Summary Report of the Review of the Geophysical Fluid Dynamics Laboratory
June 30 – July 2, 2009

Review Panel

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Introduction

The Geophysical Fluid Dynamics Laboratory (GFDL) deserves enormous credit for its conduct of this quadrennial review. The high level of thought and preparation that went into every presentation was readily apparent, and was greatly appreciated by the panelists and myself. The extent to which the entire GFDL staff cares passionately about the future of the lab is heartening, and offers great hope that GFDL will maintain and enhance its prominence within the National Oceanic and Atmospheric Administration (NOAA) and the scientific community. I was equally impressed by the dedication of the panelists involved in the review, who have all shown a genuine desire to help the lab succeed. Their constructively critical evaluations and recommendations are eloquent and perceptive, and clearly demonstrate their generous investment of time and effort to the review process. The high level of commitment on the part of the panelists, the GFDL staff, and NOAA administrators resulted in an extremely productive review process.

In accord with NOAA guidelines, the panelists did not seek consensus in their evaluations of the lab. Nevertheless, a number of common themes emerge in their recommendations, which I have attempted to summarize below. Some of the panelists' recommendations are quite specific, but many are open ended, encouraging GFDL to think strategically about its future and come up with its own answers. The panelists' comments also go beyond internal recommendations to GFDL and address broader questions regarding GFDL's role within the Office of Oceanic and Atmospheric Research and NOAA, and NOAA's expectations of GFDL.

Any recommendations for GFDL's future development must be prefaced by an acknowledgement of the remarkable accomplishments of its recent past. Panelists were unanimous in their praise for the excellent quality of the lab's research on the underlying dynamics of climate variability and climate change, arguably the core disciplines of the lab. The lab's most visible accomplishment is its coupled climate model, which was described by two panelists (Marshall and Hurrell) as among the best, if not the best, climate model in the world today. Hartmann notes further the "very high technical and scientific standards" which GFDL applies in its modeling efforts, and mentions, as does Kasibhatla, GFDL's role in advancing the representation of aerosol forcing and aerosol-cloud interaction in climate models. Panelists also expressed enthusiasm for the work presented on high-resolution model simulations of hurricanes, and their implications for forecasts of the severity of hurricane seasons as well for assessments of changes in tropical storm frequency associated with global warming.

Perhaps the most encouraging aspect of the modeling effort is the extent to which it demonstrates a high level of performance in tackling lab-wide projects. Marotzke and Marshall characterized the model development of the past 10 years as a "turnaround", Marotzke noting that GFDL has "come back in style" after falling behind around the turn of the century. The collaborative performance is evident from the wide variety of contributions that led to the success of the model, including the development of physical parameterizations, finite volume dynamics on the cubed sphere, software infrastructure for scalability, and diagnostic comparisons against observations.

Reviewers are equally enthusiastic in their assessment of GFDL's relevance to NOAA's mission and to the nation's scientific enterprise. They note in particular GFDL's role in developing global coupled climate models, which are essential to developing a predictive understanding of climate variability and change. As Marotzke puts it, "GFDL is the only lab within NOAA that is capable of comprehensive climate model development. Thus GFDL fulfills a critical strategic need." This sentiment is echoed by other panelists, for instance in Marshall's claim that "model development at GFDL is very relevant and essential to NOAA and national needs." Hartmann notes in particular the value of MOM (Modular Ocean Model), the ocean model developed at GFDL, which is "used by many operational and research organizations throughout the world."

