Past trends in atmospheric composition

Results from the RETRO Project

(**RE**analysis of the **TRO**pospheric chemical composition over the past 40 years)

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Motivation

"The primary objective of RETRO is to understand, detect and assess long-term changes and interannual variability of the tropospheric chemical composition over the last 40 years, thereby providing the essential framework within which to understand possible future changes."

from RETRO description of work

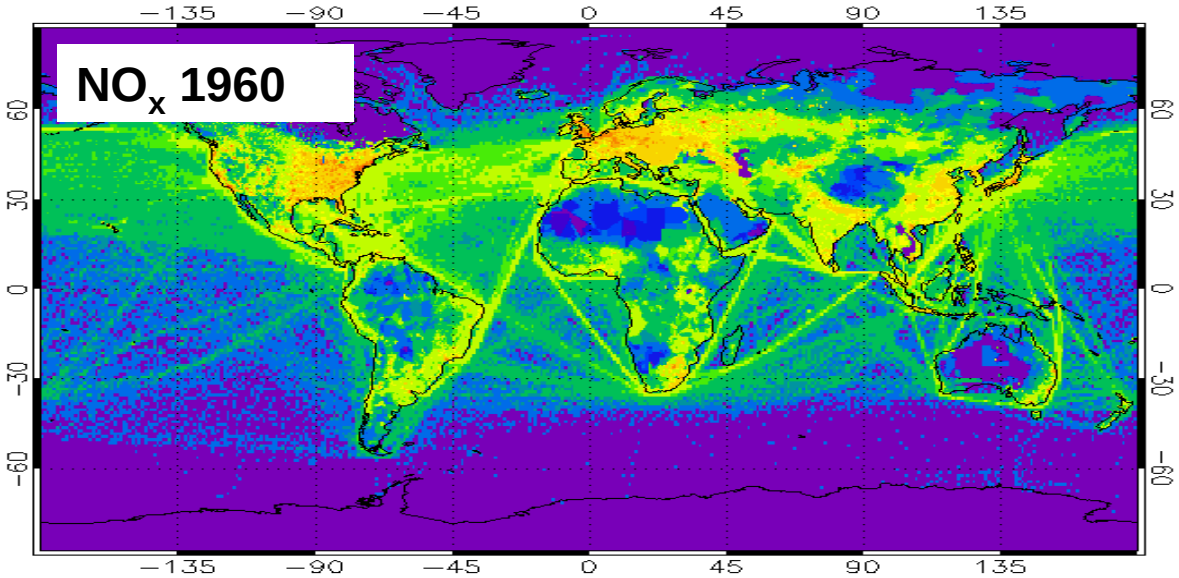
What has changed?

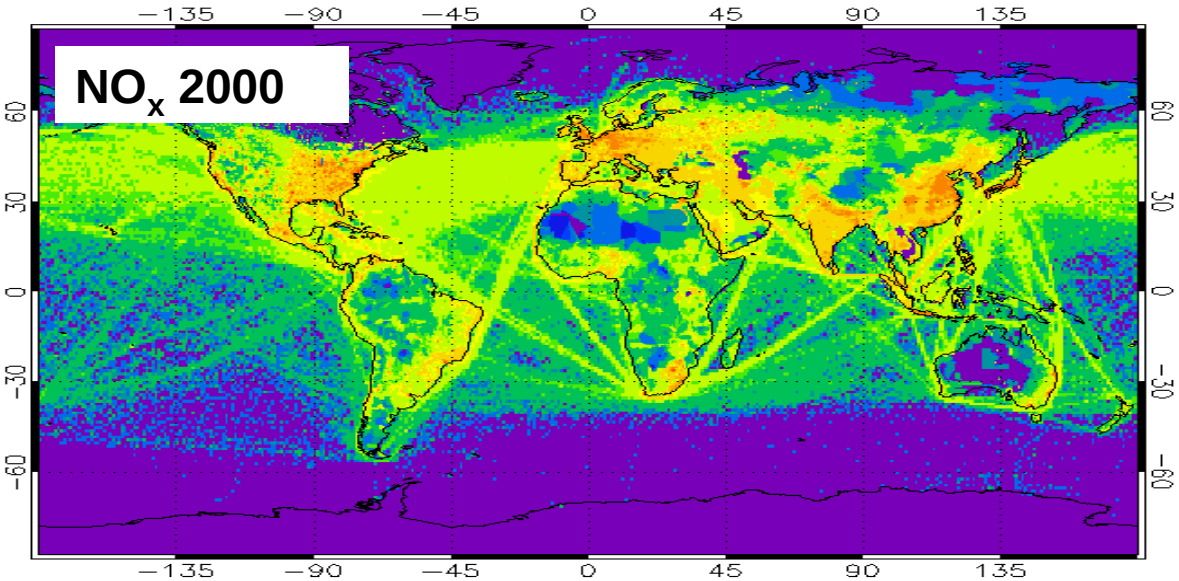
US statistical data

	1960s	1990s
Population	177.8 Mio.	281.4 Mio.
Unemployment	3.85 Mio.	5.8 Mio.
National Debt	286.3 Bio. $	5.4 Bio. $
Average Salary	4743 $	27800 $
Auto deaths	37870	49772

