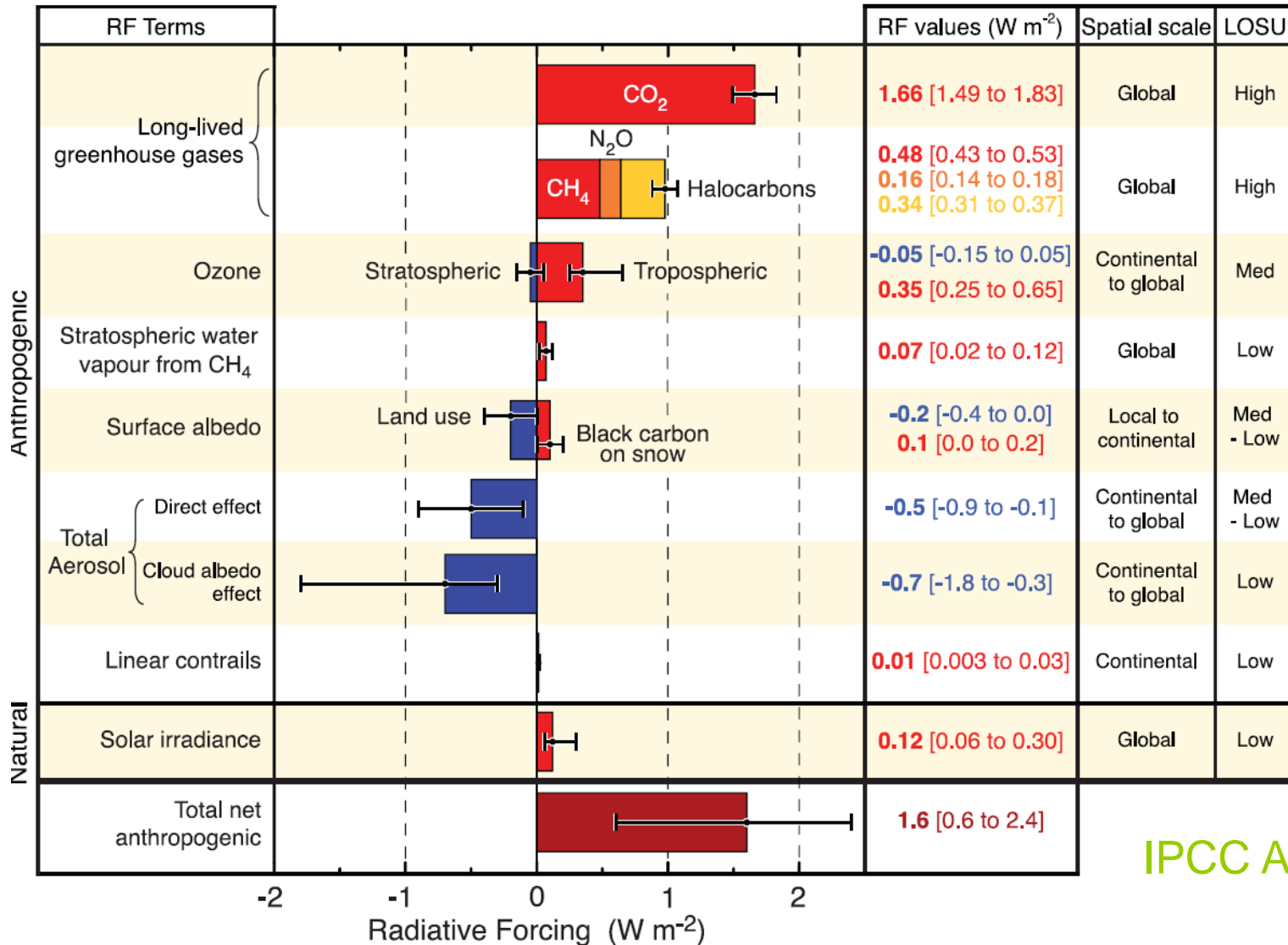


# HOW DO TROPOSPHERIC OZONE PRECURSORS CONTRIBUTE TO CLIMATE CHANGE?

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contract AQ0902

# GLOBAL MEAN RADIATIVE FORCINGS



IPCC AR4

## DIRECT AND INDIRECT RADIATIVE FORCING AGENTS

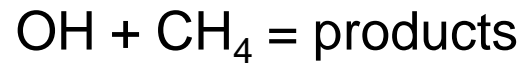
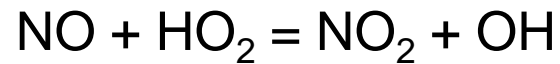
Direct radiative forcing agents are emitted into the atmosphere and force the climate system directly.

Indirect radiative forcing agents act on the global distributions of methane and tropospheric ozone and force the climate system indirectly.

