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ESP v2.0: Improved method for projecting U.S. Greenhouse Gas and air pollutant emissions through 2055

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Extended Abstract

Introduction

The Emission Scenario Projection (ESP) method produces multi-decadal forecasts of U.S. Greenhouse Gas (GHG) and air pollutant emissions. The resulting future-year emission inventories can be used in climate and air quality modeling research activities. ESP version 1.0 (ESP v1.0) was described in a 2011 publication (Loughlin et al., 2011). The method focused on the development of U.S. Census Division-level, energy-related emission growth and control factors through 2055. These multiplicative factors were applied to grow a base-year inventory to the future. ESP v1.0, however, did not account for how population migration and land use change could redistribute emissions geographically within each region.

In this presentation, we provide an overview of the next version of the method, ESP v2.0. This version builds upon v1.0 by using population migration and land use change projections to spatially allocate the future-year inventory. We demonstrate the use of ESP v2.0 in developing a 2050 gridded inventory. The 2050 inventory is compared to the base-year inventory to evaluate changes in the magnitude and spatial distribution of pollutant emissions.

Method

The ESP v2.0 method, depicted in Figure 1, begins with specification of assumptions about a wide range of emission drivers, including population growth and migration, economic growth and transformation, technological changes, land use changes, and current and potential policies (e.g., air quality, energy, and climate). The Integrated Climate and Land Use Scenarios (ICLUS) model (U.S. EPA, 2009; Bierwagen et al., 2010) uses the population- and land-use change-related assumptions to produce county-level population estimates and housing density estimates at a 100-meter resolution.

ICLUS county-level populations are aggregated to the U.S. Census Division level and used to adjust the regional energy service demands in the EPAUS9r MARKAL database (U.S. EPA, 2013). The MARKet ALlocation (MARKAL) energy system model uses this information in projecting the evolution of the U.S. energy system through 2055 (Loulou et al., 2004). In addition to producing technology penetrations and fuel use estimates, MARKAL outputs regional-, technology category-specific estimates of emissions.

Pollutant species tracked include nitrogen oxides (NOx), sulfur dioxide (SO_2), carbon monoxide (CO), particulate matter (PM), and volatile organic compounds (VOCs).

MARKAL emission projections are mapped to standard Source Classification Codes (SCCs), and then regional-, pollutant-, SCC-specific emission growth factors are calculated by dividing the future-year emissions by those of a base year. For residential, commercial and light duty vehicle SCCs, regional emissions growth factors are translated to the county-level, accounting for ICLUS county-level population projections. Thus, counties with projected declining populations have lower emission growth rates than those with projected population increases.

The Sparse Matrix Operator Kernel Emission (SMOKE) processing system applies the resulting multiplicative emission growth factors to a base-year inventory to produce a future-year emission inventory (Houyoux et al., 2000). The next step in SMOKE processing is to map the future-year, county-level inventory to a modeling grid that can be used by a photochemical transport model such as the Community Multiscale Air Quality (CMAQ) model (Byun and Schere, 2006). County-level emissions are allocated to the grid cells that overlap the county based upon spatial surrogates, such as grid-level estimates of population, housing units, or urban road mile portions to county totals. Typically, historical spatial surrogates are used in this process. Within ESP v2.0, we update these spatial surrogates based upon the population and land use outputs of ICLUS.

Application and Results

We applied ESP v2.0 to develop a 2050 gridded emissions inventory for a baseline scenario. 2050 was selected for this analysis since it was expected to show significant differences in land use compared to 2005. Several illustrative graphics are provided below. Figure 2a shows regional NOx emission growth factors for light duty vehicles. These factors, derived from MARKAL results, illustrate the success of vehicle emission standards in significantly reducing future year emissions, despite increasing regional populations and travel demands.

Figure 2b shows the associated county-level growth factors, after adjustment to account for population migration. This result indicates that light duty NOx emissions are expected to decrease in all counties, but this decrease is muted in rapidly growing areas.

