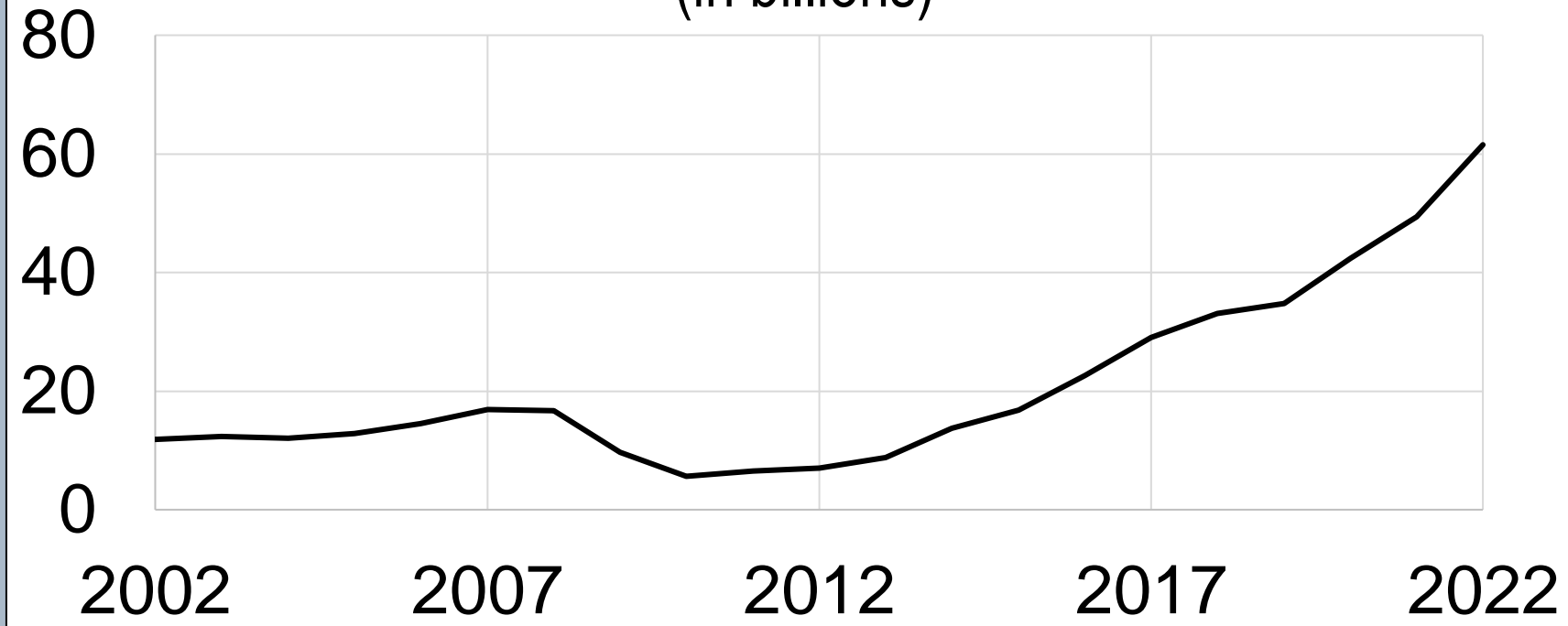


Why Warehouses?

