Impact of Climate Change on Fine Particulate Matter ($PM_{2.5}$) Air Quality Inferred from a Multi-model Analysis of Meteorological Modes

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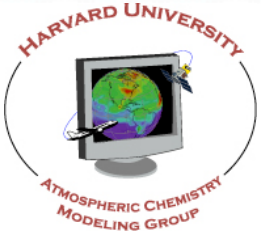

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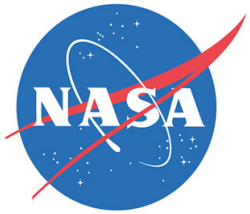


Fine Particulate Matter ($PM_{2.5}$): Composition, Sources and Sinks

emissions

fossil fuel

agriculture

vegetation

precursor gases

SO_2

NO_x

NH_3

chemistry (oxidation, condensation)

volatile organic compound (VOC)

(combustion, wildfires)

$PM_{2.5}$ components

sulfate

nitrate

ammonium

organic carbon

black carbon

removal processes

transport (ventilation)

scavenging

Effect of Climate Change on $PM_{2.5}$ Air Quality

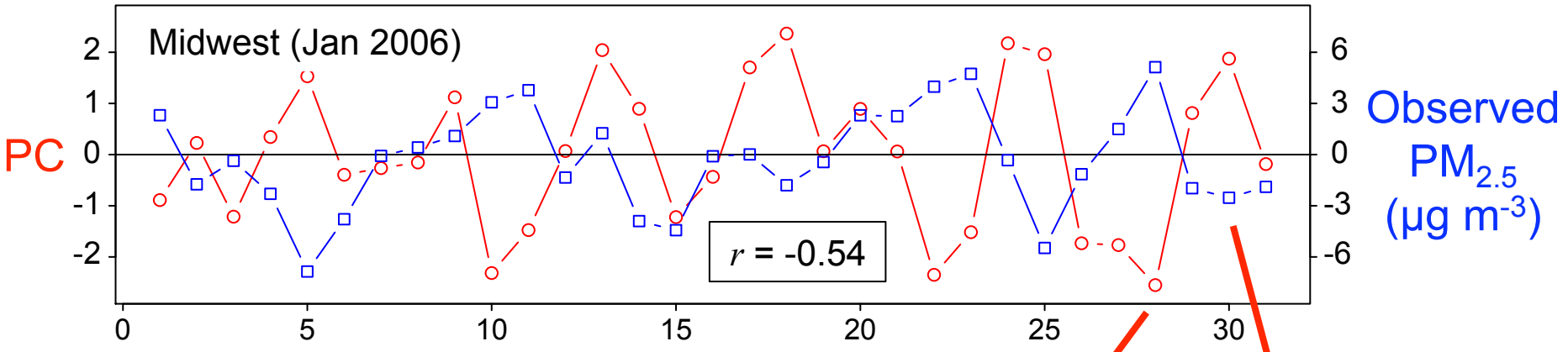
Expected effects of 21st-century climate change		$PM_{2.5}$ dependence on meteorological variables
↑	Temperature (emissions, chemistry)	↑↓
?	Relative humidity (chemistry)	↑
?	Precipitation (scavenging)	↓
↑	Stagnation (transport)	↑
?	Mixing depth (transport)	↓

- GCM-CTM studies show ±0.1-1 μg m^{-3} effect of climate change on $PM_{2.5}$ with no consistency even in sign of effect
- Reflects uncertainty of GCMs in simulating regional climate, and use of single GCM realizations in GCM-CTM studies which is not sufficient due to complex meteorological dependence

Dominant Meteorological Modes for Daily $PM_{2.5}$ Variability

- **Principal component analysis (PCA)** of 8 meteorological variables to identify dominant meteorological mode that drives day-to-day $PM_{2.5}$ variability by region:

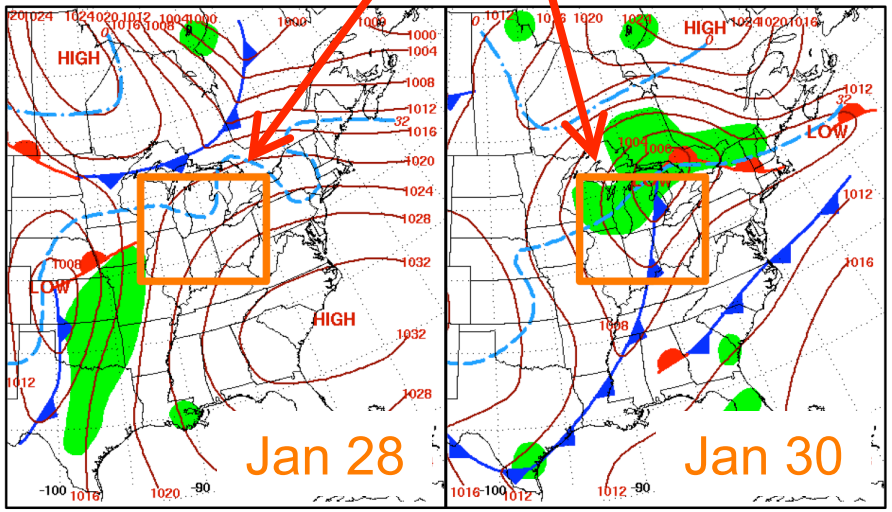
$$PC(t) = \alpha_T T(t) + \alpha_{precip} precip(t) + \alpha_{SLP} SLP(t) + \ldots$$



Transport modes for $PM_{2.5}$:

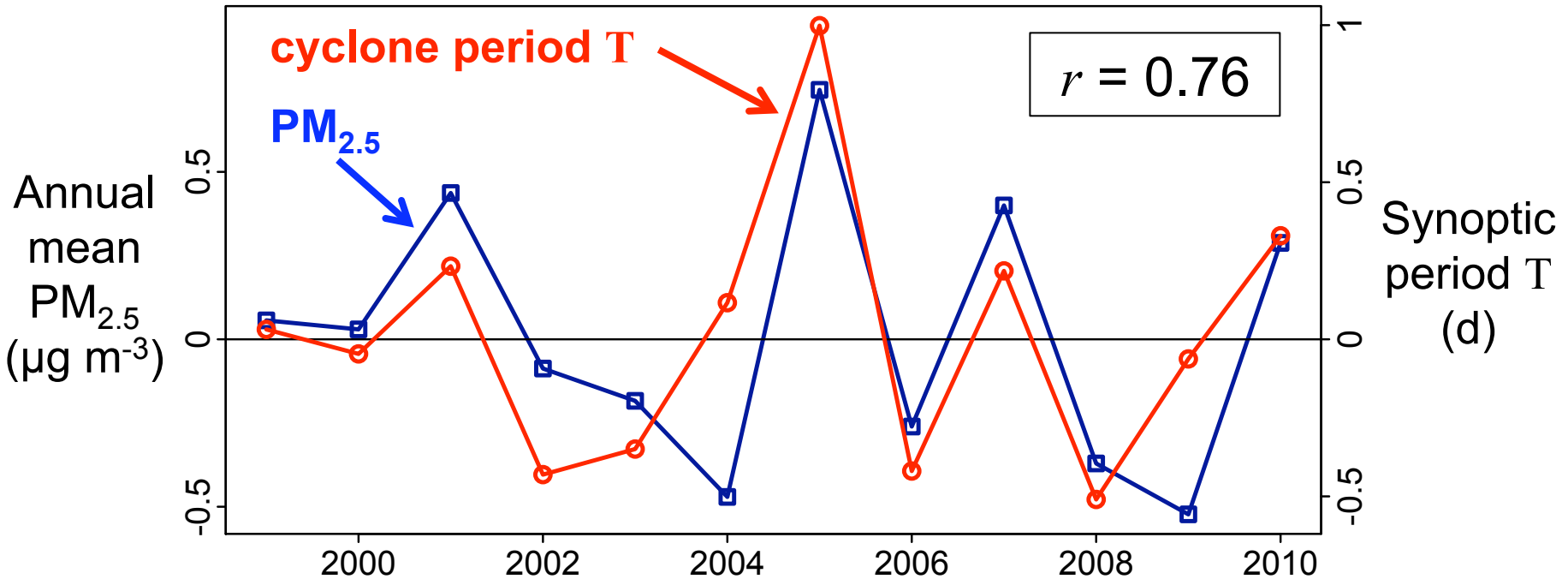
- Eastern US: **mid-latitude cyclone and cold front passage**
- Pacific coast: **synoptic-scale maritime inflow**

[Tai et al., 2012]



