Global methane emissions and impacts on climate, air quality, and vegetation

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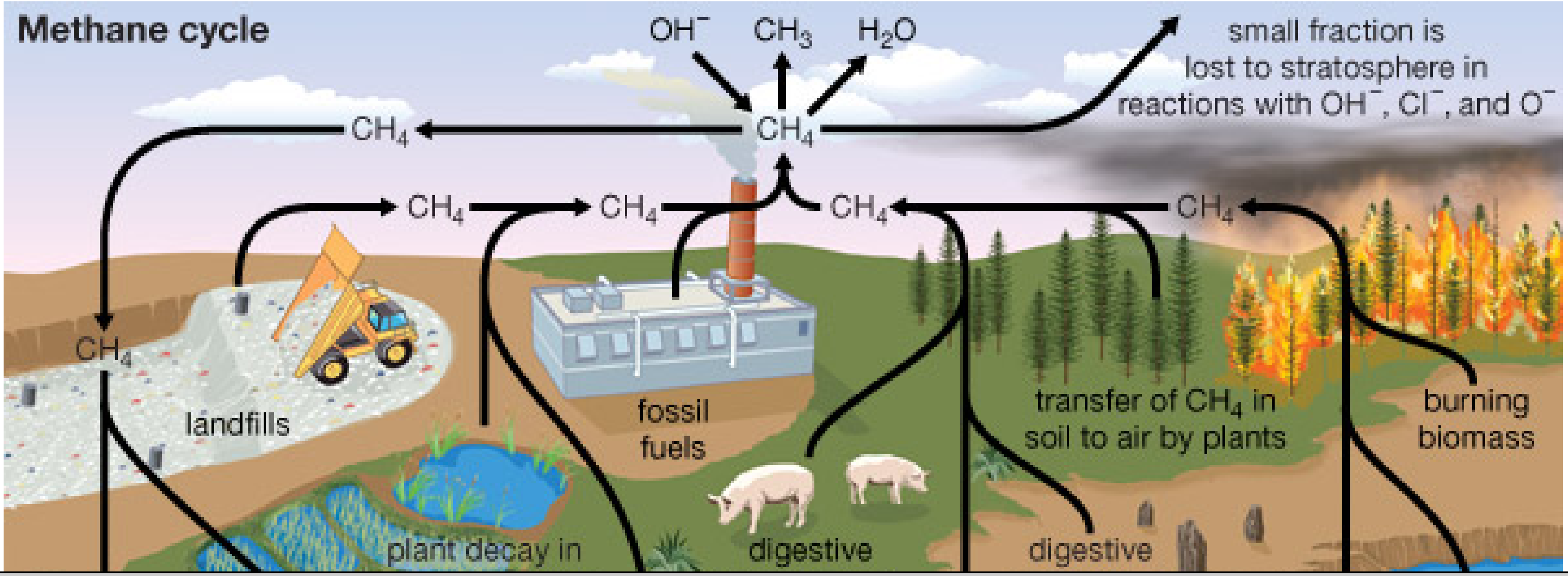
CH_4 cycles in the atmosphere



Main loss from reaction with OH in the atmosphere
- 9.8 ± 1.6 yrs (Voulgarakis et al., 2013), 11.2±1.3 year (Prather et al., 2012)

- Lifetime extended by increased CH_4 (e.g., Holmes et al., 2013)
- Products include O_3
- NO_x reductions will decrease O_3 but also decrease OH, thereby increasing CH_4

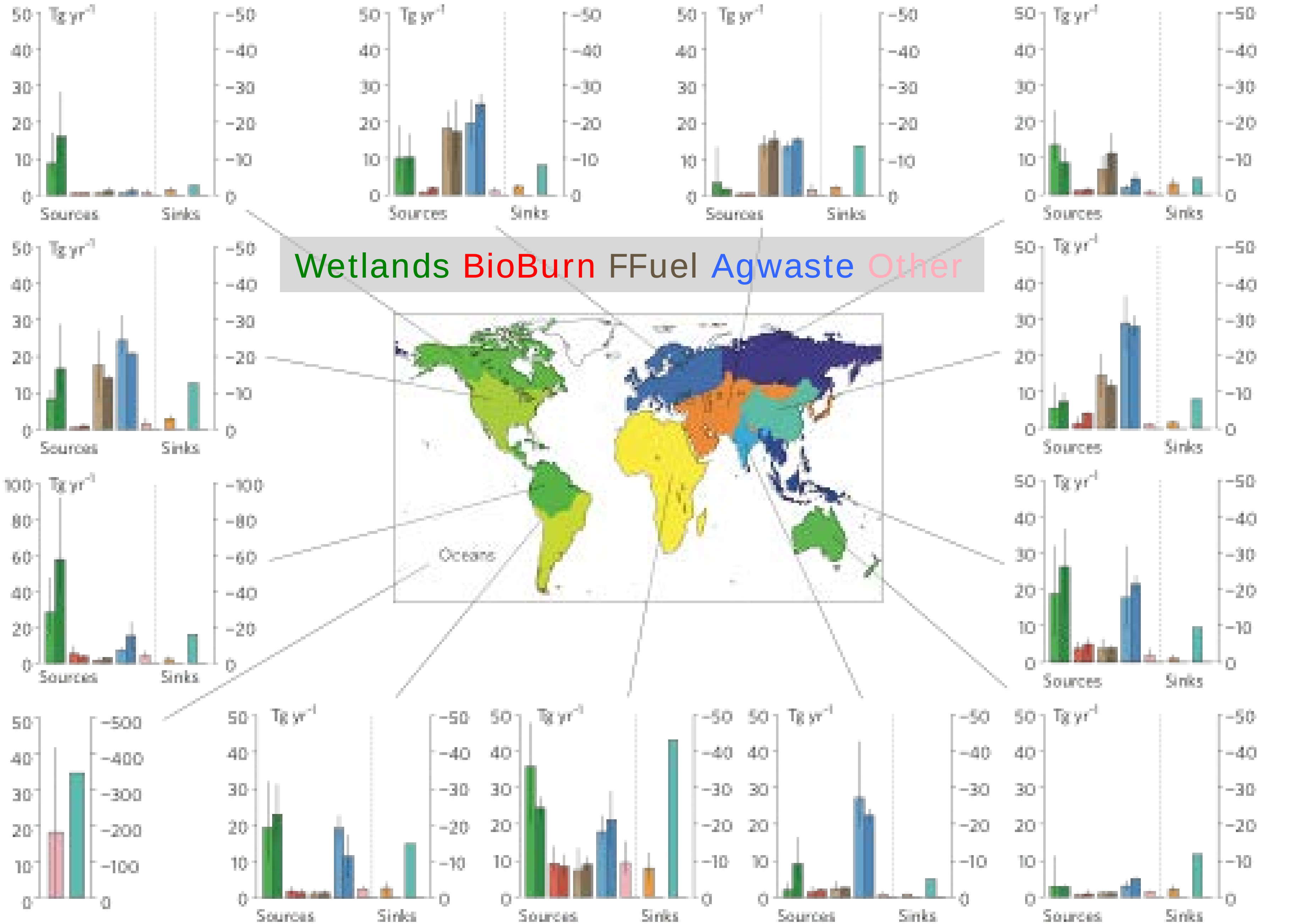
CH_4 emissions sources

Sources 2000-2009

(Kirschke et al., 2013)

Tg CH_4 yr^{-1}	**Top-down**	**Bottom-up**
Ag. & waste	209 [180-241]	200 [187-224]
Wetlands	175 [142-208]	217 [177-284]
Anthro. Fossil fuels	96 [77–123]	96 [85 – 105]
Other natural	43 [37 – 65]	130 [61-200]
Biomass burn.	30 [24–45]	35 [32– 39]
Total Sources	548 [526–569]	678 [542-852]
Total Sinks	540 [514–560]	632 [592-785]

Top-down | Bottom up estimates (Kirschke et al., 2013)



