Integrating Earth-System Modeling and Multi-Scale Observations to Support Health Studies in California

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DOE Climate Resilience Center
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NASA HAQAST2 2016 - 2021

U.S. DEPARTMENT OF ENERGY | Office of Science

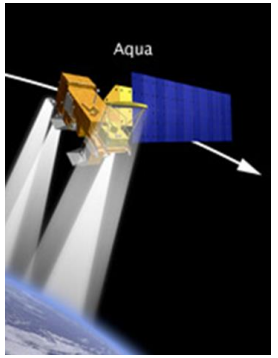
IAMA meeting, December 6, 2023,
Davis, California

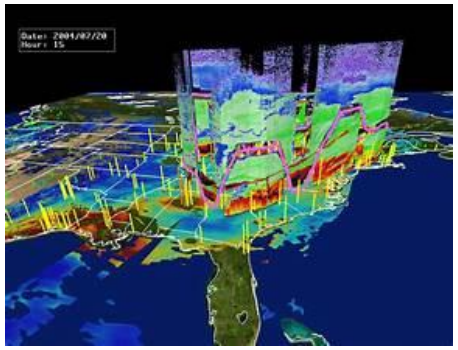
NASA

SAN JOSE STATE UNIVERSITY

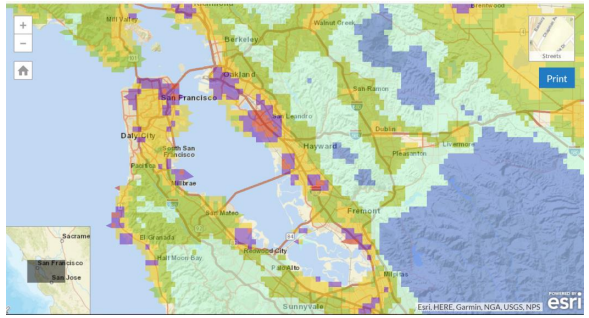
Outline

1. *Traditional approach to provide estimates of $PM_{2.5}$ for retrospective health analysis*

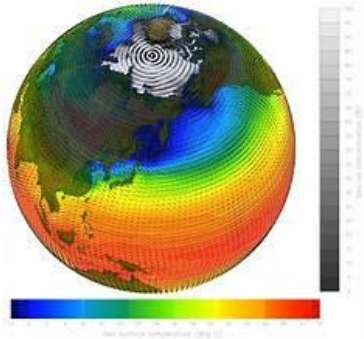




2. *Producing a community-scale $PM_{2.5}$ estimate by combining ground-based, spaceborne, and model simulations (NASA HAQAST 2016 – 2021)*



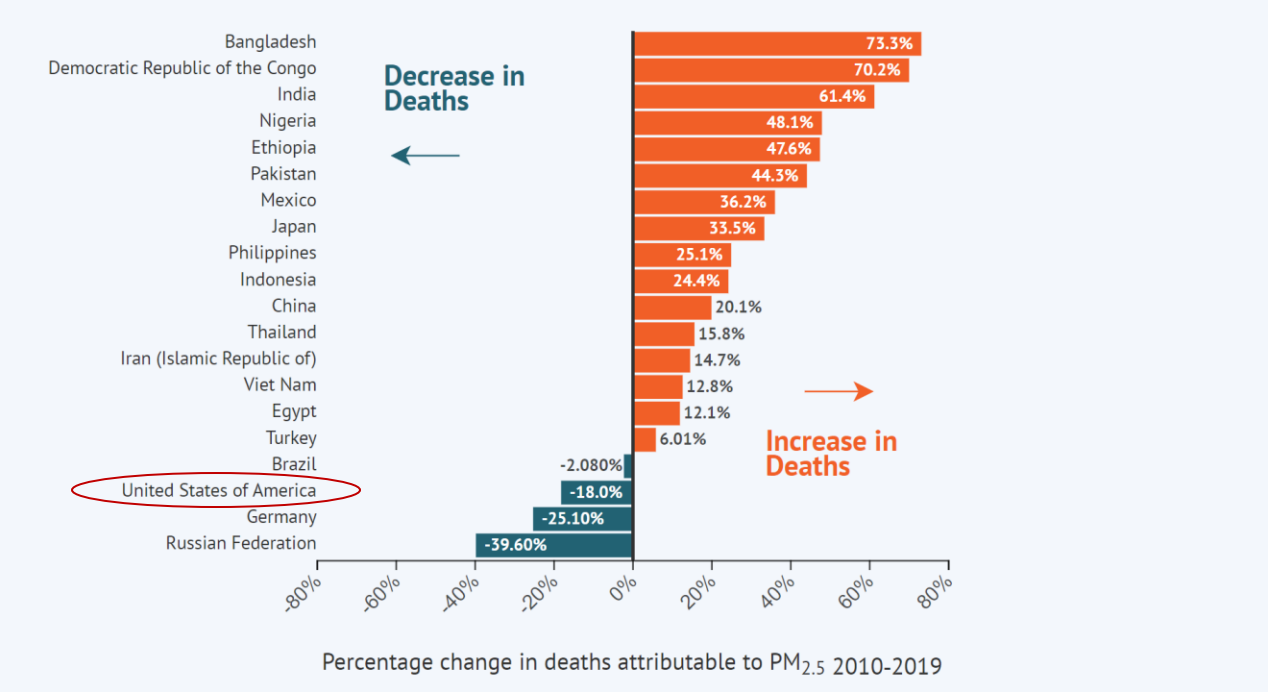
3. *New advancement of high-resolution climate modeling and applications to build community-scale climate resilience*



4. *Wildfire smoke in California and its health impacts*

Global health effects of surface $PM_{2.5}$

Long-term exposure to $PM_{2.5}$ contributed to more than 4 million deaths in 2019.



Picture credit: Stateofglobalair.org

Importance of providing $PM_{2.5}$ data in retrospective view and future projection:

(1) Epidemiological studies

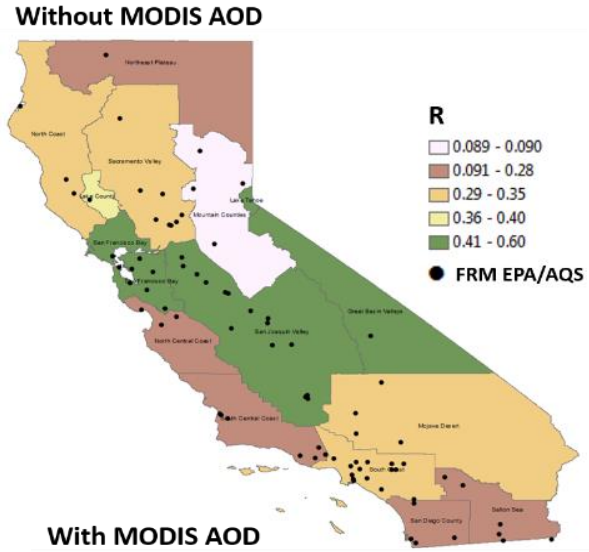
(2) Health benefit assessments

(3) Decision-support tools to support public health interventions from episodic events such as wildfires and dust storms

Part 1: A survey of frequently used $PM_{2.5}$ data and generation method for health studies

