Statistical sensitivity study on atmospheric ozone impact by SPEs and an observational case study on ozone impact by the November 2001 SPE

ISSI workshop presentation

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Outline

1st part

Sensitivity of Middle Atmospheric Ozone to Solar Proton Events: A Comparison Between a Climate Model and Satellites
K. Nilsen, A. Kero, P.T. Verronen, M.E, Szelag, N. Kalakoski and J. Jia.
DOI: https://doi.org/10.1029/2021JD034549

2nd part

First analysis of direct satellite-borne observations of ozone impact by the November 2001 solar proton event.
K. Nilsen, A. Kero, P.T. Verronen and M.E, Szelag
Paper currently in revision.

1st part: Introduction

Sensitivity of Middle Atmospheric Ozone to Solar Proton Events: A Comparison Between a Climate Model and Satellites

- Aim:
  - Validate the ion chemistry of WACCM-D for SPEs.
- Analysis method:
  - Multi-satellite approach to derive atmospheric sensitivity to the SPE forcing as a statistical relation between solar proton flux and the consequent O_3 change.
  - Identical analysis carried out for the WACCM-D model.

1st part: data description (1/2)

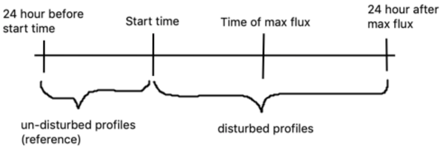
Data sources

- Observed O_3:
  - SABER
  - MIPAS
  - MLS
  - OSIRIS
- Simulated O_3: WACCM-D
- Proton flux: GOES
- SPE list (by NOAA)

Data selection

- Polar cap(s), i.e. geographic latitude $> 60^\circ$ north and south (separately)
- Daytime and nighttime (separately)
- Selected O_3 profile from WACCM-D co-located to satellite observations

1st part: data description (2/2)



Time-series selection for each SPE available to a satellite.

For each time-series

Calculate ΔO_3 from each individual disturbed profile

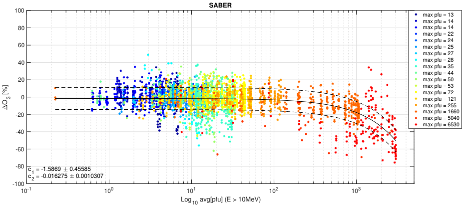
$$\Delta O_3 = \frac{O_3 - avg[O_{3,ref}]}{avg[O_{3,ref}]} \cdot 100$$

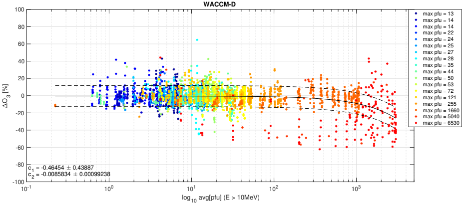
The SPE driven ΔO_3 are related to the solar proton flux. A linear fit can be derived to estimate the sensitivity.

$$\Delta \hat{O}_3 = c_1 + c_2 \cdot \phi_{pf}$$

Where c_2 is the sensitivity. However, due to time delay between measured proton flux (by GOES) and its consequence on ΔO_3, we calculate 12 hour average prior to the time co-located proton flux, ϕ_{pf}.

