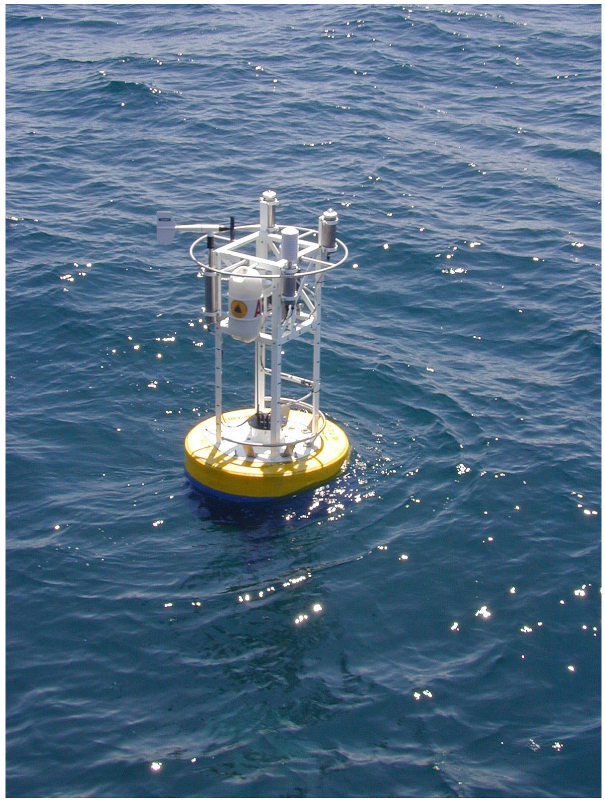
# Oceanographic Time Series Workshop



*sponsored by the*
*Ocean Observations Panel for Climate*
*CLIVAR Ocean Observations Panel*
*Partnership for Ocean Global Observations*

**May 21-23, 2001**
**Woods Hole Oceanographic Institution**
**Woods Hole, MA 02543 USA**

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**Preface**

The plans for the global ocean observing system for climate developed by the Ocean Observation System Development Panel (OOSDP) call for an integrated ocean observing system that includes time series stations, Lagrangian profilers and surface drifters, shipboard sampling, and remote sensing. These several components were discussed and reviewed at the international Ocean Obs 99 workshop held in St. Raphael, France in October 1999. At and subsequent to the St. Raphael meeting, international consensus confirmed the recommended framework for the integrated ocean observing system. In the case of the Argo profiling float array, an international effort led by a science team made good progress toward identifying support for building and deploying floats and began the shepherd the implementation of that element. The successor to the OOSDP, the Ocean Observations Panel for Climate (OOPC), together with the CLIVAR Ocean Observations Panel (COOP) recommended a similar effort by scientists involved with oceanographic time series. The Partnership for Ocean Global Observations (POGO) expressed interest in aiding the process, with the further input that planning for oceanographic time series stations should be responsive to the need for biological and chemical observations. This recommendation was echoed by groups developing plans for carbon cycle observing systems and reinforced by the success of existing multidisciplinary tome series stations such as those near Bermuda. Finally, in the last several years there has been growing interest in time series stations that include ocean bottom observations; and this interest has been advanced by the DEOS planning groups in several countries.

In an effort to bring together these diverse interests, to develop consensus on the desired locations for time series stations, and to initialize a concerted effort to garner support for and begin the implementation of the time series component of the integrated global ocean observing system, OOPC, COOP, and POGO called for a workshop and formation of a time series science team.

**Workshop Objectives**

The following are the terms of reference for the time series planning group that OOPC and COOP put forward in late 2000:

1) Define an initial set of locations for a global array of long-term time series stations for multi-disciplinary observations at the sea surface, in the ocean, and on the sea bottom.
2) Develop the rationale for establishing and maintaining each element of the array, including recommended and minimum required measurements.
3) While initially building on existing PI-driven sites or continuing previous/existing time series, carry out a critical review of these and identify gaps in the network and synergy between programs (e.g. CLIVAR and DEOS).
4) Continually review the set of locations in the light of new requirements, insights or interests of participants and program.
5) Consider resources, logistics, data delivery (real-time, delayed-mode).
6) Coordinate the implementation.
7) Coordinate data transmission/formats/streams/management.
8) Liaise with complementary programs (ARGO, ocean assimilation/prediction, inter-disciplinary groups, etc) and ensure integration into the overall observing system.
9) Consider funding mechanisms for sustained observations, and work, with help of the sponsoring and supporting bodies, towards national commitments for supporting sites

OOPC and COOP recommended the development of a strategic plan and suggested that in the near-term there be plans for a pilot project. For them, GOOS (Global ocean observing system) pilot projects are defined as follows: A GOOS pilot project is defined as an organized, planned set of activities with focused objectives designed to provide an evaluation of technology, methods, or concepts within a defined schedule and having the overall goal of advancing the development of the sustained, integrated ocean observing system.

Uwe Send (IFMK, Kiel, Germany) of COOP and Bob Weller (WHOI, Woods Hole, MA USA) were charged with getting the time series working group and the planning effort started. To do so, they called for an initial workshop to be held at the Woods Hole Oceanographic Institution in Woods Hole, Massachusetts on May 21 through 23, 2001.

The invitations sent by Send and Weller were accompanied by the following statement of the goals of the workshop and requests:

The primary goals of this workshop are to: 1) develop a consensus on a list of time series sites and the rationale for occupying those sites, 2) to develop a strategic plan for long time series stations as part of the global ocean observing system, and 3) bring together and develop material for brochures and/or a website describing time series stations as an integral component of the global ocean observing system.