Panelists also praised the lab for its relevance to U.S. and global efforts to understand and anticipate physical climate change. Cox points out that GFDL's work on physical climate change contributes strongly to NOAA's stated climate goal, which is to "understand climate variability and change to enhance society's ability to plan and understand." Hurrell notes the "leading role GFDL scientists play in community service activities such as Intergovernmental Panel on Climate Change (IPCC), Climate Change Science Program (CCSP) assessment reports, National Academy of Sciences panels, editorships, etc." He also applauds GFDL's contribution in enabling community involvement in the IPCC process by making thousands of years of climate change simulations available to the public. This is just one example of GFDL activities that have had a huge impact in "facilitating community involvement in climate variability and change science." He argues that "NOAA should recognize this, and take pride in it". Likewise, Marotzke notes the value of the lab's work on global warming mechanisms and their consequences. More generally, he points out that "GFDL is the only lab within NOAA that is capable of fundamental work on climate dynamics, as well as on developing predictive capabilities."

Assessments of the lab's work in the area of carbon, biogeochemistry, and climate, and the effort to develop an Earth system model (ESM) were mixed. Panelists noted that carbon cycle modeling is not a traditional strength of the lab, and that the lab relies on its collaborators at Princeton and elsewhere to fill the gaps. Marotzke characterizes the situation by saying that "GFDL is still building up its biogeochemistry capability", an impression reinforced by his inability to see "clearly defined and passionately debated scientific goals from this area." Kasibhatla notes the reliance of the ESM effort on external collaborations, writing that progress in ESM development has been "built on GFDL's expertise in physical climate modeling, Princeton's expertise in land vegetation modeling, United States Geological Survey contributions related to hydrology and water resources, and the combined GFDL-Princeton expertise in ocean modeling."

Cox notes further that "the translation of Princeton University expertise into GFDL models has been slow to date, as the relevant biogeochemistry was developed [at Princeton] in the early to mid 1990s." As a result, GFDL is "10 years behind the leading climate modeling groups in carrying out their first coupled climate –carbon cycle simulations, and has quite a bit of catching up to do." Hartmann offers a counterpoint to this assessment, noting that GFDL has always emphasized quality, rigor, and depth over complexity. He characterizes GFDL's approach as "limiting the scope of the model to those elements that are most critical or basic, before increasing complexity with components of what will be called an Earth System Model." He argues that this is "good scientific method and returns better value to the taxpayer and greater scientific understanding than a more complex model in which the components are of lesser quality."

In sum, the reviews paint a very positive picture of GFDL as a lab with considerable strengths in core areas of vital relevance to NOAA's goals. Nevertheless, panelists see significant challenges ahead for the lab, and they have given careful consideration to the steps GFDL should take to maintain and enhance its scientific standing and its value to NOAA and the nation. Among the major challenges are decadal prediction, Earth system modeling (ESM), and defining GFDL's role in a National Climate Service (NCS).

The remainder of this document summarizes the panelists' recommendations to GFDL and to OAR for addressing the challenges faced by the lab. The recommendations are organized into four general areas of need: 1) the need to preserve the lab's core strengths while addressing the urgent demands placed on NOAA for decadal prediction, earth system modeling, and information services related to a national climate program; 2) the need for strategic planning and development; 3) the need to form and strengthen partnerships, particularly with Princeton University; and 4) the need for greater attention to workforce development. The recommendations are followed by a brief discussion of the review process itself, intended to provide guidance to the next quadrennial review.

1. Preservation of core strengths

Decades of hard work have brought GFDL to a position of world leadership in climate modeling and in the fundamental science of climate dynamics and physical climatology. However, it is clear that the lab is expected to build new capabilities in a variety of areas including Earth system modeling, decadal climate prediction, and outreach activities including participation in a National Climate Service. The task of building these capabilities will place large demands on the lab's limited staff, thus creating the possibility that new activities will distract the lab from the areas of its traditional expertise. Panelists expressed concern that the new capabilities must be built up with minimum disruption to the lab's core strengths.

