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The Role of Short-Lived Forcers Toward Stabilizing Climate

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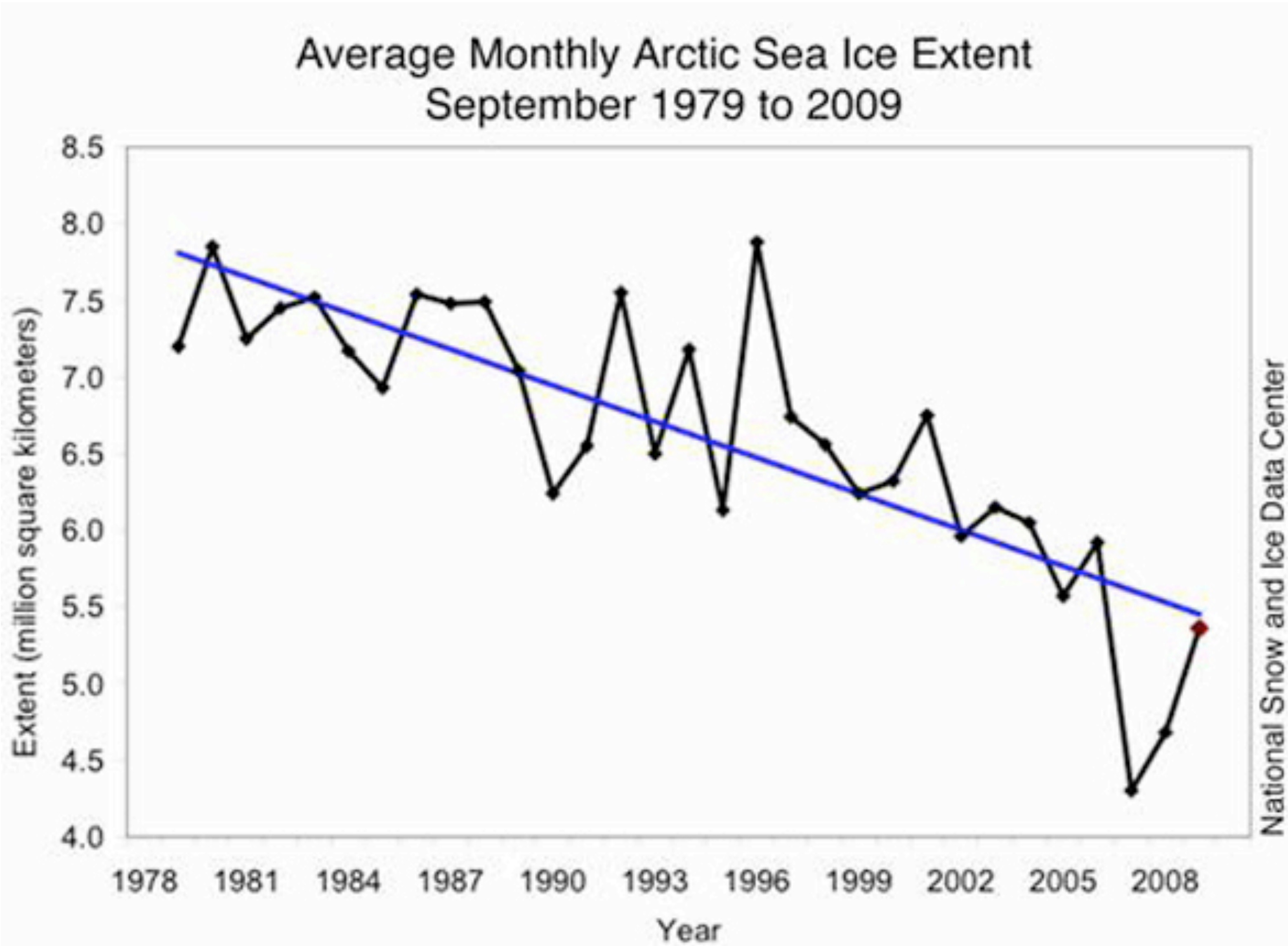
SENIOR SCIENTIST
MARCH 4, 2010



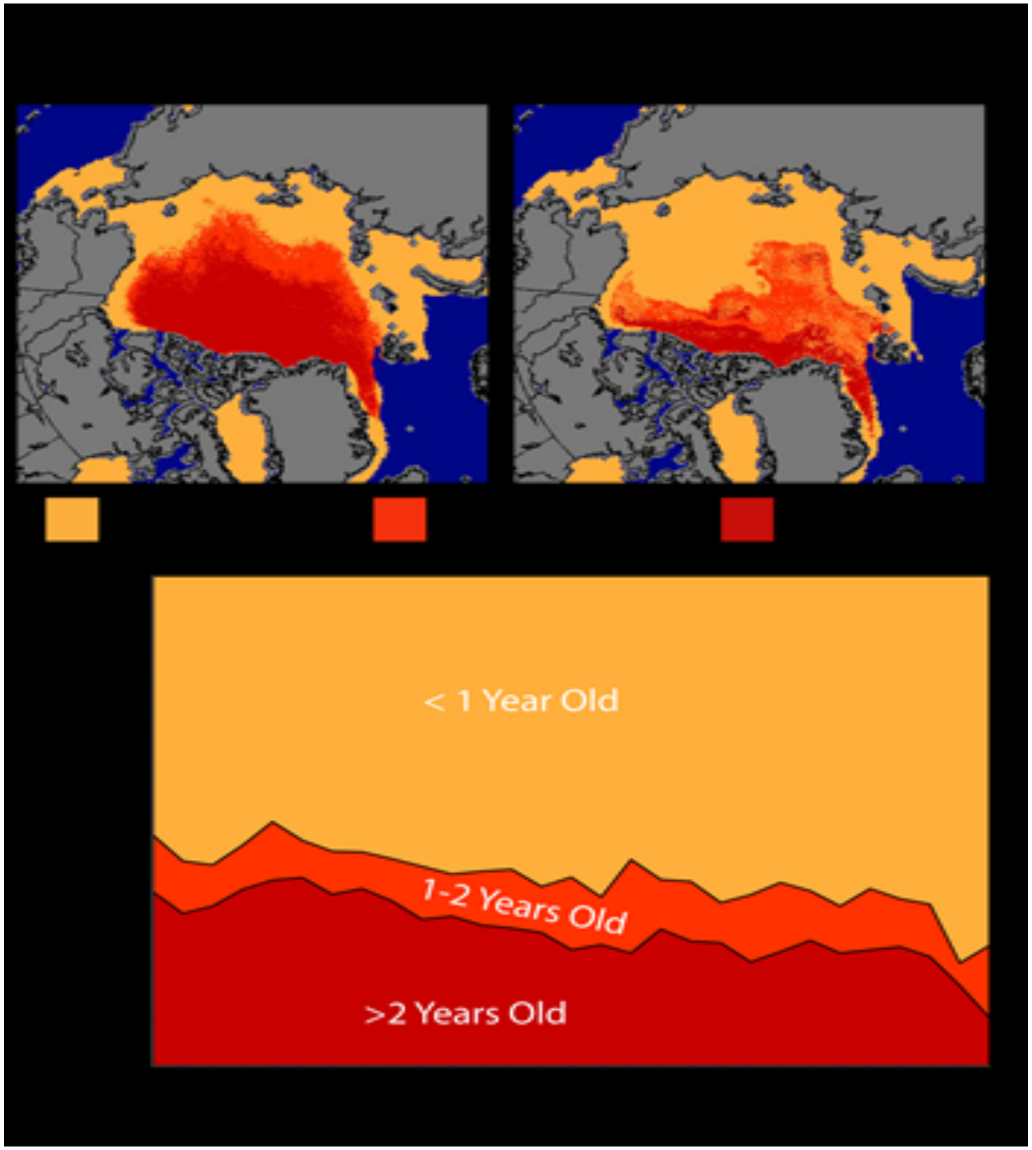


Why do we care about stabilizing climate?

