

# Black Carbon & India's Climate

What is known and need for further research



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**Anil Agarwal Dialogue 2015**  
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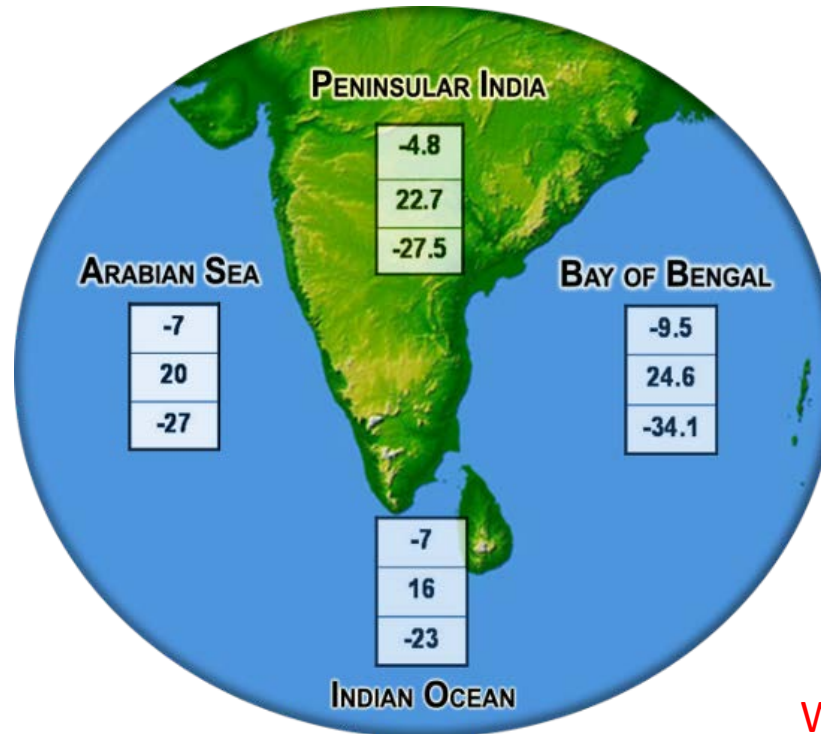
# Talk Plan

- Aerosol Radiative Forcing
- Black Carbon (BC) measurements
- Optical properties of BC and its radiative forcing
- BC emission inventories and validation
- Topics not covered



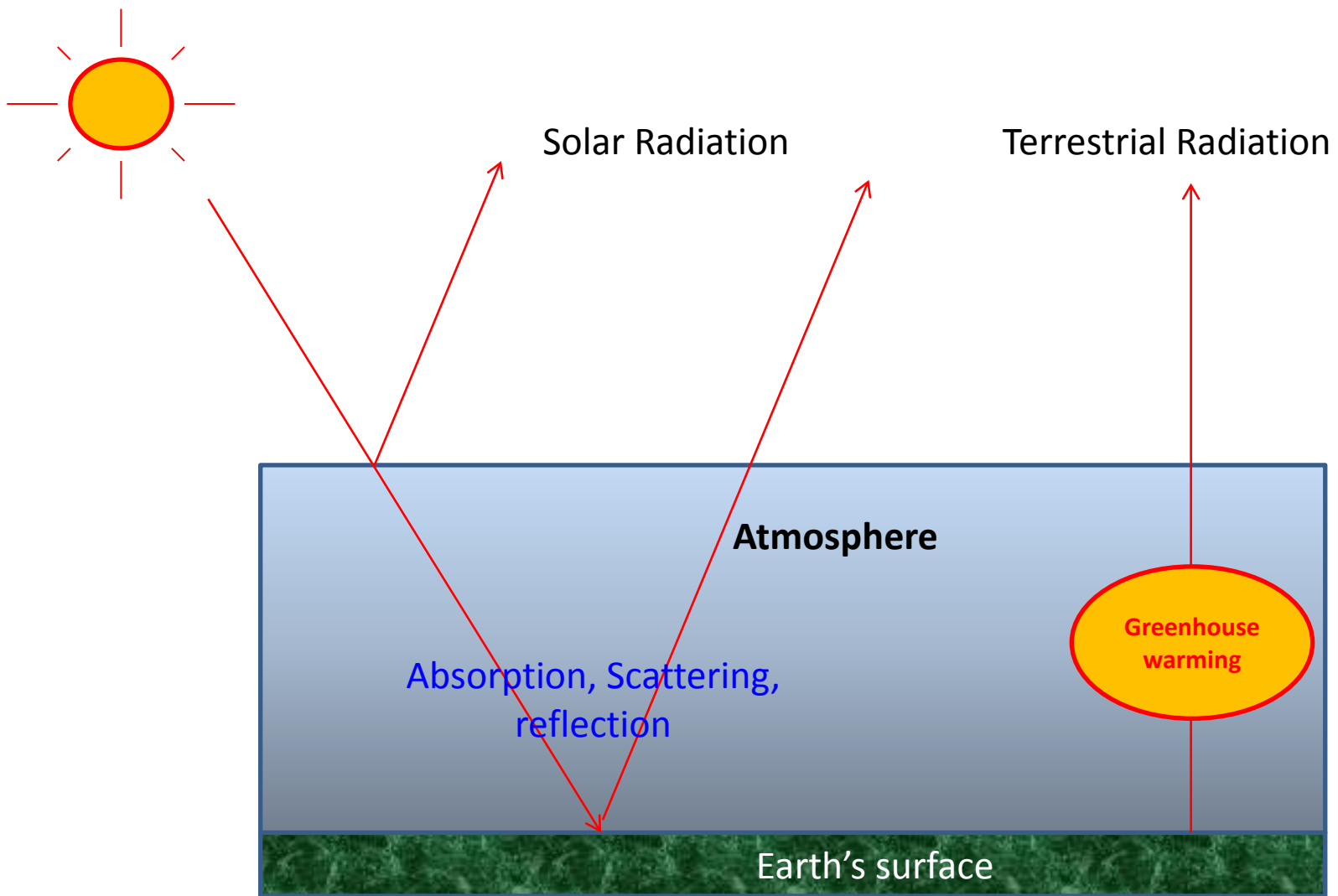
# Aerosol Radiative Forcing

(in  $\text{W/m}^2$ , for dry season)



What is radiative forcing?

