

California Environmental Protection Agency



# California Black Carbon Control

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# Premature Deaths from Air Pollution

California Estimates

Pollutant	Annual Deaths*
PM2.5	7,300 to 11,000
Ozone	300 to 1000
Toxic Air Contaminants	<400

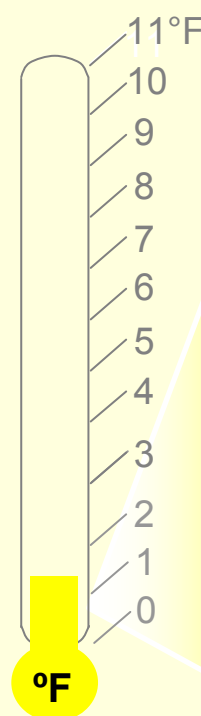
\* 2006-2008 for PM2.5; 2005 for ozone and TAC

# California Climate Impacts

## over the past 100 years



**Lyell Glacier in Yosemite NP**



**1.3°F (0.7°C) higher  
temperatures**

**7 inch sea level rise**

**12% decrease in fraction  
of runoff between April  
and July**

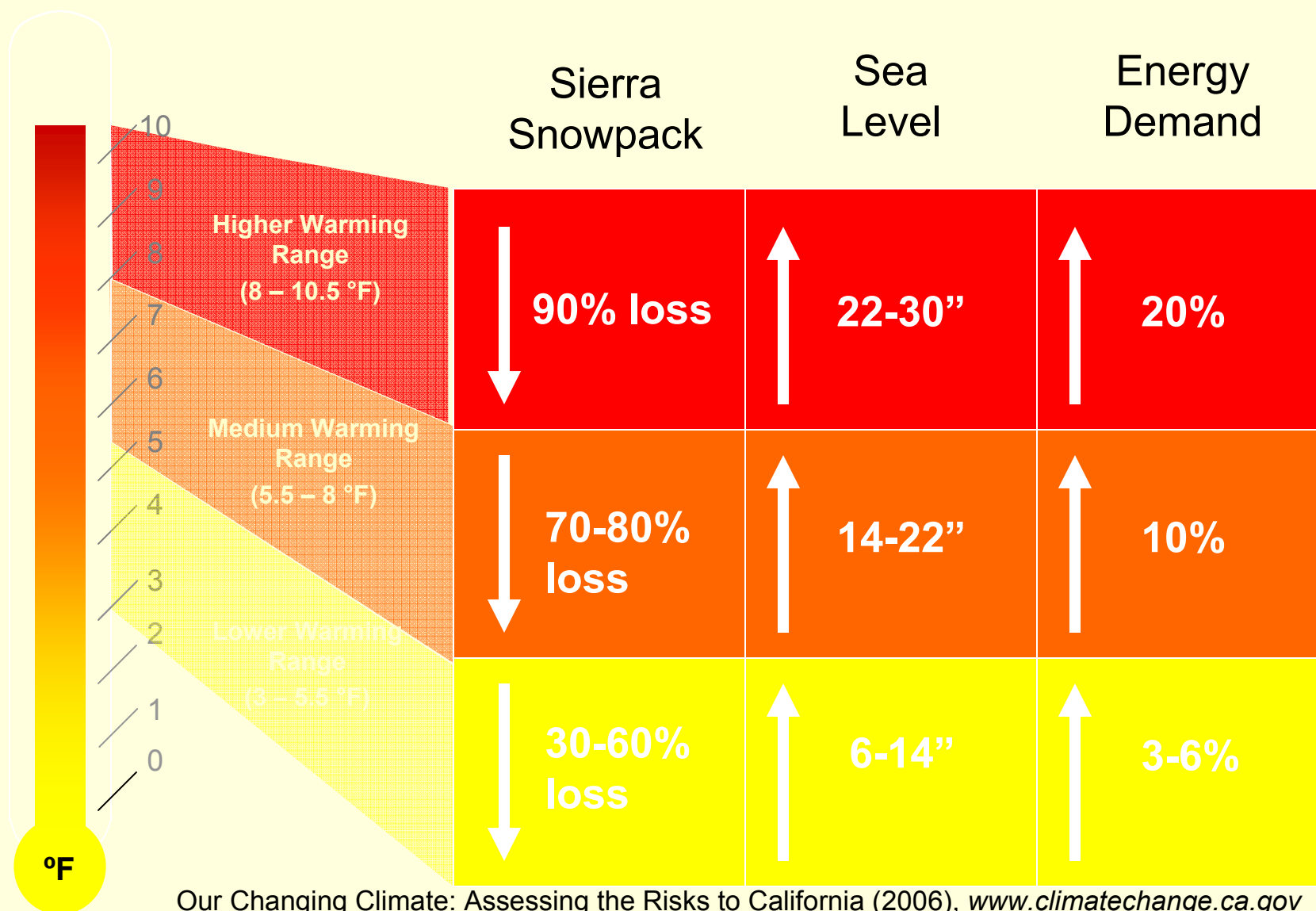
**snowmelt and spring  
blooms advanced  
2 days/decade since 1955**

**4-fold increase in wildfire  
frequency (over 34 years)**

Cal/EPA-OEHHA, "Environmental Protection Indicators for California" (2002),  
[www.oehha.ca.gov/multimedia/epic/Epicreport.html](http://www.oehha.ca.gov/multimedia/epic/Epicreport.html)

Westerling et al., "Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity", *Science* (2006)

