A Brief Overview of Ground-level Ozone Pollution

William C. Porter • March 23, 2018

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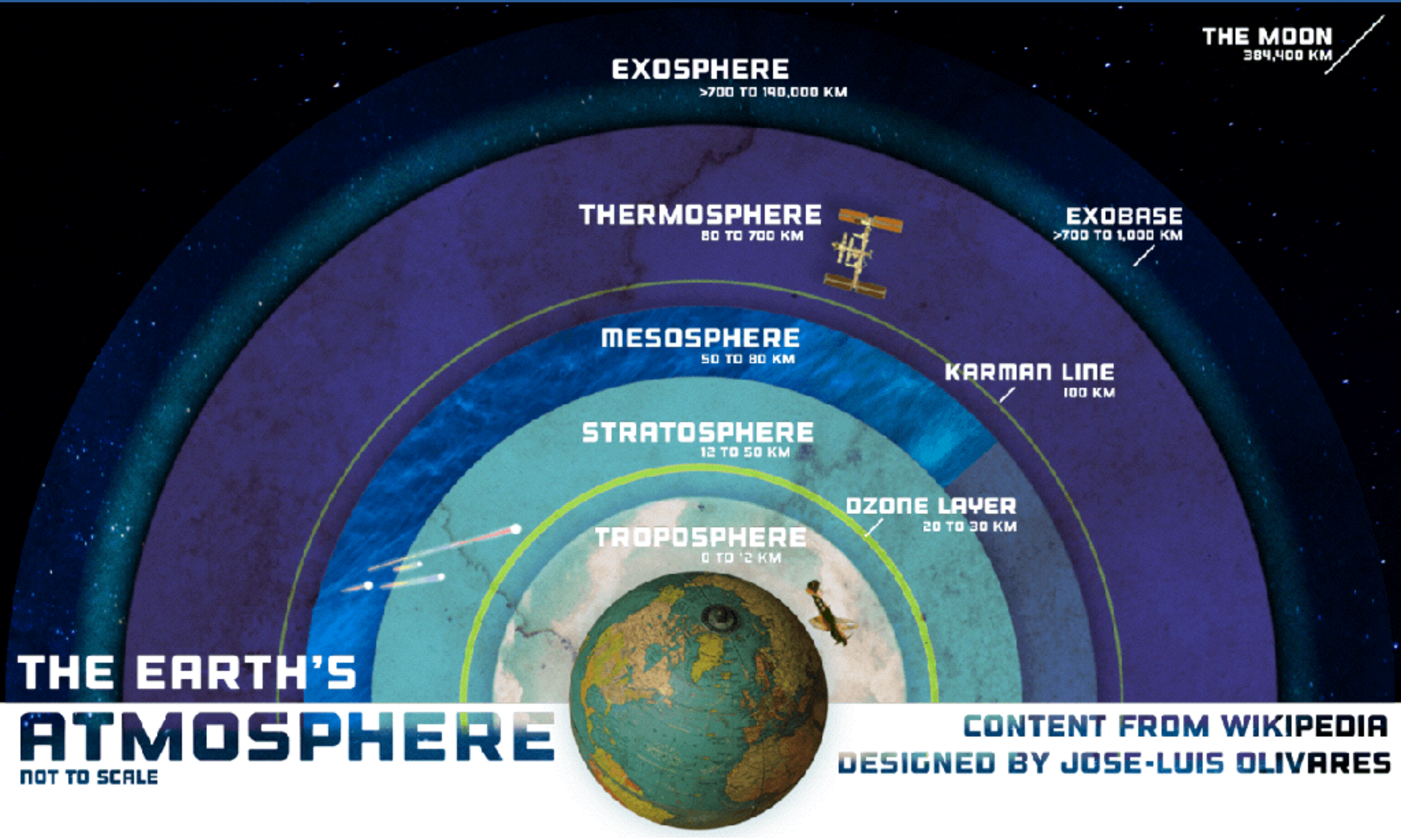
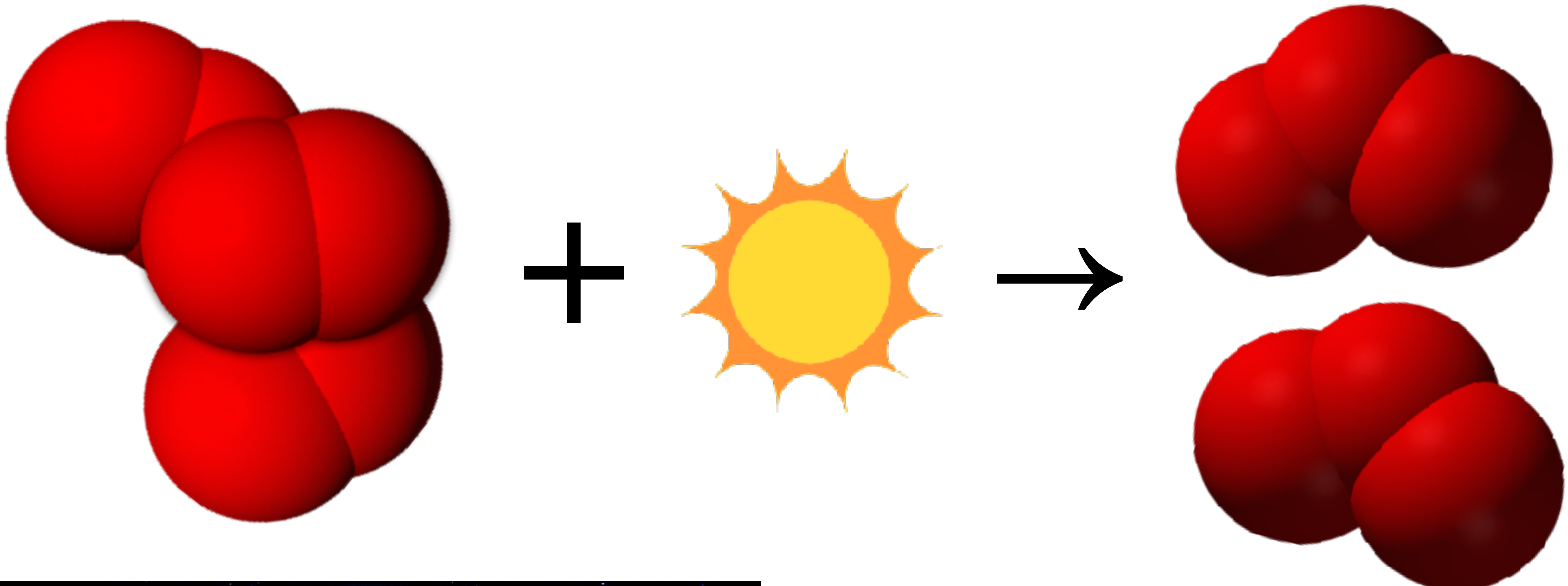
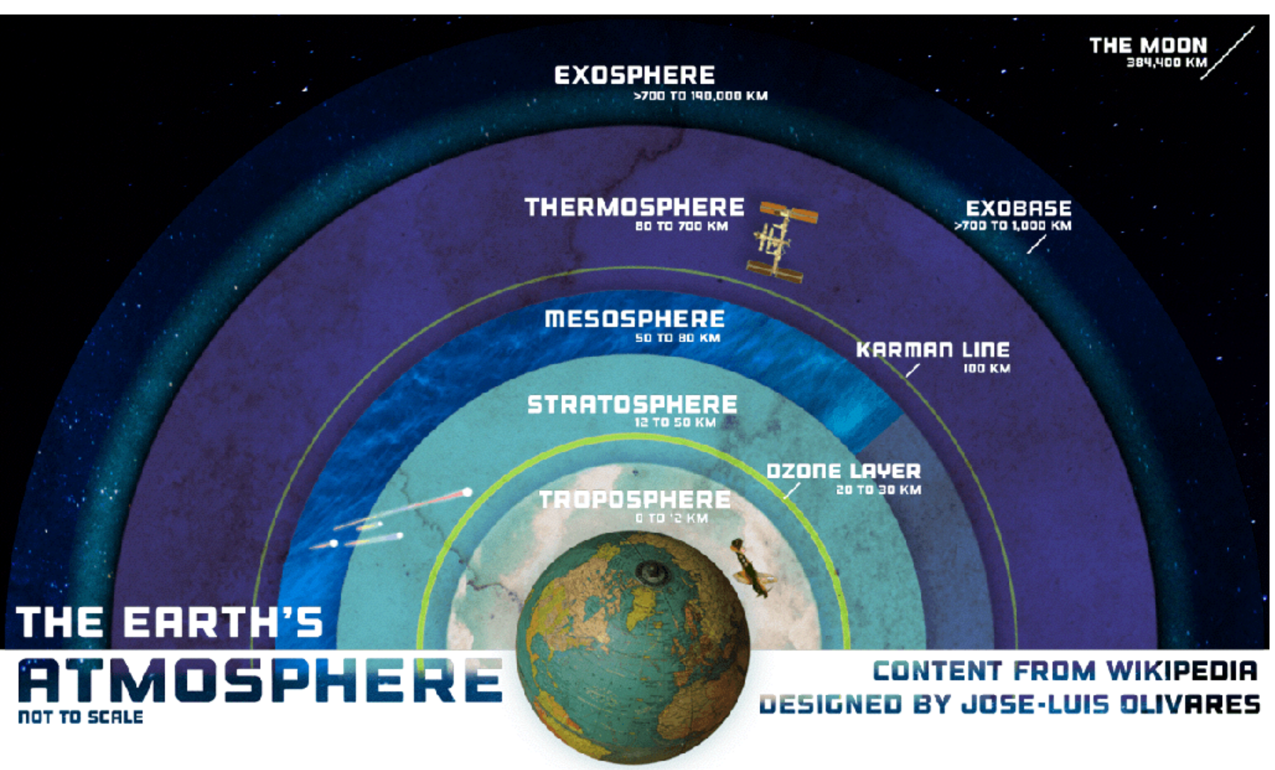
Ozone (O_3) in the atmosphere



90% of the Earth's O_3 is located in the stratosphere

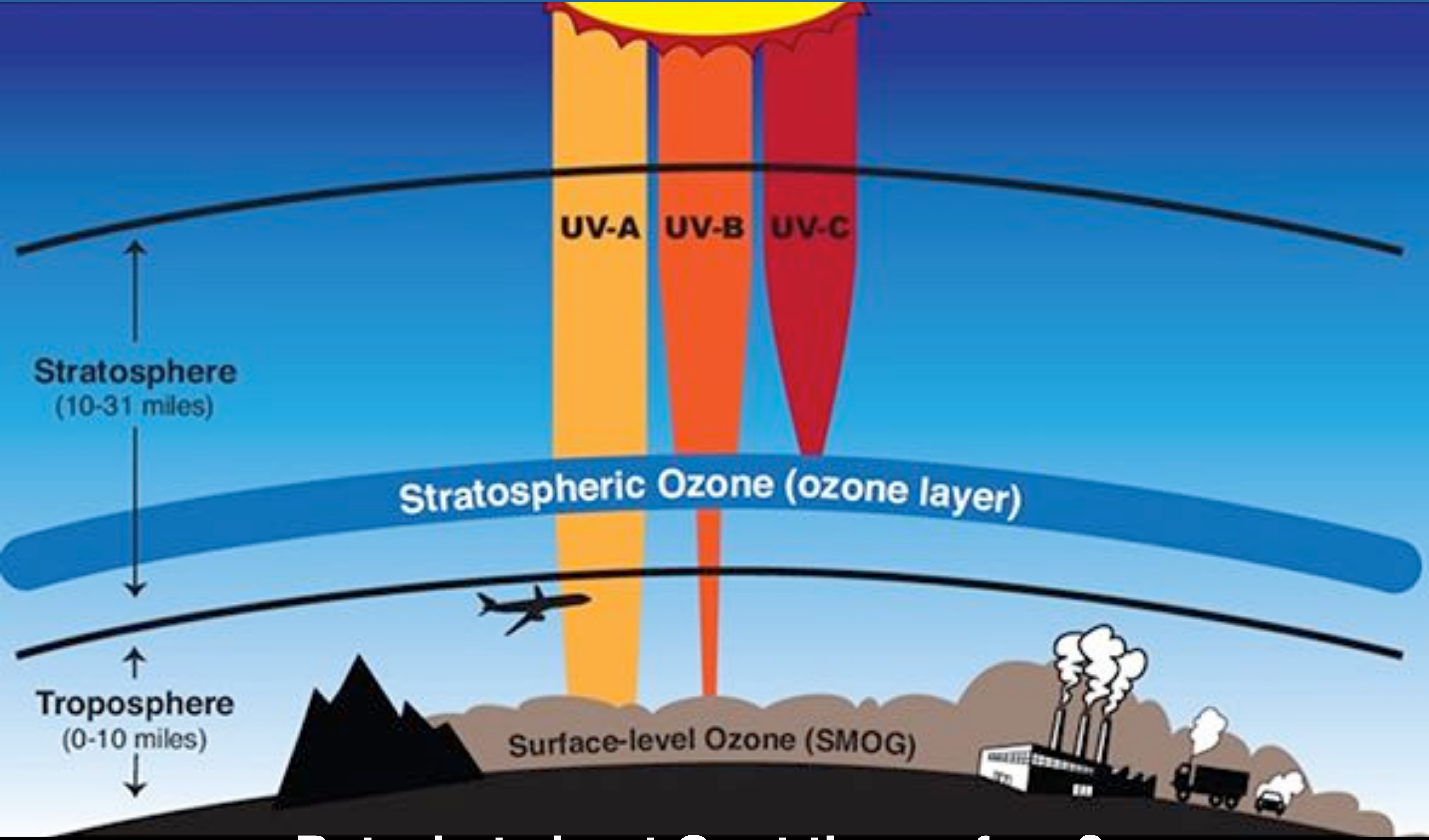




Why the stratosphere?

