Methane Lifetime in CMIP5 simulations

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Both climate and emissions exert controls on evolution of methane lifetime

$$\tau_{CH_4} = \frac{B_{CH_4}}{\int_{surface}^{tropopause} k[OH][CH_4]}$$

- 80-90 % of tropospheric methane loss by OH occurs below 500 mb
- ~75% occurs in the tropics

[*Spivakovsky et al., JGR, 2000; Lawrence et al., ACP 2001; Fiore et al., JGR, 2008*]

τ_{CH_4} SHORTENS WITH INCREASING:

- **temperature (by 2% K^{-1})**
- **[OH]**
  - **+ NO_x sources (anthrop., lightning, fires, soils)**
  - **+ water vapor (e.g., with rising temperature)**
  - **+ photolysis rates (JO^1D; e.g., from declining strat O_3)**
  - **- CO, NMVOC, CH_4 (emissions or burden)**

NCAR CAM-Chem and GFDL CM3 CMIP5 Simulations

1. CMIP5 (ACC-MIP) anthropogenic forcings and emissions:
   -- greenhouse gases (GHG)
   -- emissions of aerosols and tropospheric O_3 precursors
      note: CH_4 abundance is prescribed (not emissions)
   -- ozone-depleting substances (ODS)
2. Meteorology-dependent lightning NO_x scheme
3. Climatological isoprene emissions
4. Tropospheric and stratospheric chemistry
5. Historical volcanic eruptions and solar forcing

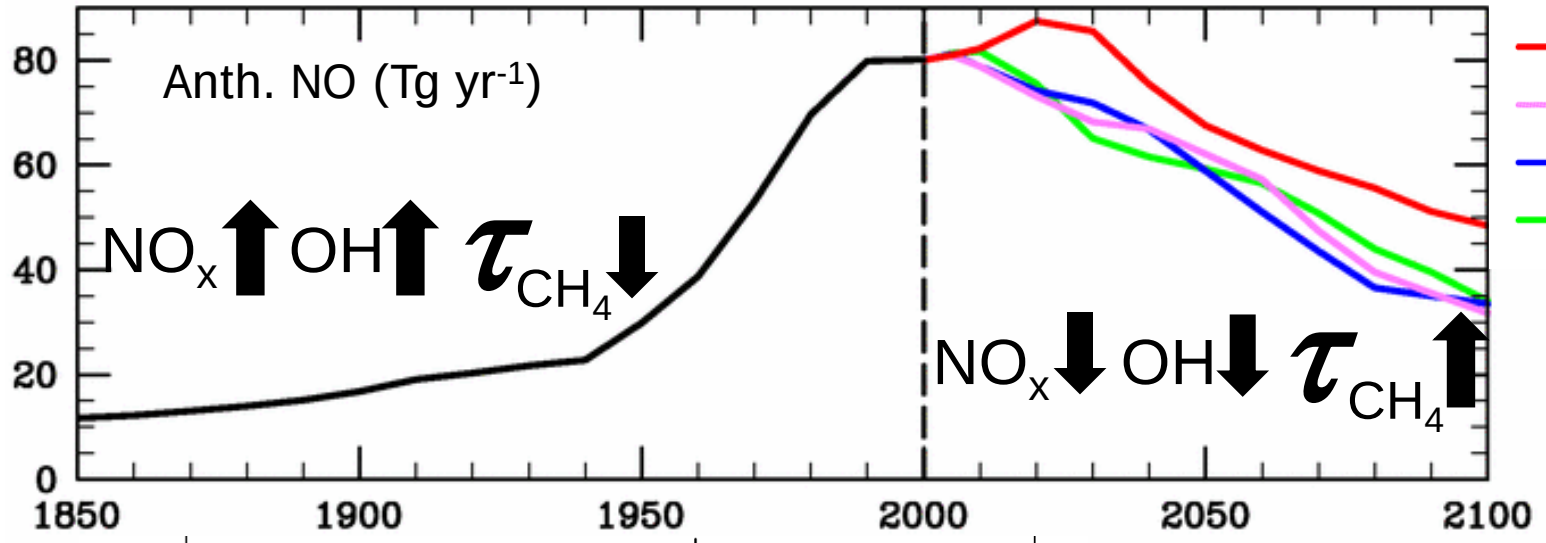
CM3 [Donner et al., 2011]

