Black Carbon

Erika N. Sasser

Senior Policy Advisor, Office of Air Quality Planning and Standards

U.S. EPA

"Two for One Special: Targeting Pollutants that Both Cause Local Air Pollution Problems and Contribute to Climate Change"

NACAA Spring Meeting

May 7, 2012

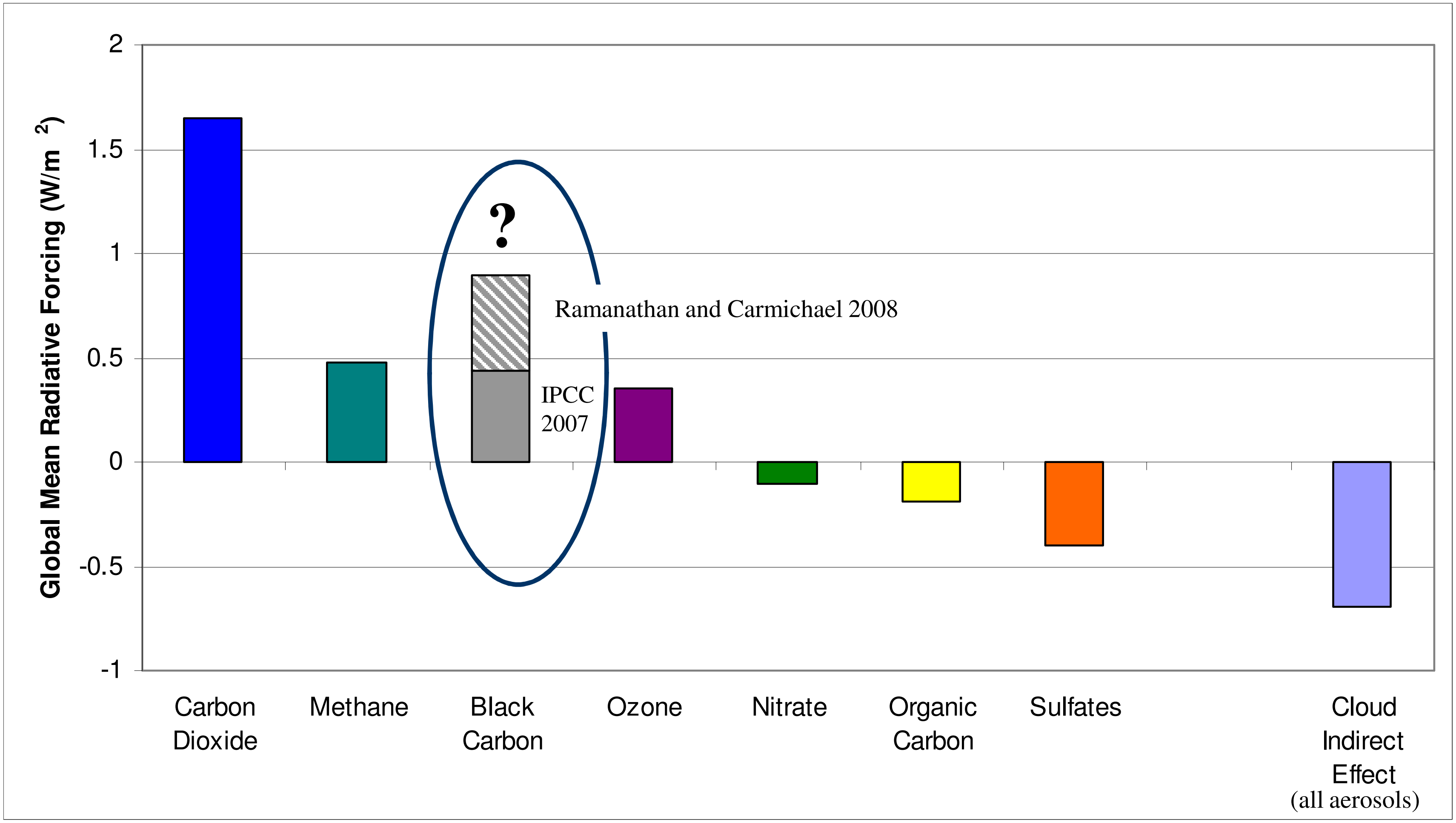
Key Questions Regarding Black Carbon in a Joint Air Quality/Climate Approach

- Why is black carbon of particular interest for climate?
- What are the benefits of reducing black carbon for climate, health and the environment?
- How well is the U.S. doing already in reducing black carbon emissions?
- How might we need to consider adjusting PM air quality programs if we want to emphasize black carbon reductions?

Growing Concern about the Climate Impacts of Black Carbon

- BC is strongly light-absorbing
- Affects climate by:
  - Absorbing sunlight
  - Darkening clouds, snow and ice
  - Altering precipitation and cloud patterns
- Remains in atmosphere days to weeks
- Principally a regional pollutant

Comparison of Global Average Radiative Forcing of Key Short-Lived Forcers vs. CO_2



(Adapted from IPCC Synthesis Report, 2007; as well as Ramanathan and Carmichael, 2008)

BC Impacts: Arctic

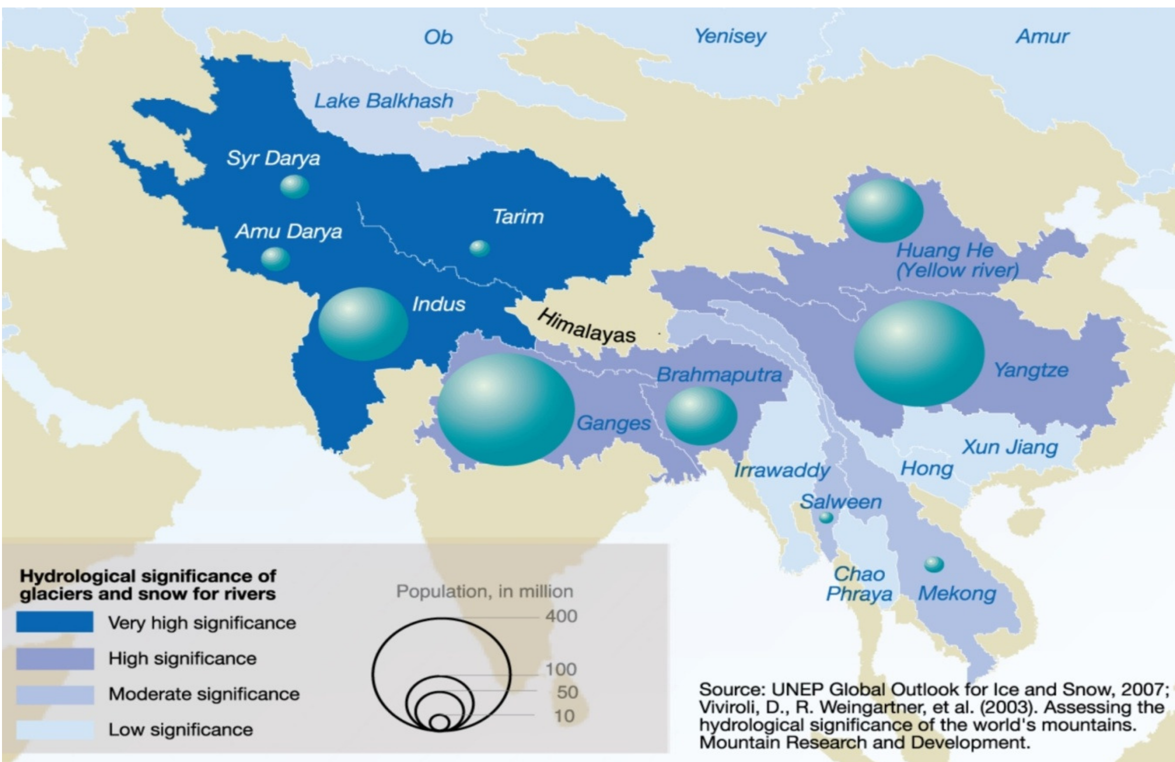
- Arctic temperatures increasing faster than global average (IPCC, 2007)
- BC may be significant contributor to Arctic warming and ice melt