http://kclibrary.nhmccd.edu/

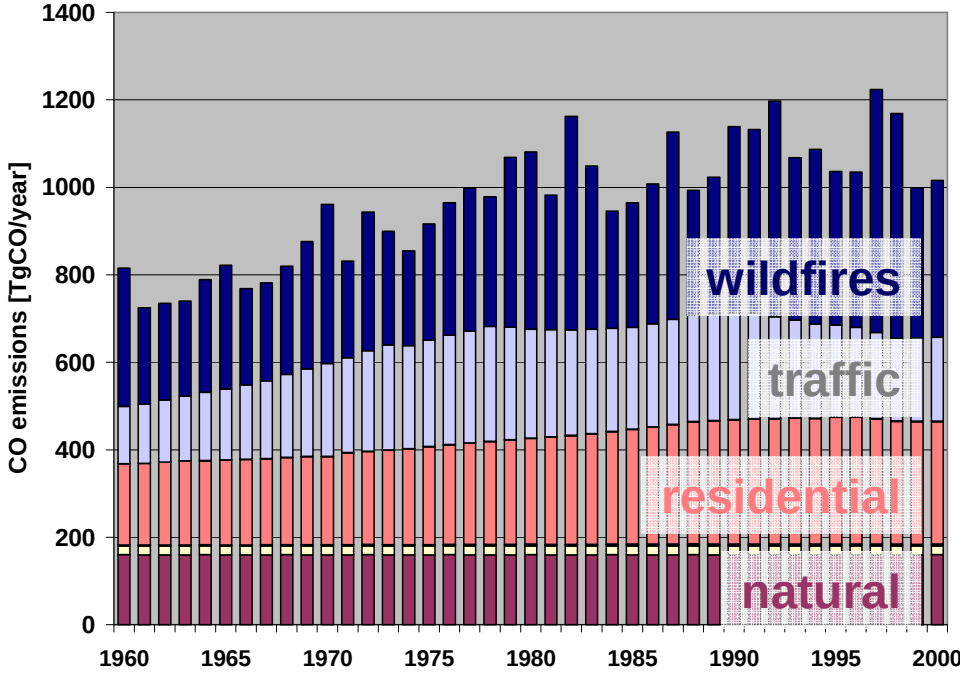
Anthropogenic Emissions



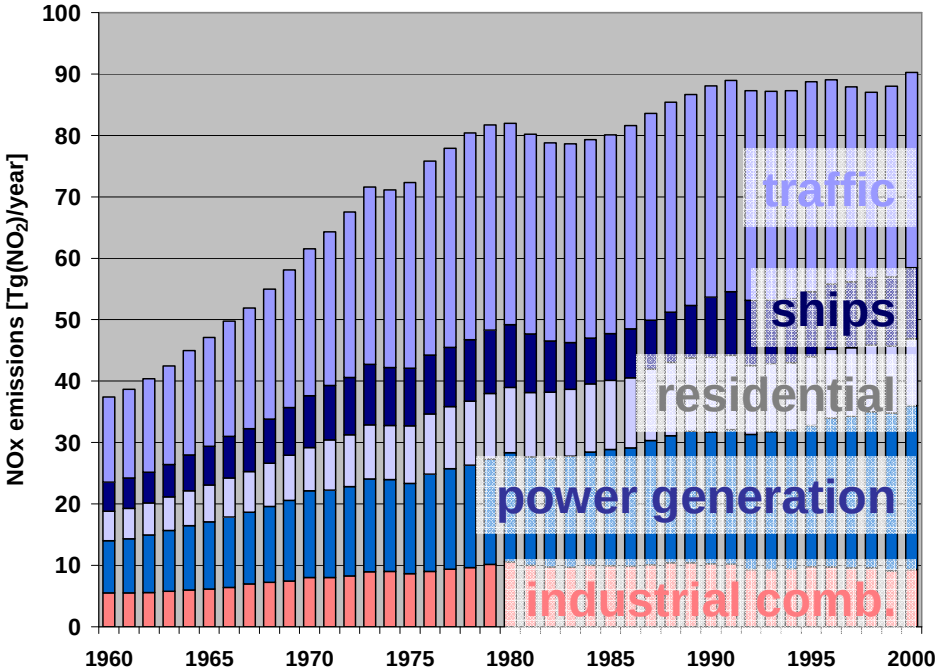


RETRO Emissions

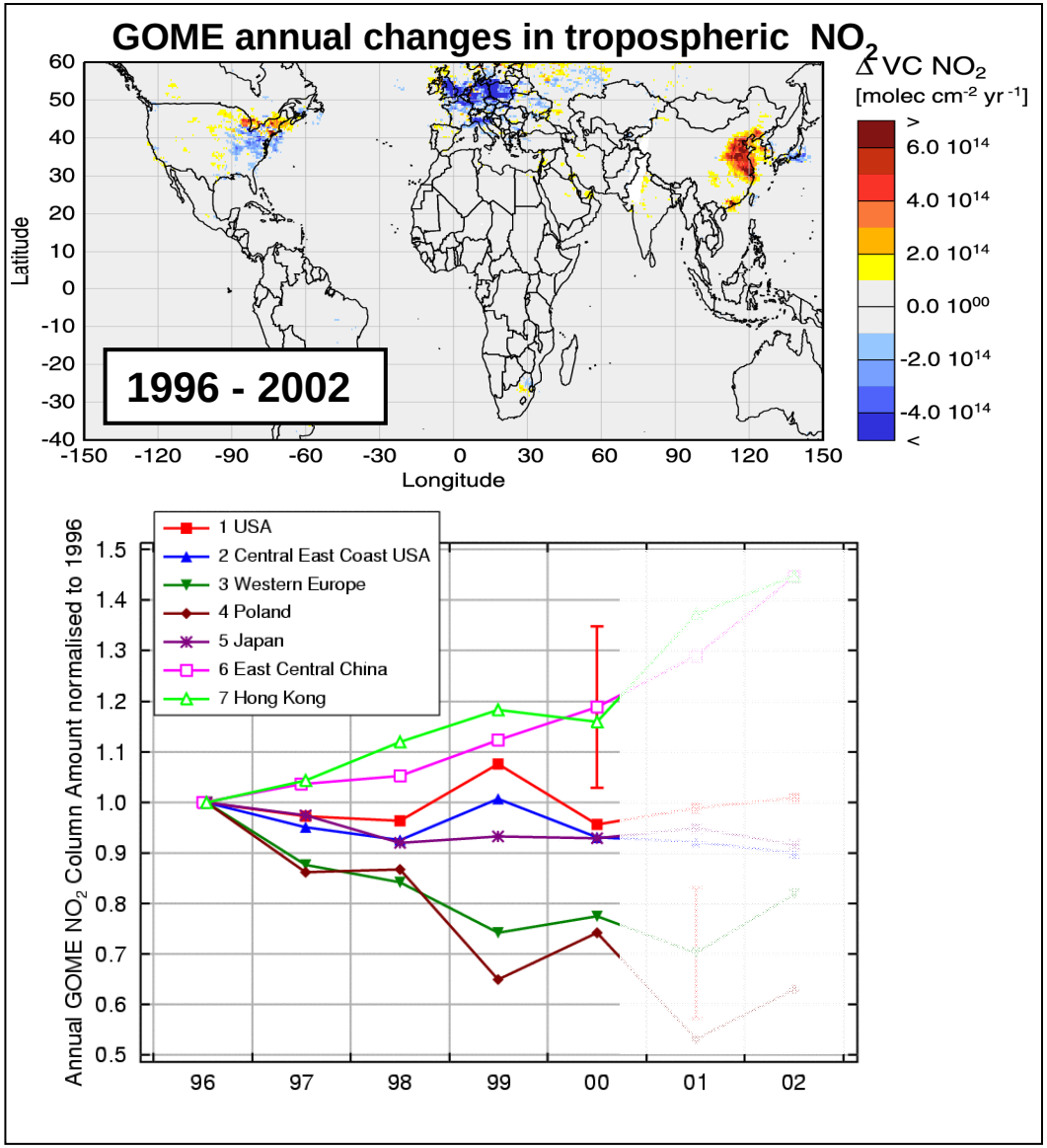
CO

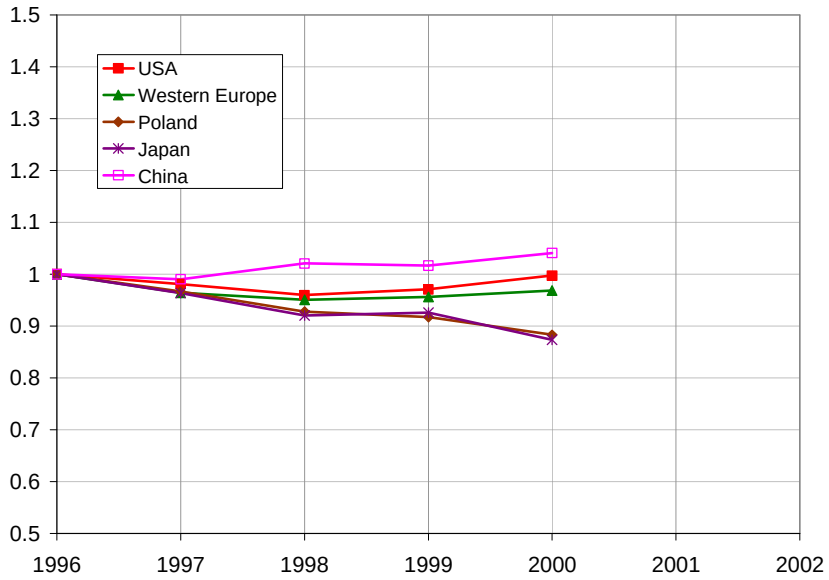


NOx



Are emission trends estimated correctly?

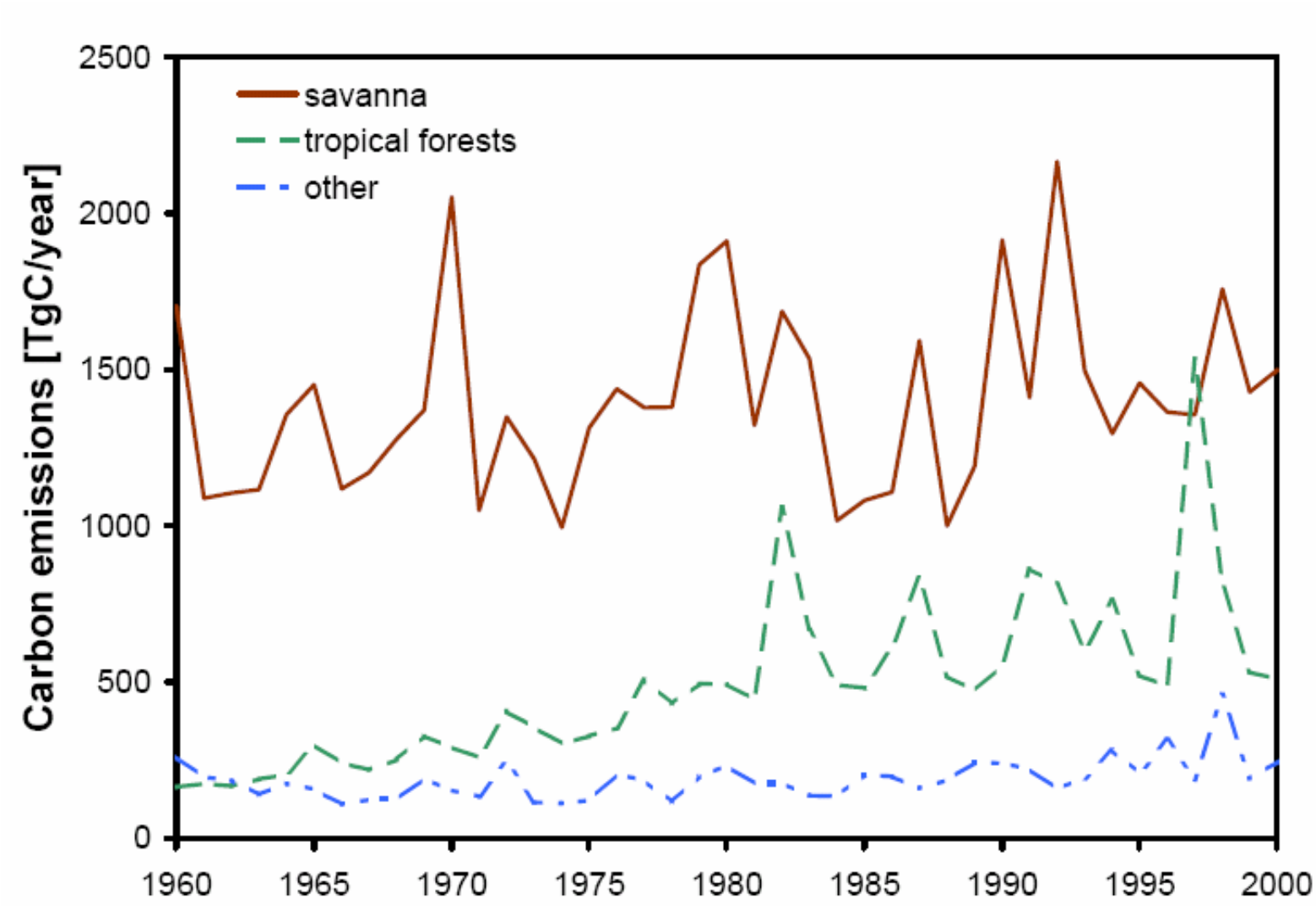




GOME NO2 columns (A. Richter)

from the RETRO NOx inventory

Fire emissions: Trends & Variability



RETRO models

- 5 global models participated:
  - 2 chemistry–GCMs
  - 3 CTMs
  - resolution 3°×3° or better
- all models used ERA–40 data
  - different variables (see below)
  - analysed versus forecasted fields
- all models used RETRO emissions
  - differences for biogenic emissions and injection height
- stratospheric boundary conditions differ

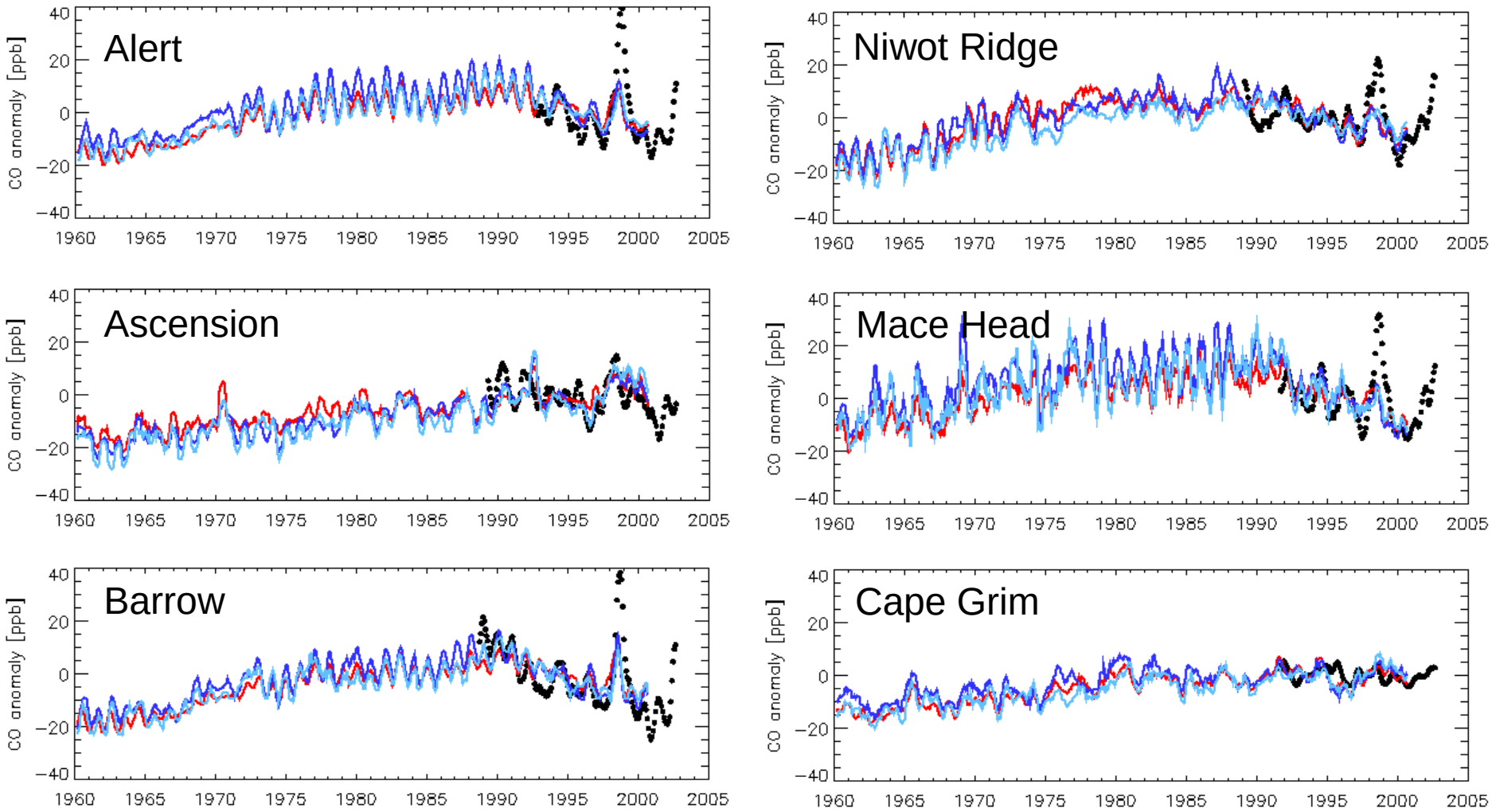
3 models (2 chemistry-GCMs and 1 CTM) ran the complete 40-year period