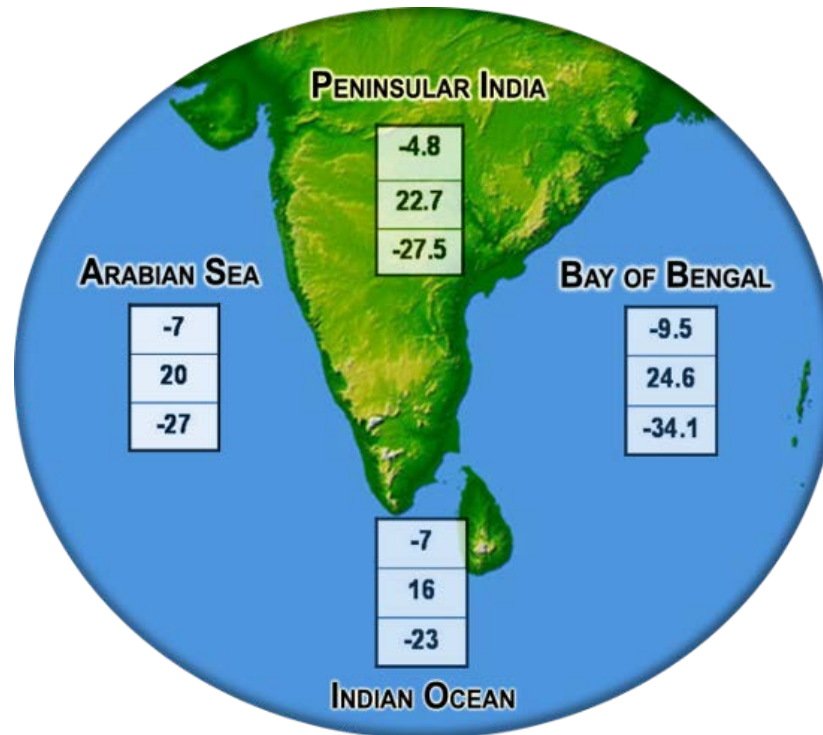
Summary of the aerosol radiative forcing obtained from experiments conducted under INDOEX and ISRO-GBP.



The Earth atmosphere system is said to be in radiative equilibrium when the incoming and the outgoing radiation energies balance each other. Difference if any between the two is referred to as **Radiative Forcing**.

# Aerosol Radiative Forcing

(in  $\text{W/m}^2$ , for dry season)



Top of the  
atmosphere

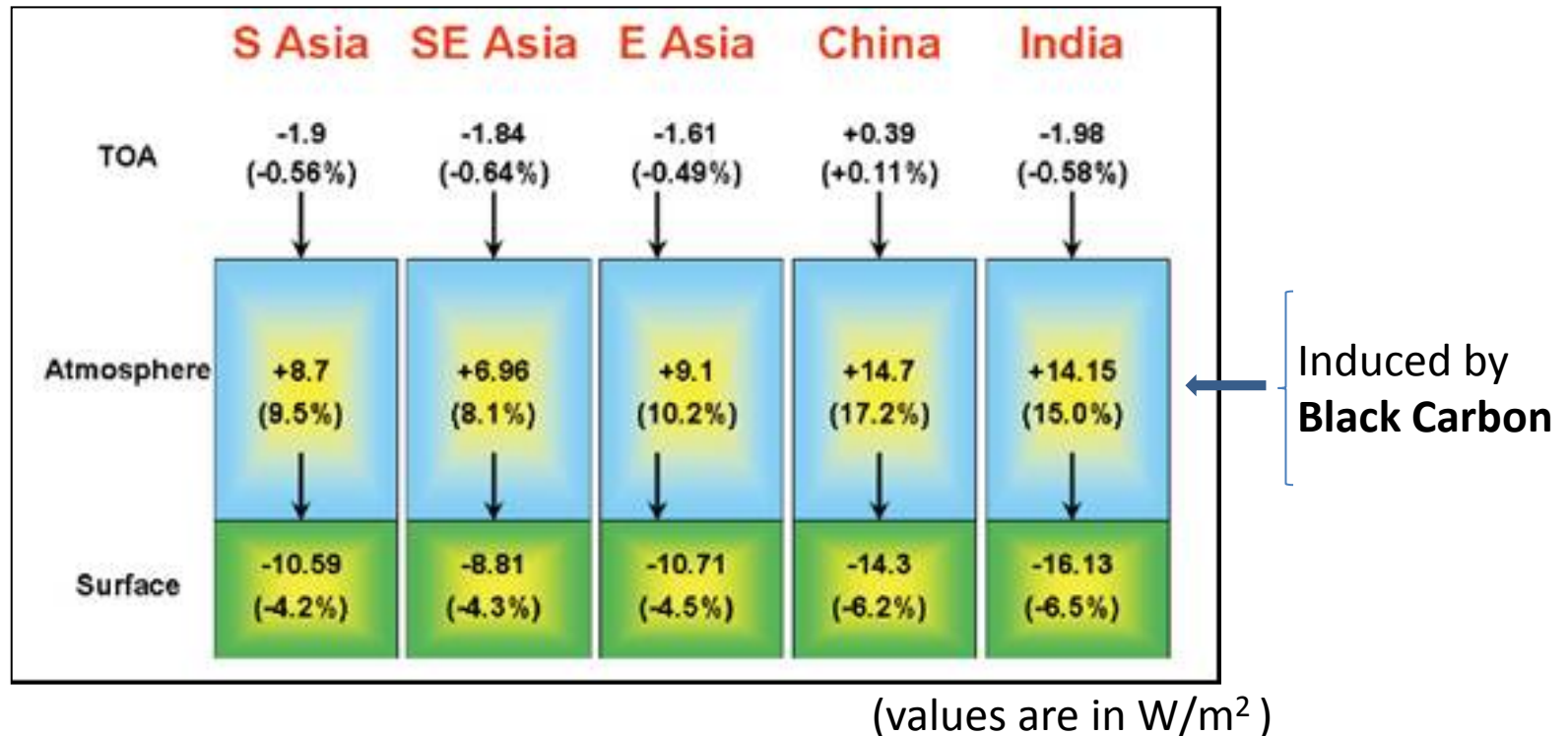
Within the  
Atmosphere

At the surface

Please note that, **Global Warming** is caused due to absorption of terrestrial radiation by **Greenhouse gases** like  $\text{CO}_2$ , methane etc while atmospheric forcing by aerosol is caused by direct absorption of solar radiation by **Black Carbon** which adds to the **Global warming**.

