PROSPECTS FOR REGIONAL OZONE UP TO 2050

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REGIONAL OZONE BUDGET FOR THE UNITED KINGDOM

The main budget terms for regional ozone are:

- inflow of baseline ozone
- exchange with the free troposphere
- import from Europe
- internal photochemical production

- internal photochemical destruction
- destruction by NO_x emissions
- dry deposition
- export to Europe

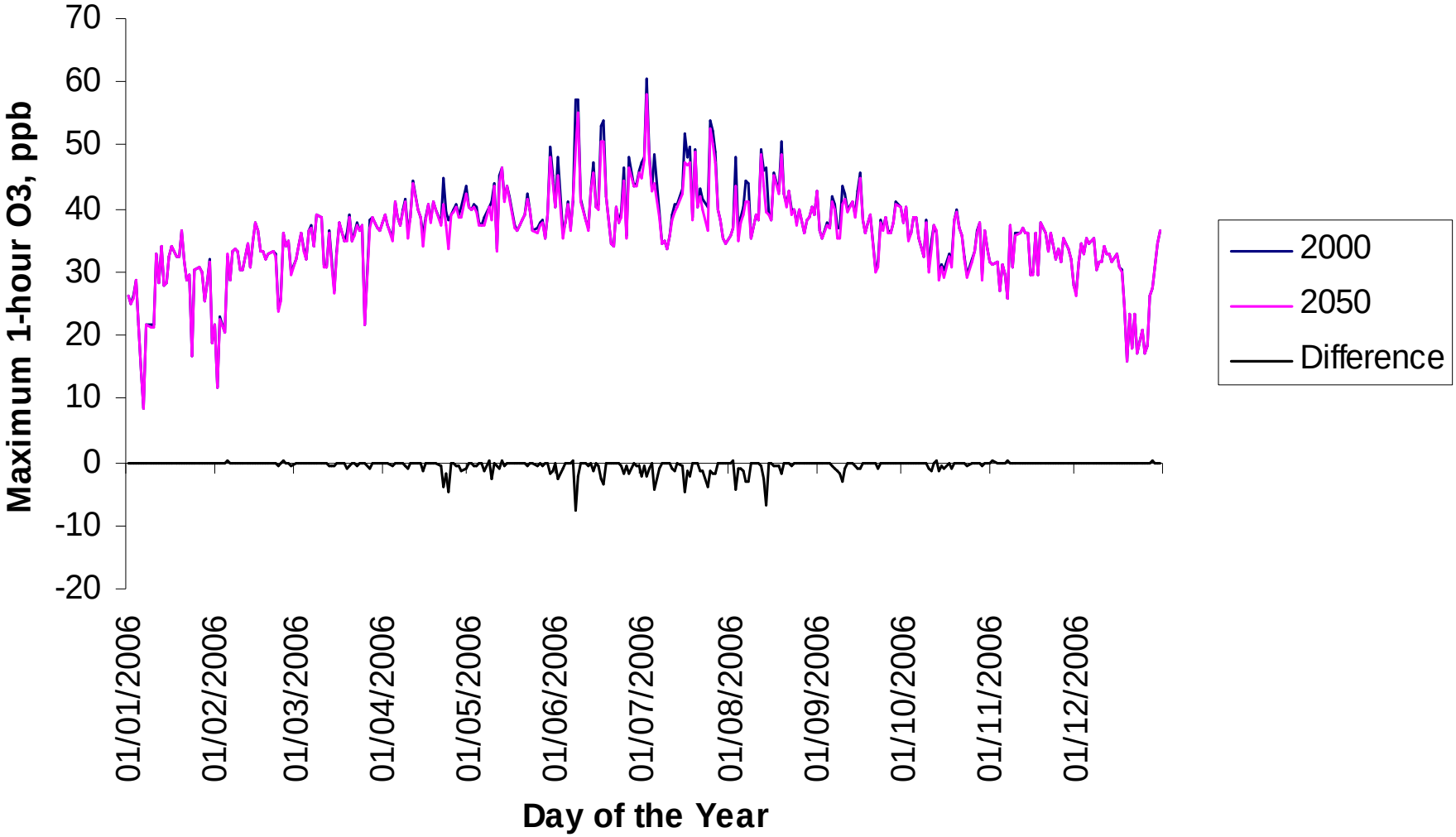
UNITED KINGDOM PHOTOCHEMICAL TRAJECTORY MODEL

- UK NAEI and EMEP emissions of SO_2, NO_x, VOCs, CO, CH_4
- natural biogenic emissions of isoprene and terpenes
- Carbon Bond IV mechanism
- model for mid-afternoon boundary layer
- initial and boundary conditions from literature data
- Met Office NAME 3-D trajectories 96-hour long 30 per mid-afternoon
- 365 days for 2006
- arrival point Harwell, Oxfordshire
- no treatment of shipping emissions

MODEL EXPERIMENTS

- base case with year 2000 emissions from UK NAEI and EMEP
- base case for 2050 with IIASA emissions (B2_11regs2)
- sensitivity cases looking at changes in ozone budget terms in 2050

2000 BASE CASE AND 2050 VOC CASE



IMPACT OF VOC EMISSION REDUCTIONS

- VOC reduction assumed to be the same as the CO reduction

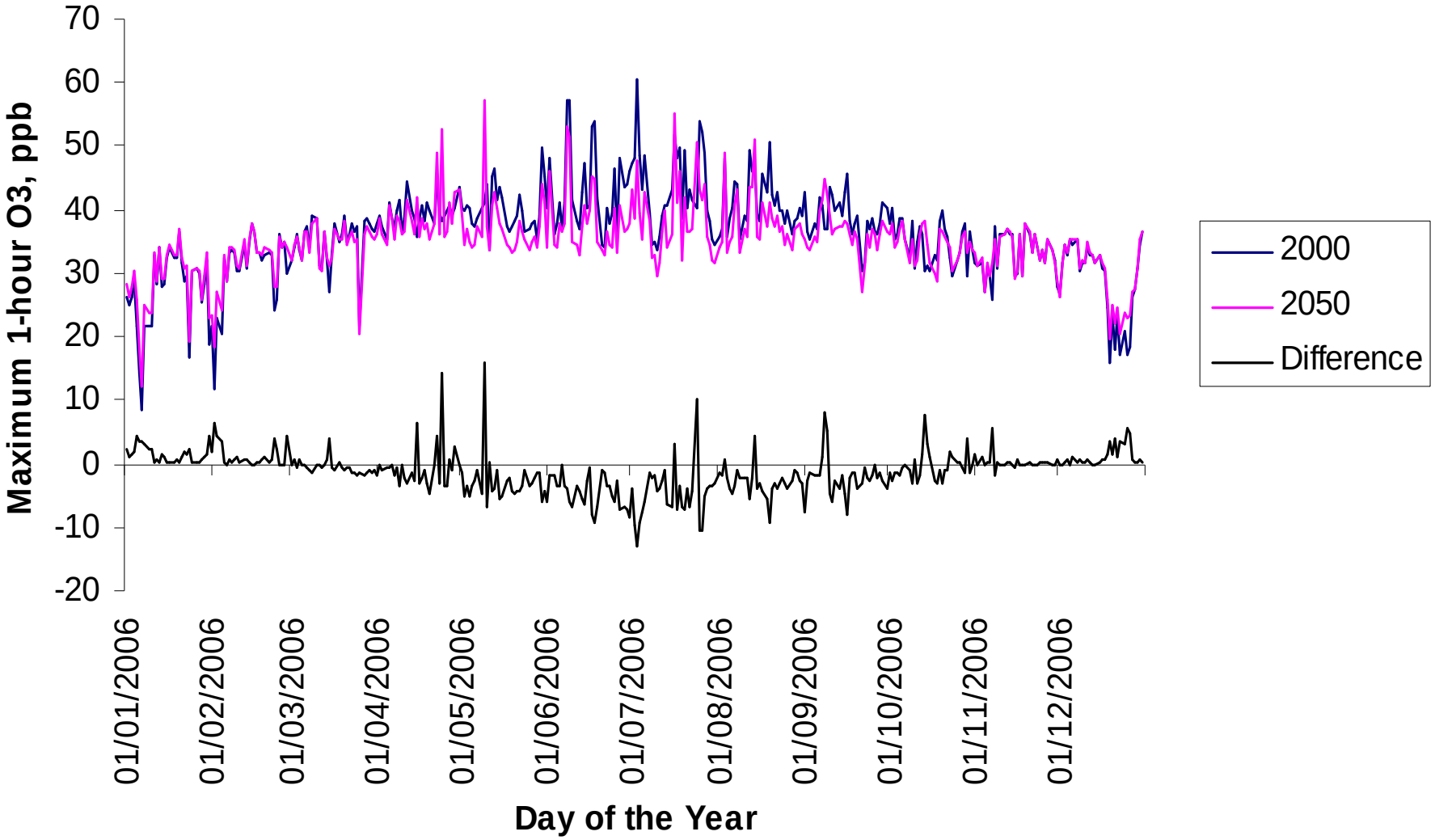
- VOC emission reductions only produce ozone reductions

- ozone reductions are concentrated during regional episodes

- 50% reduction in VOC emissions gave 1.2% reduction in annual mean of daily maximum 1-hour ozone and 3.9% reduction in maximum 1-hour mean ozone.

- Increasing VOC-limiting conditions leads to decreasing regional photochemical ozone production during spring and summer months.

2000 BASE CASE AND 2050 NO_x CASE



IMPACT OF NO_x EMISSION REDUCTIONS

- NO_x emission reductions produce both ozone reductions and ozone enhancements

- ozone reductions are concentrated during spring, summer and autumn months

- ozone enhancements are found during the winter months

- 62% reduction in NO_x emissions gave 3.3% reduction in annual mean of daily maximum 1-hour ozone and 5.4% reduction in maximum 1-hour mean ozone.

