# Air Quality Impacts of Widespread Adoption of Cool Roofing Technology in the South Coast Air Basin: Ozone and $PM_{2.5}$

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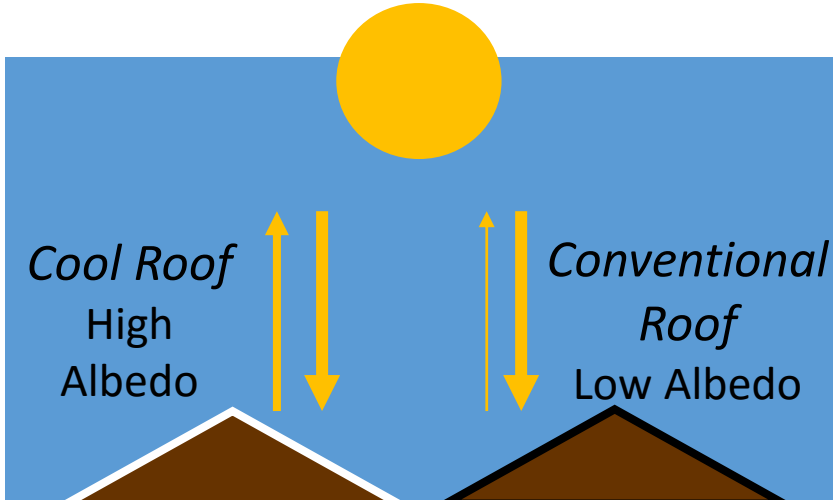
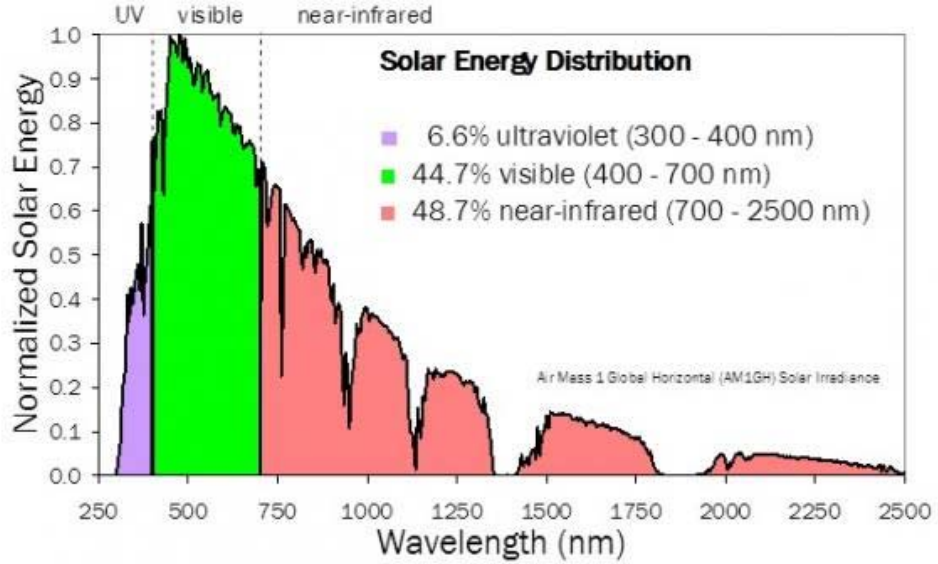
# What Are Cool Roofs?




[LBNL Heat Island Group]

[Google Maps]

Solar Reflectance (cool materials)

| | | | | | |
|---|---|---|---|---|---|
| 0.41 | 0.44 | 0.44 | 0.48 | 0.46 | 0.41 |
| 0.04 | 0.18 | 0.21 | 0.33 | 0.17 | 0.12 |

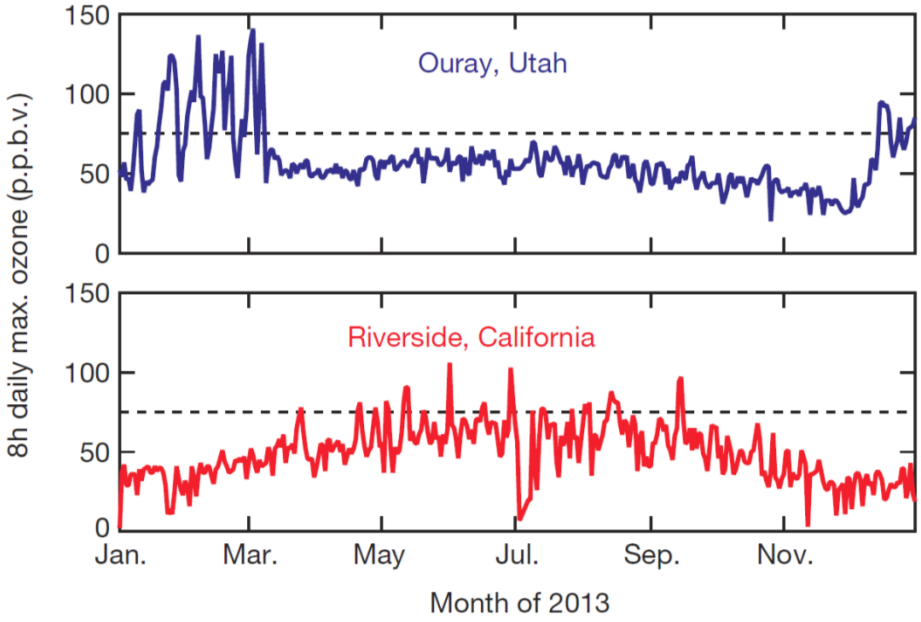
Solar Reflectance (standard materials)

[American Rooftile Coatings]

# Background

- Increased UV reflectivity of snow cover contributes to elevated O3 concentrations in Uintah Basin, Utah

[Edwards, et al. Nature 2014]



