

NOAA Pacific Marine Environmental Laboratory (PMEL)
Review

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This report is a compilation of verbatim comments from each of the
members of the review team

General

The PMEL is one of NOAA's two major ocean research laboratories, AOML being the other. It focuses on equatorial dynamics (atmosphere and upper ocean), ocean acidification issues, the ecology of the Bering Sea and Gulf of Alaska, ocean bottom vents and related geology/geophysics, and its tsunami research program. Some of these activities have advanced quite far; others are just starting, are exploratory or haven't been given the same priority as others. The focus is in part obviously geographic, the North Pacific, but for the case of equatorial processes and tsunami research the field activities extend to all oceans.

Being a federal laboratory rather than an academic institution or private research activity, the activities should not be evaluated merely as if it were an academic institution since its charge and responsibilities differ significantly. This is more than a qualifying distinction, it is one that must be clearly identified because the measures used to evaluate the productivity of the laboratory must include means for recognizing and giving credit to those activities that cannot be measured in terms of peer-reviewed papers. While PMEL recognizes this, it is curious that NOAA's 2008-1012 research program says very little about the need to better chart the climate and temporal change in the oceans. The 5-year plan is strong (impressive) on the need for NOAA to meet societal needs, but to meet those short-term needs interest is limited to the near-surface of the ocean. But NOAA is the only institution in the US (world) that is capable of developing a long-term capability to systematically track the state and trends in the ocean, but virtually all these activities are limited to conditions of and at the sea surface. For example, I could find no mention of the importance of the Argo and TOGA-TAO activities in the document?!

Dr. Bernard asked if there are any activities that are missing from PMEL's portfolio of activities. It seems to me both NOAA labs could afford to be far more aggressive in mounting long-term observation programs of the ocean water column (**recommendation #1**). Everybody agrees on the need for these (recall the session organized by Dr. J. Baker and others at the recent Ocean Sciences meeting in Orlando). Argo is a step in the right direction, but it has a limited measurement suite, and has low spatial and temporal resolution. This is not a trivial comment given that Argo misses the most energetic scales in the ocean – those set by the radius of deformation. NOAA should consider a more deliberate effort to measure currents and fluxes in selected areas (**recommendation #2**). While one would like to focus on areas that might be sensitive to climate change, the key thing is to get started rather than remain paralyzed over what models may or may not think are the best measurement sites and strategies; good judgment accounts for a lot too. NOAA, if anyone, must be at the cutting edge of ocean observation, in skill, scope and perseverance.

Numerical Modeling

Some of the NOAA/PMEL groups have benefited greatly by close integration of the field observational program with numerical modeling (e.g., EcoFOCI and the tsunami group). Having an in-house modeling capability has accelerated the data-model cycle and allowed for preliminary network design studies. The PMEL climate and carbon cycle groups have collaborations with external modeling groups, but these collaborations are more ad hoc. Given the challenges of both climate and carbon cycle modeling, it would be infeasible to build self-sufficient in-house modeling groups in these disciplines, but both groups would benefit from more systematic ties to external groups and some internal hires with modeling experience (**recommendation #3**).

Access to Ship-Time

A core strength of NOAA/PMEL is expertise on subsurface ocean observations, which depends strongly on access to sea-time on research ships for instrument deployment/recovery, sampling, and validation. Future ship-time availability NOAA/PMEL researchers, however, may be threatened by new NOAA procedures for allocating NOAA ship-time (which in some cases may be decreasing the priority level for research uses over other NOAA line applications) and by the rising costs of ship operation. Transition to autonomous platforms is helpful but will not resolve in the near term the problem for specific PMEL relevant data (e.g., hydrography below 2000 meters not covered by ARGO; spatial transects in seasonally ice-covered eastern Bering Sea; high-quality carbon system parameters; exploration of hydrothermal vent systems). Further NOAA-supported ship-based research is critical to several national and international partnerships such as the CLIVAR/CO₂ Repeat Hydrography Program. Issues with the performance of the NOAA ship Ronald Brown during the Southern Ocean Gas Exchange Experiment earlier in 2008 had significant negative repercussions on the research for this joint NOAA/NASA/NSF field effort. NOAA/PMEL needs to continue communicating with NOAA headquarters on this issue (**recommendation #4**).

Technology Development

A number of NOAA/PMEL's high-profile successes have depended on close integration of technology development and on-site engineering capabilities with the science (e.g., DART tsunami warning buoy system; surface pCO₂ moorings; gas-tight water sampler; autonomous hydrothermal sensor). But many of these developments, particularly at the early stages, have been done in a rather ad hoc basis. The laboratory would greatly benefit from a more formal seed-fund that would support pilot studies for technology development and higher-risk concepts (**recommendation #5**). The results from these pilot studies would provide the data to leverage follow-on proposals to NOAA or other agencies.

Cooperative Institutes

NOAA/PMEL depends strongly on the cooperative institutes, and a substantial fraction of the PMEL scientific staff is hired through the cooperative institutes. The benefits and drawbacks of such a system, however, were not discussed in much detail in the formal review. Because of the heavy dependence on the cooperative institutes, there is the

possibility of developing a two-tier system for scientists. This is a crucial issue to the long-term health of the laboratory and to the mentoring of junior and mid-career scientists. In informal conversations, it was noted that the cooperative institutes adds flexibility to the laboratory in terms of adjusting staff size, moving rapidly in new scientific directions and tapping into federal funds external to NOAA. But others highlighted that the procedures for promotion & salary raises for cooperative institute employees was opaque and that there were not clear mechanisms for transferring long-term scientists from the institute to the federal side of the laboratory.

Data Management:

The NOAA/PMEL laboratory should be commended for the long-term investment in data management, which has led to success such as the Live-Access Server (LAS) and the tsunami database. A number of new data management challenges are either emerging or already here, however, including the transition of the tsunami modeling to operational status and the possible formation of a National Climate Service. Further data management investments will be required, likely at levels above present allocations to address these issues (**recommendation #6**). In particular, the laboratory increasingly will have to address not only supplying data but providing it to stakeholders in more sophisticated and multi-faceted forms for decision support.

Long-term laboratory strategic planning:

At the review, the laboratory made a strong argument that the current suite of research activities is relevant to NOAA's new strategic plan in that the NOAA/PMEL activities could be matched to a sub-set of NOAA's overall objectives. A near-term path for each of the existing research groups was also outlined. Less clear was any long-term strategic plan for the laboratory. The present collection of research themes appears to be partially a historical accident of past scientific staff hires. There was no clear sense of whether the laboratory plans to move into new areas of research (which could also be strongly relevant to NOAA's overall objectives), how priorities are set across the laboratory, and how (if) the decision would be made to phase out one of the existing research themes to support other areas. This is closely linked to transition planning for the retirement at some point of some of NOAA/PMEL's science leaders. Further, it was unclear how NOAA/PMEL interacts with the other OAR labs so that all of NOAA's research needs are met.

Staff Development

NOAA/PMEL has a number of distinguished, senior-level scientists with accomplishments that match those of scientists at any top-tier institution around the country. Less well resolved during the review, however, is the quality of the larger number of mid-tier scientists and the extent to which some of the more junior scientists are developing strong, independent research programs. A strong, explicit mentoring program and base of upcoming mid-career leaders needs to be in place within the laboratory for a successful transition plan (succession plan) when the current crop of senior people retire or move (**recommendation #7**).

The overall strategy and purpose for the ecosystem forecasting was not clear. Is this activity in support of regulation? At what time scales is this activity targeted toward? Is it the centennial time scale of climate change projections? Is it the seasonal to interannual time scale of deterministic climate prediction? Or is decadal variability of prime interest? The committee heard mention of each one of these time scales.

In the final wrap up, a vision was presented for buoys everywhere in the world ocean, but for what purpose?

The concept of a Tsunami Testbed was presented. While testbeds have become fashionable within NOAA, the design and purpose of the Tsunami Testbed seems at odds with many of the others within NOAA. The Climate Test Bed, the Hurricane Test Bed, and the WRF Test Bed are designed to accelerate the transition from research to operations. Specifically, targeted areas of applied research are identified and the external community is invited to compete for resources in order to accelerate progress in these specific areas. The thinking behind the Tsunami Test Bed does not seem to be as well developed or as consistent with the other test beds within NOAA.

Other than the ocean carbon presentation, the synergistic role of the in situ ocean observations (e.g. in physical oceanography or tsunami monitoring) that PMEL obtains with respect to remotely sensed ocean observations and links to the satellite side of NESDIS was woefully lacking. There seemed to be little attempt or interest in being cognizant of present and future satellite systems and how PMEL's activities could benefit or contribute.

I'm very impressed with the combination of early identification of important problems, long-term commitment to address those problems, and the general high quality of work at PMEL. Probably the most important comment I have is: whatever you do, don't break it! **(recommendation #8)** The fact that PMEL has focused on a few important problems and has resisted spreading resources over too large a problem domain appears to be a key element of the strategy which has allowed PMEL to be successful with a comparably small budget (\$30m/year is the number we were given). Although the structure of the review is 'by area,' it is clear that the laboratory is managed as a whole, and since it seems to be working extremely well.

