ATTACHMENT 1 – TECHNICAL PROPOSAL

Rational Estimates and Assessment of Climate Horizons on Fuels, Air Quality & Scenery in the Western U.S. (REACHFAQS-West) – *Regional Air Planning Analysis and Tools under Changing Climate, Fuels, and Fire Regimes accounting for Stochastic Variations in Wildland Fire Emissions and Air Quality Impacts across the West*

Western Governors' Association / Western Regional Air Partnership

CFDA No. 15.232

JFSP Funding Opportunity Notice (FON) 2013-1, Task 1

Principal Investigator

Charles Thomas (Tom) Moore, Jr., of the Western Governors' Association (WGA) is the Principal Investigator for the REACHFAQS-West project. WGA is incorporated under Article 26 of Title 7 of the 1973 Colorado Revised Statutes as a non-profit association to advocate policies and programs before any branch or agency of state and/or federal government. WGA staffs, manages, and implements the Western Regional Air Partnership (WRAP), a voluntary partnership of states, tribes, federal land managers, local air agencies and the US EPA, whose purpose is to understand current and evolving regional air quality in the context of the federal Clean Air Act (CAA).

I. Overview

The 3-year REACHFAQS-West project will quantify the change in fuels, fire regimes, and fire emissions resulting from applying 3 scenarios of future climate change projections for the U.S. northwestern and southwestern regions (Figure 1), both specified by JFSP. These western US study areas allow us to leverage our current JFSP projects for a REACHFAQS-West study domain of which we have extensive detailed knowledge and experience in regional air quality analysis and planning, particularly for fire. We will use the downscaled climate projections in a regional-scale chemical transport model (CTM) to simulate the atmospheric transformations of these emissions. Starting from our JSFP-supported historic fire emissions inventories and extending those methodologies, we will analyze and project changes to fuels and fire regimes to estimate circa 2050 (c.2050) fire emissions scenarios resulting from the disturbance caused by the effect of the climate change projections. The modeled air quality impacts of wildfire for Ozone, Particulate Matter (PM), and Black (elemental) Carbon (BC) resulting from the future climate scenarios will be evaluated against: 1) patterns of historic fire activity, 2) historic CTM air quality results based on simulating the atmospheric transformations of the historic emissions, and 3) the departure in the future in space, time, and concentration of the field measurements from 2002, 2008, and 2011 – we will leverage and extend all the work we are currently doing from our ongoing JFSP-supported studies, Deterministic and Empirical Assessment of Smoke's Contribution to Ozone (DEASCO$_3$) and Particulate Matter Deterministic & Empirical Tagging & Assessment of Impacts on Levels (PMDETAIL). We will use a publicly available CTM (CAMx), used for regulatory purposes.

Extending the regional modeling framework from these projects to account for future climate as the meteorological driver, while also applying the climate change-caused future emissions in the regional air quality model, allows us to report the change from the historic fire-impacted years of 2002/08/11, to these modeled future air quality conditions. This technique is an extension of the standard method used for air quality planning by EPA, and state and local air agencies, i.e., using the model results in a relative way, scaling the ratio of the historic and future modeling results at each receptor site by the historic monitoring data to estimate the change in space, time, and concentration of future air quality conditions. REACHFAQS-West will deliver regulatory-grade assessments of c.2050 climate change-caused air quality impacts that will allow fire and air quality managers to visualize a range of future conditions based on historic, well-studied impacts of 3 different recent years. The results of the 3 historic years projected for each of the 3 climate change-caused air quality scenarios will be presented in a 3x3 matrix. The matrix will show the degree of difference in air quality impacts across the various climate projections and the amount of change in air quality impacts from well-understood historic conditions. This leveraging and coalescing of work from the JFSP-supported DEASCO$_3$ and PMDETAIL projects to develop a reproducible, regulatory method to project emission based on future climate projections, and evaluation of those result in a fashion used by EPA and states, will provide land managers and air quality regulators a ready-to-use, shared approach.

1. Project Justification and Expected Benefits

Adequately characterizing future transport of ozone precursors from fire sources and the photochemical transformation of precursors to ozone are complicated processes that can require the dedication of significant financial and technical resources. It is similarly challenging to characterize the photochemical processing of fire emissions over a period of many days into secondary organic aerosol (SOA) that may contribute substantially to overall $PM_{2.5}$ burden from fire emissions. Recent field and laboratory results suggest that SOA formed from fire emissions can increase total fire contributions to $PM_{2.5}$ organic carbon (OC) by a factor of two or more. This project will assist Federal Land Managers (FLMs), states, and EPA with analysis results and reproducible methods to address these air quality planning tasks. Based on the research literature predicting a longer fire season, increased fire severity, and a larger number of wildland fires in the future, FLMs and air quality managers will have an ever-growing stake in how fire emissions are addressed in air quality planning efforts.

