Air Quality and Climate Change

Center for Atmospheric Particle Studies (CAPS)

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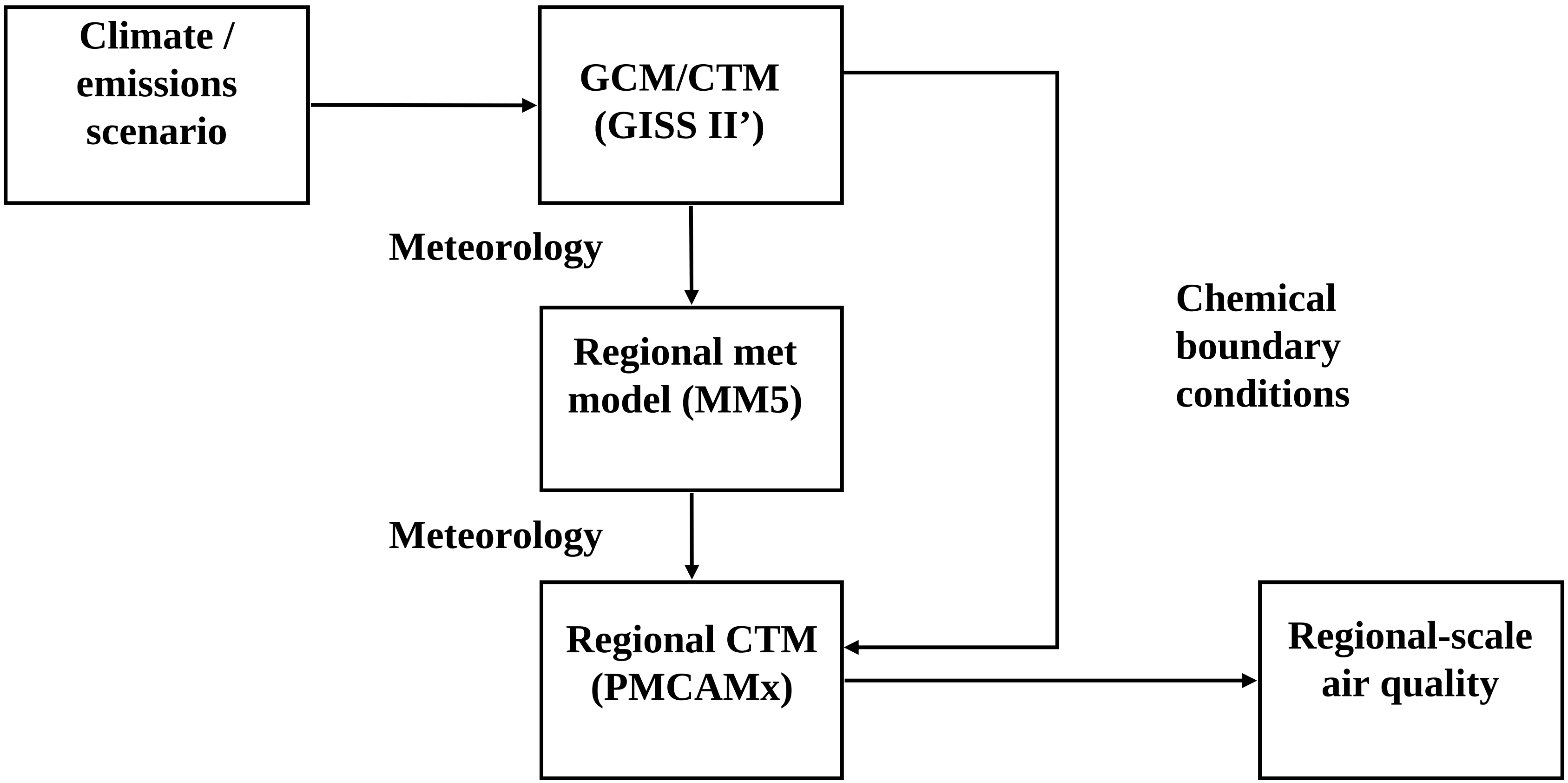
Project Overview

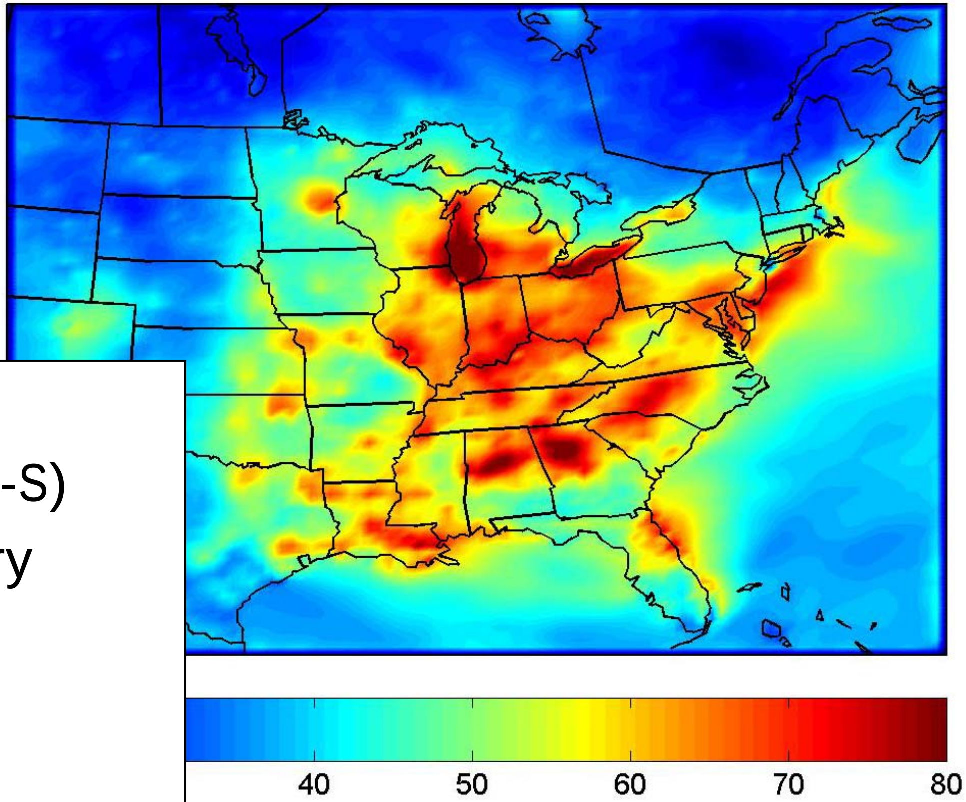


Outline

- Regional scale sensitivity studies
  - Impose controlled perturbations in individual meteorological variables
- Global scale future change
  - Holistic response to 2050 climate
- Global-Regional Climate Air Pollution Modeling System (GRE-CAPS)
  - development
  - evaluation
  - preliminary results
- Upcoming project

Regional CTM Sensitivity Studies

PMCAMx



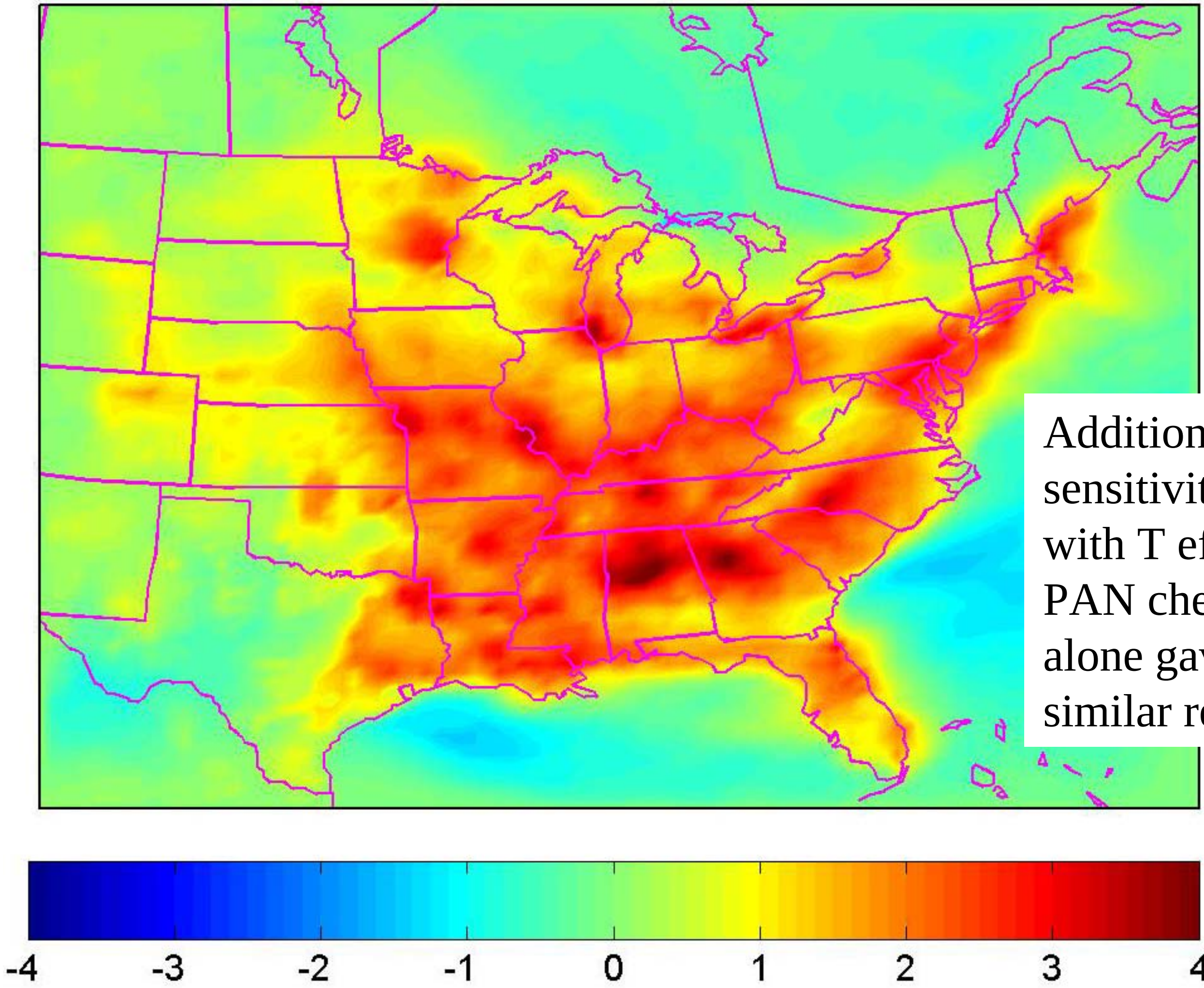
- 36 km x 36 km
- 97 cells (E-W) x 90 cells (N-S)
- CBM-IV gas phase chemistry
- CMU aerosol modules
- 14 layers (summer)
  16 layers (winter)
- Climate sensitive emissions (e.g. isoprene) <u>held constant</u>

Sensitivity Simulations

- Summer O_3 and $PM_{2.5}$: July 12-21, 2001
  Winter $PM_{2.5}$: January 6-15, 2002
- Perturbed meteorology one variable at a time

Variable	Values
Temperature	+ 0.5, 1.0, 1.5, 2.5, 4.0, 5.0 K
Absolute humidity	± 5, 10, 20%
Wind speed	± 5, 10%
Mixing height	± One layer
Cloud cover area	+ 10.9%, +4.0%, +2.2%, -2.2%, -4.7%, -10.7%
Precipitation area	+7.2%, +3.5%, -3.7%, -7.4%
Cloud LWC & OD	*± 5, 10, 20%*
Precipitation rate	*± 5, 10%*

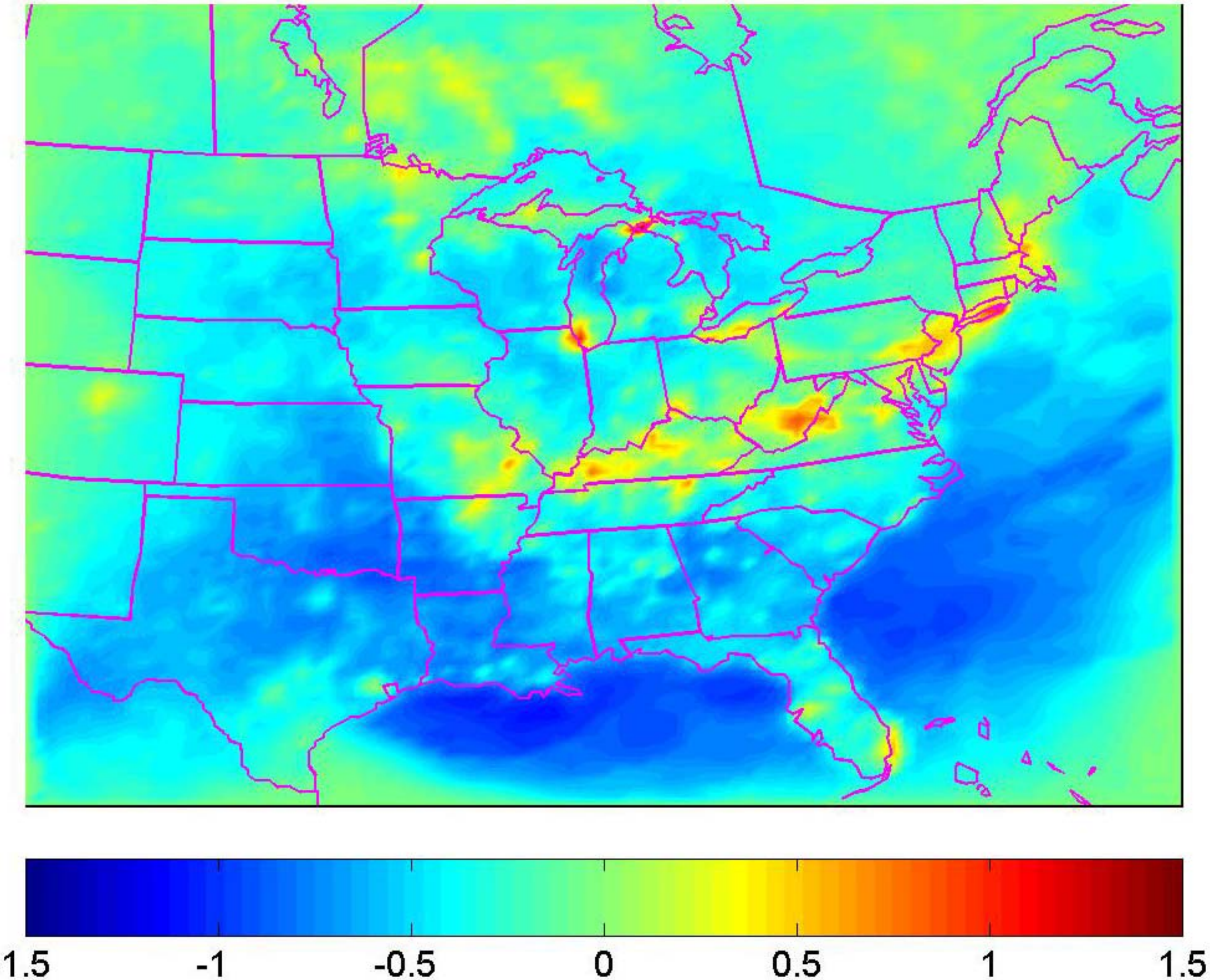
Ozone with T +2.5K



Additional sensitivity study with T effect on PAN chemistry alone gave very similar results

