Application for Federal Assistance

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Submitted for:	FY2021 Weather Program Office Research Programs
Notice of Funding Opportunity Number:	NOAA-OAR-WPO-2021-2006592
CFDA Number:	11.459

Application Documents for Review

Post-Processing of CMAQ forecast for Improving Air Quality Predictions
18 November 2020

Proposal to:
NOAA Solicitation #: **NOAA-OAR-WPO-2021-2006592**
Competition Title: FY2021 Weather Program Office Research Programs

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Institution	Year 1	Year 2	Total
NCAR	$200,065	$206,806	$406,871
CU-CIRES*	$ 71,469	$ 71,549	$143,018
NOAA PSL	$ 18,531	$ 18,451	$36,982
TOTAL	$290,065	$296,806	$586,871

* For The University of Colorado, if funded, we request that the award not be sent via the Cooperative Agreement (Award NA17OAR4320101) and we request that this Award not be linked with our cooperative agreement.

Post-Processing of CMAQ forecast for Improving Air Quality Predictions

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Abstract

This proposal aims to apply a machine learning (ML) post-processing to improve the Community Multi-scale Air Quality (CMAQ) model operational air quality forecasts issued over the US by NOAA/NCEP. Specifically, we propose an extension of the analog ensemble (AnEn) capability currently implemented at NCEP from point-based to 2D gridded predictions. The AnEn method has been successfully applied in weather prediction systems for a range of meteorological parameters, and also, in an effort funded by the National Aeronautics and Space Administration (NASA; PR No.: 4200545387, Grant No.: NNX15AH03G), on predictions of ozone and fine particulate matter ($PM_{2.5}$) at surface monitoring locations of the Environmental Protection Agency (EPA) AirNow. The AnEn method effectively reduces systematic and random errors contaminating CMAQ model forecasts (Djalalova et al., 2015, Delle Monache et al., 2020), and also provides accurate and reliable probabilistic wind speed predictions (e.g., Delle Monache et al. 2013; Alessandrini et al., 2019).

We propose to apply the AnEn to reduce the errors of CMAQ $PM_{2.5}$ and ozone surface concentrations using a combination of past gridded chemical reanalysis from the Copernicus Atmosphere Monitoring Service (CAMS) Near-Real-Time model with measurements from AirNow stations. The CAMS analysis is produced by assimilation of satellite retrievals of total column CO, tropospheric column NO_2, aerosol optical depth (AOD), and total column, partial column and profile ozone retrievals in the ECMWF's Integrated Forecasting System (IFS). While a comprehensive evaluation of the CAMS analyses against AirNow has not been performed yet, it is shown to have smaller biases compared to previous chemical reanalyses produced by ECMWF and suitable for computing climatologies, trends, evaluate models, and benchmarking other reanalyses (Inness et al., 2019). $PM_{2.5}$ and ozone 2D gridded analysis fields are generated every 12 hours with a horizontal grid spacing of about 40 km. Also, surface $PM_{2.5}$ and ozone concentration gridded forecasts are issued every 12 hours with one-hour time increments out to 5 days. The analog method requires a continuous training dataset of hourly values of observed chemical concentrations. For this purpose we will use each CAMS analysis (performed every 12h) and its subsequent 11 forecast hours to form a continuous set of hourly observations or pseudo-observations. The CAMS surface $PM_{2.5}$ and ozone fields will be merged with the respective observations from the AirNow network in order to preserve the measured values at the station locations. Hence, at these locations the forecasting system will generate forecasts consistent with the current post-processing system implemented at NAQFC.

The newly developed forecasting systems will use the same version of the AnEn code running operationally at NOAA/NCEP and will include scripts and procedures to download CAMS data and generate the input files for the AnEn. These scripts and procedures will be transitioned to NOAA/NCEP for the operational implementation during the second year of the project.

Statement of Work

1.Problem Statement

Scientific problem and goal:

Poor air quality (AQ) in the U.S. adversely affects both human health and the economy. For instance, Im et al. (2018) estimated that in 2010 alone, 160,000 premature deaths and a total economic loss of $175 billion in the U.S. were caused by air pollution. To reduce such losses, the National Air Quality Forecasting Capability (NAQFC) at the National Oceanic and Atmospheric Administration (NOAA) produces forecasts of ozone, particulate matter, and other pollutants so that advance notice and warning can be issued to help individuals and communities limit the exposure and reduce health problems caused by air pollution. Although it is difficult to quantify the benefits of accurate air quality predictions, if such predictions can reduce the premature deaths and associated costs by even 1%, then over 1,000 lives and over $1 billion could be saved annually in the U.S. Thus, more accurate air quality predictions can have a tangible, substantial benefit to society.

The NAQFC uses the U.S. Environmental Protection Agency (EPA) CMAQ model (Byun and Schere 2006) for operational air quality forecasts. Recently, the operational NAQFC CMAQ forecast, which is run twice daily for 48 h and covers the CONUS at a 12-km grid spacing, has transitioned to be driven offline by the Finite Volume Cubed-Sphere (FV3) dynamical core-based Global Forecast System (Putman and Lin 2007). The errors and biases in the CMAQ forecasts arise primarily due to errors in the meteorological forcing, uncertainties in emission estimates, and for $PM_{2.5}$ an inadequate understanding of the lifecycle of secondary organic aerosols (SOAs). The EPA continuously works on improving the emission estimates and representation of atmospheric chemical processes in CMAQ (e.g., (Nolte et al. 2015); (Appel et al. 2017); (Fahey et al. 2017)), and the NAQFC team routinely ingests these improvements into the operational version of CMAQ (Lee et al. 2017). Despite these efforts the $PM_{2.5}$ and surface ozone forecasts are still affected by systematic biases and random errors that can undermine their usefulness to issue warnings and to prevent population exposure. To further improve operational air quality forecasts at NAQFC and adding uncertainty quantification, a machine learning-based post processing technique, the analog ensemble (AnEn), has been running operationally at NAQFC since 2016.

The AnEn utilizes a training dataset comprising predictions from FV3/CMAQ and corresponding observations of the quantity to be predicted (i.e., O_3 or $PM_{2.5}$), to generate future ensemble predictions based on past observations. For a given deterministic FV3/CMAQ forecast, the ensemble is constructed by collecting past observations corresponding to the best matching past FV3/CMAQ forecasts (called analogs) to the current FV3/CMAQ prediction (Figure 1). The matching procedure is performed across a few variables such as the pollutant itself and meteorological parameters that are well correlated with it (e.g., wind, temperature and relative humidity). Also, *the AnEn can use only one deterministic model prediction to generate an ensemble, therefore avoiding the need for model perturbation strategies, and reducing considerably the real-time computational cost of generating an ensemble.*

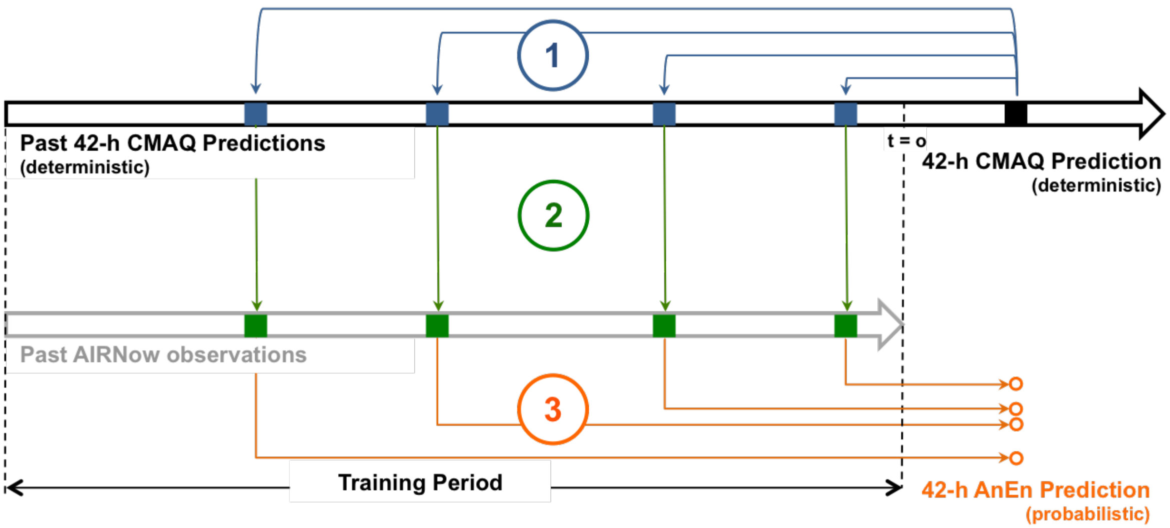

Figure 1. *Schematic representation of the process for finding analogs and to generate a 4-member analog ensemble (AnEn) at forecast lead-time 42.*

In the current operational implementation at NAQFC, the AnEn is applied to improve $PM_{2.5}$ and surface ozone 0–48 hour forecasts only at the locations (Figure 2) corresponding to the EPA's AirNow network (EPA, 2017) in the CONUS, which provide hourly concentrations of O_3 and $PM_{2.5}$ at approximately 1300 and 900 site, respectively. On the other hand, two-dimensional ground-level maps of expected pollution levels can provide important air quality information to the public beyond just specific measurement locations. **Approximately 42 million Americans are estimated to live in unmonitored areas.** Since the AnEn is applied only at locations where observations are available, the creation of a 2D deterministic forecast map is carried out by spreading the bias-correction and uncertainty information from the points where it is calculated to other nearby model grid points. To properly carry out this task, it would be necessary to know the correlation between the errors at the observation locations and at nearby grid points. In the current operational implementation, a Barnes-type (Djalalova et al. 2015) iterative objective analysis is carried out assuming that the bias of the CMAQ forecasts with respect to the AnEn spreads within a radius of influence around the locations of the measurements (Figure 3). Clearly, this procedure is less effective in areas with a low density of observations or in the case of a highly spatially discontinuous model bias such as in the presence of smoke plumes from wildfires. This problem can be overcome by applying the AnEn at each model grid point, which requires having a collocated estimate of the pollutant's concentration.

