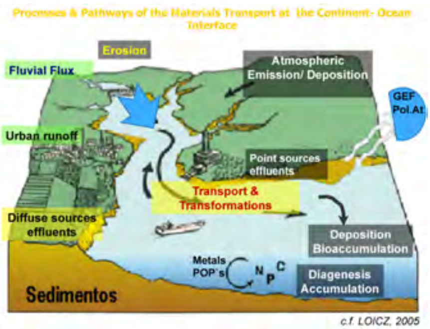
The lecturer also led the students through the numeric of the equations of motion and the balance equation for precipitation minus evaporation on the surface layer of the ocean. The laboratory exercises and questions were later worked on by the students, using the data files sent by Dr. Carton and made available at the OpenDap data server of the Summer School.

Dr. Antonio Nobre, from the National Institute for Amazonian Research (INPA), in Brazil, presented a detailed view of the thermodynamics of life and its central role in the predictability of geophysical systems.

His talk started by showing the evolution of the planet from its birth, showing that without photosynthesis, the water on Earth could be kept in only one of two stable forms: either a complete ice ball, or with all its water in vapor form. The only way Earth could sustain water in its three phases at the same time is through the presence of life-photosynthesis. The lecturer then covered Earth's paleoclimates and hydrological cycle. Dr. Nobre presented evidence that photosynthesis was also the culprit to maintaining habitable conditions on Earth for billions of years; in that it was instrumental to retrieve 95% of CO_2 from an ancient atmosphere, when the solar constant was 30% lower than today's atmosphere of 0.039% CO_2. The example given in class about self-regulatory systems, and later discussed at length by the student groups, created a synergetic link between the lecture and the laboratory work, which was experienced throughout the School. Dr. Antonio concluded his lecture by presenting a new paradigm for surface hydrology: HAND, a technique to mapping continental topography relative to the nearest river drainage point.

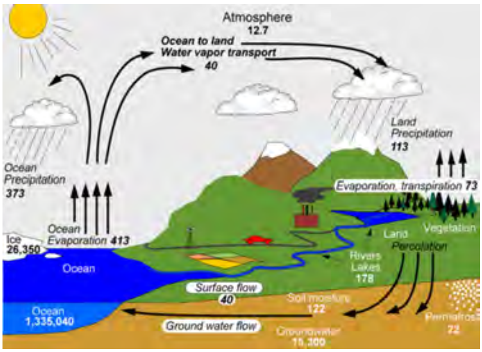


Dr. Luiz Drude, from the Federal University of Ceara (UFC), Brazil, covered the topic of material transport from the continent to the ocean. Among the many aspects discussed by Prof. Drude, the fundamental role of the mangroves and sea marches on the global carbon cycle was most salient. Sea level rise and coastal erosion were presented as two effective ways of ocean-land interaction, where large amounts of carbon storage can be quickly made available for the production chain in the ocean and re-enter the atmosphere. Another aspect of great relevance for climate research was the numbers presented about the human intervention on mangrove extension and composition. The effect of river damming for hydroelectric power generation was also discussed, showing a noticeable modification of the coastal dynamics near the river mouth on the ocean.

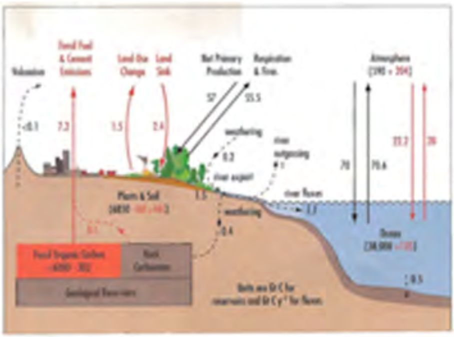


Among the main conclusions of the lecture was the fact that human activities have strongly accelerated the continent-ocean interface, the biogeochemical cycles and the magnitude of the continental runoff on a global level. Natural fluvial filters have been systematically altered, particularly due to damming, deforestation of river margins and conversion of natural coastal vegetation. River discharges to the ocean are presently controlled and reduced by hydraulic engineering works, irrigation, water withdrawal, and global climate changes.

