Using advanced statistical techniques to identify the drivers and occurrence of historical and future extreme air quality events in the United States from observations and models

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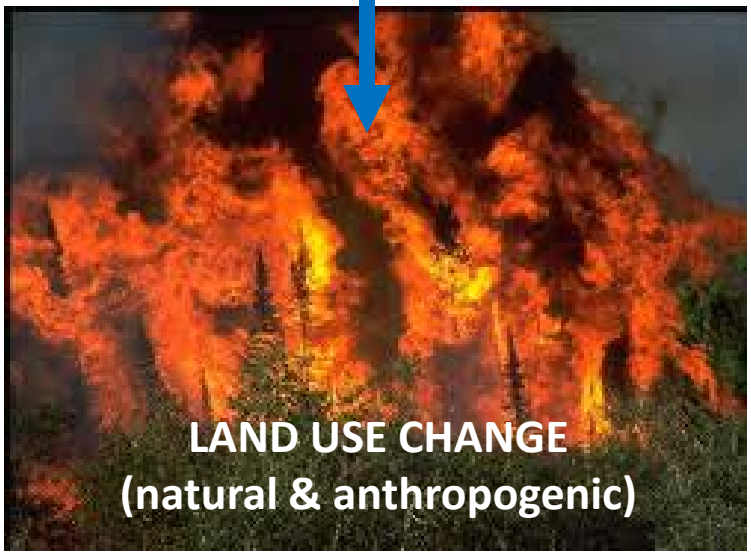
EPA Air Quality Extremes Kick-off Meeting
February 26, 2013

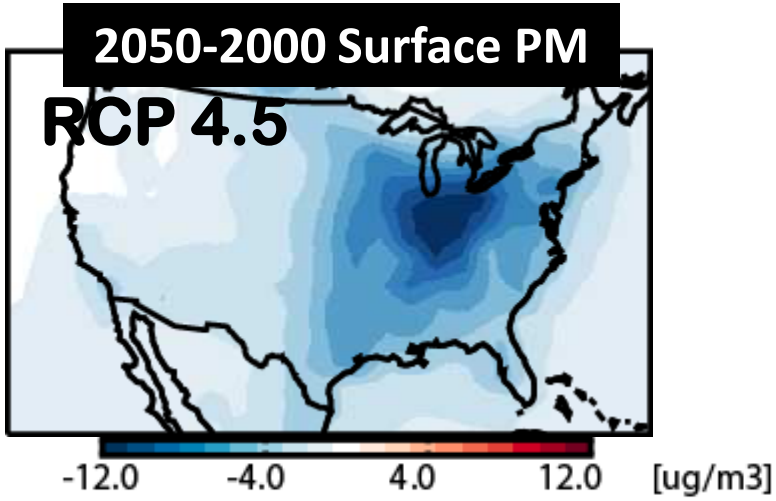

EMISSIONS
(natural & anthropogenic)