To spin up for the workshop, you will be asked to contribute material on the rational for specific sites and for the brochures/web site over the next few weeks. The strategic plan for time series stations will be a short document with an outline that will be similar to this draft outline:

1. Introduction
2. Rationale and scope for long time series stations
    a. Vision
    b. Rationale
    c. Objectives and scope
    d. Benefits and users
    e. Outcomes
3. Strategy and guiding principles
4. Time series observations - types and data provided
    a. Surface flux reference sites
    b. Physical oceanographic
    c. Bio-geochemical
    d. Sea floor
5. The unique nature of time series stations
    a. High temporal, vertical resolution
    b. Historical heritage sites
    c. Multidisciplinary
    d. Validation, verification of models and remote sensing
    e. Foci for process studies, development of observational methods
6. Implementation
    a. Overview and schedule
    b. The time series pilot project
    c. Establishing and supporting the global array
7. Summary

This draft outline is predicated upon a strategy that involves getting a select number of time series stations up and running in the near-term and using those stations to demonstrate the value of time series stations as we work toward the long-term support of the remaining sites.

**Workshop Overview and Agenda**

A specific intent at this first workshop was to have representation of the diverse disciplines (see Appendix I for the list of attendees) and to spend the time, one basin at a time, to develop consensus on which sites to occupy and to discuss the rationale for doing so.

Thus, the agenda (Appendix II) was planned to include specific blocks of time to discuss in turn the Atlantic, Pacific, Indian, and Southern Oceans. It also included sessions to review he rationale for time series stations and to develop a draft strategic plan for their implementation.

The various sessions are summarized in this report.

**Rationale for the Global Ocean Time Series Observatory System**
***Rationale:***
The science community, policy makers, and society need an observing system for the global climate and ecosystem in order to detect changes, to describe/quantify them, to understand/explain them and to develop a capability to predict them.
The overall ocean observing system should provide a 4-D description of the oceanic variables of climatic and societal relevance (global).
Fixed-point time series are an essential element of the required observing system, because:

- moorings are uniquely suited for fully sampling 2 of the 4 dimensions (depth and time), thus complementing other components of the observing system (satellites, floats, ...). They resolve a wide range of temporal variability and sample the water column from the surface to the bottom.
- fixed-point stations are the only approach for resolving multi-disciplinary variability and processes like
    - $CO_2$ uptake
    - biological productivity
    - atmospheric fluxes
    - ocean bottom processes (biological, geophysical)
- moorings are uniquely suited for sampling critical or adverse regions and periods
    - passages and boundary currents
    - under the ice, in abyssal layers
    - during storm seasons
    - events like blooms, convection, earthquakes

**Definition of the Global Ocean Time Series Observatory System**
Definition of an ocean time series site in the global system (requirements):

- in-situ observations of ocean/climate related quantities at a fixed geographic location/region
- sustained and continuous, contributing to a long-term record at the site
- autonomous moored sampling should be pursued to resolve high-frequency variability, to achieve high vertical resolution, and to obtain coincident multi-disciplinary sampling;
- shipboard observations from regular occupation of a site as at Ocean Weather Stations, historical sites or sites where moorings have not been established provide an alternate method
- coastal sites are included where they are of large-scale (deep-ocean) relevance
- site selection is determined by the value of the site as representative of a meteorological, physical, chemical, biological or geological province and/or providing key information to quantify important processes, to validate models or ground truth remote sensing or to observe change in the ocean
- provides real-time data telemetry (and dissemination) wherever possible

Features of the Observatory System:

- The system is multidisciplinary in nature, providing physical, meteorological, chemical, biological and geophysical time series observations
- The data are publicly available as soon as received and quality-controlled by the owner/operator
- An international Science Team provides guidance, coordination, outreach, and oversight for the implementation, data management and capacity building

**Draft Strategic Plan**

Discussions at the workshop led to a phased approach to implementing the time series observing system.

During phase 0, a limited set of time series sites will be used for studying and demonstrating the feasibility and usefulness of such a component of the observing system (pilot project, core network of phase 0). Every effort will need to be taken to ensure the operation of these sites.

At the same time, any other site which qualifies under the definitions is welcome and is included in the list of precursor / exploration / candidate sites for the global network.

At the end of phase 0, all sites will be reviewed and a new expanded list will be drafted which represents the new core network of phase 1. This list will be used at the international and national level to obtain support for their implementation and operation. At the same time, any new site will be added to the candidate list for review/addition in phase 2.

<u>The Pilot Project - Phase 0 (5 years, mid 2001-mid 2006):</u>

The initial implementation of the Global Ocean Time Series Observatory System consists of all operating sites and those planned to be established within 5 years, subject to evaluation in terms of the qualifying criteria by the Science Team. This is the Initial Time Series Observing System . During the Pilot the international Science Team and those that deploy and maintain the sites will undertake the following activities:

- Identify gaps in the system and encourage filling them
- Develop new technology for sensors and moorings
- Address implementation of the more challenging sites of critical importance, including multi-community and multi-national efforts
- Identify products and end users and establish routine provision of data from the sites to users
- Make a convincing case for a time series observatory system (to the public, policy makers, funding agencies)
- Capacity building, enabling participation in the observatory system
- Review all operating sites in year 5. Accept the proven ones into the longer-term system. New sites will be added for a new trial phase.

The Post-Pilot Phase - Phase 1 (next 5 years):

Carry out review of the value of all operating sites in coordination with the other elements of the global observing system (incl. outside opinions and end users) and build toward the full array, addressing:

Development of new technology
The more challenging sites
Capacity building

Phase 2 (6-10 years later):

Complete the deployment of the global array using the new capabilities developed and based on the reviews carried out

Transition to operational status

Phase 3 (years 11 onward):

Operational status and maintenance

Discussions at the workshop were aimed at developing more details of the work that must be done in PHASE):

PHASE 0 (years 1-5) activities:

*ACTIVITY 1: running of the pilot array*

The Pilot Project is a collection of sites which are considered critical to demonstrate the feasibility and usefulness of a global timeseries network and which can be used for that purpose within the timeframe of the project. Therefore, it should consist of sites which:

- can be implemented in the near future such that data streams are available during approx. years 3-5
- will routinely provide data to the community that are important for preferably several of the GLOBAL driving issues behind time series, i.e.
    - for referencing like air-sea fluxes or satellite-derived quantities
    - for obtaining information on the nature of the variability of critical quantities in critical regions (e.g. CO2 sinks/sources)
    - for detecting changes in the state of the ocean in [a]representative phys./bio. provinces
    - for providing verification data or constraints for development of ocean/climate/ecosystem/geophysical models
    - for filling an important gap in the integrated ocean observing system
- can preferably be advertised with the help of some (not all) real-time data
- can be viewed as part of the GLOBAL array of time series sites and of the global observing system as a whole

The community should take every effort to ensure the implementation of these sites. Our group will oversee the progress of these sites annually to ensure they fulfill their demonstration purpose.
Towards the end of the 5-year period, the value of the sites will be reviewed.