Marotzke views the basic science conducted at GFDL as the foundation which supports NOAA's mission-oriented activities and notes that "maintaining a science foundation such as provided by GFDL is critical for the long-term health of NOAA." He goes on to say that he fully understands and supports NOAA's "desire to tap into the phenomenal strength of GFDL, to obtain support for the emerging National Climate Service. Care must be taken, however, that this link into applications that is requested from GFDL, does not undermine the very foundation of GFDL's and thus NOAA's strength – GFDL's scientific pre-eminence must be secured." He goes further to recommend that NOAA should acknowledge the importance of GFDL's basic science and help it "by appropriately matching increases in funding to increases in expectations." Marshall also notes the importance of GFDL's fundamental research as the "primary source of knowledge" for a national climate service. He also argues more specifically for preservation of GFDL's modeling expertise: "The modeling capability at GFDL is a jewel in the crown of NOAA and the nation and must be preserved at all cost." He elaborates that "The GFDL coupled climate model … is widely considered to be among the best, and arguably the best, in the world. This attests to the depth and breadth of the scientific talent at GFDL and the skilful focusing and harnessing of those talents by GFDL management. The lab brings not just great models to bear on the climate problem, but also a staff that deeply understands both the science and the required modeling technology." Marshall is concerned about the preservation of GFDL's core strengths in basic science and model development. This concern is also expressed by Hurrell and Cox.

2. Strategic planning, development, and positioning within NOAA

It is, of course, clear that GFDL will be required to expand beyond its core strengths and traditional activities, and panelists emphasized the need for strategic planning in this expansion. In the past, GFDL has successfully employed a bottom-up academic paradigm, described by Hurrell and Marotzke as "grow branches and prune as necessary". However, Marotzke notes that this strategy is less likely to be successful in the future, and that at present the strength of GFDL "rests more than it did in the past on the ability to pool resources and talent, and thus be able to tackle problems no one else or few others can. But this strategy requires more of a systematic strategy for development than the mostly bottom-up strategy apparent to me." Calls for strategic planning (also see Section 2.4) appear in the reviews in three general areas: 1) decadal prediction; 2) development of ESM capability; 3) defining GFDL's role in a national climate service. The following sections include discussions of elements in each strategic planning area and specific, important considerations are underlined.

2.1 Decadal Prediction

On the subject of decadal prediction, reviews contain a mix of approval for GFDL's accomplishments and concern that GFDL has shown too little engagement in the problem. Hurrell writes that "GFDL scientists are at the forefront of incipient efforts to: (1) establish the predictability of the climate system on decadal time scales; (2) improve the representation of the important physical mechanisms of decadal climate variability in the modeling systems to be used for decadal predictions; (3) develop optimal methods for initializing climate model predictions with the current observational network; and (4) establish techniques to quantify forecast skill on decadal time scales". Marshall offers a qualified endorsement, saying that while GFDL lags behind its European counterparts, it is still the leader within the United States.

Despite GFDL's work on decadal prediction, panelists expressed concern that GFDL lacks a clear strategy for addressing the problem. Cox notes a "lack of clarity with regard to the strategy for decadal climate prediction," and elaborates that "Other major climate modeling centers are prioritizing decadal prediction as it is seen to have great relevance to the emerging agenda of climate change adaptation and related 'climate services'. It is vital that GFDL also has a proper strategy for engagement in this area." Hartmann's assessment is similar: "GFDL has most of the infrastructure and scientific talent to be a leader in the investigation of the utility of decadal prediction, and in defining what that means. They do not appear to have a strategy for doing this." Marotzke also exhorts GFDL to take a more proactive stance on decadal prediction, noting that "In the presentations we were given little information on what went on in this area; the approach appeared to be one of 'wait and see', content to go along since the CMIP5 protocol includes decadal prediction."

While the "wait and see" approach may be scientifically justifiable, it ignores the demands placed on NOAA to provide guidance to end-users on likely changes in climate over the next few years to decades. Given this demand, other organizations may step in to provide such guidance if GFDL chooses not to engage in the problem. Guidance from others could be less scientifically rigorous and carefully qualified than guidance from GFDL. This outcome might not adversely affect GFDL, but it would be less than ideal for NOAA and the nation.