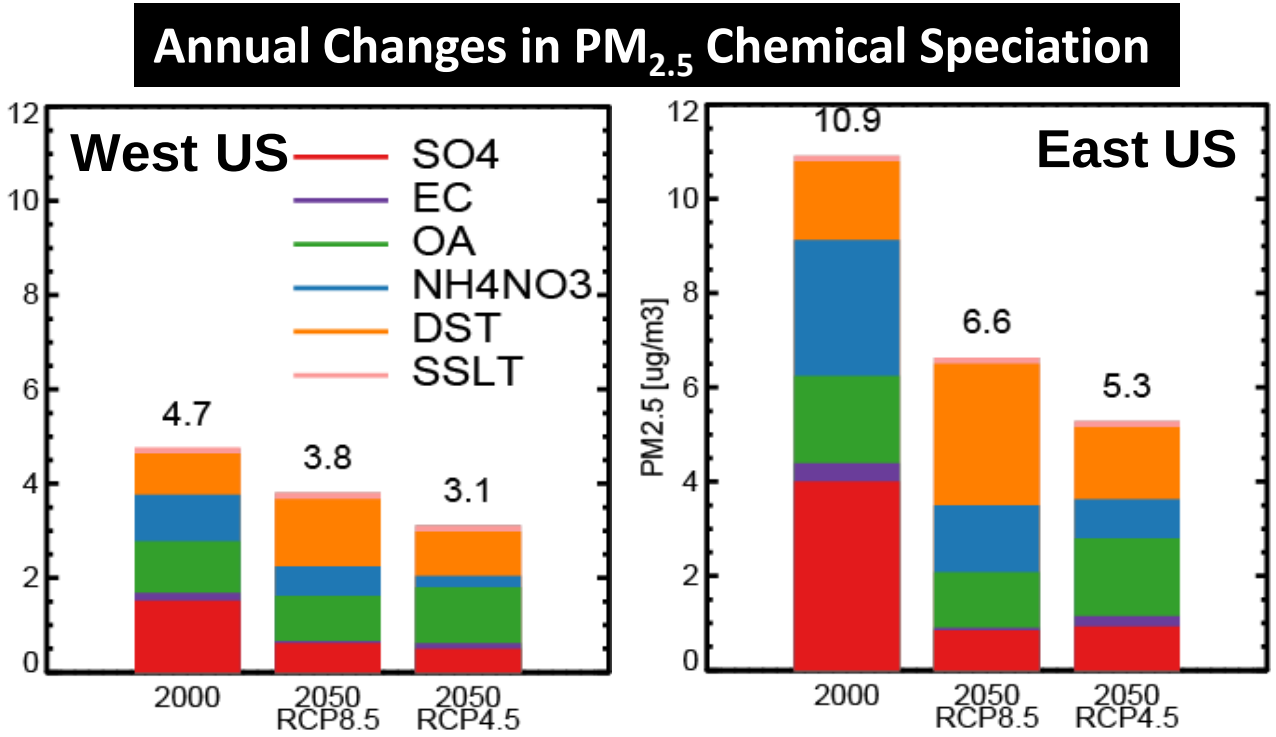

CLIMATE

AIR
QUALITY


LAND USE CHANGE
(natural & anthropogenic)

Majority of Air Quality Projections Focus on Means

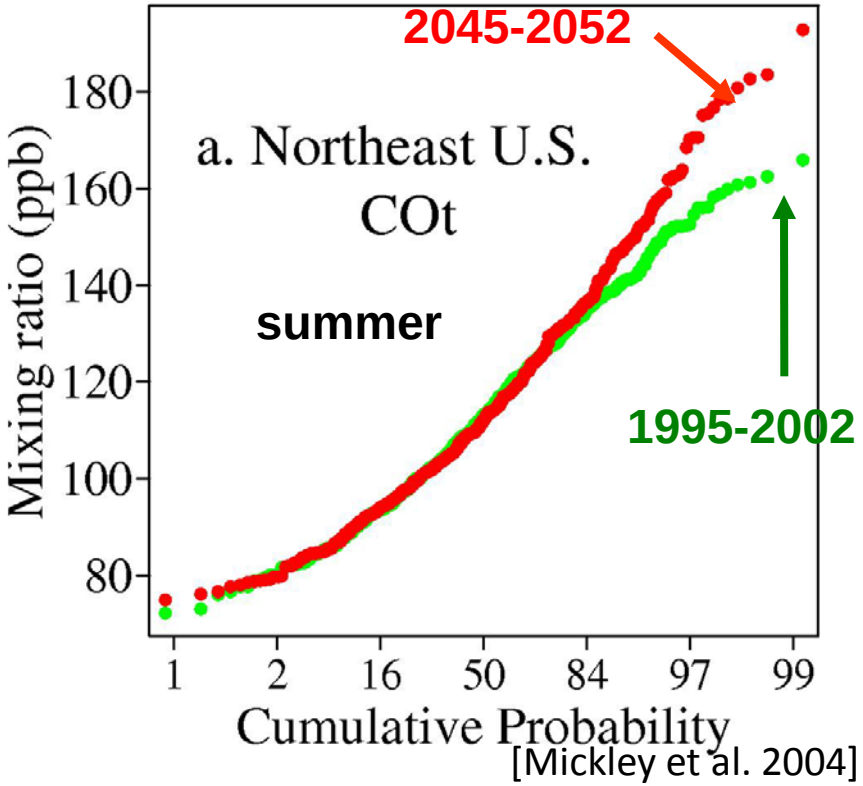




[Val Martin et al., in prep]

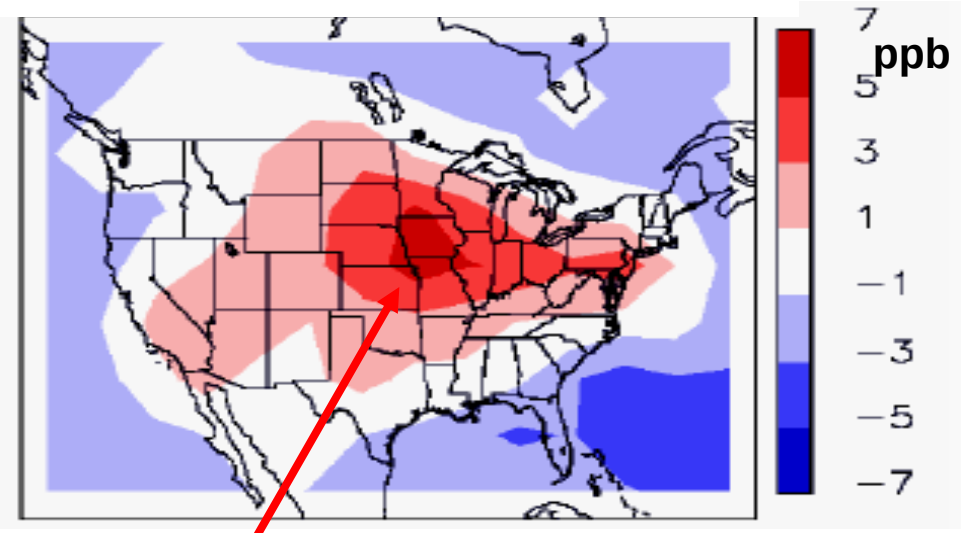
What About the Extremes?
Increasing Regional Stagnation (and AQ Events) with Climate Change

