Climate Change and Air Quality in US National Parks:

a new project sponsored by NPS



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NPS Report

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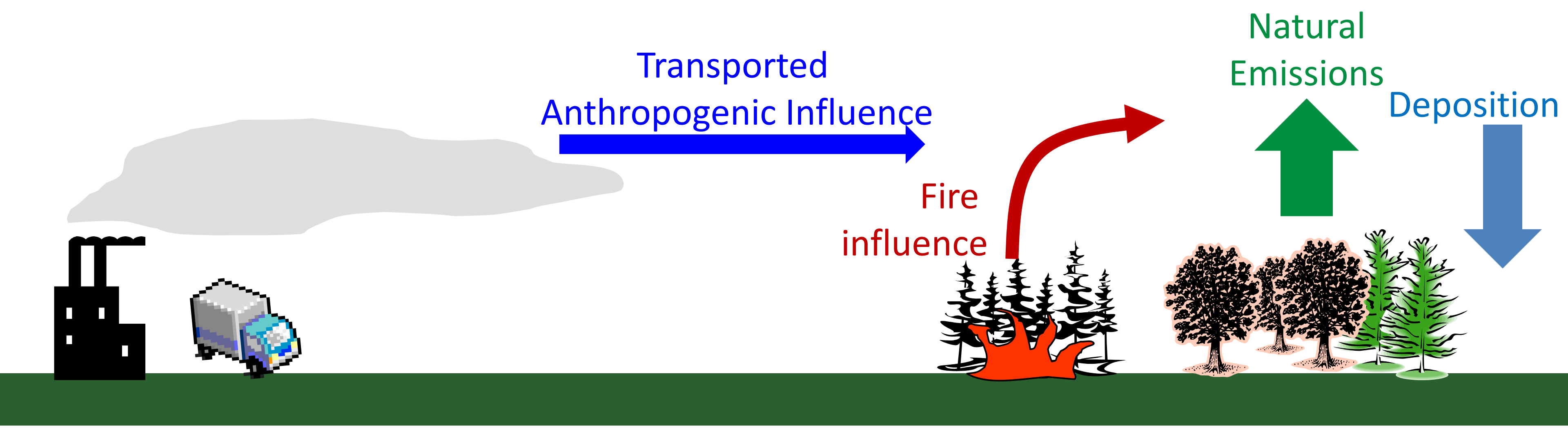
OBJECTIVE: Investigate impact of climate change on air quality in US National Parks

<u>In our national parks:</u>
AIR QUALITY
VISIBILITY



Future air quality in pristine regions will be influenced by:

(a) changes in anthropogenic emissions upwind

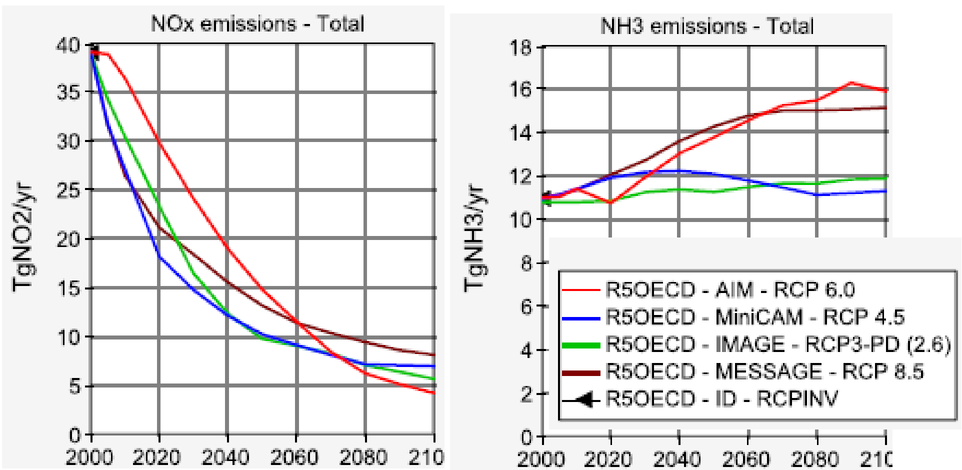
(b) anthropogenic land use change

(c) climate change impacting natural emissions, the chemical environment and removal

What is the relative importance of these players for predicted changes in ozone, haze and nitrogen deposition in US National Parks in 2050?

APPROACH: Apply global chemistry-climate model with most recent IPCC emission estimates

Emissions changes predicted from RCP Models

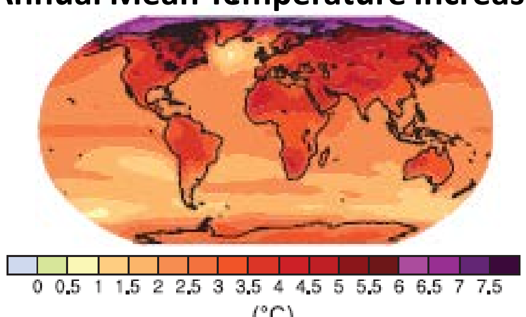


Interactive Natural Emissions

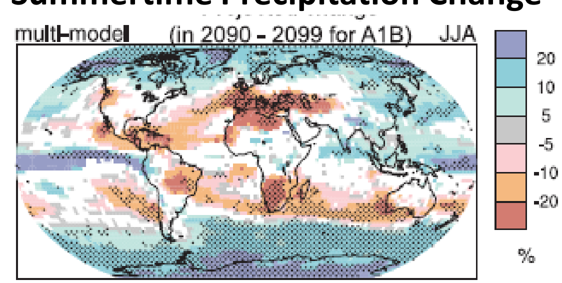
Interactive Climate Change (NCAR CESM)

(examples here from IPCC for 2090, A1B)