IMPACT OF NO_x EMISSION REDUCTIONS

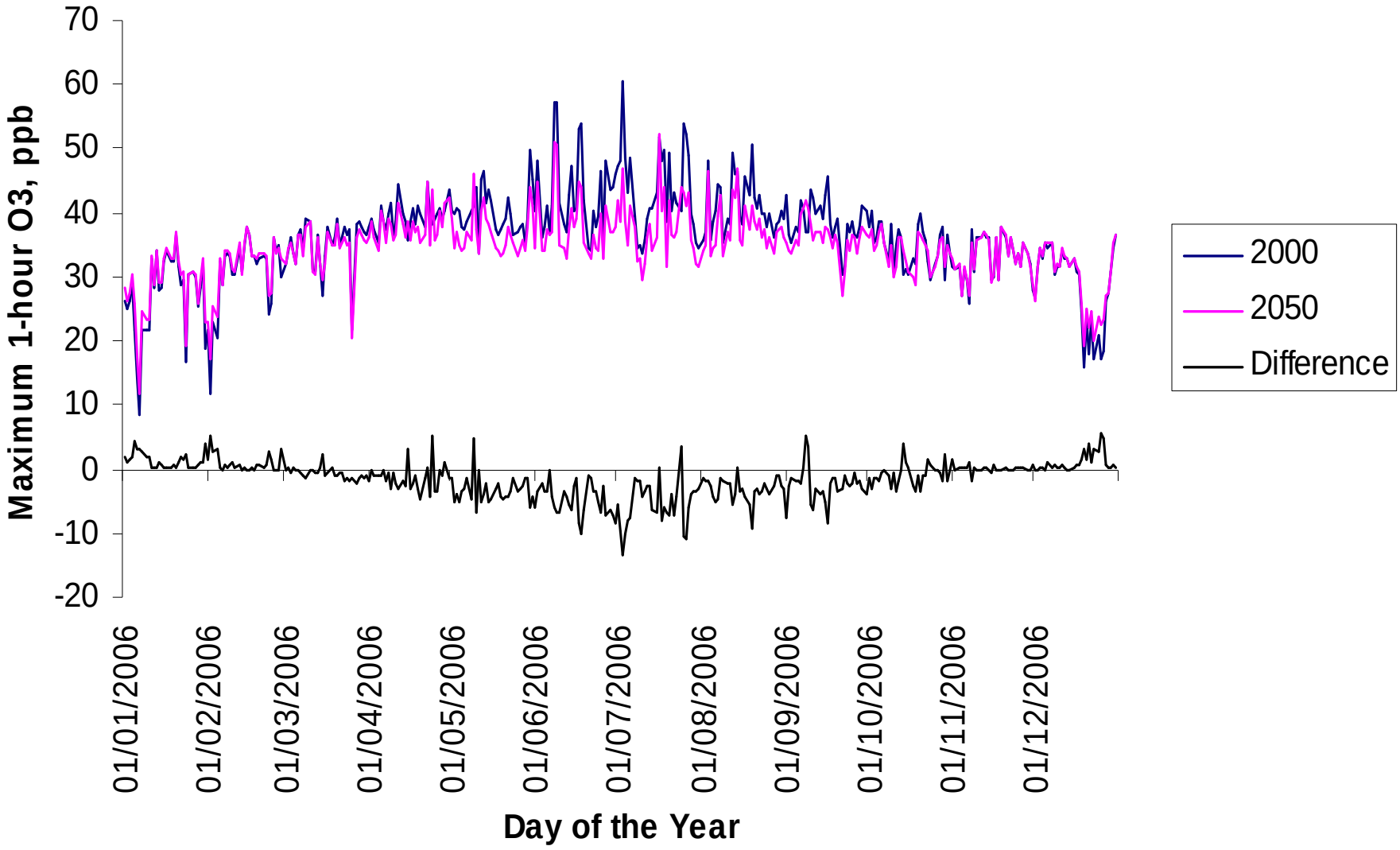
What are the main influences of NO_x control on regional ozone between 2000 and 2050?

1. Reduction of NO_x titration leads to increasing regional ozone levels all year round. (Total oxidant conserved).

2. Increasing NO_x-limiting conditions leads to decreasing regional photochemical ozone production during spring and summer months. (Total oxidant reduced).

3. Reduction of NO_x-inhibiting conditions leads to increasing regional photochemical ozone production during spring and summer months. (Total oxidant increased).

2000 BASE CASE AND 2050 VOC&NO_x CASE



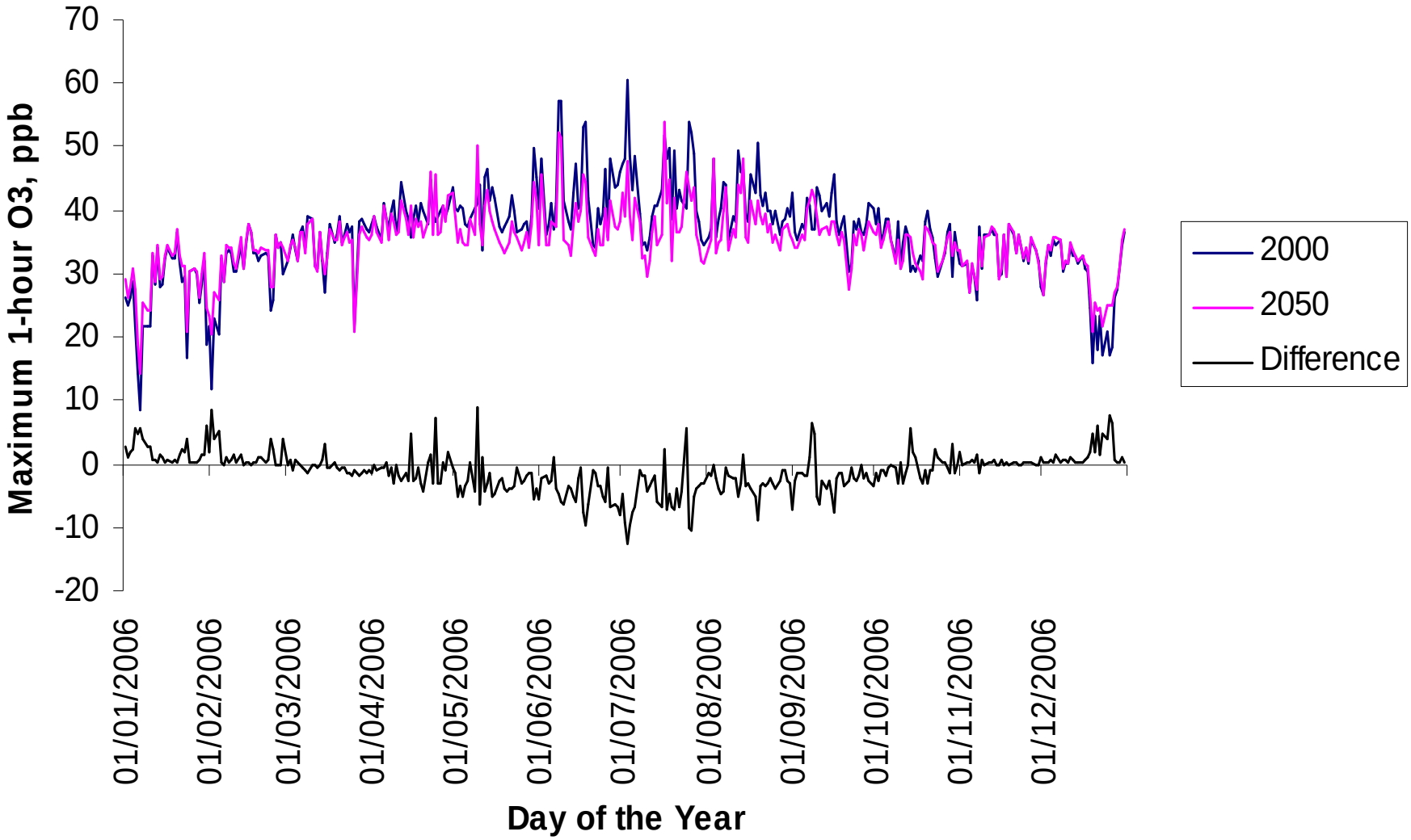
2000 BASE CASE AND 2050 VOC&NO_x CASE

- To a first approximation the reduction in the annual mean daily maximum 1-hour ozone levels is the sum of the VOC and NO_x changes.

- The impact of the reduction of NO_x-inhibiting conditions is reduced, however, because of the impact of the VOC controls.

- Overall, the reduction in VOC&NO_x emissions gave 4.4% reduction in annual mean of daily maximum 1-hour ozone and 13% reduction in maximum 1-hour mean ozone.

2000 BASE CASE AND 2050 VOC&NO_x F-NO_2 CASE



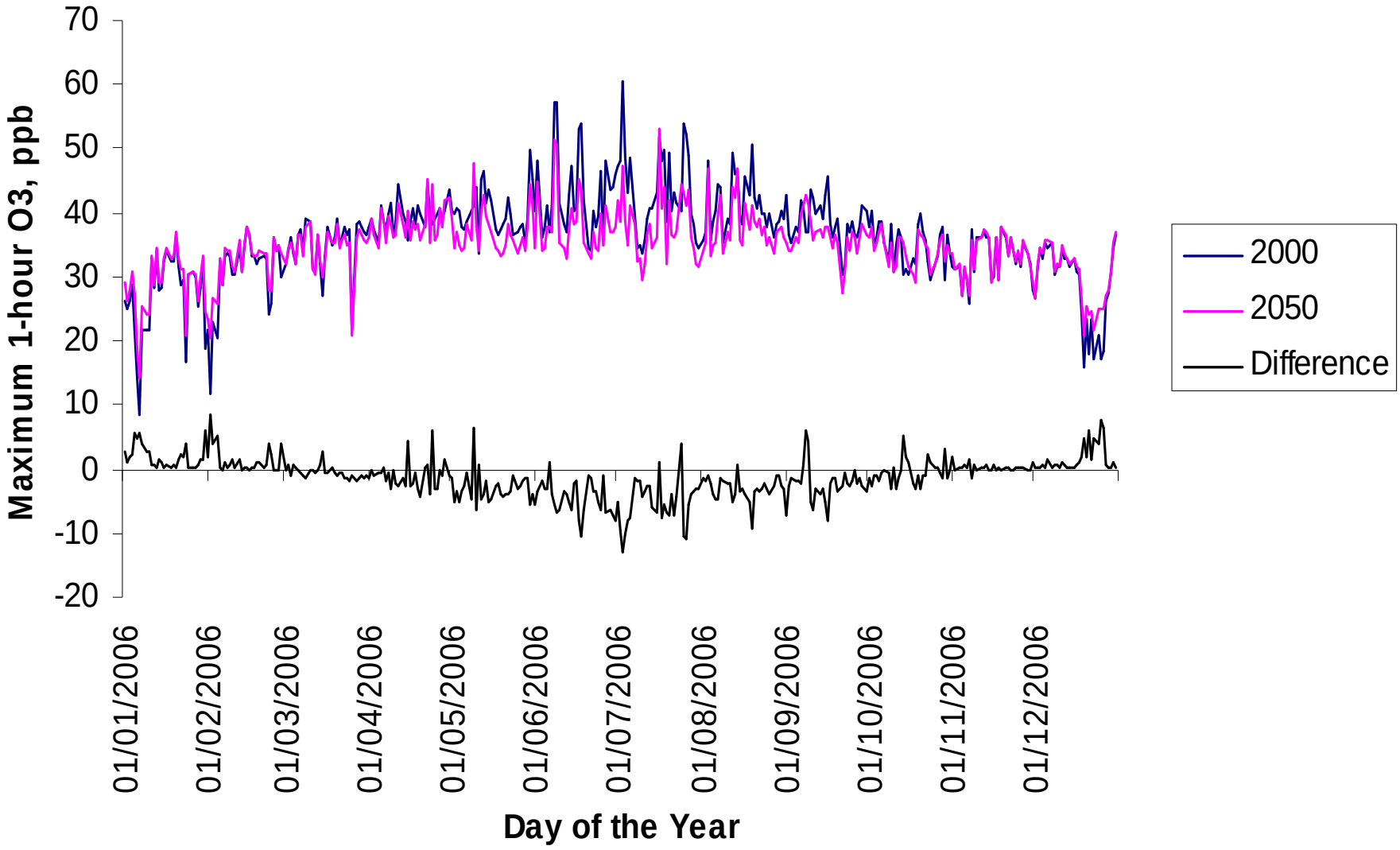
INCREASING DIRECT EMISSIONS OF NO_2 FROM DIESELS

Assume that the diesel is ‘civilised’ and there is a major switch to diesel across Europe for all transport for climate change policy reasons.