GISS GCM simulations for 2050 vs. present-day climate using pollution tracers with constant emissions



[Mickley et al. 2004]

Climate Penalty: Changes in summer 8-h avg. daily maximum ozone from 2000-2050 climate change

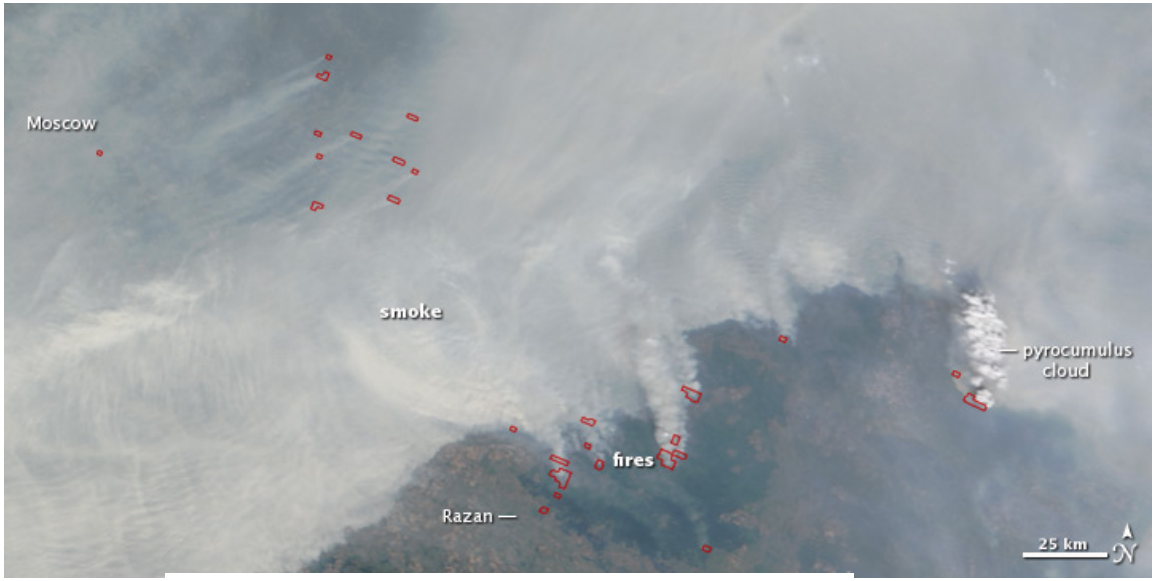


[Wu et al., 2008a]

Pollution episodes double in duration in 2050 due to decreasing frequency of cyclones ventilating the eastern U.S; expected result of climate change.

We Are Now Observing Evidence of Extreme AQ Events: Summer 2010 Fires in Russia

(links between air quality and climate change)



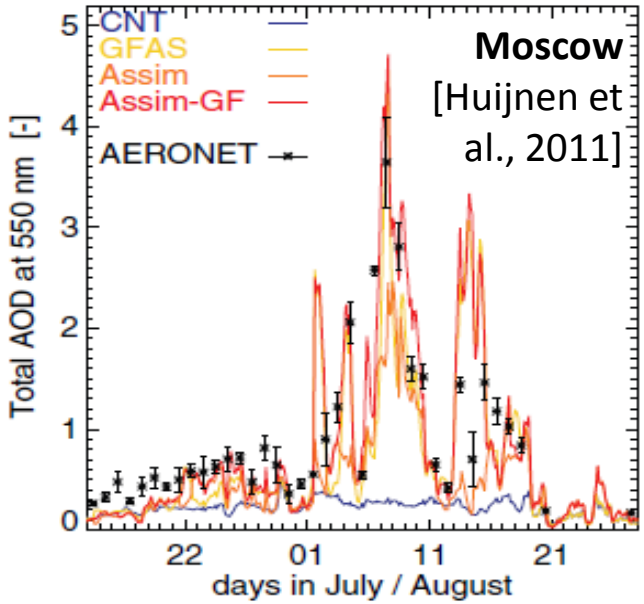
Drought + worst heatwave seen in Russia in 130 years:

