Short-lived climate forcers in CMIP5 and CMIP6

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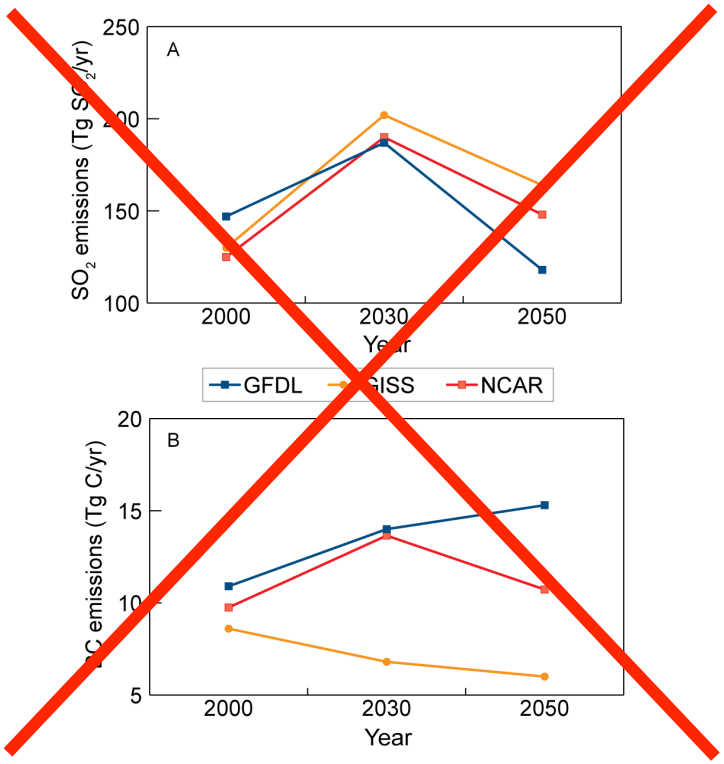
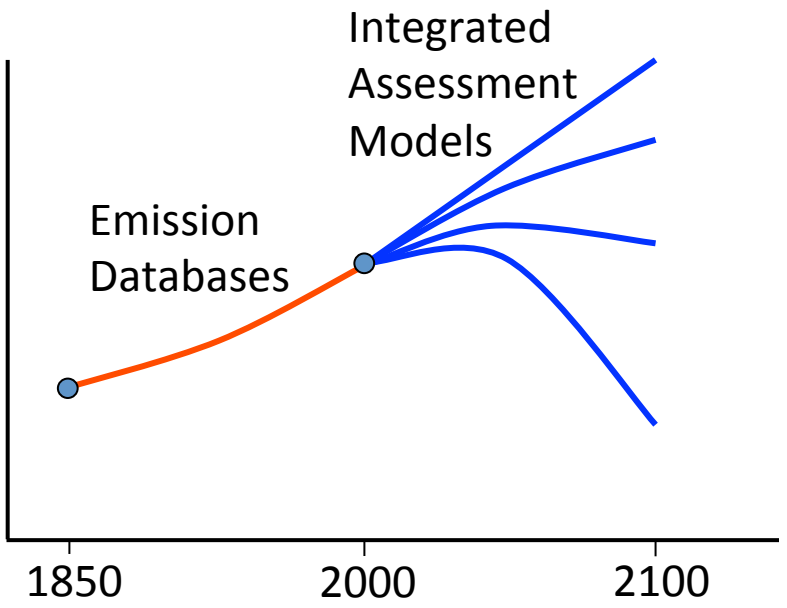
Modeling the distribution of SLCFs