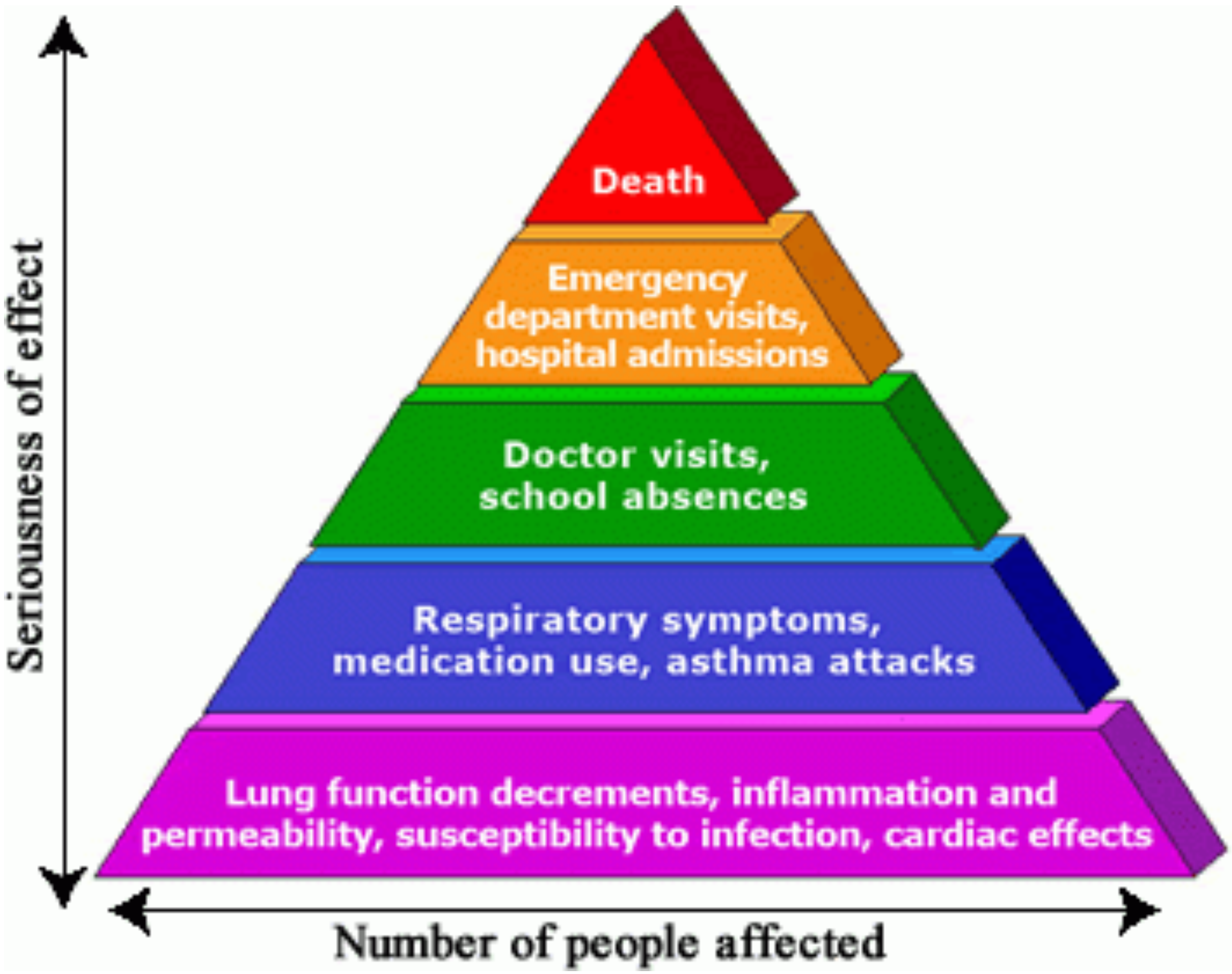
Relatively abundant O_2, few sinks (hopefully)

Stratospheric O_3 represents an important UV shield for life on Earth



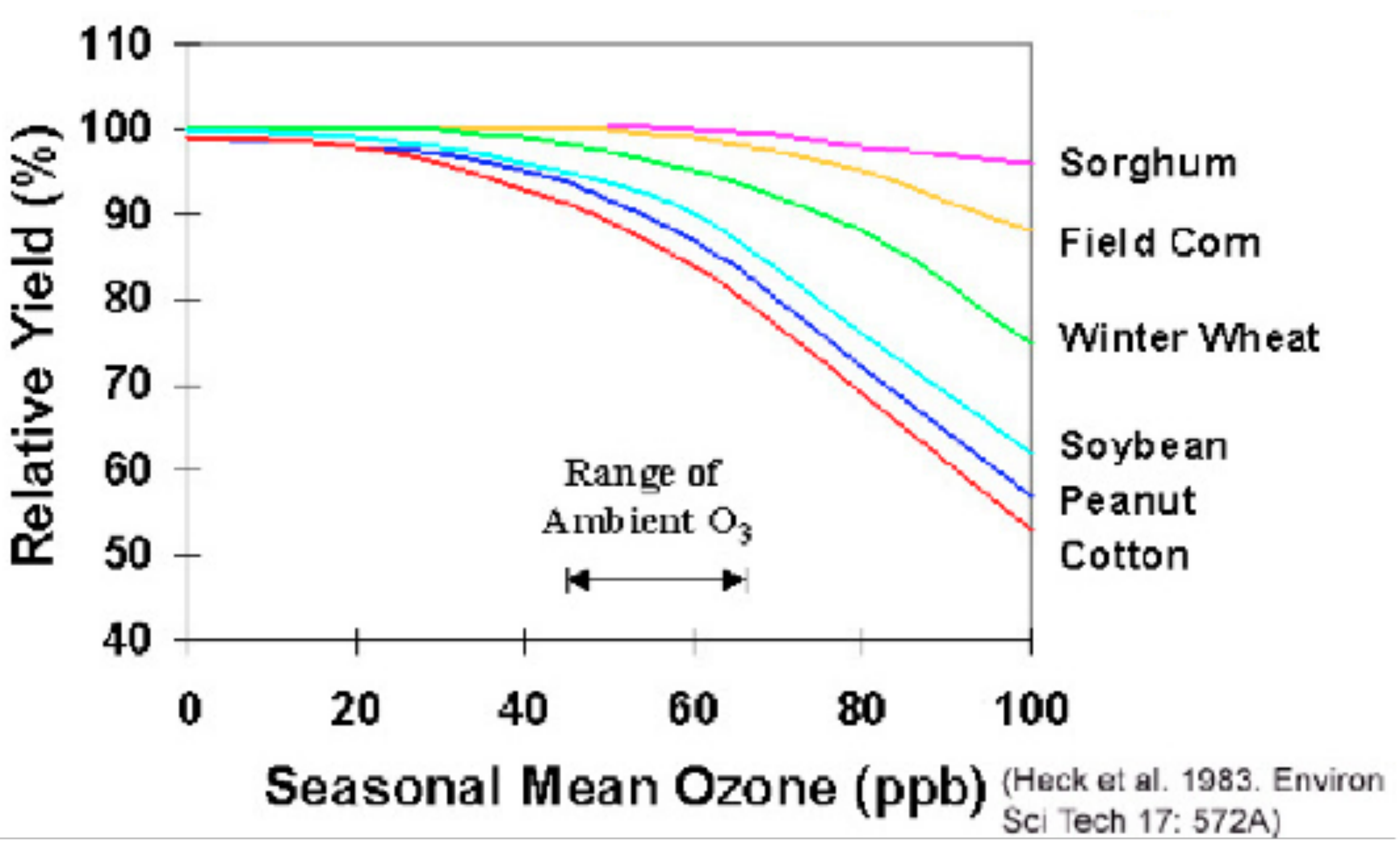
But what about O_3 at the surface?

Tropospheric O_3 is an EPA criteria pollutant with known links to respiratory and cardiovascular disease



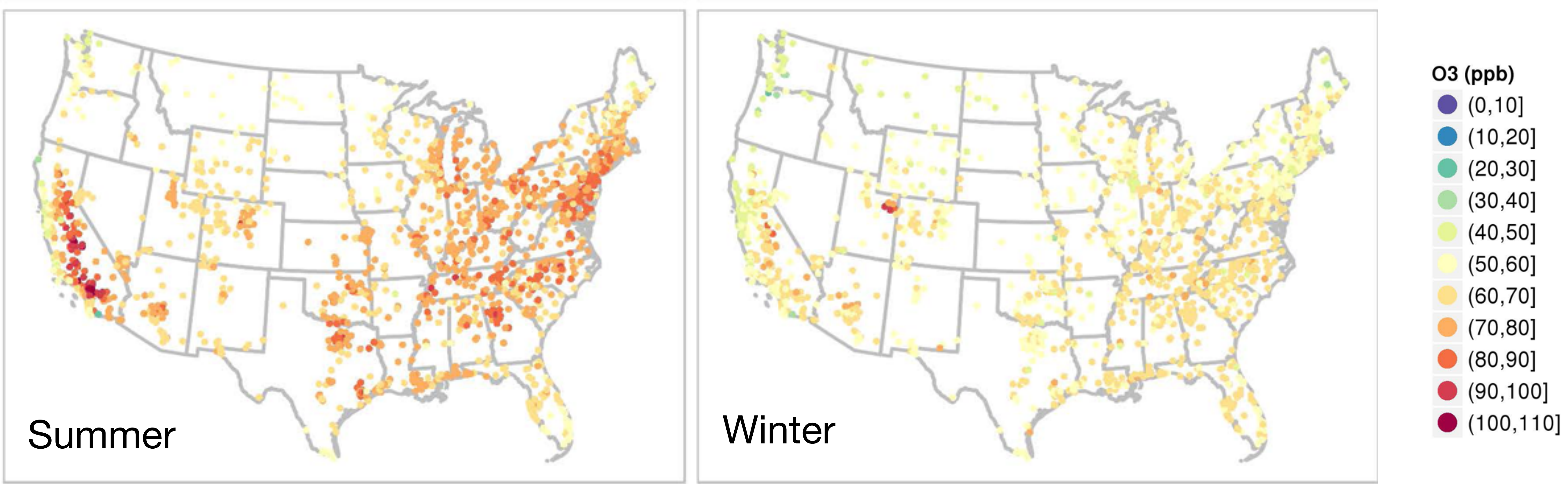
epa.gov

High O_3 levels can also damage plants and crop productivity



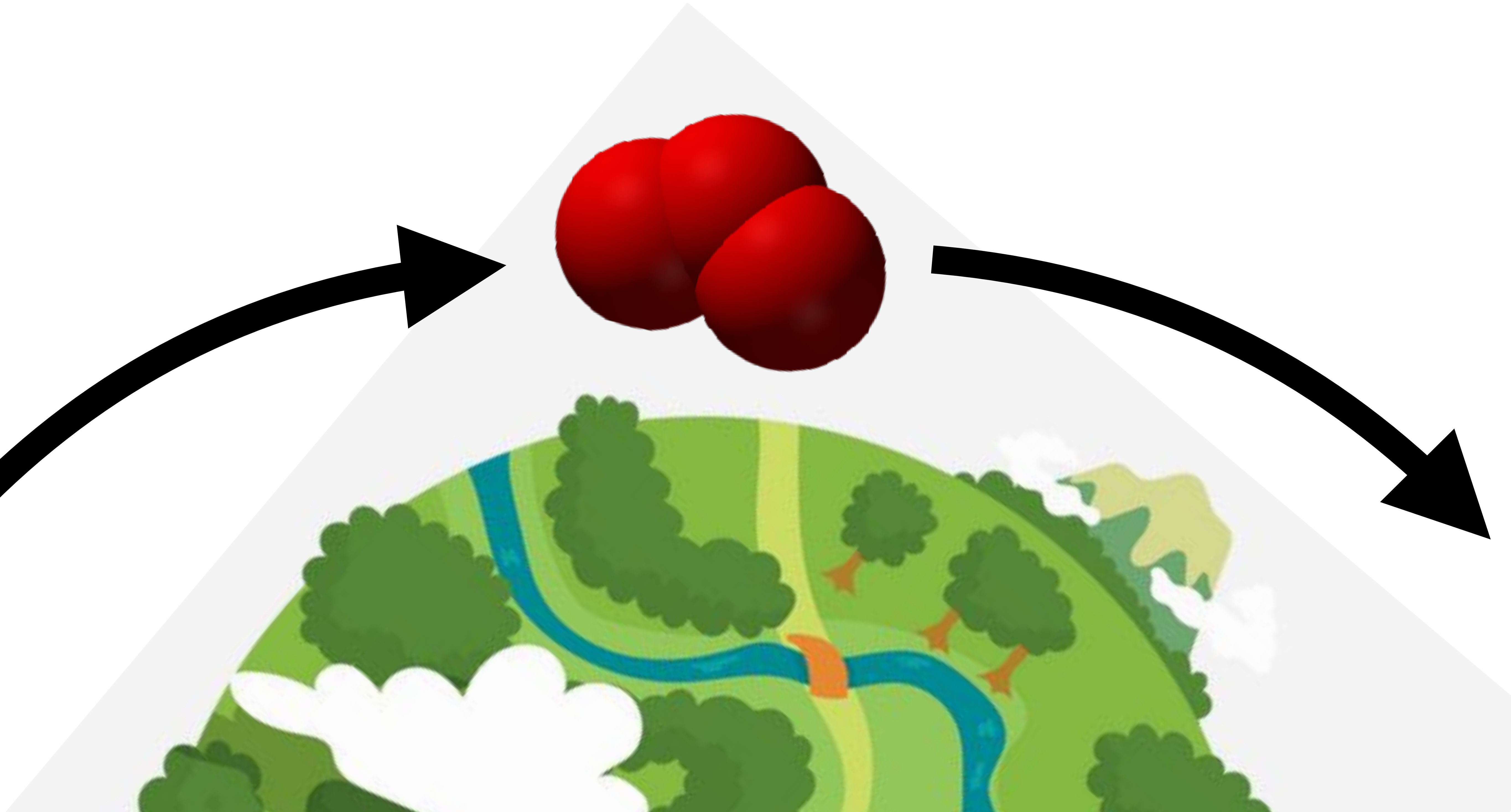
O_3 pollution is typically a summertime problem with clear regional differences

95th Percentile O_3 levels (1998-2013)

