

# ***Mitigation of Air Pollution and Climate with Black Carbon Reductions: Emerging Science***

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***Environmental Protection Agency  
Black Carbon Science Symposium***

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**project surya**  
Fighting Climate Change Now



**Some Results are from:**  
**Black Carbon and the Regional Climate of California**

***A Multi-Institutional CARB Funded Project***

**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 Contacts: B. Croes & N. Motallebi**

## **Promising Mitigation Measures:**

**1) Diesel Combustion (on-road and off-road)  
Effectiveness proven by CA-data**

**2) Residential Biomass Combustion  
Improved biomass stoves reduce BC emissions by as much as 70%; Also cuts down PM2.5 by similar magnitudes (including Brown Carbon). Consistent data from laboratory (EPA) and field data (Surya publications)**

**3) Outdated Brick Kilns (Improved Brick Kilns have successfully been deployed in S. Asia); EPA-ABC Nepal Conference, 2011; See EOS Article (upcoming issue) by Socci, Ramanathan and Zaelke**

## **Emerging Science Issues**

***BC is emitted with other particles and gases, many of which exert a cooling influence on climate. Therefore, estimates of the net effect of BC emissions sources on climate should include the offsetting effects of these co-emitted pollutants***

***EPA- Conference Briefing Paper , 2012***

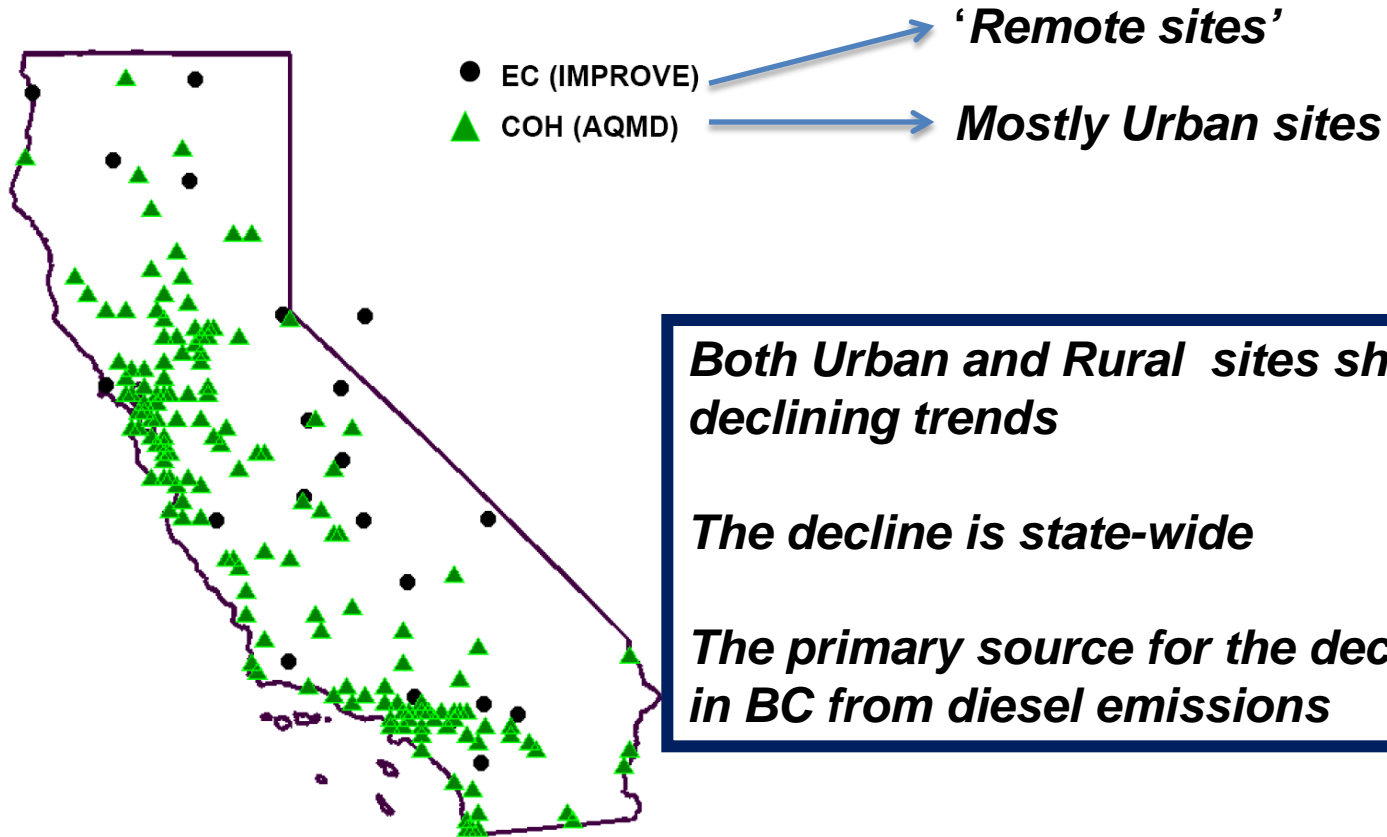
***Recent observationally based studies demonstrate that these “offsetting effects” are very likely to be much smaller or non-existent.***

***Such statements are based on top-of-atmosphere forcing; while regional climate effects of BC depend on how BC and Other aerosols impact the surface dimming And atmospheric heating. In fact, both OC and BC lead to dimming.***

