Summary Report of the Review of the NOAA Air Resources Laboratory

June 21-23, 2016

College Park, MD

Review Panel

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INTRODUCTION

A Scientific Review of the NOAA Office of Atmospheric Research (OAR), Air Resources Laboratory (ARL), was held from 21-23 June 2016 in College Park, MD. The objective of the review was to evaluate the "quality, relevance, and performance of research to both internal and external interests" and "strategically position" the ARL "in its planning of future science. " During an introductory briefing to the review team by the Assistant Administrator and Deputy AA of OAR there was mention that an overall goal of ARL and OAR is to be "World Leaders"; not only *know* for the activities within OAR and ARL, but also as a *leader* in the activities. Achievement of that goal, and providing a review with recommendations that would help reach that goal, were factors kept in mind during the preparation of this document.

The format of this Summary Report follows the format of the material presented by ARL staff during the review. A brief overall summary is provided followed by detailed discussions of the three ARL Research Areas; Atmospheric Dispersion and Boundary Layer Characterization, Atmospheric Chemistry and Deposition, and Climate Observations and Analyses.

The review team greatly appreciates the extensive preparatory efforts of the ARL staff involved with this science review. We acknowledge the considerable time and effort spent in preparation of presentations, posters, documentation and logistics related to all facets of this review including the efforts related to hosting the review team. Additionally, the consistent attendance and engagement during the review by the Assistant Administrator and Deputy AA of OAR was recognized and appreciated by the review team.

OVER-ARCHING COMMENTS AND RECOMMENDATIONS

The quality of the work performed in each of the Laboratory Divisions is exceptional. The commitment and enthusiasm of ARL staff, both federal and contract staff, is very evident from the quality and amount of work being performed by a relatively limited number of staff.

The staff at ARL consists of an outstanding group of scientists. Despite being separated across four different states, with various missions that vary from applied science/research to primarily support activities, the staff appears to have strong, open communication with each other. The lab has a very collegial work environment. The feedback received during the stakeholder interviews affirmed and highlighted the effort and commitment given by ARL staff in supporting other agencies and organizations

While OAR is involved in some international work, a large amount of the research performed by OAR is US focused. It would be very beneficial for OAR to increase their coordination with relevant international research projects. This would provide a great learning opportunity for all OAR staff (and in particular new/junior staff). In addition, it could allow OAR to influence international research to focus on scientific areas/issues of interest. There is a significant amount of international research of direct interest/relevance to OAR. Staff and financial resources are generally being reduced both in NOAA and internationally. It would be much more productive to have research into specific topics/issues coordinated globally rather than research

being carried out separately by numerous countries/agencies. This approach could help to advance knowledge on key scientific issues/challenges.

ARL struggles with balancing their resources and effort between “resource” activities and “research” activities. It’s never an easy decision which of these receives greater priority. ARL should be applauded for being one of the top NOAA labs to accomplish operational/applied missions. Historically, the ARL has tilted its efforts to the applied side. This has given the ARL a strong reputation as a resource to many other agencies (within and outside NOAA).

There are apparently budgetary or other obstacles to filling vacant positions with federal employees. Thus, over the past five years, there has been an increase in Cooperative Institute (i.e., university) and contract positions within ARL. The bottom line is that these non-federal employees do not feel their positions are as stable or long-term as those of federal employees and these individuals are likely to seek other (more stable) opportunities. This could cause challenges with project continuity and positon succession.

Recommendations for the Laboratory

1.1 Many projects or Research Areas appear to be reliant on only one or two federal (or other) staff members to provide leadership and institutional/program knowledge. If that person unexpectedly retires, is disabled, or leaves ARL employment -- critical programs could suffer a major, perhaps near-fatal, loss of knowledge, continuity, etc. (a point of concern also raised in stakeholder discussions). While this is a natural side effect of decreasing budgets and resources, a recommendation would be that management actively works to increase the depth of staff resources in critical areas.

1.2 As similarly noted in the most recent previous review, a general concern exists about the age profile of staff employed across the various Divisions related to leadership and succession. A large number of (Federal) staff are aged 50+ years. To counterbalance this, there is a high number of contract staff (often younger in age). This leaves the ARL very vulnerable should any of the contract staff get permanent employment outside NOAA. The loss of expertise could be hugely detrimental to the work of ARL and OAR.

1.3 Related to ARL staff, it was noted that relatively few women occupied research positions. While recognized that this is not unique to ARL, and that short-term solutions are few, greater visibility of the research opportunities and occupations within ARL is encouraged. Participation within activities at the primary and secondary grade levels (participation in science fairs and other similar programs) might increase and stimulate the interest in scientific studies within all students that might benefit NOAA and ARL with a more diverse workforce in the future.

1.4 A concern was identified that the schools are not producing the modelling and measurement capabilities required by ARL. A recommendation would include working with university programs to enhance courses so that students are trained within their studies in the modelling and measurement capabilities required by ARL.