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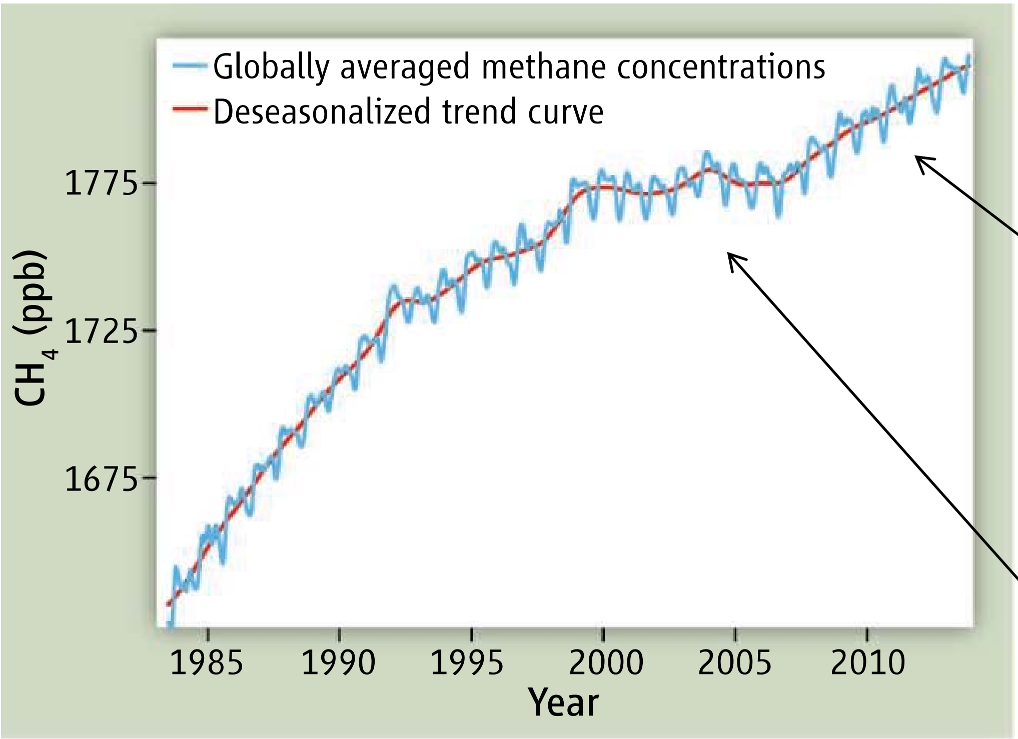
Observed CH_4 concentration trends



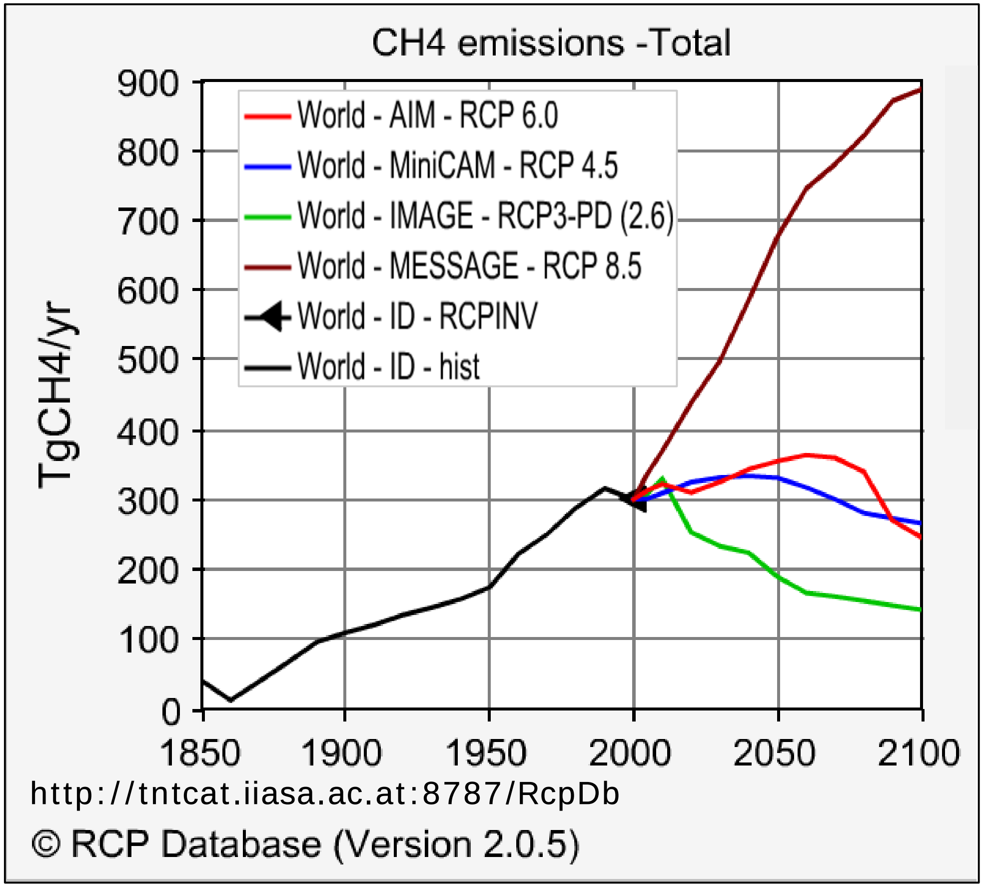
Kirschke et al., 2013:

- Increasing wetland and fossil fuel emissions?
- decrease / stabilization of fossil fuel and stable / increasing microbial activity?

Nisbet et al., 2014

CH_4 emissions trends

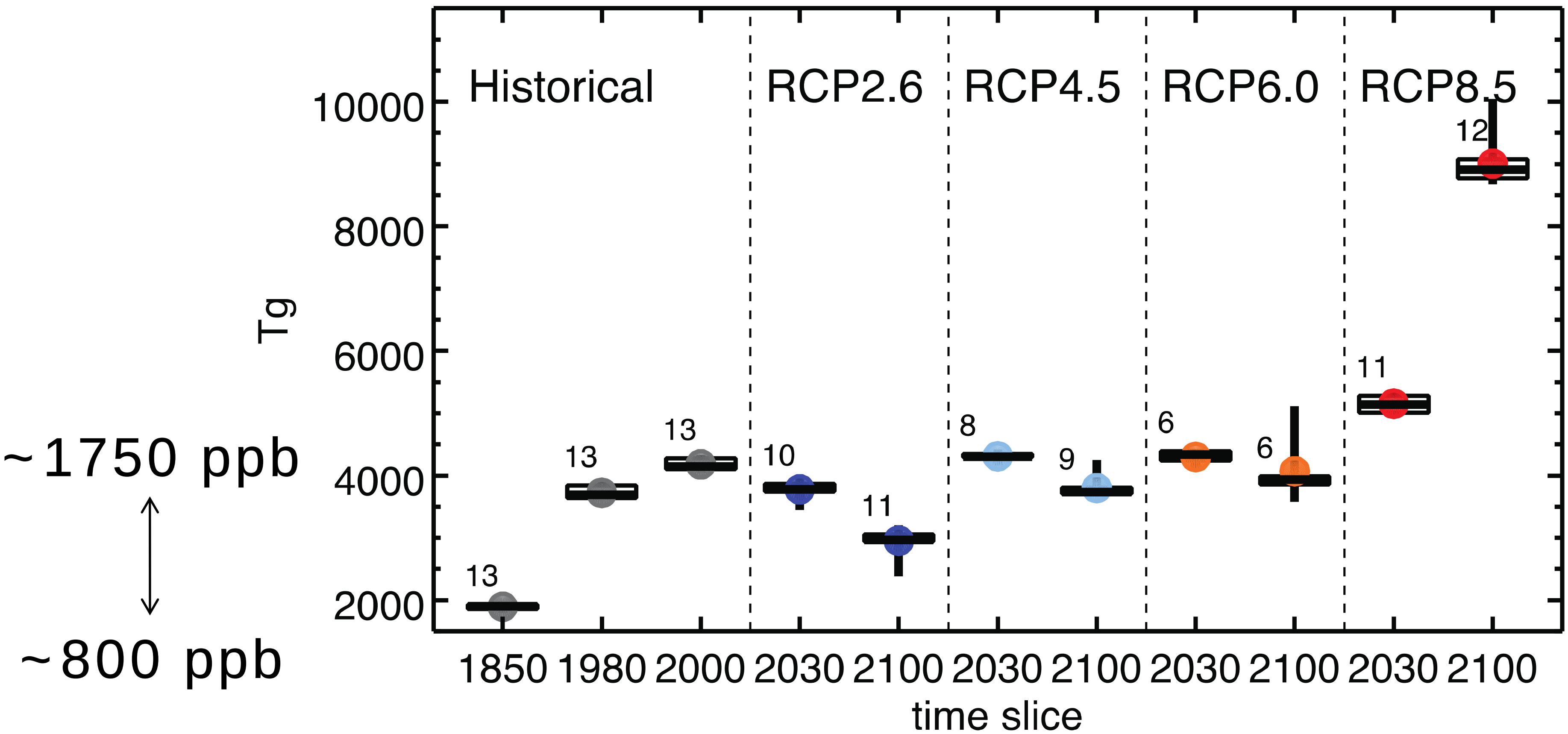
RCP Emissions trends



Lamarque et al., 2010
Moss et al., 2010

Modeled CH_4 concentration trends

Multi-model (ACCMIP) estimates of global CH_4 burden following historical and future RCPs (Young et al., 2013)