*ACTIVITY 2 :*

- Continually review list of sites that qualify for inclusion in the global network (see definition/requirements for time series)
- Evaluate those operating sites of the global network that are not included in the Pilot Project and make recommendation for inclusion in the phase 1 core network
- study, choose, encourage and implement new sites which are needed to achieve the global coverage and relevance

*ACTIVITY 3:*

- Technology development and capacity building
- formation of multi-national and multi-community consortia to address challenging sites

**Brochure**

It was decided at the workshop that the group should develop a brochure similar to that developed by the ARGO science team that would:

Present the complete vision (reference to coastal sites).
Major compelling reasons from all disciplines.
Compelling examples (generic, historical, running)
Technology and technical challenges
Societal value and end users
Free and open data exchange
Role in integrated observing system
Layout similar to ARGO brochure
Make reference to paleorecord

Action Items:
- collect figures and captions
- send us compelling reasons, societal values and end users, role in the integrated observing system

**White Paper , initial report from this meeting**

It was also decided that a white paper would be developed after the workshop to summarize the results and to be distributed for comment. For each recommended site, text (1 paragraph plus bullets) for each site will be collected from experts , develop cost estimates for providing the data to the community (quality control but no science), quantify ship time not ship cost. A brief report will be submitted to EOS.

Discussions at the workshop led to the identification of select sites which would be highlighted in the White Paper, making the case for time series stations.

**Select Atlantic Ocean Sites**

1- Subpolar North Atlantic (Irminger Sea): region strongly affected by (responding to) NAO fluctuations in terms of physics (water mass formation, maybe MOC driving) and biology (productivity, zooplankton, fish); important biological province since high-lat productive region (i.e. biol. $CO_2$ pump, fish stocks,...); often cloud-covered thus good addition to satellites; region of large $CO_2$ flux (not clear whether also for anthropogenic $CO_2$) in terms of physical and biological pump

2- BATS: representative for large ocean region and good historical context for observing and understanding physical and biological variability, used widely for developing and testing ecosystem models; useful as air-sea flux site

3- PIRATA: climate significance already given by PIRATA array itself; useful as air-sea flux site if suitably instrumented; $CO_2$ important addition due to uncertain role/response of equatorial region in carbon cycle; biological province and maybe variability in biol. pump (see McPhaden text).

4- MOC monitoring: overflows and upper/deep limbs of MOC (at present only the mature/proven sites); proposition is Station W, since Gulf Stream significance is easiest to advertise and also this may help funding of the site.

**Select Pacific Ocean Sites**

5- the subpolar Mutsu site

6- HOT

7- equatorial TAO with MBARI sensors

8- deep Monterey mooring

9- air-sea flux stratus site off Chile

**Select Indian Ocean SItes**

10- Indonesian Throughflow

11- Japanese Triton moorings

12- Bay of Bengal air-sea flux site

13- Replacement KERFIX site (60E 40S) as pre-DEOS mooring

**Select Southern Ocean Sites**

Sites in the Southern Ocean were identified as a high priority, but also technically challenging. Initial emphasis would be on developing the ability to reliably occupy such sites.

**Discussion of Biological Requirements**
A key goal of the workshop was to broaden the discussion of time series stations beyond the physical, climate-oriented variables that had been the foci of OOSDP and COOP. The discussions are summarized here.

R.Lampitt:
Why include biology: influence on global biogeochemical processes and sensitive indicator of environmental change (and thus also better at testing physical models). E.g. zooplankton correlation with NAO or long-term decrease in Diatoms and others at PAP. WHY ?? Provinces: as traversing the ocean, the rate of change of plankton communities is not constant -> boundaries, provinces. In terms of community structure (entire food webs) this is not viable. Longhurst: used physical (wind) and topographic regions as a start. Then made 57 provinces using CZCS, vertical Chl distributions, nutrients, mixed-layer depth, stratification (not using zooplankton). Then he looked for commonalities between these provinces uses models, and came up with domains like polar, westerlies (nutrient limited spring production peak), subtropical (nutrient-limited winter production), trade wind (little seasonality, monsoon regime (large seasonal variability). Many time series located are on boundaries of domains, some are in interior (has a map). Does not mean that there is no variability in the interior, but the (e.g. mesoscale) variability may be characterstic of a region. In the past it was difficult to agree on a way proceed in biology, since there have been recent dramatic changes in the understanding of processes (zooplankton interaction); also no agreement on what should be measured; and lack of sensors. All this is very recent stuff. Primary production is very hard to observe (from space and with models).
D.Karl:
Microorganisms are important, many recent discoveries, microbes are adjusted to environmental change and can easily respond. Manned time series sites were important for these discoveries, but moored sampling devices also exist now, as well as molecular probes.
F.Chavez:
Why need time series: ship sampling in the Pacific in the 80s yielded rather stable biology; but later moored time series showed VERY episodic changes, which are missed by ship and satellites (e.g. when clouds, or deep). Can also define provinces based on temporal variability, like NAO or PDO regimes (sites in the maxima of variability). Also need time series since we do not have climatologies in biology (don t have the mean and thus no anomalies).

