Some typical applications related to environmental studies

1. *Need for reliable input data*
2. *Meteorological data*
3. *Emission data*
4. *Problems with huge output sets*
5. *Need for visualization and animation of the output data*
6. *Treatment of the biogenic emissions*
7. *The impact of biogenic emissions on control strategies*
8. *Trends of the temporal variation of pollution levels in Denmark*
9. *Pollution levels in some European countries*
10. *Conclusions*

References

1. C. Ambelas Skjøth, A. Bastrup-Birk, J. Brandt and Z. Zlatev: *"Studying variations of pollution levels in a given region of Europe during a long time-period"*. Systems Analysis Modelling Simulation, **Vol. 37 (2000)**, 297-311.

2. I. Dimov, Tz. Ostromsky, I. Tzvetanov and Z. Zlatev: *"Economical estimations of the losses of crops due to high ozone levels"*. Agricultural Economics and Management **Vol. 5 (1999)**, 48-52.

3. A. Havashi and Z. Zlatev: *"Trends in Hungarian air pollution levels on a long time-scale"*. Atmospheric Environment, to appear.

4. Z. Zlatev, G. Geernaert and H. Skov: *"A study of ozone critical levels in Denmark"*, EUROSAP Newsletter, **Vol. 36, (1999)**, 1-9

5. Z. Zlatev, I. Dimov, Tz. Ostromsky, G. Geernaert, I. Tzvetanov and A. Bastrup-Birk: *"Calculating losses of crops in Denmark caused by high ozone levels"*. Environmental Modelling and Assessment, **Vol. 6 (2001),** 35-55.

Need for reliable input data

- The input data is prepared within the EMEP project (EMEP: European Monitoring and Evaluation Programme)
- Meteorological data: fields at every 6 hours (for mixing heights - 12 hours) on 150 km x150 km grid covering the whole of Europe. Linear interpolation used both in space and time when finer resolution grids are used in our models
- Emission data: annual values on a 50 km x 50 km grid. Both seasonal and diurnal variations have to me simulated.
- What is desirable? Meteorological data at 50 km x 50 km grid (at least) at every hour (or at every second or third hour). Better emission data fields are also desirable (the temporal variation of the emissions being very important).

Meteorological data

Wind velocity fields	Advection
Precipitation fields	Deposition (wet)
Humidity fields	Chemistry
Temperature fields	Chemistry
Pressure fields	Chemistry
Cloud covers	Chemistry
Mixing height fields	Diffusion (vertical)

- More meteorological data are needed (some meteorological parameters are parameterized by using appropriate mechanisms)

Emission data

Human-made emissions

- SO2 emissions — only annual values
- NOx emissions — received from EMEP
- VOC emissions — seasonal and
- NH3 emissions — diurnal variations

Natural (biogenic) emissions

- VOC — calculated on hourly basis

  Lübkert-Schöpp algorithm

Output data

- Concentrations
- Depositions
- Related quantities: numbers of days in which certain critical levels are exceeded, AOT40 values, etc.

$$AOT40 = \sum_{i=1}^{N} \max\left(c_i - 40, 0\right)$$

$$AOT40C, \quad AOT40F$$

Output data - continuation

- Hourly means (only for ozone)
- Daily means
- Monthly means
- Seasonal Means
- Annual means

Representation of the results

Comparisons with measurements

- Scatter plots
- Temporal variations

Distribution in a given area

- Maps, grid-lines, numbers in the cells
- Colours, shadows
- Animations
- Zooming

Difficulties with output data

- Huge files containing output data (up to many Gbytes)
- Often a few numbers are needed, but these have to be found by searching several very large files
- Powerful graphic tools are needed

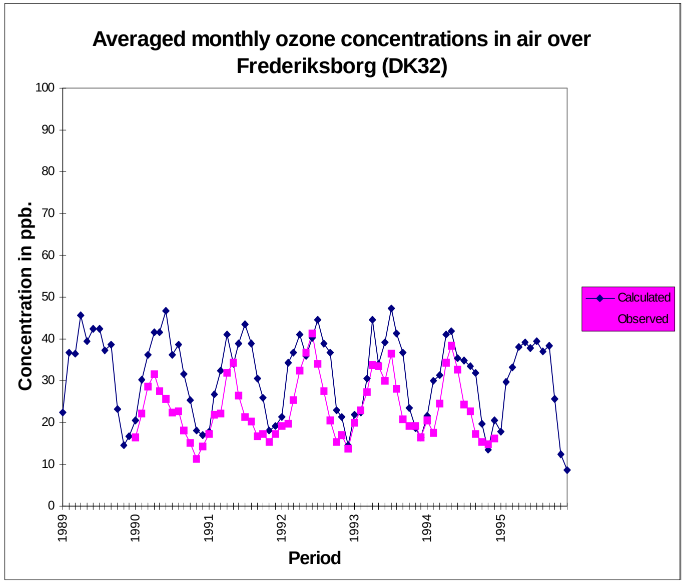


Figure 10. Comparison of averaged monthly calculated and measured ozone concentrations at Frederiksborg (Denmark) over a seven year period.

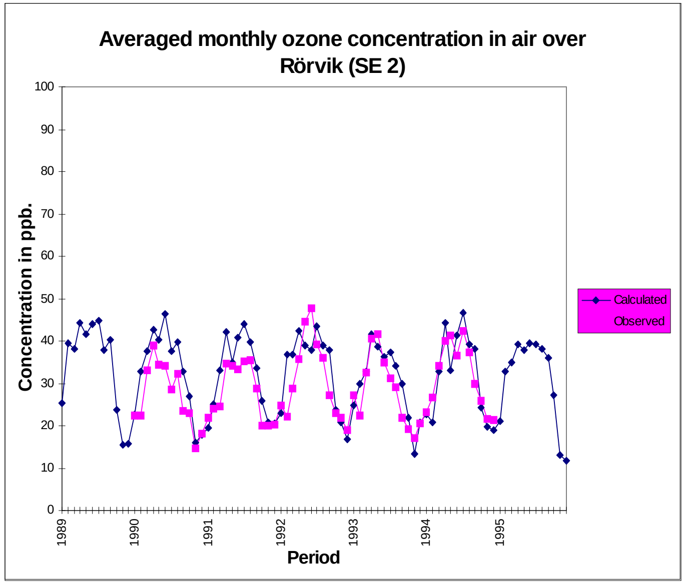


Figure 11. Comparison of averaged monthly calculated and measured ozone concentrations at Rörvik (Sweden) over a seven year period.