# Emerging Science Issues: Recent Publications

1. Brown Carbon.... A Direct Warming Agent (over 12 studies);  
Significant absorption found over CA (CARB Study); offsets direct cooling effect of other organics over biomass burning areas (Chung et al, PNAS, 2012)
2. Aerosol-Cloud Cooling Effect: 1) No direct evidence for strong cooling effect;  
2) Models are unreliable (Nature 2012)
3. Cooling particles other than OM: California data do not support it (CARB funded)  
(Bahadur et al, 2011)
4. Emission Inventory: BC Inventory used by climate models may be lower by factors ranging from 2 (CA) to as high as 5 (S. Asia). Menon et al (2010); Ganguly et al; 2010); Praveen et al (2012); Leung et al (CARB-Study; 2012)
5. Regional climate changes are significant: NH- ITCZ Shift; Atlantic decadal variability; Monsoon disruption; Deeper Clouds (Amazon); Himalayan/Tibetan Glacier Melting; Arctic sea ice melting; etc *These do not depend on TOA forcing but more on Atmospheric heating & surface dimming by BC and OC(factor of 4 to 10 larger than net TOA forcing).*  
Numerous (>25 papers) studies

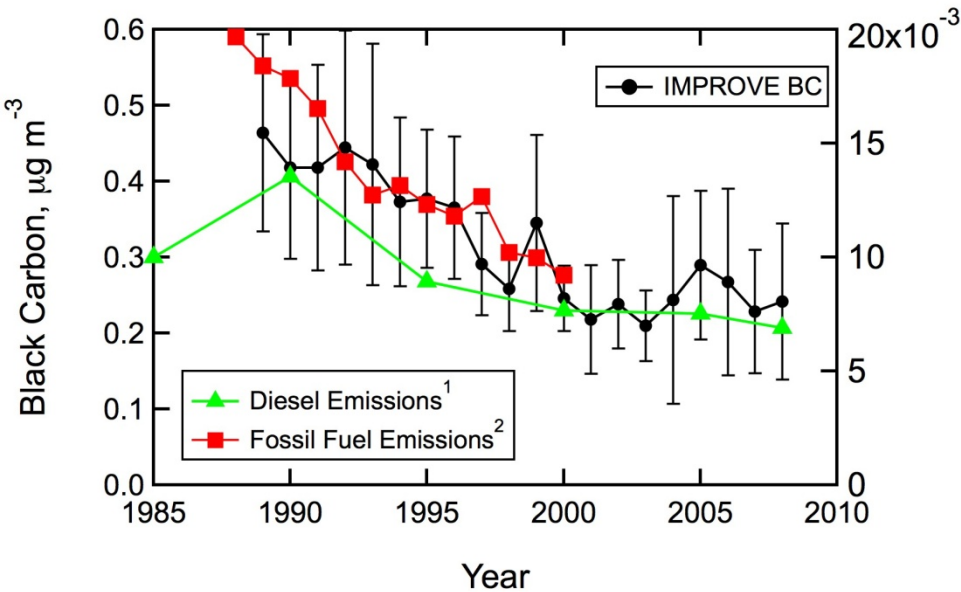
# Black Carbon Trends in California: Detection and Attribution



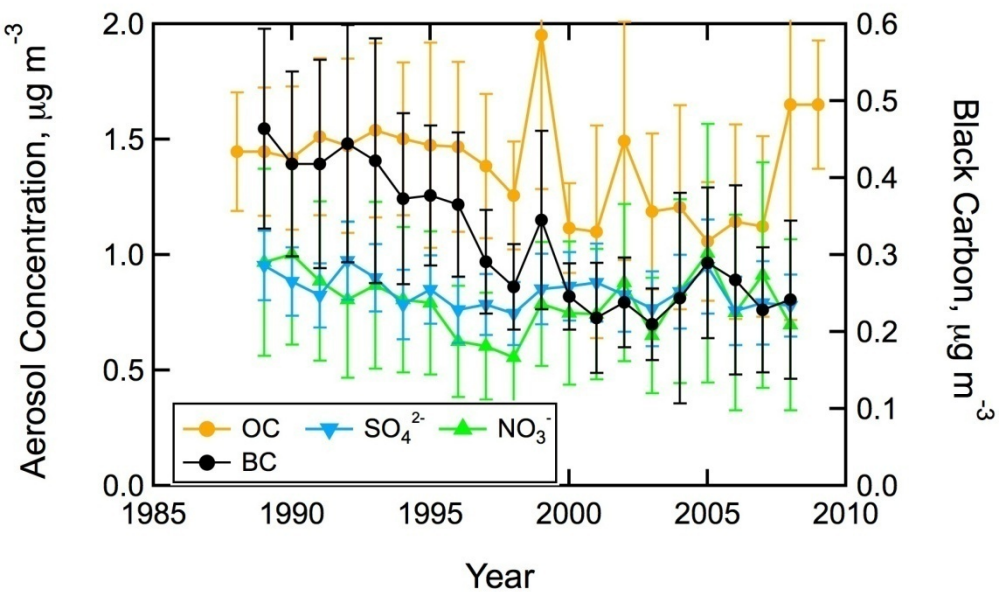
# BC Trends in California:

CARB Funded Study to Univ of California.

