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CLIVAR contributions to implementation of the WCRP Strategic Framework

(Draft 7 January 2009)

Contents

1. Introduction

CLIVAR contributes to meeting the objectives of WCRP through activities to understand the causes of climate variability, to improve our ability to predict it, to extend the observational climate record and to predict climate changes associated with the growth in radiatively active gases and aerosol concentrations. CLIVAR focuses on the variability and predictability of the slowly varying components of the climate system, investigating the physical and dynamical processes in the climate system that occur on seasonal, interannual, decadal and centennial timescales. CLIVAR recognizes that a critical measure of success in its research program is the transfer of insight and knowledge to routine production of climate forecasts, information and products. These forecasts and climate products have inherent value to decision makers. This is reflected in CLIVAR's mission which is *"to observe, simulate and predict changes in the Earth's climate system with a focus on ocean-atmosphere interactions, enabling better understanding of climate variability, predictability and change, to the benefit of society and the environment in which we live"*. CLIVAR acts to encourage and facilitate national and international activities that contribute to our understanding of climate variability and our ability to provide improved climate predictions. It seeks to encourage the development and implementation of sustained observations of the climate system, field and modelling studies that help our understanding of climate processes and how they can be represented in models, analytical studies to assist our understanding of climate variability and coordinated effort in climate prediction.

Key science themes for international CLIVAR are focussed around ENSO and other modes of tropical variability; monsoons, decadal variability and the thermohaline circulation, anthropogenic climate change and the role of the oceans in climate. These are aimed at making key contributions to the WCRP Strategic Plan 2005-2015, in particular to the concept of seamless prediction and the WCRP cross cutting activities of seasonal and decadal prediction, monsoon prediction, anthropogenic climate change, sea level rise and climate extremes. To achieve it's aims, international CLIVAR is organised into a number of panels and working groups. Two global modelling groups are focussed on seasonal to interannual and climate change prediction respectively (with both currently jointly engaged in exploring decadal timescale prediction) with a third focussed on ocean model development. Three global observationally focused groups cover observations and synthesis, the recent palaeographic record and climate change detection. In addition there are four ocean basin implementation panels and three regional panels covering the monsoons and African climate[1]. The CLIVAR Scientific Steering Group (SSG) provides oversight of the programme

[1] The global and regional panels and working groups are made up of experts from a variety of institutes around the globe**.** These currently comprise the Working Group on Coupled Modelling (WGCM); Working Group on Seasonal to Interannual Prediction (WGSIP); CLIVAR/CCl/JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI); the Global Synthesis and Observations Panel (GSOP); CLIVAR/PAGES Panel; Variability of the American Monsoon System Panel (VAMOS); Variability of the African Climate System Panel (VACS); Asian Australian Monsoon Panel (AAMP); Indian Ocean Panel (IOP); Atlantic Panel; Pacific Panel and Southern Ocean Panel.

which is managed on a day to day basis by the International CLIVAR Project Office (ICPO). Further information can be found at www.clivar.org.

2. CLIVAR contributions to unifying COPES themes

2.1 Modelling

CLIVAR's three global modelling groups, WGCM (jointly sponsored between CLIVAR and the JSC), WGSIP and WGOMD, play a key role in climate modelling and prediction within WCRP with activities directly related to WCRP goals. Current activity in WGSIP and WGCM linking to two major WCRP modelling experiments in seasonal and decadal prediction is helping, in a practical way, to progress the concept of seamless prediction that lies at the heart of the WCRP's strategic plan. In addition, WGCM leads in the organization of the climate change scenario experiments in support of the IPCC, and WGOMD in ocean model assessment and development.

A wide variety of modelling activities are also carried out through CLIVAR's ocean basin and monsoon panels. Key contributions to the aims of WCRP include:

- As noted, strategic support to the IPCC assessment process through the organization and (through PCMDI) archiving and dissemination of outputs of the climate model runs to enable science input on predictions of future climate for given scenarios. For IPCC AR4, WGCM, through CMIP, the Coupled Model Intercomparison Project, coordinated the largest ever climate modelling experiment resulting in the WCRP AR4 archive held at PCMDI for dissemination to the worldwide research community. Community access and analysis of the 35+ Tb data archive continues unabated. As of September 2008 462 Tb of data had been downloaded by 2220 users with 494 resulting publications by November 2008.

- In support of CMIP and IPCC AR4, the Climate Model Evaluation Program (CMEP), lead by US CLIVAR, and supported by international CLIVAR, catalyzed a wide range of individual projects for analysis of AR4 runs. An IPCC AR4 Climate Model Simulations Analysis Workshop was organized by US CLIVAR and co-sponsored by IPCC WGI in 2005 and was attended by 150+ researchers. Evaluation and diagnostics of coupled models remains a focus lead by CLIVAR in the US (see other examples below).

- With IGBP AIMES, WGCM recently formulated CMIP5, a five year framework for a set of coordinated climate model experiments to study short-term (decadal prediction with WGSIP) to 2035, and long term climate change to 2100 and beyond. Some of these experiments will be the basis of the upcoming IPCC AR5.

- A number of other model intercomparison activities including the Coupled Carbon Cycle Climate Model Intercomparison Project (with IGBP), the Cloud Forcing Model Intercomparison Project, the Paleoclimate Model Intercomparison Project, and sensitivity tests of the response of the Atlantic meridional overturning circulation to surface forcing (including freshwater perturbations) (WGCM).

- A US-led effort supported analysis of a range of climate models (e.g. forced and unforced coupled climate models, AGCMs, C20C models, forecast products) to identify and characterize the physical mechanisms of drought, and to address issues such as the roles of the oceans and the seasonal cycle in drought, the impacts of drought on water availability, and distinctions between drought and drying

- Stimulation of ensemble prediction techniques and the design of a number of past seasonal prediction intercomparison experiments exploring the behaviour of ENSO in coupled models, potential and actual seasonal predictability (WGSIP)

- WGSIP leadership of the WCRP Task Force on Seasonal Prediction and the design and implementation of the WCRP Climate System Historical Forecast Experiment (CHFP) to explore seasonal predictability of the fully coupled climate system, including extension to the decadal timescale.

- Ocean model assessment through Coordinated Ocean Reference Experiments (WGOMD), informing ocean model development.

- Assessment of the impacts of enhanced data networks and improved parametrizations on model predictions on regional scales provided by CLIVAR-related field studies (see below), with feed into operations and model development (e.g. use of NAME data in the NOAA Climate Test Bed).