Equally important is the ability to use prescribed fire as a viable planning tool for forest and rangeland health, which may be compromised by landscape changes brought about by climate change. Under the multi-decade planning horizon of Regional Haze Rule (RHR), assessment of progress by states and FLMS to meet the goals of the RHR is complicated by climate change and impacts of wildfire. Fires' contributions to monitored exceedances of the health-based Ozone and $PM_{2.5}$ National Ambient Air Quality Standards (NAAQS) garner significant attention and continue to be important in regional air quality planning. We expect these fire-related air quality challenges to only increase as climate change affects fire occurrence as NAAQS levels continue to become more stringent. REACHFAQS-West project benefits include:

- The range of wildfire's contribution to Ozone, PM, SOA, BC, and visibility and deposition levels under three climate change scenarios will be quantified;
- Analyses will be grounded by technical methods routinely accepted for use in air quality planning; and
- Products will provide meaningful insight into future Areas of Concern (AOCs) with regard to nonattainment designation, exceptional events, background levels, and fire emissions reduction strategies.

Products:

- Landfire-compatible maps of Western US for three future climate scenarios.
- Animations of regional AQ impacts under three climate scenarios.
- Analysis of future fire management strategies and prescribed fire viability.
- Probability map of RHR progress for Class I areas in Western states c.2050.
- Projected ozone and $PM_{2.5}$ levels c.2050 and comparison with current and potential future NAAQS.
- Interactive website with results and exploration tools.
- Data and methodologies for use and testing, project report, and peer-reviewed publications.

2. Project Objectives and Hypotheses

The REACHFAQS-West Team proposal work tasks are directly aligned with the JFSP's Task 1 objectives:

Select and downscale at least three of the 12 NARCCAP climate projections for the period 2049-2051(c.2050) to provide climate input data needed for vegetation, fuels, and fire regime modeling.

- NARCCAP (Mearns, et.al., 2007) has downscaled the results from five Atmospheric-Ocean General Circulation Models (AOGCMS) for 30-year future (2040-2070) year periods using 12 AOGCM/Regional Climate Model (AOGCM/RCM) combinations to obtain three-dimensional meteorological variables across North America at 3-hour resolution for the A2 SRES emission scenario.
- We will select three of the AOGCM/RCM scenarios and perform further downscaling to the 36 km CONUS and 12 km WESTUS modeling domains that are being used in the JSFP DEASCO3 and PMDETAIL studies.
  - For each of the three AOGCM/RCM NARCAP climate scenarios, we will use the WRF meteorological model to downscale to the 36 km CONUS and 12 km WESTUS domains for the 3-year period of 2049-51 (i.e., c.2050).
- Our UA, NOAA, and NCAR Technical Advisors who are deeply involved in the NARCCAP program will advise us on several critical aspects in the downscaling process, such as:
  - The optimal AOGCM/RCM scenarios to use based on quality of the runs, data completeness and spanning the range of possible future climate variations.

- Procedures and tools for downscaling the AOGCM/RCM results using WRF.
- The downscaled 36/12 WRF modeling results will be used to address altered ecosystems, land cover and resulting fire impacts for areas in the southwestern and northwestern U.S. at 12 km resolution.
- Downscaled 36/12 km WRF results will be processed to generate meteorological inputs for the Comprehensive Air-quality Model with extensions (CAMx) photochemical grid model for the historic and future years.

Identify potential changes in vegetation, fuels, fire occurrence, and severity in response to selected climate change scenarios.

- Use an existing landscape disturbance model, the Fire Effects Tradeoff Model (FETM[1]), to simulate changes in landscape composition and fire activity over time. FETM simulates succession, major disturbances (fire, insects, disease, drought, succession), as well as their interactions over time.
- Leverage existing data sets (MTBS, Bailey Ecoregions, WIMS, Landfire-FCCS, and/or the West Wide Wildfire Risk Assessment (WWWRS)) to initialize contemporary fire regimes for modeling.
- Leverage regional experts and previous FETM studies to assist with developing vegetation transformation pathways throughout the Western US.
- Leverage current research on changes in habitat suitability, interactions of major forest disturbances, and observed climate-induced changes to forest landscapes to validate model results.
- Develop a Landfire-compatible 1-km grid map of predicted future vegetation types for each of the three climate scenarios.

Use results of these simulations to project potential future climate impacts on mid 21st century air quality. Of particular interest are the wildfire emission consequences for particulates (including SOA), ozone, and black carbon.

