EXPLORING FUTURE CLIMATE EFFECTS ON WESTERN US AIR QUALITY

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INTRODUCTION

Air quality regulations have reduced emissions of air pollutants in the US, but previous studies suggest that the future air quality might be degraded by climate change (Chen et al., 2009; Gonzalez-Abraham et al., 2015; Nolte et al., 2018). Those studies were typically based on computationally expensive 3D Eulerian chemical transport models CTMs. To study how future air quality at a local scale will be influenced by global factors in an efficient way, we have developed a Lagrangian air quality modeling framework, called HYSPLIT-MOSAIC (H-M). It consists of HYSPLIT, an air trajectory model developed by NOAA (Stein et al., 2015) , and MOSAIC, a gas and aerosol chemistry and dynamics model developed at PNNL (Zaveri et al., 2008) .

METHOD AND DATA

To simulate future air quality in H-M at specific locations, we applied HYSPLIT cluster analysis to generate representative back trajectories for each site using historical NAM meteorology data. Next, we employed 4-km gridded statistically downscaled climate data (i.e., MACA, Abatzoglou & Brown, 2012) from 20 CMIP5 GCMs for two future climate scenarios (RCP4.5 and RCP8.5). The present-day and future anthropogenic and biogenic emissions along each trajectory were from U.S. EPA (Nolte et al., 2018). The initial and boundary conditions are from the ModelE2-TOMAS global model. (See Figure 2)