We propose to apply the AnEn to reduce the errors of CMAQ $PM_{2.5}$ and ozone surface concentrations using a combination of the past gridded chemical reanalysis from the Copernicus Atmosphere Monitoring Service (CAMS) Near-Real-Time model and measurements from the EPA AirNOW stations.

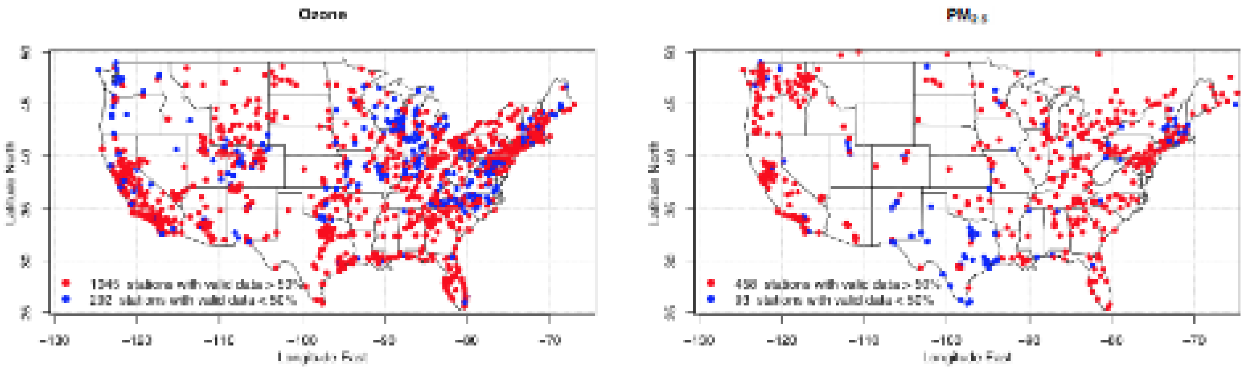

Figure 2. *O_3 (left) and $PM_{2.5}$ (right) observation sites where the AnEn is currently operationally applied at NAQFC. Red and blue colors mark the sites where hourly observations are generally available for more than 50% or less than 50% of the times (adapted from Delle Monache et al. 2020)*

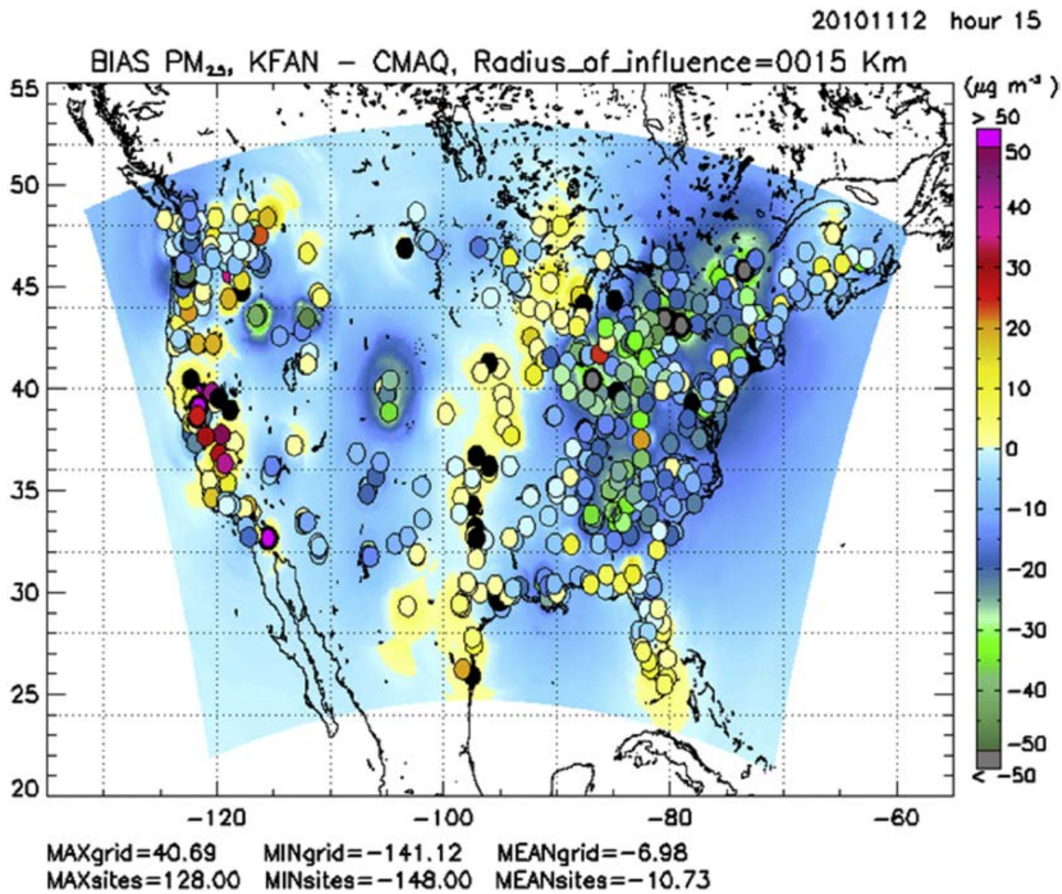

Figure 3. *The gridded AnEn forecast $PM_{2.5}$ bias field at forecast hour 15 on 12 Nov 2010. The overlaid open circles show the corresponding observed bias in the raw CMAQ model at the AirNow observation sites (adapted from Djalalova et al. 2015).*

The CAMS analysis is produced by assimilation of satellite retrievals of total column CO, tropospheric column NO_2, aerosol optical depth (AOD), and total column, partial column and profile ozone retrievals in the ECMWF's Integrated Forecasting System (IFS). While a comprehensive evaluation of the CAMS analyses against AirNow has not been performed yet, it has been shown to have smaller biases compared to previous chemical reanalyses produced by ECMWF and suitable for computing climatologies, trends, evaluate models, and benchmarking other reanalyses (Inness et al., 2019). $PM_{2.5}$ and ozone 2D gridded analysis fields are generated every 12 hours with a horizontal grid spacing of about 40 km. Also, surface $PM_{2.5}$ and ozone concentration gridded forecasts are issued every 12 hours with one-hour time increments up to 5 days ahead. The analog method requires a continuous training dataset of hourly values of observed chemical concentrations. For this purpose we will use each CAMS analyses (performed every 12 h) and its 11 forecast hours to form a continuous set of hourly observations or pseudo-observations. Also, we will combine the surface $PM_{2.5}$ and ozone observations in a unique 2D gridded field using the Satellite Enhanced Data Interpolation (SEDI) technique described by Dinku and Alessandrini (2015). In this work, SEDI was used to generate 2D gridded precipitation fields combining satellite-derived estimates with ground level station measurements. The combined surface $PM_{2.5}$ and ozone fields will preserve the values observed at the station locations and will smoothly relax to the CAMS field moving away from these locations. Figure 4 shows an example of ozone CAMS analysis for 08 Nov 2020. Recently, the NASA GEOS-5 model has also started issuing global air quality forecasts at 25 km grid spacing, it does not assimilate as many satellite observations of atmospheric composition as CAMS does and thus is not ready yet for the type of analysis proposed here.

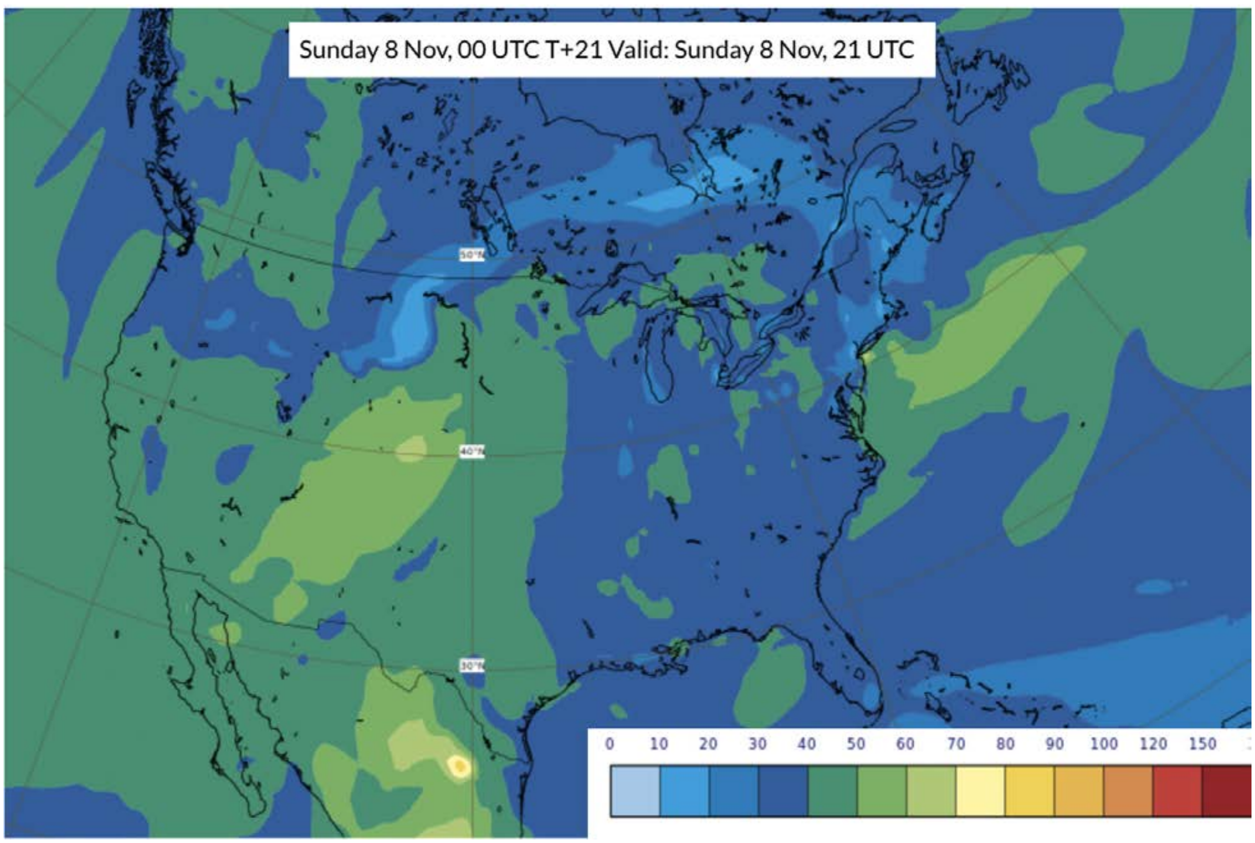

Figure 4. *Example of surface ozone CAMS analysis for 08 Nov 2020.*

Relevance to NOAA Science Priorities

The AnEn methodology presents a computational advantage because its efficiency can be enhanced through parallelization, running simultaneously for multiple locations (grid points). This is the case for 2D applications when thousands of points are considered concurrently. So, the proposed modeling system will provide the NAQFC with the capability of generating reliable, bias-free, gridded ensemble air quality forecasts at a significantly lower real-time computational cost compared to a dynamical ensemble. This fits with JTTI-1(c) priority to accelerate the use of AI in product generation in operations, particularly or better use of existing ensembles.

