Newsletter of the Climate Variability and Predictability Programme (CLIVAR)

Exchanges

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In this issue

New Director of the ICPO

Dear CLIVAR community,

It is with great pleasure that we announce the appointment of Dr. John Gould as the Director of the International CLIVAR Project Office, to be co-located with the WOCE Project Office at the Southampton Oceanography Centre, Southampton, UK. John Gould will formally become ICPO Director on 1 April, 1998. We would like to welcome John on board and look forward to working with him during the coming exciting years for CLIVAR.

The Search Committee recommended John Gould as the leading candidate after reviewing two dozen applications. There were considerable discussions between the CLIVAR and WOCE co-chairs and the Director, WCRP, concerning the co-location of the CLIVAR and WOCE project offices in Southampton. There was general agreement that co-location would be excellent with respect to the longer term evolution of elements of WOCE into elements of CLIVAR and the sharing of expertise and experience. The UK Natural Environment Research Council (NERC), from which John Gould is seconded to the

WOCE Directorship, was also very supportive of the proposed changes. On the basis of these discussions, the Director of the World Climate Research Programme, Prof. Hartmut Grassl has offered the position to John Gould and he has accepted that offer.

The initial staffing plan to be put in place during 1998 will have two quite separate office structures for WOCE and CLIVAR but with these sharing a strengthened secretarial and publications staff. The longer-term evolution of the Project Office structure will be discussed by the CLIVAR SSG at its late April meeting. Each branch of the Office will be headed be a Chief Scientist whose role will be to provide advice to the Office Director on science issues. For WOCE this person will be Dr. Peter Saunders who has been on the staff of the WOCE IPO for the past 4 years.

We are currently recruiting for the CLIVAR Chief Scientist position. Applicants for the Director's position have been informed of the outcome of that competition and have been asked whether they wish their applications to remain active for the Chief Scientist position, now in the UK. An advert (see next page) will be posted in EOS and on various web sites within the next week. Please encourage likely candidates to apply for the post.

The movement of the office from Hamburg to Southampton will take time. Andreas Villwock and Anne Stephan will continue in the Office, working out of Hamburg, until the end of 1998. You should continue to contact them at the usual phone and fax numbers, emails and web sites. We will be negotiating with nations to develop a broader funding base for the ICPO so that it will have adequate resources, including staff, to do the co-ordination and development that CLIVAR implementation requires.

Dr. Lydia Dümenil will complete her term as Acting Director and return to her research position at MPI as of 1 April. She stepped into the post at what was the busiest and most important time in the development of CLIVAR and she has successfully lead and guided the CLIVAR Project Office as it brought the Implementation Plan to fruition. We all owe her our gratitude; the SSG co-chairs and panel chairs are especially aware of how much work needs to be done to co-ordinate CLIVAR. Lydia won't be leaving CLIVAR completely. She will continue as a member of the Asian-Australian Monsoon Panel and will be contributing as a scientist to CLIVAR's goals and objectives.

Moving the CLIVAR Office out of Hamburg was not an easy decision. Germany and Prof. Lennart Bengtsson were early and strong supporters of CLIVAR. We have been well supported and housed at the Max-Planck-Institut für Meteorologie (MPI). The assistance of MPI staff with regard to scientific and technical expertise has been frequent, vital and very much appreciated. Working with Lydia over the past seven months has also made us realize what a sacrifice Lennart made when he encouraged her to serve as Acting Director. We very much appreciate Lennart's and Germany's support over the years and hope that we can find mechanisms by which Germany and MPI can continue to play strong roles in CLIVAR planning and co-ordination.

Allyn Clarke and Kevin Trenberth
CLIVAR SSG Co-chairs

Dear CLIVAR community,

I am pleased to have this opportunity to introduce myself to you as the New ICPO Director. For the past 4 1/2 years I have directed the WOCE IPO and helped steer WOCE through the end of its observations and into an active analysis phase. It was a great honour to have been selected to head both the CLIVAR and WOCE International Project Offices.

CLIVAR presents many challenges as it builds on the legacies of TOGA and WOCE to address the climate issues that are now in the minds of a large part of the earth's population. I am convinced that it is sensible to bring these various research strands together in one project stretching from the seasonal/interannual ENSO and monsoon phenomena, through the rapidly-emerging evidence of decadal variability in the climate system to the vexing questions of long-term climate change and mankind's possible influence. All of these elements interact and CLIVAR needs to explore these interactions and to fit its research foci into a global framework of observations and modelling. The CLIVAR Conference in December 1998 will be a key step in moving CLIVAR from planning to implementation.

In embarking on the task of ICPO Director I will endeavour to develop an Office that will be responsive to the needs of the project and the individual scientists working in it and will help to raise awareness of the importance of the research being undertaken by CLIVAR. To do this I seek your help and co-operation in the coming years.

John Gould

INTERNATIONAL CLIVAR CONFERENCE

UNESCO, Paris, 1-4 December 1998

Following the successful TOGA (Tropical Ocean Global Atmosphere) and WOCE (World Ocean Circulation Experiment) programmes and responding to scientific challenges which evolved during those programmes, CLIVAR, the Climate Variability and Predictability Programme, has become the primary atmosphere-ocean research component of the World Climate Research Programme (WCRP). CLIVAR focusses on the role of the coupled ocean and atmosphere within the overall climate system, with emphasis on variability, especially within the oceans, on seasonal to centennial time scales.

CLIVAR will study and continue to improve predictions of climate variability using existing, reanalyzed and new global observations, enhanced coupled ocean-atmosphere models, and paleoclimate records. CLIVAR will promote the development of skillful regional and global predictive models and will enable a more accurate detection of anthropogenic modification of the natural climate. CLIVAR will strongly support the design and implementation of global ocean and atmosphere observing systems for long-term climate research and will specifically address the variability of regional coupled ocean-atmosphere systems such as monsoons in relation to global patterns such as ENSO. The CLIVAR Science Plan (WCRP No. 89, 1995) and the summary volume of the CLIVAR Implementation Plan (WCRP No. 101) provide extensive descriptions of the CLIVAR scientific foci and research goals. A more detailed Initial Implementation Plan (WCRP No. 103) will become available in early summer 1998.

To advance the planning and begin the implementation of CLIVAR, the WCRP sponsors, namely WMO, ICSU and IOC, will hold a major international Implementation Conference on CLIVAR at UNESCO Headquarters, Paris, France, from 1 to 4December 1998. Dr. D. Carlson of NCAR, USA, chairs the international Conference Organizing Committee.

The purpose of the Conference is to:

- present the Initial CLIVAR Implementation Plan to nations;
- receive comments on and endorsement of the Plan;
- receive expressions of interest in and commitments to CLIVAR;
- set time scales and priorities for implementing individual elements of the Plan based on these commitments and subject to any major gaps which are identified;
- examine and make recommendations for institutional arrangements to support CLIVAR;

- ensure linkages are in place for society to benefit from advances made by CLIVAR

The Conference will begin with an overview of the Implementation Plan. This will be followed by national comments and responses and a detailed assessment of resource commitments and gaps. Lastly, the Conference will address ways of participating in CLIVAR, finding the needed resources, and determining whether the existing institutional arrangements are appropriate and sufficient. The outcome of the conference will provide the CLIVAR Scientific Steering Group and national funding agencies with guidance on the priorities and how to implement CLIVAR.

