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Substantial ozone enhancement over the North China Plain from increased biogenic emissions due to heat waves and land cover in summer 2017

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Supplementary Information Text

Observed ozone feature

To get a better understanding of the medium and severe pollution conditions, we calculated the MDA8 exceeding 110 ppbv with coverage of 25% and 50% of the North China Plain (NCP), shown in Table S1. The area coverage percentage was calculated using the interpolated 0.5°×0.5° grids, and only areas with data was used as the base area, which is about 32% of the entire NCP area. In 2017, there are two events covering half of NCP areas, June 15-17 and July 1-3. In addition, there are two events lasting 8 days, June 14-21 and June 26-July 3rd in 2017, covering a quarter of NCP region. For the other three years, the medium pollution events covering 25% last 2days or less, and no events covering 50% of the region.

Model evaluation of WRF

The evaluation of WRF was shown in Table S3. Hourly temperature at 2-meter (T2), specific humidity at 2-meter (Q2), wind speed (WS10) and direction (WD10) at 10-meter. The Meteorological Assimilation Data Ingest System (MADIS) data was used for the hourly evaluation. A total of four sites was available in NCP (black hexagons shown in Fig. S1). The benchmark was listed in the right side of Table S3.

Model evaluation of MDA8 ozone

A total of almost 200 observational sites, located in the NCP (red dots in Fig. 1), was interpolated to same grid as CMAQ simulations and the performance generally satisfies the threshold proposed by US EPA (USEPA, 2007). For instance, the recommendations by US EPA (2007) is 15%/35% for mean fractional bias (MFB)/mean fractional error (MFE) and the numbers located on the bottom right of the scatterplots (Fig. 8) indicate that the lower values of MFB/MFE at -7%/16% satisfy the benchmark.

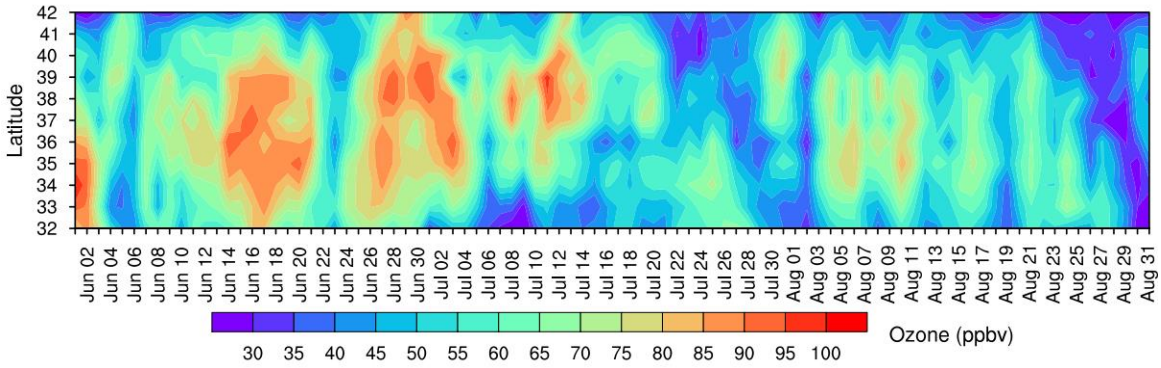

Fig. S1. The evolution of zonal (from 112°E-119°E) mean MDA8 over NCP (region shown in Fig**.** 1).