Tropospheric ozone precursors such as VOCs, CO, H<sub>2</sub> and NO<sub>x</sub> are indirect radiative forcing agents.

Methane also acts as an indirect radiative forcing agent although it is also a direct radiative forcing agent.

## INDIRECT RADIATIVE FORCING MECHANISMS



# HOW DO TROPOSPHERIC OZONE PRECURSORS CONTRIBUTE TO CLIMATE CHANGE?

## VOCs emissions

- increase  $O_3$
- decrease OH and hence increase  $CH_4$

Climate effects  
reinforce

## $NO_x$ emissions

- increase  $O_3$
- increase OH and hence decrease  $CH_4$

Climate effects  
cancel

## $CO$ and $H_2$ emissions

- increase  $O_3$
- decrease OH and hence increase  $CH_4$

Climate effects  
reinforce

# STOCHEM EMISSION PULSE EXPERIMENTS

Calculation of radiative forcing relationships for tropospheric ozone precursors

Treating :

- sources in Asia and North America
- emissions of  $\text{NO}_x$ , VOCs

Focus on mechanisms as well as quantification

Application of STOCHEM, a global Lagrangian CTM

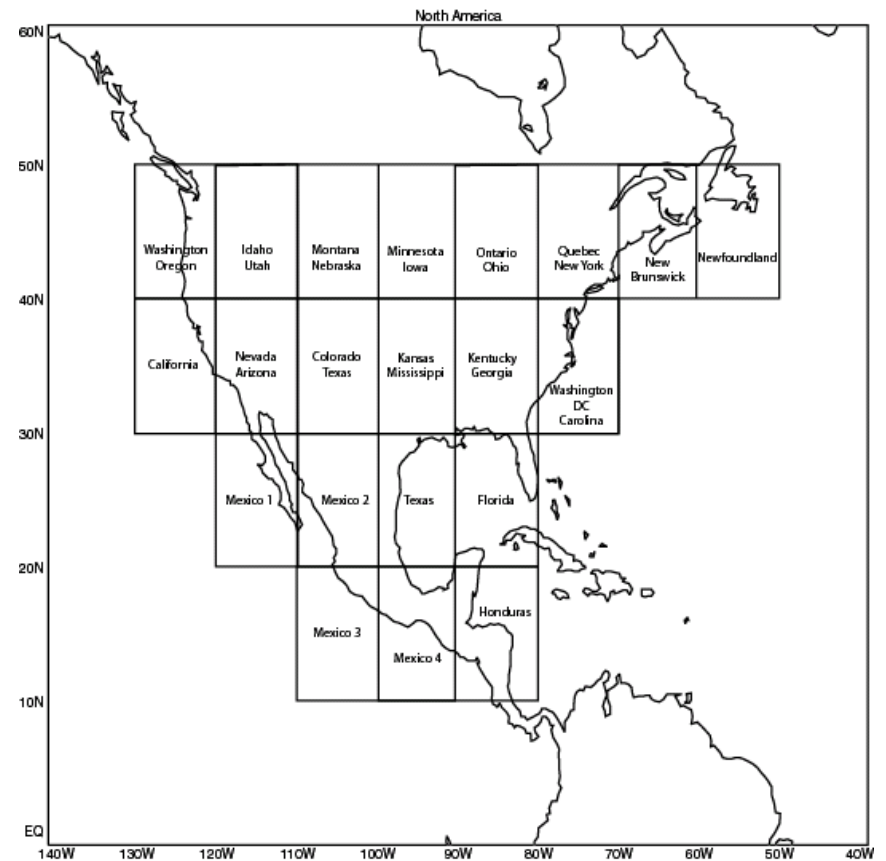
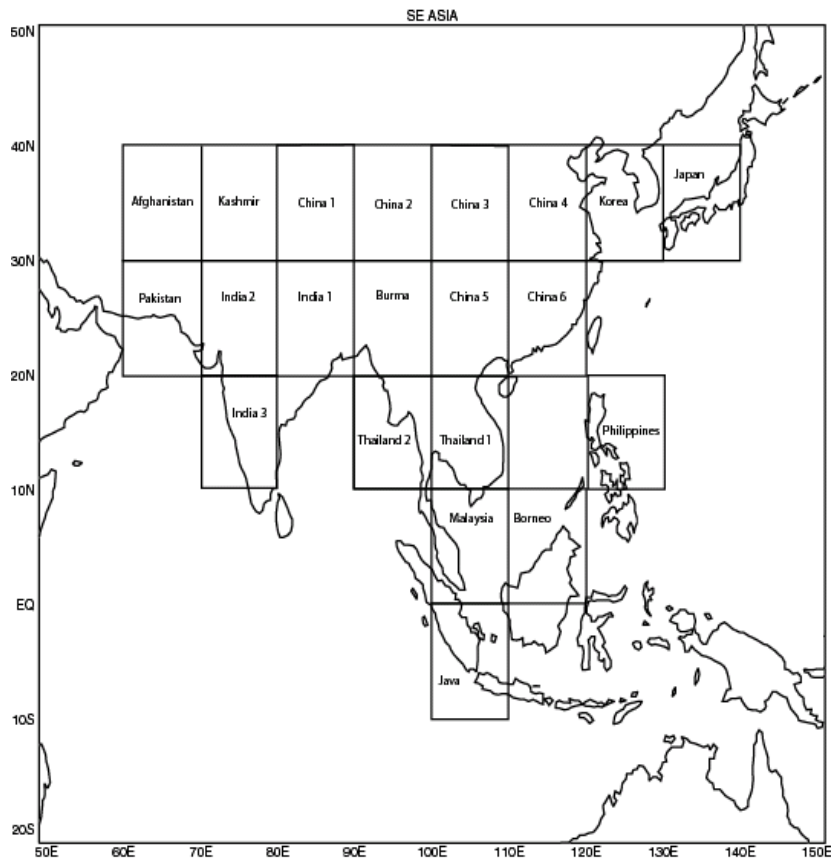
Use of month-long emission pulses of VOCs and  $\text{NO}_x$

