

# Black Carbon – Exposure and Mitigation

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**WEDNESDAY**

**MAY 8, 2013**

**7<sup>TH</sup> FLOOR BOARD ROOM**

**939 ELLIS STREET**

**9:00 A.M. SAN FRANCISCO, CA 94109**



**ADVISORY COUNCIL REGULAR MEETING**

BAY AREA  
AIR QUALITY  
MANAGEMENT  
DISTRICT

## ***Black Carbon: Product of Incomplete Combustion***



# Electron Microscopy Images

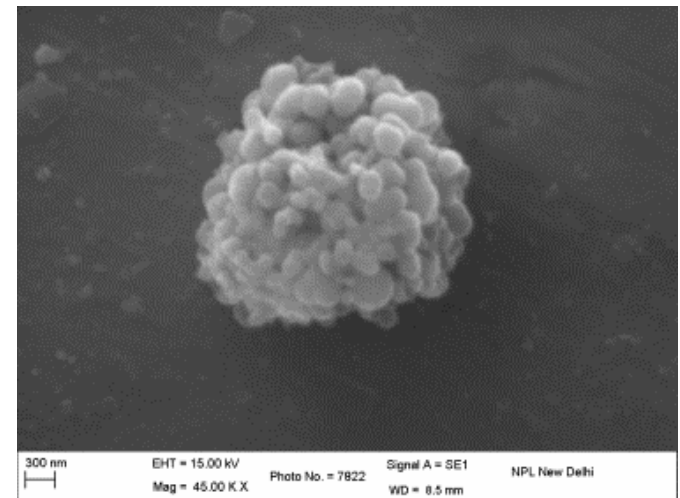
*Semi-Aged BC > 1 hr*



←————→  
**1 micron**

***EC/OC Mixtures***

*Aged BC > 1 day*





***Brown Clouds Over  
San Diego;  
Sylvia Somerville, 2013***

***IS THERE ANOTHER KNOB TO SLOW THE RATE OF WARMING?***

## ***The Short Lived Climate Pollutants***

**Methane; Black Carbon; Ozone (Lower Atmosphere); HFCs**

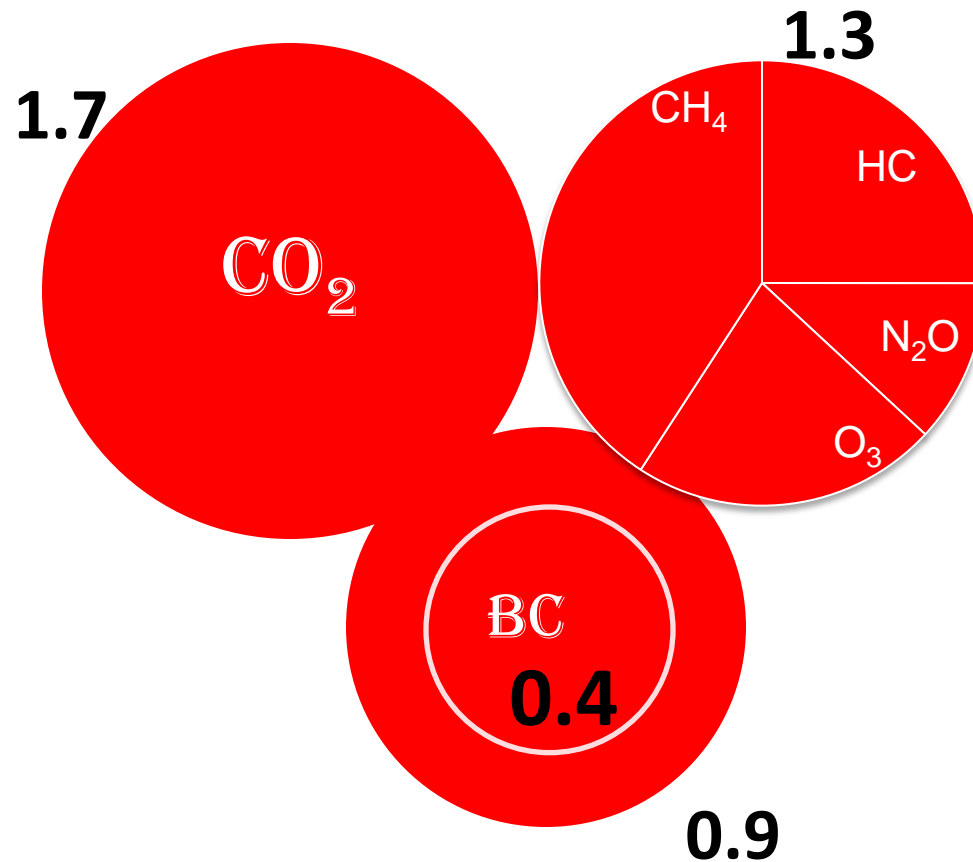
**Life times are about a decade or less**

# Pollutants that lead to positive forcing

*GHGs Forcing from IPCC 2007;*

*BC Forcing (outer Circle): Ramanathan and Carmichael, 2008*

*BC Forcing (inner circle) : IPCC-AR4*



***The Greenhouse  
Gas Forcing- 2005  
= 3 Wm<sup>-2</sup> ( 25%)***

Ramanathan and Xu, PNAS, 2010

***Effect of CO<sub>2</sub> and SLCPs Mitigation on Sea Level Rise (SLR) at 2050***  
***A study led by the Scripps Institution of Oceanography in  
Collaboration With the National center for Atmospheric  
Research and Climate Central.***