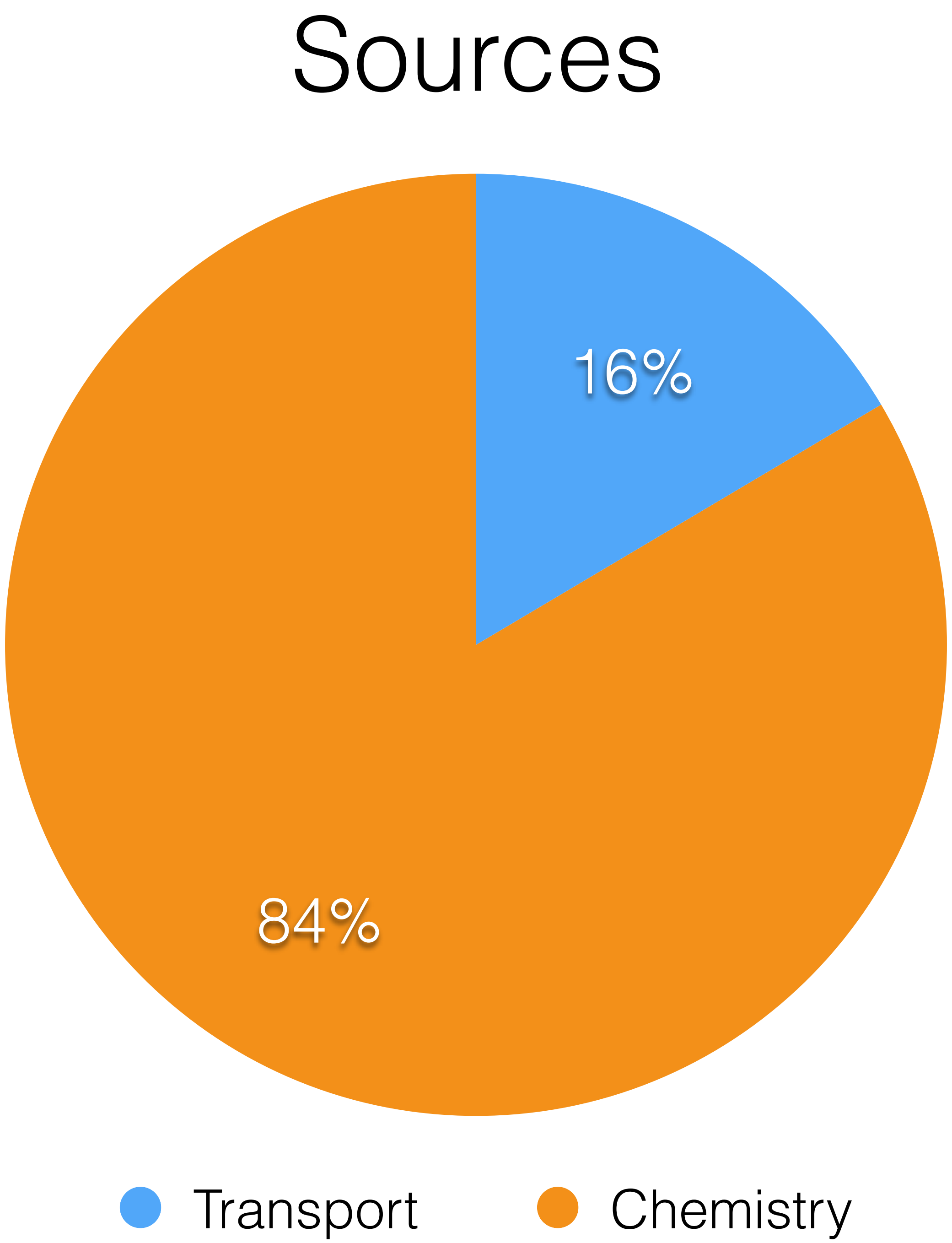


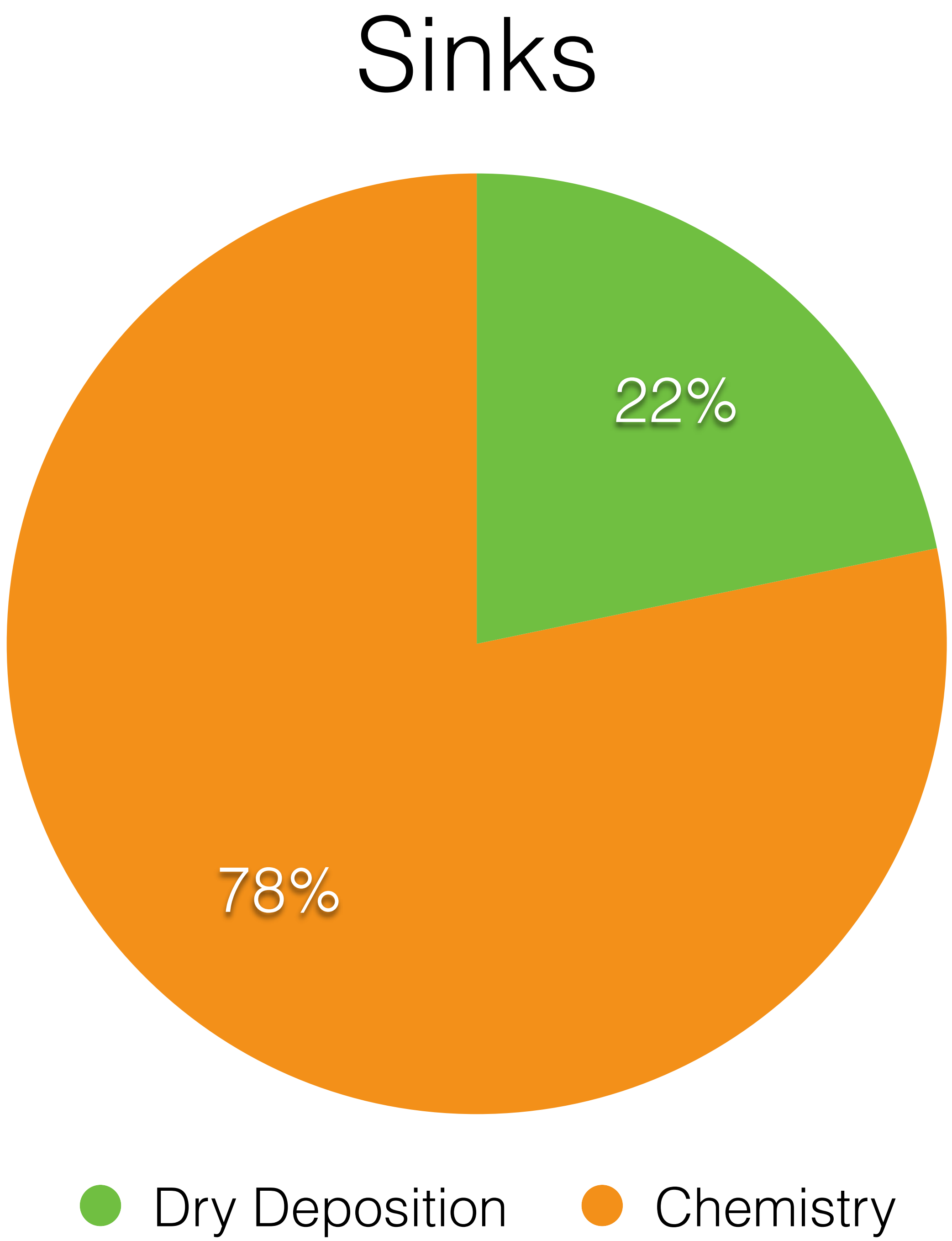
Simon et al., 2015

Where does tropospheric O_3 come from, and where does it go?



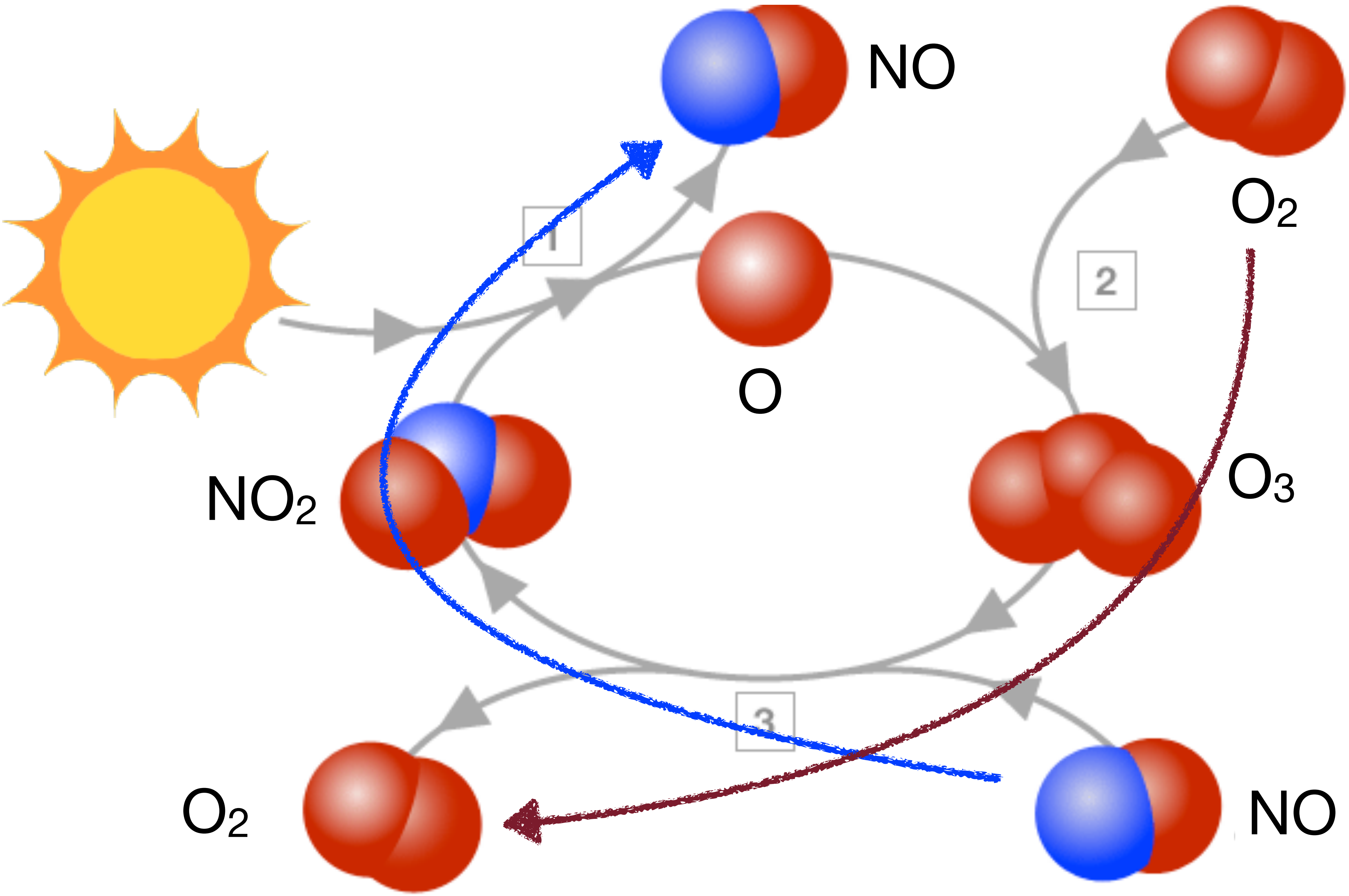
Tropospheric O_3: global sources and sinks



