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PROCEEDINGS OF NOAA LAKE CHAMPLAIN PROGRAM REVIEW - OCTOBER 29-30, 2008

Gary L. Fahnenstiel[1], Michael J. McCormick[2], and R. Artz[3]

[1]NOAA, Great Lakes Environmental Research Laboratory, Muskegon, MI 49441
[2]NOAA, Great Lakes Environmental Research Laboratory, Ann Arbor, MI 48108 (retired)
[3]NOAA, Air Resources Laboratory, Silver Spring, MD 20910

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Gary Locke
Secretary

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Jane Lubchenco
Under Secretary for Oceans & Atmosphere
NOAA Administrator

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NOAA's Mission – To understand and predict changes in Earth's environment and conserve and manage coastal and marine resources to meet our nation's economic, social and environmental needs

NOAA's Mission Goals:

- Protect, restore and manage the use of coastal and ocean resources through an ecosystem approach to management.
- Understand climate variability and change to enhance society's ability to plan and respond.
- Serve society's needs for weather and water information.
- Support the Nation's commerce with information for safe, efficient and environmentally sound transportation.
- Provide critical support for NOAA's Mission.

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1.0 INTRODUCTION

On October 29-30 2008, a formal review of NOAA's Lake Champlain Research Program was held in Burlington, Vermont. Despite being in existence for 18 years, this was the first external review of the program. The first day of the review consisted of project presentations and open discussions of existing research and future directions (see Appendix 1). Principal investigators from all four funded projects were asked to make formal presentations as well as provide a summary (1-2 pages with supplementary materials as needed). The summaries and supplementary materials were made available to the public (see Appendix 2). Five external experts (two in hydrodynamics research, two in atmospheric/mercury research, and one oceanographer/ecologist) were invited to review the research activities with special attention to the quality and quantity of existing research and future direction.

The first day of the review was open to the public, approximately 35 people attended. On the second day, NOAA program managers met with the review panel to discuss the program in a closed session. This technical report summarizes the review meeting.

2.0 PRESENTATIONS AND TOPICAL DISCUSSION

Four research projects are currently funded in the NOAA Lake Champlain Research program and can be divided into two topical areas: atmospheric mercury and hydrodynamics. Two presentations were made in each area followed by a brief discussion of the research.

Atmospheric Mercury Presentations:
Monitoring Meteorological Conditions on Lake Champlain and a Summary Analysis of Annual Mercury Deposition at Underhill, Vermont. Presentation by: D. Wang and D. Facey

Atmospheric Exchanges of Mercury with Lake Champlain and Their Influence on Rates of Mercury Accumulation in Plankton and Fish. Presentation by: E. K. Miller.

General Discussion on Mercury Projects:
After the presentations by Drs. Miller, Wang, and Facey, a general discussion on the atmospheric program followed. This discussion was very engaging and lasted for almost 1 hour.

The mercury research in the Lake Champlain basin was noted at being in the forefront of the field, and much of this notoriety is attributable to NOAA funding and direction. The NOAA funded research is highly integrated and leveraged with other programs in the region. NOAA supports the only multi-year atmospheric mercury measurements in the Lake Champlain basin, and the monitoring data from this program have contributed to numerous scientific papers by a variety of scientists.

Sampling of mercury species in biota of Lake Champlain, and linkages between temporal sampling and steady-state modeling were indentified as two areas that need attention in the future. Moreover, linking air sampling to consumption of fish and human health was important, and the PIs mentioned the possibility of doing this in the coming months/years. Tributary sources of mercury and the connection to watersheds has not received adequate attention and might be an area for future research. The research team was lauded for their integrated approach to the mercury research, as this was noted as one of the program strengths. In the future, this network might need to be expanded as the program moves more into aquatic sampling and modeling.

The links between existing research and public products were discussed as well as the public accessibility of the data. It was noted that presently, data are submitted to the Vermont Monitoring Cooperative (VMC). The limited information available to the public on the mercury issue may need some attention from this program. One PI mentioned the possibility of having a product to address those concerns in the coming months. The meteorological data collected from Colchester Reef was mentioned as a very visible and widely used product from the program.

Hydrodynamic Research Presentations
Building a Hydrodynamic Modeling System to Predict Circulation and Thermal Structure in Lake Champlain. Presentation by: D. Beletsky

Analysis of Historical data Sets and Further Investigations within the Restricted Arm of Lake Champlain. Presentation by: T. Manley

General Discussion on Hydrodynamics Projects:
After the presentations by Drs. Beletsky and Manley, a general discussion on the hydrodynamic program followed. This discussion lasted approximately 30 minutes. There was a brief discussion on the historical data and the approaches used for data archival. Several approaches were mentioned, and the need for a consistent approach across projects was emphasized. The need for development of a particle transport model for Lake Champlain was discussed. This model would have application to several problems in the basin, e.g., harmful algal blooms (HAB).

Much of the discussion centered on the need for hydrodynamic research, and how present research fits into policy decisions. There are several important issues, e.g., causeway removal and HABs, that could benefit from specific hydrodynamic research. It was mentioned that hydrodynamic research has been limited due to logistic constraints of measuring key processes in shallow regions. Without the addition of new equipment, it is doubtful that much hydrodynamic research could be conducted in these shallow regions.

General Discussion of Future Direction of Research
Following the presentations and topical discussions, there was a general discussion on the future direction of research in the Lake Champlain basin.

Part 1. In the first part of this discussion, the four speakers (PIs) were asked to address future directions and needs of their existing research.

Continued support for existing monitoring activities was determined to be critical to future research. Specifically, the two monitoring activities mentioned were the existing meteorological stations and the Underhill wet deposition site. The need to expand meteorological monitoring was also mentioned.

Specific research needs were noted by mercury and hydrodynamic researchers. Measurements of in-lake mercury concentrations (gaseous phase) and processes (methylation) are needed. The continued development of a circulation model with the ultimate goal of a Lake Champlain forecasting system was mentioned for hydrodynamic research. More reliable measurements of critical forcing factors, e.g., wind, were noted as a future need. Hydrodynamic measurements in the restricted arm are needed, and should be the focus of future hydrodynamic field measurements. The development of a long-term hydrodynamic monitoring site similar to that done at GLERL for Lake Michigan would be beneficial.

A more integrated modeling approach was encouraged, one that would include all present activities. Specifically, the need to merge present mercury dynamic modeling and hydrodynamic modeling was discussed. As the mercury research moves into the aquatic region, the coupling of this research to a hydrodynamic model is obvious.

The role that the Lake Champlain Reseach Consortium (LCRC) plays in the basin was determined to be critical and should be expanded if funding becomes available. Creating partners in the Great Lakes basin, particularly NOAA's Great Lakes Environmental Research Lab should be a priority and is necessary to the success of the program.

Part 2. This discussion was open to everyone present and lasted for approximately 45 minutes. It was mentioned that previous meetings of the LCRC have identified five areas for future research, and this group should start by using those five areas. The five areas (nutrients, biodiversity, toxins, circulation, and cultural and economic value) were deemed to be important and worthy of future research. In particular, an interdisciplinary research program in Missisquoi Bay was suggested as being a logical future research area. The limited funding for this program was mentioned as a constraint on future direction. In order to be successful, this program must identify local issues that have broad application and national appeal. The large watershed of Lake Champlain was noted, and watershed processes have been understudied.

A brief history of the funding for this program and intention of the earmark was presented. This program was initially funded to act as a seed or catalyst for other research in the basin. This has not happened as expected, e.g., large interdisciplinary research programs are missing, and there has been limited interaction with Great Lakes programs. The program has functioned mostly as an independent research program, exemplified by the recent Request for Proposals (RFP) in grants.gov. Despite this shortcoming, it was noted that the projects in the program have been used to leverage other federal, state, and local research funds, and this leverage was critical to this and other research programs. An example was presented by Dr. Tom Manley who has been a part of this program from the beginning. From his analysis, NOAA funds leveraged approximately 104-129% of their value, and this leverage was used to further additional research in the Lake Champlain basin. While this may not be exactly the intent of the program, it does

suggest that NOAA's investment in Lake Champlain research is serving to stimulate other research in the area.

3.0 PANEL DISCUSSION AND RECOMMENDATIONS

The discussion between the five reviewers and NOAA program managers took place on the morning of Day 2. An initial charge to the reviewers was given by Dr. Mike McCormick, former NOAA program manager. He asked the panel to evaluate the quality of existing science and to determine the program's future direction.

The overall quality of existing science was rated as relatively high. Several suggestions were made for improvements (see below), but there was a strong message that this should not be the time to move in a new direction. The program needs to get the most out of the existing projects that are in the maturation phase. Another funding cycle should bring several of the projects to a close, and then, other research opportunities should be available. The existing research program needs focus and more interactions within the projects. Also, the program needs more linkages to the greater community. One suggestion was to develop a kiosk at the ECHO Center where research results might be highlighted, e.g. using Dr. Manley's bathymetric data to develop an interactive display.

More integration within the existing topical areas, and throughout the program is needed. The development of a Lake Champlain forecasting system should be the focus of the hydrodynamic program. Similarly the mercury program needs to look at linkages to hydrodynamic modeling and other ecosystem modeling activities. Outreach materials need to be developed and may be integrated with funding opportunities for students. For some projects, public accessibility to the data was a question. The program was encouraged to develop a database, possibly with NOAA/ GLERL collaboration.

Meteorological monitoring was viewed as critical to all aspects of the program, however, present monitoring is limited and needs more continuity. It was strongly suggested that a plan be developed for more meteorological stations in the Lake Champlain basin, and the establishment of a long-term support network that will ensure the continued collection of this critical information.

Hydrodynamic Program Comments: The hydrodynamic program needs to focus on development of a forecasting system. Excellent observations have been made by Dr. Manley, but his scientific productivity (peer-reviewed papers in scientific journals) is limited, and it is not clear if his data are publicly available. The inability to make critical measurements in shallow bays was mentioned as a limitation, but these measurements should only be pursued if they are required for model development. The establishment of more meteorological stations will be a tremendous boost to the hydrodynamic program.

Mercury Program Comments: This program is performing high quality, productive research that serves important NOAA needs. The shift in emphasis to studying mercury in the aquatic environment was a welcome move, but it should not come at the expense of necessary air

monitoring. It would be useful in the future to link the mercury research to landscape issues and modeling, including a basin-wide hydrological model.

Finally, the program managers asked the review panel to help them develop the RFP for the next funding cycle (typically 3-5 years). The panel recommended directly supporting critical monitoring (air and meteorological) outside of the RFP process. Three areas of research were suggested: (1) single hydrodynamic project to combine needed observations to support development of a hydrodynamic forecasting system, (2) mercury observations and modeling that are linked to other basin-wide modeling, and (3) support for student outreach and education activities. Student involvement was viewed as a critical item that had been performed by the LCRC through funding of a mercury project. In the future this activity should receive direct program support in the RFP process. All funded projects should be required to have a defined plan for data flow between collection and public dissemination.

4.0 WRITTEN COMMENTS FROM REVIEWERS

The five invited reviewers were asked to provide written comments on the program with specific attention to eight questions. These comments were due approximately one month after the review.

Reviewer #1

Program 1: Atmospheric Exchanges of Mercury with Lake Champlain and Their Influence on Rates of Mercury Accumulation in Plankton and Fish. E. K. Miller.

(1) Does this research address important questions that are relevant to both NOAA and society?

Yes. This environmental mercury study is important to human health as well as better understanding of the Lake Champlain ecosystem. There are good reasons to think that Lake Champlain is a unique and efficient location in which to track anthropogenic pollution effects because of its very large watershed.

(2) Has the productivity of the project been appropriate for the resources available? Have the research products been of acceptable quality or higher? Have they been valuable contributions, and have they justified the investment of resources?

The productivity and originality of this program appear to be high. I cannot assess whether or not they are appropriate for the level of funding received.

