The atmospheric science view on climate-air pollution linkage

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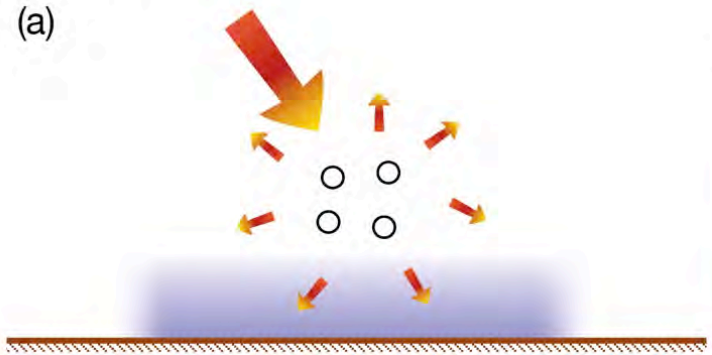
How do air-pollutions (aerosols) influence climate?

Aerosol-radiation interactions

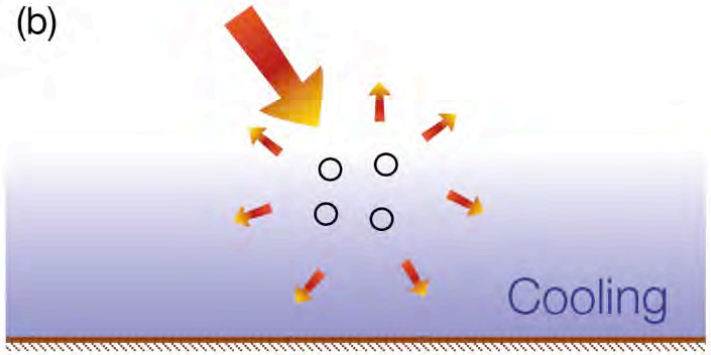
Scattering aerosols

(a)



Aerosols scatter solar radiation. Less solar radiation reaches the surface, which leads to a localised cooling.

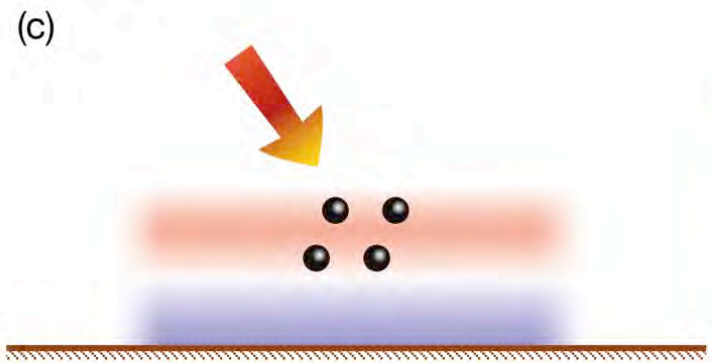
(b)



The atmospheric circulation and mixing processes spread the cooling regionally and in the vertical.

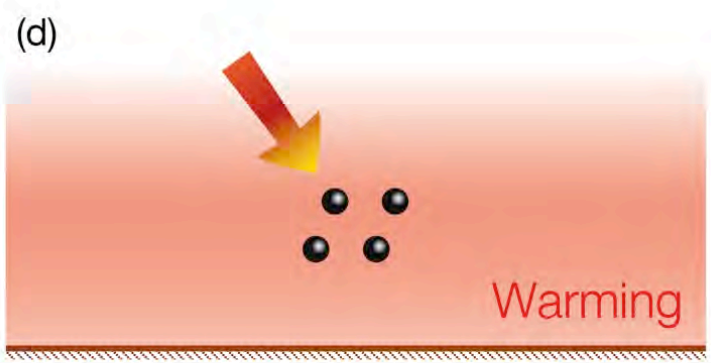
Absorbing aerosols

(c)



Aerosols absorb solar radiation. This heats the aerosol layer but the surface, which receives less solar radiation, can cool locally.

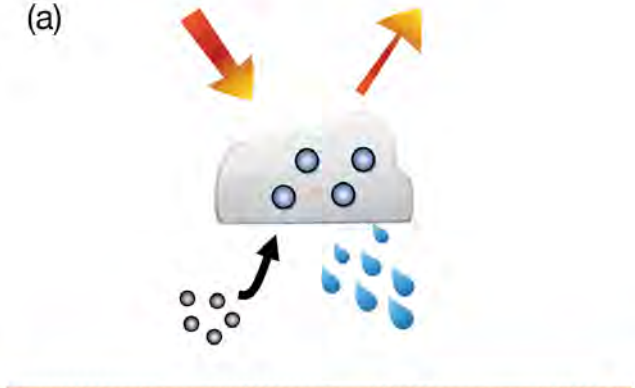
(d)



At the larger scale there is a net warming of the surface and atmosphere because the atmospheric circulation and mixing processes redistribute the thermal energy.

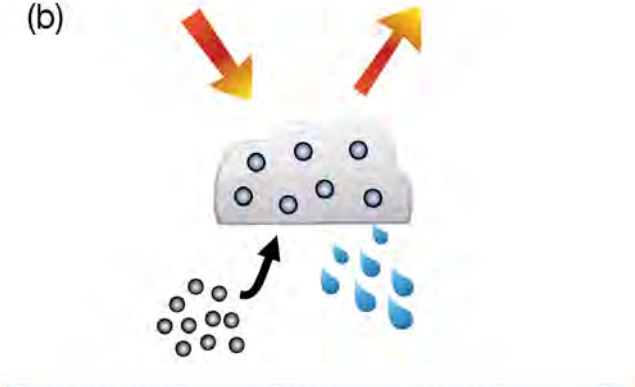
Aerosol-cloud interactions

(a)



Aerosols serve as cloud condensation nuclei upon which liquid droplets can form.

