CLIVAR in the Atlantic Sector: a Joint Effort Towards a Better Understanding of Climate Variability and Predictability

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ABSTRACT

The CLIVAR (Climate Variability and Predictability) project, established in 1995 by the WCRP (World Climate Research Programme), aims at understanding the climate variability and improving models for climate predictions by coordinating the efforts of research groups in more than 70 countries around the world. CLIVAR activities consist of a balanced approach between observations, modelling and theory as well as diagnostic studies (http://www.clivar.org).

CLIVAR objectives in the Atlantic sector focus on improving the understanding and assessing the predictability of three climate phenomena: the North Atlantic Oscillation, the tropical Atlantic variability and the variability of the Meridional Overturning Circulation. This paper attempts to give an overview of the state-of-the-art of these Atlantic modes of variability, the ongoing and planned CLIVAR activities related to these climatic phenomena and finally the recent advances in their predictability.

Keywords: Climate, variability, predictability, NAO, Tropical Atlantic, Meridional Overturning Circulation, ITCZ, SST, observations, modelling, process studies, climate impacts.

CLIVAR en la región del Atlántico: un esfuerzo conjunto hacia el mejor conocimiento de la variabilidad y predicción climática

RESUMEN

El proyecto internacional CLIVAR (*Climate Variability and Predictability*), iniciado en 1995 dentro del WCRP (*World Climate Research Programme*), tiene como objetivo principal entender la variabilidad del clima y desarrollar mejores modelos para su predicción, a partir de estudios realizados por diferentes grupos de investigación pertenecientes a más de 70 países en el mundo. CLIVAR aborda con igual peso aspectos del sistema de observaciones y del modelado, así como avances teóricos y estudios de diagnosis (http://www.clivar.org).

En la región del Atlántico, CLIVAR centra sus estudios en mejorar el conocimiento y la capacidad de predicción de tres fenómenos climáticos: la Oscilación del Atlántico Norte, la variabilidad del Atlántico tropical y la variabilidad de la circulación termohalina. El presente artículo intenta dar una visión general del conocimiento actual de estos modos de variabilidad climática, así como de las actividades presentes y futuras de CLIVAR en la región del Atlántico y los avances en la capacidad de predicción.

Palabras clave: Clima, variabilidad, predictabilidad, Oscilación del Atlántico Norte, Atlántico tropical, circulación termohalina, ITCZ, temperatura superficial del mar (SST), observaciones, modelos, estudios de procesos, impactos climáticos.

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1. WHAT IS CLIVAR?

The impacts of climate variability and the threat of future climate change are issues that are brought to our attention in one form or another almost daily. A first step in knowing what will happen and how to react will be to understand how much of the observed climate changes can be attributed to natural variability and which are due to human activities. Due to the efforts of the World Climate Research Programme (WCRP, http://www.wmo.ch/web/wcrp/wcrp-home.html), we now have the scientific basis for making climate forecasts based on modern techniques and global observations. However, much remains to be done to realize reliable and accurate climate forecasts on seasonal and longer time scales. Meeting this challenge is the primary motivation for the Climate Variability and Predictability project, CLIVAR (http://www.clivar.org).

CLIVAR was established in 1995 by WCRP as its major focus for the study of climate variability and predictability, with a particular emphasis on the role of ocean-atmosphere interactions in climate. The challenges for CLIVAR are to develop our understanding of climate variability, to apply this to provide useful prediction of climate variability and change through the use of improved climate models, and to monitor and detect changes in our climate system.

CLIVAR provides international coordination of research, in doing so it acts to encourage and facilitate national and international activities which contribute to CLIVAR research agenda. It seeks, amongst other things, to encourage the development of systems of sustained observations of the climate system, field and modelling studies which 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 modelling experiments aimed at improving our abilities for climate prediction. CLIVAR has published planning documents (http://www.clivar.org/publications/wg_reports/index.htm) that highlight the science issues and challenges within its remit.

2. MODES OF ATLANTIC VARIABILITY

The climate of the Atlantic Sector has exhibited considerable variability on a wide range of time scales. A substantial proportion of the climate variability in the Atlantic region is associated with a phenomenon known as the North Atlantic Oscillation (NAO). NAO dictates climate variability from the eastern seaboard of the United States to Siberia and from the Arctic to the subtropical Atlantic, especially during boreal winter, so variations in the NAO are important to society and for the environment.