***Funded by the National Science Foundation***

nature  
climate change

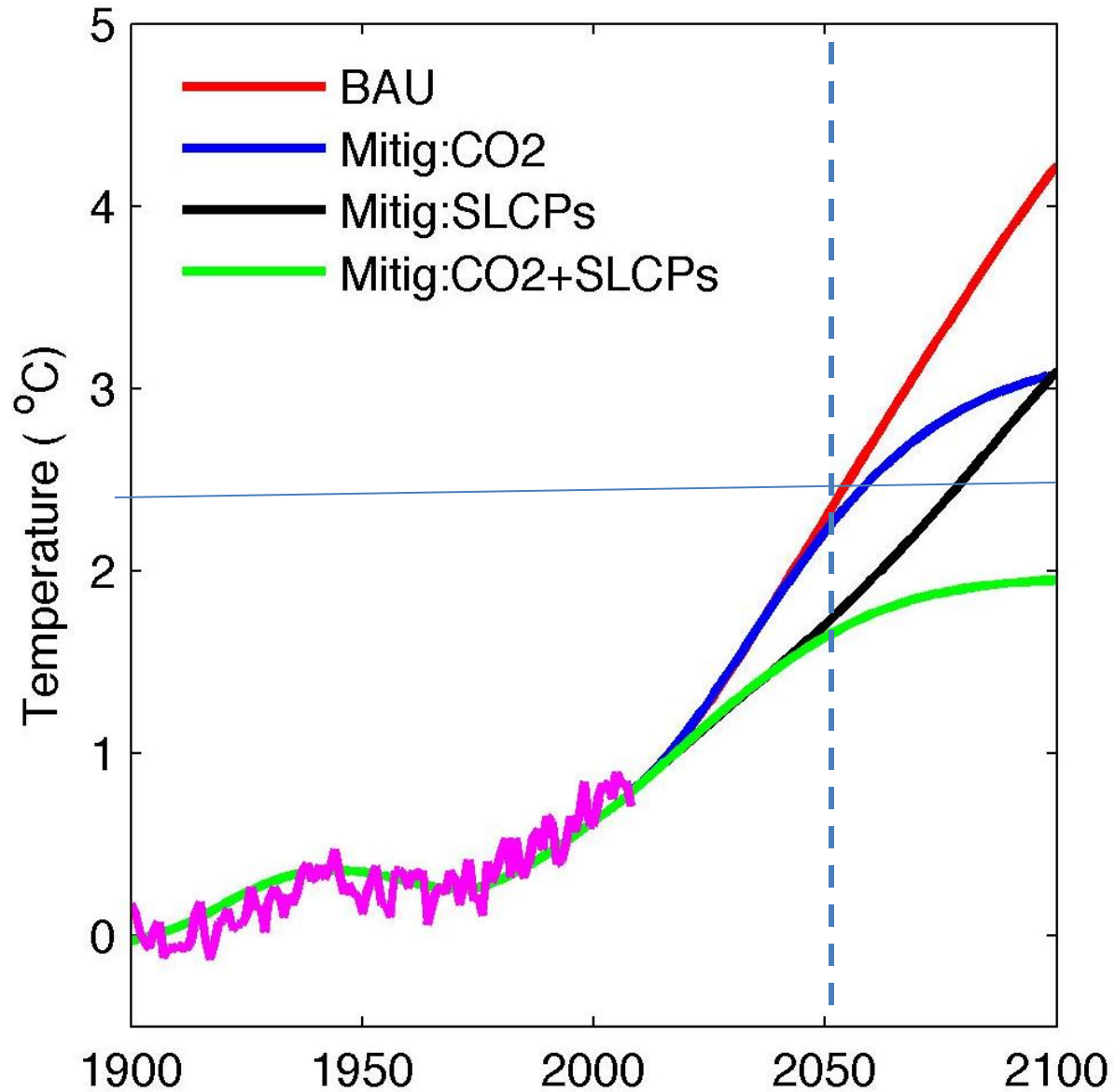
LETTERS

PUBLISHED ONLINE: 14 APRIL 2013 | DOI: 10.1038/NCLIMATE1869

# Mitigation of short-lived climate pollutants slows sea-level rise

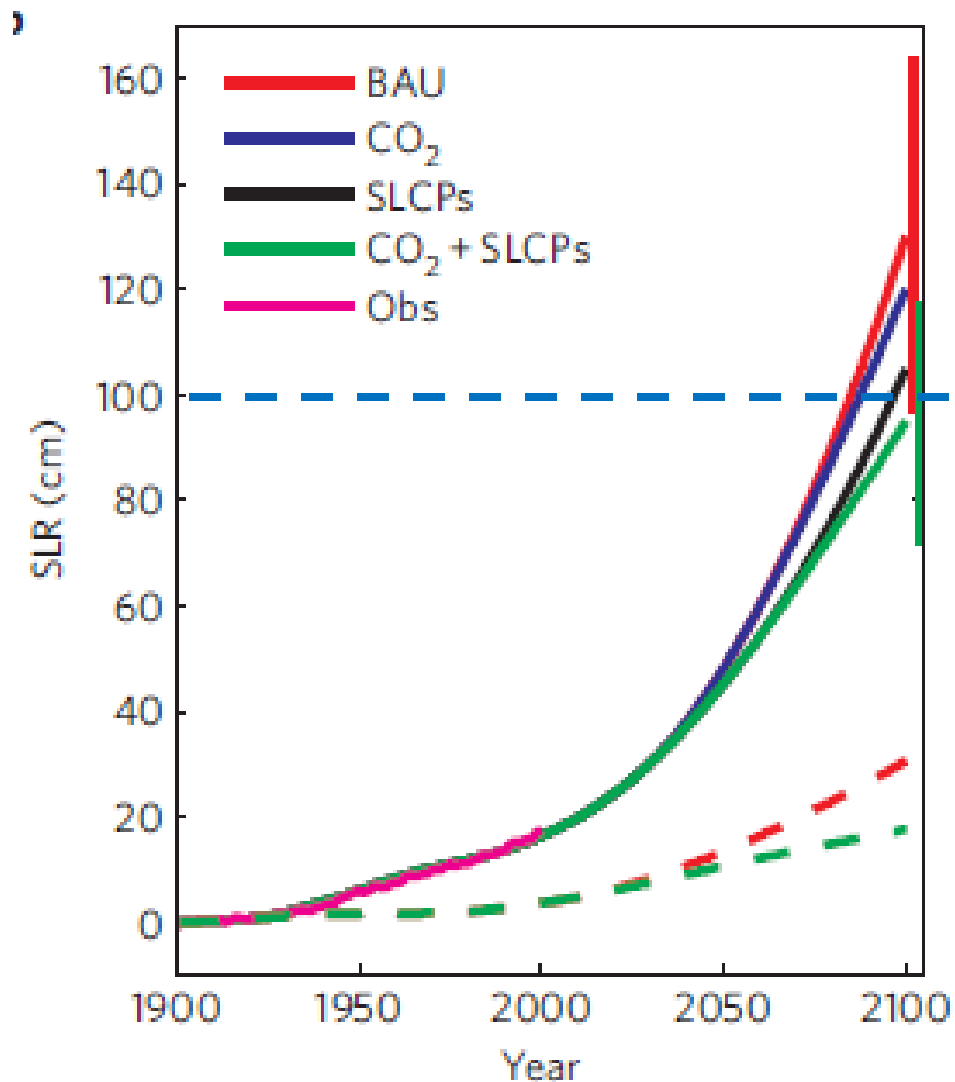
Aixue Hu<sup>1</sup>, Yangyang Xu<sup>2</sup>, Claudia Tebaldi<sup>1,3</sup>, Warren M. Washington<sup>1</sup>  
and Veerabhadran Ramanathan<sup>2\*</sup>

## NEAR AND LONG TERM MITIGATION





# PROJECTIONS OF SEA LEVEL RISE: BUSINESS AS USUAL



# Effect of CO<sub>2</sub> and SLCPs Mitigation on Global Temperatures

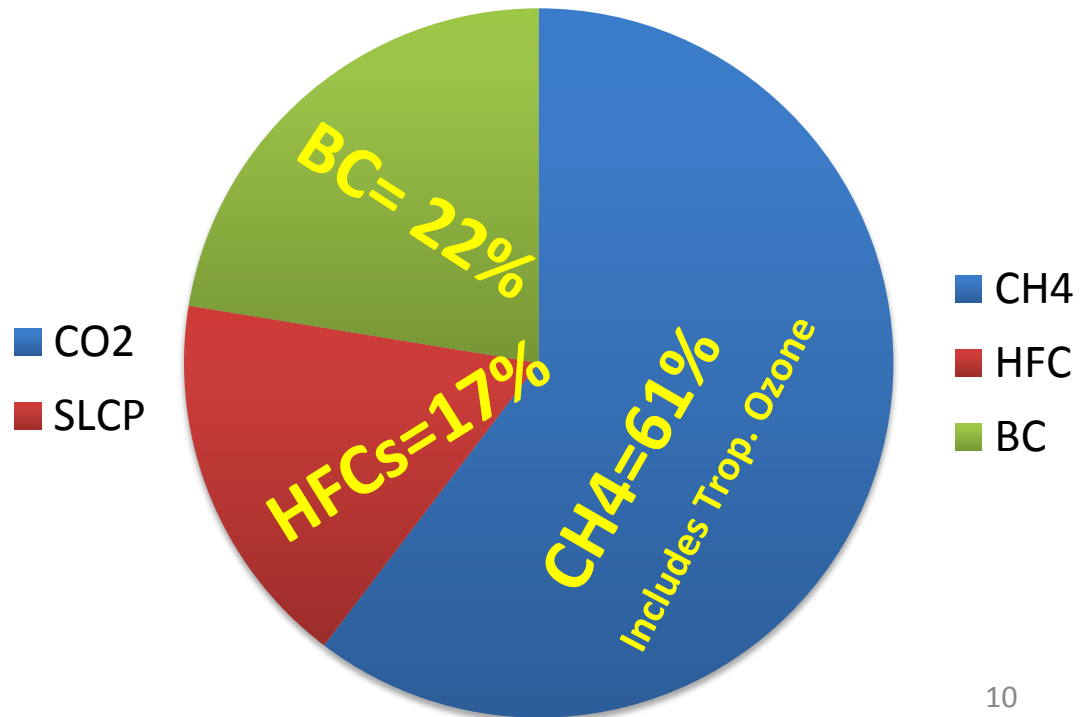
*Prepared by Ramanathan and Xu*

*Based on Ramanathan and Xu, 2010; Hu, Xu, Tibaldi, Washington and Ramanathan, 2013*

**Pre-Industrial to 2050: 1.7 C (1.3 C to 2.3 C) with mitigations**

**Warming Avoided = 0.7 C**

**Warming Avoided by SLCPs = 0.6 C**



# Effect of CO<sub>2</sub> and SLCPs Mitigation on Sea Level Rise (SLR)

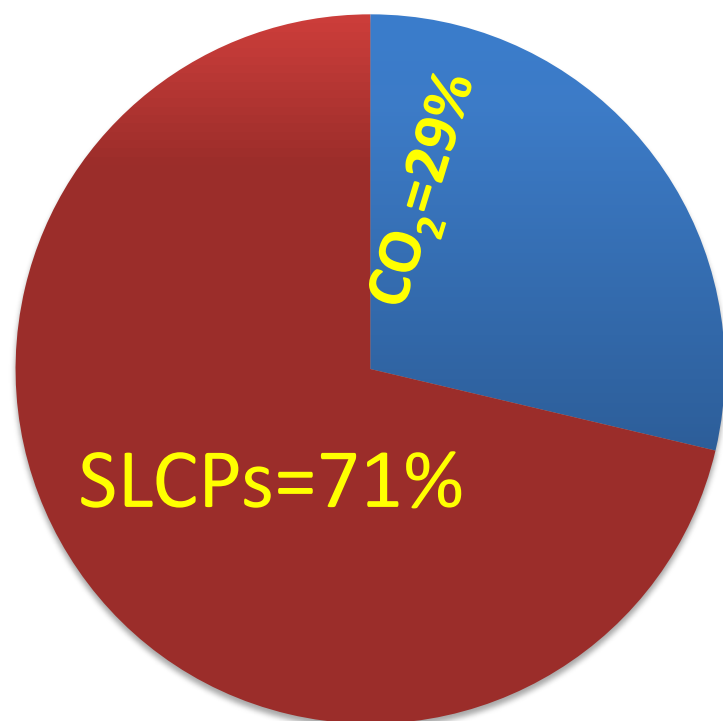
*Prepared by Ramanathan and Xu*

*Based on Ramanathan and Xu, 2010; Hu, Xu, Tibaldi, Washington and Ramanathan, 2013*

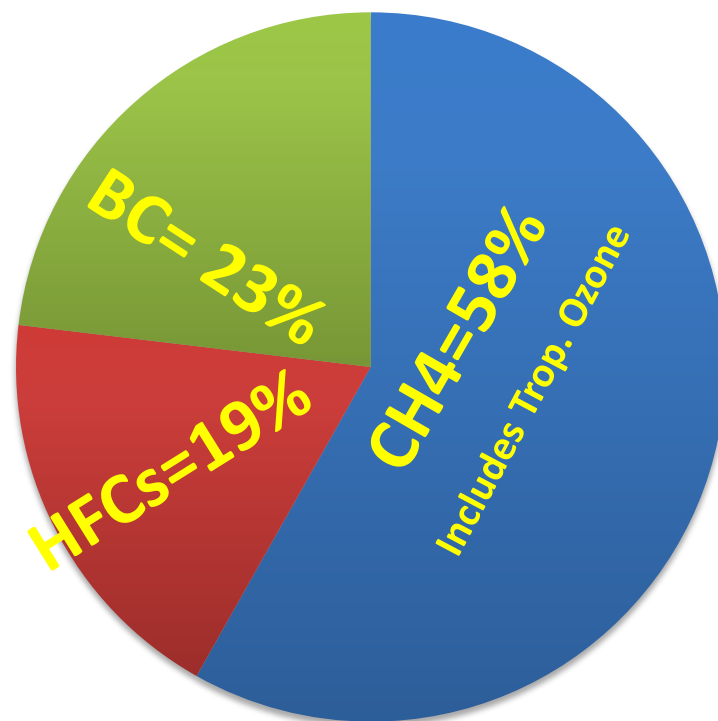
**Pre-Industrial to 2050: 97 cm (50 to 190 cm)**

