Application for Federal Assistance

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Applicant Name:	University Corporation for Atmospheric Research
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Submitted for:	FY2019 Office of Weather and Air Quality Research Programs
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Application Documents for Review

Model Forecast Post-processing of Ozone and PM2.5

Proposal to:
NOAA Solicitation #: NOAA-OAR-OWAQ-2019-2005820
Competition Title: Air Quality Research and Forecasting
Competition #: 2759256

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Funding Requested:

Institution	Year 1	Year 2	Year 3	Total
NOAA ESRL	$146,242	$150,804	$170,719	$467,765
NCAR	$ 30,288	$ 30,996	$ 28,716	$ 90,000
TOTAL	$176,530	$181,800	$199,435	$557,765

Dated: December 17, 2018

Model Forecast Post-processing of Ozone and PM2.5

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Irina Djalalova, CIRES, University of Colorado, and NOAA
Co-Is: Stefano Alessandrini (NCAR), Dave Allured (CIRES and NOAA), Laura Bianco (CIRES and NOAA)
Collaborator: Jeff McQueen, NWS/NCEP

Abstract

The Co-PIs have previously collaboratively developed and helped implement the model forecast post-processing system for ozone and PM2.5 used by the NOAA National Air Quality Forecasting Capability (NAQFC). Although that post-processing system, based on the Kalman Filter Analog Ensemble (KFAN), has provided large improvements over the raw CMAQ forecasts, there remain significant shortcomings, as well as opportunities for further advancement. In particular, high concentration values have by far the greatest importance to users of the NAQFC forecasts, including the general public, and yet these extreme events have some of the largest forecast errors after post-processing. This is due, in part, because the current operational post-processing system was largely designed to provide the best overall mean statistical correction, with minimal emphasis on getting the high concentration events correct. To overcome these limitations, we will develop, test, and implement new post-processing methods that specifically address high concentration, high impact air quality events, for both ozone and PM2.5. This includes two new methods for finding the best set of historical analog forecasts that will differ from the current method by placing greater emphasis on high concentration values. The first method alters the weights applied to the chemical species being forecast, while the second method is a "two-step" approach in which the first step limits the analog search to only high concentration analogs before using any meteorological search parameters. We will also expand the analog search procedure to include local spatial variability, which may be important for meteorological phenomena such as sea-breezes and cold fronts. Next, we will modify the use of site specific weighting to include the season of the year as a search parameter, and we will modify the site-specific weighting so that weights are computed separately for each time of day and each season. We will extend the post-processing to 72h forecasts, and apply it to FV3-driven CMAQ forecasts as well as to FV3-online chemistry forecasts. Finally, we will evaluate the skill of the FV3 at forecasting boundary layer depths and winds correctly, which have a large impact on air quality forecast skill.

Statement of Work
Proposed Duration of the Project: June 1, 2019 – May 31, 2022

1. Scientific Problem, Goal, Hypothesis, and Conceptual Framework

Scientific problem and goal: Making accurate air quality forecasts from numerical models is exceedingly difficult, much more difficult than making weather forecasts. This is because air quality depends not only on the meteorology, but also on poorly understood complex chemical reactions that occur in the atmosphere, as well as on emissions that are at best rudimentary estimates of the ultimate sources of air pollution. Because of these diverse origins of model forecast errors, numerical air quality prediction models frequently have large errors, including large long-term biases. A useful approach for reducing these model errors is through post-processing of the model forecasts. At its core, post-processing is simply applying corrections to the latest model forecast based on the recent history of how far model forecasts were from the verifying observations. To address this approach, the Co-PIs have previously collaboratively developed and helped implement the model forecast post-processing system for ozone and PM2.5 for the NOAA National Air Quality Forecasting Capability (NAQFC). Although that post-processing system, based on the Kalman Filter Analog Ensemble (KFAN), has provided large improvements over the raw CMAQ forecasts, there remain significant opportunities for further advancement. In particular, high concentration values (either observed or forecast) are by far of greatest importance to users of the NAQFC forecasts, including the general public. In contrast, the current operational post-processing system was largely designed to provide the best overall mean statistical correction, with minimal emphasis on getting the high concentration events correct. **The goal of the proposed work is to develop, test, and implement new post-processing methods that specifically address high concentration, high impact air quality events, for both ozone and PM2.5. It also addresses the transition to FV3-based forecasts, and the skill of the FV3 at forecasting boundary layer depths and winds correctly, which have a large impact on air quality forecast skill.**

Hypothesis and Conceptual Framework: The NAQFC uses the Community Multiscale Air Quality (CMAQ) model for issuing its operational air quality forecast guidance. In addition, ozone and PM2.5 observations from the EPA's AirNow network are used to evaluate the CMAQ model skill, and to derive post-processing corrections to the raw CMAQ forecasts. The current operational air quality post-processing system is based on the Kalman Filter Analog Ensemble (KFAN), which is applied to CMAQ ozone and PM2.5 forecasts (Djalalova et al., 2015; Huang et al., 2017). CMAQ in turn, is driven with meteorological inputs from the NAM operational NWP model.

The KFAN post-processing system can be broken down into two main parts, one that manipulates model and observation data only at the AirNOW sites, and a second part that deals with the entire CMAQ grid. The first part begins with taking a forecast valid at some future time and at a particular AirNOW site. The algorithm then searches all of the previous forecasts that have been made for that site location, and finds those that are most similar to the current forecast. The similarity of the current forecast with the historical forecasts is measured using a weighted combination of judiciously chosen search parameters that include meteorological variables such as temperature, wind speed and direction, solar radiation, boundary layer depth, and one or more chemical variables including the air quality variable being forecast (ozone or PM2.5). For each of these analog forecasts, we then find the corresponding AirNOW verifying observations of ozone or PM2.5, and calculate an analog ensemble mean value ANENS of those observations. We then apply a Kalman Filter to a time-series of daily ANENS forecasts to get a final correction term.

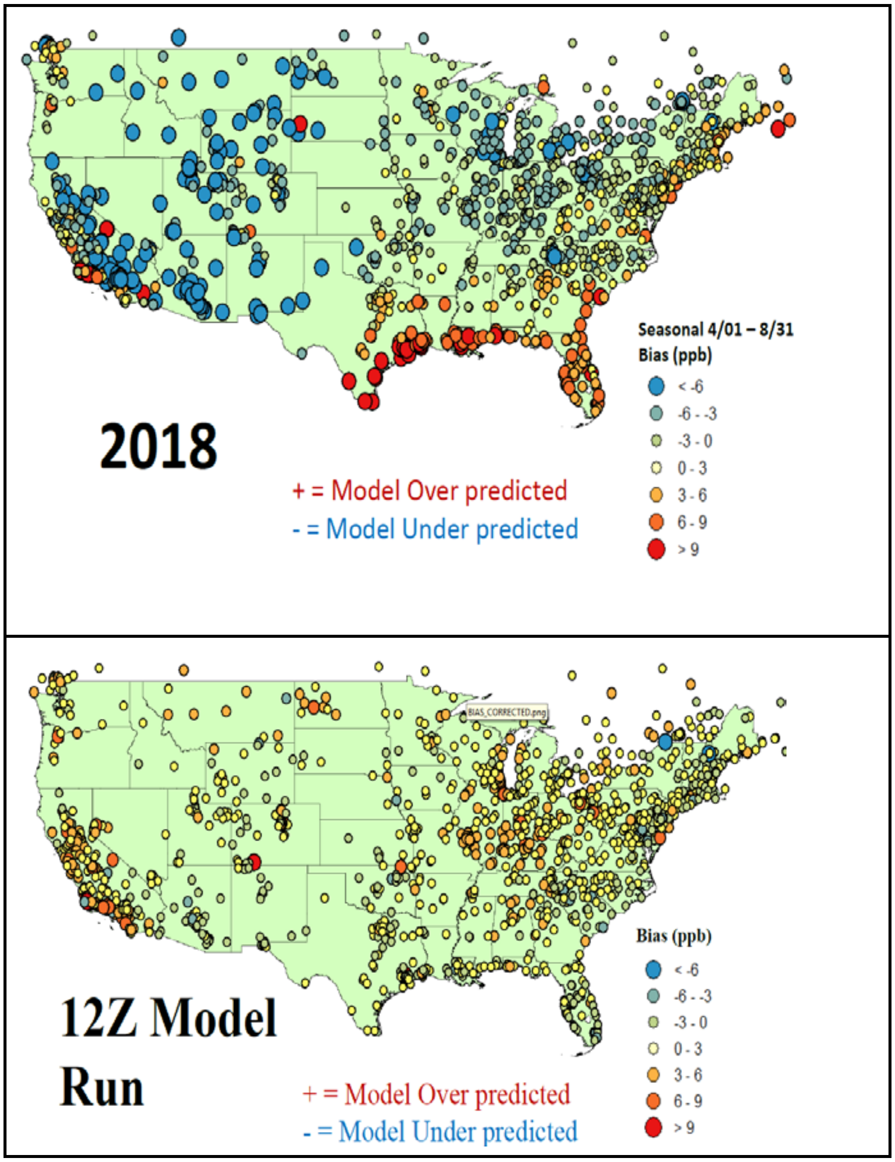

Figure 1: *[a] Biases of the raw NAQFC CMAQ ozone forecasts for the summer season (4/01 – 8/01 2018) using the EPA AirNow monitoring network for evaluation, using forecasts initialized at 12 UTC. [b] Biases after applying the new ozone post-processing algorithm, for the time period between 06/15 – 08/30/2018, also using 12 UTC forecasts. Red colors indicate a model over-prediction, blue a model under-prediction. Graphics were provided by Joel Dreesen and James Boyle from the Maryland Department of the Environment.*

The second step of the post-processing system is to interpolate those correction terms from the observation locations to every CMAQ gridpoint, and then add the interpolated corrections back to the raw forecast to get a new, bias corrected gridded forecast. Figure 1 shows summertime ozone biases (panel a) for the raw CMAQ forecasts at the AirNow observation locations, and the residual biases after post-processing. The raw CMAQ forecasts are seen to have large under-predictions in the western US, small biases in most of the Eastern U.S., and large over-predictions along the Gulf and Atlantic Coasts. After post-processing, the residual biases are small with no significant spatial patterns.

The basic assumption that must be met for KFAN to work well is that the analog search process will be able to find historical analog forecasts that are very similar to the current forecast. In its original form, KFAN doesn't work well when the analog search is unable to find a good set of analogs. This will especially occur for an extreme event, when the new forecast predicts ozone or PM2.5 values that rarely, if ever, occurred in the historical forecast training data set. The inability to find good analogs of extremely high concentration events is amplified by the relatively short training data sets available (generally no longer than 1-2 years before a new version of CMAQ is implemented).