Value of New Private Sector Warehouse Construction in the US (in billions)¹

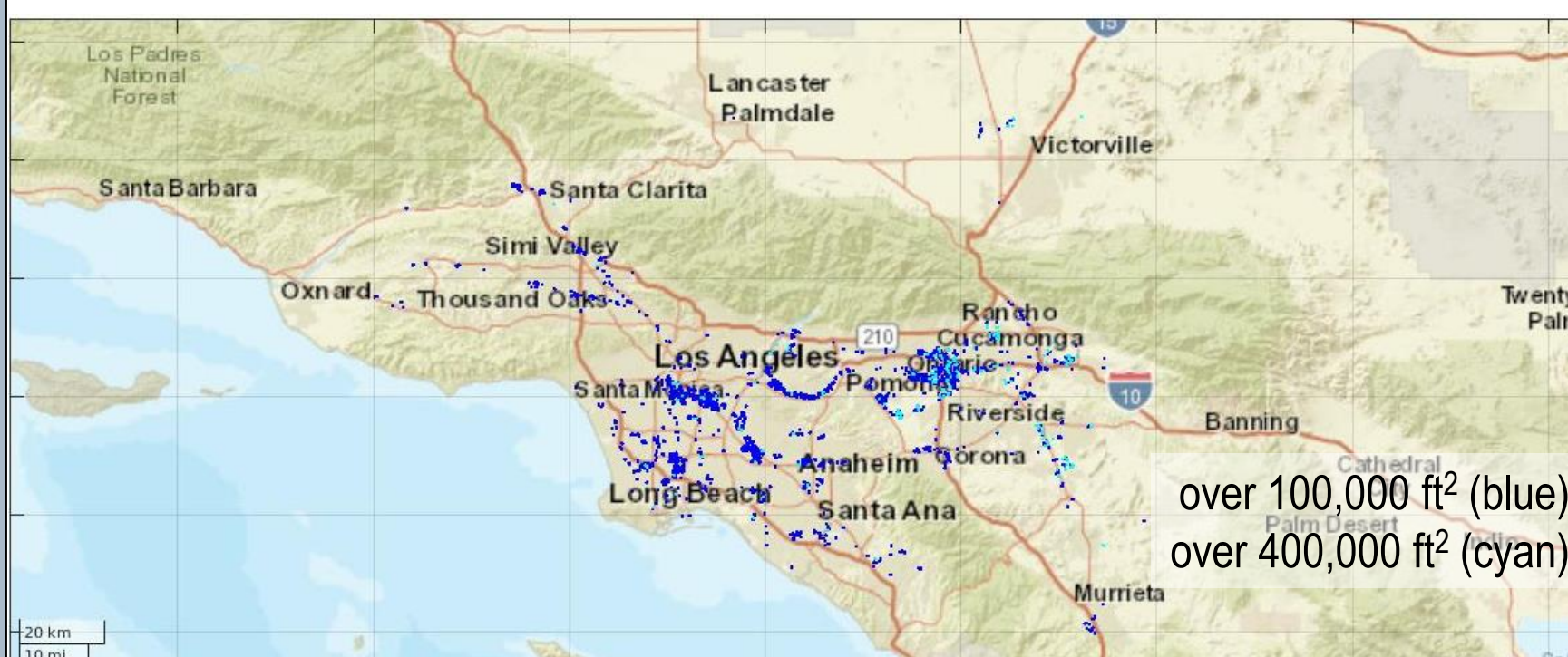


¹Data from US Census Bureau March 2023
(<https://www.statista.com/statistics/184484/new-private-sector-warehouse-construction-in-the-us-from-2002/>)

- Increased E-commerce has led to increasing numbers of warehouses/distribution centers in metropolitan areas to meet demand
- Prior research shows disproportionate warehouse citing in communities with higher proportions of low-income households and racial minorities
- Current uncertainty about best methodology to quantify impacts of diesel truck activity given long idling periods

The goal of this research is to better understand present capability to quantify warehouse associated emissions using CMAQ and satellite data

Warehouses in Los Angeles (as of End of 2022)