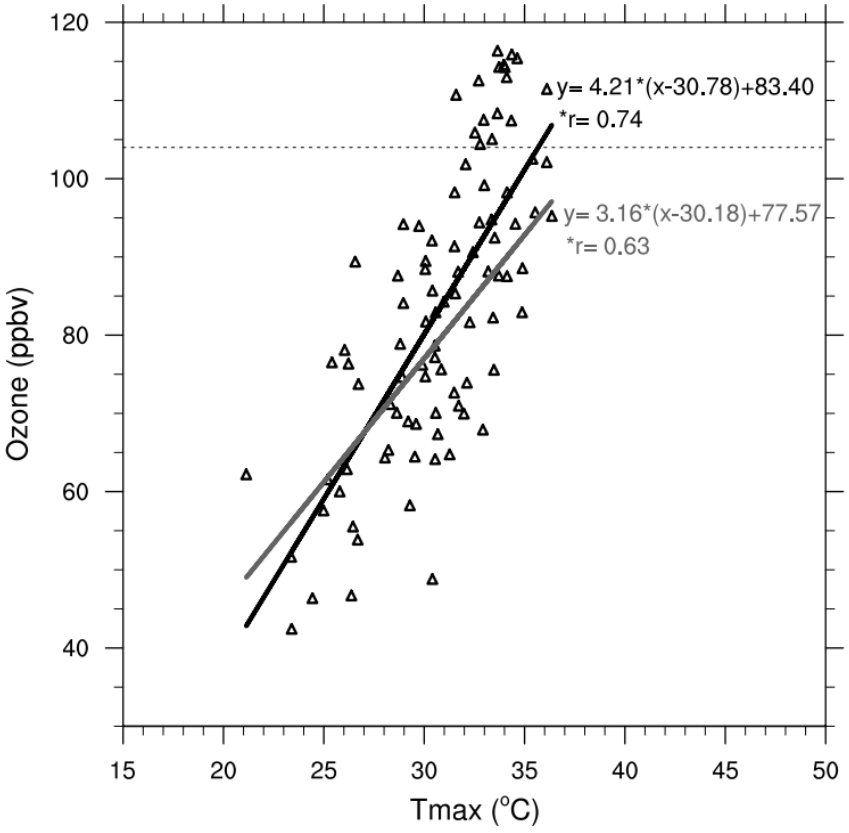

Fig. S2. The correlation between summer MDA8 ozone and daily maximum 2-meter temperature (Tmax) in the summer of 2017 over NCP. The black line is same as the black line in Fig. 3 in the main manuscript, while the grey line represents the correlation without points higher than 104 ppbv.

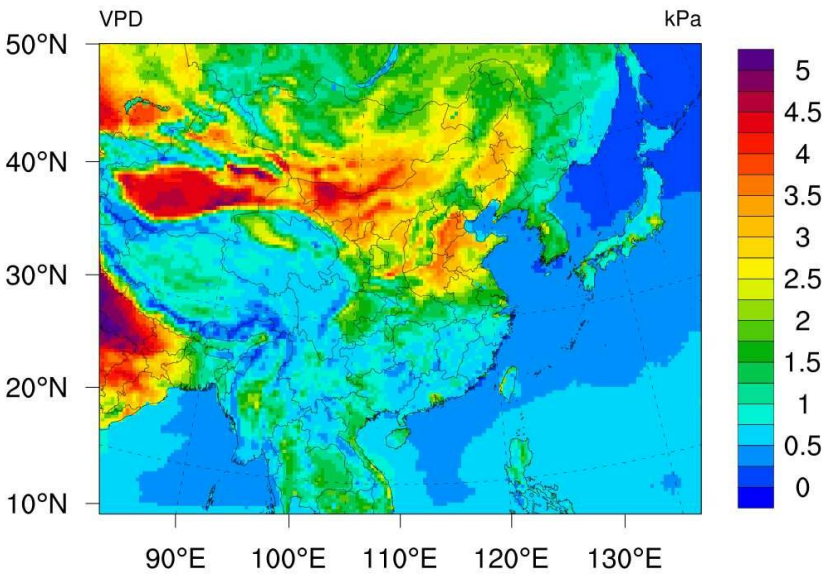

Fig. S3. The spatial distribution of monthly mean VPD in June 2017.