Bahadur et al. 2012



**BC Trends are consistent with diesel BC emission trends.**



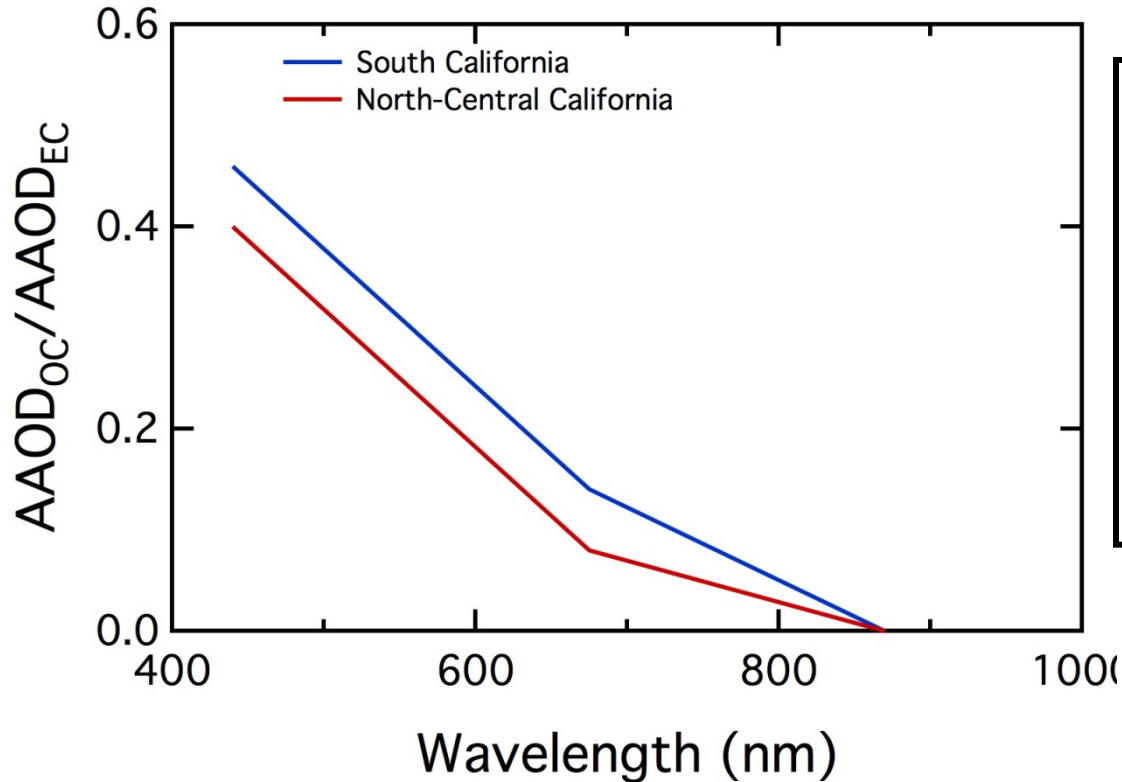
**Lack of similar trends in other 'cooling aerosols' indicate : negative trends in BC is not due to meteorology**

**Bahadur et al, 2010**

## *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.**

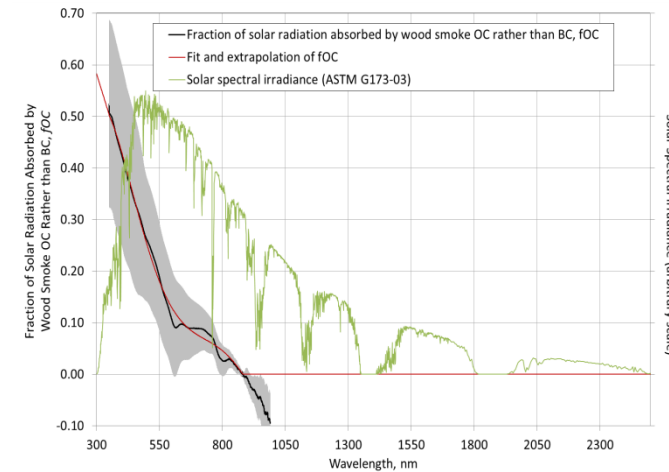
***Most Climate models  
treat organics as pure  
Scattering (cooling) aerosols***



## *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



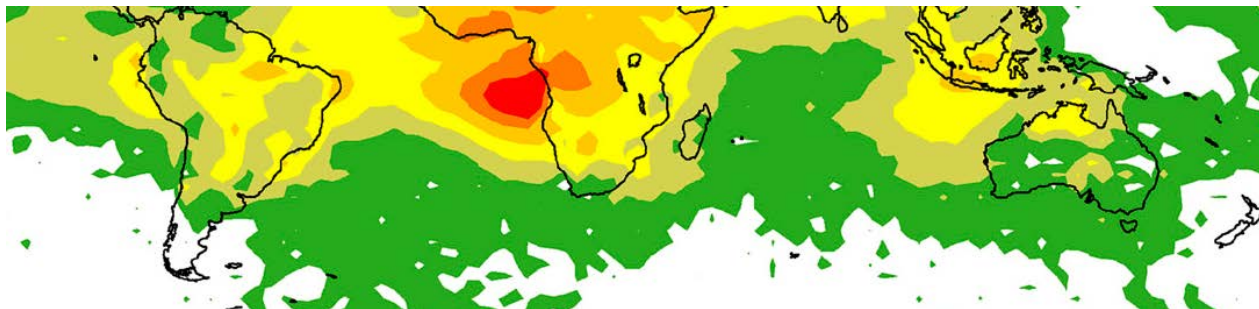
*Fraction of solar radiation absorbed by OC in residential wood smoke PM (black line = 115 sample avg) and solar spectrum at the earth's surface (green line).*