- Leverage emissions inventories and modeling framework from existing studies assessing ozone and PM impacts ($DEASCO_3$ and PMDETAIL) for historic and future years (use SIP-quality historic year emissions and future year emissions projection techniques) coupled with future year meteorology from the NARCCAP future climate model outputs, creating a range of future air quality scenarios based on historic years that are well-understood.
- Use outputs from FETM (fire frequency, size, and timing) as well as the future-year Landfire-compatible fuels map, and timing, to build fire emissions inventories for c.2050. Apply the historic years' CAMx modeling framework with projected future climate as meteorological input and the projected future emissions to create c.2050 air quality modeling scenarios for analysis.
- Through the WRAP Fire Emissions Tracking System (FETS[2]), the host site for and basis of the $DEASCO_3$ and PMDETAIL projects, extend the site for REACHFAQS-West project to store and analyze data, and produce maps and animations for the Western US, highlighting areas of interest and differences in fire characteristics (size, frequency, timing) across ecoregions.
- Perform CAMx photochemical grid model simulations for the historic years and future years.
  - Use ozone (OSAT/APCA) and Particulate Matter (PSAT) source apportionment tools to keep track of the ozone and $PM_{2.5}$ formed from fire emissions.
  - Use EPA-recommended projection techniques to project future years (c.2050) ozone, $PM_{2.5}$, BC, and visibility and deposition for comparisons against NAAQS and visibility goals at Class I areas.
  - Quantify the role and changes due to emissions from fires on ozone, $PM_{2.5}$, BC, and visibility and deposition for historic and future years under different climate scenarios.

The REACHFAQS-West Team proposes to conduct technical work and collaborative review using several hypotheses. In testing these hypotheses, we intend to address critical technical / policy issues identified in FON 2013-1, Task 1.

Technical Hypotheses

Ho1 – Novel future climate will drive a cascade of changes across the characteristics of ecosystems, fire regimes,

---

[1] http://www.fs.fed.us/r6/aq/fetm/
[2] http://www.wrapfets.org/

and air quality in the Western US, differing significantly from historic conditions.

Ho2 – The current state of information, analysis, models, and science of climate change, of landscape disturbance, and of fire emissions' contribution to Western US air quality are well-suited and vital to prepare believable and understandable projections of ecosystem, fire regime, and air quality conditions c.2050.

Ho3 – The changes in air quality impacts resulting from altered ecosystems and fire regimes will overwhelm the inter-annual variability across the three individual historic fire years.

Policy Hypotheses

Ho4 – The policy priorities of FLMs and air quality agencies will shift as the nature and locations of ecosystems under stress and air quality degradation due to emissions from fire changes over the next 40 years due to a novel climate.

Ho5 – In urban and rural areas of the Western US, the incidence of attributing monitored excursions of air quality standards to Exceptional Events will increase as more frequent, larger, and longer-burning wildfires contribute more often and in greater quantities to regional loading of air pollutants.

Ho6 – The downward trajectory of the stringency levels of health- and welfare-based air quality standards and the extended planning horizons that regulators already face in developing air quality and regional haze State Implementation Plans (SIPs) justify the development of SIP-grade analytical methods and online decision-support tools that incorporate the effects of climate change.

II. Methods

1. Study Site(s)

Modeling will focus on two regions defined in the FON: the Northwest and Southwest, which includes the entire conterminous WRAP region. Areas of interest in terms of air quality and visibility across the Western US will emerge from CAMx modeling of the years 2002/08/11 under the $DEASCO_3$ and PMDETAIL projects. Areas with ozone impacts may or may not coincide with PM impacts. Impacts will be assessed both from the perspective of human health impacts (i.e. urban and rural areas) and regional haze impacts (i.e. Class I areas).

2. Sampling Design

2.1 Downscaled 50 km climate projection scenarios

Three of the 12 climate scenarios available from NARCCAP will be chosen to assess a range of future climate impacts. The quality of the scenarios varies widely, and will be chosen based on results of a current JFSP study led by D. McKenzie, and input from leading researchers in downscaling techniques that are Technical Advisors in the study (C. Castro, Univ. of AZ; K. Mahoney, NOAA; M. Bukovsky, NCAR). Depending on the result of the McKenzie review, we would update our technical approach. We would use the historic-year CAMx modeling results for 2002/08/11 from $DEASCO_3$ and PMDETAIL to characterize historic year ozone, PM, BC and visibility conditions and variability. These historic year runs include ozone (OSAT/APCA) and particulate matter (PSAT) source apportionment runs that quantify the contributions of emissions from fires to historic year ozone, $PM_{2.5}$, BC, and visibility and deposition.

We will then downscale future year climate change scenarios using three AOGCM/RCM NARCAP scenarios and the 3-year period of 2049-2051 (c.2050) using WRF for the same 36/12 km modeling domains as used in $DEASCO_3$ and PMDETAIL. For the Heavy Duty Greenhouse Gas Rule, EPA has projected anthropogenic emissions out to 2030. These emissions would be further projected to 2050. Biogenic emissions would be generated using MEGAN[3] applying the future year downscaled WRF 36/12 km meteorology for the three NARCCAP climate scenarios for the three future years. In addition to providing MEGAN with the different temperature and other meteorological variables for each of the future year climate scenarios, the MEGAN land cover inputs would also be modified to reflect the changes in landuse estimated as described below. Fire emissions would be updated as described next.