1st part: method summary

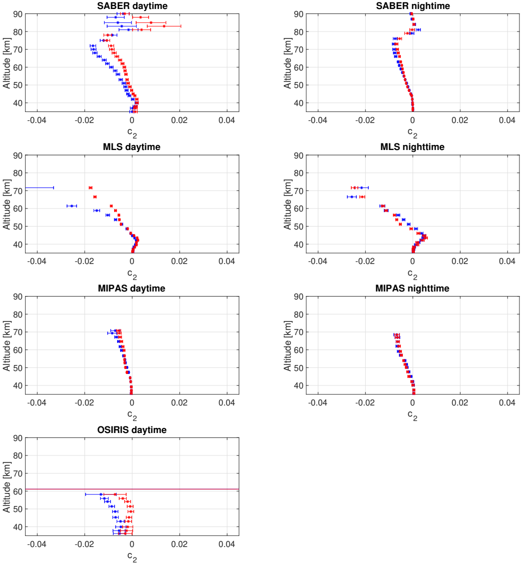




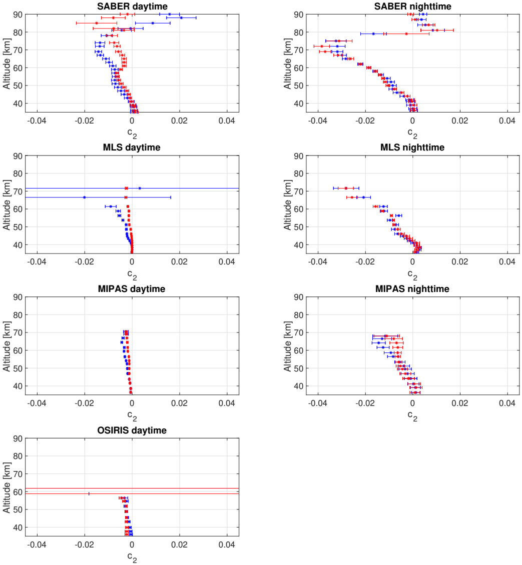
North polar cap in daytime condition at 70km altitude

1st part: main results from north polar cap

- Satellite in blue and WACCM-D in red
- Negative impact seen from around 40-45km to 80km altitude with a maximum impact near 70km altitude
- A positive impact is seen for some cases near 40-45km altitude.



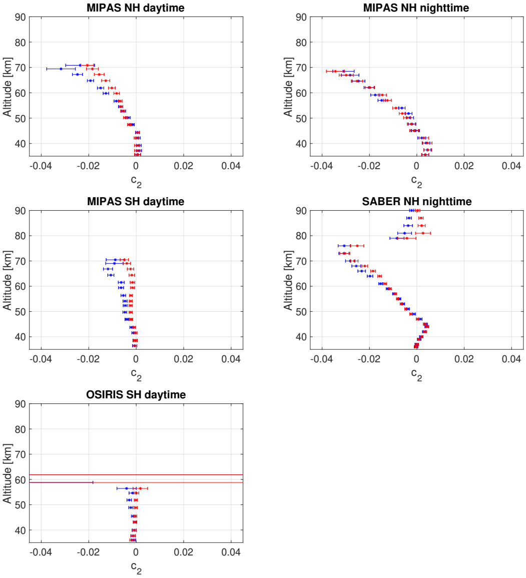
1st part: Main results from south polar region (2/2)



In general:

- Good agreement during nighttime condition.
- For daytime, good agreement for 3/8 cases (MIPAS in north and south, OSIRIS in south).
- These cases has large SPE(s) included.

1st part: Case study



In general

- Good agreement during nighttime condition.
- During daytime condition, increased gaps between satellite and model.

1st part: Summary

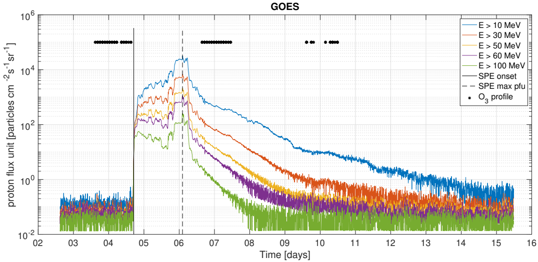
- Aim
  - Validate the ion chemistry of WACCM-D for SPEs
- Method
  - Multi-satellite approach to derive the atmospheric O_3 sensitivity to SPEs
  - Compared to co-located O_3 from WACCM-D
- Results
  - Nighttime condition:
    - General good agreement
  - Daytime condition:
    - Good agreement for satellite data-sets including large SPEs.
    - For satellite data-sets only including moderate and small SPEs, WACCM-D underestimate the sensitivity compared to the satellites.
  - Conclusion:
    - Ion chemistry model in WACCM-D provides realistic representation.

