CO_2 Emissions from Wildfires in the U.S.: Present Status and Future Trends

Yongqiang Liu and John Stanturf (USDA Forest Service)
Hanqin Tian (Auburn University)
John Qu (George Mason University)

Introduction

- Wildfire is a major natural disaster in the United States. In 2002, for example, tens of thousands of wildfires occurred that consumed nearly seven million acres of forest and other land cover (NIFC, 2003).
- Wildfires contribute to increasing atmospheric CO_2 concentration and, therefore, intensifying the greenhouse effect. The perturbation of atmospheric chemistry induced by global biomass burning is comparable in magnitude to the effect of fossil fuel burning (Lindesay et al., 1996).
- Climate is a major environmental factor for wildfire frequency and intensity (Pyne et al., 1996). Thus, the trends in CO_2 emissions from wildfire are largely determined by future climate change.
- A number of climate models (e.g., Mitchell et al. 1995) have projected significant changes in the U.S. regional climate in response to the greenhouse effect, suggesting a great impact on future wildfire emissions of CO_2.
- This study seeks to understand the role of wildfire in the carbon cycle and possible disturbance due to the greenhouse effect over the U.S..

Data and Methods

- A set of historical U.S. fire data during 1980-2002 obtained from the USDA Forest Service and other federal agencies (BLM, 2003).
- Temperature and precipitation during 1980-2002 at each of the contiguous U.S. states obtained from NOAA.
- Changes in temperature and precipitation in these states due to the greenhouse effect projected by the Hadley Center's Second Generation Coupled Ocean-Atmosphere GCM (HadCM2) (Mitchell et al., 1995).
- CO_2 emissions are estimated using the empirical formula $E = A\ S\ L$, where E is emission (in mass); A land area burned; L effective fuel consumption or fuel loading factor (mass of forest fuel per unit land area burned) and S emission factor (mass of pollutant per unit mass of forest fuel consumed) (Liu, 2004).
- The impact of the greenhouse effect on wildfire CO2 emission is analyzed using a bivariate linear regression equation connecting the emission to temperature and precipitation.

Results

Present Status

- Wildfires release over 10 tons km^{-2} of CO_2 annually in the southwestern and northwestern West, and part of the Southeast (Fig.1)
- Wildfire Emissions have remarkable inter-annual variability (Fig.2). Large amount is found for 1988, 1996, 2000, and 2002.
- The region-integrated annual emissions (see Fig.3 for various USDA Forest Service regions) are significant in the Inter-Mountain, Pacific South, Pacific North, and Southwest regions of the West, and the Southeast region of the East (Fig.4). The sum over all the regions is about 86 Tg.
- Emissions are dominant in summer in the West except the Southwest region where emissions in spring are also important, and in spring in the East. Summer emissions account for about 80% of annual amount nationwide.
- The mean square deviation (MSD) has a comparable magnitude as emission amount, corresponding to the large inter-annual variability shown in Fig.2.