# Projected Climate Impacts on California, 2070-2099 (as compared with 1961-1990)





# California Targets

## Air Quality

By 2020, attain annual PM<sub>2.5</sub> of 12 µg/m<sup>3</sup>

By 2023, attain 8-hour ozone of 80 ppb

By 2025, attain 24-hour PM<sub>2.5</sub> of 35 µg/m<sup>3</sup>

By 2032, attain 8-hour ozone of 75 ppb

## Diesel and Freight Transport

By 2020, diesel PM risk 85% below 2000 levels

## Greenhouse Gases

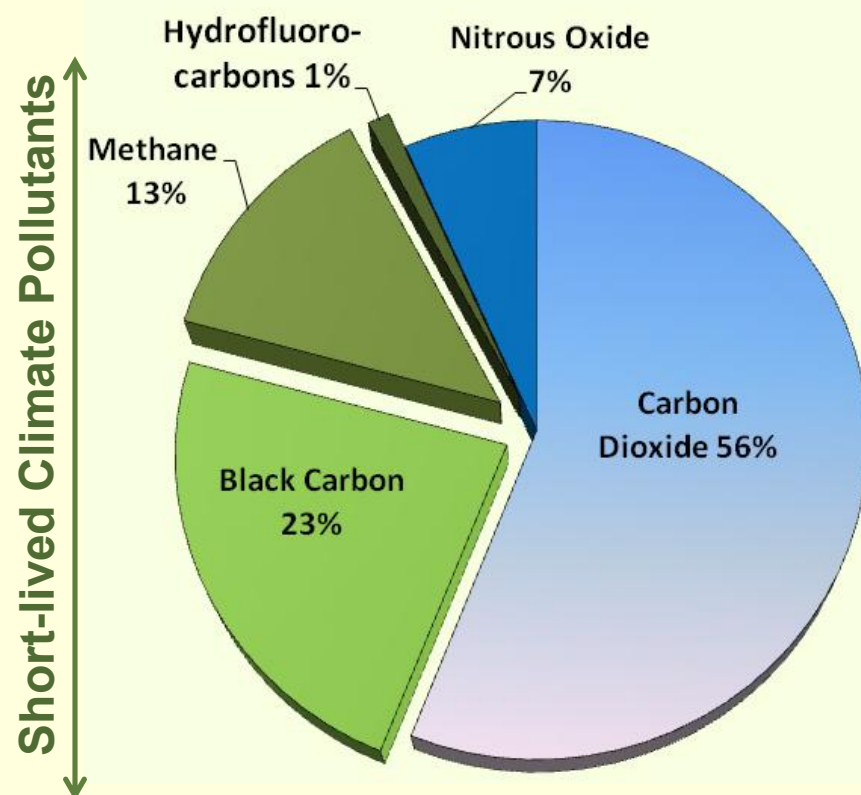
By 2020, reduce to 1990 levels

By 2050, 80% below 1990 levels

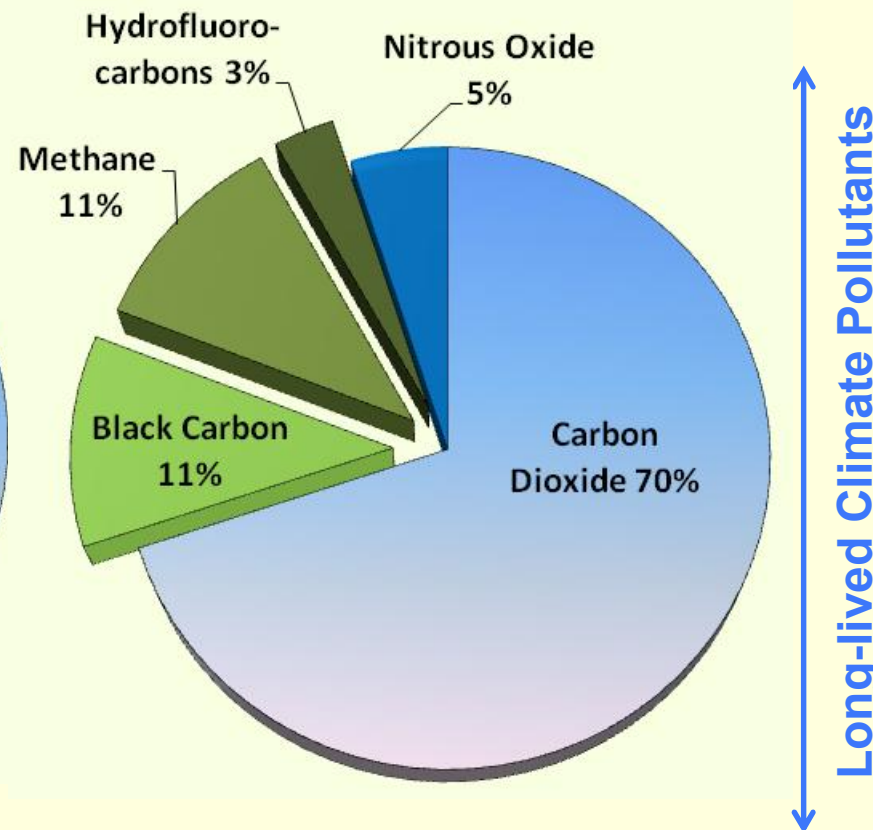
# Climate Pollutants

- Long-lived
  - Carbon dioxide: 100 years
  - Nitrous oxide: 114 years
  - Controls essential to limit global warming
- Short-lived
  - Black carbon: 1 to 2 weeks
  - Methane: 8 to 12 years
  - Hydrofluorocarbons: 1.4 to 14 years
  - Controls produce rapid climate response

