Methane, Black Carbon, Ozone and Technology Forcing: Synergistic Strategies for Clean Air and Climate

Armond Cohen
Clean Air Task Force (USA)

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Main points

- Methane and black carbon are significant ozone, PM, and climate drivers and should receive much greater policy focus.
- To move multi-emissions clean technology, CO_2 cap and trade schemes should be supplemented by technology forcing.
- More focus today on first topic.

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Why focus on Methane, Ozone and Black Carbon?

- **Tropospheric ozone, methane, black carbon, CFC replacements and nitrous oxides all warm the climate.**
- **Tropospheric ozone, methane, black carbon have a much shorter atmospheric lifetime than CO_2 -- *reductions can influence temperature much faster.***
- **CO_2 must remain central to long-term climate strategy but focus on short-lived agents could buy us some critical time and help to avoid "dangerous anthropogenic interference."**
- **For regions that are particularly vulnerable – namely the Arctic – reductions of these agents may limit the rate of warming and the speed of summer ice sheet disintegration.**
- **There are substantial health benefits from reductions as well.**
- **Unlike CO_2, reductions of these agents are generally more amenable to end of the pipe fixes.**

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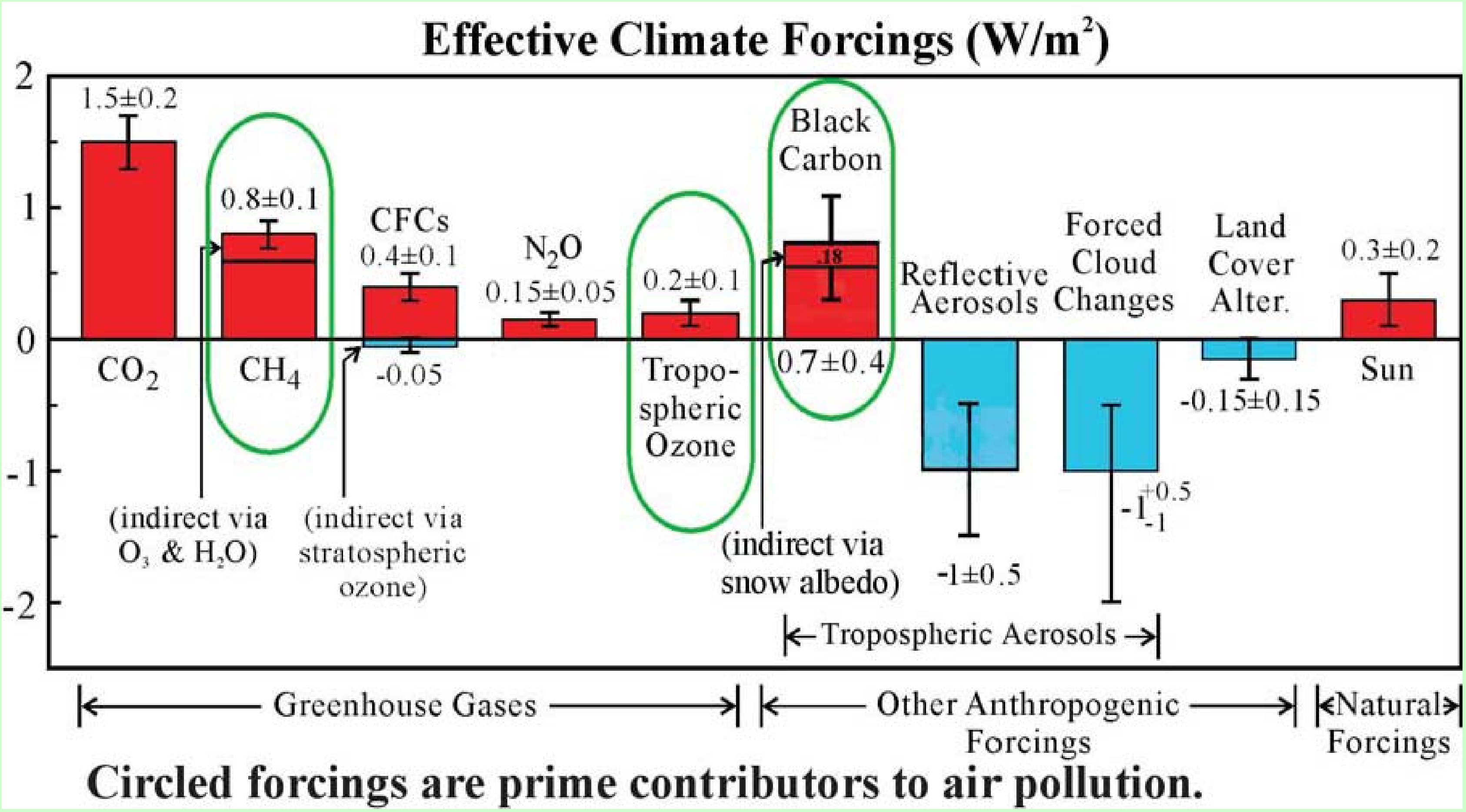
Non-CO2 forcers have had larger collective short-term impact on climate than CO2 alone



