UPWARDS
UNDERSTANDING PLANET MARS

The Open University

The first ozone reanalysis on Mars using MEx/SPICAM data

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Motivation

- Still much to learn about chemical cycles on Mars (OH,methane?)
- Development of a technique to assimilate trace gases on Mars necessary to maximise science benefit of future observations to come back from ExoMars Trace Gas Orbiter mission
- Ozone has been measured for multiple Mars years, provides ideal dataset to test newly created technique!

On the assimilation of total-ozone satellite data

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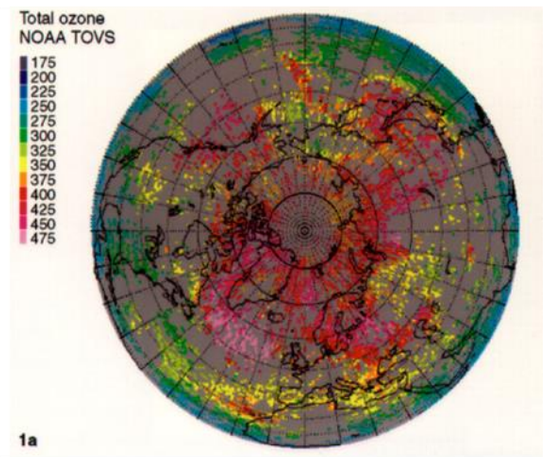
Abstract. A two-dimensional model for advection and data assimilation of total-ozone data has been developed. The Assimilation Model KNMI (AMK) is a global model describing the transport of the column amounts of ozone, by a wind field at a single pressure level, assuming that total ozone behaves as a passive tracer. In this study, ozone column amounts measured by the TIROS Operational Vertical Sounder (TOVS) instrument on the Nadir Radiometer (SBUV) (Heath *et al.*, 1975), the TIROS Operational Vertical Sounder (TOVS) (Planet *et al.*, 1984), the Global Ozone Monitoring Experiment (GOME) (Hahne *et al.*, 1993) and, in the near future, the Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (SCIAMACHY) on board of ENVISAT (ESA's, European Space Agency, Environmental Satellite) and the Ozone Monitoring Instrument (OMI) (ESA document, *in*



Motivation

- Benefits of ozone assimilation:
  - **Global mapping** - best estimate of global ozone constrained by retrievals and physical laws
  - **Chemical constraints** - Ozone assimilation can provide information on other chemical species
  - **Unified ozone datasets** - Ability to combine several sources of ozone data
  - **Ozone retrievals** - Providing more accurate initial guesses for retrieval algorithms
  - **Model validation** – Ozone assimilation provides several approaches to contribute to the validation of models

