NOAA Air Resources Laboratory

Science Review
March 22-24, 2022
Virtual

NOAA Air Resources Laboratory
Response to Panel Review Recommendations

September 30, 2022

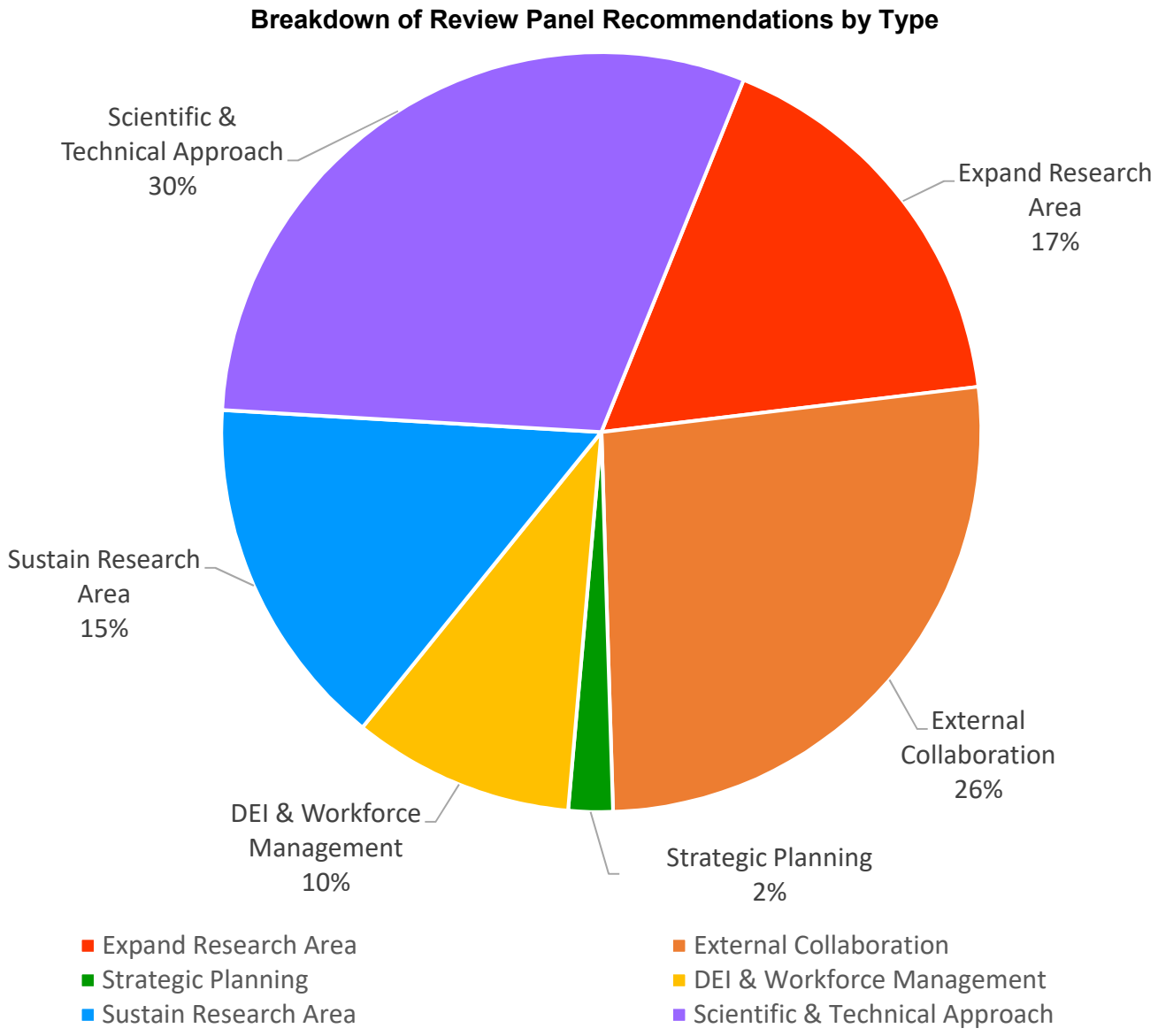
Submitted by:
Dr. Ariel Stein, Director, NOAA Air Resources Laboratory

Introduction

A review of the Air Resources Laboratory (ARL) was conducted March 22-24, 2022 in a virtual mode. The purpose of the review is to evaluate the quality, relevance, and performance of research conducted by NOAA ARL. Such reviews ensure that ARL's research is linked to strategic plans, and priorities; is of high quality; and is conducted efficiently and effectively. This response addresses the compilation and synthesis of individual panel member comments. More details on the review are available at the review website: https://www.arl.noaa.gov/about/lab-reviews/2022-lab-review/

The response is organized according to the three research themes observed by the review: surface-atmosphere exchange, atmospheric transport and dispersion, and boundary layer characterization. Within each section, a brief summary is followed by general comments and a set of actionable recommendations. A full list of abridged recommendations is included as an appendix.

The Laboratory thanks the panel members for their time, dedication and recommendations. In this report, a summary of the types of recommendations is presented, followed by a table of the actionable recommendations provided by the Science Review Panel. Lastly, the Laboratory's action plan, along with detailed recommendations and a timeline for the laboratory response can be found.