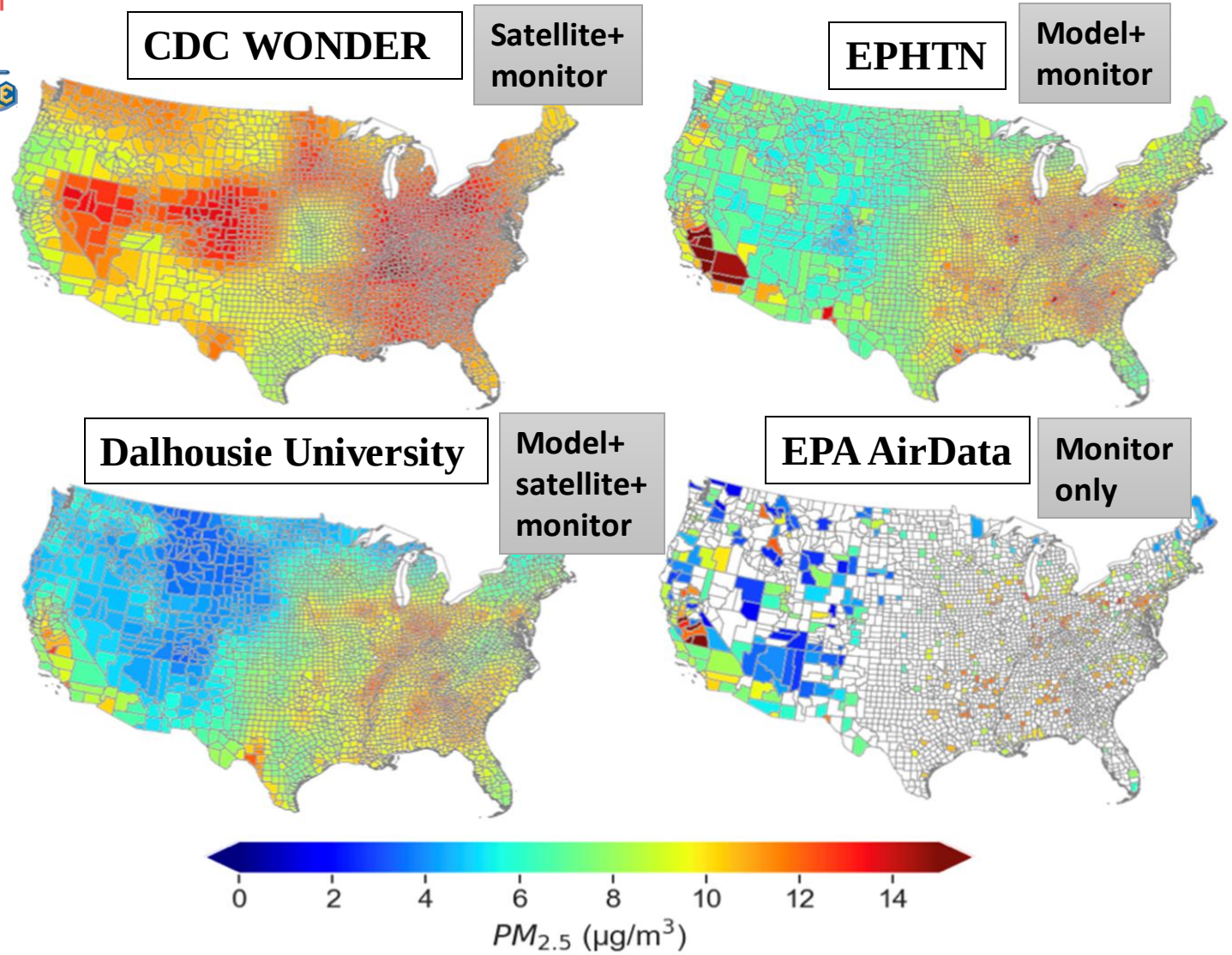
A survey of main methods of generating $PM_{2.5}$ datasets

- **1. Ground-based monitor data**
  - U.S. EPA AirData website
  - U.S. EPA Chemical Speciation Monitoring Network (CSN)
  - Wildland Fire Air Quality Response Program (WFAQRP)
- **2. Ground-based monitor + model simulations**
- **3. Ground-based monitor + satellite data**
- **4. Ground-based monitor + satellite data + model simulations**



Figures prepared by Mohammod Al-Hamdan

Comparisons of publicly available $PM_{2.5}$ datasets in the contiguous U.S.



(1) Differences are seen among publicly available, frequently used data sets for year 2011

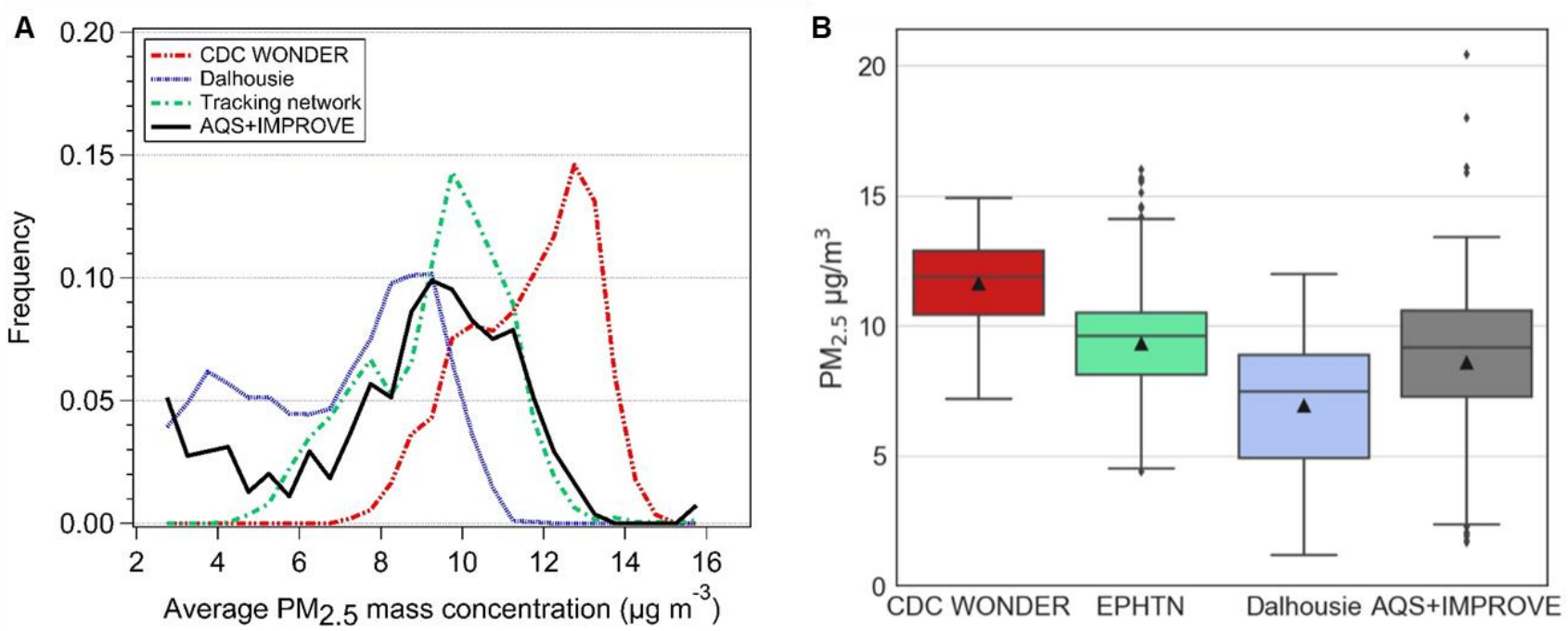
(2) $PM_{2.5}$ estimates are generated using different methods and data sources

(3) Guidance is needed for end users to access and critique various data sets.