600+ fires

2000 homes destroyed

[CO] in Moscow 4x normal

55,000+ estimated deaths from smog and heatwave



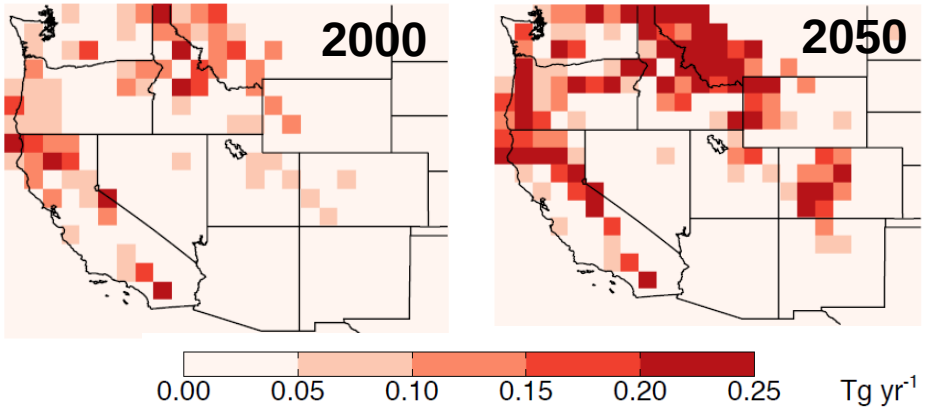
Bark Beetle Kill in Western US Raising Fire Susceptibility?

(links between climate change, land use and air quality)

High Park fire in Colorado (June 2012) burned in area of 70% beetle-killed trees

Even Our Attempts to Characterize the Growing Importance of Sporadic Events (eg. Fires) relies on Means

Projected annual total biomass burned

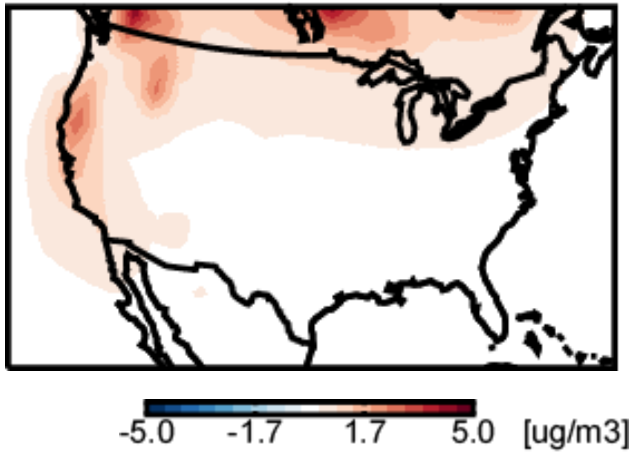


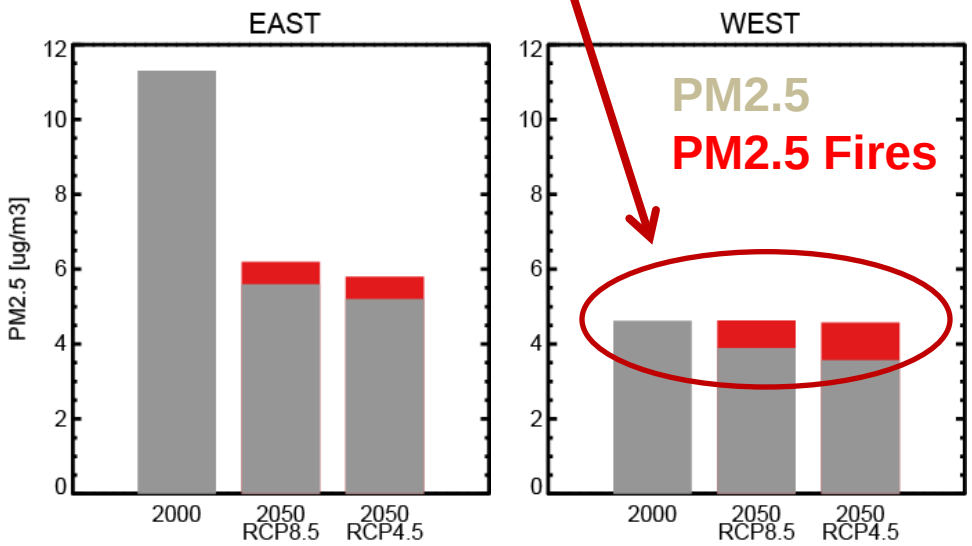
Yue et al, in review JGR

Increased area burned results in ~150% increase in BC and OC fire emissions

Future $PM_{2.5}$ may stay constant over western US due to increased fire activity.