(3) Are there any actions that NOAA should take that would improve the project and program within the constraints of the budget and resources available to the PIs?

I don't know of any.

(4) Based on the stated objective(s), is the project scientifically well thought out and designed? How could it be improved or made more effective?

Yes. The project appears to be well designed. Because the chemistry measurements are expensive to make, it is essential that the program focus on the most representative geographical sampling sites and that the program collaborates with the circulation modeling effort to help identify those sites.

(5) Does the project, as presented, come across as cohesive? If not, where are the problem areas and how might they be eliminated or reduced?

Yes. It appears to be cohesive and compact already.

(6) Is there something else we should be trying to cover under this project? Should we be considering a change in direction for any aspect of this project?

I don't know. The open questions are related to technology—can modern, less expensive sampling techniques be used? and to sampling locations—can fewer sample sites still represent the temporal changes in the Lake Champlain system?

(7) Are the future directions as outlined by the researchers realistic and do they fall within the NOAA mission?

I cannot tell based on my limited exposure to the project. Certainly continuation of the mercury sampling time series at some level is central to the NOAA mission.

Program 2: Building a Hydrodynamic Modeling System to Predict Circulation and Thermal Structure in Lake Champlain. D. Beletsky

(1) Does this research address important questions that are relevant to both NOAA and society?

Yes. This project is attempting to accurately simulate circulation in Lake Champlain from which a wide variety of process studies can be supported and, potentially, a new forecasting capability can be constructed.

(2) Has the productivity of the project been appropriate for the resources available? Have the research products been of acceptable quality or higher? Have they been valuable contributions, and have they justified the investment of resources?

I don't know. I do not have resource information. The preliminary results presented at the review represent significant progress toward constructing and validating a 3-D circulation model for Lake Champlain. Assuming that the costs were in keeping with other program components, the progress appears to be quite good.

(3) Are there any actions that NOAA should take that would improve the project and program within the constraints of the budget and resources available to the PIs?

NOAA should carefully consider the many different options available with respect to the use of a 3-D circulation model. It is often easier to construct a reasonable model than it is to restrict the model uses to those areas with clear hypotheses to be tested or to those time and space domains for which sufficient in situ data exists to be able to force the model and evaluate conclusions drawn from it. My impression of the model being used here and the

capabilities demonstrated here is that this modeling should be targeted, at least initially, to well-defined process studies of Lake Champlain rather than assuming that it is a suitable basis for a forecast system. For example, what physical conditions and forcing is required to reproduce the observed west-side against-the-wind flow? Is bathymetry or wind stress shear most implicated? The model should be able to determine this. In addition, there are a number of open questions about possible order-one changes to the Lake's circulation if certain causeways were to be removed. The modeling system is also well-suited to answering those questions.

(4) Based on the stated objective(s), is the project scientifically well thought out and designed? How could it be improved or made more effective?

Yes. The project appears to be well thought out. It could be improved or put to maximum use following the suggestions given above.

(5) Does the project, as presented, come across as cohesive? If not, where are the problem areas and how might they be eliminated or reduced?

Yes. The project is cohesive. But it must continuously identify those best-use scenarios where the modeling system can be most effective and avoid trying to answer too many questions at one time.

(6) Is there something else we should be trying to cover under this project? Should we be considering a change in direction for any aspect of this project?

Perhaps a stronger focus on creating and exercising a sediment transport sub model would be beneficial. Otherwise, the model development and planning appears to be well organized.

(7) Are the future directions as outlined by the researchers realistic and do they fall within the NOAA mission?

Yes. The suggested uses of the modeling system are realistic and they support a number of aspects of the NOAA mission.

Program 3: Analysis of Historical data Sets and Further Investigations within the Restricted Arm of Lake Champlain. T. Manley

(1) Does this research address important questions that are relevant to both NOAA and society?

Yes. This research supports the NOAA mission in that it is collecting and analyzing in-water data from Lake Champlain that is essential to a wider group of ecosystem and pollution studies.

(2) Has the productivity of the project been appropriate for the resources available? Have the research products been of acceptable quality or higher? Have they been valuable contributions, and have they justified the investment of resources?

I cannot tell based on the information I was given. However, it does appear that the productivity in terms of published work is low given the number of years that the project has

been going and the number of field programs that it has supported. The collected data sets will continue to support environmental studies into the future. However, to get the most out of them will likely require a better focus by the PI on documentation and publications.

(3) *Are there any actions that NOAA should take that would improve the project and program within the constraints of the budget and resources available to the PIs?*

Focus on writing up past results and carefully assess future proposals for additional field observations against the measure of maximum impact.

(4) *Based on the stated objective(s), is the project scientifically well thought out and designed? How could it be improved or made more effective?*

I cannot tell from the information I have seen whether or not the many components of this project are well connected. Going forward, the modeling program and other project components may be able to help define what are the few most essential in-water measurements.

(5) *Does the project, as presented, come across as cohesive? If not, where are the problem areas and how might they be eliminated or reduced?*

I cannot tell form the information I have seen. The project spans many years and has supported many different in-water observations. There is a possibility that the past measurement types and locations were not optimal given the questions that have now emerged as most important. However, the various components of the larger program should be capable of working together to review the past observations and prioritize any future in-water observations.

(6) *Is there something else we should be trying to cover under this project? Should we be considering a change in direction for any aspect of this project?*

Documentation and publications should be better covered. To the extent that that represents a change from a focus on collecting in-water data, that change may be warranted for the next few years.

(7) *Are the future directions as outlined by the researchers realistic and do they fall within the NOAA mission?*

Yes. The future directions appear realistic. But funding constraints may dictate fewer in-water measurements or simpler instrumentation. One example is the estimated cost of monitoring the inflow to Missiquoi Bay, which seemed to me to be unnecessarily high in the discussions that I heard. That shallow-water environment may be well-characterized by a relatively simple current meter design in a relatively small number of locations, particularly if combined with a circulation model.

Program 4: Monitoring Meteorological Conditions on Lake Champlain and a Summary Analysis of Annual Mercury Deposition at Underhill, Vermont. D. Wang and D. Facey

(1) Does this research address important questions that are relevant to both NOAA and society?

Yes. Monitoring atmospheric conditions and forcing functions is important for real-time weather information and as a backbone for most of the ongoig ecosystem or pollutions studies.

(2) Has the productivity of the project been appropriate for the resources available? Have the research products been of acceptable quality or higher? Have they been valuable contributions, and have they justified the investment of resources?

I cannot tell with the information I have been given. The instrumentation installed and maintained at the primary meteorological sites appears to be of very high quality and reliability. Data from the sites is widely used by others. I did not receive enough information specific to the costs and output from this project to comment further.

(3) Are there any actions that NOAA should take that would improve the project and program within the constraints of the budget and resources available to the PIs?

There was a suggestion that NOAA consider taking over the research-supported meteorological observations as part of its operational weather data network. That idea has merit, assuming there are local technicians available part time to deal with effects of the harsh environment.

(4) Based on the stated objective(s), is the project scientifically well thought out and designed? How could it be improved or made more effective?

I do not have enough information to comment fully. The monitoring design is utilizing a couple of key island or headland locations that appear to characterize well the wind stress forcing for Lake Champlain. At the same time, questions have been raised about the role of spatial wind variations in driving the circulation. Probably a permanent observing system that fully maps those variations is not practical. But short-term, targeted wind mapping experiments may be justified and fruitful.

(5) Does the project, as presented, come across as cohesive? If not, where are the problem areas and how might they be eliminated or reduced?

Yes. The project is relatively straightforward and cohesive. Continued support of the same numbers and quality of the instruments may be too costly. One fruitful exercise may be to ask what are the most essential measurements, at how many locations are they really needed, and can they be accomplished with less costly sensors?

(6) Is there something else we should be trying to cover under this project? Should we be considering a change in direction for any aspect of this project?

Probably not. If anything, the project needs to scale back to a more basic set of meteorological observations and station locations that can be sustained over time.

(7) Are the future directions as outlined by the researchers realistic and do they fall within the NOAA mission?

I did not receive enough information to comment fully.

Project Ranking

(8) Finally, please rank the projects, according to your opinion of priority, for continued funding, especially if the funding starts to drop off.

I did not receive enough information to be comfortable ranking one of these projects over another. Furthermore, the projects are quite diverse. Nonetheless, I can say that a reasonable strategy could be to require that 1) Project 3 (Manley) focus on publications only while prioritizations are developed for in-water measurements based on modeling studies and analyses of existing data, 2) Projects 1 (Miller) and 4 (Wang) implement the minimum monitoring needed to continue the mercury and wind time series, respectively, and 3) Project 2 (Beletsky) be encouraged to continue development of the circulation model with highly targeted process studies looking at, for example, the west-side against-the-wind flow, exchanges with Missisquoi Bay, disruptions related to causeway removal, and accumulation basin predictions.

Reviewer #2

Program 2: Building a Hydrodynamic Modeling System to Predict Circulation and Thermal Structure in Lake Champlain. D. Beletsky

I have reviewed short summary, paper in press (JGLR) and presentation by Beletksy during the meeting. Beletsky's main objective is to develop a 3D hydrodynamic model to predict circulation and thermal structure in Lake Champlain. This is critical for the overall management of Lake Champlain ecosystem. Hydrodynamic model studies that were carried out before are more or less based on conceptual models, which may not be adequate for either nowcasting or forecasting of lake circulation and temperature.

(1) Does this research address important questions that are relevant to both NOAA and society?

It does; I think NOAA has a mandate to provide atmospheric and lake forecasting for providing advice to protect the environment. The model is useful as a management tool in planning remediation actions or source water protection for number of users around the basin. Once the model is calibrated the PI will be in a position to couple with more detailed bio-geochemical model. This will allow to assess algal blooms that are of concern to the local community. I also think the model will provide guidance to several other issues in the basin, for example, removing causeways or for designing new outfalls and intakes.

(2) Has the productivity of the project been appropriate for the resources available? Have the research products been of acceptable quality or higher? Have they been valuable contributions, and have they justified the investment of resources?

The PI has demonstrated that prediction of circulation and thermal structure in Lake Champlain can be done with this present modeling framework. The model is up and running.

He also showed few results of model behavior with respect to surface processes and internal wave induced motion. He is a co-author of one peer-reviewed publication and in the processes of preparing another report or paper.

(3) Are there any actions that NOAA should take that would improve the project and program within the constraints of the budget and resources available to the PIs?

The budget proposed in this proposal is very appropriate and as such a large portion of it is provided as partial salary support to the principal investigator. The modeling capability will only increase with more spatial meteorological observations, and NOAA may like to continue the existing meteorological measurements in other programs and augment with new stations.

(4) Based on the stated objective(s), is the project scientifically well thought out and designed? How could it be improved or made more effective?

I think the objectives have been somewhat curtailed due to budgetary constraints, I strongly believe that the future goal should be developing a general purpose (wave, water level, temperature and currents) prediction system. This can be achieved by re-orienting the physical measurements program to support this objective, rather than measurements going as stand alone.

(5) Does the project, as presented, come across as cohesive? If not, where are the problem areas and how might they be eliminated or reduced?

I think the project is cohesive, and PI has already demonstrated that the model is capable of reproducing many of the observed characteristics in the lake. My only concern is switching between different kinds of models and testing each one of them, if possible it is ideal to chose the model with the present/past experience and move forward from there.

(6) Is there something else we should be trying to cover under this project? Should we be considering a change in direction for any aspect of this project?

Yes, the goal should be a forecasting model and as much as possible include all processes (for eg: ice, surface waves etc). Furthermore, once the model is established, the investigators may have to explore the possibility of coupling it with other bio-geochemical processes.

(7) Are the future directions as outlined by the researchers realistic and do they fall within the NOAA mission?

Yes, but I would think priorities should also include eutrophication issues in small enclosed bays or contaminant transport if applicable. These can be achieved within the modeling framework.