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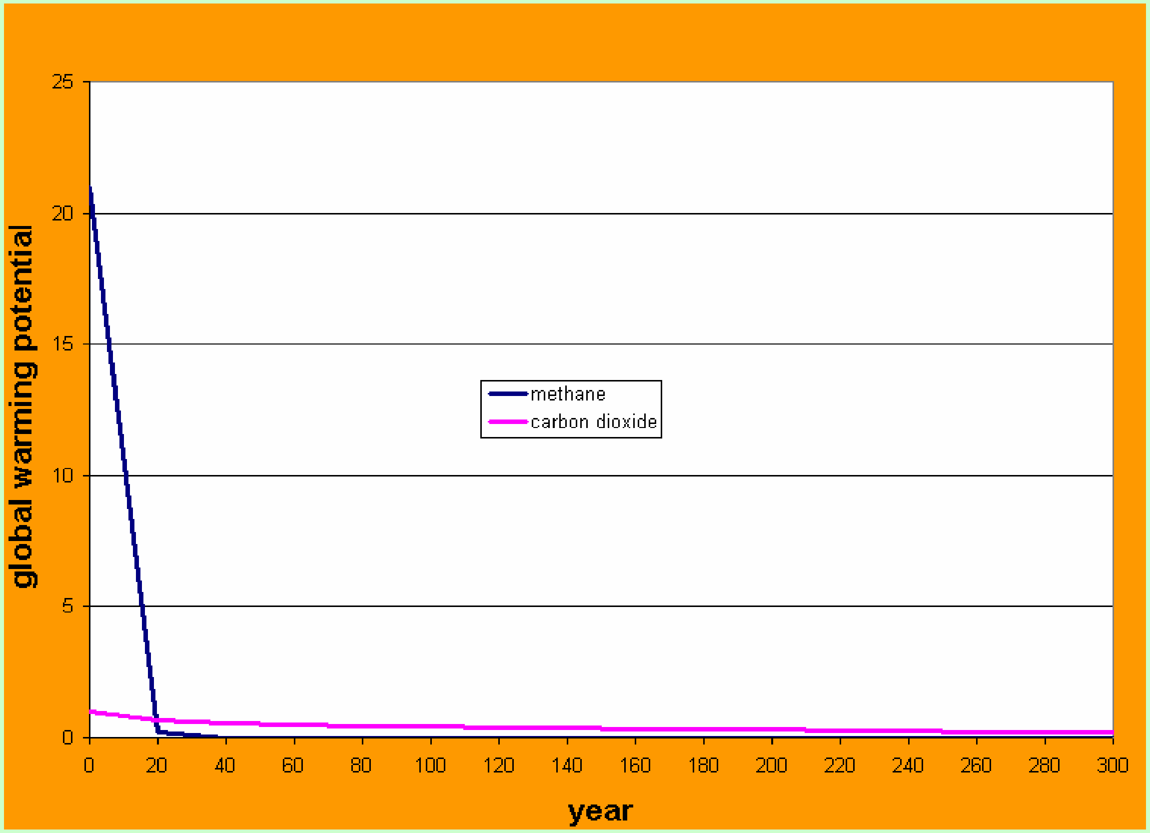
Hansen, 2005

Methane has short atmospheric lifetime

- Molecule for molecule is 23 times more potent than CO_2
- Has a lifetime of 8-12 years.
- Methane contributes to tropospheric ozone production and water vapor, which enhances the greenhouse effect so the benefits of reductions are magnified.
- Sources most amenable to reductions are likely to be from fossil fuels (coal mining, drilling and use of natural gas), municipal solid waste, manure management and perhaps livestock management.
- US EPA estimates that by 2050 a 40-60 % global reduction from a projected baseline is plausible.

Lifetime and global warming potential of methane and carbon dioxide



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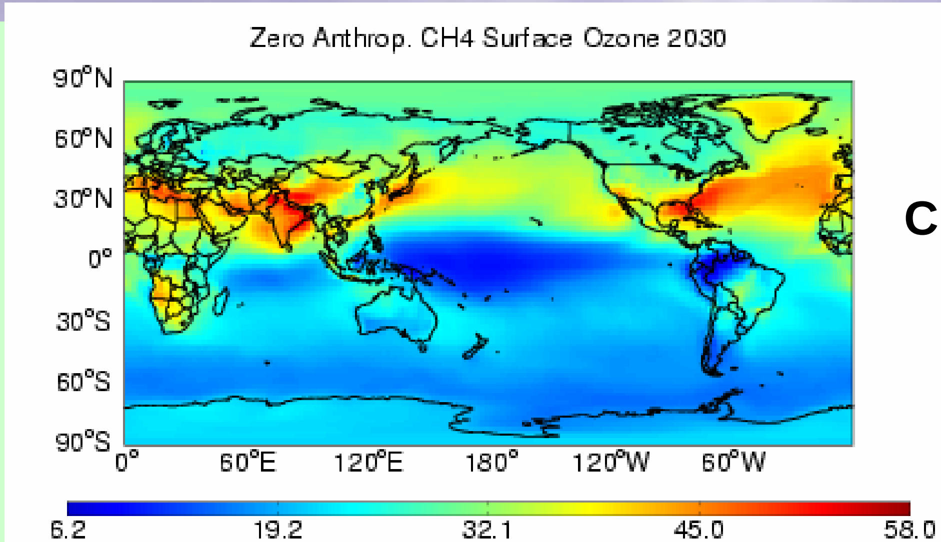
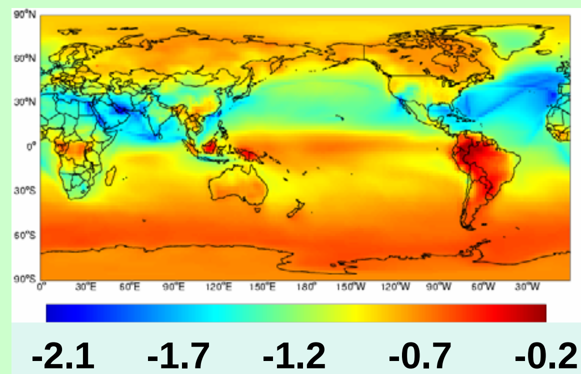
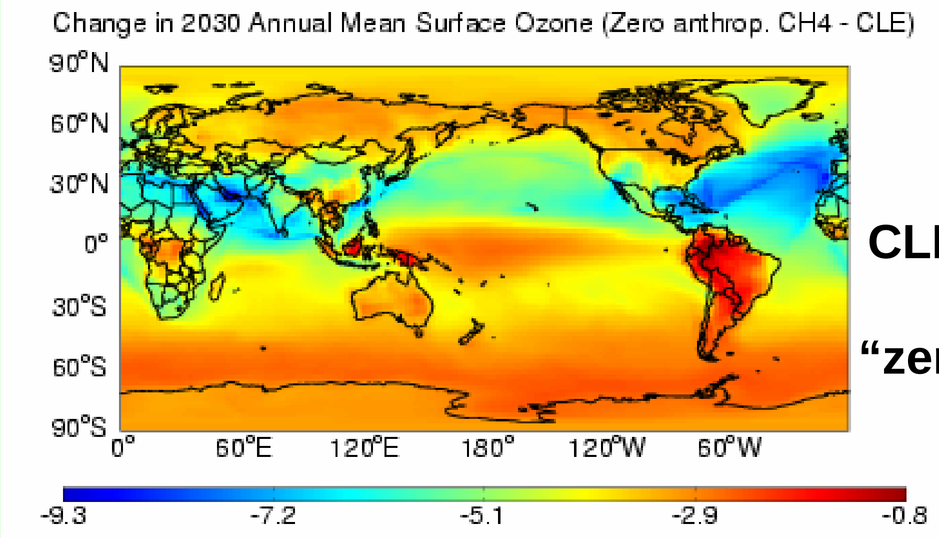
Reduction in methane has global ozone benefits



