Particulate Matter ($PM_{2.5}$) Precursor Emission Sensitivities and the Impact on Human Health in California

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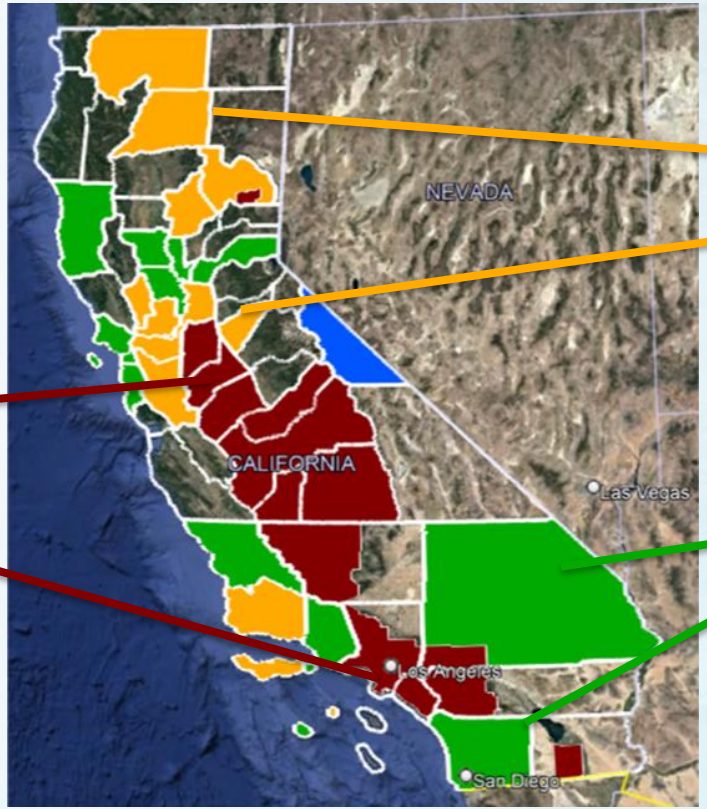
$PM_{2.5}$ NAAQS* Nonattainment Areas (NAAs) in California



Gold – Projected NAAs for 10 µg m^{-3} Standard

Red – NAAs for existing 2012 Standard 12 µg m^{-3}

Green – Projected NAAs for 8 µg m^{-3} Standard

*NAAQS – National Ambient Air Quality Standard

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CEPAM* Emissions Summary

California Statewide Emissions (tons per day)			
Precursor Species	Year 2018	Year 2037	Difference
NO_x	1254	681	-45.7%
$PM_{2.5}$	382	376	-1.6%
NH_3	621	642	3.4%
SO_x	60	63	5.0%
ROG	1506	1319	-12.4%

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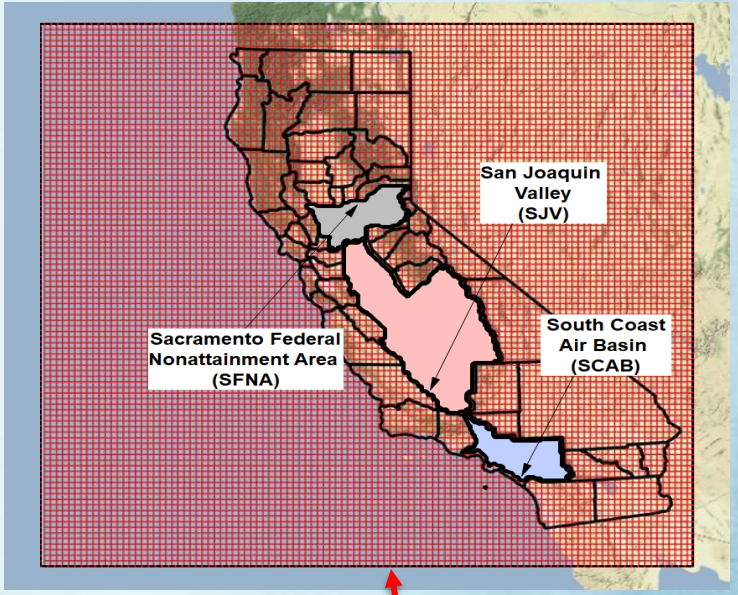
*CEPAM – California Emissions Projection Analysis Model

WRF/CMAQ Modeling Platform

CMAQv5.4 Model Configuration

Parameter	Value
Grid Cell Size	12 km x 12 km
Domain Size	107 x 97
Vertical Levels	30
Emissions	CEPAM 2022 v1.01 – base year 2018
Biogenic	Offline MEGAN 3.0
Boundary Conditions	GEOSchem Global Model v13.3.4
Chemical Mechanism	SAPRC07TIC_AE7
Deposition	Stage/Emerson 2020
Modeling years	Simulation year 2018 Base and Baseline 2018 Future year 2037



WRF nested 3-domains

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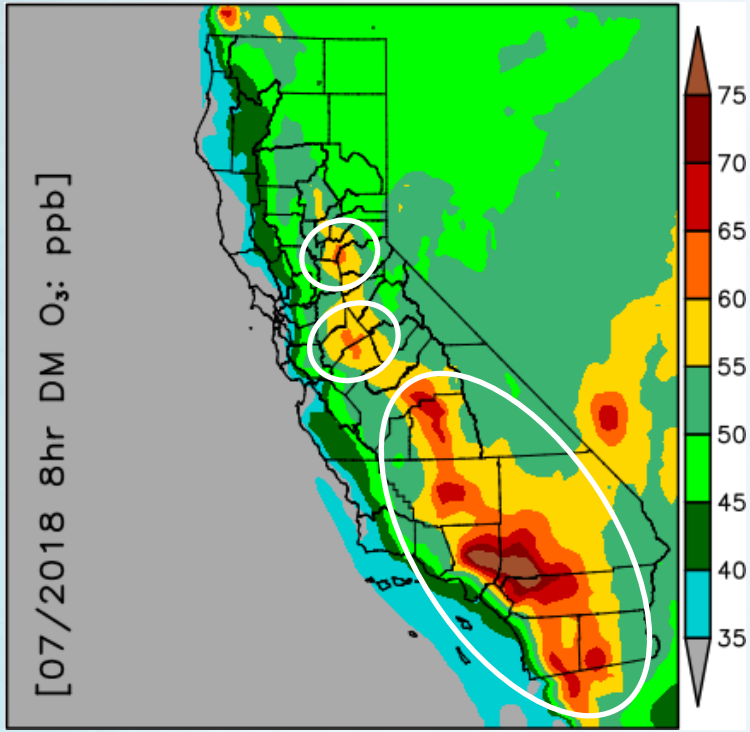
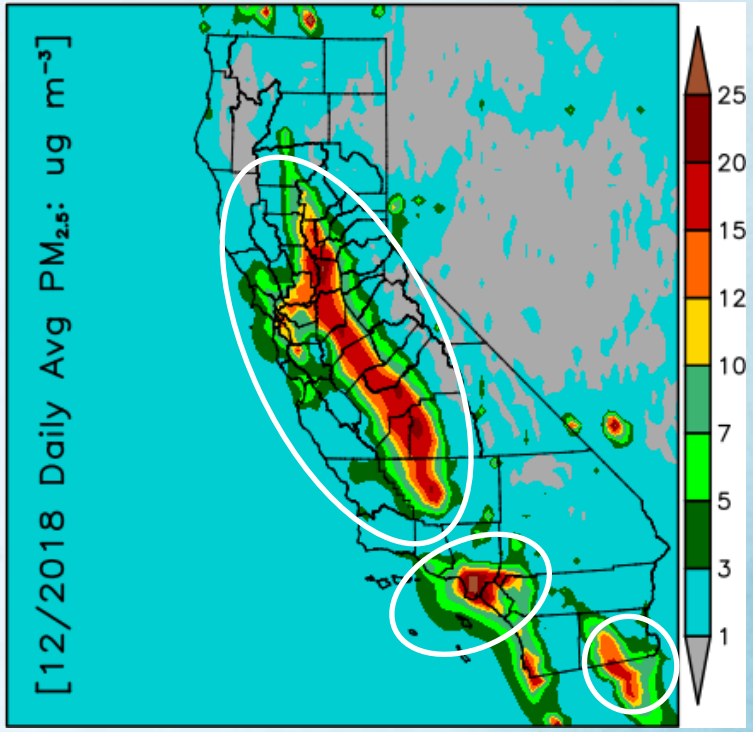
Ozone and $PM_{2.5}$ Spatial Distribution

