

## **Addendum: Targeted Improvement in the Fire Inventory from NCAR (FINN) Model for Texas Air Quality Planning**

### **AQRP Project 14-011: Rationale and Summary of Development for FINN v.2.1**

In discussions with TCEQ during March 2016, two specific issues associated with the FINN v.2 inventory were pointed out:

- 1) Biomass burning emissions in Mexico were significantly higher in the FINN v.2 estimates when compared to those from FINN v1.5 publicly available from the National Center for Atmospheric Research's (NCAR's) FINN website. Figure 1 shows VOC emissions from fire events for May 19, 2012, using FINN v1.5 and v2.0. For that particular day, total biomass burning VOC emissions in Mexico were 1,808 tons/day for FINN v1.5 and 48,355 ton/day for FINNv2.0, a difference of a factor of 26.
- 2) Unexpected elevated O<sub>3</sub> concentrations were simulated for June 14, 2012 near Port Arthur when FINNv2 emissions were included. To illustrate this point, Figure 2 shows predicted 1-hour averaged O<sub>3</sub> concentrations at 14:00 CST from the model when driven by different versions of FINN and highlights enhanced ozone concentrations over Sabine lake located south east of Port Arthur. Model simulations that used two different FINN v.2 estimates (the first driven with MODIS land cover and the second with TCEQ/CDL land cover) predicted hourly maximum ozone concentrations of 110 ppb and 304 ppb, respectively. None of the ambient monitors appeared to measure the enhanced O<sub>3</sub> concentrations simulated, regardless of the land cover database used with the FINN v.2 inputs.

In response, further evaluations of the FINN v.2 updates that were made as part of the AQRP Project 14-011 were conducted. Among the major updates in 14-011 were improvements to the fuel loadings and land cover data used to drive the emissions estimates within the FINN framework. In the FINN v.2 updates, rather than use continental defaults for the fuel loadings assigned to the generic land cover data in the model, regional data were used to constrain the fuel loadings in the United States. Specifically, the fuel loadings from the U.S. Forest Service's Fuels Characteristics and Classification System (FCCS) were applied. Fuel loadings of the specific fuel classes from the FCCS were assigned as TREE or HERBACEOUS fuel in order to be consistent with the FINN framework. The ground (duff) fuel loadings were included in this process.

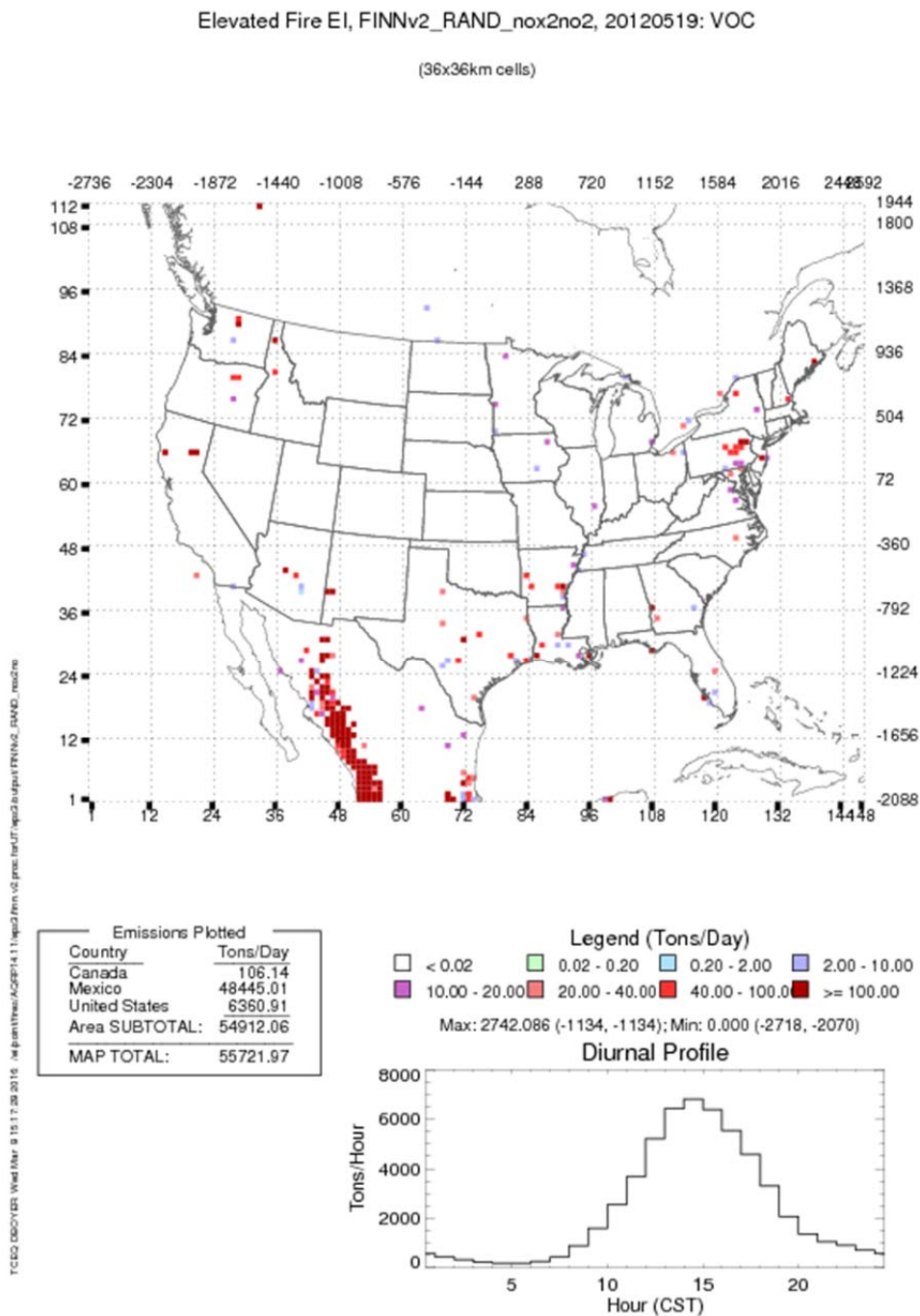
However, it became apparent during the reassessment that the inclusion of the duff fuel loadings within the HERBACEOUS classification led to unrealistically high fuel loading. Therefore, a revised version of the model, referred to as FINNv2.1, was developed in which the duff fuel loadings were removed from the calculations to produce more realistic fuel loadings within FINN. Since FINN doesn't specifically include duff smoldering/burning, and the results of leaving this out were more realistic, this correction is believed to be justified. Furthermore, the shrub fuel loadings from the FCCS were originally included in the HERBACEOUS fuel classification in FINNv2.0. This, too, led to unrealistically high fuel loadings for the HERBACEOUS FINN fuel class. Since much of the woody vegetation in Texas can be called "shrub" or "forest" (i.e., juniper woodlands, mesquite woodlands), the FCCS shrub fuel loadings were reassigned and processed in the assignment of the FINN TREE fuel loadings. In summary FINN 2.1 now includes the following modifications: (1) ground duff fuel loads from the FCCS are now not included in the

