Splitting the Combined Prescribed Burning Impact from CMAQ-DDM into Individual Burn Impacts by using HYSPLIT Dispersion Model

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Background and Objective

- Prescribed burning is a land management tool commonly utilized in the United States (U.S.) to maintain healthy ecosystems and to reduce the risk of catastrophic wildfires. Southeastern U.S. is the most active prescribed burning area.
- We forecast daily prescribed fire impacts using the Community Multiscale Air Quality (CMAQ) model and Decoupled Direct Method (DDM), a sensitivity analysis technique for computing sensitivity coefficients simultaneously while air pollutant concentrations are being computed. (https://forecast.ce.gatech.edu)
- The current forecast is for the impact of all prescribed burns combined. However, fire managers need to know the individual impact of each forecast burn. If an exceedance is forecast, burns with larger potential impacts can be deferred to another day.
- Certainly, we can compute the impact of the individual burns using CMAQ-DDM, but this would require too much computational time. Another approach is to partition the combined impact to individual burns using dispersion models.

Method

- We split the combined prescribed fire impact from CMAQ-DDM into individual burn impacts using the Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT), a dispersion model which is a hybrid of Lagrangian and Eulerian approaches, to generate the individual fire plume dispersion fields (Equation 1). The BlueSky framework is used to estimate the emissions from the burns. The results will be evaluated by comparing the split impacts with the single burn impacts simulated directly by CMAQ-DDM.

$$b_{i,j}^{p} = \frac{B_{i,j}}{\sum_{p=1}^{N} c_{i,j}^{p}} \times c_{i,j}^{p} \qquad (1)$$

i, j: column, row indices; *p*: burn ID; *N*: number of burns;
B: combined burn impact from CMAQ-DDM;
c: total vertical column concentration from HYSPLIT;
b: split single burn impact from CMAQ-DDM .

- We chose to simulate four prescribed burns (each one is 200 acres) within the domain shown in Figure 1: one isolated burn (ID01) and the other three clustered (ID02–ID04), which were forecast for April 27, 2016.

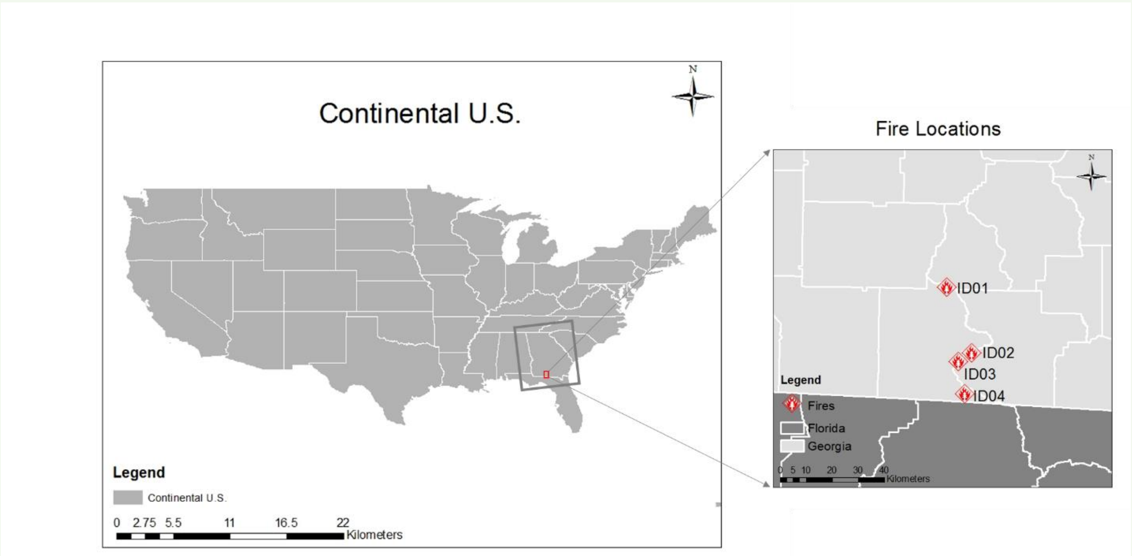

Figure 1. Model simulated domain and locations of burns

- Model configurations:
  - HYSPLIT 4 (Windows)
  - CMAQ v5.0.2; Resolution: 4km × 4km

