CLIVAR/GODAE Global Synthesis Evaluation Framework

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Version 3.1

1. Background

The planning of CLIVAR's research builds on the existence of ongoing routine global ocean synthesis (often also referred to as "ocean reanalysis") products that synthesize all available ocean observations by merging them with global circulation models. CLIVAR needs those efforts in particular to:

- Develop an improved data base and reference data sets for climate research;
- Describe the state of the time-varying ocean over the past several decades;
- Quantify the interaction of the ocean with the atmosphere;
- Study climate dynamics associated with the global ocean over the last several decades;
- Deliver improved boundary conditions for regional/basin scale modeling and assimilation efforts that are being planned or performed as part of CLIVAR's regional process studies in individual basins;
- Facilitate the initialization of coupled models for studies and prediction of seasonal-to-decadal variability.

Intrinsically those efforts can be summarized as having three different goals, namely climate-quality hintcasts, high-resolution nowcasts, and the best initialization of forecast models. For the time being, not a single synthesis approach can serve all those purposes at the same time and therefore different efforts need to coexist to serve all CLIVAR needs.

Several global ocean data assimilation products are available today that in principle can be used for climate applications. However, underlying assimilation schemes range from simple and computationally efficient (e.g., optimal interpolation) to sophisticated and computationally intensive (e.g., adjoint and Kalman filter-smoother). Some of the existing assimilation products span the period of the past several decades (e.g., the SODA product and the on-going multi-decadal ECCO synthesis product); others cover only the period from 1992 to present.

In the following, a global evaluation framework will be introduced that is intended to determine in a quantitative way the skill, usefulness and limitations of existing synthesis approaches for CLIVAR's climate research. To be focused and of high scientific relevance, such an evaluation should be oriented along GSOP science questions summarized below. It will help identify approaches that serve different CLIVAR needs the best, e.g., the analysis of ocean/climate dynamics versus initialization of coupled models. At the same time, the results of the evaluation effort will serve as the basis for recommendations with regard to future resource planning. First-guess forward runs (simulations) for the assimilation should be part of the comparison study, as should be simulation runs available from model improvement studies performed under WGOMD and possibly from coupled modeling efforts. Strong links are being sought to the CLIC community and the repeat hydrography/carbon effort.

Already regional inter-comparison efforts of assimilation products are being undertaken currently under the GODAE umbrella (e.g., the MERSEA project that focuses on the North Atlantic and the Mediterranean Sea). However, their focus is primarily on operational ocean now-casting and forecasting. In contrast, the planned evaluation effort under CLIVAR will focus on global results and their usefulness for climate research purposes. 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.

In the following, we will describe the evaluation framework along with the reference data sets that are to be used as the basis for a model-data comparison.

2. Proposed Global Synthesis Evaluation Framework

In order to determine the quality of existing global analysis/synthesis products and to assess their usefulness for climate research, a concerted evaluation framework through systematic model-data comparison is required. Such an evaluation needs to be done in a close collaboration with CLIVAR's basin panels in order to serve ongoing and planned regional process experiments and at the same time to make maximum use of the enhanced observations provided by them.

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 climate-indices and diagnostic quantities that should be produced on a regular basis by each synthesis effort to support regional and global CLIVAR analyses and process studies.
- Define and test climate-relevant indices that in the future should be provided routinely by ongoing or planned synthesis efforts in support of the wider community.

According to its nature, the synthesis evaluation effort will have its primary focus on basin-scale and global quantities such as global upper-ocean heat content, global meridional overturning transport stream function and meridional heat transport. At the same time, the global evaluation effort will also address important regional climate-relevant processes relevant for CLIVAR’s basin studies. To perform the evaluation work, individual synthesis efforts will be ask to compute integral quantities (e.g., transports) and climate-relevant indices from their results and make them available to the project for further evaluation.

To be of high scientific relevance for CLIVAR, an intercomparison study should be oriented along scientific questions. CLIVAR's Global Synthesis and Observations Panel (GSOP) has identified several scientific questions of global extend and strong societal relevance. Among those are (see GSOP White Paper on **Global Ocean Observations and Synthesis** for more details):

1) THE OCEANS IN THE PLANETARY HEAT BALANCE, including (1) Heat storage, (2) .heat transports and (3) ocean/atmosphere feedbacks.

2) THE GLOBAL HYDROLOGICAL CYCLE, including (1) Water balance, (2) rainfall variability and (3) salinity and convection.

