Air Quality and Climate Connections

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AQAST9
St. Louis University, St. Louis, MO
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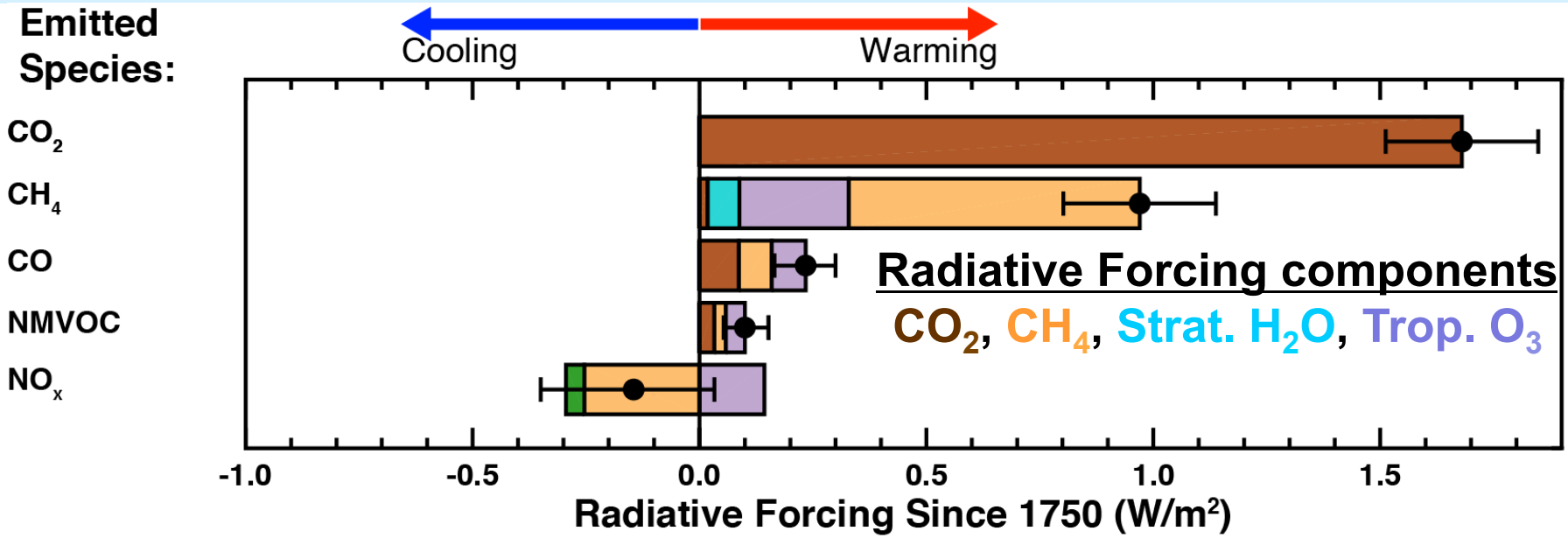
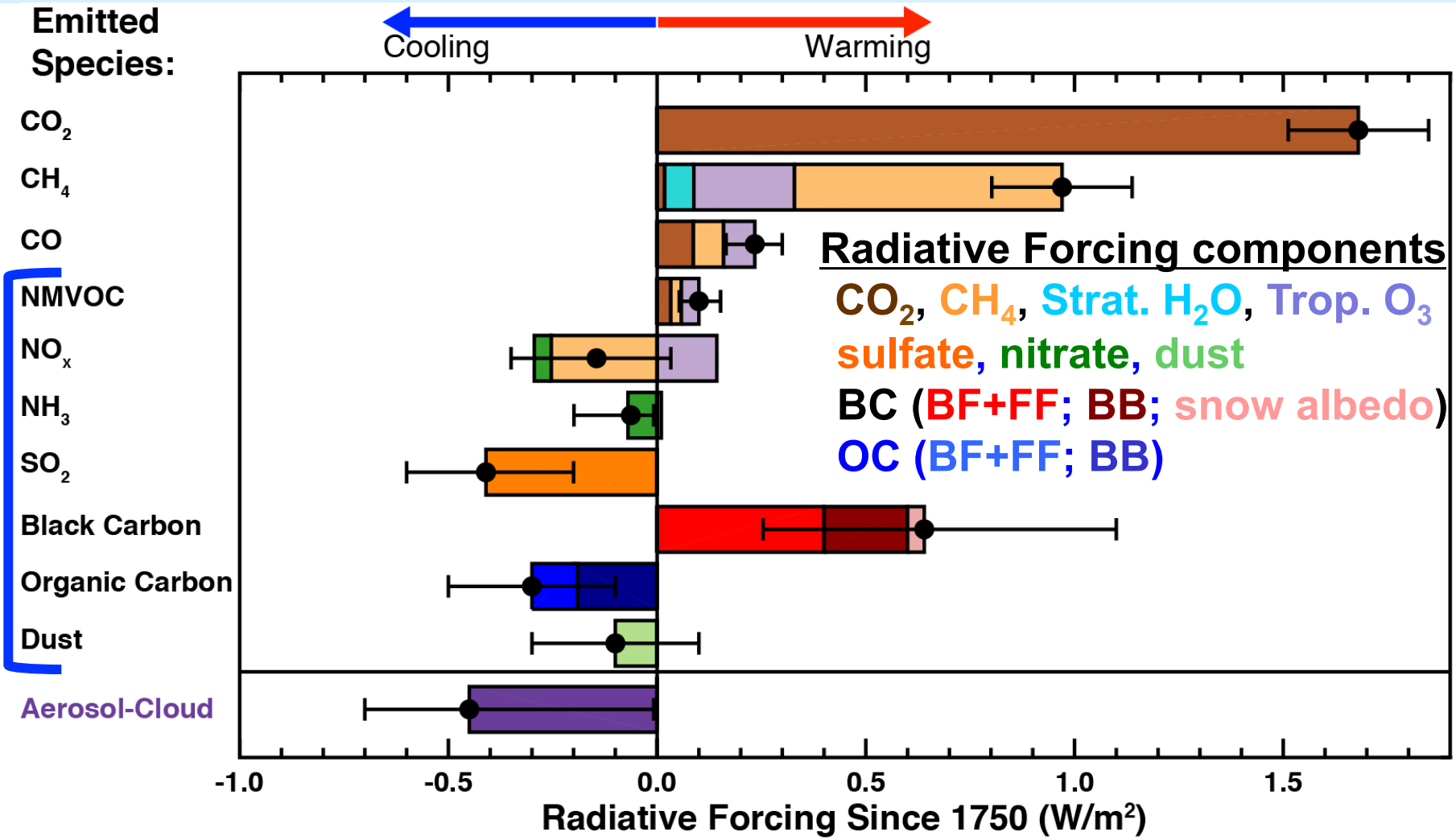
Tropospheric ozone and precursors contribute to climate forcing from pre-industrial to present-day