Difference in Plume Distribution (Burn ID01)

HYSPLIT **CMAQ-DDM**

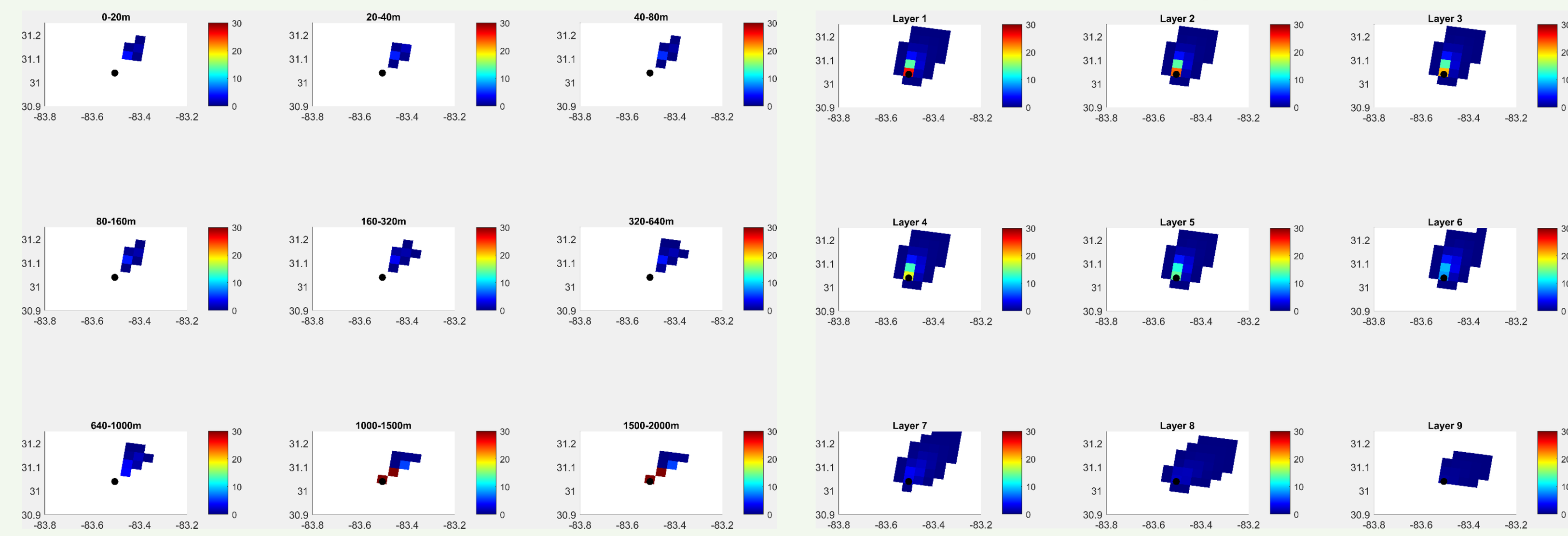

Figure 2. Different layer concentrations of $PM_{2.5}$ from HYSPLIT and CMAQ-DDM

- In HYSPLIT, almost all the mass is in the top two highest layers of the plume while in CMAQ-DDM the most concentrated layers are close to the ground (Figure 2). This difference in vertical plume distribution and the difference in the horizontal location of the largest concentration grid is mainly due to the difference in the dynamics of the two models. In order to reduce the effect of the differences between the two models, the total vertical column masses are used in the formulation (Figure 3).