All countries will be asked to come to the conference with a written statement detailing their interest and likely commitments to and comments on the Implementation Plan. These will be requested well before the start of the conference to ensure their availability to all participants and facilitate the proceedings. This exchange of information will be important to ensure the effectiveness of the conference since only limited time will be available at the conference for oral presentations.

Further information about the Conference can be obtained by returning the attached pre-registration form or by contacting the Conference Secretariat at ICPO, c/o MPI, Hamburg, Germany.

Investigating the Role of Polar Regions in Global Climate

Douglas G. Martinson, Lamont Doherty Earth Observatory, Palisades, NY, USA and CLIVAR SSG

Much of my research has been motivated by the premise that the polar regions play a significant and complex role in global climate.

Conceptually, this influence is often attributed to the fact that the poles lock the cold-end of the pole-to-equator thermal gradient which drives the Earth's climate. Changes in polar region temperature, and thus presumably this gradient, can be driven by a multitude of geographically-unique polar processes such as the ice-albedo feedback, ice-cloud feedback, ocean-ice feedback, deep convection, and ice sheet-ocean feedbacks.

Unfortunately, exactly how, or even whether, these different processes actually influence the transfer of heat from the equator to the pole is not fully understood. At the moment, our best estimate of what mechanisms are involved is determined through model studies. This reflects the fact that it is extremely difficult to collect data in the hostile polar regions so we are hindered in our ability to fully address these issues through observations themselves. However, models do provide support to the notion that changes in the polar regions may significantly influence global climate. For example, several studies using models that attempt to simulate the earth's climate suggest that reasonably-sized changes in the ice albedo or other polar surface conditions, have consequences that are ultimately felt globally. Most dramatically, recent numerical simulations of global climate, under conditions of doubled atmospheric CO_2 using the GISS atmospheric general circulation model, have shown that over one-third of the annual average global warming in that model is attributed (directly and indirectly) to the response of the sea ice distribution (Rind et al., 1995).

In addition to these expected influences on present day climate, other studies suggest that changes in the polar ice fields may help trigger the ice ages through amplification of the small Milankovitch forcing; alter the global deep water circulation; and instigate dramatic abrupt changes in climate. In addition, climate change may alter the mass balance of the polar ice sheets, or even destabilize the West Antarctic ice sheet, driving considerable sea level change. Beside their potentially unique role in the Earth's climate system, the polar regions provide some of the best diagnostics for studying climate in the form of high resolution ice cores. Finally, being one of the most easily and unambiguously observed properties of the Earth's surface from space, sea ice is often targeted as an early warning indicator of greenhouse warming - assuming we can understand how to interpret any observed change.

While the potential influences of the Ocean-Atmosphere-Ice (OAI) system on global climate are tantalizing, most have yet to be validated and mechanisms have yet to be proposed. Therefore, in order to properly represent polar oceans in global climate models and ultimately predict the influences they may impart, it is necessary to: (1) document that polar regions do indeed influence global climate, and establish the distribution and nature of the links (or teleconnections), (2) isolate those characteristics and/or variables of the polar oceans that seem most likely to drive the extra-polar responses, and (3) determine the mechanisms, interactions and various feedbacks that control the evolution and response of these critical characteristics or variables.

As an oceanographer, my particular interests lie in the role of the ocean-atmosphere-ice (OAI) system. Sea ice, at the interface in this system, is clearly the distinguishing characteristic that differentiates polar oceans from all others. The temporal and spatial distribution of this sea ice reflects a complex interaction between the ice, ocean and atmosphere. The complexities are underscored by the fact that the sea ice (and snow cover) plays a central role in the surface heat balance through its high albedo and ice-albedo feedbacks, ice-cloud feedbacks, strong insulation capability that minimizes the ocean-atmosphere exchange of heat and atmospherically-active gases, and ability to influence the ocean sensible heat flux. The latter is due to the role of sea ice in the upper ocean stratification, particularly through its prominent role in the surface freshwater balance and its salt rejection during ice growth, and its ability to modify the atmosphere-ocean momentum transfer.

Much of my research has involved process-oriented modelling studies and field programmes designed to better understand and quantify these complex OAI interactions and their role in the ice distribution, underlying ocean stratification and deep water formation. Such studies typically fall under the auspices of CLIVAR's companion WCRP programme: ACSYS, as well as SCOR and SCAR programmes, all of which, among other things, strive to improve our understanding of the important regional and local polar processes underlying the global scale impacts and interactions. Of more direct interest to CLIVAR itself, particularly Section D5 of the CLIVAR Implementation Plan, I and a Lamont colleague, Xiaojun Yuan, have undertaken a study designed to identify the linkages between the Antarctic polar sea ice fields and global climate (Yuan and Martinson, 1998). Simultaneously, I and another Lamont colleague, Richard Iannuzzi, have been examining the nature of the spatial and temporal distribution of the upper ocean characteristics within the polar gyres in an attempt to identify those physical changes in the polar ocean that covary with the extra-polar climate variations (Martinson and Iannuzzi, 1998, and work in progress).

With regard to our study investigating the role of Antarctic sea ice in global climate, our specific objectives were to quantify: (1) the variability documented in Antarctic sea ice fields themselves in an effort to identify specific patterns of variability and their characteristics; and, (2) the distribution and significance of linear covariations between the Antarctic sea ice fields and regional climate elsewhere on the globe. With regard to the latter, we wished to identify: regions around Antarctica with the strongest global connectivity; extra-polar regions with strongest links to the Antarctic sea ice fields; and linkages with fundamental modes of climate variability (e.g. ENSO, PNA, NAO, etc.).

For convenience, we used 16 years of satellite microwave data to generate a sea ice edge (SIE) index reflecting monthly anomalies from climatology of the northernmost latitude of the ice edge. The index was detrended and binned into 10 degree bands around Antarctica (which approximates the spatial decorrelation length). These SIE anomaly time/space series were then compared to extra-polar climate data consisting of: (1) Jones' (1986) monthly mean near-surface temperature anomaly data for the globe on a 5˚ x 5˚ grid from 1975 to 1993; (2) the time series (principal components) of the leading EOFs for the near surface temperature data; and (3) standard climate indices such as Niño-3 (an ENSO proxy), a tropical land precipitation index (28˚S - 28˚N), a tropical Indian Ocean SST index (an Indian monsoon intensity proxy), and indices for the NAO and PNA. Particular care was given to evaluating the statistical significance of the extensive correlations using Monte Carlo and resampling statistics to account for spatial and temporal correlations inherent in the data.