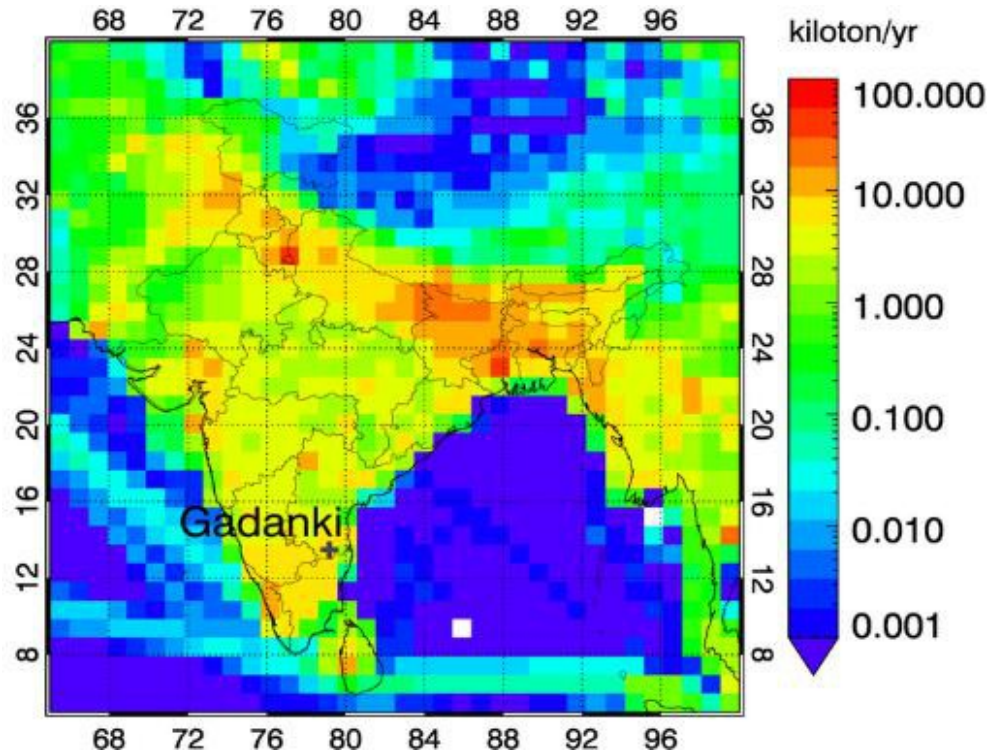
# Aerosol Radiative Forcing over India

## Comparison with other results



Ref.: UNEP-ABC Report, 2009

# Black Carbon Emissions



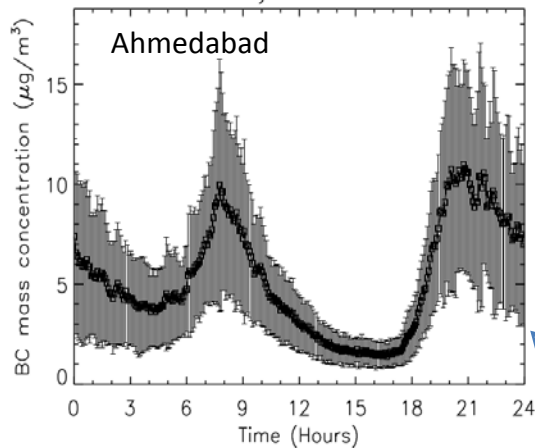
*Black carbon emissions for the year 2010 from ECLIPSE-v5 emission inventory released in 2014.*



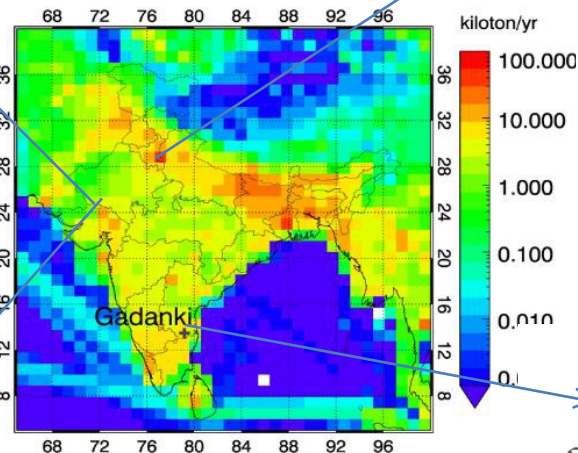
# Black Carbon concentration measured at different locations

Ahmedabad  $\cong 8 \mu\text{g}/\text{m}^3$

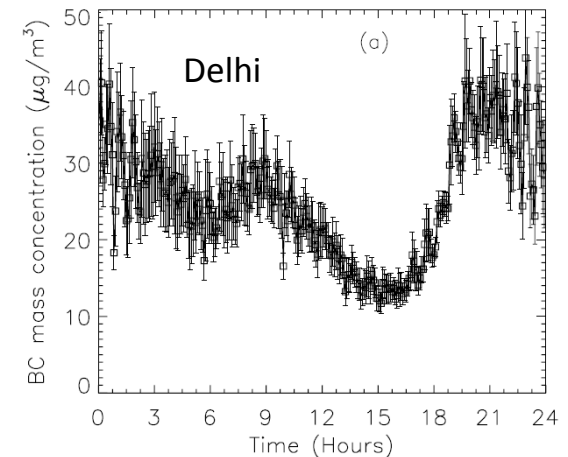
Dry Season



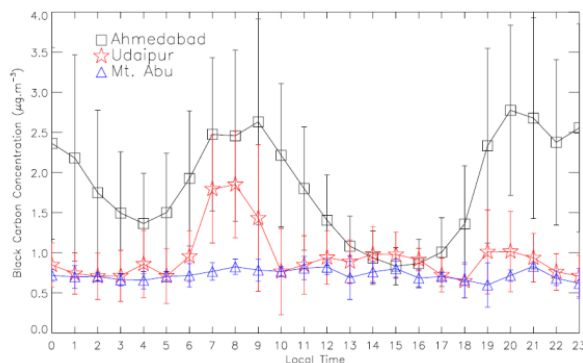
BC Emission  
ECLIPSE-v5



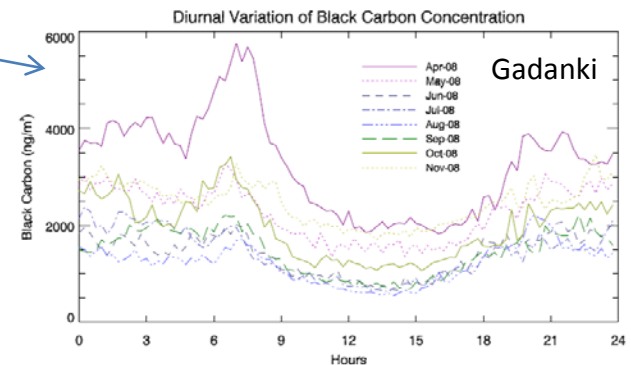
Delhi  $\cong 30 \mu\text{g}/\text{m}^3$