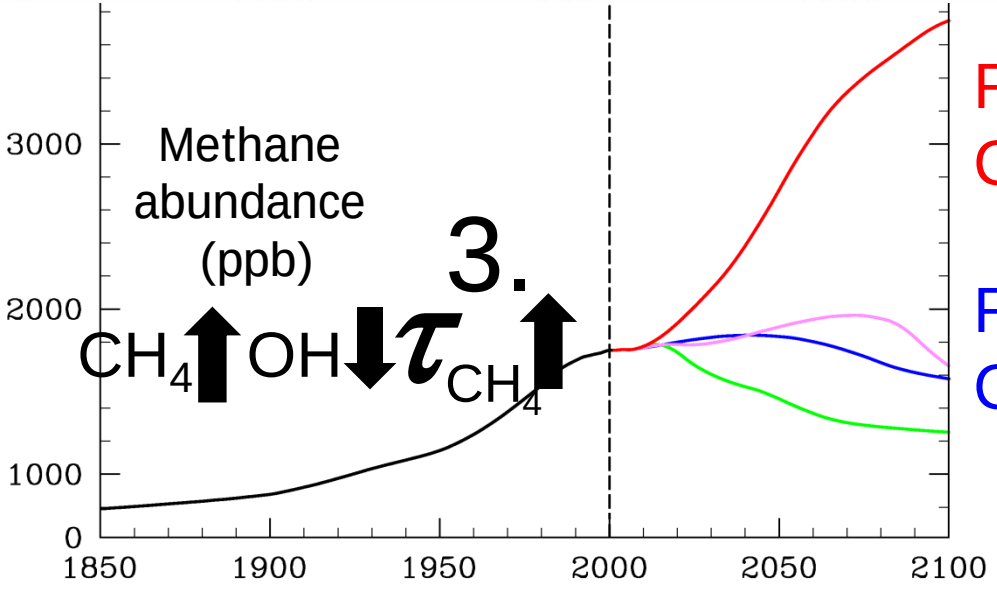
- aerosol indirect effect
- MOZART-2 mech. (trop)
- AMTRAC mech. (strat)
- Fully coupled ocean

CAM-Chem [Lamarque et al., 2011]

- No indirect effect
- reduced mech. (trop)
- MOZART-3 mech. (strat)
- SSTs from AR-4 (CCSM3)

CMIP5 NO_x emissions and CH_4 abundances: Impacts on methane lifetime?



