Sub-grid Dry Deposition Estimates from the Community Multiscale Air Quality Model (CMAQ)

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Background

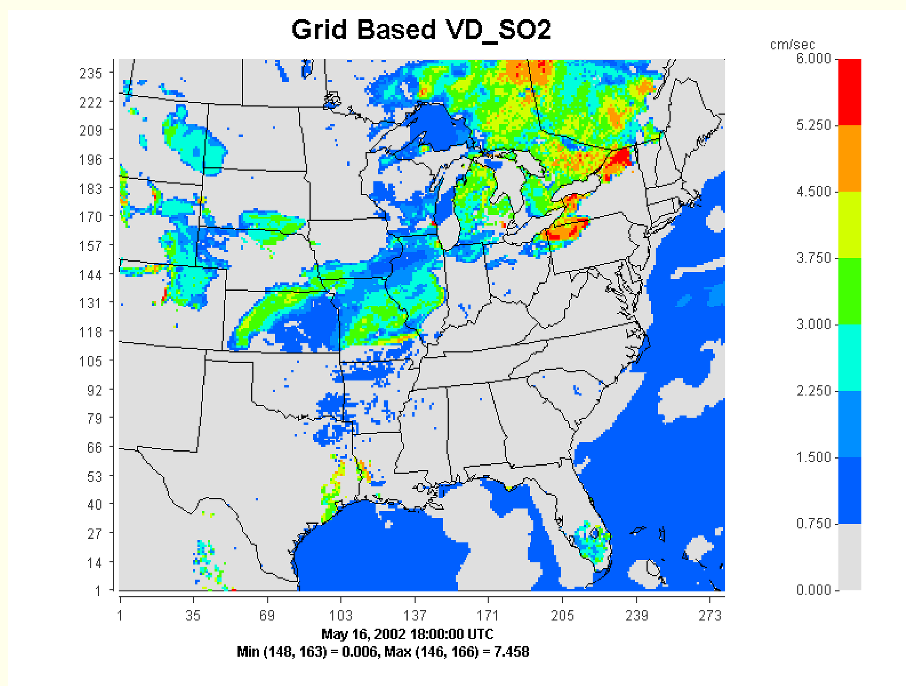
Pollutant loadings to water bodies consist of point sources of effluent (e.g. sewage treatment plants) and non-point sources that are diffused across the landscape (e.g. agriculture). Atmospheric wet and dry deposition can be important non-point source contributors to total pollutant loadings to water bodies leading to harmful effects on ecosystems

Dry deposition is not routinely monitored, so models must be used to develop deposition estimates for areas of interest. Model estimates at Clean Air Status and Trends Network (CASTNET) sites are sparsely located and in some cases may be affected by meteorological tower siting issues. Additionally, complete chemical budgets needed for ecosystem assessments are not measured. Regional scale models such as the Community Multiscale Air quality model (CMAQ) (Byun and Schere, 2006) provide complete spatial coverage as well as the complete chemical budget.

