Model ozone deficit in BASCOE

J. Debosscher, Q. Errera, S. Chabrillat
BIRA-IASB, Royal Belgian Institute for Space Aeronomy, Ringlaan-3, B-1180 Brussels, BELGIUM
Contact: jonas.debosscher@aeronomie.be

The Ozone deficit problem

Comparison of ozone measurements in the upper stratosphere (35-50 km) with photochemical model predictions shows that the models systematically underestimate the ozone abundance in this region of the atmosphere. This is a long standing problem (Prather, 1981; Eluszkiewicz et al., 1993), and despite improvements due to new observations and models, there is currently no satisfactory solution and significant deviations between observations and model predictions remain. This may point towards a flaw in our understanding of the chemistry in the middle atmosphere. Given the importance of ozone in the solar radiation budget of the atmosphere and its possible role in stratospheric climate change, we need to identify the cause(s) of, and ultimately solve the ozone deficit problem.

Here, we report results on a sensitivity study of parameters influencing the ozone budget, using the Belgian Assimilation System of Chemical ObsErvations (BASCOE).

BASCOE in brief

- Assimilation of stratospheric chemical observations.
- 4D variational (4D-Var) data assimilation method.
- 3D chemical transport model (CTM).
- 58 stratospheric species, ~200 chemical reactions.
- Resolution: 2.5°lat x 3.75°lon x 37 levels (between 0.1hPa – surface).
- Time step: 0.5h.
- Wind and temperature analysis from ECMWF.
- See Errera et al., 2008 for detailed information.

Simulations

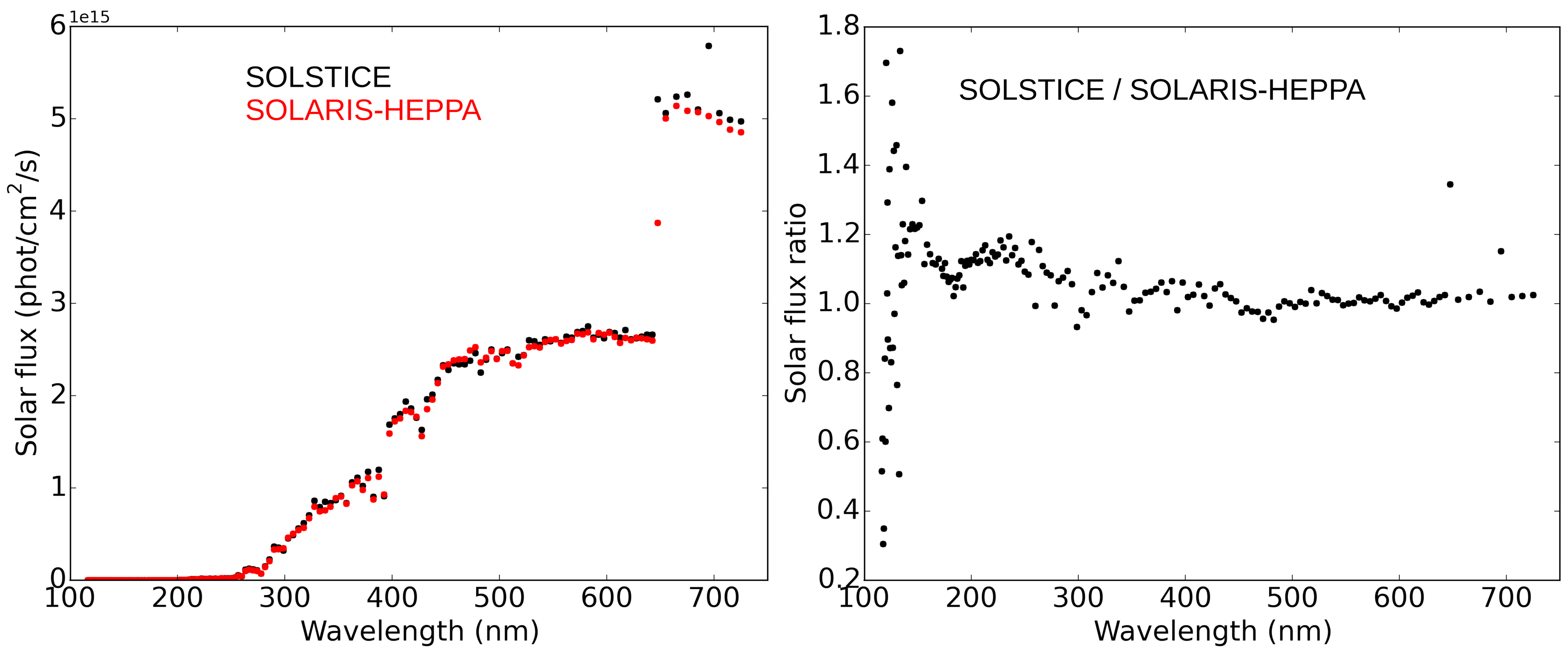
We performed BASCOE simulations in CTM mode (year 2008, profiles for 1 Feb.) to study the dependence of the ozone budget on:

- Solar irradiance input data.
- Variation of solar irradiance due to Sun-Earth distance variation.
- Albedo (currently a fixed value in BASCOE).
- O_2 photodissociation parameterization approach in the Schumann-Runge (SR) bands, commonly used to avoid expensive line-by-line integrations:
  - Kockarts (1994) reduction factor parameterization versus Koppers & Murtagh (1996) effective cross section and transmittance parameterization.
  - Scaling of O_2 cross sections.

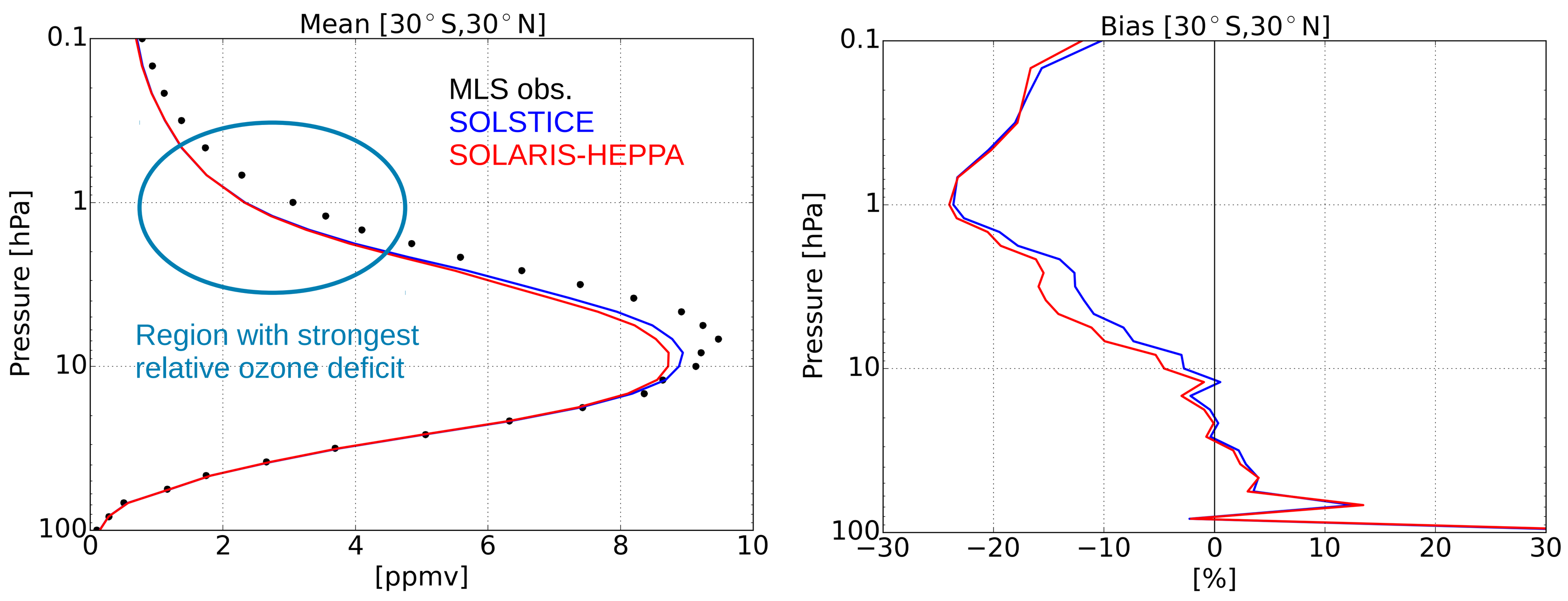
Results

Solar irradiances

Comparison of Solar irradiances used as input for BASCOE: SOLSTICE versus CMIP6 SOLARIS-HEPPA.

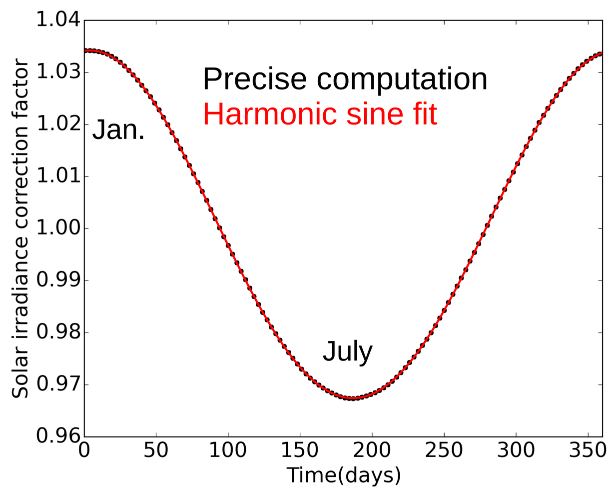


Simulation results for ozone with different solar irradiance data, compared to MLS observations: profile zonal average (left) and relative bias with respect to MLS (right).