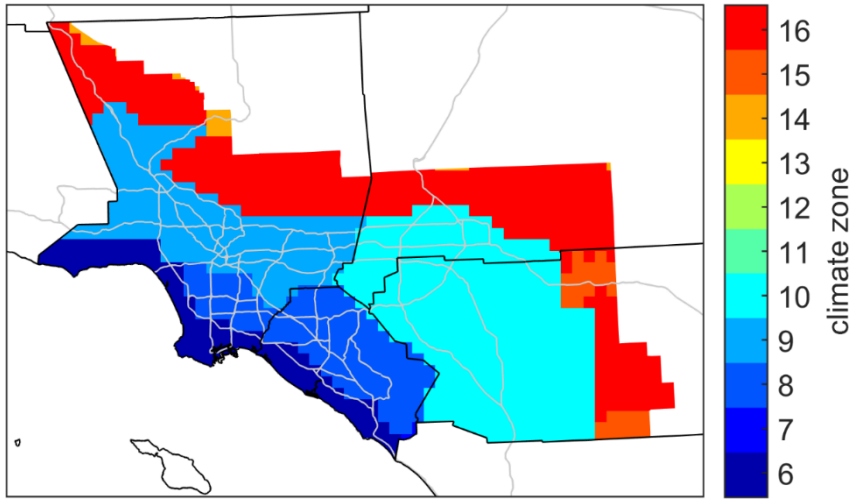

- Cool roofs are widely accepted to improve air quality *(Reasonably assumed that UV reflectance is constant)*
  [Taha, et al. 2008; Taha, et al. 2005; Akbari, et al. 2001; etc.]
- Cool roofs can decrease vertical mixing in the urban boundary layer
  [Fallmann, et al. Atmos. Environ. 2016 ]
- California Title24 Energy Efficiency standards prescribe cool roofs for renovations or new roof installations

# Project Goals

- Effects are complex and non-linear
  - UV Albedo ↑, Ozone reaction rate ↑
  - Albedo ↑, Temp ↓, Ozone reaction rate ↓
  - Albedo ↑, mixing height ↓, pollutant concentrations ↑

- **Quantify air quality impacts of cool roofs in South Coast Air Basin**
  - Simulate adoption of CA Title24 energy efficiency standards
  - Account for meteorological changes (Weather Research Forecast Model, WRF)
  - Account for increased reflectivity and photochemistry (modified CMAQ v5.0.2)
  - Simulate air quality in base year and future year

# Title 24 Simulations




| Category | Climate Zones | Current Albedo* | Title 24 New Albedo |
|---|---|---|---|
| Non-Residential Low Slope | all | 15 | 63 |
| Non-Residential High Slope | all | 20.1 | 20 |
| High-Rise Low Slope Residential, Hotel, and Motel | 9-11, 13-15 | 23 | 55 |
| High-Rise High Slope Residential, Hotel, and Motel | 2-15 | 24.7 | 20 |
| Residential Low Slope | 13-15 | 21.8 | 63 |
| Residential High Slope | 10-15 | 17.1 | 20 |

* Values calculated by integrating high resolution land use data and data from [Ban-Weiss et al. 2015]

# Rooftop Area Database Development

High resolution land use data from Southern California Association of Governments

Translate categories

Title 24 land use footprints

High resolution building footprints from US Army Corps of Engineers (~85% coverage)

Assign to 4km Grid

Fractional coverage of each Title 24 Land Use Category (~85% coverage)

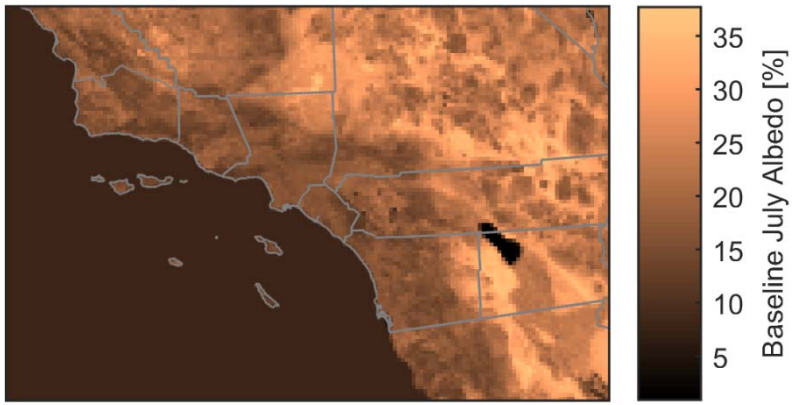
Interpolation

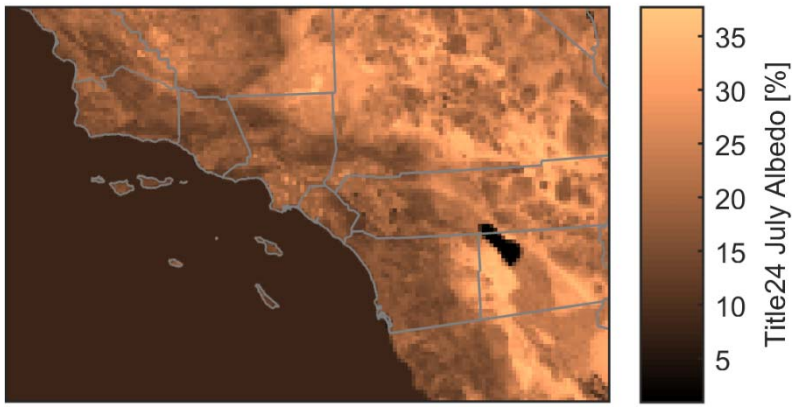
Assign to 4km Grid

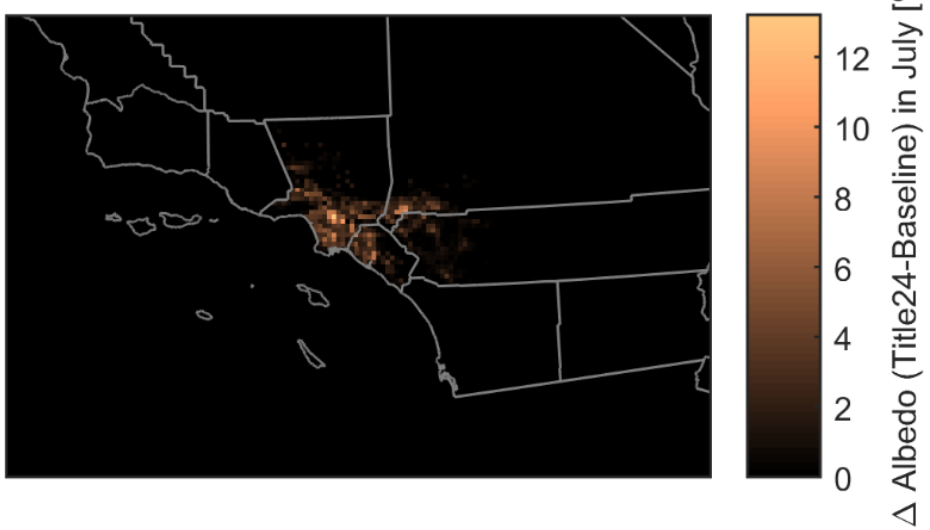
Fractional coverage of each Title 24 Land Use Category (100% coverage)