To help alleviate this problem, a simple large-concentration correction method was employed in which we calculate the difference (in ozone or PM2.5) between the current CMAQ forecast and the analog mean ANENS, and add it to our KFAN forecast. Most of the time good analogs are found and the difference between CMAQ and ANES is small, so the KFAN forecast is little changed. However, if the CMAQ value is higher than ANES, that difference when added to KFAN boosts the final post-processed forecast to a larger value. Statistical evaluations of this modified approach have shown much better results, but there still remains a tendency to under-predict high ozone and PM2.5 events, as shown in Fig. 2, while more rarely it under-predicts, creating a false alarm (Fig. 3).

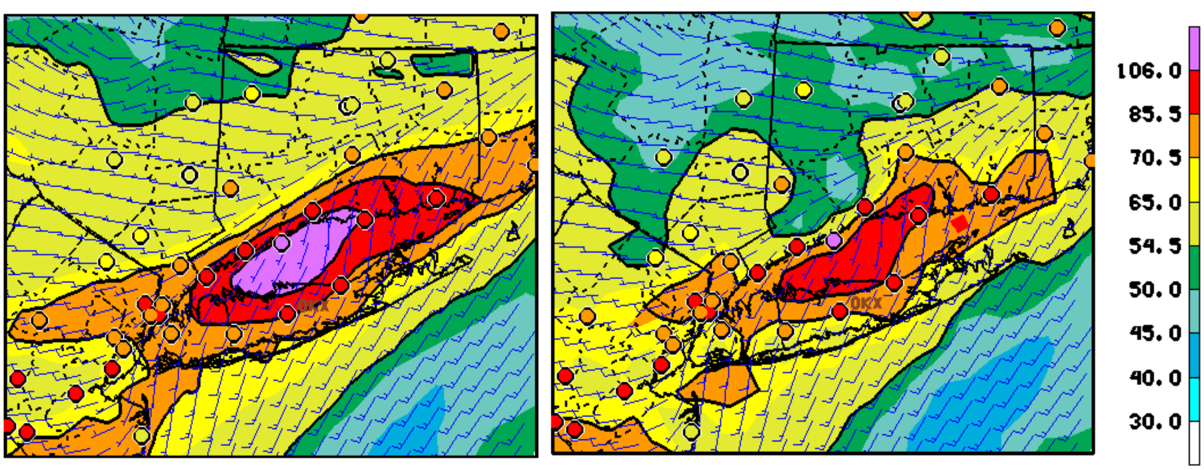

Figure 2: *A high ozone event that occurred in the Long Island/Connecticut area on July 10, 2018. The left panel displays the raw CMAQ forecast (circles indicate observed values), the right panel the KFAN forecast, where post-processing has erroneously reduced the ozone concentrations.*

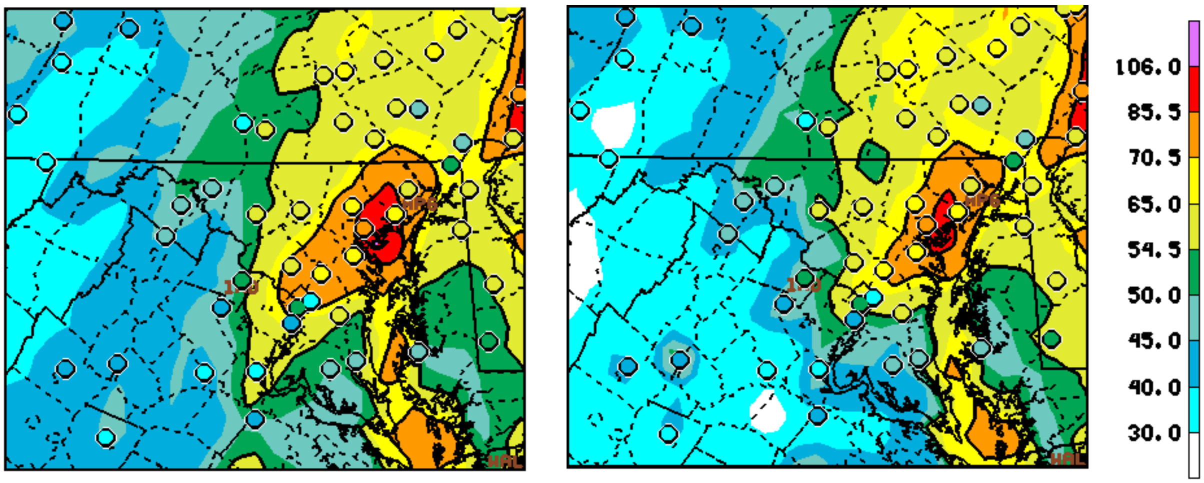

Figure 3: *A forecast high ozone event for the Chesapeake Bay/Maryland area on July 2, 2018. The left panel displays the raw CMAQ forecast (circles indicate observed values), the right panel the KFAN forecast. Although KFAN has slightly reduced the forecast ozone concentrations, both the raw and post-processed forecasts over-predict ozone, resulting in a false alarm.*

We hypothesize that more skillful post-processed forecasts of extreme ozone and PM2.5 concentrations can be obtained first by improving the methods used to find the optimal analog forecasts, and second by improving the simple large-concentration correction that is currently employed.

2. Relevance to NOAA Science Priorities

This project will develop new post-processing techniques for high concentration, high impact events, and thus will address AQRF-4. In addition, by evaluating the efficacy of the KFAN post-processing scheme when applied to CMAQ driven by the FV3 NWP model, it will also contribute to AQRF-2. Finally, good boundary layer depth predictions are crucial for accurate air quality predictions, and by evaluating FV3 boundary layer depths with our historical data base of PBL depths derived from radar wind profilers, we will contribute to AQRF-2 and AQRF-5.

3. Proposed Methodology and Work Plan

3.1. Task 1: Develop and test new post-processing methods for high concentration events

We will investigate two alternative methods for finding the best set of historical analog forecasts that will differ from the current method by placing greater emphasis on high concentration values. We note that the current method searches for historical analogs that are most similar to the current forecast, and that since the chemical species forecast is included as a search parameter (i.e. when forecasting ozone, ozone itself is a search parameter), if the forecast ozone is high, the analogs found will also tend to have higher ozone. However, since other search parameters are also included, the best analogs may not always have high concentration values, reducing the ability of the KFAN method to make good forecasts of extreme events. Therefore, we propose to investigate two methods that place greater emphasis on high concentration, extreme events. The first method alters the weights applied to the chemical species being forecast, which we will refer to as a “concentration weighted” approach. The second method is a “two-step” approach in which the first step limits the analog search to high concentration analogs. These two methods are described in more detail below.

The analog search method uses a set of model search variables to find the best historical analogs that may include wind speed, direction, temperature, boundary layer depth, and solar radiation, but also will include the chemical species that is being forecast. Since one search variable may be more important than another, the variables are weighted with a single set of weights that is constant for all times and all concentrations (Junk et al., 2015). The basic concept of the proposed “concentration weighted” method is to make the weight applied to the chemical species search parameter be a function of concentration itself. Thus, when ozone is forecast to be high, ozone as a search parameter will have greater weight (relative to winds, temperatures, etc.) than when ozone is moderate or low. This differs from the current methodology where the weight given to ozone or PM2.5 is constant for all concentration values, and we anticipate that it will do better at forecasting extremely high concentration events.

The second method we will investigate is to use a two-step approach in selecting the analogs. In the first pass, only analogs that have concentration values similar to the current forecast will be found. Then, in a second pass, other meteorological search parameters will be used on this restricted set of historical forecasts, thus guaranteeing that the final analogs found will all have the optimum high concentration values.

After both methods are developed and tested, the relative improvements from the two will be evaluated and compared, and if the better of the two results in significantly improved forecasts for ozone and PM2.5, code will be made available to NAQFC for its potential inclusion in the operational CMAQ post-processing system.

In addition to developing and testing these two methods, we will improve the current large-concentration correction scheme (which was implemented in part because the current basic KFAN system does not sufficiently emphasize high-concentration events). This scheme relies on the difference between the current forecast concentration and the mean of the best analog forecasts found. If for example the current forecast predicts that ozone will be larger than any values in the historical forecast, the analogs will by definition always have lower ozone than the current forecast. The large-concentration correction scheme assumes that the current forecast of an extreme value has some skill, and adds to the KFAN forecast the difference in concentration between the current forecast and the mean of the best analogs. We will improve this method by incorporating the technique of Alessandrini et al. (2019), which modifies the magnitude of the large-concentration correction term by multiplying it by the slope of a linear regression between the forecast and observed analogs. Ideally this slope is unity, while if it is less than one the model is too sensitive (i.e. for a given observed range of concentrations, the analog forecasts span a larger value), and for a slope greater than unity the model is under-sensitive. We will also test modifications of the Alessandrini technique to more reliably determine how much of the difference between the current extreme forecast and the mean of the best analogs should be added to the KFAN forecast.

For this task, as well as for Tasks 3.2 and 3.3, we will evaluate the improvements made to the post-processing system using a variety of metrics, including but not limited to contingency statistics (Hit Rate, False Alarm Ratio, Proportion Correct, Critical Success Index, and Frequency Bias), as well as RMSE, Correlation, and Bias.

3.2. Task 2: Expand the analog search procedure to include local spatial variability

The current system searches for historical analogs only at individual observation sites. In contrast, other analog post-processing schemes used for temperature and precipitation forecasts use information on the spatial variability of the forecasts in the vicinity of the observation site. Thus, for example, the method described by Hamill and Whitaker (2006) uses forecast values not only at the gridpoint closest to the observations site, but a set of 16 model values from a matrix of the closest 4x4 model gridpoints values. This allows for spatial gradients of the forecast values to be included in the selection of the best analogs. We anticipate that this will help finding better analogs when there is strong spatial variability associated with meteorological pheonomena such as cold fronts and sea breeze fronts.