FINNv2.1 fuel loadings, and (2) the FCCS shrub fuel loadings are included in the FINNv2.1 “tree” loadings as opposed to “herbaceous” loadings.

The attached Appendix includes an updated table of new, FCCS-derived fuel loadings associated with each of land cover products being used. To evaluate the impact of these updates, simulations completed for the 14-011 final project report were repeated with the updated fuel loading estimates using FINNv2.1, EPS3, and CAMx and are included in the following section.

**Figure 1.** Daily VOC emission for May 19, 2012, predicted with (a) FINN v2.0 with TCEQ/CDL land cover dataset and (b) FINN v.1.5.

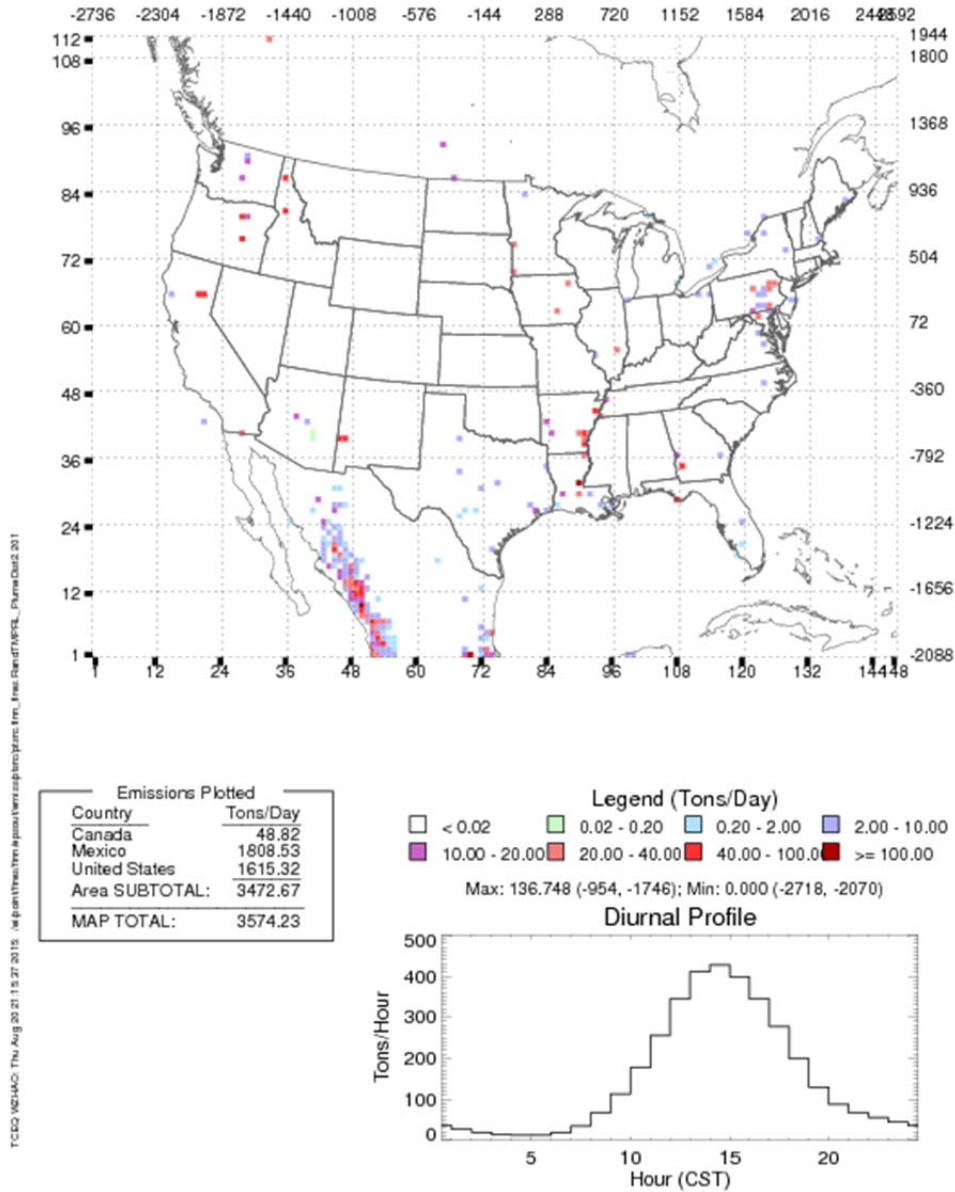
(a)



(b)