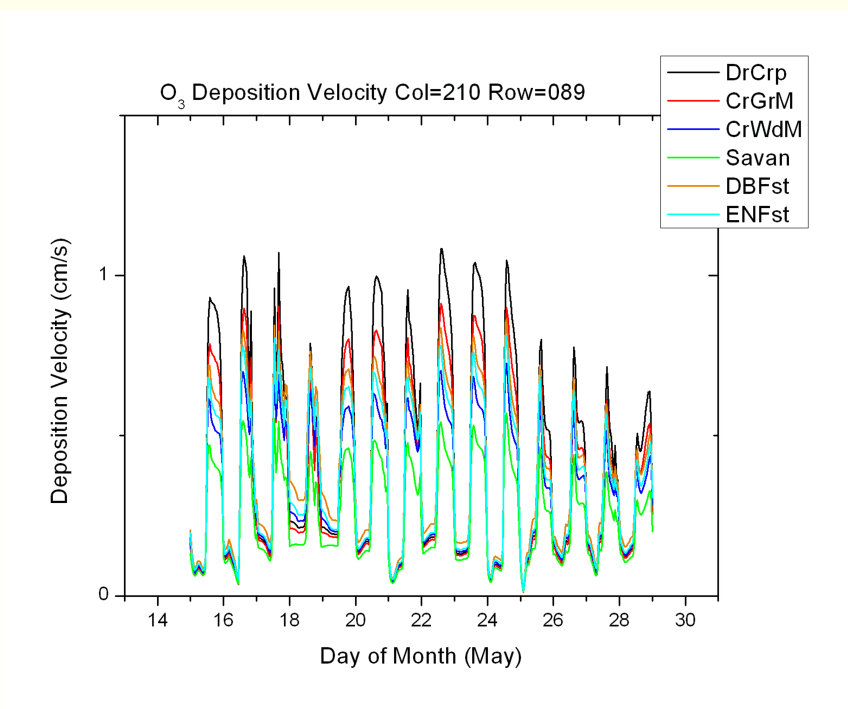
Currently, CMAQ model outputs are available at the grid scale (typically 12 km). This grid estimate is calculated based on the area-weighted average surface characteristics within the grid. Dry deposition velocities vary with the underlying surface and this information is not available from the typical gridded output. However, ecological applications often require knowledge of the deposition to individual land cover types within a grid rather than the grid-averaged value.

Approach

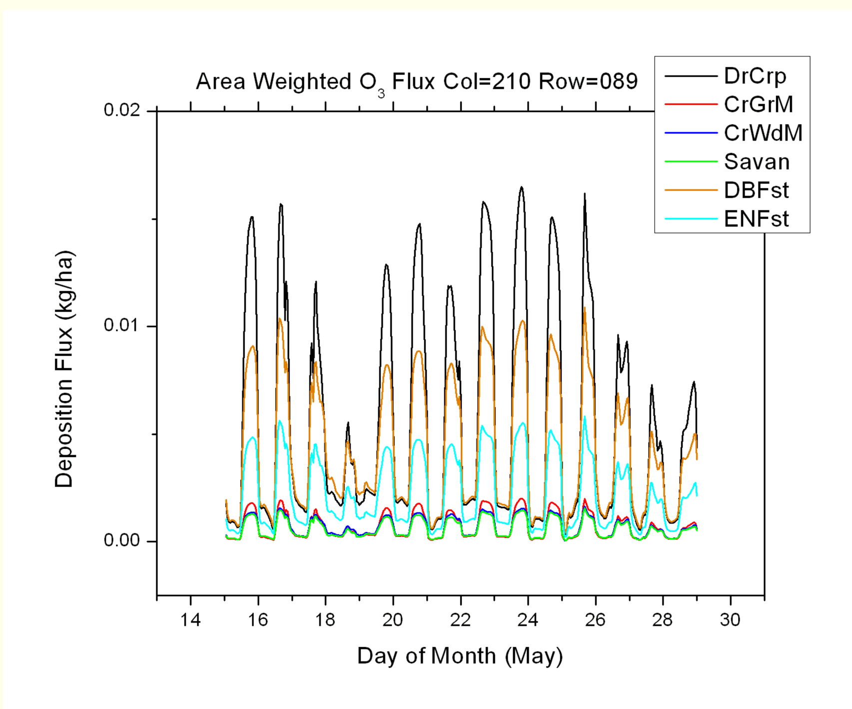
CMAQ relies on meteorological data from the Weather Research and Forecasting (WRF) model or the Fifth-Generation NCAR / Penn State Mesoscale Model (MM5) and relies on the same land use data. The meteorological models use a land-surface model (Xiu and Pleim, 2001) to calculate the stomatal and aerodynamic resistances. CMAQ is being modified to internally calculate land-use specific deposition velocities based on land-use specific characteristics such as leaf area index, surface roughness, and minimum stomatal resistance (mosaic approach). Making these changes within CMAQ rather than the meteorological model allows the use of previously generated meteorological files rather than requiring the meteorological model to be rerun. In the mosaic approach, the land-use specific deposition velocity is then paired with the grid-average concentration to calculate the deposition flux. CMAQ can then output sub-grid scale land-use specific deposition estimates which will provide the information needed for ecosystem assessments. Aggregated land-use specific fluxes within a grid cell are in good agreement with grid-based values.