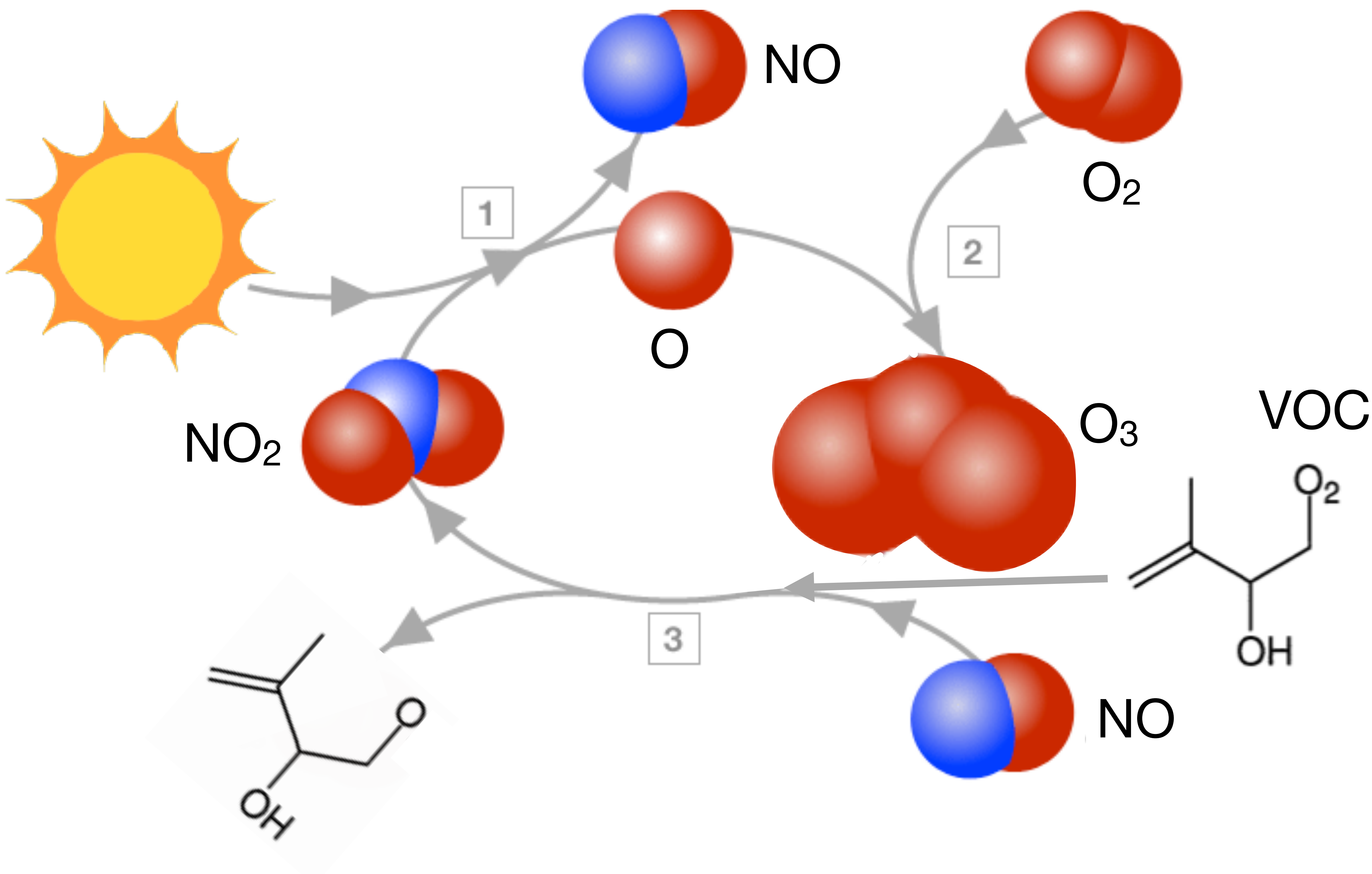


Jacob, 1999

Ozone (O_3) participates in a catalytic cycle involving O_2 and NO_x

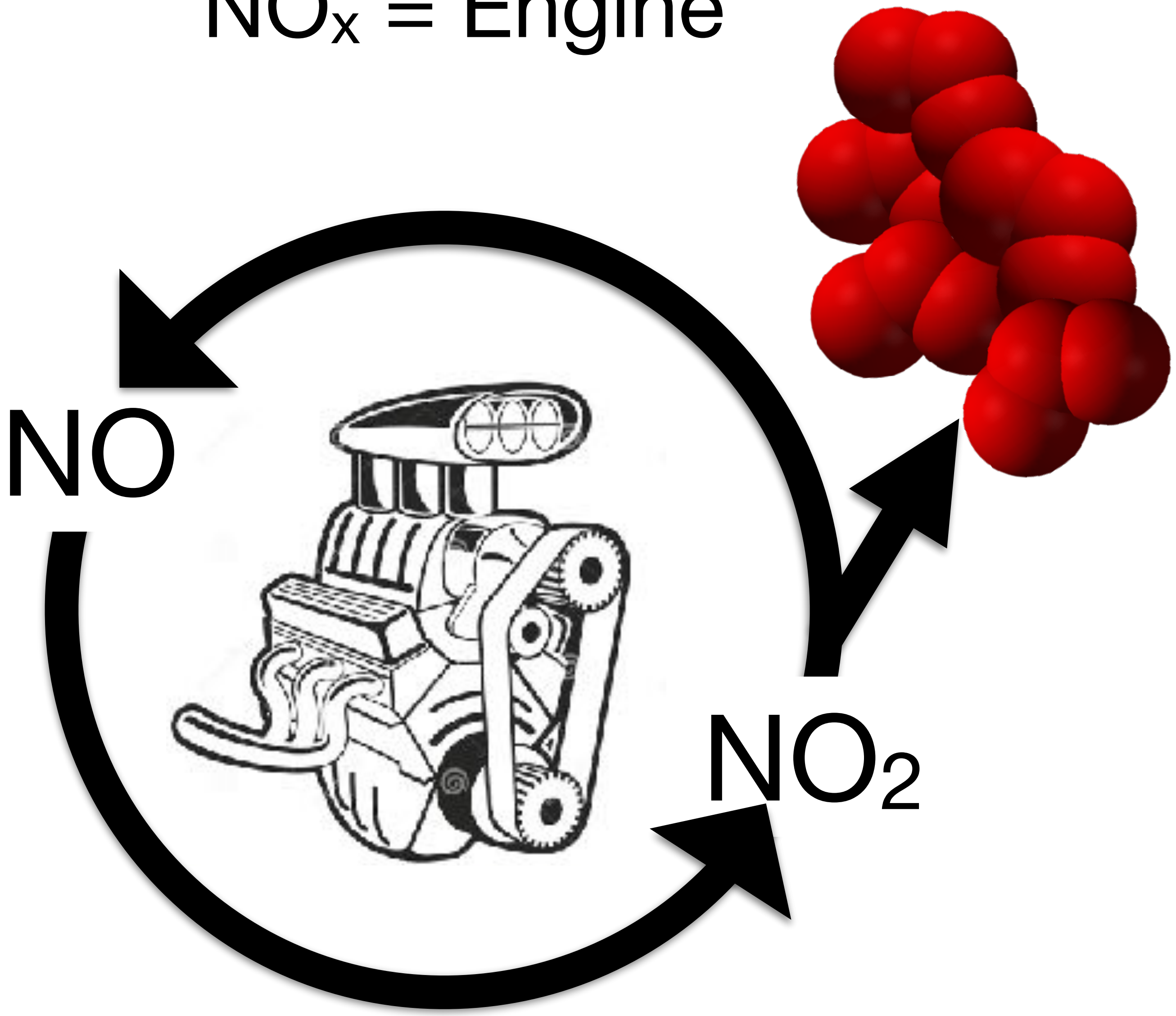


Oxidized VOCs compete for NO, replenishing NO_2 and elevating O_3 concentrations

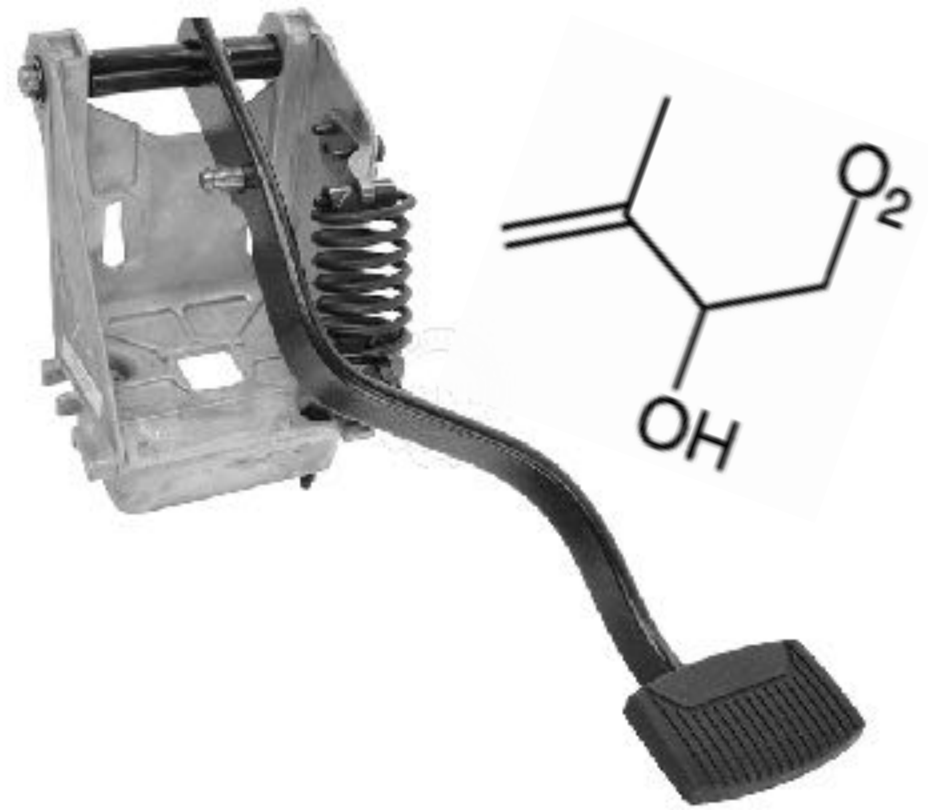


A simple engine metaphor

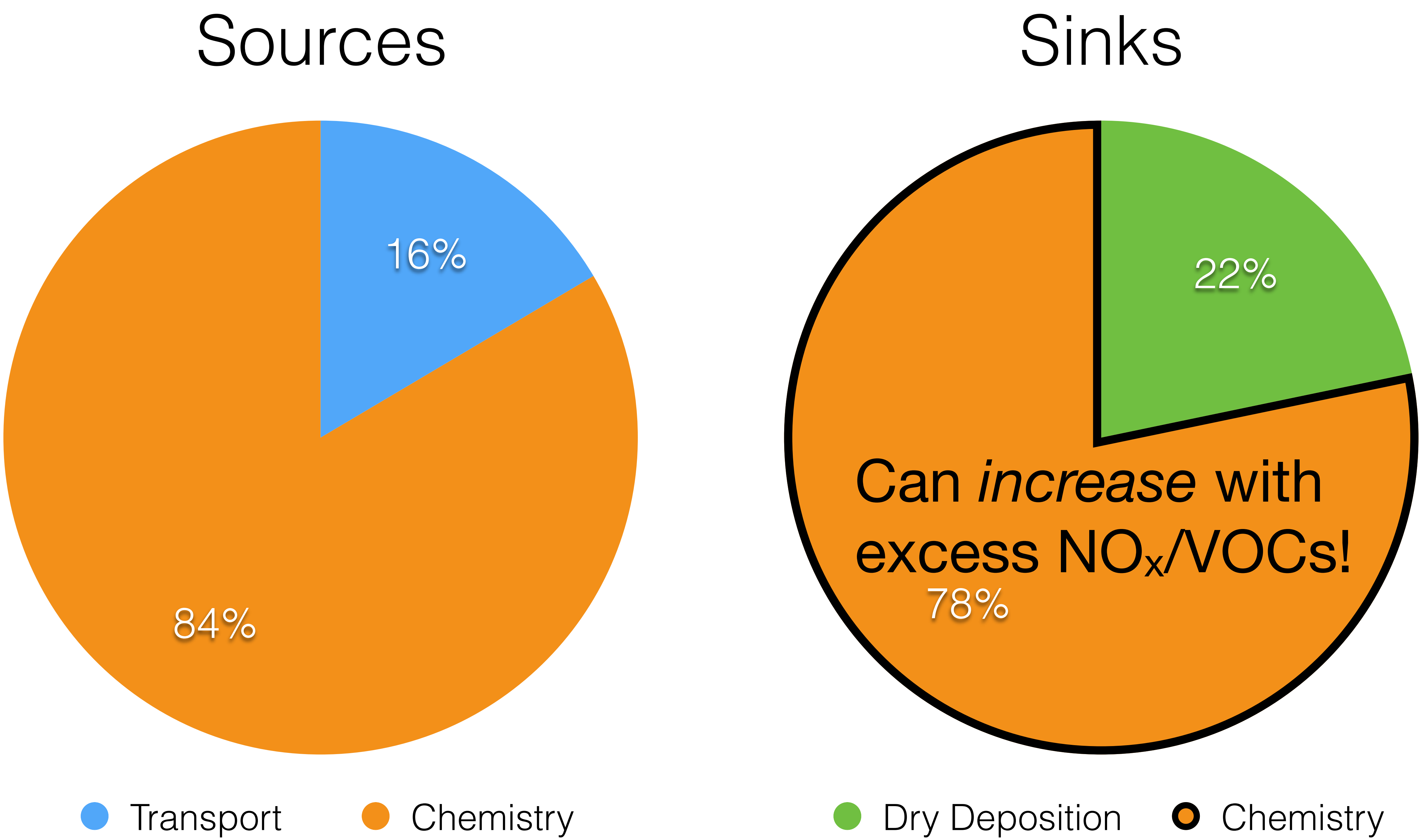
NO_x = Engine



VOCs = Clutch

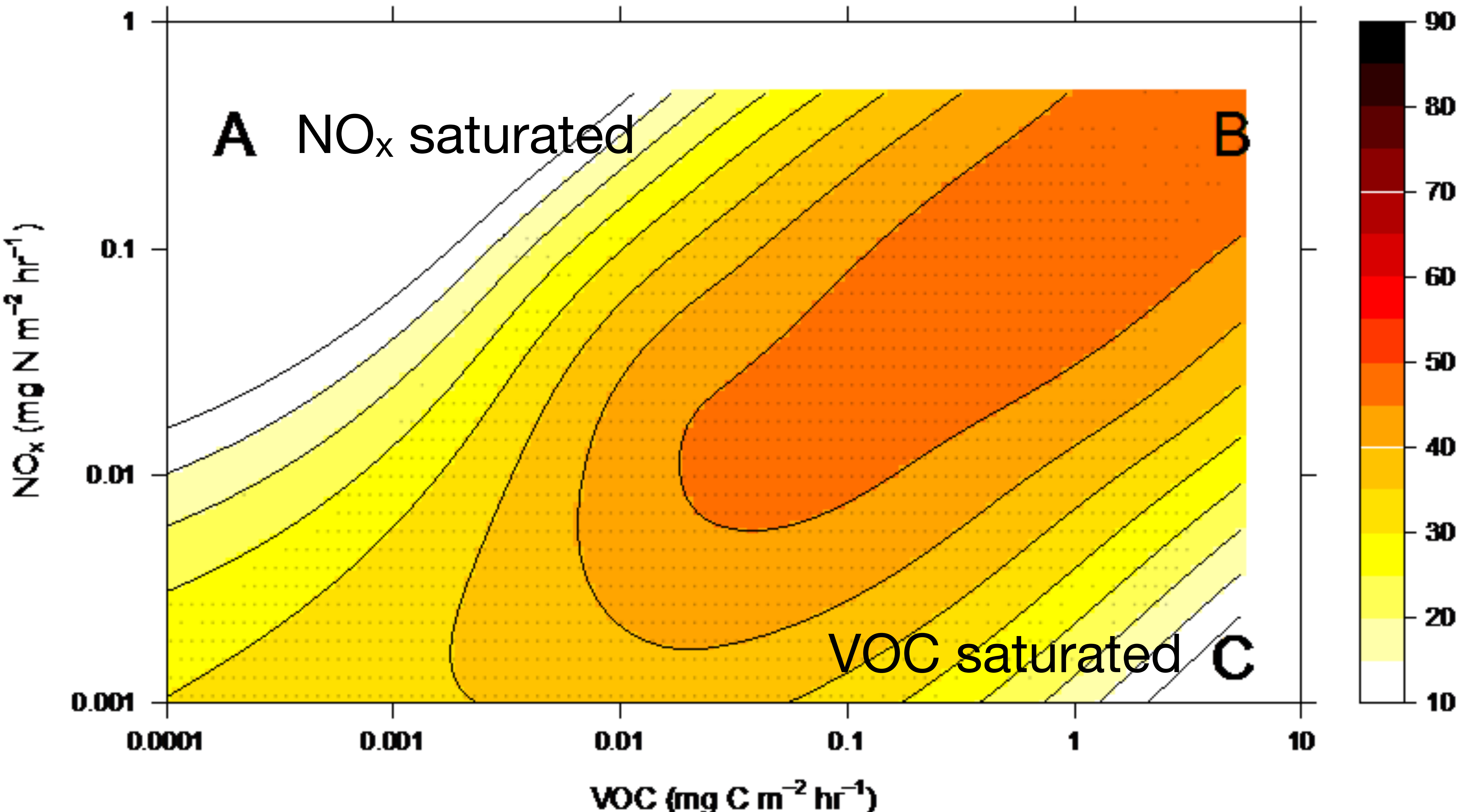


Tropospheric O_3: global sources and sinks



Jacob, 1999