A review paper for $PM_{2.5}$ exposure estimates

Diao M., T. Holloway, S. Choi, S.M. O'Neill, M.Z. Al-Hamdan, A.van Donkelaar, R.V. Martin, X. Jin, A.M. Fiore, D.K. Henze, F. Lacey, P.L. Kinney, F. Freedman, N.K. Larkin, Y. Zou, J. Kelly, A. Vaidyanathan. Methods, availability, and applications of $PM_{2.5}$ exposure estimates derived from ground measurements, models, and satellite datasets, *Journal of Air & Waste Management Association (JAMWA), 2019.*

Statistical distributions of three $PM_{2.5}$ datasets in the contiguous US in 2011



(1) CDC WONDER: overall higher values and a large regional maximum over the central U.S.

(2) Dalhousie: the lowest mean values of $PM_{2.5}$ and the largest standard deviation, also more spatially homogeneous over western U.S.

(3) For Southern California, EPHTN shows the highest $PM_{2.5}$ (over 14 µg/m^3)

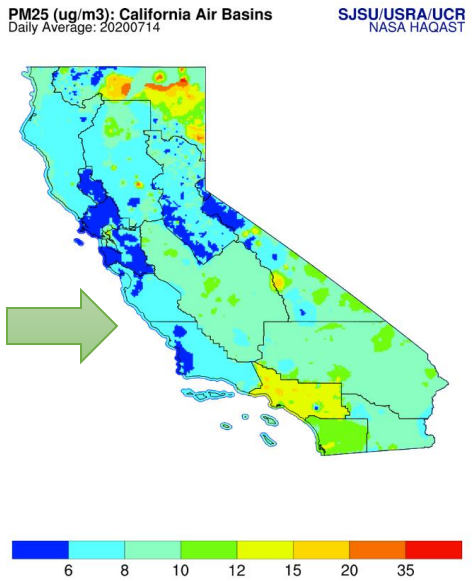
Figure prepared by Minghui Diao, Xiaomeng Jin, Grace Choi and Tracey Holloway

Diao M., T. Holloway, S. Choi, S.M. O'Neill, M.Z. Al-Hamdan, A.van Donkelaar, R.V. Martin, X. Jin, A.M. Fiore, D.K. Henze, F. Lacey, P.L. Kinney, F. Freedman, N.K. Larkin, Y. Zou, J. Kelly, A. Vaidyanathan. Methods, availability, and applications of $PM_{2.5}$ exposure estimates derived from ground measurements, models, and satellite datasets, *Journal of Air & Waste Management Association (JAMWA), 2019.*

Bridge the Gap between Data and End Users

Publicly Available Satellite-Derived $PM_{2.5}$ Data and Tools in California

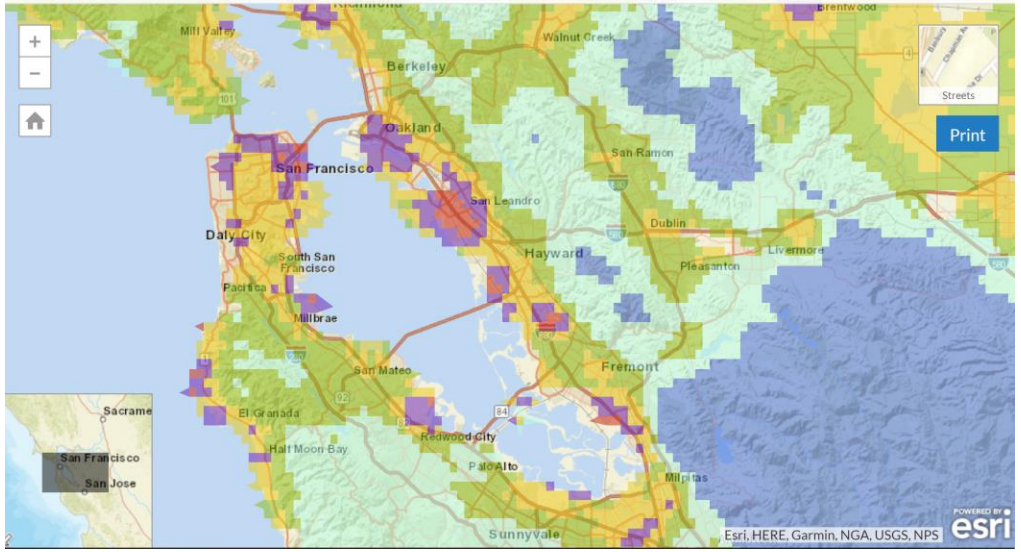
3-km, daily, near real-time



1. Daily $PM_{2.5}$ fields for entire California (2006-2021)
http://www.met.sjsu.edu/weather/HAQAST/product1.html

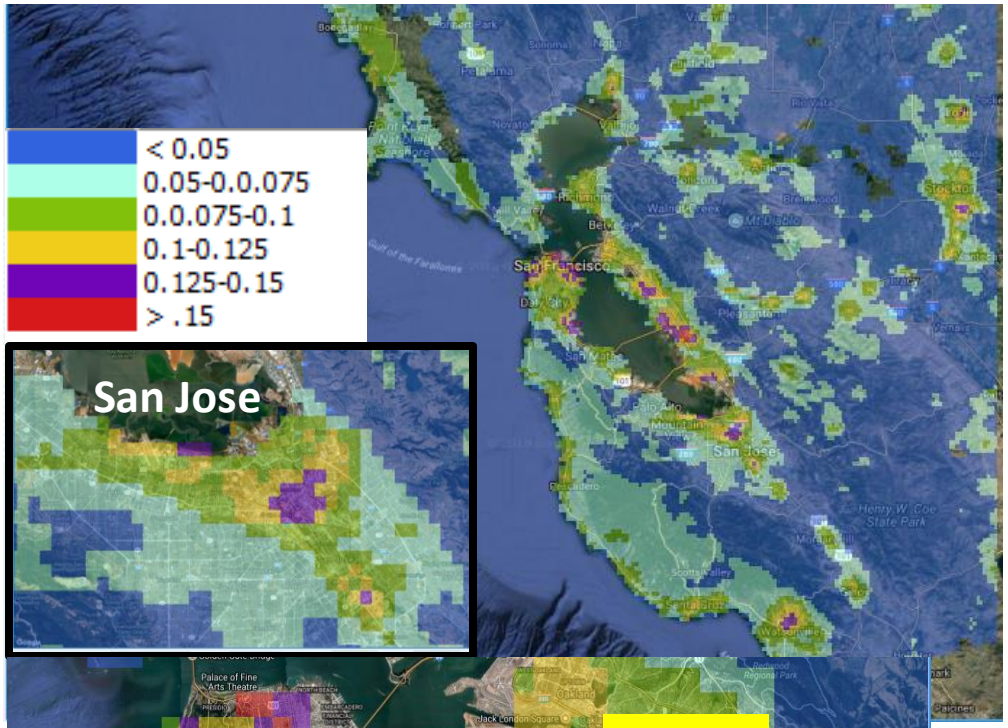
2. Daily 3-km, near real-time $PM_{2.5}$ for California (2006-2021)
http://www.met.sjsu.edu/weather/HAQAST/product2.html

