2012 Annual Progress Report for JFSP Project 11-1-7-2

(Impacts of Mega-Fire on Large U.S. Urban Area Air Quality under Changing Climate)

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Summary

A number of research activities were implemented in the first year (2012) of this project with the major accomplishments as follows:

- The future trends in wildfire potential for the continental United States under a changing climate were projected based on two fire indices calculated using dynamical regional downscaling of climate change.
- Wildfire burned areas were projected with a dynamical global vegetation model, the Dynamical Land Ecosystem Model (DLEM) to investigate temporal and spatial patterns of burn area across the conterminous U.S. under a climate change scenario.
- The future trend in fuel moisture in the United States in response to the future climate change was projected using the dynamical downscaled regional climate change scenario.
- The NASA MODIS satellite remote sensing products were processed to detect burned spots and smoke plumes for the historical mega-fires.
- Collaboration was made to bridge fire and climate change research communities.

The major findings include:

- Future fire potential is expected to increase remarkably in the continental U.S. under a changing climate.
- Major increases are expected in the Southwest, Rocky Mountains, and northern Great Plains. This will lead to fire potential to increase by one level at some regions.
- Fire season could become a few months longer.
- Future warming trend is a major contributor to the fire potential increase, while the magnitude of future fire potential increase will be reduced in the northwestern U.S. due to the impacts of future changes in humidity and wind.
- Fire potential has been increasing across the continental U.S. in recent decades.
- Most fire events projected with the dynamical global vegetation model would occur in the Western, Central-West and Eastern states. The most severe fire would occur in the southwest region.
- The most severe drying conditions in future fuel occur in the southern Great Plains and Mid-West in summer.

These findings were described in 3 manuscripts and reported in 3 conference presentations.

Accomplishments

1. Projection of U.S. wildfire potential under changing climate

The future trends in wildfire potential for the continental United States under a changing climate were projected. Fire potential was measured by two extensively used fire indices, the Keetch-Byram Drought Index (KBDI), which is determined by maximum temperature and precipitation, and by the modified Fosberg Fire Weather Index (mFFWI), which further includes the impact of humidity and wind. The two indices were calculated for the present (1971-2000) and future (2041-2070) using the regional climate conditions obtained through dynamical downscaling of the HadCM3 global projection using HCM3 regional climate model provided by the North America Regional Climate Change Assessment Program (NARCCP). The regional climate data cover the North America with a resolution of 50 km and daily outputs. The calculations were compared between the HadCM3-HCM3 climate change scenarios and a number of other scenarios from different global and regional model combinations for the South and Central U.S.

Future fire potential is expected to increase remarkably in the continental U.S. under a changing climate. Major increases are expected in the Southwest, Rocky Mountains, and northern Great Plains (Fig.1). This will lead to fire potential to increase by one level in many regions. The South, for example, will see summer fire potential to increase from around low (moderate) level at present to around moderate (high) level in future in the three eastern (western) eco-regions (Fig.2). Fire season could become a few months longer. Future warming trend is a major contributor to the fire potential increase, while the magnitude of future fire potential increase will be reduced in the northwestern U.S. due to the impacts of future changes in humidity and wind.