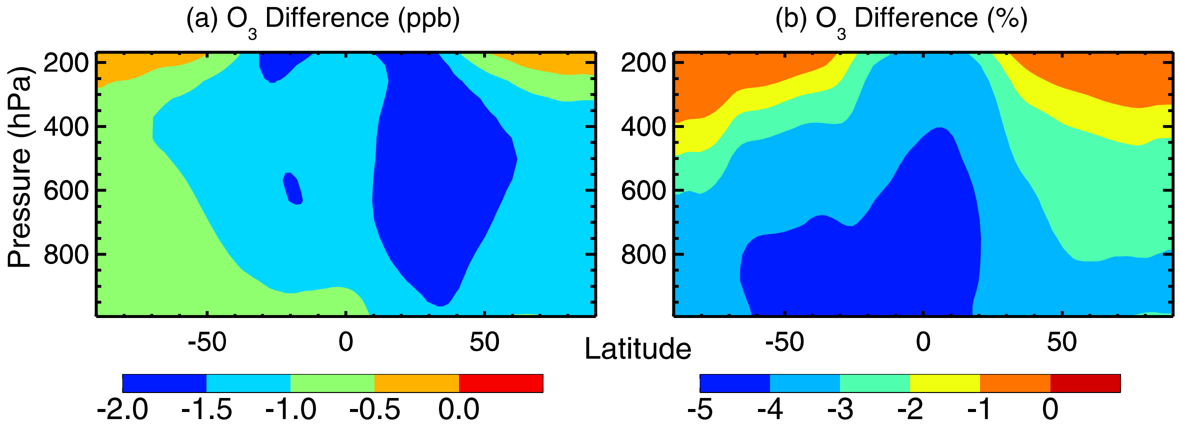
Impacts of changes in CH_4 concentrations

Climate (radiative forcings from Myhre et al., 2013)

- direct RF (0.48 ±0.05 W/m2)
- via CH_4 (0.14 W/m2)

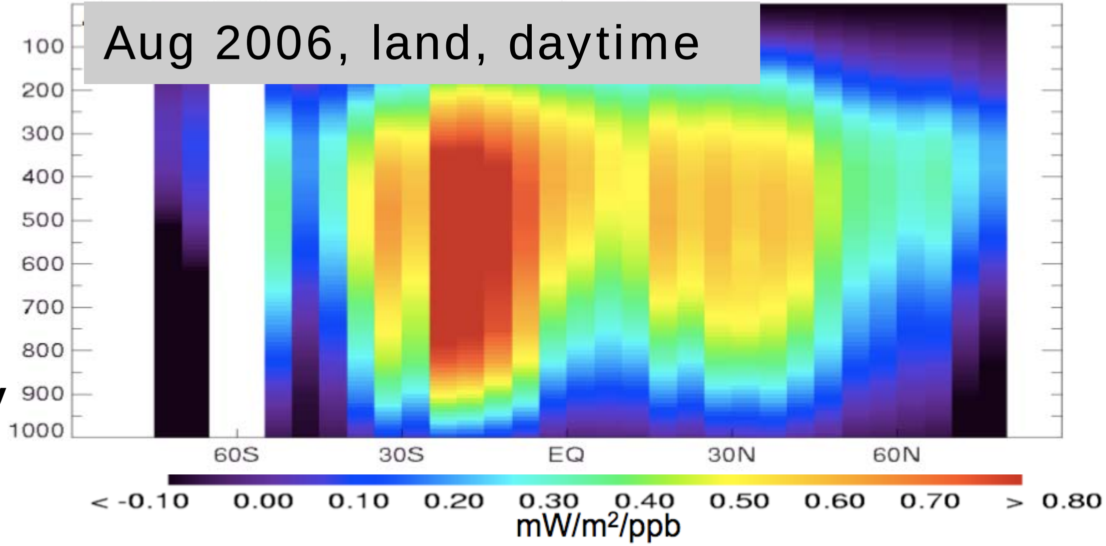
When and where does O_3 change owing to $\Delta[CH_4]$?

3D spatial distribution of O_3 response to $\Delta[CH_4]$ is not uniform (e.g., Fiore et al., 2008; Morgenstern et al., 2013; Fang et al., 2013)



O_3 response to uniform –20% $\Delta[CH_4]$ reduction (Fiore et al., 2008).

3D spatial distribution important because not all O_3 is radiatively equivalent



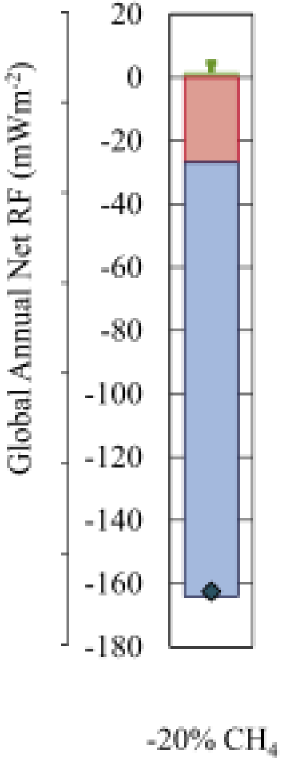
$$\frac{\partial OLR}{\partial O_3(z)}$$

Observed by TES (Worden et al., 2008; 2011)

CH_4 and long-term O_3 Radiative Forcing: response to CH_4 emissions

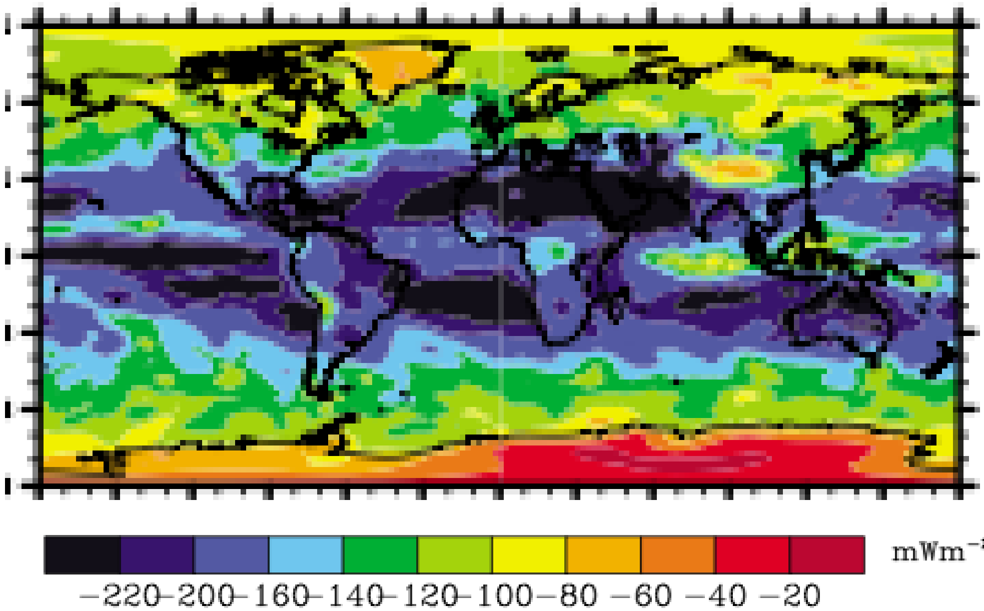
RF of -20% $\Delta[CH_4]$ from HTAP (Fry et al., 2012).

note: includes long-term impacts of CH_4 on O_3.