Figure 3 compares the 2050 and 2005 gridded NOx emissions using the Fractional Difference (FD) metric. The results indicate that ESP v2.0 predicts decreasing NOx emissions in most of the country, although several locations in the Mountain region and in Southern California are projected to see increases under the baseline scenario that was modeled. Different assumptions regarding population growth, technology change, and future policies may produce a different result, and ESP v2.0 allows those alternative scenarios to be explored.

The details of this application will be provided in a forthcoming publication.

Conclusions

The improved ESP v2.0 procedure results in a future-year inventory that more fully and more consistently accounts for factors such as population growth and migration, economic growth and transformation, technology change, land use change, and energy, climate and environmental policies.

Further, ESP v2.0 facilitates exploring how changing these assumptions results in changes to air pollutant emissions and air quality.

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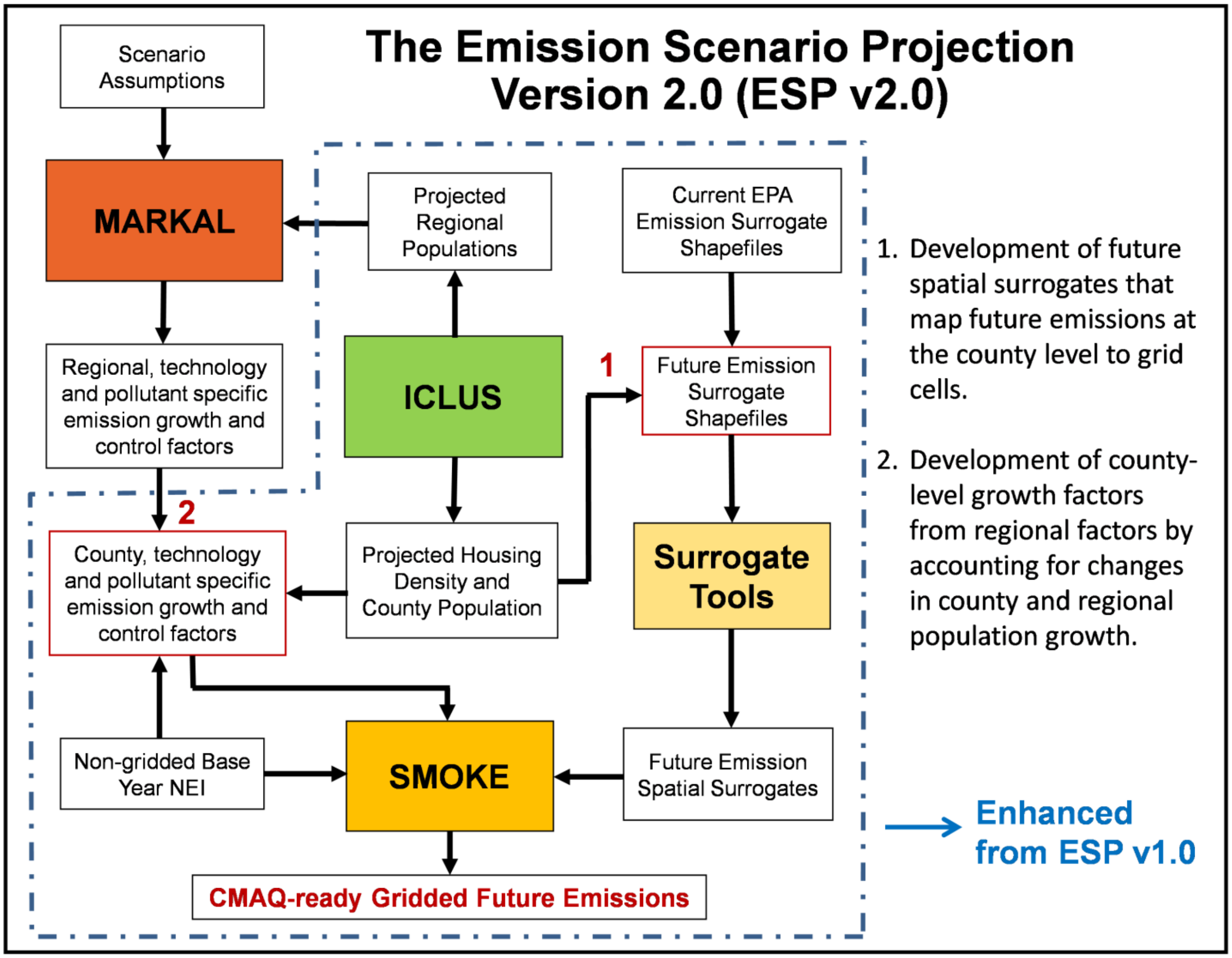

Figure 1. Schematic diagram showing components of Emission Scenario Projection v2.0 system. Dashed blue box contains enhancements from ESP v1.0.

