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Royal Society Working Group on Ground-level ozone in the 21st Century

presented at the joint TFHTAP/NAS/AC&C workshop in Washington D.C. 9-13 June 2008

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Royal Society Secretariat: Rachel Newton and Rachel Garthwaite

About the Royal Society

- The Royal Society is the science academy for the UK and Commonwealth, established in 1660
- The Society provides independent advice on science issues by drawing on the expertise of the Fellowship which is comprised of 1400 of the best scientists in the world
- The objective of its work is to influence policy making by ensuring the best scientific advice is made available to policy makers

Why the Royal Society chose to undertake a study on ozone

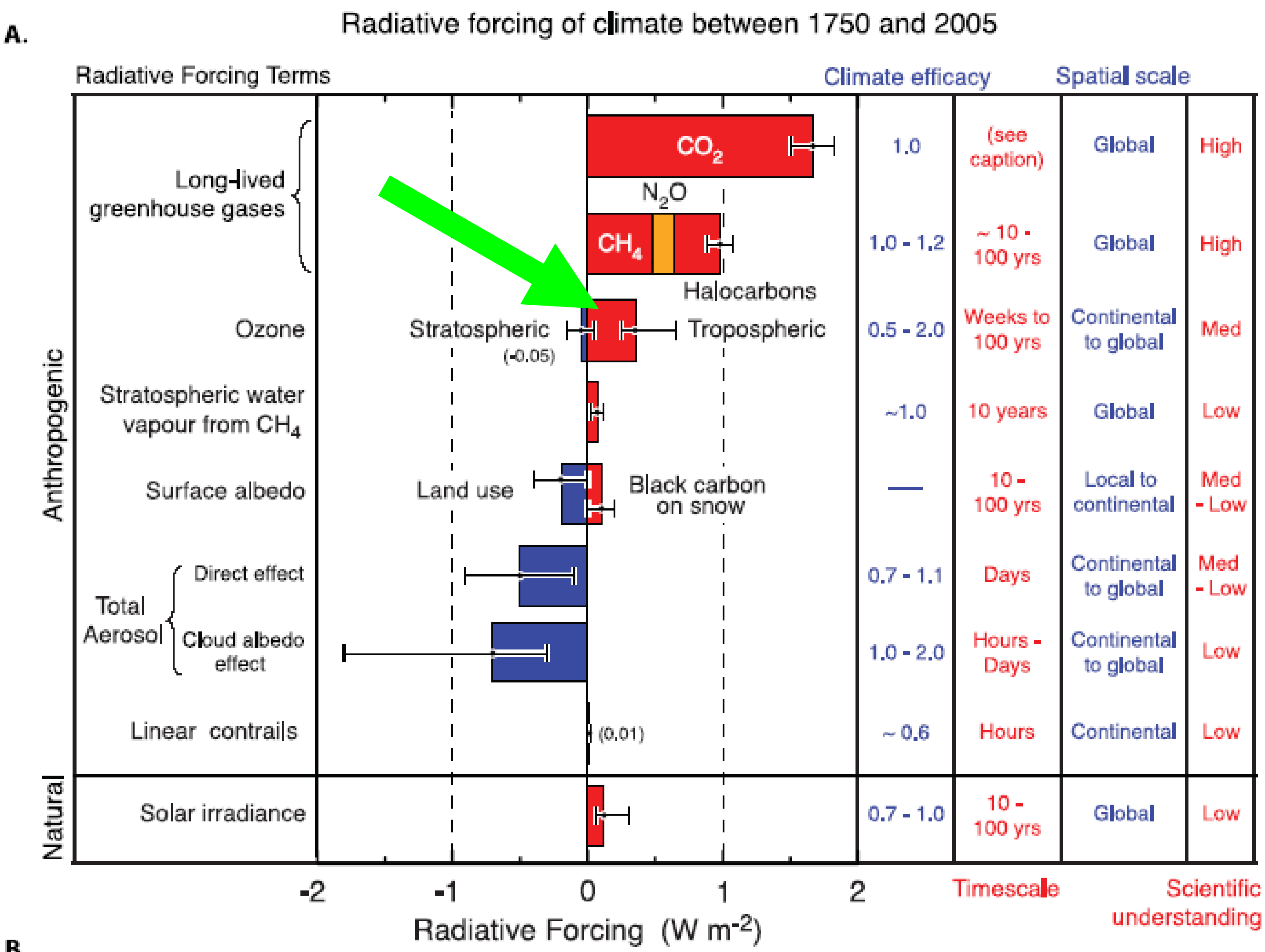
- **Reductions in emissions of ozone precursors have been large throughout Europe, (eg in UK 50% for NO_x and VOC).**

- **Effects on human health, crops and semi-natural vegetation remain substantial**

Impacts of ozone

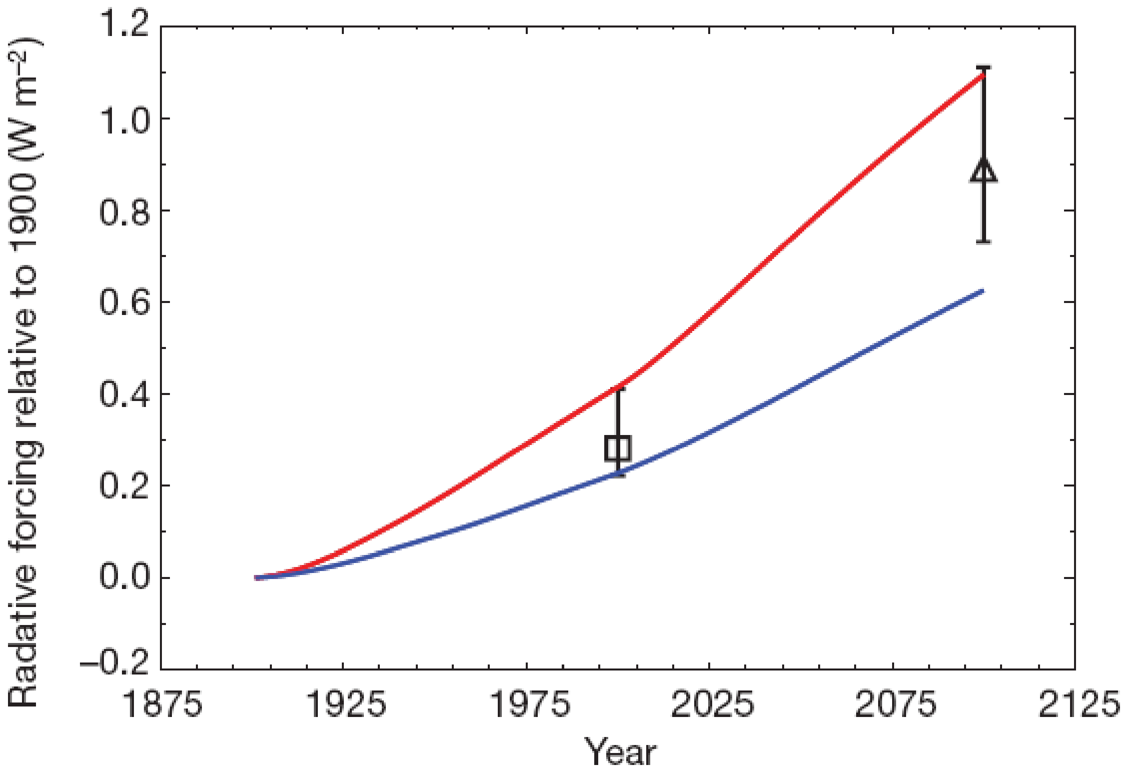
- **Present-day annual ozone impacts in the EU:**
  - **20,000 deaths brought forward**
  - **20 million respiratory hospital days**
  - **50 million restricted activity days in young adults due to respiratory symptoms**
  - **€6.7 billion loss of arable crops**

Radiative forcing from tropospheric O_3



Forster et al. (2007) IPCC-AR4 WG1 Chapter 2

Indirect and direct radiative forcings from tropospheric ozone



Symbols are direct forcings (IPCC, 2001)

Blue and red curves are indirect ozone forcing, due to ozone impacts on vegetation (high ozone sensitivity) (low ozone sensitivity)

Suggests that the indirect forcing may be similar in magnitude to the direct forcing.