Vertical Column Difference (Burn ID01)

HYSPLIT **CMAQ-DDM**

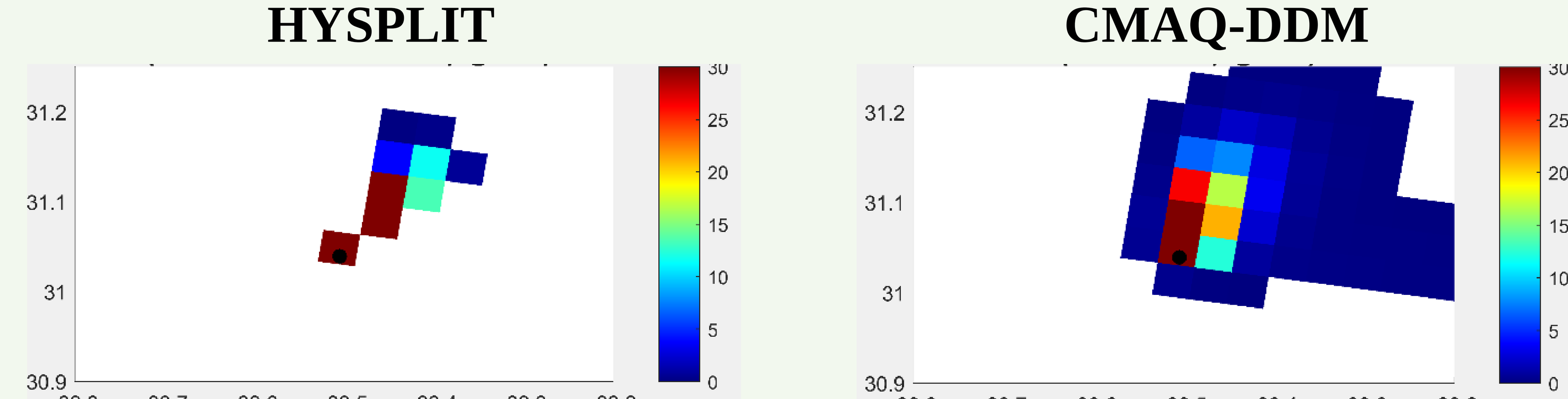

Figure 3. Vertically integrated concentration of ID01 from HYSPLIT and CMAQ-DDM

- The highest concentration grid in HYSPLIT is downwind of the burn location, while in CMAQ-DDM, it is the grid where the burn is located. Since HYSPLIT dispersion fields may not cover the entire CMAQ fields (Figure 3), we decided to artificially diffuse the HYSPLIT fields by using the following equation:

$$\frac{\partial c^{p}}{\partial t} = K\left(\frac{\partial^2 c^{p}}{\partial x^2} + \frac{\partial^2 c^{p}}{\partial y^2}\right) \qquad (2)$$

p: burn ID;
c: vertical total concentration from HYSPLIT;
K: artificial diffusion coefficient