Changes in summer $PM_{2.5}$ from fires alone

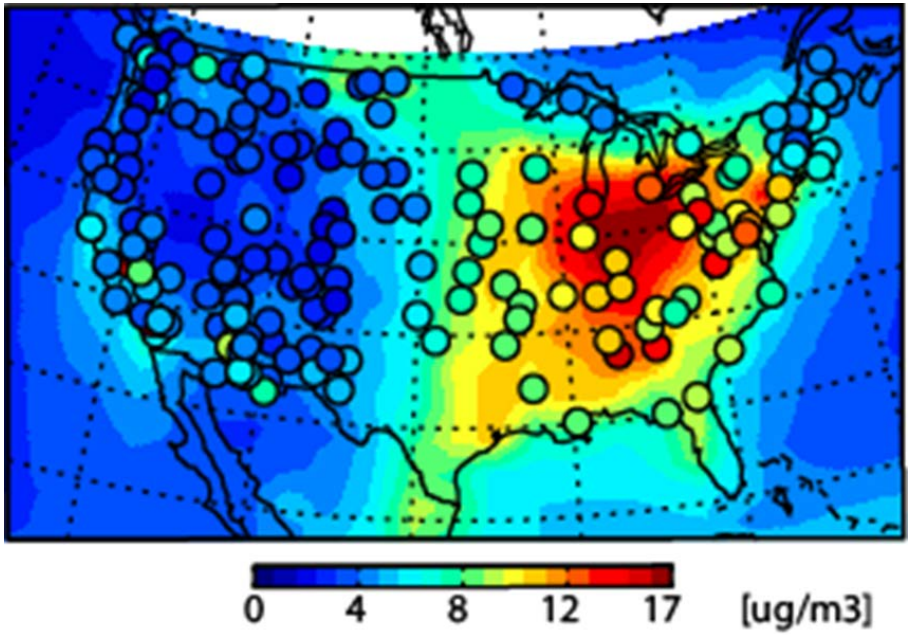


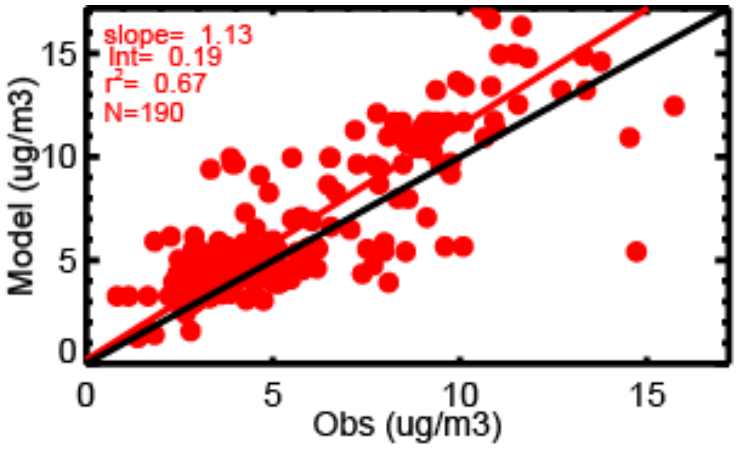


[val Martin et al., in prep]

Chemistry-Climate Model Evaluation Relies on Means

Annual Average CESM Evaluation with IMPROVE observations (1998-2010)