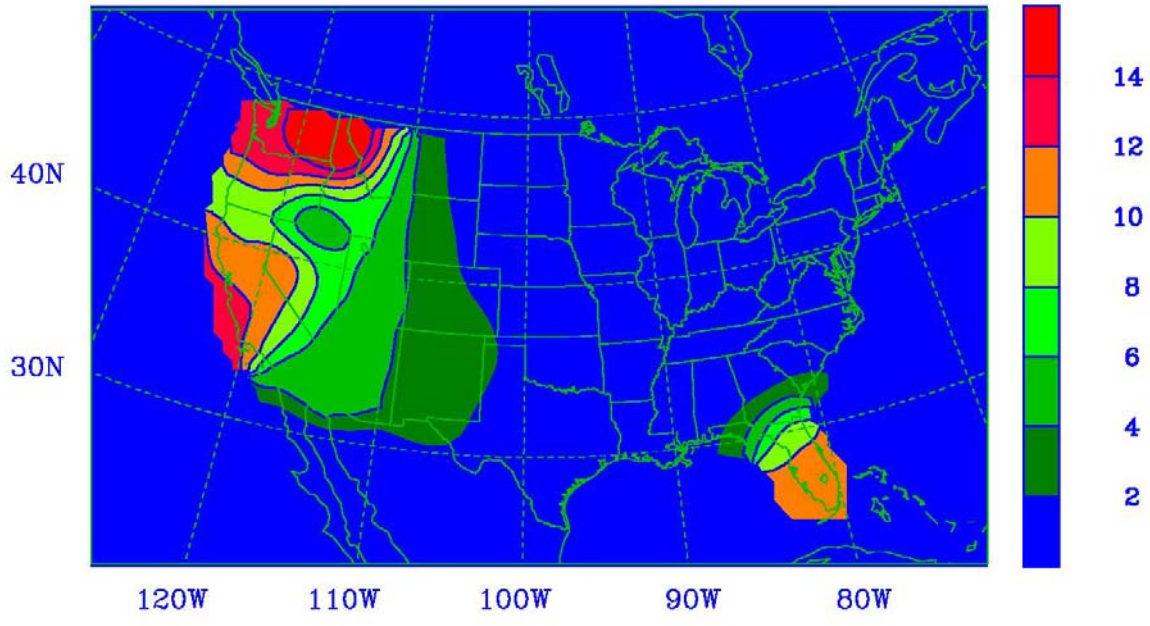

Fig.1 Spatial distribution of annual CO_2 emissions from wildfires (ton km^{-2}).

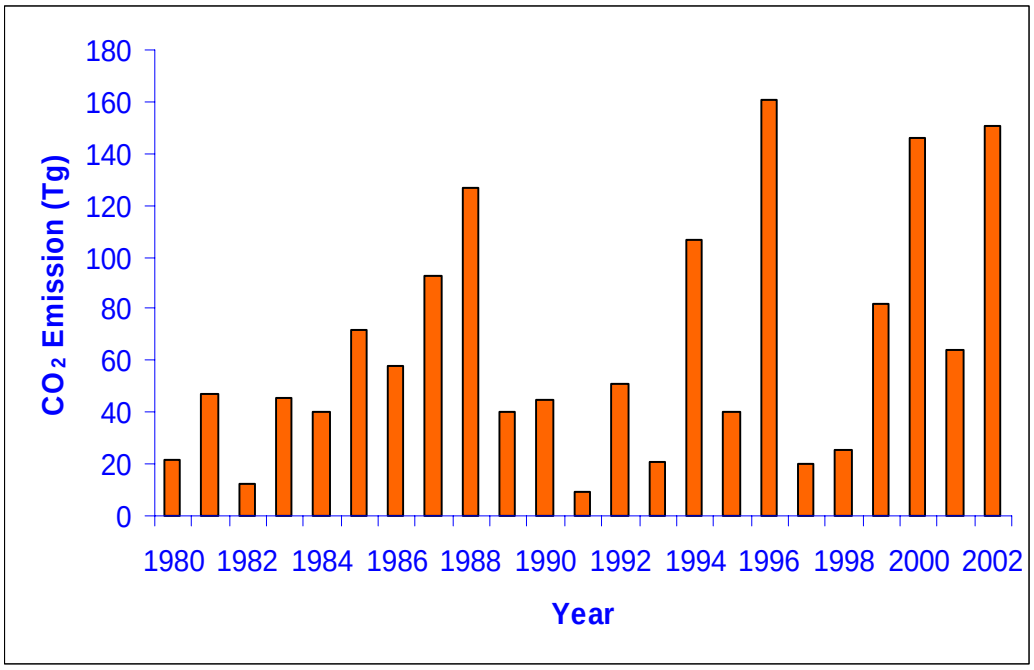

Fig.2 Variations of annual U.S. CO_2 emissions from wildfires.