Methods

TROPOspheric Monitoring Instrument (TROPOMI) NO₂ Retrievals

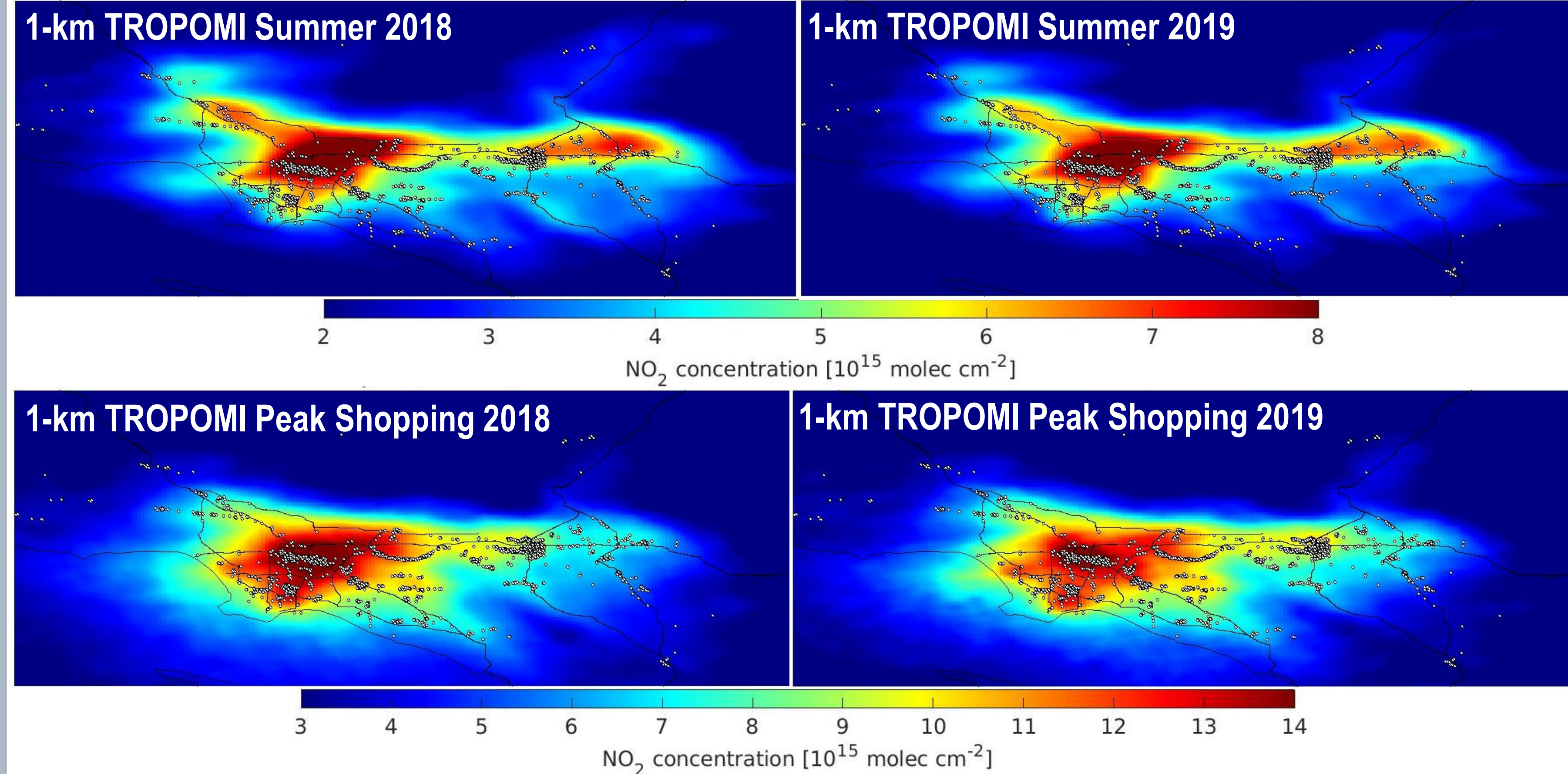
- Oversampled at 1-km and 4-km resolutions
- For 4-km resolution, CMAQ air mass factors used

Community Multiscale Air Quality Model (v5.4)

- 4-km resolution model with domain covering South Coast Air Basin
- 2016 NEI emissions platform
- WRF offline; BEIS online