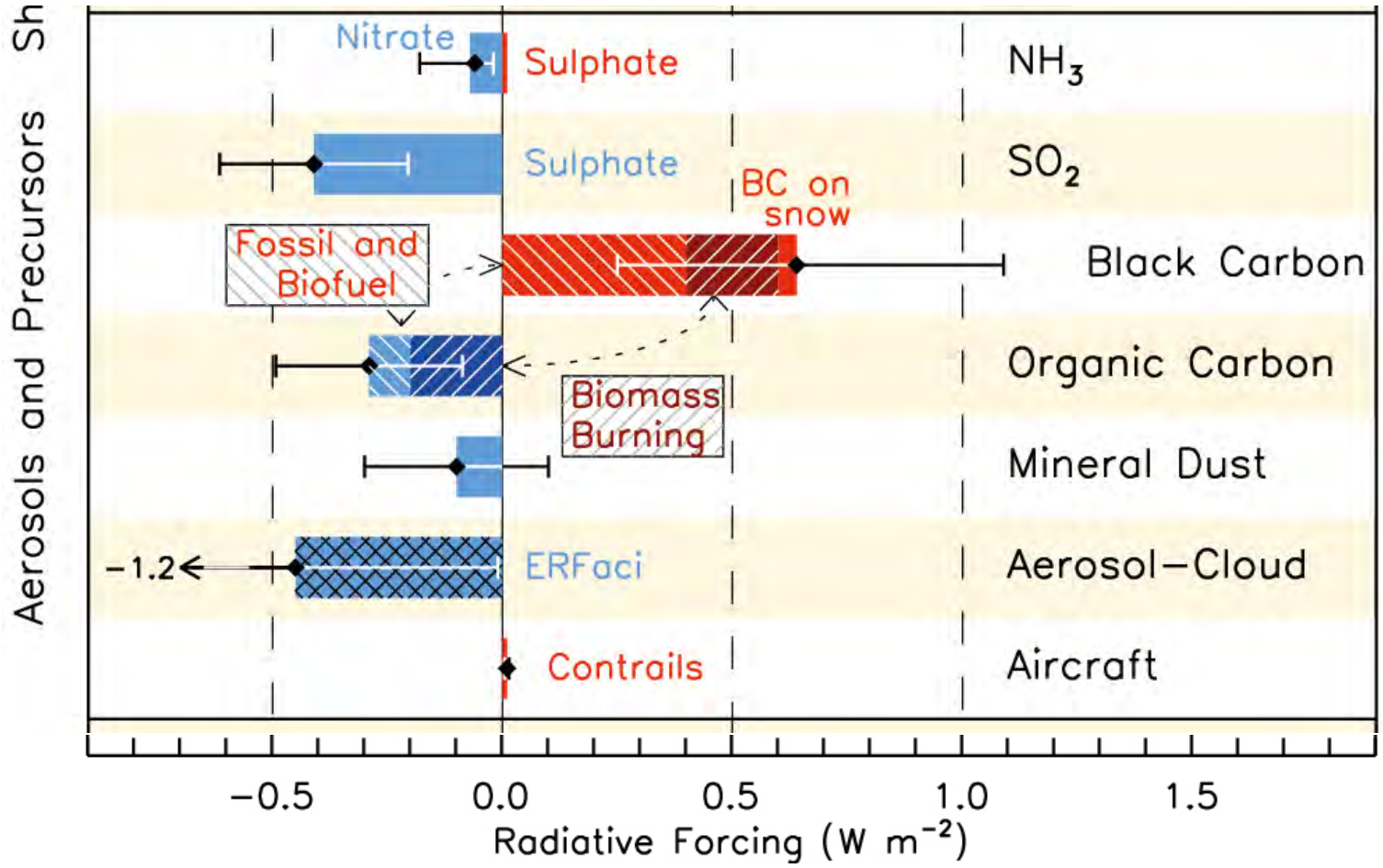
(b)



More aerosols result in a larger concentration of smaller droplets, leading to a brighter cloud. However there are many other possible aerosol–cloud–precipitation processes which may amplify or dampen this effect.