2.2 Fire Effects Trade-off Model adapted to a Changing Climate

[3] https://www2.acd.ucar.edu/bai/MEGAN

There are several studies in recent years that identify the relationships and level of importance of the major disturbance forces affecting forest succession in the future: water, disease/insects, fire, and in some places, background ozone levels. Empirical models have been built for areas in the western US (Littell 2010, McKenzie 2003 & 2006, Rehfeldt 2006 & 2012; Spracklen 2009; Hessl 2004) that address large-scale forest response to changing climate and associated disturbances (disease, insects). However, regional-scale models of changes in vegetation and fire regimes thus far have not comprehensively addressed the dynamics and interactions of multiple forest disturbances in a changing climate (e.g., Littell addresses each disturbance individually).

The Fire Effects Tradeoff Model (FETM), a landscape disturbance model developed under a previous JFSP project, is, at its core, a vegetation dynamics model that simulates changes in vegetation composition over time in response to various human-caused and natural disturbances. While not built to explicitly address changes in climate over time, the structure of the model lends itself to adaptation to include such changes. The core strength of FETM for its application on this project is that it bases (both prescribed and wild) fire effects (fire severity, area burned, fuel consumption) on mechanistic, physical principles well-founded in fire science. As such, specific anticipated changes in fuel conditions due to climate change (for example, lower fine fuel moisture) can be incorporated in the modeling from a mechanistic standpoint, while anticipated changes fire frequency would be dealt with stochastically.

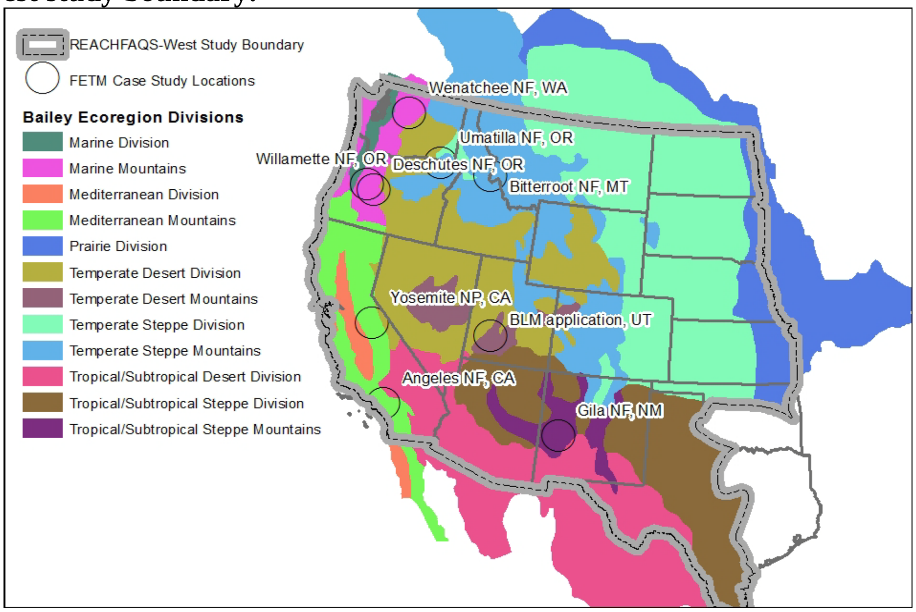
The model projects how a particular vegetation type and structural class changes over time in response to natural succession, management activities, and disturbances: a given type may change structural class, and in the case of climate change, also change potential vegetation type (PVT) as a result of various interacting processes. The modeling team defines the pathways for each process that drives changes in the landscape, as well as the associated probabilities, in advance. The distribution of PVTs over time is then determined (stochastically) by the model based on the likelihood of various disturbances and their interactions. Case studies using FETM have been developed in many types of forests, to guide forest management planning efforts in several western states (Figure 1). These prior FETM applications will provide a basis for defining PVTs, structural classes, and associated transition pathways. Bailey's ecoregions coupled with historic- and future-year climate scenarios may be used to create a simple spatial model to determine changes in ecoregion boundaries and therefore changes in the distribution of vegetation types. We will also draw on our expert technical advisors and federal collaborators that have an unambiguous understanding of historic conditions and the inter-relationships of vegetation conditions, landscape disturbance, wildfire regimes, fire emissions, air quality impacts, and land management and air quality planning.

