Impact of climate change on oxidizing capacity of the atmosphere

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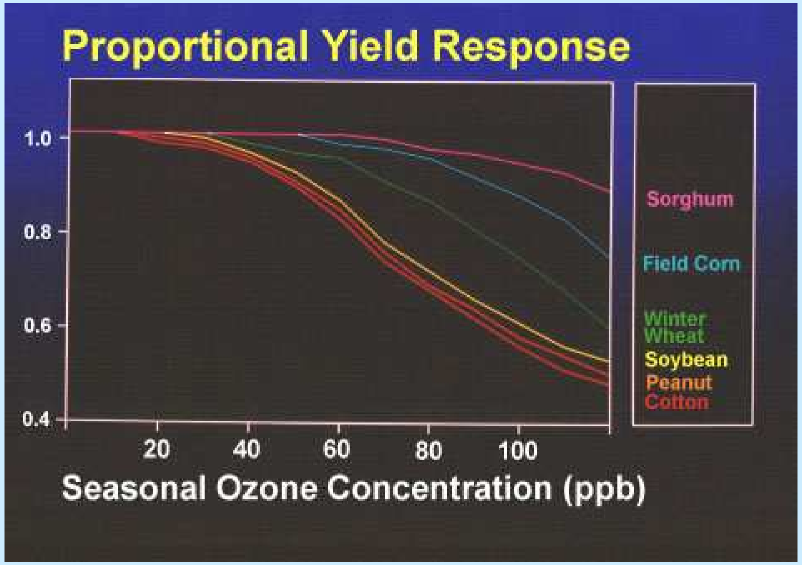
Our research interests are

- Use 3-D global chemistry climate models to understand past trends and to predict the future evolution of atmospheric composition.
- Links between climate change and stratospheric ozone recovery.
- Impact of climate change and stratospheric changes on tropospheric chemistry and air quality, and vice versa.
- Role of biogenic species in a changing climate; climate change affects both emissions and transport pathways.
- Interactions between atmosphere and biosphere.

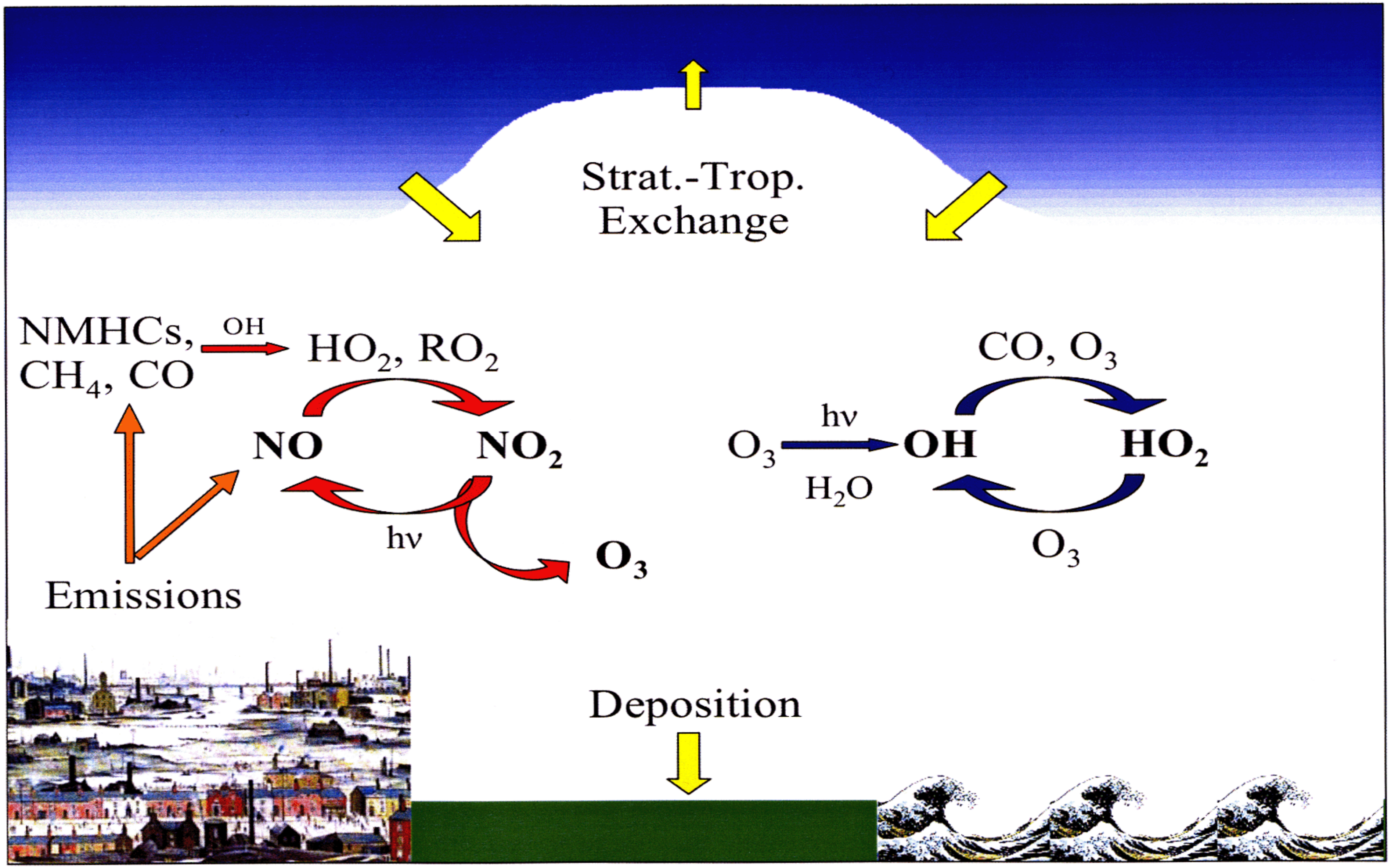
Tropospheric Ozone

- Greenhouse gas
  After CO_2 and CH_4
- Regional pollutant
  Harmful to human health and vegetation, reduce productivity of crops
- Complex chemistry
  Secondary product
- Control oxidizing capacity of the atmosphere
  Primary source of OH.
- Spatially and temporally variable