Variability within the Antarctic sea ice fields is characterized as follows. Spatially, the SIE anomaly is strongest in regions around the Antarctic: the eastern Pacific (Amundsen and Bellinghausen Seas; 50-90˚ W), eastern Weddell gyre/western Indian Ocean (0-50˚ E) and Weddell Sea (20-30˚W). Temporally, the variability is concentrated roughly in cycles of 1-2 and 4-5 years. The 4-5 year cycle is associated with a coherent mode of behaviour that displays a wavenumber 2 pattern that has been named the Antarctic Circumpolar Wave by White and Peterson (1996). This pattern is clearly apparent without any filtering of the data, and it shows eastward propagation of the SIE anomaly, strong covariability with ENSO and even stronger covariability (though only marginally so) with the Asian monsoon index. The spatial coherence of this pattern appears to be constrained to the three primary gyre regions around Antarctica, with little signature between them. This suggests to us that the signal is not spatially continuous in the SIE, and therefore, likely to represent the individual response of each polar gyre to a spatially-continuous atmospheric forcing. The 1-2 year cycle appears to be regional in extent and does not show any clear evidence of propagation.

The Antarctic sea ice fields display significantly more strong and significant correlations with the surface temperature elsewhere on the globe than expected by correlating to red noise. Specifically, the Weddell Gyre/western Indian Ocean region, and Eastern Pacific region of Antarctic shows the strongest global connectivity, particularly with regions linked by ENSO/Monsoon variability, while the Weddell Sea shows strong correlation with the climate mode dominated by the tropical and northern Atlantic SST variability. In general, the SIE appears to be well correlated to the first two modes of global climate variability as expressed by the EOF analysis; the first mode is dominated by ENSO. Some of the correlations show the ice leading changes in extra-polar surface temperature, while others show a lag. We are currently investigating the significance and implications of the leads and lags, and isolating those regional correlations that most likely reflect causal links.

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Dr. Douglas G. Martinson is senior research scientist at Lamont Doherty Earth Observatory, Palisades, USA of Columbia University, and adjunct professor in Columbia's Department of Earth and Environmental Sciences. He got his M.A and his Ph.D. at the Lamont Doherty Geological Observatory in 1979 resp. 1982. During 1982 to 1984 he did research on a postdoctoral position at Woods Hole Oceanographic Institution. In 1984 he returned to Lamont as a research associate and adjunct professor, where he has been ever since. He has also worked at the Alfred Wegener Institute for Polar and Marine Research in Germany (1988) and the Université Catholique de Louvain in Belgium (1992) as a visiting scientist. His successful scientific career is documented in a long list of publications, his participation as a PI or chief scientist on a number of cruises, mainly in the Weddell Sea and in the tropical Atlantic. Additionally, he won a number of awards and fellowships and is very active in many scientific committees, e.g. the Scientific Steering Groups of CLIVAR and ACSYS, as the chairman of the NRC DecCen panel, and his present and past memberships in various NRC, NSF and NASA committees.

Paleoclimate record of climate: Polar ice cores

Jean Jouzel, LSCE Saclay and CLIVAR SSG

Extending the record of climate variability is recognized as one of the overall objectives of CLIVAR. This recognition is largely thanks to the efforts of the PAGES-CLIVAR working group formed jointly by the IGBP and WCRP with the specific aim of providing the paleoclimatic perspective to understand climate variability and predictability (see the PAGES/CLIVAR Intersection issue published in 1996). This will be done in obtaining new paleoclimatic datasets and combining the information they provide with paleoclimate modelling aiming to simulate, for example, the climate of the last millennium, abrupt climatic changes of the past, or climate states such as the last glacial maximum. Data will be acquired from a variety of sources including corals, tree rings, ice cores and marine and lake sediments. Climate variability should be documented worldwide (ocean, continents, polar ice caps) and for different climate variables (temperature, precipitation, etc.; in addition, information on the climate forcings is also needed. It is only through the combination of records from different available sources that these ambitious CLIVAR goals will be fulfilled. In a recent Exchanges issue (April 1997), Julie Cole has given an overview of the ARTS initiative (Annual Records of Tropical Systems) aiming to improve our understanding of tropical climate variability and its teleconnection over the past. Here, I would like to present some of the potentialities offered by polar ice cores in the context of CLIVAR through two projects in which I am involved, MileClim (Millennium European Climate) and EPICA (European Project of Ice Coring in Antarctica). I first briefly introduce polar ice core records and the information they contain.

Ice cores offer the opportunity to obtain high resolution (annual or even seasonal) records and give access on a continuous and largely quantifiable basis to the most important climatic parameters. Except for regions such as the East Antarctic Plateau where accumulation is too low, the existence of seasonal variations in the isotopic or chemical composition of the ice allows accurate dating and, correspondingly, accurate estimates of the annual precipitation. Information on local temperature changes can be inferred from the deuterium or oxygen 18 content of the ice whereas annual accumulation can be estimated from the existence of seasonal variations. Information about atmospheric circulation can be retrieved from the changes in the concentration of aerosols or chemical compounds. In parallel, the analysis of trapped air bubbles and of various impurities contained in the ice allows reconstruction of changes in the chemical and gaseous composition of the atmosphere. This gives access in particular to the concentration of aerosols of various origin (terrestrial, marine, volcanic, anthropogenic or cosmogenic) and of greenhouse gases.

EPICA is a long-term (~7 years) European deep ice-core drilling project in Antarctica to derive high resolution records of climate and atmospheric composition through several glacial-interglacial cycles. The project, in which 10 European countries are involved, is designed to complement the highly successful central Greenland projects and it will allow extension and full documentation of the East Antarctic record so far essentially limited to the analysis of the Vostok core. To achieve EPICA's goals, it will be necessary to drill at two sites, both to achieve the required resolution on different time scales and an adequate continent-wide perspective. The first phase (1996-2000) focusses on the major climate shifts that have characterized the past several glacial interglacial cycles. This will be done by analyzing a 3500 m long ice core drilled at Dome Concordia, south of the Indian Ocean in East Antarctica. A core from this location, which is ideally placed to secure an undisturbed long record, will allow examination of the relative phasing of climate and climate-forcing parameters associated with these major climate-change events. During the second phase of the project, a core will be obtained from Dronning Maud Land, an area of Antarctica most strongly influenced by the Atlantic ocean, and a region of somewhat higher annual snowfall rate and thinner ice cover. This phase of the project is designed to focus specifically on the rapid climate oscillations that have been detected across Greenland throughout the last glaciation, and that are believed to have been associated with mode-shifts in the Atlantic thermohaline circulation. Recent results have shown those North Atlantic rapid changes have counterparts in Antarctica and it is useful, and probably indispensable, to decipher the links between northern and southern hemisphere climate if we want to fully understand their behaviour. In this respect, obtaining high resolution records of the Antarctic climate is of relevance to CLIVAR.