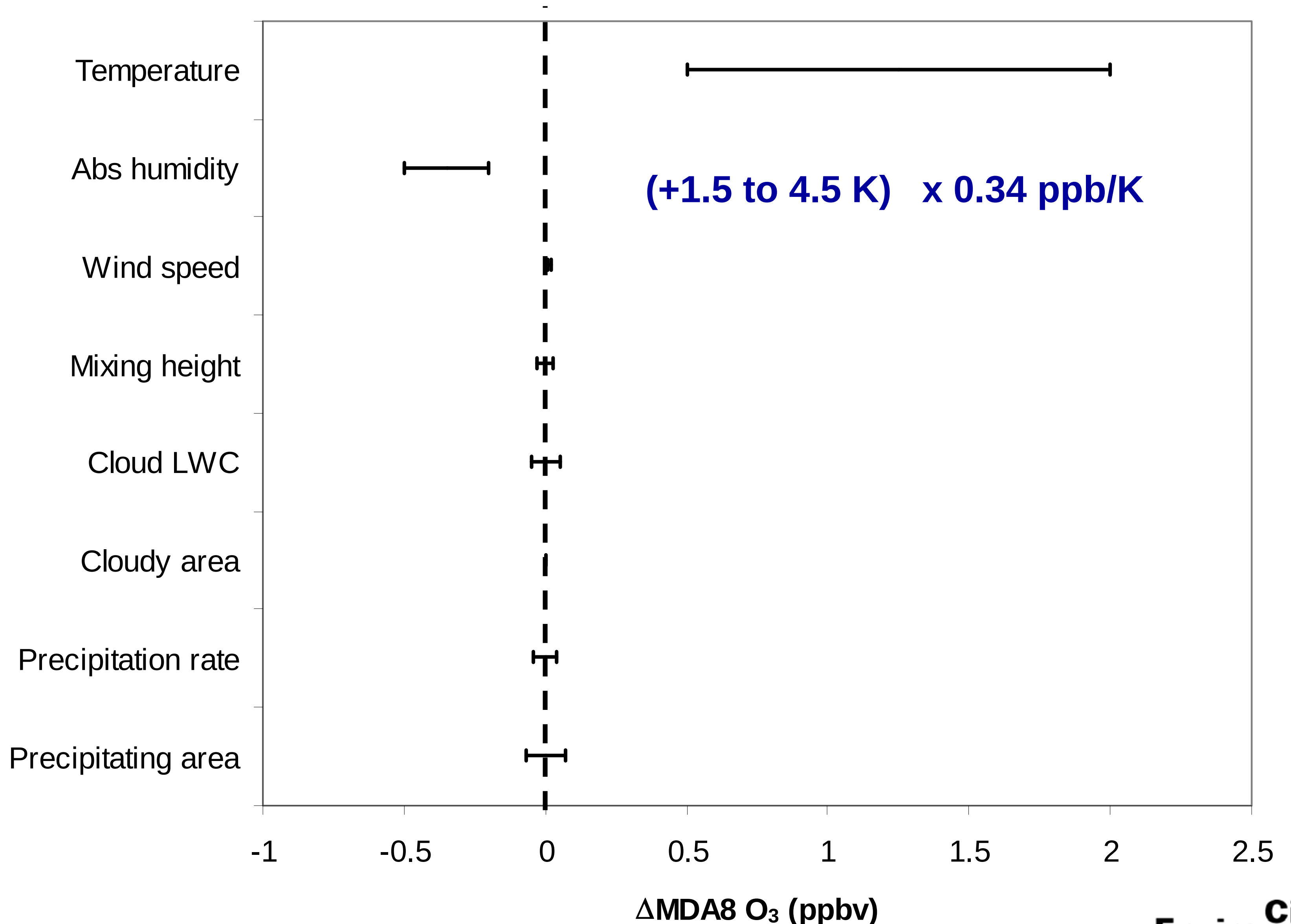
Change in MDA8 ozone (ppb) with +2.5 K (uniform)

Ozone with H2O +10%



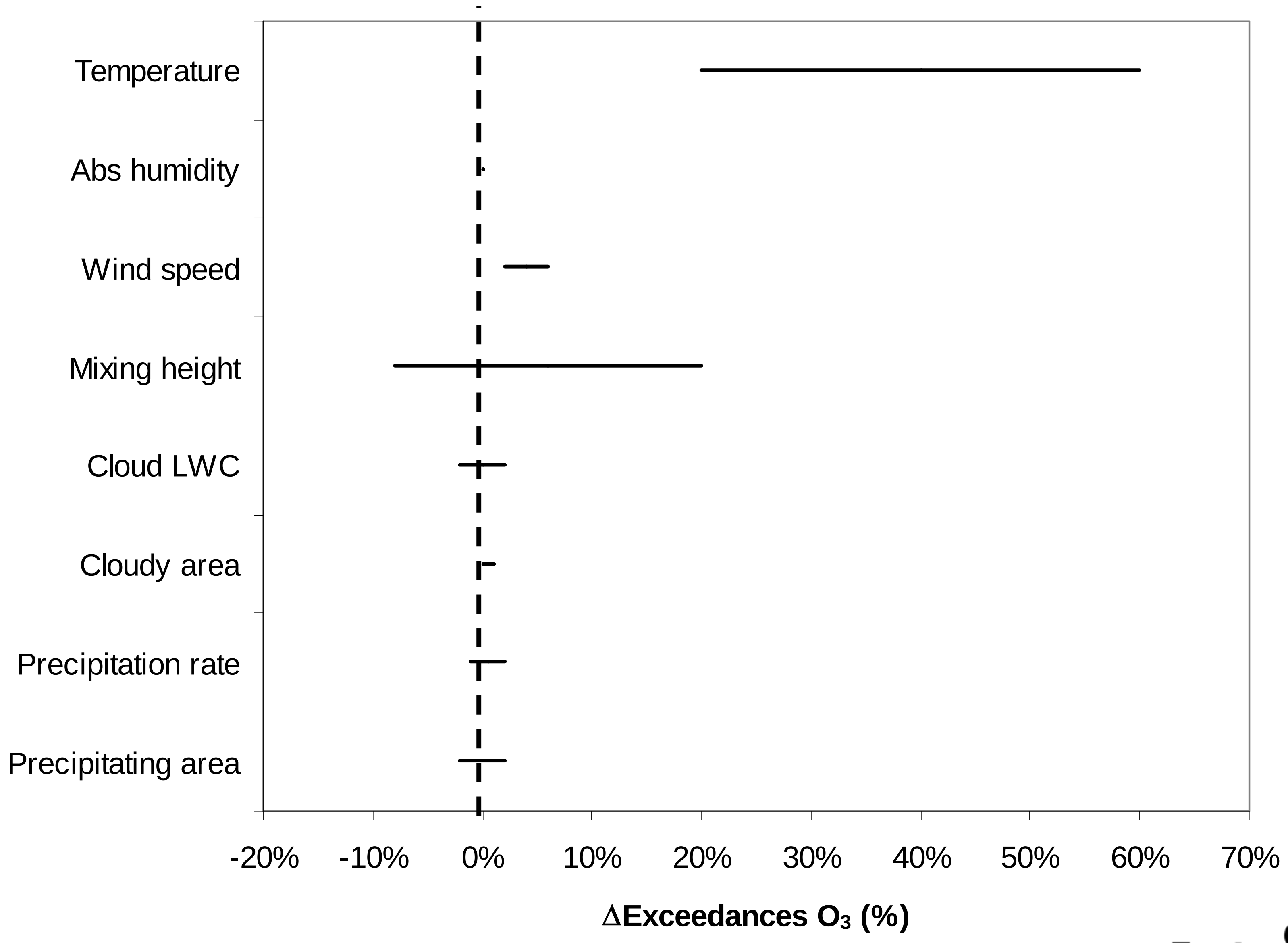
Change in MDA8 ozone (ppb) with +10% [H2O]

