THE NATURAL-ANTHROPOGENIC AEROSOL MIXTURE OVER NORTHERN EUROPE AND ITS POSSIBLE EFFECT ON REGIONAL CLIMATE

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Background

- The boreal forest in the Northern Europe has been shown to contribute substantially to the present aerosol concentrations (up to 50%)
- With a climate warming the boreal aerosol concentrations will increase. With a 5 ^{o}C warming the natural CCN might increase with 35% that will counteract the warming.
- How does this compare with present changes in anthropogenic sources due to air quality abatement?
- What can we expect in the future with changing climate and air quality abatement?

Anthropogenic sulfur emissions in Europe

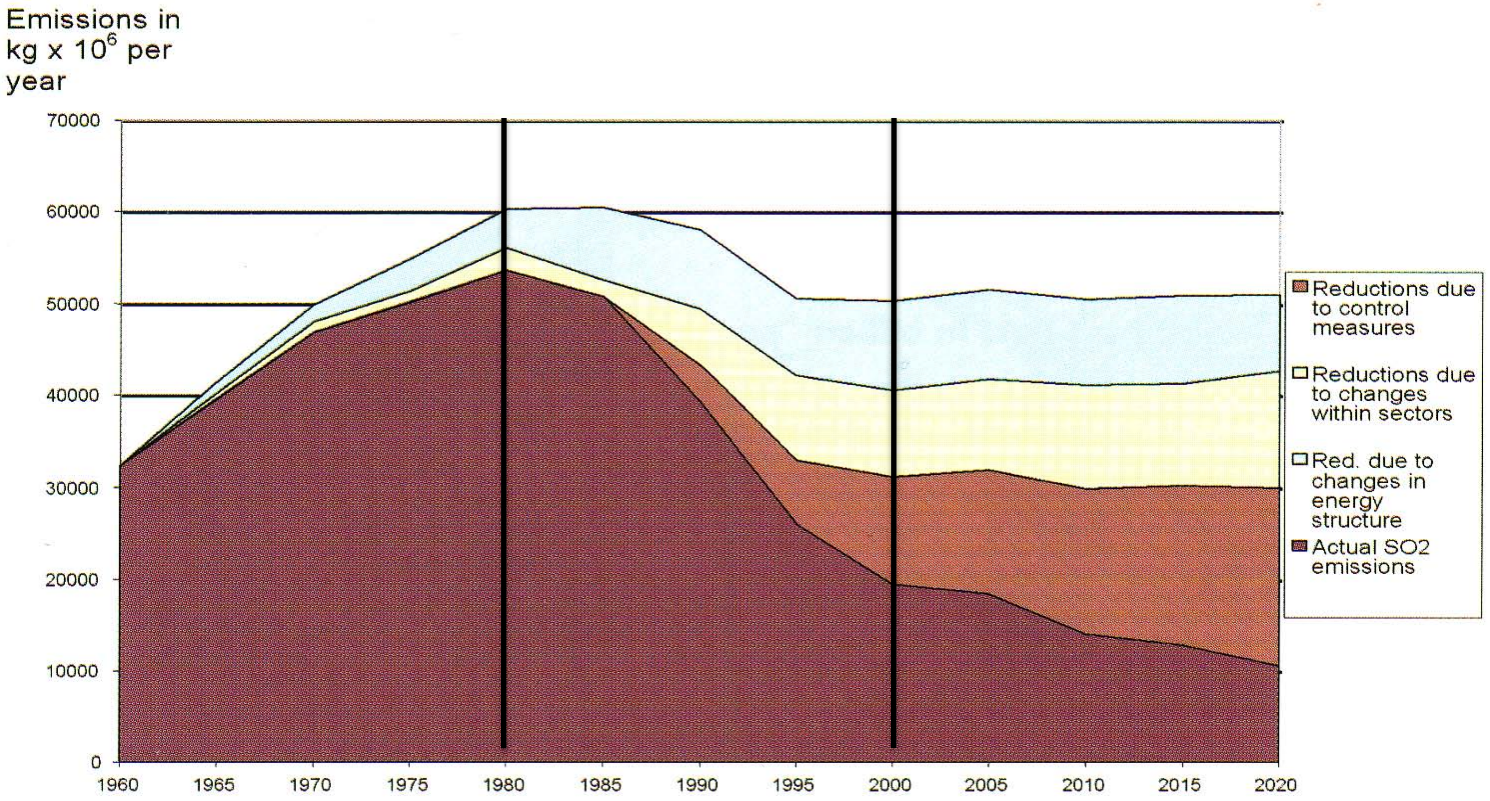
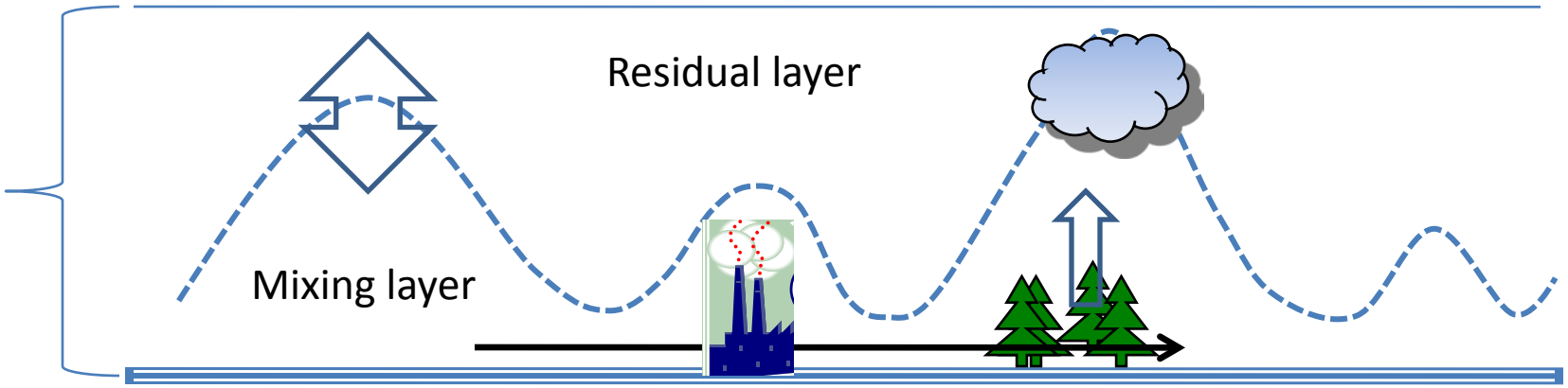