Dr. Michael Coe, from the Woods Hole Research Center (WHRC), USA opened the second week of the Summer School with his lecture on continental hydrology. Dr. Coe covered the two core aspects of hydrological modeling, balance and transport models, explaining in detail the Terrestrial Hydrology Model with Biogeochemistry (THMB) transfer model equations, limitations and applications. As the introduction to the continental scale hydrological modeling, Dr. Coe covered the global and local aspects of water availability and its several links to global climate change and human usage. The THMB model equations were then presented, with a detailed explanation about the several parameters used to tune the model outflow. The lecturer argued that parameter tuning, while a necessary tool when detailed knowledge of the physiographic and soil characteristics of the hydrographic basin is lacking, should be used with attention to its implicit limitations when trying to represent smaller components of the hydrological cycle; for example, percolation to deeper layers of the water table. Students then participated in a lively discussion and modeling exercise, installing the model code in their computers and setting varying parameters to represent various use change scenarios and transfer equation parameters. The results of a day long of modeling activities generated Amazon river discharges, which where later used to study the effect of river discharge on the coupled ocean-atmosphere model setup for the School.

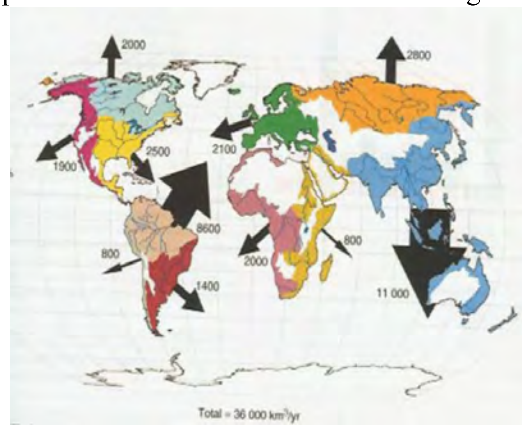


Dr. Alex Kursche, from the Center for Nuclear Energy on Agriculture (CENA), of the University of São Paulo, Brazil, lectured about the biogeochemistry of the Amazonian rivers. His lecture, rich in details of the observational aspects of river biogeochemistry, highlighted the great challenge to represent the diversity and complexity of fluvial biogeochemistry on current climate models. One of the main aspects of such complexity is the correlation between the nature of the water path to the river and the river's concentration of carbon, nitrogen, phosphorus, and sediments. Dr. Kursche depicted this through two classical examples: the waters of the Negro river, which drains the old and already heavily eroded topography of the northern Amazon, are rich in nutrients from the forest floor; and the Solimões river, on the other hand, which comes from the steep slopes of the Andes Mountain Range, brings therefore large quantities of sediments in its murky waters. Among the questions raised by Dr. Kursche during his lecture are: How will climate change affect the biogeochemistry of rivers in the Amazon? How will these changes, in turn, affect regional and global processes of the carbon cycle? What does it take to fully understand the role of the Amazon on global scales and its influence on global changes? This last question was then investigated by the groups of students in their laboratory work till the end of the School.



Dr. P.N. Vinaychandran, from the Indian Institute of Sciences (IISc), India, closed the section of lectures, covering the Summer School's central theme: the effects of river discharges on the oceans. Dr. Vinay showed the global values of the major river discharges on world oceans, analyzing the impact of river discharges as a function of both, river discharge volume and ocean basin area in which they flow in.

Dr. Vinay showed that there is a lag between the peak rainfall and peak river discharge, which is related to the area of the catchment basin and the river extension. For the Bramaputra-Ganges system, such delay is one month; for the Amazon it is up to three months. The massive impact of Amazon river discharge on Tropical Atlantic surface water freshening was showed. One process through which river discharge can affect ocean circulation is by modifying ocean waters' buoyancy. The time scale of the Meridional Overturning Cell (MOC) is of the order of 1000 years. Rennermalm et al (2012) have shown that the increase in Arctic river discharge results in the reduction of the MOC strength. Dai et al (2009) suggest that long-term trends of river discharge are decreasing on long time scales, whereas inter-annual fluctuations are increasing with time.