EPA AQS used for ground monitoring data

Comparisons between TROPOMI NO₂ and CMAQ

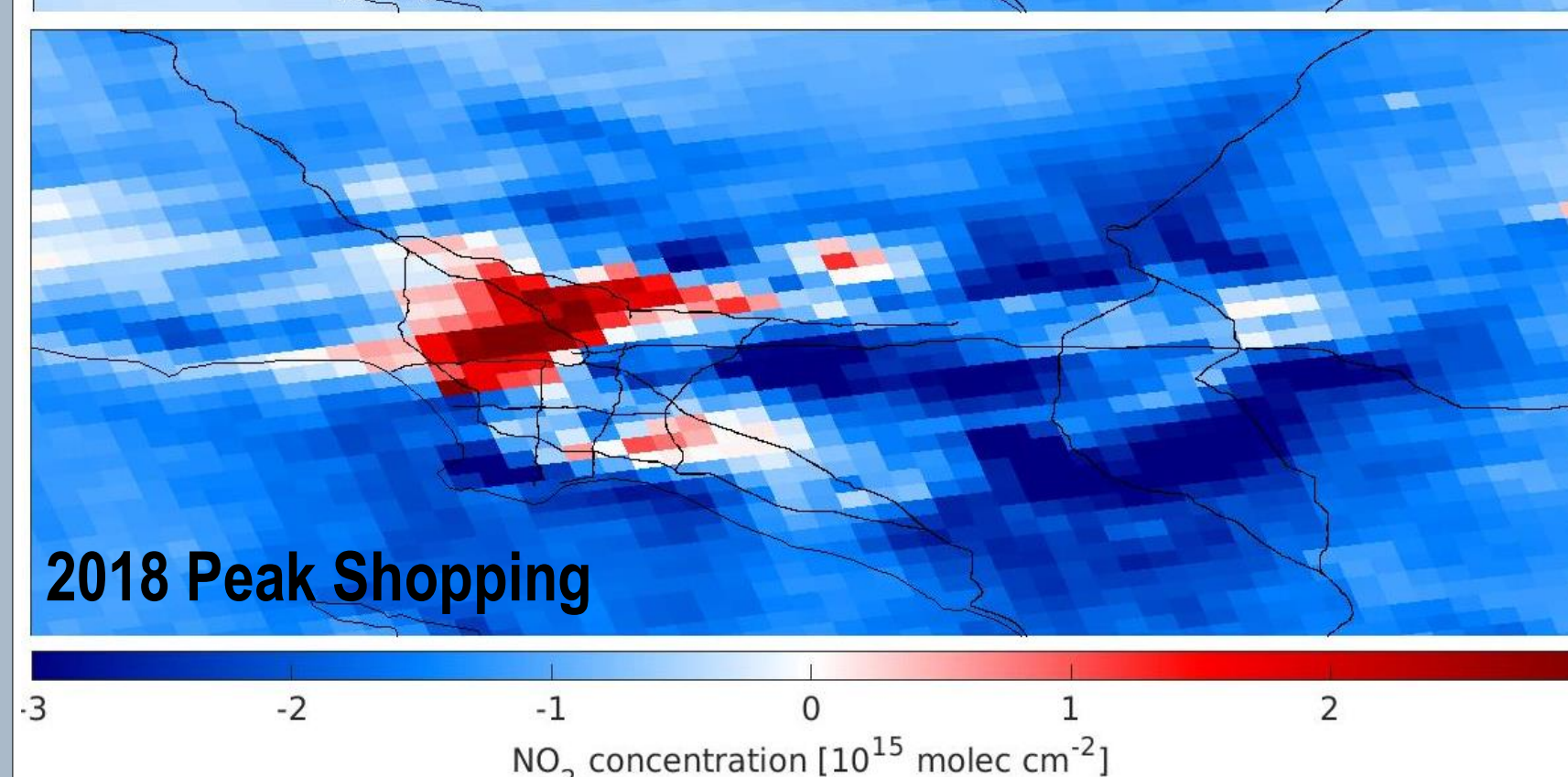