One observation I would make is that PMEL benefits tremendously from being part of a network of organizations which conduct oceanographic science and develop oceanographic instrumentation. For example, the DART moorings are enabled by acoustic communication technology pioneered at MIT and WHOI. The pCO₂ sensor was originally developed at MBARI. The gliders being used for boundary current measurements were developed at Scripps, University of Washington, and Webb Research Inc. I mention this because federal laboratories do not always interact effectively with academic and not-for-profit research organizations. I believe that the effectiveness and prosperity of PMEL is likely closely tied to its ability to 'play well' with organizations

outside of the NOAA umbrella, and should be supported and encouraged, both at PMEL and at other NOAA labs.

PMEL functions as an element of a network of NOAA entities. These other entities were largely invisible for our review other than in Dr. Bernard's initial presentation. It would have been useful to be briefed on the effective division of responsibilities between various NOAA entities within the specific research areas (**recommendation #9**). For example, NOAA's climate activities are spread across several laboratories, and it is hard to evaluate PMEL's effectiveness without understanding the division of responsibilities which has evolved in the overall enterprise.

The statistics and budgets provided for the overall lab were useful, but would have been more useful if broken down by research area (**recommendation #10**). I did this myself for publications, but someone more familiar with the laboratory would have probably done a better job.

Overall, PMEL is a most impressive operation. The top echelon of leadership and scientists are outstanding, and could be working at any one of the top research Universities in the US or Europe.

I happen to know that PMEL scientists are very active in public education and outreach activities, so it was surprising not to have heard more about such activities as parts of the discussion of research in the four broad areas. Given the importance of scientific workforce issues to the US, this discussion would have been welcome.

Several of the posters and some of the presentations had the initials PSU on their salinity plots. Salinity has been measured on the practical salinity scale since 1978. Practical salinity is a dimensionless ratio. As one of the lead government oceanographic laboratories, PMEL must make every effort to assure that the initials PSU are NEVER used with salinity (**recommendation #11**). It is unfortunate that SeaBird Electronics continues to use PSU as an indicator of salinity on their data plots. I spoke to two chemical oceanographers at PMEL and they acknowledge that PSU is meaningless. I encourage PMEL management to reinforce this with all their scientists and technical editors.

The review was conducted in a very professional manner. It was obvious that a tremendous effort was made to present a vast amount of information succinctly. The level of preparation by the researchers was impressive.

My one suggestion for the next review would be to provide some time for writing by the review team and establish an expectation that draft comments would be provided before the review team departed (**recommendation #12**). National Sea Grant reviews provide this time and the review team has a draft set of comments complete before they depart. Having time to focus and write during the review would provide more timely and perhaps better formulated review comments.

As a preamble to my very positive review of the tsunami program, I would like to stress that the PMEL tsunami group is greatly overworked trying to achieve too much in a very short period of time, and at the expense of scholarly publishing. PMEL is now "writing history" in tsunami hydrodynamics, it is now that it should be publishing aggressively. Instead, it has focused on serving the nation and the NOAA, and balance has long been lost. The publication record, while far above average with papers in Science and the Philosophical Transactions and even the Scientific American, needs to continue to grow with both high and lower profile publications as well as lab reports (**recommendation 12.2**). The group needs at least one or two additional PhD level scientists to help spread the work load (**recommendation #12.5**). If I were reviewing their publishing record for an NSF proposal, I would give them a very good. I would give them an excellent in impact and outreach.

Area 1: Ocean Climate Observations Research (Quality, Relevance, Performance)

This activity is certainly one of PMEL's crowning achievements. My sense is that it is strong on all fronts, the moored arrays, the ocean carbon and acidification programs, gliders, Argo, engineering and atmospheric chemistry. Some of these are more advanced than others. For example, the TAO array is in the process of being transferred to the NDBC. Perhaps Argo will follow in its steps in a few years? Questions were raised about the institutional cultural and scientific adjustments that will follow from these transfers. For example, the NDBC runs an operation, not a research program. All in all, and some of the pain and uncertainties of 'letting go' notwithstanding, the transition may be a good thing for it will free and indeed encourage PMEL scientists to pursue new cutting-edge issues.

An example of a new initiative would be an expansion of the glider program (or at least some of its objectives) (**recommendation #13**). However, I am far from convinced gliders are the best tool available for measuring boundary currents and transports, C-PIES are far more accurate and cost-effective for this purpose. But I agree gliders are still in their infancy and there is very likely a lot of learning yet to better delineate the power and potential of these vehicles. Gliders, or more accurately fleets of gliders, may prove very effective at better charting the eddy field of a region and its temporal evolution. But suppose PMEL does decide to measure fluxes at various sites across the Pacific, not merely WBCs, but also their extensions, flows through passages, across ridges (Aleutians), and develop the technology to assimilate such information in (near-) real time using gliders or simpler versions as modems, PMEL could become the world leader at monitoring the ocean as a dynamic or evolving system, not merely its state as a function of time. The distinction is important: measuring flux variations gives a heads-up on future states. Measuring state alone gives only partial insight into the dynamics leading to that state. Tracking and resolving both will eventually lead to a much better understanding of the oceans.

The Ocean Climate Station program is another young program with lots of potential. As with the other buoy programs it focuses on the surface and atmosphere. An oceanographer would welcome a heavier investment in monitoring the water column too. Given the technological prowess of the institution it seems to me much more could be done here (**recommendation #14**). While it no doubt is a question of priorities and resources, I sense that a more aggressive instrumentation activity is in order. Maybe the instruments can't go on the main mooring line? Consider a parallel long-term subsurface mooring with a 5-year(?) life cycle as goal. Maybe even small arrays of subsurface moorings with 100 km acoustic telemetry capability to the surface mooring (the data would have to be preprocessed and compressed, but that's u-processors are for). The acoustic telemetry should include both scalar and vector data. Then you could resolve the eddy field and examine eddy-mean flow interactions, eddy fluxes; all questions of enormous interest. Even though the moorings are motivated and justified primarily for surface observations, this way they can be used for the water column too. We still know next to nothing about low-frequency variability in the ocean – especially of currents. Significantly, any investment in these activities would be a small fraction of the existing TAO array in terms of both hardware and ship time. It is perhaps a concern that with the technology transfer to the NDBC there will be less flexibility for adding these capabilities?

The PMEL Argo program is very well run. The group partners closely with other Argo centers in the country. These are all run as research activities, but the PIs understand the need for both quality and continuity. One senses that these activities may eventually be transferred to the NDBC. But this is something I would 'hurry slowly' with because there is still a lot of learning going on, including the addition of more sensors. Of course, there is absolutely nothing that says that NDBC can't run the main program and various groups continue to explore Argo for more focused research initiatives.

In summary, the ongoing OCRD is strong in quality, relevance and performance. The above comments are not criticisms, but thoughts on how it might focus some of its resources in the future. The strength of the program is enormous and that must be a significant plus when it comes to attracting and hiring new young talent.

Quality

The NOAA/PMEL Climate group has several high-profile, quality observational programs lead by senior level scientists who are acknowledged international leaders in their fields. The quality of their work is evident clearly through the substantial number of publications, citations, awards, national and international leadership roles, etc. These scientists (e.g., Feely, McPhaden, Bates) rank as some of the best in their fields whether in academia or national laboratories by any metric. There are also some stand-out mid-career scientists (e.g., Johnson, Sabine).

The top tier personnel of the Ocean Climate Research Division are truly first-rate and world class. Be it physical oceanography or the ocean carbon cycle, a number of the personnel that briefed the review team are preeminent in their field. These scientists are

at the front rank with researchers at any Tier 1 university or any leading international institution. Having said that however it is unfortunate that the committee did not have much opportunity to hear from or interact with the full range of staff.

A unique strength of the laboratory is the science-engineering synergy that exists to support ocean climate observations. This represents not only a NOAA asset, but an international one as well. This is best illustrated by the success story of the TAO expansion via PIRATA in the Atlantic and RAMA in the Indian Ocean solely as a result of PMEL leadership. One particular concern is the role and responsibility of PMEL during the transition of the TAO moorings to NDBC. The TAO Transition Plan was written in 2004. Four years have passed and it does not seem that there has been an objective or independent assessment of how well the transition process is working. Outstanding questions remain as to who has the oversight responsibility to ensure the climate quality standards of the data stream after the transition is complete at a time of level or decreasing budgets. What are the metrics for monitoring TAO transition impact on research quality ocean climate data? Similarly, will the oceanographic research community continue to have access to the TAO array as “platforms of opportunity” for additional or new sensors or for enhancement and use in targeted process studies? Another area of concern was that for an agency in which observations play such a key role, there does not seem to be anywhere that PMEL can turn within NOAA to access technology development funds for new observations.

Historically, another particular strength of the lab has been its work to provide data to the larger oceanographic community via the Live Access Server. For a lab that rightfully prides itself on the observations it obtains, this is an important activity that is deserving of greater visibility and attention (**recommendation #15**).