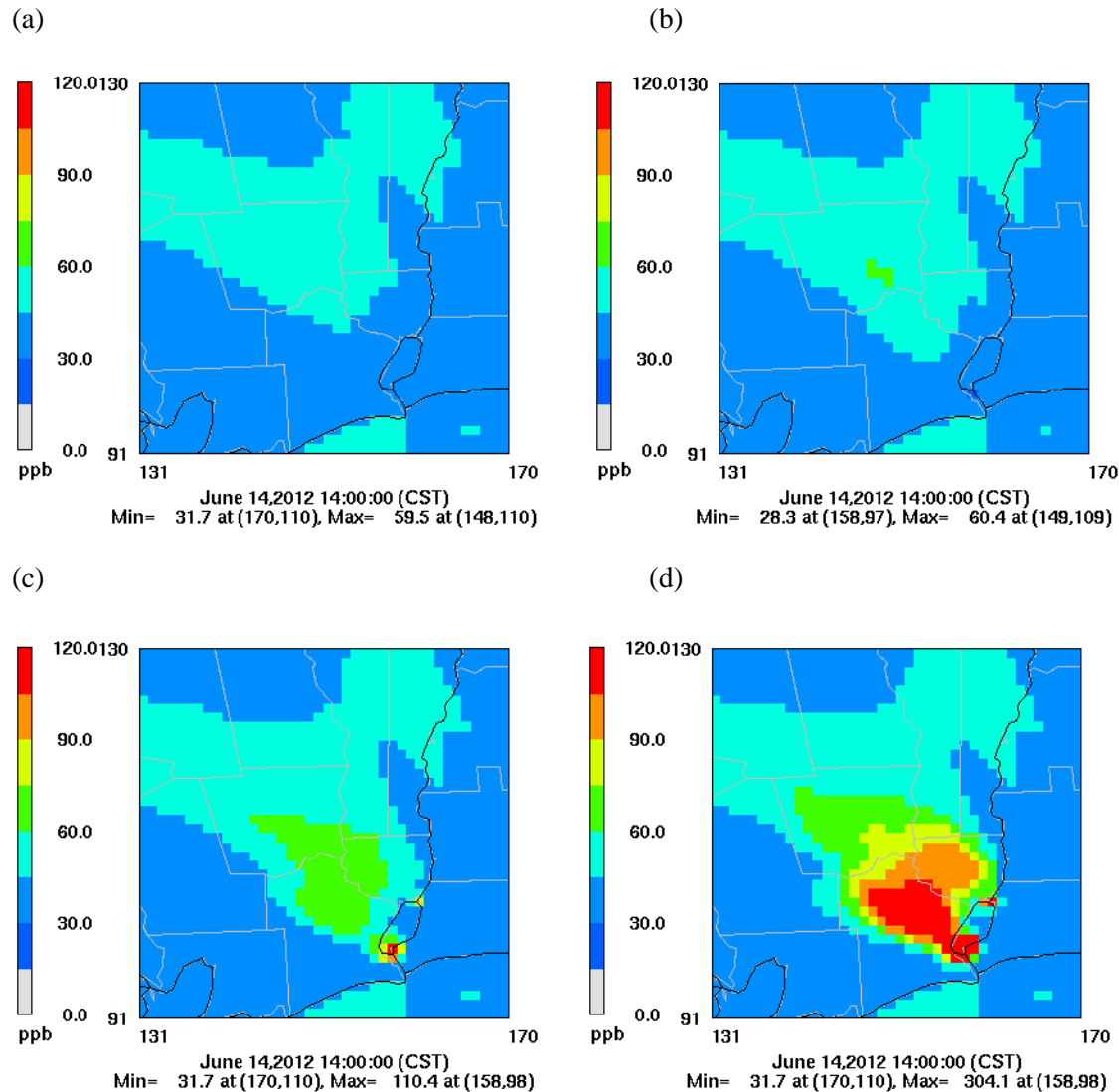
Elevated Fire EI, RandTMPRL\_PlumeDist2, 20120519: VOC

(36x36km cells)



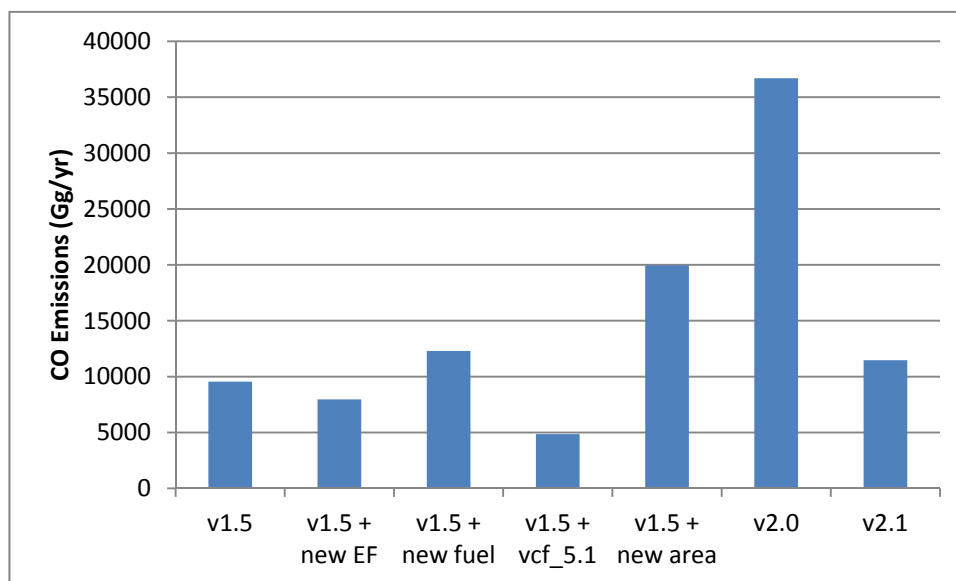
TCED\NSH\AQI\_Thu\_Aug\_20\_21\_15\_27\_2015 - Map of VOC emissions from fire, Area: RandTMPRL\_PlumeDist2, 2012

**Figure 2.** CAMx predicted ozone concentrations on June 14, 2012 at 1400: (a) without fires included and with fire emissions estimates from (b) FINNv.1.5 with land cover from the MODIS LCT, (c) FINN v.2 with land cover from the MODIS LCT product, and (d) FINN v.2 with land cover from the TCEQ\_CDL products.