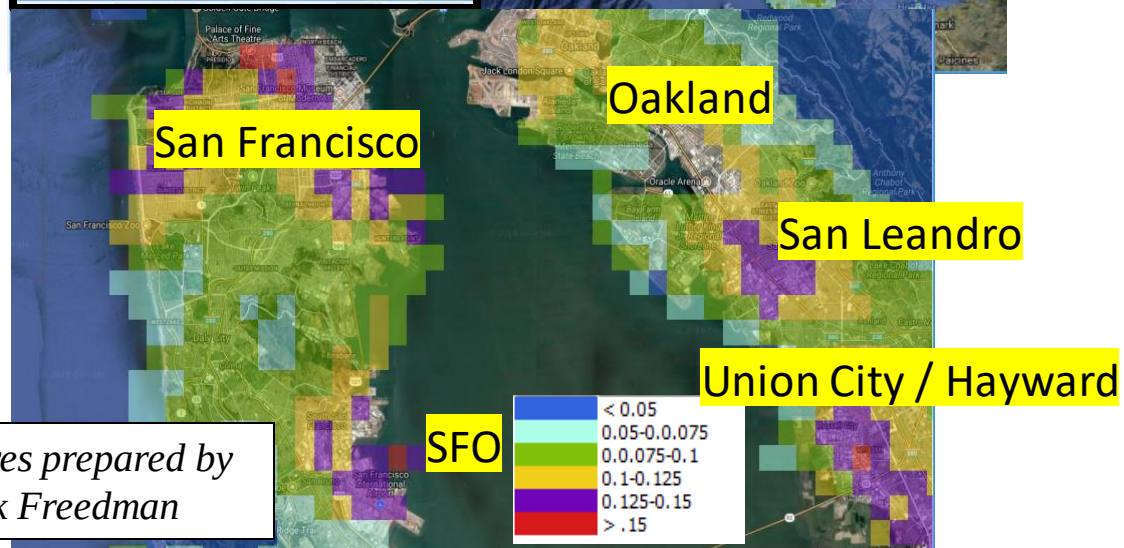
3. A visualization tool for community-scale $PM_{2.5}$:
https://www.cloud-research.org/haqast-project



http://www.met.sjsu.edu/weather/HAQAST/home.html

San Francisco Bay Area average of AOD ArcGIS visualization

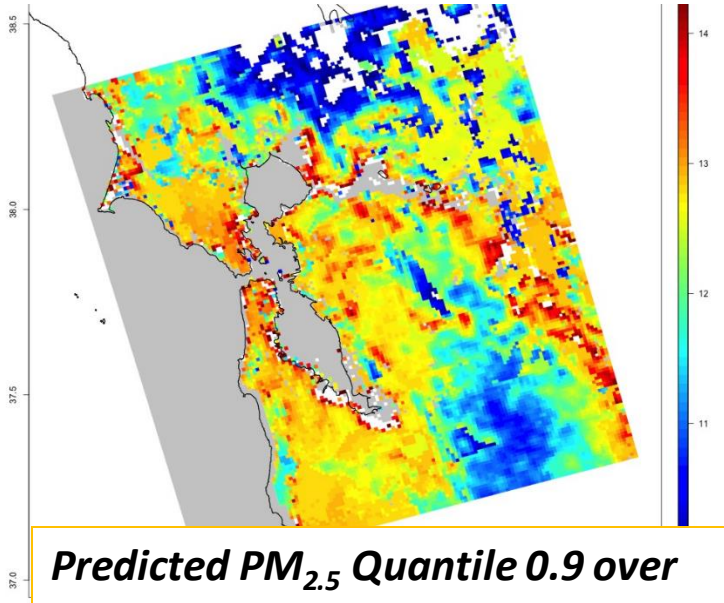




Figures prepared by Frank Freedman

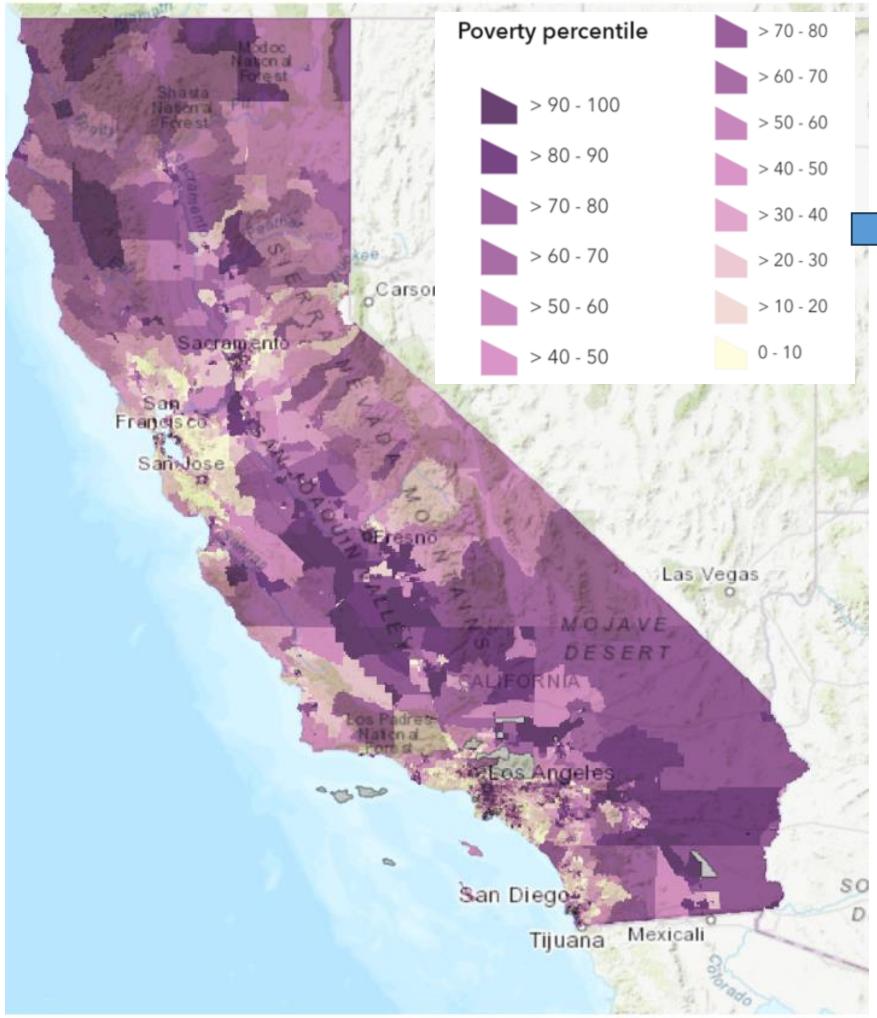
Visualization of San Francisco Bay Area in winter 2016

- Selected days (clear-sky, data coverage, 500 mb geopotential height ≥ 576 decameters, etc.)
- Average of MODIS Aqua MAIAC AOD fields

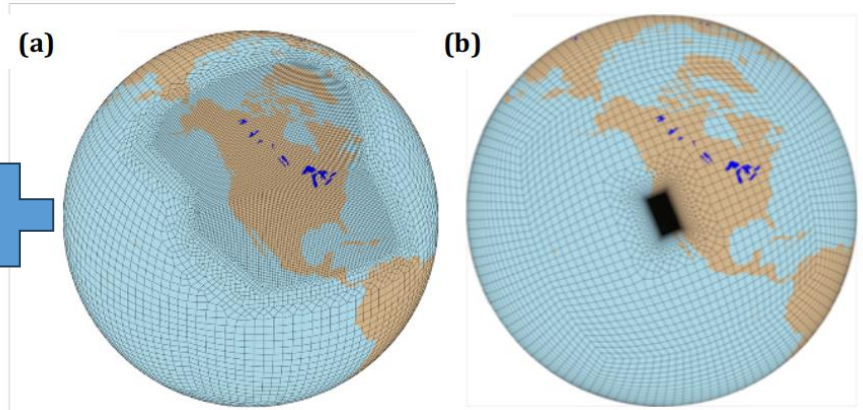


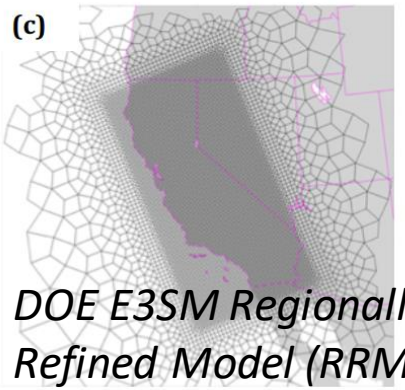
Predicted $PM_{2.5}$ Quantile 0.9 over 23 days *(prepared by Robert Chatfield and Meytar Sorek-Hamer)*