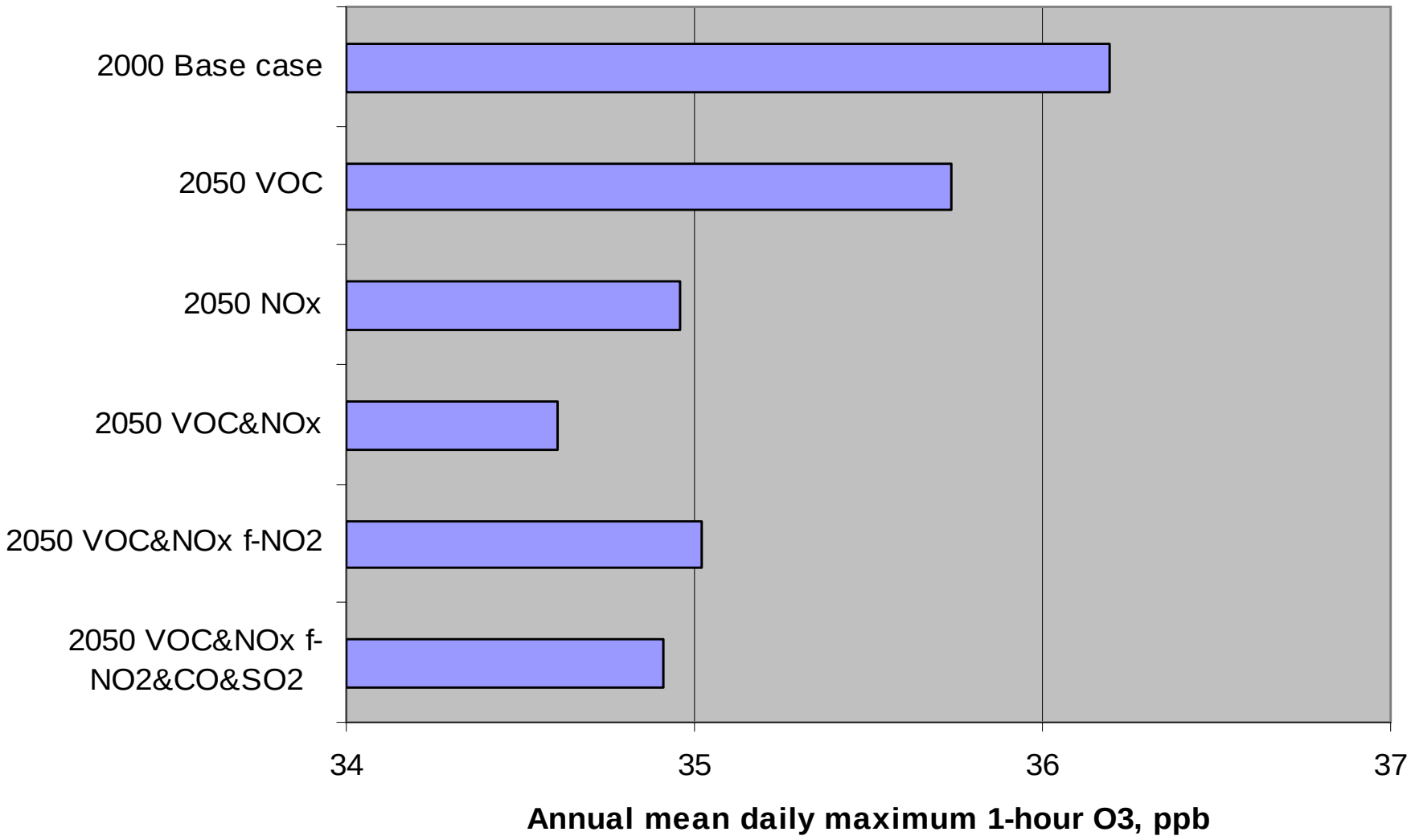
Assume f-NO_2 is 0.5 for all NO_x emissions.

Relative to f-NO_2 = 0, there is a 1.2% increase in annual mean of daily maximum 1-hour ozone and 1.9% increase in maximum 1-hour mean ozone.