CH_4 = 700 ppb

Difference of
CLE (CH_4=2090 ppb)
and
Scenario B = 1730 ppb
Surface (ppbv)





Difference of
CLE (CH_4=2090 ppb)
and
"zero CH_4" = 700 ppb

Spatial pattern of O_3 response is entirely independent of how we treat methane (depends on NO_x)

Preliminary work, Fiore, et.al. 2007.

Preliminary Analysis: 2030 Avoided Premature Mortalities by World Region from a 42% Methane Reduction

Per Million People

	Total	C & R	Total	C & R
N. America	2180	1370	5.95	3.74
L. America	2710	1460	3.06	1.65
W. Europe	3650	2420	8.03	5.31
E. Europe & FSU	3210	2810	7.08	6.19
SE. Asia (India)	16040	9370	7.60	4.44
Africa	12130	3640	10.54	3.16
E. Mediterranean	6510	3420	8.27	4.35
E. Asia (China)	9770	6720	4.88	3.36
W. Pacific	990	610	6.14	3.79
Total	57200	31800	6.83	3.80

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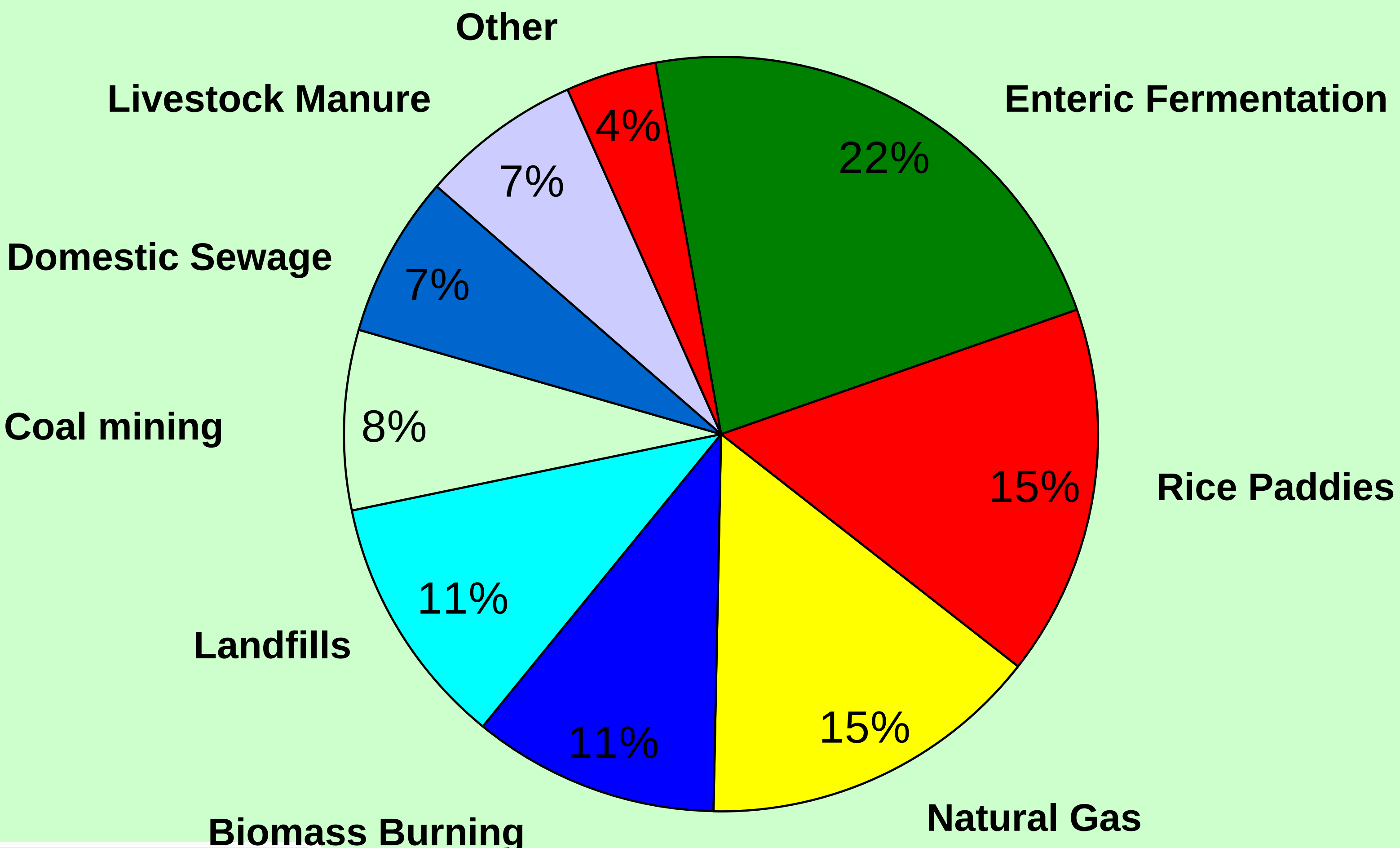
Global Methane Emissions



Total (1990) = 2,150 MMTCE

Source:
US EPA

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Tropospheric ozone

- Has a lifetime of about a week.
- Reduction strategy is complicated by the fact that reducing NOx – which drives much of the O3 peaks -- results in increasing the lifetime of methane.
- Reductions in methane will result in less tropospheric ozone and less climate forcing, but NOx reductions are needed for the deep O3 cuts.