3.3. Task 3: Modify site specific weighting, apply KFAN to FV3 driven forecasts, and extend to 72h

In addition to the above changes, we will implement a number of changes that each could make significant overall forecast skill improvements, including:

1) Modify the analog search to include the season of the year as a search parameter. The rationale for including this change is that the biases of PM2.5 and ozone both strongly vary, and even change signs with season. The current post-processing system only imprecisely accounts for the seasonal dependency through its inclusion of temperature as a search parameter. Explicit inclusion of season could improve the KFAN skill. We will modify the algorithm so that it will include time of year, so that summertime forecast analog searches will be primarily limited to summertime historical forecasts, and winter to winter.
2) Modify the site-specific weighting so that weights are computed separately for each time of day and each season. Currently the analog search method uses a set of search parameters that have a set of weights that vary from site to site, but that are constant in time. For example, an ozone bias correction at a given site will weight temperature the same in selecting analogs whether for a forecast hour at midnight or noon, or whether the forecast is in July or February. Temporal dependencies of the parameter weights could in fact be very large, reducing the overall skill of the current post-processed forecasts, perhaps having the greatest negative impact for extreme events.

3) When the planned extension of the NAQFC forecast guidance from 48 to 72h reaches the evaluation stage at NCEP, we will evaluate the skill of the post-processing scheme for the longer forecasts, and determine if any changes to the post-processing method need to be made.
4) With the planned modification of the NAQFC forecast system to use FV3 meteorology instead of the NAM, we will evaluate the skill of the post-processing scheme for the FV3-based forecasts, and determine if any changes to the post-processing method need to be made. In particular, we anticipate that the relative weights to the meteorological search parameters may be different for the FV3 than they are for the NAM.
5) When online FV3 air quality forecasts become available during the 3-year timeframe of the proposal, we will evaluate the post-processing scheme for those forecasts. Again we anticipate that the relative weights to the meteorological and chemical search parameters may be different in the online FV3 version than in the current system or in an FV3-driven offline system.

3.4. Task 4: Add MPI code parallelization

The current KFAN system makes use of simple OpenMP parallel processing, which severely limits the number of processors that can be run in parallel. In its current configuration, KFAN uses all of the approximately 15 min time slot allocated each forecast cycle for post-processing. As a result, it is currently impossible to add any significant new capabilities to KFAN, or even to significantly increase the lengths of the training data sets used. We will eliminate this limitation on future development of the KFAN system by incorporating MPI parallel processing, which allows for a much greater number of processors to be used. Once MPI is implemented, it will allow for each of the above tasks to be implemented, all running operationally within the allowed time slot, and for longer training data sets to be used in the future if they become available.

3.5. Task 5: FV3 boundary layer depth evaluation

ESRL/PSD maintains a large data base of observed boundary layer depths derived from 915 MHz radar wind profiler observations. The signal-to-noise ratio (SNR) from these radar wind profilers is directly proportional to the atmospheric refractive index structure parameter, C_n^2, which has large values at the capping inversion. In addition, the variance of vertical velocity measured by the profilers and the spectral width of the vertical velocity (a measure of non-resolved pulse-volume turbulence) are also large within the convective boundary layer and small above it. These three measurements have been combined in a Fuzzy Logic algorithm (Bianco and Wilczak, 2002) to provide automated measurements of the boundary layer depth (Bianco et al. 2008). Although our data base extends back to the year 2000 (e.g. Bianco et al., 2011), more recent data over the past 5 years (2014-2018) has 14 sites with 3,849 site-days of quality-controlled PBL depth measurements. In addition, we expect that additional profiler deployments will occur over the 3 years of this proposal, providing yet more data that could be used for FV3 model verification. We will use this data base to evaluate FV3 forecasts of boundary layer depths.

3.6. Task 4: Transition to Operations

After successful evaluation of the new post-processing code in a relevant test environment (achieving RL 6-7), we will transfer and test the code within a quasioperational environment (RL 8). We also will discuss with NCEP the transitioning of these new capabilities to operations with NOAA (RL 9). To facilitate a smooth transition of any potential new code we will assure that the code meets NCEP operational modeling system requirements, including file formats, coding styles, and scripting systems.

4. Operational applicability and past collaboration with operational community

Our team has developed a strong collaboration with the NAQFC team over the past several years, working closely with Ivanaka Stajner, Jianping Huang, and Jose Tirado- Delgado on the development and implementation of the current post-processing component of the operational NAQFC modeling system. The proposed new changes are directly applicable to the current post-processing system, and will be fully capable of becoming part of the operational NAQFC system incrementally at the end of each of the three years of this proposal.

5. Current and projected Readiness Level and Project Beneficiary

Several components of the proposed research have already been shown to improve the accuracy of post-processed forecasts in other settings or for purely weather forecasts but not air quality quantities. We estimate that overall the proposed project will begin at RL 5. By transitioning new capabilities to the NAQFC (as discussed in Section 3.6), we expect to reach the RL 8. The NAQFC at the Environmental Modeling Center (EMC) will be the beneficiary organization.

6. Project Management, Timeline, Key Milestones and Deliverables

We propose a 3-year study with team members possessing complementary expertise in post-processing numerical forecasts (Wilczak, Djalalova, Alessandrini), and in Fotran code development for large, complex forecast systems (Allured). The main goal of this proposal will be achieved through the 6 tasks discussed in Section 3. The timeline of different tasks along with the deliverables is shown in Table 1.

The team will closely collaborate to complete each of the tasks and meet the stated goals. The overall responsibility of the project will reside with **James Wilczak (NOAA, Co-PI) and Irina Djalalova (CU Boulder, Co-PI)**, who led the implementation of the current NAQFC post-processing system. They both have extensive experience in air quality forecasting, evaluation of air quality models, and numerical model post-processing.
Stefano Alessandrini (NCAR, CO-I) has extensive experience in using the analog ensemble across multiple applications including air quality predictions, including its use for rare events. **Dave Allured (NOAA, Co-I)** has extensive experience in developing Fotran code for complex forecasting systems. He wrote the Fortran code (over 15,000 lines) for the current post-processing system. **Jeff McQueen (Collaborator, NWS/NCEP)** has a deep understanding of forecast user requirements and will provide guidance on the direction and impacts of the post-processing system changes.

Table 1: Timelines and project deliverables

Year	Task	Deliverable
Year 1	➢ Apply KFAN to FV3-online chemistry ➢ Convert code to MPI parallel processing ➢ Implement "concentration-weighting" and "two-step" methods for extreme events ➢ Test and improve slope of linear regression method for extreme events ➢ Add season of year as search parameter	New version of the post-processing code
Year 2	➢ Complete changes to site specific weighting ➢ Complete evaluation of FV3 PBL depths ➢ Evaluate and modify KFAN for FV3 meteorology ➢ Extend post-processing to 72h forecasts	New version of the post-processing code
Year 3	➢ Add spatial variability to searches ➢ Apply KFAN to FV3-online chemistry	New version of the post-processing code Submission of a peer-reviewed paper

7. Results from prior research

OWAQ Award entitled "Post-Processing of CMAQ Air Quality Predictions: Research to Operations": Co-PIs: Irina Djalalova and James Wilczak - June 2016- May 2019.

The current proposal is for a continuation of a previous OWAQ grant (S8R2WRP) for the development of a post-processing scheme for ozone and PM.25 predictions for the NAQFC forecast system. Specifically, in that grant we are improving the post-processing algorithm for PM2.5 to better account for wildfire events, extending the system to also correct ozone predictions, and finally creating probabilistic forecasts using the members of the analog ensemble. During this project the first two yearly upgrades have been adopted by NCEP for inclusion in the operational NAQFC, and we are hopeful that the third and final year's task, creating probabilistic air quality forecasts, will also become operational in the next implementation update to the NAQFC system. This project will end in May 2019 and by that date we will have transferred all of the new code and scripts to NCEP so that they can potentially be used in a future version of the NAQFC prediction system.

8. Travel

We request funding for Wilczak to attend the annual forecast users group meeting held at NCEP in 2019-2021. We also request funding for Djalalova to attend either the American Geophysical Union (AGU) Fall Meetings or an alternative air quality conference in 2020 and 2021 so that the results from this project can be shared with the international community. In addition, we have requested a travel budget for Alessandrini to attend two AMS annual meetings.

9. References

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10. **Data Management Plan** We will make all the environmental data created under this project discoverable by and accessible to the general public in accordance with the NOAA Administrative and National Policy Requirements. Steps involved in our data management plan are described below.

1. Overview of the data to be produced by the project

The proposed project will produce ozone and PM2.5 forecast data over the CONUS region.

2. Data types, volume, formats, and standards

AirNow observational data are available as Binary Universal Form for the Representation of meteorological data (BUFR) files, and raw CMAQ forecasts are available as General Regularly-distributed Information in Binary form Format (GRIB or GRIB2) files. Both of these sets of input files are publically available; the AirNow data from the EPA and the CMAQ forecasts from NOAA/NCEP. The post-processed data files will be output as Network Common Data Format (NetCDF) files. For each year of the proposal we expect to generate at most one year of 2D post-processed data files for ozone and PM2.5 (2x per day, 48 hour forecasts), which will require approximately 500 GB of storage.

3. Data archiving, sharing, and sharing schedule

The post-processed data files along with metadata documentation will be submitted to the NOAA National Centers for Environmental Information (NCEI) for archival, from which they will be publically available. For each of the three years of the proposal, data files will be submitted within 6 months of the end of each proposal year.

4. Software archiving plan

The post-processing software used in this project will be made available to the community via the NOAA/ESRL/Physical Sciences Division products website (https://www.esrl.noaa.gov/psd/products/).

5. Roles and responsibilities

Irina Djalalova (Co-PI) will be responsible for the overall data management and specifically for archiving post-processing data sets and software.

6. Team experience

James Wilczak and Irina Djalaova Irina (Co-PIs) have experience archiving large amounts of field campaign data both internally within NOAA/ESRL/PSD and on the DOE Data Archive and Portal. Stefano Alessandrini (co-I) has managed several multi-institution projects producing and distributing large data sets, and used data portals as the Earth System Grid (ESG) Gateway, NCAR's High Performance Storage System (HPSS), and project-tailored web portals. Dave Allured has experience writing and modifying large Fortran codes for NWP applications.

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Employment

2006-present:	Research Meteorologist, NOAA Earth Systems Research Laboratory/PSD
2001-2006:	Team Lead, Model Assessment Team, NOAA/Environmental Technology Laboratory
1993-2001:	Supervisory Research Meteorologist, NOAA/Environmental Technology Laboratory
1985-1993:	Research Meteorologist, NOAA/Wave Propagation Laboratory
1983-1985:	Research Associate, Cooperative Institute for Research in Environmental Sciences (CIRES)
1982-1983:	National Research Council Postdoctoral Fellow, NOAA/Wave Propagation Laboratory

Journal Publications – Prior 3 years and selected publications

Olson, J., J. Kenyon, M. Toy, J. M. Brown, W. Angevine, J.-W. Bao, P. Jimenez, B. Kosovic, K. Lundquist, J. K. Lundquist, J. McCaa, C. Draxl, L. K. Berg, I. Djalalova, L. Bianco, K. McCaffrey, J. M. Wilczak, 2019: Model Development in Support of the Second Wind Forecast improvement Project (WFIP 2), Submitted to Bull. Amer. Meteor. Soc.

