CLIMATE VARIABILITY AND PREDICTABILITY

Workshop on Tropical Atlantic Variability
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Working Groups Reports

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Working Group 1:
Coupled Ocean-Atmospheric Systems

Recent analyses and modeling works concerning the variability in the Tropical Atlantic have brought to light several interesting issues :

- There is a convergence of model results on the existence of a local ocean-atmosphere coupling in the equatorial region. This local coupling however remains weak and more work is needed to clarify the mechanisms involved in this coupling.
- The variability in the tropical Atlantic is strongly influenced by the variability originating from remote regions (like the ENSO, or the NAO). Other atmospheric or oceanic teleconnections may also be involved in its variability.
- A large range of variability from interannual to decadal scales is observed and these scales are not independent. The continuum of scales should be considered.
- Moreover the specific meridional configuration of the Atlantic basin, bordered by two large land masses (South America and Africa) with complex boundaries, confers a strong predominance to the seasonal cycle, which comes to interact strongly with the variability.

The variability in the tropical Atlatntic remains a difficult and complex issue and several scientific questions were formulated as a guideline to get an increase understanding of the TAV :

- What are the processes (wind evaporative feedback? oceanic horizontal advection? oceanic Ekman pumping? wave dynamics? STC?) which contribute to the interannual TAV, and what time-scales are they driving? what are the positive feedbacks and their quantitative contribution? and the negative feedbacks?
- what is the contribution of external factors to the TAV? which scales are predominantly influenced by atmospheric teleconnections (ENSO, NAO…)? or by oceanic teleconnections (MOC, STC…)? How do these remote sources of variability influence the TAV?
- what are the interactions between the mean seasonal cycle and the variability ? are there positive or negative feedbacks between the seasonal cycle and the interannual variability ?
- what are the key-ingredients in the land surface/ocean/atmosphere system that contribute to the mean seasonal cycle and its variability? what are the relative importance of land-surface versus ocean for driving the location and amplitude of convection, moisture flux and monsoon ? What are the mechanisms controlling the variability of these fields? are they coupled (with land-surface processes ? or with oceanic processes)?

Recommendations:
To advance on the questions, several recommendations were issued from the group discussions.

- Modelling efforts should be integrated; this means that both interactions of the atmosphere with the land surface system and the ocean should be considered and included in models. Their respective importance (and potential interactions) should be studied in function of the scale of interest.

- Systematic biases from the mean background state exist in present coupled models and they could modify the variability patterns. Both mean background state and variability should be discussed and documented in function of the observations, and their interactions should be clarified.
- Perturbation experiments are recommended to clarify the interactions between the different interactions between atmospheric/land surface/oceanic patterns (how does a modification of the thermocline structure by subtropical subduction interact with the interannual variability? how does the land surface conditions influence the ocean-atmosphere variability? …). The robustness of a proposed mechanism could be assessed through ensemble analyses of different models.
- It is necessary to improve the understanding and to quantify how TAV is influenced by remote variability. Regional coupled modelling studies are recommended to explore the atmospheric teleconnections acting in the tropical Atlantic; perturbations experiments are also needed to clarify the slower oceanic teleconnections between the tropical region and the mid-latitudes.
- It is recommended to establish what is needed, in present coupled models, to accurately preproduce the typical patterns in amplitude and phase of the annual cycle. Climatic anomalies (and thus climatic impacts) are strongly linked to the regional seasonal cycle. Accurate data sets are needed to improve the description of the mean seasonal state and to evaluate the coupled models.
- An improved understanding of the processes which control the SST variability requires further modelling studies and analyses. Processes may vary in space and time, and the exact nature (forced, and/or coupled) of the variability needs to be investigated. Quantitative evaluation of the different processes contributing to the SST variability is needed (oceanic advective processes, Ekman pumping, heat flux (and wind evaporative feedback)…), and their associated time-scale should be determined. Several key-regions have been identified as critical for the ocean-atmosphere coupling : the atmospheric convective regions above warm water, extending westward from North Africa, where a better understanding of the atmospheric structure and variability is needed, and the cold oceanic upwelling regions in atmospheric subsidence regions. A specific effort is recommended to fill the gaps in the southern hemisphere where the upwelling and subduction regions are poorly described.