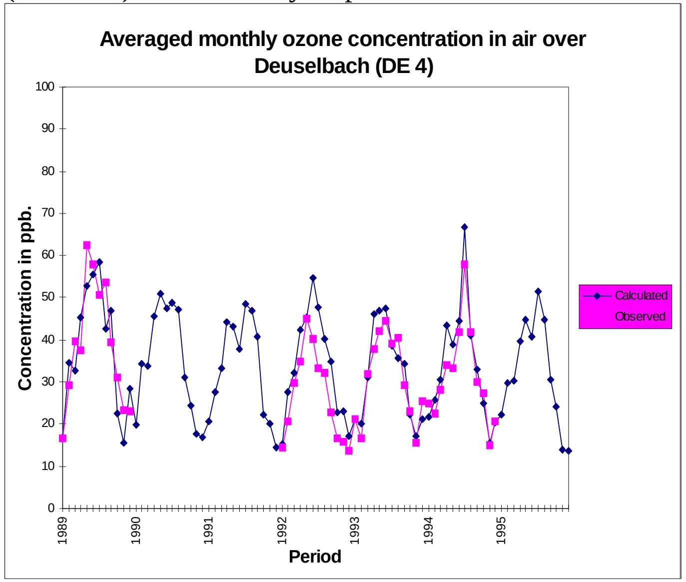


Figure 12. Comparison of averaged monthly calculated and measured ozone concentrations at Deuselbach (Germany) over a seven year period.

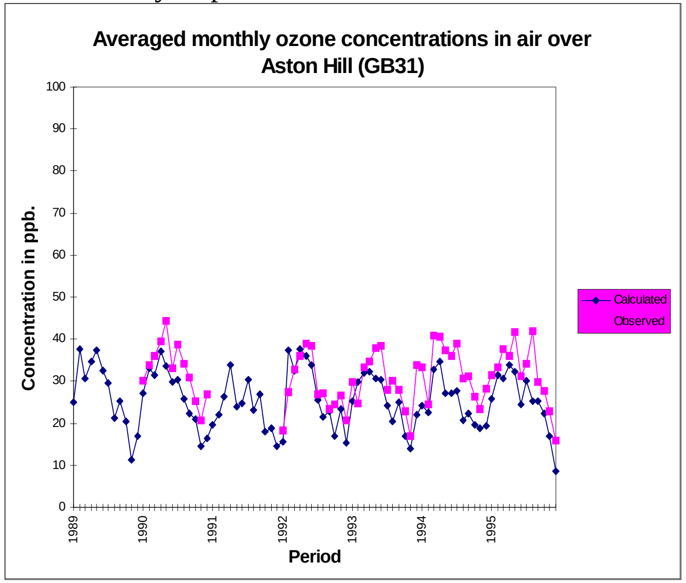


Figure 13. Comparison of averaged monthly calculated and measured ozone concentrations at Aston Hill (Great Britain) over a seven year period.

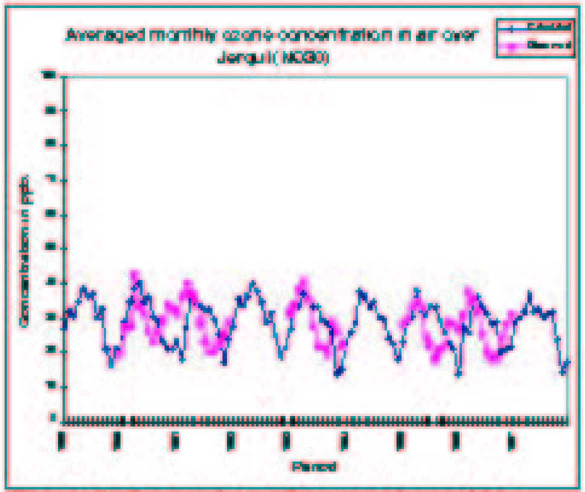


Figure 9. Comparison of averaged monthly calculated and measured ozone concentration at Jergul (Norway) over a nine year period

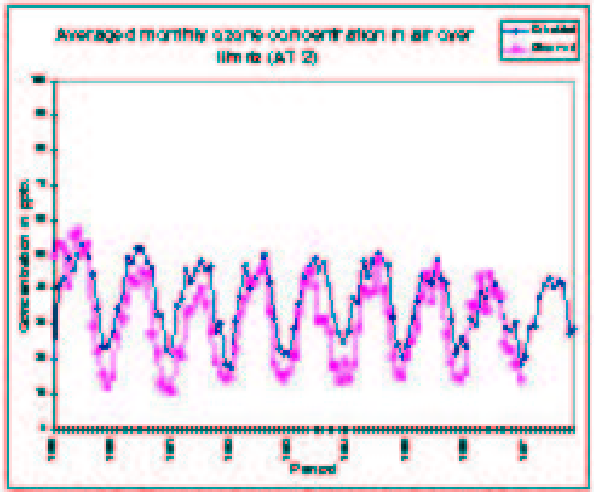


Figure 10. Comparison of averaged monthly calculated and measured ozone concentration at Illmitz (Austria) over a nine year period

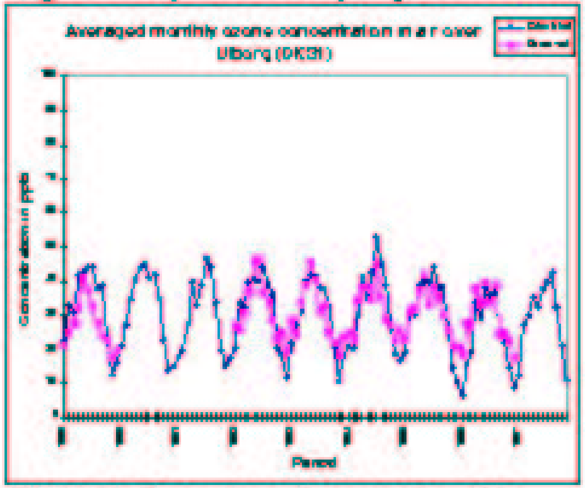


Figure 11. Comparison of averaged monthly calculated and measured ozone concentration at Ulborg (Denmark) over a nine year period