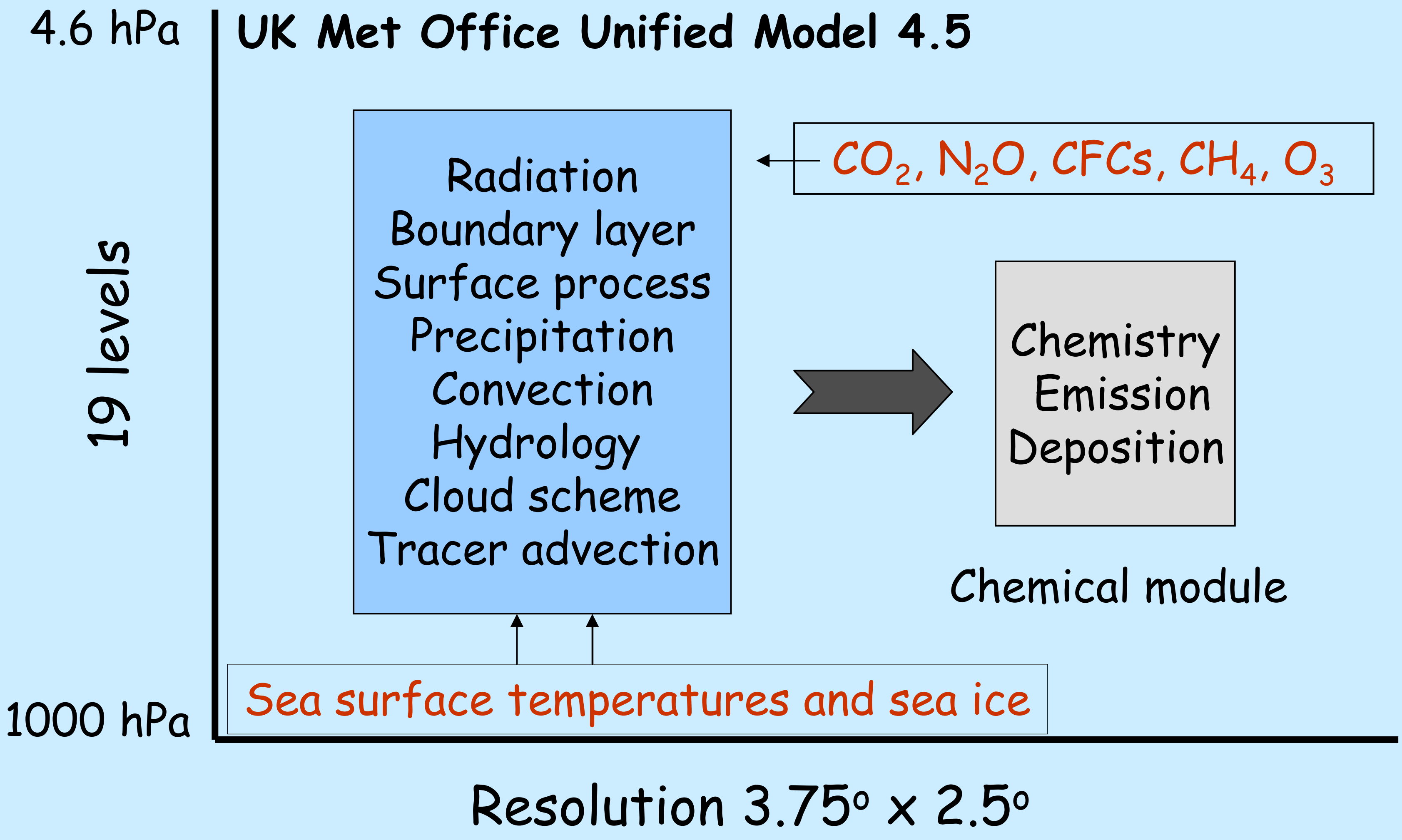
http://www.ars.usda.gov

Chemical process in the troposphere

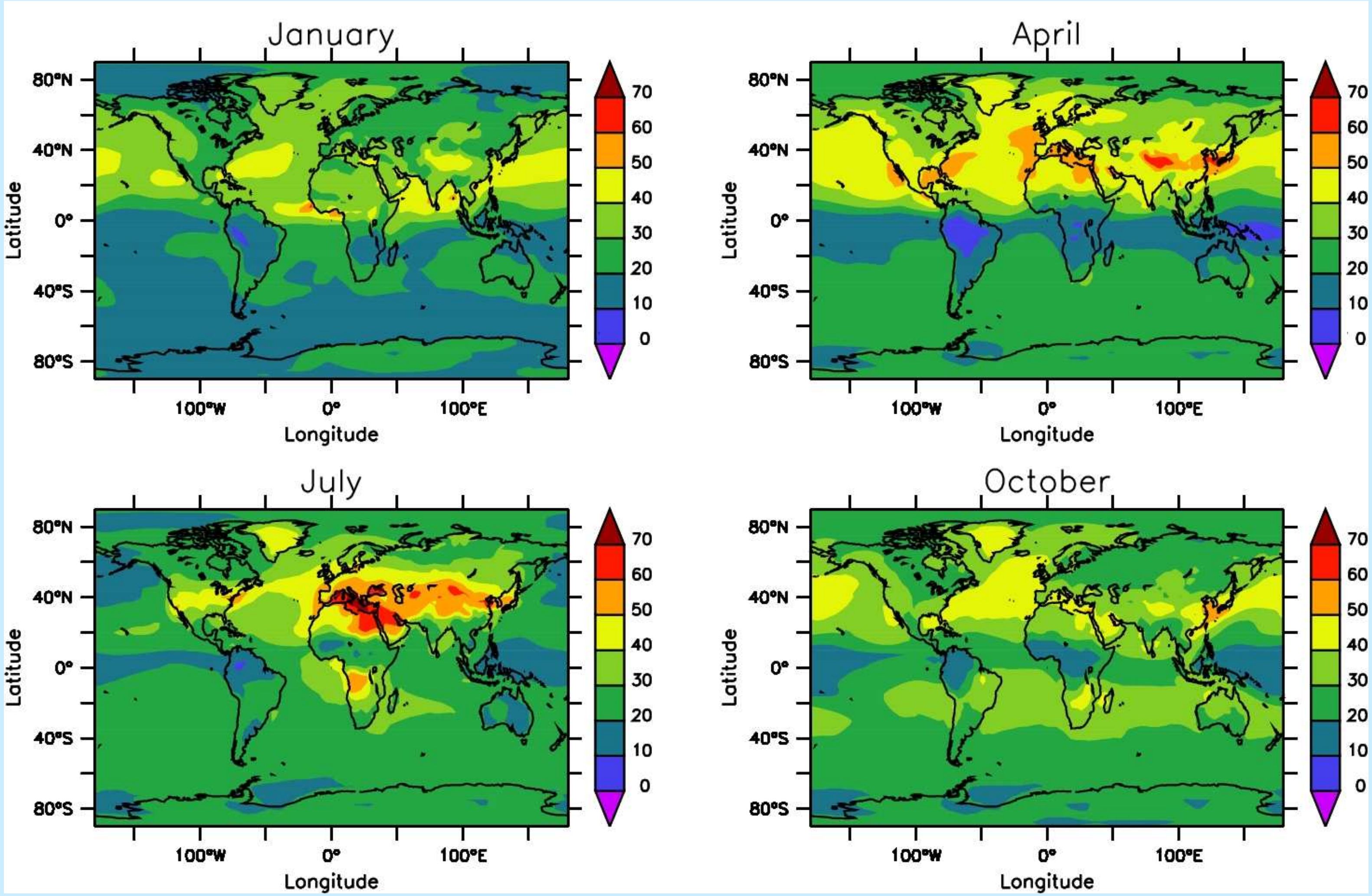


J.A. Pyle et al., The Royal Society, London, Nov. 2006

Chemistry-climate model



Seasonal distribution of surface ozone (ppbv)



Predicting future changes of tropospheric ozone rely on

- future evolutions of Ozone Precursors
  - Population growth