RETRO Models (2)

	MOZ	LMDz	TM 4	CTM 2	TOM CAT
Temperature	X		X	X	X
Specific humidity			X	X	X
Geopotential height			X		
Wind vector (u, v)		X			
Wind divergence	X			X	X
Potential vorticity	X				X
Surface pressure	X		X		X
Horizontal mass flux			X		
Convective mass flux			X	X	
LWC			X	X	
IWC			X	X	
Cloud fraction			X	X	
Cloud levels			X	X	
Large-scale precipitation			X	X	
Convective precipitation			X	X	
Aerodynamical resistance			X		
Friction velocity			X		
Temperature 2m			X		
Wind speed 10m		X			

NOAA ESRL stations – CO Anomalies

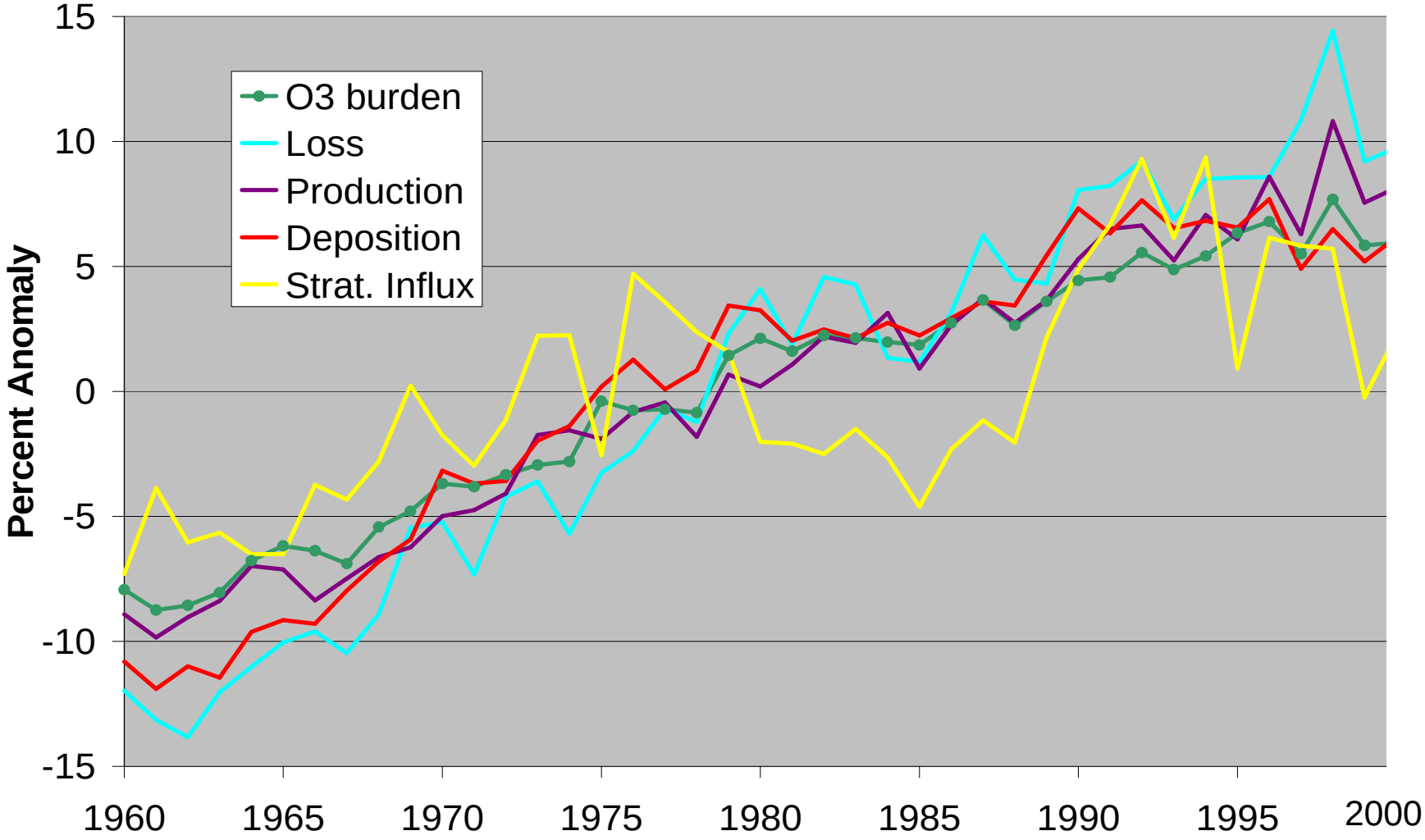