PMEL’s Ocean Climate and Observations Research program makes up a large fraction of PMEL – 75 out of about 200 employees, and is outstanding on a variety of fronts:

- this group has played a central roll in measuring acidification of ocean due to increasing atmospheric CO₂
- the team continues improvements in understanding of ocean-atmosphere coupled oscillations, including
 - improving understanding of ENSO
 - understanding coupling of Indian Ocean forcing to ENSO
- the group plays an important role in measuring the overall heat content of the oceans
- the study of Arctic climate is contributing to the understanding of the dramatic reduction in summer ice extent in the Arctic
- the publication track record is very strong (as reviewed below)
- the group has made key contributions to global ocean observation capability, including
 - establishing and growing equatorial mooring array
 - substantial contribution to Argo array
 - experimentation with boundary current observation capability

- improvement and broad application of MBARI pCO₂ sensor
- development of technology to support atmospheric chemistry at sea

I used the PMEL Publications document and the 2007 & 2006 lists of papers to understand the distribution of publications by discipline. Of the top 20 publishing scientists at PMEL 11 or 12 are publishing on climate topics.

Name	Pubs.	Cit.	H-index
Feely, Richard, A	174	5005	38
Mcphaden, Michael J	167	5646	41
Bates, Tim	114	5443	41
Overland, James E	93	2097	29
Quinn, Patricia K	93	3270	33
Harrison D E	90	1811	26
Johnson, Gregory C	63	1357	23
Bullister, John L	52	1941	23
Sabine, Christopher L	48	1474	18
Johnson, James E	41	1198	23
Lavelle, J William	60	1165	19

(JISAO)

Note that some of these individuals are published in multiple areas, for example William Lavelle has VENT program related publications as well.

The H index developed by Jorge Hirsch is described as having the following significance:

“Hirsch suggests that after 20 years in research, an h of 20 is a sign of success, and one of 40 indicates "outstanding scientists likely to be found only at the major research laboratories". An h of about 12 should be good enough to secure university tenure, he says, and fellowship of the APS, for example, should occur typically for an h of 15–20, and of the NAS for an h of about 45. In 2005, new NAS members in physics and astronomy had an average h of 44.” *From: Philip Ball, “Index aims for fair ranking of scientists,” Nature 436, 900 (18 August 2005) | doi:10.1038/436900a.*

Consequently, it is clear that the cumulative publication history of individuals working on climate is impressive. There are a large number of multi-author papers, reflecting the team- oriented nature of work at PMEL, and the interdisciplinary nature of work. However, this may distort the publication index, e.g. an associate scientist who has engaged in routine activity in support of a leading PMEL scientist, may have a higher publication index than another associate scientist who is beginning their own independent research direction. Clearly both activities are valuable to PMEL, however the point is that in an environment like PMEL, the use of publications as an indicator of creative contribution might provide some misleading results.

Finally, the excellence of PMEL’s climate program is also reflected in the large number of awards accumulated by its researchers, including in 2008 the NOAA Administrator’s

Award, the Department of Commerce Bronze Medal, and election of Dr. McPhaden to President Elect of AGU. In 2007, among other awards, five PMEL scientists participated in the Nobel Peace Prize awarded to former Vice President A. Gore and the IPCC.

In observations, there is no question that PMEL is one of the leading laboratories addressing climate change and the uptake of carbon dioxide into the ocean. The number of publications by McPhaden, Feely, Sabine and others is a testament to the quality of the work. The tropical Pacific work on El Nino has established PMEL as perhaps “the” world leader in long term, high precision oceanographic measurements.

Relevance

The climate observational components are clearly relevant to NOAA’s objectives, and the NOAA/PMEL group is making critical contributions to international ocean observing system through the Argo profiling floats, moored tropical arrays (TAO/TRITON, PIRATA, and RAMA), CLIVAR/CO₂ repeat surveys, extratropical flux moorings, and surface CO₂ underway systems.

The laboratory is well-placed to move into some emerging fields relevant to NOAA’s overall mission. For example, within ocean carbon, present laboratory scientists have led efforts to define the scientific framework for ocean acidification and develop new national and international programs in this area. Ocean acidification could serve as an important theme to bridge across many of the research groups within NOAA/PMEL by connecting the water chemistry studies to ecosystem impacts and the discovery-exploration of CO₂ release by underwater volcanic systems (**recommendation #16**). Similarly, NOAA/PMEL could play a role in the scientific assessment of ocean carbon mitigation and geoengineering strategies such as iron fertilization and ocean CO₂ injection.

The ocean climate observations obtained by PMEL represent a fundamental underpinning of NOAA’s climate program and its move toward the development of a National Climate Service. In this regard the interaction between the Ocean Climate Research Division and Mike Johnson’s Ocean Climate Observation Program in Washington is a model working relationship between a field center and the larger overall program managed within the Climate Program Office with oversight and guidance by the larger overall ocean climate research community. While it is often fashionable to criticize NOAA for lack of coordination across line organizations the performance and delivery of the PMEL Ocean Climate Research Division is an excellent example of the synergetic working relationship between a NOAA program office (e.g. Mike Johnson) and an OAR lab. OCRD implements, deploys, monitors, and provides access to ocean climate observations, while performing world-class research. In parallel the program office in concert with the various NOAA line organizations determines the programs goals interacts with the academic community, national and international science programs, and provides overall guidance to observational priorities and accountability. Given that the Ocean Climate Research Division is closely tied to and supportive of Mike Johnson’s program it would

have been instructive to have received the perspective of Mike Johnson or meet with him one on one (**recommendation #17**).

Although beyond the control of PMEL, the labs efforts suffer to some extent in that NOAA as an agency does not have an operational or routine ocean data assimilation system for state estimation of the ocean climate. While NOAA has some work directed toward the initialization of coupled ocean-atmosphere prediction models, it does not have a dedicated effort for monitoring the ocean climate. The impact of this is that the sustained demand or pull for the observations that PMEL provides is not as defined as they could or should be at this point, nor are these observations being taken advantage of to the extent possible.

This program directly addresses the NOAA Strategic Plan goal: “Understand Climate Variability and Change to Enhance Society’s Ability to Plan and Respond.” The Strategic Plan identifies several actions which support the goals. Of the five actions listed, PMEL’s climate activity most directly addresses: “Monitor and observe the land, sea, atmosphere, and space to create an observational and data collection network that tracks Earth’s changing systems,” and “Understand and describe how natural systems work together through investigation and interpretation of information.”

There are two ways to evaluate this program, the first is to ask whether the problems the program is taking on address national needs in line with the NOAA strategic plan, and the second is to ask whether how completely the programs are meeting those needs.

For the first question, it is clear to this reviewer that PMEL’s research efforts are highly relevant. For example, the work on ocean acidification has gained national exposure in recent Congressional testimony by Dr. Feely. (<http://www.google.com/search?source=ig&hl=en&rlz=&q=Feely+congressional+testimony>). This is particularly noteworthy in that ocean acidification was of concern to a comparatively small number of scientists only a few years ago. As with the Tsunami research program, this is an area where PMEL is to be commended in identifying and pursuing research areas well in advance of much of the climate community. It is also clear that PMEL’s contributions to creating a global ocean observing capability for climate have had a profound impact, providing an international community of climate researchers with invaluable data to understand such processes as coupled ocean-atmosphere oscillations as well as enabling the study of global warming.

The question of how completely PMEL’s climate program is meeting national needs is impossible to answer without a better understanding of the relationship of climate research programs at various NOAA entities. However, the question is worth raising. As our understanding of anthropogenic climate change improves, the risks appear greater. Thus it seems likely that NOAA’s climate program will have to ‘operationalize’ in a manner analogous, but on a larger scale than the Tsunami program has had to undertake. Consequently, a good planning exercise for OAR would be to ask how one might scale up efforts in various NOAA laboratories (**recommendation #18**). PMEL could play a

leading role in such an effort both because of the excellence of its ongoing efforts, and because of its close ties to academic research organizations, which could be strong allies.

Understanding climate change is paramount to NOAA's mission and PMEL has taken the lead in using its technological capabilities and its scientists to make some significant progress in several areas. Most notable and most mature is the ENSO work through the success of the TAO array that is now being transitioned to NDBC. The carbon dioxide and ocean acidification work is moving in a similar direction. My assessment is the PMEL is leading the nation in our understanding on ocean acidification and the potential effect on ocean ecosystems. While PMEL is conducting this work worldwide, the importance of ocean acidification is especially important in the Bering Sea because of the economic importance of the fishery.

Performance

The overall performance of the climate and carbon cycle groups is high. There are a number of specific issues, however, that are either a concern now or could become an issue in the near-term:

More effort is needed to demonstrate the importance and utility of the tropical oceanographic data products to seasonal to interannual forecasts (in conjunction with stronger two-way interactions with the "clients", weather and seasonal climate forecast groups) (**recommendation #19**).

It is not readily apparent that the comprehensive plan was in place for the transition of the tropical Pacific mooring array to the NDBC operational group within NOAA. For example, the NOAA/PMEL group should be involved in developing a strategy for maintaining climate quality data, that is data that can be used by the research community as well as seasonal climate forecasters (**recommendation #20**).