IPCC AR5

Aerosol impacts on climate: heating and cooling



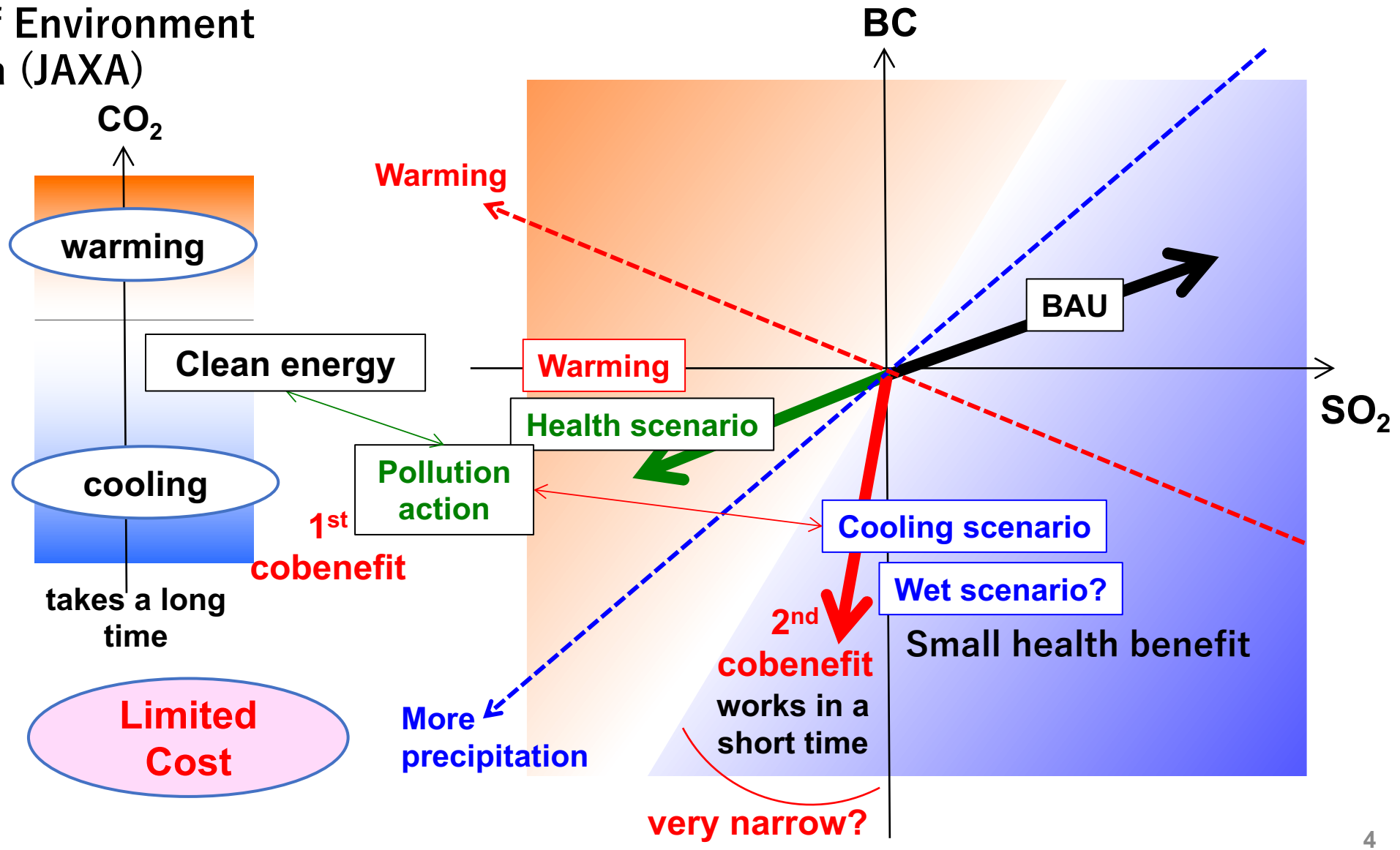
IPCC-AR5

- There are heating and cooling aerosols
- Net cooling with large uncertainty

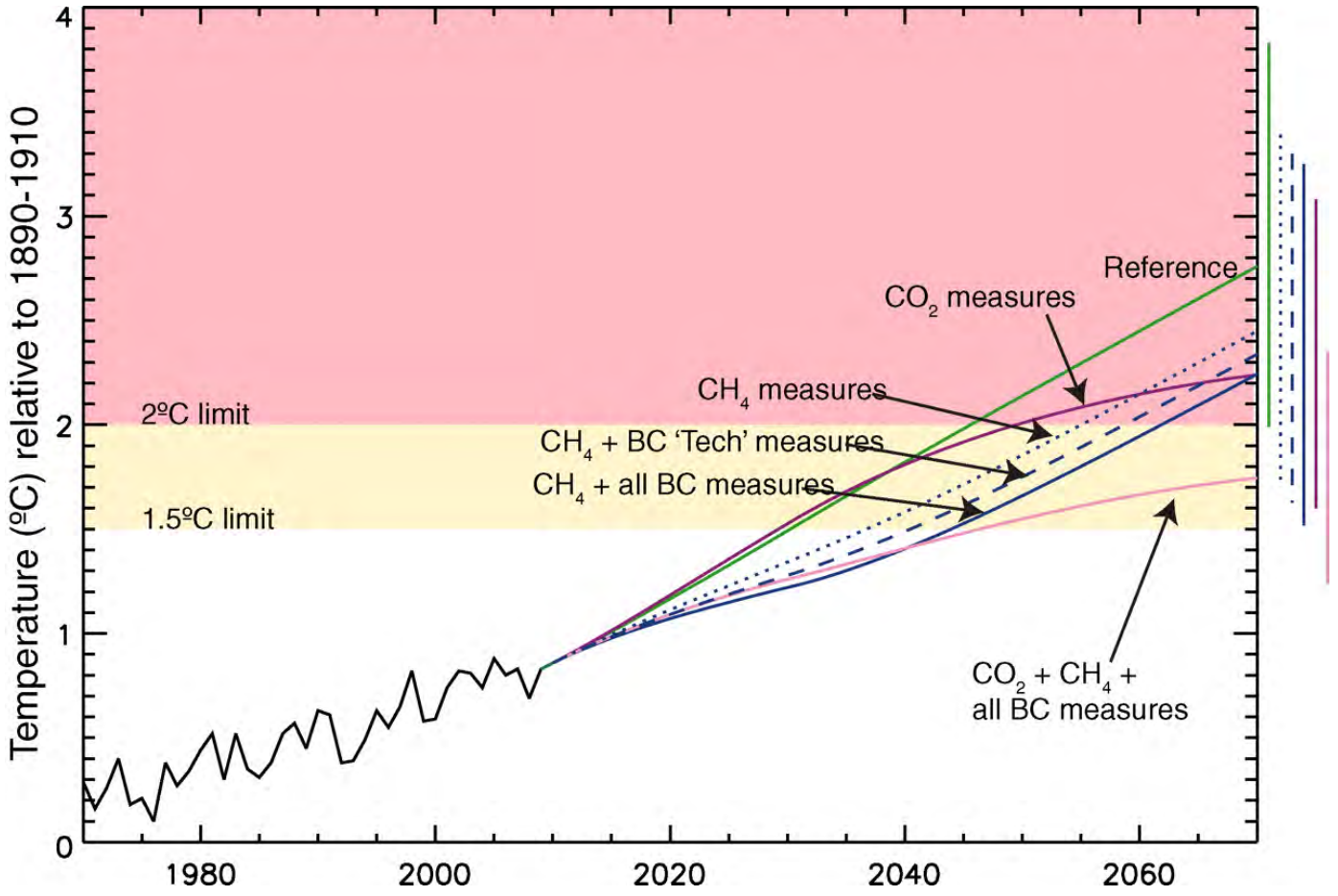
S-12 project: Seeking for mitigation paths of SLCPs