In addition, data soon to be available from the West Wide Wildfire Risk Assessment (WWWRA) will provide the inputs necessary to initialize FETM. These data include Landfire vegetation grids (at 1km) (ensuring the outputs of the model are Landfire-compatible) and information on contemporary fire weather. Modeling scenarios will be developed for each of the 12 Bailey's Ecoregion divisions present in the Western US (Figure 1). The model will characterize climate changes over time by running in discrete time-steps, after which the model will be re-initialized with "nudged" fire weather parameters, developed with assistance from expert technical advisors. Alterations to the stochastic elements of the model (which predict magnitude of disturbances) may also be perturbed if appropriate. Current literature relating to forest stress interactions (McKenzie et al 2009), the effects of individual disturbances (Littell et al 2010), and projections of wildfire behavior (Flannigan et al 2000; Brown et al 2004; Spracklen et al 2009) and vegetation changes (Rehfeldt et al 2006; Rehfeldt et al 2012) in response to global warming will inform and validate the initialization and outputs of FETM.

2.4 Air Quality Impacts Modeling and Assessment Approach

Under this task, the Team will apply the future climate data and resulting future emissions in air quality modeling and source apportionment studies (using the CAMx modeling framework and monitoring data from in the DEASCO$_3$ and PMDETAIL studies) to identify areas in the West c.2050 where wildfire emissions contribute to air quality impacts. Because the future year modeling results cannot be "truthed" to observed data, other metrics will be developed to 1) validate changes in vegetation and fire regimes and 2) assess the range of air quality impacts in c.2050 by grounding analyses in the results of work already done or in-process for 2002, 2008 and 2011, where model results and sensitivity are evaluated against observations from ozone and PM mass / chemical species, including BC, visibility, and deposition data. We plan to use 2002, 2008, 2011 Ozone, $PM_{2.5}$, and BC monitoring data in a modified EPA Relative Response Factor (RRF[4]) methodology to scale each future scenario's projection of air quality results. By evaluating the uncertainty of the historic-year modeling results against observed data, we can have more confidence in the behavior of the model predicting air quality impacts for the future-year scenarios. For each of the three NARCCAP downscaled AOGCM/RCM scenarios and the three future year modeling scenarios, we would perform CAMx 36/12 km simulations using ozone and PM source apportionment to isolate the contributions of fires to ozone, PM, visibility and deposition. The future year fire ozone, PM, BC and visibility and deposition contributions will be compared across the three alternative NARCCAP climate scenarios, as well as the interannual variability across the three modeling years (2049-2051) for each climate scenario. The future year fire contributions to ozone, PM, BC, visibility, and deposition will also be compared against those from the 2002/08/11 historic years to quantify the changes in the impact of fires in the future under climate change conditions.

Figure 1: Bailey's Ecoregion Divisions in the western U.S., existing FETM case studies, and REACHFAQS-West study boundary.



3. Field Measurements – No new measurements will be made.

4. Data Analysis

A distinctive strength of the REACHFAQS-West Team is the combined analytical horsepower of consulting firms, federal agency collaborators, technical advisors (from University of Arizona, NCAR, NOAA, Forest Service), and PI. During the execution of every major technical task we will execute two important steps to promote excellent deliverables: 1) technical results will be deliberately organized and data presentations and displays will be carefully designed to promote effective review and interpretation, and 2) Task Teams (e.g., landscape disturbance; fire behavior and emissions; climate change and meteorology; photochemical grid modeling; air quality effects) formed from REACHFAQS-West Team members (and, likely, other interested experts/stakeholders) will convene to review and interpret data and develop findings. The REACHFAQS-West Team's model for executing the technical work of each major task will be: Model & Data Gathering → Establish Historic Conditions → Projections Analysis & QA/QC → Organize/Present Data → Review/Interpret → Develop Findings/Lessons-Learned → Build Bridges to Final Deliverables → Document.

We will assess changes in air quality impacts from climate change-caused wildfire emissions relative to historic fire years. This assessment from the air quality modeling results will provide a springboard for analysis of urban and rural areas of interest c.2050 related to air quality standards, nonattainment areas, exceptional events, and regional haze progress goals. We will assess the geographic, temporal, and concentration changes for these. Vegetation

[4] http://www.epa.gov/ttn/scram/guidance/guide/final-03-pm-rh-guidance.pdf

simulation results, combined with regional modeling outputs, will provide insight into the viability of Rx fire as it is currently practiced today. Comparison of the historic year (2002/08/11) and future year (c.2050) fire source apportionment contributions to ozone, PM, BC, visibility, and deposition will allow the quantification of fires effects under alternative climate change scenarios; fires may have larger impacts under increasing more stringent standards potentially increasing their importance even more so than today. The effects of climate change may cause fire weather conditions that eliminate or significantly reduce the frequency and duration of favorable weather/fuels conditions that allow controlled burning. Alternatively, the timing of controlled burning may shift dramatically, both from a fire weather and air quality impact standpoint. Also, we will explore opportunities to fully extend analysis to address FLM concerns being investigated in the DEASCO$_3$ and PMDETAIL projects (nitrogen deposition, elevated background ozone and effects on forest health, W126). Example question include: 1) are potential impacts exacerbated? 2) Is climate-induced succession a greater threat? 3) Are there mitigating factors that will counter-act each other?