Average MDA* 8-hr O_3 July 2018



Average $PM_{2.5}$ Dec 2018



Enhanced Ozone and $PM_{2.5}$ values over Central Valley and LA Air Basin

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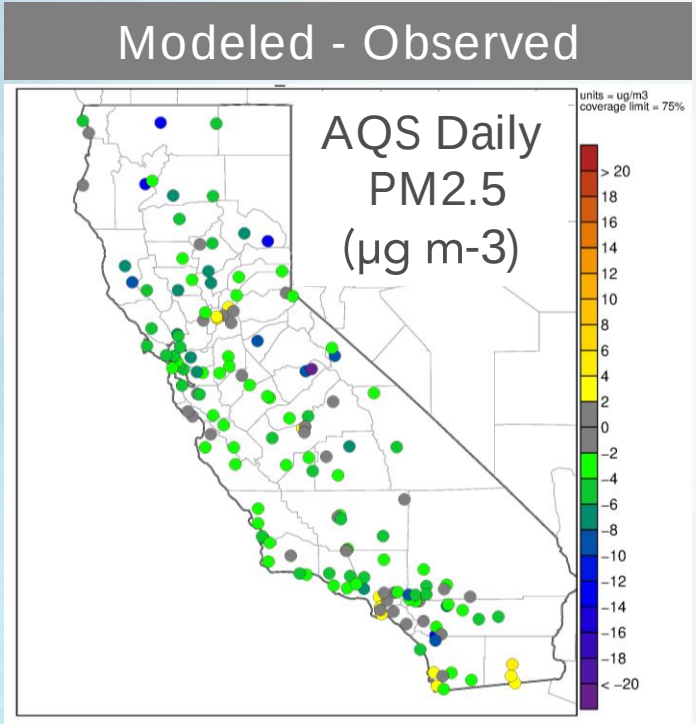
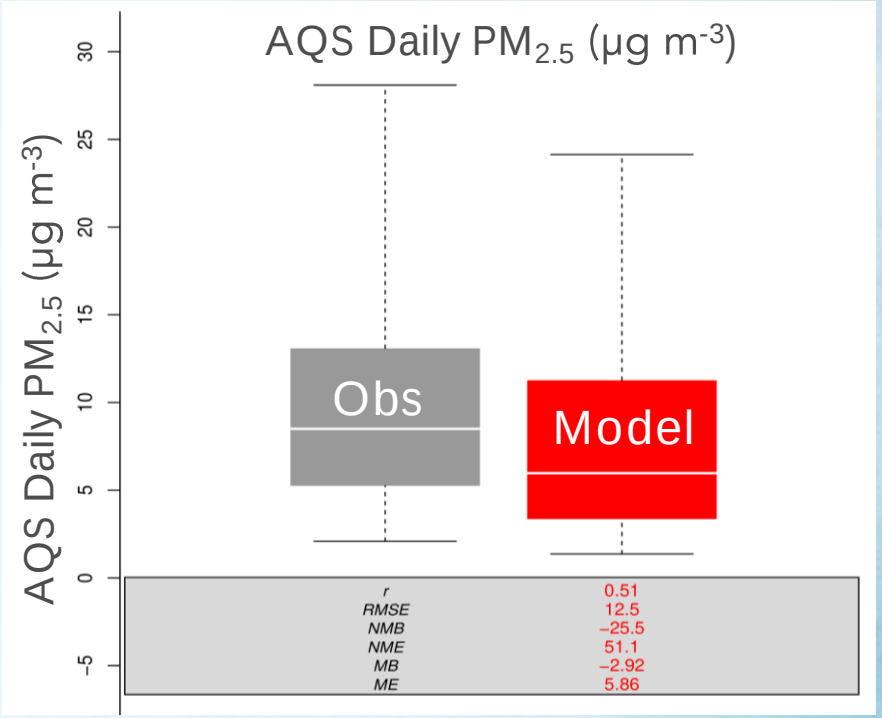
*MDA – Maximum Daily Average