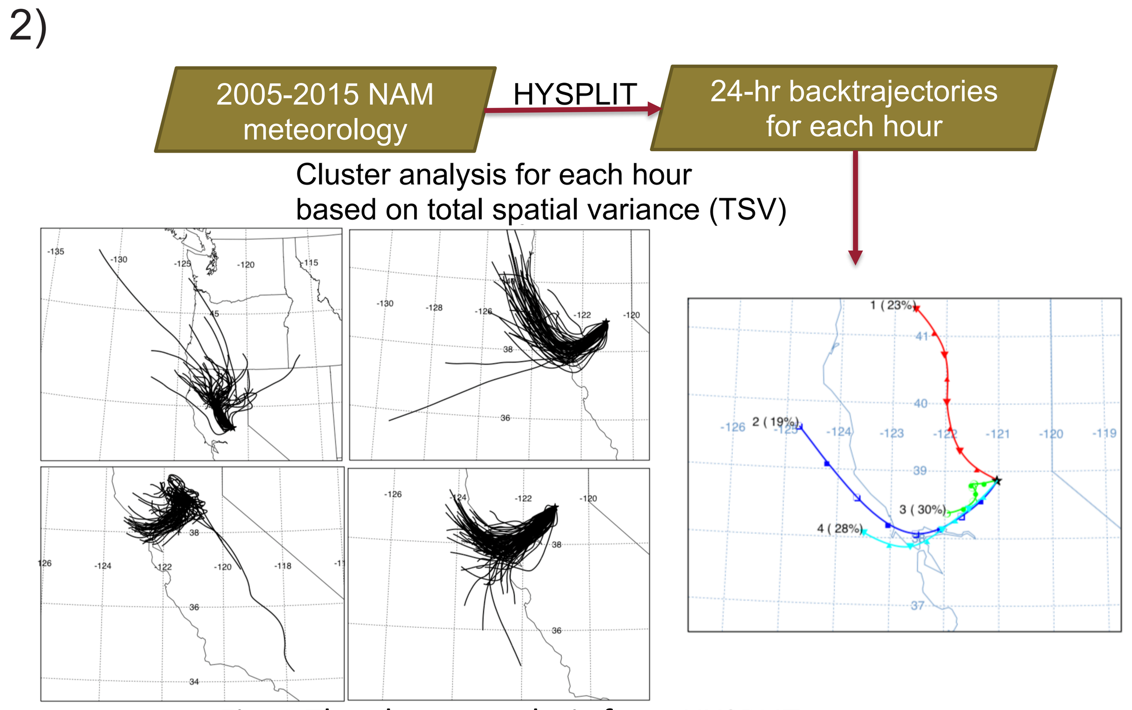


Fig. 1 The cluster analysis from HYSPLIT to get climatological backtrajectories

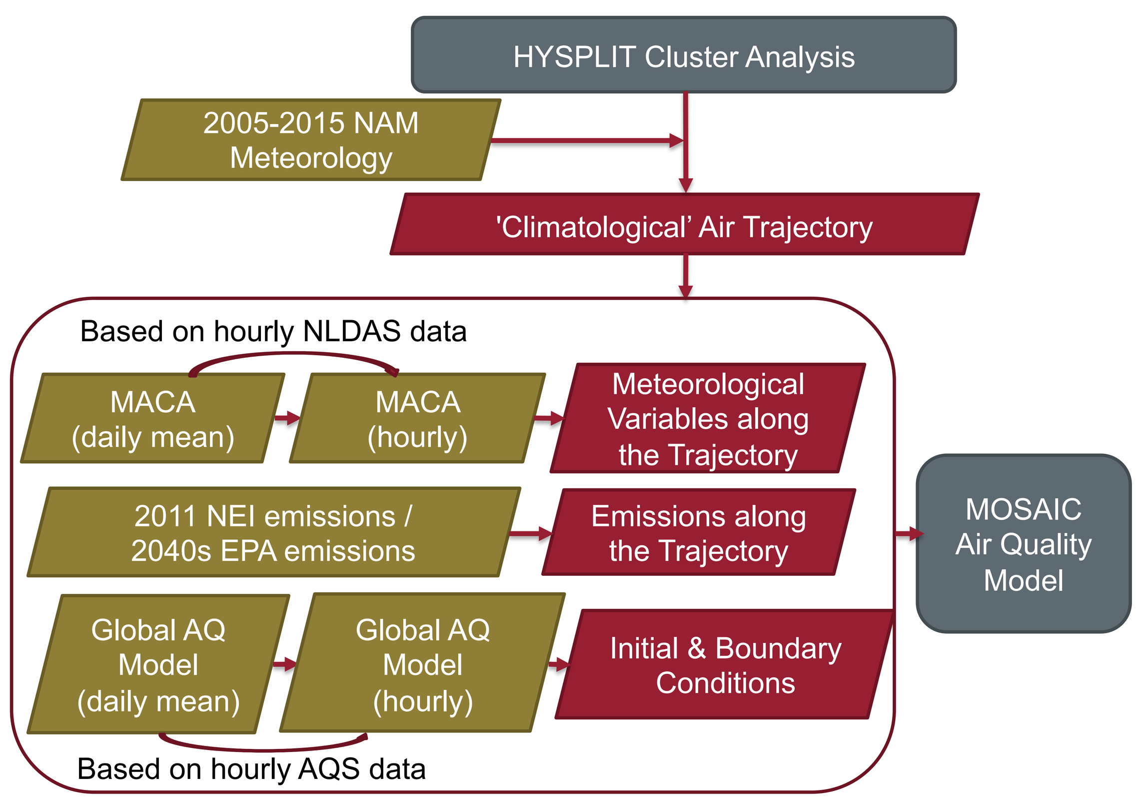
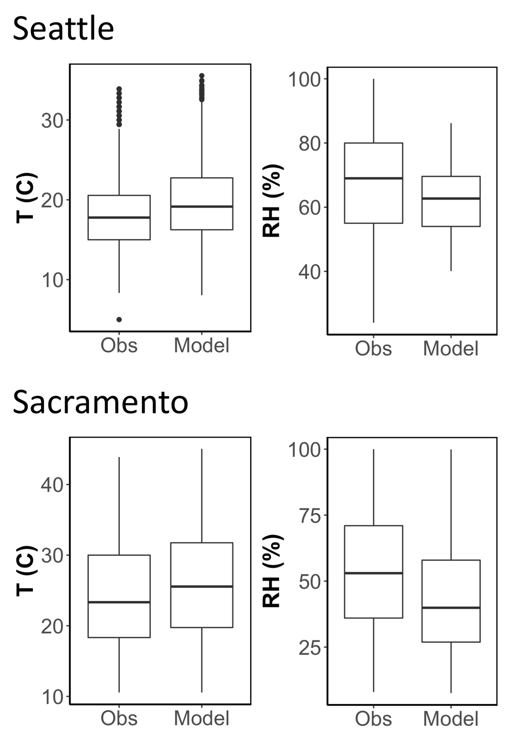