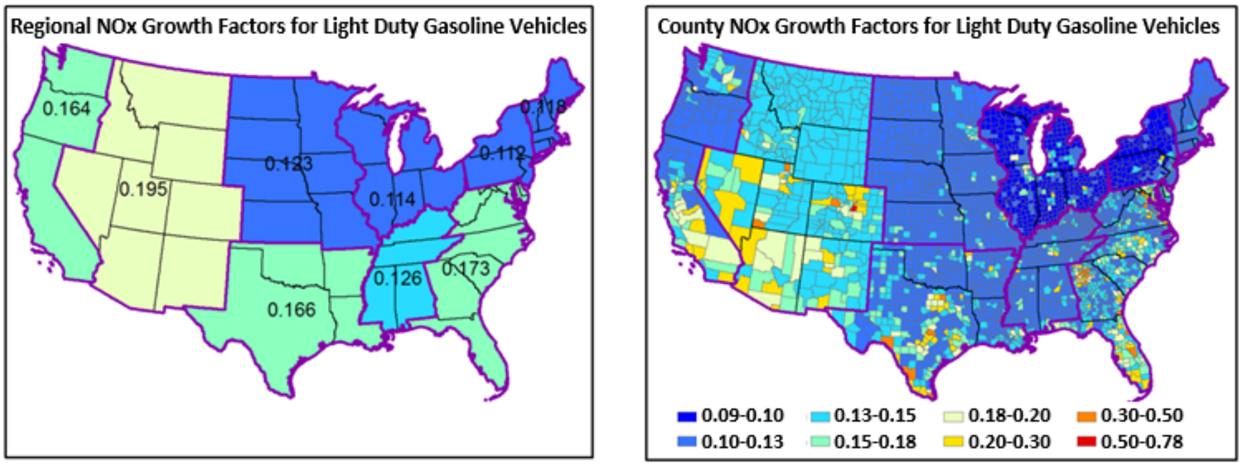

Figure 2. Illustrative examples of light duty vehicle emission growth factors for NOx. The graphic on the left shows regional factors that were derived from MARKAL outputs. The graphic to the right shows county-level factors that account for population growth and migration.

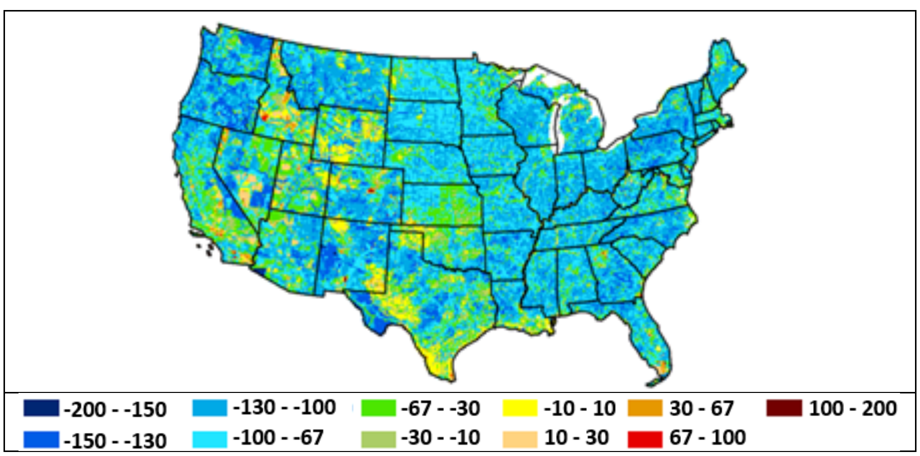

Figure 3. Fractional differences in NOx emissions between a 2050 inventory grown using ESP2.0 and a 2005 inventory.