Ozone in the UK

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4th March 2020 SQAD Glasgow

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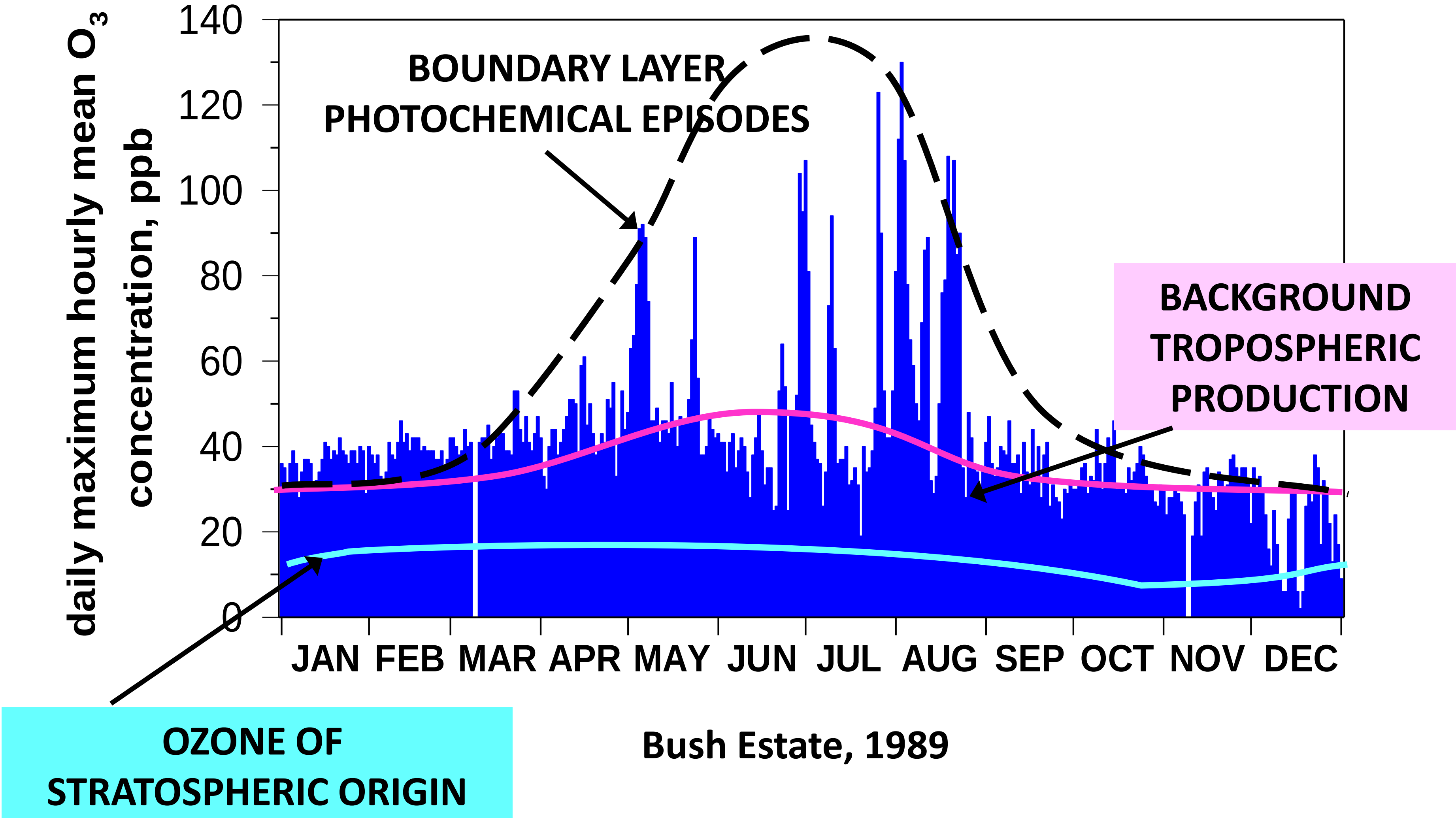
NERC SCIENCE OF THE ENVIRONMENT

Outline

- A little background on ozone
- Effects on human health and ecosystems?
- Ozone concentrations in the UK
- Trends
- Future Ozone



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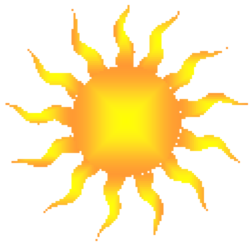

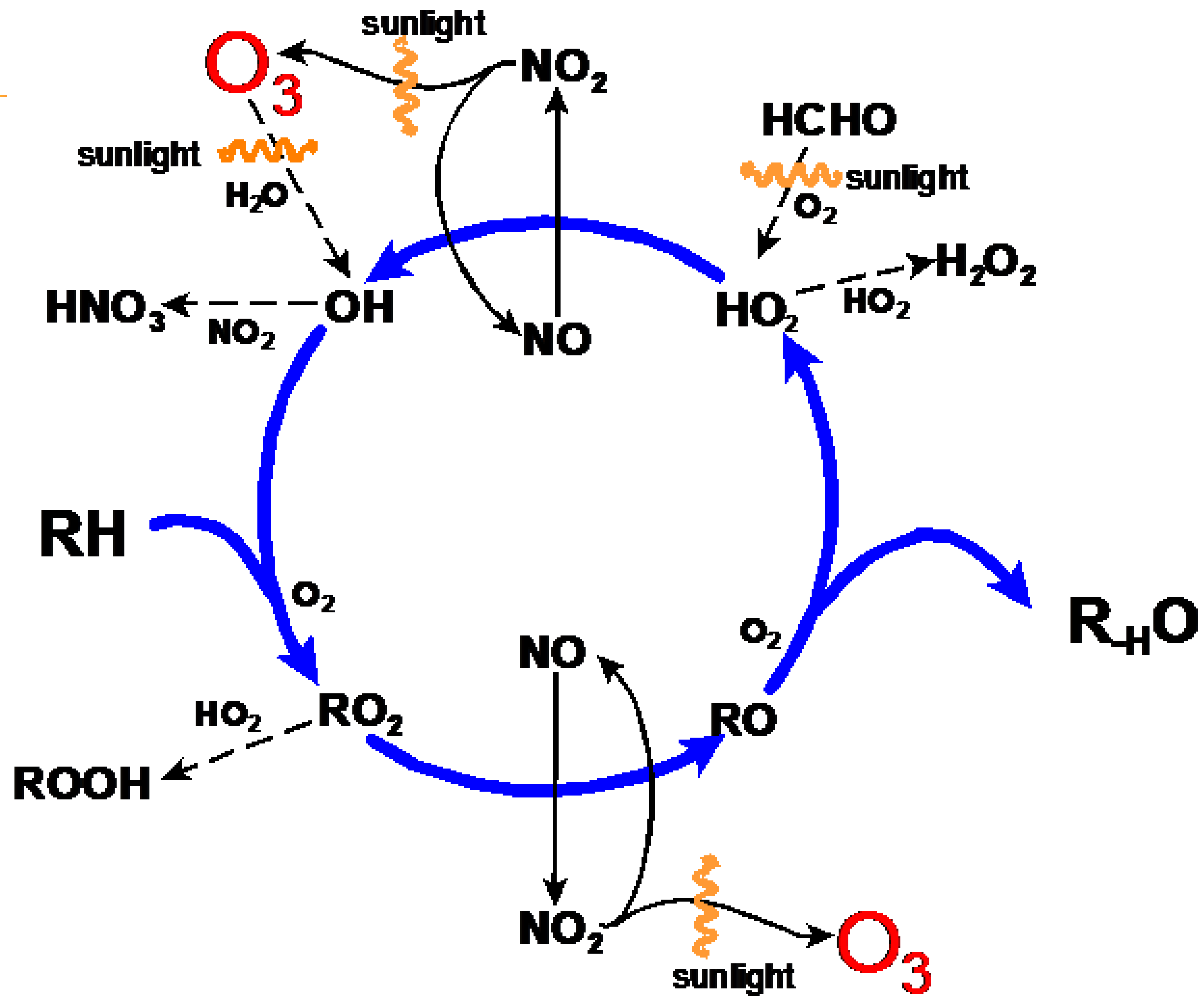

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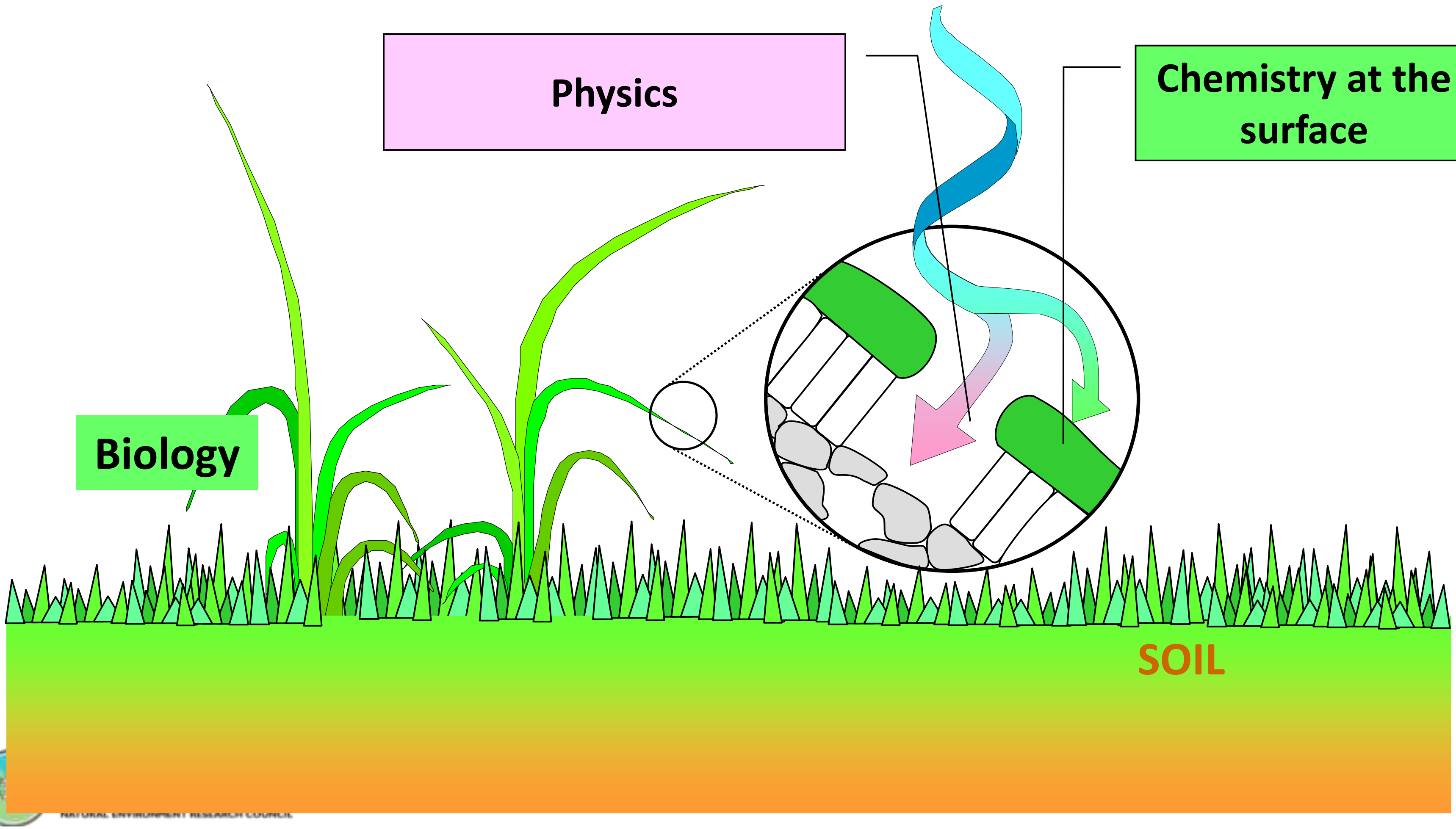
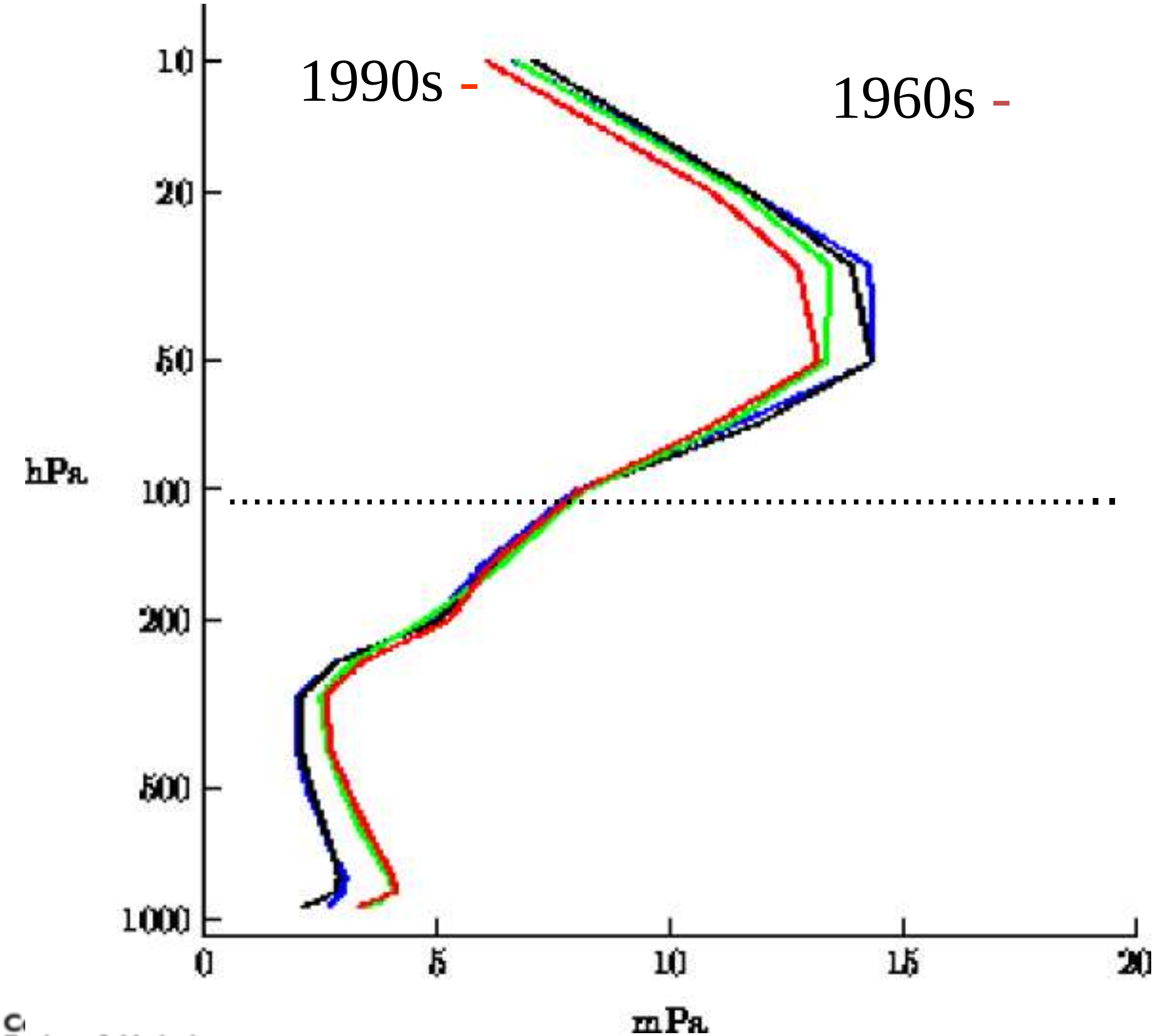
Exchange processes at the Earth's surface O_3……