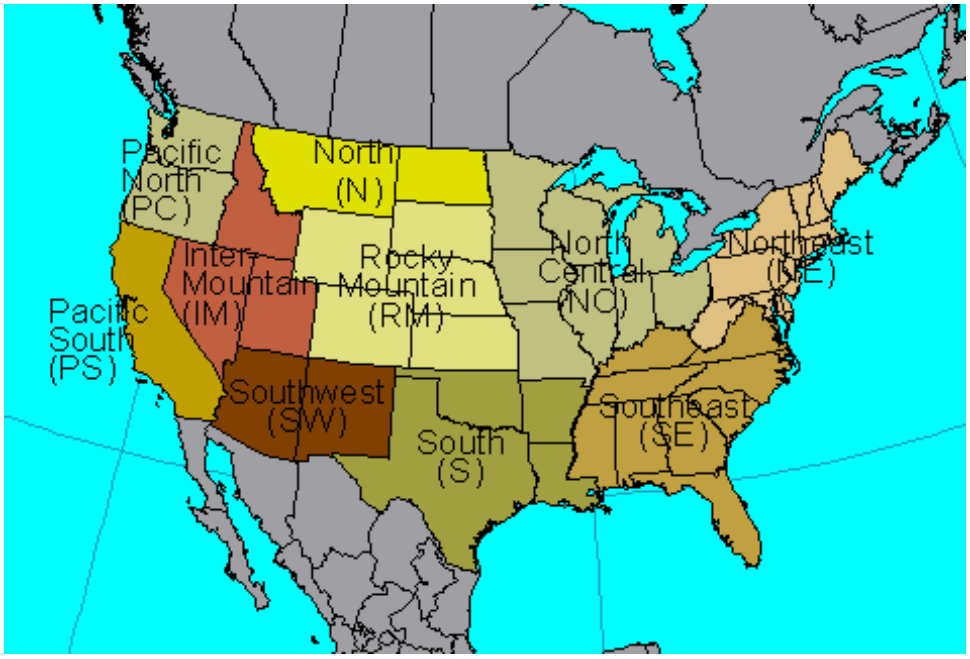

Fig.3 The old USDA Forest Service regions.

