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Surface ozone trends and radiative forcing implications

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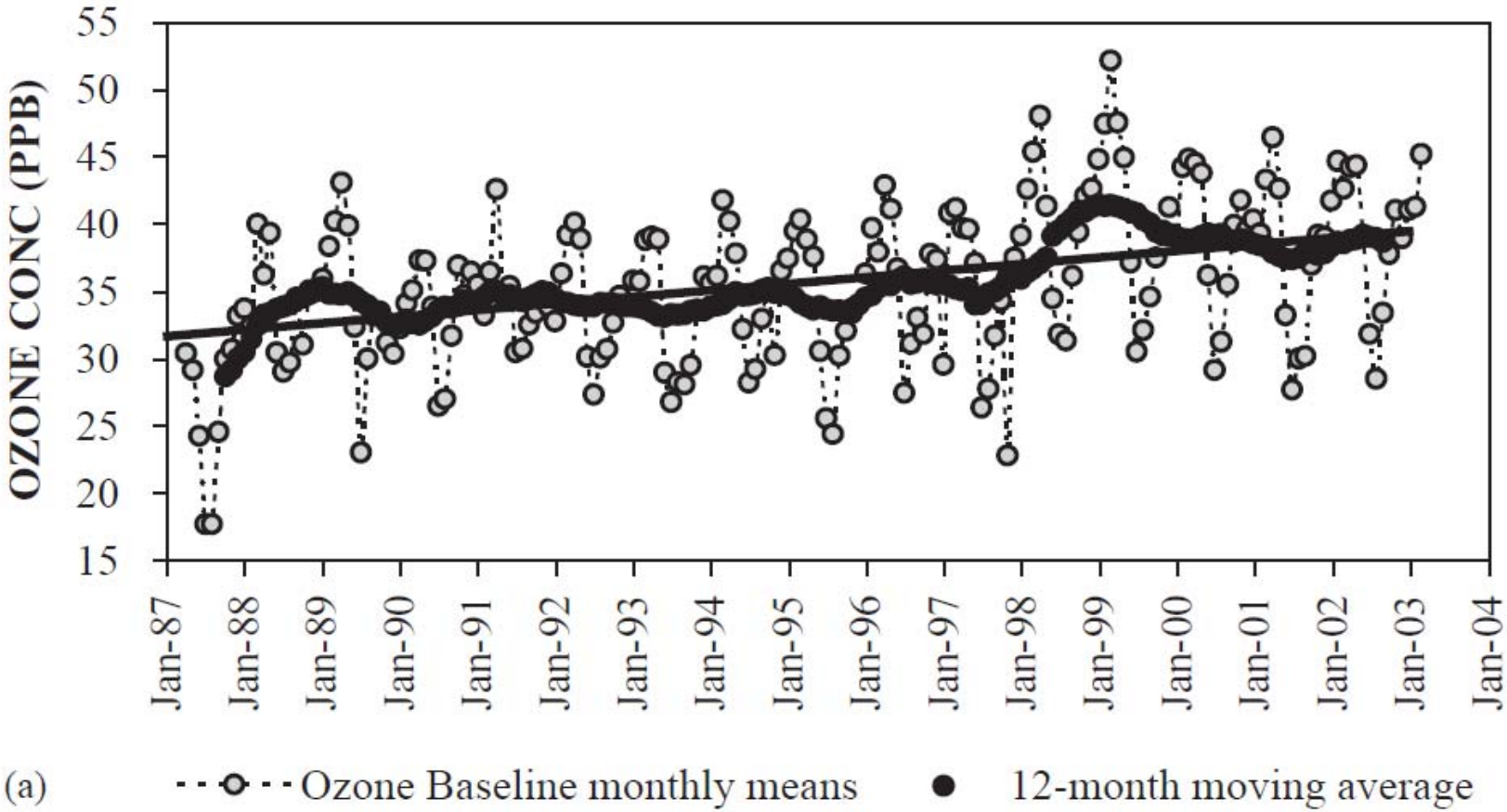
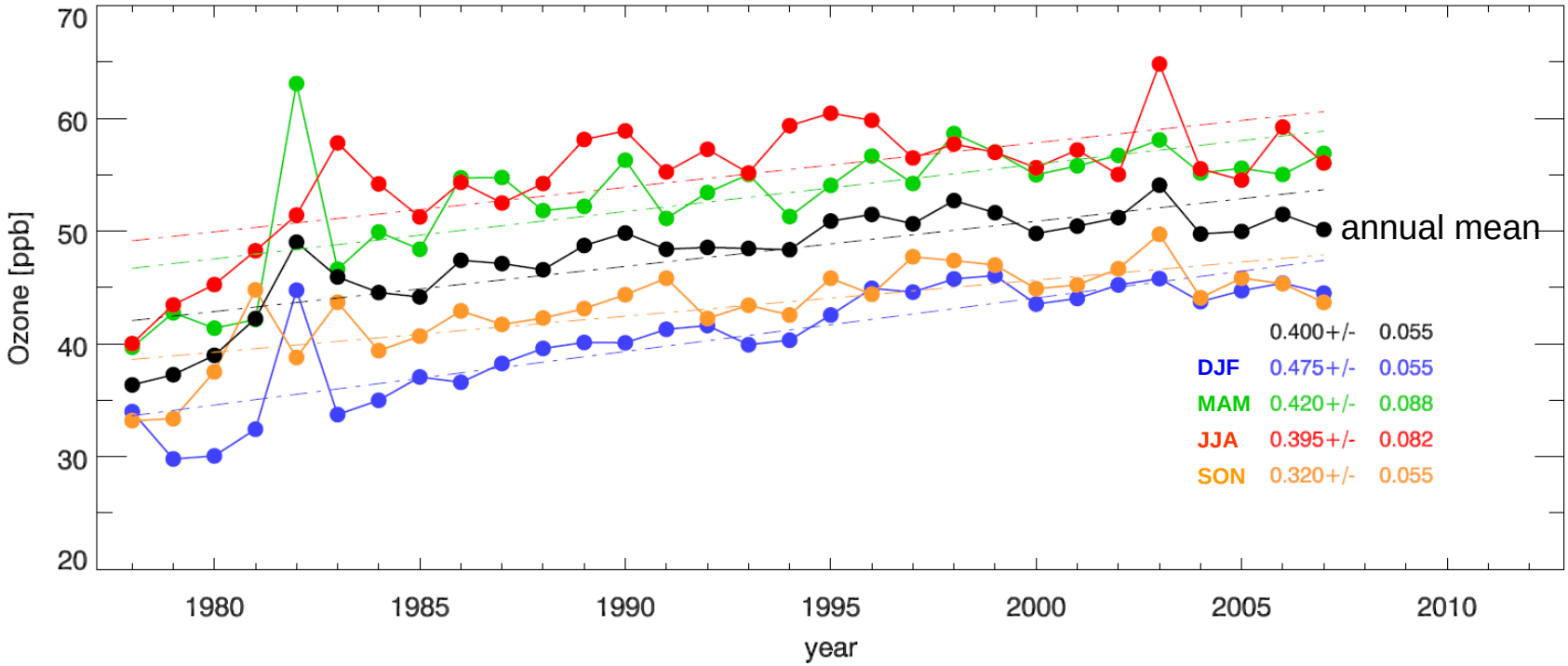
Surface ozone trend at Mace Head, Ireland