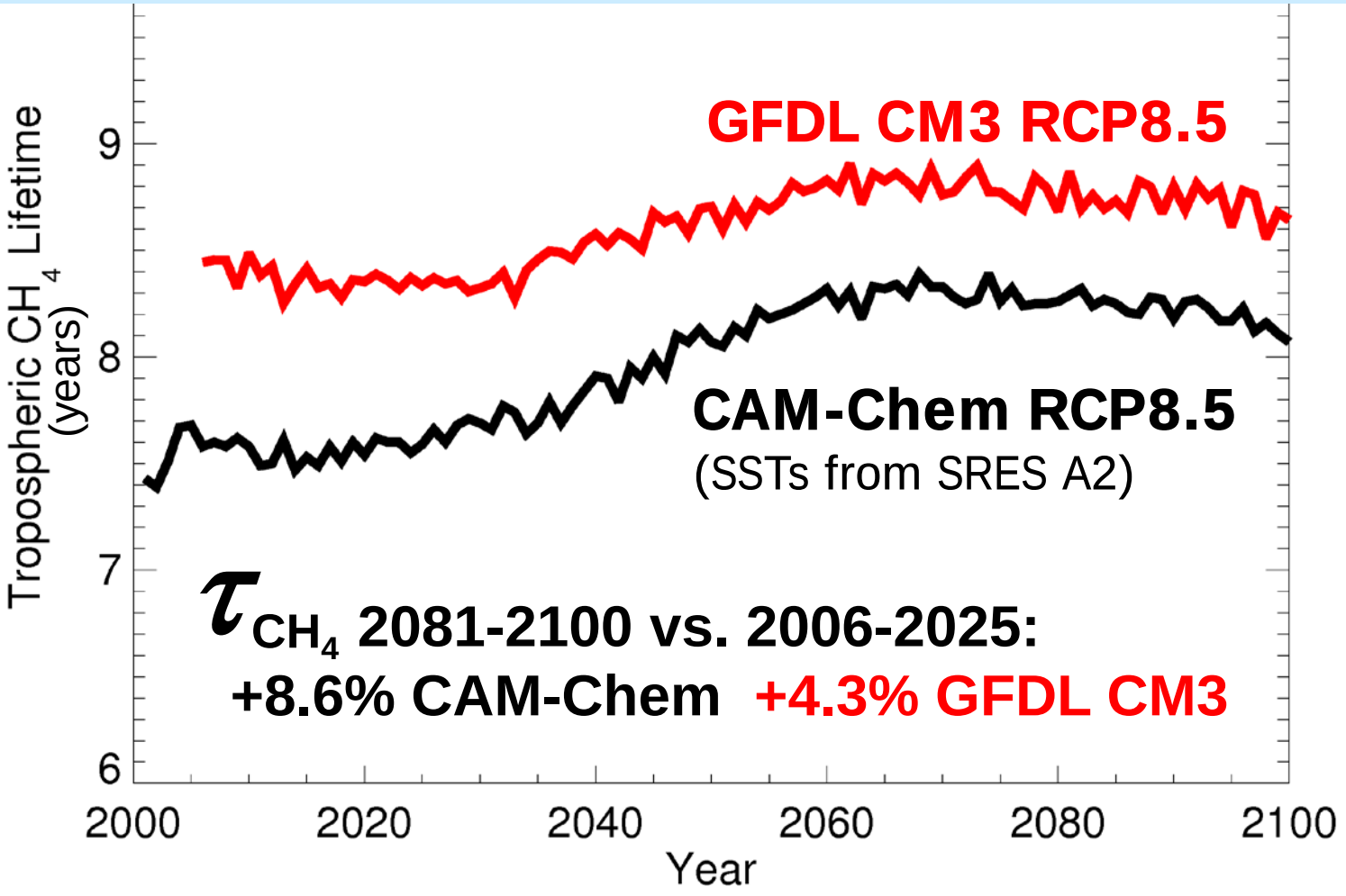


RCP8.5:
CH_4 ↑ OH ↓ τ_{CH_4} ↑ 1.

RCP4.5:
CH_4 ↓ OH ↑ τ_{CH_4} ↓ 2.