Martian ozone observations

Global distribution of total ozone on Mars from SPICAM/MEX UV measurements

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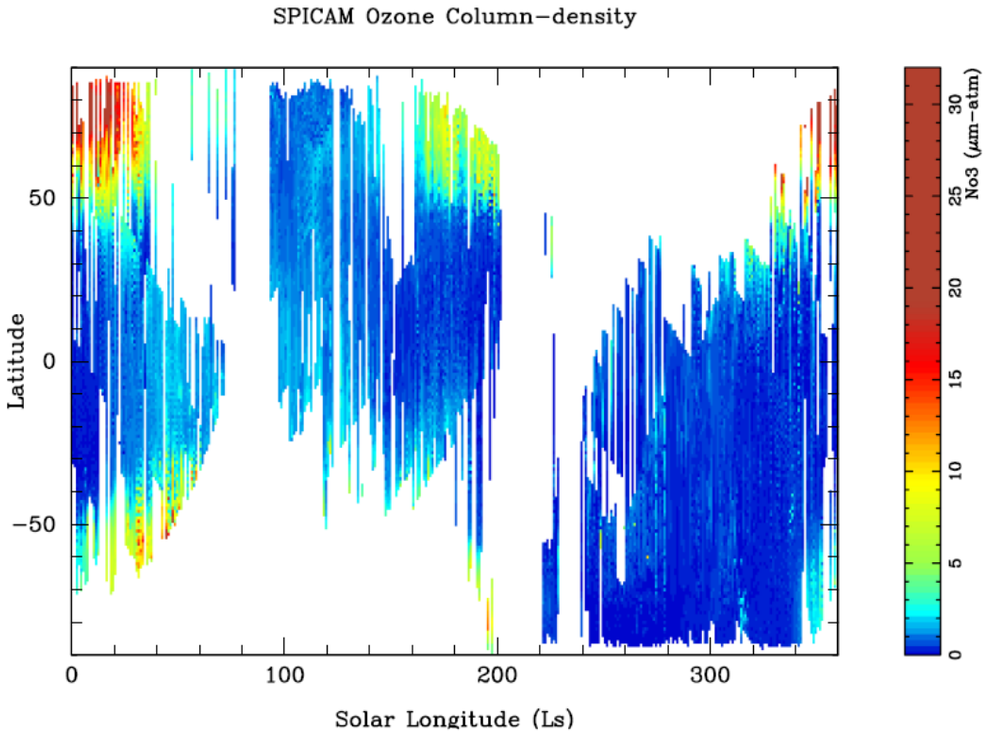
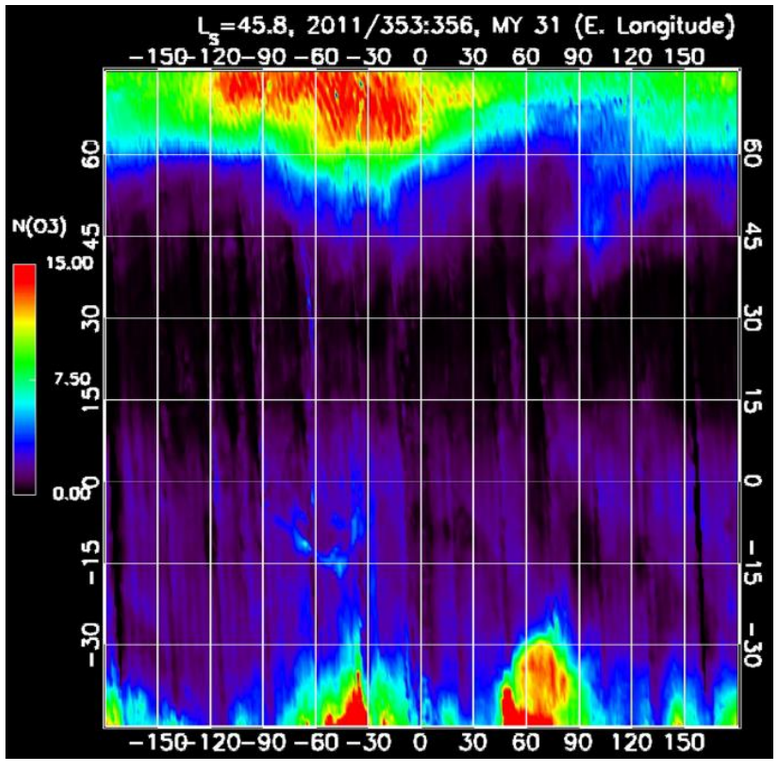
Received 22 January 2006; revised 14 June 2006; accepted 12 July 2006; published 27 September 2006.

[1] The dual UV/IR spectrometer SPICAM on board the European mission Mars Express is dedicated to monitoring the Martian atmosphere and has recorded spectra for more than one Martian year, from January 2004 to April 2006, over a large range of latitudes and longitudes. SPICAM UV spectra were recorded on the day side in a nadir geometry, in the 110–320 nm range, allowing measurement of ozone absorption around 250 nm. The method used to retrieve column-integrated ozone quantities is described. A full radiative transfer forward model of the radiance factor is used in an iterative loop to fit the data with four parameters: the surface albedo at 210 and 300 nm, the dust opacity, and the total ozone column. The analysis of the complete data set is presented. The global climatology of ozone on Mars is retrieved for the first time with spatial and temporal coverage. The most significant findings are (1) large increases in the ozone column density at high latitudes during late winter-early spring of each hemisphere that totally disappear during summer, (2) a large