Mount Abu  $\cong 0.7 \mu\text{g}/\text{m}^3$

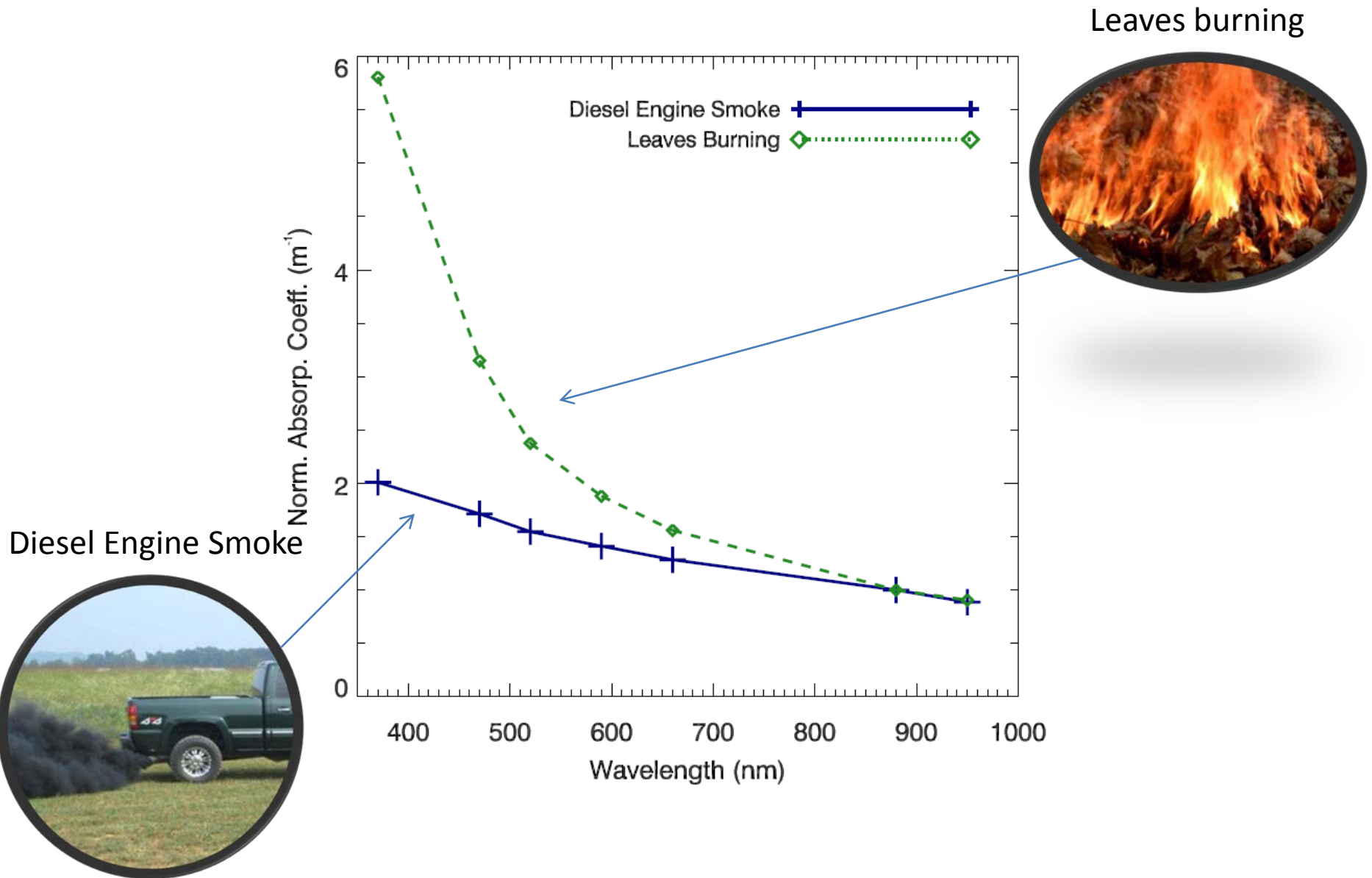


Gadanki  $\cong 3.5 \mu\text{g}/\text{m}^3$

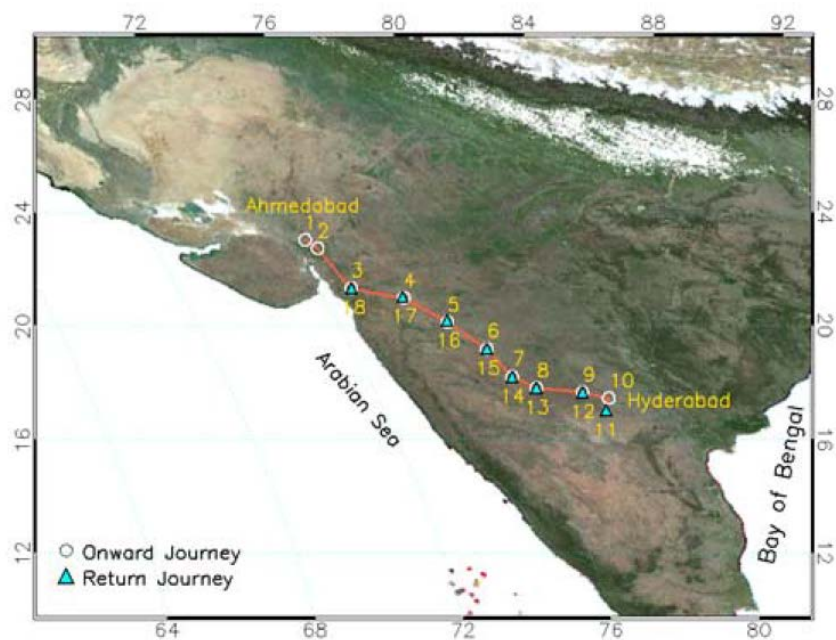




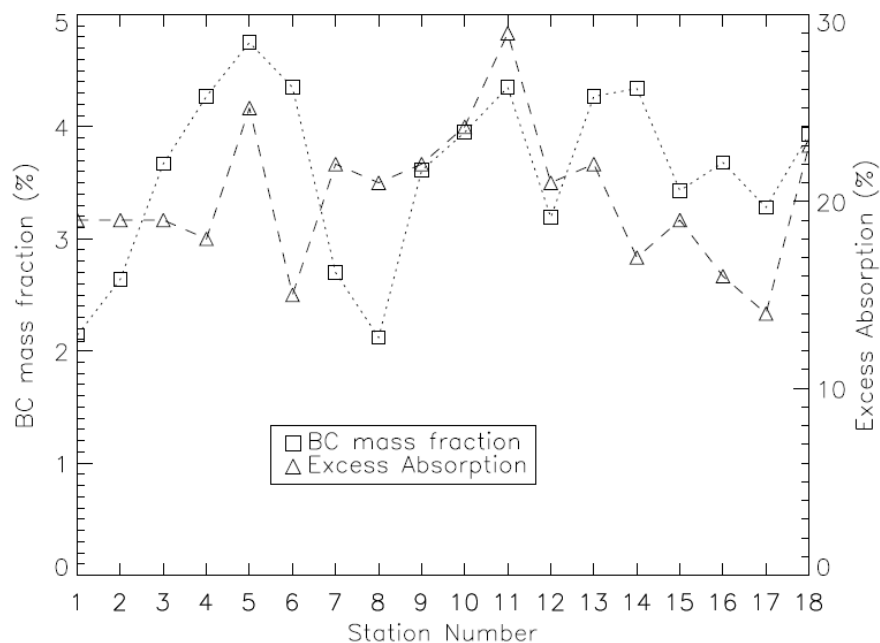
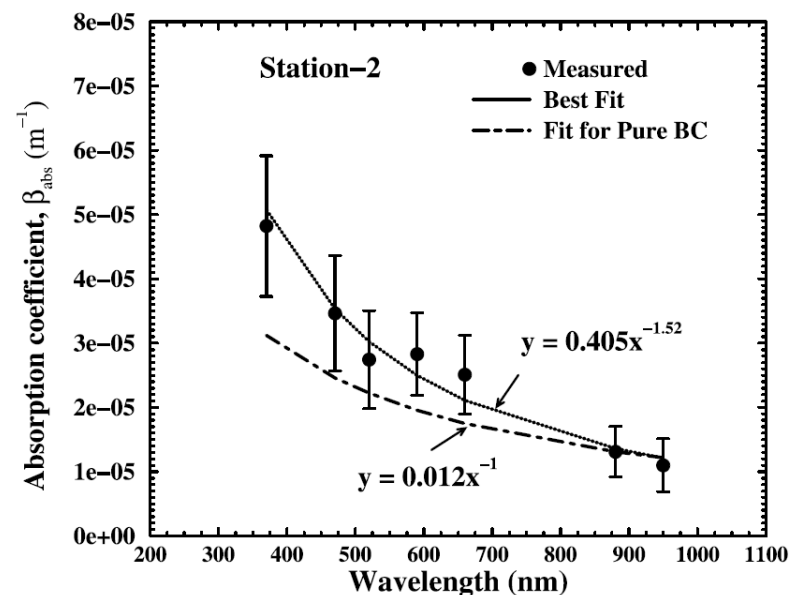
# Spectral Dependence of BC Absorption