The need for strategic thinking about decadal prediction extends beyond GFDL to NOAA management, and GFDL will require OAR's and NOAA's help in formulating a strategy. Marshall assesses the situation by stating that, "Whatever the prospect for decadal prediction, GFDL is in the modeling and intellectual driving seat. It must also be an active player politically, however, in ongoing and future discussions in NOAA management. This is an opportune time for GFDL to define its role in decadal prediction in the emerging NCS." He further spells out the options by noting that a decision is required as to whether decadal prediction will be done at GFDL. If not, models and knowledge will have to be transitioned to other agencies. If so, GFDL will need more resources. The choice here is not easy: from a NOAA management perspective, GFDL is the most logical place to conduct routine, operational decadal prediction, despite the accompanying requirements for disseminating the forecasts and responding to user queries on a continuing basis. Yet, as discussed in item 1 above, routine operational prediction will impose a heavy burden on the lab. Marshall sums up the danger to GFDL's core strengths by saying that "Operational prediction, combined with the onerous IPCC cycle, will likely kill the 'hen that laid the golden egg'."

Hurrell suggests that the lab consider "developing a more formal (organizing) framework for attribution activities". He points out that "Attribution research is central toward clarifying climate predictability on seasonal to decadal time scales … the ability to explain what has happened and why [it happened] is a prerequisite for having confidence in future predictions." "Organizing more research around the attribution theme would build on GFDL expertise and success in climate analysis, data assimilation and initialization approaches, and physical climate system modeling. Moreover, it would encourage the use of the GFDL models more as research tools to routinely establish cause and effect for observed climate variations, thereby directly addressing many problems of societal relevance." Hurrell does not give a precise outline of the "more formal framework for attribution activities" which he recommends, but he does offer one concrete suggestion: "One component of this [framework] might be more routine (but not "operational") production of initialized coupled predictions of a decade or more (beyond CMIP5). This should be a component of the push toward higher resolution coupled models. It would also likely involve the need to build effective, strategic collaborative efforts in more 'real-time' attribution research and initialized prediction with other modeling and analysis groups exploring these issues."

2.2 Earth System Modeling

GFDL's lack of prominence in biogeochemical modeling is clearly an issue, given the importance of ESM capabilities for NOAA's goals, and a strategic plan is required as a first step to address this deficiency. The Panel viewed GFDL as the appropriate entity within NOAA to spearhead the ESM effort. However, panelists expressed concern that the lab does not have the staff and resources to address the problem in a comprehensive way. A key question, raised by Hurrell, is "how much of the ESM problem is GFDL willing to tackle?" To some extent the lab can rely on outside collaborators to make up for the lack of in-house resources and personnel, "but even then GFDL will not be able to take on a leadership role in any one area without at least some core expertise in that area of model development or application." New directions require developing leadership capabilities in those areas; otherwise, GFDL will not lead and partnerships with external groups will not be effective." Hartmann also alludes to the need to be strategic in addressing ESM development. His preference is for a "strategy that emphasizes quality, rigor, and depth in a slightly less complete Earth System Model, rather than a more complex model in which the individual components are not well validated or understood." Marotzke's advice is more direct: "To bring this area to the same high level as physical climate modeling, GFDL must appoint [i.e. recruit and hire] a scientific leader from outside." The issue of ESM development and its link to Princeton University is further discussed in section 3.

2.3 GFDL's role in the National Climate Service

It seems clear that some form of NCS will be developed within NOAA over the next two years, and GFDL will inevitably be involved. GFDL should plan for this and attempt to define its role within the NCS in way that emphasizes its "strength as the primary source of knowledge" for this enterprise, as Marshall points out. Marshall also notes that "GFDL has little experience with users to create a meaningful 'service' without reinventing the wheel," a sentiment echoed in Hartmann's comment that "direct outreach to the public is not efficient for GFDL." Suggestions from panelists on GFDL participation in the NCS are not limited to model development and basic science, however, as Marshall suggests participation through operational forecasts (despite the drawbacks listed in item 1). The take-home message is, as Kasibhatla puts it, that "GFDL should be proactively involved in defining its role" in the NCS.