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Education and Training

Moscow State University, Russia	School of Mathematics and Mechanics	BS 1978
Moscow State University, Russia	School of Mathematics and Mechanics	MS 1980

Appointments

2010-present: Senior Associate Scientist at CIRES
2005-2010: Associate Scientist III at CIRES
1997-2005: Senior Application Engineer, a contractor to NOAA/ESRL through the Science and Technology Corporation (STC).

Publications

Djalalova, I, L Delle Monache and J Wilczak (2015), PM2.5 analog forecast and Kalman filter post-processing for the Community Multiscale Air Quality (CMAQ) model. Atmos. Environ., 108 76-87, issn: 1352-2310, ids: CE4OB, doi: 10.1016/j.atmosenv.2015.02.021

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Appointments

2000-present: Associate Scientist, CIRES/University of Colorado, Boulder, Colorado. Joint project with NOAA/OAR/ESRL/PSD. Scientific computer support. Software engineering, data management, climate model operation, application support.

1983-1999: Consulting engineer, Boulder, Colorado. Hardware and software development for microprocessor based applications. Intermittent employment.

1980-1982: Software engineer, NBI, Boulder, Colorado.

1971-1977: Programmer and system analyst, Pittsfield Public Schools, Pittsfield, Massachusetts. Business data processing

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Education

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M.S. in Physics, University of L'Aquila, Italy, 1998

Employment

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Mar 2004–Mar 2006: Half time position as Research Scientist, CIRES, University of Colorado (NOAA Environmental Technology Laboratory division).

Feb 2002–Feb 2006: Young scientist at CETEMPS (*Center of Excellence for integration of remote sensing techniques and numerical modeling for the forecast of severe weather*) University of L'Aquila, via Vetoio, 67010, Coppito (L'Aquila), Italy.

1998–2002: PhD student, Department of Physics, University of L'Aquila, Italy.

1998–1999: Research Assistantship, University of L'Aquila, Italy, Dept. of Atmospheric Physics.

Journal Publications – Prior 3 years and selected publications

Olson, J. B., J. S. Kenyon, I. Djalalova, L. Bianco, D. D. Turner, Y. Pichugina, A. Chokulkar, M. D. Toy, J. M. Brown, W. Angevine, E. Akish, J.-W. Bao, P. Jimenez, B. Kosovic, K. A. Lundquist, C. Draxl, J. K. Lundquist, J. McCaa, K. McCaffrey, K. Lantz, C. Long, J. Wilczak, M. Marquis, S. Redfern, L. K. Berg, W. Shaw, J. Cline, 2018: Improving Wind Energy Forecasting through Numerical Weather Prediction Model Development, *submitted to BAMS*.

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Stefano Alessandrini
National Center for Atmospheric Research, Research Applications Laboratory
3090 Center Green Dr., Boulder, CO 80301, alessand@ucar.edu, 303-497-8377

Education and Training

Univ. of Milano, Milan, Italy,	Physics	Laurea (MS) 1996
Univ. of Piemonte Orientale, Alessandria, Italy	Environmental Science	PhD 2011

Appointments

2013–present:	Project Scientist II, National Center for Atmospheric Research.
2006-2011:	Part time consultant, Food and Agriculture Organization (FAO) of United Nations, Italy.
2001–2013:	Scientist, Research on Energy System (RSE), Italy.
1999–2001:	Meteorology Consultant, Meteorological Center of Tuscany (ARSIA), Italy.
1995–1996:	Grad. Research Asst., Research Center on Environment (ENEL-CRAM), Italy.

Publications

Cervone, G., Clemente-Harding, L., Alessandrini, S., Delle Monache, L.. 2017: Short-term photovoltaic power forecasting using Artificial Neural Networks and an Analog Ensemble. Renewable Energy, Renewable Energy 108, 274-286.

Sperati, S., Alessandrini, S., & Delle Monache, L. (2017). Gridded probabilistic weather forecasts with an analog ensemble. Quarterly Journal of the Royal Meteorological Society, 143(708), 2874-2885.

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Jiménez, P.A., Alessandrini, S., Haupt, S.E., Deng, A., Kosovic, B., Lee, J.A., Delle Monache. L., 2016: The role of unresolved clouds on short-range global horizontal irradiance predictability. Monthly Weather Review, *144*(9), 3099-3107.

Davò, F., Alessandrini, S., Sperati, S., Delle Monache, L., Airoldi, D., & Vespucci, M.T., 2016: Post-processing techniques and principal component analysis for regional wind power and solar irradiance forecasting. Solar Energy, 134, 327-338.

Sperati, S., Alessandrini, S., & Delle Monache, L. (2016). An application of the ECMWF Ensemble Prediction System for short-term solar power forecasting. Solar Energy, 133, 437-450.

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Alessandrini,S., Delle Monache, L., Sperati, S., and Cervone, G., 2015: Solar forecasting with an analog ensemble. Applied Energy 157, 95–110.

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Junk, C., Delle Monache, L., Alessandrini, S., 2015: Analog-based Ensemble Model Output Statistics, Monthly Weather Review, 143(7), 2909-2917.

Alessandrini, S., Delle Monache, L., Sperati, S., Nissen, J.N., 2015: Short-term wind power forecasting with an analog ensemble. Renewable Energy 76, 768-781.

Junk, C., Delle Monache, L., Alessandrini, S., von Bremen, L. and Cervone, G., 2015: Predictor-weighting strategies for probabilistic wind power forecasting with an analog ensemble. Meteorologische Zeitschrift, 24(4), 361-79.

Michiorri, A., Nguyen, H. M., Alessandrini, S., Bremnes, J. B., Dierer, S., Ferrero, E., & Uski, S. (2015). Forecasting for dynamic line rating. Renewable and Sustainable Energy Reviews, 52, 1713-1730.

CURRENT AND PENDING SUPPORT

Note: In the event that an unanticipated overlap does occur, the level of effort would be adjusted and/or additional personnel would be added, in concurrence with funding sources.

Investigator: James Wilczak DATE: December 2018

James Wilczak is fully supported through NOAA/ESRL/Physical Sciences Division base funding. The portion of his salary spent on this project will be covered through those base funds.

CURRENT AND PENDING SUPPORT

Note: In the event that an unanticipated overlap does occur, the level of effort would be adjusted and/or additional personnel would be added, in concurrence with funding sources.

Investigator: Irina Djalalova DATE: December 2018

Current Support

Title: Post-processing of CMAQ Air Quality Predictions: Research to Operations
Source of Support: NOAA – Oceanic and Atmospheric Research/OWAQ
Person-Months per year: 4.5 months
Total Award: $387,450
Period of Performance: June 1, 2016 – May 31, 2019

Title: Wind Boundary Layer
Source of Support: NOAA
Total Person-Months over Period of Performance: 5 months
Total Award: $317,000
Period of Performance: October 1, 2017 – Sept. 30, 2019

Title: Second Wind Forecast Improvement Project
Source of Support: DOE
Total Person-Months over Period of Performance: 8.5 months
Total Award: $506,000
Period of Performance: October 1, 2017 – Sept. 24, 2020

Pending Support

Title: Atmospheric Sciences for Renewable Energy
Source of Support: NOAA
Total Person-Months over Period of Performance: 5.0 months
Total Award: $480,000
Period of Performance: October 1, 2018 – Sept. 30, 2020

Title: A Novel Method for Improving Fine Particle Matter Air Quality Forecasts During Wildfires
Source of Support: NOAA OWAQ
Person-Months per year: 1.5 months
Total Award: $75,018
Period of Performance: June 1, 2019 – May 31, 2022

Title: Model Forecast Post-Processing of Ozone and PM2.5 (THIS PROPOSAL)
Source of Support: NOAA OWAQ

Person-Months per year: 4.3 months
Total Award: $467,765
Period of Performance: June 1, 2019 – May 31, 2022

CURRENT AND PENDING SUPPORT

Note: In the event that an unanticipated overlap does occur, the level of effort would be adjusted and/or additional personnel would be added, in concurrence with funding sources.

Investigator: Dave Allured DATE: December 2018

Current Support

Title: Post-processing of CMAQ Air Quality Predictions: Research to Operations
Source of Support: NOAA – Oceanic and Atmospheric Research/OWAQ
Person-Months per year: 2.7 months
Total Award: $387,450
Period of Performance: June 1, 2016 – May 31, 2019

Title: NOAA/ESRL/PSD base support
Source of Support: NOAA
Total Person-Months: 0.3 months
Total Award: $3,380
Period of Performance: October 1, 2018 – December 31, 2018

Pending Support

Title: A Novel Method for Improving Fine Particle Matter Air Quality Forecasts During Wildfires
Source of Support: NOAA OWAQ
Person-Months per year: 0.25 months
Total Award: $75,018
Period of Performance: June 1, 2019 – May 31, 2022

Title: Model Forecast Post-Processing of Ozone and PM2.5
Source of Support: NOAA OWAQ
Person-Months per year: 3.0 months
Total Award: $467,765
Period of Performance: June 1, 2019 – May 31, 2022

CURRENT AND PENDING SUPPORT

Note: In the event that an unanticipated overlap does occur, the level of effort would be adjusted and/or additional personnel would be added, in concurrence with funding sources.

Investigator: Laura Bianco DATE: December 2018

Current Support

Title: NOAA/ESRL/Physical Sciences Division base support
Source of Support: NOAA/ESRL/PSD
Total Person-Months per year: 1.8 months
Total Award: $317,000
Period of Performance: October 1, 2018 – Sept. 30, 2019

Title: Wind Boundary Layer
Source of Support: NOAA
Total Person-Months over Period of Performance: 7.5 months
Total Award: $317,000
Period of Performance: October 1, 2017 – Sept. 30, 2019

Title: Second Wind Forecast Improvement Project
Source of Support: DOE
Total Person-Months over Period of Performance: 4.4 months
Total Award: $506,000
Period of Performance: October 1, 2017 – Sept. 24, 2020

Pending Support

Title: Atmospheric Sciences for Renewable Energy
Source of Support: NOAA
Total Person-Months over Period of Performance: 9.0 months
Total Award: $480,000
Period of Performance: October 1, 2018 – Sept. 30, 2020

Title: Model Forecast Post-Processing of Ozone and PM2.5 (THIS PROPOSAL)
Source of Support: NOAA OWAQ
Person-Months per year: 1.0 months
Total Award: $467,765
Period of Performance: June 1, 2019 – May 31, 2022

CURRENT AND PENDING SUPPORT

"In the event that an unanticipated overlap does occur, the level of effort would be adjusted and/or additional personnel would be added, in concurrence with funding sources."

