NOAA Air Resources Laboratory

Laboratory Science Review

June 21-23, 2016

College Park, MD

ARL's Response to Review Recommendations and Implementation Plan

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Submitted by:

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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, with the objective to evaluate the quality, relevance, and performance of its research activities to both internal and external interests and to strategically position the ARL in its planning of future science. This review covered ARL's research activities since 2011. The research themes presented included Atmospheric Dispersion and Boundary Layer Characterization, Atmospheric Chemistry and Deposition, and Climate Observations and Analyses.

The Air Resources Laboratory acknowledges the time and effort the Review Panel dedicated to thoroughly review our research programs. We really appreciate the constructive and insightful comments.

ARL's responses to each recommendation follow the format of the Summary Report provided by the Review Panel. ARL responded to the overall summary as well as to the comments provided for the three ARL Research Areas; Atmospheric Dispersion and Boundary Layer Characterization, Atmospheric Chemistry and Deposition, and Climate Observations and Analyses. A table summarizing the actions and timelines for completion of the recommendations is provided at the end of this report.

ARL Response

Overarching 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.

Response: ARL agrees with the assessment and the recommendation. In fact, over the last 3 years 4 senior scientists have retired from ARL and only one senior scientist has been hired. In addition, the ARL director left for another institution. While it is highly desirable to replace these positions, the Federal budget climate is bleak. There is a greater likelihood of funding cuts than increases, and the directive from the executive branch is to reduce the size of the Federal workforce.

Action: When possible, hire two new federal employees for HYSPLIT group. The profile of one of the hires will be on the study of model uncertainty through the construction of dispersion ensembles. The second position will focus on the incorporation and development of new dispersion parameterizations geared toward emergency applications such as nuclear or chemical hazards.

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.

Response: ARL agrees with the comment and recognizes that there are scientists in the laboratory who have knowledge and expertise essential to the continuation of core, ongoing ARL capabilities. ARL has worked to spread this knowledge and expertise among multiple staff members to support continuity of activities. For instance, this has included close collaboration with more junior scientists (CI employees) to work with lead scientists. ARL will continue identifying and addressing risks in this area.

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.

Response: ARL agrees that visibility of science is important for broadening participation of traditionally underrepresented groups, including women, African-Americans, American Indians/Alaska Natives, and Latinos. ARL staff are routinely involved in outreach activities at all divisions. Collectively, ARL has hosted 22 student interns since 2011, of which 12 have been from underrepresented groups. In addition, ARL scientists routinely serve as judges at local and regional science fairs and as classroom speakers at elementary and middle schools. ARL staff have participated in conferences that target underrepresented groups including the National Organization of Black Chemists and Chemical Engineers (NOBCChE) Conference, and the White House Initiative on Historically Black Colleges and Universities National Conference. For over 10 years, ARL staff have attended the NOAA EPP Education and Science Forum and have plans to attend the 2018 Forum. ARL staff have also been active in diversity, equity, and inclusion sessions at AGU, AMS, and GSA and plan to continue similar outreach strategies. Further, several ARL outreach activities have been featured in the EEO Connections newsletter that Nicole Mason and Georgia Madrid publish for OAR. The current cover story of the newsletter (November 2017 issue) describes a geoscience diversity and inclusion project with an ARL scientist as co-PI. Due to fiscal constraints, ARL has been unable to hire staff in recent years, though there has been one postdoc (from an underrepresented group) recruited to ARL.

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.

Response: Close interaction with higher education institutions is key to keeping ARL up to date with the latest scientific developments. ARL will further leverage its close ties with the Cooperative Institute for Climate and Satellites, the University of Maryland and other universities to identify and mentor students interested in topics related to modeling and measurements relevant to ARL's research activities. Also, ARL will continue to encourage its scientists to actively participate in PhD thesis committees to foster interaction with higher education.

Action: teach HYSPLIT course at U. of MD. Mentor undergraduate and graduate students through the U. of MD Maryland Earth Science Applications (MESA).

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.

Response: ARL agrees with the observation. However, the hiring of new federal scientists is increasingly cumbersome, and hiring non-federal staff has become the only viable alternative to keep the high level of scientific work at ARL. This issue seems to be ubiquitous all over OAR.