# Climate Pollutant Emissions (current)



Global

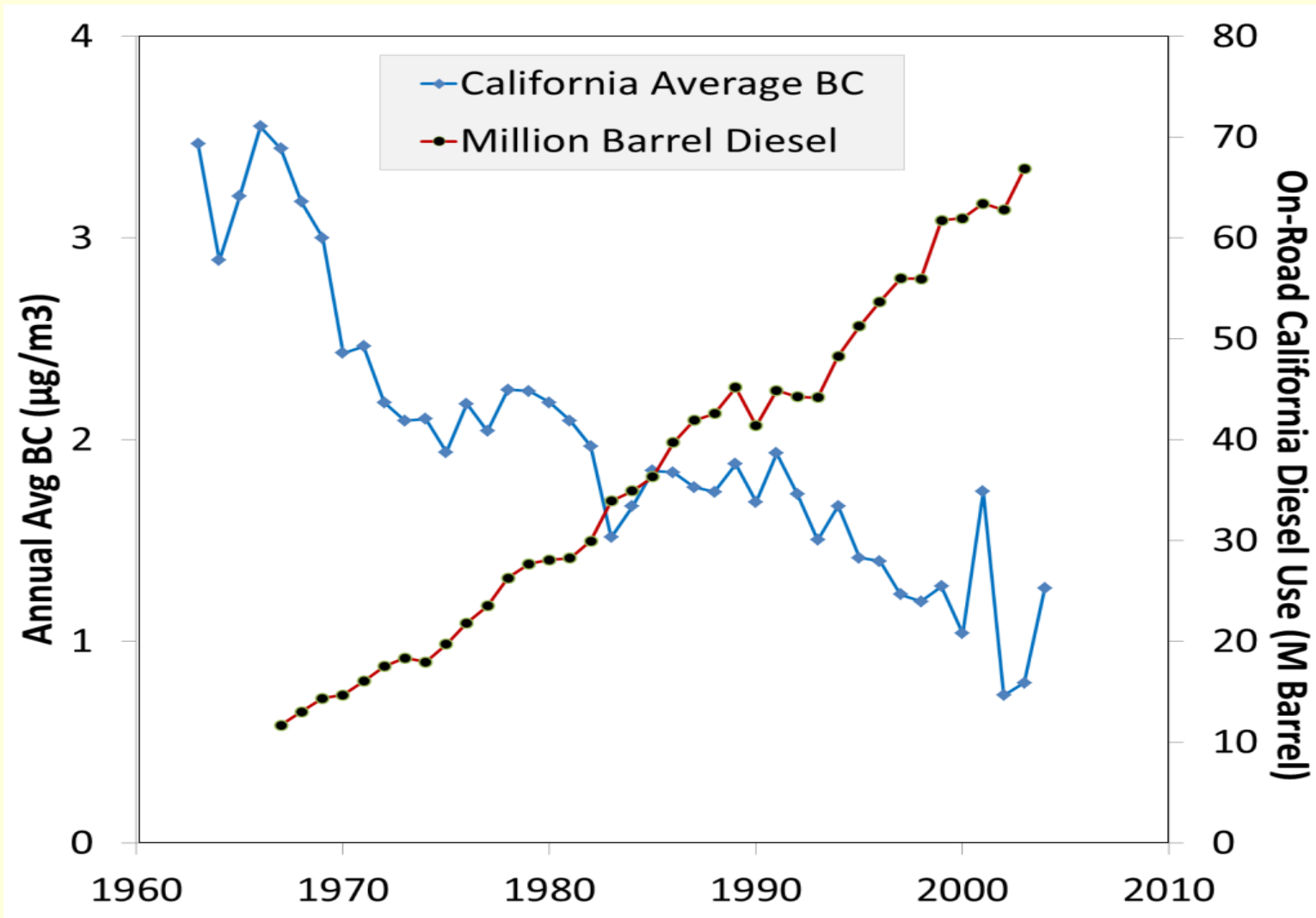


California

# California Actions

- Black Carbon
  - Diesel engine controls, Advanced Clean Cars, burning restrictions
- Methane
  - Landfill controls, oil and gas regulations, dairy digester offset protocol
- Hydrofluorocarbons
  - Refrigerant Management Program, Advanced Clean Cars, other regulations

# 40 Years of Progress on Black Carbon



Kirchstetter et al. (2011) Black Carbon and the Regional Climate of California, CARB Contract No. 08-323

# Diesel Risk Reduction Plan

(By 2020, reduce diesel PM risk 85% below 2000 levels)

- 2007 new engine standards (90% control)
- Low-sulfur (15 ppmw) diesel and alternative fuels
- Retrofit/re-power with incentives (\$500M / year)
- International Diesel Retrofit Advisory Committee
- Anti-idling measures
- Enforcement programs





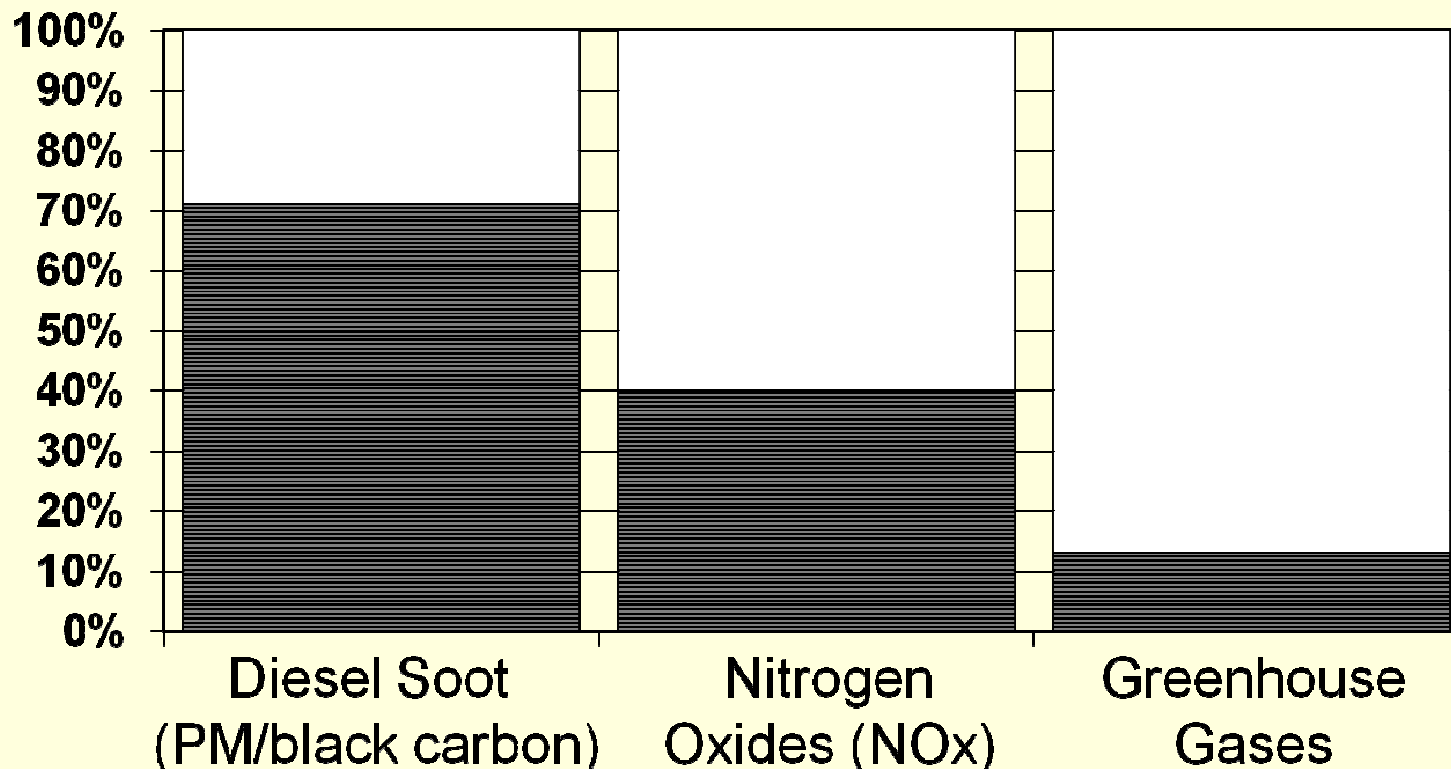
# In-Use Diesel Regulations

Urban Buses (2000)  
Garbage Trucks (2003)  
Stationary Engines (2004)  
Transport Refrigeration Units (2004)  
Portable Engines (2004)  
Transit Fleet Vehicles (2005)  
Public Fleets & Utilities (2005)  
Cargo Handling Equipment (2005)

Drayage Trucks (2007)  
Off-Road Vehicles (2007)  
Trucks and Buses (2008)  
Tractor-Trailer GHG (2008)