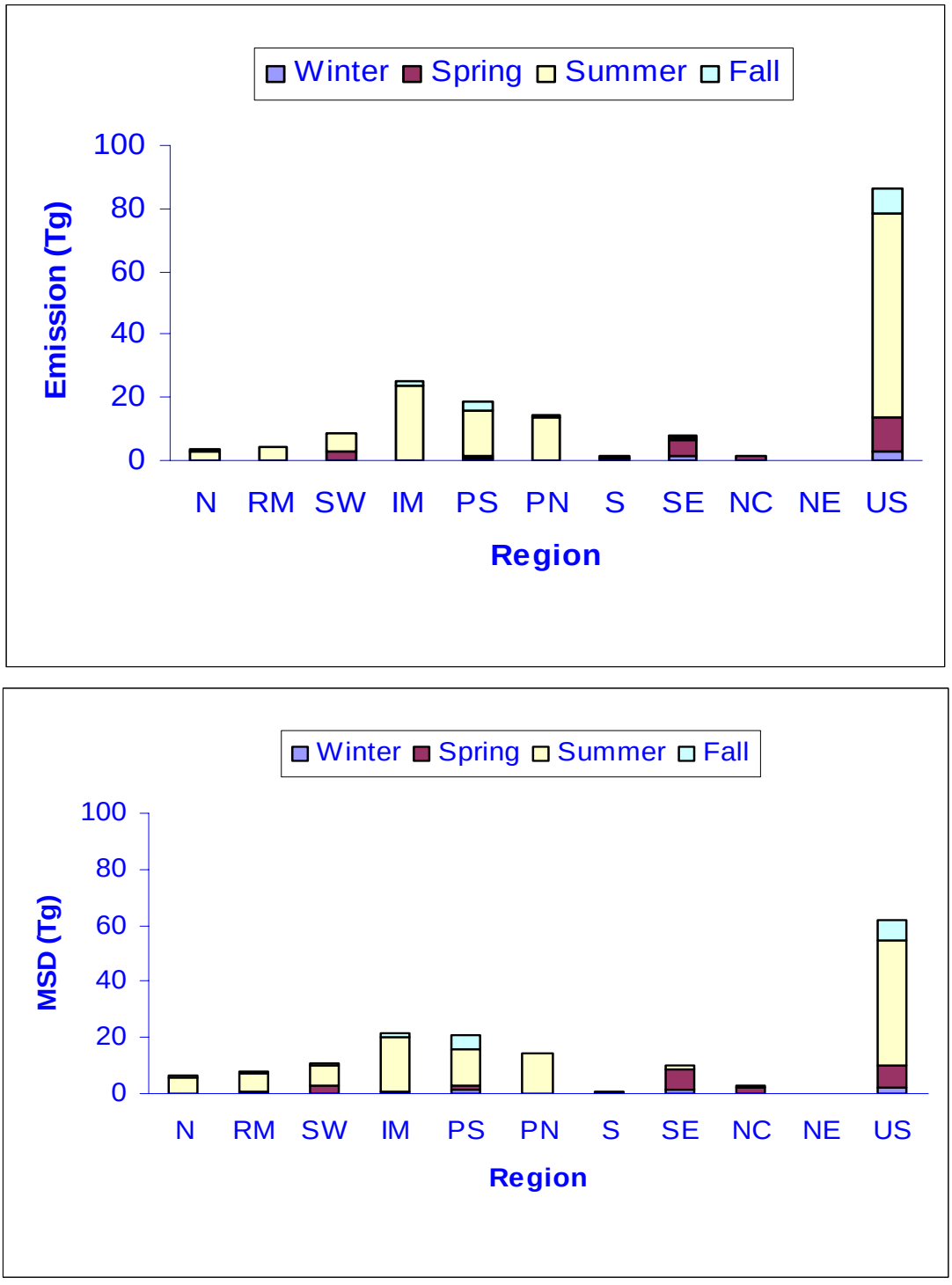

Fig.4 Regional CO_2 emissions from wildfires (top) and mean square deviation (MSD) (bottom).

Relationships with Temperature and Precipitation

- Large emissions are usually accompanied by dry and hot climate (Fig.5).
- Relationships between emission and climate are more significant in the western regions, especially in summer (Fig.6).
- The multiple correlation coefficients in summer are significant at the 99% confidence level (the critical correlation coefficient=0.505) in all the western regions except Pacific South (Fig.7).

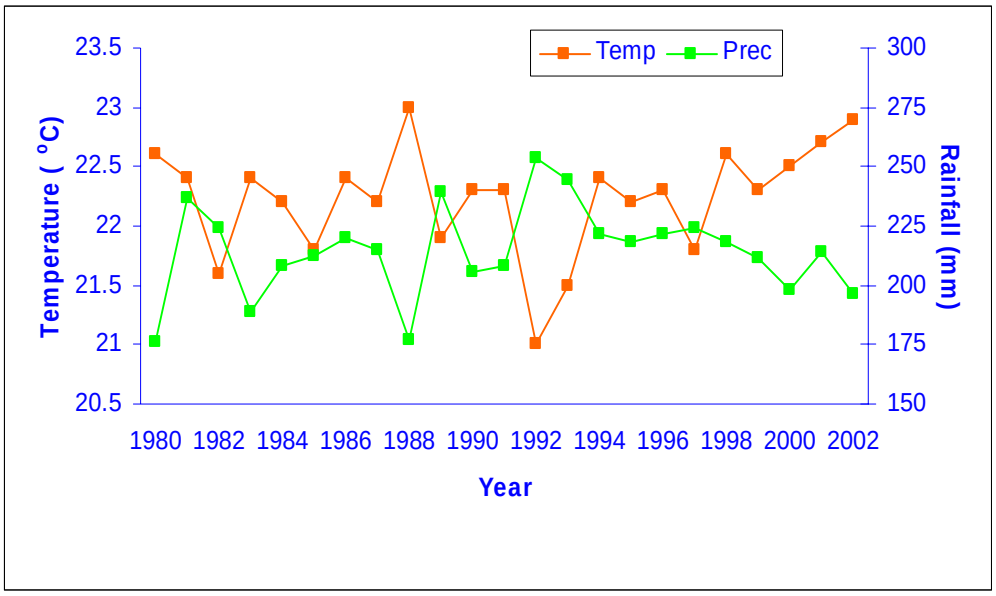

Fig.5 Variations of summer temperature and rainfall averaged over the contiguous states.