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

Response: Civil service regulations explicitly prohibit the appointment of successors to positions that are expected to become vacant. Succession planning for federal positions is therefore largely limited to providing both federal and contract staff with the skills and experience that would be beneficial in applying when vacancies become available. ARL agrees that mentoring existing staff to provide a pool of potential successors is important, but federal hiring restrictions make formal succession planning difficult.

Action: ARL will review its mentoring and training approaches to determine whether more can be done to increase the pool of potential successors having the required skills. ARL will also consider career ladder positions for new hires so that increasing responsibilities do not require recompetition of positions. ARL will consider the use of Temporary promotions and internal details to expand the number of qualified leaders in the organization.

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

Response: ARL agrees that decreasing funding levels are a real threat to the continuity of the long term monitoring efforts. However, ARL's funding levels are at the mercy of both Congress and higher levels within the Executive Branch.

Action: ARL will hire a contractor to serve as the communication specialist that will closely interact with OAR Communications and the Formulation and Congressional Analysis Division to highlight ARL's research activities at the appropriate Government level.

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.

Response: ARL agrees and we will encourage our scientists to continue the interaction with such a community. A new project funded by US Weather Research Program that includes the use of GOES-R data that is being developed at ARL is a clear example of the path forward. In addition, ARL is closely interacting with the Joint Polar Satellite System at NOAA's Satellite and Information Service to explore future collaboration in using their satellite data.

Action: continue fostering relationship with JPSS, GOES-R community.

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

Response: ARL is working on a common set of procedures that will be shared among ATDD, SORD, and FRD regarding monitoring networks/systems.

Action: develop procedure manual for replication of met monitoring networks.

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.

Response: ARL invests its limited resources in the continuous scientific development of the model. Currently, HYSPLIT includes the state-of-the-art scientific knowledge of its kind and ARL is constantly developing or incorporating new algorithms to keep it as a world-class product. ARL continuously has to strike a balance between system support and development. However, ARL has managed to keep up with the current science.

Action: reach out to universities (e.g. U. of MD. / U. of FL / Penn State) to leverage basic research and incorporate new science. Take advantage of interagency agreements with DOE and reach out to other federal agencies that are end users of the HYSPLIT modeling system (e.g. DOD, EPA, USFS, etc.) to increase resources available for model development.

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 other research

areas currently within ARL.

Response: ARL agrees with this suggestion. Indeed, ARL has already started a frank conversation among senior scientists to identify these critical projects/programs.

Action: ARL will consider consolidating several research projects so that more critical ones may be better supported. This will be done as part of the future ARL strategic planning process.

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.

Response: ARL will continue to encourage publication in high quality journals. To support this, over the last few years ARL modified its internal paper review process to further encourage publication in such journals.

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.

Response: ARL agrees with the assessment and we thank the panel for the recommendation. At the end of March 2017, the ARL Acting Director retired, and a new Acting Deputy Director was assigned. OAR has confirmed that they are taking steps to begin the process to hire the ARL Director as a permanent position.

Recommendations for Atmospheric Dispersion and Boundary Layer Characterization Research Area:

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.

Response: ARL agrees with this statement. ARL has started investigating alternative ways to evaluate the impact of its work besides the number of publications. For instance, counting the number of runs and identifying users on our READY web-based system can provide such information. Also, the metrics should take into account transferring research to operations or applications.

Action: ARL is adding performance measures in the OAR Annual Operating Plan that are directly related to the services provided to ARL's stakeholders (NOAA, DOD, DOE, EPA, WMO, academia, national and international research community).

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.

Response: See Response 2.3

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.

Response: ARL agrees that some of the poster presentations neglected to include project goals and objectives. Rest assured, ARL's field experiments are driven by well-defined scientific goals and objectives. The Project Sagebrush Phase 1 campaign in 2013 was based on an experiment plan that included specific science objectives. Due to time constraints during the review, scientists naturally wanted to emphasize experiment results, which may have given the impression that the

experiments were not designed with specific hypotheses in mind. This was not the case, and actions will be taken to communicate goals and objectives more clearly in the future.

Action: ARL is investigating opportunities to have all ARL divisions involved in the planning and experiment design of future phases of Project Sagebrush.

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.

Response: The Data Archive of Tracer Experiments and Meteorology (DATEM) on ARL's web page provides access to experimental data, relevant reports, meteorological data, statistical analysis, and display software, all in a common format for PC or UNIX applications. By the time of the Lab review ARL has incorporated 9 tracer experiments. Furthermore, ARL is currently working on incorporating Sagebrush 2013, the latest experiment performed at FRD.