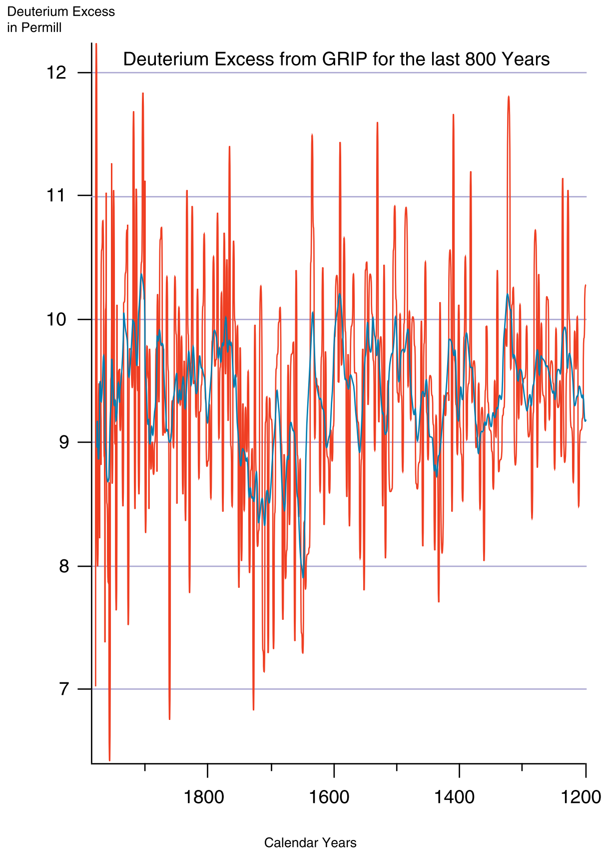

Fig. 1: The Deuterium Excess d=δD-8*δ^{18}O of the central Greenland ice core GRIP. The precision of the d measurements is +/- 0.9 permill. The excess signal is interpreted as a signal transporting information on the climatic conditions (temperature, relative humidity) in the vapour source region to the deposition site. The anomalous low deuterium excess in the 18th and 17th century indicates about 1 degree cooler conditions in the subtropical North Atlantic and thus corresponds to a cool period in Europe known as the Little Ice Age.

In MileClim, also a European project, information derived from ice-cores, corals and tree-rings will be combined to study the decadal-centennial climatic variability by looking at long time series of climatic and oceanographic parameters in the North Atlantic area over the last few centuries. In relatively high accumulation areas such as central Greenland ice cores can be dated year by year by using seasonal changes in various indices and absolutely dated volcanic events. Whereas past temperatures can be estimated from profiles of either deuterium, δD, or oxygen 18, $\delta^{18}O$ additional information on the water cycle can be obtained from the combination of these two isotopes through the deuterium excess ($d=\delta D-8*\delta^{18}O$). The deuterium-excess of a precipitation depends on the conditions (temperature, relative humidity and wind-speed) prevailing in the oceanic source region, and model results support the idea that polar deuterium excess values contain information on meteorological conditions at distant evaporative sources. For example, we interpret the deuterium-excess decrease seen in the GRIP record between years 1640 and 1800 (see Figure 1) as reflecting lower temperatures in the North Atlantic during the Little Ice Age. This result, obtained in collaboration with the Geophysical Institute in Copenhagen, illustrates one promising use of water isotopes in ice cores in the context of CLIVAR.

Jean Jouzel is with the Laboratoire des Sciences du Climat et de l'Environnement (LSCE), a joint laboratory between the French Atomic Energy agency (CEA) and the Centre National de la Recherche Scientifique (CNRS). In this laboratory located near Paris (Saclay and Gif sur Yvette) he is in charge of the climate group. Jean Jouzel has worked at CEA Saclay since 1968 and has also been with CNRS from 1988 to 1995 (as associate Director of LGGE, Laboratoire de Glaciologie et Géophysique de l'Environnement, in Grenoble). A geochemist, Jean Jouzel is a specialist of water stable isotopes in precipitation (deuterium and oxygen 18) and of their use to reconstruct past climates from ice cores.

As a result of isotopic fractionations that occur at each phase change of the water during its atmospheric cycle, the isotopic content of a precipitation strongly depends on the meteorological conditions that have prevailed from the origin of the air mass to the precipitation site. The present-day isotopic distributions are well documented with, at middle and high latitudes, a linear relationship between water isotopes and surface temperature particularly well obeyed over polar ice caps. Jean Jouzel has dedicated part of his research to modelling the relationship between the deuterium and oxygen 18 content of precipitation and meteorological parameters. This encompasses the development of dynamically simple isotopic models in which the complexity of the fractionation processes that occur in an air mass can be explicitly treated, as well as the implementation of water isotopes in atmospheric General Circulation Models. In this latter case, fractionation processes are highly parameterized but the dynamical complexity of the atmospheric processes leading to the formation of precipitation can be taken into account. One of the advantages of isotopic GCMs is that they allow to simulate isotopic distributions for different climate conditions such as those of the Last Glacial Maximum. It is through this isotopic approach that he gained interest in paleoclimate modelling and initiated the launching of PMIP (Paleoclimate Modelling Project) which under the responsibility of Sylvie Joussaume and Karl Taylor is now one key element of the global modelling effort in the CLIVAR programme.

One of the most useful characteristics of water isotopes is that they allow reconstructing past temperature changes from the isotopic content of ancient precipitation; even if the present-day relationship between cannot be directly used for interpreting paleodata it is recognized that the change in water isotopic contents registered in ice cores is a faithful paleothermometer. Polar, and more recently tropical, ice cores have provided climatic series covering a variety of time scales. In close collaboration with his colleagues of LGGE Grenoble, Jean Jouzel has been involved in major international ice coring programmes, Vostok in Antarctica (collaboration between Russia, France and USA) and GRIP, a European Programme conducted in Central Greenland; he is currently chairman of EPICA (European Programme for Ice Coring in Antarctica).

Vostok records have shown the existence of a relationship between the concentration in greenhouse gases and climate at the glacial-interglacial time scales whereas, along with the US GISP2 data, GRIP records have played a key role in the discovery of abrupt climatic changes in the past. These are two examples of the relevance of paleodata to climate change in general and indeed Jean Jouzel has long been convinced of the usefulness of paleoclimate data and modelling in the context of programmes dedicated to current and future climate changes. It is with this motivation that he has been, or is, part of PAGES (the PAst Global ChangES of IGBP) of PAGES/CLIVAR, of IPCC, and now of CLIVAR.

CLIVAR related research in the tropical Atlantic

Antonio J. Busalacchi, GSFC, Greenbelt, MD, USA and CLIVAR SSG

Even though significant advances in our ability to monitor, understand, and predict the coupled climate system were made during the TOGA Programme, most of the research on seasonal to interannual climate variability was centred in the tropical Pacific Ocean. At the outset of CLIVAR, steps have been taken to build upon the accomplishments of TOGA and expand this focus both meridionally and zonally out from the low-latitude Pacific Ocean. This is being enabled, in part, by routine global altimeter, scatterometer, passive microwave, and rain radar observations that were never realized during TOGA. Connections with higher latitudes are being considered from the point of view of tropical-subtropical Pacific ocean interactions and possible links to decadal variability of the El Niño/Southern Oscillation (ENSO). Studies of the western Pacific warm pool are being broadened to include consideration of the Indonesian Throughflow and extension to the warm pool in the eastern Indian Ocean. Similarly, the tropical Atlantic Ocean is receiving increased attention not seen since the joint US-France SEQUAL-FOCAL experiment of 1982-1984.