Annual Mean Temperature Increase

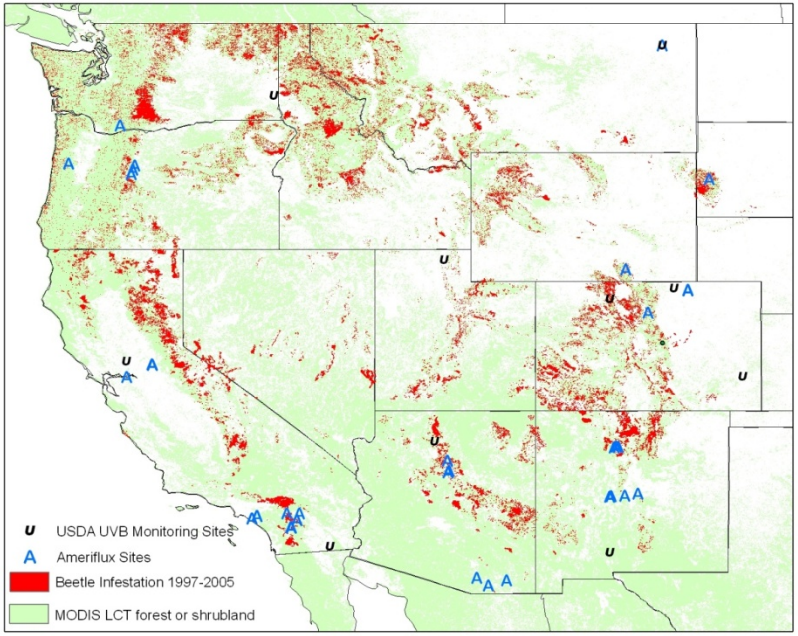


Summertime Precipitation Change



IMPACT OF BARK BEETLE INFESTATION ON AIR QUALITY IN WESTERN NORTH AMERICA

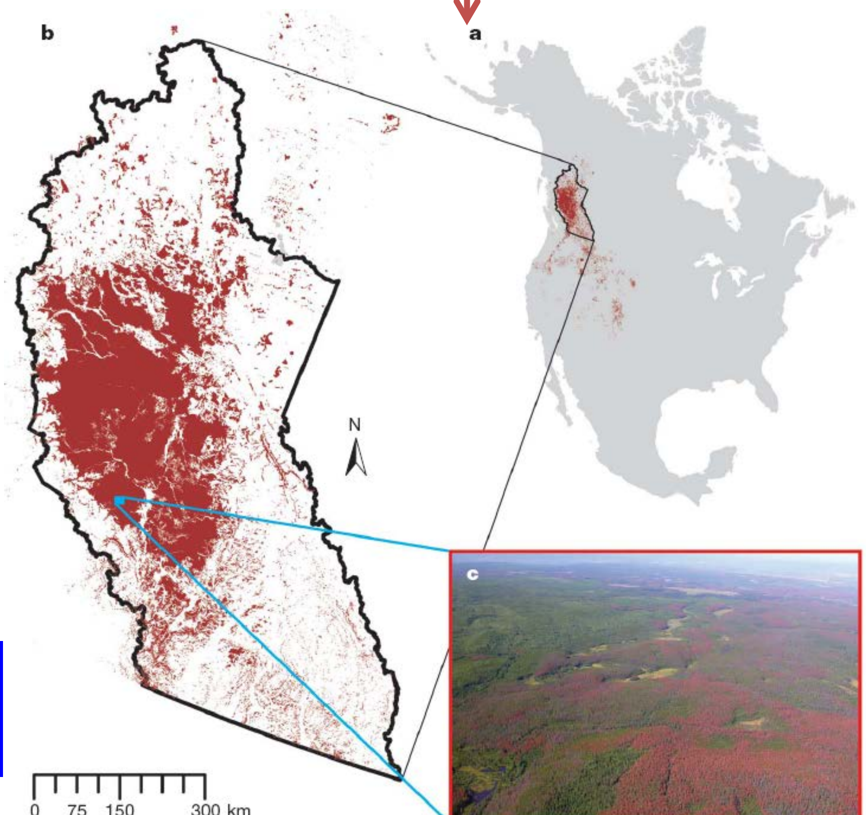
NSF supported project (Ashley Berg)



Christine Wiedinmyer, NCAR

In bad years equivalent carbon source to 75% of all Canadian fires

Kurz et al., 2008



Measurements have shown dramatic increase in VOC emissions from trees under pine beetle attack.

GOAL: model the impact of pine beetle kill on VOC and SOA concentrations in Western North America

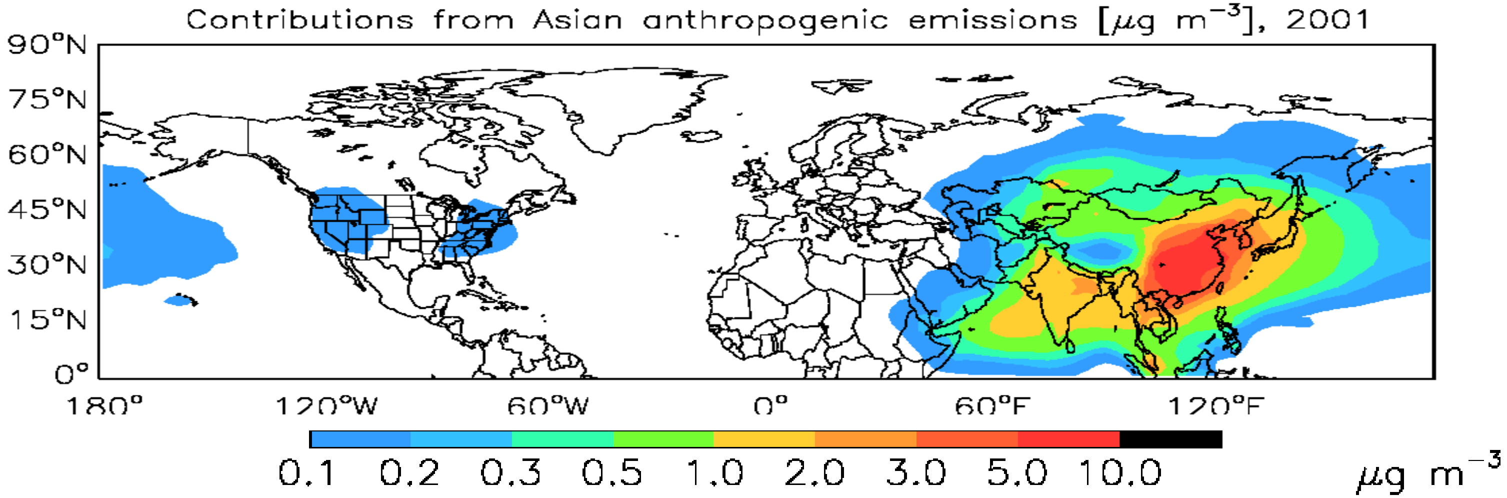
TRANSPACIFIC TRANSPORT OF ASIAN AEROSOLS

Despite their short lifetimes, aerosols can be transported across the Pacific and can affect North American air quality standards and visibility.

Most documented cases consist of transport of dust:

Visibility reduction at Glen Canyon, Arizona due to transpacific transport of Asian dust

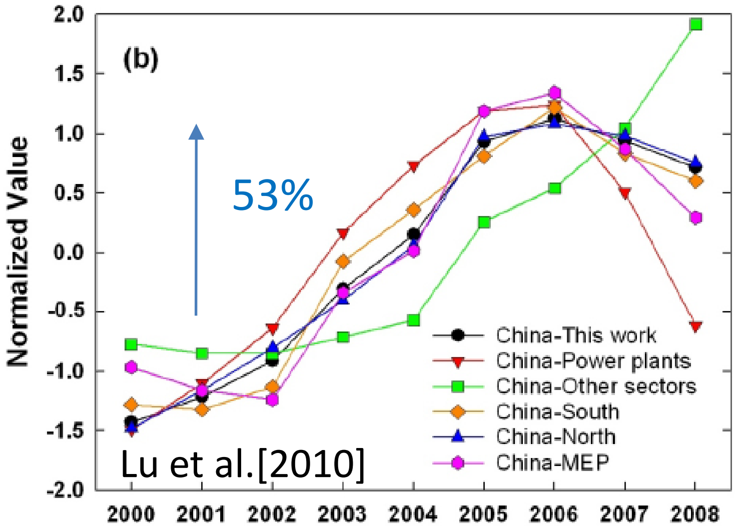
BUT **Model** simulations suggest that anthropogenic aerosols from Asia can **ALSO** be transported to the United States [*Park et al*., 2004]. Relevant to Regional Haze Rule….