Ozone: ΔMDA8

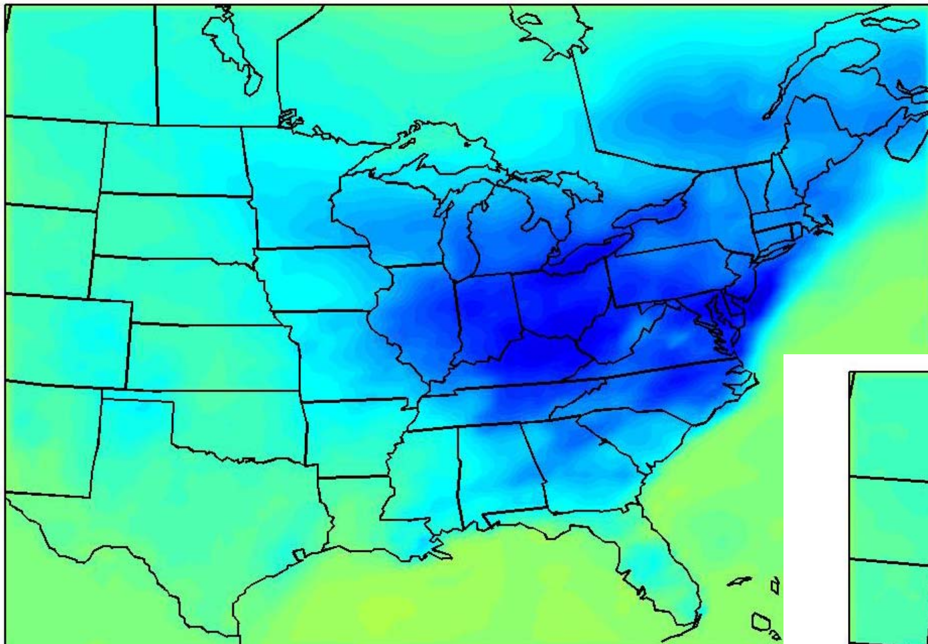


Carnegie Mellon
Civil and Environmental Engineering

Ozone: ΔExceedances

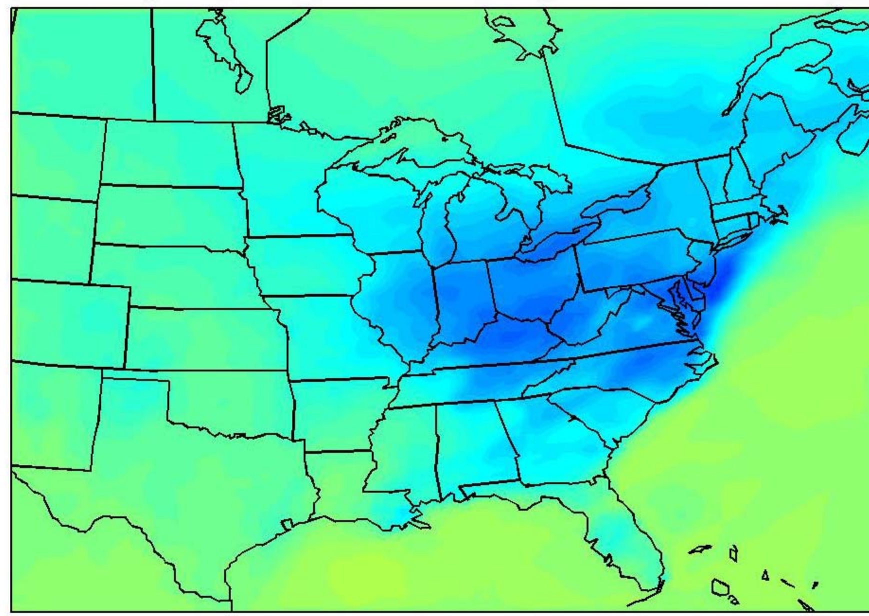


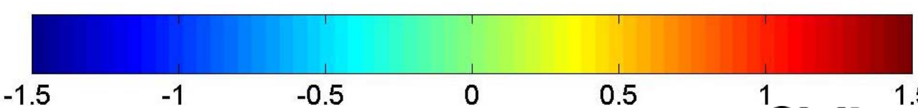
Winter PM2.5 with T +2.5K



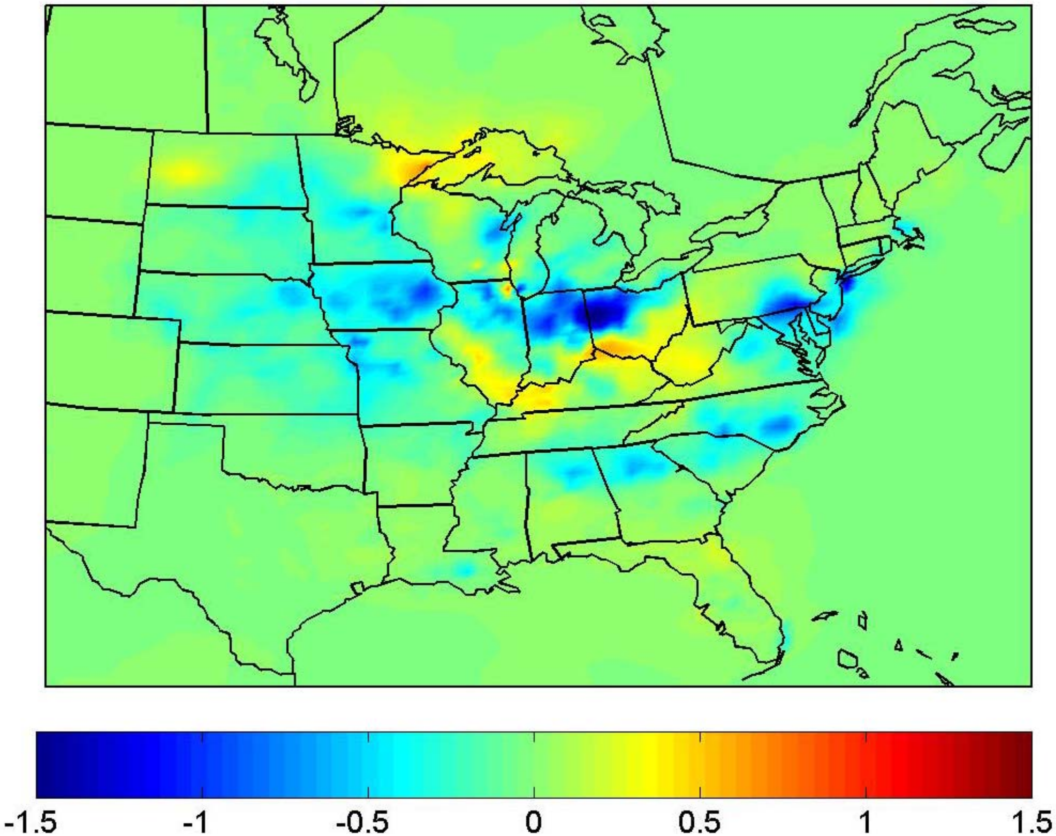
Total $PM_{2.5}$

$PM_{2.5}$ Nitrate



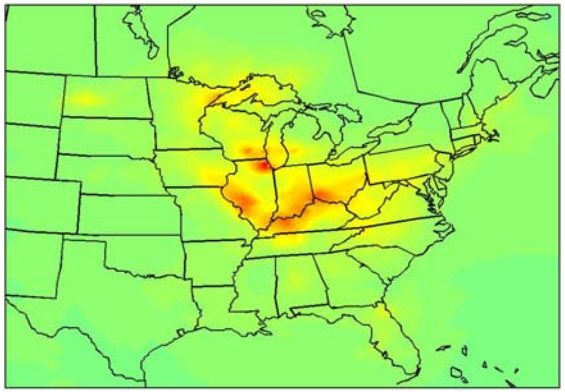


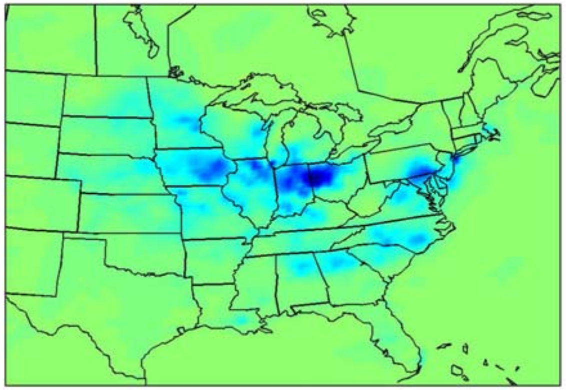
July PM2.5: T +2.5K



Total $PM_{2.5}$ Change ($\mu g\ m^{-3}$)

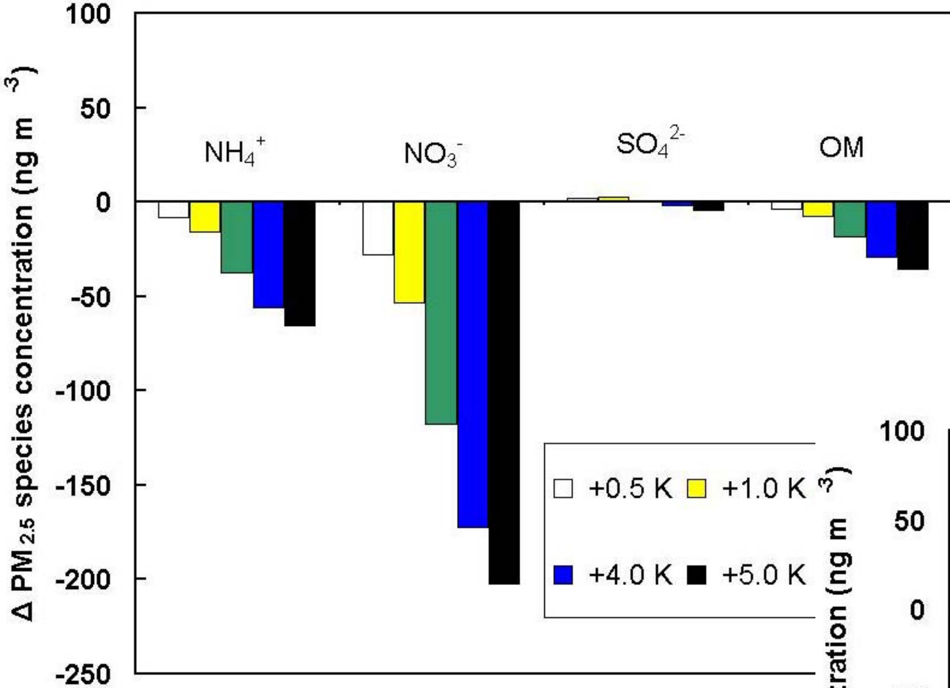
$PM_{2.5}$ Sulfate





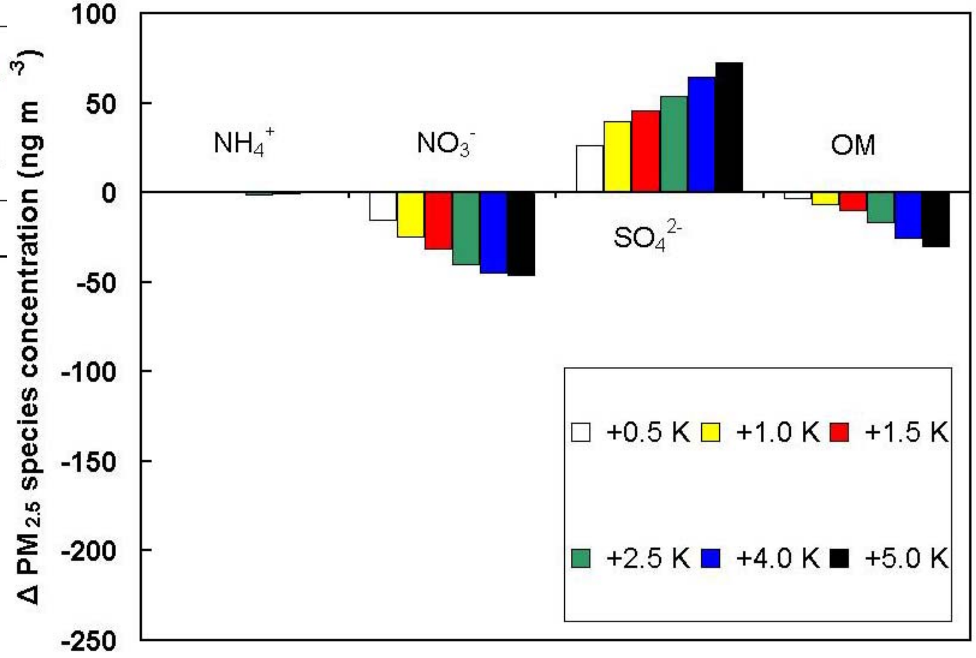
$PM_{2.5}$ Nitrate

Winter vs Summer: PM2.5 and T

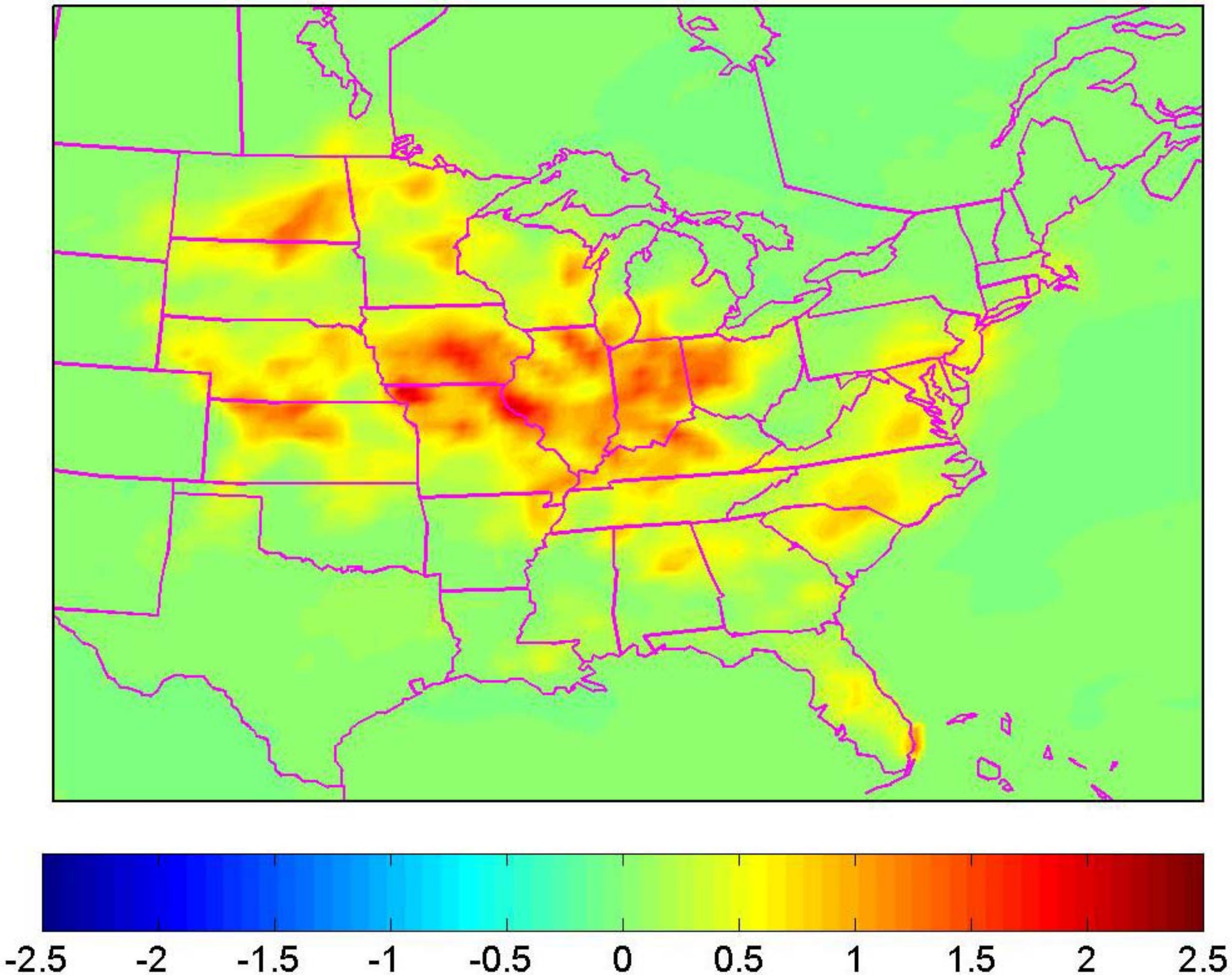


Winter

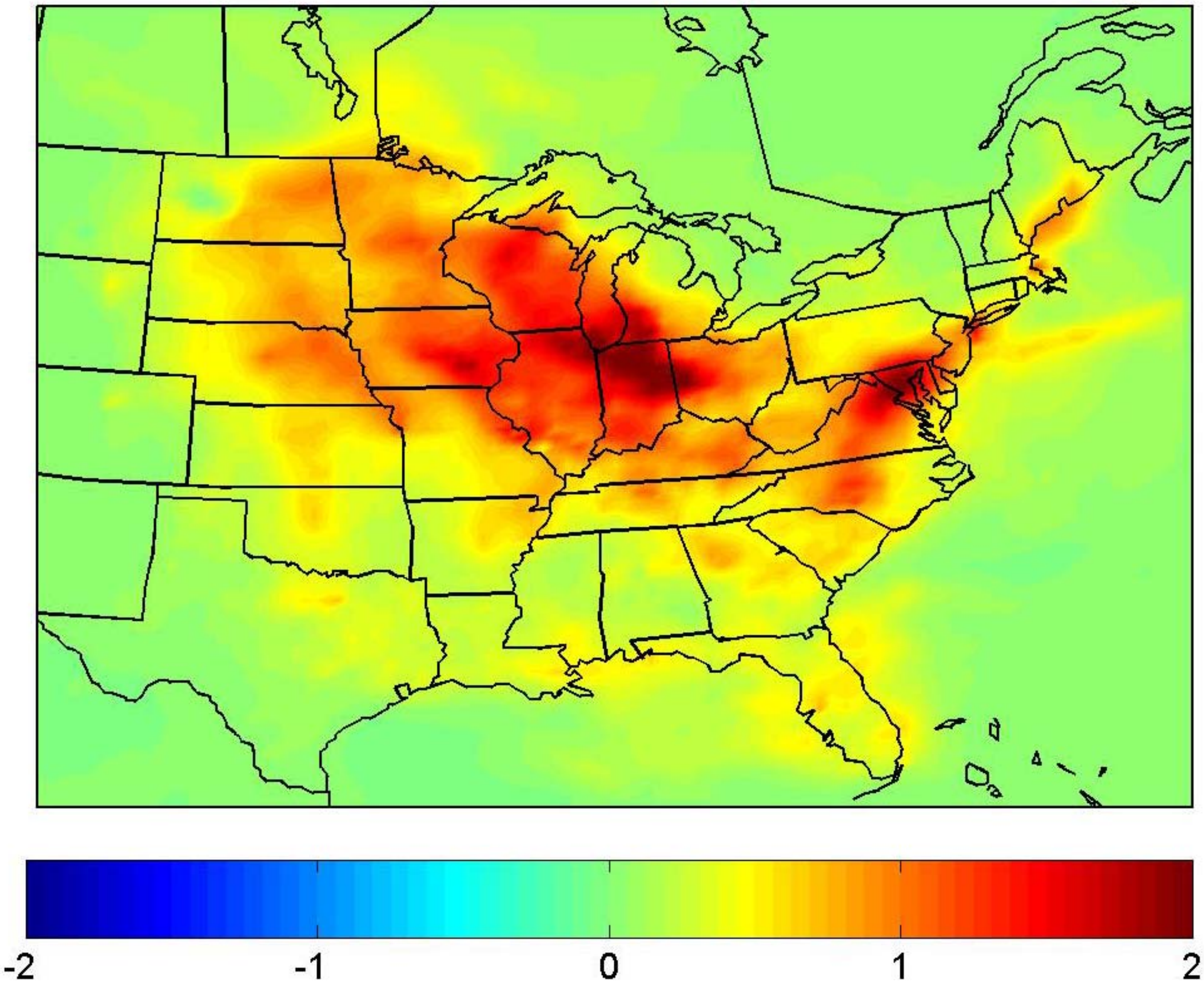
Summer



Nitrate: Humidity +10% (July)