Breakdown of Review Panel Recommendations by Type
Scientific & Technical Approach 30%
Expand Research Area 17%
Sustain Research Area 15%
External Collaboration 26%
DEI & Workforce Management 10%
Strategic Planning 2%
Expand Research Area
External Collaboration
Strategic Planning
DEI & Workforce Management
Sustain Research Area
Scientific & Technical Approach

ARL Laboratory Action items:

General Items

Number	Action	Target start & Completion Dates
1	ARL will develop a targeted set of thrust areas as an addendum to the strategic plan.	FY2023, Q4
2	ARL will continue to seek opportunities that balance and connect short-term and long-term anticipatory research activities.	FY2026, Q4
4	ARL will complete the current website refresh and, as funding becomes available, hire additional IT staff to improve data repositories.	FY2026, Q4
5	In ARL's approved staffing plan, recruitments for an additional four Federal scientists are targeted by the end of FY23.	FY2023, Q4
6	ARL is actively engaged in the hiring process to fill vacancies and reduce acting roles in leadership.	FY2023, Q4
7	ARL will continue to recruit federal employees in line with the approved staffing plan and budget considerations as well as leverage expertise through Cooperative Institutes, NOAA Cooperative Science Centers, and contracts.	FY2026, Q4
8	ARL will highlight its international engagement strategy in the lab's strategic plan.	FY2023, Q4
9	ARL will support attendance at meetings with the fire research community in alignment with new fire weather research initiatives.	FY2024, Q4
10	ARL will actively support professional development and leadership training opportunities for female scientific staff.	Ongoing
14	ARL is actively engaged with OAR programs that have environmental justice components and that could leverage ARL's urban meteorology and air quality observations (e.g. NIHHIS).	FY2026, Q4

ARL Laboratory Action items:

Boundary Layer

Item	Action	Target start & Completion Dates
1	We will work with our partners at NOAA's National Centers for Environmental Information (NCEI) to review the work undertaken by the UK's NPL.	FY2026, Q4
2	We will try to meet this review recommendation, but there are issues here with some GSRN requirements that impinge on our limited resources and the ability to manage a national network in a consistent fashion. As GSRN requirements possibly evolve, we will reassess what we can and cannot do.	FY2026, Q4
3	We are committed to the continued maintenance of the USCRN for the long-term, and realize that increased resources will be required over time. However, we are dependent upon annual appropriations from the US Congress for our USCRN budget.	Planned on an annual and continuing basis
4	We plan to install the final 6-7 stations in Alaska by 2026; with two station installations per year planned from 2023-25, and one possible final station installation in 2026.	FY2026, Q4
5	Currently participating in SPLASH. Longer term plans include 4 boundary layer supersites in the Western U.S. as part of the Fire Weather Program.	FY2026, Q4
6	A LIDAR system is currently being procured and will be installed sometime in FY23 at the Chestnut Ridge Surface Energy Balance Network (SEBN) site.	FY2026, Q4
7	ARL will procure several more UAS platforms in support of fire weather and boundary layer research.	FY2026, Q4
8	SORD will participate in at least two briefings to DOE scientists and/or participation in a wider range of scientific meetings attended by DOE scientists. This is to be accomplished as the budget allows.	FY2026, Q4
9	Our plan is to both maintain and expand DCNet and hire a dedicated Federal scientist to oversee that effort	Beginning in late FY2022 and planned on an on-going and continual basis after that.
10	SPLASH campaign will increase datasets on complex terrain.	FY2026, Q4

ARL Laboratory Action items:

Surface Atmosphere Exchange

Item	Action	Target start & Completion Dates
1	ARL will continue participating in development and testing of UFS-based air quality model components and will explore the feasibility of a coarse resolution UFS-CMAQ (or equivalent) to provide enhanced lateral boundary conditions for CONUS-scale UFS models.	Completion: Q4FY2026
2	ARL will attempt to continue NACC and FV3GFS data on the AWS cloud platform.	Completion: Q4FY2023
3	ARL will continue to develop the NEXUS emissions processing system and work to have it included in the UFS as a model component.	Completion: Q4FY2026
4a	ARL will continue to develop the NEXUS emissions processing system and work to have it included in the UFS as a model component.	Completion: Q4FY2026
4b	ARL will continue to develop interactions with land-surface modelers to develop collaborations that will use ARL observations to evaluate and improve the modeling systems in NOAA atmospheric models.	Completion: Q4FY2026
4c	ARL's measurements are made freely available to interested researchers through the National Atmospheric Deposition Program, and ARL scientists will continue to actively pursue collaborations with the mercury modeling community. In addition, ARL is engaged in improving methodologies to better measure all atmospheric mercury species, and these activities will continue and expand.	Completion: Q4FY2026
5	ARL will continue to seek out collaborations with external partners for the research and development of NOAA air quality modeling systems.	Completion: Q4FY2026
6	ARL will assess the feasibility of an SEBN site in Alaska and evaluate whether resources can be located to establish and reliably maintain such a site.	Completion: Q4FY2023
7	ARL will continue to support NWS in its effort to transition UFS-based atmospheric composition models to operations. However, ARL has limited control on the decision making process regarding UFS model applications.	Completion: Q4FY2023
8	ARL will explore the feasibility of a coarse resolution UFS-CMAQ (or equivalent) to provide enhanced lateral boundary conditions for CONUS-scale UFS models.	Completion: Q4FY2023
9	ARL will continue its efforts in multi-layer modeling to better understand dynamic in-canopy processes that influence net canopy-scale fluxes of reactive gases and aerosols.	Completion: Q4FY2026
10	ARL will explore the use of large eddy simulation (LES) tools as a complement to its surface-atmosphere exchange and boundary-layer measurement capabilities.	Completion: Q4FY2026
11	ARL will continue to pursue collaborations and resources to support reactive nitrogen surface-atmosphere exchange measurements.	Completion: Q4FY2026
12	ARL will pursue opportunities to work more closely with state environmental agencies, such as the Maryland Department of the Environment, the New York State Department of Environmental Conservation, and the Northeast States for Coordinated Air Use Management, and the National Institutes of Standards and Technology (NIST) to quantify GHG emissions in other urban areas such as New York City, Boston and Philadelphia.	Completion: Q4FY2026
13	ARL will encourage scientists engaged in activities related to atmospheric deposition to participate more fully in NADP.	Completion: Q4FY2026
14	ARL will appoint appropriate leadership for the SAE theme to provide coordination, develop efficiencies and promote SAE science.	Completion: Q1FY2023

