Appendix 11.0
Comments Received

D&I Workshop
27-30 March 2006

comments submitted in writing during the workshop and electronically after the workshop

23 May 2006
Comments Received During D&I Workshop:

[comments are verbatim as received, presented here in alphabetical order by author]

**Beaulieu, Stace:**

Overall in the end I am satisfied with the discussions that we had in the global group sessions. I applaud the organizers (Uwe, John Collins, Dan F, Bruce H) for their hard work and thank you for getting to all 5 questions by the end of Weds afternoon! This was a really diverse group of people to handle in a group discussion. My only major comment is that I would have liked to go through, briefly, each of the 16 chosen site descriptions from the CND. I see that we did not spend much (if any) time discussing the Peru Basin, Irminger Sea, Eq. Atl, or Brazil-Argentien Basin. I realize that with our very limited $ we can only choose a few sites...but I want to make sure that we didn’t miss some part of the oceanogr./geophys. community’s interest by not talking much about these particular sites. Again thank you for your amazing efforts and contributions.

**Costa, Dan:**

Flexible infrastructure as part of ORION site-observatory
1) Group of gliders that can be deployed to follow unique events or to track mesoscale events, structures or processes

Modeling issue - there is a need to be able to deliver data products from core array measurements (i.e. model output that shows fronts, productivity etc, similar to MODIS or SeaWifs. Raw data streams will have limited value to many PIs’.

Global array - it would serve the RCO and west coast coastal site if there was better coverage of the North Pacific. More than one mooring in NPAC
Core Asset of mooring/array - Acoustics: place hi frequency hydrophones on all or as many moorings as possible. Adaptively sample to cut down bandwidth issues. Cheap to install, may not use all bandwidth.
To facilitate comparison across sites; need same sensors at all sites. Need equivalent calibrations.

**Drennan, Will:**

At present the phase 1 Southern Ocean buoy will likely be of the discus type seen in Fig 2,3. For the Southern Ocean, solar power requires very large panels which are incompatible with turbulent flow measurements - flow distortion will be severe. I encourage the design committee to i) include someone with knowledge in flow distortion on the design team ii) Consider alternate designs, especially for the Southern Ocean. Our group has been funded by ONR to develop a high wind air-sea flux buoy and I would encourage the design group to consider some of what we are doing. Our approach is different, but not incompatible with the ORION/global goals

**Oleson, Erin:**

High frequency passive acoustic monitoring (> 200KHz) is the most efficient means of tracking and monitoring cetacean distribution, abundance and habitat. The bandwidth considerations for this should be considered when designing the arrays. This monitoring will also serve the meteorology, geophysics and telemetry community

**Samelson, Roger:**

If SE node of Cape Blanco is added to RCO, the possibility of adding a mooring site with water column instrumentation should be explored, to supplement the West Coast Endurance array
Air-sea climate issues in the PNW region (RCO, CSO, GSO) include stratus formation. Large impact climate regime, aerosol effects etc
Not possible to add significantly to global warming knowledge with the GSO

Schultz, Adam:

1. Global scales has prudently reserved at least 20% for instrumentation. This may be inadequate. the great concern shared by many is that inadequate provision of instrumentation within the MREFC budget is a high risk strategy that imposes a serious risk to OCE core funding at a time when prospects for increasing core (funding) are not good, or at least not apparent to the community. RCO is an extreme example.

2. All major acquisitions including MREFC-funded instrumentation should be sought through open competitive bids and contracts: not grants, to avoid even the appearance of COI.

3. The electromagnetic induction/geomagnetic component of the RCO that was in the RECONN and appears as a NeptuneCANADA reserve project (pending CFI funding) did not appear in an RFA for fairly trivial reasons. It is essential to re-insert this to take maximum advantage of a) RCO's physical oceanographic measurements, which will allow us to strip off motional induction effects and obtain clear images of the mid-deep mantle beneath the plate (for the first time) and b) to leverage the investment by EarthScope in magnetotelluric arrays on the west coast

Please be aware that the geophysics community is larger than just the seismic community.

Anonymous:

I was extremely disappointed with the outcome of the coastal component group. It was not science driven but territory driven. WestCoast and EastCoast groups divided to plan (at each other's expense)...and each plan was to benefit themselves - not a science objective.

Comments Received By Email After Workshop:

[Comments are presented in the order they were received, and are verbatim as much as possible with no editing for typographical or grammatical errors. Where reference was made to an attached document and the document is appended, the wording is altered to reflect that. Where suggestions are made to text pasted from the draft report, those suggestions are underlined where necessary to differentiate them from the draft text]

Dushaw, Brian: received 3 April 2006

Dear ORION,
This will be my “index card” commentary on last week’s ORION Design and Implementation Workshop in Salt Lake City. I am CC’ing Daly, Detrick, and Luther to be sure this commentary is properly included in the index card pile. If e-mail to “oriondi@joiscience.org” will be properly submitted as an "Index Card” commentary on the Workshop, and you are otherwise overloaded, you may stop reading. Before I give my commentary, I would like to outline my OOS participation over the past 6-7 years. I attended the OceanObs’99 conference in San Rafael, France and wrote, with a number of other participants, an extensive review paper on the role of acoustic tomography/thermometry in the OOS for the conference proceedings book. Tomography was accepted as part of the OOS by the OceanObs’99 conference. I attended an early pre-ORION workshop in Dallas, TX (2001?). I have also attended several CLIVAR workshops or meetings and the “WOCE and Beyond” Conference in San Antonio, TX. At all of these workshops/meetings, I presented material (talks, posters, conference papers) on the ever lengthening timeseries of basin-scale ocean temperature that ATOC/NPAL has been acquiring in the central North Pacific (1996-present). A consistent theme in all this material was the way in which the line-integral observations are a unique measurement, quite different than the kind of data offered by ARGO floats. And more recently, I was a co-author of the acoustic thermometry RFA proposal for ORION
by Worcester et al. (The choices for many of the thermometry sites were my doing...)

In the past few years, I have also been involved at the coastal/regional IOOS level in the OOS for the North-west (Northwest Association of Networked Ocean Observing Systems (NANOOS)). I have attended most of the northwest regional IOOS workshops; I am the webmaster for http://www.nanoos.org. Last year I attended the workshop for all the regional IOOS's held in Washington, D.C.

I have three main points to make concerning the ORION workshop:

(1) Acoustic thermometry will be a valuable addition to the ocean observing system by providing a data type that is a unique measure of ocean climate variability. I dispute the notion that, with the ARGO system of floats, the acoustic observations of large-scale temperature are redundant. What is more, the global network of thermometry moorings to fits the basic goal and rationale for ORION quite well. These points, all discussed in the Worcester, et al. RFA proposal, seemed to me to have been lost during the workshop, so I reiterate them. The notion of an ORION global network has unfortunately by-and-large collapsed because of the funding limitations, even though this global network was one of the original primary rationales for ORION.

(2) Prof. C. Eriksen's summary of the Physical Oceanography breakout group conclusions omitted an important aspect of our discussions. Several of us discussed the role of long-range acoustics in global ORION (lagrangian float tracking, large-scale thermometry), although not much time was available to thoroughly discuss this or any other subject. It is unfortunate that there have been few, if any, serious discussions of the ARGO v. thermometry issue during the many workshops/conferences I have attended the past several years, and that another opportunity to have this discussion was lost - seems to me a rather suspect way to approach science. In any case, Prof. Eriksen gave no mention of acoustics in his plenary summary. Should Prof. Eriksen's report become an official record of the ORION workshop proceedings, however, I wanted be sure the discussions we had concerning the observation of large-scale thermometry/basin dynamics through acoustic remote sensing and lagrangian float tracking were included in that record.