STUDENTS' MODELING LABORATORY WORK

The lab works done during SPSGCM 2011 consisted mainly of science related questions focusing on the morning lectures topics or practical applications (i.e. model integrations and model output data analysis). They aimed to analyze and discuss how to evolve or develop tools to improve the studied phenomena representation in hydrological models and in INPE's coupled ocean-atmosphere general circulation model.

In the first lab work, linked to the lecture delivered by Prof. Brasseur, the participants were asked about science issues and the dissemination of scientific knowledge. Other topics discussed were communication problems between scientists and policy makers.

In the second lab, Dr. Antonio Nobre posed the question of dynamical equilibrium in a complex system, using the adrenalin and cortisol interplay case to exemplify it. The lab work proposed the students to exemplify where the adrenalin-cortisol kind of system could be found in nature. Among the solutions submitted was a set of conjugate equations derived by Dr. Leo Siqueira (Brazil, Ph.D. candidate at the University of Miami, and one of the Summer School teaching assistants), to explain how the system works. Depending on parameter choices, and without external forcing, trajectories from both components converge/diverge to/from equilibrium (Fig. 1a). By adding adrenaline in the system, another steady state solution was reached where cortisol is not able to follow adrenaline increase: adrenalin was always at a higher concentration than cortisol (Fig. 1b). Including an external forcing in the cortisol, reduces the amplitude of adrenalin until it reaches the concentration of cortisol, neutralizing adrenalin after some time steps (Fig. 1c).

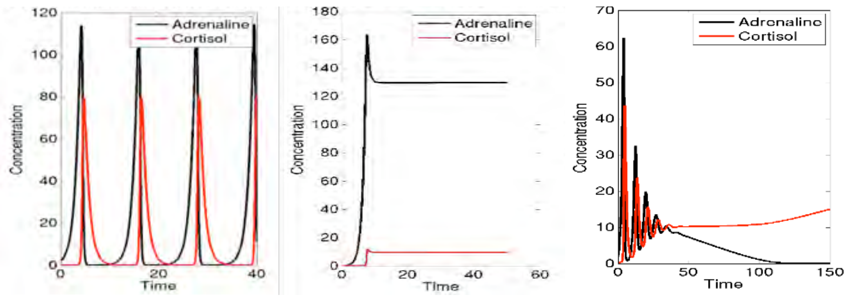


Figure 1 – Adrenalin-cortisol system responses with (a) CTRL run: no forcing; (b) adrenalin increase; (c) cortisol increase.

Dr. Jim Carton delivered his lecture via skype, having sent some of his own research model output before hand. The students were asked to analyze the importance of the salt budget equation terms in a time scale of pentads, seasonal, and annual averages; and to study the significance of diffusion in salinity distribution.

Dr. Luis Drude asked the participants to discuss the Artic-Northeast Brazil paradox: that the reduction of continental runoff and sea level rise result in the blocking of the continental water flux inside the estuary; for global climate changes increase water residence time in estuaries due to stronger blocking of river outflow by the elevation of sea level. With an increase of residence time inside semiarid estuaries, the production of bioavailable Hg (mercury) will increase. Contrary to what happens in the arctic, where the concentration of Hg increases with the increase of runoff. The implication of such paradox in terms of global climate modeling is to encompass two opposite perturbations that lead to same response, in this case increases of Hg concentration in the tropics and the arctic. In the Northeast Brazil the reduction/increase of river flow will result in an increase/decrease Hg concentration on Biota.

Dra. Luz Adriana introduced the THMB component models. Participants performed controlled experiments changing Amazon vegetation, mimicking anthropogenic effects. Results presented discharge decrease for less vegetation cover and increase for relatively higher vegetation cover.