Emissions from
A1B scenario

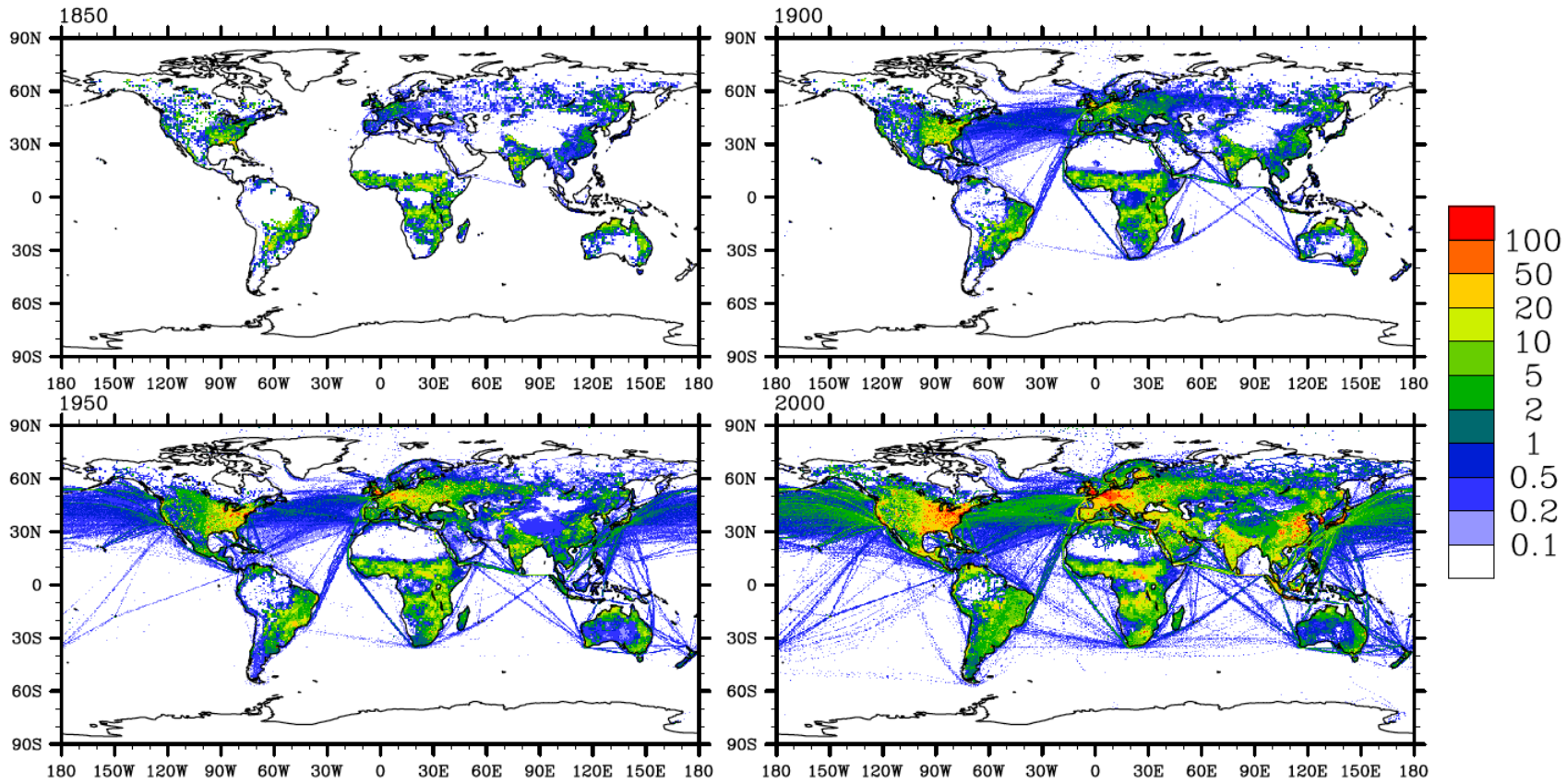


Shindell et al., JGR, 2008

Emissions (anthro+bb) for CMIP5 and AR5



Example: NO_x emissions



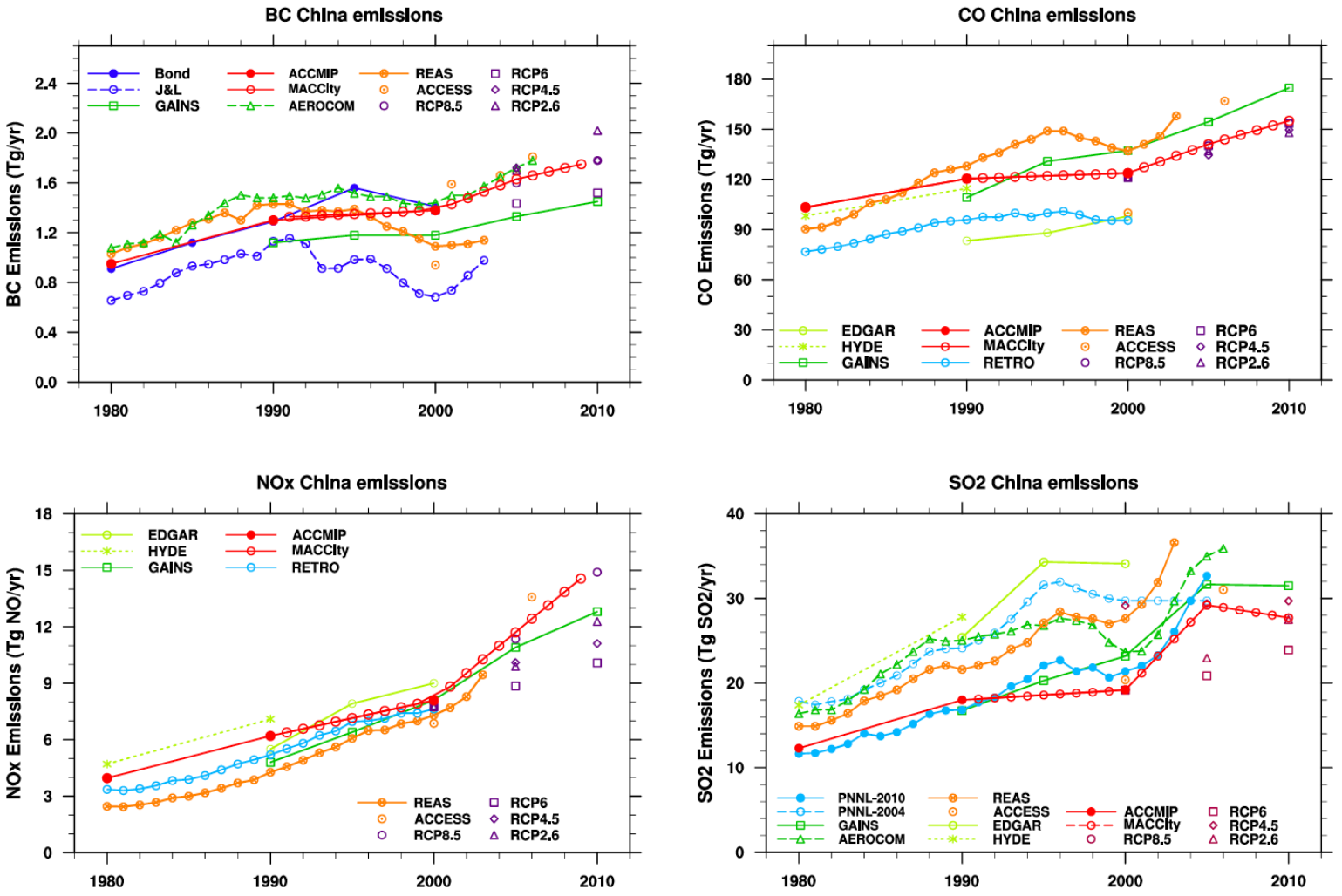
Anthropogenic + biomass burning + ships: kg(N)/year

Lamarque et al., ACP, 2010

ACCMIP: Chemistry and RF

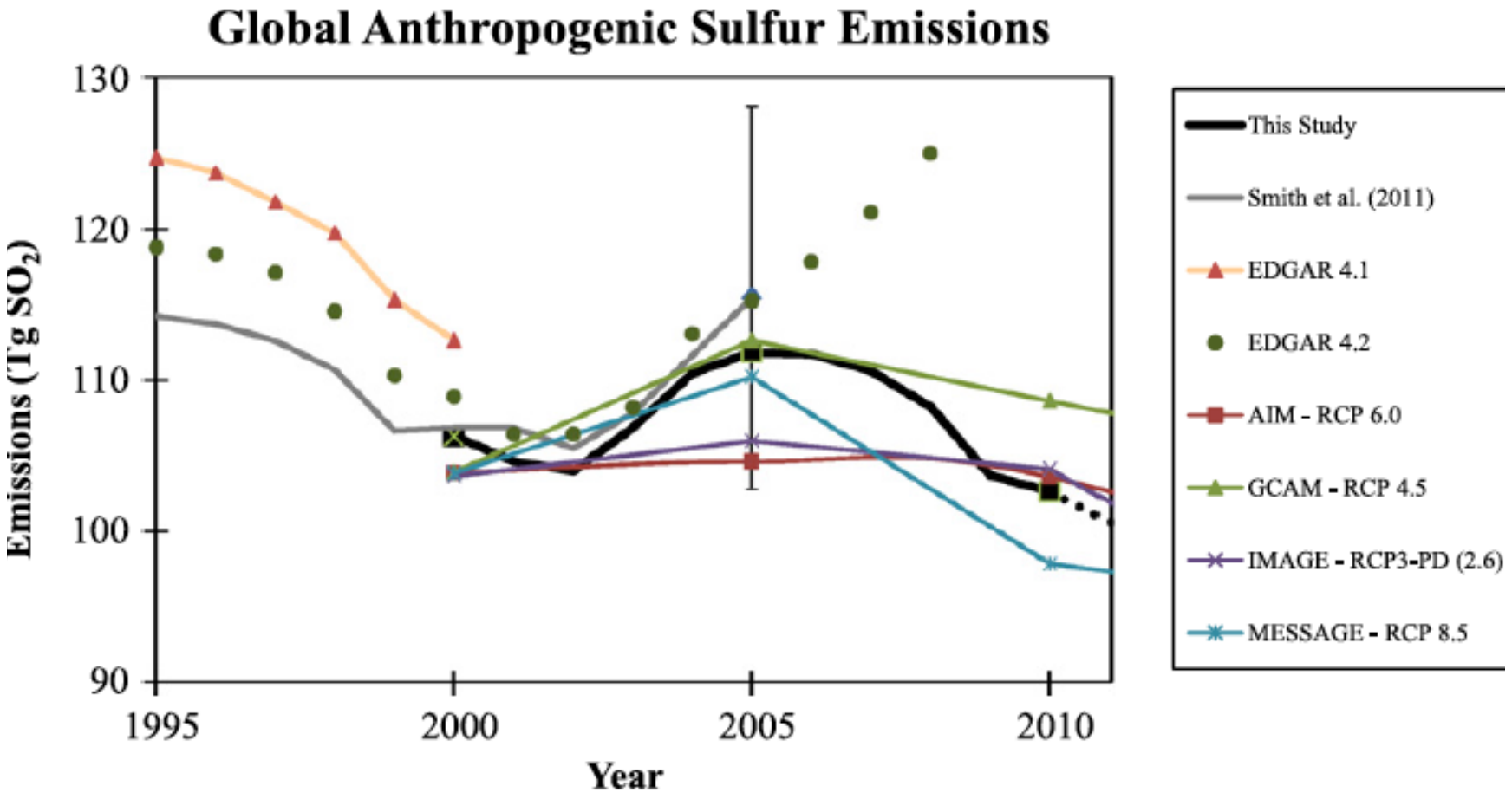
- Co-led by D. Shindell
- 15 models
- 10+ papers (including health impact)
- Critical to provide documentation of radiative forcing for AR5
- Analysis of concentration and deposition changes

How do the RCPs compare to other inventories?