IMPACT OF ASIAN EMISSIONS ON AIR QUALITY IN THE UNITED STATES

NASA supported project (Kateryna Lapina)

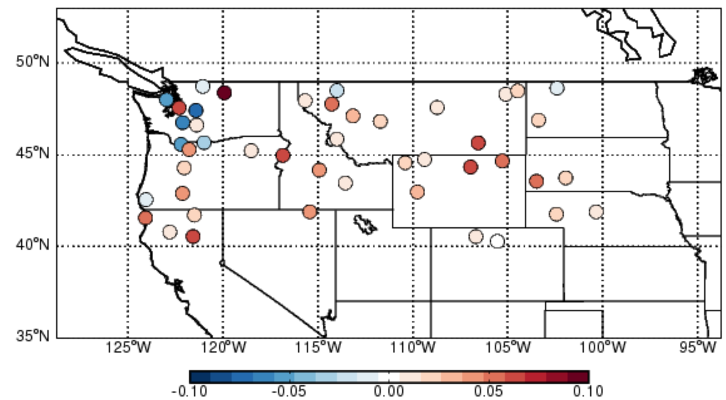
Normalized Chinese SO_2 Emissions



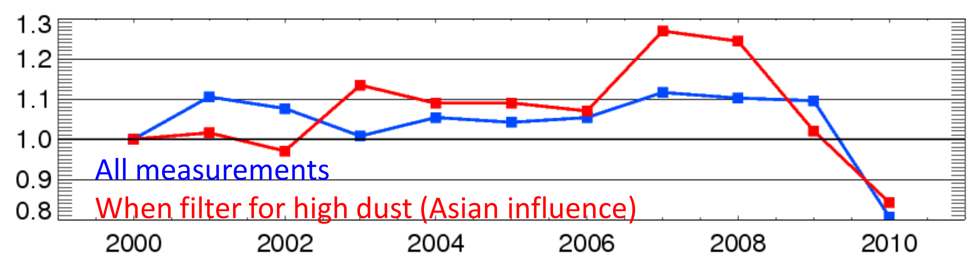
Increase (2000-2006) due to industrialization. Recent downward trend due to flue-gas desulfurization technology and economic downturn.

Question: can we see the impact at down-wind IMPROVE sites in the US?

Springtime Sulfate Trend (2000-2007)



Normalized Trend in Springtime Sulfate at IMPROVE sites in the NW US



Currently testing with a global model if predicted impact of Asian emissions trend is consistent with observations at IMPROVE

EXTRAS

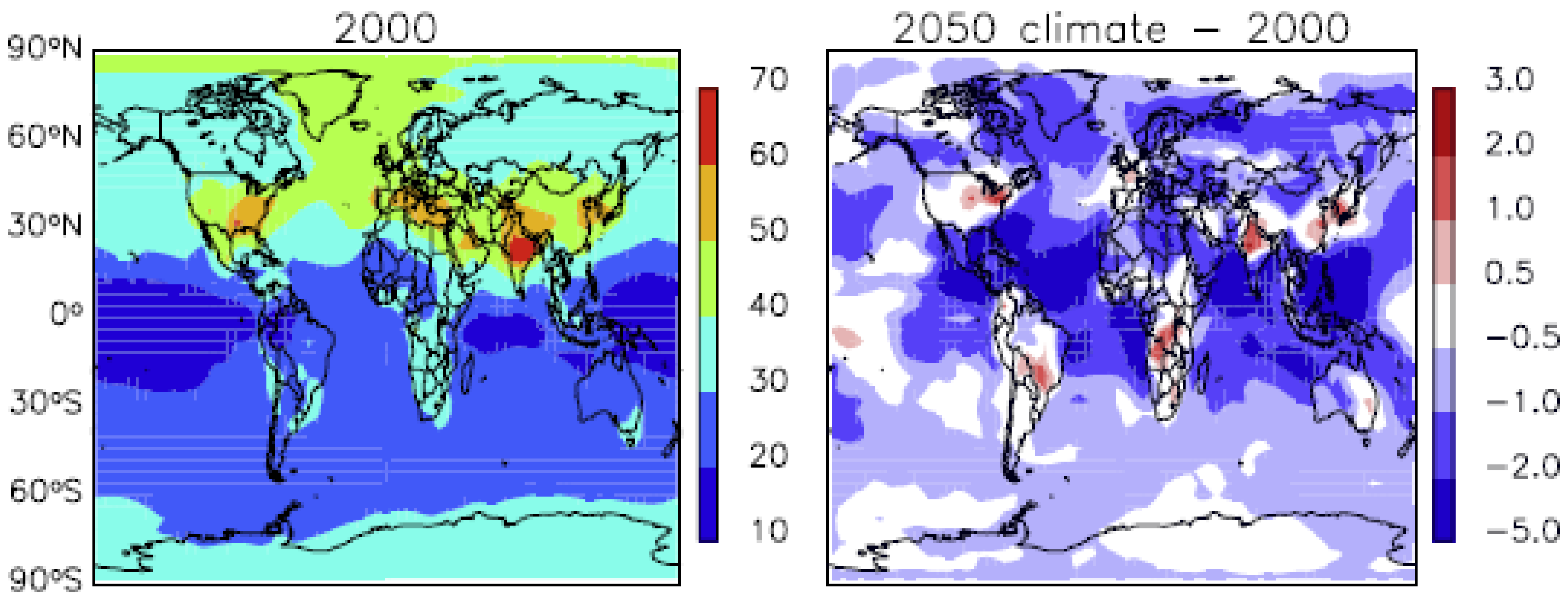
SENSITIVITY OF SURFACE AIR QUALITY TO METEOROLOGICAL VARIABLES

Insights into the effect of climate change on air quality

Effect of climate change		Ozone	PM (aerosol)
↑	Stagnation	↑	↑
↑	Temperature	↑	↓
?	Mixing depth	=	↓
?	Precipitation	=	↓
?	Cloud cover	↓	↓
?	Humidity	=	↑ (relative)

[Jacob and Winner, 2008]