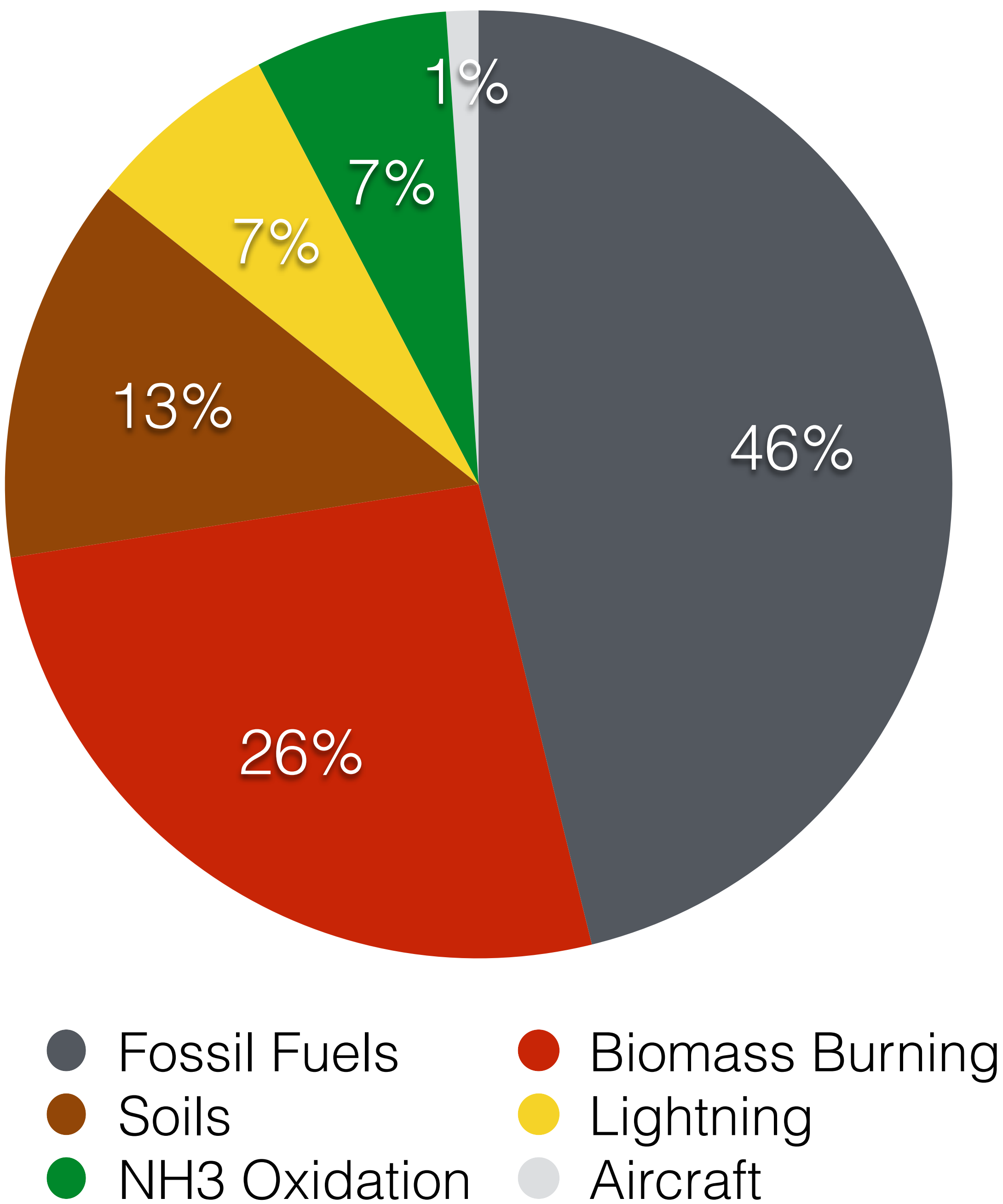
Modeled O_3 mixing ratio (ppb) vs. VOC and NO_x emissions



Monks et al., 2015

$NO_x = NO + NO_2$

Sources



Dominant Sink: Oxidation to HNO_3

Lifetime is relatively short — around one day

Jacob, 1999

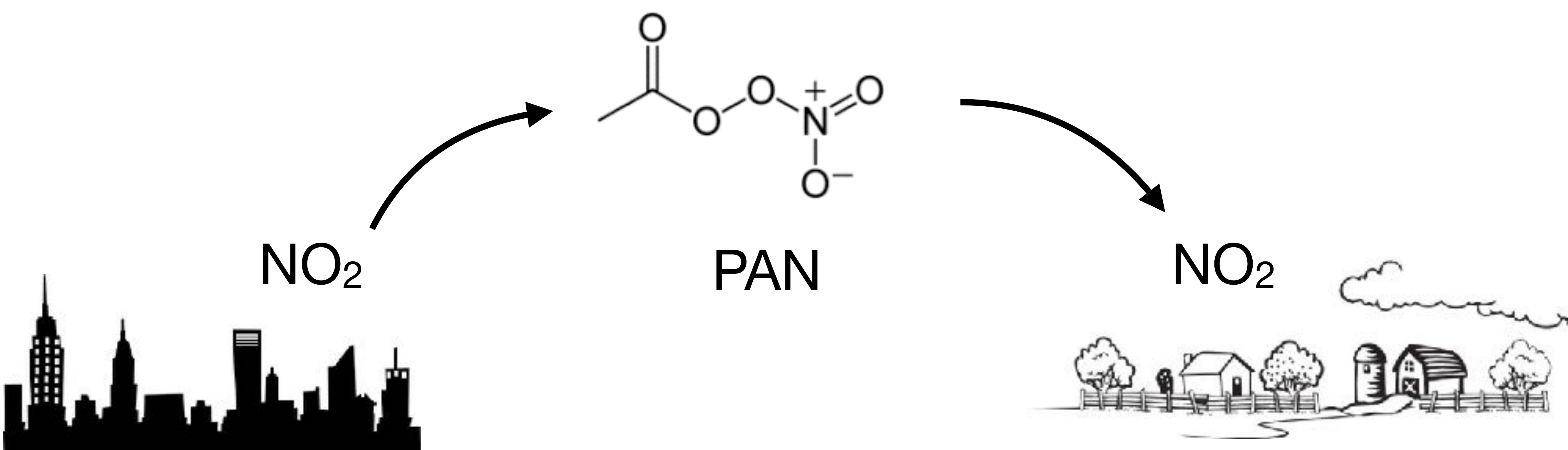
NO_x “reservoir species” can lead to longer-range transport

PAN

Forms from reaction with VOC oxidation products and NO_2

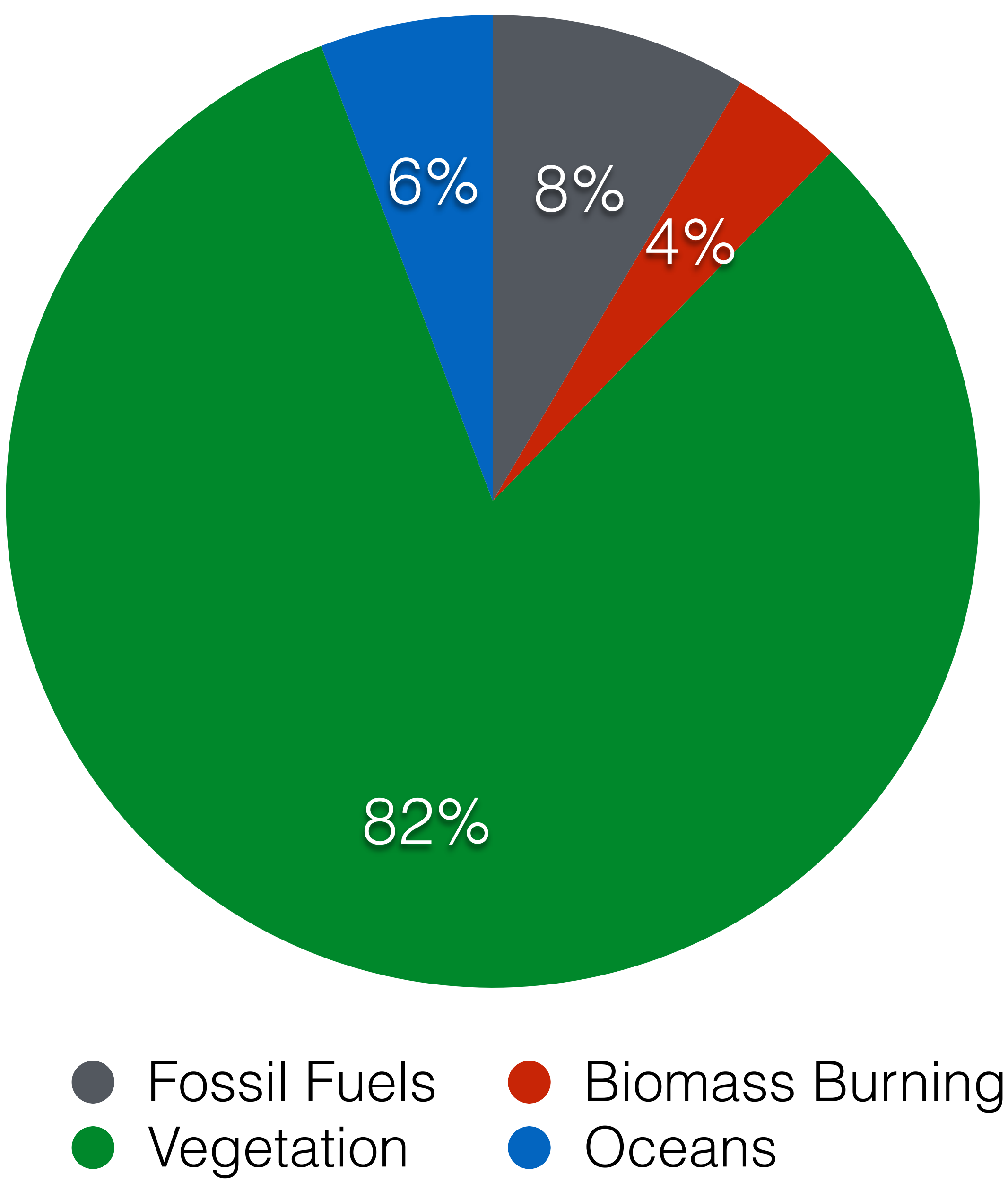
Lifetime can range from hours to months, depending on temperature