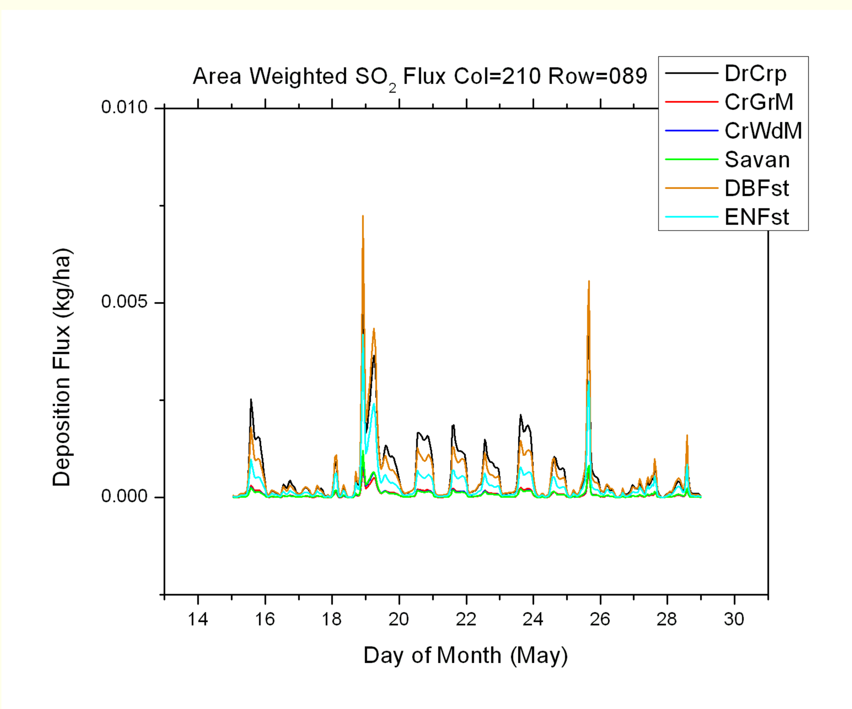
CMAQ predicted grid-averaged SO_2 v_d for one hourly time step



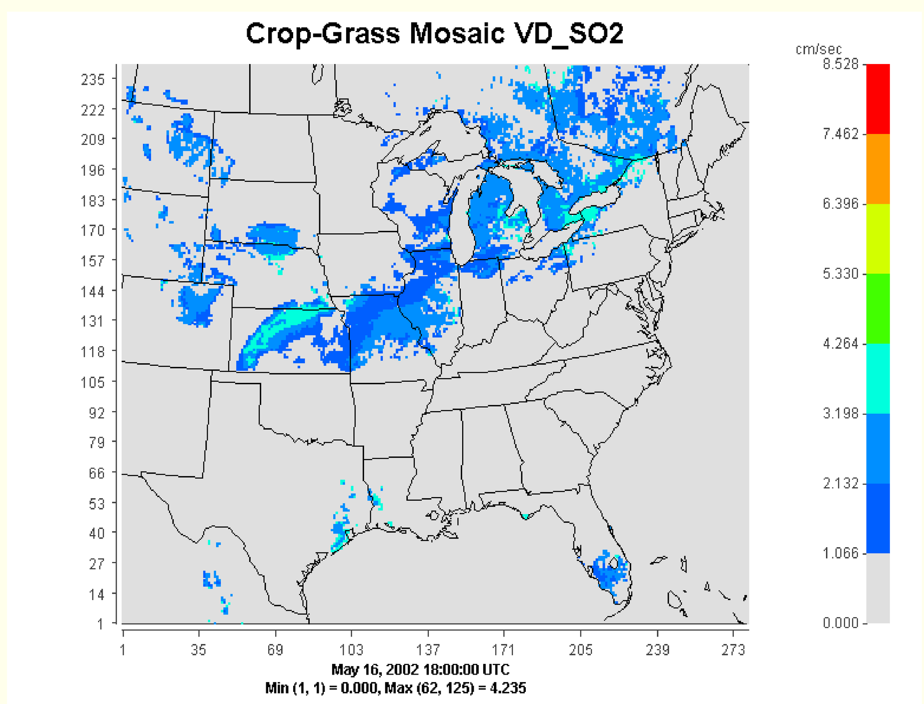
Time series of CMAQ predicted land-use specific O_3 v_d



