Ozone trend analysis from 1980-2015: Models vs observations

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Motivation

Ozone (O_3) is a secondary greenhouse gas in the atmosphere. Known facts about O_3:

- It is important for climate (greenhouse gas).
- It impacts human health and ecosystems.
- It impacts visibility.

These led to an EU Directive for a long-term threshold of 120μg/m^3 (8h daytime) not to be exceeded more than 25 days per year.

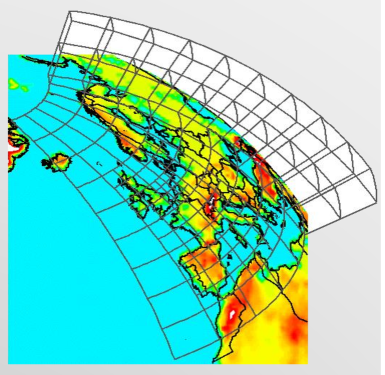
Its secondary nature makes it hard to control through emission mitigation.

The following questions subsequently arise:

- What are the background O_3 tendencies over the past 4 decades?
- What is driving them?

Models Description

The **TM4-ECPL and TM5MP** models are used to simulate O_3 concentration in the global atmosphere.



The model has:

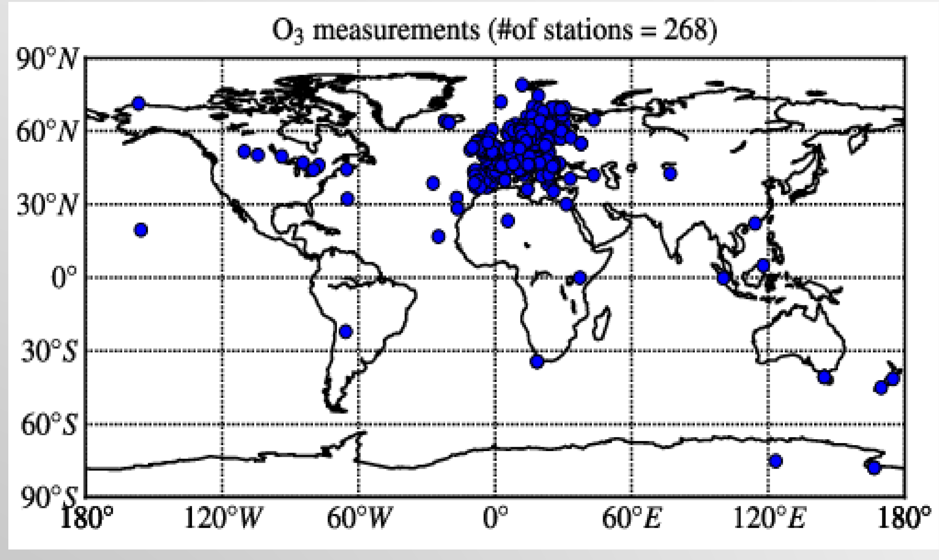
- Horizontal resolution:
  - **TM4-ECPL:** 3°x2° lon x lat
  - **TM5MP:** 1°x1° lon x lat
- Vertical resolution:
  - 34 hybrid pressure levels up to 0.1hPa (~65 km)
- **TM4-ECPL** emissions:
  - Anthropogenic and Biomass Burning from ACCMIP[1]
  - Biogenic from MEGAN-MACC[2]
  - Dust from AEROCOM [3]
  - On-line sea salt and marine POA
- **TM5MP** emissions:
  - CMIP6
  - Biogenic from MEGAN
  - On-line dust calculation
  - On-line sea salt
- **TM4-ECPL** Analytical chemistry
  - 120 tracers
  - 186 thermal reactions
  - 44 photolysis reactions
  - 48 aqueous phase reactions
- **TM5MP –** CBM5 chemistry
  - 54 tracers
  - 109 chemical reactions
    - 89 thermal, 20 photolysis
- Driven by ERA-Interim Meteorology [4]
- Validated in AEROCOM [5]
- Description of TM4-EPCL: Daskalakis et al., *ACP*, 2014.
- Description of TM5MP: Huijnen et al., *GMD,* 2010.

Acknowledgements

All the simulations of TM4-ECPL and TM5MP, as well as all computations of this work were performed on the HPC cluster Aether at the University of Bremen, financed by DFG in the scope of the Excellence Initiative.