- The US program has led the development of Climate Process and modeling Teams (CPTs) that integrate efforts by observationalists, theoreticians, parameterization builders, and modelers to exploit available process-oriented observations to develop and test new process-parameterizations in the context of IPCC-class models. These efforts have led to the development of new parameterizations for ocean mixing and low-latitude stratus clouds.

- Regionally-focussed model i experiments, in particular for the monsoons under AAMP and VAMOS. VAMOS has focussed, in particular on studies of the interplay between process study observations (see 2.2.2 below) and modelling recognizing three distinct, but related roles that observations play in model development and assessment. These are (1) to guide model development by providing constraints on model simulations at the process level (e.g. convection, land/atmosphere and ocean/atmosphere interactions); (2) to help assess the veracity of model simulations of the various key pan-American phenomena (e.g. low level jets, land/sea breezes, tropical storms), and the linkages to regional and larger-scale climate variability; and (3) to provide initial and boundary conditions, and verification data for model predictions. In this context, the following main objectives are emphasized

- Development of metrics by which climate models and ocean syntheses may be assessed, including Madden-Julian Oscillation (MJO) metrics by the US CLIVAR MJO Working Group. This Group developed a standardized set of diagnostics to assess the fidelity of models to simulate key aspects of the MJO, providing a key tool for testing of climate models, and applied them to a variety of AGCMs and coupled climate models. Discussions with WGNE led to several national forecast centers adopting and comparing these MJO diagnostics for their intra-seasonal forecast products.

2.2 Observations

2.2.1 Global sustained observations and monitoring

Climate studies require comprehensive observations over the globe. CLIVAR recognizes the need to develop and maintain global datasets as a function spanning WCRP and that both ocean and land surface conditions are equally important for climate analysis, modelling and prediction. Post WOCE, CLIVAR has had a particular responsibility within WCRP for promoting the sustained ocean observing system and enhanced monitoring of the ocean which it does through it's ocean basin panels and GSOP in collaboration with the GOOS/GCOS/WCRP Ocean Observing Panel for Climate (OOPC) in particular. Key CLIVAR contributions to the global sustained observation and monitoring of the ocean include:

- CLIVAR's initial co-sponsorship of Argo (which has now reached its target array of 3000 floats globally) feeding into operational ocean prediction, seasonal prediction and climate analyses.

- OCEANsites monitoring (CLIVAR co-sponsored).

- CLIVAR's early promotion of the Prediction and Research Moored Array in the Atlantic (PIRATA) in the tropical AtaIntic; its advocacy in support of further developing and maintaining the tropical Pacific moored buoy array and the initial development under the CLIVAR/GOOS IOP of the Indian Ocean Moored Buoy Array (the Research moored Array for African-Asian-Australian Monsoon Analysis and prediction, RAMA). These observational systems feed directly into operational seasonal prediction.

- Development of the wider Indian Ocean sustained observing system (IndOOS) under IOP consisting of several observation platforms, including Argo floats, Volunteer Observing Ship XBT/XCTD sections, surface drifting buoys, the regional tide gauge network, the tropical moored buoy array referred to above, as well as satellite observations.

- Development of planning for the Southern Ocean Observing System as a post-IPY legacy (Southern Ocean Panel, with SCAR as lead).

- With the IGBP-Carbon programme and the IOC's International Ocean Carbon Coordination Project (IOCCP), continued coordination of decadal revisit of deep hydrography sections. Promotion of deep hydrography and carbon sections post WOCE/JGOFS (with IOC) and participation in the IOCCP/CLIVAR Global Ocean Ship-based Hydrographic Investigation Panel (GO_SHIP), to set the post-CLIVAR strategy for these, including biogeochemistry.

- Coordination of programmes to monitor the Atlantic Meridional Overturning Circulation under the Atlantic Implementation Panel (AIP) and efforts to develop the South Atlantic ocean observing system.

- ASOF, the Arctic Sub-arctic Ocean Fluxes programme, a CLIVAR-endorsed activity to measure and model the variability of fluxes between the Arctic Ocean and the Atlantic Ocean with the view to implementing a longer-term system of critical measurements needed to understand the high-latitude ocean's steering role in decadal climate variability. Legacy outputs are included in the ASOF book (http://www.springer.com/geosciences/oceanography/book/978-1-4020-6773-0) and at http://asof.npolar.no/library/content.html

- A US-led special focus group focused on identifying the role of ocean salinity in ocean variability, climate and climate predictions, and the hydrological cycle. Their workshop in 2006, a series of papers in Oceanography magazine, and a report provides guidance to the ocean salinity community, especially on preparations required in advance of future salinity satellite missions.

- CLIVAR Panels have also advocated for the effective use of the suite of in-situ and ocean remote-sensing satellite data (e.g. particularly ocean surface vector winds, sea surface altimetry, sea surface temperature) in analysis and prediction of ocean and ocean-atmosphere variability.

2.2.2 Process study observations and modelling

CLIVAR has stimulated a number of important process studies over the oceans and, in collaboration with GEWEX, over land. These include:

- VAMOS MESA(Monsoon Experiment South America)/GEWEX South American Low Level Jet Experiment (SALLJEX) and archive, aimed at obtaining improved temporal and spatial description of the tropospheric flow over central South America for the validation and improvement of short- and long-term predictions over the region. For data archiving see http://www.eol.ucar.edu/projects/salljex/

- VAMOS NAME/GEWEX North American Monsoon Experiment, NAME 2004 & data archive - a joint CLIVAR-GEWEX process study aimed at determining the sources and limits of predictability of warm season precipitation over North America, with emphasis on time scales ranging from seasonal-to-interannual. For data archiving see http://www.eol.ucar.edu/projects/name/

- CLIVAR/GEWEX La Plata Basin Regional Hydroclimate project (LPB) - CLIVAR/VAMOS and GEWEX/CEOP identified the *Río La Plata* Basin as a climate-hydrology system with components that are potentially predictable with useful skill from seasons in advance, and whose variability has important impacts on human activities. For data archiving see http://www.eol.ucar.edu/projects/lpb/

- The KESS and CLIMODE, process studies focusing on the physics of western boundary current regions, and their relationships to climate variability and change. KESS aims to identify and quantify the processes governing the oceanic circulations of the Kuroshio region, and how this relates to the intense air sea heat exchange in this region – a potential contributor to decadal variability (http://uskess.org/index.html). CLIMODE investigates the region to the south of the Gulf Stream where key air-sea and ocean processes that govern ocean mixing and transfer of properties into the deep ocean are poorly understood and poorly represented in ocean climate models (http://www.climode.org/index.html)

- The Atlantic Implementation Panel (AIP)-coordinated Tropical Atlantic Climate Experiment (TACE), running from 2006-10 to improve coverage of surface and subsurface data and provide dedicated process studies in the eastern tropical Atlantic through: extension of the PIRATA array, French EGEE cruises, US and German programs, extended Argo coverage and a meteorological station at Sao Tome. Working with WGSIP, WGOMD and AMMA (see below) TACE is providing data in the tropical Atlantic that will be used for model-data intercomparison, model validation and improvement. TACE ocean data will be available to the community through appropriate data centres

- The CLIVAR-endorsed South Pacific Ocean Circulation and Climate Experiment (SPICE), the major fieldwork for which is expected to take place between 2008 and 2011 with continued monitoring afterwards. A legacy archive will be developed (see http://www.clivar.org/organization/pacific/pacific_SPICE.php).

