Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Near-Term Climate Change: Projections and Mitigation

STEVEN J. SMITH
Joint Global Change Research Institute
College Park, MD

Department of Atmospheric and Oceanic Science
University of Maryland

2015 Emissions Inventory Conference
San Diego, Ca

April 15, 2015

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965
UNIVERSITY OF MARYLAND

PNNL-SA-107832

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

First, an Advertisement

(JGCRI & GCAM)

The Joint Global Change Institute (JGCRI)

Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

- Established in 2001 as joint venture between Pacific Northwest National Laboratory (PNNL) and the University of Maryland.
  - JGCRI staff are largely PNNL (Battelle) employees.
  - JGCRI is part of the Atmospheric Sciences and Global Change Division (ASGC)-PNNL.
  - About 60 people– roughly 1/3 are students, UMD associates, & visitors
  - Research staff with terminal degrees in more than 10 different disciplines.
- Research funded by DOE, EPA, other agencies, and some private sector funding.
- Co-located with Earth System Science Interdisciplinary Center near the UMD Campus in College Park
- Focused on studies of global change – emissions mitigation, energy technologies, biogeochemical cycles of the major greenhouse gases, climate impacts, adaptation and vulnerability
- Major emphasis on the development of integrated assessment models; one of only 5 such centers in the world

On To The Main Talk

Outline

How much can reductions in methane and black carbon reduce near-term climate change?

Motivation

- Near-term rates of climate change

Near-Term Mitigation by SLCFs

- Background: Climate mitigation and radiative forcing
- Previous UNEP results
- Experimental set-up and SLCF scenarios
- Central Results
- Uncertainty
- Summary

Conclusion

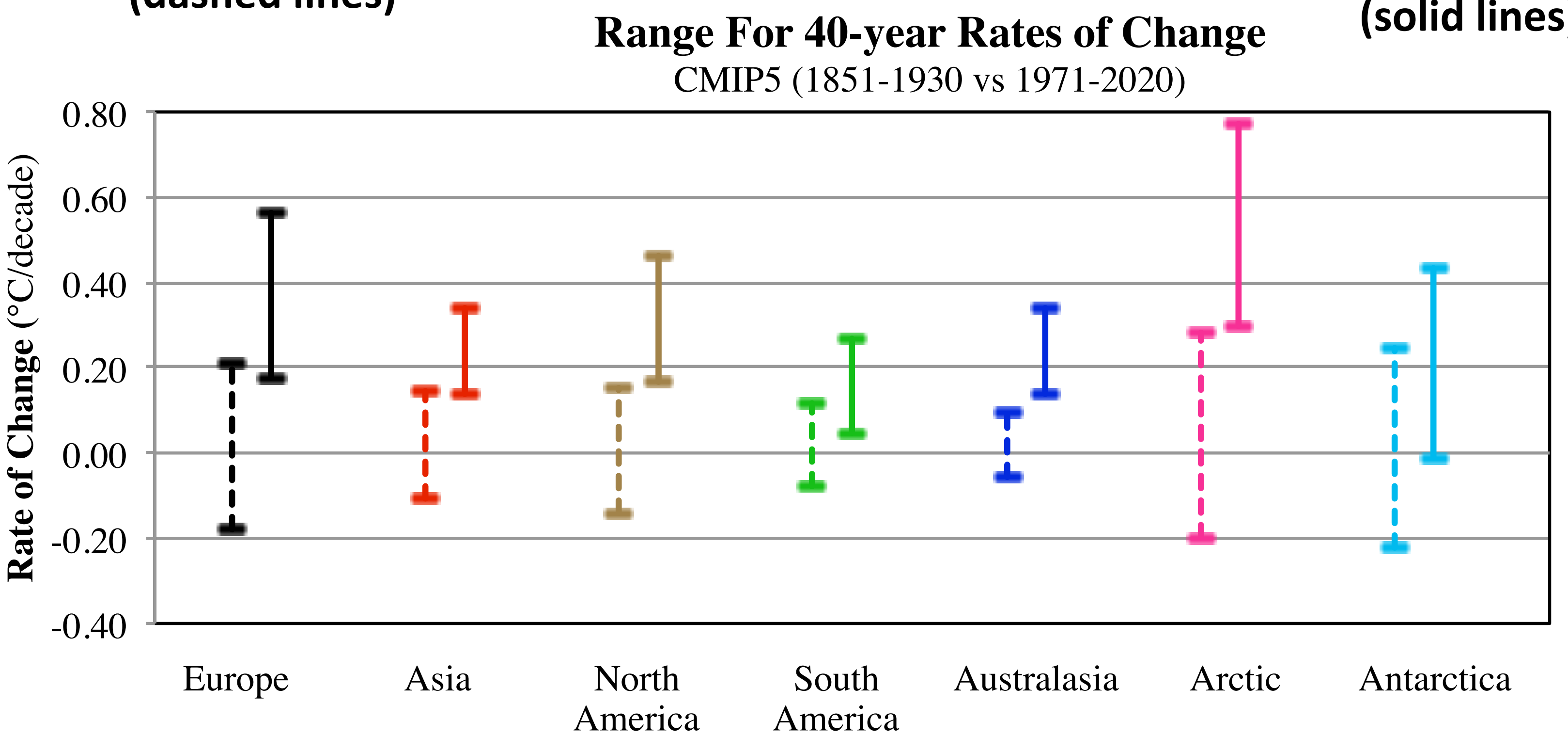
Funding for SLCF research Provided by the EPA Climate Change Division.

