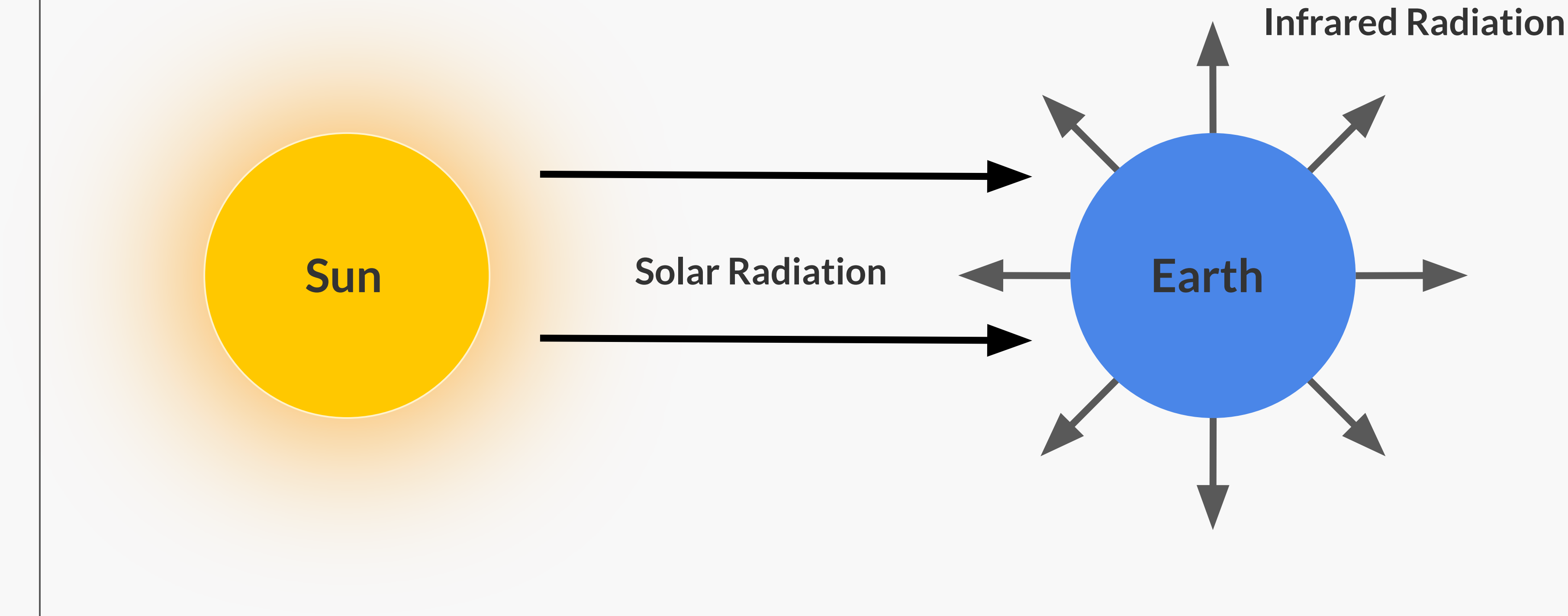
Estimating Aerosol Optical Properties Using Mie Theory and Analyzing Their Impact on Radiative Forcing in California