6-months running averages RETRO models



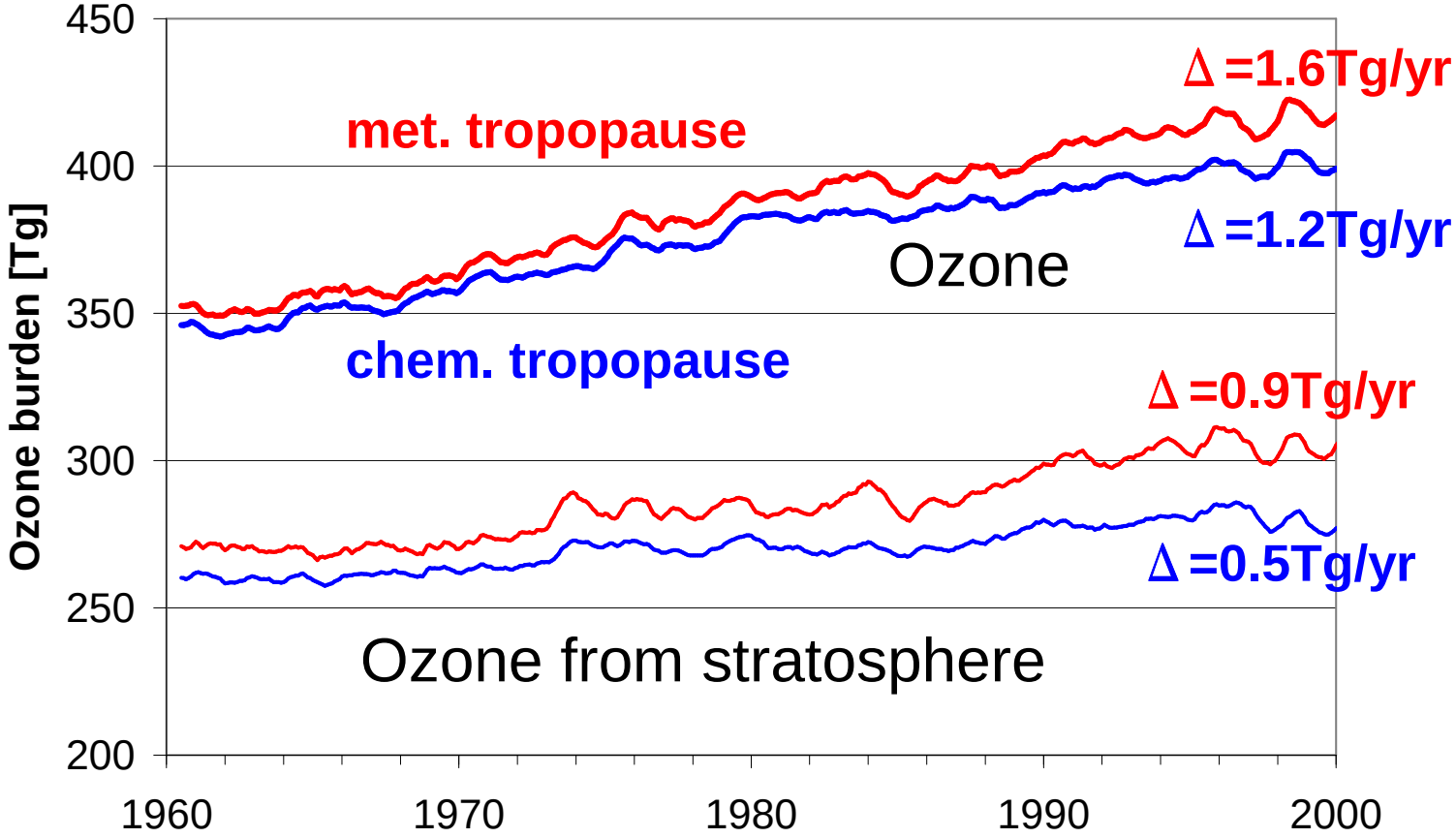
● obs. — LMDz — TM4 — ECHAM5-MOZ

Tropos. ozone budget

ECHAM5-MOZ results

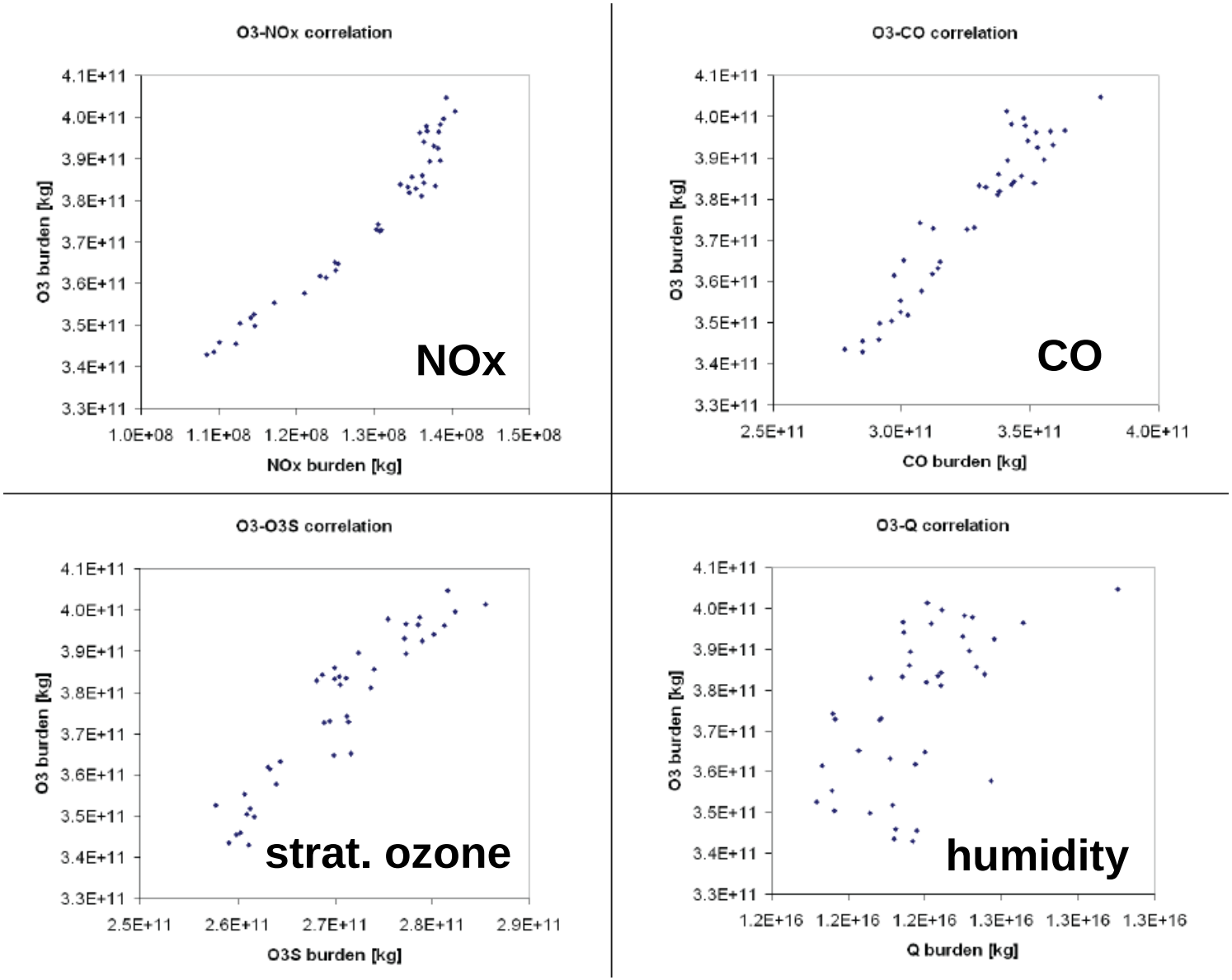


Ozone burden



- Ozone burden trend: about 10% difference between chemical and meteorological tropopause
- Correlation R=0.987
- Increase about 20% over 41 years

Tropospheric ozone burdens



Modell-Intercomparison

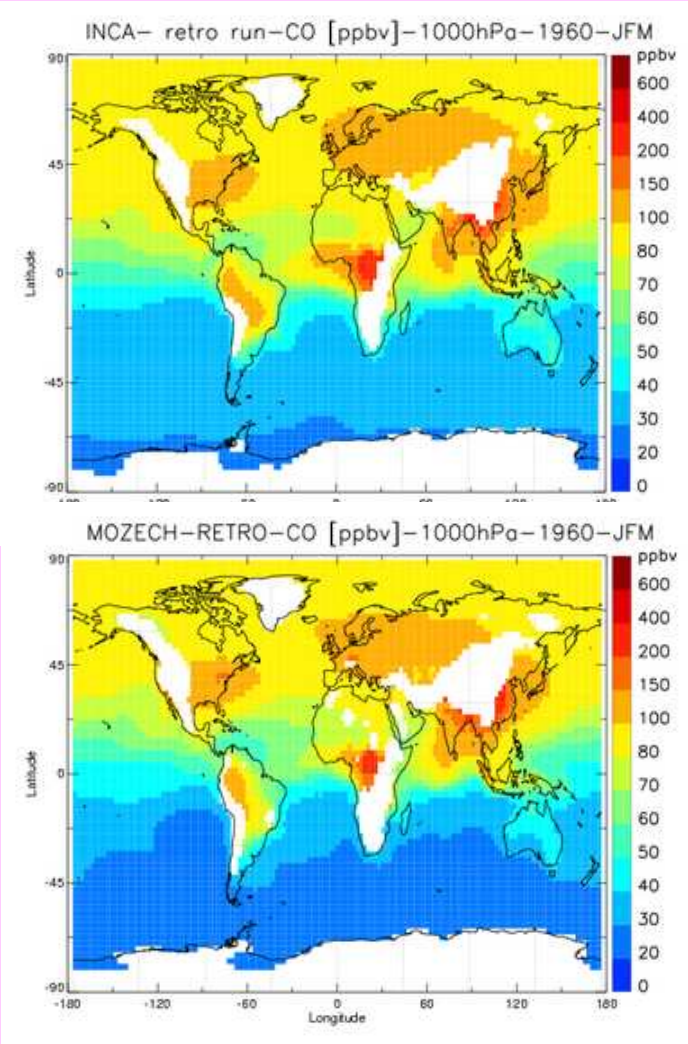
Near surface CO

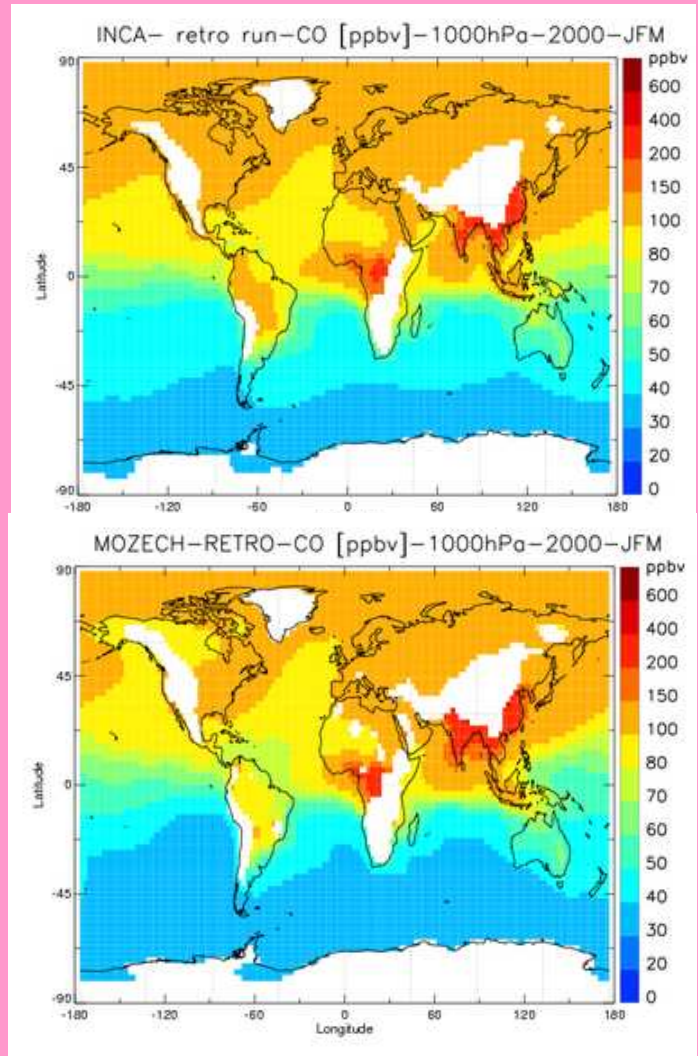
1960

2000

LMDz INCA

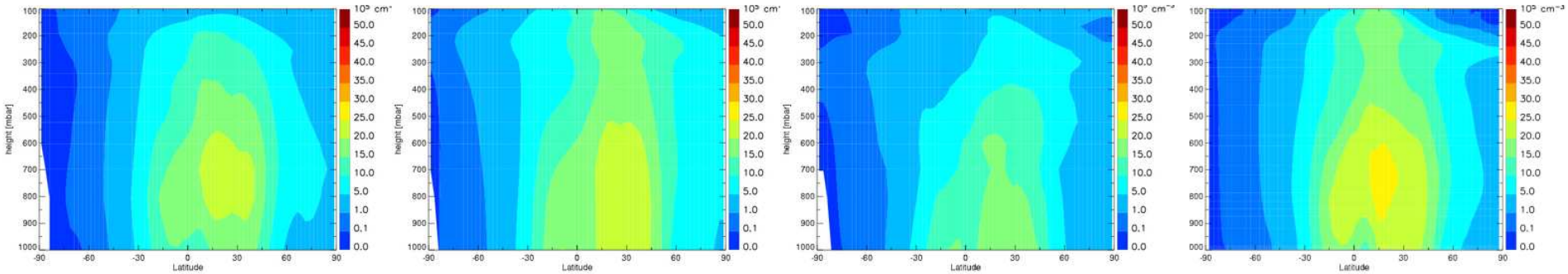
ECHAM5 MOZ





The OH story ?

