



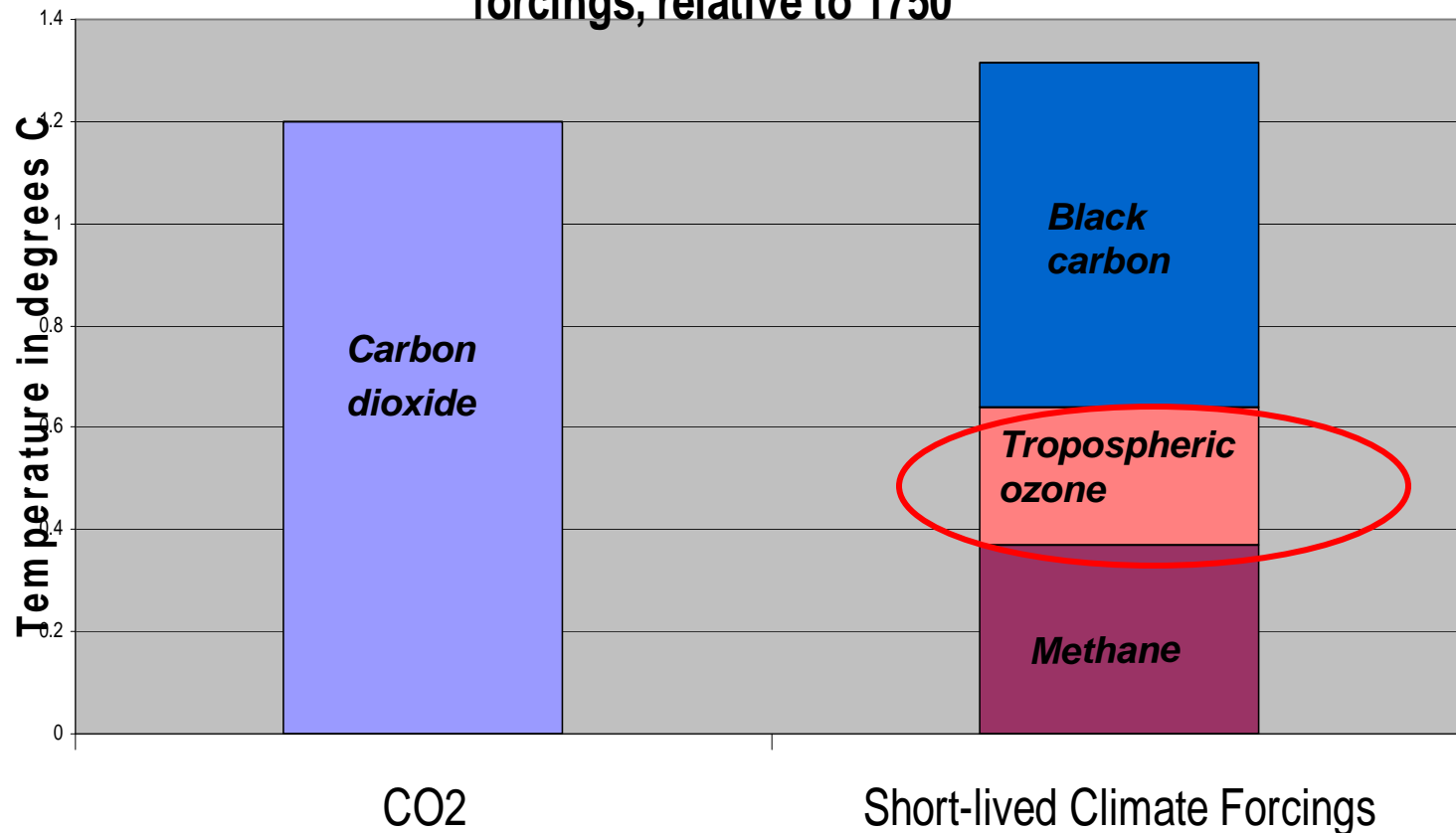
# **Introduction to the Role of Tropospheric Ozone and Arctic Climate**

