



Long term temperature and stratospheric ozone changes

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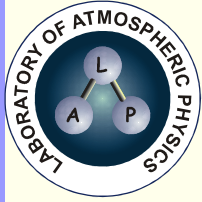


The aim:

to investigate temperature and ozone changes in a climate under global warming stress and changing aerosol

The problems:

- Global warming/cooling (GHGs)
- Ozone depletion / recovery (chemistry)
- Global dimming and brightening: the effect of tropospheric aerosols



Data

Temperature:

Long - term global data sets of temperature from the troposphere to the stratosphere

- layer - mean temperatures derived from thickness of atmospheric layers
NCEP reanalysis (troposphere and stratosphere)
ERA-40 (troposphere and stratosphere)
Berlin data (stratosphere)
- Additionally we have used radiosonde temperature data (RICH anomalies, other radiosondes)

Tropopause pressure changes

- Zonal-mean tropopause pressure

Total Ozone

All the above: Observations and CCM simulations (E39CA)

Ancillary data / proxies

- QBO time series (equatorial zonal wind at 30hPa and 50hPa)
- Solar radio flux F10.7
- Stratospheric aerosols (e.g. update from Sato et al)
- Aerosols in the troposphere: visibility reverse (1/vis) as index



- ***Statistical Methodology:***

Data are deseasonalized to their long-term mean

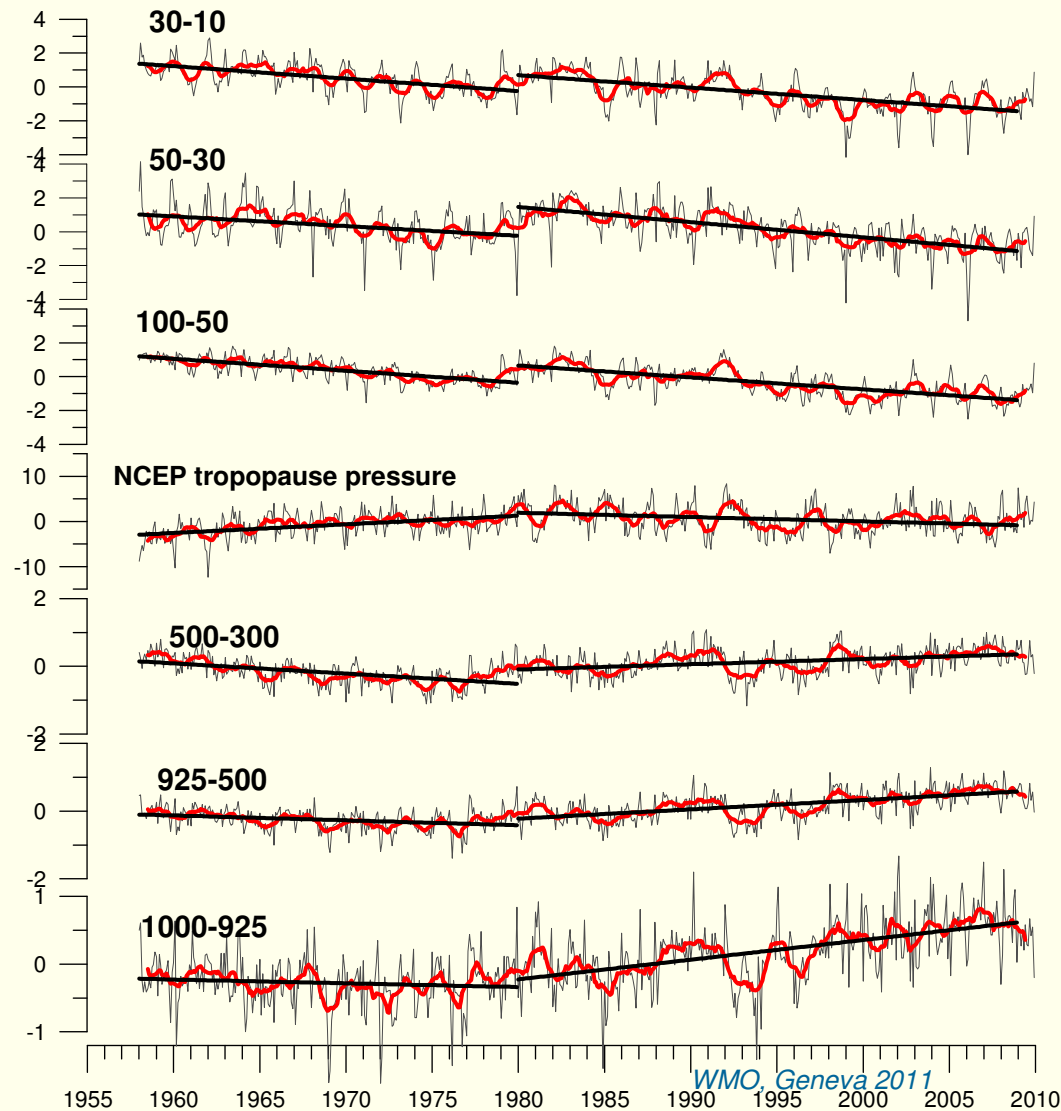
Multiple linear regression time series analysis with an autoregressive statistical model is applied on the deseasonalized time series of zonally averaged layer mean temperature

