OUTLINE OF IMPLEMENTATION PLAN
SECOND DRAFT 12 MAR 2004 BASED ON IOP-1 CONTRIBUTIONS

TITLE (SUGGESTIONS WELCOME)
Executive Summary (to be written after body of report)
PREAMBLE
The goal of this Implementation Plan is to provide mutually agreed guidelines for implementing a sustained Indian Ocean observing system to support climate research, operational climate prediction and routine estimation of real time oceanic circulation. The Plan draws on the activity and resources of various operational and research agencies located in the Indian Ocean rim-nations, and external partner-nations with Indian Ocean interests. The Plan will follow the high level, global implementation guidelines of GCOS and GOOS, focussing on the specific issues relevant to the Indian Ocean. The plan will be reported to OOPC and JCOMM for assessment and management.

I. Introduction and Background
A. Scientific background—relevance to CLIVAR
1. Unique geography and physics (see IOGOOS paper by Shetye)
2. Research issues
- Seasonal monsoon variability
- Intraseasonal oscillations
- Indian Ocean dipole mode
- Decadal warming trends
- Indonesian throughflow
- Global ocean linkages
- Shallow overturning cells
- Deep meridional overturning
- Carbon and Biogeochemistry

B. Operational background
1. Relevance to operational climate prediction
2. Relevance to GODAE (operational ocean-state estimation)
3. Intergovernmental agreements
a. Earth Observation Summit in July 2003
b. GCOS 2nd Adequacy Report to COP9/UNFCCC
c. GCOS Implementation Plan—the "essential climate variables"

C. Unique political and economic situation of Indian Ocean (see Strategy paper by Bill Erb.)
1. Most developing nations, but capability to contribute exists.
2. Need for capacity building
3. Interests of developed nations

II. Developing the system
A. The concept of an integrated system
1. Synergy of observing a variable with many measurement-types
2. Synergy of serving many goals (research and societal benefits)
3. Cost-effectiveness
4. Integration of in situ and satellite observations
5. Integration of physics and biogeochemistry

6. Integration of observing systems, modeling and data mgm't
7. The existing elements of the observing system and gaps

B. Mooring Array

1. Why we need a moored array to address scientific and operational issues identified in I A&B
   - High resolution time series needed to resolve broad spectrum of variability (diurnal to interannual) particularly in deep tropics
   - Allows for basin-scale coherent array of Eulerian measurements for quantification of climate relevant ocean wave signals
   - Provides data to derive estimates of mass, heat, and fresh water transport either directly via current meters or indirectly via geostrophy
   - Provides meteorological measurements for computation of air-sea fluxes of heat, moisture and momentum
   - Provides platforms for multivariate interdisciplinary studies
   - Provides data for model and satellite validation, ocean and atmospheric model data assimilation, and development of blended data products.

   o
2. The present status of moored observations

   • These are regional studies for ITF, Weather forecasting, Port and coastal management, Air-sea interaction, Mozambique Channel, Equatorial currents, Deep circulation, Intraseasonal variability, IODZM, etc.

   • Brief description of each program conducted by nations working in the region:

   India, Japan, France, Netherlands, Indonesia, Australia, USA
   INSTANT
   OASIS
   CIRENE
   Mozambique Channel
   Indian Buoy program
   NIO equatorial moorings
   UK moorings at Mascarene plateau

   • These are possible contributions to a sustained array.
   • At present, all operate on different time lines
   • The needs of CLIVAR and GOOS are only partially met by this system

3. The proposed array

   Rationale summary:

   • Need a sustained basin scale array of basic measurements:
      -Tropical waveguide array
      -Air-sea flux sites (BoB, AS, Sub, Eq [3-W/C/E], Sumatra?)
      -Interdisciplinary (biogeochemical)-Kerguelen, Etc (TBD)

-ITF
-Western Boundary currents
-Other?

