GSOP Report

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- Report on GSOP Activities
- Current Status of GSOP Synthesis
- GSOP Synthesis Evaluation Effort
- CLIVAR Data Management Issues
- WOAP and WCRP Re-Processing

CLIVAR needs for Synthesis

- To develop improved (more coherent, better organised, more widely available and more useful) databases and reference data sets for the climate community (1950 through present);
- To provide a basis to study the climate dynamics in the ocean, and the interaction of the ocean with the atmosphere and cryosphere over the last several decades.
- To provide a global framework to bring regional and basin scale research efforts back into a global climate context.
- To provide the basis for the initialization of coupled models on monthly to interannual, decadal and longer time scales.
- To provide guidance on the effectiveness of the ocean observing system for monitoring climate variability and climate change, in order to to address CLIVAR needs.

GSOP Science Issues

- Climate variability and change is intrinsically a global problem. The melting of ice in Greenland or Antarctica raises sea level in all of the oceans.
- The distribution of heat in the equatorial oceans causes rainfall or drought thousands of kilometers away.
- Decadal changes in the atmospheric annular modes influence ocean temperature and circulation as well as terrestrial temperature and rainfall patterns around the globe.
- The impacts of climate variability and change are felt on a regional basis, but understanding and improved prediction will only come from viewing the complete ocean/atmosphere/ land climate system with a global perspective.
- These are all science questions that need to be addressed by GSOP using global data sets and global syntheses.

1. THE PLANETARY HEAT BALANCE

Heat storage. What is the rate of heat storage in the global oceans for the past 50 years, the past 10 years, and at present? How is it distributed with depth and location? What accounts for large regional inhomogeneities? How does global ocean heat storage compare to the imbalance in the planetary radiation budget?

Heat transport. What is the meridional heat transport of the oceans and its variability on seasonal, interannual, and decadal timescales? What is the variability on global scale of the deep and shallow meridional overturning circulations, and of the inter-oceanic exchanges of heat?

Ocean/atmosphere feedbacks. What are the key regions and their significance for ocean/atmosphere feedbacks?

Includes inter-basin exchanges!

2. THE GLOBAL HYDROLOGICAL CYCLE:

Water balance. How does the mean salinity of the global ocean vary on seasonal to interannual to decadal time scale in relation to changes of the volume of sea-ice, to changes of the terrestrial storage of water, and to changes of continental ice sheets? How do the relative salinities of each of the oceans vary in relation to the transport of atmospheric water vapor and the inter-basin exchanges of freshwater?

Rainfall variability. What is the seasonal-to-interannual variability of near-surface salinity and the decadal variability of salinity in subducted water masses in relation to patterns of precipitation-minus-evaporation? What are the global patterns of interannual anomalies in P-E? Is there a recent acceleration in the global hydrological cycle?

Salinity and convection. What is the impact of near-surface salinity anomalies on water mass formation rates and characteristics?

3. SEA LEVEL:

- **Sea level rise.** What is the rate of sea level rise over the past 50 years, the past 10 years, and at the present time? What are the steric and eustatic components of global sea level rise? How are the global signals distributed regionally?
- **Sea level variability.** What is the pattern of variability in sea level on seasonal to decadal timescales?

4. OTHER GLOBAL-SCALE CLIMATE PHENOMENA:

ENSO: What is the ocean's role in the initiating and sustaining El Nino and La Nina episodes? Do the oceans play a part in ENSO teleconnections?

Monsoons: What are the oceanic influences on monsoon onset, evolution, and rainfall amounts? What oceanic factors influence the pattern of rainfall on land and on the oceans?

Atmospheric annular modes: What are the oceanic impacts due to variability in the Northern and Southern Hemisphere atmospheric annular modes? Do the annular modes have an anthropogenic trend? Do the oceans play a feedback role in variability of the annular modes.

