Shifting seasonal cycles of surface ozone: the role of regional vs. global emission changes in Northeast & Mountainous West U.S.

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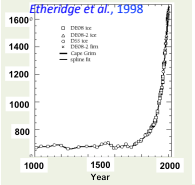
Motivation

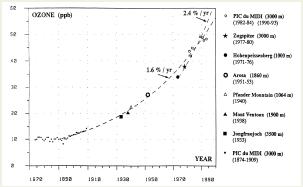
Historical increases in atmospheric methane and ozone (#2 and #3 greenhouse gases after carbon dioxide [Forster et al., 2007])

Methane Abundance (ppb) past 1000 years



Ozone at European mountain sites 1870-1990

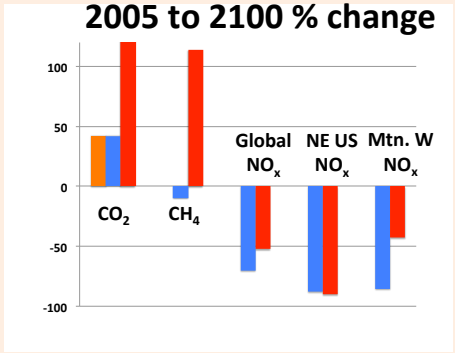
Marenco et al., 1994



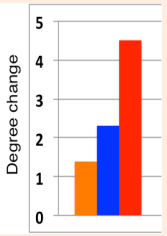
Methane raises tropospheric ozone abundances, including in surface air, thereby influencing background levels of air pollution (Fiore et al., 2002; Fiore et al., 2008]

21st Century Scenarios

Emissions Projections 2005 to 2100 % change

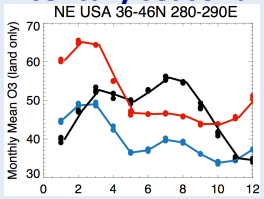


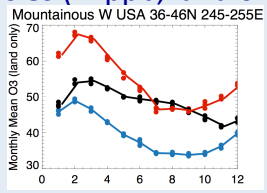
Global Mean Temperature (>500 hPa)



RCP8.5 extreme
RCP4.5 moderate
RCP4.5_WMGG

21st century seasonal cycles (in ppb; land only)





2006-2015 BASE
2091-2100 RCP8.5
2091-2100 RCP4.5

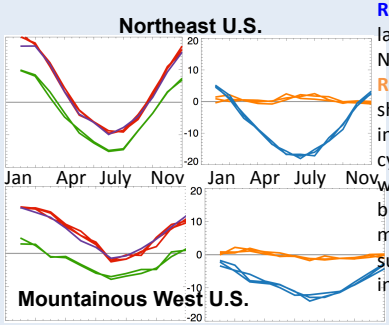
Each simulation has three ensemble members

- Higher O_3 in RCP8.5 in cooler months despite NO_x emissions controls
- NO_x reductions decrease O_3 in most months under RCP4.5

Change in monthly mean surface O_3 from 2006-2015 to 2091-2100 (in ppb; land only)

Doubling CH_4 by end of 21st century (RCP8.5 & RCP8.5_2005CH4_rad)

- contributes to higher increases in O_3 in winter & early spring
- offsets decreasing effect of NO_x controls on summer O_3 (as determined by comparing with a simulation with CH_4 set at 2005 levels for chemistry)



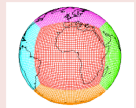
RCP4.5 shows a large impact from NO_x controls

RCP4.5_WMGG shows little change in the seasonal cycle due to a warming climate but all 3 ensemble members show summer O3 increases in NE US

GFDL CM3 Model and Evaluation

atmosphere cubed sphere grid (c48) ~2°x2°; 48 levels (to 86km)

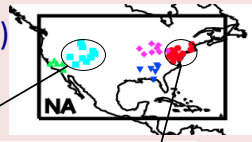
Donner et al., 2011; Golaz et al., 2011; Levy et al., 2013; Naik et al., 2013.

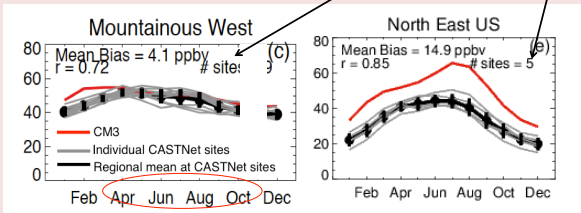


Monthly mean surface O_3 (ppb)

Observed vs. CM3 model

1988-2009 mean 1990-2005 mean





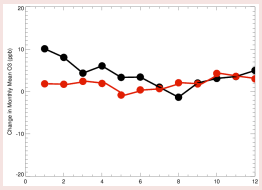
Change in monthly mean surface O_3 (ppb)

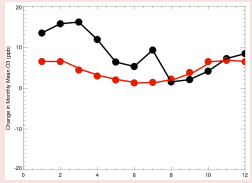
Observed vs. CM3 model

Reported in Parrish et al., 2013

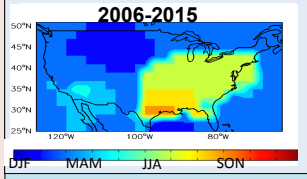
3 ensemble mean

Zugspitze (47º25'N/10º59'E, 3.0km) (2005-2009) – (1983-1987)	Hohenpeissenberg (47º48'N/9º30'W, 1.0km) (2005-2010) – (1971-1975)



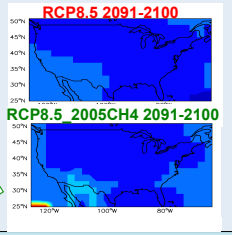


Regional NO_x decreases control timing of peak in decadal average O_3 seasonal cycle



Large NO_x decreases but CH_4 emissions double

Large NO_x decreases and CH_4 emissions stay at 2005 levels



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