

Climatology of Air Mass Transport to the Arctic from Locations of Prescribed Burning in the United States

Jennifer L. DeWinter¹, Narasimhan K. Larkin², Tara T. Strand², Sean M. Raffuse¹, Steven G. Brown¹, Kenneth J. Craig¹, Paul T. Roberts¹, Roland R. Draxler³
¹Sonoma Technology, Inc., Petaluma, California, ²U.S. Forest Service Pacific Northwest Research Station, Seattle, Washington, ³Air Resources Laboratory, NOAA, Silver Spring, Maryland
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ABSTRACT

The region above the Arctic Circle is very sensitive to global warming and changes in atmospheric composition. Black Carbon (BC) aerosol from sources including diesel engines, coal-fired power plants, and biomass burning is thought to be the second greatest anthropogenic contributor to global warming trends 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, which could affect fire management and prescribed burning strategies throughout the United States, including shifting the seasonal timing of continental U.S. (CONUS) prescribed burning. However, the likelihood of transport from CONUS fires (prescribed or wildfire) needs to be adequately quantified by time of year, source area, and transport height in order to accurately inform policy decisions. Therefore, a transport analysis was conducted to ascertain the frequency and characteristics of aerosol transport from CONUS to the Arctic Circle. Back trajectories from receptors along the Arctic Circle were modeled for 30 years to capture synoptic-scale meteorological patterns and identify the necessary conditions and associated uncertainty for CONUS fires to impact the Arctic. Preliminary results are presented for March and April 2005, describing transport from various source regions by month, day, and pressure levels.

BACKGROUND

Black Carbon

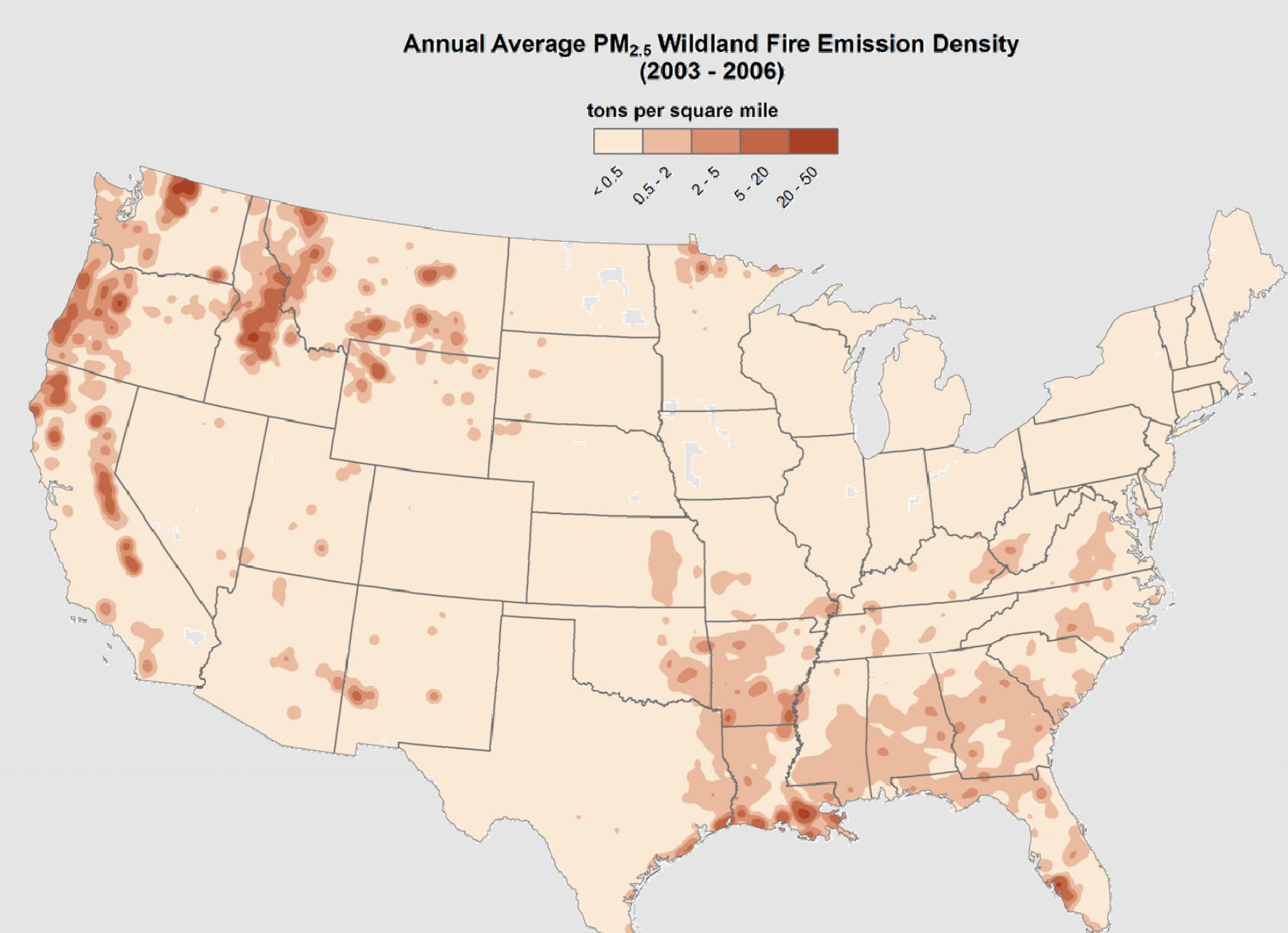
- Carbonaceous aerosol (particulate matter suspended in air).
- Important agent in global climate change.
- Absorbs sunlight in the atmosphere.
- Deposits on bright surfaces, such as snow and ice regions in the Arctic, and enhances melting (U.S. Environmental Protection Agency, 2010).
- Estimated warming effect is highly uncertain (Ramanathan, 2010).
- Regulation of BC emissions is a short-term strategy to reduce warming due to its short atmospheric lifetime (days to weeks) (Ramanathan, 2010).