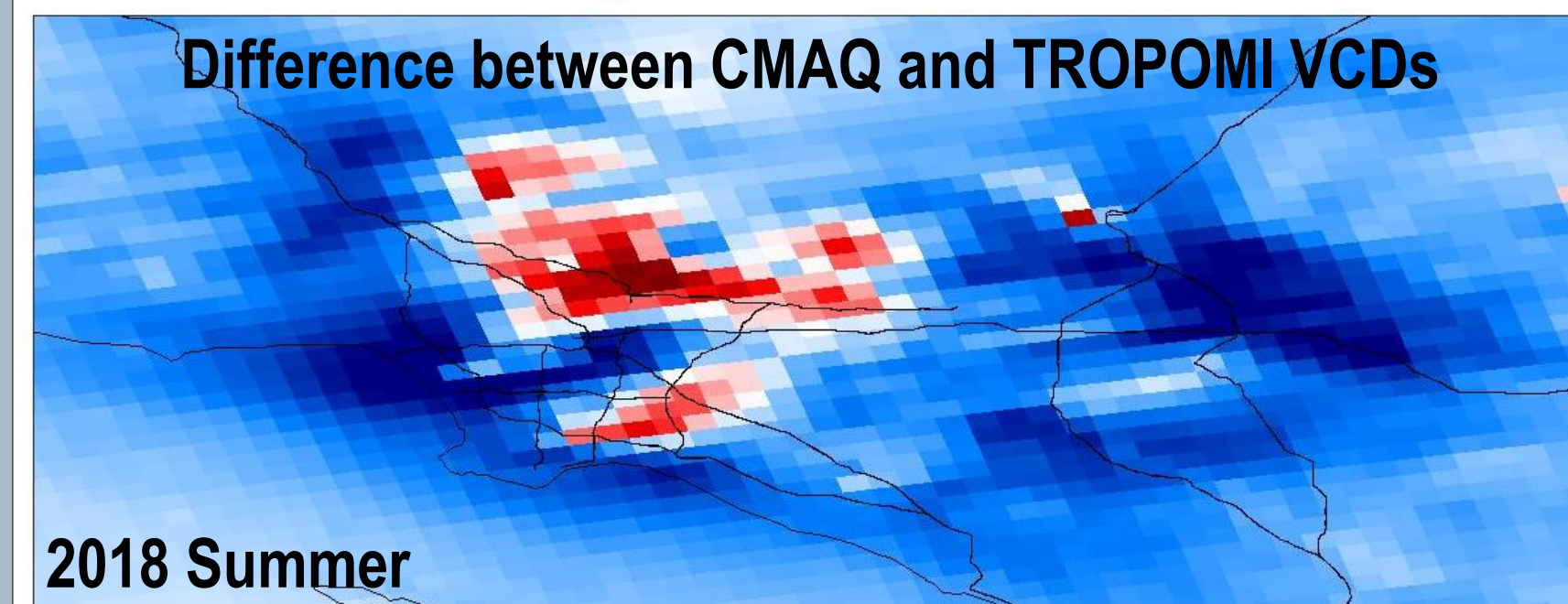
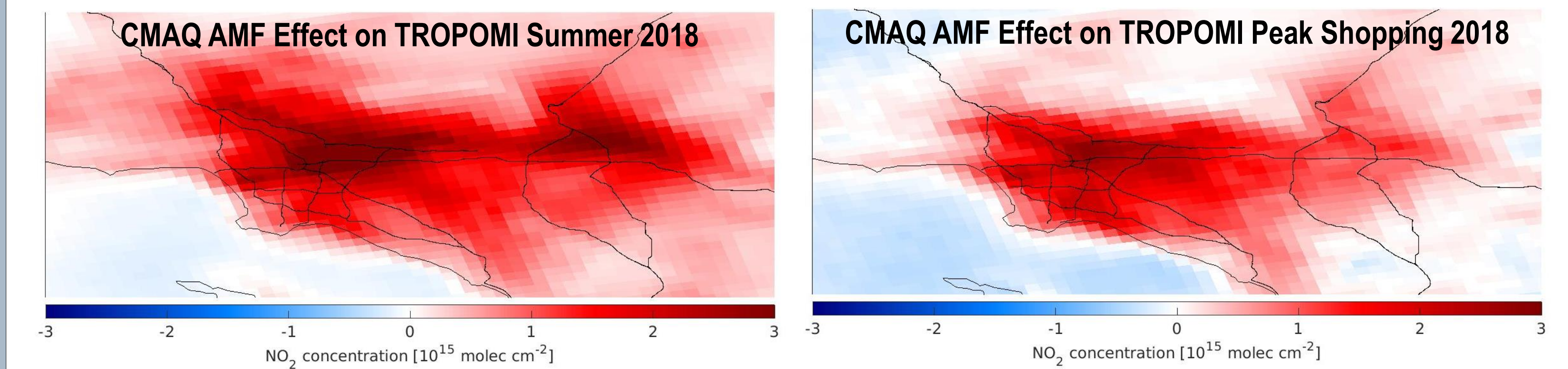