(8) Finally, please rank the projects, according to your opinion of priority, for continued funding, especially if the funding starts to drop off.

For most of the lake issues, the basic necessity is good quality hydrodynamics, therefore I would rank this project as number 1 priority and should be continued to take it to the logical conclusion.

Program 3: Analysis of Historical data Sets and Further Investigations within the Restricted Arm of Lake Champlain. T. Manley

During this period Manley's research is mainly focused on continuation or better characterization of flow dynamics that was started in mid 90s in Lake Champlain. In particular, studies are carried out to provide flow dynamics in many areas of the lake for multi-disciplinary studies. It appears that obtaining mean circulation using Lagrangian drifters (surface and sub-surface floats) in both the Main Lake and Restricted Arm is one of the main goals. I have reviewed a short summary, edited volume and the presentation by Manley during the meeting. He has provided an extensive summary on the work carried out before 2003, which is important. Understanding physical limnology is critical for the Lake Champlain ecosystem. Manley's observations are critical for the hydrodynamic model developed in another project. Some physical processes are explained using the data and by conceptual models. In my opinion the bathymetry map produced by the researchers is by far the most important product of their work. It is not clear to me that this ancillary research is funded by NOAA or not.

(1) Does this research address important questions that are relevant to both NOAA and society?

Understanding Physical Limnology of the lake is critical for many studies and very much relevant to NOAA's research to support sound environmental decisions in order to protect, conserve and enhance the environment. Manley's research has many dimensions and several leverage projects are generated that are quite relevant to the local issues.

(2) Has the productivity of the project been appropriate for the resources available? Have the research products been of acceptable quality or higher? Have they been valuable contributions, and have they justified the investment of resources?

Productivity of this project has been demonstrated in several ways. Between 2003-2008 the main publication seems to be an edited volume (Lake Champlain in Transition). The PI is the lead editor of this volume published by Kluwer. I think papers might have gone through peer-review. Other than this, the rest of the publications appears to be semi-reviewed (I may be wrong, but they are not mainstream journals). Manley is a co-author in another paper that is accepted for publication in JGLR. However, the participants presented several of their results in many conferences (some of those are looking repetitive from the titles). Apart from these, several undergraduate theses have been generated from these programs. After Manley's presentation in the review meeting, I thought with the extent of data collected over the years, the peer-reviewed publication record is rather limited. NOAA also asked in their RFP to continue and develop and apply new techniques and instrumentation for both the main body and other regions- In this respect I think Manley's projects used many oceanographic instruments for defining the circulation in the lake. My main concern is some of the equipment that was used was not really meant for shallow waters, where I guess clearer understanding is needed.

(3) Are there any actions that NOAA should take that would improve the project and program within the constraints of the budget and resources available to the PIs?

NOAA should define more clearly what kind of products they would like see at the end of the project, and how the data gathered in this project will be shared with researchers and public.

(4) Based on the stated objective(s), is the project scientifically well thought out and designed? How could it be improved or made more effective?

This project has many dimensions, which is good for leveraging additional support, however, my main difficulty with this project is that the objectives appears to be changing with each year. Most of the dynamical characteristics that were addressed are somewhat known in this lake from previous studies and also in other lake systems, and probably it is important to see how these basic scientific issues contribute to the overall ecology of the lake. I agree with the authors that it is difficult to obtain lake-wide seasonal mean circulation dominated by basin-scale waves using limited fixed moorings. But it is important that their conceptual or 3D models should use those observations to provide that understanding. Lagrangian measurements may be useful in providing some characteristics, but as demonstrated it is difficult to get long-term transport from these measurements in a small land-locked lake; it appeared that drifters either got into shallow waters or struck somewhere after a few days. I also had difficulties in properly assessing the coastal dynamics using sub-surface oceanographic trajectories mainly due to extrapolations used. I think the coastal current modeling (conceptual model study) carried out to explain the movements of these sub-surface floats can be better explained by Beletsky's studies more conclusively.

(5) Does the project, as presented, come across as cohesive? If not, where are the problem areas and how might they be eliminated or reduced?

I don't think the project is as cohesive as one would like to see. There are too many objectives and changed every now and then depending upon the availability of instruments etc. I also think the forcing data that is required to explain some of the dynamics are not available. With some modifications physical limnological observations can be aligned with integrated modeling of the lake.

(6) Is there something else we should be trying to cover under this project? Should we be considering a change in direction for any aspect of this project?

Yes, the goal should be a forecasting model and physical limnological observations along with meteorological and hydrological observations should support that activity.

(7) Are the future directions as outlined by the researchers realistic and do they fall within the NOAA mission?

Some of it is achievable, but as mentioned earlier, this program should focus to help the 3D forecasting model.

(8) Finally, please rank the projects, according to your opinion of priority, for continued funding, especially if the funding starts to drop off.

I think Physical Limnological measurements are crucial to get an overall understanding of the lake, and they are also critical to validate the 3D model.

Reviewer #3

Program 1: Atmospheric Exchanges of Mercury with Lake Champlain and Their Influence on Rates of Mercury Accumulation in Plankton and Fish. E. K. Miller.

(1) Does this research address important questions that are relevant to both NOAA and society?

Yes. The atmospheric mercury measurements presented here represent the longest historical record of atmospheric mercury. This is very important as the nation embarks on a national program to reduce emissions of mercury, particularly emission from coal-fire power plants. This is a major national policy and having data to document the affect of policy is critical to understanding the adequacy of implemented policy and its ability to achieve stated goals.

(2) Has the productivity of the project been appropriate for the resources available? Have the research products been of acceptable quality or higher? Have they been valuable contributions, and have they justified the investment of resources?

Yes, the productivity has been appropriate, if not exceptional, for the resources available. These is particularly true when it is considered how these data are developed (leveraged) in conjunction with other coincident projects conducted at the site. The long duration of measurements at this site makes continuation of this project valuable and justifies the investment.

(3) Are there any actions that NOAA should take that would improve the project and program within the constraints of the budget and resources available to the PIs?

These data are interest to NOAA in the development of NOAA's atmospheric mercury model, if NOAA's efforts in developing HY-SPLPIT for mercury could work more closely with this project, it would represent another valued use of these data.

(4) Based on the stated objective(s), is the project scientifically well thought out and designed? How could it be improved or made more effective?

Yes, project is scientifically well thought out and designed. Within the budget constraints of these projects, the design has been optimized.

(5) Does the project, as presented, come across as cohesive? If not, where are the problem areas and how might they be eliminated or reduced?

Yes the product does come across as cohesive.

(6) Is there something else we should be trying to cover under this project? Should we be considering a change in direction for any aspect of this project?

I think the project direction is fine at present. I would like to see future efforts to better understand the air-land-water pollutant exchange as opposed to continued efforts to understand in-lake processes. As the watershed of Lake Champlain is some 20x the lake surface area it is important to understand how this catchment delivers pollutants to the water.

(7) Are the future directions as outlined by the researchers realistic and do they fall within the NOAA mission?

Yes.

(8) Finally, please rank the projects, according to your opinion of priority, for continued funding, especially if the funding starts to drop off. 1.

Program 2: Building a Hydrodynamic Modeling System to Predict Circulation and Thermal Structure in Lake Champlain. D. Beletsky

(1) Does this research address important questions that are relevant to both NOAA and society?

Yes, this effort is building the first forecast model for Lake Champlain. Having a forecast model would serve many purposes including lake hydrodynamic research, air-water dynamics, recreational forecasts, etc.

(2) Has the productivity of the project been appropriate for the resources available? Have the research products been of acceptable quality or higher? Have they been valuable contributions, and have they justified the investment of resources?

Yes, productivity has been appropriate for the resources available. Yes, through this effort a first generation forecast model is now available for Lake Champlain; this has not existed before.

(3) Are there any actions that NOAA should take that would improve the project and program within the constraints of the budget and resources available to the PIs?

Yes, NOAA could play the rote of coordinator to link the work being conducted in Lake Champlain with relevant work being conducted in the Great Lakes.

(4) Based on the stated objective(s), is the project scientifically well thought out and designed? How could it be improved or made more effective?

Yes. The technical project is sound, but attention needs to be paid to outreach and coordination to potential users of the tool being developed, e.g. National Weather Service, air-water interface, resource mangers, etc.

(5) Does the project, as presented, come across as cohesive? If not, where are the problem areas and how might they be eliminated or reduced?

Yes.

(6) Is there something else we should be trying to cover under this project? Should we be considering a change in direction for any aspect of this project?

Not a change in direction, but to ensure that the work is coordinated with other related work that is ongoing.

(7) Are the future directions as outlined by the researchers realistic and do they fall within the NOAA mission?

Yes.

(8) Finally, please rank the projects, according to your opinion of priority, for continued funding, especially if the funding starts to drop off.

3.

Program 3: Analysis of Historical data Sets and Further Investigations within the Restricted Arm of Lake Champlain. T. Manley

(1) Does this research address important questions that are relevant to both NOAA and society?

The project is analysis of historical observations of the Lake. These observations have identified interesting phenomena in the Lake.

(2) Has the productivity of the project been appropriate for the resources available? Have the research products been of acceptable quality or higher? Have they been valuable contributions, and have they justified the investment of resources?

I would say No; it appears to me while much of the work is interesting is observational in nature and not leading to scientific understandings, nor toward public policy development/ support.

Of note is the 3-D bathymetry of the Lake that was developed. It would be an excellent outreach and educational tool to develop this data set into an educational kiosk at ECHO.

(3) Are there any actions that NOAA should take that would improve the project and program within the constraints of the budget and resources available to the PIs?

It seems much effort is being put into adapting deep water measurement techniques to shallow water areas, NOAA could direct the PI to established shallow water measurement instruments.

These are a significant amount of observational data available on Lake Champlain however it is not readily accessible. NOAA should consider developing a publicly accessible data base of this information and make it available through their website.

(4) Based on the stated objective(s), is the project scientifically well thought out and designed? How could it be improved or made more effective?

Integrate observations with the forecast model under development.

(5) Does the project, as presented, come across as cohesive? If not, where are the problem areas and how might they be eliminated or reduced?

No. Project would be improved by coordination with other efforts to understand hydrodynamics of the Lake and the air-water interface. Efforts to develop measurement techniques'/instruments should be refocused to enhancing the understanding of lake processes.

(6) Is there something else we should be trying to cover under this project? Should we be considering a change in direction for any aspect of this project?

Possibly: developing a better understanding of the affect of the causeways and their pending removal would have a public policy tie-in.

(7) Are the future directions as outlined by the researchers realistic and do they fall within the NOAA mission?

(8) Finally, please rank the projects, according to your opinion of priority, for continued funding, especially if the funding starts to drop off.

4.

Program 4: Monitoring Meteorological Conditions on Lake Champlain and a Summary Analysis of Annual Mercury Deposition at Underhill, Vermont. D. Wang and D. Facey

(1) Does this research address important questions that are relevant to both NOAA and society?

Yes. The output from this effort provides meteorological information that forms the underpinning of understanding pollutant transport into/out of the Lake Champlain Basin. These data represent the only high resolution meteorological data collected near/at the Lake surface.
With regard to societal value, these data are used by a number of external organizations, the Burlington Office of the National Weather Service principle among them, for public good.

(2) Has the productivity of the project been appropriate for the resources available? Have the research products been of acceptable quality or higher? Have they been valuable contributions, and have they justified the investment of resources?

Yes. In my opinion the productivity has been outstanding for the resources provided to this project. Yes. The research products (data) have been of high quality. These data are valuable in that they have enable understanding of pollutant transport into/out of the Basin to be developed.

(3) Are there any actions that NOAA should take that would improve the project and program within the constraints of the budget and resources available to the PIs?