Daily global mapping of Mars ozone column abundances with MARCI UV band imaging

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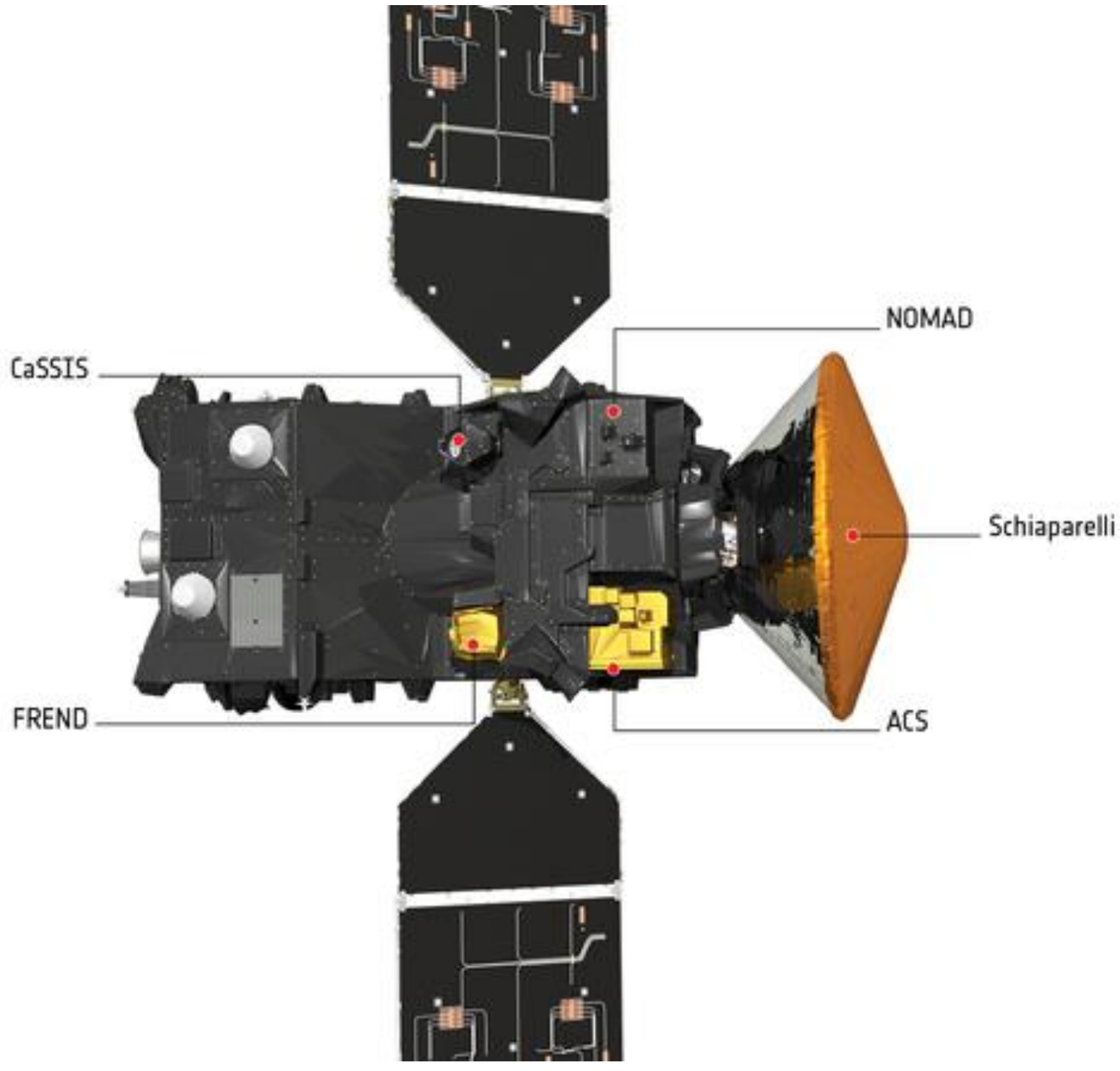
ABSTRACT