There is no unique way to define the spatial structure of the NAO, or thus its temporal evolution. NAO's time dependence, for instance, appear central to the global change debate. Surface temperatures over the Northern Hemisphere (NH) are likely warmer now than at any other time over the past millennium (Jones et al. 2001) with a rate of warming especially high (~0.15°C per decade) over the past 40 years or so (Folland et al. 2001). A substantial fraction of this recent warming is linked to the

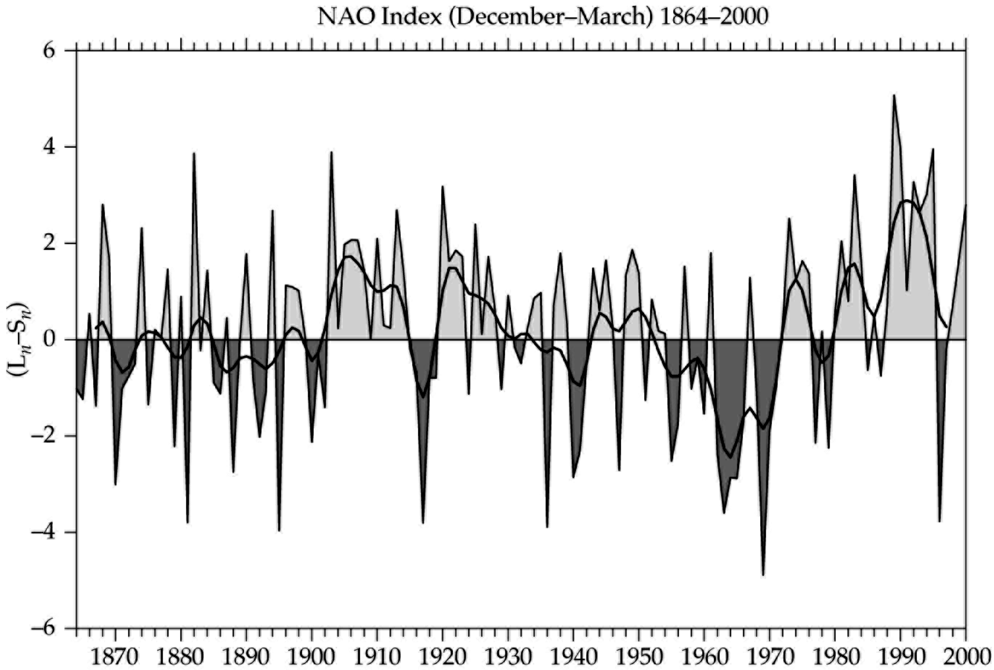

Figure 1. Winter (December-March) index of the NAO based on the difference of normalized SLP between Lisbon (Portugal) and Stykkisholmur/Reykjavik (Iceland) from 1864 through 2000. The indicated year corresponds to January (e.g. 1950 is December 1949-March1950). The average winter SLP data at each station were normalized by division of each seasonal pressure by the long-term mean (1864-1983) standard deviation. The heavy solid line representsthe index smoothed to remove fluctuations with periods less than 4 years.

behaviour of the NAO (Thompson et al. 2000), in particular a trend in its index from large amplitude anomalies of one phase in the 1960s to large amplitude anomalies in the opposite phase since the early 1980s (Fig. 1). The rising NAO state over the past twenty years has been accompanied by a strengthening of the Pacific-North America (PNA) pattern of atmospheric variability, and together they have resulted in a global pattern of cooling of the mid-latitude oceans, and warming over northern hemisphere land masses. Improved understanding of the relationship between the NAO and anthropogenic climate change has emerged as a key goal of modern climate research.

Although the spatial pattern of the NAO appears to be a natural mode of atmospheric variability, its phase may be influenced by surface and stratospheric processes. Changes in stratospheric wind patterns might exert some downward control on surface climate. A statistical connection between the month-to-month variability of the NH stratospheric polar vortex and the tropospheric NAO was established several years ago and more recently it has been documented that large amplitude anomalies in the wintertime stratospheric winds precede anomalous behaviour of the NAO by 1-2 weeks (Baldwin and Dunkerton 2001). Similarly, processes that affect the stratospheric circulation on longer time scales, such as reductions in stratospheric ozone and increases in greenhouse gases, could factor into the trend in Atlantic surface climate observed over the past several decades.

