Ozone trend analysis from 1980-2015: Models vs observations

Nikos Daskalakis[1], Maria Kanakidou[2], Stelios Myriokefalitakis[3], Laura Gallardo Klenner[4], Rasmus Nüß[1], **Mihalis Vrekoussis[1,5]**

[1]Laboratory for Modeling and Observation of the Earth System (LAMOS), Institute of Environmental Physics (IUP), University of Bremen, Bremen, Germany,
[2]Environmental Chemical Processes Laboratory (ECPL), Department of Chemistry, University of Crete, 70013 Heraklion, Greece
[3]Institute for Marine and Atmospheric Research (IMAU), Department of Physics and Astronomy, Utrecht University, Utrecht, Netherlands
[4]Center for Climate and Resilience Research (CR2), Department of Geophysics, Faculty of Physical Sciences and Mathematics, University of Chile, Chile
[5]The Cyprus Institute, Nicosia, Cyprus

Motivation

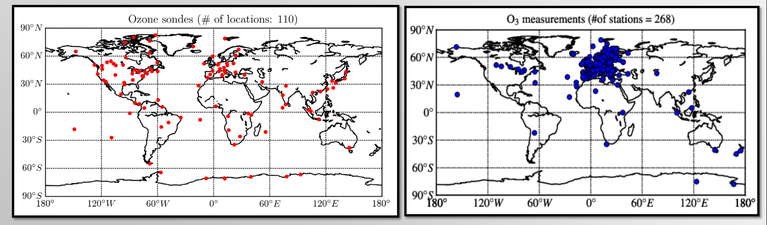
Ozone (O_3) is a secondary greenhouse gas in the atmosphere. Known facts about O_3:
a) It is important for **climate** (greenhouse gas), b) It impacts **human health** and ecosystems and c) It impacts **visibility**.
These led to an EU Directive for a long-term threshold of 120μg/m³ (8h daytime) not 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:

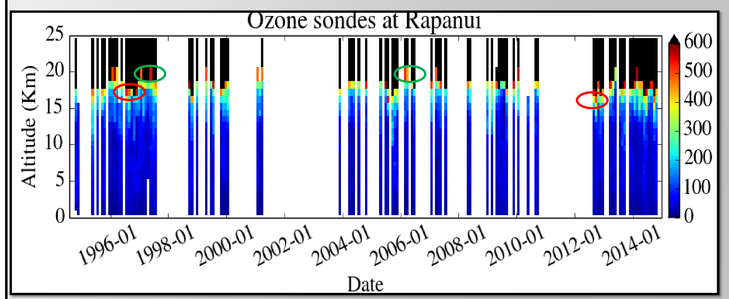
- **What are the background O_3 tendencies over the past 4 decades? What is driving them?**

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.

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

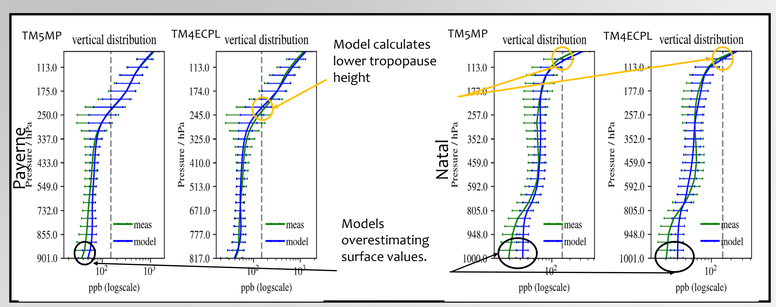




At all locations **stratospheric intrusions** are evident both at the measurements (e.g. **red circles** at Easter Island on the figure on the left) and in the simulations (not shown).

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

- **TM4-ECPL** tends to **simulate higher ozone concentrations near the surface** than what was measured by the sondes and measurements but **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 TM5MP 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.



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 as well as 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.*

Models Description

For this work the **TM4-ECPL and TM5MP** models are used to simulate O_3 concentration in the global atmosphere. The models have:

TM4-ECPL:

- **Horizontal resolution:** 3°x2° lon x lat
- **Vertical resolution:**
  - 34 hybrid pressure levels up to 0.1hPa (~65 km)
- **Emissions:**
  - Anthropogenic and Biomass Burning:ACCMIP[1]
  - Biogenic from MEGAN-MACC[2]
  - Dust from AEROCOM [3]
  - On-line sea salt and marine POA
- **Analytical chemistry**
  - **120** tracers
  - **186** thermal, **44** photolysis, **48** aqueous reactions
- **Driven by** ERA-Interim Meteorology [4]
- **Validated** in AEROCOM [5]
- **Detailed description** in Daskalakis et al., *ACP*, 2014.

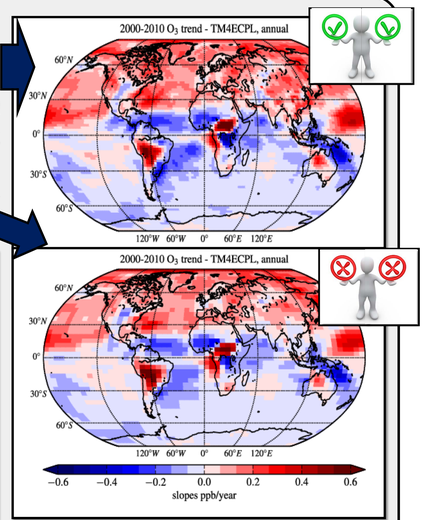
TM5MP:

- **Horizontal resolution:** 1°x1° lon x lat
- **Vertical resolution:**
  - 34 hybrid pressure levels up to 0.1hPa (~65 km)
- **Emissions:**
  - Anthropogenic and Biomass Burning : CMIP6
  - Biogenic from MEGAN
  - On-line dust calculation
  - On-line sea salt
- **CBM5 chemistry**
  - 54 tracers
  - 109 chemical reactions (**89** thermal, **20** photolysis)
- **Driven by** ERA-Interim Meteorology [4]
- **Validated** in AEROCOM [5]
- **Description of TM5MP**: Huijnen et al., *GMD*, 2010.

Results

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).



The **seasonal trend analysis** for the same period (figure above) shows that:

- Over ***central Africa and Indonesia*** the simulated annual ozone trends are mostly caused by the JJA contribution which is, in turn, attributed to O_3 ***precursor emissions by wildfires***.
- During the ***NH winter*** (December-January-February, DJF, right panel) higher simulated trends emanate from ***anthropogenic activities***.
- Over the **remote southern oceans** (→minimal anthropogenic activity) the simulations reveal the additional dependence of O_3 trends on **meteorology** (and climate) with lower values during winter.

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***.

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