**Avoided SLR = 35 cm**

**Avoided SLR by SLCPs = 25 cm (71%)**



■ CO<sub>2</sub>  
■ SLCP



■ CH<sub>4</sub>  
■ HFC  
■ BC

# ***Health Impacts of Aerosols***

## **A Major New Study was released two weeks ago:**

A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990—2010: a systematic analysis for the Global Burden of Disease Study 2010:

***Lin et al, LANCET, 2013***

***Household air pollution from solid fuels accounted for 3·5 million (2·7 million to 4·4 million) deaths.***

***Ambient particulate matter pollution accounted for 3·1 million (2·7 million to 3·5 million) deaths***

# Black Carbon and the Regional Climate of California

Report to the  
California Air Resources Board  
Contract 08-323

Prepared by:  
V. Ramanathan  
Principal Investigator

Dr. R. Bahadur<sup>1</sup>  
Dr. V. Ramanathan<sup>1</sup>  
Dr. P. S. Praveen<sup>1</sup>

Dr. K. A. Prather<sup>2</sup>  
Dr. A. Cazorla<sup>2</sup>  
Dr. T. Kirchstetter<sup>3</sup>

Dr. O. L. Hadley<sup>3</sup>  
Dr. R. Leung<sup>4</sup>  
Dr. C. Zhao<sup>4</sup>

<sup>1</sup>Scripps Institution of Oceanography  
University of California at San Diego

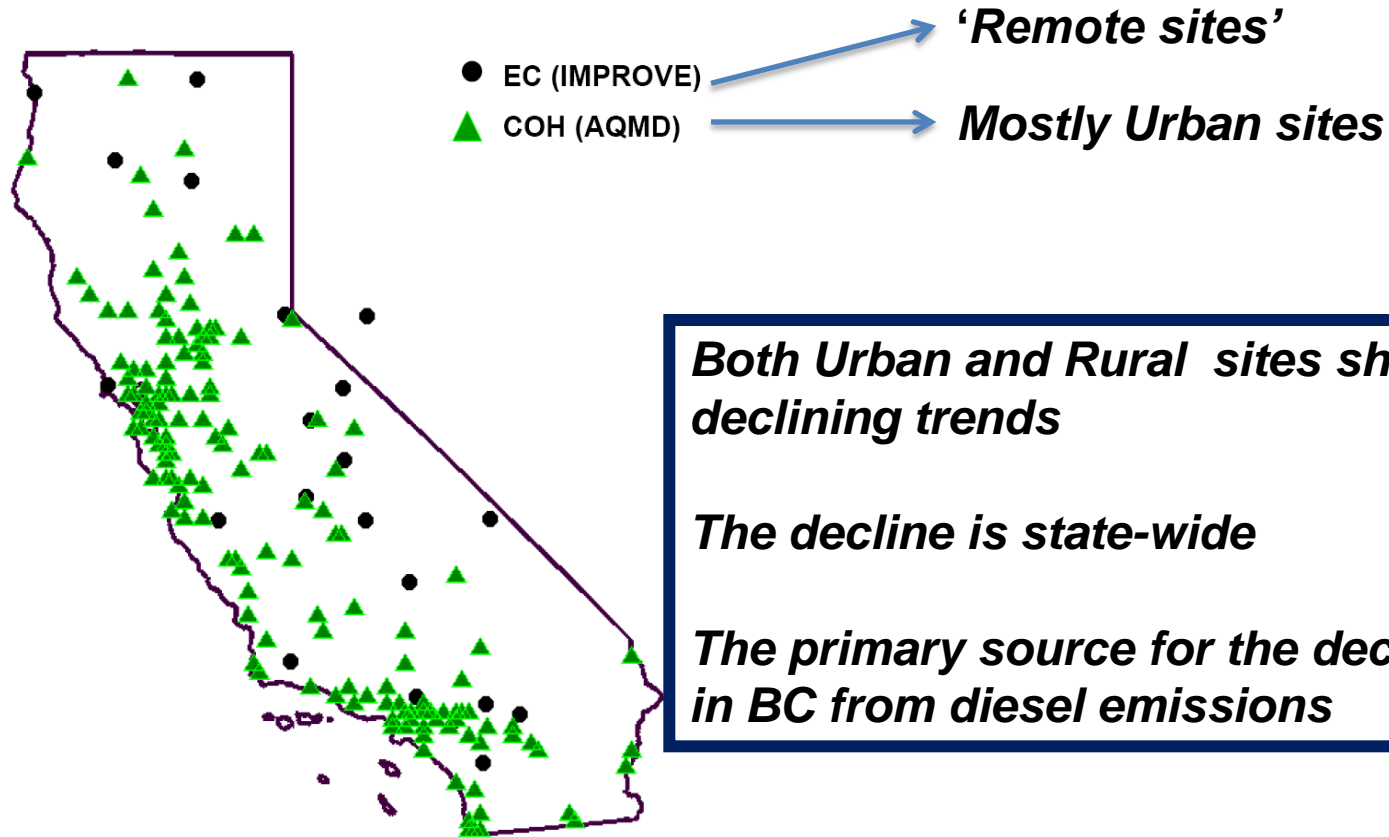
<sup>2</sup>Department of Chemistry and Biochemistry  
University of California at San Diego

<sup>3</sup>Lawrence Berkeley National Lab.

<sup>4</sup>Pacific Northwest National Lab.

April 15, 2013

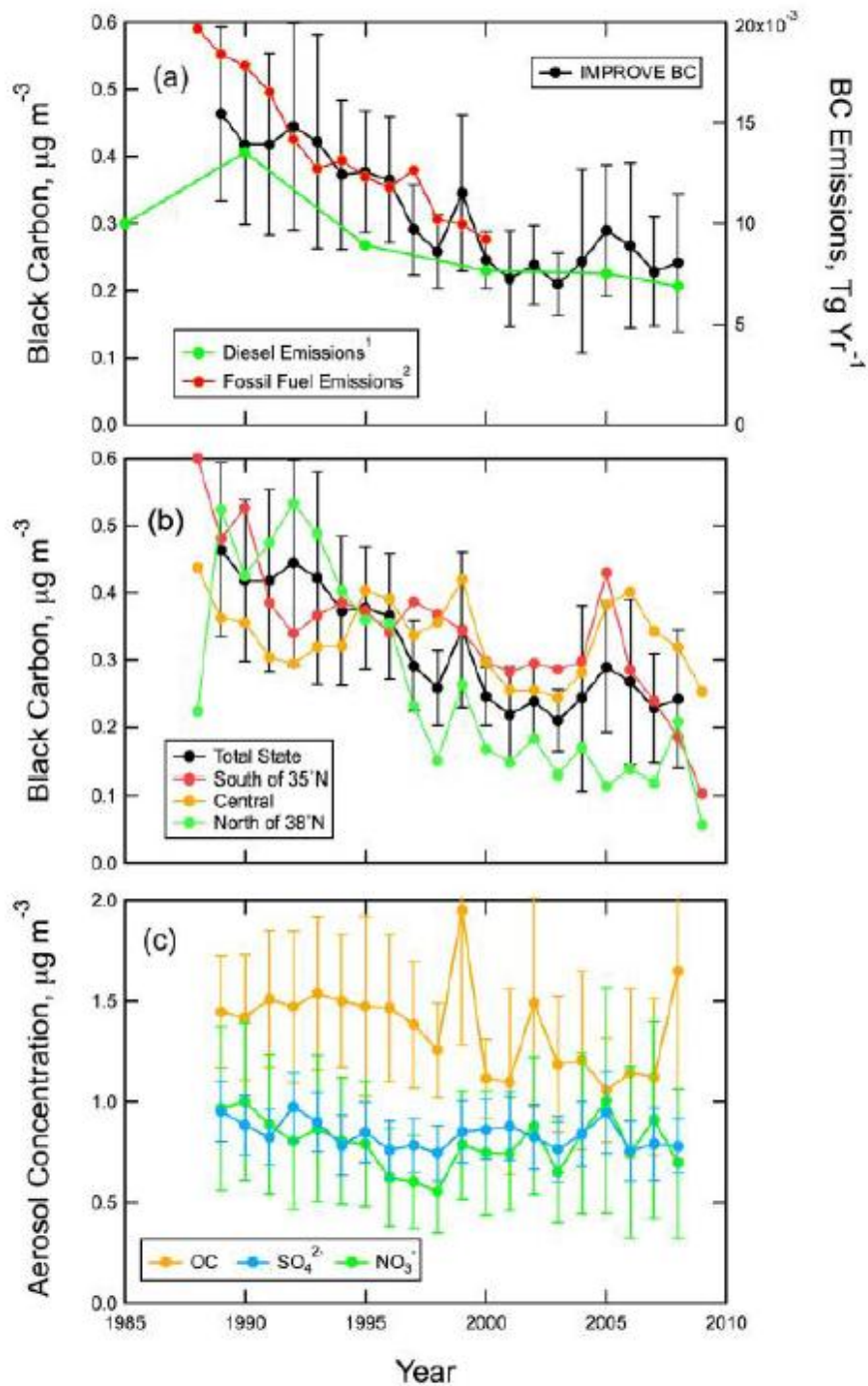
# Black Carbon Trends in California: Detection and Attribution