Results from prior research

The AnEn method has been successfully applied in weather prediction systems for a range of meteorological parameters such as wind speed and temperature, and also, in an effort funded by the National Aeronautics and Space Administration (NASA; PR No.: 4200545387, Grant No.: NNX15AH03G), on predictions of ozone and $PM_{2.5}$ at surface monitoring locations of the EPA AirNow network. The AnEn method effectively reduces systematic and random errors contaminating CMAQ model forecasts (Djalalova et al., 2015, Delle Monache et al., 2020), and also provides accurate and reliable probabilistic wind speed predictions (e.g., Delle Monache et al. 2013; Alessandrini et al., 2019).

Past studies have monitored and assessed the performance of the operational product (Djalalova et al., 2015; Delle Monache et al., 2020) during the last few years proving that the AnEn drastically reduces both systematic and random errors of the CMAQ $PM_{2.5}$ and O_3 deterministic predictions, while considerably increasing the correlation between the predictions and the observations. Also, the AnEn has demonstrated the ability to produce reliable probabilistic forecasts (i.e., no ensemble calibration is required). In Figure 5, we show a comparison from Delle Monache et al. (2020) between raw CMAQ and the AnEn for $PM_{2.5}$ and O_3 in terms of the root mean squared error, bias and correlation for the period 1 December 2015 to 29 February 2016 over EPA AirNow network stations.

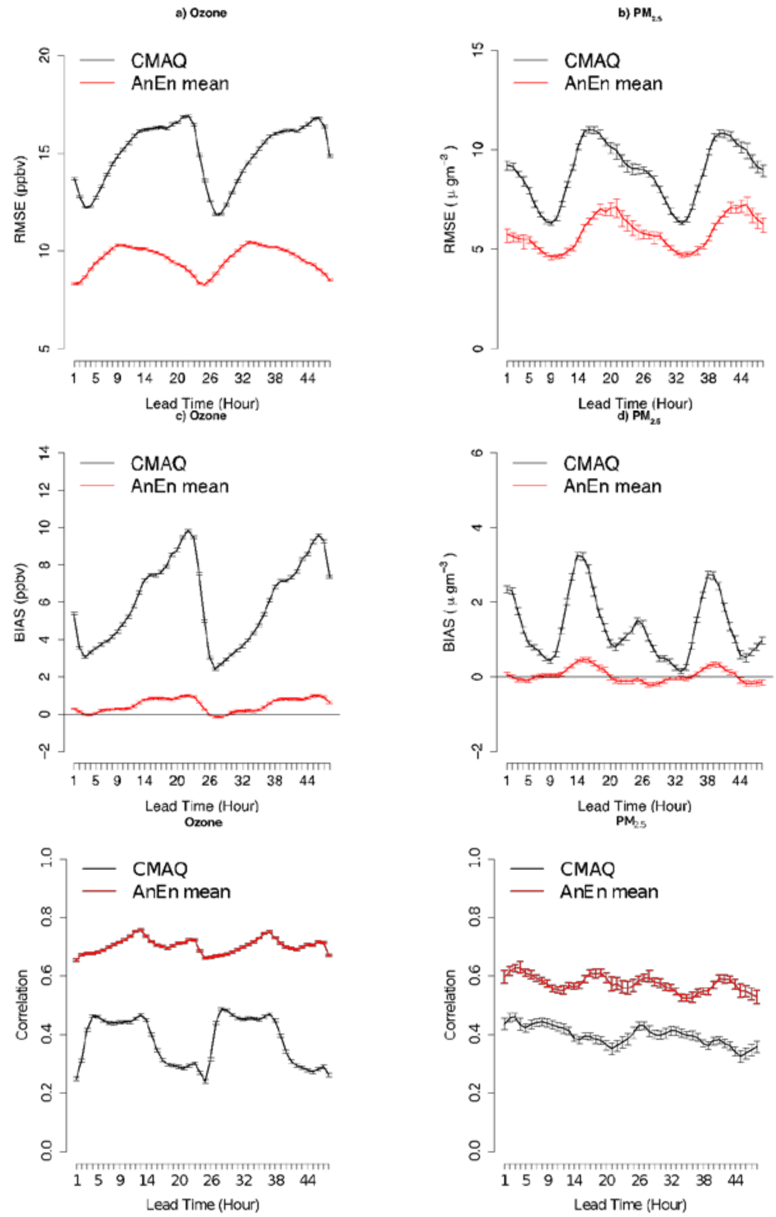

Figure 5. *RMSE (top), bias (middle), and correlation (bottom), of O_3 (left) and $PM_{2.5}$ (right), vs. lead time in forecasts from CMAQ (black) and AnEn mean (red). Calculations are averages over all sites during the periods of study described in the text (adapted from Delle Monache et al. 2020).*

The CAMS air quality forecasts are produced by the ECMWF IFS, which is also used for operational weather forecasts. The gas-phase chemistry in the IFS is represented using an extended version of the CB05 chemical mechanism (Yarwood et al., 2005), and aerosol processes are represented using a bulk model with size resolved dust and sea-salt emissions (Morcrette et al., 2009; Benedetti et al., 2009). Some of the recent updates in IFS include transitioning to more recent global anthropogenic emission estimates, updates to parameterizations of sea-salt and dust emissions, an improved hybrid linear ozone scheme for modeling of stratospheric ozone, and assimilation of volcanic SO_2 observations from the Sentinel-5p/TROPOMI instrument. The CAMS analysis is produced by assimilation of satellite retrievals of total column CO, tropospheric column NO_2, AOD, and total column, partial column and profile ozone retrievals in the IFS. While a comprehensive evaluation of the CAMS analyses against AirNow has not been performed yet, it is shown to have smaller biases compared to previous chemical reanalyses produced by ECMWF and suitable for computing climatologies, trends, evaluate models, and benchmarking other reanalyses (Inness et al., 2019). Another routine comparison of the CAMS global forecasts with independent observations concluded that the recent developments have led to some improvements in surface ozone and $PM_{2.5}$ at midlatitudes (Eskes et al., 2020).

2.Project Outputs/Products

Products

- A system based on FV3/CMAQ, the AnEn, and CAMS analysis fields to generate 0–48 hour $PM_{2.5}$ and O_3 2D hourly ensemble predictions over CONUS.
- The AnEn model is currently running operationally at the NOAA/NWS (RL9) to bias correct CMAQ predictions at the AirNow station locations.

The proposed system will include the same version of the AnEn used for operations at NAQFC which does not require any significant adaptation. The other component of the system will include a procedure to automatically download CAMS analysis fields from the Copernicus website and create the training dataset in a format (netCDF) compatible with the AnEn code. We anticipate that this procedure will have to run once a week to update the training dataset with the most recent CAMS fields. The system will be built and operationally tested at the NCAR High Performance supercomputer "Cheyenne" where it will reach a RL8. The transition to NOAA/NWS will occur during the last 6 months of the project.

Outputs

1) 0-72 hour $PM_{2.5}$ and O_3 hourly ensemble (20 members) 2D gridded predictions over CONUS. The same grid used by FV3/CMAQ will be maintained in the final product.
2) An offline evaluation of the performances of both the newly developed CMAQ-AnEn and the current operational air quality predictions, against observations from the EPA's AirNow network (EPA, 2017) in the CONUS, providing hourly concentrations of O_3 and $PM_{2.5}$ at approximately 1300 and 900 sites, respectively.

3.Outcomes and Impact

Performance assessment: The scope of this work is to improve the performance of the currently implemented post-processing technique in areas with a poor density of surface $PM_{2.5}$ and ozone observations. The proposed forecast systems will generate the same forecasts and keep the same performances as the currently implemented version at the AirNow station locations while we expect a significant improvement of the order of 10–40%, in terms of the metrics described here after, in other poorly monitored areas.

The performance of newly developed post-processed gridded deterministic and probabilistic predictions will be assessed against one-third of the EPA AirNow available observations, that will be used only for verification purposes, and compared with the current operational product. The post-processed deterministic predictions will be obtained by taking the ensemble mean. The performance will be assessed in terms of root-mean-square-error (RMSE) and its components, i.e., systematic errors (bias) and random errors (centered RMSE or error variance); correlation between observations and predictions, and compilation of statistical summary plots such as Taylor diagrams (Taylor 2001). The important attributes of probabilistic predictions will be evaluated with established metrics, including statistical consistency, resolution, reliability, sharpness, economic value, and spread-skill relationship.

Beneficiary: The NAQFC at EMC will be the beneficiary organization.