### Effects of FINN v.2.1 Application on Emissions and Air Quality Predictions

Figure 3 below is a revision of Figure 7 of the 14-011 final project report showing the sensitivity of CO emissions to individual improvements made to FINN v.1.5. These included updates to emission factors, incorporation of the FCCS fuel loadings, use of version 5.1 of the MODIS Vegetation Continuous Fields (VCF) product, and application of a new algorithm for burned area estimation and land cover assignment. These improvements collectively formed FINN v.2. The current version, FINN v.2.1, includes modifications to the ground duff and shrub fuel loads as described above. Overall FINN v.2.1 resulted in increases in domain-wide CO emissions of 20% for FINN v.2.1 versus FINN v.1.5.



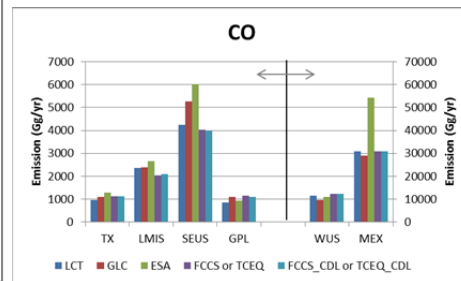
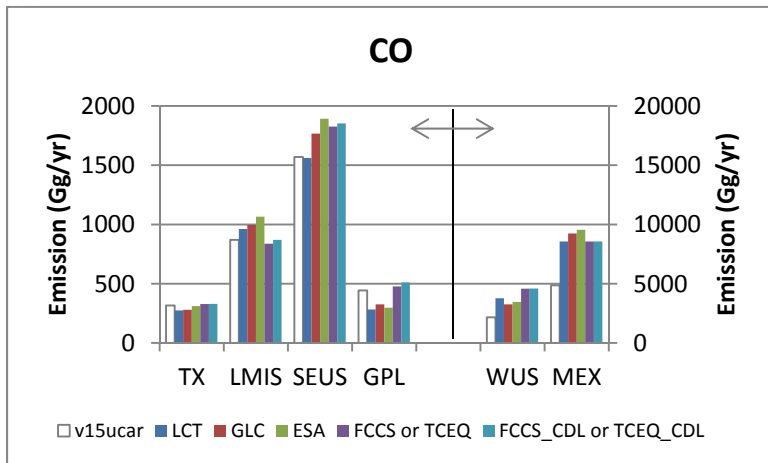
**Figure 3.** Correction to Figure 7 of the final report for AQRP Project 14-011 showing the effects of FINN modifications on CO emissions estimates for the entire CAMx modeling domain.

Figure 4 compares domain-wide total annual CO, NO<sub>x</sub>, and PM<sub>2.5</sub> emissions from FINN v.1.5 with estimates from FINN v.2.1 with different land cover databases. Similar results for FINN v.2.0 were presented in Figure 12 in the 14-011 final project report and are shown for reference in the smaller plots of Figure 4. The FINN v2.1 emission estimates with updated fuel loadings were considerably lower than those based on FINN v2.0. Reductions were especially marked when the ESA land cover database was used due to reductions in fuel loading associated with the ESA “mangrove” land cover classification.

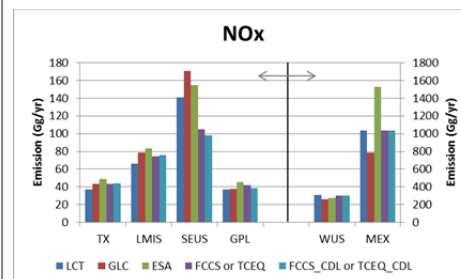
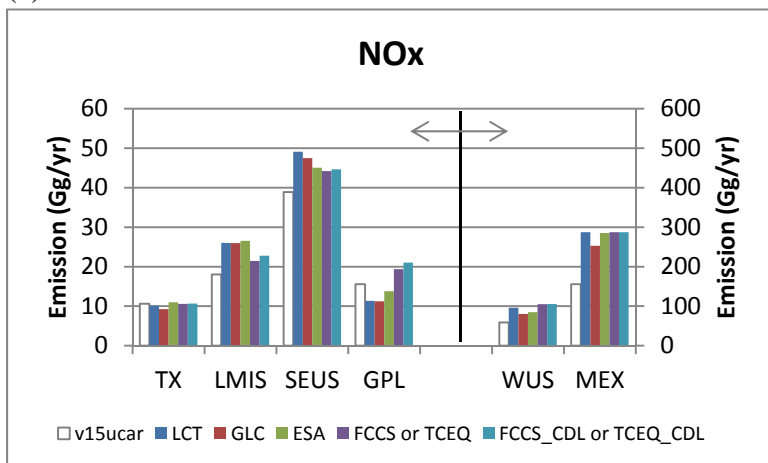
Figure 5 shows total annual domain-wide annual CO emissions by region and land cover type from FINN v.2.1. Similar results from Figure 13 of the 14-011 final project report that were based on FINN v.2.0 are also shown. The updated fuel loadings of FINN v2.1 had little impact on the overall influence of different land cover types for each scenario.

**Figure 4.** Annual total domain-wide emissions estimate for (a) CO, (b) NO<sub>x</sub>, (c) PM<sub>2.5</sub> by region for FINN v. 1.5 and FINN v.2.1 with different land cover databases. The smaller plots on the right show similar estimates from FINN v.2.0 shown in Figure 12 of the 14-011 final project report.