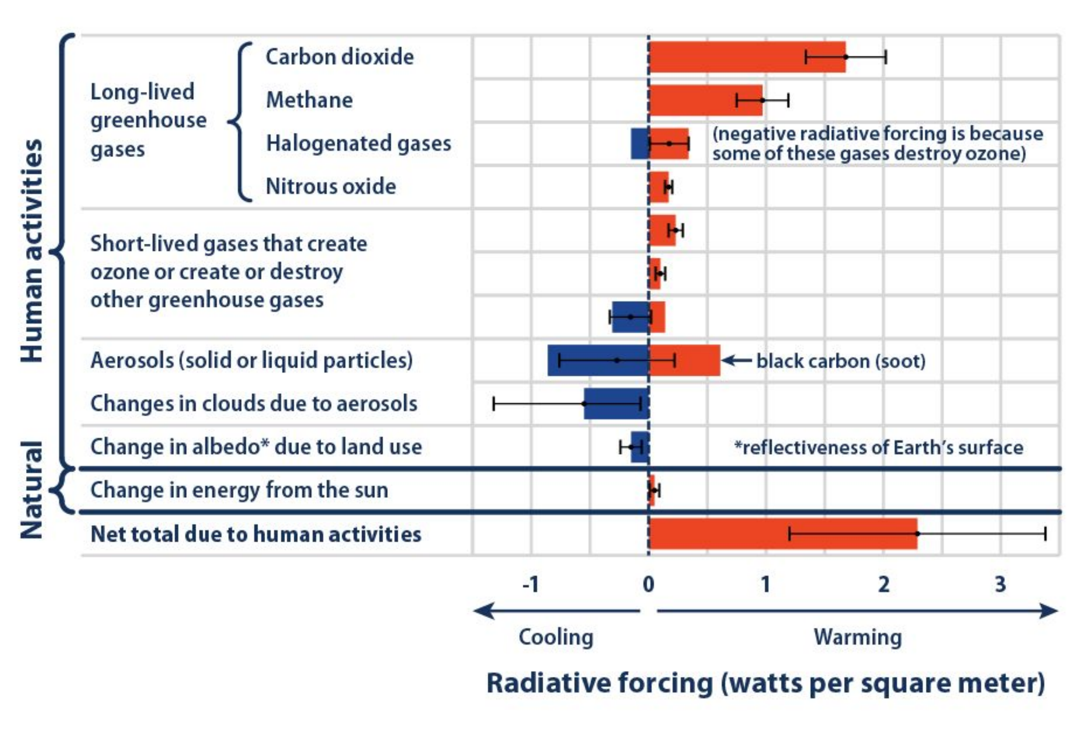
Alison Thieberg[1], Andreas Beyersdorf[2], Maddy Landi[3], Ann Marie Carlton[3]

Emory University[1], California State University, San Bernardino[2], University of California, Irvine[3]

Radiation Balance on Earth

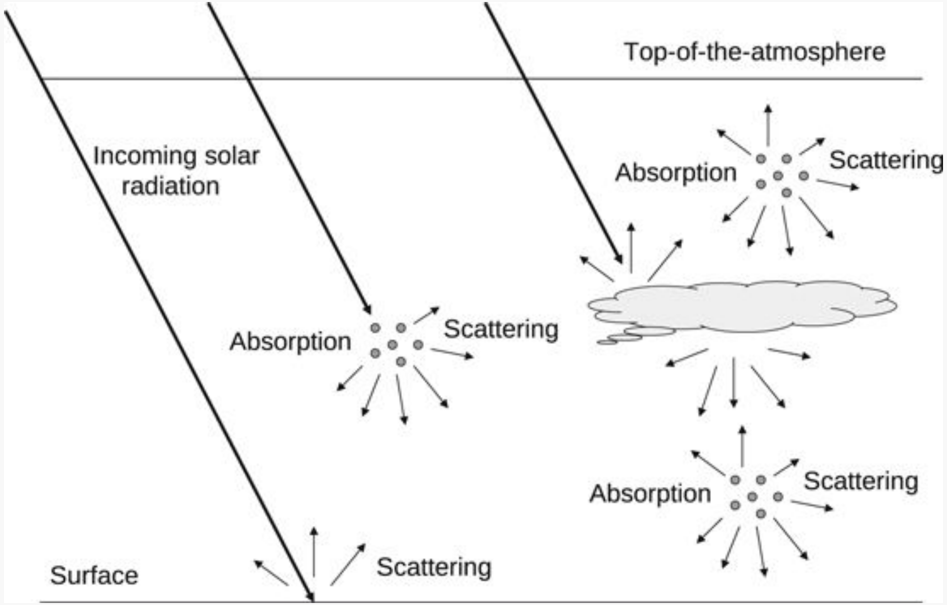


Radiative Forcing in the Anthropocene



(IPCC 2013)

Aerosols and Cooling



(Boucher 2015)

How has radiative forcing from aerosols changed over time in Southern California?