Source: Reuters

BC Impacts: Glaciers

In the Himalayan region, solar heating from BLACK CARBON at high elevations may be just as important as carbon dioxide in the melting of snowpacks and glaciers (Ramanathan & Carmichael, 2008)

Himalayas: Source of 14 Major Rivers in Asia Under Threat



Western U.S.

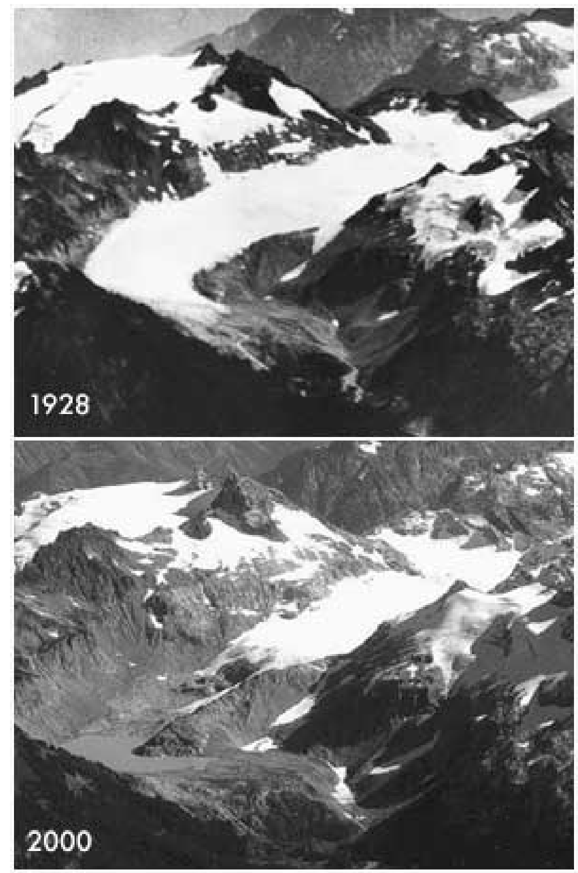
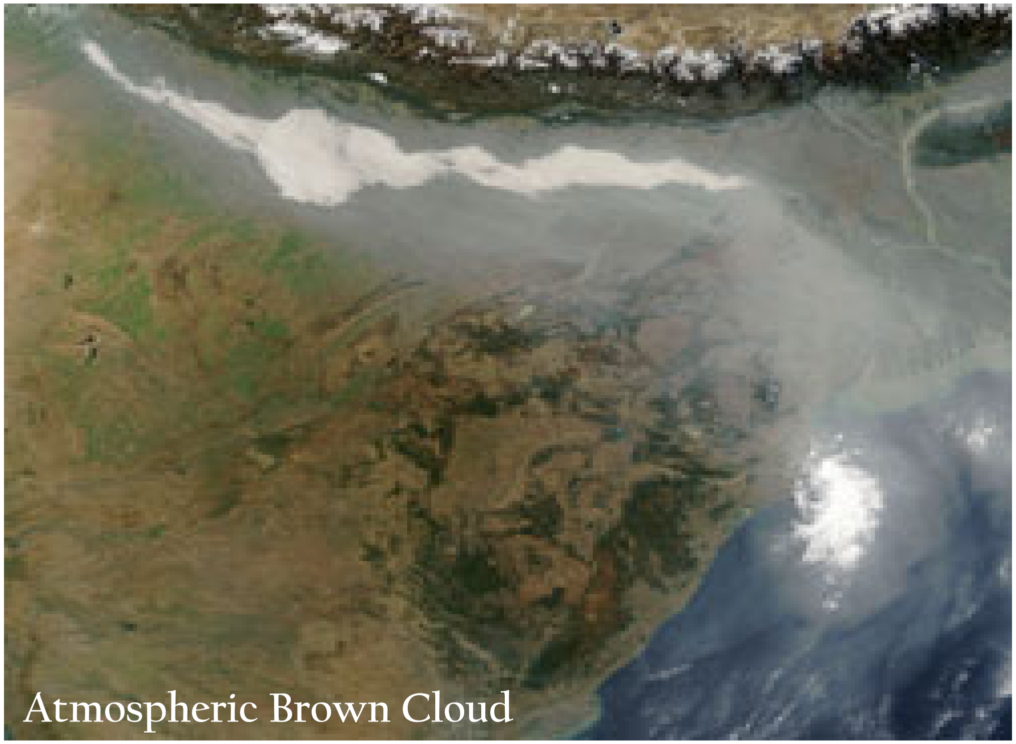