Motivation: Rates of Change over 40-year periods from Climate Model Projections

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Before Large Anthropogenic Influence (dashed lines)

Ending in Current Decade (solid lines)



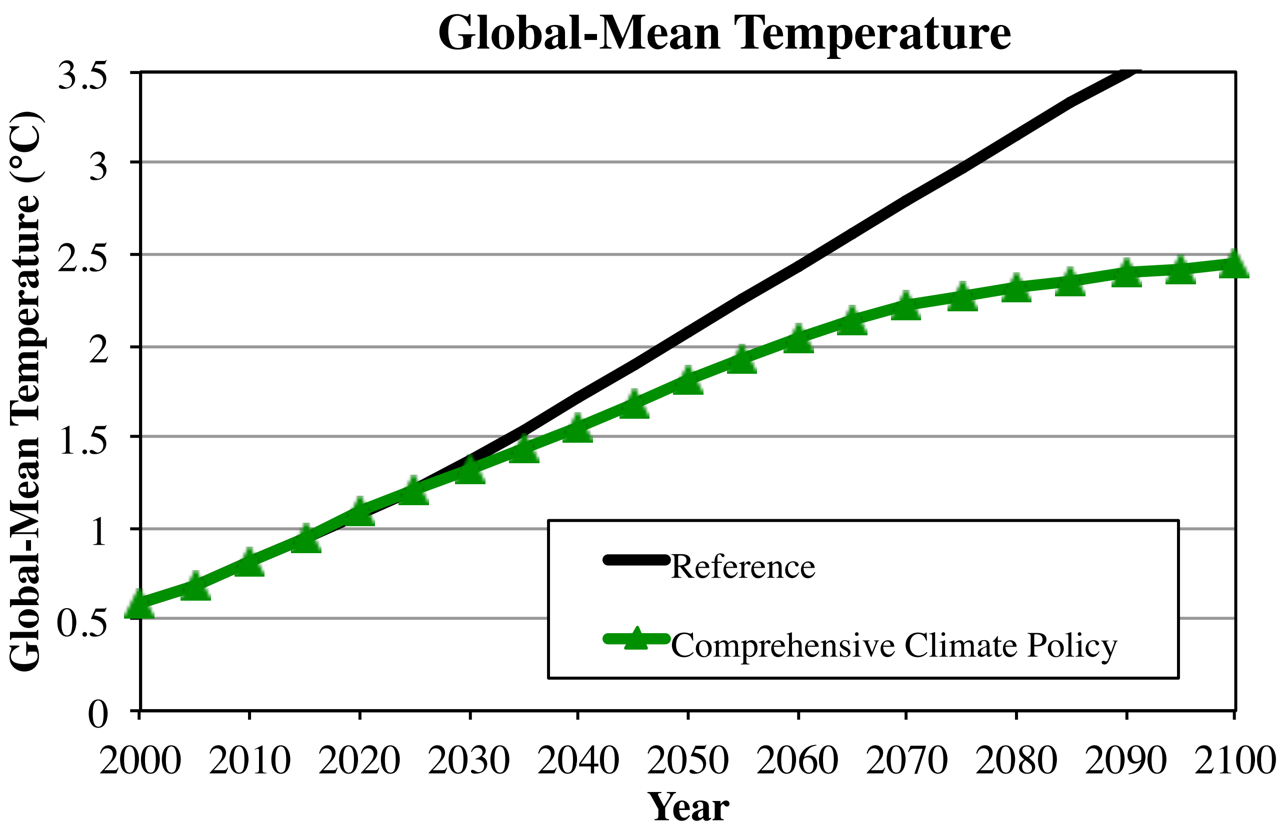
CMIP5 projections indicate that multi-decadal rates of climate change are entering a new regime with rates of change are larger than those seen over the past millennia

- Our best understanding is that the current "pause" in surface temperature increase will delay this transition, however rates of change are already at the upper end of historical levels.

Smith SJ, JA Edmonds, CA Hartin, A Mundra and KV Calvin (2015) "Near-Term Acceleration In The Rate of Climate Change" *Nature Climate Change* **5** 333–336. doi:10.1038/nclimate2552b

How much can we slow the rate of climate change by reducing CH_4 and BC emissions?

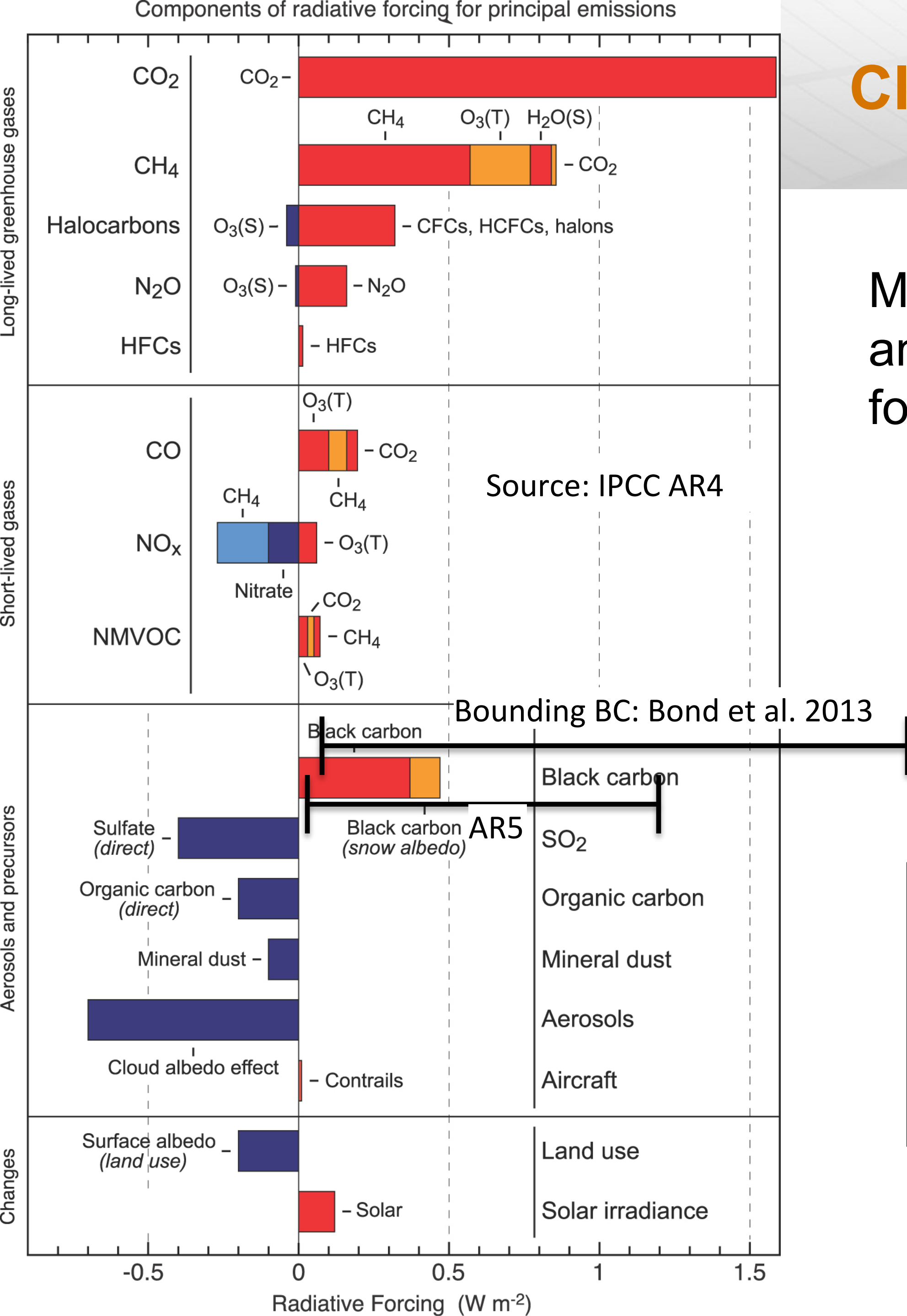
Climate Policy: “The Standard Model”



Back to Global Average Surface Temperature

Reference (no climate policy) vs a comprehensive climate policy

The climate system responds slowly to a climate policy.