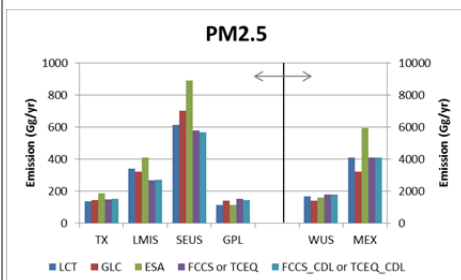
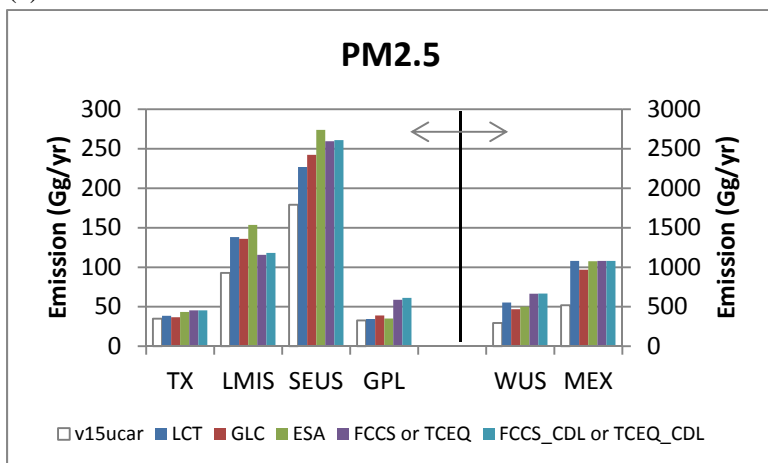
(a)



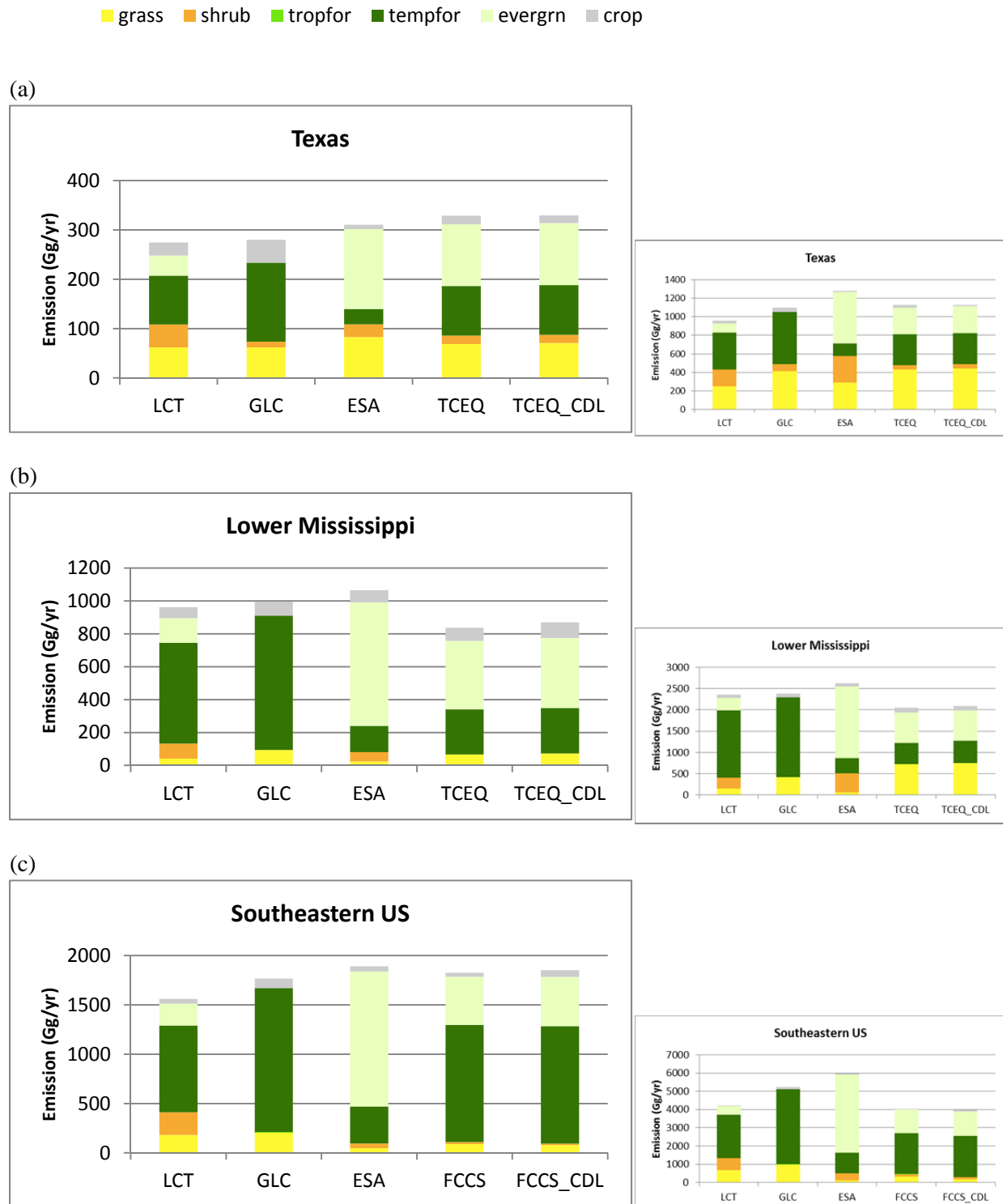
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(c)

