Tropical Atlantic Observing System (TAOS) Review

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Tropical Atlantic Observing System Review Report

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- Key recommendations

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- Research and Discovery

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Cited References

Important processes and modes of interannual variability in the tropical Atlantic

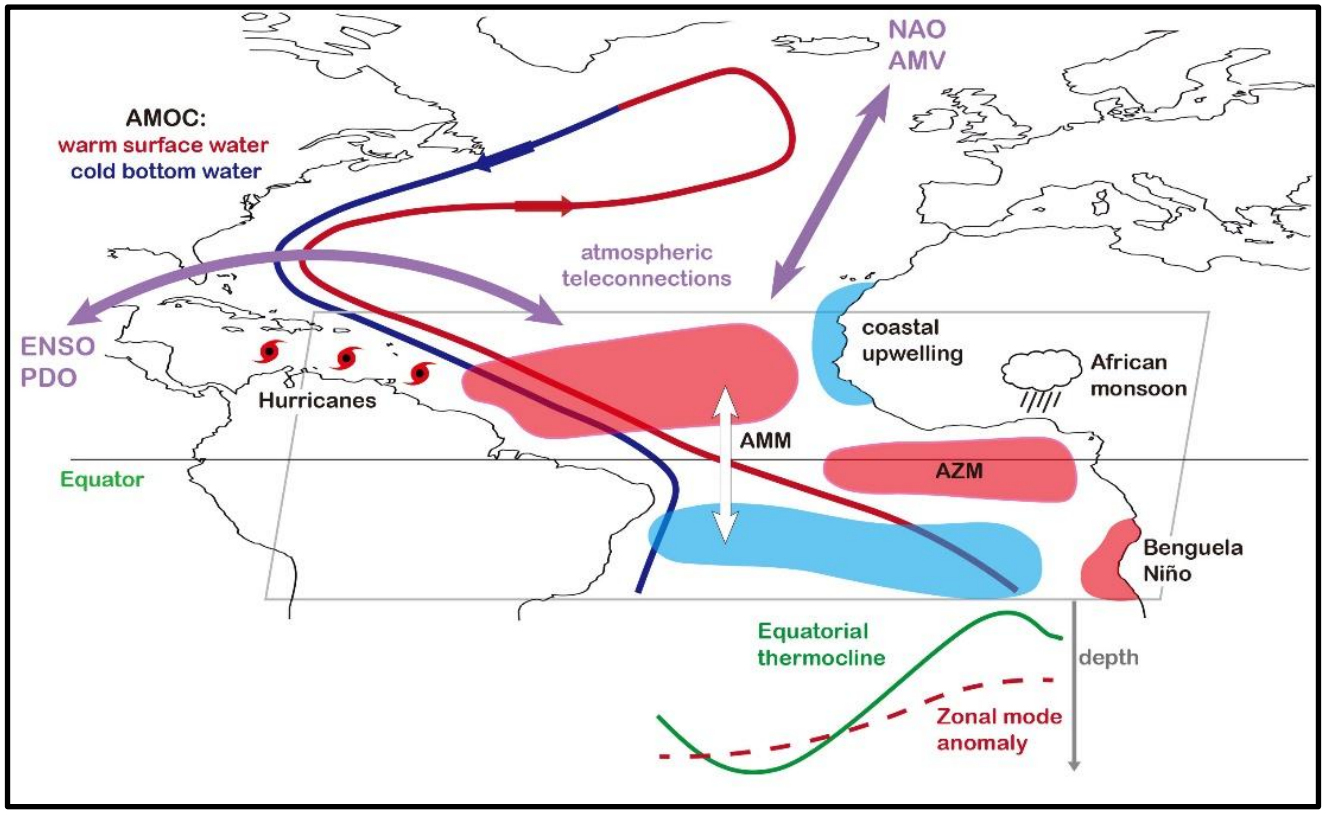
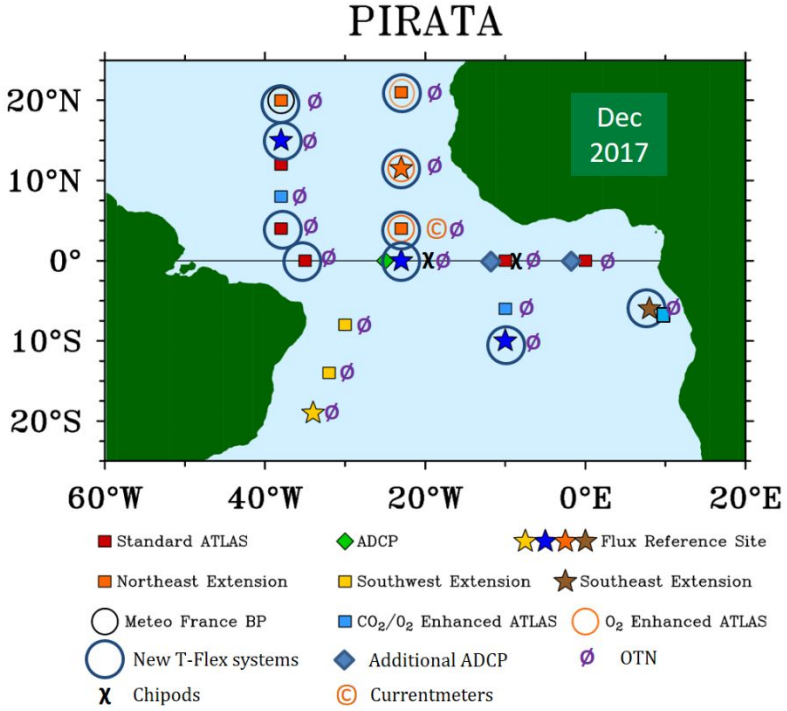
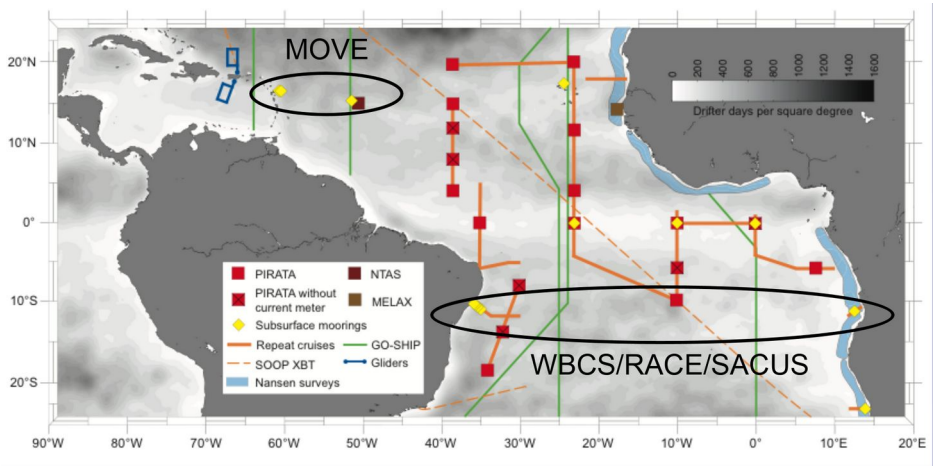