2.4 More general strategic planning

The strategic planning advocated by the panelists extends beyond these specific issues. In particular, Marshall chides the lab for allowing its agenda to be set by the IPCC: "Indeed the lab seems to be hopelessly entangled in IPCC, to which it willingly acquiesces." The extent to which the IPCC influences the lab's agenda, and the extent to which the IPCC's influence is pernicious, is a point of disagreement among the panelists. But the same sense of acquiescence appears in Marotzke's description of decadal prediction efforts, which he describes as going along with the CMIP5 protocol rather than driven by an internally defined agenda. A similar lack of planning is evident in the parallel development of two ocean models, which is criticized as counterproductive by Marshall, Hartmann, and Marotzke. While Hurrell does not object to the IPCC emphasis, he argues that a planning process is necessary to look beyond the time frame of the IPCC cycle: "The involvement in the IPCC cycle makes it critical that GFDL leaders determine realistic scientific and model development goals for the next 5-10 years." Recommendations for facilitating this sort of long-range planning include maintaining a 5-year plan, updated every two years, strategic planning retreats to be held every other year, and periodic "town hall" meetings. Long-range planning should also involve academic collaborators, who can provide a broader perspective on the grand challenges of climate science.

3. Partnerships, particularly with Princeton University

Partnerships are a natural way to alleviate the squeezing effect caused by the imposition of progressively greater demands on GFDL's limited personnel and resources. The promise of such partnerships is discussed in several reviews, as are the potential challenges. Panelists were pleased by the extent to which GFDL has already engaged in partnerships, and encourage the lab to expand its partnerships. Hartmann writes that "GFDL has become more open to collaborations with government labs and universities than it was a decade ago. This should continue." Marshall notes GFDL's collaborative efforts in providing short-term forecasts to NCEP and IRI for their forecast ensembles. He also acknowledges GFDL's efforts to establish a collaboration with the NOAA Fisheries Service, and advocates more such collaborations as an outreach activity: "with a modest resource investment by GFDL, the lab could significantly enhance its visibility as a provider of societally-relevant science and products through, e.g., links to CPO's RISA and to other OAR labs." The idea of outreach through partnership with RISAs is also mentioned by Hartmann. Collaborations such as these would also provide an attractive way for scientists at GFDL, particularly the young scientists, to engage in public speaking activities with collaborating counterparts that communicate the importance of NOAA's GFDL research in the context of societally-relevant services. Although not mentioned in the reviews, panelists verbally advocated collaborations with other OAR labs, such as the Global Monitoring Division of NOAA's Earth System Research Laboratory, which can provide observational datasets for GFDL's aerosol modeling efforts.

Particular emphasis is placed on the value of GFDL's partnership with Princeton University, formalized through the Cooperative Institute for Climate Science (CICS). GFDL relies heavily on collaborators at Princeton, primarily Jorge Sarmiento and Steven Pacala, for expertise on biogeochemistry in developing its nascent ESM capability. Cox acknowledges the success of this collaboration, but argues that the collaboration should be strengthened to speed up the "pull-through" of findings at Princeton into model development at GFDL. More specifically, he says that he would like to see Princeton academics "taking overall responsibility for the implementation and testing of particular GFDL model components." The panelists' endorsement of the Princeton-GFDL partnership is most forcefully stated by Marshall, who calls it a "match made in heaven".