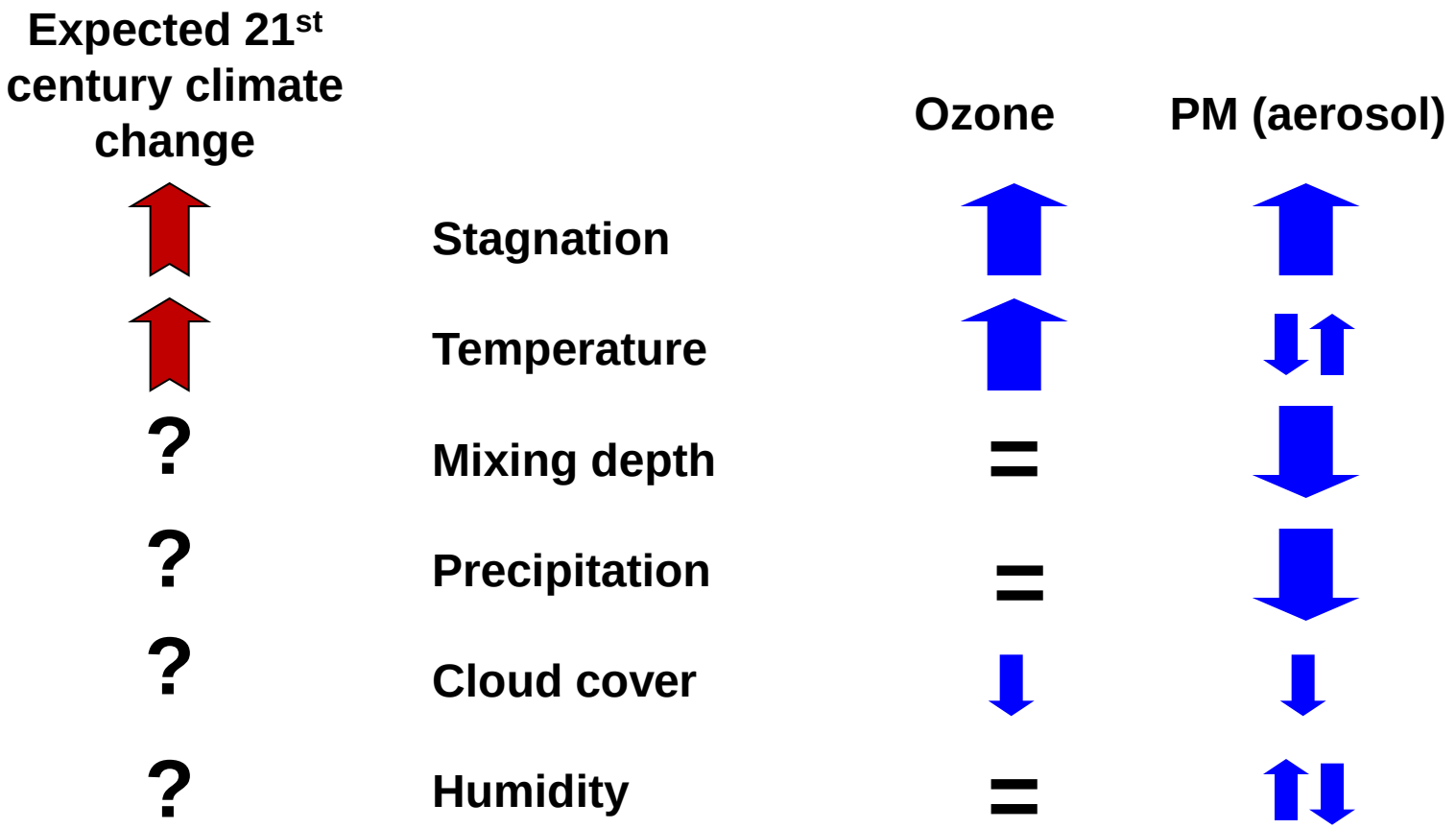
Right for the right reason?

Relationship between meteorology & air quality, particularly at the extremes, is largely untested.

[val Martin et al., in prep]

SENSITIVITY OF SURFACE AIR QUALITY TO METEOROLOGICAL VARIABLES

Insights into the effect of climate change on air quality

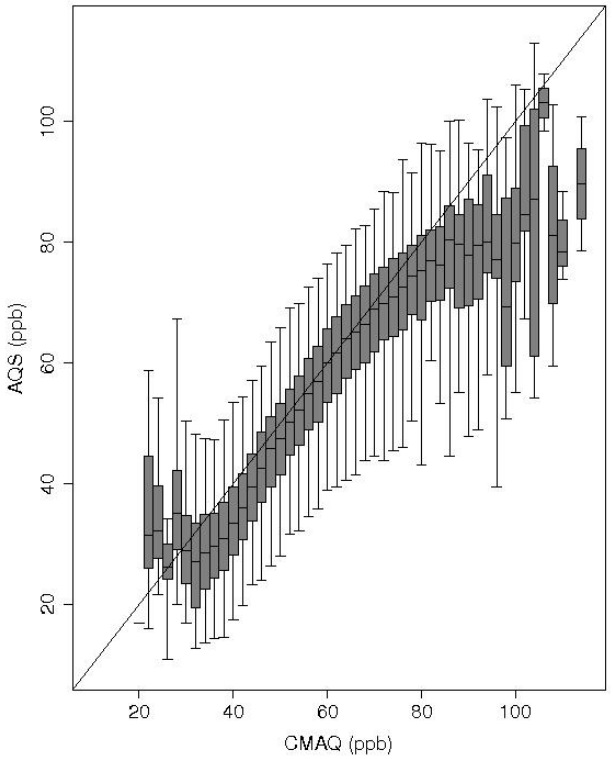


Climate change is expected to degrade ozone air quality; Tai et al. [2010] showed that impacts of climate on PM are complex and uncertain.