ARL Laboratory Action items:
Atmospheric Transport and Dispersion

Item	Action	Target start & Completion Dates
1	ARL will continue its ongoing investments in the development of the HYSPLIT model and the integration of new and relevant capabilities into the modeling system.	Q4 2026
2	ARL will continue to develop the scientific methodologies for estimating emissions for wildfires and volcanoes based on inversions of observations and will make them publicly available for broader use whenever possible and appropriate.	Q4 2026
3	We plan to enhance collaboration among the two groups for wildfire research, sharing and synthesizing information about fire behavior, emissions, transport, and model evaluation. Emissions from HYSPLIT-based inversion methods will be tested in NAQFC models.	Q4 2026
5	We will continue work on incorporation of UAS and ground-based measurements into the HYSPLIT model, with and without incorporation into a numerical weather prediction model like WRF. Beyond our current scope; action is contingent on expanded resources, otherwise, it is difficult to achieve.	Q4 2026
6	This capability already exists, but we will make the capability to process more than 12 meteorological files clearer -- in the User Guide, and in the Graphical User Interface (GUI) context-sensitive help.	Q4 2026
7	We will continue to incorporate the following software engineering principles, as resources allow: (a) unit testing of program modules; (b) more quantitative version-testing methods; (c) re-engineering interfaces to more modern languages.	Q4 2026
8	We will continue to provide comprehensive tracer-experiment datasets to the public, including the international community. If new tracer experiments are conducted, we will add these datasets to our existing DATEM repository	Q4 2026
9	We will continue these activities as much as resources allow.	Q4 2026
10	We will continue to provide well-documented, well-tested, and robust model products, and continue to provide version information in model outputs.	Q4 2026
11	A newsletter is being implemented and will continue to be released periodically. We will continue to advocate the use of the HYSPLIT Forum for questions. We will continue to provide documentation for new features.	Q4 2023

Detailed Recommendations, Responses, Action Plan and Timeline

General Recommendations				
Recommendation	**Action**	**Champion**	**Target start & Completion Dates**	**Notes**
1. ARL should supplement its strategic plan with prioritized thrust areas that consolidate complimentary research objectives across the Surface-Atmosphere Exchange, Atmospheric Transport and Dispersion, and Boundary Layer Characterization program areas.	ARL will develop a targeted set of thrust areas as an addendum to the strategic plan.	Ariel Stein/LaToya Myles	FY2023, Q4	
2. Though the diversity of projects that ARL staff contribute to is impressive, in some instances the level of involvement was not apparent. While this may be a consequence of changing stakeholder needs, in the long-term some balance between fulfilling short-term stakeholder needs and building an anticipatory research program that cultivates the lab's core capabilities may be desirable. Where possible, OAR and ARL management should seek opportunities that also help with the formulation of anticipatory research.	ARL will continue to seek opportunities that balance and connect short-term and long-term anticipatory research activities.	Ariel Stein/LaToya Myles	FY2026, Q4	
3. ARL should prioritize the modernization of the HYSPLIT code and web-based functionalities to ensure portability and adequate (or enhanced) performance in emerging computational platforms (e.g., HPC, cloud, GPUs). To enable these efforts, ARL is encouraged to continue to identify and inject its infrastructure needs into OAR strategic planning.	See atmospheric transport recommendations, item 4	See Item 4 on the ATD tab.		
4. ARL needs to update its websites and improve data repositories to make them more accessible (e.g., improved APIs, discoverability, and metadata). This was a common suggestion for improvement among stakeholders.	ARL will complete the current website refresh and, as funding becomes available, hire additional IT staff to improve data repositories.	Margaret Simon	FY2026, Q4	
5. There is concern about program continuity, as it seems some ARL programs are led by a single federal staff member (with several nearing retirement age). ARL should actively work to build redundancy of expertise in scientific and technical areas that could be affected by retirements in the near term. The development of a strategic plan to address gaps resulting from lack of redundancy due to talent attrition (e.g., retirements, promotions, lateral moves) should be pursued.	In ARL's approved staffing plan, recruitments for an additional four Federal scientists are targeted by the end of FY23.	Michelle Howard	FY2023, Q4	