5. Materials

Table 1: Data sources and software to be used in the REACHFAQS-West project.

Data sources and software for use are either publicly available or already belong to Team members. REACHFAQS-West deliverables will not be encumbered by software licensing fees or use-limiting intellectual property agreements.

Item	Description	Location	Method to Acquire
Air Quality Assessment			
WRAP 2000-04 Baseline Fire EI	Episodic fire emissions: Wx, Rx, Ag.	Public Doman	Team has
Historic wildfire occurrence data	Federal databases; Monitoring Trends in Burn Severity fire perimeters	Public Domain	Team has
Ozone, PM, Black Carbon (BC) Observations 2000-04, '08, '11	• State/EPA Air Quality System (AQS) data for PM mass • State/EPA/IMPROVE/NADP/CASTNet PM by chemical species including BC • State/EPA/FLM Ozone: AQS / CASTNet	Public Domain	Team has
NARCCAP Climate Scenarios	3 future year climate model results downscaled to 50km grid	Public Domain	Available on NARCCAP Website
WRAP's Fire Emissions Tracking System	Data and emissions inventory framework from the DEASCO$_3$ & PMDETAIL projects	WRAP	Team has
2008 DEASCO$_3$ & 2008/2011 PMDETAIL Model Framework	Emission Inventories (Incl. fire), model setup	CAMx, Public Doman	Team has
Vegetation, Fuels, Fire Regimes Modeling			
Results of Rehfeldt (2006, 2012)	Gridded results of habitat changes for major vegetation types in 2060	USFS Rocky Mtn. Res. Stn.	Team has
GIS data to support FETM development	MTBS perimeters & severity, Daily WIMS, Landfire-FCCS, Ecoregions	Public Domain	Team has
NOAA HMS-based 2008/11 Daily Fire Incident detections		Public Domain	Team has
Model of Emissions of Gases and Aerosols from Nature (MEGAN)	https://www2.acd.ucar.edu/bai/MEGAN	Public Domain	Team has
Modeling Software / Extensions			
Fire Effects Tradeoff Model	http://www.fs.fed.us/r6/aq/fetm/	Air Sciences Inc.	Team has
Weather Research Forecast Model	http://www.wrf-model.org/index.php	Public Domain	Team has
CAMx/APCA	www.camx.com	Public Domain	Team has

III. Project Duration and Timeline

This project will last 3 years, assuming a start date of October 2013, with completion in September 2016.

Table 2: Project Timeline

Project Milestone	Delivery Dates
Task 1 – Historic Years' Assessment	March 2014, June 2015
Task 2 - Climate downscaling	April 2014, August 2015
Task 3 - Vegetation/Fuels Modeling	Summer 2014, Fall 2015
Task 4 - Future emissions and modeling scenarios	Summer 2014, Fall 2015
Task 5 – Historic/Future Air Quality Impacts Assessment	Fall 2014, Winter 2016
Task 6 - Reporting	2016
Task 7 - Management / Coordination	Throughout project

IV. Project Compliance - NEPA and other clearances – Not Applicable.

V. Research Linkage

The REACHFAQS-West Team recognizes and appreciates the JFSP's continued significant investment in the advancement of wildland fire science. The REACHFAQS-West project will leverage and coalesce the projects listed below to address the issues in FON 2013-1, Task 1, using both recently-completed studies and other studies currently underway. For the future climate change-caused emissions scenarios, based on each of the three historic years we are studying in DEASCO$_3$, and PMDETAIL, we will develop three future emissions scenarios for each of the 12 Bailey's Ecoregion divisions present in the Western US, a total of nine future scenarios. The emissions model will characterize climate changes over time by running in discrete time-steps, after which the model will be re-initialized with "nudged" fire weather parameters. Alterations to the stochastic elements of the model (which predict magnitude of disturbances) may also be perturbed if appropriate. For the air quality modeling, the CAMx configurations from the WestJumpAQMS, DEASCO$_3$, and PMDETAIL projects will be fully integrated and applied to the future climate change-caused emissions scenarios proposed here in REACHFAQS-West. The WestJumpAQMS regional modeling framework is assessing regional air pollution transport and source contributions for Ozone, PM, BC, visibility, and nitrogen deposition in support of air quality planning by western states, using emissions, meteorological, and air quality modeling tools, source apportionment methods, and data analysis techniques. Also, as an input to modeling work here in REACHFAQS-West, as we are doing in PMDETAIL, DEASCO$_3$, and WestJumpAQMS, we will apply MEGAN v2.1 developed through a Biogenic Emission Inventory Improvement study for WESTAR Council. Results and data from REACHFAQS-West will be published and shared on request through the WRAP review and collaboration process with states and local air agencies, FLMs, U.S. EPA Regional Offices and the Office of Air Quality Planning and Standards' (OAQPS) Modeling Group.

