Supplement of

Tight physics and chemistry coupling improves air quality forecasts: a case study of the 2020 North American wildfires with the Rapid Refresh model coupled to Chemistry (RAP-Chem v1.0)

Jordan Schnell et al.

Correspondence to: Jordan Schnell (jordan.schnell@colorado.edu)

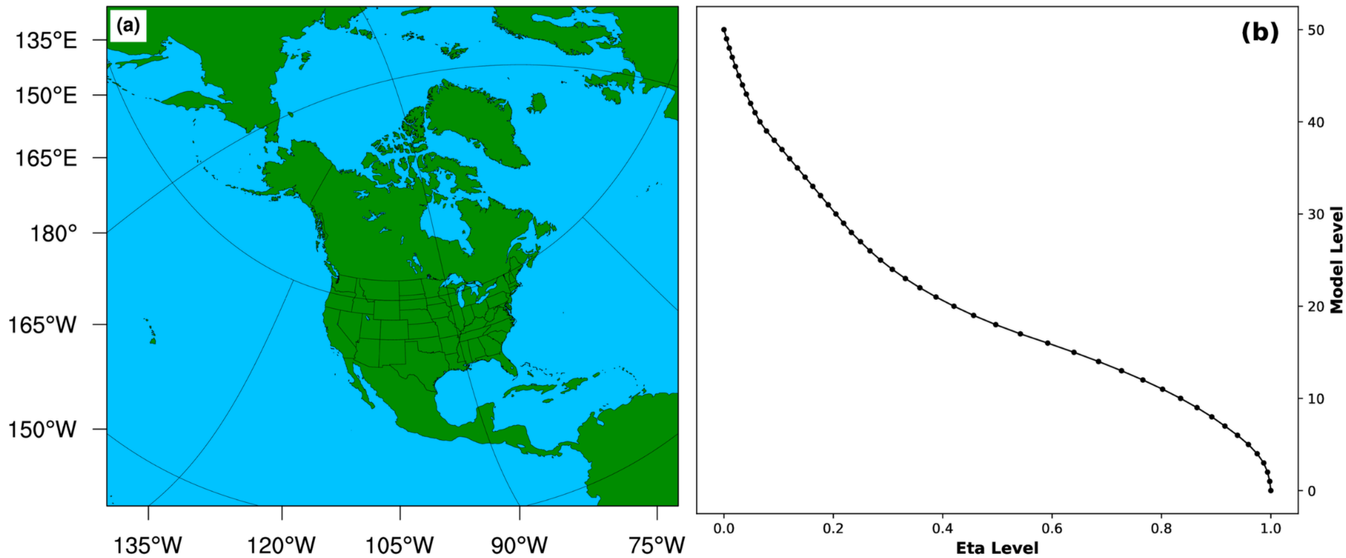

Figure S1. RAP-Chem simulation (**a**) horizontal domain and (**b**) vertical layer structure