Adapted by E. Leibensperger (SUNY Plattsburgh) from IPCC, 2013 for Fiore, Naik, Leibensperger, in press

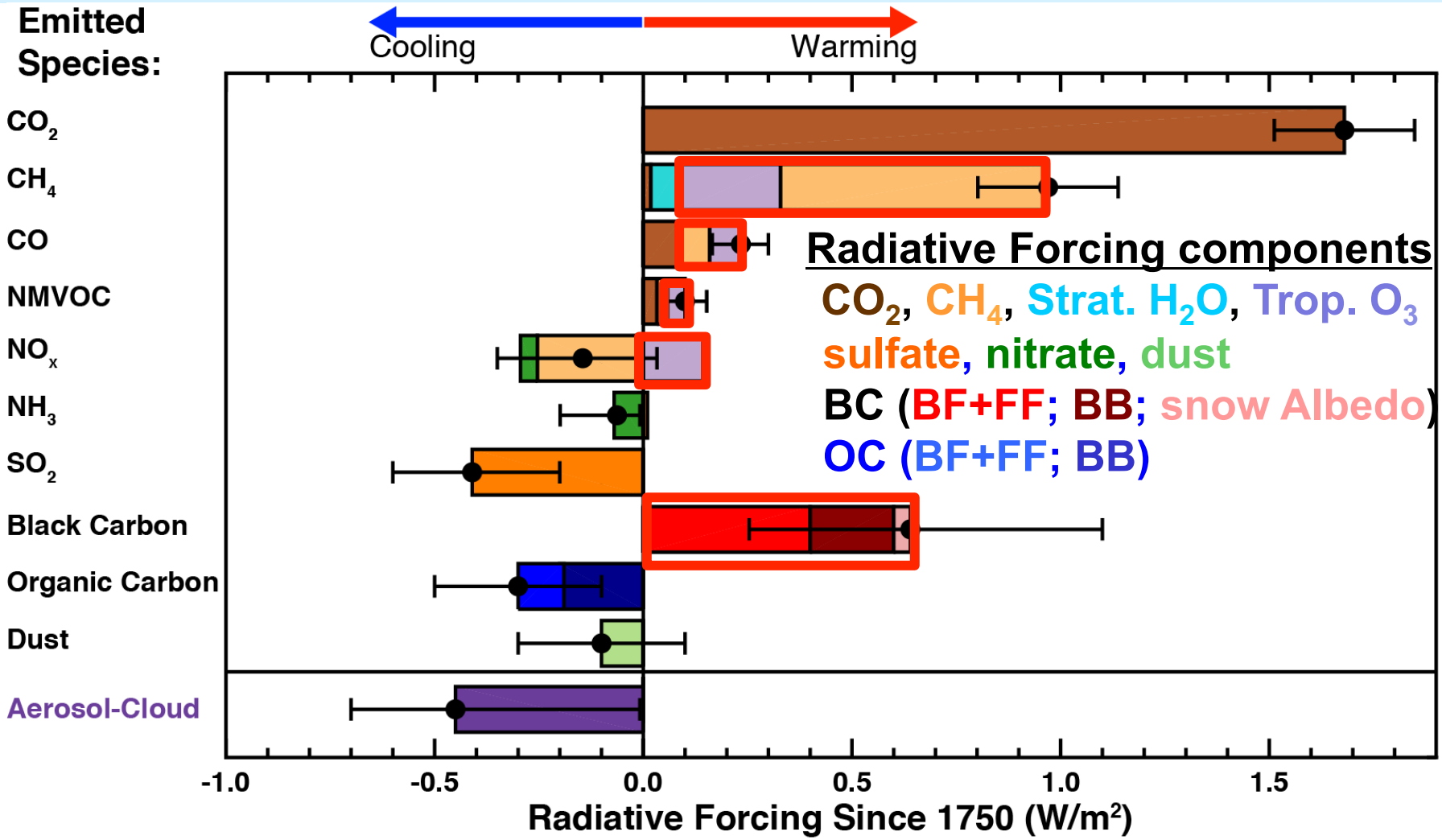
PM and precursors also contribute to climate forcing from pre-industrial to present-day



Net impact of aerosols (-0.9 W m^{-2}) opposes warming from GHGs

Adapted by E. Leibensperger (SUNY Plattsburgh) from IPCC, 2013 for Fiore, Naik, Leibensperger, in press