Climate Forcing

Pacific Northwest NATIONAL LABORATORY

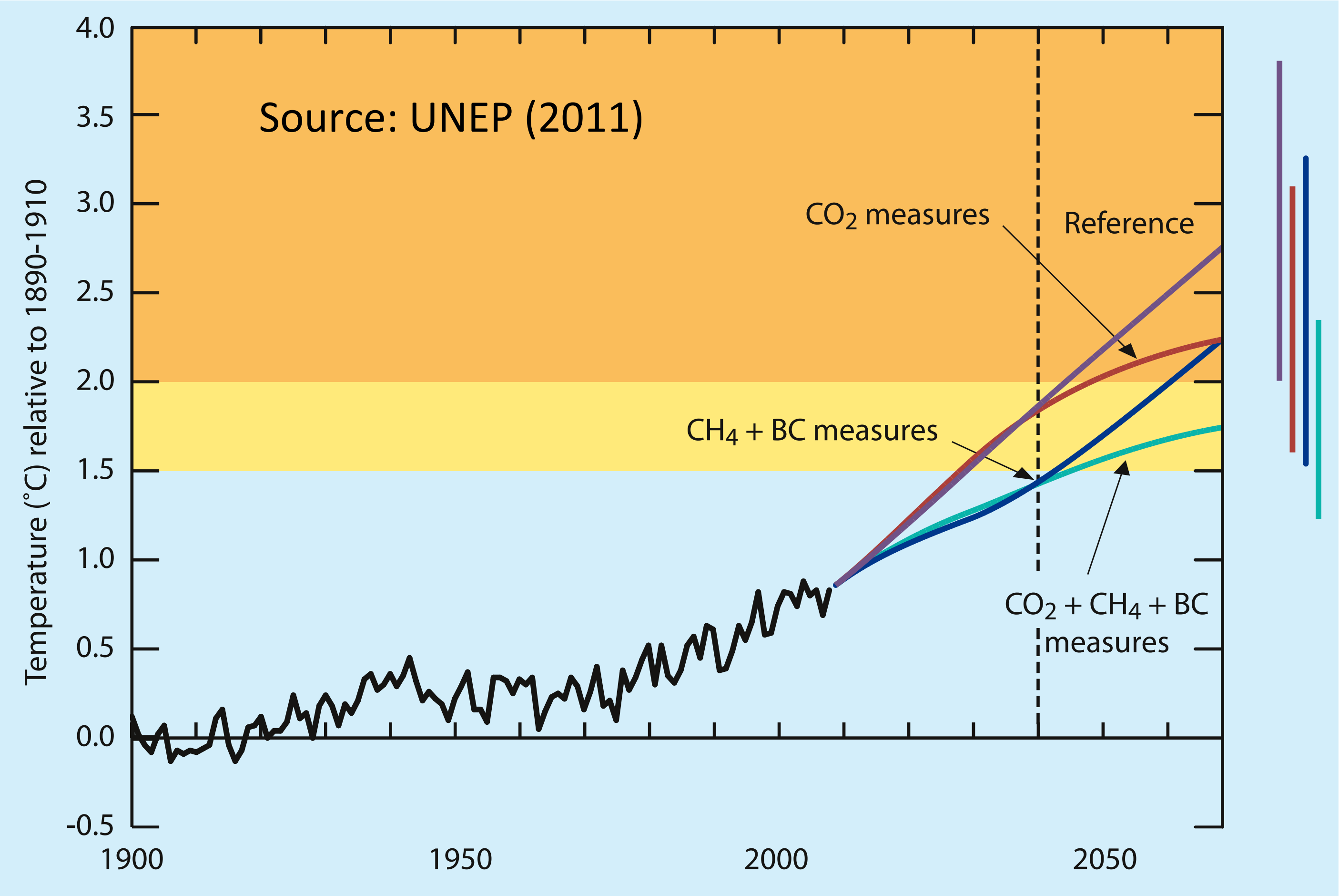
Proudly Operated by Battelle *Since 1965*

Methane and Black Carbon are the 2nd and 3d most important anthropogenic forcing agents after CO_2.

If forcing could be reduced by 0.5 W/m^2, then global-mean temperature would ultimately be reduced by 0.4 °C. This would be a big deal, if feasible!

Background

A UNEP report, and subsequent *Science* paper, claimed that mitigating BC, CH_4, could dramatically reduce near-term climate change (by ~ 0.5°C by about 2050).



Separate work by Ramanathan & Xu (2010) came to a similar conclusion.

Analytical Approach

Some Issues

- Huge uncertainty in both emissions and forcing (per unit emissions) for BC/OC.
- Aerosol forcing is net negative, so reducing all aerosols will ultimately increase climate change. So need to consider all forcing agents.
- Emissions reductions will not occur immediately, nor will the climate and atmosphere respond immediately.