DOE California Community and Earth-system Integrated Climate Resilience Center (CalCEI CRC)



High spatial heterogeneities of poverty percentiles in California





DOE E3SM Regionally Refined Model (RRM)

Core Team Members:

Lead: Minghui Diao, San Jose State University

Co-I: Qi Tang, Lawrence Livermore National Laboratory

Tarik Benmarhnia, University of California, San Diego

Rupa Basu, California Environmental Protection Agency (EPA)

Stakeholder/Community Advisory Board

U.S. EPA

U.S. Centers for Disease Control and Prevention (CDC)

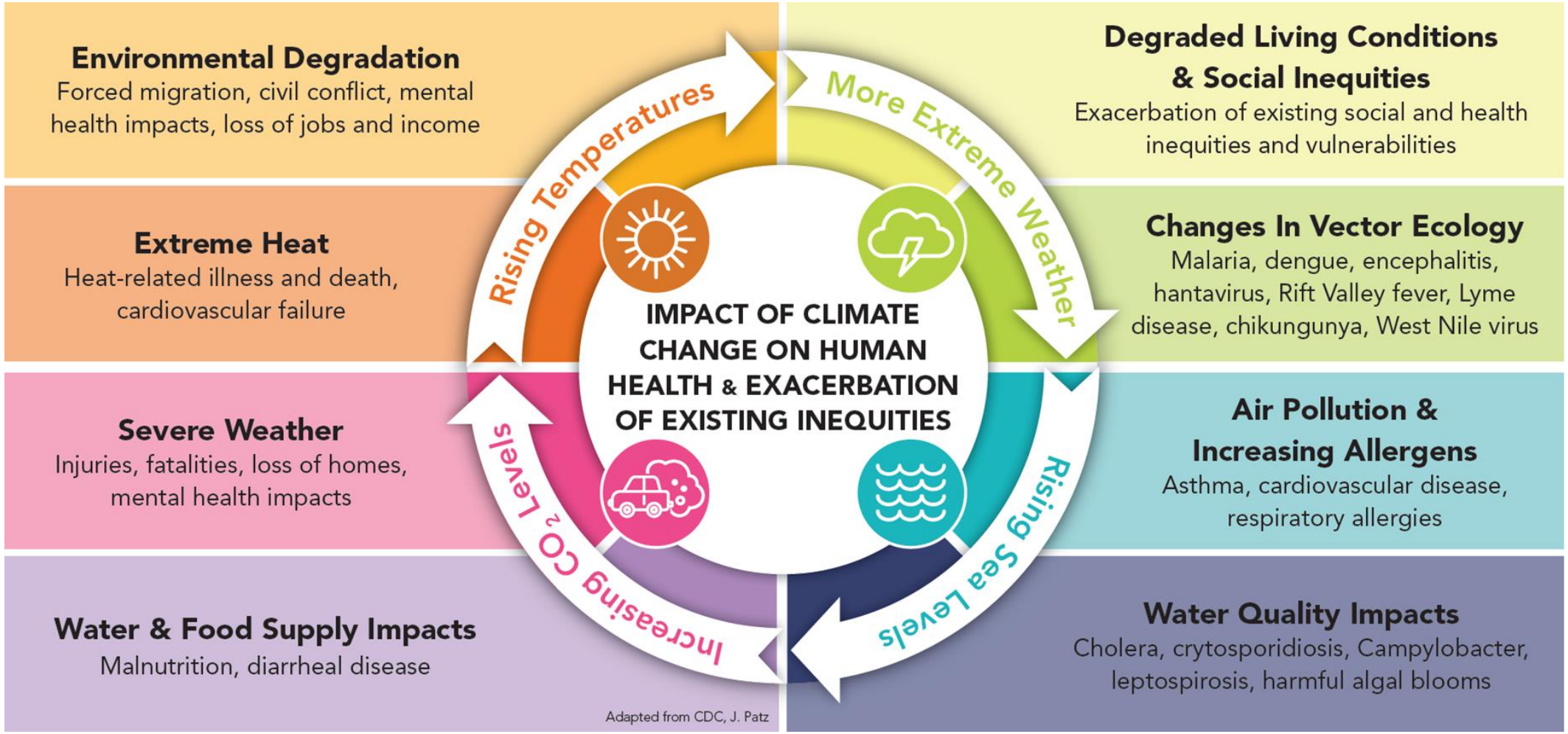
California Environmental Protection Agency (EPA) OEHHA

CSAA Insurance Exchange; Clarity Co.

American Red Cross; Blue Forest

California Council on Science and Technology

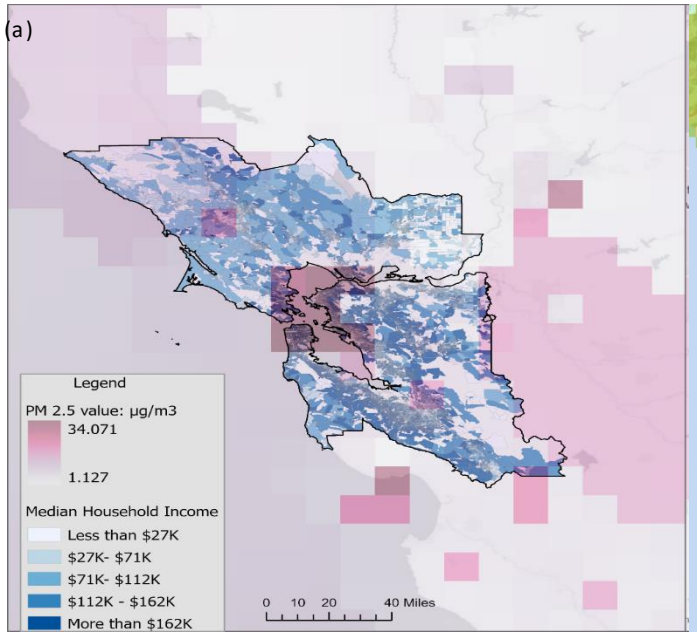
Assessing climate impacts in a wide spatial and temporal span