Rooftop Area of Each Title24 Land Use Category

# Baseline Albedo From MODIS Adjusted to Represent Full Implementation of Title24

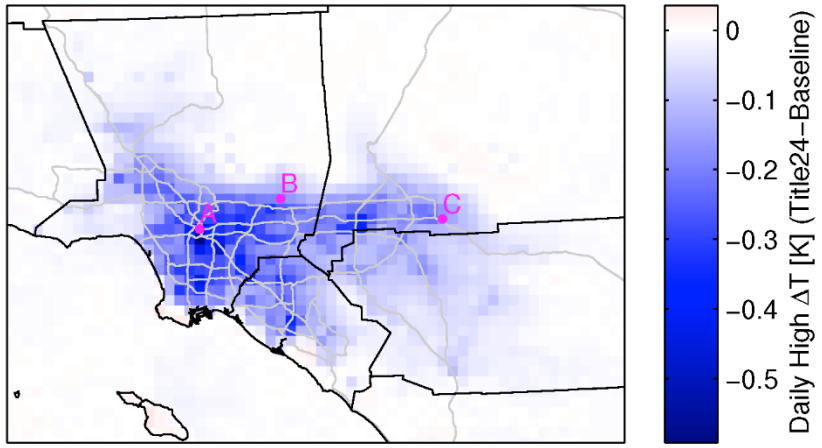


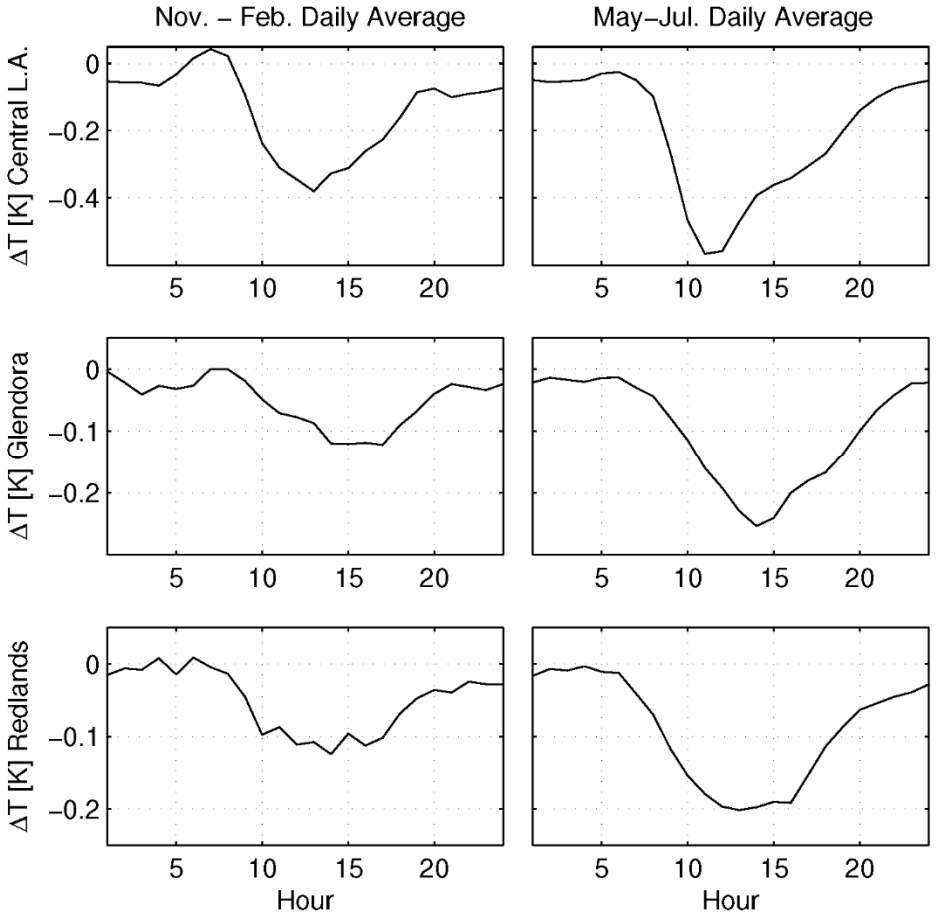



# Title24 and Baseline Temperature Differences

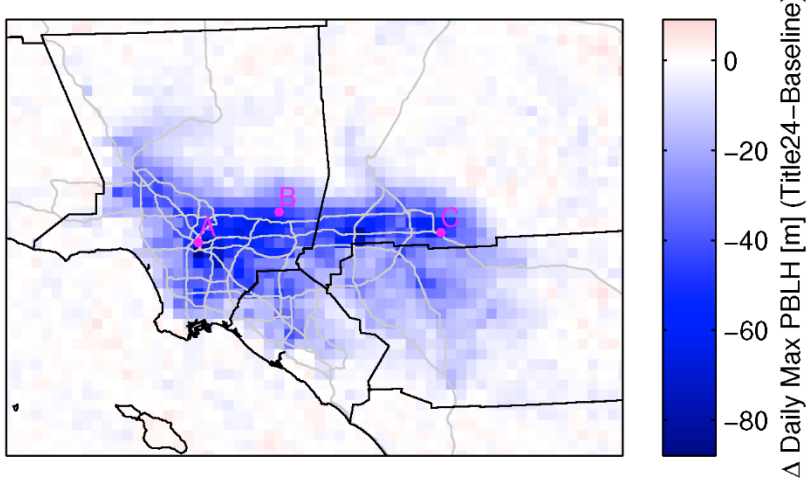
Difference in Yearly Averaged Daily High Temperatures