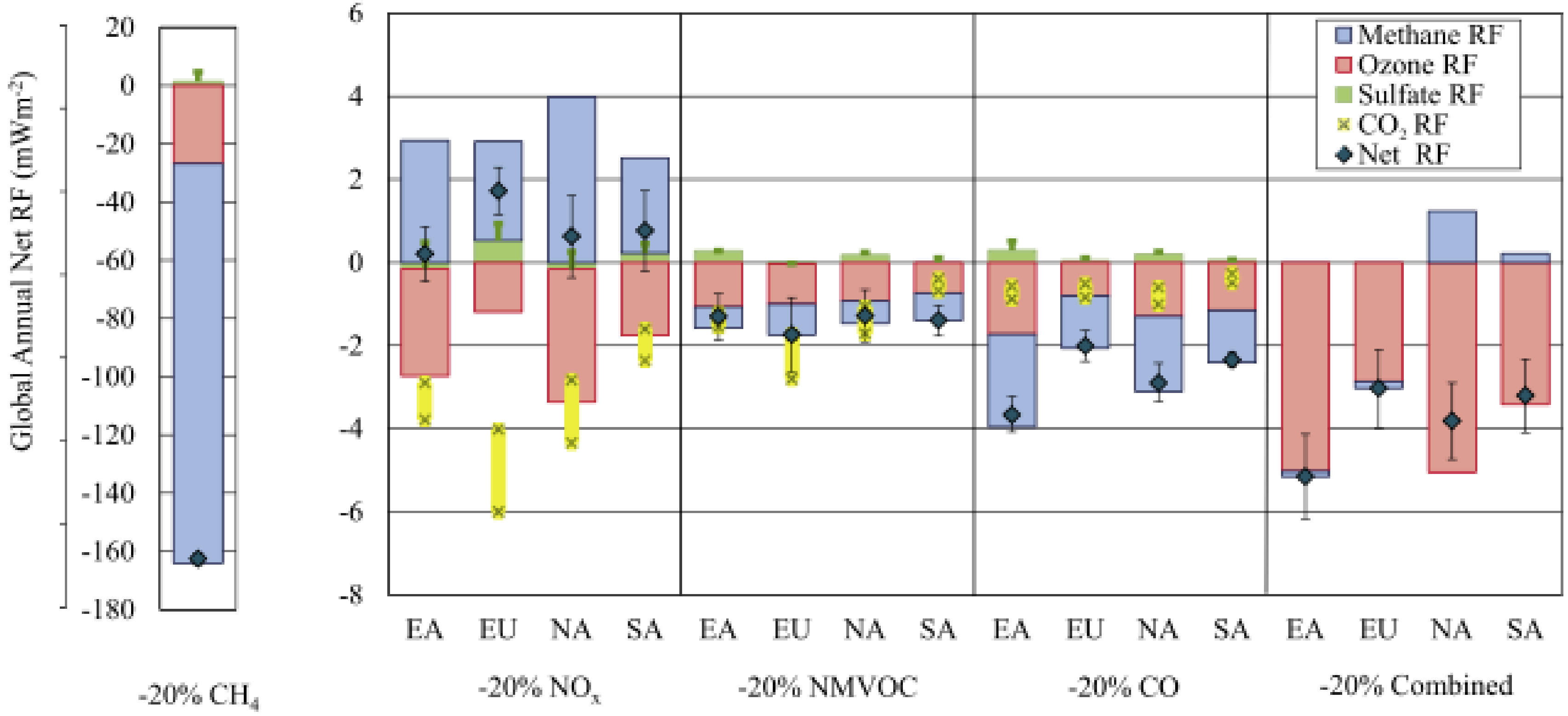
←O_3

←CH_4



CH_4 and long-term O_3 Radiative Forcing: response to CH_4 emissions

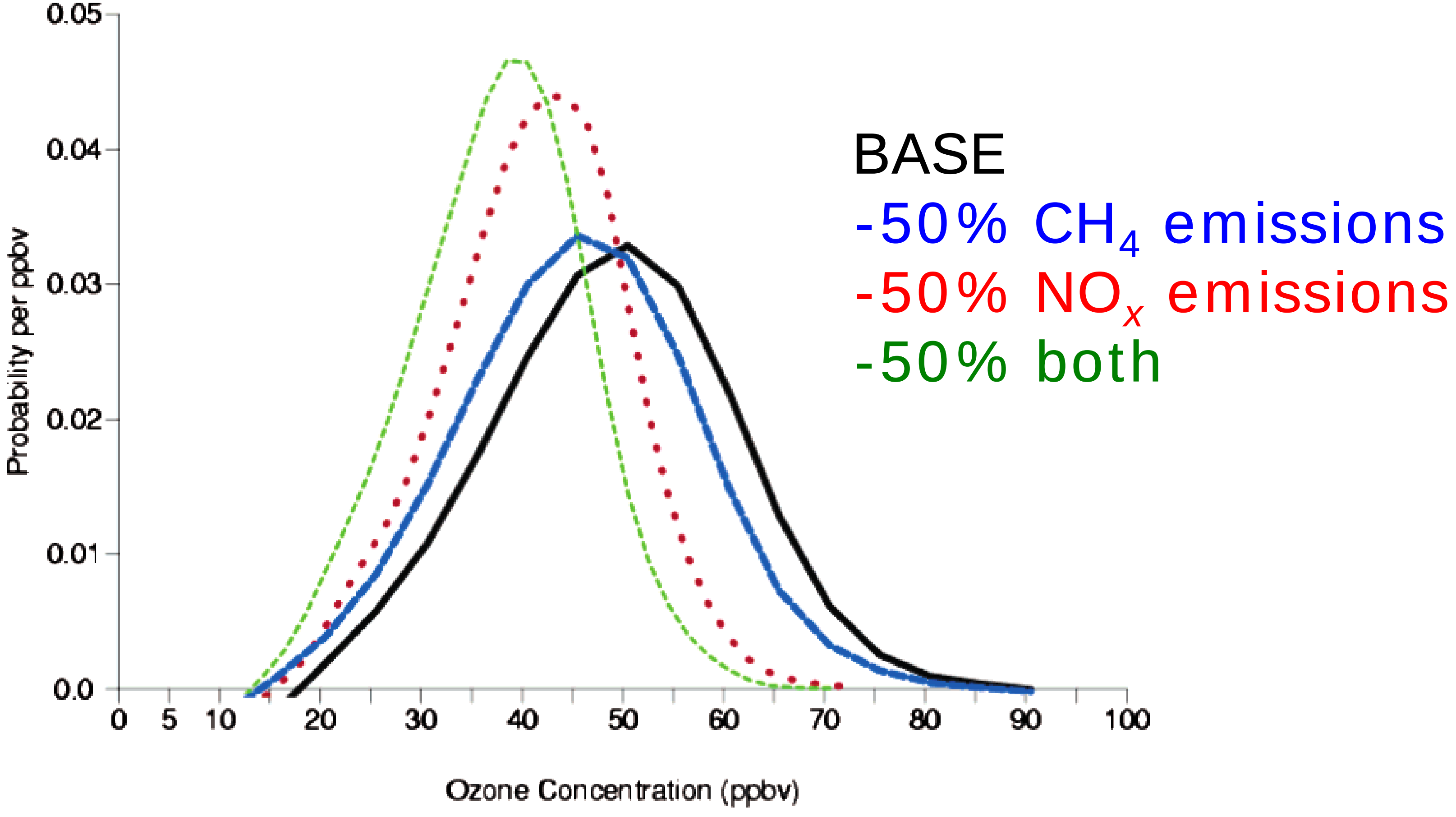
RF of -20% $\Delta[CH_4]$ from HTAP (Fry et al., 2012).
compare to -20 NOx, NMVOC or CO



Methane buffers the climate benefits of NO_x reductions and amplifies that of NMVOCs, CO.

When and where does O_3 change owing to $\Delta[CH_4]$?