1.5 The contractors, university and the Cooperative Institute staff supporting ARL are very capable, but they do not appear to add the combination of scientific leadership, longevity and continuity that one desires in a healthy and robust research laboratory.

1.6 Development of a strategic plan for ARL staff succession management is highly recommended. This plan should identify key skills/knowledge that are in danger of being lost if personnel (Federal staff or contractor) leaves (or retires from) the ARL. A long term strategy should address how to best balance between how to get long term scientists hired in the positions to maintain longevity, versus short term scientists being hired because the process is easier. Additionally, the lab needs to consider the shift in the future workforce mentality that potentially could result in employees less committed to remaining at one facility/laboratory than past employees

1.7 Funding concerns were a common theme among Research Areas including the possibility that funding could threaten long-term observations. The continuity of the long term monitoring efforts within ARL requires continued support by ARL, OAR, and NOAA.

1.8 Increased interaction of ARL with the scientific community that conducts and uses satellite-based data is encouraged. While there were some ties noted by the ARL staff, there would seem to be ample room to increase those interactions both within and outside of NOAA.

1.9 The equipment replacement program developed for the SORD mesonet should be considered for replication at all ARLs monitoring networks/systems.

1.10 There are ways that the science being conducted by the ARL could be furthered through more high level planning and support from upper management in recognition of the importance off their role. A great example of this is HYSPLIT. Most of the science and development of this product occurred years ago. HYSPLIT is now an extremely widely used and valued tool. While it has continued to evolve, it appears as though the limited resources now available go more to support the system than making technical and technological improvements to ensure it continues to be a world-class product.

1.11 ARL should identify the more critical projects and programs and consider adding depth to these projects/programs, even if it means decreasing the breadth of research areas currently within ARL.

1.12 While the number of publications has decreased since 2008 due to loss in joint EPA-NOAA division, the number has been relatively stable and roughly one third of the most highly cited papers have been published since 2010. ARL scientists are encouraged to continue to publish the results of their research, and other appropriate activities, within the quality scientific journals selected for publication in the last five years.

1.13 Lack of consistency and continuity in senior leadership at ARL is a problem. The current acting director has been acting for a considerable period of time. It is not clear if this acting designation would continue indefinitely. Concern was expressed by staff that due to the “Acting” designation, ARL was not being fully represented within OAR and NOAA. Removal of “Acting” designation from the current director or acquiring a new permanent director would provide an increased level of leadership for ARL, allow ARL to prioritize

current or establish new objectives, and be more effective in competing for resources within OAR and NOAA. We recommended that OAR immediately begin the process to hire/fill the ARL Director as a “Permanent” position.

Summary of Individual Ratings

Reviewer	Rating Categories	Atmospheric Dispersion and Boundary Layer Characterization	Atmospheric Chemistry and Deposition	Climate Observations and Analyses
Gallo	Overall Quality Relevance Performance			Highest Perf//Exceeds Expectations Highest Performance Highest Performance Exceeds Expectations
de Wekker	Overall Quality Relevance Performance	Exceeds Expectations Exceeds Expectations Exceeds Expectations Satisfactory		
Fiebrich	Overall Quality Relevance Performance			Highest Performance Highest Performance Highest Performance Exceeds Expectations
Glantz	Overall Quality Relevance Performance	Exceeds Expectations Exceeds Expectations Exceeds Expectations Exceeds Expectations		
Russell	Overall Quality Relevance Performance	Exceeds Expectations Exceeds Expectation Highest Performance Exceeds Expectations	Highest Perf/Exceeds Expectations Highest Performance Highest Performance Exceeds Expectations	
Smith	Overall Quality Relevance Performance	Highest Performance Highest Performance Highest Performance Highest Performance		
Steffen	Overall Quality Relevance Performance		Exceeds Expectations Exceeds Expectations Exceeds Expectations Exceeds Expectations	

Research Area: Atmospheric Dispersion and Boundary Layer Characterization (Lead Reviewers: Stephan de Wekker, Clifford Glantz, and Killian Smith)

ARL conducts observational and modeling studies to investigate the transport of gases and particulates within the atmospheric boundary layer. The observational studies mostly focus on boundary layer processes on the micro-to-mesocale. The labs conduct an impressive number of boundary layer field projects throughout the US that involve many employees from the individual labs. The observations from these field studies are used, for example, to evaluate and improve various numerical models including the HYSPLIT modeling system. HYSPLIT continues to be a tool that is widely recognized and used in many applications, including the transport of air pollutants, wildfire smoke, and radioactive materials.

Quality

The review presentations, discussions, and stakeholder feedback indicate that ARL continues to provide quality products that are widely used and valued. Overall the work in the atmospheric dispersion and boundary layer characterization air quality research area is of high quality. The HYSPLIT program is superb but it is at risk because of lack of depth within ARL's ranks to ensure long-term support and continuity for the program. The meteorological support program is strong, but a lack of sufficient staffing at Nevada (and to some extent Idaho Falls) makes it difficult to also perform additional research activities. However, the tracer work being conducted at Idaho Falls is unique and of key interest. In addition the boundary layer and special convection initiation programs are of high quality.

