Year 2 – Interim Progress Report

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Development of decision products for spatial quantification of carbon emissions from wildfire for North America

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Nancy H.F. French, PI, Michigan Tech Research Institute,
3600 Green Ct, Suite 100, Ann Arbor, MI 48105
Donald McKenzie, Institutional PI, Pacific Wildland Fire Sciences Lab, USDA Forest Service
Tyler Erickson, Co-I, Michigan Tech Research Institute, Ann Arbor, MI
Roger D. Ottmar, **Co-I**, Pacific Wildland Fire Sciences Lab, USDA Forest Service
Eric S. Kasischke, Co-I, Department of Geography, University of Maryland, College Park
Ernesto C. Alvarado, Pacific Wildland Fire Sciences Lab, USDA Forest Service
William de Groot, Great Lakes Forestry Research Centre, Canadian Forest Service

Introduction

Michigan Tech Research Institute (MTRI) has teamed with specialists at the USDA Forest Service Pacific Northwest Research Center's Fire and Environmental Research Applications (FERA) lab to provide information for mapping fire-derived carbon emissions by adapting existing Forest Service fire information products and tools using NASA data and products. The Goal of the proposed project is: To provide improved information on carbon emissions from wildfire to users who manage carbon or model the carbon cycle. The objectives are:

1. To develop a prototype information system for disseminating and using improved, user-accessible spatial information products for modeling and estimating fire emissions across North America.
2. To develop improved products to estimate carbon emissions from North American fires, including fuels maps and fire consumption estimates, based on:
   - NASA-sponsored science and NASA-derived datasets and models; and
   - The adaptation of USFS-FERA information products and models.

Estimating fire emissions from ground-based data requires calculation from four parameters (French et al. 2004): area burned, fuel loading (biomass per unit area), fuel consumption (fraction of biomass consumed), and emission factors (mass of a given chemical species emitted per mass of fuel/biomass consumed). The project planned will collect data for all of these factors so information users will have the latest and most accurate data for use in models and emissions estimations. The information will be provided at a 1 km spatial resolution and have relevance for understanding fire-affected carbon cycling at regional scales for the North American continent.

Project plan & progress to date

The approach to achieving the proposed objectives was planned as five steps:

1. Coordination of user needs – *Obj. 1 & 2*
   (user advisory group meeting & surveys)
2. Building the information system – *Obj. 1*
3. Developing fire emission information products – *Obj. 2*
4. Testing the information system & emission products – *Obj. 1 & 2*
   (feedback from user advisory group)
5. Finalization of the prototype information system & products – *Obj. 1 & 2*

Steps 1-4 are underway and progressing. Step 1 was initiated in Year 1 with no activity in Year 2 and is reviewed in the Year 1 progress report. Step 2 and 3 were initiated in Year 1 and continued in Year 2; details are given below. Based on the planned project timeline provided in the final work plan and revised as the project has progressed, we are on or ahead of schedule for all of the tasks listed (Appendix).

Summary of Progress in Year 2 (details follow)

- Initial development of W.F.E.I.S. web pages underway. Entry page can be found at: http:\\wfeis.mtri.org
- Python-CONSUME developed from the US Forest Service CONSUME model. The software is currently in the testing phase and will be completed for use within W.F.E.I.S. and to be distributed as a stand-alone software package.
- Integration of MODIS direct readout burn area products (provided by L Giglio) and MTBS burn perimeters into W.F.E.I.S. complete.
- Development of an additional 78 FCCS fuelbeds by the USFS funded through this NASA grant added to the 112 existing – a 40% increase in fuelbed descriptions for the US.
- Development of new 1 km-scale FCCS map for the US west from LANDFIRE program FCCS maps. Same for US East and Alaska expected soon.
- Completion of fire timing maps expected for use in developing default fuel moisture conditions.
- The CanFIRE model has been modified to use CONSUME-based emissions factors to model trace gas emissions.
- Particiption in eight project meetings and relevant conferences.
- Started drafting, as first author, a journal manuscript on estimating fire emissions as part of the NACP Disturbance Synthesis activity.