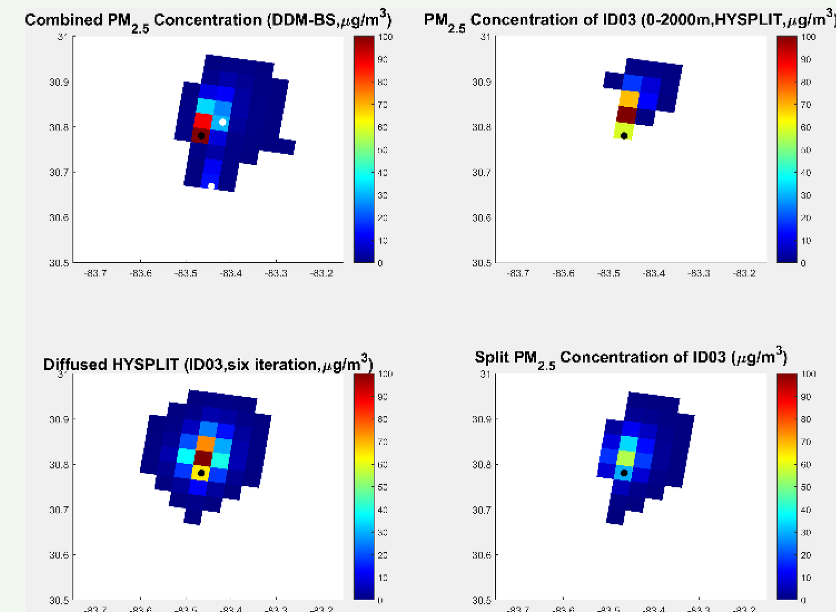

Figure 4. Split combined fire impact ($PM_{2.5}$) based on diffused HYSPLIT fields for burn ID03