NOAA should consider including the operations of the meteorological stations into their operations budget as these data serve a number of public services and is a core function of NOAA. Further, NOAA should convene an expert group to identify and recommend

the complete nature and extent of meteorological monitoring network for the entire Lake Champlain Basin. The output of this expert group should become the basis of a multi-year implementation plan for location meteorological measurements throughout the Basin.

(4) Based on the stated objective(s), is the project scientifically well thought out and designed? How could it be improved or made more effective?

Yes, the project is well thought out and designed. The way to improve the effort and make it more effective would the implementation of a multi-year expansion plan as presented in (3) above.

(5) Does the project, as presented, come across as cohesive? If not, where are the problem areas and how might they be eliminated or reduced?

Yes.

(6) Is there something else we should be trying to cover under this project? Should we be considering a change in direction for any aspect of this project?

Not a change in direction, but to consider incorporating current met station as part of NOAA's operational budget and develop a plan for defining and citing an adequate basin network.

(7) Are the future directions as outlined by the researchers realistic and do they fall within the NOAA mission?

Yes.

(8) Finally, please rank the projects, according to your opinion of priority, for continued funding, especially if the funding starts to drop off.

2.

Reviewer #4

Overall Comments

From this reviewer's perspective, each of these research projects connects to the others. The meteorology of the basin provides a basis on how the hydrodynamics of the lake works (as now understood by observations). It is also the driver for the hydrodynamic model which relies on (observed) hydrological data for verification/validation. These research pieces provide meaning to how mercury flows through the biological systems and its potential for biomagnification. Bio translocation of mercury is critical to understanding mercury contamination (and other contaminants) in the various biological compartments of the lake. Knowledge of long-term and episodic mercury input (MMHg and Hg +2 in wet and dry deposition) to the surface of the lake (as well as evasion) and from the lake's watersheds provides additional information relevant to bio translocation. Separately, each of these research projects provides policy relevant information. Together, however, these research projects provide policy relevant information greater than just the sum of their parts. Knitting together these research efforts is of utmost importance.

Program 1: Atmospheric Exchanges of Mercury with Lake Champlain and Their Influence on Rates of Mercury Accumulation in Plankton and Fish. E. K. Miller.

Dr. Miller provided an in depth discussion of several research efforts focused on understating mercury fate and transport to and within the lake. Importantly, this was done by showing the information path for the results and how research results provided information to larger (policy) questions. As understood from another researcher's perspective, this reviewer believes a bit more attention should be given to provide where/how the research project(s) are positioned in place and time. A lot is known about mercury, its fate and transport in the environment. However, it remains a challenge to provide a comprehensive context for this research. Overall, Dr. Miller did an extraordinary job of providing local context. Regional context needed a bit more emphasis, however. (This may have been accomplished had there been more time allotted.) The reviewer recommends that this work, conducted at Lake Champlain, extend to other major freshwater waterbodies of the Northeast and that the Lake Champlain research consortium extend itself to other research/researchers efforts in the Northeast.

This research resulted in very good methods development, which may be used elsewhere and may provide cutting edge data (i.e., CVAFS method for MeHg). With regards to onboard (over lake) mercury measurements, it was not altogether clear how the investigator accounted for diurnal changes in the response of instruments (Teckran), although the investigator did indicate that such instrument behavior had been taken into account. The emission inventory that was used in the transport/deposition component of the research was based on existing inventories that (probably) do not reflect actual emissions. Because of this, some additional uncertainty may have been introduced into the results which were not fully addressed. Further, the reviewer recommends that the PI conduct isotope analysis to help de-convolute food-web studies.

Program 2: Building a Hydrodynamic Modeling System to Predict Circulation and Thermal Structure in Lake Champlain. D. Beletsky

Dr. Beletsky provided an update to his three year research project to develop a 3-dimensional hydrological model for Lake Champlain. The model was based on the POM developed for the Great Lakes and modified to Lake Champlain. Unlike the Great Lakes, Lake Champlain has one of the most complex bathymetries of all world lakes. This has made the effort complicated. The basic question for the model is to estimate sedimentation of material in the lake. Complicated internal changes in bathymetry and concomitant complex surface and thermocline seiches (driven by meteorology) proved challenging to model (but possible). Although the model can predict with some accuracy, lake hydrodynamics, it was evident that additional information from meteorological systems and observed hydrodynamic measurements would benefit model development. The presenter stated strongly that it was important to have reliable forcing functions. These forcing functions would be necessary to account for dynamic internal lake jets. This reviewer considers it paramount that additional model development occurs, and that future development is closely tied to hydrodynamic measurements and enhanced (additional) meteorological measurements.

Program 3: Analysis of Historical Data Sets and Further Investigations within the Restricted Arm of Lake Champlain. T. Manley

Dr. Manley provided a very strong insightful presentation on the state-of-the-knowledge of Lake Champlain's hydrodynamics and the research performed by his group to understand the lake's hydrodynamics. As stated in Dr. Beletsky's presentation, the hydrodynamics of the lake are quite dynamic. This is due to several factors: a very complex bathymetry, strong meteorology forcing conditions, and (not discussed by Dr. Beletsky) partially decoupled hydrological branches of the lake (sa. the restricted arm). Dr. Manley has, as did Dr. Wang, leveraged large graduate and undergraduate resources, providing a very important academic link to UVT and other colleges. This reviewer believes that a more diverse effort to use sondes should be undertaken to provide more certainty to how various parts of the lake interact. (This is apparent when discussing the future hydrodynamics of the restricted arm [and its biology], which cannot use many of the oceanographic tools on which Dr. Manley relies.) This reviewer believes that building science expertise in graduate and undergraduate students is one of the fundamental benefits of the research projects funded by these NOAA grants and that this research certainly provides a vehicle for this benefit.

Program 4: Monitoring Meteorological Conditions on Lake Champlain and a Summary Analysis of Annual Mercury Deposition at Underhill, Vermont. D. Wang and D. Facey.

Dr. Wang provided information on meteorological monitoring and mercury monitoring on and around Lake Champlain. From the description of the project and its history, it appears that the project has lead to extensive partnerships. The work requires and fulfills the need to connect research efforts and complete data synthesis on two key areas. The effort goes a very long way towards building science within the academic (graduate and undergraduate) communities of the University of Vermont and Middlebury College. This is to be commended. There has been a very strong effort made to provide small grant components for undergraduates and provide stipends for undergraduate and graduate work. Additional faculty from UVT and MC has been brought into the research project, enriching the overall results. This was evident in the projects data management and distribution component (through the Vermont Monitoring Cooperative) and supporting information.

Recommendations

The greatest advantage of each of these research efforts is that they can be knit together to tell a very cohesive story about how the lake behaves, from a hydro-biogeochemical perspective. However, the work is not done. We currently have several distinct parts of the story. The most pressing need, therefore, is to make sure that the combined research matures. Each of these research efforts now needs to connect with the others. In addition, the current research needs to be brought to public awareness.

- The meteorological network needs to be taken over by the National Weather Service. Additional core meteorological monitoring sites (possibly 5 or more) need to be deployed within the Lake Champlain basin. Efforts by the current research team and those of the NWS need to prioritize additional network sites.

- Feedback from the 3-D make model must also provide the basis for decision making with regards to additional met sites.
- Establish a kiosk in the ECHO Lake Aquarium/Leahy Center, the purpose of which is to provide the public with information about ongoing and future research. This kiosk should highlight all of the research projects and provide state of the science information and GUI interphase. Fore instance, the public should be able to fly within the lake's waters in a 3-D simulator. Linkages should be made to historical sites that lie on the bottom of the lake and any would-be public "aquanaut" should be able to learn about the myriad of complex biogeochemical components of the lake.
- A convergence of the Lake Champlain hydrodynamic model, observational data (meteorological, deposition, hydrological) and landscape modeling should be pursued to estimate potential changes of mercury loading to Lake Champlain. Within the region, EPA and its partners are building and testing the MERGANSER model. This model uses depositional inputs from EPA's RMSAD and CMAQ atmospheric models to drive watershed/landscape translocation for mercury. Landscape topography and vegetation intercept dry and wet mercury deposition and move it through individual watersheds to the Lake. More than two dozen watersheds provide runoff to the Lake. Each one provides different inputs to different locations. It should be possible to run the MERGANSER model and the Lake Champlain hydrodynamic model to get a clear picture of how event and long-term mercury depositing on the watershed influences mercury inputs (HG +2 and MMHg) to the lake and subsequent biomagnifications of methyl mercury in the Lakes ecosystems. Ultimately, it may be possible to "game" mercury inputs to determine the potential for long-term improvements in mercury contamination of key aquatic species.
- The data that has been developed under the observational lake hydrodynamics needs to be useable database. This may be part of the public outreach effort that is part of the idea of deploying a kiosk at the Leahy Center.

(1) Does this research address important questions that are relevant to both NOAA and society?

Each of the research projects address important questions, relevant to NOAA and the public.

(2) Has the productivity of the project been appropriate for the resources available? Have the research products been of acceptable quality or higher? Have they been valuable contributions, and have they justified the investment of resources?

Each of the research project, singularly, matched effort with resources. Several leveraged resources very well (Wang and Manley). Each project provided quality research and valuable scientific knowledge and methods.

(3) Are there any actions that NOAA should take that would improve the project and program within the constraints of the budget and resources available to the PIs?

As stated previously, the challenge to NOAA is to now provide a framework to knit together the major components of the four research projects.

(4) Based on the stated objective(s), is the project scientifically well thought out and designed? How could it be improved or made more effective?

The only criticism that I have, which bears on each of the four efforts, is that each project should have been more cognizant of the other projects and each should have begun to tie together the research projects. I have provided my vision of how this may evolve in my recommendations.

(5) Does the project, as presented, come across as cohesive? If not, where are the problem areas and how might they be eliminated or reduced?

Each of the research projects came across as cohesive. Each presenter provided context to their research.

(6) Is there something else we should be trying to cover under this project? Should we be considering a change in direction for any aspect of this project?

See Recommendations.

(7) Are the future directions as outlined by the researchers realistic and do they fall within the NOAA mission?

I think that the PIs were a bit nearsighted. None looked at their research, tied it to other projects and projected it out as a comprehensive effort. The individual expectations for the research projects appeared to be fine, although a bit too conservative for my tastes. See Recommendations.

(8) Finally, please rank the projects, according to your opinion of priority, for continued funding, especially if the funding starts to drop off. 4.

#1 Miller
#2 Beletsky
#3 Wang (see recommendations)
#4 Manley
BUT WAIT! Future efforts should be using crochet hooks and not pairing knives.

Reviewer #5

Program 1: Atmospheric Exchanges of Mercury with Lake Champlain and Their Influence on Rates of Mercury Accumulation in Plankton and Fish. E. K. Miller.

(1) Does the research address important questions relevant to NOAA and society?

Dr. Miller's research program adequately addresses the stated NOAA objectives (per the Announcement of Funding Opportunity for NOAA's Great Lakes Ecosystem Research), specifically the a) development a framework of coordination for activities among atmospheric research participants (via the establishment of a collaborative research program with diverse academic, agency, and private researchers throughout the Lake Champlain basin), b) continue current long-term atmospheric/meteorological monitoring (through direct

collaboration with Dr. Wang, University of Vermont) and c) coupling of monitoring and modeling of activities to project annual deposition rates of measured pollutants.

(2) Has the productivity/contributions of the project been appropriate and are research project of acceptable quality?

The establishment of additional meteorological stations, strategically placed throughout the Lake basin and accompanying watershed is a required component for continued monitoring of atmospheric ('wet') mercury deposition on a spatially-specific basis. Accurate assessment of contaminant transfer to the Lake (directly or via indirect land-water transfer) will aid potential calculation of biotic uptake of mercury (as well as future hydrodynamic/ contaminant modeling efforts). A paper addressing the assessment of a mass balance for mercury has been the most significant contribution. An additional contribution of the NOAA funds directed to this program (albeit, much less tangible), is the use of such funds by the researcher to acquire other extramural funding.