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**May 8, 2008**

# There is a significant global role for tropospheric ozone and climate

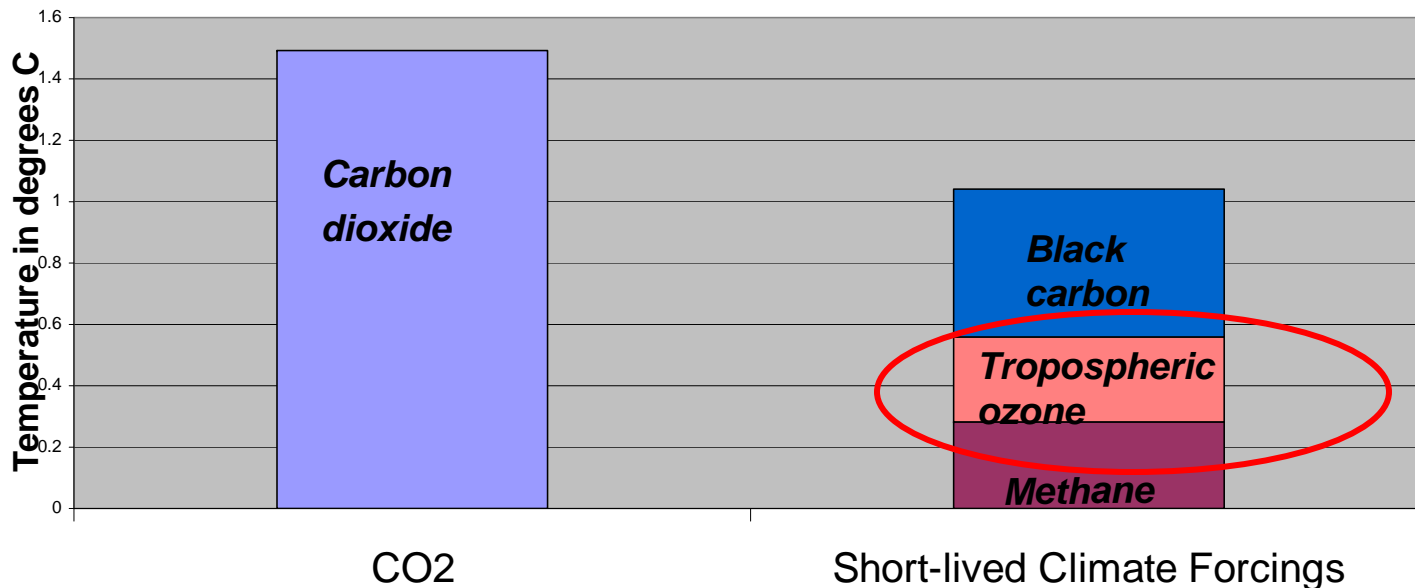
Temperature impact from CO2 compared to other climate forcings, relative to 1750



Ramanathan, 2008

# Initial Arctic modeling suggests a seasonally, averaged tropospheric ozone-derive temperature increase of 0.28° C

Temperature impact from CO2 compared to other climate forcings, relative to 1880



Calculated from Quinn, et.al., ACP, 2008

**Note: Different models were used to derive Global (previous slide) and Arctic (this slide) values.**

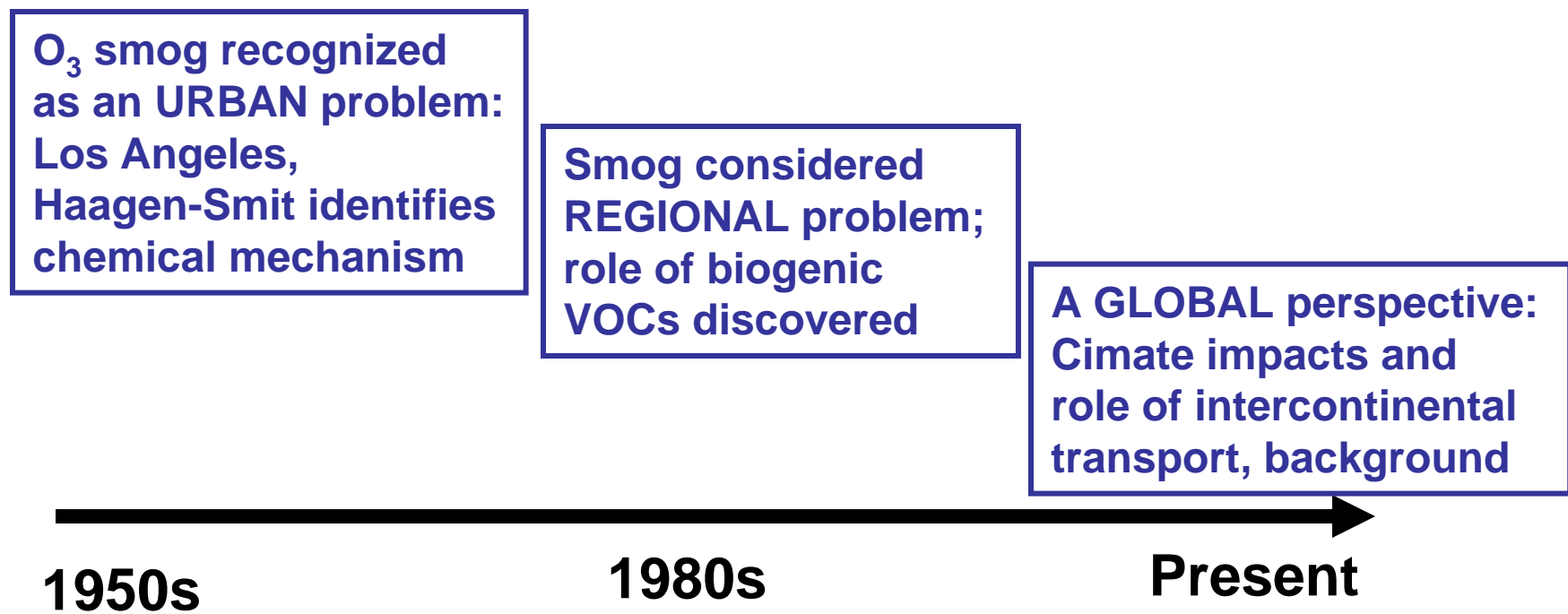
# Tropospheric ozone is formed in the atmosphere, not emitted

- 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.