The coupled modeling lab work done after Dr. Vinay's presentation on the importance of river discharge in ocean salinity and circulation represented one of the most promising results and major contributions of the Summer School. The numerical experiments consisted of doing pairs of coupled model runs, one with climatological river discharges on the world oceans, and a twin run with zero discharge from the Amazon and Congo rivers. Such drastic changes of the two largest river discharges on the oceans were meant to test the sensibility of the coupled model to the fresh water input into the oceans. Fresh water input changes to the oceans showed large-scale variations of salinity and temperature over global oceans (Fig. 2), suggesting the importance of fresh water discharge to modulate global climate variability. These results are being evaluated and shall be part of a scientific paper originated from the research work started at the Summer School.

The ensemble mean, annual average difference map between control runs (CTR2 minus CTR1) is shown in Figure 2. CTR1 runs were done with river discharges off and CTR2 with all river discharges on. Coupled model initial conditions for both experiments were for days 1, 2, and 3 of January 2007. Note in Figure 2 the large-scale temperature response to the freshwater input into the oceans. It is also noteworthy the two main paths of fresh water advection from the mouth of the Amazon River; with one branch entering the interior of the basin at the approximate position of the North Equatorial Counter Current (NECC), and the other along the North Brazil Current, in the direction of the Gulf of Mexico.

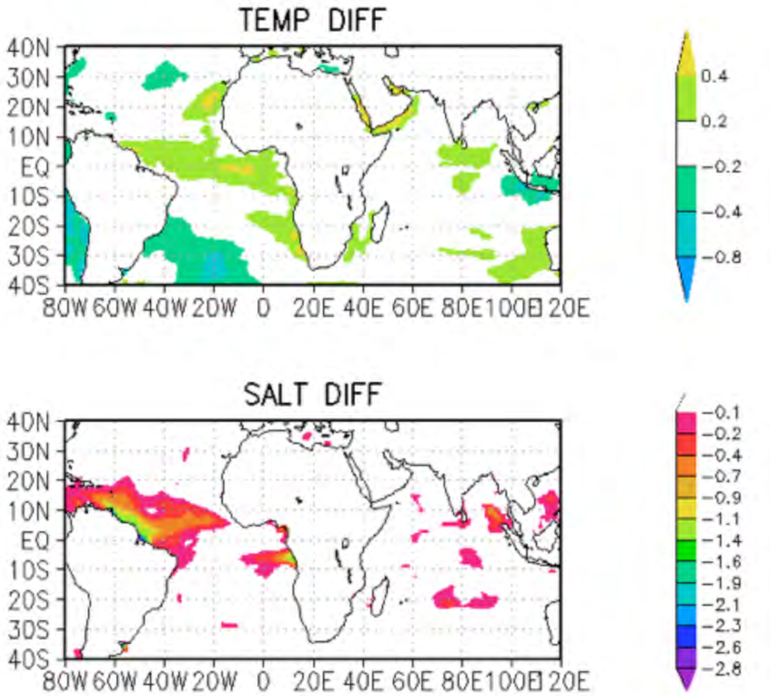


Figure 2 – Annual average ensemble mean of sea surface (a) temperature and (b) salinity difference fields CTR2 (with river discharges on) minus CTR1 (with river discharges off) for INPE's coupled ocean-atmosphere model experiments done during the FAPESP's São Paulo Summer School on Global Climate Modeling. The three ensemble members of CTR1 were results from the experiments conducted by A. Chatterjee (India), C. Ali (India), and K. Telekepalli (India); while the CTR2 runs with river discharges off were done by L. Alves (Brazil), C. Aguirre (Chile), I. Pinto (South Africa).

STUDENTS EVALUATION

A month after the Summer School, students were asked to respond to the following questionnaire, rating their evaluation from (1) very poor/completely disagree to (5) very good/completely agree. The table below summarizes the students' responses.