**Discussion of Geochemical requirements**
M.Hood (from IOC, one of the sponsors of GOOS):
IGOS is Integrated Global Observation System, sponsored a IOC ocean carbon advisory panel. General carbon observations: required by international treaties; need data for technological and political decisions; need ocean sinks and their changes. Need in-situ observations on appropriate space and time scales; relate these to satellite data; improve models. Need process studies for understanding

surface ocean carbon (air-sea gas exchange, convection/mixing, nutrients and trace elements, ecosystem dynamics, .... Also water column and ocean bottom observations important for solubility pump. Not enough to put CO2 sensors on moorings but need the other variables (physical, biological, ...).
Requirements for moored buoy measurements: pCO2, DIC, alkalinity, pH (each with accuracy) and ancillary physical/biological measurements.
Table of available automated sensors available (commercial and private ), but many not used for time series yet (no available or published data).
Sites: historical places or funded sites, known signals (ENSO, NAO), biogeographical regimes, and ocean color sites. Table of funded and planned CO2 sites exists. US carbon document has estimated number of samples required from known variability, and comes up with typically 12 per year - cannot do with ships.
L.Merlivat:
Variability of pCO2 is due to dynamics (wind, SST, salinity), biology, etc, and thus need to measure them all. Example from Med (DYFAMED) show that one loses much of the variability without continuous measurements. CARIOCA measures everything . Need high-frequency wind data to calculate CO2 air-sea flux, big difference if only daily values. Maybe that is reason for inability to close carbon budget e.g. at BATS. I.e. measure also wind if measure Delta CO2. Biofouling not problem for CO2 (Carioca uses Seabird antifouling and pump intake), buoy designed for 1 year, longest successful deployments have been 6months.
E.Boyle:
Trace metals (incl. iron). They have developed a moored water sampler, for 12 samples, for analysis in the lab. Many sensors do not exist yet, also good for verification of sensors that do, and also can archive samples for later analyses of new variables. Has been deployed on BATS and ALOHA moorings. Actual data show large variability, up to 6x over weeks for iron. Verified causes: eddies, dust fluxes, biol. patchiness, hurricanes,... Now can manage with much smaller samples, thus future instruments would be smaller and take more samples. In some biological provinces iron information is very important (even profiles), in others not so essential.

**Discussion of Geophysical requirements**
J.Orcutt:
DEOS includes Neptune, global network of buoys, and relocatable buoys (also a coastal component actually). Initial 5-year plan would probably cover the first 8 buoys of 22 total. Probably no in-line instruments on mail mooring line (i.e. not to break into power and data cable), but clip-ons might be ok.

**Example from HOTS/BATS**
T.Knap:
Bermuda hydrostation S, biweekly sampling since 1954 (more climatic, CTD, oxygen, plus ancillary stuff) BATS biweekly/monthly sampling since 1988 (more biogeochemical, CTD, oxygen, PAR, fluorescence, beam attenuation, and many

more). BATS supports lots of process studies too, including various moorings like BTM. Proposal out to put another 3 moorings around BATS to observe eddy field.

D.Karl:

HOT (not HOTS) has 2 components, R.Lukas' physical station, and biogeochemical one (D.Karl). CD exists with 10 years of data, virtual cruise, also Deep-Sea volume. Cruises since 1988 nearly monthly, station is called ALOHA. There are other biogeochemical time series sites around the world. No mooring anymore there (funding problems). Also have an Antarctic program (COLD) on AA side of Drake Passage: ship-based (annual), bottom station (sediment traps, seacats, ice sonar), island met station, theme is ice variability (anticorelated with SOI) influence on biogeochemistry,

T.Dickey:

Interdisciplinary time series moorings. E.g. JGOFS sites in Arabian Seam EqPac, MedFlux, MLML (at NABE), BTM. Very few ongoing biogeochemical moorings now, like BTM, no more HOT mooring. New sensors have been produced. BTM since 1994. Used to be test bed mooring, now also used for science (though funding still as test bed). 40-45 people put instruments on BTM or use/mode the data, Right near BATS site, most instruments above 200m, CARIOCA tethered to the buoy, also had been enhanced by Autosub in one year to get spatial surroundings. Plan now for Sargasso Sea Observatory for larger regional observing system. HOT mooring is in a re-proposal stage, similar to BTM mooring.

**Atlantic Basin Discussion**

Osterhus:

Fisheries Institutes are maintaining sections/observations for decades.

- Station Mike: committed, also measures oxygen, nutrients, etc
- Fram Strait: only ice and freshwater transport (from 2 moorings)
- Faroer Bank Channel: several mooring and standard sections
- Denmark Strait: not certain how committed
- CIS:
- PAP: R.Lampitt wants to include annual benthic measurements as integrator of water column processes
- ESTOC: propose moving to more open ocean location ?
- Denmark Strait:
- Bravo as presented:
- Station W with WHOI profiler maybe enhanced with some simple sensors (optical), form a pair with Bermuda where may also deploy a profiler, may be a problem for the air sea flux site that is wanted further south over Gulf Stream
- Bermuda: already had presentation
- Florida Strait:
- Abaco:
- 24N UK section: (moorings, repeat section) only physical, for transport

- MOVE:
- PIRATA: want to add Carioca package to the buoy but no funding yet, other groups also want to add sensors
- VEMA channel: might want to have 4 moorings (instead of 2) to have volume flux in addition to temperature changes.
- UK DEOS on Reykjanes Ridge: proposal submitted, CIS mooring would be the end member of that
- DYFAMED in Med:
- DEOS will put

What are the requirements or models that we want to address, e.g. for data assimilation, model verification and improvement. What is unique about the Atlantic. There are also coastal biogeochemical observatories (e.g. off Venezuela and Puerto Rico)

**Technology**

Ultramoor effort: designed for 5 years, 10 data capsules, i.e. data every 6 months, should end up a 25% of usual price, 1-year tests have been successful

**Lessons from ARGO**

When defined what time series are, can make table with what is out there and what is proposed. Can make table with national commitments, and it helped in one country to see what another country funded, and to see the increase with time. Table with proposed plans, to make it happen try to use a simple message like in ARGO (brochure) and on its cover. Once message and graphics are available, can advertise more easily (web, newspapers, magazines). Use data policy as a driver as well (a resource to the science community). IF some data are in real-time, try to see if these are used by operational center. Use existing examples to make a powerful case for time series.