  - Social and economical developments
  - Technological implementations
- anticipated Climate Change
  - Temperature, winds, precipitation, clouds
  - Circulation
  - Biogenic emissions
- Stratospheric Ozone Changes

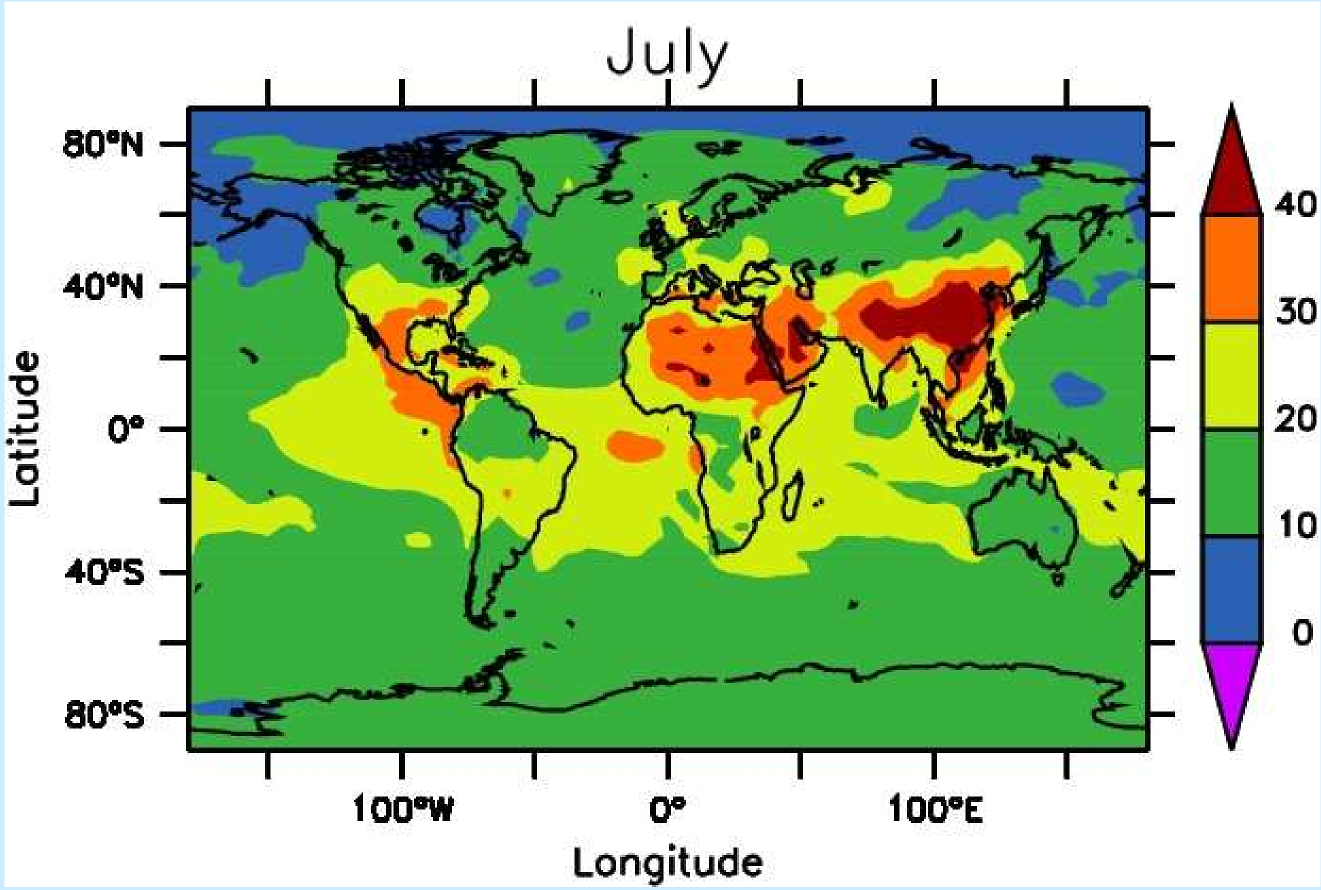
Experiments

Simulations	Emissions	Meteorology
Base	IIASA-2000	2000s
Emi	A2-2100	2000s
CC	A2-2100	2090s
Isop	A2-2100+Δisoprene	2090s
SNO_x	A2-2100+Δsoil-NO_x	2090s