Arctic Sea Ice Extent is Declining

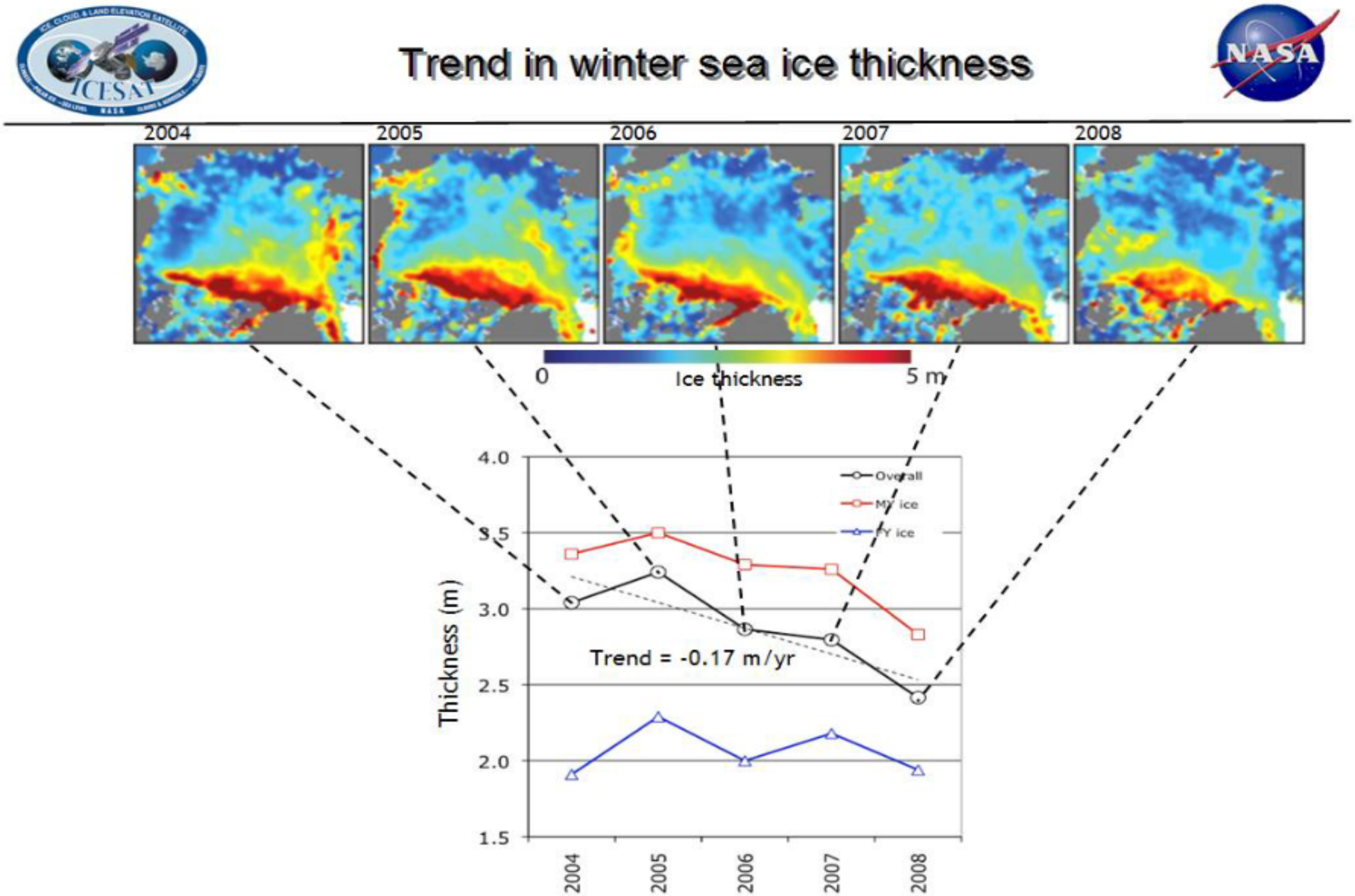


…along with multi year Arctic sea ice

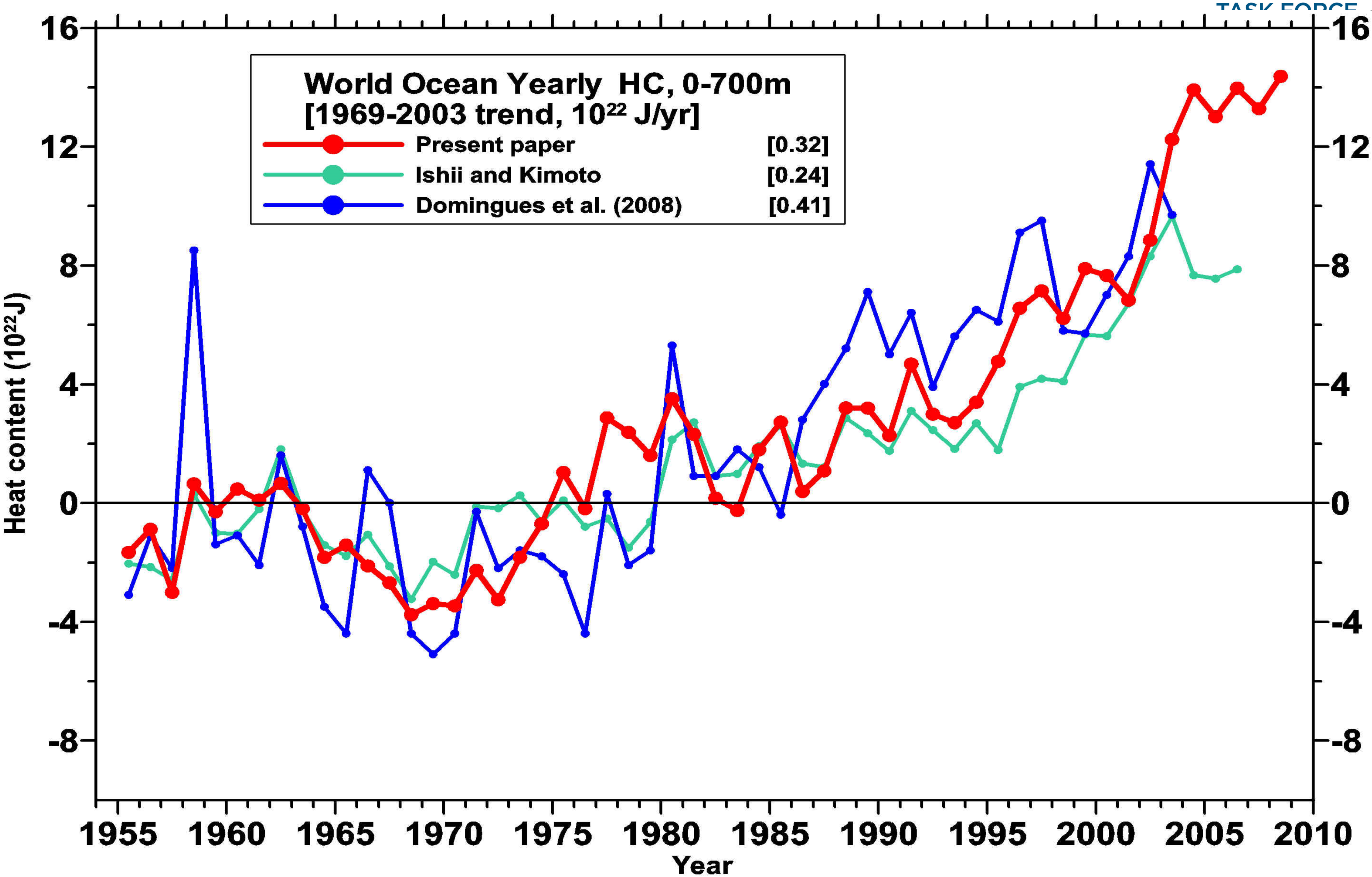


National Snow and Ice Data Center

and winter ice thickness

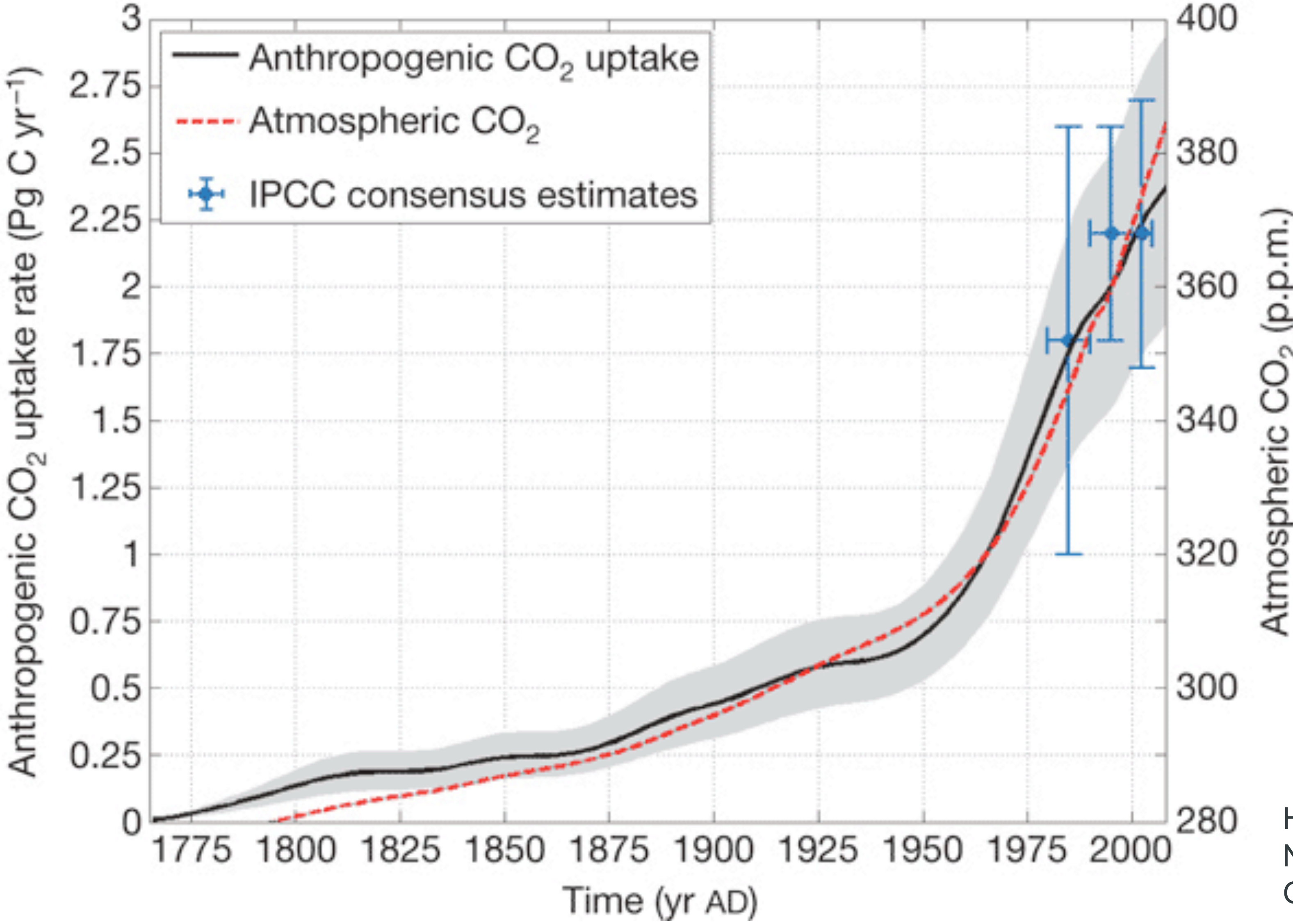


Heat content in oceans is increasing



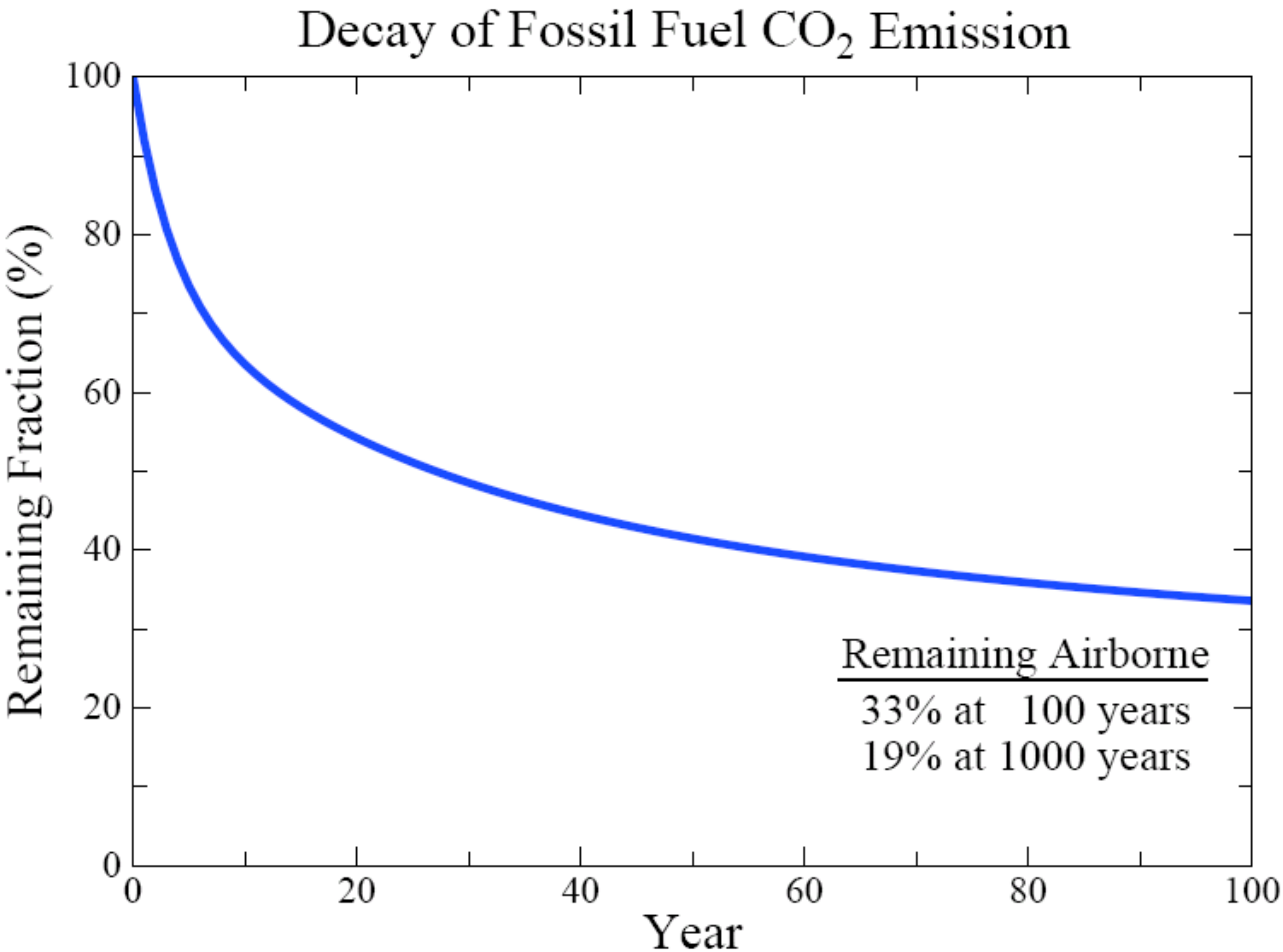
Domingues et al., *Nature* 2008

Oceans may be struggling to serve as a sink for rising CO_2 emissions

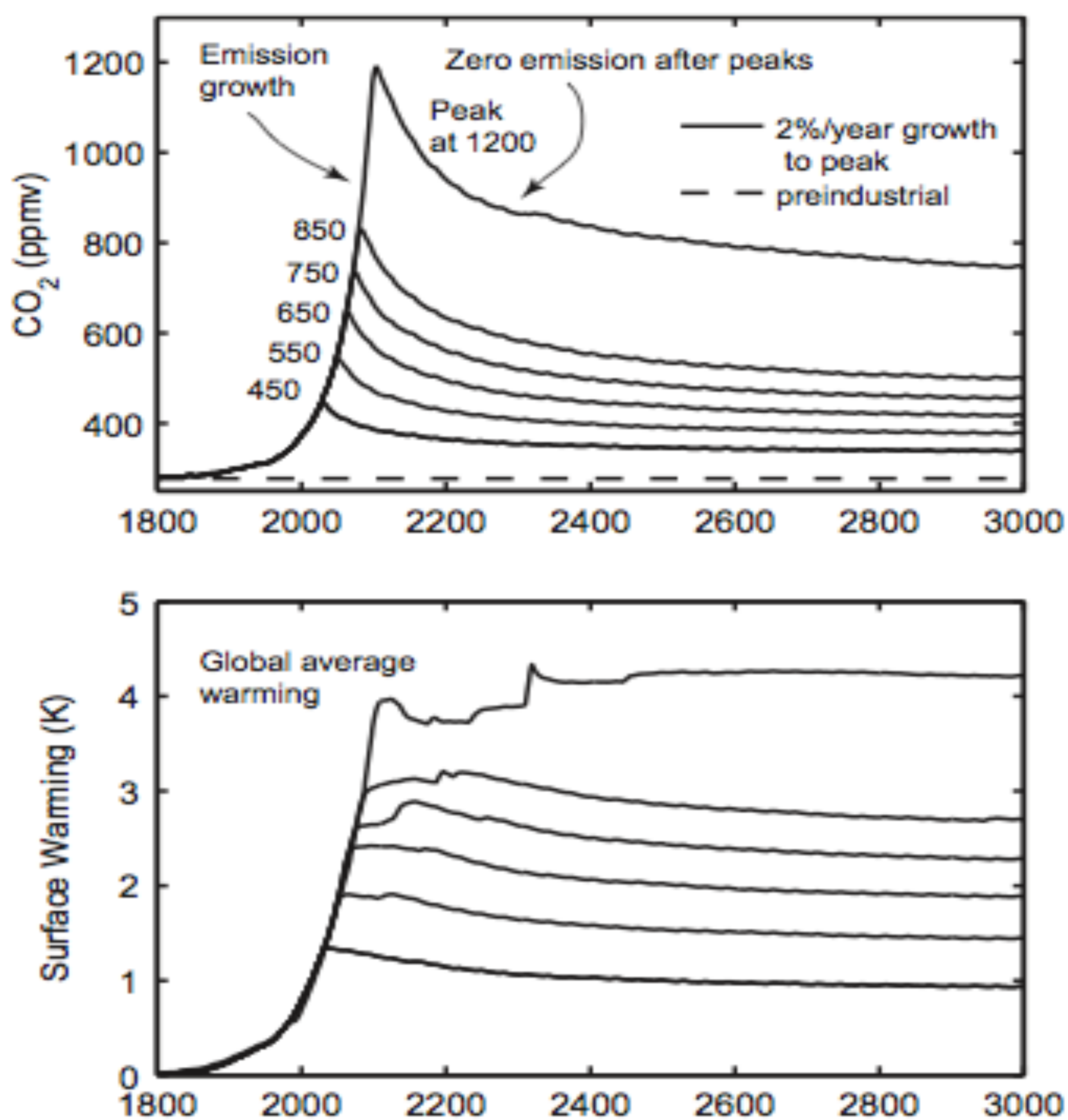


Hall, NASA/ GISS

CO_2 has a very long lifetime

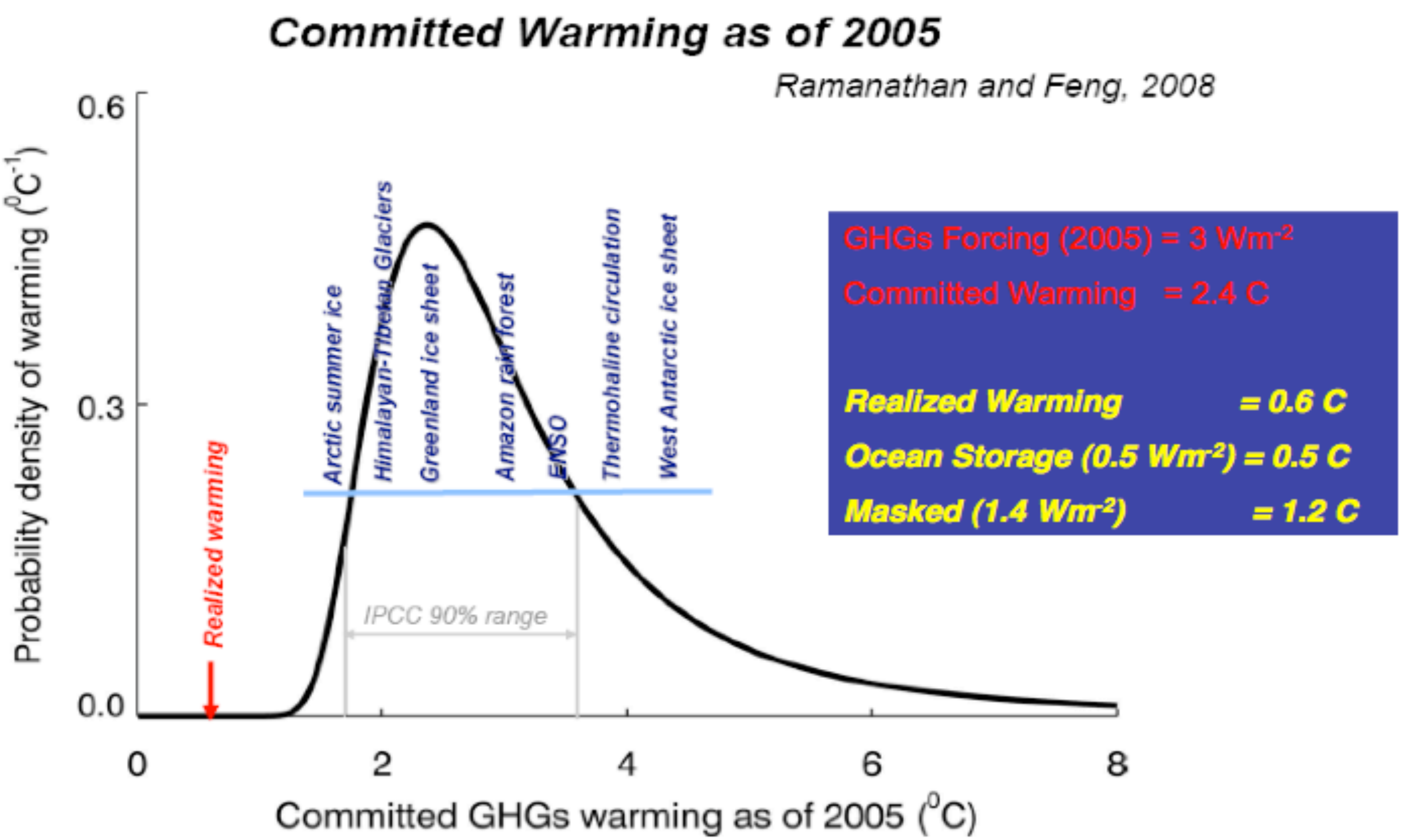


Its impact may last a thousand years



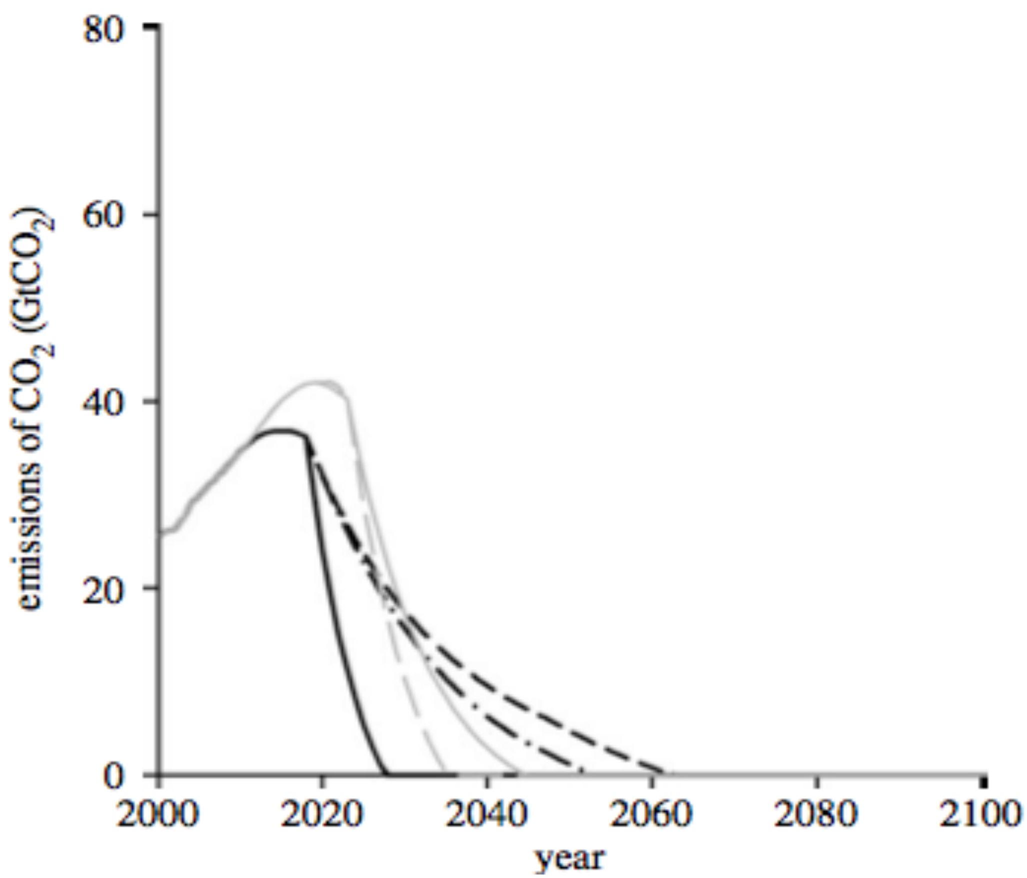
Solomon, PNAS (2009)