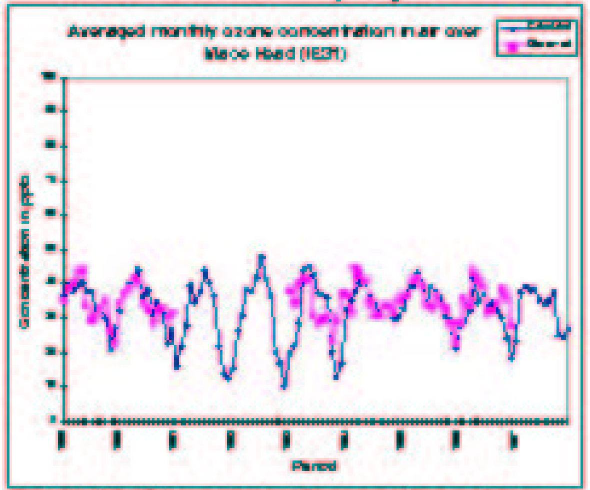


Figure 12. Comparison of averaged monthly calculated and measured ozone concentration at Mace Head (Eireland) over a nine year period

Generic formula for biogenic emissions

$$E_j = \sum_{i=1}^{N} PORTION_j \, TEMPFACT_{ij} \, EMISFACT_{ij}$$

$$j = 1, 2, \ldots, M$$

M is the number of vegetation categories

N is the number of hours

It is necessary to achieve good balancing

Parameters in the generic formula

$PORTION_j$	the part of the area selected covered by vegetation *j*
$TEMPFACT_{ij}$	factor depending on the temperature in hour *i* and on vegetation *j*
$EMISFACT_{ij}$	VOC emited by vegetation *j* at hour *i* if the temperature is 30 degree C

Temporal variations

Month	Forests	Crops
January	265 (2.3%)	0.606 (0.38%)
February	260 (2.3%)	0.716 (0.45%)
March	327 (2.8%)	1.150 (0.75%)
April	605 (5.2%)	4.450 (2.80%)
May	1411 (12.3%)	20.800 (13.10%)
June	2130 (18.5%)	38.200 (24.00%)
July	2341 (20.3%)	43.900 (27.60%)
August	1989 (17.3%)	32.100 (20.20%)
September	1015 (8.8%)	11.300 (7.10%)
October	658 (5.7%)	3.800 (2.40%)
November	295 (2.6%)	1.130 (0.71%)
December	217 (1.9%)	0.672 (0.42%)
1995	**11513**	**159.000**
Simpson et al., 1995	**10044**	**79.000**

The third parameter

Vegetation	Discrepancy factor
Forest trees	5
Crops	20

Discrepancy factor =

(Anastasi et al. 1991)/(Simpson et al., 1995)

Anthropogenic scenarios

Basic scenario	EMEP 1989-1998
Scenario 2010	IIASA
Scenario H1	IIASA
Scenario MFR	IIASA
Scenario HREFA	
Scenario HREFB	
Scenario HREF1	
Scenario HREF2	

Biogenic scenarios

- Scenario with low biogenic emissions
- Scenario with normal biogenic emissions
- Scenario with high biogenic emissions

Normal: EMISFACT as in Simpson et al., 1995

High: EMISFACT as in Anastasi et al., 1991

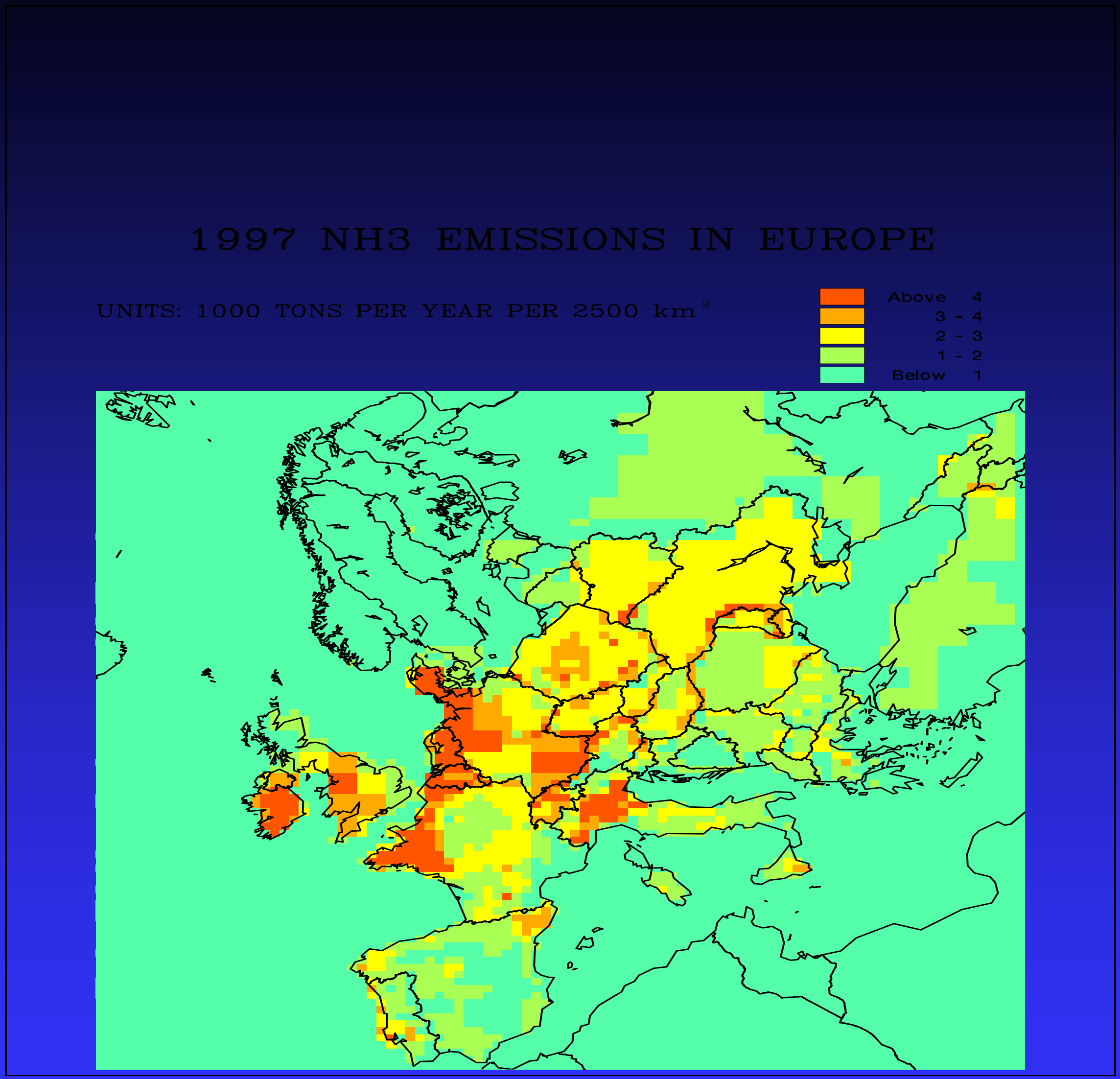
Low: Symmetric to HIGH with regard to NORMAL