The extent to which the influence of the ocean extends beyond the local thermodynamic coupling to affect the evolution and dynamical properties of the atmospheric flow is probably small, but the effect is non-zero (Kushnir et al. 2002a) The role of ocean-atmophere coupling in determining the overall variability of the NAO is, therefore, a topic of much interest and ongoing research. The NAO influences on the North Atlantic Ocean are becoming better documented and understood: The intensity of wintertime convective renewal of intermediate and deep waters in the Labrador Sea and the Greenland-Iceland-Norwegian (GIN) Seas, for instance, is not only characterized by large interannual variability, but also by interdecadal variations that appear to be synchronized with fluctuations in the NAO (Dickson et al. 1996). These changes in turn affect the strength and character of the Atlantic thermohaline circulation (THC) and the horizontal flow of the upper ocean, thereby altering the oceanic poleward heat transport and the distribution of Sea Surface Temperature (SST).

Substantial variability is observed in the tropical Atlantic region on interannual and decadal timescales. The pattern of the seasonal Atlantic Inter Tropical Convergence Zone (ITCZ), which includes the wind convergence zone, with its convection region and precipitation maximum, the surface low-pressure trough and the maximum in regional SST distribution (Fig. 2) varies from year to year. The most notable climate impacts in the region, the variability of rainfall over NE Brazil and the coastal regions surrounding the Gulf of Guinea, and the fluctuations in rainfall and dustiness in sub-Saharan Africa (Sahel), are tied in with anomalies in the ITCZ seasonal position and intensity. In addition, SST anomalies have been observed both north and south of the equator, in association with rainfall anomalies in Brazil and West Africa. The meridional position of the Atlantic ITCZ is sensitive to the anomalous cross-equatorial SST gradient (Seager et al. 2001) and off-equatorial SST anomalies are associated with changes in the strength of the easterly trades on either side of the equator/ITCZ (Chang et al. 2000).

Coupled modeling studies generally support the notion that interannual variability in cross-equatorial SST gradient and the Atlantic ITCZ is coupled and involves some degree of their mutual interaction (Kushnir et al. 2002b). The tropical Atlantic is subject to strong external forcing. Through the PNA teleconnection and an anomalous Walker circulation subsidence ENSO warming in the equatorial Pacific reduces the northeasterly trades and gives rise to a delayed warming in the northern tropical Atlantic (Huang et al. 2002). NAO also modulates the strength of the northeasterly trades and hence SST in the subtropical North Atlantic. Such external forcing of the northeasterly trades explains a large percentage of observed SST variability in the northern tropical Atlantic. There may also be an impact via extratropical South Atlantic climate variability (Mo and Häkkinen 2001) in addition to the impact of ENSO on the Walker Cell. A dipole in the South Atlantic that constitutes of a warming around 20°S and cooling around 35°S (and vice versa) induces anomalously westerly low level flow in the tropical Atlantic, increased rain fall over the eastern cold tongue and southward shift of the ITCZ. The response of the ITCZ in the Sahel to SST in the