2000 BASE CASE AND 2050 VOC&NO_x&SO_2&CO



IMPACT OF EUROPEAN EMISSION CONTROLS 2000 - 2050



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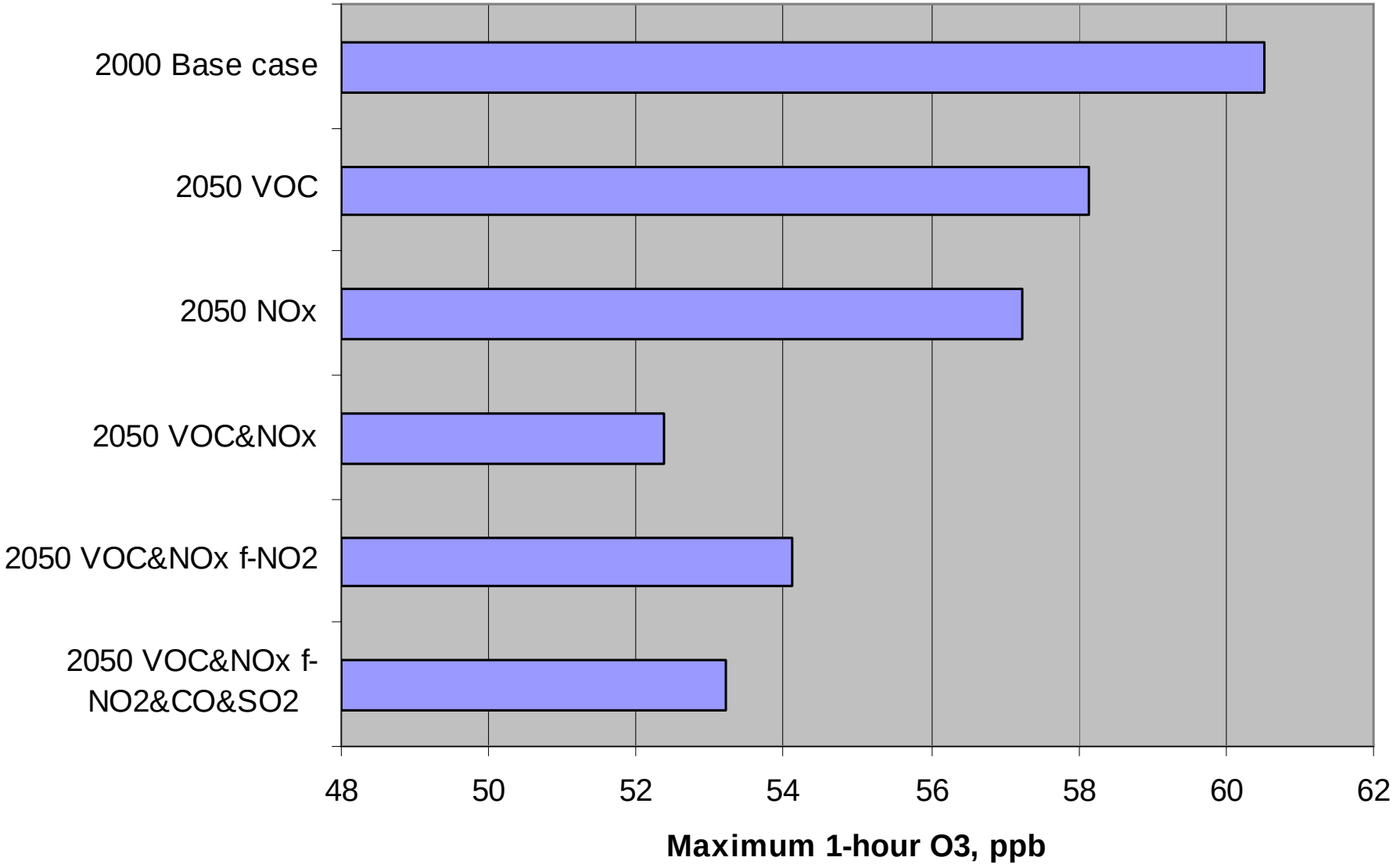
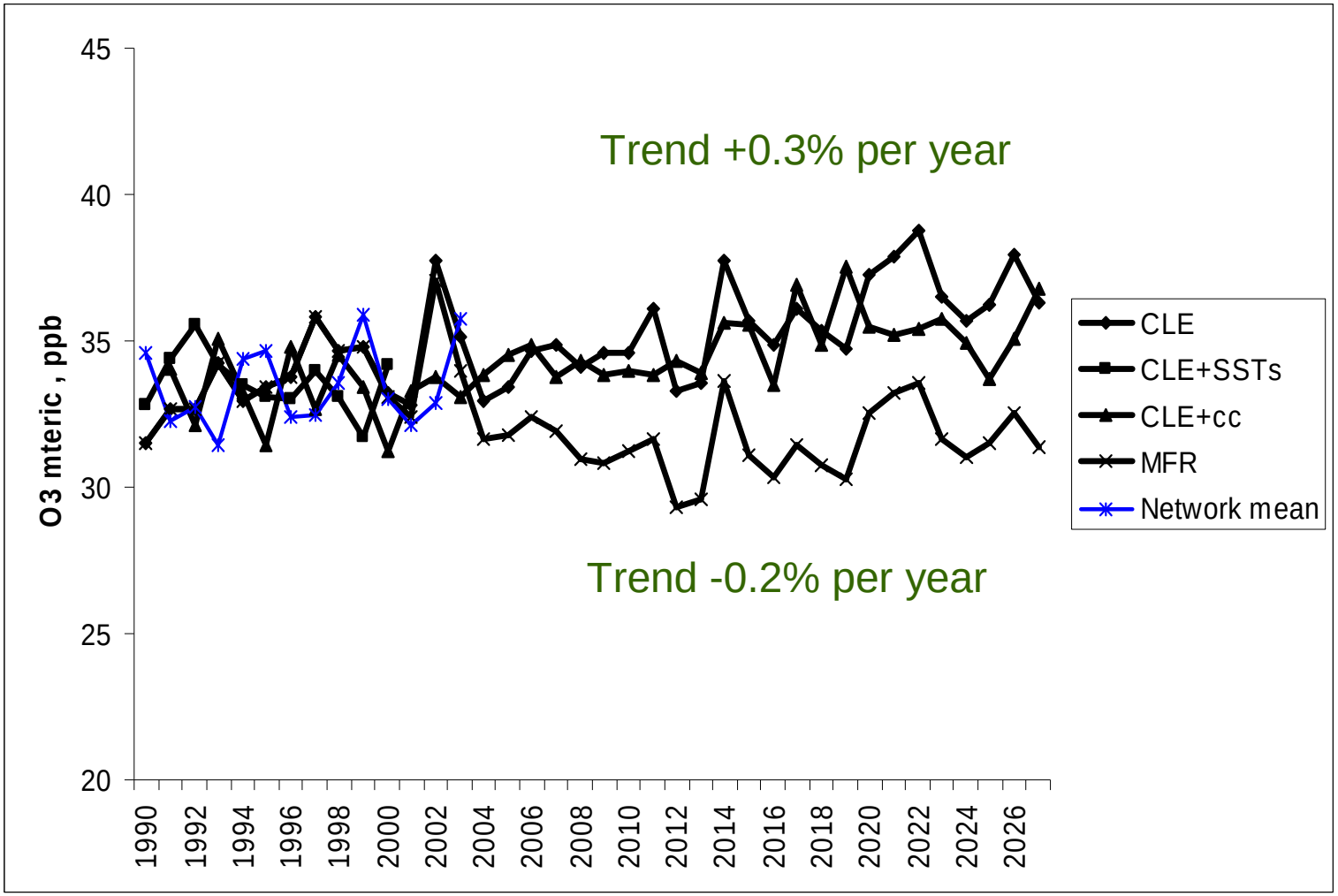
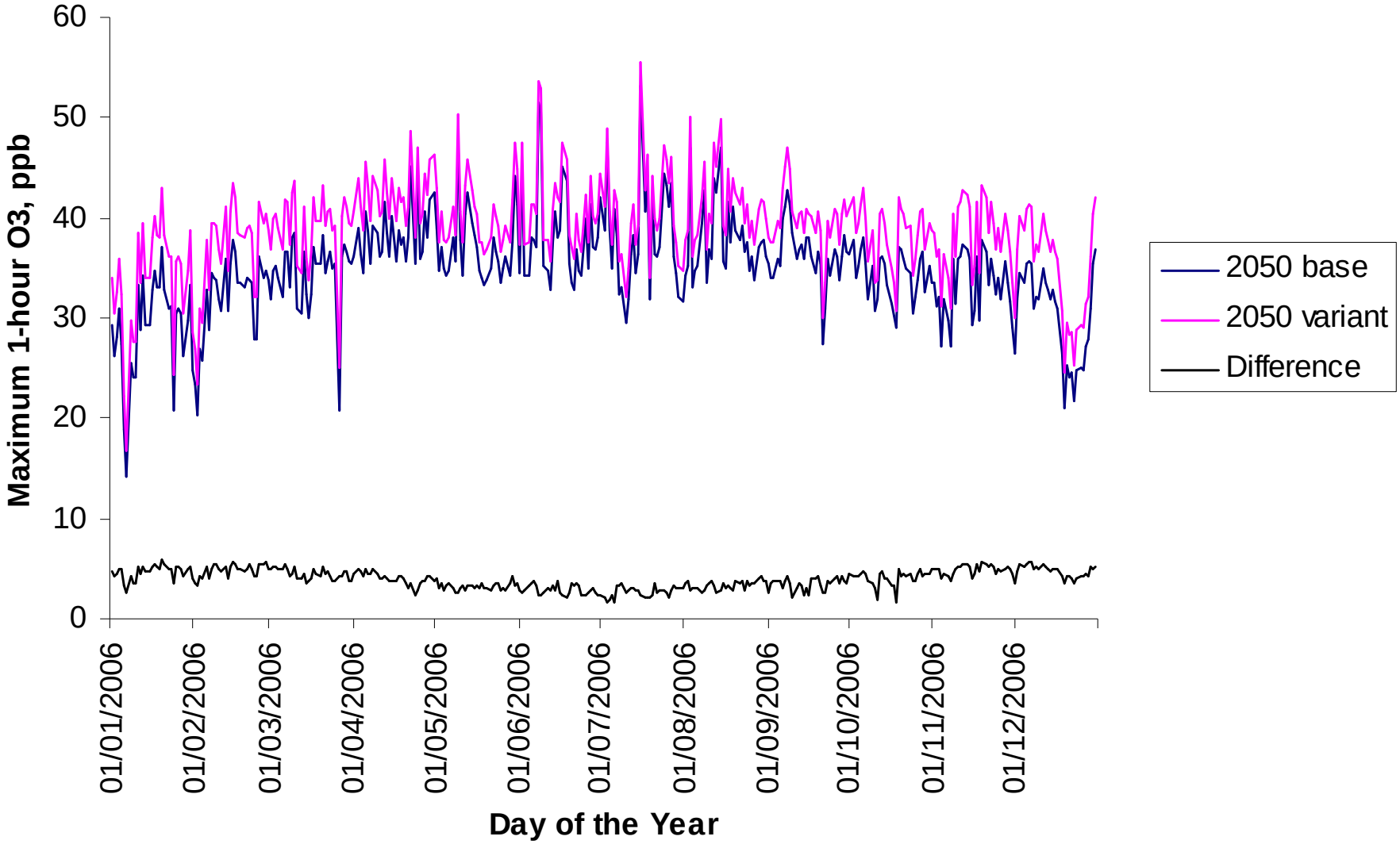


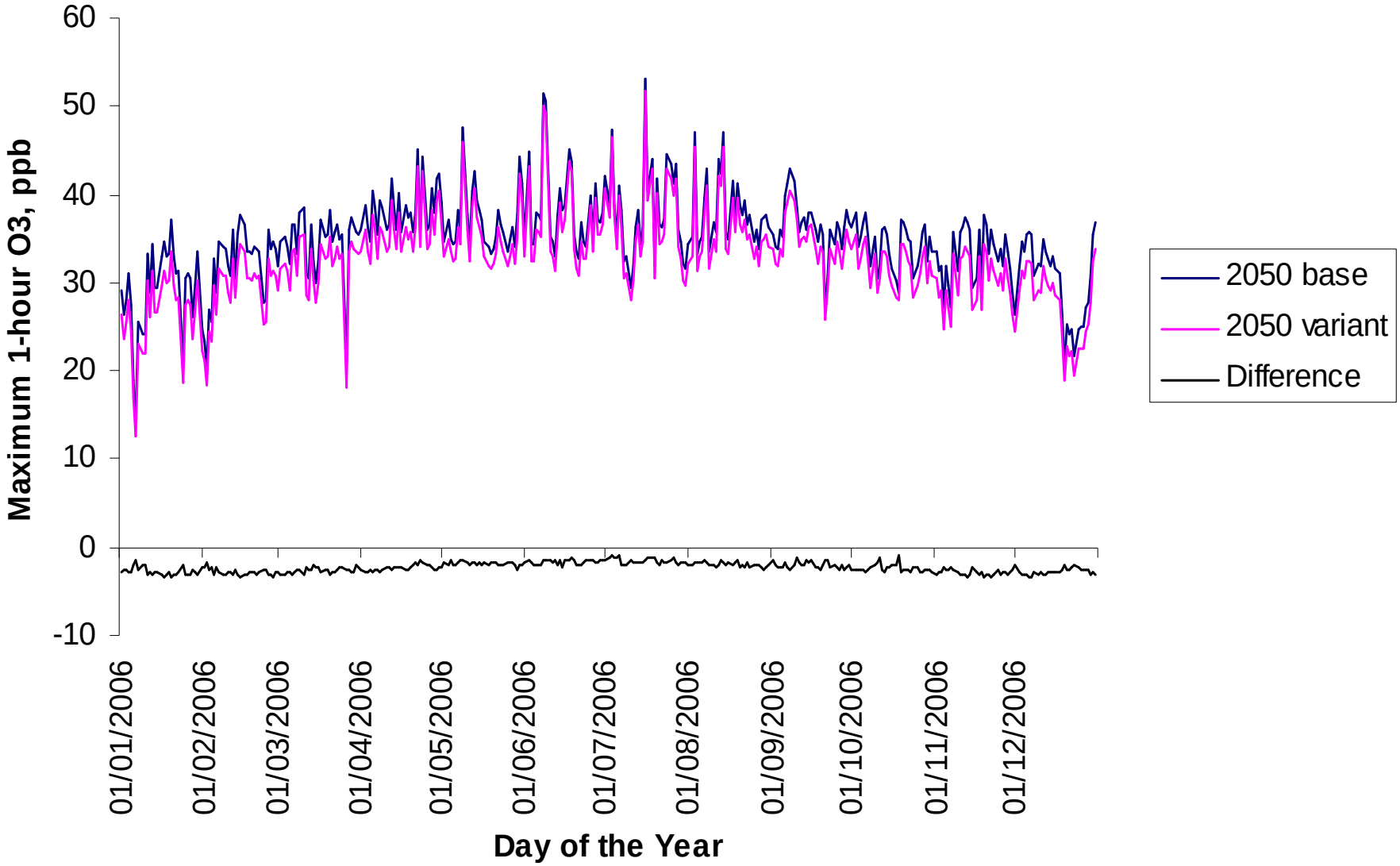
ANNUAL OZONE IN STOCHEM FROM 1990 THROUGH TO 2030 IN THE IIASA EMISSION SCENARIOS FOR SOUTHERN UK