- DIMES (http://dimes.ucsd.edu/) , an international experiment to diapycnal and isopycnal mixing in the Southern Ocean in order to better predict the ocean's response to atmospheric climate change, and better characterize feedbacks from the ocean to the atmosphere.

- Currently underway, the VAMOS Ocean-Cloud-Atmosphere-Land Study (VOCALS), includes the VOCALS Regional Experiment (VOCALS Rex) to better understand physical and chemical processes central to the climate system of the Southeast Pacific (SEP) region. The climate of the SEP region is a tightly coupled system involving poorly understood interactions between the ocean, the atmosphere, and the land. For data archiving see http://www.eol.ucar.edu/projects/vocals/

- The past VAMOS/US CLIVAR Eastern Pacific Investigations of Climate (EPIC) and archive – an early US CLIVAR field programme to understand coupled processes relevant to modelling in the tropical eastern Pacific. For data archiving see http://www.eol.ucar.edu/projects/epic/

- Endorsed by CLIVAR (and with the status of a GEWEXRegional Hydroclimate Project), the African Monsoon Multidisciplinary Analysis (AMMA) is an international project to improve our knowledge and understanding of the West African monsoon

(WAM) and its variability with an emphasis on daily-to-interannual timescales. AMMA is motivated by an interest in fundamental scientific issues and by the societal need for improved prediction of the WAM and its impacts on West African nations. The data portal is at http://database.amma-international.org/

- The Asian Monsoon Years, 2007-12 activity, endorsed by CLIVAR (and GEWEX) coordinates some 21 regional field projects and integrative modelling studies to improve understanding and prediction of the Asian monsoon system.

2.2.3 Improved historical data

CLIVAR's primary effort to provide improved historical datasets comes through the activities of the ETCCDI for which extreme events continue to be the primary focal point. Their indices of temperature and precipitation extremes were used both in climate change detection work (benefiting from increased coverage enabled by capacity-building ET sponsored workshops) and to describe observed and future changes in extremes projected by CMIP models. Both aspects contributed significantly to the IPCC WG1 AR4 Report. ETCCDI is further developing and publicizing indices and indicators of climate change and variability through standardized software packages. New indices, with global coverage, are also being developed for heat stress, drought and greenhouse gas climate response.
Indices and software developed under the auspices of the ETCCDI can be found at http://cccma.seos.uvic.ca/ETCCDI/

From the perspective of ocean observations, CLIVAR has sponsored several Data Assembly Centers (DACs) that continue to assemble, check, and provide ocean data for a variety of analyses and uses

2.3 Climate system analysis

2.3.1 Integration of models and observations, data assimilation

Data assimilation activities impact on three primary areas of CLIVAR research – seasonal (to decadal) prediction, regional modelling studies (especially through SALLJEX and NAME) and ocean syntheses.

2.3.2 Reanalysis

CLIVAR has been a keen proponent of atmospheric reanalysis. Through its Panels, CLIVAR has encouraged regional evaluation of global reanalysis products. Ocean reanalysis and ocean state estimation are a critical need for CLIVAR because of their value in initialization of climate forecasts, identifying and characterizing ocean and coupled ocean-atmosphere processes important for longer-term climate variability, and ocean uptake of heat and carbon. One of CLIVAR's primary activities in the ocean reanalysis area has been the evaluation, through a series of GSOP-sponsored workshops, of the current generation of ocean synthesis/reanalysis products. Climate-relevant ocean analysis diagnostics were first identified. Then these were compared across several ocean reanalysis products. This evaluation has lead to numerous improvements in the ocean products. Furthermore, there is a renewed international focus on improving the simulation of ocean variability and change, and identifying/addressing key observational problems in the historical databases. For links to ocean synthesis data see the "Ocean Synthesis Directory" at http://www.clivar.org/data/synthesis/directory.php

2.3.3 Paleoclimate data and modelling

CLIVAR activity in these areas has been through:

- CLIVAR/PAGES which has worked through workshop activities to stimulate in particular efforts in proxy-based reconstructions, modelling and methodology for climate variability over recent millennia, the 8.2kyr BP event and on reducing uncertainties in paleo reconstructions. Climate forcings have provided a further focus of activity.

- The Paleoclimate Model Intercomparison Study (PMIP) overseen by WGCM.

3. CLIVAR contributions to WCRP cross cuts

CLIVAR has specific management responsibility for four of WCRP's underlying themes: Seasonal Prediction; Decadal Prediction; Monsoons and Climate Extremes. Responsibility for the last two of these is jointly with GEWEX and is carried out through the respective IPOs. However CLIVAR also contributes to the remaining unifying themes as summarized below for each theme:

3.1 Anthropogenic Climate Change (ACC)

CLIVAR's primary contributions to this cross cut come through the activities of WGCM and the ETCCDI (see above). Others come through analysis by CLIVAR panels of regional response to changing climate forcing through analysis of the WCRP AR4 archive at PCMDI The impact of climate changes forced by increasing green-house-gases and other means are also likely to influence the naturally occurring patterns of climate variability. CLIVAR Panels are addressing how forced climate changes are impacting regional variability patterns such as ENSO and the NAO. In support of the ACC cross cut, the VAMOS Panel has formed an ACC task force that itself cross cuts the different VAMOS science components. This task force has prepared a document that identifies the approach to be followed in regional climate studies (particularly those over the Americas) which can be extended to other panels. The document is available at http://www.clivar.org/organization/vamos/Publications/VAMOS_ACC_12Nov2008.pdf.

3.2 Atmospheric Chemistry and Climate (AC&C)

CLIVAR's primary relevance to this cross cut comes again through the WGCM links (forcing scenarios) and through the aerosol activities under VOCALS.

