

Black Carbon and the Regional Climate of California

A Multi-Institutional CARB Funded Project

CARB Board Meeting

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Univ of California at San Diego: V. Ramanathan, R. Bahadur, Y. Xu & P. S. Praveen (SIO); K. Prather and A. Cazorla (Chemistry)

Univ of California at Berkeley: T. Kirchstetter & O. Hadley (Lawrence Berkley Labs); R. Cohen (UC Berkeley).

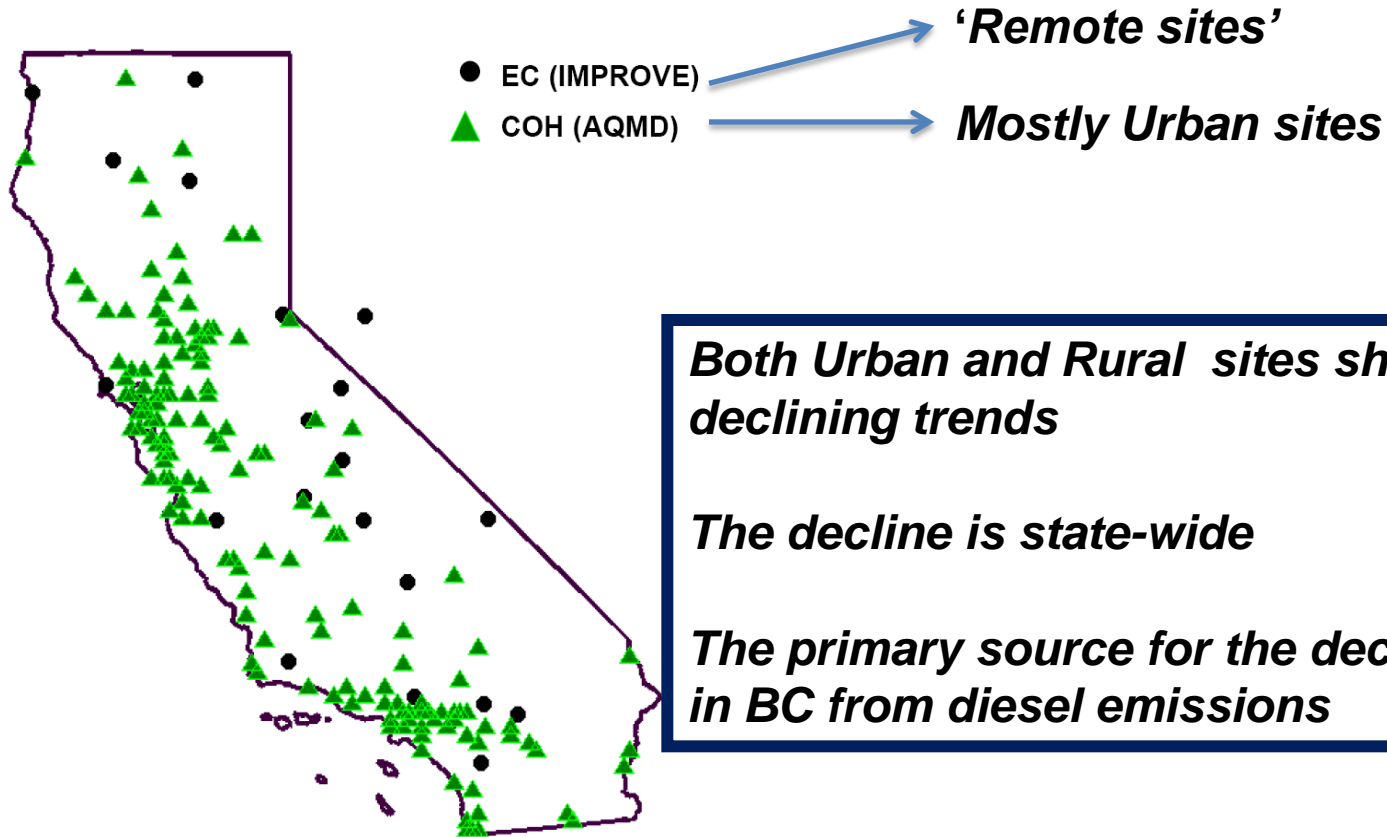
Pacific Northwest National Laboratory: R. Leung and Dr. Zhao Chun (PNNL)