Sitch et al. (Nature, 2007)

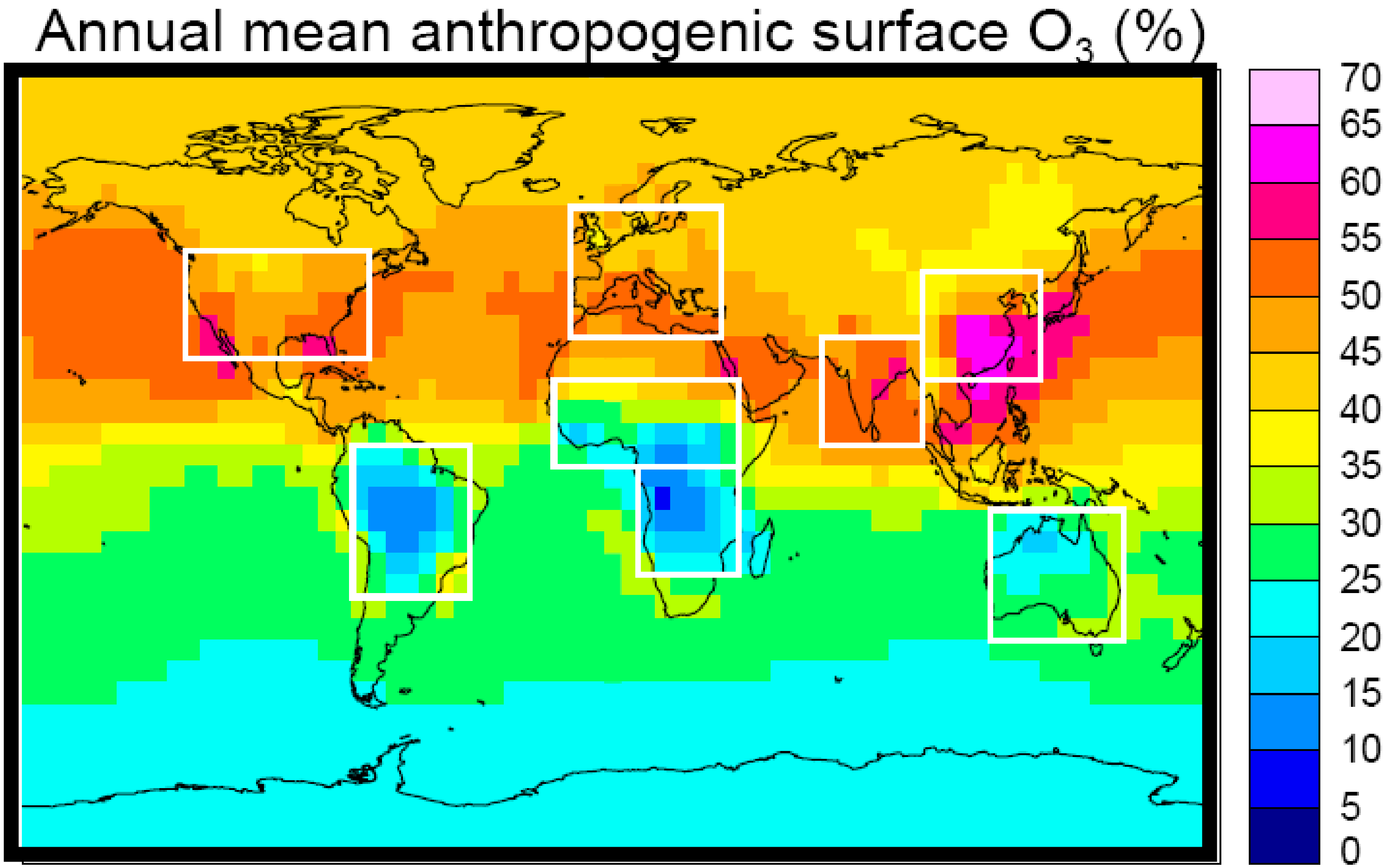
Controls are regional

- **Controls on ozone precursor gases have to date been at country or regional scale, yet all countries in each hemisphere share each other's ozone.**

Objectives

- **To quantify the changes in ground level ozone through the 21st century**
- **Identify the scale of effects of ozone on human health and vegetation**
- **Identify policy options to reduce the scale of effects**

Model result:
In Northern mid-latitudes, 35-65% of present-day surface O_3 originates from anthropogenic NO_x, CH_4, CO and NMVOCs