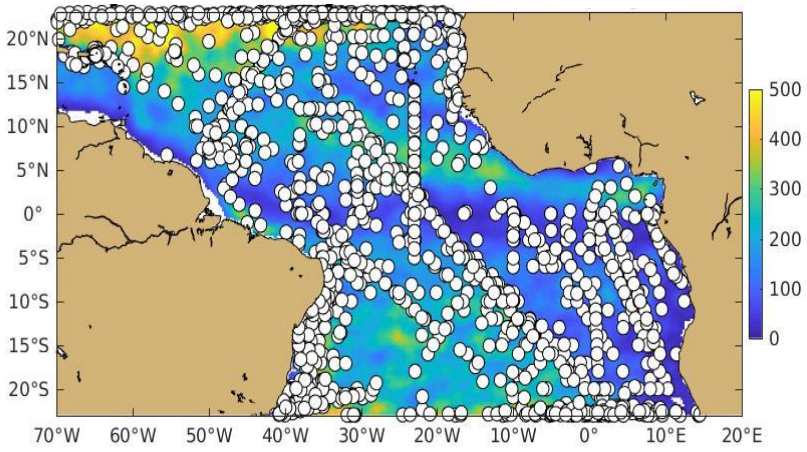
Figure 1.1: Important processes and modes of interannual variability in the tropical Atlantic. AMM: Atlantic Meridional Mode; AZM: Atlantic Zonal Mode (or Atlantic Niño); AMOC: Atlantic Meridional Overturning Circulation; ENSO: El-Niño/Southern Oscillation; PDO: Pacific Decadal Oscillation; NAO: North Atlantic Oscillation; AMV: Atlantic Multidecadal Variability.