Step 2 (Obj 1): Building the Information System

MTRI is in the process of developing an on-line geospatial information system that pulls together fire location data with corresponding fuel consumption and fuel loading data layers for fuel emission modeling. The geospatial data system will be built from open-source software components that work with open international standards developed by the Open Geospatial Consortium (OGC) in order to facilitate future enhancements to the system. The *Wildland Fire Emissions Information System* (W.F.E.I.S.; http://wfeis.mtri.org; Fig. 1) is being developed using open-source software components. The core application is the GeoDjango web framework, which queries data stored in a spatially-enabled relational database (PostGIS), processes the geospatial data, and provides output in a wide variety of output formats for client tools. The GeoDjango framework is Python based (http://www.python.org/), which allows for running external scientific models, such as the CONSUME emissions model.

The W.F.E.I.S. is past the initial development phase and is in the process of being tested and functionality implemented in the web environment. Data sets to estimate emissions are now integrated with the system, including formatting of the fire perimeter layers and fuels map for the conterminous US (details on data sets are given in the next report section). Translation of the fuel consumption and emissions model to be used for the US and Mexico into Python (http://www.python.org/) was required for use in the W.F.E.I.S. This step is complete and the Python version of the CONSUME model (Python-CONSUME) is being tested and packaged for integration with W.F.E.I.S. and to be disseminated as an ope-source stand-alone tool.

The W.F.E.I.S. web pages are under construction with the initial roll-out planned for the first quarter of 2010. The initial version will cover just the conterminous US (and possibly Alaska). The system will be reviewed by our Canadian partners to work out some inconsistencies in the approach they have to emissions modeling. Data sets anticipated from Mexican collaborators will be included in future version to come on-line within the first half of 2010. The expectation is that final version of the W.F.E.I.S. will be a North America-wide system to access emissions data products that will be consistent across international borders.

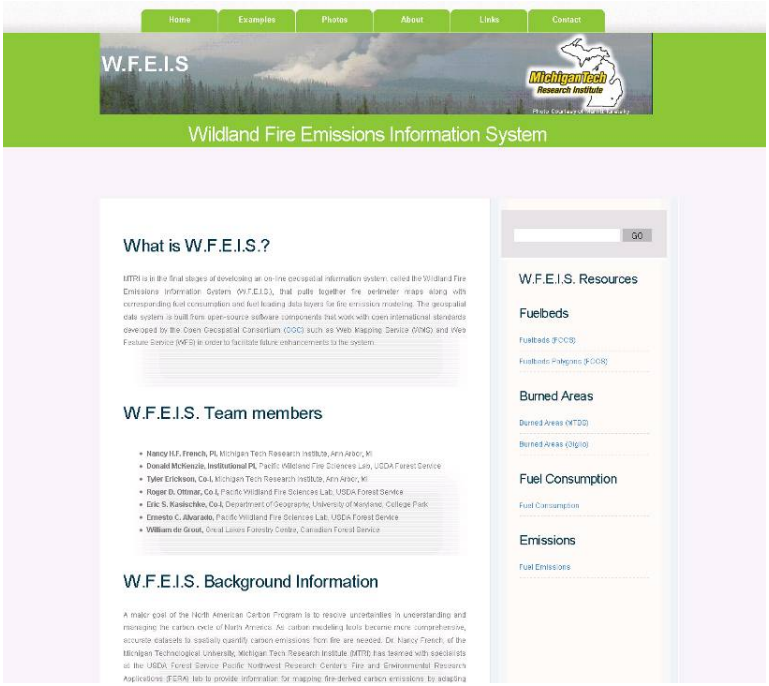

Figure 1: Screenshot of the W.F.E.I.S. web page - http://wfeis.mtri.org

Step 3 (Obj. 2): Developing fire emission information products

The information system will provide access to data representing all four of the data layers needed for estimating fire emissions. Information products will be provided as GIS-based and tabular products at a 1-km cell-size covering North America, including Alaska, Canada, the

conterminous United States, and Mexico. US model-based emissions products will be provided for the US and Canadian model-based estimates for Canada. Estimates for Mexico will likely be derived using Mexican fuels data in conjunction with US-developed emissions modeling.