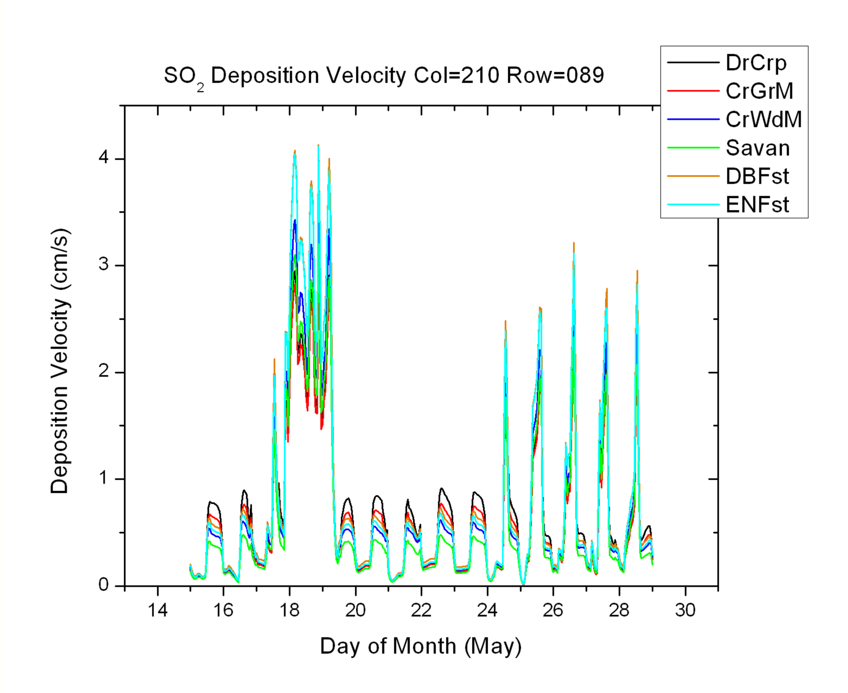
Time series of CMAQ predicted land-use specific area-weighted O_3 flux



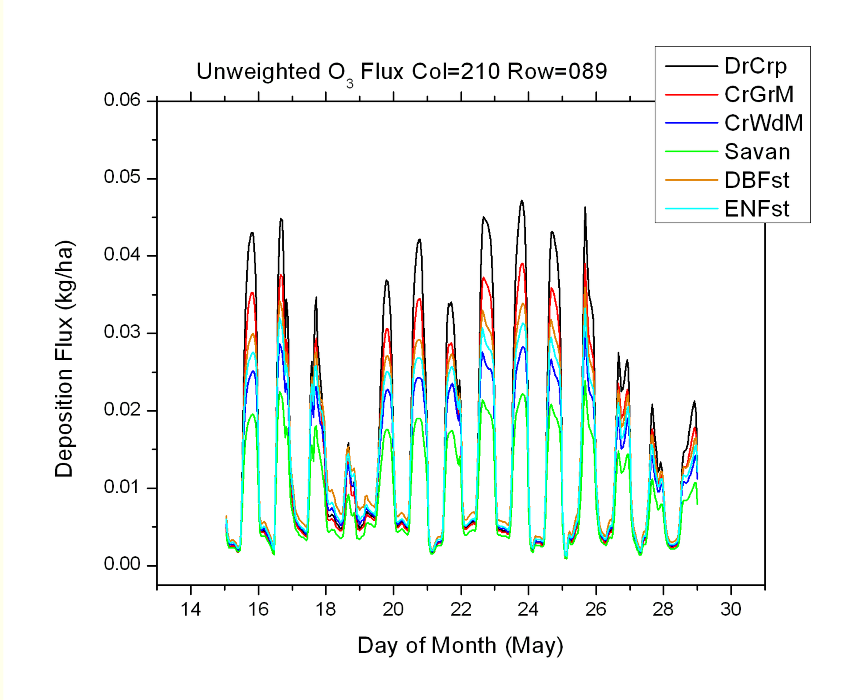
Time series of CMAQ predicted land-use specific area-weighted SO_2 flux