ARL is actively working towards making the data from tracer experiments available in a more organized manner online. In fact, NOAA now has a policy on Public Access to Research Results (PARR, see https://docs.lib.noaa.gov/noaa_documents/NOAA_Research_Council/NOAA_PARR_Plan_v5.04.pdf) that requires research data resulting from federal funding to be made publically available. ARL is implementing this policy as resources permit.

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

Response: In the 2017-2018 timeframe, ARL will be working on an update of the HYRad system, partly to address the disappearance of the Flash plugin for web browsers. This update will also investigate making the server code more generic so it is easier to adapt to other applications. The current version of HYRad was designed for emergency response applications at the Idaho National Laboratory before interest was expressed in adapting it to other locations.

Action: ARL is already working on updates to HYRad that include making it more portable.

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?

Response: There is a long history of other federal agencies seeking NOAA's meteorological and atmospheric chemistry capabilities. The vast majority of ARL's tracer work has been funded by other federal agencies, but the projects have been of limited duration. Having NOAA support would allow the laboratory to take a more strategic approach with its tracer study program; one that better aligns with NOAA mission goals.

Action: see Action 2.3 + leveraging with NIST, DOE, and DOD.

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.

Response: ARL established a HYSPLIT Forum in 2012. The Forum was referenced in the oral presentation titled Dispersion Modeling by Dr. Ariel Stein. The Forum web page is for HYSPLIT dispersion model users to communicate questions, problems, ideas for upgrades, etc. ARL staff have answered more than 700 questions since its inception. In addition, ARL has several projects with government agencies, academia, and the international community to foster the continuous development of the model.

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.

Response: ARL agrees and is continuously developing this research area. ARL has recently incorporated into the READY web system a HYSPLIT test run driven by the Short Range Ensemble Forecast (SREF) 26 member system. In the near future, ARL will use this meteorological dataset as a basis to develop an experimental fire smoke system for the Contiguous US.

Action: Develop a prototype of a smoke dispersion ensemble based on SREF or the future ensemble meteorological model run operationally by NWS.

2.9 ARL has staff located in four locations, yet the ARL teams in Idaho Falls 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.

Response: We thank the reviewers for the suggestion. ARL has supported meteorological services at DOE sites over the years. However, it must be pointed out that the contractors at many DOE sites would likely resist any attempt by NOAA to take over the meteorological support. Any expansion of ARL's support to other DOE facilities would require significant initiative on DOE's part.

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, it is 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.

Response: ARL apologizes for not being clear about the wind energy CRADA. ARL has a long history of research capabilities focused on low level winds and turbulence in the planetary boundary layer. The CRADA allowed ARL to evaluate its data collection techniques along with Duke Energy's techniques. One of the purposes of the CRADA was to specifically develop improvements to Duke Energy's wind power forecast model. The CRADA was initiated in 2010 prior to the ESRL-led Wind Forecast Improvement Project (WFIP). When the WFIP became a significant field study (about two years after the CRADA) ARL was not in position to participate. The CRADA ended April, 2016.

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.

Response: See the response and actions for recommendation 1.6.

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.

Response: ARL agrees with this assessment and would welcome the implementation of an infrastructure planning framework. However, instrument lifecycle planning and implementation is lacking across the entire OAR line office, and it should be addressed at that level. Within OAR, infrastructure is acquired, maintained, and replaced subject to the budgetary limitations of each laboratory. Given these fiscal pressures, acquisition of used, surplus, and in some cases obsolete equipment on the secondary market is the only viable way to maintain measurement and monitoring programs within ARL.

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

Response: The air quality modeling program has been and continues to be a priority for ARL. However, the deep funding cuts that ARL experienced from the NWS produced a sizable reduction in the workforce. ARL is currently reaching out to other OAR laboratories to establish strong research ties to maintain an air quality modeling research program across NOAA.

Action: ARL is organizing a chemistry summit with ESRL to establish future collaboration.