$$M_t = a_1 T_{r_t} + \sum g_i Z_i + N_t$$

where M_t is the monthly deseasonalized zonal mean variable and the terms $g_i Z_i$ reflect variability related to the natural (QBO, Solar, volcanic) and anthropogenic (chemistry, aerosols) factors



Layer mean temperature anomalies

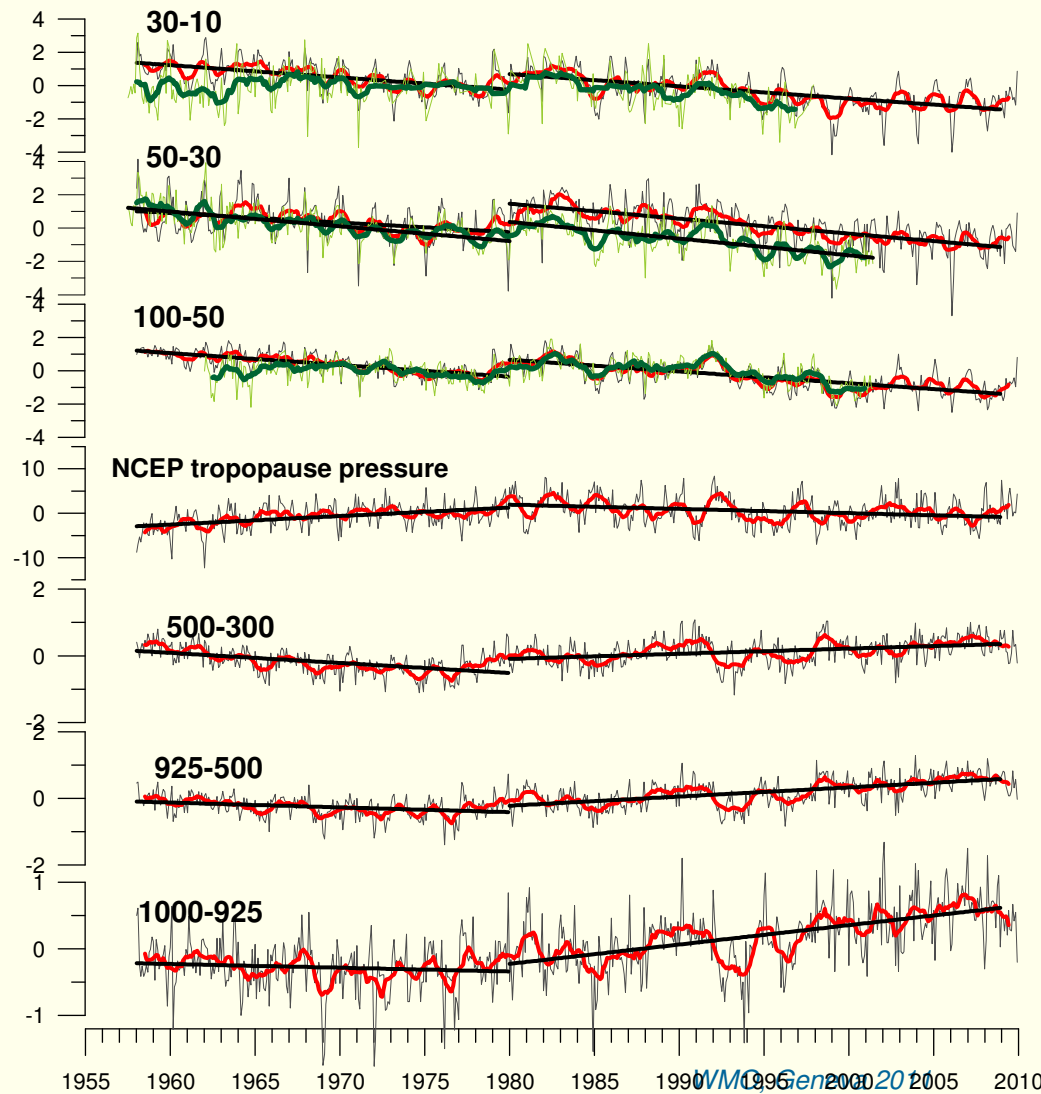


30N -60N

 NCEP (running mean)
 Linear trend



Layer mean temperature anomalies

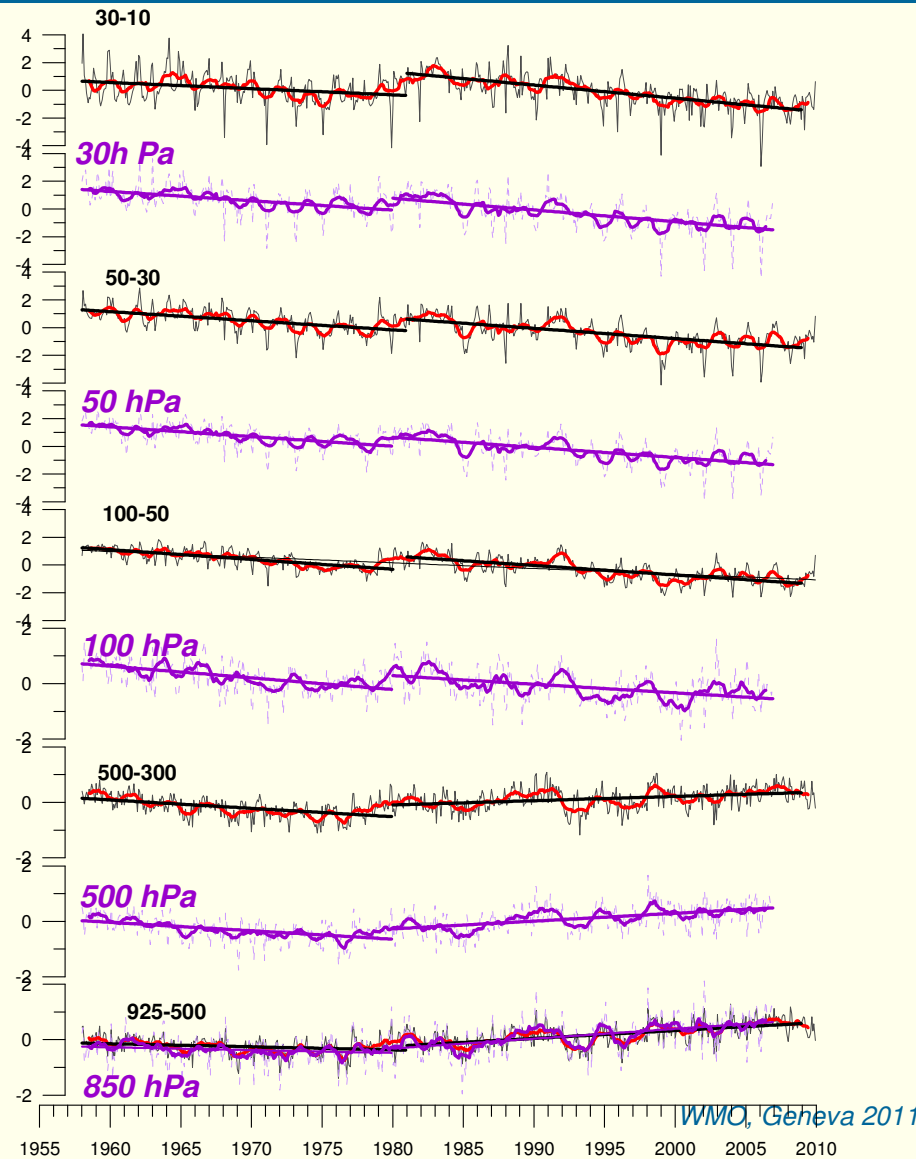


30N -60N

— NCEP
— Berlin analysis



temperature anomalies

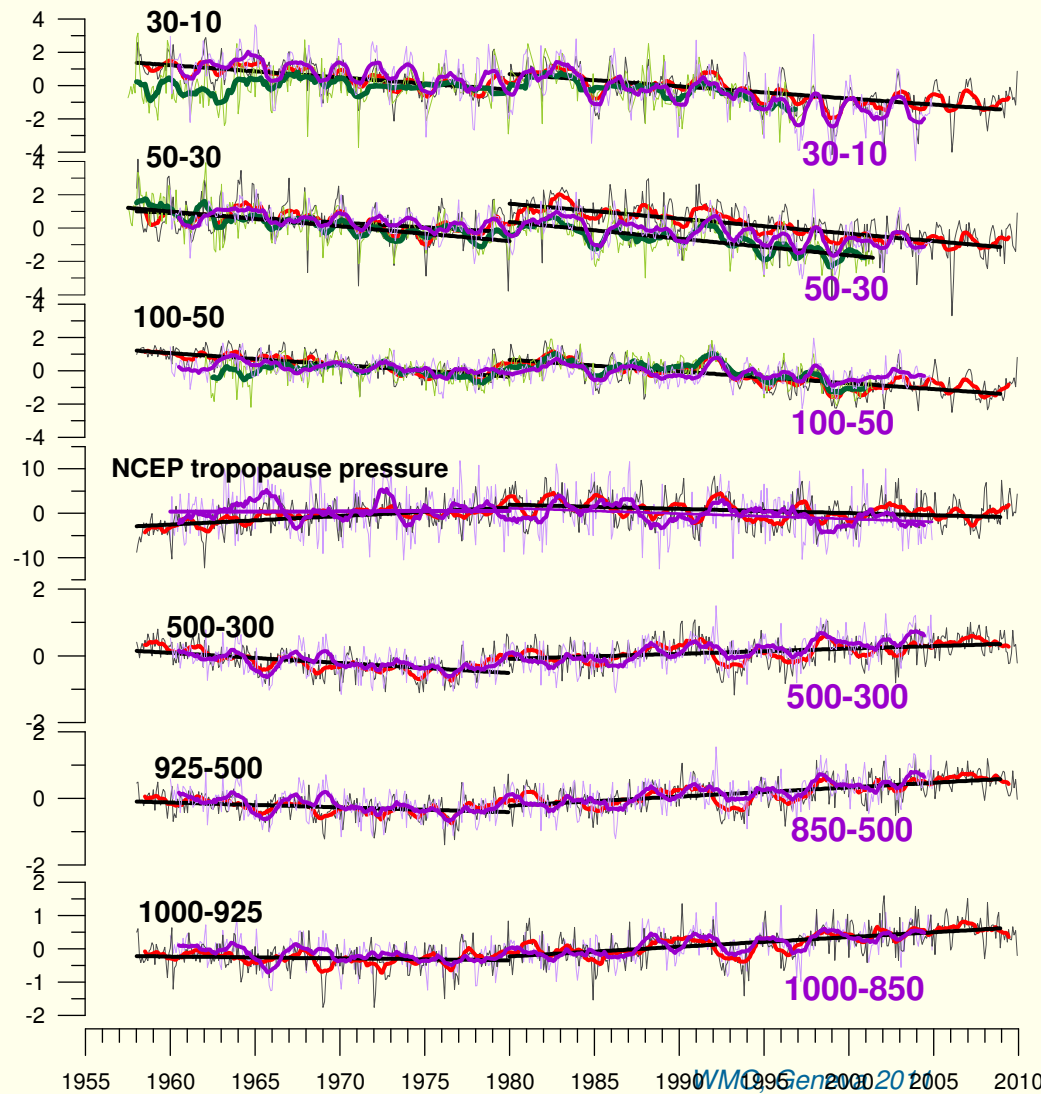