Dominant Meteorological Modes for Interannual $PM_{2.5}$ Variability

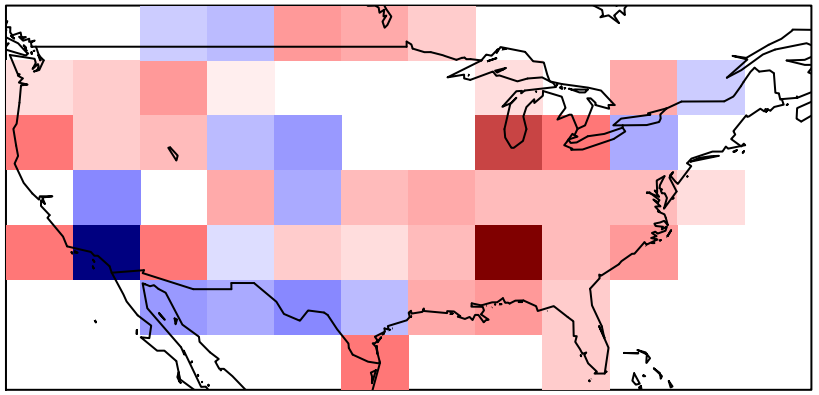
- Identify dominant meteorological mode for interannual $PM_{2.5}$ variability whose mean period T (~5-10 days) is most strongly correlated with annual mean $PM_{2.5}$
- Midwest: local $dPM_{2.5}/dT$ = ~1 μg m^{-3} d^{-1}



Anomaly of annual mean $PM_{2.5}$ and period of dominant meteorological mode (cyclone passage) for US Midwest

[Tai et al., 2012]

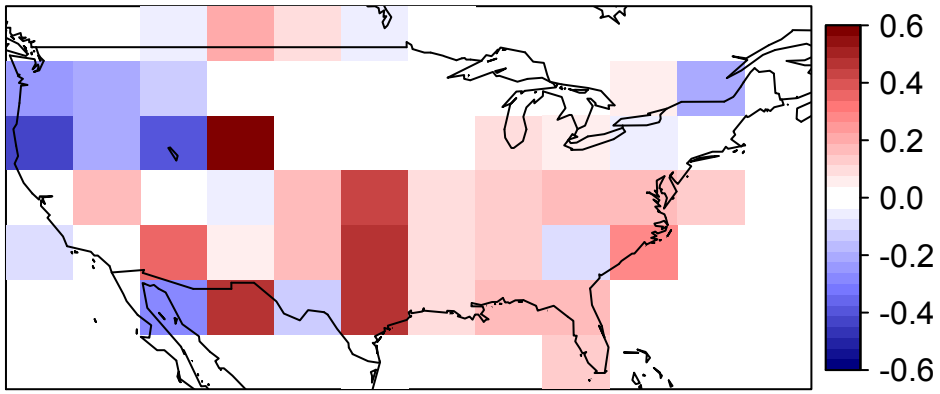
Multi-model Projection of Synoptic Period and $PM_{2.5}$



$d\mathrm{PM}_{2.5}/d\mathrm{T}$
(μg m^{-3} d^{-1})

Climatological observation of $d\mathrm{PM}_{2.5}/d\mathrm{T}$

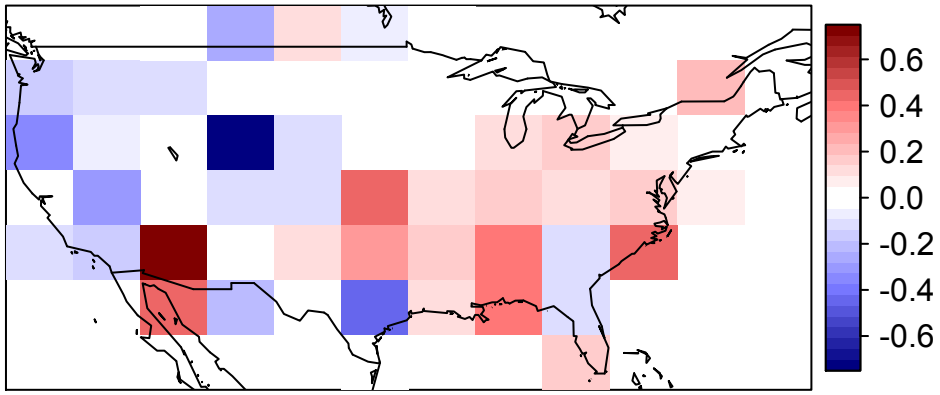
×



$\Delta\mathrm{T}$
(d)

Weighted average 2000-2050 change in T (15 IPCC AR4 GCMs)

