Modeling the impacts of green infrastructure land use changes on air quality and meteorology—case study and sensitivity analysis in Kansas City

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Motivation

- Green infrastructure can be a cost-effective approach for reducing storm-water runoff and improving water quality as a result, but it could also bring co-benefits for air quality: less impervious surfaces and more vegetation can decrease the urban heat island effect, and also result in more removal of air pollutants via dry deposition with increased vegetative surfaces;
- Cooler surface temperatures can also decrease ozone formation through increases in NO_X titration; however, cooler surface temperatures also lower the height of the planetary boundary layer resulting in more concentrated pollutants within the same volume of air, especially for primary emitted pollutants (e.g. NO_X, CO, primary particulate matter).

Objectives

- To better understand how changes in vegetation cover associated with urban planning efforts may affect regional meteorology and air quality in Kansas City (KC).
- Pilot project to demonstrate use of the WRF/CMAQ modeling system for estimating potential green infrastructure impacts on air quality.

Methodology

- Apply a comprehensive coupled meteorology-air quality model (WRFv3.8.1-CMAQv5.2 Gamma) for 12 km CONUS, 4 km KC and 1 km KC domains.
- Current and a plausible green infrastructure land use scenarios (BASE) were provided by the Mid-America Regional Council for 2012 and a scenario with land use changes due to green infrastructure implementation only (SENS).
- Both the BASE and SENS cases were run for a whole year with constant emission inventory in 2011. All the results are presented as annual average or seasonal averages.