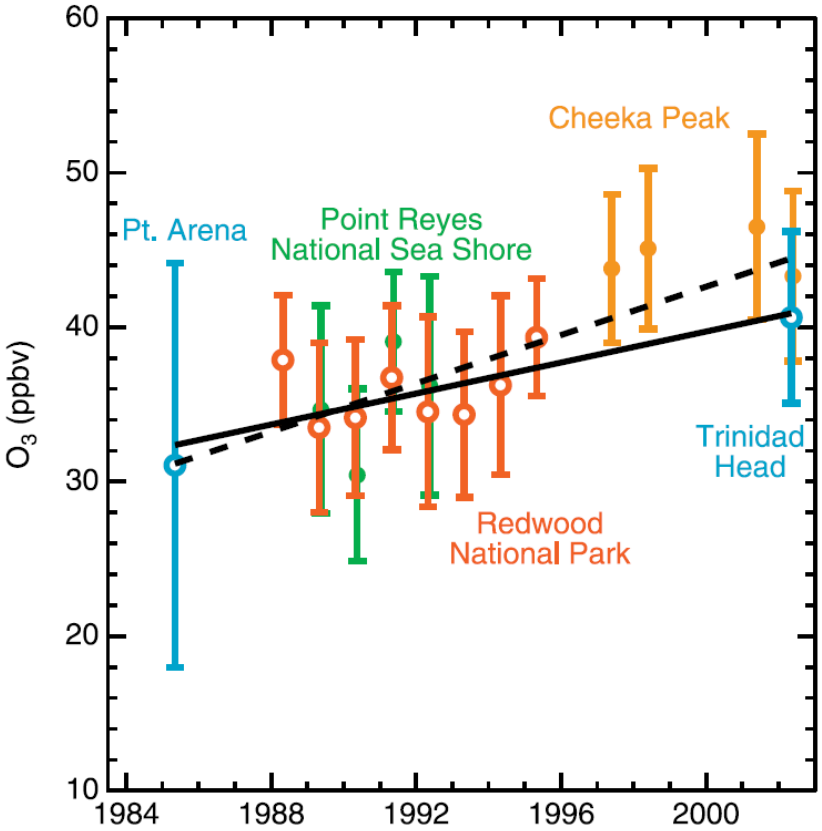
Simmonds et al., 2004

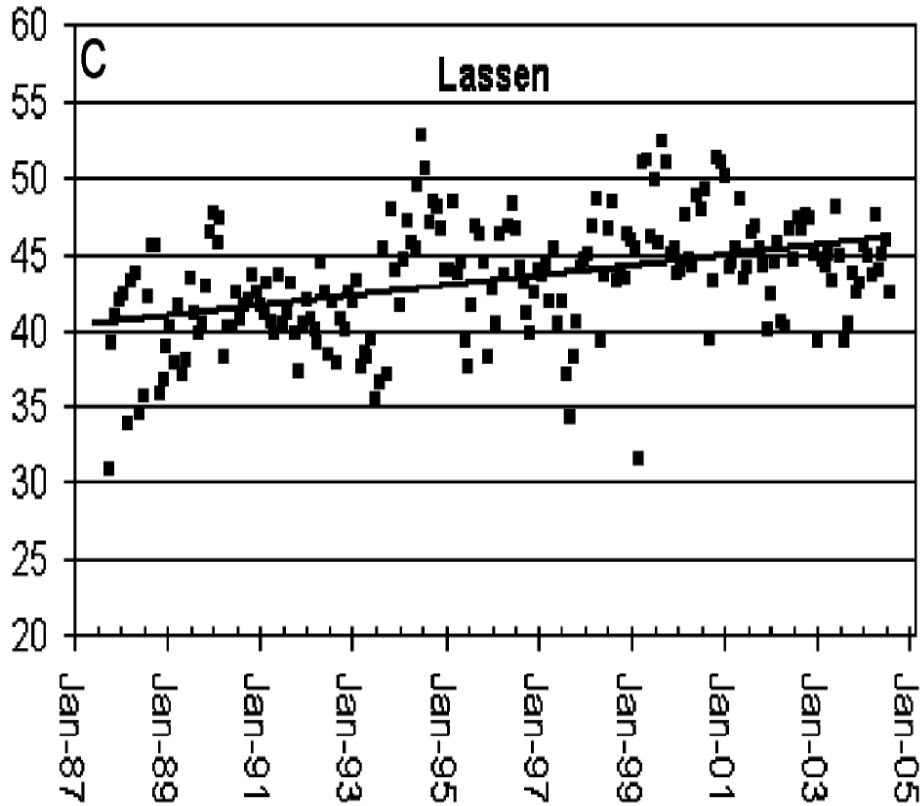
Ozone trend at Zugspitze, Germany



Data courtesy of H.E. Scheel

Ozone trends US West coast





Jaffe et al., 2004; 2007

Conclusions:

Mixed signals (time series often too short)

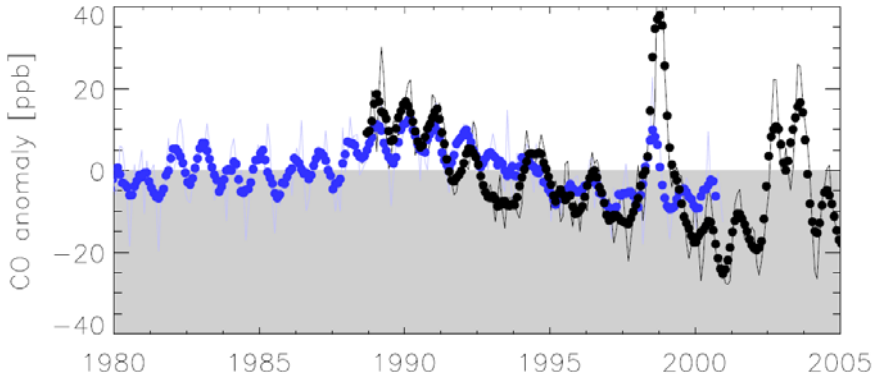
IT DOESN‘T GO DOWN!

Strongest increase usually in winter

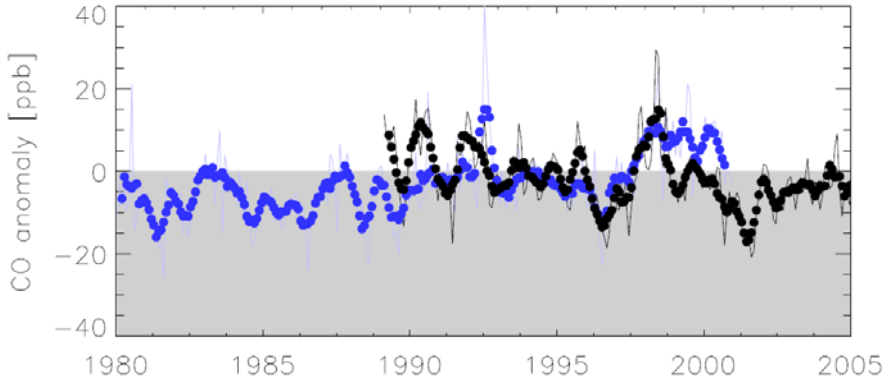
So, what do the models say ? …

Surface CO anomalies

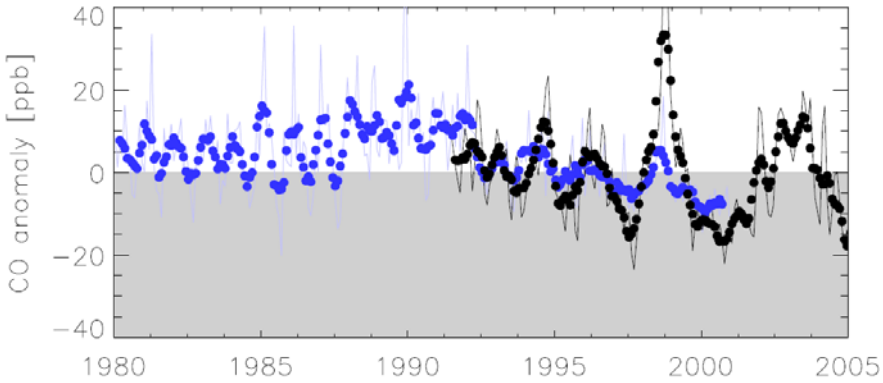
Barrow (71°N)



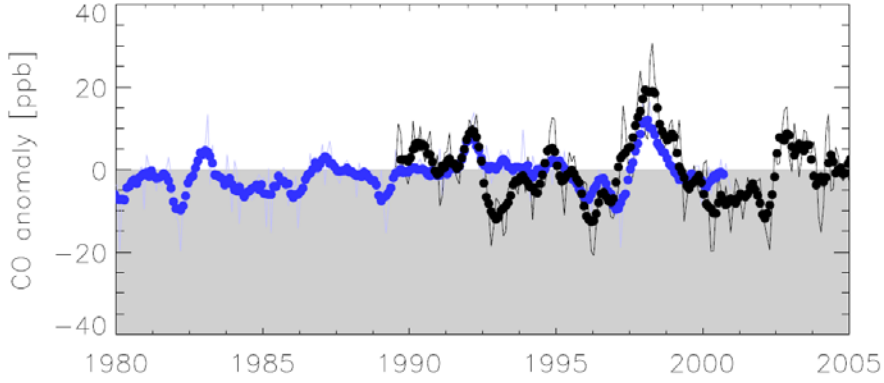
Ascension (27°N)



Mace Head (53°N)



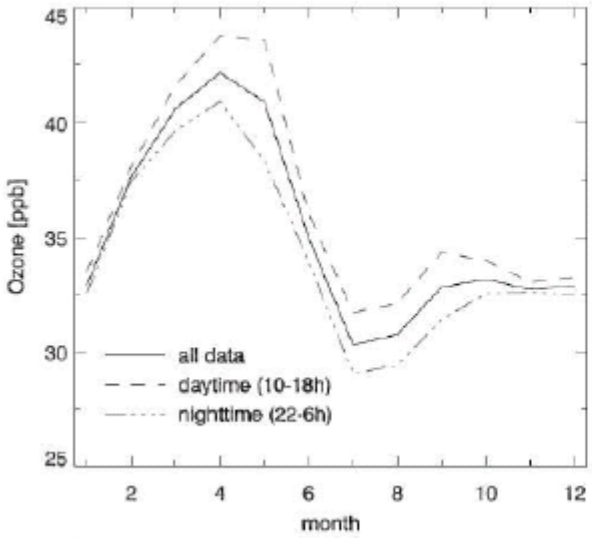
Mauna Loa (19°N)

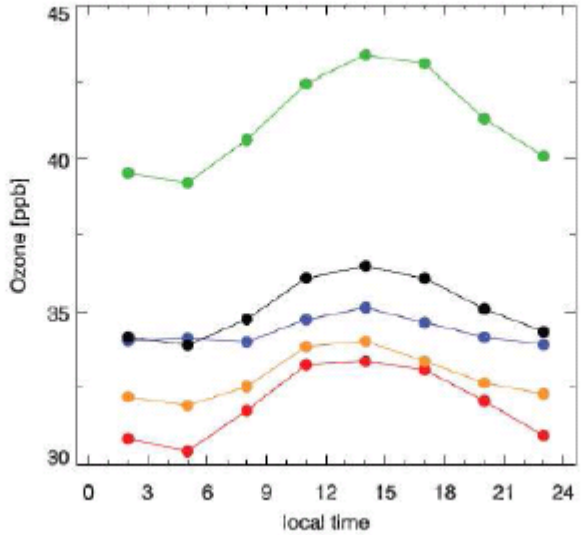


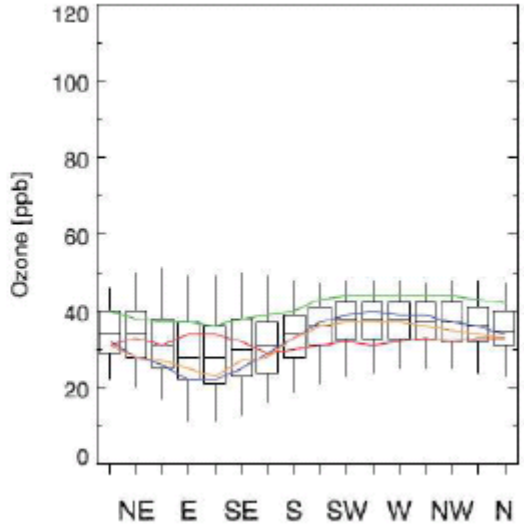
ECHAM5-MOZ (Rast et al., submitted)