$PM_{2.5}$ Model Performance*





Simulated values are lower with Mean Bias -2.92 and Mean Error 5.86

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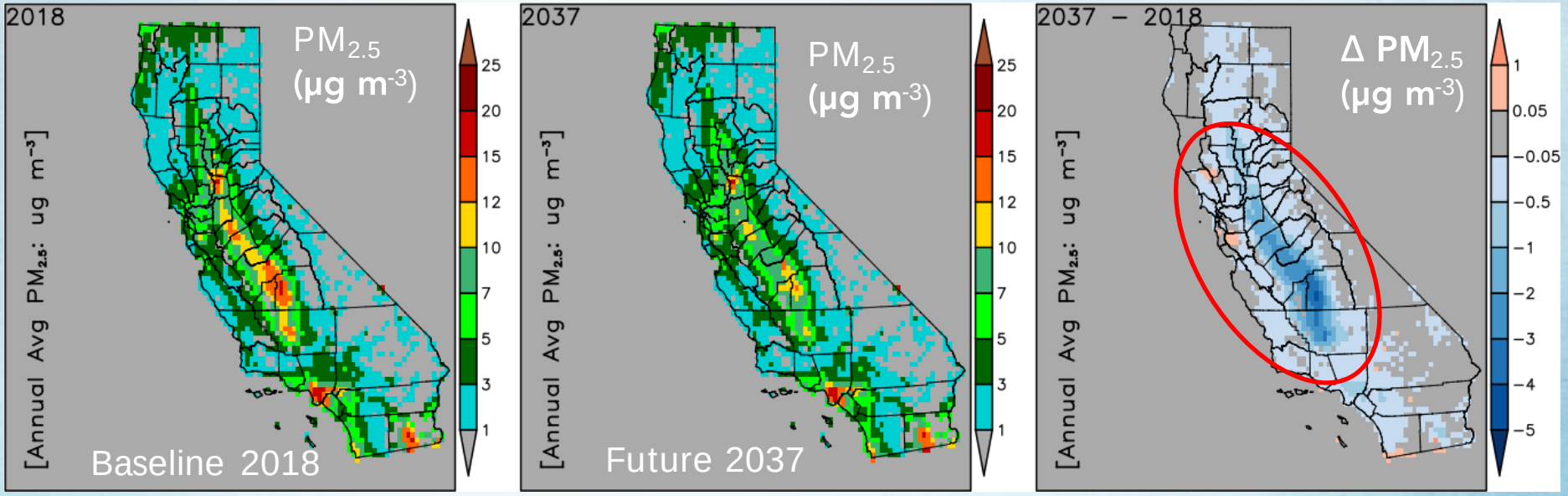
* Based on Atmospheric Model Evaluation Tool (AMET) and EPA's AQS Observations

$PM_{2.5}$ Concentration ($\mu g\ m^{-3}$)*

2018 | 2037 | Difference (2037-2018)



Lower $PM_{2.5}$ values in 2037 over California, particularly over Central Valley

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* Weighted Concentration based on 2018 population

Public Health Assessment

- Standard U.S. EPA's method was used; mortality only
- Concentration-Response function from Pope et al (2019)*:

$$\frac{10\% \text{ increase in mortality}}{10\ \mu g\ PM_{2.5}/m^3}$$

- Value of Statistical Life (VSL):

$11 Million in 2020 USD

- The same VSL, population, and baseline mortality were used for both years (2018 and 2037) to isolate the effect of air quality modeling

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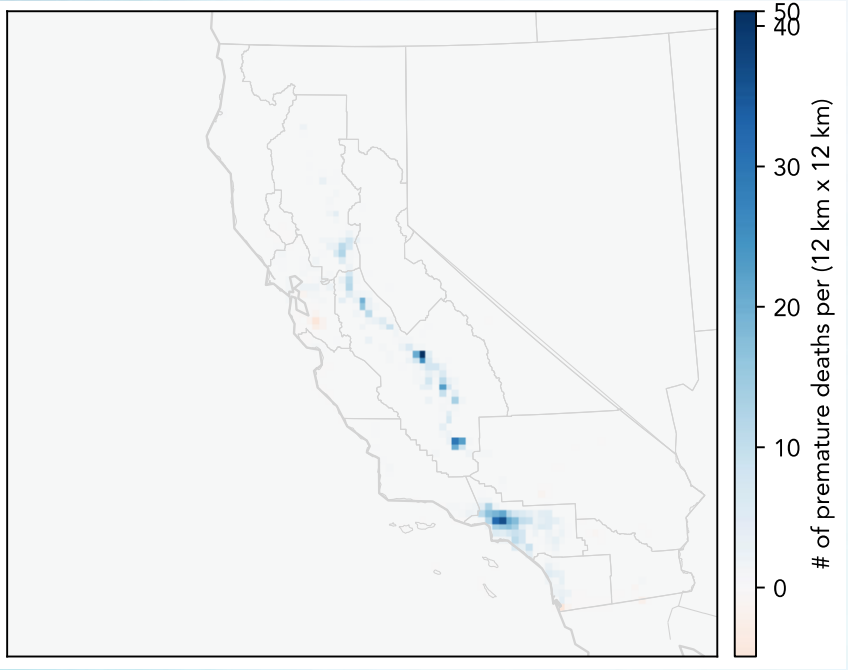
*Pope et al (2019) https://doi.org/10.1289/EHP4438

Annual Health Benefits in 2037*

Avoided premature deaths in 2037



Air Basin	Annual Avoided Mortality	%
San Joaquin Valley	520	44%
South Coast	460	40%
Sacramento Valley	100	9%
Others	75	6%
Total	1200	100%

*Relative to 2018

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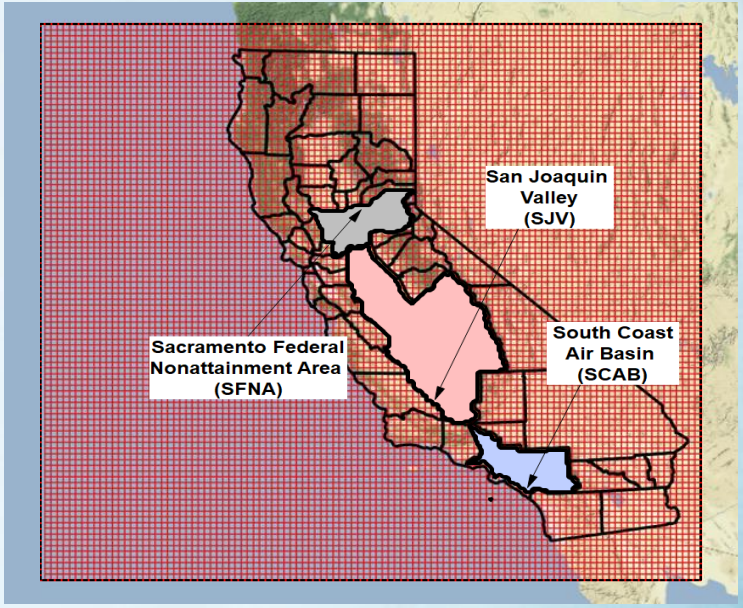
Sensitivity to Emission Precursors

Parameter	Value
Emissions	CEPAM 2022 v1.01
Biogenic	MEGAN 3.0
Boundary Conditions	GEOS-Chem Global Model
Chemical Mechanism	SAPRC07TIC_AE7
Baseline	2018
Future year	2037
Nonattainment Areas	SJV, SCAB, SFNA
Emission Sensitivities	25% cut emissions specific to each NAA
Emission Precursors (5)	Primary PM, NH_3 NO_x, SO_x and ROG