# How ozone heats the Arctic

- **The dominant heating pathway is probably transfer of heat produced by Northern Hemisphere ozone into the Arctic.**
- **Followed by transport of ozone from outside the Arctic**
- **To a smaller extent, ozone formation within the Arctic**
- **At the same time, there remain research questions to tease out the relative contributions and better understand precursor roles, including**
  - **Contribution formed in the Arctic, both from in-Arctic precursors and precursors transported into the Arctic. How will this change with a warmer Arctic?**
  - **Importance of lifetimes, locations and seasonality of the shorter-lived precursors**
  - **Relevance of looking at specific VOCs**

# Ozone abatement strategies have evolved along with understanding of the O<sub>3</sub> issues



## Abatement Strategy:

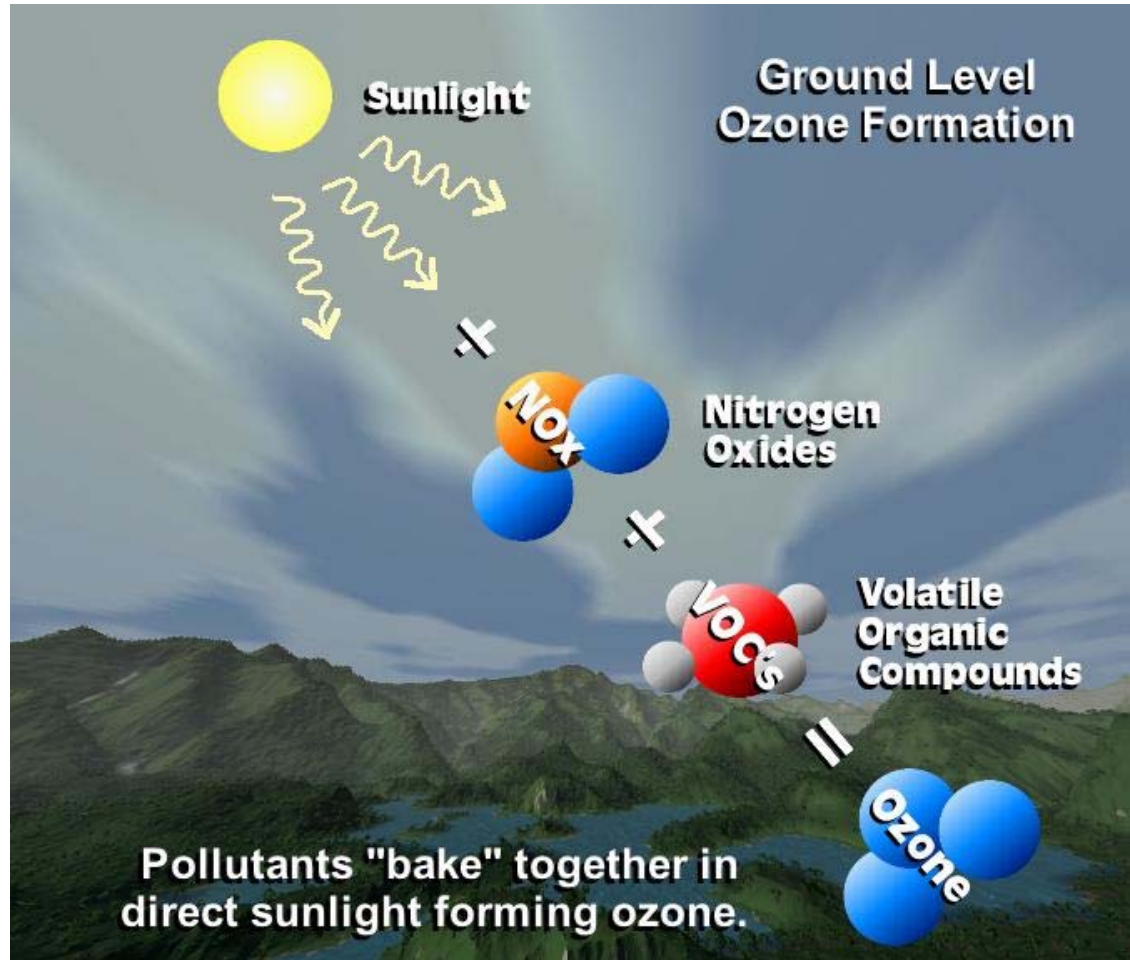
NMVOCs

+ NO<sub>x</sub>

+CH<sub>4</sub>, CO

# Different strategies and need for air quality versus climate benefits

- Air quality programs to reduce ozone levels focus largely on reducing peak ozone levels to protect human health and crop production.
- This favors strategies reducing “local” precursors - NOX and non-methane VOCs – that are major contributors to peak ozone levels.