Model evaluation: Mace Head surface ozone

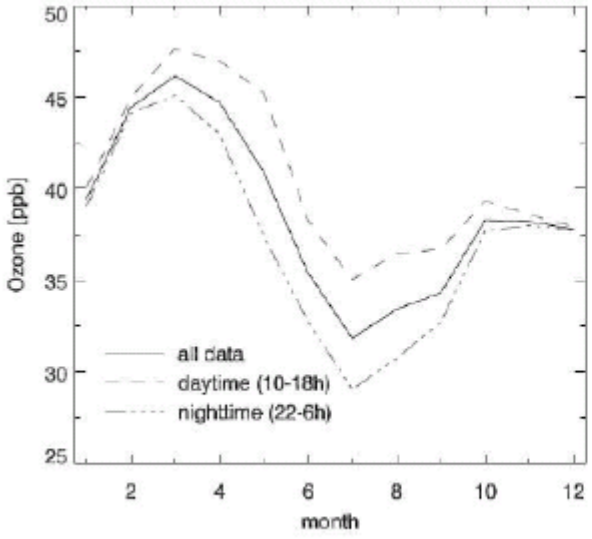
obs

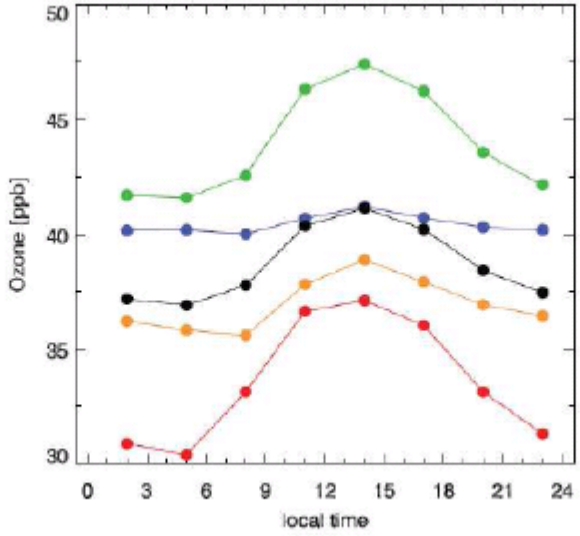


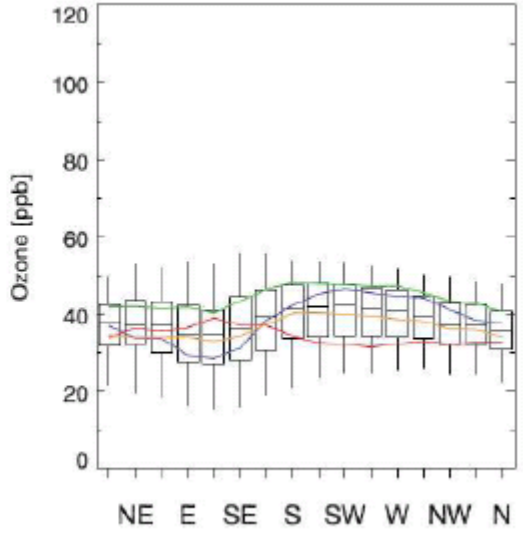




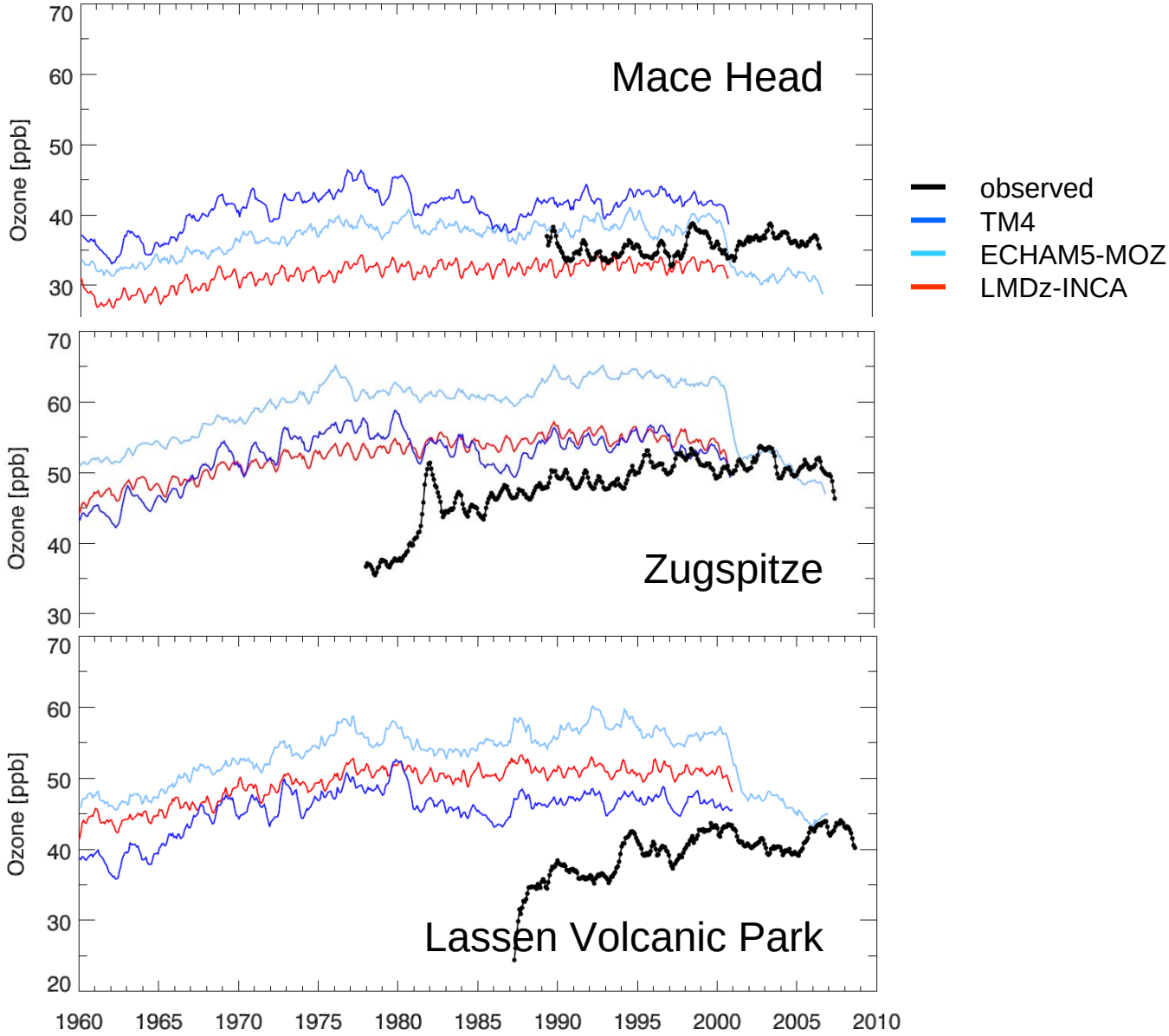
model





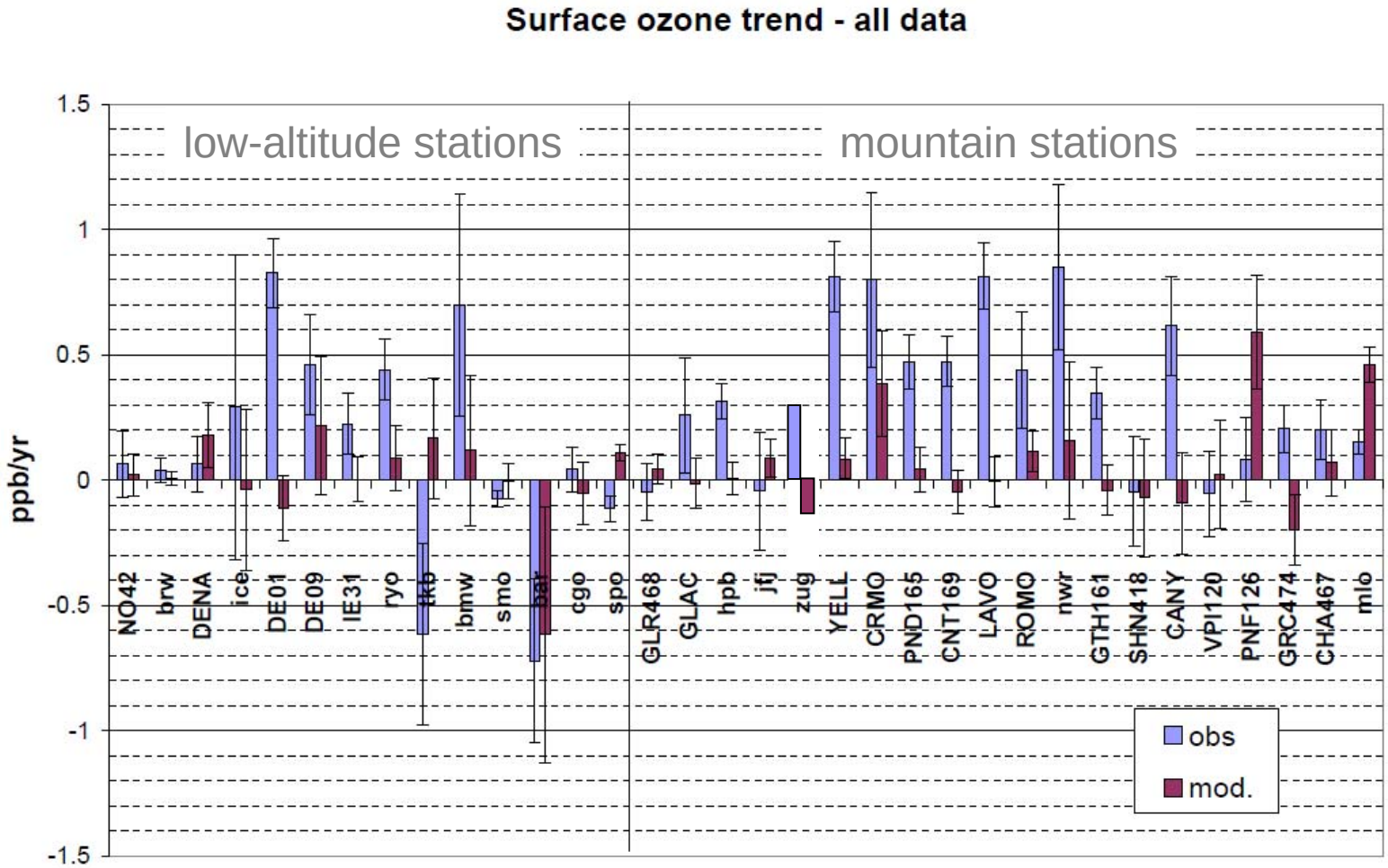


Simulated ozone trends (RETRO)



12-month running means

Observed and simulated ozone trends



Conclusions:

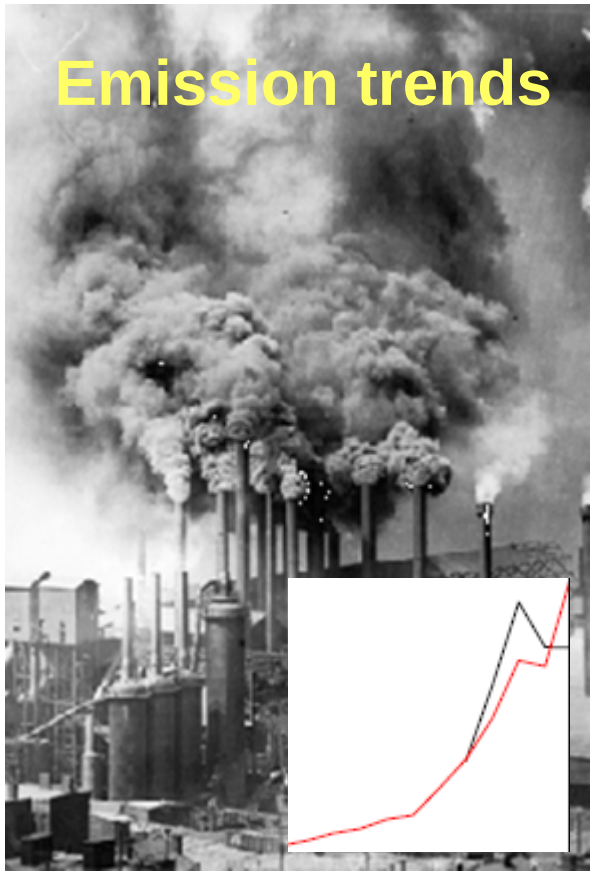