The current TAOS

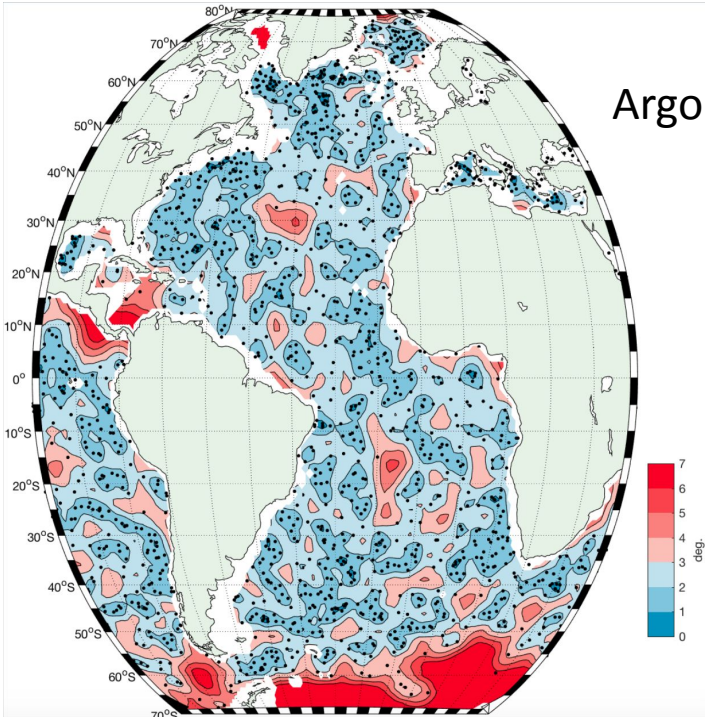




Drifters



Argo



Recommendations for the TAOS

PIRATA Bouys:

- Vertical sampling of upper ocean temperature and salinity (0-100 m) should be enhanced on all PIRATA moorings so that the mixed layer depth and underlying stratification can be determined with greater accuracy.
- Near-surface current measurements (at least one point current meter at ~5 m depth) should be installed at all PIRATA sites.
- All PIRATA surface buoys should be equipped with sensors for barometric pressure and downwelling longwave radiation, allowing them to serve as flux reference sites.
- Additional ocean turbulence sensors should be deployed on a subset of PIRATA moorings to extend the existing pilot measurements with chi-pods already obtained on two of the equatorial moorings.
- pCO2/fCO2 sensors should be installed on an extended set of PIRATA moorings to complement the three sites where they are currently deployed.
- Additional BGC sensors should be added to PIRATA moorings, including dissolved oxygen, pH, and nitrate.

Recommendations for the TAOS

Recommended new PIRATA sites:

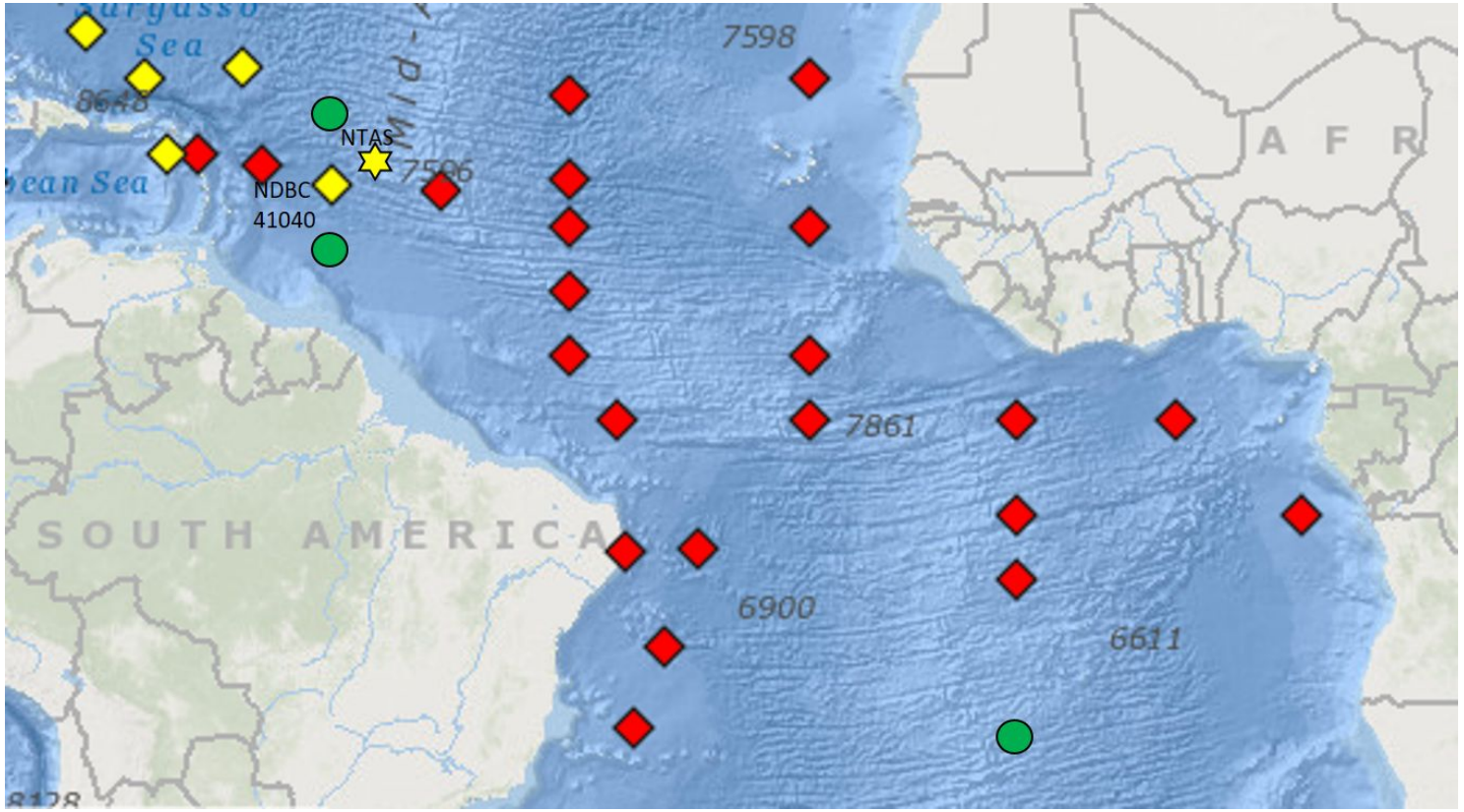


Figure 5.1. Green symbols show recommended new PIRATA sites to combine with the NTAS/NDBC buoys to establish a new buoy line along ~53°W, and the recommended new PIRATA buoy at 20°S, 10°W.

Recommendations for the TAOS

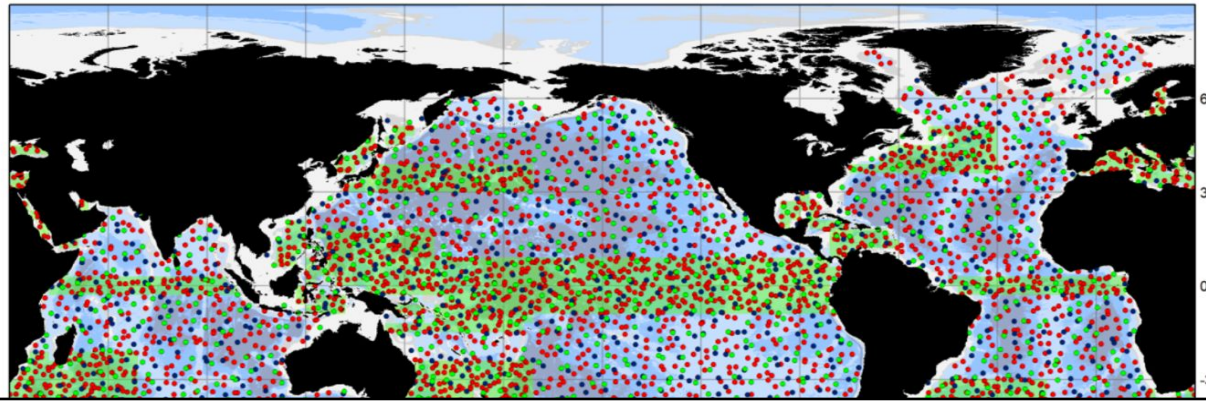
Drifters:

- Increase the number of SVP drifters in the tropical Atlantic that measure barometric pressure. Currently ~60%; ideally all SVP drifters deployed in the region should include barometric pressure (SVPB drifters).
- An effort should be made to deploy an increased number of drifters in the northeast tropical Atlantic during boreal spring of each year, that would provide enhanced data for TC prediction (including barometric pressure) in summer and fall as they spread westward across the tropical Atlantic toward the Caribbean Sea.
- The feasibility of deploying an array of thermistor-chain drifters along the equatorial waveguide should be explored as a way to increase the number of SST and upper ocean temperature observations available near the equator.

Recommendations for the TAOS

Argo:

- The TAOS Review endorses and recommends full implementation of the “Argo 2025” vision of a globally integrated Argo program including approximately 2500 core Argo floats, 1000 BGC-Argo and 1250 Deep Argo floats.



=> Implementation of BGC-Argo as envisioned in the Argo 2025 design is realistically the only way that consistent, broad-scale data on biogeochemical processes at the desired temporal and spatial scales can begin to be gathered at the basin scale.