3) SEA LEVEL: (1) Sea level rise and (2) sea level variability.

4) Other GLOBAL-SCALE CLIMATE PHENOMENA such as ENSO, monsoons or atmospheric annular modes.

Theses or similar quantities and questions will be of particular interest also 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 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 appendices.

In the context of CLIVAR's synthesis, CLIVAR reference data sets 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 are described below and will be discussed in more detail by 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.

In the following, we will describe the proposed list of quantities that will be requested from individual synthesis efforts. They are grouped into (a) surface forcing fields; (b) scalar surface and subsurface products; (c) surface and subsurface currents and transports; and (d) other climate indices. We envision that these fields obtained from existing synthesis efforts will be evaluated against each other and against CLIVAR reference data sets. The diagnostics will be made available to the public through the CLIVAR/GSOP web pages and through CLIVAR/GODAE data servers.

2.1. Inter-comparison Quantities:

A. Surface forcing fields

Each synthesis effort will inevitably be run with different surface forcing fields, including wind stress, net heat and net freshwater fluxes (including contributions from the relaxation term and ice model, if available). For a comprehensive synthesis evaluation, those surface forcing fields need to be compared with each other and with CLIVAR flux reference data sets. Moreover, because filter schemes usually are associated with innovations in temperature and salinity which in effect are equivalent to subsurface heat and freshwater sources, those innovations need to be taken into account as well.

The forcing fields that will be requested from individual synthesis products include:

- Time mean map of the net surface heat, freshwater fluxes and wind stress.
- RMS variability of the same quantities and their seasonal cycle.
- Interannual and longer-term variability in form of annual-mean anomaly fields.
- Globally-averaged net heat and freshwater forcing over model domain.
- Comparison of forcing fields with CLIVAR reference data set as described by Josey et al. (2006).

B. Surface and Subsurface Scalar Fields.

- Daily averages of SSH and bottom pressure fields.
- Time-mean and RMS fields of SSH, SST and SSS.
- Annual anomalies of heat content, salinity and SSH over the period 1950 through present.
- Time-mean and RMS fields of subsurface temperature and salinity over water column.
- Seasonal cycle in SSH, SST and SSS.
- Time-mean mixed layer depths, its seasonal cycle and inter-annual changes.
- Annual maps of top 300-m, top 2000m and top-to-bottom heat and salt content as a function of year, longitude, and latitude.
- Top 300-m, top 2000m and top-to-bottom heat and salt content integrated over global oceans and individual basins (Pacific, Atlantic, Indian, and Southern).
- Monthly mean temperature and salinity fields along standard hydrography and XBT lines.
- Time mean and RMS model-data SSH and SST difference.
- Time mean and RMS model-data difference relative to Levitus and to hydrography and XBT lines.
- Trends in annual-mean SSH and in T, S at 200m, 1000m and 2000m depths over period 1950 to present and 1992 to present.

C. Surface and Subsurface Currents and Transports

- Time-mean and monthly mean fields of u, v, and <u,v> at the surface (15m), 100m, 1000m, 2000m (TBD)
- RMS of u, v, <u,v>.
- Global barotropic (depth-integrated) stream function.
- Monthly-mean meridional overturning transport stream function for the global ocean, Atlantic, Indo-Pacific Oceans, as well as for Pacific and Indian Ocean separately north of the Indonesian throughflow (south of the throughflow, the stream function is ill-defined for the Pacific and Indian Ocean separately); as a function of latitude-depth and latitude-

density.

- Transports of heat, freshwater and volume meridionally for the global ocean, and separately for the Atlantic, and Indo-Pacific.
- Transports of volume, heat and freshwater for Florida Current, ITF, ACC at Drake Passage, Madagascar Current, ... (TBD)
- Comparison of 15m currents with drifter results (geostrophic, ageostrophic, time mean, seasonal cycle).
- Comparison of time-mean and seasonal cycle with float velocities: at 1000m and 2000m depth.

D. Other Climate Indices

- 60ºS-60ºN averaged equivalent SSH increase (i.e., bottom pressure change).
- Temperature, salinity, sea level and u and v profiles at TAO sites (165º E, 140º W, 110º W), 0º N, at Station S (Bermuda, 32º10'N, 64º30'W), at HOTS and at Station P (50º N, 145º W).
- SSH time series at selected tide-gauge stations and bottom pressure timeseries at selected bottom pressure gauge locations.
- Top 300-m heat content integrated over the equatorial Pacific (120º E-80º W, 5º S-5º N).
- NINO3, NINO4, and NINO3.4 SST index.
- MOC index for Atlantic Ocean.
- Hurricane (heat capacity) index in the tropical Atlantic.