Despite the good work of the Princeton collaborators, panelists argue that the biogeochemistry effort will require additional in-house expertise. The notion that a successful collaboration requires in-house experts of the same professional stature as the Princeton collaborators is common to several reviews. Cox writes that GFDL needs to "properly resource this area from their end." Currently, the 'Climate and Ecosystems' group consists of just seven people … This effort is significantly less than (most) Earth System modeling efforts elsewhere. Most importantly, GFDL needs an intellectual leader in climate-biogeochemistry modeling of its own to balance the expertise at Princeton." Marotzke argues that "GFDL must further develop its biogeochemistry science and models. To bring this area to the same high level as physical climate modeling, I believe that GFDL must recruit and hire a scientific leader from outside. The collaboration with Princeton University offers some great opportunities, but GFDL needs… sufficiently strong intellectual counterweight".

Kasibhatla recommends that GFDL should "carefully consider how best to develop additional in-house leadership in earth system science to be an equal partner in, and take full advantage of, collaborations with groups such as Princeton." Marshall expresses the same sentiment: "Planning for transition to earth system modeling needs more thought. The lab currently does not include sufficient expertise to enable it to set up balanced partnerships with outside collaborators, e.g. Princeton and elsewhere." Finally, Hartmann notes that "to have a world-leading program without some level of world-class in-house scientific leadership is probably not tenable."

Panelists voice strong support for moving GFDL to the Princeton campus. Such a move would benefit GFDL in several ways, most significantly by strengthening the lab's connection to the university. Hurrell notes that there appear to be "many positives and relatively few negatives" to the move, and elaborates that such a move "would only strengthen GFDL's already formidable intellectual talent pool." He also mentions the benefit of the move to NOAA's goals: "a move would promote stronger collaboration with both regular and visiting faculty to Princeton that would benefit serving the NOAA mission on climate, policy, energy and the environment." These sentiments are shared by Marshall, who writes that "the oft-spoken-about move of GFDL to the Princeton campus should be vigorously pursued. This will enable GFDL to tap into the outstanding capabilities, broader/different perspectives, creativity, and fundraising skills of the university. It will also help to bring the two institutions together." Marshall is particularly interested in the potential for Princeton's collaborations in widening the focus of the lab to include pure science subjects like paleoclimate, planetary atmospheres, runaway greenhouses, and the co-evolution of life and climate.

In addition to the scientific motivation for the move, reviews also discuss benefits of the move to the work life and professional advancement of GFDL scientists. Hurrell argues that the move "would address the concerns raised by some of the graduate students, postdoctoral fellows and early career scientists at GFDL of feeling 'isolated' and 'disconnected' from campus. Perhaps it would also provide opportunities to increase the number of students working at GFDL. Current graduate students unanimously felt as though they would benefit from more interactions with more students. Seminar series would also draw more faculty, etc." Hartmann suggests that "The proposed move to Princeton campus would be good for the quality and stature of the GFDL/NOAA effort in terms of recruiting and retaining talent and in engaging the resources of the campus in the NOAA effort." Marshall also feels that the move would be beneficial for GFDL scientists who "yearn to work with and supervise students."

4. Workforce issues

The overall impression given by the reviews is that morale is quite high among GFDL scientists, and the lab director is perceived to be doing a good job. As Marshall puts it, "Bench scientists are, in general, happy with their local group dynamics, lab support, group interactions and great research environment, 'fired up' about research."

Similarly, Hartmann writes that "Junior PhD scientists, who were termed 'bench' scientists, are generally happy with the career opportunities presented to them by their presence at GFDL."

However, the high morale is accompanied by a desire for better communication with lab management, together with some uncertainty regarding advancement within the lab. Hartmann claims that the bench scientists want "greater clarity about how they can advance themselves at GFDL, and more consistent feedback about how they are doing. Human resource management of the junior scientific staff seems to be left to the group leaders with no uniform procedures in evidence. Postdocs would appreciate more opportunities for involvement, mentoring and growth opportunities in areas beyond their immediate projects and research groups." Marshall writes that most bench scientists "feel uninformed about how decisions are made by management and the mechanisms by which they (the bench scientists) can make their views known. The planning process is unclear."