## CLIMATE CHANGE RESPONSES

These depend on :

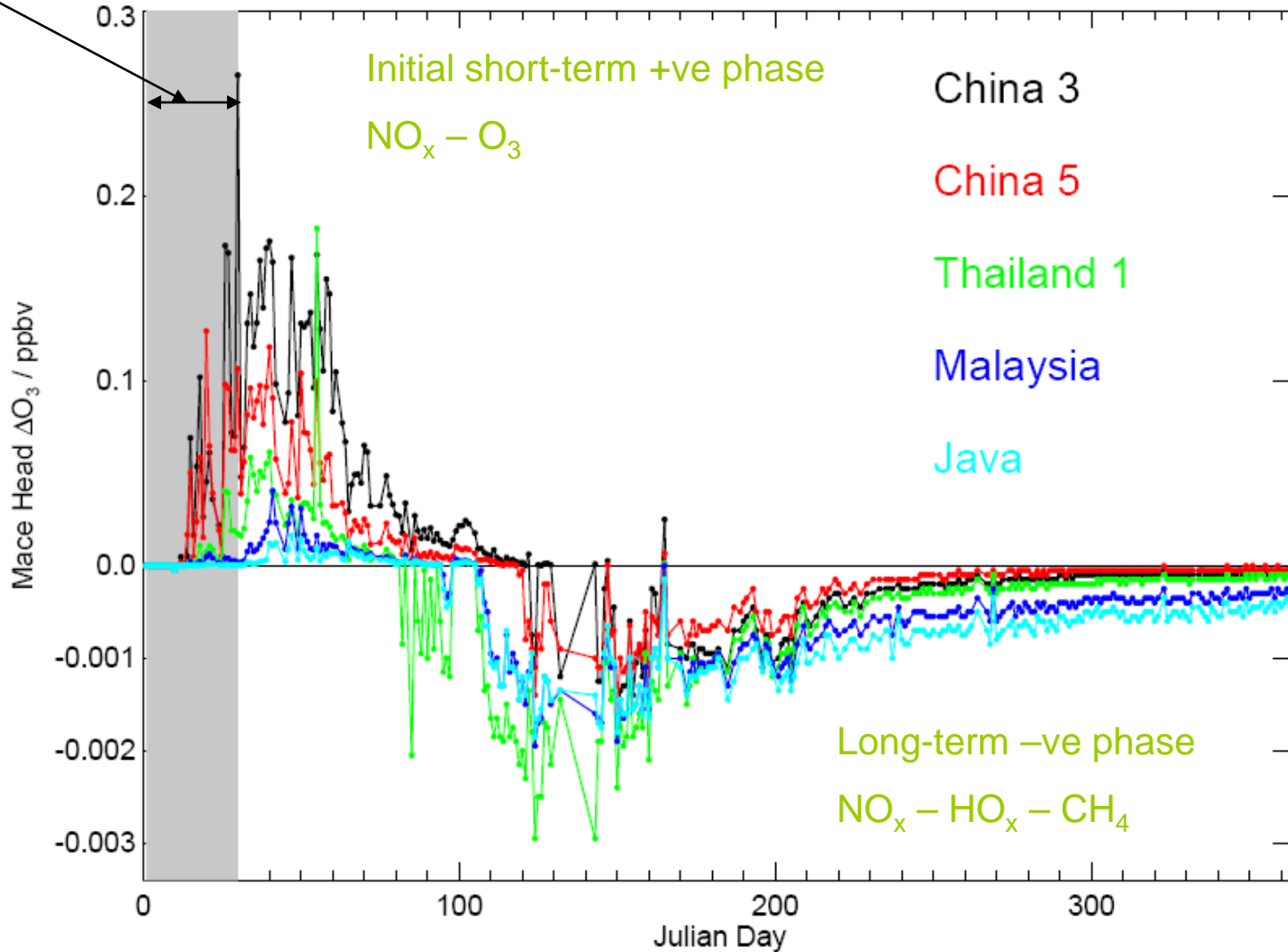
- Tropospheric ozone precursor whether VOCs, CO or NO<sub>x</sub>
- Altitude of emission whether at the surface or from aircraft
- Location of emission dependent on latitude and longitude
- Magnitude of emission