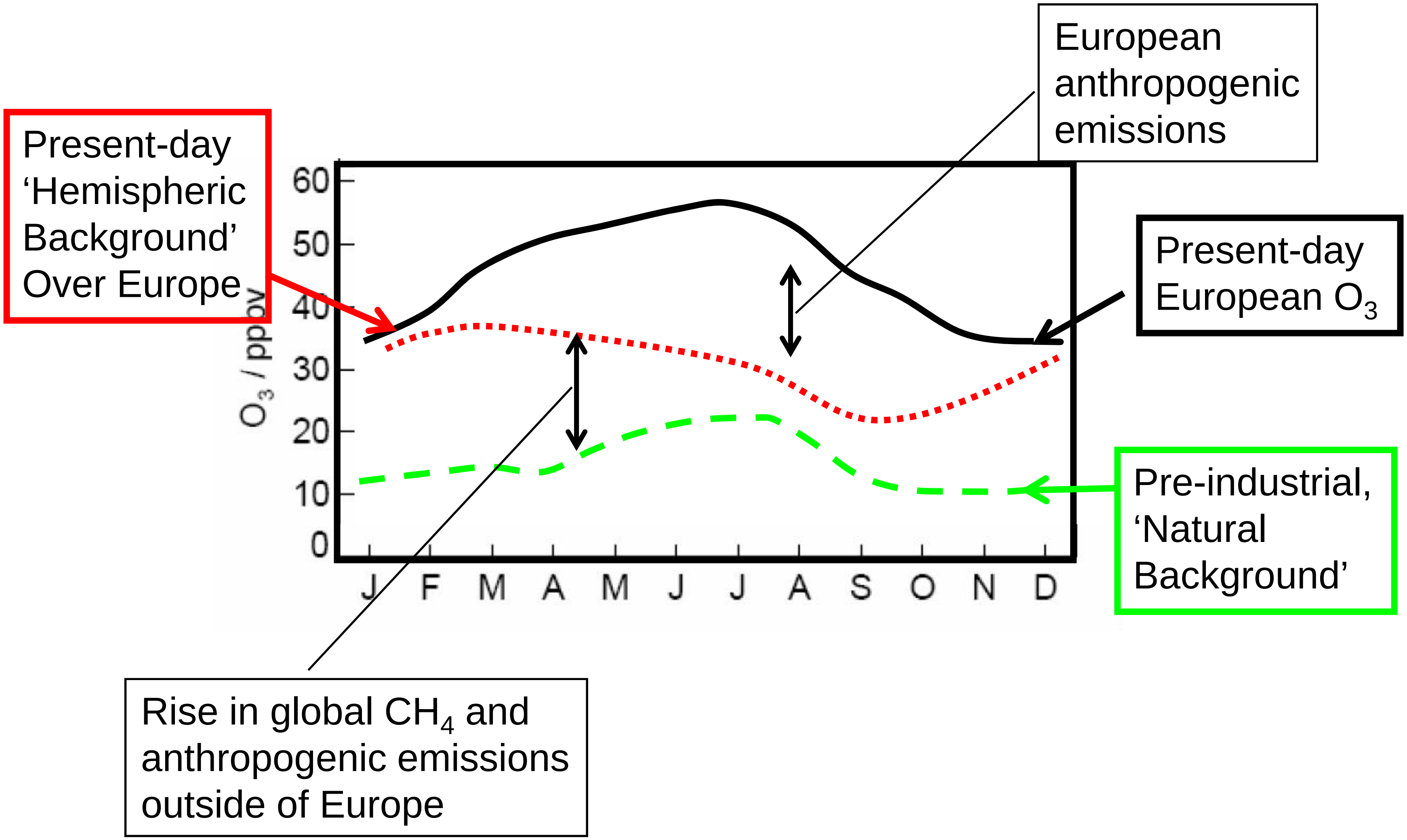


Assumes no change in biomass burning or soil NO_x between 1750 and present

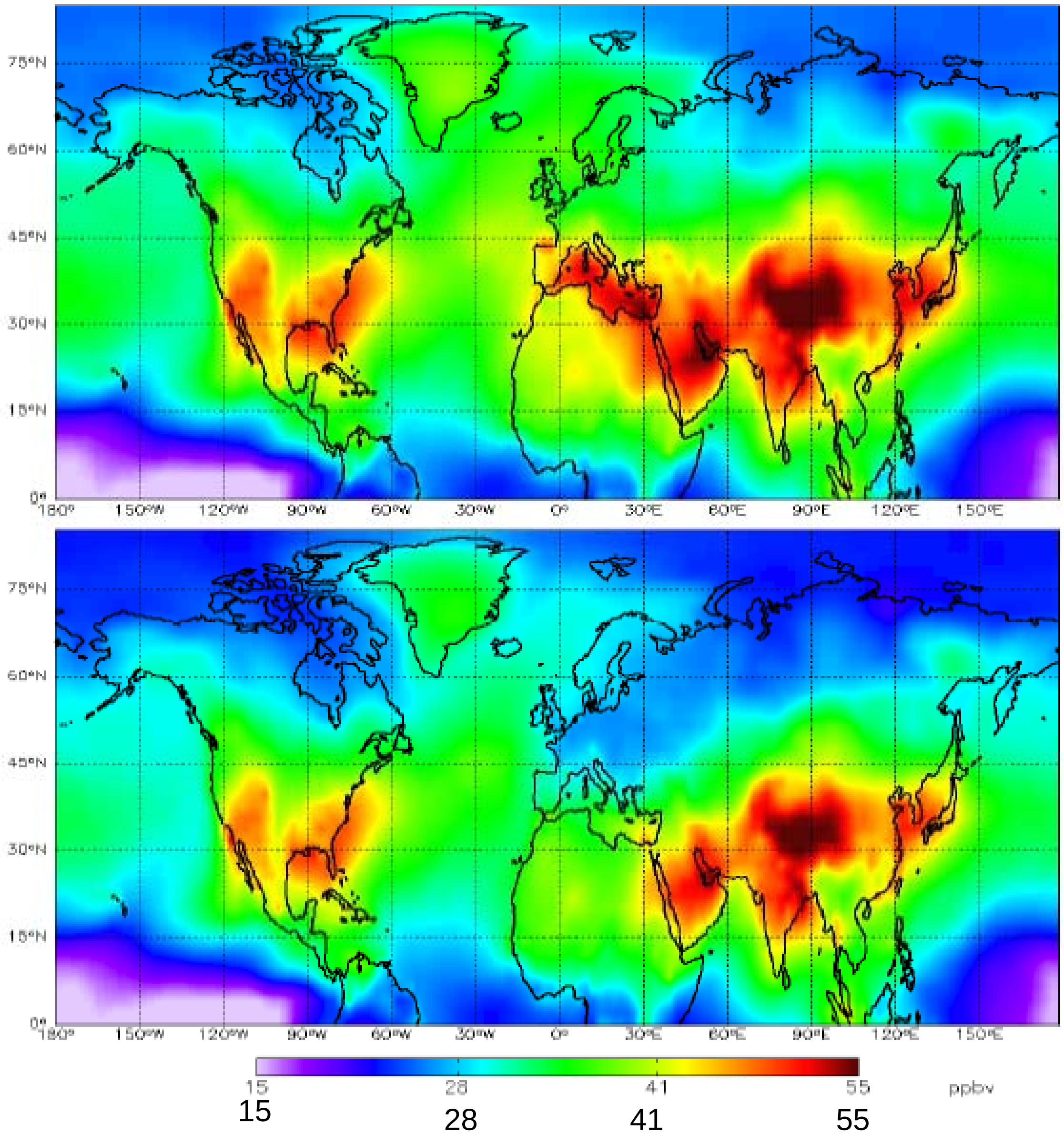
Average of 5 model calculations STOCHEM-HadAM3 (Edinburgh), STOCHEM-HadGEM (UKMO), UMCAM (Cambridge), TM4 (KNMI), FR56C (O Wild)

Origins of European Ozone

(RS model calculations)



Background Ozone over Europe



All emissions on

European anthropogenic emissions switched off, revealing European background ozone

Courtesy Isabelle Bey (Raes et al., 2006)
Answers to the Urbino Questions

ACCENT
ATMOSPHERIC COMPOSITION CHANGE
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New analysis

- **Prior to this study, analysis of future ozone concentrations out to the end of the century was based on a high emission scenario which did not take into account air quality legislation**