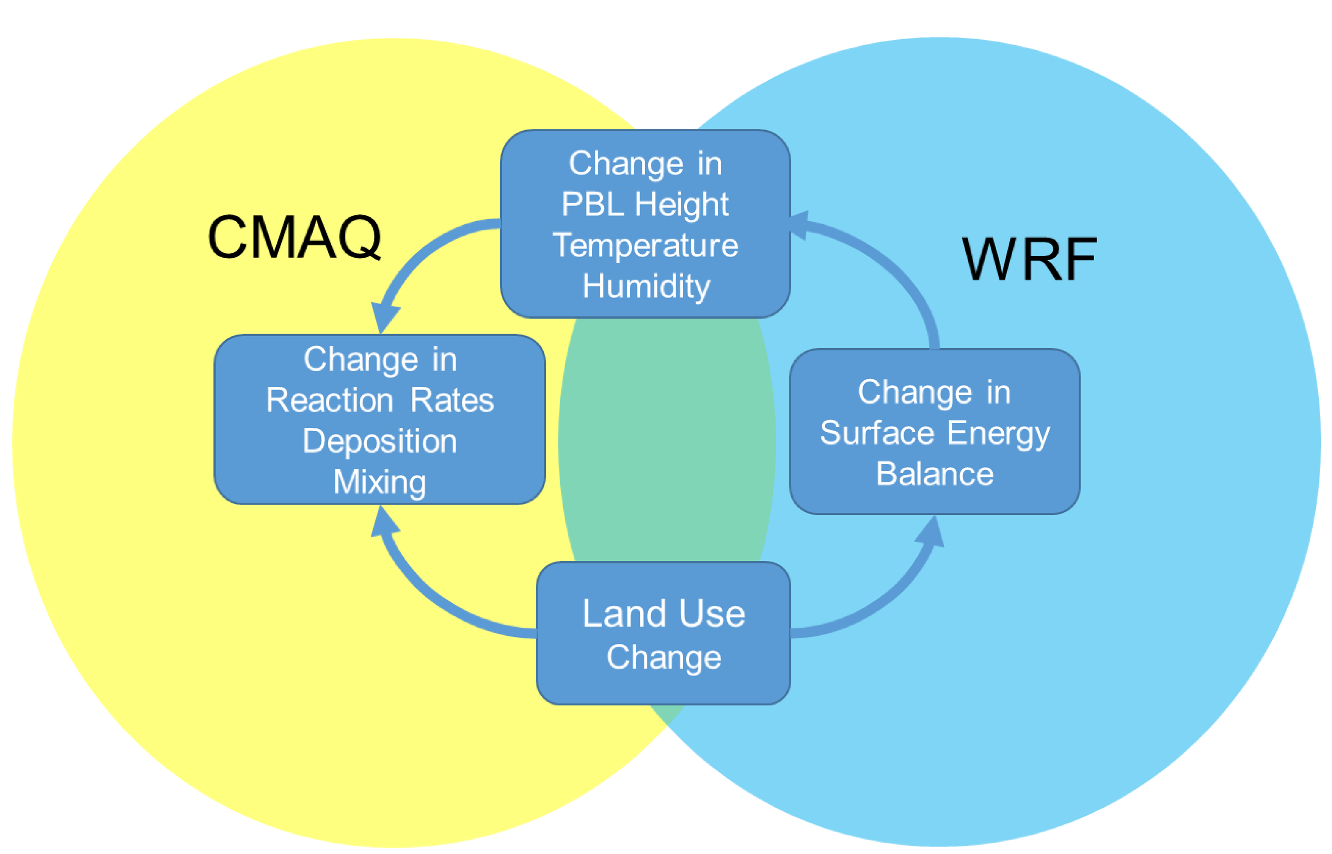

Fig. 1 Schematic flow of the changes in land use effect on the coupled WRF-CMAQ system

Results

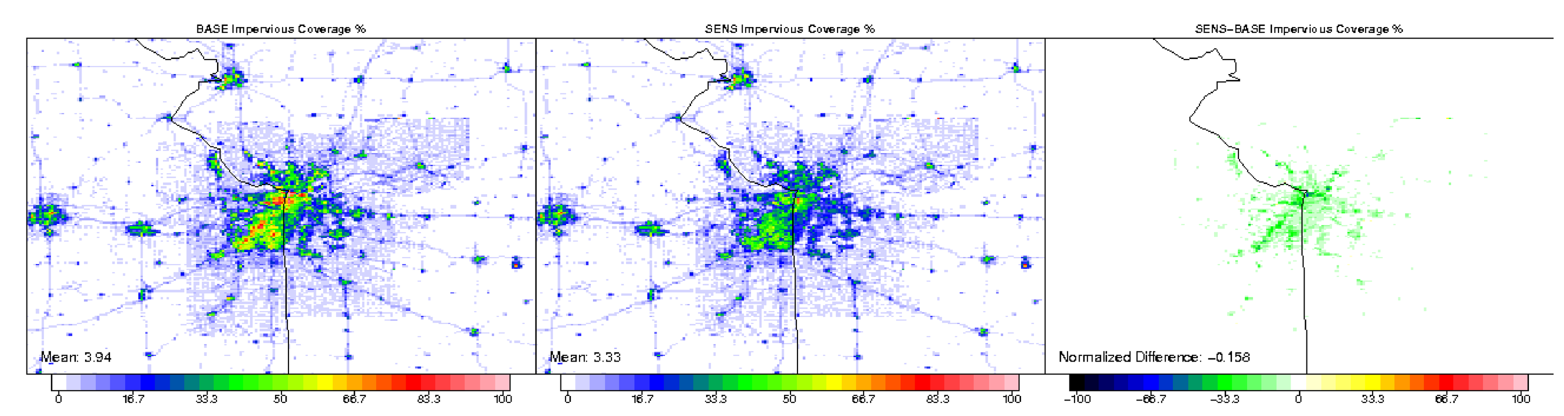

Fig. 2 Impervious surface coverages in the BASE case scenario (left), SENS case scenario (middle), and the differences between these two (SENS-BASE, right). Cold colors mean the impervious surface are decreasing.

- ➢ The impervious surface coverages are reduced in the SENS case.