3.3 Seasonal Prediction:

3.3.1 Climate system Historical Forecast Project (CHFP))
As noted above, WGSIP has carried out a number of past modelling experiments relevant to seasonal prediction and more recently it took the lead in the JSC's Task Force on Seasonal Prediction (TFSP). Through the ICPO, it organised the First WCRP Seasonal Prediction Workshop (Barcelona, June 2007) which included contributions from all of the WCRP's core projects (CLIVAR, GEWEX, CliC and SPARC) and resulted in a Statement on the current status of seasonal to interannual prediction. WGSIP has taken on the task of managing the TFSP's proposed Climate System Historical Forecast Project (CHFP) as a primary activity. The CHFP is a multi-model and multi-institutional experimental framework for sub-seasonal to interannual prediction of the complete physical climate system comprising the atmosphere, oceans, land surface and cryosphere including also chemistry and composition. The experimental framework is based on advances in climate research during the past decade and the understanding that predicting regional and global climate anomalies requires the proper treatment of SST, sea ice, snow cover, soil wetness, vegetation, stratospheric processes, and atmospheric composition (carbon dioxide, ozone, etc.). CHFP experiments are currently underway with international partners and a mixed data sharing strategy is in place whereby participants may serve their own data or appeal to two international hosts (APCC in South Korea and CIMA in Argentina). The CHFP therefore looks to inputs from all projects of WCRP in determining initial conditions (a particular activity with GEWEX is active involvement in GLACE, the Global Land-Atmosphere Coupling Experiment) and in development of diagnostic sub-projects utilising and building on the core CHFP runs. Further information on CHFP is at http://www.clivar.org/organization/wgsip/chfp/chfp.php

Legacy datasets will be the 6 hourly/daily outputs from the CHFP runs carried out for each February, May, August and November of each year from 1979-present with forecasts

suggested to be initialized on 00Z and 12Z on the last five days of each preceding month forming a 10-member ensemble. A distributed archiving system is being adopted with data provided in netCDF via THREDDS or via OpenDAP servers. In most cases aggregation servers are used, and data retrievals from a single data host will typically contain output from multiple models. A CHFP data webpage has been set up at www.clivar.org/organization/wgsip/chfp/chfp_data.php providing further details. Further legacy datasets should emerge from supplementary experiments both from recommended additional retrospective forecasts and as part of diagnostic sub-projects, for example.

It is expected that the outcomes and benefits of the CHFP experiments will feed directly to participating national centres as well as S-I prediction centres more widely, impacting operational seasonal prediction activities at these places

3.3.2 Other CLIVAR inputs to the seasonal prediction theme.
The issue of seasonal prediction pervades much of CLIVAR regional panel activity, through VAMOS (SALLJEX, NAME, VOCALS); the Atlantic Panel (TACE; PIRATA); the Pacific Panel (focus on ENSO and ENSO variability); development of the Indian Ocean network (through IOP) and the development of ocean observing networks more generally (GSOP, OOPC); AAMP (monsoon prediction); VACS (AMMA, capacity building).

3.4 Decadal prediction

For the next 10, 20 or even 30 years the natural variability of the climate system could be of the same order of magnitude as the response to external forcing (e.g., greenhouse gases, aerosols and land cover). Adaptation and mitigation strategies require decadal forecasts of the natural variability, the climate change commitment already made, and the response to additional greenhouse gases and aerosol forcing. We currently have no robust estimates of the part of the natural variability that can or cannot be predicted over 10 to 30 years. Collaboration between WGCM, WGSIP and the AIP (for which the issue of decadal variability and predictability of the Atlantic MOC is a primary focus) has resulted in an experimental protocol for assessing prospects for decadal prediction and estimating the limit of decadal predictability. Ensuring the implementation of this experimental protocol, the understanding of the results and design of follow-on hypothesis testing will be a major thrusts of CLIVAR activities of the coming years to 2013 and even beyond.

A primary cross cut activity has thus been the development of experiments to explore decadal predictability and prediction out to 2035 using coupled models run from initialized atmospheric and oceanic states and with changing climate forcing. These are now part of the IPCC AR5 experimental protocols and are a major component of the newly-configured CMIP5 which provides a five year framework for not only predictions to 2035, but also hindcasts to assess predictability. Legacy datasets from these runs will be managed and organized through PCMDI and the outputs available for analysis and inclusion in IPCC AR5.

The AIP is also working to coordinate new US (AMOC) and European (e.g. RAPID-WATCH, THOR) activities focusing on the thermohaline and Atlantic meridional overturning circulation and its role in decadal variability and possible predictability. A new US-lead 2-year effort addressing decadal predictability will begin in early 2009.

A key issue for decadal prediction is the determination of the initial conditions for the state of the climate system and the ocean in particular and a number of ocean data assimilation approaches have been employed to provide ocean initial conditions. The activities of CLIVAR's Global Synthesis and observations Panel (GSOP) in promoting and evaluating ocean synthesis activities provide an essential input to the decadal prediction activity.

Decadal prediction is extremely policy-relevant. Reliable decadal predictions have application in many sectors: health, agriculture, water management, tourism, forestry, fisheries, hurricane predictions, arctic navigation, permafrost and methane gas emission, electrical power generation, shipping and offshore construction to name a few (Crawford et

al., 2006, www.clivar.org/organization/pacific/BenefitsDecadalPredictions.pdf). Because of the importance of short-range climate prediction for climate adaptation decisions, it is expected that multi-decadal climate prediction from observed initial states will play a prominent role in the next IPCC assessment report.

3.5 Monsoons

This is a joint activity between GEWEX and CLIVAR. Monsoons are a central component of the global climate system: large enough to influence it yet small enough to have distinct regional characteristics and be responsive to the global circulation. Monsoonal circulations dominate southeast Asia and are also significant in Africa and the Americas. Through the complementary efforts of CLIVAR and GEWEX, WCRP has clearly played a major role in launching and supporting monsoon studies. CLIVAR's Asian-Australian Monsoon and Indian Ocean Panels (AAMP and IOP) have focussed on the prediction of the Indian and Australian monsoons whilst the GEWEX Asian Monsoon Experiment (GAME) and the SCSMEX (South China Sea Monsoon Experiment), both focussed on the eastern Asian monsoon. These and the other regional monsoon experiments including, under CLIVAR's Variability of the American Monsoon System (VAMOS) Panel, the North American Monsoon Experiment (NAME), the Monsoon Experiment in South America (MESA), and the La Plata Basin Regional Hydroclimate Project (LPB), all have distinctly regional approaches to monsoon issues as has the African Monsoon Multidisciplinary Analysis (AMMA). In Asia, since the closure of GAME, GEWEX has launched the Monsoon Asian Hydro-Atmosphere Scientific Research and prediction Initiative (MAHASRI). In addition, VAMOS, whose activities are co-sponsored by CLIVAR and GEWEX, is exploring the descending part of the monsoon over the southeastern Pacific Ocean through the VAMOS Ocean-Cloud-Atmosphere-Land Study (VOCALS) and is delineating its involvement with the Intra American Study of Climate Processes (IASCLIP) which bridges the gaps between climate research for North America (NAME), South America (MESA/SALLJEX/LPB), the Pacific (VOCALS) and Atlantic. IASCLIP, which will investigate the role of the intra-American seas in the climate variability of the Americas, will act as a scientific connection among all the science components already established. These regional activities have made, and are making, many contributions to our understanding of monsoon phenomena giving WCRP a high profile in the climate community and in nations affected by monsoon phenomena.