Fig. 2 HYSPLIT-MOSAIC modeling framework for long-term simulations

RESULTS

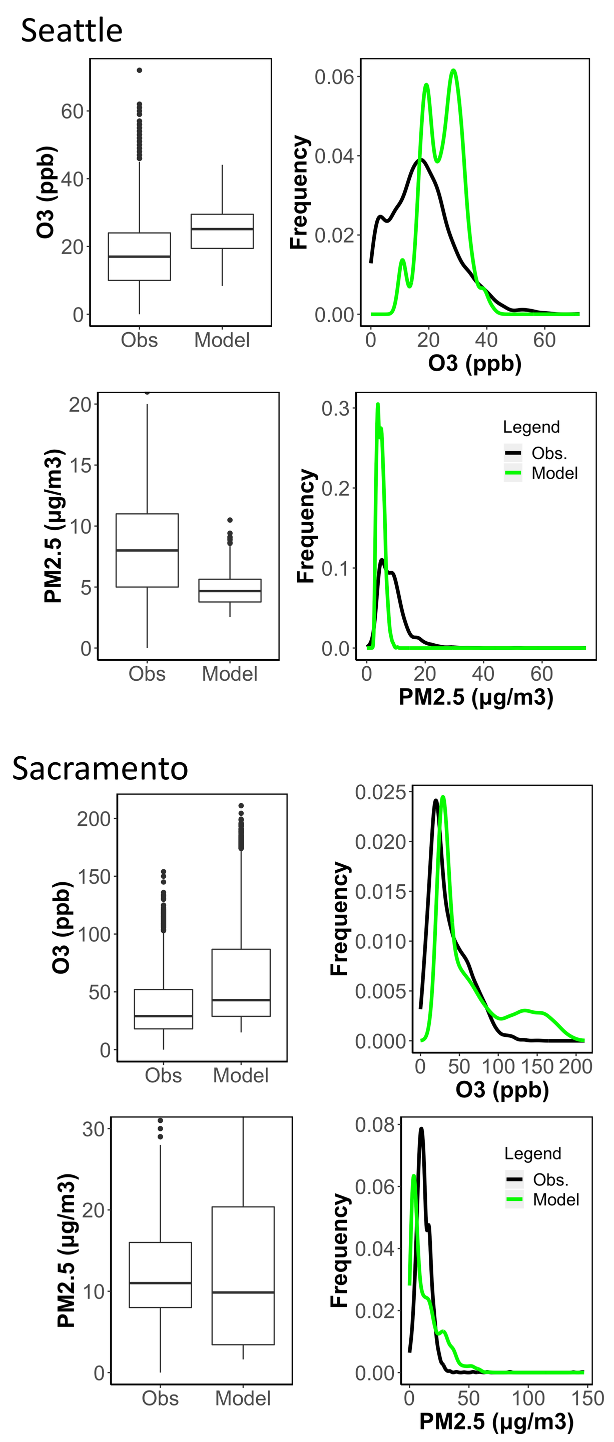
We evaluated the historical simulations of July from 1995-2005 at two AQS sites of Seattle and Sacramento. Because the historical MACA data are close among GCMs, so we chose one GCM for historical period. Note that median values are used to describe the changes in this study.



	T (C)		RH (%)	
	Obs.	Mod.	Obs.	Mod.
	Seattle			
25%	15	16	55	54
Median	18	19	69	63
75%	21	23	80	70
	Sacramento			
25%	18	20	36	27
Median	23	26	53	40
75%	30	32	70	58

Fig. 3 MACA temperature (T) and relative humidity (RH) at Seattle and Sacramento in July of 1995-2005 against observation

- The model T is 1-3 °C higher than observations, and the model RH is 7-13% lower.