The role of the NOAA PMEL research effort in a possible future NOAA Climate Services organization will have to be carefully designed in order to clarify the boundary between research and operations, the prioritization of field efforts, and the two-way information exchange required to translate field observations into decision support tools (**recommendation #21**). This is both an opportunity and possibly a major challenge to the current workings of the laboratory.

The present funding model for many NOAA/PMEL PIs involves heavy reliance on funds from the NOAA Climate Program Office. For projects such as CLIVAR/CO2 Repeat Hydrography and Argo these funds are dedicated to support the making of the observations but does not provide the scientists with adequate time and resources required to actually analyze their results. This is not a healthy situation and endangers both the long-term quality of the observations and the ability of the laboratory to attract and retain the best scientists.

The NOAA/PMEL carbon program has been quite successful both nationally and internationally and has shown extensive leadership both in leading field efforts and in

developing a national ocean carbon science agenda. The long-term health of the program, however, may be threatened by several emerging issues listed below.

The U.S. component of the CLIVAR/CO₂ Repeat Hydrography program is a very successful, high profile field program jointly supported by NSF and NOAA. There are serious concerns that NOAA will not be able to hold up its end of the program if the problems with NOAA ship-time allocation, already noted above, are not resolved and CLIVAR/CO₂ program be given high priority either to be given NOAA ship time on the Ron Brown or for NOAA funds to charter an equivalent Class I research vessel (**recommendation #22**).

The recent NOAA/PMEL spearheaded coastal ocean carbon survey along the US West Coast was conducted through one-off support from the Climate Program Office Global Carbon Cycle Program. Given the timeliness of the research findings and implications of the low pH water found along the shelf, this type of survey needs to be repeated on a regular basis and integrated into the NOAA observational network with observational (rather than research) funding (**recommendation #23**).

The departure of the program manager, Mete Uz, for the Global Carbon Cycle program in the NOAA Climate Program Office is worrisome for both the NOAA/PMEL carbon program as well as for the external academic community. The Global Carbon Cycle program has been quite innovative in its support of research cutting across traditional ocean, atmosphere, and land disciplinary boundaries (in ways still not matched by NSF). But GCC has lacked continuity and strong leadership at the program manager level, with 3 relatively junior people over the last six years.

The development of instrumentation to autonomously measure two components of the ocean carbonate system on a mooring (Ocean Station P pH mooring) is a great success story. It would be a great boon for the US and international carbon community if this technology could be incorporated into a wider network of moorings (**recommendation #24**).

The performance metrics we were presented with were rather weak. All the metrics we received were presented in an absolute context, but there was no relative comparison or context with peer institutions be they other NOAA labs, other government labs, or academic institutions. For a mission oriented agency such as NOAA the number of peer reviewed publications need not be the overriding metric. Even though the number of publications is going up, are these numbers significant? For a total of 140 scientists, 81 publications do not come across as a particularly strong total absent other performance measures. During the period 2004-2007 covered by this review, 83 PMEL authors published 323 journal articles in the refereed literature. They also published 22 book chapters and one book. These authors include 40 federal employees and 43 joint institute employees. Moreover, given the strong role PMEL has for obtaining ocean observations, there does not seem to be any performance metric to track and recognize those individuals involved in obtaining ocean observations and making them available to the larger community. Given that the main metric is publications, a

danger exists that this could work against free and timely access to the data by the larger external community if the provision of data is not assessed and recognized by a formal performance measure (**recommendation #25**).

As mentioned above, beyond the interaction with the top tier scientists at PMEL, the review team heard little about the mentoring of junior scientists, succession planning, recruitment of new staff, and career development. It would have been helpful to have had a closed lunch session with just junior staff members and postdocs. In addition, we were not given much information regarding the role and responsibilities of personnel from the PMEL cooperative institutes. Are the CIs viewed as a source of supplemental manpower, what is the breakdown from post doc to senior scientist, are there opportunities to transition to the civil service?

Both great people and high quality instrumentation is needed to make precise measurements in the ocean. One of the real strengths of PMEL that perhaps sets it apart from other NOAA laboratories is the strong Engineering Development Division led by Chris Meinig. It is obvious that PMEL has a gem here and the administration and scientists have been able to use this technology development group to great advantage. The level of innovation by the engineers and the positive way in which they interact with the staff is impressive. This science engineering partnership should continue to be strongly supported as it will continue to yield dividend to future PMEL programs (**recommendation #26**).

Research Leadership and Planning:

This program has a long history of excellence. The investment in ocean carbon measurement has paid rich dividends, providing insights to processes like ocean acidification which were only vaguely anticipated. However, arguably the distinguishing aspect of PMEL's program is its great in situ observational capabilities which have been built up over more than a decade of investments. The legacy of the TAO array continues to pay dividends, and the long term vision of global arrays of moorings is approaching reality. The adoption of technologies like floats and gliders complements the mooring systems, and enables measurements on basin scales and in the boundary currents, respectively.

Efficiency and Effectiveness:

The ability of the program to maintain a vigorous research program, in which scientists publish high profile, much cited papers, while at the same time maintaining an ambitious observational program literally spanning the global ocean is impressive.

A notable feature of observational component of the climate science efforts are the ingenuity of initiatives to improve observational capability achieved per dollar spent. Methods range from the building of international relationships to the development of cost effective technologies. For example, the growing use of external ship time, obtained via collaborative arrangements with other nations is an imaginative way to mitigate ship

expenses. This practice allows PMEL to focus on the elements of a global observation system which it can uniquely provide. The continued development of low cost moorings which are more resistant to vandalism and easier to deploy is particularly commendable. Other organizations such as MBARI, WHOI, and Scripps have been investing in more sophisticated moorings to support complex instrumentation in the ocean. PMEL has chosen to take a different approach enabling distributed networks of moorings. The value of this approach has already been proven with the TAO array, and the combination of international alliances and cost effective moorings is enabling a growing array of moorings which should provide great insights into global climate in the coming decades.

Transition:

This program is transitioning several systems to operational status. The TAO array is being transitioned to NWS/NDBC. The Kuroshio extension current array is being transitioned to JAMTEC. The pCO₂ sensor design is being licensed to industry for manufacture. The easy-to-deploy mooring is being used for research, and as the system proves itself, will likely be a prime candidate for technology transfer to industry.

Area 2: Alaska Marine Ecosystem Research (Quality, Relevance, Performance)

Although this program is one I am not familiar with, I would like to suggest that it consider a more proactive use of Lagrangian techniques to explore, chart and understand the mesoscale dynamics of the region (**recommendation #27**). Much has indeed been accomplished using remote sensing techniques (of the surface) coupled with hydrographic surveys. Four site moorings provide a wealth of information on the annual cycle and longer time scales, but sparse arrays can't give much insight into the structure of the circulation, the eddy field, mixing processes, role of topography. And yet these advective and dispersive processes play a major role in fixing the water properties.

Two techniques could be quite helpful. One is the glider, or more specifically fleets of gliders (single gliders would quickly lose appeal). These can map out basic hydrographic properties and give some ideas of the eddy field. Although gliders are sometimes 'lumped' together with Lagrangian techniques, they are in fact mapping devices, and have little in common with floats. There is probably a lot of learning yet to be gained regarding the power and limitations of gliders and AUVs (**recommendation #28**).

Subsurface floats (below the wind-forced Ekman layer), on the other hand, tell us exactly how fluid moves about in space. Dispersion of clusters gives us insight into scales of motion, displacement of clusters tells us about circulation. Multiple clusters allow one to map out and distinguish between advective, dispersive and mixing processes. These technologies are highly developed for the open ocean, not yet for shelves. But PMEL has a very strong engineering group, and would be quite capable of developing corresponding techniques for shallow water applications.

As for tracking there several options exist. First, the standard RAFOS acoustic navigation, adapted to shallow seas. Second, Argo-like instruments that drift along constantly adjusting their buoyancy to hover a certain distance above the bottom or at some fractional depth (or 'behave biologically' with some program to cycle in the vertical). On some schedule the floats surface very briefly to report its position. Third, the instruments could be drogued like drifters, but rather than hang at a fixed depth, winch and position the drogue to track fluid motion at some depth (as with the previous example). The point is that there are cost-effective Lagrangian possibilities. While Lagrangian data (tracks) don't fit into our Eulerian training or frame of mind, oceanographers are fundamentally interested in how stuff moves about and mixes in the ocean. At heart these are Lagrangian questions and helps to explain why these technologies have been so helpful. These comments should not be seen as a criticism of the very impressive EcoFOCI activities, but as suggestions for how to further improve observation of water column dynamics in a very challenging area.

Quality

The group has also demonstrated quality through both the standard metrics of science success (journal publications, citations, etc.) as well as non-traditional metrics such as inputs to fishery assessments.

The EcoFOCI program has established itself as a leader in the field of integrated assessment of climate forcing and population dynamics through its pioneering work on Walleye Pollock recruitment processes. The field component of the work is conducted in an extremely large and challenging physical setting and the program has very successfully operated in this environment despite the difficulties. The effective integration of modeling, technological advances, and field research has been a key ingredient of program success. The program has also made important contributions to ocean observing system capabilities in the region of operations. The program has established a peer-reviewed publication record per individual per year (since 2004) that meets or exceeds levels for other PMEL program elements and comparable to that of high quality academic institutions engaged in comparable marine ecological research. Other external measures of success -- awards, representation on national and international committees, editorial boards and the active involvement in externally funded programs point to a thriving intellectual environment.