30N - 60N

— NCEP
— RICH anomalies



Layer mean temperature anomalies

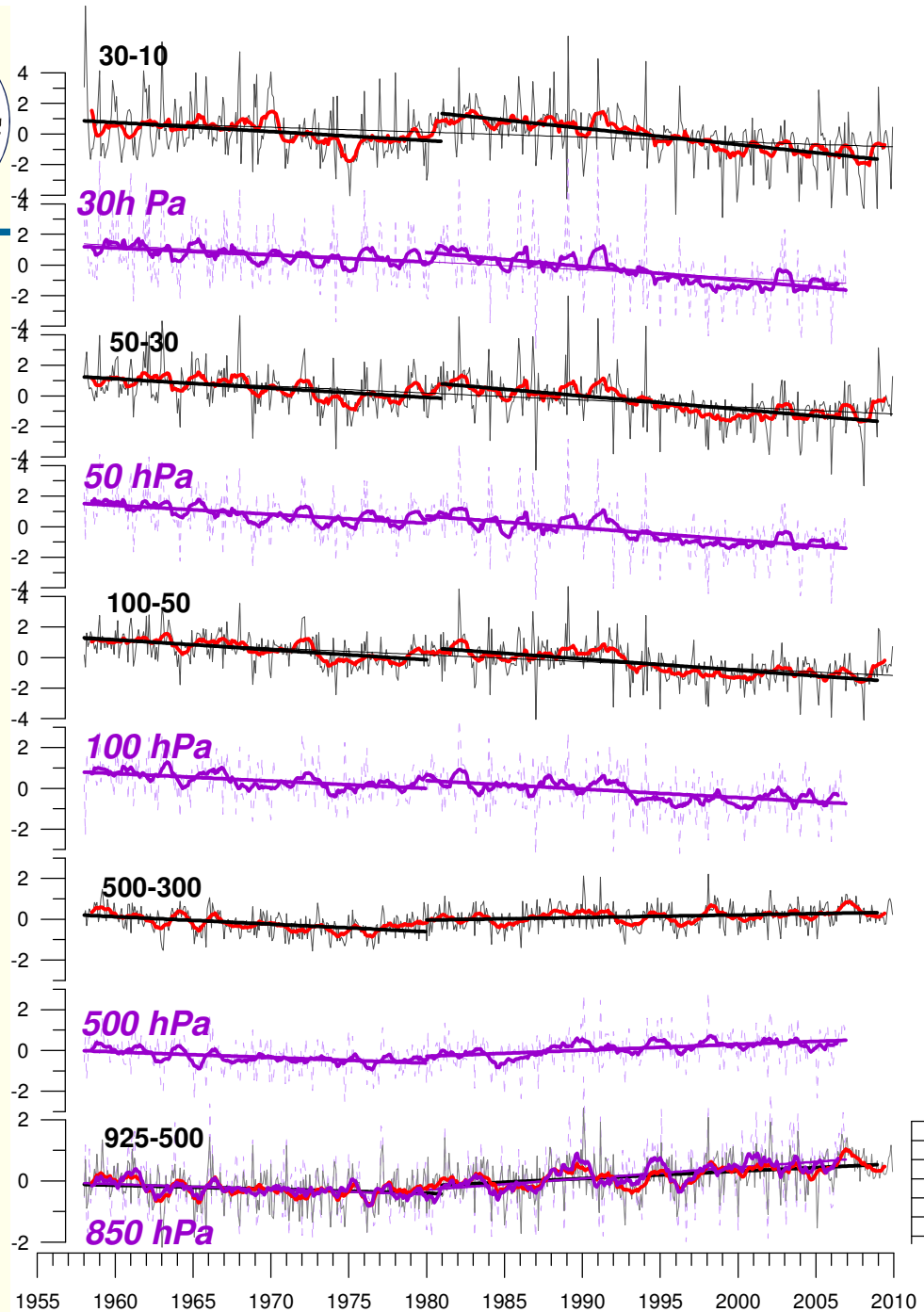


30N - 60N

— NCEP
— Berlin analysis
— E39CA

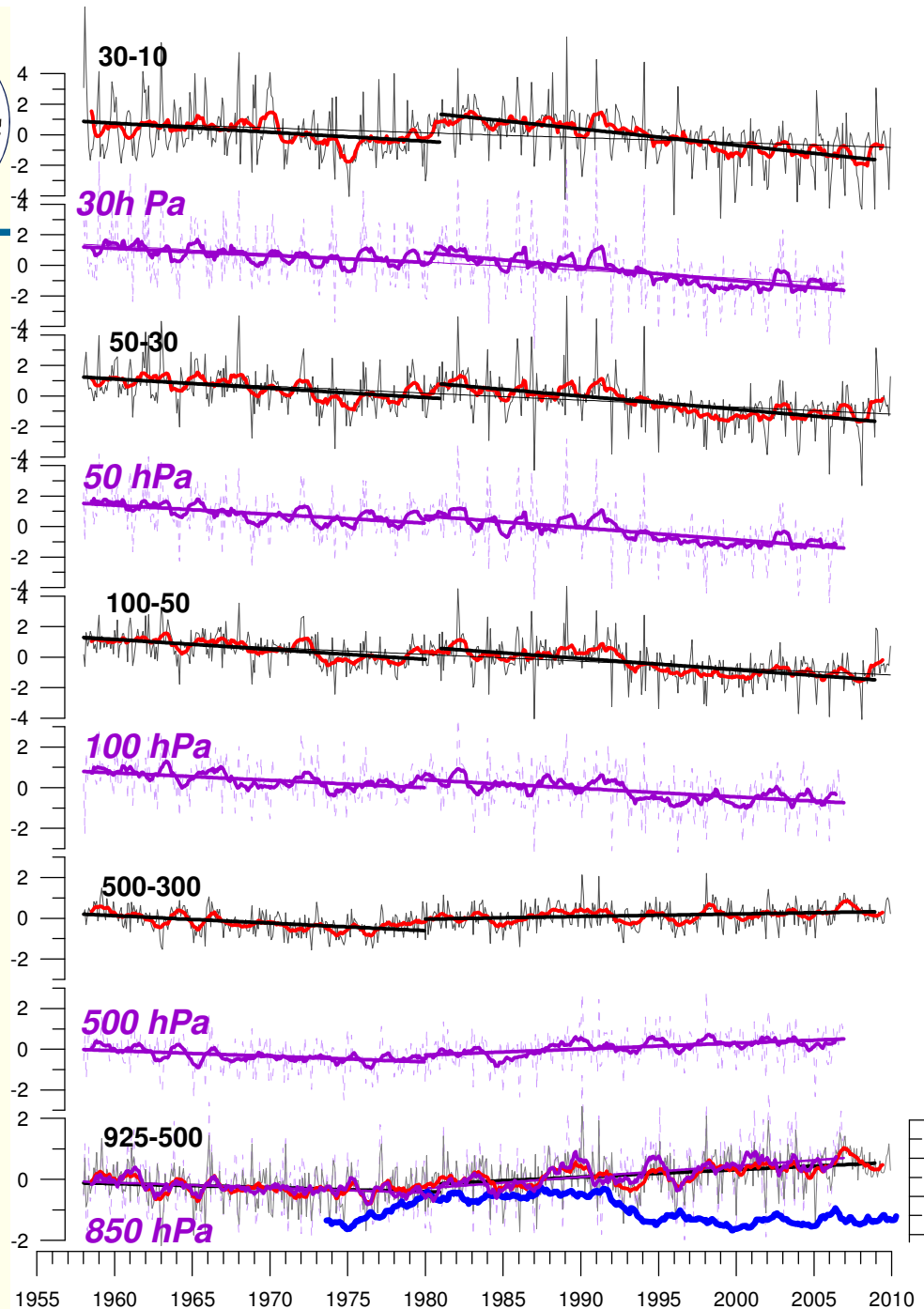


- Changes over a region: Europe