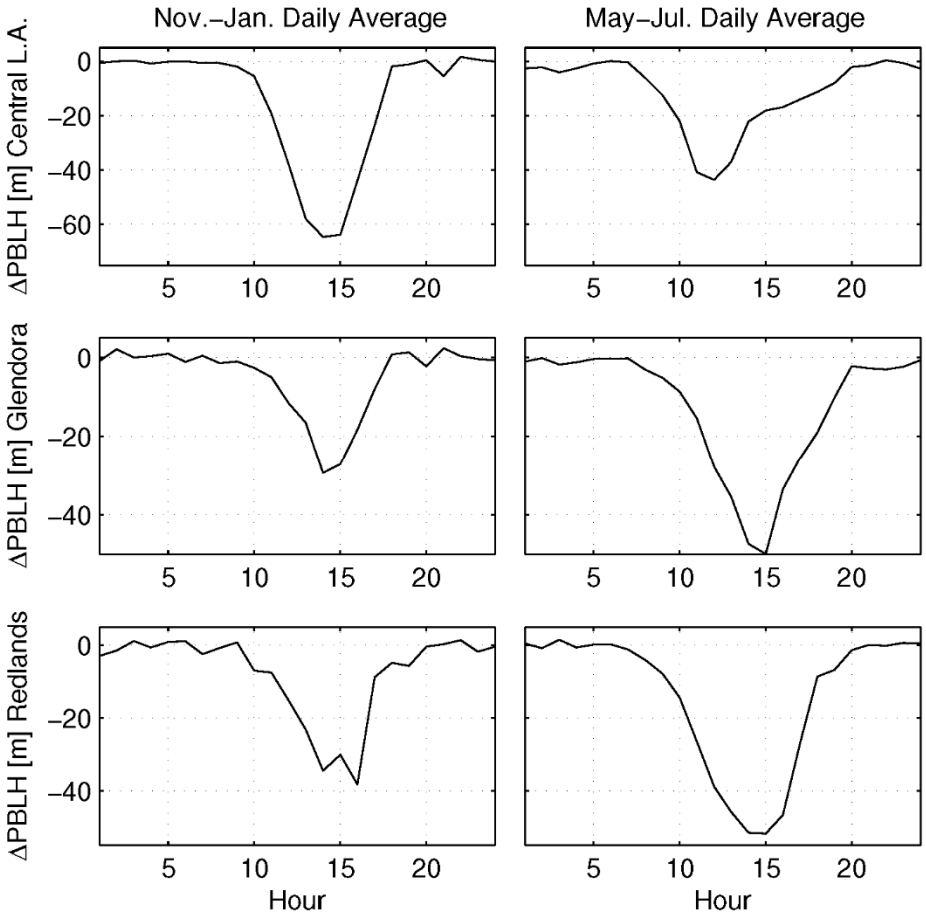


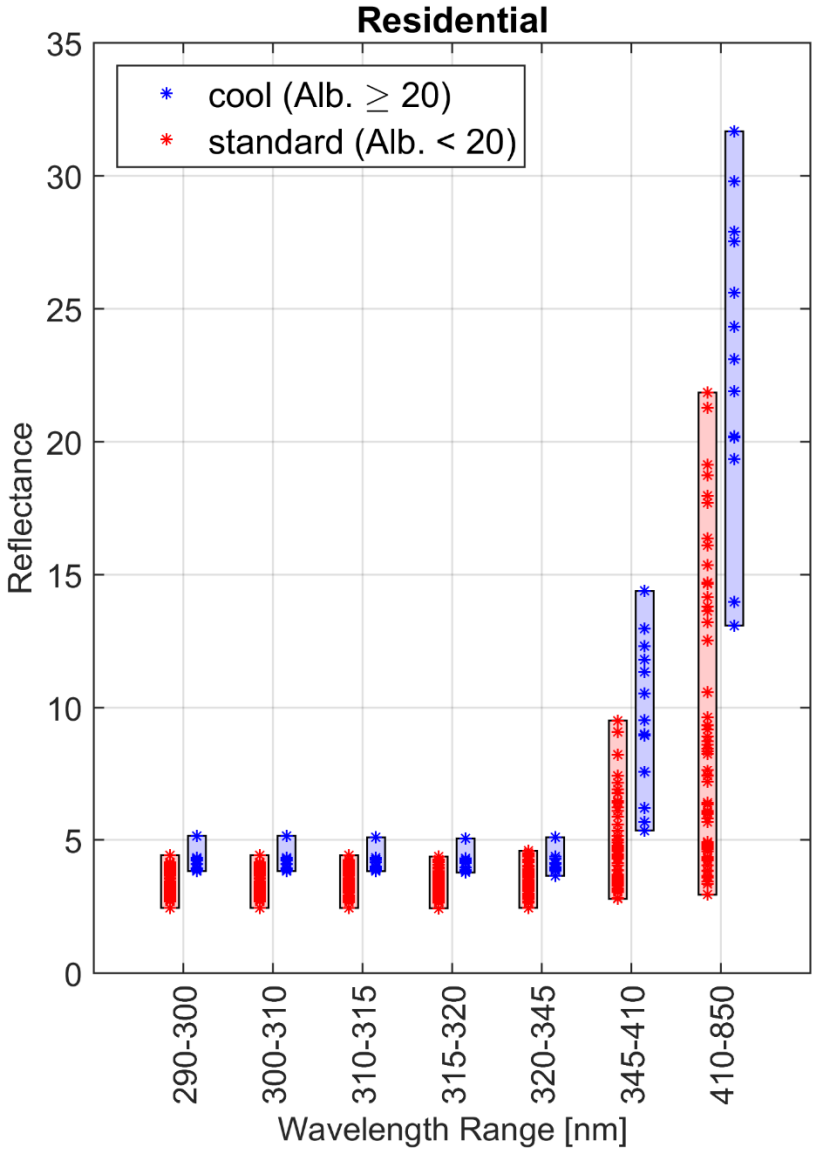
# Title24 and Baseline PBL Height Differences