BC deposition shown as dark areas on snow and ice. Sunlight is absorbed rather than reflected. Image credit: NASA

Prescribed Burning

- BC emissions sources include diesel engines, coal-fired power plants, and biomass burning (wildfires and prescribed burns).
- Prescribed burning of forest areas is a strategy utilized by forest management agencies and private land owners to maintain healthy ecosystems and minimize risks to property and health from larger wildfire events.
- Prescribed burns are most common in the southeastern states and Pacific Northwest during winter and spring but vary in intensity, timing, and frequency.
- It is critical to design burn strategies that enable effective prescribed burning but limit impacts to the Arctic region.



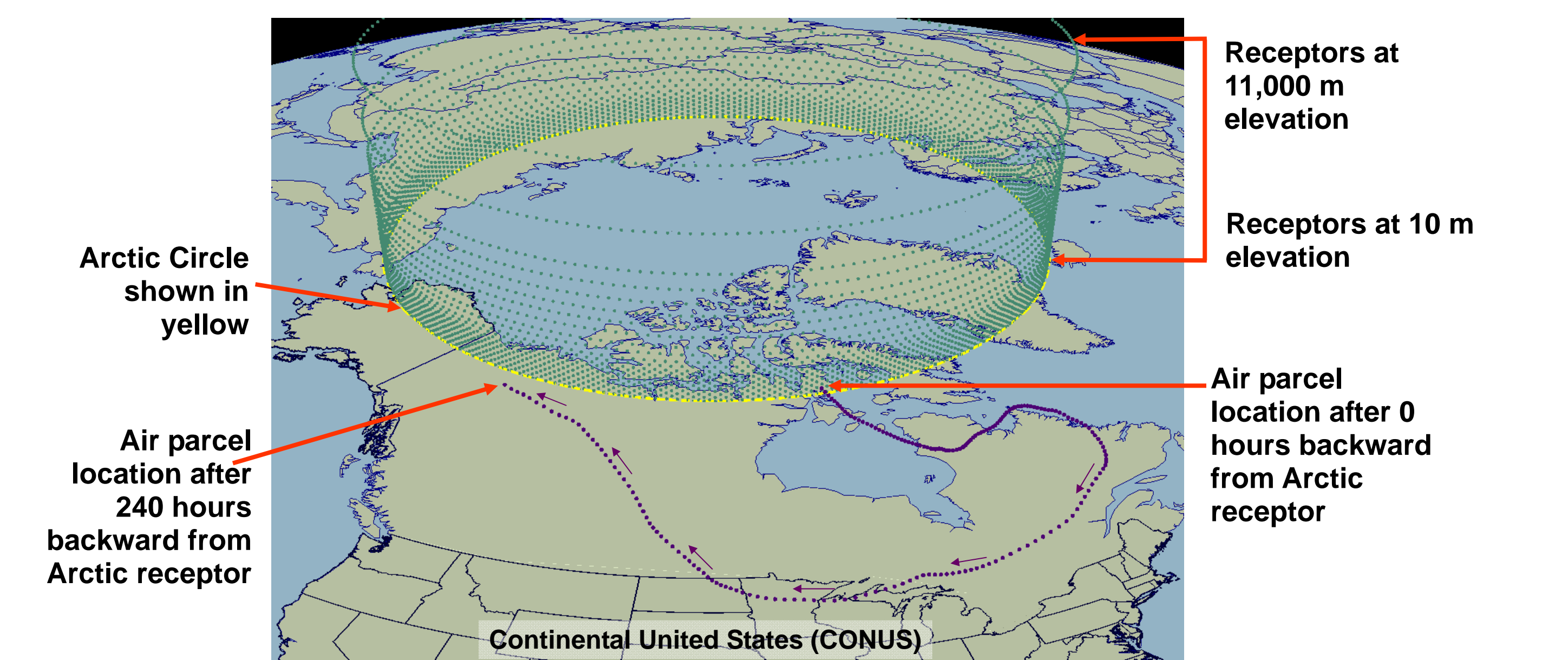
National emissions of annual average PM_{2.5} (2003-2006) from fires. Fires in the southeastern United States are predominantly prescribed burns.

METHODS

The National Oceanic and Atmospheric Administration (NOAA) Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPPLIT) model was used to simulate air parcel transport between the Arctic Circle and BC emission source areas in CONUS. We modeled backward from a wall of receptors (green dots in the figure to the right) along the Arctic Circle.

Modeling details:

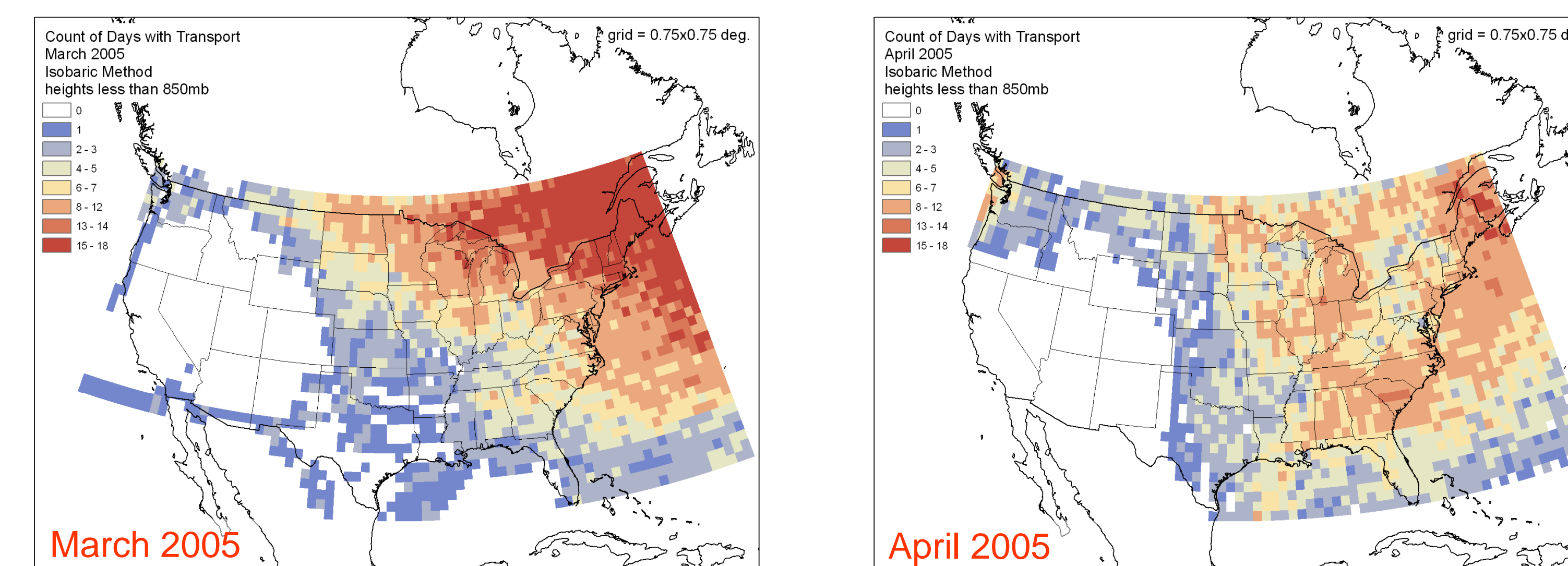
- Once completed, 30 years of model runs (1979-2008)
- Isobaric vertical velocity method to capture synoptic-scale meteorological patterns
- Nested meteorological grids - North American Regional Reanalysis (NARR) within the National Center for Atmospheric Research (NCAR)/National Center for Environmental Prediction (NCEP) global reanalysis grid
- 384 geographic points along the Arctic Circle (66.56 decimal degrees of latitude)
- Endpoints on the Arctic Circle at every NARR grid cell (0.75 degrees) and twice per global grid cell (1.25 degrees)
- 10 pressure levels (mb) (925, 850, 775, 700, 600, 500, 400, 300, 200, 100)
- 240 hours (10 days) backward for each trajectory
- Four start times per day (00z, 06z, 12z, 18z)



Transport (purple path in figure) was modeled backward from receptors (green dots in figure) along the Arctic Circle (yellow circle in figure). Each trajectory is defined by location and attributes at each hour of transport (purple dots in figure).