# Freight Transport Today: Contribution to Statewide Emissions

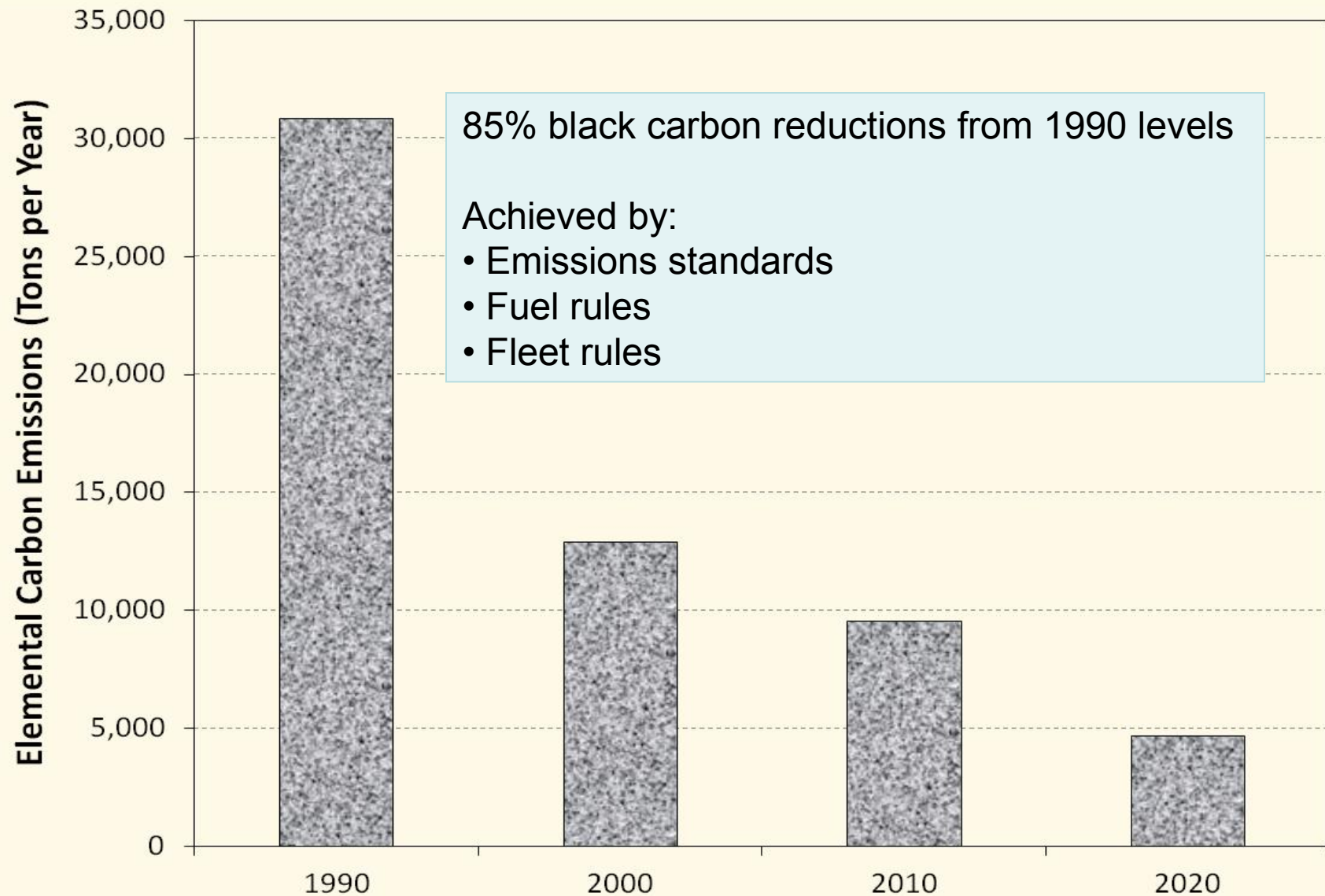




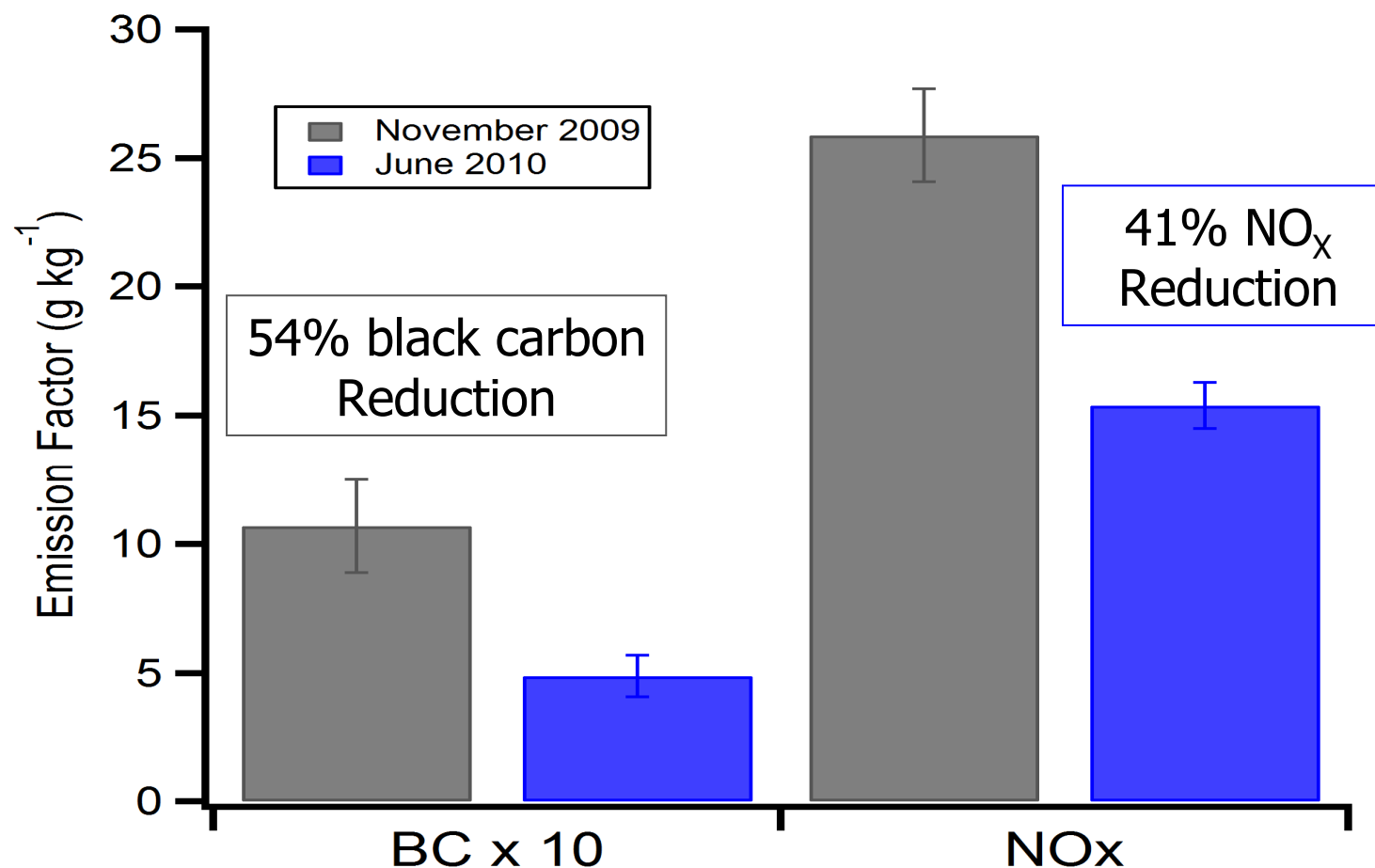
# Adopted ARB Freight Regulations

- ✓ Cleaner diesel fuel rules
- ✓ Statewide truck rules
- ✓ Port and railyard truck rule
- ✓ Truck/trailer efficiency rule
- ✓ Truck idling and refrigeration unit rules
- ✓ Ship fuel and shore power rules
- ✓ Harbor craft rules
- ✓ Cargo equipment rule
- ✓ Locomotive/rail yard agreements