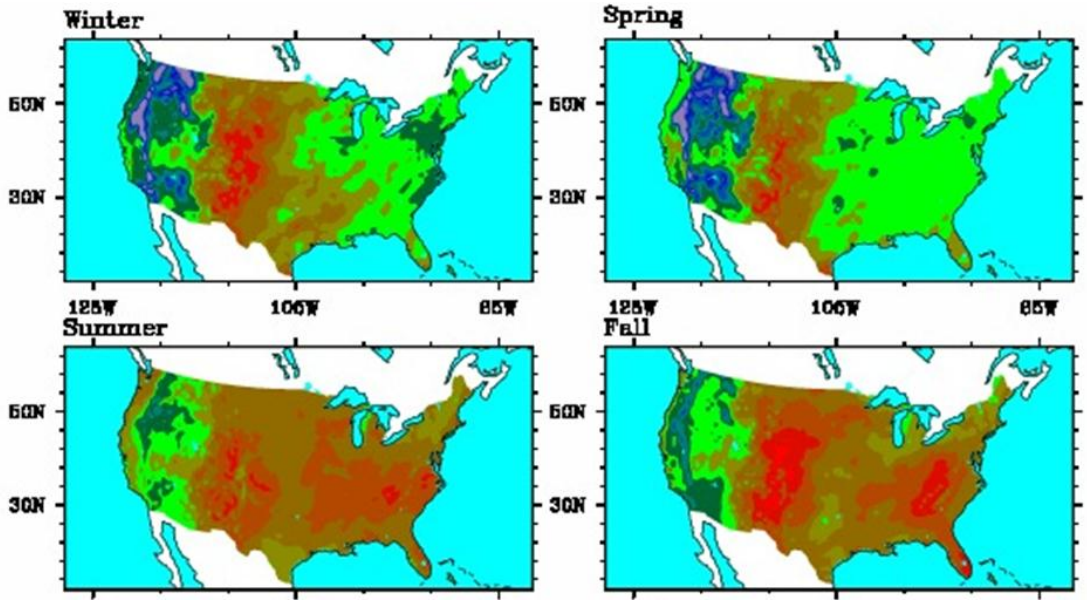

Figure 1 Spatial patterns of future change in fire potential measured by KBDI between 2041-2070 and 1971-2000. The four panels are for winter, spring, summer, and autumn.

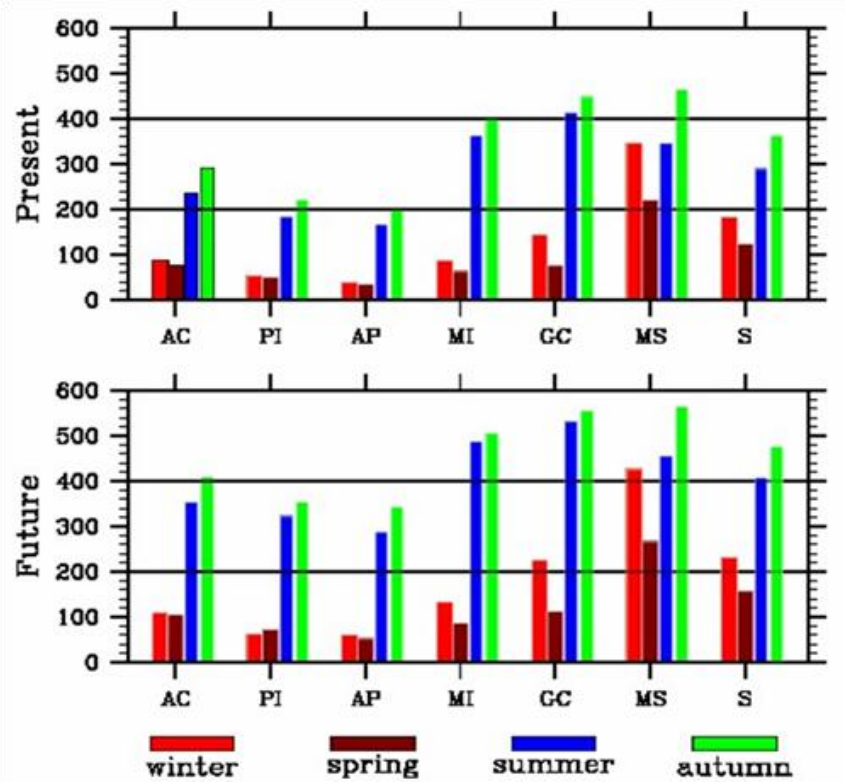

Figure 2 KBDI in the southern eco-regions. The top and bottom panels are for the present period of 1971-2000 and future period of 2041-2070. The regions indicated below each panel are Atlantic Coast (AP), Piedmont (PI), Appalachian (AP), Mississippi (MI), Gulf Coast (GC), Mid-South (MS), and entire southern U.S. (US).

Fire potential has been increasing across the continental U.S. in recent decades. Fire potential anomalies during 1971-2000 (Fig.3) are expressed as departures of individual summers from the average of all summers divided by standard deviation. The overall trend of the variations, measured by the slope of a linear line fitting the normalized KBDI time series (real line in the figure), is positive, indicating an increasing trend in fire potential during. This suggests that the impact of global warming on wildfire actually has been happening.

The results will provide basis for statistical predictions of future mega-fire activity including burned areas, which will be further used to calculate fire emissions.