Challenges (1)

- The spectrum of applications of ocean reanalyses for climate variability and prediction purposes spans over seasonal-to-interannual, decadal-to-centennial, and even millennial time scales.
- It is therefore likely that different assimilation/synthesis approaches and methods will need to coexist for some time in support of these applications. These applications pose a range of accuracy and robustness requirements on ocean reanalyses. Consequently, they necessitate somewhat different data assimilation approaches and evaluation.
- But there are some needs common across the multiple applications outlined above.

Challenges (2)

- Prototype ocean synthesis products exist with varying complexity. An earnest fundamental R&D program needs to be maintained in order to continue improving those ocean reanalysis efforts so that these improvements can be transitioned into coupled reanalysis and forecasting frameworks.
- While there are a small number of sustained efforts institutionalized for real-time and seasonal-to-interannual forecasting and respective ocean assimilation work, there are only critically few sustained activities in place to provide needed climate-quality hindcasts, climate model initializations for decadal to millennial time-scale problems, carbon, and other products.

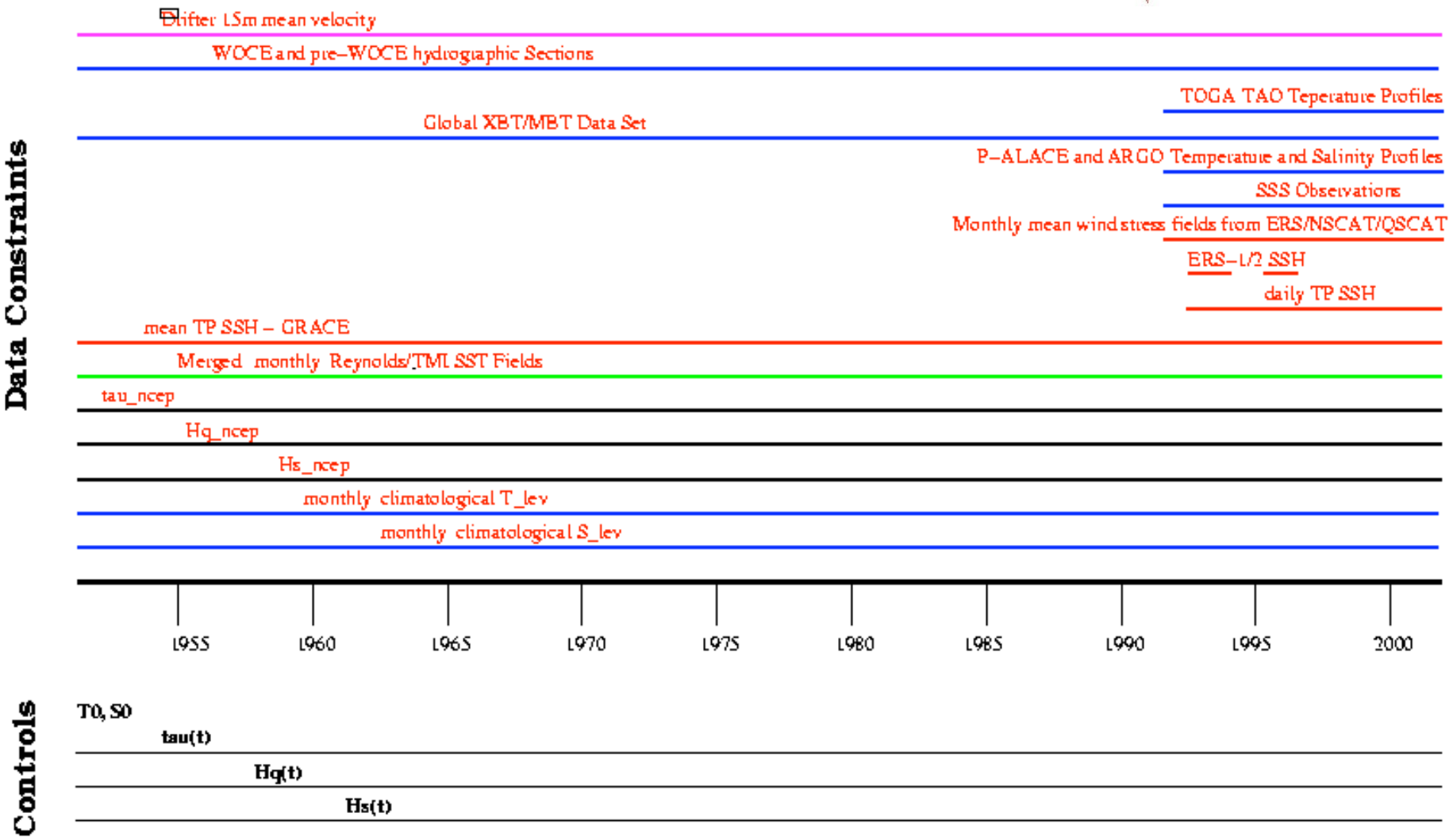
Ocean Syntheses

- Several synthesis attempts are underway regionally, some also globally; most are 1992 to present ...
- The community is now approaching 50 year long syntheses paralleling the NCEP reanalysis. SODA (Simple Ocean Data Assimilation) is an example.
- Such syntheses based on mathematically rigorous assimilation approaches are now becoming available which will enabling analysis of CLIVAR relevant climate indices, e.g., strength of the MOC and sea level change.

GECCO 50-Year Synthesis
(Köhl and Stammer)

- GECCO is the German counterpart to the US ECCO effort.
- It ran a 50-year long synthesis over the last year which is now finished.
- This is the first CLIVAR 50-year long synthesis of almost all available ocean data on a global scale.
- The synthesis is mathematically rigorous and dynamically self consistent.
- It should serve as the benchmark of any future improvement.

Input Data Sets and Controls



Köhl and Stammer (in preparation, 2006)