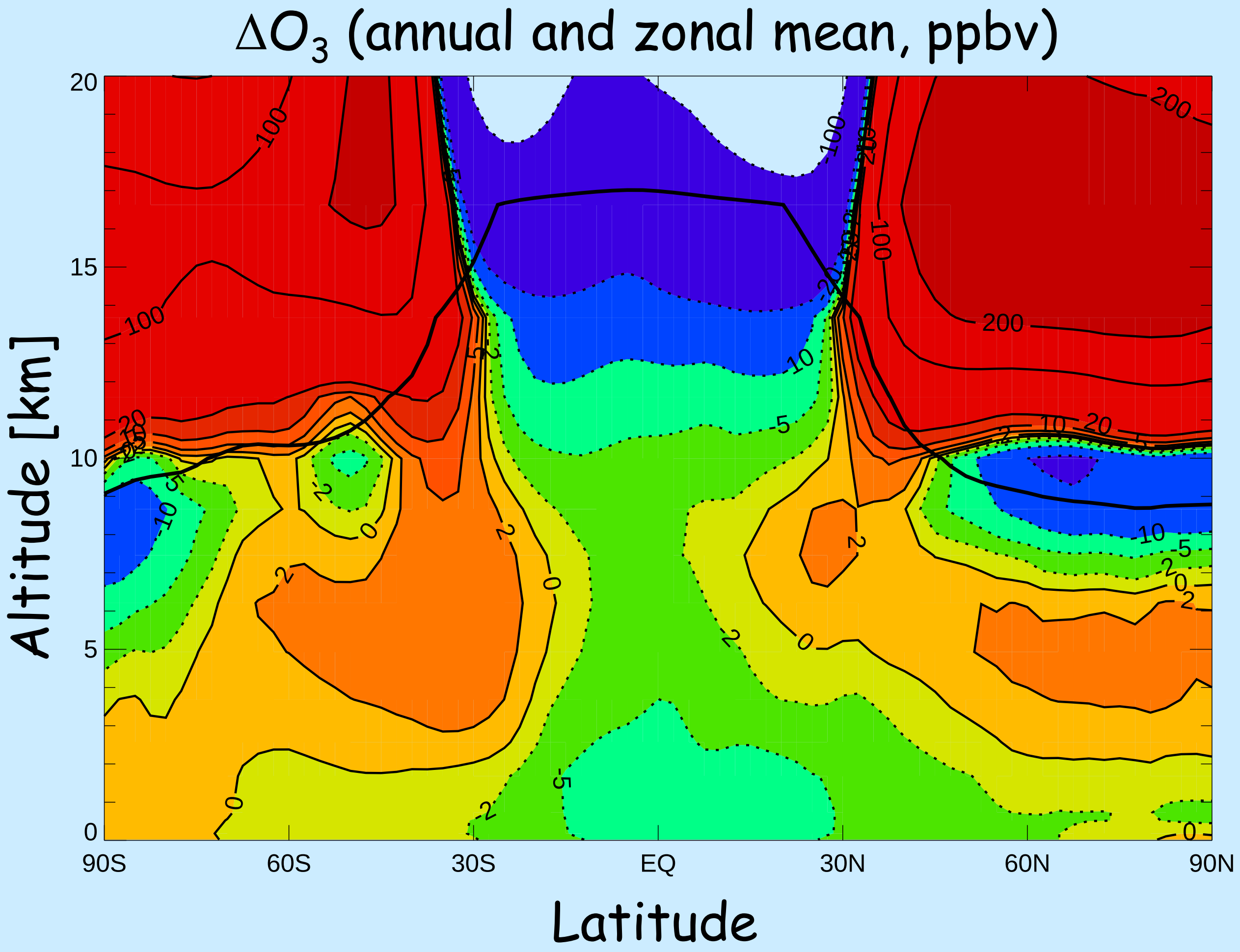
Assess ozone changes due to changes in emission, climate ($2xCO_2$) and biogenic emissions

Surface O_3 change between 2000 and 2100 due to changes in anthropogenic emissions

Substantial increase in the source regions



O_3 changes due to future climate changes; warmer, wetter, enhanced circulations



Stronger ascent in tropics combined with stronger descent in mid-latitudes.