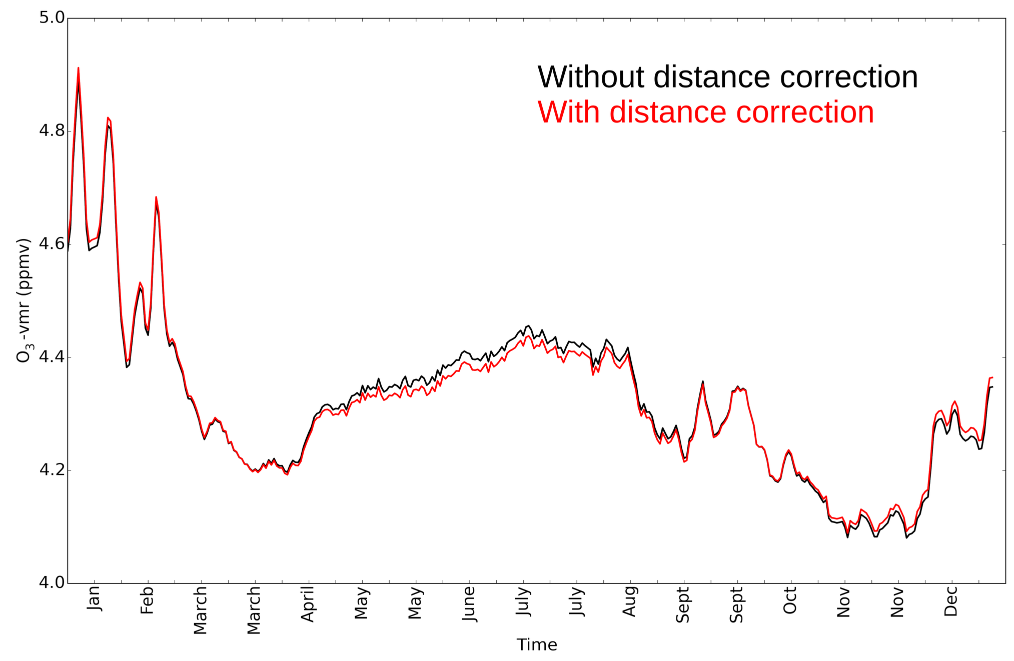


Sun-Earth distance variation

Irradiance variation due to Earth's orbit around the Sun: precise computation and harmonic sine fit (used for practical computations).

