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Application Documents for Review

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A novel method for improving fine particulate matter air quality forecasts during wildfires
19 December 2018

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Competition Title: Air Quality Research and Forecasting
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Institution	Year 1	Year 2	Year 3	Total
NCAR	$169,923	$169,875	$169,916	$509,714
NOAA ESRL	$ 0	$ 0	$ 0	$ 0
UCSD	$ 0	$ 0	$ 0	$ 0
TOTAL	$169,923	$169,875	$169,916	$509,714

A novel method for improving fine particulate matter air quality forecasts during wildfires

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Abstract

Fine particulate matter ($PM_{2.5}$) continues to be a major air quality problem in the United States (US), especially during wildfires. The National Air Quality Forecasting Capability (NAQFC) at the National Oceanic and Atmospheric Administration (NOAA) uses the Community Multiscale Air Quality (CMAQ) model to produce sophisticated daily $PM_{2.5}$ forecasts, which are then used by decision-makers across the US to notify the public of forthcoming air pollution days. However, several factors (e.g., errors in initial and boundary conditions, uncertainties in fire emission estimates, and poor understanding of the evolution of fire plumes) degrade the accuracy of NAQFC $PM_{2.5}$ forecasts and reduce their value in the decision-making process. This project aims to develop a novel method to significantly improve the accuracy of the NAQFC $PM_{2.5}$ forecasts by improving initialization of the NAQFC via chemical data assimilation of satellite aerosol optical depth (AOD) retrievals in the NAQFC, and by generating a more accurate long-term forecast archive for better training of analog-based post-processing techniques. To achieve this aim, we will perform the following two tasks:

- Constrain 48-h deterministic CMAQ $PM_{2.5}$ forecasts via assimilation of Geostationary Operational Environmental Satellite (GOES) and Moderate Resolution Imaging Spectroradiometer (MODIS) AOD in CMAQ.
- Generate a long-term forecast data set to further improve the accuracy of Analog Ensemble deterministic $PM_{2.5}$ forecasts and reliably quantify their uncertainty.

The performance of the newly developed air quality forecasting system will be assessed against the near real-time air quality measurements from the US Environmental Protection Agency's (EPA) AirNOW network and recent and upcoming field campaigns focused on better characterizing and understanding the wildfires in the US using a set of widely used statistical metrics. The new capabilities will significantly enhance the decision-making activity in the area of public health and air quality. Furthermore, all the new developments regarding the chemical data assimilation will follow the JEDI (Joint Effort for Data Assimilation) framework so that the capabilities developed here can also be beneficial for the assimilation of satellite radiances in numerical weather prediction.

Statement of Work

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

Scientific problem and goal: Fine particulate matter ($PM_{2.5}$) continues to be a major air quality problem in the wildfire-prone areas of the United States (US) (McClure and Jaffe, 2018) despite a 41% decrease in national average $PM_{2.5}$ concentrations over 2000-2017 (EPA, 2018). For example, the recent devastating fires in California in 2018 reduced air quality so much that some California cities ranked among the dirtiest in the world. Exposure to polluted air affects human health and causes economic losses. Poor air quality is reported to have caused about 160,000 premature deaths in the US with a total economic loss of about $175 billion (Im et al., 2018). To protect the public health from acute air pollution episodes due to wildfires and other causes, the National Air Quality Forecasting Capability (NAQFC) produces sophisticated $PM_{2.5}$ forecasts every day, which are then used by the decision-makers across the nation to alert vulnerable groups and individuals of forthcoming air pollution episodes so that they can take appropriate actions to limit their exposure. The importance of timely air quality alerts has been demonstrated, for example by helping 57% of asthmatic people reduce their exposure in six US states (Wen et al., 2009) and reduce asthma-related emergency department visits in Canada by about 25% (Chen et al., 2018). However, errors and biases in the NAQFC $PM_{2.5}$ forecasts can undermine their value in the decision-making process. Thus, **the overarching goal of this project is to significantly improve the accuracy of the NAQFC deterministic $PM_{2.5}$ forecasts [a] via assimilation of space-borne aerosol optical depth (AOD) retrievals in the NAQFC air quality model, and [b] by providing an improved long-term training dataset for the analog-based post-processing bias correction method implemented in the NAQFC.**

Hypothesis and Conceptual Framework: The NAQFC uses the Community Multiscale Air Quality (CMAQ) model for operational air quality forecasting. The errors and biases in the CMAQ forecasts arise to a large part due to errors in initial and boundary conditions, uncertainties in fire and other emission estimates, and poor understanding of the evolution of fire plumes and their interaction with emissions from other sources. The US Environmental Protection Agency (EPA) continuously works on improving the emission estimates and representation of atmospheric chemical processes in CMAQ (e.g., Fahey et al., 2017; Appel et al., 2017; Nolte et al., 2015). The NAQFC team routinely introduces such improvements to the operational version of CMAQ (e.g., Lee et al., 2017). In addition to improving the model and input emissions, a recent study led by the PI showed that improving the initialization of aerosol chemical composition in CMAQ via assimilation of Moderate Resolution Imaging Spectroradiometer (MODIS) AOD retrievals significantly improved how CMAQ reproduces day to day variability of EPA AirNOW observed $PM_{2.5}$ by about 67% and reduced the mean bias by about 38% (Kumar et al., 2017) when uncertainties in both transport and anthropogenic emissions are accounted for in the data assimilation (DA) framework (compare blue line to the red line in Figure 1b). Furthermore, our team has also developed a hybrid-dynamical statistical method called “Analog Ensemble” (AnEn) to further improve the deterministic $PM_{2.5}$ predictions and reliably quantify their uncertainties (Djalalova et al., 2015; Delle Monache et al., 2017). The AnEn reduces biases by about 95% in 48-h $PM_{2.5}$ forecasts (red line in Figure 1c). The AnEn has been transitioned to NAQFC operations.

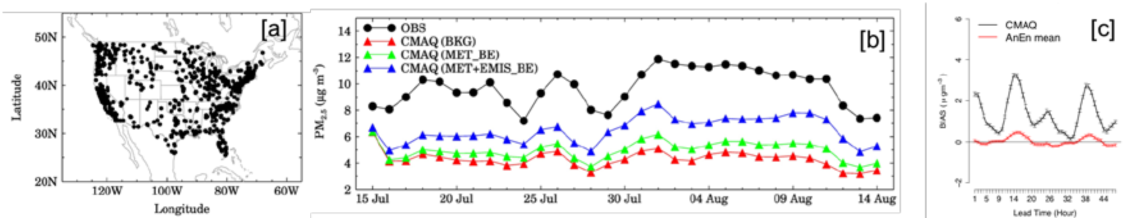

Figure 1: *[a] EPA AirNOW $PM_{2.5}$ monitoring sites used for evaluating CMAQ. [b] Time series of observed and CMAQ simulated daily average $PM_{2.5}$ mass concentrations over sites in panel [a]. CMAQ (BKG; red line) represents experiment without assimilation; CMAQ (MET_BE; green line) and CMAQ (MET+EMIS_BE; blue line) represent assimilation experiments accounting for transport errors only and transport plus anthropogenic emission errors, respectively. [c] Bias in raw CMAQ (black line) and AnEn processed (red line) 48-h $PM_{2.5}$ forecasts averaged over sites in panel [a].*

While both the MODIS AOD assimilation and AnEn based post-processing have significantly improved the NAQFC $PM_{2.5}$ forecasts, the maximum benefits of these techniques are hindered because

I. MODIS AOD retrievals constrain the aerosol chemical composition only once per day.
II. Uncertainties in biomass burning emissions are not accounted for in the DA.
III. Errors in deterministic forecasts that are used to train the AnEn during extreme events (e.g., wildfires) limit the ability of AnEn in finding similar past situations.

