Development of Regional Fire Emissions Products for NASA's Carbon Monitoring System using the Wildland Fire Emissions Information System

Short Title: Regional Fire Emissions Mapping with WFEIS

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Contents

1 Summary of Research Activities

While measures of biomass burning emissions were included in the CMS Phase 1 pilot project, the estimates would greatly benefit from further refinement, and an improved assessment of the uncertainty in biomass burning emissions is needed. Under this CNS Phase 2 project we are using tools developed from collaborations with the US Forest Service and US Environmental Protection Agency, as well as recent research carried out for NASA, to refine the fire emissions module of the CASA-GFED model currently used by CMS. We plan to use the Wildland Fire Emissions Information System (WFEIS to assess GFED estimates over North America. WFEIS operates at a 1-km spatial grid scale, while GFED operates at a 0.5 deg grid scale. While the two approaches use the same general construct they have different data sources for the model parameters and make different assumptions when applying the general model. WFEIS uses a ground-based method to map biomass (fuel loading) and a more direct method to estimate combustion completeness (fuel consumption) than GFED. WFEIS was developed as a regional to landscape-scale method, making it an appropriate tool to refine the GFED estimates of emissions for areas where the two methods can be implemented.

The project goal is to use WFEIS to develop a set of fire emissions products that represents total carbon and carbon dioxide (CO_2) emissions from biomass burning at a 1-km grid scale for the US, including the conterminous states (CONUS) and Alaska (AK). These WFEIS-derived estimates, along with a measure of estimate uncertainty, will be compared to fire emissions derived from the GFED approach for the same regions and timeframes. WFEIS results could then be used to modify input parameters within CASA-GFED, the carbon modeling approach currently being used in the CMS Flux Pilot study, in order to improve upon the current methods.

Objective 1: Improve current fuels mapping and fuel consumption methods to improve the performance of WFEIS;

Objective 2: Create monthly WFEIS emissions estimates for CONUS & AK for 2001 to 2011 that include uncertainty measures of fire emissions that can be included in WFEIS model outputs;

Objective 3: Compare WFEIS inputs and results to the GFED model and work with CASA-GFED team to integrate results from the WFEIS work to improve CMS flux estimates.

Our overall approach is to connect regional-scale products derived from WFEIS to currently used CASA-GFED estimates to develop improved fire emissions estimates for CMS. The process will involve some initial work to improve WFEIS fuel loadings (biomass maps; Obj 1), and develop a method to use the known variation in the fuel loadings and fuel consumption estimates to assess the uncertainty in the regional emissions maps (Obj 2). The WFEIS system will be exercised for CONUS and AK (Obj. 2) and results, along with an estimate of emissions uncertainty will be compared to GFED estimates. Working with the CASA-GFED team, WFEIS results will then be used to modify input parameters within CASA-GFED to improve CASA-GFED-based estimates of fire emissions (Obj. 3).

2 Progress and Status by Task

2.1 Objective 1: Improve current fuels mapping and fuel consumption methods to improve the performance of WFEIS.

Task 1: Develop methods to capture explicit variability in canopy fuels for forests and non-forests:

- We have explored the feasibility of using VCF and other data sets to improve canopy fuel loadings within the 1-km fuels map used within WFEIS. We have explored the feasibility of using MODIS Vegetation Continuous Fields (VCF) and other data sets to improve canopy fuel loadings within the 1-km fuels map used within WFEIS. We overlaid VCF on the FCCS fuelbeds to produce a data layer that improves the representation of spatial variability in canopy fuel loadings across the CONUS. This applies to dominant vegetation in forests and shrublands. This is very tractable because of the limited number of unique values in the VCF. This database has just been delivered to the WFEIS software engineers.
- We obtained a forest biomass layer for the CONUS from CMS collaborators <name of Sassan's project>. These data will be overlain on the FCCS map and crosswalked to FCCS fuelbeds differently from the VCF, providing an explicit comparison of methods.
- We will be exploring ways to verify/validate the fuels loading maps. Leveraging off of current activities, such as activities under the Biomass Mapping Pilot from CMS, may be the best avenue.

Task 2: Develop methods to create annual fuels maps with the current FCCS map as the base:

- We have integrated the 2009 and 2010 cropland data layer (CDL)-derived maps of cropland fuels with the Forest Service/Landfire FCCS map of CONUS. The 2010 product is available for download at the ORNL-DAAC.
- We plan to demonstrate the use of MTBS fire perimeter maps to tag forest age in order to include some forest successional information in the FCCS fuels map. We are also considering integrating products from other projects (e.g. Landfire or NASA disturbance products) for this task.
- These annual-scale changes will be grounded in new VCF-based data layers at regular intervals (~ 5 years) when updated VCF becomes available.

Task 3: Assess the ground-layer fuel consumption estimates for Alaskan forests from WFEIS using independent data sets from previous NASA research.

- Created an integrated data layer for annual disturbance in Alaska including insects and fire. The product includes major insect disturbances and 221 fire events (>1,000 ha) that represent 90% of the area burned for the study period (2001 to 2010).
- Complied vegetation, weather, and elevation data for the time period.
- Under a related NASA project, made improvements to TEM model for estimating organic soil burning. Co-Is Genet and McGuire are currently further modifying TEM to produce the fuel types and layers that will be used in the data product produced under project. They expect to have these modifications completed by the end of August 2013.