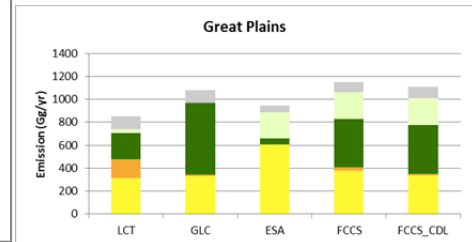
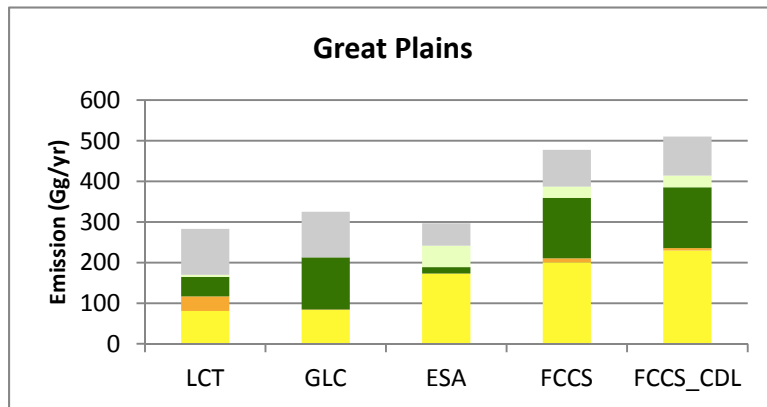


**Figure 5.** Annual domain-wide total CO emissions estimates by land cover class for (a) Texas, (b) the Lower Mississippi Valley, (c) Southeastern U.S., (d) Great Plains, (e) Western U.S., and (f) Mexico from FINN v.2.1 with different land cover databases. Results for FINN v.2.0 are shown in the smaller plots on the right from Figure 13 of the 14-011 final project report. Note difference in scale in each plot.

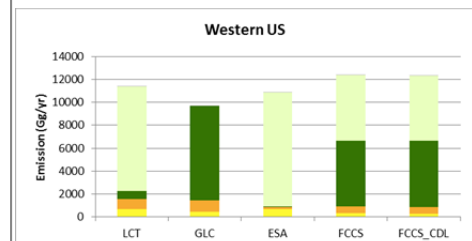
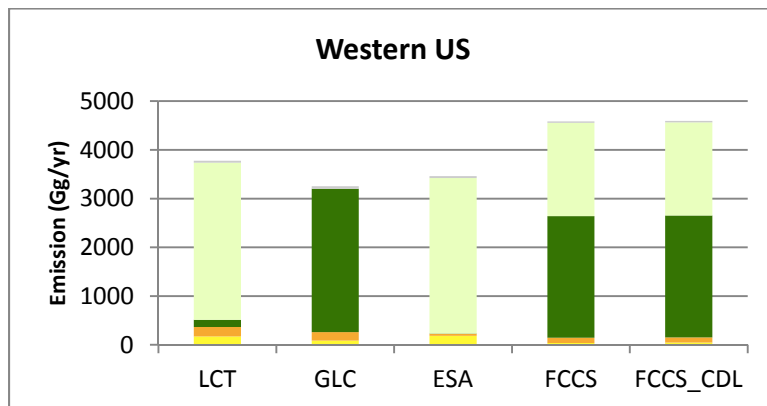




(d)



(e)



(f)