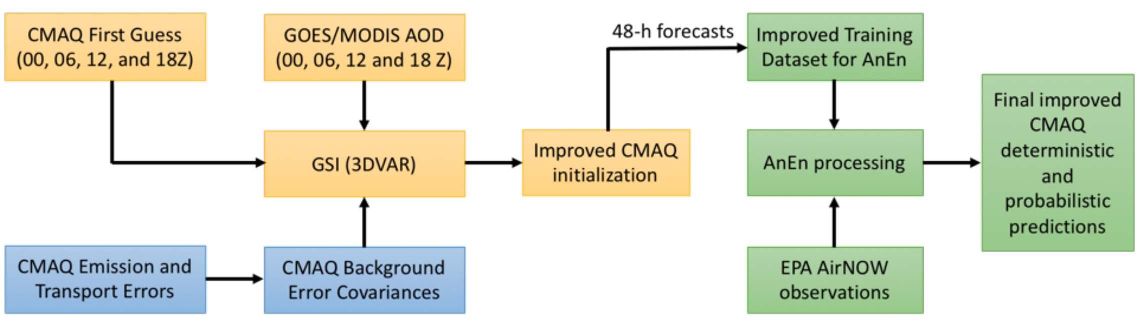

Figure 2: *Conceptual framework proposed to address limitations I (orange boxes), II (blue boxes), and III (green boxes), respectively.*

We hypothesize that the above limitations can be addressed with the conceptual framework depicted in Figure 2. Limitation I can be addressed by assimilating the AOD retrievals from the NOAA Geostationary Operational Environmental Satellite (GOES) satellites along with the MODIS AOD retrievals (orange boxes in Figure 2) because GOES AOD retrievals are available every 30 mins. To address limitation II, we will quantify the uncertainties in biomass burning emissions over the NAQFC domain through comparison of different biomass burning emission inventories, i.e., Bluesky fire emissions, Fire INventory from NCAR (FINN), Global Fire Emission Database (GFED), and Quick Fire Emission Database (QFED). The quantified uncertainties will then be ingested into GSI through the CMAQ background error covariance matrix (blue boxes in Figure 2). Addressing the first two limitations will improve CMAQ's deterministic $PM_{2.5}$ forecasts and help address limitation III by serving as an improved training dataset for the AnEn and thus enhancing its performance (green boxes in Figure 3). To better isolate the influence of wildfires on measurement sites, we will also include a tracer that will track carbon monoxide (CO) emitted by wildfires in our model domain. This tracer will be used as an additional predictor in our AnEn algorithm.

2. Relevance to NOAA Science Priorities

This project will contribute to AQRF-3 by using NOAA satellite measurements to improve analyses of the distributions of $PM_{2.5}$ over the US. By post-processing CMAQ $PM_{2.5}$ forecasts using AnEn, the project will also contribute to AQRF-4.

3. Proposed Methodology and Work Plan

3.1. Task 1: Evaluation datasets

This project will obtain hourly $PM_{2.5}$ observations from the AIRNow network, which currently measures $PM_{2.5}$ at ~900 stations across the U.S. We will use the real-time raw data, which can be used in an operational setting, compared to the quality-controlled data that EPA provides with a time lag of several months. We will follow the quality control procedure of Djalalova et al. (2015) to filter erroneous, missing, constant, and outlier data to ensure continuity in $PM_{2.5}$ measurements. For $PM_{2.5}$, 570 of 900 sites have at least 80% data availability since 2010. We will also use intensive chemistry measurements conducted for selected time periods during recent and upcoming intensive field campaigns (NCAR/NSF WE-CAN and NASA/NOAA FIREX-AQ) focused on characterizing and understanding wildfires. GOES retrievals that are not assimilated in CMAQ will be used for evaluation along with independent retrievals from the National Aeronautics and Space Administration (NASA) Multi-angle Imaging Spectroradiometer (MISR).

3.2. Task 2: Improving Deterministic $PM_{2.5}$ Forecasts via Chemical Data Assimilation

This work will replicate the NAQFC CMAQ configuration to simulate the spatial and temporal distributions of aerosols over the US. The NAQFC horizontal grid uses the Lambert Conformal map projection with Arakawa C grid staggering, a horizontal grid spacing of 12 km x 12 km (Figure 3), and 41 levels from the surface to about 20 km (50 hPa). Table 1 summarizes the selected physics and chemistry packages used in CMAQ. Anthropogenic emissions from point, area (non-road), and mobile sources over the domain will be obtained from the 2014 EPA National Emission Inventory (NEI). Near real-time wildfire emissions of aerosols and trace gases within the model domain will be represented using FINN, which provides daily biomass burning emissions at 1 km x 1 km resolution. A preprocessor to ingest FINN emissions in CMAQ has been developed by the PI. Biogenic emissions will be calculated online within the model using the Biogenic Emissions Inventory System (BEIS). All emission sectors will be processed using the Sparse Matrix Operator Kernel Emission (SMOKE) system to meet the requirements of the CMAQ gas-chemistry Carbon-bond Mechanism (CB05) and AERO6 aerosol treatment. We will use the Model for Ozone and Related Tracers – version 4 (MOZART-4) output to provide initial and boundary conditions to our CMAQ simulations to account for intercontinental transport of aerosols and trace gases into the US. The Weather Research and Forecasting (WRF) model simulations will be processed through the Meteorology Chemistry Interface

Processor (MCIP) to represent meteorological fields in CMAQ simulations. We will also add a CO-fire tracer in CMAQ that will be introduced as a new predictor in the AnEn.