Total 30 Annual Simulations with 25% emissions cut

- NAAs x3, Years x2, Precursors x5

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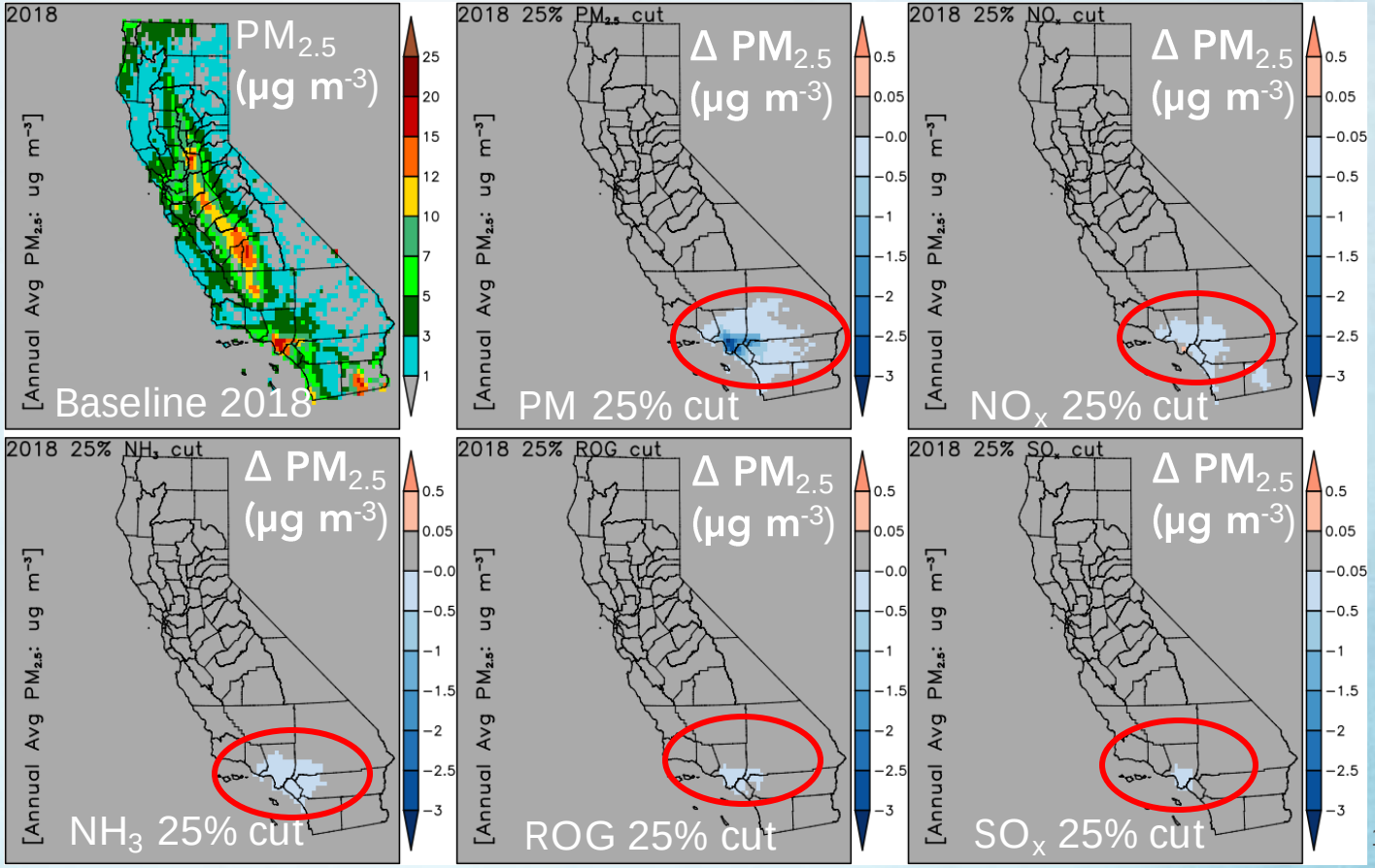
$PM_{2.5}$ Precursor Sensitivity: 2018 SCAB

South Coast Air Basin (SCAB):

25 % emission cut relative to 2018



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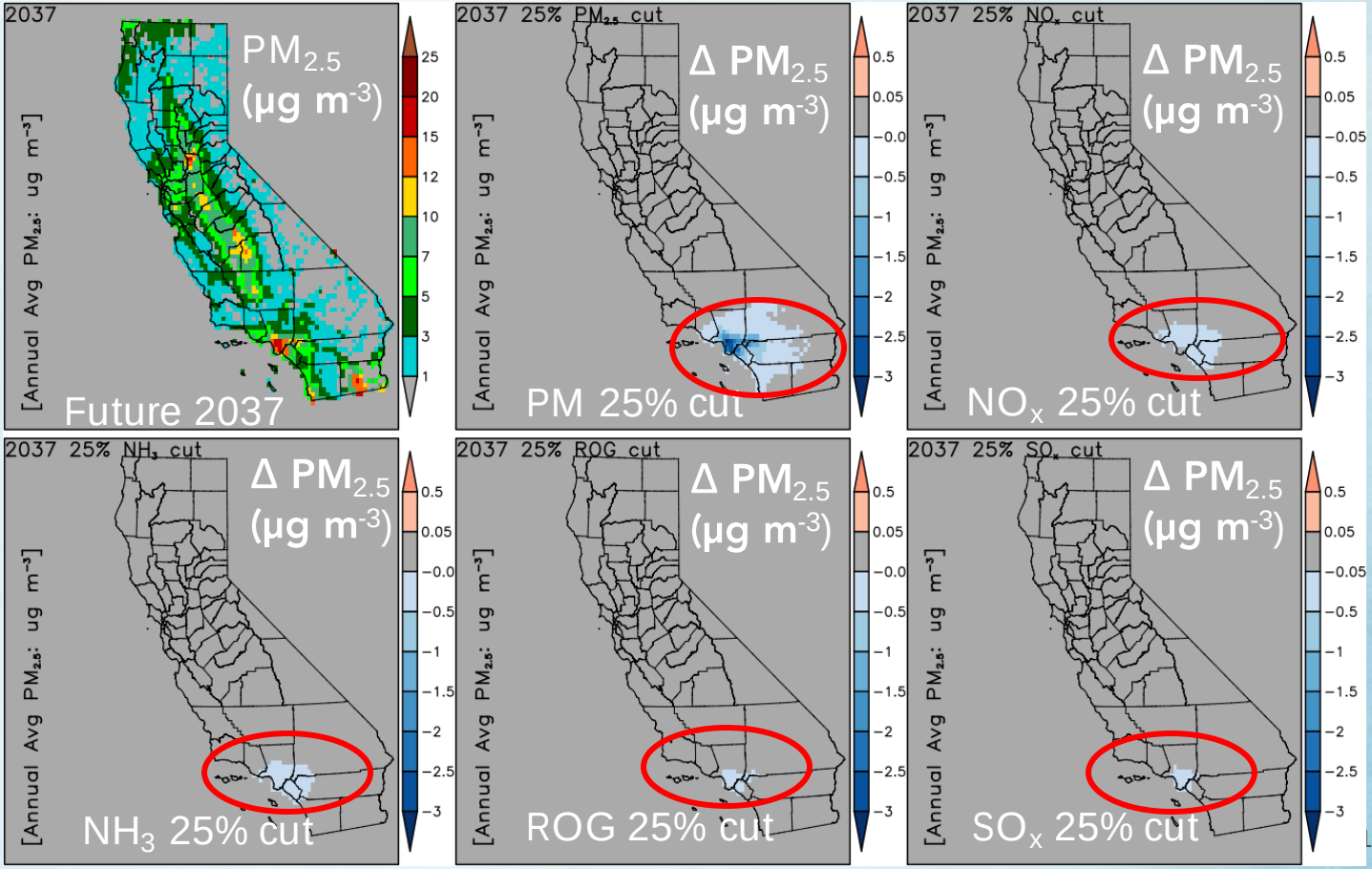
$PM_{2.5}$ Precursor Sensitivity: 2037 SCAB