Approach

- Will examine the impact of an idealized SLCF reductions using GCAM, which will allow us to have:
  - Consistent representation of all emissions in 5-year increments for a reference and SLCF-reduction scenario
  - Consistent, albeit simplified, atmospheric chemistry and global radiative forcing
  - Consistent climate responses
  - Multi-gas and pollutant forcing and climate response estimated globally using the MAGICC simple climate model

Smith SJ, A Mizrahi (2013) "Near-Term Climate Mitigation by Short-Lived Forcers" **110**, 14202-14206. *PNAS. doi: 10.1073/pnas.1308470110 .*

We consider an idealized SLCF Reduction Scenario

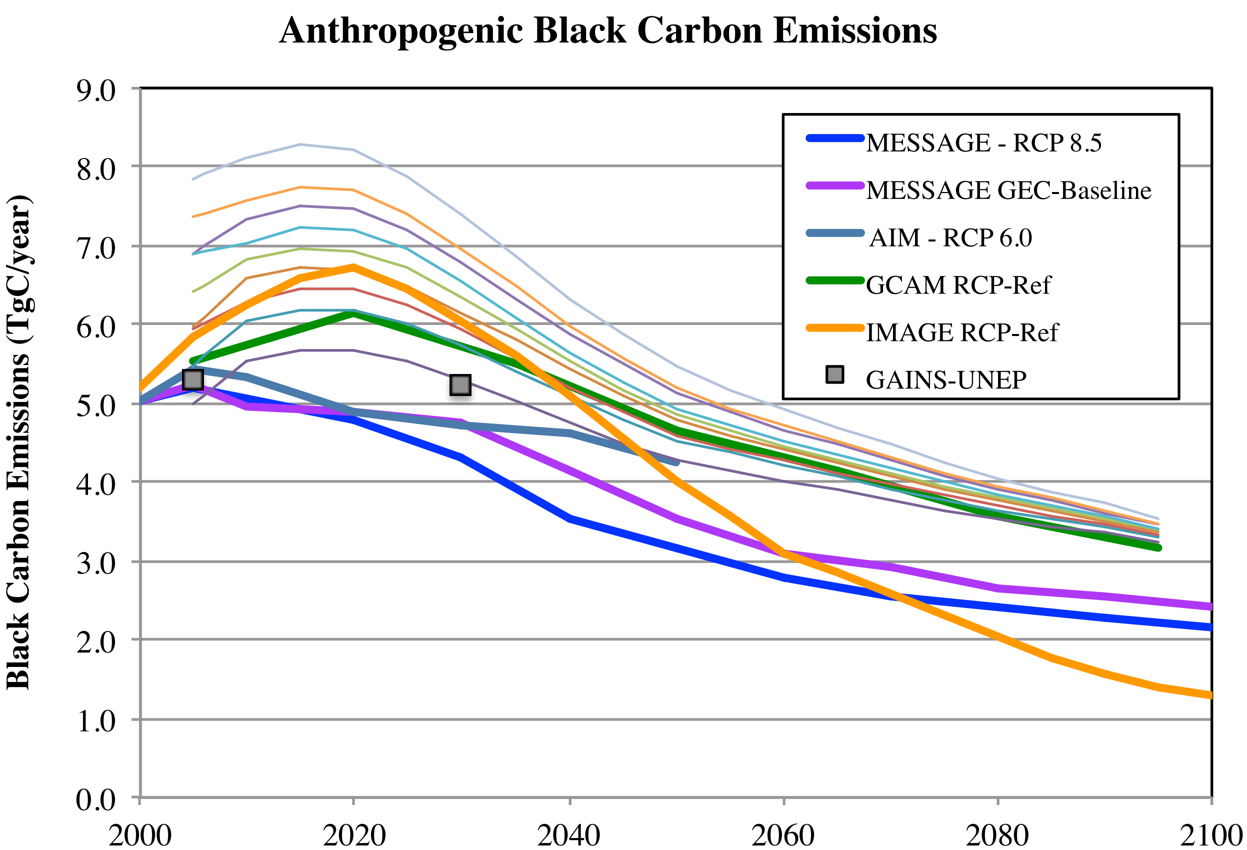
- **Emission Reductions**: Examine an idealistic “strawman” scenario with three elements: methane generally, road vehicles, and residential use of coal and biomass.
  1) Complete phase out of all residential coal and biomass use by 2035. (Consistent changes in associated emissions and energy system changes.)
  2) Control of road vehicle particulate emissions to approximately EURO 6 standards by 2030, with no super-emitters. (All sulfur in vehicle fuels also assumed to be removed by this time as well. Ozone precursors not changed.)
  3) Maximum feasible reductions of methane in place by 2035. (No impacts on energy sys)

This is a scenario that provides a bounding value, since it is likely not possible to achieve all of these reductions.

- This analysis focuses on these three categories to keep this simple. These are other BC reductions that have high potential for positive climate mitigation and health benefits.
- Also examine a counterfactual scenario with no economically-attractive methane reductions (e.g., all CH_4 emissions factors constant) and constant transportation & building BC and OC emission factors. (Technology shifts still occur.)