***Both Urban and Rural sites show consistent declining trends***

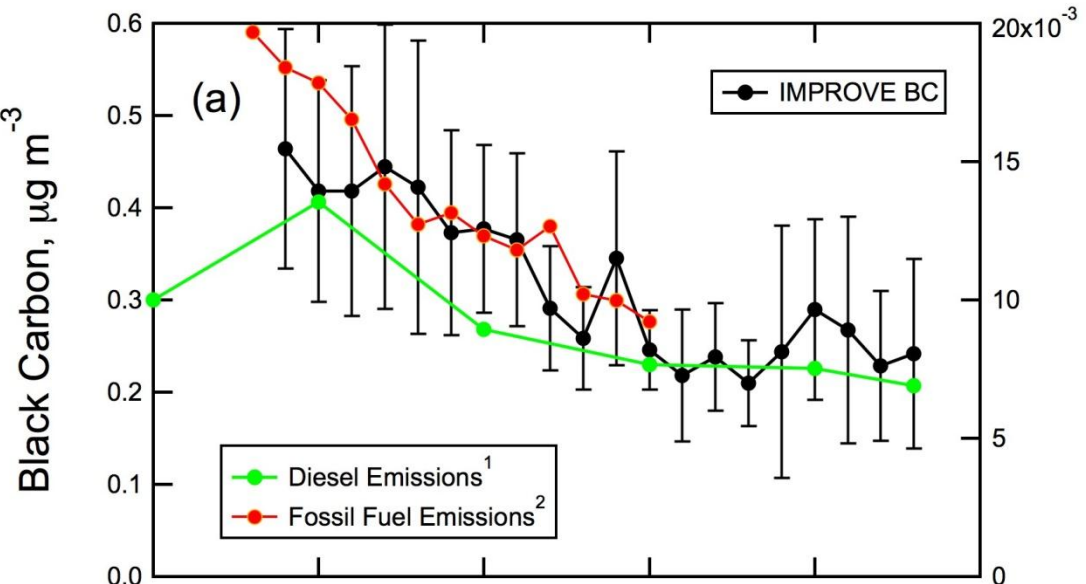
***The decline is state-wide***

***The primary source for the decline is reduction in BC from diesel emissions***



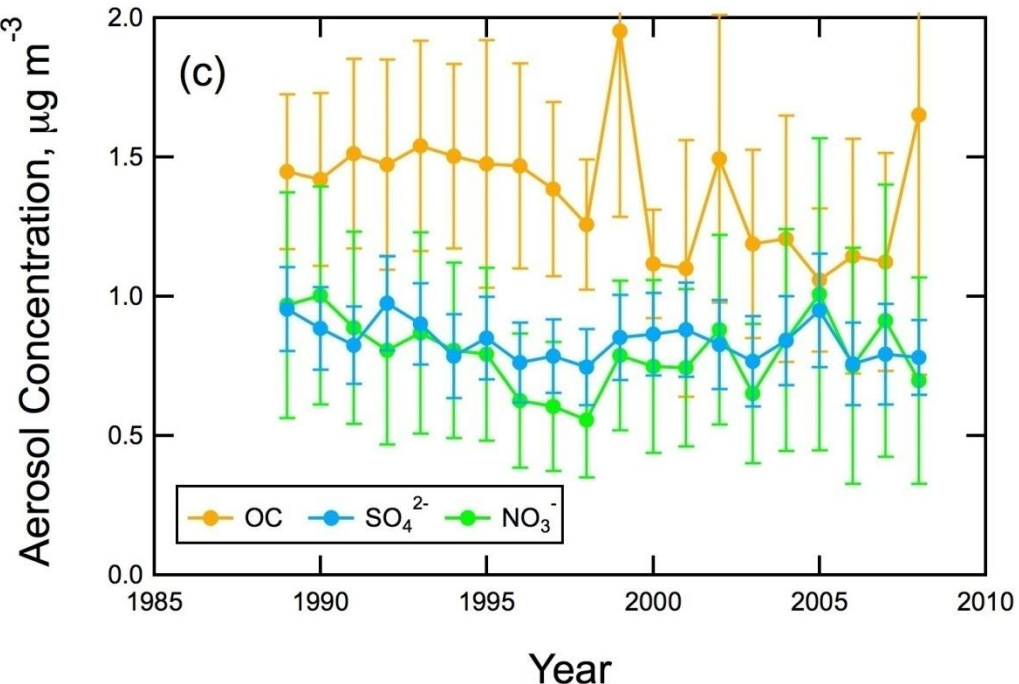
CARB Black Carbon Report, 2013: [V. Ramanathan](#), R. Bahadur, Y. Xu & P. S. Praveen, [K. Prather](#) and A. Cazorla; [T. Kirchstetter](#) & O. Hadley; R. Cohen. [R. Leung](#) and Dr. Zhao Chun (PNNL)

*BC is about 10% to 15%  
Of total PM*



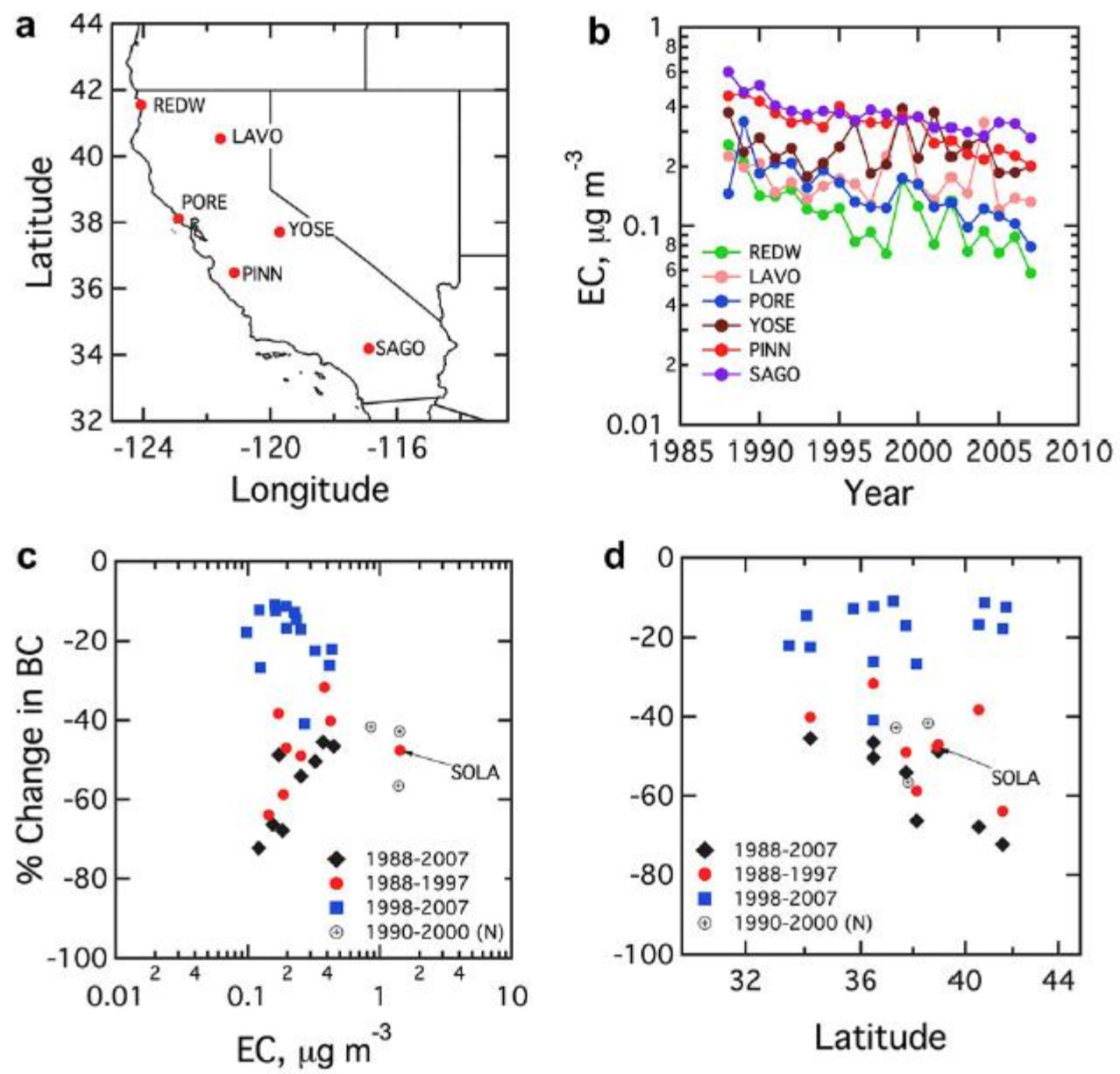
BC Emissions,  $\text{Tg Yr}^{-1}$

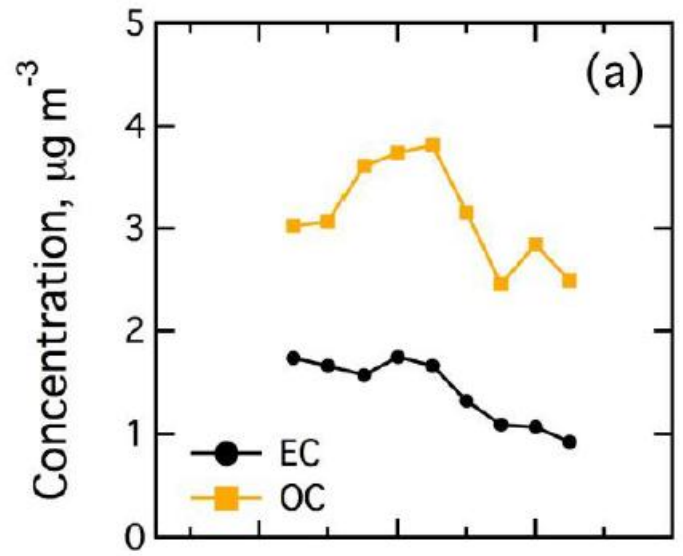
**California's BC Decreased drastically Due to mitigation of Diesel emissions**