South Coast Air Basin (SCAB):

25 % emission cut relative to 2037



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Health Benefits Per Ton of Emissions

Year	2018			2037		
	Sac Metro	Los Angles South Coast	San Joaquin Valley	Sac Metro	Los Angles South Coast	San Joaquin Valley
PM	$1,300,000	$2,800,000	$640,000	$1,200,000	$2,900,000	$620,000
NO_X	$84,000	$63,000	$59,000	$120,000	$200,000	$67,000
NH_3	$58,000	$76,000	$130,000	$31,000	$49,000	$50,000
ROG	$17,000	$39,000	$5,100	$7,500	$31,000	$860
SO_X	-$150,000	$1,400,000	$14,000	$32,000	$1,600,000	$33,000

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Summary/Preliminary Findings

- Simulated $PM_{2.5}$ concentration shows an overall decrease over California with the projected 2037 emissions: particularly in SJV
  - Avoided 1200 premature deaths per year (relative to 2018)

- The 25% cut emission precursor sensitivity analysis for 2018 and 2037 identified primary PM and NO_x are the limiting precursors for $PM_{2.5}$ formation in SCAB, SJV and Sac Metro.

- Predicted $PM_{2.5}$ from NO_x sensitivity simulations shows higher Health Benefits per Ton in 2037 than 2018
  - using the same 25% cut emissions

Acknowledgements

- Majiong Jiang of CARB's Regional Air Quality Modeling Section
  - MEGAN Biogenic Emissions
- CARB's Atmospheric Modeling and Support Section
  - Gridded Emissions Inventory
- CARB's High Performance Computing (HPC) Cluster

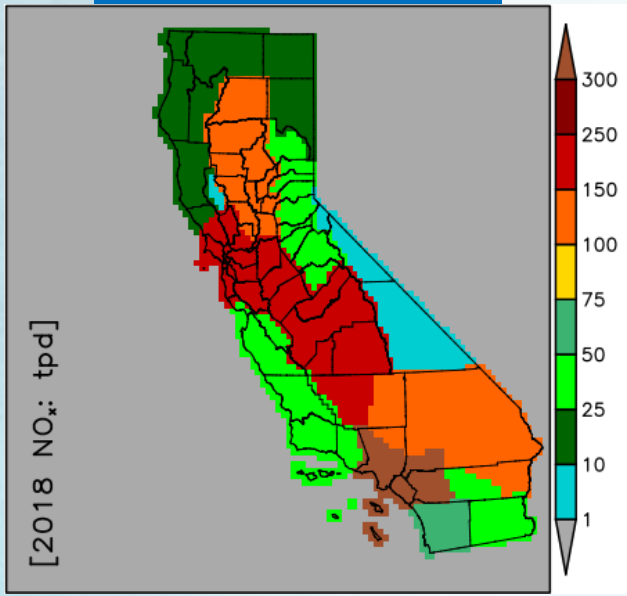
Backup slides

Ongoing/Future Work

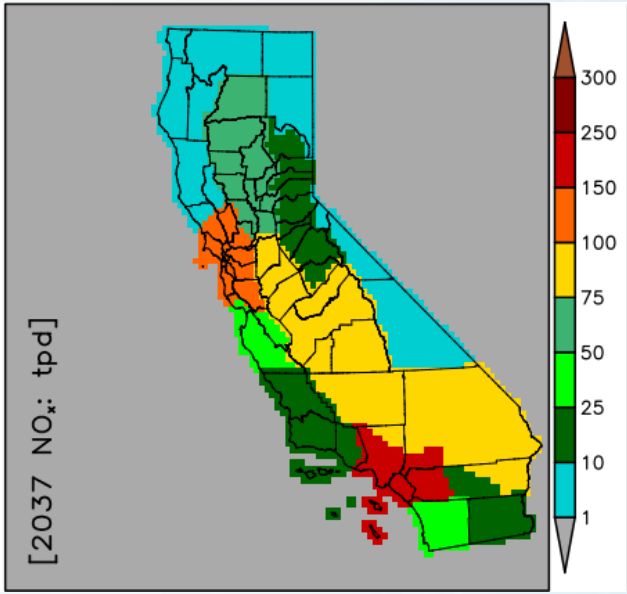
- Extend this analysis to other regions in California identify the limiting precursor for $PM_{2.5}$ formation
- Impact of boundary conditions and biogenic emissions on the simulated $PM_{2.5}$ over California and the associated health impacts

Spatial Distribution: NO_x Emissions

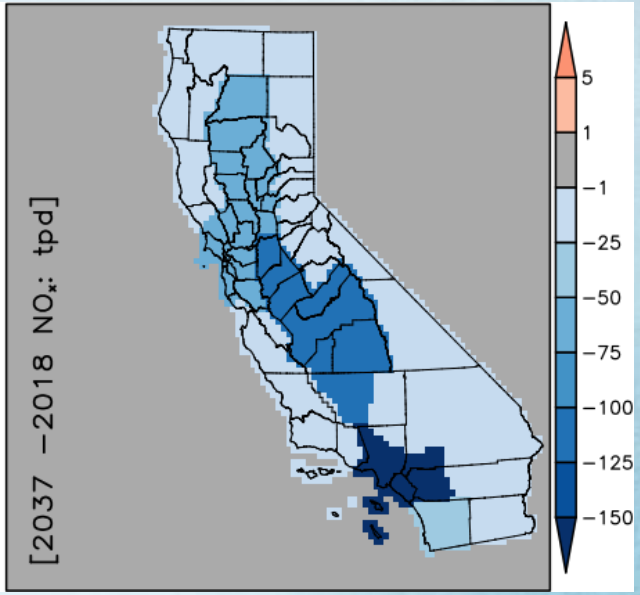
2018



2037



Delta (2037-2018)