Nonlinear Interaction of Plumes

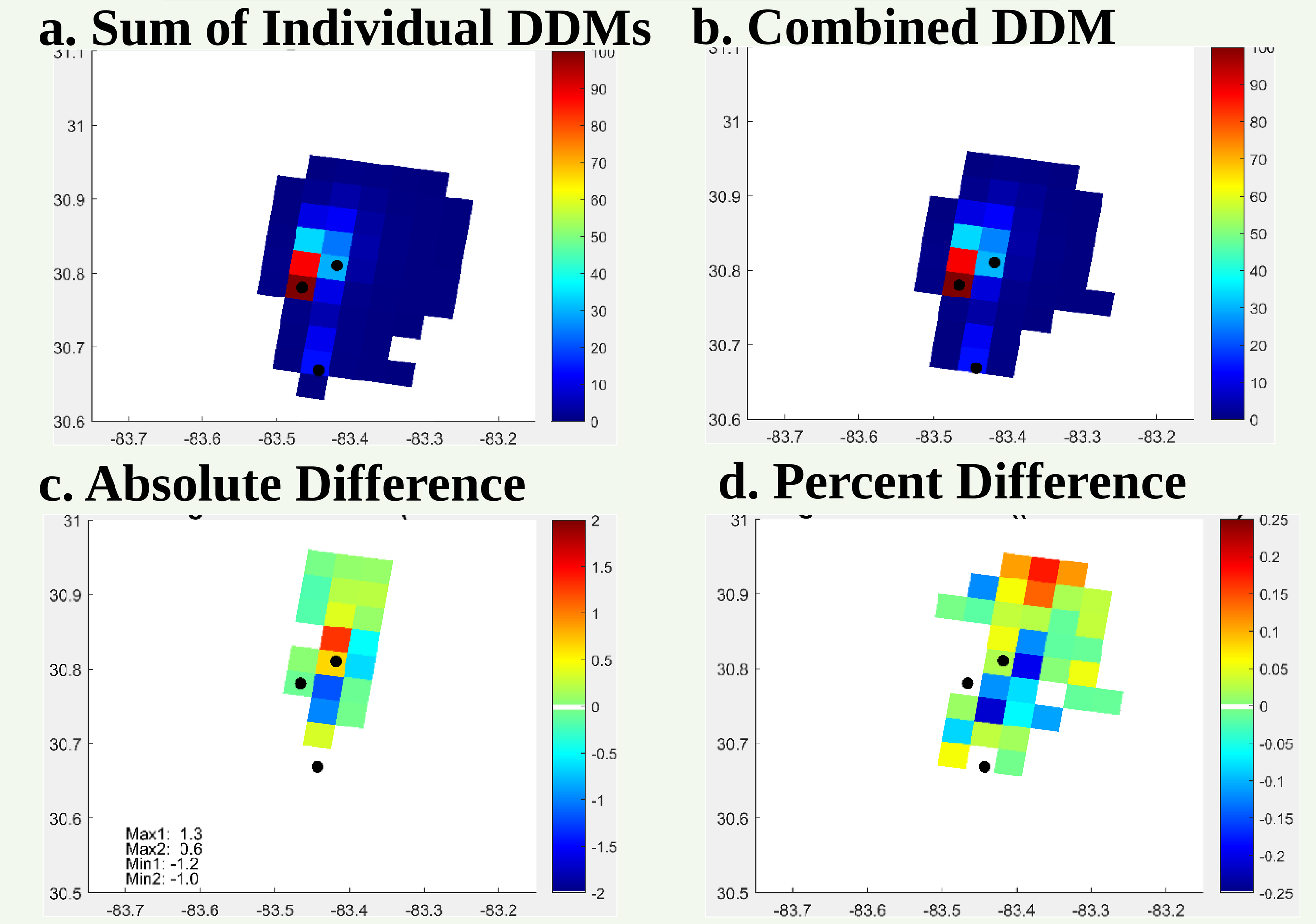

Figure 5. Comparison of the summation of individual burn impacts with the combined impact and the difference between those two

- Figure 5 shows the prescribed fire impact on $PM_{2.5}$ concentrations based on the sum of all three single burn impacts (a) and combined fire impact (b) and the difference (c, d) between those two. In this case, the concentrations from CMAQ-DDM are near-linearly correlated with fire emissions. The difference between the concentrations from the two runs is less than 1.3 μg/m³ (5%). This shows there is little non-linear interaction among the three plumes.

Evaluation: Comparison to Single Burn Impact (Burn ID03)

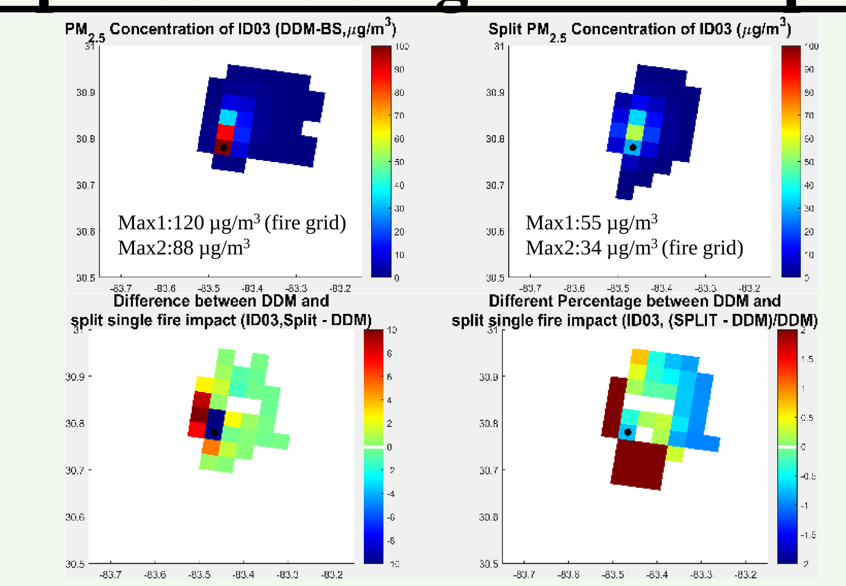

Figure 6. Comparison between split fire impact for ID03 and single burn impact from CMAQ-DDM

- The differences in fuel loads, hence fire emissions, lead to burn ID03 having the largest contribution to $PM_{2.5}$ concentrations.
- For burn ID03, which has the largest impact of the three clustered burns, the difference between the split fire impact and single CMAQ-DDM impact is large: the split impact at the fire location grid is 72% smaller.

Conclusions

- We provide a new method to help land and air quality managers quickly identify the prescribed burns with the largest impact.
- The method could also be used to split the $PM_{2.5}$ (or other secondary pollutant) concentrations into contributions from different emission sources.

Acknowledgement and Contact Information

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- For more information contact Ran Huang (*rhuang48@gatech.edu*).