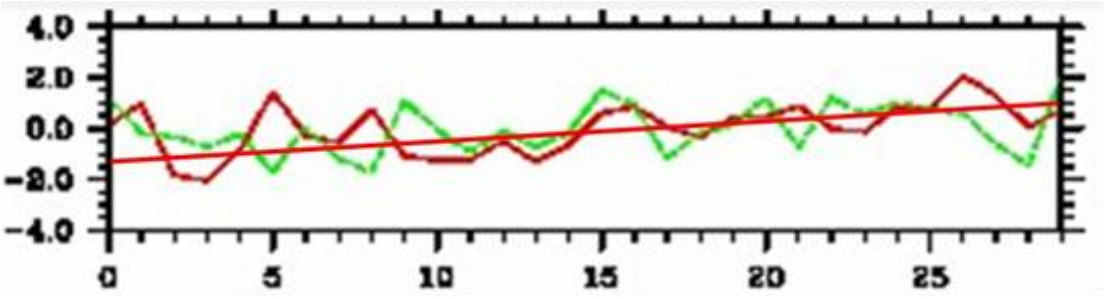

Figure 3 Variations of summer U.S. KBDI. The red and green curves represent the present period of 1971-2000 and future period of 2041-2070. The red line is slope of present variations.

2. Projection of wildfire burned area with vegetation model

Simulations and projections were made with DLEM to investigate temporal and spatial patterns of burn area across the conterminous U.S. under a climate change scenario. The North America Regional Reanalysis (NARR) climate variables, including temperature, precipitation, and shortwave radiation, at a resolution of 32 km were statistically downscaled to a spatial resolution of 5 minutes (about 9.2 km at the equator) from 1979 to 2010. Projections of future climate from 3AOGCMs (CCSM3.01, echam5.1, and cccma_cgcm3_1) for A2 and B1emission scenarios) were used, which are originally at a resolution of 1/8 degree latitude/longitude and were statistically downscaled to a resolution of 5 minutes to match other input data sets. The decadal mean climate from 2011 to 2020 were used to drive DLEM to reach the equilibration stage (i.e. the annual carbon, nitrogen, and water fluxes and pools did not change for 10 consecutive years). Then the de-trend climate between 2011 and 2020 were repeated three times (i.e. 30 years in total) to drive the model for spin-up. Finally, the model was run in transient mode with daily climate data under A1B emission scenario.

Most fire events are projected to occur in the Western, Central-West and Eastern states (Fig. 4). The most severe fire would occur in the southwest region. The projected burned areas will be used to estimate the impacts of climate change induced fuel disturbances on fire emissions.

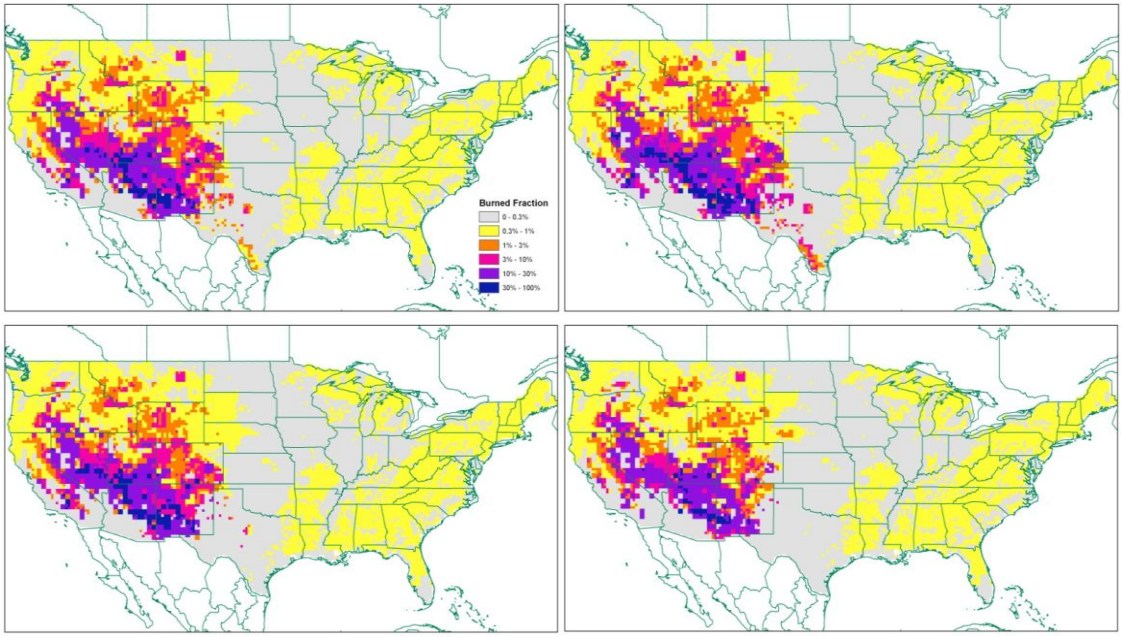

Figure 4 Mean of annual burned fraction under the A1B climate scenario (a) 2011-2099, (b) 2011-2040, (c) 2041-2070, (d) 2071-2099.