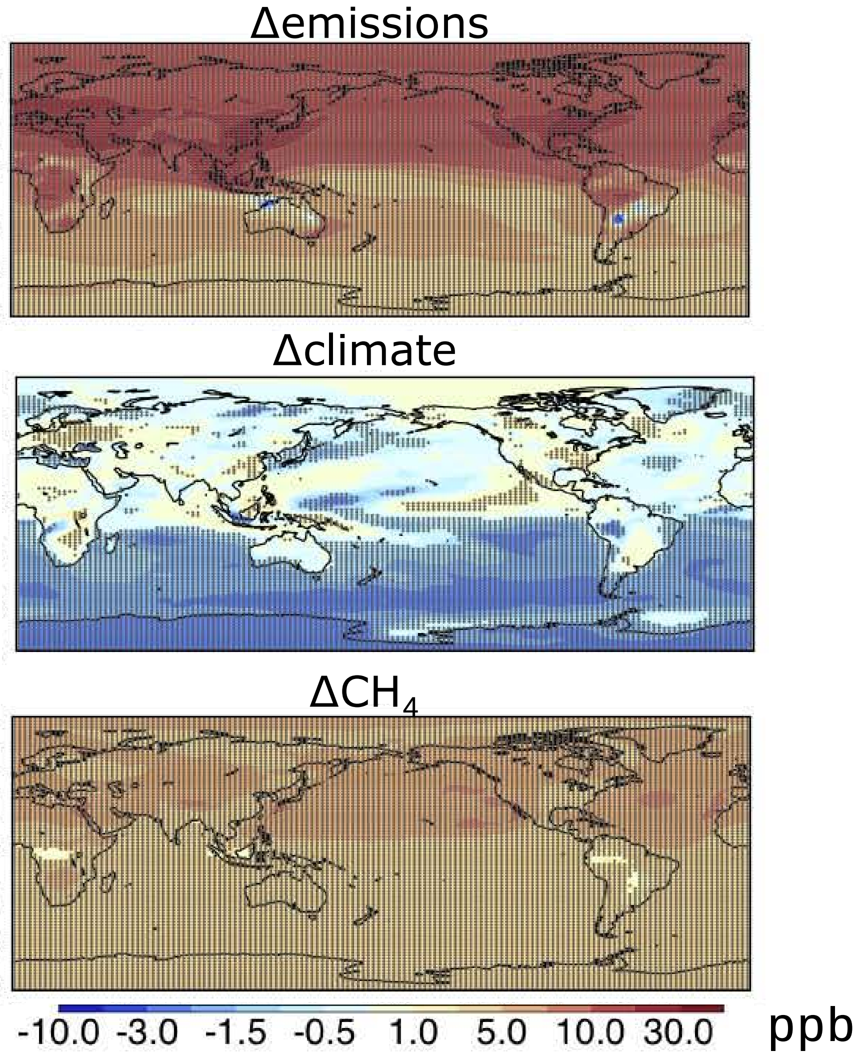
Response of North American daily mean afternoon (1300-1700 local time) summertime surface O_3 (Fiore et al., 2002)



West et al., 2005

When and where does O_3 change owing to $\Delta[CH_4]$?

Present – PreIndust surface O_3 (Fang et al., 2013)



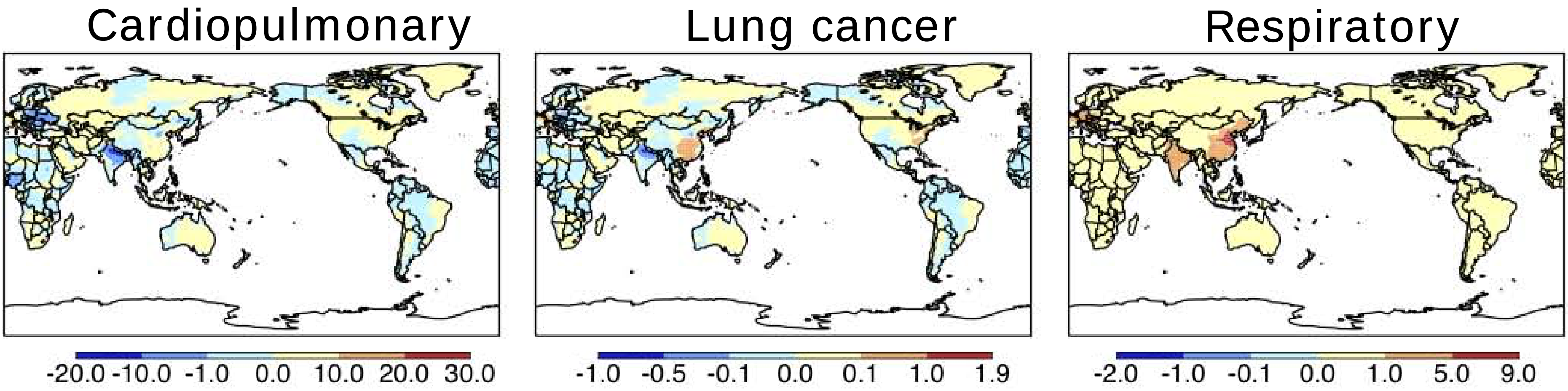
Present CH_4 accounts for ~5 ppbv of surface O_3 (5-10 in NH, 2-5 in SH)

Population-weighted changes:

- \+ 25 ppb (emissions)
- \+ 0.5 ppb (climate)
- \+ 4.3 ppb (CH_4 abundance)

Health impacts from preindustrial to present $\Delta[CH_4]$

Deaths / 1000 km^2 (Fang et al., 2013):



- About 50,000 increase in annual respiratory deaths.

- Combined impacts of Δclimate and $\Delta[CH_4]$ lead to 20% increase in respiratory mortality from O_3 in some regions (e.g., Australia)

Health impacts from preindustrial to present Δ[CH_4]

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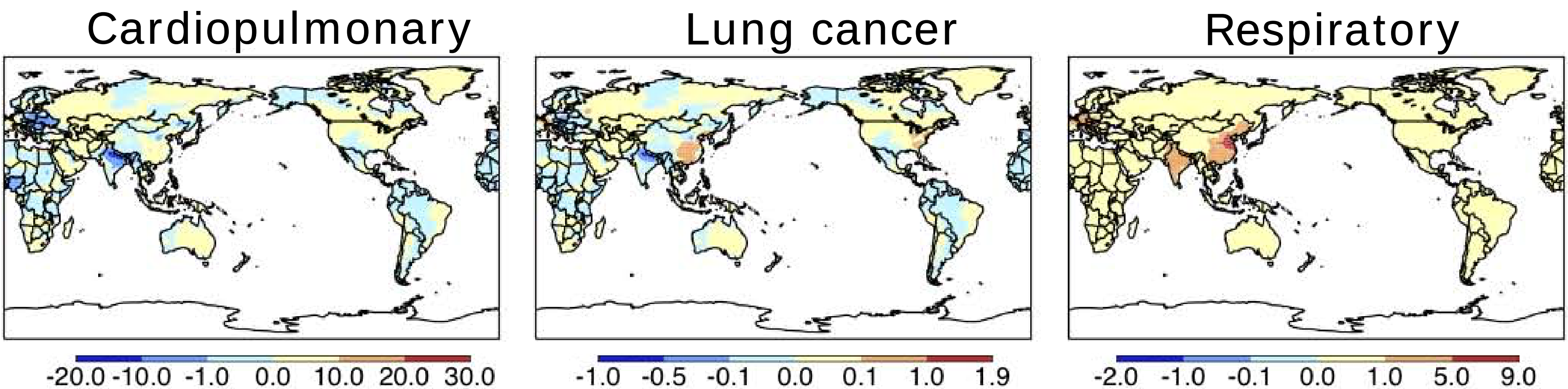

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- Regionally significant cardio health impacts of Δ[CH_4] via aerosols? Large compared to health impacts via respiratory, but small (<5%) of increase in cardiopulmonary deaths owing to Δemissions of aerosols and aerosol precursors

Air quality, health, and climate impacts of CH_4 emissions controls in the next several decades