1) In your opinion, how was SPSGCM 2011 concerning your expectations on the contents covered during the two weeks course?	4.5
2) How effective in your opinion was the structure of the course, i.e. lectures in the mornings and lab work in the afternoon/evenings, during the Summer School?	4.5
3) How would you rate the lectures contents in terms of accessibility and completeness?	4.3
4) How was the connection between the topics covered in each lecture?	4.5
5) How do you grade the lab work and model implementation exercises?	4.0
6) How was the interaction between the lecturers, instructors and participants?	4.7
7) How important was the integral funding for your attendance of the Summer School?	4.7
8) How committed are you concerning the continuity of the group work developed during SPSGCM 2011 now that you're back home?	3.4
9) How often have you interacted with the other members of your study group since the adjourn of the Summer School in Ubatuba, Brazil, last October 2011?	3.4
10) Would you enroll yourself and/or recommend a friend for a future issue of the Summer School on Earth System Modeling in one of the IBSA countries (India, Brazil, South Africa)?	5.0

It is noted in the Table above that while students evaluation were generally high regarding the lecture contents and School structure, the lower grades to questions 8 and 9 indicate that extra efforts are needed to further the collaboration and networking among students and lecturers once the School is over and each of them are back to their home institution. Also, from the experience gained during the activities in Ubatuba, it is possible that an extra week of hands-on modeling and analyses work could have represented a potent fix to creating the international networking that the School intended to foster.

CONCLUDING REMARKS

Dr. Carlos Nobre, vice-Minister for R&D of MCTI closed the SPSGCM with a talk on the challenges that the detailed knowledge of global climate change represents for science and society. Dr. Carlos delivered an ample overview of the efforts in place in Brazil to create a solid research infrastructure allowing the formation of a new generation of researchers, aware of the multi-disciplinary nature of global climate change. Along these lines, he stressed the importance of international cooperation in the context of creating a truly integrative research network, allowing young and seasoned researchers to multiply their experience and new ideas on how to handle the challenges that climate change represents. Declaring his satisfaction with the results of the 2011 São Paulo School on Global Climate Modeling, Dr. Carlos Nobre stated his support to the mission of creating an IBSA Earth System Model, with the active participation of scientists from India, Brazil, and South Africa, among other nations.

The 2011 São Paulo School on Global Climate Modeling was conducted during the two-week period 3-14 October 2011, in Ubatuba, SP, Brazil. A total of nine lecturers and thirty graduate students and early Ph.D. participated in the School, which resulted in a very intense period of exchange of experiences among South American, South African and Indian students; and lecturers. The daily activities of lectures, modeling lab work, and student-lecturer evening discussions, intertwined with cultural activities in a beach resort, coronate the SPSGCM experience with great success.

In particular, the ability to remotely submit, run, and locally analyze the results of over a hundred global coupled model runs, one year long each, in INPE's supercomputer facility, one hundred kilometers away from Ubatuba, was a success story; with each student using a personal Linux notebook computer locally, provided by the School.

Most importantly, the global coupled model results which started pouring from the model runs analyses at the closing of the SPSGCM, with robust, multi-member ensemble means, picturing large scale coupled ocean-atmosphere responses to the river discharge sensibility experiments, was a most gratifying experience brought about by the School; result of the compromise, competence and enthusiasm of all involved.

The culmination of the Summer School with such positive results was a clear indication of the correct path chosen: to promote a loosely structured research environment; with a blend of experienced lecturers, graduate students, and teaching assistants; all of which immersed in an appropriate local environment; connected to INPE's state-of-the-art supercomputer facility with access to a suite of continental hydrology and coupled ocean-atmosphere global models.

It is therefore our conclusion that the São Paulo School on Global Climate Modeling, certainly the first of a sequence of such IBSA-ESM oriented structuring activities was a great success.

Yet, it will deliver its most important results only with the consolidation and expansion of the South-South scientific network, seeded by the SPSGCM and to be continued with the forthcoming IBSA-ESM initiatives in the years to come.

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