(3) It seemed to me that much of the coastal system that was described during the workshop is redundant with many of the things that have been discussed as part of the IOOS. Ideally, the IOOS Regional Associations (RAs) would examine the ORION coastal and regional plans and provide commentary and guidance based on their priorities. I have talked to David Martin about this issue. It looked to me like the coastal plans had considerable overlap with what the RAs were already planning to do. It would be sad if the RAs were to use ORION money as a way to get an early start on the IOOS, given the financial pain that has been inflicted on, e.g., the global component. IOOS money will appear eventually from a separate source (Dept. of Commerce); it should not come from ORION. Money for the IOOS, which is likely to appear, will eventually dwarf the ORION budget.

Seems to me that one possible reason for the shortfall of funding in the global network may be that many of the coastal RFA's were more appropriate for the IOOS, rather than ORION. I thought I knew the basic goals and purposes of ORION, but many of the ORION coastal plans came as a surprise to me - some of the plans do not look like major infrastructure for a specific science purpose. It would be a large task reconciling IOOS and ORION coastal plans in a consistent way, however.

During the workshop, there was repeated discussion of the need to have a clear, impressive science plan requiring major infrastructure to present to Congress as the rationale for ORION. Another problem is that ORION runs the risk of being confused with the IOOS in the congressional venue. This would be awkward, in my opinion. Thanks for the large index card
Dear ORION D&I Organizing Committee:

Thank you for all the effort you put into the workshop, and the on-going, extremely difficult task of trying to bring order and focus to the program.

The two of us spent most of our time in the Global and Climate Variability groups at the workshop. The RFA concept proposals we were associated with directly were the global and RCO elements (and tied to one coastal). They specifically proposed the use of acoustic remote sensing methods to help provide the 4-D sampling needed to address a variety of issues in physical oceanography. We address the global scale array here. We hope that you find the following comments and suggestions helpful:

1. Draft CND Section 2.7, Basin-Scale Acoustics, needs to be given a new title and modified to emphasize the science. The goal is to use acoustic remote sensing methods (ocean acoustic thermometry/tomography) to study the ocean, rather than to improve our knowledge of basin-scale acoustics. The navigation and communication networks are of interest in the context of using these capabilities with floats, gliders, and AUVs to study the ocean for a wide variety of purposes. We propose the following revised version:

2.7 Ocean's Role in Climate

The ocean is under-sampled in both space and time. The OOI global moored buoy array will enable adequate temporal sampling, but at a relatively small number of spatial locations. Acoustic remote sensing, using acoustic transmitters and receivers installed at each moored buoy location, will allow us to measure changes in large-scale ocean temperature and heat content between the buoy locations. Further, acoustic measurements are sensitive to variability over the full ocean depth, offering one of the few ways to effectively sample both the upper and abyssal ocean. The full ocean depth sampling provided by acoustic measurements complements satellite altimetry, which provides global spatial coverage of the ocean surface at 10-day intervals, and Argo profiling floats, which provide high vertical resolution profiles of temperature and salinity in the upper 2000 m. Acoustic measurements have the advantages that (i) they provide high-precision measurements of gyre-scale temperature in the presence of high-wave number mesoscale variability and (ii) they can be rapidly repeated at little incremental cost, providing excellent temporal resolution. (In cases where the ORION network design gives shorter ranges, up to perhaps a few thousand kilometers, simultaneous transmissions in opposite directions also provide direct measurements of ocean circulation, including both large-scale velocity and relative vorticity.) By combining the integral constraints provided by acoustic data with other data and ocean models, the global moored buoy array will enable the long-term sampling needed to improve our understanding of seasonal, annual, and inter-annual gyre-scale processes and to quantify the ocean's role as part of the climate system. These measurements will help illuminate the causes of recent sea level rise and the role of the abyssal ocean in storing heat.

Basin-scale mooring arrays can also be used to improve our understanding of ocean circulation from observations of neutrally buoyant floats by increasing the reliable range of float tracking and increasing the precision of float locations. The improved precision will enable measurements of Lagrangian motion associated with topography, tides and inertial motions, submesoscale vortices, high latitude (small deformation radius) mesoscale motions, and isopycnal stirring and relative dispersion at small scales.

2. The sites chosen for the global-scale observatory moorings need to be selected to enable the use of acoustic thermometry between the moorings, which means that the acoustic paths between the moorings need to be free of bathymetric obstructions. In some cases (e.g., existing seafloor boreholes) the sites are fixed, but in other cases the sites can be shifted to obtain clear acoustic paths. The site selections should not be considered final until they have been adjusted to enable the application of acoustic tomography. We will be happy to suggest the shifts in the tentative positions needed to obtain clear acoustic paths once we are provided with the tentative positions that have emerged from the ORION D&I Workshop.
3. The phasing of the deployment of the global moored buoy array should take into account the fact that a single mooring is not useful for either acoustic thermometry or acoustic navigation. Consideration should therefore be given to installation of at least three sites in a single basin early in the program, to enable acoustic thermometry and navigation.

4. The ORION plans must be presented in the context of other ongoing ocean observing efforts and infrastructure, such as Argo, TAO, DART, and satellites. Coordination with other programs is particularly important in the context of acoustic thermometry and tomography, because relatively low-cost acoustic receivers could rather easily be deployed in conjunction with other ongoing mooring programs, such as the TAO array and planned DART tsunami detection system, with the potential to dramatically increase the network coverage, as shown in the attached figure. Early planning for such eventual coordinated efforts is essential to ensure clear acoustic paths, however. Please feel free to contact either of us if we can provide additional information or assistance.

![Figure. Acoustic network in the North Pacific assuming three sources (Aloha, H2O, and PAPA) and acoustic receivers at the locations of the planned DART moorings. Dart moorings to the west of the Emperor Seamount chain and located too far south to provide useful acoustic paths have been omitted.](image)

**Luther, Doug:**
**10 April 2006 response to Worcester**

Thank you for the suggestions. I continue to appreciate your and Bruce’s help in guiding and designing the OOI. I’d like to take advantage of your offer for more information. Would you please amplify a couple of points?

First, with regard to the complementary nature of acoustic thermometry and ARGO float data, would you please remind me about the depth issues? Can AT provide accurate estimates of temperature variability of the deep water (>2 km depth)? If so, in how many depth bins?

Second, as you know I’ve been a big fan of the utility of observations of “integrating variables” that are a spatial integral of a particular variable like temperature or velocity, and I’ve thought that they should be particularly useful in numerical model validations. But the experience of altimeter data assimilation in tidal models is causing me to have doubts about this. Pressure (sea level) is effectively a horizontal integral of currents (in the sense that it is dominated by the largest horizontal scales) and yet, even in barotropic tide models, the fluid equations have so many degrees of freedom (and the parameterizations of sub-grid-scale processes are so uncertain) that tidal solutions can be quite different in the interior of the ocean, even when the sea level is rather well constrained, depending on the bathymetry employed, or the parameterization of dissipation, etc. So, given your mention of “integral constraints provided by acoustic data” and “ocean models” in the same sentence, I thought I’d ask you to expand upon how useful the AT “integral constraints” will be, and how best they can be employed in “ocean models”.

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Duda, Tim:
received 12 April 2006

Thank you for the work thus far on the ORION OOI program.