Granier et al, 2011

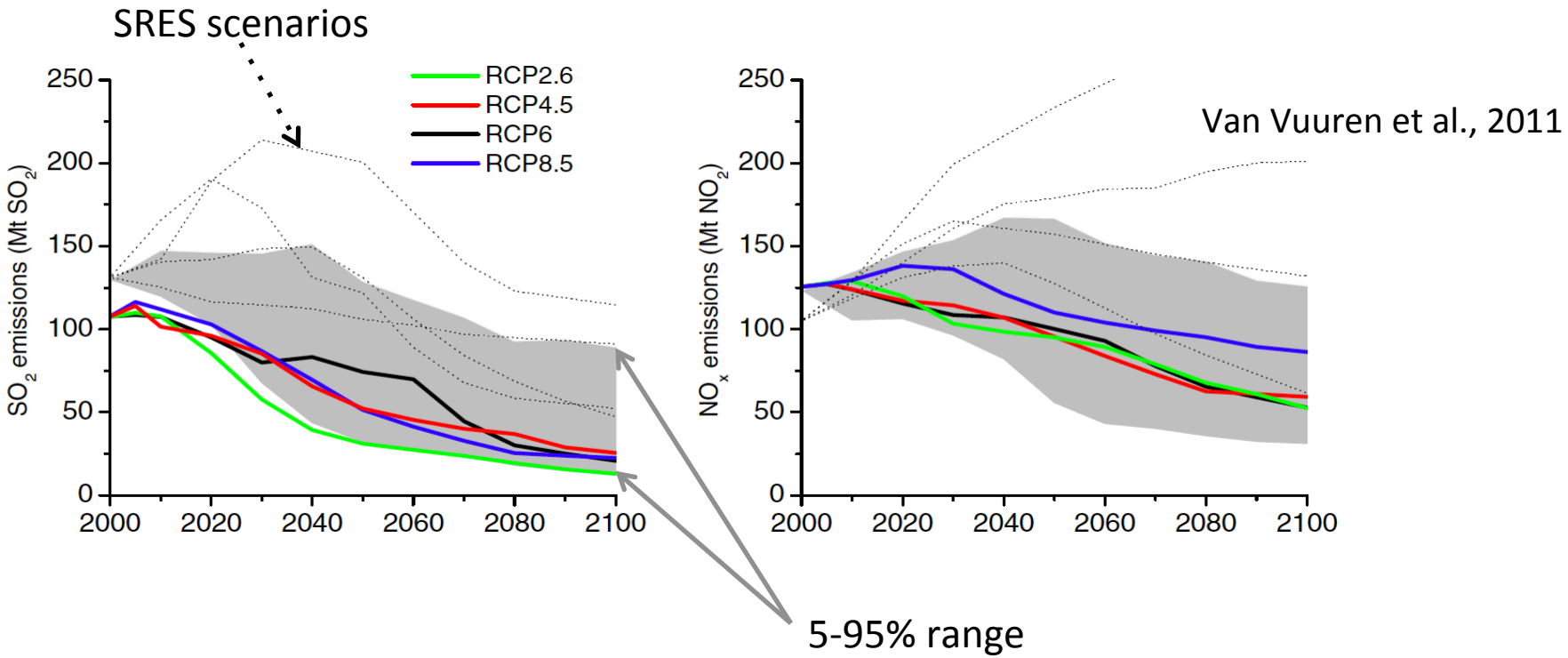
Focus on SO2 and recent hiatus



Klimont et al., 2013

Issues with RCPs

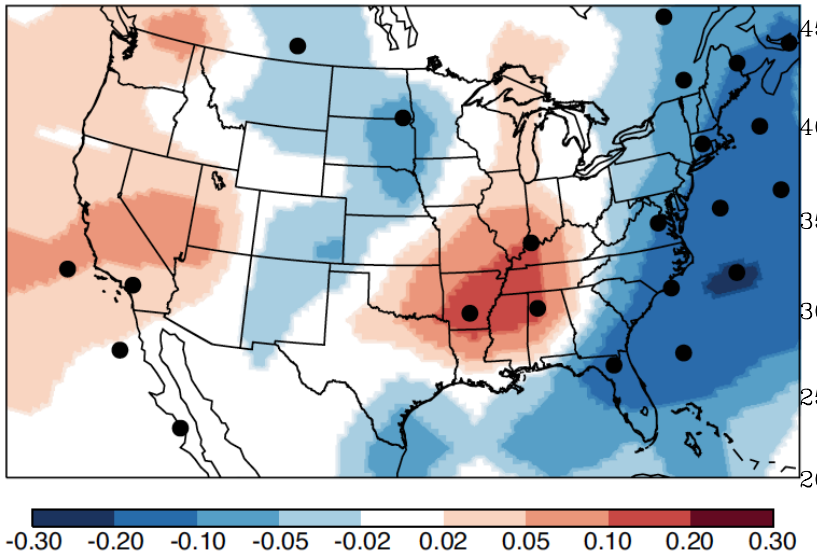
1. Emissions not capturing range



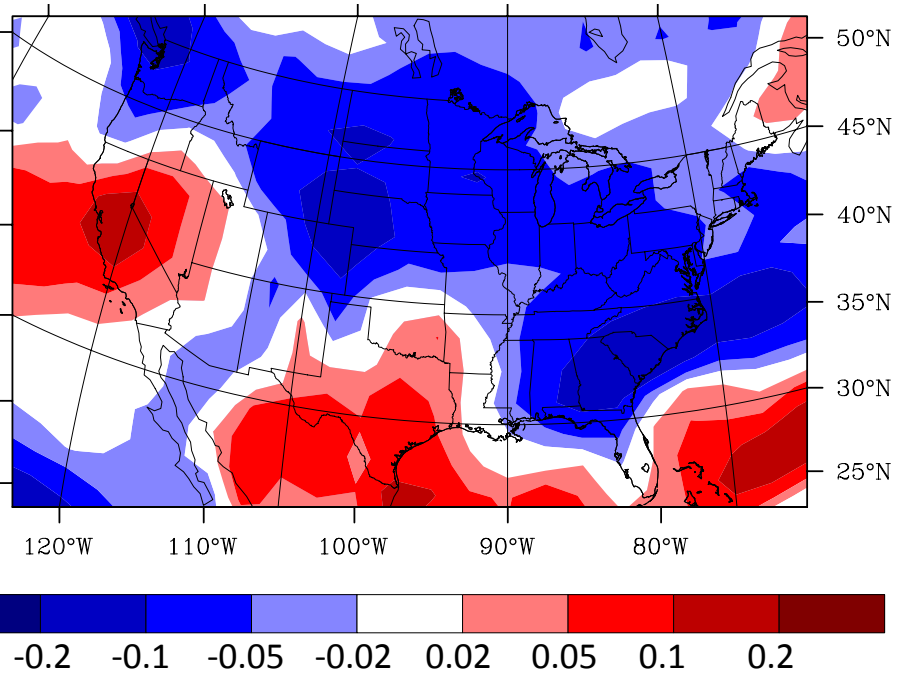
2. Cannot isolate the impact of SLCFs

Annual precipitation impact of US aerosol emissions

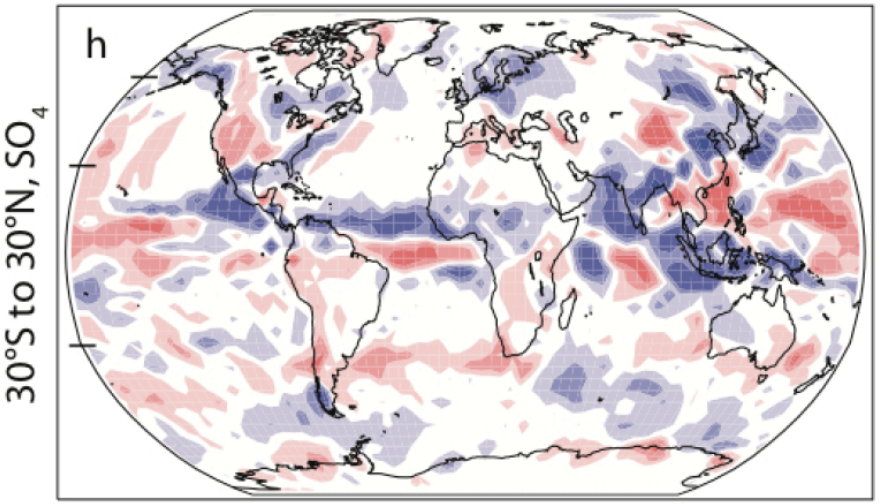
Leibensperger et al., 2012; all aerosols