FIGURE 6.1. THE PREVENTION OF SO2 EMISSIONS IN EUROPE 1960-2020: ACTUAL LEVELS COMPARED TO HYPOTHETICAL LEVELS TAKING INTO ACCOUNT ENERGY CONSUMPTION GROWTH

SOURCE: IIASA

The current box model design

- Lagrangian trajectory driven two layer model (mixing and residual layer). Exchange between layers controlled by variation in mixing layer height. Mixing layer heights provided by met-data
- University of Helsinki Multi-Component Aerosol Model (UHMA; Korhonen et al., 2004), A size-segregated aerosol dynamics model, incl nucleation, condensation, coagulation, deposition
- UHMA used concurrent with a *chemical boxmodel and optional clouds*
- Meteorological data supplied by trajectories and meteorological profiles (i.e. Hysplit+GDAS)



The chemical box model

- To UHMA, a chemical box model has been added
  - In total ca 90 reactions considered.
  - Calculates, adopting the pseudo-stationary-state assumption, the chemistry of major oxidants HOx, NO_3 and O_3 as well as sulfur, nitrogen oxides, methane, organics and other trace constituents.
  - In current version anthropogenic organics represented by ethane only
  - Treatment of monoterpene oxidation as in Simpson et al. (1999)
  - Photolytical rate constants solved with freely available JVAL
  - the model lacks: nitrate chemistry

Emissions

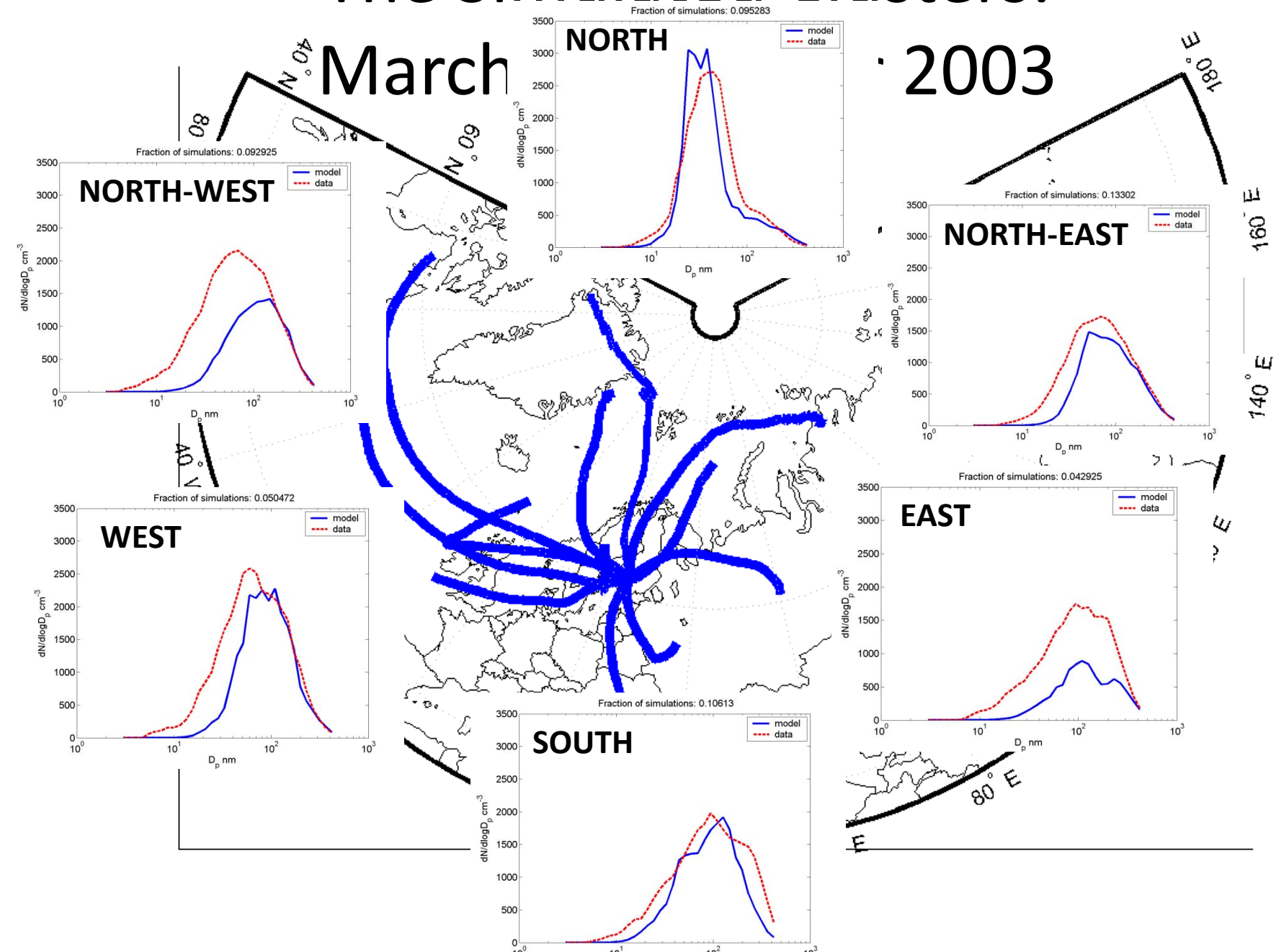
- EMEP expert emission maps (50x50km) for:
  - NOx, SO_2, CO, PM2.5 and volatile organics (NMVOC). The latter is represented by ethane in the model
  - Includes anthropogenic and forest fire OC/EC emissions

- Temperature and light dependent emissions from vegetation:
  - Monoterpenes (as α-pinene; 15% yield)
  - Sesquiterpenes (immediately oxidized→20% yield of low volatile compound)
  - Isoprene (0.2% yield of condensables)