I would like to say that from my view the process has been very fair-minded and well managed so far. It is difficult to merge all of the objectives of the different oceanographic subdisciplines. I agree 100 percent with the April 9 recommendations of Peter Worcester and Bruce Howe concerning low-frequency acoustic assets for the purposes of thermometry and float/AUV navigation (tracking). Here are three comments:

Note that the Worcester et al. and Duda et al. RFA proposals have similar objectives and suggest similar infrastructure. One acoustic source at each global site would be sufficient, rather than two as written in in the March 15, 2006 Global network draft. The Worcester RFA suggested a lower frequency band than the Duda RFA, but the measurements to be made are not frequency specific to the degree that a single system at each of the pertinent sites would enable the studies outlined in each proposal to be made. (To be clear, the plan included 2 acoustic sources at a few sites. Only one is needed, as long as it is of the appropriate type.) This is merely a detail, but the attainment of goals mentioned in the two RFAs with a unified acoustic system is an important detail. Next, note that the prospect of ensonifying an ocean basin for a long time period would allow a time series of deep float trajectories to be collected, helping to define the mean and variability of deep transport in a manner not obtainable with itinerant source mooring deployments funded through the usual short-term funding cycles.

Finally, acoustic source assets mentioned at this time for the global network could also be deployed at RCO or cabled coastal network locations, should the locations prove suitable. The power and data transfer capabilities of those sites could then be applied to acoustic measurements of much greater spatial scope. The water would need to be deep enough to reduce problematic interaction of sound with the seafloor.

Worcester, Peter and Howe, Bruce:
15 April 2006
response to Doug Luther 10 April 2006

I didn’t think that you would be surprised by anything in our 3” x 5” card, as you’ve heard it all before. Your questions are all good ones; indeed such questions have been rare in the discussions of the ocean observing system. Let us respond to them in turn.

1. Vertical sampling. As you know, the vertical sampling provided by acoustic methods depends on the ray path structure. This means that the vertical sampling properties depend strongly on the sound-speed profile, the range of the tomographic path, and the effects of internal waves in scattering the later arriving rays, and so reducing their utility. In mid-latitudes where there is a deep sound channel, the rays cycle above and below the sound channel axis. There is then a fundamental “up-down ambiguity,” in that it is impossible from the acoustic data alone to tell whether a sound-speed perturbation is above or below the axis (Munk et al., 1995). The implication is that in mid-latitudes the acoustic data would need to be combined with Argo and other upper-ocean data in order to determine the extent to which observed sound-speed perturbations are located above or below the axis. In theory, Argo and other data could be used to subtract the upper ocean signal from the acoustic travel times, leaving the signal from the deep ocean. It is very much a research issue to sort out just how well this would work. (Indeed, Brian proposed such work to NSF a couple of years ago). The result will depend strongly on how well the other measurements constrain the upper ocean.

In contrast, in subarctic and polar regions, where sound-speed increases more-or-less monotonically with depth, the ray paths are all surface-reflected. In this situation there is no up-down ambiguity, and the acoustic data directly provides unambiguous measurements of the deep ocean. There are generally a variety of rays turning at various depths, providing depth resolution. At longer ranges, however, this depth resolution may be reduced because many of the shallower-turning rays may no longer be adequately resolved. The vertical resolution obtained depends on the richness of the ray path structure, specifically on the lower turning depths
of the ray paths, and therefore depends on the source-receiver geometry, the detailed sound-speed profile, and the effects of internal waves on the actual resolution of the ray arrivals in the recorded signals. This issue is discussed briefly in our Conceptual RFA proposal, in the section entitled “Role of the abyssal ocean in storing heat.”

2. Integral constraints. With respect to HOME, we too were surprised that both the bottom pressure and tomographically-derived currents in HOME, which seemed somewhat at odds relative to the prior model, were found to be consistent with Egbert and Zaron’s tidal model and were able to be simultaneously assimilated into it without large changes in the overall modeled tidal dissipation. However, the conclusions from the data assimilation are not yet final, and the issues are sufficiently unique to the tidal modeling in this case [best discussed elsewhere], so that we think that one cannot conclude from the HOME case that integral data fail to provide valuable constraints on basin-scale ocean models.

Taking the tides as an example, however, note that the effectiveness of modeling and data assimilation depends on what it is you want from the model. A single pressure measurement does indeed adequately constrain surface elevation of the tides over a large area, though it may not constrain currents. If you wanted just elevation you’d be happy. However, a single Argo profile does not similarly constrain the large-scale thermal state of the ocean because of the small-scale noise issue. Tomography does constrain the large-scale thermal state. But neither data could be said to provide much resolution of currents - Argo by the movement of the drifters, tomography by reciprocal transmissions, or perhaps indirectly by constraints on heat transport.

With respect to the ORION case, I think that the relative contributions of point data (e.g., Argo) and integral acoustic data to constraining the large-scale thermal variability in the models is a research issue. Some preliminary work that Brian Dushaw has done shows that the acoustic data gives substantially lower uncertainties for range-averaged temperatures than similar averages constructed from Argo data along the acoustic path, largely because of the noise inherent in the point data and the relatively few Argo data available in the general vicinity of any given acoustic path at a specific point in time. The nominal spacing of the sampling from Argo is 300-km. This is discussed briefly in our conceptual RFA proposal, in the section entitled “ATOC and Argo Profiling Float Data.”

This is not quite the same question as asking how well the different data types constrain the large-scale variability in a GCM. The answer will depend on how many acoustic paths there are in any given basin. A small number of acoustic data can constrain the large-scale model behavior and statistical, path-integral properties of the smaller scale behavior. A large number of acoustic data can start to resolve individual features of the smaller-scale variability.

The best way to use integral acoustic constraints in an ocean model is clear. It must be done within the context of ocean data assimilation so that all the data types be considered at the same time because they all have different properties pertaining to model resolution. For this purpose and from the very beginning ATOC has had a strong modeling and data assimilation component:


Several members of ATOC (Wunsch, Cornuelle, Menemenlis) are now working on the ECCO project, which
during the past seven years has developed methodologies that allow quasi-optimal utilization of all available oceanic observations in GCMs provided that (i) the observations can be related to model variables and (ii) reasonable estimates for the data errors exist. During this same period, the resolution and realism of ocean simulations has evolved to the point where it is now possible and sensible to propagate acoustic transmissions directly through the model fields. The classified nature of the ATOC/NPAL data and SOSUS geometry have kept us from using this data in constraining the ECCO model. But the technology to do so is available and it would be applied to any acoustic data collected by ORION.

Schultz, Adam:
received 19 April 2006

I’d like to comment on a few areas of the draft D&I report. This is in regard to:

Page 11 - right hand column - Global Scale Observatory Science Priorities:
1) Seismology is misspelled. Also - the “seismic sites” have always intended to be “geophysical sites” - that
is, multidisciplinary. The boreholes are required for installing broadband seismometers - to assure they are well
coupled to the seafloor; but the observatory infrastructure has always been meant to support other geophysical
measurements as well. Specifically, observatory-quality long-period magnetic field measurements, and
goelectrical measurements, have been part of the planning process for selecting these sites for many years,
and have helped inform the location of these sites. It would be prudent to add a line indicating that the “bore-
hole observatory sites will also support geomagnetic, geoelectric and where appropriate, geodetic observa-
tory measurements”. We’ve been using “seismology” as shorthand to stand in for “geophysics”, but in this
sort of document, it is important to indicate that there is a larger constituency and a larger range of scientific
problems than earthquake tomography that has driven the selection of these sites, and the expensive ODP
drilling activities that took place there.

Page 28-29 - the RCO working models. Regrettably, the organization of the Salt Lake workshop meant I had
to spend all of my time in the Global Group, where input was needed, and I was not able to attend the RCO
meetings. Having seen what has been produced in the RCO meetings, I am concerned that the scientific jus-
tification for the run of cable running north from Nedonna Beach, through the Willapa Bay array (N6) then west
past N5, ultimately connecting to Axial at N4 - seems weak.