# California's Diesel Program



# Black Carbon Emission Reductions from Trucks Operating at Port of Oakland



Dallmann et al. (2011) *Environmental Science & Technology*, 45, 10773-10779

# High Emitting Heavy-Duty Trucks

- 809 trucks sampled July 2010
  - Caldecott Tunnel (4% grade)
- BC emissions lowered  $37 \pm 10\%$  from 2006
- 10% dirtiest trucks emitted half total BC

# Light-Duty Gasoline Vehicles

(Gasoline Direct Injection versus Port Fuel Injection)

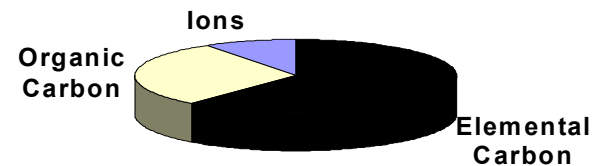
**PFI: Very little BC**



**GDI: BC comparable to diesel**

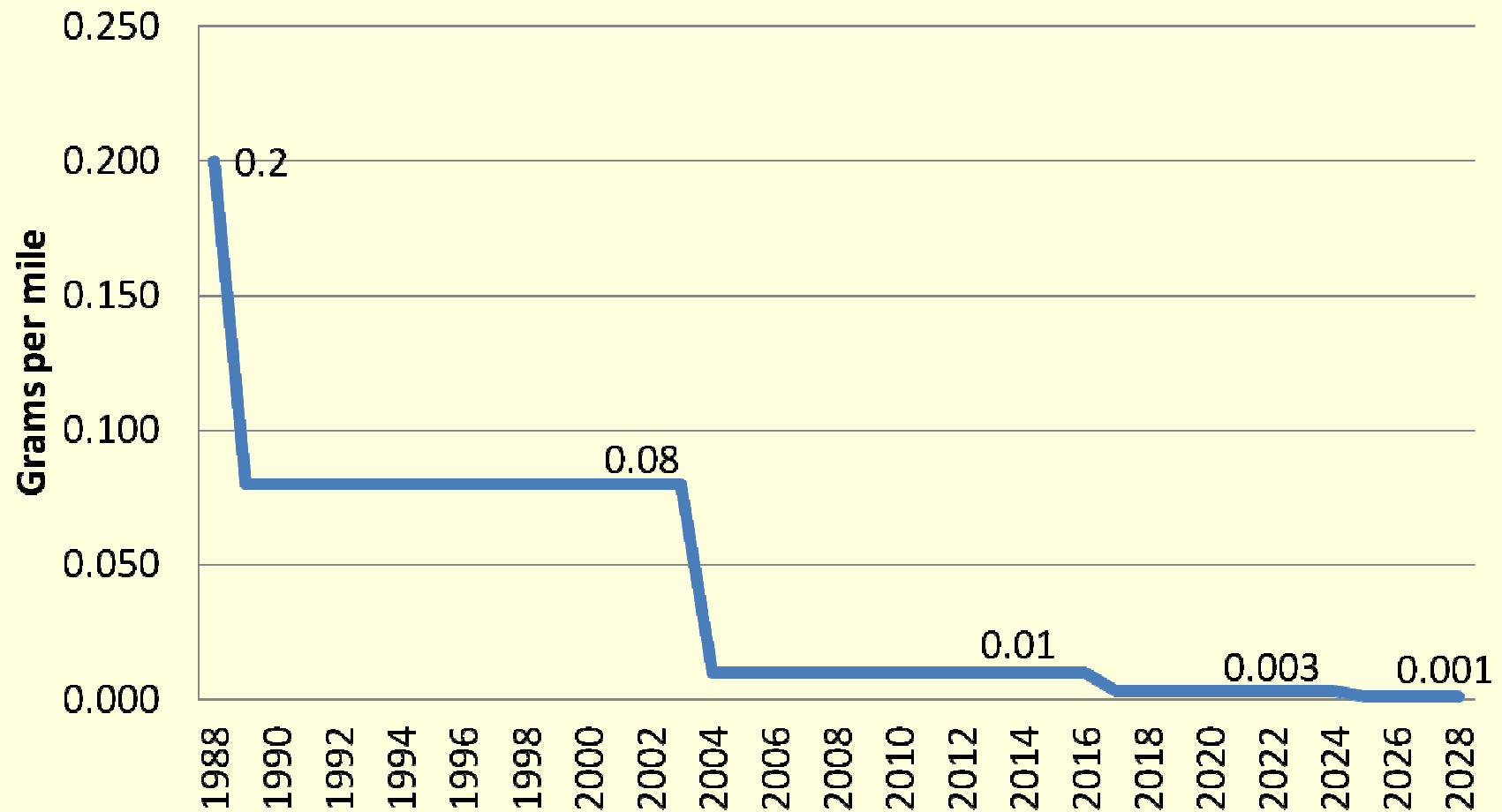


**GDI: PM Analysis**



# California Tailpipe PM Standards

(passenger cars, light trucks < 8,500 lbs. GVW)



Gasoline vehicles subject to PM standard beginning in 2004

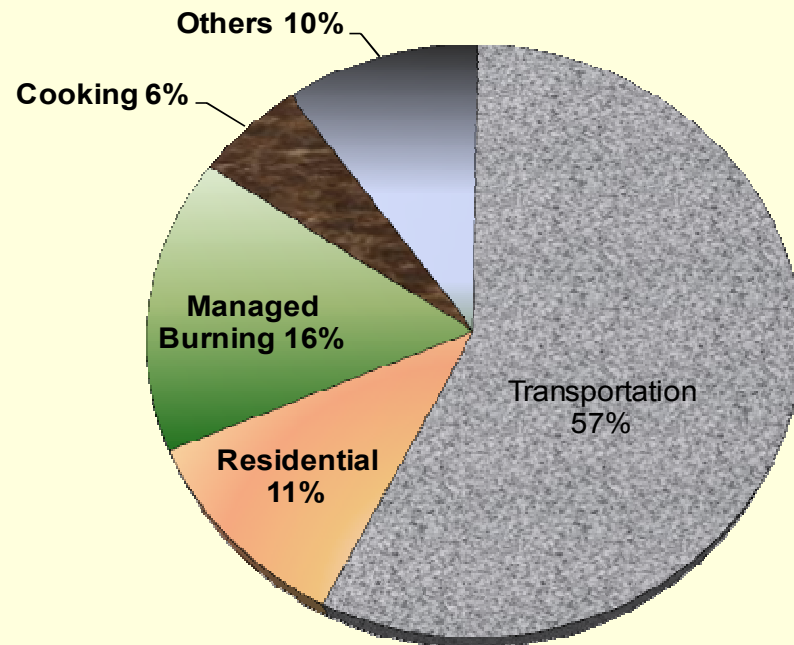
# California Burning Restrictions

- Agricultural burning
  - Sacramento Valley reduced 90% since 1990
  - San Joaquin Valley reduced 80% since 2002
- Residential burning
  - Mandatory programs in most urban areas