Main conclusions from the runs with 24 scenarios for biogenic emissions

- **One normally runs scenarios where only the human-made emissions are varied with meteorological data for one year**
- **Typical scenarios: basic scenario for year 19xx and Scenario 2010 (predicted emissions for 2010 with meteorology for 19xx)**
- **Our runs indicate that this is not sufficient**
- **It is necessary to run over a time period of many years (to see the variability due to changed meteorology)**
- **The biogenic emissions must also be taken into account**

Ammonia pollution in Denmark

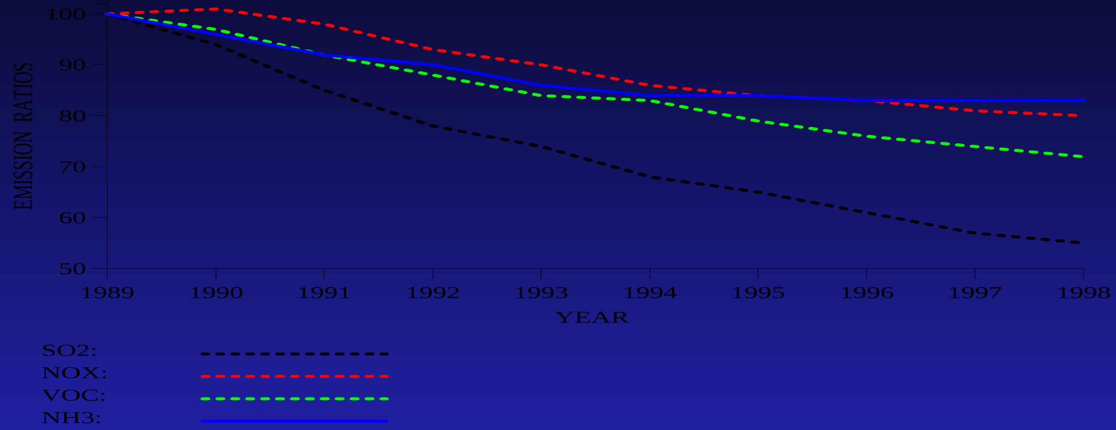
- **High pollution levels in Denmark**
- **Practically no reduction of the Danish ammonia emissions in 1989-1998**
- **Reduction of the ammonia-ammonium concentrations in Denmark**
- **Why is this so?**


1997 NH3 EMISSIONS IN EUROPE
UNITS: 1000 TONS PER YEAR PER 2500 km²
Above 4
3 - 4
2 - 3
1 - 2
Below 1

THE EUROPEAN EMISSIONS

IN THE PERIOD FROM 1989 TO 1998

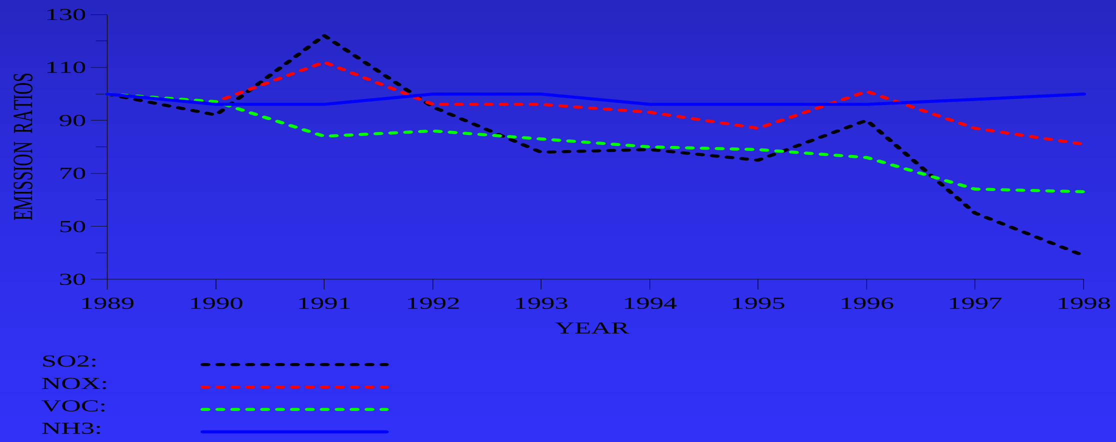
CHANGES (RELATIVE TO 1989) IN PERCENT

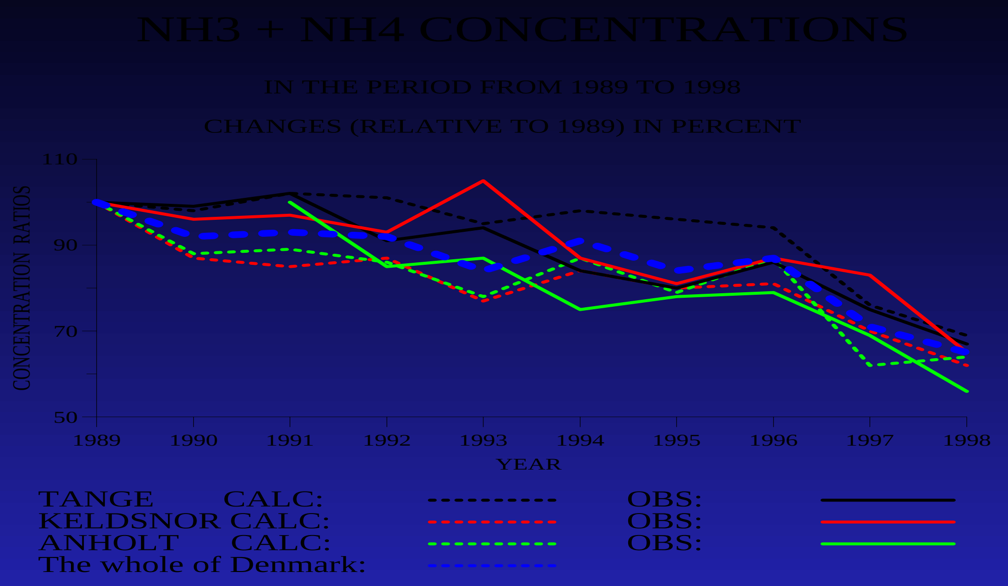


THE DANISH EMISSIONS

IN THE PERIOD FROM 1989 TO 1998

CHANGES (RELATIVE TO 1989) IN PERCENT





Country	1989	1998	Reduction
Germany	661	502	24%
The Netherlands	232	171	24%
Denmark	104	104	0%