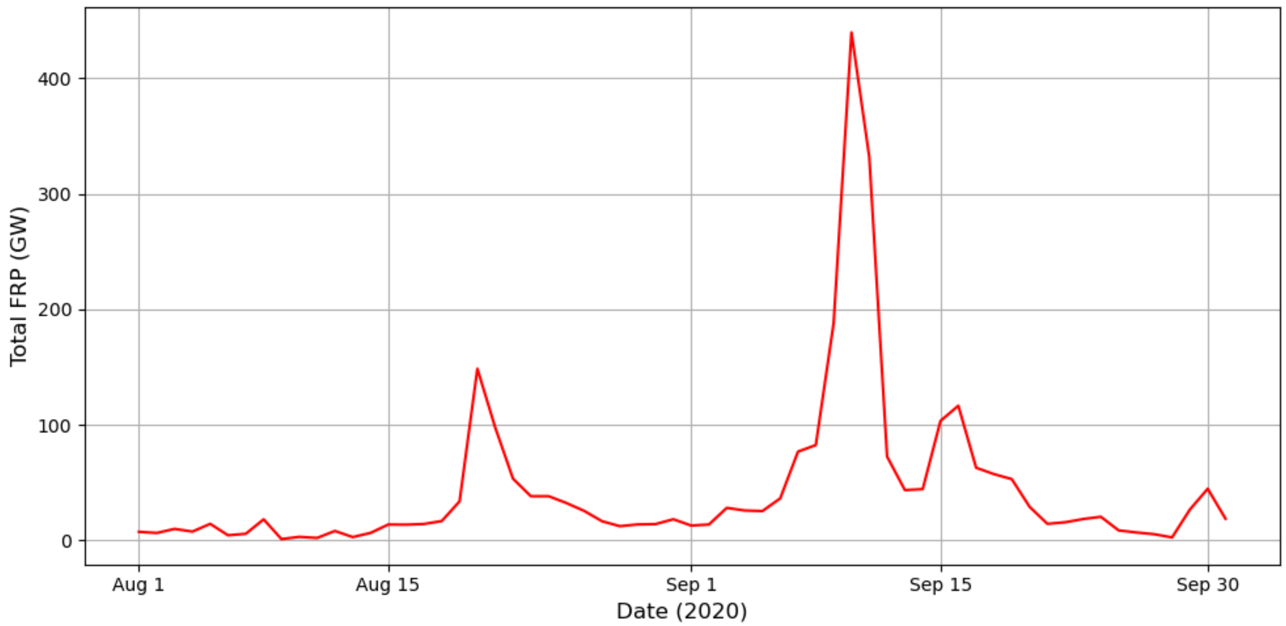

Figure S2. Time series of total FRP over the western US (30°N–49°N, 130°W–110°W) from 1 August - 30 September 2020 obtained from the RAP/HRRR-Smoke preprocessing of MODIS (AQUA and TERRA) and VIIRS (S-NPP and NOAA20) FRP detections. MODIS data courtesy of NASA. VIIRS data courtesy of the National Oceanic and Atmospheric Administration.

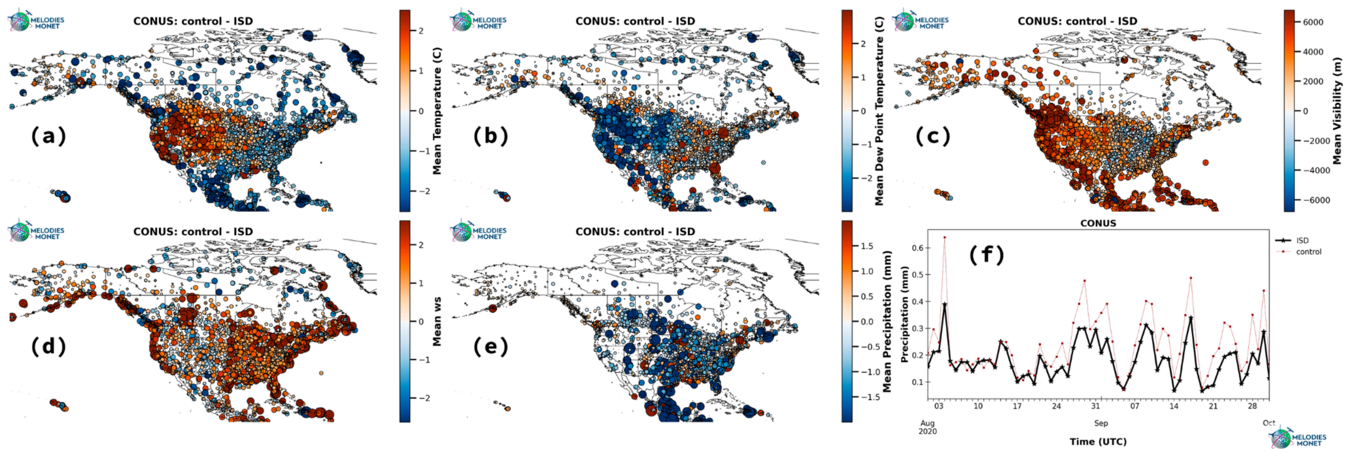

Figure S3. (a-e) Spatial bias of *control* compared to NOAA ISD over the period 1 August - 30 September, 2020 for **(a)** T_{2m}, **(b)** Td_{2m}, (c) visibility, (d) wind speed, (e) precipitation. (e) Time series of domain wide precipitation for *control* (red) and NOAA ISD (black). NOAA ISD data courtesy of the National Oceanic and Atmospheric Administration.