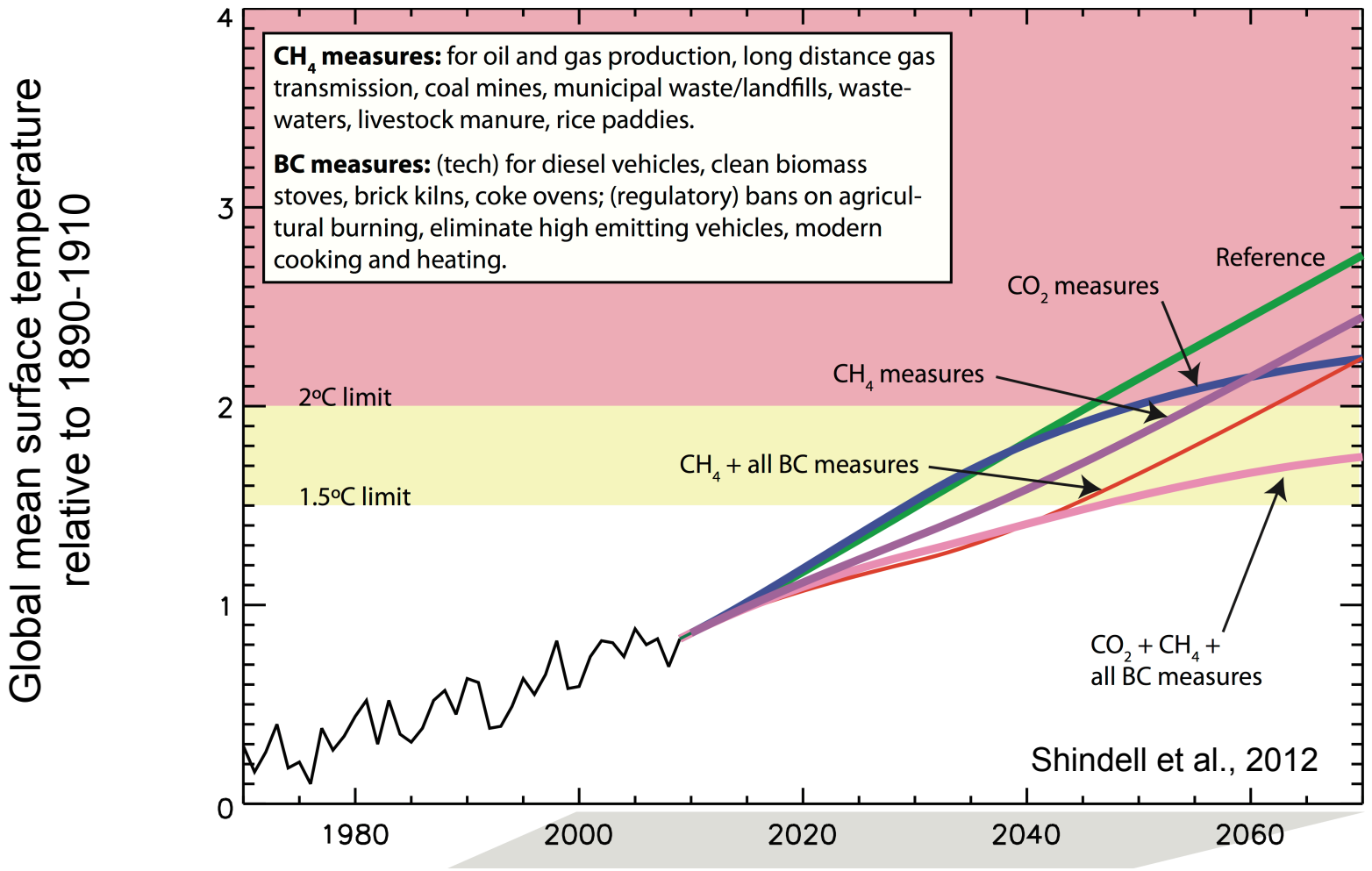
Air pollutants are Near-Term Climate Forcers (NTCFs); CO_2 dominates long-term climate (peak warming)



Short-Lived Climate Pollutants (SLCPs) = warming NTCFs

Adapted by E. Leibensperger (SUNY Plattsburgh) from IPCC, 2013 for Fiore, Naik, Leibensperger, in press

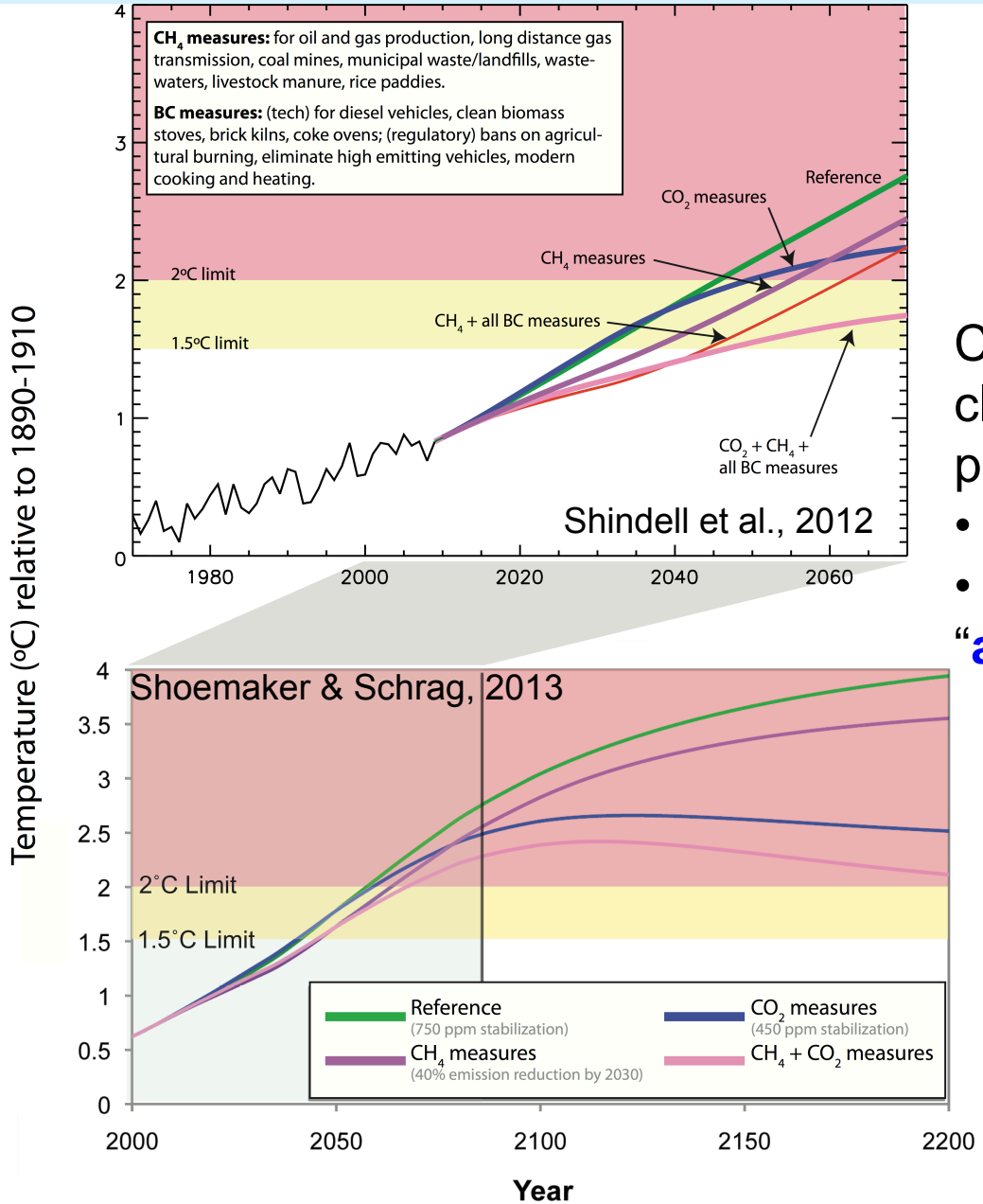
Reducing air pollutant SLCPs lessens near-term climate warming (and improves air quality by decreasing background O_3; $PM_{2.5}$)