(Barboza 2021)

Using Airborne Data

The NASA Langley Aerosol Research Group has been collecting data on SARP flights:

- Aerosol composition (AMS)
- Aerosol size (UHSAS or LAS)
- Aerosol optical properties

- (NASA LARGE 2024)

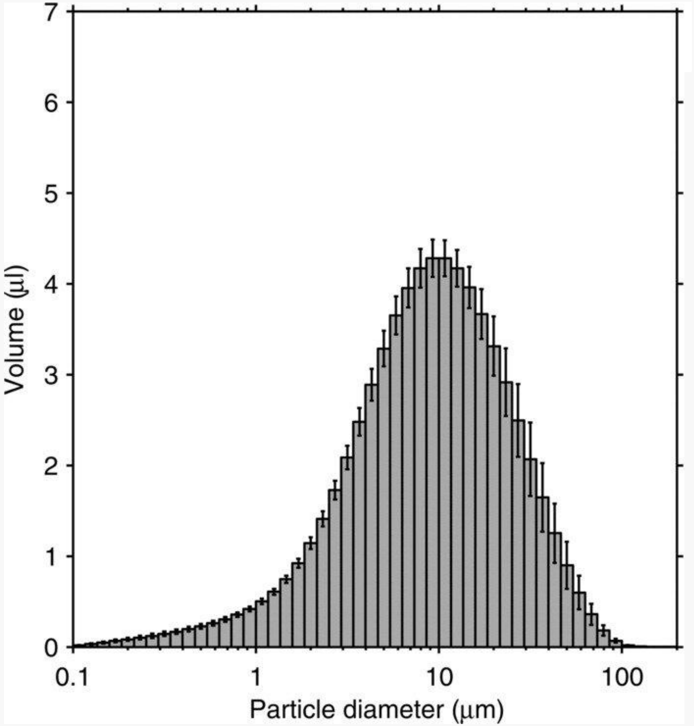
Estimating Size and Refractive Parameters

Determining a refractive index from the weight of:

- Organics
- Ammonium Nitrate
- Ammonium Sulfate
- Black Carbon

Determining an aerosol diameter from:

- Weight of size distribution bins

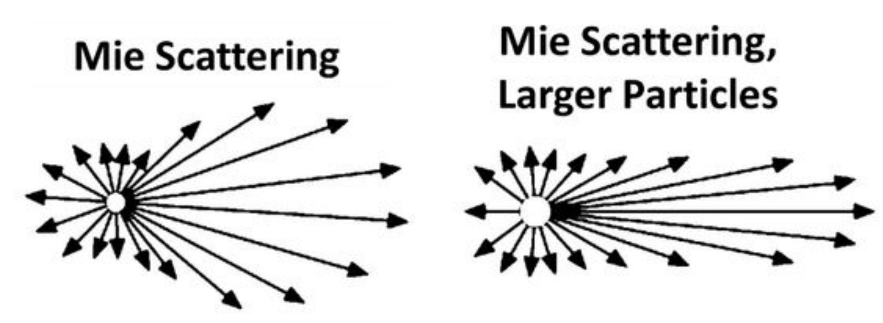


(Lindsley 2023)

Determining Upscatter Fraction

[in]: miepython.mie(refractive index, size parameter)
[out]: scattering efficiency (Q_{sca}) and back-scattering efficiency (Q_{back})

$$\frac{Q_{back}}{(Q_{sca})(4\pi)} = \text{backscatter fraction (b)}$$



$$0.082 + 1.85b - 2.97b^2 = \text{upscatter fraction } (\beta)$$

(Anderson 1999)

(Barnhart 2020)

Determining Relative Radiative Forcing

Equation calculates radiative forcing due to the aerosol

$$\Delta F_{eff} = -0.5\, S_0\, T^2\, (1-A_C)\ \mathbf{SSA}\, \boldsymbol{\beta}\ \{(1-R)^2 - (2R/\boldsymbol{\beta})[(1/\mathbf{SSA}) - 1]\}$$

(Langridge 2012)

Constants:

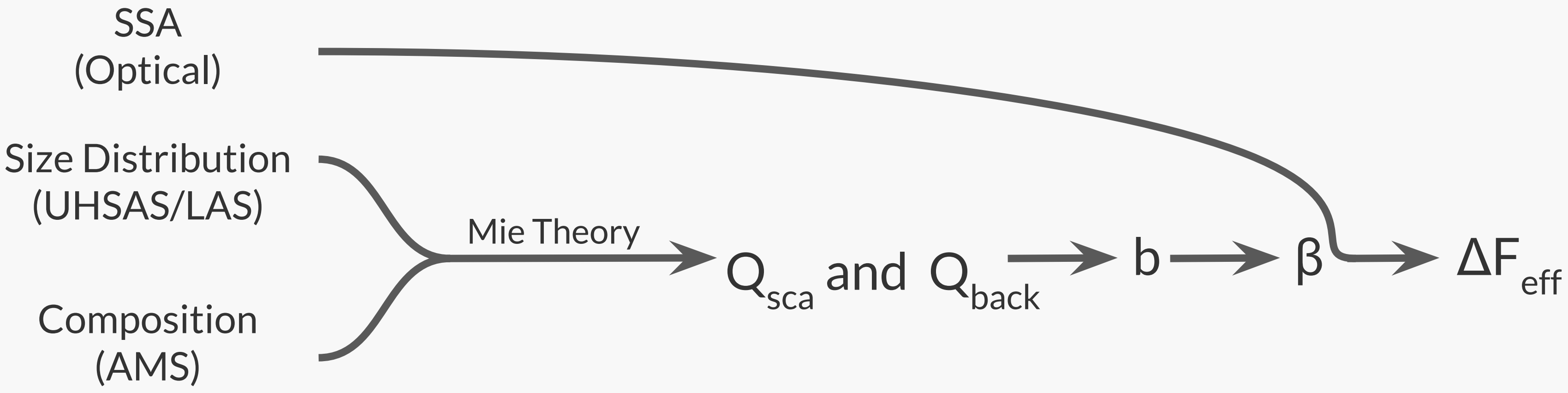
- S_0 :Solar constant
- T :Atmospheric transmission
- A_C :Cloud fraction
- R :Surface albedo

Variables:

- **β** :Upscatter fraction (calculated using mie theory)
- **SSA** :Single scattering albedo (measured or calculated using scattering and absorption measurements)
-

Data Flow Overview

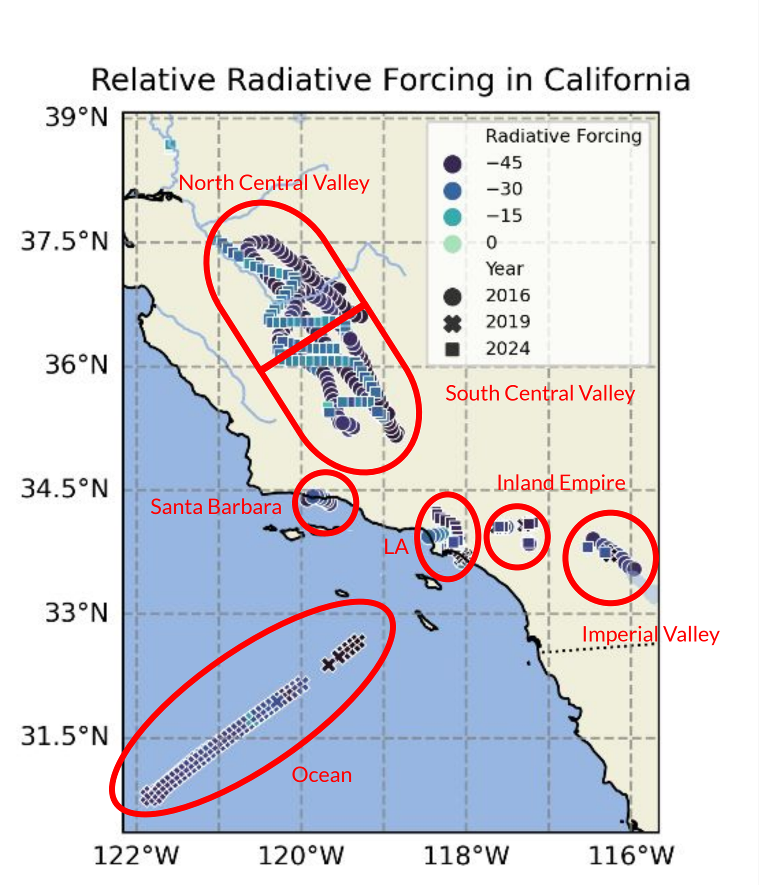
SARP Data



Applying Theory

Methodology was applied to SARP data from 2016, 2019, and 2024:

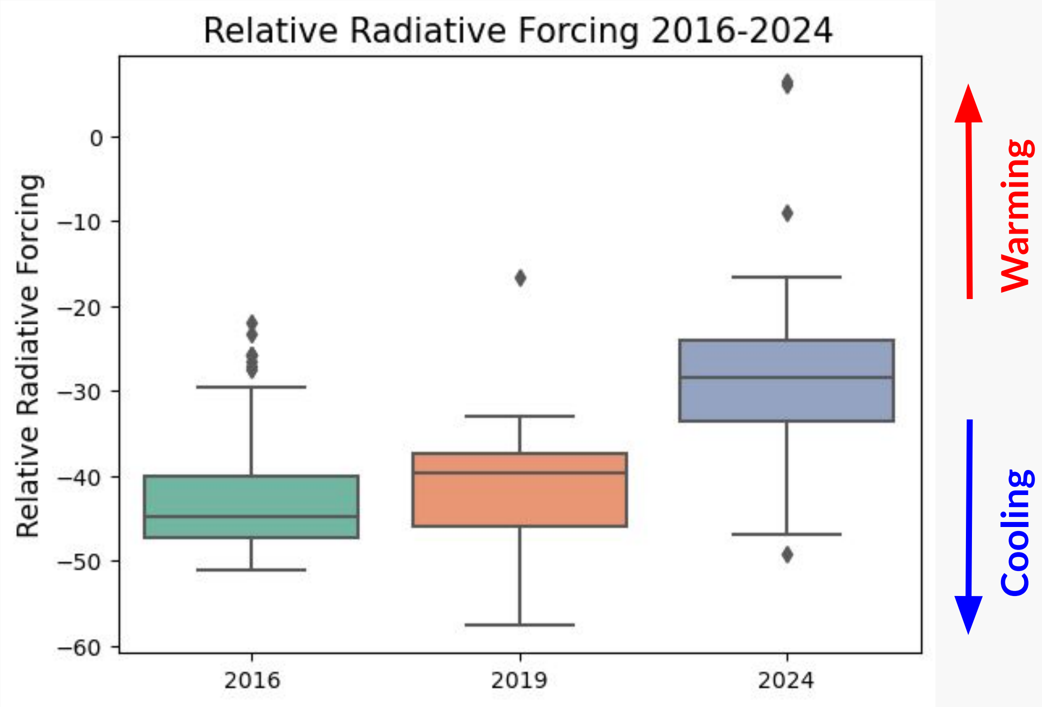
- Only observations underneath 2000ft were analyzed
- Observations with missing size, composition, or optical data were disregarded
- Relative radiative forcing was calculated for 383 minute averages
- Regional bounds were created for further analysis