The reviews convey a sense that these issues can be addressed without great difficulty. Panelists specifically recommend making the minutes of the Research Council meetings available to all laboratory scientists. Marotzke advises in addition the lab to "develop some more systematic procedures on how to entrain younger scientists into student advising and more generally growing into more senior roles." Hartmann suggests that "greater communication from management downward and for input from junior scientists would be good, especially about goals and strategies of the laboratory." Cox advises that "the process of prioritizing activities and resources at GFDL needs to be clarified and communicated to junior scientists." As noted above, Marshall senses that lab scientists would like to work with Princeton students, and suggests that the lab should help them to obtain adjunct professor status so that they can engage directly with university students.

Another way in which the lab could help advance the careers of its scientists is suggested by Hurrell, who notes that the number of awards received by lab scientists from professional societies is relatively low considering their contribution to community efforts like the IPCC reports. "Given the quality of the staff, this perhaps indicates insufficient attention is being given to developing and submitting strong nominations. … The lab should have a nomination committee to survey awards, formalize a nomination process, and ensure high-quality nomination packages are coming forward for national and international awards."

Minority recruitment and gender balance continue to be unresolved issues at the lab. "GFDL remains stubbornly white and male," writes Marshall. "Gender equality at higher levels of management is particularly poor. There is better gender balance in the group of younger scientists and students. NOAA has methods in place to enhance minority recruitment, but there is little sign of progress at GFDL."

Concluding Remarks

I am happy to report that this quadrennial review finds GFDL in good health. All panelists were impressed by the exciting scientific results presented over the course of the review. These presentations demonstrate GFDL's continuing excellence as a world-class climate research center. GFDL's success is evident in the review panel's foremost recommendation: that the lab's strengths in its core disciplines be preserved as it responds to new challenges. This is, of course, as much a recommendation to NOAA management as it is to the lab. It will be challenging for NOAA management to follow this advice, given the demands on NOAA to provide new climate services, and NOAA's need for GFDL's assistance in meeting those demands. As Marshall puts it, "GFDL directly addresses NOAA's mission statement, perhaps more now than any time in its history." GFDL and its managers must work together to find the most productive – and least disruptive – ways to leverage GFDL's assets as the primary knowledge generator for a National Climate Service.

Decadal prediction is central to the strategic decisions that GFDL must make in consultation with its NOAA managers. It would be unwise to overlook the scientific uncertainty surrounding the issue, but it may also be unrealistic to think that GFDL can maintain an ambivalent stance toward the problem. While further study of the basic science is clearly in order, NOAA will be obliged to provide some form of decadal guidance in the near future. Thus, decisions must be made as to how NOAA will partition the relevant tasks among its centers, and GFDL will either need a strategy for the transition of models and knowledge to other centers or it will need additional resources to deal with the daily tasks that go along with routine operational forecasting.

In the case of Earth system modeling, panelists express a clear view that GFDL requires strategic planning, enhanced collaborations, and additional personnel. ESM development thus requires the support of NOAA management, since additional funds will have to be allocated to support the additional personnel. However, as discussed in section 2.2, the necessity of the expansion seems clear: The panelists believe that GFDL is the only lab within NOAA that has the potential to develop a world-class ESM, and ESMs are essential to achieve the goals of a National Climate Service (to which should be added, at a minimum, developing a predictive understanding of ocean acidification).

The move to the Princeton campus is another area where the involvement of NOAA management is critical. The move was also recommended in the summary report of the 1999 review, and one wonders if the move is any more likely now than it was 10 years ago. For the move to actually occur, it will have to be supported at the highest levels of the NOAA hierarchy. Again, the guidance of this summary is to both the lab and to its managers: to the lab, to plan strategically for the move and to provide the "intellectual counterweight" required for productive collaboration whist maintaining its own identity and culture; and to NOAA management, to make the move a priority and undertake the necessary negotiations with Princeton administrators.