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Black carbon

- Black carbon (BC) is a product of incomplete combustion of diesel fuels, coal, biofuels and biomass burning. It has a 100 year global warming potential (GWP) of 500-680* and a GWP_{20} of 2000-2200.*
- Lifetime of days to weeks.
- No source just emits BC. Instead it is co-emitted with other aerosols and gases that have positive and negative climate impact – namely organic carbon, nitrogen oxides and sulfur dioxide.
- In the atmosphere, it affects climate both directly and indirectly.
  - Directly, the dark colors absorb heat, which is then transferred around the globe.
  - Indirectly, it affects clouds, which can shade and cool the earth's surface.
  - When deposited on light surfaces such as Arctic ice, energy absorption is increased.
- Added together, these processes result in net warming.

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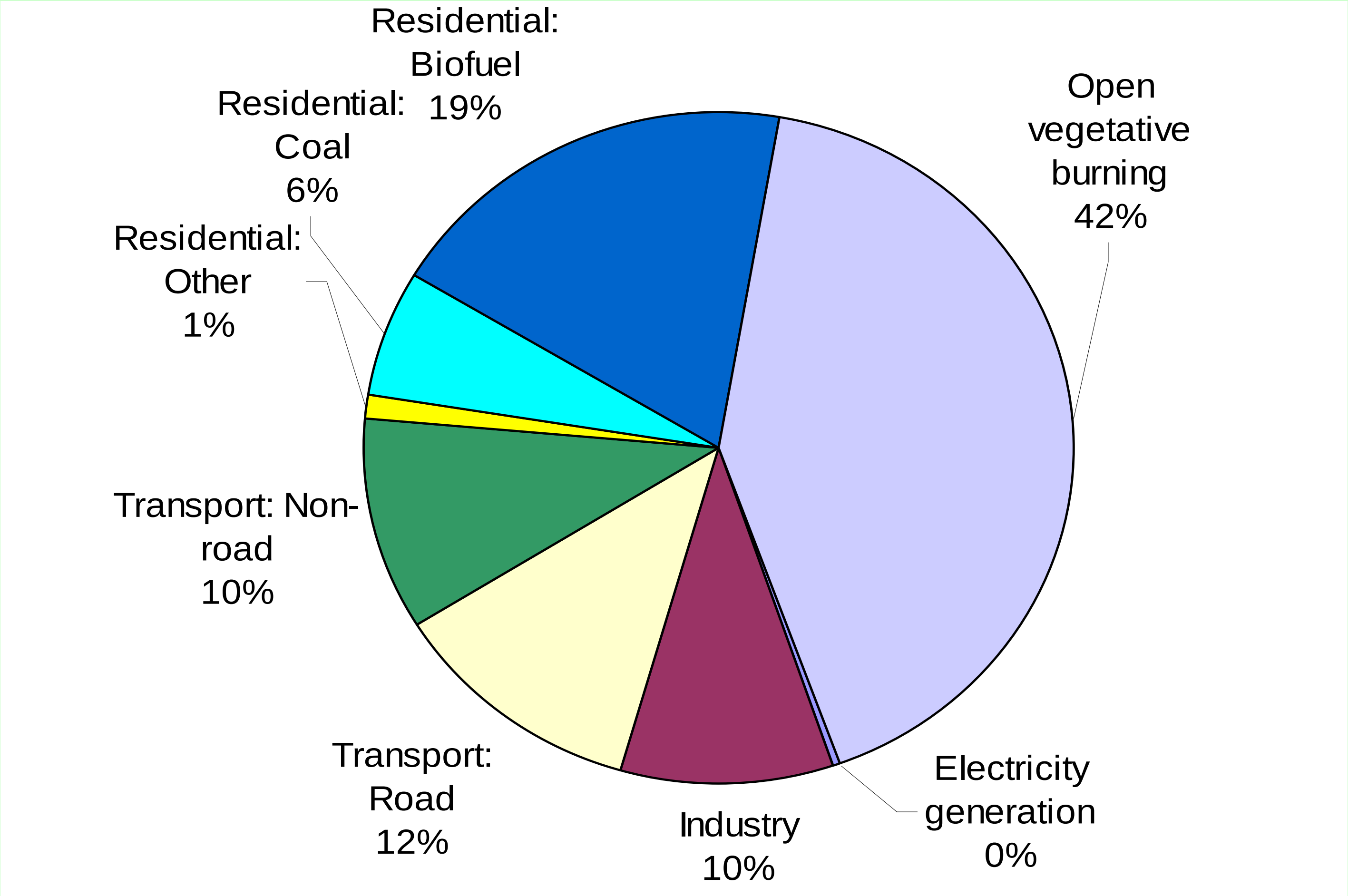
**Estimates from Hansen and Bond*