→ Target CH_4 and some BC-rich sources to offset near-term warming from health-motivated controls on SO_2 emissions

Adapted from Fig 12 Fiore et al. 2015

Mitigate BOTH near-term AND long-term climate change by reducing SLCPs AND CO_2

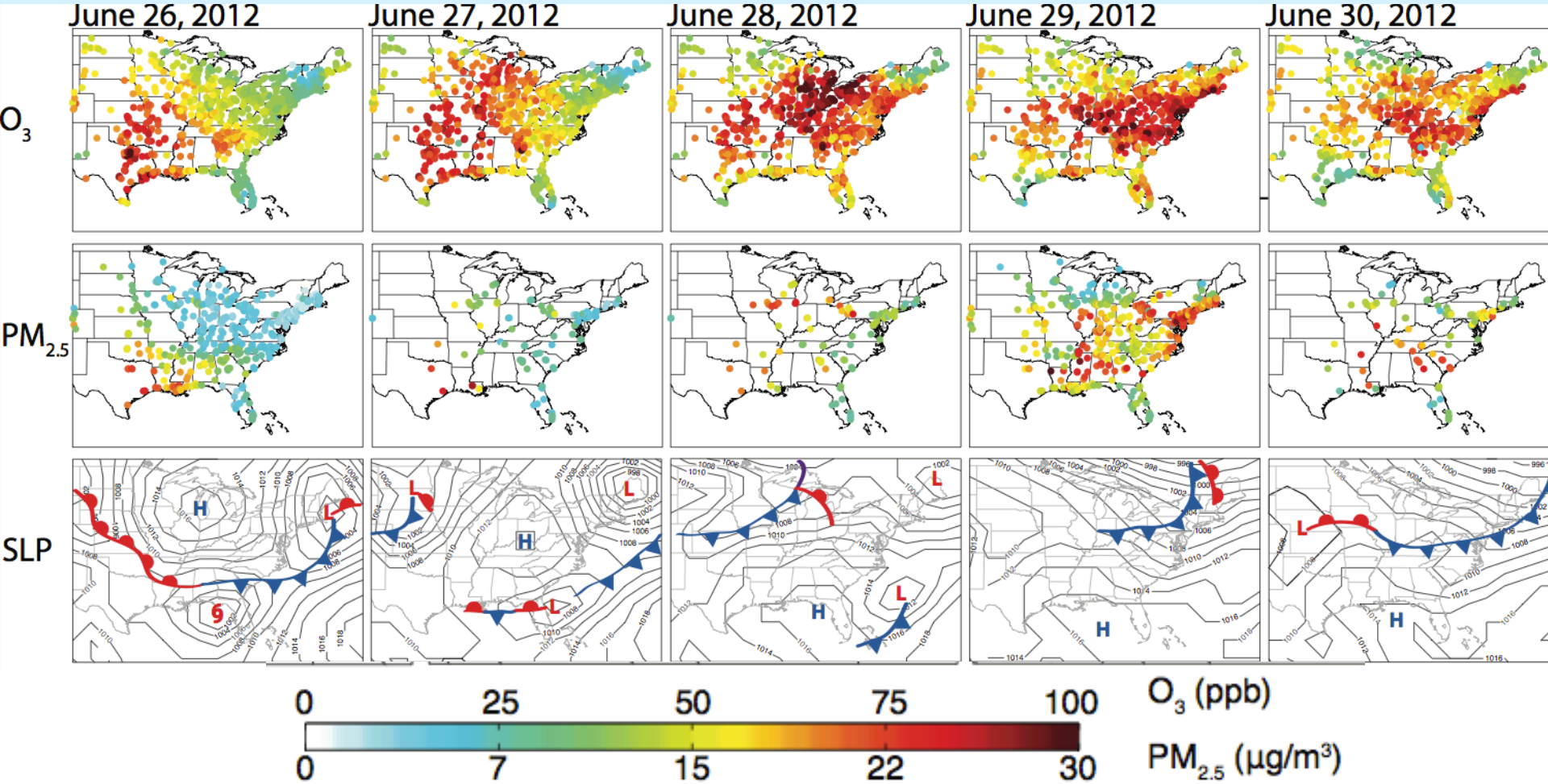


CO_2 and SLCPs can induce other climate responses that affect pollution levels:

- Hydrologic cycle
- Circulation patterns (including "**air pollution meteorology**")

Adapted from Fig 12 Fiore et al. 2015

Ozone and particulate matter build up during heat wave; cold fronts ventilate the polluted boundary layer



Warmer climate → more heat waves → more pollution?

Figure 7 of Fiore, Naik, Leibensperger, JAWMA, 2015

O_3 correlates with surface temperature on daily to inter-annual time scales in polluted regions [e.g., Bloomer et al., 2009; Camalier et al., 2007; Cardelino and Chameides, 1990; Clark and Karl, 1982; Korsog and Wolff, 1991]