=> The enhanced Argo density near the equator will also help to resolve subsurface temperature and thermocline variability associated with development of the zonal mode, and deep Argo will provide needed data to track deep water property changes and heat storage on sub-decadal time scales.

Recommendations for the TAOS

Vessel-based observations:

- *The TAOS review recommends that an increased emphasis be placed on collecting multi-disciplinary vessel-based observations, particularly on the annual PIRATA mooring servicing cruises, to serve the needs of the broader TAOS science community and operational centers.*
- Seawater samples for:
  - Nutrients
  - Inorganic carbon and alkalinity analysis (pH, dissolved inorganic carbon, total alkalinity, pCO2)
  - Chlorophyll pigments
- Turbulent flux measurements from ship-mounted towers
- Radiosonde/ozonesonde vertical profiles
- Biological sampling (phytoplankton/zooplankton)
- Sustain current GO-SHIP, VOS-XBT sampling
- Maintain, and expand on, the current frequency of high-quality pCO2 (as well as SST and SSS) from the VOS fleet that transits the tropical Atlantic and on RVs operating in the area.

Recommendations for the TAOS

Satellite observations:

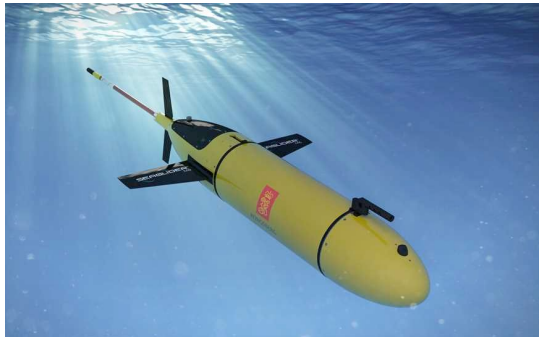
- Continuity of passive microwave SST sensor missions is vital to the TAOS; particularly important in the tropical Atlantic due to a high incidence of cloudy conditions.
- Continued satellite SSS missions with improved accuracy are vital to the TAOS, to address issues on the water cycle, subseasonal to decadal prediction, and climate change.
- New Doppler-based surface velocity satellite missions (e.g., SKIM; DopplerScatt) should be supported as key future elements of the TAOS; of high value for the TAOS - and for the tropics in general - due to limits on the applicability of geostrophy near the equator.

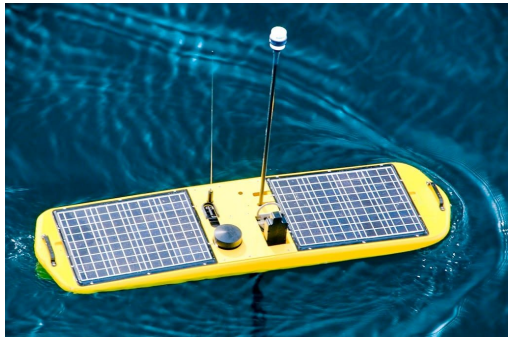
=> Satellite missions for SSH (Altimetry/SWOT), IR SST, and scatterometer winds are adequately planned for maintenance through ~2030.

Recommendations for the TAOS

Other observing platforms:

- Newer observing platforms such as ocean gliders and ASVs (e.g., SailDrones, Wavegliders) should be considered for potential niche roles in the TAOS, as part of both targeted regional process studies and also possibly in a sustained mode, where they could be particularly valuable in extending in-situ data coverage into poorly sampled coastal regions.
- Pathway to broader sustained use of these technologies in observing systems is through pilot studies in targeted regimes where their usefulness and capabilities for extended use can be demonstrated.





Recommended Process/Pilot Studies:

- Improved quantification of near-surface ocean mixing processes in different tropical Atlantic regimes using microstructure gliders and/or time-series observations of upper ocean shear and stratification, such as those enabled by the recent TACOS enhancements on the PIRATA mooring at 4°N, 23°W.
- Pilot studies using ASV technology (e.g., Saildrone) to:

  - sample surface ocean and atmospheric parameters (including pCO_2) in poorly sampled regions in order to fill important gaps in the present observing system

  - sample winds and surface ocean-atmosphere parameters in the SE tropical Atlantic eastern boundary region (Benguela upwelling zone) to improve understanding of processes leading to model biases in that region, possibly together with a targeted glider program

- A pilot study with drifting thermistor chains in the near-equatorial Atlantic to test their capabilities and what their potential impact could be on the reconstruction of subsurface thermal fields.
- Investigation of atmospheric vertical momentum transport in the central and western tropical Atlantic to improve model representations of atmospheric processes and to help reduce climate model biases in surface and lower tropospheric winds.