+0.3% per year GROWTH IN BASELINE OZONE BY 2050



-0.2% per year DECLINE IN BASELINE OZONE BY 2050



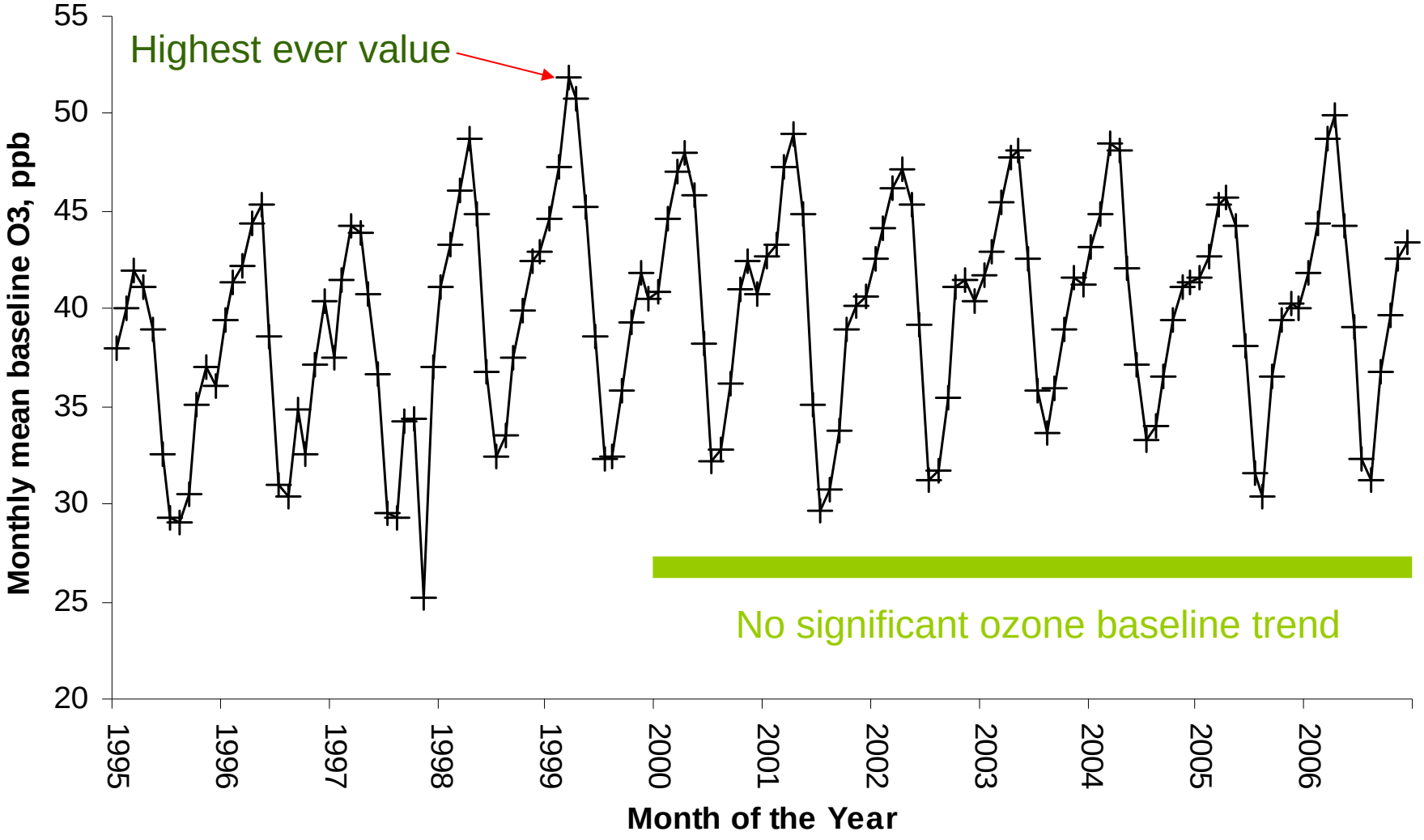
IMPACT OF CHANGED BASELINE OZONE LEVELS

- Reflected by changed initial and boundary conditions and changed exchange with the free troposphere

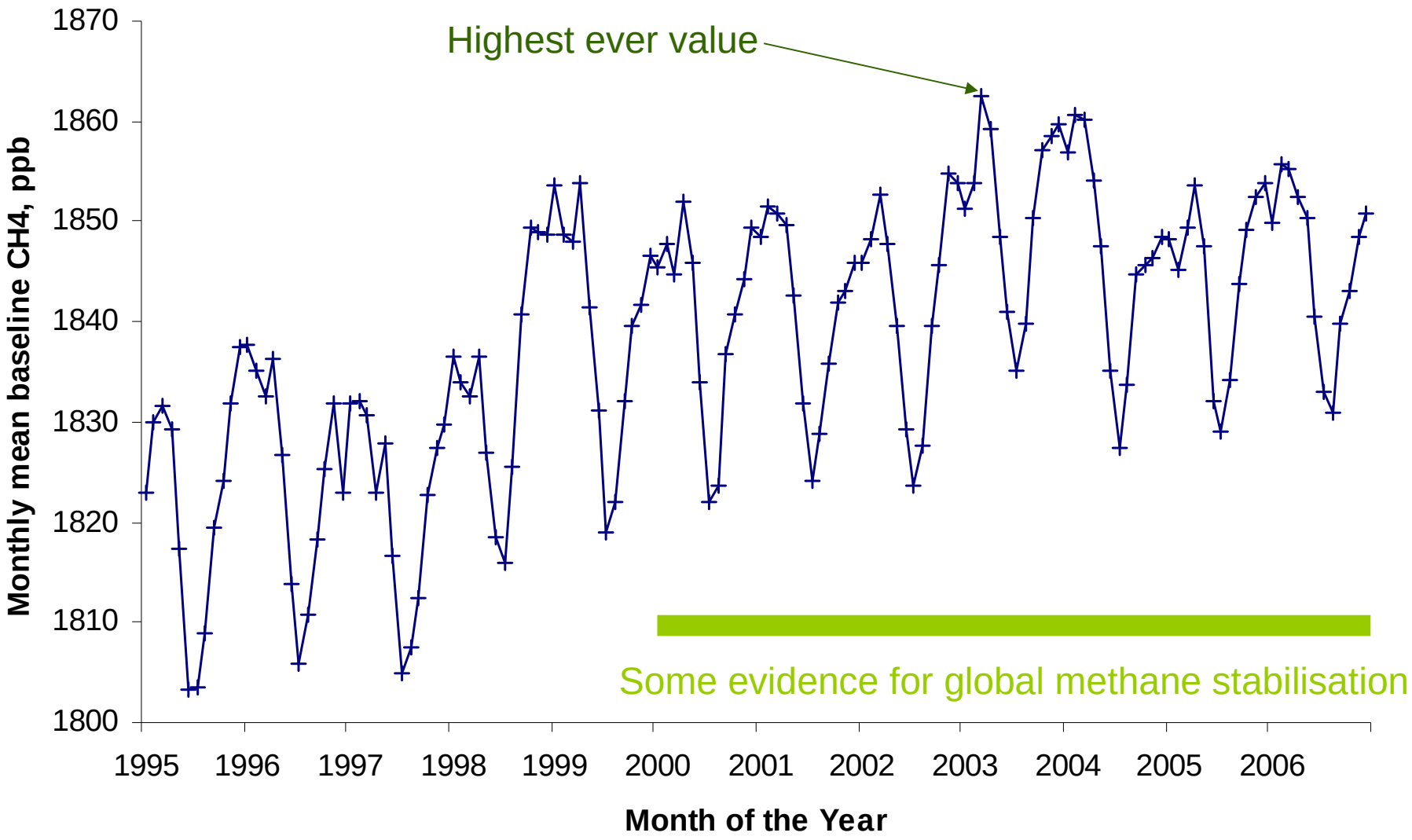
- Impact is stronger in the winter than in the summer because of faster advection times and so less dry deposition and because of slower photochemical turnover times

$$d/dt\,[O_3] = P - L[O_3]$$

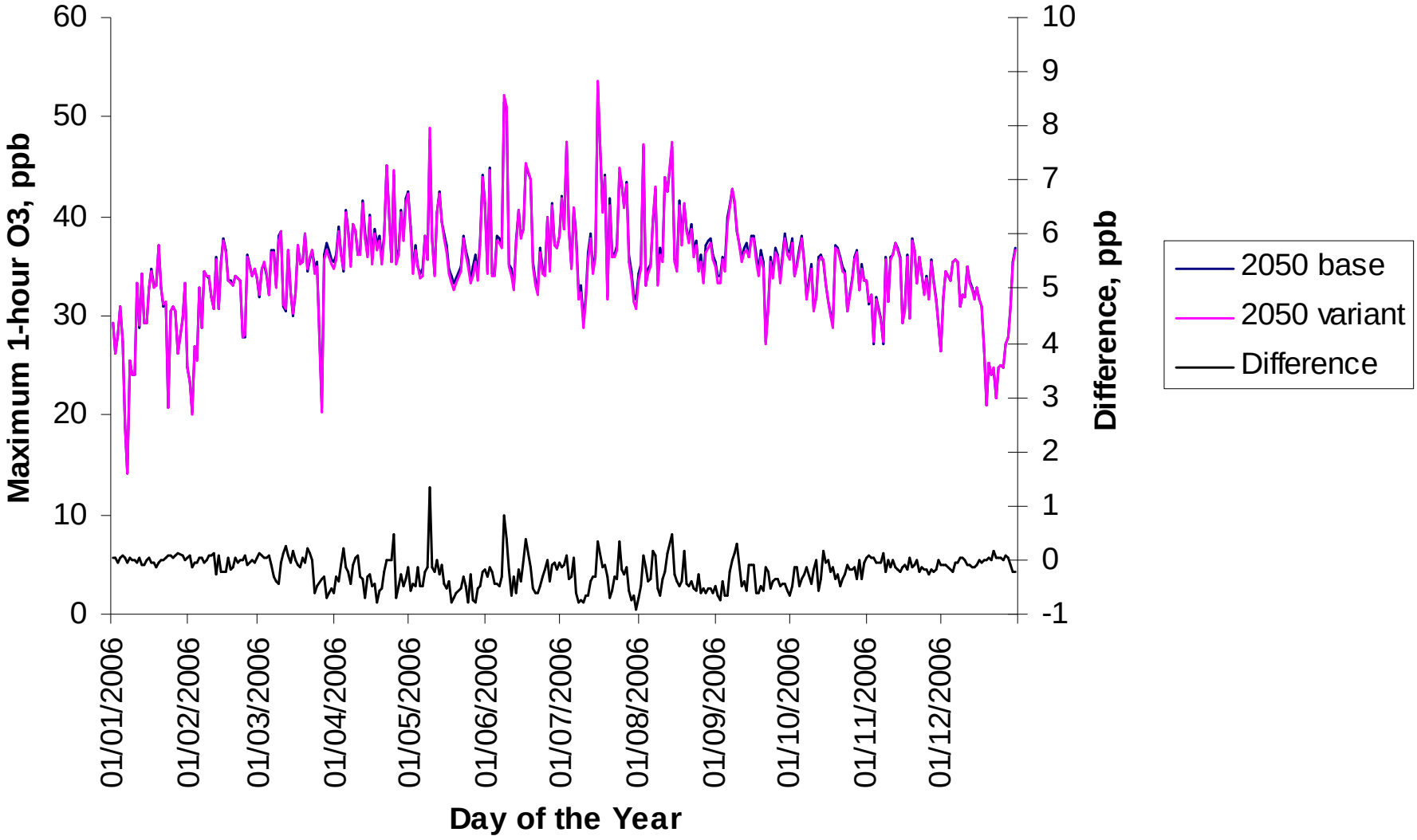
MONTHLY MEAN BASELINE OZONE LEVELS AT MACE HEAD FROM JANUARY 1995 TO DECEMBER 2006