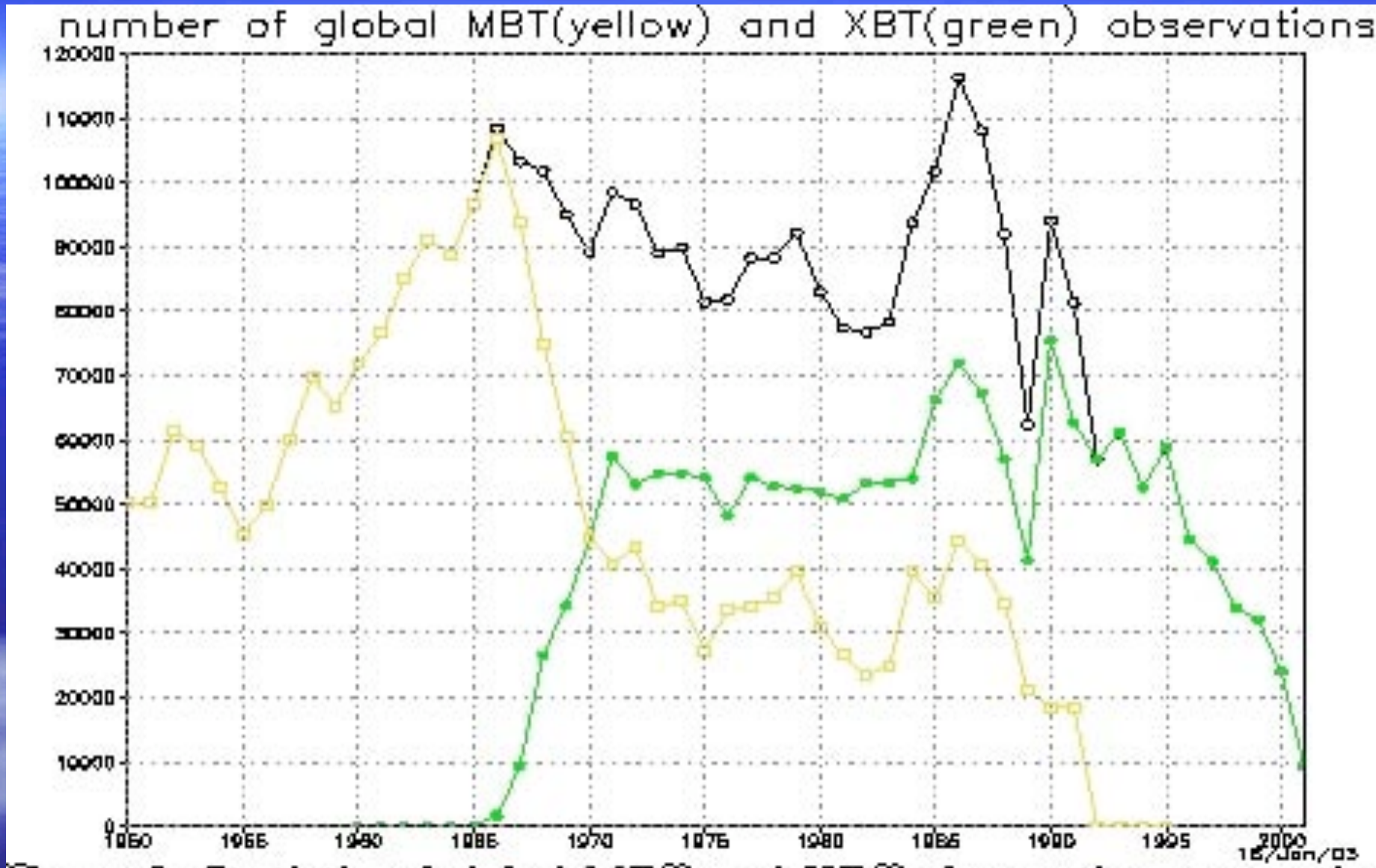