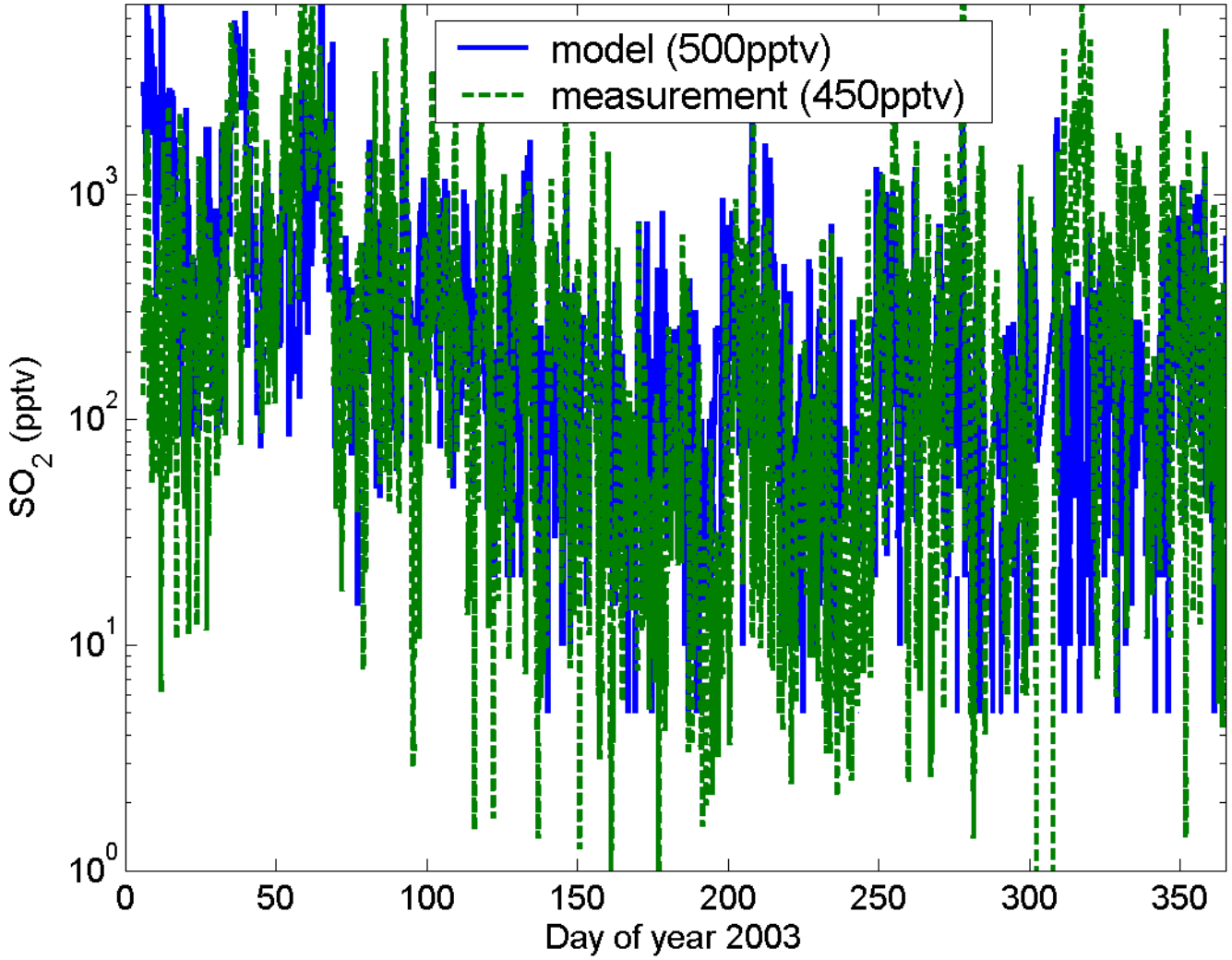
Clouds and precipitation

- ~12 % cumulus-type clouds in mixing layer
  - 4/8 cloud coverage
  - 1-3 m s^{-1} updraft
- ~20 % stratus-type clouds top mixing layer
  - 6/8 cloud coverage
  - ~ 0.1 m s^{-1} updraft
- Precipitation (mm h^{-1}) as prescribed by the individual trajectories:
  - Only below cloud scavenging considered
    - Particles: parameterisation by Laakso et al. (2003)
    - SO_2: Zhang et al.