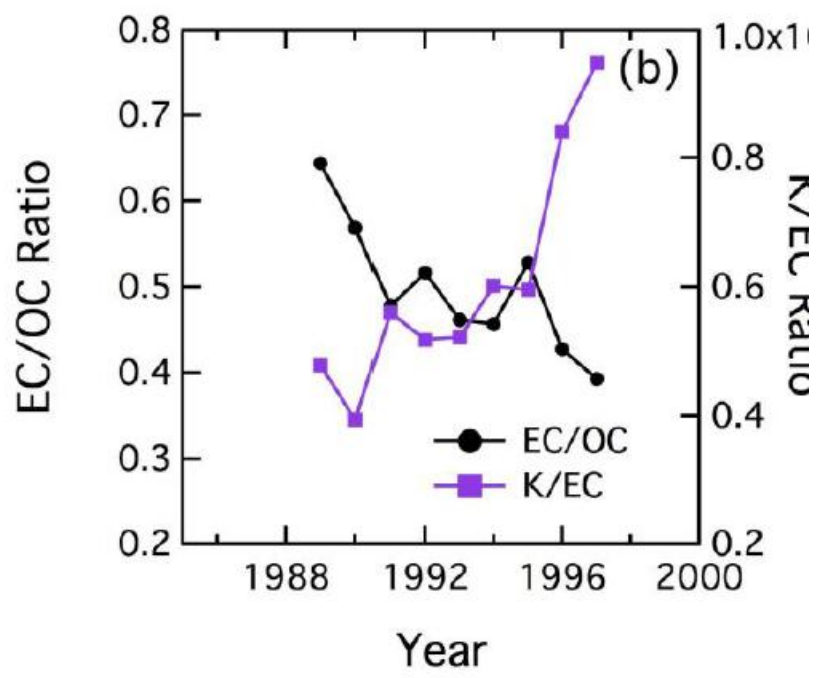
**Trends in Co-emitted Cooling Species was negligible**