**Pacific Basin Discussion**

B.Weller:

Science drivers from Clivar plan. Few moorings committed apart from TAO.
- 4 TAO buoys have good met sensors for air-sea flux
- proposal for air-sea flux at PAPA or further west, and at HOT

J.Toole:

New Mutsu Institute - funding for 10 years for up to 6 moorings which are physical and biogeochemical. Site choice based a lot on organic carbon flux (high in subpolar region). Very intensively instrumented moorings including samplers. First 2 moorings in this summer (central subpolar and subtropical N.Pac.), more next year, all equipment exists, large ship is part of the institute.
- Mutsu buoys

D.Karl:

new technologies - solar powered AUV exists as prototype, will be used around HOT program to connect spatial with mooring information (daily transit 30-50km, depth 1000m), unlimited endurance. Nearby phone cables will be used for HOT station ALOHA. Also NDBC (NOAA) buoys around Hawaii could be used to add sensors.

- HOT

O.Pizarro:

- 2 moorings proposed at 30S
- 1 mooring at 55S (AAIW formation)
- plus coastal stations for eastern boundary current observations and ENSO variability

F.Chavez:

- biogeochemical sensors on 2 TAO moorings incl. pCO2
- moorings off Monterey: coastal region can extend 1000km out in terms of ocean color/chlorophyll
- plan for California Coastal Observing System (CalCOOS)

Technology: have own CO2 sensor (does the measurement in air after bubbling air through the water sample until equilibrated), and smaller unit for floats maybe. Also developed DEOS type mooring

T.Dickey:

- Time series of sections out to PAPA continues
- Canada intends to put a mooring back at PAPA (at least for process study)
- not clear about the status of KNOT, apparently plan for a new Japanese mooring there
- 2 New Zealand moorings on Subtropical and Subarctic sides of SA front (for biogeochemistry)
- DEOS mooring might fill gaps in subtropical south Pacific and also in N.Pacific (towards PAPA)
- junction box exists half way between Hawaii and California

Phase 0:

pilot moorings:

* the subpolar Mutsu site
* HOT
* equatorial TAO with MBARI sensors
* deep Monterey mooring
* air-sea flux stratus off Chile

**Indian Basin Discussion:**

P.Hacker:

Meyers papers summarizes observations that are important for resource managements around the Indian Ocean, as well as identifies important scientific issues, includes the Oceans-to-Farms perspective/program (seasonal climate forecasting). Indian Ocean dipole, strong annual signal, interannual variability, new also strong intraseasonal signal (10-45 days), includes also strawman for

sustained observations with also TAO-like moorings (ARGO not designed for temporal and spatial resolution required for the equatorial processes), text exists for this. Then SOCIO workshop (sustained observations of climate in the Indian Ocean), to identify science issues and users; drivers/users identified as function of timescale (daily to years). Predictability of intraseasonal events/signals (carries variability/weather on week scales into the continents). Short timescales (a few days) are very important.
- Strawman tropical mooring array: WIMAP
- around India 12 surface moorings, 2/3 inshore, 1/3 offshore, data return not known, maybe more a technology trial
- 2 Japanese triton moorings (Oct.01-04)
- XBT line along 110E for outflow
- 2 flux sites (Arabian Sea and Bay of Bengal)
- occasional Indian current meter mooring on equator (nothing right now)

Strategy how to move forward is very difficult for the Indian Ocean.

Dwi Susanto:
-Indonesian throughflow future program (ARLINDO).
-2 sediment trap moorings off southern Indonesia (hopefully 10year program)
-the eastern of the Japanese Triton mooring is near an area of large biogeochemical interest. After a pilot phase, one would hope to have arguments to maintain the Japanese moorings and throughflow moorings there after the current planned observation phase (3 years or so).

L.Merlivat:
- OISO (Indian Ocean Observing System): ship-based, 2x per year (La Reunion-Amsterdam Island-Kerguelen-Crozet)
-no more Kerfix station
-CLIOKER monthly CTD near Kerguelen (max.1500m), not well calibrated
-profiler mooring proposal planned by C.Provost, but very uncertain

SURFA group has recommended an air-sea flux mooring near Kerfix

Sites to recommend:
* 40S 60E could be a compromise for DEOS, air-sea flux, and biogeochemistry/CO2 site (subtropical convergence - F.Chavez)
* would need an equatorial mooring in western Indian ocean

Phase 0 pilot sites:
* Indonesian Throughflow
* Japanese Triton buoys
*

**Southern Basin Discussion**

Rintoul presentation:
- subsurface mooring proposed 47S, 142E for CO2, but this could be upgraded to surface mooring
- AAIW formation 47S-54S, 90W

it is technically feasible and we should work toward an implementation during phase 1. ask for ice thickness time series as examples.

also Osterhus:
- plan to maintain a mooring on Maud Rise (on 0deg meridian)
- had a mooring under the ice (1000m of ice) on Filchner Ice Shelf, new 10y deployment planned on Ronne Ice Shelf
- long term mooring program on sill of Filchner shelf outflow planned, Norwegian government want to support monitoring activity there

**General Discussion**
- make connection with global environmentalists (ocean conservation foundations) and with global industrialists
- also mention application for sustaining living resources

anonymous ftp directory exists for depositing figures and examples
contact David Pugh at SOC (d.pugh@....) to disseminate request for advertising material , he will forward to CPR, repeat hydro lines, etc. He&H.Rowe think that POGO can also help (funds ?) with the brochure.
NWP is an important customer (not flux referencing...) who want the data right now (like old OWS s)
JCOMM products bulletin is a web site for distribution ocean data and information with 10000 hits per week. Use this.
Distribute infoormation to India via Radha, he will disseminate them
Indicate on map and in list, which sites are running or funded and which are not.
have a special session on time series at AGU Ocean Sciences Hawaii, Feb 02.
Meet next time a few days BEFORE AGU meeting.