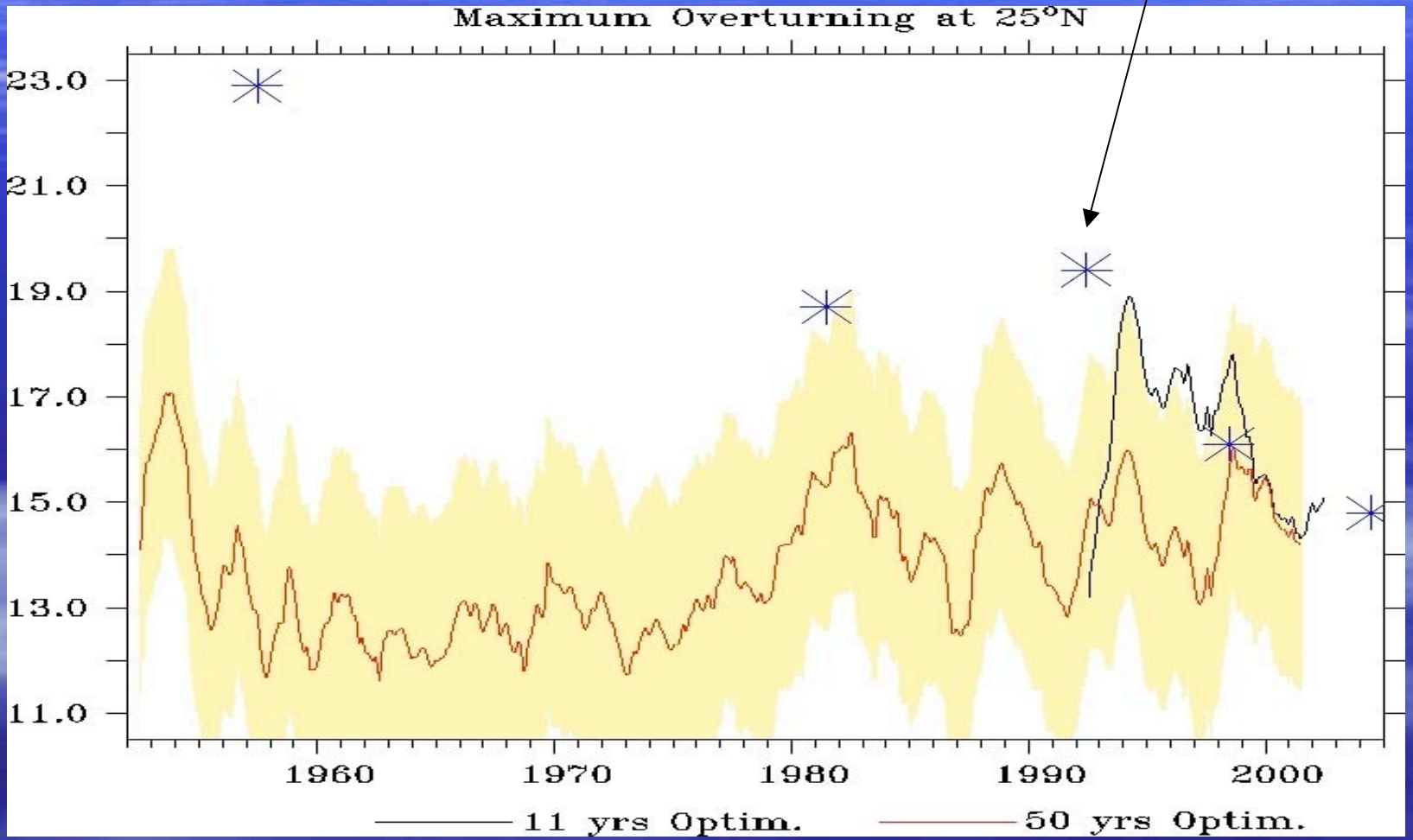