=

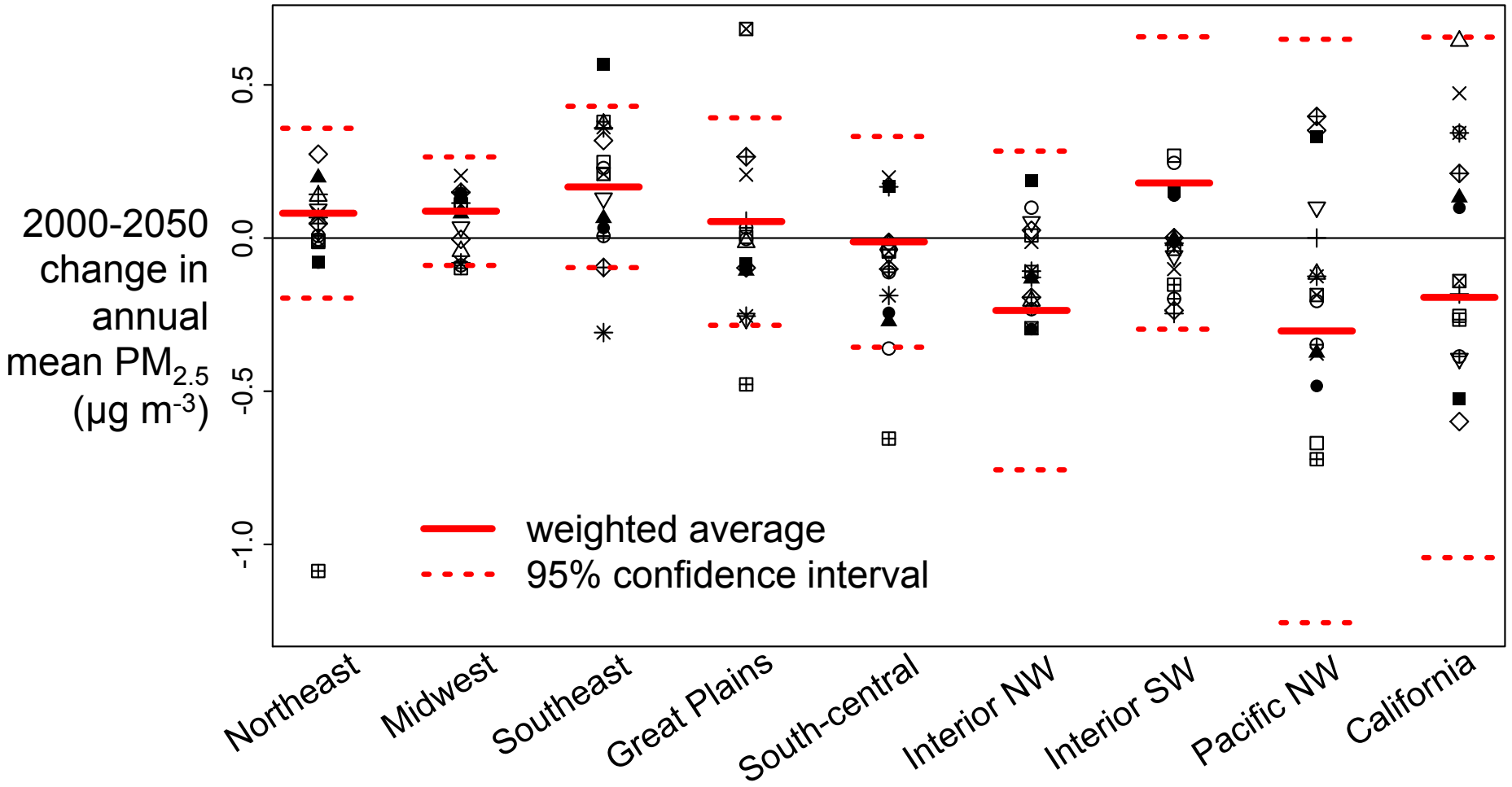


$\Delta\mathrm{PM}_{2.5}$
(μg m^{-3})

Resulting 2000-2050 change in $PM_{2.5}$

[Tai et al., in prep]

Inter-model Variability of Circulation-driven Projection of $PM_{2.5}$



- Likely **increase of ~0.1 μg m^{-3} in eastern US** due to more stagnant atmosphere; likely **decrease of ~0.3 μg m^{-3} in Northwest** due to more frequent maritime inflows
- Uncertain in other regions