Photo: USGS

BC Impacts: Precipitation

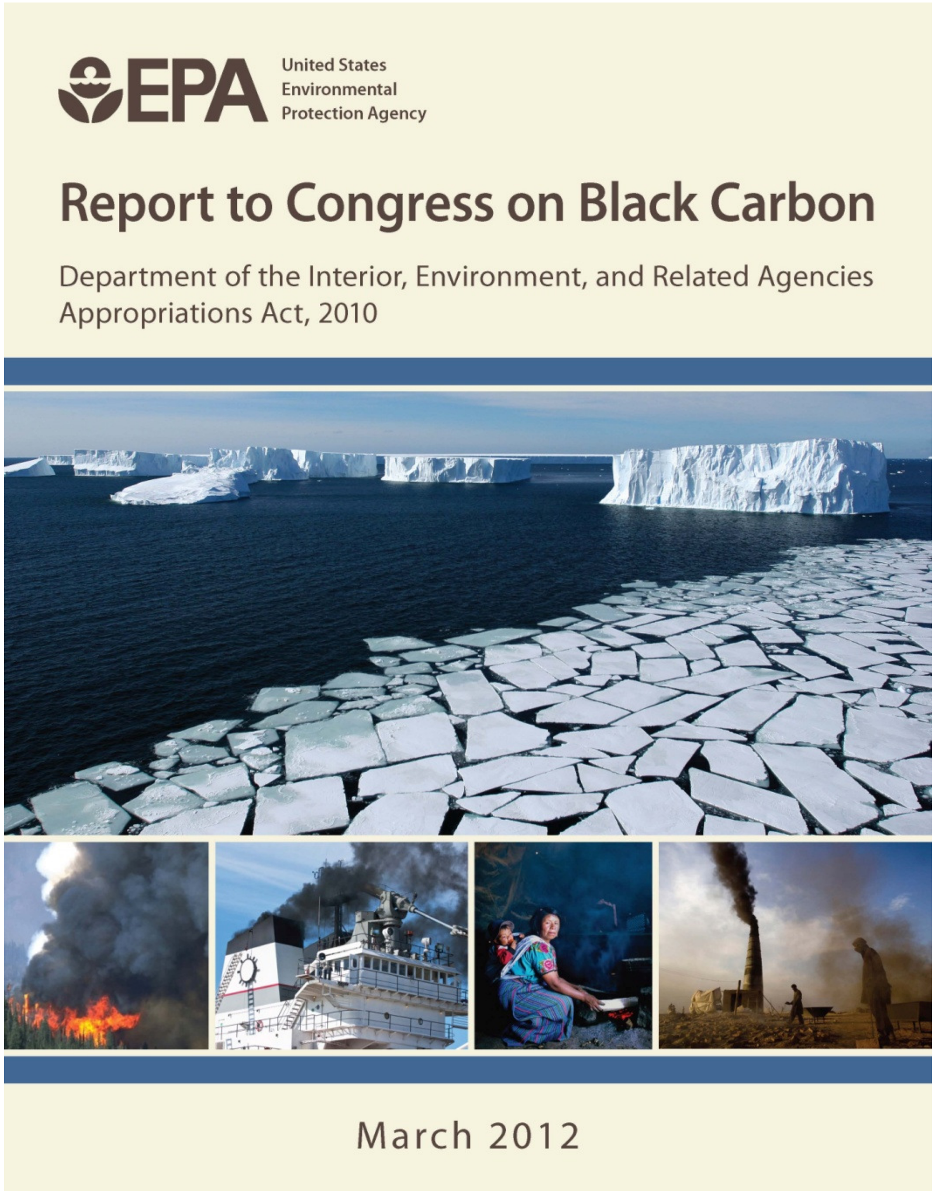
- Pollution plumes known as Atmospheric Brown Clouds (ABCs) may also affect rainfall patterns
  - ABCs contain significant amounts of BC, as well as organic carbon, sulfates, nitrates, and dust
- Can persist up to 7 months per year



NASA Goddard Space Flight Center/Jeff Schmaltz

EPA’s Report to Congress on Black Carbon

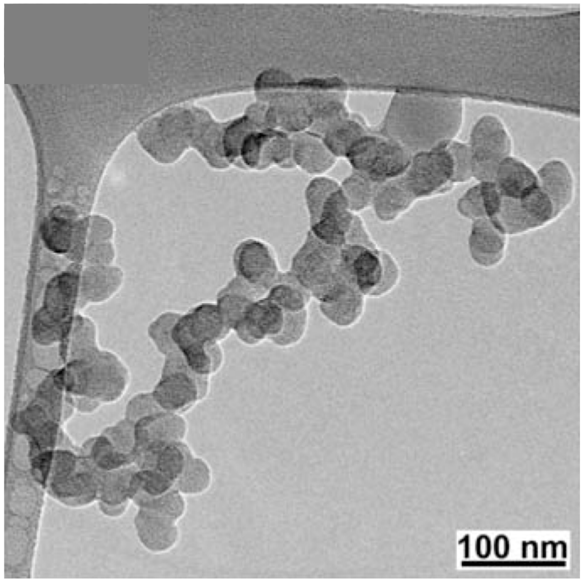
- In October 2009, Congress requested that EPA conduct a comprehensive study on black carbon to evaluate domestic and international sources, and climate/health impacts
- EPA completed this report on March 30, 2012
- Available online at: www.epa.gov/blackcarbon



The Report:

- Defines black carbon (BC) and describes its role in climate change.
- Characterizes the full impacts of BC on climate, public health, and the environment based on recent scientific studies.
- Summarizes data on domestic and global BC emissions, ambient concentrations, deposition, and trends.
- Discusses currently available mitigation approaches and technologies for four main sectors:
  - Mobile Sources
  - Stationary Sources
  - Residential Cooking and Heating
  - Open Biomass Burning
- Considers the potential benefits of BC mitigation for climate, public health, and the environment.

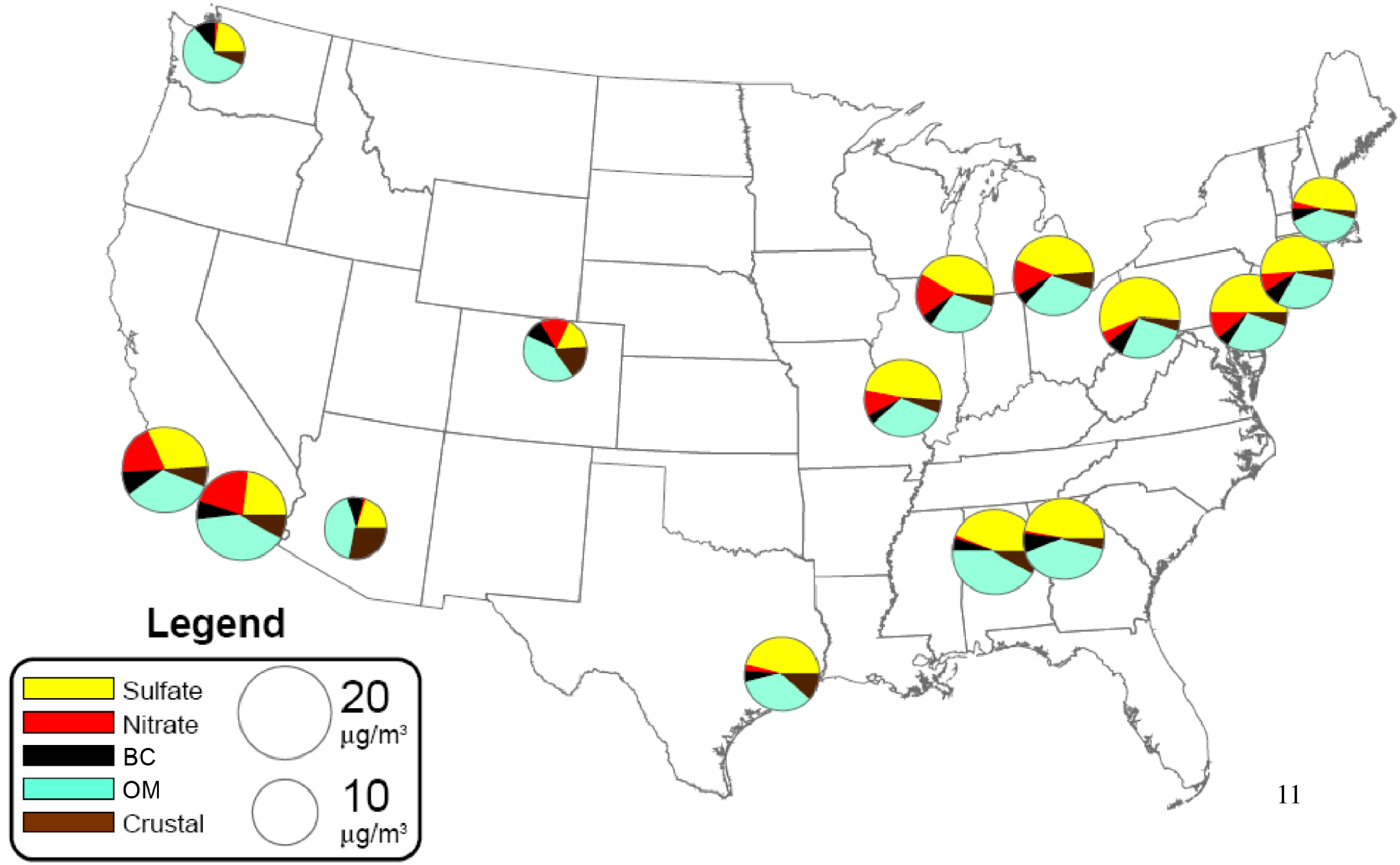
What is Black Carbon?