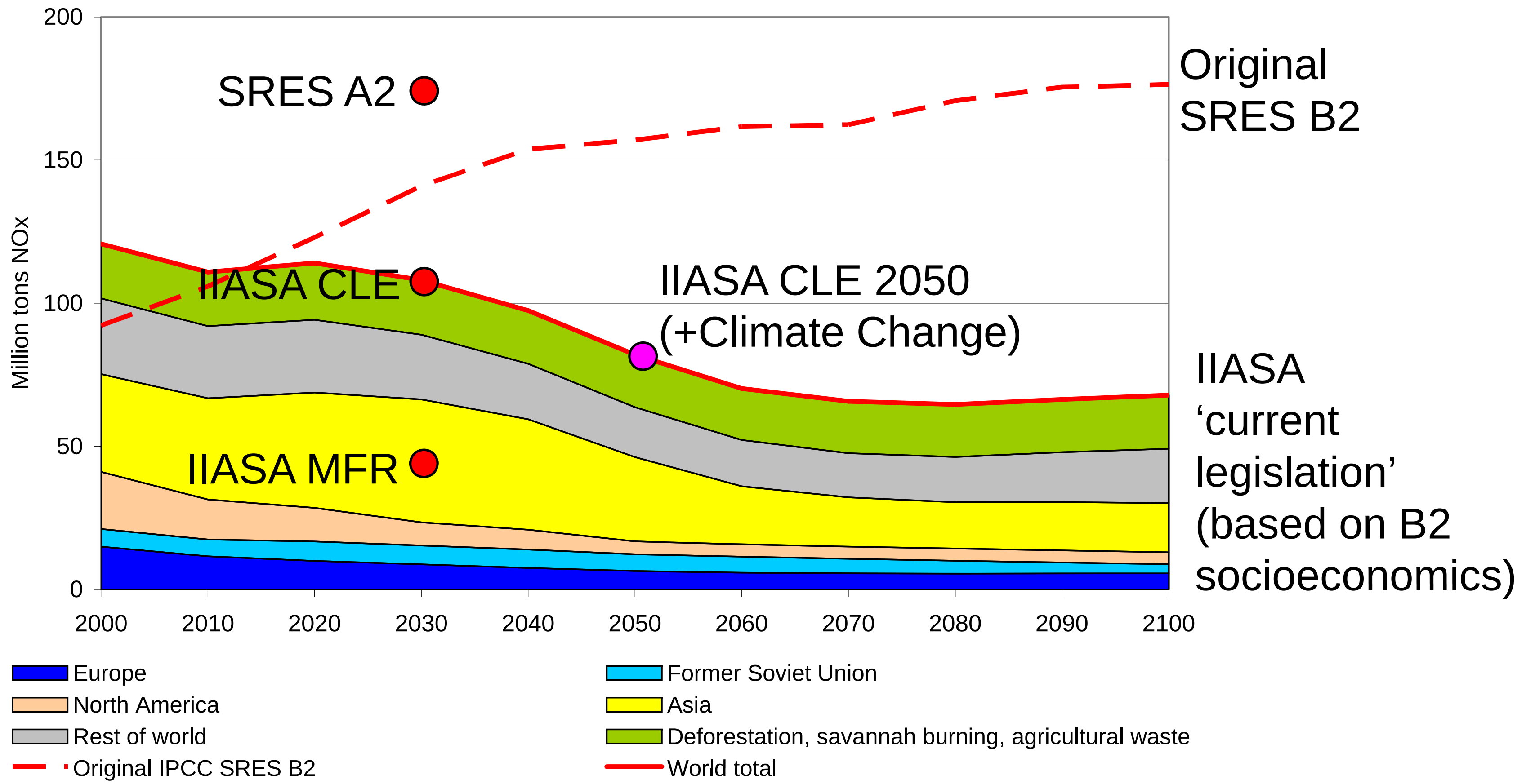
- **The earlier modelling studies of future ozone concentrations looked only to 2030 and included a scenario that did include air quality legislation (NO_x, VOC, CO) but only to 2000**

Additional work to update estimates of future ozone

- **New IIASA scenarios to include legislation adopted between 2000-end of 2006**

- **Extending the previous global modelling work to 2050 using the updated scenario and a 2050's climate.**

Global anthropogenic NO_x emission scenarios 2000-2100



ACCENT Photocomp runs

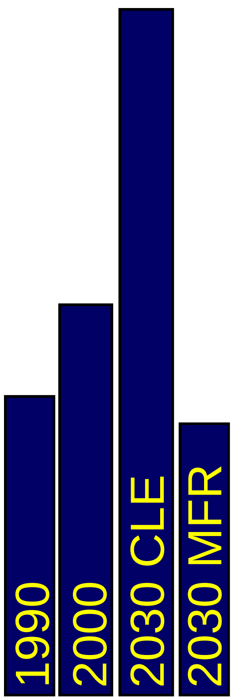
Royal Society runs

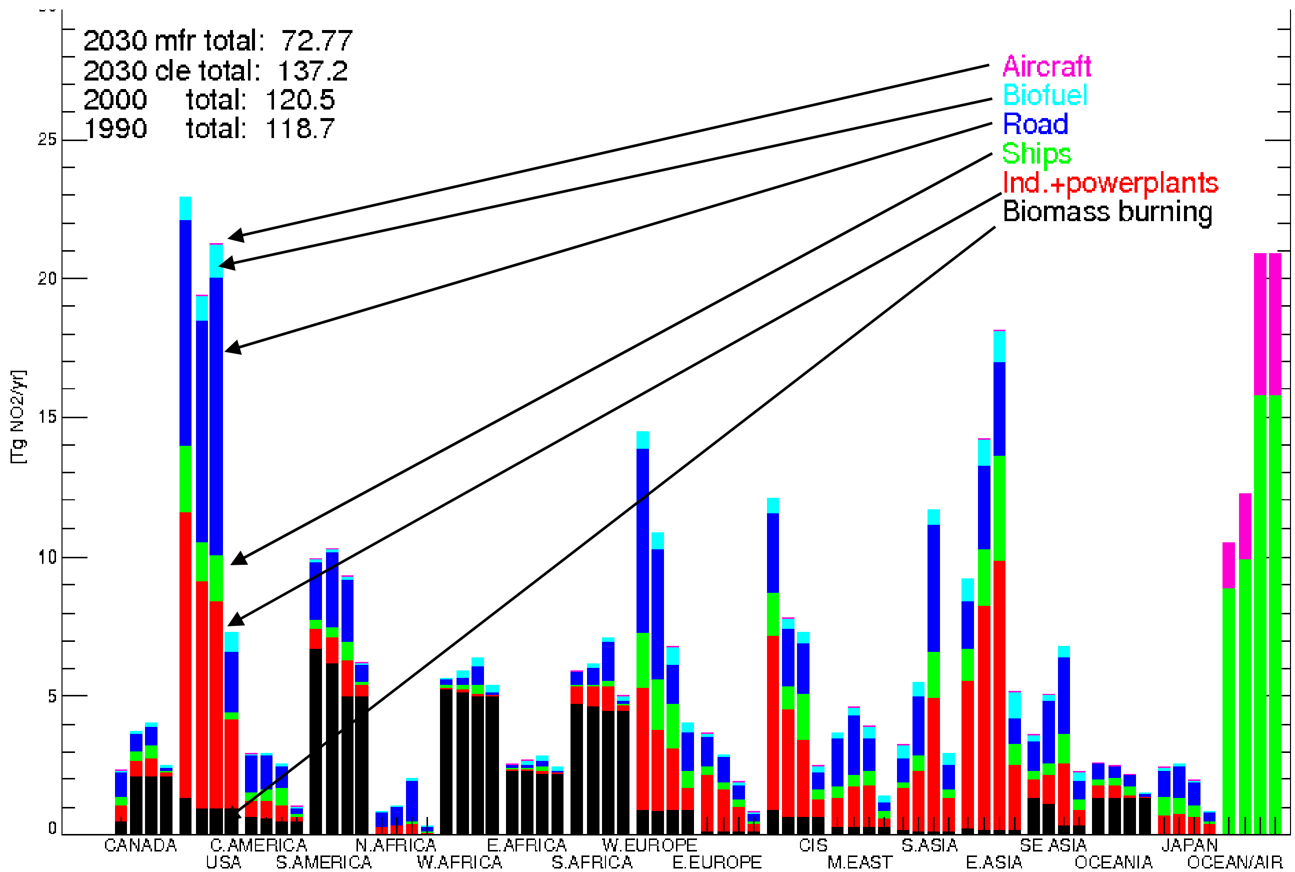
(+Climate Change: T- and PAR-change influence on isoprene and lightning NO_x emissions)