If 2 degrees beyond preindustrial is target, we are likely exceeding it and exceeding “tipping points”



Committed warming derived from IPCC Forcing & IPCC climate sensitivity

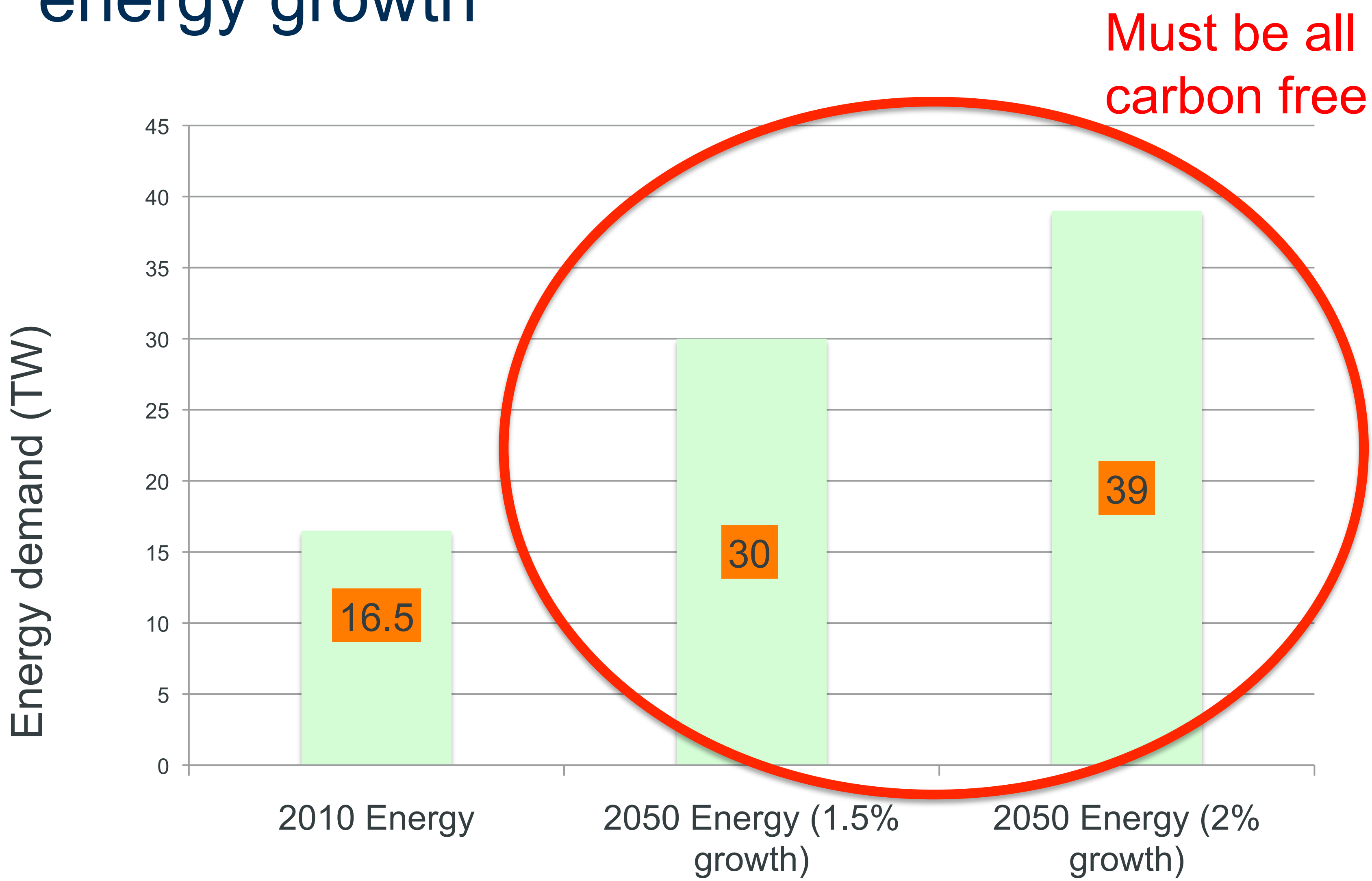
If we focus on CO_2, we need to get close to zero emissions



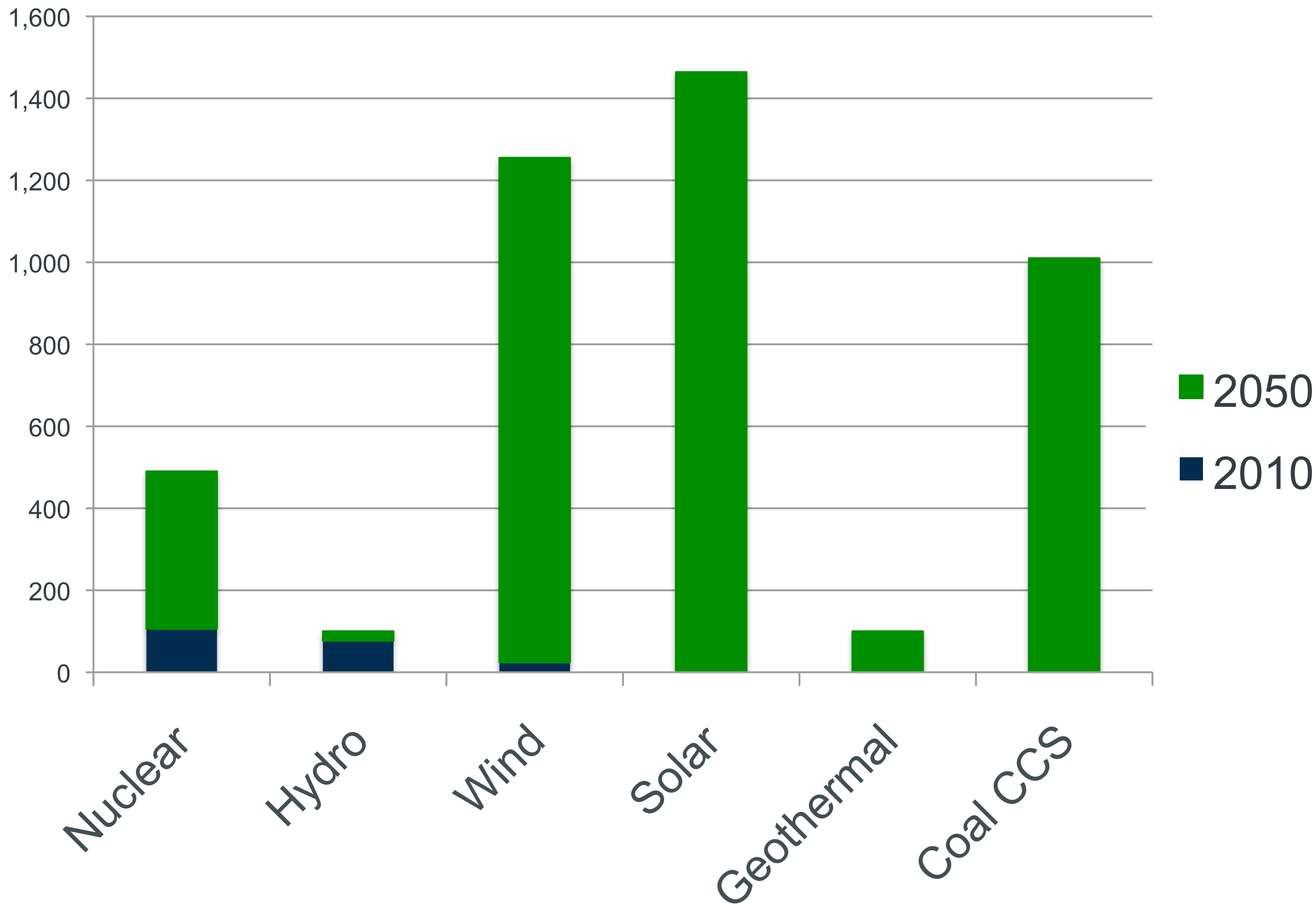
- Unlikely that any global agreement will deliver the radical reversal in emission trends required for stabilization at 450 ppm carbon dioxide equivalent (CO2e).
- Stabilization much below 650 ppm CO2e is improbable.

Anderson and Bows, 2009

This is a big lift, especially given energy growth



2010 capacity in gigawatts versus capacity needed to reduce CO_2 by 80% in 2050



CATF from EIA and Lester and Finan, MIT 2009

What are our choices?