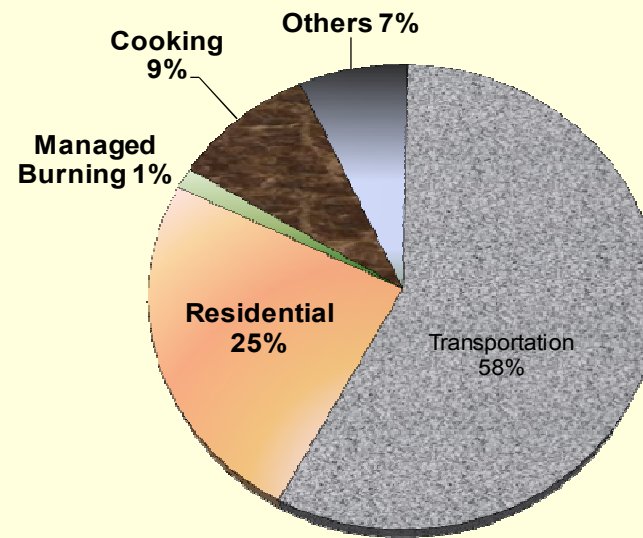
# Black Carbon Emissions

(excludes wildfires)

2010



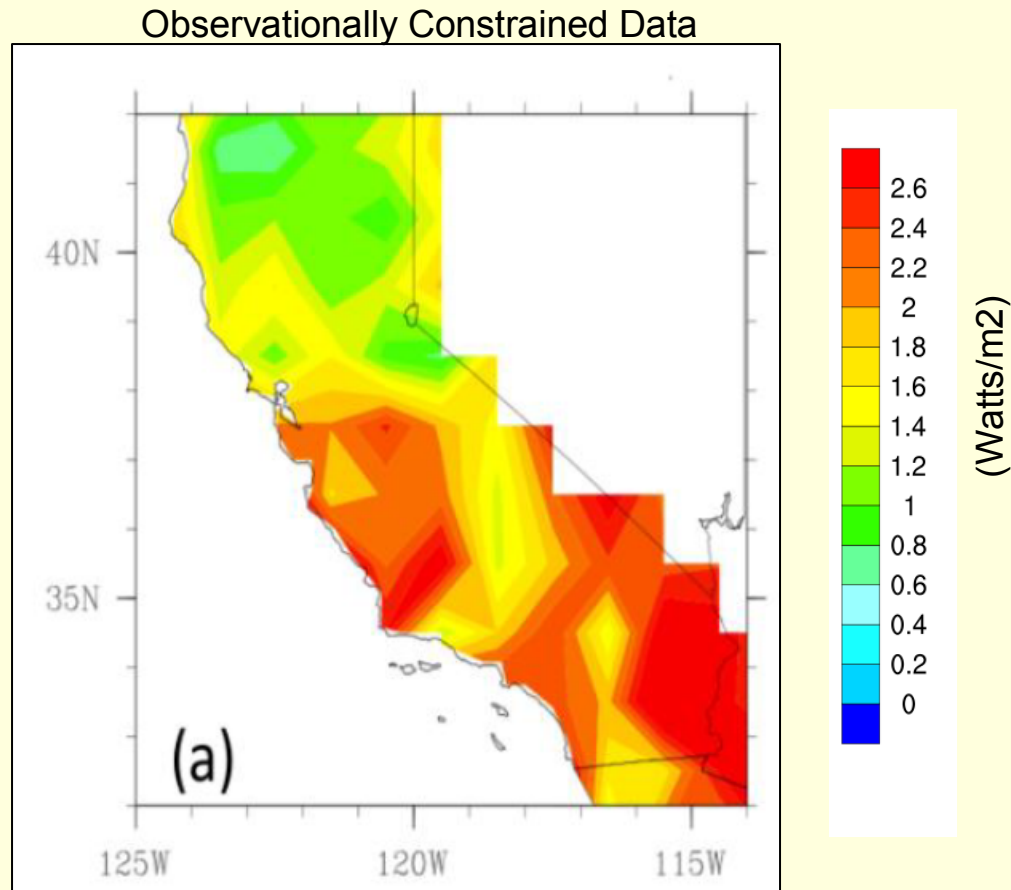
California  
BC ~ 18,200 tons per year



San Francisco Bay Area  
BC ~ 2,400 tons per year



# Climate Forcing by Black Carbon and Brown Carbon



More atmospheric heating in southern California, in part due to more diesel BC and less clouds

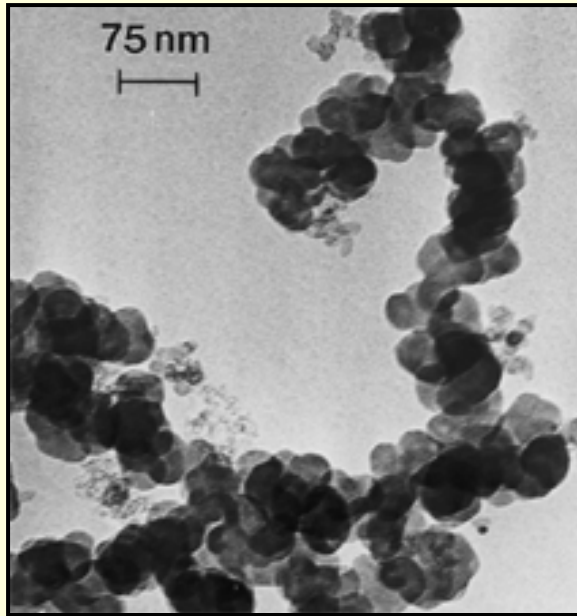
Ramanathan et al. (2013) Black Carbon and the Regional Climate of California, CARB Contract No. 08-323

# Summary

- Black carbon contributes to both air pollution health and climate change problems
- Diesel engines primary source in California
  - Factor of 3 reduction observed past 40 years
  - Factor of 3 reduction expected next 20 years
- Light-duty PM standard lowered to prevent black carbon increases from GDI engines
- Agricultural and residential burning controls likely reduced both black and brown carbon