Table 3: Current and Pending Research Grants

Grant Program	Project or Proposal Description/Identification	Funding Amount	Project Completion Date
WESTAR Council	Biogenic Emissions Inventory Improvement	\$130,000	Winter 2011-12
Federal & State Agencies and Private Industry	WestJumpAQMS - Modeling and Analysis of Regional Ozone and Related Air Quality Indicators.	\$721,000	Summer 2013
JFSP Project 11-1-6-6	DEASCO$_3$ - Deterministic and Empirical Assessment of Smoke's Contribution to Ozone	\$370,000	May 2013
JFSP Project 12-1-08-31	PMDETAIL - Particulate Matter Deterministic & Empirical Tagging & Assessment of Impacts on Levels	\$703,000	Spring 2016

VI. Deliverables and Science Delivery

We will deliver innovative and useful technical data, results, and web tools products for evaluation and use by FLMs, states, EPA, and others. Every step in all of the tasks in this technical proposal has been thought through and developed with the purpose of delivering innovative and useful technical products. REACHFAQS-West's centerpiece deliverable will be an interactive website that provides a gateway to access the emission inventories, modeling scenarios, and vegetation maps produced over the course of the project, as well as animated impact assessment results and other visualizations that allow users to "drill-down" into the technical products to facilitate useful analysis. The results matrix of 3 future emissions scenarios (derived from the base years 2002, 2008, and 2011) modeled using each of the 3 chosen climate scenarios (totaling 9 result sets) will be presented dynamically such that they may be compared in different combinations, with the underlying technical assumptions and input data for each result set viewable and downloadable. Always-on, web-based access will be an effective and efficient way to transfer data, analytical tools, and findings of the project to end-users. Other deliverables for REACHFAQS-West include: 1) essential documentation explaining data sources, technical methods, QA/QC, results, data interpretation, and assessments of uncertainty (or other potential limitations to the technical work and findings); 2) a 20-40 page final report that presents the major methodologies of the project, describes the significant findings, and identifies ways that the results could be effectively used in air quality planning processes (the Team will prepare this report with the intention of submitting the document for two publications—one focused on the air quality assessment and one focused on the vegetation/fuels simulations—in a refereed journal); and 3) an annual progress report 12 and 24 months after the start month.

Table 4: Deliverables, Description, and Delivery Dates

Deliverable Type	Description	Delivery Dates
Historic Years' Baseline Assessment	2002 / 08 / 11 historic years' monitoring and emissions data to relate Wx fire emissions to observed ozone, PM, and BC air quality	March 2014, June 2015
Climate Downscaling	• Downscaled projections of climate for the northwestern and southwestern regions of the US in the mid-21st century (c.2050) • Refine/design and test coupling of results from global AQ models and future climate simulations, to regional AQ model domain(s)	April 2014, August 2015
Vegetation/Fuels Modeling	From future climate simulations, develop changes to vegetation, fuel loading, and fire regimes for modeling domain	Summer 2014, Fall 2015
Future Emissions & Modeling scenarios	Model projections of potential future smoke emissions to estimate air quality impacts to identify areas of concern for achieving air quality standards	Summer 2014, Fall 2015
Future Air Quality Impacts Assessment	Evaluate range of effects of changes in Wx fire emissions to modeled air quality, deliver via visualization and reporting tools on FETS website	Fall 2014, Winter 2016
Reporting	Report range of Ozone, $PM_{2.5}$, and Black Carbon impacts under future climate and emissions scenarios, relative to historic fire years	2016

VII. Roles of Investigators and Associated Personnel

The proposed project has Tom Moore as Principal Investigator to coordinate and manage the project. In the context of supporting air quality planning to comply with CAA requirements, he has significant experience with large-scale air quality data analysis/assessment projects and detailed knowledge of fire emissions and applications of PGM results, and he has led projects to develop and deliver well-regarded web database tools for state air agency and FLMs' use, through the Regional Haze planning process. He also has a proven track record in managing the experienced and well-regarded key technical contractor personnel assigned to technical analysis and work product delivery activities for fire emissions and empirical analyses and tools (David Randall and Matthew Mavko) and ozone photochemical grid modeling and source apportionment (Ralph Morris and colleagues). Both technical contractors have performed comprehensive SIP-quality analyses under Mr. Moore's direction in support of state air quality implementation plans, within specified time frames and limited resources.