CARB Contract Manager: N. Motallebi

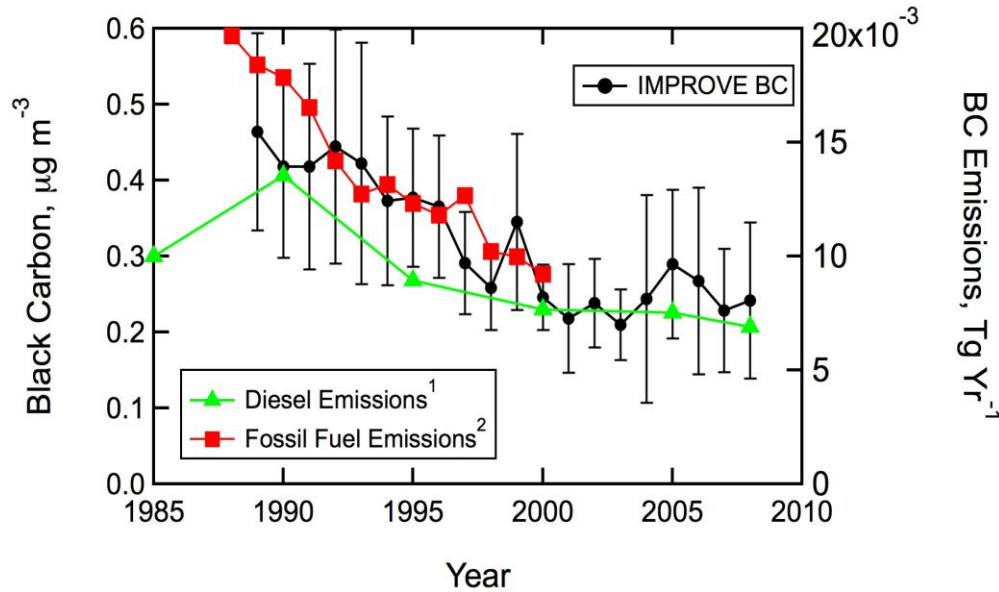
Major Topics

- Black Carbon Trends in California: Detection and Attribution
- Brown Carbon (BrC) Identification:
 - Organic Aerosols that absorb solar radiation are called BrC.*
 - IPCC-models treat Organics as scattering, i.e, cooling aerosols*
- Source Identification
- Radiative Forcing by Black and Organic Carbon Aerosols
- Mitigation of BC Radiative Forcing by California *(The forcing numbers are preliminary; will be finalized in few months)*
- Simulations by a Regional Model

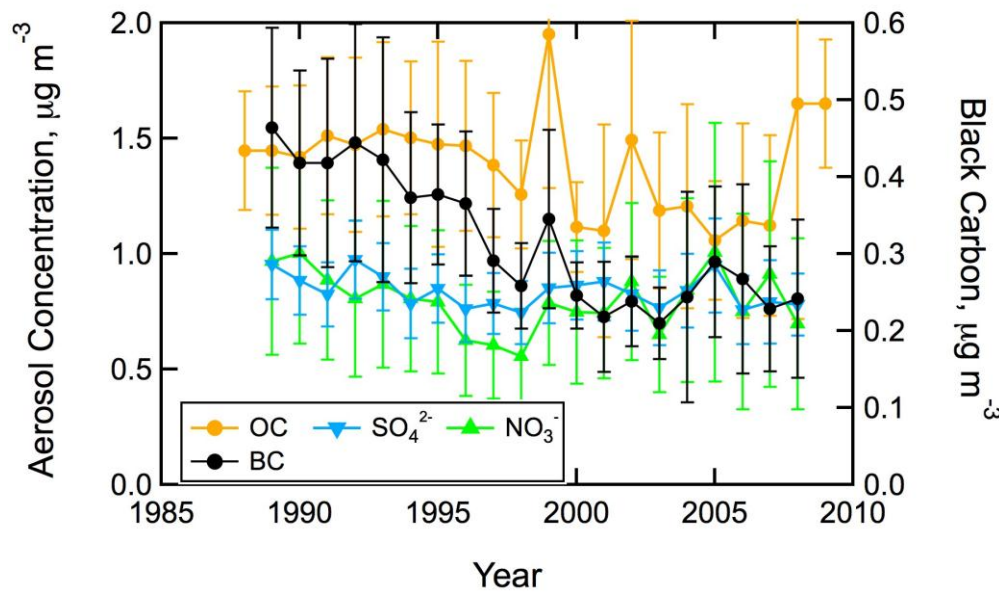
Black Carbon Trends in California: Detection and Attribution