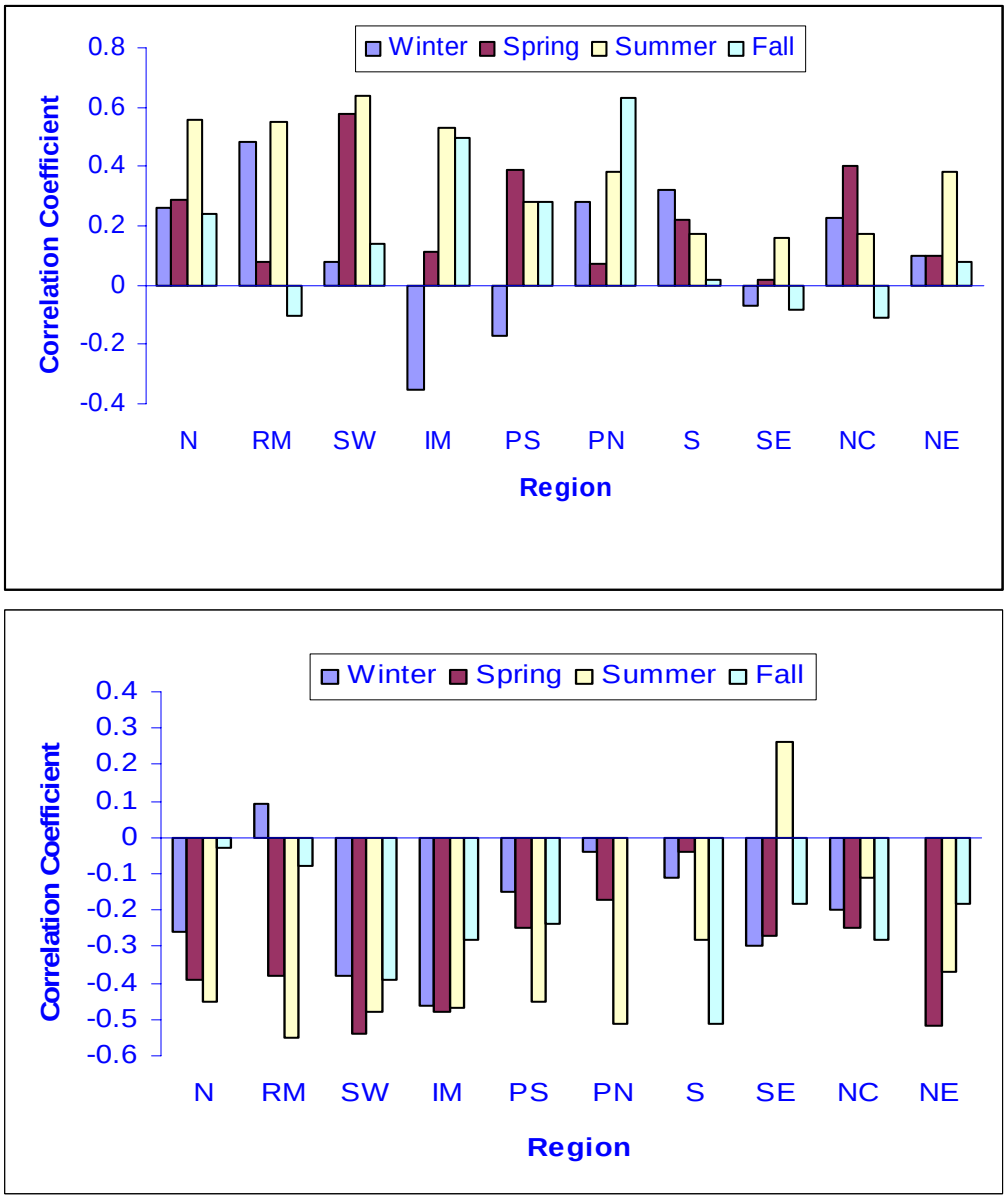

Fig.6 Correlation coefficients between CO_2 emission and temperature (top) and rainfall (bottom).