Consistency of model results: zonal mean OH (summer)



RETRO model results JJA 1997 (first runs, 4 models)

RETRO scenario calculations

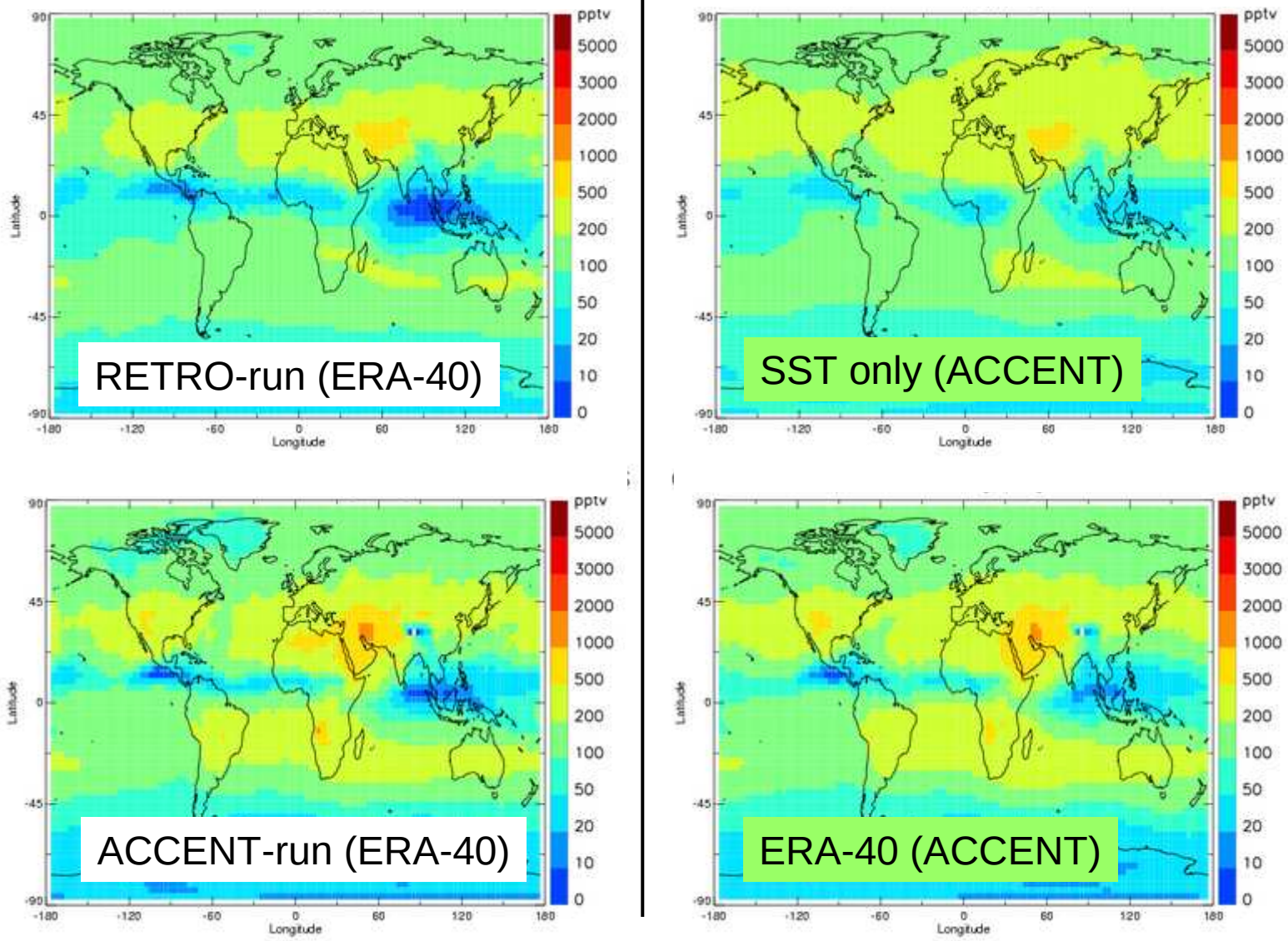
Table 29: Relative summertime (Jul-Aug-Sep mean) ozone changes (%) at 950 hpa over central western Europe (37.5º-55ºN, -10º-25º E covering ar region from southwest Portugal to eastern Greece and from northwest Great Britan to the Baltics) for the different scenario simulations.

Sensitivity study/Model	Average concentration (ppbv)	GOINGNUCLEAR	NOCATALYST	EURO3	EURO4	EURO5
UiO	45.0	-1.5	17.5			-9.7
TM4	62.4	-2.2	14.6			-10.7
LMZ	57.8	-1.9	13.0			-8.2
MOZ	63.5	-1.8	12.1	-7.1	-7.9	-8.1
Average	**57.2**	**-1.9**	**14.3**			**-9.2**

Model sensitivities: ECHAM5-MOZ

HNO_3-Concentration at 500 hPa: Summer (JAS)

Year 2000 | **5-Year Means**

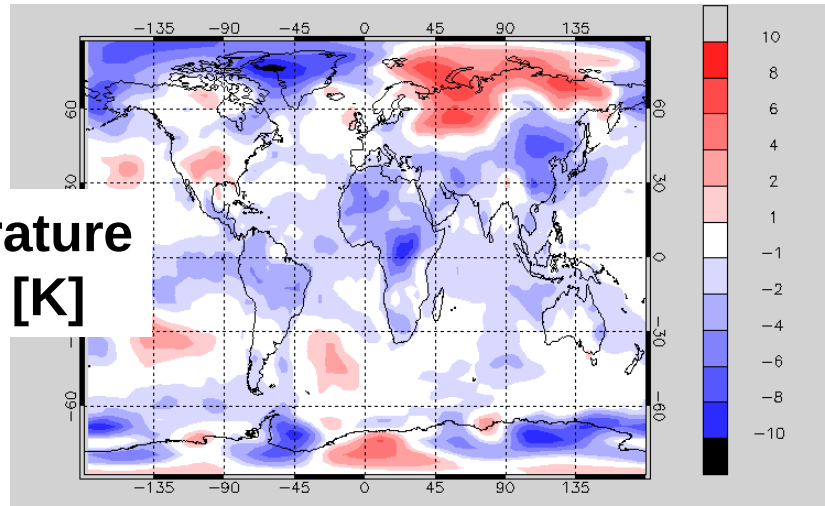


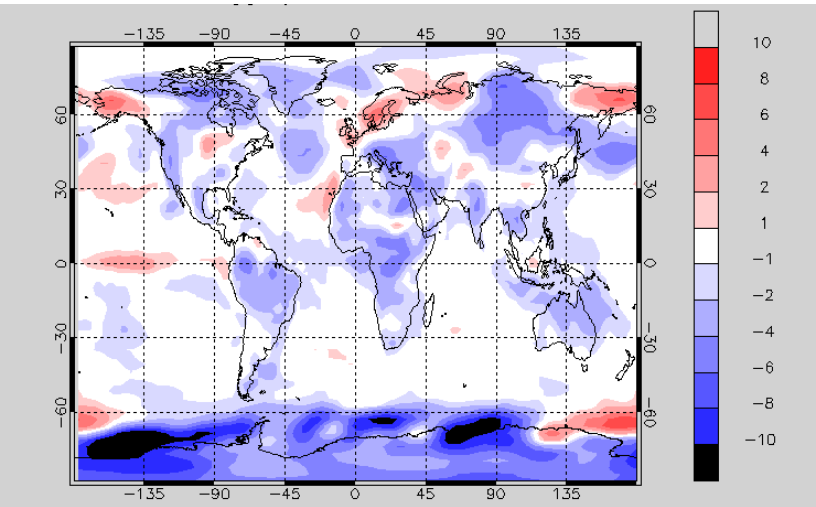
Schultz

1998 (hot) vs. 1976 (cold)

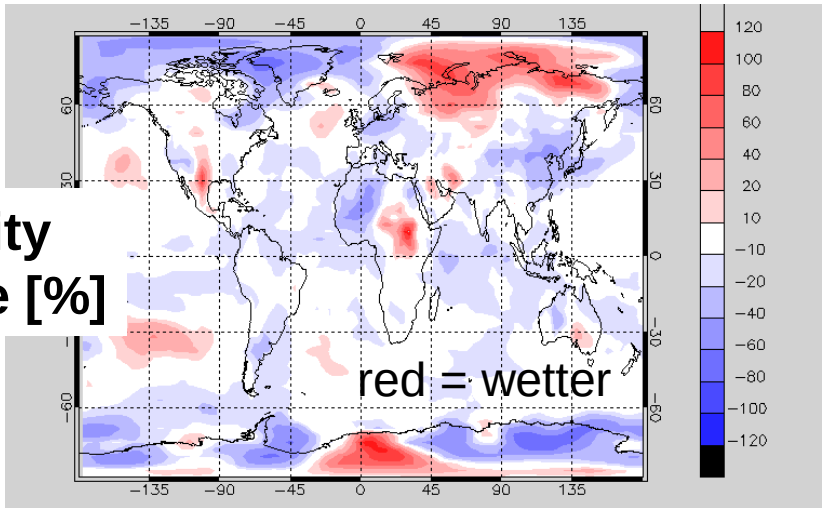
March **July**

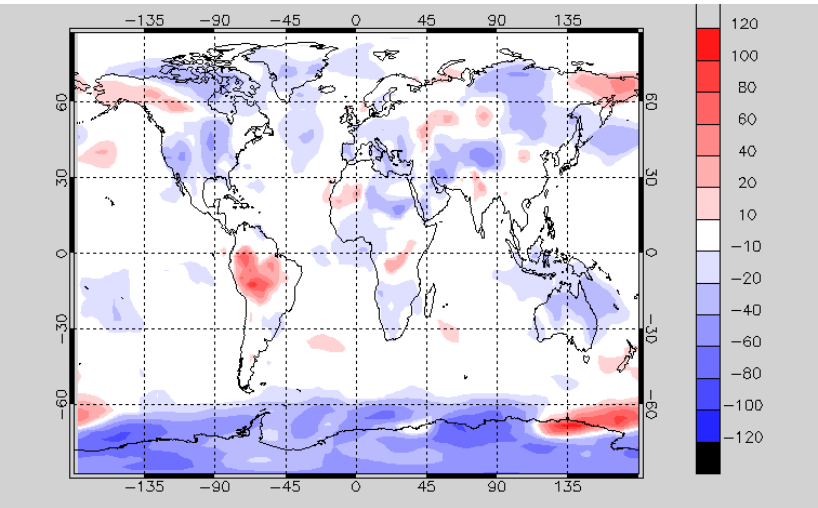
Temperature change [K]





Humidity change [%]