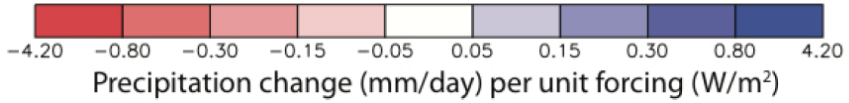
SO_2 emissions only



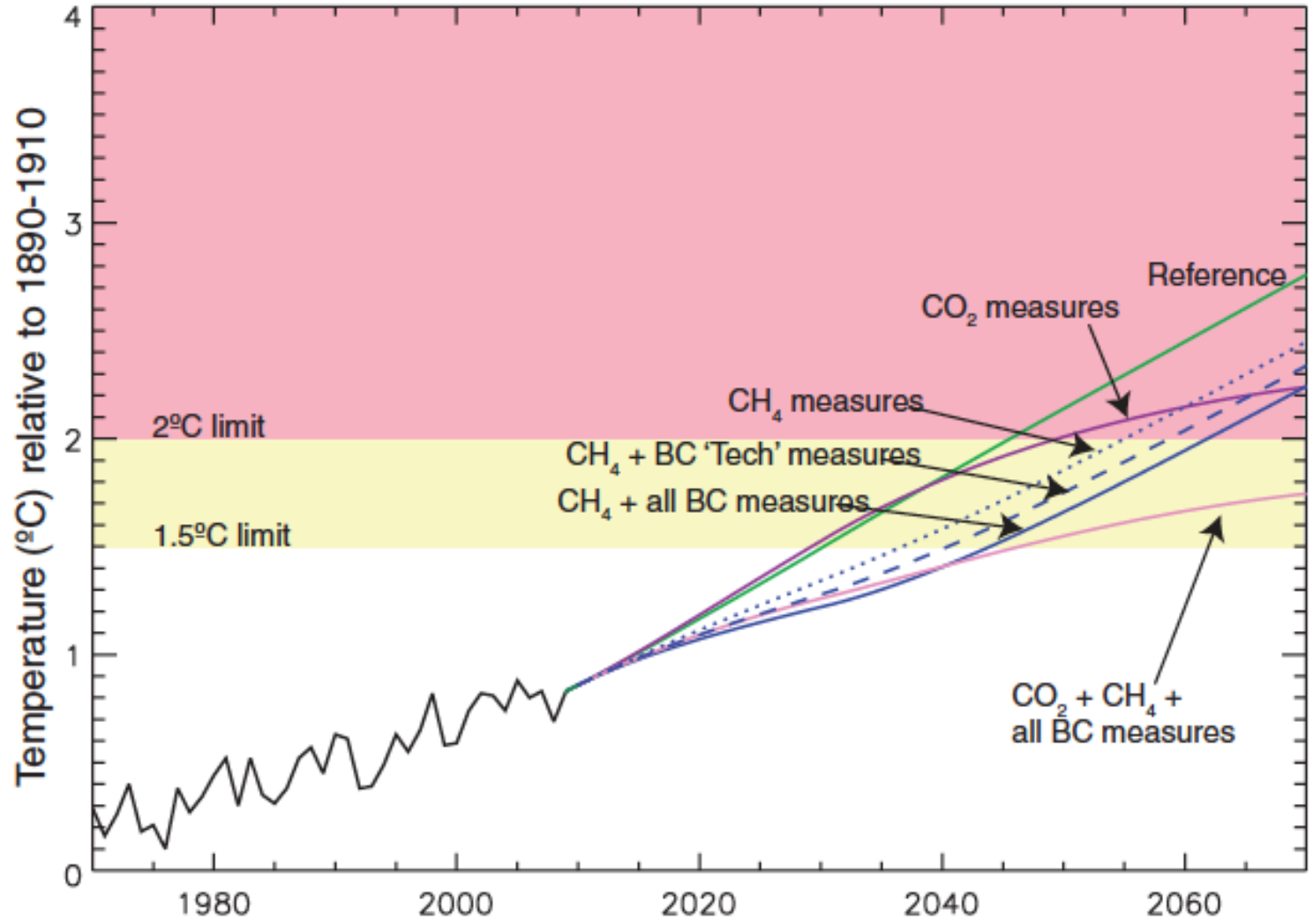
Precipitation impact: mm/day



Shindell et al., 2012



Recent focus on CH_4 and BC as win-win



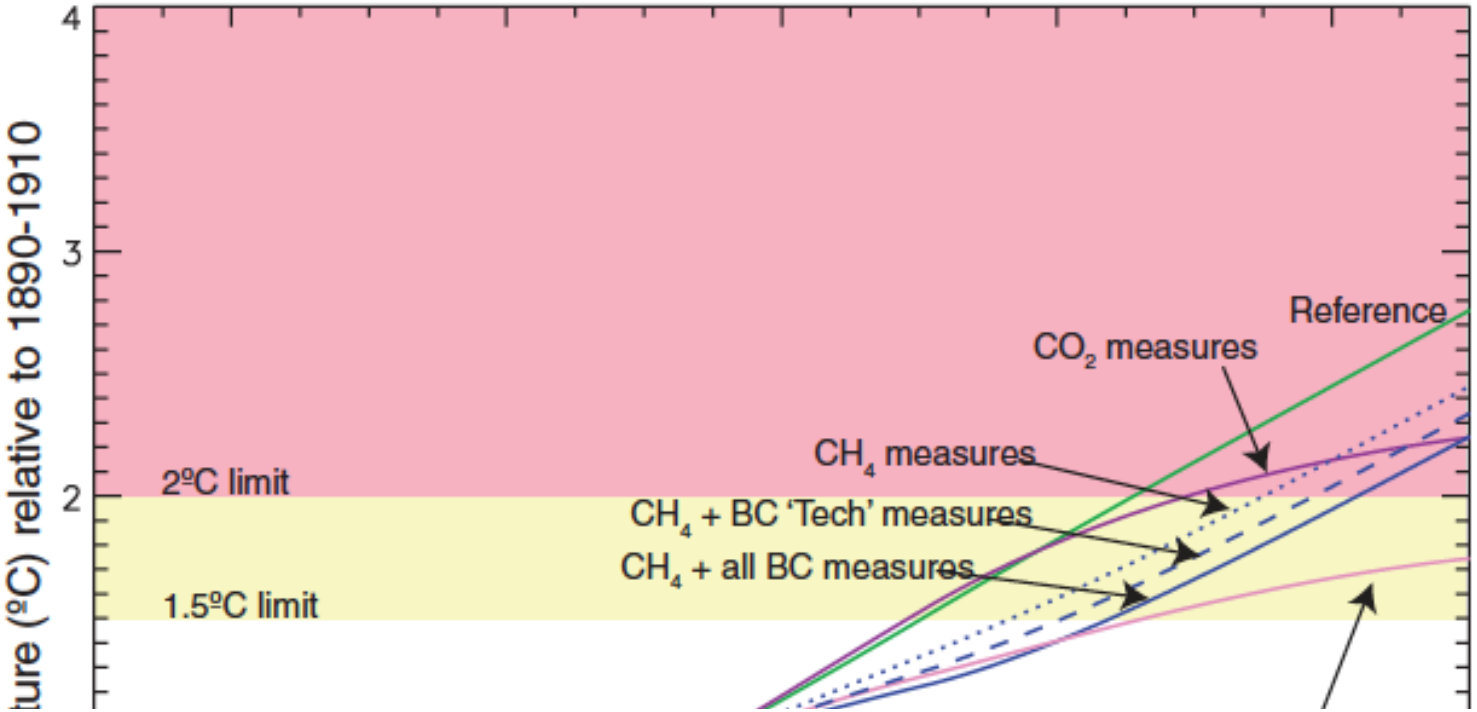
Reference

CH_4 measures

CH_4 + BC measures

Shindell et al., Science, 2012

Focus on CH_4 and BC: win-win



Reference

CH_4 measures

CH_4 + BC measures

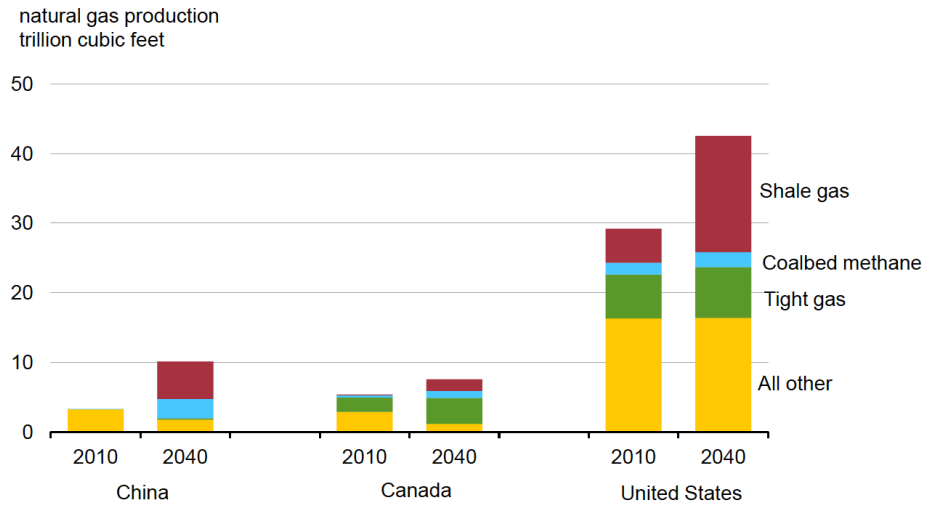
Obama climate action plan (6/25/13): Leverages new opportunities to reduce pollution of highly-potent greenhouse gases known as hydrofluorocarbons; directs agencies to develop a comprehensive methane strategy; and commits to protect our forests and critical landscapes.

Shindell et al., Science, 2012

Oil and gas from shale formations

Present US consumption: 2-2.8 million cubic feet

Shale gas, tight gas, and coalbed methane are increasingly important to the United States, China and Canada



Source: EIA, International Energy Outlook 2013

Table 5. Top 10 countries with technically recoverable shale oil resources

Rank	Country	Shale oil (billion barrels)	
1	Russia	75	
2	U.S.[1]	58	(48)
3	China	32	
4	Argentina	27	
5	Libya	26	
6	Venezuela	13	
7	Mexico	13	
8	Pakistan	9	
9	Canada	9	
10	Indonesia	8	
	World Total	345	(335)

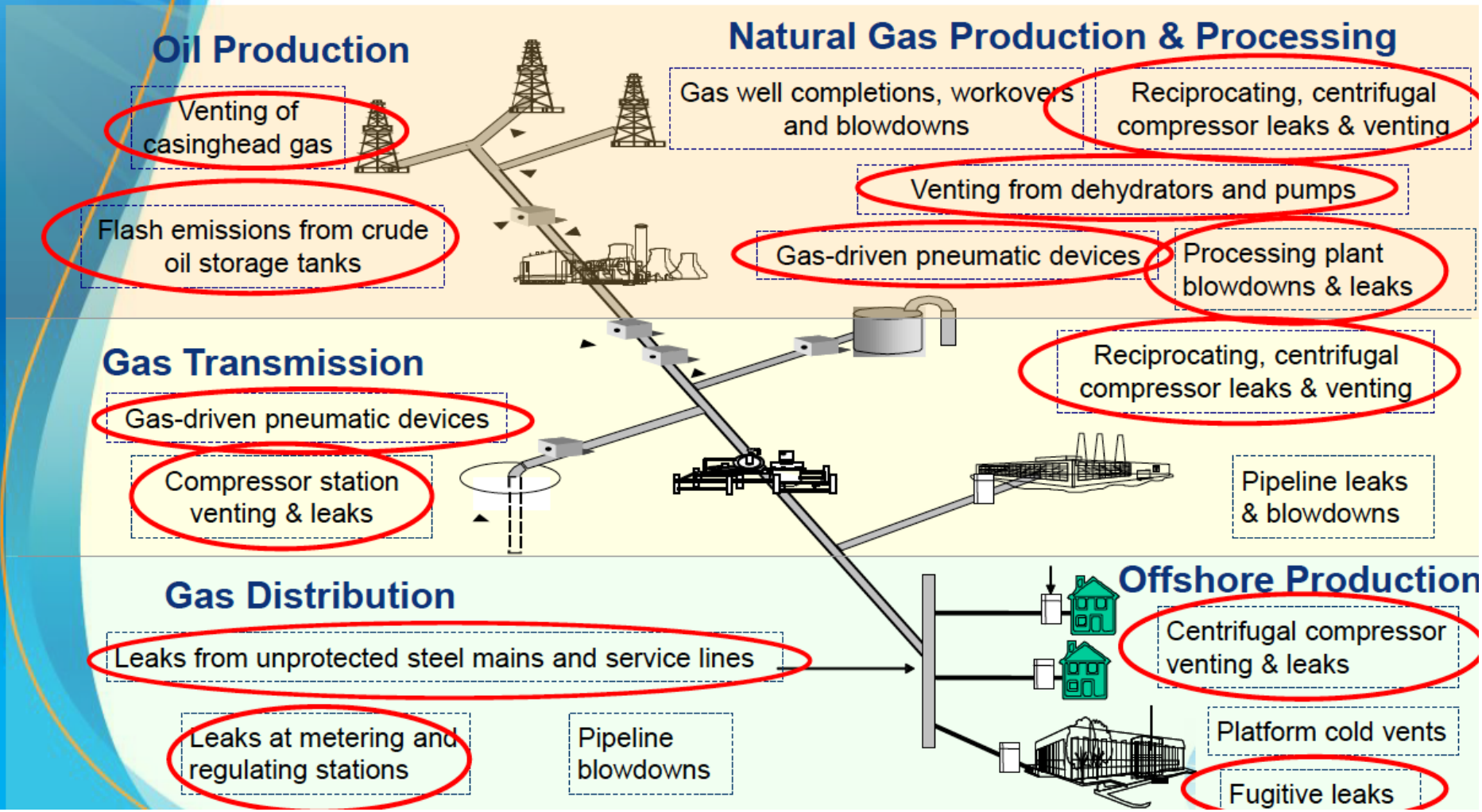
[1] EIA estimates used for ranking order. ARI estimates in parentheses.