Fire perimeter maps:

Fire location and perimeters will be included in the W.F.E.I.S. from existing burn area products. The burn area datasets for use in the information system will be NASA's MODIS 500m Monthly Burned Area Product (MCD45A1; Roy et al. 2005; Roy et al. 2008), MODIS direct readout 500m product (Giglio et al. 2009), the Monitoring Trends in Burn Severity (MTBS) burn severity vector perimeters, and the archived fire perimeter data held in the Alaska and Canada Large Fire Databases (LFDB). Currently, fire perimeters from MTBS for June 1984 to 2005 and the direct broadcast MODIS products for 2001 to 2008 are integrated with the W.F.E.I.S. Addition of MTBS for 2006 and 2007 is underway with 2008 and 2009 to be added. Integration of fire record-based perimeter maps for Alaska and possibly Canada as well as integration of the NASA Burn Area Product (MCD45A1) is forthcoming.

Fuels maps:

We are improving the Fuel Characterization and Classification (FCCS) fuelbed descriptions and spatial fuelbed database for use in the W.F.E.I.S. (Co-Is McKenzie and Ottmar). An additional 78 fuelbeds have been described for the FCCS, a 40% increase in fuelbeds from the set available before the project start. Additionally, the fuelbed spatial database has been upgraded using the LANDFIRE vegetation layers and is now available for the conterminous US at a 30 m cell size. An aggregated map of FCCS fuelbeds produced from LANDFIRE maps at a 1 km cell size to be integrated with the W.F.E.I.S. is complete for the West and underway for the East. Over the next year, we will also extend this to Alaska. Fuelbeds are currently being developed for Mexico (Co-I Alvarado), using inventory data from both northern Mexico and the tropical regions, combined with a vegetation classification provided by the Mexican Forest Service. All new fuelbeds (descriptions of fuels) for the US and Mexico are created based on the procedure developed by the US Forest Service (McKenzie et al. 2007; Ottmar et al. 2007).

The plan for improving the FCCS-based spatial fuelbed database has changed since the start of the project. Our original intent was to develop a raster data layer with more than 20 attributes, each of which would represent a unique fuel characteristic (e.g., canopy fuel loading, dead wood < 10 cm diameter, etc.). This raster layer was to be derived from a combination of MODIS VCF (vegetation continuous fields) and an optimization routine involving iterations of a process-based simulation model. For two reasons explained below, we have decided instead to use a much simpler spatial representation of fuels in the W.F.E.I.S. database developed from the LANDFIRE products, one involving a raster layer of unique classes (FCCS fuelbed IDs) and a master lookup table that links each class to default fuel characteristics (the aforementioned 20+ attributes).

First, after some estimates of the computational time associated with the unwieldy raster layer our original method entailed, it became evident that for W.F.E.I.S. to operate efficiently, major modifications to its open-source software components would be required. We therefore decided to trade the “potential” increased accuracy of the fuels data layer for an alternative that will ensure an order-of-magnitude more efficient operation of the W.F.E.I.S.. Second, preliminary trials of the optimization routine using MODIS VCF suggested that for many, if not most, vegetation/fuel types, existing allometries for converting MODIS data to fuel loadings were not robust enough to ensure that this procedure would net us much of a gain in accuracy. The

optimization procedure has promise, but will likely only work effectively in a few conifer forest types without much more work. Given the logistical difficulties and the possibiliy of minimal improvement, we decided to concentrate on assuring the consistency of the simpler classification scheme and to leave the MODIS-based modeling for a future effort.

As reported in the Year 1 inetrim report, we had originally intended to include an FCCS data layer for Canada in the W.F.E.I.S., but in our meetings with partners in the Canadian Forest Service (CFS), we concluded that the fire emissions prepared for the W.F.E.I.S. over Canada will be derived using the procedures employed by the Canadian Forest Service's Forest Carbon Accounting Program. This decision means using a fuels map created using Canada-specific protocols rather than one based on FCCS, and that a full map of FCCS fuelbeds across Canada will not be developed in the course of this project. The CFS, however, is considering options to integrate Canadian fire emissions results into W.F.E.I.S. in Year 3 of the project.