I discussed with people involved with designing the Willapa Bay conceptual instrumentation array whether
they really needed a cable connection, and was left with the distinct impression that they would just as eas-
ily be able to work with inexpensive coastal buoys - i.e. it is really a Duration Array in the coastal observatory
sense. If that is the case, and if the intention is NOT to connect N5 to N8, then it would seem there would be
enormous savings to be made by running the RCO cable straight out from Nedonna Beach to Axial, and form-
ing the cable loop that way (under the assumption that a loop is really required at all - I understand the redu-
dancy argument for it - although the redundancy comes at a very high cost).

The savings made by straightening out the northern spur of the Stage 2 loop could be turned into additional
funding for instrumentation for the RCO, and perhaps for expansion of the global buoy array by at least one,
if not more sites. these are the two most glaring problems in my view - the underallocation of resources for
RCO instrumentation, and the underallocation of resources for additional global sites.

The position of the RCO advocates at Salt Lake was that “this is our one chance at cabling, so all the re-
sources should be going to that; and that the funds for instrumentation would appear later”. I understand why
that view has developed, but I think that approach is risky. Data will need to stream down the RCO ASAP,
or Congressional oversight will not be a smooth process. The RCO was always intended (and sold) as the
“first” RCO - not the only one. One could equally argue that a somewhat smaller cable array - with many more
instruments - is more likely to generate the scientific outcomes that will lead to the future ability to lay more
cable and extend this paradigm - than would a larger array with little instrumentation. Congress won’t care
about the route of the cable lay - but it will care about a conspicuous lack of scientific return in short order...
The instrumentation is the big issue to me - not the cable. The cable with no instrumentation has no intrinsic value. The observatory IS the instrumentation. The data transport/power infrastructure isn’t the end-goal - the data from the instrumentation is the key. So I recommend that this issue be reviewed very carefully.

NSF core science simply does not have the capacity to build the instrumentation needed to populate an empty RCO - and NSF cannot afford to have an unpopulated observatory. Anyone can look at the NSF budget increase projects, factor in inflation and super-inflationary operating expenses (ship time, salaries, benefits) and see there will be no significant capacity to fund instrumentation at a faster rate than today. Remember ARTFAB? This program was sold on that basis - but the tide is definitely not rising - so it is best to be prudent and assume that the MREFC will bear all the core infrastructure costs - and this includes the bulk of the instrumentation. This is a change from a couple of years ago - but I think this is fiscal reality.

The view by some proponents of the RCO that private foundation and other non-NSF money can somehow be raised to meet the $25M (I think an underestimate) required for instrumentation is risky - it puts NSF at risk, and Congress may ask why NSF is counting on private Foundation funding to complete its own project. It also introduces various ethical questions. For instance, say a Bill Gates (or similar) person decides to bestow largess on a given scientist - so that scientist is privately funded and not subject to peer review. Will that scientist, now equipped with privately-funded instrumentation, be in a position to exclude other peer-reviewed NSF-funded scientists from gaining access to the RCO? There are only so many ports and so much bandwidth. If it takes longer for a peer-reviewed scientist to obtain instrumentation than someone who has received donated, private foundation money, then this scenario is possible - the ports and bandwidth may be gone. Certainly it is desirable to consider supplementing an NSF project with private partnership funding - this is leveraging - as long as the rules are consistent with NSF policy - but is it right for NSF to hinge the success of a high profile MREFC program on as yet unspecified private foundation funds to complete its core work? That makes me very nervous... It seems farfetched to assume other agencies (NASA, USGS, NOAA) can fill in this gap. Anyone familiar with NASA’s change of mission will see this is unlikely, and the FY’07 budget isn’t pointing in a direction that suggests other agencies will be in shape to provide instrumenting at this level. Perhaps this will turn around eventually, but I think we need a healthy data stream almost from the start - or this WILL be the only RCO.

It seems that by routing the cable more optimally to match the scientific requirements, funds should be sufficient to cable the major science nodes, to populate them with instruments, and to increase the number of global sites (which are far too few). If a run of cable isn’t strictly required on scientific/technical grounds - and the current scenarios seem to have hundreds of km of unnecessary cable, then this seems to be a misallocation of resources. This view won’t necessary be popular, but I think it does need to be looked at again.

Page 25 - top line - “there was a sense that approx 20% of the available support should be allocated for sensors...”. There was quite a bit of discussion about this - and I don’t think a clear consensus was reached. I personally advocate for 25-30% as a better figure (some others shared this view). I also feel that we should be attempting to make as many sites as possible truly multidisciplinary. There is the risk that the available sites will simply be designated as “Phys. Ocean” or “Solid Earth”, and there will be no cross-fertilization between disciplines.

One comment outside the Draft D&I report - there was a difficulty in the process leading to the RFA responses. Time was limited, and it was not possible to involve all groups/constituents in all parts of the process (as for me I was involved in 4 RFA responses, and couldn’t do more). For instance, for fairly trivial reasons, the sections in the RECONN report (and other earlier reports leading in to RECONN and the OOI) that included magnetotelluric and controlled source EM measurements within the RCO, were not part of any of the submitted RFA responses. In discussions with those submitting RCO responses, it was indicated that this could be added later. It is not clear when or where this can be added. These sites also benefitted from mid-plate locations - so this does help argue for at least one mid-plate node in the RCO. There is an MT/controlled source EM component in reserve within NEPTUNE/Canada (lead PI - Nigel Edward, U. Toronto), and similar efforts for time-dependent EM (as in RECONN) should be reinserted into the planning process at this stage. How do we
Thanks, and sorry to be playing the devils advocate! I know there is a legitimate range of views and disagreements within the community over the level of acceptable risk, with RCO and Global being the two end-members with regard to provision of instrumentation with the MREFC, and coastal somewhere in the middle. There is also a great deal of tension over the scope of cabling and integration with NEPTUNE/Canada. I think that as soon as we consider the reality that the “Stage 1” and “Stage 2” RCO cable lays may end up being physically independent (and the sooner we take a decision one way or another, the better), then possibilities such as those raised in my comments become real - with attendant cost savings. Anyway, I’d be interested to hear what STAC thinks about this.

Sosik, Heidi:  
received 19 April 2006

I attended the breakout group on Biogeochemistry and Ecosystems described in Section 5.2 of the draft D&I workshop report. The section represents a reasonable summary of the diverse topics discussed, however, I believe the last sentence is really incorrect. The sentence reads, “No consideration was given to regional or global ORION assets and larger-scale connections.” (p. 0)

My recollection is that we had a discussion of global and regional sites that would be relevant, especially for assessing climate signals propagating from the larger northern hemisphere system to coastal zones. I recall consideration of the role of specific sites in the northern and subtropical Pacific and in the north Atlantic, combined with appropriate sites on the continental shelves. Jim Yoder would likely be able to provide more details on which global/regional sites emerged and the motivation for their selection. I also recall discussion of global/coastal connections being a critical component for other focus areas, such as research involving the migratory patterns of large animals.

Yoder, Jim:  
received 21 April 2006 in response to Sosik comment

I agree with Heidi’s comment. It is true that there was virtually no discussion, nor comments from the audience in response to my invitation to comment or make a brief presentation, specifically directed at biogeochemical cycling in the open ocean using the global assets. However, there was a presentation to the group by Breaa Govenar related to the non-sunlight driven ecosystems associated with various seafloor environments, and and she specifically stated (in response to my question) that the research areas she promoted could be well-served using RCO assets. In addition, I made the point in my summary to the Plenary that the ocean climate system has major impacts on ecosystem, biogeochemical and other processes on North American ocean margin waters via ENSO, PDO and NAO and that to understand these effects, we needed data from global assets. I specifically mentioned NOAA assets in the Equatorial Pacific, the proposed open ocean observatory site near or at “Papa” and something in the Labrador Sea. I also pointed out the advantages of linking the proposed NW U.S. margin observatory (along the California and Oregon coasts) with the RCO, since the effects of the PDO will propagate from N to S, and thus through the RCO site, before reaching ocean margin waters off Oregon.