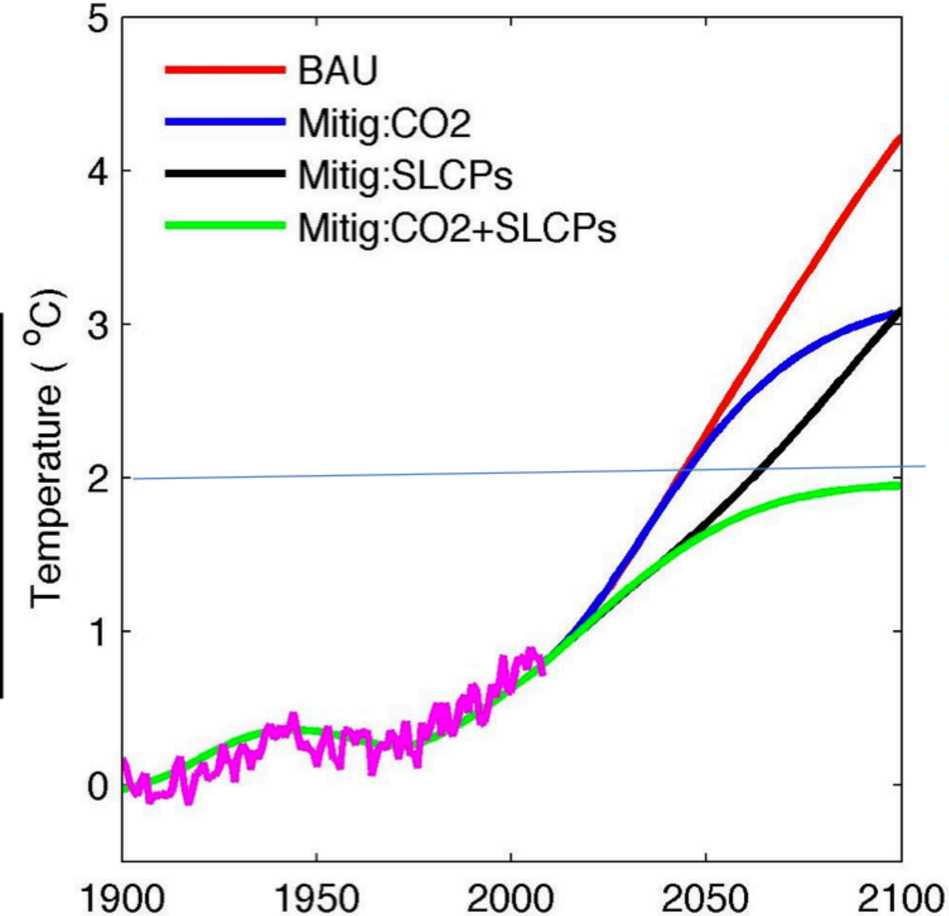
- 20% CH_4 reductions lead to 1 ppb reduction and reduce cardiopulmonary deaths by 17,000 (West et al., 2006; Anenberg et al., 2010).

- CH_4 mitigation measures could reduce surface O_3 by 3-4 ppb and respiratory deaths by 70,000 (Anenberg et al., 2012).

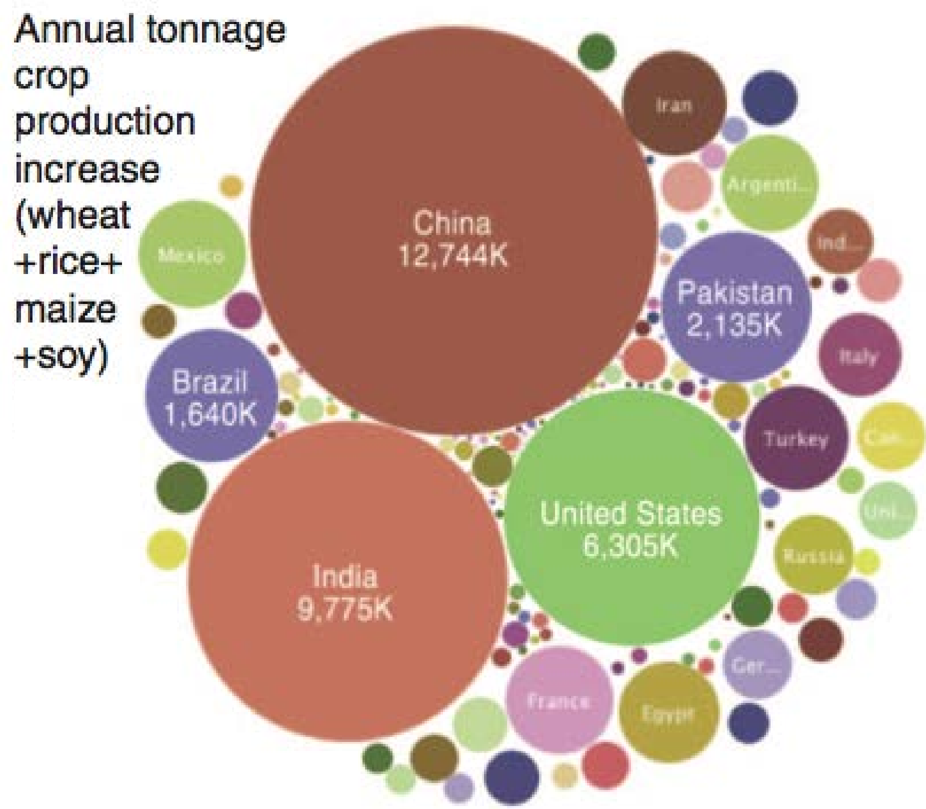
- Cost of CH_4 reduction measures are cost effective with air quality and climate benefits (e.g., West et al., 2012; UNEP 2011), although benefits of SLCP-only measures perhaps overestimated (e.g., Smith and Mizrahi, 2013).

Climate and health impacts of Short Lived Climate Pollutants (SLCPs)

SLCPs = $\mathbf{CH_4}$, BC, OC, CO, VOCs, NO_x, SO_2, NH_3, (HFCs)

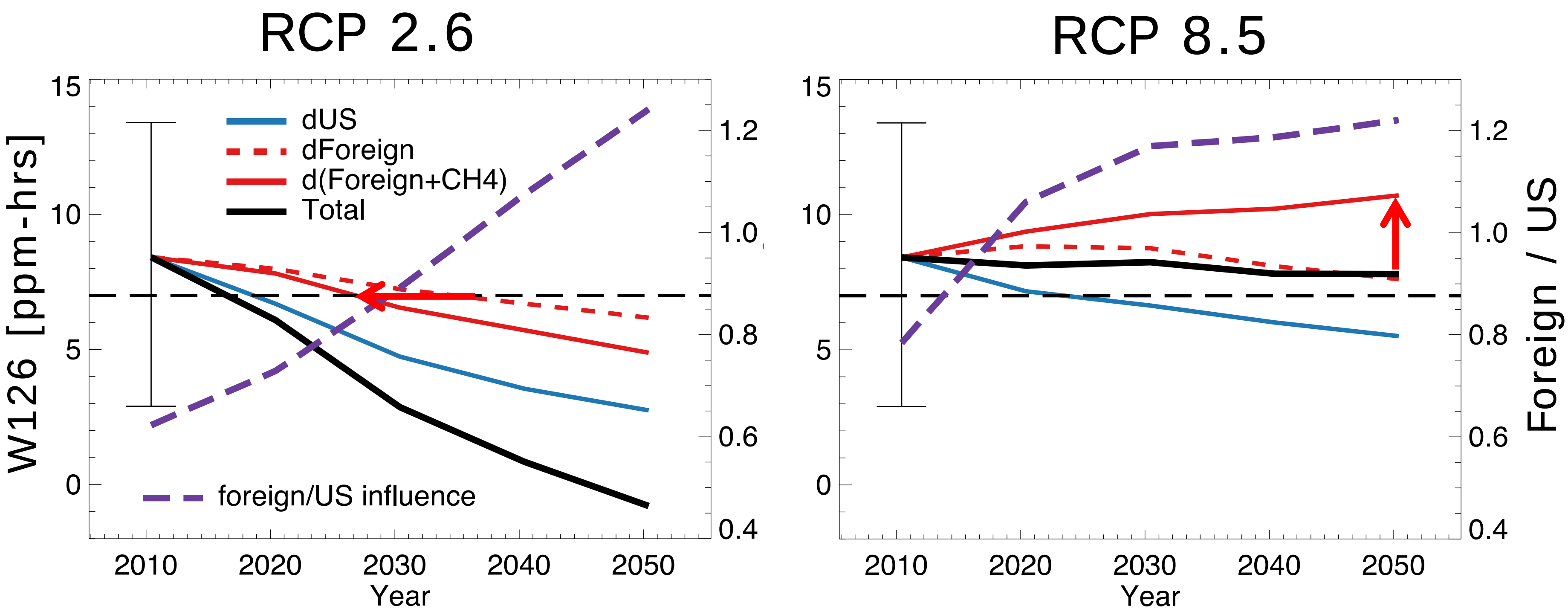


Ramanathan and Xu, PNAS, 2010;
Hu et al., Nature CC, 2013
Ramanathan and Carmichael, Nature Geo, 2008



UNEP 2011;
Shindell et al., Science, 2012
Also: Avery et al., 2013

Impacts of global CH_4 emissions on vegetative O_3 exposure in Western US following RCPs



RCP 2.6: Global CH_4 emissions reductions shifts attainment forward by a decade.