FRD and SORD provide meteorological support for the safe operation of DOE research facilities in Idaho and Nevada and also conduct atmospheric dispersion modeling for DOE sites to support regulatory requirements. The FRD group has a positive national reputation and an impressive history in conducting tracer field studies and is viewed as the "go-to agency" for research using tracers in field studies. A major goal of these field studies is the improvement of dispersion models in complex and urban terrain. Project Sagebrush is the most recent field study and the importance of this type of field study is recognized by experts in the field. The project is mostly focused on supplementing classic dispersion studies using modern turbulence and tracer detection equipment.

ARL has become more involved in wind energy projects including WFIP (FRD), mostly by deploying a suite of meteorological instruments in support of the general objectives of the project. There is also a connection with wind energy research through a Duke Energy Generation CRADA. In comparison with the dispersion studies, the participation in wind energy studies is much weaker and ARL appears to be more a follower than a leader in this field.

ATDD is making good attempts to explore novel ways to accurately sample the atmospheric boundary layer. Their recent involvement in the use of small unmanned aerial system (UAS) is

particularly commendable. Also, the recent work on eddy covariance flux corrections that resolves part of the uncertainty in surface energy balance closure is important and needed.

Stakeholder comments were very positive and repeatedly mentioned the high quality of the work done by ARL employees and the pleasure of working with them. The quality of the research conducted by the various labs appears of high quality, evidenced also by the number of publications and citations.

Relevance

The research being conducted in this area by ARL is quite relevant. This was clearly demonstrated by the number of stakeholders of the HYSPLIT model, citations for ARL research, and feedback provided by ARL's stakeholders. In particular, HYSPLIT is demonstrating its relevance through its work with multiple national and international organizations, incorporation of new technologies, and its integration with other models (e.g., ALOHA).

It was clearly demonstrated that ARL boundary layer and dispersion research addresses the NOAA strategic goals and plans and is relevant for many topics of national concern including homeland security, emergency response, and air quality. ARL capabilities are quite unique, especially in the field of dispersion experiments and modeling.

Performance

ARL data and products are often used by the basic and applied research community. HYSPLIT in particular has many users around the world in research and operations (e.g., the local weather forecast offices). A web-based system that has been developed over the years provides quick access to generate HYSPLIT dispersion simulations. The addition of the CTBTO capability to HYSPLIT is an important development. This will have an important role in in the CTBTO verification regime. The HYSPLIT ALOHA system is a very valuable resource/tool for emergency responders. However, there seems to be a relatively small number of scientific staff providing substantial support to HYSPLIT users. In addition, these limited numbers of staff are also responsible for the on-going model development and publication of research articles.

The quality of the work performed in Atmospheric Dispersion and Boundary Layer Characterization was clearly illustrated in the research area presentations and poster sessions. The performance in terms of scientific publications seems satisfactory for most labs except for the SORD and FRD labs. However, it is also recognized that valuable services are provided by these labs to DOE and NNSA. Also, their observational and local forecasting capabilities and their data collection and analysis capabilities are highly regarded.

There is some current uncertainty on the future of the leadership of the ARL and it was not clearly demonstrated if ARL could respond to unanticipated events or opportunities that require new research and development activities. It became clear during the review that ARL

implemented some recommendations from previous science reviews. However, there are a number of recommendations that still appear to be valid for this review, indicating that not all recommendations were implemented sufficiently.

ARL appears quite well organized to efficiently and effectively conduct high quality research and it is especially good to see some support of creativity, including, for example, related to the UAS work. Diversity within research activities, as in many other organizations, could be improved, but does not stand out as a weakness in the organization. There are many active collaborations and sufficient attempts to secure external funding.

ARL is generally doing well in delivering products and communicating the results of their research. This was also clear from the conversations with stakeholders.

Recommendations for Atmospheric Dispersion and Boundary Layer Characterization Research Area:

Specific recommendations based upon the review of this Research Area are provided below.

2.1 The existing metrics appear to favor research applications rather than services that support a large and varied community, such as the HYSPLIT modeling community or safe and efficient DOE Site operations. ARL should consider developing other metrics to appropriately value operational programs and services that support the majority of ARL's stakeholders.

2.2 Many posters presented during the review meeting reported results from the field experiments. The majority of the research appears of high quality; however, some studies would benefit from the formulation of specific goals. Clearly stating the applicable research questions could help focus and improve several of these studies.

2.3 Field experiments led by ATDD, and in particular the convective initiation project and VORTEX-SE funded by the Sandy supplement, are some great examples where ARL takes a leadership position with well-defined scientific goals and interesting preliminary results. ATDD has two post-docs in the group that have been actively involved in the experiments and in the subsequent analysis and modeling activities. The FRD groups could improve the scientific basis of their experiments by including specific questions and hypotheses following the approach used by ATDD.