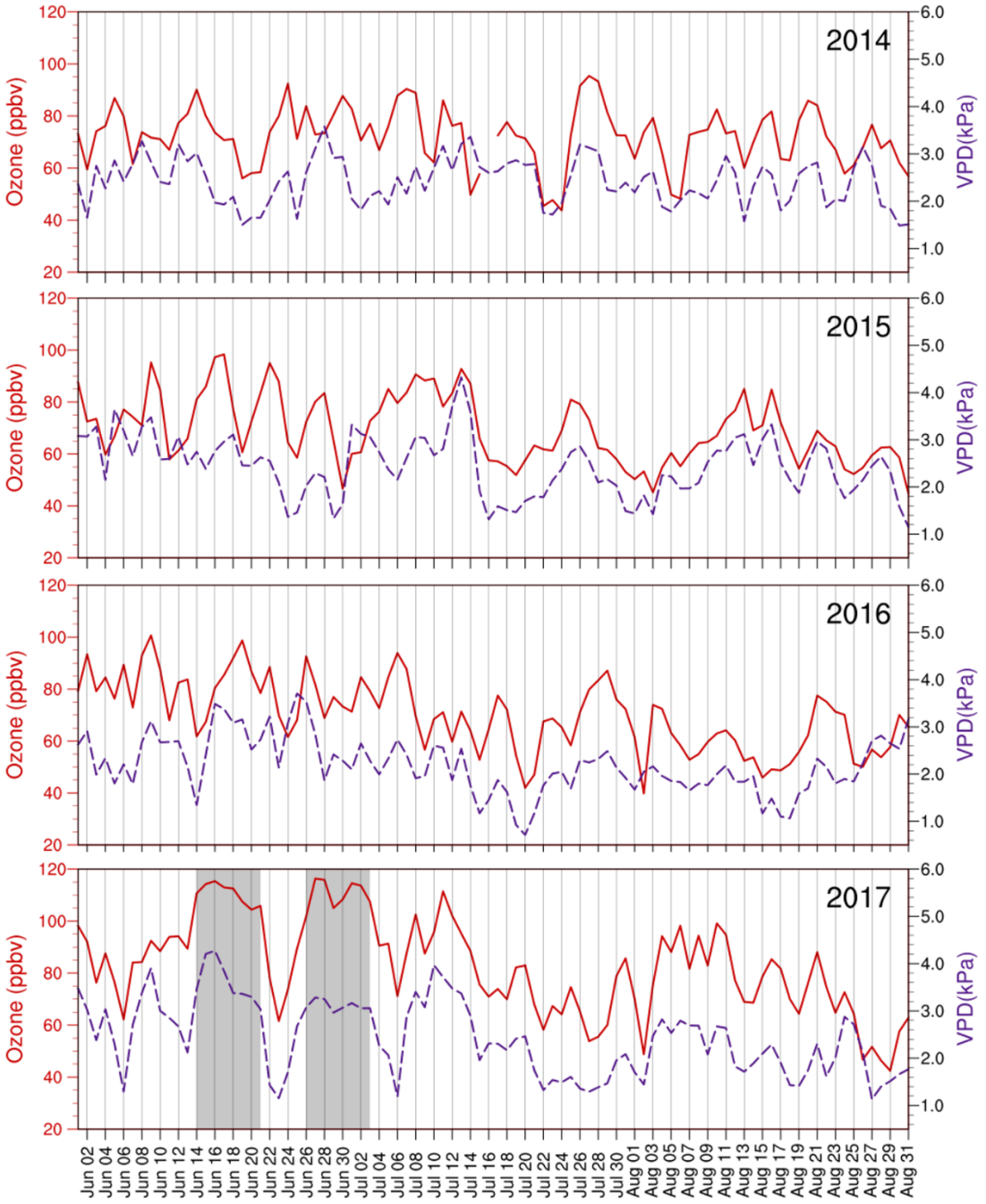

Fig. S4 Time series of observed MDA8 O_3 (red lines; based on sites from China National Environmental Monitoring Centre; red points in Fig. 1) and vapor pressure deficit (VPD; purple lines) during the summer from 2014 to 2017.

Table S1. The number of medium ozone pollution events (MDA8 exceeding 110 ppbv) with pollution area 25% (top row) or 50% (bottom row) in NCP.

Area ratio	Days	Events number			
		2014	2015	2016	2017
0.25	1	3	2	2	3
	2	-	2	-	2
	3~7	-	-	-	-
	8				2
0.5	1	-	-	-	-
	2	-	-	-	1
	3	-	-	-	2

Table S2. The classification of MDA8 ozone (larger than 110ppbv) during two events (June 14-21 and June 26-July 3, 2017) based upon daily precipitation and wind speed in NCP. For each category, there are two types of numbers: the total occurrences of days and observational stations (station locations are red dots shown in Fig. 1) with MDA8 ozone exceeding 110 ppbv during event 1 (June 14-21; third column) and event 2 (June 26-July 3; fourth column). The total number of occurrences is listed in the last row. The relative (percentage) contribution for each category (occurrence divided by the summation) was listed in the fifth column (event 1) and sixth column (event 2).

Daily precipitation (mm)	Wind speed (m/s)	MDA8 ozone >110ppbv		%	
		Event 1	Event 2	Event 1	Event 2
0-1	0-1	16	7	2	1
	1-2	198	373	27	48
	2-3	239	247	33	32
	3-4	142	82	20	11
	4-8	37	30	5	4
	>8	0	0	0	0
1-3	0-1	6	2	1	0
	1-2	0	1	0	0
	2-3	11	1	2	0
	3-4	0	6	0	1
	4-8	0	0	0	0
	>8	0	0	0	0
>3	0-1	0	0	0	0
	1-2	16	15	2	2
	2-3	36	7	5	1
	3-4	17	0	2	0
	4-8	8	2	1	0
	>8	0	0	0	0
Summation		726	773	100	100

Table S3. Evaluation of meteorology from WRF over NCP.

	Model evaluation				Benchmark (1)			
	T2 (°C)	Q2 (g/kg)	WD10 (deg)	WS10 (m/s)	T2 (°C)	Q2 (g/kg)	WD10 (deg)	WS10 (m/s)
Bias	0.54	-0.05	-13.77	0.58	$\leq \pm 0.5$	$\leq \pm 1$	$\leq \pm 10$	$\leq \pm 0.5$
Gross Error	1.74	1.70	73.46	/	≤ 2	≤ 2	≤ 30	/
RMSE	/	/	/	1.84	/	/	/	≤ 2

Table S4. PFTs matching to the corresponding MODIS vegetation types. There are 16 PFTs in MEGAN2.1, while 8 vegetation types in MODIS land cover datasets.

MODIS	PFT
Evergreen Needleleaf trees	Needle evergreen temperate trees
	Needle evergreen boreal trees
Deciduous Needleleaf trees	Needle deciduous boreal trees
Evergreen Broadleaf trees	Broadleaf evergreen tropical trees
	Broadleaf evergreen temperate trees
Deciduous Broadleaf trees	Broadleaf deciduous tropical trees
	Broadleaf deciduous temperate trees
	Broadleaf deciduous boreal trees
Shrub	Broadleaf evergreen temperate shrub
	Broadleaf deciduous temperate shrub
	Broadleaf deciduous boreal shrub
Grass	Cold C3 grass
	Cool C3 grass
	Warm C3 grass
Broadleaf Crop	Other Crop
Cereal Crop	Corn

Supplementary References

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