Societal benefit: This project is expected to provide more accurate air quality predictions along with uncertainty information which will help air quality forecasters around the country determine the value of air quality forecasts in their decision-making process. Timely and high confidence air quality alerts resulting from these products will help the public reduce their exposure to air pollution. Although it is difficult to quantify the benefits of accurate air quality predictions, if such predictions can reduce the premature deaths and associated costs by even 1%, then over 1,000 lives and over $1 billion could be saved annually in the U.S.

Complementing ongoing NOAA efforts: We realize that efforts are underway at NOAA to develop a chemical reanalysis system via assimilation of satellite observations of atmospheric composition similar to CAMS. To assure that CAMS reanalysis can be replaced with the future in-house chemical reanalysis to be produced at NOAA, we will develop a generic framework that will be capable of blending a gridded chemical reanalysis from any atmospheric composition model with the in situ AirNOW observations. In addition, this project will answer the important scientific question of whether a gridded analysis can improve the accuracy of the raw CMAQ forecasts. It's also important to underscore that the framework developed here can be easily adapted to a new model configuration including the likely future CMAQ replacement with FV3.

4. Methods and Activities

The proposed effort will involve the following tasks presented below. The people assigned to each task are also highlighted between parenthesis.

Task 1 (Alessandrini, Lee, NCAR Software Engineer, SE): Building the input training dataset for the AnEn including at least one year of past CAMS analyses and forecasts, and past CMAQ predictions of $PM_{2.5}$ and ozone concentration.

We will build a procedure to automatically download CAMS data over CONUS, interpolate them over the CMAQ grid, combine them with the ground observations from the EPA AirNow network, and create a netCDF file compatible with the AnEn version running at NAQFC. During this process, we will also compare the CAMS analysis and CMAQ forecasts against the AirNow observations and we expect that CAMS analysis will outperform CMAQ forecasts. We will also build a procedure to extract FV3/CMAQ forecasts at all the grid points and convert them in the proper format compatible to the AnEn input. This task will be carried out after consulting with NAQFC personnel to meet their requirements for the subsequent implementation in the operational environment.

Task 2 (NCAR SE, Alessandrini, Kumar): Implementing the CMAQ-AnEn based prediction system over the Contiguous United States (CONUS) in a quasi-operational environment for real-time testing;

The procedures developed in Task 1 will be linked to the AnEn code to have the whole forecast system working on an NCAR HPC. We will perform a specific grid point-dependent optimization off-line to assign different weights to the predictors. Similarly to our past work described in Sperati et al. (2017), each grid point will be treated as an independent location where the past observations will be retrieved by the CAMS analysis gridded field, used as the "ground truth". We will run the forecasting system twice a day (at 00 UTC and 12 UTC) at least for 4 months (one for each season: January, April, July and October) in a quasi operational environment.

Task 3 (Djalalova, Alessandrini, Lee, Kumar): Evaluating the results of the real-time testing;
We will use the metrics outlined in section 3 to assess the performance of the forecasting system for the four months covered by the simulations carried out in Task 2. These metrics will be compiled by comparing the $PM_{2.5}$ and ozone forecasts against the EPA AirNow station measurements. For $PM_{2.5}$, we will also focus on a few episodes involving wildfire smoke plumes. The performance of newly developed post-processed gridded deterministic and probabilistic predictions will be assessed against one-third of the EPA AirNow available observations, that will be used only for verification purposes without combining them with the CAMS field, and compared with the current operational product. In this process, NCAR will also rerun the current operational product for the same four months without using the stations selected for the verification during the spatial spreading of the bias.

Task 4 (Alessandrini, Kumar, Djalalova, Wilczak, McQueen, Peuch): Work with the NAQFC to communicate validation results.
Stefano Alessandrini and Rajesh Kumar attend the bi-weekly remote meetings with NAQFC scientists. We will have the possibility to present the validation results from Task 3 at these meetings.

Task 5 (NCAR SE): Automate the AnEn system to run in real-time on NOAA computing systems, including automatization of the required download of CAMS data.
We will work with NAQFC personnel and provide them with the procedures developed in the tasks above. We will provide assistance for a smooth transition to the NAQFC operations. We will write documentation to explain the different components of the forecasting system. The current implementation of AnEn in NOAA operations takes about 20 minutes to run for post-processing of ozone and PM2.5 forecasts at about 1300 stations using one processor. Since we will apply the post-processing to the full CMAQ grid (442 x 265 grid points), we will parallelize the AnEn simulations so that the CMAQ grid can be divided into multiple tiles with each tile handled by an independent AnEn run. We estimate that running parallelized AnEn simulations on 90 processors with each processor handling ~1300 grid points will complete the post-processing of the entire CMAQ grid in about 20 minutes. This time is nearly 7 times smaller compared to the time taken (~ 140 mins) by a 72 h CMAQ deterministic forecast using 90 processors.

5.Timeline

We propose a 2-year (1 August 2021 to 31 July 2022) study. Team members have complementary expertise in air quality modeling and DA (Alessandrini, Kumar, and Lee) and in AnEn development and application (Alessandrini, Djalalova, NCAR SE, Wilczak). 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 1: Timeline of the tasks described in section 4 and RL achieved at the end of each task

	Year 1				Year 2			
Time (quarters)	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*
Task 1		*RL5*						
Task 2				*RL6*				
Task 3						*RL7*		
Task 4							*RL7*	
Task 5								*RL8*

6. Outreach and Education

NAQFC $PM_{2.5}$ and O_3 forecasts are currently available for visualization and download at https://www.emc.ncep.noaa.gov/mmb/aq/. The newly developed predictions will be able to be distributed through the same website pending NAQFC approval.

We will submit a paper regarding the validation carried out in Task 3 of the working plan in a scientific journal. We will also present our results at the AMS Annual Meeting for which we have requested funding in the proposed budget.

7. Diversity and inclusion

The UCAR and NCAR community is a diverse and vibrant group, composed of individuals with a wide array of backgrounds, identities, and perspectives. We acknowledge that in order to create an inclusive and welcoming environment that maximizes scientific, engineering, business, and education excellence, we must understand and value the myriad voices and perspectives of those in our community, and develop a culture of respect, inclusivity, and belonging that enables all of us to reach our full potential. As a result, we recognize that diversity, equity, and inclusion cannot be separated from the core mission of our organization. In 2019, UCAR published a DEI Strategic Plan that lays out UCAR's commitment to increasing excellence through hiring and promoting a talented and diverse workforce, establishing an environment of equity and inclusion, and to integrating these principles into our research, management, administrative, and educational practices at UCAR and NCAR.

8. ADDITIONAL REQUIRED INFORMATION, IF APPLICABLE:

i. Use of Human Subjects: Not Applicable
ii. Use of Testbeds: Not Applicable

iii. High-Performance Computing Request: Not Applicable
iv. NOAA Collaborators and/or Resources: Jeff Mcqueen and James Wilczak are included as unfunded NOAA collaborators. Jeff Mcqueen works at NAQFC where the technology proposed here will be transitioned. James Wilczak has been one of the main developers of the current operational post-processing system at NAQFC

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. The 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: observational data (from in situ stations and CAMS analyses), and computer-generated model simulations. 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), and Network Common Data Format (NetCDF). The processed data (i.e., final model analyses, 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 15 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. A link to the publicly archived data will be created on the NCAR RDA webpage.

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 the archival of data at these websites will enable long-term access to the datasets to the users.

6. Software archiving plan

The main software to be used in this project is the AnEn code which is already available to the community for research through GitHub. The numerical chemical transport model CMAQ CMAQ is freely available to the community via https://www.epa.gov/cmaq/cmaq-models-0, and FV3 can be accessed through NOAA VLab (https://vlab.ncep.noaa.gov/). The computer programs to process the observational and modeling data will be written in Fortran or other shell languages (i.e., bash) 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

Stefano Alessandrini (PI) will be responsible for the overall data management and for the AnEn application and analysis. Rajesh Kumar (Co-PI) and Jared Lee (Co-I) will be responsible for the overall data management and for archiving FV3-CMAQ, CAMS data.

8. Team experience

Stefano Alessandrini (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. Rajesh Kumar (Co-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). Rajesh Kumar has archived 50 TB numerical weather prediction model output related to decadal air quality simulations in South Asia and the U.S. on the NCAR High-Performance Storage System (HPSS). Jared Lee (Co-I) has archived over 4 TB of numerical weather prediction data on NCAR's Campaign Storage, and actively migrated data holdings off of the soon-to-be-decommissioned NCAR HPSS to Campaign Storage to ensure continued preservation of important data.

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Education and Training

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Appointments

2013–present:	Project Scientist III, 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 – Prior 3+ Years

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Positions

I.Djalalova is a Senior Research Scientist in CIRES. She works in CIRES/NOAA since 2005. Previously she worked for 8 years in NOAA as a Senior Application Engineer being a contractor through the Science and Technology Corporation.

Summary of air quality research

Djalalova has been working on air quality forecasting research for over 16 years. She was a team member during the multi-agency air quality experiments of NEAQS (2004) and TEXAQS II (2006). She developed, organized and supported the programming tools for visual comparison of observed and modeled meteorological and chemical variables, and evaluated several bias-corrected and model ensemble techniques for surface ozone and PM2.5. Most recent collaborative projects with NOAA/NWS are applied to the creation and evaluation of the operational bias-correction scheme to be used for ozone and PM2.5 forecasts. The code works operationally for PM 2.5 since January, 2016 and for ozone since December, 2018. The latest work related to the air-quality includes the collaborative research with NCEP and NCAR to improve the high-concentration ozone or PM 2.5 forecasting.