Seattle

	O3 (ppb)	
	Obs.	Mod.
25%	10	19
Median	17	25
75%	24	30

	PM2.5 (μg/m3)	
	Obs.	Mod.
25%	5	4
Median	8	5
75%	11	6

Sacramento

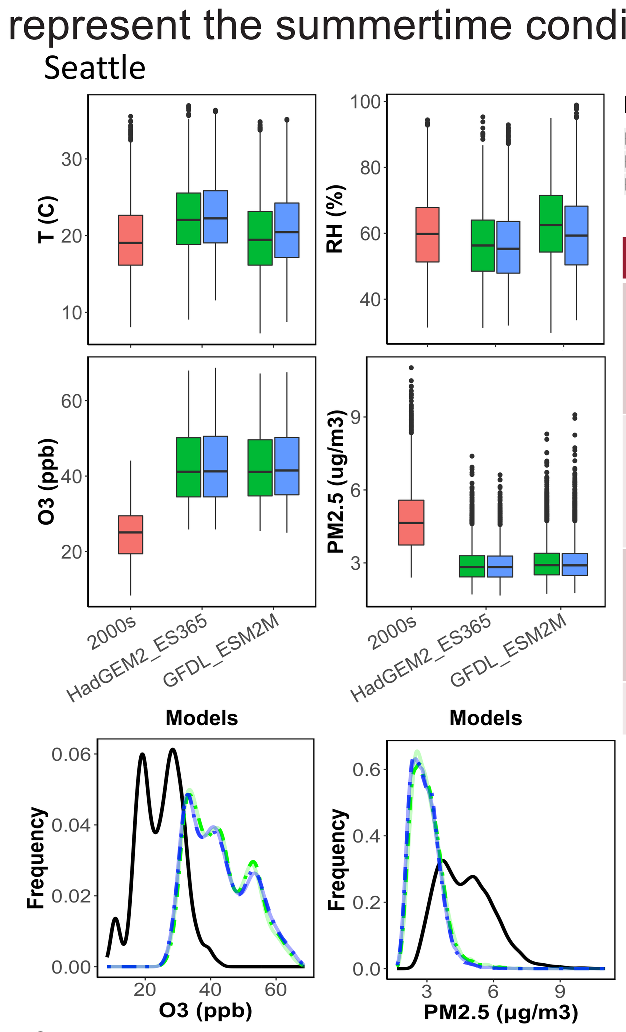
	O3 (ppb)	
	Obs.	Mod.
25%	18	29
Median	30	43
75%	53	87

	PM2.5 (μg/m3)	
	Obs.	Mod.
25%	8	3
Median	11	10
75%	16	20

Fig. 4 H-M simulated O_3 and PM2.5 at Seattle and Sacramento in July of 1995-2005 against observations

- The simulated O_3 is 8-13 ppb higher than observations, and for PM2.5 it is 1-3 μg/m^3 lower.
- The distributions of simulated O_3 and PM2.5 are similar to observations.

For future runs, we chose two GCMs from MACA for each AQS site. The simulations of Salt Lake City and Boise were run for January to represent the wintertime conditions; Seattle and Sacramento were ran for July to represent the summertime conditions.

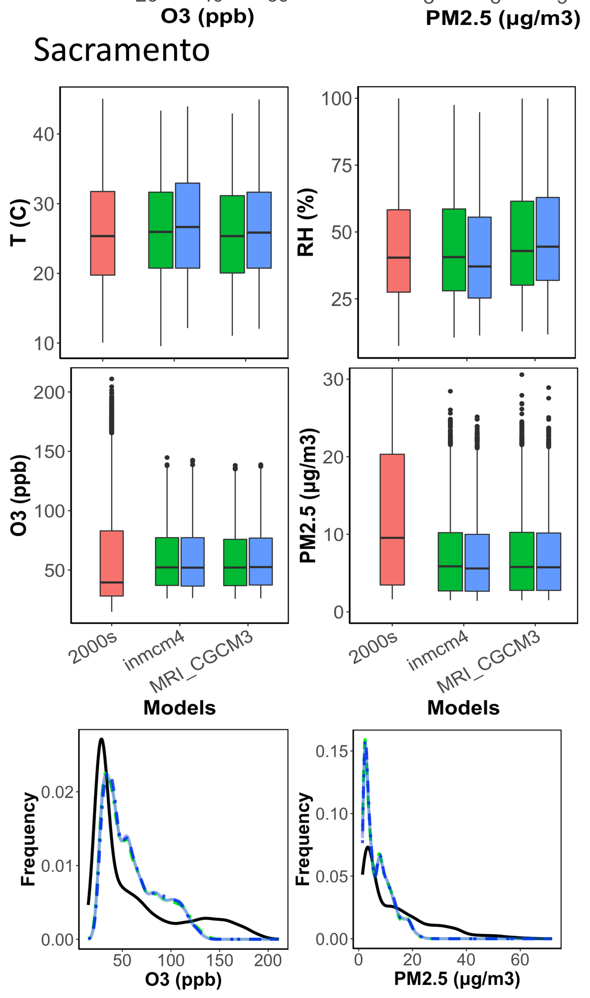


Seattle

		2000s	2050s
T (C)	25%	16	16-19
	Median	19	19-22
	75%	23	23-26
RH (%)	25%	51	48-54
	Median	60	55-63
	75%	68	64-72
O3 (ppb)	25%	19	34-35
	Median	25	41-42
	75%	29	50-51
PM2.5 (μg/m³)	25%	3.7	2.4-2.5
	Median	4.6	2.8-2.9
	75%	5.6	3.3-3.4

Models: 2000s, GFDL_ESM2M, HadGEM2_ES365; RCP: 4.5, 8.5

*The tables show ranges for 2050s, because there is not significant difference between two GCMs and two RCPs.