Field experiments conducted in central India showed that up to 30% of BC absorption comes from Biomass/Biofuel burning



Ganguly et al., GRL, 2005

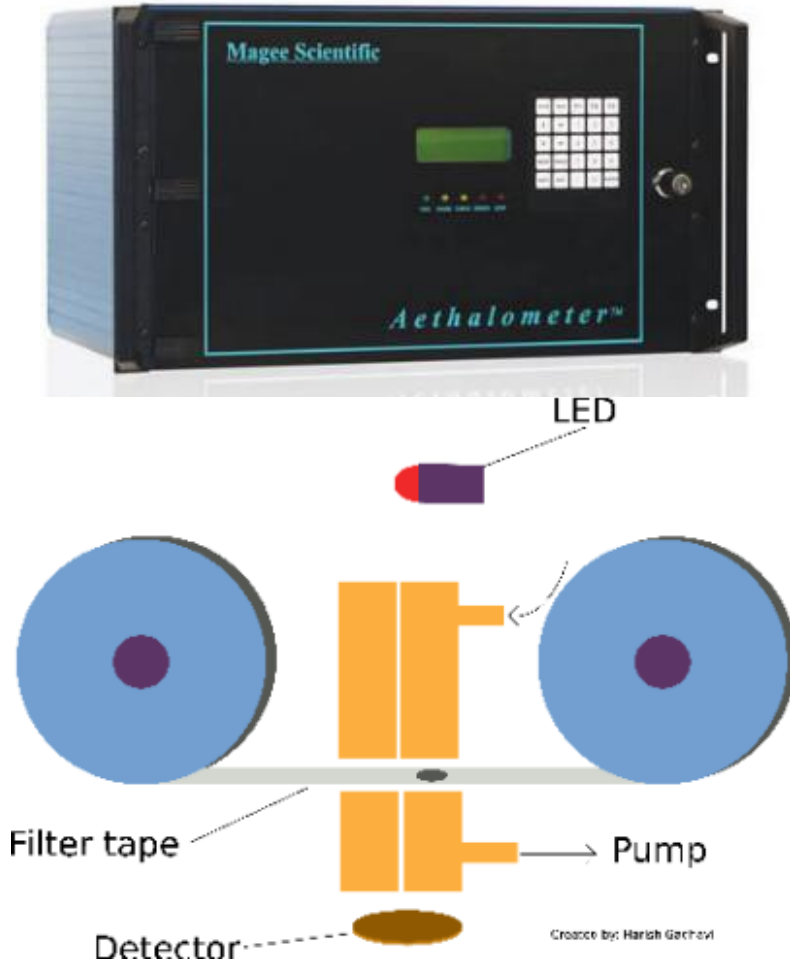




# Climate Observatory @ National Atmospheric Research Laboratory Gadanki 517112, AP, India



# Aethalometer\*

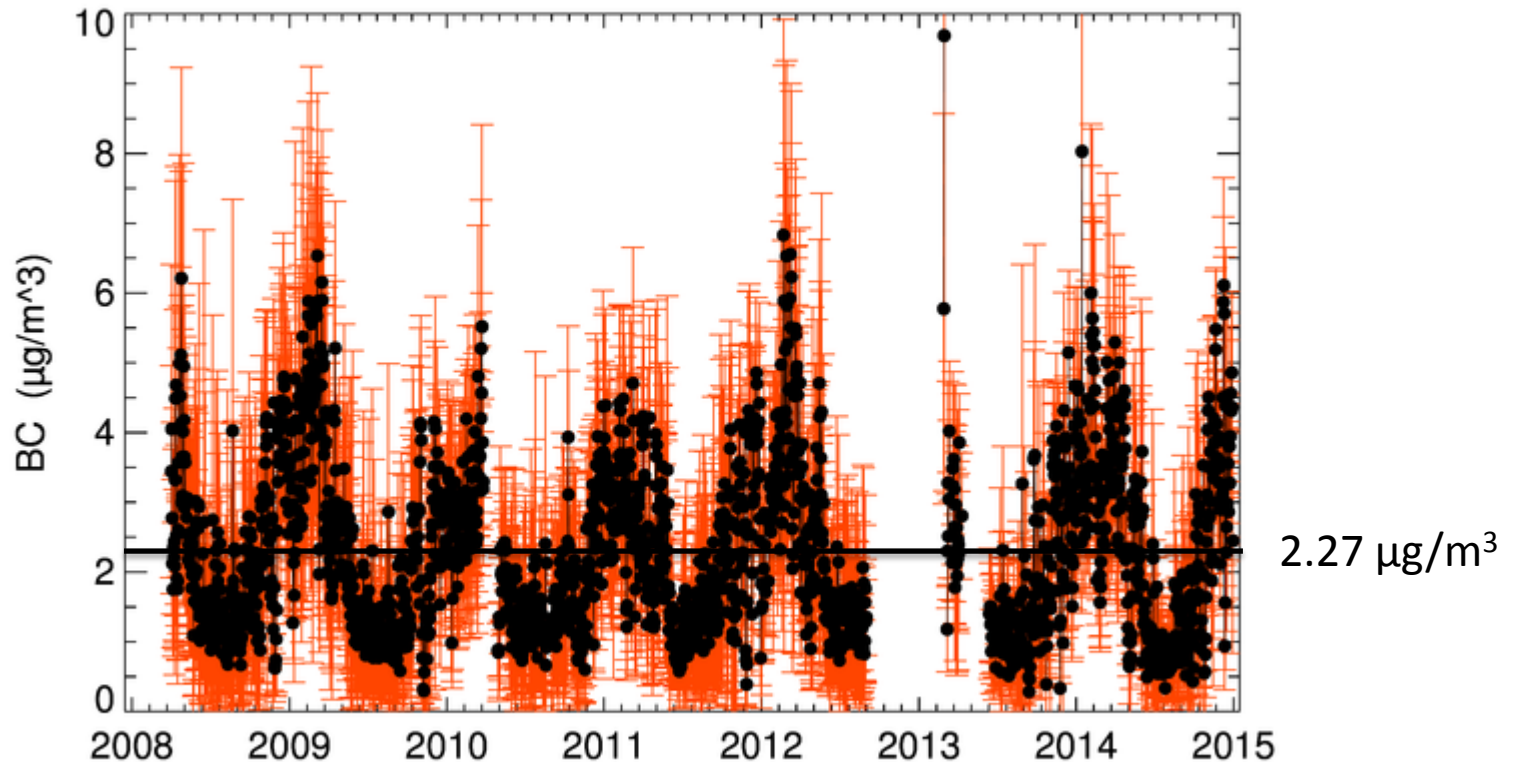


Aethalometer relates changes in transmission through filter paper to the load of black carbon particles.