Journal Publications (last three years plus other relevant publications)

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Nat Center for Atmos. Res, Boulder, CO	Atmospheric Sciences	Postdoc 2013-2016

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Publications and Presentations – Prior 3+ Years

2020

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Education and Training

The Pennsylvania State University	Meteorology	Ph.D., 2012
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Gustavus Adolphus College	Physics	B.A., 2005
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Appointments

2018–present:	Project Scientist II, Research Applications Laboratory, NCAR, Boulder, CO
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2012–2013:	National Research Council Research Associate, Department of Meteorology, Naval Postgraduate School, Monterey, CA

Publications and Presentations – Prior 3+ Years

2020

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Lee, J. A., S. E. Haupt, B. Kosović, G. Wiener, and M. Al-Rasheedi, 2020: Development of the Kuwait Renewable Energy Prediction System (KREPS). 11th Conf. on Weather, Water, Climate, and the New Energy Economy, Boston, MA, Amer. Meteor. Soc., 3.1, https://ams.confex.com/ams/2020Annual/meetingapp.cgi/Paper/367679.

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Lee, J. A., M. Jacobson, T. Capozzola, C. Draxl, F. Vandenberghe, T. Jimenez, and S. E. Haupt, 2019: Assessment of the wind energy potential in Bangladesh. 10th Conf. on Weather, Climate, and the New Energy Economy, Phoenix, AZ, Amer. Meteor. Soc., 9.2, https://ams.confex.com/ams/2019Annual/meetingapp.cgi/Paper/353210.

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2018

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Lee, J. A., L. Xue, A. J. Newman, A. J. Monaghan, P. Doubrawa, X. Draxl, L. Kilcher, and G. Scott, 2018: Validation of a 14-year high-resolution WRF dataset for wind resource assessment over Alaska. 9th Conf. on Weather, Climate, and the New Energy Economy, Austin, TX, Amer. Meteor. Soc., 1.3, https://ams.confex.com/ams/98Annual/webprogram/Paper327317.html.

2017

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2016

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2009

Lee, J. A., L. J. Peltier, S. E. Haupt, J. C. Wyngaard, D. R. Stauffer, and A. Deng, 2009: Improving SCIPUFF dispersion forecasts with NWP ensembles. J. Appl. Meteor. Climatol., 48, 2305–2319, https://doi.org/10.1175/2009JAMC2171.1.

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: Alessandrini, Stefano DATE: October 2020

CURRENT SUPPORT

Project Title: Enhancing Decision-making Activities in the Area of Air Quality in Delhi
Principal Investigator: Alessandrini, Stefano
Source of Support: Indian Institute of Tropical Meterology; Contract #18INT10
Contact Information: Dr. V. V. Gopalakrishna; Ph: 00-91-20-25904476; wgkxbt@gmail.com
Total Award Amount: $306, 894
Total Award Period Covered: 12/18/2018 - 12/17/2020
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 1.4 Co-Sponsorship:

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: Kumar, Rajesh
Source of Support: NASA-HQ; Contract #C19K0982
Contact Information: Grant Officer, NSSC; NSSC-GRANT-Report@mail.nasa.gov
Total Award Amount: $599,873
Total Award Period Covered: 05/2/2019 - 05/1/2022
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 1.0 Co-Sponsorship:

Project Title: A Novel Method for Improving Fine Particulate Matter Air Quality Forecasts During Wildfires
Principal Investigator: Kumar, Rajesh
Source of Support: NOAA - Oceanic and Atmospheric Research; Contract #R4590083
Contact Information: Janet Russell; Ph: 301-713-1942; janet.j.russell@noaa.gov
Total Award Amount: $509,714
Total Award Period Covered: 06/01/2019 - 05/31/2022
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 1.75 Co-Sponsorship:

Project Title: High-Resolution Wind Atlas for Italy
Principal Investigator: Alessandrini, Stefano
Source of Support: Ricerca sul Sitema Energetico (RSE); Contract #20200222
Contact Information: Simone Sperati, Ph: +39 023 992 5337 Simone.Sperati@rse-web.it
Total Award Amount: $108,023
Total Award Period Covered: 07/01/2020 - 06/30/2021
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 1.5 Co-Sponsorship:

Project Title: Global Climatological Analysis Tool NGIC FY2020
Principal Investigator: Alessandrini, Stefano
Source of Support: Army National Ground Intelligence Center; Contract #1940618
Contact Information: Kristin Spencer; Ph: 703-292-8242; kspencer@nsf.gov
Total Award Amount: $610,078
Total Award Period Covered: 07/15/2019 - 09/30/2023
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 2.0   Co-Sponsorship:

Project Title: FY17-21 Chemical/Biological Defense Modeling and Virtual Environment Development
Principal Investigator: Swerdlin, Scott
Source of Support: Defense Threat Reduction Agency; Contract #1924949
Contact Information: Kristin Spencer; Ph: 703-292-8242; kspencer@nsf.gov
Total Award Amount: $491,781
Total Award Period Covered: 03/01/2019 - 09/30/2023
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 1.3   Co-Sponsorship:

Project Title: A Renewable Energy Forecasting System for Kuwait
Principal Investigator: Haupt, Sue Ellen
Source of Support: Kuwait Institute for Scientific Research; Contract #PKISR12
Contact Information: Dr. Samira Omar; Ph: 24-98-9000
Total Award Amount: $5,137,603
Total Award Period Covered: 07/07/2017 - 01/05/2021
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: .38   Co-Sponsorship:
Project Title: Probabilistic Cloud Optimized Day-ahead Forecasting System Based on WRF-Solar
Principal Investigator: Jimenez Munoz, Pedro
Source of Support: National Renewable Energy Lab – Alliance for Sustainable Energy; Contract #98228701
Contact Information: Kathleen Slaverson; Ph: 303-275-4260; kathleen.salverson@nrel.gov
Total Award Amount: $719,848
Total Award Period Covered: 12/09/2018 - 06/30/2021
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: .5   Co-Sponsorship:

PENDING SUPPORT
Proposal Title: Enhancing Air Quality Decision-making Activity in the United States Through Integration of Multi-satellite Air Pollution Observations with Numerical Models
Principal Investigator: Kumar, Rajesh
Source of Support: NASA
Contact Information: John Haynes, Ph: (202) 358-4665, jhaynes@nasa.gov
Total Award Amount: $499,860
Total Award Period Covered: 10/01/2020 - 09/30/2024

Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal:.31 Y1, 1.55 Y2, 1.03 Y3, .52 Y4 Co-Sponsorship:

Proposal Title: Post-Processing of CMAQ Forecast for Improving Air Quality Predictions (THIS PROPOSAL)
Principal Investigator: Alessandrini, Stefano
Source of Support: NOAA-OAR-OWAQ/Office of Weather and Air Quality
Contact Information: Chandra Kondragunta; Ph: 301-734-1034; Chandra.kondragunta@noaa.gov
Total Award Amount: $406,871
Total Award Period Covered: 08/01/2021 - 07/31/2023
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 2.06 Y1-2 Co-Sponsorship

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: November 2020

Current Support

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
Source of Support: NOAA/NGGPS
Total Person-Months over Period of Performance: 4.3 months
Total Award: $146,242
Period of Performance: June 1, 2019 – December 31, 2020

Title: Bias-correction of PM 2.5 and ozone for CAM-CMAQ predictions including wildfires
Source of Support: NOAA Disaster Supplemental FY 19 IFHFW
Total Person-Months over Period of Performance: 6.9 months
Total Award: $250,094
Period of Performance: May 1, 2020 – April 20, 2023

Pending Support

Title: Post-Processing of CMAQ forecast for Improving Air Quality Predictions (THIS PROPOSAL)
Source of Support: NOAA/WPO
Total Person-Months over Period of Performance: 4.3 months
Total Award: $143,018
Period of Performance: August 1, 2021 – July 31, 2023

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: Kumar, Rajesh DATE: October 2020

CURRENT SUPPORT

Project Title: Enhancing Decision-making Activities in the Area of Air Quality in Delhi
Principal Investigator: Alessandrini, Stefano
Source of Support: Indian Institute of Tropical Meterology; Contract #18INT10
Contact Information: Dr. V. V. Gopalakrishna; Ph: 00-91-20-25904476; wgkxbt@gmail.com
Total Award Amount: $306, 894
Total Award Period Covered: 12/18/2018 - 12/17/2020
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 2.2 Co-Sponsorship:

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: Kumar, Rajesh
Source of Support: NASA-HQ; Contract #C19K0982
Contact Information: Grant Officer, NSSC; NSSC-GRANT-Report@mail.nasa.gov
Total Award Amount: $599,873
Total Award Period Covered: 05/2/2019 - 05/1/2022
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 1.9 Co-Sponsorship:

Project Title: A Novel Method for Improving Fine Particulate Matter Air Quality Forecasts During Wildfires
Principal Investigator: Kumar, Rajesh
Source of Support: NOAA - Oceanic and Atmospheric Research; Contract #R4590083
Contact Information: Janet Russell; Ph: 301-713-1942; janet.j.russell@noaa.gov
Total Award Amount: $509,714
Total Award Period Covered: 06/01/2019 - 05/31/2022
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 2.19 Co-Sponsorship:

Project Title: Air Quality: Worldwide Analysis and Forecasting of Atmospheric Composition for Health
Principal Investigator: Kumar, Rajesh
Source of Support: Max Planck Institute for Meteorology; Contract #20190262
Contact Information: Chenbo Guo; Chenbo.guo@mpimet.mpg.de
Total Award Amount: $193,474
Total Award Period Covered: 01/01/2020 - 12/31/2022
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 1.69 Co-Sponsorship:

Project Title: Constraining the Deposition of Light Absorbing Particles in High Mountain Asia (HMA) via Assimilation of Two Decades of NASA Observations of Atmospheric Composition
Principal Investigator: Kumar, Rajesh
Source of Support: NASA; Contract #C20K1342
Contact Information: Grant Officer, NSSC; NSSC-GRANT-Report@mail.nasa.gov
Total Award Amount: $867,158
Total Award Period Covered: 08/01/2020 - 07/31/2023
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 2.06 Co-Sponsorship:

Project Title: Role of Soil Moisture on the Earth's Radiative Balance Through Modulations of the Dust Direct and Indirect Effects
Principal Investigator: Jimenez Munoz, Pedro
Source of Support: NASA-HQ; Contract #C20K1798
Contact Information: Grant Officer, NSSC; NSSC-GRANT-Report@mail.nasa.gov
Total Award Amount: $449,069
Total Award Period Covered: 9/09/2020 - 9/08/2023
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: .63 Co-Sponsorship:

Project Title: Remote-sensing of Surface-level Ozone Sensitivity to Nitrogen Oxides and Volatile Organic Compounds
Principal Investigator: Kumar, Rajesh
Source of Support: NASA - Ames Research Center; Contract # C20K1234
Contact Information: Grant Officer, NSSC; NSSC-GRANT-Report@mail.nasa.gov
Total Award Amount: $109,313
Total Award Period Covered: 06/25/2020 - 06/24/2023
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: .14 Co-Sponsorship:

Project Title: Implementing an Advanced Dust Emission scheme in the Weather Research and Forecasting Model Coupled with Chemistry (WRF-Chem)
Principal Investigator: Kumar, Rajesh
Source of Support: Formation Environmental, LLC; Contract #6101211
Contact Information: Jesse Schwend; Ph: 303-550-0993; jschwend@formationenv.com
Total Award Amount: $102,573
Total Award Period Covered: 05/04/2020 - 12/31/2020
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 1.1 Co-Sponsorship:

PENDING SUPPORT
Proposal Title: Enhancing Air Quality Decision-making Activity in the United States Through Integration of Multi-satellite Air Pollution Observations with Numerical Models
Principal Investigator: Kumar, Rajesh
Source of Support: NASA
Contact Information: John Haynes, jhaynes@nasa.gov, (202) 358-4665

Total Award Amount: $499,860
Total Award Period Covered: 10/01/2020 - 09/30/2024
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 1.88 Y1, 1.12 Y2, 1.3 Y3, 1.61 Y4 Co-Sponsorship:

Proposal Title: The Impact of Urbanization on the Formation and Transport of Summertime Ozone in the Colorado Northern Front Range
Principal Investigator: Kumar, Rajesh
Source of Support: NASA
Contact Information: Richard Eckman, richard.s.eckman@nasa.gov, 202-358-2567
Total Award Amount: $599,727
Total Award Period Covered: 03/18/2021 - 03/17/2024
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 1.0 Y1-2, 2.23 Y3 Co-Sponsorship:

Proposal Title: Post-Processing of CMAQ Forecast for Improving Air Quality Predictions (THIS PROPOSAL)
Principal Investigator: Alessandrini, Stefano
Source of Support: NOAA-OAR-OWAQ/Office of Weather and Air Quality
Contact Information: Chandra Kondragunta; Ph: 301-734-1034; Chandra.kondragunta@noaa.gov
Total Award Amount: $406,871
Total Award Period Covered: 08/01/2021 - 07/31/2023
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 1.55 Y1-2 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: Lee, Jared DATE: October 2020

CURRENT SUPPORT

Project Title: Role of Soil Moisture on the Earth's Radiative Balance Through Modulations of the Dust Direct and Indirect Effects
Principal Investigator: Jimenez Munoz, Pedro
Source of Support: NASA-HQ; Contract #C20K1798
Contact Information: Grant Officer, NSSC; NSSC-GRANT-Report@mail.nasa.gov
Total Award Amount: $449,069
Total Award Period Covered: 9/09/2020 - 9/08/2023
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 2.5 Co-Sponsorship:

Project Title: MAD-WRF: A Solar Irradiance Nowcasting System to Support the GEOVENER Element
Principal Investigator: Jimenez Munoz, Pedro
Source of Support: NASA-HQ; Contract #C18K0330
Contact Information: Grant Officer, NSSC; NSSC-GRANT-Report@mail.nasa.gov
Total Award Amount: $586,874
Total Award Period Covered: 02/01/2018 - 01/31/2021
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 1.9 Co-Sponsorship:

Project Title: A Renewable Energy Forecasting System for Kuwait
Principal Investigator: Haupt, Sue Ellen
Source of Support: Kuwait Institute for Scientific Research; Contract #PKISR12
Contact Information: Dr. Samira Omar; Ph: 24-98-9000
Total Award Amount: $5,137,603
Total Award Period Covered: 07/07/2017 - 01/05/2021
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 1.5 Co-Sponsorship:

Project Title: UAE Weather Mod Research Program
Principal Investigator: Rasmussen, Roy
Source of Support: Hua Xin Chuang Zhi Science and Technology LLC; Contract #20170327
Contact Information: Zhenjun Li; Ph: +86 010-6201-9120; business@hxczst.com
Total Award Amount: $401,415
Total Award Period Covered: 07/23/2018 - 07/22/2021
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 2.0 Co-Sponsorship:

Project Title: NCAR Support for Advanced Solar & Load forecasting operations, Incorporating HD Sky Imaging: Phase 3 Project
Principal Investigator: Lee, Jared
Source of Support: Electric Power Research Institute; Contract #10011288

Contact Information: Bethany Thompson; Ph: 865-218-5925; bthompson@epri.com
Total Award Amount: $550,000
Total Award Period Covered: 08/12/2019 - 12/31/2022
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: .9 Co-Sponsorship:

PENDING SUPPORT
Proposal ID: 2019-0205
Proposal Title: Development of an operational solar energy forecast system for Thailand with real-time data assimilation
Principal Investigator: McCandless, Tyler
Source of Support: Ramkhamhaeng University
Contact Information: Jerasorn Santisirisomboon, , 66 23 108 5778 #229jerasorn@ru.ac.th
Total Award Amount: $1,092,257
Total Award Period Covered: 07/01/2019 - 06/30/2022
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 1.38 Y1, .58 Y2, .46 Y3 Co-Sponsorship:

Proposal ID: 2020-0789
Proposal Title: Post-Processing of CMAQ forecast for Improving Air Quality Predictions (THIS PROPOSAL)
Principal Investigator: Alessandrini, Stefano
Source of Support: NOAA-OAR-OWAQ/Office of Weather and Air Quality
Contact Information: Chandra Kondragunta; Ph: 301-734-1034; Chandra.kondragunta@noaa.gov
Total Award Amount: $406,871
Total Award Period Covered: 08/01/2021 - 07/31/2023
Location of Project: Boulder, CO
Person-Months Committed to the Project: Cal: 1.55 Y1-2 Co-Sponsorship:

FY21 WEATHER PROGRAM OFFICE NOTICE OF FUNDING OPPORTUNITY

STANDARD FORM FOR ACKNOWLEDGEMENT OF NOAA COLLABORATION

DATE: 11/13/2020

MEMORANDUM FOR: NOAA/OAR Weather Program Office Competition Manager

FROM: Robert S. Webb, Director, Physical Sciences Laboratory

SUBJECT: NOAA Collaboration on WPO Proposal

Physical Sciences Laboratory (PSL) acknowledges NOAA collaboration with Principal Investigator(s) Irina Djalalova on the development of proposal titled Post-Processing of CMAQ forecast for Improving Air Quality Predictions. The applicants have sufficiently coordinated the development of this proposal, including any relevant infrastructure costs and/or plans for proposed Testbed activities.

Our role in this collaborative project will include (check all that apply):

- [x] Providing (unfunded) research and development support
- [x] Providing equipment, office space, or computer access to non-federal PIs
- [x] Providing operational guidance to support the eventual transition of this project
- [ ] Coordinating NOAA Testbed activities for this project
- [ ] Other: ____________________

Any major comments or concerns are listed below: Permission granted for James Wilczak.

WEBB.ROBERT.S.1365824254 Digitally signed by WEBB.ROBERT.S.1365824254

Signature

(Robert S. Webb, Director, Physical Sciences Laboratory)

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office of Oceanic and Atmospheric Research
Physical Sciences Laboratory
325 Broadway – David Skaggs Research Center
Boulder, Colorado 80305-3337

November 12, 2020

Program Manager
NOAA Office of Weather and Air Quality

I understand that Irina Djalalova is a Co-PI on a proposal submitted through the University of Colorado Boulder in response to the NOAA OAR Weather Program Office. The proposed research titled, *Post-Processing of CMAQ forecast for Improving Air Quality Predictions,* will directly contribute to the mission of NOAA OAR Physical Sciences Laboratory (PSL).

In response to Federal Funding Opportunity FY2021 Weather Program Office Research Programs FY 2021 Joint Technology Transfer Initiative, NOAA-OAR-WPO-2021-2006592, I am providing a letter of commitment to support the collaboration and substantial involvement of NOAA/OAR/PSL. Support of this proposal includes Indirect Costs that consist of the following: IT support includes email, internet access, data storage for both basic and scientific software, helpdesk, and backup services. Administrative support includes office space, telephone, conference rooms, purchasing, grant processing, security/badges, budget development, etc.

Below are the Indirect Costs:

Year 1	Year 2
$18,531	$18,451

Sincerely,

WEBB.ROBERT.S.1365824254 Digitally signed by WEBB.ROBERT.S.1365824254 Date: 2020.11.12 18:46:04 -05'00'

Robert S. Webb
Director, Physical Sciences Laboratory

FY21 WEATHER PROGRAM OFFICE NOTICE OF FUNDING OPPORTUNITY STANDARD FORM FOR ACKNOWLEDGEMENT OF NOAA COLLABORATION

DATE: November 9, 2020

MEMORANDUM FOR: NOAA/OAR Weather Program Office Competition Manager

FROM: Jeff McQueen, NWS

SUBJECT: NOAA Collaboration on WPO Proposal

NOAA/NWS/NCEP/EMC acknowledges NOAA collaboration with Principal Investigator(s) Stefano Allasandrini on the development of a proposal titled: *"Post-Processing of CMAQ forecasts for Improving Air Quality Predictions."* The applicants have sufficiently coordinated the development of this proposal, including any relevant infrastructure costs and/or plans for proposed Testbed activities.

