How do plants affect air quality?

Estimated Biogenic Emissions from a Dynamic Global Vegetation Model in the U.S. for 2050

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Introduction

Most plant species emit trace amounts of gas into the atmosphere called biogenic volatile organic compounds (BVOCs). BVOCs play a vital role in atmospheric chemistry by affecting the:

- Atmosphere's oxidizing capacity
- Global carbon cycle
- Production of aerosols
- Concentration of ozone

http://earthobservatory.nasa.gov/

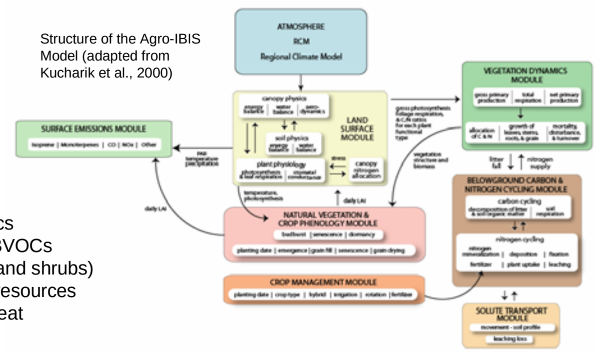
What are Biogenic Volatile Organic Compounds?

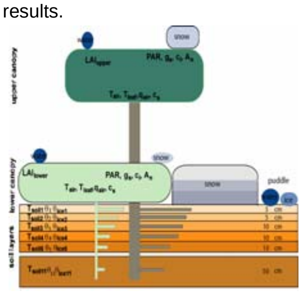
The majority of BVOCs from plants are in the form of isoprene and monoterpenes. All other trace gases are included in the Other Biogenic Volatile Compounds (OBVOCs) category. Emissions from soil are in the form of NOx (NO and NO_2). Emissions of BVOCs are sensitive to plant species, temperature, light (for isoprene), and a variety of other factors including plant age, pollution, and stress. Thus, climate has a major influence on the flux of trace gases and suggests that: (1) as temperature increases in the future, the emissions from vegetation will also increase and (2) as biomes shift and/or as species migrate or disappear locally, regional BVOC emissions will be altered.

Methods

Used the global dynamic vegetation model Integrated Biosphere Simulator (IBIS) and the Agro-Ecosystem IBIS (Agro-IBIS) to simulate future vegetation with an alternate climate scenario. IBIS was driven by cycling through meteorology data from the year 2050 based on the IPCCs A1Fi ("Business as Usual") scenario as calculated by the Regional Climate Model. A simulation with current climate was also performed for the year 1995 as a control to compare future results.

Structure of the Agro-IBIS Model (adapted from Kucharik et al., 2000)

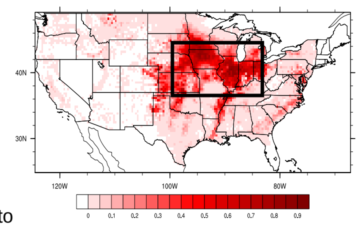




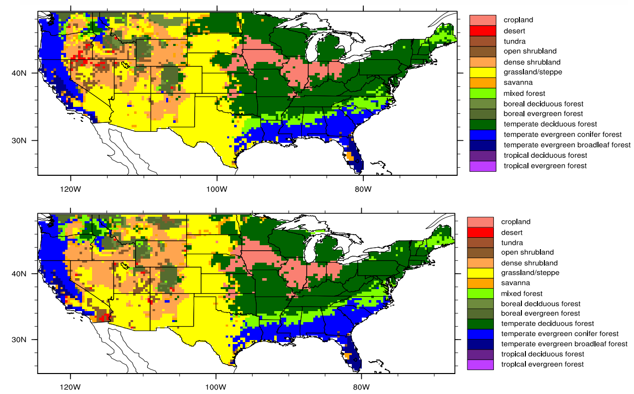
An IBIS grid cell (T. Twine, personal communication)

Integrated Biosphere Simulator (IBIS)