Effective transport mechanism for NO_x in middle/upper troposphere

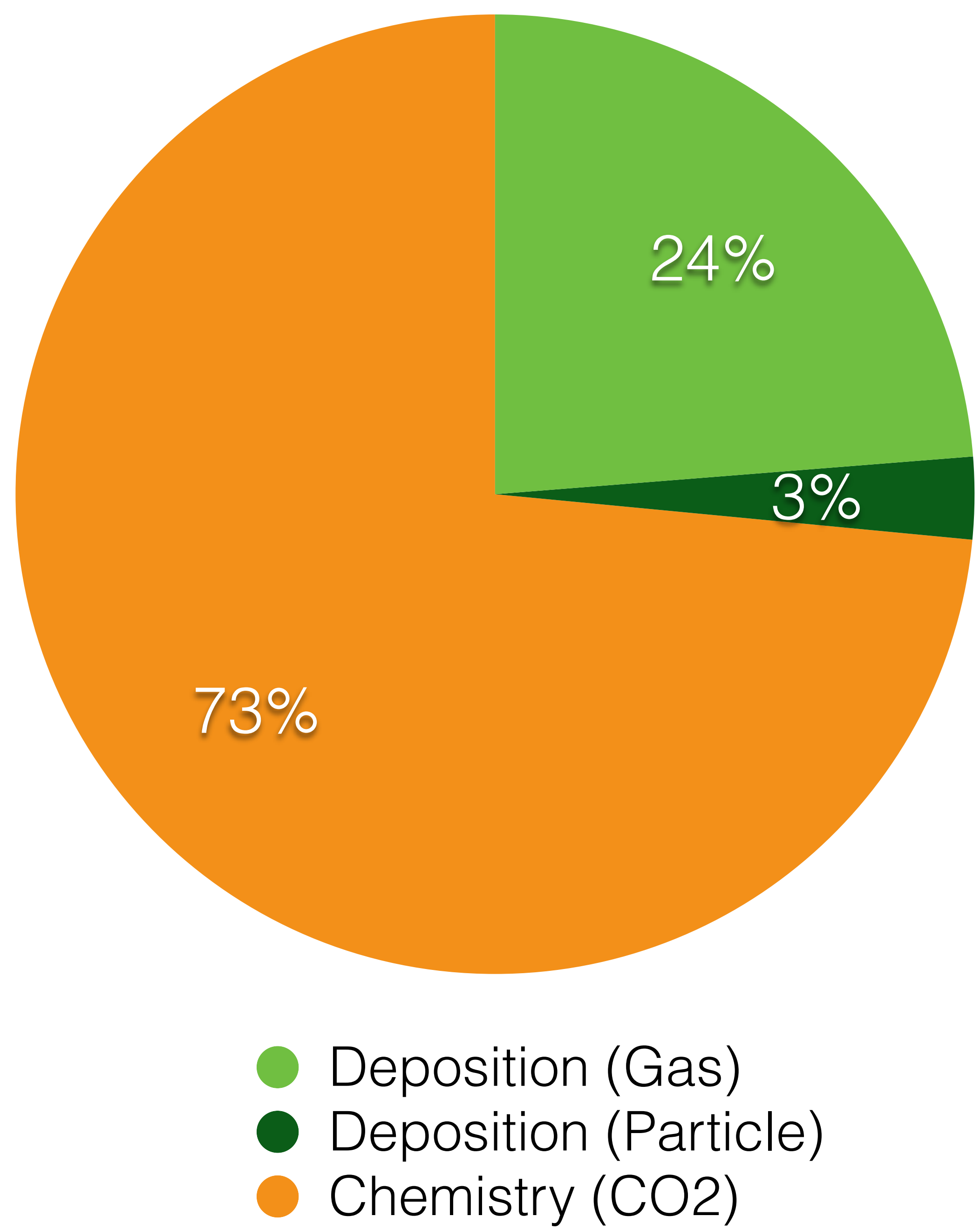


Non-methane VOCs

Sources

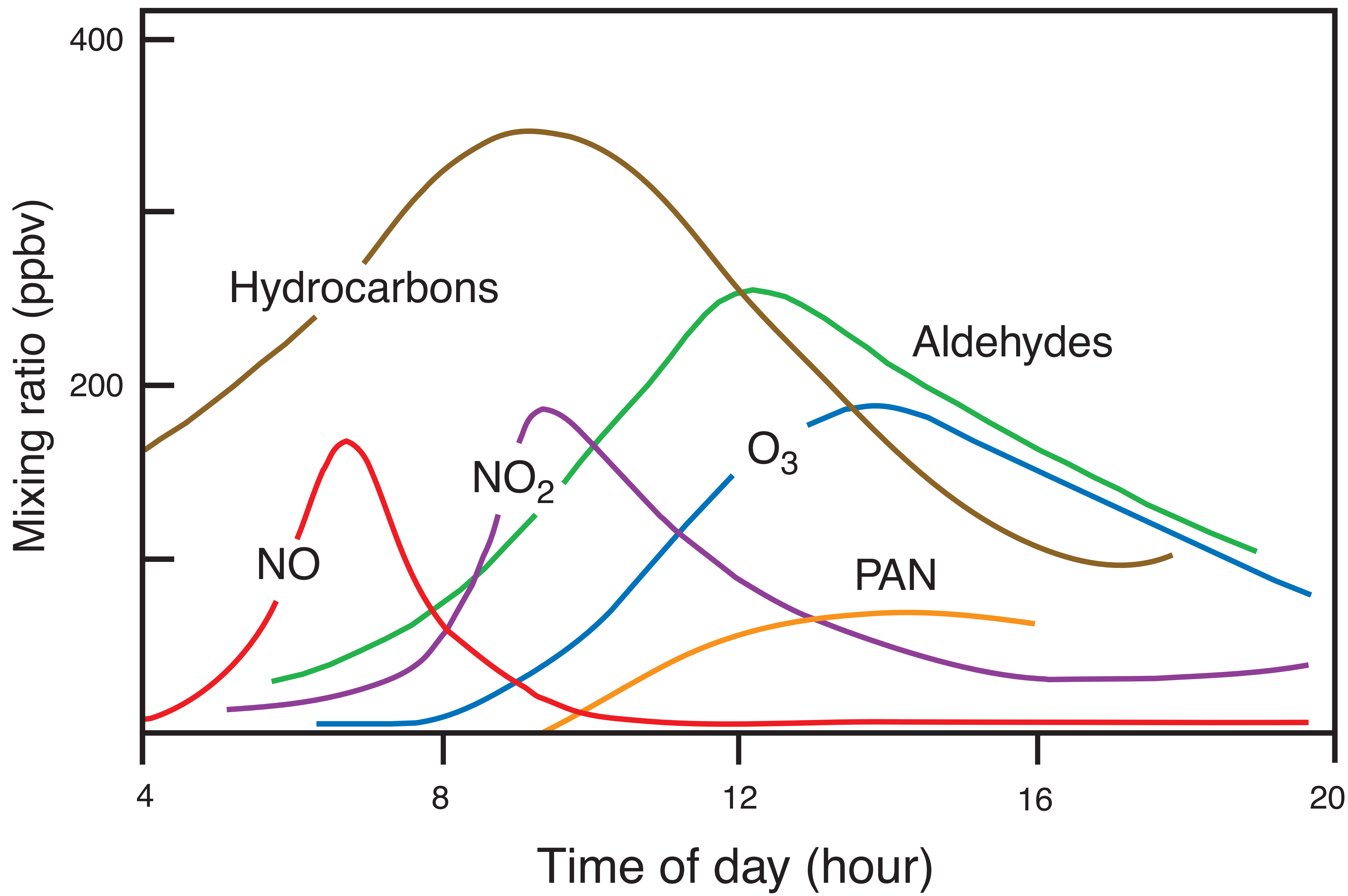


Sinks



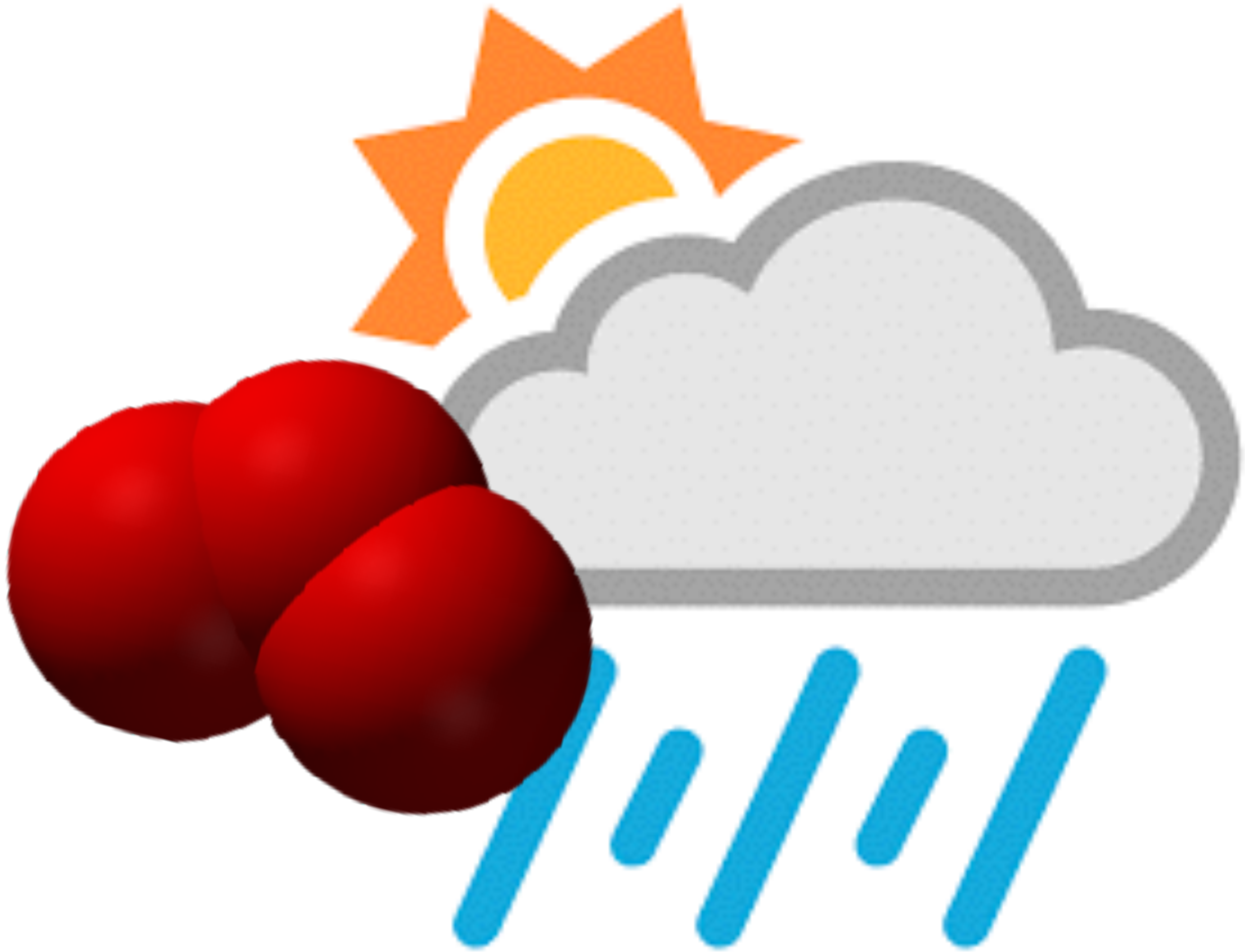
Safieddine et al., 2017

Typical urban O_3/precursor diurnal cycle

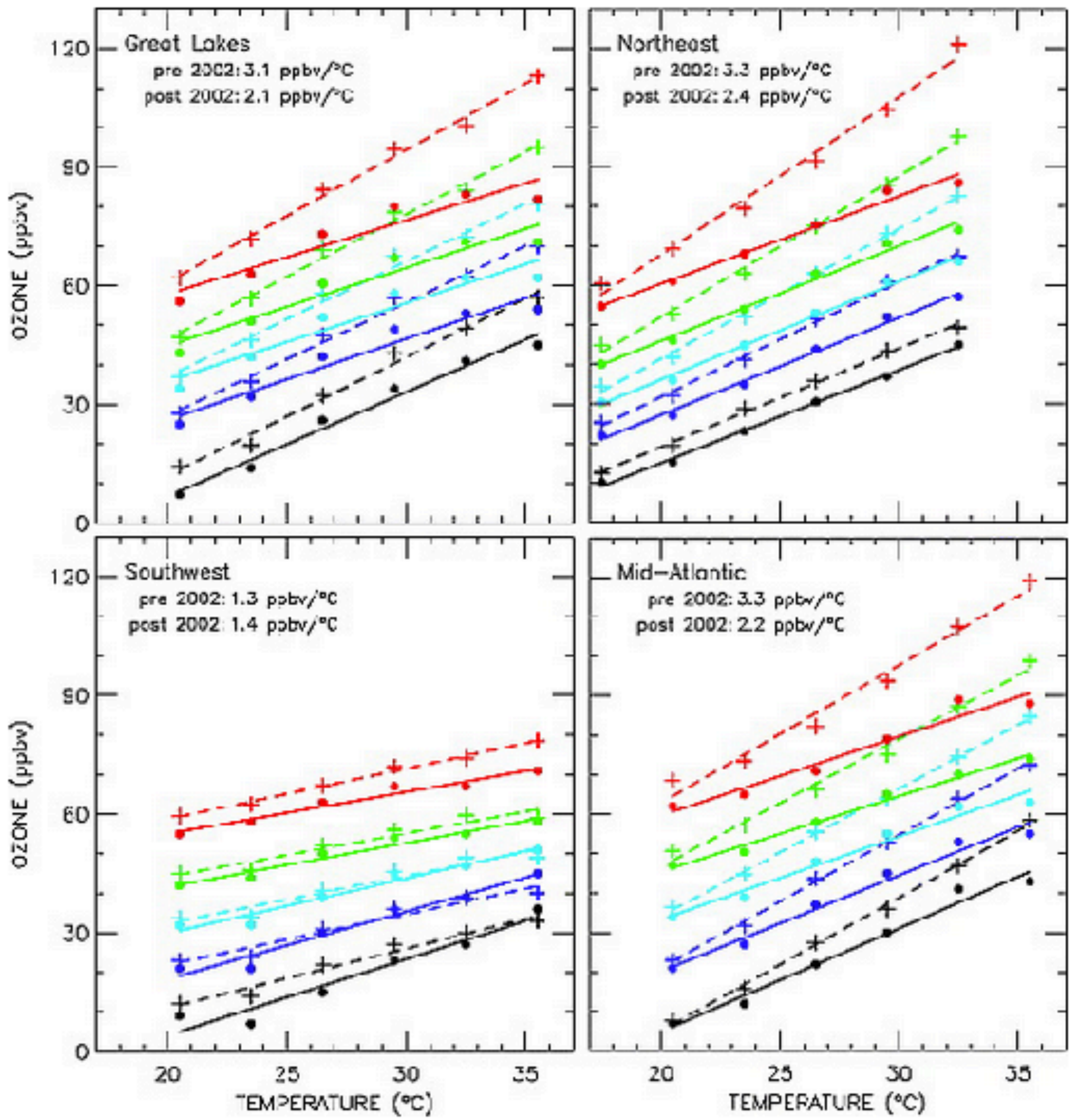


Wallace and Hobbs, 2006

The role of atmospheric dynamics

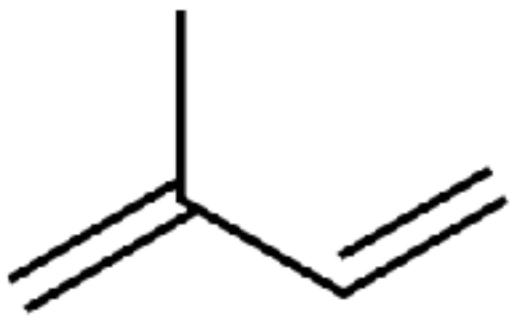


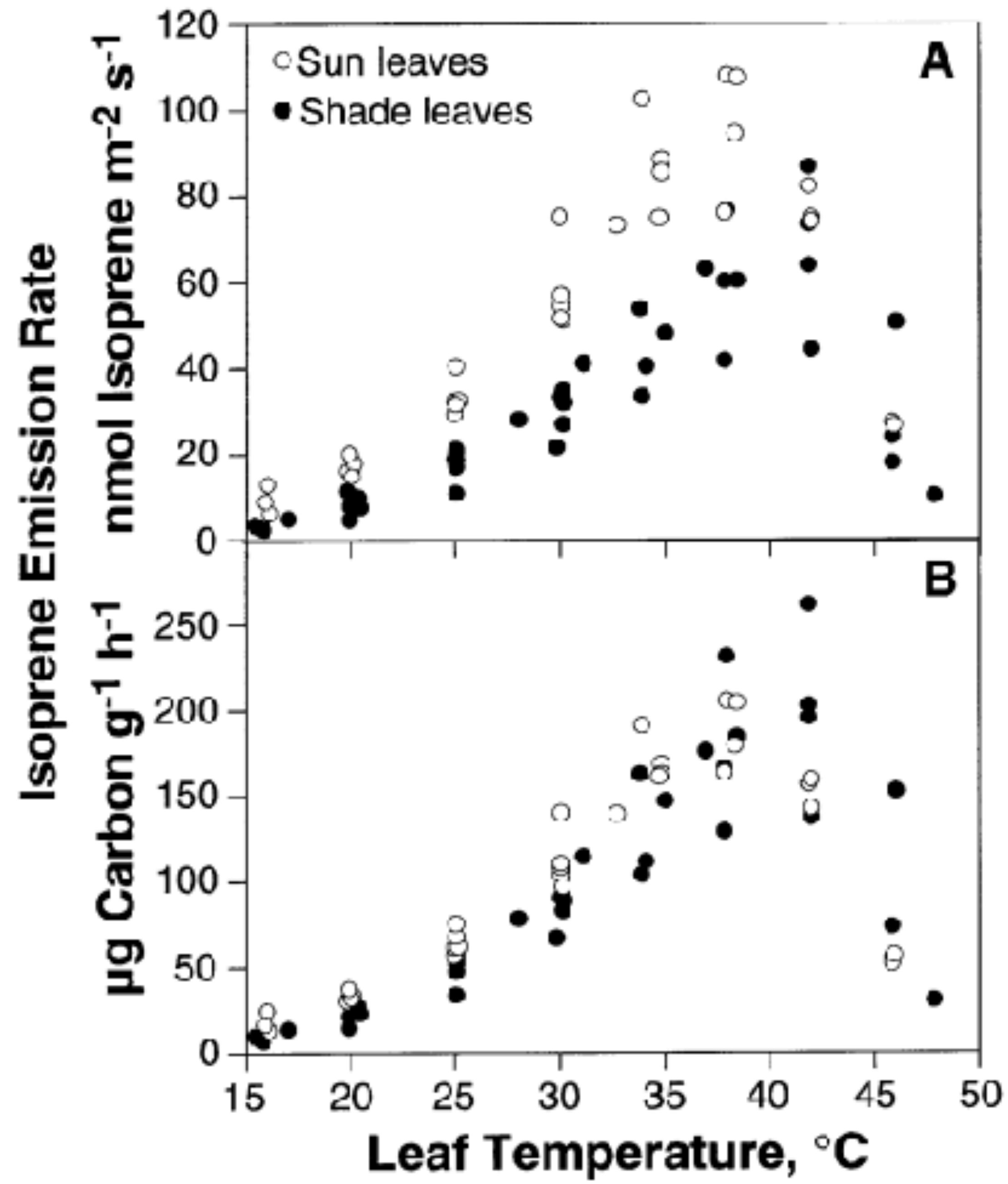
Daily O_3 has a known positive correlation with daily temperature