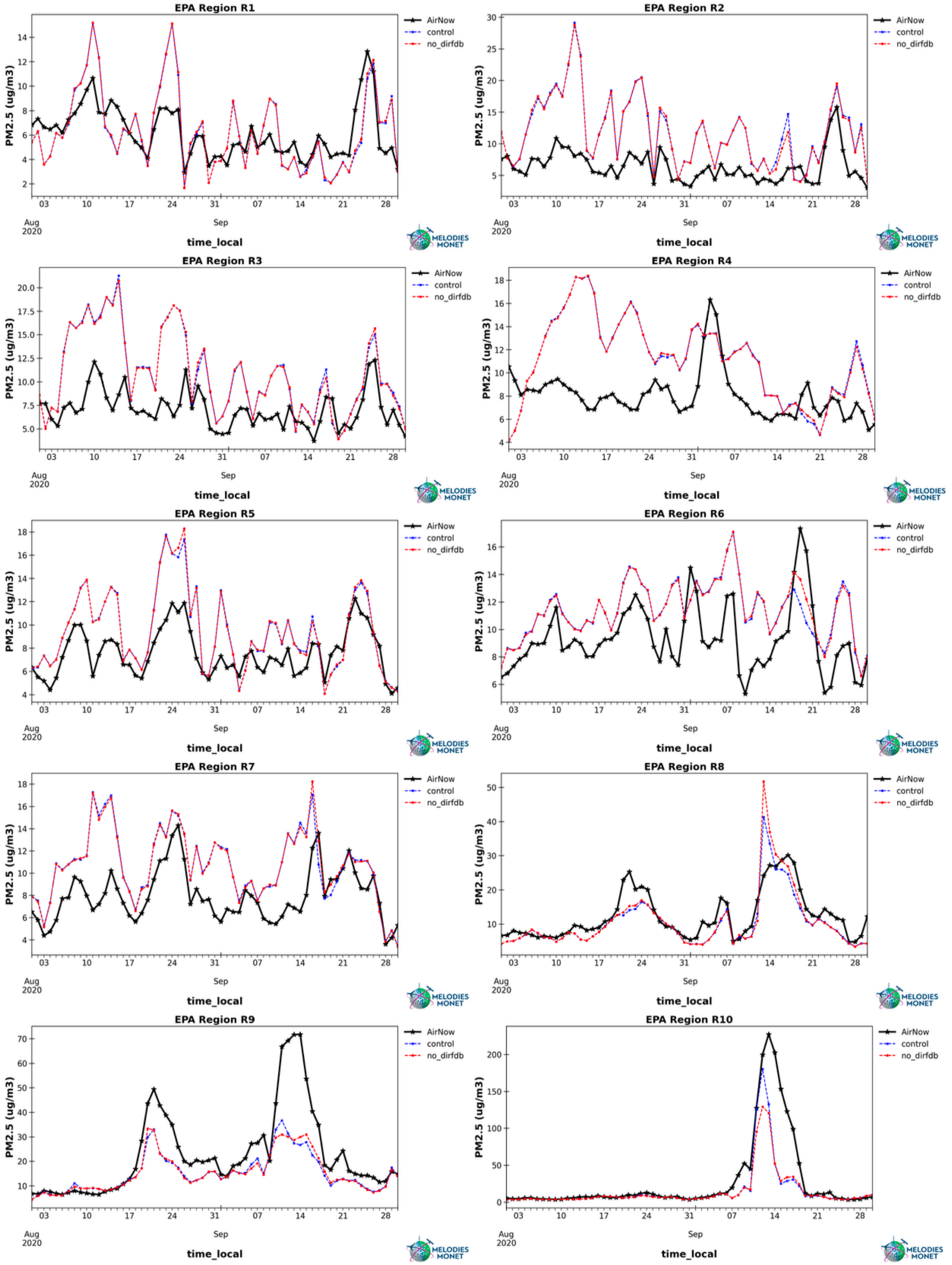

Figure S4. Time series of daily averaged surface $PM_{2.5}$ as observed by EPA AirNOW and simulated by *control* and *no_dirfdb* EPA Regions and station. EPA AirNow data courtesy of the U.S. Environmental Protection Agency.