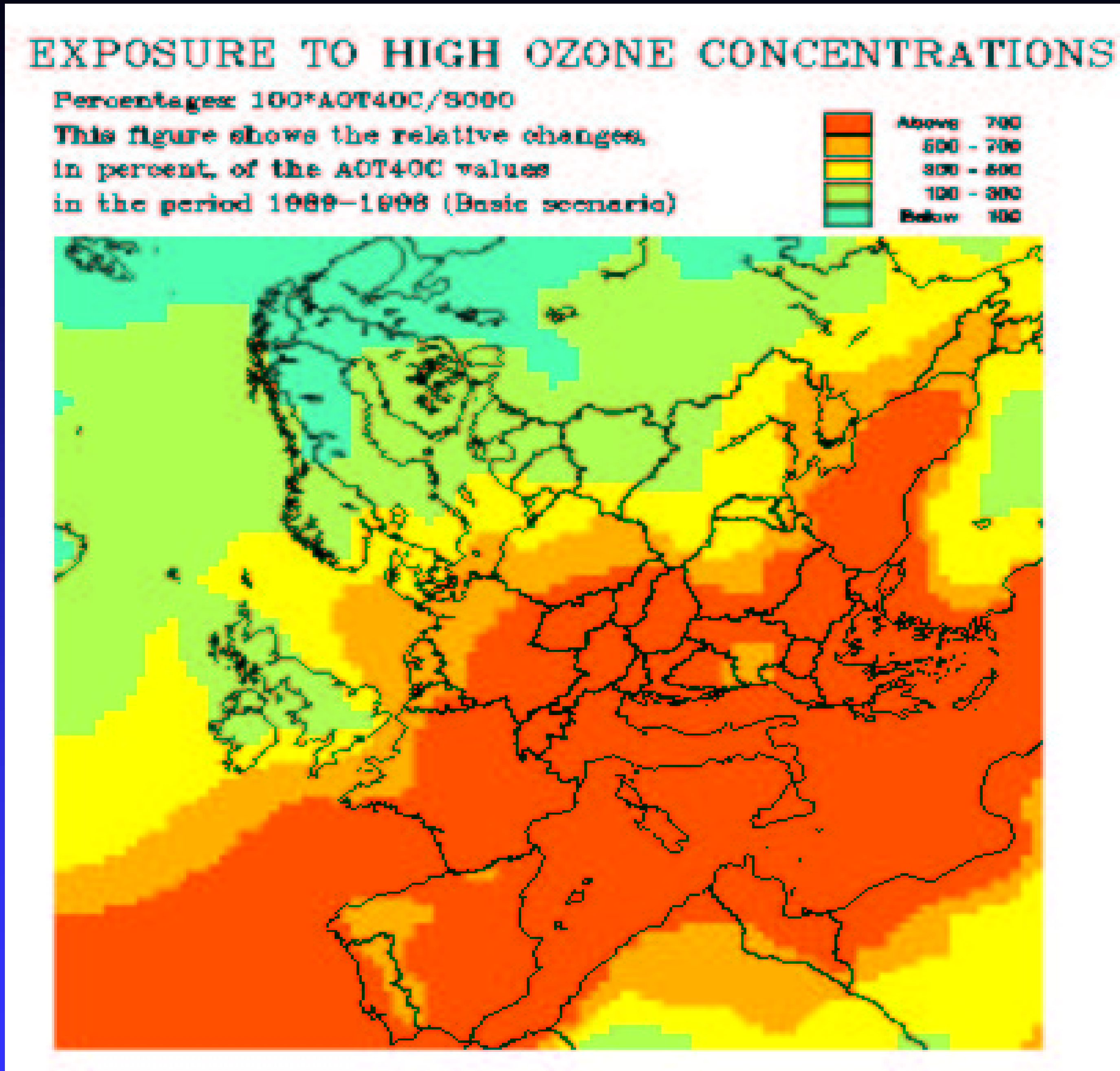
Table 3 - NH3+NH4 concentrations in 1989 and 1998 in three European countries