Principal Investigator: **Stefano Alessandrini**

DATE: December 2018

CURRENT SUPPORT

Project Title: A Novel Ensemble Design for PM2.5 Probabilistic Predictions and Quantification of Their Uncertainty
Principal Investigator: Luca Delle Monache
Source of Support/Contract: NOAA – Oceanic and Atmospheric Research; Contract #R4590116
Contact Information: Richard Fulton; Richard.Fulton@noaa.gov
Total Award Amount: $449,249
Total Award Period Covered: 6/1/2016-5/31/2019
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 2.04 Co-Sponsorship:

Project Title: A Renewable Energy Forecasting System for Kuwait
Principal Investigator: Sue Ellen Haupt
Source of Support/Contract: Kuwait Institute for Scientific Research; Contract #PKISR12
Contact Information: Majed Al-Raheedi; +965 24989755; mrashedi@kisr.edu.kw
Total Award Amount: $5,137,603
Total Award Period Covered: 7/7/2017-7/6/2020
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 3.36 Co-Sponsorship:

Proposal Title: Global Climatological Analysis Tool NGIC FY2017
Principal Investigator: Stefano Alessandrini
Source of Support: Army National Ground Intelligence Center (NGIC); Contract #M0963687
Contact Information: Richard Babarsky; Richard.j.babarsky.civ@mail.mil
Total Award Amount: $308,451
Total Award Period Covered: 6/1/2017-7/31/2019
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 3.12 Co-Sponsorship:

Proposal Title: FY17-21 Chemical/Biological Defense Modeling and Virtual Environment Development
Principal Investigator: Scott Swerdlin
Source of Support: Defense Threat Reduction Agency (DTRA): Contract #M0963687
Contact Information: Rick Fry; (703) 767-3193; Rick.Fry@dtra.mil
Total Award Amount: $750,000
Total Award Period Covered: 10/1/2018-9/30/2019
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 2.16 Co-Sponsorship:

PENDING SUPPORT

Proposal Title: Enhancing Decision-Making Activities in the Area of Air Quality in Delhi
Principal Investigator: Stefano Alessandrini
Source of Support: India Ministry of Earth Sciences
Contact Information: Sachin Ghude; Ph: 91 (020)25904350; sachinghude@tropmet.res.in
Total Award Amount: $496,089
Total Award Period Covered: 5/1/2018-4/30/2020
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 2.01 Y1, Y2 Co-Sponsorship:

Proposal Title: The Global Climatological Analysis Tool (GCAT) – NGIC FY2018
Principal Investigator: Stefano Alessandrini
Source of Support: Army National Ground Intelligence Center
Contact Information: Richard Babarsky; richard.j.babarsky.civ@mail.mil
Total Award Amount: $330,000
Total Award Period Covered: 7/1/2018-6/30/2019
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 2.63 Co-Sponsorship:

Proposal Title: Quantification and Attribution of Past (2005-2018) Air Quality Trends over the Contiguous United States (CONUS) Via Assimilation of NASA Atmospheric Composition Observations
Principal Investigator: Rajesh Kumar
Source of Support: NASA
Contact Information: Richard Eckman; Ph: 202-358-2567; Richard.S.Eckman@nasa.gov
Total Award Amount: $599,873
Total Award Period Covered: 2/24/2019-2/23/2022
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: .31 Y1, 1.65 Y2, .62 Y3 Co-Sponsorship:

Proposal Title: Global and Regional Trends of Atmospheric Methane in the Recent Decades and Possible Connections with Climate Variability
Principal Investigator: Yongxin Zhang
Source of Support: NOAA – Oceanic and Atmospheric Research
Contact Information: Diane Brown; diane.brown@noaa.gov
Total Award Amount: $546,640
Total Award Period Covered: 9/1/2019-8/31/2022
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 2.0 Co-Sponsorship:

Proposal Title: Ensemble Hydrometeorological Prediction System for Colombia
Principal Investigator: Stefano Alessandrini
Source of Support: NASA
Contact Information: Nancy Searby; Ph: 202-358-0395; Nancy.D.Searby@nasa.gov
Total Award Amount: $661,842
Total Award Period Covered: 10/1/2019-9/30/2022
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 2.06 Co-Sponsorship::

Proposal Title: A Novel Method for Improving Fine Particle Matter Air Quality Forecasts During Wildfires
Principal Investigator: Rajesh Kumar
Source of Support: NOAA – Oceanic and Atmospheric Research
Contact Information: Richard Fulton; richard.fulton@noaa.gov
Total Award Amount: $474,900
Total Award Period Covered: 6/1/2019-5/31/2022
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 2.06 Y1, 2.58 Y2 & 3 Co-Sponsorship:

Proposal Title: Model Forecast Post-processing of Ozone and PM2.5 (THIS PROPOSAL)
Principal Investigator: Stefano Alessandrini
Source of Support: NOAA – Oceanic and Atmospheric Research
Contact Information: Richard Fulton; richard.fulton@noaa.gov
Total Award Amount: $90,000
Total Award Period Covered: 6/1/2019-5/31/2022
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: .98 Y1, .88 Y2, .76 Y3 Co-Sponsorship:

Proposal Title: Tropical Cyclone Intensity Prediction with Spatial Machine Learning Methods

Principal Investigator: Christopher Rozoff
Source of Support: NOAA – Oceanic and Atmospheric Research
Contact Information: Richard Fulton; richard.fulton@noaa.gov
Total Award Amount: $314,853
Total Award Period Covered: 7/1/2019-6/30/2022
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 2.06 Co-Sponsorship:

Proposal Title: Transitioning to Operations a Novel Air Quality Forecast Ensemble Design
Principal Investigator: Jared Lee
Source of Support: NOAA – Oceanic and Atmospheric Research
Contact Information: Richard Fulton; richard.fulton@noaa.gov
Total Award Amount: $349,982
Total Award Period Covered: 6/1/2019-5/31/2022
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: .46 Co-Sponsorship:

UCAR

UCAR Proposal Budget Detail

Proposal #	2019-0025
Proposal Title:	Model Forecast Post-processing of Ozone and PM2.5
UCAR Entity:	NCAR
Period of Performance:	06-01-2019 - 05-31-2022
Principal Investigator	STEFANO ALESSANDRINI

			Unit / Rate	Effort Year 1	Effort Year 2	Effort Year 3	Year 1 National Oceanic and Atmospheric Administration	Year 2 National Oceanic and Atmospheric Administration	Year 3 National Oceanic and Atmospheric Administration	Cumulative Grand Total
Salaries	Regular Salaries	PROJ SCIENTIST III	FTE	0.09	0.09	0.07	10,359	9,639	8,727	28,725
	Subtotal Salaries						10,359	9,639	8,727	28,725
Fringe Benefits		Regular Benefits @	54.90 %				5,687	5,292	4,791	15,770
	Subtotal Fringe Benefits						5,687	5,292	4,791	15,770
	Total Salaries and Benefits						16,046	14,931	13,518	44,495
Materials and Supplies		Publication / Page Charges					0	2,000	2,000	4,000
	Subtotal Materials and Supplies						0	2,000	2,000	4,000
Travel		Domestic - Present Results at AMS Conference					2,463	2,114	2,167	6,744
	Subtotal Travel						2,463	2,114	2,167	6,744
	Modified Total Direct Costs (MTDC)						18,509	19,045	17,685	55,239
Indirect Costs		NCAR Indirect Cost Rate (MTDC)	56.90 %				10,532	10,837	10,063	31,432
	Total Indirect Costs						10,532	10,837	10,063	31,432
MTDC Costs that Include Indirect Costs	Computing Service Center	Computing Service Center	$7.33 / hr				1,247	1,114	968	3,329
	Subtotal MTDC Costs that Include Indirect Costs						1,247	1,114	968	3,329
	Total MTDC + Applied Indirect Costs						30,288	30,996	28,716	90,000
	Total Funding To UCAR						30,288	30,996	28,716	90,000

NCAR Proposal 2019-0025 - Budget Justification

COMBINED BUDGET FOR FULL PROPOSAL (by institution and budget year)

Institution	Year 1	Year 2	Year 3	Total
NOAA ESRL (Lead)	$146,242	$150,804	$170,719	$467,765
NCAR	$ 30,288	$ 30,996	$ 28,716	$ 90,000
Total Funds	$176,530	$181,800	$199,435	$557,765

NCAR BUDGET JUSTIFICATION: $90,000

A. Personnel: $28,725

Position Title & Name	Yearly Salary	% of Time	No. of Months	$ Amount
PI, Project Scientist III, Stefano Alessandrini	$126,793 Year 1	9.5%	0.98	$10,359
	$131,860 Year 2	8.5%	0.88	$ 9,639
	$137,135 Year 3	7.4%	0.76	$ 8,727
	Total	25.4%	2.62	$28,725

A Project Scientist III (Dr. Stefano Alessandrini) will serve as Principal Investigator and charge approximately 0.98 months in Year 1, 0.88 months in Year 2 and 0.76 months in Year 3 on this project with a salary range between $126,793 and $137,135. This labor will include:

1) Modify the site-specific weighting so that weights are computed separately for each time of day and each season. It means that a separate and independent brute force optimization will be carried out for each season and forecast lead time over a training period. A comparison between this new approach (variable weights by lead time and season) and the previous one (static

weights) will be carried over a verification period in terms of several metrics such as the mean absolute error and the continuous ranked probability score.

2) NCAR version of the analog ensemble code is now different from the NOAA's one since they went through separate developments in the last five years. NCAR will provide site-specific weighting results (using NCAR AnEn version) for a sample data set provided by NOAA that can be used to confirm that this component of the operational code is properly working.

3) NCAR PI will consult with and assist NOAA personnel in further Kalman filter analog ensemble forecast (KFAN) improvements, including the extension to 72h forecasts, and the novel Finite-Volume Cubed-Sphere Dynamical Core (NOAA FV3) driven CMAQ forecasts.

4) NCAR PI will assist NOAA personnel in developing the code to expand the analog search to include the local pattern of concentration values. This will be carried out by testing newly computed predictors, such as O3 and PM2.5 concentrations gradient along x and y horizontal coordinates, for the analog searching.