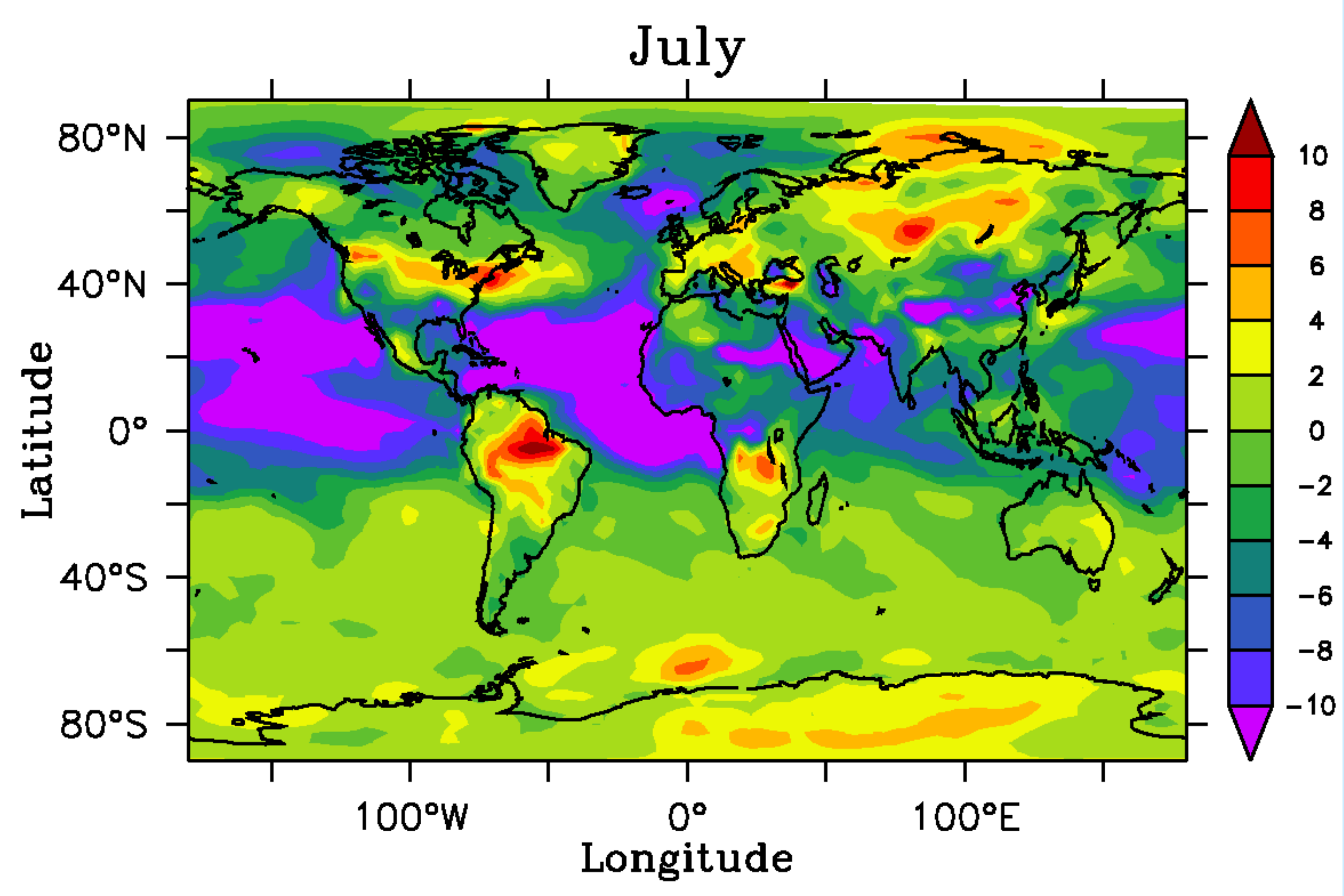
Enhanced chemical destruction through reaction $O(^1D)+H_2O$ following O_3 photolysis..

Zeng and Pyle (2003)

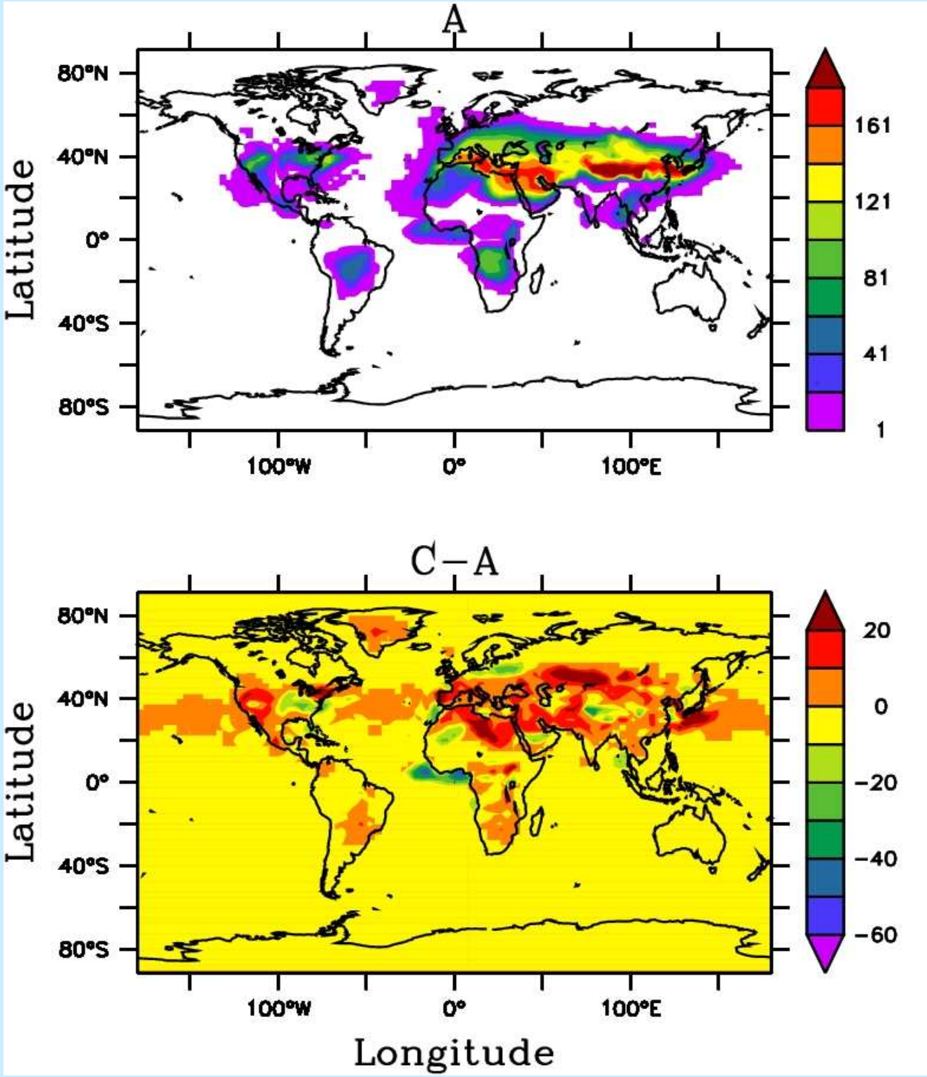
Surface O_3 change due to climate change