2.4 A web-based system that has been developed over the years provides quick access to HYSPLIT dispersion simulations. Data products from field experiments, however, are not well organized and quickly accessible. The availability on a website of data products from the field experiments should be reviewed for greater accessibility.

2.5 The HYRad system is particularly relevant in Emergency Preparedness and Response and should be made more widely available.

2.6 ARL's tracer study work (e.g. Project Sagebrush) is widely referenced and extremely important. This work should remain a priority. More robust funding and wider scope of

experimentation is recommended to support this important experimental program. Has ARL done enough to reach out to other organizations (the EPA, DOD, and DOE) to gain additional funding to expand the scope of this tracer work?

2.7 NOAA should consider establishing an association of HYSPLIT users. This would create a forum for exchanging knowledge and ideas about the use of HYSPLIT, and to further develop the system as an emergency preparedness and response tool.

2.8 ARL's activities in quantifying uncertainties through the ENSEMBLE work and communication to decision makers is extremely important and useful. This work is to be encouraged.

2.9 ARL has staff located in four locations, yet the ARL teams in Idaho Fall and Nevada are quite small (especially in Nevada). It is perfectly OK to have small groups that have as their only key mission to support meteorological services at key DOE sites. ARL should explore opportunities to offer similar services at other major DOE sites like Hanford, Savannah River, Los Alamos, and Oak Ridge. Meteorological support at those sites is not consistent – the quality of those non-ARL programs varies from site to site. If ARL supported an increased number of DOE sites there would be performance benefits and cost savings from the sharing of technologies and tools. Greater consistency in meteorological technical performance at these sites is needed.

2.10 ARL should clarify and clearly justify its wind energy CRADA. It is not clear how/if this activity is beneficial to ARL given the limited staff resources. Also, somewhat unclear if, or how well, the wind energy efforts are coordinated with NOAA's ESRL lab. Clear demonstration on how various research activities in ARL are coordinated with ESRL's activities would be recommended, and include how each lab benefits from each other's contributions.

2.11 Given the lack of a critical mass of junior scientists and potential upcoming retirements, it is not entirely clear how the high quality of work can be sustained. Plans for staff succession are recommended. For example, within the HYSPLIT program, leadership and direction for these programs is paper thin. One or two retirements or departures would jeopardize the continuity of these programs. Yes, there are non-Federal people supporting these programs, but there is no guarantee that key individuals could become ARL Federal staff members. Even if they could, the time it takes to bring them on board might not be sufficient to maintain program direction and continuity.

Research Area: Atmospheric Chemistry and Deposition (Lead Reviewers: Armistead (Ted) Russell and Alexandra (Sandy) Steffen)

The goal of this Research Area includes understanding and modelling the emission through air-surface exchange of the air pollutants that can impact human and ecosystem health. The air quality forecasting, combined with the emissions modeling, work is a national resource (as is HYSPLIT). The other standout work within this Research Area is the combined experimental and modeling work on mercury. This work stands out, in part, by the timeliness of the scientific results, in addition to the quality of the modeling and measurements.

Quality

The quality of the work was very impressive. It is clear that the group members are all very dedicated researchers with tremendous interest and enthusiasm for their work and this reflect in exemplary high standards of work. The Atmospheric Chemistry and Deposition area has two standout projects in terms of visibility; air quality forecasting and mercury measurements and modeling.

The air quality forecasting, combined with the emissions modeling, work is a national resource (as is HYSPLIT). Supporting a national level forecasting effort and to keep it progressing is not trivial, and they are hampered by institutional constraints (they cannot change the tools to improve the science until they have shown improved performance, which is not always the result of improving the science). However, the team finds ways to accomplish their task. They are also trying to really push the science in their forecasting efforts (e.g., using satellite data, advanced methods for emissions updating). The forecasting/emissions modeling group published a number of papers over the 2010-2015 period in high quality journals, including EHP. This attests to their range of capabilities.

The other standout work is the combined experimental and modeling work on mercury. This is, in part, is due to the timeliness of the scientific results, in addition to the quality of the modeling and measurements. Scientific results were provided in a timely fashion when such results were of national importance, while other agencies were not able to do so. There were 11 papers published on the topics of analysis/modeling over the 2010-2015 period, about half of which have been cited 10 times or more.

Relevance

The work that the Atmospheric Chemistry and Deposition group does is very relevant to the mandates of the ARL, NOAA, its stakeholders, and to the scientific community. The work that this group does with big national programs under NADP (AIRMoN and AMNet) is key to national and international policy initiatives. The work of ARL in the Atmospheric Chemistry/surface exchange area is extremely relevant, much more than most labs can boast. The forecasting/emissions group is key to having national air quality forecasts. When this activity was proposed to be cut, the importance became immediately apparent by the outcry from the

scientific and air quality management communities. This product is widely used by air quality managers and susceptible individuals.

The mercury work has proven to be quite relevant as NOAA really has one of the few groups that can provide the type of analysis needed to answer key questions on local vs. long range impacts, and showed itself to being one of the more agile, quickly addressing a need that arose.