BC Trends in California: All IMPROVE Sites



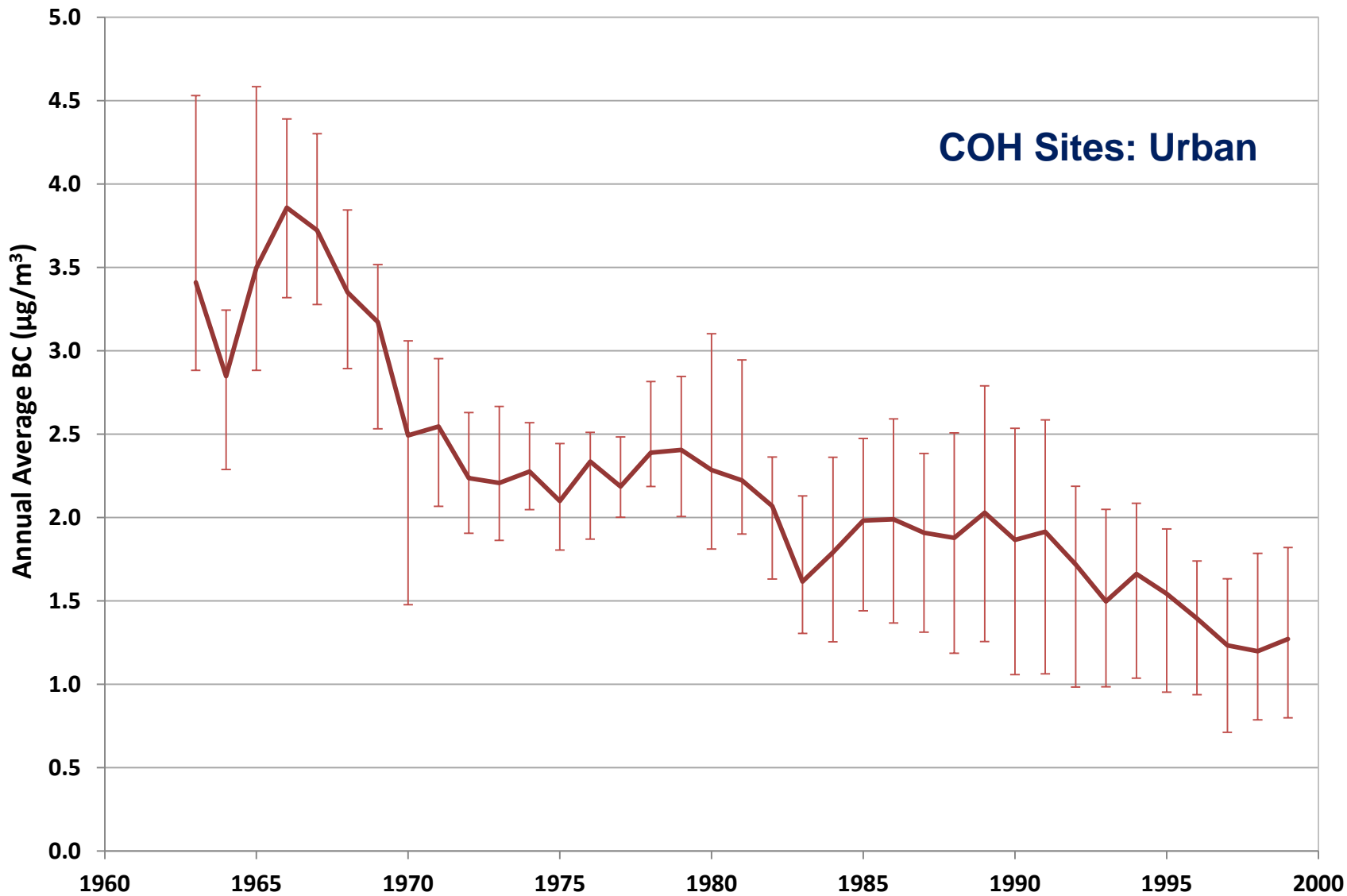
BC Trends are consistent with diesel BC emission trends.