(3) Are there actions NOAA should take to improve the project and/or the program?

The research has utilized the NOAA monies to adequately address wet deposition of mercury within the Lake Champlain basin (at the 'regional' monitoring site of Underhill). Continuation of such monitoring is advised; however, the actual integration of NOAA-funded research activities into ancillary mercury research projects and/or other governmental-funded mercury programs is 'cloudy' at best. Better definition of NOAA-funded research activities would improve this picture.

(4) Based on the scientific objectives, if the project well thought out and designed?

Given the use of NOAA-funded research activities as a 'core scientific component' within a much larger research 'program' addressing the atmospheric and potentially, hydrologic mercury contamination, the initial objectives for (and actual results arising from) the NOAA funding appear appears functional and adequate.

(5) Is the project cohesive?

The Given the expanse of the mercury research 'program', as presented by the researcher, the NOAA-funded data products appear functional, with an apparent future direction (given it's overall funding budget). Research concerning the transfer of mercury into the Lake and its bioaccumulation within the Lake's biota role of mercury supports ancillary research activities and political mandates of the Lake Champlain Research Consortium.

(6) What additional items might be addressed within this project?

Besides expanding the funding for additional (future) meteorological stations and potentially expanding the funding for increased research, Dr. Miller's function/role within the NOAA-sponsored program activities for Lake Champlain appears confined to mercury monitoring activities. However, successful completion of research directives addressing land/water contaminant transfer and/or mercury bioaccumulation will require additional, sustained funding and interagency collaboration (on both a federal and state level) and is most likely,

beyond the immediate potential of the NOAA funding 7) Are future directions of the researcher realistic and/or within NOAA's mission? Given NOAA's stated research and political goals/achievements for the Lake Champlain research program, the researcher's contributions and future direction appear realistic.

(8) Rank of project, in relation to the four programs under review, for continued funding.

Given the apparent importance and requirement of the historical and evolving mercury deposition data within any current/future atmospheric modeling products, I rank the importance of continued and potential increased funding for this program as: 3 of 4 (with 1 having the greatest importance/need for increased/continued funding).

Program 2: Building a Hydrodynamic Modeling System to Predict Circulation and Thermal Structure in Lake Champlain. D. Beletsky

(1) Does the research address important questions relevant to NOAA and society?

Dr. Beletsky's research program adequately addresses the stated NOAA objectives (per the Announcement of Funding Opportunity for NOAA's Great Lakes Ecosystem Research), specifically the development of predictive modeling capabilities (via operative 3-D models).

(2) Has the productivity/contributions of the project been appropriate and are research projects of acceptable quality?

Given the duration of the funded research (which is in the final year of the project), his contributions appear adequate (Dr. Beletsky has completed model development and is now comparing model output to historical hydrodynamic data, contributed by Dr. T. Manley). Manuscript contributions, to date, include co-authorship of peer-reveiwed manuscript –accepted for journal publication and presently, 'in press', concerning surface flow within Lake Champlain. Given the quality of research contributions presented to the panel, I envision one (or several) additional publishable scientific contribution(s) from the immediate research project.

(3) Are there actions NOAA should take to improve the project and/or the program?

Given the requirement for transfer of scientific outcomes for public use and/or the Lake Champlain research community, the generation of a predictive (nowcast, forecast) model for Lake Champlain hydrodynamics is imperative. As such, model development, validation, and incorporation into operational Lake Observing System will require close collaboration and data sharing among researchers within the hydrodynamic, atmospheric, and modeling research components. Besides continuing the development of operational hydrodynamic models, future funding should be directed, in part, to the establishment of universal data portal (for all NOAA-funded Lake research projects to contribute to) and from which, operational models within a Lake observing system can 'updated' as new data streams are made available.

(4) Based on the scientific objectives, if the project well thought out and designed?

Given the initial paucity of data from which to build such a model, Dr. Beletsky undertook a 'step-bystep' approach in advancing the complexity of the hydrodynamic model (i.e., first a 2dimensional and then a 3-dimensional model). Such an approach is necessary for model development/validation, particularly given that the modeling project is within its initial funding stage. As more data is made available to Dr. Beletsky (from past and current collaborative atmospheric and hydrodynamic research projects), the spatial/temporal coverage afforded by an operative model should dramatically increase.

(5) Is the project cohesive?

The model and accompanying data products appear functional, with a definite future direction (given it's initial funding status). Such an operational model supports activities and research/political mandates of the Lake Champlain Research Consortium.

(6) What additional items might be addressed within this project?

Dr. Beletsky's function/role within the NOAA-sponsored program activities for Lake Champlain should continue and is best suited to refining and advancing the hydrodynamic model in an effort to increase spatial/and temporal coverage, particularly in regard to synoptic- to meso-scale hydrodynamic variability (i.e. east/west cross-lake variability and water-exchanges between the deep middle portion of the Lake and the northern/southern reaches).

(7) Are future directions of the researcher realistic and/or within NOAA's mission?

Given NOAA's stated research and political goals/achievements for the Lake Champlain research program (particularly in light of requirement for developing an operational Lake observing/forecasting system), the researcher's contributions and future direction appear quite realistic.

(8) Rank of project, in relation to the four programs under review, for continued funding.

Given the apparent importance and requirement of current/future hydrodynamic modeling products (including event-scale forecasting efforts), I rank the importance of continued and potential increased funding for this program as: 1 of 4 (with 1 having the greatest importance/ need for increased funding).

Program 3: Analysis of Historical data Sets and Further Investigations within the Restricted Arm of Lake Champlain. Presentation by: T. Manley

(1) Does the research address important questions relevant to NOAA and society?

Since the early- to mid-1990's, Dr. Manley has conducted an exhaustive survey of Lake Champlain hydrodynamic processes (throughout diverse regions of the Lake). Dr. Manley's program addresses the stated NOAA objectives (per the Announcement of Funding Opportunity for NOAA's Great Lakes Ecosystem Research), specifically to: continue to develop and apply new techniques and instrumentation for exploring both the Lake's main

body and other regions. From Dr. Manley's presentation, it was quite apparent that a massive collection data has been acquired, particularly in regard to hydrodynamic variables that could be included in nowcast-/forecast-modeling efforts.

(2) Has the productivity/contributions of the project been appropriate and are research project of acceptable quality?

The amount of data generated throughout Dr. Manely's funded tenure appears massive and on an informational basis, quite diverse. In regards to peer-reviewed manuscripts, the production (scientific contributions) of the funded research is inadequate, particularly given the longevity and amount of funded research activities. Several manuscripts that are senior- and/or co-authored by the investigator currently are submitted (but not yet, accepted for publication within scientific journals). In contrast, the investigator has produced numerous 'grey' literature and documentary-type contributions for the general public.

(3) Are there actions NOAA should take to improve the project and/or the program?

Given the amount of hydrodynamic data currently archived by Dr. Manley and the importance of select hydrological data to now-/fore-cast efforts, the best direction for future NOAA funding is to a) initiate scientific-manuscript preparation assessing/analyzing archived hydrodynamic data, for dispersal to the scientific community and b) initiate collaboration of Dr. Manley's program with currently-funded modeling efforts with an intent to incorporate the historical dataset into modeling programs. Funding for additional acquisition of hydrodynamic data should be allocated on informational 'need to know bases', as dictated by modeling efforts.

(4) Based on the scientific objectives, is the project well thought out and designed?

Given the diversity and (apparent) size of the hydrodynamic data set, in conjunction with the paucity of peer-reviewed scientific contributions, the hydrodynamic research program exhibits little continuity and/or direction. During the presentation, the phrase that struck my mind, in regards to detailed hydrodynamic characterization of Lake Champlain by an endless stream of state-of-the art oceanographic instrument, was…'how many ways can one pound a nail!…' .

(5) Is the project cohesive?

Although impressive in scope and magnitude, the hydrodynamic program does not appear cohesive – in fact, the program appears to be a collection of small, often independent projects, not yet synthesized into a final hydrodynamic framework for the lake. This occurrence may, in part, be due to the means by which a majority of data products were generated – specifically, through under-graduate student-sponsored research (rather than through dedicated graduate student research)

(6) What additional items might be addressed within this project?

Besides the aforementioned need for scientific technology-transfer (via peer-reviewed manuscripts), data collected (to date) needs to be collated and released to an archived NOAA

data set, accessible to NOAA and Lake Champlain researchers, as dictated by the NOAA program staff.

(7) Are future directions of the researcher realistic and/or within NOAA's mission?

Given NOAA's stated research and political goals/achievements for the Lake Champlain research program, collection of data pertaining to hydrodynamic processes should be determined by data requirements of modeling efforts.

(8) Rank of project, in relation to the four programs under review, for continued funding.

Overall, I rank the importance of continued and potential increased funding for continued collection of additional hydrological data without regard to current/future modeling efforts as: 4 of 4 (with 1 having the greatest importance/need for increased funding). However, the apparent importance and requirement of incorporating collected hydrological data into current/future modeling and forecasting efforts is recognized.

Program 4: Monitoring Meteorological Conditions on Lake Champlain and a Summary Analysis of Annual Mercury Deposition at Underhill, Vermont. D. Wang and D. Facey

(1) Does the research address important questions relevant to NOAA and society?

Dr. Wang's research program adequately addresses the stated NOAA objectives (per the Announcement of Funding Opportunity for NOAA's Great Lakes Ecosystem Research), specifically the a) current and long-term atmospheric/meteorological monitoring activities (via establishment/'upkeep' of meteorological stations) and b) development a framework of coordination for activities among atmospheric research participants (via the established conduit of graduate student recruitment/support).

(2) Has the productivity/contributions of the project been appropriate and are research project of acceptable quality?

The establishment of meteorological stations, strategically placed throughout the Lake basin and accompanying watershed is a required and invaluable component for related atmospheric research projects (e. g. mercury deposition) and aids current and future hydrodynamic modeling efforts (particularly small-scale, wind-driven forcing events). Although such contributions do not fall within the strict production 'criteria'of peer-reviewed manuscripts, related atmospheric and hydrodynamic research is severely curtailed.

(3) Are there actions NOAA should take to improve the project and/or the program?

The number of NOAA-funded meteorological stations (Colchester Reef and Diamond Island) throughout the Lake's expanse appears woefully inadequate (albeit, the weather station at Burlington airport provides ancillary data), given the variability and hydrologic importance of select meteorological parameters at the air/water interface. Future funding should be directed, in part, to the establishment and upkeep of an increased number of stations.

(4) Based on the scientific objectives, if the project well thought out and designed?

Given the limitations of producing only two relevant meteorological data streams for the entire Lake, data distribution (to collaborating atmospheric projects and NOAA's National Weather Service) appears functional and adequate.

(5) Is the project cohesive?

The meteorological stations and accompanying data products appear functional, with an apparent future direction (given it's 'shoe-string' budget). Dr. Wang's active role of a funding conduit for graduate student research supports activities and research/political mandates of the Lake Champlain Research Consortium

6) What additional items might be addressed within this project?

Besides expanding the funding for additional (future) meteorological stations and potentially expanding the funding for increased graduate student training (via the University of Vermont's graduate program), Dr.Wang's function/role within the NOAA-sponsored program activities for Lake Champlain appears confined to atmospheric monitoring activities.

7) Are future directions of the researcher realistic and/or within NOAA's mission?

Given NOAA's stated research and political goals/achievements for the Lake Champlain research program, the researcher's contributions and future direction appear are realistic.

8) Rank of project, in relation to the four programs under review, for continued funding.

Given the apparent importance and requirement of the historical and evolving meteorological data within current/future atmospheric and hydrodynamic modeling products (including event-scale forecasting efforts), I rank the importance of continued and potential increased funding for this program as: 2 of 4 (with 1 having the greatest importance/need for increased funding).