The lead investigators who presented during the review (Stabeno, Napp, Overland) and most others involved with this EcoFOCI program have strong publication records in major refereed journals. The quality of the observations, data analysis, and impact of the results are impressive. Much of what we know about the Bering Sea ecosystem has come from the work of the EcoFOCI investigators and the scientist with whom they have partnered during the past 25 years.

The emphasis on observations for this program is important. Long time series are needed to understand the climate related changes that are taking place in the Bering Sea. Only NOAA has the ability to collect these long time series data and assure the data collection

continues. No other agency can do this in the long term. It is important that NOAA continue to support these time series to assure a quality long-term time series is available for assessing the changes in both ocean climatology and fisheries (**recommendation #29**).

The funding leverage for the Alaska ecosystem work is both good news and a challenge. The high proposal success is a reflection of the excellent science conducted by the PIs. At the same time, the high leveraging presents a challenge in keeping supporting long term activities.

Relevance

The EcoFOCI activity is directly relevant to NOAA's goals on understanding and managing marine living resources as laid out in NOAA's research plan. EcoFOCI combines effectively multi-disciplinary research from two lines within NOAA (research and fisheries) on physical climate (OAR PMEL) and biology (NMFS Alaska Fishery Science Center) to address specific application questions on Bering Sea ecosystems (e.g., fishery stock assessment; climate and environmental factors affecting those stocks; scientific assessment for listing of species to endangered status; scientific input to US Arctic Research Commission Transportation Report). EcoFOCI is a particularly good example of the synergy between research and applications and the utility of NOAA research to the broader NOAA mission.

EcoFOCI has clearly demonstrated the direct relevance of its research through contributions to fishery stock assessment and management of Walleye Pollock and, more recently, through work directly relevant to marine conservation biology on polar bears and ribbon seals. The pollock research has been used to dynamically adjust biological reference points in response to environmental change. The successful partnership forged with the National Marine Fisheries Service should be highly commended as an example of strong within-agency cooperation and coordination to address societally relevant goals (**recommendation #30**). The research conducted and applied in this way makes a strong contribution to meeting NOAA's mission and the work is directly relevant to established NOAA Goal Team objectives. There is good evidence of effective communication with stakeholder groups to ensure the relevance of the research.

As the agency moves toward the definition and implementation of an ecosystem approach to management, the challenge will be to build on the approaches developed by program with a single species focus to a broader ecosystem-wide orientation (**recommendation #31**). There is evidence that this is recognized at the program level and evolving research in the Bering Sea incorporates with broader ecosystem perspective. This direction is to be encouraged if PMEL is to play a leadership role in the transition to a full ecosystem approach to management.

The Bering Sea ecosystem, the location of the EcoFOCI program, is one of the largest fisheries in the world with significant ecological and economic importance. In its broadest sense the EcoFOCI program is directly relevant to NOAA's mission and

represents an important partnership between NOAA Fisheries and OAR. The combination of oceanographers, modelers and fisheries scientists assembled for this program allows a full ecosystem approach to understanding the linkages between the physical and biological systems in the Bering Sea and Arctic.

Of all the programs conducted by PMEL, this program addresses a most important societal need – sustainable production of seafood. With the apparent changes in Bering Sea climatology and the response of the biological system and fishery to these changes, this program is important to NOAA’s mission to understand the long term changes in the ocean.

The program appears to be well engaged with the broad scientific community, the fishing industry, and the indigenous people of Alaska. The PIs have strong records of collaboration which has allowed them to build important partnerships to assure the sustainability of the data record.

Performance

The research components from the EcoFOCI appear to function well. There are significant concerns, however, about the lack of long-term funding and potential loss of continuity for some of the critical observing elements. The moorings, in particular, provide invaluable temporal context for the ship-based observations. In fact, it is not immediately evident that the current number of moorings and network is adequate, and that the program might benefit from a more thorough observational network design study (**recommendation #32**).

On other issues, the ecosystem group is doing a good job in moving from oceanographic observations to indices and models that can be fed into forecasts, assessments. The group is well positioned to address the growing need for better assessments of climate impacts on ocean ecosystems. In this regard, the group would benefit from greater contact with regional climate modeling groups, who could provide projections of future climate change, climate downscaling products and boundary conditions (atmospheric and lateral) for local numerical models (**recommendation #33**).

EcoFOCI has focused on highly visible problems [e.g. through its research on pollock (arguably the most important single species fishery in the nation) and on (newly classified) endangered species such as the polar bear]. Although not directly indicated as such in the review, I assume the priorities and research directions for the program have been shaped by consideration of potential impact on these high profile issues. This approach is appropriate within the context of broad agency goals and objectives in resource management.

There is little question that a dominant emerging agency mandate will be to conduct Integrated Ecosystem Assessments (IEAs) throughout U.S. waters. There are strong indications that NOAA funding will be made available to meet these mandates and it can be anticipated that in not too distant future IEAs will emerge as a full complement to

single species assessments. I would recommend that the program set priorities and research directions to meet the emerging focus on IEAs in support of ecosystem approaches to management (**recommendation #34**).

Without the effective partnerships forged by the program with other NOAA line offices and through its strong connection with the cooperative institute, it is clear that the staffing and funding levels would be inadequate to the task. As it is, the program has effectively leveraged resources to conduct important research on societally relevant problems. In recognition of the important scientific and societal contributions of the program, I would like to see base funding support a higher fraction of the activities of the group (**recommendation #35**). This would allow greater buffering against variation in external funding and therefore help ensure continuity in program elements. A commitment to shaping IEAs in the Gulf of Alaska and the Bering Sea would provide one possible avenue to enhancing base funding in the near future.

The EcoFOCI program shows the value of the partnership with NOAA Fisheries. The changes in Alaskan waters make this a critical part of the PMEL mission. PMEL has created a strong team with partners from the adjacent Alaska Fisheries Science Center. The longevity of this partnership has allowed a strong team to work together to produce important time-series data in an area that is important both oceanographically and economically.

While PMEL has a clear organizational structure for the Bering Sea work and recognizes the importance of this program, the low level of core funding for such a long term program is an area of concern. The four moorings in the Bering Sea are important to the entire North Pacific scientific community that seeks to understand the changes in the region. Because of the low level of core support, there is significant risk that the mooring may not be able to be maintained in continuous operation. The PIs of this program have been creative in leveraging additional funding to keep the Bering Sea moorings operational and to expand their capabilities. PMEL should assure that the basic funding for maintaining these moorings is provided (**recommendation #36**).

While the transition potential from PMEL to another NOAA group is not high for this work, one must realize that not everything can be transitioned. PMEL must decide what is planned for transition and what will be supported in the long term (**recommendation #37**). Unless NOAA Fisheries is willing to support the Bering Sea moorings long term, it is likely that PMEL will have to continue to support these important mooring. As the AFSC-PMEL partnership has produced significant scientific results and a workable model of the climate-fisheries interactions in the Bering Sea, I would envision PMEL continuing this strong partnership and not trying to transition this effort. The two groups have worked together successfully for the past 25 years and this partnership should be a point of pride for both groups.

Area 3: Seafloor Hydrothermal Vents/Ecosystem Research (Quality, Relevance, Performance)

Of all the programs at PMEL the Vents program has the strongest flavor of basic or curiosity-driven research. By this we mean that the studies and resulting outcomes, while of general and societal interest, do not appear to couple that tightly to immediate needs or issues. On the other hand, there is SO much we have no idea about with respect to the deep ocean, that it is highly appropriate for NOAA and PMEL to push these activities. Much technology is being developed (sonar methods for bathymetric mapping, deep ocean vehicles, sampling techniques, ...) and these have spin-offs in many directions. We have only begun to scratch the bottom when it comes to questions of gas and heat exchange, sources of minerals and unknown chemical and biological species that may have value to humankind. What makes much of these studies particularly challenging is that these hot spots (vents) are intense and highly localized. What is the integrated or global impact of all these sites? It may be quite a bit larger than we think given our ignorance of their distribution and density around the globe. Vents are a significant source of CO₂, for example, but how important they may be in the global scheme of things will depend upon better knowledge of their size and space distributions. (As I understood it, most of this CO₂ is recycled CO₂ and not primordial.) Clearly the existence of megaplumes hints at their impact on the water column. Vents are symptoms of underlying geological processes and thus provide important windows on seafloor spreading and subduction processes.

The Vents Ocean Acoustics Program is fascinating for it brings in a large number of issues we have little knowledge of. Noise to some is another's signal, and this program is showing the way; the list of relevant applications is long. Some if not most sources of noise are natural (seismic, earthquake, marine life, weather), but others are not (shipping, nuclear test ban monitoring, illegal activities). The deployment of hydrophone moorings around the globe is a solid start to gain measures of geophysical activity. Documenting how much ambient noise has increased over time in various areas should be of considerable interest. Shipping has increased, is there a commensurate (or measurable) increase in ambient noise as well? How much?