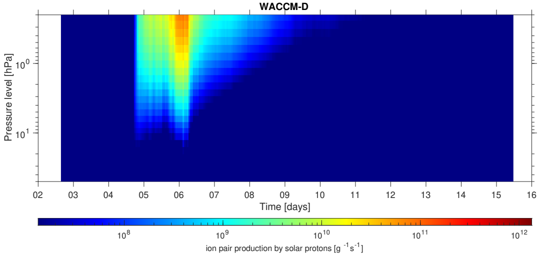
2nd part: introduction

First analysis of direct satellite-borne observations of ozone impact by the November 2001 solar proton event.

- Aim:
  - Report the observed impact by the November 2001 solar proton event
- Analysis method:
  - Use O_3 observation from OSIRIS to analyse the SPE impact
  - Sunlight dependent
    - Southern summer hemisphere
  - identical analysis and comparison with WACCM-D model, including:
    - ionization
    - NO_x
    - HO_x

2nd part: GOES pfu and WACCM-D ionization rate

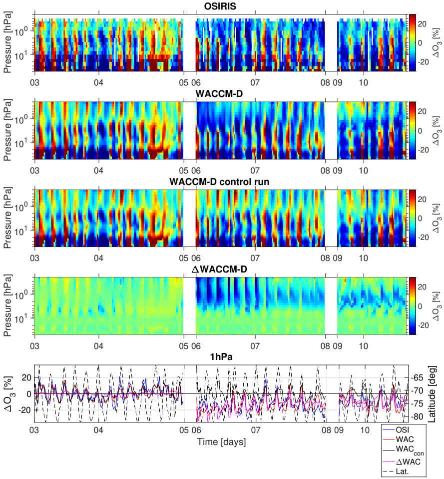




2nd part: raw profiles from geographic lat. > 60°S

$$\Delta O_3 = 100 \cdot \frac{O_3 - \mathrm{avg}[O_{3,\mathrm{ref}}]}{\mathrm{avg}[O_{3,\mathrm{ref}}]}$$

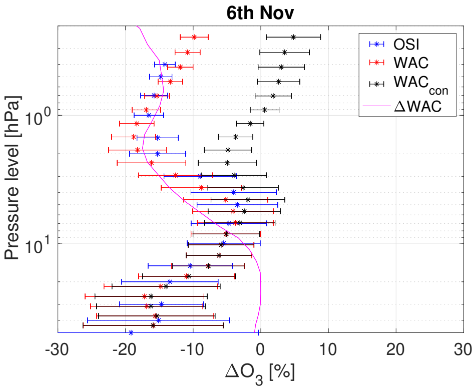
$$[\Delta O_3] = [\%]$$



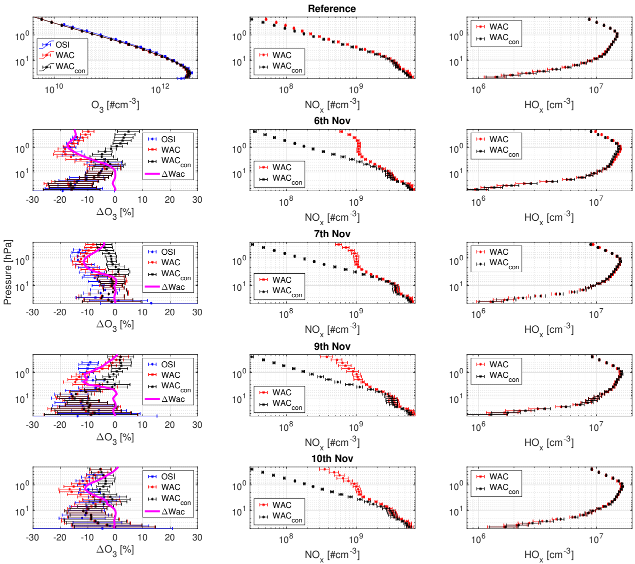
2nd part: Daily averaged O_3 profile from geographic lat. $> 60°$S. Day of peak pfu (6th Nov.)