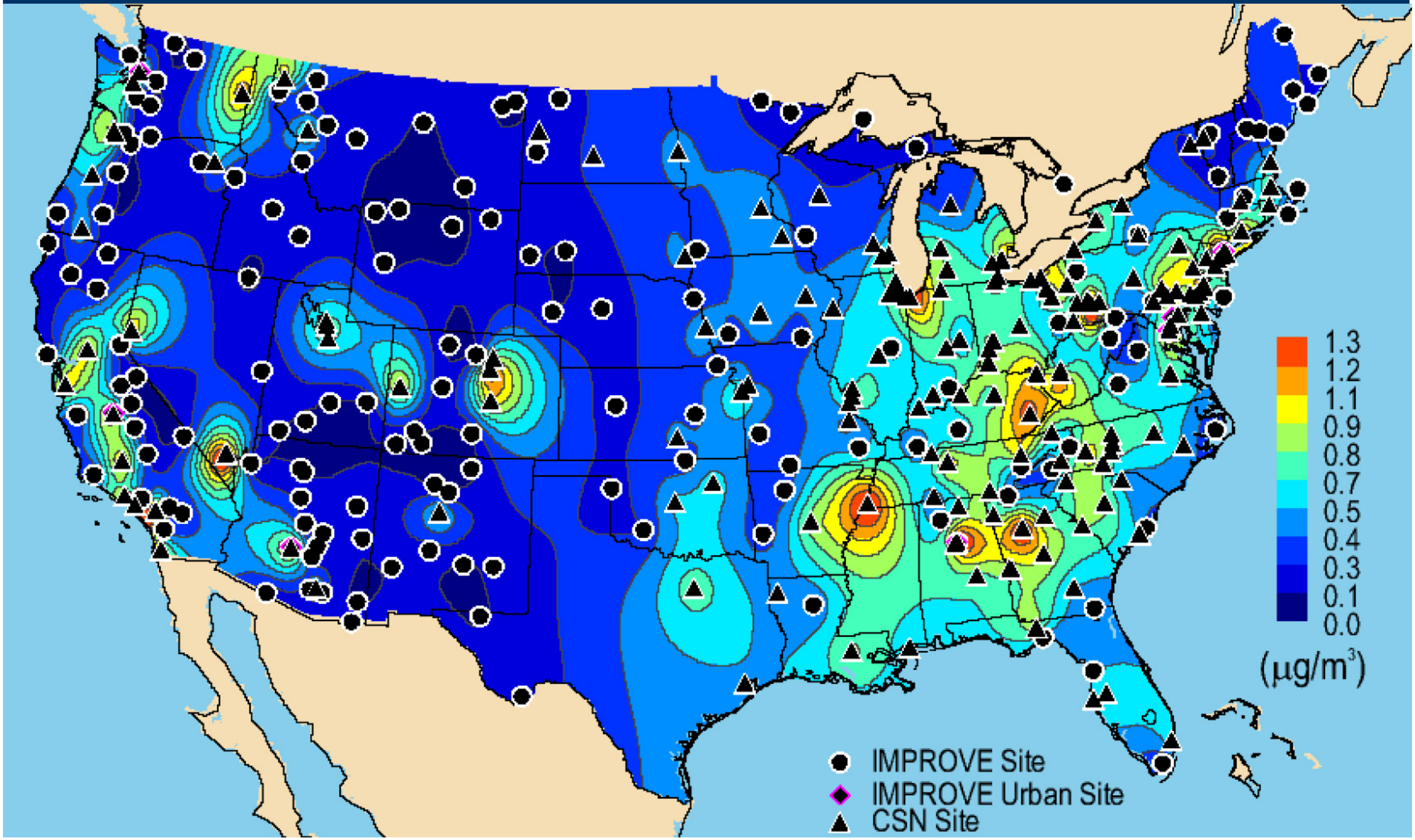
- Black carbon is the most strongly light-absorbing component of particulate matter (PM).
  - BC is a solid form of mostly pure carbon that absorbs solar radiation (light) at all wavelengths.
- Other types of particles, including sulfates, nitrates and organic carbon (OC), generally reflect light.

- BC is formed by incomplete combustion of fossil fuels, biofuels, and biomass.
- BC is emitted directly into the atmosphere in the form of fine particles (i.e., “direct $PM_{2.5}$”).
- BC is a major component of “soot”, a complex light-absorbing mixture that also contains organic carbon.

Composition of $PM_{2.5}$ for 15 Selected Urban Areas in the United States



Annual Mean BC Concentrations (µg/m3) for 2005-2008



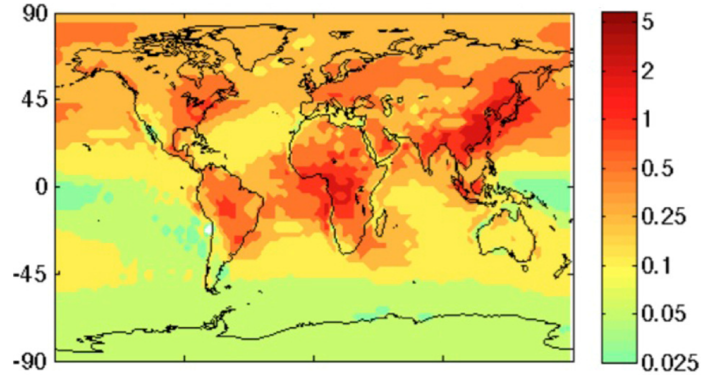
Climate Effects of Black Carbon

- BC influences climate by:
  - directly absorbing light (⇒ warming)
  - reducing the reflectivity ("albedo") of snow and ice through deposition (⇒ warming)
  - interacting with clouds (⇒ cooling and/or warming)

- BC's climate impacts likely include increased global average temperatures and accelerated ice/snow melt.

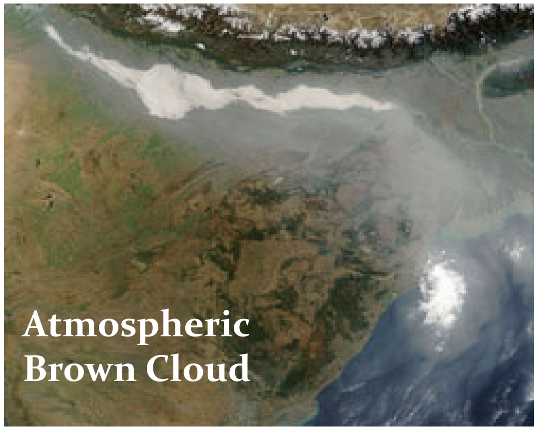
- Sensitive regions such as the Arctic and the Himalayas are particularly vulnerable to warming/melting effects of BC.