Our role in this collaborative project will include (check all that apply):

___ Providing (unfunded) research and development support

___ Providing equipment, office space, or computer access to non-federal PIs

___ Providing operational guidance to support the eventual transition of this project

___ Coordinating NOAA Testbed activities for this project

_**X**__ Other: ________________________________

Any major comments or concerns are listed below.

The project will extend already existing operations bias correction approach and potentially improve upon it by allowing for air quality analyses in addition to observations.

Jeffrey McQueen ______ Signature
(Name, Title, Organization)

JEFFERY MCQUEEN, METEOROLOGIST
NWS/NCEP

39

ECMWF EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS

Europäisches Zentrum für mittelfristige Wettervorhersage | Centre européen pour les prévisions météorologiques à moyen terme

Dr. Vincent-Henri Peuch
European Centre for Medium-Range Weather Forecasts
Director, Copernicus Atmosphere Monitoring Service (CAMS)
Tel +44 118 949 9102 Fax +44 118 986 9450
www.ecmwf.int atmosphere.copernicus.eu

16 November 2020

To the Members of the Evaluation Panel,

This letter is for confirming my intent to collaborate and provide guidance on the use of CAMS forecasts (as detailed in the Project Description) if the proposal entitled "Post-Processing of CMAQ forecast for Improving Air Quality Predictions" submitted by Dr. Stefano Alessandrini is selected for funding by NOAA.

Yours sincerely

Dr. Vincent-Henri Peuch, ECMWF, Director CAMS

NCAR Proposal 2020-0789 - Budget Justification

Proposed Total Budget:

Institution	Year 1	Year 2	Total
NCAR	$200,065	$206,806	$406,871
CU-CIRES	$ 71,469	$ 71,549	$143,018
NOAA PSL	$ 18,531	$ 18,451	$36,982
TOTAL	$290,065	$296,806	$586,871

NCAR BUDGET

UCAR

UCAR Proposal Budget Detail

Proposal #	2020-0789
Proposal Title:	Post-Processing of CMAQ forecast for Improving Air Quality Predictions
UCAR Entity:	NCAR
Period of Performance:	08-01-2021 - 07-31-2023
Principal Investigator	Stefano Alessandrini

			Unit / Rate	Effort Year 1	Effort Year 2	Year 1 NOAA-OAR-OWAQ/Office of Weather and Air Quality	Year 2 NOAA-OAR-OWAQ/Office of Weather and Air Quality	Cumulative Grand Total
Salaries	Regular Salaries	Proj Scientist II	FTE	0.15	0.15	14,950	15,398	30,348
		Proj Scientist III	FTE	0.20	0.20	23,099	23,792	46,891
		Soft EngProg III	FTE	0.25	0.25	25,806	26,580	52,386
		Proj Scientist II	FTE	0.15	0.15	14,583	15,021	29,604
	Subtotal Salaries					**78,438**	**80,791**	**159,229**
Fringe Benefits		Regular Benefits @	54.50 %			42,749	44,031	86,780
	Subtotal Fringe Benefits					**42,749**	**44,031**	**86,780**
	Total Salaries and Benefits					**121,187**	**124,822**	**246,009**
Travel		Domestic - Attend AMS				0	670	670
	Subtotal Travel					**0**	**670**	**670**
	Modified Total Direct Costs (MTDC)					**121,187**	**125,492**	**246,679**
Indirect Costs		NCAR Indirect Cost Rate (MTDC)	56.60 %			68,592	71,028	139,620
	Total Indirect Costs					**68,592**	**71,028**	**139,620**
MTDC Costs that Include Indirect Costs	Computing Service Center	Computing Service Center	$7.67 / hr			10,286	10,286	20,572
	Subtotal MTDC Costs that Include Indirect Costs					**10,286**	**10,286**	**20,572**
	Total MTDC + Applied Indirect Costs					**200,065**	**206,806**	**406,871**
	Total Funding To UCAR					**200,065**	**206,806**	**406,871**

NCAR BUDGET JUSTIFICATION: $406,871

A. Personnel: $159,229

Position Title & Name	Yearly Salary	% of Time	No. of Months	$ Amount
PI, Project Scientist III, Dr. Stefano Alessandrini	$134,295 Year 1 $138,324 Year 2 Total	20.0% 20.0% 40.0%	2.06 2.06 4.12	$23,099 $23,792 $46,891
Co-PI, Project Scientist II, Dr. Jared Lee	$113,045 Year 1 $116,437 Year 2 Total	15.0% 15.0% 30.0%	1.55 1.55 3.10	$14,583 $15,021 $29,604
Co-I, Project Scientist	$115,890 Year 1	15.0%	1.55	$14,950

II, Dr. Rajesh Kumar	$119,366 Year 2 Total	15.0% 30.0%	1.55 3.10	$15,398 $30,348
Other Personnel, Software Engineer/Programmer III	$120,027 Year 1 $123,628 Year 2 Total	25.0% 25.0% 50.0%	2.58 2.58 5.16	$25,806 $26,580 $52,386

A Project Scientist III, Dr. Stefano Alessandrini, will serve as the Principal Investigator and charge approximately 2.06 months in Year 1 and 2.06 months in Year 2 on this project with a salary range between $134,295 and $138,324. This labor will include primary responsibility for a general supervision of all the tasks, the analog ensemble optimizations and the procedure to merge the concentration observations from the stations with CAMS field.

A Project Scientist II, Dr. Jared Lee, will serve as Co-Principal Investigator and charge approximately 1.55 months in Year 1 and 1.55 months in Year 2 on this project with a salary range between $113,045 and $116,437. This labor will include primary responsibility for validation of the analog ensemble forecasts, the CAMS fields download and interpolation to the CMAQ grid.

A Project Scientist II, Dr. Rajesh Kumar, will serve as Co-Investigator and charge approximately 1.55 months in Year 1 and 1.55 months in Year 2 on this project with a salary range between $115,890 and $119,366. This labor will include primary responsibility for the performance verification of the overall system with a particular focus on the analysis of some wildfire episodes.

A Software Engineer/Programmer III will serve as Other Personnel and charge approximately 2.58 months in Year 1 and 2.58 months in Year 2 on this project with a salary range between $120,027 and $123,628. This labor will include primary responsibility for writing the procedure to download CAMS data, interpolating the data to CMAQ grid, generating the input files to the AnEn code and optimizing the AnEn performance in terms of CPU time to meet NAQFC requirements.

A 3% annual salary increase has been included.

B. Fringe Benefits: $86,780

Position Title & Name	Yearly Salary	% Rate	$ Amount
PI, Project Scientist III, Dr. Stefano Alessandrini	$134,295 Year 1 $138,324 Year 2 Total	54.5% 54.5% 54.5%	$12,589 $12,967 $25,556
Co-PI, Project Scientist II, Dr. Jared Lee	$113,045 Year 1 $116,437 Year 2 Total	54.5% 54.5% 54.5%	$7,948 $8,186 $16,134
Co-I, Project Scientist II, Dr. Rajesh Kumar	$115,890 Year 1 $119,366 Year 2 Total	54.5% 54.5% 54.5%	$8,148 $8,392 $16,540

Other Personnel, Software Engineer/Programmer III	$120,027 Year 1 $123,628 Year 2 Total	54.5% 54.5% 54.5%	$14,064 $14,486 $28,550

The salary budget includes a full-time employee benefit rate of 54.5% for non-work time of vacation, sick leave, holidays and other paid leave, as well as standard staff benefits. % of Time is based on hours budgeted for project divided by 2080 work hours in a year.

C. Travel: $670

Domestic Travel: A total of $670 is budgeted for domestic travel, which includes the following trips:
- 1 trip in Year 2 for one person to Denver, CO to attend and present project results at the AMS Annual Meeting.

All costs include airfare and car rental (based on web searches), lodging and per diem (based on GSA rates), and registration costs. Trips are escalated by 3% per year.

PROPOSAL NUMBER:	**2020-0789**							
PI:	**Stefano Alessandrini**							
Destination	**Purpose**	**# of Travelers**	**Airfare**	**Per Diem**	**Car**	**Hotel**	**Conf. Reg & Misc**	**Total Trip Cost**
Year 2 - Travel 1								
Denver, CO	Present at AMS	1	$0	$0	$0	$0	$670	**$670**
Total for Yr 2 Travel								**$670**
Total All Years								**$670**

D. Equipment: None

E. Supplies: None

F. Contractual: None

G. Construction: None

H. Other: $20,572

Subawards: None

Computer Services: $20,572
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 2020 is $7.67 per labor hour.

I. Total Direct Charges: $267,251

A. Personnel:	$159,229
B. Fringe:	$86,780
C. Travel:	$670
D. Equipment:	$0
E. Supplies:	$0
F. Contractual:	$0
G. Construction:	$0
H. Other:	$20,572
Total Direct Costs:	$267,251

J. Indirect Charges: $139,620

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 FY20 rate for Indirect Costs is 56.6%. Cognizant Agency: National Science Foundation (NSF).

INDIRECT COSTS Total: $139,620
The rate is 56.6% and is computed on the following direct cost base $246,679.

Personnel:	$159,229
Fringe:	$86,780
Travel:	$670
Supplies:	$0
Other:	$0
Total:	$246,679

Multiplied by Indirect Cost Rate 56.6%
Total Indirect Costs: $139,620

K. NCAR TOTALS – Direct and Indirect Charges: $406,871

NATIONAL SCIENCE FOUNDATION
2415 Eisenhower Avenue
Alexandria, VA 22314

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

May 7, 2020

Geoff Cheeseman
Director, UCAR Budget and Planning
University Corporation for Atmospheric Research
P. O. Box 3000
Boulder, CO 80307-3000

Dear Mr. Cheeseman:

We have completed our review of the indirect cost proposal and supporting financial data submitted to the National Science Foundation (NSF) for your fiscal year ended September 30, 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.