# Need lower background for climate benefits

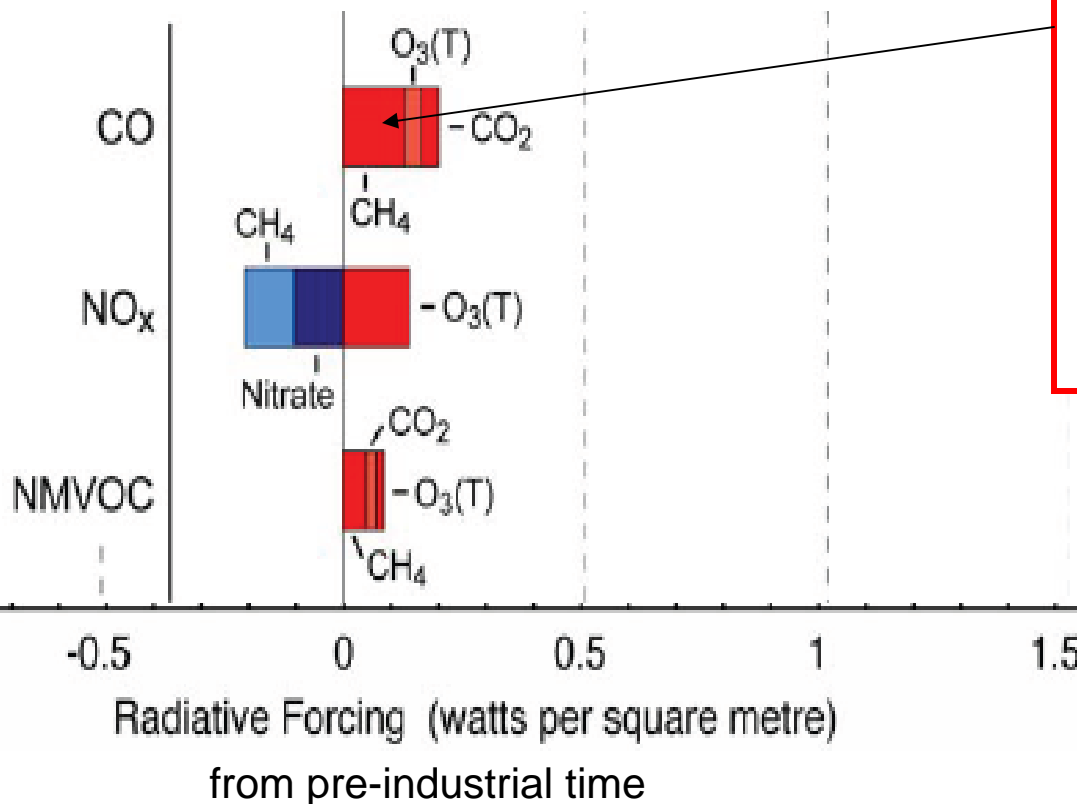
- To benefit climate by reducing net warming, a balanced approach must be taken to reducing all major ozone precursors – given their complex atmospheric interactions.
- NO<sub>x</sub> is the most complicated precursor. In the *short run*, it reduces ozone and the radiative forcing from ozone. Over a longer period, however, reductions increase the lifetime of methane, and therefore contribute to warming. Also the nitrate aerosol has a cooling effect, which reductions remove.
- It's unclear where the balance lies between the negative impacts from increased in methane lifetime and aerosols, particularly nitrate, and the positive climate benefits from ozone reductions. This suggests that NO<sub>x</sub> reductions continue to be pursued for air quality benefits, with the recognition that climate benefits will need to come largely from *carbon monoxide and methane* reductions

NO<sub>x</sub> ↓ →

OH ↓ →

CH<sub>4</sub> lifetime ↑

# Climate role of CO, NO<sub>x</sub> and NMVOC



**Because CO also uses OH as an atmospheric sink, reducing it will make more OH available as methane sink.**

Using same calculations, and without double counting, methane is 0.59 W/m<sup>2</sup>, plus another 0.20 W/m<sup>2</sup> from methane emissions via ozone.

# Methane is different

- Unlike other ozone precursors, methane is not a typical, short-lived ozone precursor.
- Because methane has a long atmospheric lifetime (8-10 years), emissions become well mixed.
- Neither air quality nor climate benefits depend strongly on the location of the CH<sub>4</sub> emission reductions, implying that the lowest cost emission controls can be targeted.
- There are, though, regions where methane effects on O<sub>3</sub> are enhanced. These include locations with high NO<sub>x</sub> emissions (e.g., in southern California); regions near the down welling branches of the Hadley cell, at roughly 30°N and 30°S (over the Sahara region of North Africa, the Middle East), or regions with active convection (Caribbean Sea and Gulf Coast of the United States).
  - Given that most of the ozone-related temperature in the Arctic comes from global transport, the benefits of these reductions should be felt in the Arctic.