General Recommendations				
Recommendation	**Action**	**Champion**	**Target start & Completion Dates**	**Notes**
6. The extended use of "acting" roles within the ARL ranks, especially leadership roles, is troubling. OAR should prioritize completing all hiring actions for ARL leadership staff.	ARL is actively engaged in the hiring process to fill vacancies and reduce acting roles in leadership.	Ariel Stein/Michelle Howard	FY2023, Q4	ARL has a permanent director as of May 2022, Deputy Director recruitment is underway. All division roles are now filled.
7. The precarity of non-federal positions and declining federal workforce present medium to long-term risks. While there is a role for contractors and cooperative institutes, they should be value-added and not critical to core mission aspects. As such, efforts should be undertaken to convert posts where possible to federal positions.	ARL will continue to recruit federal employees in line with the approved staffing plan and budget considerations as well as leverage expertise through Cooperative Institutes, NOAA CSCs (Cooperative Science Centers), and contracts.	Ariel Stein/Michelle Howard	FY2026, Q4	
8. International engagement is principally in the form of committees and working groups with little evidence for sustained collaboration with international partners, particularly outside North America. This risks under-exploitation of the useful tools and approaches developed by the lab. An international engagement strategy would be valuable. Long-term win-win partnerships should be sought which may increase support either directly or through in-kind collaborations. Examples exist such as the collaboration between NOAA NCEI and C3S on collection and management of global in-situ data holdings.	ARL will highlight its international engagement strategy in the lab's strategic plan.	Margaret Simon/LaToya Myles	FY2023, Q4	
9. Principal reported conference engagements were at AGU and AMS. While these are undoubtedly valuable and have high visibility, more specialized conferences and workshops on focused topics (e.g., fire) are oftentimes more valuable in terms of networking and gaining insights and engagement. A more balanced portfolio of meetings attended may yield dividends and better community engagement. Consideration should also be given to attendance at relevant international meetings to broaden impact.	ARL will support attendance at new meetings in alignment with new and developing ARL research initiatives as budget and resources allow.	Ariel Stein/Tilden Meyers	FY2024, Q4	
10. ARL is to be commended for its mentoring and outreach efforts. However, ARL should continue to develop and provide leadership opportunities to its female scientific staff.	ARL will actively support professional development and leadership training opportunities for female scientific staff.	Ariel Stein/LaToya Myles	Ongoing	

General Recommendations				
Recommendation	**Action**	**Champion**	**Target start & Completion Dates**	**Notes**
11. ARL should actively engage users in DOD, DOE, and other US government organizations to identify opportunities for collaboration, including classified applications. To facilitate these efforts, a greater number of staff members with clearances might be needed.	ARL will increase efforts to reach out to the Federal community to conduct and participate in a combination of at least two high level briefings to other Federal Agencies and/or attend a wider range of scientific meetings attended by other Federal agencies, as budget allows	Walt Schalk, Ariel Stein	FY2026, Q4	Increased clearances depend on sponsor and budget identified.
12. ARL should invest into growing support staff for the HYSPLIT model to better balance research and development efforts with ever-growing operational support requirements, including code dissemination and management, user training, and real-time support (e.g., READY).	Refer to atmospheric transport recommendations, Item 1	Move to ATD.		
13. ARL's plans for the advancement of atmospheric transport and dispersion applications appear well aligned with user community needs and requirements. The organization is encouraged to pursue these very critical topics fully.	Refer to atmospheric transport recommendations, Item 9	Move to ATD.		
14. ARL should explore opportunities to align its current efforts in urban air quality research to more directly address environmental justice issues. ARL seems very well positioned in this regard.	ARL is actively engaged with OAR programs that have environmental justice components and that could leverage ARL's urban meteorology and air quality observations (e.g. NIHHIS).	Ariel Stein/LaToya Myles	FY2026, Q4	

Detailed Recommendations, Responses, Action Plan and Timeline: Boundary Layer Characterization

Boundary Layer Characterization				
Recommendation	**Action**	**Champion**	**Target start & Completion Dates**	**Notes**
1. Consideration should be given to addition, including retrospective reprocessing, of meteorologically quantified uncertainties to USCRN primary measurement series to increase potential applications of these data. Work on temperature undertaken by UK NPL colleagues should be reviewed and operationalized. Similar work should be undertaken on remaining primary variables.	We will work with our partners at NOAA's National Centers for Environmental Information (NCEI) to review the work undertaken by the UK's NPL.	Howard Diamond	FY2026, Q4	USCRN has always reviewed the real-time monitoring of a triplicate-sensor set of primary air temperature, precipitation, and soil sensors, coupled with an annual maintenance strategy to ensure that the system meets its uncertainty ranges as advertised. Resources for an on-going metrological effort are simply not budgeted for and with limited resources, we prefer to focus on instrumentation refresh and on-going maintenance, coupled with careful on-line monitoring to ensure that we keep the highest standards with regard to minimizing uncertainty.
2. A subset of USCRN should be put forward for the new Global Surface Reference Network once progress has gotten that far. NOAA ARL should continue active engagement in the process of setting up the GSRN.	We will try to meet this review recommendation, but there are issues here with some GSRN requirements that impinge on our limited resources and the ability to manage a national network in a consistent fashion. As GSRN requirements possibly evolve, we will reassess what we can and cannot do.	Howard Diamond	Dependent on the schedule of the GSRN implementation which is outside of ARL's sphere of control, as well as our ability to meet some rather stringent GSRN requirements for maintenance and data averaging periodicity that could make fulfilling this recommendation problematic. Would probably be completed and/or resolved in some fashion prior to the next ARL Review in 2027.	While ARL supports the GSRN concept, some of the requirements (e.g., 1-minute averaging of temperature and precipitation as well as monthly maintenance of stations) are even more stringent than USCRN requirements. As such any sub-set of USCRN stations for consideration to be part of the GSRN would have to be limited to a few stations that are more easily maintained on a more than annual basis which is the current USCRN standard; and therefore that subset may be no more than 2-3 stations. Doing 1-minute averaging of temperature and precipitation data will be dependent on ARL's partner in USCRN at NESDIS/NCEI and will also be dependent on storage and communications resources as that would multiply the data volume by 5 times and so not something we really want to do for more than just a few sites for the GSRN effort.