Looking ahead to the next quadrennial review, panelists offered some constructive comments on the conduct of the review process by OAR management. Hartmann recommends that the panelists be encouraged to work together to produce a consensus document rather than create independent evaluations. In this review, panelists were specifically instructed not to seek consensus, but the rationale for this prohibition was not given. Marotzke feels that the lab should write a "synthetic assessment", which would provide an overview of the lab and its activities, to go along with the impressive binder of PowerPoint presentations. Cox suggests that the panelists meet some of the GFDL research groups, and particularly the more junior scientists in them, over lunch or in a similarly informal setting. Hurrell proposes that the review should include a session featuring open discussion of the problems and challenges facing the lab. He argues that it would be helpful for panelists to hear firsthand what the lab personnel perceive as their greatest challenges, the "ones that keep them up at night."

However, the constructive criticism presented above does not in any way detract from the panelists' high regard for the conduct of the review, and their appreciation for the lab's tremendous effort in hosting it.

Summary of Recommendations

The following list summarizes the recommendations made by the review panelists. As noted above, these recommendations are directed partly to the lab and partly to the NOAA administrators who oversee the lab.

1. GFDL's core strengths, in climate model development and in basic research on climate processes and climate change, should be preserved at all costs. These core strengths are unique within NOAA and vital to NOAA's mission. Any reconsideration of GFDL's activities and role within NOAA should acknowledge the importance of these core strengths. New activities should only be mandated for the lab to the extent that they can be undertaken without compromising the lab's strengths in its core areas.
2. The panel strongly recommends that GFDL be moved from its present location to the main Princeton campus. GFDL would benefit tremendously from greater access to Princeton's intellectual talent pool and fundraising resources. In addition, the move would facilitate interaction between lab scientists and Princeton students, to the benefit of both.
3. To further its efforts in Earth System Modeling, GFDL should recruit and hire a scientific leader in biogeochemistry. Among other things, a strong in-house leader for ESM activities would help to build the partnership with collaborators at Princeton University.
4. GFDL should become more engaged with the decadal climate prediction problem. While there may be valid scientific reasons for a cautious approach, GFDL should not ignore the demands placed on NOAA to provide forecast

guidance on timescales of years to decades. One first step in this direction could be an organized research effort focused on the attribution problem.

5. The lab should work proactively with NOAA administrators to define its role within the NCS. If routine, operational prediction on multi-year and longer timescales is mandated as part of the NCS, decisions must be made regarding the involvement of GFDL. These are not easy decisions, and GFDL must take an active role in the decision process.
6. The lab should expand its efforts to build partnerships within NOAA (e.g. other OAR labs, the CPO RISAs, and service branches like the Fisheries Service), other federal agencies, and academia. In particular, GFDL should seek to strengthen its partnership with Princeton University.
7. The lab should engage in more strategic planning activities. The lab should make a conscious, collective effort to define its research agenda, rather than relying entirely on an organic, bottom-up evolution of the agenda or an agenda set externally by the IPCC or other entity. Recommendations include a 5-year strategic R&D plan, updated every other year, periodic strategic planning retreats, and “town hall” meetings.
8. The lab should address its shortcomings in minority recruitment and gender balance.
9. Lab managers should strive for greater transparency and participation in the decision-making process, so that junior scientific staff are more informed and involved in management decisions affecting the lab.
10. The lab should strive to create and strengthen opportunities for the advancement of junior scientists. Procedures should be established to help junior scientists grow into more senior roles, including procedures to facilitate the involvement of younger scientists in advising students.
11. The lab should establish a nominations committee for achievement awards, to ensure that lab scientists are publicly recognized for their scientific achievements and community service work.
12. For the next quadrennial review, the lab should write a synthetic assessment of its activities to accompany its PowerPoint presentations. Furthermore, panelists should be encouraged to work together to produce a consensus document. Finally, time should be allotted during the review for informal meetings with scientists, particularly junior scientists, and for an open session to discuss the problems and challenges facing the lab.