Simulated ozone increases only until ~1980

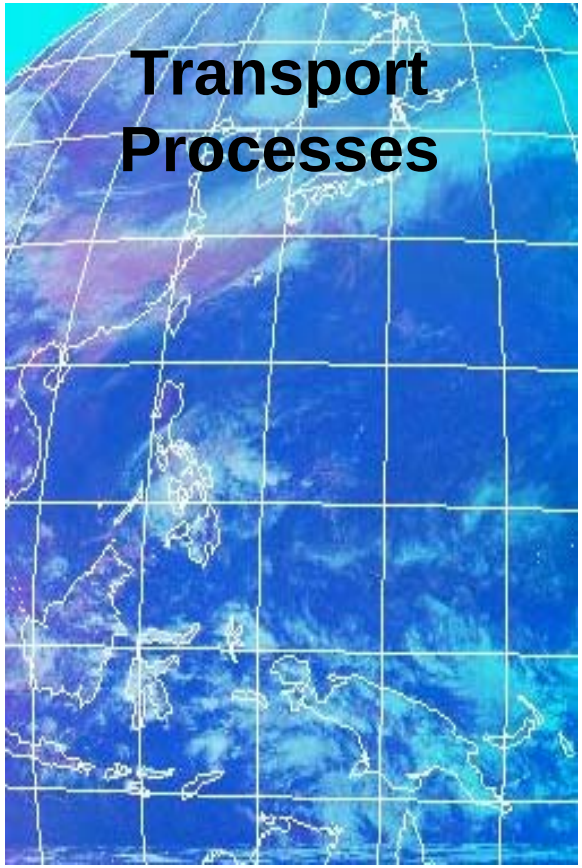
IT TENDS TO GO DOWN DURING 1990s

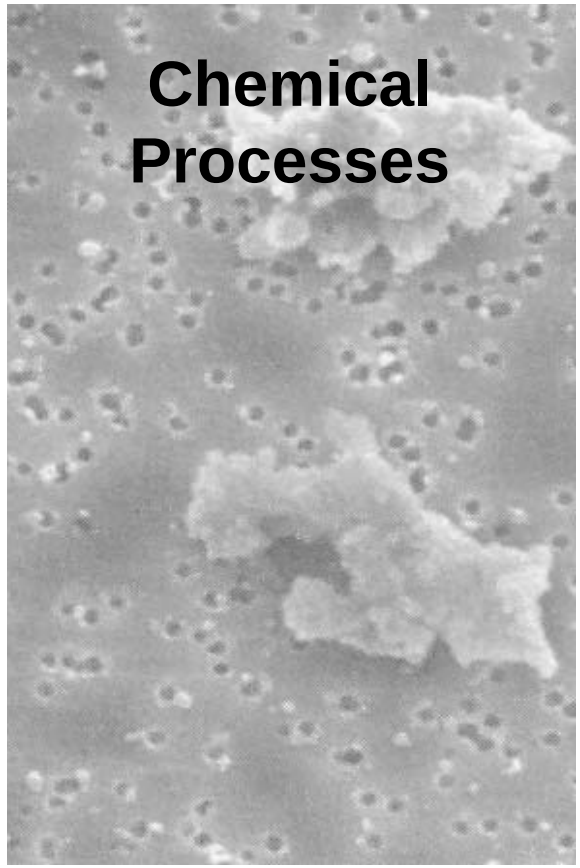
Observed increase and IAV not well captured
(see also Koumoutsaris et al., 2008)

What‘s wrong with the models ? …

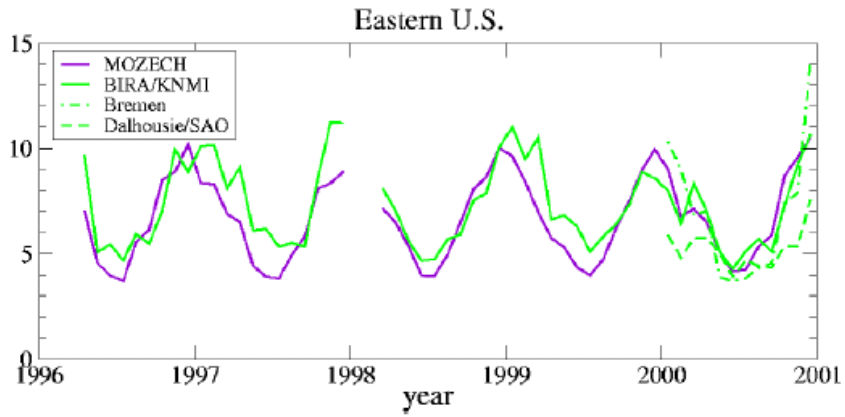
Possible reasons for model failure to capture ground-level ozone trends