Lack of similar trends in other aerosols indicate : negative trends in BC is not due to meteorology

Bahadur et al, 2010

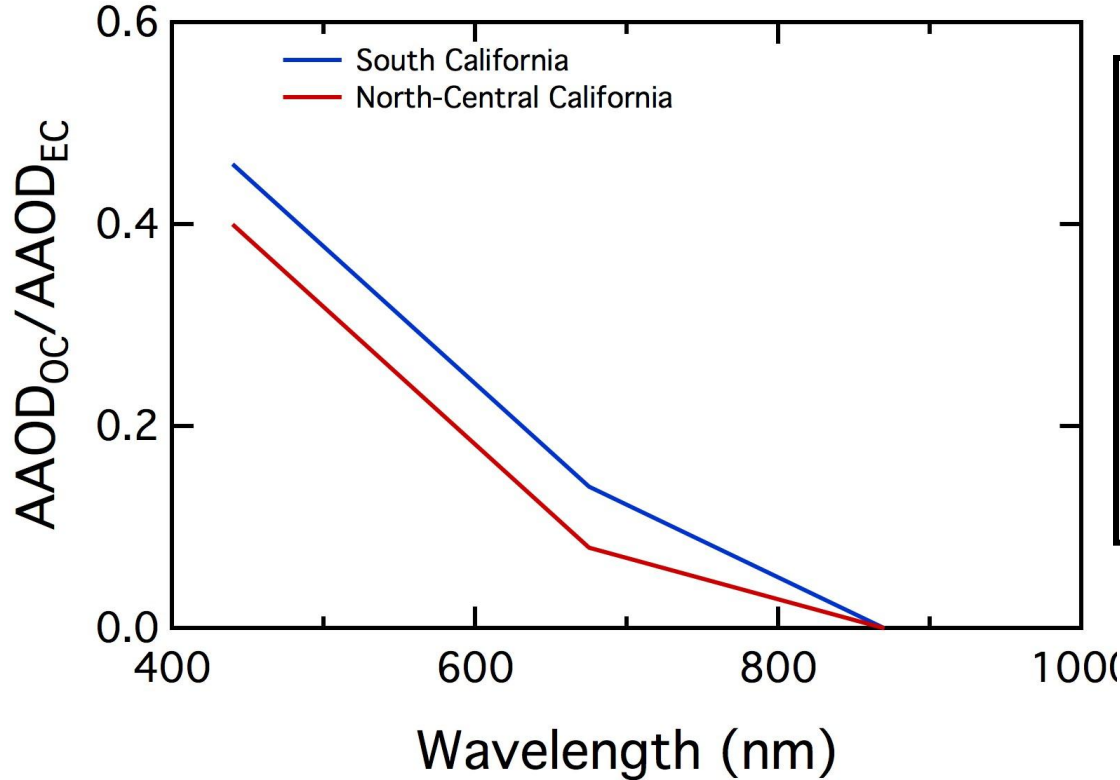
Declining Black Carbon Concentrations in Urban California



Ref: Kirchstetter et al, 2012

Brown Carbon:
Significant OC absorption detected over California
Column Data (NASA-AERONET Ground Network):

Ratio of OC to BC Vertical Column Absorption



Solar absorption by Organics can be as much as 20% to 40% at visible wavelengths.