**Draft Content of the White Paper**

What are timeseries (sites) - provocative statements
*Proposed properties required to qualify:*
*1) Sustained in-situ observations at fixed geographic locations of ocean/climate related quantities at a sampling rate high enough to avoid undersampling and to resolve high-frequency variability.*
Sustained: plan/commitment for longer than one project/proposal period and intention to pursue funding from observing system programs when available.
*Therefore:*
*Wherever possible, the observations should be achieved with autonomous instrumentation, in a moored or virtually moored mode.*
*Where/while this option is not available (certain variables, logistical*

*constraints, etc), ship-occupied time series may qualify an interim approach.*

Rationale: - Only in this mode can high temporal resolution be achieved, e.g. absolutely critical for some observations like currents, events (convection, blooms, seismic, etc).

- Only this way can long-term goal of unattended operation over many years be approached or remote glider-based methods be explored.

*3) Real-time data telemetry of operational variables will be pursued.*

Rationale: - Monitoring of instrument functioning (essential for targeting uninterrupted time series);

- Some end users may have requirement for real-time data (ocean forecasting, real-time assimilation, politicians to demonstrate Kyoto monitoring obligations)
- Helpful for outreach and publicity (online public information about ocean state and changes, e.g. feed news about events to media), like TAO array
- verification, validation
- event-driven sampling

*4) Does a classification make sense in terms of*

*(a) air-sea flux sites (above water)*

*(b) transport sites (horizontal integral)*

*(c) general observatories (water column and sea floor)*

*5) Coastal time series are included when they are of large-scale relevance.*

*6) Data should be made public in near real-time for real-time data or as soon as processed and post-calibrated for other data; certain quality control standards, data formats, and data centers need to be established*

*7) Should area survey type systems (for budgets) be part of the system ?* Yes, see (1)

*8) What is the role in an/the integrated observing systems:*

- essential role in an observing system for currents/transports in
    a) equatorial regions
    b) abyssal currents
    c) boundary and overflow currents

model validation, initialization filling in the dimensions not well samples by the other elements ... (provide local/regional interdisciplinary data in the water column spanning time scales from minutes to decades)

*The overall observing system should provide a 4-D description of the oceanic variables of climatic and societal relevance (global).*

- moorings are uniquely suited for fully sampling 2 of the 4 dimensions (depth and time)

- fixed-point stations are the only approach for multi-disciplinary time series; such data are essential for biological/ecological/geophysical modelling
- uniquely suited for sampling critical or adverse regions/periods (upper 10m, under the ice, storm seasons, confined current systems, abyssal layers)

*9) Who are the (end) users:*

- NWP
- climate policy makers (long time scales)
- tsunami warning
- seismic users (earthquake centers)
- nuclear weapon detection
- scientific community
- fisheries
- pollution/contamination policy
- maritime operations
- public interest groups and NGOs
- industry (oil, insurance, ...)

*Try to establish for each site:*

*- rationale*
*- feasibility (logistics, technology)*
*- commitments (present, future, likelihood for sustaining)*
*- readiness for inclusion in pilot project*
*- type of observations and sampling*
*- requirements/availability for data telemetry*
*- role in the integrated observing system*
*- multi-community support ?*
*- cost estimates (initial investment, running cost, data management and analysis,...)*

*General points to discuss:*

- calibration: uniformity, intercalibration, pre- and post-calibration, quality and accuracy (linked to ARGO and other observing system elements)
- Deployment and maintenance: document ship time, servicing, etc needs
- Indicate the utility of select time series stations as test-beds/prototypes for the development of the program
- Explore links to marine industries as a source of support and that might use Time Series sites as test-beds and/or provide instrumentation and telecommunication resources

*Mission (what to we want to have at the end of the day):*

- develop a pilot project (phase 0) with implementation plan

The Pilot Project should address evaluation, logistics and funding. The Pilot project should have a fixed life, say 5 years, after which the global time series stations are transitioned under JCOMM.

- keep developing plan for desired future global array (first cut here)
- path to this array (phases 1,2,...)

## Tables of Selected Sites

Initial Atlantic Ocean Sites OB: Observatory, FL: Air-Sea Flux reference TR: transport