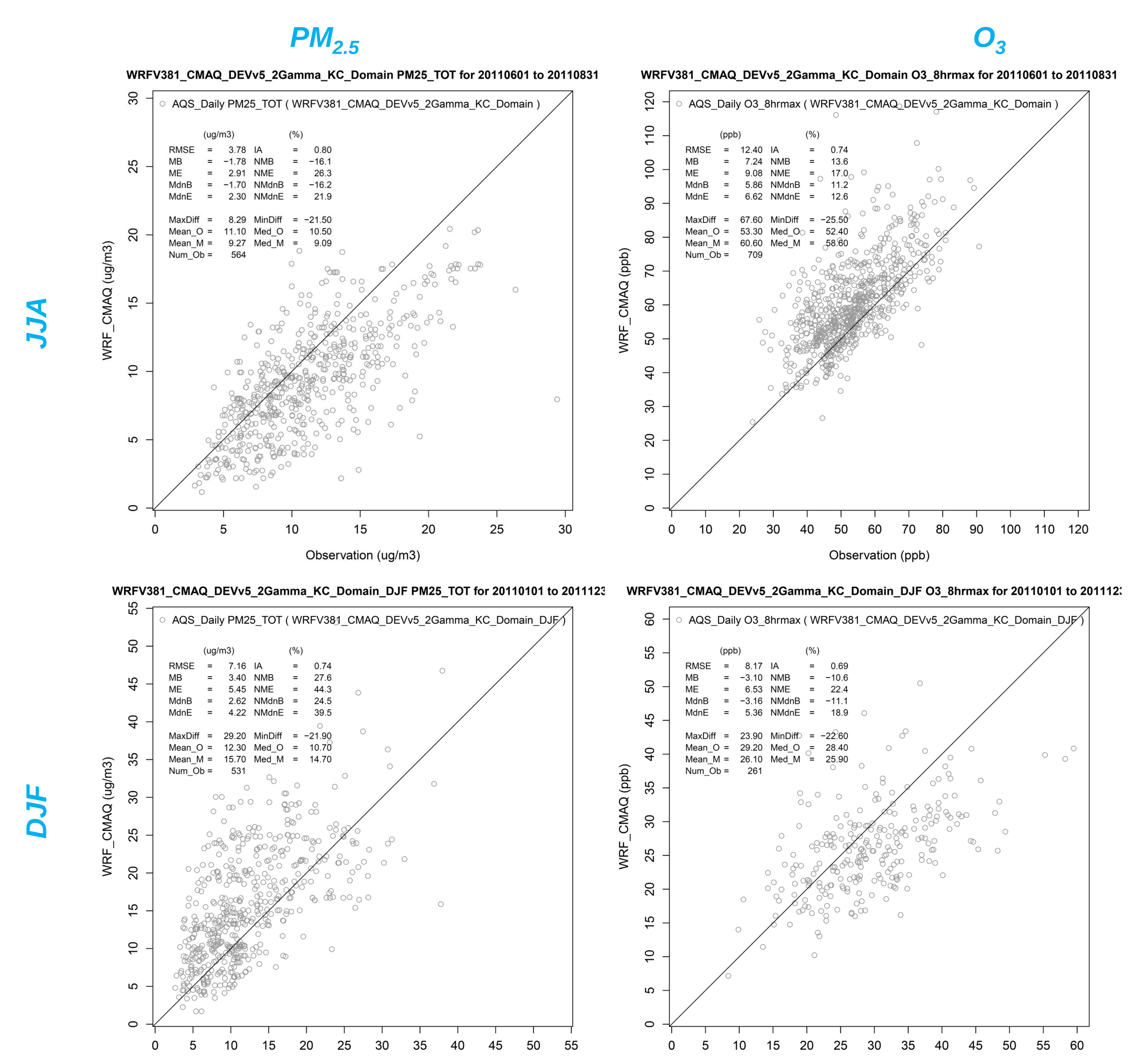

Fig. 3 Model evaluation for summertime (including June July and August, top) and wintertime (including December, January and February, bottom) for both 24-hr $PM_{2.5}$ (left) and MDA8 O_3 (right).

- ➢ In summertime, the coupled WRF-CMAQ underestimates the $PM_{2.5}$ (mean bias, MB of -1.78 μg/m³), but overestimates the MDA8 O_3 (MB of 7.24 ppbv).
- ➢ In wintertime, the model overestimates the $PM_{2.5}$ (MB of 3.4 μg/m³), but underestimates the MDA8 O_3 (MB of -3.10 ppbv).