stratosphere

…..10 km……

tropopause

troposphere

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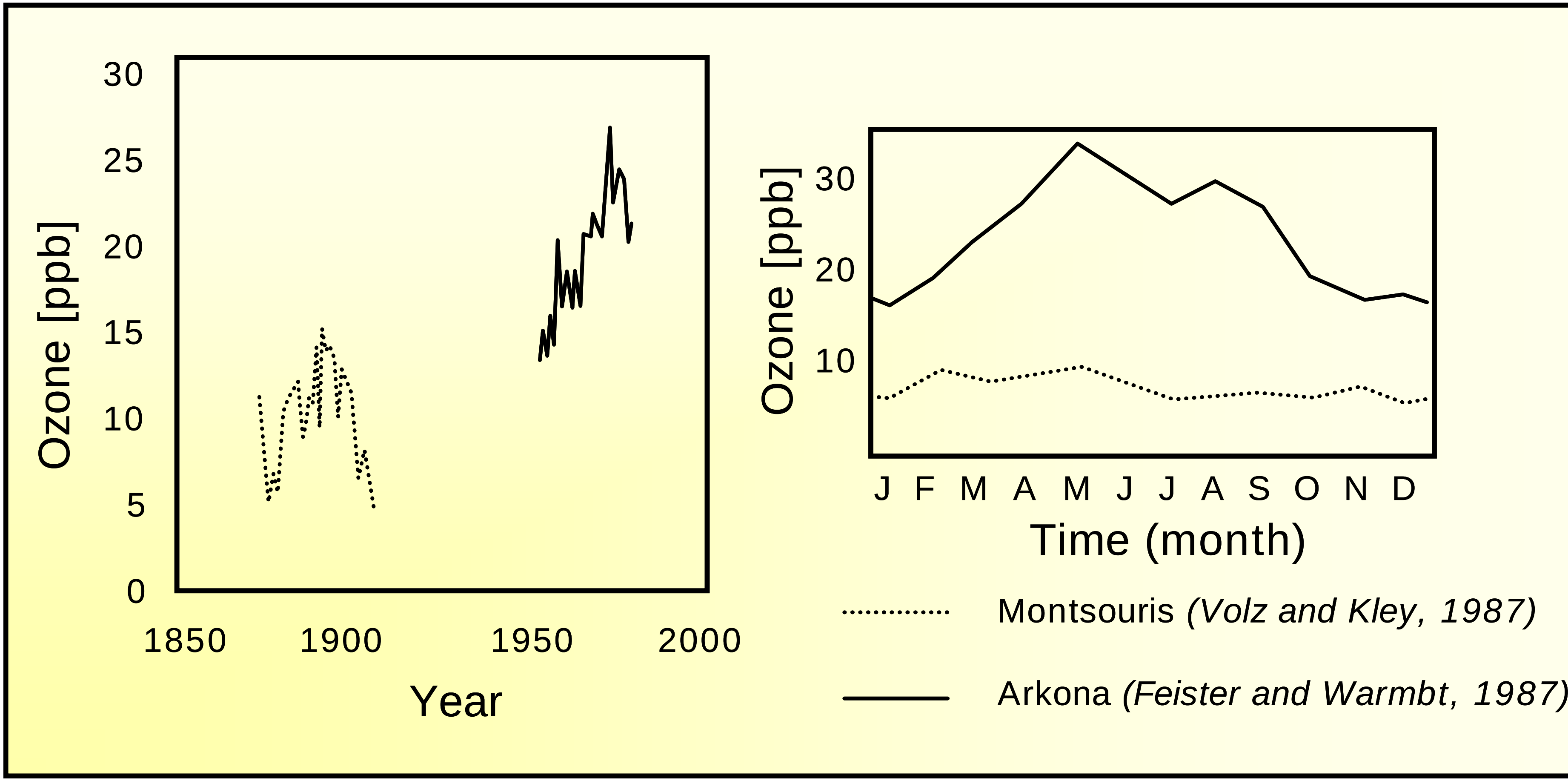
How has ozone changed since 1750?



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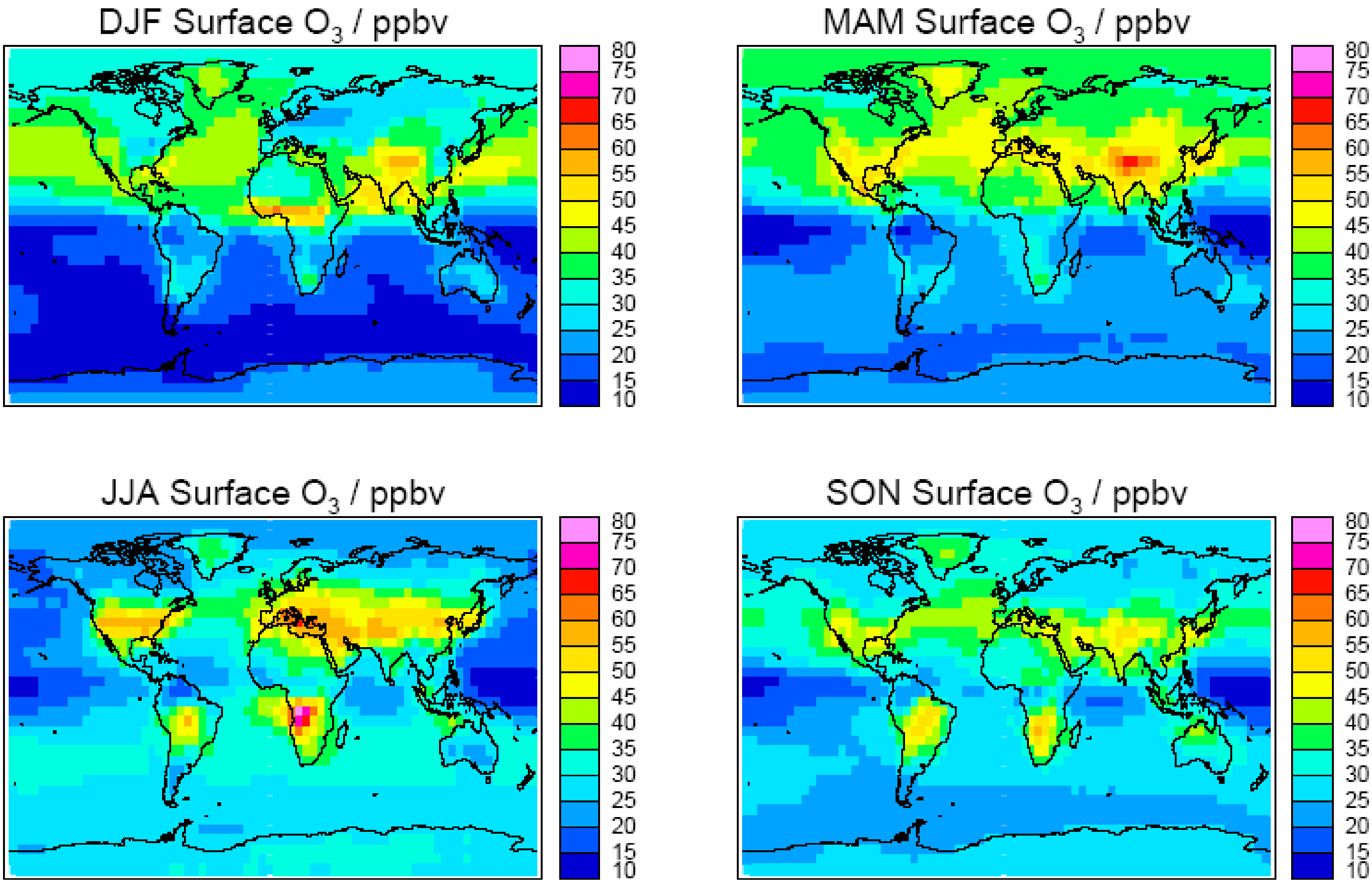
O_3 concentrations have roughly doubled since the early 1900's.

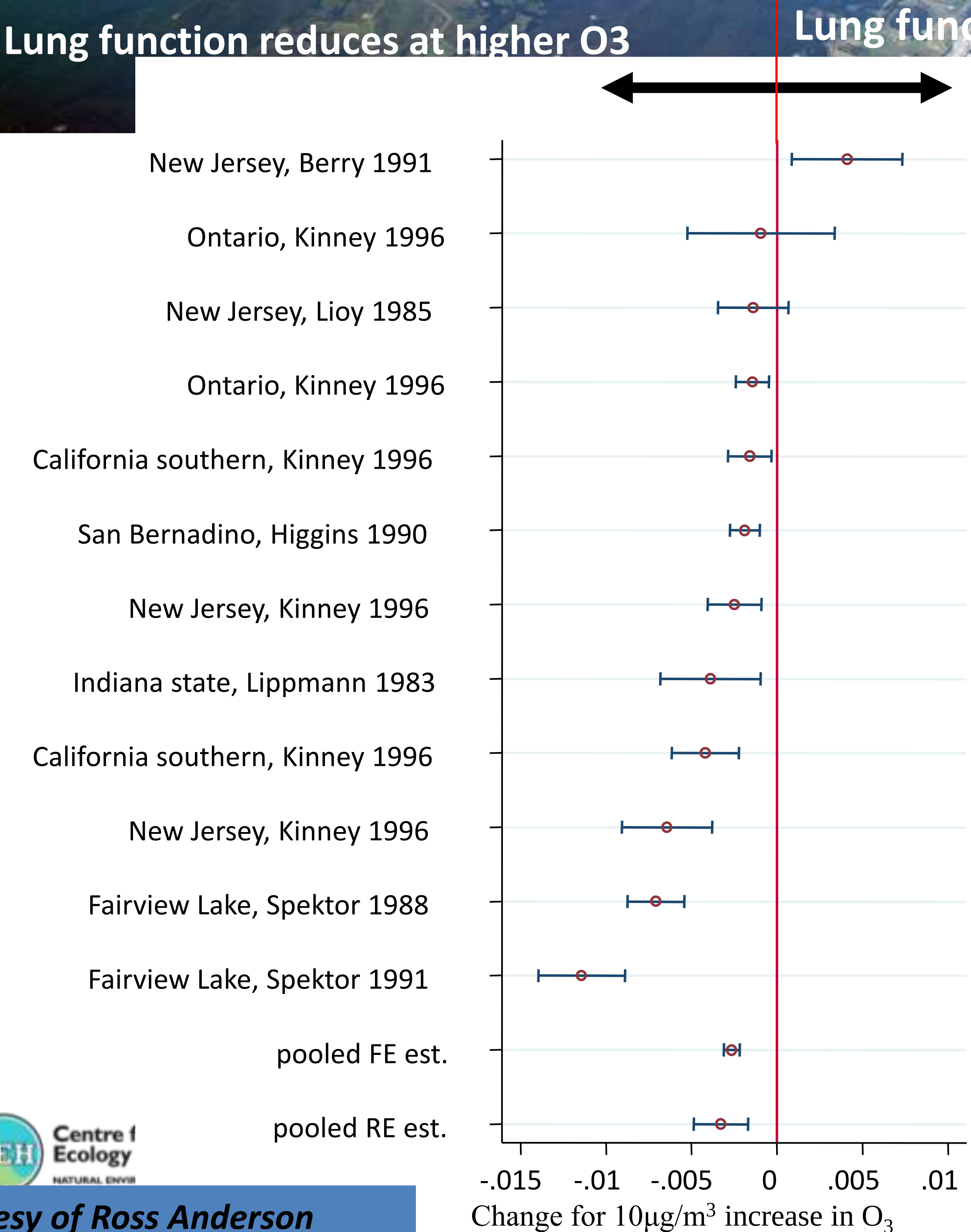
Seasonal variation of surface ozone (Stevenson et al 2006)