# Observationally constrained estimates of carbonaceous aerosol radiative forcing

Chul E. Chung<sup>a,1</sup>, Veerabhadran Ramanathan<sup>b</sup>, and Damien Decremet<sup>a</sup>

This study identifies the global importance of BrC, which is shown to contribute about 20% to 550-nm CA solar absorption globally. Because of the inclusion of BrC, the net effect of OM is close to zero and the CA forcing is nearly equal to that of black carbon.

Caused in part by BrC absorption, CAs have a net warming effect even over open biomass-burning regions in Africa and the Amazon.



## The aerosol effect

Anthropogenic aerosols in the atmosphere undoubtedly influence climate. But do the approaches taken in climate models to account for the effects of aerosols provide meaningful estimates of those effects? Two climate scientists offer their opinions.

### THE TOPIC IN BRIEF

- Aerosol particles in the atmosphere influence clouds, and thereby climate, because they act as nuclei for cloud formation.
- Computational models of climate systems have sought to incorporate the effects of aerosols on clouds through parameterizations.

- However, the representation of aerosol–cloud interactions in climate models is based on simplifications that ignore the complexity of the small-scale physical processes governing such interactions in the real world.
- The value of studying the effects of aerosol–cloud interactions in climate models has therefore been questioned.

better or more reliable, just more complex. Additional complexity can be great fun, but it should not disguise the fact that, at least for aerosol–cloud interactions, much is speculative, and the results of such complex models should be taken with a grain of salt.

*Bjorn Stevens is at the Max Planck Institute for Meteorology, Hamburg 20146, Germany. e-mail: bjorn.stevens@mpimet.mpg.de*

## Grains of salt

**BJORN STEVENS**

There is something captivating about the

To determine the correct sign — let alone the magnitude — of the effect of some important aerosol–cloud interactions, one may, to borrow words from elsewhere, need a weatherman to know which way the wind blows<sup>5</sup>. Models can make good weathermen, and thus provide information about the wind, as well as about many of the other factors on which aero-

## An essential pursuit

**OLIVIER BOUCHER**

▲ aerosols and clouds influence each other

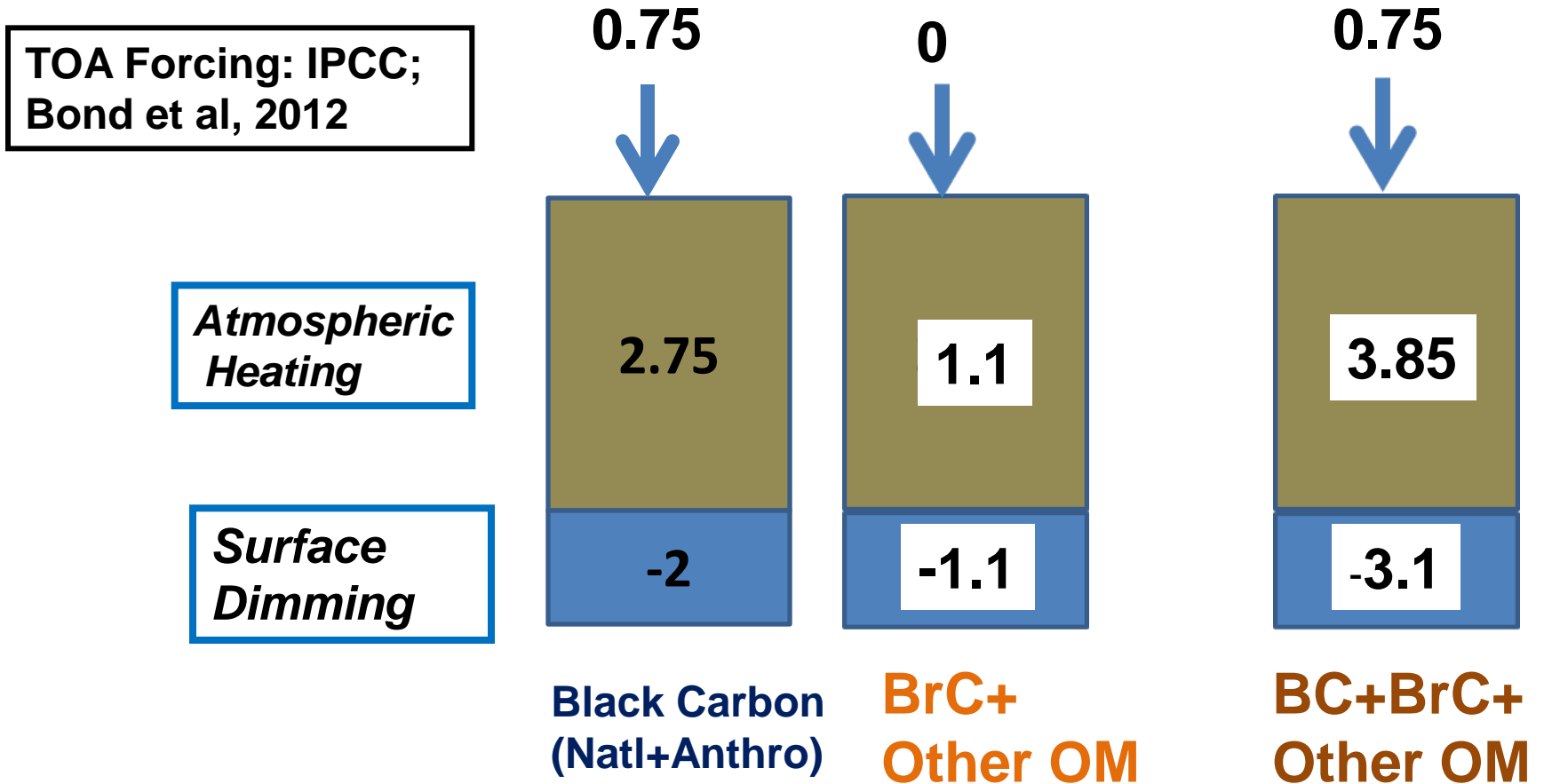
# Investigation of aerosol–cloud interactions using a chemical transport model constrained by satellite observations