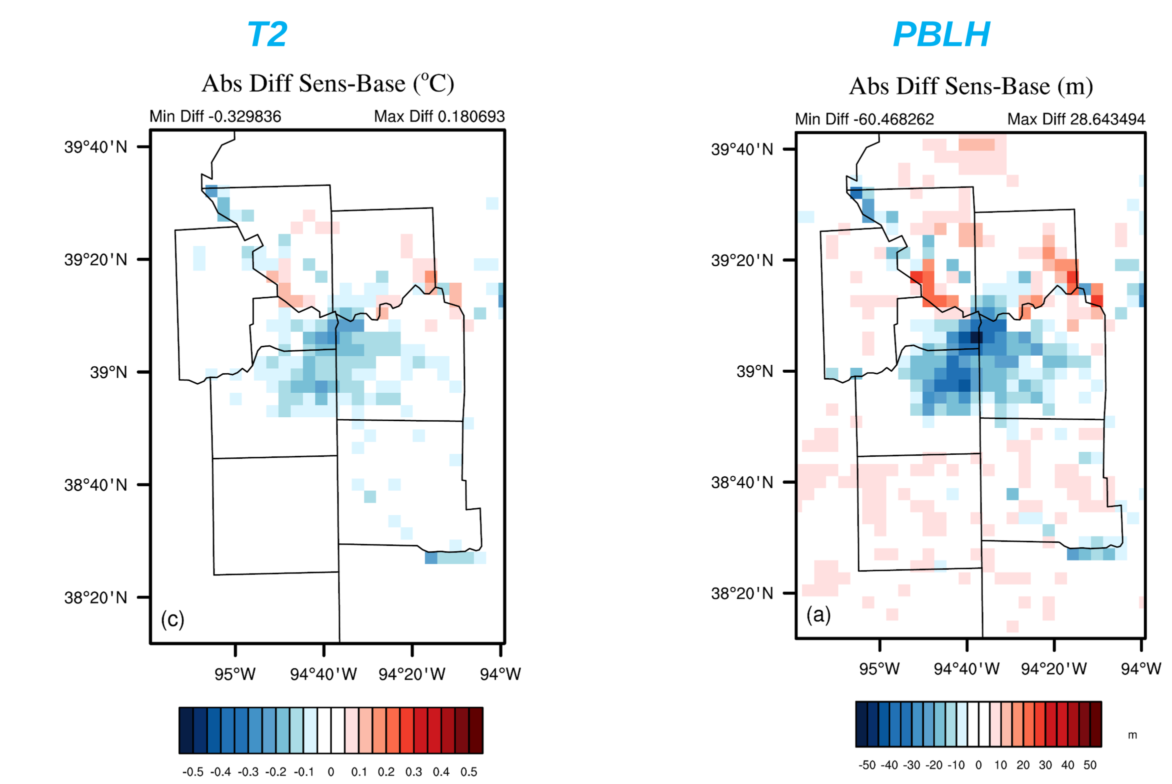

Fig. 4 T2 (left) and PBLH (right) changes in the summertime between BASE and SENS case (Sens-Base). Colors in blue means the T2(PBLH) are decreasing in the SENS case.

- ➢ Overall, the 2-meter temperature (T2) decreases over the downtown of KC, consistent with impervious surface changes.
- ➢ Slight increases in T2 over the county boundaries in the northern part of the domain result from shifting cultivated crops in the BASE case to the herbaceous wetlands, which has smaller vegetation fraction (VF) and leaf area index (LAI) during the summertime.
- ➢ The planetary boundary layer height (PBLH) has similar patterns as T2.