Recommendations for the TAOS

Biogeochemical Observations:

- An optimized observing system is needed to quantify the tropical CO_2 flux on annual time-scales, involving a combination of high-quality pCO_2 observations obtained from volunteer observing ships, expanded time-series pCO_2 data from moorings, and potentially additional pCO_2 observations from autonomous surface vehicles (ASVs) to fill spatial and temporal gaps. Data from BGC Argo floats in the region will also be useful for constraining estimates of surface fluxes.
- Measurements of particulate matter, dissolved organic carbon and microbe biomass and diversity are also needed to develop a more quantitative understanding of the mechanisms linking dissolved oxygen concentration, remineralization efficiency and microbial community structure.
- A joint definition of observing needs with the fisheries and biodiversity communities is recommended to identify joint opportunities between fishery surveys and more climate driven observing needs, especially within the highly-productive eastern upwelling zones.

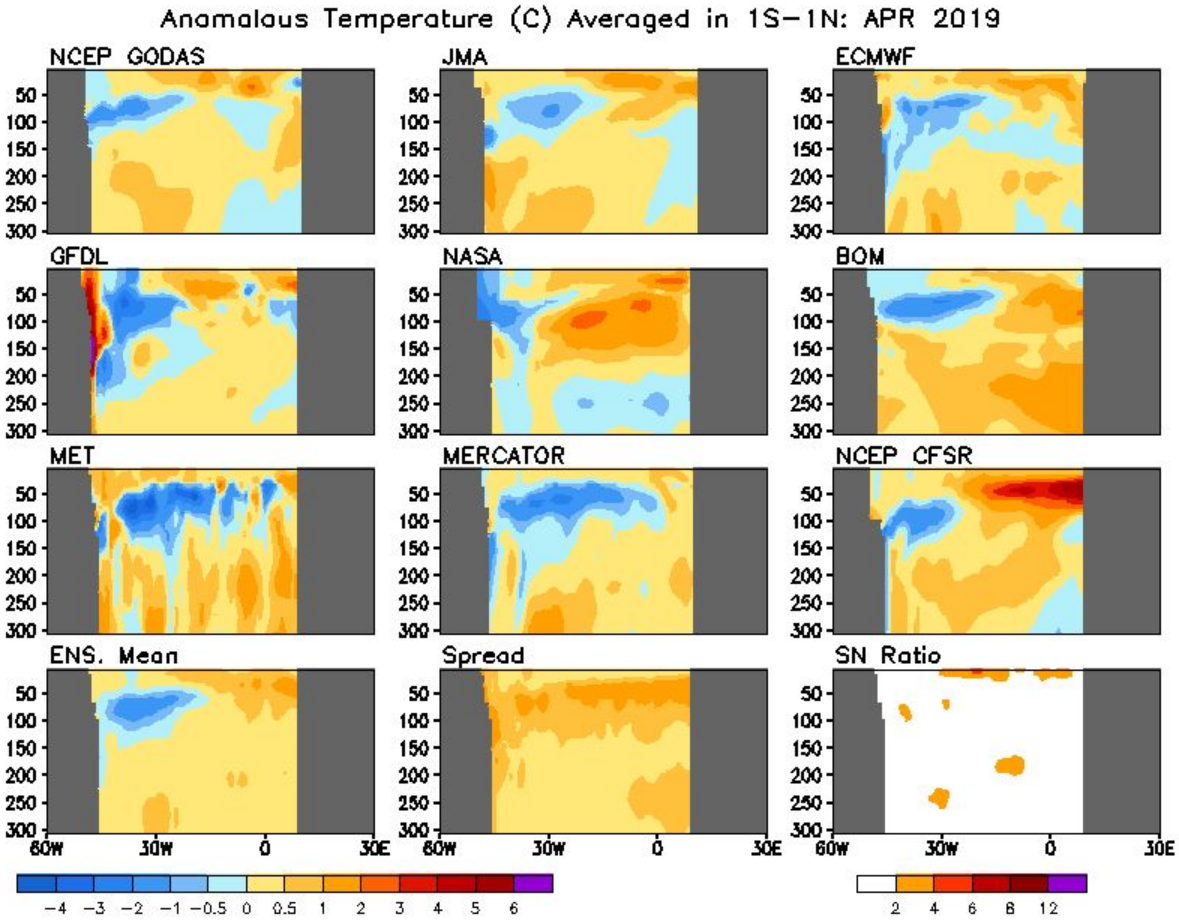
Recommendations for the TAOS

Fisheries and Ecosystems:

- Fisheries management in the tropical Atlantic must continue its evolution from traditional single species management of capture fisheries to an ecosystem-based approach to fisheries management, in which fish stocks are managed in the context of other organisms (prey, predators, and competitors) and their environment.
- Improved management of living resources across the tropical Atlantic requires a better assessment of the active fisheries themselves, including fishing capacity, fishing effort, and catch, as well as more fisheries-independent data on life stages (egg-larvae-juvenile-adult) of fish stocks acquired through trawl and hydroacoustic surveys. Promotion of open data policies for ecological and fisheries data is strongly recommended.
- Coordinated national survey programs need to be linked and supported, including existing programmes like the EAF Nansen Programme, the LME Programmes and Regional Fisheries Management Organizations like ICCAT.