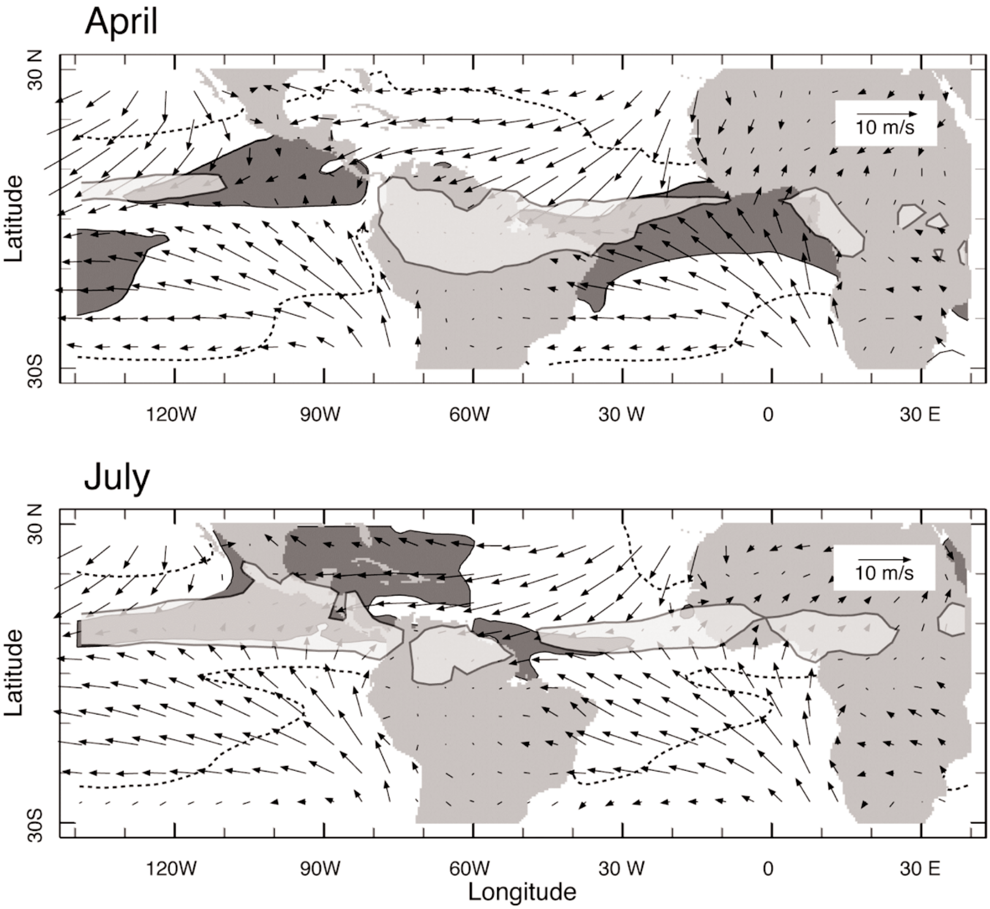

Figure 2. April and July climatologies of the tropical Atlantic and eastern Pacific. Dark shaded areas are regions with SST≥28°C. Light, semi-transparent areas are regions with rainfall≥6 mm/day (the ITCZ). The arrows depict the surface (0 m) wind vectors with scale indicated in the figure. The dotted contour is the 24°C isotherm demarking the regions of relatively cold water and the eastern ocean cold tongues. SST and wind data are from NCEP/NCAR CDAS-1 (Reanalysis) and rainfall from GPCP.

South Atlantic, tropical Pacific and Indian Ocean has been highlighted recently by Giannini et al. (2003).

The Meridional Overturning Circulation (MOC) in the Atlantic transports approximately 20 Sv (1 Sv = 10^6 $m^3 \cdot s^{-1}$) of warm water northward in surface layers, with compensating southward flow at depth. Associated with this overturning is a northward heat transport, peaking at about 1 PW (1 PW = 10^{15} Watt), in the subtropical north Atlantic. It is widely accepted that this heat is an important factor determining surface air temperatures over much of the north Atlantic sector. On long time scales the strength of the MOC is dominated by this thermohaline driving (a balance between surface buoyancy loss in high latitudes and buoyancy gain by diapycnal mixing in the tropical oceans and/or Southern Ocean). In contrast, on interannual and shorter time scales wind-driven Ekman cells dominate its variability. The role of the Atlantic in a world of increasing CO_2 emissions has received special attention. About 60% of the global oceanic CO_2 uptake may take place in the Atlantic sector, a consequence of its intense meridional overturning circulation. However, a significant number of projections of greenhousegas induced climate change over the next century indicate that the Atlantic climate might radically shift into a different equilibrium with much reduced MOC due to freshening of the subpolar ocean (Stocker and Schmittner 1997). Observations reveal consistent evidence of long-term changes in the properties of the overflows and in convectively renewed water masses in the Labrador Sea (Dickson et al. 2002). Evidence for rapid climate shifts in the past has been found in several paleo records and is attributed to changes in the strength of the MOC. A weaker MOC will result in a reduced poleward oceanic heat transport and might dramatically reduce oceanic CO_2 uptake and more importantly, rapidly cool Europe and the northeastern American continent.

3. CLIVAR OBJECTIVES AND ACTIVITIES IN THE ATLANTIC SECTOR

The major elements of CLIVAR in the Atlantic sector focus on climate phenomena, process and regional studies. Phenomena include:

- The North Atlantic Oscillation: how NAO controls the atmospheric factors, which effect change in the ocean? Is there an indication of a coupled North Atlantic Atmosphere-Ocean Oscillation? The NAO seems to have made the largest contribution to the observed hemispheric warming trend: is this due to human activity? Is the amplitude of its decadal/interdecadal variability increasing with time?
- Tropical Atlantic Variability: are the two component of the Atlantic dipole dynamically related? What are the physical processes responsible for this variability? How much tropical Atlantic SST variability is attributed to «remote» influences and how much is due to local air-sea interactions? Are ENSO-like modes in the Atlantic predicable? What are the effect of extra-tropical influences as NAO?
- Atlantic Meridional Overturning Circulation: how sensitive is the MOC to changes in the surface fluxes, in particular those changes that can cause abrupt transitions? What are the critical physical processes for the dynamics of the MOC? What are the space-time characteristics of past decadal-to-centennial variability that may be related to MOC variability? What is the degree of predictability arising from the influence of MOC on atmospheric climate?