Working Group 2:
Climate Impacts and Prediction

WG2 was created in recognition of a need to link existing national and international operational prediction/outlook activities concerned with the climate in and around the tropical Atlantic and the need to link between these operational activities and the CLIVAR scientific agenda. It is the goal of such communication to improve the understanding, modeling, and prediction of TAV and stimulate improvement in the areas of:

- Sustained ocean/atmosphere/land observations for research and operations.
- Models and methods for simulation, data assimilation and prediction of tropical Atlantic climate.
- Process studies intended to improve understanding of local and remote mechanisms governing TAV.

CLIVAR tropical Atlantic Workshop plan WG2 identified four areas that need attention.

1.Data and Data Assimilation

The problem: There are well-known gaps in tropical Atlantic observations that continue to limit progress in understanding and predicting local climate variability. For example, there is inadequate information on SST climatology and variability in and downstream of the coastal upwelling regions along the coast of Africa north and south of the equator (~10-20ºN). These gaps are due to several compounding factors: the year round stratocumulus deck sheltering the regions from visible and IR satellite observations, the infrequent passages of ships of opportunity, and the tendency of drifters and floats to diverge out of these regions due to the prevailing circulation.
These regions are centers of variability on all time scales connected to significant impacts over land. Availability of upper ocean data in those regions is important for prediction and modeling of TAV. Shortfalls of current ocean and atmosphere data assimilation procedures in the tropical Atlantic region may also indicate a lack of observations. It appears that the performance of existing assimilation procedures in the tropical Atlantic is far less satisfactory than in other regions (e.g., the tropical Pacific). There is a close link between such problems and the reliability of ocean models as far as the simulation of the climate in this region. It is not clear what part of the problem is due to lack of key observations in key locations, and what part is due to the model performance.

Recommendations:

- Identify the needs for data to improve simulation, assimilation, and prediction of mean and anomalous tropical Atlantic climate and liase with GCOS and GOOS regarding these issues.
- Direct assimilation efforts to objectively identify and prioritize what variables should be measured and in what location and temporal and spatial resolution. Resolution to this problem should be sought together with continuous model development.

- Identify the special issues regarding the tropical Atlantic data assimilation efforts. Seek to identify the reasons for existing discrepancies and determine the implied data needs. Liase with WGCIP and GODAE to get attention to these problems.
- Identify ongoing and upcoming regional special observational efforts conducted by CLIVAR and non-CLIVAR organizations that could help fill data gaps in the tropical Atlantic Basin (e.g., the CLIVAR VACS and VAMOS activities or the World Bank funded fisheries experiment - BCLME).

2. Impacts

The problem: While a great deal is known on the links between fluctuations of climate variable important to society (e.g., rainfall) and TA SST there is much more that needs to be done in terms of identifying the actual societal effects of this variability, the extent of the end user community, and the implied priorities. In addition, there is a clear need to extend the study of climate variability and related impacts to all seasons and into the less well studied regions of the south tropical Atlantic. Also incomplete is knowledge on the full range of climate variables that are relevant for society. The improvement of knowledge and understanding in these areas is necessary for improving prediction, increasing its utility, and drawing support from governments and corporations for continued research.

Recommendations:

- Continue emphasizing the needs for impact related research (if possible end-to-end) and the needed increase attention to year-round variability and the south tropical Atlantic region.
- Liase with the CLIVAR programs studying climate over the tropical Atlantic landmasses, VAMOS and VACS, to coordinate efforts to identify climate impacts and societal connections over land.

3. Predictability

The problem: There is need to better define the predictability limits of TAV and related phenomena through data-studies and model experiments. This also implies the improved definition of model (numerical and statistical) limitations.

Recommendations:

- Liase with CLIVAR WGCIP and WGCM to increase attention for predictability studies in the tropical Atlantic region.
- Encourage the scientific CLIVAR Atlantic community to study/develop models of the tropical Atlantic region with the intention of quantifying the predictability of TAV.