During the course of this rate negotiation, NSF found that UCAR had adjusted its FY 2018 pools to include costs from FY 2017 that had not been accurately captured or recorded in the proper fiscal year. Final rates are calculated based on actual, allowable costs from the fiscal period to which they apply and are not to include costs from prior periods. For this reason, NSF has determined to remove costs associated with FY 2017 adjustments from the FY 2018 pools. At the conclusion of this rate negotiation, UCAR had requested that NSF provide written approval to allow the organization to include these adjustments in the FY 2018 rates; this request has been denied.

Going forward, NSF reiterates that differences from provisional to final rates must be calculated on a per award basis and returned to federal funding agencies as appropriate; changes to indirect cost rate billings from past fiscal periods should not be carried forward as adjustments in future periods. Should a final rate be higher than the provisional rate initially awarded, the organization may be able to draw additional funding from open awards, pending availability of funds. Finally, UCAR should only be charging indirect costs at the rates stipulated in formal rate agreements – the provisional rate governs until the final rate is issued. The organization should refrain from making preliminary adjustments to its indirect costs billings based on calculated or proposed final rates that have not yet been formally approved by the cognizant agency for indirect costs.

-cont'd-

Should you wish to appeal any of the indirect cost pool adjustments NSF made as part of this rate negotiation, you may follow the dispute resolution procedures contained in Chapter XII of the NSF Proposal & Award Policies and Procedures Guide (PAPPG). These may be found online at: https://www.nsf.gov/publications/pub_summ.jsp?ods_key=papp.

Per the rates that have established, the organization will not be required to submit a new indirect cost rate proposal until the end of your FY 2019. 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 Sylvanus Davies at (703) 292-8867.

Sincerely,

Meghan A. Benson

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

Enclosure: Rate Agreement

NATIONAL SCIENCE FOUNDATION

OFFICE OF BUDGET, FINANCE & AWARD MANAGEMENT
Division of Institution and Award Support

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: May 7, 2020

FILING REF: The preceding agreement was dated March 25, 2019.

The indirect cost rates contained herein are for use on grants, contracts, and other agreements with the Federal Government to which 2 CFR Part 200 apply, subject to the terms and conditions of Section II of this agreement. The rates were negotiated by the National Science Foundation and the subject organization in accordance with the authority contained in applicable regulations.

SECTION I: RATES

FY 2018 - FINAL

Rate Description	Effective Period	Rate	Base
UCAR			
UCAR G&A	10/01/17 – 09/30/18	15.852%	(a)
UCAR Community Programs (UCP) G&A			
Onsite	10/01/17 – 09/30/18	33.566%	(b)
Offsite	10/01/17 – 09/30/18	23.342%	(b)
NCAR			
NCAR G&A			
Onsite	10/01/17 – 09/30/18	53.154%	(b)
Offsite/NWSC	10/01/17 – 09/30/18	40.422%	(b)
Fringe Benefits			
Full Benefits	10/01/17 – 09/30/18	54.047%	(c)
Reduced Benefits	10/01/17 – 09/30/18	9.402%	(c)

FY 2020 - PROVISIONAL

Rate Description	Effective Period	Rate	Base
UCAR			
UCAR G&A	10/01/19 – 09/30/20	15.90%	(a)
UCAR Community Programs (UCP) G&A			
Onsite	10/01/19 – 09/30/20	34.20%	(b)
Offsite	10/01/19 – 09/30/20	24.70%	(b)
NCAR			
NCAR G&A			
Onsite	10/01/19 – 09/30/20	56.60%	(b)
Offsite/NWSC	10/01/19 – 09/30/20	43.30%	(b)
Fringe Benefits			
Full Benefits	10/01/19 – 09/30/20	54.50%	(c)
Reduced Benefits	10/01/19 – 09/30/20	9.40%	(c)

SECTION I: RATES (cont'd)

Rate Application Bases

(a) Total direct costs of each entity, excluding equipment, participant support, Intergovernmental Personnel Assignments (IPAs), subaward or subcontract costs and other direct costs that are 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), subaward or subcontract costs, and other direct costs that are 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).

-cont'd-

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)

Justin Young
(Signature)

JUSTIN YOUNG
(Name)

Interim CFO
(Title)

5/28/2020
(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)

5/7/2020
(Date)

NSF Negotiator: Sylvanus P. Davies
Telephone: 703-292-8867

National Center for Atmospheric Research
Boulder, Colorado
FY 2020 Proposed Rate Summary

1. Aircraft Maintenance Rate

Aircraft Maintenance Rate (AMR)	FY 2018 Actual	FY 2019 Submitted	FY 2020 Proposed
C-130 Aircraft	$221 /Hour	$575 /Hour	$585 /Hour
GV Aircraft (Gulfstream HIAPER)	$2,618 /Hour	$1,568 /Hour	$2,311 /Hour

2. Service Center Rates

Computing Service Centers	FY 2018 Actual	FY 2019 Submitted	FY 2020 Proposed
Climate and Global Dynamics (CGD)	$6.93 /Hour	$6.85 /Hour	$6.95 /Hour
Atmospheric Chemistry Observations & Modeling (ACOM)	$6.71 /Hour	$7.25 /Hour	$7.50 /Hour
High Altitude Observatory (HAO)	$7.55 /Hour	$8.24 /Hour	$8.22 /Hour
Mesoscale & Microscale Meteorology (MMM)	$6.78 /Hour	$6.70 /Hour	$6.50 /Hour
Research Applications Laboratory (RAL)	$7.39 /Hour	$7.33 /Hour	$7.67 /Hour
Machine Shop			
Machine Shop Rate	$84 /Hour	$83 /Hour	$83 /Hour

3. System User Rates

Earth Observing Laboratory (EOL)	FY 2018 Actual	FY 2019 Submitted	FY 2020 Proposed
ISFS	$738 /Day	$557 /Day	$557 /Day
ISS	$759 /Day	$608 /Day	$608 /Day
Dropsonde Data System	$1,150 /Day	$1,673 /Day	$1,299 /Day
Calibration Lab / Wind Tunnel	$0 /Day	$0 /Day	$783 /Day
ELDORA	$0 /Day	$2,135 /Day	$2,135 /Day
S-Pol Radar	$7,067 /Day	$9,132 /Day	$9,132 /Day
HCR	$3,421 /Day	$5,313 /Day	$5,313 /Day
HAIS	$571 /Day	$599 /Day	$599 /Day
C-130 Aircraft	$16,213 /Day	$11,738 /Day	$11,738 /Day
Gulfstream Aircraft (HIAPER)	$12,365 /Day	$10,759 /Day	$10,759 /Day
Mechanical Design	$1,275 /Day	$923 /Day	$923 /Day
Machine Shop	$282 /Day	$106 /Day	$106 /Day

Comp. & Information Systems Lab (CISL)	FY 2018 Actual	FY 2019 Submitted	FY 2020 Proposed
Rate Per Core Hour	$0.0050 /Hour	$0.0049 /Hour	$0.0050 /Hour
Rate per 100 Core Hours	$0.50 /100 Hours	$0.49 /100 Hours	$0.50 /100 Hours

High Altitude Observatory (HAO)	FY 2018 Actual	FY 2019 Submitted	FY 2020 Proposed
Vacuum Tunnel	$0 /Day	$0 /Day	$189 /Day

4. Data Management Services Rate (DMSR)

Comp. & Information Systems Lab (CISL)	FY 2020 Proposed
Processing Services*: 0-50 TB Vol	$4,125.00 /Project
Processing Services: 50-100 TB Vol	$6,187.50 /Project
Processing Services: 100+ TB Vol	$8,250.00 /Project
CISL Storage Services Rate**	$45.00 /TB/Yr (ea.)

**Processing Services costs assume storage needs are known at time of proposal and current SE-II fully loaded salary midpoint.*
***All projects will be assessed the Processing Services fee plus the storage rate.*

BUDGET INFORMATION - Non-Construction Programs

OMB Number: 4040-0006
Expiration Date: 02/28/2022

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	$	$	$ 406,871.00	$	$ 406,871.00
2.						
3.						
4.						
5. **Totals**		$	$	$ 406,871.00	$	$ 406,871.00

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SECTION B - BUDGET CATEGORIES

6. Object Class Categories	GRANT PROGRAM, FUNCTION OR ACTIVITY				Total
	(1) Weather and Air Quality Research	(2) N/A	(3)	(4)	(5)
a. Personnel	$ 78,438.00	$ 80,791.00	$	$	$ 159,229.00
b. Fringe Benefits	42,749.00	44,031.00			86,780.00
c. Travel	0.00	670.00			670.00
d. Equipment	0.00	0.00			0.00
e. Supplies	0.00	0.00			0.00
f. Contractual	0.00	0.00			0.00
g. Construction	0.00	0.00			0.00
h. Other	10,286.00	10,286.00			20,572.00
i. Total Direct Charges (sum of 6a-6h)	131,473.00	135,778.00			$ 267,251.00
j. Indirect Charges	68,592.00	71,028.00			$ 139,620.00
k. TOTALS (sum of 6i and 6j)	$ 200,065.00	$ 206,806.00	$	$	$ 406,871.00
7. Program Income	$	$	$	$	$

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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	$ 200,065.00	$ 50,017.00	$ 50,016.00	$ 50,016.00	$ 50,016.00
14. Non-Federal	$				
15. TOTAL (sum of lines 13 and 14)	$ 200,065.00	$ 50,017.00	$ 50,016.00	$ 50,016.00	$ 50,016.00

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	$ 206,806.00	$	$	$
17.					
18.					
19.					
20. TOTAL (sum of lines 16 - 19)		$ 206,806.00	$	$	$

SECTION F - OTHER BUDGET INFORMATION

21. Direct Charges: Modified Total Direct Costs (MTDC) = $246,679

22. Indirect Charges: Indirect Costs on MTDC = $139,620

23. Remarks: Indirect Costs = FY20 rate of 56.6% x MTDC = .566 x $246,679 = $139,620

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