CLIVAR's activities in the Atlantic sector consist of a balanced approach between observations, modeling and theory as well as diagnostic studies to better understand

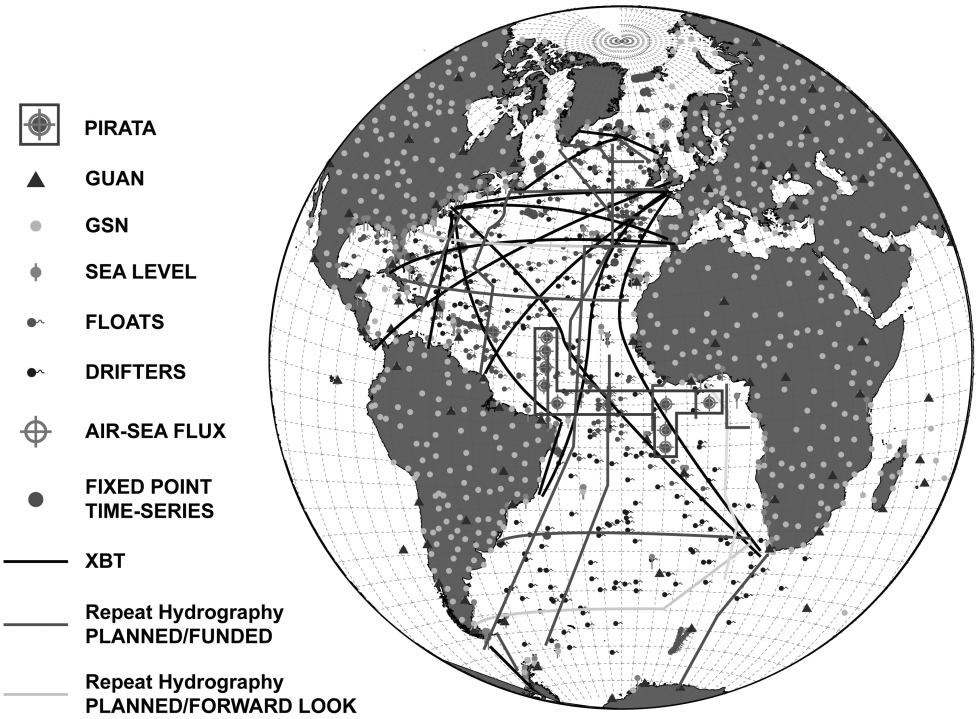

Figure 3. The Atlantic climate observing network: present and future plans.

the primary climate phenomena, their interactions and the potential for predictability. Central to CLIVAR's implementation is a network of sustained observations, which will serve as backbone for diagnostic studies and coupled data assimilation.

3.1. THE BASIN-SCALE OBSERVATIONAL NETWORK

CLIVAR jointly with GCOS (Global Climate Observing System) aims to promote an observing system that produce monthly estimates of the strength of the Atlantic MOC, the tropical Atlantic SST variability and NAO phases. Once established, the observational network (Fig. 3) will provide databases from which to initiate and validate predictive models of future climate variability and change.

The current existing components of the international effort for ocean-based observations comprise *in situ* 1) fixed point time series 2) Global Surface drifting Buoy Array; 3) Global Ships of Opportunity Network; 4) Tropical Moored Buoy Network; 5) ARGO profiling float array; 6) Global Tide gauge Network; 7) Dedicated Ship Operations 8) Moored Buoy. Several elements are part of the Sustained Ocean Observing System for Climate while the rest are short-term measurements as part of specific process studies. More information can be found at:

http://www.clivar.org/organization/atlantic/IMPL/index.htm
http://www.clivar.org/organization/atlantic/IMPL/proc-stud.html

An observational system targeting the Atlantic MOC in the Northern Hemisphere is now taking shape. This includes ongoing national CLIVAR programs in Canada, Norway, France, Germany, and USA as well as two international thematic programs:

- The activities under and associated with the Arctic - Subarctic Ocean Fluxes study (ASOF; http://asof.npolar.no/).
- The activities under and associated to the RAPID Climate Change programme (http://www.soc.soton.ac.uk/rapid/rapid.php). In particular a moored array at 26.5°N to measure directly the meridional mass flux, time series of transient tracers in North Atlantic deep waters, an array along the western margin of the Atlantic to look at boundary wave signals, and an array between New England and Bermuda funded by the UK and USA.

