Mitigating the Impact of Prescribed Burning in the Continental United States Using Trends in Synoptic Scale Transport to the Arctic Region

Extended Abstract # 55

Jennifer L. DeWinter[1], Sean M. Raffuse[1], Narasimhan K. Larkin[2], Tara T. Strand[2], Steven G. Brown[1], Kenneth J. Craig[1], Paul T. Roberts[1]

[1]Sonoma Technology, Inc., 1455 N. McDowell Blvd., Suite D, Petaluma, CA 94954
[2]U.S. Forest Service Pacific Northwest Research Station, 400 N. 34th Street, #201, Seattle, WA 98103

INTRODUCTION

Thousands of acres of land are burned each year in the United States due to wildfires, or as part of prescribed burn programs used by land managers such as ranchers, farmers, and foresters to maintain the health and productivity of the land for multiple applications. This biomass burning can release large amounts of climate forcers into the atmosphere, including black carbon (BC), CO_2, and methane[1]. A study of U.S. emissions reported that fires emit 4-6% of anthropogenic CO_2 at the continental scale, and more CO_2 than fossil fuels in certain states and years during which wildfire seasons are strong[2]. BC can have an atmospheric lifetime of over ten days before undergoing deposition and can be transported long distances, including to the Arctic Circle. Biomass burning emissions are thought to be the primary source of aerosols in the Arctic during the summer[3]. Long-range transport of absorbing aerosol such as BC, as well as subsequent haze and deposition to the Arctic region, substantially alters cloud and snow albedo, which affects snow cover, snowmelt, and the polar climate[4]. BC aerosol is thought to be the second greatest anthropogenic contributor to global warming trends[5] and one of the greatest contributors to warming in the Arctic.

Congress and the U.S. Environmental Protection Agency (EPA) are interested in potential mitigation strategies for BC and are considering near-term controls to reduce BC emissions. Specifically:

- Bill HR2996 requires the EPA to complete a report on BC that will identify approaches to reduce BC and contain an inventory of BC emissions.
- In a December 17, 2009, press release, the White House announced U.S. involvement in an international effort to reduce BC emissions affecting the Arctic.

Because biomass burning is one of the major sources of BC, questions have been posed about limiting prescribed burning as a reduction technique[6]. This restriction could affect fire management and prescribed burning strategies throughout the U.S., including a shift in the seasonal timing of continental U.S. (CONUS) prescribed burning. BC in the Arctic region contains large contributions from biomass burning emissions, possibly originating as far away as South East Asia[7] and high-latitude boreal forest fires[8]. However, there are large uncertainties in the current estimates of the sources, source regions, transport, and transformation pathways of BC in the Arctic region[9-11]. Despite these significant uncertainties, regulation to prevent BC transport may be promulgated in the next few years. Therefore, the likelihood of transport from

CONUS fires (prescribed or wildfire) needs to be adequately quantified by time of year, source area, and transport height to accurately inform policy decisions.

In response to Congress and the EPA and in an effort to characterize the impact of CONUS-prescribed burning emissions on the Arctic region, the Joint Fire Science Program (JFSP) and U.S. Forest Service (USFS) initiated this work to investigate synoptic scale transport of BC emitted from fires to the Arctic. Arctic impact could be mitigated by combining local and regional fire management strategies with an understanding of the potential for poleward transport of biomass burning emissions, including a shift in the timing of a prescribed burn based on the likelihood of transport given current meteorological conditions. Thus, a transport analysis was conducted to ascertain the frequency and characteristics of synoptic transport from various CONUS locations to the Arctic Circle. Transport was modeled for 30 years to capture synoptic-scale meteorological patterns and identify necessary conditions and associated uncertainty for CONUS fires to impact the Arctic. The likelihood of transport from locations in CONUS were estimated by time of year, source area, and transport height. Seasonal patterns for several years were compared to assess inter-seasonal variability in transport conditions as they relate to source areas. Lastly, a forecast system will be designed to leverage the transport climatology developed in the trajectory modeling and provide a means for estimating the level of impact of a prescribed burn based on current meteorological conditions.

BODY

Methods

The National Oceanic and Atmospheric Administration's (NOAA) Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model v4.9, January 2010 release, Linus version, was used to simulate air parcel transport between BC emission source areas in CONUS and the Arctic Circle[12]. The widely used HYSPLIT model calculates the path of a single air parcel from a specific location and height above the ground over a period of time; this path is called a trajectory. HYSPLIT trajectories were modeled using gridded meteorological data sets from two sources: the global National Center for Atmospheric Research/National Center for Environmental Prediction Reanalysis Project (NNRP)[13], and the much higher-resolution regional North American Regional Reanalysis (NARR)[14]. Trajectory transport is modeled with the NARR data when trajectories reside within the NARR domain and with the global NNRP data when trajectories reside elsewhere. Both products combine a consistent set of models and parameterizations with an observational data assimilation system to create dynamically consistent long-term weather and climate data sets. The NNRP data used in this study were obtained from the NOAA Air Resources Laboratory (ARL) in HYSPLIT-ready format. The NARR data were obtained from the National Climatic Data Center in GRIB format, then converted to HYSPLIT-ready format using software developed by ARL.