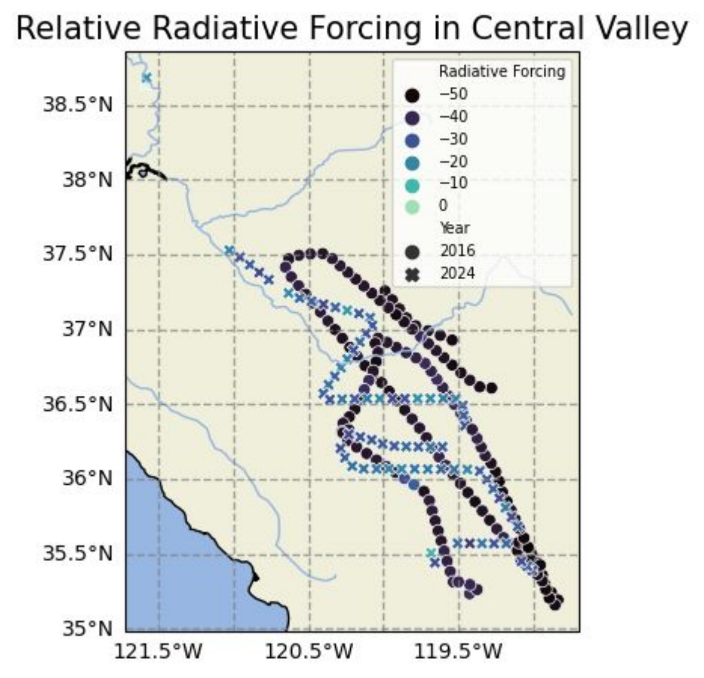
Results by Year

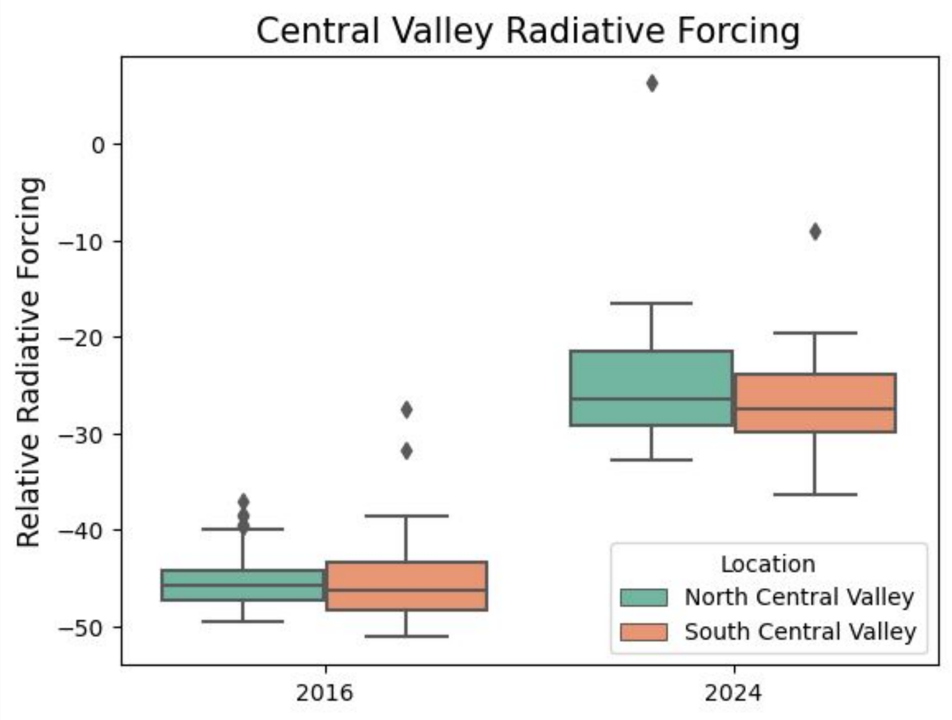
A more negative radiative forcing means more cooling and a less negative radiative forcing means less cooling