Jumars, Pete:  
received 24 April 2006

Attached please find suggested revisions of the draft report of the Salt Lake City Meeting (mostly typos and grammar issues). Three might bear some scrutiny by someone in addition to your copy editor:

(1) The opening quotation (p. 1) appears to have some missing text.

Bartlett’s lists it as:  
I find the great thing in this world is not so much where we stand,
as in what direction we are moving:
To reach the port of heaven,
we must sail sometimes with the wind and sometimes against it,
—but we must sail, and not drift, nor lie at anchor.
OLIVER WENDELL HOLMES, The Autocrat of the Breakfast-Table, p. 93 (1891).

(2) There is a set of comments on p. 7 directed at the authors of that section. Waters traceable to slope water make it very close to shore, particularly in the eastern GoM but at least as far as Penobscot Bay. More importantly, the role of the cabled instruments was never envisaged as a sentry of physical changes, which would be best detected considerably upstream and would not require the power and bandwidth of a cabled system. The cabled instruments proposed were aimed primarily at mid levels in the food web that require high power and bandwidth to resolve their targets. Thus to be useful the cable has to be downstream of the phytoplankton response that is forced by the physical signal.

(3) Those of us on the Gulf of Maine RFA proposal would like to see a structure for our section on p. 22 that is parallel to that for the Hawaii and SAB sections that sandwich us in the text. Because you may also find it easier, I also provide those changes in the text below and as a Word attachment with track changes showing our proposed changes. All the bullets come from the original summary in our RFA response.

Gulf of Maine

The Gulf of Maine is a semi isolated basin, simplifying the task of modeling and measuring its outer boundary conditions and inputs. Fresh water from the Scotian shelf drives the overall circulation in the gulf, which comprises two separate, cyclonic eddies. Deep water is exchanged mostly through the NE Channel. Temperatures of the eastern gyre are controlled by the influx of deep water and are generally correlated with the North Atlantic Oscillation. In general, heating and mixing of colder waters coming down from the north, especially at the boundary between the two gyres, provide a strong thermal gradient that represents the northern limit of many temperate species and the southern limit of many arctic boreal species. Thus, the ecology and species composition of this region is expected to be sensitive to climate variations. In addition, this region displays extensive and repeated outbreaks of harmful algal blooms.

The revised plan presented at the meeting is to install a cable to 20 meters, which will be one of the few sites on the eastern seaboard where muddy, accumulating sediments can be reached within a modest distance from the coast. Glider lines and independent buoys are proposed to monitor water motions and properties in the far field from the cabled nodes.

Science in this section fell under the general question of “How does climate variability effect change in primary productivity and benthic-pelagic coupling in the Gulf of Maine (GoM)?” Highlighted issues included:
- Interannual variation in delivery of Labrador Slope Water versus Warm Slope Water.
- Phytoplankton response (type and abundance) to delivery versus local conditions as water is transported southwestward, eventually into the western gyre.
- Benthic processes (including non-invasively measured bioturbation) affected by phytoplankton inputs and boundary-layer flows.
- Benthic-pelagic coupling, especially by vertically migrating mysids sensitive to both benthic and planktonic conditions.
- Use of benthic sonar to provide a coordinate system (x,y,z,t) for benthic experiments and a measure of observatory artifacts (reef effects).
- Accelerated development of cabled, scanning sonar, PIV and holography.

Emphasis was placed on assessing forcings that propagate to mid levels in the food web, requiring power and bandwidth that only a cabled system can provide.

[note in proof: Peter Jumars also provided corrections for numerous typographical errors as well as errors of grammar and style throughout the report. Corrections were welcome and incorporated but are too numerous to list here.]
The following information includes comments on the roles of ocean observatory science and engineering at Station ALOHA relative to the global component of the ORION Design and Implementation Plan. Some elements of this document were part of a “water column” component of an RFA response that was submitted for ORION global observatories (and thus a formal part of the workshop input), and some elements were discussed at the workshop. The important matter of the relationship of ocean observatory efforts at Station ALOHA to the ORION project was raised in plenary by NSF program management at the ORION D&I Workshop, but there were no opportunities at the workshop to adequately address the various and complex issues that are involved. This document attempts to rectify that rather unfortunate situation.

Please let me know if you have any questions regarding this input. We hope that it will be useful to you in developing the best possible plans for a successful ORION project.

The Case for Station ALOHA as an ORION Global Observatory

Although Station ALOHA is an existing time-series site, the establishment of a global observatory there as part of ORION will be transformative, using new technology that is not now available to enable important new scientific studies that are not now possible. This would be a wise investment of ORION resources for several reasons that are given below.

Scientific Research

More than 17-year long time-series measurements of physical and biogeochemical properties at this deep-ocean site provide a very rare and incredibly valuable foundation for new interdisciplinary oceanographic studies. Newly established ORION global sites will not have the important temporal context needed to understand the nature of variations at the site, and such context will require years of continuing measurements (cf. Karl et al., 2001). Innovative ORION science can start now at and around Station ALOHA, with full climatological context (e.g. Corno et al., 2006).

At least one of the sites in the global observatory array for ORION should be in a subtropical gyre. Subtropical gyres cover a major fraction of the surface area of the oceans, and they include unique ecosystems that are affected by, and contribute to climate variations. Station ALOHA is near the center of the North Pacific subtropical gyre far from basin margins and in a unique mesoscale eddy forcing regime. The fact that it has simpler logistics than many other proposed ORION sites is a plus for sophisticated process studies.

The old subtropical gyre paradigm of a simple one-dimensional (vertical) balance between time-mean advection and diffusion nutrients and other biogeochemically-active compounds has given way to a time-varying, fully three-dimensional balance where eddies are no longer simply lumped in with other unresolved processes and labelled “diffusion” (Karl et al., 2001). Episodes of strong surface flux forcing and Ekman pumping, modulated by interannual climate variability, entrain nutrients and other upper pycnocline properties into the surface layer. These pycnocline properties are set by air-sea interactions in remote locations and advected into the gyre, subject to variability at their surface sources as well as to variable advection (Lukas, 2001). Mesoscale eddies not only perturb the vertical velocity field and the depth of the pycnocline, with subsequent impacts on productivity (Letelier et al., 2000), but they also enhance vertical mixing and also may result in long-range transport of water properties up property gradients (e.g., Lukas and Santiago-Mandujano, 2001).

A recent genomics-based survey of the microbial community at Station ALOHA from the sea-surface to the sea-bed has revealed the presence of many novel genes that were differentiated by habitat depth (DeLong et al., 2006). The future application of these and related molecular techniques will likely transform our understanding of open ocean biology and ecology in the near future. A fundamental strength of the DeLong et al. (2006) study was the fact that it was conducted at a well sampled site and had a comprehensive environmental context for its interpretation.
An important process study that will be enabled by the OOI infrastructure and the ORION project would focus on separating the influences of along-isopycnal eddy transports of ecologically important properties from their influence via vertical advection and mixing. This requires the multi-variate high resolution observations at observatory sites in conjunction with spatial coverage that can only be provided by mobile platforms such as gliders. Using state-of-the-art data assimilation techniques and high-resolution ocean circulation models, gliders would be directed to sample eddy genesis regions that are most likely to produce eddies that will impact the particular observatory site. Following these eddies over time and along their pathway with gliders will quantify their interaction with their environment. As they arrive at the observatory site, their ecological impacts will be quantified in a comprehensive manner, including measurements that can only be conducted from shipboard. To do this work successfully will require research in predicting mesoscale eddy movements, and will require numerous cases to provide high statistical confidence in the results. This absolutely requires the sustained ocean observatory infrastructure.