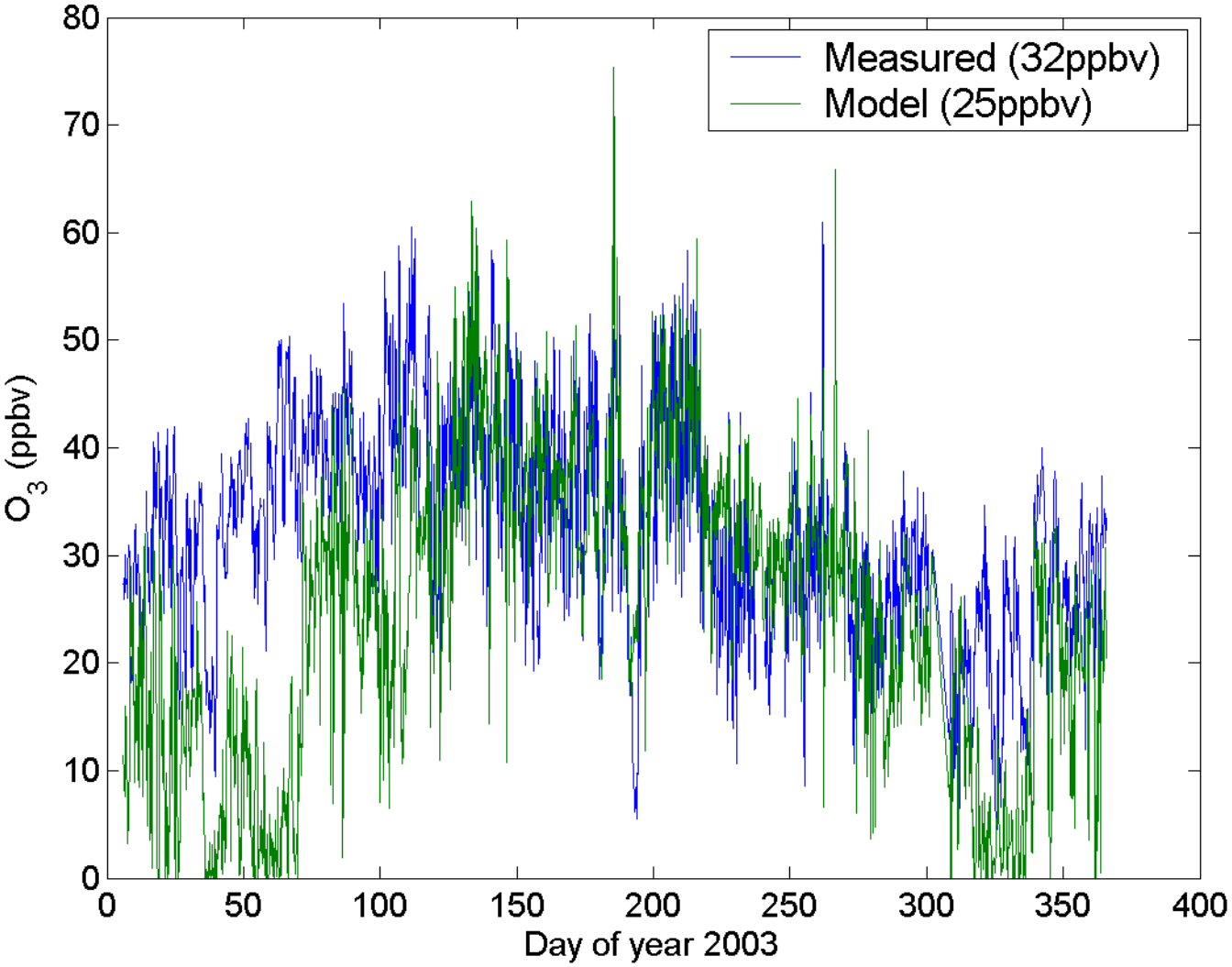
The Simulated Clusters: March 2003



SO_2 in Hyytiälä, 2003
Modeled and measured



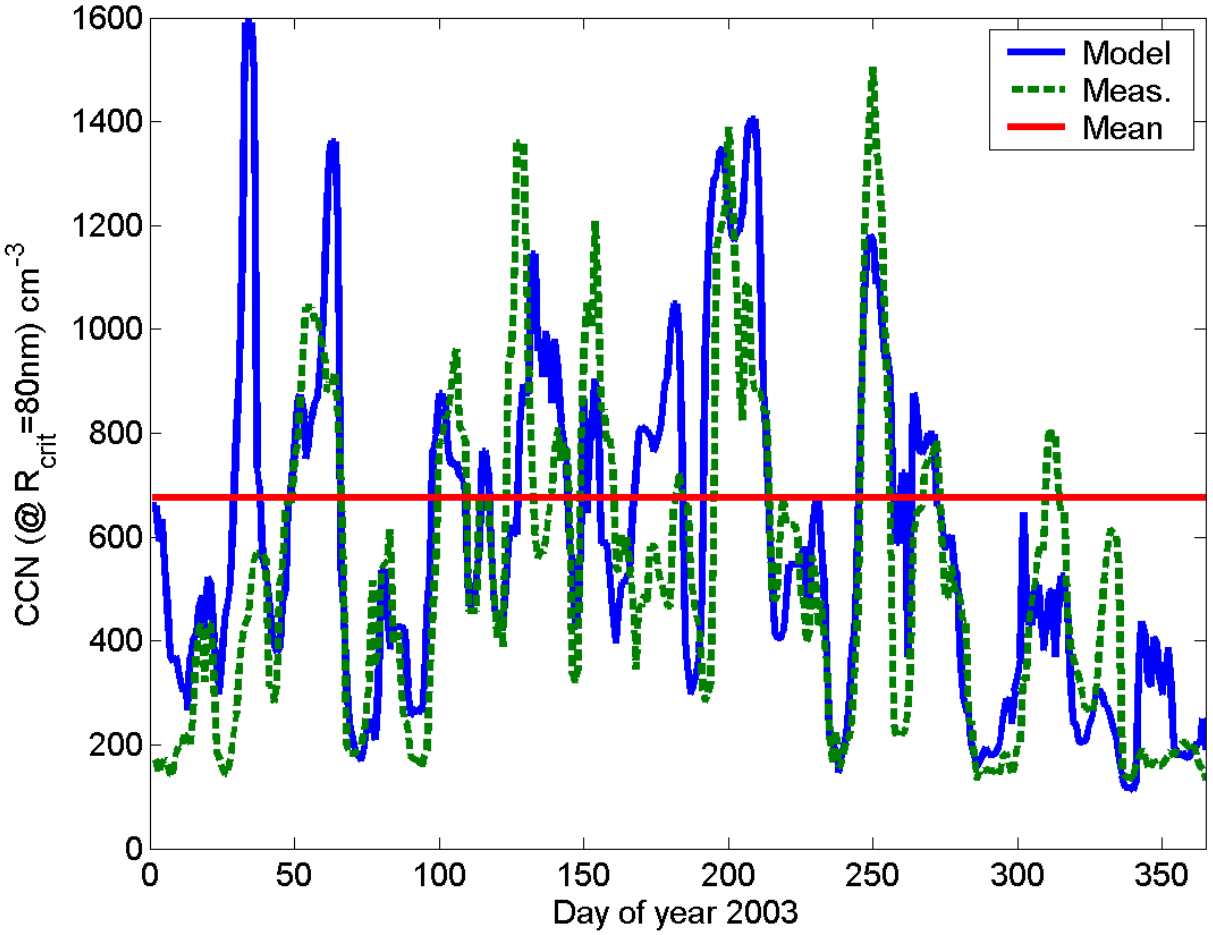
Ozone in Hyytiälä, 2003
Modeled and measured



CCN number assuming $D_{p,\,crit}$ =80nm

Model and measurements from Hyytiälä

7-Days running mean



Average CCN-number:

Model 674 cm^{-3}
Measurements 677 cm^{-3}

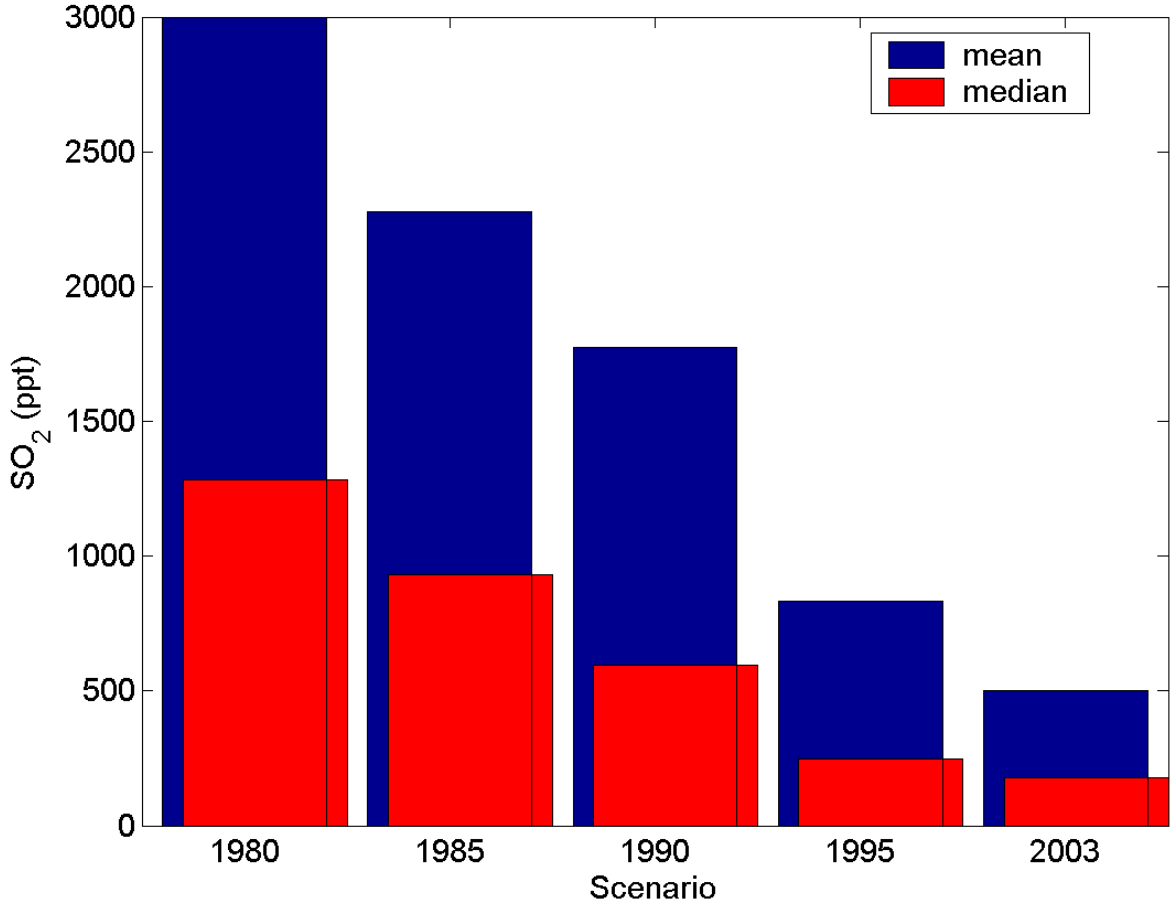
Weak seasonality

Good correlation between model and measurments

Model runs

- Assuming year 2003 meteorology, different emission scenarios have been set up:
  - Scenarios using EMEP emission inventories for years 1980, 1985, 1990, 1995 and 2003 have been compared (regarding SO_2, CO, NO_X, NMVOC)
  - Future scenarios assuming a temperature increase of 5 degrees and one scenario with 5 degrees temperature increase but with half todays' SO_2 emissions

SO_2 decreasing trend 1980-2003 Means and medians

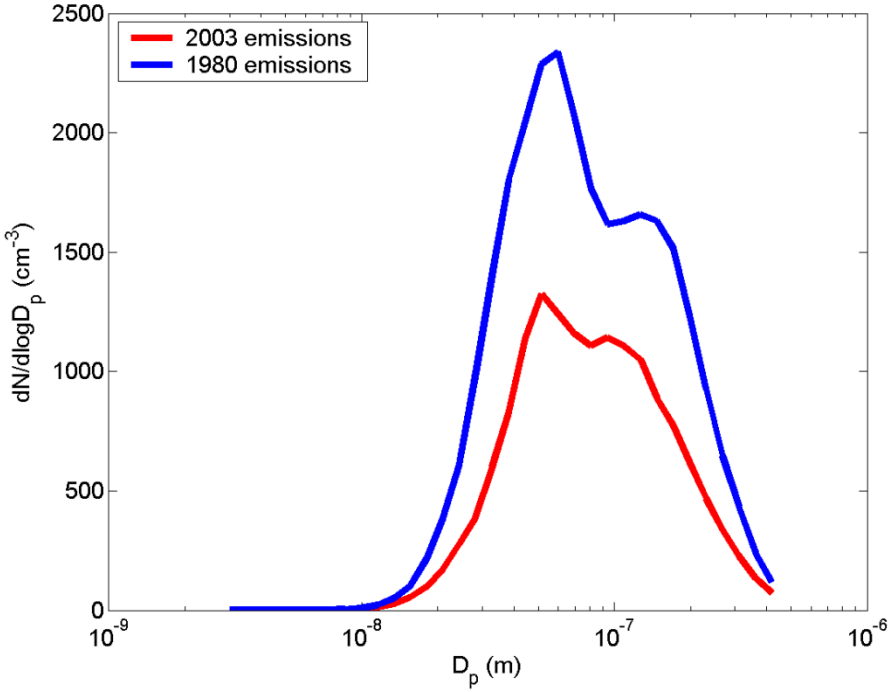


Assuming 2003 meteorology

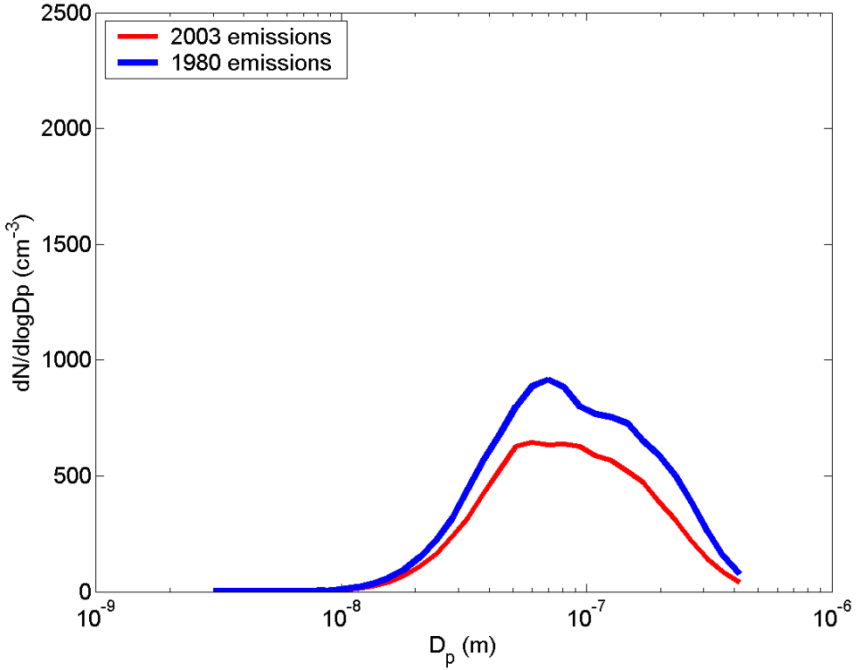
Average SO_2 decreased by a factor 6 comparing 1980 and 2003

2003 average SO_2 (~500 ppt) compare well with both Hyytiälä (~450ppt) and Utö (EMEP site) (~500ppt) observations

How is the size distributions affected by emission changes?