Boundary Layer Characterization				
Recommendation	**Action**	**Champion**	**Target start & Completion Dates**	**Notes**
3. USCRN must be maintained for decades and hence this will require increases in funding, at a minimum to account for inflation impacts, moving forward to avoid placing aspects of the program under undue stress. Both personnel and material costs will increase with time and the base funding request must rise accordingly if USCRN is to be maintained to the highest standards.	We are committed to the continued maintenance of the USCRN for the long-term, and realize that increased resources will be required over time. However, we are dependent upon annual appropriations from the US Congress for our USCRN budget.	Howard Diamond	Planned on an annual and continuing basis	In June 2021, OAR made its first bit of funding available to its Labs to support requirements expressed by the Labs with respect to aging instrumentation and infrastructure, and as a result $200K was made available to ARL, and while there are many needs, we have elected to apply those funds to incrementally fund new solar radiation and wind sensors (not primary but essential supporting QC equipment for temperature), as well as to incrementally fund the replacement of our satellite transmitters to a new version which must be in place by 2026 to meet a critical satellite transmission upgrade.
4. USCRN expansion throughout Alaska, understandably delayed by the pandemic, should be completed within the next review period.	We plan to install the final 6-7 stations in Alaska by 2026; with two station installations per year planned from 2023-25, and one possible final station installation in 2026.	Howard Diamond	Completion of this activity is slated for September 2026.	As with anything, these plans are all dependent on continued budgeting and no unanticipated events such as a pandemic.
5. The work using new boundary layer techniques should be expanded to consider underrepresented complex/challenging environments where present flux behaviors are most poorly known (e.g., open water, coastal and topographically complex regions) and in particular, deployments should prioritize those environments not amenable to fixed instrumentation. For example, IPCC AR6 WGI highlighted the criticality of understanding ocean-atmosphere fluxes across globally representative ocean zones and across the seasonal cycle. Via cooperation with other line offices and federal agencies, as well as international partners, scope for use in these contexts would be valuable.	ARL is a key participant in SPLASH to expand our knowledge of hydrological processes and prediction in complex terrain.	Tilden Meyers	FY2026, Q4	
6. ARL needs to push their BL profiling capabilities and datasets higher into the PBL, ideally up to the top of the PBL. This may require working more closely with other OAR labs to develop expertise in remote sensing technology.	A LIDAR system is currently being procured and will be installed sometime in FY23 at the Chestnut Ridge Surface Energy Balance Network (SEBN) site.	Tilden Meyers, John Kochendorfer, and Temple Lee	FY2026, Q4	

Boundary Layer Characterization				
Recommendation	**Action**	**Champion**	**Target start & Completion Dates**	**Notes**
7. ARL should continue to pursue UAS research and look for ways to expand.	ARL will procure several more UAS platforms in support of fire weather and boundary layer research.	Tilden Meyers and Temple Lee	FY2026, Q4	
8. SORD does a great job supporting their customers at the NNSS and should develop collaborations with entities such as DOE national laboratories. This could involve convening information sessions with representatives from DOE laboratories to find avenues for collaboration.	SORD will participate in at least two briefings to DOE scientists and/or participation in a wider range of scientific meetings attended by DOE scientists. This is to be accomplished as the budget allows.	Walt Schalk	FY2026, Q4	Accept and consider. Use of mesonet leveraged to aid in National Laboratory projects.
9. While resources are understandably limited, opportunities to expand DCNet to other urban areas should be explored. Such measurements can serve as a focal point for integration of atmospheric monitoring in urban areas, e.g., coordination with air quality networks. ARL seems well positioned to be leaders in this area.	Our plan is to both maintain and expand DCNet and hire a dedicated Federal scientist to oversee that effort	Howard Diamond for now; a dedicated scientist is still TBD	Beginning in late FY2022 and planned on an on-going and continual basis after that.	ATDD will be the focus for the DCNet program with assistance in maintenance activities from personnel at ASMD.
10. Support for efforts to better understand boundary layer processes in complex natural landscapes should continue. Among other applications, such datasets are needed to improve the ability of models to simulate land-atmosphere exchange processes in pristine environments with complex topography, e.g., high elevation Class I wilderness areas, where uncertainty in model predictions of ecosystem exposure to atmospheric deposition is high.	SPLASH campaign will address the utility of land surface interactions in complex terrain.	Tilden Meyers	FY2026, Q4	

Detailed Recommendations, Responses, Action Plan and Timeline: Surface Atmosphere Exchange