During the past few decades, real-time observations from the tropical Atlantic in-situ observing system were derived primarily from volunteer observing ship (VOS) program, coastal and island tide-gauges, and a small number of drifting buoys. Improvements started in 1990 by increasing the number of classical expendable instrumentation (surface drifters, XBT, HD-XBT, …) launched by the VOS system and other oceanographic vessels. Regarded as the centre piece of the tropical Atlantic observing system, the Pilot Research moored Array in the Tropical Atlantic (PIRATA) (Servain et al. 1998) is a network of in-situ observations enable to monitor changes in oceanic weather conditions in the tropical Atlantic. The PIRATA network currently consists of 10 ATLAS systems: 4 along 38°W from 15°N to 4°N, 4 along the equator from 35°W to 0° and 3 (including the one in the equator) along 10°W from 0° to 10°S. Sensors (wind, temperature and humidity of the air, SST, solar radiation and precipitation) allow to estimate the energy transfer at the air-sea interface. The temperature and salinity profiles for the deeper oceanic layers (down to 500 m), that are of fundamental importance in longer-term climatic fluctuations, are also measured and transmitted in real time.

The South Atlantic (SA) remains a relatively poorly sampled ocean. Long-term observations are needed to better quantify the role of the SA on climate. A monitoring program for the SA should involve measurements of the varying ocean meridional fluxes and the air-sea fluxes and estimates of the modifications in the two major blending regions in the southwest and southeast Atlantic. To monitor the net effect of the varying interocean exchanges and subsequent mixing and water mass modifications on the buoyancy characteristics of the SA and the basin-scale overturning fluxes, a zonal section has been proposed across the SA at about 25°-30°S. In addition, direct, long-term current and temperature measurements are needed in the eastern and western boundaries.

Sustained land-based observations for climate are facilitated by the Global Climate Observing System (GCOS). GCOS defined two networks as sub-systems of the World Weather Watch (WWW) Global Observing System. The GCOS Upper-Air Network

(GUAN, http://www.metoffice.gov.uk/research/hadleycentre/guan/index.html) has been established to ensure that appropriate upper-atmospheric observations for climate purposes are available to scientists. One hundred and fifty stations were selected from the roughly 1000 WWW upper-air stations on the basis of their location, quality and record length. Similarly, for surface observations, GCOS worked with climate change detection experts to define a global network of high-quality stations for monitoring global temperatures. The GCOS Surface Network (GSN, http://www.gsnmc.dwd.de/GSNMC.htm) consists of 989 stations.

There is no single program aimed at circum-Atlantic land observations. The Coordinated Enhanced Observing Period (CEOP) initiated by GEWEX (Global Energy and Water Experiment), with its emphasis on global reference sites and satellite observation, collects consistently formatted land and atmosphere data from around the world for the period 2001-2004.

Recently great strides have been made to link the traditionally more separate ocean-atmosphere and land-atmosphere observations. Few programs started to extend beyond radiation measurement to include physical land properties as well as carbon measurements. In South America, there is the long tradition of international research interest in the Amazon basin. A major ongoing project is the Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA). LBA emphasizes not only atmosphere and land processes but also ecological processes such as carbon cycle. Further south, CLIVAR VAMOS (Variability of the Americas Monsoon Systems) is playing a major role in coordinating the land observations through the South American Low Level Jet Experiment (SALLJEX) and at the La Plata Basin (PLATIN). On the east side of the Atlantic, there are extensive observations over Europe through numerous national and European efforts. There is little coordinated land observation around the Mediterranean region and West and Central Asia despite the strong need for such data in this region of high climate sensitivity. Over Africa, most observations have been over the Sahel, the most populated region in Africa. These observations include long-term rainfall data that have shown the well-known multi-decadal drought. The African Monsoon Multidisciplinary Analyses (AMMA) will study the West African monsoon system through intensive and extended observations. Within CLIVAR, AMMA is endorsed and supported by the Variability of the African Climate System (VACS) panel.