Table 6. Top 10 countries with technically recoverable shale gas resources

Rank	Country	Shale gas (trillion cubic feet)	
1	China	1,115	
2	Argentina	802	
3	Algeria	707	
4	U.S.[1]	665	(1,161)
5	Canada	573	
6	Mexico	545	
7	Australia	437	
8	South Africa	390	
9	Russia	285	
10	Brazil	245	
	World Total	7,299	(7,795)

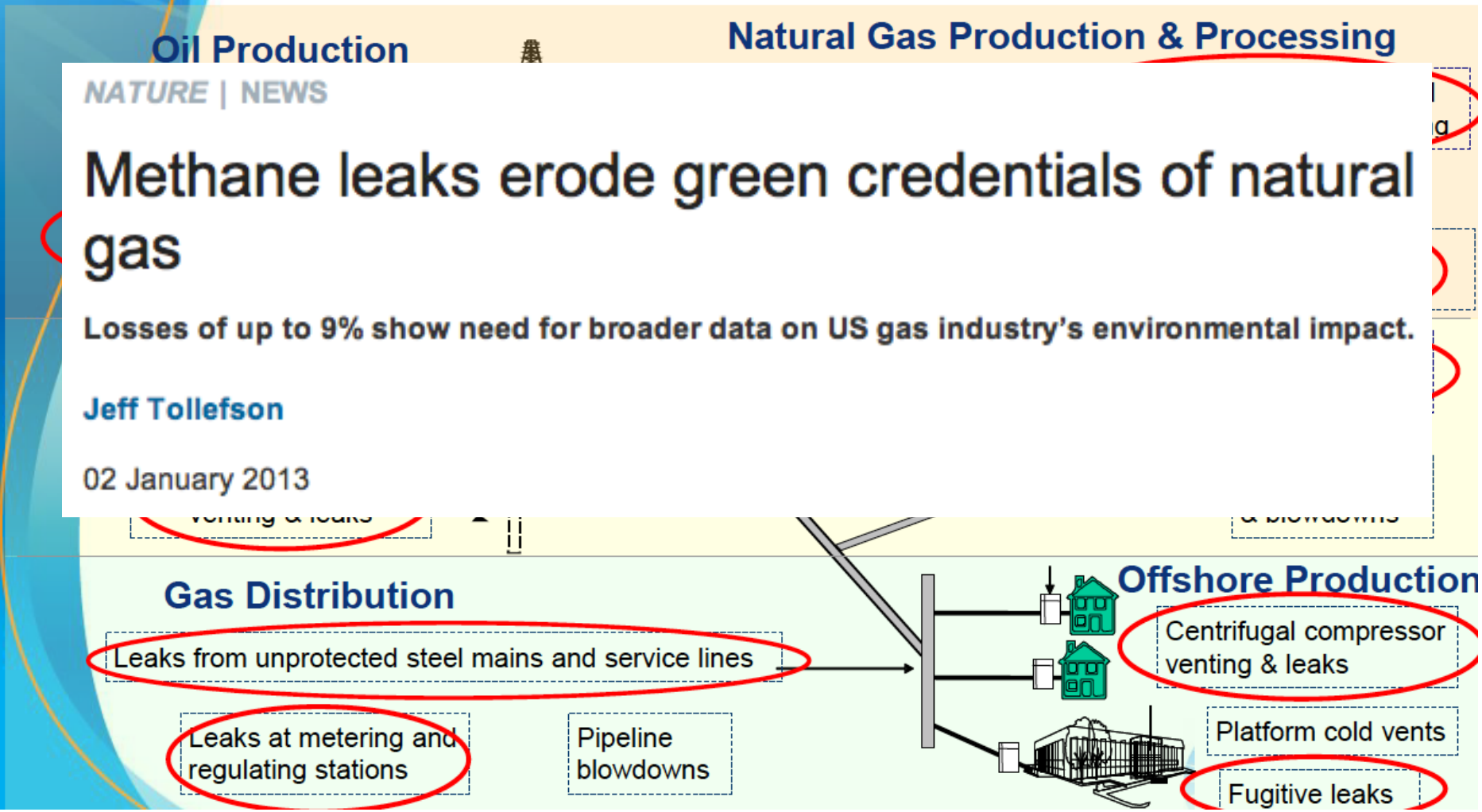
[1] EIA estimates used for ranking order. ARI estimates in parentheses.

Top Sources of Oil and Gas Methane Emissions



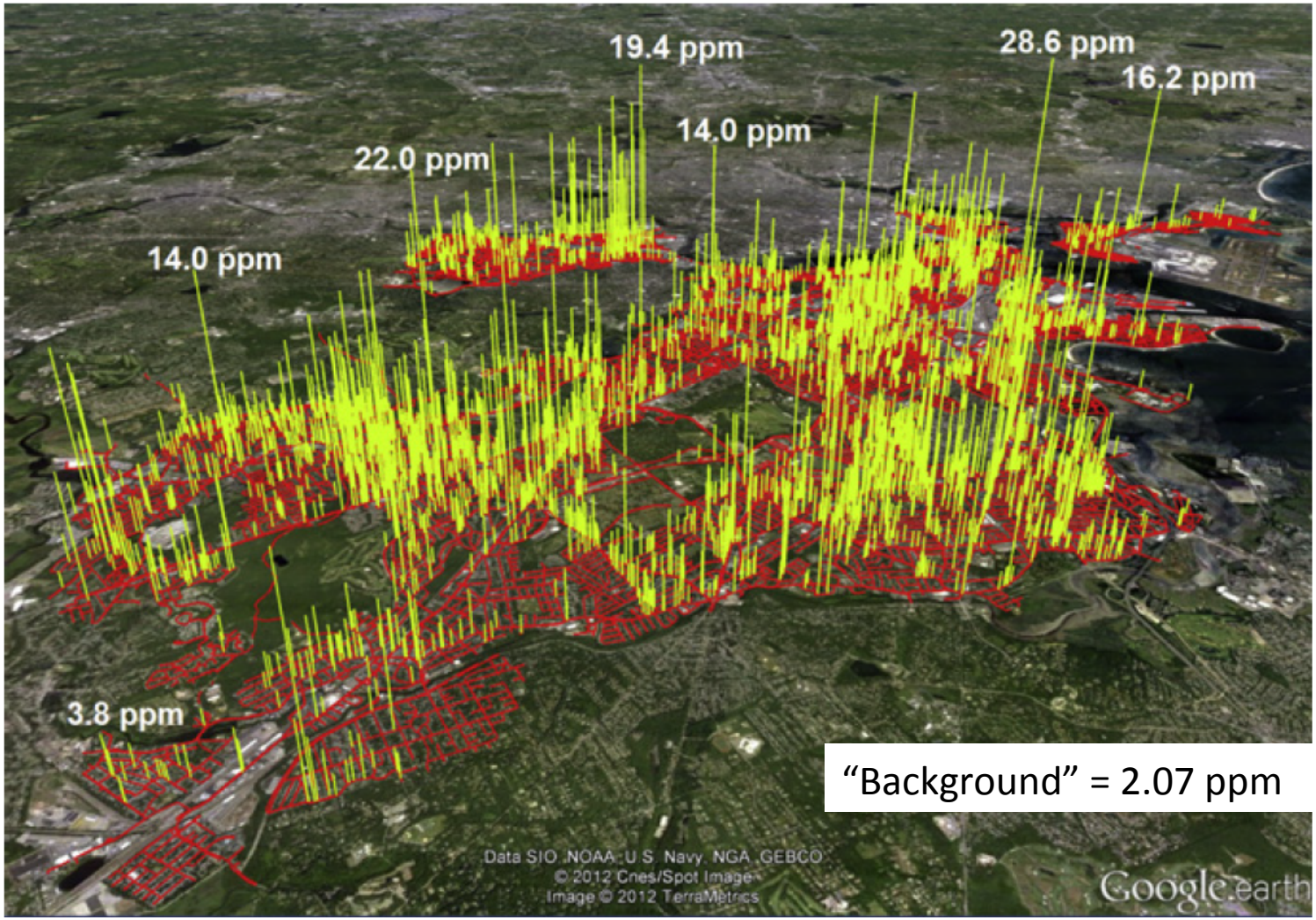
Picture courtesy of American Gas Association