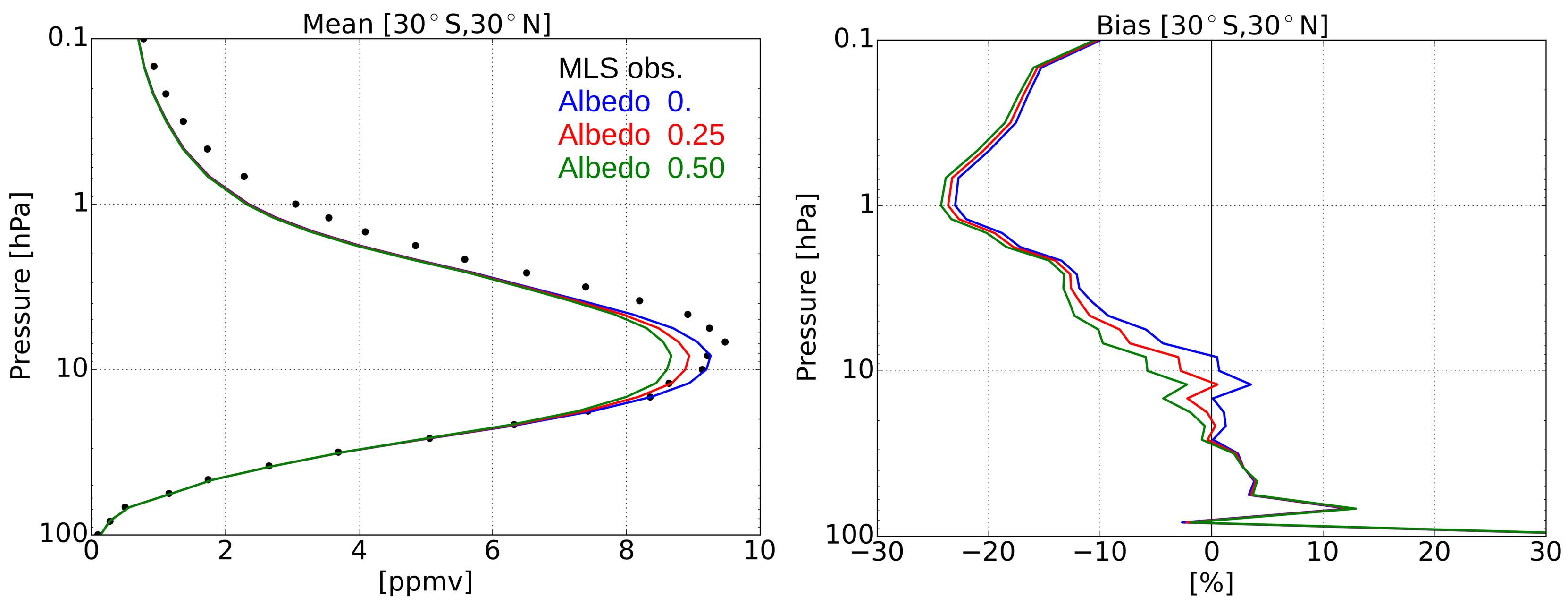


Simulation results with and without distance correction: Ozone time series (at ~1hPa, zonal average [30S-30N]).