Optimization of the TAOS – the need for improved data assimilation

Example: Temperature structure along the equator



http://www.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html

Optimization of the TAOS

A consensus recommendation from the TAOS Review is that a large-scale and adequately-resourced effort needs to be undertaken to investigate deficiencies in data assimilation systems and how existing data available from observing systems can be most effectively used to constrain reanalysis and forecast products. Such an effort might logically consist of two components:

- An OSSE framework in which data are extracted from a base (nature) model run and ingested in other models to explore the required temporal and spatial resolution of data to recover the "correct" model state in reanalysis mode, using current data assimilation schemes. Experiments with different assimilation methods and parameters could also be used to test which strategies can produce more accurate field reconstructions with fewer observations.
- An OSE framework in which results of the above OSSE experiments are applied to assess the influence of particular observational platforms and discrete observations on ocean analysis and subsequent forecast skill.

=> Need specific "targets" for model skill assessment that involve key regional phenomena and observables.

=> Recommended that the regional CLIVAR panels (e.g., the ARP) work to develop such indices that can be used as benchmarks in these recommended OSSE/OSE studies. Assessing the role of model errors in reanalysis or forecast skill should also be a critical part of this effort.

Recommendations for data/information products and delivery

Conclusion: No major TAOS-specific issues regarding data and information management; the TAOS community is doing a relatively good job of making observing system data widely available and accessible, through PIRATA buoy/cruise data servers, and other data centers (satellite, Argo, SVP, XBT, etc.)

The TAOS Review recommends:

- As an underlying principle, around 10% of the investment in the TAOS observing infrastructure should support data and information management, including for new technologies.
- TAOS data management should conform with the FAIR Principles, and that data stewardship, and the engagement of all TAOS stakeholders in data management, are a central priority for the sustainability of TAOS.
- The TAOS community should adopt a strategy that supports greater integration, more consistent adoption of standards and best practice, and technologies that provide virtual data management environments (e.g. THREDDS, ERDDAP).
- Improved systems for monitoring TAOS data production and use should be in place.

Governance, Review and Resourcing

The TAOS Review recommends the establishment of a "TAOS Forum" whose purpose would be to:

- Foster close coordination among observing system elements
- Provide a vehicle to share information on implementation strategies challenges, and best practices
- Help to define new observing system initiatives
- Advocate for resources necessary to sustain the overall effort
- Encourage increased participation in the TAOS from bordering countries of the tropical Atlantic to whatever resource level may be possible - even if initially limited
- Facilitate more active participation in data access and usage by bordering countries, including capacity development for accessing the data and observing technology
- Link to the emerging AtlantOS governing framework; link with the LME consortia in the tropical Atlantic region
- Engage in a regulated manner with JCOMM and WMO Integrated Global Observing System (WIGOS) in discussions of future governance

Governance, Review and Resourcing

TAOS Forum membership:

1) scientists involved in the implementation of the observing system
2) agency representatives with some control of resources that can be applied to help build and sustain the observing system
3) end users who make use of the data and/or data products generated from the observing system

The TAOS Forum should be open to all interested parties but would include at least one representative from each of the major observing system components that comprise TAOS (Argo, Drifter, PIRATA) and agencies providing funding at a national level to TAOS (NOAA, MétéoFrance, IRD, CNRS, Ifremer, INPE, DHN).

An appropriate frequency for TAOS Forum meetings is two years.

Meetings venue should move between PIRATA/TAV meetings, large conferences like EGU/AGU, and other relevant program meetings like AtlantOS, SOLAS and IMBeR, trying to visit regularly each of the four continents (Africa, Europe, North and South America including the Caribbean Islands states).

Periodic TAOS Review

The TAOS Review recommends that major reviews of the TAOS take place at a decadal pace.