Top Sources of Oil and Gas Methane Emissions



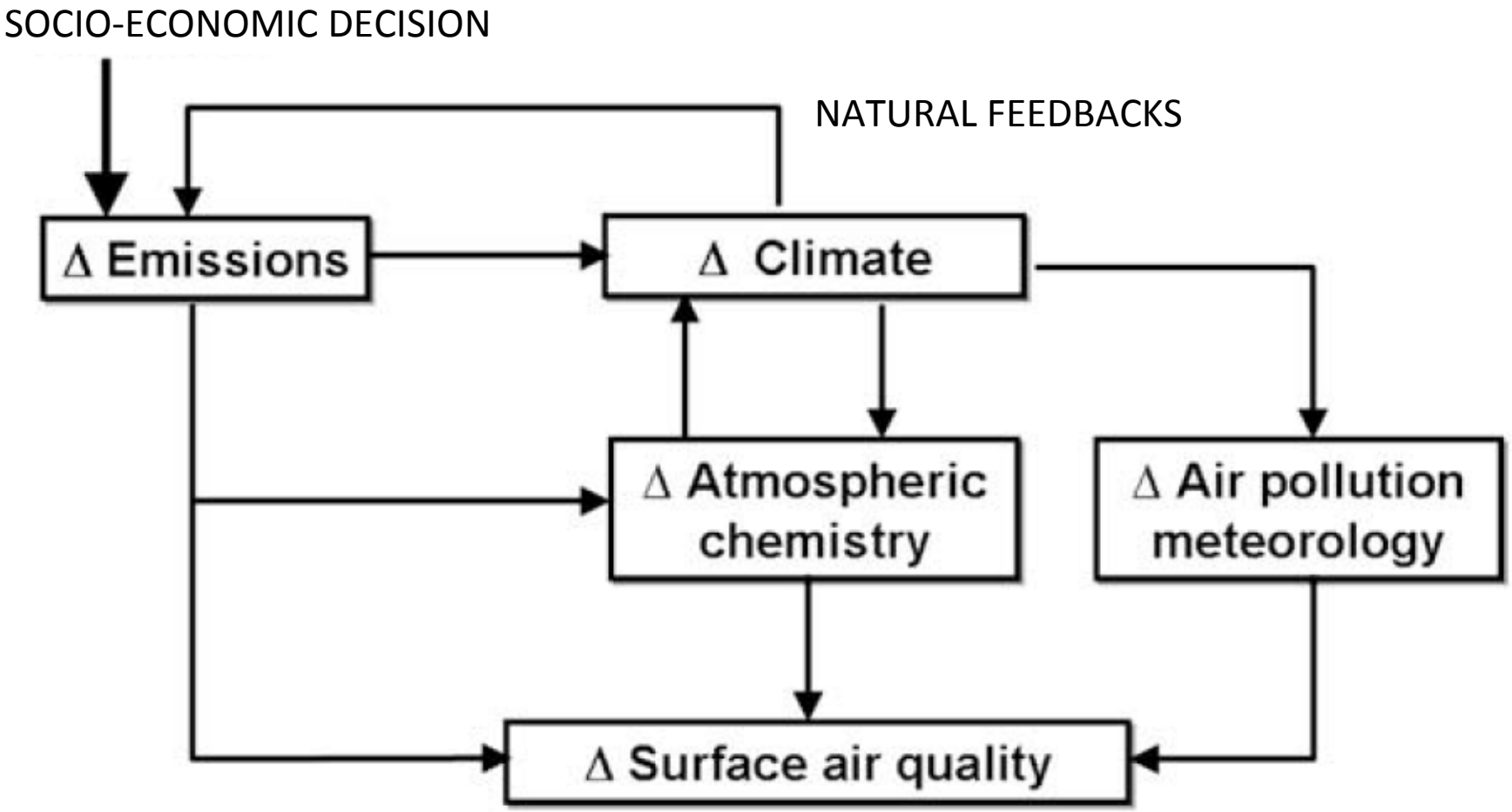
Picture courtesy of American Gas Association

Natural gas leaks = $3.1 B in US ($12-28 B worldwide)



Phillips et al., Env. Poll., 2013

Chemistry-climate and AQ



Jacob and Winner, Atmos. Env, 2009

Early discussions

- Drew Shindell
- Arlene Fiore
- Michael Prather
- Denise Mauzerall
- Claire Granier
- Greg Frost

Proposal for next-gen(C^6) climate-study scenarios

Goal – be able to identify/quantify a specific alternate (mitigation) pathway that separates two scenarios: e.g.

- Switching coal power plants to natural gas
- Policy/regulation on transportation or air quality

1. Define a Reference Scenario and associated emissions. Based primarily on current trajectory of emissions and regulations.
2. Quantify the delta(emissions) associated with change in pathway (specific actions) for each of the IAMs (e.g., actions to keep <2°C). Treat this as a climate model ensemble. Look for agreement global/regional, check for consensus, define ensemble mean emissions/land-use change if possible
3. Perform climate simulations with reference and a single perturbed emissions case (allows calculation of climate sensitivity for specific action)

Proposal for AQ studies

- The main target is to understand the role of climate change on atmospheric composition (change in T, H2O + precip, …)
- Key assessment is (i) how is background changing from climate and global/regional emissions, and (ii) how is this changing the efficiency of local emissions to produce local pollution.
  - Start from reference case (which must have significant emissions of AQ precursors over the whole simulation period)
  - Use a separate scenario with a large enough climate signal but keep the same precursor emissions as reference.

A few more points

- Will need to update harmonization (2010?)
- No effort for revising historical emissions!
- Resolution beyond 0.5^{o}? Gridding?

Anthropogenic climate forcing (1750-2005)