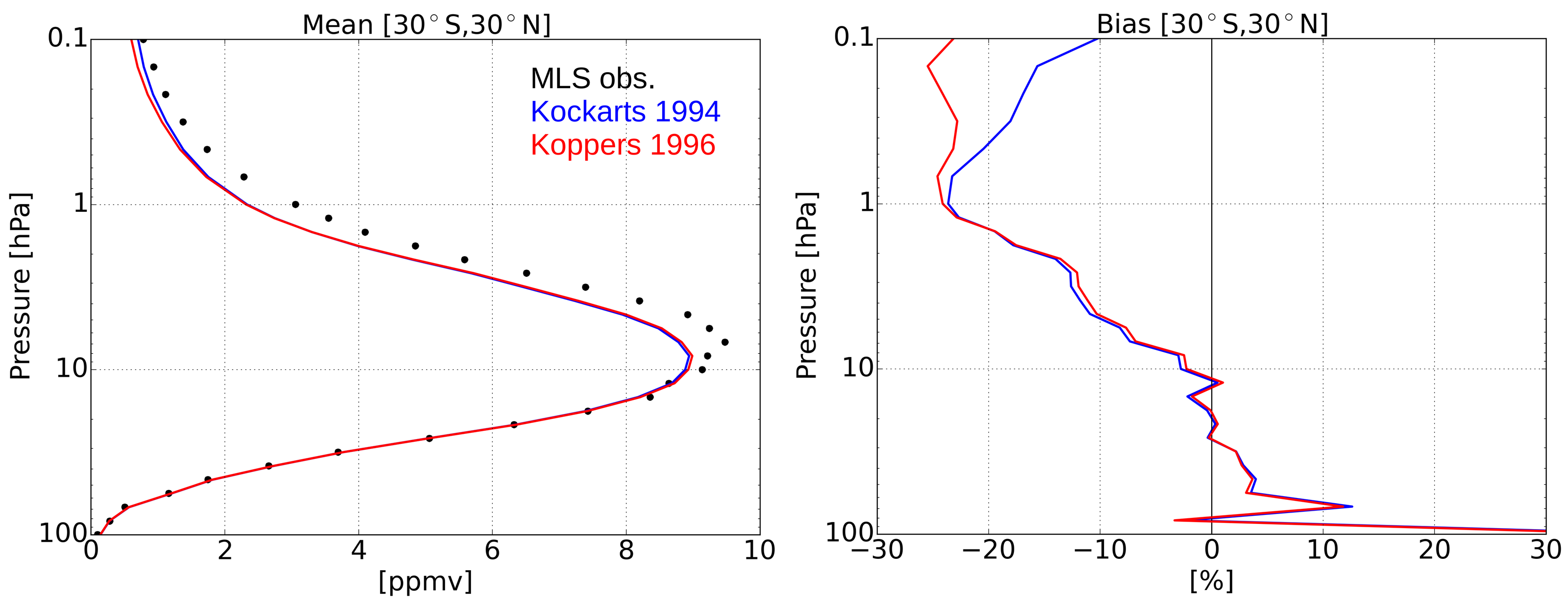
Albedo

Simulation results for ozone for different albedo values, compared to MLS observations: profile zonal average (left) and relative bias with respect to MLS (right).