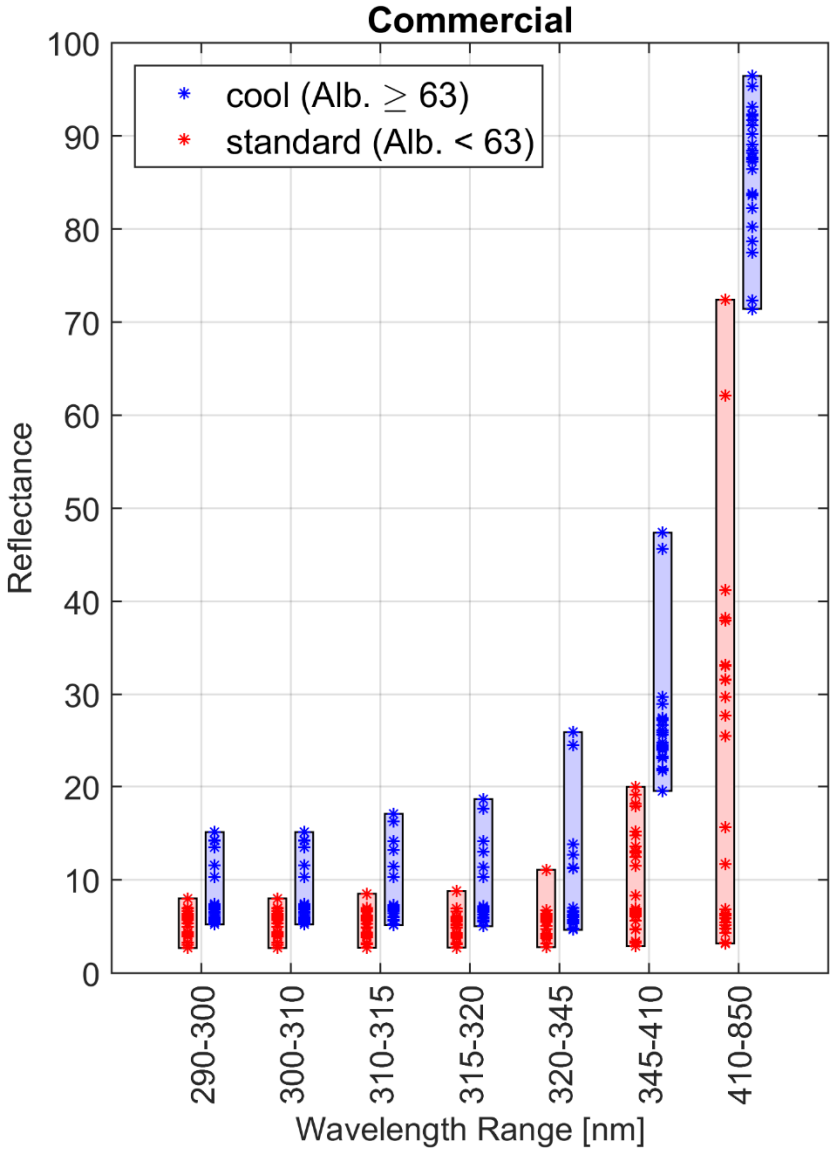
Difference in Yearly Averaged Maximum Mixing Layer Height