Although the tropical Atlantic basin is characterized by a fairly regular seasonal cycle, it can also experience significant anomalous perturbations (Figure 1). While the frequency and amplitude of such deviations from climatology may be smaller than in the Pacific, their socio-economic ramifications can be, nonetheless, quite severe. This holds for countries that border the Atlantic on both ends of the basin where societies have become accustomed to a regular and unbroken seasonal cycle. Hence, when significant perturbations occur the societal impacts can be severe. For example, the Nordeste region of Brasil is a semi-arid area typified by subsistence farming among the population of approximately 30 million people. Through the course of Brasilian history this economically depressed portion of the country has undergone severe periodic droughts. It has been estimated that one of every three individuals born in the Northeast emigrates from the region. Brasilian literature contains many accounts of large-scale migrations tied to the drought phases. More often than not the 'Nordestinos' flee to the favelas, or shantytowns, of the big cities such as Rio de Janeiro and São Paulo, or where they become a major source of labor involved in the tropical deforestation. Thus there is an intricate link between climatic and social change (and possible feedback onto the climate system in the case of Amazonia) going back at least 100 years. However, it has only been in the last 20 years that the scientific community has established a link between these droughts and cross-equatorial sea surface temperature (SST) patterns in the tropical Atlantic Ocean.

The overarching scientific question for the

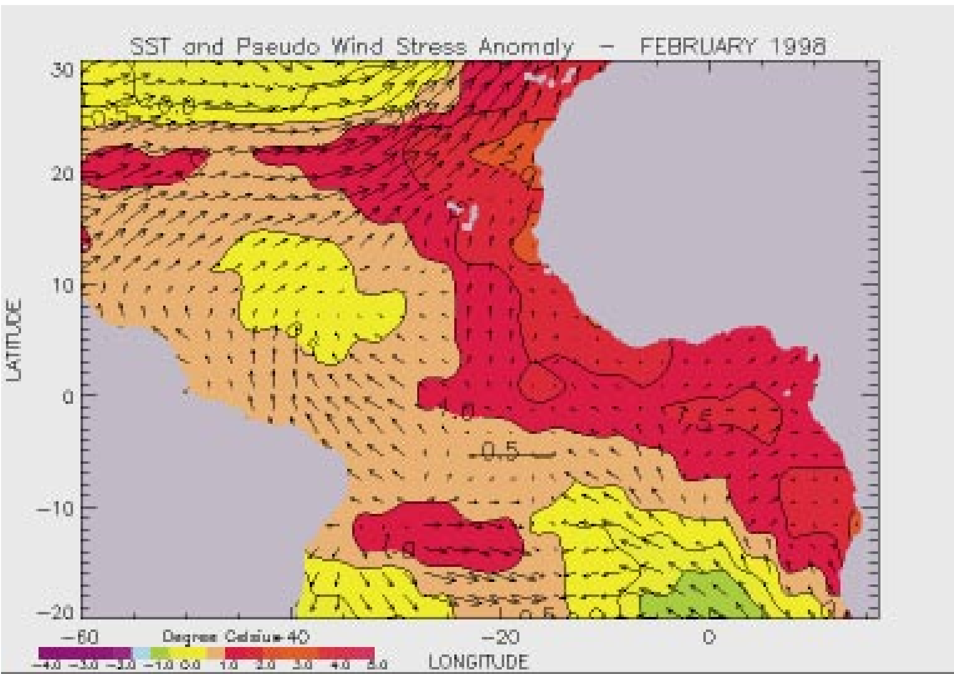

Figure 1: Sea surface temperature and pseudo wind stress for February, 1998. Analyses and figure courtesy of Jacques Servain.

tropical Atlantic sector centres on the role of the tropical Atlantic Ocean in influencing (i.e., initiating, regulating, and modulating) seasonal, interannual, and longer time scale climate anomalies both regionally and hemispherically. The key to an improved understanding of the climatic influence of the tropical Atlantic Ocean is a better appreciation for the processes that determine the space-time variability in SST within the basin. Superimposed on the mean seasonal cycle are two types of ocean-atmosphere variability. One potential mode of variability, which has no counterpart in the Pacific, is characterized by a north-south interhemispheric gradient in SST. This so called Atlantic dipole consists of anomalies of opposite sign in each hemisphere with seasonal, interannual, and decadal time scales. The occurrence of these antisymmetric SST anomalies is not always simultaneous and there is considerable debate regarding whether the northern and southern components are dynamically related in the form of a coupled mode. Notwithstanding this, changes in the meridional gradient in SST are highly correlated with the north-south translation of the ITCZ and its influence on continental precipitation over South America and Africa.

A second type of climate variability in the tropical Atlantic is similar to the ENSO mode in the Pacific, with attributes centred mainly near the equator. This equatorial mode, like the interhemispheric dipole, varies on seasonal to interannual time scales. During a warm phase, tradewinds in the western equatorial Atlantic are weak and SST near the equator is unusually high, especially in the east. During a cold phase, the tradewinds in the western equatorial Atlantic are strong and SST near the equator is anomalously low. The onset of an equatorial cold or warm event can occur rapidly on time scales of weeks to months, involving the excitation and propagation of wind-forced equatorial Kelvin and Rossby waves. Climatic impacts of equatorial warm events include increased rainfall in the Gulf of Guinea and the disruption of the marine ecosystem in the Benguela current region.

The in situ observation system in the tropical Atlantic Ocean consists primarily of volunteer observing ships. The space-time coverage of these observations is insufficient for monitoring the interannual variability across the basin. Recently, a Pilot Research Array in the Tropical Atlantic (PIRATA) has begun to be implemented to provide an improved description of the seasonal to interannual variability in the upper ocean and at the air-sea interface. Following the success of the TAO Array of moored buoys in the tropical Pacific, the joint Brasil-France-US PIRATA programme will deploy 12 moored ATLAS buoys between 1997 to 2000 for monitoring the surface variables and upper ocean thermal structure at key locations in the tropical Atlantic (Figure 2).

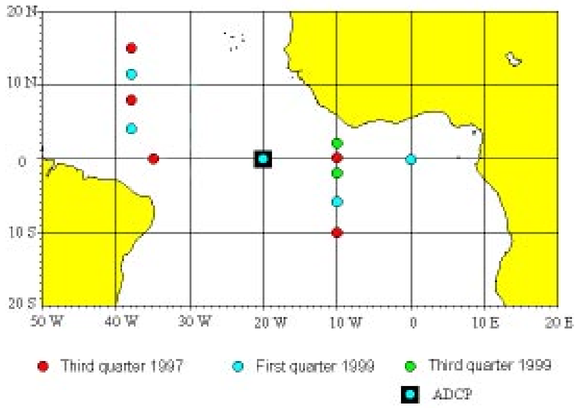

Fig. 2: Array design and deployment schedule for the PIRATA moorings in the tropical Atlantic.

The PIRATA array has been designed to provide an improved understanding of the relative contributions of the different components of the surface heat flux and ocean dynamics to the seasonal and interannual variability of SST within the tropical Atlantic basin. The deployment of the first PIRATA moorings came at an opportune time as the tropical Atlantic Ocean was undergoing a significant anomalous warming (Figure 1) coincident with the ENSO event in the Pacific basin. More information on PIRATA and the real-time data stream can be obtained from:
http://www.ifremer.fr/orstom/pirata/pirataus.html.