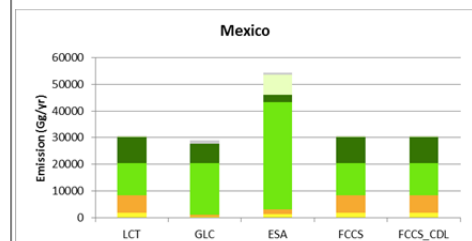
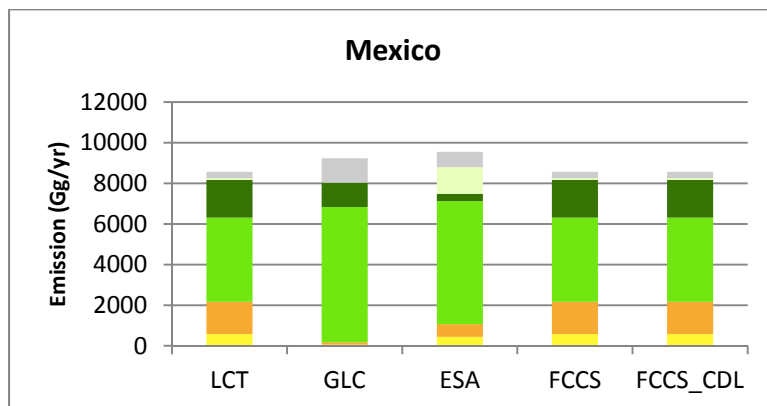
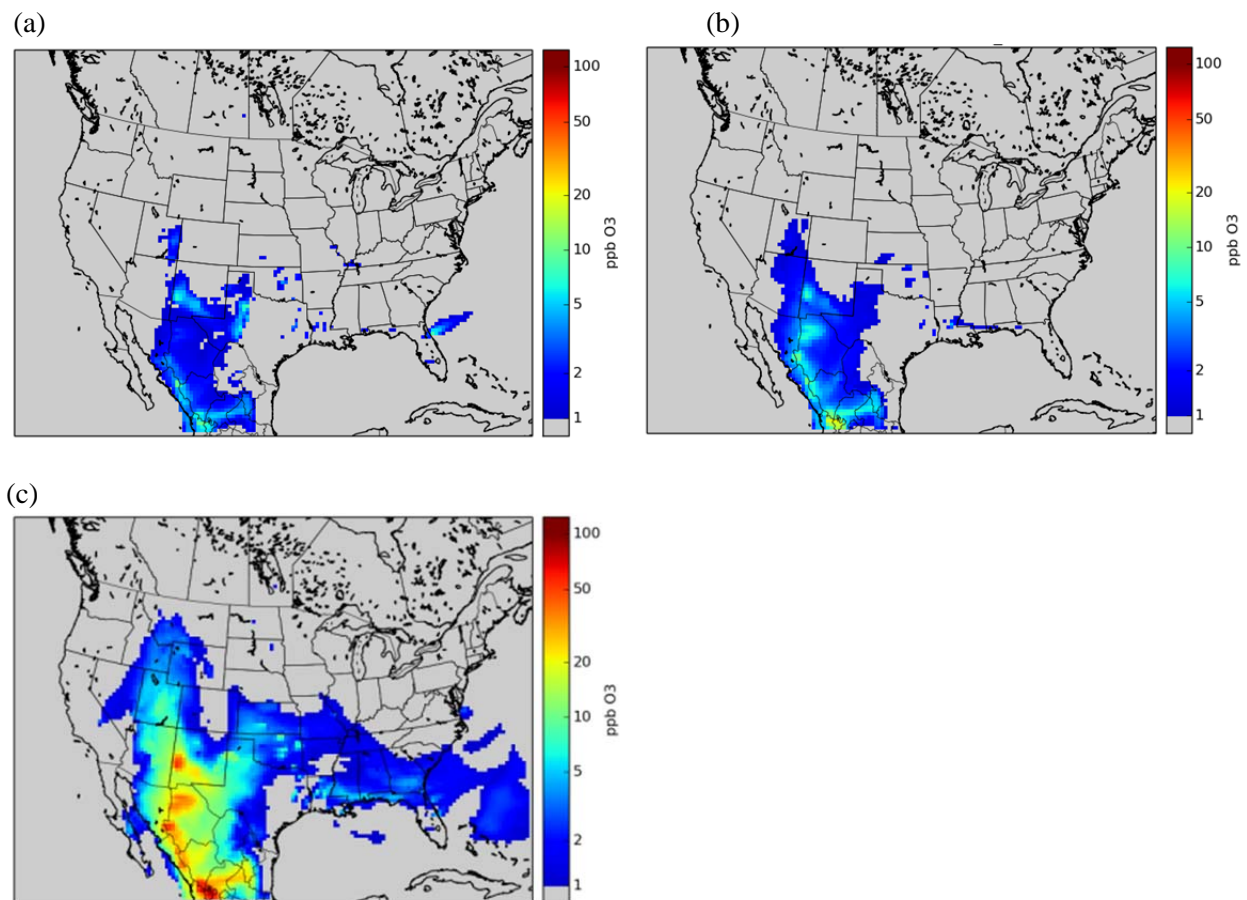
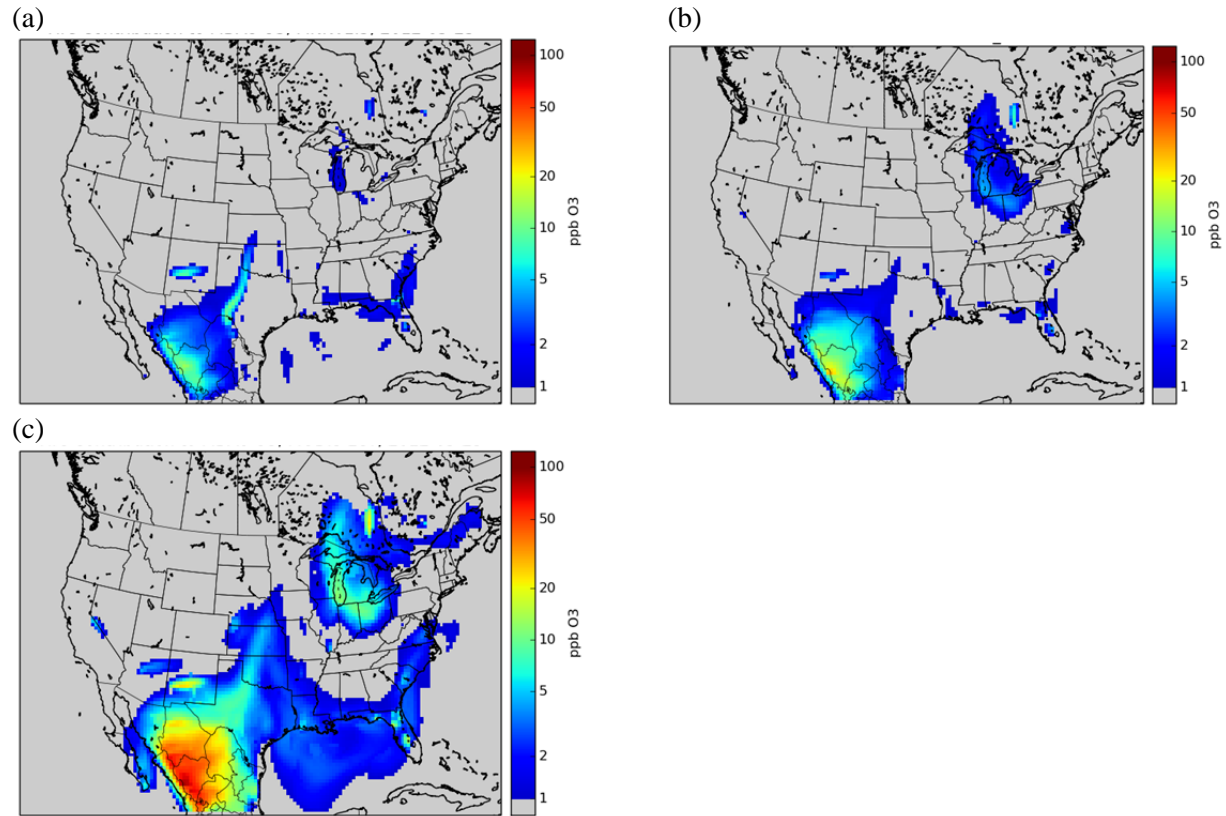


Figure 6 illustrates differences in maximum daily averaged (MDA8) 8-hour ozone concentrations from CAMx with fire emissions estimates from FINN v.1.5, v.2.0, and v.2.1, respectively, on June 4<sup>th</sup>, 2012, a day with active fire events in Mexico. Results based on FINN v.2.0 were presented in Figure 18 of the 14-011 final project report. Predicted MDA8 ozone concentrations based on FINN v2.0 estimates are considerably higher in Mexico, Texas, and neighboring western states than those based on the other versions of the model. A similar comparison of CAMx predicted MDA8 ozone concentrations based on different FINN model versions is shown in Figure 7 for May 23<sup>rd</sup>, 2012, also a day with significant fire activity in Mexico. Figure 8 summarizes regional changes in median, percentile, and minimum and maximum MDA8 ozone concentrations during June 2012.