Why not put the output of an ocean hydrophone on the net, listening to these has enormous outreach and educational potential (maybe this will be easier when the Orion array has been installed?) (**recommendation #38**). The AWI PALAOA hydrophone in the Antarctic is such an example. You might also want to consider a hydrophone offshore of a harbor (perhaps not so exciting but will give the listener an idea of the impact or signature of anthropogenic activity) (**recommendation #39**). If you are going to do this I would post the gain of the system so people can actually use the numbers. As someone with a physics background I see no reason not to provide quantitative information (and suggestions for how to use it). Lots of kids have Garageband on their computers.

In summary, the quality of the vents activities is excellent. The relevance is high but must be appreciated using a longer time horizon than the Ocean Climate Observations program; it has a higher element of exploration rather than meeting mission requirements (although they are there too). The performance of the team seems to be first-class.

Quality

The VENTS program has, for the last 20 years, provided a high standard of excellence for other programs, such as RIDGE and RIDGE2000 to follow. The VENTS program has also provided a great deal of impetus for time series measurements and monitoring of seafloor systems. The early leadership of the VENTS program has now culminated in the Venus program and Ocean Observing Initiative (OOI). The personnel in the VENTS program are community leaders whose work has had enormous impact on the vents community worldwide.

Relevance

The NOAA VENTS program is certainly relevant to the NOAA mission of understanding the dynamics of ocean ecological systems.

Performance

The performance of the VENTS program is outstanding in every way- excellent science has been the result. The VENTS Program really is a good model for other programs to follow. Having the new vessel *Okeanos Explorer* should certainly make the VENTS program even more productive. One question I have is whether the VENTS program includes biologists. If so, are the abyssal ecosystems studied after they are discovered?

Area 4: Tsunami Research

Quality

The quality of the Tsunami Research Program is exemplary by any standard or metric. It is a program of which NOAA can be justifiably proud. The PMEL tsunami program involves cutting edge observation and modeling capabilities to address life and death issues. The stakes and levels of responsibility are as high as any within the NOAA mandate. It is not at all clear to me that this program has any peers at the national or international levels -- it is in a class of its own in my opinion.

The publication record, high level awards garnered, technology development and transition, modeling capability, international collaboration and capacity building all point to a highly focused, scientifically important, and societally relevant program of the highest order.

PMEL is the world leader in the science and technology relevant to tsunami early warning systems. At present, PMEL is applying its expertise to the creation of a real-time monitoring and forecasting system to provide advance warning of tsunamis. It is clear that this is a product many years, perhaps even decades, of investment. The value of this investment is unambiguous in the wake of the 2004 Indian Ocean Tsunami. The loss of hundreds of thousands of lives was mostly preventable if a

detection/forecasting/warning system had been in place in that area. The tragedy has led to a wider appreciation for PMEL's long standing efforts to develop detection and forecasting systems. The result has been a push to deploy tsunami detection systems (the DART moorings) and to build on tsunami modeling capabilities to create an operational prediction capability. These systems are being transitioned to NWS.

My overall impression of the Tsunami Research program at PMEL is of a research team which was asked to step forward to create operational systems to answer a critical international need, and which has done so with dedication and ingenuity. The precomputation of tsunami propagation for likely generation locations is one example of a practical approach to forecasting which could advance warning times by precious minutes. The accomplishments of this team are very impressive.

Clearly NOAA recognizes the contributions of PMEL's Tsunami program, as the following recognitions associated with various aspects of PMEL's contributions to tsunami detection, forecasting, and the Indian Ocean Tsunami.

- 2008 NOAA TECHNOLOGY TRANSFER AWARD **Christian Meinig and Scott**
- 2008 DEPARTMENT OF COMMERCE BRONZE MEDAL
David McKinnie (OAR), Jennifer S. Lewis (NWS), Elaine Denning, Shannon C. McArthur (NWS), Paul F. Moersdorf (NWS), **Eddie N. Bernard** (OAR),
Curtis B. Barrett (NWS)
- 2007 NOAA BRONZE MEDAL
- 2007 THE TSUNAMI SOCIETY AWARD, **Eddie N. Bernard**
- 2006 NOAA TEAM MEMBER OF THE MONTH (May) **Vasily Titov**
- 2005 DEPARTMENT OF COMMERCE GOLD MEDAL **Eddie Bernard , Marie Eble , Frank Gonzalez, Christian Meinig, Hugh Milburn, Harold Mofjeld, Scott Stalin**
- 2005 OAR EMPLOYEE OF THE YEAR **Ann Thomason Ruth Curl**

However, it is also clear that some of the more traditional academic measures of success have suffered while the research team has focused on developing operational capabilities. Only one of the top 20 publishing scientists in PMEL is a tsunami researcher. I seriously doubt that NOAA would have preferred more publications at the cost of delay in the development of the operational tsunami forecasting system, so this seems to be one of those areas where the mission-driven nature of PMEL must trump the academic aspects of the organization, and metrics for success must be adjusted accordingly (**recommendation #40**).

The quality of PMEL's NOAA Center for Tsunami Research is exceptionally high. I would place it squarely ahead of any university based program, both in its scope and broader objectives. The NCTR is well on its way on developing a real-time forecast tool that will allow site-specific inundation predictions at specific locales. The tool will assimilate data from the DART system of buoys - also developed at PMEL- which

measures the water surface elevation. This had been the missing link for the implementation of focused and realistic tsunami warnings by NOAA's warning centers.

There are two advanced technologies that have been developed at PMEL

1) The DART buoys. This is the only working system in the world which monitors bottom pressure in the deep ocean and provides the "free field signature" of tsunamis. The basic difference compared to the distant "alternative", the tide gage station, is that the latter detects the tsunami arrival, post facto, and is thus useless in providing a warning to the community where it is installed. The DART buoys not only provide a free-field measurement which is uncontaminated by local coastal effects, but it is also available tens to hundreds of minutes travel times to target communities. It is a testament to the robustness of the system that German scientists, heavily subsidized by their government, have been trying to deploy two DART clones in Indonesia since early 2005, they have lost the moorings several times, and the system is still not working three years later. If they have a buoy out, then this occurred very very recently and after close-door consultations with PMEL DART has been patented, and the technology commercialized already.

2) The Real Time Forecast, known by different names such as SIFT. This is incredible technology which has remained unsung because PMEL scientists have been too busy deploying it instead of "selling" it. Real time buoy data are incorporated into the tsunami forecast through hydrodynamic inversion to predict not just offshore heights, but also inundation - a calculation never attempted before. Dr. Titov and his group tried it out with the 2003 South American tsunami. There have been seven (see performance section) successful forecasts since for the seven tsunamis that were potential threats to communities in the Pacific. This advance represents the frontiers of tsunami research ; many other groups in the US are still struggling with developing inundation codes and benchmarking them for historic events ; PMEL has the technology to do all that in real time as an event unfolds.

In terms of collaboration with other groups, PMEL is as open as any other National Laboratory is. There is a parade of uninvited guests from around the world who consider a PMEL visit as a pilgrimage to the holly of hollies of tsunami research. There is active collaboration with Northwestern, Texas A&M, Hawaii and USC, which are the universities most heavily into cutting edge tsunami research. I would border on the conflict of interest to suggest that PMEL could be doing more here, there is always room for improvement. I can say without hesitation that its culture towards intramural and extramural collaboration and for interdisciplinary research puts most of academia to shame.

In terms of contributing data to national and GEOSS databases, the buoy data are rapidly becoming the standard benchmarks to help validate numerical codes to predict tsunami evolution. It is high quality, and PMEL's user friendly interface to retrieve them should be an example for the National Data Buoy Center.

In terms of awards, the tsunami PMEL group was awarded the Department of Commerce's Gold Medal in 2004 for the creation and use of a new moored buoy system to provide accurate and timely warning information on tsunamis and another Gold Medal in 2005 for research and development leading to the creation of a tsunami forecasting capability. There have been other more minor awards for excellent papers, etc, but they fall within the usual of academic life.

In terms of membership in societies, etc, PMEL scientists are very visible in different international bodies, for example UNESCO's Intergovernmental Oceanographic Commission and its working group on tsunamis, the Natural Hazards Society, ITSU and are slowly becoming more visible in the American Society of Civil Engineers. Any more presence and visibility in international bodies would actually work against the US's overall objectives which are to build consensus, and spearhead research and development without appearing meddlesome and dominating in every international group, at least in this field.

Relevance

There can be no question that the program is highly relevant for the reasons identified above. It meets an extremely important need. Throughout a long history, the program has effectively carved a unique niche within the agency. The program, with its focus on predictive capability, is clearly responsive to overarching NOAA objectives for development and refinement of forecasting capabilities for earth systems.

While not specifically highlighted in the recently released NOAA Five Year Plan for fiscal years 2008-2012, the work of the tsunami group clearly is responsive to NOAA's responsibility for public safety.

It does appear that interaction with stakeholders has been effective, leading both to more relevant products and improving public safety at the national and international levels.