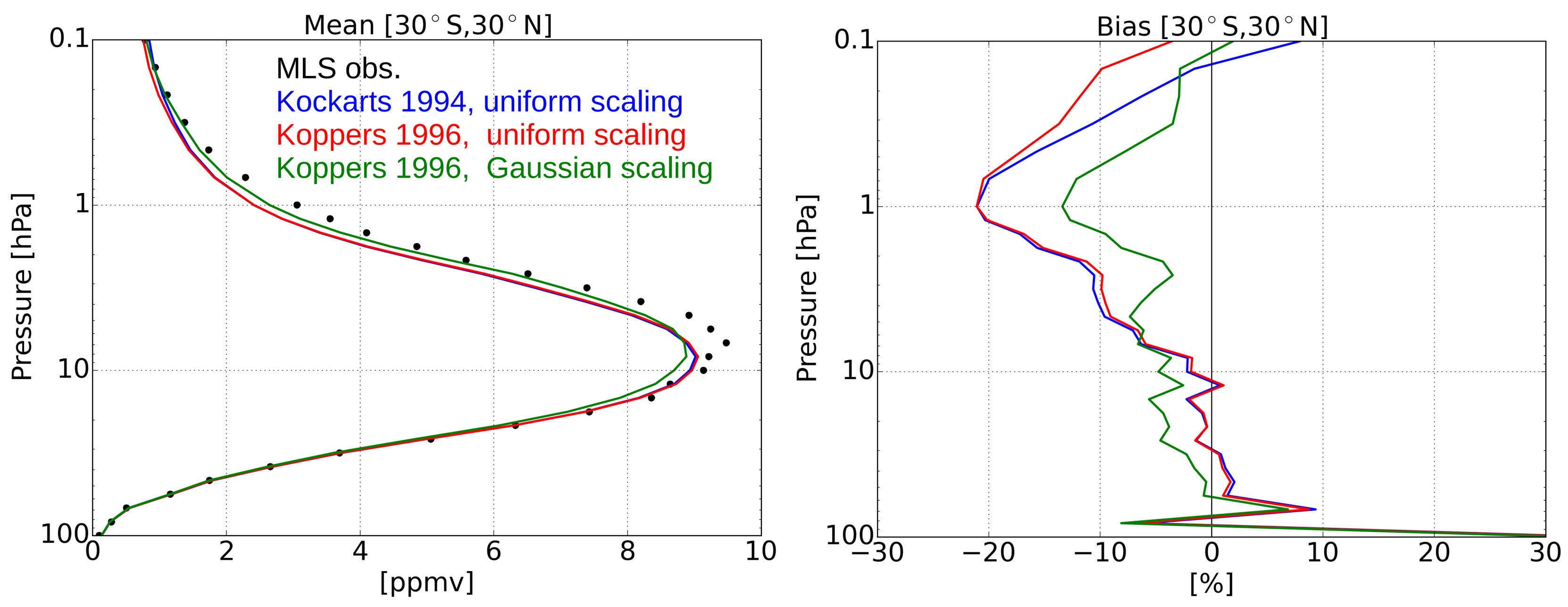


O_2 photodissociation in the SR bands

Simulation results for ozone for two O_2 photodissociation parameterization methods, compared to MLS observations: profile zonal average (left) and relative bias with respect to MLS (right).



Same as above, but with scaled O_2 cross sections (uniform scaling by factor 1.4; Gaussian profile scaling in function of pressure, max. scaling factor of 3 at ~1hPa).



Conclusions and prospects

We have performed a parameter sensitivity study with BASCOE with the goal to identify possible causes for the ozone deficit problem in the upper stratosphere. We find that most of the investigated parameters only have a small effect on the ozone concentrations, and cannot account for the BASCOE ozone deficit. The change of O_2 photodissociation parameterization method has significant effects, but increases the deficit above 1hPa, which should be further investigated. Only an increase of the O_2 cross sections in the SR bands is able to significantly reduce the deficit (see also Eluszkiewicz et al., 1993). We obtain the best results when pressure dependent scaling factors are used. However, unrealistically large factors have to be used, assuming typical relative uncertainties on the O_2 cross sections in the order of 40 percent. As a next step, we will implement a more detailed radiation transfer code in BASCOE (such as TUV 5.3.1) and evaluate the effect on ozone concentrations. Model temperature biases will be investigated as well.

Poster presented at the SRIP 2017 and 13th SPARC-DA Workshop, Reading, 23-25 October 2017.