3. Calculation and projection of fuel moisture

Future trend in fuel moisture in the United States in response to the future climate change was projected using the dynamical downscaled projections from NARCCAP were used. Fuel moisture was estimated using the empirical relations with meteorological conditions. The results show general drying trends in fuel moisture conditions across the United States (Fig. 5). There is however large spatial variability with the most severe drying conditions found in the southern Great Plains and Mid-West. Significant seasonal variations were also found. The projected forest fuel moisture will be used as a factor for projecting future fire and smoke behavior and calculating fire emissions.

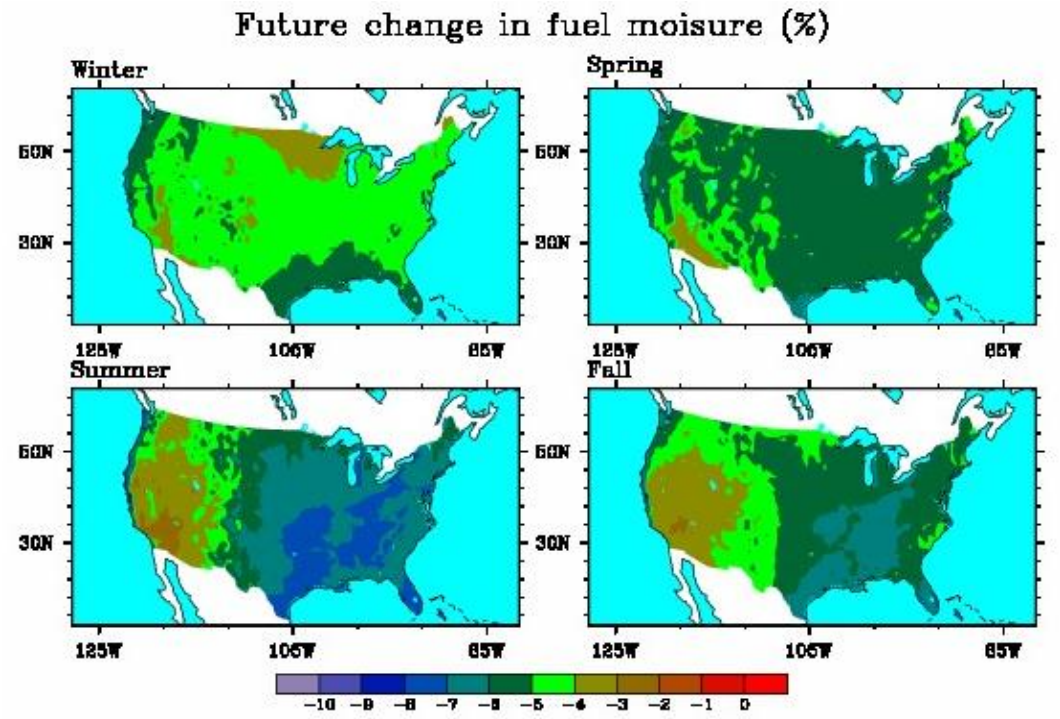

Figure 5 Spatial patterns of future change in one-hour fuel moisture between 2041-2070 and 1971-2000. The four panels are for winter, spring, summer, and autumn.

4. Detection of smoke from mega-fires

The NASA MODIS satellite remote sensing products were processed to detect burned areas and smoke plume for the historical mega-fires. Terra MODIS true color composite (1-4-3), and false color composite (7-2-1) were provided in jpeg formats, associated with .jgw for basic coordination system. These images were re-projected into UTM system, with zone of 12, 12, and 10, respectively. Smokes were detected by an automatic algorithm. Generally the algorithm gives us where the smokes were located. All these jpeg files have been stretched using square root enhance method for better demonstrations. The detected smoke plumes will be used to evaluate simulation of smoke transport and dispersion.

Fig. 6 shows satellite remote sensed burns and smoke for the Murphy fire. The 653,000-acre Murphy Complex Fire started on July 16-17, 2007 as a combination of six lightning-caused wildfires in south-central Idaho and north-central Nevada. Fanned by high winds in dry, hot conditions, the fire spread quickly through brush, grass and juniper. It was the largest wildfire in Idaho since 1910.