Courtesy Markus Amann, IIASA

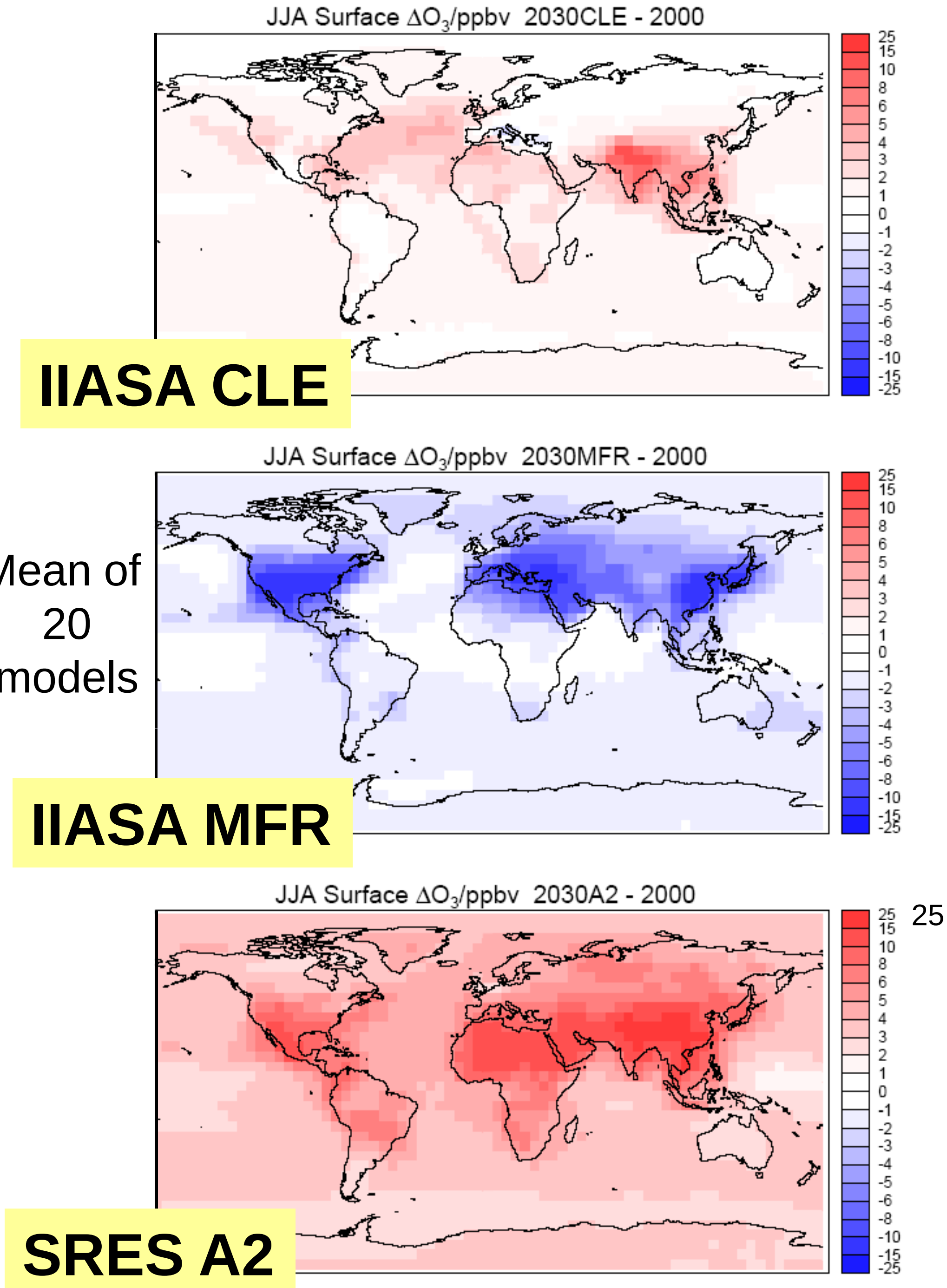
An international or hemispheric scale policy framework for the regulation of O_3 precursor emissions is necessary if significant increases in future O_3 concentrations are to be avoided. Any new framework of this kind must include the shipping and aviation sectors.

Global NO_x emission trends distributed on regions





Regional emissions separated for sources categories in 1990, 2000, 2030-CLE and 2030-MFR for NO_x [Tg NO_2 yr^{-1}]



Mean of 20 models

Projected changes in JJA surface O_3 for three 2030 scenarios

ACCENT models ensemble mean JJA surface O_3 changes 2000-2030 under three scenarios:
IIASA CLE
IIASA MFR
SRES A2