| OB | FL | TR | Lat / Long | Status | Remarks |
|---|---|---|---|---|---|
| x | | | 75N 3.5W | operating (AWI) | Greenland Sea, physical |
| x | x | | 66N 2E | operating (Norway) | OWS M, Norwegian Sea, physical, meteorology, biogeochemical |
| x | | | 60N 36W | funded (EU) | CIS, Central Irminger Sea, physical, biogeochemical |
| x | | | 57N 53W | operating (BIO, IfMK) | Bravo, Labrador Sea, physical, CO2 |
| x | x | | 49N 16.5W | funded (EU) | PAP, Porcupine Abyssal Plain, meteorol., physical, biogeochemical |
| x | x | | 40N 70W | partially funded (WHOI) | Station W, meteorology, physical |
| | x | | 36N 70W | recommended | Gulf Stream extension flux reference |
| x | x | | 30N 42W | planned (DEOS) | North Atlantic DEOS, geophysics, meteorol., physical, biogeochemical |
| x | | | 33N 22W | operating (IfMK) | K276, Azores Front/Madeira Abyss. Plain, physical/biogeochem. |
| x | x | | 32N 65W | observatory operating (US) | BATS/Station S/BTM, physical, meteorology, biogeochemical |
| x | | | 29N 16W | funded, partially operating (EU) | ESTOC, Canary Islands, physical, meteorology, biogeochemical |
| x | | | 27N 77W | planned (RSMAS) | Abaco, physical |
| x | | | 16N 60W | operating (IfMK) | CLIVAR/MOVE western site, physical |
| x | x | | 15N 51W | operating (WHOI, IfMK) | NTAS and MOVE eastern site, meteorology, physical |
| x | | | 0N 20W | recommended | biogeochemical sensors on existing PIRATA mooring |
| | x | | 10S 10W | recommended | flux reference on existing PIRATA mooring |
| x | | | 31S 39W | planned (WHOI, IfMK) | VEMA channel, physical |
| x | x | | 35S 15W | recommended (DEOS) | South Atlantic DEOS, geophysics, meteorol., physical, biogeochemical |
| x | | | 40S 53W | recommended (Brazil/Argentina) | Malvinas Confluence, physical |
| | | x | 78.5N 9E-5W | operating (Norway, Germany) | Fram Strait, physical, ice |
| | | x | 68-66N 29-24W | operating (Iceland, IfMK) | Denmark Strait overflow |
| | | x | 64-59N 3-9W | operating (Norw.,Faroer,Scotland) | Iceland-Scotland overflow, 3 sections, physical |
| | | x | 53N 50-53W | operating (IfMK) | Labrador Sea export |
| | | x | 44 –41N 45-49W | operating (BIO, IfMK) | Grand Banks boundary current |
| | | x | 36N 5.5W | planned (EU) | Gibraltar transport |
| | | x | 27N 77-81W | operating (RSMAS) | Florida strait transport |
| | | x | 16N 50-60W | operating (IfMK) | CLIVAR/MOVE deep transport |
| | | x | 9-13S 33-36W | operating (IfMK) | CLIVAR upper transport |

Initial Pacific Ocean Sites

| OB | FL | TR | Lat/Long | Status | Remarks |
|---|---|---|---|---|---|
| x | x | | 50N 145W | recommended | PAPA, meteorology; physical, biogeochemical |
| x | | | 50N 165E | planned (JAMSTEC) | Northwest Pacific, biogeochemical, physical |
| x | | | 44N 155E | planned (JAMSTEC) | KNOT, Northwest Pacific, biogeochemical, physical |
| | x | | 40N 150E | recommended | Kuroshio Extension, meteorology |
| x | | | 32N 120W | operating (MBARI) | MBARI deep biogeochemical mooring |
| x | x | | 23N 158W | observatory operating (SOEST) | HOT, meteorology; physical, biogeochemical |
| x | | | 20N 115E | planned (Taiwan) | South China Sea |
| | x | | 2N 156E | recommended | Warm Pool flux reference on existing TAO/TRITON mooring |
| x | x | | 0N 165E | recommended | flux & biogeochemical sensors on existing TAO/TRITON mooring |
| x | x | | 0N 145W | observatory operating (MBARI) | flux & biogeochemical sensors on existing TAO/TRITON mooring |
| | x | | 0N 170W | recommended | flux reference on existing TAO/TRITON mooring |
| | x | | 0N 110W | recommended | flux reference on existing TAO/TRITON mooring |
| x | x | | 20S 85W | operating (WHOI) | Stratocumulus deck off Peru, meteorology; physical |
| x | | | 30S 73W | operating (Chile) | deep water off Chile, physical |
| x | | | 33S 74W | planned (Chile) | 200nm off Chile, physical |
| x | x | | 40S 115W | planned (DEOS) | South Pacific DEOS, geophysics, meteorol., physical, biogeochem. |
| x | x | | 35S 150W | planned (DEOS) | South Pacific DEOS, geophysics, meteorol., physical, biogeochem. |

OB: Observatory, FL: Air-Sea Flux reference site, TR: transport site

## Initial Indian Ocean Sites

| OB | FL | TR | Lat / Long | Status | Remarks |
|---|---|---|---|---|---|
| x | x | | 15N 65E | recommended | Arabian Sea, meteorology; physical, biogeochemical |
| x | x | | 12N 88E | recommended | Bay of Bengal, meteorology; physical, biogeochemical |
| x | x | | 0N 90E | planned (JAMSTEC) | TRITON north, meteorology; physical |
| x | | | 0N 50E | recommended | Indian Ocean monsoon array, physical, meteorology |
| x | | | 0N 65E | recommended | Indian Ocean monsoon array, physical, meteorology |
| x | | | 0N 80E | recommended | Indian Ocean monsoon array, physical, meteorology |
| x | x | | 5S 95E | planned (JAMSTEC) | TRITON south, meteorology; physical |
| x | | | 9.5S 113E | operating (Indonesia, Germany) | south of Indonesia, biogeochemical |
| x | x | | 25S 97E | planned (DEOS) | Indian Ocean DEOS, geophysics, physical, meteorol., biogeochem. |
| x | x | | 47.7S 60E | recommended | KERFIX follow-on, physical, meteorology, biogeochemistry |
| | | x | 3N-12S 116-125E | planned (LDEO, SIO) | Indonesian throughflow, several locations, physical |