The Tsunami program addresses the third of NOAA 5 strategic goals: "to serve society's needs for weather and water information." The program addresses a class or risk that is the purview of government: events which may have a low probability of occurrence at any given time, but which have catastrophic consequences when they occur. The program implements the following actions outlined in the NOAA strategic plan: to monitor and observe the land, sea, atmosphere, and space to create an observational and data collection network that tracks Earth's changing systems, and to manage coastal and ocean resources to optimize benefits to the environment, the economy, and public safety. The first action has been addressed by the creation of technology for early detection of tsunamis and rapid prediction of their propagation. I list the second because the tsunami program, through its growing ability to predict coastal impacts provides an important tool to coastal managers and policy makers, and because of the obvious link to safety.

As explained in detail in the performance category, PMEL has implemented the technology for real-time buoy data assimilation to perform real time forecast. These forecasts are now the world standard and are instrumental in evaluating whether any given earthquake with characteristic parameters in ranges that make it theoretically possible to generate a tsunami has in fact done so. Further, the real time forecast allows

for a fairly accurate evaluation of the area to be affected, all in real time. This kind of real time forecast had been the holy grail of tsunami research for decades. In fact, in contrast to hurricane flooding forecasts that still have moderate margins of error, tsunami forecasts generally don't.

Shortly after a large earthquake occurs in the Pacific, it is well known that the PMEL site either shuts down intentionally so that the lab scientists can have unimpeded access to the buoy data or just slows down, as literally thousands of scientists and lay people from around the world "tune in" to watch the tsunami evolution. It is here that PMEL needs to carefully consider expanding the capabilities of its servers (**recommendation #40.1**). The phasing out of the older server FACTS is in my view premature. While the newer system ComMIT is more powerful for it allows actual calculations on specific bathymetries, the older system stored thousands of pre-computed scenarios for rapid access and research. My recommendation is that both systems need to co-exist in perpetuity, and that PMEL rapidly publishes a paper with the FACTS details, it is likely to be one of the most widely referenced PMEL publications (**recommendation #40.2**).

In terms of future challenges, PMEL must remain vigilant in maintaining the "branding" of its code MOST (**recommendation #40.3**). While it does make it available to scientists trained in special workshops and to visitors, numerous new comers are marketing codes with far lesser capabilities. PMEL has de facto the most validated code, and on occasion it does need to spend time and resources in debunking some wild claims. To wit a group known for its outlandish statements has claimed that their model for has had 97% success in predicting the measurements made in Thailand during the megatsunami, or that the run-up from future earthquakes in Cascadia is over four times larger than the established paleotsunami record. While the core scientific community doesn't take such statements seriously, news media do. PMEL needs to be more assertive in exposing charlatanism, this is one of the responsibilities of the leader (**recommendation #40.4**).

Performance

As an outsider to the field, I cannot fully assess whether the Research and Development component should be reassessed or could be improved but my clear impression is that PMEL is setting the direction globally in this area of research and application. Certainly the patenting and transitioning of the DART technology is an impressive demonstration of the quality of the R&D function. I have little doubt that the modeling and forecasting system will be viewed similarly.

The long evolutionary history of the program appears to have shaped an important set of clearly defined priorities that are effectively pursued. The monitoring system development is clear indication that a transition plan has been carefully considered and implemented for worldwide application for this product. Again, I would anticipate a similar pathway for the forecasting capability.

There is every indication that the tsunami research program is conducted efficiently and effectively. The use of base funding and external grants has been effective in leading to product development.

Research Leadership and Planning:

PMEL's successful Tsunami activity of the last several years is possible because of a long term commitment to develop the technology and scientific understanding necessary to enable an early warning system. The foresight and long term dedication of laboratory leadership meant that NOAA as an agency was in a position to respond when the terrible destruction of a tsunami was made clear by the Indian Ocean Tsunami. Their follow-through has been, if anything, even more impressive.

Efficiency and Effectiveness:

The ratio of the scale of the risk (extremely large) to size of the investment (very small) must make this program among the federal government's best investments.

Transition:

This program is also a poster child for transition, as the DART mooring has already been transitioned to industry, and the forecast capability is being transitioned to NWS.

As a preamble, it is hard for me to differentiate between leadership in research and effectiveness or transition to applications and effectiveness. Leadership in research is never coincidental; it arises from a long history of effectiveness in the implementation of new ideas. The same can be argued for transition to applications, only effectiveness leads to transitioning to useful products. PMEL does all three categories.

In terms of research leadership, PMEL is currently the world's center of research in real time tsunami forecasts. Little else can be added, there is no other center that even comes close. Most importantly, PMEL is widely recognized as such. In terms of numerical code development, arguments could be made that Texas A&M or Cornell are close and some may argue slightly ahead. And the "race" is for the eventual implementation of landslide modules to better define initial conditions for waves triggered by landslides, not for tectonic tsunamis which are by far the most common.

In terms of transition to applications, since 2005, there have been seven real time forecasts for tsunami in the Pacific Ocean - following the "experimental" forecast of the 2003 Adreanoff tsunami. The forecasts have led to cancellation of the warnings. While one may argue that three of the seven might have been cancelled anyway with pre-existing procedures, having access to NOAA's maps of maximum tsunami heights and to the DART buoys made the decision easier and far more defensible.

Another excellent relevant application of NOAA-PMEL's tsunami forecasts has been in ComMIT. This is a web based product that allows web-access to the inundation code MOST. The end user can specify extreme nearshore topography at the desired resolution

and then use the web-based MOST to calculate inundation. This is an excellent tool both for teaching the basics of tsunami hydrodynamics and for allowing wide worldwide access to emergency planners to cutting edge tools to save lives. It is perhaps the best product in PMEL's arsenal for public outreach.

Appendix 1- Charge to Reviewers:

Charge to the Review Team

Purpose of the Review: Laboratory scientific reviews are conducted every four years to evaluate the quality, relevance, and performance of research conducted in Oceanic and Atmospheric Research (OAR) laboratories to both internal and external interests, and to help strategically position the laboratory in its planning of its future science. These reviews are intended to ensure that OAR laboratory research is linked to the National Oceanic and Atmospheric Administration (NOAA) Strategic Plan, relevant to NOAA Research mission and priorities, and consistent with NOAA planning, programming, and budgeting.

Each reviewer will independently prepare their written assessments; the co-Chairs, federal employees, will create a five to ten page report summarizing the individual assessments. The co-Chairs will not analyze individual comments or seek a consensus of the reviewers.

Scope of the Review: This review will cover the research of the Pacific Marine Environmental Laboratory in Seattle, Washington over the last four years. The research themes and related topics are: 1. Ocean Climate Observations Research; 2. Alaska Marine Ecosystem Research; 3. Seafloor Hydrothermal Vents/Ecosystem Research; and 4. Tsunami Research

Focus Areas for Review/Questions to be Addressed:

1. **Quality:** Assess the quality of the laboratory's research and development. Assess whether appropriate approaches are in place to ensure that high quality work will be performed in the future. Assess progress toward meeting OAR's goal to conduct preeminent research as listed in the "Indicators of Preeminence."
 - How does the quality of the laboratory's research and development rank among Research and Development (R&D) programs in other U.S. federal agencies? Other science agencies/institutions?
 - Are appropriate approaches in place to ensure that high quality work will be done in the future?

Indicators of Preeminence: Types of Indicators can include the following; not all may be relevant to each laboratory.

- a. A lab's total number of refereed publications per unit time and/or per scientific Full Time Equivalent staff.
 - b. A list of technologies (e.g. observing systems, information technology, numerical modeling algorithms) transferred to operations/application and an assessment of their significance/impact on operations.
 - c. The number of citations for a lab's scientific staff by individual or some aggregate.
 - d. A list of awards won by groups and individuals for research, development, and/or application.
 - e. Memberships and involvement in prestigious organizations (e.g., the National Academy of Sciences, National Academy of Engineering, or fellowship in the American Meteorological Society, American Geophysical Union or the American Association for the Advancement of Science etc.).
 - f. Service of individuals in technical and scientific societies such as journal editorships, election to boards or executive level offices, service on U.S. interagency groups, service of individuals on boards and committees of international research-coordination organizations.
 - g. A list of research products, information and services and an assessment of their impact by end users, including participation or leadership in national and international state-of-science assessments.
 - h. Evidence of collaboration with other national and international research groups, both inside and outside of NOAA as well as reimbursable support from non-NOAA sponsors.
 - i. Significance and impact of involvement with patents, Cooperative Research and Development Agreements and other activities with industry.
 - j. Other forms of recognition from NOAA information customers such as decision makers in government, private industry, the media, education communities, and the public.
 - k. Contributions of data to national and Global Earth Observing System of Systems (GEOSS)-related data bases and programs, and involvement in international quality-control activities to ensure accuracy, precision, inter-comparability, and accessibility of global data sets.
2. **Relevance:** Assess the degree to which the research and development is relevant to NOAA's mission and of value to the Nation.
- Does the research address existing (or future) societally relevant needs (national and international)?
 - How well does it address issues identified in the NOAA research plans or other policy or guiding documents?
 - Are customers engaged to ensure relevance of the research?
 - Are there R&D topics relevant to national needs that the laboratory should be pursuing but is not? Are there R&D topics in NOAA and OAR plans that the laboratory should be pursuing but is not?
3. **Performance:** Assess the overall effectiveness with which the laboratory plans and conducts its research and development, given the resources provided, to meet

NOAA Strategic Plan objectives and the needs of the nation. The evaluation will be conducted within the context of three sub-categories: research leadership and planning, effectiveness, and transition of research to applications.