# LOCATIONS OF SURFACE NO<sub>x</sub> EMISSION PULSES

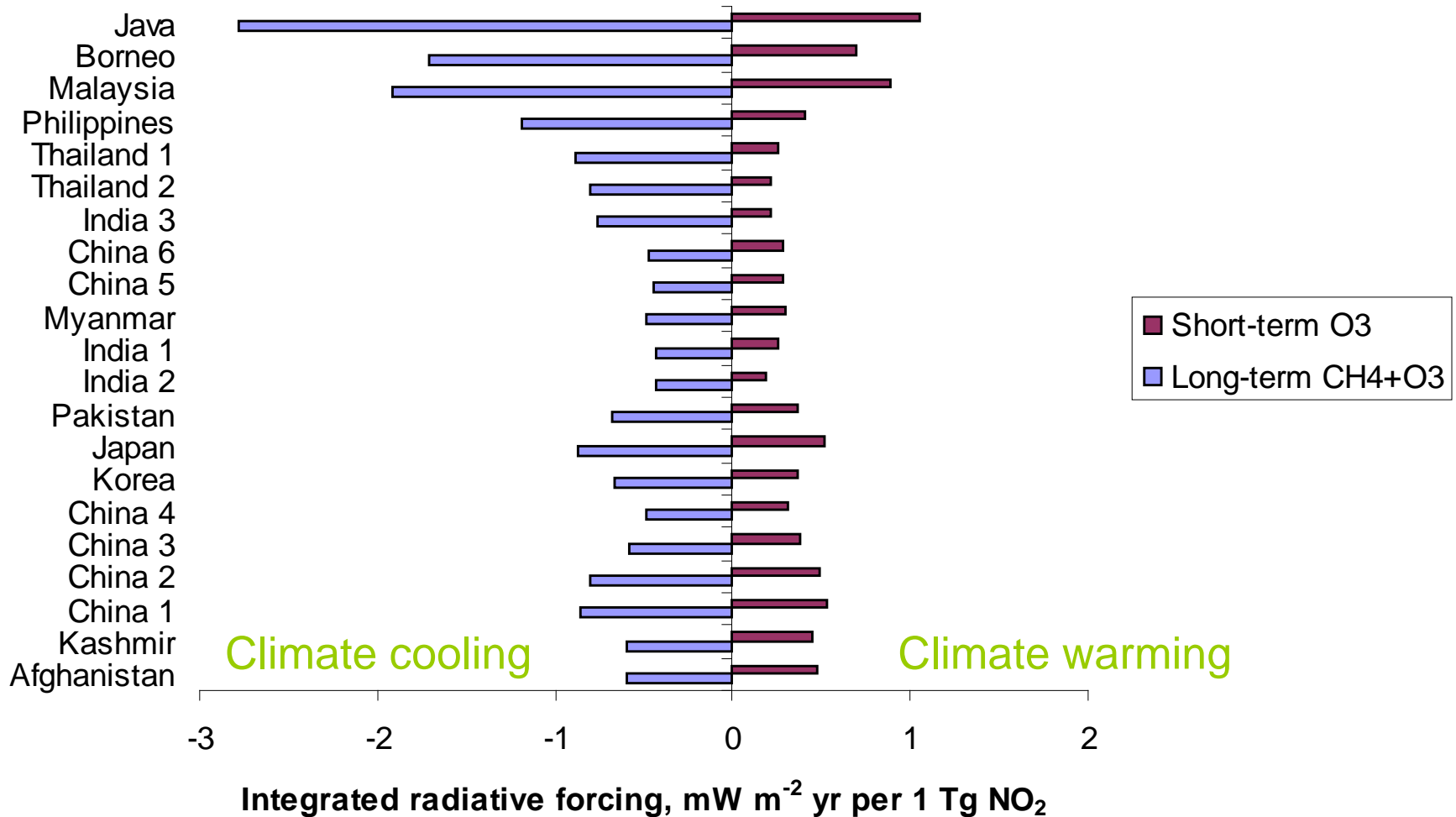


# GLOBAL OZONE RESPONSE TO EMISSION PULSES

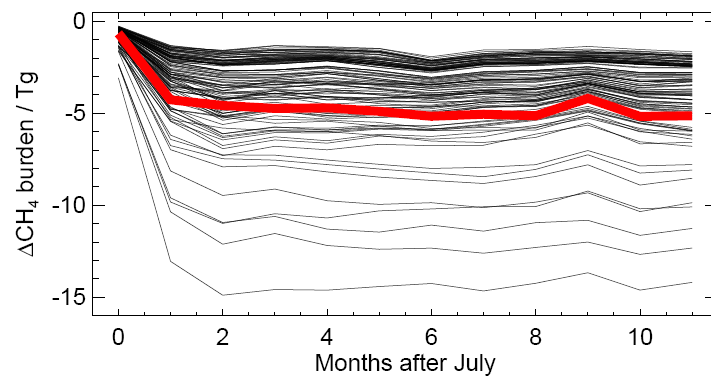
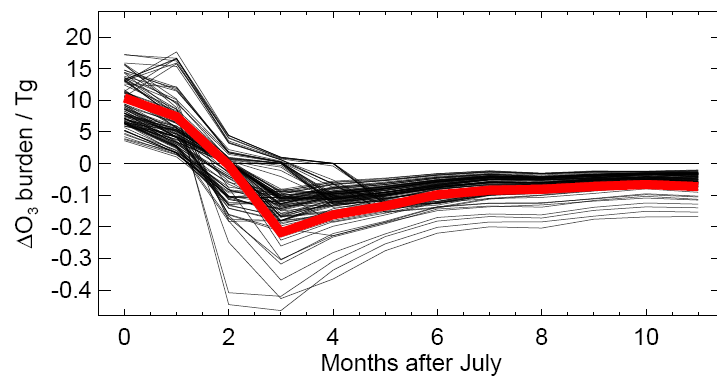
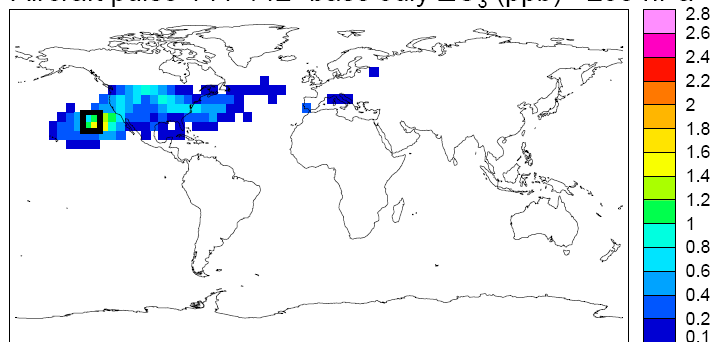
Emission pulse