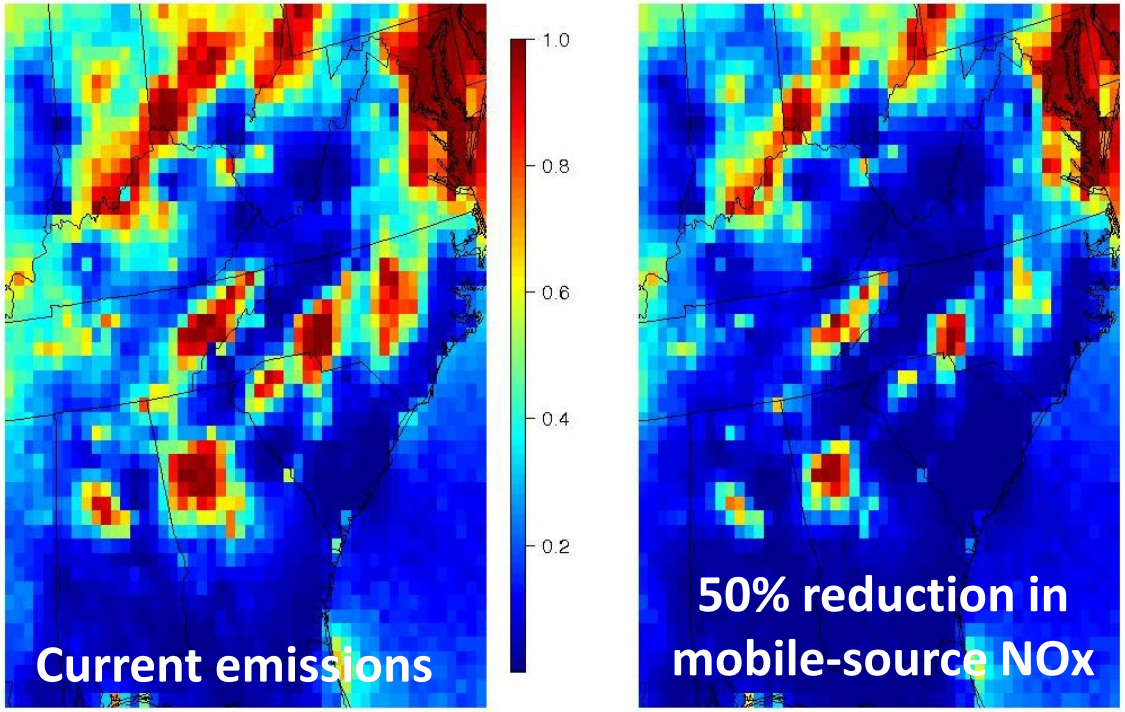
[Jacob and Winner, 2008]

Extreme Value Analysis for Evaluating Ozone Control Strategies

Model Calibration



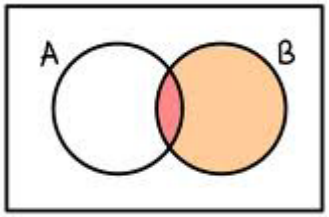
Probability of non-compliance with ozone standard



Developed a reduced form model (RFM) to approximate CMAQ O_3, calibrate model with AQS observations (using QR + EVT) and then evaluate control strategies using RFM.

[Reich, Cooley et al., submitted]

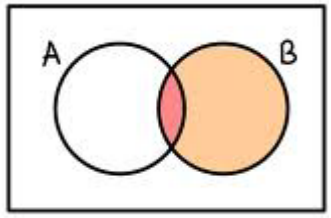
This Project: Develop Sophisticated Statistics Approach to Identifying & Testing Drivers of AQ Extremes



OBJECTIVES:

1. Develop/apply new statistical approaches for investigating drivers of extreme AQ/exceedances.
2. Analyse 10+ year observational record of O_3 and $PM_{2.5}$ in the US to quantify the joint & conditional probability of extreme air quality events & exceedances.
3. Apply the same analysis to regional and global chemistry-climate simulations for present-day to investigate how well these extremes, exceedances, and driving relationships are represented.
4. Forecast AQ extremes based on projected climate and observed historical relationships.

The Tools: Stats, Data and 3D Models



Quantile Regression (QR)

Extreme Value Theory (EVT)

Spatial Data Analysis

Surface O_3 Observations
EPA AIRS
(1979-2010)