Surface-Atmosphere Exchange				
Recommendation	**Action**	**Champion**	**Target start & Completion Dates**	**Notes**
1. Development and testing of the air quality components in the UFS framework should be continued as they often help identify issues related to transport and conservation that may not be diagnosed through NWP applications alone. It appears that some representation of the large-scale forcing beyond the current GEFS-GOCART system may be needed to capture changes in global emissions and their impacts on long-range pollution transport to North America. Development of a low resolution UFS-CMAQ system for creating space and time varying chemical lateral boundary conditions or use of other systems (e.g., Copernicus) could be explored.	ARL will continue participating in development and testing of UFS-based air quality model components and will explore the feasibility of a coarse resolution UFS-CMAQ (or equivalent) to provide enhanced lateral boundary conditions for CONUS-scale UFS models.	Barry Baker	Completion: Q4FY2026	
2. Migration of the NACC code to the AWS platform to expand userbase for the FV3GFS-CMAQ for other regional domains across the globe is a worthwhile activity and should be continued.	ARL will attempt to continue NACC and FV3GFS data on the AWS cloud platform.	Patrick Campbell	Completion: Q4FY2023	If new funding is not secured for continuation in the AWS cloud, then the project will end.
3. ARL invests significant effort in creating emission data sets to drive the NAQFC system and in the future may be pursuing similar efforts on the global scale for the UFS. Documenting the changes in these data sets (for instance relative to the NEI for the U.S.) and making them publicly available may help increase their utility and promote transparency in the overall forecast products.	ARL will continue to develop the NEXUS emissions processing system and work to have it included in the UFS as a model component.	Barry Baker	Completion: Q4FY2026	
4. In many instances it seems that opportunities exist to broaden the utility and impact of ARL's research and development activities:				
• Several examples were presented where ARL research led to development of new emission data sets for select species (e.g., CH_4 for Maryland, Volcanic SO_2) or sectors (wildfires in the future). These data have broad potential use and should be made publicly available for use by the broader scientific community, which would help promote ARL and NOAA's research efforts.	ARL will continue to develop the NEXUS emissions processing system and work to have it included in the UFS as a model component.	Barry Baker	Completion: Q4FY2026	ARL agrees that making these improved emissions datasets available to the broader scientific community is a desirable goal. As noted previously, the NEXUS emissions processing system and the datasets that are input to it will eventually be part of the UFS codebase that will be available publicly.

Surface-Atmosphere Exchange				
Recommendation	**Action**	**Champion**	**Target start & Completion Dates**	**Notes**
• The initiation of collaboration between ARL and GFDL to apply the SEBN data for evaluation and improvement of land-surface models is a positive development. Similar collaborative efforts where ARL measurements can help inform development of scale-aware processes in earth system models should be actively pursued and encouraged.	ARL will continue to develop interactions with land-surface modelers to develop collaborations that will use ARL observations to evaluate and improve the modeling systems in NOAA atmospheric models.	Rick Saylor	Completion: Q4FY2026	ARL agrees that interactions between our laboratory and GFDL for the evaluation and improvement of land-surface models is a good development. ARL scientists have reached out to GFDL scientists several times over the past five years and that interaction is now bearing positive results. ARL has also established dialogue with the land-surface modeling team in the NWS Environmental Modeling Center and has discussed a variety of possible mutually beneficial projects.
• Long-term Hg measurements provide unique opportunities to assess and contrast trends in Hg speciation and possible shifts in seasonal behavior across different locations (background, suburban, Arctic) and serve as useful tests for models. Continued analysis of this nature and collaboration with modeling groups should be pursued.	ARL's measurements are made freely available to interested researchers through the National Atmospheric Deposition Program, and ARL scientists will continue to actively pursue collaborations with the mercury modeling community. In addition, ARL is engaged in improving methodologies to better measure all atmospheric mercury species, and these activities will continue and expand.	Winston Luke	Completion: Q4FY2026	Recent establishment of Hg measurements at the NOAA Barrow Atmospheric Baseline Observatory will allow us to better understand long-term trends in the Arctic, where pronounced changes in mercury biogeochemistry dynamics may result from rapid warming in polar regions.
5. New collaborations (e.g., with DOE's Atmospheric System Research program) would provide additional opportunities and datasets to improve air quality model (NAQFC) and should be encouraged.	ARL will continue to seek out collaborations with external partners for the research and development of NOAA air quality modeling systems.	Barry Baker	Completion: Q4FY2026	
6. Consider viability of expansion of the SEBN network to have a permanent presence in Alaska to monitor the rapidly changing Arctic climate, preferably paired with a USCRN site.	ARL will assess the feasibility of an SEBN site in Alaska and evaluate whether resources can be located to establish and reliably maintain such a site.	Tilden Meyers	Completion: Q4FY2023	