- •Simulates natural and managed vegetation characteristics
- •Emissions include isoprene, monoterpene, NOx, and OBVOCs
- •Two canopy layers – Upper (trees) and Lower (grasses and shrubs)
- •Vegetation competes for carbon, light, water, and other resources
- •16 vegetation biomes including maize, soybean, and wheat
- •0.33 degree x 0.33 degree resolution



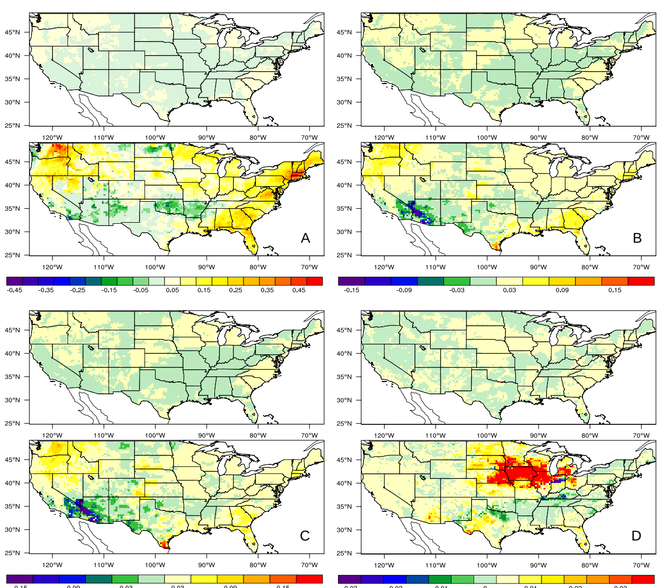
Fractional coverage of crops over the U.S. as calculated by Donner (2003). Boxed region indicates the domain used for this study



Top: IBIS and Agro-IBIS simulated potential vegetation distribution for the 1995 climate period
Bottom: IBIS and Agro-IBIS simulated potential vegetation distribution for the 2050 climate period

Important Vegetation Changes

- •West: open shrubland becomes dense shrubland due to increasing precipitation
- •Southwest: grassland in southern California shifted to desert due to a precipitation decrease
- •East: slight northward movement of mixed and temperate evergreen conifer forests
- •Central: Cropland held constant (not assumed to expand or contract over that period)



Difference between 2050 and 1995 simulated emission rates during January (top) and July (bottom) of (A) isoprene (g C m^{-2} $month^{-1}$), (B) monoterpenes (g C m^{-2} $month^{-1}$), (C) OBVOCs (g C m^{-2} $month^{-1}$), and (D) NOx (g N m^{-2} $month^{-1}$).

Results

During 2050, isoprene emissions increased 23%, monoterpene emissions increased 11%, OBVOC emissions increased 10%, and NOx fluxes increased by 24%. Changes in emissions were highly dependent on local and regional environments. BVOCs were sensitive to light (isoprene), temperature, foliar density (or plant growth), plant distribution, and precipitation. The largest increases in BVOC emissions occurred during the summer. These results show the potential for significant change in local and regional atmospheric chemistry.

Future Questions

1. How might an increase in emissions impact air quality such as ozone concentrations and aerosol formation in the atmosphere?
2. How would an elevated CO_2 environment affect plant growth and emissions?
3. What results are possible if a different climate scenario is used to drive the model?

References

Donner, S. D., 2003: The Impact of Cropland Cover on River Nutrient Levels in the Mississippi Basin. *Global Ecol. Biogeogr.*, **12**, 341-355.

Kucharik, C., J. Foley, C. Delire, V. Fisher, M. Coe, J. Lenters, C. Young-Molling, and N. Ramankutty, 2000: Testing the Performance of a Dynamic Global Ecosystem Model: Water Balance, Carbon Balance, and Vegetation Structure. *Global Biogeochem. Cycles*, **14**, 796-825.

Author Background

Beth Bye is a recent graduate of the University of Illinois at Champaign-Urbana. Although this project is part of her Masters thesis in the Atmospheric Sciences Department, this study along with her experiences during this project helped her become a member of the Air Quality group in the Environmental Sciences Division at Argonne National Laboratory. Currently, she is working on another modeling study using the Chemical Transport Model MOZART to look at mercury deposition. Email: bbye@anl.gov

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