RCP: 2000s, 4.5, 8.5

Sacramento

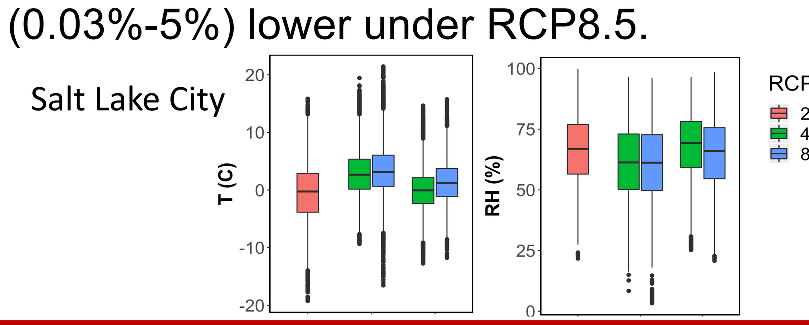
		2000s	2050s
T (C)	25%	20	20-21
	Median	25	25-27
	75%	32	31-33
RH (%)	25%	28	25-32
	Median	40	37-45
	75%	58	56-63
O3 (ppb)	25%	28	36-37
	Median	40	52-53
	75%	83	76-77
PM2.5 (μg/m³)	25%	3.5	2.7-2.8
	Median	9.5	5.6-5.9
	75%	20	~10

Models: 2000s, inmcm4, MRI_CGCM3; RCP: 4.5, 8.5

Fig. 5 Historical (1995-2005) vs. future (2045-2055) simulations in July at Seattle and Sacramento

- Compared to July in the 2000s, the 2050s show 0-3°C higher in T and differ little in RH. The difference between two RCPs is smaller than the ones between GCMs.
- The 2050s O_3 shows 10-20 ppb higher than 2000s and more high O_3 events. For PM2.5, it shows 2-4 μg/m^3 lower and fewer high PM2.5 events.
- Between two GCMs in 2050s, O_3 differs by 0.02-0.5 ppb (0.05%-1%), and PM2.5 by 0.07-0.15 μg/m^3 (1%-3%). Generally, O_3 is 0.1-0.4 ppb (0.3%-0.9%) higher under RCP8.5 than RCP4.5, but PM2.5 is 0.001-0.3 μg/m3 (0.03%-5%) lower under RCP8.5.