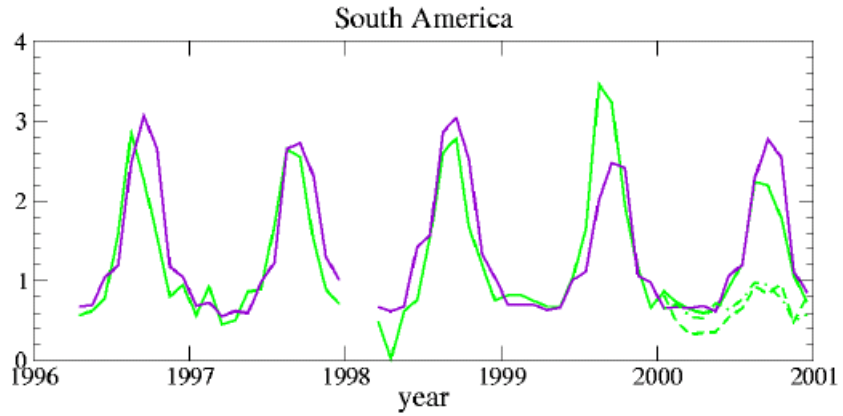


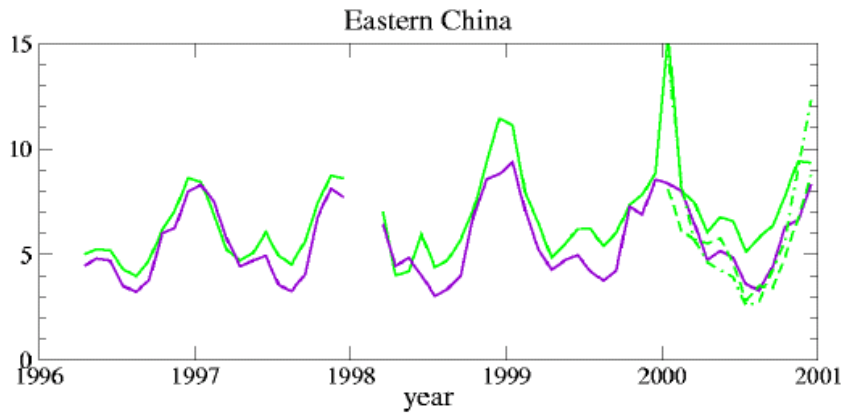


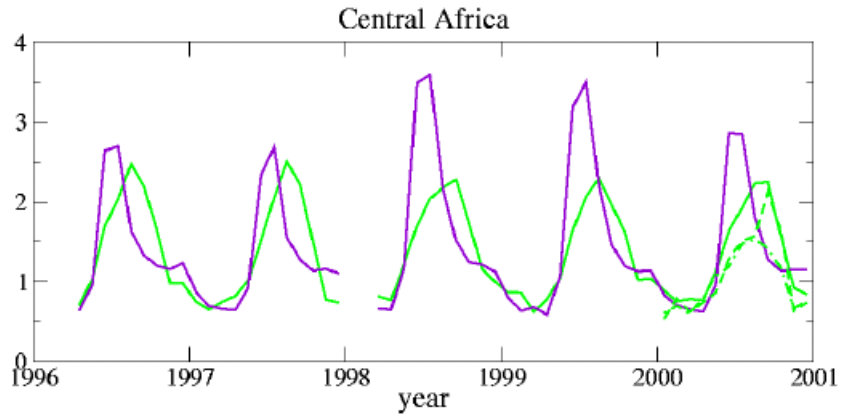


NO_x evaluation

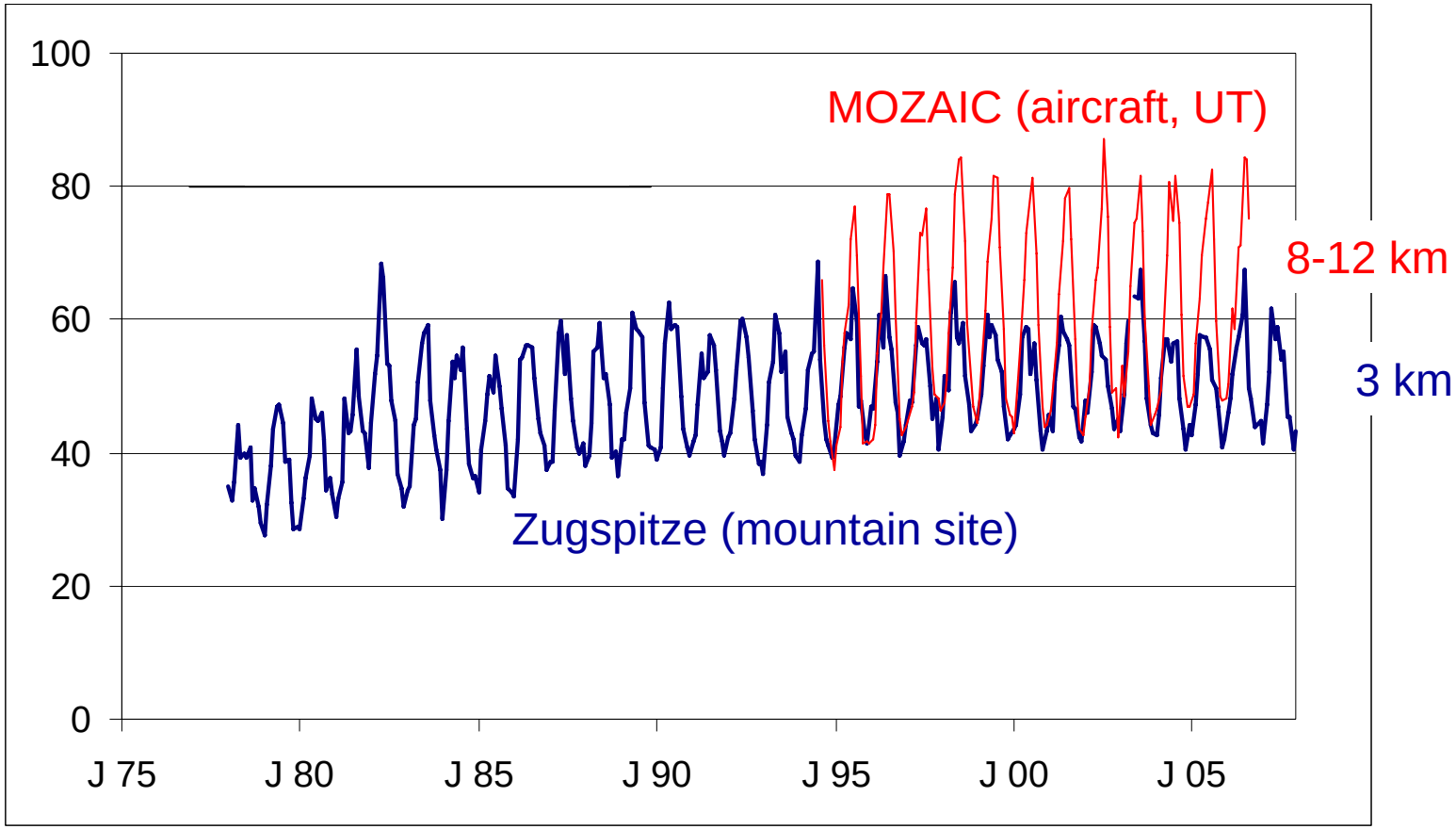






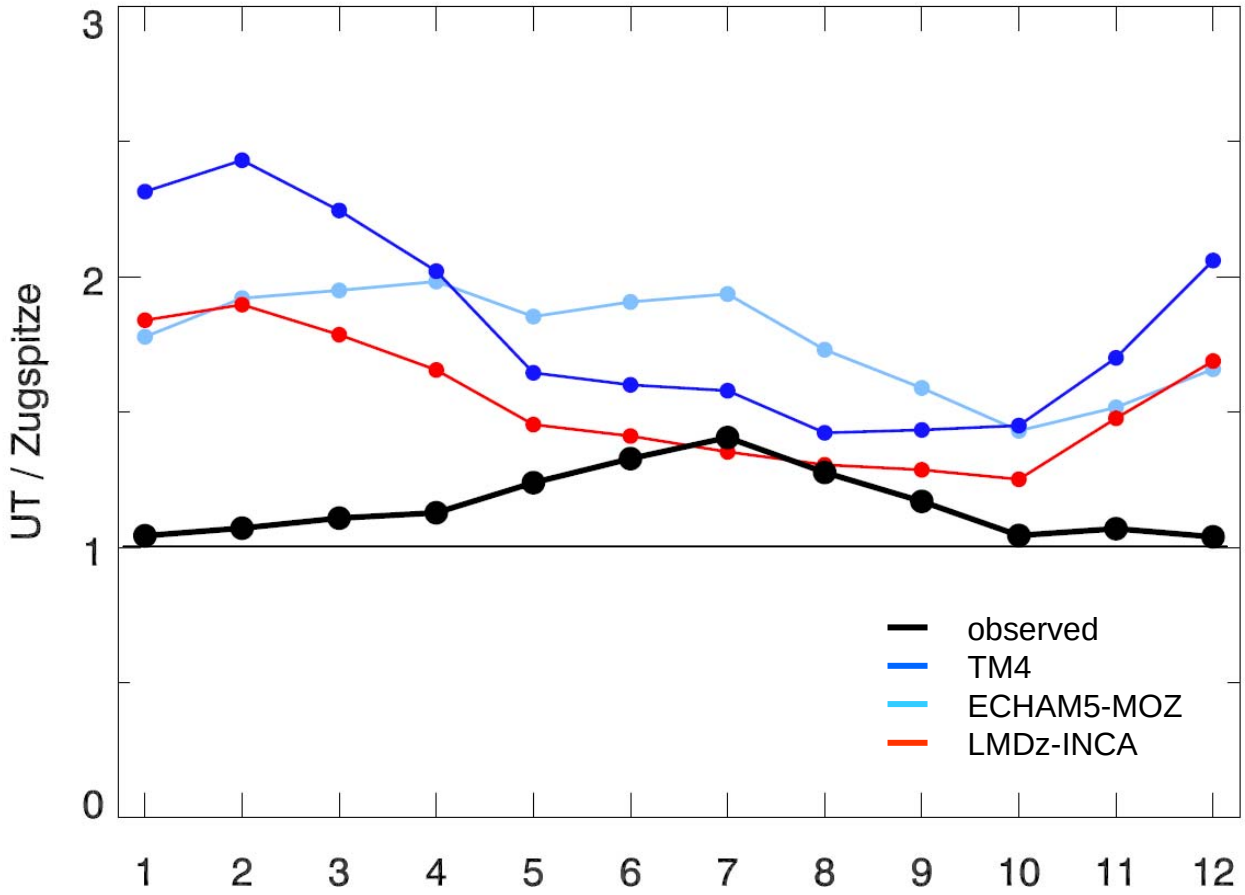


How well mixed is the free troposphere?