$$\Delta O_{3,d} = \frac{avg[O_{3,d}] - avg[O_{3,ref}]}{avg[O_{3,ref}]}$$

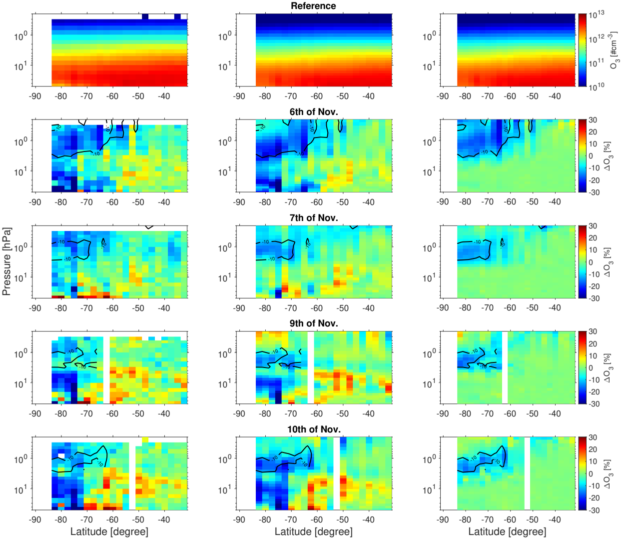
$$[\Delta O_{3,d}] = [\%]$$



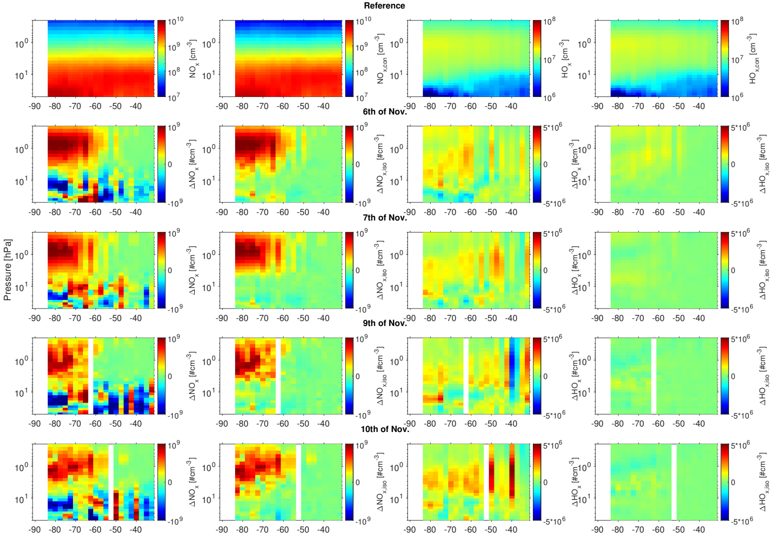
2nd part: Daily averaged profiles from lat. > 60°S



2nd part: Daily zonally averaged relative diff. O_3



2nd part: Daily zonally averaged $\mathrm{NO_x}$ (left) and $\mathrm{HO_x}$ (right)



2nd part: summary

- Aim
  - Report observational case study of the Nov. 2001 SPE impact on O_3
- Method
  - Observation from OSIRIS to analyse O_3 depletion from the Nov. 2001 SPE
    - Sunlight dependent: Southern summer hemisphere
  - Observation compared with co-located O_3 from WACCM-D, including:
    - ionization rate, NO_x and HO_x.
- Results:
  - Modest but detectable O_3 depletion
  - O_3 depletion extends to 55°S (during 6th, i.e. day of peak pfu)
  - NO_x is the dominant specie for O_3 depletion.
  - General good agreement between obs. and model.