This long-term process study will require both fixed depth, high-resolution time-series and high vertical resolution profiles of physical and biogeochemical properties at the observatory sites (in conjunction with comprehensive air-sea flux measurements). The APL-modified McLane Moored Profiler is being developed now with NSF funding (Howe, Lukas and Boss, co-PIs) and is scheduled for testing at the MARS observatory in Monterey Bay in 2007. This improved profiler mooring is designed for cabled observatories, but can be adapted for the autonomous ORION global observatories if they include an adequate source of power. The adaptive sampling that is enabled by this profiling system is essential for deconvolving the influences of vertical and horizontal processes in the presence of a rich spectrum of temporal variability.

On larger scales, the North Pacific Ocean displays interdecadal variability in both physical and biological time series (e.g., Chavez et al., 2003). “Regime shifts” occurred in the mid-1970’s and, possibly, in the mid-1990’s, for example. The ALOHA Observatory is an ideal - and essential - acoustic tomography node site linking the coastal, regional cable, and global components of ORION in the North Pacific (see Worcester et al. ORION RFA concept proposal). With similar nodes at PAPA, the RCO, MARS, and possibly DART buoys in the future, higher spatial resolution measurements can be obtained to study the structure of gyrescale variability more directly. (The geometry of nodes is of utmost importance in an acoustic network.) The integral constraints provided by the acoustic data combined with ocean models can be used to study changes in the shape, position, and intensity of the subtropical and subarctic gyres in the North Pacific in response to wind-forcing and other events, such as ENSO, enabling the long-term sampling needed to improve our understanding of seasonal, annual, interannual and interdecadal gyre-scale processes. With a tomography array as part of the RCO and links to the coastal components, this is an explicit example of a transformative nested, coupled array made up of all three ORION components.

Infrastructure Development

Transformative science engenders risk, as the planners of ORION are now confronting. The program managers of the National Science Foundation understand well that scientific research and discovery is fraught with uncertainty. However, the National Science Board, in overseeing the Major Research Equipment and Facilities Construction activities of NSF, obviously seeks to minimize the risk of failure to provide transformative infrastructure for the Nation’s basic research enterprise.

An ORION global observatory at Station ALOHA, whether cabled or autonomous, would provide a critically important test bed for new OOI technology, complementing the MARS 3 observatory in Monterey Bay. Water depths of about 5000 m are available only 2 hours from Honolulu, which has excellent logistics including superior research vessel support. Current ORION plans are to deploy new global mooring technology first at remote sites, such as the Southern Ocean off Chile. Testing the equipment and mooring deployment techniques first at ALOHA will reduce the risk of failure at sites for which even annual maintenance visits will be difficult. This is particularly critical with respect to experimental biogeochemical sensors, where waiting a year to recover and redeploy them at remote sites will severely slow the pace of development. As new molecular techniques are developed, including the emergent genomic sensors, the observatory at Station ALOHA
would be an excellent test bed for their evaluation. The history of efforts to develop an observatory at Station ALOHA provides examples of risk and uncertainty. Fred Duennebier, Dave Karl and Lukas were funded by NSF to transform the Hawaii Ocean Time-series into the ALOHA Observatory by reusing a nearby abandoned copper telephone cable for power and two-way, real-time communications with instruments and sensors connected to a seafloor junction box. Bruce Howe, Emmanuel Boss and Lukas were funded by NSF to develop an enhanced version of the McLane moored profiler for deployment at the ALOHA Observatory, to continue the time-series and to conduct research on adaptive interdisciplinary sampling of the water column. While this new infrastructure would require significant research vessel support for deployment and maintenance, we realized that it would also allow better use of valuable ship time for water sampling and enhanced scientific studies. It would support the continuation of the increasingly valuable time-series at Station ALOHA, while enhancing the infrastructure for experimental oceanography.

We experienced a serious setback when the company that was about to transfer ownership of the copper telephone cable went into bankruptcy. This was not something that could have been reasonably anticipated. AT&T offered one of its abandoned fiber optic telephone cables for the ALOHA Observatory, which provides more electrical power and much larger bandwidth for communications than the copper cable. However, the junction box required extensive modification and extra funding to convert electronic signals from oceanographic instrumentation to the optical signals required to use that cable. These funds were not available, and the program was put on hold. While working to solve this problem and take advantage of the new opportunity, the project was put on hold by NSF program managers when the H2O observatory experienced an unfortunate failure. A lengthy review was undertaken to determine whether the University of Hawaii junction box design was at fault. While this review was highly appropriate, the process was seriously encumbered and drawn out by unfortunate and unpleasant politics. During this time, however, a retired AT&T engineer solved the interface problem for us at a cost that was an order of magnitude less than originally believed, and the project is now on-track for installation.

The ALOHA Observatory junction box will soon be completed. The deployment is waiting for a cable ship to pick up the cable, terminate it, and move it to Station ALOHA. A deep-sea Remotely Operated Vehicle is required to connect the observatory junction box, and to plug in instruments. Because of the delay in our schedule, the ALOHA profiling mooring will be deployed at the MARS observatory some time during the next year. We hope to move it to the ALOHA Observatory, or install a replicate, after sufficient experience with operations at MARS. These initial observatory operations at MARS and ALOHA will provide essential experience with activities that are critical to the success of the ORION project, and that need to be conducted routinely and with minimal failure. MARS and ALOHA offer logistically favorable test beds to work out problems in observatory deployment and maintenance, forming the basis for “best practices” for the ORION project.

Going Forward

We think that a strong science and engineering case has been made for establishment of an ORION global observatory at Station ALOHA, with a high priority. Whether the global observatory deployed at Station ALOHA is cabled or autonomous is a decision that should be made after careful consideration of several factors. It makes sense for the ORION project to take full advantage of the substantial investments in the long time-series at Station ALOHA, and to attempt to fully leverage the previous development of infrastructure for a cabled observatory there.

In addition, we have recently established a new Center for Microbial Oceanography at the University of Hawaii. Research in the Center will be linked to ongoing activities at Station ALOHA and will be leveraged with financial support from the Gordon and Betty Moore Foundation (GBMF) and the Agouron Institute who have both recently established long-term initiatives in marine microbiology. Karl, a founding HOT program PI, and a recently designated GBMF investigator in marine microbiology, will serve as the Center Director which will ensure close collaboration among these related programs.

The successful development of the cabled ALOHA Observatory depends on the broad involvement of the research community, however that involvement depends in subtle, but critical, ways on the sense of potential
principal investigators that it will be successful. At issue now is whether the operations and maintenance of ALOHA will be supported by NSF. At the current priority ranking, it is not clear that this support will be forthcoming soon enough to allow smooth transition of the observatory infrastructure from R&D to operations. Funding will be required starting in 2007.

A Scientific Advisory Group is being assembled, made up of an interdisciplinary group of investigators from a variety of US institutions. In consultation with this group, and we hope with ORION, we plan to develop an operations proposal that will include support for ongoing costs for land-based infrastructure and data communications, data management, and governance. We expect that the proposal will be submitted as a consortium effort.

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**Howe, Bruce and Worcester, Peter:**

*received 15 May 2006*

Comments on the D&I Workshop and Draft Report

Good draft. Some of the following is rhetorical, some though if very concrete. I hope my informal style is useful.

**General comments**

Please be sure to address all the comments submitted before, during, and after the workshop. My understanding is there were not so many, and so it is manageable to explicitly respond to each (with a message to each person as to how their comments were addressed).

During the committee meetings of 1-3 May, Doug Luther circulated some of the comments, but not all. The ones I submitted at the workshop were not included, and ones submitted afterward by Dushaw and Duda were not. The comments by Worcester, Duda, and Dushaw (each separate emails/docs) are of especial interest to me, and are included elsewhere in this document.