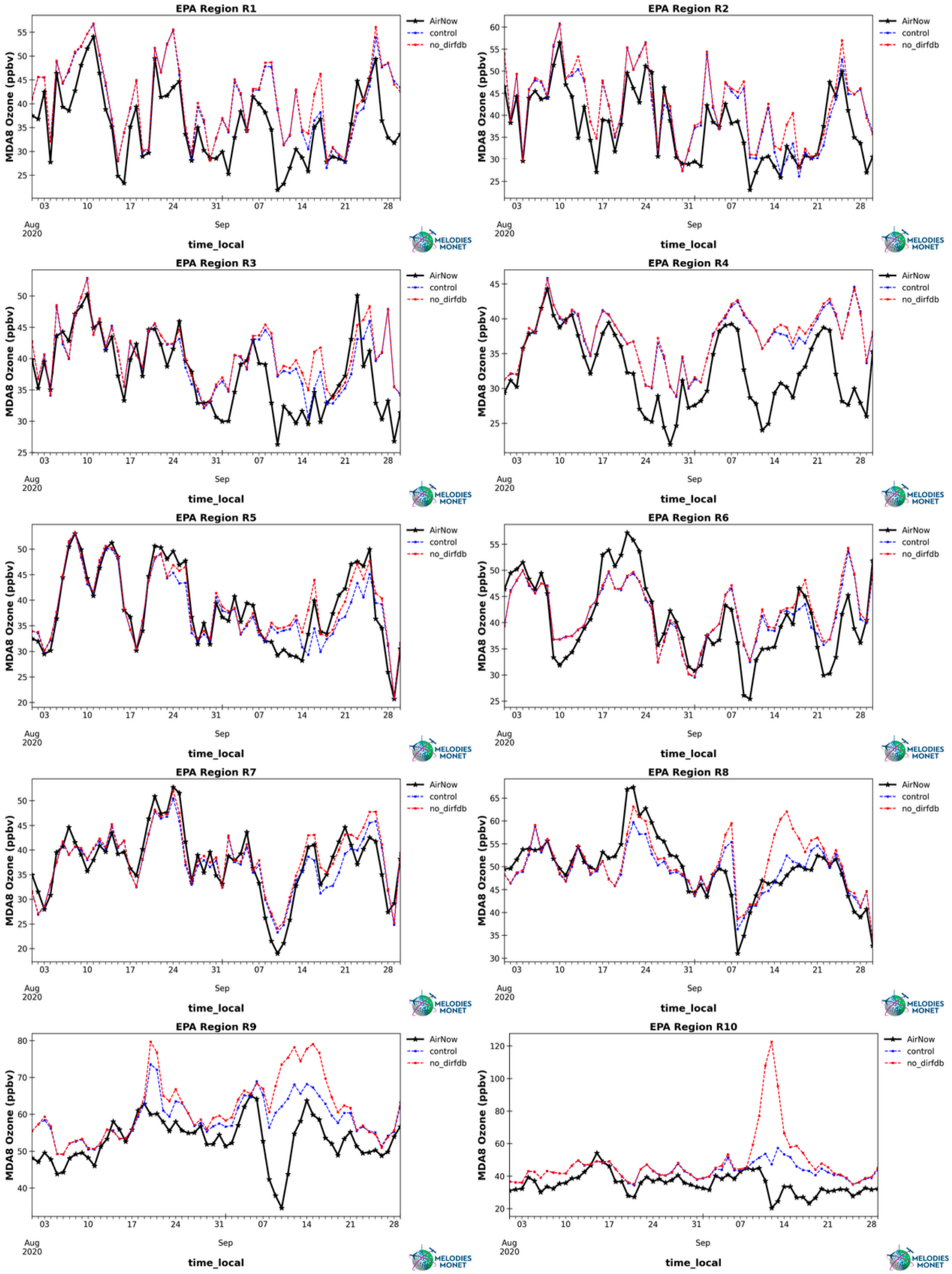

Figure S5. Time series of daily averaged surface O_3 as observed by EPA AirNOW (black) and simulated by *control* (blue) and *no_dirfdb* (red) over EPA Regions 1-10. EPA AirNow data courtesy of the U.S. Environmental Protection Agency.