Salt Lake City



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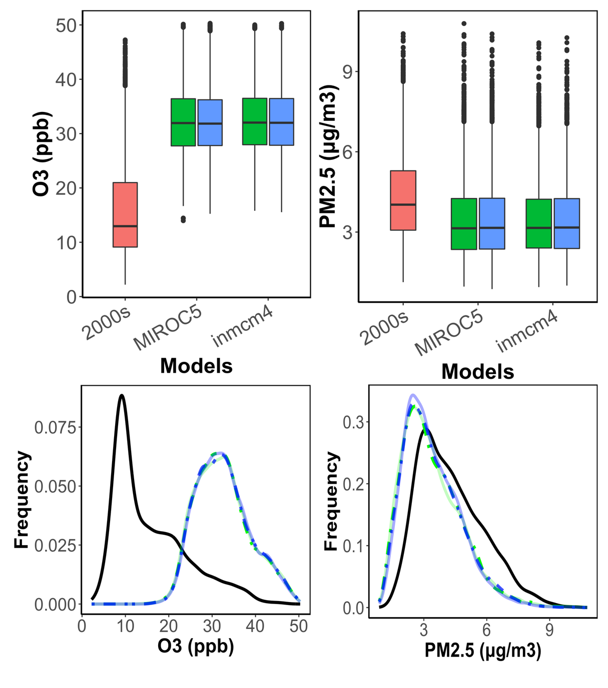
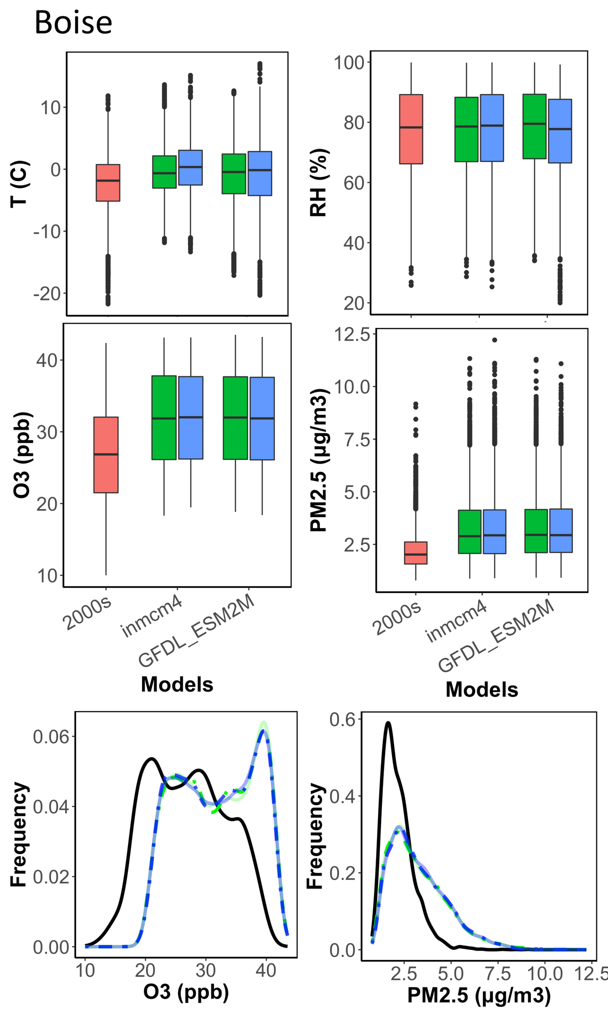


Salt Lake City

		2000s	2050s
T (C)	25%	-3.9	-2.4-0.7
	Median	-0.3	-0.05-3.2
	75%	2.9	2.1-6.1
RH (%)	25%	56	50-59
	Median	67	61-69
	75%	77	73-78
O3 (ppb)	25%	9	~28
	Median	13	~32
	75%	21	~36
PM2.5 (μg/m³)	25%	3.1	2.3-2.4
	Median	4.0	3.1-3.2
	75%	5.3	4.2-4.3

Models: 2000s, MIROC5, inmcm4; RCP: 4.5, 8.5

Boise



RCP: 2000s, 4.5, 8.5

Boise

		2000s	2050s
T (C)	25%	-5.2	-4.3~-2.6
	Median	-1.9	-0.7-0.4
	75%	0.8	2.2-3.1
RH (%)	25%	66	67-68
	Median	78	78-80
	75%	89	88-89
O3 (ppb)	25%	22	~26
	Median	27	~32
	75%	32	~38
PM2.5 (μg/m³)	25%	1.6	~2.1
	Median	2.0	2.9-3.0
	75%	2.6	4.1-4.2

Models: 2000s, inmcm4, GFDL_ESM2M; RCP: 4.5, 8.5

Fig. 6 Historical (1995-2005) vs. future (2045-2055) simulations in January at Salt Lake City and Boise

- Compared to 2000s, 2050s O_3 is 5-20 ppb higher with a peak at 30-40 ppb, while 2050s PM2.5 is 1 μg/m^3 lower at Salt Lake City and 1 μg/m^3 higher at Boise with more high PM2.5 events.
- Between two GCMs in 2050s, O_3 varies by 0.09-0.16 ppb (0.3%-0.5%), and PM2.5 by 0.01-0.06 μg/m^3 (0.2%-2%). Generally, O_3 is 0.04-0.12 ppb (0.1%-0.4%) lower under RCP8.5, but the PM2.5 is 0.01-0.04 μg/m3 (0.5%-1.5%) higher under RCP8.5.

CONCLUSION AND FUTURE PLANS

- Our 2050s future O_3 shows 5-20 ppb increase in the median value in all cases but the changes in PM2.5 depends on sites and season.
- Air quality is very similar in the all future runs used here, but using two GCMs adds 1% variation of O_3 and 3% of PM2.5, and using two RCPs adds 1% variation of O_3 and 5% of PM2.5.
- The biogenic emissions vary with meteorology, but it is not included in this study yet. We plan to run MEGAN biogenic emission model with MACA meteorology in order to better estimate the influence of future meteorology on air quality.

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Question?

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