IF the OOI slips out of the budget this year, NSF should push hard to get the funding level increased for the
next attempt, more realistic and in line with what is really needed (and better matching expectations).

There still needs to be a uniform treatment and description of how sensors and science funding will happen. There should be some concrete scenarios used to illustrate the various possible proposal paths/timelines and funding sources (perhaps based on the more detailed RFAs), over the entire life of the program. Some of the OOI “infrastructure” will be “secondary infrastructure” called for by RFAs. There has been no peer review of this – so will significant infrastructure be installed to support science that has not been peer reviewed (and is quite specific to a single topic, e.g., all the geophysical sites like Endeavor, Axial, Blanco, 9N, etc)? At a minimum, will RFPs for science at a particular site/sites/network be issued for science? In my and others thinking, sensor secondary network infrastructure was to have been funded by “community experiments”. NSF has not stated how large community experiments can be funded (other than more workshops/time/etc). Are there any intentions to issue specific science topic RFPs – or will it really just be part of “core”. How is phasing of large and small experiments handled? So budgets are satisfied.

Funding any observing system in this day and age without rigorous observing system simulation experiments (OSSEs) is not scientifically or fiscally responsible. How does ORION intend to enforce OSSEs before committing significant funds?

Considering that “acoustic buoys” are now operational within NOAA/DART, they are no longer in and of themselves transformational (like EOM and Spars). This contradiction should be addressed. Should there be less emphasis on acoustic buoys and more on the other flavors (needing more money)?

The present CND design was not done with any real accounting of O&M costs, and lifetime cost considerations. This is a great weakness. It is coupled with a lack of definition of how sensors and science will be funded over the long term, flavors of money, etc.

Specific comments

P3 bottom right. : In order to expand the spatial “footprint” around junction boxes, acoustic modem or extension cable links up to 100 km will be employed. Mobile assets (e.g., ROVs, AUVs, gliders) and supporting acoustic tomography, navigation and communications networks are essential elements of the OOI infrastructure that further extend and resolve the spatial coverage of the observatories and link components together.

P4 lower right 3. Provide opportunities, in the context of these intense infrastructure discussions, for the formation of collaborative groups focused on developing future, observatory-based, integrated research projects. Was there any success in this at the workshop. My impression was people were so occupied with the more "global" picture to deal with this.

P 6. Evening sessions were also organized to facilitate information exchange on specific topics of critical importance to the OOI/ORION effort. These sessions were: I organized an informal meeting Sunday evening of the workshop aimed at the scientific users of acoustics. Given the other evening meetings, I should have made this more public and on the official agenda – the opportunity to do so was not advertised. Should this acoustics meeting be mentioned here in the report – 20 people attended (I sent ppt around). For future workshops, the process for having “officially sponsored” secondary meetings (on the agenda) and white papers posted on the ORION web site needs to be more open. Perhaps with a more explicit treatment of scientific uses of acoustics within ORION, this will resolve itself.

5.1. Physical Processes/Climate Variability

Group Leaders for the breakout were Charlie Eriksen, Roger Samelson, David Farmer and Roger Lukas. Rapporteur was Katrina Hoffman.

This group focused their discussions on two major science themes. These were:

Examine the connections in climate signals between the open (deep) and coastal ocean.
Examine variability of vertical and horizontal mixing in the ocean.
Here is the comment Brian Dushaw wrote:
2) Prof. C. Eriksen’s summary of the Physical Oceanography breakout group conclusions omitted an important aspect of our discussions. Several of us discussed the role of long-range acoustics in global ORION (lar-gangian float tracking, large-scale thermometry), although not much time was available to thoroughly discuss this or any other subject. It is unfortunate that there have been few, if any, serious discussions of the ARGO v. thermometry issue during the many workshops/conferences I have attended the past several years, and that another opportunity to have this discussion was lost - seems to me a rather suspect way to approach sci-ence. In any case, Prof. Eriksen gave no mention of acoustics in his plenary summary. Should Prof. Eriksen’s report become an official record of the ORION workshop proceedings, however, I wanted be sure the discus-sions we had concerning the observation of large-scale thermometry/basin dynamics through acoustic re-mote sensing and lagrangian float tracking were included in that record.

Mixing
With the exception of mixing and basin-scale tomography, the global array design is not focused on other compelling physical oceanographic issues. As a physical oceanographer, I am extremely displeased with the phrasing of this statement – it is as if physical oceanography has not really compelling issues. Could say: Mixing and basin scale thermometry and float tracking were identified as compelling physical oceano-graphic issues. Then mixing discussion, then thermometry/float tracking – from Worcester and Duda com-ments below.

Global Pioneer array – a question that was raised is “how is this different from any typical present NSF core project”? There was no good answer given (in my opinion). (many current projects often deploy a number of moorings) What is the funding process here?

Calibration for climate and consistent data processing
It was recognized by the participants that there is a need to promote system-wide calibration and consistency in data processing. The goal is to have a data set that will be a long term resource for retrospective climate studies. It was recognized at the workshop that certain instruments were more robust wrt calibration, i.e., those systems that basically measure time, such as tomography, have no calibration issues.

P 18 - Ocean acidification – instruments – include acoustics – the absorption of sound as a function of fre-quency is a function of pH (~300-800 Hz is optimal). The importance of the ocean acidification problem should be more highlighted. Being only a lay person in this regard, my gut reaction is acidification will be a large problem than warming in the long term…

P19 Hazards to navigation, undersea volcanism, ice (scouring, bergs, etc.), surface gravity waves (wave climates):
These represent challenges, and we contribute to mapping these hazards. Although this is not a primary goal, we will make contributions (maybe helping ship routing).
Instruments: bathymetric surveys to shore, directional wave buoys, hydrography, seismic arrays,
sea floor acoustic and optical imaging
add acoustic arrays here to map large area surface noise field = wind field.

P21 – need to address – how long will a pioneer array actually last – O&M, and will the hardware even exist after a 5 yr deployment. Will pioneer array 2 have to be part of the next OOI?

P24 AUV discussion – how is subsurface navigation and communications handled – acoustically?

P25 what are the policy implications of adding coastal components to MARS. MARS could never come to a clear statement if it would support long term science installations rather than just be an instrument test bed. This has impacts on how other “test bed” sites are treated, e.g., HOT and BATS.
P26 - and nine water column moorings (two moorings to the north are non-cabled moored profiling buoys). It was recognized that the RCO is in a unique position to serve as an integrator of science at the global (Station PAPA and ALOHA), regional, and coastal (west coast endurance and pioneer arrays) scales.

P31 In the spirit of the MREFC, there needs to be strong links between the coastal and global programs. Although some of these science linkages were outlined in the draft CND for the RCO, they are not fully developed and the three components of the OOI are not well integrated in the coastal and global CND’s Acoustic networks provide an explicit connection between coastal, RCo, and global/basin.

P31 Consideration should be given to the tradeoffs between a full scale mooring experiment, or fewer moorings with a suite of core instruments how will these core instruments be chosen – peer review proposals/RFPs/?

P31 Full water column moorings that breach the surface should be considered to allow characterization of sea-atmosphere exchange
A suite of water column moorings should be considered, one that has a surface expression (e.g., for met measurements), one for profilers, and one for fixed instruments (e.g., high power active acoustics for fish and tomography)

P34 In addition, it was recognized that acoustic thermometry paths and acoustic navigation and communication geometry should be considered in the final siting of the global observatory buoys.

P34 – Argo, not ARGO (do global replace)
The fixity of sites must also be made clear if they are to host long-term acoustic thermometry and navigation and communications nodes.

To provide a spatial context and examine far field influences, a lagrangian component at and between sites was also suggested, supported by the above mentioned acoustic network.