- BC also contributes to surface dimming, the formation of ABCs, and changes in the pattern and intensity of precipitation.



Global Direct Forcing due to Black Carbon
(Watts per square meter, from Bond. et al., 2007)

Deposition on Snow/Ice



NASA Goddard Space Flight Center/Jeff Schmaltz

Health Effects of Black Carbon

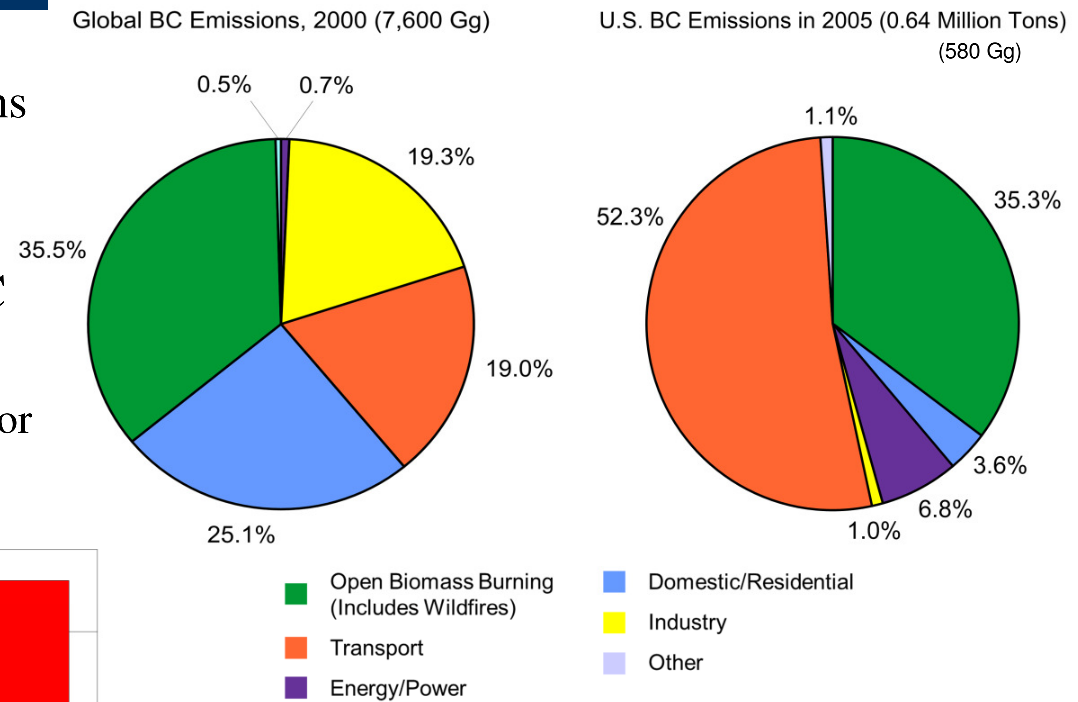
Brick Kiln in Kathmandu

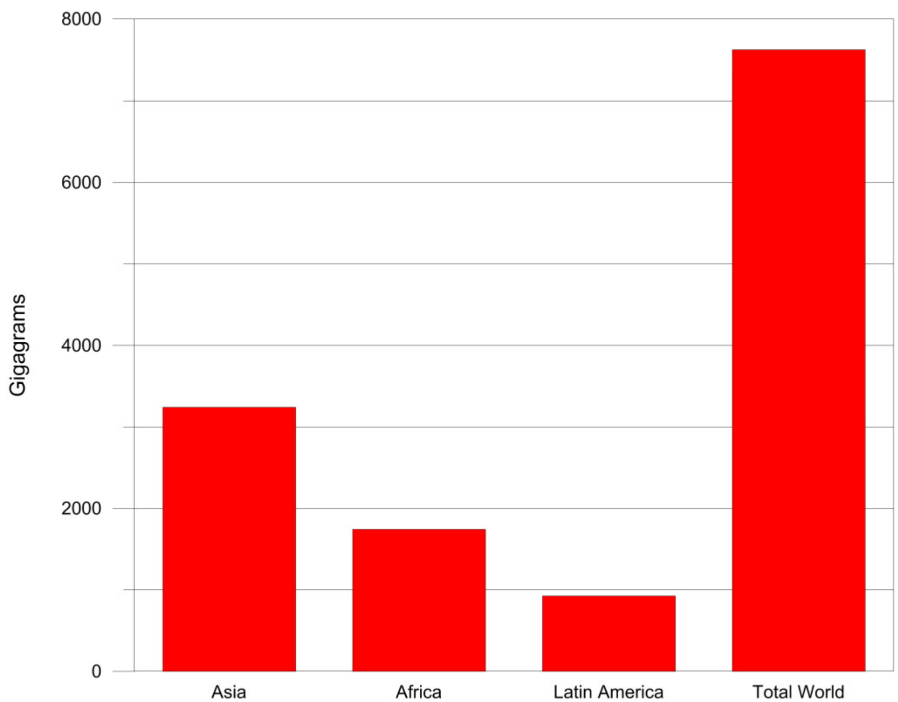
- BC contributes to the adverse impacts on human health, ecosystems, and visibility associated with $PM_{2.5}$.
- Short-term and long-term exposures to $PM_{2.5}$ are associated with a broad range of human health impacts, including respiratory and cardiovascular effects and premature death.
- The World Health Organization (WHO) estimates that indoor smoke from solid fuels is among the top 10 major mortality risk factors globally, contributing to approximately 2 million deaths each year (mainly among women and children).
- Emissions and ambient concentrations of directly emitted $PM_{2.5}$ are often highest in urban areas, where large numbers of people live.

Traditional Cookstove in India

Black Carbon Emissions

- U.S. 2005 BC emissions = 640,000 tons (580 Gg), or approximately 12% of all direct $PM_{2.5}$ emissions nationwide.
- Mobile sources are the largest U.S. BC emissions category.
  - Diesel engines and vehicles account for 93% of mobile source BC emissions.