AOT40C values

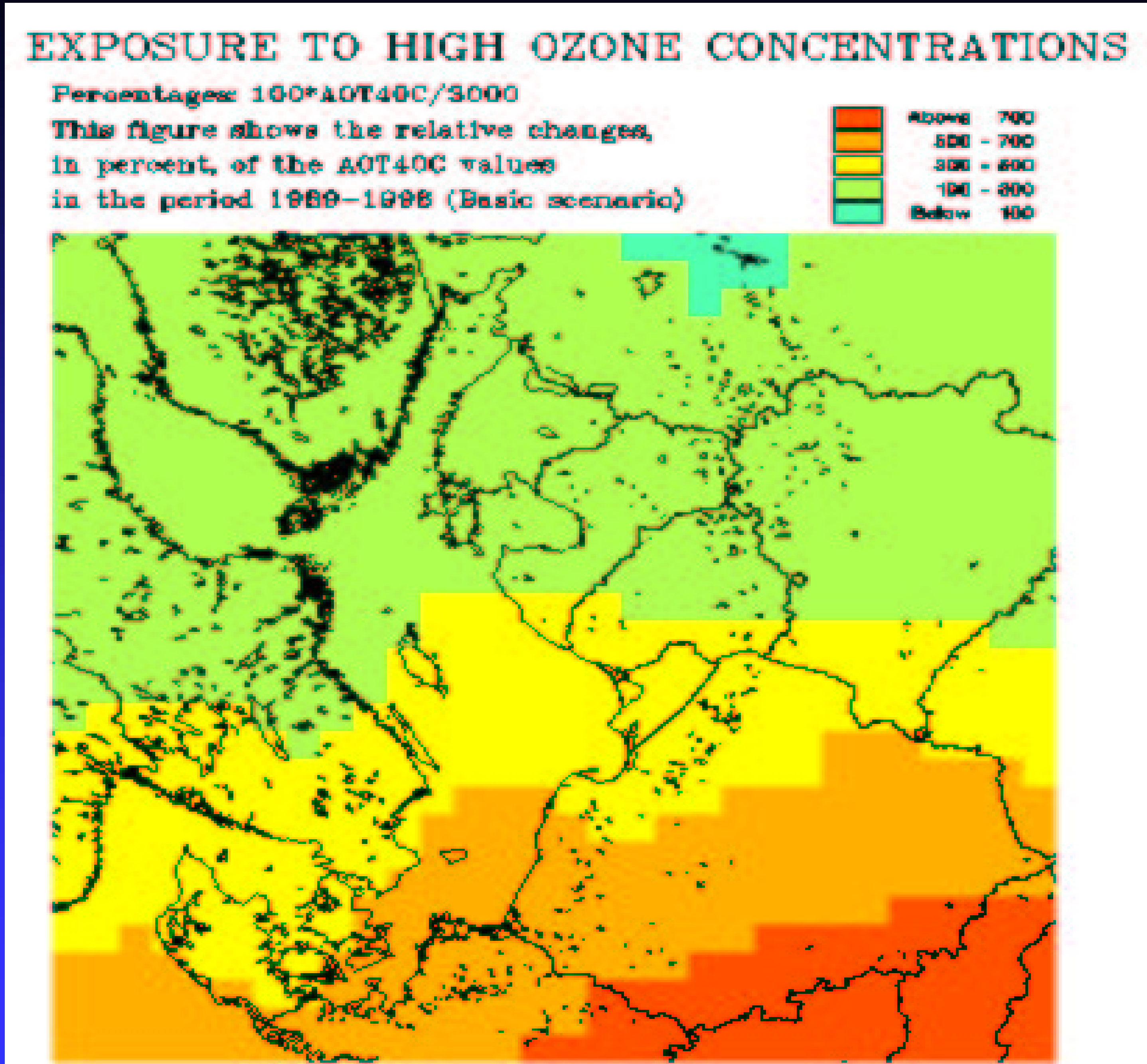
- Measuring damages on crops

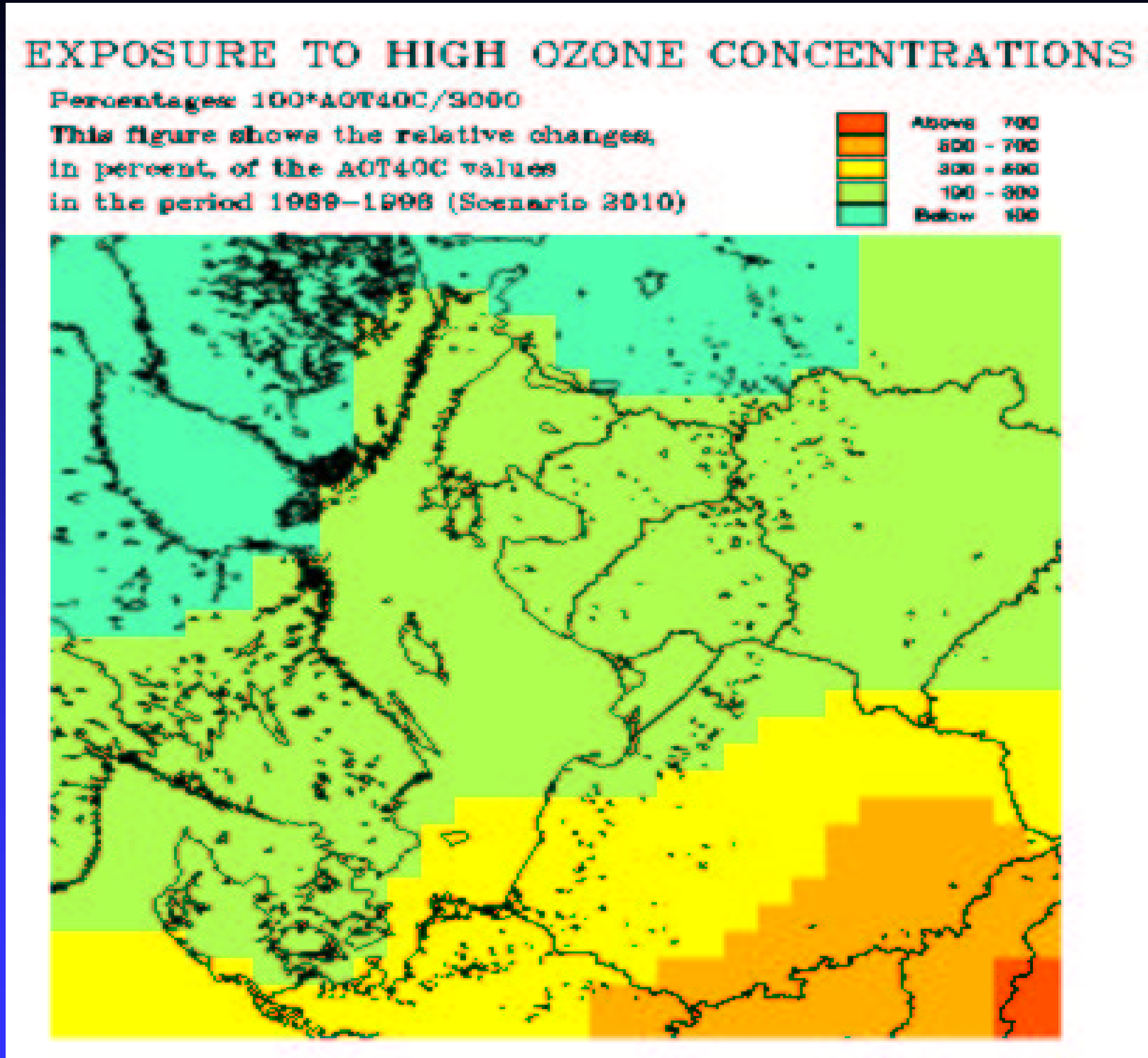
$$AOT40 = \sum_{i=1}^{N} \max\left(c_i - 40, 0\right)$$

$$AOT40C, \quad AOT40F$$



EXPOSURE TO HIGH OZONE CONCENTRATIONS
Percentages: 100*AOT40C/3000
This figure shows the relative changes,
in percent, of the AOT40C values
Above 700
600 - 700
300 - 600
100 - 300
Below 100


EXPOSURE TO HIGH OZONE CONCENTRATIONS
Percentages: 100*AOT40C/3000
This figure shows the relative changes,
in percent, of the AOT40C values
in the period 1989–1998 (Basic scenario)
Above 700
500 - 700
300 - 500
100 - 300
Below 100