Fuel consumption modeling:

Two fuel consumption/fire emissions models will be employed for the W.F.E.I.S., the US Forest Sevice's CONSUME model (Co-I Ottmar) and CanFIRE (previously BORFIRE), developed by the CFS (Co-I de Groot). Fuel consumption will be estimated by employing the CONSUME fuel consumption model in the US and Mexico, which works from estimated fuel loads mapped from FCCS fuel bed descriptions. Canadian fire emissions will be estimated with the Canadian Forest Service's CanFIRE model (de Groot et al. 2007). In this past year, the CONSUME model was translated into a new format using Python in order to integrate the model with the W.F.E.I.S. The task of re-writing CONSUME 3.0 in Python allowed a full review of the model implementation and revealed a few code errors in the software distributed by FERA, which are now corrected for the Python implementation. The Python-CONSUME model currently produces consumption and emissions for wildfires, and not for "activity fuels", a fuel class that the original CONSUME 3.0 works with. The new version also does not estimate heat release, as does CONSUME 3.0. Both of these features will be added to Python-COMSUME in the next version.

Fuel consumption (and emissions) is strongly driven by the moisture conditions of the fuel at the time of the fire. The CanFIRE model explicitly includes fire weather in fuel consumption and emissions estimations. The CONSUME model requires user input for fuel moisture. We plan to develop default fuel moisture inputs for all fires. For fires within the MODIS era, these will be based on fire weather at the time of burning, which can be determined using the MODIS active fire data. For fires before the MODIS era, we will determine a set of options for the user – a low, moderate, and high fuel moisture – as defaults. For any "automated" runs in the W.F.E.I.S., the moderate scenario will be employed. To develop these defaults, maps of fire timing are being developed for the MODIS era. Completion of these maps is expected by the end of project year 1.

Since two models will be employed to estimate emissions, and consistency of data across North America was one of the goals of this project, we have started conducting an analysis using the CONSUME 3.0 and CanFIRE fire emissions models within the same fuel types. The two models use the same basic approach to consumption and emissions modeling, so it is expected that the results from the two models will be comparable. Variations in fuel load and moisture are being tested using both models at sites with the same fuel type and fire size to estimate fire emissions using each model. By varying input data, we are assessing how the two models compare. Differences will then be considered and models modified, if needed.

Emissions factors:

Development of new emissions factors is not part of this project. Emissions factors (information to partition total carbon into specific emissions gases and aerosols) are available and are used in the CONSUME 3.0 emissions model and now integrated in Python-CONSUME. As a result of discussions for this project, the CanFIRE model has been modified to use these emissions factors to model trace gas emissions.

Project administration, coordination, and outreach

Year 2 Project meetings and workshops:

- PI French met with Collaborator de Groot to review Canada W.F.E.I.S. in Sault Ste Marie, Ontario – Jan 2009
- Co-I Erickson attended the *NACP All Investigators Meeting* in San Diego – Feb 2009
- PI French attended and served as co-host at the *Workshop on Land Use/Land Cover Change and the Carbon Cycle* held in Ann Arbor – June 2009
- PI French and Co-I Erickson attended project meeting hosted by Co-I Kasischke at the Univ. of Maryland – Jul 2009
- PI French met with A Soja and others to review the use of W.F.E.I.S. in a new NASA applications project in Hampton, VA – Oct 2009
- PI French met with Co-Is McKenzie, Ottmar, and Alvarado to review project progress at the FERA lab, Seattle, WA – Nov 2009

Presentations & publications

- Oral presentation "Quantifying wildland fire emissions at landscape to continental scales" presented at the Spring AGU, Toronto, ON – May 2009
- Poster presentation "The Wildland Fire Emissions Information System: Providing information for scientists and managers with open source GIS tools" at the 4th International Fire Ecology and Management Congress, Savannah, GA – Dec 2009
- Initiated manuscript on fire emissions for the NACP Disturbance Synthesis activity lead by E S Kasischke
- Serving as co-editor and contributing author on a book "Land Use and the Carbon Cycle" to be published by Cambridge University Press in 2001 or 2011

Project web sites

Fire Emissions Project wiki

URL: http://wiki.mtri.org/display/FIRE/Home
Audience: Internal project members (password protected)
Purpose: internal development content

WFEIS Advisory Group

URL: http://wiki.mtri.org/display/WFEISadv/Home
Audience: WFEIS Advisory Group (password protected)
Purpose: enables sharing of content with the advisory group WFEIS Users

WFEIS Web site (under development)

URL: http://wfeis.mtri.org
Audience: Users of the WFEIS
Purpose: public-facing website that describes WFEIS and provides interface with information system