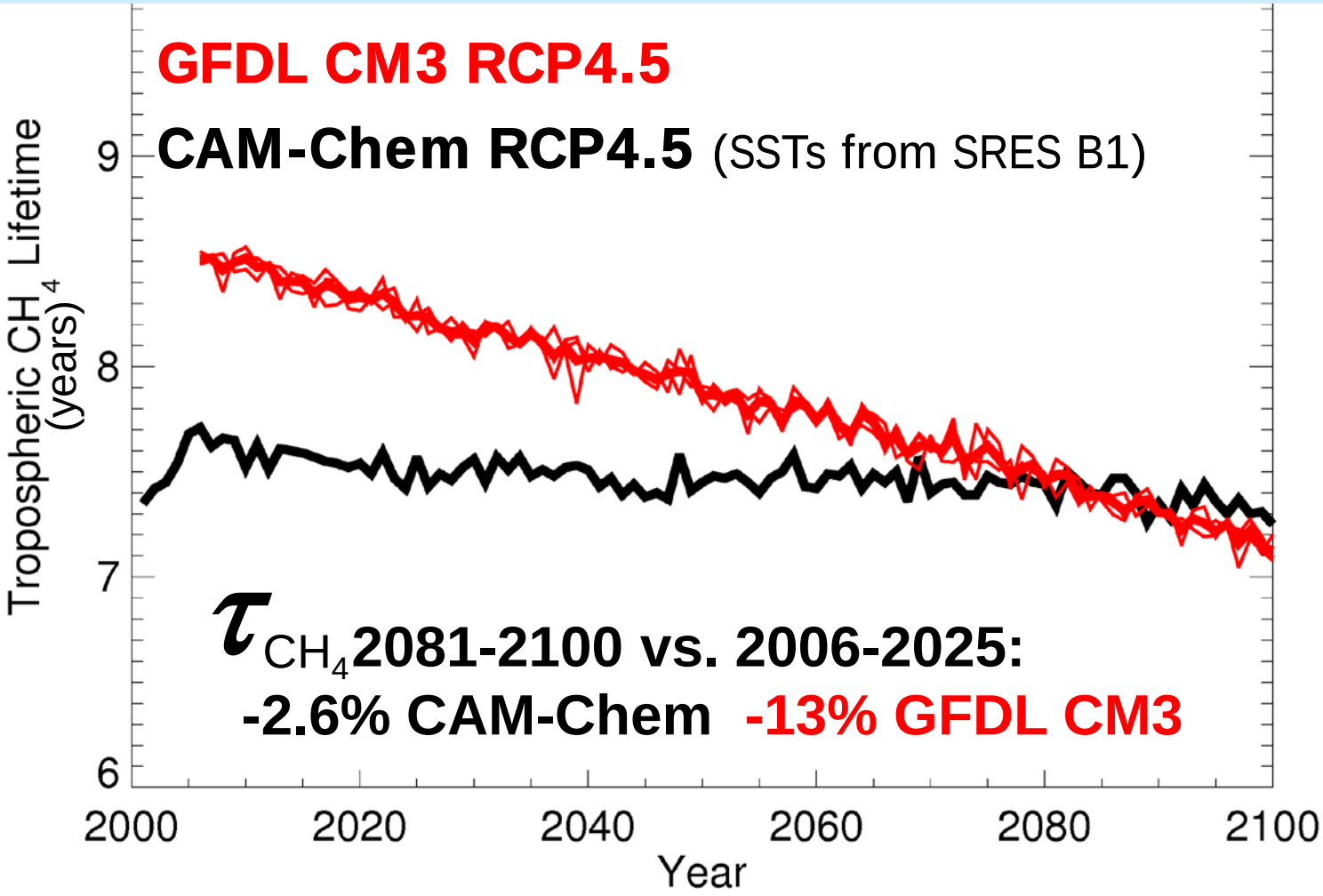
Figures c/o V. Naik

CAM-Chem and GFDL CM3 models both project increases in methane lifetime under RCP8.5