C. Existing elements (See SOCIO paper by Molinari et al.)

Table 1. SUMMARY OF EXISTING ELEMENTS AND RELEVANCE TO RESEARCH ISSUES

	Argo	SOOP/ XBT	Tide gauge	Drifters
Seasonal monsoon variability	yes	yes	yes	yes
Intraseasonal oscillations	no	no	yes	yes
Indian Ocean dipole mode	yes	yes	yes	yes
Decadal warming trends	yes	yes	yes	no
Indonesian throughflow	no	yes	yes	no
Global ocean linkages	yes	yes	yes	yes
Shallow overturning cells	yes	no	no	yes
Deep meridional overturning	no	no	no	no
Biogeochemistry	no	yes	no	no

1. Argo (see INCOIS document by Ravichandran)
   - Applications
     - Argo is directly relevant to most CLIVAR research issues dealing with longer than seasonal timescales.
     - Particularly useful for low salinity role in surface layer heat budget (e.g. BoB and Indonesia)
     - Useful for model altimeter validation needed for application to internal mode variability
     - Useful for ocean state estimation based mainly on altimeter data
     - Cyclone prediction
   - Issues
     - Assess status of implementation, including who is doing the work, resources needed to complete (need 450 floats, have 330)
     - Plans for future deployment: N of 5N no problem to use Indian RV's; S or 5N use ships servicing equatorial moorings or SOOP vessels
     - The sampling strategy in the tropical IO needs to be adapted to the fast and equatorially confined variability in the IO. (See AAMP Schiller et al. paper.)
     - Oxygen on Argo floats are potentially useful for ventilation of water masses and carbon uptake in the Southern IO

2. XBT Network (See IOGOOS paper by Gopalakrishna et al.)
   - Applications

- SOOP XBT lines are directly relevant to most CLIVAR research issues dealing with longer than seasonal time scales
- High density XBT (HDX) lines are particularly useful for measurement of boundary currents and net transports through enclosed regions
- Frequently repeated XBT (FRX) lines are useful for accurately measuring seasonal to interannual variability on long transects (See

- Issues
  - Integration with the Argo array.
  - Implementation of the Melbourne review of SOOP Plan (See OceanObs99 Smith et al. paper)
  - Need more XBT's
  - Enhancement of salinity, pCO2 and other BGC measurement

3. Sea Level Network (see IOP Wilson and Meyers paper)
   - Applications
     - Tide gauge data are relevant to CLIVAR research issues at all time scales
     - Particularly important for liking off shore variability to coastal environment (e.g. storm surge prediction; coastal erosion)
   - Issues
     - Need real time, hourly data (very little exists now for Indian Ocean)
     - This is not high tech or particularly expensive
     - Local capacity building required

4. Drifter network
   - Applications
     - SST, atmospheric pressure
     - Currents, Ekman drift
   - Issues
     - Completion of IBPIO plan (~5deg x ~5deg array)
     - <50% complete, need more drifters

III. Biogeochemistry and Repeat Hydrographic Sections (See IOP1 talk by Bronte Tilbrook)

IV. Data Management (See IOP1 talks/papers by Ravichandran and P. Hacker)
V. Modeling need for observations (See IOP1 McCreary's paper)
VI. Process Studies and relationships with sustained observations. (IOP1 paper by P. Hacker) "Every new observation in the Indian Ocean is a process study!" (INSTANT, JASMIN2?, OASIS/CIRENE others?)

WRITING ASSIGNMENTS
(Lead authors below will recruit other Panel members as required)

Outline section I.A.1 Unique geography and physics Satish Shetye

Outline section: I.A.2 Research issues (about a page with references and a figure or two for each item):
Seasonal Monsoon Variability: Peter Webster
Intraseasonal oscillations: Peter Hacker
Indian Ocean Dipole: Jay McCreary
Decadal warming trends: Gary Meyers
Indonesian Throughflow: Robert Molcard
Cross Equatorial overturning cells: Fritz Schott
Deep Meridional overturning: Fritz Schott
Carbon and Biogeochemistry: Bronte Tilbrook
Links to Global Circulation: To be decided later

Outline section I.B Operational issues Gary Meyers hopefully with a lot of assistance from Neville Smith

Outline section I.C Unique political and economic situation Bill Erb

Outline section II.A The concept of an integrated OS (to be decided later)

Outline section II.B Mooring Array Mike McPhaden

Outline section II.C Existing elements
1. Argo Ravichandran
2-4 XBT, SL, Drifters Gary Meyers

Outline section III. Biogeochemistry and Repeat hydrography Bronte Tilbrook

Outline section IV. Data management To be decided later

Outline section V. Modeling need for observations McCreary

Outline section VI. Process studies and need for sustained observations To be decided later.