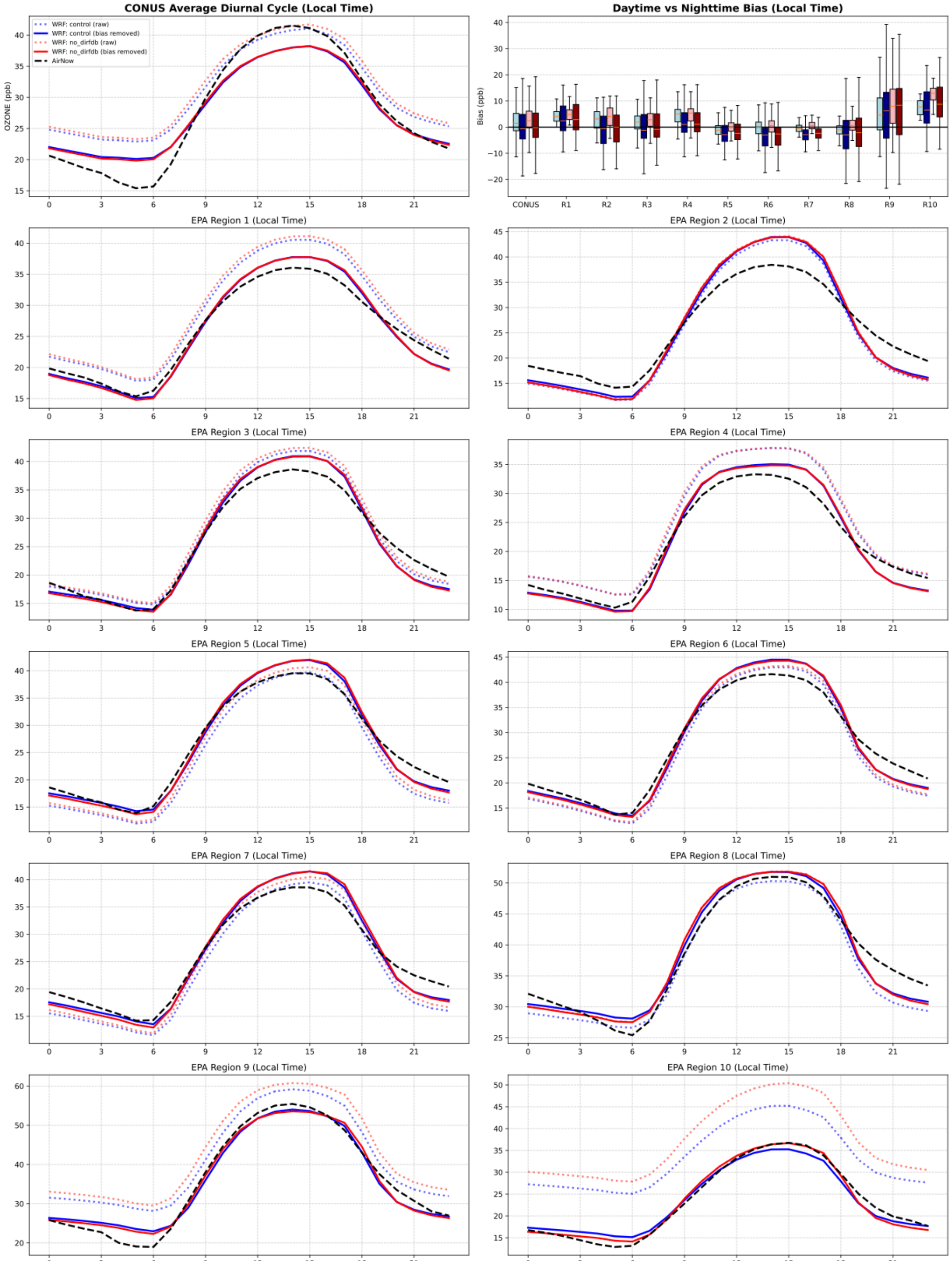

Figure S6. Average diurnal cycle of EPA AirNOW O_3 as compared to *control* (blue) and *no_dirfdb* (red) over CONUS and each of the EPA regions. Both the raw diurnal cycle (dashed) and the diurnal cycle with the mean bias removed (solid) are shown. The top right panel shows the bias over CONUS and the EPA regions for each experiment, averaged separately over daytime (8AM–8PM) and nighttime (8PM–8AM). EPA AirNow data courtesy of the U.S. Environmental Protection Agency.