MONTHLY MEAN BASELINE METHANE LEVELS AT MACE HEAD FROM JANUARY 1995 TO DECEMBER 2006



5°C INCREASE IN TEMPERATURE BY 2050



IMPACT OF INCREASING TEMPERATURES

- Reflected by constant increase of 5°C throughout the year on reaction rate coefficients only and not emissions

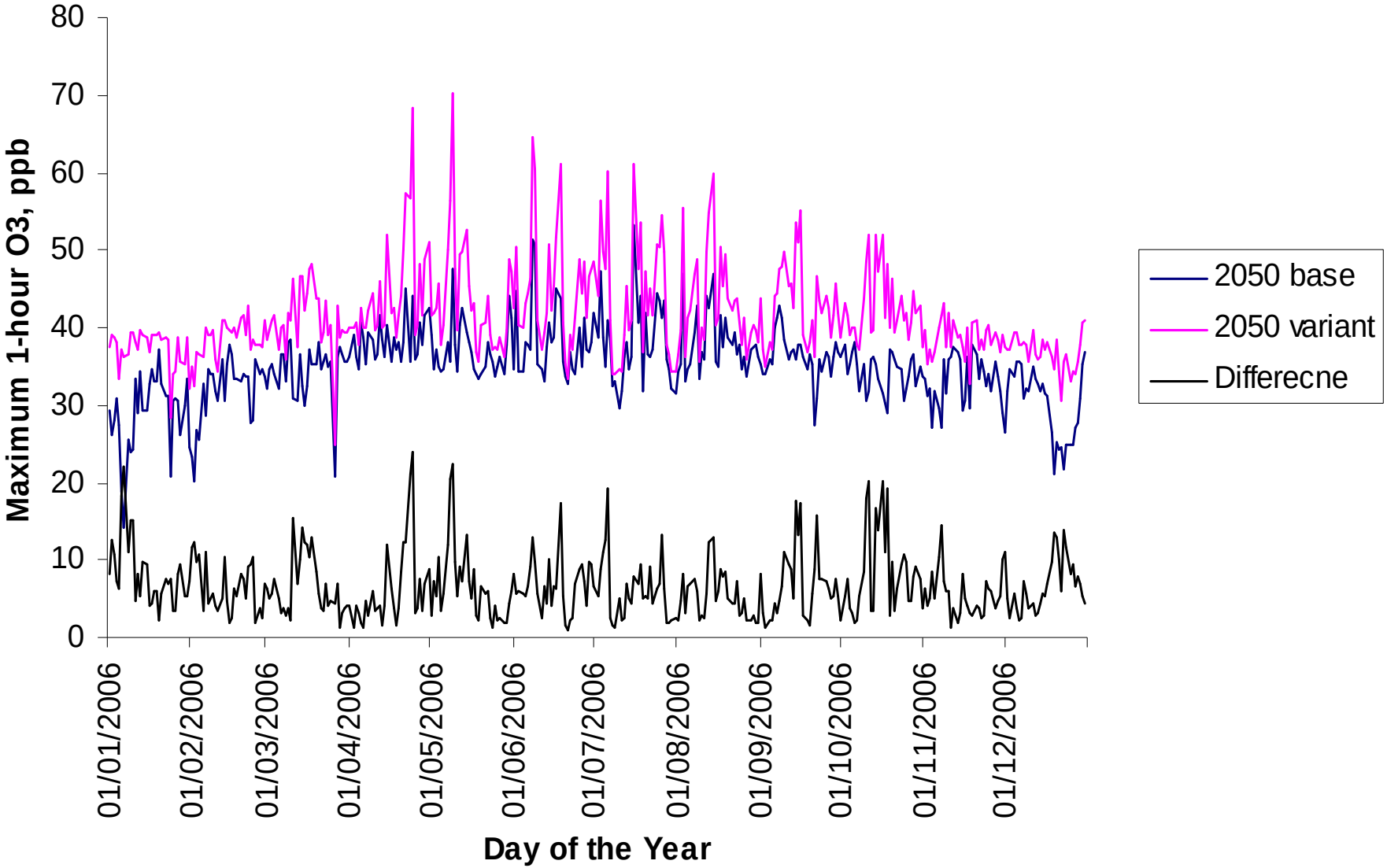
- Some rate coefficients increase with increasing temperature such as $NO + O_3$, $NO_2 + O_3$, $OH + CH_4$, etc

- Some species are thermally unstable such as PAN, N_2O_5, etc

- With a constant relative humidity, water vapour mixing ratios increase and hence OH radical production and O_3 photolysis

$$O_3 + hv = O^1D + O_2$$
$$O^1D + H_2O = OH + OH$$

NO OZONE DRY DEPOSITION IN 2050



IMPACT OF CHANGES TO DRY DEPOSITION OF OZONE

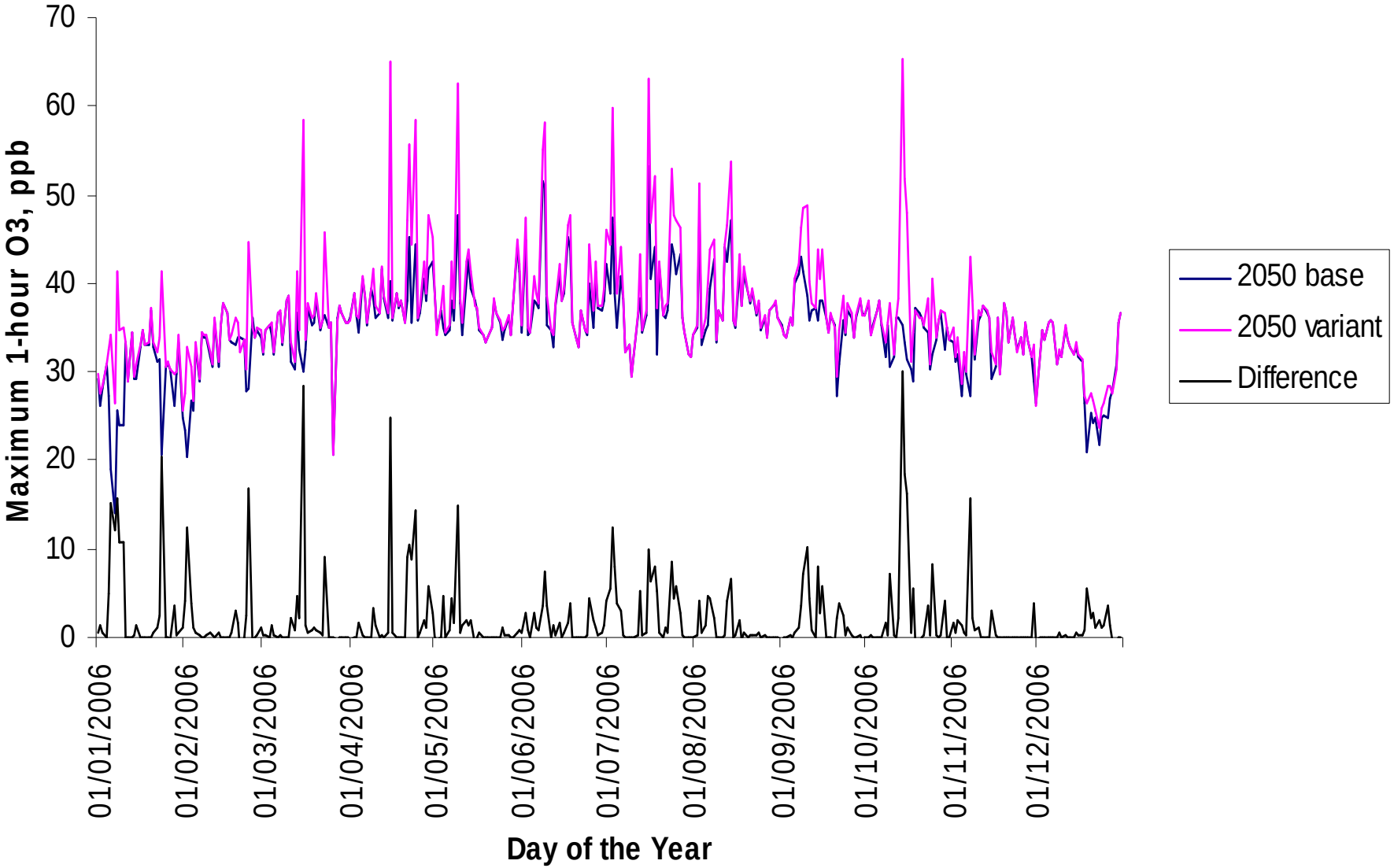
- Reflected crudely by switching off ozone dry deposition

- Major term in budget of surface ozone

- Will future stomatal conductances be influenced by drying out of surfaces and what about non-stomatal terms?