Surface-Atmosphere Exchange				
Recommendation	**Action**	**Champion**	**Target start & Completion Dates**	**Notes**
7. A contingency plan is required for if UFS leads to unacceptable degradation of model-based applications. Is there a formal lock on UFS release depending upon implications for the composition models? If not, is there a fall-back plan for continuity of existing products unless and until acceptable (comparable or better) performance than existing systems can be found?	ARL will continue to support NWS in its effort to transition UFS-based atmospheric composition models to operations. However, ARL has limited control on the decision making process regarding UFS model applications.	Barry Baker	Completion: Q4FY2023	
8. Setting up a research version of a low resolution global UFS-CMAQ system for creating space and time varying chemical lateral boundary conditions for regional NAQFC could help explore possible impacts of changing large-scale forcing and global emissions on daily air quality forecasts and provide guidance for evolution of the operational system.	ARL will explore the feasibility of a coarse resolution UFS-CMAQ (or equivalent) to provide enhanced lateral boundary conditions for CONUS-scale UFS models.	Barry Baker	Completion: Q4FY2023	
9. ARL efforts to apply multi-layer models to better understand in-canopy processes influencing net canopy-scale fluxes of reactive gases and aerosols is unique relative to other agencies and academia and should be continued.	ARL will continue its efforts in multi-layer modeling to better understand dynamic in-canopy processes that influence net canopy-scale fluxes of reactive gases and aerosols.	Rick Saylor	Completion: Q4FY2026	
10. Development and application of large eddy simulation as a tool to better understand surface-atmosphere exchange processes is encouraged, particularly for deep canopies and complex environments.	ARL will explore the use of large eddy simulation (LES) tools as a complement to its surface-atmosphere exchange and boundary-layer measurement capabilities.	Rick Saylor	Completion: Q4FY2026	
11. Direct measurements of surface-atmosphere exchange of ammonia and relevant biogeochemistry/surface conditions in natural and agricultural landscapes are urgently needed to improve models of bi-directional exchange. Continued effort in this area is encouraged.	ARL will continue to pursue collaborations and resources to support reactive nitrogen surface-atmosphere exchange measurements.	Rick Saylor	Completion: Q4FY2026	

Surface-Atmosphere Exchange				
Recommendation	**Action**	**Champion**	**Target start & Completion Dates**	**Notes**
12. The program to develop mass-balance estimates of urban GHG emissions is unique and should be expanded to other areas through development of partnerships with state environmental agencies.	ARL will pursue opportunities to work more closely with state environmental agencies, such as the Maryland Department of the Environment, the New York State Department of Environmental Conservation, and the Northeast States for Coordinated Air Use Management, and the National Institutes of Standards and Technology (NIST) to quantify GHG emissions in other urban areas such as New York City, Boston and Philadelphia.	Xinrong Ren	Completion: Q4FY2026	
13. Much of the work on surface atmosphere exchange of reactive trace gases and particles is relevant to efforts by the National Atmospheric Deposition Program to advance understanding of total atmospheric deposition to support ecosystem exposure assessments. Some NOAA ARL staff participate in and hold leadership positions within NADP but wider engagement among other ARL staff is encouraged.	ARL will encourage scientists engaged in activities related to atmospheric deposition to participate more fully in NADP.	Rick Saylor	Completion: Q4FY2026	
14. The breadth of the SAE research program is impressive, and the individual elements are successful. However, the level of coordination across research efforts was in some case unclear (e.g., aircraft work and ground-based reactive chemical fluxes). Perhaps some efficiencies could be gained through closer coordination and strategic planning among teams.	ARL will appoint appropriate leadership for the SAE theme to provide coordination, develop efficiencies and promote SAE science.	Rick Saylor	Completion: Q1FY2023	

Detailed Recommendations, Responses, Action Plan and Timeline: Atmospheric Transport and Dispersion

Atmospheric Transport and Dispersion				
Recommendation	**Action**	**Champion**	**Target start & Completion Dates**	**Notes**
1. ARL should continue to invest in the development of the HYSPLIT model (e.g., parametrization, numerics) and the integration of new and relevant capabilities into the modeling system (e.g., STILT, TCM).	ARL will continue its ongoing investments in the development of the HYSPLIT model and the integration of new and relevant capabilities into the modeling system.	Mark Cohen	Q4 2026	
2. Efforts related to inverse modeling and developing refined emission estimates for wildfire and time-height resolved volcanic emissions are extremely useful and have broad applications beyond those of ARL. Making these emission data sets publicly available for broader use is recommended.	ARL will continue to develop the scientific methodologies for estimating emissions for wildfires and volcanoes based on inversions of observations and will make them publicly available for broader use whenever possible and appropriate.	Mark Cohen	Q4 2026	
3. Closer integration of research efforts by the HYSPLIT and NAQFC groups could help in development of a more cohesive research program. In particular, the use of refined emissions from HYSPLIT based inversion methods (for select sectors) in the NAQFC should be tested.	We plan to enhance collaboration among the two groups for wildfire research, sharing and synthesizing information about fire behavior, emissions, transport, and model evaluation. Emissions from HYSPLIT-based inversion methods will be tested in NAQFC models.	Mark Cohen, Barry Baker	Q4 2026	
4. Improvements in memory usage and parallelization of the HYSPLIT code are needed to allow for time steps less than one minute to accommodate higher resolution (e.g., sub-kilometer, urban modeling) runs. Alternative strategies to address resourcing deficiencies with HPC and cloud computing (e.g., leveraging external HPC for research and development efforts) should be explored. These improvements will make HYSPLIT more scalable.	ARL will consider HYSPLIT model modifications that would allow time steps less than one minute. Cloud-based HYSPLIT implementations have already been implemented, e.g., in the NWS-HYSPLIT system used operationally by the Weather Forecast Offices. The model is already parallelized and its computational efficiency is already a central feature. The model's long-time role as an emergency response tool has already led to a highly efficient code. HPC resources are not a high priority as the model's Lagrangian (plume-based) structure makes it inherently much faster and efficient than comparable Eulerian (grid-based) models.	Mark Cohen, Sonny Zinn	Q4 2026	NO HPC allocations have been made available
5. Capability to generate meteorological fields using only observed meteorology from surface-based, profiling instruments, etc. is needed. This can be done now by assimilating observations into WRF, running	We will continue work on incorporation of UAS and ground-based measurements into the HYSPLIT model, with and without	Mark Cohen and others in HYSPLIT group	Q4 2026	