[Tai et al., in prep]

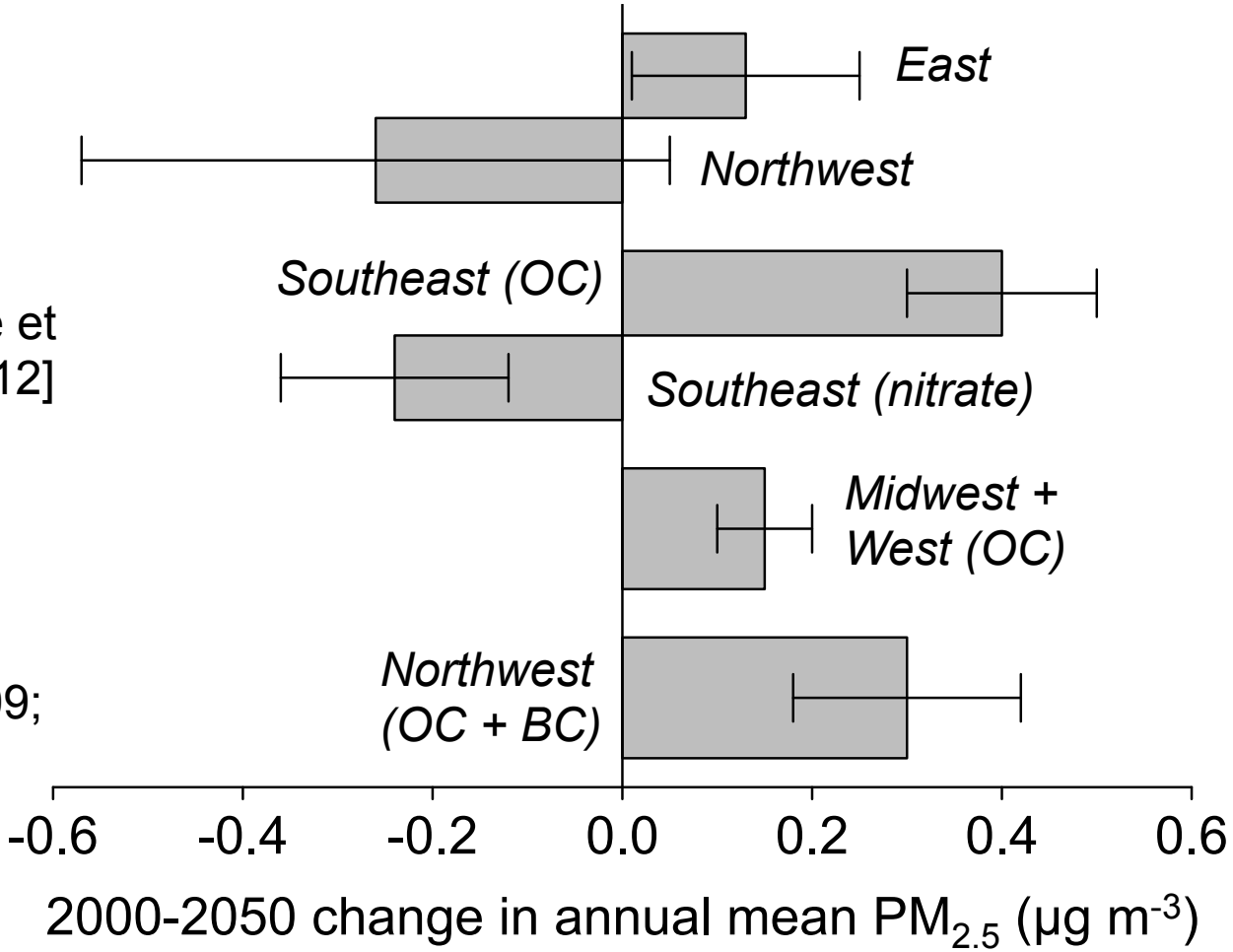
Overall Assessment of $PM_{2.5}$ Response to Climate Change

Circulation
[Tai et al., in prep]

Temperature
[Heald et al, 2008; Pye et al., 2009; Tai et al., 2012]

Vegetation
[Wu et al., 2012]

Wildfires
[Spracklen et al., 2009; Yue et al., in prep]



- Overall climate effect on annual $PM_{2.5}$ unlikely to exceed ±0.5 μg m^{-3}
- Effect of fires on daily $PM_{2.5}$ in the West may be more prominent issue