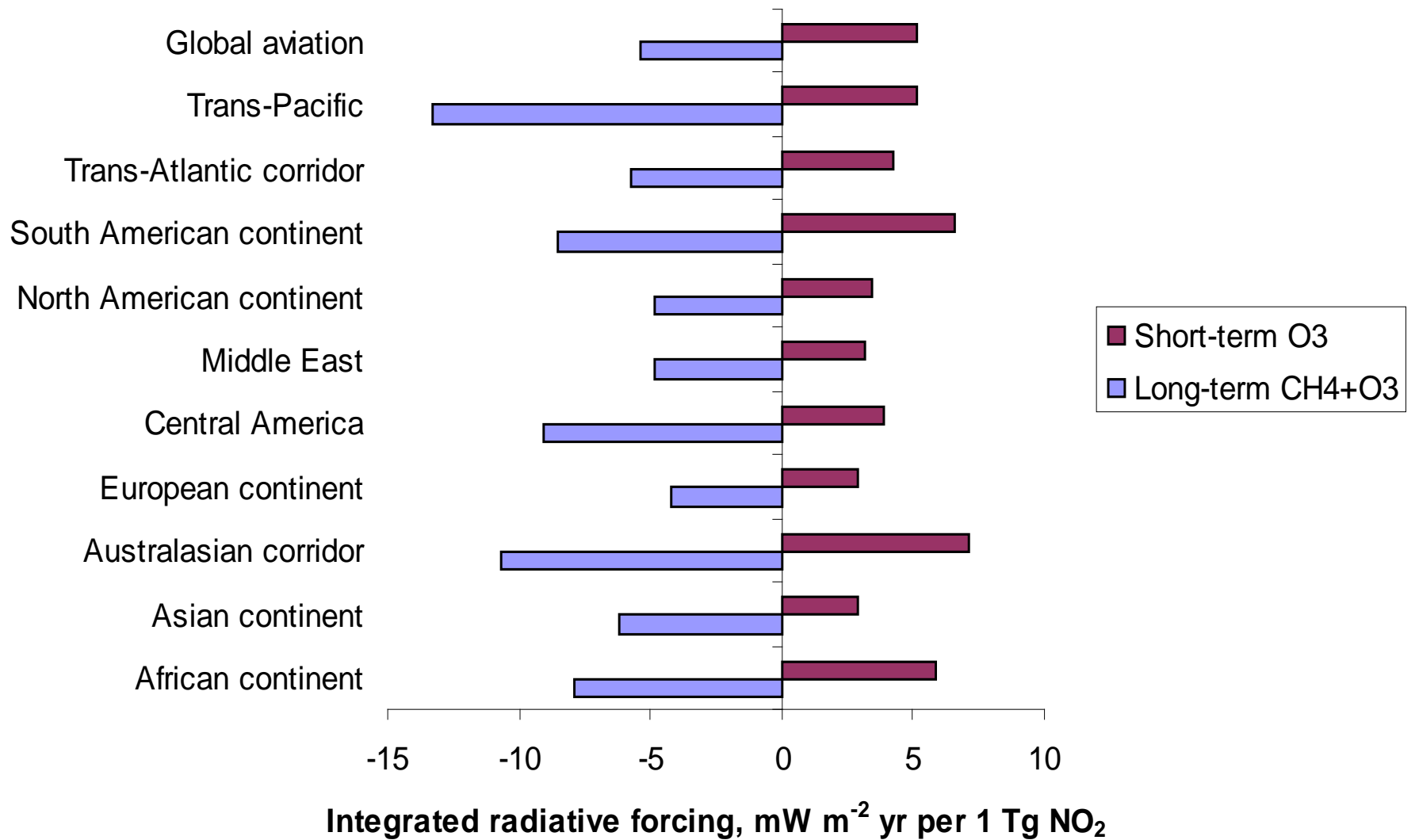
# HOW DO SURFACE NO<sub>x</sub> EMISSIONS CONTRIBUTE TO CLIMATE CHANGE ?