A 4% annual salary increase has been included.

B. Fringe Benefits: $15,770

Position Title & Name	Yearly Salary	% Rate	$ Amount
PI, Project Scientist II, Stefano Alessandrini	$126,793 Year 1	54.9%	$ 5,687
	$131,860 Year 2	54.9%	$ 5,292
	$137,135 Year 3	54.9%	$ 4,791
	Total	54.9%	$15,770

The salary budget includes a full time employee benefit rate of 54.9% for non-work time of vacation, sick leave, holidays and other paid leave, as well as standard staff benefits. Worked hours are based on 86% of 2080 hrs. in a year.

C. Travel: $6,744

Domestic Travel: A total of $6,744 is budgeted for domestic travel. This includes the following travel in each year of the project: One trip for one person, 5 days (4 nights) to Boston, MA in Year 1, New Orleans, LA in Year 2 and Houston, TX in Year 3 to attend the annual AMS Conference and share project results.

All costs (based on NCAR travel rates) include airfare, lodging, car rental, IRS-approved per diem rates, and registration costs and are escalated by 4% per year.

PROPOSAL NUMBER:	**2019-0025**							
PI:	**Stefano Alessandrini**							
Destination	**Purpose**	**# of Travelers**	**Airfare**	**Per Diem**	**Car**	**Hotel**	**Conf. Reg & Misc**	**Total Trip Cost**
Year 1 - Travel 1								
Boston, MA	AMS	1	$469	$320	$0	$978	$648	**$2,415**
Total for Yr 1 Travel								**$2,463**
Year 2 - Travel 1								
New Orleans, LA	AMS	1	$172	$332	$0	$936	$674	**$2,114**
Total for Yr 2 Travel								**$2,114**
Year 3 - Travel 1								
Houston, TX	AMS	1	$319	$297	$0	$850	$701	**$2,167**
Total for Yr 3 Travel								**$2,167**
Total All Years								**$6,744**

D. Equipment: None

E. Supplies: None

F. Contractual: None

G. Construction: None

H. Other: $7,329

Publications: $4,000
$4,000 total ($2,000 per year in Years 2 and 3) has been budgeted for two journal article(s) in peer-reviewed publications. Cost estimate is based on recent costs to publish in AMS journals.

Computer Services: $3,329
Scientific, computing and networking support costs have been allocated to this project through the Computer Service Center (CSC), in accordance with OMB circulars and NCAR management policy. The RAL CSC rate for 2018 is $7.33 per labor hour.

I. Total Direct Charges: $58,568

A. Personnel:	$ 28,725
B. Fringe:	$ 15,770
C. Travel:	$ 6,744
D. Equipment:	$0
E. Supplies:	$0
F. Contractual:	$0
G. Construction:	$0
H. Other:	$ 7,329
Total Direct Costs:	$58,568

J. Indirect Charges: $31,432

Indirect Costs are applied to all modified total direct costs (MTDC). Excluded from MTDC are items of equipment costing $5,000 or more, and individual subcontract amounts in excess of at least $25,000 per fiscal year. The provisional FY18 rate for Indirect Costs is 56.9%. Cognizant Agency: National Science Foundation (NSF).

K. NCAR TOTALS – Direct and Indirect Charges: $90,000

NATIONAL SCIENCE FOUNDATION
2415 Eisenhower Avenue
Alexandria, VA 22314

Division of Institution and Award Support
(703) 292-8244 VOICE
(703) 292-9440 FAX

December 11, 2017

Melissa D. Miller
Vice President for Finance and Administration
University Corporation for Atmospheric Research (UCAR)
P.O. Box 3000
Boulder, CO 80307-3000

Dear Ms. Miller:

We have completed our review of the final indirect cost proposal and supporting financial data submitted to the National Science Foundation (NSF) for your fiscal years ended September 30, 2014, along with your provisional indirect cost rate proposals for FYs 2016, 2017, and 2018.

The enclosed rate agreement indicates the rates approved by this office. Please indicate your concurrence with these rates by signing, dating and returning a copy of the agreement to my attention at the above address. The rates included in the agreement may not be used until the agreement has been ratified through signatures from both your organization and NSF.

Per the rates that have established and the proposals that have already been received by NSF, the organization will not be required to submit a new indirect cost rate proposal until the end of your FY 2017. This proposal should be submitted to this office within 6 months after the end of the organization's fiscal year, and should follow NSF's current submission procedures (https://www.nsf.gov/bfa/dias/caar/docs/idcsubmissions.pdf). If you have any questions concerning the contents of this letter or the rate agreement, please contact me.

Sincerely,

MG Meghan A. Benson

Meghan A. Benson
Lead Analyst, Indirect Cost Rates
Cost-Analysis and Pre-Award Branch (CAP)
Division of Institution and Award Support

Enclosure: Rate Agreement

NON-PROFIT ORGANIZATION
NEGOTIATED INDIRECT COST RATE AGREEMENT (NICRA)

EIN #: 84-0412668

NSF INS CODE: 4062600000

ORGANIZATION:
University Corporation for Atmospheric Research (UCAR)
P.O. Box 3000
Boulder, CO 80307-3000

DATE: December 11, 2017

FILING REF: The preceding agreement was dated December 13, 2016.

The rates approved in this agreement are for use on grants, contracts and other agreements with the Federal Government, subject to the conditions in Section II.

SECTION I: RATES

FY 2014 - FINAL

Description	Effective Period	Rate	Base
UCAR			
UCAR G&A	10/01/13 – 09/30/14	14.873%	(a)
UCAR Community Programs (UCP) G&A			
Onsite	10/01/13 – 09/30/14	33.549%	(b)
Offsite	10/01/13 – 09/30/14	22.061%	(b)
NCAR			
NCAR G&A			
Onsite	10/01/13 – 09/30/14	56.687%	(b)
Offsite/NWSC	10/01/13 – 09/30/14	41.033%	(b)
Fringe Benefits			
Full Benefits	10/01/13 – 09/30/14	55.409%	(c)
Reduced Benefits	10/01/13 – 09/30/14	9.842%	(c)

FY 2016 - PROVISIONAL

Description	Effective Period	Rate	Base
UCAR			
UCAR G&A	10/01/15 – 09/30/16	15.563%	(a)
UCAR Community Programs (UCP) G&A			
Onsite	10/01/15 – 09/30/16	33.493%	(b)
Offsite	10/01/15 – 09/30/16	23.186%	(b)
NCAR			
NCAR G&A			
Onsite	10/01/15 – 09/30/16	53.927%	(b)
Offsite/NWSC	10/01/15 – 09/30/16	40.583%	(b)
Fringe Benefits			
Full Benefits	10/01/15 – 09/30/16	53.596%	(c)
Reduced Benefits	10/01/15 – 09/30/16	9.291%	(c)

FY 2017 - PROVISIONAL

Description	Effective Period	Rate	Base
UCAR			
UCAR G&A	10/01/16 – 09/30/17	15.798%	(a)
UCAR Community Programs (UCP) G&A			
Onsite	10/01/16 – 09/30/17	33.504%	(b)
Offsite	10/01/16 – 09/30/17	23.017%	(b)
NCAR			
NCAR G&A			
Onsite	10/01/16 – 09/30/17	55.796%	(b)
Offsite/NWSC	10/01/16 – 09/30/17	41.837%	(b)
Fringe Benefits			
Full Benefits	10/01/16 – 09/30/17	53.294%	(c)
Reduced Benefits	10/01/16 – 09/30/17	9.326%	(c)

FY 2018 - PROVISIONAL

Description	Effective Period	Rate	Base
UCAR			
UCAR G&A	10/01/17 – 09/30/18	15.90%	(a)
UCAR Community Programs (UCP) G&A			
Onsite	10/01/17 – 09/30/18	35.30%	(b)
Offsite	10/01/17 – 09/30/18	24.10%	(b)
NCAR			
NCAR G&A			
Onsite	10/01/17 – 09/30/18	56.90%	(b)
Offsite/NWSC	10/01/17 – 09/30/18	43.00%	(b)
Fringe Benefits			
Full Benefits	10/01/17 – 09/30/18	54.90%	(c)
Reduced Benefits	10/01/17 – 09/30/18	9.40%	(c)

Rate Application Bases

(a) Total direct costs of each entity, excluding equipment, participant support, Intergovernmental Personnel Assignments (IPAs), and subaward or subcontract costs in excess of $25,000 per year, plus entity G&A before UCAR G&A. The UCAR G&A rate is part of the National Center for Atmospheric Research (NCAR) and UCAR Community Program (UCP) rates and is generally not proposed separately on grant, contract, or cooperative agreement proposal budgets.

(b) Total direct costs, excluding equipment, participant support, Intergovernmental Personnel Assignments (IPAs), and subaward or subcontract costs in excess of $25,000 per year.

(c) Direct salaries and wages excluding paid absences. The Reduced Benefit rate is applicable to the salaries of student assistants, student visitors and other hourly staff that work "on call." The Full Benefit rate is applicable to the salaries of "regular" employees.

Fringe Benefits: Fringe benefits consist of: Payroll Taxes, Group Life and Major Medical Insurances, Retirement Contributions (TIAA/CREF), Unemployment Insurance, Worker's Compensation, Disability Insurance, Severance, Educational Assistance, Travel Accident Insurance, Transportation Benefits (RTD Bus Passes), and Employee Wellness. Fringe Benefits also include the costs of Paid Time Off (holiday, vacation, sick leave and other "non-work" time).

SECTION II: GENERAL TERMS

A. LIMITATIONS: Use of the rates contained in this agreement is subject to any applicable contractual or grant limitations. Acceptance of these rates agreed to herein is predicated upon the conditions: (1) that no costs other than those incurred by the contractor or grantee were included in its indirect cost proposal and that such costs are legal obligations of the contractor or grantee, (2) that the same costs that have been treated as indirect costs have not been claimed as direct costs, and (3) that similar types of costs have been accorded consistent treatment.

B. AUDIT: All costs, direct and indirect, Federal and non-Federal are subject to audit. Adjustments to amounts resulting from audit of cost allocation plan or indirect rate proposal upon which the negotiation of this agreement was based will be compensated for in subsequent negotiation.

C. ACCOUNTING CHANGES: The rates contained in this agreement are based on the accounting system in effect at the time the proposal was prepared and the rates were negotiated. Changes to the method of accounting which effect the amount of reimbursement resulting from the use of these rates require the prior approval of this office. Failure to obtain such approval may result in subsequent cost disallowances.