Observations at U.S. EPA CASTNet site Penn State, PA 41N, 78W, 378m

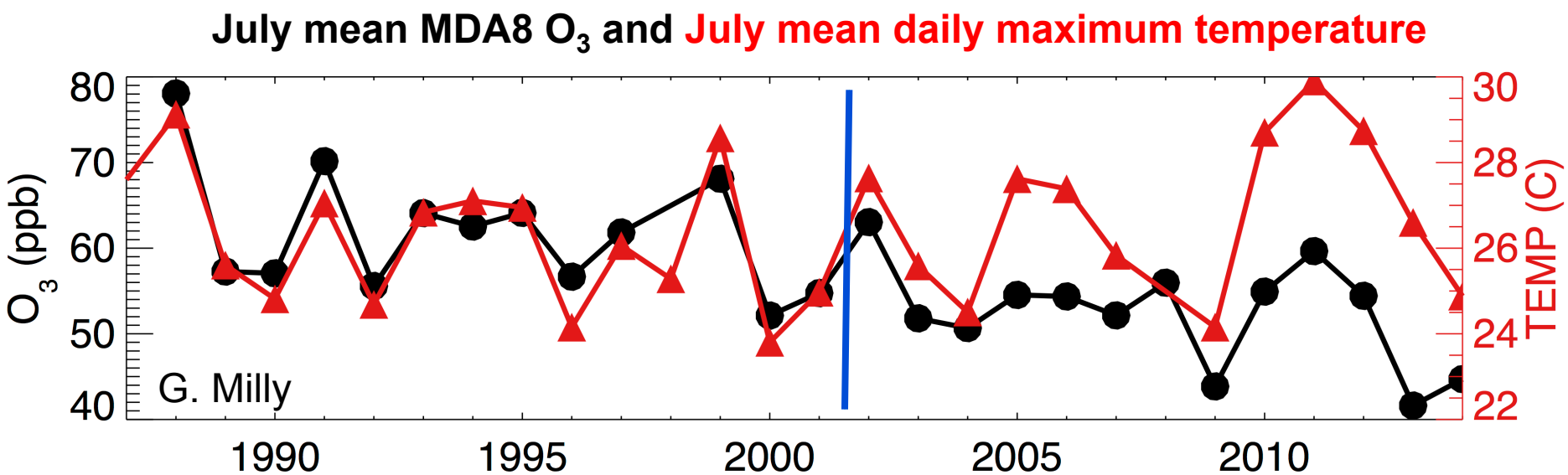


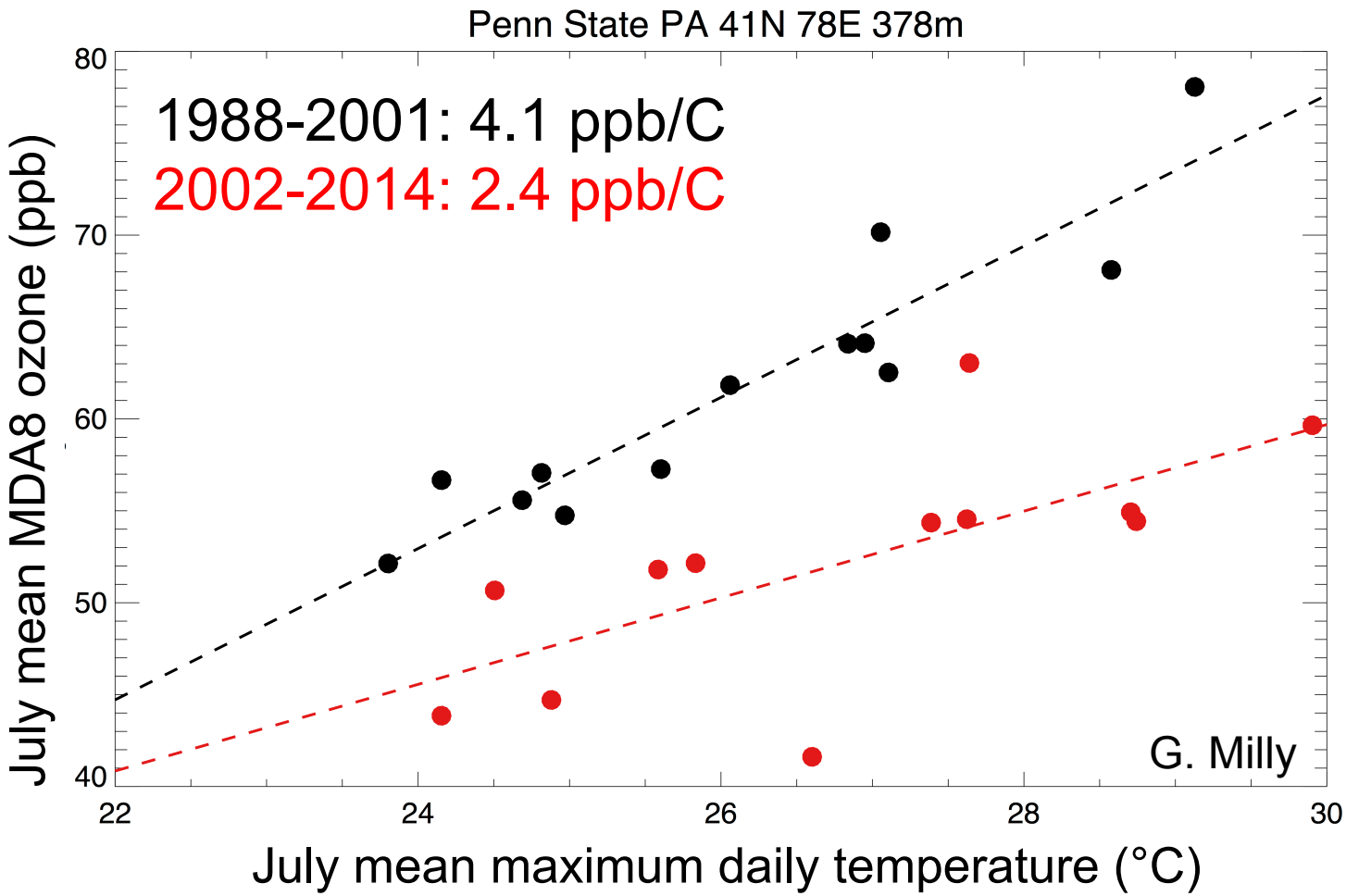
Figure 6a of Fiore, Naik, Leibensperger, JAWMA, 2015

→ **Implies that changes in climate (via regional air pollution meteorology) will influence air quality**

→ **Downward trend in O_3 as EUS NO_x emission controls are implemented**

Decreasing NO_x emissions reduces sensitivity of O_3 to temperature; helps to guard against any "climate penalty"

[e.g., Bloomer et al., 2009; Rasmussen et al., 2012; Brown-Steiner et al., 2015]



→ Historically observed relationships may not hold as emissions change

→ Meteorology may also change [e.g., Barnes & Fiore, 2013; Shen et al., 2015]

Figure 6b of Fiore, Naik, Leibensperger, JAWMA, 2015

Projected changes in U.S. surface ozone in summer (JJA) under climate and precursor emission scenarios: declines due to continued controls on precursor emissions