Dentener et al., 2006

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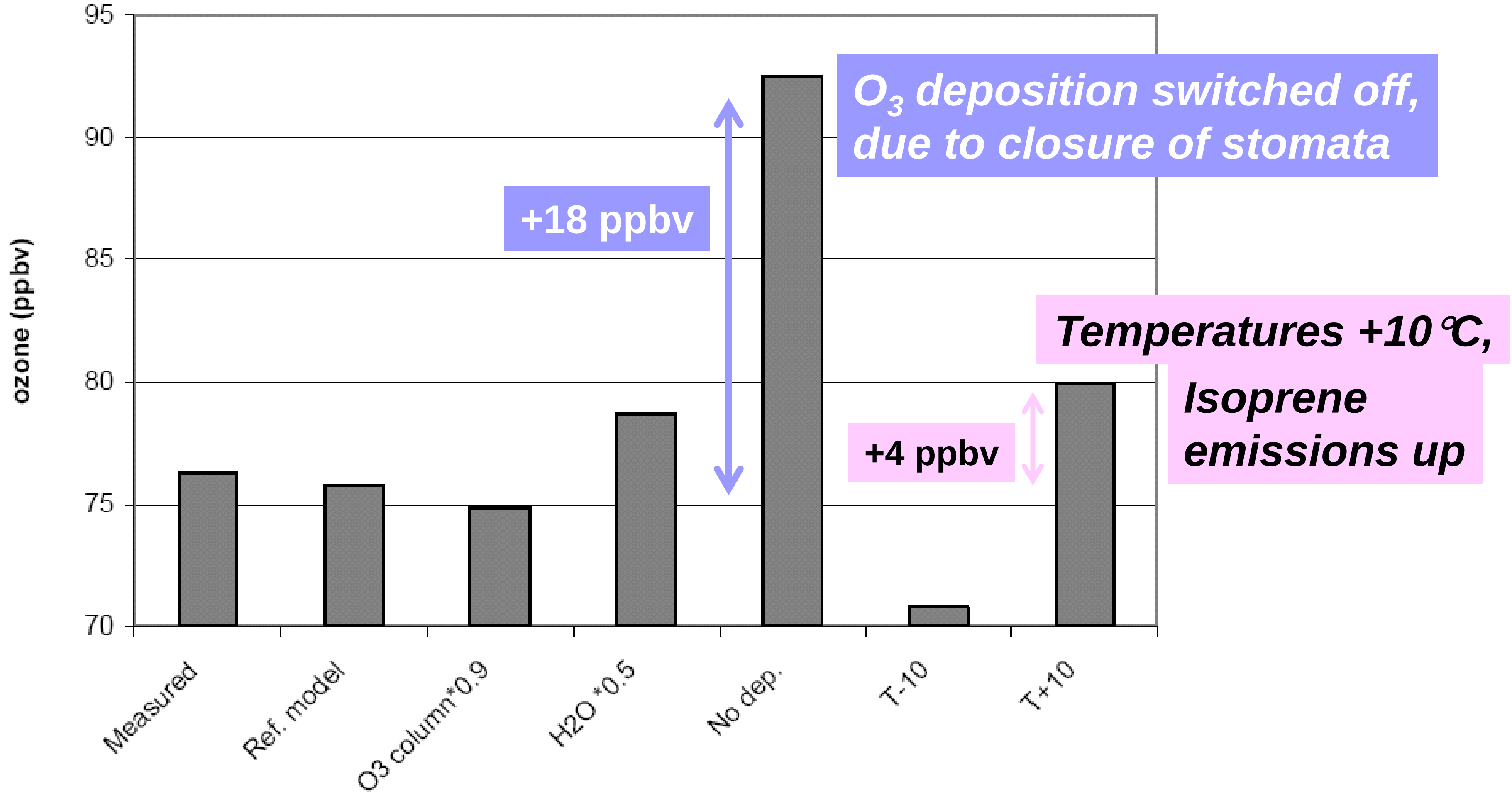
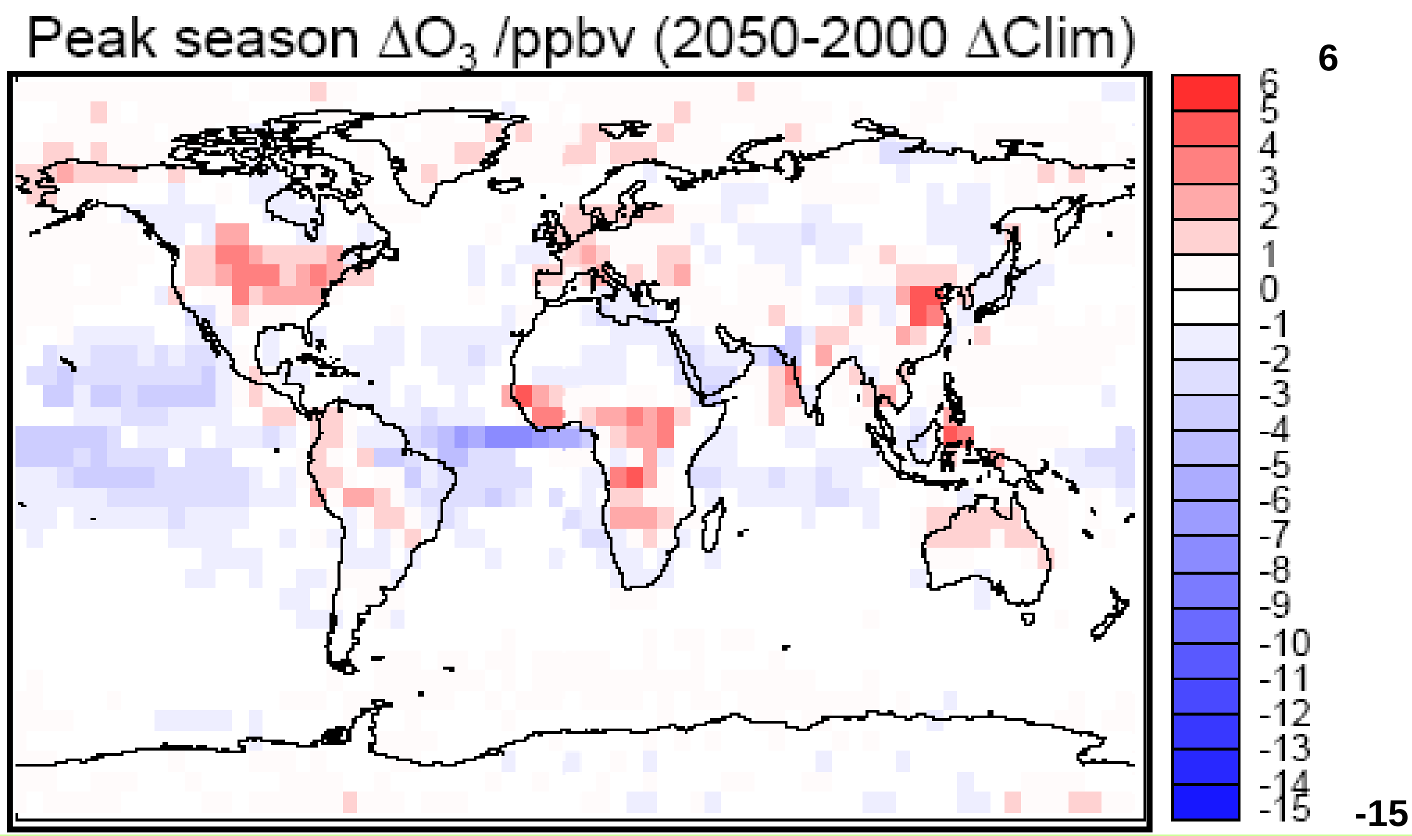
Regional ozone during episodes may be strongly affected by climate change



Sensitivity studies of regional O_3 during the 2003 heatwave (Solberg et al., 2008): 8 August 2003, region limited by 10ºE to 15.5ºW and 36ºN to 56ºN and below 3.5 km height. Measurements average of 8 sites.

Projected changes in surface O_3 (2050-2000) during the peak O_3 season due to ***climate change***