Antonio J. Busalacchi received his Ph.D. in oceanography from Florida State University in 1982. He has studied tropical ocean circulation and its role in the coupled climate system. His interests include the development and application of numerical models combined with in situ and space-based ocean observations to study the tropical ocean circulation and response to surface fluxes of momentum and heat. His research in these areas has supported a range of international and national research programmes dealing with global change and climate, particularly as affected by the oceans. Most notably, he has helped to define and plan the Tropical Ocean Global Atmosphere (TOGA) Programme within the US. From 1989-1996 he served on the National Academy of Sciences/National Research Council (NAS/NRC) TOGA Advisory Panel and for 1991-1993 he was a member of the NAS/NRC Panel on Ocean Atmosphere Observations Supporting Short-Term Climate Predictions. More recently, he has served on the International Science Steering Groups for CLIVAR, PIRATA, and VAMOS. Since 1985 he has served as Associate Editor of JGR Oceans and in 1997 began service as Editor of the Journal of Climate.

Since 1982 he has been an oceanographer at the NASA/Goddard Space Flight Center in Greenbelt, Maryland. In 1991, he was appointed to the Senior Executive Service in the U.S. Government as the Chief of the NASA/Goddard Laboratory for Hydrospheric Processes. In this capacity he furnishes scientific direction to a broad, many-faceted programme in Earth system science. NASA's Laboratory for Hydrospheric Processes is responsible for an extensive range of programmes dealing with theoretical and experimental research in the oceanic, cryospheric, and hydrologic sciences. The expertise within the laboratory constitutes an end-to-end capability involving instrument, algorithm, and numerical model development; the validation and analysis of remotely sensed data from a wide variety of sensors with in situ hydrological data, and ultimately, the application of these data to geophysical process studies and global change investigations. One example of which is the SeaWiFS ocean colour project within the laboratory which provides space-based daily estimates of chlorophyll concentration for the world's oceans. Dr. Busalacchi has received numerous awards internal and external to NASA. Among these, in 1991, he was the recipient of the prestigious Arthur S. Flemming Award, as one of five outstanding young scientists in the US Federal Government. In 1995 he was selected as Alumnus of the Year at Florida State University and in 1997 he was the H. Burr Steinbach Visiting Scholar at the Woods Hole Oceanographic Institution.

The 1997-98 El Niño event

The development of the 1997-98 El Niño event into, by some measures, the biggest on record in over a century has given the CLIVAR community a wonderful opportunity to exploit an experiment mounted for us by nature. This event is the best observed ever and the worth of the TAO moored buoy system straddling the equatorial Pacific has been clearly demonstrated by its ability to provide data:

1. that showed the evolution of subsurface temperature anomalies exceeding 10^{o}C at about 100 m depth, which developed into sea surface temperature anomalies exceeding 5^{o}C, and subsequently into a cooling of over 5^{o}C that progressed eastward; and
2. for initializing models for successful prediction of the future evolution.

Clearly, this event demands a careful, in-depth analysis of its many aspects and has lessons for CLIVAR. It is expected that several workshops and conferences will touch on aspects important for a full post mortem of the 1997-98 event. There are a huge number of possible subtopics, with many of direct concern to CLIVAR. These would include a comprehensive description of the event, diagnosis of processes, verification of numerical predictions, verification of forecasts, forecast verification techniques, implications for the observing system, implications for model development, whether global warming is playing any role, and possible process studies that should follow. Also of interest to CLIVAR, but more on the human dimensions and applications side, are topics such as: proliferation of "information" (e.g. on the World Wide Web - which has been of mixed quality), attribution of local and regional climate anomalies to the event, impacts of El Niño, the assessment of human dimensions information, actions taken or not taken, impacts of invalid forecasts, utility of information, communication, and benefits of forecasts (mitigating losses etc.).

The CLIVAR plans in this area are developing and will be discussed at the next CLIVAR SSG meeting in April. They also fit well within a United Nations framework on El Niño that has occurred independently of the CLIVAR initiative. The UN General Assembly passed a resolution in December 1997 on International Cooperation to Reduce the Impact of the El Niño Phenomenon. The resolution, which was coordinated under the framework of the International Decade for Natural Disaster Reduction

(IDNDR), has led to the establishment of an El Niño "Task Force" encompassing several UN agencies and programmes. The WMO, for example, has been asked to take the lead in coordinating the provision of scientific and technical advice on El Niño, other agencies will coordinate the socioeconomic impacts and response aspects.

As the 1997/98 El Niño event has unfolded there have been several joint agency meetings and briefings for the press and Permanent Missions in Geneva on its status and expected course. These briefings and the fact that the WMO Secretariat itself felt compelled to issue a monthly "ENSO Update" has brought to the fore, with some force, the question of how the international community should approach the infrastructure requirements for making and disseminating information on operational seasonal predictions. The number of groups producing seasonal predictions is continuing to grow, and significantly we are beginning to see some of those predictions based on ensemble runs of coupled models.

To accelerate discussion on the question of infrastructure and to link it to the response to the UN Resolution, the WMO under its Climate Information and Prediction Services (CLIPS) Project is conducting a scientific and technical retrospective on the 1997/98 El Niño event. The results of this review will serve as a basis for discussion in a wider review of the event being organized by the UN Task Team. Specifically, the science and technical review will focus on the following three aspects:

- How good were the predictions of the 1997/98 El Niño event?
- How well was the event monitored?
- How effective was the communication of information on the event to governments, international relief agencies and to the public at large?

The review will make a preliminary assessment of the range of significant climate anomalies observed during the course of the event throughout the world that were due directly or indirectly to the event. However, as noted above, it is expected that the 1997/98 El Niño event will occupy the interest and resources of the climate research community for some time to come.

Kevin Trenberth and Mike Coughlan

U.S. Atlantic Climate Variability Experiment

Antonio J. Busalacchi, GSFC, Greenbelt, MD, USA

A planning meeting for the U.S. Atlantic Climate Variability Experiment (ACVE) was held in Dallas, Texas, from Feb. 2-4, 1998. This meeting was developed to put together a plan for a U.S. contribution to CLIVAR along the lines of an Atlantic BECS (Basin-wide Extended Climate Study) activity.

The meeting was opened with a series of scientific overview presentations on various aspects of the North Atlantic Oscillation (NAO) and tropical Atlantic variability. A historical overview of the NAO given by J. Hurrell was followed by a presentation by P. Rhines on NAO and sub-polar gyres, and M. McCartney talked about the NAO and its signal at mid-latitudes. I. Held spoke about the NAO and atmospheric dynamics and Y. Kushnir gave a presentation on statistical analyses of the NAO. Lastly, S. Zebiak spoke about climate variability in the tropical Atlantic.