- Interacts with rising ozone baseline

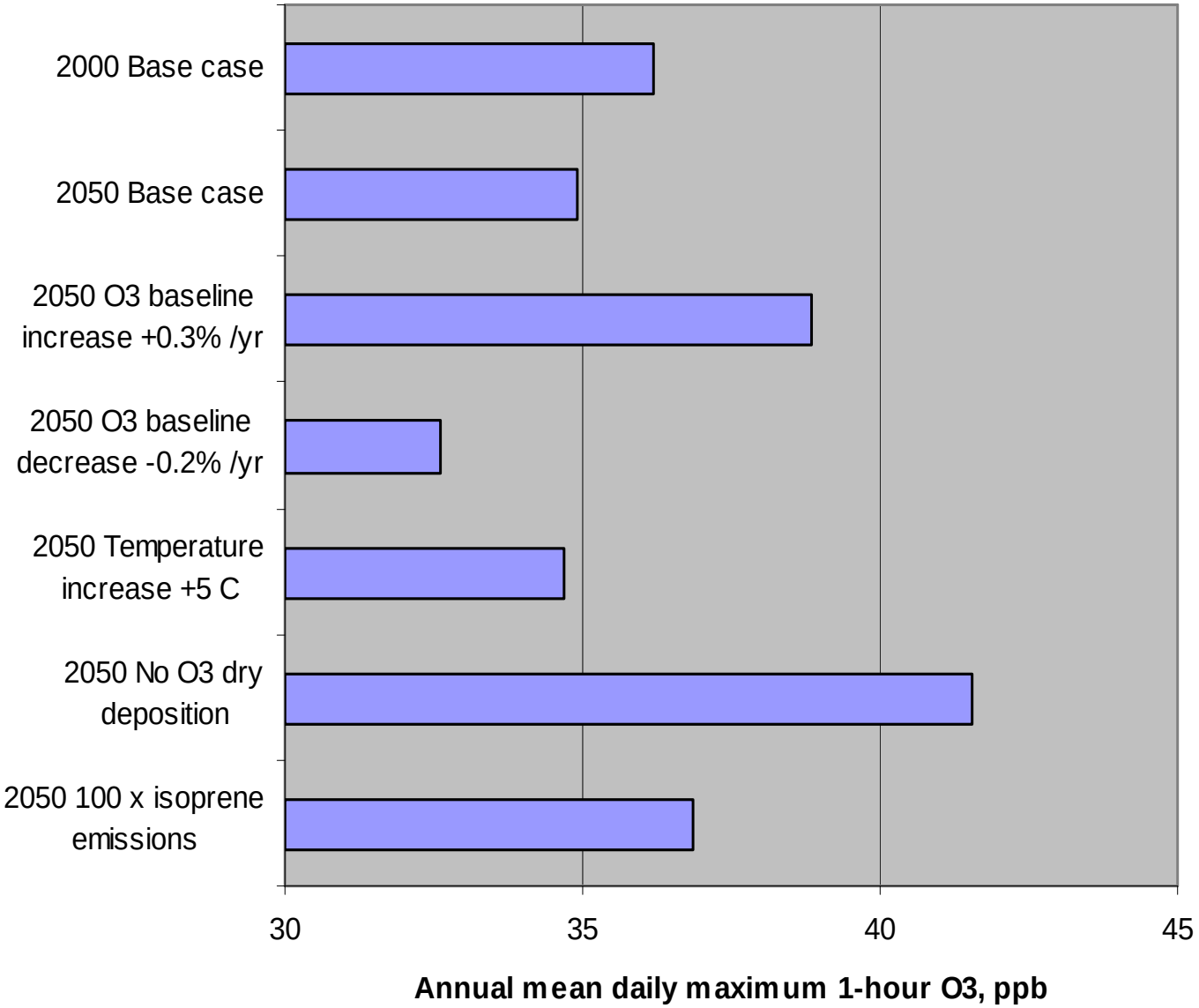
100 x ISOPRENE EMISSIONS IN 2050



IMPACTS OF CHANGING NATURAL ISOPRENE EMISSIONS

- Major cause of uncertainty in VOC emission inventories
- Currently using EMEP (1995) isoprene emissions and distribution
- How will these change in the future?

2050 VARIANTS



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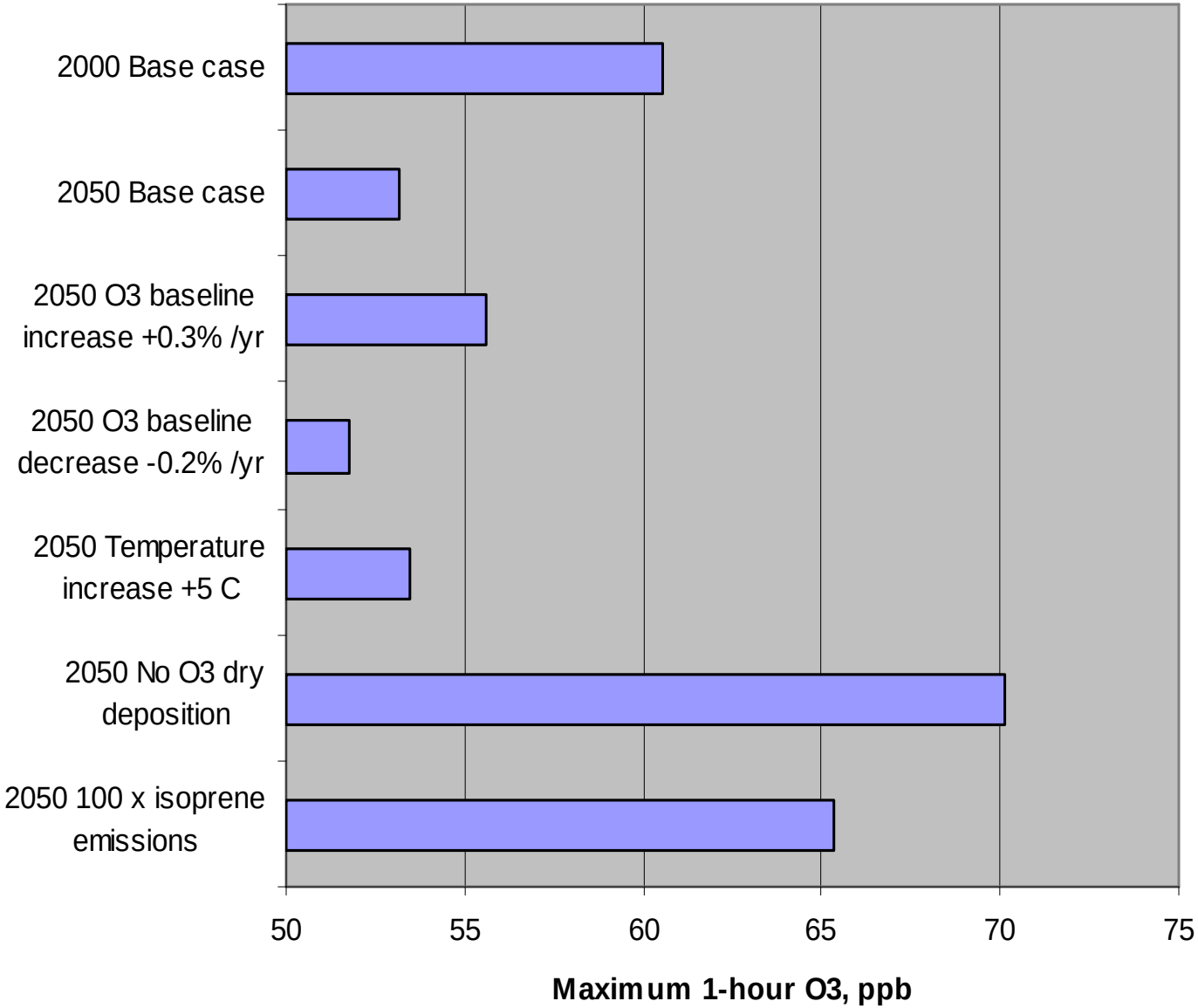
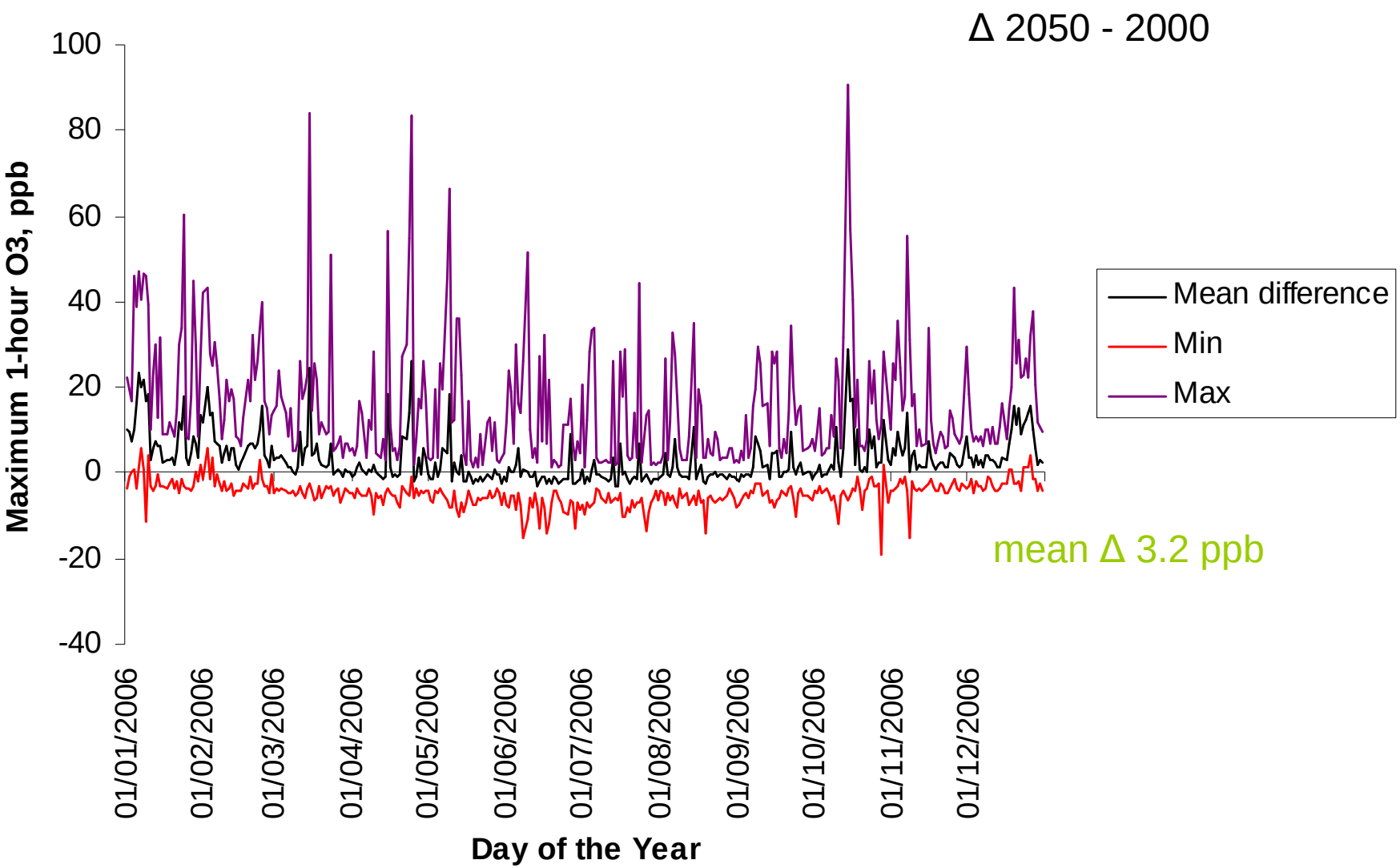