Figure 3: Statistic of global MBT and XBT observation versus time

Strength of the MOC: shown ins the change in MOC strengths at 25 degree N from 50 yr optimization, from 11 yr optimization and from Bryden et al., 2005



Decadal Variability and the MOC

- Analyses of data and of ocean reanalyses with respect to decadal variability of heat content, ocean transports, surface fluxes are ongoing.
- Ocean reanalyses are in particular one of the few tools to investigate MOC changes. Those studies have started and more are in preparation.
- The GSOP reanalysis evaluation effort will test, among other quantities, the quality of MOC estimates from various reanalysis efforts with the goal to identify best possible estimates and approaches for decadal and antropogenic climate change studies.

GSOP Road Map for Decadal Variability:

- Sustain, jointly with GOOS, GCOS, GEOSS, global ocean observing system, syntheses and product generation
  - Apply it to coupled data assimilation and synthesis systems and perform SI and decadal predictions
- Decadal predictability:
  - - Assess the potential for developing decadal prediction systems
  - - Development coupled data assimilation and synthesis systems
- Evaluate 20th century runs of syntheses and coupled models against observations (indices, metrics): Mechanisms of decadal variability and global connections (NAO/NAM,PDO,SAM,TAV,AMO):
  - Projections of hypotheses on observations and vice versa
  - Establish changes in patterns of decadal variability in AR4 models
  - Increased understanding heat content variability and sea level variability
- Assess quality of global carbon cycle in coupled models
- Meaningful downscaling of global scale climate change predictions to regional climate changes and impacts
- Initialize decadal variability and THC changes in AR5 models

GSOP Status

- GSOP has finalised guidelines for a joint CLIVAR/GODAE Global Synthesis/Reanalysis Evaluation effort, with the intention to evaluate the existing reanalysis product against observations to identify reanalysis efforts suitable to meet CLIVAR needs.
- GSOP has requested and received from CLIVAR Basin Panels a list of climate indices that should be computed routinely by reanalysis efforts in support of the CLIVAR community.
- GSOP has identified the need for CLIVAR reference datasets to be used for evaluation of the reanalysis and WGOMD products but also as input for reanalysis.

IOCCP/CLIVAR International Repeat Hydrography Workshop

- IOCCP/CLIVAR International Repeat Hydrography Workshop, held in Japan in November 2005 to discuss the global priorities for ship based hydrography to fulfil the specific science aims of CLIVAR and the ocean carbon and tracer community, and in light of the existence and needs of the Argo program.
- **Longer-term goal: to develop a sustained interntional hydrography program and its data management and synthesis elements.**

IOCCP/CLIVAR International Repeat Hydrography Workshop

- The three main outcomes of the workshop were:
- the creation of an a small oversight group to develop a cohesive and comprehensive international repeat hydrography program, in line with a GSOP recommendation to have an ad hoc group on hydrography.
- To develop synthesis activities around scientific issues and through science workshops using an integrated approach (physics, chemistry, observations and models) for each basin, facilitated through existing global and regional research programs.
- The data management component of the hydrography program will have to work closely with these groups to make sure the data is available in the data centres.