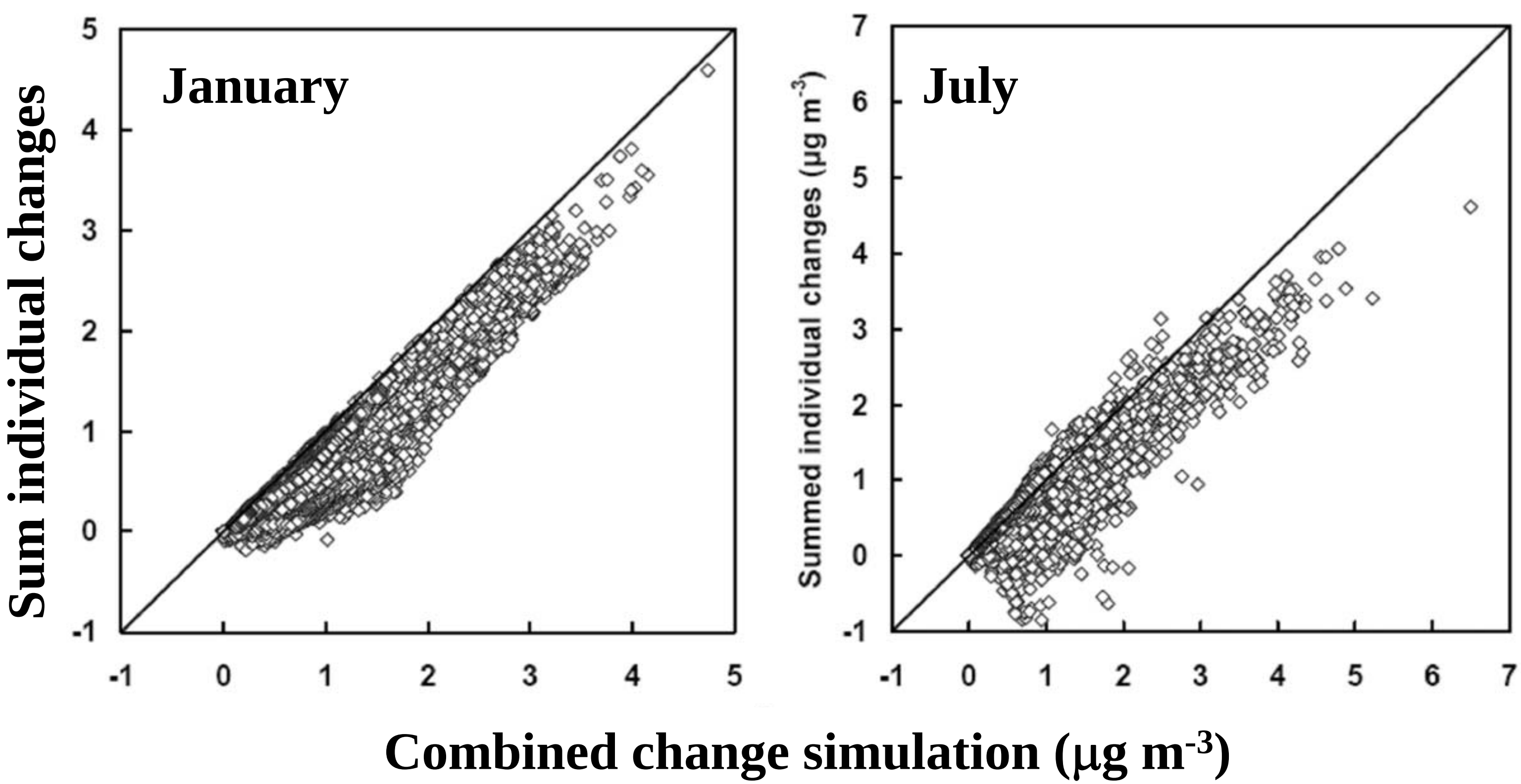
Dilution/Ventilation



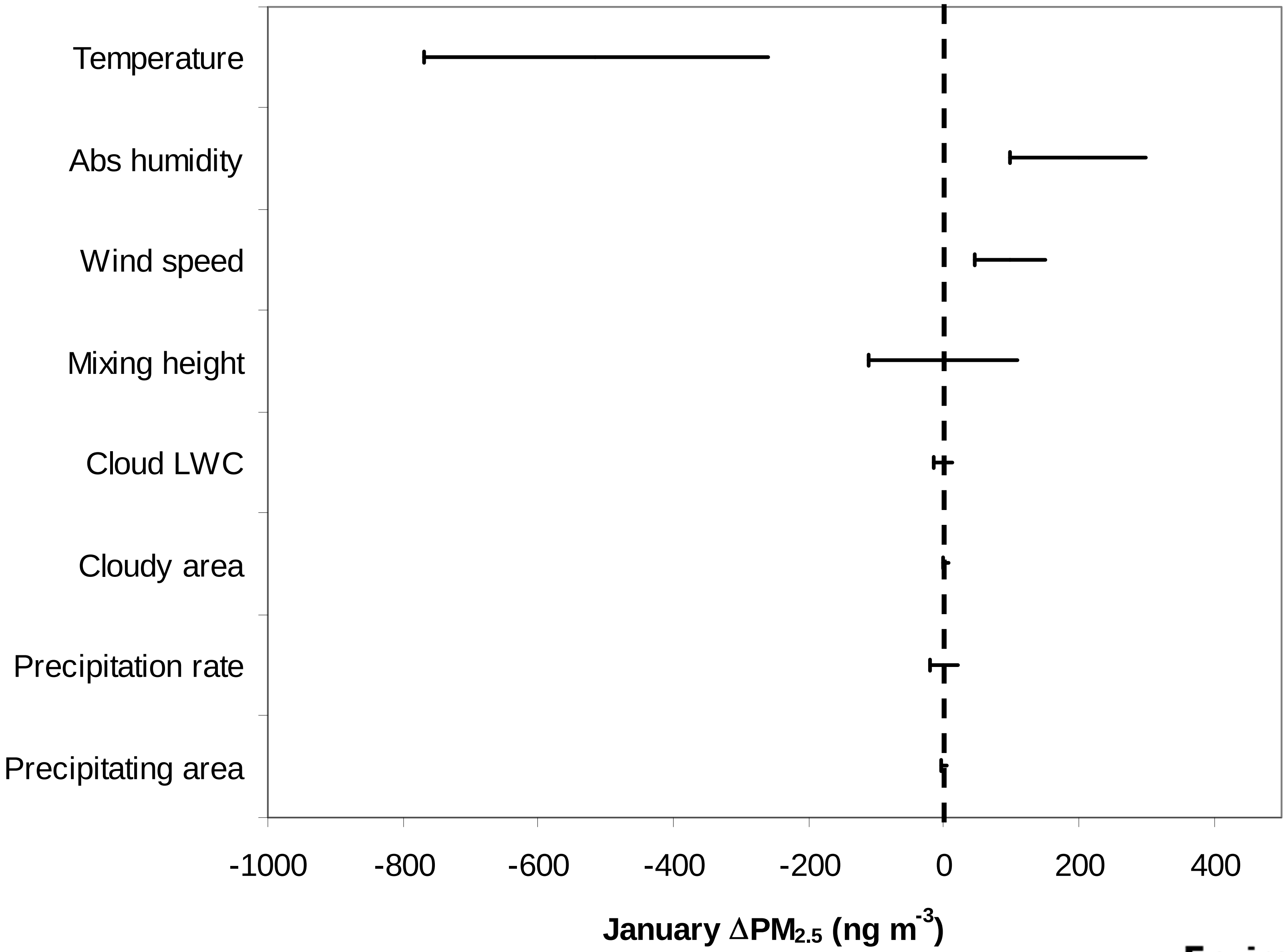
July change in PM2.5 ($\mu g\ m^{-3}$) when mixing height decreased one model layer

Multiple Parameter Changes

- One simulation with simultaneous changes in all parameters
- Is total PM2.5 change a linear combination of individual changes?

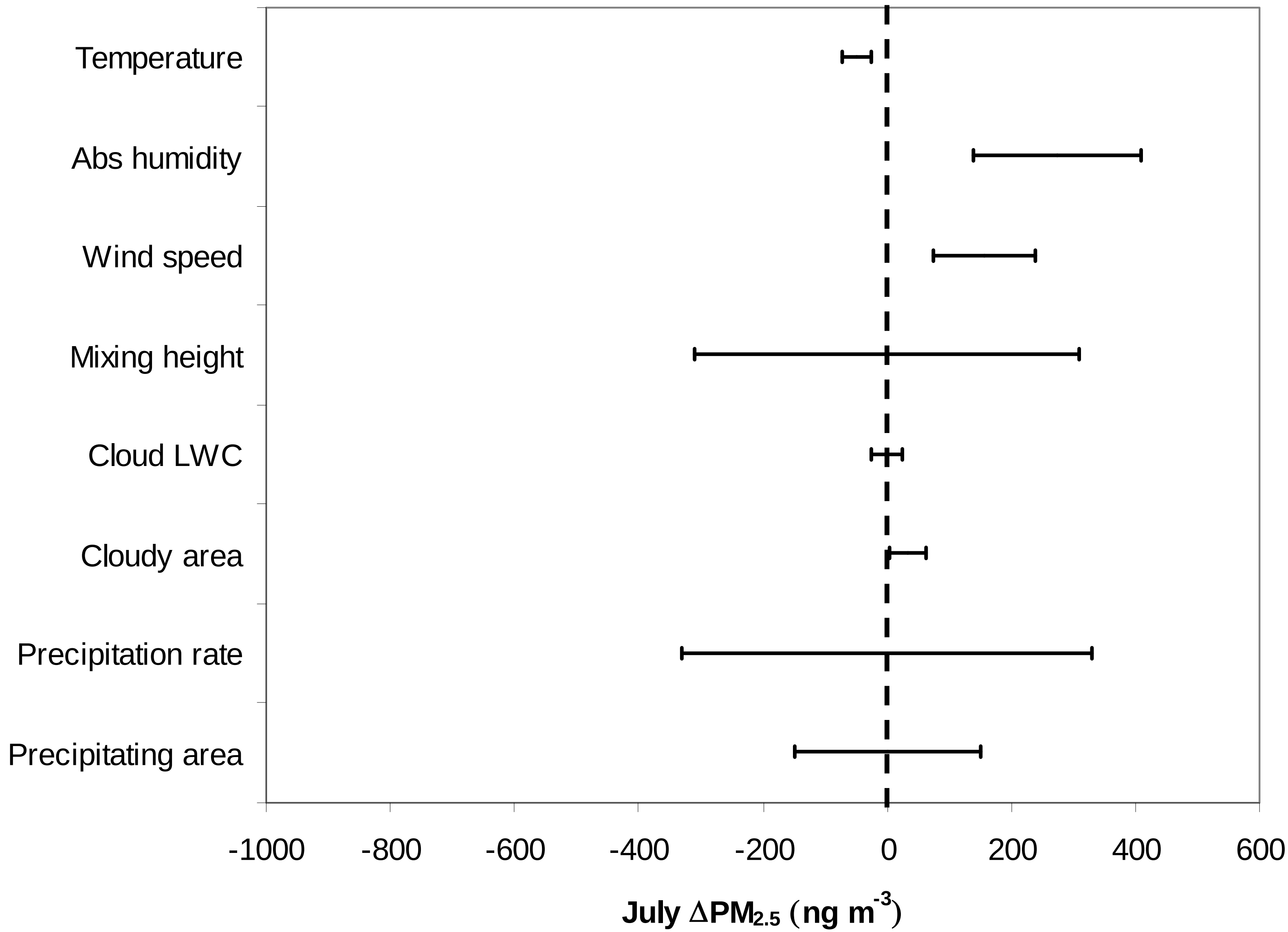


ΔPM2.5 (Jan)



Temperature
Abs humidity
Wind speed
Mixing height
Cloud LWC
Cloudy area
Precipitation rate
Precipitating area
-1000
-800
-600
-400
-200
0
200
400
January ΔPM2.5 (ng m-3)

ΔPM2.5 (Jul)


Temperature
Abs humidity
Wind speed
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Cloudy area
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-1000
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-400
-200
0
200
400
600
July ΔPM2.5 (ng m-3)