NO_x ↓ + CH_4 ↑ + strat. O_3 ↑ → OH ↓ τ_{CH_4} ↑

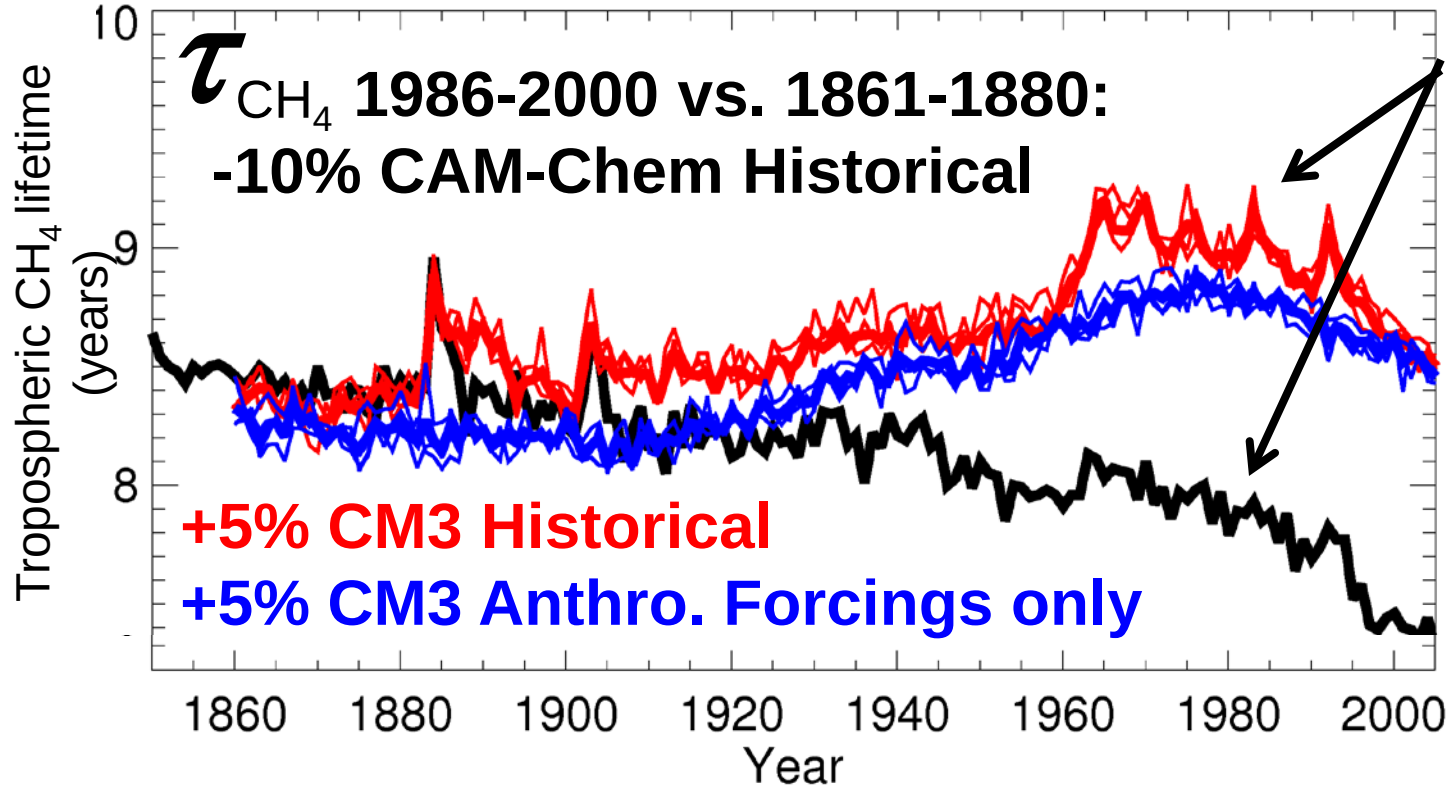
Methane lifetime evolution less consistent under other RCPs, e.g. RCP4.5



→ More warming in CM3 than CAM-Chem?

→ Role of aerosol indirect effect in CM3 response?

Historical (1850-2005) evolution of methane lifetime: CAM-Chem & CM3 differ in sign; CM3 increase is anthrop.



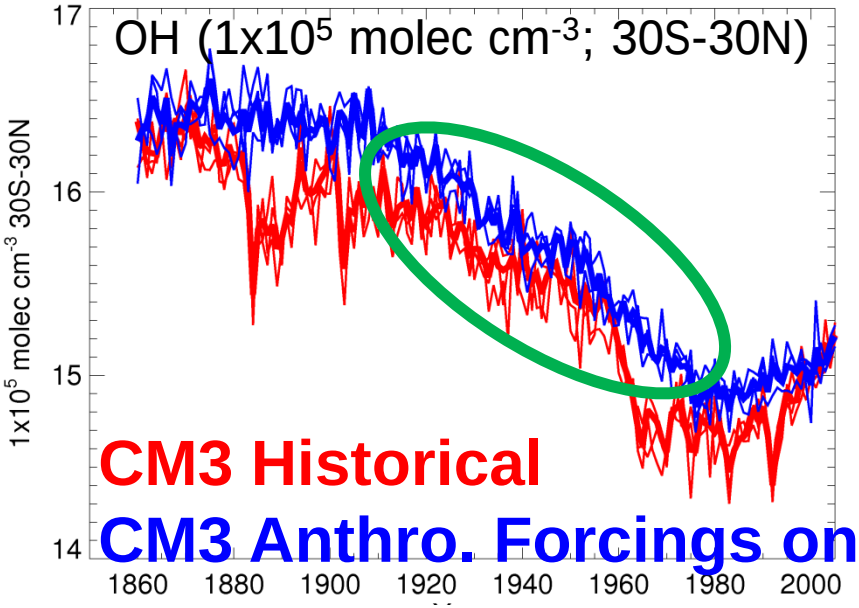
Both models show downward trend in recent decades: warming (T, H_2O)

GFDL ACC-MIP 2000 emissions + 1860(SST+ODS+GHG) - ACC-MIP 1860 = -13% decrease in CH_4 lifetime