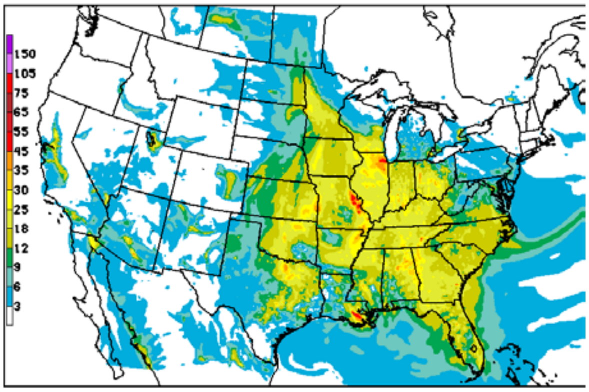

Figure 3: *Hourly averaged NAQFC experimental surface $PM_{2.5}$ ($\mu g/m^3$) prediction on 18 December 2018 at 12Z. Graph obtained from* *http://www.emc.ncep.noaa.gov/mmb/aq/cmaq/web/html/index.html*

Table 1. *Physics and chemistry packages of the CMAQ v5.1 configuration.*

Physics	Scheme
Planetary boundary scheme	Asymmetric convective mixing 2
Dry deposition	Electric circuit analog
Land surface model	Noah
Gas-phase chemistry	CB05 with 156 reactions
Aerosol chemistry	AERO6

Chemical Data Assimilation

The community Gridpoint Statistical Interpolation (GSI) system will be used to assimilate the GOES and MODIS AOD retrievals in CMAQ. The GSI/CMAQ system to assimilate MODIS AOD retrievals has already been developed in an ongoing NASA funded project (Grant # NNX15AH03G entitled "Chemical Data Assimilation (DA) and Analog-Based Uncertainty Quantification to Improve Decision-Making in Public Health and AQ"). Here, we will develop a new capability to assimilate GOES AOD retrievals in CMAQ. Developments from the NASA project and this project will be unified under the JEDI (Joint Effort for Data assimilation Integration) framework (Figure 4). The proposed unified DA system will have three major components, described below, along with the components they leverage from the recently developed GSI/CMAQ system that assimilates MODIS AOD retrievals in CMAQ.

(1) *Unified Observation Preprocessor*: This unified preprocessor will read satellite AOD retrievals from multiple space-borne sensors (e.g., MODIS and GOES), select the best AOD retrievals for assimilation using quality assurance flags included in the satellite data products, and convert those retrievals to a format required by the solver. For example, MODIS AOD retrievals are in the Hierarchical Data Format (HDF) and GOES retrievals are in binary format, while GSI ingests observations in the Binary Universal Form for Representation (BUFR). Our recently developed MODIS AOD preprocessing system already performs these operations on the MODIS AOD retrievals and will be transferred directly to the unified observation preprocessor. New developments for this component will focus on similar preprocessing for the GOES AOD retrievals. Here, we focus only on

MODIS and GOES, but the preprocessor will follow a modular object-oriented design to facilitate preprocessing of any chemical species retrieved by the satellites and in-situ monitoring platforms.

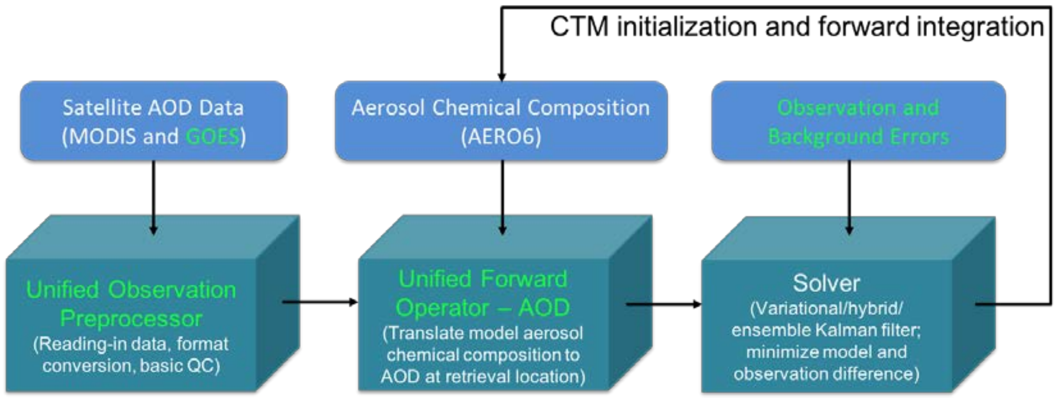

Figure 4. *Proposed design of the unified chemical DA system. Teal cubes represent major components of the system; blue boxes represent required inputs. Green text represents either the new capabilities that we will develop in JEDI (unified observation preprocessor and forward operator) or the new capabilities to process additional satellite observations.*

(2) *Unified Forward Operator for AOD*: In our current chemical DA system, the forward operator is based on a simple parametric expression (Malm and Hand, 2007) and is implemented outside the Community Radiative Transfer Model (CRTM). However, the JEDI framework requires the use of CRTM to simulate the relationship between model state vectors (aerosol chemical composition here) and satellite observed parameters (AOD here). The CRTM currently supports the GOCART aerosol chemical composition, so new developments in this project will focus on interfacing the CRTM with AERO6. This will require developing new modules specifying the structures containing AERO6 aerosol chemical composition and the corresponding aerosol scattering and absorption coefficients for calculating radiative transfer in an atmosphere with aerosols. These developments will then feed into another new routine that will calculate the tangent linear and adjoint models of the unified forward operator for AOD. These new capabilities will also be beneficial for the assimilation of satellite radiances for NWP, because aerosol-radiation interaction becomes significant in the short wavelength region, and can potentially affect the CRTM calculation of model radiances.

(3) *Solver*: The 3DVAR capability of GSI, which is adopted as one of the solvers in the JEDI, will be used here. In this stage, the most important parameters to be specified are the observation and background covariance matrix errors. We will use the same observation errors for MODIS as we are using in our ongoing NASA funded project, and will specify GOES observation errors based on GOES validation studies (e.g., Green et al., 2009). We discovered through other projects that traditional methods of generating the BE underestimate the variances significantly because they only include meteorological uncertainties. In our implementation of the BE, we added for the first time in a 3DVAR-based system for chemical DA uncertainties in anthropogenic emissions, and we found large improvements in both the initialization and deterministic predictions of $PM_{2.5}$ (figures 1b).

In this project, we will include other sources of uncertainties in $PM_{2.5}$ simulations in our BE generation such as the biomass burning, biogenic emissions, and secondary organic aerosol formation. Quantifying these uncertainties will leverage our ongoing NOAA funded project (Award # NA16OAR4590116 entitled “A Novel Ensemble Design for $PM_{2.5}$ Probabilistic Predictions and Quantification of Their Uncertainty”), where we are exploring different perturbation strategies involving meteorology, emissions, and chemical composition. The National Meteorological Center (NMC; Parrish and Derber, 1992) method of a community Generalized Background Error (GEN_BE) system will be employed for calculating monthly varying BEC. The NMC method requires two different CMAQ forecasts valid at the same time to calculate the BEC statistical parameters. We will initialize two CMAQ forecasts of 24 and 48 hours length with different meteorological and emissions input, which will then be fed to the GEN_BE to calculate the BEC statistical parameters at the proposed assimilation times of 00, 06, 12, and 18 Z. The solver will ingest these errors along with co-located model and observation information from the unified forward operator to iteratively minimize the differences between the model and observed states. Changes in AOD will be translated back to the aerosol chemical composition using the Jacobian estimated by the unified operator, and the updated aerosol chemical composition will be written to the model restart/initialization file.

The newly developed system will be used to initialize four 48-h CMAQ forecasts at 00, 06, 12 and 18 Z every day for the last 10 summers (June-September) of 2010-2019 via assimilation of both the GOES (at all 4 forecast times) and MODIS (at 18 Z) AOD. We will assimilate only 4 times a day to limit computational cost. Experiments with and without AOD assimilation will be performed to quantify the improvement to the CMAQ forecasts from assimilation of AOD.