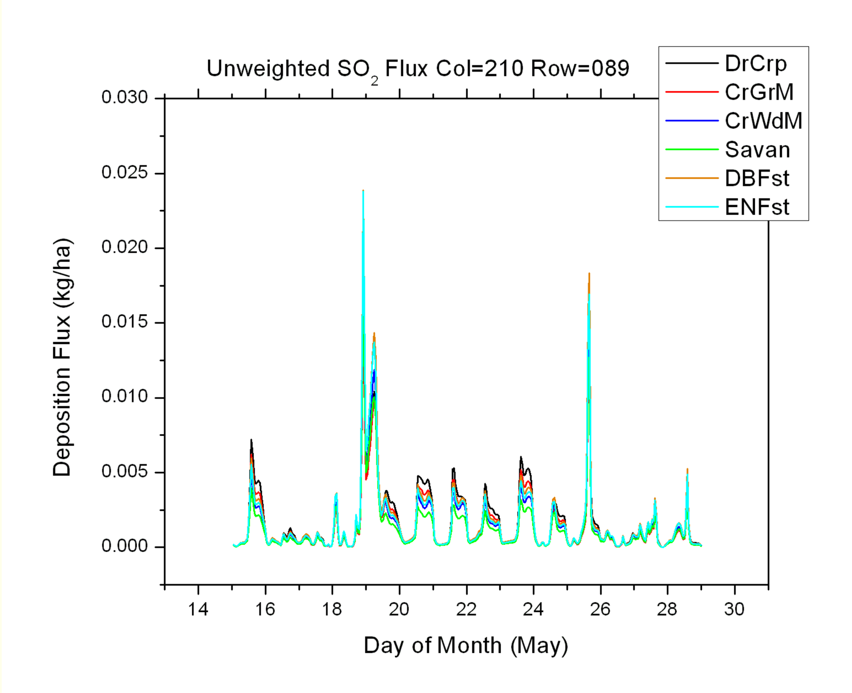
CMAQ predicted land-use specific SO_2 v_d for one hourly time step



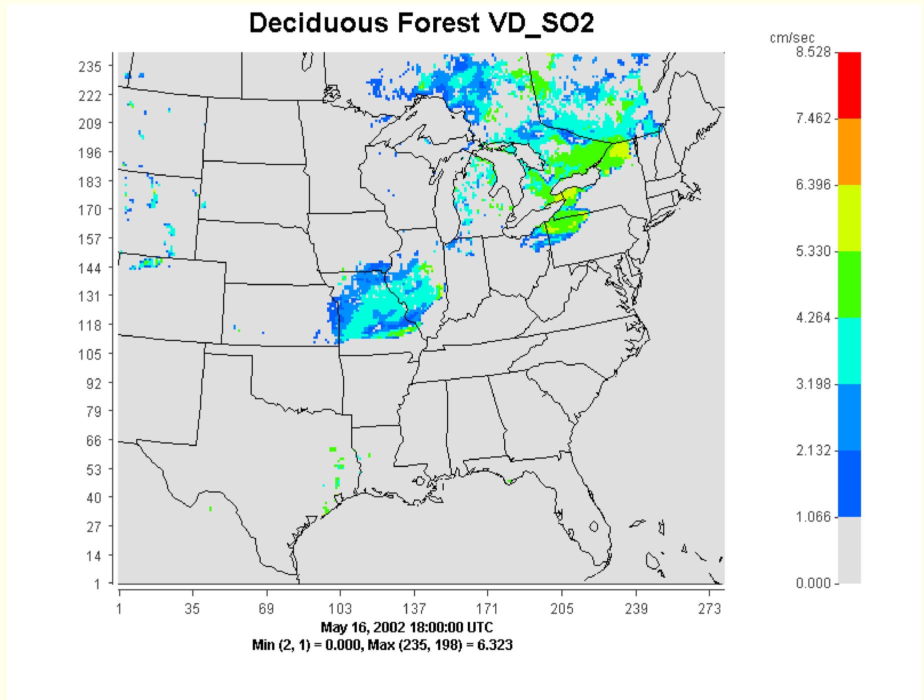
Time series of CMAQ predicted land-use specific SO_2 v_d