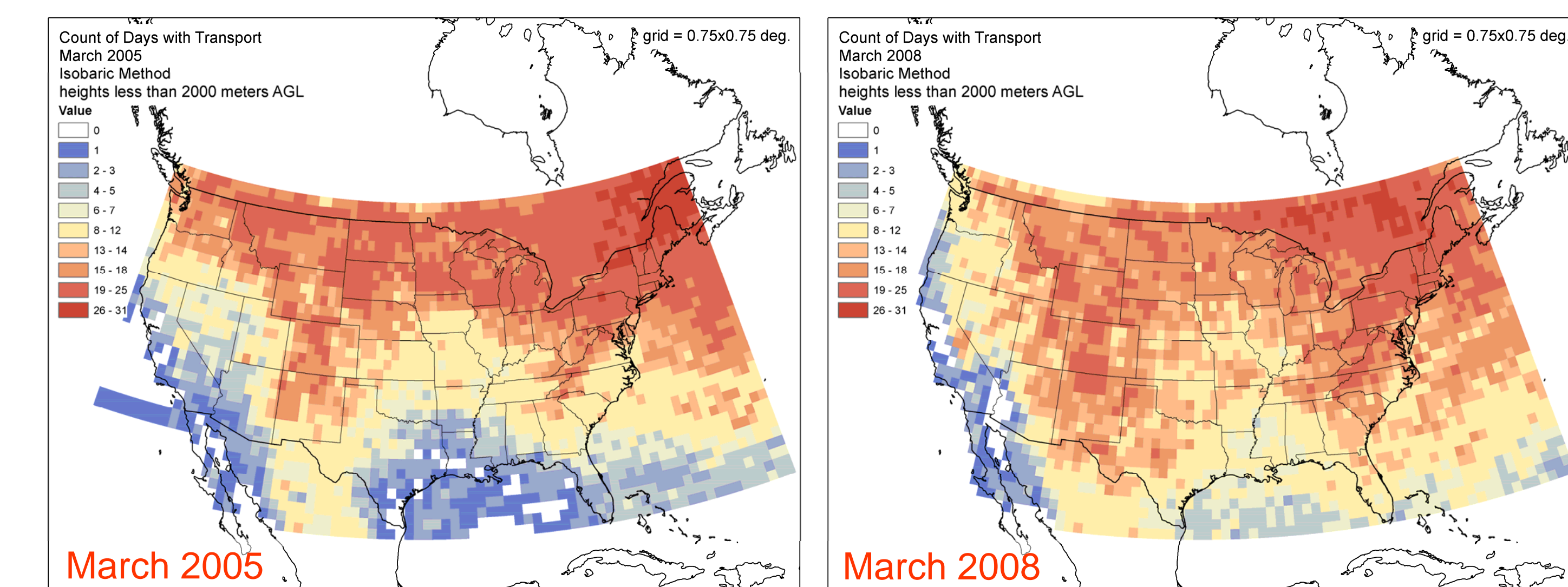
PRELIMINARY ANALYSIS

Transport by Month



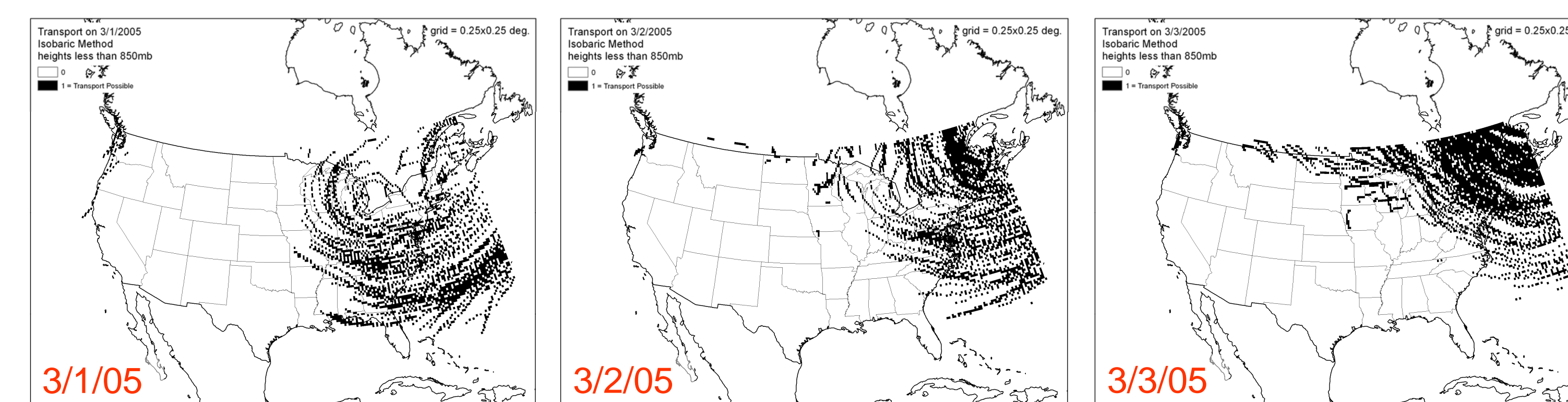
The number of days in March 2005 and April 2005 with transport to the Arctic Circle from heights below 850 mb are shown.