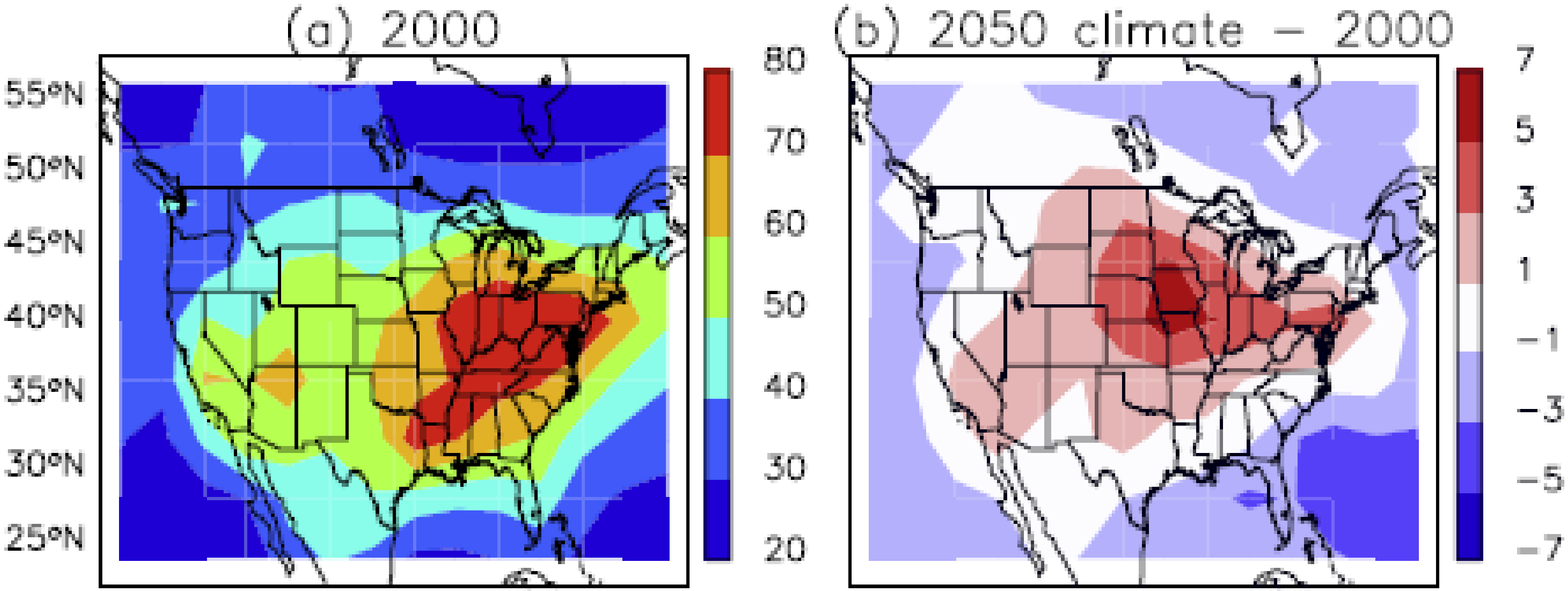
EFFECT OF 2000-2050 CLIMATE CHANGE (A1B) ON GLOBAL AFTERNOON SURFACE OZONE



Ozone is predicted to increase over polluted continental regions (complex meteorological factors + natural emission changes) and decrease over the ocean (due to enhanced water vapour)

[Wu et al., 2008b]

CLIMATE CHANGE ALONE DEGRADES "MEAN" AQ IN THE US



Climate change causes a 2–5 ppb positive offset over the Midwest and northeastern United States, partly driven by decreased ventilation from convection and frontal passages.

[Wu et al., 2008a]

CHANGES IN AQ (SUMMER) OVER THE US (A2)

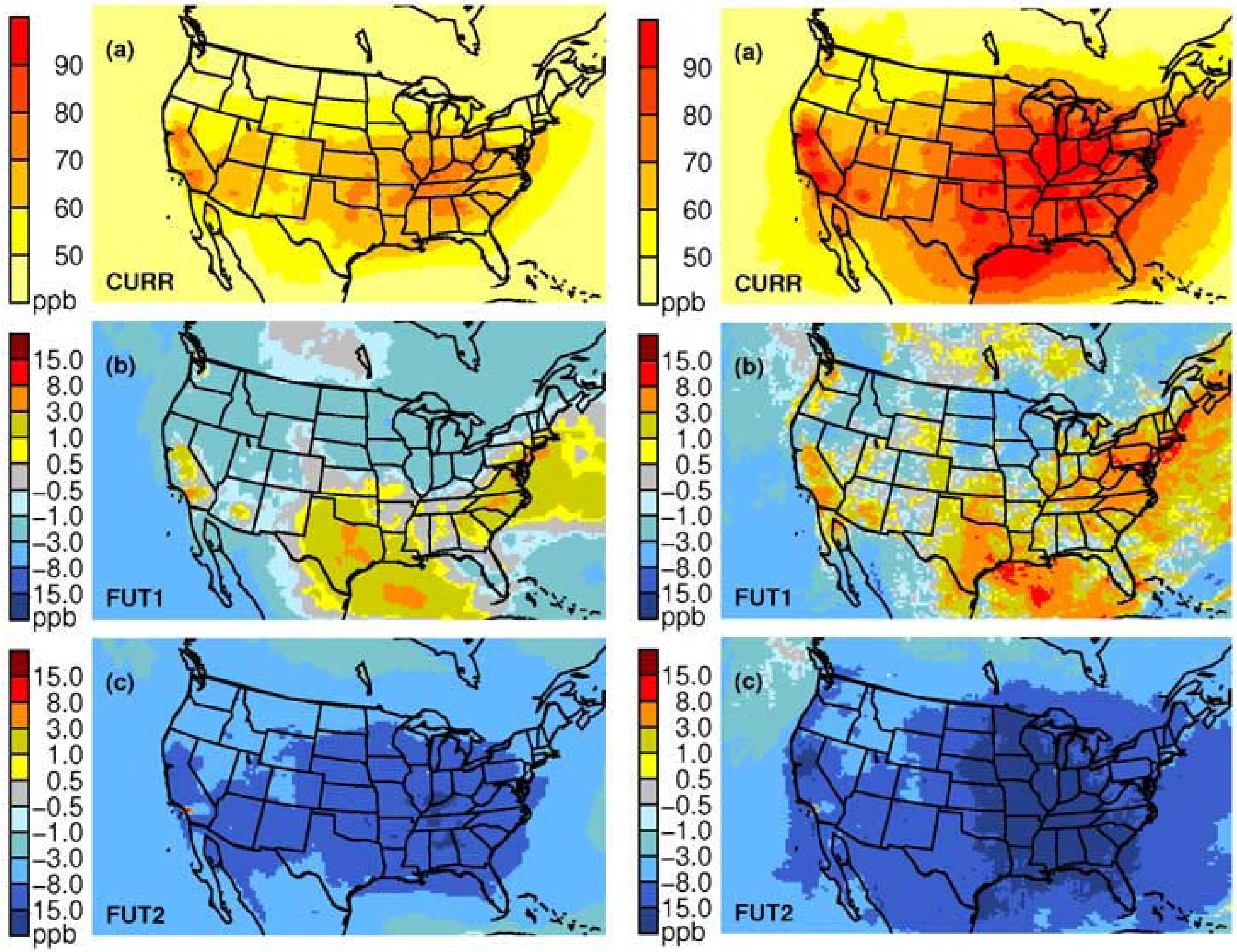
mean

95th percentile

Present Day O_3

ΔO_3 Climate only

ΔO_3 Emissions only



Changes in O_3 due to climate (driven primarily by cloud cover) are significantly smaller than impact of emission reductions in the mean, although a larger effect on extremes is predicted (similar to Wu et al.).