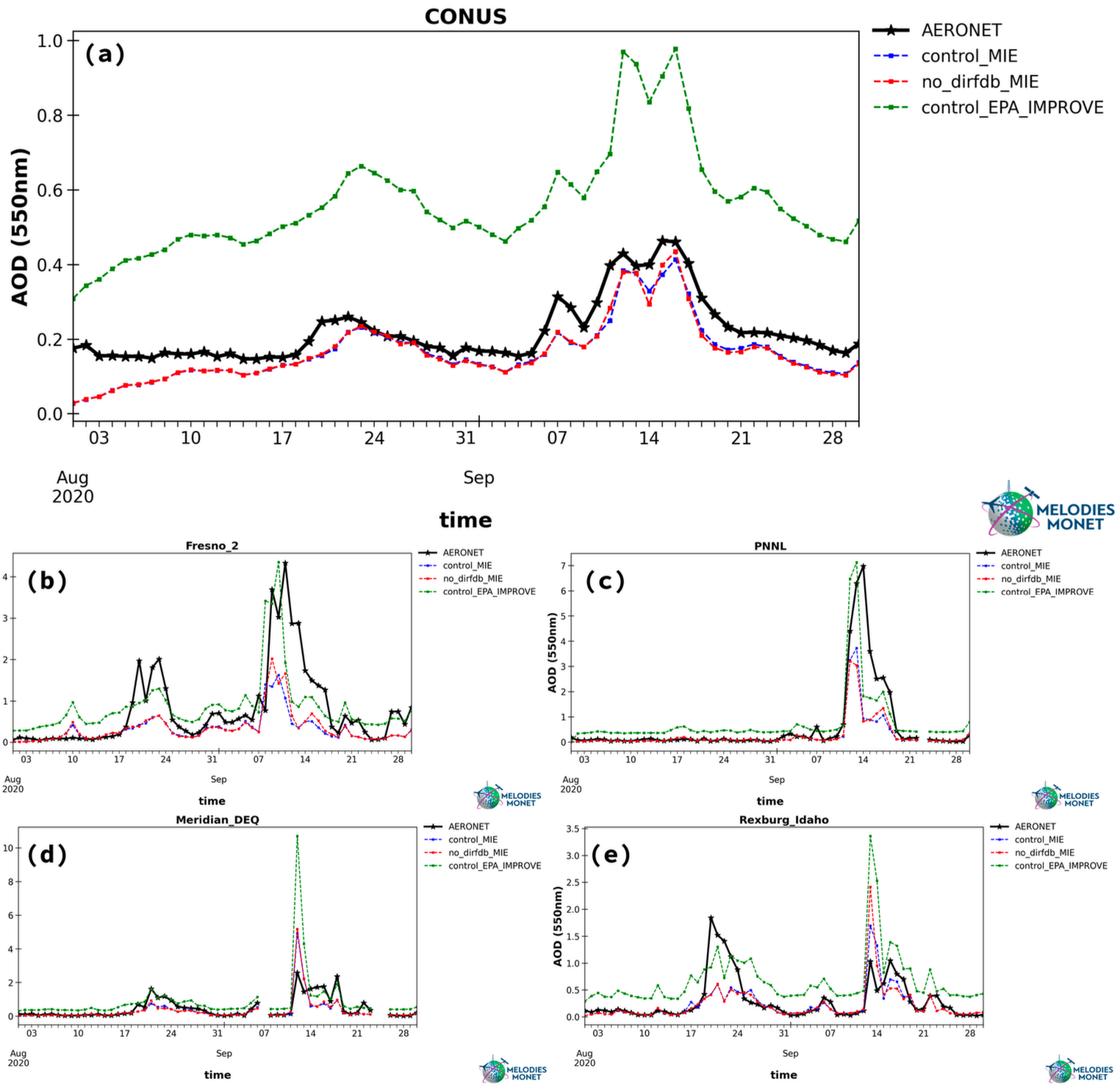

Figure S7. Time series of AERONET AOD_{550} as compared to Mie-calculated AOD_{550} for *control* (blue) and *no_dirfdb* (red) and using the EPA IMPROVE look-up-table (LUT) approach for *control* (green) over (a) CONUS and (b-e) four select AERONET sites. AERONET data courtesy of NASA.