Forster and Ramaswamy, AR4 Chapter 2

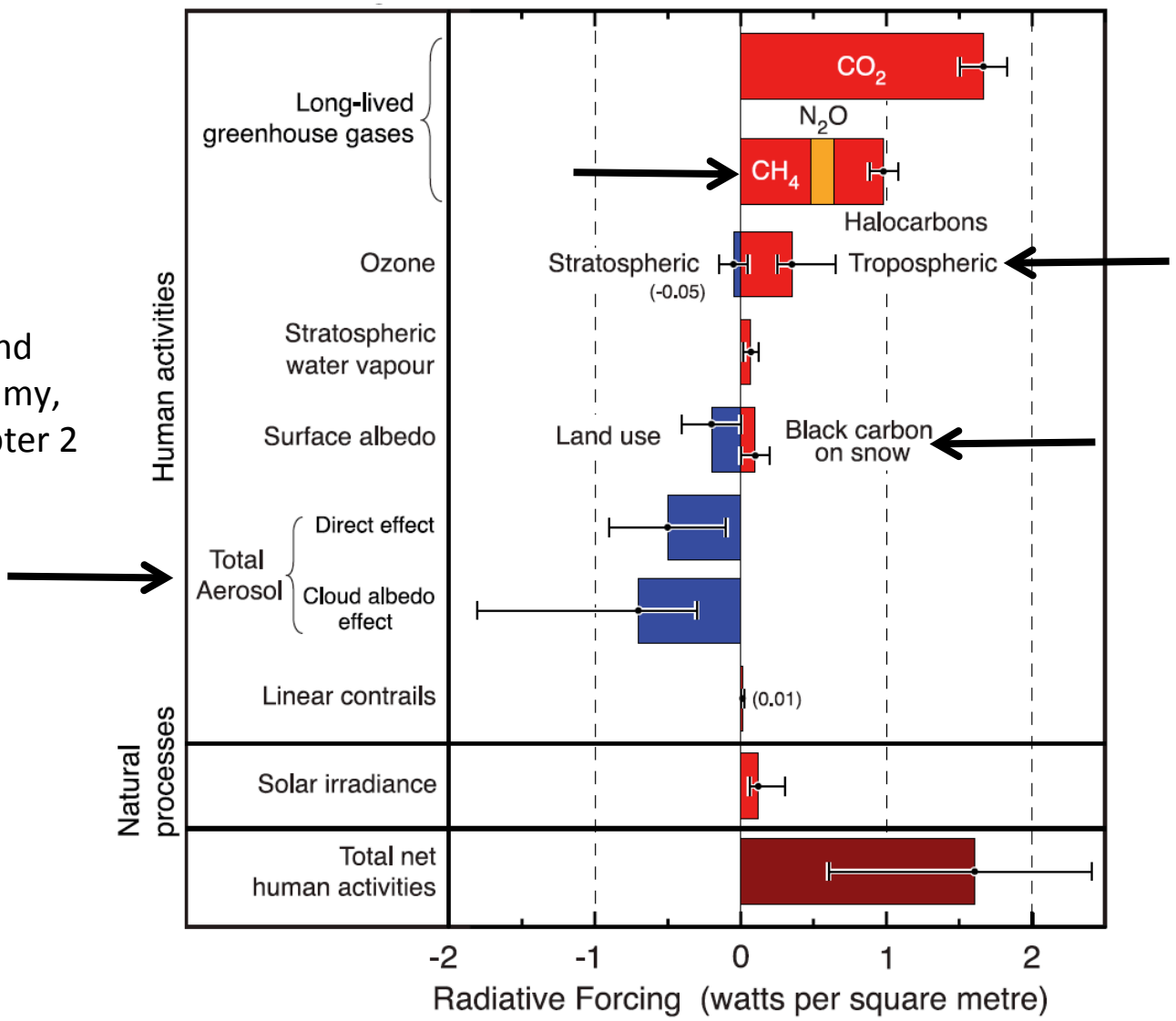
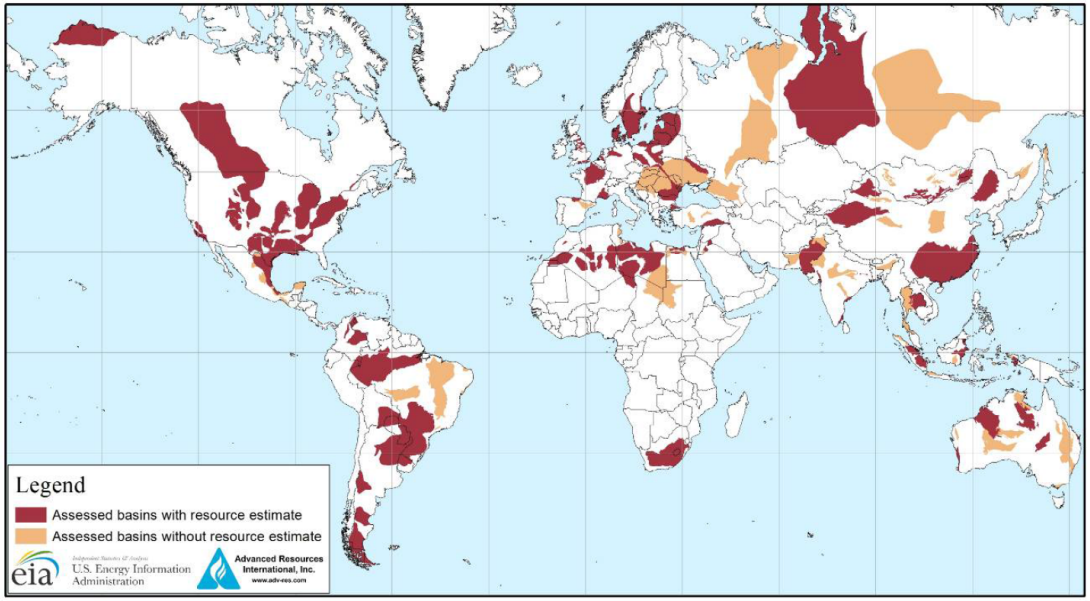
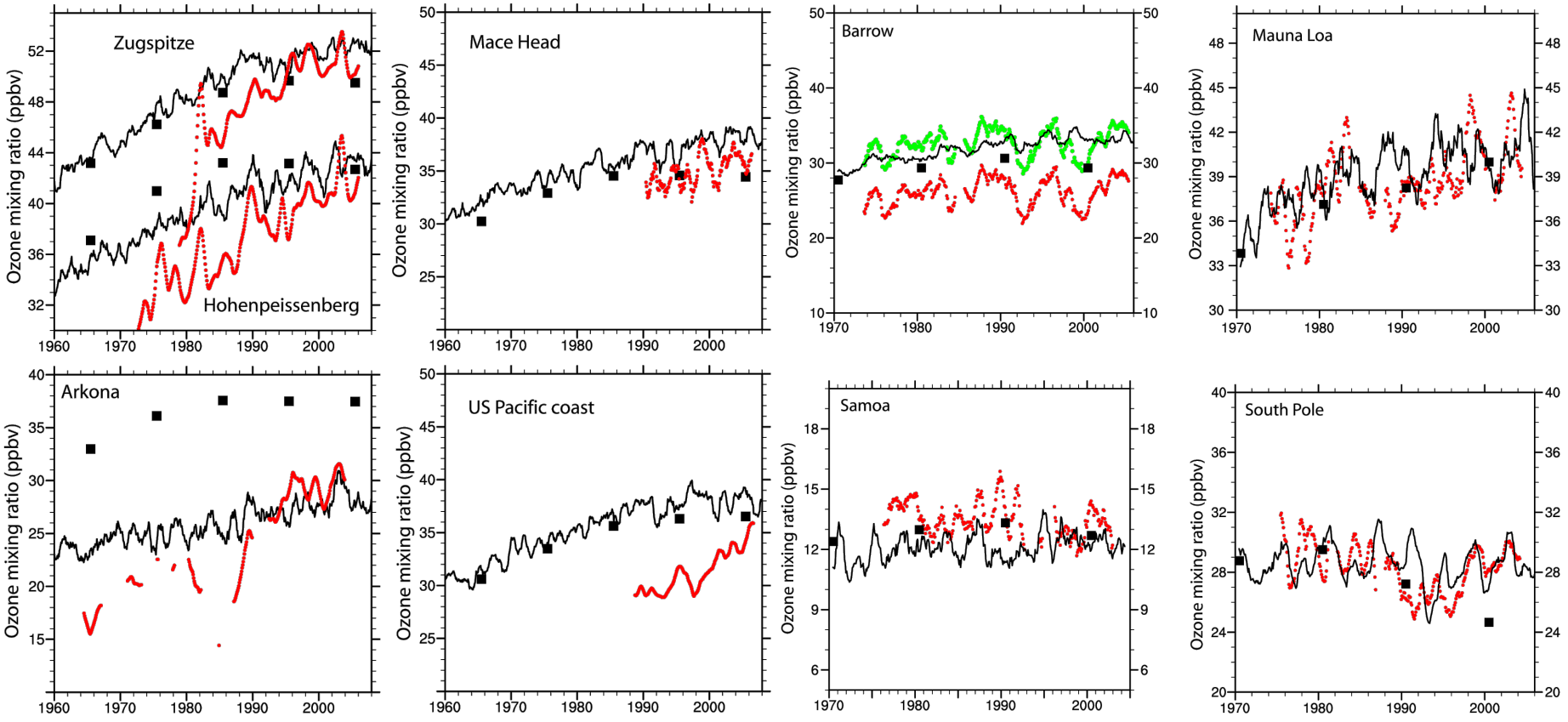


Figure 1. Map of basins with assessed shale oil and shale gas formations, as of May 2013



Tropospheric ozone trends



Observations in red

Model results in black

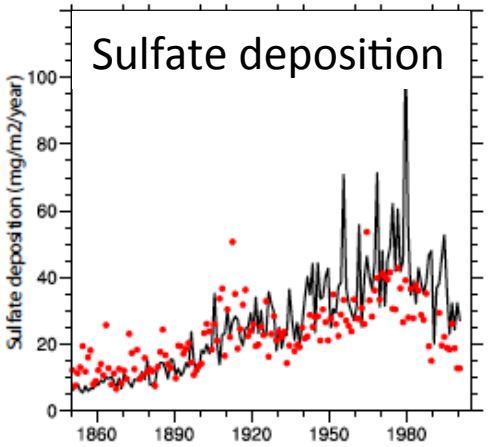
Lamarque et al., ACP, 2010

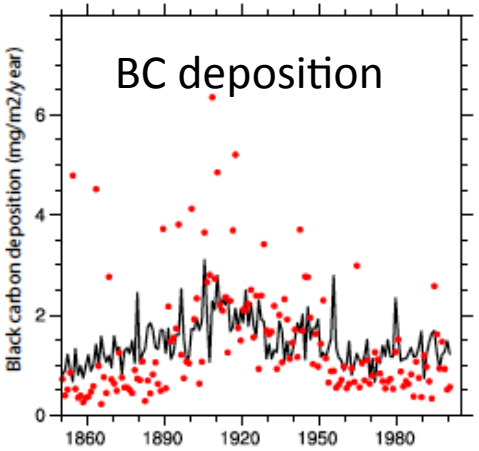
Aerosol deposition

Model: CAM-chem (Lamarque et al., 2012)