[Nolte et al., 2008]

PROJECT OBJECTIVES

Quantify the contributions from:

1. Anthropogenic emission changes
2. Natural emission changes (BVOC, dust, BB)
3. Climate Change
4. Land use change (RCP scenarios, not DGVM)

Also investigate the role of resolution: do some hi-res runs (1x1)

RCP EMISSIONS SPECIATED FOR USE IN CESM

(example for year 2000)

	RCP45	CAM
BC	5.15	4.67
BIGALK	120.21	223.67
BIGENE	4.85	7.16
C10H16	--	--
C2H2	3.29	3.45
C2H4	7.73	6.73
C2H5OH	2.84	5.38
C2H6	3.34	7.56
C3H6	3.46	2.78
C3H8	3.86	8.07
CH2O	3.18	0.96
CH3CHO	1.23	2.14
CH3CN	0.89	0.72
CH3COCH3	1.10	0.30
CH3COOH	5.09	6.63
CH3OH	1.97	0.42
CO	609.45	600.69
HCN	1.76	1.00
HCOOH	3.90	6.63
ISOP	--	--
MEK	1.37	1.26
NH3	37.33	48.97
NO	68.41	61.08
OC	12.70	16.17
SO2	103.79	130.71
TOLUENE	93.57	117.1

"Standard" emissions = POET

Contact Maria Val Martin if interested (mval@atmos.colostate.edu)

EPA PARTICULATE MATTER REGULATIONS

Particulate Matter Standards (NAAQS)

- 24-hour: 35 µg/m^3 ($PM_{2.5}$) 150 µg/m^3 (PM_{10})
- Annual: 15 µg/m^3 ($PM_{2.5}$) 50 µg/m^3 (PM_{10})

Regional Haze Rule: improve visibility in 156 national parks and wilderness areas

EPA Estimated Natural Conditions (Target for 2064)

	West (µg/m^3)	**East (µg/m^3)**
Ammonium sulfate	0.12	0.23
Ammonium nitrate	0.10	0.10
Organic carbon mass	0.47	1.40
Elemental carbon	0.02	0.02
Soil	0.50	0.50
Coarse Mass	3.0	3.0

LAND COVER AND LAND USE CHANGE CAN HAVE DRAMATIC IMPACT ON EMISSIONS

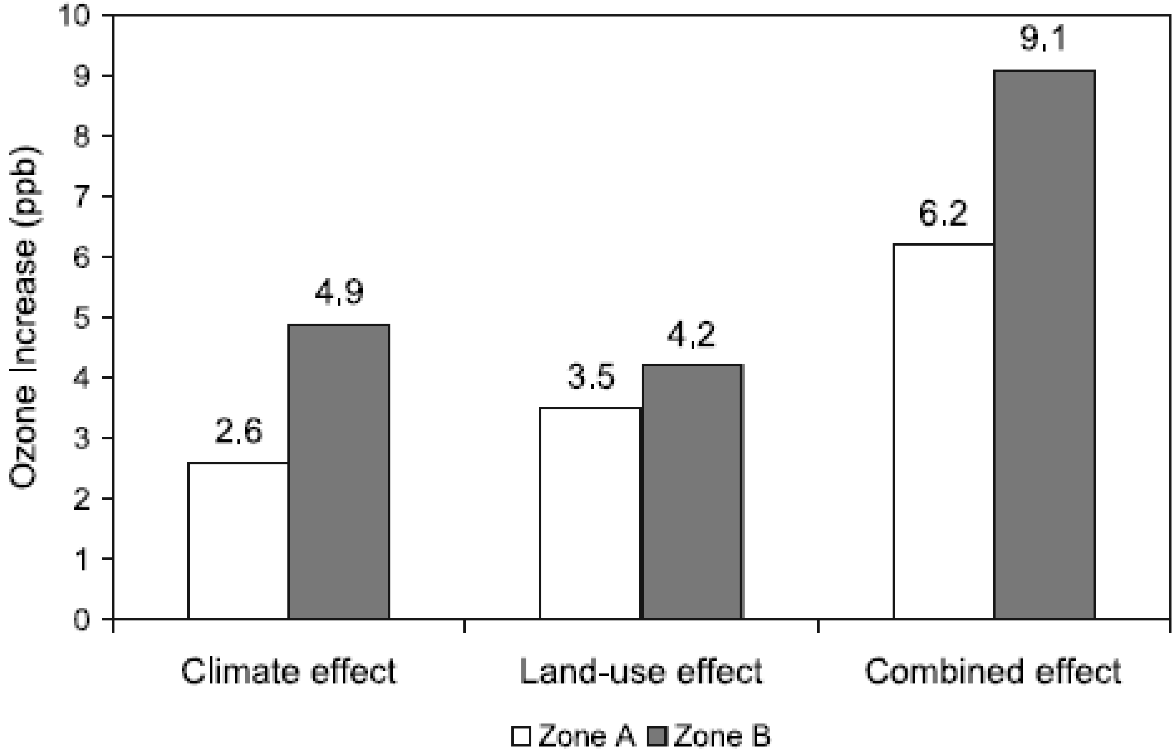
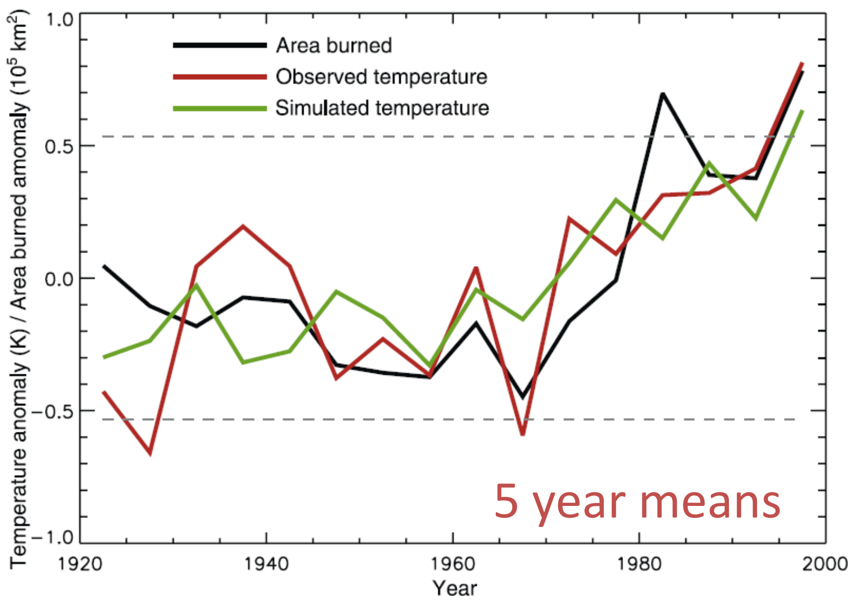


Figure 13. Spatially averaged contributions of climate-induced change, land use–induced change, and combined climate and land use change from the 2000s to the 2050s to changes in daily maximum 8-h O_3 concentrations.

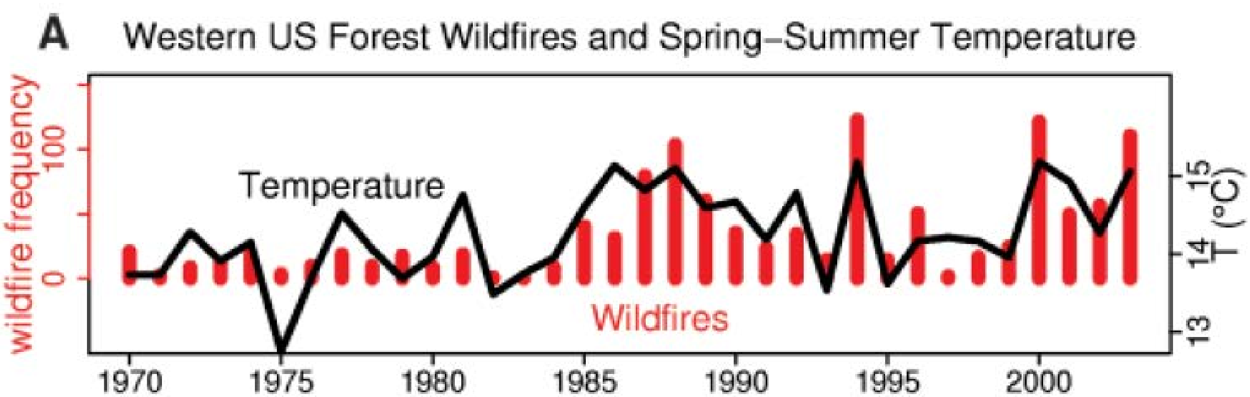
Jiang et al., 2008

OBSERVED INCREASES IN FIRES IN NORTH AMERICA (Related to temperature)



Area burned in Canada has increased since the 1960s, correlated with T increase.