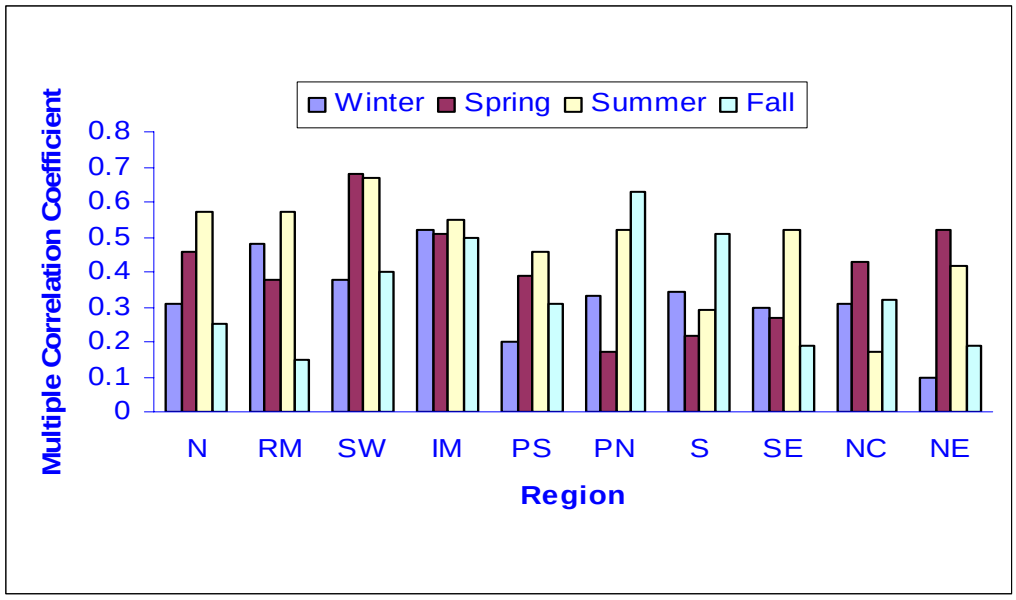

Fig.7 Multiple correlation coefficients between CO_2 emission and temperature and rainfall.

Impacts of Greenhouse Effect

- HadCM2 projects an increase in summer temperature by 1~ 1.5^{o}C with a uncertainty range between about 0.5 and 2.5^{o}C by 2050 in the western regions due to the greenhouse effect (Fig.8).
- HadCM2 projects an increase in summer rainfall by up to 8 mm with a uncertainty range between about 2.5 and 16 mm by 2050 in all western regions except Inter-Mountain and Pacific North (Fig.8).
- The changes in temperature and rainfall would play opposite roles by increasing and decreasing CO_2 emissions, respectively. The change in temperature, however, is more important.
- The projected climate change would lead to increase in summer wildfire emissions of CO_2 by 14.5 (with a range of 6~26) ton km^{-2} in Inter-Mountain and 8 (3~14) ton km^{-2} in Southwest by 2050. Nationally, an increase by 33 (13~58) ton km^{-2} is expected.
- The relative increase is about 140% (60~250%) in Southwest and 105% (30~200%) in North. Nationally, the relative increase is 50% (20~90%).
- The magnitude of the climate change and, accordingly, the increase in CO_2 emissions will be doubled by 2100.