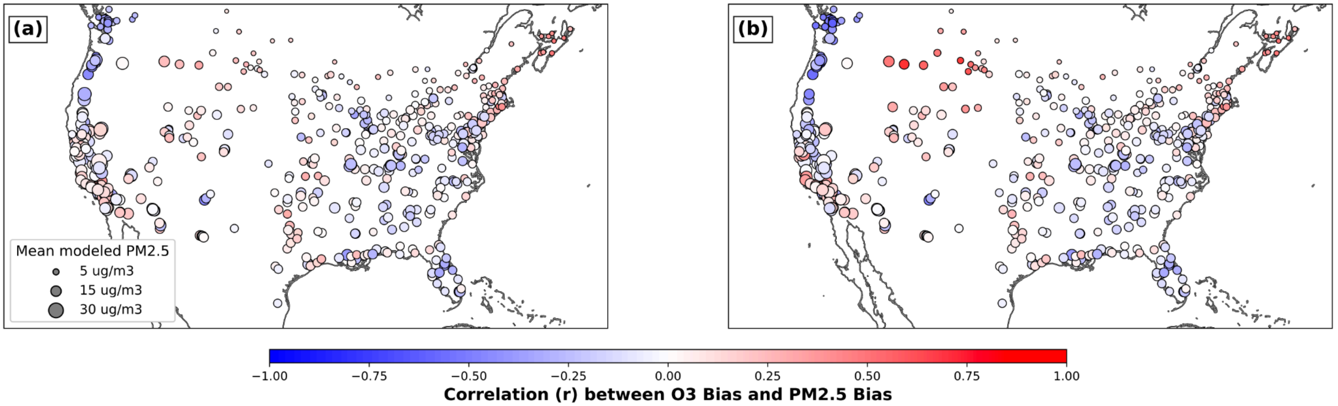

Figure S8. Correlation between the hourly bias in O_3 and $PM_{2.5}$ for (**a**) *control* and (**b**) *no_dirfdb* over the simulation period at each of the EPA AirNow sites.. Dot sizes correspond to the average modeled $PM_{2.5}$ at the EPA site location