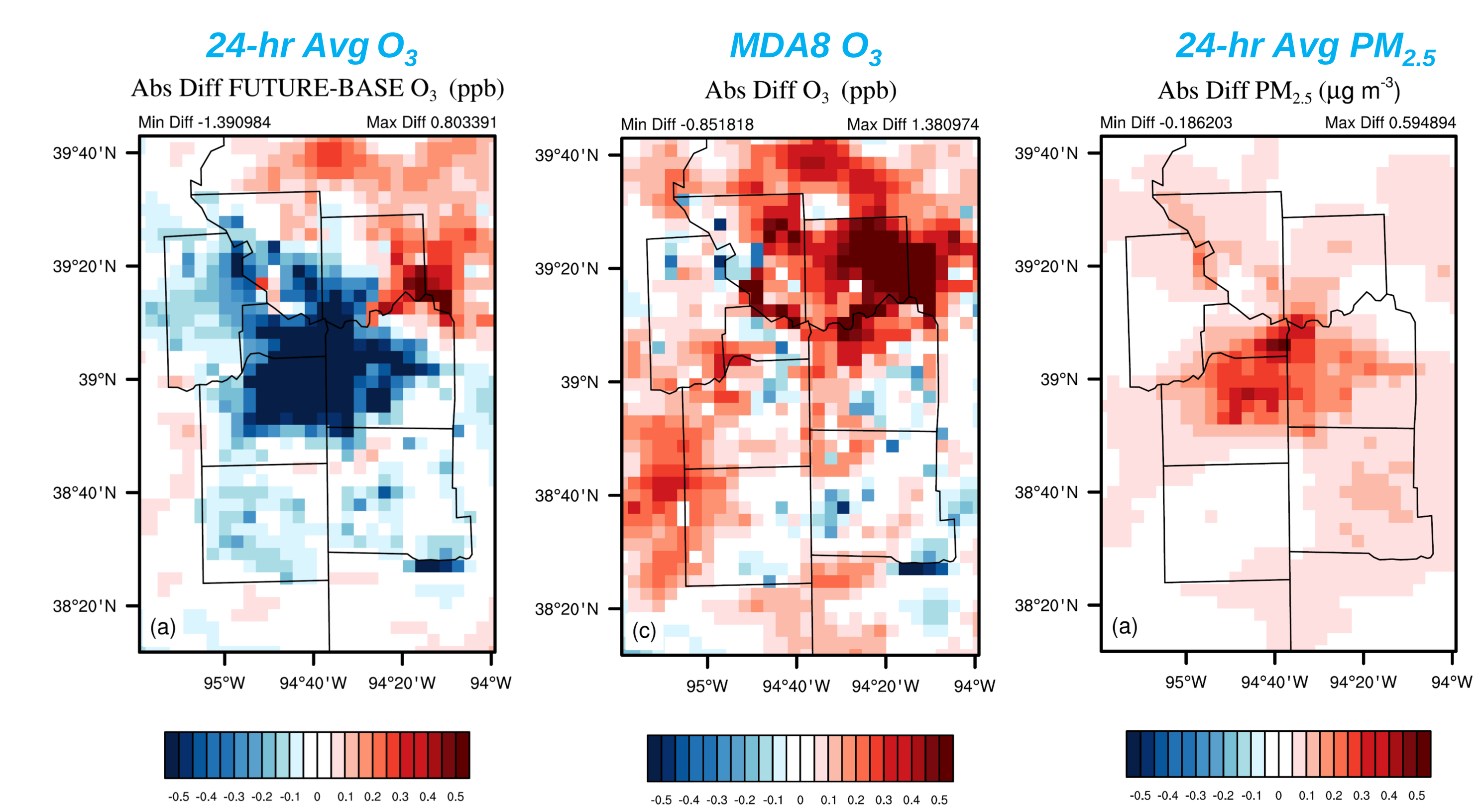

Fig. 5 Summertime 24hr-Avg O_3 (left), MDA8 O_3 (middle), and 24hr-Avg $PM_{2.5}$ changes between BASE and SENS case (Sens-Base). Colors in blue means the decreases.

- ➢ Simulated summertime 24-hr Avg O_3 (left) decreased over the main KC area due to the increased NO_X titration effect from lower PBLH during the nighttime.
- ➢ Changes in MDA8 O_3 reflect the combined effects of increased deposition to vegetation and the higher concentration of pollutants in a lower planetary boundary layer due to the cooling of urban areas.
- ➢ Simulated summertime 24-hr Avg $PM_{2.5}$ (right) increased due to the lower PBLH. The $PM_{2.5}$ increases are mainly from primary species.