Plot does not account for regional differences

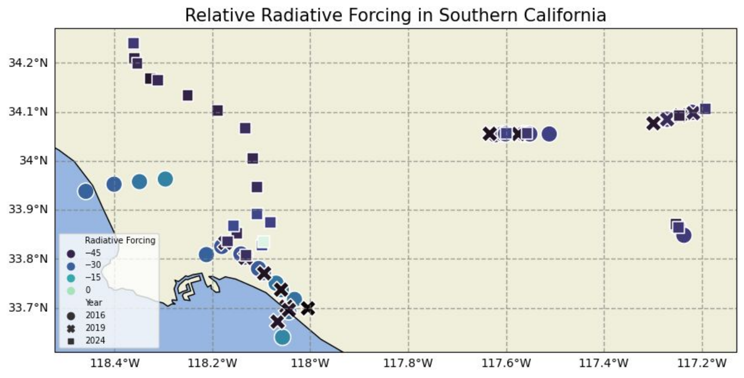


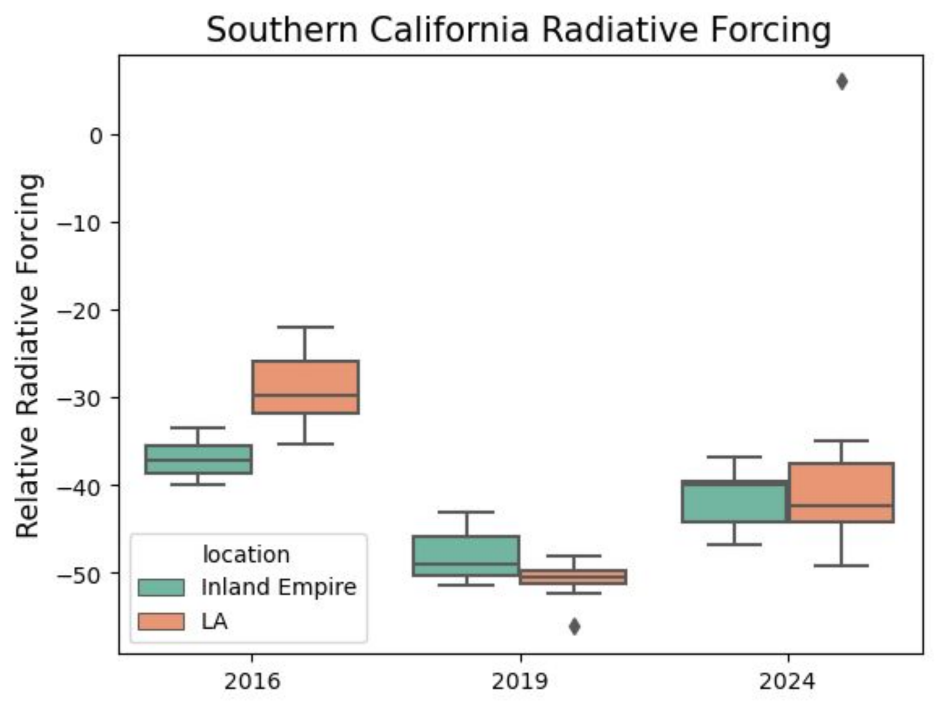
Less Cooling Regions

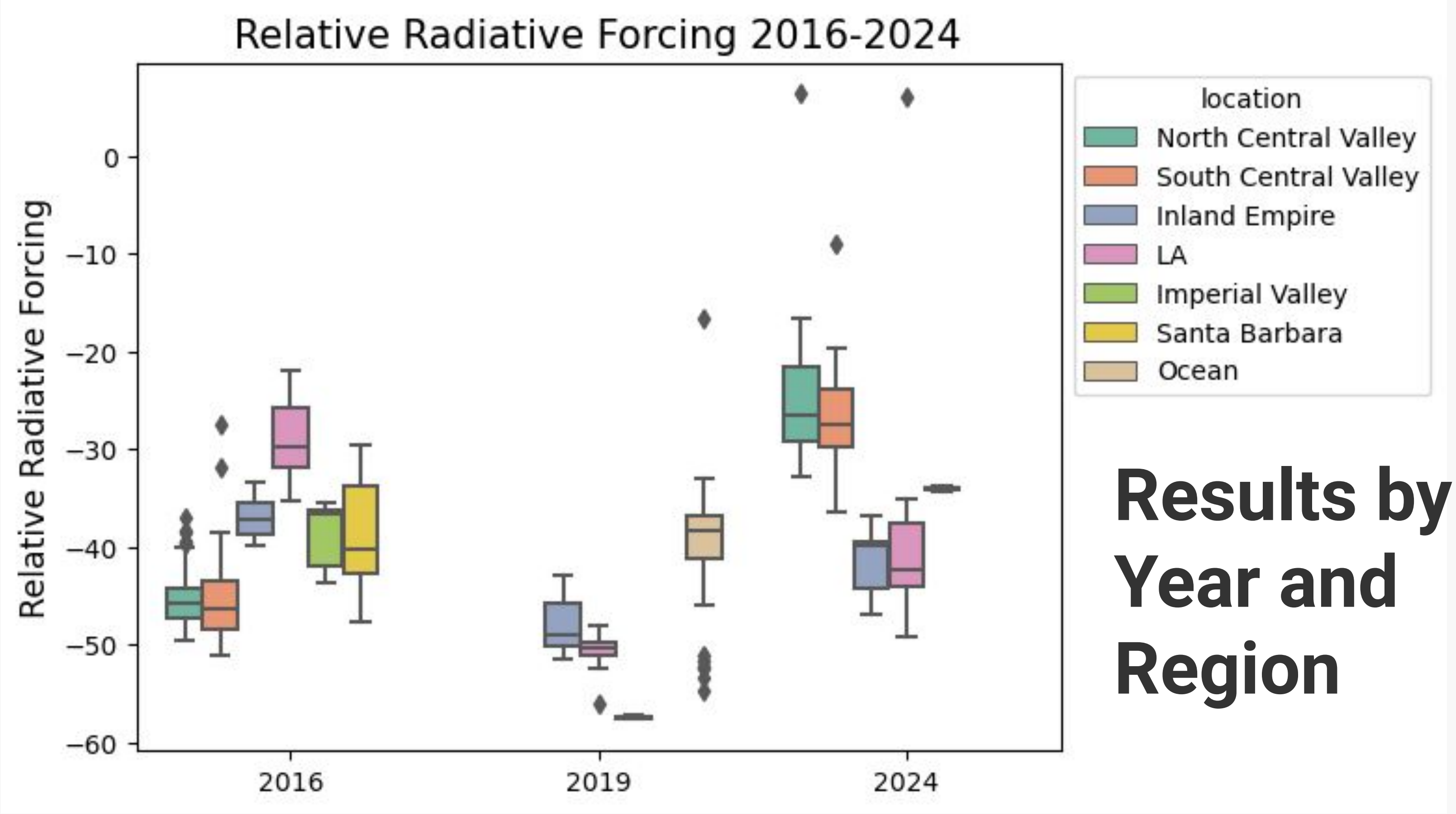




More Cooling Regions







Results by Year and Region

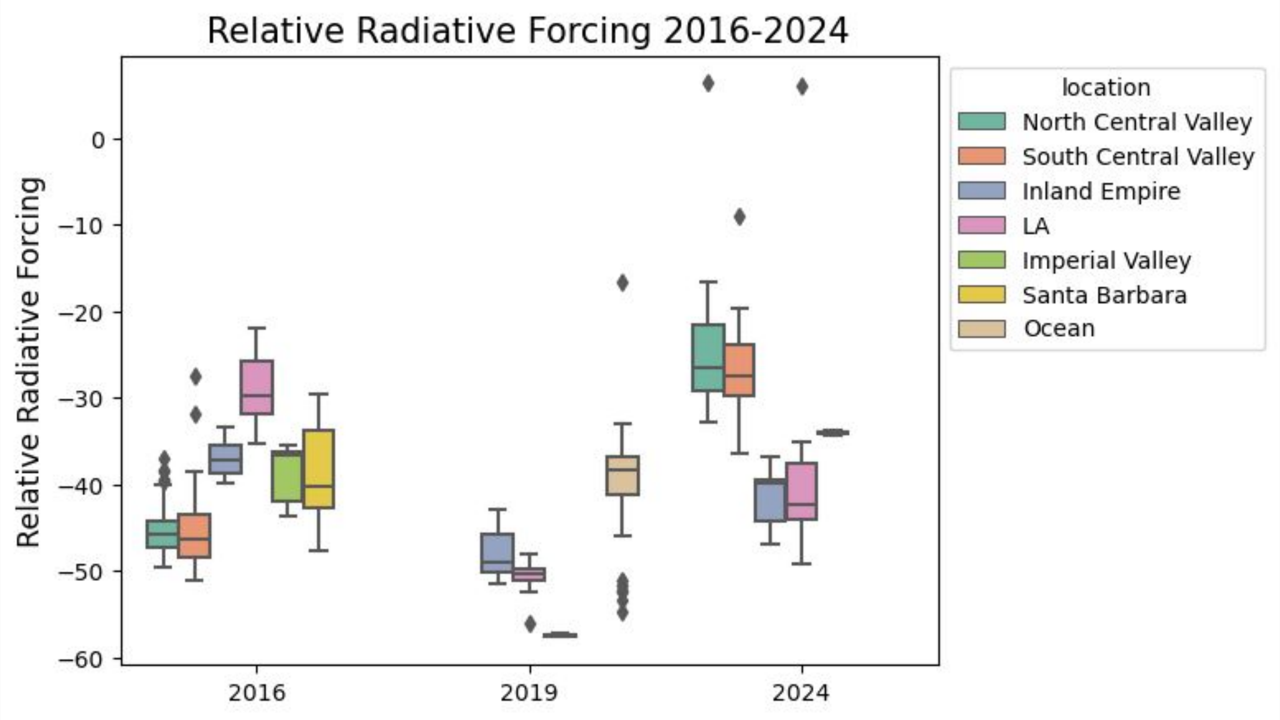
Conclusion

From radiative forcing calculations:

- LA and Inland Empire are cooling more
- Central Valley is cooling less

Future Work:

- Analyze the difference between the aerosol properties of these regions



Acknowledgments

github.com/alisonthieberg

Faculty Mentors:

- Dr. Andreas Beyerdorf
- Dr. Ann Marie Carlton

Research Mentors:

- Maddy Landi
- Dr. Disha Sardana

Former SARP Students:

- **Aly Fritzmann**
- **Julia Alvarez**

Python Developers:

- Scott Prahl

Data Source:

- Langley Aerosol Research Group

NASA and SARP:

- Stephanie Olaya
- Dr. Karen St. Germain
- Dr. Julie Robinson
- Dr. Jack Kaye
- Dr. Barry Lefer
- Dr. Melissa Martin
- Rachel Wegener

Organizations:

- NASA
- ESD, SMD
- ECR
- UCI