D. RATE TYPES:
   1. Provisional/Final Rate: Within six (6) months after fiscal year end, a final indirect cost rate proposal must be submitted based on actual costs. Billings and charges to federal grants and contracts must be adjusted if the final rate varies from the provisional rate. If the final rate is greater than the provisional rate and there are no funds to cover the additional indirect costs, the organization may not recover all indirect costs. Conversely, if the final rate is less than the provisional rate, the organization will be required to pay back the difference to the funding agency.

   2. Predetermined Rate: Predetermined rates are applicable to a current or future period, and are based upon an estimate of the costs to be incurred during the period. A predetermined rate is not subject to adjustment.

E. NOTIFICATION TO FEDERAL AGENCIES: Copies of this document may be provided to other Federal offices as a means of notifying them of the rates agreed to herein.

SECTION III: ACCEPTANCE

BY THE ORGANIZATION:

University Corporation for Atmospheric Research (UCAR)
(Organization)

Melissa D. Miller
(Signature)

Melissa D. Miller
(Name)

Vice President, Finance & Administration
(Title)

12/29/17
(Date)

ON BEHALF OF THE FEDERAL GOVERNMENT:

National Science Foundation
(Agency)

Meghan A. Benson
(Signature)

Meghan A. Benson
(Name)

Lead Analyst, Indirect Cost Rates
Cost-Analysis and Pre-Award Branch
(Title)

12/11/17
(Date)

NSF Negotiator: Meghan A. Benson
Telephone: 703-292-4884

NCAR

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

OFFICE OF THE DIRECTOR

June 14, 2017

Mr. Charles D. Zeigler
Special Assistant
National Science Foundation
Division of Institution and Award Support
Attn: CAAR Branch – Indirect Cost
4201 Wilson Boulevard, Room 485
Arlington, VA 22230

Dear Mr. Zeigler,

Enclosed for review and approval are UCAR's proposed **FY2018 Aircraft Maintenance Rates (AMR), Service Center Rates** (Computer Service Center (CSC) and Machine Shop) and **User Rates** (System User Rates (SUR) and Core Hour Rate).

Rates have either stayed the same as proposed in FY 2017, or had slight increases or decreases. The Earth Observing Laboratory (EOL) is requesting to change Dropsonde Data System SUR rate; the number of available dropsonde data systems increased from two to three systems. The Computational and Information Systems Laboratory (CISL) Core Hour Rate is increasing slightly. In FY 2018, the procurement of NWSC-2 Cheyenne will be in production with 3.3B core hours available. In the FY 2017 rate submission, the core hour estimate was higher because it included NWSC-1 Yellowstone, which is scheduled to be decommissioned by the end of CY 2017.

As with previous rate submissions, the attached summary page has an approval line for the NCAR/Facilities Section Head signature. If you have any questions regarding the FY 2018 proposed rates, please call Rena Brasher-Alleva at (303) 497-1116 or by email at rena@ucar.edu.

Sincerely,

Rena Brasher-Alleva
NCAR Budget & Planning Director

cc: L. Avallone, S. Ahmed, S. Ruth, K. Spencer; NSF
UCAR President's Council
Center Administrators
G. Cheeseman, R. Lovell, M. Miller, G. Taberski, J. Young

National Center for Atmospheric Research
Boulder, Colorado
FY 2018 Proposed Rate Summary

1. Aircraft Maintenance Rate

Aircraft Maintenance Rate (AMR)	FY 2016 Actual	FY 2017 Submitted	FY 2018 Proposed
C-130 Aircraft	$454 /Hour	$552 /Hour	$564 /Hour
GV Aircraft (Gulfstream HIAPER)	$1,447 /Hour	$1,914 /Hour	$1,412 /Hour

2. Service Center Rates

Computing Service Centers	FY 2016 Actual	FY 2017 Submitted	FY 2018 Proposed
Climate and Global Dynamics (CGD)	$6.36 /Hour	$6.50 /Hour	$6.65 /Hour
Atmospheric Chemistry Observations & Modeling (ACOM)	$6.93 /Hour	$7.25 /Hour	$7.00 /Hour
High Altitude Observatory (HAO)	$7.42 /Hour	$7.41 /Hour	$7.21 /Hour
Mesoscale & Microscale Meteorology (MMM)	$6.51 /Hour	$6.50 /Hour	$6.70 /Hour
Research Applications Laboratory (RAL)	$7.02 /Hour	$7.33 /Hour	$7.33 /Hour
Machine Shop			
Machine Shop Rate	$79 /Hour	$83 /Hour	$83 /Hour

3. System User Rates

Earth Observing Laboratory (EOL)	FY 2016 Actual	FY 2017 Submitted	FY 2018 Proposed
Systems User Rates (SUR)			
ISFS	$700 /Day	$557 /Day	$557 /Day
ISS	$554 /Day	$608 /Day	$608 /Day
Dropsonde Data System	$1,456 /Day	$2,224 /Day	$1,673 /Day
ELDORA	$0 /Day	$2,135 /Day	$2,135 /Day
S-Pol Radar	$5,382 /Day	$9,132 /Day	$9,132 /Day
HCR	$3,435 /Day	$5,313 /Day	$5,313 /Day
HAIS	$604 /Day	$599 /Day	$599 /Day
C-130 Aircraft	$9,797 /Day	$11,738 /Day	$11,738 /Day
Gulfstream Aircraft (HIAPER)	$16,592 /Day	$10,759 /Day	$10,759 /Day
Mechanical Design	$746 /Day	$923 /Day	$923 /Day
Machine Shop	$367 /Day	$106 /Day	$106 /Day

Comp. & Information Systems Lab (CISL)	FY 2016 Actual	FY 2017 Submitted	FY 2018 Proposed
Rate Per Core Hour	$0.0039 /Hour	$0.0045 /Hour	$0.0049 /Hour
Rate per 100 Core Hours	$0.39 /100 Hours	$0.45 /100 Hours	$0.49 /100 Hours

APPROVED:

Sarah L. Ruth, Ph.D.
Section Head, NCAR and Facilities Section

Date

University Corporation for Atmospheric Research
National Center for Atmospheric Research
FY 2018 Proposed Aircraft Maintenance Rates (AMR)

Aircraft Maintenance Rates (AMR)	**Actual FY 2016**	**Submitted FY 2017**	**Proposed FY 2018**
C-130 Aircraft			
Operating Expenses	$13,153	$110,408	$112,726
Number of Hours	29	200	200
C-130 AMR Rate/Hour	**$454**	**$552**	**$564**

C-130 Notes: (1) Actual aircraft flight hours are dependent on OFAP approved deployments and the deployment schedule. (2) AMR revenue and associated expenditures are not always realized in the same fiscal year.

GV Aircraft Maintenance Rate (AMR)	**Actual FY 2016**	**Submitted FY 2017**	**Proposed FY 2018**
Operating Expenses	$454,393	$135,894	$303,580
Number of Hours	314	71	215
GV Rate/Hour	**$1,447**	**$1,914**	**$1,412**

GV Notes: (1) Many of these hourly expenses have a lifecycle in excess of a year; therefore, yearly actual rates are not relevant. (2) Beginning in FY 2012, an engine service contract was initiated so that virtually all engine costs are covered, not just the hot-section and full overhaul. This accounts for the increase in this component and the overall rate. (3) The GV's component AMRs have been updated with the latest cost information from industry and incorporate EOL's growing experience with operating the aircraft.

University Corporation for Atmospheric Research
National Center for Atmospheric Research
FY 2018 Proposed Service Center Rates

Computing Service Centers (CSC)	Actual FY 2016	Submitted FY 2017	Proposed FY 2018
Climate & Global Dynamics			
Operating Expenses	$1,148,976	$1,180,117	$1,291,303
Worktime Hours	180,521	181,584	194,285
CGD CSC Rate/Hour	**$6.36**	**$6.50**	**$6.65**
Atmospheric Chemistry Observations & Modeling			
Operating Expenses	$739,383	$738,257	$719,184
Worktime Hours	106,691	101,891	102,690
ACOM CSC Rate/Hour	**$6.93**	**$7.25**	**$7.00**
High Altitude Observatory			
Operating Expenses	$658,421	$648,421	$587,394
Worktime Hours	88,727	87,460	81,469
HAO CSC Rate/Hour	**$7.42**	**$7.41**	**$7.21**
Mesoscale & Microscale Meteorology			
Operating Expenses	801,110	739,652	742,906
Worktime Hours	123,070	113,782	110,841
MMM CSC Rate/Hour	**$6.51**	**$6.50**	**$6.70**
Research Applications Laboratory			
Operating Expenses	$1,853,440	$2,069,193	$2,036,974
Worktime Hours	264,007	282,110	277,837
RAL CSC Rate/Hour	**$7.02**	**$7.33**	**$7.33**
Machine Shop			
Operating Expenses	$560,444	$674,964	$793,595
Number of Hours	7,095	8,103	9,520
Machine Shop Rate/Hour	**$79**	**$83**	**$83**

University Corporation for Atmospheric Research
National Center for Atmospheric Research
FY 2018 Proposed System User Rates

Earth Observing Laboratory (EOL)	Actual FY 2016	Submitted FY 2017	Proposed FY 2018
Systems User Rates (SUR)			
ISFS			
Operating Expenses	$1,638,093	$1,736,385	$1,736,385
Number of Systems	9	12	12
Number of Days[2]	260	260	260
ISFS Rate/Day[3]	**$700**	**$557**	**$557**
ISS/MISS/GAUS/MGAUS			
Operating Expenses	$1,151,803	$1,265,074	$1,265,074
Number of Systems	8	6	6
Number of Days[2]	260	260	260
ISS Rate/Day[3]	**$554**	**$808**	**$808**
ISS / GAU combined in FY 2007.			
Dropsonde Data System			
Operating Expenses	$1,135,706	$1,735,003	$1,305,001
Number of Systems	3	3	3
Number of Days[2]	260	260	260
Dropsonde Data System Rate/Day[3]	**$1,456**	**$2,224**	**$1,673**
ELDORA[4]			
Operating Expenses	$0	$555,001	$555,001
Number of Systems	1	1	1
Number of Days[2]	260	260	260
ELDORA Rate/Day[3]	**$0**	**$2,135**	**$2,135**
S-Pol Radar[1]			
Operating Expenses	$1,399,411	$2,374,284	$2,374,284
Number of Systems	1	1	1
Number of Days[2]	260	260	260
S-Pol Rate/Day[3]	**$5,382**	**$9,132**	**$9,132**
HIAPER Cloud Radar (HCR)			
Operating Expenses	$893,168	$1,381,322	$1,381,322
Number of Systems	1	1	1
Number of Days[2]	260	260	260
HCR Rate/Day[3]	**$3,435**	**$5,313**	**$5,313**
HIAPER Aircraft Solicitation Instrumentation (HAIS)			
Operating Expenses	$2,199,314	$2,178,928	$2,178,928
Number of Systems	14	14.0	14.0
Number of Days[2]	260	260	260
HAIS Rate/Day[3]	**$604**	**$599**	**$599**
C-130 Aircraft			
Operating Expenses	$2,547,247	$3,051,858	$3,051,858
Number of Days[2]	260	260	260
C-130 Aircraft Rate/Day[3]	**$9,797**	**$11,738**	**$11,738**
GV (HIAPER) Gulfstream Aircraft			
Operating Expenses	$4,313,816	$2,797,322	$2,797,322
Number of Days[2]	260	260	260
GV Aircraft Rate/Day[3]	**$16,592**	**$10,759**	**$10,759**
Mechanical Design			
Operating Expenses	$475,908	$821,862	$821,862
Number of FTEs	2.5	3.4	3.4
Number of Days[2]	260	260	260
Mechanical Design Rate/Day[3]	**$746**	**$923**	**$923**
Machine Shop			
Operating Expenses	$496,640	$235,224	$235,224
Number of FTEs	5.2	8.6	8.6
Number of Days[2]	260	260	260
Machine Shop Rate/Day[3]	**$387**	**$106**	**$106**
This represents an add on user rate for non-NSF users, for recovery of base funded supervisory and support			