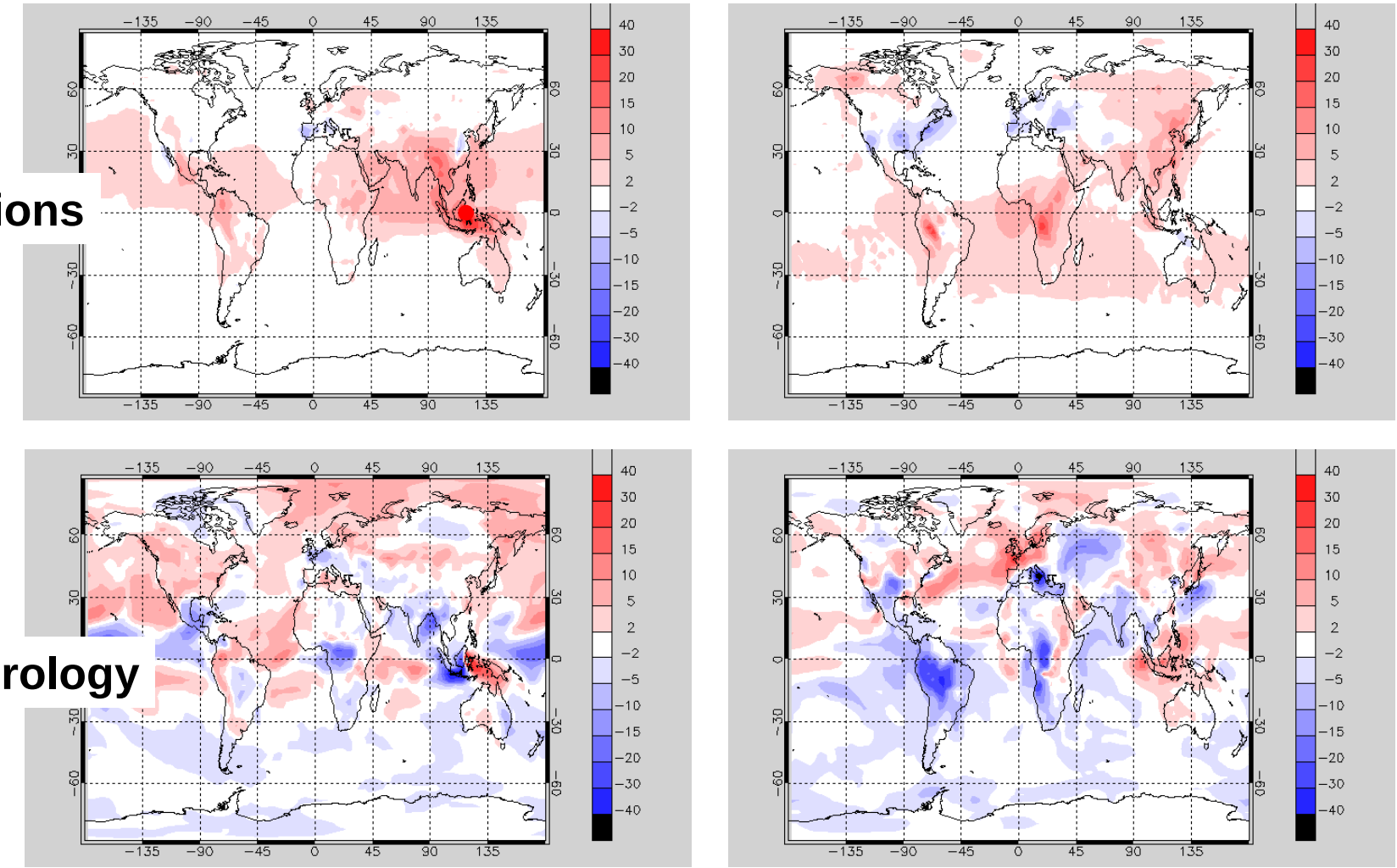


1998 vs 1976: Surface ozone changes

March **July**

Emissions

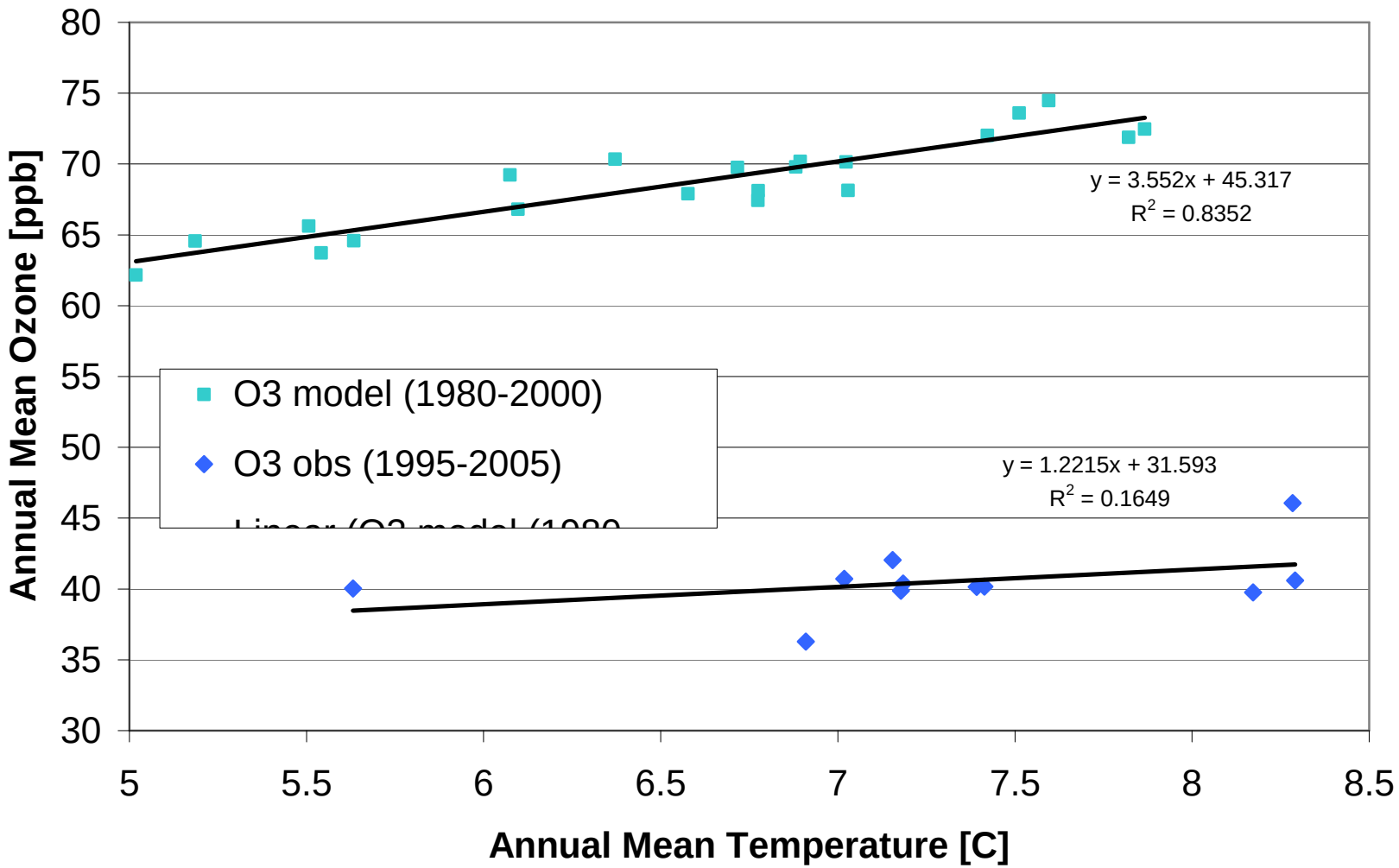
Meteorology



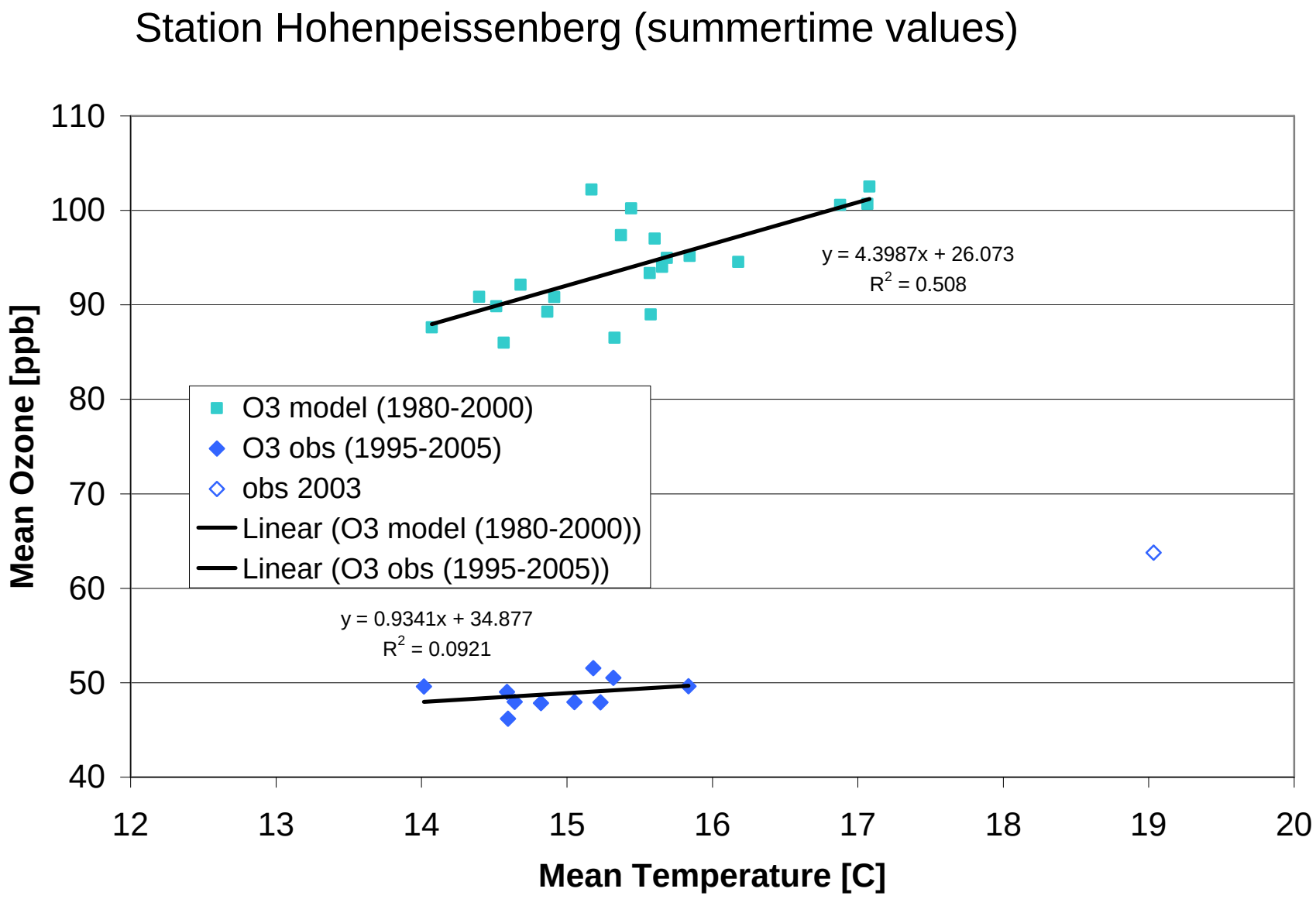
Emissions: both simulations with 1976 meteorology
Meteorology: both runs with 1998 emissions

Ozone temperature relationship

Station Hohenpeissenberg (annual mean values)