A major activity, co-sponsored by CLIVAR and GEWEX, over the past year has been the development of Science and Implementation Plans for the Asian Monsoon Years (AMY) 2007-2012. AMY has also been identified as a cross cutting weather and climate activity by the WMO World Weather Research Programme (WWRP) Monsoon Panel in the WWRP Strategic Plan. The long-term goal of AMY is "to improve Asian monsoon prediction for societal benefits through coordinated efforts to improve our understanding of Asian monsoon variability and predictability". AMY 2007-2012 is a cross-cutting initiative as part of the JSC's concept of an International Monsoon Study (IMS). It seeks to integrate some 21 regional projects over the Asian-Australian Monsoon region together with existing WCRP activities under CLIVAR and GEWEX and links to a number of other programmes including MAIRS, the Monsoon Asia Integrated Regional Study under START and the ESSP. A further CLIVAR contribution to IMS will arise through implementation of the VAMOS Modelling Plan.

In addition, the WCRP/THORPEX Year of Tropical Convection (YOTC), endorsed by CLIVAR at an early stage, has direct relevance to monsoon studies across the globe. This project will play a key role in development of the emerging WCRP IMS/WWRP project on "Reproduction and Prediction of Monsoon Intraseasonal Oscillation. Which will also directly involve the AMY activity and GEWEX/CEOP. In addition, CLIVAR's AAMP will play a key role in CLIVAR's input to this project for which the activities of the US CLIVAR MJO Working Group are highly relevant.

More than 60% of the world's population is affected by monsoons on an annual basis. Monsoon related processes are responsible for floods leading to extensive death and

damage on an annual basis. The delay in or failure of monsoon events gives rise to drought and crop failures leading to agricultural and community stresses. The capability to predict the onset, duration and intensity of monsoons would enable societies to mitigate some of the negative impacts of the monsoons and to maximize their benefits. Facilitating the development under WCRP of effective monsoon research and prediction services will enable WCRP to demonstrate relevance to the governments responsible for many of the countries with the largest populations and the greatest vulnerability to poverty. Accurate monsoon forecasts on synoptic, sub-seasonal and seasonal time scales could enable aid agencies to more effectively administer their programs.

3.6 Climate Extremes

CLIVAR's primary efforts in the study of Extremes contributing to the cross cut are as follows:

- CCl/CLIVAR/JCOMM ETCCDI activity
    - Development of new indices/develop global indices database
- Near term (decadal cross cut, out to ~2035) climate experiments aim to give guidance on the changing risk of extremes
- WGCM: The International Detection and Attribution group on Design of Twentieth Century Simulations will address issues related to detection of extremes providing input to IPCC
- VAMOS:. The VAMOS Extremes Working Group has prepared a document at http://www.clivar.org/organization/vamos/Publications/vamos_extremes_21jul08.pdf that identifies the approach to be followed in regional climate studies (particularly those over the Americas).
- On drought, a US CLIVAR-led short-term working group designed and executed a set of modeling experiments at five leading US modeling centers to characterize sources of predictability of multi-season drought. The models were forced with idealized patterns of SST, soil moisture, and a warming signal. These global model runs are available and accessible for anyone to analyze. A major drought workshop (100+ attendees) was organized in conjunction with NOAA's Climate Diagnostic and Predictions Workshop (October 2008) and a special issue of J. Climate is being prepared. Efforts are now being made to broaden this activity under the Extremes cross cut (see below).

3.7 Sea level rise

Ocean thermal expansion with warming climate, including abyssal region warming, is an important contributor to sea level rise. CLIVAR's focus on the development of the sustained observation system provides an important contribution to the datasets needed for studies of sea level rise. Ocean reanalysis efforts also provide insight.

3.8 IPY

CLIVAR's primary input to IPY has been through the Southern Ocean Panel's lead for the IPY Climate of Antarctica and Southern Ocean (CASO) umbrella project

4. Imperatives for CLIVAR research over the next 5+ years

IPCC AR5 (due to report in 2013) will be a key motivation for CLIVAR over the coming years. As well as the involvement of individual scientists, this will require input across the

whole range of CLIVAR activities. Key will be (a) WGCM's coordination of the planned "long term" and "short term" (decadal prediction) climate change experiments as part of CMIP5, aided by PCMDI for dataset management and distribution; (b) feed in from GSOP on issues of ocean initialization of decadal timescale predictions and initial steps in coupled reanalysis as well as work by WGOMD on ocean model improvement; (c) WGSIP's contributions to decadal timescale prediction and the seamless link from it's planned CHFP; (d) efforts by CLIVAR's panels to stimulate and facilitate diagnostic studies of outputs, bringing a regional perspective to these in particular; (e) contributions from ETCCDI and CLIVAR PAGES in analysis of extremes and the wider perspective of paleoclimate studies as well as outcomes of monitoring and process studies coordinated through the CLIVAR panels.

In addition, CLIVAR will need to develop a wider perspective of users of climate change and climate variability science, building on the outputs of the key experiments currently being planned but also on the wider range of CLIVAR activities aimed at understanding and predicting climate variability science.

Imperatives for CLIVAR, i.e. those activities and/or plans that "must" be continued and/or implemented over the next 5+ years because they are of the highest scientific importance with a high likelihood of success, have been identified through the CLIVAR Panels and Working Groups to be as follows.

4.1 Anthropogenic climate change

Imperative 1: Realise the long-term climate change integrations under WGCM and contributions to their analysis and feed through to the impacts area

Comment: Use of emerging Earth System Models, with additional components of, e.g., carbon cycle, chemistry, aerosols, and dynamic vegetation for climate prediction, requires connections to a number of different communities. This has begun with WGCM linkages with AIMES and the Integrated Assessment Model Consortium, as well as to AC&C. The piece that is missing is a connection to the impacts community. It will be essential for the IPCC WG2 community to form a representative panel (not unlike WGCM but for impacts) so that planning and formulation of model experiments can carry through more transparently to climate impacts studies.