APPENDIX 1. Invitation and Agenda

Lake Champlain Program Review of NOAA Sponsored Research

When: 29 & 30 October 2008 (Wednesday & Thursday)

Where: Burlington, VT (ECHO Center at Leahy Center, 1 College St.)

Why: Formal periodic reviews are essential for maintaining the highest research effectiveness and helping to ensure relevancy both to NOAA's goals and societal needs. Since the beginning of this program there has not been a NOAA review.

Details: The review will consist of four or five external reviewers who will be evaluating the atmospheric and hydrodynamic research over the course of this program's existence with emphasis on research conducted during the previous 5 years and the future direction. All funded proposals, project summaries prepared by the lead PI, and additional supporting materials will be made available to the review panel prior to the review date.

The funded proposals and their lead PI are:

(1) Atmospheric Exchanges of Mercury with Lake Champlain and Their Influence on Rates of Mercury Accumulation in Plankton and Fish. Lead PI: E. K. Miller.

(2) Building a Hydrodynamic Modeling System to Predict Circulation and Thermal Structure in Lake Champlain. Lead PI: D. Beletsky.

(3) Analysis of Historical data Sets and Further Investigations within the Restricted Arm of Lake Champlain. Lead PI: T. Manley.

(4) Monitoring Meteorological Conditions on Lake Champlain and a Summary Analysis of Annual Mercury Deposition at Underhill, Vermont. Lead PI: D. Wang.

AGENDA FOR REVIEW OF LAKE CHAMPLAIN RESEARCH

	Wednesday
Time	Activity
9:00 - 9:15	Introductions and charge to review panel
9:15 - 9:45	First atmospheric project presentation: Wang
9:50 - 10:50	Second atmospheric project presentation: Miller
10:55 - 11:25	Q & A on atmospheric projects
11:25 - 12:30	Lunch
12:30 - 1:15	First hydrodynamic project presentation: Beletsky
1:20 - 2:20	Second hydrodynamic project presentation: Manley
2:25 - 2:55	Q & A on hydrodynamic projects
2:55 - 3:15	Break
3:15 - 3:45	Open Q & A on all research activities
3:50 - 4:30	Discussion of future direction
4:30 - 5:00	Wrap-up & final interaction between panel and researchers
5:30	Dinner
	Thursday
8:30 - noon	**Closed session for review panel and program managers**

Review Panel Questions

The review panel will be asked to address the following questions with respect to each of the four projects:

(1) Does this research address important questions that are relevant to both NOAA and society?

(2) Has the productivity of the project been appropriate for the resources available? Have the research products been of acceptable quality or higher? Have they been valuable contributions, and have they justified the investment of resources?

(3) Are there any actions that NOAA should take that would improve the project and program within the constraints of the budget and resources available to the PIs?

(4) Based on the stated objective(s), is the project scientifically well thought out and designed? How could it be improved or made more effective?

(5) Does the project, as presented, come across as cohesive? If not, where are the problem areas and how might they be eliminated or reduced?

(6) Is there something else we should be trying to cover under this project? Should we be considering a change in direction for any aspect of this project?

(7) Are the future directions as outlined by the researchers realistic and do they fall within the NOAA mission?

(8). Finally, please rank the projects, according to your opinion of priority, for continued funding, especially if the funding starts to drop off.

APPENDIX 2. Summaries of Research Activities Provided by Principal Investigators

MILLER ET AL. SUMMARY

NOAA Lake Champlain Project Review (5-years) 2003-2008 Atmospheric Projects
This document summarizes and introduces written materials provided for the NOAA Lake Champlain Program Review October 29th and 30th, 2008. Additional written materials may be provided prior to or during the October 29th meeting.

Activities reviewed below cover several of the atmospheric research projects in which Dr. Eric Miller of Ecosystems Research Group, Ltd. has been involved. Investigators for other atmospheric projects may provide other materials.

Prepared by:
Eric K. Miller
Ecosystems Research Group, Ltd.
(802) 649-5550

in collaboration with research partners at the University of Vermont, University of Michigan, Saint Lawrence University, Dartmouth College, USGS, VTANR-APCD, VTANR-WQD, USEPA, and VMC.

Deane Wang, Melody Burkins, Carl Waite UVM
Neil Kamman, Sean Lawson, Rich Poirot VTANR
Jamie Shanley, Ann Chalmers USGS
Celia Chen, Brian Jackson, Vivien Taylor, Dartmouth College
Ning Gao, Saint Lawrence University
Gerry Keeler, University of Michigan

10/1/2008

Overview

NOAA - Lake Champlain Research Consortium (LCRC) supported atmospheric research is highly integrated both within the LCRC-funded projects and with external projects and national programs. This integration occurs both in terms of science objectives and funding. The NOAA-LCRC core research funding has provided the opportunity for significant leverage of funding from partner institutions such as USEPA-ORD, USEPA-OAR, USEPA-Region 1, USGS, NADP/MDN, Vermont Agency of Natural Resources (VTANR) Air Quality Division, VTANR Water Quality Division, and the Vermont Monitoring Cooperative.

The program review period (2005-2008) covers the period of several different individually funded atmospheric projects relating the deposition rate and fate of atmospheric mercury in the Lake Champlain Basin. Different investigators led the different projects over this period although most of the currently funded investigators have participated in some form in the atmospheric projects conducted during the period covered by the review.

Due to the high level of project integration there is considerable overlap in the reporting and discussion of results from the separately funded atmospheric projects. Generally speaking, Atmospheric Project #1 - "Wet Deposition" is a "core" project providing critical data on mercury and major-ion wet deposition to the Lake Champlain Basin. As will be evident from the materials submitted, the wet-deposition measurements at Underbill are critical for regional studies as well.

Because of the foundation of NOAA-funded wet-deposition measurements (NADP/AIRMoN daily major ions, NADP/MDN event total mercury, and NADP/MDN methyl mercury), the Underbill site (VT99) has emerged as a regional supersite for air pollution measurements. NADP has elected to conduct several long-running collector collocation studies at VT99 for both major ions and mercury. VT99 is serving as a test-bed site for the introductions of new collectors (MDN-NCON, NTN-NCON) and rain gages (ETI NOAH II). VT99 also hosts one of the first generation of NADP/MTN ambient-air mercury speciation network sites and an IMPROVE fine particle site. The Vermont Agency of Natural Resources Air Pollution Control Division also conducts low-level Os, SO2, CO, air-toxics, and continuous PM2.5 (FDMS-TEOM) measurements at the site. The VTAPCD, NADP/MTN, and the VMC collect a full suite of meteorological measurements exceeding the requirements of an EPA-CASTNET site. This extensive set of collocated atmospheric measurements increases the value of the NOAA-supported wet deposition measurements. As will be discussed in the program review presentations, this has permitted integrated analysis of co-pollutant transport and deposition.

Atmospheric Project #1: Wet Deposition of Mercury at Underbill, VT
Funding partners: NOAA (core), USGS, EPA, VMC Prior Accomplishments (through 2006)

- Event Hg wet deposition measurements began in 1992 funded by NOAA using the University of Michigan MICE collector.
- 1998 Publication of stream water mercury fluxes investigation funded by NOAA-LCRC investigating fate of atmospheric mercury, uses wet deposition data.
- NOAA dropped funding for MICE -2002, investigators limped it along.
- EPA-ORD-HEASD picked up funding for MICE in 2003, including analysis of archived samples.
- 2003 Publication of cloud water and rain water mercury comparisons on Mt. Mansfield funded partly by NOAA-LCRC.
- 2004 NOAA LCRC funded start-up of NADP/MDN collector (weekly), EPA continued support for MICE.
- 2005 NOAA LCRC funded event-based sampling with NADP/MDN.
- 2005 Publication of 10-year MICE record (1993-2003) Ecotoxicology, Data made accessible through VMC.
- 2005 publication of regional mercury deposition model using data from Underbill site.
- 2005-2006 NOAA, EPA, USGS, MDN jointly funded ACM, NCON, MICE collector comparison. This study was necessary to facilitate transition from the MICE to MDN collector and maintain the longest-running event Hg wet deposition record in the world.

Current Activities (2006-2009)

- 2006 initiate monthly composite analysis for methyl-Hg (NOAA-funded).
- Manuscript prepared on collector comparison, authors conclude sample-train comparison is needed to complete the study.
- 2007 conducted sample-train comparison on very limited funding.
- 2007 NOAA-LCRC grant to Miller et al. (Atmospheric exchanges with Lake Champlain) funds additional event-based methyl-Hg sampling and analysis.
- 2008 collector comparison paper revised (will be submitted Nov/Dec 2008) - informs mercury science and policy community on issues related to interpreting MDN- and MICB-based mercury measurements.
- 2008 culmination of collector comparison study permits successful integration of long-term MICE record with on-going MDN event record to maintain longest event wet-deposition record in the world.
- NOAA LCRC-2006 and EPA-ORD-HEASD funding facilitates joint analysis of recent (MDN) and MICE long-term records in conjunction with AIRMoN data (to be discussed on 10/29).
- Analysis is currently being conducted on regional transport and climate influences on wet deposition of total and methyl mercury.
- Manuscript will be prepared and submitted on total and methyl mercury wet deposition.

Supplementary Materials Provided to NOAA Program Review Panel as of 10/1/2008:
Please review the supporting materials in this submission. Details on the most recent results are provided in the form of an abstract and presentation slides from the most recent conference presentation.

Manuscripts

- Burke et al. 1995 - initial publication from NOAA-funded start-up.
- Scherbatskoy et al. 1998 - subsequent NOAA-funded investigation.
- Lawson et al. 2003 - cloud water study uses data from NOAA measurements.
- Malcolm et al. 2003 - cloud water / precipitation study funded in part by NOAA.
- Keeler et al. 2005 - analysis of 10-year record with MICB collector (1993-2003).
- Miller et al. 2005 - regional model using data from Underbill.
- Miller et al. (draft 2008) collector comparison study.

Presentations

- Miller et al. 2008 - LCRC conference abstract providing an overview of recent accomplishments in NOAA-LCRC-funded atmospheric deposition studies.
- Miller et al. 2008 - LCRC conference slides providing an overview of recent accomplishments in NOAA-LCRC-funded atmospheric deposition studies.

Atmospheric Project #2: Fate of Atmospheric Mercury in the Lake Champlain Basin Prior Accomplishments (2003-2006)

This research effort has been conducted in three different funding phases with each phase initiated by a separate competitive proposal and led by different Pis. Initial efforts (2003-2005) were to develop a mass-balance model for mercury in Lake Champlain. This project was led by Dr. Ning Gao of Saint Lawrence University and resulted in a 2005 ES&T publication describing the model. Dr. Gao also conducted source-receptor modeling studies using the deposition data gathered under the early years of atmospheric project #1, but funded through atmospheric project #2. This work resulted in a publication in 2004. In 2005, the same group of investigators led by Dr. Gao received funding for 1-year pilot studies to explore methods for advancing the development of the mass-balance model and eventually incorporating model of atmospheric mercury transfers to the Lake Champlain food-web. The results of these pilot studies were used to develop a new modeling framework and experimental design for assessing atmospheric exchanges of mercury with Lake Champlain and their influence on rates of mercury accumulation in plankton and fish. The researchers now led by Dr. Eric Miller of Ecosystems Research Group, Ltd. were awarded a 3-year grant (2006-2009) to conduct the observations and modeling under this new investigational framework.

Current Activities (2006-2009)
Atmospheric Exchanges of Mercury with Lake Champlain and Their Influence on Rates of Mercury Accumulation in Plankton and Fish (started fall 2006)

Lake Champlain continues to experience mercury contamination problems resulting in public advisories to limit or curtail human consumption of top trophic level fish such as walleye. Prior work by the project team quantifying the annual mass-balance for mercury in Lake Champlain demonstrated that direct atmospheric deposition was the dominant source of mercury to the ecosystem despite Lake Champlain's high watershed area to lake surface area ratio. The mass-balance study also identified the emission of volatile mercury from the lake surface as a critical process - even more important than sedimentation - in limiting the amount of mercury accumulating in the lake.