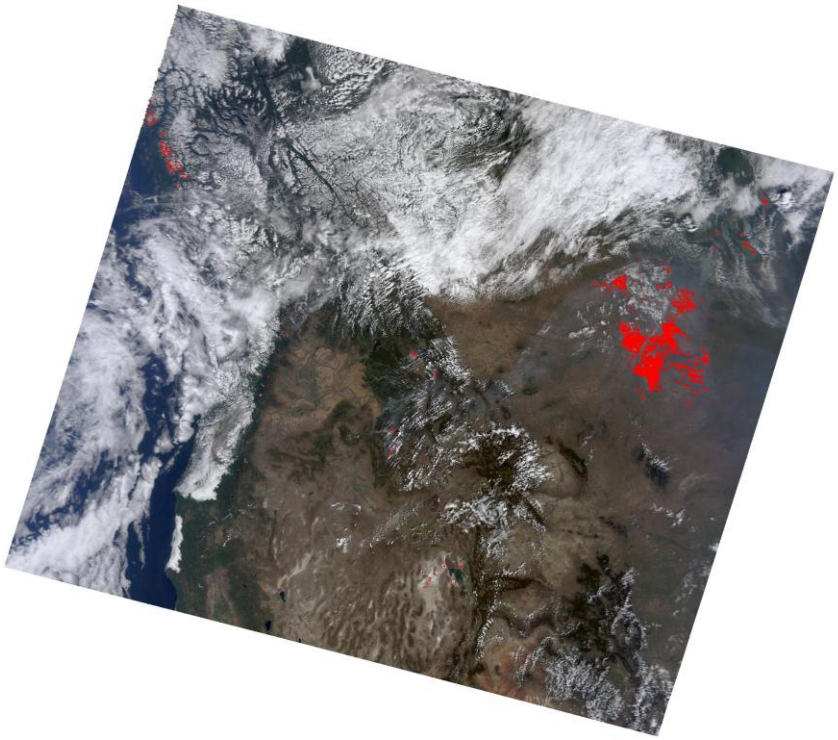

Figure 6 MODIS detection of burn spots and smoke for the 2007 Murphy Complex fire.

5. Bridging fire and climate modeling communities

The NARCCAP regional climate change scenarios used for this project were produced by several research institutions led by the National Center for Atmospheric Research (NCAR). This JFSP project has actively sought for collaboration opportunities with the regional climate change projection community. We attended the 2012 NARCCAP user workshop and presented the mega-fire research. We had chances during the workshop to describe the JFSP fire and smoke research and our project and to indicate to the climate community that the NARCCAP data were extremely valuable to our fire-climate research. Many researchers from the climate community also showed interests in fire-climate interactions. We discussed with Linda Mearns, the head of NCAR's environmental program and chair of the workshop, about working together on fire-climate research, which is actually getting started. Linda also invited us to talk fire-climate research at the 2012 American Geophysical Union in a session she and another climate modeler will moderate.

This collaboration would contribute to achieving the major objective of JFSP's climate change and smoke theme, namely bringing the fire and smoke issue onto the table for global climate science community.

Deliverables

1. Manuscripts

Liu, Y. –Q., Goodrick, S. L., Stanturf, J.A., 2012, Future U.S. wildfire potential trends projected using a dynamically downscaled climate change scenario, Forest Ecology and Management.

Liu, Y.-Q., Goodrick, S., Heilman, W., 2012, Wildland fire emissions, carbon and climate: Wildfire-climate interactions, Forest Ecology and Management. (under internal copy-editing. To be submitted)

Liu, Y.-Q., Prestemon, J., Goodrick, S., Holmes, T., Stanturf, J., Vose, J., Sun, G., 2012, Future Wildfire Trends, Impacts, and Mitigation Options in the Southern United States, in "Climate Change Adaptation and Mitigation Management Options in Southern United States" (tentative title. (under review).

2. Presentations

Liu, Y. –Q., Goodrick, S. L., Stanturf, J.A. Tian, H., 2011, Future trends and impacts of mega-fires in the United States under changing climate and fuels, Exploring the Mega-fire Reality, November 14-17, 2011. Tallahassee, FL, USA.

Liu, Y.-Q., 2012, Projecting future changes in U.S. forest fuel and fire conditions using NARCCAP regional climate change scenarios. The 2012 North American Regional Climate Change Assessment Program Users' Meeting, Boulder, Colorado, April 10-11, 2012.

Yang, J., H. Tian, B. Tao, Y. Liu, Predict wild fire severity and post-fire vegetation dynamics in terrestrial ecosystems of the United States during the 21st century, Exploring the Mega-fire Reality, November 14-17, 2011. Tallahassee, FL, USA.