- Cuts in emissions
  - – Decarbonize the electric sector
  - – Decarbonize the transport sector
- Aggressive capture, storage and sequestration of carbon and emitted CO_2
- Geo-engineering options as potential insurance
- **Rapid black carbon, tropospheric ozone and methane mitigation.**

Focusing on short-lived pollutants can play a role

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Global warming in the twenty-first century: An alternative scenario

James Hansen*†, Makiko Sato*‡, Reto Ruedy*, Andrew Lacis*, and Valdar Oinas*§

Contributed by James Hansen, June 16, 2000

If sources of CH4 and O3 precursors were reduced in the future, the change in climate forcing by non-CO2 GHGs in the next 50 years could be near zero. Combined with a reduction of black carbon emissions and plausible success in slowing CO2 emissions, this reduction of non-CO2 GHGs could lead to a decline in the rate of global warming, reducing the danger of dramatic climate change.

Short-lived climate forcers have likely been a significant contributor to global and Arctic climate to date

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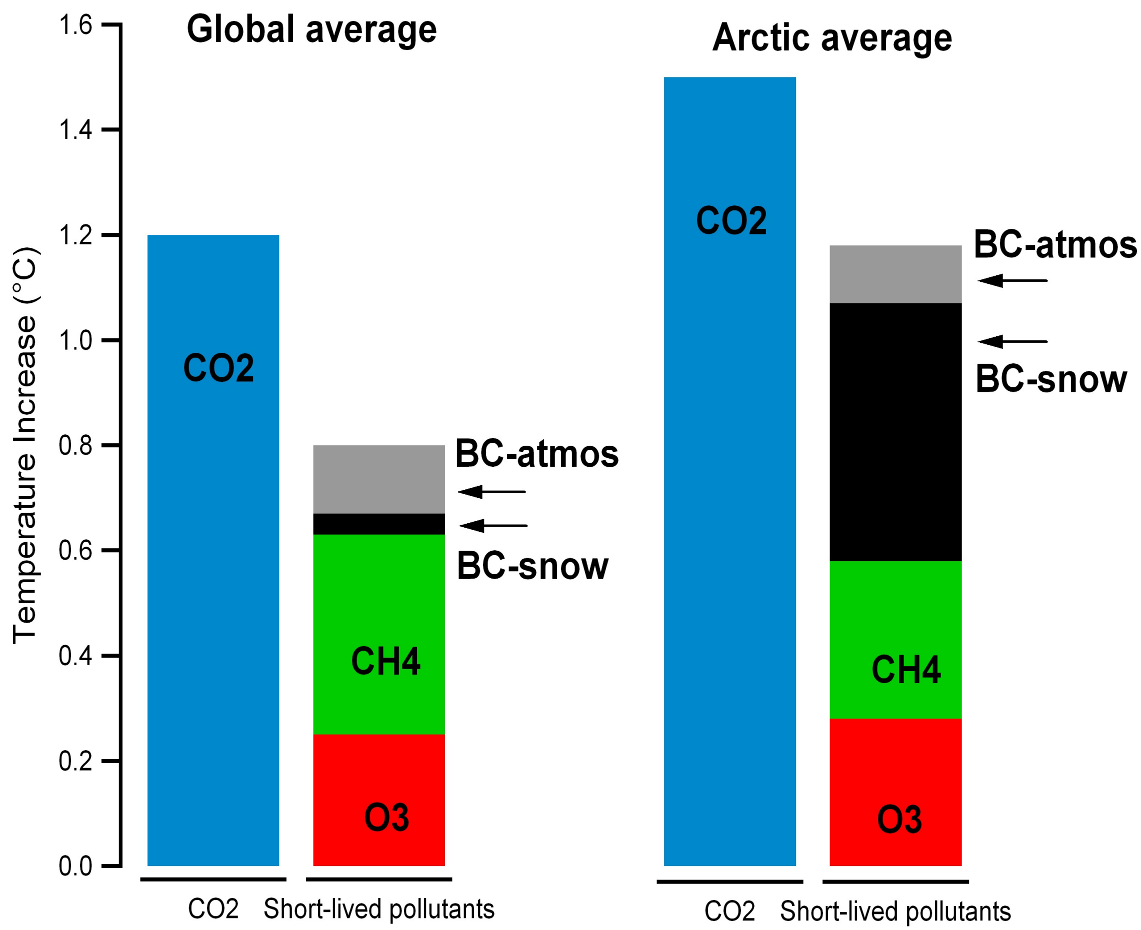
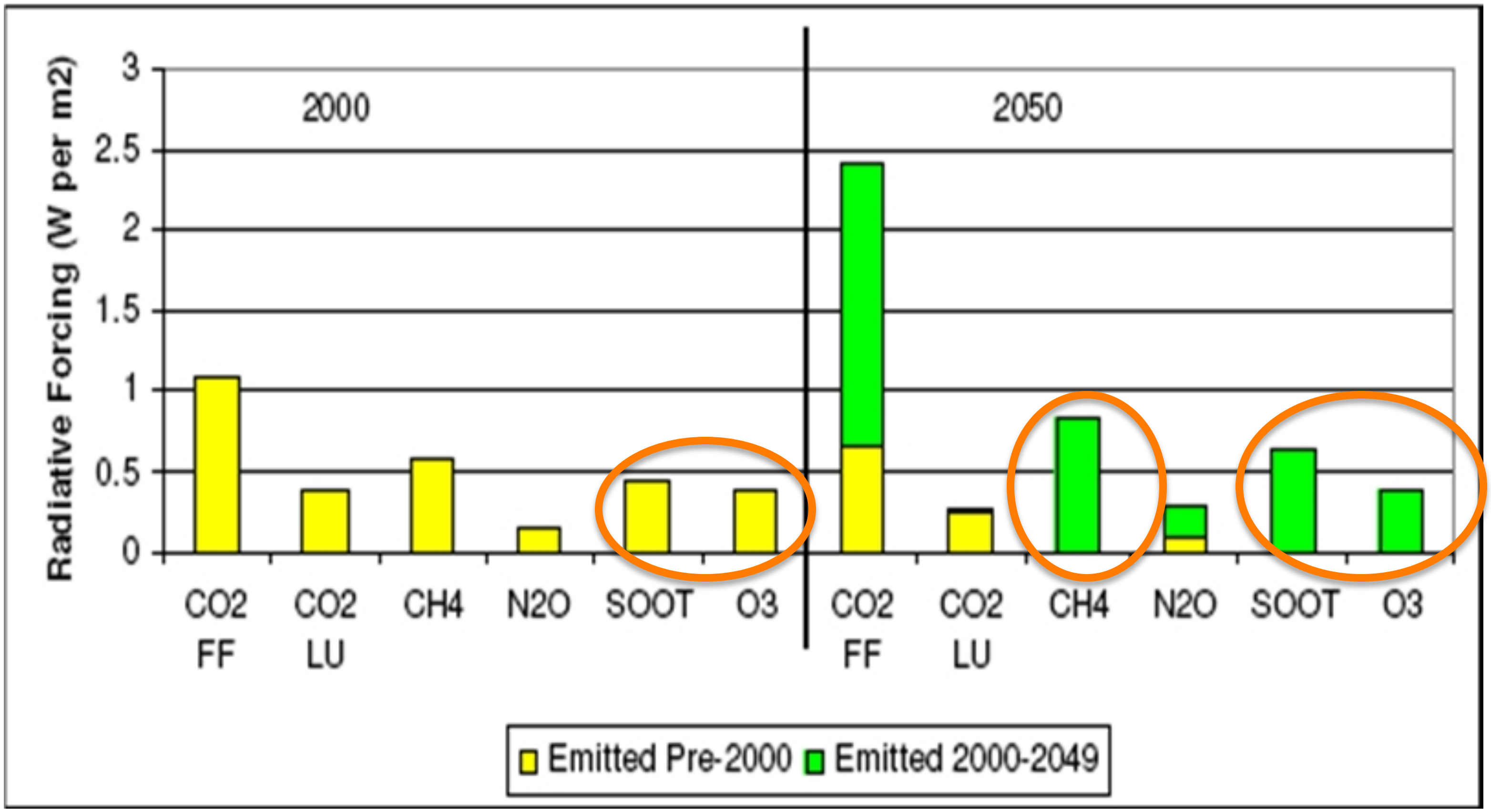