Transport was modeled for 30 years (1979 to 2008) to capture a robust climatology of synoptic scale meteorological patterns and identify the probability and uncertainty for CONUS fires to impact the Arctic region. HYSPLIT-forward trajectories were initialized every 6 hours (0000, 0600, 1200, and 1800 UTC) for the 30-year study period from 13,482 source points within CONUS. These source points represent the centroid of every second NARR grid cell that intersects CONUS (1926 source locations at an equivalent spatial resolution of 64 km) at 500, 1000, 1500, 2000, 2500, 3000, and 5000 meters above ground level. These source heights were chosen to adequately capture transport from the typical range of smoke injection heights from the vast majority of fires[15]. Each trajectory was modeled in the forward direction for 10 days.

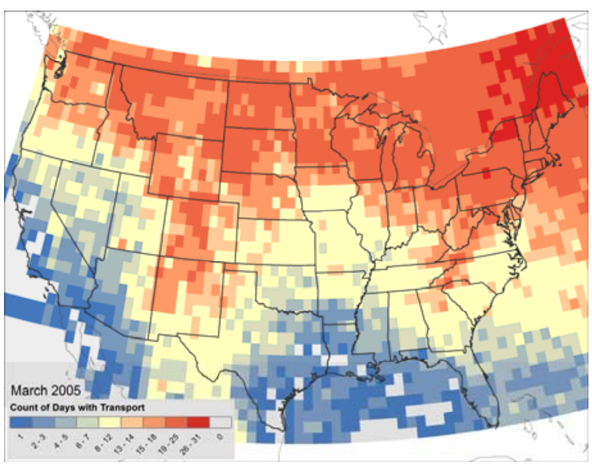
This HYSPLIT setup implies modeling of nearly 600 x 10^6 individual trajectories and requires storing 1.4 x 10^{11} individual trajectory locations. A "trajectory system" was developed to make maximum use of today's modest-cost multi-core computing architectures and multi-terabyte storage platforms. Custom automations, data formats, and data processing routines were developed to handle the resulting multi-terabyte data set. A new tool provides users with access to customizable graphics showing trajectory plots from specific locations.

The trajectory data set could also be used to develop a forecast tool that uses the synoptic scale transport patterns identified in the transport analysis. Each day, weather forecast data would be obtained and used to identify a number of "analog" days in the trajectory data set based on a series of meteorological parameters that capture the likelihood for transport. Analog periods in the 30-year data set where these conditions are most similar could be mapped and highlighted on a website. The tool could enable regulators to evaluate typical patterns likely to transport BC from CONUS fires to the Arctic and grant land managers access to data that could be used to make effective decisions that minimize impact on the Arctic. The tool could also be used to characterize potential transport from other emissions sources.

Results

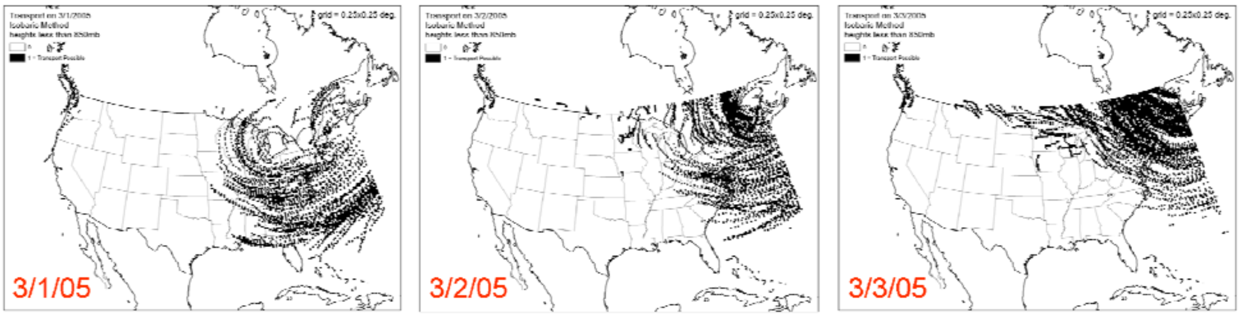
Preliminary results were developed using a pilot data set of backward trajectories. All results are shown for a grid covering the CONUS; however, the trajectories extend from CONUS to the Arctic region. The initial results indicate potential for transport from regions of prescribed burning in the U.S., as shown in Figure 1. The north-south pattern evident in March 2005 was consistent across other months and years. Transport was less likely to occur during the late spring and summer months than during the winter and early spring months.

Figure 1. The number of days in March 2005 on which transport to the Arctic Circle occurred from heights below 2,000 meters. The count of days was higher in the red areas than in blue areas. Transport occurred in seven days or fewer.



Transport potential varies by day, as shown in Figure 2. The variability in daily transport potential can be used to inform a near real-time forecast tool to guide prescribed burn planners. For example, when considering long-range transport to the Arctic, a large burn occurring in the southeastern U.S. may have had less Arctic impact if planned for March 3, 2005, rather than March 1, 2005, based on climate data.

Figure 2. A comparison of the occurrence of HYSPLIT hourly trajectory points (black grid cells) on three consecutive days in March 2005. The black cells represent a location where a trajectory impacted the Arctic within the following seven days or less.



SUMMARY

A transport modeling system was developed in order to efficiently process and store 30 years of trajectory results. The data set can be used to characterize the potential for transport from areas within the CONUS to the Arctic. An evaluation of transport potential by day, month, season, and across multiple years can be used to design mitigation strategies for reducing emissions of aerosol and gases emitted from fires in the U.S. The data set could also be used in real time to evaluate transport potential from a variety of emissions sources within the U.S. In order to fully analyze the transport and impact of BC from CONUS fires, a full chemical and deposition model must be used to capture these processes. This work helps to inform further studies of the type of computationally demanding modeling that may need to be done in the future.

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