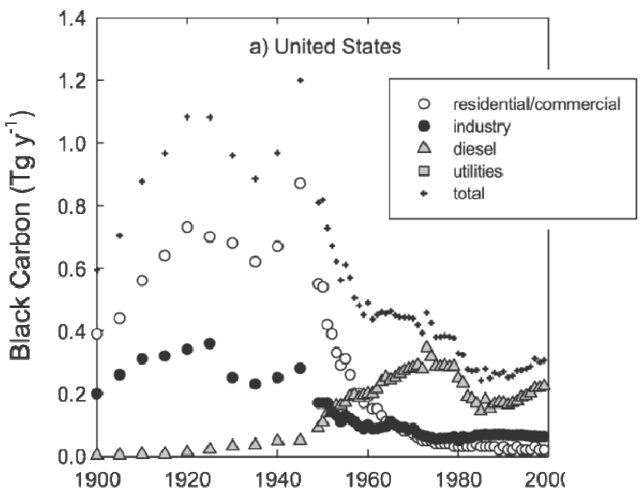


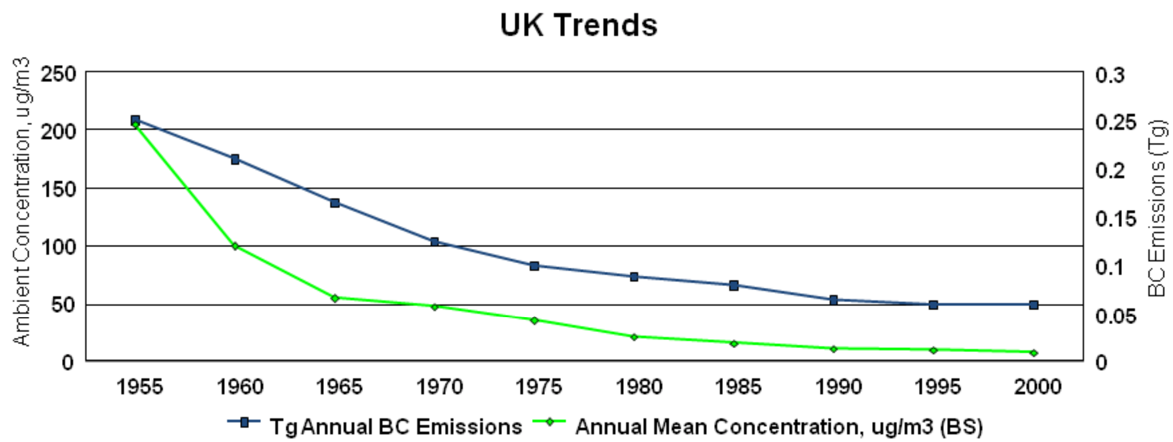
Aggregate BC Emissions in Selected World Regions (2000)

- Globally, the majority (75%) of global BC emissions come from Asia, Africa and Latin America.
- The United States currently accounts for approximately 8% of the global total, and this fraction is declining.
- Emissions patterns and trends across regions, countries and sources vary significantly.

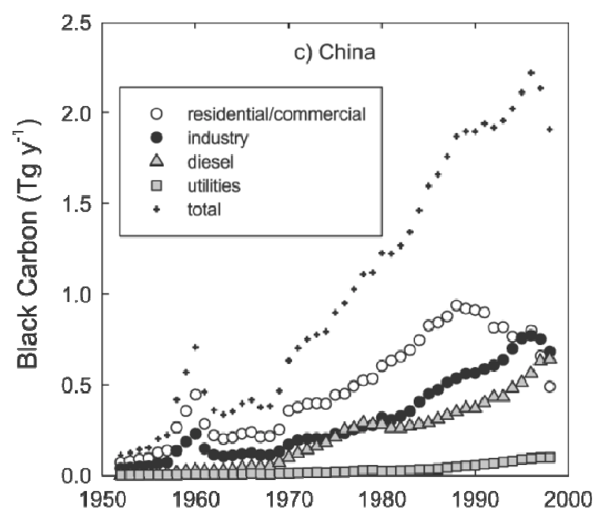
Black Carbon Emissions: Trends

- Long-term historic trends of BC emissions in the United States and other developed countries reveal a steep decline in emissions over the last several decades.
- Ambient BC concentrations have declined as emissions have been reduced.





- Developing countries (e.g., China and India) have shown a very sharp rise in BC emissions over the past 50 years.
- Total global BC emissions are likely to decrease in the future, but developing countries may experience emissions growth in key sectors (transportation, residential).



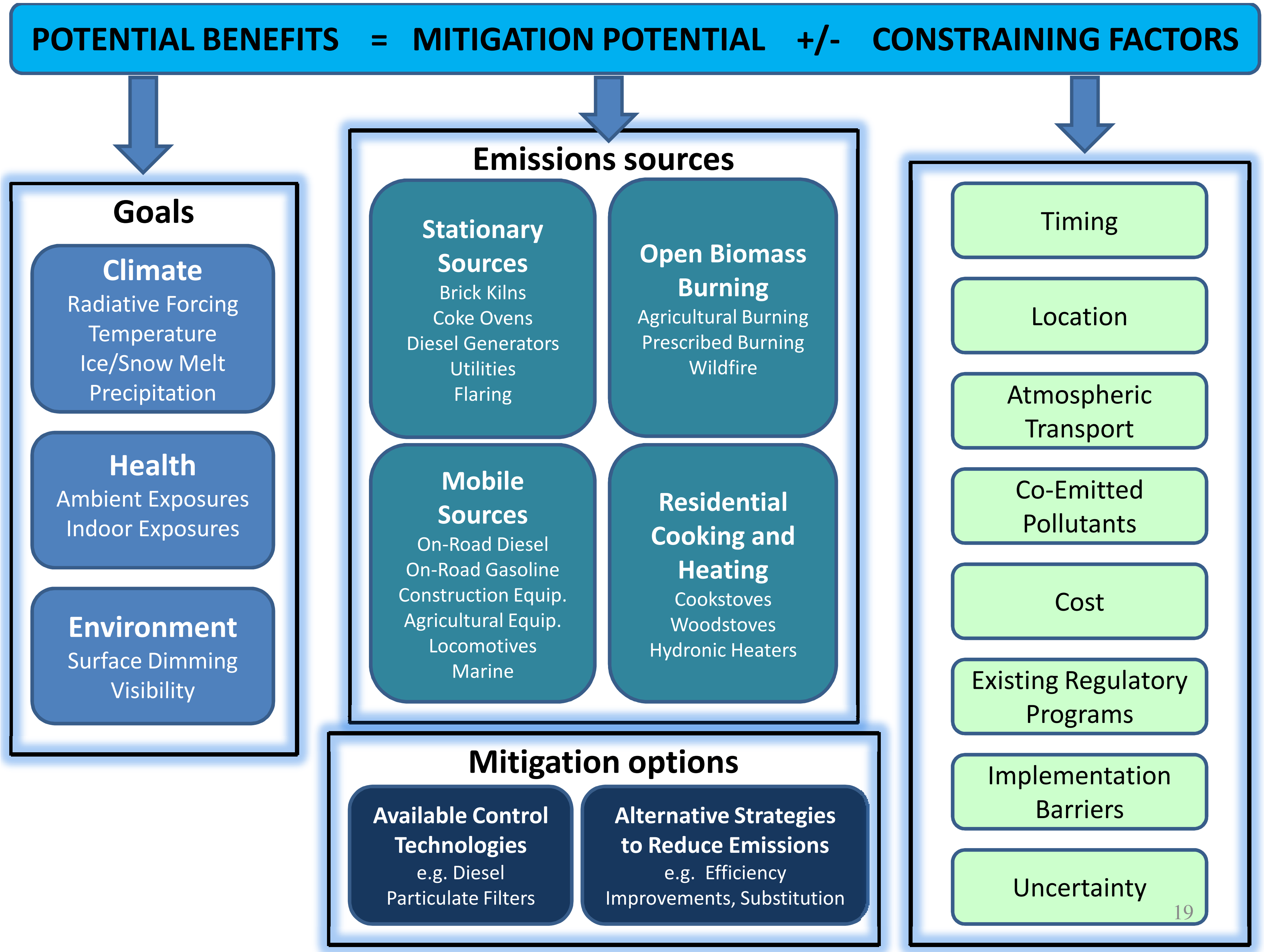
Potential Benefits of BC Mitigation

- Reducing current emissions of BC may help slow the near-term rate of climate change, particularly in sensitive regions such as the Arctic.
- BC's short atmospheric lifetime (days to weeks), combined with its strong warming potential, means that targeted strategies to reduce BC emissions can be expected to provide climate benefits within the next several decades.
- Reductions in BC and GHGs are complementary strategies for mitigating climate change.
- The health and environmental benefits of BC reductions are also substantial.
    - Average public health benefits of reducing directly emitted $PM_{2.5}$ in the U.S. are estimated to range from \$290,000 to \$1.2 million per ton $PM_{2.5}$ in 2030.