\*The word aethalometer is derived from classical greek verb '**aethaloun**' meaning blacken with soot

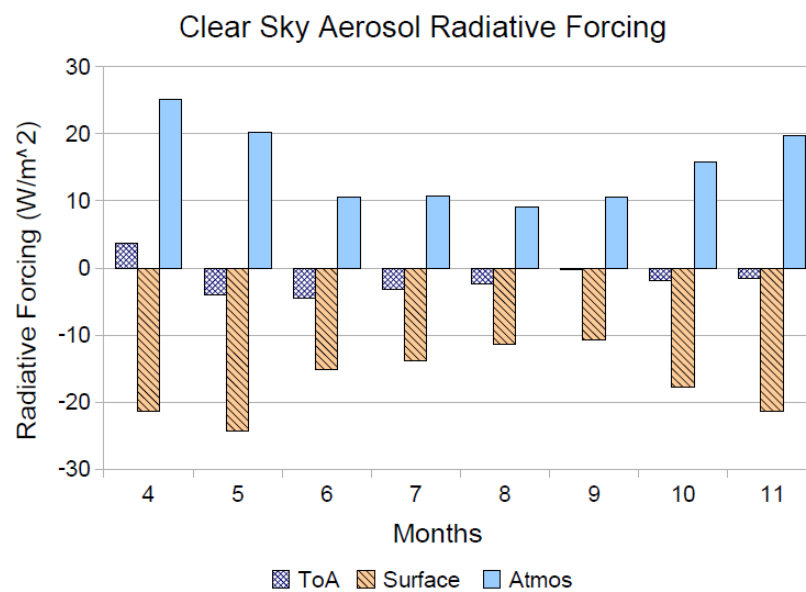
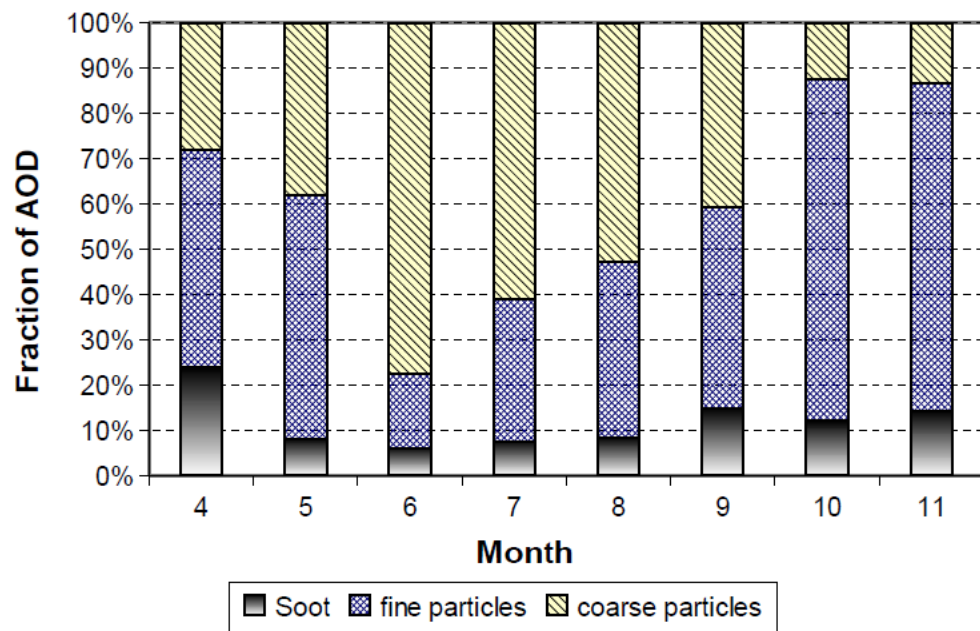


## Black Carbon Concentrations Observed over Gadanki (Apr 2008 to Dec 2014)



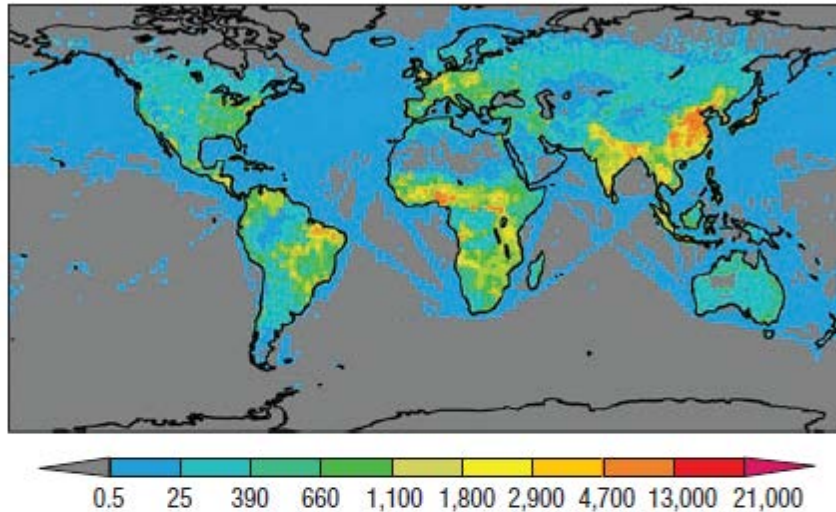
More or less similar seasonal variations are seen for all the years with maximum in spring and minimum in summer.

# Contribution of **BC** to column aerosol optical depth and the aerosol radiative forcing over Gadanki



## BC emission strength in tons per year

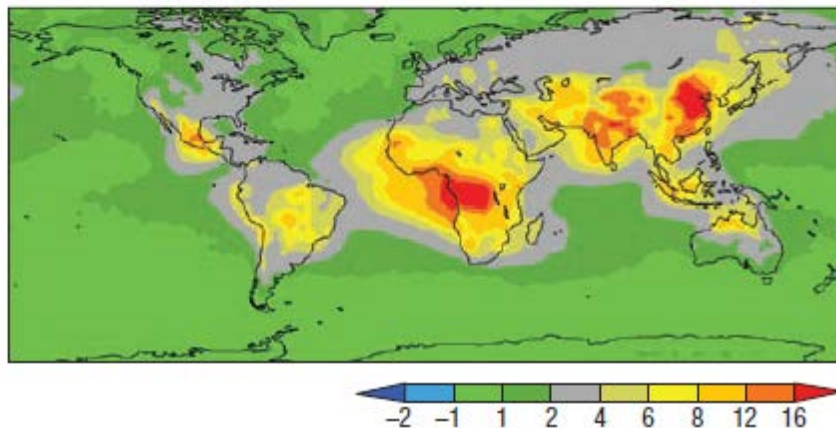
**a**



[a] BC emission strength in tons per year (Bond et al. 2004) which includes emissions from fossil fuels and biofuels combustion and open biomass burning. The uncertainty in the regional emission is about  $\pm 100\%$  or more.

**b**

## Atmospheric hotspots due to BC



[b] Atmospheric solar heating (deg K per day) due to BC (Chung et al. 2005) computed from radiative forcing. Uncertainty in the forcing is  $\pm 30\%$ .



# What is the uncertainty in the regional BC emission?

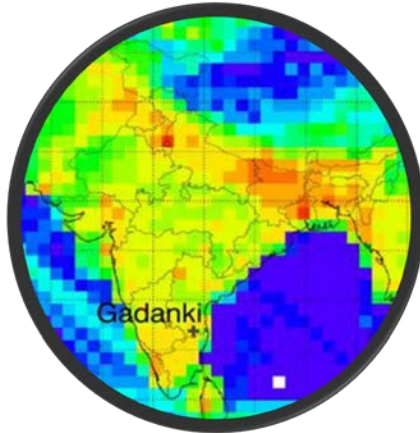
The following three emission inventories available in the literature are evaluated for the Indian region.