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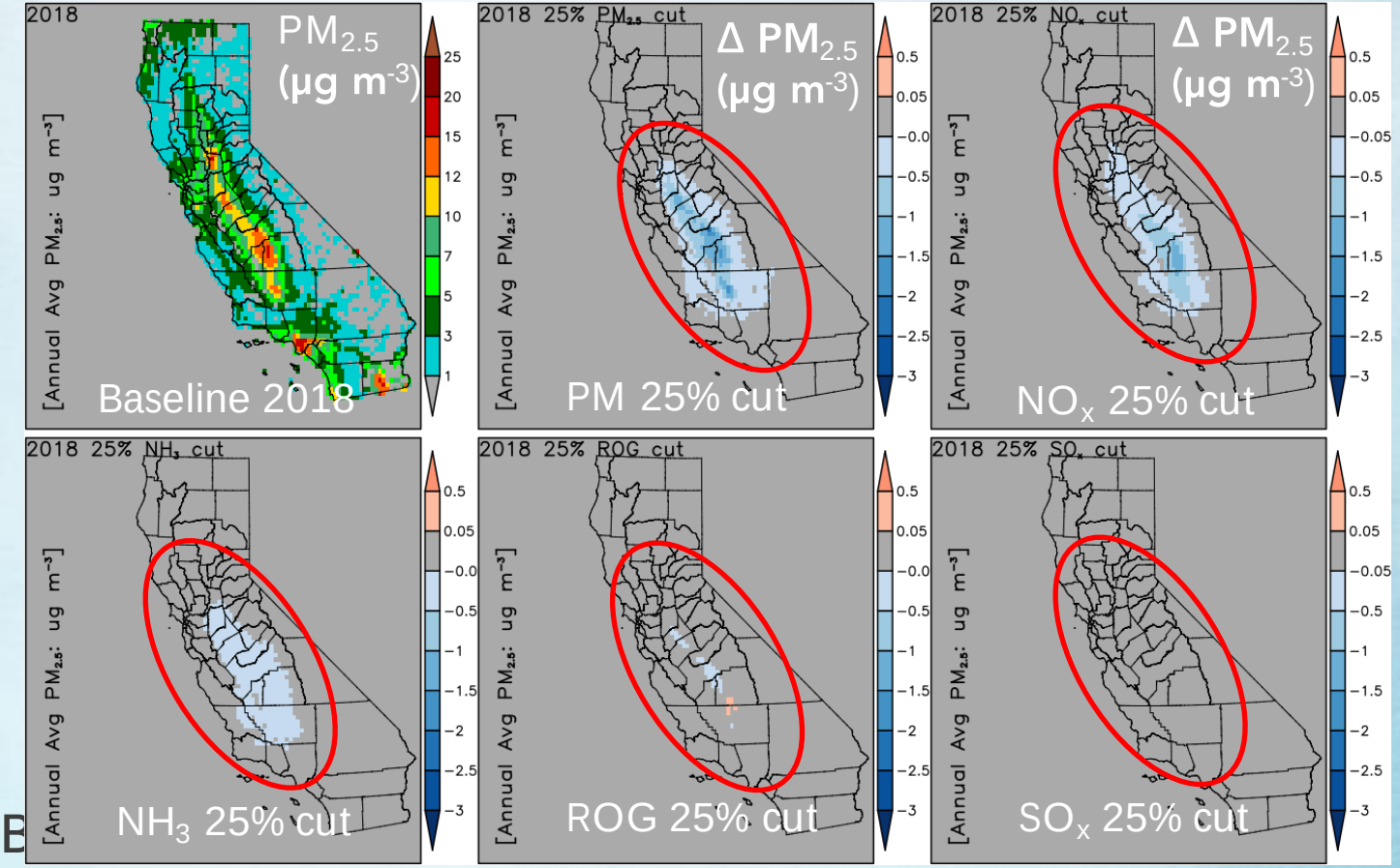
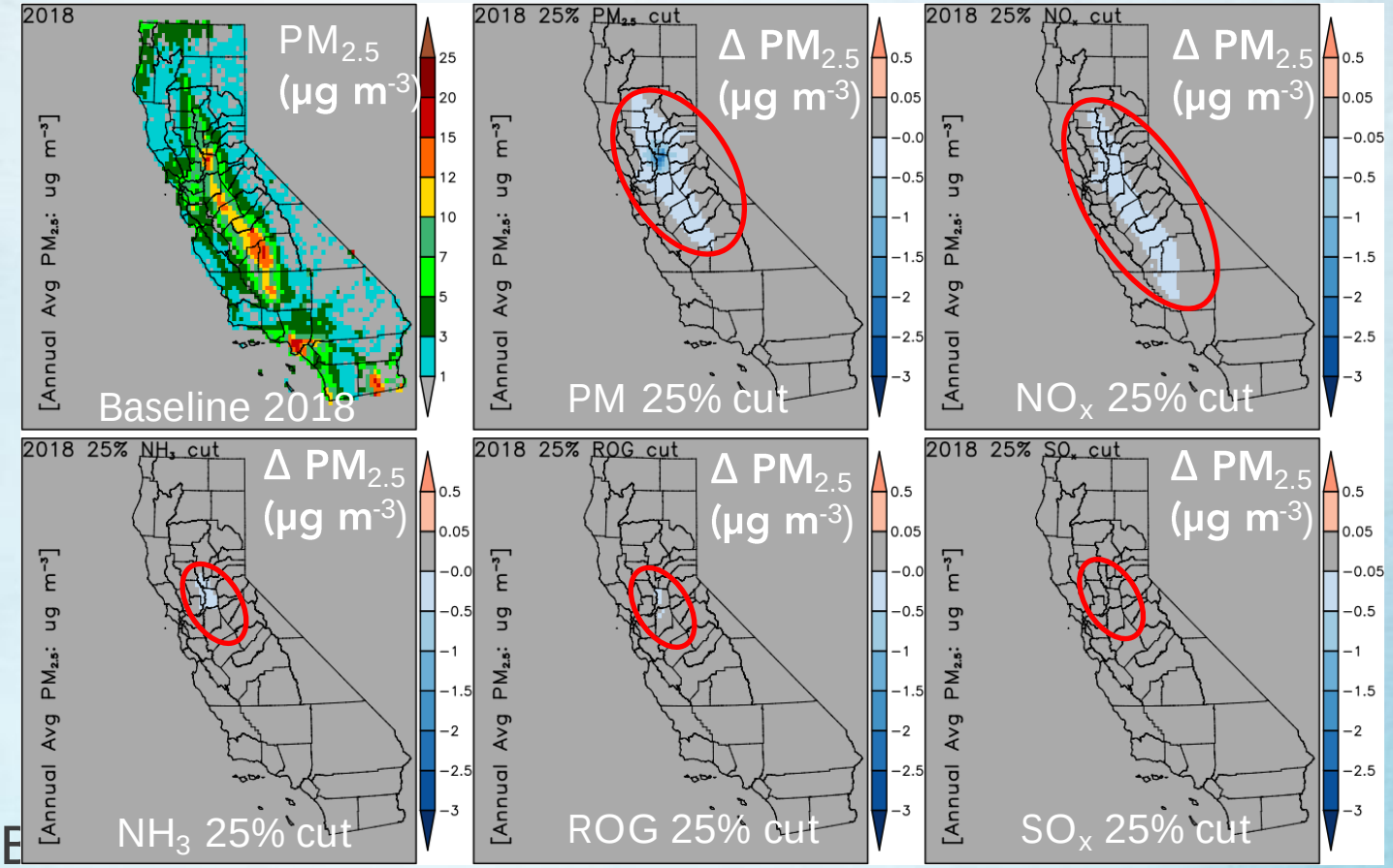
25% Cut Precursor Sensitivities Baseline 2018