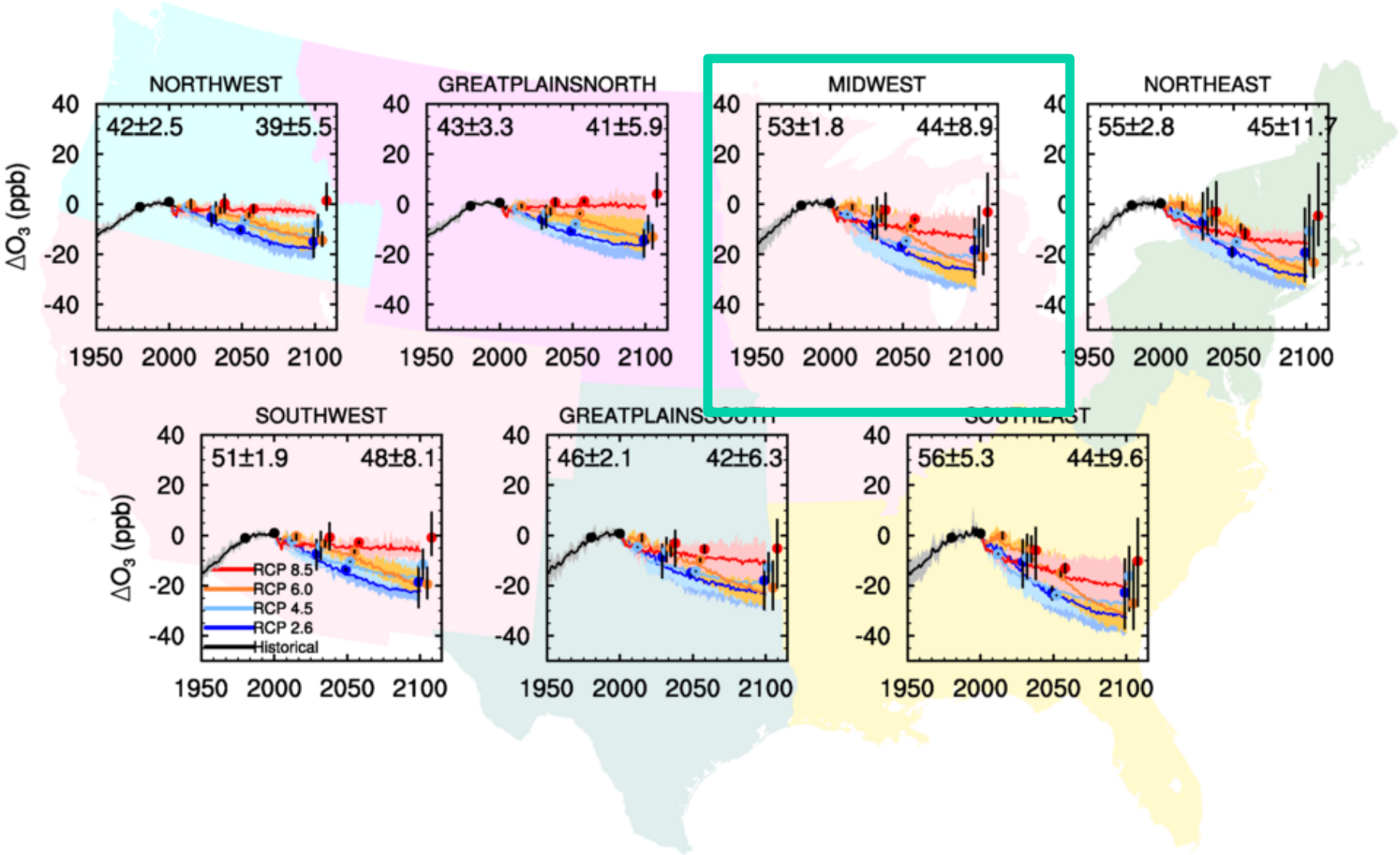
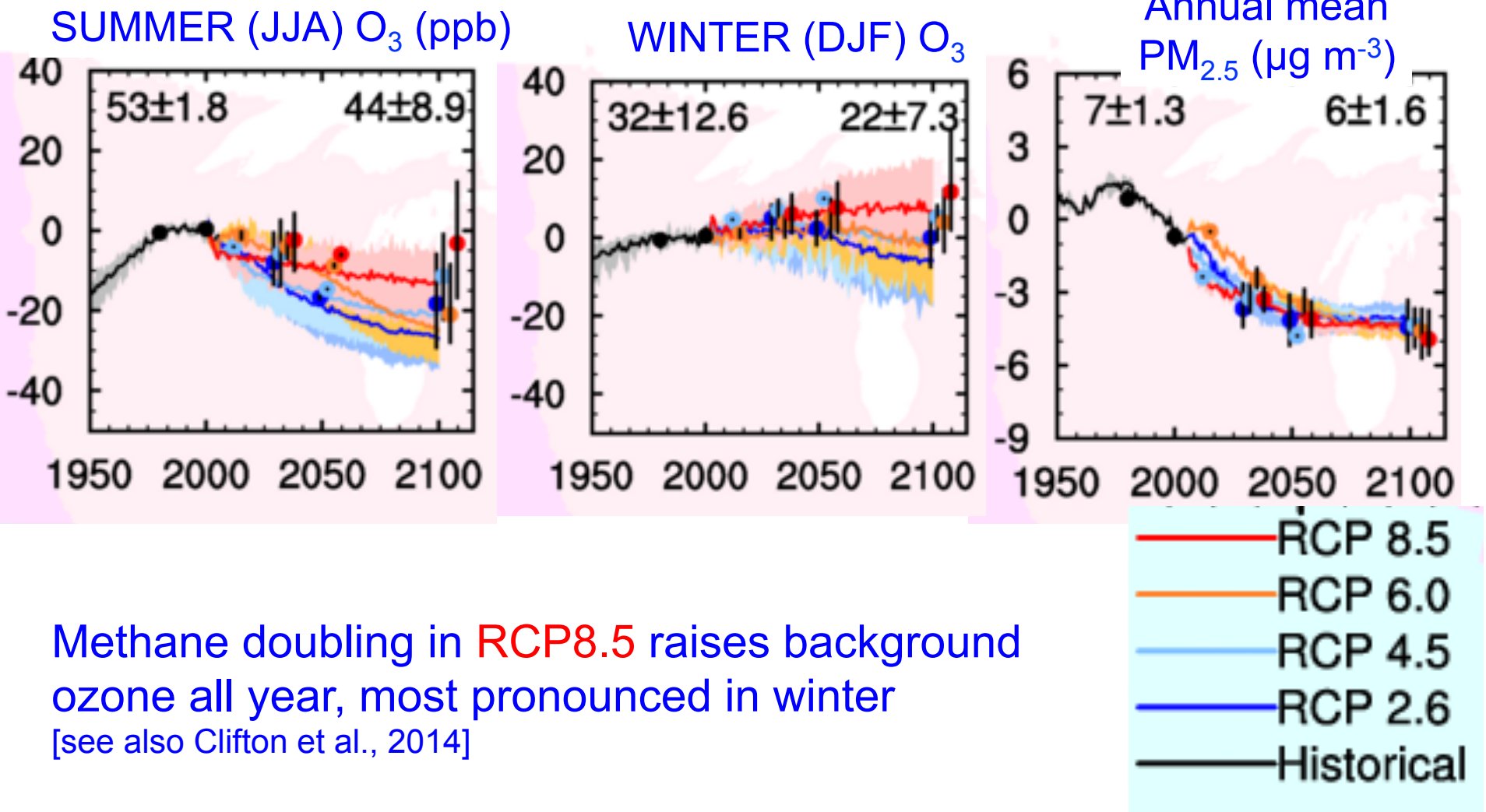