Increasing WCRP visibility:

CLIVAR GSOP promotes a wider use of reanalyses result for science and societal needs.

White paper in preparation:

- Understanding climate dynamics from reanalyses.
- Reanalysis, sea level rise and 5th IPCC assessment.
- Use of reanalyses for CO2 sequestering.
- Regional impact studies.
- Initializing coupled models from ocean reanalyses.
- OSE.
- Others.

GSOP/GODAE Synthesis Evaluation Workshop, Aug.31,Sept. 1, 2006 at ECMWF.

The overall goals of the inter-comparison of global synthesis efforts are to:

- **Evaluate the quality and skill** of available global synthesis products and determine their usefulness for CLIVAR.
- **Identify the common strength and weakness** of these systems and the differences among them, as well as to identify what application can be best served by what synthesis approach.
- **Define and test climate-relevant indices** that in the future should be provided routinely by ongoing or planned synthesis efforts in support CLIVAR and of the wider community.

GSOP Synthesis Evaluation

- The results of the evaluation effort will serve as prototype synthesis support and as the basis for recommendations with regard to future resource planning.
- The planned evaluation effort will focus on global results and their usefulness for climate research purposes (e.g., GSOP Science Questions).
- The evaluation effort will be based on results available from the period 1950 to present, including those that cover the TOPEX/Poseidon and JASON-1 era.

Synthesis Evaluation

- Individual synthesis efforts will be ask to compute indices from their results prior to the workshop and make them available to the project for further evaluation.
- Theses quantities can be of particular interest to CLIVAR's regional implementation panels as they coordinate observationally intensive process studies such as PUMP (http://www.usclivar.org/pump-index.html) in the equatorial Pacific and CLIMODE (http://www.climode.org/) in the Atlantic.
- To have an optimal interconnect between GSOP and the basin panels, input has been solicited already from the panels with regard to the metrics for global reanalyses and the identification of CLIVAR reference data sets (from the perspectives of various basin panels) which is summarized in the white paper.

Potential List of First Discussion Topics:

1. Annual means of meridional (overturning) transport stream function of the global ocean, Atlantic (north of 34S), and Indo-Pacific (north of 32S) as a function of latitude, depth as well as potential density, and year.
2. Annual means of meridional heat and salt transports of the global ocean, Atlantic (north of 34S), and Indo-Pacific (north of 32S) as a function of latitude and year.
3. Annual means of heat and salt content integrated over 0-750 m and 0-3000 m. Different diagnostics will be derived from these time sequence of maps:
4. Spatial averages for the global ocean, tropical ocean (20S-20N), Atlantic (north of 34S), Pacific (north of 40S), Indian (north of 32S), and Southern Ocean (south of 40S).
5. Linear trend of top 750-m and 3000-m heat and salt content as a function of longitude and latitude.
6. Annual means of sea level as a function of longitude, latitude, and year, from which the linear trend of sea level will also be calculated.
7. Annual means of Indonesian Throughflow volume transport as a function of year.
8. Annual means of ACC volume transport through the Drake passage as a function of year.
9. Annual means of Florida Strait volume transport and temperature flux, salinity flux as a function of year.
10. Annual means of 18-C water volume in the Atlantic Ocean (computed at least from monthly output as opposed to annual-mean field) as a function of year.
11. Annual means of warm water volume in the tropical Pacific (20S-20N, above 20C) as a function of year.
12. Curry and McCartney transport index for the Atlantic Ocean as a function of year
13. ENSO indices (NINO3 1,2,3,4,3.4) as a function of year.
14. Indian Ocean Zonal Dipole index.