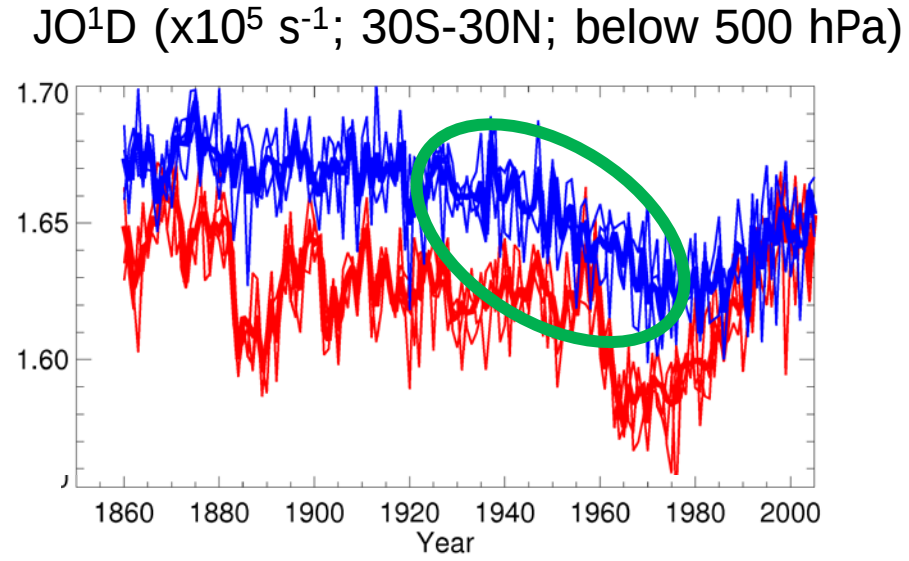
1. Trop O_3 and aerosol precursor emission changes decrease lifetime (NO_x)
2. Increasing SSTs and ODS over historical should also decrease lifetime

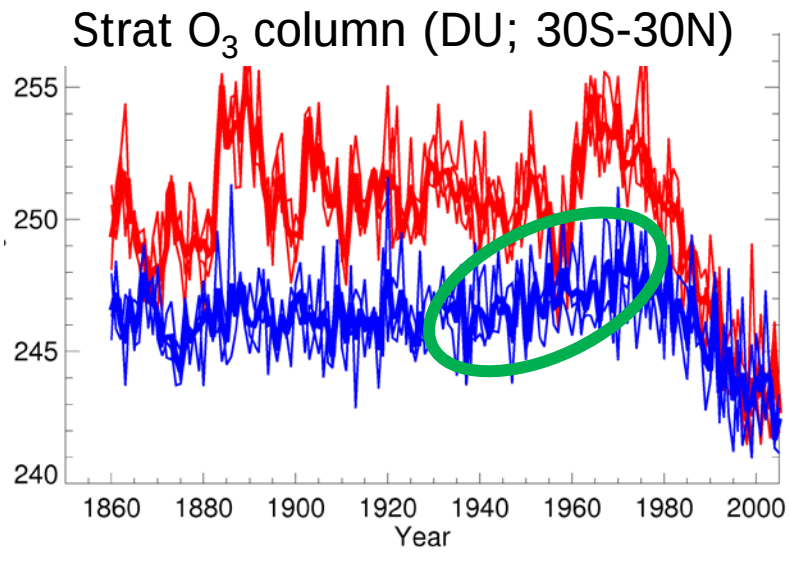
→ Implies a role for GHG (incl. CH_4) in CM3 historical increase, though NO_x + temperature rise "wins" in CAM-Chem

Tropical OH decreases 1910-1970
role of declining photolysis rates 1940-1970?



Next steps: Examine role of
-- JO^1D, lightning NO_x on OH
-- aerosols vs. strat O_3 on JO^1D





Concluding thoughts: Key drivers on methane lifetimes in CMIP5 simulations

- NCAR and GFDL models differ in terms of driving role for emissions of short-lived species vs. “climate”.

  → ACC-MIP should aid in interpreting relative roles

- Multiple, sometimes offsetting influences from water vapor, photolysis rates, OH precursor emissions (natural and anthropogenic), temperature.

- Roles of stratospheric chemistry, aerosol-cloud interactions, and associated climate responses, require further investigation.

  → Need carefully designed simulations for attribution

  → Observational constraints from historical period?