2.2 Objective 2: Create monthly WFEIS emissions estimates for CONUS & AK for 2001 to 2011 that include uncertainty measures of fire emissions that can be included in WFEIS model outputs

Task 4: Develop methods to assess fire emissions model uncertainties.

- We have begun the development of an uncertainty assessment methodology for WFEIS. The potential sources of error have been identified, and these include errors derived from the empirically developed Consume equations that relate field-measured fire variables (pre-and post-fire variables) to consumption.
- An demonstration of how to assess the errors form the Consume model is nearly complete and will be a main focus of the uncertainty approach report.
- We plan to complete a comprehensive report on how to perform a rigorous uncertainty assessment of WFEIS as well as creating some initial assessments of uncertainty using a sensitivity analysis approach that will be less rigorous but more quickly available for the project outcomes.

Task 5: Exercise WFEIS under a variety of conditions.

- This task is underway with plans to complete before the end of the calendar year. We are awaiting system updates.

2.3 Objective 3: Compare WFEIS inputs and results to the GFED model and work with CASA-GFED team in integrating results of WFEIS work to improve CMS flux estimates from the CASA-GFED approach.

Task 6: Compare to GFED.

- Not started.

2.4 Status of Project Deliverables & Outputs

Summary of outputs from this activity (status as of August 2013):

- *CONUS & AK 1-km emissions maps with uncertainly for 2001 to 2011.*
  Product production underway. Awaiting additional WFEIS improvements.
- *Improvements in WFEIS fuels maps and fuel consumption in deep-organic boreal fuels.*
  In process, including substantial improvements to the canopy fuels maps.
- *Development of uncertainty measure for emissions mapping.*
  Uncertainty assessment methodology and demonstration underway.
- *Comparison & possible improvement of GFED emissions estimates for use in CASA-GFED.*
  Not started

One dataset has been published from this and previous work on the WFEIS:

- French, N.H.F., D. McKenzie, N. Hamermesh, and J. McCarty. 2013. *NACP Integrated Wildland and Cropland 30-m Fuel Characteristics Map, U.S.A., 2010.* Data set. Available on-line [http://daac.ornl.gov] from ORNL DAAC, Oak Ridge, Tennessee, U.S.A. http://dx.doi.org/10.3334/ORNLDAAC/1163.

The project activities have been presented at three conferences:

- *ForestSAT 2012, 14 Sept 2012, Corvallis, OR, USA:* "Remote sensing and geospatial data and tools for estimating pyrogenic carbon emissions" French, NHF, D McKenzie, J McCarty, T Erickson, B Koziol, M Billmire. Oral Presenation
- *AGU Fall'12, 7 Dec 2012, San Francisco, CA, USA:* "Estimating Biomass Burning Emissions for Carbon Cycle Science and Resource Monitoring & Management" Poster

Presentation" French, NHF, D McKenzie, T Erickson, J McCarty, R Ottmar, ES Kasischke, S Prichard, E Hoy, KA Endsley, N Hamermesh. Poster Presentation #NH53A-1807.

- *IAWF 4th Fire Behavior & Fuels Conference, 3 July 2013, St Petersburg, Russia:* "A US national fuels database and map for calculating carbon emissions from wildland and prescribed fire" French, NHF, D McKenzie, R Ottmar, J McCarty, R Norheim, N Hamermesh, Poster Presentation.

3 CMS Science Team Member Participation

Drs Nancy French, Eric Kasischke, and Donald McKenzie are members of the CMS Science Team. All attended the initial Science Team meeting in November 2012 and all are participating in one or more of the sub-groups of the Science Team. Dr. French is participating on the Biomass/Flux , Algorithm Assessment, and System Framework working groups with minor involvement with the Uncertainty working group. She has attended all but two of the monthly telecons. Dr. Kasischke is participating in the ABoVE group that Sean Healy has organized as well as the Product Definition team organized by Steve Pawson. He has participated in about half the telecons. Dr. McKenzie has attended three of the monthly telecons, and participates in the Biomass/Flux working group.

4 Project Plan, Personnel & Management

The project work plan is generally unchanged from the proposal, but it has been combined with tasks being conducted for a related project funded through the NASA Applications Program. While related, the two projects do have different end goals and foci. Overlapping tasks were merged, and the MTRI project team is involved with both projects in order to efficiently complete the activities of the two projects.

Dr. Nancy French serves as the PI of the proposed investigation. Dr. French is assisted on technical tasks by research assistants at MTRI. As proposed, Dr. Donald McKenzie of the USFS FERA and Dr. Eric Kasischke are serving as Co-Is to assist the MTRI team, and Dr. Collatz remains collaborator to connect the project to the GFED activity. However, the project no longer includes participation by the two Post-Doc associates. Instead, Dr. McKenzie is assisted by a geospatial analyst and a software engineer to complete task 1, and Dr. Kasischke has support from graduate students under his supervision.

Internal MTRI project team meetings are held monthly. We have had two full team meetings with FERA and UMd via teleconference to review tasks at the start and to update task progress later in the year. Several additional meetings with the FERA project team have been called during this project year including travel by PI French and a research assistant to Seattle in December.