3a. Research Leadership and Planning. Assess whether the laboratory has clearly defined objectives, scope, and methodologies for its key projects.

- Does the laboratory have clearly defined and documented scientific objectives, rationale and methodologies for key projects?
- Has the scope of key projects been identified including methods for determining when areas of investigation should end or be transitioned to operations or information services?

3b. Efficiency and Effectiveness. Assess the efficiency and effectiveness of the laboratory's research and development, given the laboratory's goals, resources, and constraints and how effective the laboratory is in obtaining needed resources through NOAA and other sources.

- Does the laboratory execute its research in an efficient and effective manner?
- Is the laboratory organized and managed to optimize the conduct and planning of research, including the support of creativity?
- How well integrated is the work with NOAA's planning and execution activities? Are there adequate inputs to the planning process of NOAA's Programming, Planning and Budgeting and Execution System?
- Is the proportion of the external funding appropriate relative to its NOAA funding?
- Are human resources adequate to meet current and future needs? Is the laboratory organized and managed to ensure diversity in its workforce?
- Are appropriate resources and support services available?

3c. Transition: How well has the laboratory delivered products? Assess laboratory's effectiveness in transitioning and/or disseminating its research into applications (operations and /or information services).

- How well is the transition of research to applications and/or dissemination of knowledge planned and executed?
- Are there appropriate interactions with stakeholders and customers? Are end users of the research and development involved in the planning and delivery of applications and/or information services?
- Are the research results communicated to stakeholders and the public?

Proposed Schedule and Time Commitment for Reviewers

The on-site review will be conducted over a three day period – August 26-28, 2008, in Seattle, Washington. Two teleconferences are planned with the Deputy Assistant Administrator for OAR, who will be the liaison with the review team and for the completion of the report. The goal of the first teleconference, by June 2008, will be to discuss the charge to you, a reviewer, as well as the scope of the review, focus areas for the review questions to be addressed, and initial information provided to reviewers that

addresses the questions. In the second phone call, scheduled for July 2008, the Deputy Assistant Administrator will discuss the draft review agenda and the proposed template for reviewers to use for their assessments. During this call, we ask that you as a reviewer identify any additional information needs. All relevant information requested by the review team will be provided on the review website by July 2008 before the second call with the review team.

Each reviewer is asked to independently prepare their written assessments; the co-Chairs, federal employees, will create a five to ten page report summarizing the individual assessments. The co-Chairs will not analyze individual comments or seek a consensus of the reviewers. We request that within 45 days of the review, the review team provide the draft summary report to the Deputy Assistant Administrator, OAR. Once the report is received, OAR staff will review the report to identify any factual errors and will send corrections to the review team. The final individual assessments and the summary report are to be submitted to the Assistant Administrator, OAR.

Review Team Resources:

The Deputy Assistant Administrator will provide resources necessary for the review team to complete its work.

1. Review Team Support: Information to address the focus areas of the review will be prepared and posted on a password-protected web page for reviewers. The first round of information will be compiled and posted in June and the second major update, to respond to reviewers' requests, will be provided by the end of July. A hard copy of all the information on the website will also be provided to reviewers at the review.
2. Travel arrangements for the onsite review will be made and paid for by OAR.

Appendix 2- Review Agenda

Draft Agenda for PMEL Science Review

Tuesday, August 26 Theme: OCEAN CLIMATE

7:30 - 8:00 Breakfast for Reviewers, Dr. Spinrad, and Dr. MacDonald at Hotel

8:00 - 8:30 Depart Hotel by Van for Sand Point, Security, and Badging in Building 3

8:30 Welcome, Charge to Reviewers and Introduction; Rick Spinrad, Sandy MacDonald

8:45 Logistics Details; Mark Koehn

8:50 Director's Welcome and Lab Overview: Eddie Bernard

9:20 Ocean Climate Overview: Dennis Moore

9:35 Tropical Ocean Research and Discussion: Mike McPhaden

11:00 *Break*

11:15 Ocean Carbon & Ocean Acidification, Discussion: Dick Feely, Chris Sabine

12:15 *Lunch*

13:15 Tropical Circulation and Discussion: Billy Kessler

13:45 Reference Stations and Discussion: Meghan Cronin

14:15 Leave for Walking Tour of Building 8: Dennis Moore

14:25 ARGO Float Lab: Greg Johnson

15:00 Engineering/UAS - PMEL Shops: Chris Meinig

15:30 Atmospheric Chemistry/Air Quality - Van Park: Tim Bates/Trish Quinn

16:10 Return to Seminar Room

16:20 Climate Wrap-up: Dennis Moore

16:40 Reviewers' closed session

17:15 Conclude for the day

18:30 *Dinner with Reviewers and Sr. NOAA folks*

Wednesday, August 27 Theme: MARINE ECOSYSTEMS

06:00-08:00 Breakfast Available at Hotel

8:00 Depart Hotel for PMEL

8:15 PMEL Ecosystem Research Overview: Steve Hammond

8:30 Ecosystem Forecasting and Discussion: Phyllis Stabeno, Jeff Napp

9:15 Arctic Climate Impacts on Ecosystems and Discussion: Jim Overland

10:00 *Break*

10:15 Demonstrations, Poster Session, and Lab Tour Al Hermann, others

11:15 Ecosystem Forecasting Wrap-up Phyllis Stabeno

11:30 *Lunch with PMEL Scientists*

12:30 Hydrothermal Vents/Ocean Exploration Overview: Steve Hammond

13:00 Patterns in Global Hydrothermal Activity; Discussion: Ed Baker

13:35 Submarine Ring of Fire and NeMO; Discussion: Bob Embley

14:10 Break; Tour of Command Center, VENTS Highlights Reel, Posters: Steve Hammond

15:10 Natural CO₂ and Extreme Chemistries; Discussion John Lupton

15:45 Ocean Acoustics; Discussion: Bob Dziak

16:20 VENTS/OE Wrap-up: Steve Hammond

16:30 Reviewer Closed Session

17:00 *Adjourn for the Day - Dinner on your own*

Thursday, August 28 Theme: TSUNAMI

06:00-07:45 Breakfast Available at Hotel

7:45 Depart Hotel for PMEL

8:00 Tsunami Overview: Eddie Bernard

8:45 Tsunami Forecast Modeling and Discussion: Vasily Titov

9:45 Tsunami Hazard Assessment and Discussion: Diego Arcas

10:30 Break

10:45 Tsunami Measurements: Tour and Discussion: Chris Meinig

11:30 Tsunami Forecast System Demo (Multimedia Center): Don Denbo, Chris Moore

12:15 Tsunami Wrap-up: Eddie Bernard

12:30 Lunch: Closed Lunch for Reviewers

13:45 Lab Review Wrap-up: Eddie Bernard

14:00 Reviewer Closed Session/Tour for non-reviewers

15:30 Reviewer Report-out to OAR and PMEL Management Review Team; OAR mgmt.

16:00 Adjourn and Thank You to Review Team: Sandy MacDonald

Appendix 3- List of review material made available to the Review Team on the Web

National Oceanic and Atmospheric Administration

 **Pacific Marine Environmental Laboratory**
A leader in developing ocean observational systems to address NOAA's mission

[About us](#) [Research](#) [Publications](#) [Data](#) [Theme pages](#) [Infrastructure](#)

LAB REVIEW	
PRESENTATIONS	
Tuesday, August 26th	Indicators of Preeminence
Lab Directors Overview	Publications/Citations
Climate Overview	Patents/ License/Transitions to applications
Tropical Ocean Moored Buoys	Awards
	Leadership and Community Service

[Ocean Carbon/Ocean Acidification](#)
[Ocean Currents Solomon Sea](#)
[Ocean Climate Stations](#)
[ARGO](#)
[Atmospheric Chemistry](#)
[Climate Wrapup](#)

Wednesday, August 27th

[Ecosystem Introduction](#)
[Alaska Marine Ecosystem Overview](#)
[EcoFOCI](#)
[Arctic Climate](#)
[Alaska Marine Ecosystem Wrapup](#)

[VENTS Overview](#)
[Global Hydrothermal Activity](#)
[Ring of Fire](#)
[VENT Chemistry](#)
[Ocean Acoustics](#)
[Vents Wrapup](#)

Thursday, August 28th

[Tsunami Overview](#)
[Tsunami Forecast Modeling](#)
[Tsunami Hazard Assessment](#)
[Tsunami Measurements](#)
[Tsunami Forecast System](#)
[Tsunami Wrapup](#)

[Lab Review Wrapup](#)

[Proposals](#)
[Staff](#)
[Budget](#)
[PMEL In The News](#)

NOAA Links

[NOAA Strategic Plan](#)
[NOAA 5 Year Research Plan](#)

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