3.3. Task 3: Improving Deterministic and Probabilistic $PM_{2.5}$ Forecasts via AnEn

The AnEn developed by NCAR and NOAA has been extensively tested for the probabilistic prediction of meteorological variables, renewable energy, and air quality. The AnEn is based on a historical set of deterministic predictions and observations of the variable to be predicted (predictand). For each forecast lead time and location, the ensemble prediction of a predictand comprises a set of past measurements (e.g., hourly $PM_{2.5}$ averages from the AIRNow network). These past measurements correspond to the past deterministic predictions for the same lead time and location that are chosen based on their similarity to the current forecast. Forecast variables used to identify past forecasts similar to the current one are called analog predictors. As previously mentioned, we will generate a long-term (10 years, 2010-2019) historical $PM_{2.5}$ forecast dataset that will be used to train the AnEn as implemented in the NAQFC operation. Surface $PM_{2.5}$ mass concentrations along with 2-m temperature (T2M), 10-m wind speed (WSPD) and wind direction (WDIR), and specific humidity (Q) will be used as the predictors. To select the predictor weights, we will use the brute force approach of Alessandrini et al. (2015), which defines the set of optimal weights by choosing the combination that minimizes the continuous ranked probability score (CRPS), computed over a training dataset and over all possible combinations. For $PM_{2.5}$ forecasting, the most useful predictors are CMAQ’s $PM_{2.5}$ concentrations and T2M (Figure 5).

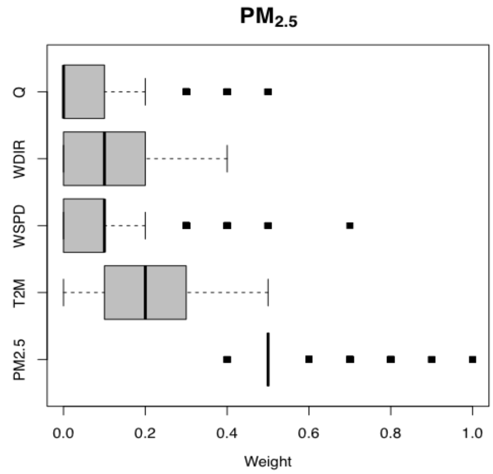

Figure 5. *Distribution of analog predictor weights across the available stations (Delle Monache et al., 2018). The grey boxes indicate the 25th–75th interquartile range, the black line within the box is the median, solid filled squares are the outliers, and the vertical black lines at the edges of the dashed lines are the minimum and maximum excluding the outliers.*

To further enhance the AnEn performance, we will include CO-fire as an additional predictor. This will help the AnEn to isolate past similar situations in which a station was affected by a wildfire plume. In those wildfire affected situations, the model would likely have made a similar error that can be more easily corrected in the current prediction. We understand that the training dataset may become invalid with routine upgrades of the NAQFC system. To minimize the impact of such routine upgrades, we will deliver automated scripts that can re-generate the training dataset within a couple of weeks. Furthermore, we will investigate the impact of training length on the AnEn $PM_{2.5}$ prediction accuracy. These experiments will provide guidance about the computing resources required to regenerate the optimal training forecast dataset for real-time operations.

3.4. Task 4: Evaluation and Performance Measure

For adequate comparison with the observations, CMAQ aerosol chemical composition will be converted to $PM_{2.5}$ mass concentrations using the sharp-cut $PM_{2.5}$ inlet method (Jiang et al., 2006). CMAQ simulated values will be paired with the observations using the CMAQ "sitecmp" utility that finds the CMAQ grid box containing the observation location. The evaluation will be performed at the diurnal and daily scales using time series, scatter plots, frequency distribution, and box plots. The model performance will be quantified using standard statistical metrics such as correlation coefficient, mean bias, root mean square error (RMSE), centered RMSE, normalized mean bias, and index of agreement. Figures 1b and 1c show an example of CMAQ simulated $PM_{2.5}$ mass concentration vs. AirNOW observations. Figure 6 shows the correlation coefficient (CC) in MET_BE and MET+EMIS_BE CMAQ experiments. Large variability in CC values across the US indicates heterogeneity in the model's ability to reproduce day-to-day variability in observed $PM_{2.5}$. DA improves the CC at more than 80% of the sites across the US, with larger improvements in the MET+EMIS_BE than the MET_BE. A similar approach will be applied with other statistical metrics to evaluate the performance of CMAQ $PM_{2.5}$ forecasts.

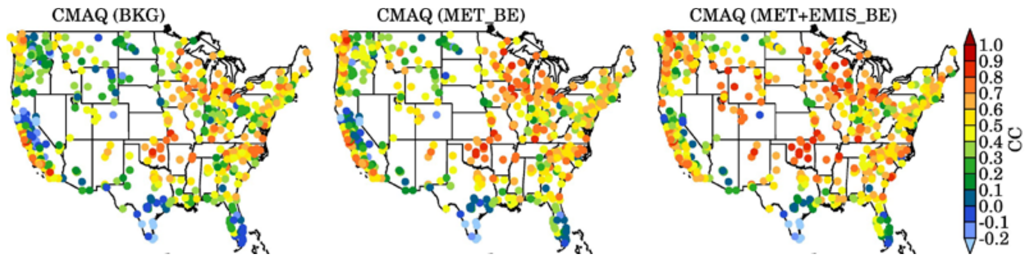

Figure 6: *Spatial distributions of the correlation coefficient (CC) for the three CMAQ experiments: BKG, MET_BE, and MET+EMIS_BE compared to AirNOW observations. Please see caption of Figure 1 for the description of CMAQ experiments.*

4. Operational applicability and past collaboration with operational community

Since all the components of the proposed system (i.e., CMAQ, GSI, and AnEn) are already used in NOAA operations, and since we will replicate the NAQFC configuration in our testing (as described in Section 3.1), we do not anticipate any problems in the operational applicability of the proposed system. We will rigorously test the chemical DA and the AnEn systems to demonstrate their performance in a relevant environment (i.e., achieving RL 5-7). The following steps will be taken to ensure success in a quasi-operational environment (RL 8):

- Ensure that the developed capabilities comply with the NCEP Central Operation (NCO) protocol that is enforced by NCO on all NCEP operational modeling systems, which requires that strict file formats, coding styles, scripting systems, and preferred scientific computer languages are used.
- Build contingency "fall back" logic in the forecast system to minimize forecast gaps, in the situation of missed observations downstream from satellites or a computer machine-maintenance issue, and to account for when DA and a forecast model simulation are unexpectedly interrupted. The forecast run stream subsequent to such an interruption should be able to analyze the situation and choose the best link to a recent forecast for the best-guessed field for model initialization. There are numerous other contingencies that require redundancy in an operational setting.
- All the developments will be tested on the NCAR supercomputer "Cheyenne", whose architecture is very similar to the NOAA supercomputer Theia. If the NAQFC decides that the project has sufficient merit to move it into operations (RL 9), the system will be tested and implemented on the NOAA supercomputer Theia, provided that the NAQFC can make it available.