Most Climate models treat organics as pure Scattering (cooling) aerosols

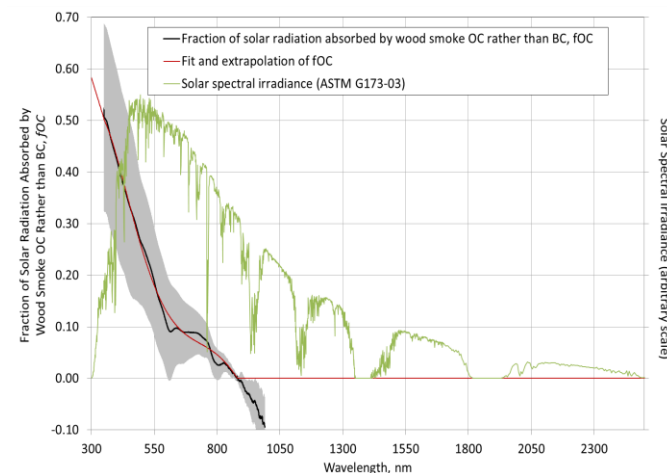
Ref: Bahadur et al. *PNAS* (in review, 2012)

Fraction of solar radiation absorbed by OC in residential wood smoke PM (black line = 115 sample avg) and solar spectrum at the earth's surface (green line).

Brown Carbon: Significant solar absorption by Organics

Supporting Data from surface measurements of wood smoke in San Luis Obispo Region

- **Independent in-situ data of 115 wood smoke samples confirms the Brown Carbon (BrC) absorption inferred from the NASA-Ground based network.**
- **The in-situ data also confirms that BrC absorption is taking place at wavelengths where sunlight is near its peak intensity**

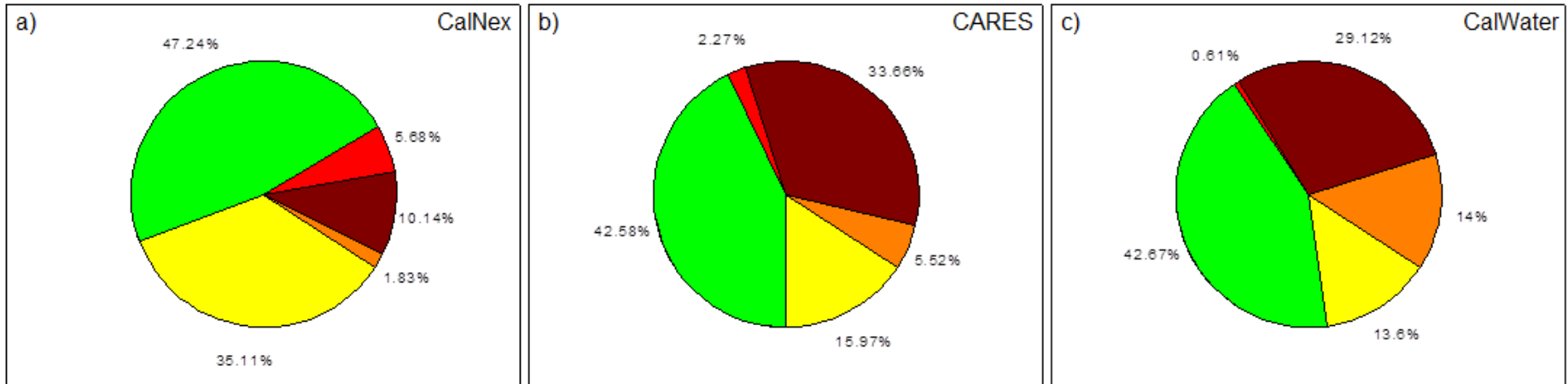


Fraction of solar radiation absorbed by OC in residential wood smoke PM (black line = 115 sample avg) and solar spectrum at the earth's surface (green line).