By YAN FENG\* and V. RAMANATHAN, *Center for Atmospheric Sciences, Scripps Institution of Oceanography, University of California, San Diego, La Jolla, CA 92093-0221, USA*

**ANNUAL MEAN: 45 N TO 45 S**

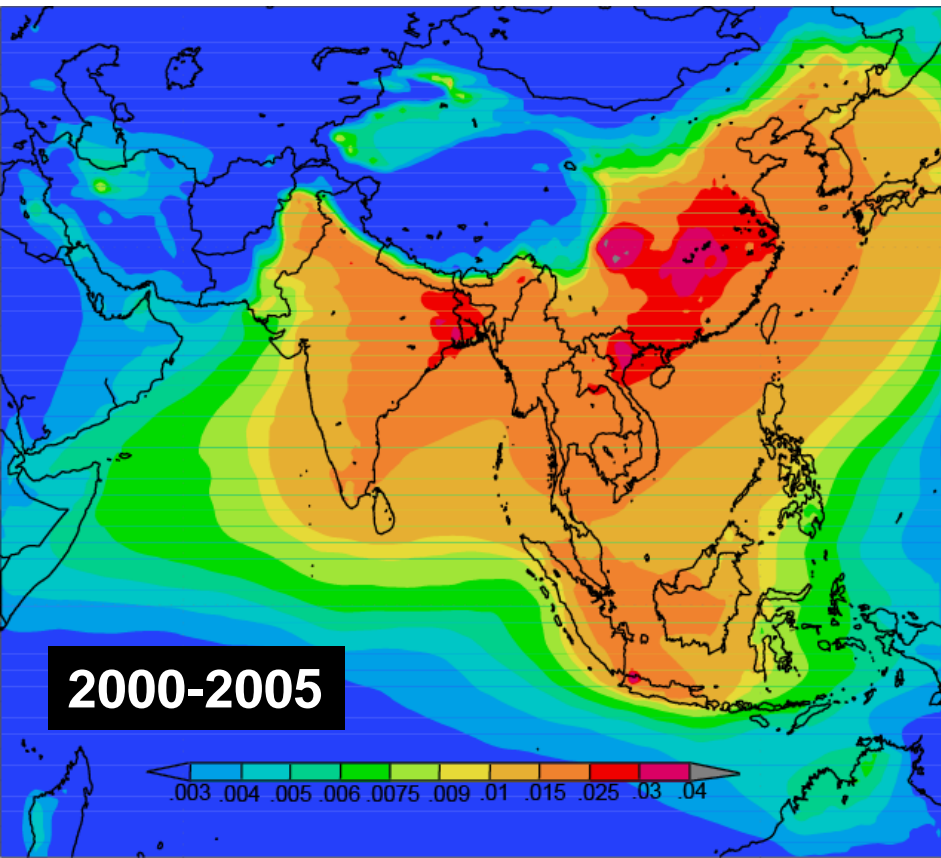
	Simulated	Obs_M ODIS
<b>Fine-Mode aerosol optical depth (550nm)</b>		
NH Oceans	<b>0.091</b>	<b>0.094</b>
SH Oceans	<b>0.055</b>	<b>0.061</b>
<b>Cloud Optical Depth</b>		
NH Oceans	<b>14.7</b>	<b>12.6 (10.4; Liq)</b>
SH Oceans	<b>12.1</b>	<b>12.1(10.3;Liq)</b>

**Why Top-of- Atmosphere (TOA) Forcing is not a reliable metric for Climate Effects?**  
*Data: Chung, Demian and Ramanathan, PNAS 2012*