Our team has developed a strong collaboration with the operational community over the past few years. We worked closely with Jun Du and Jeff McQueen of Environmental Modeling Center (EMC) to obtain the Short-Range Ensemble Forecast (SREF) members output, which were then down selected to drive CMAQ simulations in our ongoing NOAA project (Award # NA16OAR4590116). The GSI/CMAQ system was developed collaboratively with Pius Lee's group in the Air Resource Laboratory (ARL). We have also developed an air quality forecasting system for India in collaboration with the Indian Institute for Tropical Meteorology (IITM). That system will be transitioned to the IITM in January 2019 for operational use.

5. Current and projected Readiness Level and Project Beneficiary

The chemical DA and AnEn have already been shown to improve the accuracy of deterministic air quality forecasts and to reliably quantify their uncertainty; we estimate that the proposed project will begin at RL 4. As detailed in Section 4, we expect to reach RL 8 but will take the necessary steps to assure a smooth transition to RL 9 later. The NAQFC at EMC will be the beneficiary organization.

6. Project Management, Timeline, and Deliverables

We propose a 3-year (1 June 2019 to 31 May 2022) study. Team members have complementary expertise in air quality modeling and chemical DA (Kumar, Pfister, Alessandrini, and Delle Monache) and in AnEn development and application (Alessandrini, Delle Monache, Wilczak, Djalalova, and Allured). The timeline of different tasks, along with the deliverables, is shown in Table 2. The project will be managed via a collaborative management model that is supported by the collaborative track record of co-authorship among the proposal team.

Table 2: *Timelines and project deliverables.*

Year	Task	Deliverable
Year 1	Obtain evaluation datasets and develop/evaluate the chemical DA system	Submission of a peer-reviewed paper
Year 2	Generate long-term training dataset for AnEn and evaluate the AnEn performance	Submission of a peer-reviewed paper
Year 3	Test new capabilities in quasi-operational environment	Achieve RL 8

Overall responsibility for the project will reside with **Rajesh Kumar (NCAR, PI)**, who is the lead developer of the GSI/CMAQ chemical DA system. He has extensive experience in multiscale air quality forecasting and is currently leading developments of regional air quality forecasting systems for India and the upcoming FIREX-AQ campaign. He will lead the design, testing, and evaluation of the unified chemical DA system; collection, processing and quality control of the EPA observations for model evaluation; and will also contribute to the evaluation and testing of AnEn system. **Stefano Alessandrini (NCAR, Co-PI)** has extensive experience in using the AnEn across multiple applications, including air quality predictions. He is one of the main developers of the code, and he designed a bias correction scheme for rare/extreme events. He will lead the AnEn task. **Gabriele Pfister (NCAR, Co-I)** has extensive experience in combining satellite and in-situ observations (e.g. aircraft and ground-based measurements from field campaigns) in conjunction with regional and global atmospheric models to study local and regional air quality. She is a lead developer of WRF-Chem and the suite of NCAR WRF-Chem preprocessing tools. She will advise Kumar on the chemical DA task and contribute to the evaluation with field campaign data. **James Wilczak (NOAA, collaborator)** leads a team working on boundary layer processes and applications at NOAA with extensive experience in AnEn post-processing. He will advise the team on operational aspects of AnEn post-processing. **Irina Djalalova (NOAA, collaborator)** has extensive experience in air quality modeling and post-processing and will advise Kumar on the collection, quality control, and processing of the AirNOW data, and collaborate with Alessandrini on the AnEn task. **David Allured (NOAA, collaborator)** has extensive experience in scientific computing support, software engineering, and NCO protocols. He will advise Kumar to make all the developments NCO compliant. **Luca Delle Monache (UCSD, Collaborator)** is one of the lead developers of AnEn and will advise the team on the AnEn task.

7. Results from prior research

Award # NA16OAR4590116 entitled "A Novel Ensemble Design for $PM_{2.5}$ Probabilistic Predictions and Quantification of Their Uncertainty": PI: Rajesh Kumar - June 2016-present: This grant is supporting the development of a novel dynamical ensemble design for probabilistic predictions of $PM_{2.5}$ over the US. The ensemble is designed to capture three major sources of uncertainties in $PM_{2.5}$ forecasts: meteorological biases, emission uncertainties, and poor understanding of secondary organic aerosol processes. The meteorological part of the ensemble has already been designed, and a manuscript is under review on those results. Design of emission and chemistry ensemble is in progress. Data supporting the conclusions of the manuscript have been archived and a link to the archive is provided in the manuscript. This project will end in May 2019. During its final six months, we will transfer all the ensemble member configuration and associated scripts to the EMC.

8. Travel

We request funding for Rajesh Kumar to attend the American Geophysical Union (AGU) Fall Meetings in 2021 and 2022 so that the results from this project can be shared with the international community. In addition, we have requested funding for our collaborator, Luca Delle Monache (lead developer of the AnEn technique) to travel from San Diego to Boulder in 2021 to discuss the AnEn's performance and to seek his advice on further improving the AnEn.

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Data Management Plan

We will make all the environmental data collected or 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 two types of data: raw observational data (largely from satellites and in situ stations), and computer-generated model simulations and emission inventories. The raw data will be processed using computer-generated scripts that will lead to figures, maps, and tables in the manuscripts.

2. Data types, volume, formats, and standards

Raw observational data and model simulations are available in American Standard Code for Information Interchange (ASCII), Hierarchical Data Format (HDF), HDF-Earth Observing System (HDF-EOS), and Network Common Data Format (NetCDF). The processed data (i.e., final model analyses, satellite data collocated with model output for use in assimilation and model evaluation, paired model and in situ observations used in AnEn, and data used for manuscripts figures) will be stored in either ASCII or NetCDF formats, which are widely used standard formats in Earth science research. The total volume of data to be generated from this project is about 20 TB.

3. Data archiving and sharing schedule

All the processed datasets that will be used to produce figures, maps, and tables in manuscripts will be submitted as supplementary material at the time of manuscript submission to peer-reviewed journals. The accepted versions of manuscripts, along with supplementary material, will be uploaded into NCAR/UCAR Opensky, which provides free and open access to scientific output and other intellectual resources created at NCAR/UCAR(https://opensky.ucar.edu/). All the raw observational data to be used in this project are already publicly available. Raw model output in NetCDF and processed observational data will be stored on the NCAR Research Data Archive (RDA; https://rda.ucar.edu/) .

4. Intended repositories for archived data and mechanisms for public access and distribution

A master data catalog of model experiments and their purpose will be created for this project within an Excel spreadsheet and will be uploaded on the NCAR RDA website along with raw model output. A link to the publicly archived data will be created on the NCAR RDA webpage as well as on the NCAR website for community tools (https://www2.acom.ucar.edu/wrf-chem/wrf-chem-tools-community).

5. Plan for enabling long-term preservation of the data

The NCAR websites are already known for years to decadal-scale preservation of data. Thus, we expect that archival of data at these websites will enable long-term access of the datasets to the users.