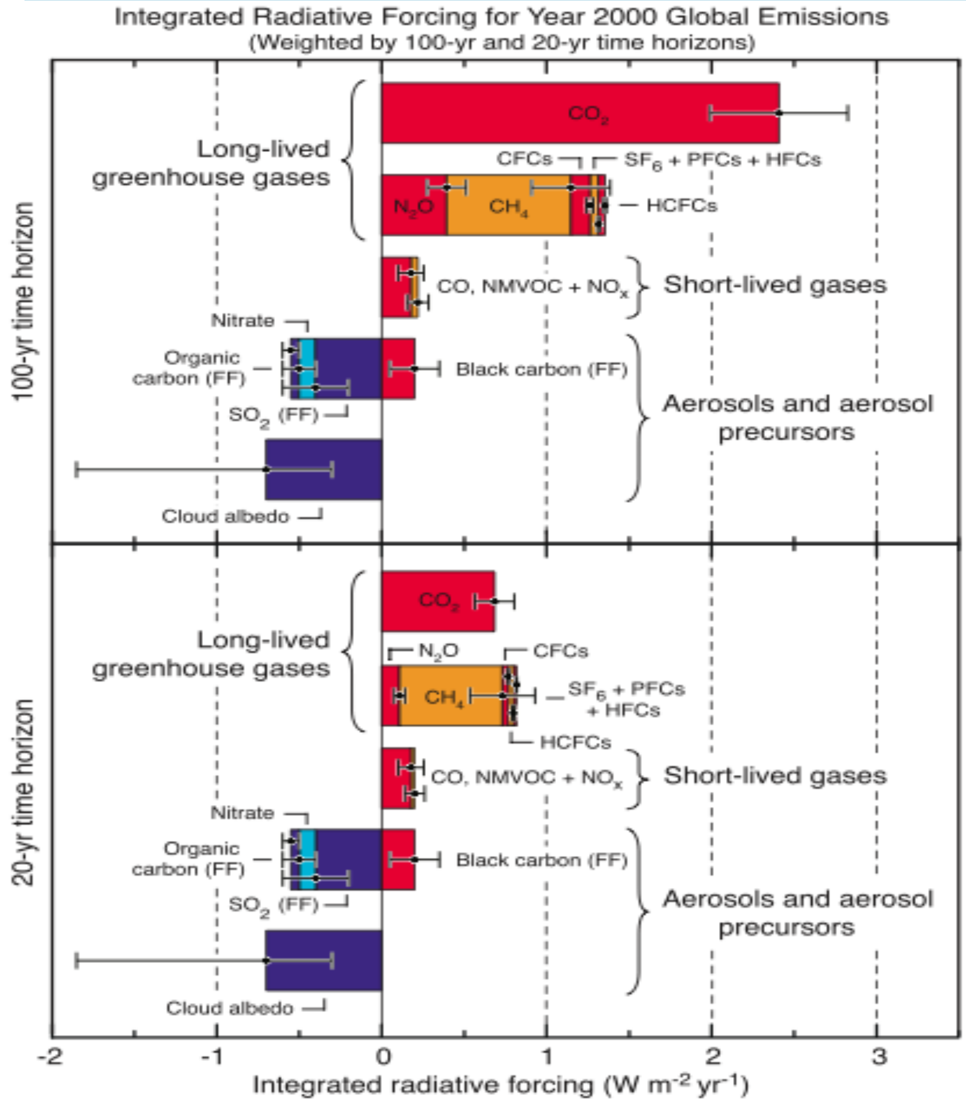
Quinn et.al , 2008

The benefits of reductions is that response occurs quickly

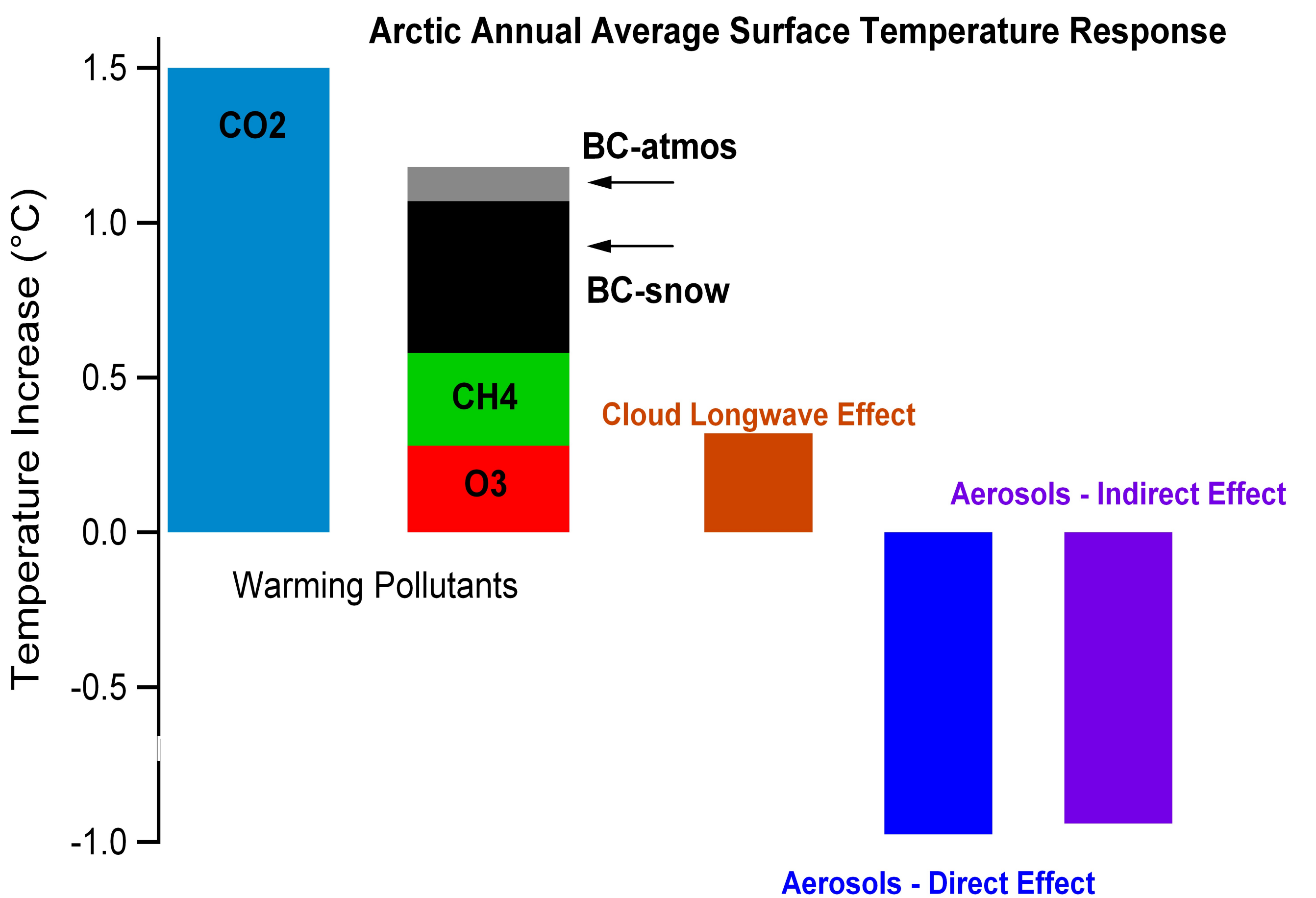


Moore, McCraken, 2009

Radiative forcing

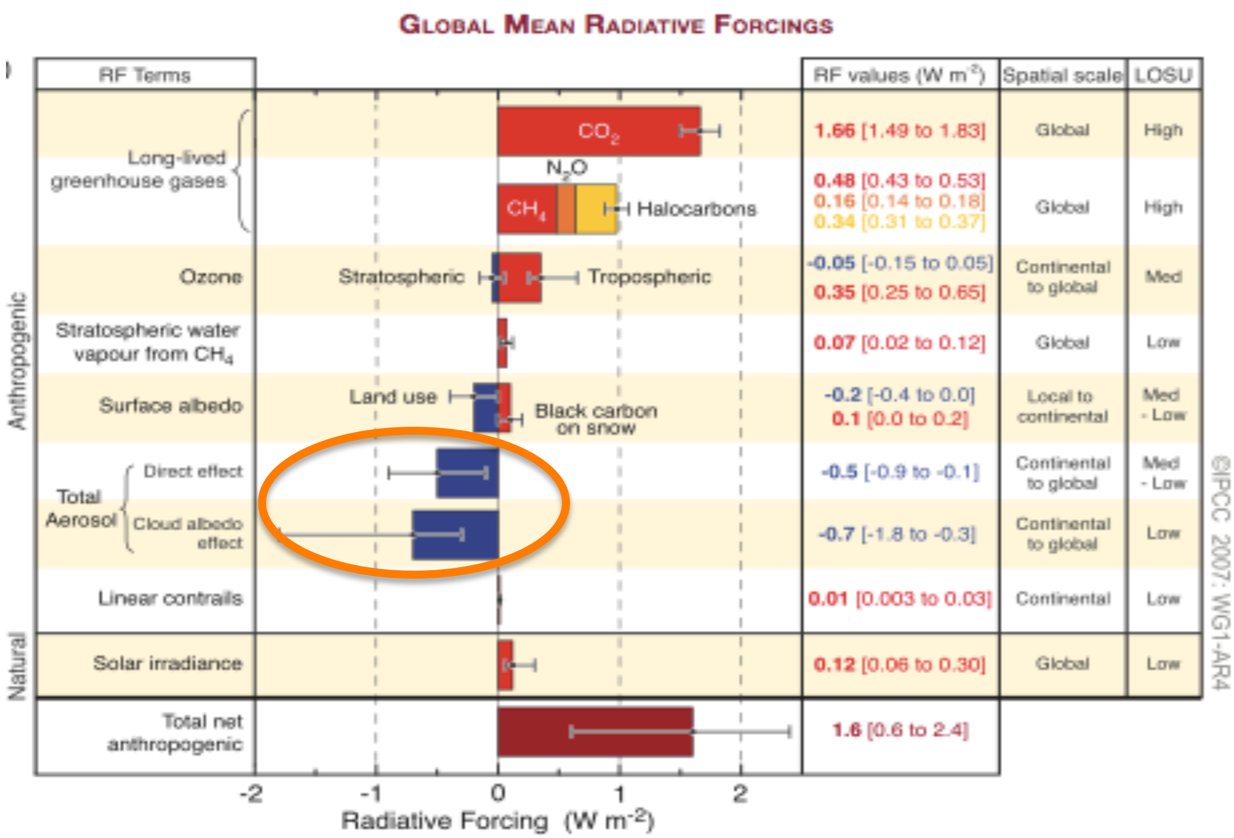


With aerosols the reductions more complicated than at first blush



Quinn et.al , 2008

Adding uncertainty makes the clearer picture even less clear



But opportunities persist
What is black carbon?

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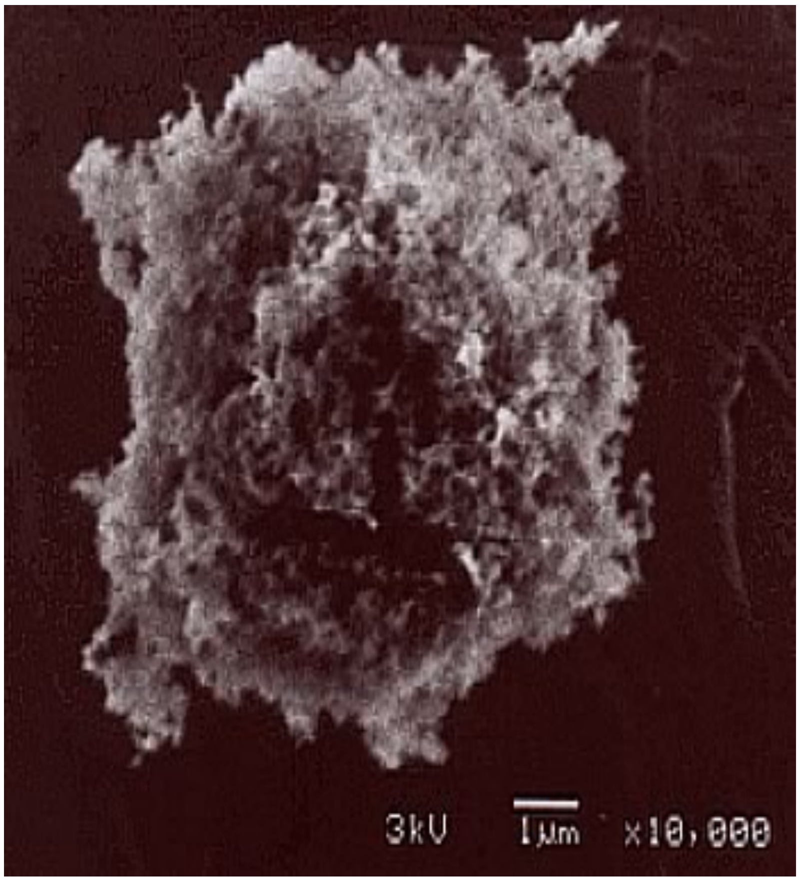


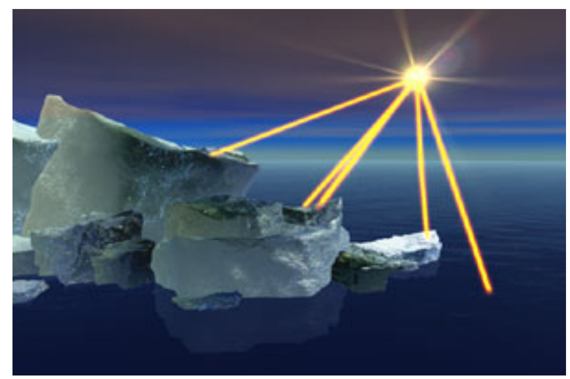
- Black carbon -- soot -- consists of dark particles left over from incomplete combustion of fossil fuels and biomass.
- Absorbs sunlight and heats up the atmosphere.
- Black carbon also harms human health.

Black Carbon Warms both in the Atmosphere and by Darkening Arctic Ice, Accelerating Melting

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, but is likely affecting land-based glaciers as well.

In the atmosphere, like an asphalt road, black carbon soot absorbs sunlight.

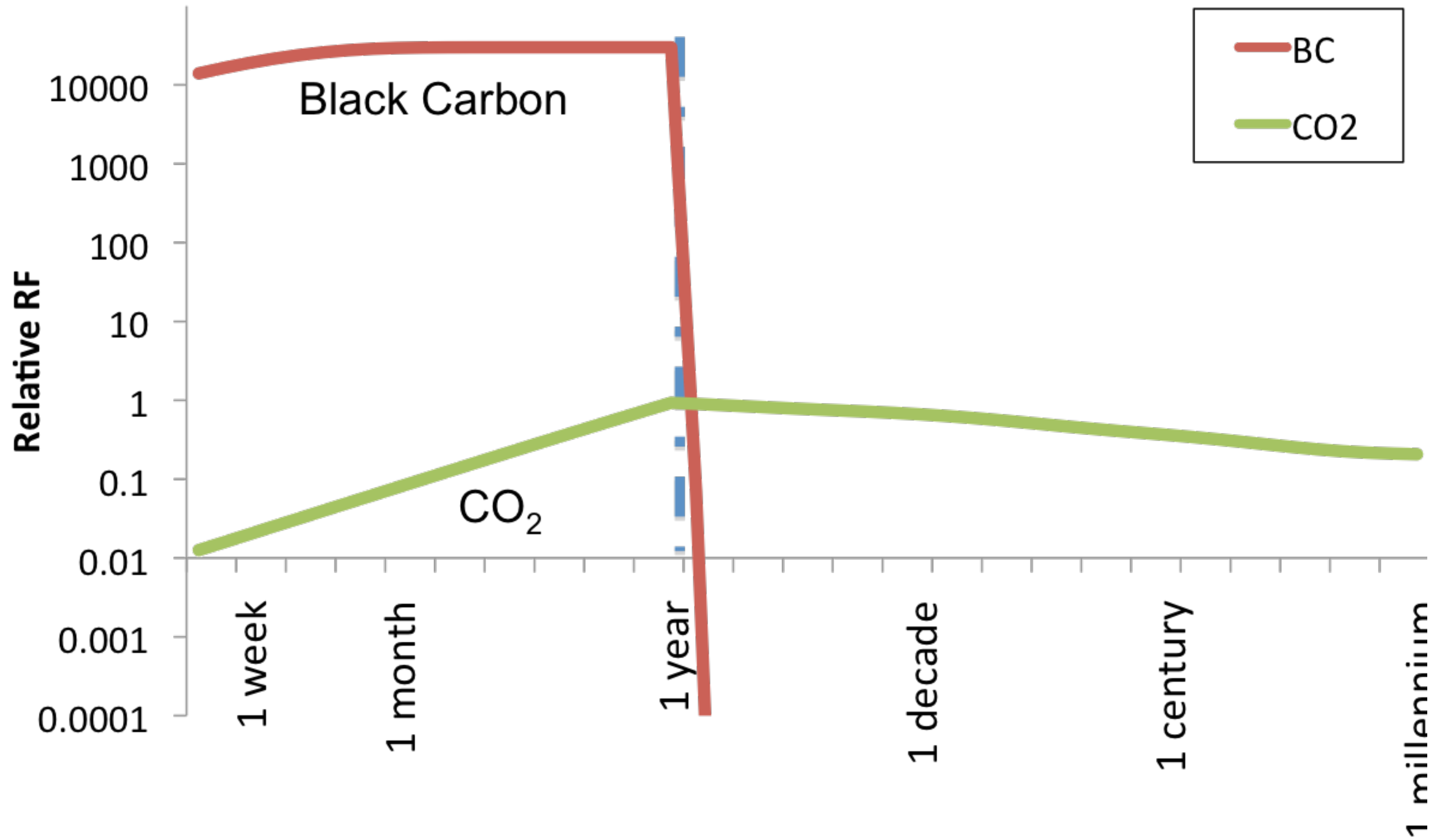
Ice and Snow Reflect Solar Radiation



Black Carbon Deposits Darken Surface and Reduce Reflectivity

Other atmospheric impacts result in cooling

Short atmospheric lifetime of black carbon means impacts of reductions can happen quickly