The area of surface exchange is important and there is a need to keep moving forward. The ARL provides this foundation, and it is one of their historical strengths.

The rationale for why the chemicals investigated were chosen was not always clear and will affect the relevance of a program. There needs to be a more focused rationale for why the chemicals investigated were chosen. While all are relevant in their own manner, a more cohesive picture of the team and its relevance to national issues could be better explained for some of the measurements undertaken.

The atmospheric deposition program linked with WMO is highly regarded and relevant from a global perspective.

Performance

Members of the Atmospheric Chemistry and Deposition group are high performers. The amount of work that is delivered from a reasonably small group exceeds expectations. The phrase “they punch above their weight” reflects the accomplishments of this team. For example, the air quality forecasting is doing a great national service yet doesn’t have adequate funding. Combining satellite data with the more recent NEI emissions data to help with information to the inventory to make the overall predictions more accurate is innovative and shows that the team can perform even with the lack of timely emission data. The performance is excellent in spite of the limitations that have been imposed on them in the past several years (e.g. hiring freeze, budgetary cuts and NWS changing direction on the air quality issue). As a result of these limitations, there have been creative ways engaged to maintain the research programs and this is very commendable and demonstrates the dedication the group have to its work. However, this can lead to spreading things out too thinly and not enabling teams to go into more depth on a certain topic.

Recommendations for Atmospheric Chemistry and Deposition Research Area: Specific recommendations based upon the review of this Research Area are provided below.

3.1 Equipment infrastructure planning needs to be taken into consideration. Innovation is great (i.e. buying old instruments on ebay and using for parts) but that is not a long term solution.

3.2 The air quality modelling program is good but needs to become a higher priority

3.3 Increased international collaborations and intercomparisons (methods and models) with other countries is warranted.

3.4 Air quality forecasting is doing a great national service. Combining satellite data and getting more recent emissions data is innovative and encouraged to continue. Recommendations include continued updating of the NEI emissions as additional information to the inventory, to make the overall predictions more accurate.

3.5 There is a lack of monitoring of mercury by the United States in the Arctic region, namely in Barrow, Alaska where previous measurements have been collected by NOAA. This is a NOAA run site and this addition would not pose a significant burden on the current program at this location. Given that the US is currently the head of the Arctic Council, we recommend that funds be properly invested to reignite the measurements at Barrow, Alaska (or similar site in the US Arctic that are appropriate).The mercury program should initiate Arctic work as recommended, with the appropriate funding included (i.e. not from current programs and with appropriate capacity).

3.6 Data handling and storage needs to be addressed. There was relatively little mention of data flow, data QC, and data storage considerations in all presentations.

3.7 The mercury data that has been collected should be reflected in the upcoming global mercury assessment report.

3.8 Due to various imposed staffing and other limitations within ARL, a small consolidation of some of the peripheral projects should be made to direct more of the capacity into the programs currently designated as higher priority for the lab. Perhaps, there can be some consolidation of the deposition measurements and modelling between nitrogen and mercury.

3.9 The Atmospheric Chemistry/Surface Exchange group should develop one or two scientific questions/hypotheses to address over the coming five years in which all of the facilities can participate. They might also identify a single modeling platform for use between the various efforts to take advantage of the pool of skills.

3.10 There needs to be a more focused rationale for why the chemicals investigated were chosen. While all are relevant in their own manner, a more cohesive picture of the team and its relevance to national issues could be better explained for some of the measurements undertaken. Mercury was clearly outlined and perhaps the type of rationale presented for Mercury from them can be used as a platform for the other chemicals under research in the group.

3.11 Air quality is a global issue; however, the excellent work being done on air quality forecasting seems to be largely US focused. ARL should seek international partners/projects to work on this issue. The scale and nature of this issue is of huge interest internationally. ARL should aim to provide world leadership on addressing air quality forecasting.

3.12 ARL, or in partnership with other interested parties, is encouraged to install mercury monitoring equipment at some of the USCRN monitoring stations that are located on the West Coast of the US. This would enable some consolidation of resources and address the gap of geographical coverage of mercury monitoring.

3.13 There seems to be very limited funding available to support the mercury monitoring network. The mercury monitoring equipment used in the network is heavily reliant on the expertise of a small number of experts. ARL should identify alternative funding streams (e.g. health organizations) to support this important work. In addition, additional staff should be trained on the knowledge and skills required to maintain the monitoring equipment.

3.14 The methodology developed in the WMO science advisory group on precipitation chemistry for reporting laboratory intercomparison measurement results is very novel and should be used in reporting other laboratory intercomparison results.

Research Area: Climate Observations and Analyses (Lead Reviewers: Chris Fiebrich and Kevin Gallo)

The Climate Observation and Analysis Research Area includes siting and maintenance of several climate observation reference networks, research on land surface – atmosphere interactions, analysis of climate variability, and assessments of regional climate impacts.