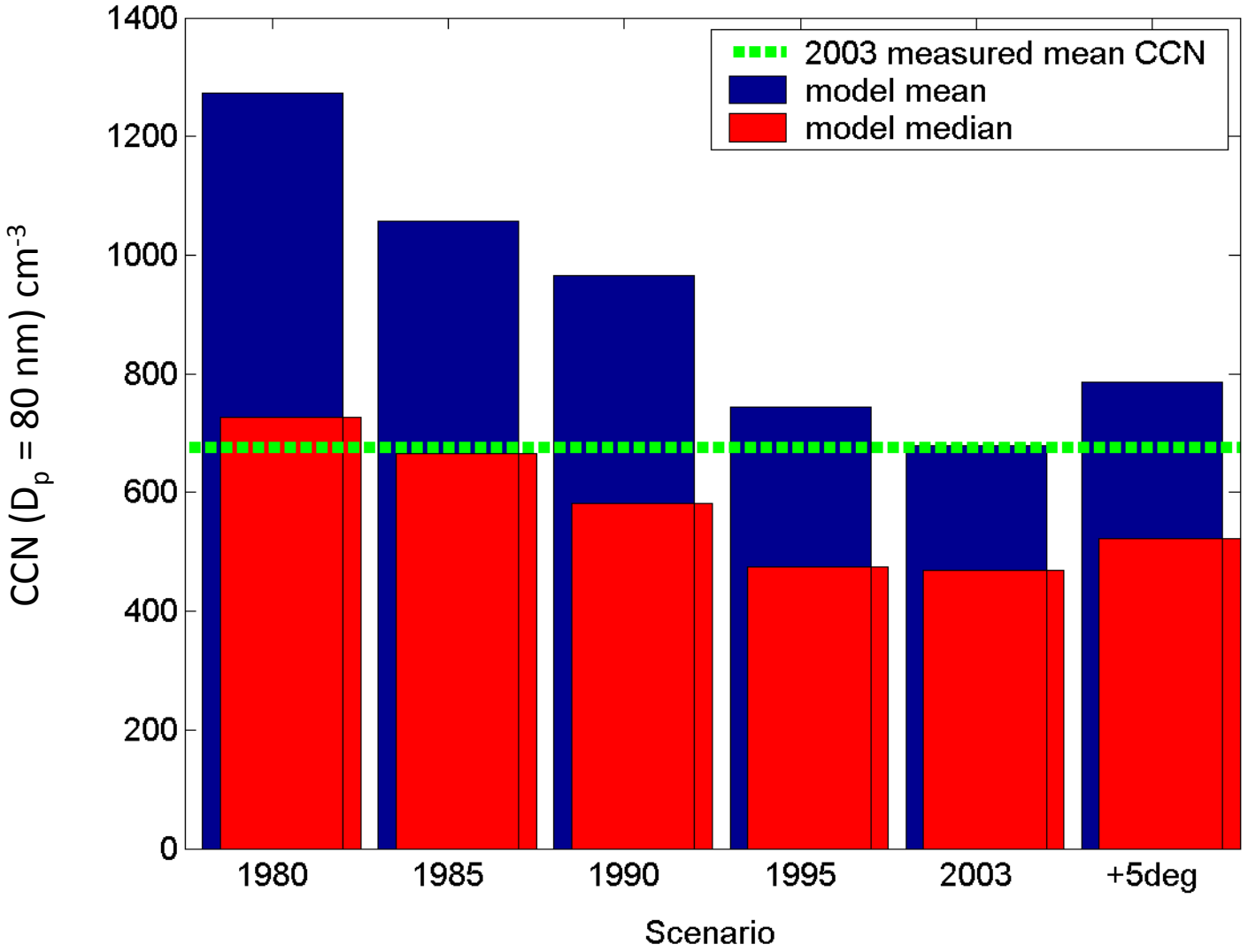


2003 vs 1980:
April-September



2003 vs 1980:
October-March

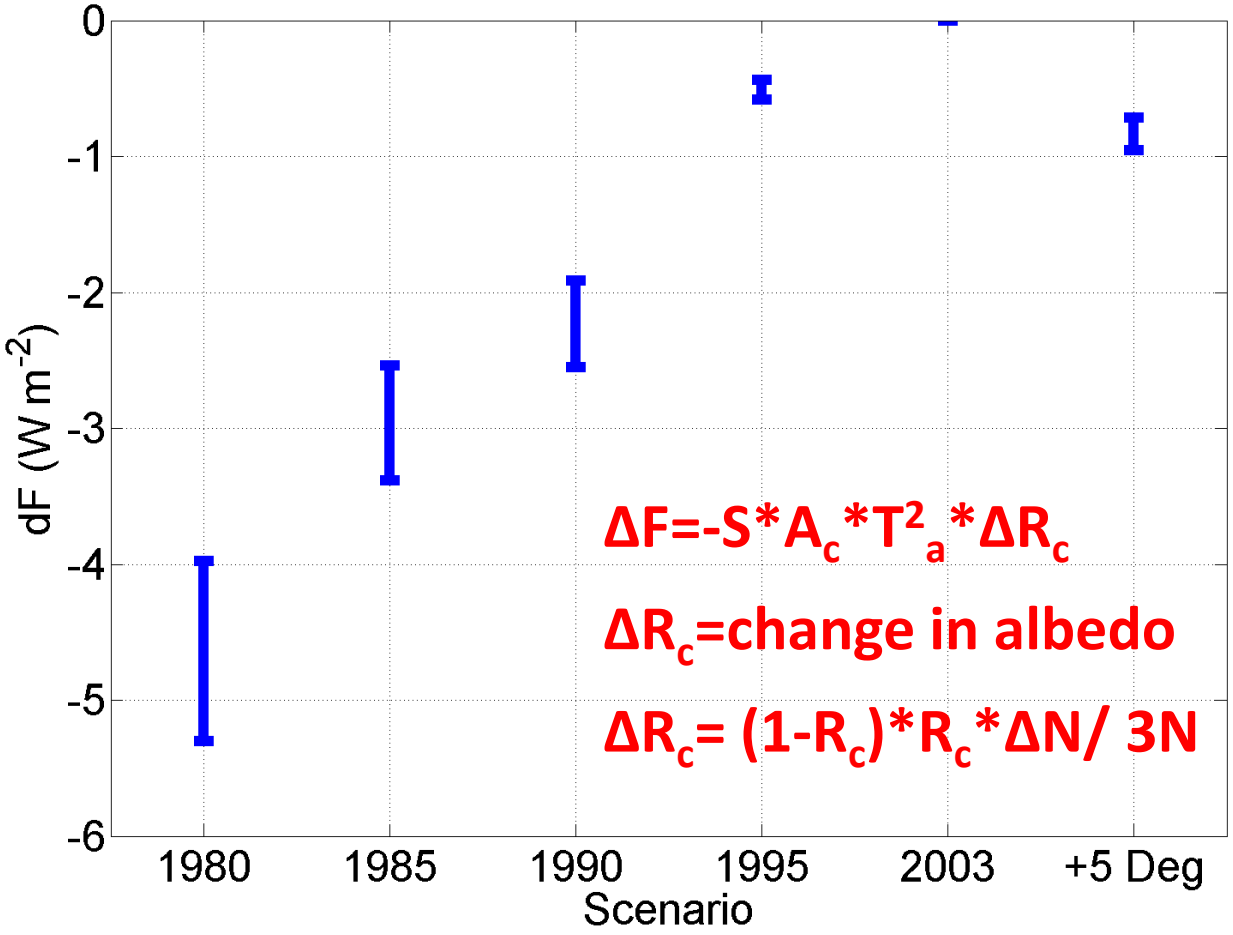
CCN assuming different emissions scenarios