6. Software archiving plan

The main software to be used in this project are the numerical chemical transport model CMAQ and the numerical weather prediction model WRF. These models are freely available to the community via https://www.epa.gov/cmaq/cmaq-models-0, and http://www2.mmm.ucar.edu/wrf/users/downloads.html. The computer programs to process the observational and modeling data will be written in Interactive Data Language (IDL) and NCAR command language (NCL), and will be made available to the community via NCAR's website for community tools. The software source code will be kept in NCAR's version control system using Git (or GitHub if appropriate) and will be shared with NOAA and other interested parties as needed.

7. Roles and responsibilities

Rajesh Kumar (PI) will be responsible for the overall data management and for archiving WRF-CMAQ simulations, DA experiments, collocating model output with satellite data, and the associated master catalog. Gabriele Pfister (co-I) will advise on WRF-CMAQ and chemical DA experiments. Stefano Alessandrini (co-PI) will be responsible for the AnEn application and analysis, with help from James Wilczak (collaborator), Irina Djalalova (collaborator), and Luca Delle Monache (collaborator).

8. Team experience

Rajesh Kumar (PI) currently provides anthropogenic emissions from the global Emission Database for Global Atmospheric Research developed as a part of the Hemispheric Transport of Air Pollution (EDGAR-HTAP), and Gabriele Pfister (co-I) provides a number of WRF-Chem preprocessing tools to the community via the NCAR WRF-Chem website for community tools. Both Rajesh Kumar and Gabriele Pfister have archived 50 TB of WRF-Chem output related to decadal air quality simulations in South Asia and the US on the NCAR High Performance Storage System (HPSS). Stefano Alessandrini (co-PI) has managed several multi-institution projects, producing and distributing large data sets, and has used data portals as the Earth System Grid (ESG) Gateway, NCAR's HPSS, and project-tailored web portals.

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Education and Training

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Kurukshetra Univ., Haryana, India	Physics	M.Sc. 2006
Univ. of Hamburg, Hamburg, Germany	Earth Sciences	Ph.D. 2012
Nat Center for Atmos. Res, Boulder, CO	Atmospheric Sciences	Postdoc 2013-2016

Appointments

2018-present:	Project Scientist II, RAL, National Center for Atmospheric Research (NCAR)
2016-2018:	Project Scientist I, RAL, National Center for Atmospheric Research (NCAR)
2015-2016:	Post-doctoral Scientist, RAL, NCAR
2015:	Post-doctoral Scientist, ACOM, NCAR
2013-2014:	Post-doctoral fellow, Advanced Study Program (ASP), NCAR
2011-2012:	Visiting Scientist, Max Planck Institute for Meteorology/Climate Service Center, Hamburg, Germany
2006-2012:	Research Fellow, Aryabhatta Research Institute of Observational Sciences, Nainital, India

Publications

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Education and Training

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2013–present:	Project Scientist II, National Center for Atmospheric Research.
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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: Rajesh Kumar DATE: December 2018

CURRENT SUPPORT

Project Title: A Novel Ensemble Design for PM2.5 Probabilistic Predictions and Quantification of Their Uncertainty
Principal Investigator: Rajesh Kumar
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: 6.48 Co-Sponsorship:

Project Title: Evaluation and Recommendation of State-of-the-Art Source Term Estimation Models for Methane Emission Applications
Principal Investigator: Daniel Steinhoff
Source of Support/Contract: ExxonMobil; Contract #EM10673
Contact Information: Heide Mairs; heide.l.mairs@exxonmobil.com
Total Award Amount: $300,000
Total Award Period Covered: 11/21/2016-3/31/2019
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 1.68 Co-Sponsorship:

Project Title: Chemical Data Assimilation and Analog-Based Uncertainty Quantification to Improve Decision-Making in Public Health and Air Quality
Principal Investigator: Rajesh Kumar
Source of Support/Contract: NASA; Contract #X15AH03G
Contact Information: John Haynes; (202) 358-4665; jhaynes@nasa.gov
Total Award Amount: $1,416,586
Total Award Period Covered: 3/19/2015-1/31/2019
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: .48 Co-Sponsorship:

Project Title: Multi-scale Chemical Forecasting and Analysis for FIREChem
Principal Investigator: Louisa Emmons
Source of Support/Contract: NASA; Contract #C18K0681
Contact Information: Barry Lefer; Ph: 202-358-3857; barry.lefer@nasa.gov
Total Award Amount: $525,000
Total Award Period Covered: 3/20/2018/-3/19/2021

Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 1.8   Co-Sponsorship:

PENDING SUPPORT

Proposal Title: Crowd-Sourced Environment Sensing and Terrain Analysis using Mobile Devices
Principal Investigator: Rajesh Kumar
Source of Support: Creare LLC
Contact Information: Jerry Bieszczad; Ph: 603-640-2445; jyb@creare.com
Total Award Amount: $93,026
Total Award Period Covered: 10/1/2017-9/30/2019
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 0   Co-Sponsorship:

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: Parvinder Maini; Ph: +91 11 2466 9557; parvinder.maini@moes.gov.in
Total Award Amount: $496,089
Total Award Period Covered: 9/15/2018-9/14/2020
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 8.67 Y1, 9.6 Y2   Co-Sponsorship:

Proposal Title: Understanding the Impact of Dust in the Formation and Evolution of Clouds Using Mesoscale and Microscale Modeling with CALIPSO and CloudSat Observations
Principal Investigator: Pedro Jimenez Munoz
Source of Support: NASA- Science Mission Directive
Contact Information: David Considine; Ph:202-358-2277; david.b.considine@nasa.gov
Total Award Amount: $597,734
Total Award Period Covered: 2/1/2019-1/31/2022
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: .41 Y1, 2.06 Y2, 1.96 Y3 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: 4.0 Y1, 3.01 Y2, 3.59 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: A Novel Method for Improving Fine Particulate Matter Air Quality Forecasts during Wildfires (THIS PROPOSAL)
Principal Investigator: Rajesh Kumar
Source of Support: NOAA – Oceanic and Atmospheric Research
Contact Information: Richard Fulton; richard.fulton@noaa.gov
Total Award Amount: $509,714
Total Award Period Covered: 6/1/2019-5/31/2022
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 3.82 Y1, 2.48 Y2 & 3 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: 1.96 Co-Sponsorship:

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 (THIS PROPOSAL)
Principal Investigator: Rajesh Kumar
Source of Support: NOAA – Oceanic and Atmospheric Research
Contact Information: Richard Fulton; richard.fulton@noaa.gov
Total Award Amount: $509,714
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
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:

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: Gabriele Pfister DATE: December 2018

CURRENT SUPPORT

Project Title: Chemical Data Assimilation and Analog-Based Uncertainty Quantification to Improve Decision-Making in Public Health and Air Quality
Principal Investigator: Rajesh Kumar
Source of Support/Contract: NASA / X15AH03G
Contact Information: John Haynes, jhaynes@nasa.gov, 202-358-4665
Total Award Amount: $1,416,586
Total Award Period Covered: 3/19/2015-1/31/2019
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 1.0 Co-Sponsorship: 0.0