- ✓ ECLIPSE – Evaluating the CLimate and air quality ImPacts of Short-livEd pollutants (Klimont et al., 2013,2014)
- ✓ SAFAR – System of Air quality Forecast And Research (Sahu et al., 2008)
- ✓ RETRO - REanalysis of Tropospheric Chemical Composition (Schultz et al., 2007)

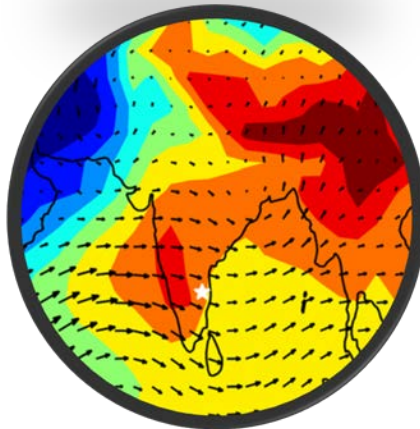
# Simulation of Black Carbon concentration

## Methodology

BC emission data

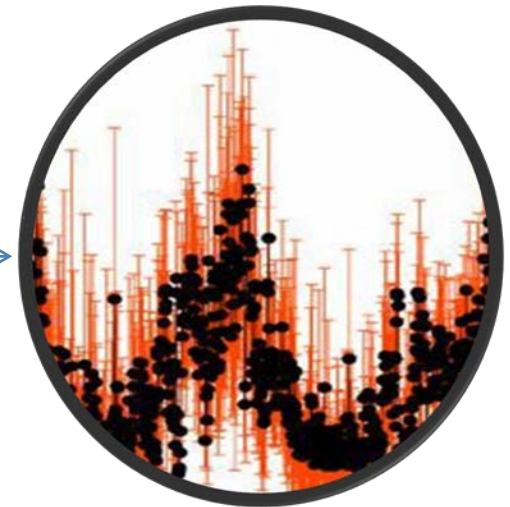


Wind data

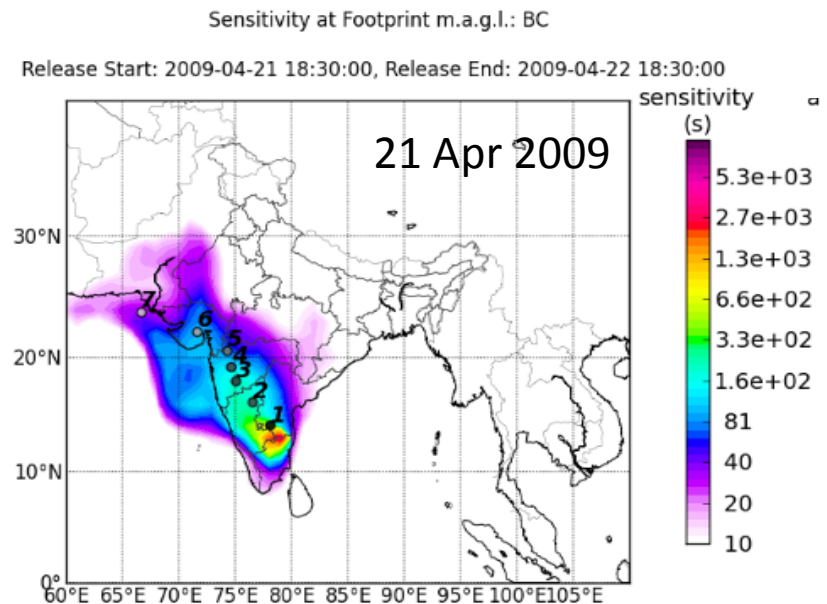
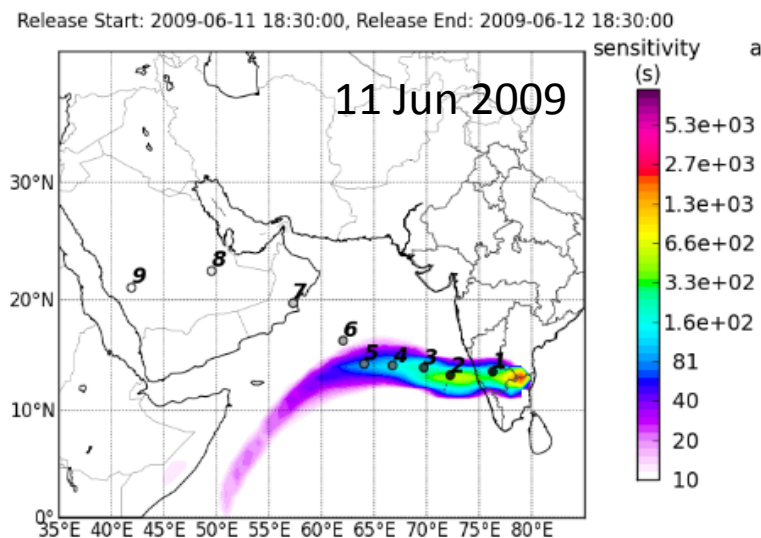
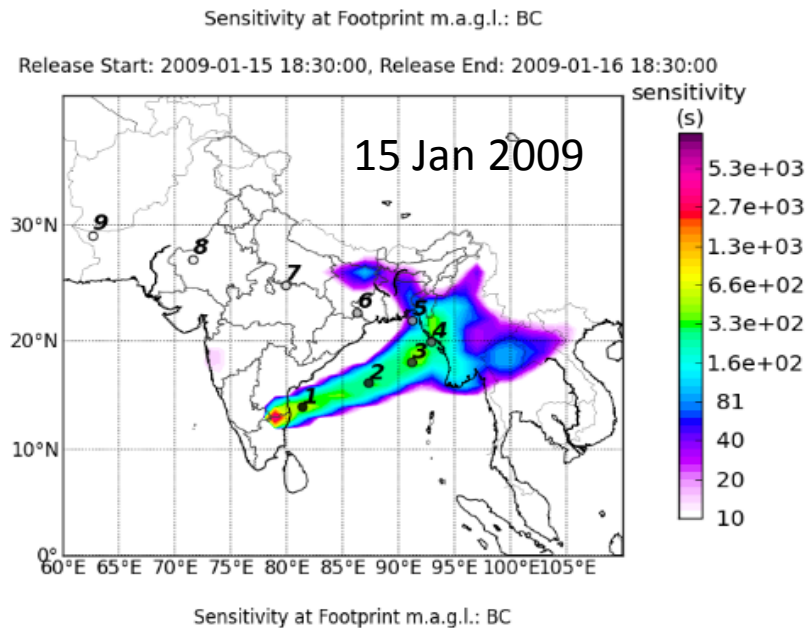