Appendix 1: (RE: II.C) The GCOS Implementation Plan has defined a set of "essential climate variables" and an approach to assess of the present day observation of each variable. The *Implementation Status* of each network (e.g. Argo, XBT network, etc) indicates the degree to which the existing effort is adequate within the framework of the agreed composite integrated system and the agreed GCOS and UNFCCC goals, including accuracy, resolution, global coverage, metadata and quality, among other things.

- *Fully adequate* indicates the network requires no further enhancement/adjustment.
- *Adequate* indicates the network meets most (75%?) but not all of the desired characteristics.
- *Marginal* indicates the network meets some (50-65%) of the desired characteristics but requires significant enhancement/improvement.
- *Unsatisfactory* indicates the network meets only a few (20-30%) of the desired characteristics.
- *Missing* indicates the network makes no functional contribution to the sustained observing system at present.

As part of the Indian Ocean Implementation plan we will asses the in situ networks for a subset of the 13 essential climate variables

1. Sea surface temperature
   - Surface drifters, moored buoy arrays, VOSCLIM, VOS, Reference stations
   - Issues
2. Sea Level
   - GLOSS, subsurface temperature
3. Sea surface salinity
   - VOS T/S, moored buoy arrays, R/V's, repeat hydrography
4. Surface current
   - Moored current meters, drifters
5. Ocean color
6. Surface carbon dioxide partial pressure
7. Subsurface temperature
   - SOOP repeat XBT, Argo, Full depth hydrographic survey, moored arrays, reference stations
8. Subsurface salinity (as for 7)
9. Subsurface currents
   - Moored current meters, Argo floats
10. Nutrients
11. Carbon
12. Tracers
13. Phytoplankton

Appendix II: The SOCIO Workshop (Perth, 2000) and the IOGOOS Conference (Mauritius, 2002) produced a number of working papers that may be useful in writing the Implementation Plan. The papers can be accessed from the websites below or from Gary Meyers.

A) Titles of Discussion Papers from the SOCIO Workshop in Perth, Australia, November 2000.

http://www.marine.csiro.au/conf/socio/papers.html

1. Review of monsoons, inter-annual variability and decadal trends that underpin climate prediction.
Lead Authors: Stuart Godfrey, Yukio Masumoto

2. Review of intra-seasonal processes.
Lead Authors: Peter Hacker, Peter Webster, Roger Lukas

3. Indonesian throughflow: Past, Present and Future Monitoring
Lead Authors: Janet Sprintall, Arnold Gordon, Robert Molcaid

4. Applications of ocean- and climate-prediction requiring long lead-time (months).
Lead Authors: Mark Jury, Sulochana Gadgil, Gary Meyers