Kirchstetter & Thatcher, ACPD, 2012

Source Identification: ATOMFS

S. California. Summer N. California. Summer N. California. Winter



Primary Fossil Fuel Secondary Fossil Fuel Primary Biomass Burning Secondary Biomass Burning Dust

S. California dominated by fossil fuels



N. CA: Biomass plays larger role



Ref: Cazorla and Prather

Observationally Constrained Forcing

Data sets:

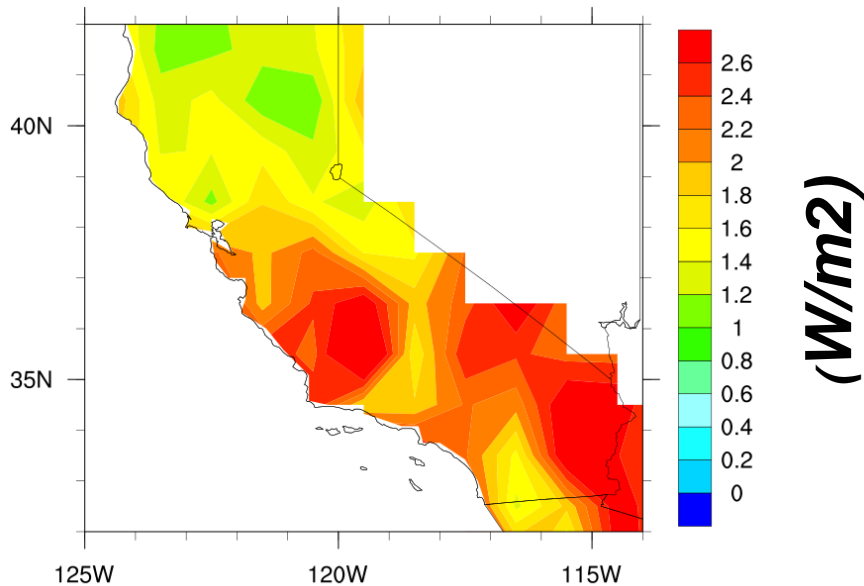
- **Satellite Aerosol Optical Data (MISR)**
- **Gives the total Scattering+ Absorbing effect of aerosols in the column**
- **NASA-Ground Network: AERONET:**
- **Gives the absorbing component(BC; BrC; Dust) in the column**

DEFINITION OF FORCING

- **BC absorbs solar radiation. This adds solar energy to the atmosphere-surface System**
- **This added energy is referred to as Forcing**
- **The unit is: Watts per Square Meter of surface area; the symbol is: WM^{-2}**
- **We next show the energy added to the atmosphere**
- **Then we show the vertically integrated energy added to the surface-atmosphere System**