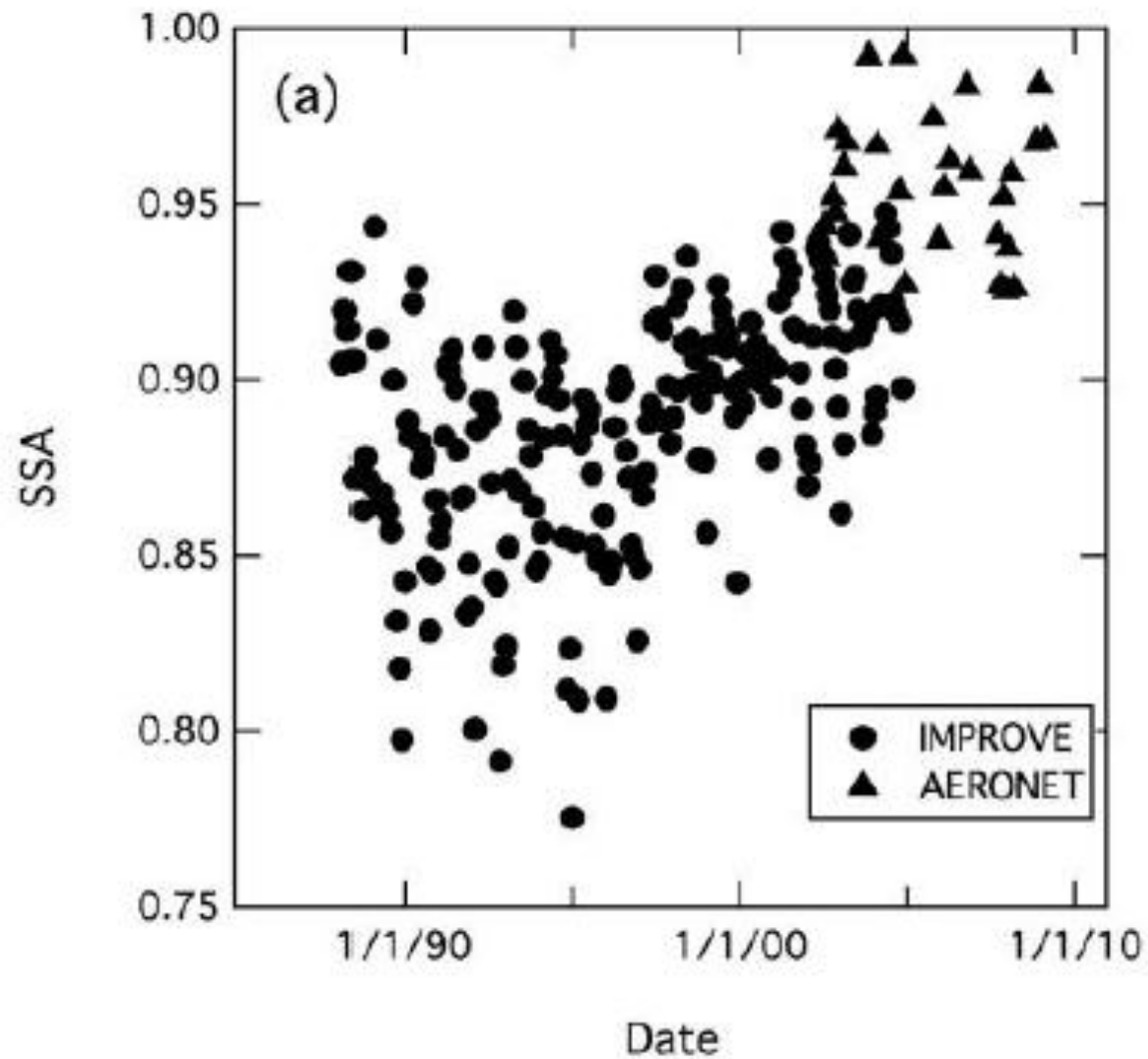




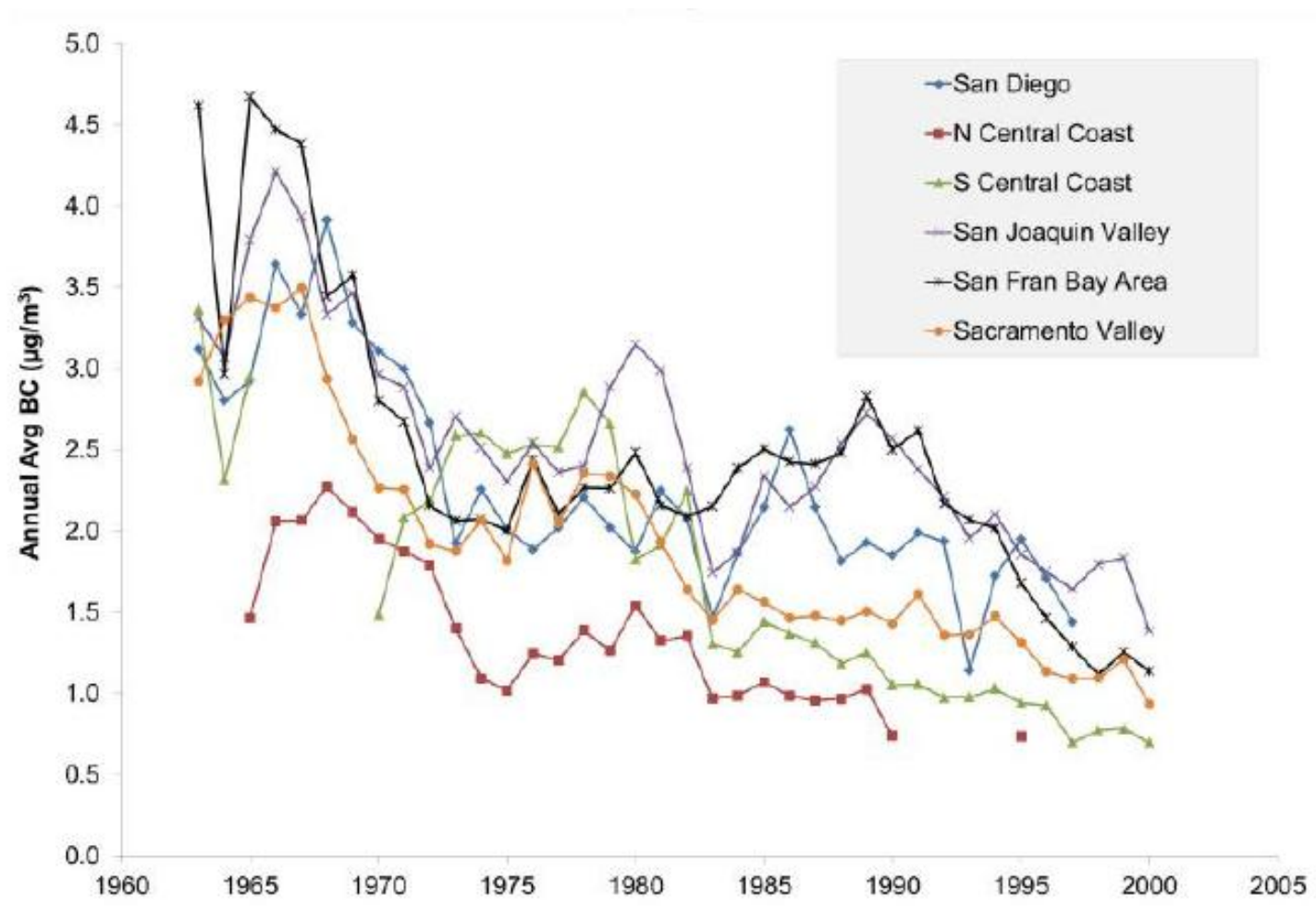
LAKE TAHOE

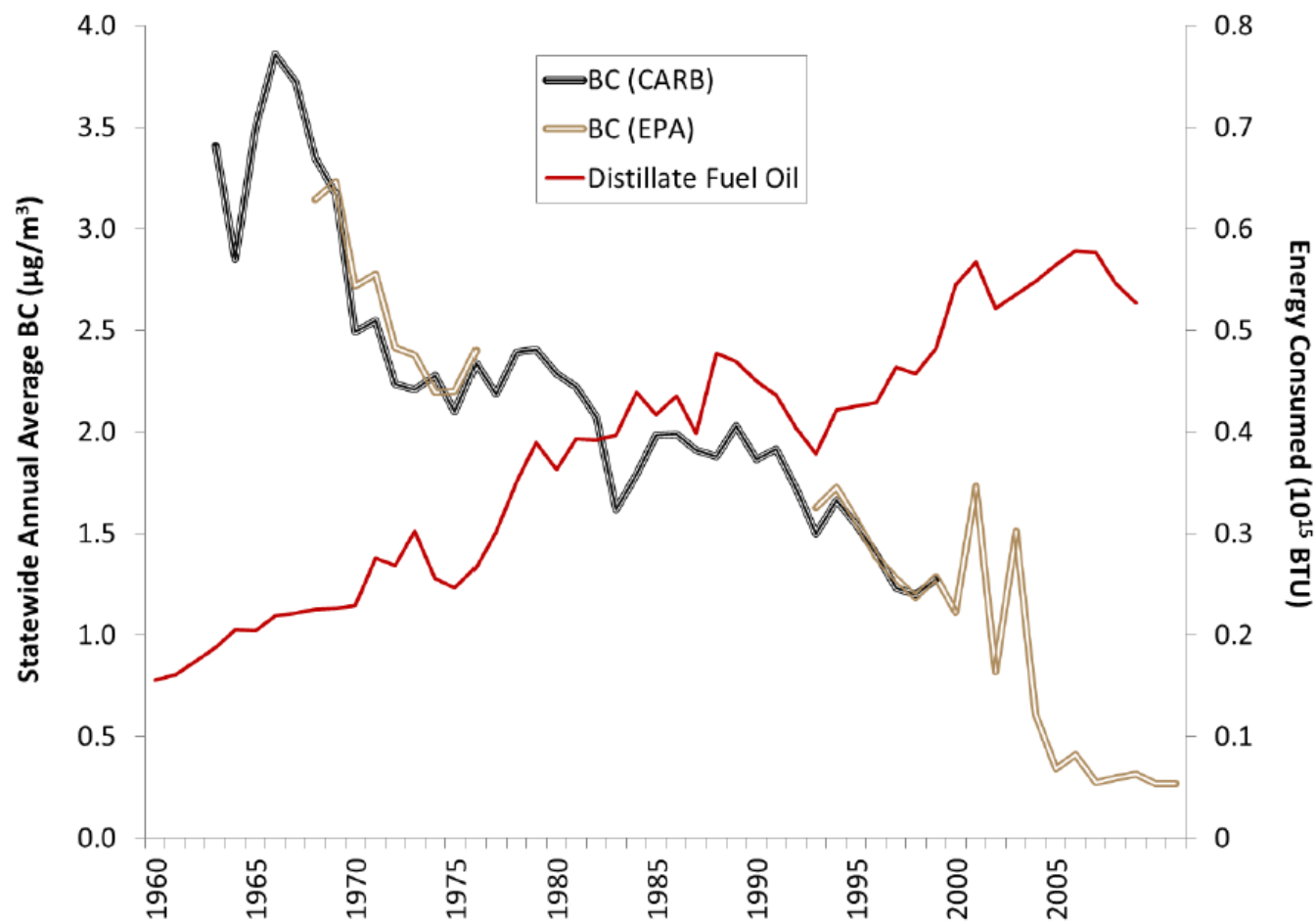


**BOTH RESIDENTIAL COMBSUTION  
AND DIESEL CAME DOWN;  
BUT THE DIESEL EFFECT OVERWHELMED THE  
WOODBUTNIG EFFECT**



CARB Black Carbon Report, 2013: [V. Ramanathan](#), R. Bahadur, Y. Xu &P. S. Praveen, [K. Prather](#) and A. Cazorla; [T. Kirchstetter](#) & O. Hadley; R. Cohen. [R. Leung](#) and Dr. Zhao Chun (PNNL)





**Figure 3.3** Statewide average BC concentrations based on COH data sets obtained from CARB and EPA and distillate fuel oil (i.e., diesel fuel) consumption, a source of BC, in California since 1960.