OB: Observatory, FL: Air-Sea Flux reference site, TR: transport site

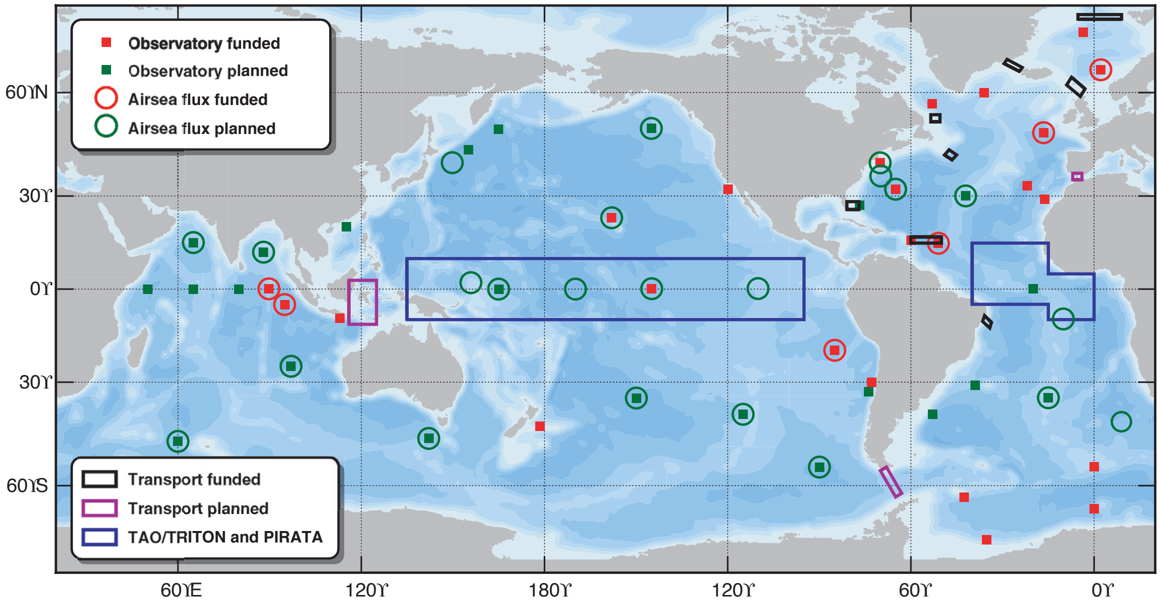
## Initial Southern Ocean Sites

| OB | FL | TR | Lat / Long | Status | Remarks |
|---|---|---|---|---|---|
| | x | | 42S 9E | recommended | SW of Cape Town, meteorology |
| x | | | 55S 0E | operating (AWI, Norway) | Weddell Sea, physical, several moorings |
| x | | | 63S 42.5W | operating (LDEO) | Weddell Sea, bottom water, physical, several moorings |
| x | | | 66S 0W | operating (Norway, AWI) | Maud Rise/Weddell Sea, physical, several moorings |
| x | | | 73.5S 35W | funded (Norway/UK) | southern Weddell Sea, ISW overflow, physical, 2 moorings |
| x | x | | 55S 90W | recommended | AAIW formation region, meteorology, physical, $CO_2$ |
| x | x | | 47 S 142 E | planned (CSIRO, WHOI) | south of Tasmania, meteorology, physical, biogeochemical |
| x | | | 43.5S 178.5 E | operating (New Zealand) | off New Zealand, physical, biogeochemical, $CO_2$, 2 moorings |
| | | x | 56-62S 70-63W | planned (UK and WHOI) | Drake Passage transport |

OB: Observatory, FL: Air-Sea Flux reference site, TR: transport site

## Map of Selected Sites

### Time Series Observatories



**Appendix I:  Attendees**

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## Appendix II: Meeting Agenda

**Agenda**

Monday, May 21

**08:30 Coffee**
09:00 Sign-in
09:30 Welcome, logistics, statement of objective
Terms of reference, charge (Weller, Send)

**<u>Science Interests, definition/types of timeseries</u>**

*Focus: What are timeseries sites, what is needed (make a general case !)*

09:45 General physical oceanography interests and requirements
(extract from OceanObs99) (Send, Weller, Toole, others)
10:15 General biological requirements and applications (Lampitt, others)
10:45 Coffee
11:00 General geochemical interests/applications (Hood, Merlivat, Boyle, others)
11:45 General geophysical interests and synergies (Orcutt, others)

12:15 Lunch

13:15 Status/plans/capabilities/technology of BATS/HOTS (Dickey,Karl, Knap)
14:00 What are time series sites? (Discussion leader – Send)
Moored only? Unique attributes, use as an element of an
Integrated observing system. Telemetry essential? Users?

*<u>Atlantic : presentations for specific sites (rationale, status, plans) and discussion</u>*

14:45 Atlantic Ocean basin sites (discussion leader - Toole)
10min presentations by Toole, Osterhus, Send, Lampitt, Merlivat, others
15:30 Coffee
16:00 continue site presentations
17:00 Wrap-up discussion on Atlantic (leader Send)
site selection, schedule, pilot project, objectives

18:00 Reception

Tuesday, May 22

08:30 Coffee
09:00 What are time series sites? (Discussion leader – Send)
    Moored only? Unique attributes, use as an element of an
    Integrated observing system. Telemetry essential? Users?
10:00 Wrap-up discussion on Atlantic (leader Send)
    site selection, schedule, pilot project, objectives
11:00 Coffee

*Pacific: presentations for specific sites (rationale, status, plans) and discussion*

11:15 Pacific Ocean basin sites, discussion leaders - Weller, Pizzaro

12:15 Lunch
13:15 Continue Pacific Ocean sites presentations
14:15 Wrap-up discussion on Pacific, leader Weller
    sites, schedule, rationale, plan
15:30 Coffee

*Indian Oc.: presentations for specific sites (rationale, status, plans) and discussion*

16:00 Indian Ocean basin sites, discussion leaders - Hacker, Merlivat
17:30 Wrap-up discussion on Indian Ocean, leader Hacker
    sites, schedule, pilot project, objectives
18:00 End for day

Wednesday, May 23

08:30 Coffee

09:00 Review previous day
09:30 Wrap up Indian Ocean Plan

10:00 Synthesizing basin plans - the global time series project
    objectives, schedule, pilot project, deliverables,
    people/coutries responsible for which sites,
    links to modeling, remote sensing and other
        near-real time users
    links to users of delayed mode data, outreach
10:30 Coffee
10:45 Continue
12:15 Lunch

*Southern Oc: presentations for specific sites (rationale, status, plans) and discussion*

13:15	Southern Ocean sites, discussion leader – Toole ?
Powerpoint file presentation from Rintoul,
sites, rationale, plan, pilot project

15:00	Coffee

**General business**

15:15	Time Series Science Team
membership, goals, name, next meeting, meeting report

16:00	Meeting report outline and writing assignments,
Time Series sites outreach - graphics, website,

17:00	Adjourn