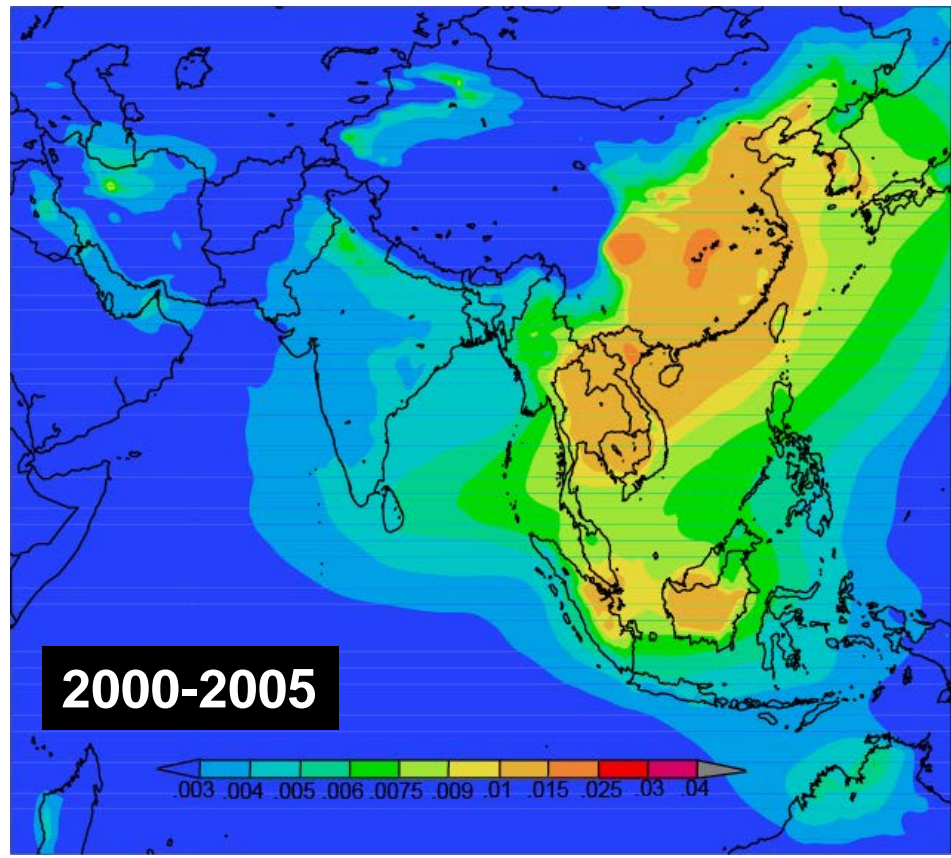


**Predicted in 2008: Eliminating solid fuel cooking can have dramatic Impact on Air Pollution & Climate in China and India: Ramanathan and Carmichael, 2008**

**With traditional biomass stoves**



**Eliminating BC from Cooking**



**Simulated Column Black Carbon**

# ***A Grand Climate Change and Mitigation Experiment***

***Providing Clean Cooking and Lighting Technologies & documenting their impacts on Air pollution, Climate Forcing, Health Exposure Indoors and outdoors***

***PIs: V. Ramanathan, I.H. Rehman and N. Ramanathan***

## **CORE INSTITUTIONS**

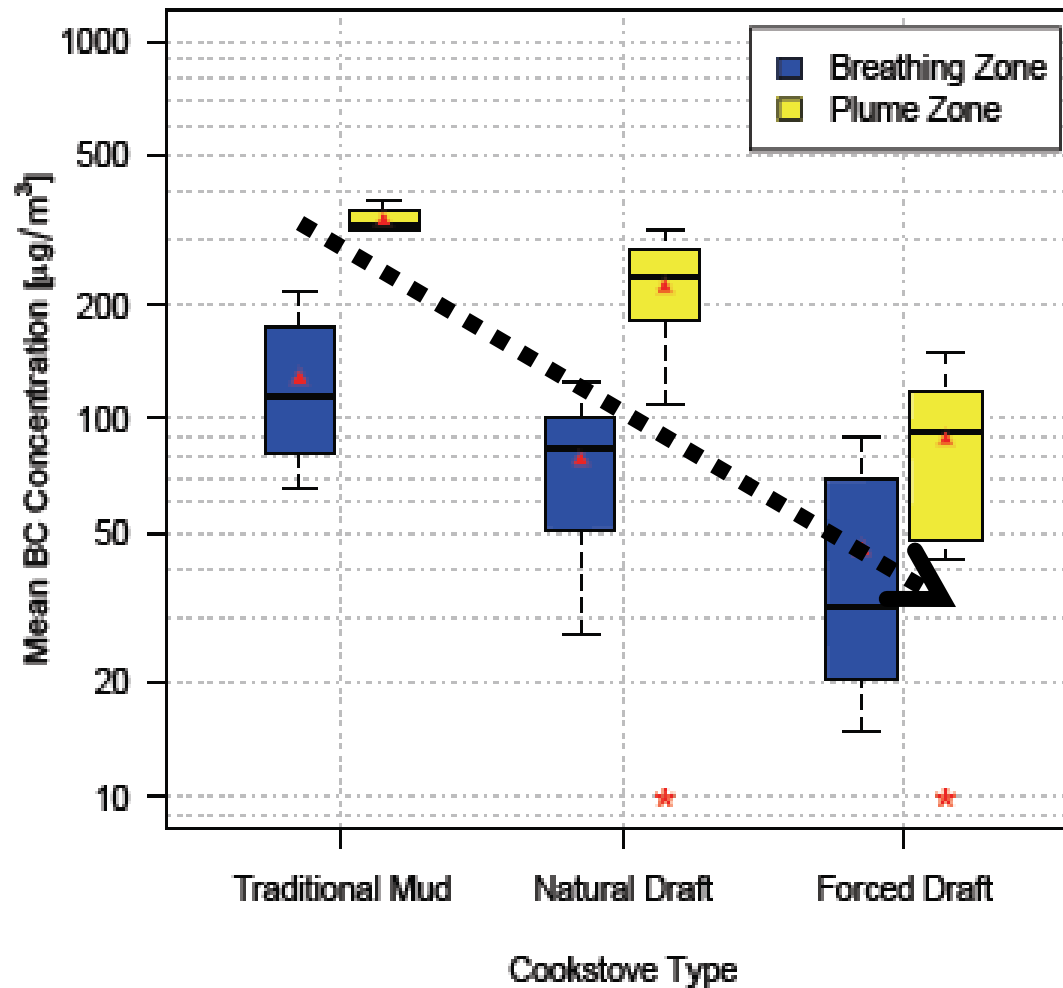
University of California at San Diego, USA  
The Energy Resources Institute, Delhi, India  
Nexleaf Analytics, Los Angeles, USA