# Wavelength Dependent Changes in Albedo for CMAQ Simulations



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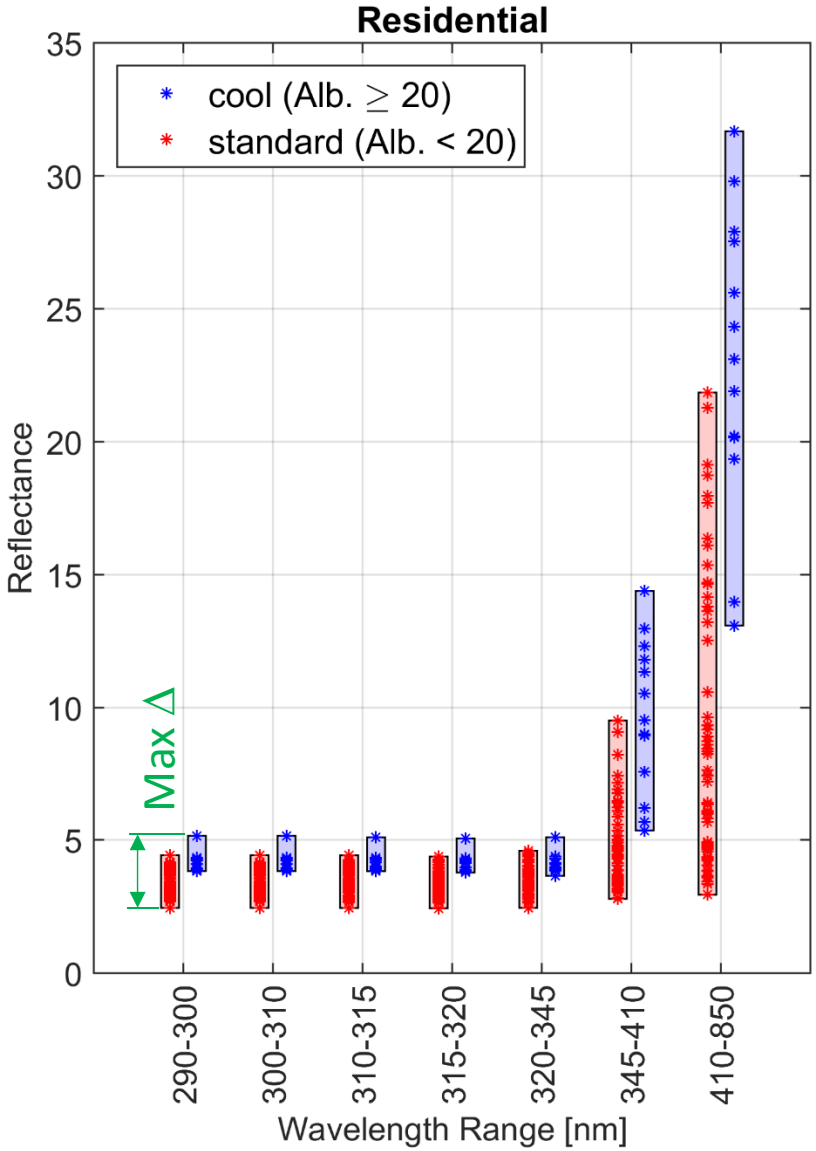
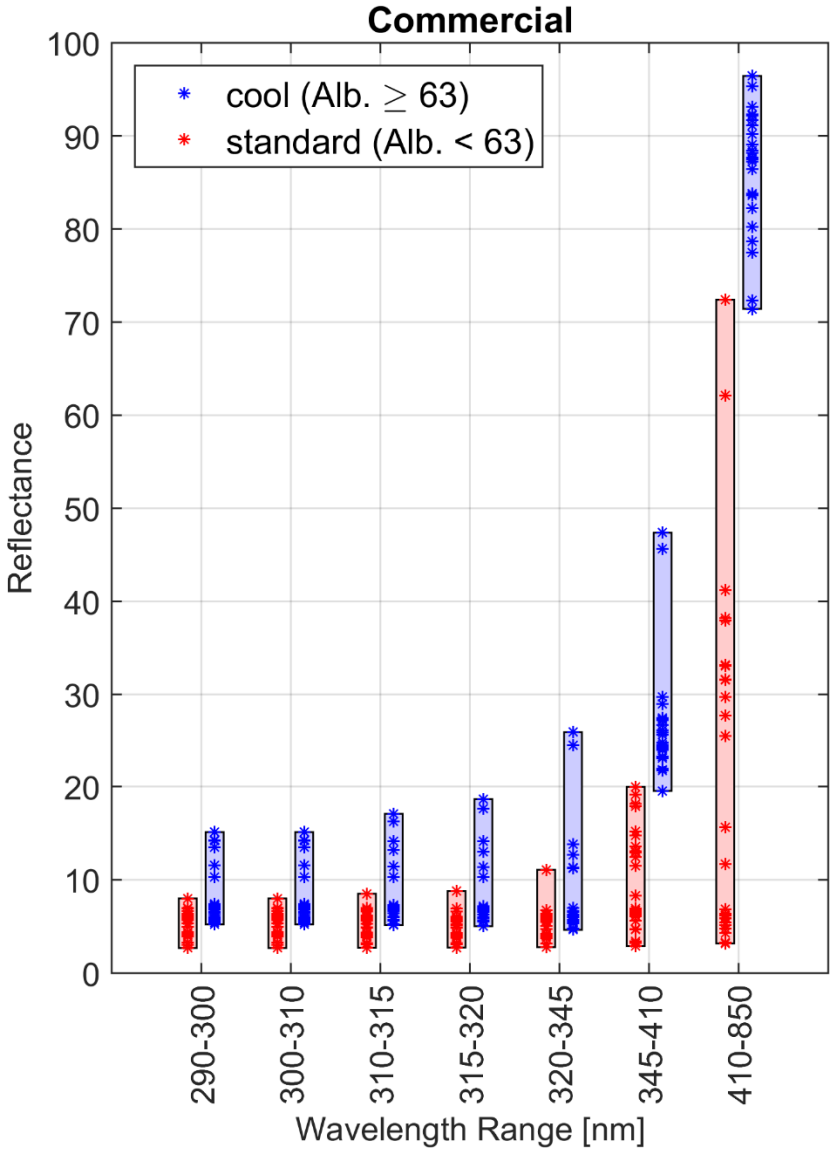
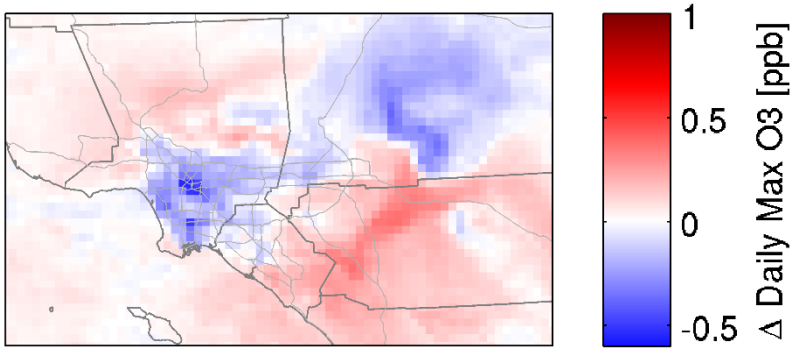