RCP 8.5: Global CH_4 emissions increases more than counteract domestic efforts.

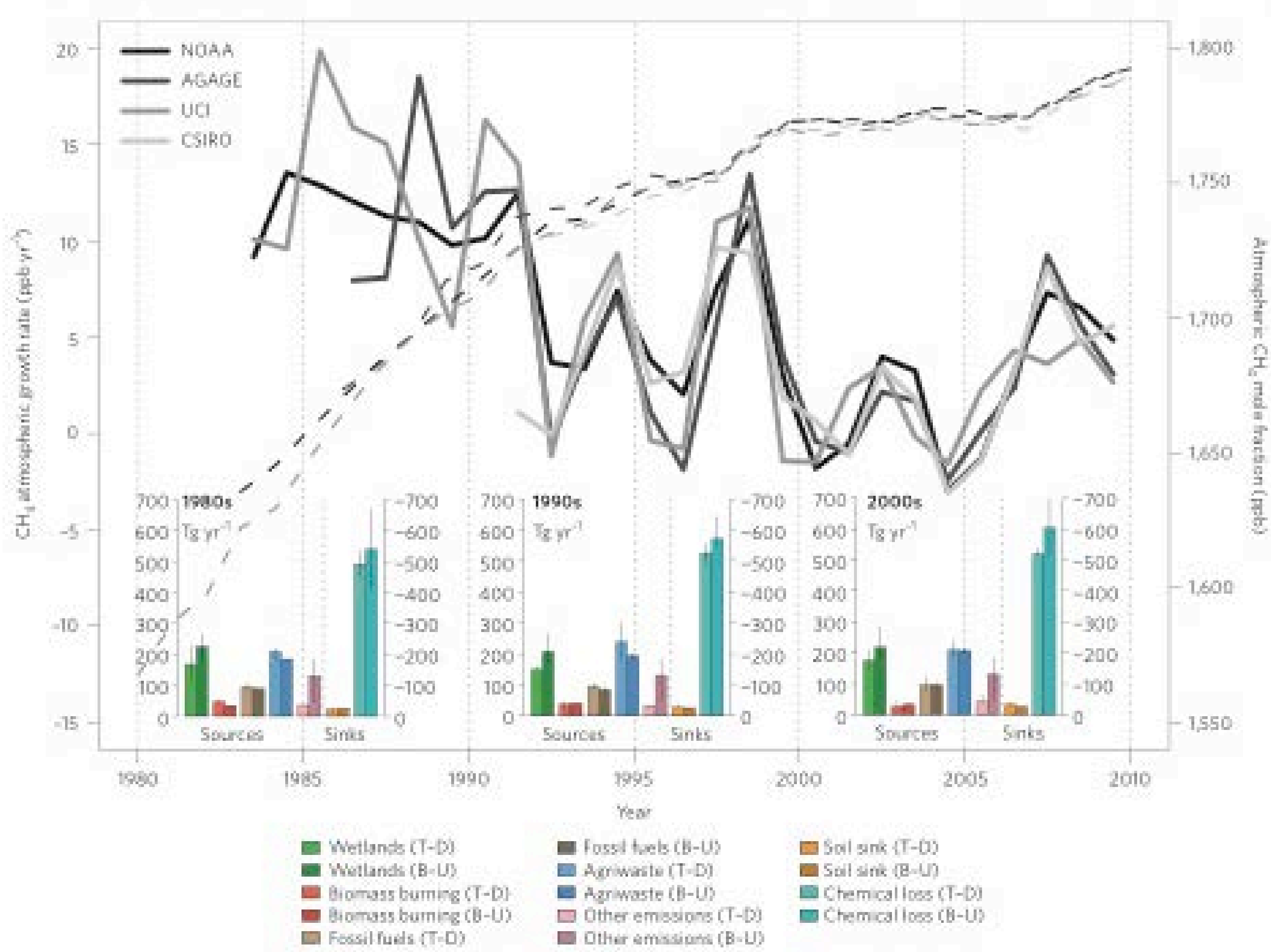
Lapina et al., in revision for GRL

Considerations for CH_4 abatement strategies (adapted / updated from West et al., 2012)

	NOx and NMVOCs	CH_4
Abatement cost?	high (least cost options exhausted)	low
O_3 reductions?	large	several ppb
Time scale?	hours / weeks	decade
Spatial scale?	local/regional	global (more in NOx saturated regions)
Impact on peak O_3?	strong	not preferentially
Climate impacts?	Small (from NOx)	large (w/O_3)
Health impacts of 10% reduction?	22,000 (via $PM_{2.5}$) + similar amount via O_3	17,000 deaths per year from O_3
Co-benefits?	reduce $PM_{2.5}$, reactive nitrogen deposition, toxics	energy security, NMVOC reductions, crop and vegetation

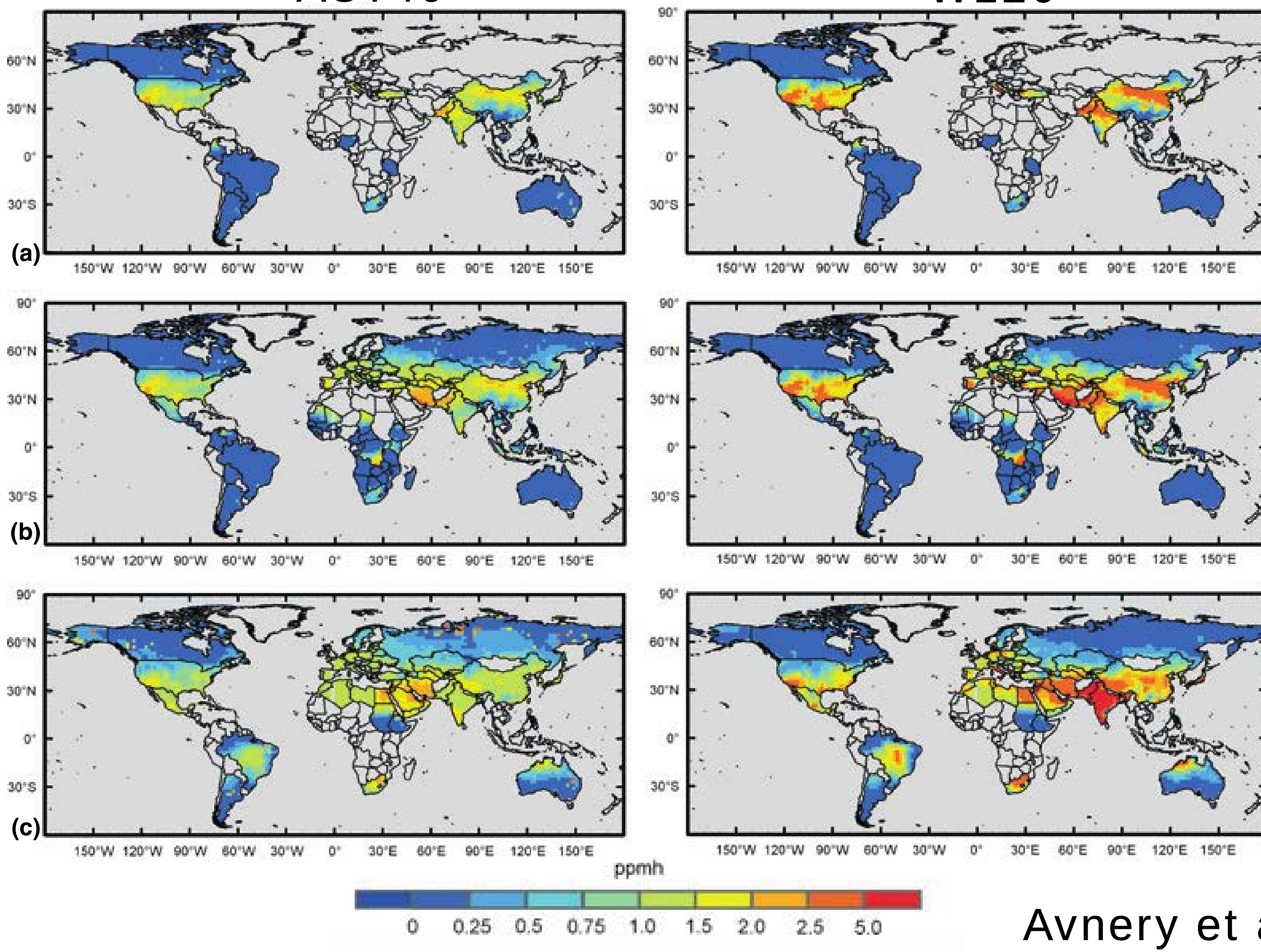
Questions?