In the following, three working groups were formed for the tropics, mid-latitudes, and sub-polar regions. The main topics or hypothesis of these working groups can be summarized as follows:

1. Within the tropics, three main hypotheses were considered.
   (i) The first being the negative/positive coupled ocean atmosphere feedback mechanisms forwarded by P. Chang as it relates to the meridional SST gradient and changes in location of the ITCZ.
   (ii) Next, was the discussion of tropical subtropical interactions. The mechanism of Gu and Philander was discussed as probably not being operant whereby a |v|T' signal comes in to the tropics, but rather in the tropical Atlantic there may be a possibility of a v'|T| impact on tropics.
   (iii) The third hypothesis discussed was the impact of the ENSO signal projecting into the Atlantic Ocean.
2. The mid-latitude working group discussed SST forcing of the mid-latitude atmosphere, the need for enhanced work on coupled ocean atmosphere modelling, and the extent to which there is coupling at mid-latitudes, and the need for enhanced resolution in these coupled studies. The need to better understand the propagation of heat content anomalies was emphasized.
3. The sub-polar working group discussed the degree to which there is ocean atmosphere feedback at high-latitudes, the role of sub-polar water masses,

how to measure air sea fluxes and energy balance of the atmosphere, the NAO with apparent interaction with the stratospheric polar vortex, and a white/red noise model for the ocean.

The second day of the meeting started with some brief presentations of related and relevant activities. C. Wunsch spoke about global ocean data assimilation followed by a presentation of B. Owens on the proposed ARGO array, a global array of 3,000 PALACE floats of which order 750 per year are to be deployed to monitor the upper 1,000 meters of temperature and salinity. B. Molinari talked about the ACCE cross gyre exchanges being measured with floats and drifters whereas M. Visbeck reviewed some of the European activities in the Atlantic. W. Robinson presented AGCM responses to mid-latitude SST anomalies, followed by R. Saravanan speaking on coupled model responses to SST as they compare with correlation analyses of observations.

In summary there is little evidence of the NAO being a coupled mode in terms of the mid-latitude atmosphere responding to sea surface temperature anomalies. It was evident that there was a certain amount of "hope" from some of the oceanographers in attendance that there might exist a coupled mid-latitude SST atmosphere mode. In terms of predictability, the prospects are much better in the tropics for coupled mode behaviour. In terms of the clarity of understanding at this point, there was mention that the order might rank tropical dipole, North Atlantic Oscillation, and then the link between the two phenomena.

The participants formed two new working groups, one addressing numerical studies and the other one working on historical data.

The working group on historical data came out with two major recommendations. One was to secure resources to establish an Atlantic Climate Variability Data Center and the other was the need for strong connection to the Paleo climate community.

The modelling group addressed the issues related to the tropics and to the NAO / resp. anthropogenic change separately.

The discussions for the tropics can be summarized as follows: There were three main hypotheses:

1. The Atlantic dipole as modelled by P. Chang and that this approach was really the bottom of a required hierarchy of systems that needed to be considered in more sophisticated coupled models.
2. The second hypothesis was the interaction between tropics and subtropics for the ocean via a subduction mechanism which could be attacked initially from an ocean only mode forced with NAO wind patterns (and also the need to consider the links from the south Atlantic). Next might come atmospheric AGCM studies to consider the feedback from the ocean to the atmosphere.
3. The last hypothesis question was how do ENSO anomalies manifest themselves over the Atlantic Ocean? This is primarily an AGCM approach.

For modelling issues addressing the NAO and higher latitudes, the question involved is, how much of the observed variability in the NAO is internal to the atmosphere. This would require a quantification of modes of variability in the atmosphere, how does the atmosphere respond to SST anomalies, what are the time scales in which the ocean is active, and the use of ocean models as synthesis tool to perform budget experiments. Another area of interest was the potential anthropogenic affect on the collapse of the thermohaline cell.

The proposed observation strategies were discussed thereafter. J. McCreary summarized the tropics again starting with the three hypotheses being the coupled dipole mode, the second being tropical subtropical interactions and changes to subduction, and the third being the ENSO influence on the Atlantic. Most of the discussion revolved around the possible coupled ocean atmosphere mode in the tropics. Recommendations were first to enhance PIRATA and fill in a number of holes with extra Atlas buoys; two of which were situated off of northwest Africa between, e.g. 12^{o}N and 20^{o}N to investigate the offshore extension of coastal upwelling affected by dry air being advected off of northwest Africa, and the role of aerosols on the radiation in the region. A third mooring would be situated farther to the west of the 38^{o}W PIRATA line in a region that has a significant SST signal for the dipole. Also, this is a region that has important changes on ENSO time scales. A fourth mooring would be in the southeastern tropical Atlantic off the coast of Africa underneath the stratus deck and the fifth would be in the south Atlantic farther to the west of the PIRATA mooring line. A second enhancement would be the deployment of order 85 surface drifters, a third would be the reliance on the ACVE PALACE floats and the need to extend this array farther to the south to approximately 20^{o}S, fourth was the need to maintain the existing tide gauges, and fifth was the need to maintain the existing radiosonde network. With respect to tropical subtropical interactions, the PALACE floats would provide important observations of the variability of the subtropical overturning. With respect to the ENSO affect on the Atlantic, there is a need to maintain and possibly enhance radiosondes along the line of the Antillies. N. Hogg then presented the summary for mid-latitudes. Here the overarching question was what determines ocean heat content variability and does the atmosphere respond to this? Observations and support of this question would involve tracking water mass anomalies, studies of atmospheric boundary layer physics, budgets in the atmosphere and the ocean, and sustained observations, e.g. in Florida Straits, Bermuda, Labrador, etc.

P. Rhines presented the observational strategy for the sub-polar regions. This is an area of important water mass transformation in the center of activity for the NAO, and an area of fast transients in the ocean. Among the topics and issues were the need to better understand the freshwater cycle, Arctic-Atlantic convection, which would include instrumentation of the Canadian Archipelago, hydrographic studies, monitoring the Fram and Denmark straits. Next, sub-polar water masses for which it was proposed to implement a VOS line along 60°N, standard hydrography moorings, and PALACE floats. For sub-polar subtropical connections, monitoring boundary current outflow, and the use of IES and deep ADCP's was mentioned. Not much was discussed with respect to the atmosphere other than the need for extended high resolution studies of the ETA model and high resolution re-analyses. Potential process experiments at the high latitudes might involve studies of entrainment and water mass transformation and overflows, the rapid recycling pathways, and wind/buoyancy forced transients.

The third day of the conference started with another set of short presentations on relevant activities in which S. Esbensen spoke about PACS, R. Mechoso on VAMOS, and B. Large speaking about the European Center and NCEP re-analyses.

In summary the following issues were addressed by ACVE:

- the response of the atmosphere to SST anomalies,
- coupled interactions of tropical Atlantic variability,
- the basin scale ocean response to atmospheric or to NAO forcing, and
- coupling between tropical Atlantic variability and the mid-latitude/NAO.

At the end of the meeting a potential timeline was discussed for ACVE planning: March 30, first draft of ACVE document; April 30, revised draft to larger group; May 12, Euroclivar meeting on Atlantic variability; mid-June, the formation of an observing system design group. A workshop on atmospheric response to SST anomalies in autumn was discussed as well as a timeline for the launching of proposals to the funding agencies (NSF).