Imperative 2: To explore regional aspects of ACC through CLIVAR regional studies, including use of regional models in collaboration with the ACC cross cut.

Comment: The recent formation of a panel to address and represent the regional climate modelling and downscaling community is a positive step forward to the more widespread use of these tools to formulate regional and local climate change information. This panel is being coordinated by WGCM where the interface lies between the global and regional modelling activities. To arrive at local climate change information, such tools will be used for at least the foreseeable future, and the value of such information must continually be calibrated and validated since stakeholders and other users of climate change information are in need of that scale of information. CLIVAR regional panels will also provide a focus for addressing regional aspects of ACC, for example through the VAMOS ACC activity.

4.2 Decadal Prediction and decadal variability

This is a key focus for CLIVAR. Some primary questions include:

- What are the variables that exhibit highest predictive skill?
- How do we initialize coupled models for decadal predictions?
- How predictable are the modes of variability and what are their regional impacts?
- How do we validate decadal predictions, given the limitations of the instrumental record?

- What are the potential applications and how can CLIVAR help to develop interfaces between decadal predictions and society?

4.2.1 Decadal prediction

Imperative 3: To realise the planned decadal timescale predictions and contributions to their analysis and feed into the impacts area

Comment: As already noted, for the next 10, 20 or even 30 years the natural variability of the climate system could be on the same order of magnitude as the response to external forcing (e.g., greenhouse gases, aerosols and land cover). Therefore practical planning of adaptation and mitigation options requires decadal predictions that resolve natural variability, the climate change commitment we have already made, and the response to additional greenhouse gas and aerosol forcing. The problem is that we currently have no robust estimates of what part of the natural variability can and cannot be predicted during the next 30 years. This is a crucial science question since there is no consensus on how to clearly delineate the natural variability from the externally forced response on these time scales.

As indicated earlier, WGCM in collaboration with WGSIP has developed an experimental protocol for assessing prospects for decadal prediction and estimating the limit of decadal predictability. Ensuring the implementation of this experimental protocol including provision of initial conditions, the understanding of the results and design of follow-on hypothesis testing will be major thrusts of CLIVAR activities in the coming years to 2013 and even beyond. This activity will also be a major contribution to IPCC AR5.

The outputs and analyses of these experiments and their potential application to issues of societal relevance, including adaptation and mitigation studies, will provide a key WCRP legacy. They will provide datasets for broad community diagnosis across CLIVAR and beyond and help to stimulate regional studies of decadal variability through CLIVAR panels.

4.2.2 Decadal variability

Imperative 4: Understand the impacts of anthropogenic forcing on natural modes of variability and the interactions between the two.

Comment: To aid progress with decadal prediction, it is essential that we continue to understand and monitor decadal variability across the globe, the interactions between models of variability and changing climate forcing and to assess and develop the ability of models to represent it.

This will be done through utilising the outputs from both the “long term” and short term decadal prediction climate experiments. There are some indications that external forcing influences natural modes of variability, but the nature and extent of such influence is still largely unknown. Thus, this is a major science question that must be addressed with improved models and observations.

Imperative 5: To improve understanding of the role of the meridional ocean circulation in decadal variability through coordinated monitoring and modelling studies

Comment: A continuous record of the zonally-integrated, full water column, trans-basin fluxes of heat, mass and fresh water transported in the MOC is essential to assessing its influences on the climate system and potential predictability. This will be realized through the activities of CLIVAR’s ocean basin panels to facilitate coordination of initiatives to monitor the global MOC.

For the Atlantic, the next step must be to discern the meridional connectivity of the Atlantic MOC variability on various time scales through development and implementation of additional (beyond RAPID/MOCHA 26°N) trans-basin measurements in the subpolar North Atlantic and subtropical South Atlantic, as well as the flows through Drake Passage and around the tip of South Africa. For the Atlantic polar and sub polar region, ASOF, while continuing to monitor fluxes between the Arctic and North Atlantic, is actively seeking to synthesize and apply that collective knowledge toward understanding and anticipating decadal climate variability. A fully coordinated monitoring system will also depend upon sustained basin wide observations (i.e. Argo, surface drifters, high density XBT programs) and satellite altimetry with sufficient spatial and temporal resolution to resolve mesoscale features. Analysis of data and model products, process modeling studies and Observing System Simulation Experiments (OSSEs) will be necessary to determine the most efficient and cost effective monitoring system for the Atlantic MOC of the near future.

[Other basin inputs?]

4.3 Seasonal Prediction

Imperative 6: To realise the Climate System Historical Forecast Project (CHFP) as a WCRP-wide activity leading to improved seasonal predictions.

Comment: As noted above, the CHFP as a multi-model and multi-institutional experimental framework for sub-seasonal to interannual complete physical climate system prediction. The experiments are currently underway by a number of international partners and there we have developed a strategy sharing and distributing the data via two different international hosts (APCC in South Korea and CIMA in Argentina). This project: (i) is fairly mature; (ii) will be the basis for assessing progress in seasonal prediction; (iii) is the control experiment for coupled initialization, predictability and climate system interaction research and (iv) is the forerunner for the decadal historical forecast project. The utility of this data and experimental protocol will continue to serve CLIVAR and WCRP more widely to 2013 and beyond.

Imperative 7: To facilitate completion of key CLIVAR-endorsed observational campaigns and the realization of their data legacy for improved understanding and prediction on seasonal and longer timescales

Comment: These include:

- The Tropical Atlantic Climate Experiment (TACE) under AIP which seeks to narrow down uncertainties in the role of the eastern tropical Atlantic in seasonal to interannual prediction
- The realization of SPICE and the North pacific ocean Circulation Experiment (NPOCE) under the Pacific Panel;
- The VOCALS field experiment under VAMOS and field activities under VAMOS-MESA.
- The CLIVAR/GEWEX endorsed LPB project, including monitoring of hydroclimate variables and a field experiment in support of modeling activities, diagnostic studies, predictability studies, transfer to operations in support to water resources management and agricultural practices. The field campaign will develop a set of unique data that will (a) help understand the land surface-atmosphere processes that may lead to persistent events, (b) provide unique information on aerosol production, and (c) obtain a better description of the PBL structure, with the aim of calibrating and improving parameterizations in regional and global models employed for forecasting and prediction up to seasons.
- The realization of WAVES (south West Atlantic climate Variability Experiment), a coupled ocean-atmosphere observational and modelling program under AIP.
- The realization of the CLIVAR AAMP/IOP-endorsed TRIO (Thermocline Ridge of the Indian Ocean project which will investigate the role of air-sea interactions on the

initiation and evolution of MJO events in a region where the associated intraseasonal SST perturbations are strongest.