Global BC emissions



Bond, 2004

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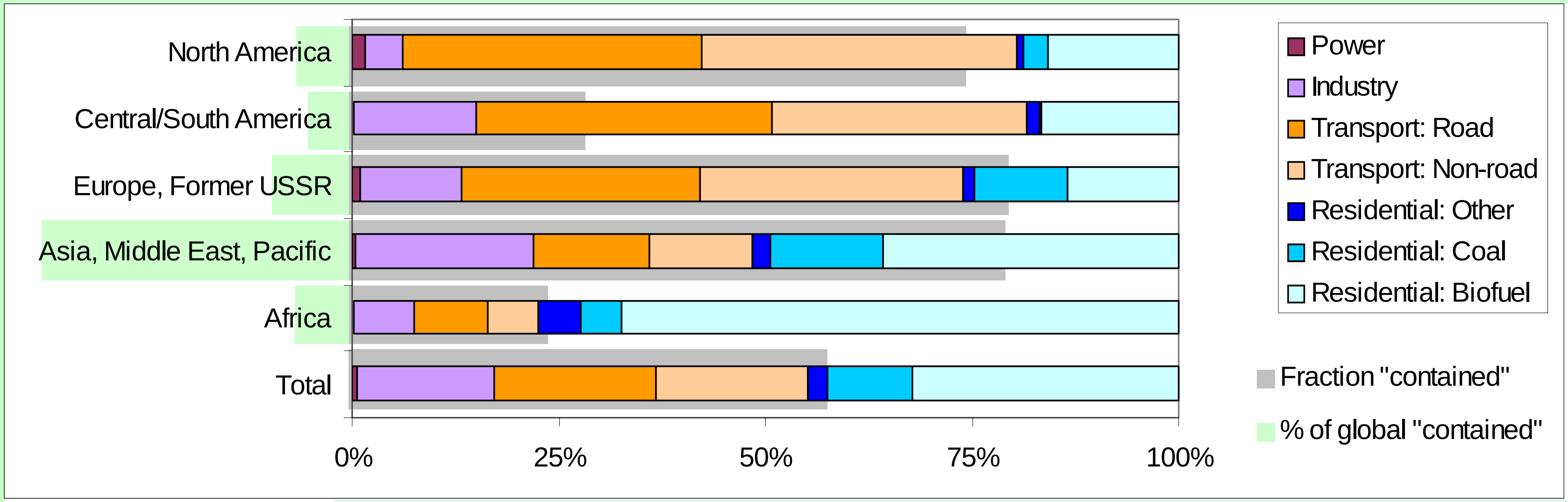
Major sources/regions of black carbon

Sources: Solid fuels in residential sector, industry, transportation/diesel. These sources have emit a higher proportion of BC when compared to OC in their emissions.

Regions, in order or importance: Asia/Middle East; Europe and Former Soviet Union; N. America, Africa; Central/South America

Note: Energy-related only– excludes open burning (~equal)

Black carbon



Bond, Streets et al., JGR 109, D14203, doi:10.1029/2003JD003697

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Super emitters are disproportionate BC contributors

- **Normal vehicle with current Euro standards: 0.8 g BC/kg fuel**
- **Superemitting vehicle: 6.8 g BC/kg fuel**
- **If 5% superemitters: Fleet average = 1.1 g/kg**
- **One-third of emissions come from 5% of the vehicles**

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Bond, presentation Arctic workshop, January 7, 2007, NYC

Could Reductions in Black Carbon, Methane, and Ozone Slow Arctic Climate Change and Ice Melt?

- **Initial meeting of 28 Polar air pollution experts, New York, 8-9 January 2007 to discuss this question**
- **Focus on:**
  - **BC Darkening Ice**
  - **PM → Polar Haze**
  - **Ozone**
- **Meeting summary and EOS article in preparation: short summary of themes follows**

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Deposited black carbon changes snow and ice reflectance (albedo)

- Soot deposited on snow and ice absorbs more of the sun's energy and warmth than an icy, white surface that reflects sunlight. Such soot deposition can both warm the air above the ground surface and also contribute to snow and ice melting. These effects suggest that soot may play a particularly important role in arctic climate change.
- Current modeling suggests Asia, Europe, Russia and local Arctic sources are the major contributors of black carbon in the Arctic.
- Current fieldwork underway by University of Washington to measure extent of Arctic black carbon deposition and albedo impact. Greenland and Canada measured last field season; Russia to be measured in 2007

Without soot, rays reflected

With soot, rays (and heat) absorbed

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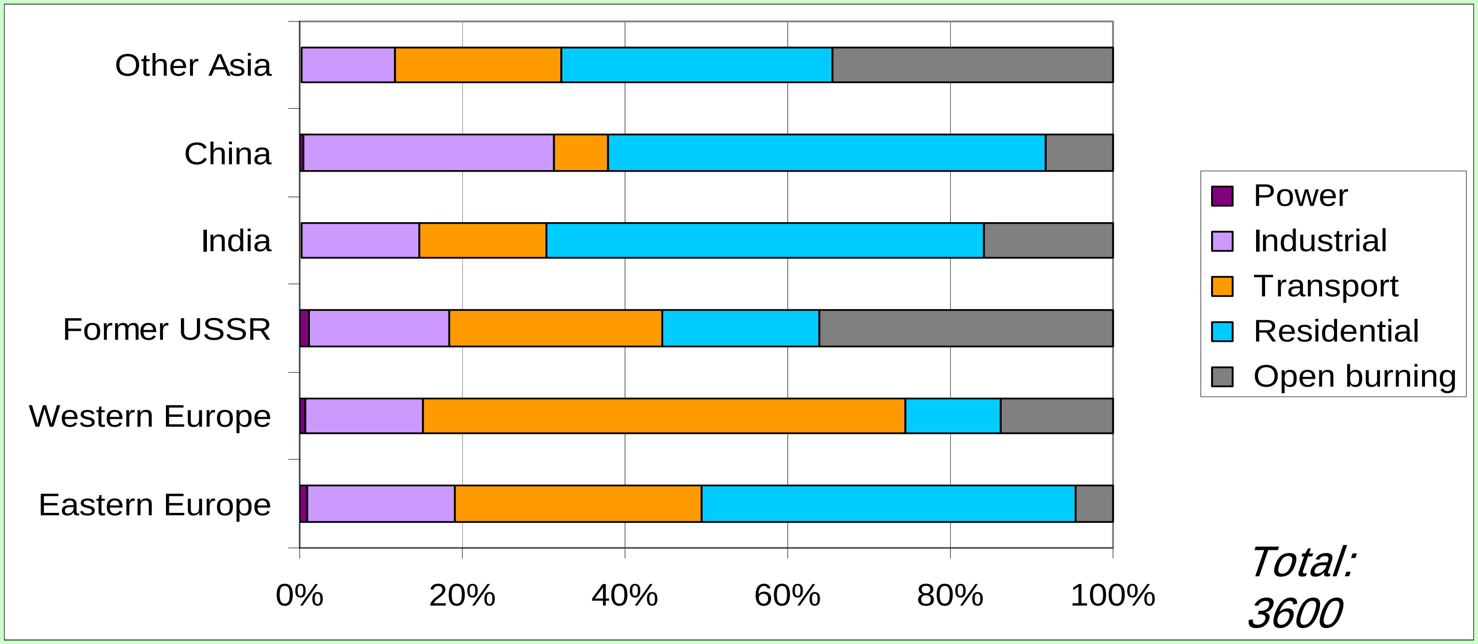
NASA, Black Soot and Snow: A Warmer Combination, 2004