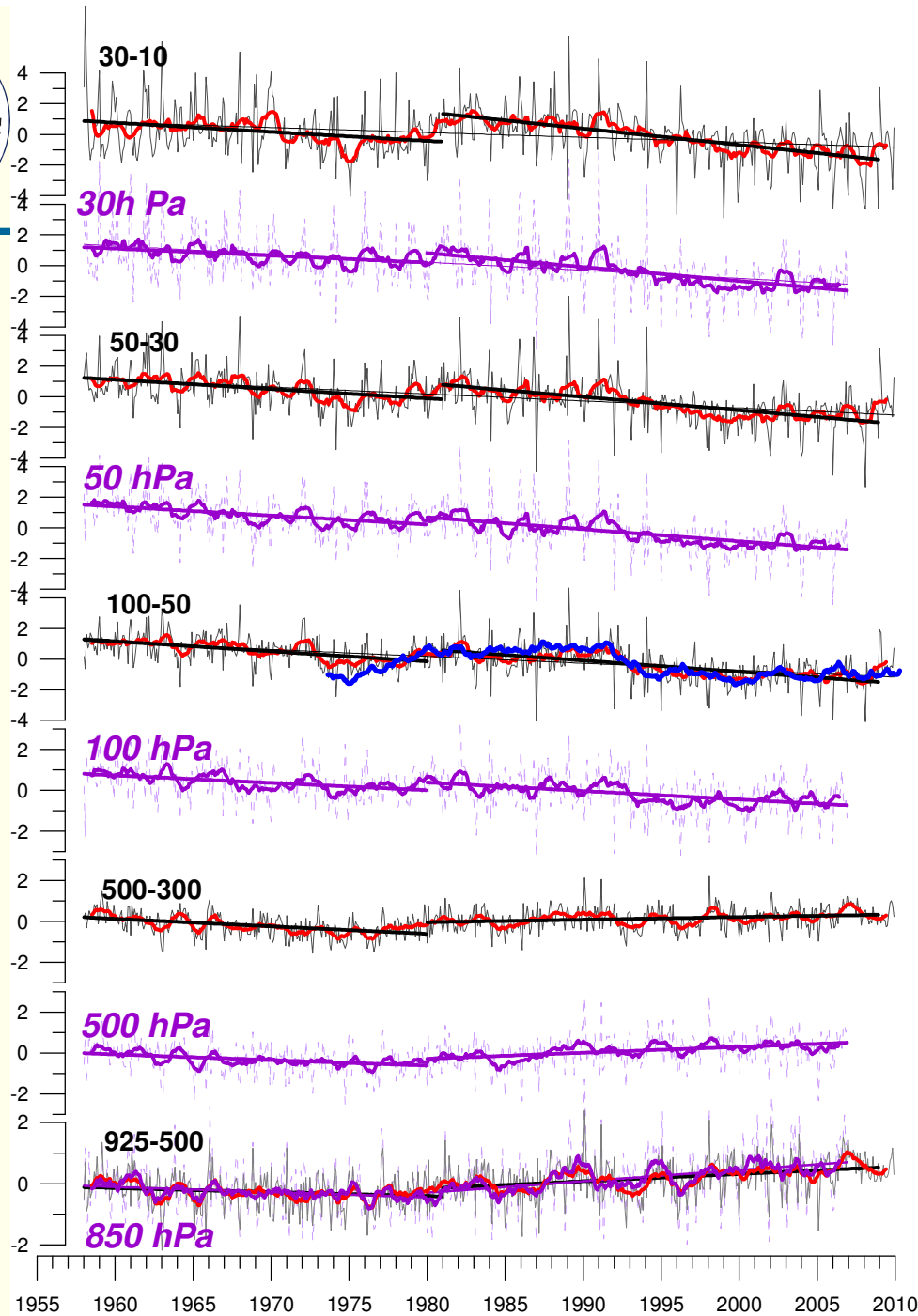
- Europe
20W - 40E
30N - 60N

— NCEP
— RICH anomalies



- Europe
20W - 40E
30N - 60N

— NCEP
— RICH anomalies
— 1/visibility



• Europe
20W - 40E
30N - 60N

— NCEP
— RICH anomalies
— 1/visibility



Summary

Observed temperature trends are affected by a synergy of aerosol trends and greenhouse warming in the troposphere
These temperature trends affect tropopause height which in turn affects total ozone.

Ozone depletion at high latitudes is well understood, but some aspects of total ozone long term behavior over middle latitudes are not.

The overall aim is to have a new look at the relations of the observed global troposphere warming / stratosphere cooling with ozone depletion / recovery processes and the synergy of aerosol changes.



Thank you !