Participating Groups

ECCO (Estimation of the Circulation and Climate of the Ocean) (US)

GECCO

SODA (Simple Ocean Data Assimilation) POP (US)

GFDL/NOAA (US)

NCEP/NOAA (US)

HYCOM (US)GMAO/GSFC (US)

ECMWF

INGV/ENACT

CERFACS-LODYC/ENACT

UK Met Office?

MERCATOR/MERSEA?

MOVE-G

K-7

BlueLink

WGOMD and/or IPCC????

Reference Data Sets

In the context of CLIVAR's synthesis, CLIVAR reference data sets and there error fields are required for (1) the analysis of climate processes; (2) for the evaluation of assimilation and WGOMD simulations and (3) as data constraints input to global synthesis.

Such data sets will be discussed in more detail in the GSOP white paper on CLIVAR's data needs (Legler et al., 2006).

CLIVAR reference data sets include in situ and satellite data sets, as well as surface flux reference data sets, among others.

Reference Data Sets

Examples include:

- SST Fields: Reynolds or Pathfinder SST, GHRSST-PP SST Reanalysis
- SSH Fields: TOPEX/Poseidon and JASON-1 sea level anomaly from AVISO or PO-DAAC
- Time-mean sea surface topography synthesized from drifter data and T/P data (Niiler) and GRACE data.
- De-tided tide-gauge data at selected stations with IB correction applied.
- Selected WOCE lines and corresponding times P01 (50º N), P03 (25º N), P04 (10º N), P06 (30º S), P14 (dateline). A05 (25º N), A16N (20º W). I03 (20º S), I08N (80º E). TOGA-TAO, BATS, HOT, and Station P time series.
- Levitus climatological of temperature and salinity.
- Velocity Fields: Surface drifter (Niiler), 900-m float (Davis) velocities; ADCP data.
- Surface Flux fields: as defined by white paper of Josey and Smith (2006).

Global Synthesis and Observations Panel (GSOP)
Activity in framework of COPES

- **GSOP co-chair (D. Stammer) represents CLIVAR in the First WCRP Observation and Assimilation Panel (WOAP) meeting, held in New York, 1-3 June 2005.**
- **The group there proposed that GSOP activities should be closely coordinated with CLIC activities.**
- **A number of task groups have been setup by WOAP, and CLIVAR is currently involved in several of them: Reanalyses and Data Assimilation, Data/Reprocessing.**
- **Coupled data assimilations is being discussed repeatedly and might be subject of the Reanalysis Workshop in Japan.**

WCRP Data Re-Processing Effort

- **Form a collaboration that can sustain a data refresh cycle and create high quality data sets for reanalysis.**
- **It should be based on existing data sets available from basin activities, such as the IO or the Pacific.**
- **Develop improved record tracking control for observations to further improve the use of feedback data from reanalyses targeted especially for data providers/developers:**

To promote full exploitation of the scientific value of climate data by current and future users, four functions, each with several constituent components, must be achieved. These functions include:

- the careful monitoring of observing system performance for long-term applications
- the generation of authoritative long-term records, for both reprocessing and reanalysis, from multiple observing platforms
- the assessment of the state of the atmospheric, oceanic, land, cryospheric and space environments
- the proper archival of and timely access to data and metadata.

WCRP Observations and Assimilation Panel (WOAP) to appoint a working group of experts charged with developing a plan for "The On-going Development of Improved Observational Data Sets for Reanalysis", that describes the necessary resources, infrastructure, institutional commitments, and coordination on technical issues outlined in this report.

- **Recommendation 1: All centers should prepare inventories of reanalysis observations (on the level of observation records)**
- **Recommendation 2: A collaboration be formed that can sustain a data refresh cycle and create high quality merged datasets for reanalysis**
- **Recommendation 3: Develop improved record tracking control for observations to further improve the use of feedback data from reanalyses targeted especially for data providers/developers**
- **Recommendation 4: The observational, reanalysis, and climate communities should take a coordinated approach to further optimizing reanalysis for climate**