Starting Point: GCAM Reference Scenario

Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

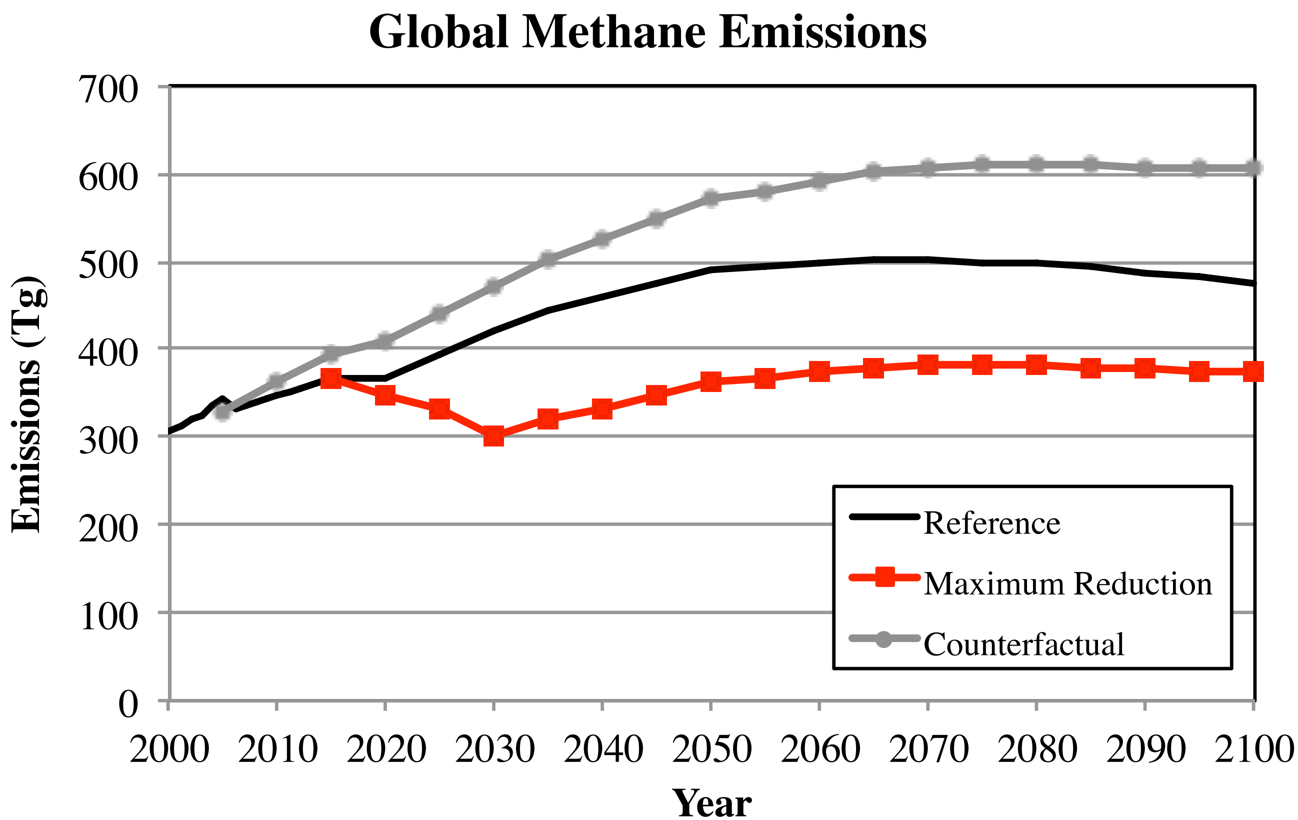


- Given evidence for an underestimate of current BC emissions (Bond et al. 2013), we used current inventory data as our lower bound.
- Similar in near-term to other scenarios in the literature, including GAINS used in UNEP.
- The GCAM reference scenario is a bit higher than some other scenarios in the long-term.

Smith & Mizrahi (2013)- Fig SI-2

Methane Reductions

Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by **Battelle** *Since 1965*



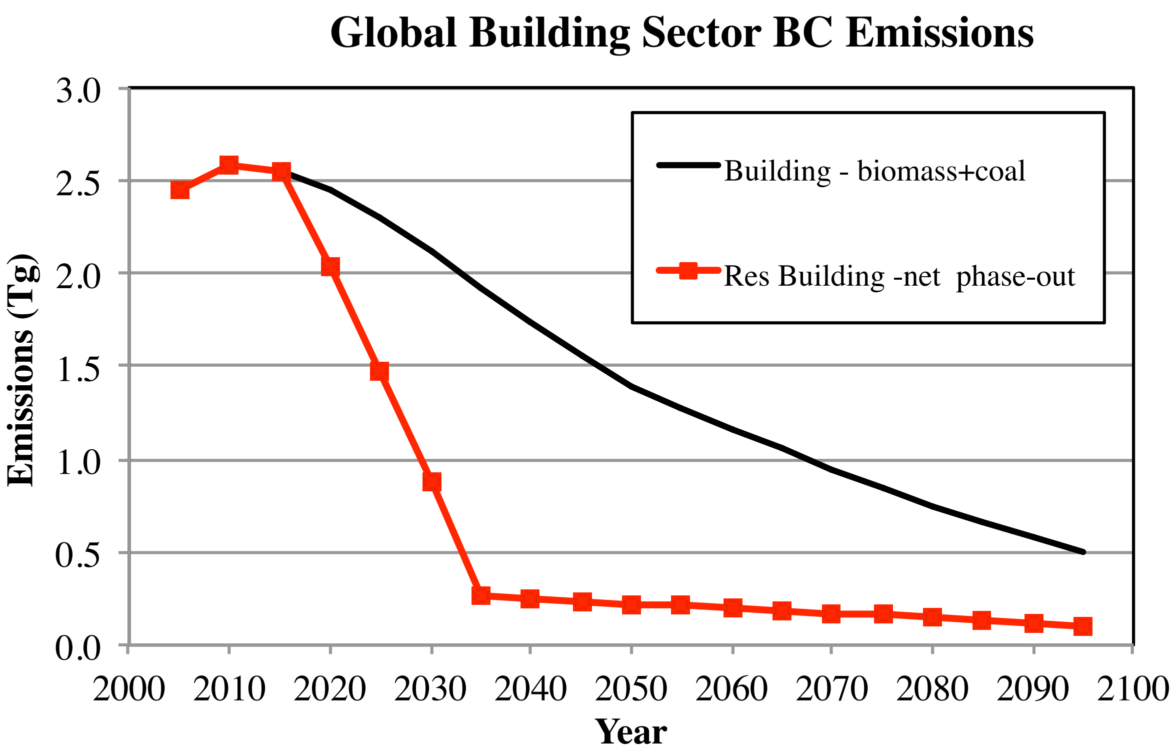
With constant CH_4 emission factors over all time, CH_4 emissions increase to 600 Tg/yr

The SLCF-case reductions are linearly phased in (exogenously) from 2015 to 2030, assuming reference case reductions (relative to counter-factual) occur first (which results in a slightly sub-linear introduction of additional reductions).

Smith & Mizrahi (2013)- Figure SI-4

BC Reductions: Residential Buildings

Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965



Technology phase-out in SLCF scenario implemented in GCAM.