- Others [Need contributions from panels]

Imperative 8: To narrow down uncertainties in the role of ENSO and other modes of tropical variability for seasonal prediction

Comment: To be achieved through, for example:

- Continuing studies on ENSO dynamics and prediction under the Pacific Panel: issues needing to be solved include westerly wind burst/ENSO interactions; coupled initialization; decadal variations of ENSO and ENSO prediction skill; model biases and the role of ocean noise and TIWs….
- TACE outputs
- Cross panel activities to identify the role of ENSO, the Indian Ocean dipole and tropical Atlantic variability on monsoon prediction and African climate.

4.4 Monsoons and African climate variability

Imperative 9: To contribute to improved prediction of the global monsoon systems and African climate variability, including capacity building.

Comment: CLIVAR will seek to do this through joint management with GEWEX of the monsoon cross cut and in particular by:

- Promoting monsoon-relevant diagnostic sub projects relevant to monsoons of the key WCRP climate modelling experiments on long term climate change and decadal and seasonal prediction
- Active participation in the WCRP IMS project on Reproduction and Prediction of Monsoon Intraseasonal Oscillation
- Continued efforts to facilitate coordination of the 21 projects of the Asian Monsoon Years 2007-12 activity and associated modelling studies linked also to the outputs of the YOTC with the aim of improving capacity for AA monsoon prediction.
- Continued interaction with AMMA, in particular through the links to TACE and the role of the eastern tropical Atlantic for monsoon prediction.
- Implementation of the VAMOS Modeling Plan
- [Need VACS inputs]

4.5 Extremes

Imperative 10: To organise focussed WCRP activity on climate extremes (with GEWEX).

Comment: CLIVAR contributions to this activity will come through the continuing activities identified in section 3.6 above. In particular, CLIVAR and GEWEX are now developing a focus on studies of drought, building on present GEWEX activities under CEOP and the US CLIVAR drought activity outlined in 3.6, utilizing outputs from global models, including the coordinated WCRP seasonal and (IPCC) decadal model experiments outlined above. This activity is currently being scoped; later it is planned to extend these efforts to study of precipitation extremes.

Other potential areas of activity have been identified as:

- Changes in hurricanecharacteristics in the context of global and regional climate change.

- Predicting extremes on the regional scale and expanded development of the statistics of extreme events.

4.6 Development of the global ocean observing system, ocean modelling and reanalysis/synthesis

Imperative 11: Realize scientifically robust simulations of the ocean and their application in coupled models and synthesis/reanalysis

Comment: This activity will require close collaboration between WGOMD, the ocean basin panels, GSOP, WGOMD and WGCM. Realizing scientifically robust simulations of the ocean, from regional to global scales and throughout the full water column, is key to achieving CLIVAR goals for ocean analysis, decadal prediction and anthropogenic climate change. WGOMD will play the leading role within CLIVAR to

- Support the science forming the basis of ocean models (e.g., through identifying and promoting sound numerical methods and key physical parameterizations);

- Design and promote the scientific use of ocean models (e.g., by developing experimental protocols for global ocean-ice simulations);

- Identify analysis methodologies that help to present an honest and thorough examination of the simulations (e.g., by coordinating and organizing a wide suite of analysis products and methods).

Particular activities to meet these aims include:

- Coordinated Ocean-ice Reference Experiments (COREs): Building on the success of CORE Phase I, WGOMD will design a community-wide protocol for simulations of the ocean-ice system over the observational period starting in 1958. The protocol will be tested and illustrated by an inter-comparison of commonly forced global ocean-ice simulations. This CORE-II protocol aims to support CLIVAR's ocean analysis goals, which include developing an understanding of the mechanisms responsible for the observed ocean variability seen in the past century. Initialization questions will also need to be addressed, which then touch on CLIVAR's decadal prediction goals.

- A Repository for Evaluating Ocean Simulations (REOS): REOS is a web site developed by WGOMD in support of the analysis of ocean models. It aims to facilitate access to observational data sets, develop a discussion on ocean metrics and ocean model evaluation, provide tools and references for the community and promote scientifically intelligent analyses of ocean simulations.

- Engagement (already underway) with the WGCM CMIP experimental protocol on sampling physical ocean fields in simulations participating in the WCRP CMIP5 experiments,

Imperative 12: To develop ocean and coupled synthesis/reanalysis systems providing input to present and future decadal prediction efforts

[need input from GSOP]

Imperative 13: With OOPC and others, to facilitate continued development of the global ocean observing system, building on the outcomes of OceanObs'09

Comment: This will be facilitated in particular by:

- Continued interaction of CLIVAR's ocean basin panels and GSOP with OOPC
- Growth in the implementation of the Indian Ocean Observing System under IOP
- The development of the Southern Ocean Observing System in collaboration with SCAR
- The development of the South Atlantic Observing System under AIP and a drive towards sustained observation of the Atlantic MOC.
- Continued facilitation of the current programme of global hydrography and carbon through interaction with the International Ocean Carbon Coordination Project (IOCCP); development with IOCCP and IGBP IMBER and SOLAS of the strategy for future ocean hydrography, carbon and biogeochemistry measurements through the GO_SHIP activity and stimulation of the international community to participate in future measurement programmes.
- Facilitating implementation of an instrumental network for autonomous measurements of the deep ocean basins (deep ARGO).
- Facilitating refinement and augmentation of the present ARGO network to enable better sampling of strong flow regions (floats preferentially converge into gyre interiors).

Imperative 14: To develop and strengthen the interactions and activities between CLIVAR's ocean activities and programmes focussed on ocean biology, biogeochemistry and ecology.

Comment: This will be achieved through building on existing links to GO_SHIP, IMBER (Atlantic panel), PICES (Pacific Panel) and SIBER (IOP) and carbon representatives on basin panels, but also by proactively seeking joint activities

5 Beyond 2013: Frontiers of CLIVAR science

Facilitate inputs (model runs etc) to future (post AR5) IPCC assessments

- Increased involvement in scenario development that has recently started with connections to the Integrated Assessment Modeling Consortium
- Incorporate integrated assessment model components into Earth System Models
- Run Earth System Models at high resolution (e.g. 10 km) with interactive components of ice sheets, chemistry, aerosols, dynamic vegetation, carbon cycle, etc. to fully resolve time-evolving regional climate change from present to 2100 and beyond.
- Further develop regional focus of climate variability change both in short and long term and links to impacts community; issues might include climate change impacts on small islands and corals.