Funded by Ministry of Environment
PI: Teruyuki Nakajima (JAXA)
Period: FY'14-'18

Four subjects:
- ☐ Air pollutions
- ☐ Social scenarios
- ☐ Climate impacts
- ☐ Integrated system



Reduction of SLCPs might help mitigate the global warming

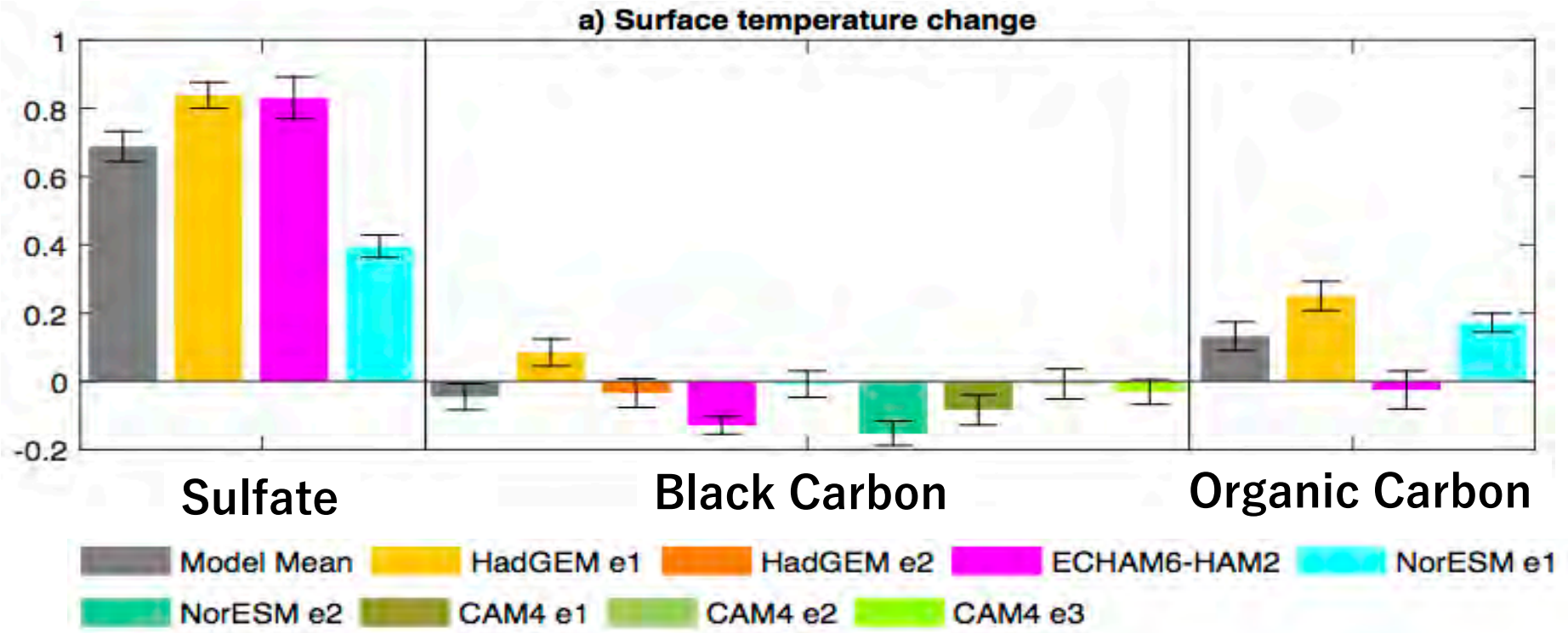


Shindell *et al.* ('12)

- SLCPs = Short-Lived Climate Pollutants
- Example: Black Carbon (BC), Methane (CH_4), Tropospheric Ozone (O_3)

Is the story simple enough?