BC reaching the Arctic by source and source region



Total: 3600 Gg

Note this does not indicate the relative contribution of each source region

Bond, presentation Arctic workshop, January 7, 2007, NYC

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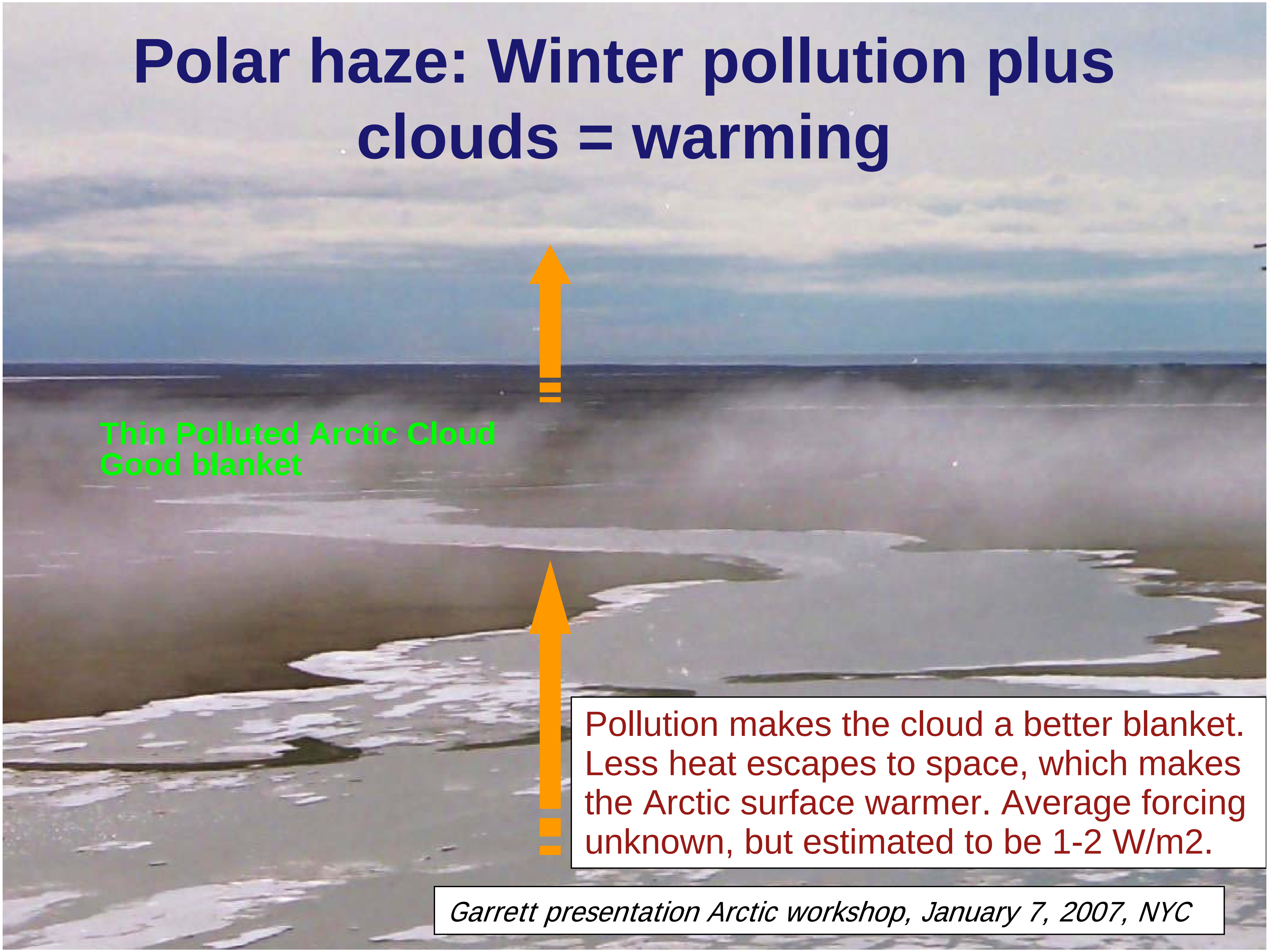
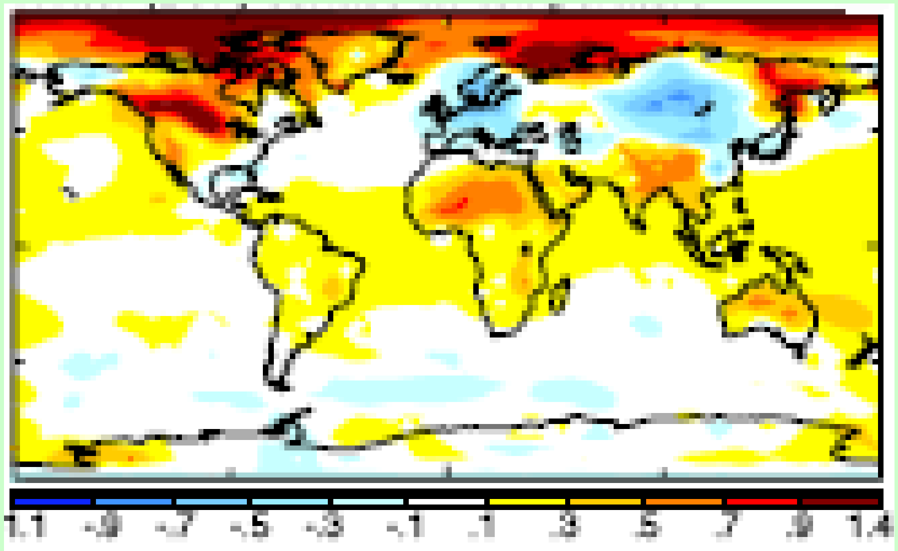