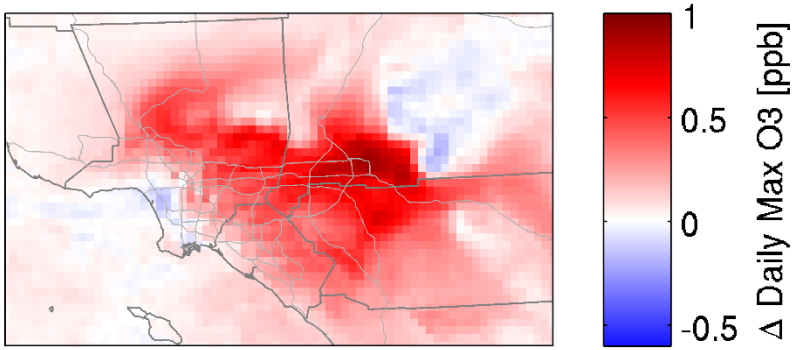
# Spatial Changes in Ozone

## Increase in 8-hour Daily Maximum $O_3$

No Increase in UV

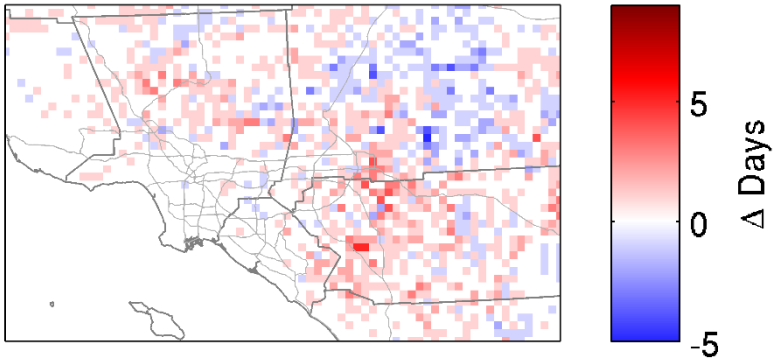



Increase in UV = max

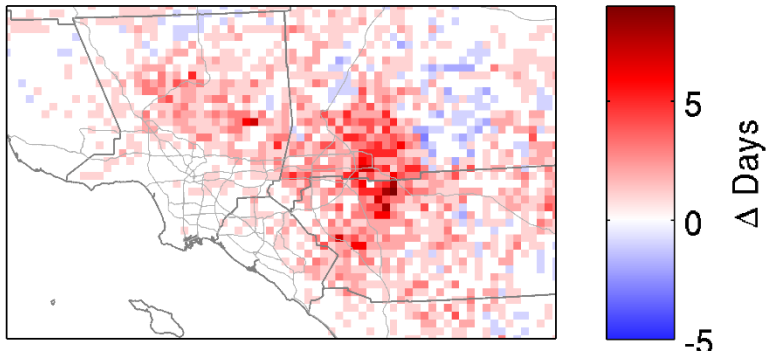



## Increase in $O_3$ Exceedance Days (75 ppb 8-hr standard)

No Increase in UV




Increase in UV = max



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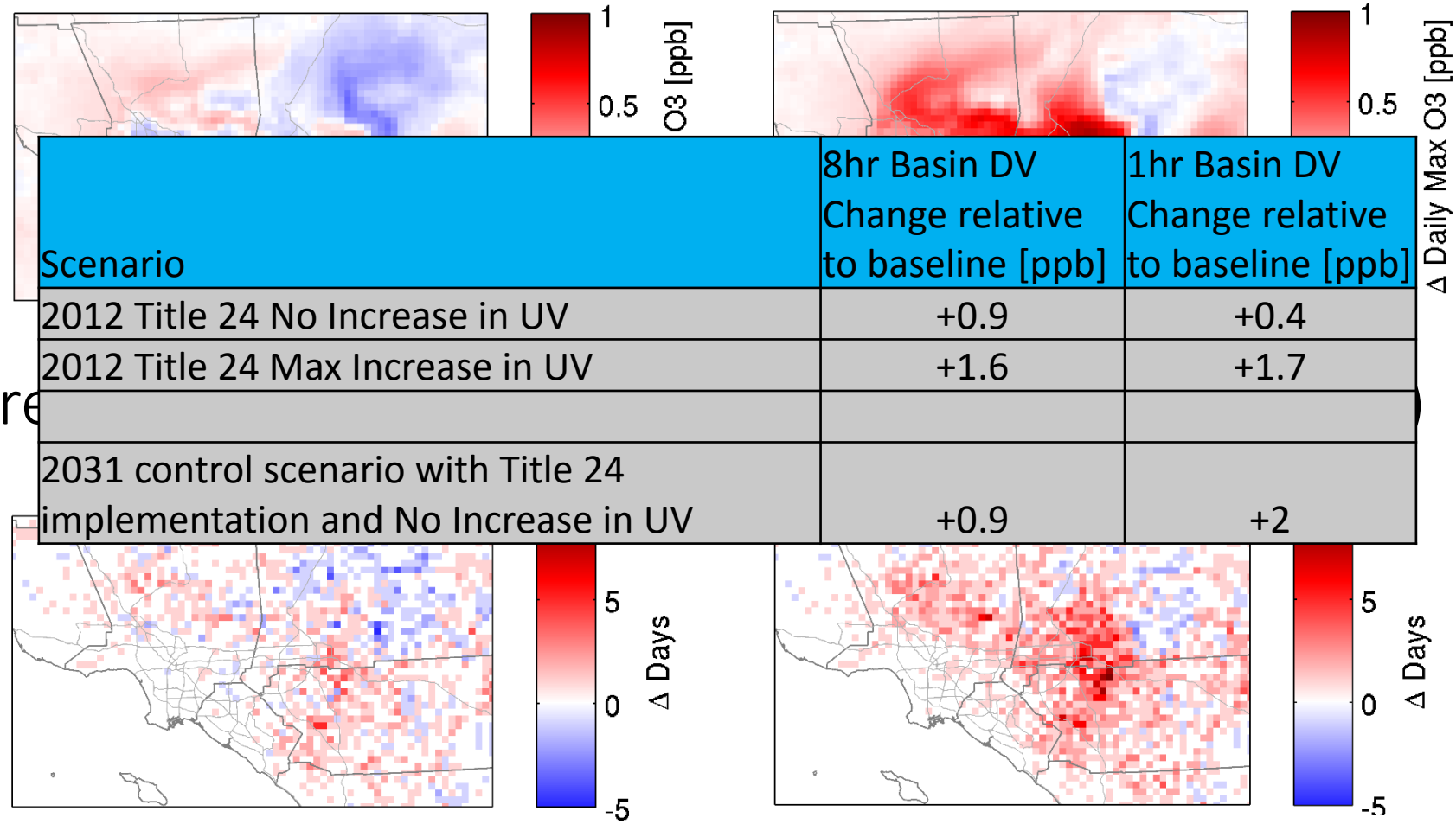
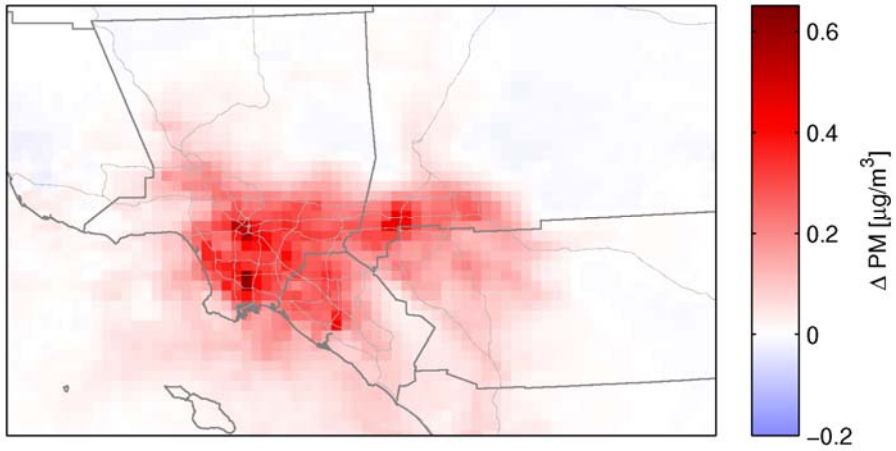



| Scenario | 8hr Basin DV Change relative to baseline [ppb] | 1hr Basin DV Change relative to baseline [ppb] |
|---|---|---|
| 2012 Title 24 No Increase in UV | +0.9 | +0.4 |
| 2012 Title 24 Max Increase in UV | +1.6 | +1.7 |
| | | |
| 2031 control scenario with Title 24 implementation and No Increase in UV | +0.9 | +2 |