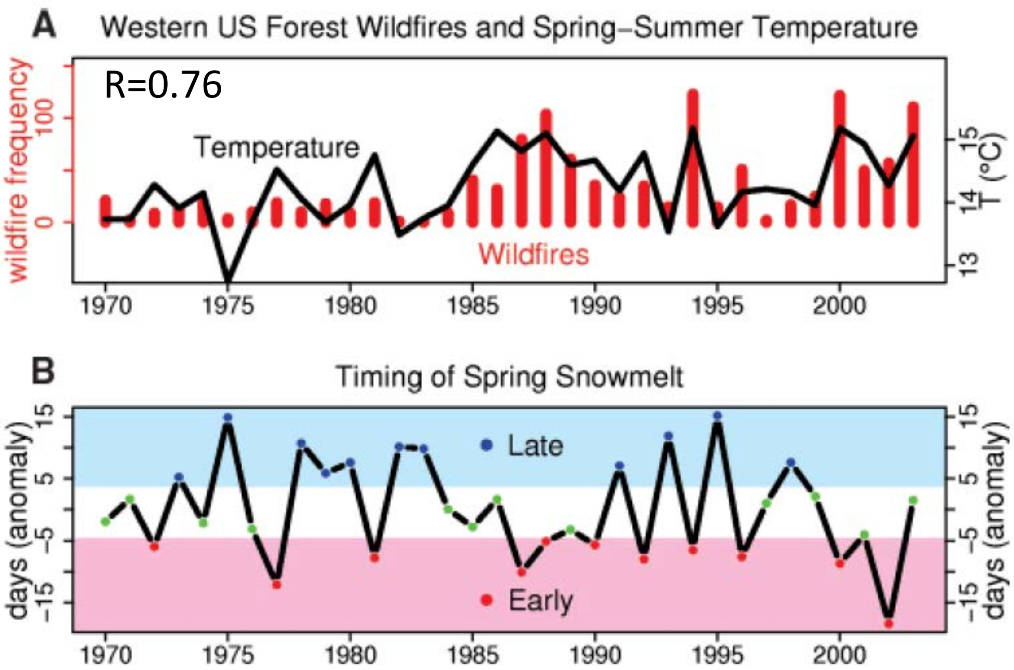
Gillett et al., 2004



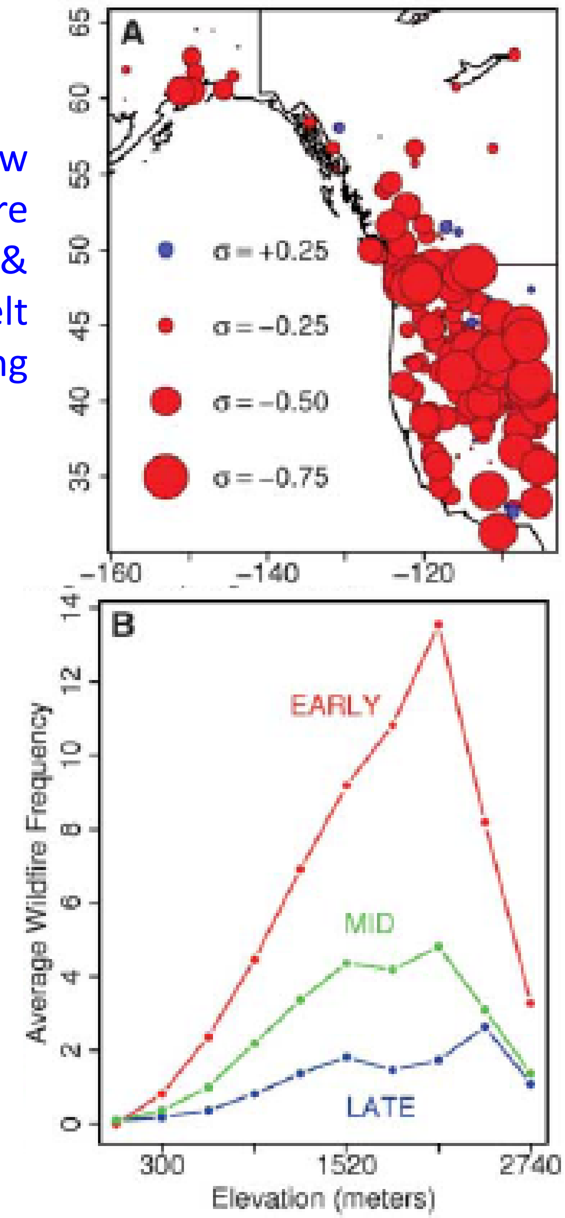
Increased fire frequency over western U.S. in recent decades – related to warmer T, earlier snow melt.

Westerling et al., 2007

INCREASED FIRE ACTIVITY RELATED TO TIMING OF SNOWMELT (ESP. AT ELEVATION)



Correlation b/w wildfire frequency & snowmelt timing



Length of fire season increased by 78 days (between 1970-1986 and 1987-2003).

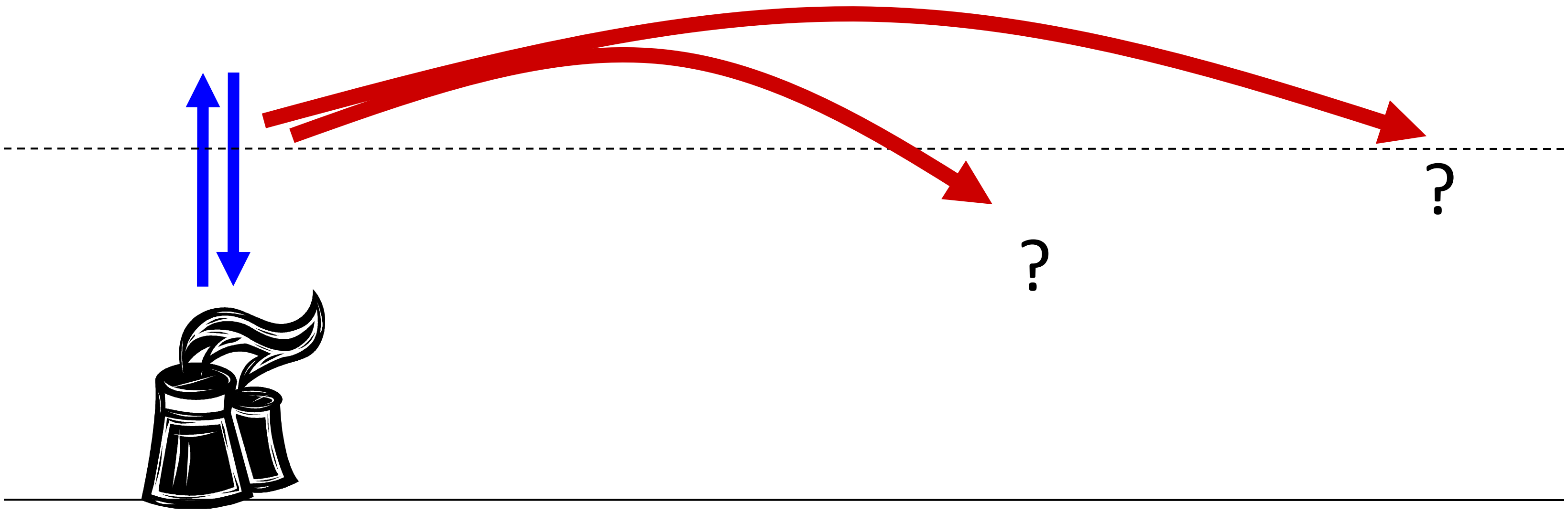
Increase concentrated between 1680-2590 m elevation (more susceptible to drought).