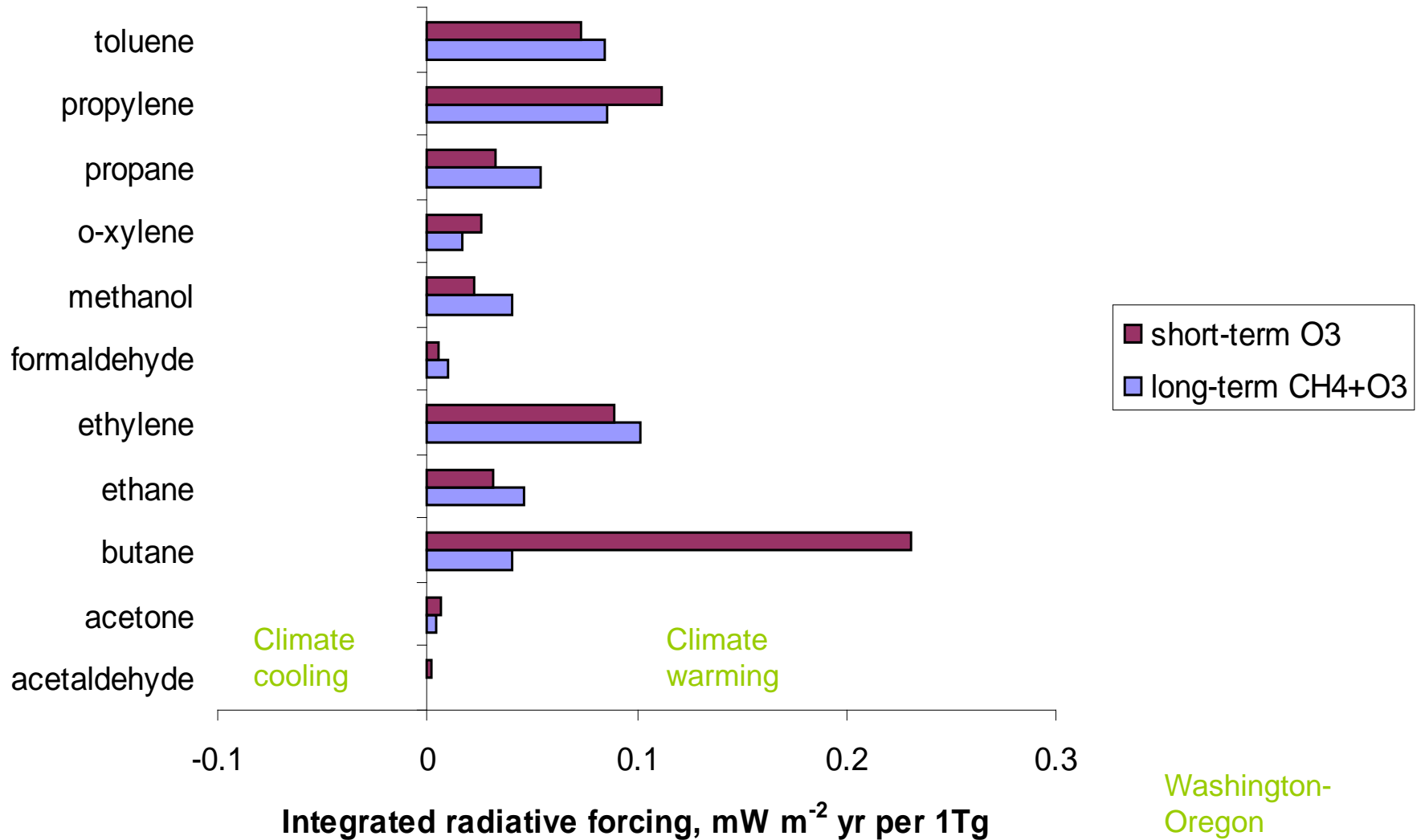
July Aircraft pulse 141-142 -base July  $\Delta O_3$  (ppb)  $\sim 250$  hPa