- Further develop decadal prediction studies (potentially to some sort of operational status) and increasingly provide outputs for mitigation/adaptation studies; many strengthened links to and demands from these.

- Use of coupled models to test abrupt climate change scenaros

Climate prediction for weeks to decades

- Increased emphasis on climate prediction for 2-4 week periods (that is the range between deterministic forecasts and intra-seasonal variability)

- Build on CHFP to develop “new” facets to seasonal prediction across the complete coupled climate system

- Initialization of the entire climate system for sub-seasonal to decadal time scales

- Estimating the limit of regional and global predictability on sub-seasonal to decadal time scales

- Climate prediction using models with process resolving resolution (e.g. 1 km?)

- Continued focus on monsoon prediction and impacts, including prediction with cloud resolving capability – of key societal importance

- Construct a true probabilistic framework to represent and communicate climate projections among various disciplines and communities

Ocean and coupled reanalysis/synthesis

- Development of integrated earth system analyses through coupled data assimilation

Climate variability

- Develop concepts of regime predictability, inter-basin connections plus other aspects of climate variability

- SPCZ dynamics ….

- Invest significant effort in understanding uncertainties and develop strategies to reduce those that are structural (representation of physical processes) relative to the intrinsic or externally forced climate variability.

Model development and validation

- Reduce the spectrum and spread of climate projections by concentrating effort on eliminating model biases in key regions (such as the equatorial thermocline).

Climate and ocean processes

- The role of mesoscale eddies in ocean climate, the oceans role in decadal variability and prediction and in climate change [WGOMD text amplifies…]

- Continued efforts on clouds and climate feedbacks in the climate system

- Develop fuller understanding of the role of turbulent processes in climate

Climate extremes

- Process studies to investigate the complementary nature of ocean and land forcings in determining the mechanisms that favour extreme events.

Links with other global programmes

- Strengthen links with other global programme science through joint activities, mainly with IGBP but potentially IHDP also. Areas of interest include:
    - Physical climate links to biospheric processes
    - Potential importance of linking ecosystem processes to models for decadal prediction

Sea level rise

- Improve understanding of ice sheet dynamics, their coupling with the ocean-atmosphere, and future impacts on the MOC and sea level projections.

6. Comments on needed developments in infrastructure

6.1 Computational and information technology

We need computational resources to tackle the science properly. Computer power is growing, yet never sufficient to satisfy the needs of climate science. Decadal work, for example, needs large numbers of decadal-length model runs. Only the very largest organizations or consortia are likely to be able to provide the resources needed, particularly if some of the processes that turn out to be important require higher resolution and/or complex models. Thus the real computational power for doing climate science will become more concentrated at major computer centres in the future, since the expertise to run these machines is difficult to garner, and the resources required to build the machines is immense. There are thus strong incentives to plan for national and international multi-institutional partnerships to ensure that resources are available and (importantly) easy to access.

This situation also warrants increased sophistication in how we transfer information, how data protocols and standards are set and maintained, and how user friendly the databases are that house the model results. Short of such sophistication, the scientific wealth associated with simulations will remain in the hands of few, and will in general be poorly utilized. We need resources for international data sharing, both of model inputs and model outputs. This is absolutely vital. The data sharing arrangements for the numerical experiments associated with CMIP5 will be a start, but we need support that is open to all sorts of data and model runs.

Following on from the modelling summit, the above areas are recognized as an important components of WCRP influence and planning.

6.2 Joining up the chain of model developers (and the wider community)

There is also real value in "joining up" the chain of model developers, those running experiments, those analyzing model output, and those providing verification data. A common data system is a good starting point, but common metrics, verification tools and verification datasets can go a long way beyond that, and would be of great value in assessing and improving model forecasts. Such tools should be open and shared within the international community. It is also clear that the avenue to achieving the goals of climate prediction will require dedicated teamwork amongst the modelling, assimilation/reanalysis, and observational communities. Standardization (of data formats and evaluation tools) is one element. The feedback process to those involved in observational studies is also essential: where do models /reanalysis products need improvements <-> what process experiments need to be run to do so. These are key areas that WCRP/CLIVAR can address.

6.3 Commitments to maintain the (ocean) observing system

Observing and monitoring the ocean is a necessary component for evaluating ocean models, initializing prediction models, and understanding the changing ocean climate. At a minimum, this will require commitments to maintaining global ocean coverage with ARGO, tide gauges, gliders, and remote sensing. Certain elements of the climate system will require enhancements tailored to specific regions: e.g. monitoring western boundary currents and choke points, developing key trans-basin arrays to quantify ocean transports of heat, carbon, freshwater, development of flux moorings for high wind conditions and remote locations and expanded measurement of skin SST. This will require expansion of "new technologies such as routine use of ocean gliders. Still needed are technologies to enable routine deep ocean coverage and autonomous measurements of physical and chemical properties such as carbon, pH, velocity, nutrients. OceanObs'09 will provide input on needs for ocean observational structure but a key issue is effective transition of ocean observations systems from research to operations with an enabling funding structure and, from a remote sensing viewpoint the continuing issue of continuity of satellite observing systems.

There is, in addition a need to strive to acquire all *in situ* data in (near) real time, implement and use common formats for both data and metadata and further develop networks of repositories for observational (and model – see above) climate data as IT evolves.

The above need continuing efforts by CLIVAR in collaboration with OPCC and others.

6.4 Human resources

Individuals who understand the fundamental ocean process science well enough to contribute to model development are few. This paucity remains a handicap to the science conducted within CLIVAR, since numerical models are the only tools we have to mechanistically understand the real climate system. Scientists should be supported and encouraged to attack the hard problems of our field (e.g., subgrid scale parameterizations; development of flexible, documents, and robust community models with state-of-science numerical methods). The implicit stratification that can separate "model developers" from "model users" should be resisted. Models used as "black boxes" are generally of less value to the community than those where the relationship between developers and users is intimate. CLIVAR//WCRP can provide advocacy here.

6.5 Workshops

The success of CLIVAR efforts to coordinate and educate require scientific workshops, some coincident with the panel and working group. Face-to-face gatherings and interactions amongst top scientists are key to CLIVAR, as for other elements of WCRP. Continued WCRP financial support for these remains is both appreciated and crucial.

Others …?