Studies in large and small lakes have shown that mercury concentrations in phytoplankton and zooplankton increase from the onset of stratification to the period just prior to fall turnover. However, these studies have generally characterized only initial and final concentrations, with possibly 1 intermediate sampling. Thus it is not known from these limited observations if mercury levels in biota increase steadily through the stratified period or if they respond to short-term fluctuations in mercury loading from the atmosphere or tributaries. Lower levels of the pelagic food web, i.e. bacteria, phytoplankton and zooplankton, are more likely to respond to shorter term increases in Hg availability given their shorter lifespans and higher seasonal turnover. Preliminary analysis of new data gathered by the project team on reactive gaseous mercury concentration in air, total and methyl-mercury concentrations in precipitation, and total and methyl mercury concentrations in epilimnetic waters of Lake Champlain suggest that specific deposition events and/or high deposition weeks may result in significant short term elevations of both total and methyl mercury in the surface water layer. Potential short-term increases in surface water Hg^{2+} and methyl

mercury suggest the possibility that biotic mercury assimilation is at least somewhat episodic (with the possibility of time lags). Biotic assimilation is likely to be responsive to episodic atmospheric mercury loading in Lake Champlain because of the lake's very low total and methyl mercury concentrations and the dominance of atmospheric inputs, particularly during the stratified period.

This project is studying the influence of total- and methyl-mercury deposition on the rate of mercury accumulation in plankton and fish. Atmospheric exchanges are assessed through a combination of direct measurements and modeling based on the results of the measurements. The surface water and biotic response to different levels of mercury loading are assessed via bi¬weekly sampling of water, micro-seston (bacteria and phytoplankton), and zooplankton resulting in up to 10 sampling periods per year throughout the stratified period. Prey fish are sampled toward the end of the season. Biotic response is being assessed in one eutrophic (Missisquoi Bay) and one oligotrophic (Malletts Bay) segment of the lake. Differences in planktonic biomass, food-web structure, and fish growth rates produce different responses between these segments. In a related project, source regions for high total- and methyl-mercury deposition events are being determined by back-trajectory analysis, offering the possibility of linking observations of biotic accumulation - via response to high deposition periods - and to the source regions responsible for the deposited mercury.

This project was proposed and approved as a 3-yr study, but with funding injected annually based on NOAA budget allocations. Years 1&2 were fully funded, allowing field seasons in 2007 and 2008 (which will end in late October 2008). Year 3 funding was reduced due to a NOAA budget shortfall. The third planned field season has been canceled due to the budget shortfall. The investigators will focus on analysis and writing in year three with several manuscripts possible. The first of these manuscripts describing the analytical methodology breakthrough that was required to conduct the research has been submitted to ES&T. A second manuscript describing the observations and methods used to determine tributary fluxes of dissolved and particulate total and methyl mercury to Lake Champlain for the food-web model is nearly completed.

The pilot studies conducted prior to the current project revealed that methyl mercury levels in Lake Champlain surface waters were frequently below the detection limit (0.04 ng/L) of the current standard method as performed by one of the most capable surface water laboratories (USGS). The project team realized that frequent observations of surface water methyl-mercury near or below the detection limit would have severely limited the ability to observe and model methyl mercury dynamics in the water column. Therefore, an initial priority of the group was to push forward the development of a new method using isotope-dilution GC-ICP-MS with a high-resolution sector mass spectrometer. The analysis utilizes species-specific isotope dilution, purge and trap, gas chromatography ICP-MS and provides a method detection limit of 0.0015 ng/L for methyl-mercury. This detection limit improvement of well over an order of magnitude (with excellent precision at observed concentrations) has permitted robust observations of temporal and spatial variation in surface water methyl mercury not previously achievable (see Jackson et al. submitted - attached to this submission).

Using this powerful new method, the team has been able observe the dynamics of Hg2+ and methyl-mercury response to changes in atmospheric loadings to the lake (see Miller et al abstract and slides provided with this submission).

Supplementary Materials Provided to NOAA Program Review Panel as of 10/1/2008:
Please review the supporting materials in this submission. Details on the most recent results are provided in the form of an abstract and presentation slides from the most recent conference presentation.

Manuscripts

- Gao et al. (2004) Underbill Mercury Source-Receptor Modeling.
- Gao et al. (2006) ES&T Lake Champlain Mass Balance Model with supporting information.
- Jackson et al. (2008 - submitted to ES&T) Low level mercury speciation in freshwaters by isotope dilution GC-ICP-MS.

Project Reports

- Miller (2007) Final Report NA17RJ1225 - Lake-Atmosphere Mercury Exchange.

Processes

- Miller et al. Progress Report NA06OAR4600222 - 2007-07-27.
- Miller et al. Progress Report NA06OAR4600222 - 2008-01 -31.
- Miller et al. Progress Report NA06OAR4600222 - 2008-07-29.

Abstracts

- Shanley and Chalmers (2008) The Dynamics of Streamwater Inputs of Total Mercury and Methylmercury to Lake Champlain.
- Miller et al. (2008) Episodic and Chronic Atmospheric Mercury Deposition to the Lake Champlain Basin.
- Miller et al. (2008) Dynamics of Mercury Cycling and Biotic Assimilation in Malletts and Missisquoi Bays.

Slides

- Miller et al. LCRC Conference 2008 Dynamics of Mercury Cycling and Biotic Assimilation in Malletts and Missisquoi Bays slides.
- Miller et al. LCRC Conference 2008 Episodic and Chronic Atmospheric Mercury Deposition to the Lake Champlain Basin slide.

WANG ET AL. SUMMARY

Report for NOAA Funding of:

(1) Monitoring Meteorological Conditions on Lake Champlain.

(2) The Lake Champlain Research Consortium.

(3) Summary Analysis of Annual Mercury Deposition at Underbill, Vermont.

Deane Wang, University of Vermont
Douglas Facey, Saint Michael's College
Eric Miller, Ecosystems Research Group

October 2008

Overview

Over the last five year period, our research on various aspects of the environment in the Lake Champlain Basin has been conducted in concert with many partners including the Vermont Monitoring Cooperative, the Proctor Maple Research Center, the Lake Champlain Basin Program, and the institutional members of the Lake Champlain Research Consortium (University of Vermont, Saint Michael's College, Middlebury College, Green Mountain College, Johnson State College, SUNY-Plattsburgh, and Castleton State College). While each of the components reported here are quite distinct, they form important pieces of the overall puzzle to understand environmental conditions in the Lake Champlain Basin.

The meteorological monitoring complements a large number of other measurements taken throughout the Basin by many other research institutions and government agencies. Without these data, a significant hole in our ability to understand, model, and predict would appear. The LCRC supports the continuing interaction of the scientists and policy makers/ managers in the Basin so that both planning, synthesis, and action are better informed by the complex scope of activities among LCRC institutional members and other public and private groups working on Lake Basin issues. In addition, the LCRC supports the large number of students (undergraduate and graduate) that actually conduct a large amount of the field and laboratory research needed to advance our understanding. In this region, we have some of the best mercury deposition data in the country, and the last component of this funding supports the synthesis of these data into a story of the long-term depositional history of this increasingly important anthropogenic hazard.

More detailed outcomes of these research efforts as distinct components of a larger program of research are presented in each section, below.

(1) Monitoring Meteorological Conditions on Lake Champlain

Lake Champlain meteorological stations were established at Colchester Reef (1996) and Diamond Island (2004), and have been operated by the University of Vermont (UVM), Rubenstein School of Environment and Natural Resources in conjunction with their membership in the Vermont Monitoring Cooperative (VMC). Variables measured include: precipitation (non-freezing months), wind speed and direction, air temperature, relative humidity, barometric pressure, total solar radiation, (all at 38 m msl), and water temperature (26.5 m msl). In addition, at the Colchester Reef site, additional air temperature, wind speed, and relative humidity are collected at 33.5 m msl. Data

are automatically transmitted from the station once per hour to a server at the Rubenstein Ecosystem Science Laboratory in Burlington.

The Vermont Monitoring Cooperative (VMC) and UVM are responsible for 1) management and maintenance of these stations as core activities, 2) data collection (data are downloaded to the VMC server) and data management, 3) most of the data distribution, and 4) all data archiving. The VMC data manager has been working hard to update data QA/QC and archiving procedures so that the most recent data, along with all archived data, will soon available online at: http://sal.snr.uvm.edu/vmc/. Data have been available to all researchers and have contributed to work on hydrodynamics, pollutant movement, modeling studies, and predictions about pollutant loading and dispersal. VMC also publishes these data in near-real time on their homepage at the same URL. The National Weather Service (NWS) in Burlington, VT receives these data in near-real time from VMC, and in turn, makes the data available to the public over the internet at: http;// www.erh.nQaa.gov/.ei/btv/html/lake2.shtml and over the NOAA weather radio. The NWS uses these real-time meteorological data from Colchester Reef and Diamond Island in their forecasts for Lake Champlain, hourly mesoscale analysis, daily climate maps, and for climatological analysis. The data are used to provide ground-truth and verification of their forecasts, lake wind advisories, and severe weather warnings in and around Lake Champlain. The data are also accessed by the public at http://www.burlmgtonecoinfo.net.

(2) The Lake Champlain Research Consortium (LCRC)

The LCRC was established 1991 with membership from Univ. of Vermont, Middlebury College, Saint Michael's College, Green Mountain College, Johnson State College, SUNY-Plattsburgh, and Castleton State College. The mission of the Lake Champlain Research Consortium is to coordinate and facilitate research and scholarship of the Lake Champlain ecosystem and related issues; to provide opportunities for training and education of students on lake issues; and to aid in the dissemination of information gathered through lake endeavors.

The LCRC has convened nine conferences/workshops since its inception to share information, coordinate research activities, prioritize research efforts, and help policy makers and managers plan for future action steps in the Lake Champlain Basin. Recent meetings include:

- May 2002 Research Conference with Quebec partners
- September 2005 Research Conference focusing on Missisquoi Bay
- September 2006 Water Quality Conference
- January 2008 Research Conference (co-hosted by LCBP)

The LCRC has also published two books and one web-published series of abstracts (past 5 years listed below):

- Lake Champlain: Partnerships and Research in the New Millennium (2004) - book of submitted papers from research conference - published by Kluwer Academic / Plenum Publishers.

- Lake Champlain: Our Lake, Our Future (2008) - web-published abstracts from conference presentations.

The LCRC has also sponsored the Annual Spring Student Research Symposium - every spring since 1993 (except in 2008 because of larger LCRC meeting in January, which included student papers) totaling 147 student presentations. In addition, it has supported many student research project with 34 small grants provided since July 2002.

(3) Summary Analysis of Annual Mercury Deposition at Underbill, Vermont

This analysis is dependent on verifying comparability of data across the full span of years that it was collected. Variation in both collection methods and chemical analyses (protocols and detectors) needed to be evaluated prior to developing a single dataset suitable for a time series analysis. It was first necessary to develop and document an approach for standardizing data collected at Underbill using the MICE collector and the UMAQL laboratory from 1993-2006 and the MDN data collected at Underbill from 2004 (2005 first full year) and going forward. Our initial studies confirmed a large (22%) bias between the MDN ACM-HAL measurements and the MIC -UMAQL measurements. A recent MDN study (Wetherbee et al. 2008) suggests MDN data users should be prepared to live with large (8-15%) uncertainties in wet-deposition measurements related to collector performance. Our review of EPA Method 1631 performance data from the MDN HAL as well as our analysis of data from a USGS 6-lab blind sample quality assurance study (Greg Wetherbee, USGS, written communication 2008; see also Wetherbee et al. 2006) suggested that additional laboratory uncertainties of anywhere from 9 to 34% must be added to the collector uncertainties when using MDN wet deposition data as provided on the web. We found that the differences in mercury wet deposition measurements made by different collectors and labs at VT99 were explainable with statistical significance in terms of laboratory bias, and collector sampling efficiency and, therefore, can be mathematically accounted for. The data normalization functions we developed allow us to have greater confidence (report lower uncertainty envelopes) in the accuracy of wet deposition measurements at VT99. Critical laboratory QA data necessary for completion of the analysis was made available by MDN-HAL on September 22, 2008, and thus report does not include the completed historical analysis of a seamless long-term record of wet deposition (1993-2007).