Global Future Change Simulations

“Unified” Global Climate/Chemistry Model

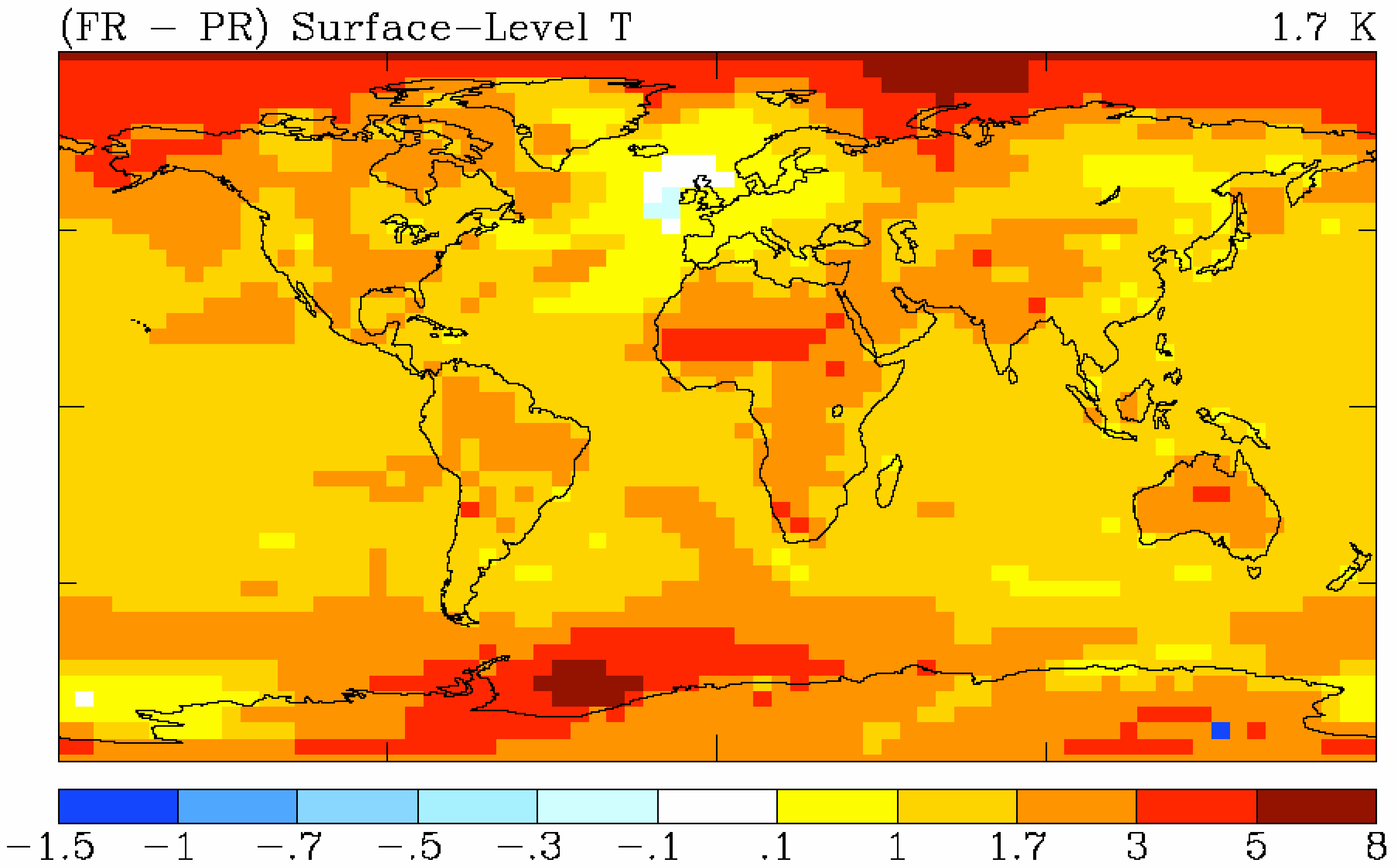
- General Circulation Model
  - GISS GCM II-prime
  - 4 x 5 lat/long horizontal resolution
  - 9 vertical layers
- Ozone Photochemistry
  - Harvard scheme
- Aerosols
  - Sulfur from Dorothy Koch (GISS)
  - Ammonium, nitrate, carbonaceous, sea-salt, dust (CalTech)
- Climate sensitive emissions
  - isoprene, biogenic acetone, lightning/soil NOx
  - monoterpenes/sesquiterpenes climate sensitivity <u>neglected</u>

Liao et al., JGR, 2003, 2004

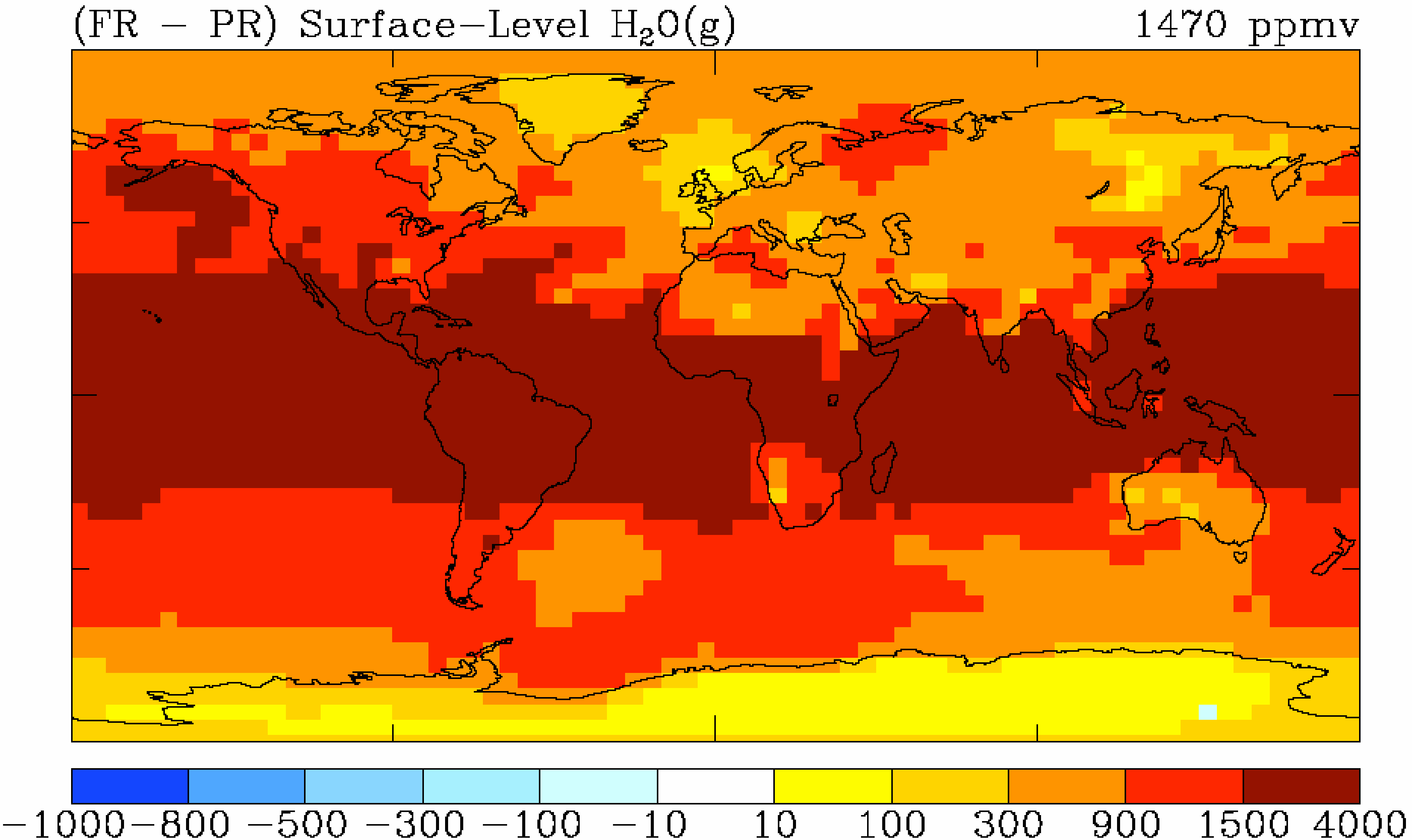
Simulations

- Scenarios
  - Present climate
  - Future climate: IPCC SRES A2
  - 10 years each
- Emissions
  - Anthropogenic emissions unchanged
  - Climate sensitive natural emissions change
- Atmosphere-only GCM
  - Present/future climate “dialed in” via ocean boundary conditions (SSTs and ice)
  - No need for multi-decadal, “transient” climate simulations