Increase water vapour leads to decreased surface O_3

Hotter and drier climate leads to high surface O_3 episode



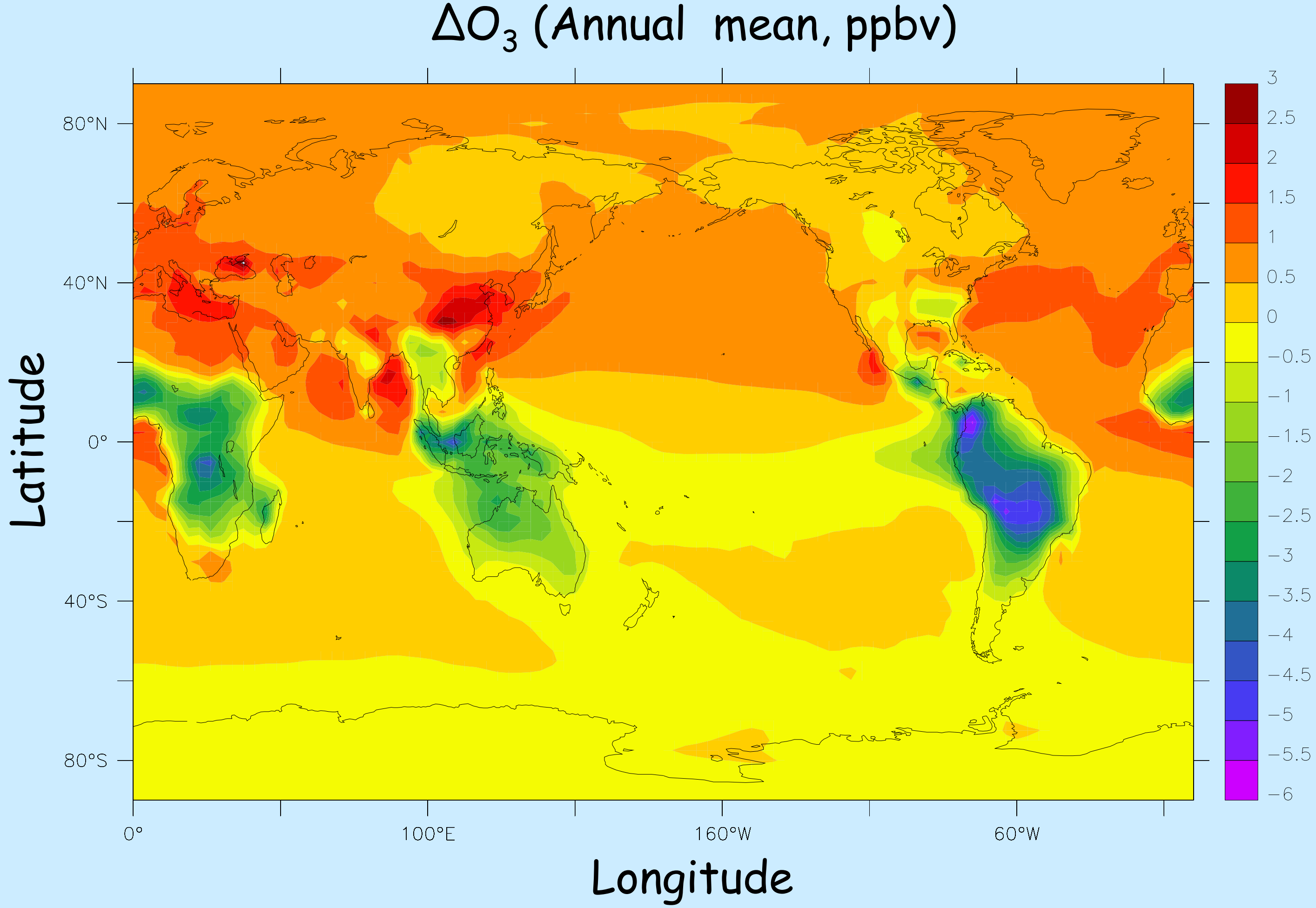
Surface O_3 exceedence measured by EU60 index (number of days with maximum 8-hour average O_3 exceeding 60 ppbv)



2000 climate

2100-2000 climate

Surface O_3 change due to increase of isoprene (2100isop-2100cc)

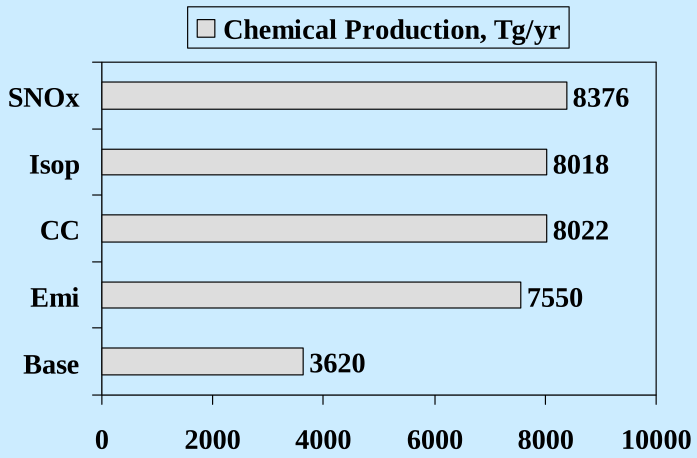


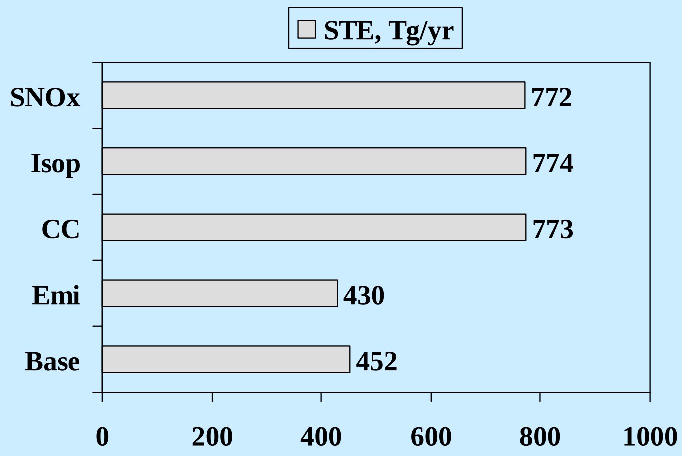
O_3 production in VOC-limited regime.