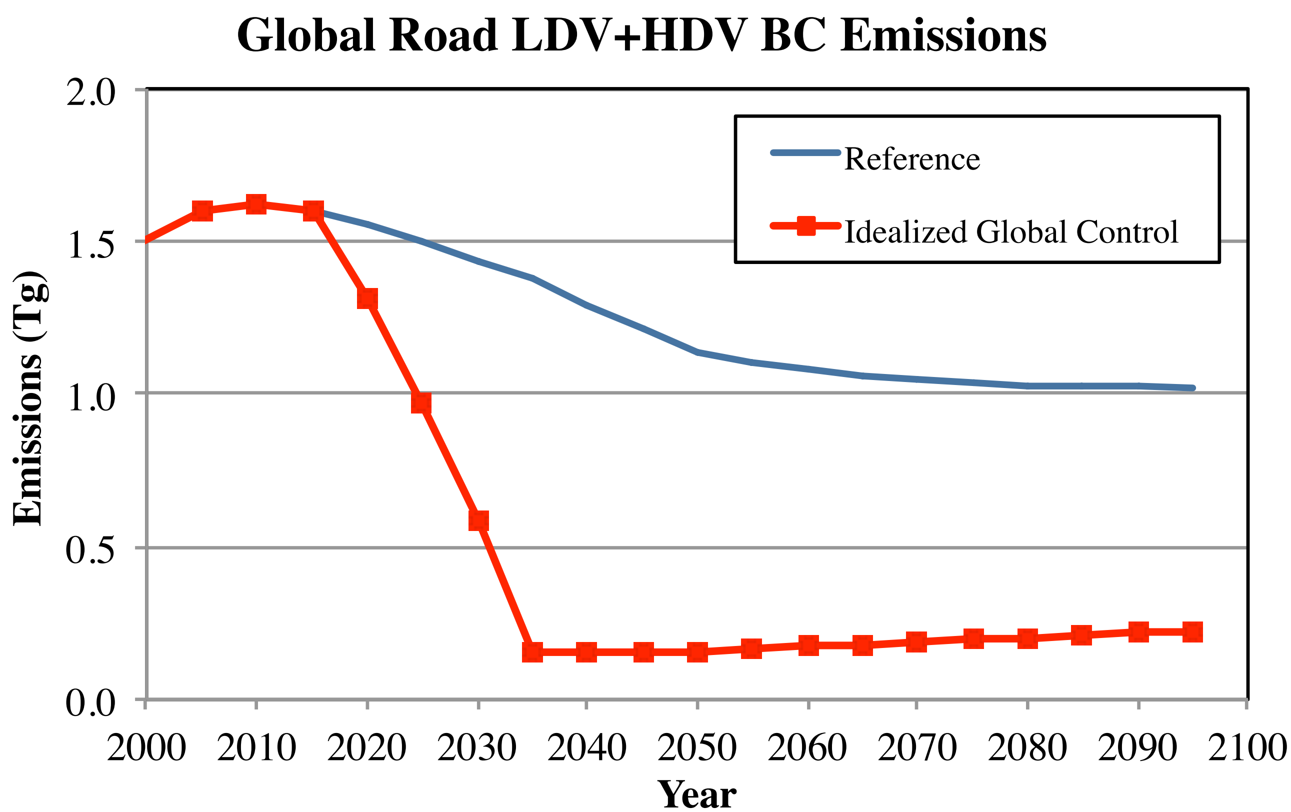
Assuming economic development proceeds as assumed in the baseline GDP pathway, these emissions will eventually decrease even without additional "climate-focused" policy action.

Complete phase-out of residential building biomass and coal consumption:

- Simpler to model than introduction of improved cookstoves, but both are idealized policies in any event.
- Building sector biomass phase-out results in substantial decrease in BC emissions

Smith & Mizrahi (2013)- Figure SI-5

BC Reductions: Road Transport



Note that ref scenario emissions also decrease.

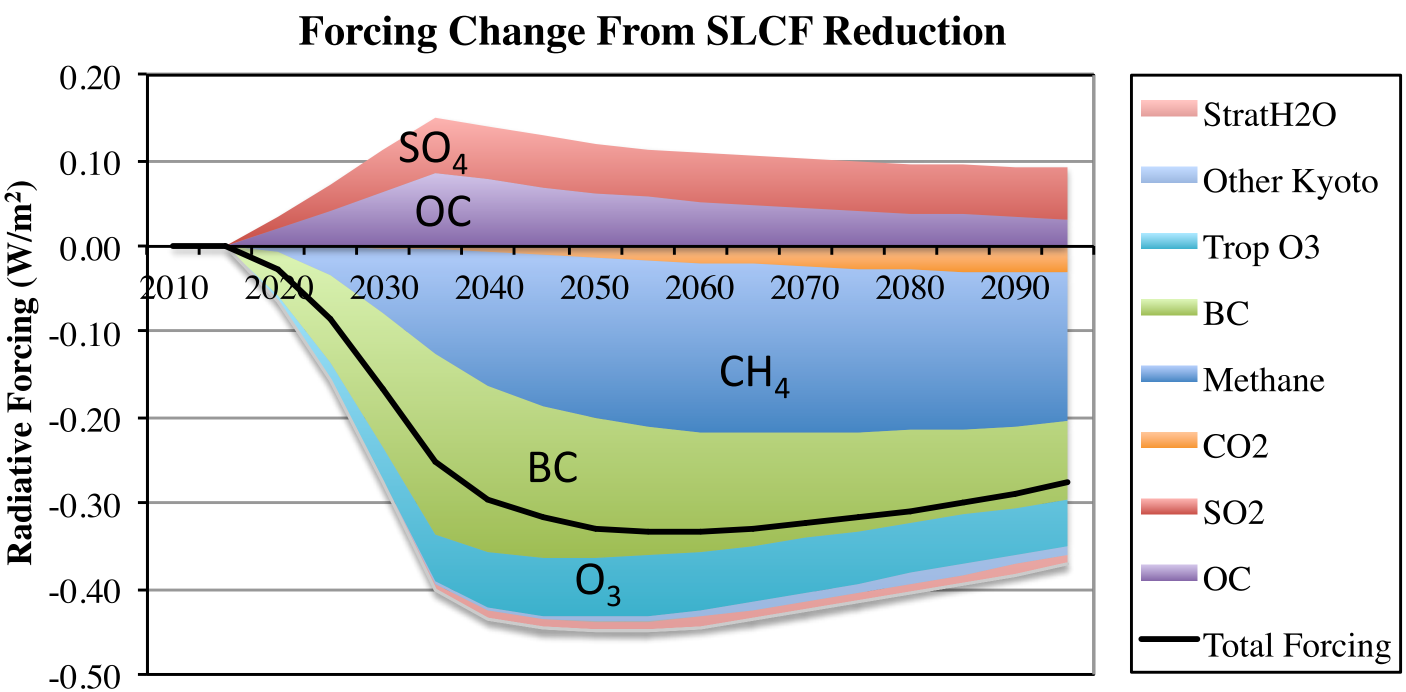
Reductions in 2030 relative to ref:

- Total LDV + HDV reduction of 1.2 Tg BC in 2035 relative to reference
- Somewhat less stringent (Euro 6) target for HDVs (~ 0.004 Tg/EJ)

Smith & Mizrahi (2013)- Figure SI-8

RESULTS

Central Case Forcing Change from SLCF Policy



Results for central assumptions for:

- Emissions Factors
- Radiative Forcing

Largest impact due to Methane, BC, and Tropospheric Ozone

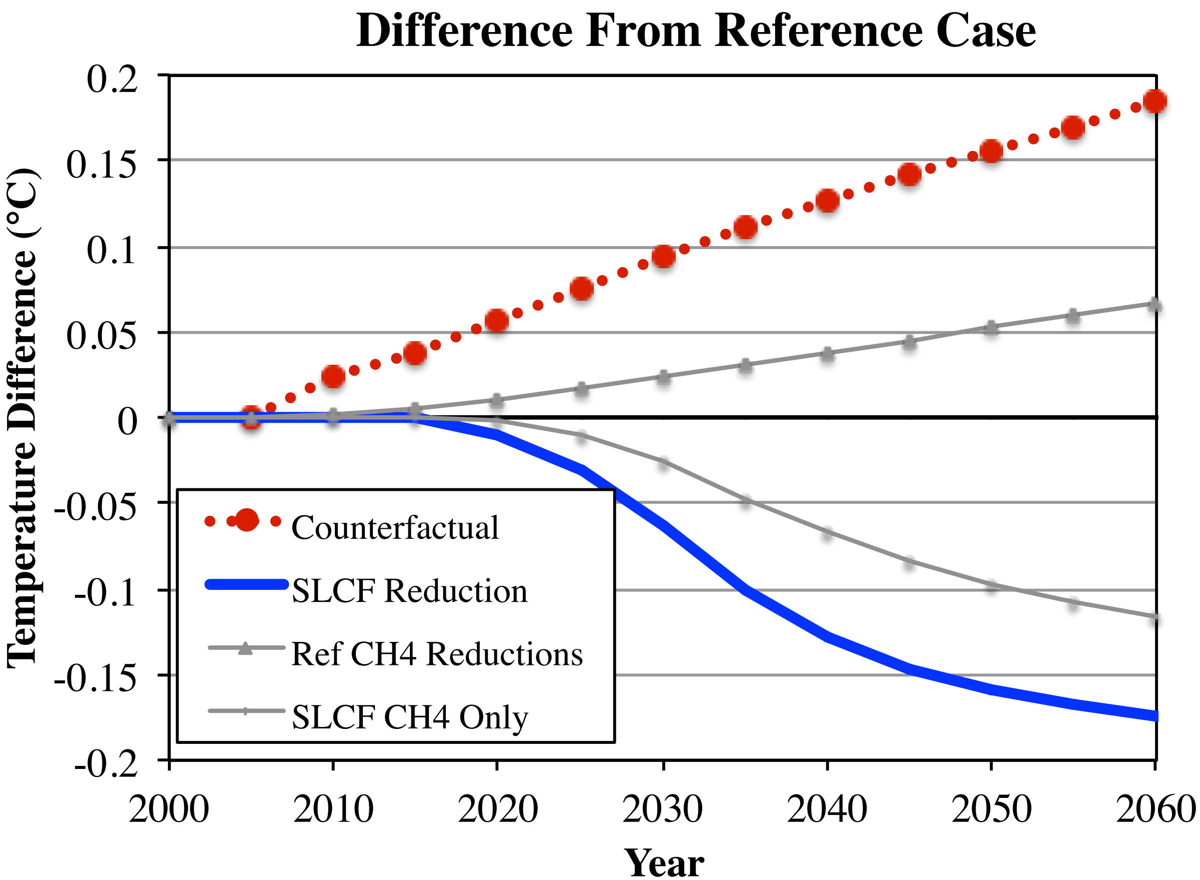
Small forcing increase due to OC and SO_2

Forcing impact decreases in 2nd half of century as conditions approach reference

For Methane, forcing is not within 90% of maximum until 2045, 15 years after reductions were fully in place.

Smith & Mizrahi (2013)- Figure 1

Result: Central Case Temperature



Using central assumptions for:

- Emissions Factors
- Radiative Forcing
- Climate Sensitivity

Under central assumptions, methane has the largest impact

Temperature decrease of ~0.16°C by 2050

Temperature reduction in 2050 is only 60% of equilibrium temperature reduction.

Smith & Mizrahi (2013)- Figure 2 (adapted)

UNCERTAINTY

Uncertainty

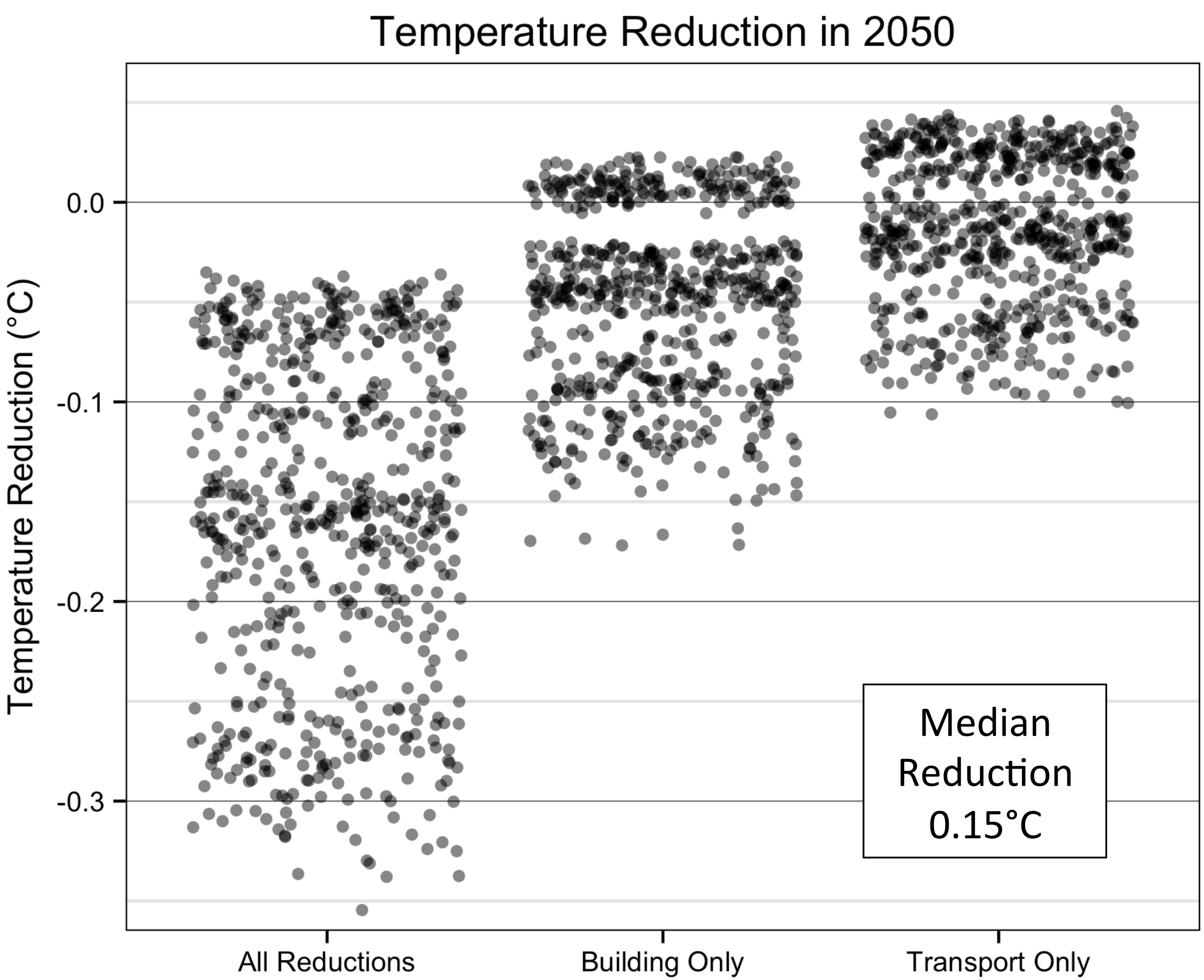
One scenario result is not sufficient, since there is large uncertainty:

- Aerosol forcing for all components,
- BC and OC emissions
- Climate Sensitivity (relatively small impact on diff ~ 20%, discussed in paper)

To examine a fuller range of possibilities, consider all combinations of:

- High, medium, and low forcing per unit emission for: SO_2 cloud indirect, BC, OC, and SO_2 direct. (From Bond et al. 2013)
- High, medium, and low emissions factors for building biomass BC/OC
- High, medium, and low emissions factors for LDV/HDV BC/OC
- BC/OC ratio taken to be constant
- 1458 cases
- Screened for total BC+OC+SO_2+Cloud ind forcing between -1.6 and -0.1 W/m^2
  - Minimal constraint for this broad range

Uncertainty Analysis: SLCF Temperature Reduction



Smith & Mizrahi (2013)- Figure 3a

- Very wide range of potential results
- Uncertainty in impact of CH_4 reduction not shown (is small)
- There is a potential for temperature increase from building reductions
- Potential for temperature increase from transportation reductions: depends on assumed ref-case level of petroleum system de-sulfurization.
- Climate sensitivity uncertainty adds ±20% (not shown)

Comparison With UNEP and Summary

Summary : Impact of SLCF Reductions

The global impact of SLCF reductions can be summarized as:

$$\Delta T \approx \Delta F \bullet ClimSens \bullet f_{realized}$$

The temperature change at a given time due to SLCF reductions will be roughly equal to the forcing reduction caused by those changes times the climate sensitivity times the fraction of the equilibrium temperature change realized by that time.

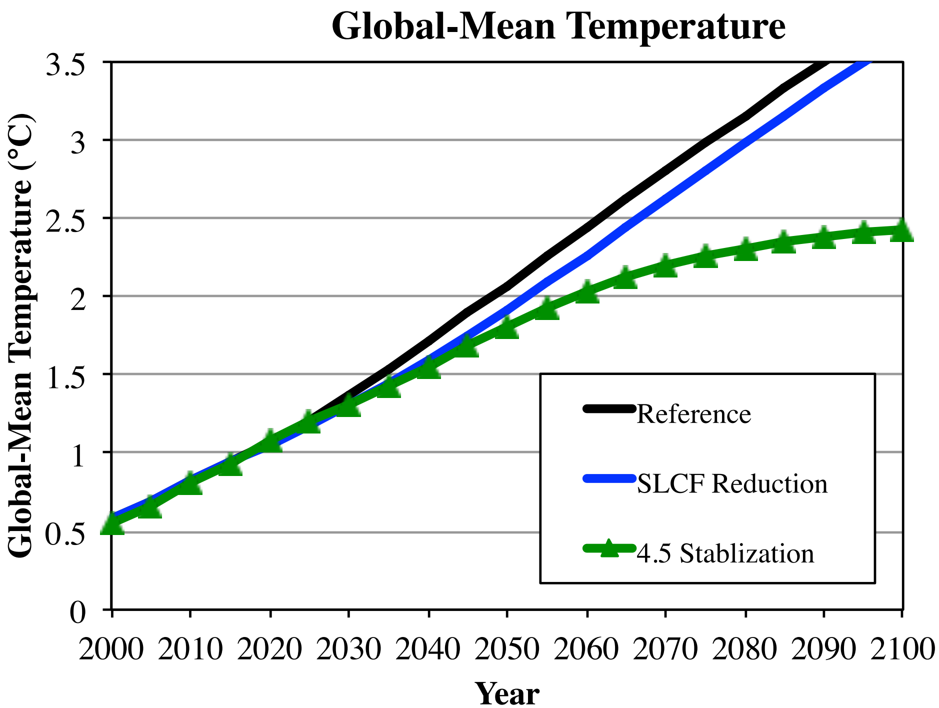
The **impact of SLCF reductions is smaller than previously estimated** due primarily to

1) a more realistic representation of the climate system,

   OR: -> $f_{realized} < 1$

2) use of fully consistent scenarios over time, and
3) the inclusion of some improvement in methane emissions factors in the reference scenario.

2) + 3) -> smaller ΔF



Conclusions

- A policy focused on reducing methane and black carbon is likely to also reduce near-term climate change.
- We find, however, that the reduction is likely to be smaller than previously estimated, of order 0.16 °C in 2050.
  - This is of the same order as the reduction from an idealized climate policy.
  - There is some probability of a net warming from a policy focused on reducing global BC emissions.
- There is large uncertainty in this value (~0.04°C – 0.35°C)
- The high end of temperature reduction depends on current total aerosol forcing being relatively small in magnitude.
- Results are smaller than previously estimated due to simplifications in previous temperature calculations, more consistent scenarios over time, the assumption of reference case CH_4 reductions, and several other smaller differences.
- These results do not alter estimates of the potential health benefits of reductions in methane and black carbon.

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle *Since 1965*

THE END