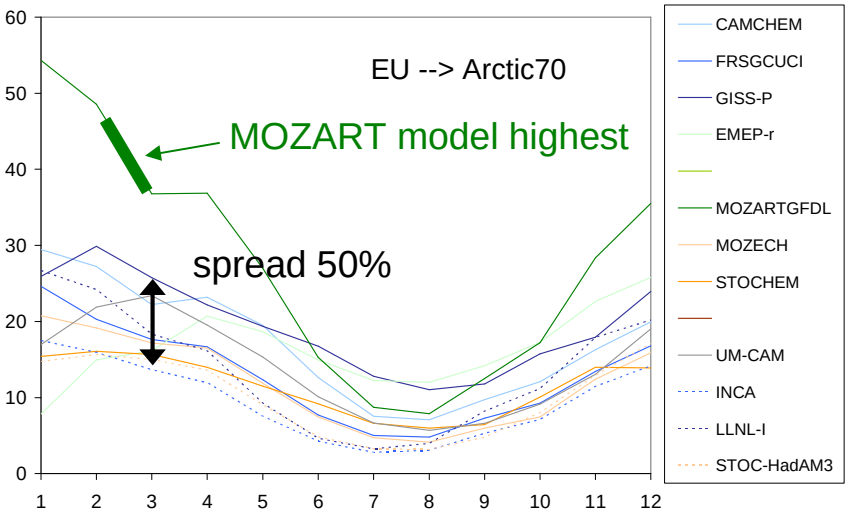


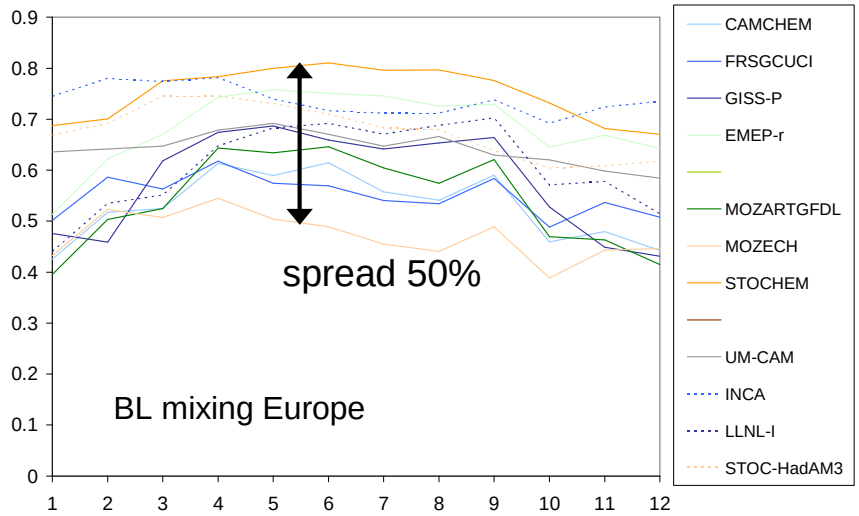
Ozone temperature relationship



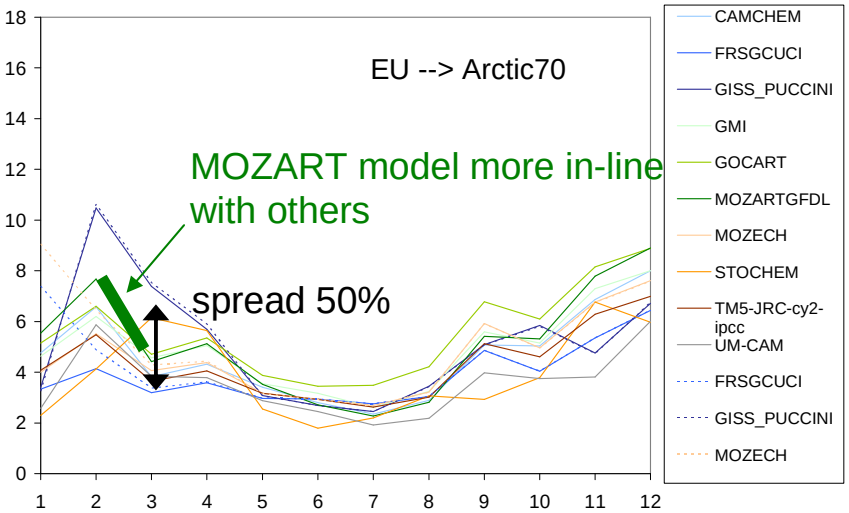
The role of transport (TFHTAP)

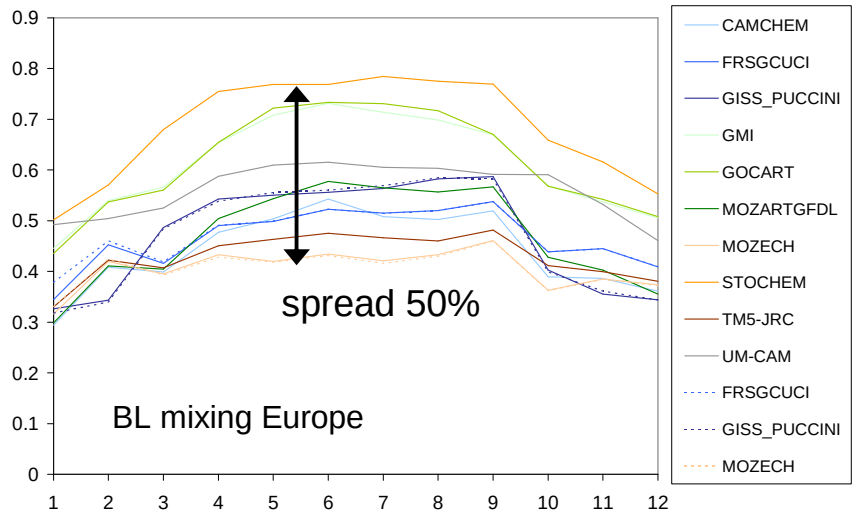
SR5 experiment: full chemistry simulation (delta-CO scaled with factor 5)





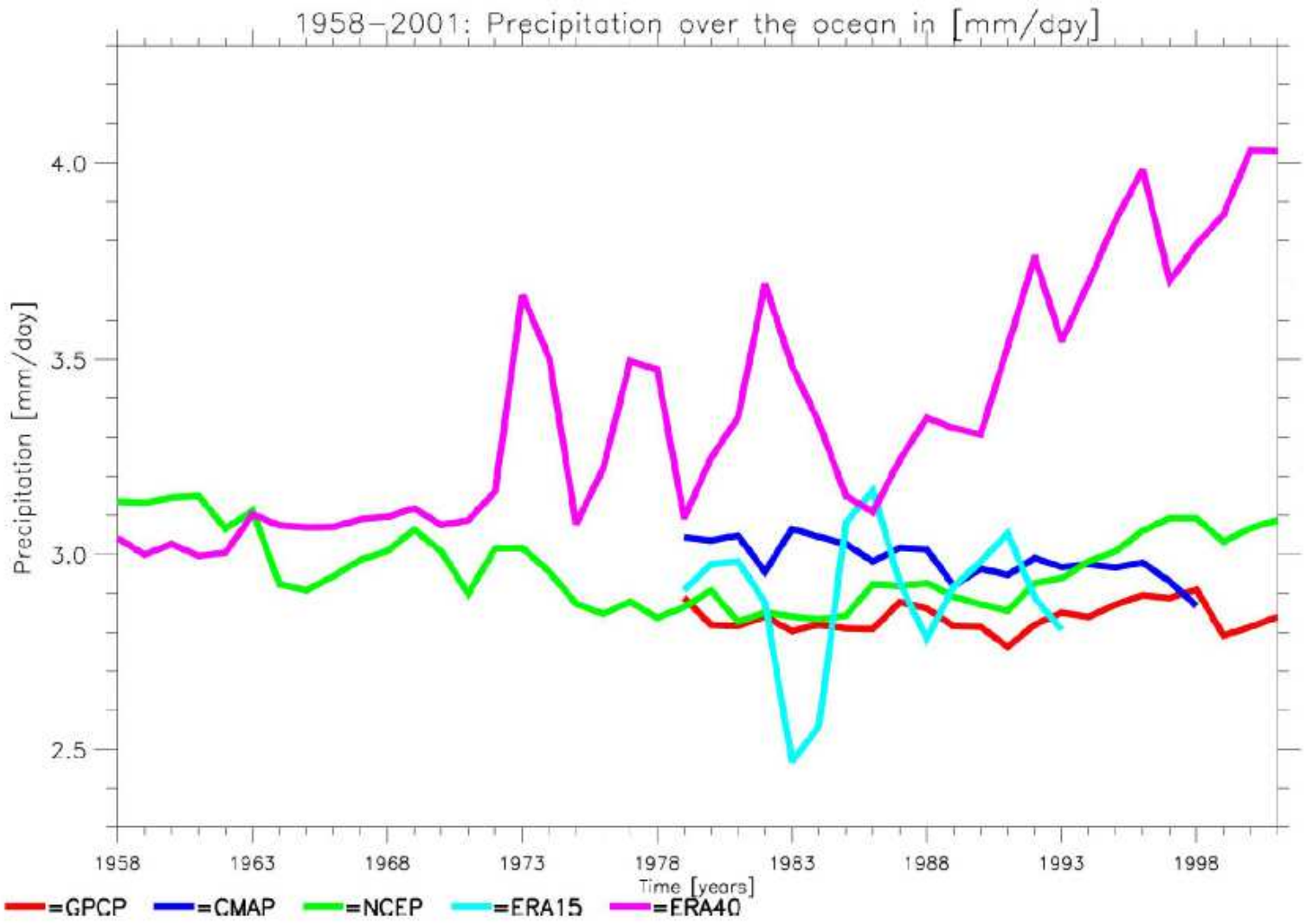
TP1 experiment: passive CO tracer with fixed uniform lifetime