TROPOMI 1-km resolution for 2 seasons in 2018 and 2019 (above)

- Three hotspots (Los Angeles, warehouse dense area near Fontana, and San Bernardino) visible in summer
- Near warehouse hotspot further west along highway during peak shopping season (Oct-Jan)
- TROPOMI shows NO₂ follows highway closely

CMAQ AMF Effect on TROPOMI VCDs at 4-km resolution in 2018 (below)

- Substitution of finer resolution CMAQ AMF increased TROPOMI VCD over land with higher increases over summer periods than winter periods
- This pattern remained true across other years with increases up to 5×10^{15} mol/cm²

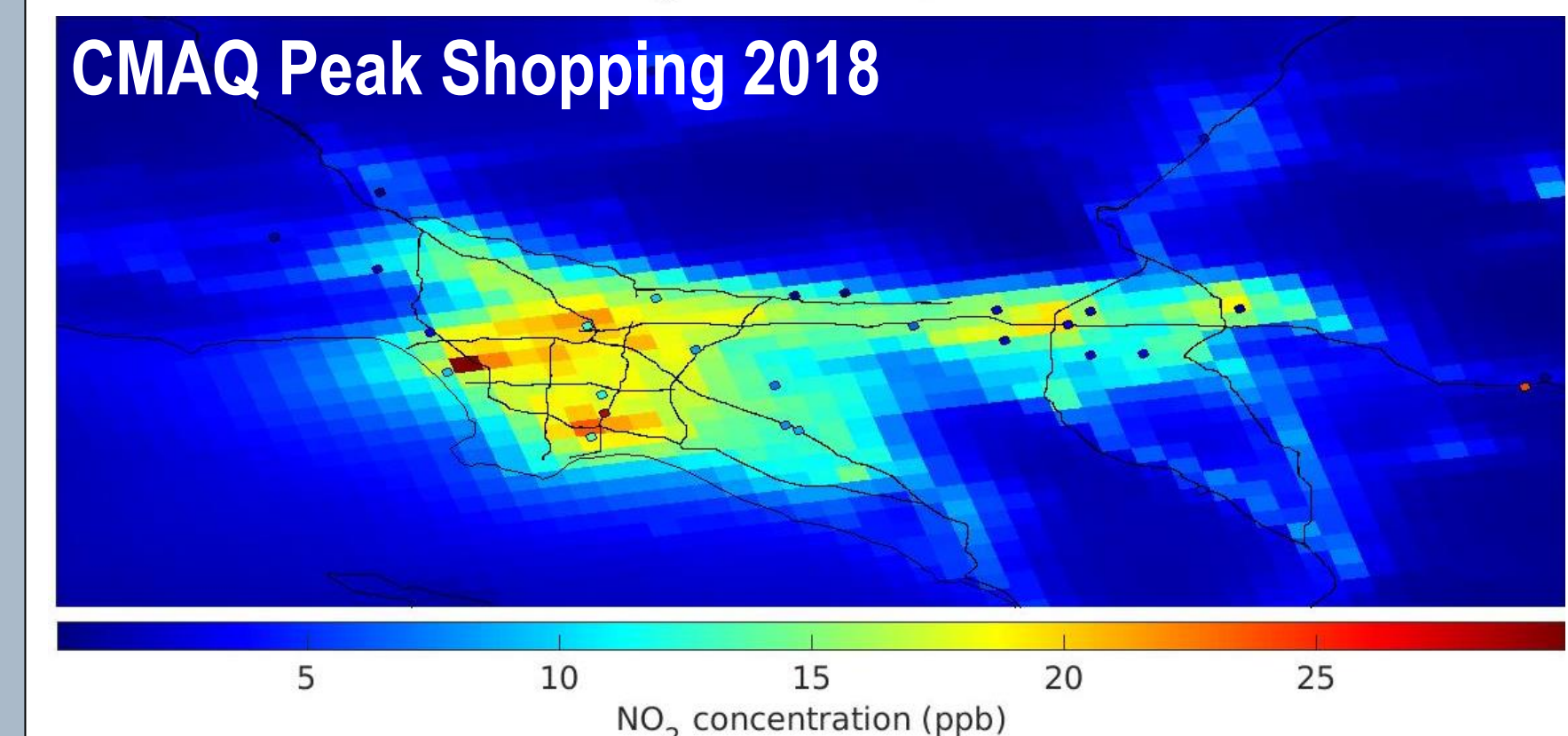
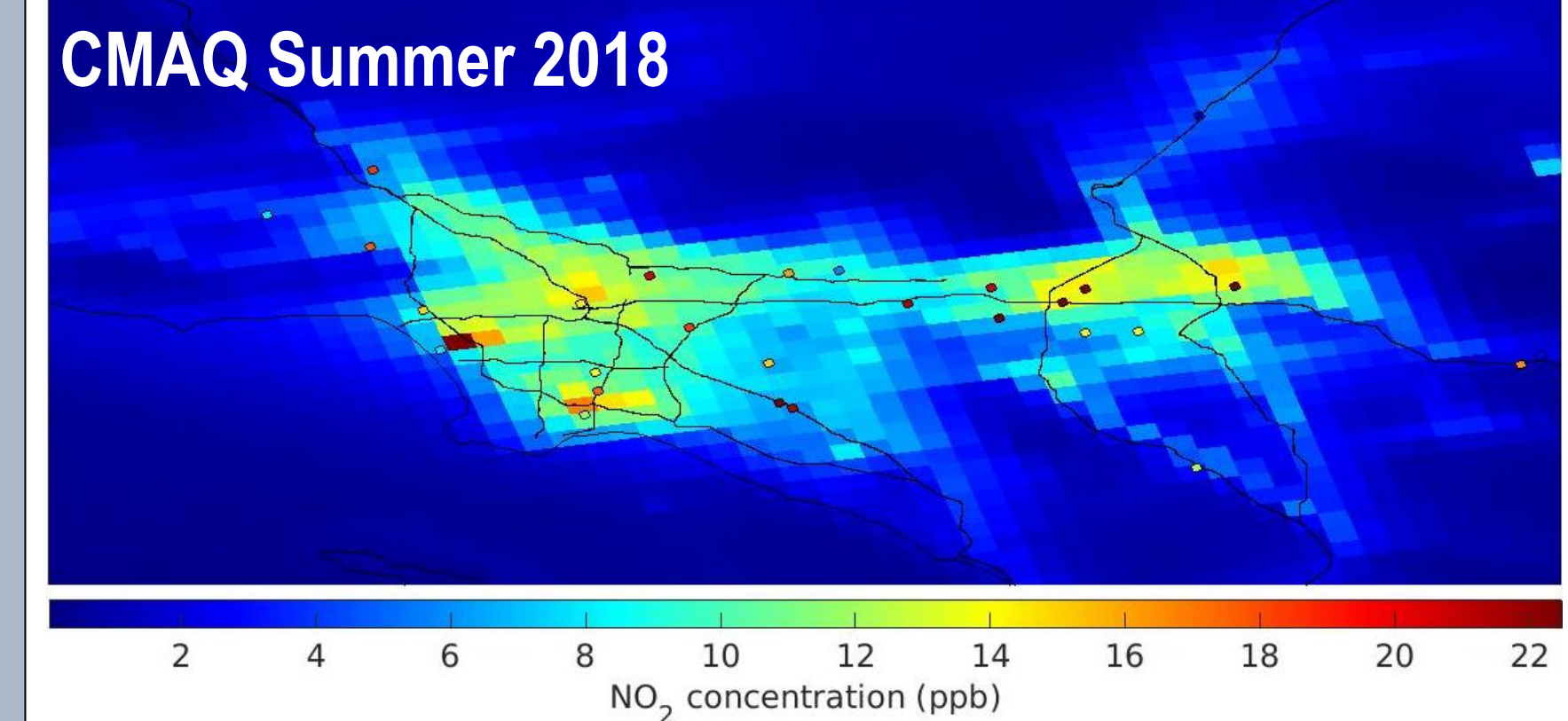