Only emissions changed between scenarios, 2003 meteorology

Forcing estimate relative 2003:

Twomey, 1991, Platnick and Twomey 1994



Average insolation (S):
210 W m^{-2}

Typical cloud cover (A_c):
0.6

Transmissivity (T_a):
0.76

Typical cloud albedo 2003 (R_c)
0.25-0.75

Cloud Droplet Number (N);
Number of particles
D_p> 80 nm

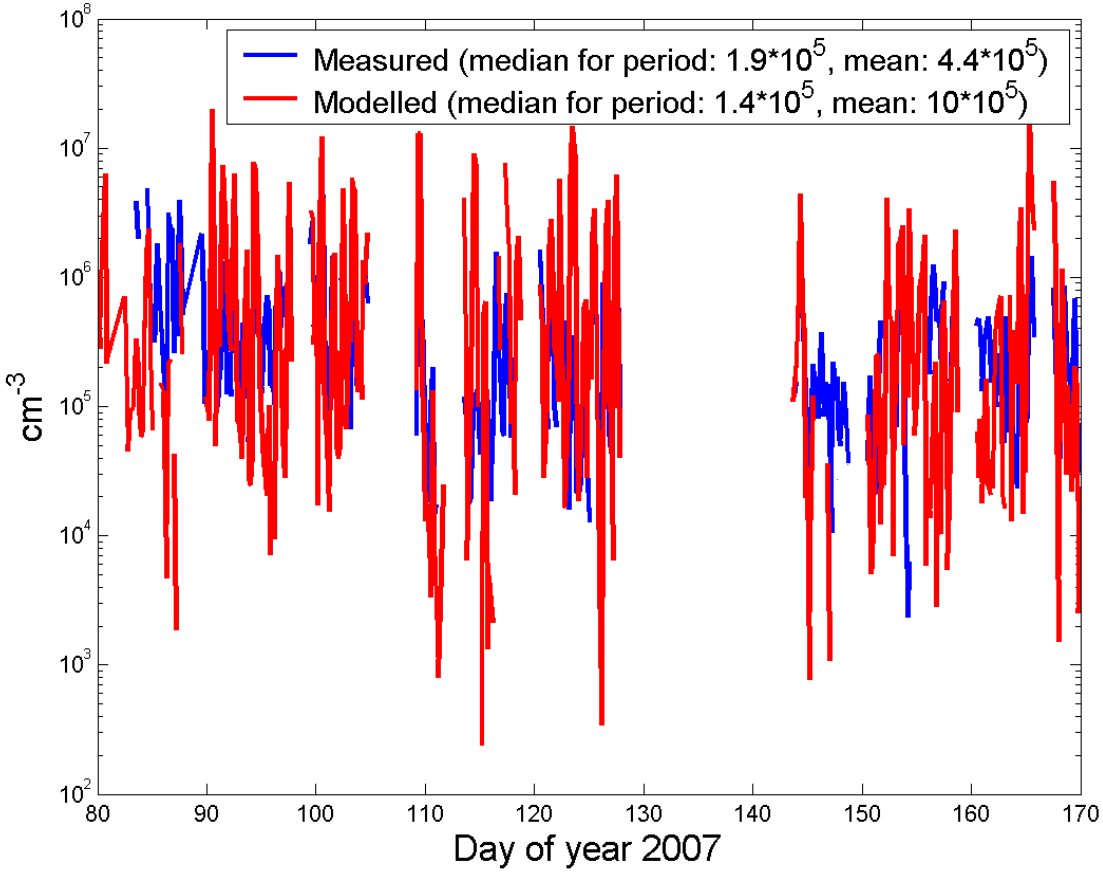
Forcing

- Thus,
  - Between 1980 and 2003, the estimated change in forcing is between 4-5 W m^{-2}
  - An assumed increase of temperature (relative 2003 average) is estimated to yield a forcing of -0.72-0.96 W m^{-2} (if all other parameters held constant)
  - A decrease of SO_2 by a factor of 2 conjunct with a 5 degree temperature increase would result in negliable change of CCN and thus no change in forcing

Conclusions

- Both natural and anthropogenic sources, i.e. all atmospheric particles have to be taken into account when estimating climate forcing.
- All climate driven changes, i.e. feedback processes, have to be taken into account.
- Earth system modeling is necessary