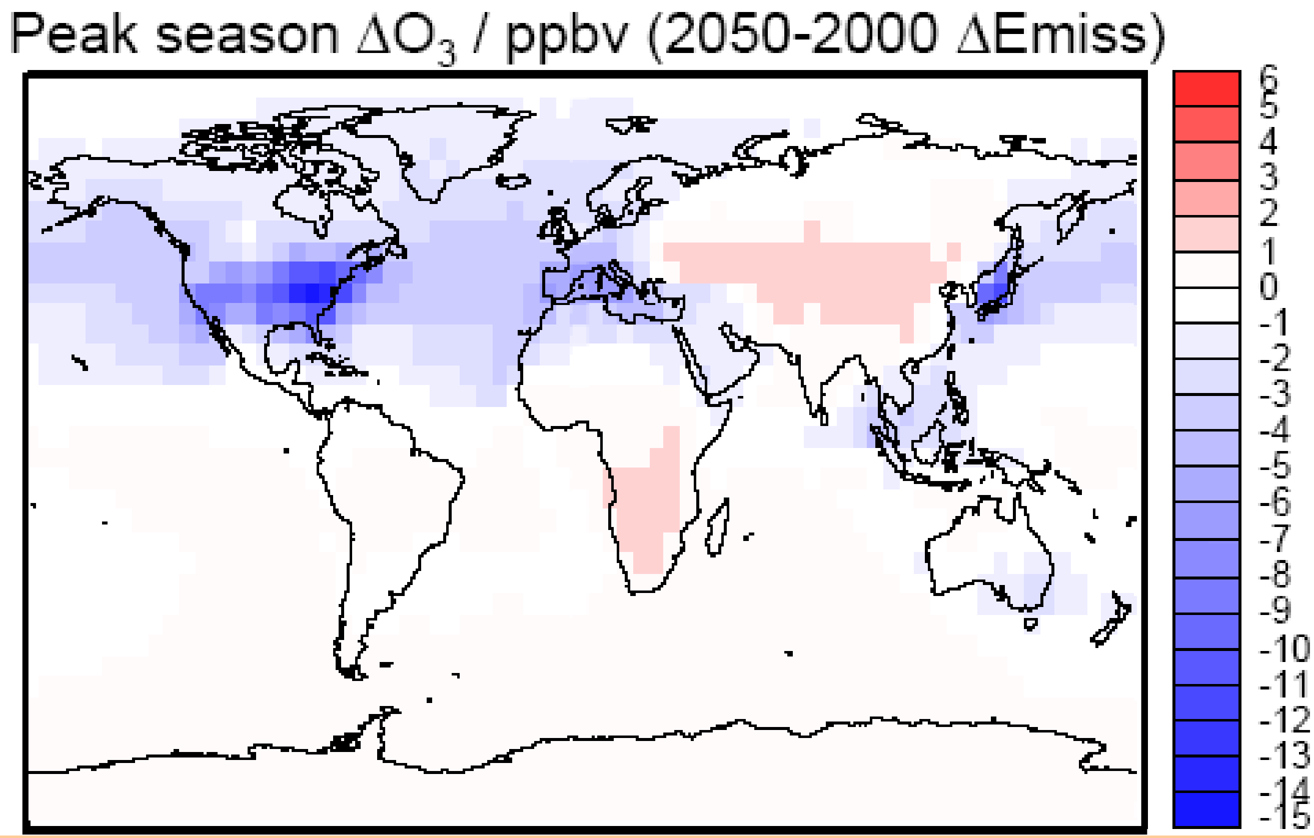
Average over 10 years

Impact of 2000-2050 climate change only

(prescribed future climate: HadGEM SRES A1B)

Mean of 3 models: STOCHEM-HadAM3 (Edinburgh), STOCHEM-HadGEM (UKMO), UMCAM (Cambridge). T- and PAR-change influence on isoprene and lightning NO_x emissions.

Projected changes in surface O_3 (2050-2000) during the peak O_3 season due to ***emissions changes***



Average over 10 years

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

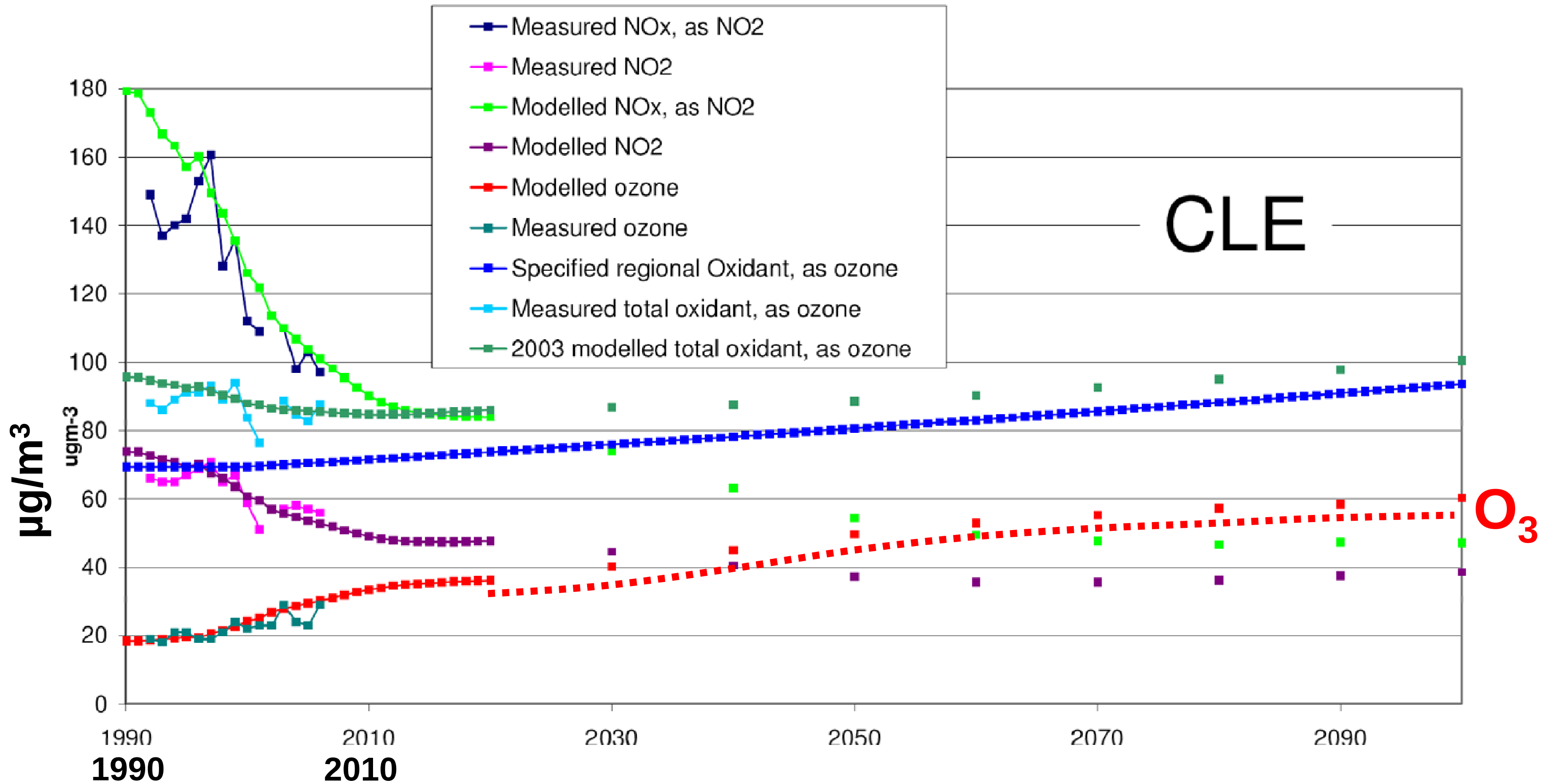
Mean of 5 models: STOCHEM-HadAM3 (Edinburgh), STOCHEM-HadGEM (UKMO), UMCAM (Cambridge), TM4 (KNMI), FR56C (O Wild)

Impacts of ozone up to 2030

- **Future global impacts under CLE by 2030:**
  - **3% less wheat production**
  - **10% less soybean production**
  - **Possible impacts on carbon sequestration**

- **Up to 2030, over Asia, O_3 represents as great a threat to food security as climate change**

In urban areas, if NO_x emissions reduce, O_3 levels will rise, towards hemispheric background levels



Red = modelled urban (London Bloomsbury) ozone (goes up as NO_x reduces)