4. Links to operational centers

The problem: The science and ocean observing communities involved in CLIVAR Atlantic research need to build better links to national and international operational prediction centers and regional Climate Forum activities concerned with the tropical Atlantic region. Such links will help improve climate prediction methodology as well as stimulate research directed to improve forecast models of various complexity.

Recommendations:

- Identify the centers of climate prediction and forecasting and the regional Climate Outlook Forum activities that direct attention to TAV and seek contacts in these organizations.
- Plan an international workshop directed towards a meeting between the operational and research communities working on all aspects of TAV. This workshop needs to be well prepared, preferably by a committee representing all sides involved. The committee should be assigned with the task of identifying the goals, the participants and a list of pre-workshop assignments to these participants, so as to facilitate successful outcome. This puts the time frame for the workshop to 2-3 years.

Working Group 3:
Links between the upper tropical Atlantic, the deeper ocean and the other basins

1. Science Questions

The overarching question discussed in this working group was the role of the 3D timevarying advection in tropical Atlantic SST, and specifically the role of subsurface to deep circulation in determining Tropical Atlantic Variability (TAV), ITCZ position and SST. The WG deliberations were structured around two main themes, the subtropical cells (STCs) and the top-to-bottom meridional overturning circulation (MOC) and their respective roles in TAV.

1.1. STCs:

The main questions regarding the STCs focus on the mean pathways within the STCs and on the variability of the STCs. Results of numerical simulations show considerable differences in the mean pathways within the STCs. Thus, further investigations of the mean pathways that connect the subduction areas with the upwelling areas are needed. At this point, reference was made to the recommendations of the workshop on STCs and their interaction with the atmosphere, held in Venice, Italy, in October 2000.

a) Mean STCs. Specific topics regarding the mean pathways within the STCs that were discussed are

- roles of interior meridional transport vs. transport within the western boundary undercurrents,
- roles of equatorial vs. off-equatorial upwelling,
- physical mechanisms of the transformation of thermocline waters into surface waters, and
- role of the NBC rings in the interhemispheric water mass exchange.

b) STC variability. Specific topics regarding the STC variability that were discussed are

- roles of velocity anomalies transporting mean temperatures vs. temperature anomalies transported by the mean advection,
- relation between the variability of the NBUC, the equatorial upwelling and the SST,
- the effect of subduction variability vs. equatorial Ekman divergence on the STCs, resulting in the question: Is the STC “pushed” or “pulled”?, and
- role of equatorial Kelvin and Rossby waves, coastal Kelvin waves propagating poleward along the eastern margins and off-equatorial Rossby waves and related possible predictability of TAV.

1.2 Deep circulation / MOC

Regarding the relation between TAV and larger scale circulation, the discussion centred on the determination of pathways of the mean cross-equatorial exchange, the water mass transformations involved and the exchange variability.

a) Processes involved in cross-equatorial exchange. Of particular interest here was the transformation of lower North Atlantic Deep Water (NADW) into warmer water mass classes in the western and central tropical Atlantic and the physical processes that are possibly responsible like, e.g., deep upwelling, interaction with topography and effects of “stacked jets”. Although not directly related to TAV, realistic representation of these processes may be important for long-time scale and GH response models. The equatorial zonal current system may introduce delays in the arrival time of propagating climate signals and thus may act as a “buffer zone” and the question raised was the degree of realism required in representing this buffer zone in GH models.

b) Mutual effects of MOC and TAV. The need to understand the role of MOC/NADW pulses that originate in variability of the LSW production or in the overflows for TAV was addressed. There are two time scales involved that represent the propagation of such pulses from the subpolar sources to the tropical Atlantic: the time scale for the propagation of momentum by baroclinic Kelvin waves (approximately 1 year) and the time scale for the advection of passive tracers (approximately 15 years).

The discussion also included the effect of decadal/interdecadal variability of the warm-water return flow by the upper limb of the MOC due to the variability in the relative importance of the South Atlantic source water masses i.e., “warm path” with more surface waters from the Indian Ocean vs. “cold path” with more intermediate waters out of the Drake Passage. These variations in warm-water inflow composition may affect the tropical circulation, STCs and TAV.