EXPOSURE TO HIGH OZONE CONCENTRATIONS
Percentages: 100*AOT40C/3000
This figure shows the relative changes,
in percent, of the AOT40C values
in the period 1989-1998 (Scenario 2010)
Above 700
600 - 700
300 - 600
100 - 300
Below 100

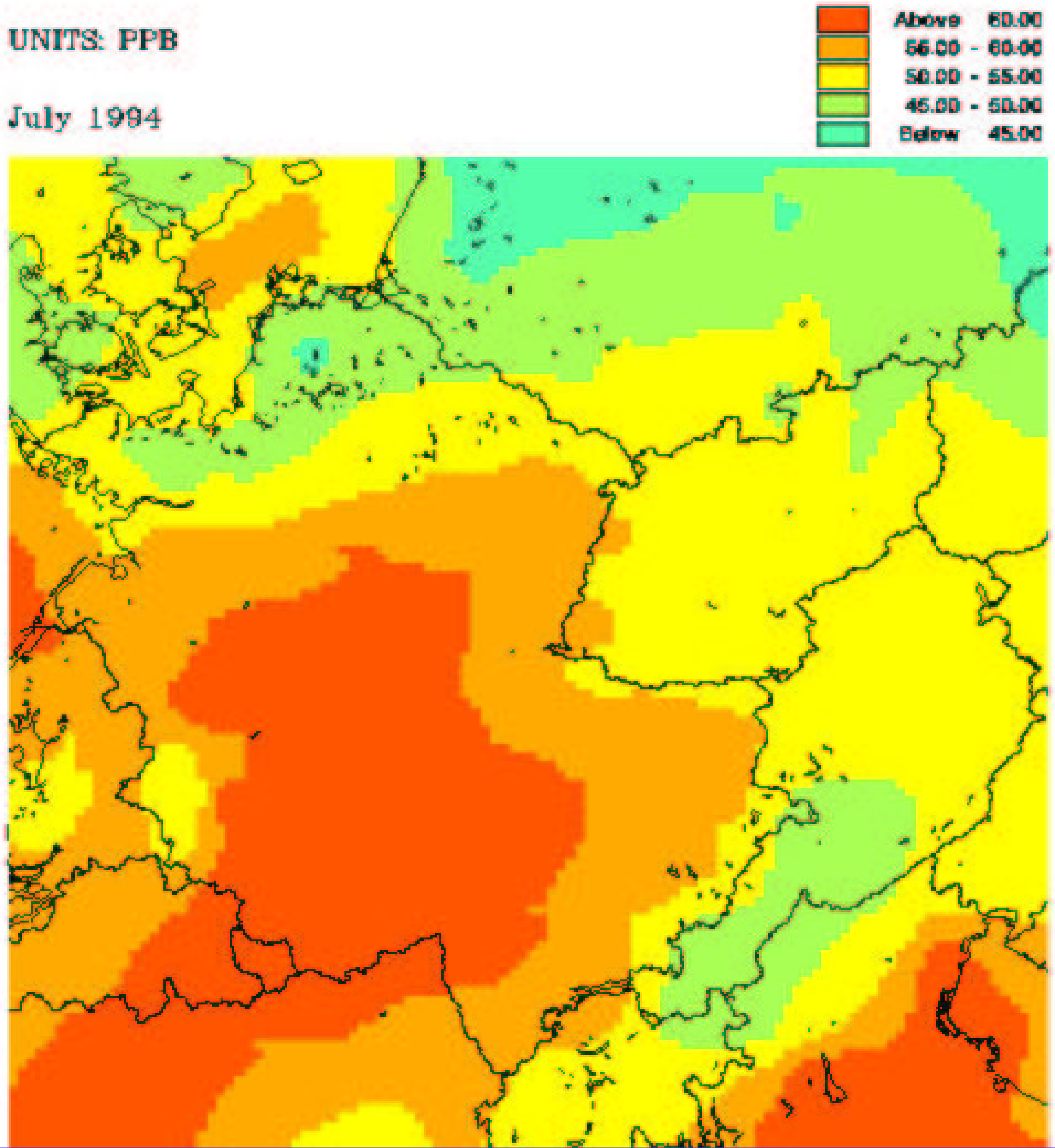
Pollution levels in different European countries

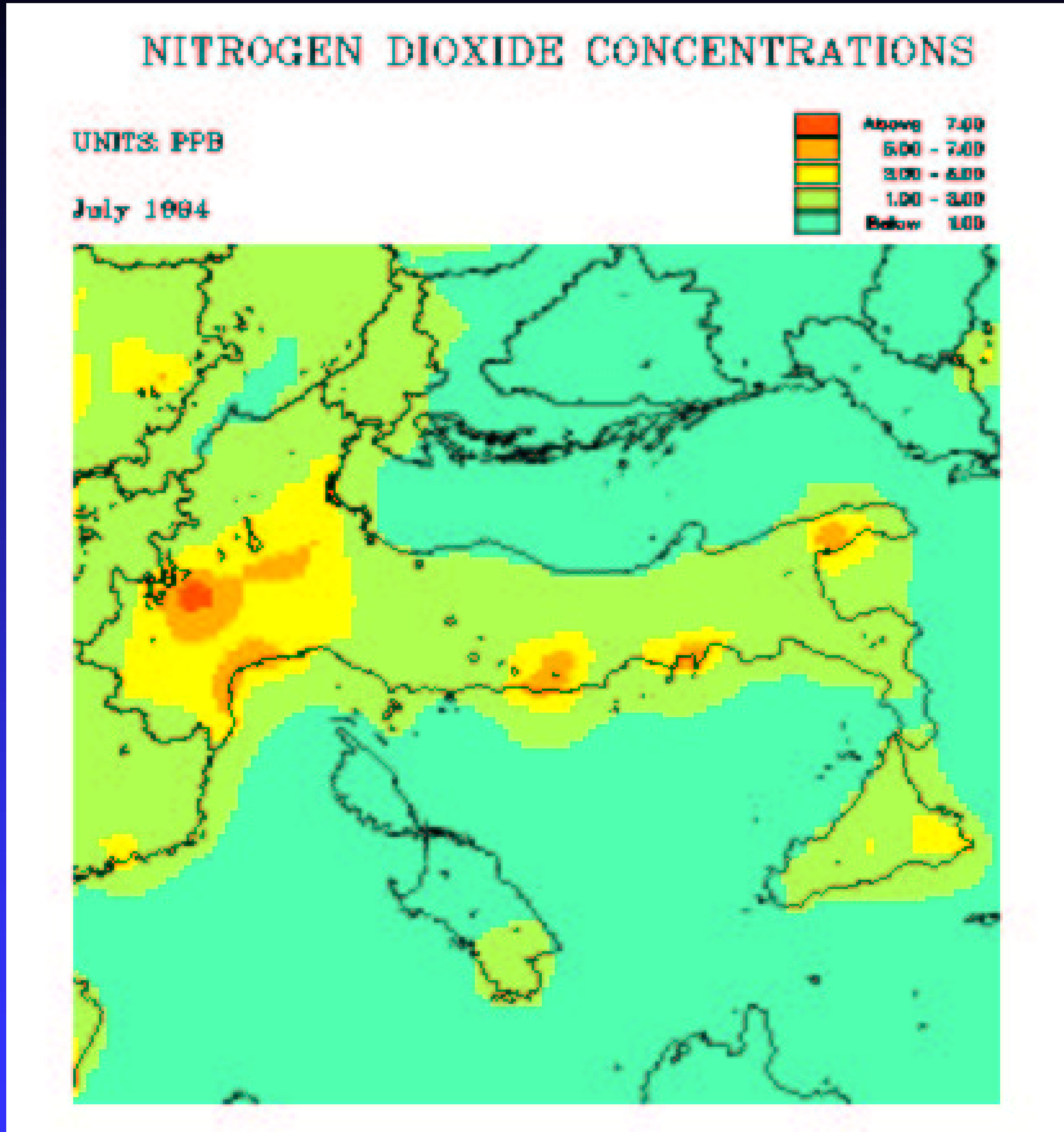
- Some results concerning pollution levels in Denmark have been shown
- Germany
- Italy
- Switzerland