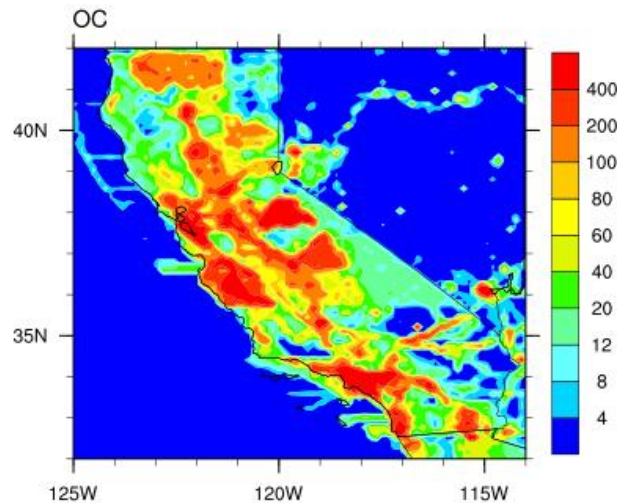
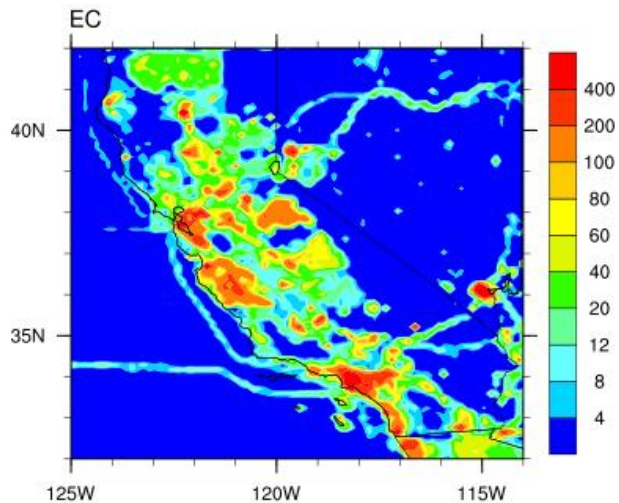
Carbonaceous Aerosol (BC+OC) Atmospheric Forcing Annual Mean 2001 to 2010

Atm. Forcing



*Heating of the atmosphere
By BC and BrC*

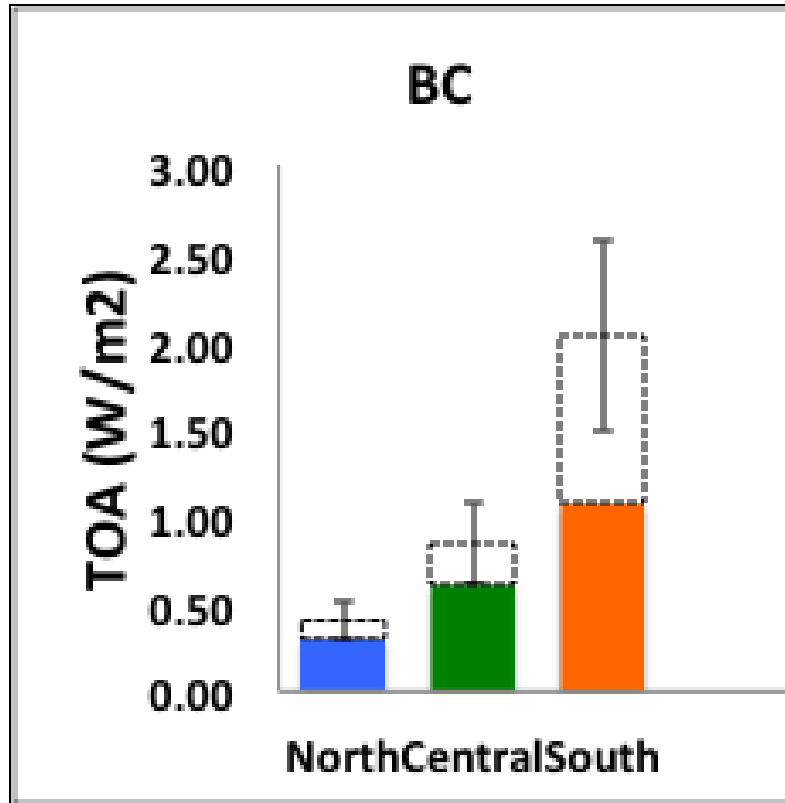
*Much larger in S. California; in part
due to Diesel BC; less clouds*