Quality

Relevant and high-quality measurements of climate variables are essential to the resulting climate research that utilizes these climate observations. The activities in this Research Area are focused on ensuring the quality of the climate observations and include plans to maintain and further advance the quality of the observations. Stakeholders were enthusiastically supportive of the quality of products available from this ARL Research Area. These activities have been completed with the highest quality and due attention in the past. However, stable or decreasing budgets do not assure the level of quality that should be preserved.

There was no mention of quality problems with the ARL Mesonets, Reference Network(s), boundary layer measurements, or mercury observations. However, there appears to be a continuing decrease in funds and resources for these activities. Thus, several projects have downsized (e.g., DCNet has decreased to 7 sites, Surface Radiation sites decreased to 3 sites, USRCRN operations and maintenance reduced to support only 90 sites from planned 122 CONUS and 30 Alaska).

The Climate Observations and Analyses research area has had an impressive record of publications with over 69 since the last review. This speaks highly of the quality of the area's

work. The staff are regarded as experts in their field, especially with regard to climate monitoring and solid precipitation sensor testing.

Three of the Climate Observing and Monitoring research area's staff are leaders in national and international efforts. J. Wang has been an Advisory Board member to both the NOAA Center of Atmospheric Science at Howard University and to NOAA Cooperative Remote Sensing Science and Technology Center at City College of New York. B. Baker is Chairman of the American Meteorological Society Committee on Meteorological Observations and Instrumentations as well as Vice President of the WMO Committee on Instruments and Observations. J. Kochendorfer is the Chair of the Quantification of Uncertainty team for the WMO Solid Precipitation Intercomparison Experiment. Two staff members are active reviewers for scientific journals.

Relevance

The activities of this Research Area related to the establishment and maintenance of climate observing systems, and related research, are critical to the understanding and prediction of climate variations and changes in climate. The activities related to climate monitoring (surface energy balance, GRUAN, CRN) clearly address societally relevant needs. The CRN data are used by scientists worldwide. The SEBN data are used by NCEP land surface modelers for testing and evaluation purposes.

The ARL's leadership role in the WMO Solid Precipitation Intercomparison Experiment is commendable. This project is highly applicable and relevant to the global measurement methods in use for precipitation.

The use of the surface flux data supported by ARL by individuals within the NCEP Land Surface Modelling group is a key indicator of the relevance of this data.

The identification of biases associated with specific sonic anemometers, and solid precipitation measurements related to wind shields, provides highly significant benefits to the entire community of users of these data.

The addition of soil moisture and temperature measurements within the CRN network of stations was a substantial landmark and enhances the utility of this network.

OAR's mission and vision spans basic research to applied research. ARL's activities strongly tilt towards the applied research, which appears to be both intentional and needed. Thus, a few of the more basic research activities do not receive as much emphasis. The climate variability and analyses work has made significant discoveries regarding the capabilities of regional scale models. The ARL has a broad array of climate analyses work, but does not appear to have the quantity of staff resources (i.e., number of full-time employees) for in-depth research and development in this area.

Performance

The performance and overall effectiveness of this Research Area is evident in the quality of attention to activities in which the ARL scientists are engaged and the number of publications within this Research Area. There are a lot of activities taking place, many on a very grand scale. For instance, the expansion of the U.S. CRN into Alaska is a major undertaking. The U.S. CRN has also recently added capacity with new soil moisture and soil temperature sensors. These efforts and accomplishments are outstanding.

The leadership of the ATDD office (where a large portion of the Climate group resides) has made significant improvement to the funding of that office. In the past, there was inadequate funding for existing staff. Today, the Director of ATDD has secured funding through numerous sources and grants to stabilize funds for personnel.

The stakeholders appear to be quite satisfied with the performance of the ARL. Much of the work performed is directed science.

Recommendations for Climate Observations and Analyses Research Area: Specific recommendations based upon the review of this Research Area are provided below.

4.1 The Climate Observations and Analyses group is made up largely of contract employees (ORAU or otherwise). While management has done an admirable job to ensure that all staff are treated equally and fairly, it is difficult for some non-Federal employees to truly feel they are “long-term” employees. This is human nature. It is recommended that efforts be made to convert some of these non-Federal positions to Federal positions over time, rather than to continue tilting the employee population to non-Federal positions.

4.2 Additionally, maintaining the quality of research within this Research Area would seem to require backfill of the recently retired climate scientists within ARL. Specifically an individual with a background in research related to upper-air observations and analysis would seem critical to future activities on this topic.

4.3 If staff resources and funding diminish, it is recommended that the group focus on quality rather than quantity in terms of sites/networks/sensors it operates and maintains.

4.4 This Research Area group should consider adding depth to some of its critical projects, even if it means decreasing the breadth of activities within this Research Area.

4.5 The ARL should develop a long-term strategy for climate monitoring for the next 5 to 10 years with specific needs and funding identified to support and upgrade its long term monitoring stations. Since budgets are difficult to predict, it is expected that this strategy will need to be updated on an annual basis (at minimum).

4.6 The ARL should continue to tilt its priorities towards applied research since both its history and its unique capabilities give it significant opportunities within NOAA.