# MODELED CLIMATE IMPACTS OF 50% REDUCTIONS IN ANTHROPOGENIC EMISSIONS

	CH <sub>4</sub>	NO <sub>x</sub> *	VOC	NO <sub>x</sub> &VOC	CO
Methane Radiative Forcing (W/m <sup>2</sup> )	-0.3	+0.06	-0.01	+0.05	-0.02
Ozone Radiative Forcing (W/m <sup>2</sup> )	-0.07	-0.06	-0.01	-0.07	-0.01
Total Forcing (W/m <sup>2</sup> )	-0.37	0	-0.02	-0.02	-0.03

\* doesn't include aerosol  
climate effects

# Near-term climate impacts are critical to Arctic protection

- **Given concerns about irreversible arctic climate impacts that may occur within the next two decades, should a 20 year GWP, instead of the typical 100 year equivalency, be used to evaluate arctic impact reduction options?**
- **Using 20 year impacts more than doubles the warming benefits from methane emissions reductions and would increase CO reduction warming benefits by at least 50 percent.**
- **This will also increase the economic value of such emissions, which means much more expensive reductions than typically addressed in current “supply curves” are feasible.**

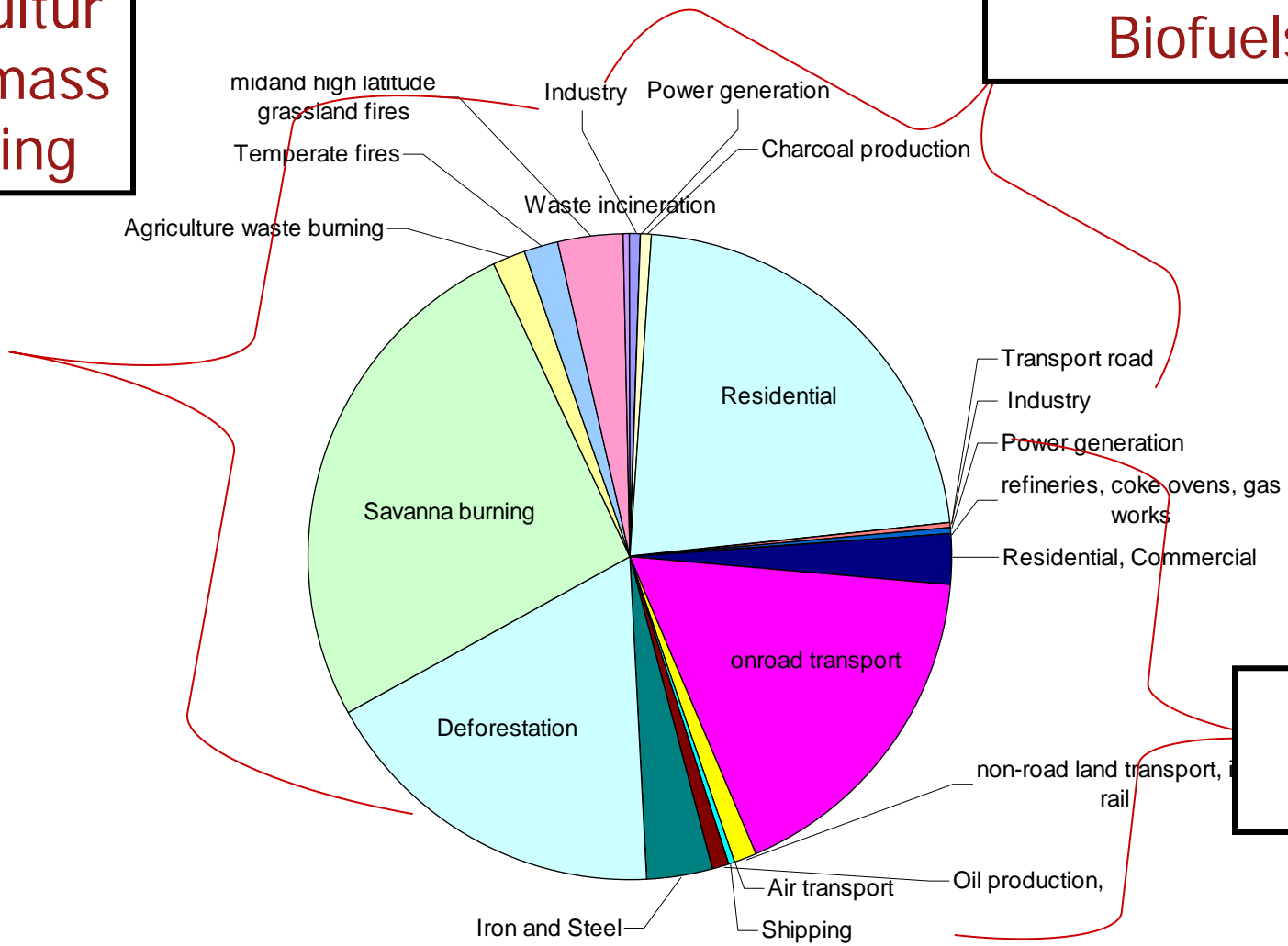
# Where are emissions occurring?