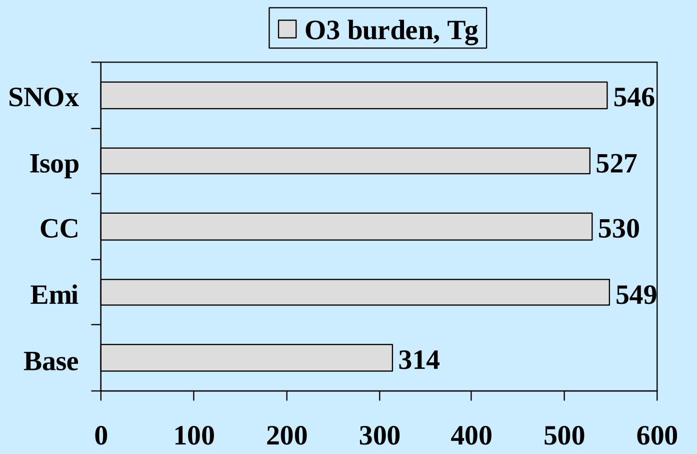
PAN formation contribute to O_3 increase in subtropical ocean.

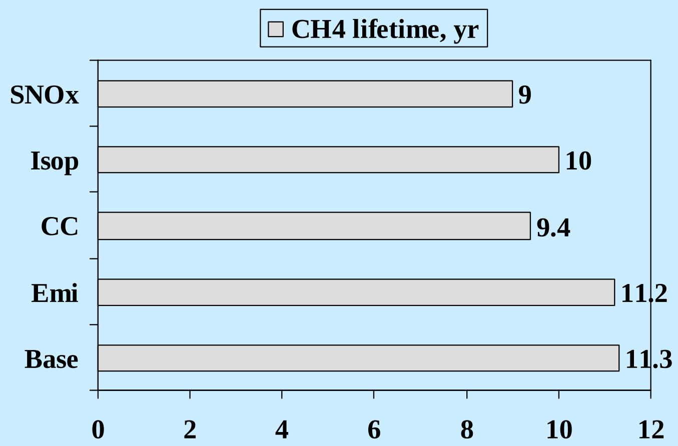
O_3 decrease in NOx-limited regime and ozonelysis in source regions.