An intercomparison between products can highlight the common strength and weakness of existing synthesis products. However, to better understand the differences and to facilitate climate research, it is ideal to make available the tendencies (budgets) of quantities derived from prognostic variables (e.g., heat content variation derived from the temperature field). It is envisioned that, in the future, all synthesis efforts should work towards providing the budget of key prognostic variables such as temperature and salinity.

2.2. CLIVAR Reference Datasets

The CLIVAR/GODAE synthesis evaluation study proposed here depends on the availability of various reference CLIVAR data sets and prior information on their accuracy. CLIVAR reference data sets should be high-quality data sets that CLIVAR accepts as its standard reference observing data sets over maximum possible time span and that will be publicly available through known data servers. Those data sets that will be part of the heritage of CLIVAR, are especially required for the evaluation of existing synthesis or model simulations. Equally important, they should also serve as the standard high-quality data sets used in synthesis efforts. On the other hand, many derived transport quantities or other climate indices have no direct observational equivalent. In those cases, published estimates based on observational analysis will be used as a reference (e.g., top-300 m heat content for global oceans and individual basins by Levitus et al. 2000, Science). Each data set should be accompanied by an error field that specifies its accuracy as function of geographic position. Ideally this error information should be available as function of space and time scale (error covariance function). At the current time this mihgt be too demanding, though.

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).

3. Participating Groups and Relation to Other Activities

Participating synthesis groups could include several of the following ongoing activities:

- ECCO (Estimation of the Circulation and Climate of the Ocean) (US)
- GECCO (German Estimation of the Circulation and Climate of the Ocean)
- 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
- MOVE-G
- K-7
- BlueLink

The proposed time line for this effort is to solicit input from the above groups in the next six months. A first workshop is being planned for the August/September 2006 time frame where first, selected results will be presented and discussed. At the same time, GSOP will interface with WGOMD and GODAE to determine how ongoing ocean assimilation and ocean model inter-comparison activities could be better coordinated. Participating groups will be asked to produce the products suggested above. GSOP, in coordination with GODAE, the synthesis groups, and the CLIVAR regional panels, will lead the overall planning and coordination of the synthesis evaluation, including identifying CLIVAR reference data sets and developing an agreed-upon set of diagnostic fields and metrics. The CLIVAR GSOP will lead efforts to synthesize the results and make recommendations based on the outcome.

The proposed global model-data comparison will capitalize on the experiences of regional GODAE model inter-comparison efforts such as MERSEA. It will also benefit from the experience of the ENACT effort of assimilation system assessment that had a somewhat similar objectives and approach. Significant leadership is required to combine all information into a coherent analysis from which an unambiguous conclusion can be drawn with respect to CLIVAR support and required resources. GSOP will take a lead in this effort. However, a proper CLIVAR community involvement is required to reach the goals of the effort.

Appendix A: Input from the Atlantic Implementation Panel:

<u>Model-Data Comparisons for Climate Variability</u>

Wright, Johns and Stammer

This communication is to provide input to the WGOMD regarding indices and metrics that could be used to evaluate the performance of ocean models in reproducing observed climate variability. We note that GSOP will be assembling an extensive set of measures suitable for testing the ability of models to reproduce climatological conditions as well as variability about the climatology. We limit the scope of the present note consistent with the following points.

1) We are concerned with measures of the low-frequency, large-scale variability since these are most relevant to climate.
2) We are interested in measures that can be directly compared with observational estimates that can be derived from available historical data sets.
3) We are interested in quantities that are not terribly sensitive to the details of how they are calculated. (Otherwise the model-data comparison will likely be useless because the data won't resolve the details often enough or because the algorithm will be too cumbersome to use.)