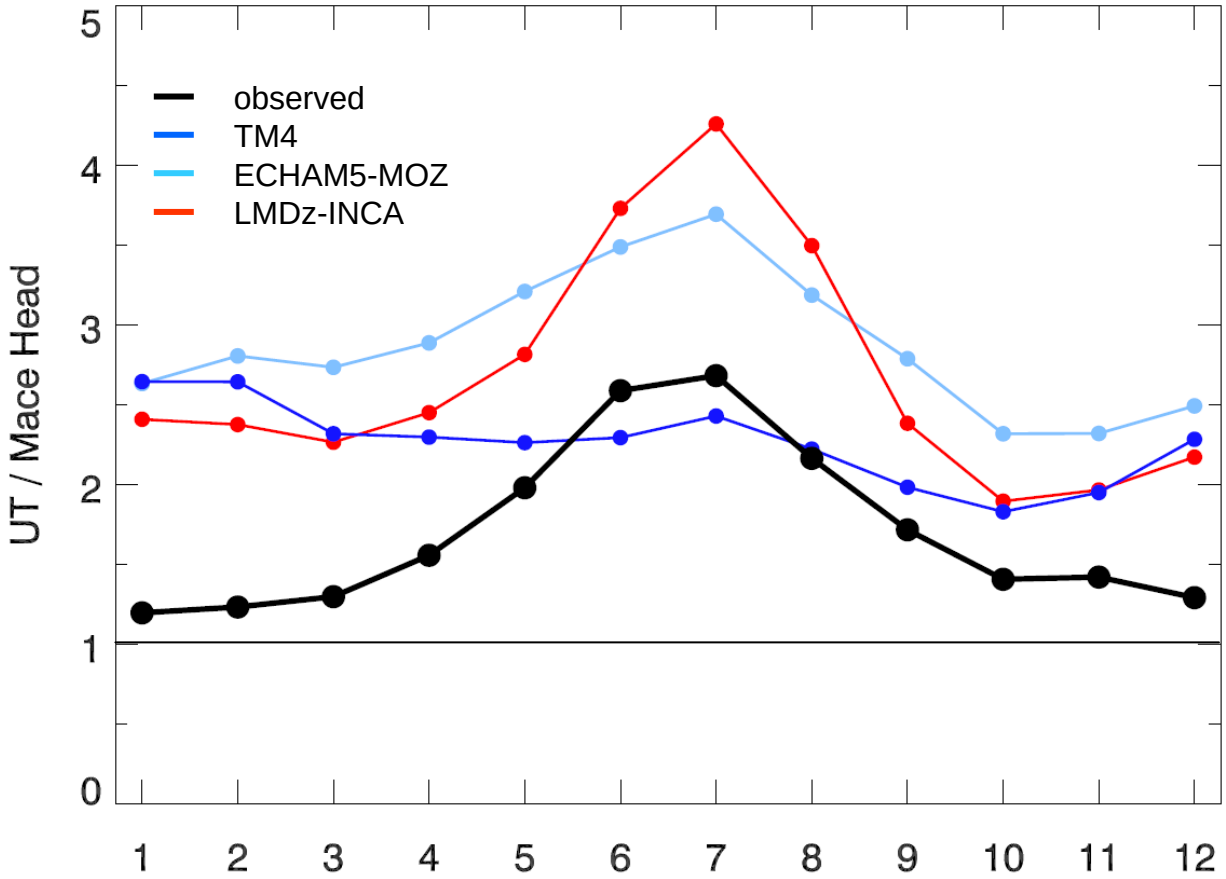
Zugspitze data courtesy of H.E. Scheel

Ozone in flight altitude vs. Zugspitze

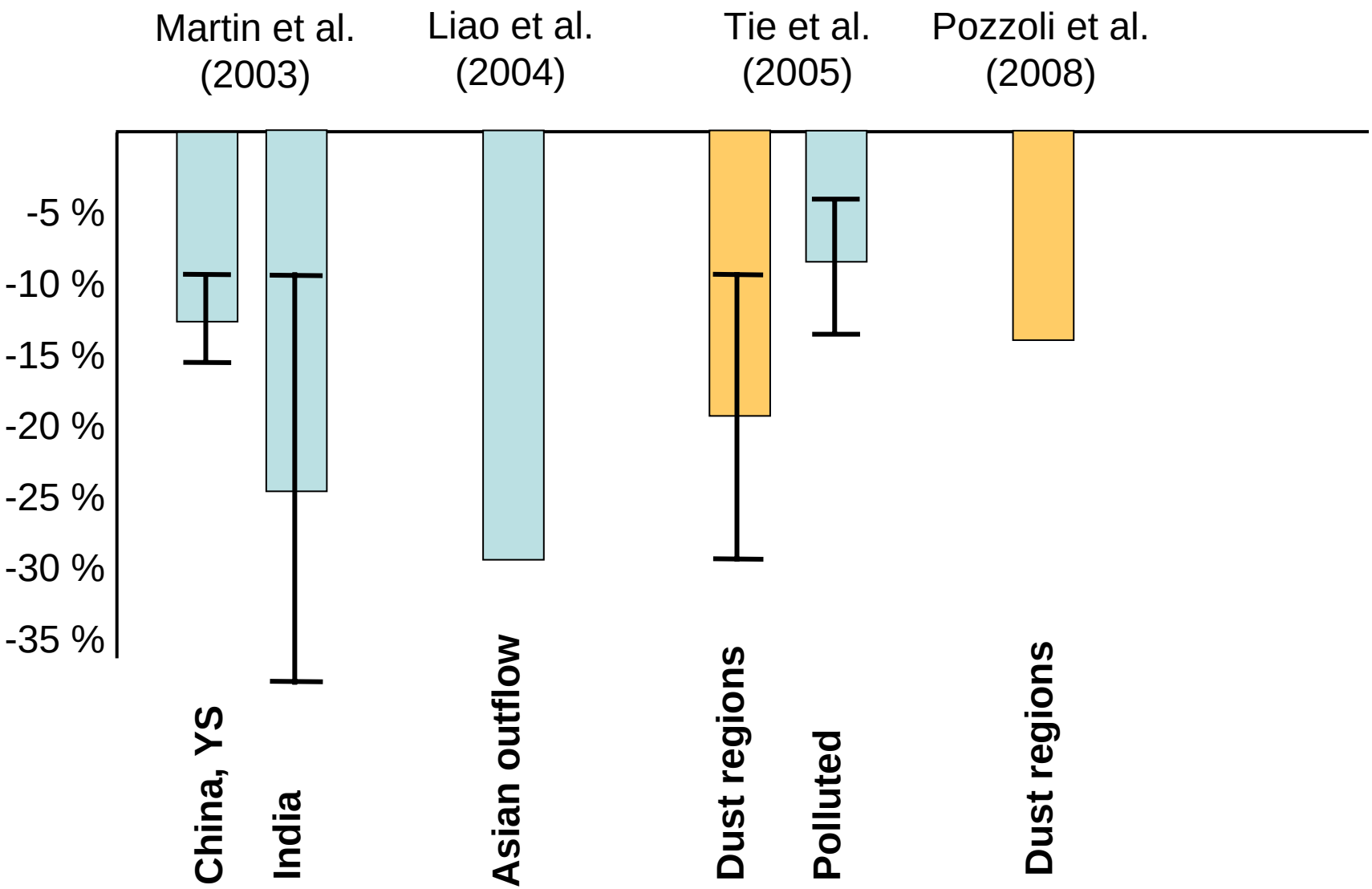


Zugspitze data courtesy of H.E. Scheel

Ozone in flight altitude vs. Mace Head

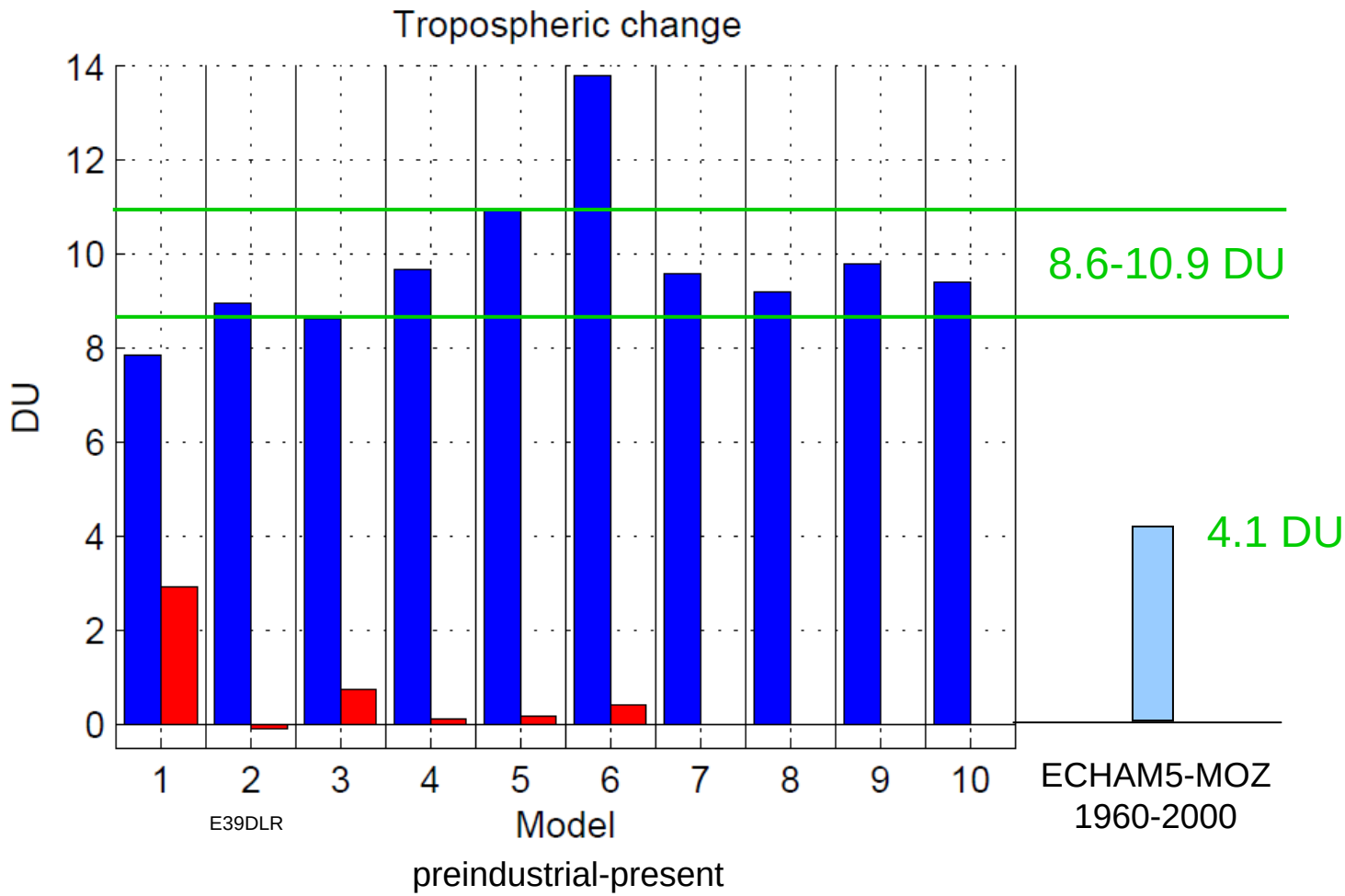


Other processes: Heterogeneous Reactions (…)



Implications

Tropospheric ozone column change