Methane (CH_4) sources



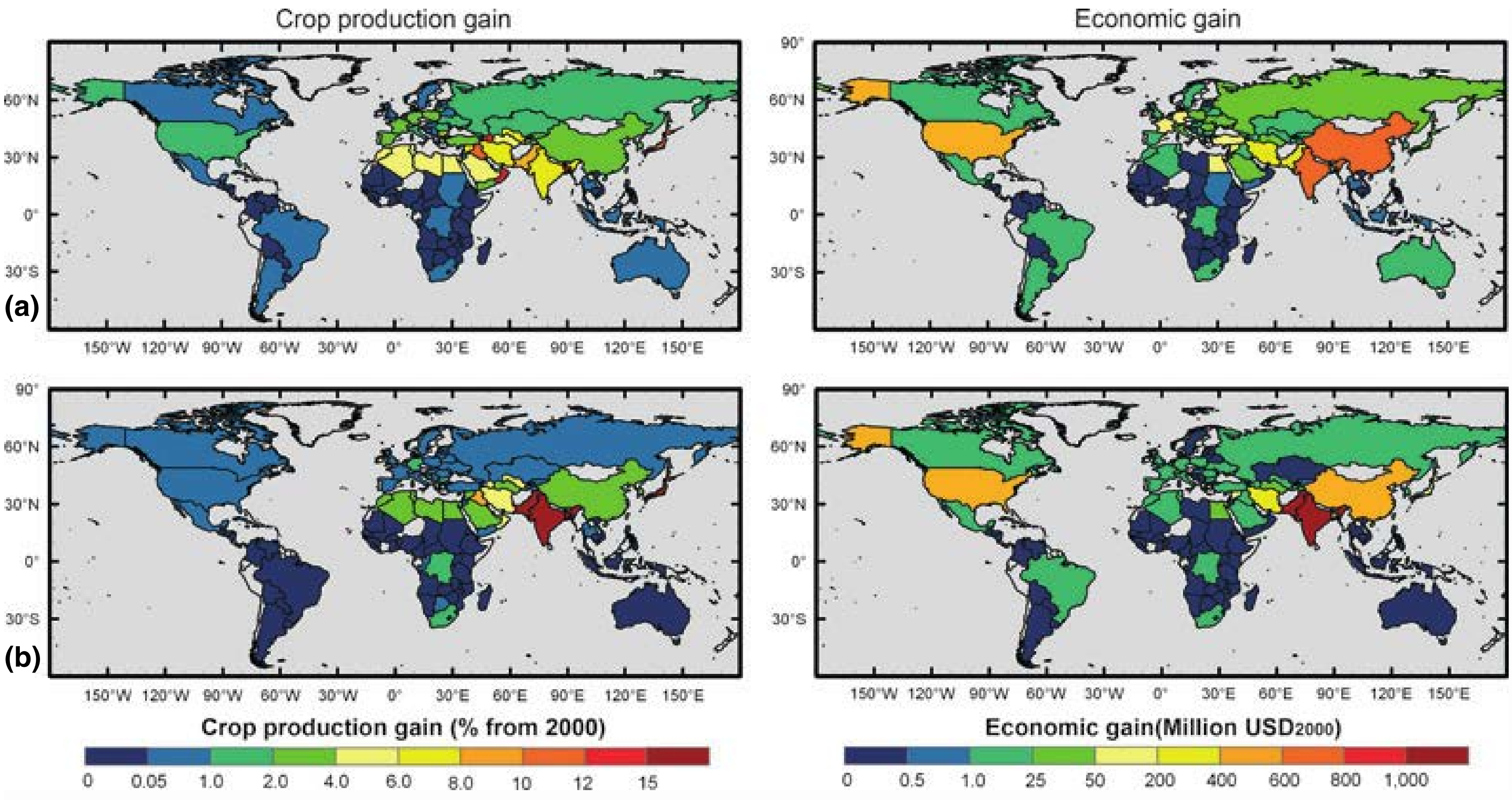
Impacts of global CH_4 reductions on vegetative O_3 exposure metrics

AOT40 W126



Avnery et al., 2013

Impacts of global CH_4 reductions on crops

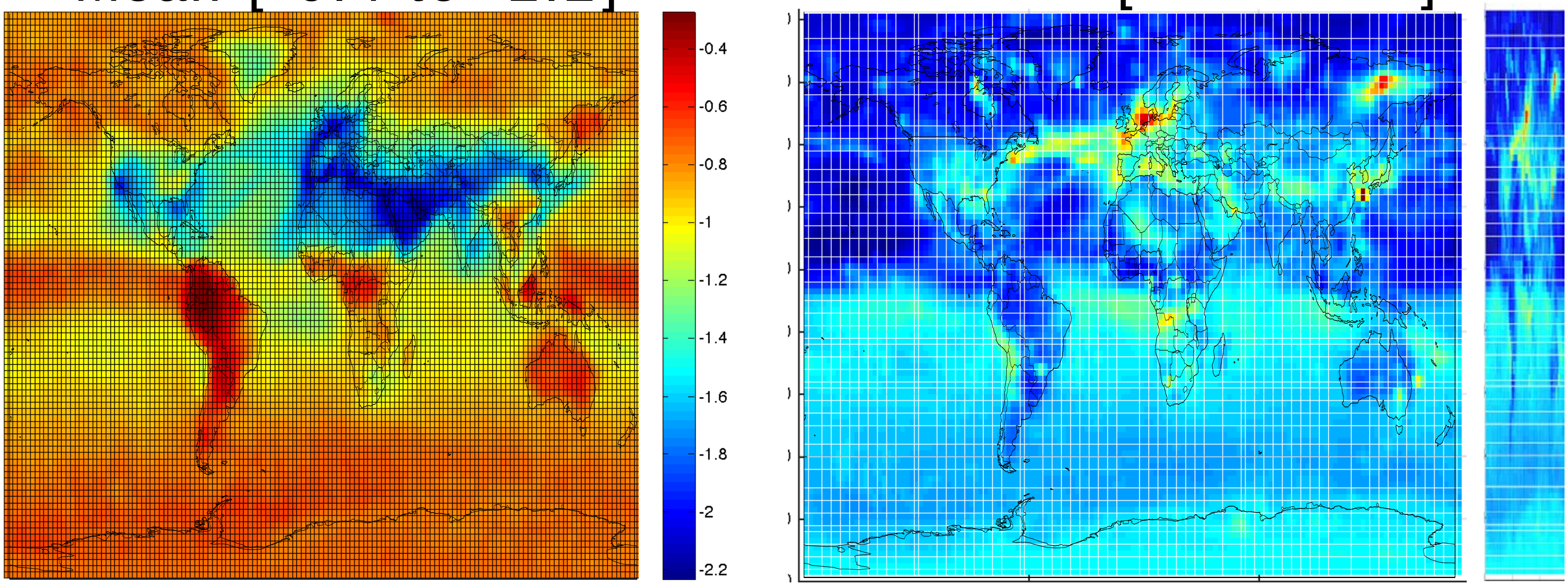


Avnery et al., 2013

When and where does O_3 change owing to $\Delta[CH_4]$?

HTAP multi-model mean change from $\Delta[CH_4]$ of -20%

Mean [-0.4 to -2.2] std dev [0.1 to 0.8]



Change in surface-level daytime O_3 (M12) in June [ppb]

Kees Cuvelier, Michael Seltzer