Mitigating BC: Key Considerations

- For both climate and health, it is important to consider the location and timing of emissions and to account for co-emissions.
- Available control technologies can reduce BC, generally by improving combustion and/or controlling direct $PM_{2.5}$ emissions from sources.
- Some state and local areas in the U.S. have already identified control measures aimed at direct $PM_{2.5}$ as particularly effective strategies for meeting air quality goals.

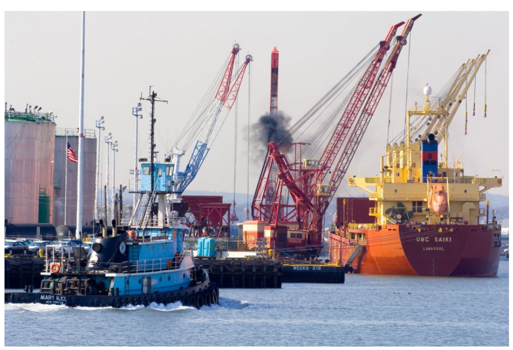
- Though the costs vary, many reductions can be achieved at reasonable costs. Controls applied to reduce BC will help reduce total $PM_{2.5}$ and other co-pollutants.


POTENTIAL BENEFITS = MITIGATION POTENTIAL +/- CONSTRAINING FACTORS
Goals
Climate
Radiative Forcing
Temperature
Ice/Snow Melt
Precipitation
Health
Ambient Exposures
Indoor Exposures
Environment
Surface Dimming
Visibility
Emissions sources
Stationary Sources
Brick Kilns
Coke Ovens
Diesel Generators
Utilities
Flaring
Open Biomass Burning
Agricultural Burning
Prescribed Burning
Wildfire
Mobile Sources
On-Road Diesel
On-Road Gasoline
Construction Equip.
Agricultural Equip.
Locomotives
Marine
Residential Cooking and Heating
Cookstoves
Woodstoves
Hydronic Heaters
Mitigation options
Available Control Technologies
e.g. Diesel Particulate Filters
Alternative Strategies to Reduce Emissions
e.g. Efficiency Improvements, Substitution
Timing
Location
Atmospheric Transport
Co-Emitted Pollutants
Cost
Existing Regulatory Programs
Implementation Barriers
Uncertainty

BC Mitigation Opportunities

United States

- The U.S. will achieve substantial BC emissions reductions by 2030, largely due to controls on new mobile diesel engines.
  - Diesel retrofit programs for in-use mobile sources are a valuable complement to new engine standards for reducing emissions.
- Other U.S. source categories have more limited mitigation potential due to smaller remaining emissions in these categories, or limits on the availability of effective BC control strategies:
  - Stationary sources
  - Residential wood combustion
  - Open biomass burning



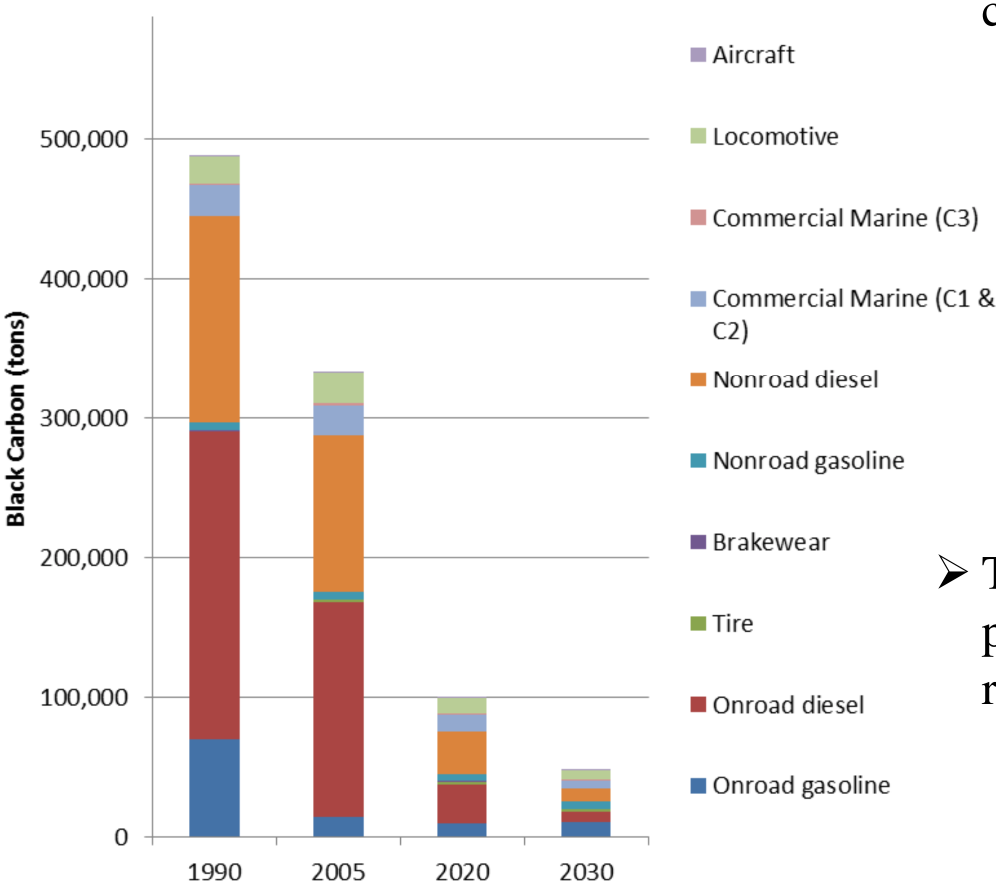
Global

- The most important BC emissions reduction opportunities globally include:
  - residential cookstoves in all regions
  - brick kilns and coke ovens in Asia
  - mobile diesels in all regions
- A variety of other opportunities may exist in individual countries or regions.

Sensitive Regions

- Arctic: transportation sector (land-based diesel engines and Arctic shipping); residential heating (wood); and biomass burning.
- Himalayas: residential cooking; industrial sources (especially coal-fired brick kilns); and transportation (diesel engines).