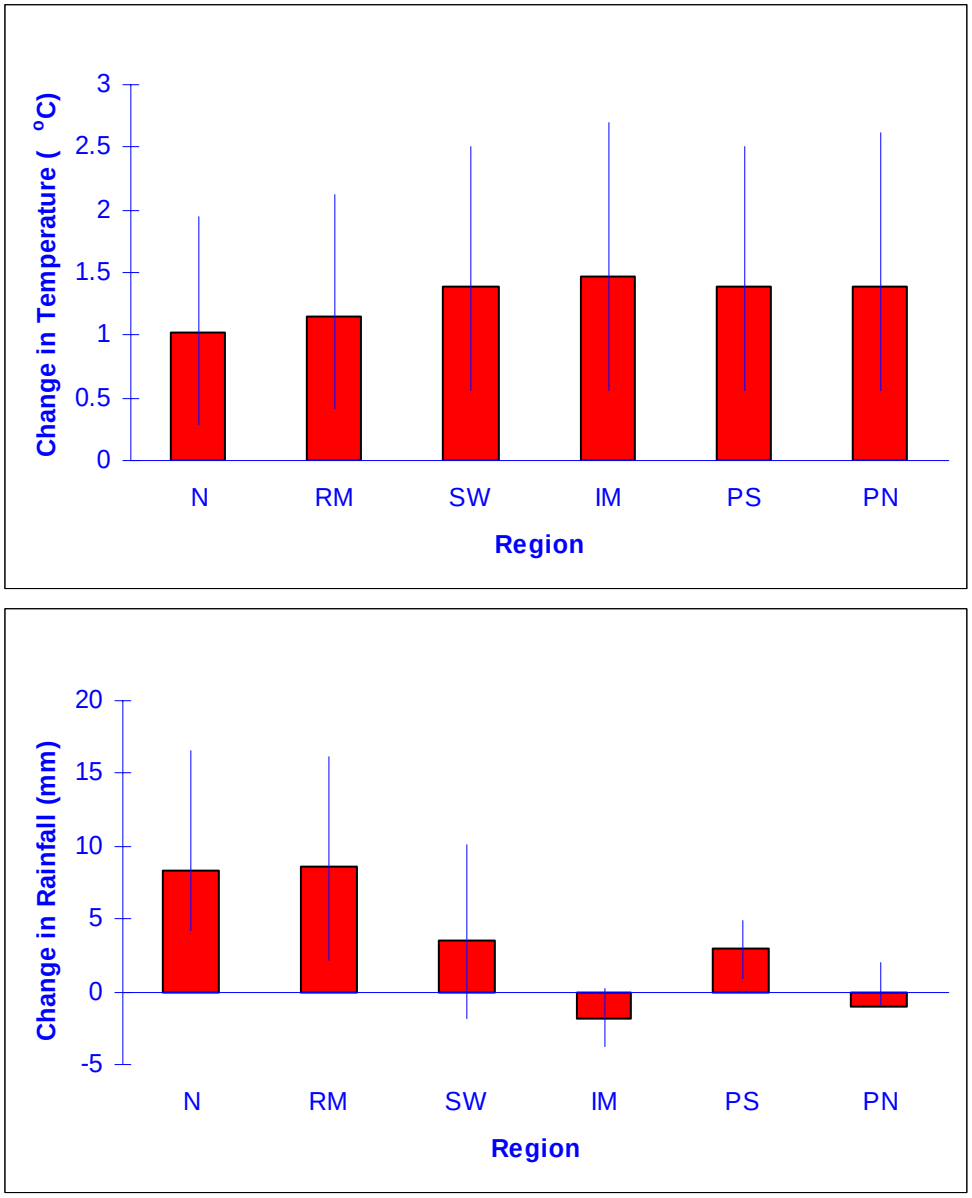

Fig. 8 Changes in summer temperature (top) and rainfall (bottom) by 2050 due to the greenhouse effect projected by HadCM2. The columns and vertical lines represent the averages and uncertainty ranges, respectively.