EXPOSURE TO HIGH OZONE CONCENTRATIONS

UNITS: PPB

July 1994




NITROGEN DIOXIDE CONCENTRATIONS
UNITS: PPB
1.00 - 3.00
Below 1.00

EXPOSURE TO HIGH OZONE CONCENTRATIONS

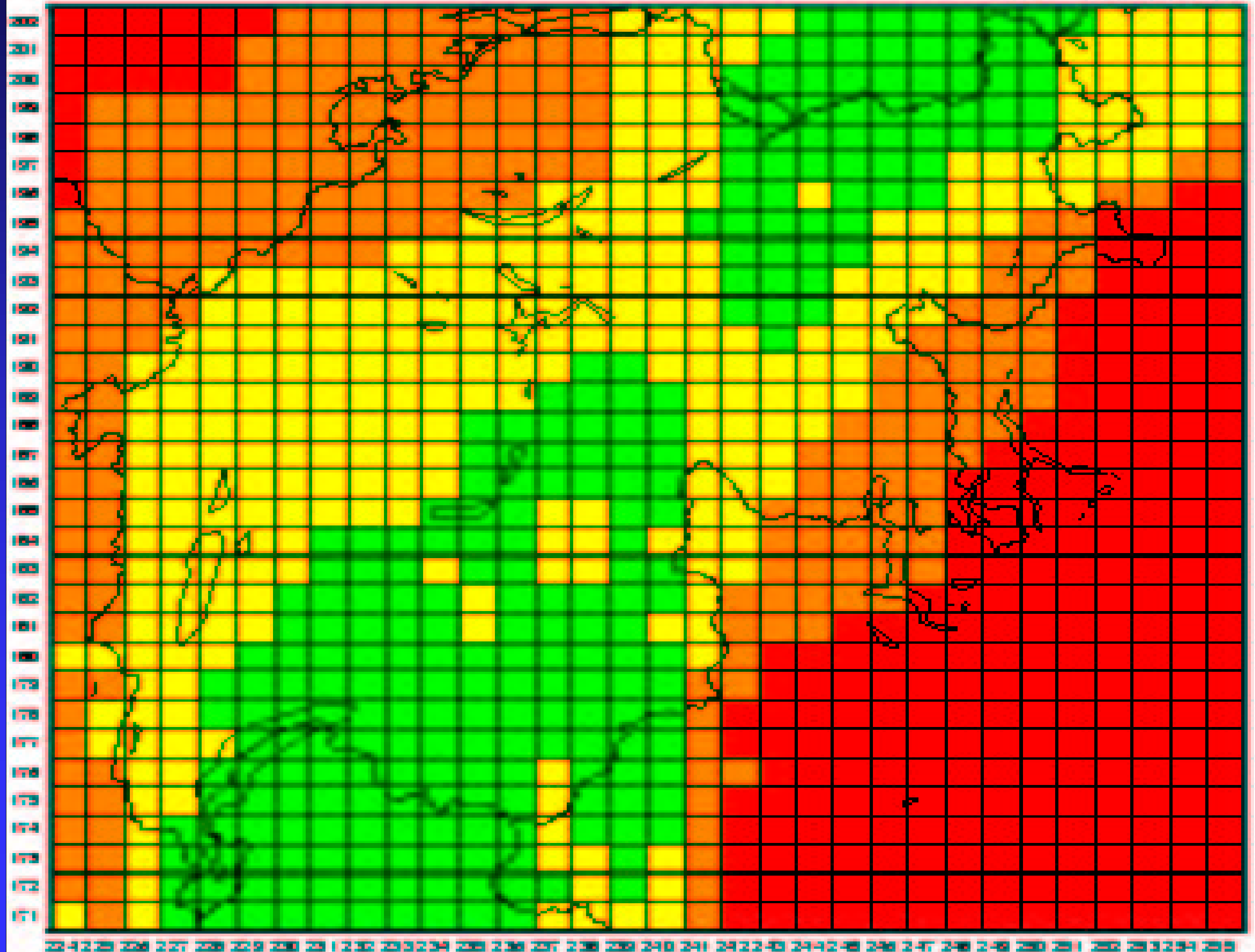
Numbers of days in which 8-hour rolling averages of ozone concentrations exceeded 60 ppb.

The fine resolution version of DEM (480x480).

Anthropogenic emissions for 1995 are used.

Maximum value in the domain: 59

- Above 40
- 31 – 40
- 21 – 30
- 11 – 20
- 0 – 10
- Water areas



Conclusions

- Useful information can be obtrained by running many scenarios
- Powerful graphic tools are needed in order to represent the enormous digital information so that different relationships and trends can easily be seen
- Data handling of massive output files is also a very challenging task