Bloomer et al., 2009

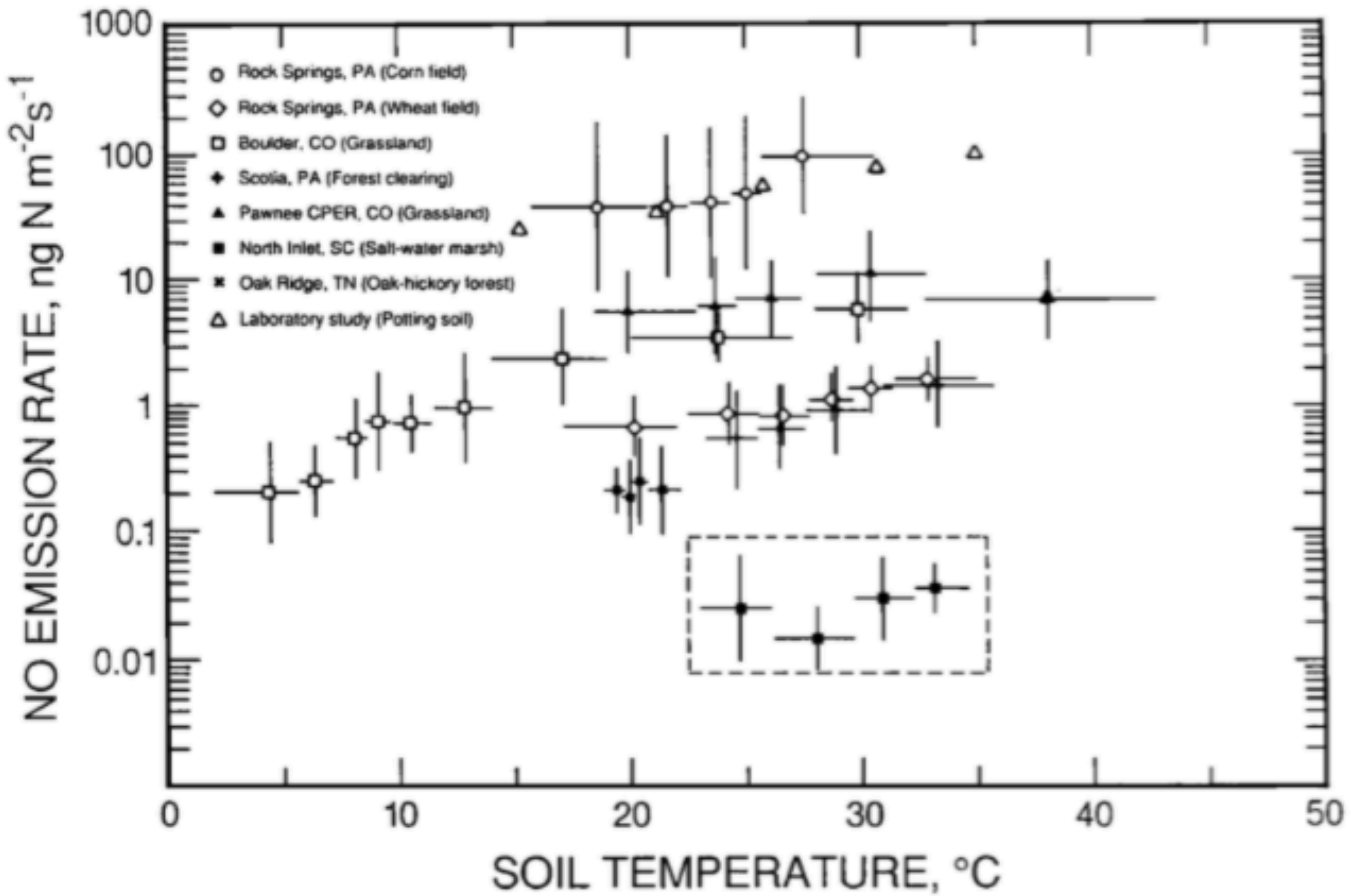
Higher temperatures → more isoprene



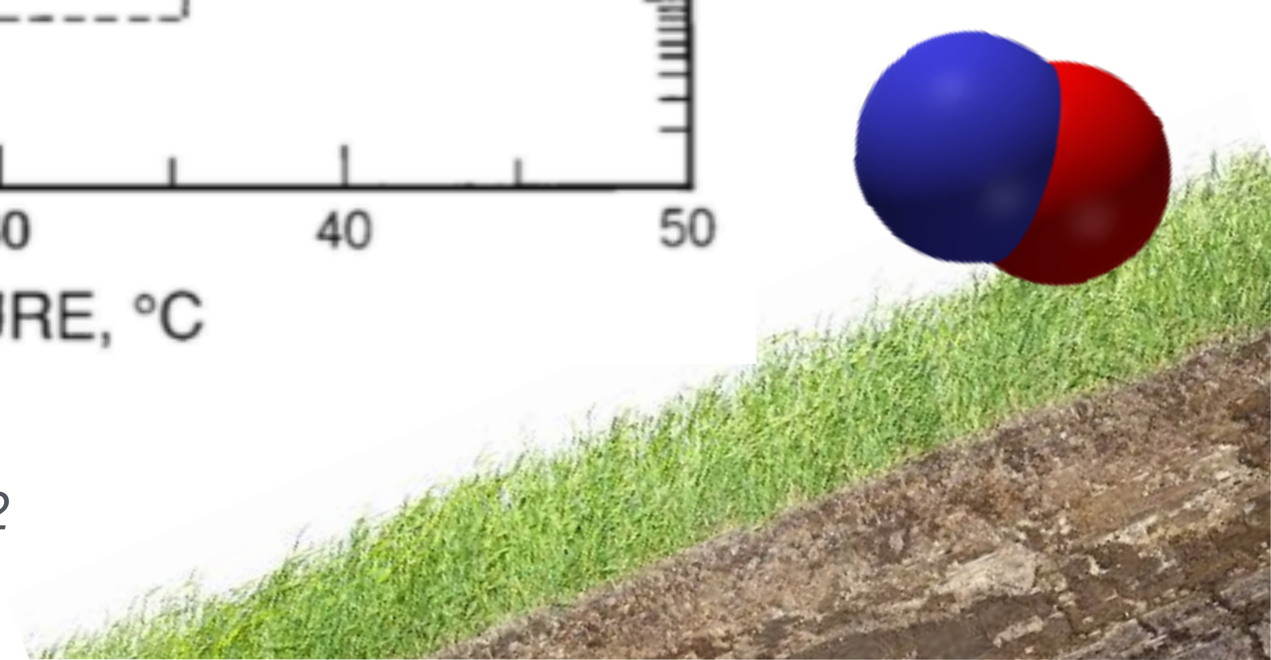


Harley 1997

Higher temperature → more soil NO_x



Williams et al., 1992

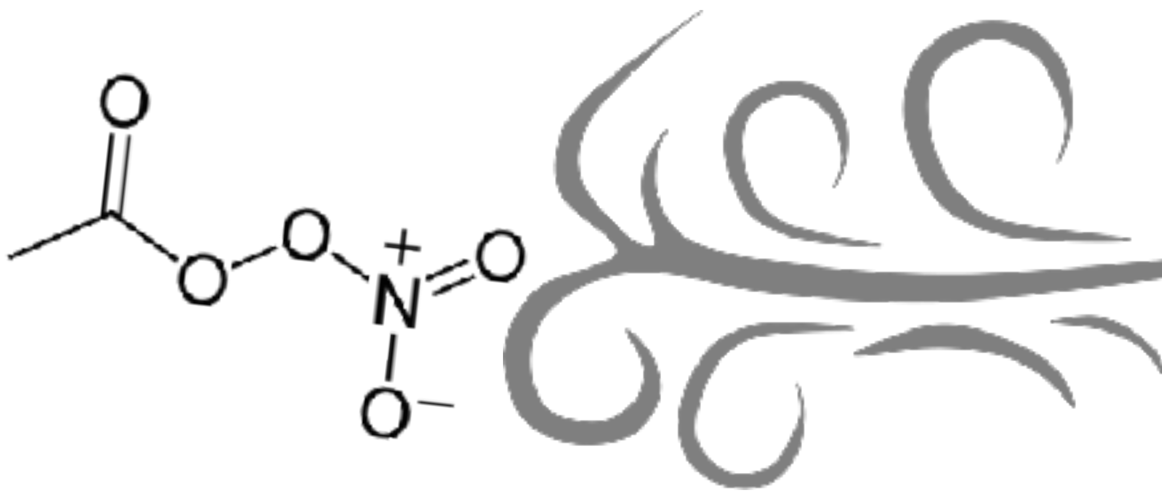


Higher temperature → shorter PAN lifetime

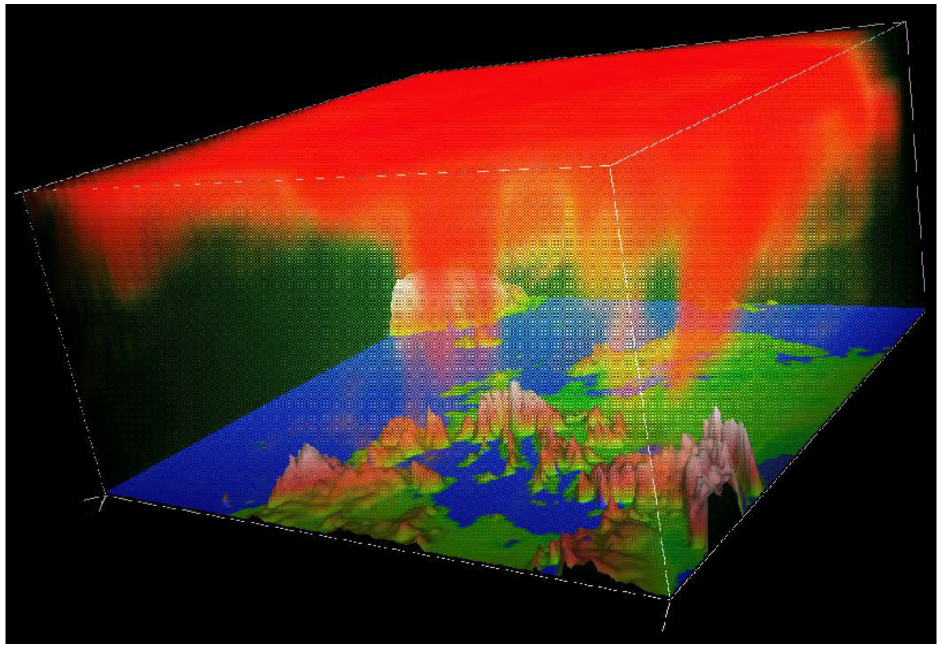
Table 7. Temperature and corresponding lifetime k^{-1} of PAN