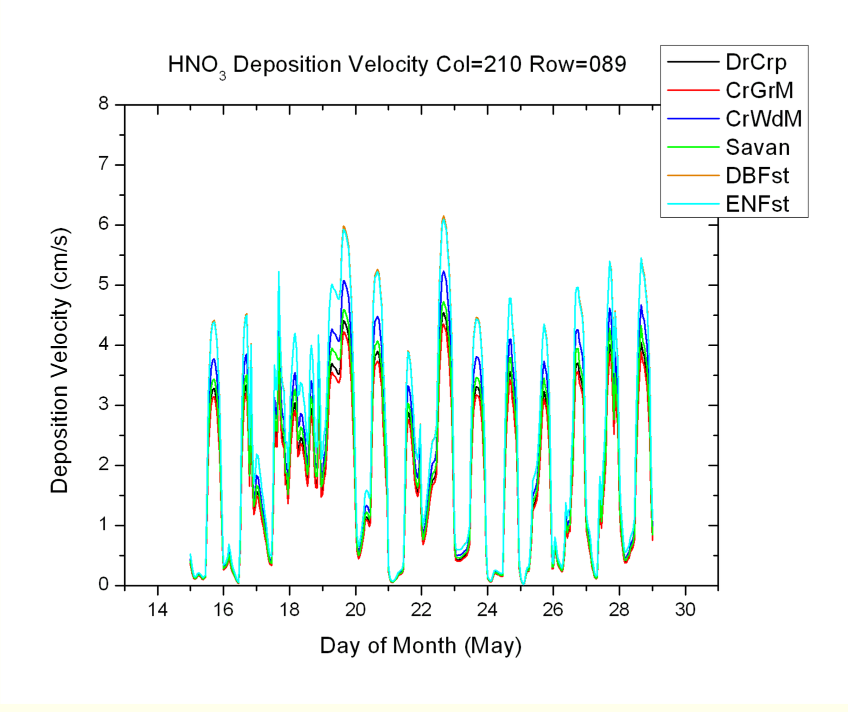
Time series of CMAQ predicted land-use specific unweighted O_3 flux



Time series of CMAQ predicted land-use specific unweighted SO_2 flux



CMAQ predicted land-use specific SO_2 v_d for one hourly time step



Time series of CMAQ predicted land-use specific HNO_3 v_d

Conclusions

- Deposition velocities and therefore deposition fluxes vary with surface characteristics
- Land-use make-up within a grid cell significantly influences the total net deposition flux within the cell
- CMAQ is now able to provide land-use specific deposition information within a grid cell with complete spatial coverage and chemical speciation

References

Byun, D. and K. L. Schere, 2006. Review of the governing equations, computational algorithms, and other components of the Models-3 Community Multiscale Air Quality (CMAQ) modeling system. Applied Mechanics Reviews 59:51-77.
Xiu, A. and J. E. Pleim, 2001, Development of a land surface model part I: Application in a mesoscale meteorology model. J. Appl. Meteor., 40, 192-209