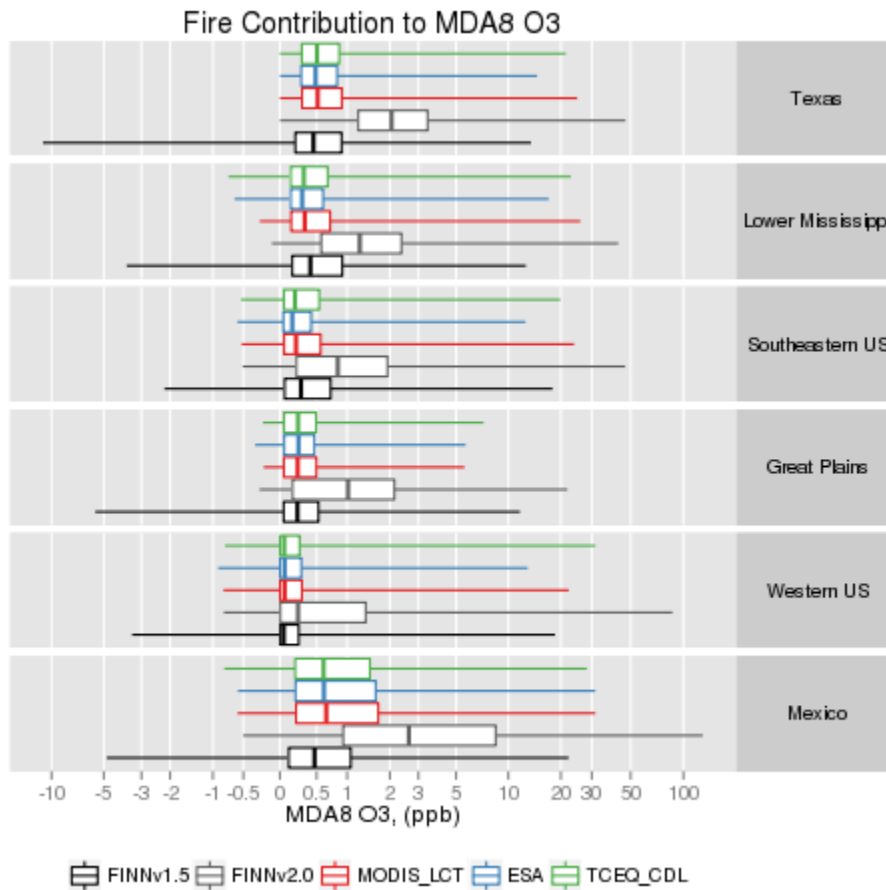
**Figure 6.** Contribution of fire events to predicted MDA8 ozone concentration on June 4<sup>th</sup>, 2012 based on three versions of FINN: (a) v.1.5, (b) v.2.1, and (c) v.2.0. The contribution was determined as the difference in CAMx predicted MDA8 ozone concentrations by grid cell using FINN with the MODIS LCT product and a simulation without fire emissions included. Results using FINN v.2.0 were shown as Figure 18 in the 14-011 final project report.



**Figure 7.** Contribution of fire events to predicted MDA8 ozone concentration on May 23<sup>th</sup>, 2012 based on three versions of FINN: (a) v.1.5, (b) v.2.1, and (c) v.2.0. The contribution was determined as the difference in CAMx predicted MDA8 ozone concentrations by grid cell using FINN with the MODIS LCT product and a simulation without fire emissions included. Results using FINN v.2.0 were shown as Figure 18 in the 14-011 final project report.



**Figure 8.** Contribution of fire events to CAMx predictions of MDA8 ozone concentrations in each geographic region during June 2012 using emissions estimates from FINN v1.5, v.2.0 and v2.1, respectively. FINN simulations were conducted with the MODIS\_LCT land cover product except when indicated for FINN v2.1. The box represents 25<sup>th</sup> to 75<sup>th</sup> percentiles with a vertical line showing the median. Whiskers stretch to the minimum and maximum values. Values represent predictions for 36-km resolution grid cells regardless of location. The concentration axis uses inverse hyperbolic sine transformation ( $\sinh^{-1} x \equiv \ln(x + \sqrt{1 + x^2})$ ) to facilitate interpretation.



## Summary

The primary objective of AQRP project 14-011 was to conduct targeted improvements in the FINN model to address a recognized bias in burned area estimates for large wildfires in earlier versions of the model, to obtain greater specificity in fuel loadings for the United States using U.S. Forest Service data, and to provide the flexibility to apply recent resources for global, national, and regional land cover characterization. The project resulted in the development of FINN v.2.0. In reassessments following the project, two modifications were made to address extremely high fuel loadings in some circumstances involving land cover classes with high ground duff or shrubs. FINN 2.1 now includes the following modifications: (1) ground duff fuel loads from the FCCS are now not included in the FINNv2.1 fuel loadings, and (2) the FCCS shrub fuel loadings are included in the FINNv2.1 “tree” loadings as opposed

to “herbaceous” loadings. It is important to recognize that FINN and other global fire emissions models should continue to evolve, drawing on emerging input data resources and ambient measurements at the surface and aloft where available.

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