Courtesy John Stedman/Mike Jenkin/Dick Derwent

The main policy messages

- **Controls on emissions at a global scale are required to control ozone effectively**
- **Shipping and aviation need to be included in any strategy**
- **<u>Implementing existing legislation is vital to prevent the ground level ozone problem becoming worse</u>**
- **<u>Climate change will tend to increase ozone in the polluted regions of the world</u>**
- **Improved integration of sectoral policies is needed to maximise emission reductions across sectors and to reduce ozone impacts. Ozone is not just an air quality issue; it is a human health, environment, climate change, and economic development problem**

Co-bene-fits of cont-rol of ozone pre-cursor emis-sions

Environmental problem	NO_x control	VOC control	CH_4 control	Combined control
Human health				
NO_2 urban	Large	Negligible	Negligible	Large
O_3 urban	Medium	Medium	Small	Medium
O_3 rural	Medium	Medium	Medium	Large
PM	Medium	Small	Negligible	Medium
Biodiversity				
N deposition	Medium	Negligible	Negligible	Medium
O_3	Small	Small	Small	Small
Acidification and Eutrophication				
N deposition	Medium	Negligible	Negligible	Medium
O_3	Negligible	Negligible	Negligible	Negligible
Visibility				
PM	Medium	Small	Negligible	Medium
O_3	Small	Small	Small	Small
Climate change				
O_3	Medium	Negligible	Medium	Medium
PM direct	Small	Negligible	Negligible	Small
PM indirect (cloud)	Small	Negligible	Negligible	Small
Carbon sequestration				
N deposition	Medium	Negligible	Negligible	Medium
O_3	Medium	Medium	Medium	Medium

Conclusions and main messages (1)

- **ozone is a global problem requiring policy interventions on a bigger scale (global/hemispheric) than is currently the case**
- **the implementation of existing global air quality abatement measures is critical for avoiding a more serious ozone problem in the future**
- **even with full implementation, some regions are likely to suffer from worsening ozone over the next couple of decades and stronger controls will be needed in these regions to avoid this future**

Conclusions and main messages (2)

- projected changes in climate will have an effect on future ozone concentrations and are expected to increase ozone levels where emissions are high, and in other less polluted regions, will reduce the benefits obtained from emission controls;
- poorly regulated sectors must be integrated into the current abatement controls policy mix - particularly aviation and shipping
- improved integration between policies is necessary for maximising emission reductions and minimising the impacts of ozone

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Thank you for your attention

The report will be printed in July/August 2008. Copies can be retrieved from www.royalsociety.org or from Rachel.Garthwaite@royalsociety.org

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Co-benefits of control of ozone precursor emissions

Environmental problem	NO_x control	VOC control	CH_4 control	Combined control
Human health				
NO_2 urban	Large	Negligible	Negligible	Large
O_3 urban	Medium	Medium	Small	Medium
O_3 rural	Medium	Medium	Medium	Large
PM	Medium	Small	Negligible	Medium
Biodiversity				
N deposition	Medium	Negligible	Negligible	Medium
O_3	Small	Small	Small	Small
Acidification and Eutrophication				
N deposition	Medium	Negligible	Negligible	Medium
O_3	Negligible	Negligible	Negligible	Negligible
Visibility				
PM	Medium	Small	Negligible	Medium
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Climate change				
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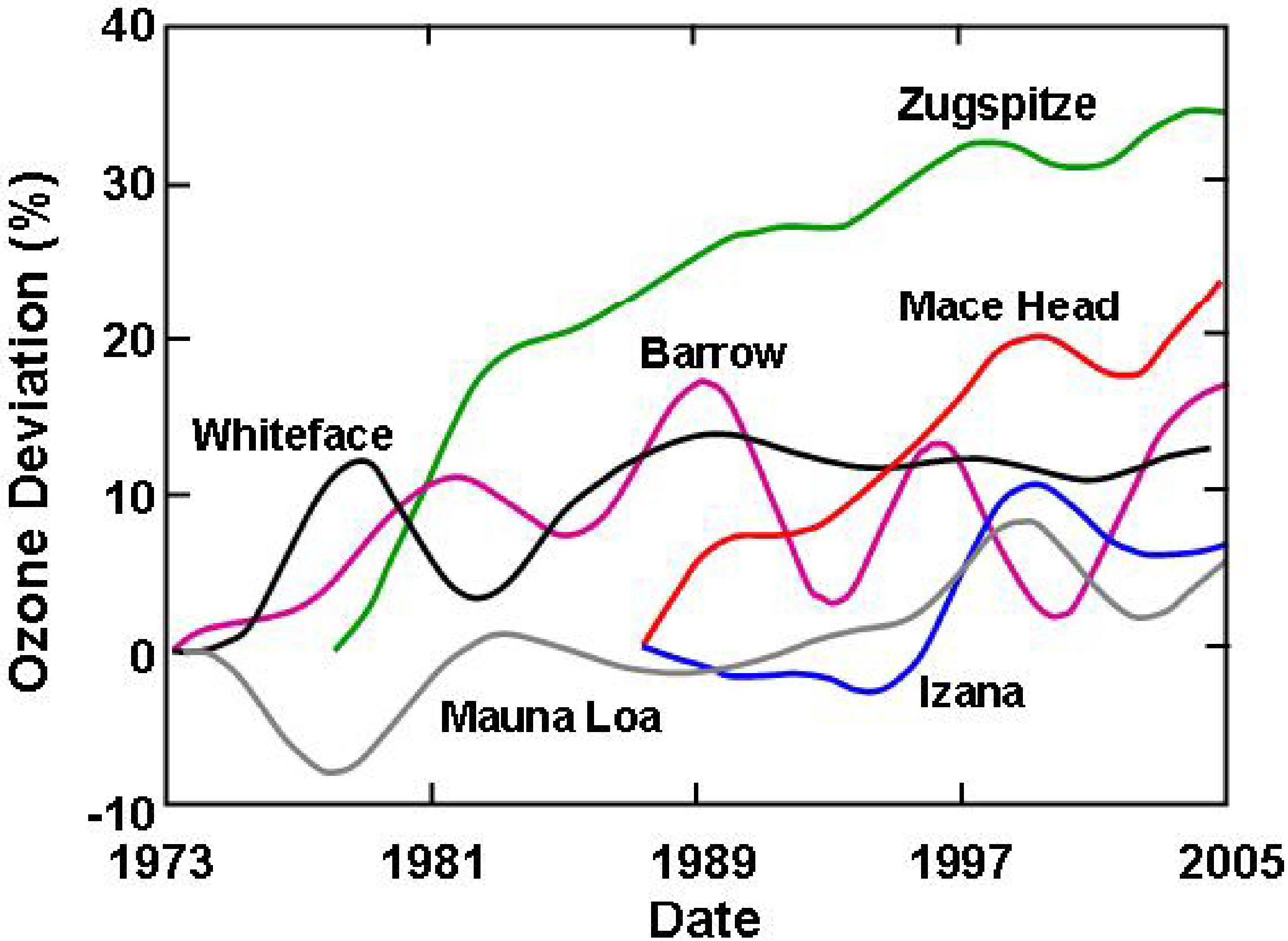
Carbon sequestration				
N deposition	Medium	Negligible	Negligible	Medium
O_3	Medium	Medium	Medium	Medium

Observed trends in surface O_3 since the 1970s at various relatively remote sites



Oltmans et al., 2006