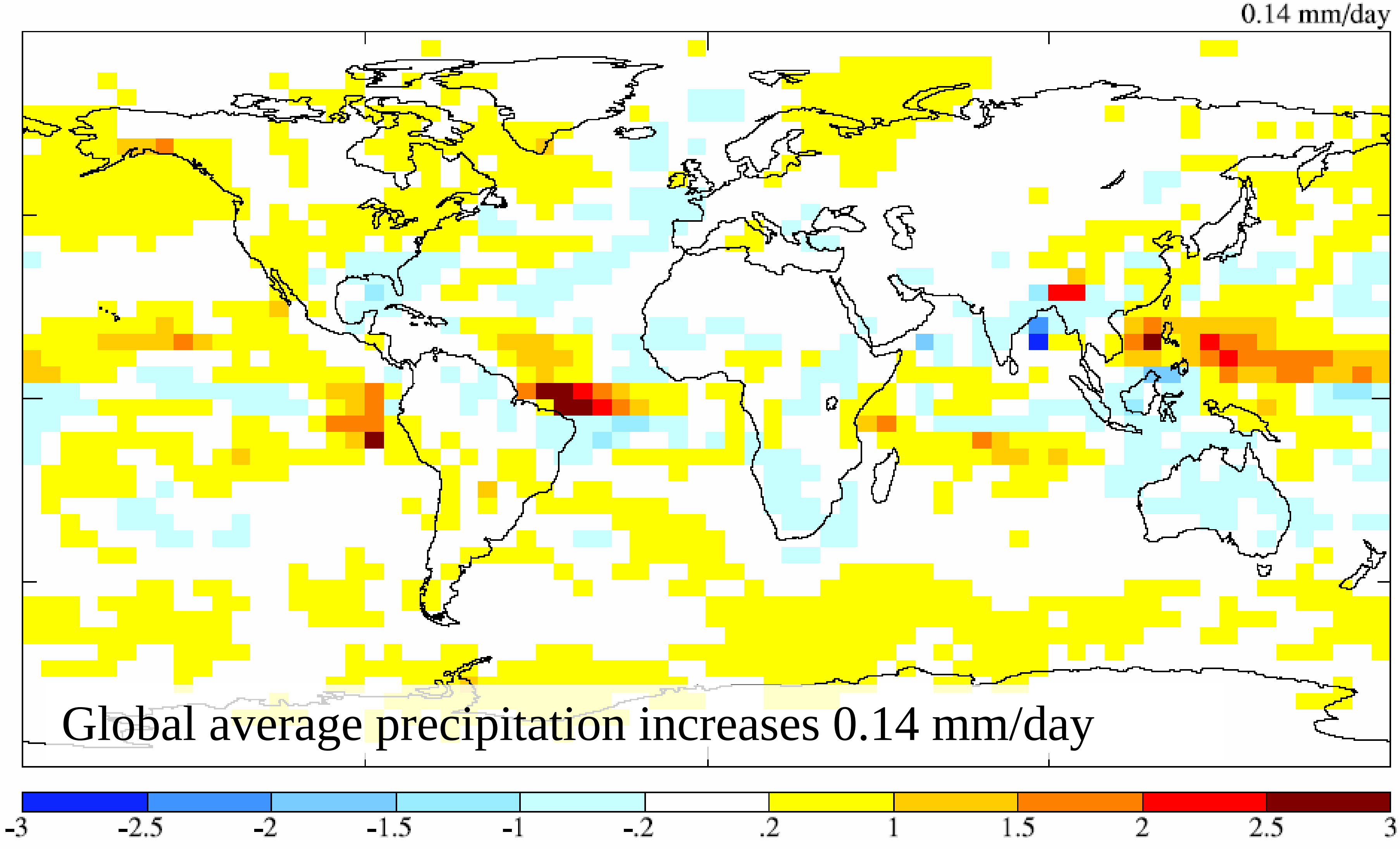
Temperature Increase



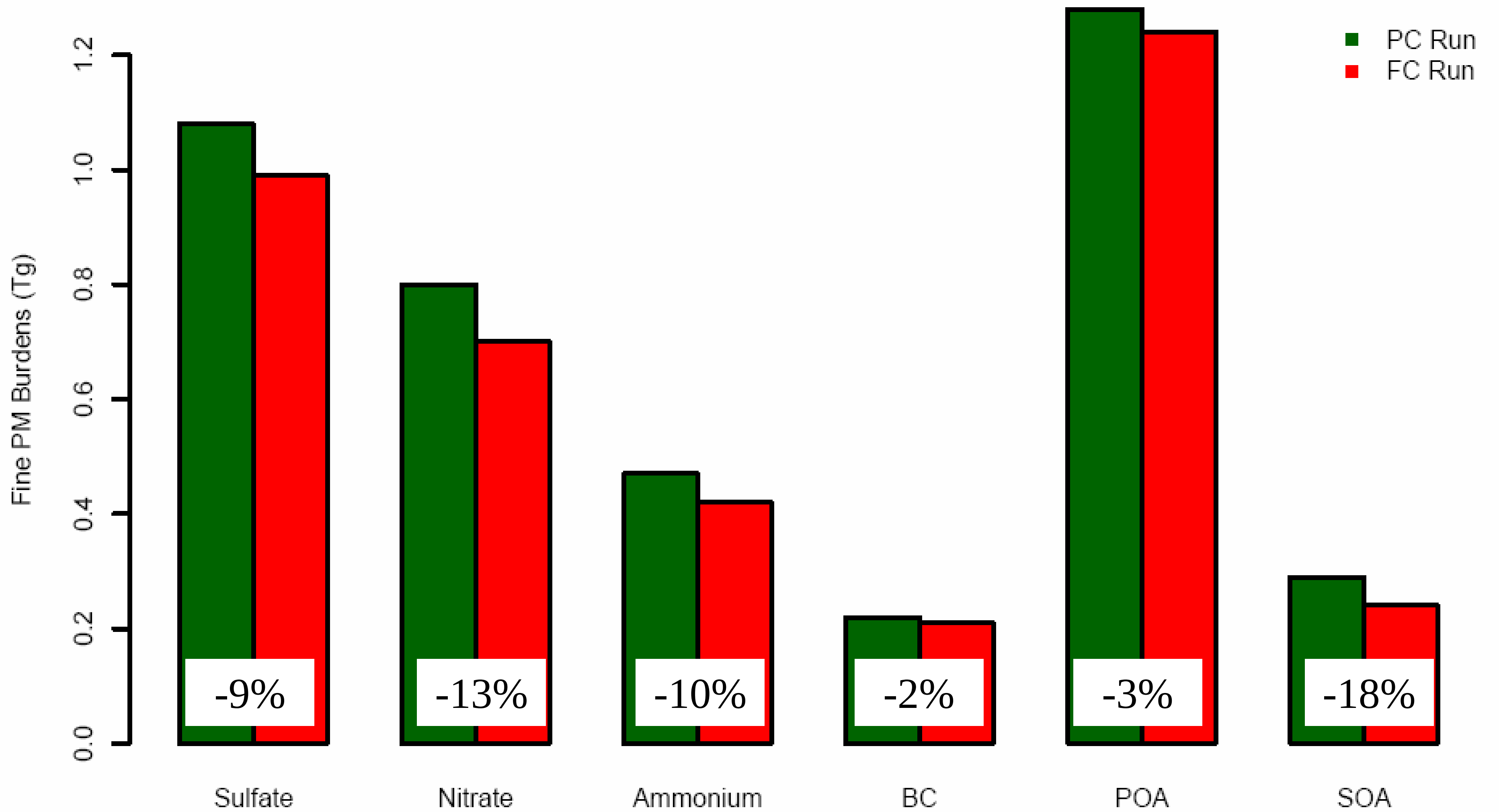
Humidity Increase



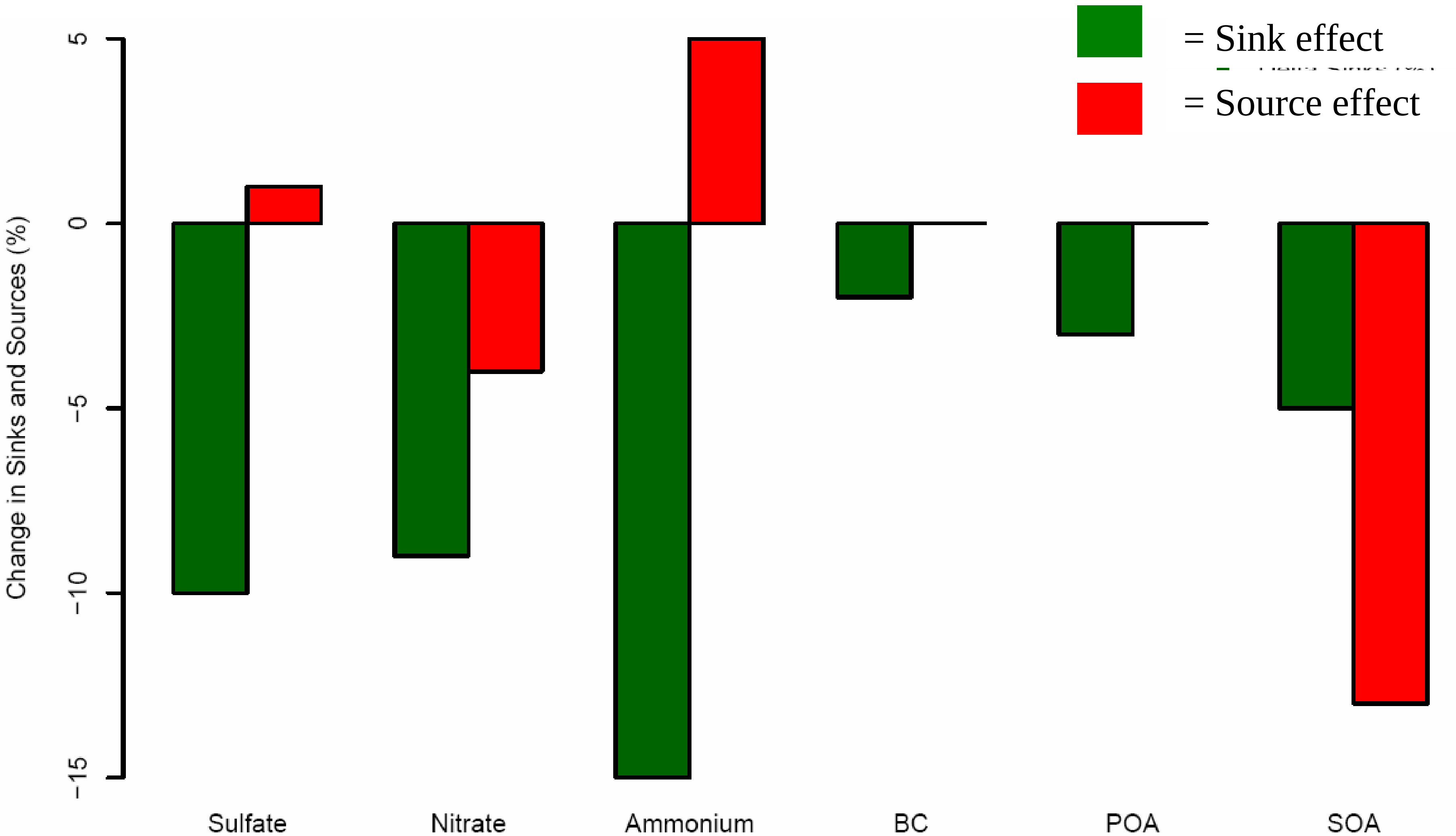
Precipitation Increase



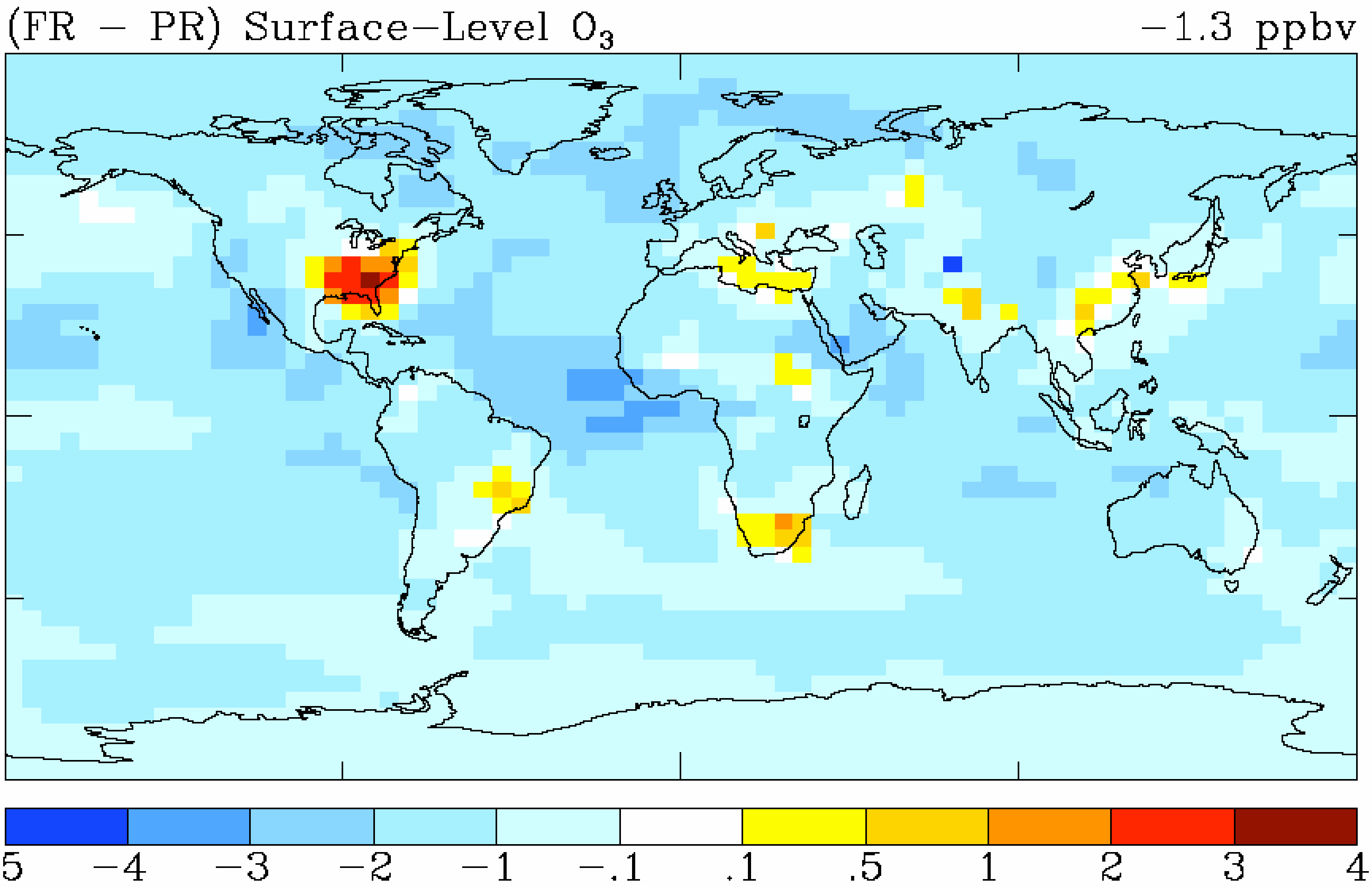
Global PM Decreases



PM: Sources and Sinks

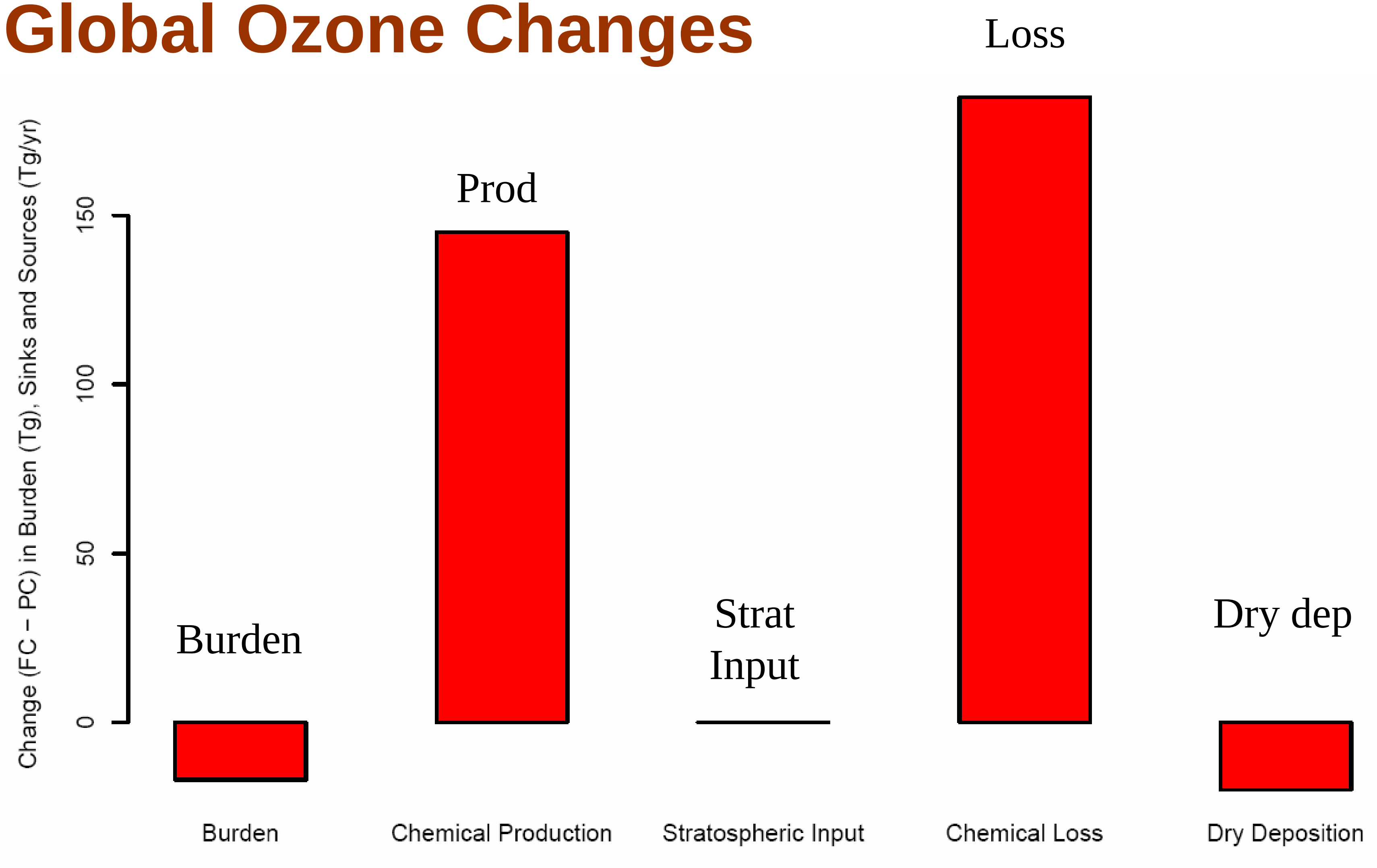


Ozone Change (Future – Present)



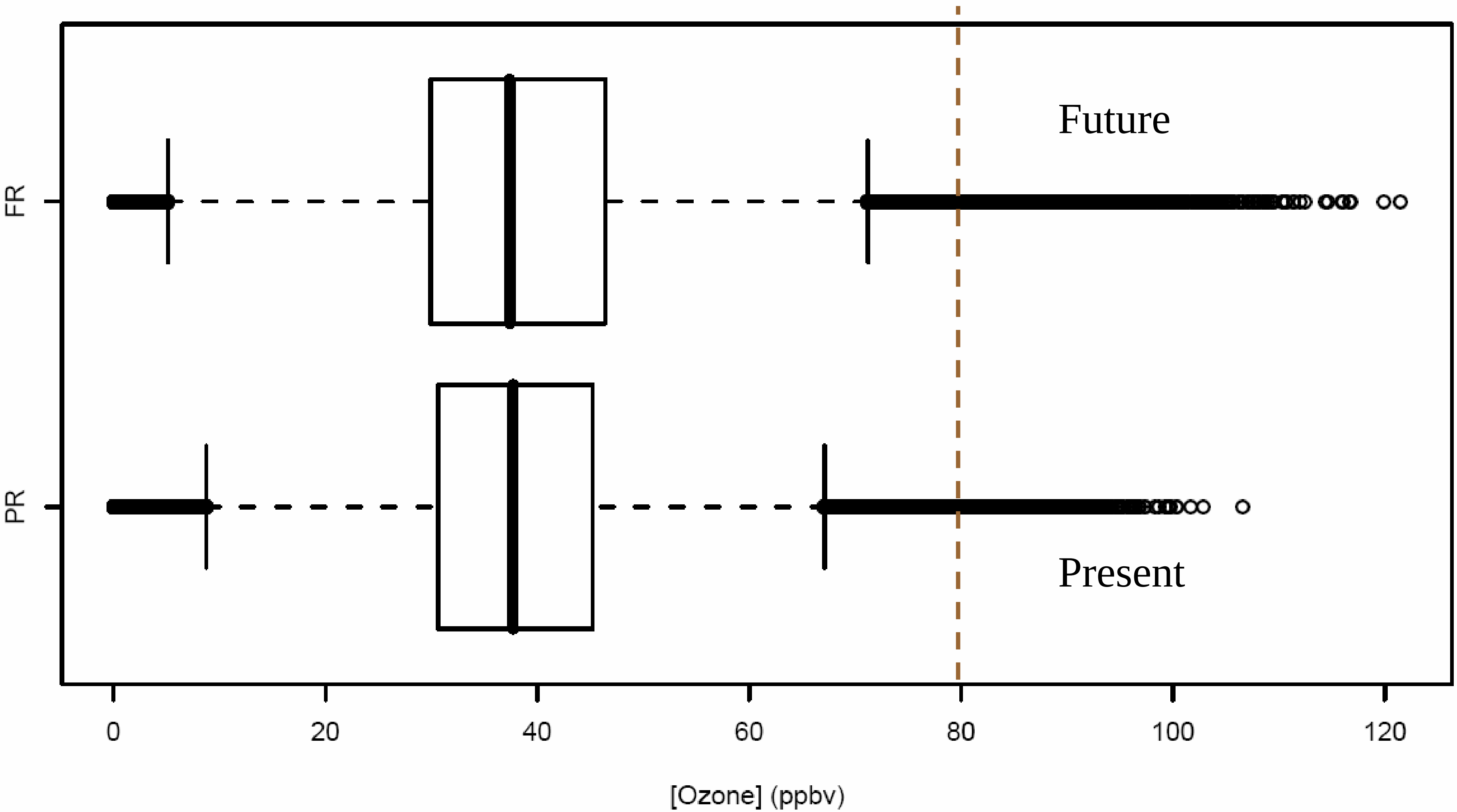
ΔO_3 (ppbv)