Bice et al, 2008

Sources of Black Carbon

Brick Kilns

Smoking Cookstoves

Dirty Diesels

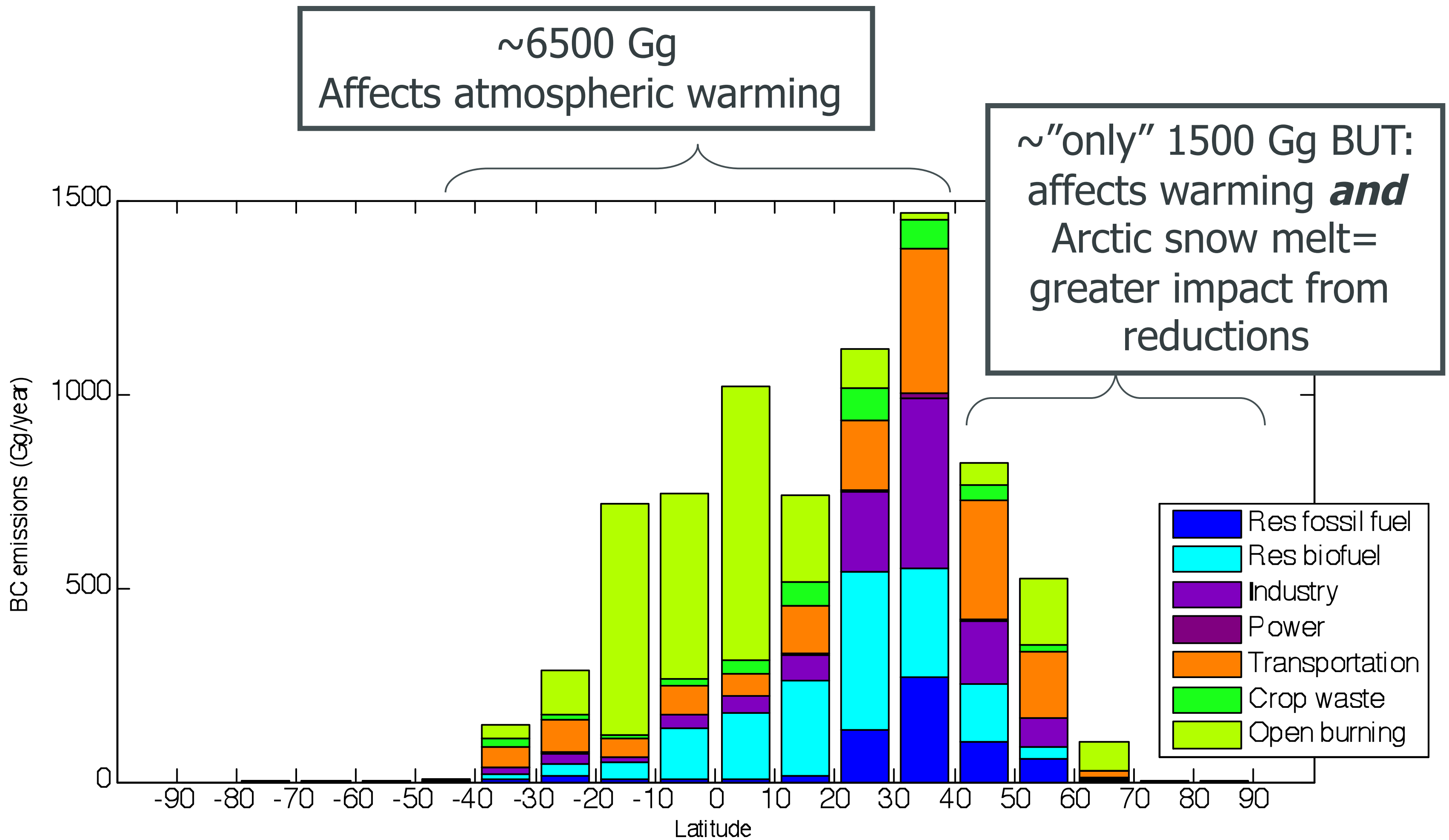
Burning Fields

24

The challenge: there is no such thing a "just" black carbon emissions

- All sources that emit black carbon also emit organic carbon and other aerosols, which have a largely cooling impact.
- While molecule for molecule the warming from black carbon is more potent than the warming from other forcings, policymakers need to be aware of the balance of black carbon, organic carbon, sulfates and nitrates.
- Adding to the complexity, aerosols affect climate through direct and indirect – affect on clouds – actions, and some of the impact results in non temperature responses.

Major controllable sources: diesel; cookstoves; industries; other burning



Source: Bond et al., 2004 (updated to year 2000 data); GFEDv2 (van der Werf, 2006)

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We can develop mitigation strategies that, will, on balance result in climate benefit

		Known Arctic deposition	Atmospheric warming	Mitigation feasibility	
Diesel engines	24%	yes	STRONG	EXISTS	POSSIBLE
Domestic biofuel	18%	Probably	STRONG-MOD	EXISTS	POSSIBLE
Domestic coal	6%	OPEN Q	OPEN Q	EXISTS	POSSIBLE
Industry	10%	yes	OPEN Q	EXISTS	POSSIBLE
Ag burning	4%	yes	OPEN Q	EXISTS	POSSIBLE
Open biomass	38%	yes	OPEN Q	QUESTIONABLE	

Adapted from Bond et al., 2004 (updated to year 2000 data); GFEDv2 (van der Werf, 2006)

Diesel Particulate Filters (DPFs) can reduce black carbon emissions by more than 90 percent relative to an uncontrolled engine.

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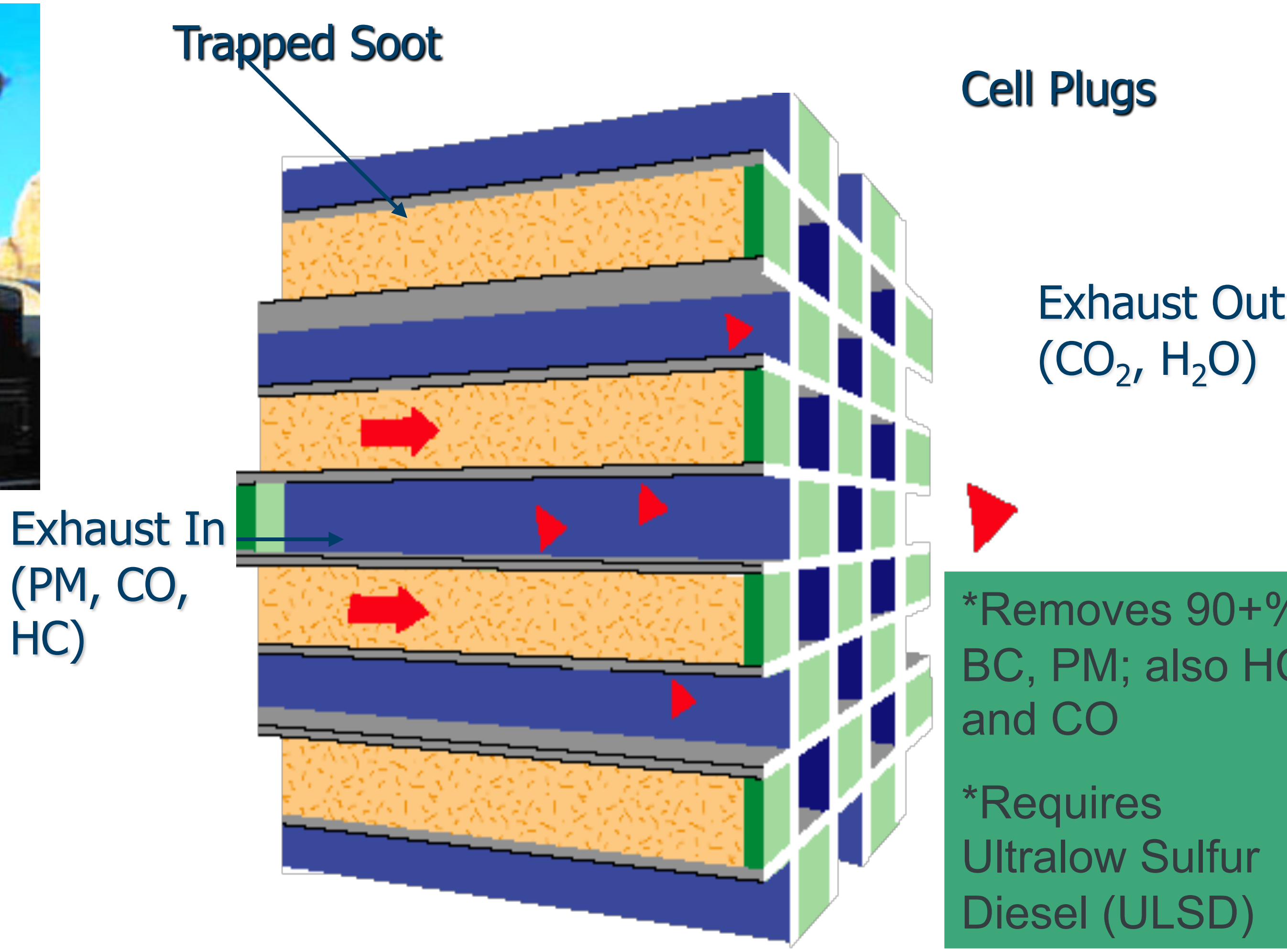


*Removes 90+% BC, PM; also HC and CO

*Requires Ultralow Sulfur Diesel (ULSD)

Marine Vessels

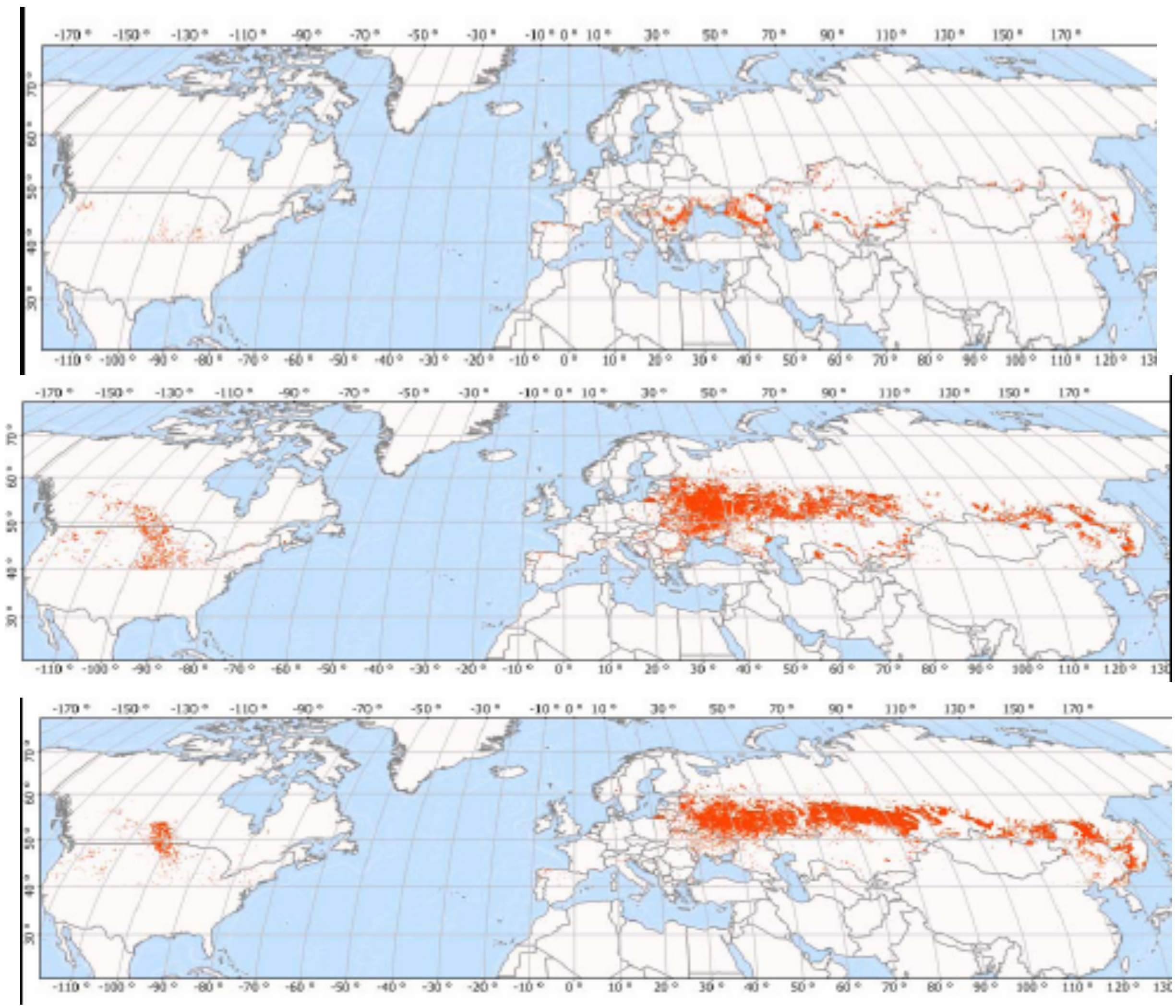
- Marine vessels emit an estimated 2% of total global BC
  - Greatest concern is the release of BC in northern shipping routes close to the Arctic.
- Air emissions from ships traveling in international waters are subject to international regulations set by the International Maritime Organization (IMO).
- On January 15, 2010, Norway, Sweden, and the US filed a joint paper to the Marine Environment Protection Committee (*MEPC*) of the *IMO* requesting that "the Committee discuss how to address BC by examining potential measures to be recommended or required to significantly reduce black carbon emissions from shipping having an impact in the Arctic."
  - Improved fuel injection systems and modified turbochargers.
  - Diesel particulate filters
  - Water mixing and injection technologies,
  - Slide valves produce more complete combustion than conventional valves, reducing PM and black carbon by 25% or more.

Emissions from spring agricultural waste burns reaching the Arctic

March

April

May



From, MODIS Terra Global Land Cover and Burned Area, 1 km

2006 fire burn locations, on croplands north of 40 degrees latitude, during spring months 2006 is a typical fire year.

Options to reduce agricultural burning

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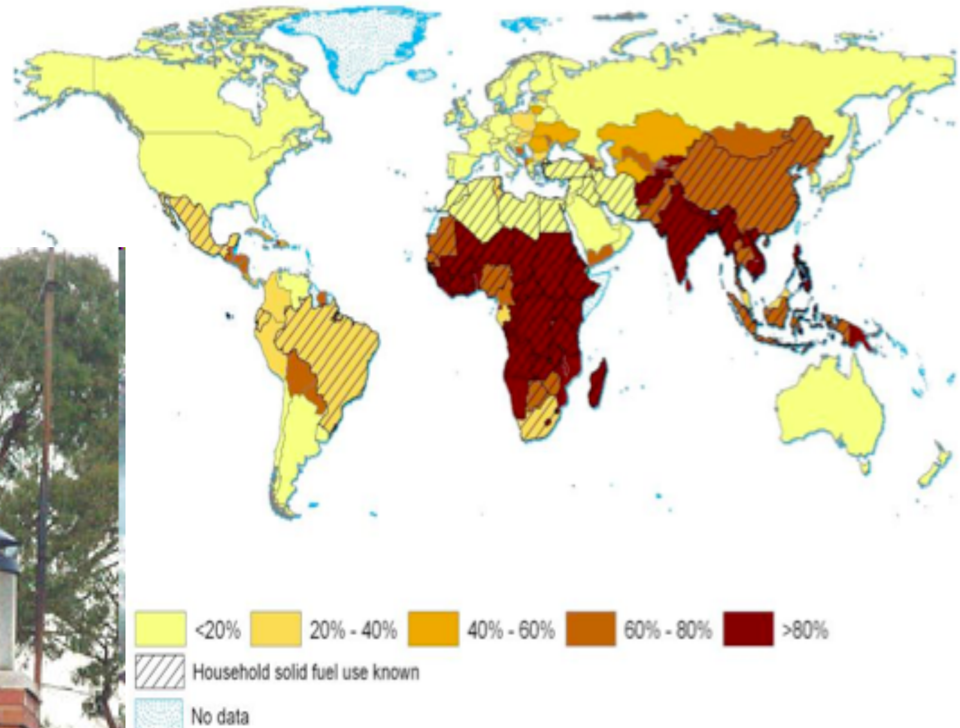
- Ban springtime burning in northern latitude countries that affect the Arctic.
- Expand uses for crop waste, including biochar production *via* pyrolysis.
- Timing and permit fires, based on meteorological conditions and forecasts to avoid transport of black carbon to the Arctic and other vulnerable snow covered areas.