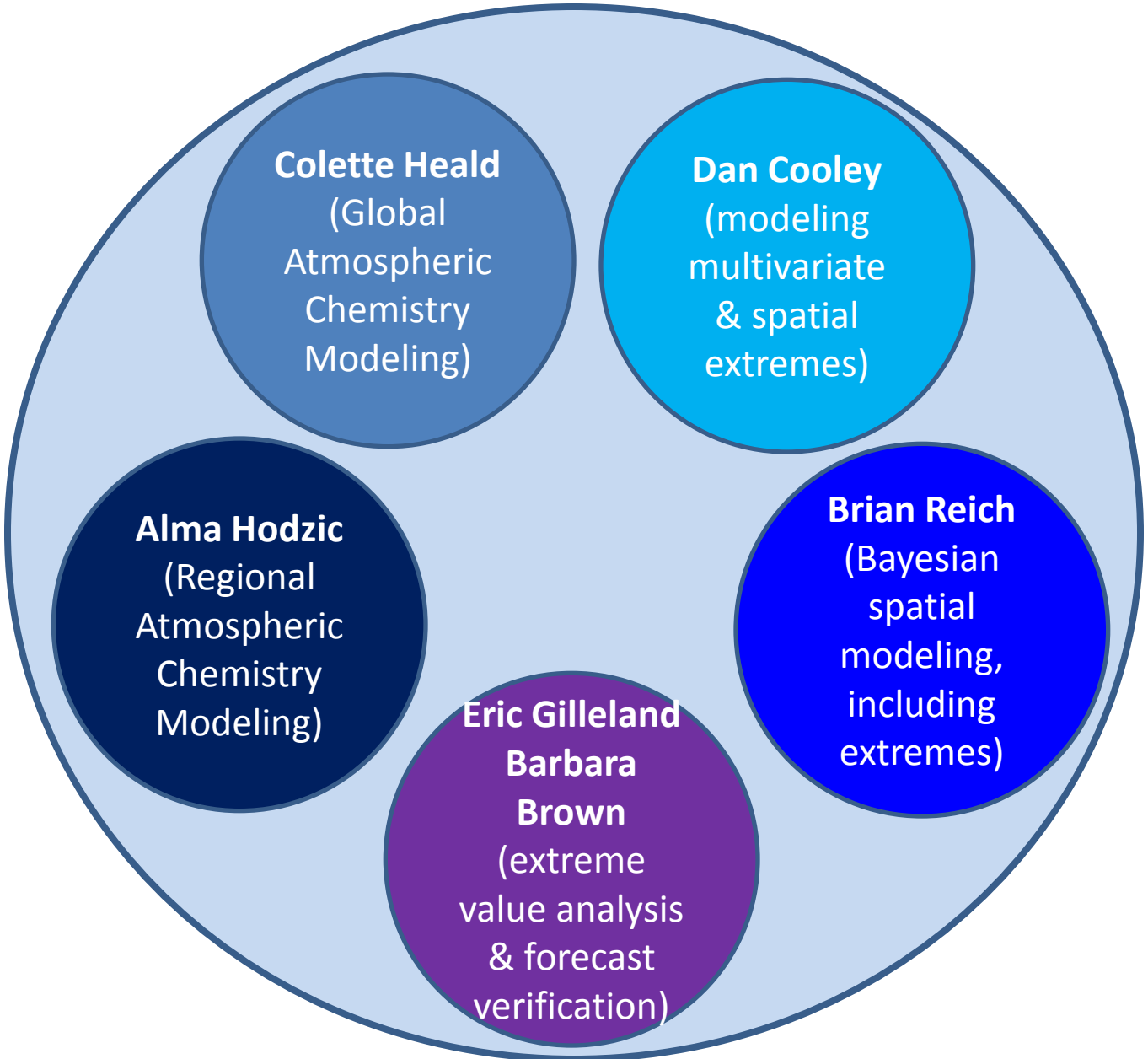
Surface $PM_{2.5}$ Observations
EPA AIRS + IMPROVE
(1999-2010)

Meteorological Data
NCEP NARR (~32 km)
(1979-2010)

GLOBAL:
Community Earth System Model (CESM), coupled gas-aerosol chemistry (CAM-Chem), modal aerosols (MAM), specified (GEOS-5) or free-running dynamics, 1.9 x2.5 resolution

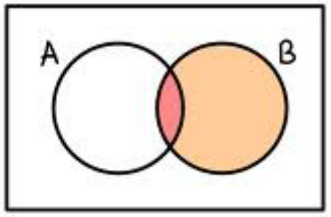
REGIONAL:
NCAR Weather Research Forecasting model with online chemistry (WRF-Chem), several chemical mechanisms, 36 km resolution

The Team: Bridging Expertise



Timeline of Activities

YEAR 1 (Jul 2012) | YEAR 2 (Jul 2013) | YEAR 3 (Jul 2014) | END (Jun 2015)



- Theory Development
- Data Mining (O_3/PM) *for both EVT & QR*
- Develop framework for spatial modeling of extremes

- Analysis of US-wide observations of AQ extremes for several decades (EVT & QR)
- Characterize coherent observed relationships

- Perform series of regional & global present-day chemistry-climate simulations
- Apply extremes analysis framework to simulation.
- Verification & calibration of response
- Perform regional & global 2100 chemistry-climate simulations

- Characterize future simulated AQ extremes
- Apply historical AQ extremes predictors to future simulated climate