Global Ozone Changes



Increased ozone loss by O(1D) + H2O was major explaining factor in global ozone decrease

Ozone Variability: US Domain

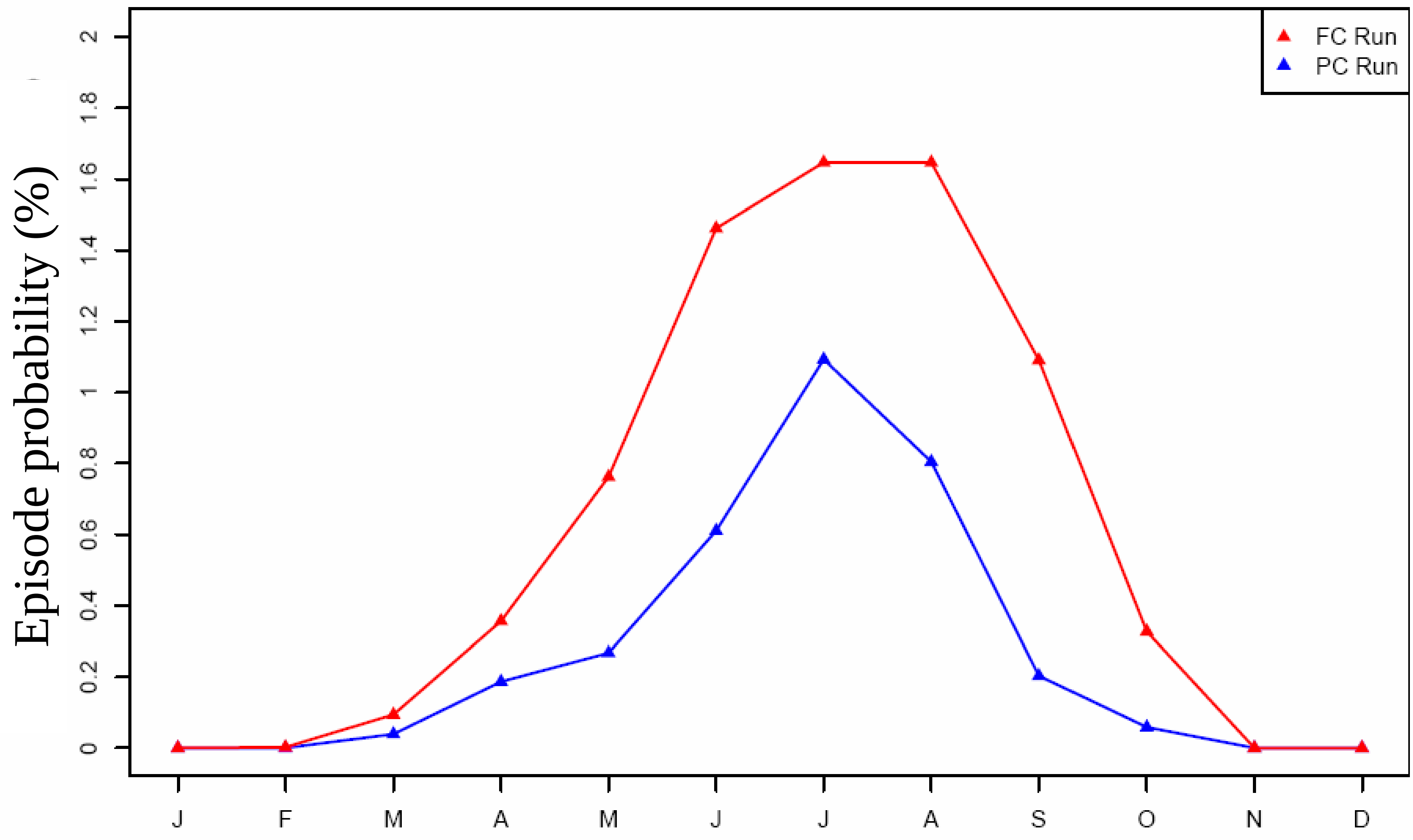


Ozone Episodes

Change in number of episodes per year

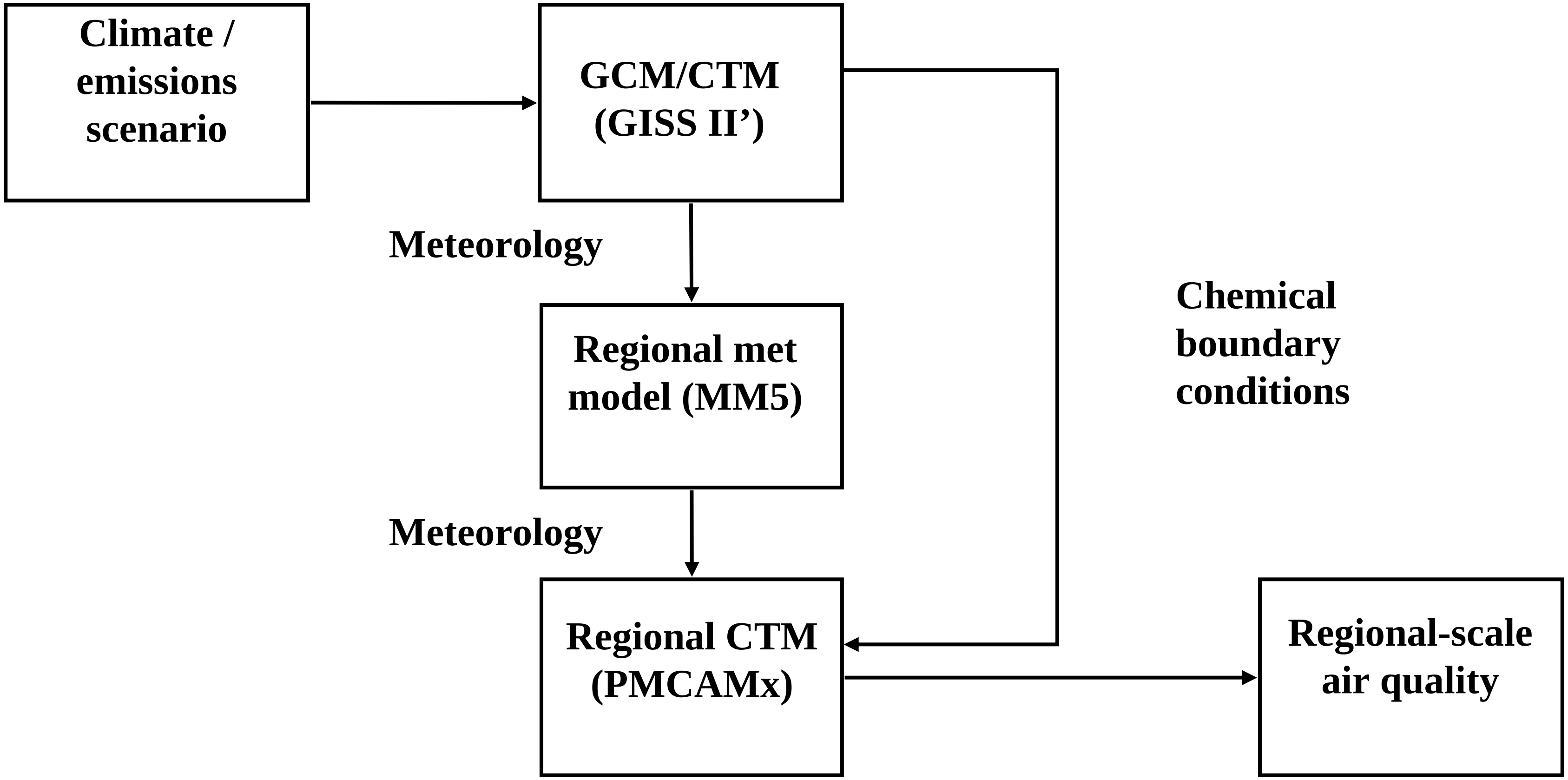
(Episodes defined here as 4-hour period with ozone > 80 ppbv)

Seasonal Ozone Response



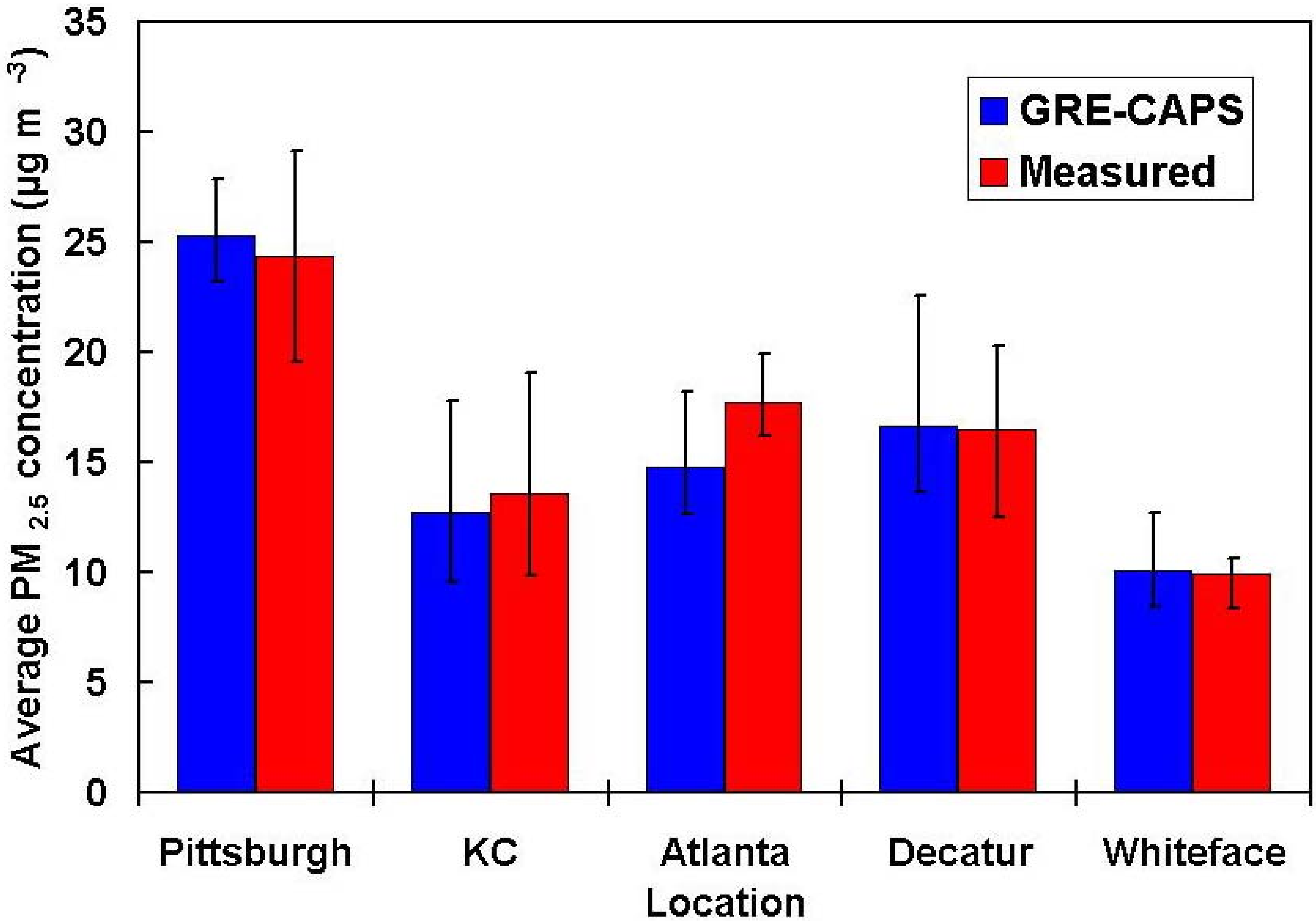
Global-Regional Climate and Air Pollution Modeling System (GRE-CAPS)

GRE-CAPS Overview



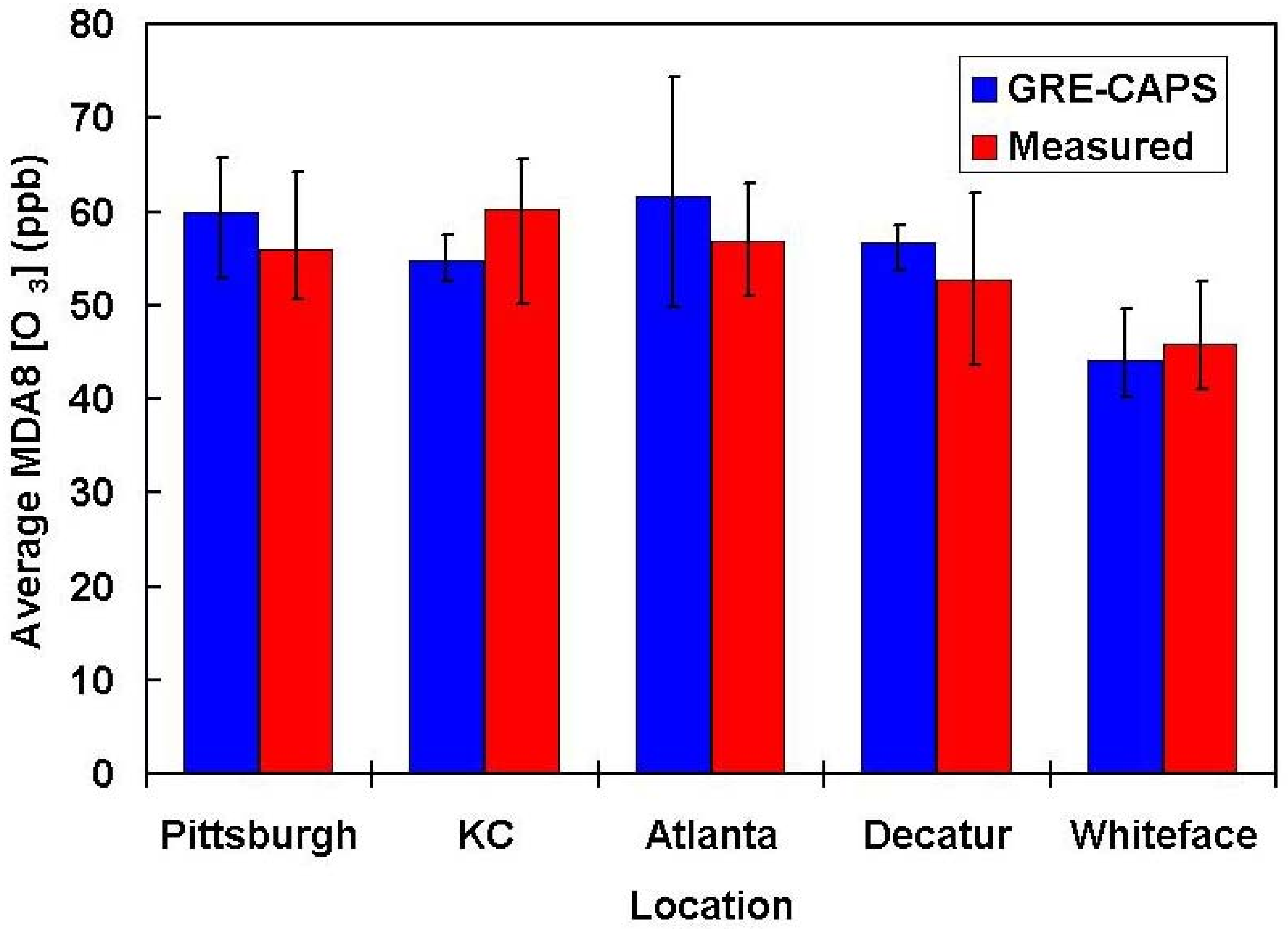
- Meteorology and boundary conditions passed to PMCAMx every 4 hours
- Global aerosol concentrations were mapped to the 10 PMCAMx size sections
- Global gas-phase species were mapped to PMCAMx species