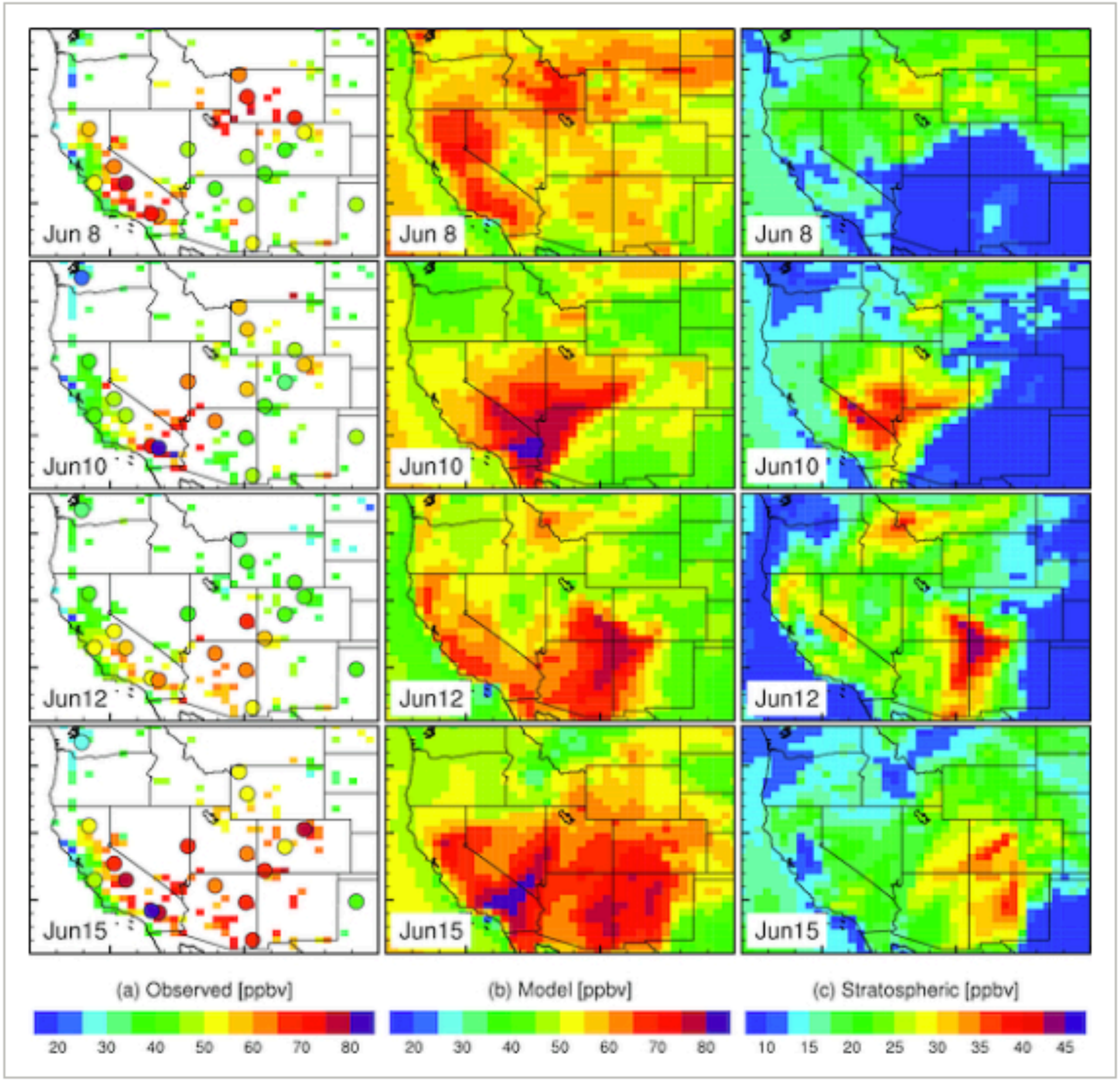
Temperature (°C)	k^{-1} (h)
−15	660.7
−10	247.7
−5	96.3
0	38.8
5	16.1
10	6.9
15	3.1
20	1.4
25	0.65

Wunderli & Gehrig, 1991



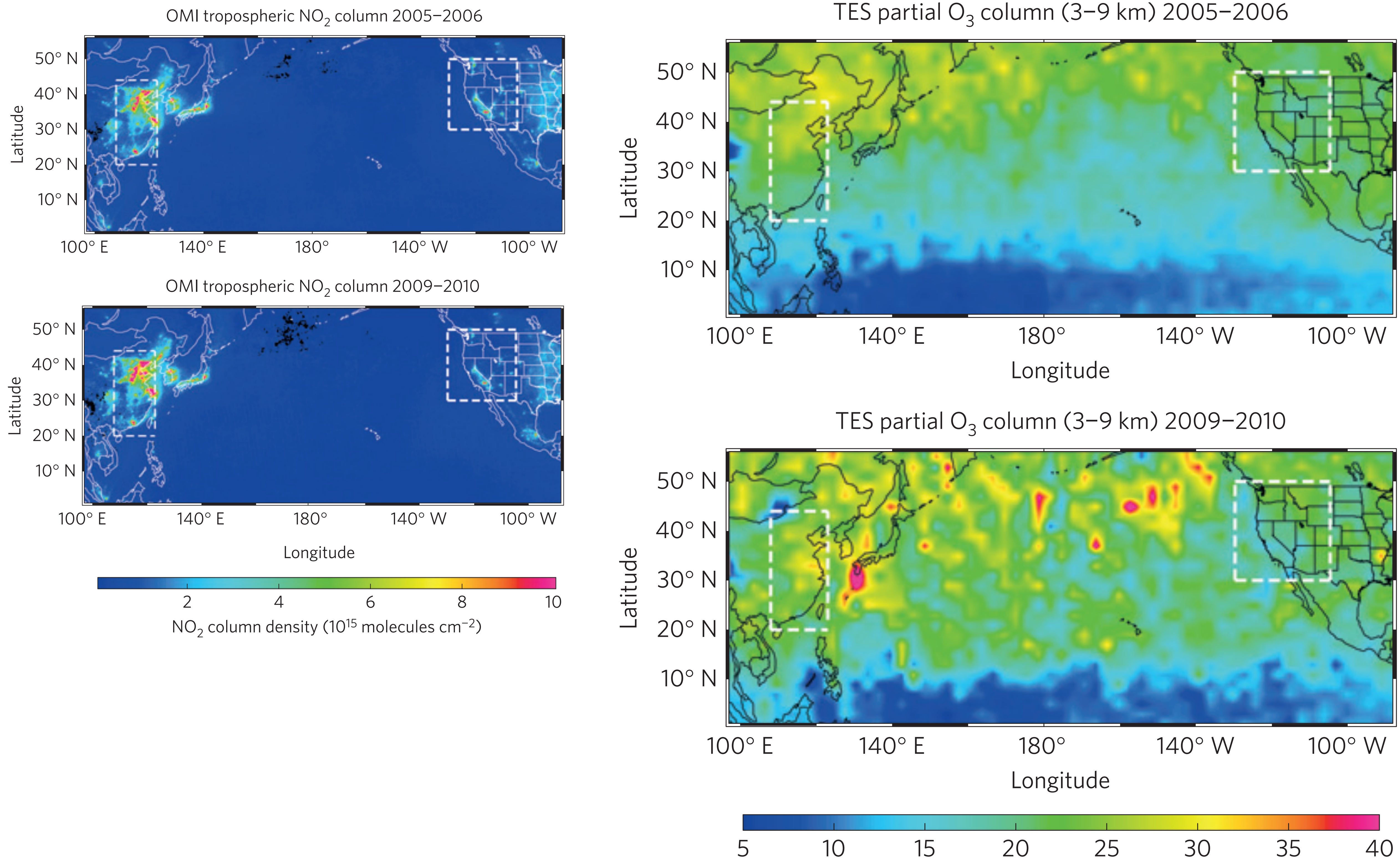
Stratospheric intrusions can pull O_3 down to surface, especially at higher elevations





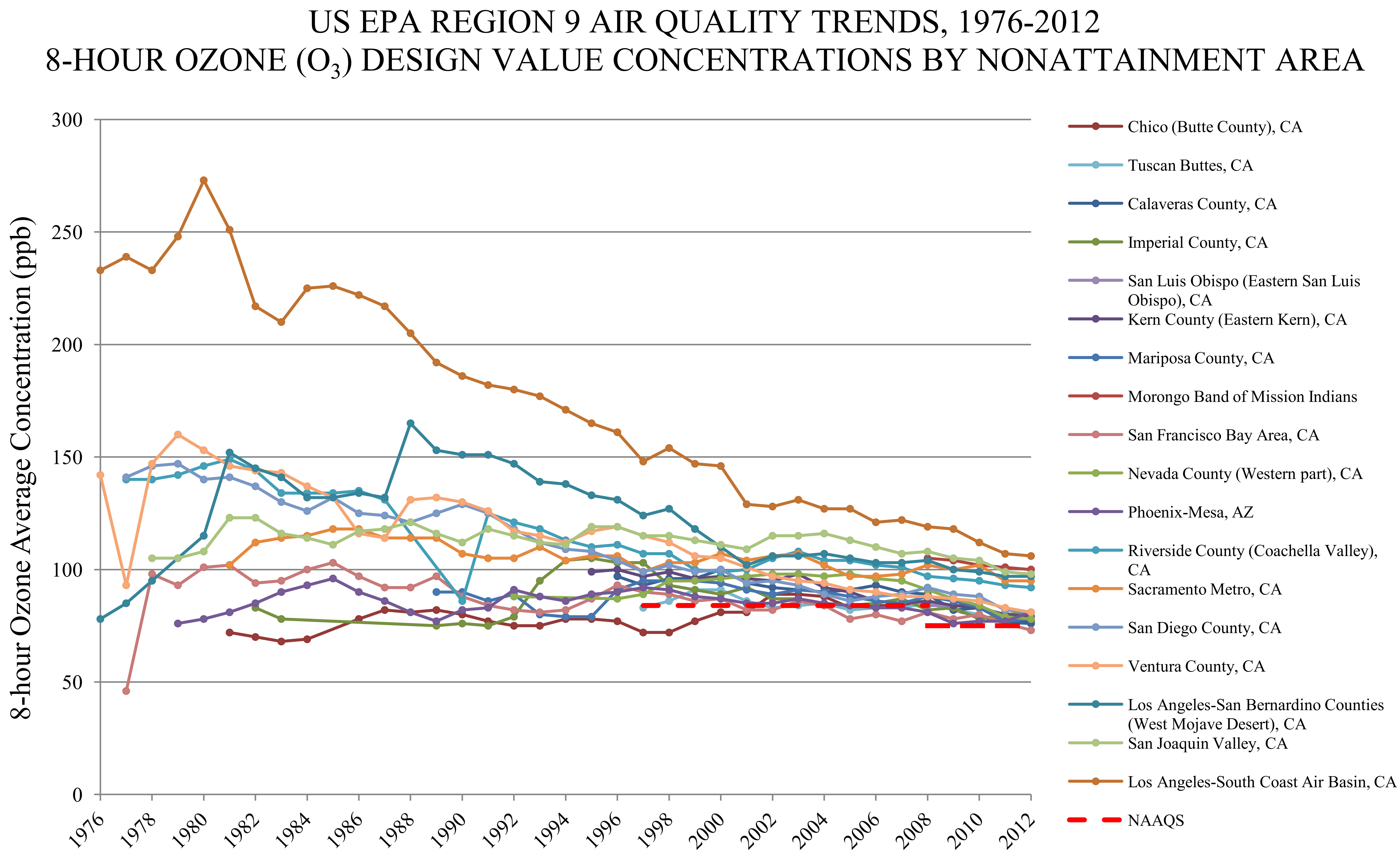
Lin et al., 2012

O_3 lifetime is sufficient for long-range transport under certain conditions

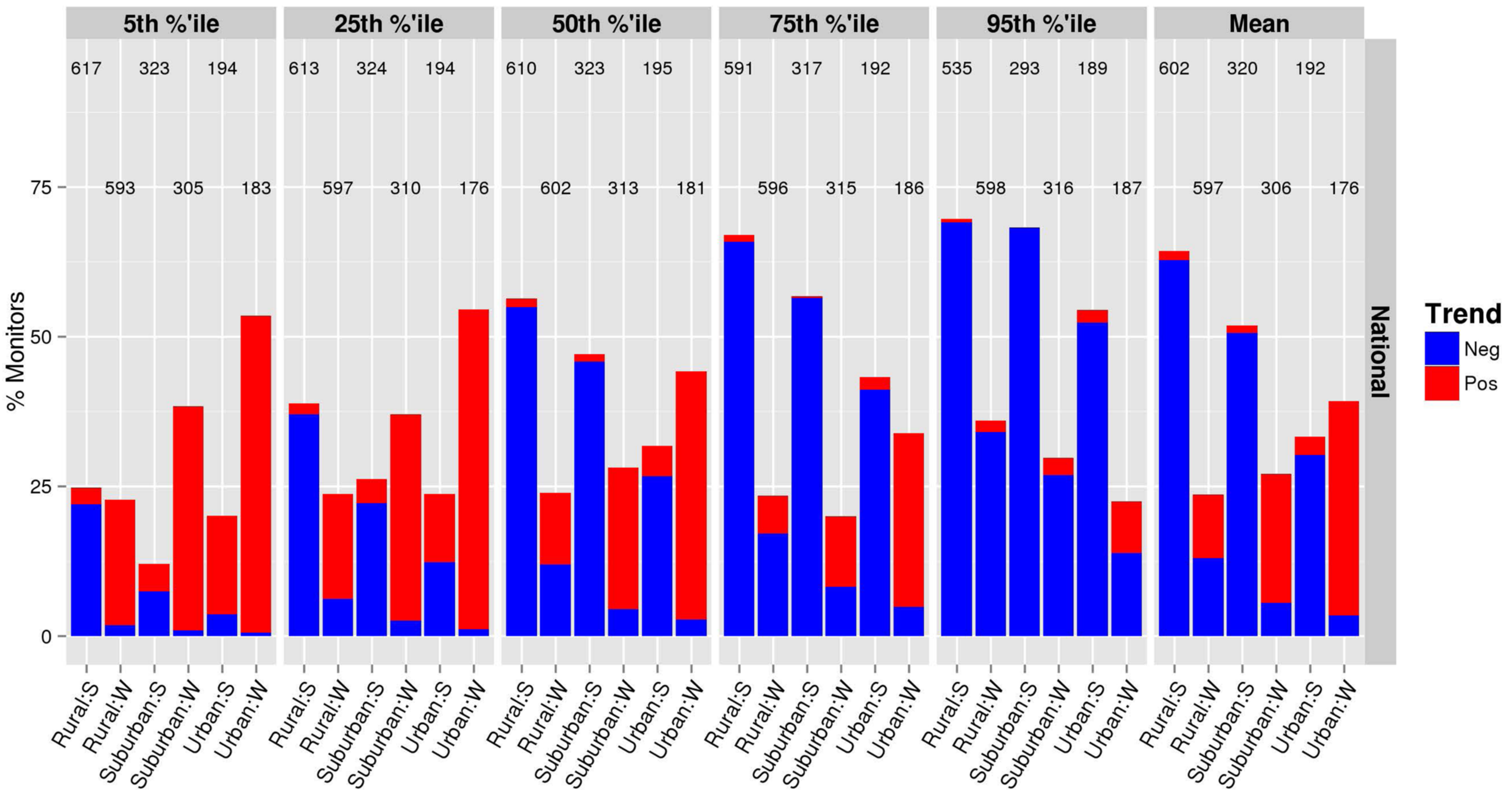


Verstraeten et al., 2015

Overall trend at most polluted regions has been moving in the right direction



Observed trends show significant improvements in the reduction of extreme summertime values (1998-2013)



Simon et al., 2015

Future improvements will depend on comprehensive and region-specific understanding of local drivers