Polar haze: Winter pollution plus clouds = warming
Thin Polluted Arctic Cloud
Good blanket
Pollution makes the cloud a better blanket. Less heat escapes to space, which makes the Arctic surface warmer. Average forcing unknown, but estimated to be 1-2 W/m2.
Garrett presentation Arctic workshop, January 7, 2007, NYC

Tropospheric ozone: enhanced effect in Arctic in non-summer months

- **Climate response to tropospheric ozone increases is large in the Arctic during fall, winter, and spring when ozone's lifetime is comparatively long and pollution transported from mid-latitudes is abundant.**
- **Climate simulations indicate that tropospheric ozone increases have potentially contributed to the rapid 20th century Arctic warming, about 0.3°C annual average and about 0.4-0.5°C during winter and spring.**
- ***Ozone concentrations in Arctic could substantially increase in Arctic with increased marine shipping due to ice free passageways.***

Surface temperature trends (°C/century), winter 1900-2000, in response to tropospheric ozone changes



Shindell, D., 2006.The role of tropospheric ozone increases in 20th century climate change. J. Geophys. Res.

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Black carbon has regional climate effects

- **Black carbon can affect regional climate by absorbing sunlight, heating the air and thereby altering large scale atmospheric circulation and the hydrologic cycle.**
- **Large amounts of black carbon and other particles are causing changes in precipitation and temperatures over China and may be at least partially responsible for the tendency toward increased floods and droughts in those regions over the last several decades.**

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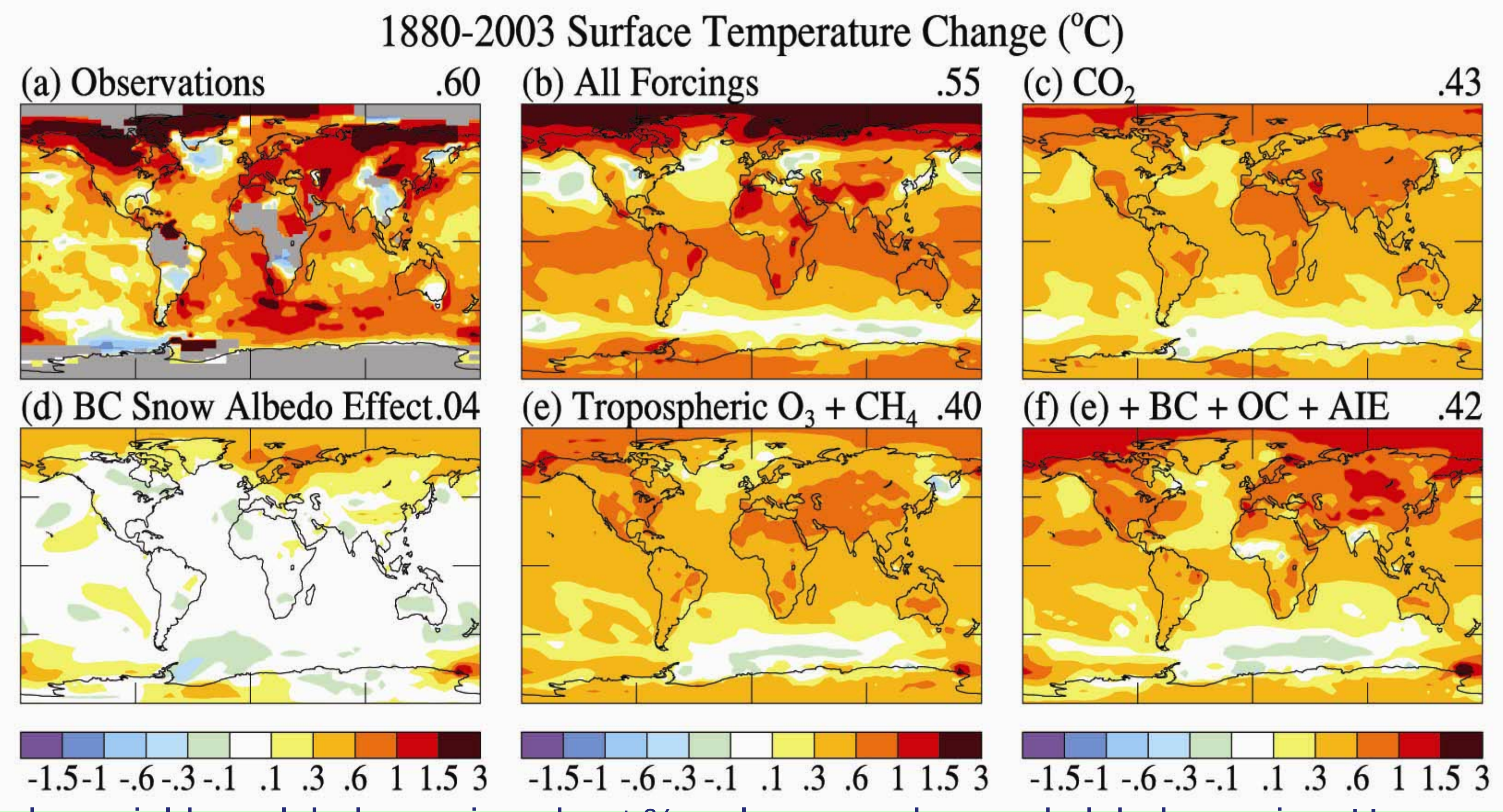
Surface Temperature Changes from Different Climate Forcings



CO2 alone yields a global warming about ¾ as large as observed global warming. However, the global response to the sum of the "air pollutants" (tropospheric O3, CH4, BC, OC and the aerosol indirect effect (AEI) of BC and OC) is as large as that for CO2. In the Arctic warming due to pollutants, exceeds the Arctic warming due to CO2.