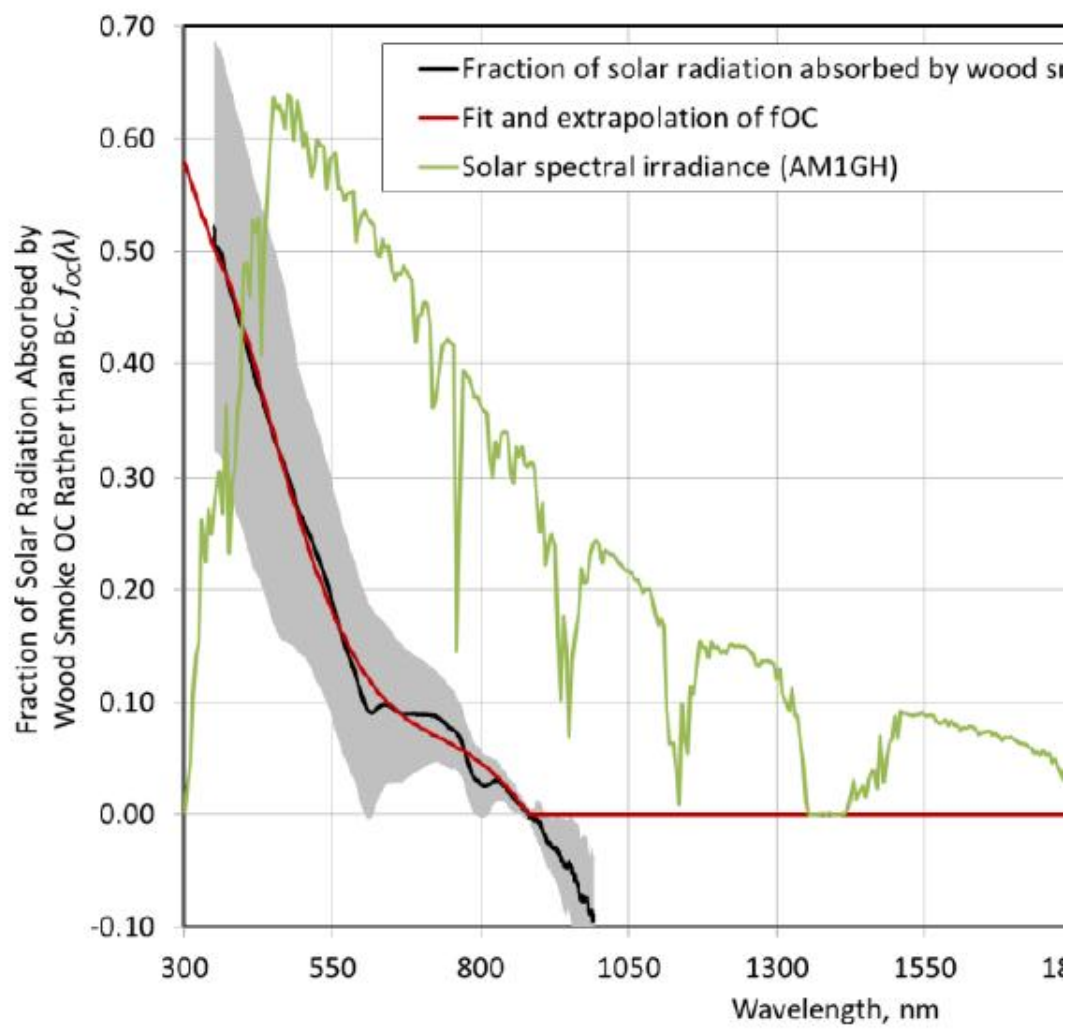
# ***Now Brown Carbon ?***



***March 18, 2013, Maharashtra, India***  
***Photo: Ramanathan***

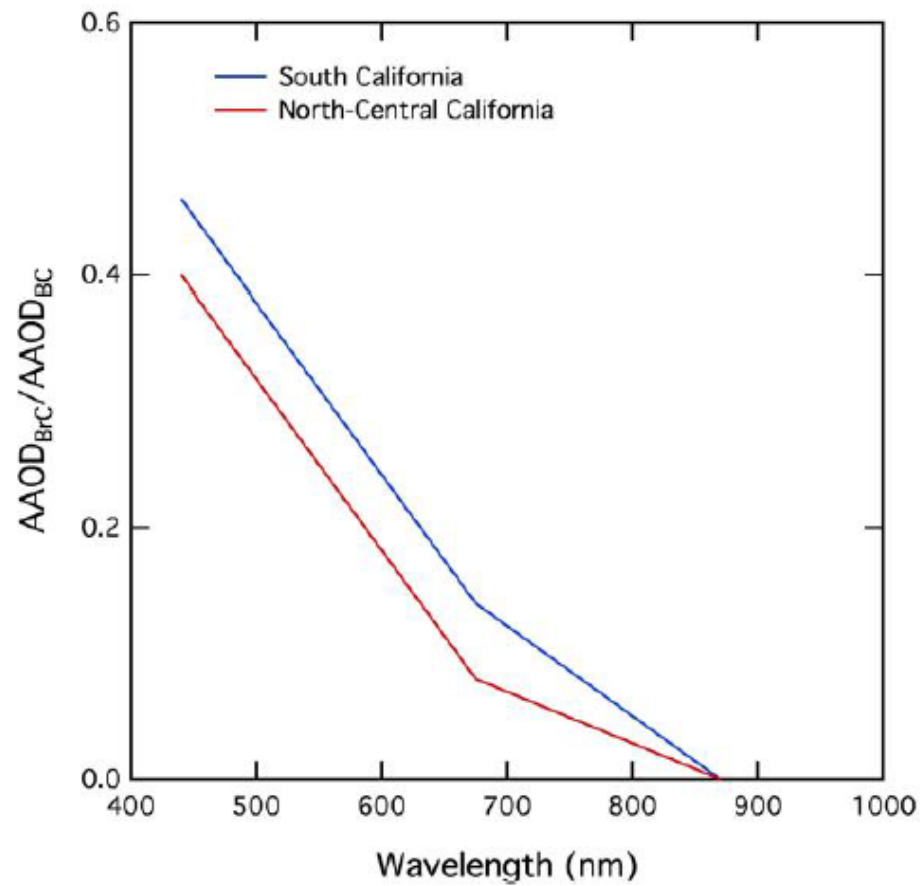
03/18/2013 02:33



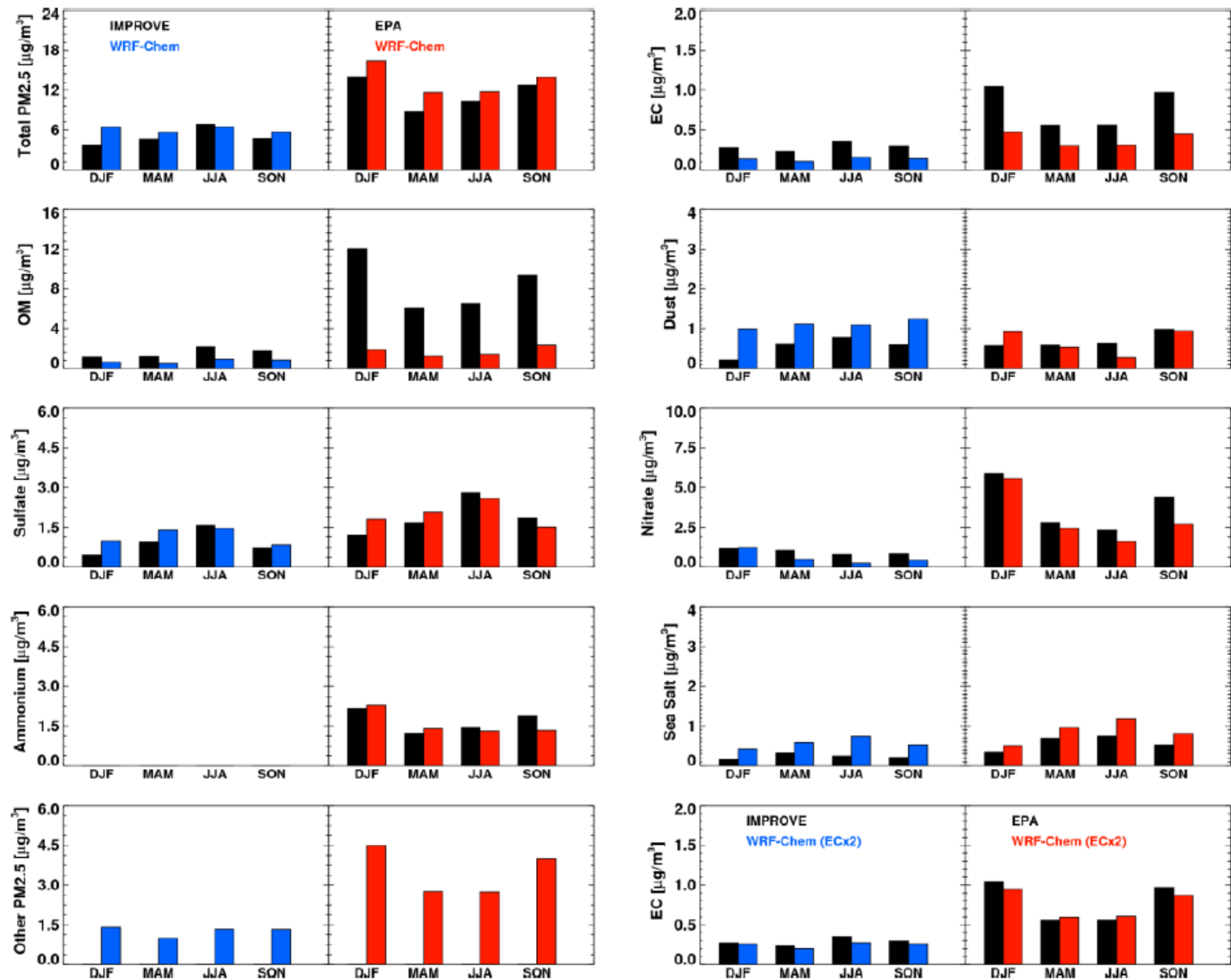


**Figure 7.3.** Fraction of solar radiation absorbed by organic carbon rather than black carbon in residential wood smoke particulate matter,  $f_{OC}(\lambda)$ : (black line and

3. BrC emissions are likely both from biomass burning (forest fires and residential wood burning) as previously thought, and also from large aged particles indicating that secondary organics may also be absorbing.

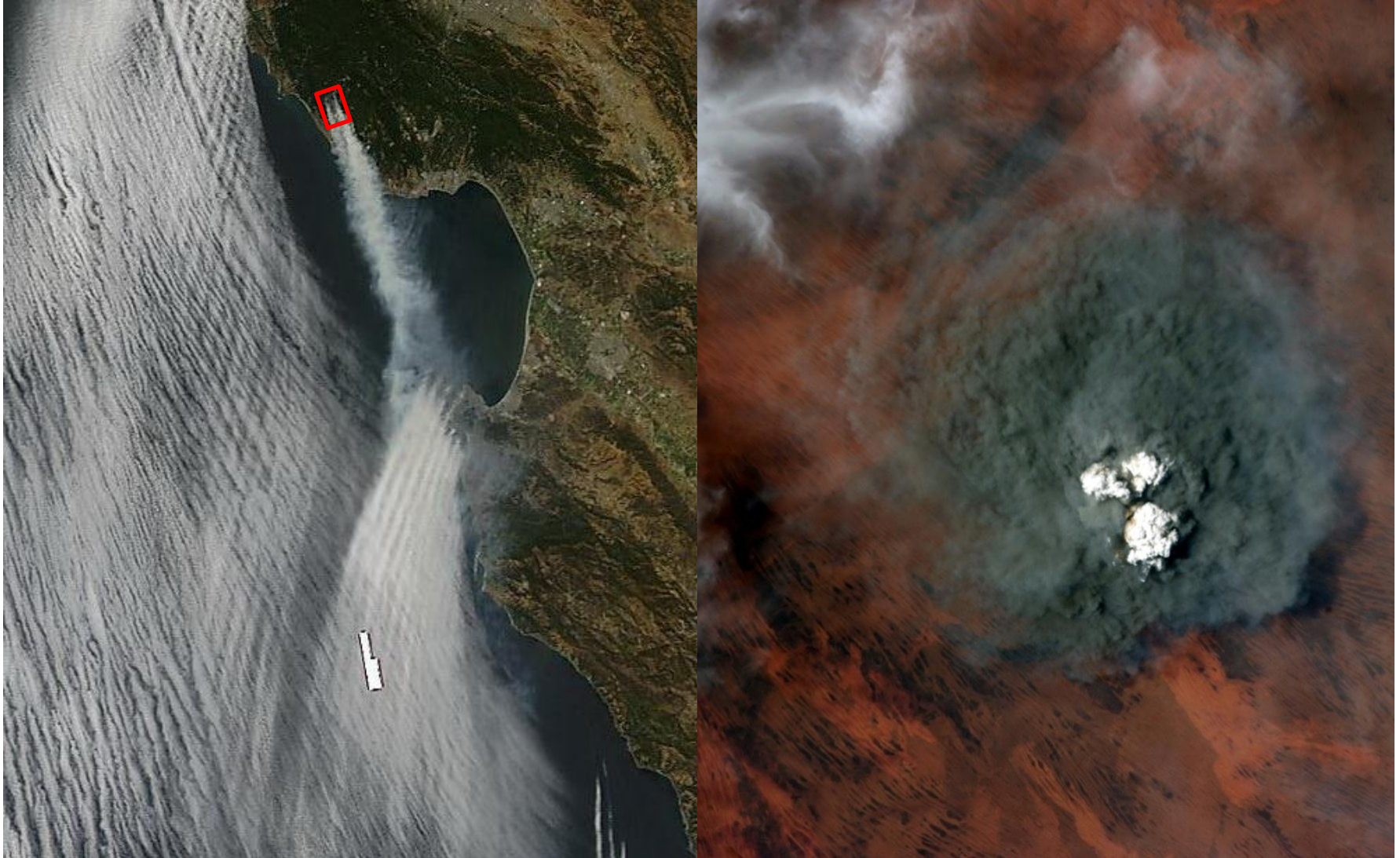






# Climate's Dark Forcings: Role of BC-Cloud Interactions

M. Andreae<sup>A</sup> and Ramanathan<sup>B</sup>, *Science*, April 2013

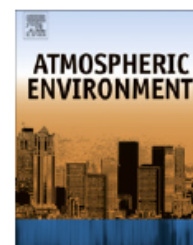




Contents lists available at [ScienceDirect](#)

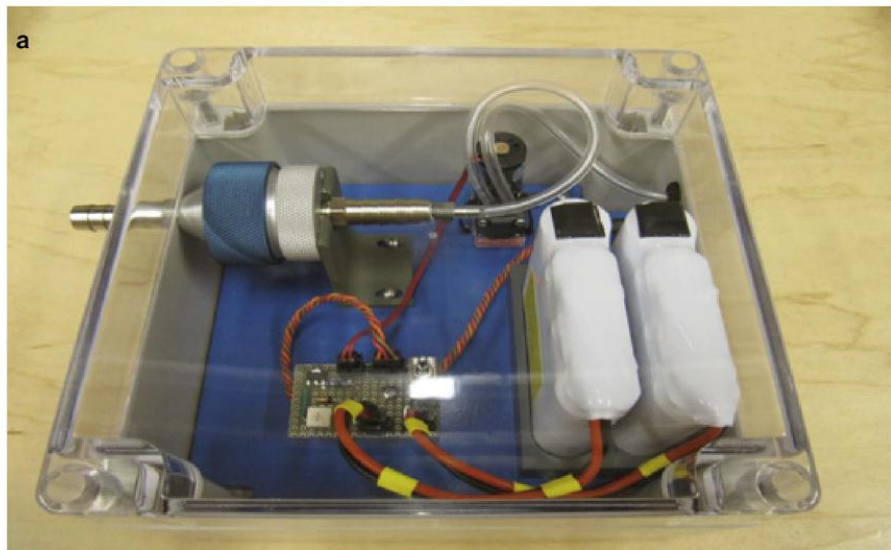
## Atmospheric Environment

journal homepage: [www.elsevier.com/locate/atmosenv](http://www.elsevier.com/locate/atmosenv)