Based on the above, at least initially, our proposed comparisons involve integral measures of variability. Thus, we seek a set of ***<u>indices</u>*** that represent large-scale, low-frequency variability in the ocean. The set of ***<u>metrics</u>*** with which we propose to judge the success of models are simply defined in terms of these indices as:

1. $\frac{\overline{I_n^o - I_n^o - \quad I_n^m - I_n^m \;^2}}{\overline{I_n^o - I_n^o \;^2}}$, a "noise-to-signal" ratio,

2. $\frac{\overline{I_n^o - I_n^o \quad I_n^m - I_n^m}}{\left[\overline{I_n^o - I_n^o \;^2}\;\; \overline{I_n^o - I_n^o \;^2}\right]^{1/2}}$, the correlation between modelled and observed variability,

3. $\frac{\overline{I_n^m - I_n^m \;^2}}{\overline{I_n^o - I_n^o \;^2}}$, the ratio of variances,

for n=1…# of indices. Note that the correlation and ratio of variance together will show if the model variability is strongly correlated with observations but with an incorrect gain; the first measure above won't distinguish this case. If the annual cycle is strong for any particular series, it will be necessary to filter this component to obtain a meaningful comparison of lower frequency variability. Care will be required to avoid aliasing problems.

We offer the following as possible indices (with associated metrics).

a. Florida Strait transports of heat, salt and mass (the interannual signal back to 1982 is on the AOML website)

b. Baroclinic transport through Drake Passage, referenced to the bottom. We have a 30-year time series now and SO winds appear to be increasing. (Contact Harry Bryden for additional information.)
c. Variation in mode waters (LS water, 18 degree water, Greenland Sea deep water, etc; need robust and efficient algorithms). Probably best to focus on major water masses observed at Ocean Weather Stations. The upstream "head" for deep Greenland Sea waters overflowing the Iceland-Faroe-Scotland sills is a particularly important example in this class.
d. Curry and McCartney baroclinic transport index (store the integrated potential energy anomalies for each sight and for heat and salt contributions separately)
e. Sea ice extent (area north of the ice margin). For the satellite era (1978 onward), the best source is the National Snow and Ice Data Center in Boulder, http://nsidc.org/noaa/. Contacts there are Julienne Stroeve, Florence Fetterer, and Mark Serreze. They can put you in touch with the appropriate databases, which originated with NASA. For the longer historical period, e.g., back to 1900, a good contact is Nick Rayner at the Hadley Centre in the U.K. (she is the keeper of the sea ice portion of HadISST, a gridded dataset designed for modelers -- and for the type of application you have in mind.
f. Changes in annual or decadal mean heat and freshwater contents as a function of latitude (above and below 1000m). This may only be possible to estimate between the 60's and the 90's. (Currie, Dickson and Yashayaev, 2003)
g. Integral of tracer concentration as a function of latitude and time (compare basin wide CFC-11,12 inventories and their distributions.) Data available from WOCE DACs and further information can be found in Rhein et al. 97 JPO, Kieke et al. 05, JPO (in press).

Other possibilities of shorter duration include:

h. MOVE transports of heat, salt and mass
i. RAPID transports of heat, salt and mass
j. ASOF transports of heat, salt and mass
k. A measure of Gulf Stream position [perhaps the area north of Cape Hatteras and west of the tail of the Bank that lies between the 1000m isobath and the position of maximum annual mean density gradient at 300m]
l. Altimetric measurements of sea surface height from TOPOEX/POSEIDON and Jason1 1992 - present; metric could be spatial averages over predefined regions, or time series of EOF amplitudes. (Global gridded fields of altimetric sea surface height at 10-day intervals are freely available from e.g. French Aviso system [http://www.jason.oceanobs.com/html/donnees/welcome_uk.html].)

Appendix B: Input from the Pacific Implementation Panel:

Recommendations for the CLIVAR/GODAE Global Ocean synthesis Evaluation Framework

CLIVAR Pacific Implementation Panel
A. Timmerrmann
November, 2005

The following is a list of preferred diagnostics to be provided from assimilation products:

- ENSO indices (Nino1,2,3,4,3.4)
- PDO index (defined a la Mantua)
- Warm water volume indices (similar to http://www.pmel.noaa.gov/tao/elnino/wwv/)
- Atmosphere-ocean fluxes obtained from assimilation products
- Mean state/climatology and interannual variability of thermocline depth (20C isotherm, or sharpest gradient) for different latitudinal bands as time-longitude diagrams
- Mean state/climatology and interannual variability of sea level for different latitudinal bands as time-longitude diagrams
- Mean state/climatology and interannual variability of mixed layer depth (different definitions) for different latitudinal bands as time-longitude diagrams
- Transport estimates for: Indonesian Throughflow, Kuroshio
- Timeseries for mean zonally integrated meridional transports in the pycnocline relative to 900 dbar and along 9S-9N (a la McPhaden and Zhang Nature, 2002, 415, 603-608).
- Time-longitude diagram of meridional heat transport in Pacific
- Time-longitude diagram of heat transport separated into gyre and Ekman components (Hazeleger, 2004 Journal of Physical Oceanography, 34, 320-333.)
- Meridional Streamfunction Mean state/climatology and interannual variability (grid information required).
- Equatorial depth-longitude sections of mean state/climatology and interannual variability of T, S, U, and W
- Sections of temperature and salinity along XBT lines, line P and WOCE repeated sections, and other sections contained in the CLIVAR Hydrography database
- Sections of simulated temperature and salinity along the "A-line" (http://www.hnf.affrc.go.jp/a-line/intro/index_e.html)
- Barotropic Streamfunction for Tropical, subtropical and subpolar gyres (mean, climatology and variability)
- Interbasin exchange (transport of mass, heat and salinity) between Indian and Pacific and Atlantic and Pacific ocean)
- Surface currents
- Dynamic topography (mean, climatology and variability)
- time series of top-700m" and "top-3000m" heat content averaged over tropical, subtropical Pacific and whole Pacific, to be compared with the equivalent indices from Levitus data.

List of CLIVAR Reference Data Sets:

A list of preferred validation data sets include for the Pacific Ocean:

- ENSO indices (Nino1,2,3,4,3.4) from Climate Diagnostic center
- PDO index from Mantua
- Warm water volume indices (similar to http://www.pmel.noaa.gov/tao/elnino/wwv/)
- Atmosphere-ocean fluxes obtained from Re-analysis, COADS, SOC
- Mean state/climatology and interannual variability of thermocline depth (20C isotherm, or sharpest gradient) for different latitudinal bands as time-longitude diagrams taken from TOGA/TAO
- Mean state/climatology and interannual variability of sea level for
- different latitudinal bands as time-longitude diagrams taken altimeter data and the sea level data compiled by the University of Hawaii
- Timeseries of mean zonally integrated meridional transports in the pycnocline relative to 900 dbar and along 9S-9N (McPhaden and Zhang Nature, 2002, 415, 603-608).
- Sections of temperature and salinity along XBT lines, line P and WOCE repeated sections, and other sections contained in the CLIVAR Hydrography database
- Sections of temperature and salinity along the "A-line" (http://www.hnf.affrc.go.jp/a-line/intro/index_e.html)
- TAO currents
- OSCAR surface currents (http://www.oscar.noaa.gov/)
- Dynamic topography (from GRACE http://www.csr.utexas.edu/grace/publications/brochure/page7.html)
- time-series of top-700m" and "top-3000m" heat content averaged over tropical, subtropical Pacific and whole Pacific from Levitus data

Appendix C: Input from the Southern Ocean Implementation Panel

Recommendations for the
CLIVAR/GODAE Global Ocean synthesis Evaluation Framework

International Southern Ocean CLIVAR/CliC/SCAR Panel
K. Speer, I. Renfrew, co-chairs
November, 2005

Summary of Panel Recommendations

The Panel is asked to support the synthesis of ocean observations in a global ocean synthesis project, aid the development of appropriate metrics and diagnostics, assist in the scientific evaluation of the results, and to provide reference datasets. The panel strongly supports the effort to produce a synthesis of the global ocean circulation, and to evaluate the resulting fields with various observations and data-based analyses.

Some concerns of the panel are that while the comparison to key indices and global fields such as SST are fundamental, the evaluation procedure should incorporate fluxes from alternative data-based analyses, such as box inverse models, regional inversions, and other analyses that produce flux estimates. Presumably any global analysis will be at reduced resolution and transport by small-scale currents may be missing. Also, diapycnal mixing is likely to exert a strong control on solutions and some procedure for evaluating this component is needed, for instance coming from direct measurements and box models.

Several other items have been raised, especially related to surface fluxes and dense overflows.