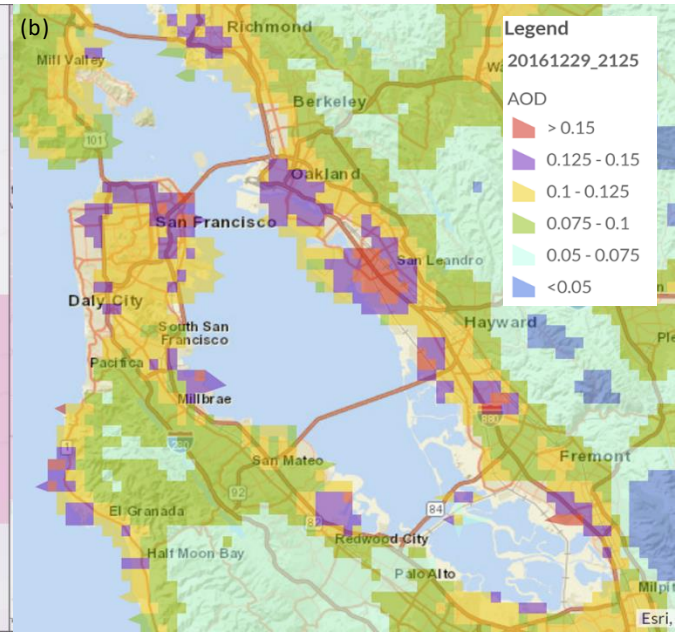
Picture source: CDPH, CA

Linking climate models with community-scale decision-making activities

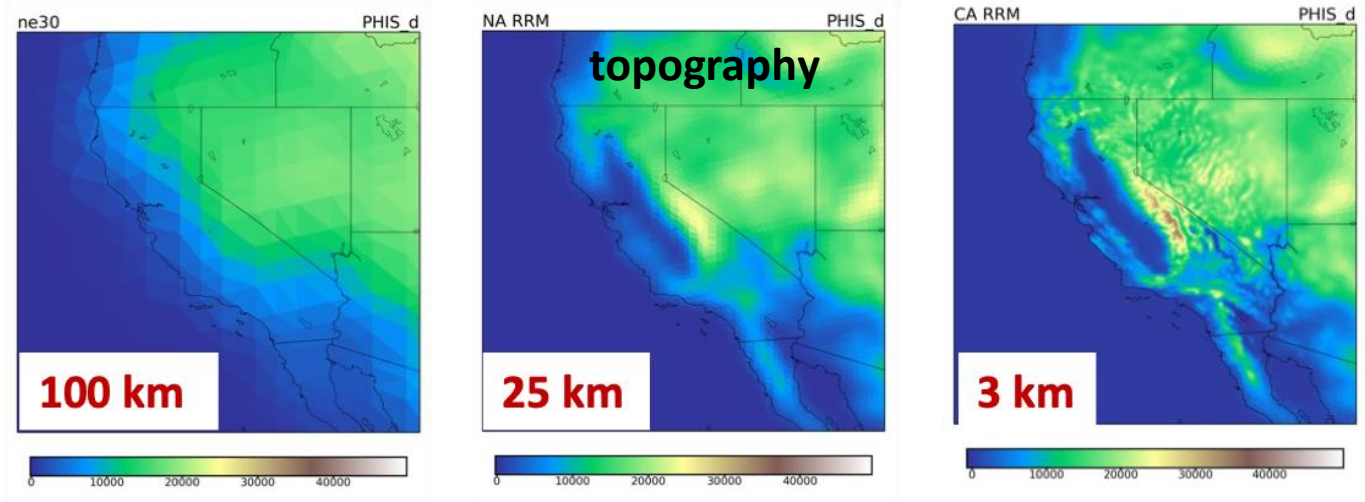
Median household income



NASA MAIAC satellite AOD



DOE E3SM Regionally Refined Model (RRM) domain for California



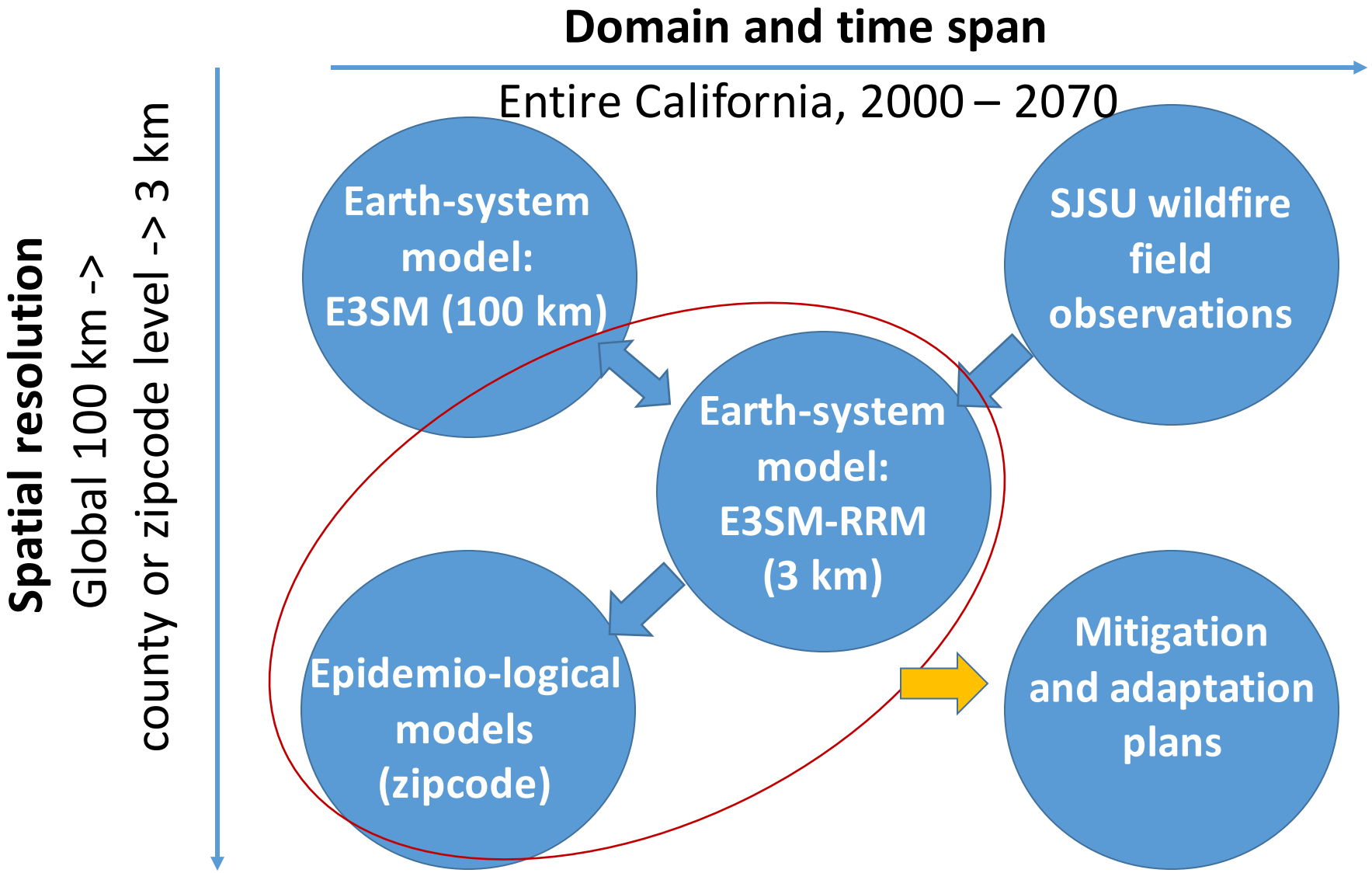
DOE E3SM RRM
(Tang et al., 2019):

3 main challenges:

1. High-resolution — ***3 km***
2. Two-way interactions of physical processes between global domain and regional domain (not a regional downscaling model) — ***Global+regional physical processes***
3. Computationally economical with chemical processes to allow decadal simulations — ***1 simulation month of per wall-clock day***

A new type of model-observation framework is needed

An integrated modeling and observation framework to quantify climate impacts (2000 – 2070) and build climate resilience