Figure 10a of Fiore, Naik, Leibensperger, JAWMA, 2015

CMIP5 and ACCMIP models

Projected air quality changes over the Midwest mainly follow precursor emission trajectories

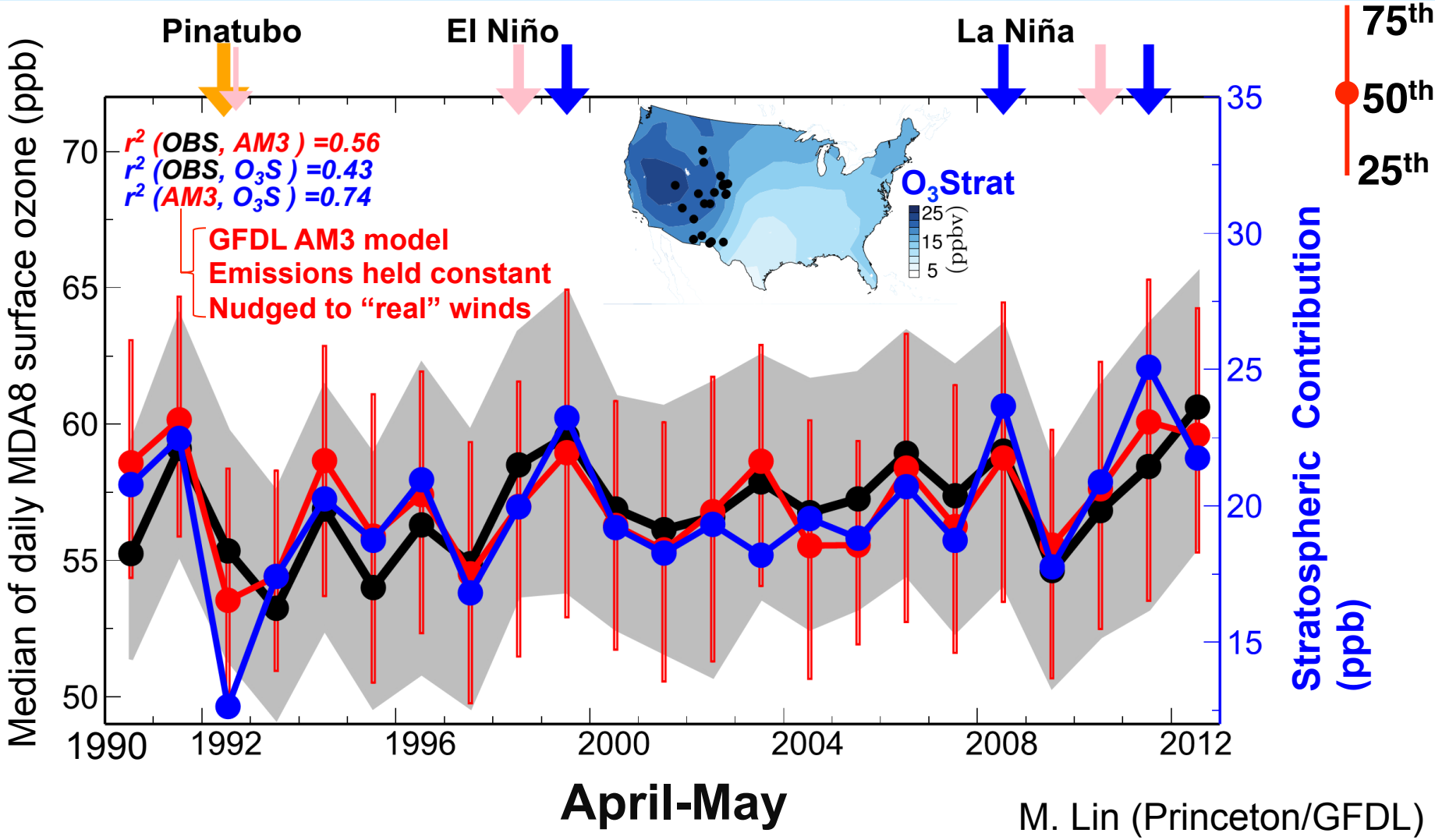


Methane doubling in RCP8.5 raises background ozone all year, most pronounced in winter
[see also Clifton et al., 2014]

CMIP5 and ACCMIP models

Figure 10 of Fiore, Naik, Leibensperger, JAWMA, 2015

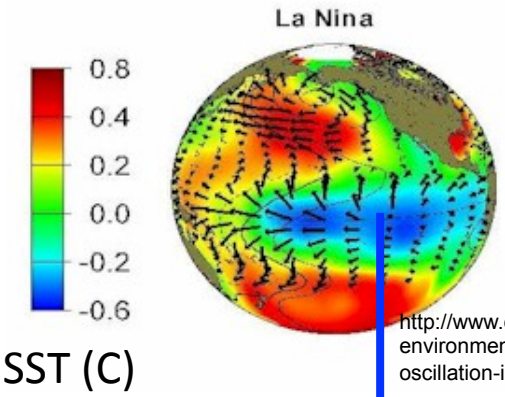
Climate variability can modulate background ozone sources: e.g., frequency of deep stratospheric intrusions over WUS