GRE-CAPS Evaluation

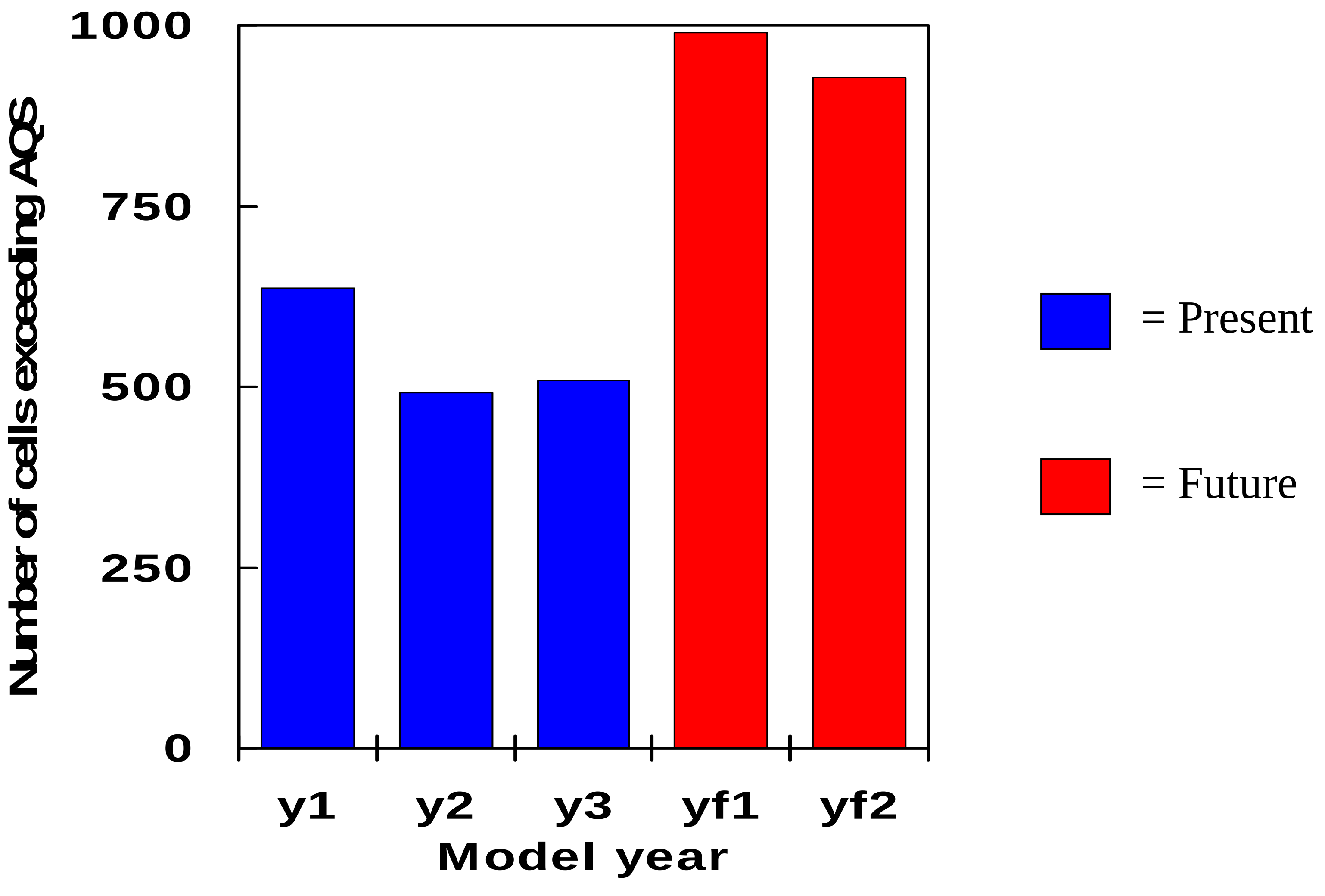


Bars are max/min values of model (3 Julys) and observations (5 Julys)

GRE-CAPS Evaluation



GRE-CAPS Ozone Exceedences



GRE-CAPS: Ongoing Work

Range of scenarios including various permutations of:

- Climate: present, 2050s (A2), 2050s (B1)
- US emissions: present, A2, B1
- Climate-sensitive emissions: on/off
- Rest-of-world emissions: present, A2, B1

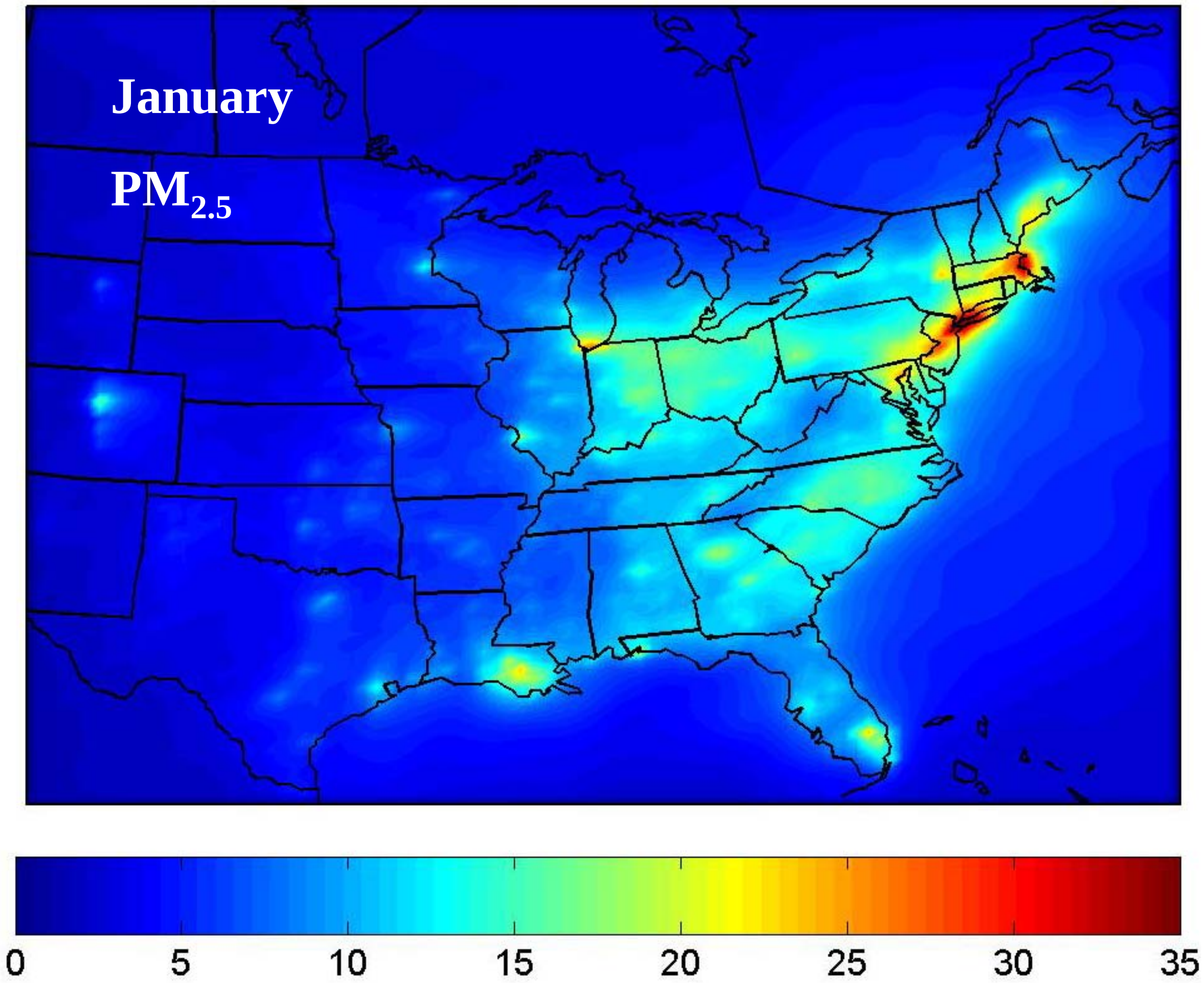
New Project

- Mercury
  - implement into GRE-CAPS (global and regional)
- Organic aerosol “volatility bins”
  - evaporation of primary organics
  - improved treatment of SOA
- Ultrafine particles
  - nucleation
  - combustion emissions
- Climate-sensitive emissions
  - implement into regional (PMCAMx) side of GRE-CAPS
- Uncertainty assessment

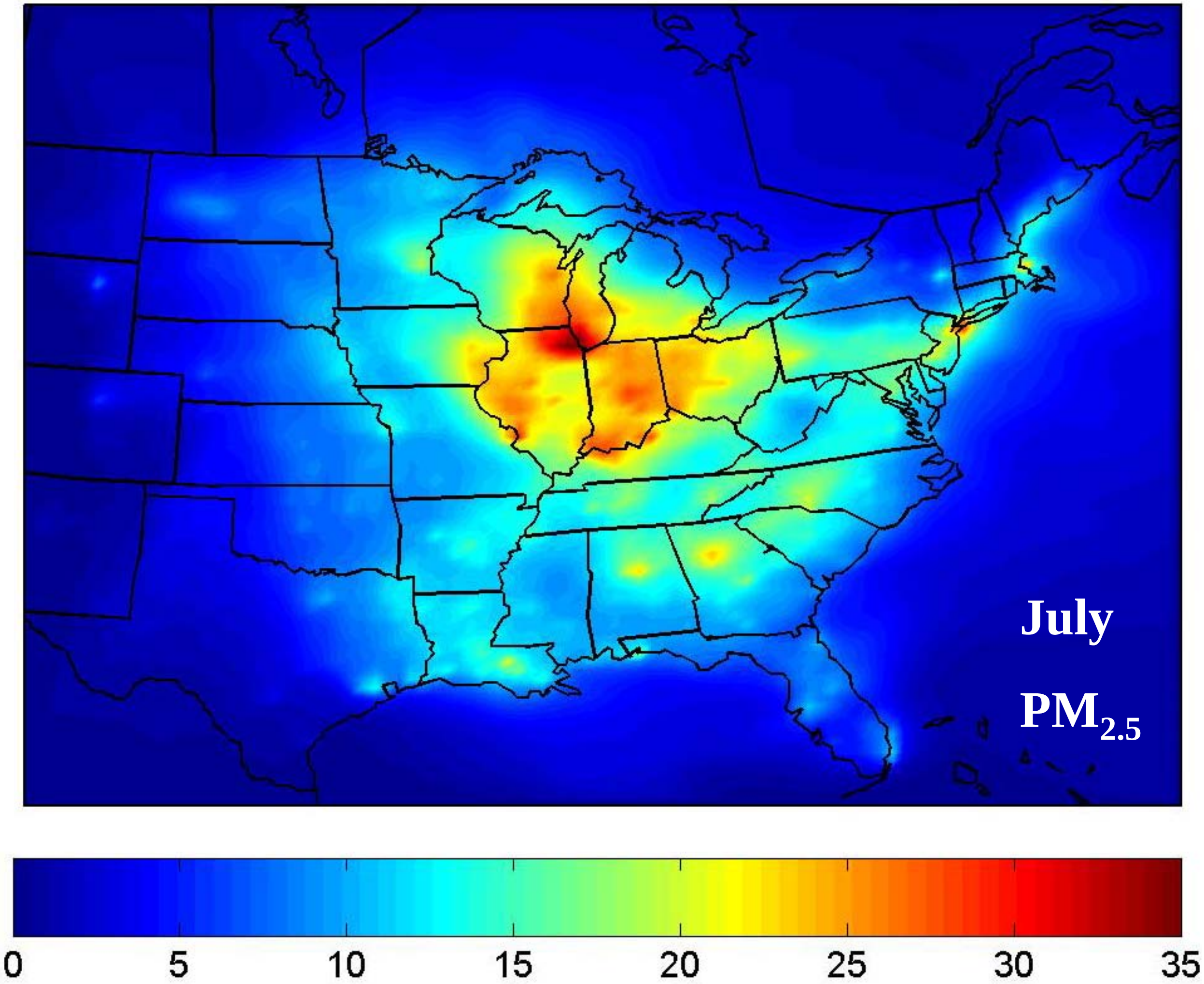
Conclusions

- Ozone: +few ppb, more frequent episodes
  - Temperature → PAN/NOx
  - Temperature → isoprene
  - Episode conditions more sensitive than average
  - Humidity increase lowers global background
- PM2.5: overall impact unclear
  - Precipitation rate (and frequency) important but sign uncertain
  - Temperature volatilization of nitrate/SOA
- Circulation, wind, mixing height important for both

PMCAMx Base Case Scenarios



PMCAMx Base Case Scenarios



PMCAMx Base Case Scenarios