5. Instruments, technologies and commercial opportunities.
Lead Authors: Ian Barton, Kensuke Takeuchi, Chet Koblinsky

6. Overview of existing and planned observations
Lead Author: Bob Molinari

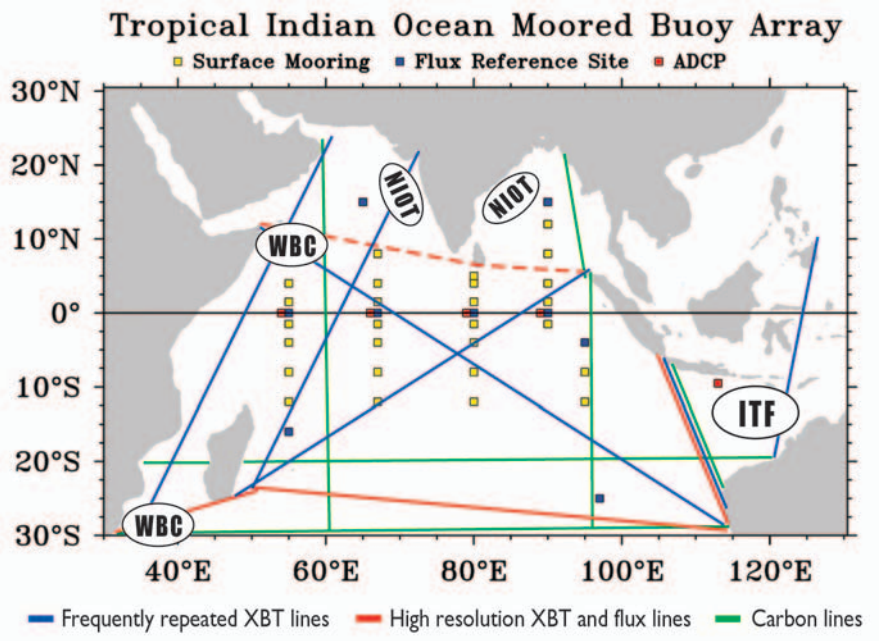
7. Draft Indian Ocean Observing Strategy
Lead Author: Bill Erb

B) Titles of Extended Abstracts from the Oceans and Climate Workshop held at the First Conference of Indian Ocean GOOS, Grande Baie, Mauritius, November 2002.

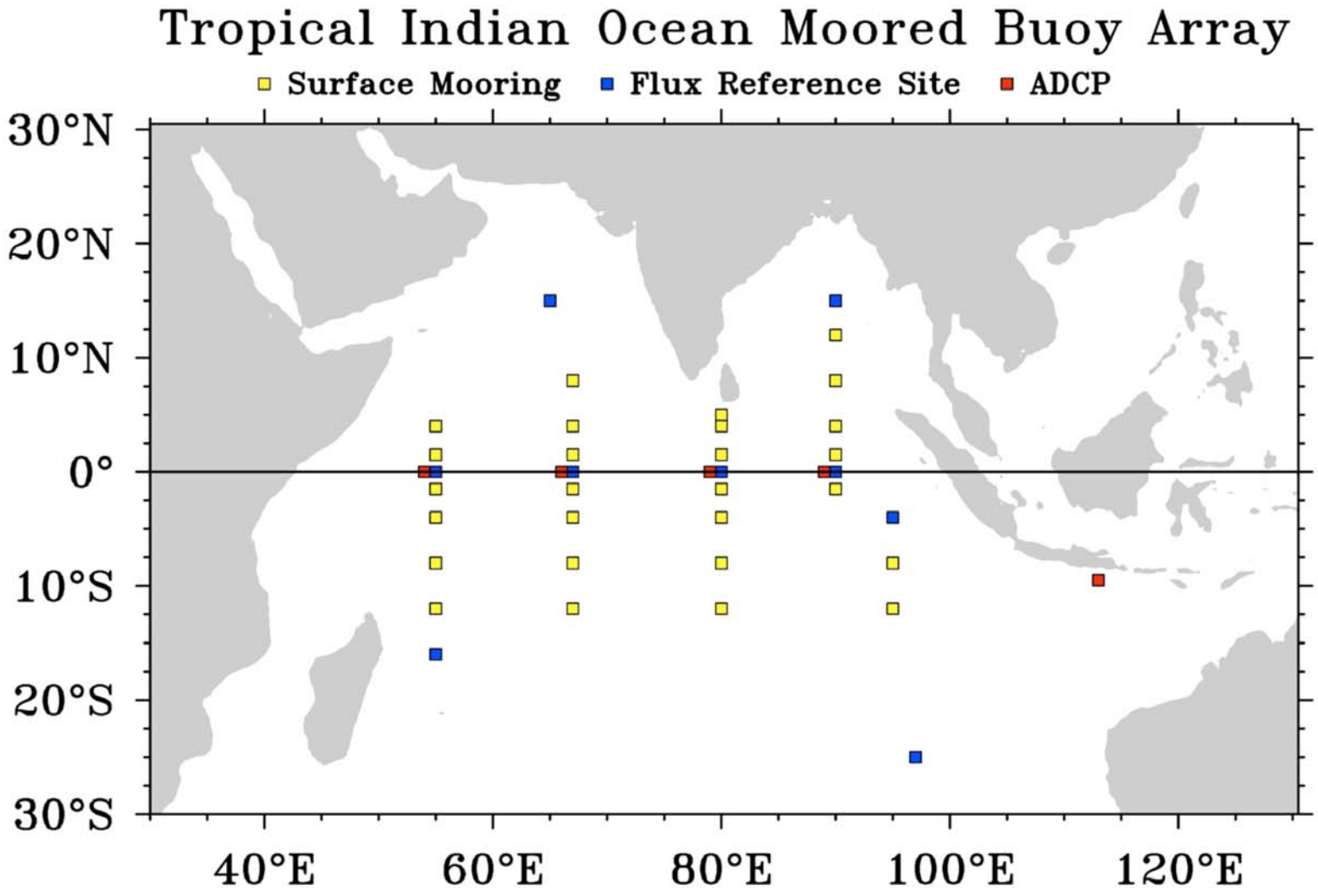
The papers and powerpoint talks are available at the IOGOOS website:
http://www.incois.gov.in/Incois/iogoos/home.jsp