Further, Mr. Moore's time will coordinate analysis and review activities by FLM collaborators. We collaborate with the same strong team of FLMs with extensive air quality and fire experience as in the PMDETAIL and $DEASCO_3$ projects. Mark Fitch has extensive experience with fire activity and emissions through his career with a state air agency, a USFS regional office, and now with the NPS at NIFC. Significant experience with photochemical modeling applications for air quality issues affecting national parks from fire and other sources is contributed by Michael Barna of NPS as well as by Bret Anderson of USFS. With respect to interpreting technical results for FLM use in SIP air quality planning processes and evaluation of exceptional events, Michael George and John Vimont of NPS, and Ann Acheson of USFS bring strong technical and management backgrounds to this project, respectively, with their current responsibilities for air resource protection, planning, and policy analysis.

We have added expert technical advisors and an additional collaborator to bring specific skills and experience to aid our analysis of interpreting fuels and fire regime changes resulting from the disturbance caused by projected climate change (Don Carlton, retired Forest Service, is a co-developer of FETM and is a forest fuels specialist; Paul Werth, retired Forest Service, has extensive experience with fire weather and meteorology; Craig Allen, USGS, has done extensive research on the affects of climate and other disturbances on forests in the Southwest) and in climate modeling projections and downscaling techniques (Christopher Castro at UA and Kelly Mahoney at NOAA have direct experience in downloading NARCAP AOGCM/RCM scenarios to study future climate issues and Melissa Bukovsky at NCAR is part of the NARCCAP team and the go-to person for downscaling issues and software). The unified PI-technical contractor-collaborator-advisor team will assess data, analysis results, and deliverables for each proposed task.

VIII. Literature Cited

Air Sciences. 2005. 2002 Phase II Fire Emission Inventory for WRAP Region. Air Sciences Golden, CO, July.

Brewer, P. and T. Moore, 2009. Source Contributions to Visibility Impairment in the Southeastern and Western United States. *AWMA Journal*, Air & Waste Management Association; September.

Brown, T.J., B.L. Hall, and A.L. Westerling. "The impact of twenty-first century climate change on wildland fire danger in the western United States: an applications perspective." Climatic Change 62, no.1 (2004): 365-388.

ENVIRON. 2010. Users Guide to the Comprehensive Air-quality Model with extensions (CAMx) – Version 5.3. ENVIRON International Corporation, Novato, CA.

EPA. 2007. Guidance on Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$ and Regional Haze. U.S. EPA, Research Triangle Park, NC. EPA-454/B-07-002. April.

Flannigan, M. D., B.J. Stocks, and B.M. Wotton. "Climate change and forest fires." Science of the total environment 262, no. 3 (2000): 221-229.

Littell, Jeremy S., Elaine E. Oneil, Donald McKenzie, Jeffrey A. Hicke, James A. Lutz, Robert A. Norheim, and Marketa M. Elsner. "Forest ecosystems, disturbance, and climatic change in Washington State, USA." Climatic Change 102, no. 1 (2010): 129-158.

McKenzie, Donald, David L. Peterson, and Jeremy J. Littell. "Global warming and stress complexes in forests of western North America." Developments in Environmental Science 8 (2008): 319-337.

Mearns, L.O. et al. 2007. The North American Regional Climate Change Assessment Program Dataset. National Center for Atmospheric Research Earth System Grid Data Portal, Boulder, CO. (doi: 10.5065/D6RN35ST; http://www.narccap.ucar.edu/).

Moore, T. and P. Brewer, 2007. Regional Haze Planning in the Western and Southeastern United States. *Environmental Manager*, Air & Waste Management Association; September.

Morris, R.E., M. W. Gery, M. Liu, G. E. Moore, C. Daley, and S. M. Greenfield. 1989. Sensitivity of a Regional Oxidant Model to Variations in Climate Parameters. Prepared for USEPA Research and Development - Atmospheric Research and Exposure Assessment Laboratory. EPAJ600/S3-89i068. September.

Rehfeldt, G.E., N.L. Crookston, M.V. Warwell, and J.S. Evans, 2006. "Empirical analyses of plant-climate relationships for the western United States." International Journal of Plant Sciences 167, no.6: 1123-1150.

Rehfeldt, Gerald E., Nicholas L. Crookston, Cuauhtémoc Sáenz-Romero, and Elizabeth M. Campbell. "North American vegetation model for land-use planning in a changing climate: a solution to large classification problems." Ecological Applications 22, no. 1 (2012): 119-141.

Spracklen, D. V., L. J. Mickley, J. A. Logan, R. C. Hudman, R. Yevich, M. D. Flannigan, and A. L. Westerling. "Impacts of climate change from 2000 to 2050 on wildfire activity and carbonaceous aerosol concentrations in the western United States." Journal of Geophysical Research 114, no. D20 (2009): D20301.

Tai, et.al. 2008. Boundary Conditions and Fire Emissions Modeling. Prepared for the Texas Commission on Environmental Quality by ENVIRON, Novato, CA.

UNC. 2009. Peer Review of Source Apportionment Tools in CAMx and CMAQ. University of North Carolina, Institute for the Environment, Chapel Hill, North Carolina. August 31.