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

Response: ARL agrees that international collaborations and intercomparisons are extremely important. ARL has and will continue to participate and take leadership roles as resources become available. Examples of ARL activities are:

- **ARL will continue to provide technical guidance (along with EPA and NADP partners) for the development and implementation of a mercury monitoring program in the Asia Pacific region.**
- **ARL has organized and hosted an international workshop to establish "best practices" in mercury monitoring networks.**
- **ARL will co-host a workshop at the 2017 International Conference on Mercury as a Global Pollutant in July 2017.**

- **ARL is preparing for an international mercury measurement intercomparison at the Mauna Loa Atmospheric Mercury Network site.**
- **ARL is collaborating with the 2018 UNEP Global Mercury Assessment.**
- **ARL is collaborating with the French National Institute for Agricultural Research to develop and refine parameterizations of ammonia emission potential in the SURFATM-NH3 model using data from ARL field studies.**
- **ARL will continue to stay involved with the International Workshop on Air Quality Forecasting Research.**

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.

Response: ARL agrees with this recommendation. ARL scientists are exploring ways of expanding the use of satellite information to update the emissions. In fact, since the laboratory review ARL has been funded by U.S. Weather Research Program to develop a smoke emission system based on GOES-R data. We are directly collaborating with Dr. S. Kondragunta from NESDIS in this project.

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 a similar site in the US Arctic that is 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).

Response: ARL agrees that agrees that establishing a long-term mercury monitoring site at the Barrow observatory would be useful to improve the understanding of mercury trends and biogeochemical cycling in the Arctic. ARL has previously measured atmospheric mercury species at Barrow, but those past campaigns have been of short duration. While ARL has the capability and expertise to conduct long-term mercury monitoring at the site, such an activity is not possible under current budgetary limitations.

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.

Response: ARL recognizes that, given the time constraints on the presentations in the laboratory review, data flow, QC, and storage protocols were not discussed

at length. Monitoring data are automatically retrieved from each remote field site by ftp, then are concatenated and processed according to data reduction protocols, while QC codes are applied to the data stream automatically. Calibration factors are applied to the processed trace gas (ancillary data). The processed data are then examined by expert operators and spurious data are identified and flagged. Quality assured data are then archived at ARL. Mercury species concentration raw data are automatically uploaded to servers at the National Atmospheric Deposition Program (NADP) office and reduced according to AMNet protocols. The reduced data are publicly available from the NADP website. Processed nitrogen concentration and flux data are publicly available from an ARL ftp site.

Action: Codify and document in greater detail ARL's QA/QC protocols and assemble a comprehensive set of QA'd/QC'd data from each of the three ARL AMNet sites

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

Response: ARL agrees that mercury data collected by ARL should be reflected in the upcoming 2018 UNEP Global Mercury Assessment. Dr. Mark Cohen of ARL is helping to write this report and is working to ensure that ARL mercury data (and models) are appropriately included. Furthermore, ARL mercury data are already included in formal networks (the Mercury Deposition Network and the Atmospheric Mercury Network), and data from these preeminent networks will be strongly represented in the Assessment.

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.

Response: ARL continues to support targeted research of atmospheric pollutants, including mercury and nitrogen, which are known to have an impact on human health and/or the environment. Mercury and nitrogen research are priorities for ARL, as outlined in the strategic plan, and both programs have continued to produce high-quality data and information through national and international collaborations despite staffing challenges. Also, measurement sites of interest will generally vary between nitrogen and mercury. For example, Mauna Loa is a very important measurement site for mercury, but not for nitrogen. Agricultural

sites in the Midwest take precedence for nitrogen measurements from a scientific perspective, in terms of addressing key questions and uncertainties, but not for mercury. As appropriate, ARL will identify and pursue opportunities to more closely align and leverage opportunities for mercury and nitrogen.

Action: Explore options for nitrogen and mercury measurement studies in locations of mutual scientific significance.

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.

Response: ARL agrees that development of additional scientific questions may facilitate engagement of staff in various divisions. Activities are underway to leverage more ARL data across modeling platforms. A recent example is the use of tracer data from FRD in HYSPLIT modeling efforts at ARL HQ. While the use of a single modeling platform might seem desirable, there are many scientific and practical considerations that require a more nuanced approach to modeling efforts.

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.