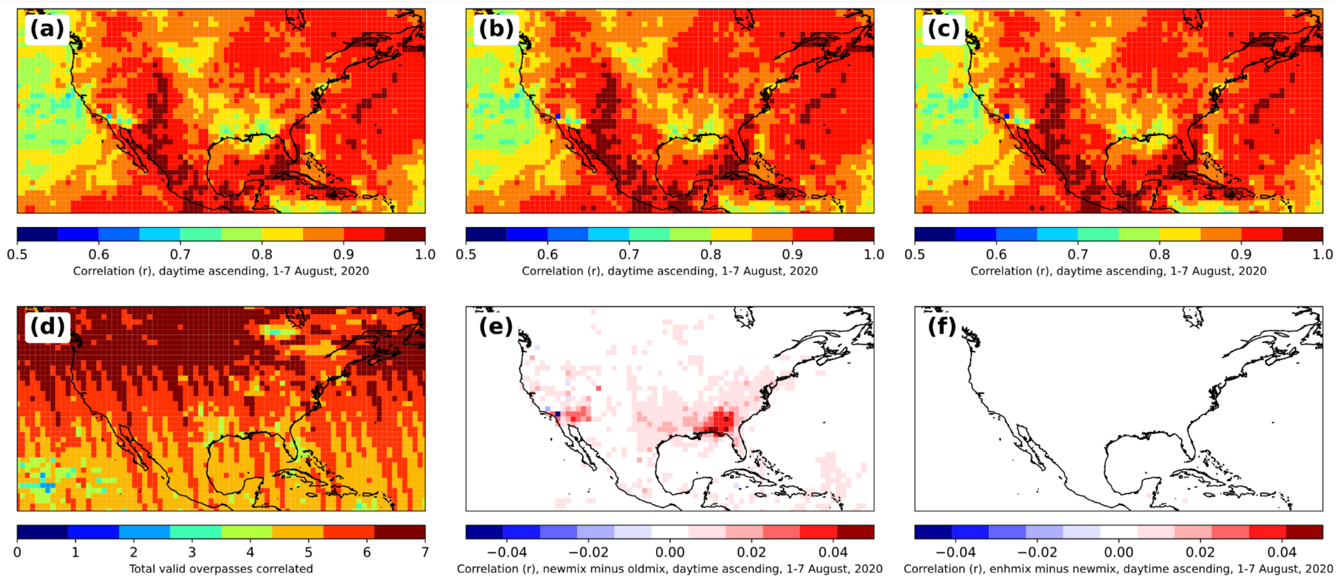

Figure S9. Correlation of daytime ascending vertical CO distribution over 1–7 August 2020 between AQUA AIRS and (**a**) *oldmix*, (**b**) *newmix,* and (**c**) *enhmix*. (**d**) shows the number of vertical layers with at least 75% data coverage through the time period. (**e**) difference in correlation between *new_mix* and *old_mix* (i.e., (**b**) minus (**a**)) and (**f**) difference between *enh_mix* and *old_mix* (i.e., (**c**) minus (**a**)). AIRS data courtesy of NASA.

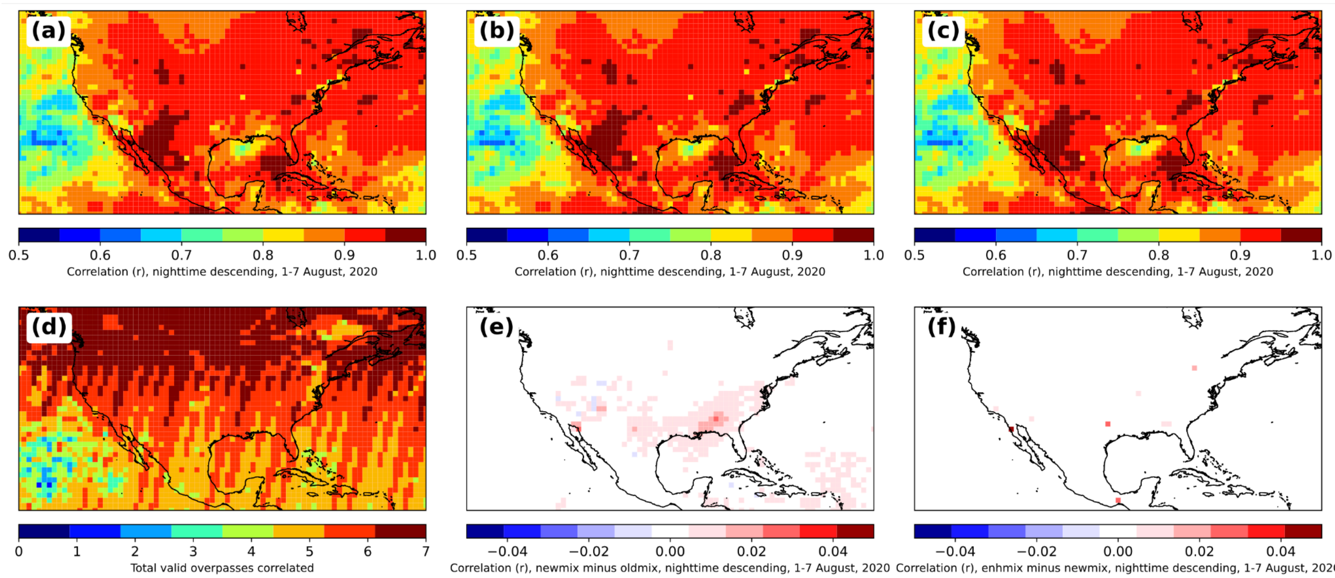

Figure S10. Correlation of nighttime descending vertical CO distribution over 1–7 August 2020 between AQUA AIRS and (**a**) *oldmix*, (**b**) *newmix,* and (**c**) *enhmix*. (**d**) shows the number of vertical layers with at least 75% data coverage through the time period. (**e**) difference in correlation between *new_mix* and *old_mix* (i.e., (**b**) minus (**a**)) and (**f**) difference between *enh_mix* and *old_mix* (i.e., (**c**) minus (**a**)). AIRS data courtesy of NASA.

$$khdz(k) = MAX(1.1khdz(k), \frac{\sqrt{emis\_ant\_no \,/\, no\_threshold}}{dz(k)\, rhoz(k)}) \tag{S1}$$

$$kfire = ceil(log(FRP)) \tag{S2}$$

$$khdz(k) = MAX(1.1khdz(k), \frac{(1 - k/(2kfire))((log(FRP)) - 2.FRP))}{dz(k)rhoz(k)}) \tag{S3}$$