[1] *Changes in S-Pol SURs primarily driven by fluctuations in OFAP approved yearly deployment and planned usage of the facility.*
[2] *For all SUR rates, the number of working days in a year is 5 days per week for 52 weeks in a year, per NSF-AGS.*
[3] *For all SUR rates, duration and complexity of field programs may affect the required size of the base funded field crew. Subject to NSF Program Official approval, the SUR can be adjusted to reflect lower or higher labor requirements.*
[4] *The ELDORA system is not currently available for deployment. The FY 2018 ELDORA rate will be used if ELDORA is made available to the community.*

Comp. & Information Systems Laboratory (CISL)	Actual FY 2016	Submitted FY 2017	Proposed FY 2018[5]
Core Hours			
Operating Expenses	$ 18,274,222	$20,807,222	$16,334,653
Estimated Core Hours	4,660,000,000	4,660,000,000	3,300,000,000
CISL Core Hour Rate	$0.0039	$0.0045	$0.0049
CISL Core Hour Rate per 100 Core Hours	$0.39	$0.45	$0.49

[5] *In FY 2018, NWSC-2 Cheyenne will be in production with 3,300,000,000 core hours available. In FY 2017, the core hours were higher because it included NWSC-1 Yellowstone which will be decomissioned by the end of CY 2017. Operating expenses were adjusted for FY 2018 based on Operational costs less Research.*

BUDGET INFORMATION - Non-Construction Programs

OMB Number: 4040-0006
Expiration Date: 01/31/2019

SECTION A - BUDGET SUMMARY

Grant Program Function or Activity (a)	Catalog of Federal Domestic Assistance Number (b)	Estimated Unobligated Funds		New or Revised Budget		
		Federal (c)	Non-Federal (d)	Federal (e)	Non-Federal (f)	Total (g)
1. Weather and Air Quality Research	11.459	$	$	$ 90,000.00	$	$ 90,000.00
2.						
3.						
4.						
5. Totals		$	$	$ 90,000.00	$	$ 90,000.00

Standard Form 424A (Rev. 7- 97)
Prescribed by OMB (Circular A -102) Page 1

SECTION B - BUDGET CATEGORIES

6. Object Class Categories	GRANT PROGRAM, FUNCTION OR ACTIVITY				Total
	(1)	(2)	(3)	(4)	(5)
	Weather and Air Quality Research	N/A	N/A		
a. Personnel	$ 10,359.00	$ 9,639.00	$ 8,727.00	$	$ 28,725.00
b. Fringe Benefits	5,687.00	5,292.00	4,791.00		15,770.00
c. Travel	2,463.00	2,114.00	2,167.00		6,744.00
d. Equipment					
e. Supplies					
f. Contractual					
g. Construction					
h. Other	1,247.00	3,114.00	2,968.00		7,329.00
i. Total Direct Charges (sum of 6a-6h)	19,756.00	20,159.00	18,653.00		$ 58,568.00
j. Indirect Charges	10,532.00	10,837.00	10,063.00		$ 31,432.00
k. TOTALS (sum of 6i and 6j)	$ 30,288.00	$ 30,996.00	$ 28,716.00	$	$ 90,000.00
7. Program Income	$	$	$	$	$

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Tracking Number:GRANT12762883 Funding Opportunity Number:NOAA-OAR-OWAQ-2019-2005820 Received Date:Dec 18, 2018 05:27:32 PM EST

SECTION C - NON-FEDERAL RESOURCES

	(a) Grant Program	(b) Applicant	(c) State	(d) Other Sources	(e)TOTALS
8.	Weather and Air Quality Research	$	$	$	$
9.					
10.					
11.					
12. TOTAL (sum of lines 8-11)		$	$	$	$

SECTION D - FORECASTED CASH NEEDS

	Total for 1st Year	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
13. Federal	$ 30,288.00	$ 7,572.00	$ 7,572.00	$ 7,572.00	$ 7,572.00
14. Non-Federal	$				
15. TOTAL (sum of lines 13 and 14)	$ 30,288.00	$ 7,572.00	$ 7,572.00	$ 7,572.00	$ 7,572.00

SECTION E - BUDGET ESTIMATES OF FEDERAL FUNDS NEEDED FOR BALANCE OF THE PROJECT

	(a) Grant Program	FUTURE FUNDING PERIODS (YEARS)			
		(b)First	(c) Second	(d) Third	(e) Fourth
16.	Weather and Air Quality Research - 1st Quarter	$ 7,749.00	$ 7,179.00	$	$
17.	Weather and Air Quality Research - 2nd Quarter	7,749.00	7,179.00		
18.	Weather and Air Quality Research - 3rd Quarter	7,749.00	7,179.00		
19.	Weather and Air Quality Research - 4th Quarter	7,749.00	7,179.00		
20. TOTAL (sum of lines 16 - 19)		$ 30,996.00	$ 28,716.00	$	$

SECTION F - OTHER BUDGET INFORMATION

21. Direct Charges: Modified Total Direct Costs (MTDC) = $55,239

22. Indirect Charges: Indirect Costs on MTDC = $31,432

23. Remarks: Indirect Costs = FY18 rate of 56.9% x MTDC = .569 x $55,239 = $31,432

NOAA Budget - Proposal

TITLE: Post-Processing of CMAQ Air Quality Predictions: Research to Operations

Principal Investigator:
James Wilczak

AMOUNT:										**$467,765**
SPONSOR:						**OWAQ**				
PROJECT NUMBER:		**NEW**								
		YEAR 1			**YEAR 2**		**YEAR 3**		**TOTAL FY 2019 - 2022**	
BUDGET ESTIMATE										
FEDERAL LABOR	**MO RATE**	**UNITS**	**MOS**	**AMOUNT**	**MOS**	**AMOUNT**	**MOS**	**AMOUNT**	**MOS**	**AMOUNT**
J. Wilczak		month		0		0		0	0.0	0
		month							0.0	0
Subtotal NOAA Federal Salaries			0	0	0	0	0	0	0.0	0
Subtotal w/NOAA Leave	21.00%			**0**		**0**		**0**		0
NOAA Support	0.00%			**0**		**0**		**0**		0
Reimbursable Funds only -Benefits, NOAA				**0**		**0**		**0**		0
TOTAL FEDERAL LABOR				**0**		**0**		**0**		**0**
COOPERATIVE INSTITUTE (CI) LABOR	**AMOUNT PER MONTH**	**UNITS**	**MOS**	**AMOUNT**	**MOS**	**AMOUNT**	**MOS**	**AMOUNT**	**MOS**	**AMOUNT**
I. Djalalova	8,879	month	4.3	38,181	4.3	40,090	4.3	42,095	13	120,366
D. Allured	6,850	month	3	20,549	3	21,576	3	22,655	9.0	64,780
L. Bianco	8,876	month	1	8,876	1	9,320	1	9,786	3.0	27,981
Subtotal, CI labor		**months**	**7**	**67,606**	**7**	**70,986**	**7**	**74,535**	**22**	213,127
FICA, TIAA, Work Comp.	36.60%			**24,744**		**25,981**		**27,280**		78,004
Subtotal CI Labor and Benefits				**92,349**		**96,967**		**101,815**		291,131
CI Support	20.00%			**18,470**		**19,393**		**20,363**		58,226
TOTAL CI LABOR				**110,819**		**116,360**		**122,178**		**349,357**
CONTRACT LABOR	**AMOUNT PER MONTH**	**UNITS**	**MOS**	**AMOUNT**	**MOS**	**AMOUNT**	**MOS**	**AMOUNT**	**MOS**	**AMOUNT**
		month		0		0		0	0	0
Subtotal, CONTRACT labor	**0**	**months**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	0
Billable hourly rate for Contractor Benefits and Overheads Includec										
TOTAL CONTRACT LABOR				**0**		**0**		**0**		0
OTHER DIRECT COSTS				**AMOUNT**		**AMOUNT**		**AMOUNT**		**AMOUNT**
Shipping				0		0		0		0
Repairs				0		0		0		0
Publications				0		0		10,000		10,000
Contracts				0		0		0		0
Travel (Foreign) (Location undetermined at this time)				5,000		2,500		5,000		12,500
Travel (Domestic)				0		0		0		0
Supplies & Materials (Equipment Upgrades/Parts)				0		0		0		0
Equipment [x] Capital				0		0		0		0
IT Support				15,211		15,972		16,770		47,954
Administrative Support				15,211		15,972		16,770		47,954
TOTAL OTHER DIRECT COSTS				**35,423**		**34,444**		**48,541**		**118,407**
TOTAL				**146,242**		**150,804**		**170,719**		**467,765**

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Organization: DoC/NOAA/OAR/ ESRL/Physical Sciences Division

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Director of Physical Sciences Division, Robert S. Webb

Comments: ESRL/PSD's indirect costs are separated into two categories, i.e. IT and Administrative Support; both are at an equal rate of 22.5%. IT support includes email, internet access, data storage for both basic an scientific software, helpdesk, and backup services. Administrative support includes office space, telephone, conference rooms, purchasing, grant processing, security/badges, budget development, etc.