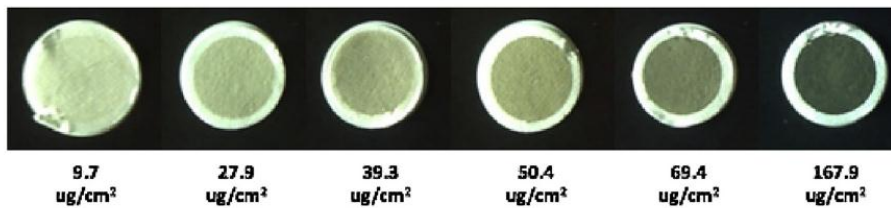


### A cellphone based system for large-scale monitoring of black carbon

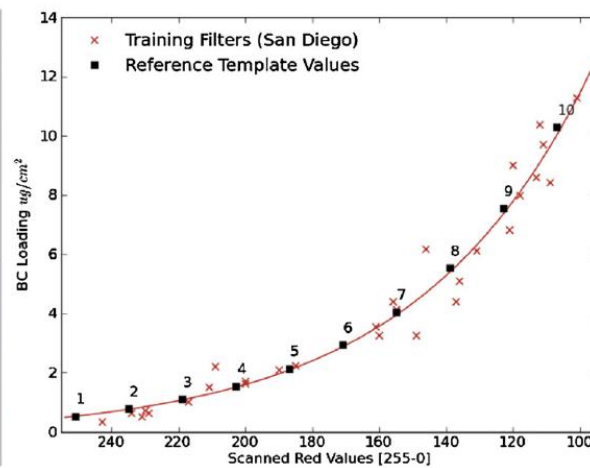
N. Ramanathan<sup>a,b,\*</sup>, M. Lukac<sup>b</sup>, T. Ahmed<sup>c</sup>, A. Kar<sup>d</sup>, P.S. Praveen<sup>c,e</sup>, T. Honles<sup>a</sup>,  
I. Leong<sup>a</sup>, I.H. Rehman<sup>d</sup>, J.J. Schauer<sup>f</sup>, V. Ramanathan<sup>c</sup>



Sample Filters



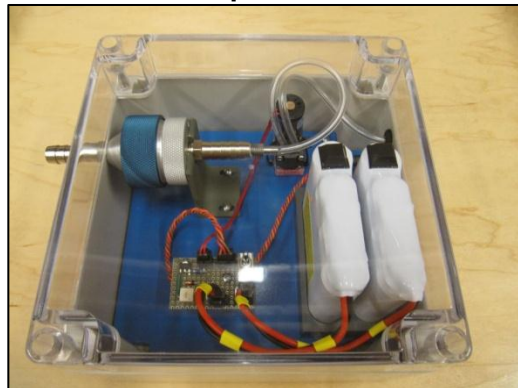
**b**



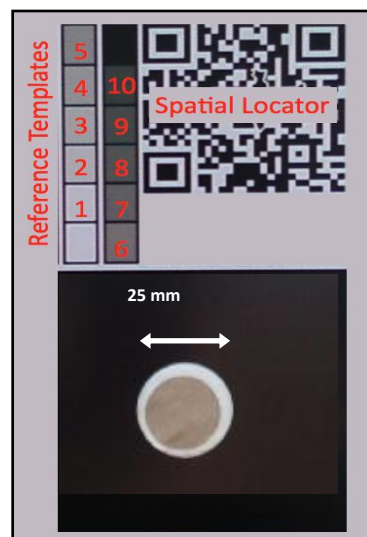


# Monitoring Stove BC Emissions Using Mobile Phones

Micro-Pump and Filter



Filter, placed on  
reference template



Picture sent  
to server

## Innovations

- \$500 per unit, ultra low power.
- Low-tech: works with **any** camera cellphone.
- Real-time reporting.

Results sent  
back via SMS

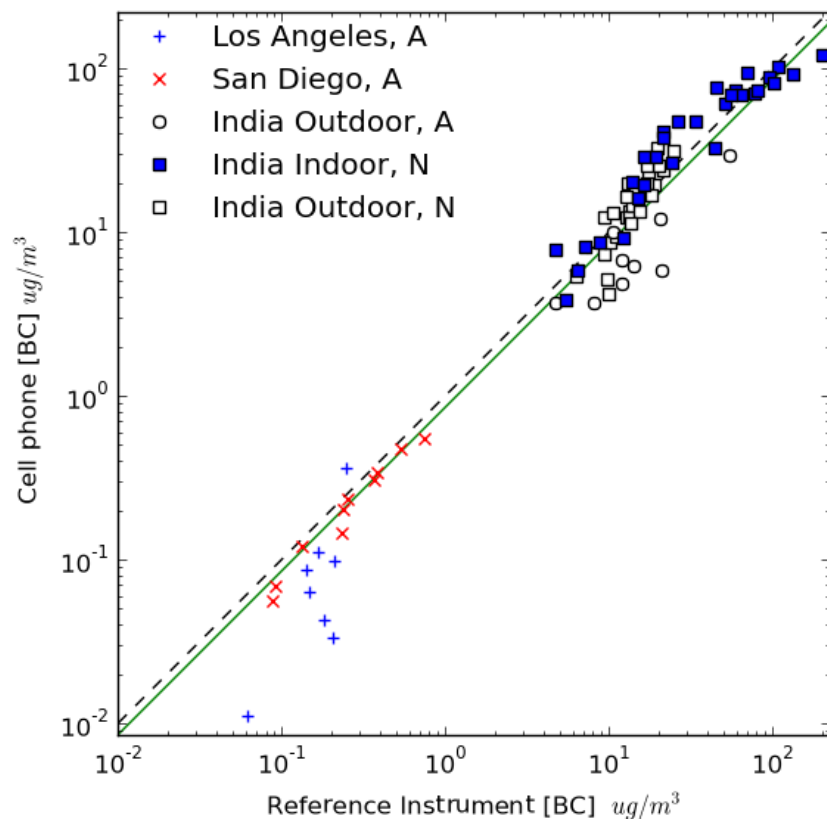


# Deployment in India for Surya Pilot Phase

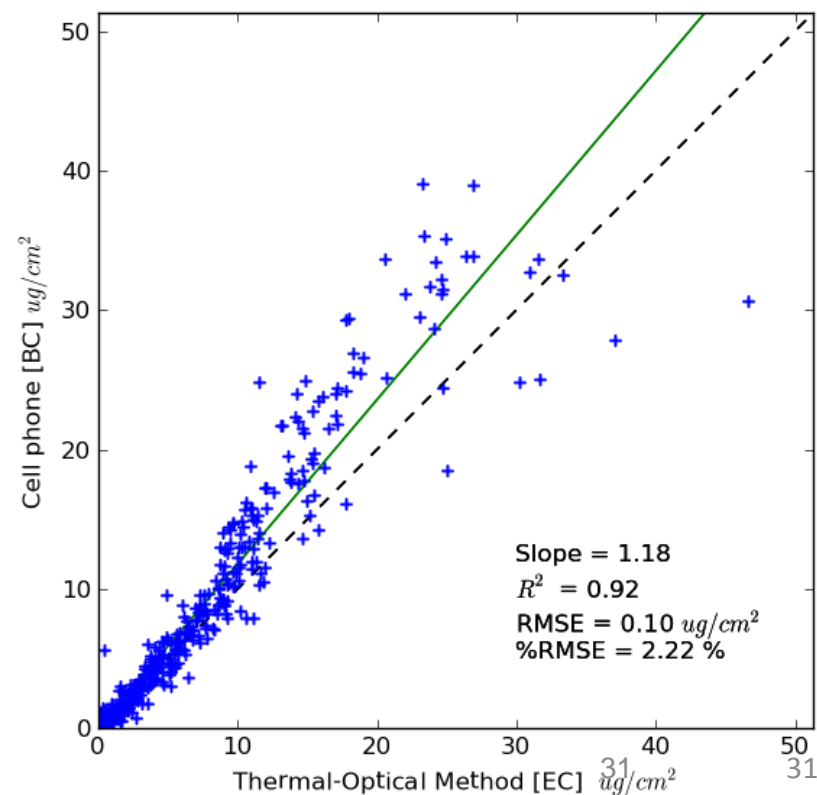


# Validation with four independent gold standard instruments: Error < 10%

Cookstove samples collected in India, urban samples in California (n=80), comparison with Thermal-optical and Aethalometer



Cookstove samples collected by the EPA (n=600), comparison with Thermal-optical reflectance and transmittance methods.





1. *Our findings thus far suggest that policies enacted by California to reduce diesel emissions should have led to a measurable mitigation of the global warming associated with anthropogenic aerosols, equivalent to the elimination of 21 million metric tons of CO<sub>2</sub> annually.*

This conclusion is derived from the following observations and model simulations:

2. *The observed decrease in surface-BC by a factor of 2 from 1989 to 2008 and by a factor of 3.5 from 1960s to 2008.*
3. *This decrease was not accompanied by a comparable decrease in OC or other cooling aerosols such as sulfates.*
4. *As a result the decrease of BC was accompanied by a decrease in ratio of BC to Non-BC aerosols, which implies the warming aerosols decreased more in relation to cooling aerosols.*
5. *The observed BC decreases were largely attributed to the decrease in diesel emissions of BC.*
6. *Targeted emission controls adopted by the State of California are shown to be effective in reducing BC concentrations, by a factor of at least 2 dating back to the 1980s, and by as much as a factor of 3.5 dating back to the 1960s. At the regional level this decrease is associated with a TOA cooling of between 0.5 and 1.5 W m<sup>-2</sup>.*



## Indo-California Air Pollution Mitigation Initiative

### **Identifying Practical Approaches to Reduce Emissions from Transport Sector**

**A Collaborative Effort between UCSD, TERI and CARB**

***Goal: To convene stakeholders and experts concerned with public health, environmental damage and climate change, environmental justice, economic development, and transport industry competitiveness to develop an action agenda of scientific research, technology development, and innovative pilot programs To reduce black carbon and ozone precursor emissions from The transportation sector in India.***