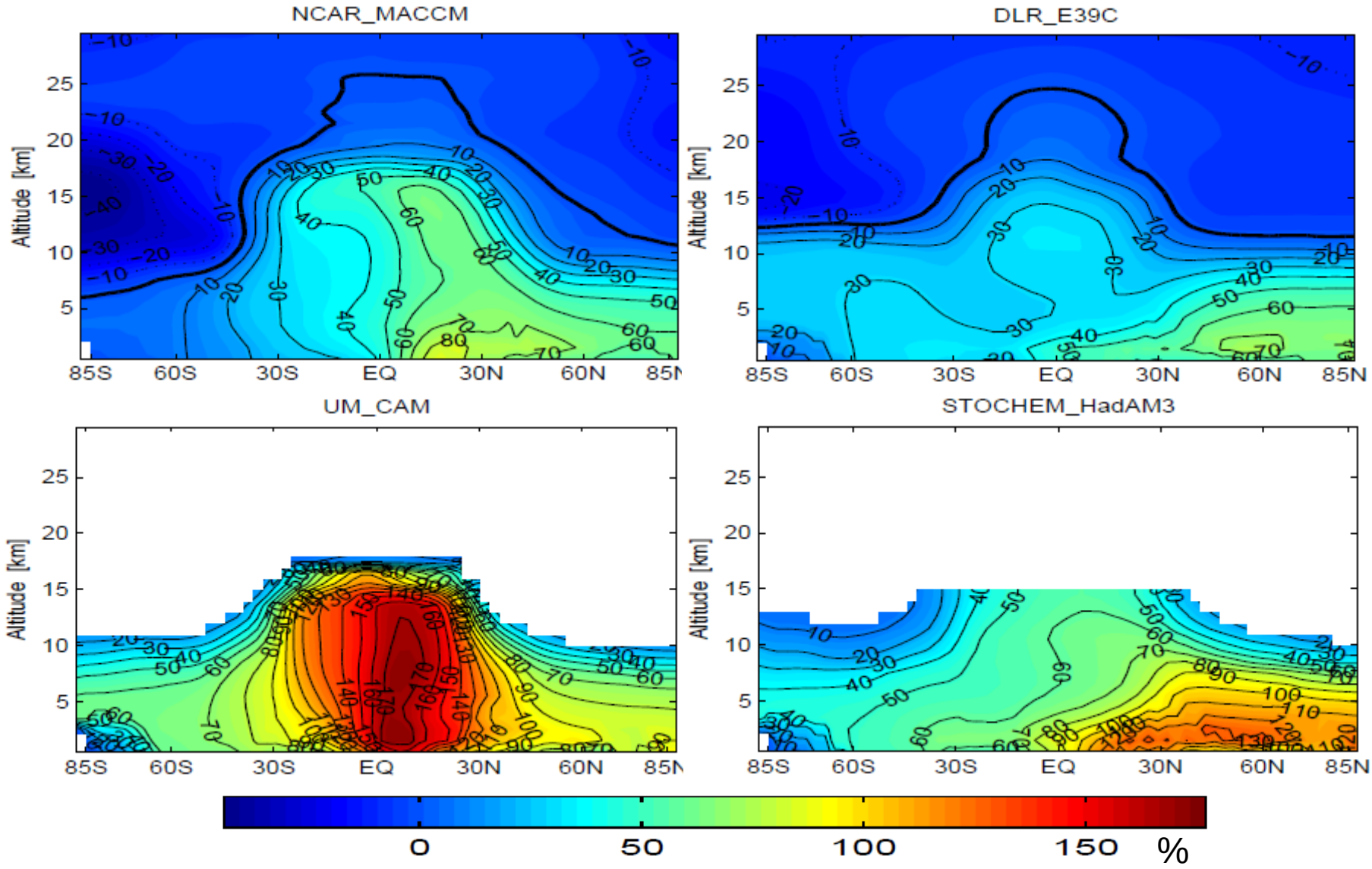


- No anthropogenic emissions
- 10% of Y2000 biomass burning
  (→ 30% of Y2000 NO_x)

- ca. 50% of anthropogenic emissions
- ca. 75% of Y2000 biomass burning
  (→ 60% of Y2000 NO_x)

Gauss et al., 2006 (ACP)

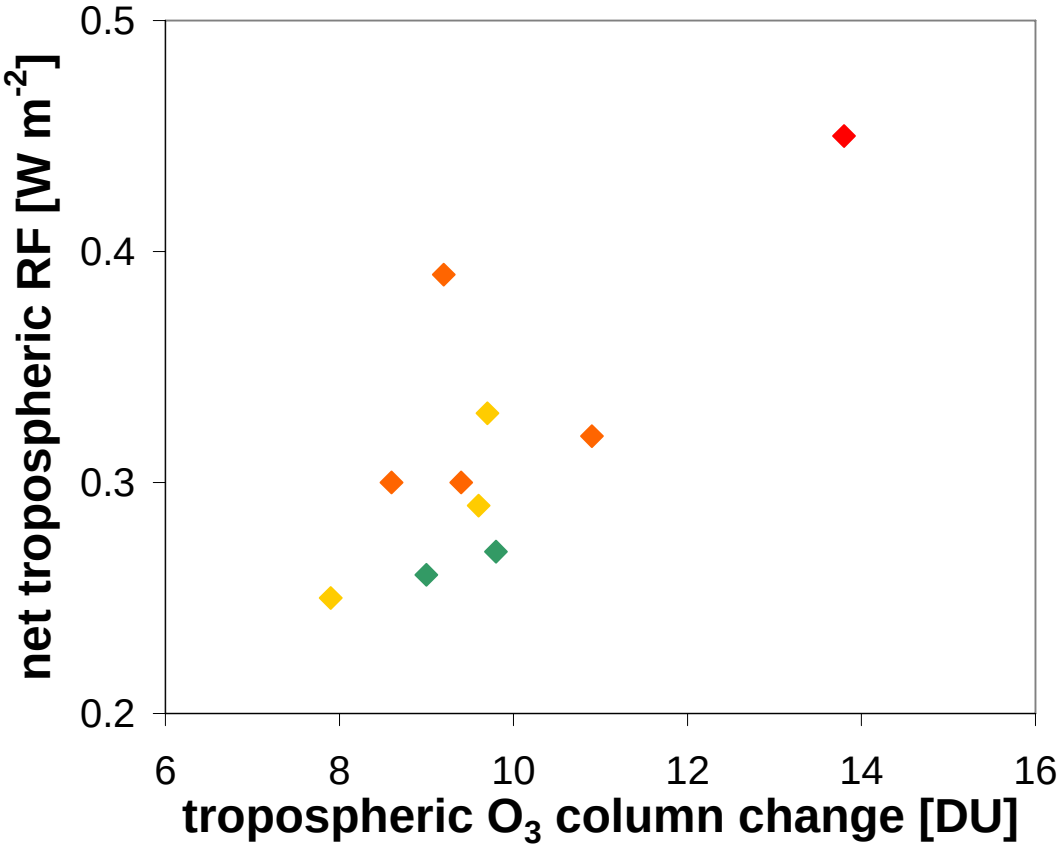
Tropospheric ozone change from preindustrial to present