Ensemble mean of 26 ACCENT Photocomp models

Effects

- Human Health
- Vegetation
- Climate



Ozone reduces the lung function of healthy children

Courtesy of Ross Anderson

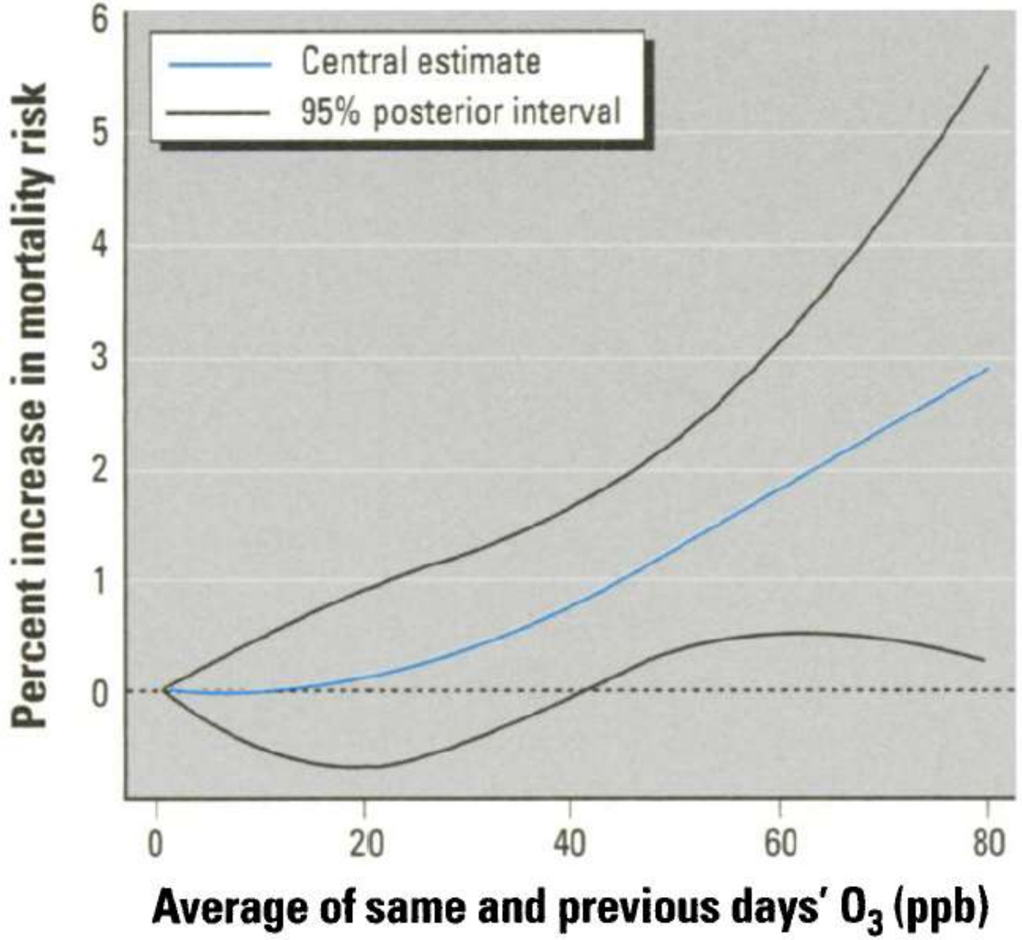


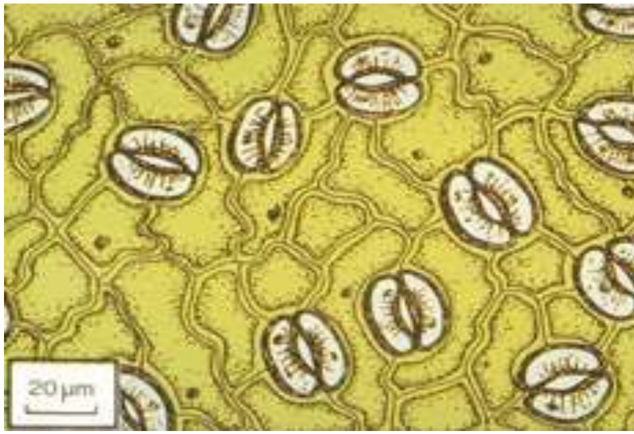
Figure 3. Exposure–response curve for O_3 and mortality using the spline approach: percentage increase in daily nonaccidental mortality at various O_3 concentrations.

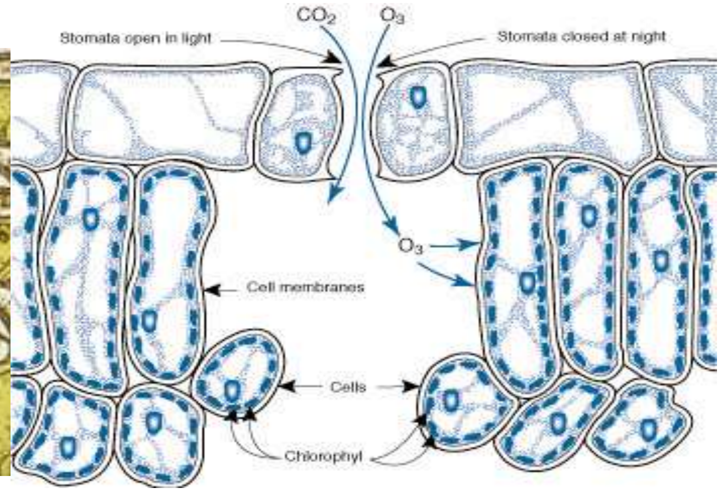
High levels of ozone increase mortality

Meta-analysis based on 98 US cities

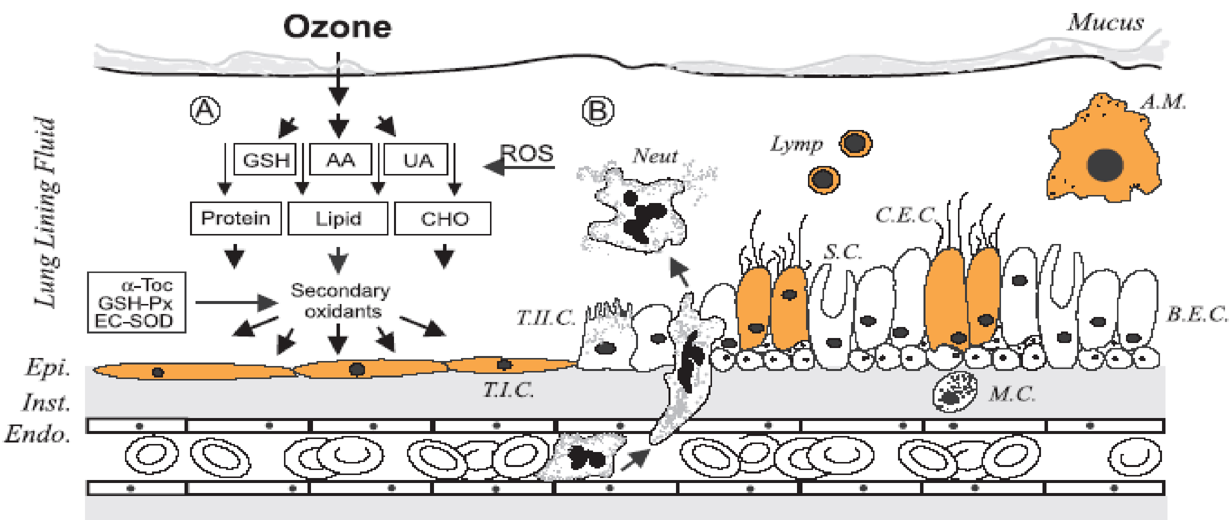
Bell et al. (2006, Environmental Health Perspectives)

The biosphere-atmosphere boundary



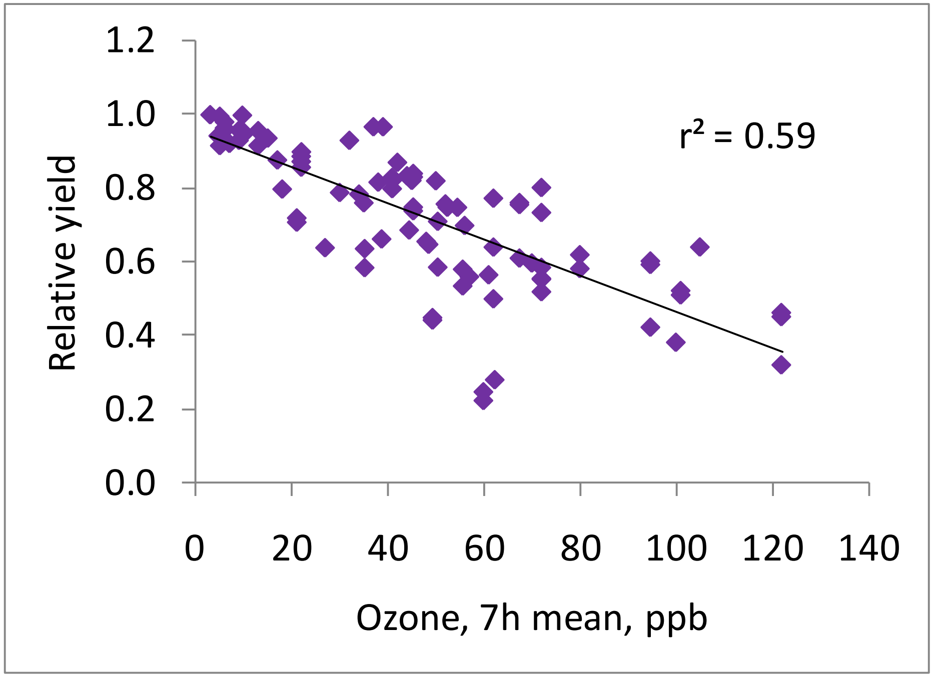


Ozone enters a plant via stomata; attacks plant cells

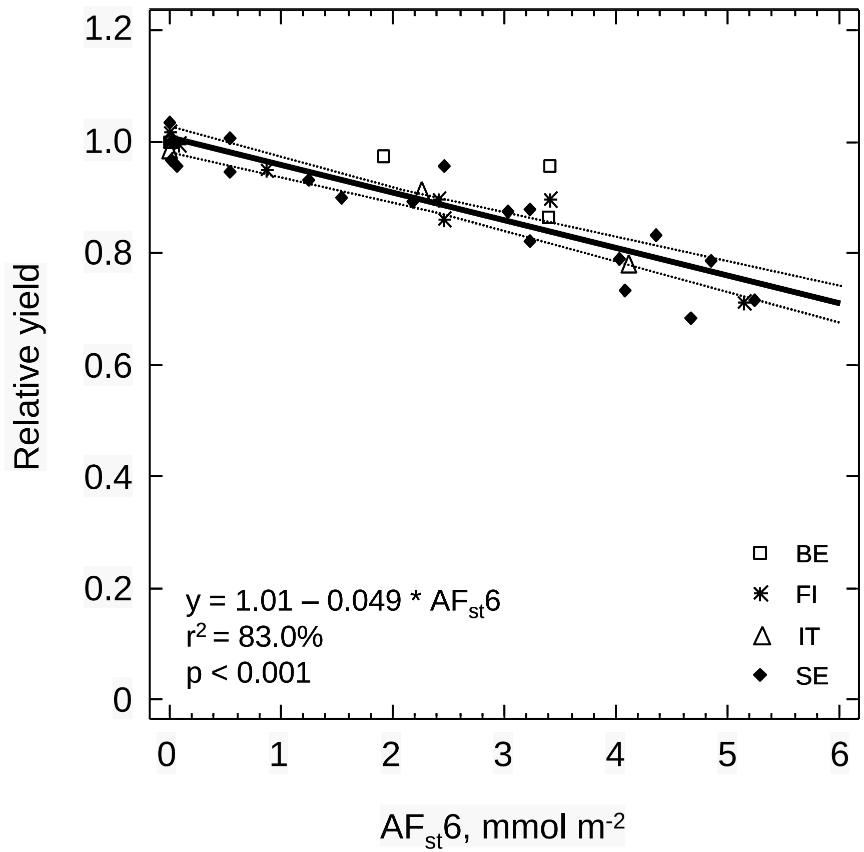


Ozone crosses the fluid lining of the lungs, and stimulates a variety of responses at the cell level