Since November of 2006, The Mars Color Imager (MARCI) onboard the Mars Reconnaissance Orbiter (MRO) has obtained multiple-filter daily global images of Mars centered upon a local time (LT) of 3 pm. Ultraviolet imaging bands placed within (260 nm) and longward (320 nm) of Hartley band (240–300 nm) ozone (O_3) absorption support retrievals of atmospheric ozone columns, with detection limits (~1 μm-atm) appropriate to mapping elevated O_3 abundances at low latitudes around Mars aphelion, and over mid-to-high latitudes during fall/winter/spring seasons. MARCI O_3 maps for these regions reveal the detailed spatial (~1° lat/long, for 8 × 8 pixel binned resolution) and temporal (daily, with substantial LT coverage at pole) behaviors of water vapor saturation conditions that force large variations in water vapor photolysis products (HO_x-OH, HO_2, and H) responsible for the catalytic destruction of O_3 in the Mars atmosphere. A detailed description of the MARCI O_3 data set, including measurement and retrieval characteristics, is provided in conjunction with comparisons to Mars Express SPICAM ozone measurements (Perrier, S. et al. [2006]. J. Geophys. Res. (Planets) 111) and LMD GCM simulated O_3 abundances (Lefèvre, F. [2004]. J. Geophys. Res. (Planets) 109). Presented aspects of the MARCI ozone mapping

Future observations

ExoMars Trace Gas Orbiter mission



- NOMAD-UVIS will provide nadir column and vertical profiles of ozone

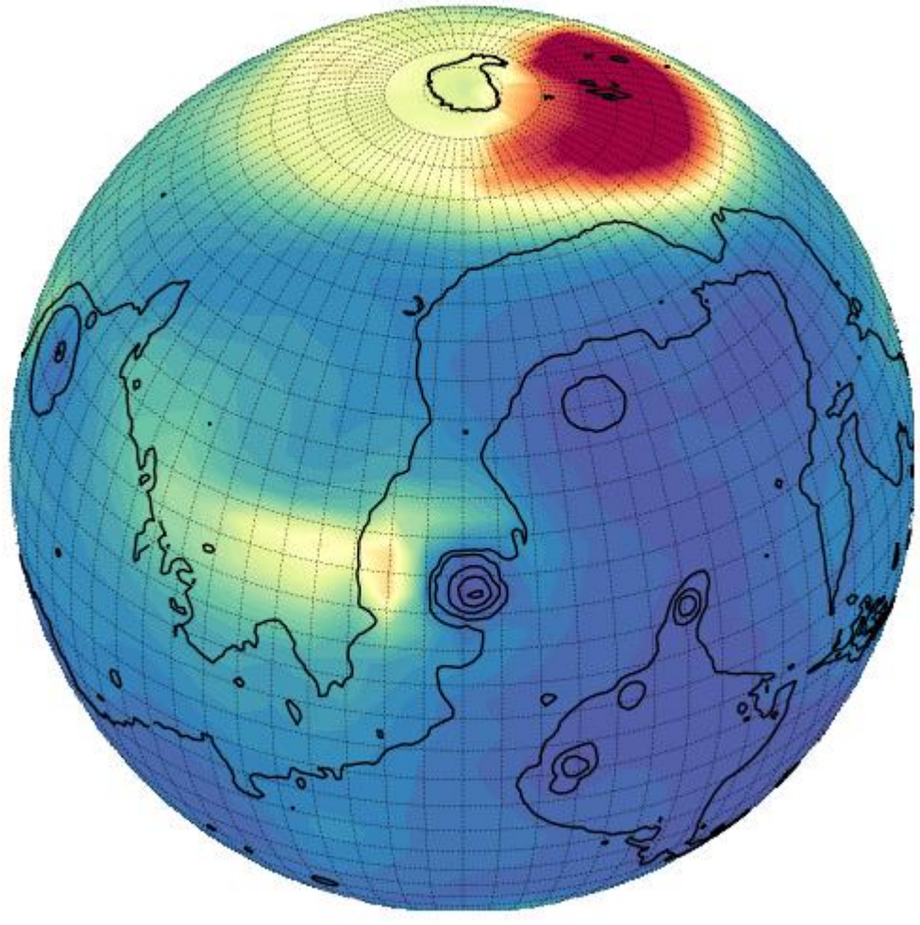
- MAVEN/IUVS semi-global ozone maps (oral presentation yesterday by Lefèvre et al.)