- **Next four slides.**

# CO<sub>2</sub> emissions, Edgar 2000

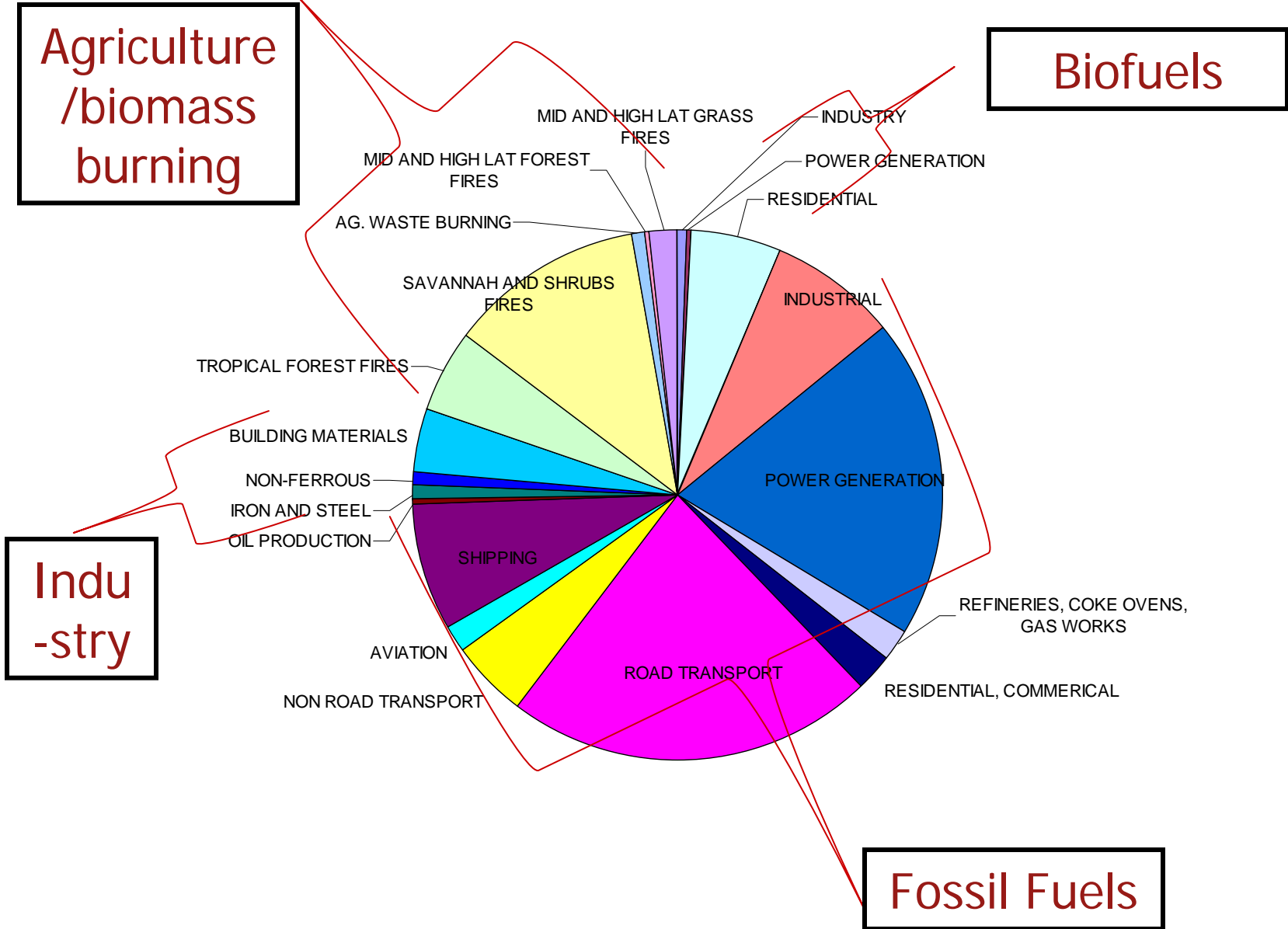
Agriculture/biomass burning

Biofuels

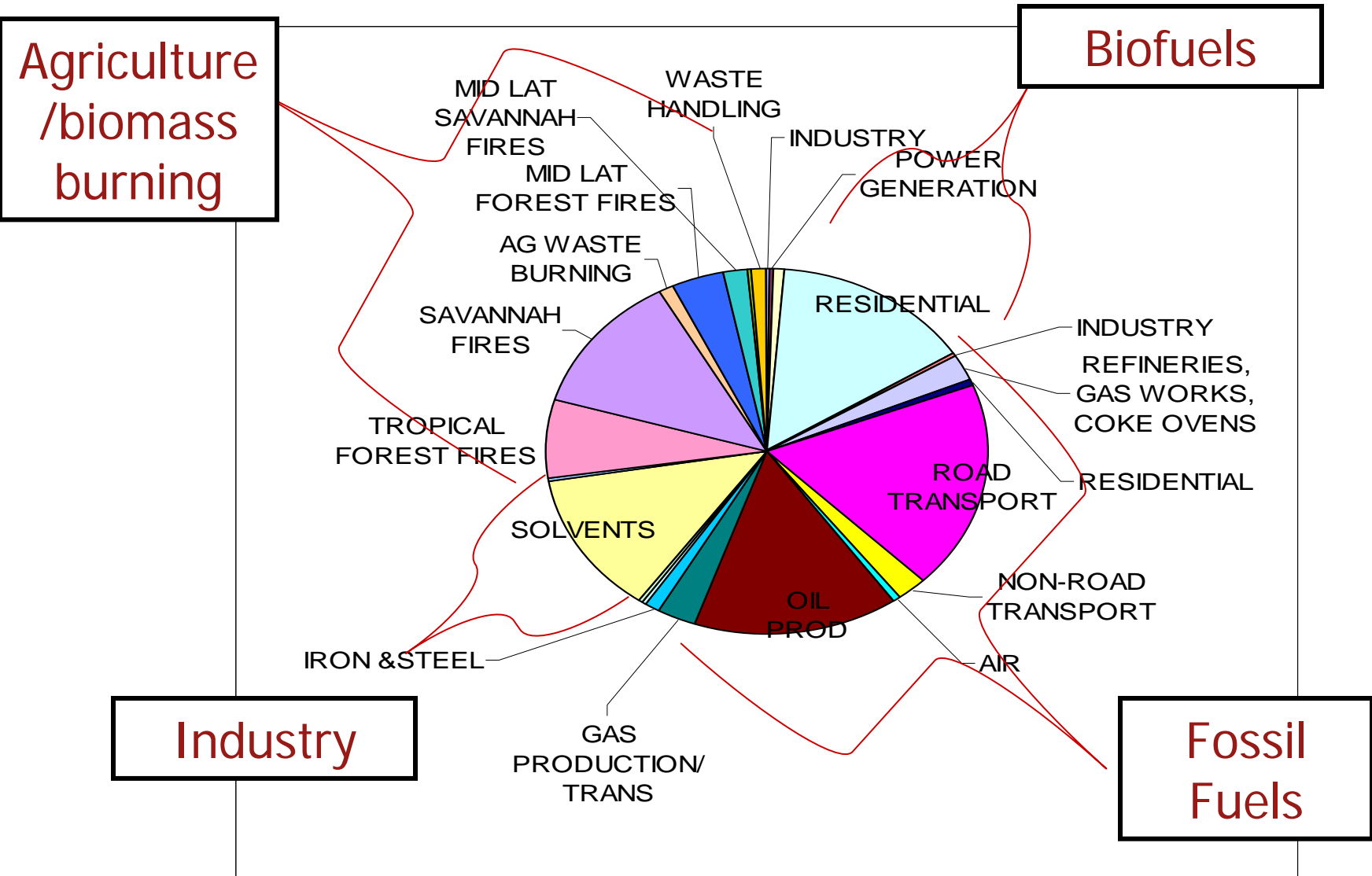


Fossil Fuels

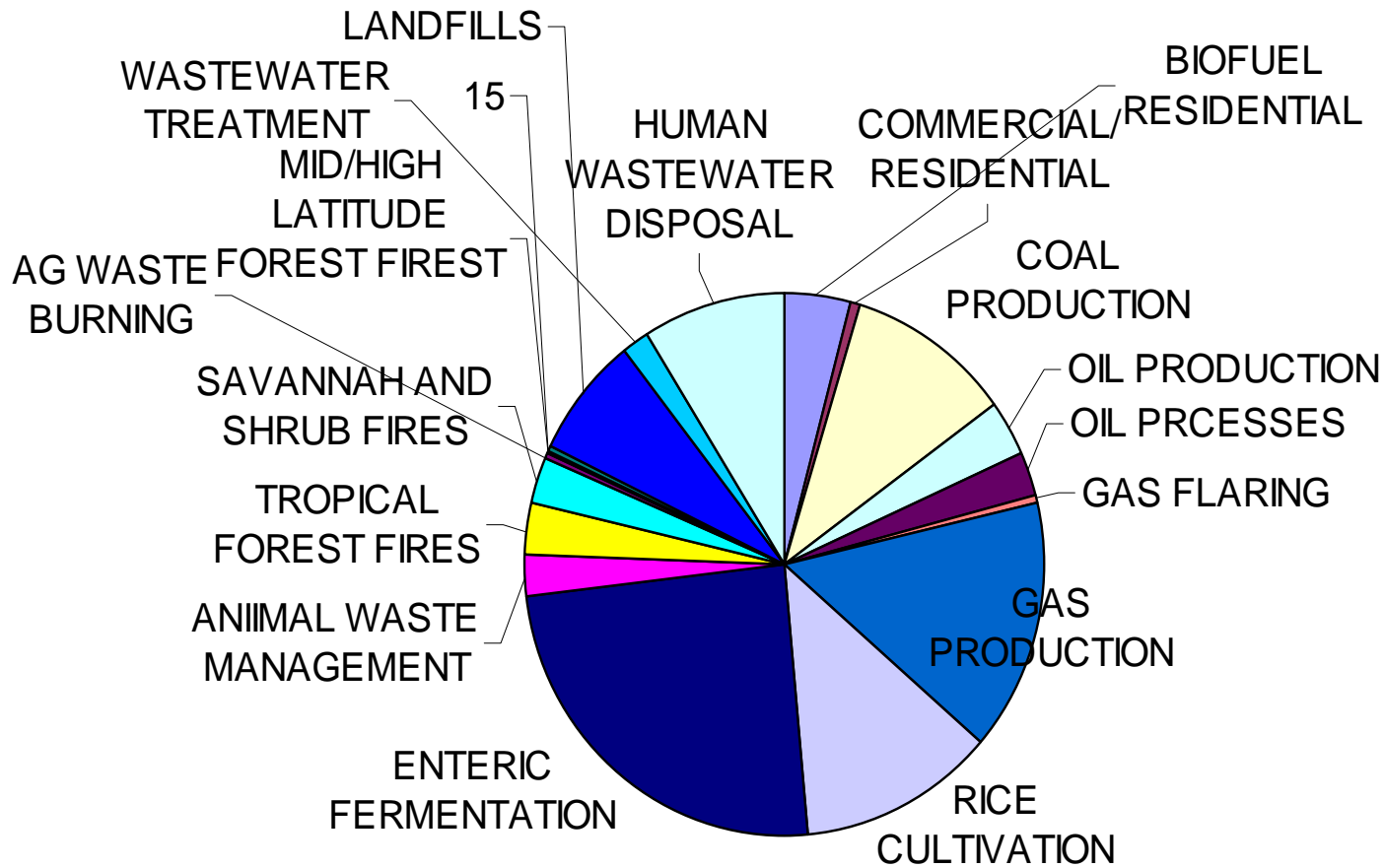
# NOX, 2000 FROM EDGAR



# Non-methane VOCs, 2000



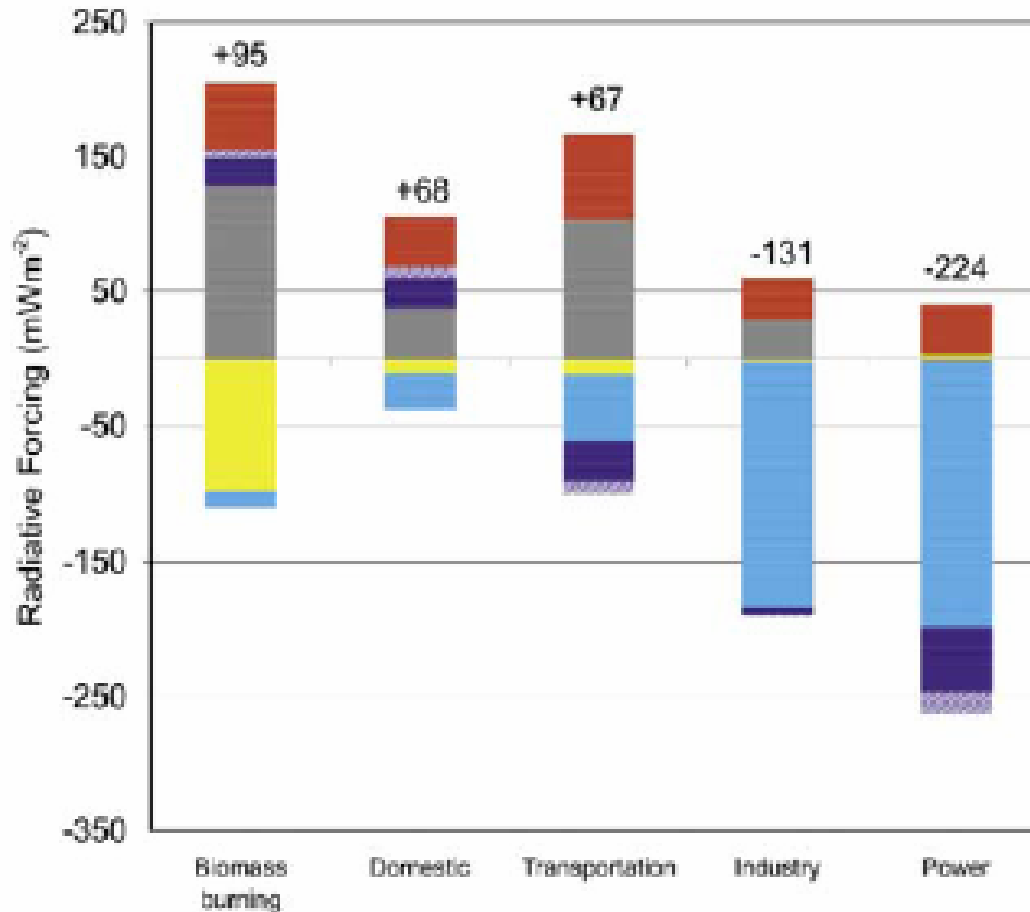
# METHANE, 2000 EDGAR



# Conclusions

- **Traditional clean air regulation programs addressing ozone will not benefit climate and thus the Arctic.**
- **Substantial methane and CO reductions are needed reduce ozone warming of the Arctic.**
- **Research and analytical questions remain, including whether targeting global hot spots to reduce ozone could have an enhanced benefit in the Arctic.**

# Climate impact, by source category, from multiple emissions, in 2030, SRES A1B



O3 ST = ozone impact

O3 LT = CH4 affects

Black number a top each column is total forcing

# Relative importance of different regions to annual mean Arctic concentration at surface and atmosphere.