Annual Comparison



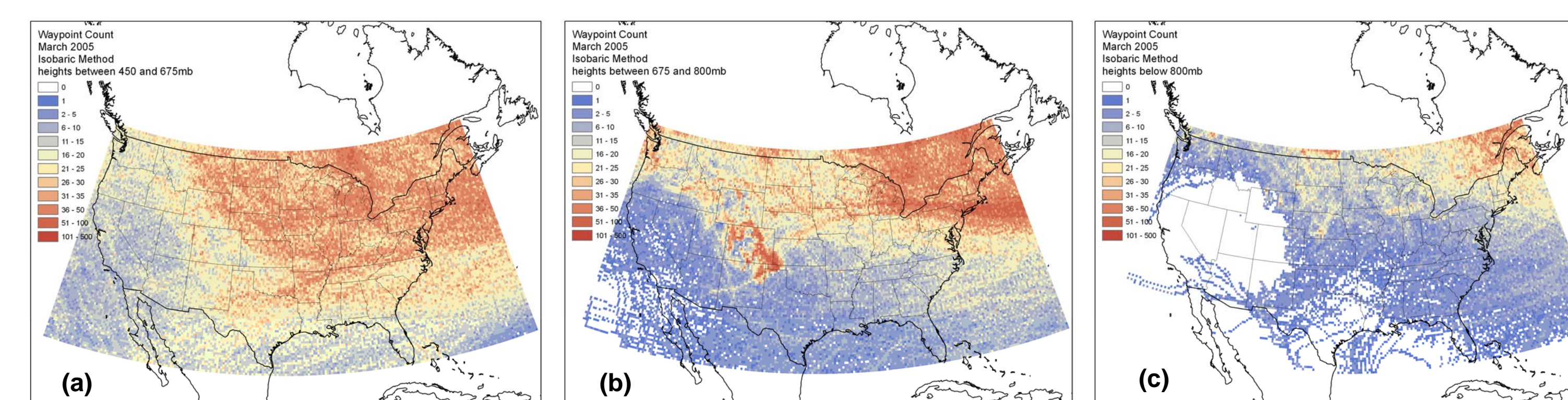
The number of days in March 2005 and 2008 with transport to the Arctic Circle from heights below 2000 meters are shown.

Transport by Day



A comparison of the occurrence of any HYSPLIT hourly trajectory points (black grid cells) on three consecutive days in March 2005 at heights below 850 mb.

Transport by Pressure Level



The frequency of transport (waypoint count) from CONUS to the Arctic for March 2005 are shown at atmospheric pressure levels: (a) between 450 and 675 mb, (b) between 675 and 800 mb, and (c) above 800 mb. A waypoint is a single hour along the trajectory.

Summary and Next Steps

Our preliminary findings:

- There is potential for transport from regions of prescribed burning.
- Transport potential varies by month. Transport of air masses from the southeastern states occurred more frequently in April than March (6-14 days vs. 1-5 days).
- Transport patterns vary daily. For example, meteorological conditions on 3/1/2005 were conducive to transport from the southeastern states to the Arctic.
- Transport is more likely at higher atmospheric pressure levels, but this may not be useful to predict the likelihood of transport at elevations typical of prescribed fire injection heights.

Next steps:

- Assess transport by month and season throughout the 30-year climatology.
- Identify and categorize synoptic meteorological conditions that lead to transport.
- Evaluate atmospheric pressure levels to understand transport in the lower atmosphere.
- Calculate accuracy of results in order to define our spatial resolution.
- Assess model uncertainty.

REFERENCES & ACKNOWLEDGMENTS

Ramanathan V. (2010) Climate impacts of black carbon: testimonial to the House Select Committee on energy independence and global warming. Presented at the House Hearing entitled *Clearing the smoke: understanding the impacts of black carbon pollution*, 2175 Rayburn House Office Building, Washington, D.C., March 16, Scripps Institution of Oceanography, University of California, San Diego.

U.S. Environmental Protection Agency (2010) Our nation's air: status and trends through 2008. Report prepared by the Office of Air Quality Planning and Standards, Air Quality Assessment Division, Research Triangle Park, NC, EPA-454/R-09-002, February. Available on the Internet at <http://epa.gov/airtrends/2010report/fullreport.pdf>.

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