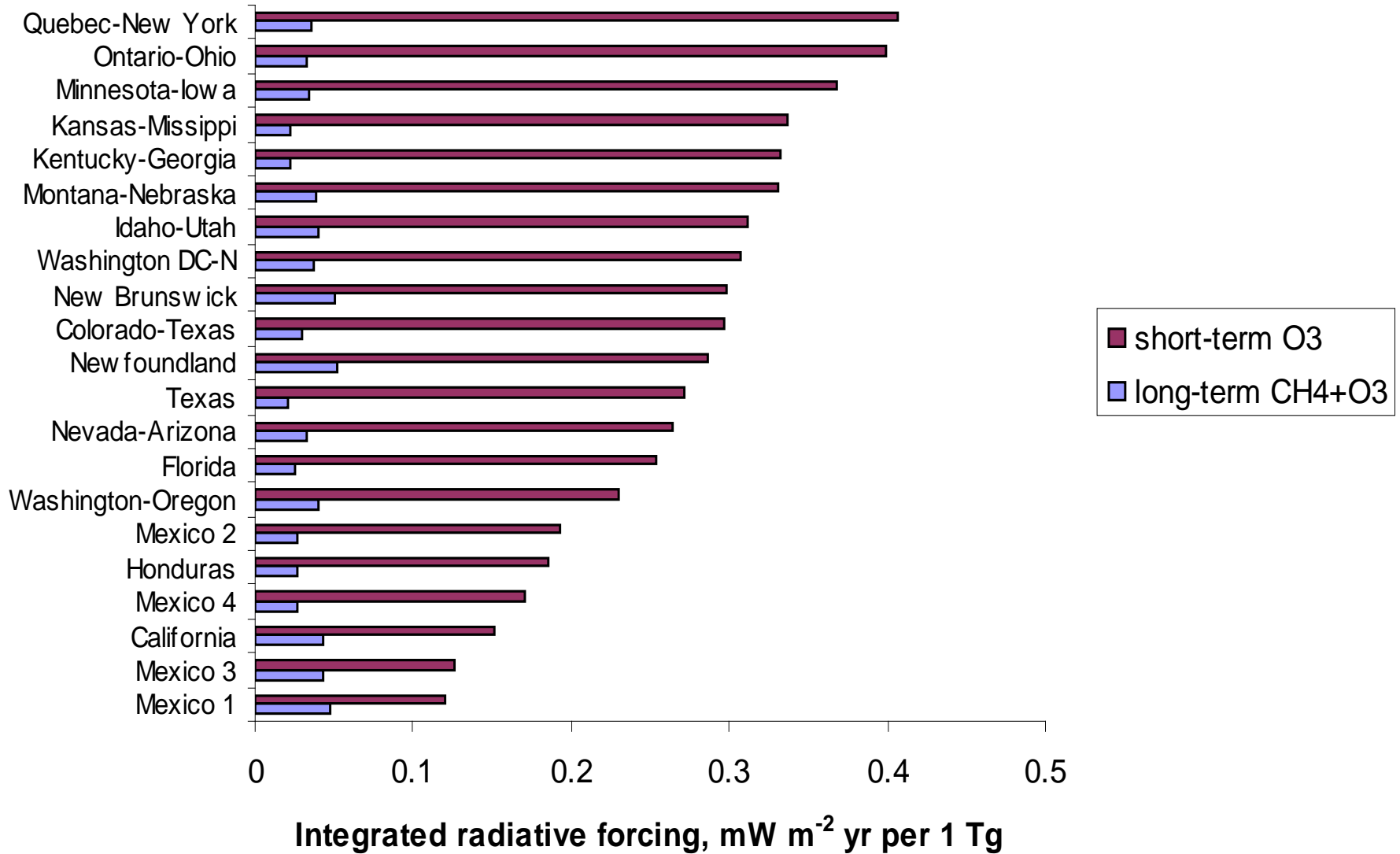
# HOW DO AIRCRAFT NO<sub>x</sub> EMISSIONS CONTRIBUTE TO CLIMATE CHANGE ?