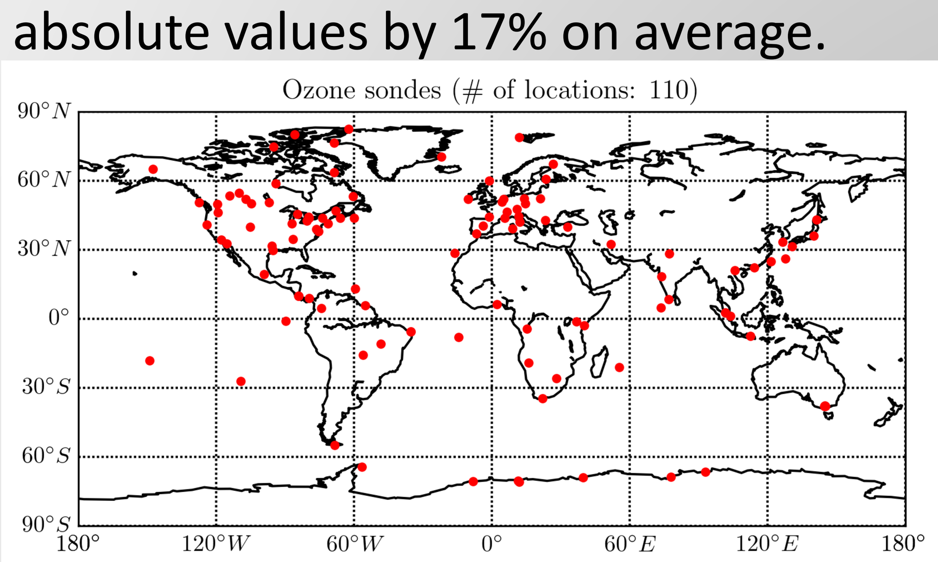
Measurements and model evaluation

Data from the EMEP monitoring network, the WDCGG network together with individual studies were used to evaluate the TM4-ECPL performance. The map shows the locations of the measurements (blue dots) used in the validation of the surface simulated values.