**FLEXPART Model**  
An open source  
atmospheric  
trajectory and  
particle dispersion  
model

BC concentration

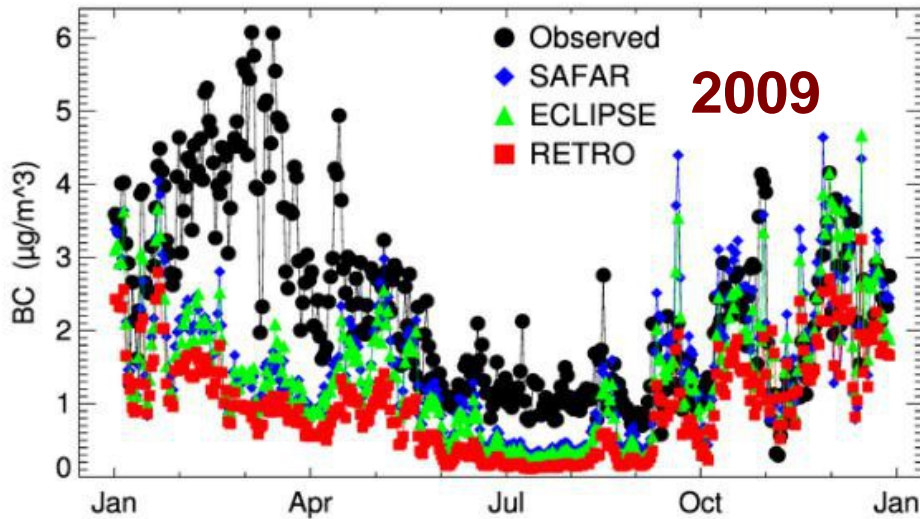


# Potential Emission Sensitivity (PES) Maps

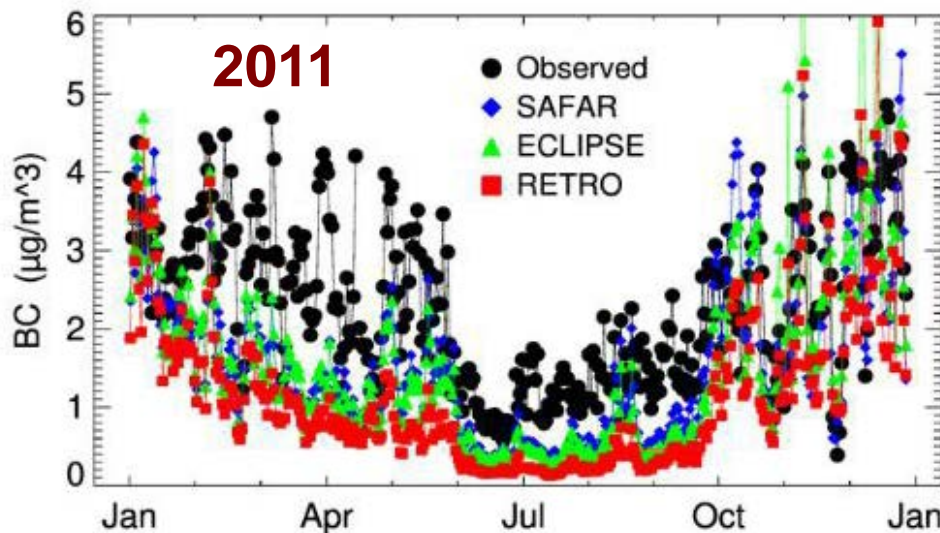


*PES maps for different days showing that the air masses are coming from different locations in different seasons to the observation site.*

# Simulation of Black Carbon Concentration over Gadanki using Three Different Emission Inventories

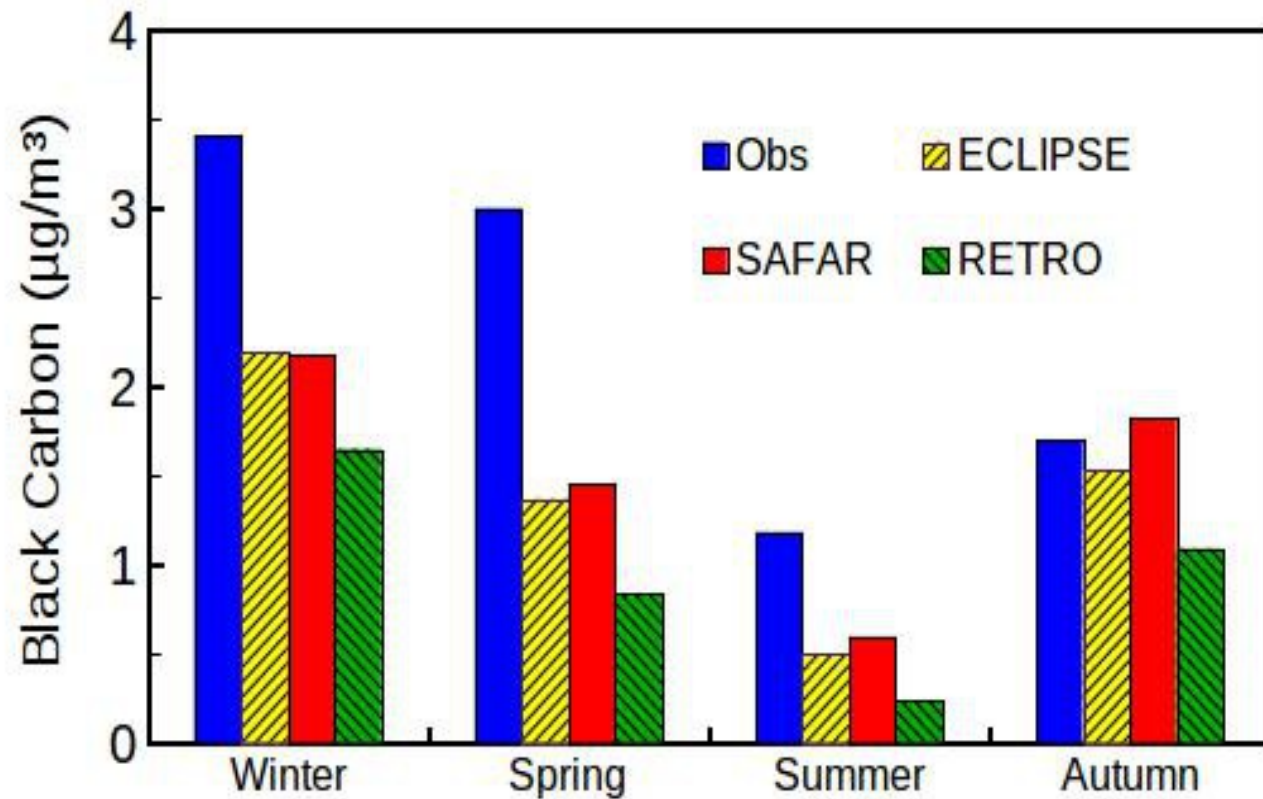


➤ Observed BC concentration data could be simulated using emission inventories and wind data.



➤ Major underestimation is noticed during winter and spring seasons.

## Seasonal Averages of BC from Observations and Simulations



Ratio of annual average of observation to model is found to be 1.5 for SAFAR inventory, 1.7 for ECLIPSE inventory and 2.4 for RETRO inventory

## Summary

- BC contributes to Global Warming by absorbing the incoming solar radiation.
- Model simulations based on available BC emission inventories for India underestimates black carbon concentration by a factor of 1.5 to 2.5 depending on season.
- Biomass burning is possibly the main sector being underestimated for black carbon emissions.

# Issues not addressed

- OC/BC ratio
- Vertical profiles of BC
- Effect of BC absorption on regional climate change





- Acknowledgement:

Dr. Harish Gadhavi & Group, NARL, Gadanki

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# Thank You

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