Atmospheric Transport and Dispersion				
Recommendation	**Action**	**Champion**	**Target start & Completion Dates**	**Notes**
WRF, then post-processing the WRF file for HYSPLIT usage. Being able to generate a 4D, mass-consistent meteorology field using only observations and having the result available relatively quickly would enhance HYSPLIT capability. I believe a version of this capability exists with HYRAD (developed at NOAA ARL FRD) but allowing this capability out to the user community could really aid in further development.	incorporation into a numerical weather prediction model like WRF. Beyond our current scope; action is contingent on expanded resources, otherwise, it is difficult to achieve.			
6. Capability to process more than 12 meteorological files for a HYSPLIT run is needed.	This capability already exists, but we will make the capability to process more than 12 meteorological files clearer -- in the User Guide, and in the Graphical User Interface (GUI) context-sensitive help.	Mark Cohen	Q4 2026	
7. Continuing to incorporate more software engineering principles into HYSPLIT (and other) codes is encouraged.	We will continue to incorporate the following software engineering principles, as resources allow: (a) unit testing of program modules; (b) more quantitative version-testing methods; (c) re-engineering interfaces to more modern languages.	Mark Cohen & Sonny Zinn	Q4 2026	
8. ARL should leverage collaborations with the international community to increase its repository of tracer data and to further its model verification, uncertainty estimation, and data assimilation efforts.	We will continue to provide comprehensive tracer-experiment datasets to the public, including the international community. If new tracer experiments are conducted, we will add these datasets to our existing DATEM repository	Mark Cohen and Fantine Ngan	Q4 2026	
9. Continued work in the areas of inverse modeling, the transfer coefficient matrix, ensemble modeling and analysis, and Gaussian mixture method is strongly encouraged.	We will continue these activities as much as resources allow.	Mark Cohen and Alice Crawford	Q4 2026	
10. Ensure robust version control and FAIR principals are followed for all publicly facing products (in particular HYSPLIT) to enable reproducibility of analyses performed by users.	We will continue to provide well-documented, well-tested, and robust model products, and continue to provide version information in model outputs.	Mark Cohen and Sonny Zinn	Q4 2026	We can provide obsolete model versions upon request, but general dissemination of older versions make support too resource-intensive and inefficient.

Atmospheric Transport and Dispersion				
Recommendation	**Action**	**Champion**	**Target start & Completion Dates**	**Notes**
11. Consider hosting an annual HYSPLIT user-group conference to facilitate exchange of ideas, sharing of research results, and further cultivation of community-based user support. This would further enhance the utility of HYSPLIT.	Beyond our current scope; action is contingent on expanded resources, otherwise, it is difficult to achieve.			We provided support for the 2022 Atmospheric Transport and Dispersion conference at George Mason University, and solicited HYSPLIT-user talks to be submitted to this conference. We will continue this effort if resources allow.
12. ARL should more effectively leverage social media networks to engage with the scientific and technical community and to promote HYSPLIT developments, scientific publications, and/or other breakthroughs.	We agree with the intent, but action is likely beyond the scope of our capabilities without an expansion of staff and funding.			
13. Consider a quarterly HYSPLIT newsletter noting recent updates, publications, and summary of important topics discussed in the existing HYSPLIT user forum. Encourage the use of the online Forum to get questions answered when a new release is made. When a new HYSPLIT release is made, have short online videos or tutorials for users to learn more about the new options. Ex. STILT, Sofiev plume rise.	A newsletter is being implemented and will continue to be released periodically. We will continue to advocate the use of the HYSPLIT Forum for questions. We will continue to provide documentation for new features.	Margaret Simon	Q4 2023	
14. Consider how to internationalize the user base and applications of the models and insights developed by this group. How can the models and tools be more broadly applied in service to global society? Possibilities to engage users outside N. America via workshops, WMO, etc. could be explored.	We will continue to make our tools -- e.g., the HYSPLIT model -- highly accessible and useful to users in the U.S. and around the world.			See Item 8 on General recommendations. International collaborations and services exist, e.g, ICAO (volcanic ash), UN-FAO Locust migration forecasting, WMO, GHG (greenhouse gas emissions), RSMC (nuclear), and CTBTO (nuclear event backtracking). Note also that the HYSPLIT model (online and local installation), the Annual Workshop, the self-paced Tutorial, and meteorological data in HYSPLIT format to drive the HYSPLIT model are available to the global public.
15. All ARL team members appear to make the effort to present at conferences, which is great. For wildfire related work, I recommend targeting conferences where wildland fire smoke is a focus such as: • Wildland Fire Canada Conference, Oct 31-Nov 4, 2022, Edmonton, Canada	See item 9 in General Recommendations for a general statement on conference attendance.			

Atmospheric Transport and Dispersion				
Recommendation	**Action**	**Champion**	**Target start & Completion Dates**	**Notes**
• International Association of Wildland Fire (IAWF), Fire and Climate Conference, May 2022, Pasadena, California. • International Smoke Symposium (every three years) • AMS Fire and Forest Meteorology (every three years) • Other IAWF conferences such as the Fire Behavior and Fuels Conference. These conferences often have an international component, such as a dual US/Australia conference.				