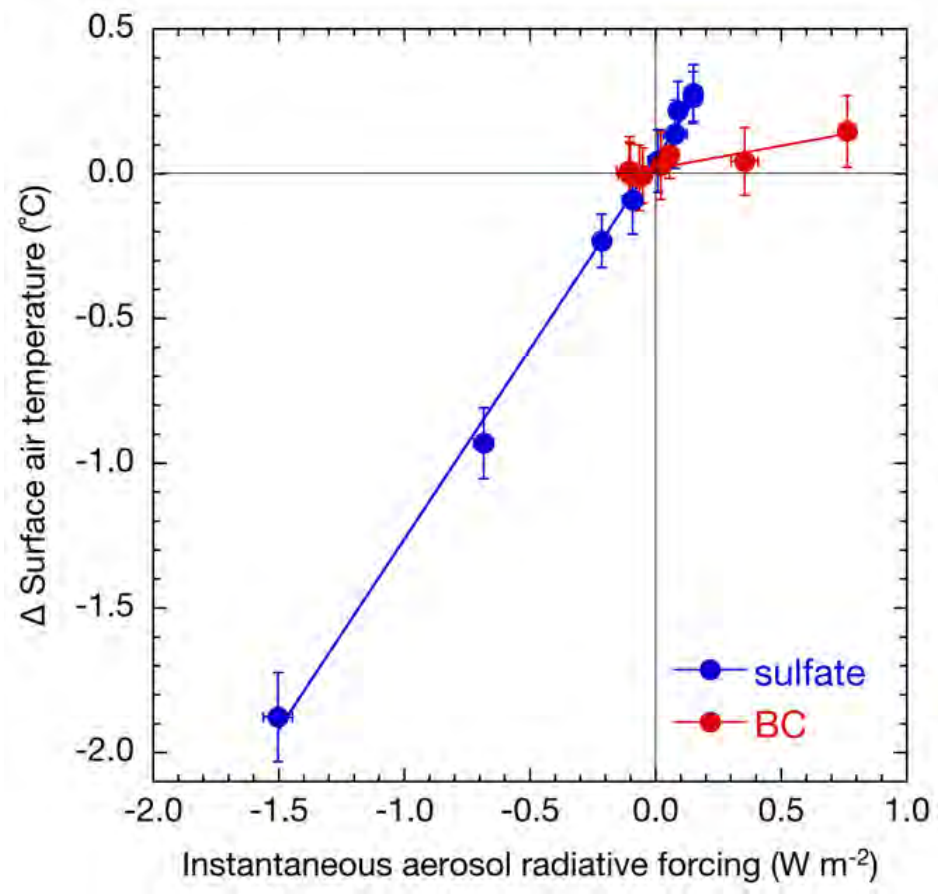
Response of surface temperature to emission removal



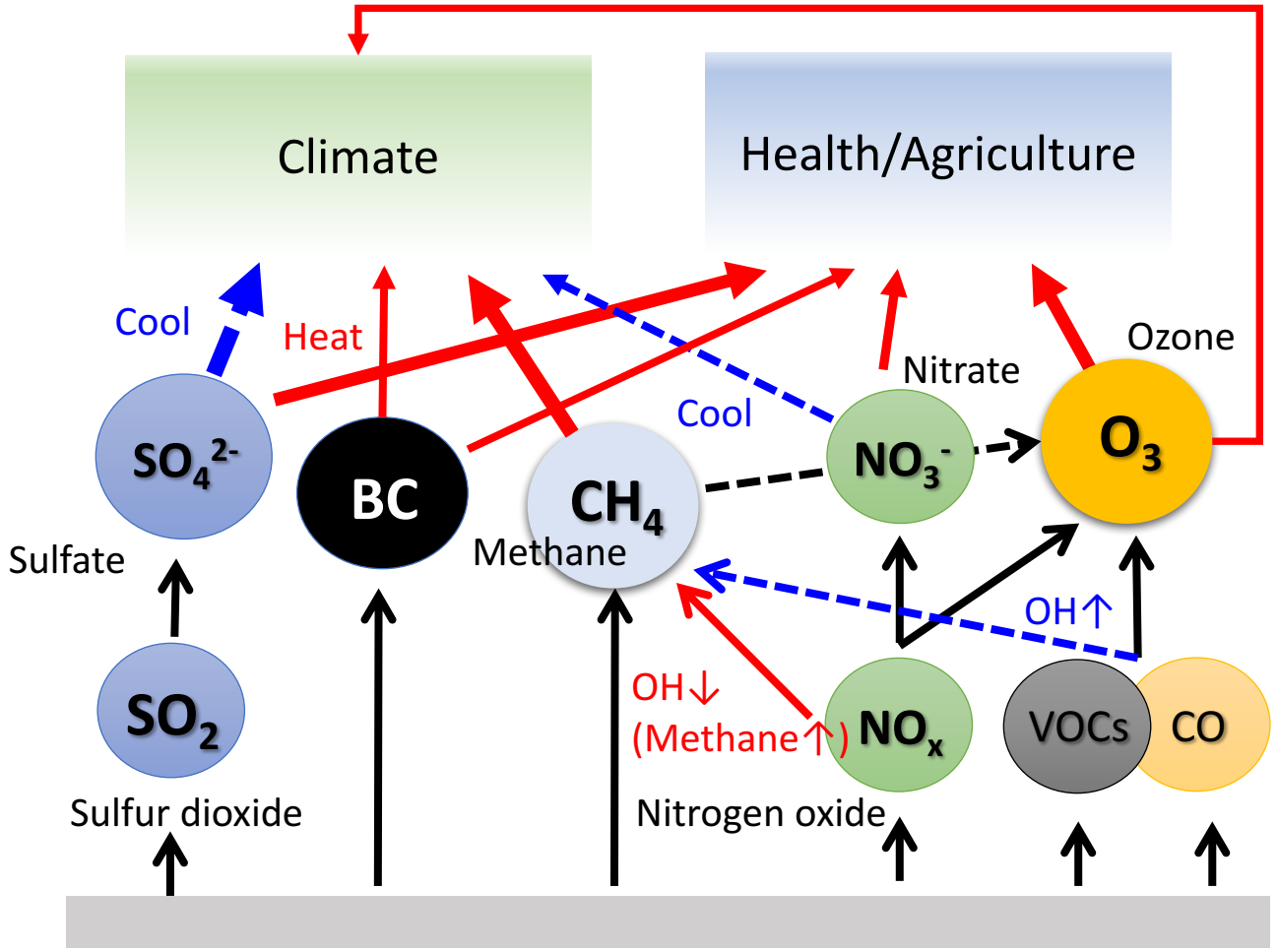
- Sulfate effect is conspicuous
- BC effect seems ambiguous