Solid fuels– cooking and heating Not just a lower latitude source

Household solid fuel use 2000

Solid fuels are the major source of black carbon in Scandina-vian countries.



Controls -- International

- A myriad international and country-specific programs exist to promote the use of cleaner cookstoves.
  – Few have reached the commercial scale needed to meaningfully address the nature of this global problem and have fail to achieve measurable improvements in health and safety, combustion efficiency, or reduced emissions of BC and other pollutants

Some specific program initiatives include:

- The UN Foundation seeks to build a Global Alliance for Clean Cookstoves, with the goal of deploying millions of stoves in target countries by 2015.
- EPA's Partnership for Clean Indoor Air (PCIA) has over 330 partners operating in 115 countries and is growing.
- In December 2009, India announced a major national initiative on biomass cookstoves, with a goal of scaling up to replacing over 150 million cookstoves.

Industrial BC Emissions

- Industrial sources are estimated to produce a significant fraction, 18 percent, of ”human caused” global black carbon emissions. Major source fractions are uncertain, but in order of contribution:
  - Kilns (mostly brick making)
  - Coke making
  - Boilers, industrial process, steel, lime
- ***Emissions information for most sources are quite limited, and based on very few measurements.***

Brick Kilns

- 300,000 brick kilns worldwide
- Primary fuels are coal, plus any low-cost fuel that can be scavenged (tires, battery cases, dung, etc.)
- Most brick kilns in developing countries are primitive and appear to significant BC and other emissions.
- 75% global brick production
  - China: 54% 700 billion bricks/yr
  - India: 10% 144 billion bricks/yr
  - Pakistan: 8% 100 billion bricks/yr
  - Bangladesh: 4% 50 billion bricks /yr
- Shifting to improved technology kilns will typically reduce fuel consumption and CO_2 emissions. .
- Measurement of climate-relevant emissions are needed to quantify the climate mitigation opportunity from improving brick kilns.

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Coke Making

- Relatively small number of global coke making facilities ~ 1500 worldwide
- Recent – 2006 production – is dominated by China
  - China 59%
  - Russian Federation 6%
  - Ukraine 4%
  - US 3%
  - India 2.5%

- Most traditional coke ovens (prevalent through the late 1990s) are probably gone.
- Plausible BC emissions reduction measures will come from a complex range of small particulate emissions control, most of which achieve or go beyond current US EPA control levels.

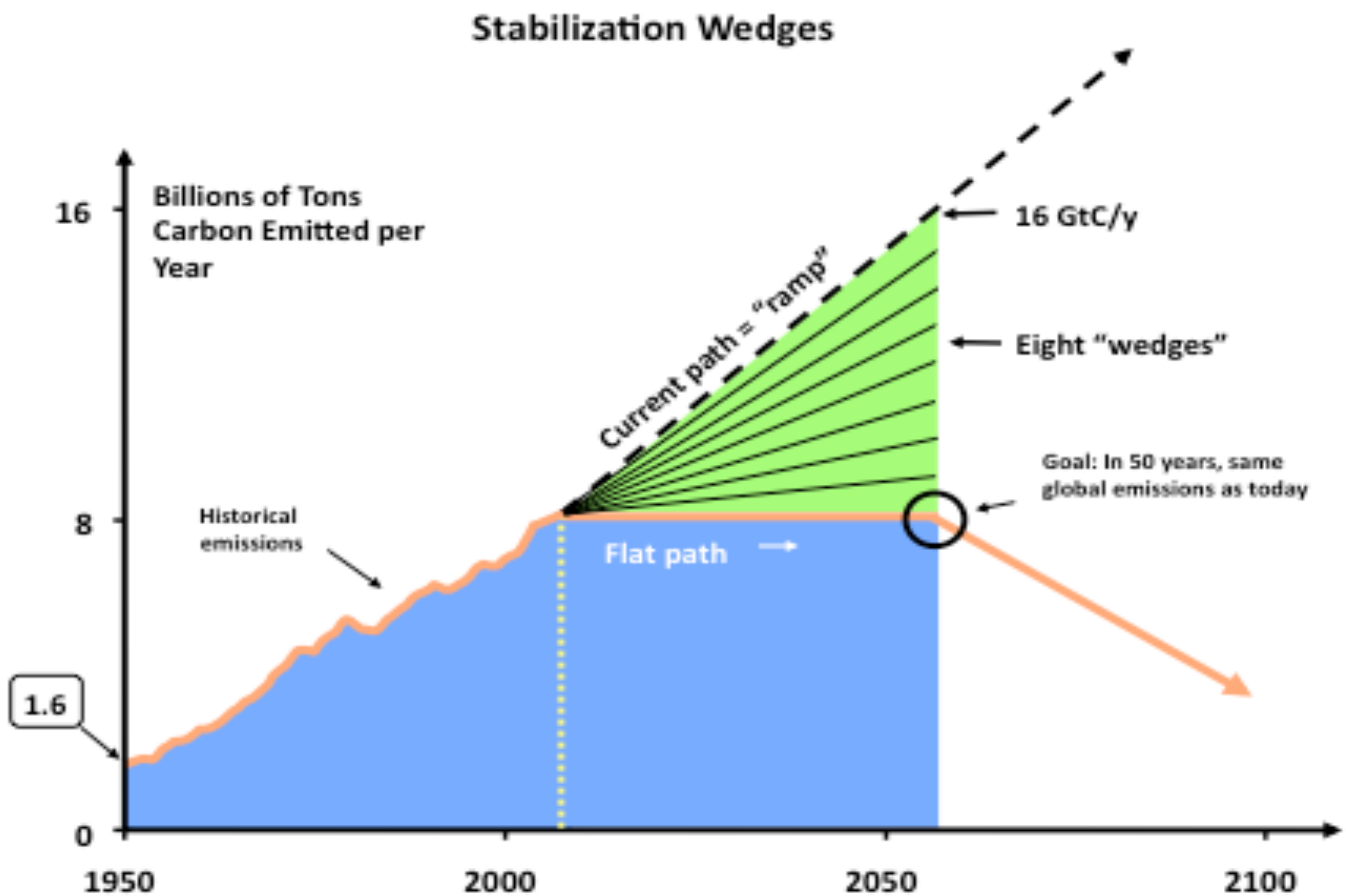
Flaring from oil and gas

- Oil and gas flaring is a source of PM and black carbon.
- Questions/Issues
  - How much PM and black carbon are produced?
  - How does this vary by location and conditions?
  - How will this change in the Arctic with increased oil and gas exploration?
- No accepted protocols for quantifying PM from these or other open sources
- Need a mechanism to insure methane capture to reduce BC emissions that can result from increased exploration that is likely to occur.

Back of the envelope: could see significant reductions and benefits

- With ***very*** aggressive cuts in ***black carbon-rich*** sources – diesel, household energy, agricultural waste burning (particularly near snow-covered surfaces) AND
- Using a GWP 20 (2200) that only considers direct impacts AND
- Considering for co-emissions of OC and SO2
- 3 Gt of C reduction by 2030 (1 Gt E reduction assuming 100 year)
- GCM simulations show a radiative forcing from these reductions in 2030, relative to 2000 of -0.24 W/m2.
- Need a lot of technology deployment, measurements (particularly industrial sources like brick kilns and coke ovens in) and national policy implementation to get there.

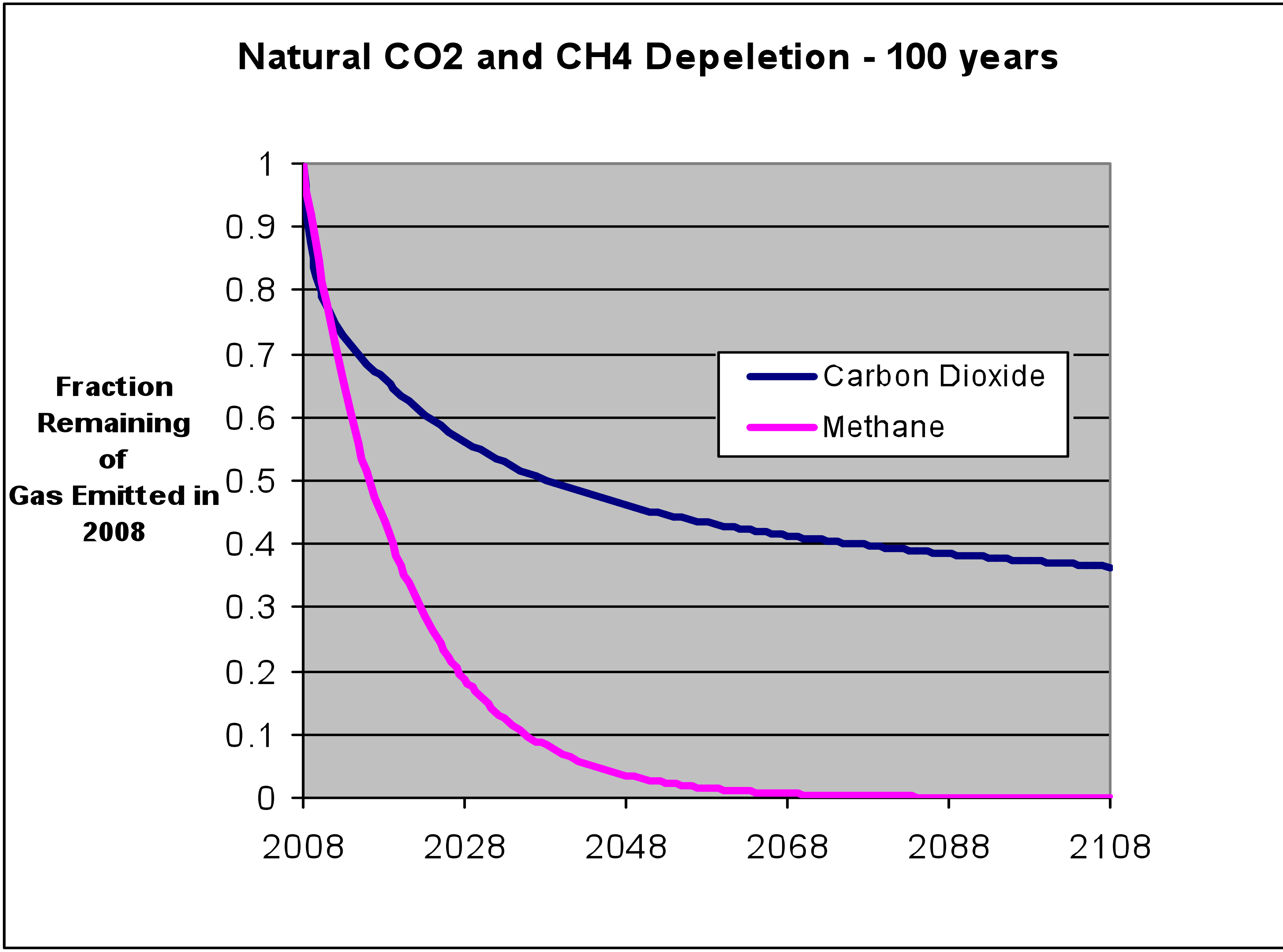
Could be at least a stabilization wedge



Methane offers promising benefits

- Faster climate response because much more potent and much shorter atmospheric lifetime compared to CO_2.
- Reduces background levels of tropospheric ozone, which benefits climate and air quality.
- Because it is globally well mixed, least-cost reductions can be made anywhere in the world.

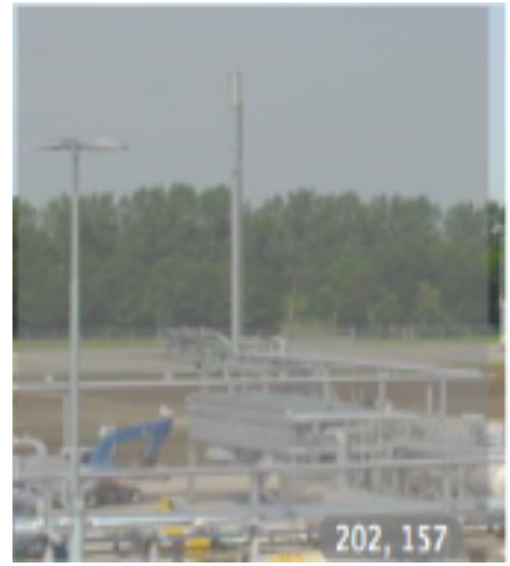
23 MW landfill methane power plant



Smith, CARB presentation, 2008

Many methane options are technically straightforward and “end of pipe”