Diagnostic: CO from EU over EU; ratio 0-2 km / surface

ERA-40 artifacts

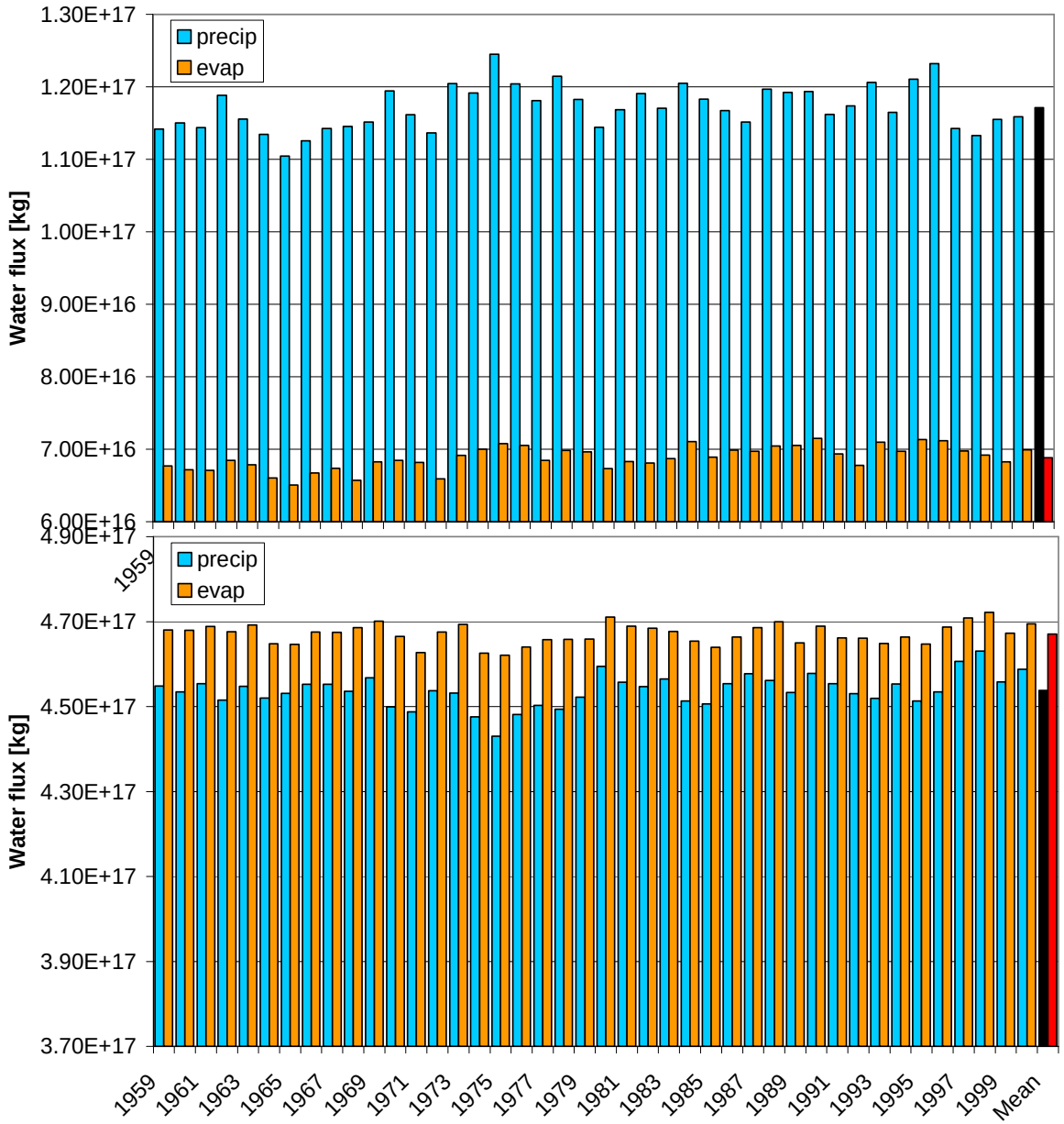


from Hagemann et al., 2006

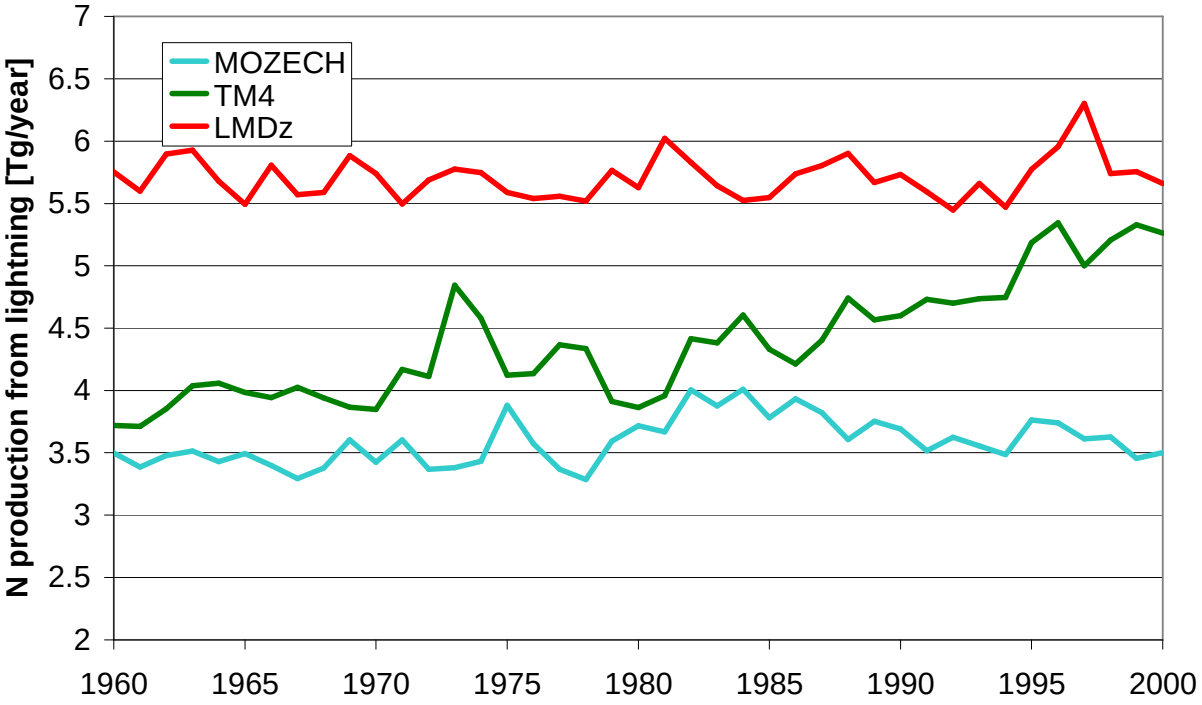
Hydrological cycle

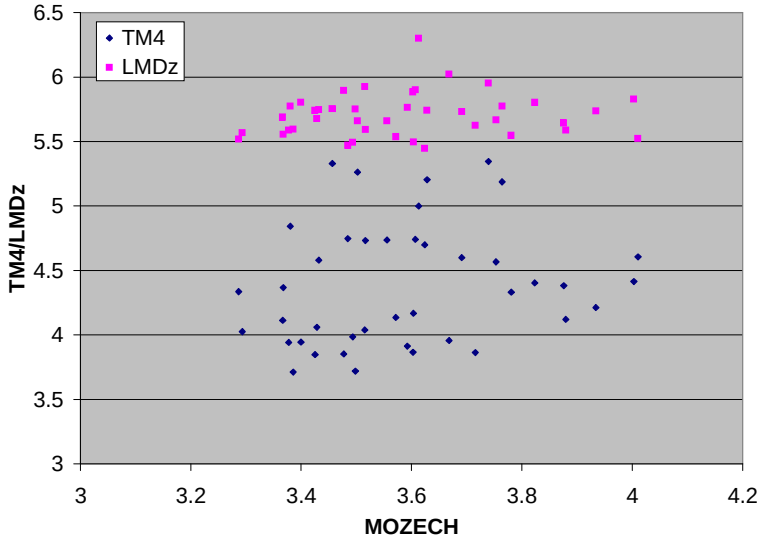
Land

Water



Trends in lightning NOx





almost no correlation for annual mean lightning NOx!

Conclusions

- Global tropospheric ozone budget changes driven by emissions
- Interannual variability driven by meteorology

Too simple?

Acknowledgements

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- Guido van der Werf, VU, Amsterdam
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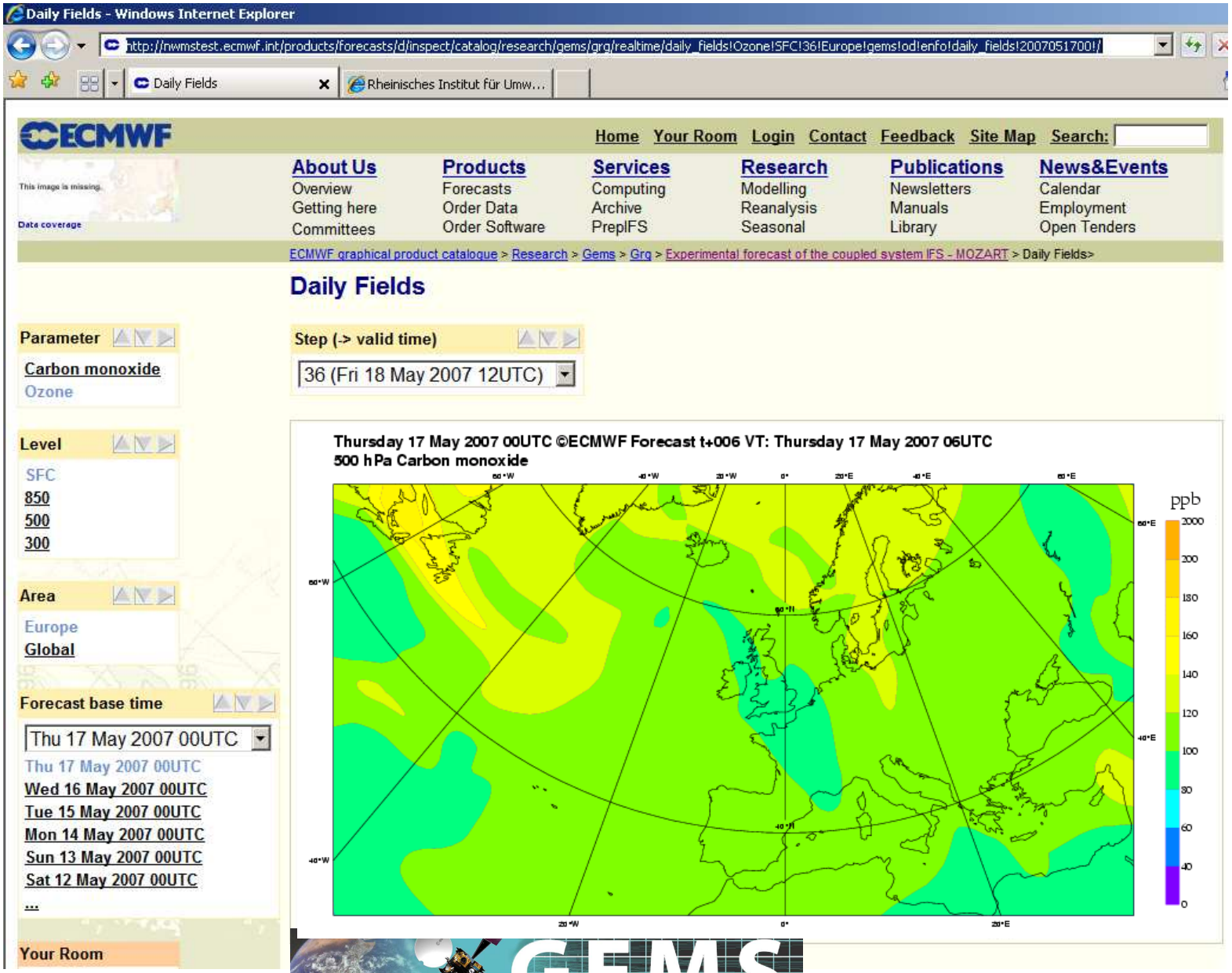
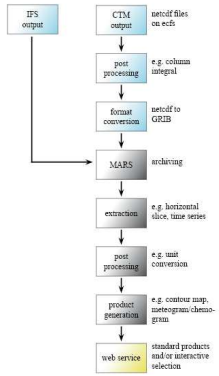
- and many others…

GEMS: first near-realtime forecasts