Normalized Mean Bias (%) between CMAQ and TROPOMI

	Summer			Peak Shopping Season		
	Overall	Warehouses >100K ft ²	Warehouses >400K ft ²	Overall	Warehouses >100K ft ²	Warehouses >400K ft ²
2018	-9.3	-18	-21	-9.1	-11	-15
2019	-6.8	-13	-17	-6.2	-2.1	-8.9
2021	-5.6	-5.7	-8.8	-7.6	-31	-31

- For figures to left, red represents CMAQ overestimation and blue represents CMAQ underestimation.
- CMAQ overestimates over the city of Los Angeles (north of downtown Los Angeles for summer, downtown for peak shopping season)
- Underestimation everywhere else with notable underestimations over San Bernardino
- CMAQ VCDs highly correlated with TROPOMI VCDs during all time periods analyzed ($r > 0.9$)
- Normalized mean bias (NMB) for grid cells with warehouses generally more negative than NMB of entire domain (with notable exception for warehouses over 100k ft² in 2019 peak shopping season)

Ground Measurement Comparisons



CMAQ surface hourly NO₂ averaged over the period with monitor data overlaid (in colored circles)

- During summer, CMAQ underestimates surface NO₂ at most monitors, notably at monitors along highways
- Although peak shopping season map seems to show CMAQ overestimation of surface NO₂, diurnal and NMB analyses do not support said result. Further analysis necessary to understand trend.

Conclusions

- A NO₂ hotspot in a warehouse-dense area was identified using TROPOMI VCDs, but it is uncertain how much is apportioned to warehouse-activity considering collocation with highways
- CMAQ AMF application to TROPOMI increases observed VCDs in domain
- More negative NMB for warehouse-only CMAQ to TROPOMI analyses indicate potential underestimation over warehouse grid cells compared to overall domain
- Summer CMAQ underestimates surface NO₂ at monitors along I-210 which includes warehouse-dense region

Acknowledgement

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