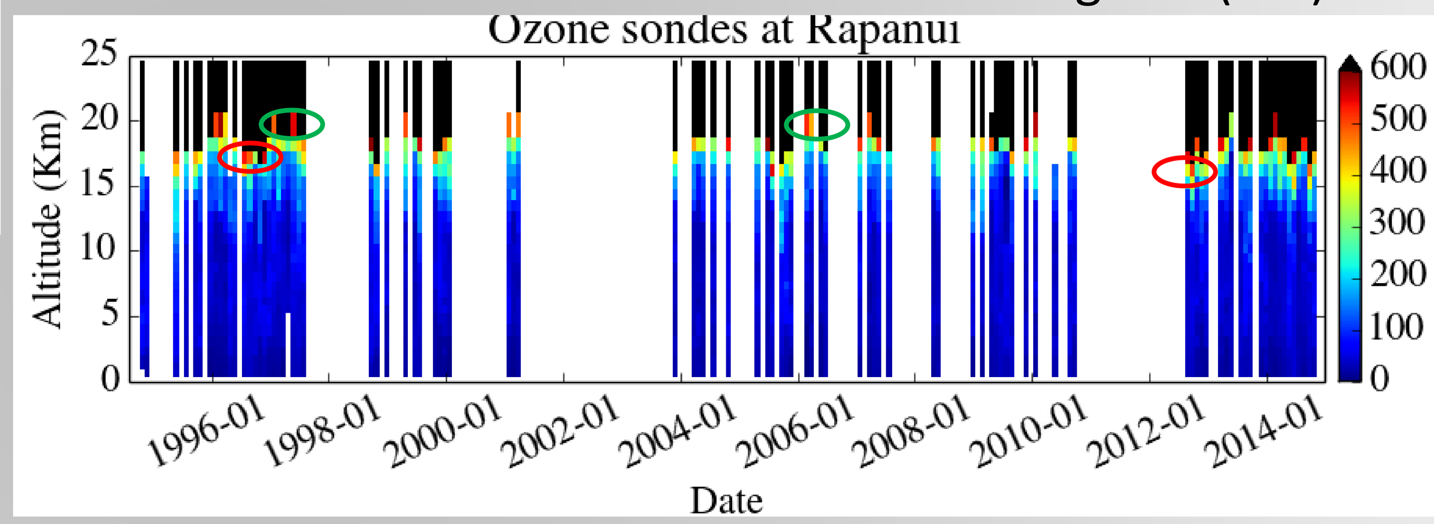


	# pairs	meas	model	R	NMB
O_3	2417	31.08	36.32	0.48	17%

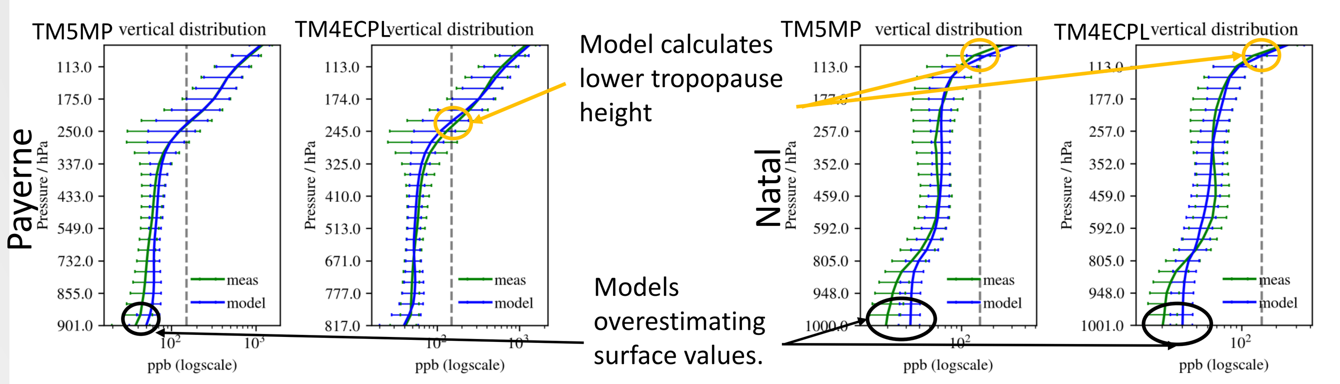
The table shows the summary of the statistical analysis of the comparison between the simulations and the ground based measurements. TM4-ECPL captures satisfactorily the interanual variability (not shown) and overestimates the absolute values by 17% on average.



For validating the vertical distribution of ozone as calculated by the models, the ozone sonde collection of the World Ozone and Ultraviolet Radiation Data Centre is used. The database consists of 110 locations all over the globe (left).



At all locations stratospheric intrusions are evident both at the measurements (e.g. red circles at Easter Island on the right) and in the simulations (not shown)