Stohl *et al.* (ACP '15)

Major findings from S-12



Takemura & Suzuki (revised)

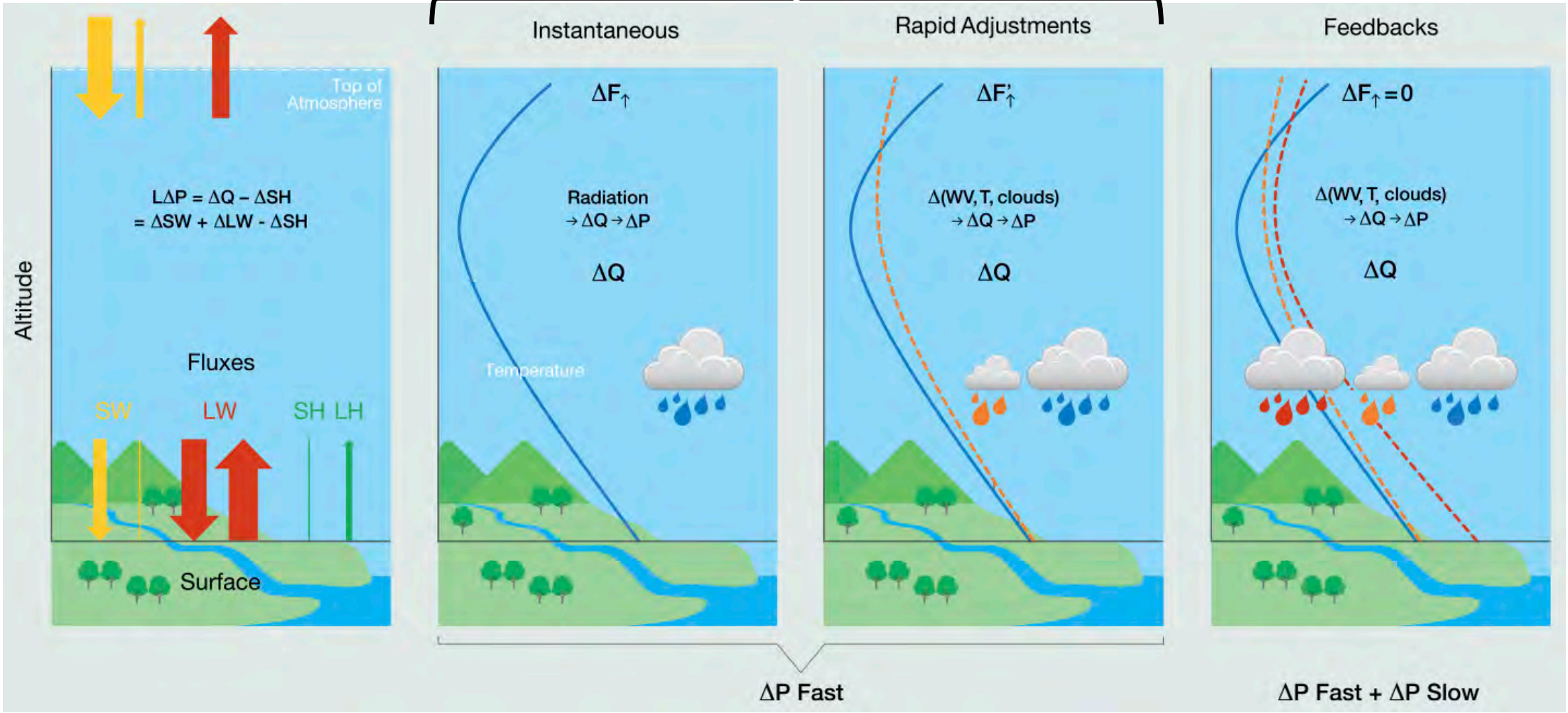


- BC has a small impact on global temperature
- Multifaceted impacts of SLCPs are identified