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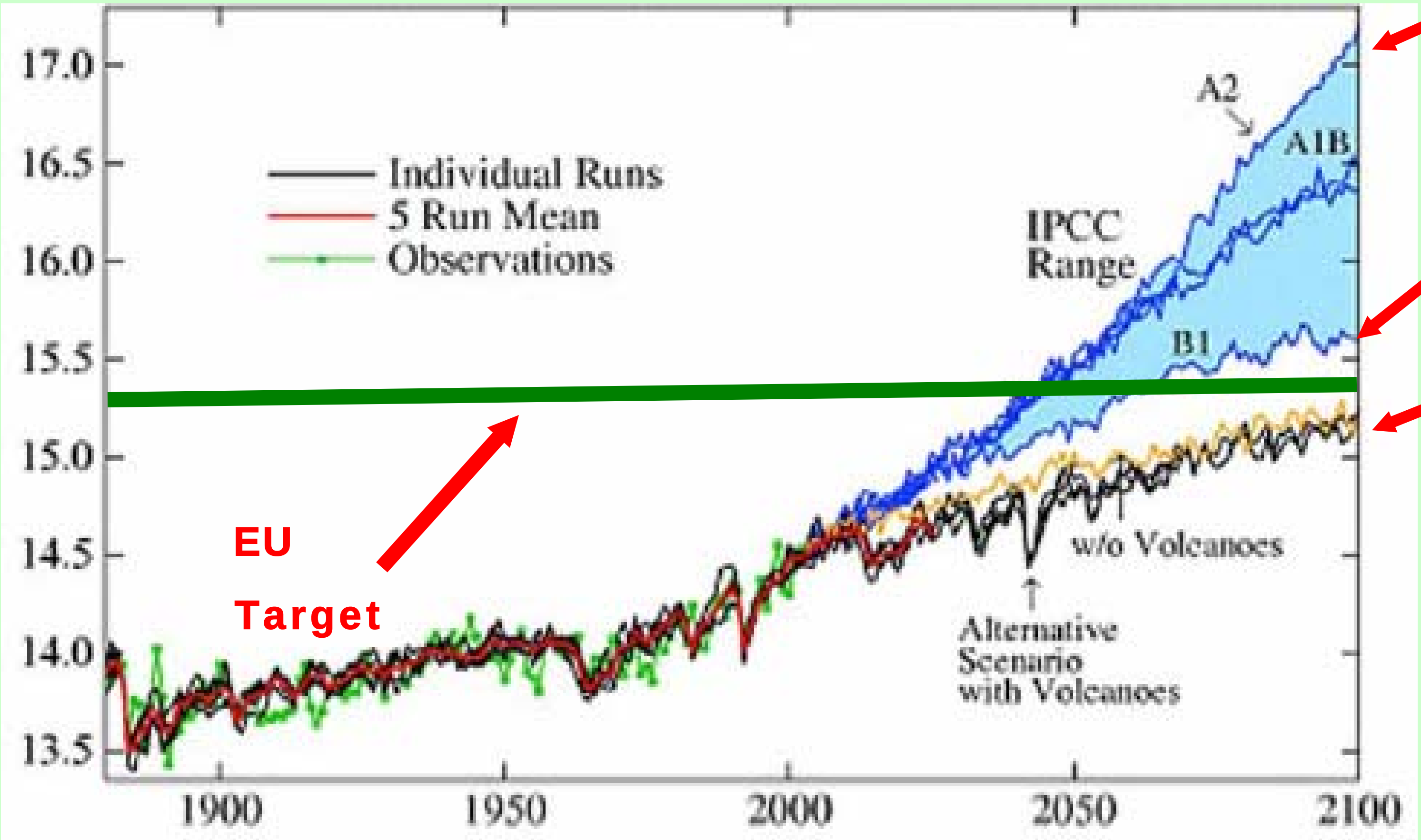
Hansen, et. al, 2007 submitted

BC-CH4-O3 reductions could make a difference to climate



CO_2 and less aggressive non-CO_2 reduction scenarios

Scenarios with more aggressive CH_4 and other non-CO_2 reductions

Source: NASA GISS

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Policy Implications: Methane

- **Focus directly and aggressively on global methane reduction for clean air and climate reasons.**
  - **So far methane reduction efforts have been largely voluntary or a by-product of GHG trading system.**
- **Possible approaches:**
  - **Technology forcing commitments (e.g. performance standards for coal mining, agriculture waste).**
  - **Multilateral global "buy down" fund for methane reductions.**

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Policy implications: Black carbon

- State and multilateral level commitments for accelerated black carbon reductions, focusing on industrial sources, land-based and marine diesel engine retrofits, residential cook stoves, vegetation burning.
- Accelerated research program on black carbon sources/impacts for Arctic.
- Multilateral commitments to curb black carbon emissions affecting Arctic.

Technology forcing regulation: another important synergistic policy

- **CO_2 cap and trade schemes unlikely to force big clean technology leaps in the near-mid term:**
  - **Uncertain price signals**
  - **Relatively low price signals (example: $30/ton price threshold for coal gasification/carbon sequestration unlikely to be consistently reached)**
  - **Much global offset money likely will be spent for some time on inexpensive low technology substitutes (recent China CFC example).**

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Examples of important climate/clean air technology forcing policy

- **British Columbia/EC proposal to mandate carbon capture and storage for all new coal plants by 2015-2020.**
- **Recent Australia proposal to ban sale of incandescent light bulbs.**
- **EU and US state CO2 car tailpipe requirements.**
- **US proposals to require coal gasification as BACT (for clean air as well as climate).**

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