Project Title: Global and Regional Chemical Forecasting and Analysis using CAM-chem, Data Assimilation and WRF-Chem for KORUS-AQ
Principal Investigator: Louisa Emmons
Source of Support/Contract: NASA / X16AD96G
Contact Information: Barry Lefer, barry.lefer@nasa.gov, 202-358-3857
Total Award Amount: $508,568
Total Award Period Covered: 10/1/2015-9/30/2019
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 1.2 Co-Sponsorship: 0.0

Project Title: Multi-scale chemical forecasting and analysis for FIREChem
Principal Investigator: Louisa Emmons
Source of Support/Contract: NASA / C18K0681
Contact Information: Barry Lefer, barry.lefer@nasa.gov, 202-358-3857
Total Award Amount: $525,000
Total Award Period Covered: 3/20/2018-3/19/2021
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 1.2 Co-Sponsorship: 0.0

PENDING SUPPORT

Project 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/Contract: NASA / NNH18ZDA001N-ACMAP
Contact Information: Richard S. Eckman, richard.s.eckman@nasa.gov, 202-358-2567
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: 0.4 Co-Sponsorship: 0.0

Project Title: Improved wildland fire emissions using a multi-sensor and coupled weather-fire model approach
Principal Investigator: Gabriele Pfister
Source of Support/Contract: NASA / NNH18ZDA001N-ACMAP
Contact Information: Richard S. Eckman, richard.s.eckman@nasa.gov, 202-358-2567
Total Award Amount: $530,692
Total Award Period Covered: 2/24/2019-2/23/2022
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 1.2 Co-Sponsorship: 0.0

Project Title: Collaborative: Cyberlearning, Real-World Research and Job opportunities as Enhancing Tools to STEM education at USFSP
Principal Investigator: Gabriele Pfister
Source of Support/Contract: NSF / 18-583
Contact Information: Amanda S. Adams, amadams@nsf.gov, 703-292-8521
Total Award Amount: $103,698
Total Award Period Covered: 7/1/2019-6/30/2022
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 0.1 Co-Sponsorship: 0.0

Project Title: A Novel Method for Improving Fine Particle Matter Air Quality Forecasts During Wildfires (THIS PROPOSAL)
Principal Investigator: Rajesh Kumar
Source of Support/Contract: NOAA / OAR-OWAQ-2019-2005820
Contact Information: Richard Fulton, richard.fulton@noaa.gov, 301-734-1289
Total Award Amount: $509,714
Total Award Period Covered: 6/1/2019-5/31/2022
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 0.41 Co-Sponsorship: 0.0

UCAR

UCAR Proposal Budget Detail

Proposal #	2019-0021
Proposal Title:	A novel method for improving fine particulate matter air quality forecasts during wildfires
UCAR Entity:	NCAR
Period of Performance:	06-01-2019 - 05-31-2022
Principal Investigator	RAJESH KUMAR

			Unit / Rate	Effort Year 1	Effort Year 2	Effort Year 3	Year 1 NOAA - Oceanic and Atmospheric Research	Year 2 NOAA - Oceanic and Atmospheric Research	Year 3 NOAA - Oceanic and Atmospheric Research	Cumulative Grand Total
Salaries	**Regular Salaries**	PROJ SCIENTIST II	FTE	0.39	0.26	0.26	36,252	25,392	25,803	**87,447**
		PROJ SCIENTIST III	FTE	0.23	0.27	0.27	25,079	31,072	31,607	**87,758**
		SCIENT III SECT HEAD	FTE	0.04	0.04	0.04	4,975	5,175	5,381	**15,531**
	Subtotal Salaries						**66,306**	**61,639**	**62,791**	**190,736**
Fringe Benefits		Regular Benefits @	54.90 %				36,401	33,840	34,472	**104,713**
	Subtotal Fringe Benefits						**36,401**	**33,840**	**34,472**	**104,713**
	Total Salaries and Benefits						**102,707**	**95,479**	**97,263**	**295,449**
Materials and Supplies		Publication / Page Charges					0	3,000	3,000	**6,000**
	Subtotal Materials and Supplies						**0**	**3,000**	**3,000**	**6,000**
Purchased Services		Communications					100	100	100	**300**
	Subtotal Purchased Services						**100**	**100**	**100**	**300**
Travel		Domestic - Collaborator to Visit NCAR					0	1,779	0	**1,779**
		Domestic - Present results at AGU Meeting					0	3,110	3,234	**6,344**
	Subtotal Travel						**0**	**4,889**	**3,234**	**8,123**
	Modified Total Direct Costs (MTDC)						**102,807**	**103,468**	**103,597**	**309,872**
Indirect Costs		NCAR Indirect Cost Rate (MTDC)	56.90 %				58,497	58,873	58,947	**176,317**
	Total Indirect Costs						**58,497**	**58,873**	**58,947**	**176,317**
MTDC Costs that Include Indirect Costs	**Computing Service Center**	Computing Service Center	$7.00 / hr				504	504	504	**1,512**
		Computing Service Center	$7.33 / hr				8,115	7,030	6,868	**22,013**
	Subtotal MTDC Costs that Include Indirect Costs						**8,619**	**7,534**	**7,372**	**23,525**
	Total MTDC + Applied Indirect Costs						**169,923**	**169,875**	**169,916**	**509,714**
	Total Funding To UCAR						**169,923**	**169,875**	**169,916**	**509,714**

NCAR Proposal 2019-0021 - Budget Justification

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

Institution	Year 1	Year 2	Year 3	Total
NCAR	$169,923	$169,875	$169,916	$509,714
NOAA ESRL	$ 0	$ 0	$ 0	$ 0
UCSD	$ 0	$ 0	$ 0	$ 0
TOTAL	$169,923	$169,875	$169,916	$509,714

NCAR BUDGET JUSTIFICATION: $509,714

A. Personnel: $190,736

Position Title & Name	Yearly Salary	% of Time	No. of Months	$ Amount
PI, Project Scientist II, Rajesh Kumar	$108,364 Year 1 $112,695 Year 2 $117,203 Year 3 Total	38.9% 26.2% 25.6% 90.7%	4.01 2.70 2.64 9.35	$36,252 $25,392 $25,803 $87,447
Co-PI, Project Scientist III, Stefano Alessandrini	$126,793 Year 1 $131,860 Year 2 $137,135 Year 3 Total	23.0% 27.4% 26.8% 77.2%	2.37 2.83 2.77 7.97	$25,079 $31,072 $31,607 $87,758
Co-PI, Scientist III,	$144,637 Year 1	4.0%	0.41	$ 4,975

Section Head, Gabriele Pfister	$150,417 Year 2 $156,434 Year 3 Total	4.0% 4.0% 12.0%	0.41 0.41 1.23	$ 5,175 $ 5,381 $15,531

A Project Scientist II (Dr. Rajesh Kumar) will serve as the Principal Investigator and charge approximately 4.01 months in Year 1, 2.7 months in Year 2 and 2.64 months in Year 3 on this project with a salary range between $108,364 and $117,203. This labor will include overall management of the project. He will also lead the design of the unified chemical data assimilation system, perform the data assimilation experiments, evaluate the model results. He will also be responsible for downloading, quality controlling, and processing the EPA AirNOW raw observations. He will also contribute to the analog-ensemble task and work on ensuring NCO compliance of the new developments. He will participate in national and international meetings to disseminate the results of this project.