Decadal reviews should provide:

- An assessment of successes, failures and gaps of TAOS in relation to evolving societal requirements and with respect to new technology and scientific developments and demand.
- Evaluation of the current state of TAOS to determine the most efficient and effective observational solutions to support prediction systems for ocean, weather and climate services, management of ocean ecosystems, fisheries, and coastal risks, and to develop a sustainable blue economy.
- Review the governance structure of the TAOS and its effectiveness in engaging stakeholders across the tropical Atlantic region and promoting sharing of observing system data and resources.

Recommendations for the TAOS (overarching)

- Maintaining existing observational records is of paramount importance to ensure the continuous monitoring of long-term changes.
- Better constrained and validated surface heat flux measurements are needed within the tropical Atlantic observing system to improve understanding and prediction of SST anomalies associated with TAV modes, and particularly that of the meridional mode.
- Better constrained estimates of subsurface thermal variability along the equatorial waveguide are needed to detect Kelvin waves that can induce Atlantic Niño and/or Benguela Niño.
- More time series measurements of microstructure and turbulence in the upper ocean are needed to improve the understanding of mixed layer heat and salinity budgets.
- Remote sensing of the surface velocity field, e.g. by using Doppler radar measurements, is a high priority for future satellite missions.

Recommendations for the TAOS (overarching)

- Continuous monitoring of tropical Atlantic salinity, in addition to SST, is mandatory to achieve an accurate forecast system and to infer the state of the regional hydrological cycle and the availability of moisture to feed rainfall over land.
- The extratropical influence of TAV requires good characterization of the location and strength of deep convective systems across the tropical Atlantic. Better instrumentation for oceanic surface rainfall measurements within the TAOS are needed to provide vital comparisons for improving satellite products.
- An increase in the number of radiosonde observations in the tropical Atlantic would be beneficial for constraining the dynamical aspects of tropical-extratropical interactions.
- Continued research is needed to overcome the deficiencies in numerical climate prediction models' simulation of the tropical Atlantic mean ocean and atmosphere climate conditions, climate variability, and extremes.
- Sustained measurements of the AMOC in the tropical Atlantic - in conjunction with those at other latitudes (e.g. RAPID, SAMOC, OSNAP) - are needed to understand the meridional coherence of the AMOC on different time scales and the dynamics of the basin-wide AMOC response to changes in forcing.

Recommendations for the TAOS (overarching)

- An optimized observing system is needed to quantify the tropical CO2 flux on annual time-scales, involving a combination of high-quality pCO2 observations obtained from volunteer observing ships, expanded time-series pCO2 data from moorings, and potentially additional pCO2 observations from autonomous surface vehicles (ASVs) to fill spatial and temporal gaps. Data from BGC Argo floats in the region can also be useful for constraining estimates of surface fluxes.
- Sustained measurements and improved geographical coverage of key biogeochemical EOVs including dissolved oxygen, transient tracers and nutrients are needed to understand the ocean mixing and ventilation processes that influence oxygen concentrations, and the impact of low oxygen concentrations on nutrient concentrations.
- Measurements of particulate matter, dissolved organic carbon and microbe biomass and diversity are also needed to develop a more quantitative understanding of the mechanisms linking dissolved oxygen concentration, remineralization efficiency and microbial community structure.
- A joint definition of observing needs with the fisheries and biodiversity communities is recommended to identify joint opportunities between fishery surveys and more climate driven observing needs, especially within the highly-productive eastern upwelling zones.

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- Improved management of living resources across the tropical Atlantic requires a better assessment of the active fisheries themselves, including fishing capacity, fishing effort, and catch, as well as more fisheries-independent data on life stages (egg-larvae-juvenile-adult) of fish stocks acquired through trawl and hydroacoustic surveys. Promotion of open data policies for ecological and fisheries data is strongly recommended.
- Coordinated national survey programs need to be linked and supported, including existing programmes like the EAF Nansen Programme, the LME Programmes and Regional Fisheries Management Organizations like ICCAT.

Recommendations for the TAOS (overarching)

- Optimal use of TAOS observations can be achieved through “Seamless Earth System” approaches to forecasting, spanning time scales from subseasonal to decadal, which should be a continued developmental focus at operational centers.
- Modelling relies on parameterizations, which need to be continuously improved with the aid of both sustained observations and targeted observational campaigns.
- Improving hurricane forecasts at both synoptic and climate time-scales is a top priority of Atlantic climate research. Enhanced observations in the Atlantic hurricane main development region are needed to improve forecast capabilities and to help resolve the cool SST bias problem in the northern tropics.
- Improving the ability of climate models to predict “Atmospheric Rivers” - plumes of intense water vapor transport emanating from the tropics – has important implications for water resource management and flood/drought hazard assessment, and should be a further top priority for Atlantic Basin climate research.