- Red arrows should be weakened
- Blue arrows should be strengthened

“Fast” & “Slow” climate responses

$$\Delta F_{eff} = \Delta F_{int} + \Delta F_{adj}$$

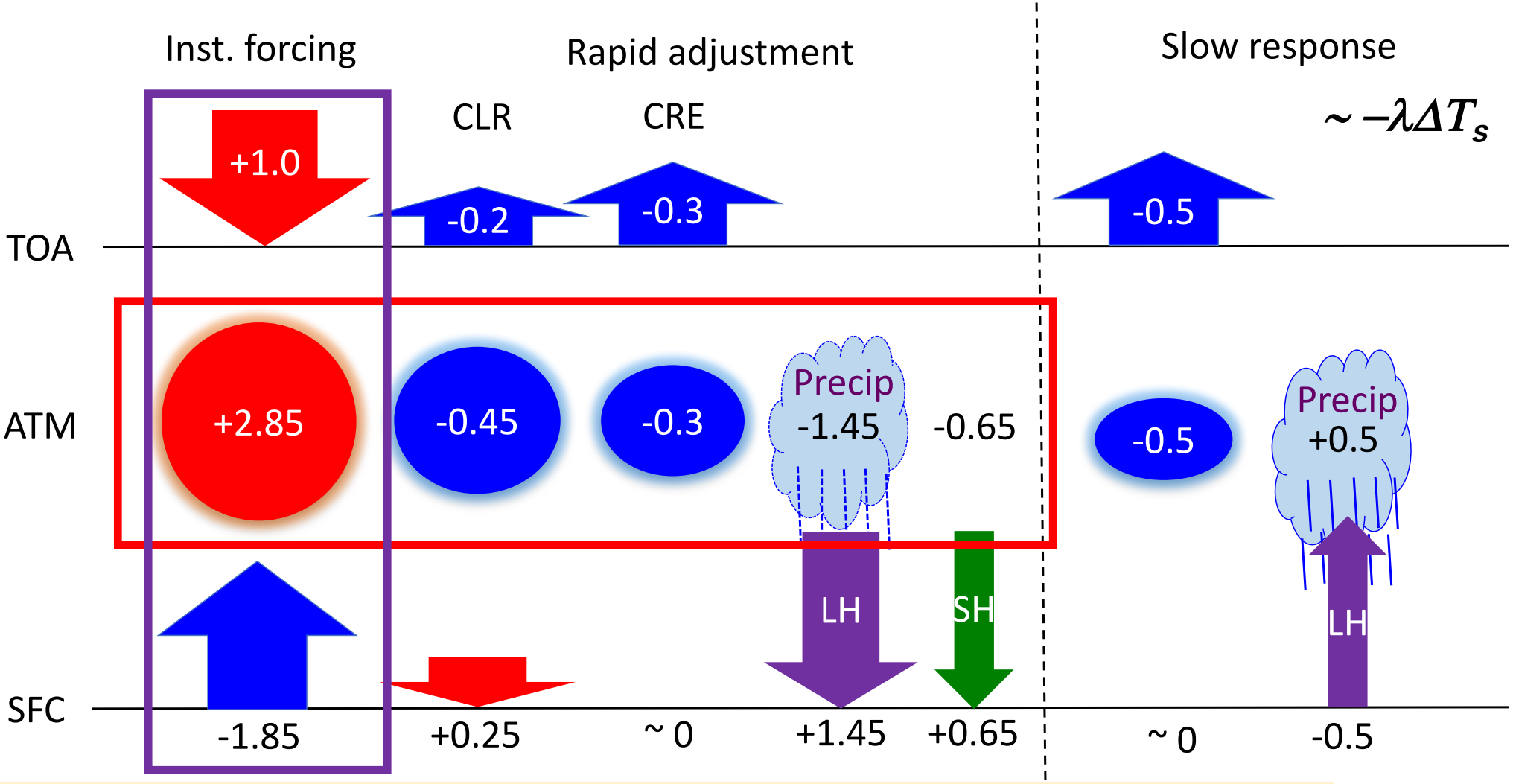


Myhre *et al.* (BAMS ’17)

$\Delta T_s \sim 0$

$\Delta T_s \neq 0$

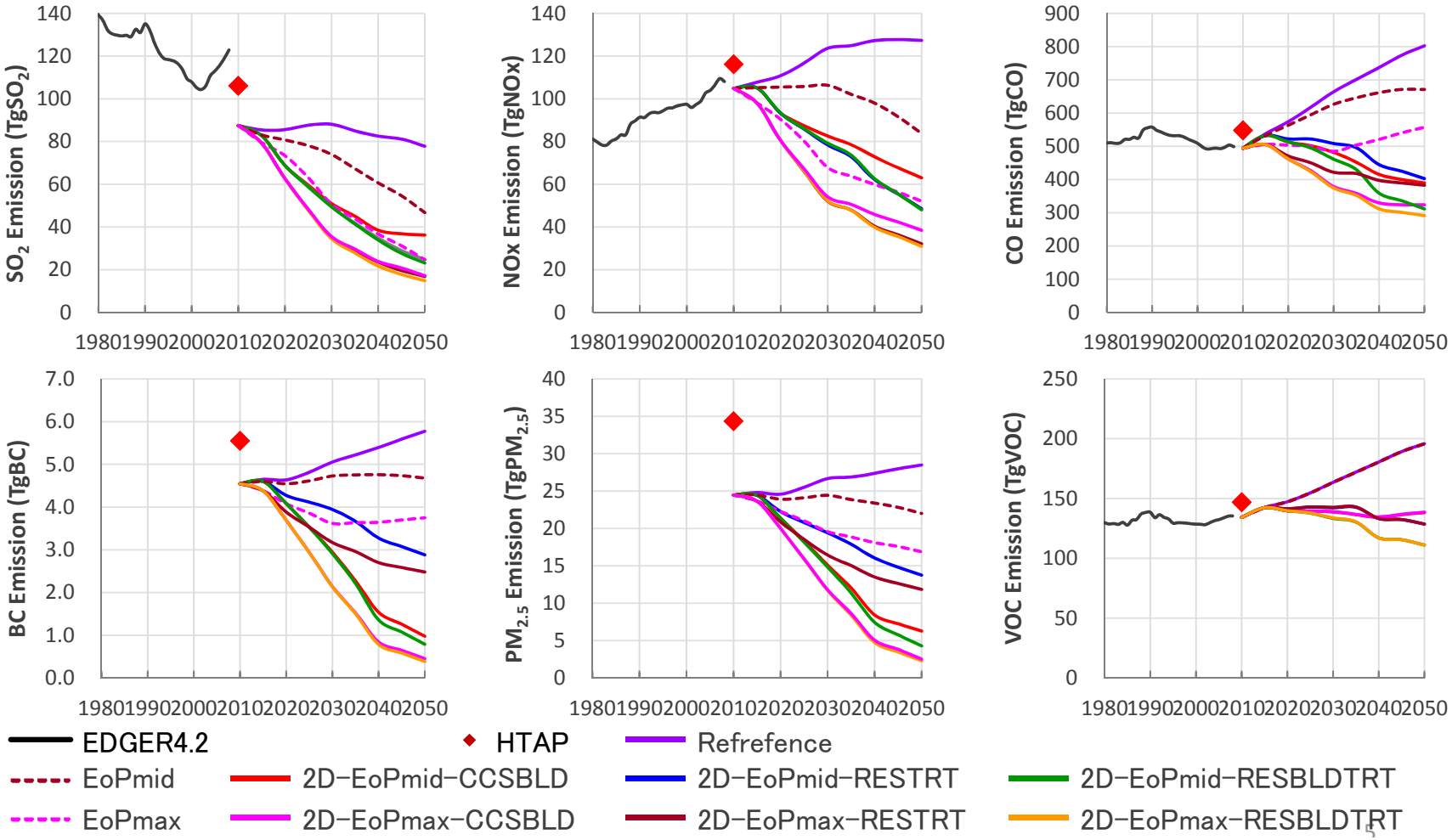
Modulation of Earth's energy budget by black carbon