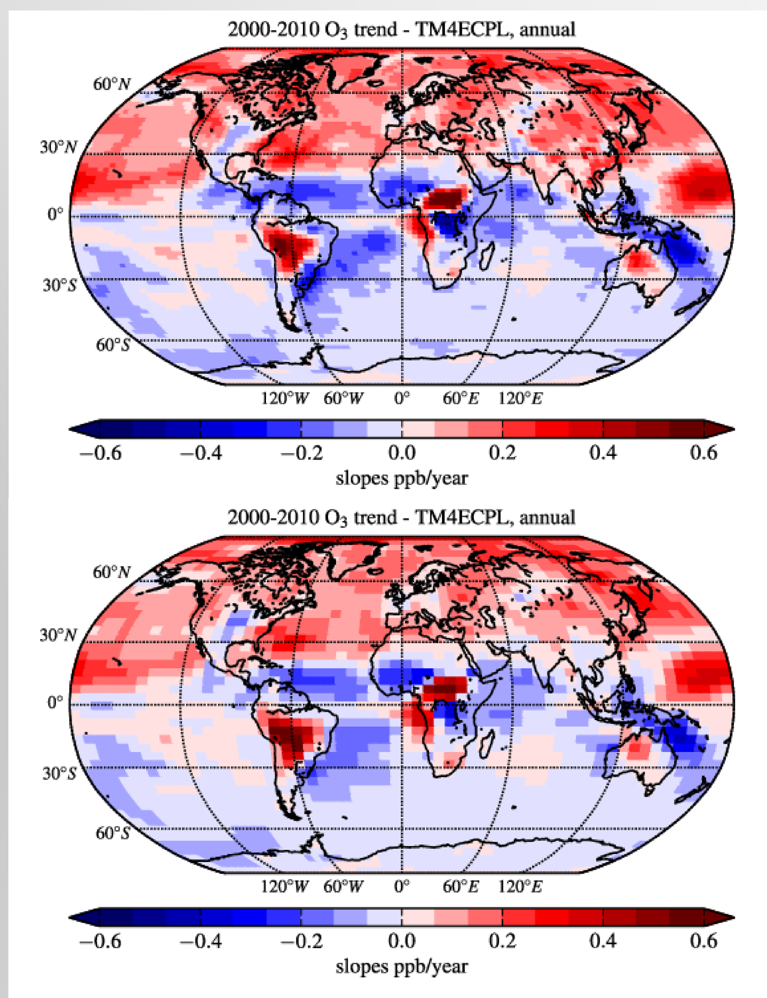


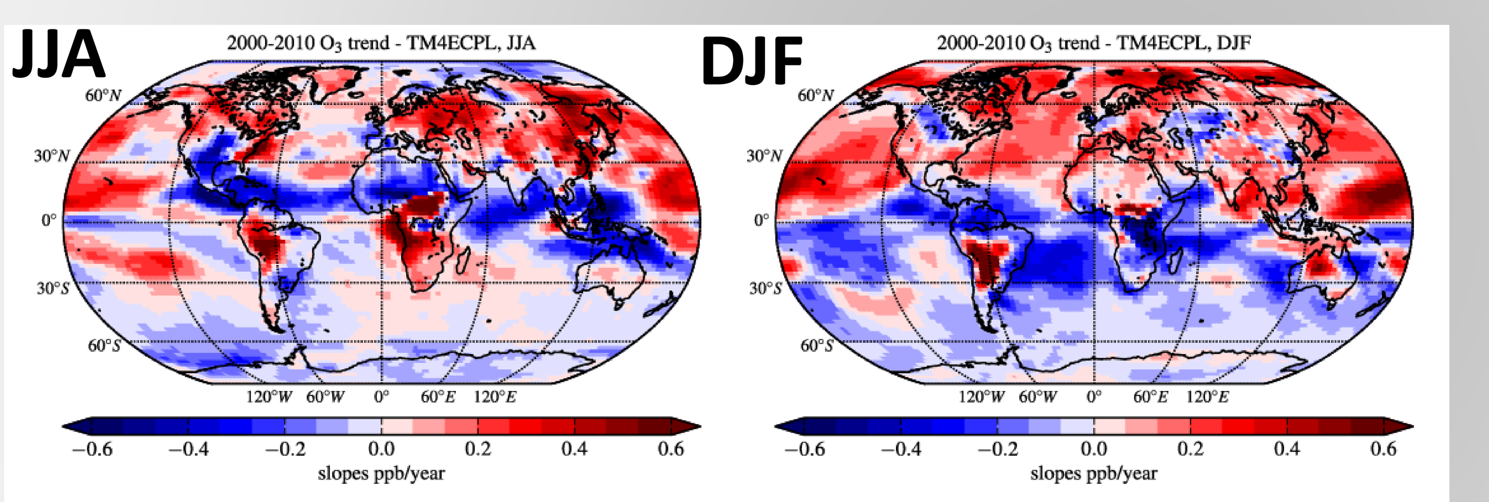
The summertime convection is also observed and simulated and examples are highlighted with green circles on the figure. Both models tend to overestimate the values near the tropopause resulting to a lower tropopause height.

The majority of differences where above 20 km for both models. TM4-ECPL tends to simulate higher ozone concentrations near the surface than what was measured by the sondes, which was evident in the comparison with the surface measurements also. It captures well the mid-troposphere concentrations. TM5MP also simulates higher ozone than the measurements near the surface, but also in the mid troposphere, result of the simpler chemical scheme compared to the TM4-ECPL. The higher resolution of the model does not seem to have a high impact on the ozone concentrations at remote locations. We do not have enough urban locations to deduct conclusions.

Simulated O_3 Trends

The figure to the right shows the annual O_3 surface concentration trends as simulated for the years 2000-2010 including (top panel) and excluding (bottom panel) the impact of anthropogenic emission change. Higher O_3 trends, more pronounced in the NH are calculated over areas with high anthropogenic activity (enhanced precursor species).





Analyzing the seasonal trends for the same period (figure above) shows that the high trend over central Africa and Indonesia are dominated by the JJA (June-July-August, left panel) trends attributed mainly to O_3 precursor emissions by wildfires. Similarly for the NH winter (December-January-February, DJF, right panel) higher trends are simulated mainly attributed to higher anthropogenic activity. The trend tendencies over the southern oceans with minimal anthropogenic activity reveal the dependency of O_3 to meteorology and climate with lower values on winter.

Conclusions

- Understanding background O_3 is important for AQ improvement.
- TM4-ECPL model captures the stratospheric intrusions in late winter and spring seen in the observations
- TM4-ECPL captures the convective summer minimum.
- Lower tropopause in TM4-ECPL model than the observations in a subset of the measurements locations.
- Trends in O_3 depend on location and season.

References

[1] J.-F. Lamarque et al., *GMD*, 2013
[2] K. Sindelarova et al., *ACP*, 2016
[3] F. Dentener et al., *ACP*, 2006
[4] D.-P. Dee et al., *QJRMS*, 2011
[5] K. Tsigaridis et al., *ACP*, 2014
[6] N. Daskalakis et al., *ACP*, 2016
[7] L. Gallardo et al., *Tellus B*, 2016