Ozone exposure or absorbed dose



exposure



Absorbed flux

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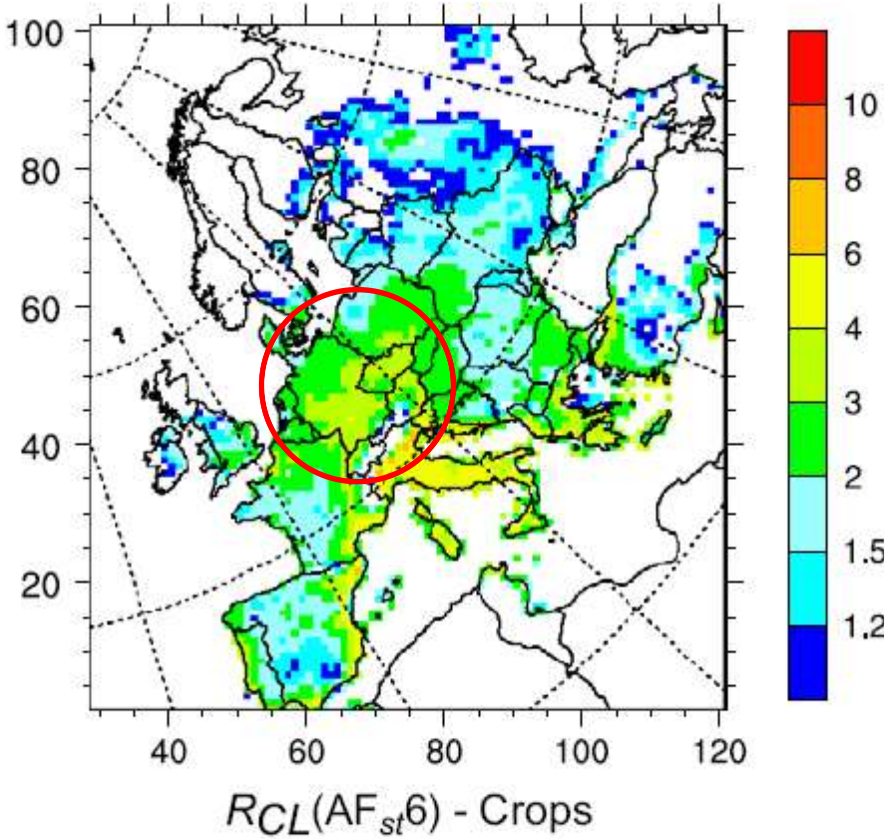
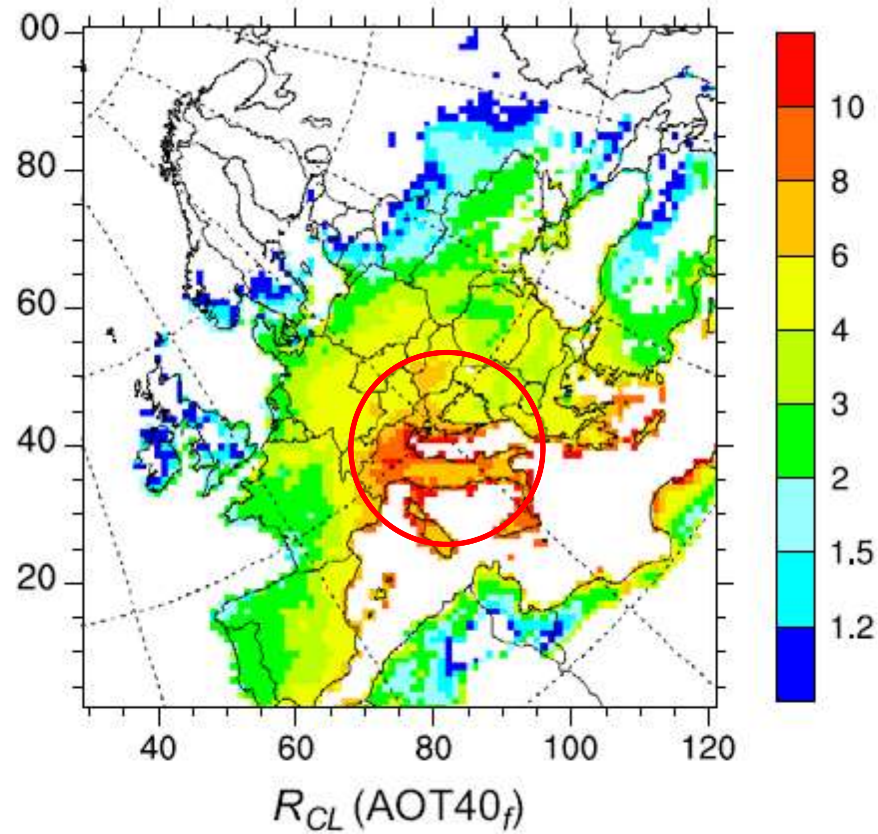
Concentration (AOT40) vs. stomatal flux (AFstY) risk assessments

2000

CL: AFstY Generic wheat



CL: AOT40 - Crops



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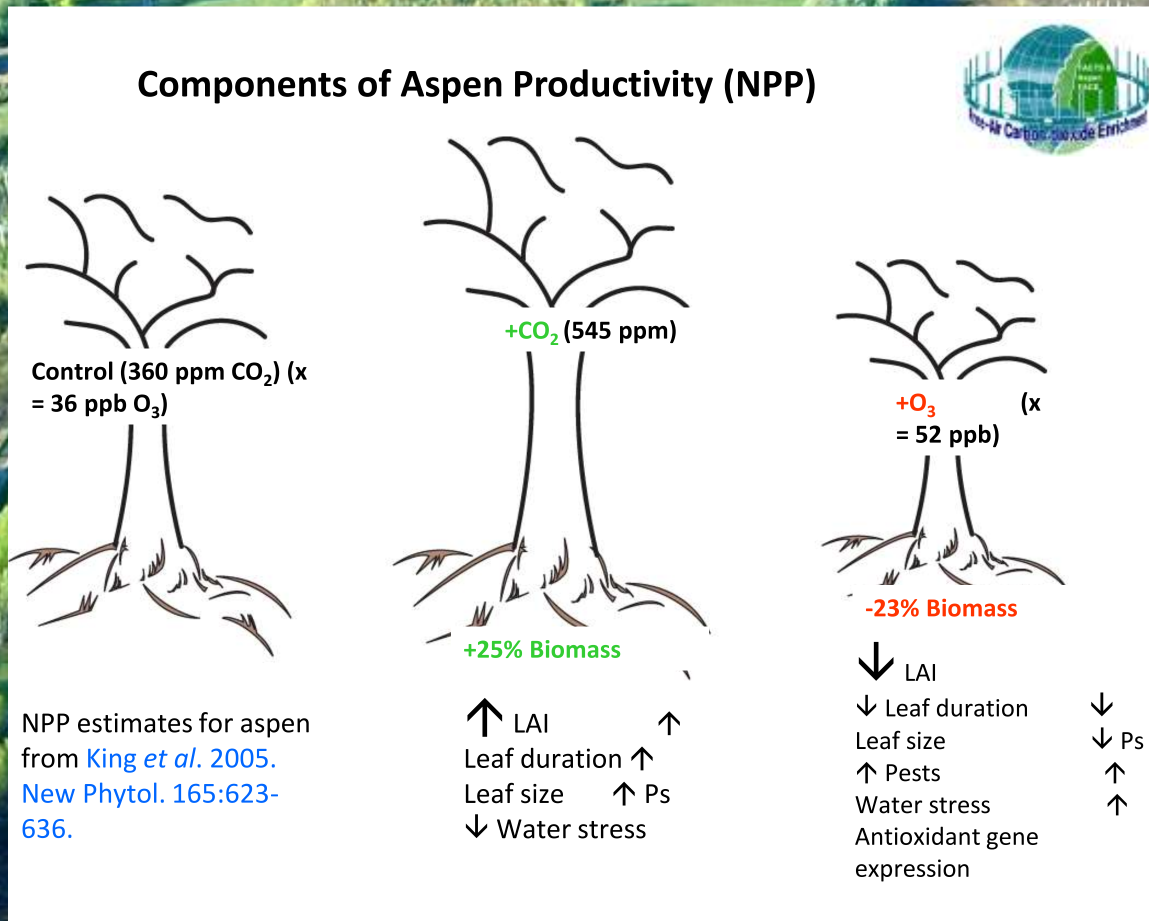
Simpson et al (2007)

Ozone contributes to climate change

- IPCC (2007): Tropospheric O_3 is the third largest greenhouse gas contributor to radiative forcing of climate change:

  0.35 Wm^{-2} *(CO_2: 1.66 Wm^{-2}; CH_4: 0.48 Wm^{-2})*

AspenFACE: Exposure of tree stands to elevated CO_2 and O_3



Radiative forcing from ozone

- The direct radiative forcing from tropospheric ozone is +0.35 W m^{-2} (range +0.25 to +0.65 W m^{-2})
- An indirect effect of O_3, via reduced growth of vegetation, may add a further 0.2 to 0.4 W m^{-2}, suggesting O_3 may approach CO_2 in terms of radiative forcing

Trends

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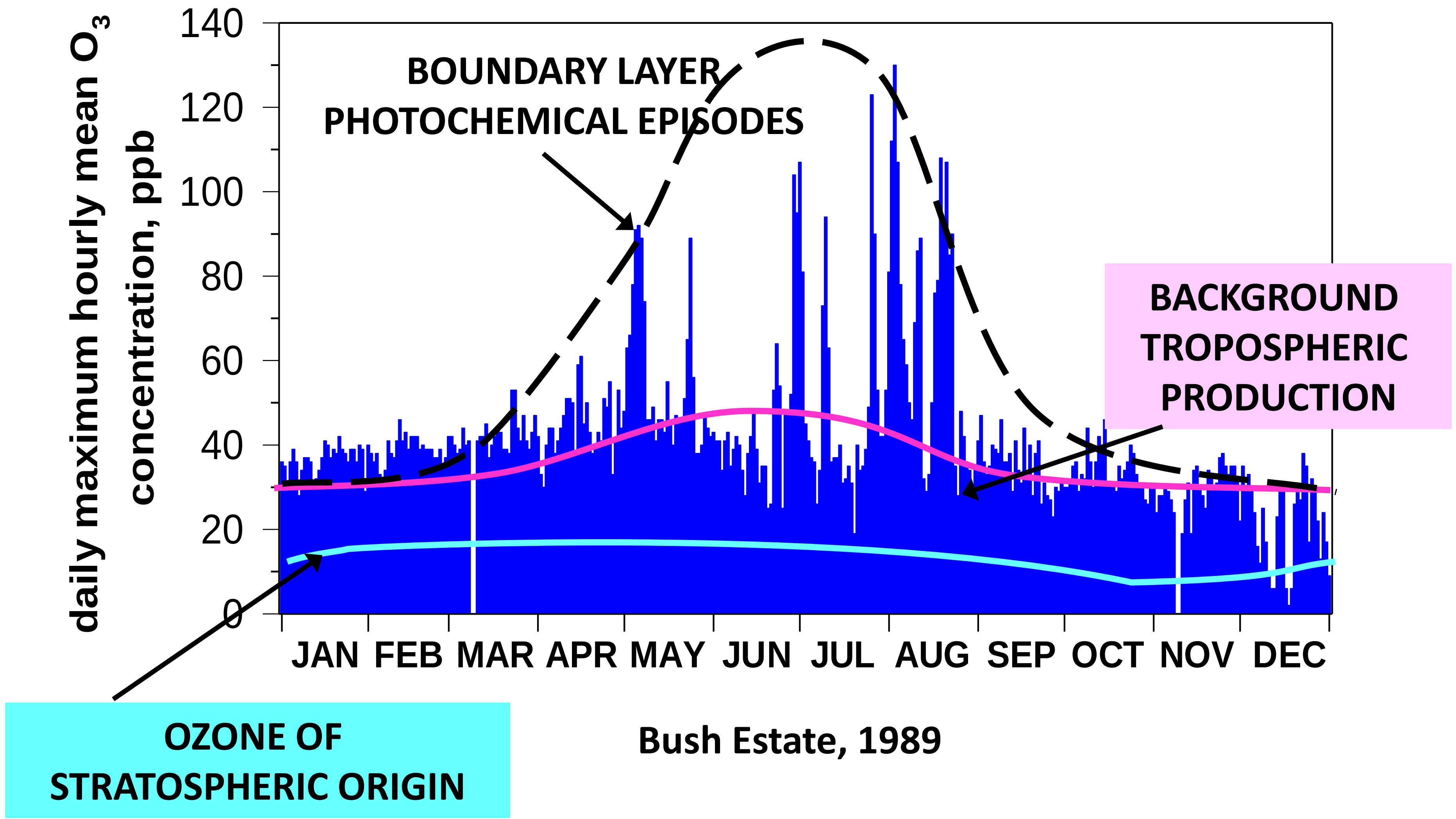