# Backup Slides

# Properties of Black Carbon



It looks like this under a very strong microscope

- Product of combustion of fossil and biomass fuels
- Aggregate of small spheres
- Insoluble in water and organic solvents
- Strongly absorbs visible light

# Black Carbon Climate Impact

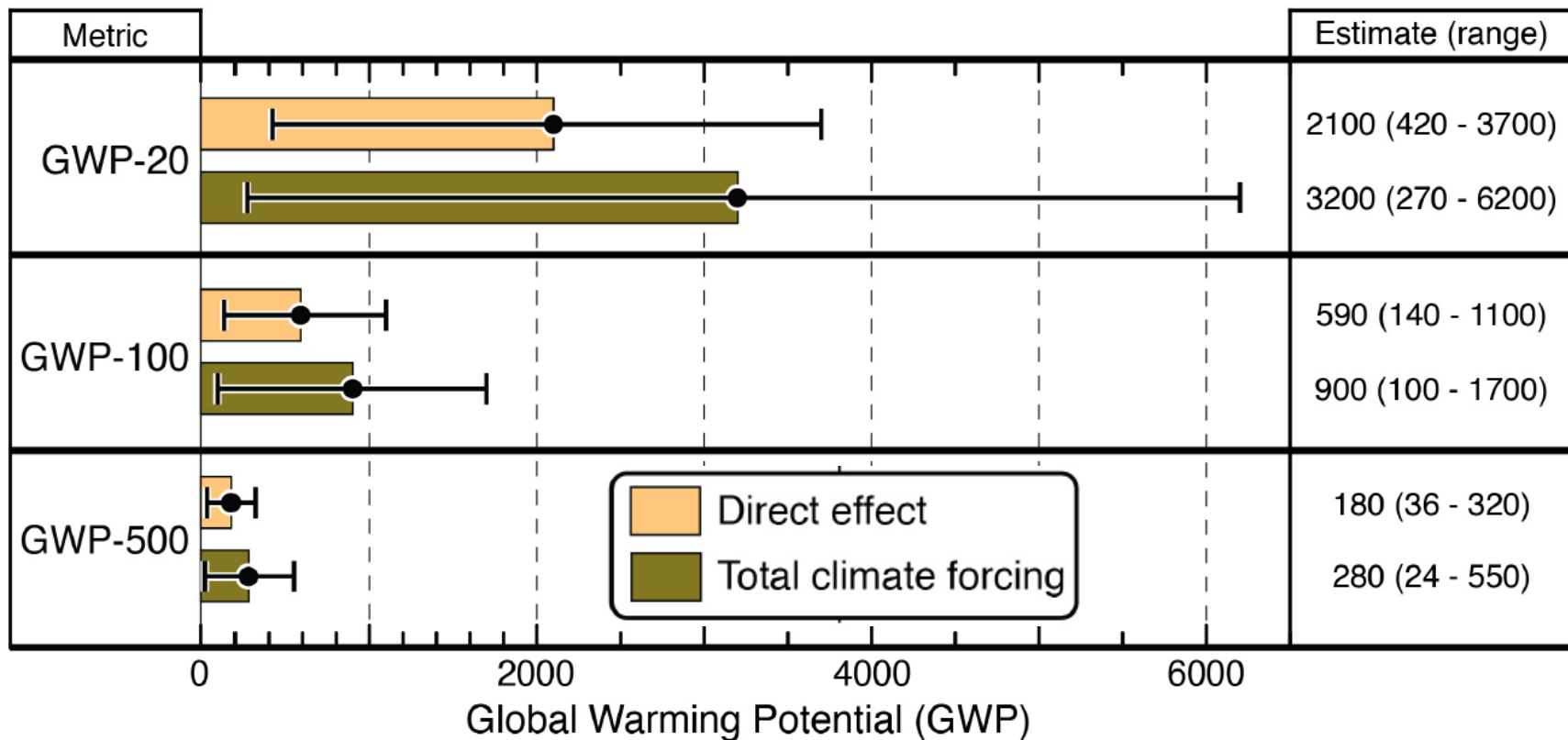
- Black carbon, like a greenhouse gas, traps heat in the atmosphere. Also,
  - When deposited on snow and ice, enhances melting rate by decreasing reflected sunlight
    - Important implications for California's water supply
  - Decreases cloud formation due to warming
  - Linked with increased Arctic ice melting and loss of glaciers



# Black Carbon Global Warming Potential Values from Research Literature

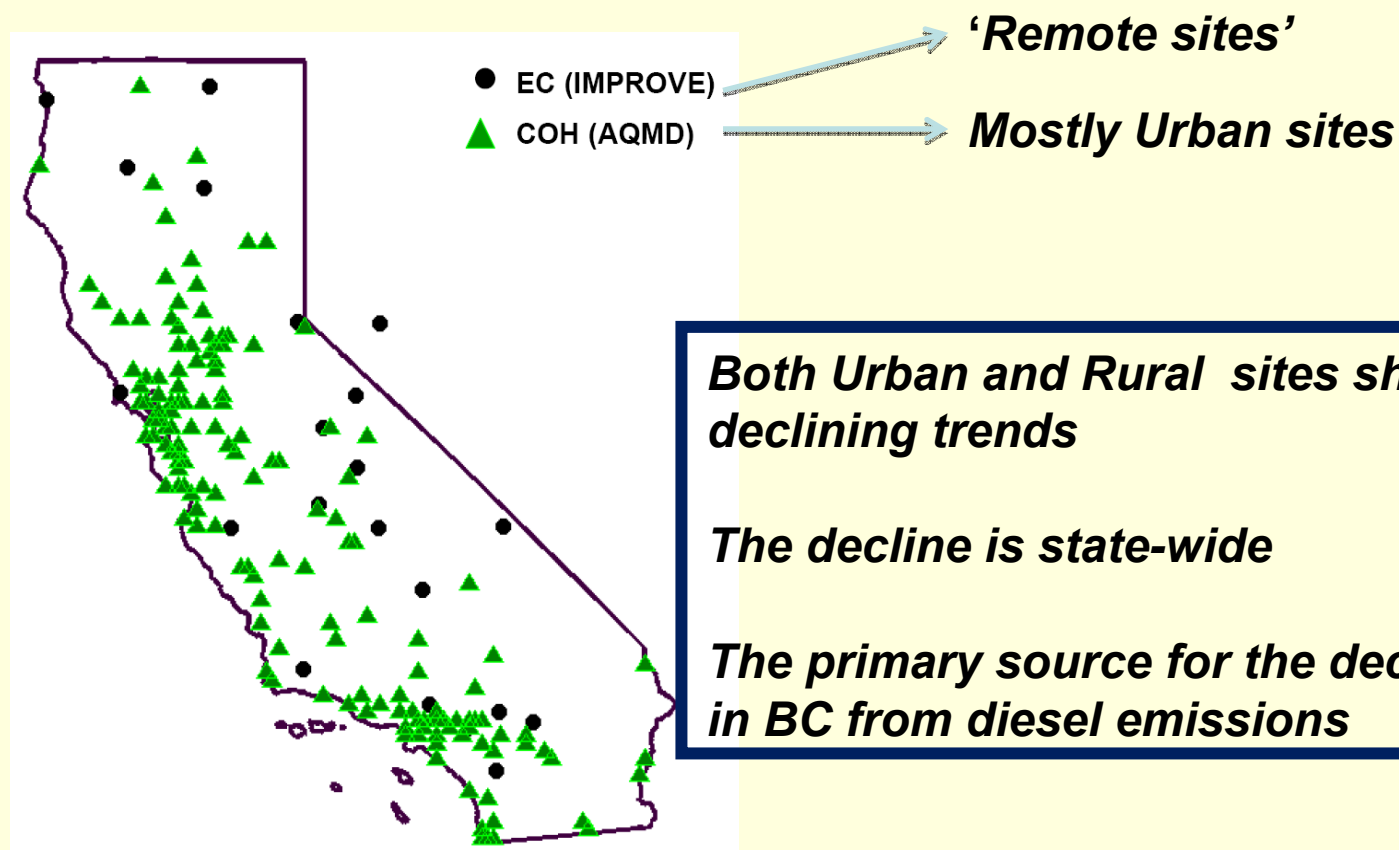
Source	Black Carbon GWP		Indirect (cloud change) forcing
	100-yr	20-yr	
Hansen et al, 2007	~500	~2,000	Yes
Bond and Sun, 2005	680	2,200	No
Jacobson, 2007	840–2,240	2,530	Yes
Reddy and Boucher 2007	480	--	No
Rypdahl et al, 2009	830	2,900	No
Fuglestad et al, 2010	460	1,600	No
Jacobson, 2010			
Fossil □ Fuel Soot	2900–4600	4500–7200	Yes
Biofuel Soot	1060–2020	2100–4000	
Bond et al, 2013	900 (120–1,800)	3,200	Yes