Compared to ocean observations, a great challenge with land observation systems is how to extrapolate point observations to larger scales. Remote sensing provides one of the most useful scaling tools. For this reason, projects such as CEOP coordinate closely with the Committee on Earth Observation Satellites (CEOS). Success in TRMM, TERRA, AQUA, ESA ENVISAT missions have provided or will provide key information in integrating ground based land observations. For instance, the MODIS sensor on board TERRA, with its balanced resolution and coverage has already provided a suite of information from vegetation characteristics to land cover change of unprecedented quality since 1999.

The present suite of remotely sensed observations that provide coverage of the Atlantic Ocean and adjacent continents is expected to continue into the foreseeable future. NASA, NOAA, ESA, CNES, and JAXA are all striving to continue the data continuity from the research and operational satellites that provide SST, scatterometry, altimetry, and chlorophyll concentration for the ocean, temperature profiles, humidity profiles, radiation, cloud properties, aerosols, and precipitation for the atmosphere, and surface temperature and vegetation cover for the land surface. This suite of Earth observations will continue via a series of discipline specific Earth Probe and Earth Explorer research missions and multi-discipline/operational platforms such as ENVISAT, NPOESS, GOES, and EUMETSAT platforms. New sensors expected over the next decade will focus on the hydrological cycle. ESA's SMOS mission will provide information on Soil Moisture and Ocean Salinity (SMOS), NASA's Aquarius and HYDROS satellites will provide complementary information on salinity and soil moisture, respectively. NASA's Global Precipitation Mission will serve to extend in both space and time rainfall rate estimates that began with the Tropical Rainfall Measurement Mission (TRMM).

3.2. PROCESS STUDIES

In addition to the continuing development of a sustained observation system, focused process experiments are required to improve mechanistic understanding in support of the main research themes. A substantial portfolio of process studies targeting the interpretation of observations and modelling of the dynamic response of the ocean to surface forcing is now taking shape.

On high latitudes Northern Hemisphere, ASOF, the Arctic Subarctic Ocean Fluxes study (http://asof.npolar.no), is measuring and modelling the variability of fluxes between the Arctic Ocean and the Atlantic Ocean with a view of implementing a longer-term system of critical measurements needed to understand the high-latitude ocean's steering role in decadal climate variability. ASOF is defined in terms of six main regional tasks:

- Warm water inflow to Nordic Seas
- Exchanges with the Arctic ocean
- Ice and freshwater outflow
- Greenland-Scotland Ridge exchanges
- Overflow and storage basins to Deep Western Boundary Current
- Canadian Arctic Archipelago throughflow

Successful completion of these tasks would meet the ASOF goals.

Complementing ASOF activities in North Atlantic is the RAPID Climate Change thematic programme (http://www.soc.soton.ac.uk/rapid/rapid.php). RAPID aims to investigate and understand the causes of rapid climate change, with a main (but not exclusive) focus on the role of the Atlantic MOC. Using a novel combination of present day observations, palaeo data and a hierarchy of models (from local process models to global general circulation models) the programme will improve our understanding of the roles of the Thermohaline Circulation and other processes in rapid climate change, and the global and regional impacts of such change. Specific objectives of the programme are:

- To establish a pre-operational prototype system to continuously observe the strength and structure of the Atlantic MOC.
- To construct well-calibrated and time-resolved palaeo data records of past climate change, with a particular emphasis on the quantification of the timing and magnitude of rapid change at annual to centennial time-scales.
- To develop and use high-resolution physical models to synthesize observational data.
- To apply a hierarchy of modelling approaches to understand the processes that connect changes in ocean convection and its atmospheric forcing to the large-scale transports relevant to the modulation of climate.
- To understand, using model experimentation and data (palaeo and present day), the atmosphere's response to large changes in Atlantic northward heat transport, in particular changes in storm tracks, storm frequency, storm strengths, and energy and moisture transports.
- To quantify the probability and magnitude of potential future rapid climate change, and the uncertainties in these estimates.

A large number of ongoing research projects are focusing on mechanism or indicators that could lead to some degree of predictability of NAO, including studies of:

- SST anomalies in the tropical ocean (Indian, Pacific and Atlantic).
- Stratospheric circulation and its connectivity to stratospheric chemistry and climate.
- Snow cover.

Many such projects study both the natural variability as well as the expected response of the NAO to human induced global climate change.