Bush Estate, 1989

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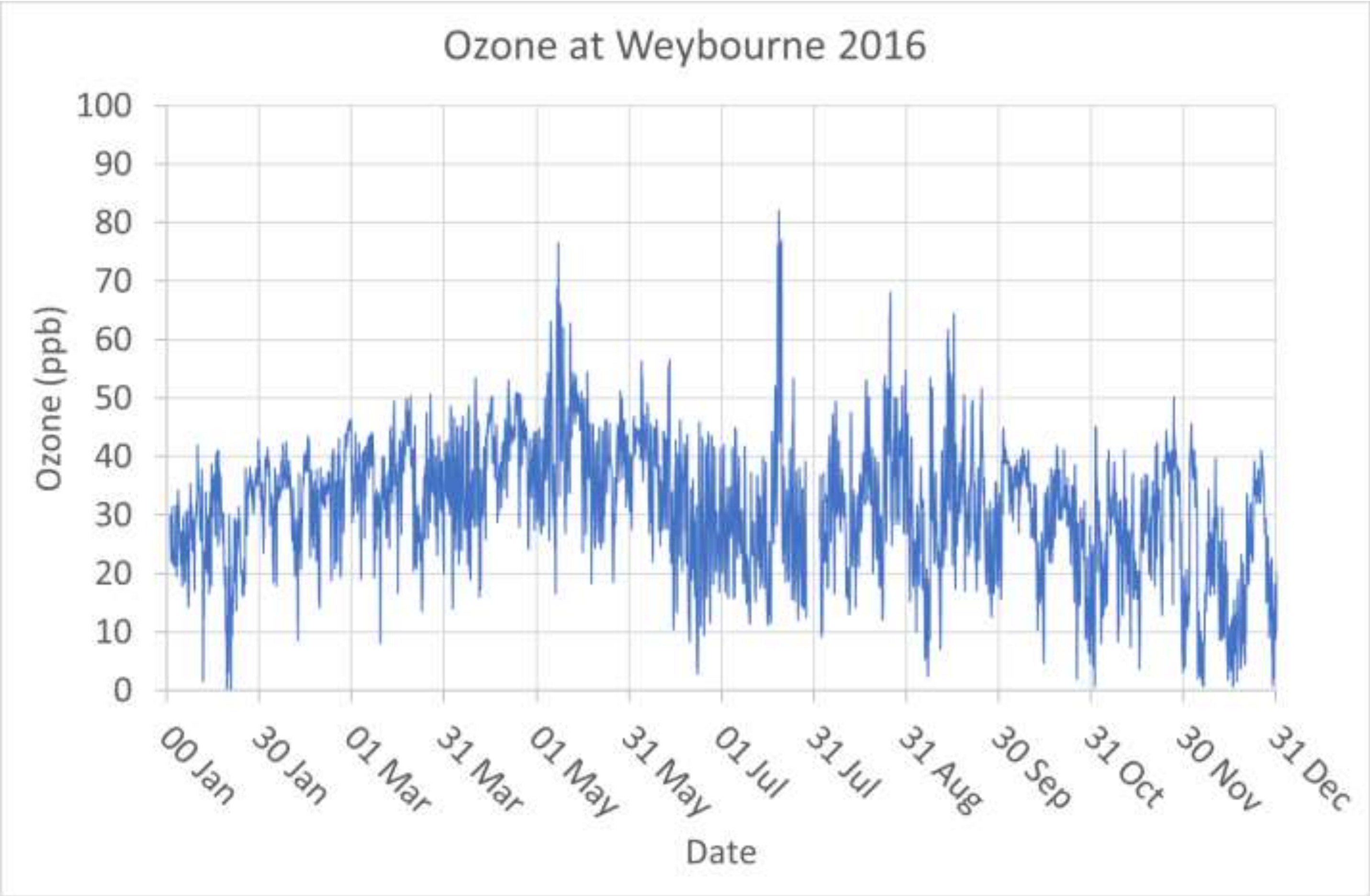

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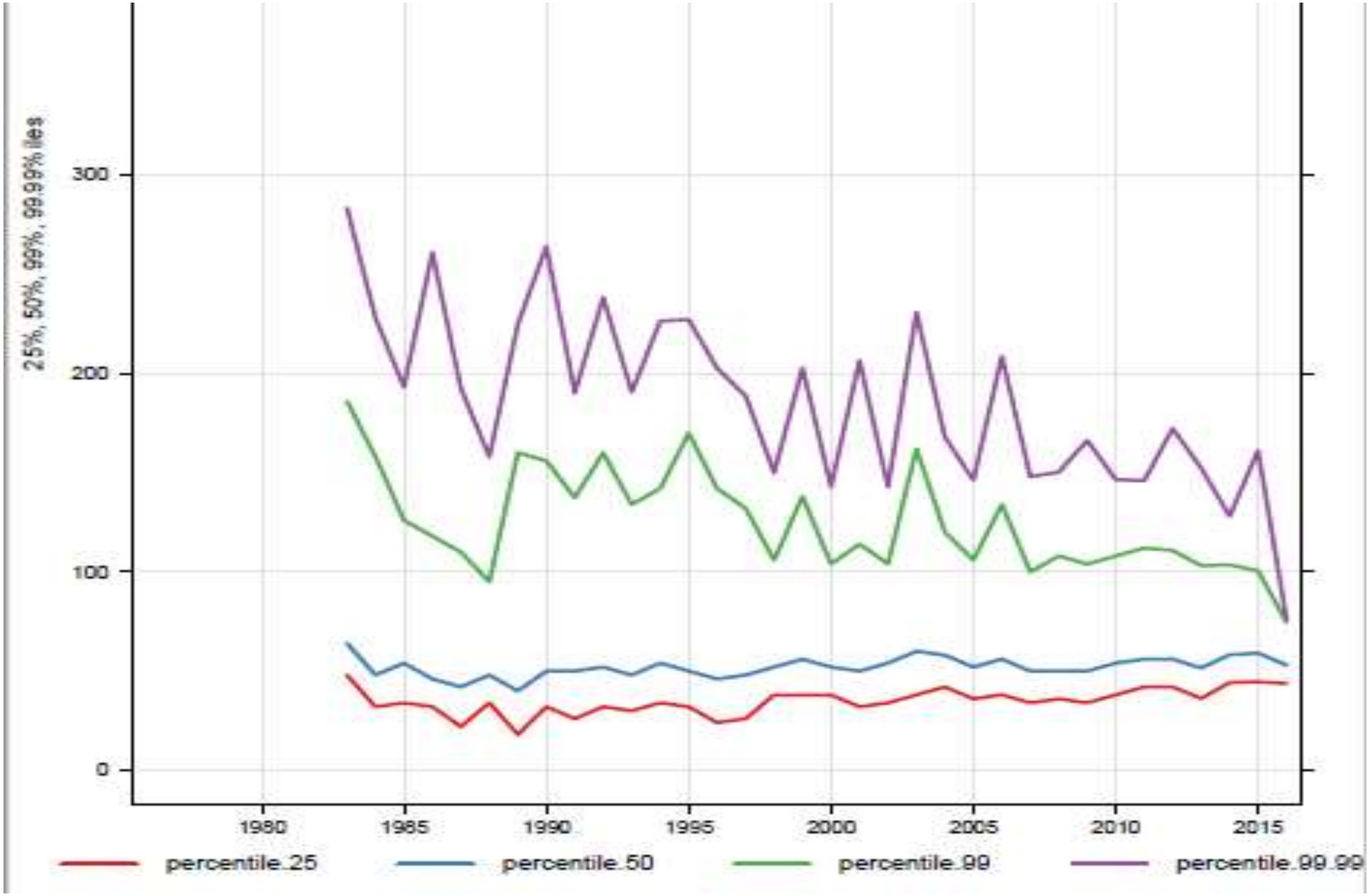
Ozone at Harwell 1984-2016



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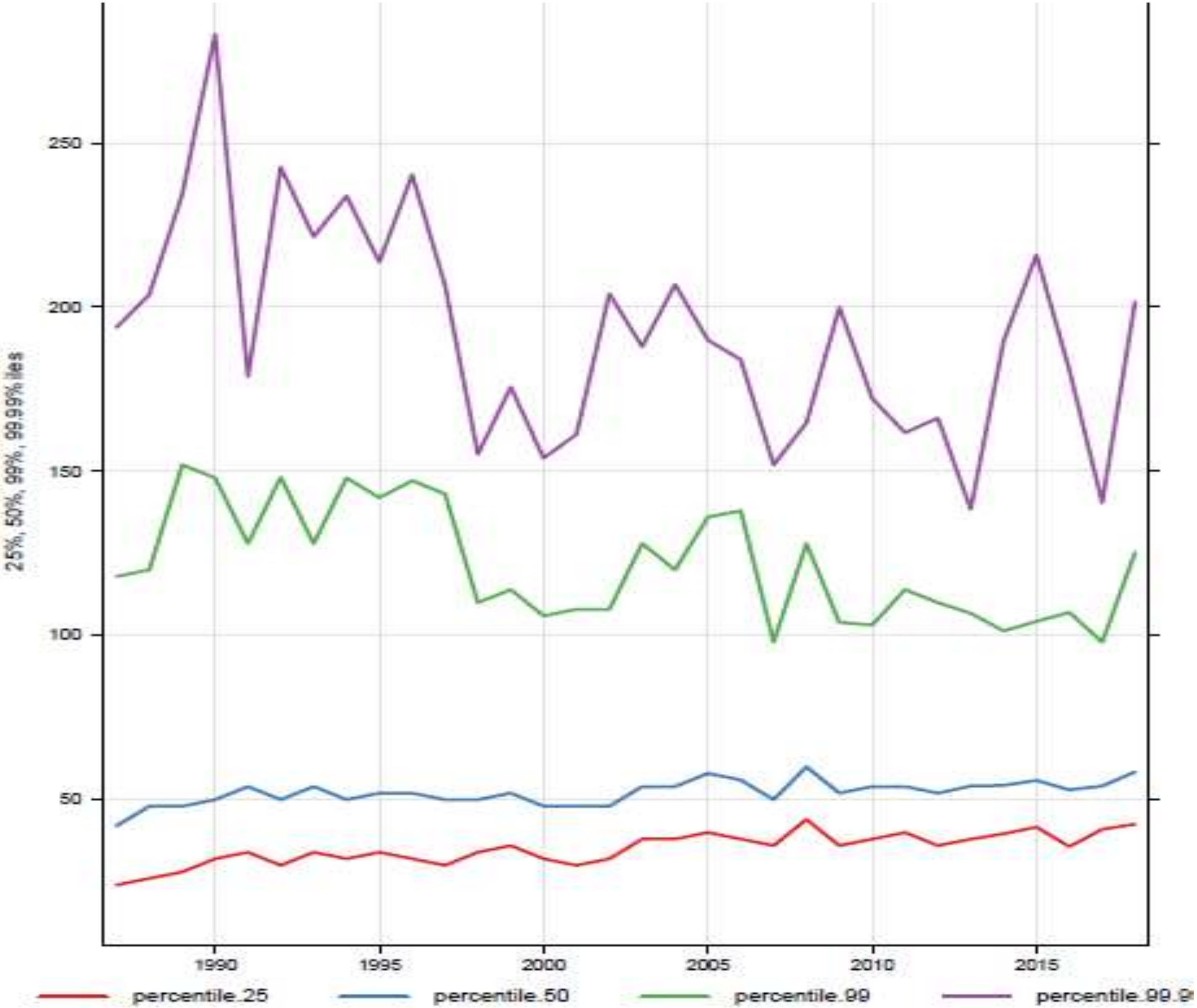
Ozone at Sibton 1986-2017