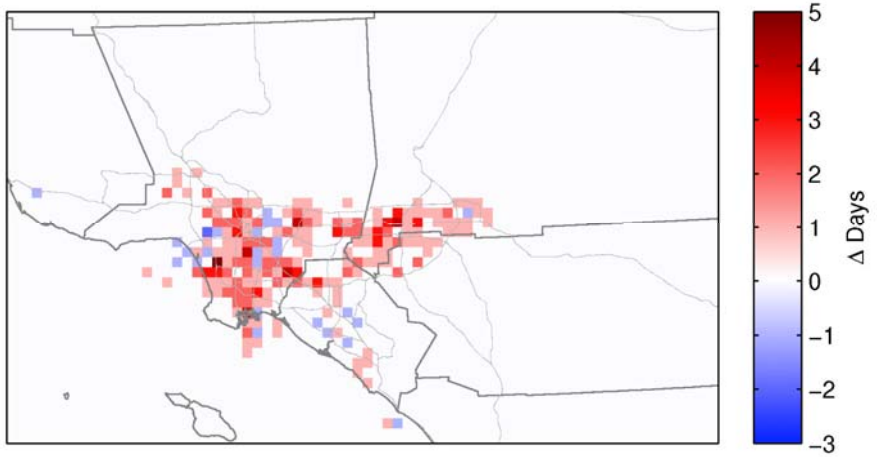
Incre

# Increase in PM2.5 Levels

Change in Annual $PM_{2.5}$



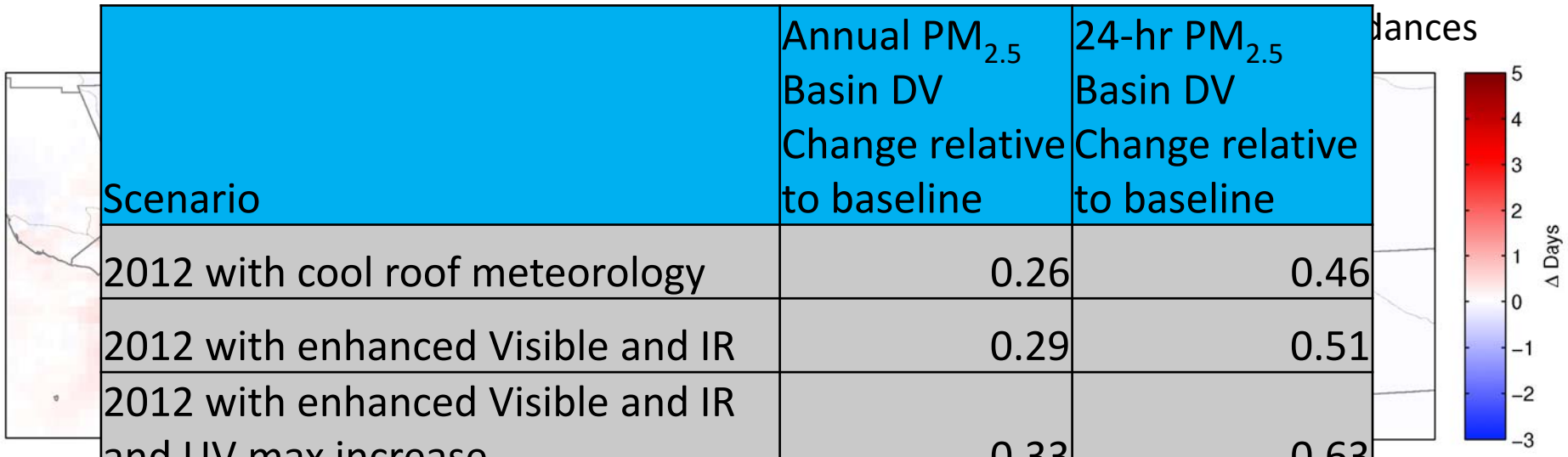

Change in 24-hour $PM_{2.5}$ Exceedances




- Elevated concentrations likely due mostly to reduced mixing height in cool roof scenario.

# Increase in PM2.5 Levels

| Scenario | Annual $PM_{2.5}$ Basin DV Change relative to baseline | 24-hr $PM_{2.5}$ Basin DV Change relative to baseline |
|---|---|---|
| 2012 with cool roof meteorology | 0.26 | 0.46 |
| 2012 with enhanced Visible and IR | 0.29 | 0.51 |
| 2012 with enhanced Visible and IR and UV max increase | 0.33 | 0.63 |




- Elevated concentrations likely due mostly to reduced mixing height in cool roof scenario.
- PM concentrations not significantly affected by increased UV albedo

# Conclusions

- Widespread installation of cool roofs in the SoCAB will likely lead to slightly elevated PM2.5 levels
  - Simulations with Temperature-dependent biogenic and anthropogenic emissions currently being simulated
- Magnitude of $O_3$ impacts heavily dependent on changes in UV reflectance
  - Policy relevant $O_3$ concentrations in the most polluted areas of the Basin increase with widespread installation
  - If UV reflectance remains constant, $O_3$ increases are mitigated in most polluted areas of the Basin and Basin-wide population-weighted $O_3$ exposure is reduced
  - If UV reflectance increases significantly, $O_3$ concentrations increase Basin-wide
- Important to consider other non-air quality related benefits of cool roofs (climate and health)