Greatest increase in Northern Rockies (accounts for 60%).

Westerling et al., 2007

HOW ARE CHANGING TRANSPORT PATTERNS IMPORTANT FOR ATMOSPHERIC COMPOSITION?

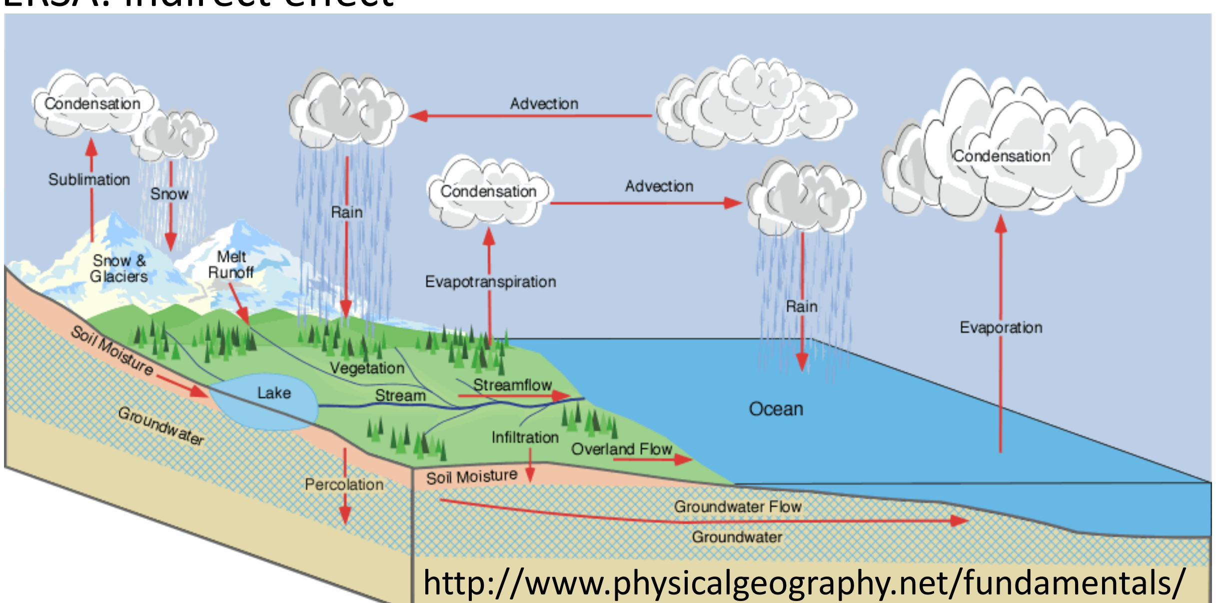
1. Changing lifetimes of pollutants (longer at higher altitudes)
2. Changing vertical mixing, ventilation
3. Changing transport efficiency
4. Changing locations of down-wind impact
5. Changing winds affecting emission (dust, sea salt)



Can impact tropospheric background and local pollution events

HOW ARE CHANGES TO THE HYDROLOGICAL CYCLE IMPORTANT FOR ATMOSPHERIC COMPOSITION?

1. Precipitation: Changing lifetimes of pollutants, transport efficiency
2. Precipitation: Changing acid deposition
3. Drought / soil moisture: Impact on vegetation, biogenic emissions
4. Drought: enhances likelihood of fires and dust emission
5. Water vapour: enhanced O_3 destruction, more OH
6. Clouds: changing photolysis rates & heterogeneous chemistry
7. Clouds: impact on biogenic emissions, ocean productivity
8. Convection: vertical transport & LNOx
9. VICE VERSA: indirect effect

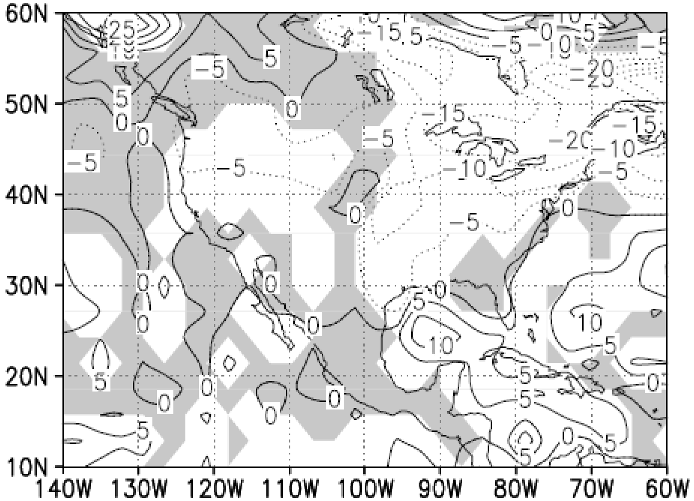


http://www.physicalgeography.net/fundamentals/

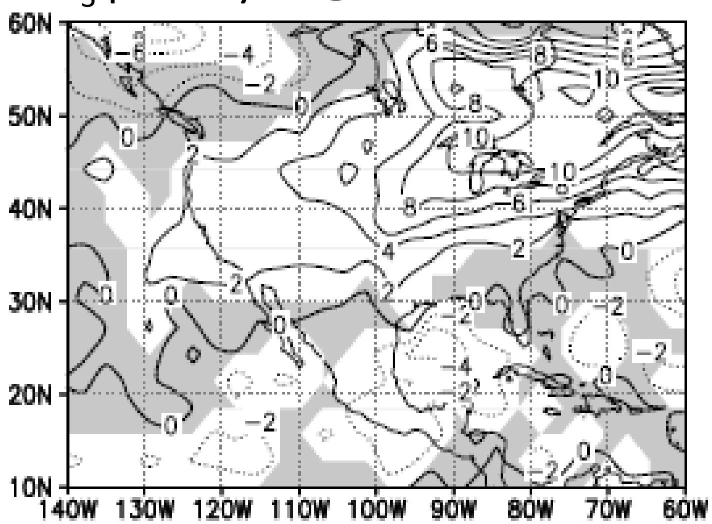
CLOUDINESS AND ATMOSPHERIC COMPOSITION

2100-2000

Cloud Water (surface–700 hPa)