Response: ARL has a focused rationale for the chemical pollutants investigated in its research program with specific scientific motivations for measurement and modeling activities. As provided in the Atmospheric Deposition presentation by Dr. LaToya Myles and the Surface Atmosphere Exchange Modeling presentation by Dr. Rick Saylor, it has been well-established that an overabundance of reactive nitrogen results in a number of harmful environmental conditions (e.g., eutrophication, acidification, and reduced biodiversity) that can negatively impact communities. In recent decades, reduced reactive nitrogen emissions have increased in the U.S., resulting in growing national concerns about effects on air chemistry and ecosystem health. ARL data informs characterization of ammonia emission sources and improves understanding of the complex chemical and physical processes that drive deposition on local and regional scales. Given limited resources, ARL has focused attention on a few chemicals (mercury and

nitrogen) that have been and continue to be very important. Also, given the investment ARL has made in equipment and expertise, arbitrarily switching focus to other compounds would be very costly. If a compelling reason arose, this could certainly be considered. For example, ARL used a variant of the HYSPLIT-Hg model to study dioxin emissions during the Deepwater Horizon Oil Spill disaster (when surface oil was being burned), at the urgent request of EPA.

Action: Relevance of ARL's chemistry research will be further explained in future planning and guidance documents.

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.

Response: We agree with the recommendation. In fact, the NWS recently announced the choice of the FV3 as the new meteorological model core that will include aerosols. Given this important development, ARL will dedicate resources toward the development of a global emission system geared toward forecasting applications. In addition, ARL is a primary organizer of the International Workshop for Air Quality Forecasting Research. This was pointed out for the review in the Indicators of Quality, Relevance, and Performance document on Collaborations.

Action: ARL to devote resources to the Next Generation Global Prediction System (NGGPS) emissions. In particular, we will collaborate with ESRL scientists to test new emissions algorithms for aerosols into the FV3 system.

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.

Response: ARL agrees with the stated need to reduce the gap in mercury monitoring in the western United States. However, while ARL possesses the ability and willingness to deploy additional mercury samplers, such an effort is impossible under current budgetary realities. In addition, there is a real concern that USCRN sites may not be ideal for co-location with mercury monitoring equipment. Equipment deployed at USCRN sites typically operates at low power; the costs to provide sufficient electrical capacity to operate mercury monitoring equipment may be prohibitive at these locations. In addition, the presence of large, air-conditioned enclosures necessary to house the mercury equipment may

violate the stringent USCRN siting criteria. Nevertheless, ARL will explore all available options.

Action: Investigate other monitoring sites and networks as targets of opportunity to expand long- or short-term mercury measurement activities

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.

Response: ARL agrees that there is limited funding available from NOAA to support current mercury monitoring efforts. ARL does receive funding from other federal agencies (notably EPA), but recognizes that these funding streams, too, can be uncertain. ARL will explore additional funding avenues to support the monitoring effort to the fullest extent possible. At this time, ARL does not have additional staff to train on the monitoring equipment.

Action: Seek out new opportunities and research funding streams for mercury

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.

Response: ARL agrees with the recommendation. The WMO Science Advisory Group (SAG) continuously reaches out to several laboratories around to globe to encourage their participation in the laboratory intercomparison. For instance, very recently and through the SAG, ARL reached out to the China Meteorological Administration (CMA) and to the Brazilian Institute of Space Research (INPE) to include new datasets in the laboratory intercomparison.

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.

Response: ARL agrees that giving the opportunity to non-federal workers to apply to federal positions would be an optimal solution. In the past, ARL has opened federal positions but contract employees have declined to apply. The uncertainty in the federal budget and the impacts to ARL as a whole creates an element of long-term financial risk that in the near term prohibits implementing this model.

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.

Response: ARL agrees that a senior-level climate scientist is needed who has experience to aid in the coordination and collaboration of ARL's varied climate science efforts and who also can coordinate with NOAA's Climate Program Office (CPO).

Action: Since the Lab Review, ARL has obtained a senior-level climate scientist, through a reassignment, who will help coordinate ARL's climate program.

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.

Response: ARL agrees that quantity may need to be sacrificed if there are resource cuts. ARL's program is constantly developing new cost effective ways to measure, maintain and test systems. Since this concern was raised by the review committee, funding for the USCRN in FY18 has been converted to base funding. The priorities for other networks that ARL is responsible for initially would be to decrease the number of sites to a level that would be sustainable given diminished resources and funding. However, OAR may have an additional financial burden if the decease in funding is not sufficient to remove or maintain the stations.

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.

Response: ARL has begun to develop value-added products from the USCRN data.