*Emission($kg/km^2/yr$)
ARCTA (baseline yr:
2006)*

Black Carbon Forcing for California

Annual Mean 2001 to 2010

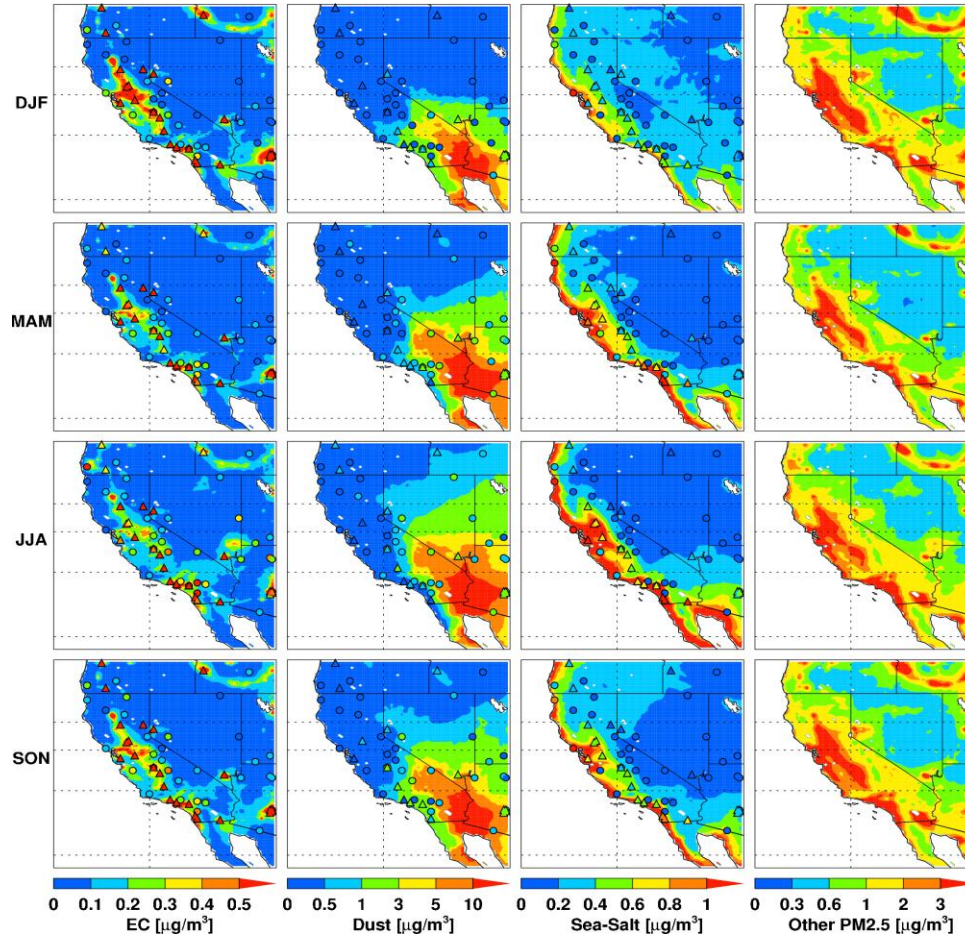


The dashed bar shows the range due to uncertainty in the ground network data; the error bar is the uncertainty due to satellite data

- The warming effect can range from 0.4 Wm⁻² over N California to as high as 2.5 Wm⁻² over S. California.
- The Statewide average forcing can range from 0.5 Wm⁻² to 1.4 Wm⁻²
- A similar estimate for the 1980s will be double these forcing values
- **The forcing numbers are preliminary; will be finalized in two months**

Regional Climate Change of BC trends: We need regional down-scaled models.

But model simulations of BC forcing have to agree with observed forcing



Ref: Leung et al, 2012

Major Findings

This study is the first of its kind to evaluate an observationally based regional scale BC forcing and its impact on regional climate

- **Statewide, BC has been reduced by as much as 50% since the 1980s**
- **Brown Carbon adds significant amount to BC heating**
- **The reduction in the State-averaged Direct forcing due to BC reduction can range from 0.5 to 1.4 Wm⁻²; should also have reduced forcing outside CA. The forcing numbers are preliminary; will be finalized in two months**
- **The regional Climate Effects will be evaluated soon, including the semi-direct forcing**
- **California's successful policies for reducing BC and its support of Science to evaluate regional climate impacts should serve as a model for the climate and clean-air coalition: Knowledge to Action example for the World**