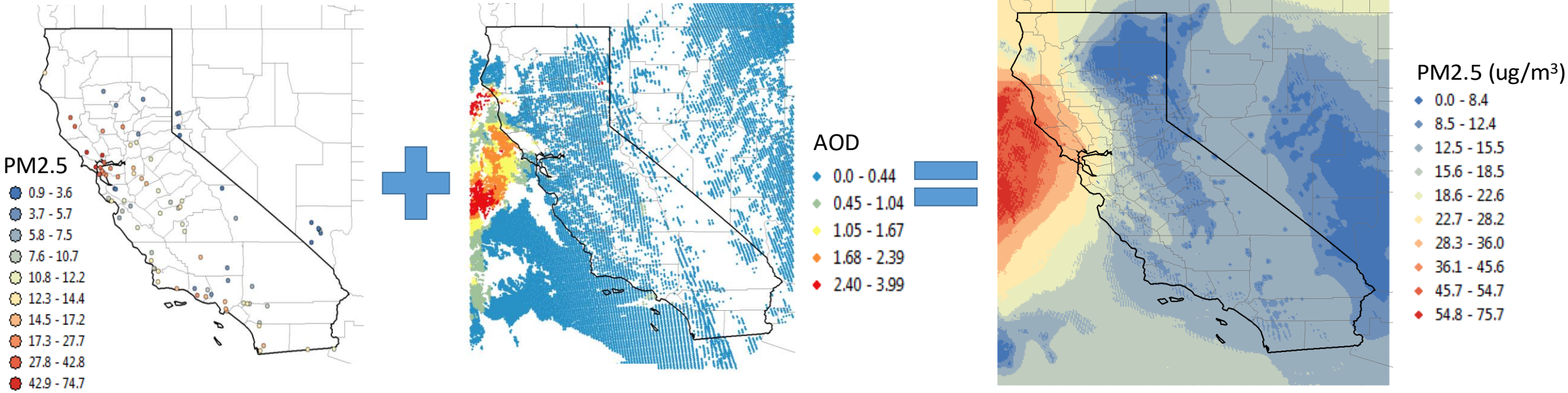


Part 4: Wildfire smoke and its health impacts

Satellite data in health studies of California wildfires in 2017

EPA/AQS PM2.5

NASA/MODIS AOD



Example of October 9, 2017

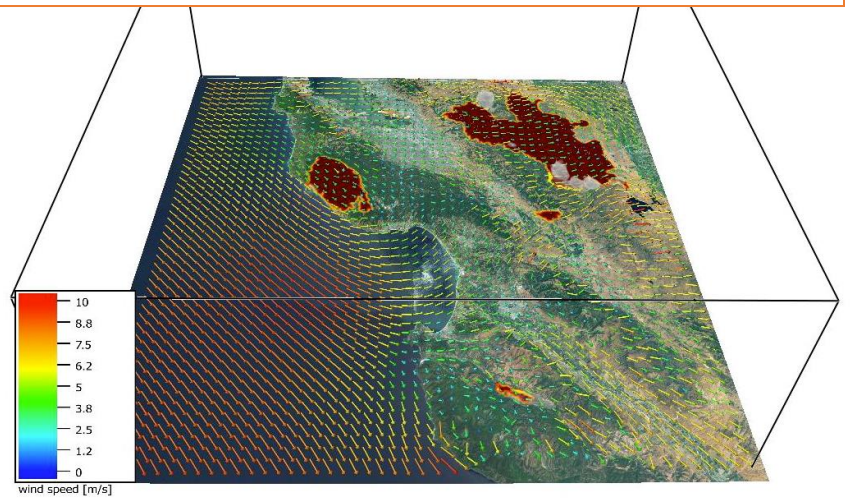
3-km, daily NASA Aqua MODIS satellite AOD data (Dark Target product) and EPA ground monitors are combined to provide daily estimates of PM2.5 on a 3-km grid (surface).

Figures prepared by: Dr. Mohammad Al-Hamdan
USRA at NASA/MSFC
mohammad.alhamdan@nasa.gov

O'Neill, S., M. Diao, et al. A Multi-Analysis Approach for Estimating Regional Health Impacts from the 2017 Northern California Wildfires. JA&WMA, 2021.

Developing Partnership between San Jose State University and DOE Lawrence Livermore National Laboratory to Enhance Climate Research Equity and Inclusion

SJSU wildfire observations and WRF-SFIRE simulations



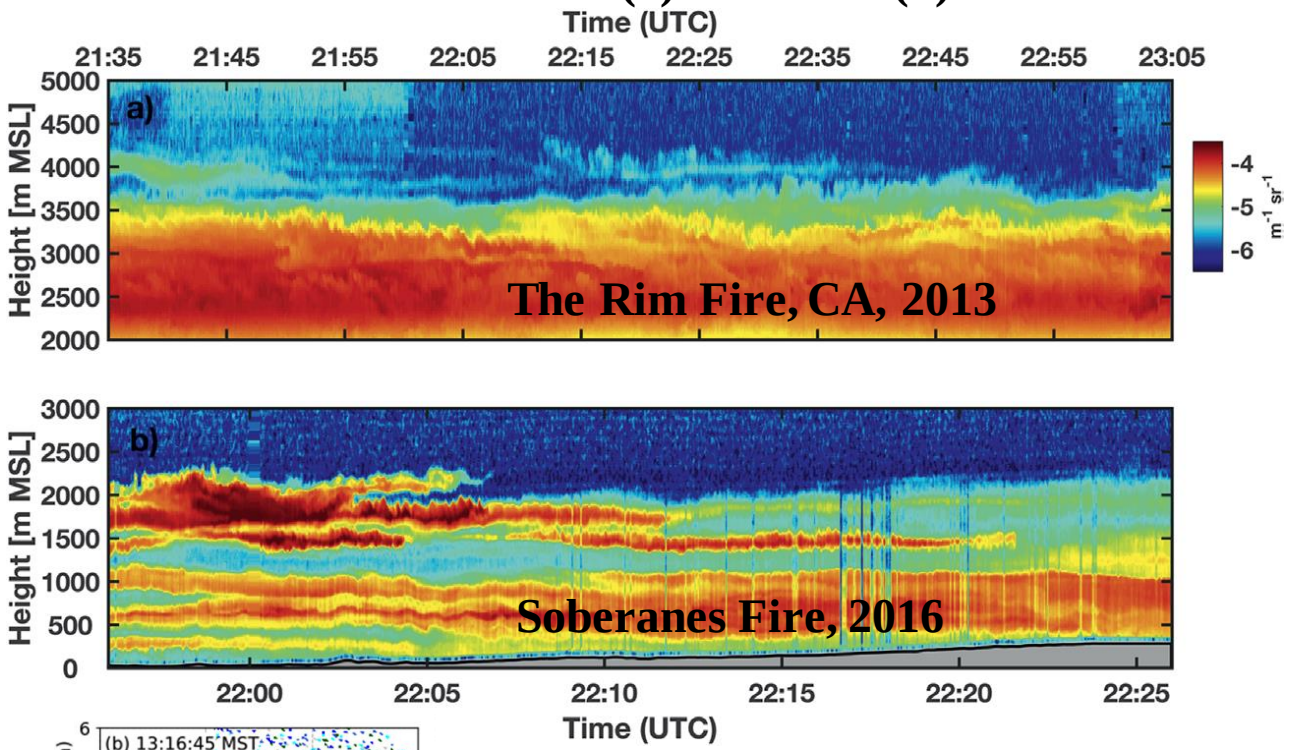
SJSU Wildfire Research Interdisciplinary Center (SJSU-WIRC), also funded as an NSF IUCRC since 2020 (Director: Craig Clements)

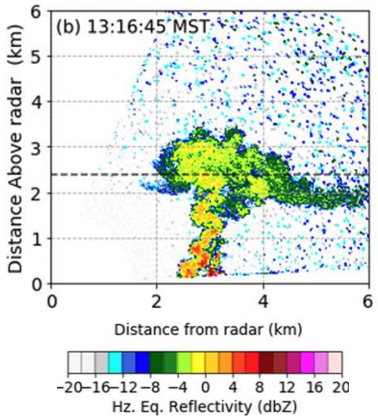
DOE Research Development and Partnership Pilot (RDPP) Project (2023 – 2025):

- San Jose State University
  - PI: Minghui Diao
  - Co-I: Adam Kochanski
- Non-funded collaborators:
  - Shaocheng Xie, Qi Tang, Lawrence Livermore National Laboratory
- Expectations from the DOE RDPP Activity
  - Enhance data analysis proficiency for utilizing ARM data and diagnostic tools
  - Build climate modeling expertise at SJSU
  - Broaden collaboration between the SJSU Wildfire Research Interdisciplinary Center (SJSU-WIRC) and LLNL.
  - Develop a workforce of graduate and undergraduate students from underserved communities