U.S. Mobile Sources



Emissions from U.S. Mobile Sources

- BC emissions from U.S. mobile diesel engines controlled via:
  - Emissions standards for new engines, including requirements resulting in use of diesel particulate filters (DPFs) in conjunction with ultra low sulfur diesel fuel.
  - Retrofit programs for in-use mobile diesel engines, such as EPA's National Clean Diesel Campaign and the SmartWay Transport Partnership Program.
- Total U.S. mobile source BC emissions are projected to decline by 86% by 2030 due to regulations already promulgated.
  - EPA has estimated the cost of controlling $PM_{2.5}$ from new diesel engines at ~ \$14,000/ton (2010\$).

U.S. Stationary Sources

- Controls on industrial sources, combined with improvements in technology and broader deployment of cleaner fuels such as natural gas, have helped reduce U.S. BC emissions more than 70% since the early 1900s.
- Regulations limiting direct PM emissions (including BC) affect more than 40 categories of industrial sources, including coke ovens, cement plants, industrial boilers, and stationary diesel engines.
- Available control technologies and strategies include:
  - Use of cleaner fuels.
  - Direct $PM_{2.5}$ reduction technologies (e.g. fabric filters (baghouses), electrostatic precipitators (ESPs), and diesel particulate filters (DPFs)).
  - The control technologies range in cost-effectiveness from \$48/ton $PM_{2.5}$ to \$685/ton $PM_{2.5}$ (2010\$) or more, depending on the source category. However, they also may involve tens of millions in initial capital costs.

U.S. Residential Heating and Cooking

- Emissions from residential wood combustion are currently being evaluated as part of EPA's ongoing review of emissions standards for residential wood heaters, including hydronic heaters, woodstoves, and furnaces.

- Mitigation options include replacing or retrofitting existing units, or switching to alternative fuels such as natural gas.
  - New EPA-certified wood stoves have a cost-effectiveness of about \$3,600/ton $PM_{2.5}$ reduced, while gas fireplace inserts average \$1,800/ton $PM_{2.5}$ reduced (2010\$).

Open Biomass Burning

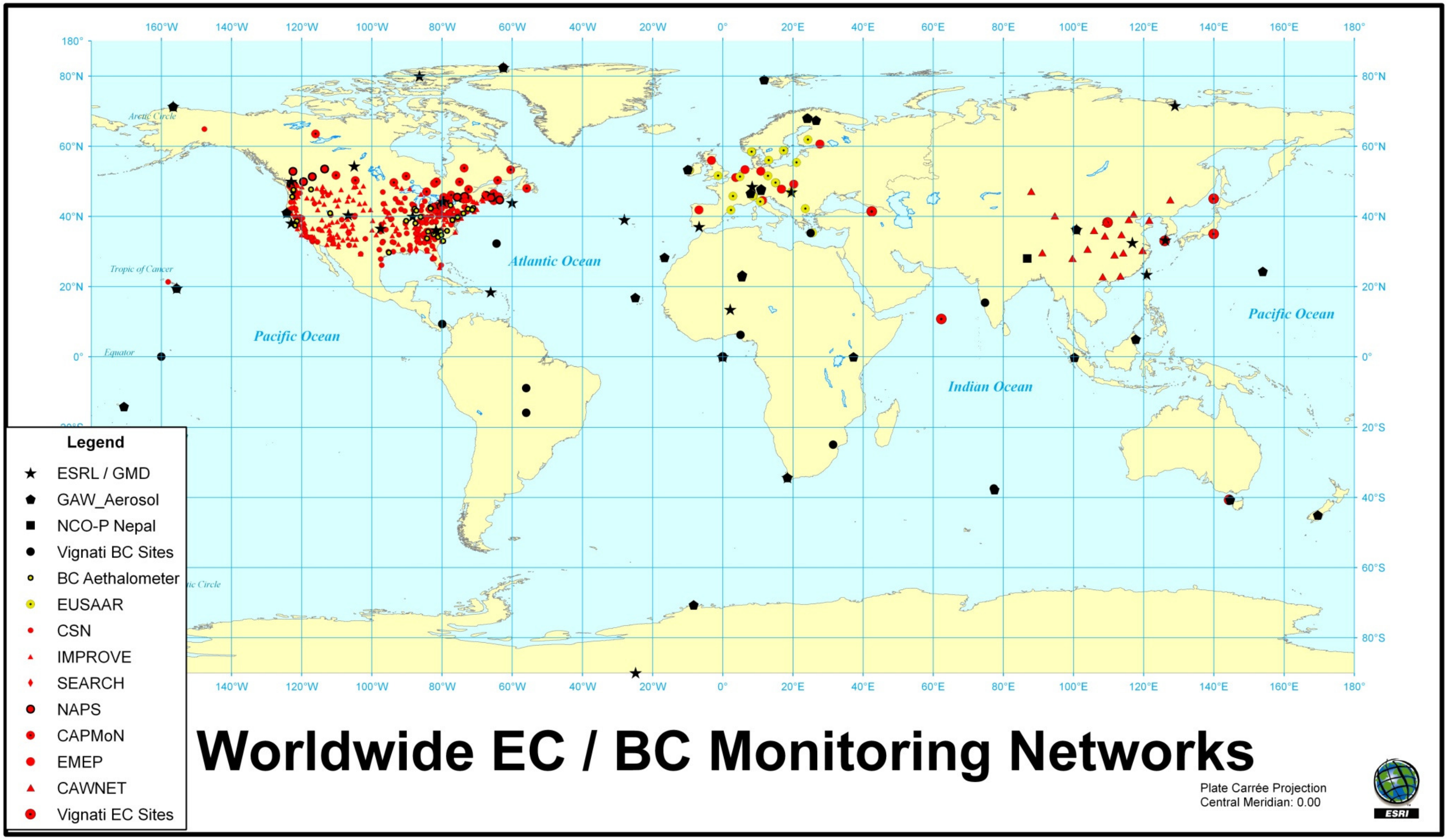
- Open biomass burning is the largest source of BC emissions globally, and these emissions have been tied to reduced snow and ice albedo in the Arctic.
  - A large percentage of these emissions are due to wildfire (e.g., U.S. Alaskan fires).
  - Total organic carbon (OC) emissions (which may be cooling) are seven times higher than total BC emissions from this sector.
- $PM_{2.5}$ emissions reductions techniques (e.g., smoke management programs) may help reduce BC emissions.
- Appropriate mitigation measures depend on the timing and location of burning, resource management objectives, vegetation type, and available resources.
- Expanded wildfire prevention efforts may help to reduce BC emissions worldwide.

Conclusions

- Mitigation of BC offers a clear opportunity: continued reductions in BC emissions can provide significant near-term benefits for climate, public health, and the environment.
- Effective control technologies and approaches are available to reduce BC emissions from a number of key source categories.
- Achieving further BC reductions, both domestically and globally, will require adding a specific focus on reducing direct $PM_{2.5}$ emissions to overarching fine particle control programs.
- The options identified in this report for reducing BC emissions are consistent with control opportunities emphasized in other recent assessments. These represent important mitigation opportunities for key world regions, including the United States.

Additional Slides

Ambient BC Measurement Locations Worldwide



Red = thermal measurement locations (EC)
Black = light-absorption measurement locations (BC)
Yellow = locations taking both types of measurements