4.7 The introduction of CRN soil moisture data within drought monitoring activities is commendable. Continued and increased levels of collaboration with the Hydrologic community within and outside of NOAA are encouraged.

4.8 The reduction in number of SEBN observation sites is discouraging. Suggest that the instrumentation critical to support the observations previously made at the SEBN sites be co-located at CRN or other network sites where feasible.

4.9 Additional instrumentation at CRN station locations, in support of cal/val of remotely sensed (aerial or satellite) systems should be considered. Additional sites that include instrumentation that measures surface reflectance in visible and near-IR wavelengths are required for comprehensive cal/val of these variables.

4.10 Characterization of CRN station locations is recommended. The local and regional environment that surrounds the stations can influence the observations at the stations. Changes in the environment at the stations may result in deceptive observations of the measured climate variables.

4.11 Recommend follow-through on presented Future Directions associated with WMO Solid Precipitation Intercomparison Experiment that included publication of results from additional sites and producing corrected NOAA climate records as appropriate.

APPENDIX

A Complete List of Abridged Concerns and Recommendations:

1: Overarching Laboratory:

1.1 Many programs appear to rely on one key Federal staff person to provide leadership and institutional/program knowledge. An individual should be identified that can backfill these responsibilities if needed.

1.2 ARL should consider and address the age profile of staff employed across the various Divisions. A large number of (Federal) staff are aged 50+ years.

1.3 Related to ARL staff, it was noted that relatively few women occupied research positions. Participation within activities at the primary and secondary grade levels (participation in science fairs and other similar programs) might increase and stimulate the interest in scientific studies within all students that might benefit NOAA and ARL with a more diverse workforce in the future.

1.4 A concern was identified that the schools are not producing the modelling and measurement capabilities required by ARL. A recommendation would include working

with university programs to enhance courses so that students are trained within their studies in the modelling and measurement capabilities required by ARL.

1.5 The contractors, university and the Cooperative Institute staff supporting ARL are very capable, but they do not appear to add the combination of scientific leadership and continuity that one desires in a healthy and robust research laboratory.

1.6 Development of a strategic plan for ARL staff succession management is highly recommended. This plan should identify key skills/knowledge that are in danger of being lost if personnel (Federal staff or contractor) leaves (or retires from) the ARL. Additionally, the lab needs to consider the shift in the future workforce mentality.

1.7 Funding concerns were a common theme among Research Areas and the possibility that funding could threaten long-term observations was very concerning. The continuity of the long term monitoring efforts within ARL requires continued support by ARL, OAR, and NOAA.

1.8 Increased interaction of ARL with the scientific community that conducts and uses satellite-based data is encouraged. While there were some ties noted by the ARL staff, there would seem to be ample room to increase those interactions both within and outside of NOAA. .

1.9 The equipment replacement program developed for the SORD mesonet should be replicated at all ARLs monitoring networks/systems.

1.10 The science being conducted by the ARL could be furthered through more high level planning and support. For example, due to past scientific and development efforts HYSPLIT is now a widely used and valued tool. While it has continued to evolve, it appears as though the limited resources now available go more to support of the system than making sure it continues to develop and be a world-class product.

1.11 ARL should identify the more critical projects and programs and consider adding depth to these projects/programs, even if it means decreasing the breadth of research areas currently within ARL.

1.12 While the number of publications has decreased since 2008 due to loss in joint EPA-NOAA division, the number has been relatively stable and roughly one third of the most highly cited papers have been published since 2010. ARL scientists are encouraged to continue to publish the results of their research, and appropriate other activities, within the quality journals selected for publications in the last five years.

1.13 Lack of consistency and continuity in senior leadership at ARL is a problem. The current acting director has been acting for a considerable period of time. OAR is recommended to immediately begin the process to hire/fill the ARL Director position as a “Permanent” rather than “Acting” position.

2: Atmospheric Dispersion and Boundary Layer Characterization

2.1 The existing metrics appear to favor research applications rather than services that support a large and varied community. ARL should consider developing other metrics to appropriately value operational programs and services that support the majority of ARL's stakeholders.

2.2 While the majority of the research appears of high quality; however, some studies would benefit from the formulation of specific goals. The formulation of specific goals and research questions could be improved in several of these studies.

2.3 The FRD and SORD groups could seem to improve the scientific basis of their experiments by including specific questions and hypotheses.

2.4 Data products from field experiments appear not as well organized and quickly accessible as would be recommended. The availability on a website of data products from field experiments should be reviewed for greater accessibility.

2.5 The HyRad system is particularly relevant in Emergency Preparedness and Response and should be made more widely available.

2.6 ARL's tracer study work (e.g. Project Sagebrush) is widely referenced and extremely important. More robust funding and wider scope of experimentation is recommended to support this important experimental program.

2.7 NOAA should consider establishing an association of HYSPLIT users.

2.8 ARL's activities in quantifying uncertainties through the ENSEMBLE work and communication to decision makers is extremely important and useful. This work is to be encouraged.