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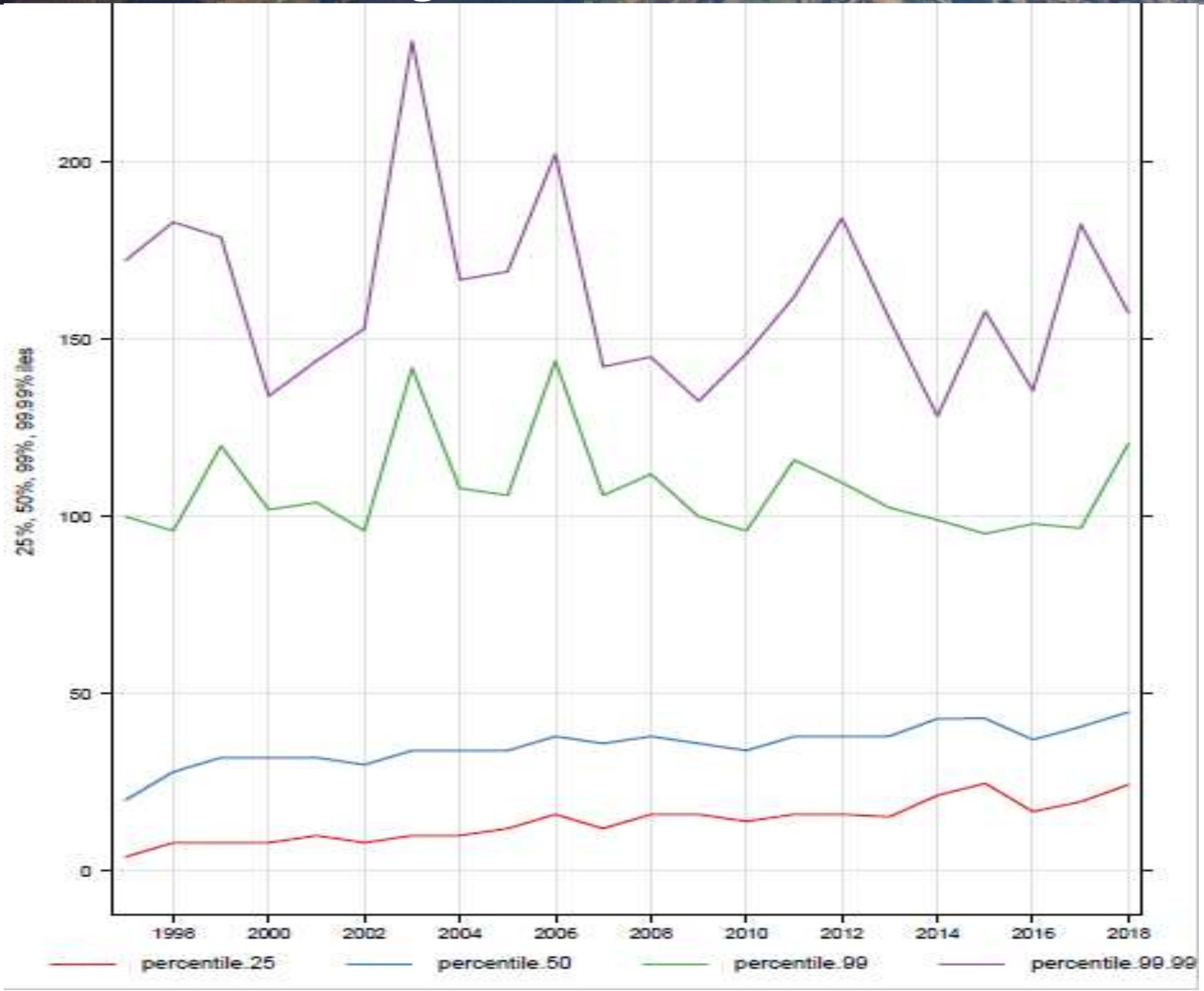
Ozone at N.Kensington 1997-2018



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Trends

- Peak values have declined substantially
- Lower percentiles have increased at most sites
- Mean concentrations have changed little at rural sites but have increased at urban sites due to the decline in urban NOx

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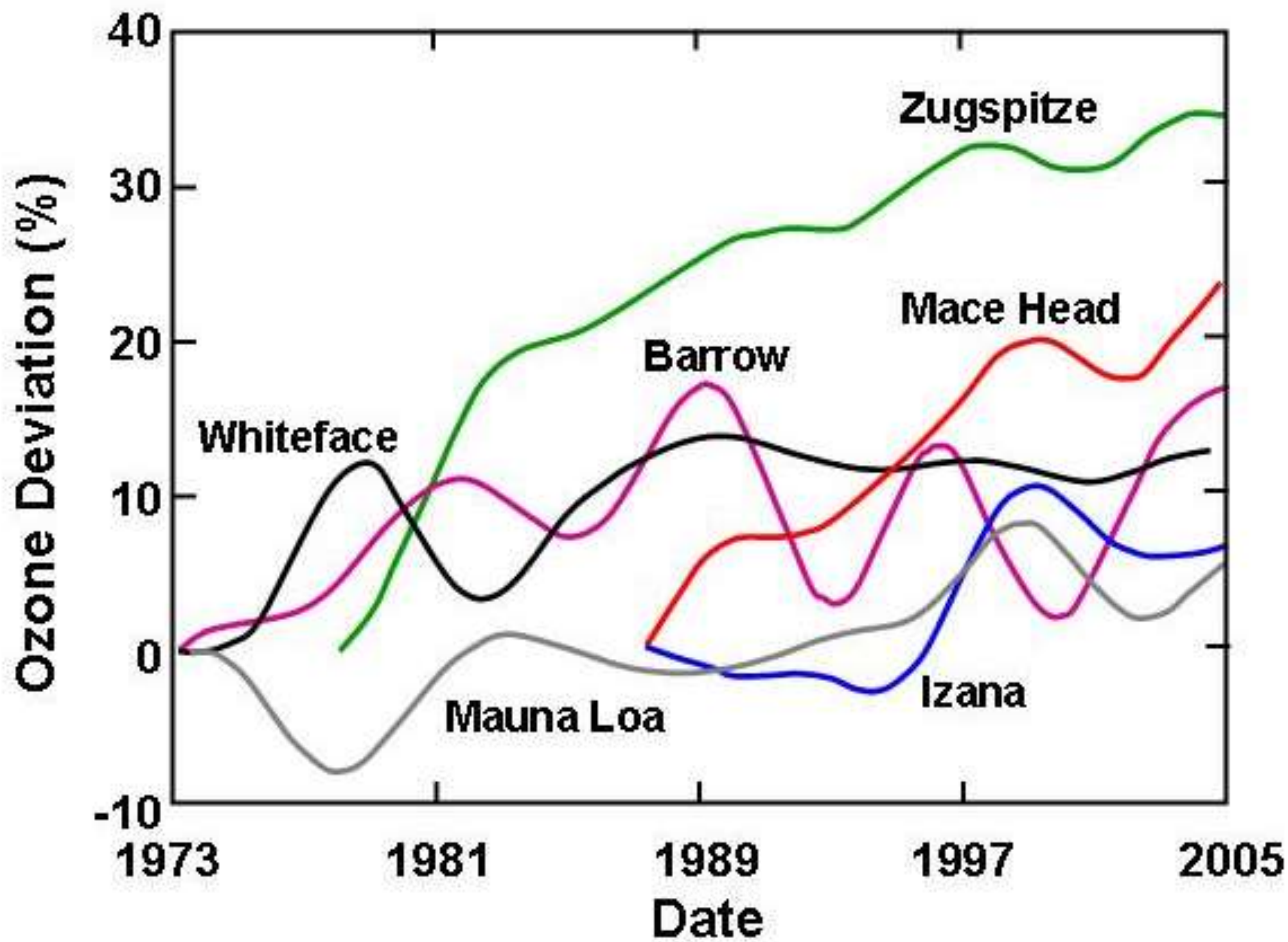
Observed trends in surface O3 since the 1970s at



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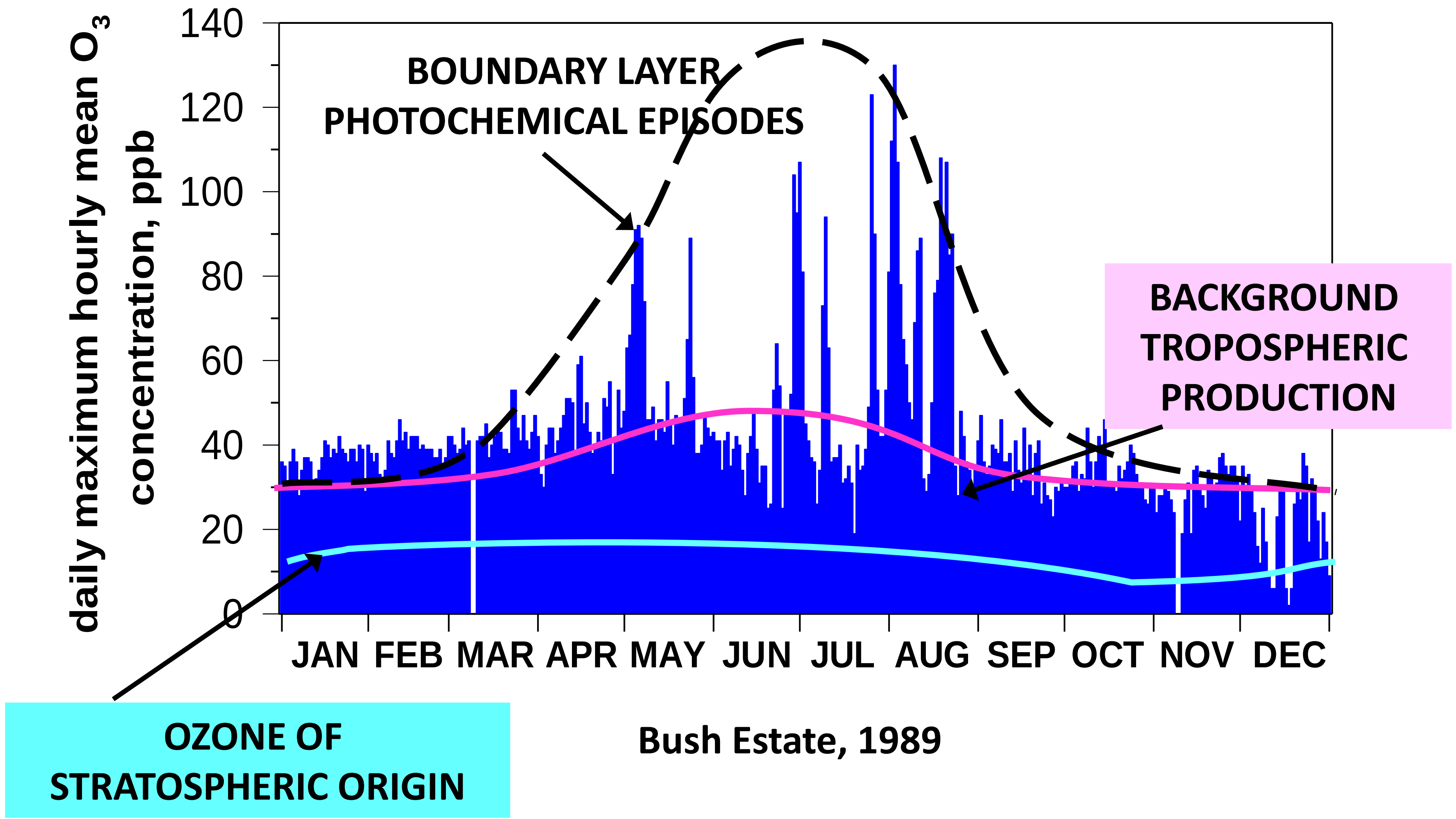
Oltmans et al., 2006



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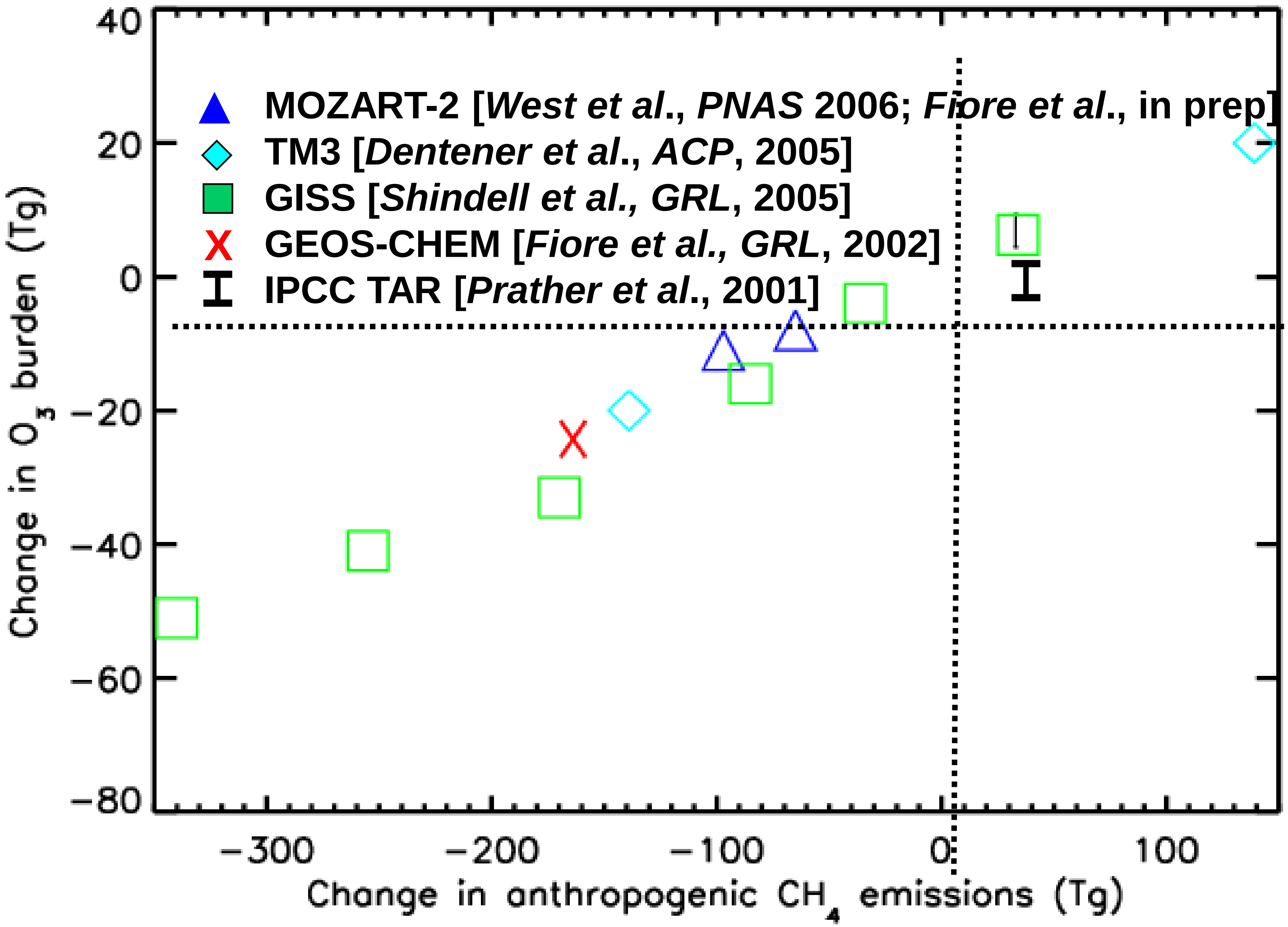
TROPOSPHERIC O_3 RESPONDS APPROXIMATELY LINEARLY TO ANTHROPOGENIC CH_4 EMISSION CHANGES ACROSS MODELS