A possible feedback from the subpolar North Atlantic to the subpolar atmosphere may be indirect and involving TAV, since TAV is known to have an impact on the NAO. This feedback may operate by the following route: first, subpolar atmospheric (NAO) variability generates NADW anomalies, these in turn cause circulation and stratification anomalies in the tropical system which then influence the subpolar latitudes via the atmosphere.

Furthermore, the effects of TAV on NAO and NADW production as well as the stability of the MOC due to salinity anomaly advection in the northward warm-water MOC branch were discussed as well as the effects in off-equatorial areas and other ocean basins caused by the generation of anomalies in the MOC when passing the tropical Atlantic.

Finally, the WG addressed the questions: Can more be learnt from paleo data on the TAV/MOC connections? and: What is the effect of TAV in oceanic CO2 uptake?.

2. Recommendations and implementation

2.1Wind products

There is still a large uncertainty in the different wind and wind stress products and the conclusion was reached in the discussion that interannual to decadal wind stress anomalies and the resulting Sverdrup/ Ekman transports from the tropical Atlantic differ more strongly for different wind products than for the Pacific. Two main questions resulted: What can be done to improve them in the future? and: What was the real variability in the past?

2.2 Process studies

Process studies were proposed for three of the science questions after different preparatory steps:

a) STC variability study. The recommendations regarding the STC variability are based on those formulated at the Venice Workshop. The following elements should be covered in such a study:

- Direct measurements of the equatorward western boundary current transports and water mass properties related to the STCs,
- Determination of the relative importance of equatorial vs. off-equatorial upwelling,
- Determination of the relative importance of interior vs. western boundary pathways by Lagrangian measurements including deliberate tracer release experiments in subduction areas,
- Study of the role of NBC rings in the cross-equatorial water exchange, and
- Study of the role of STC variability in the heat budget.

b) MOC transformation study. Regarding the MOC transformation, the focus should be on the transformation of lower to middle NADW in the tropical zone, but the dynamics of the deep recirculation gyres were also considered important.

c) Study of the effect of NADW pulses on TAV.A case study may offer itself soon, since a large pulse of LSW formed in the early 70ies has been documented to propagate down the western boundary and is now arriving at about 15°N. It was recommended that the modeling community decide on sensitivity experiments to study the role of overflow and LSW pulses when arriving in the equatorial zone.

Out of the three process studies, the STC variability study was judged to be the most ready one for implementation and on the basis of the Venice Workshop it was felt that the time has come to proceed with it. It was therefore recommended that an Implementation Workshop be organized for an STC process study.

2.3 Sustained observations

A comprehensive observing system in the tropical Atlantic is crucial to advance our current understanding of the underlying physics of TAV. The recommendations include sustained observations of MOC and STC transports. Urgently needed are MOC transport timeseries, and efforts that are already underway along 16°N (MOVE/GAGE) or planned along 24°N (UK program) were welcomed. Also required are repeat water mass inventories (T, S, CO_2, tracers). The measurements of the warm-water inflow into the equatorial zone by the moored array off Brazil are a substantial contribution to the determination of the equatorward STC transport. To measure the interior thermocline STC flow, geostrophic moorings across the interior basin like, e.g., moored cycling CTDs, gliders or moorings that provides sufficient vertical resolution of the obtained T/S fields are recommended.

It was also recommended to improve the VOS fleet that crosses the tropical Atlantic by adding ADCPs and thermosalinographs. The addition of current measurements for the existing PIRATA moorings was found to be an important issue and the French efforts to add deep current measurements were welcomed. The proposed extensions of the PIRATA network were considered to be of interest for STC studies, in particular if the additional stations in the interior South Atlantic or in the eastern upwelling regions would be upgraded to serve as geostrophic moorings. However, the WG left it for the appropriate bodies (CLIVAR Atlantic Implementation Panel) to judge the benefits of the individual PIRATA extension proposals.