In association with the planning for AMMA, CLIVAR is proposing a process study on the ocean's role in the tropical Atlantic climate variability. The Tropical Atlantic Climate Experiment (TACE) will consist of a dedicated observational and coupled modelling study for determining the importance of the surface and subsurface oceanic circulation for tropical SST variability as well as CO_2 uptake and storage changes. While the study of air-sea interaction and convection-circulation interaction associated with the Atlantic Marine ITCZ (AMI) is the focus of a proposed US CLIVAR project. The overall objective of this study is to provide information needed for improving the understanding of the physical and dynamic processes key to the determination of the predictability of AMI and its limits, improving their representations in climate models, and assessing their representations in global reanalyses.

4. TOWARDS PREDICTABILITY

SST data suggest that there is a fair degree of correlation between interannual variability in the equatorial Atlantic, and SST variability further south. Off-equatorial SST anomalies are normally ascribed to latent heat anomalies and on decadal time scales this is argued to be a possible mechanism for variability.

For decadal variability in the North Atlantic more work has been done on predictability of the MOC. Attempt to initialize models with an observed decadally varying state, and test our ability to make actual decadal predictions, are as yet not very visible.

There are operational coupled global seasonal forecasting systems around the world and an useful set of integrations are those from EU-funded DEMETER project which has run seasonal forecasts with a set of seven different global coupled models. Models still have difficulty in reproducing the seasonal cooling in the eastern equatorial Atlantic in July and in this time of the year, the zonal SST gradients are poorly represented. Clearly in the Atlantic basin, a failure to position convection correctly with respect to land/ocean is a very serious problem which is likely to cause a range of problems in simulating interannual variability. Another problem in the atmospheric modelling is the difficulty of simulating the low level status decks.

CLIVAR priority is to address all these issues that limit our ability to predict climate in the Atlantic sector and several are the implemented improvements:

- The observing system, both in terms of in-situ data and data available to create forcing fields. Testing of the models and their forecast abilities might benefit from detailed work in this (very short) data rich period.
- Assimilation schemes to reconstruct the tropical Atlantic ocean state from limited data, in order to have reasonable estimates for some historical period.
- More analysis of the Atlantic climate variability.
- Visibly acknowledge the importance of Atlantic, especially regionally, and its presently inadequately treatment in forecast systems.
- Work done to try to understand the mechanisms and degree of decadal predictability in coupled models. Only when decadal prediction systems start to be applied to real world forecasting problems will we be able to understand how the world really works.

5. CONCLUSIONS

Overall the implementation of CLIVAR in the Atlantic sector is well underway. Links have been established with operational climate prediction and assessment centers/initiatives and anthropogenic climate change including the IPCC assessment process. At the same time CLIVAR promote the data from various global and regional climate-observing systems (including satellites) to be available to the research community. Efforts on reanalysis/synthesis are beginning and improvements on climate predictions are expected. In summary there are still many challenges ahead but CLIVAR in the Atlantic Sector is in the track to reach its goals.

6. ACRONYMS

AMMA	*African Monsoon Multidisciplinary Analyses*
AMI	*Atlantic Marine ITCZ*

ARGO	*(http://floats.pmel.noaa.gov/floats/)*
ASOF	*Arctic-Subarctic Ocean Fluxes*
CEOP	*Coordinated Enhanced Observing Period*
CEOS	*Earth Observation Satellites*
CLIVAR	*Climate Variability and Predictability*
ENSO	*El Niño-Southern Oscillation*
GCOS	*Global Climate Observing System*
GEWEX	*Global Energy and Water Experiment*
GIN	*Greenland-Iceland-Norwegian*
GSN	*GCOS Surface Network*
GUAN	*GCOS Upper-Air Network*
IPCC	*Intergovernmental Panel on Climate Change*
ITCZ	*Inter-Tropical Convergence Zone*
LBA	*Large Scale Biosphere-Atmosphere Experiment*
MOC	*Meridional Overturning Circulation*
NAO	*North Atlantic* Oscillation
PIRATA	*Pilot Research moored Array in the Tropical Atlantic*
PLATIN	*La Plata Basin*
PNA	*Pacific-North America*
RAPID	*(http://www.soc.soton.ac.uk/rapid/rapid.php)*
SALLJEX	*South American Low Level Jet Experiment*
SMOS	*Soil Moisture and Ocean Salinity*
TACE	*Tropical Atlantic Climate Experiment*
THC	*Thermohaline Circulation*
VACS	*Variability of the African Climate System*
TRMM	*Tropical Rainfall Measurement Mission*
VAMOS	*Variability of the Americas Monsoon Systems*
VOS	*Volunteer Observing Ship*
WCRP	*World Climate Research Programme*
WWW	*World Weather Watch*

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