M. Lin (Princeton/GFDL)

Meiyun Lin, Fiore AM, Horowitz LW, Langford AO, Oltmans SJ, Tarasick D, Rieder H, Nature Communications, May 2015

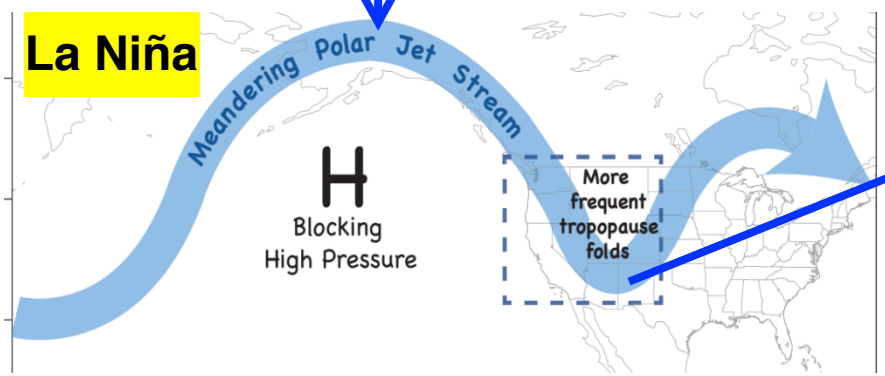
Connection of frequent deep stratospheric intrusions over WUS to known mode of climate variability (La Niña)

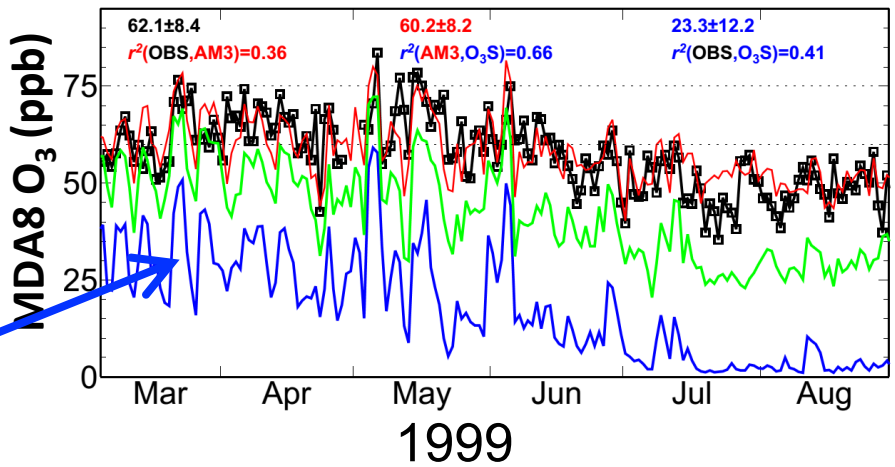


http://www.enr.gov.nt.ca/state-environment/22-pacific-decadal-oscillation-index-and-el-ninola-nina

Tropical SST cooling typically peaks in winter

More frequent stratospheric intrusions the following spring over WUS?





→ **May offer a few months lead time to aid WUS preparations for an active stratospheric intrusion season**

M. Lin et al., Nature Communications, May 2015

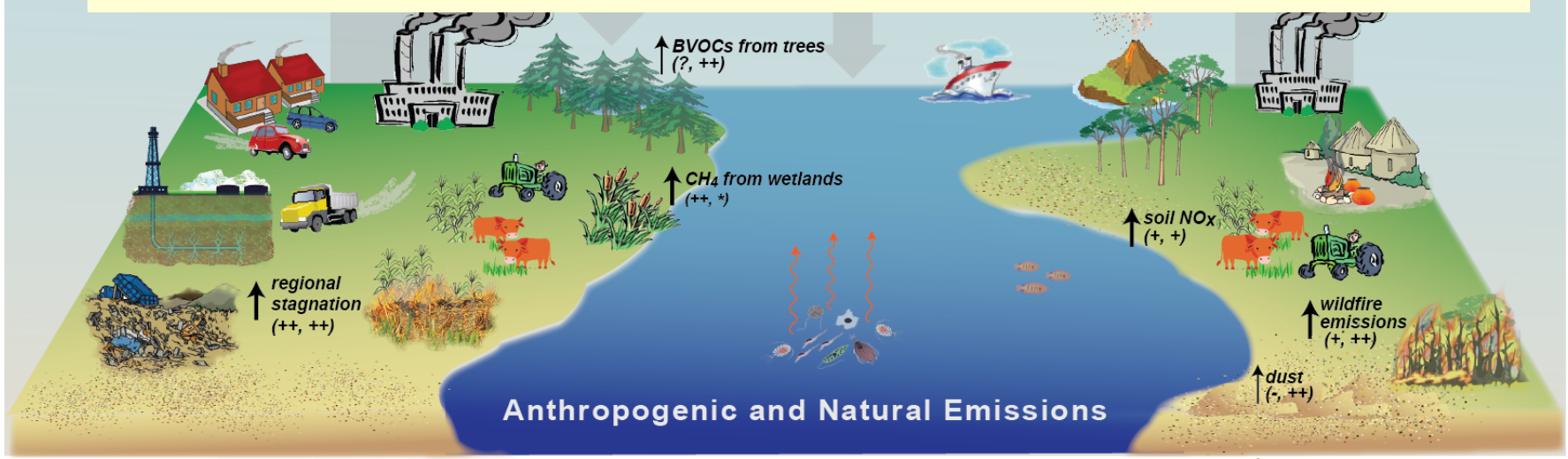
M. Lin (Princeton/GFDL)

Summary schematic of air quality-climate connections

Figure 2, Fiore, Naik, Leibensperger, JAWMA, 2015
schematic c/o C. Raphael, GFDL

Improved accuracy and trends in emission inventories are critical for accountability analyses of historical and projected air pollution and climate mitigation policies [AQAST!]

Translating research into digestible products and training air managers in using data products and analysis tools [AQAST! Jacob et al., 2014; Duncan et al., 2014; Streets et al., 2014; Witman et al., 2014]



Summary schematic of air quality-climate connections