Courtesy of Arlene Fiore

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Anthropogenic CH_4 contributes ~50 Tg (~15%) to tropospheric O_3 burden

~5 ppbv to surface O_3

Ozone

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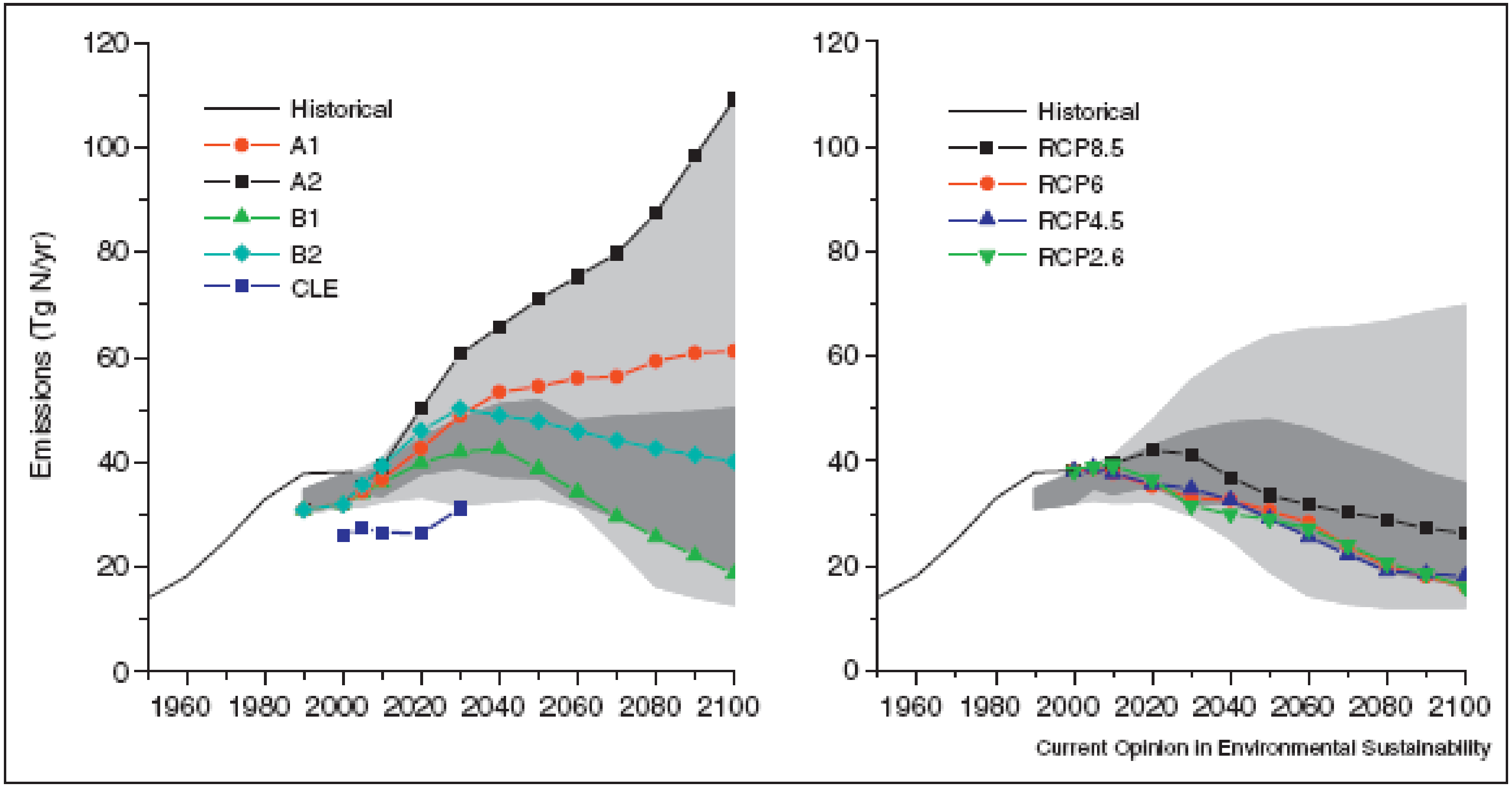
Ozone in the future…

- Will depend strongly on the trajectory of anthropogenic emissions, in particular NOx, but also CH_4, CO and VOCs.

NOx emissions (Van Vuren et al 2011)



Future NO_x emissions according to various scenarios (light grey area covers the 10–90th percentile; dark grey area the 25–75th percentile). The right hand panel only includes scenarios without climate policy (22 scenarios); the left hand panel includes the full set of scenarios (with and without climate policy) (40 scenarios). The graph also shows the scenarios of the IPCC-SRES set [37], the IIASA-CLE scenario (both sets do not include climate policy) [26] and the RCPs (including climate policy) [40].

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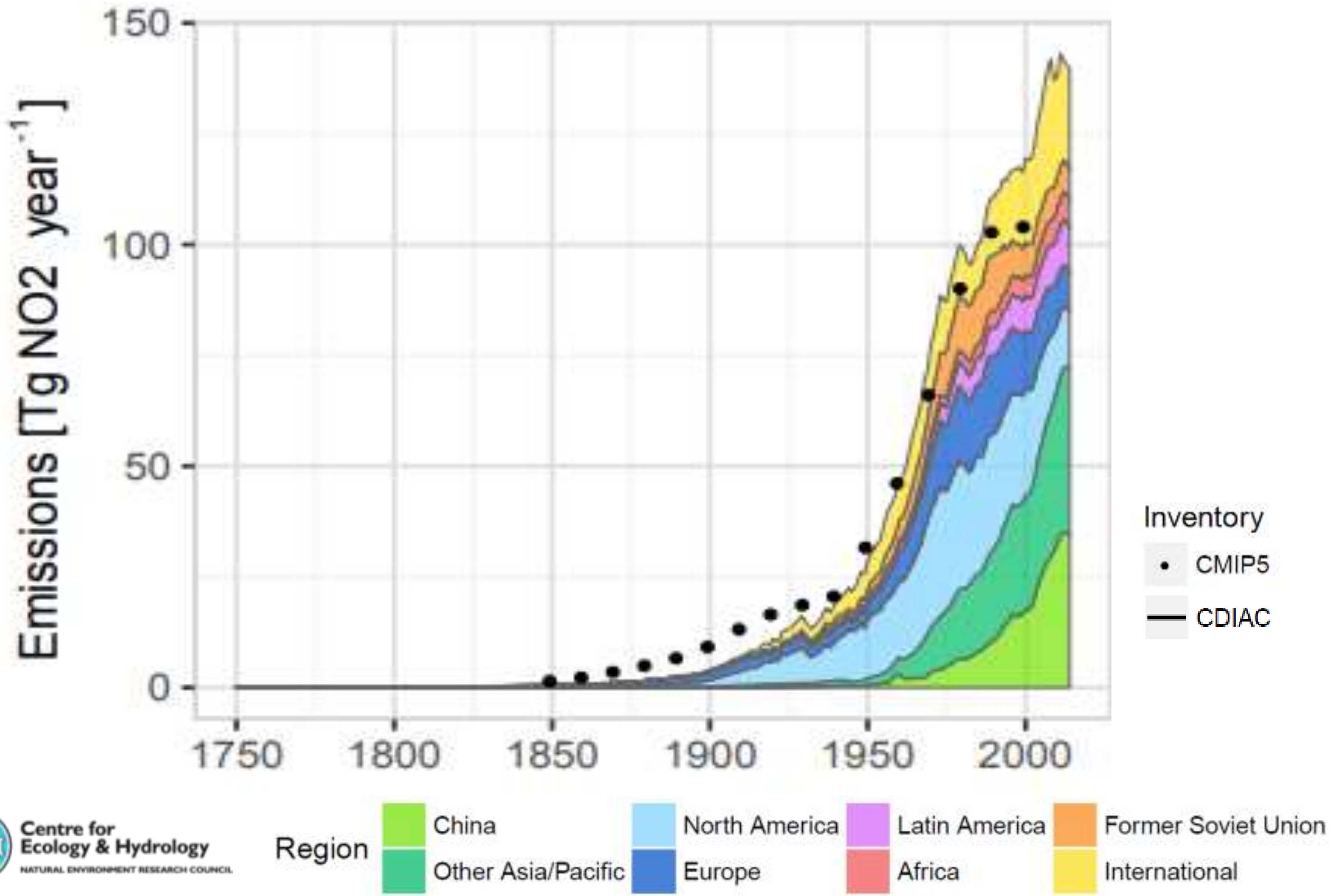
Global NO_2 Emissions (Hoesly et al 2018)