4/10 models

Gauss et al., 2006 (ACP)

Radiative forcing from tropospheric ozone



$RF = 0.032\ Wm^{-2}\ DU^{-1}$

(all models)

$RF = 0.028\ Wm^{-2}\ DU^{-1}$

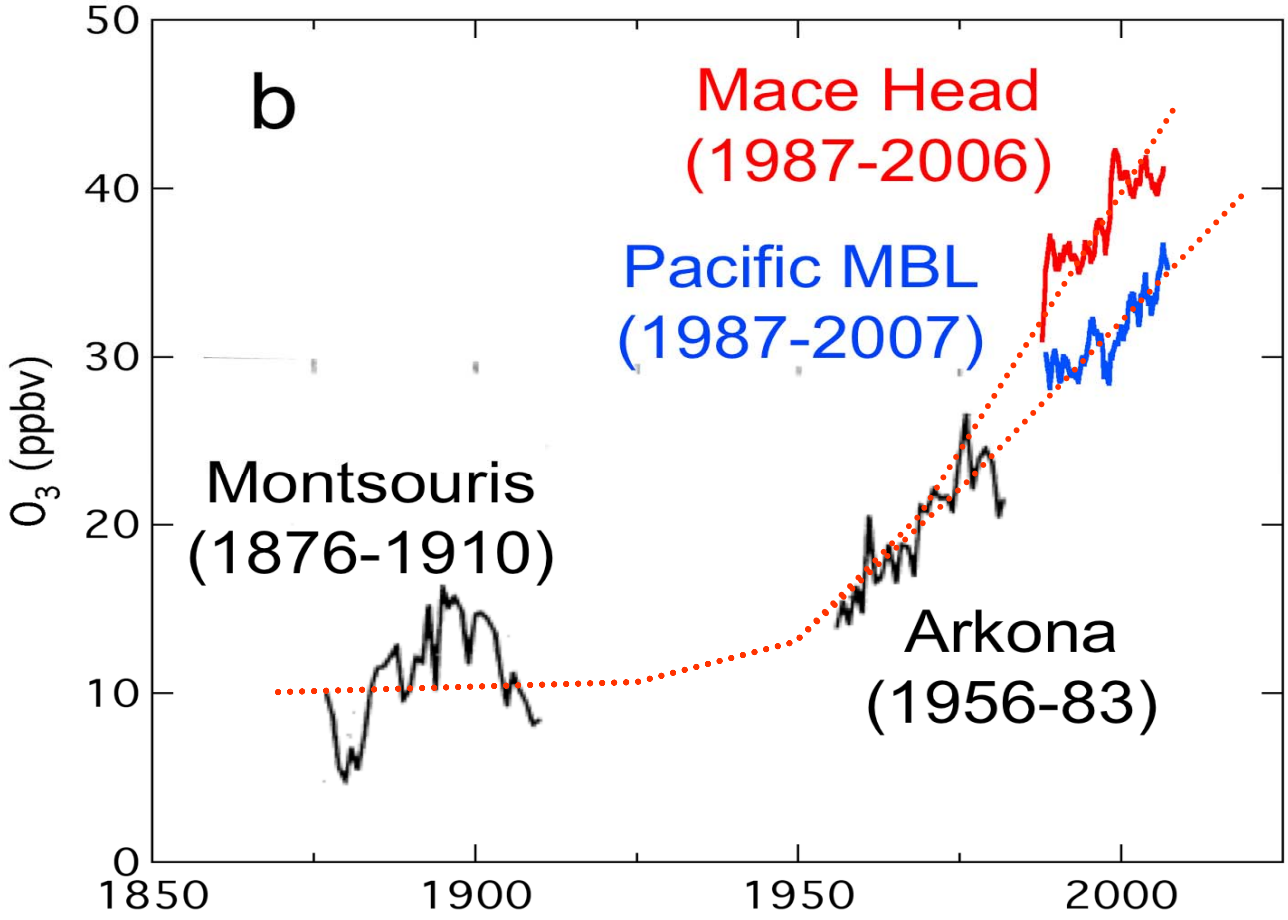
(if ozone changes are confined to lower troposphere)

- strong change in tropical UT
- changes confined to lower troposphere

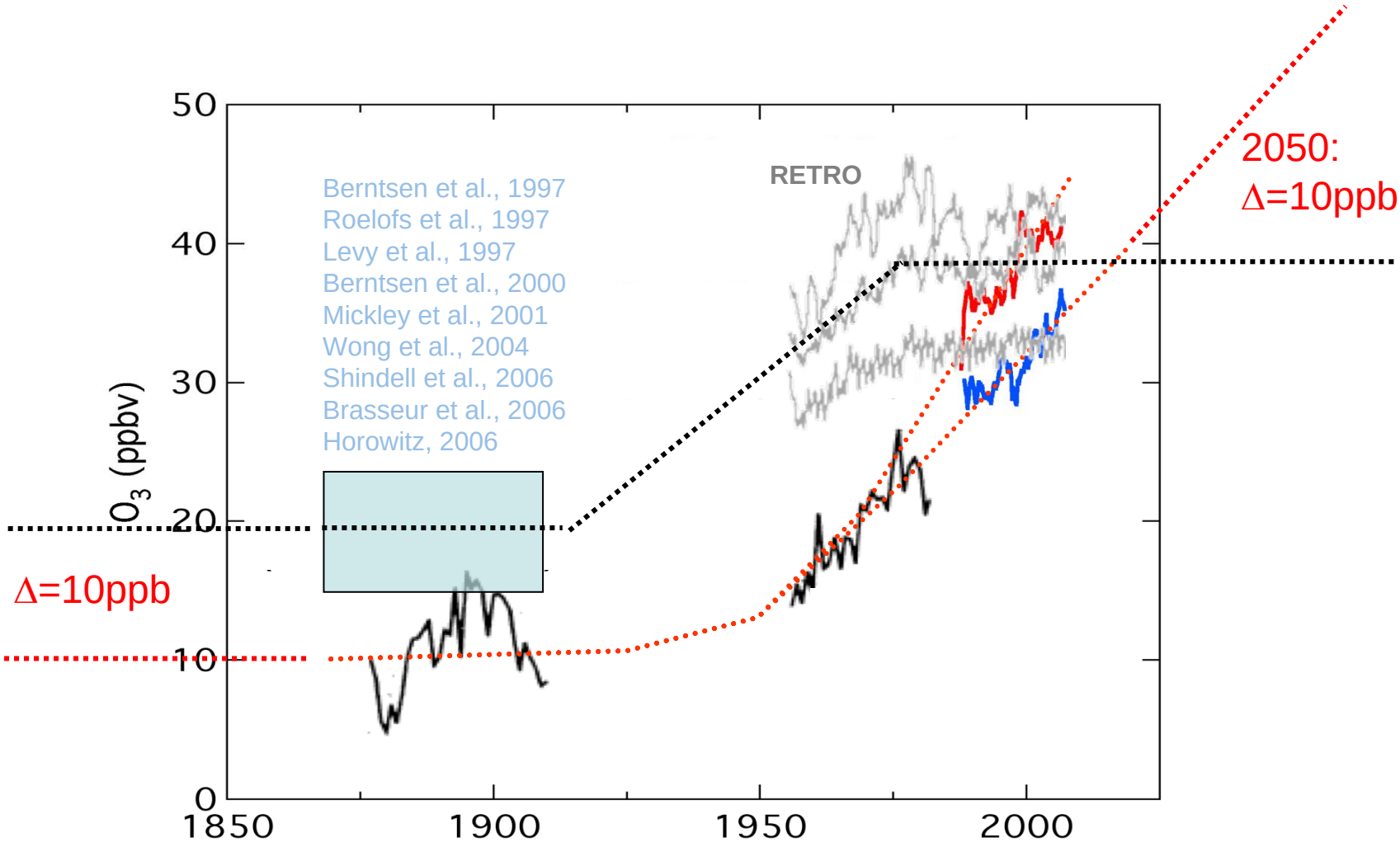
Data from Gauss et al., 2006

Background surface ozone: The longer-term perspective

April monthly means



Parrish et al., 2009


50
40
30
20
10
0
1850
1900
1950
2000
O_3 (ppbv)
Berntsen et al., 1997
Roelofs et al., 1997
Levy et al., 1997
Berntsen et al., 2000
Mickley et al., 2001
Wong et al., 2004
Shindell et al., 2006
Brasseur et al., 2006
Horowitz, 2006
RETRO
Δ=10ppb
2050:
Δ=10ppb

Conclusions

- NH background ozone increases (at least until 2000)
- Models don‘t capture the ozone trend well
- Vertical mixing of atmosphere not well understood
- Preindustrial ozone concentrations are overestimated
- Future ozone concentrations may be underestimated

→ Radiative forcing of tropospheric ozone may be underestimated by a factor of 1.5 – 2

We have to ask the old question again:

What controls tropospheric ozone?