- BC heats atmosphere and cools surface
- Precipitation change occurs via two competing pathways
- Only a fraction of energy is consumed to give rise to temperature

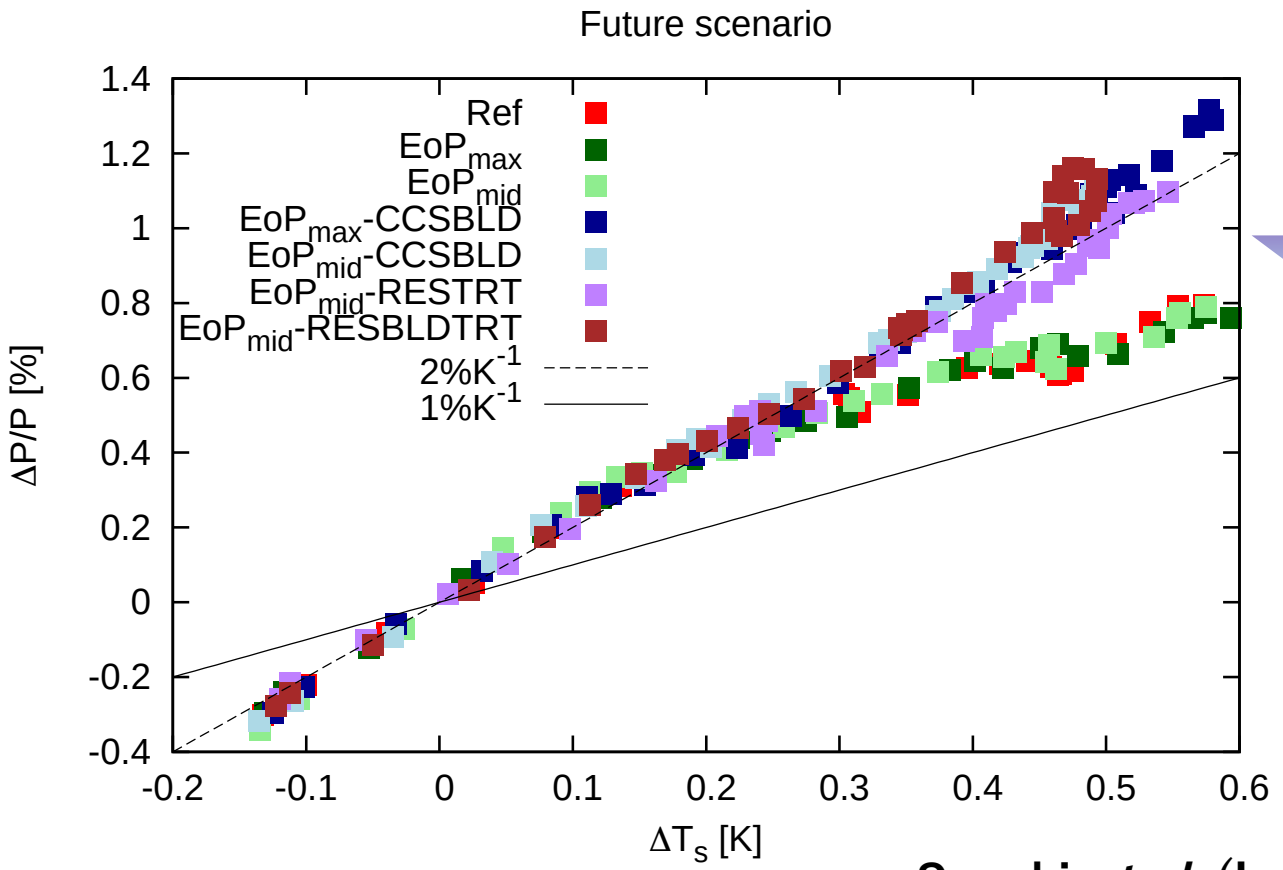
Suzuki & Takemura (JGR '19)

Exploring future emission scenarios in S-12



Hanaoka *et al.* (under review)

How does climate respond to different scenarios?



Reduction of precipitation

Suzuki *et al.* (In prep)

- Climate impacts of SLCPs: Temperature & Precipitation
- Global precipitation overall increases with global warming
- "Warming species" significantly reduce the precipitation

Take-home messages

- The impact of SLCPs is multifaceted
  - Climate/Health/Agriculture impacts co-exist
  - “Indirect effect” complicates the cause-and-effect relationship
  - Beneficial paths of mitigating SLCPs appear to lie in a narrow realm
- Unexpected features of BC’s climate impact are found
  - Effect on temperature is small
  - Precipitation is significantly modulated
  - These are understood from the global energy budget perspective
- What is implied for policy making?
  - Removing “black pollutants” is not likely to mitigate the global warming
  - Impacts on water cycle are significant
  - “Chain reactions” among species/paths need to be considered