1	Regional Interests in Ocean, Climate and Coastal Observing System	S.R. Shetye K. Radhakrishnan
2	Status of the Ocean and Climate Observing System	G. Meyers
3	The role of the Indian Ocean in Asian/Australian/African Monsoons and climate predictability : A review of what is known about Monsoon variability and its links to the Indian Ocean.	P Webster
4	The inintegrated design plan for coastal GOOS	T. Malone
5	Hyperspectral imaging for environmental monitoring	W. McKeown

6	Exploring The Impacts Of Ocean - Climate Variability On Marine Resources Along The East African Coast : A Prototype Multi-Disciplinary Project	M. Jury, J. Maina T. McClanaha L. Rydberg
7	Impacts of ocean climate variability on large marine ecosystems - a perspective from the tuna fisheries in the Indian Ocean	F. Marsac, J. Gunn P. Lehody, W. B. White Y. M. Tourre
8	Operational Ocean Analysis	N. Smith, J. Turton Mahadevan
9	Tropical Indian Ocean mooring array: Present status and future plans	Y. Masumoto, G. Meyers V.S.N. Murty, J.Vialard M. J. McPhaden, M. Jury P. Hacker, R. Molcard
10	Scientific basis and plans for Argo float array	S. Wijffels C. Reason K Radhakrishnan
11	Scientific basis and Plans for XBT network in the Indian Ocean	V.V.Gopalakrishna G .Meyers
12	An array of current meter moorings in the Mozambique Channel: results from a pilot study and plans for future observations	H. Ridderinkhof W.P.M. de Ruijter
13	Presentation of Météo-France marine activities in the Indian Ocean	L. Perron
14	GCOS Action Plan for Eastern and Southern Africa	Appadu
15	Importance of the salinity changes in driving the SST and the rainfalls in the Indian Ocean	C. Perigaud J.P.McCreary (IPRC) D.J.Neelin (UCLA)
16	Importance of the daily and decadal fluctuations of the wind and rainfall in driving the circulation and temperatures of the Indian Ocean	C. Perigaud
17	Indian Ocean Climate Research Data Centers	P. Hacker, E. Desa K. Radhakrishnan S. Wijffels
18	The Global Climate Observing System - Summary for IOGOOS	GCOS Secretariat
19	State estimation using satellite data to study seasonal-to-interannual variabilities of the Indian Ocean	Tony Lee
20	Sub-seasonal Indian Ocean Variability and Climate	G. Vecchi, E Harrison
21	Health-Status Of The Coastal Marine Environment Of India	M D Zingdet
22	Indian Ocean ITF	Robert Molcard



The evolving design of a sustained observing system for the Indian Ocean. The system includes 3°x3° Argo profiling float array, 5°x5° surface drifting bouy array and a real-time tide gauge network. NIOT will establish arrays of meteorological and deep sea moorings.


Tropical Indian Ocean Moored Buoy Array
Surface Mooring
Flux Reference Site
ADCP
30°N
20°N
10°N
0°
10°S
20°S
30°S
40°E
60°E
80°E
100°E
120°E