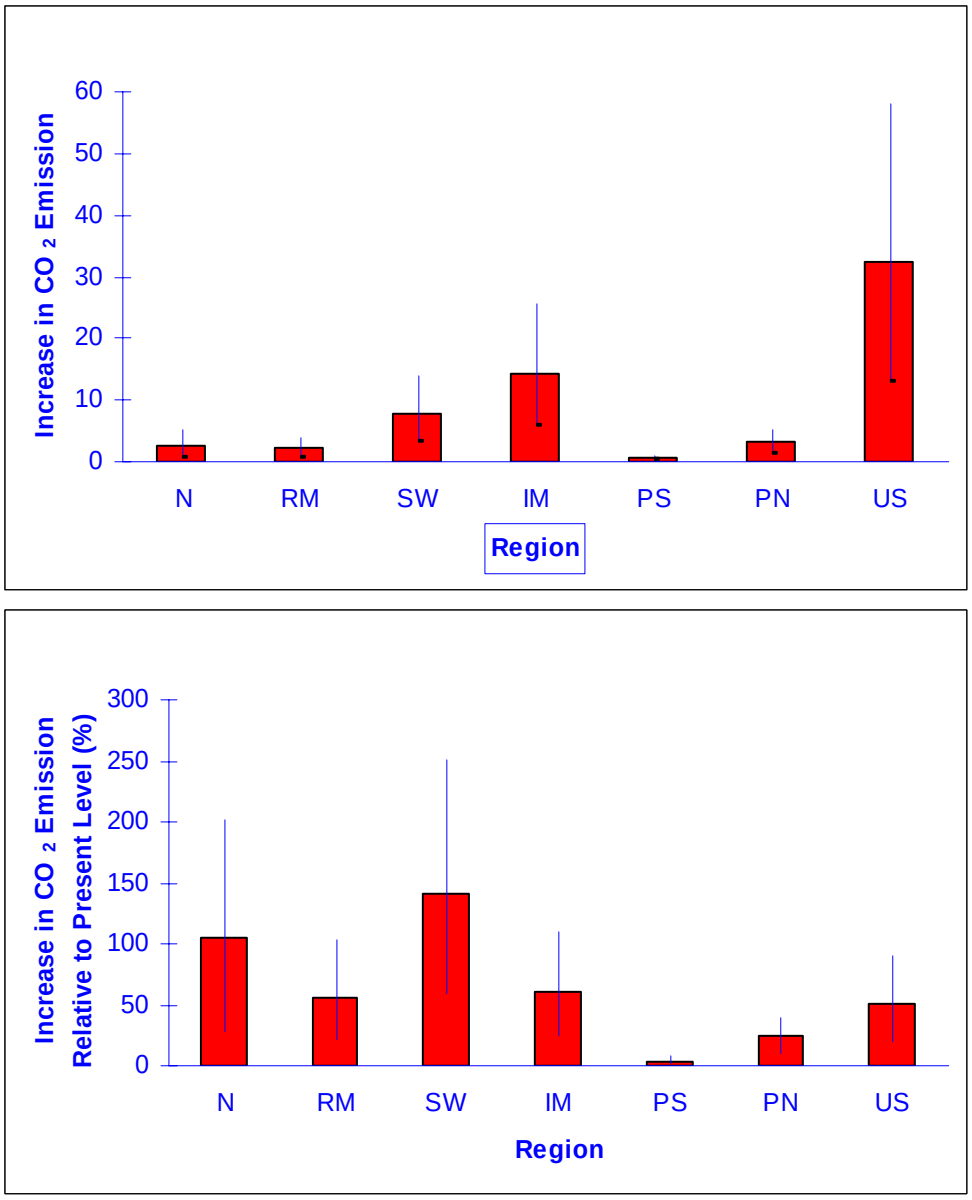

Fig. 9 Increase in summer wildfire emissions of CO_2 induced by the climate changes due to the greenhouse effect projected by HadCM2 (top) by 2050 and the values relative to their present levels (bottom). The columns and vertical lines represent the averages and uncertainty ranges, respectively.

Concluding Remarks

- Wildfires, which release about 90 Tg CO_2 annually into the atmosphere over the continuous U.S., are an important factor for the carbon cycle in this region.
- The wildfire emissions of CO_2 in the contiguous U.S. are expected to increase by 50% by 2050 and be doubled by 2100 due to the greenhouse effect.
- The estimated emissions are from fires on the federal lands only.
- Uncertainties in estimating the trends in future wildfire emissions of CO_2 include the uncertainty in projecting climate change with climate models and the impact of changes in forest fuel due to the greenhouse effect among others.
- The increase in wildfires due to the greenhouse effect would also contribute to the carbon cycle by affecting the ecosystem uptake of atmospheric carbon.

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Author Contacts

- Yongqiang Liu, Research Meteorologist, USDA Forest Service/Forestry Sciences Laboratory, 320 Green St., Athens, GA 30602, yliu@fs.fed.us

- John Stanturf, Research Ecologist, jstanturf@fs.fed.us
- Hanqin Tian, Professor, Auburn University, tianhan@auburn.edu
- John Qu, Professor, George Mason University, jqu@gmu.edu