Finally, it was noted that a relocatable “Pioneer” array capable of deployment in the deep sea could provide important spatial resolution (from 10s of km to gyre scale)

p35 The group thought that better development of the Lagrangian component (with supporting acoustic navigation) would serve longer-term science needs although no specific science questions or issues were posed.

P35 This system could be deployed around selected global mooring sites for a pre-set period of time to examine horizontal spatial scale features (from 10s of km to gyre scale) not observable by the central mooring array itself.

• Modify the draft CND in accordance to recommendations from the RIDGE and MARGINS programs. Clarify the fixity of the global sites to permit long-term planning of acoustic thermometry experiments and acoustic navigation and communications nodes.
• Investigate the possibility of implementing a lagrangian observing component at and between global sites, supported by acoustic navigation.
• Investigate the possibility of developing an open ocean “Pioneer” array consisting of relocatable subsurface moorings and associated gliders, on scales from 10s of km to gyre.
Coordination of the ORION Global Array with Existing Ocean Observatories

Coordination of the ORION global array with existing ocean time-series observatories has many substantial scientific and logistical advantages that will broaden ORION scientific benefits while simultaneously providing the infrastructure and operational capabilities to address the science needs of the large, established oceanographic community that conducts research at time-series sites.

The comments below outline the many benefits to be gained by establishing a global ORION site that is coordinated with the ongoing time-series programs at Bermuda (i.e. the 50+yr Hydrostation S, the 28+ year Oceanic Flux Program [OFP], the 15+ yr Bermuda Atlantic Time-Series [BATS], and 12+ yr Bermuda Testbed Mooring [BTM], atmospheric studies at Tudor Hill, BM). Similar benefits also exist for establishing ORION sites at the HOT and PAPA time-series sites.

- **ORION will provide the novel and innovative technical and operational capabilities that are needed to answer fundamental, global questions concerning climate/ocean coupling that have been posed by the Bermuda time-series observations.** Studies of the northern Sargasso Sea region have been key to our present understanding of biogeochemical cycles within mid-ocean gyres. The Bermuda time-series site sits at the northern edge of a transition between relatively eutrophic waters to the north and oligotrophic subtropical waters to the south, and is sensitive to large scale climatic forcing such as the NAO. Synoptic scale weather systems typically pass every few days and hurricanes every few years, Weak surface fronts and energetic sub-mesoscale and mesoscale features introduce variability in physical forcing, while aeolian dust input may stimulate plankton productivity and alter species composition.

The long data records from this region have clearly documented that important ocean drivers operate across multiple spatial and temporal scales. It is now known that short-lived, episodic surface phenomena (e.g. passage of mesoscale features, hurricanes, atmospheric dust deposition) play an important role in structuring ecosystems and biogeochemical cycles over longer time-scales.

An overarching question is posed by the Bermuda time-series studies: How will changing physical forcing due to climate change perturb surface ocean ecosystems and in turn, the fluxes of carbon and other materials to the deep sea and seafloor? The answer is critical because alteration of biogeochemical cycles in the oligotrophic gyres is certain to have global consequences.

At present the time-series programs at the Bermuda Observatory (and other time-series sites) are unable to fully tackle this important question because they lack the infrastructure and operational capabilities to sample the multiple time and space scales over which important ocean drivers operate and over which the biogeochemical consequences occur.

ORION is poised to truly transform the nature of Bermuda time-series research and long-term observatory science. A coordinated deployment of ORION observational platforms (moorings, gliders, floats) at Bermuda will enable us to fully characterize, for the first time, the time and space scales of ocean drivers and to assess the nonlinear, and complex response of ocean ecosystems and biogeochemical processes to this forcing. ORION cyberinfrastructure and real-time 2-way communications will provide a new capability at Bermuda for event-based deployment of “opportunity” cruises and control of measurement and sampling protocols of moored instrumentation to optimally measure how variability in external forcing (for example hurricanes, severe storms, eddies, etc) affects ocean biogeochemical processes. The ORION subsurface infrastructure will be especially transformative for study of phenomena operating within the ocean interior, much like how development of remote sensing allowed surface features sampled by ships to be placed in a mesoscale spatial context.

- **Establishment of an ORION site at the Bermuda time-series observatory leverages the long history of sustained NSF investment in this region and scientifically benefits a long-established and cohesive regionally-
based oceanographic community. The unsurpassed history of ocean and atmospheric observations in the northern Sargasso Sea region provides many value-added benefits of ORION investment. The fundamental questions are well documented; the infrastructure and operational capabilities needed to address these questions are clearly defined.

ORION infrastructure and cyberinfrastructure has a chance to bring a coordinating influence to the time-series observatories resulting in a large enhancement in organizational capabilities with a small investment of funds. The priming of ORION data management with real data early on will also help development of this system. In addition to direct benefits to the ongoing time-series research, numerous shorter duration studies are conducted by collaborators who utilize resources (sample materials, ship time and mooring platforms) and data products of the time-series programs. ORION investment will benefit PI directed science as well.

- **Establishment of an ORION site at the Bermuda time-series site will provide a clear demonstration of technical feasibility at the earliest stages at very low risk, and will deliver significant results early in the program.** Strong scientific synergy will immediately benefit both ORION and the time-series programs. The four-dimensional sensor network on ORION observational platforms (moorings, gliders, floats) provides a more complete oceanographic context for the time-series observations, and the infrastructure’s novel capabilities will enable the time-series programs to target activities for maximal scientific benefit. In turn, the ongoing time-series programs generate a suite of observations on ocean and atmospheric parameters that can not be measured using sensor infrastructure (e.g. detailed analyses of recovered sample materials, various biological rate measurements, fluxes, etc). These products will bring greater context to the ORION data streams and significantly increase the scientific value of ORION investment. Because of mature time-series sampling techniques, new ORION measurements can immediately be assessed for stability and repeatability.

- **A northern Sargasso Sea site off Bermuda has many important logistical and cost advantages.** A deep water (4500 m) mid ocean site can be reached within a six hours steam from Bermuda, providing a much lower cost basis. The newly refit 170’ R/V Atlantic Explorer based at BBSR is fully capable and expressly configured for large mooring and ROV deployments and instrument operation and maintenance. The short transit time from its BBSR base provides unsurpassed flexibility in cruise scheduling for extended or multiple short cruises. Short deployment periods for development of prototype sensors and cyberinfrastructure hardware are possible, and even a return to port for re-engineered elements. The location also provides for a short response time if unscheduled servicing is required, significantly reducing downtime. Existing moorings (BTM, OFP) are potentially available for deployment of ORION sensors, increasing the spatial array coverage at low infrastructure cost. Much of the needed logistical support is already in place at BBSR so an ORION site can easily be up and running by 2008.

- **BBSR will provide a well-equipped and convenient base for seagoing ORION educational initiatives.** BBSR has onshore classrooms, labs and hotel accommodations for resident student activities. The R/V Atlantic Explorer has a dedicated, fully equipped teaching classroom and can berth up to 15 students for seagoing education. In summary, establishment of an ORION global site partnered with the ongoing time-series observatory at Bermuda will be truly transformative and establish a new operational mode for the ocean time-series observatories. The proposed ORION activities and the observational programs of the ongoing time-series efforts are highly complementary. By providing the infrastructure and operational capabilities to characterize the ocean’s four dimensional structure, ORION can greatly benefit the established time-series community. In turn, ORION program benefits substantially by building upon an existing science base and logistical infrastructure. A coordinated ORION/TS partnership presents an unparalleled opportunity to study in depth the coupled interactions among ocean physics, biology and chemistry, and their links to atmospheric and climatic forcing over multiple scales. The leveraging of existing NSF investment at Bermuda will bring major and immediate scientific benefits with only a minimum expenditure of ORION funds.