MONTE CARLO UNCERTAINTY ANALYSIS TO EXAMINE OVERALL IMPACT OF VARIANTS



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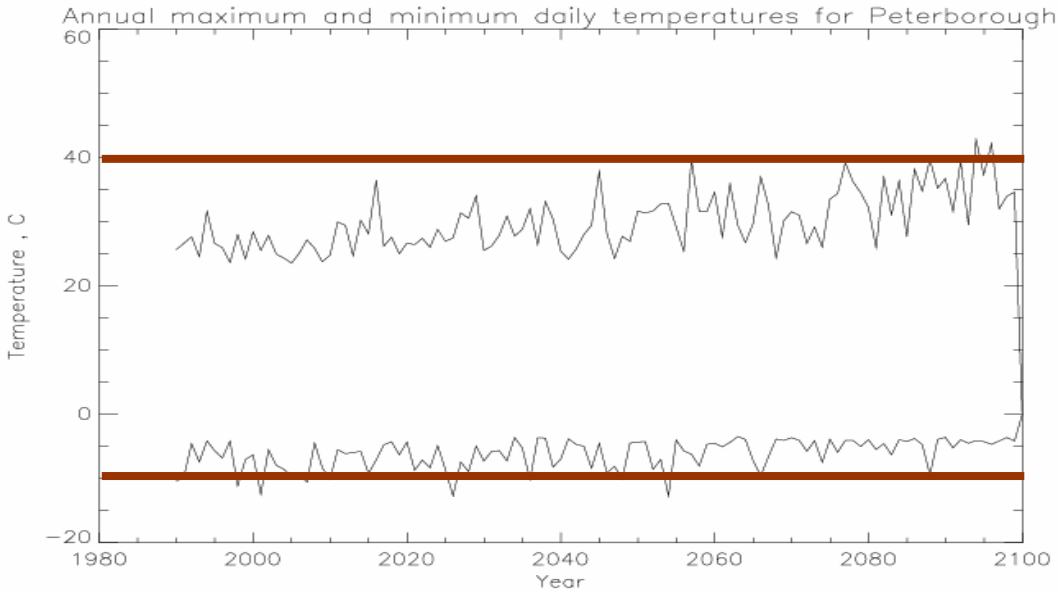
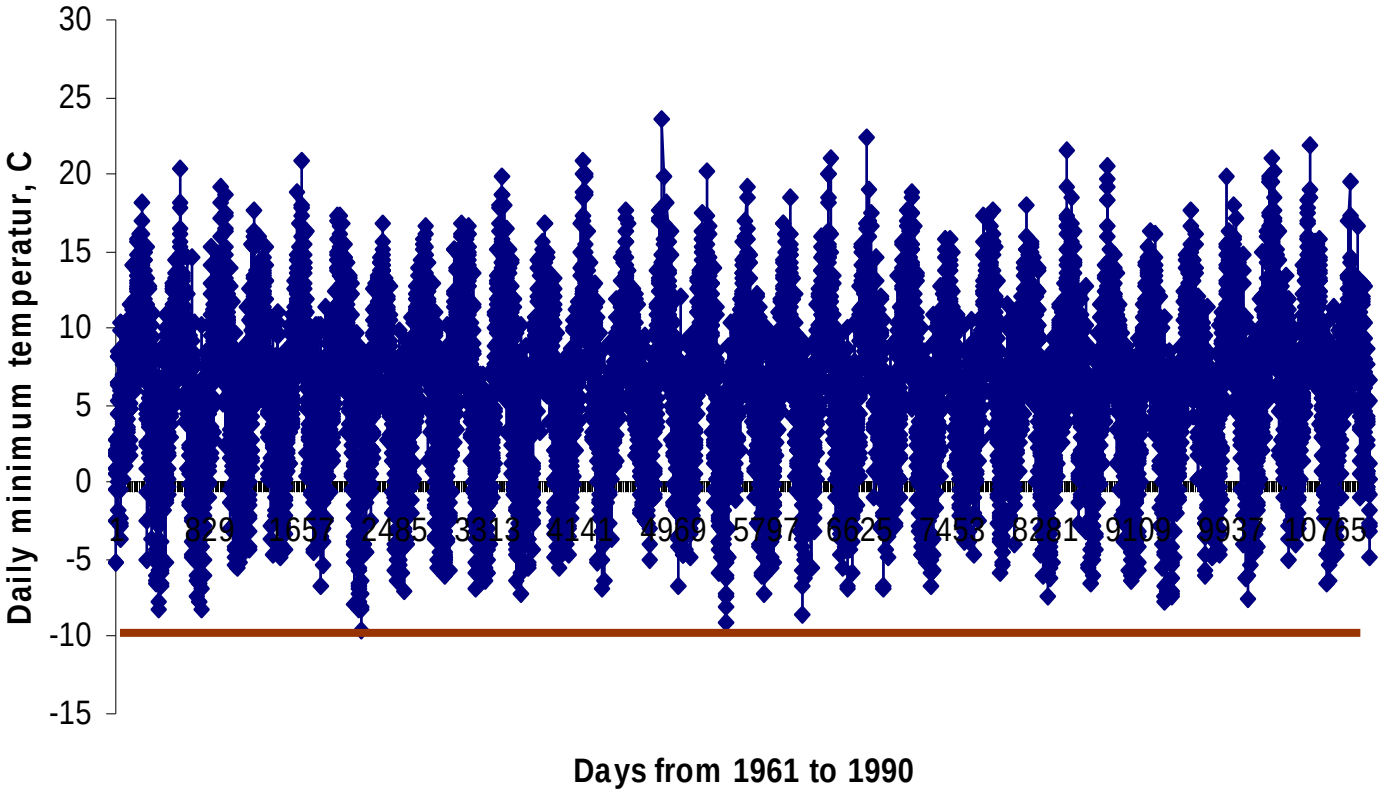


OUTPUT FROM HadCM3 GCM

REGIONAL CLIMATE MODEL OUTPUT
HadRM3P

Peterborough



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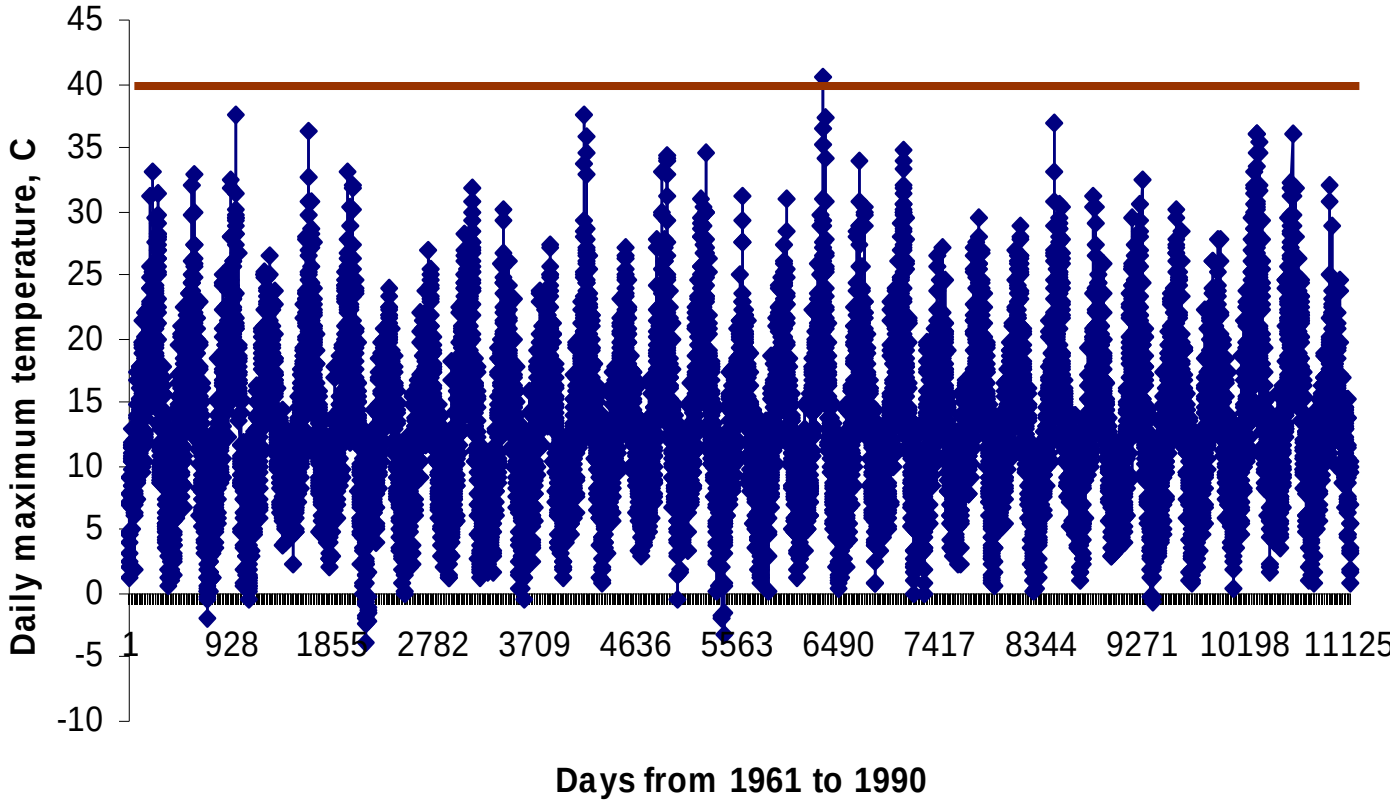
Peterborough