Observations and simulations of wildfire smoke dispersion

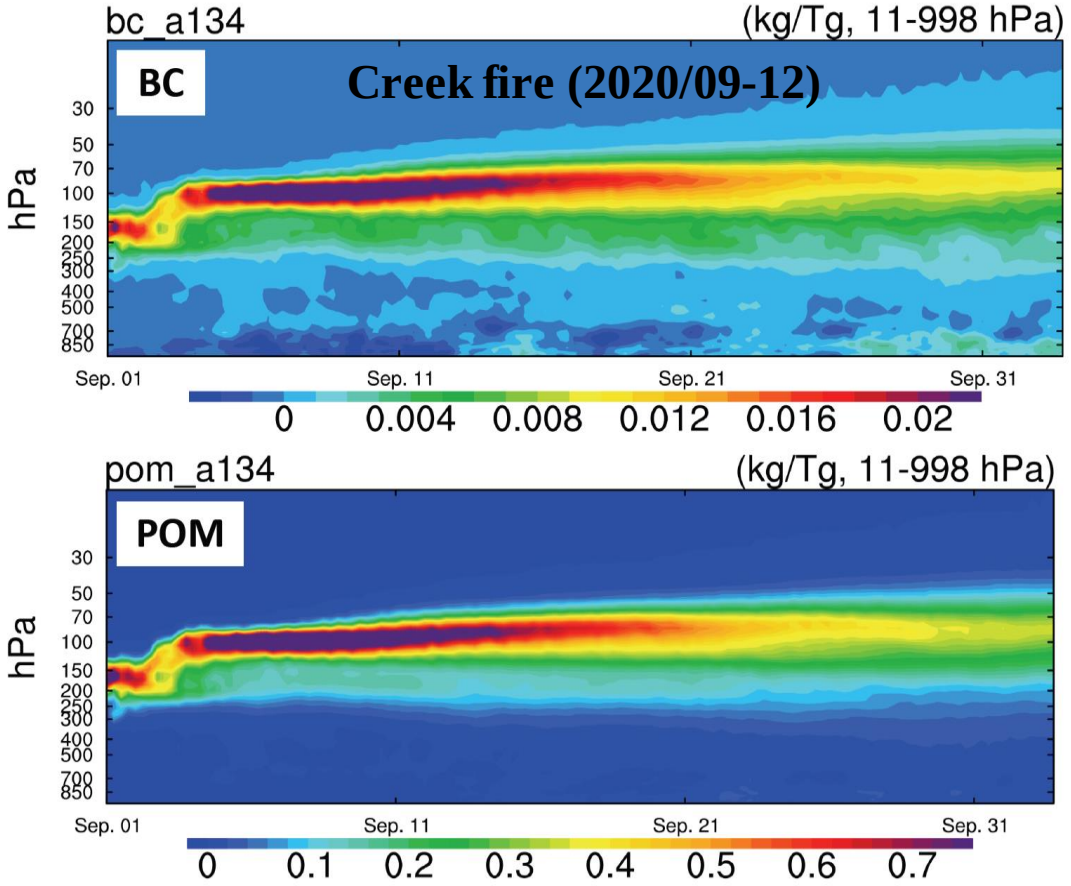
Lidar backscatter from both (a) fixed and (b) mobile modes





Radar RHI scan of reflectivity

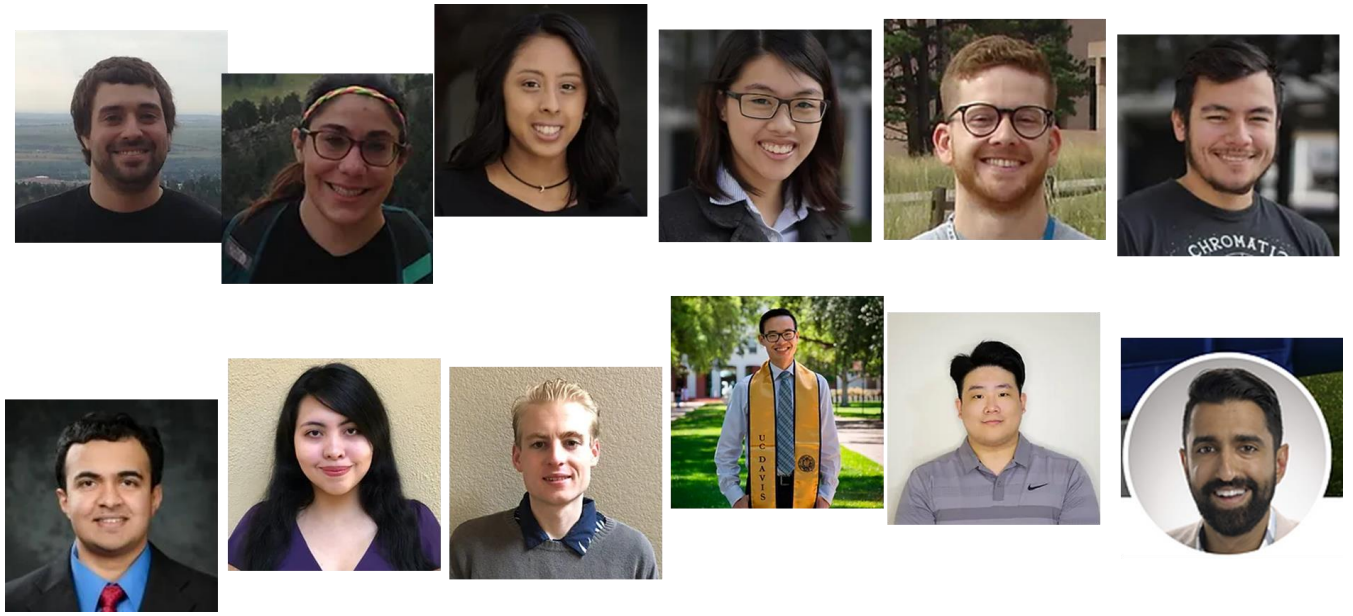
Clements et al. (2018); Aydell and Clements (2021)



E3SM RRM simulations at 3-km of black carbon (BC) and primary organic matter (POM) from Creek fire (2020/09-12) near Shaver Lake, CA. Figure prepared by Qi Tang.

Conclusions

- **1. A survey on publicly available $PM_{2.5}$ exposure estimates data sets**
  - Discrepancies exist in four frequently-used, publicly available datasets
- **2. Towards community-scale, near-real time estimates of surface $PM_{2.5}$**
  - Fused NASA MODIS satellite-derived $PM_{2.5}$ and ground monitor data at 3-km resolution for California (2016 – 2021)
- **3. Reaching both high-resolution and long-term simulations of the past and future**
  - Developing an integrated model-observations framework to connect Earth-system modeling with epidemiological models
- **4. Improving model simulations of California wildfire smoke using mobile observations**
  - SJSU Wildfire Interdisciplinary Research Center / NSF IUCRC on wildfire provides mobile radar + lidar observations
  - Ongoing collaboration between university and DOE national laboratories



Former and current group members of SJSU Cloud and Aerosol Group:

www.cloud-research.org

Acknowledgement

- DOE Climate Resilience Center (PI)
- DOE RDPP grant DE-SC0023155 (PI)
- NASA HAQAST2 NNX16AQ91G (PI)
- NSF MRI grant 1727052 (co-I)
- LLNL Faculty Sabbatical Fellowship 2021
- NCAR ASP Faculty Fellowship 2016 2018
- SJSU Early Career Investigator Award 2019