A summary of the day also included discussions of data analysis, modelling, and observations, as the three components of ACVE. At this point, however, no real process studies have been brought to the table. As a result of this meeting, a U.S. perspective on Atlantic CLIVAR will be brought to the Euroclivar meeting in Florence to determine to what extent it matches and is complementary to European interests. This will then serve as a basis to establish the level of commitment and co-ordination with Europe.

CLIVAR - VAMOS Planning Meeting

Jan. 12, 1998, Hyatt Regency Hotel, Phoenix, USA

The session was opened by the chairman of the CLIVAR - VAMOS panel, Prof. C. R. Mechoso. 15 participants were able to attend this planning meeting.

The purpose of this meeting was to review the progress since the CONAM (Conference on American Monsoons) conference held in March 1997 and to prepare the future panel meetings and a workshop to be held by this group. In particular this meeting should:

- Review the VAMOS panel objectives and their place in CLIVAR;
- Discuss the way in which programme components will participate in the overall structure of CLIVAR;
- Develop plans for future activities.

Prof. Mechoso recalled the draft terms of reference given by the CLIVAR SSG for the CLIVAR VAMOS panel:

- To be responsible to the CLIVAR SSG for the formation of a detailed scientific plan and conceptual design of an international project to investigate the variability and predictability of the American monsoon systems (VAMOS) in the context of global climate variability and predictability.
- To develop an implementation plan for a VAMOS project for consideration by the CLIVAR SSG.
- To co-ordinate and promote interactions amongst meteorologists, oceanographers and hydrologists from interested nations to work on VAMOS problems.
- To oversee the implementation of a VAMOS project.
- To advise the CLIVAR numerical experimentation groups on modelling investigations which need to be carried out to meet VAMOS objectives.
- To work closely and co-ordinate with other national, regional and international projects and

organizations interested in this area of research, e.g. the Inter-American Institute, the International Research Institute for Seasonal to Interannual Prediction, PACS, GEWEX and START.

Prof. Mechoso emphasised the importance of this programme especially for the South American countries. He reported from a tour he made in December taking him to Brazil, Argentina, Uruguay and Chile to promote the VAMOS programme in South America. The initiative was very well received at funding agencies, universities and meteorological services. Prof. Mechoso recommended that work on this programme should start as soon as possible. In the following there was a comprehensive discussion about the programmes participating in VAMOS. Dr. Victor Magaña, one of the panel vice-chairs, was encouraged to soon make a similar tour within Central America.

In the discussion about the framework that VAMOS will provide, a number of participants stated that programmes like PACS, LBA, GCIP will certainly support the needs of VAMOS and VAMOS may build on the outcome of those programme. On the other hand those programmes are independent projects from VAMOS, i.e. VAMOS cannot set the directions of those programmes but can contribute to the closer co-operation between these projects and to the identification and remedy of gaps in their science plans.

The representative of the CLIVAR Project Office, Dr. A. Villwock, reported about the progress made with the Initial CLIVAR Implementation Plan and the plans for the International CLIVAR conference. As all other CLIVAR groups, the VAMOS panel should prepare a presentation of the project at the Conference. Thereafter, the co-chair of the CLIVAR SSG, Dr. K. Trenberth presented some guidelines how the CLIVAR core projects should work out their specific implementation plans with special emphasis on readiness, feasibility and prioritization.

In the following, the planned VAMOS/PACS Workshop on Field Programmes and the first session on the VAMOS panel were discussed in depth. The original plan to have the workshop in March and a full panel meeting the following September was revised. First it was argued that there were issues of programme definition that required the panel to meet as early as possible. One example of this is the extent which VAMOS would like to achieve beyond the goals of PACS, LBA, etc. Second, it was considered that those issues had to be clarified in preparation to the VAMOS presentation at the CLIVAR SSG meeting in late April. It was decided that the workshop be held in conjunction with the first panel session in late March 1998. A general discussion about the principal scientific goals of VAMOS will be included as the first part of the workshop. The meeting should then review the existing observing system and the field programmes, identify the gaps and then develop plans to achieve the scientific goals of VAMOS. On the last day the VAMOS panel will meet to sum up the results achieved in the workshop, and to prepare for future activities.

The venue for the meeting will be São Paulo, Brazil. It was felt that a location in South America would set a positive sign on CLIVAR commitment for the countries involved in this project. About 30-40 people will be invited. NOAA/OGP and the CLIVAR will jointly fund and organise this meeting with local support. Prof. Edmo Campos (Univ. of São Paulo) would be asked to chair the local organizing committee.

A. Villwock and C.R. Mechoso

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CLIVAR Calendar

1998	Meeting	Location	Attendance
March 29 - April 3	VAMOS/PACS Workshop in Field Programmes and CLIVAR VAMOS Panel - 1st Session	São Paulo, Brazil	Invitation
April 20 - 24	23rd European Geophysical Society Meeting	Nice, France	Open
April 20 - 22	CLIVAR Asian - Australian Monsoon Panel, 2nd Session	Kyongju, Korea	Invitation
April 21 - 23	International Conference on Monsoon and Hydrologic Cycle	Kyongju, Korea	Open
April 27 - 30	CLIVAR Scientific Steering Group, 7th Session	Santiago de Chile, Chile	Invitation
April 27 - 29	CLIVAR Upper Ocean Panel, 3rd Session	Toulouse, France	Invitation
May 7 - 9	CLIVAR Africa Study Group	Abidjan, Ivory Coast	Invitation
May 11 - 14	Euroclivar Workshop on “The role of the Atlantic in climate variability”	Florence, Italy	Invitation
May 24 - 29	International WOCE Conference	Halifax, Canada	Open
May 25 - 29	9th Conference on Satellite Meteorology and Oceanography	Paris, France	Open
May 26 - 29	AGU Spring Meeting	Boston, USA	Open
June 3 - 5	Euroclivar Workshop on “African Climate Variability”	Bologna, Italy	Invitation
July 7 - 14	COARE 98	Boulder, CO, USA	Open
August 10 - 13	WOCE/CLIVAR Workshop on Ocean Modelling for Climate Studies	Boulder, CO, USA	Limited
August 17 - 21	International Conference on Satellites, Oceanography and Society (Expo'98)	Lisbon, Portugal	Open
September 14 - 16	Euroclivar Workshop on Climatic Impact of Scale Interactions for the tropical Ocean-Atmosphere System	Paris, France	Invitation
September 22 - 25	WOCE Indian Ocean Workshop	New Orleans, USA	Limited
October 12 - 16	WOCE Scientific Steering Group, 25th Session	Brest, France	Invitation
October 19-24	JSC/CLIVAR Working Group on Coupled Modelling, 2ndSession	Melbourne, Australia	Invitation
November 9 -13	CLIVAR - NEG-1 (preliminary date !)	Palisades, NY, USA	Invitation
November 9 - 13	CLIVAR/GCOS TAO Implementation Panel, 7th Session, PIRATA-5	Abidjan, Ivory Coast	Invitation
December 1 - 4	International CLIVAR Conference	Paris, France	Limited

For more information, please contact the ICPO or check out our web-page: http://www.dkrz.de/clivar/latest.html

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