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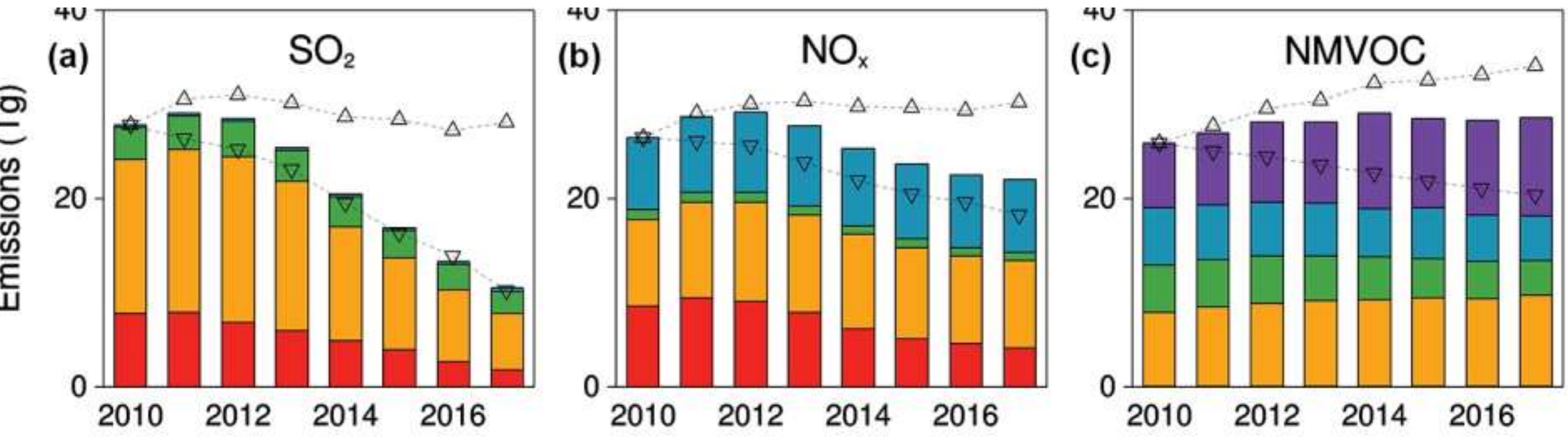
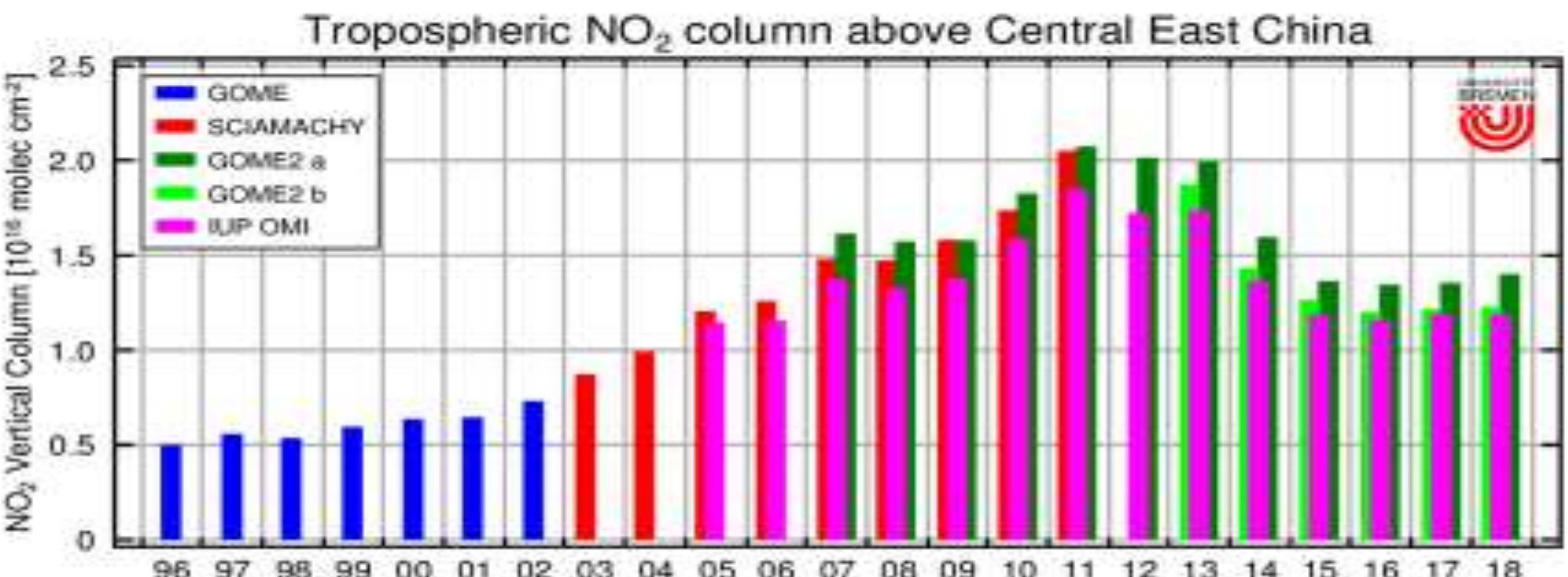
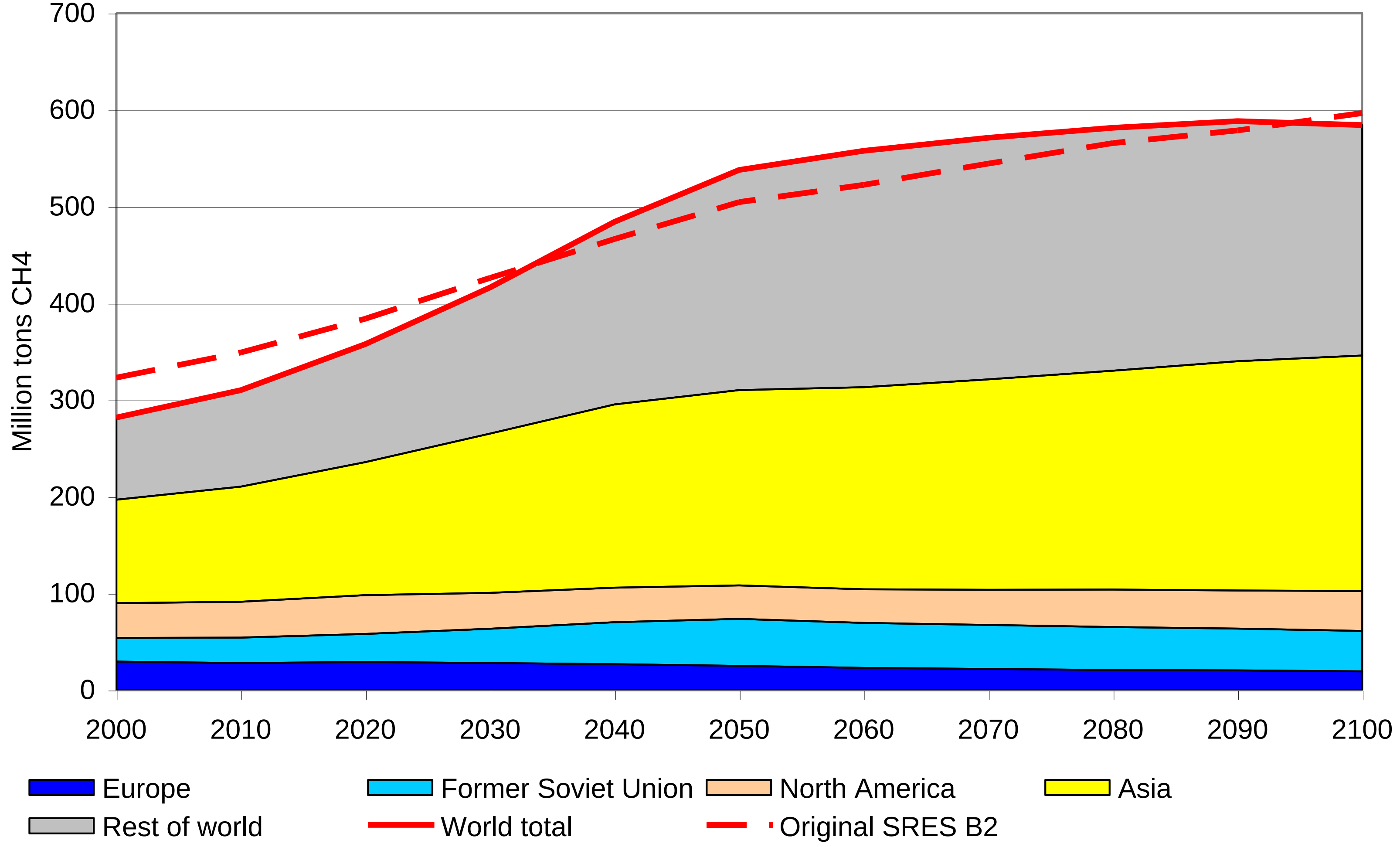
EMISSION REDUCTIONS IN CHINA 2010-2018



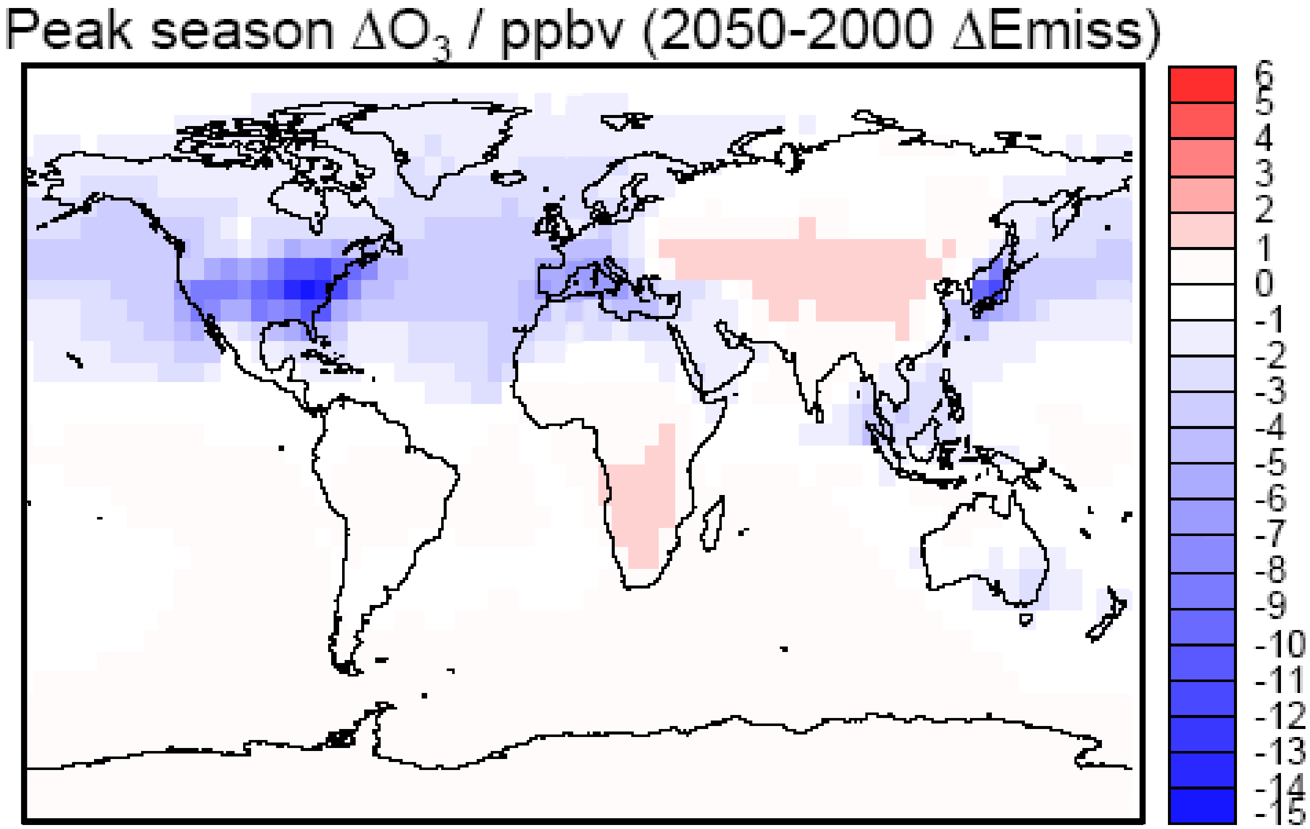


Methane emissions 2000-2100



Courtesy Markus Amann, IIASA

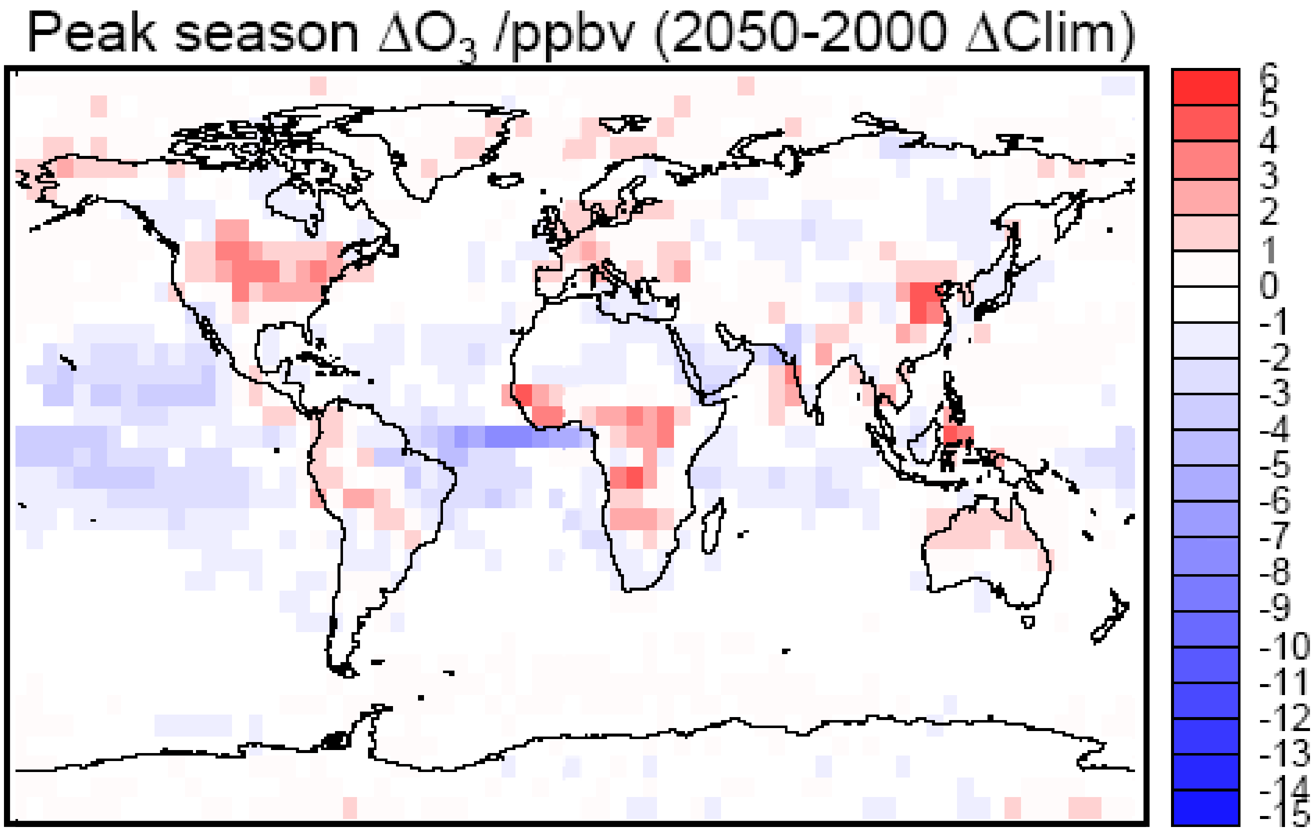
PROJECTED CHANGES IN SURFACE O_3 (2050-2000) DURING THE PEAK O_3 SEASON DUE TO *EMISSIONS CHANGES*



Mean of 5 models

Impact of IIASA CLE 2050 emissions changes only (relative to 2000)

PROJECTED CHANGES IN SURFACE O_3 (2050-2000) DURING THE PEAK O_3 SEASON DUE TO ***CLIMATE CHANGE***



Mean of 3 models

Impact of 2000-2050 climate change only
(prescribed future climate: HadGEM SRES A1B)

Control of ozone precursors, air quality and climate

- **Current legislation should modestly reduce ozone in Europe and North America**
- **Ozone in rapidly developing regions is projected to increase**
- **Climate changes will erode benefits of CLE and may lead to higher ozone in most low and mid latitude regions**
- **Fully interactive Earth system models are required to simulate the full range of feedbacks**