O_3 photolysis @ the surface



Decreases in low-level clouds over the US

→Photolysis of O_3 increases by 10%

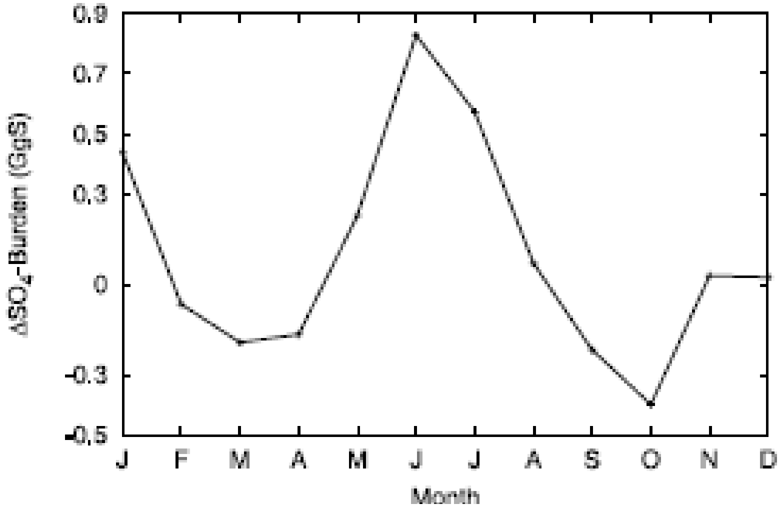
→Photolysis of NO_2 increases up to 4%

[Murazaki and Hess, 2006]

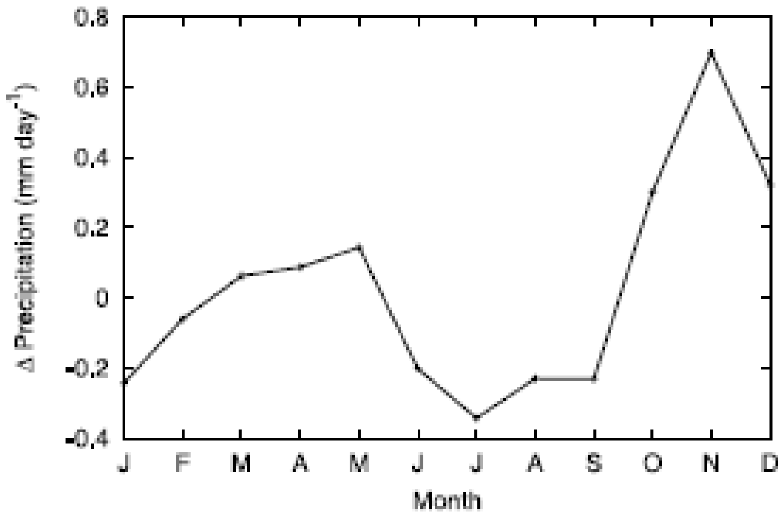
PRECIPITATION AND SULFATE IN THE US

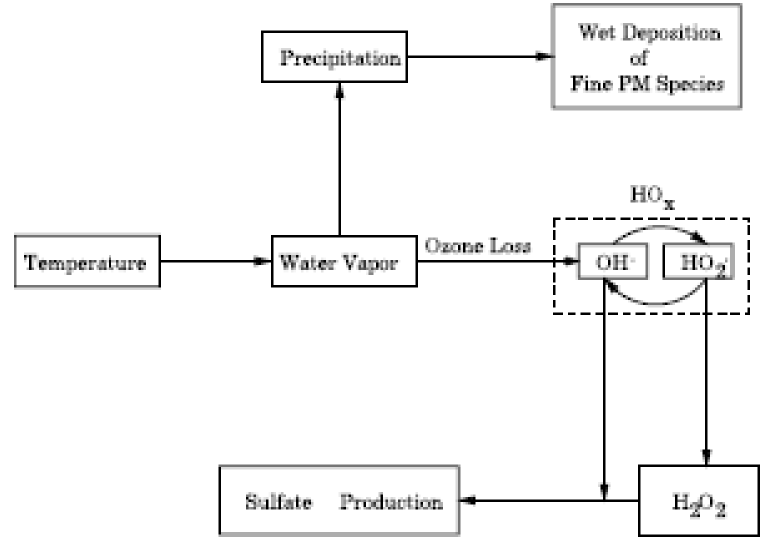
2050-1990

Δ Sulfate Burden



Δ Precipitation



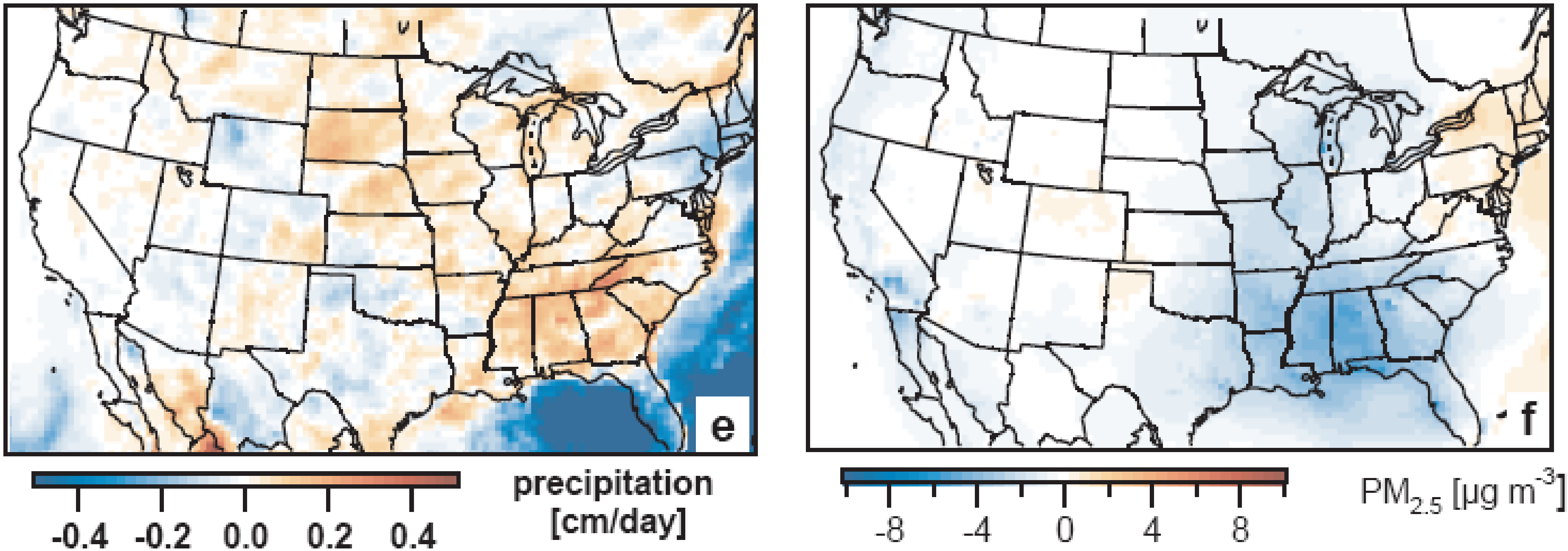


MJJ sulfate increase due to reduced precipitation (longer lifetime), which outweighs decrease caused by reduced in-cloud SO_2 oxidation

[Racherla and Adams, 2006]

SUMMERTIME PRECIPITATION CHANGES IN THE US

2050-2000



Suggest that $PM_{2.5}$ reductions projected in the SE due to precipitation.

[Avise et al., 2009]