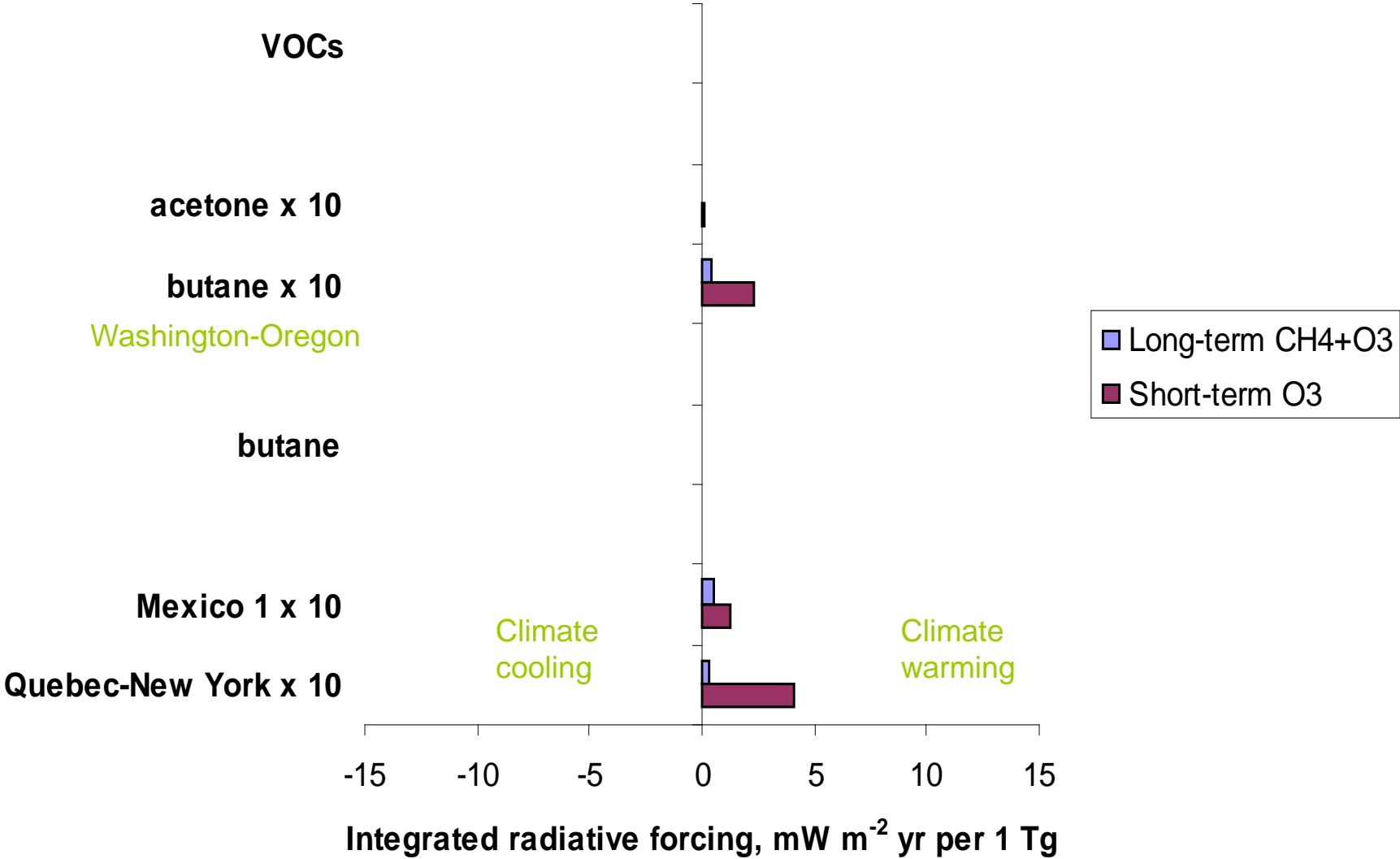
# HOW DO VOC EMISSIONS CONTRIBUTE TO CLIMATE CHANGE ?



# HOW DO BUTANE EMISSIONS CONTRIBUTE TO CLIMATE CHANGE ?



# SUMMARY FOR VOCs AND CLIMATE CHANGE



# SUMMARY FOR NO<sub>x</sub> AND CLIMATE CHANGE