H_2SO_4: model and measurements Test for spring 2007



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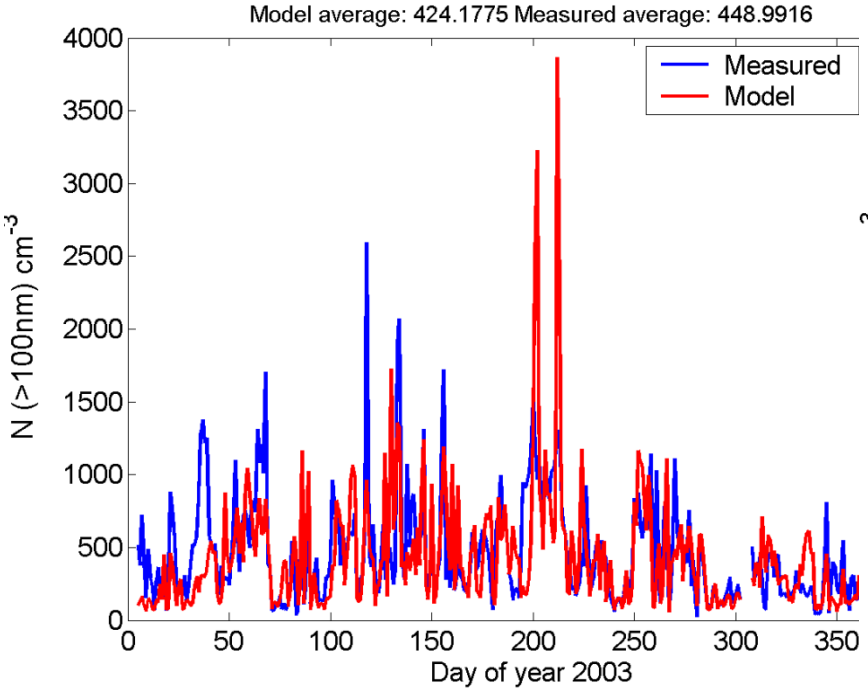
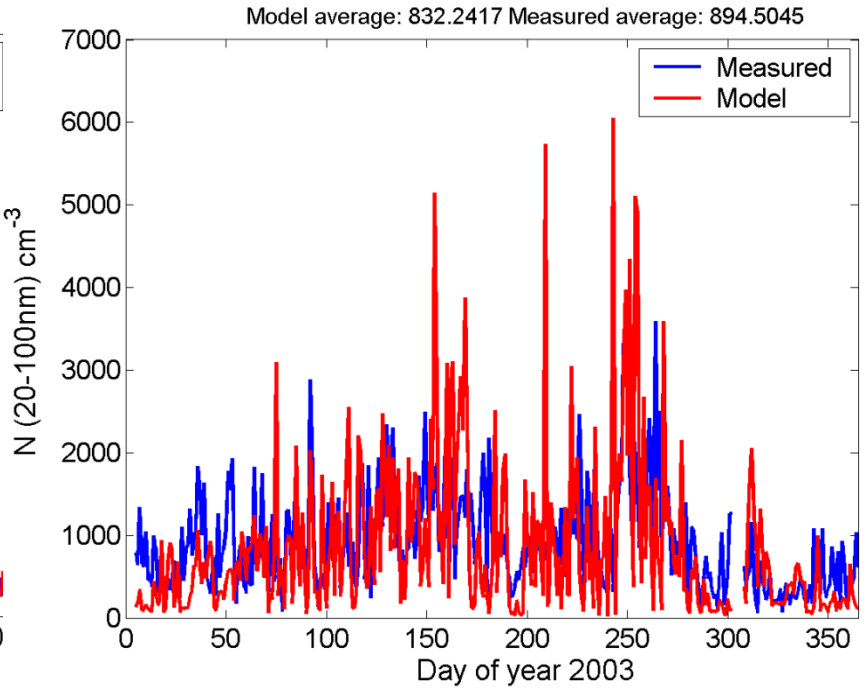
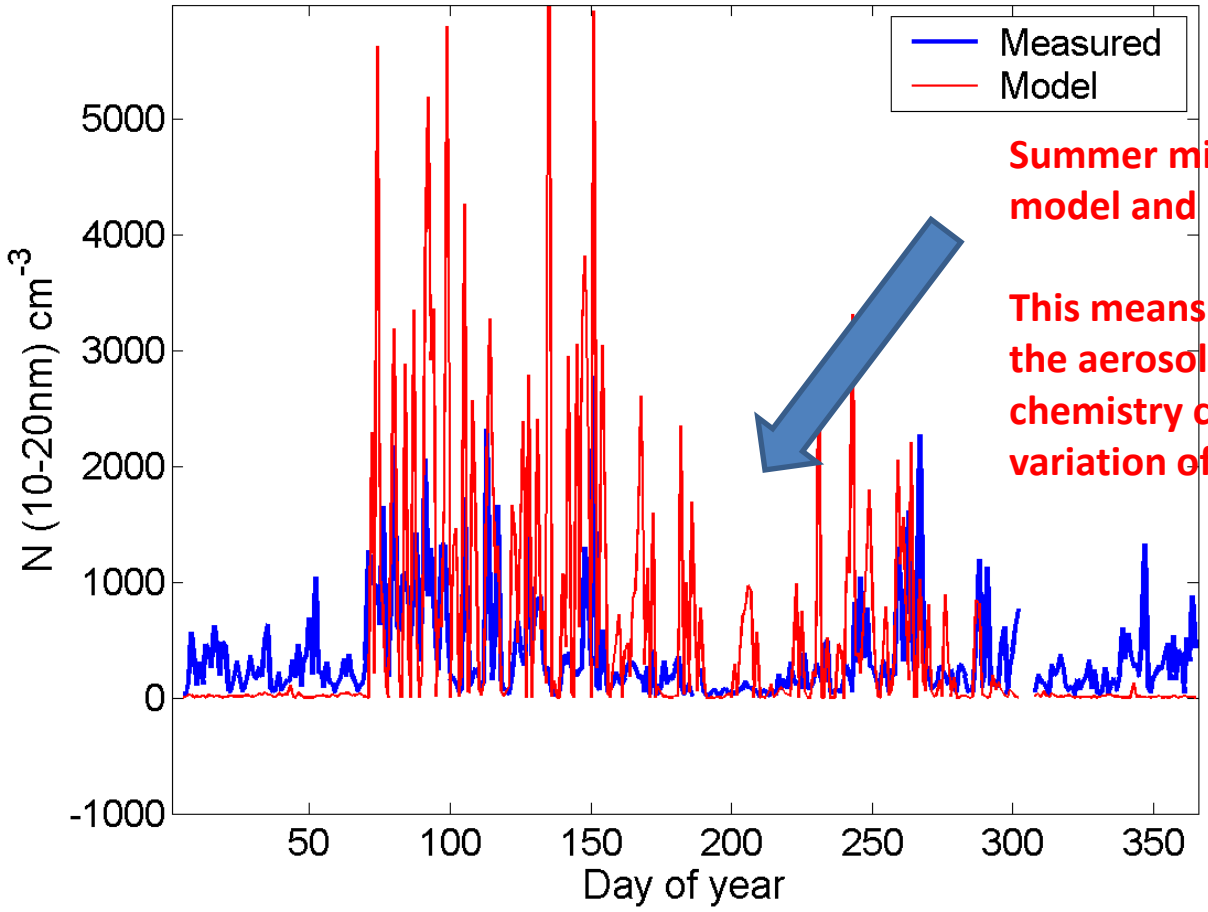
Accumulation and Aitken mode





Nucleation mode particles



Summer minimum apparent both in model and measured data

This means that dynamical aspects of the aerosol population+basic photo-chemistry can explain the seasonal variation of nucleation