1) The surface flux component will be determined from calculations that include ice models in some form. The ice cycle and associated fluxes are important for setting the stratification and driving convection and circulation in the Southern Ocean. How do these models fit into the evaluation procedure?
2) The surface fluxes determined by the inversion are likely to depend on model physics and numerical implementation (mixing parameterizations, advection scheme, etc.). In the course of a workshop (June 2005) the goal of an Antarctic Meteorological synthesis was put forward as a way to improve the representation of high-latitude mesoscale weather systems and also to improve surface fluxes. This is a possible source of forcing for a regional reference dataset. How would other such efforts fit in (e.g. the Arctic synthesis)?
3) Some ocean boundary lies against glacial ice that melts and freezes. Is circulation on the Antarctic slope and shelf part of the global analysis?
4) To what extent are dense overflows, which constitute large local transports, expected to be resolved? This reflects on the utility of outflow transport measurements as evaluation tools.

Southern Ocean indices, metrics and diagnostics

The Panel suggests that the following quantities be used as data-based metrics for the evaluation procedure.

1) Drake Passage transport index, bottom pressure, etc.
2) Drake Passage, Hobart-AA, Greenwich meridian XBT repeat temperature time series
3) Antarctic Dipole ocean-sea-ice index
4) Greenwich meridian current meter based transport of Weddell Gyre
5) Comparison with ARGO direct current estimates (versus assimilated dynamic height)
6) Sea-ice advection, area (and possibly thickness?) from drifters and remote sensing
7) Snow thickness (from remote sensing) on sea-ice for freshwater fluxes

Southern Ocean CLIVAR Reference Datasets:

1) Modified Reynolds SST (additional data and new correction for proximity of sea-ice)
2) Process studies for velocity (GOODHOPE, ANSLOPE, DIMES)
3) Under sea-ice velocity and hydrography – Weddell Sea?
4) Orkney Passage and Ross Sea bottom water outflow and property time series.
5) FOAM 1/4 deg. Southern Ocean analysis
6) Hydrography. IPY (07-08) CASO and SASSI hydrographic sections, MARGINEX (06), SAMFLOC (05-06), and GOODHOPE/Greenwich Meridian repeat sections. Summary at http://www.clivar.org/organization/southern/.

Appendix D: Input from the Indian Ocean Panel:

Input for the CLIVAR/GODAE global ocean synthesis intercomparison framework by the Indian Ocean Panel

IOP discussed the inter-comparison framework at the recent meeting in Honolulu. Before summarizing the recommended metrics and reference data sets, the Panel discussed the objective of the framework and associated activity. The Panel noted that rapid access to the full, dynamical fields (e.g. T, S, u, v, p etc) in a data format is needed for a scientific analysis and validation of the re-analysis products. The metrics on the other hand might be visually displayed and/or available in a data-format and would be used for “quick-look” checks on the validity of the products. The Panel felt that a metric has to be unambiguously defined so that it can be calculated with any further decision. For example, volume transport of Indonesian throughflow above a certain level is a well defined metric; volume transport of the South Equatorial Current is not because a decision is required to define the boundaries of the current. This said, the Panel selected metrics that were ranked as high or low priority.

High Priority Metrics:

1. Indonesian throughflow volume, heat and salt transport in the upper 400 m and over the entire depth integrated over all straits and passages.
2. Mozambique Channel volume, heat and salt transport in the upper 400 m and over the full depth at 17S.
3. Volume, heat and salt transport across the equator and at 17S between Madagascar and Australia, in the upper 400 m and over the full depth.
4. Heat storage in the North Indian Ocean (north of the equator) and South Indian Ocean (0-17S) for the depth ranges of 0-50 m, 50-400 m, and 400 m to bottom.
5. Mean and variability of temperature along the IX1 and IX12 XBT lines.
6. Zonal volume transports at 80E, 2S-2N, 0-80 m (Wyrtki Jet) and 80-300 m (Undercurrent).
7. SST, MLD and Depth of 20C isotherm in the thermocline dome region (5-12S, 60-80E) and in both poles of the Indian Ocean Dipole as defined by Saji et al. (1999).

Second Priority Metrics

8. Monsoon Current transport south of Sri Lanka in the top 400 m at 80E, 4-6N.
9. South equatorial current transport west of 46E in the upper 400 m.
10. Mooring locations MLD T(z), S(z), u(z), v(z) daily: (8S, 67E), (zonal line at 12S), (12N, 87E), (0, 90E), (0, 80E)

Monthly time series are recommended except for 10.

Reference data sets:

1. IX 1 and 12 frequently repeated XBT lines.
2. Current meter measurements at 80E, 0N for the period of 1993-1994.

3. Current meter measurements at 17S in the Mozambique Channel at 17S.
4. Near equatorial TAO/triton and ADCP moorings at 80E and 90E.