Action: ARL is in the development stage of adding gridded data of all of the USCRN measured parameters that will useful to the NOAA water center, NIDIS and the climate community.

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).

Response: In light of budget uncertainties, ARL's strategy is to maintain certain sites for testing new technologies. These include a precipitation testbed site in Boulder, Colorado operated in partnership with the National Center for Atmospheric Research and a soil moisture testbed site in Oak Ridge, TN.

Action: ARL is taking a short term and long term approach within budget constraints. In FY17 ARL began purchasing new GOES transmitters that will need to be in place at all USCRN stations by 2025.

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.

Response: ARL is working with the NOAA National Center for Environmental Information (NCEI) to develop value-added products from the USCRN data. In particular, ARL will be utilizing soil temperature and soil moisture measurements across the USCRN to develop a new national water availability index.

Action: ARL will continue to work with NCEI and CDC to develop web based products using the USCRN observations to develop indices related to health and drought.

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.

Response: ARL agrees. See 4.6

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.

Response: ARL has collocated USCRN stations at SEBN sites where possible, including sites in Arizona, Illinois, and Nevada. This will also allow ARL to develop value-added products from USCRN stations that can be validated against SEBN measurements.

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.

Response: ARL agrees that the USCRN as a whole would make a great cal/val testbed for remotely sensed systems. ARL has done some work looking at the representativeness of certain USCRN stations for cal/val purposes. These were short field studies. Unfortunately, ARL is both budget and bandwidth constrained to develop a cal/val plan for the entire network.

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.

Response: ARL agrees with the recommendation. The CRN program went through a rigorous site selection process that was based on WMO siting criteria which includes scoring criteria for each parameter measured. On the annual maintenance visit the site is re-scored and a set of pictures are taken. These become part of the metadata package that is sent to the NCEI for analysis for changes in the surrounding environment on an annual basis.

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.

Response: Since the review ARL has published a paper entitled: "The quantification and correction of wind-induced precipitation measurement errors." This is the first of a series of three papers that will be published; all of which are looking at the various aspects of developing a universal transfer function that can be applied to different gauges in different climate regimes. The ultimate goal is to test the transfer function against known gridded precipitation datasets to determine the impact this will have on hydrologic processes on short- and long-

term timescales.

Action: There have been two additional papers published in FY17 and ARL scientists are also actively involved with completing the final report.

Response #	Action Item	Due Date	Status as of March 2019
1.1	Hire two new federal employees for HYSPLIT group. The profile of one of the hires will be on the study of model uncertainty through the construction of dispersion ensembles. The second position will focus on the incorporation and development of new dispersion parameterizations geared toward emergency applications such as nuclear or chemical hazards.	Sep, 2019	Hired 1 federal employee March 2019. Developing paperwork for 2nd position.
1.4	Teach HYSPLIT course at U. of MD. Mentor undergraduate and graduate students through the U. of MD Maryland Earth Science Applications (MESA).	Sep, 2018	Activity postponed. New HYSPLIT course is given via web.
1.6	ARL will review its mentoring and training approaches to determine whether more can be done to increase the pool of potential successors having the required skills. ARL will also consider career ladder positions for new hires so that increasing responsibilities do not require recompetition of positions. ARL will consider the use of Temporary promotions and internal details to expand the number of qualified leaders in the organization.	Ongoing	
1.7	ARL will hire a contractor to serve as the communication specialist that will closely interact with OAR Communications and the Formulation and Congressional Analysis Division to highlight ARL's research activities at the appropriate Government level.	November, 2017	Completed.
1.8	Continue fostering relationship with JPSS, GOES-R community.	Ongoing	Got funding from JPSS to build emergency modeling capability to respond to volcanic ash.
1.9	Develop procedure manual for replication of met monitoring networks.	Dec, 2019	