A Project Scientist III (Dr. Stefano Alessandrini) will serve as Co-Investigator and charge approximately 2.37 months in Year 1, 2.83 months in Year 2 and 2.77 months in Year 3 on this project with a salary range between $126,793 and $137,135. This labor will include leading the analog-ensemble task especially design, evaluation and analysis of analog-ensemble produced results. He will also contribute to the evaluation of the chemical data assimilation task and help Kumar in downloading and processing the EPA raw observations.

A Scientist III, Section Head (Dr. Gabriele Pfister) will serve as Co-Investigator and charge approximately 0.41 months in each year on this project with a salary range between $144,637 and $156,434. This labor will include advising Rajesh Kumar on the chemical data assimilation task. She will also contribute to the evaluation of model results.

All the personnel will participate in discussion of scientific results and manuscript writing.

A 4% annual salary increase has been included.

B. Fringe Benefits: $104,713

Position Title & Name	Yearly Salary	% Rate	$ Amount
PI, Project Scientist II, Rajesh Kumar	$108,364 Year 1 $112,695 Year 2 $117,203 Year 3 Total	54.9% 54.9% 54.9% 54.9%	$19,902 $13,940 $14,166 $48,008
Co-PI, Project Scientist III, Stefano Alessandrini	$126,793 Year 1 $131,860 Year 2 $137,135 Year 3 Total	54.9% 54.9% 54.9% 54.9%	$13,768 $17,059 $17,352 $48,179
Co-PI, Scientist III, Section Head, Gabriele Pfister	$144,637 Year 1 $150,417 Year 2 $156,434 Year 3 Total	54.9% 54.9% 54.9% 54.9%	$ 2,731 $ 2,841 $ 2,954 $ 8,526

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: $8,123

Domestic Travel: A total of $8,123 is budgeted for domestic travel. This includes the following travel:

1. Years 2 and 3: One person, 6 days (5 nights) to San Francisco, CA to attend the annual AGU Conference and share results with the community.
2. Year 2: One person, 6 days (5 nights) for UC San Diego collaborator trip to Boulder CO for discussion on the analog-ensemble results and performance.

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:	2019-0021							
PI:	Rajesh Kumar							
Destination	Purpose	# of Travelers	Airfare	Per Diem	Car	Hotel	Conf. Reg & Misc	Total Trip Cost
Year 2 - Travel 1								
San Francisco, CA	AGU	1	$591	$356	$0	$1,541	$622	**$3,110**
Year 2 - Travel 2								
From UC San Diego to Boulder	Collaborator Trip	1	$363	$309	$187	$817	$102	**$1,779**
Total for Yr 2 Travel								**$4,888**
Year 3 - Travel 1								
San Francisco, CA	AGU	1	$614	$370	$0	$1,603	$647	**$3,234**
Total for Yr 3 Travel								**$3,234**
Total All Years								**$8,123**

D. Equipment: None

E. Supplies: None

F. Contractual: None

G. Construction: None

H. Other: $29,825

Communications: $300
$300 total ($100 per year) has been budgeted for communications costs. Cost estimate is based on previous experience.

Publications: $6,000
$6,000 total ($3,000 per year in Years 2 and 3) has been budgeted for two journal articles in peer-reviewed publications. Cost estimate is based on recent costs to publish in Journal of Geophysical Research – Atmospheres journals.

Computer Services: $23,525
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. The ACOM CSC rate for 2018 is $7.00 per labor hour.

I. Total Direct Charges: $333,397

A. Personnel:	$190,736
B. Fringe:	$104,713
C. Travel:	$ 8,123
D. Equipment:	$0
E. Supplies:	$0
F. Contractual:	$0
G. Construction:	$0
H. Other:	$29,825
Total Direct Costs:	$333,397

J. Indirect Charges: $176,317

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: $509,714

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:	**ON BEHALF OF THE FEDERAL GOVERNMENT:**
University Corporation for Atmospheric Research (UCAR) (Organization)	National Science Foundation (Agency)
Meli D. Miller (Signature)	Meghan A. Benson (Signature)
Melissa D. Miller (Name)	Meghan A. Benson (Name)
Vice President, Finance & Administration (Title)	Lead Analyst, Indirect Cost Rates Cost-Analysis and Pre-Award Branch (Title)
12/29/17 (Date)	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 B A

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

P.O. BOX 3000 | BOULDER, CO 80307-3000 USA | 303-497-1000 | WWW.NCAR.UCAR.EDU

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	8	8
Number of Days[2]	260	260	260
ISS Rate/Day[3]	**$554**	**$608**	**$608**
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]	**$748**	**$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: Federal (c)	Estimated Unobligated Funds: Non-Federal (d)	New or Revised Budget: Federal (e)	New or Revised Budget: Non-Federal (f)	New or Revised Budget: Total (g)
1.	Weather and Air Quality Research	11.459	$	$	$ 509,714.00	$	$ 509,714.00
2.							
3.							
4.							
5.	Totals		$	$	$ 509,714.00	$	$ 509,714.00

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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	$ 66,306.00	$ 61,639.00	$ 62,791.00	$	$ 190,736.00
b. Fringe Benefits	36,401.00	33,840.00	34,472.00		104,713.00
c. Travel	0.00	4,889.00	3,234.00		8,123.00
d. Equipment					
e. Supplies					
f. Contractual					
g. Construction					
h. Other	8,719.00	10,634.00	10,472.00		29,825.00
i. Total Direct Charges (sum of 6a-6h)	111,426.00	111,002.00	110,969.00		$ 333,397.00
j. Indirect Charges	58,497.00	58,873.00	58,947.00		$ 176,317.00
k. TOTALS (sum of 6i and 6j)	$ 169,923.00	$ 169,875.00	$ 169,916.00	$	$ 509,714.00
7. Program Income	$	$	$	$	$

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Tracking Number:GRANT12763161 Funding Opportunity Number:NOAA-OAR-OWAQ-2019-2005820 Received Date:Dec 19, 2018 04:24:40 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	$ 169,923.00	$ 42,481.00	$ 42,481.00	$ 42,481.00	$ 42,480.00
14. Non-Federal	$				
15. TOTAL (sum of lines 13 and 14)	$ 169,923.00	$ 42,481.00	$ 42,481.00	$ 42,481.00	$ 42,480.00

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	$ 169,875.00	$ 169,916.00	$	$
17.				
18.				
19.				
20. TOTAL (sum of lines 16 - 19)	$ 169,875.00	$ 169,916.00	$	$

SECTION F - OTHER BUDGET INFORMATION

21. Direct Charges: Modified Total Direct Costs (MTDC) = $309,872

22. Indirect Charges: Indirect Costs on MTDC = $176,317

23. Remarks: Indirect Costs = FY18 rate of 56.9% x MTDC = .569 x $309,872 = $176,317