$PM_{2.5}$ precursor sensitivity: 2018 SJV

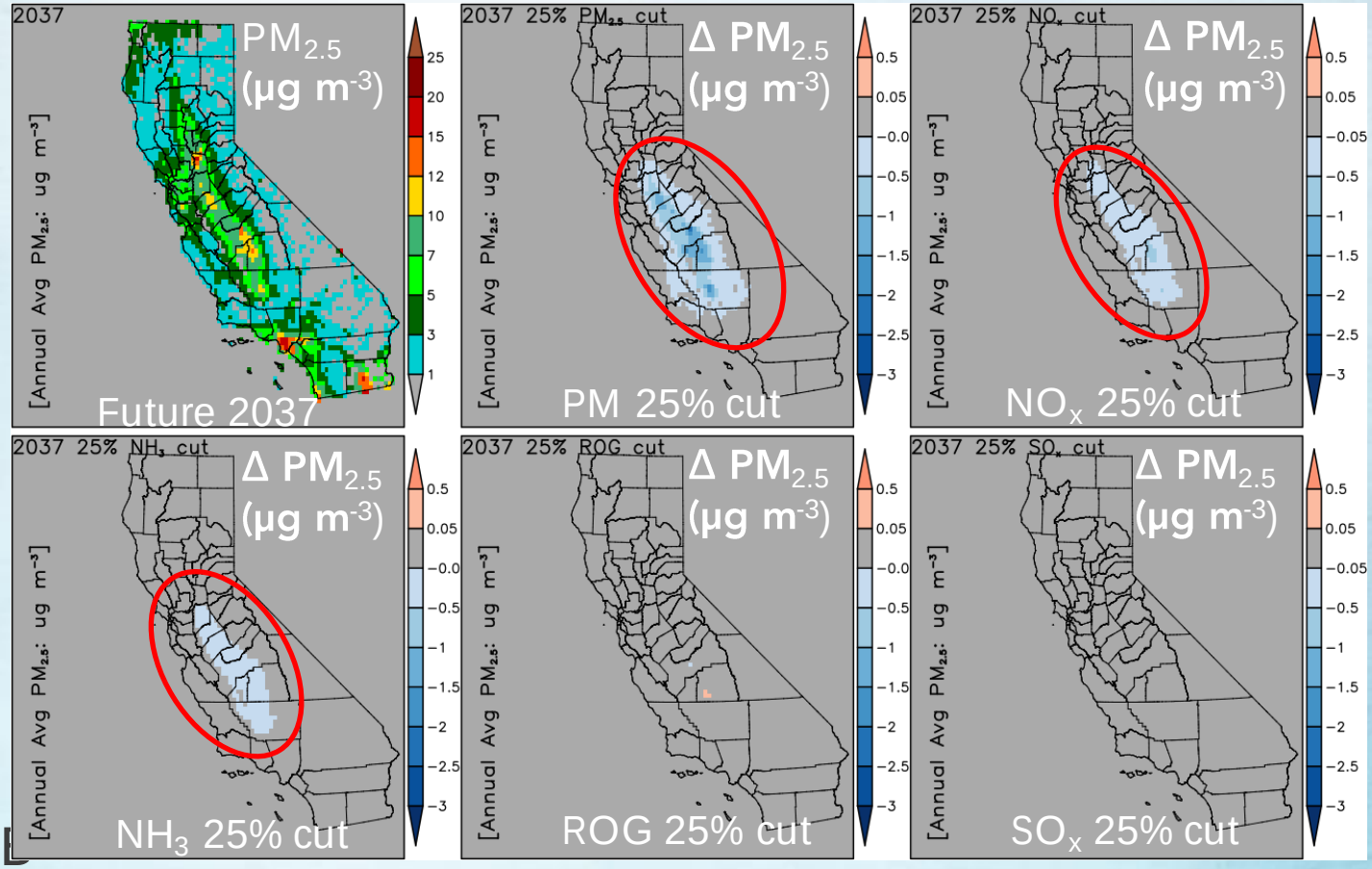


$PM_{2.5}$ precursor sensitivity: 2018 SFNA

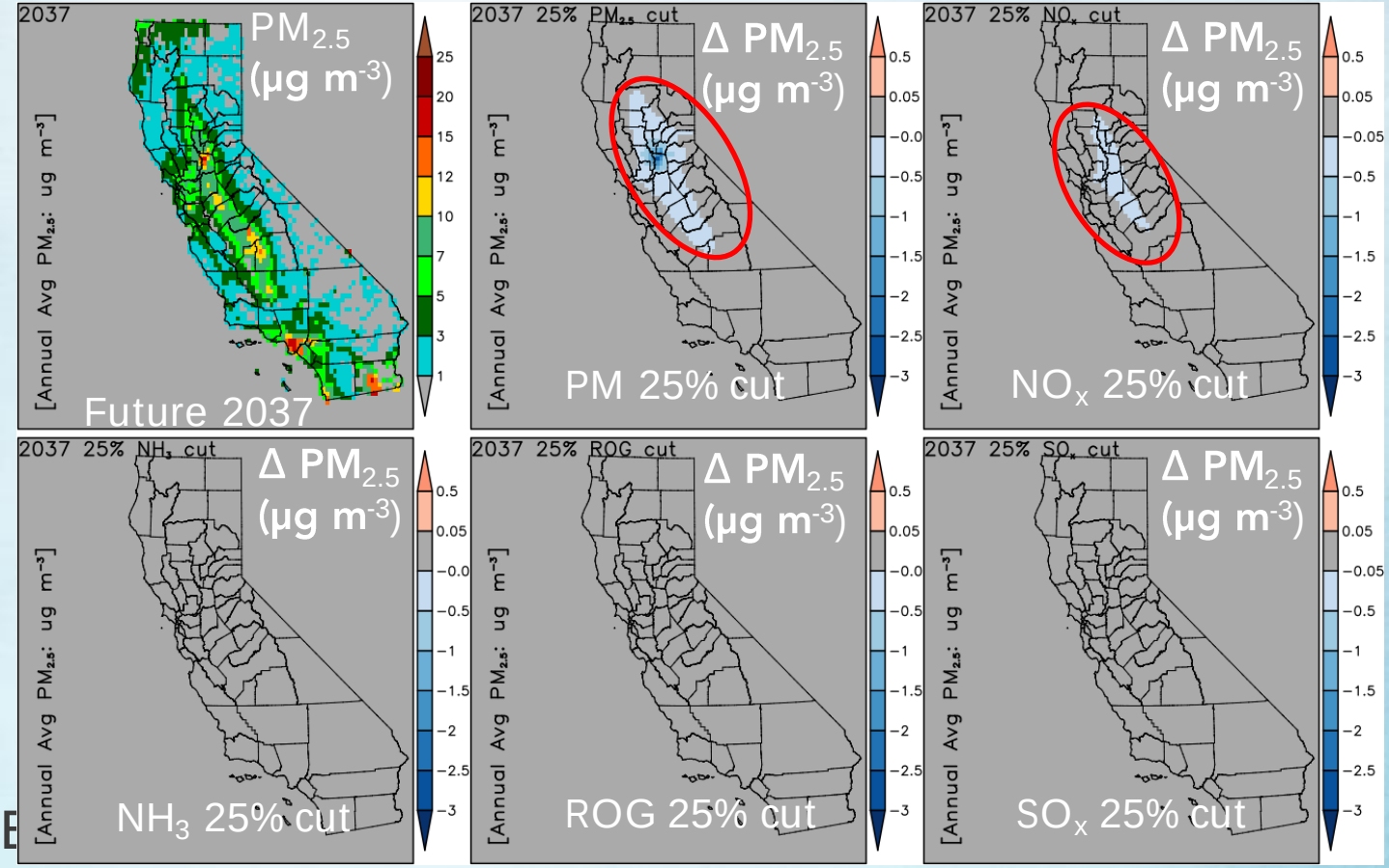


25 % Cut Precursor Sensitivities Future 2037

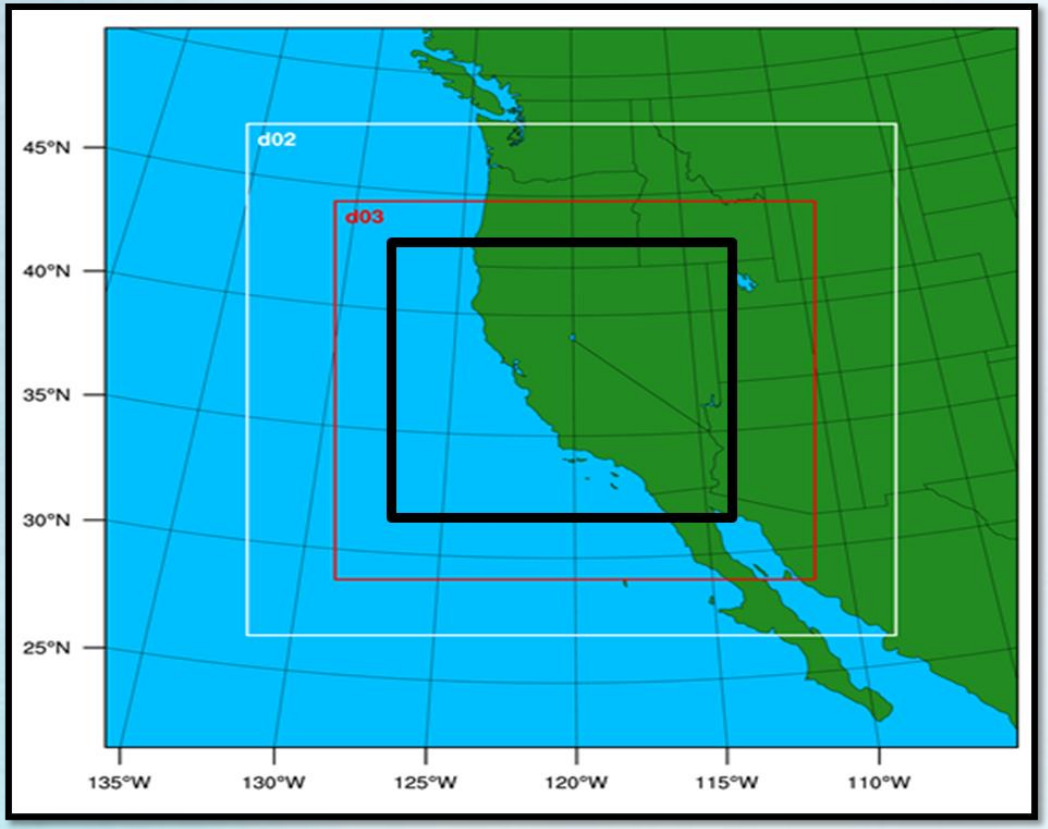
$PM_{2.5}$ precursor sensitivity: 2037 SJV



$PM_{2.5}$ precursor sensitivity: 2037 SFNA



WRF Model Configuration



Physics Option	
Microphysics	WSM 6-class
Longwave Radiation	RRTM
Shortwave Radiation	Dudhia
Surface Layer	Revised MM5 Monin-Obukhov
Land Surface Model	5-layer Thermal diffusion
Planetary Boundary Layer	YSU
Cumulus Parameterization	Kain-Fritsch Scheme (for D01 and D02 only)

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WRF model performance: Sacramento Valley

	2m Temperature (K)	2m RH (%)	Wind Speed (m/s)
Obs	288.28	59.1	1.91
Mod	287.65	66.8	2.55
MB	-0.63	7.75	0.63
ME	1.54	10.54	0.72
IOA	0.98	0.89	0.78

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WRF model performance: SJV

Name	2m Temperature (K)	2m RH (%)	Wind Speed (m/s)
Obs	290.19	59.7	1.81
Mod	290.1	70.5	2.21
MB	-0.1	10.82	0.41
ME	2.36	13.1	0.48
IOA	0.96	0.83	0.85

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WRF model performance: SCAB

	2m Temperature (K)	2m RH (%)	Wind Speed (m/s)
Obs	290.53	55.84	2.06
Mod	289.5	61.5	2.46
MB	-0.98	5.67	0.4
ME	1.32	8.75	0.55
IOA	0.98	0.93	0.88

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