# GWP Values for Several Time Horizons for BC Climate Forcing (Bond et al. 2013)



Bond et al, Journal of Geophysical Research-Atmospheres, doi10.1002/jgrd.50171, published January 15, 2013

## Black Carbon Trends in California: Detection and Attribution



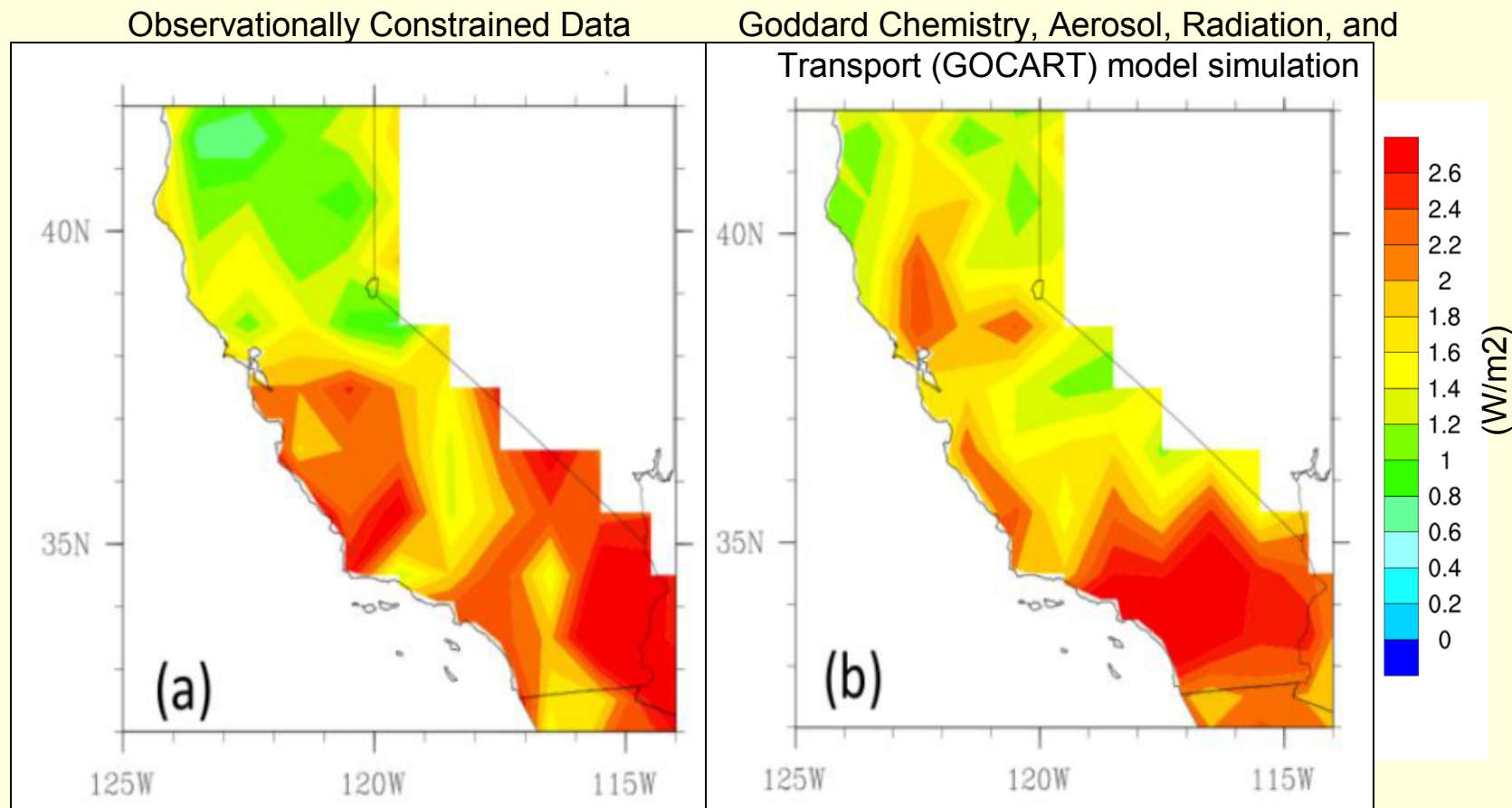
***Both Urban and Rural sites show consistent declining trends***

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

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



# Climate Forcing by Black Carbon and Brown Carbon



Ramanathan et al. (2013) Black Carbon and the Regional Climate of California,  
CARB Contract No. 08-323

# BC Equivalence Scenarios

Source	Activity	
Post 2007 HD Diesel	Sacramento to San Diego (~500 miles)	
Light Duty Gasoline	Sacramento to Stockton (~50 miles)	
Pre 2007 HD Diesel	Barely out of Sacramento (~5 miles)	
Charbroiling	8 hamburger patties (1/4 lb each)	
Woodburning	Burning 1 kg pinewood	