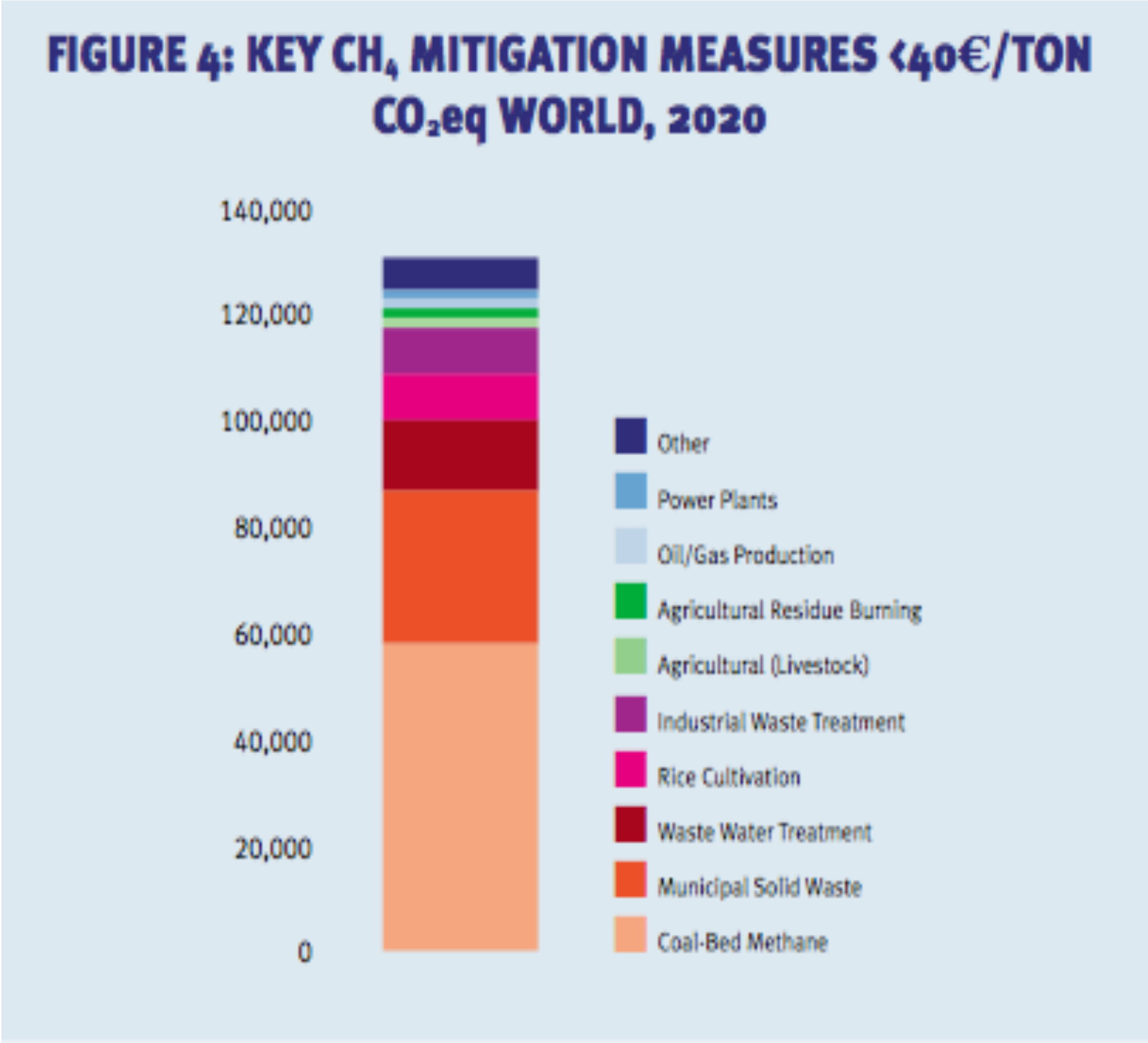
Coal Mine



Gas capture

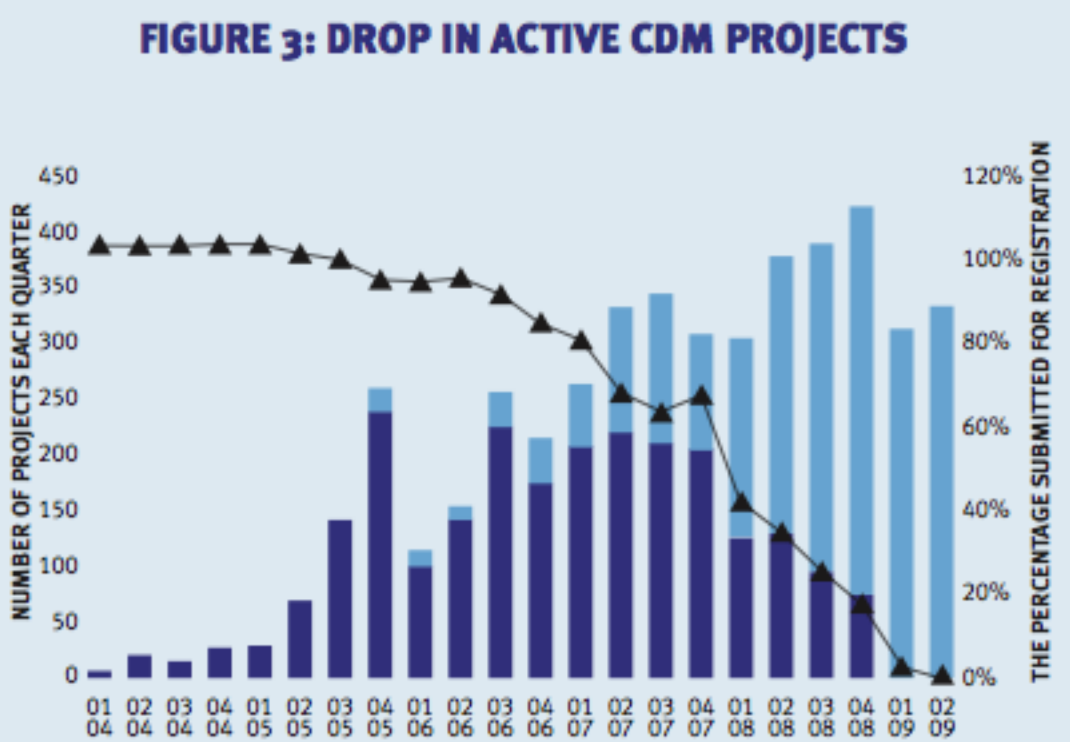
Landfill

Coal bed methane, municipal solid waste and waste water treatment are major sources



IIASA

Credit crunch is drying up projects



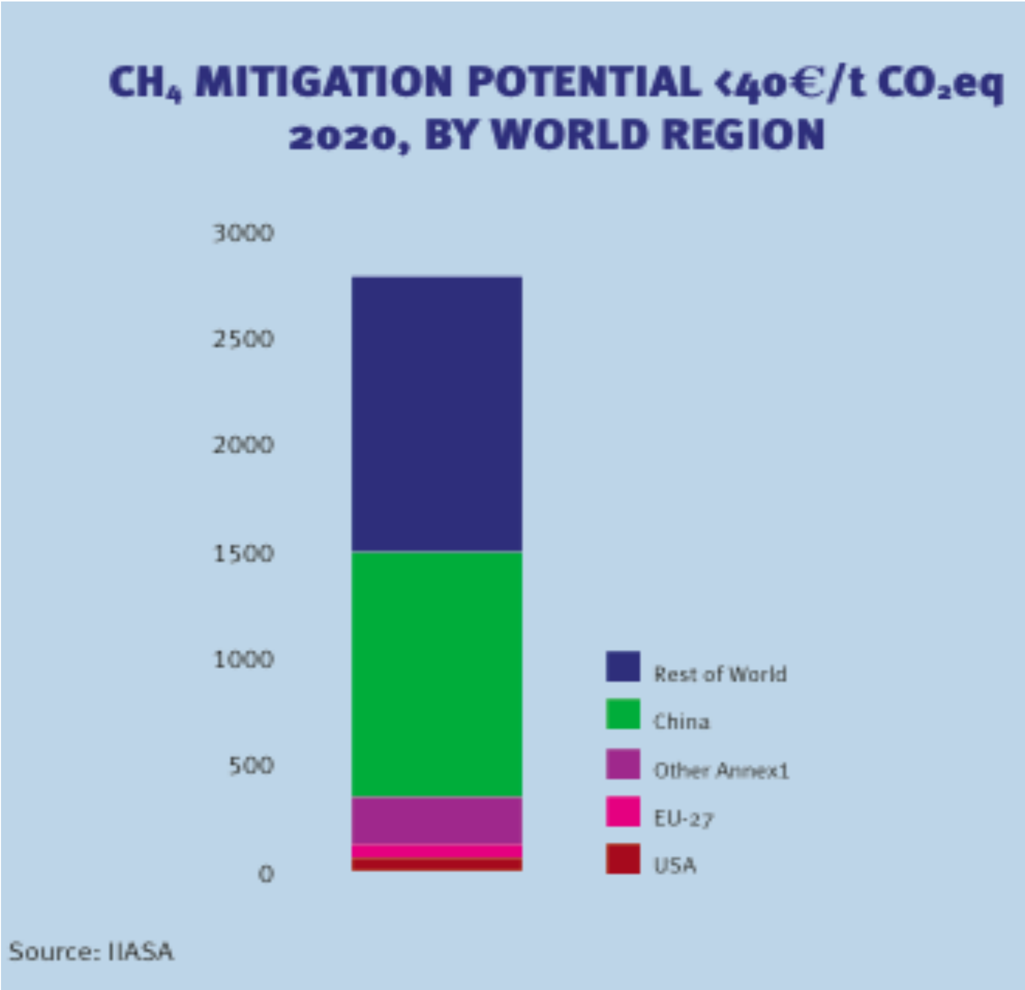
UNEP Risøe database.

Number of CDM projects starting the public comments period each quarter, the number of them that have requested registration, and the fraction in % as a curve.

We have barely scratched the surface

50% of IIASA's potential = 0.9 GT CO2e on a 100 year GWP, or about 3 GT CO2e on a 20 year GWP.

Converting to carbon this is about 80% of a wedge.



Co-benefits from reducing short-lived climate forcers are great

- Methane reductions of 65 Mt/yr beginning in 2010 would prevent 370,000 premature deaths over the next 20 years.
- Outdoor air pollution causes 1.3M - 2.4M annual deaths worldwide.
- Background tropospheric ozone reduces crop yield.

Tropospheric ozone is formed in the atmosphere, not emitted

- Tropospheric ozone is *formed in the atmosphere* from "precursor" pollutants - oxides of nitrogen, volatile organic compounds, carbon monoxide, and methane in the presence of light – and thus not directly emitted like most other air pollutants.
- Atmospheric lifetime of ozone is 1 to 2 weeks in summer and 1 to 2 months in winter.
- Ozone produced in a polluted region of one continent can be transported to another continent.

Ozone abatement strategies have evolved along with understanding of the O_3 issues

O_3 smog recognized as an URBAN problem: Los Angeles, Haagen-Smit identifies chemical mechanism

Smog considered REGIONAL problem; role of biogenic VOCs discovered

A GLOBAL perspective: Cimate impacts and role of intercontinental transport, background

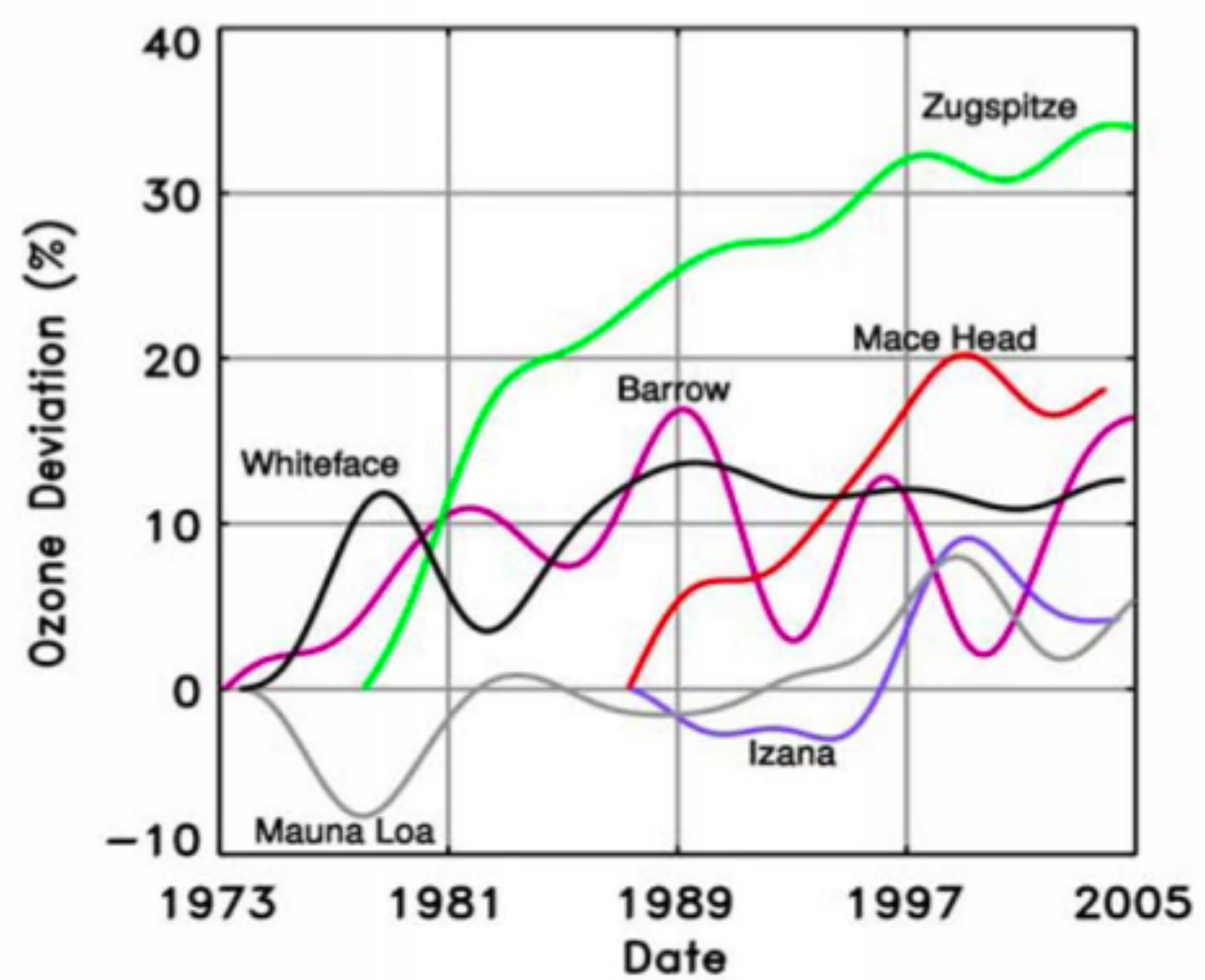
1950s → **1980s** → **Present**

Abatement Strategy:

NMVOCs | **+ NO_x** | **+CH_4, CO**

adapted from Fiore, 2002

General upward trend for background ozone



Oltmans, 2006

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Conclusions

- There are many examples of climate under stress.
- Reducing CO_2 is not easy and long lifetime of CO_2 means that the effects of reductions might not be felt for years.
- Reductions in short-lived climate forcers: black carbon, methane and tropospheric ozone offer swift climate benefits, but many challenges remain.