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Appendix

Lead	Task	2008 Q2	2008 Q3	2008 Q4	2009 Q1	2009 Q2	2009 Q3	2009 Q4	2010 Q1	2010 Q2	2010 Q3	2010 Q4	2011 Q1	Deadline	Expected Output/outcome
TE/ NHFF	**Objective 1: Info system tasks**														
NHFF	Prep for user group meeting (establish baseline)		complete											complete	meeting report; ideas on structure & content of WFEIS
NHFF	Conduct user group meeting/surveys		▲						△				△	as shown	feedback on WFEIS utility for users
TE	Build initial Info System (WFEIS)		●	→	→	→	→	→	→					Mar-10	The initial WFEIS will be developed with existing FCCS fuelbeds for CONUS
TE	Refine WFEIS to full system								●	→	→	→		Dec-10	Full WFEIS will be NA-wide; Canada estimates will be integrated into system
TE	Finalize WFEIS & roll-out											●	→	Jan-11	
NHFF/ DM	**Objective 2: Product development tasks**														
NHFF	Gather/update data products for WFEIS (baseline/benchmark)		●	→	→	→	→	→	→	→	→	→		ongoing	update data inputs fro WFEIS as needed
ESK	Improved burn area products	●	·····	●	→	→	→	→	→	→				Apr-10	Burn day will be used to ID fire weather for CONSUME
EA	Produce new fuelbeds for Mexico				●	→	→	→	→	→				May-10	
EA	Produce Mexico fuelbed (FCCS) map						●	→	→	→				May-10	Mexico funded to create fuelbeds and map
RO	Field data collection for fuels work (travel)					started	→	→	→	→				as shown	
DM	Create new NA fuelbed map			started	→	→	→	→	→	→	→	→		Aug-10	
MB	Improve Consume 3.0 for use in WFEIS (Python code)		●	→	→	→	→	→	→					complete	Python version of CONSUME 3.0 avail to public
NHFF	Compare CONSUME with BORFIRE at designated sites						●	→	→	→				May-10	To assess differences in emissions estimates
MB	Develop CONSUME fuel moisture inputs								●	→				Feb-10	Use fire date maps with daily weather by ecoregion
BD	Develop "CanWFEIS"	previous & on-going CFS work												Jul-10	WFEIS for Canada - FBP-based fuels w/CanFI loadings; CANFIRE derived
MB	Develop emissions scenarios for historic fires in WFEIS									●	→	→		Jun-10	Define fuel moisture variability scenarios (low/mod,severe)
All	**WFEIS Analysis & Studies (some TBD)**														
NHFF	Quantify emissions for defined regions/times w/WFEIS														
MB	Make ecoregion-based estiamtes for NA						●	→	→					Mar-10	for CONUS
ESK	Quantify AK emissions for 1990 to 2009								●	→	→	→		Nov-10	Use LFD as perimeter inputs compared to MODIS in 2000's
NHFF	Quantify NA emissions for 2000 to 2009								●	→	→	→		Nov-10	Use MODIS perimeters
BD	Quantify Canada emissions w/years TBD									●	→	→		Nov-10	
NHFF	Compare WFEIS-based outputs to independent info									●	→	→	→		journal articlesand presentations
All	Review of WFEIS and FCCS, Consume, BORFIRE improvements											●	→	May-11	journal article/ benchmark report

Lead	Task	2008 Q2	2008 Q3	2008 Q4	2009 Q1	2009 Q2	2009 Q3	2009 Q4	2010 Q1	2010 Q2	2010 Q3	2010 Q4	2011 Q1	Deadline	Expected Output/outcome
NHFF	**Program Management & Reporting**														
NHFF	Initiate planning and assignments	complete												complete	
NHFF	Update project plans					in progress				●	→	→		as shown	
NHFF	Submit progress/final reports to NASA (incl. benchmarks)				▲				△				△	as shown	Reports must include baseline/benchmarks
All	Attend program meetings (travel)	Umd		Victoria		Umd		Seattle		△				as shown	phone meetings are scheduled every 4-6 weeks
TE	WFEIS demos							▲	△			△	△	as shown	Inernal review complete - Demo to Advisor group, Mar/Apr 2010
All	Deliver paper at scientific conference (travel)			AGU		AGU		Firemtg & AGU				AGU		as shown	AGU & Fire meeting
All	Prepare and submit paper(s) to scientific journal(s)							●	→	→	→	→	→	as shown	

▲ = actual △ = planned