Global Tropospheric Ozone Budgets

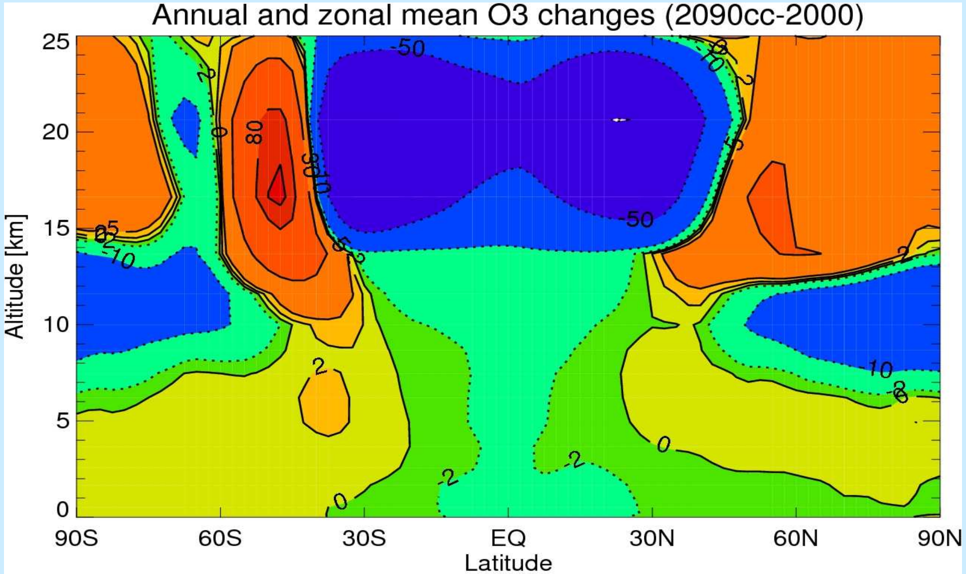




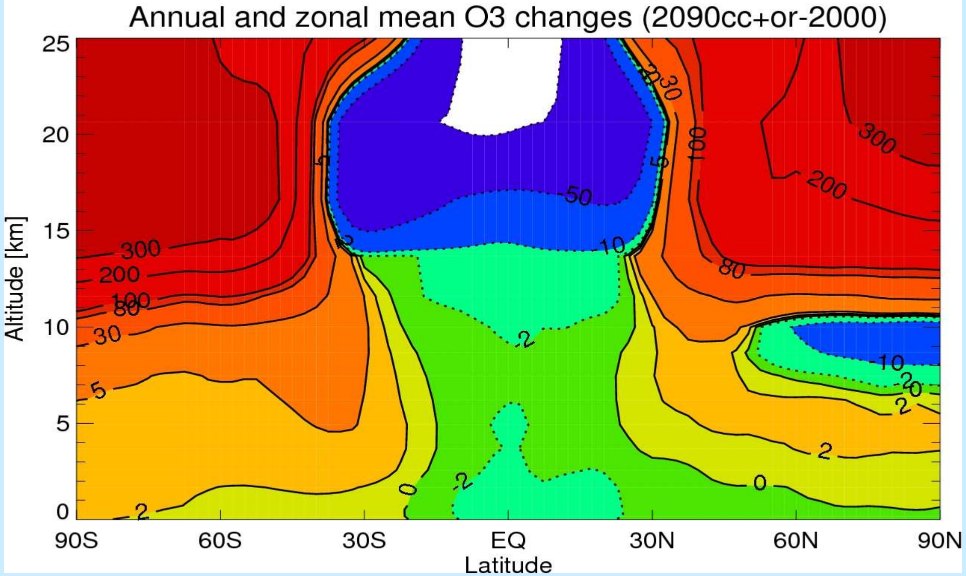




Impact of stratospheric ozone recovery



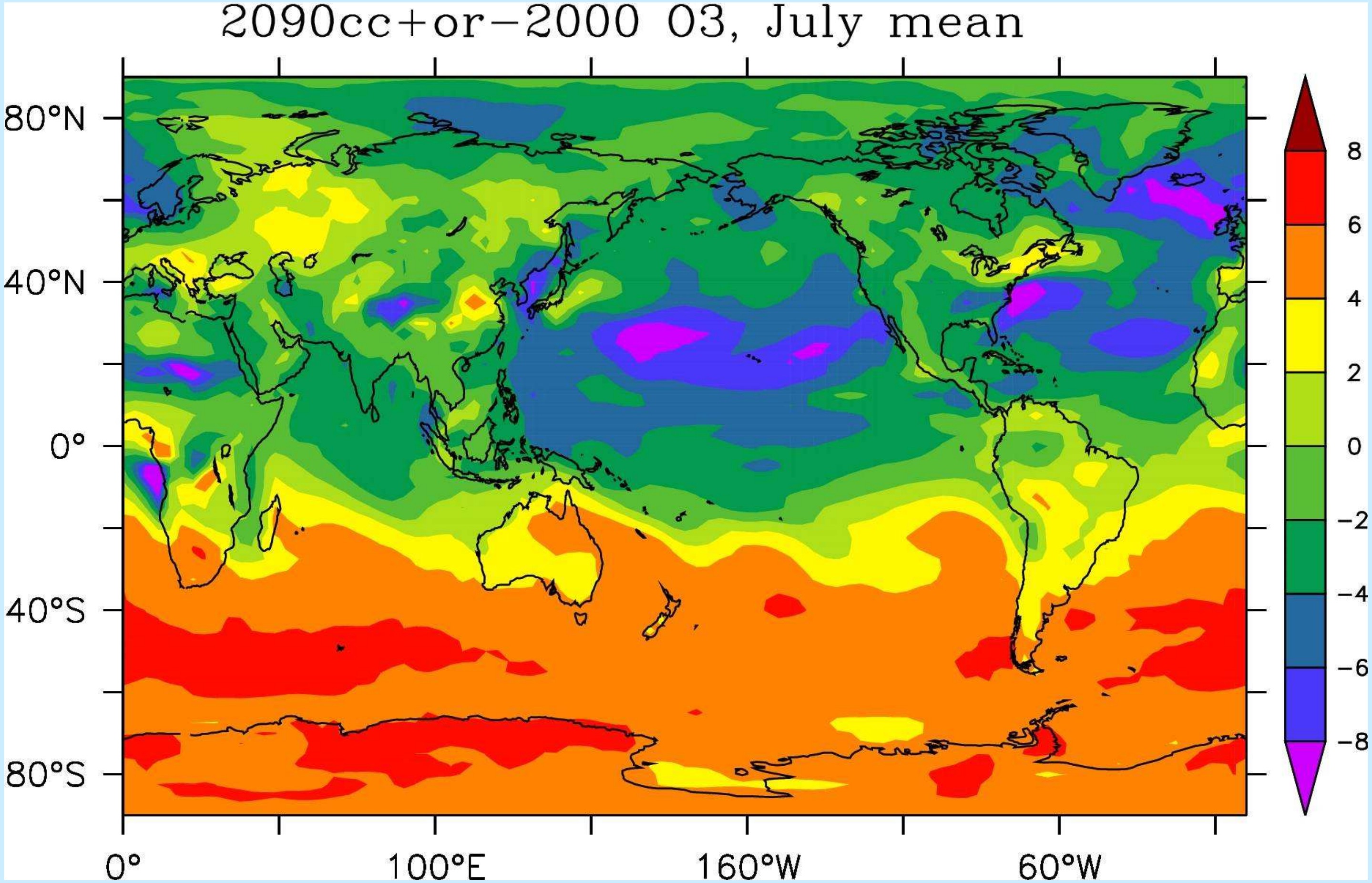
2090clim-2000clim



2090clim+Sozone
-2000clim

Surface ozone changes (Ozone recovery+CC)

Substantial increase of surface ozone in the SH;
strong stratospheric input + weak chemical destruction



Summary

- Anthropogenic emissions are a major factor determining future tropospheric ozone levels.
- Climate feedbacks are important, substantial increase of STE.
- Stratospheric ozone recovery has significant impact on tropospheric ozone, especially over the southern mid-latitudes.
- Oxidizing capacity set to change significantly in the future.
- Future climate change will reduce the background ozone in remote regions but likely to increase the frequency and the magnitude of high ozone episodes in populated regions.
- Emission control is essential for a reduction of ground-level ozone, but climate change will partially offset these efforts.
- Biogenic emissions have large uncertainties and can contribute significantly to O_3 changes both regionally and globally.

New capability; The UM-UKCA model

- Jointly developed by the UKMO and UK National Centre for Atmospheric Sciences, continuing development at NIWA.
- Whole-atmosphere chemistry-climate model
- Coupled gas phase-aerosols model
- Flexible chemistry
- At present, focus is on stratospheric and tropospheric ozone
- Can be used in global and limited-area configurations

Courtesy Olaf Morgenstern

Applications of the UKCA model

- Stratospheric chemistry-climate integrations
- Stratosphere-troposphere coupling (e.g. VSLS)
- Global air quality and climate change
- Support measurement programmes
- Move into ocean- and land-atmosphere exchange studies ("Earth System")
- Mesoscale modelling

Courtesy Olaf Morgenstern

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