## **Collaborating Institutions**

U. Iowa, USA  
Jawaharlal Nehru University, Delhi, India  
Duke University, USA  
Carbonomics, USA  
Environmental Financial products LLC, USA  
U. Of Southern California, USA  
University of Nairobi (Kenya)  
African Center for Technology Studies (Kenya)  
Appropriate Solar and Wood Energy Network (Kenya)  
Department of Environment (Bangladesh)  
Dhaka University (Bangladesh)  
Alternative Energy Promotion Center (Nepal)  
National Environment Commission (Bhutan)

# Forced draft better than natural draft

Kar et al, 2011

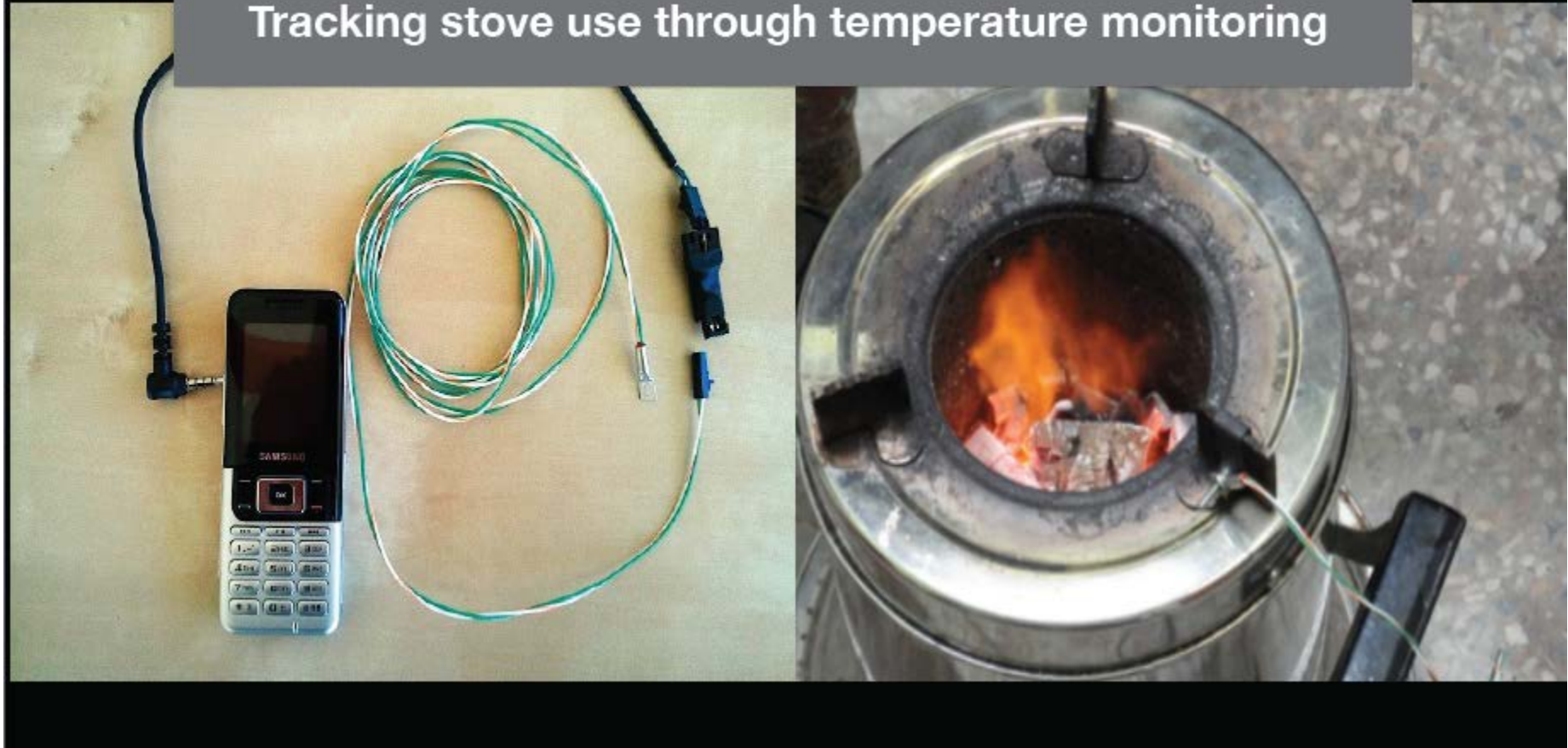




# ***How do we monitor Stove Useage?***

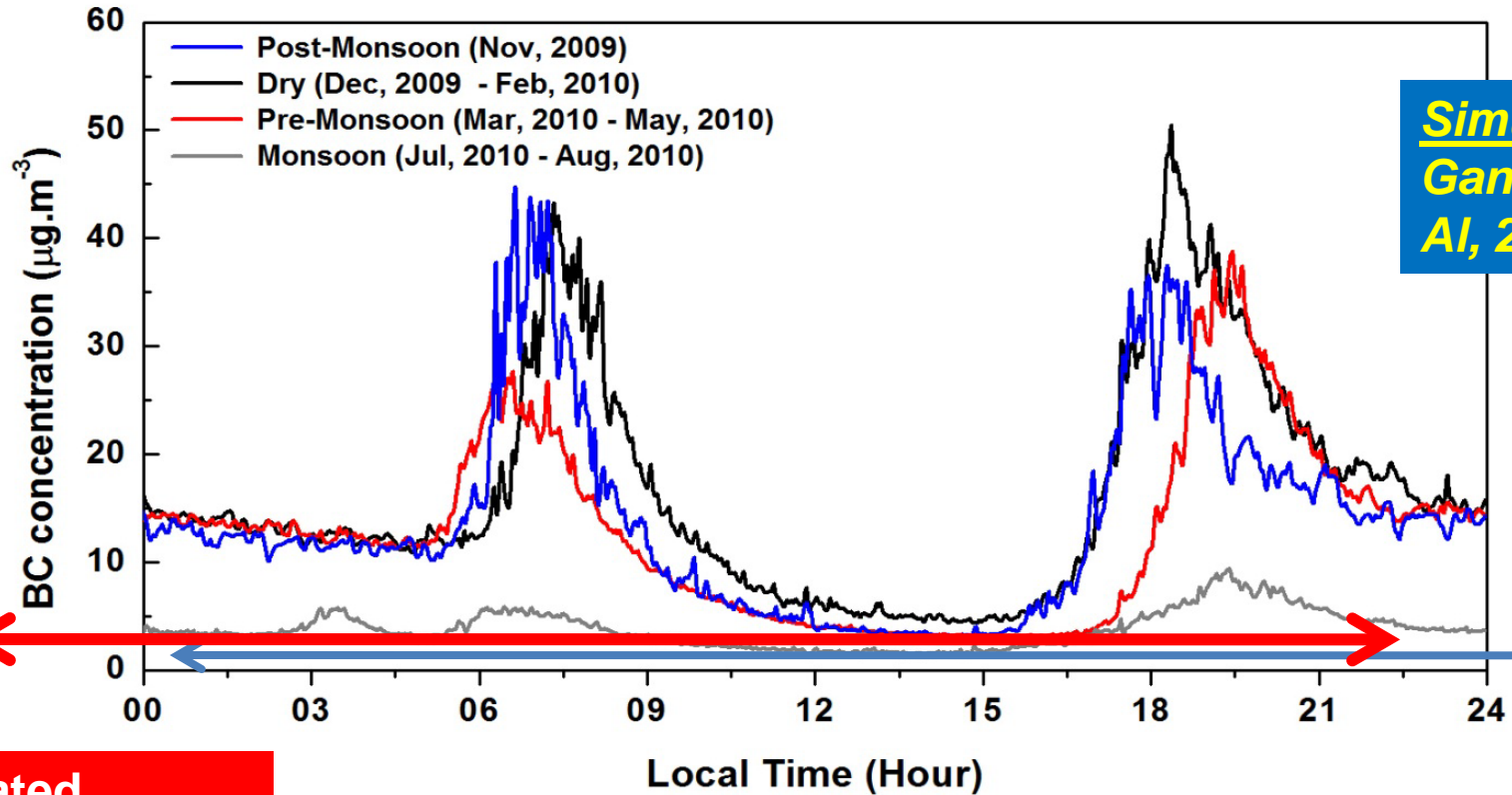
***Wireless Innovation : (N. Ramanathan et al, 2012)***

Tracking stove use through temperature monitoring



# ***Surya Data shows Emission Inventories need to be Revised Upwards Substantially***

## **Comparison with IPCC Climate Models**



***Seasonal mean BC concentration at Surya Village***

**Ramanathan et al, 2011**

## Energy Access, Health and Climate Mitigation

**We have known for a long time that soot is closely linked to Adverse Health ..... All countries have compelling reasons to address.**

***We have known for a long time how to control these emissions.....  
The controls are even more at hand than originally thought.***

***We have NOT known for a long time just how powerful soot is on the climate... But here the evidence is pouring in.***

**When you put items 1-3 together you end up with an attractive Political Strategy..... particularly in -China, India and the US.**

**Ref: V. Ramanathan & David Victor, NY Times, 2010**

**Mukteshwar, Himalayas**

**23.10.2009 07:26**

**Photo: Ramanathan**