Observations in red

Model results in black

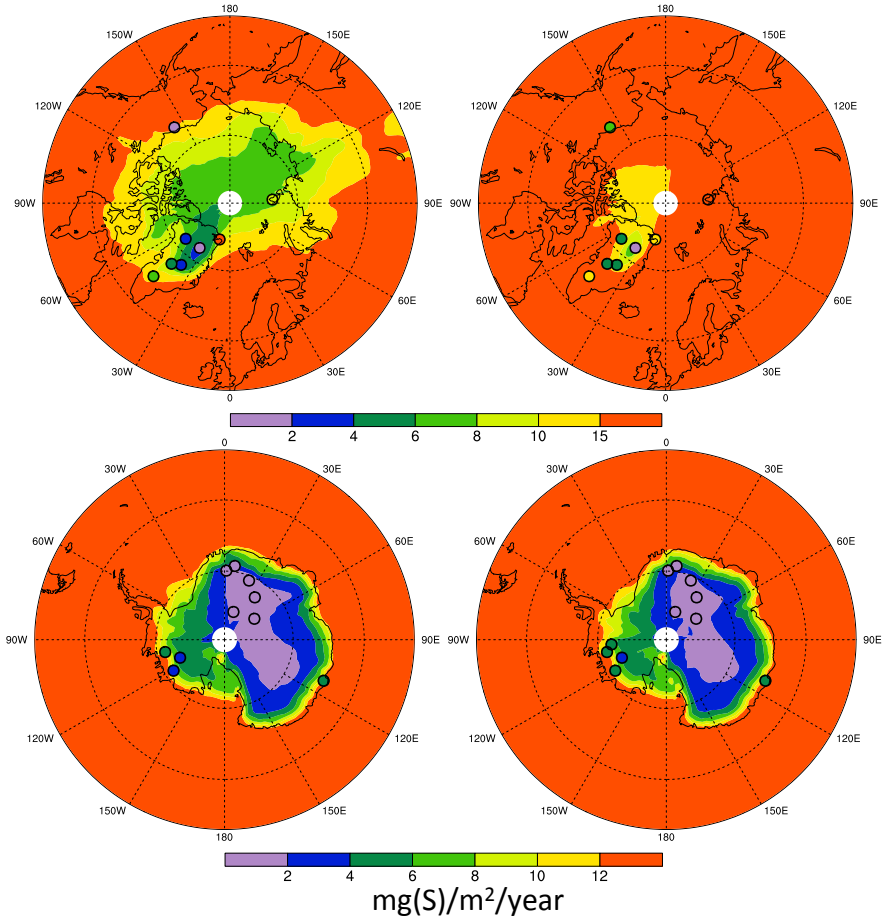




Lamarque et al., ACP, 2010

Sulfate deposition

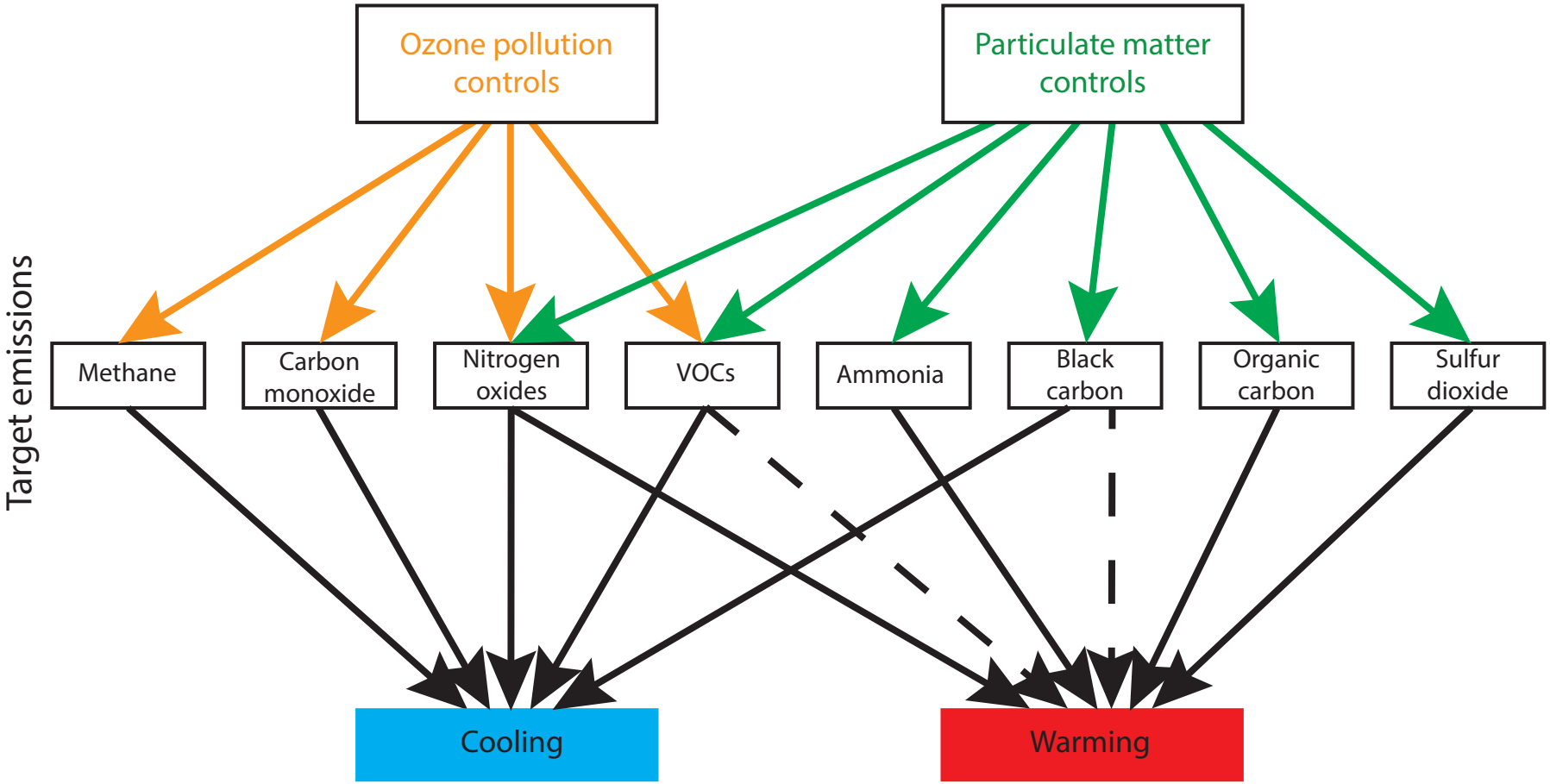
1850 2000



Lamarque et al., ACP, 2013

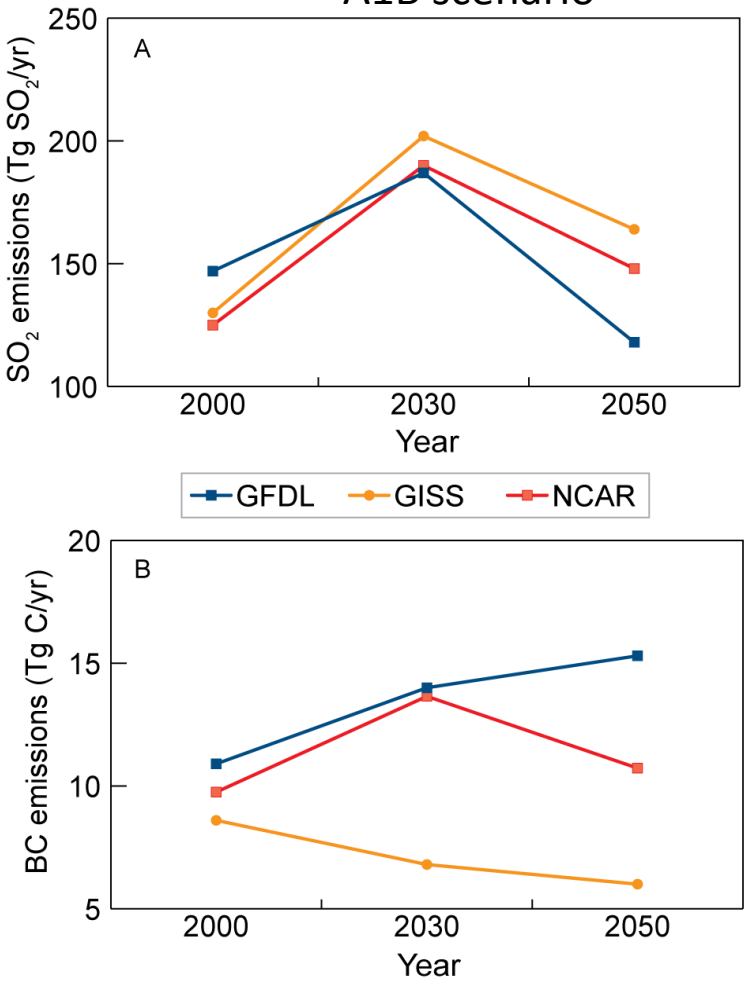
Filled circles are ice-core observations

Linking air pollution controls and global climate

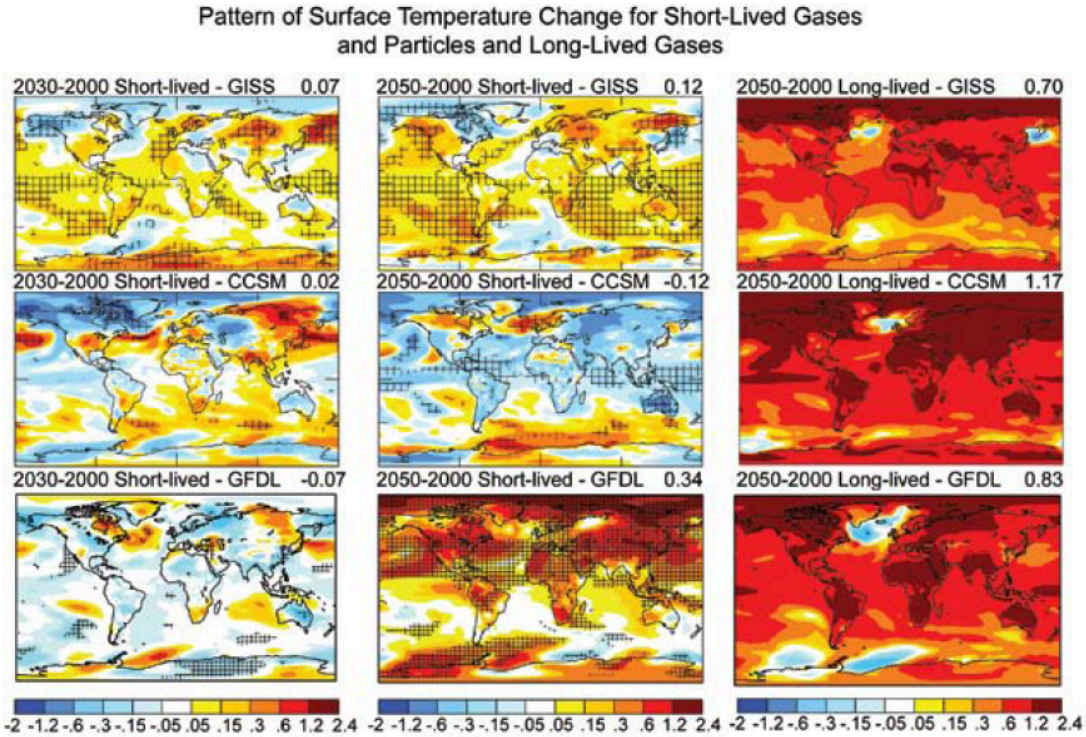


Modeling the distribution of SLCFs

Emissions from
A1B scenario



Shindell et al., JGR, 2008



USGCRP SAP3.1, 2007