1.10	Reach out to universities (e.g. U. of MD. / U. of FL / Penn State) to leverage basic research and incorporate new science. Take advantage of interagency agreements with DOE and reach out to other federal agencies that are end users of the HYSPLIT modeling system (e.g. DOD, EPA, USFS, etc.) to increase resources available for model development.	Ongoing	Closely interacting with NIST, U. of MD. and PSU to develop new parameterizations for HYSPLIT.
1.11	ARL will consider consolidating several research projects so that more critical ones may be better supported. This will be done as part of the future ARL strategic planning process.	Dec, 2020	Developed tracers of opportunity project bringing new focus to the measurement and modeling personnel
2.1	ARL is adding performance measures in the OAR Annual Operating Plan that are directly related to the services provided to ARL stakeholders (NOAA, DOD, DOE, EPA, WMO, academia, national and international research community).	Oct, 2017	Completed.
2.3	ARL is investigating opportunities to have all ARL divisions involved in the planning and experiment design of future phases of Project Sagebrush.	Sep, 2019	Started discussions. However, due to retirement of key personnel at FRD this activity is being reevaluated.
2.5	ARL is already working on updates to HYRad that include making it more portable.	Sep, 2018	Completed.
2.6	see Action 2.3 + leveraging with NIST, DOE, and DOD.	Sep, 2019	Leveraging assets with NIST and DOD to use known sources as tracer of opportunity to evaluate the HYSPLIT model. Started flight planning.

2.8	Develop a prototype of a smoke dispersion ensemble based on SREF or the future ensemble meteorological model run operationally by NWS.	Dec, 2018	Completed. It is available in our Ready web page
3.2	ARL is organizing a chemistry summit with ESRL to establish future collaboration.	Jan, 2018	Completed. The summit was a success. We have different ongoing research activities that were initiated after the summit. e.g. NGGPS.
3.6	Codify and document in greater detail ARL's QA/QC protocols and assemble a comprehensive set of QA'd/QC'd data from each of the three ARL AMNet sites.	Dec, 2019	Assembled the data from the three sites to date. We have adopted NADP's QA protocols led and these are well documented
3.8	Explore options for nitrogen and mercury measurement studies in locations of mutual scientific significance	Ongoing	ARL continues to explore options for co-located nitrogen and mercury measurement studies through participation in OAR's Oceans Portfolio, which enhances collaboration and coordination of research activities in oceans, coasts, and the Great Lakes (locations where deposition of nitrogen and mercury may have significant effects) and through discussions of ARL's ongoing scientific engagement in the NERRs, including Grand Bay, MS (long-term ARL mercury site where nitrogen measurements may be added). This task is complete.
3.10	Relevance of ARL's chemistry research will be	Dec, 2020	

	further explained in future planning and guidance documents.		
3.11	ARL to devote resources to NGGPS emissions. In particular, we will collaborate with ESRL scientists to test new emissions algorithms for aerosols into the FV3 system.	Sep, 2017	Completed and continuing. We are actively collaborating with ESRL in the evaluation of the aerosol parameterization included in FV3.
3.12	Investigate other monitoring sites and networks as targets of opportunity to expand long- or short-term mercury measurement activities	Ongoing	Made mercury measurements on Hart Miller island last summer for OWLETS.
3.13	Seek out new opportunities and research funding streams for mercury	Ongoing	Have not been successful in securing funding.
4.2	Since the Lab Review, ARL has obtained a senior-level climate scientist, through a reassignment, who will help coordinate ARL's climate program.	May, 2017	Completed. Howard Diamond has been transferred to College Park, MD.
4.4	ARL is in the development stage of adding gridded data of all of the USCRN measured parameters that will useful to the NOAA water center, NIDIS and the climate community.	Ongoing	Maps depicting the percentage of 4-km grid cells that match soil properties from at least one USCRN station both with and without vegetation have been produced.
4.5	ARL is taking a short term and long term approach within budget constraints. In FY17 ARL began purchasing new GOES transmitters that will need to be in place at all USCRN stations by 2025.	Ongoing	That process has begun and we are well on our way to having the entire network changed over to the new

			transmitters in time for the overall changeover deadline in 2025.
4.6	ARL will continue to work with NCEI and CDC to develop web based products using the USCRN observations to develop indices related to health and drought.	Ongoing	Beta product development was completed on schedule in 2018, and consisted of developing a soil moisture climatology and standardized soil moisture data files for each USCRN station. A paper (Leeper et al 2017) evaluated how well the North American Regional Reanalysis (NARR) captured the evolution, intensity, and spatial extent of the 2012 drought in the U.S. by using USCRN soil moisture data as a validation source. A new journal article has now been submitted for publication describing the standardized soil moisture product and the early work on the drought indices product.
4.11	There have been two additional papers published in FY17 and ARL scientists are also actively involved with completing the final report.	Sep, 2018	Completed