2.9 ARL should explore the opportunity to offer similar services currently ongoing at Nevada and Idaho facilities to other major DOE sites like Hanford, Savannah River, Los Alamos, and Oak Ridge. Greater consistency in meteorological technical performance at these sites is needed.

2.10 ARL should clarify and clearly justify its wind energy CRADA. Clear demonstration on how various wind energy research activities in ARL are coordinated with ESRL's activities would be recommended, and include how each lab benefits from each other's contributions.

2.11 Given the lack of a critical mass of junior scientists and potential upcoming retirements, it is not entirely clear how the high quality of work can be sustained. Plans for staff succession are recommended.

3: Atmospheric Chemistry and Deposition:

3.1 Equipment infrastructure planning needs to be taken into consideration. Innovation is great (i.e. buying old instruments on ebay and using for parts) but that is not a long term solution.

3.2 Higher priority should be given to the air quality modelling program.

3.3 Increased international collaborations and intercomparisons (methods and models) with other countries is warranted.

3.4 Air quality forecasting is doing a great national service. Combining satellite data and getting more recent emissions data is innovative and encouraged to continue.

3.5 The mercury program should initiate Arctic work as recommended, with the appropriate funding included (i.e. not from current programs).

3.6 Data handling and storage needs to be addressed. There was relatively little mention of data flow, data QC, and data storage considerations in all presentations.

3.7 The mercury data that has been collected should be reflected in the upcoming global mercury assessment report.

3.8 Due to various imposed staffing and other limitations within ARL, a small consolidation of some of the peripheral projects should be made to direct more of the capacity into the programs currently designated as higher priority for the lab. Perhaps, there can be some consolidation of the deposition measurements and modelling between nitrogen and mercury.

3.9 The Atmospheric Chemistry/Surface Exchange group should develop one or two fundamental scientific questions/hypotheses to address over the coming five years in which all of the facilities can participate. They might also identify a single modeling platform for use between the various efforts to take advantage of the pool of skills.

3.10 There needs to be a more focused rationale for why some of the chemicals investigated were chosen. Mercury was clearly outlined and perhaps the type of rationale presented for Mercury can be used for the other chemicals under research in the group.

3.11 ARL should seek international partners/projects to work on this issue. The scale and nature of this issue is of huge interest internationally. ARL should aim to provide world leadership on addressing air quality forecasting.

3.12 ARL or others in partnership with ARL are encouraged to install mercury monitoring equipment at some of the USCRN monitoring stations that are located on the West Coast of the US.

3.13 The mercury monitoring equipment used in the network is heavily reliant on the expertise of a small number of experts. ARL should identify alternative funding streams (e.g. health organizations) to support this important work. In addition, additional staff should be trained on the knowledge and skills required to maintain the monitoring equipment.

3.14 The methodology developed in the WMO science advisory group on precipitation chemistry for reporting laboratory intercomparison measurement results is very novel and should be used in reporting other laboratory intercomparison results.

4: Climate Observations and Analyses:

4.1 The Climate Observations and Analyses group is made up largely of contract employees (ORAU or otherwise). It is recommended that efforts be made to convert some of these non-Federal positions to Federal positions over time, rather than to continue tilting the employee population to non-Federal positions.

4.2 Additionally, maintaining the quality of research within this Research Area would seem to require backfill of the recently retired climate scientists within ARL. An individual with a background in research related to upper-air observations and analysis would seem critical to future activities on this topic.

4.3 If staff resources and funding diminish, it is recommended that the group focus on quality rather than quantity in terms of sites/networks/sensors it operates and maintains.

4.4 This Research Area should consider adding depth to some of its critical projects, even if it means decreasing the breadth of activities within this Research Area.

4.5 The ARL should develop a long-term strategy for climate monitoring for the next 5 to 10 years with specific needs and funding identified to support and upgrade its long term monitoring stations.

4.6 The ARL should continue to tilt its priorities towards applied research since both its history and its unique capabilities give it significant opportunities within NOAA.

4.7 The introduction of CRN soil moisture data within drought monitoring activities is commendable. Continued and increased levels of collaboration with the Hydrologic community within and outside of NOAA are encouraged.

4.8 The reduction in number of SEBN observation sites is discouraging. Suggest that the instrumentation critical to support the observations previously made at the SEBN sites be co-located at CRN or other network sites where feasible.

4.9 Additional instrumentation at CRN station locations, in support of cal/val of remotely sensed (aerial or satellite) systems should be considered. Additional sites that include instrumentation that measures surface reflectance in visible and near-IR wavelengths are required for comprehensive cal/val of these variables.

4.10 Characterization of CRN station locations is recommended. The local and regional environment that surrounds the stations can influence the observations at the stations. Changes in the environment at the stations may result in deceptive observations of the measured climate variables.

4.11 Recommend follow-through on presented Future Directions associated with WMO Solid Precipitation Intercomparison Experiment that included publication of results from additional sites and producing corrected NOAA climate records as appropriate.