As a large amount of preparatory work was completed in advance of finalizing the normalization functions, we are working to complete this task by October 24th, 2008, prior to the NOAA Lake Champlain Program review. Preliminary review of the normalized data set indicates that there is no trend in precipitation mercury concentrations or wet deposition of mercury. The temporal variance in concentrations and deposition is largely explained by climatic variations in precipitation amount. There are 4 outlier years (spread throughout the record) where deposition was substantially higher than the long-term mean. We are investigating climatic and transport conditions to attempt to explain the observed differences.

Wetherbee, G.A., Latysh, N.E., and Greene, S.M. (2006) External quality-assurance results for the National Atmospheric Deposition Program/National Trends Network and Mercury Deposition Network, 2004, U.S. Geological Survey Scientific Investigations Report 2006-5067, 52 p.

Wetherbee, G.A., Gay, D.A., Brunette, R.C., and Sweet, C.W. (2008) Estimated Variability of National Atmospheric Deposition Program/Mercury Deposition Network Measurements Using Collocated Samplers. Environ. Monit. Assess. DOI 10.1007s 10661-006-9456-6.

BELETSKY SUMMARY

Dmitry Beletsky, University of Michigan, (http://www.snre.umich.edu/profile/beletskyX

Background and Objectives

Lake Champlain faces a variety of environmental problems ranging from cultural eutrophication and toxic pollution to invasive species problem. In most cases, knowledge of physical processes in the lake is needed for developing comprehensive lake management and restoration plans. All this generates a need for a state-of-the-art modeling system capable of predicting 3D circulation and temperature fields in the lake. Currently, only the Great Lakes possess this type of a system -the Great Lakes Forecasting System (http://www.glerl.noaa.gov/res/glcfsX The goal of this project is to begin developing a similar predictive system for Lake Champlain. Due to budget cuts, however, the scope of this project was reduced. Currently, the main objective of the project is to develop a robust 3D hydrodynamic model of Lake Champlain capable of hindcasting thermal structure and circulation in the lake, and to test model results with observations.

Progress

The hydrodynamic model selected for this task is the Princeton Ocean Model (POM) of Blumberg and Mellor (1987). It is a nonlinear three-dimensional hydrostatic model with embedded turbulence submodel. The standard POM employs a terrain-following vertical coordinate (sigma coordinate). The model was used previously to study internal waves and currents in various coastal environments including the Great Lakes (Beletsky and Schwab, 2001). In the original proposal I planned to use extensively the z-coordinate version of POM (due to steep bottom topography), and such model was indeed developed for Lake Champlain. It turned out later that the standard POM appears to be working as well (although a lot more testing will be required), so for the time-being I continue to use the standard POM. The advantage of using standard POM over its z-version is that NOAA/GLERL is in the process of developing a coupled ice-lake model based on standard POM, which can be easily transferred to Lake Champlain in the future.

To resolve steep bottom topography and facilitate water exchange in narrow southern portion of the lake, I developed a new 200 m bathymetric grid. The grid is based on the new 10x1 Om bathymetric dataset for Lake Champlain. Currently, all model boundaries are closed but eventually river flows will be included in long-term model simulations, since the retention time for Lake Champlain is only about 2 years (Myer and Gruendling, 1979). I explored data availability for 20 major rivers and determined that both climatological and real-time data are available from USGS for use in future simulations.

During summer of 2004, several thermistor chains were deployed in the lake by Dr. Tom Manley and several drifters were deployed in the central part of the lake by Dr. Michael McCormick as well. This presented an opportunity to model conditions in the lake and also use abundant observations for model evaluation. Winds observed at the Burlington International Airport (BIA) and Colchester

Reef meteorological station were used to generate forcing functions for the model. The model was initialized with 3-layer thermal structure based on temperature observations at several moorings. Vertical model resolution is 20 levels, with higher concentration near the surface. While working on model initialization, it became clear that surface layer measurements are frequently not available and one way of dealing with that problem could be the use of satellite measurements of surface temperature. Preliminary analysis of NOAA AVHRR data showed that information is sparse (because of clouds), but still can be useful for model initialization and evaluation, and for studies of wind-driven upwellings in the lake as well. Therefore, I installed NOAA Coast Watch software for viewing and analysis of Lake Champlain data, and obtained AVHRR regional lake surface temperature data for 2004.

New model grid testing began with July-August 2004 barotropic (3D but thermally homogeneous) model simulations to explore the influence of bottom topography on lake currents. Next, the model was run for July 2004 in a baroclinic mode with realistic wind forcing but zero net heat flux at the surface (computational time is about 10 hours per one month). Analysis of model results showed very dynamic response of lake's thermal structure to changing wind. In particular, several Ekman upwellings were seen at the west coast in the surface temperature field as a result of strong periodic pulses (about every 4 days) of southerly winds. The SST field looks extremely dynamic in animations, with jets, eddies, and instabilities constantly generated at the upwelling front. Vertical fluctuations of temperature look similarly complex, with internal seiche-type motion highlighted by Hunkins et al. (1998). I am planning additional model runs to determine which part of this response is due to direct wind forcing and which is due to seiching (which has about the same period). Currently, I am entering the stage of comparison model results with observations of temperature and currents. I began by plotting progressive vector diagrams of winds observed at Colchester Reef and compared with observed drifter tracks using 3% wind factor. Results (being published in a paper of which I am a co-author) showed that in most cases this empirical model predicts surface current speed in the lake well (McCormick et al, 2008). This finding will help to calibrate 3D model further. Next, surface currents from a hydrodynamic model will be used to drive a particle transport model to predict Lagrangian drifter movements in the lake and compare results with observed drifter tracks. Future work will also include model runs with added surface heat flux to test spring-summer thermocline development, tests with increased vertical resolution, and tests with idealized forcing.

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MANLEY ET. AL. SUMMARY

1991-2002

Hydrodynamics

1) Long-term hydrodynamic monitoring of the Main Lake

- Kelvin wave characteristics.
- Contour currents.
- Winter time dynamics.
- Internal surges & deep gravity currents.
- Models show wind stress, cross-sectional area and stratification defining a high percentage of the internal seiche dynamics.

2) Sediment transport and resuspension

- Identification of sediment furrows as erosional and causing resuspension.
- Furrow formation tied to deep gravity currents.

3) Shallow Bays

- Internal seiche effects wave movement and chemical constituents in shallow bays.

4) South Main Lake

- Enhanced mixing across the metalimnion.
- Dominant southerly component of current in a net counter-clockwise movement.
- Determined which wind-forced models explain the observations.

5) Passage Exchange Network (PENs)

- Grand Isle and Alburg bridges instrumented to monitor water exchange in restricted arm.
- Strong coherence at both sites with upstream/downstream flow.
- No vertical shear observed.

6) Pilot project on Langrangian Drifters

- Tested feasibility of using RAFOS float technology in a lacustrine setting.

Integrated Ancillary Research

1) Shelburne- Burlington Bay

- Impacts of Main Lake seiche observed in these bays.
- Counter clockwise circulation noted.
- Internal surges.

- Sub-gyres within the bay.
- Linked Shelburne-Burlington Bay internal seiche (nearly diurnal).
- Begin co-operative investigations with Champlain Water District (CWD) for water source protection program.

Summary of Work 1991-2002

- 6 peer reviewed papers
- 34 abstracts/presentations
- 3 technical reports
- 15 Middlebury College Geology Undergraduate Theses
- 1 edited volume on Lake Champlain Research

2003-2008

Hydrodynamics

1) Shelburne - Burlington Bay

- Better characterization of flow dynamics within Shelburne Bay.
- Integrated study (biology, resuspension, hydrodynamics) on deep-aquifer input into the lake via pockmarks.
- Characterized inflowing water (high in cyanobacteria) to out flowing (clear of bacteria) but affected by sediment plumes with high runoff events (rain, snow pack melt).
- Deep hypolimnic water enriched in Fe, Mg, and correlates to near anoxic conditions during summer months.

2) Subsurface Lagrangian Drifters

- Main Lake Circulations.
- Net-Orbital displacement away from shore line due to seiche.
- Flow is linear to curvilinear along shore.
- Subsurface has a westward flow across the central Main Lake.
- Near shore jets (25 cm/s) directly above the metalimnion.

3) Lagrangian Drifter Development

- Generation Model 2 - used subsurface tracking.
- Generation Model 3 - stable, 2-way iridium satellite communication and GPS positioning.
- Generation Model 4 - (to be released in 2009) vertical profiling, data telemetry, Doppler Velocity Log (DVL).

4) Coastal Current Modeling

- Observation : Lagrangian drifters show southerly flowing boundary under southerly winds
- Numerical models using constant winds, curved bottom match observation.
- Numerical models using wind shear and flat bottom match observation.

5) Inland Sea (Restricted Arm)

- Utilized Lagrangian drifters.
- First documentation of 1 st mode -3.3 days (less than Main Lake).
- Two layer flow at northern and southern ends driven by internal seiche.
- Southern end also shows uniform flow through water column occasionally.
- High speed winds induce high speed bottom currents in same direction.
- Very turbid water showing indicating resuspension.
- LISST data show high turbidity related to algal bloom settling.
- Current Middlebury Undergraduate Student working on this data for senior thesis.

6) St. Albans Bay

- Difficulties doing hydrodynamic modeling in shallow areas with current ADCPs.
- Moorings with deep water ADCP, LISST deployed in 2006.
- Preliminary results show upper and lower layer circulation cells hinder removal of nutrients from the inner bay => hence large algal blooms and impaired water quality.
- Current Middlebury Undergraduate Student working on this data for senior thesis.

7) Passage Exchange Network (PENs) resumed

- New technology - Channel Master installed this fall.
- Gathering velocity data at 1 m intervals across the channel through the water column.

Integrated Ancillary Research

1) Whole Lake Mapping Project

Bathymetric Data

- Side-scan and PDR mapping of entire Lake bottom - 8 years to complete.
- New bathymetric map produced.
- Map is released for public access through Vermont Center of Geographic Information (VCGI).
- Bathymetry data incorporated into new Navionics navigational tools for boaters.

Bathymetric Movie

- Developed a 20 minute movie of historical maps and the development of the new high-resolution map.

- Public outreach - Movie at ECHO, LCMM and to be used in the Quadracentennical celebration of the founding of Lake Champlain by Samuel Champlain 1609.

Side-scan mosaic map

- Five years of post-processing to make a side-scan mosaic of the bottom of Lake Champlain
- Public outreach - Mosaic will be released to public through VCGI when server can handle the large data set.

2) Hydrodynamics and Climate Change

- Compressed High Intensity Radar Pulse (CHRIP) sonar - coring program investigated last 12,000 years.
- Identification of salinity drop during 11.4-11.2 years correlated with freshwater pulses from mid-continent glacial lakes - Preboreal Oscillation.
- Documentation of lacustrine sediment drifts formed from velocity shear in hypolimnion.
- Large-scale slumps and debris flows are being identified.

3) Public Access to all CHIRP data; a 3 - 5 year project

Summary of Work 2003-2008

- 13 peer reviewed papers
- 30 abstracts/presentations
- 2 technical reports
- 8 Middlebury College Geology Undergraduate Theses
- 1 edited volume on Lake Champlain Research