http://exploration.esa.int/mars/56666-exomars-2016-trace-gas-orbiter-and-schiaparelli/

Model setup

The LMD-UK Mars Global Circulation Model

- Physical parameterisations shared with LMD
- UK-only spectral dynamical core
- Typical resolution of T31, 5º x 5º in longitude and latitude
- Interaction and transport of 16 chemical species by LMD photochemical model and UK-only semi-Lagrangian advection scheme respectively
- Assimilation of MEx/SPICAM total ozone column retrievals using AC scheme



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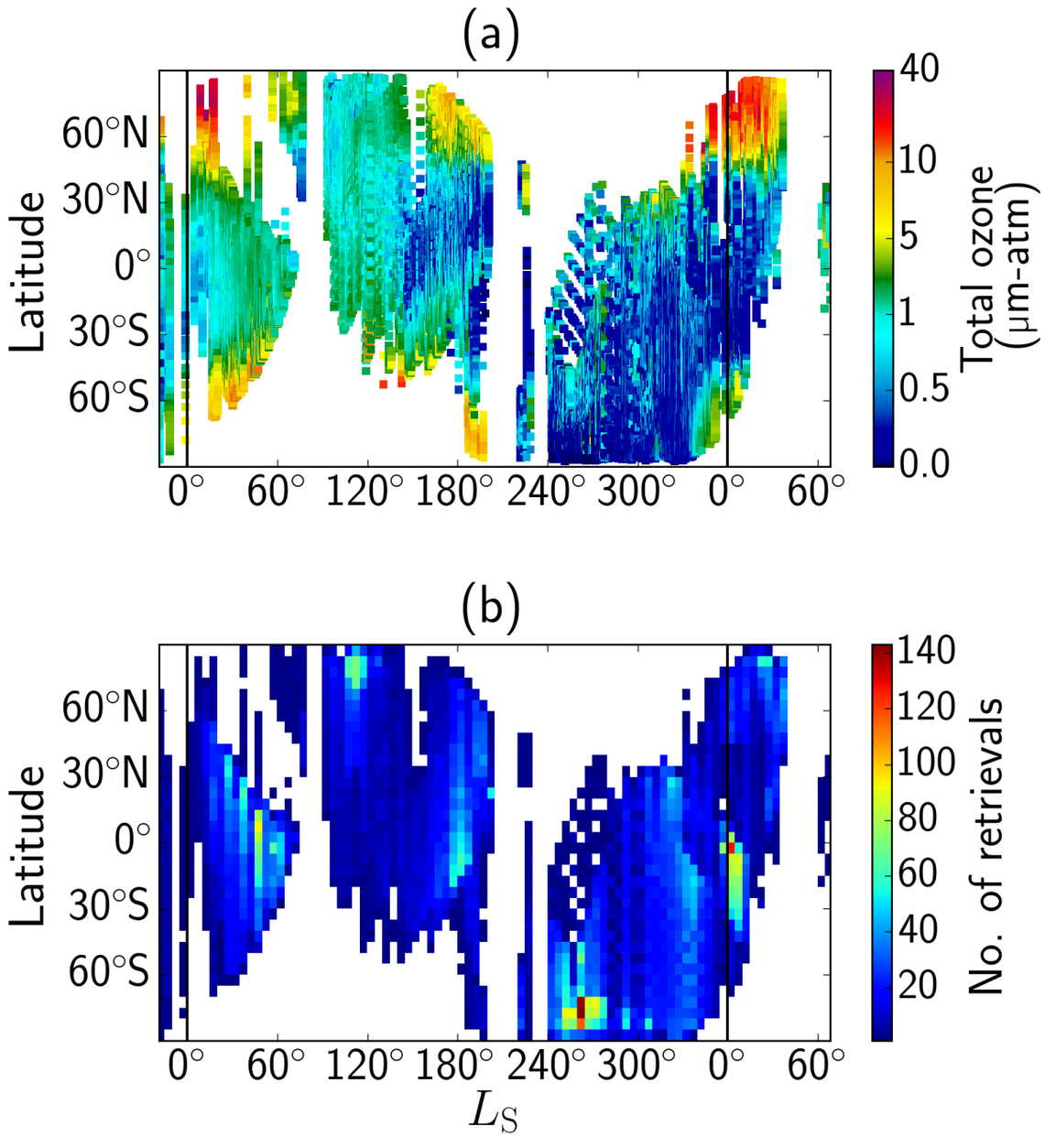
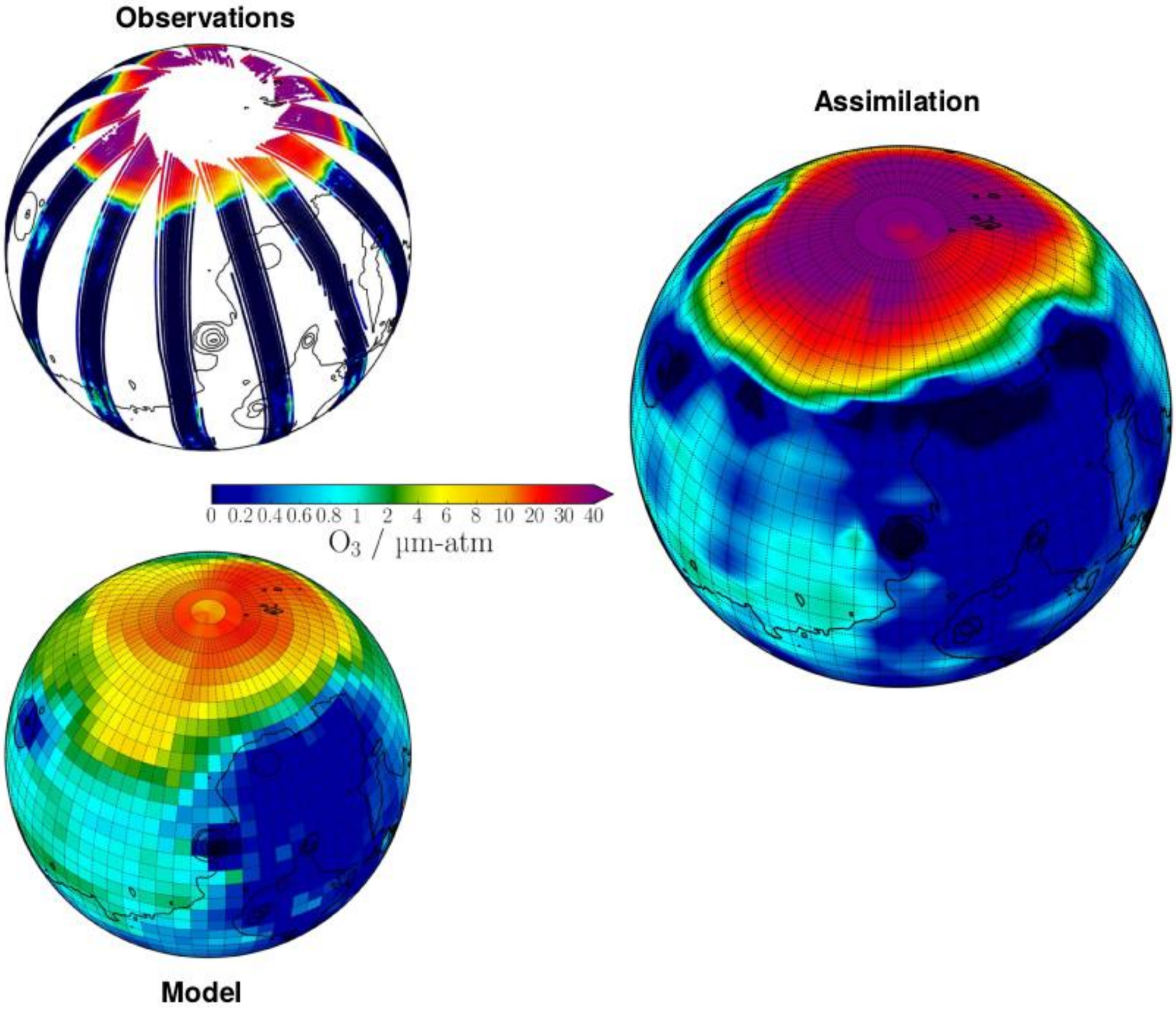
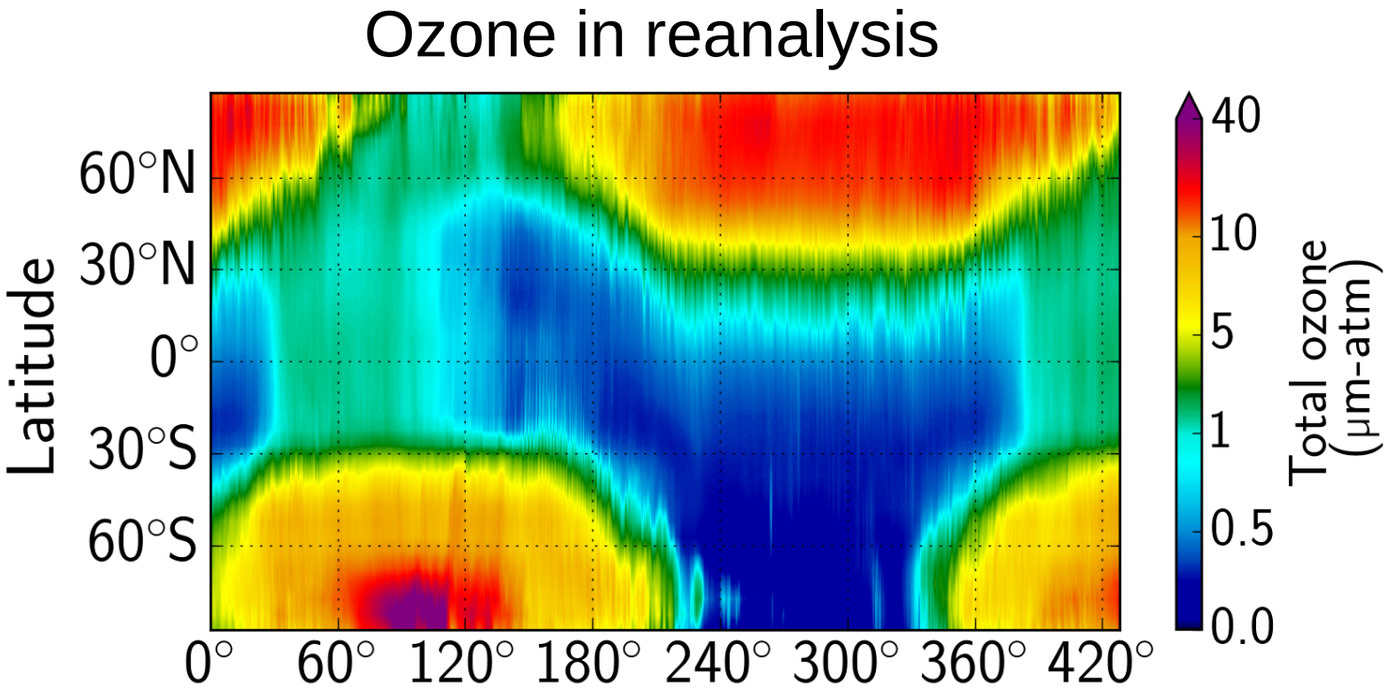
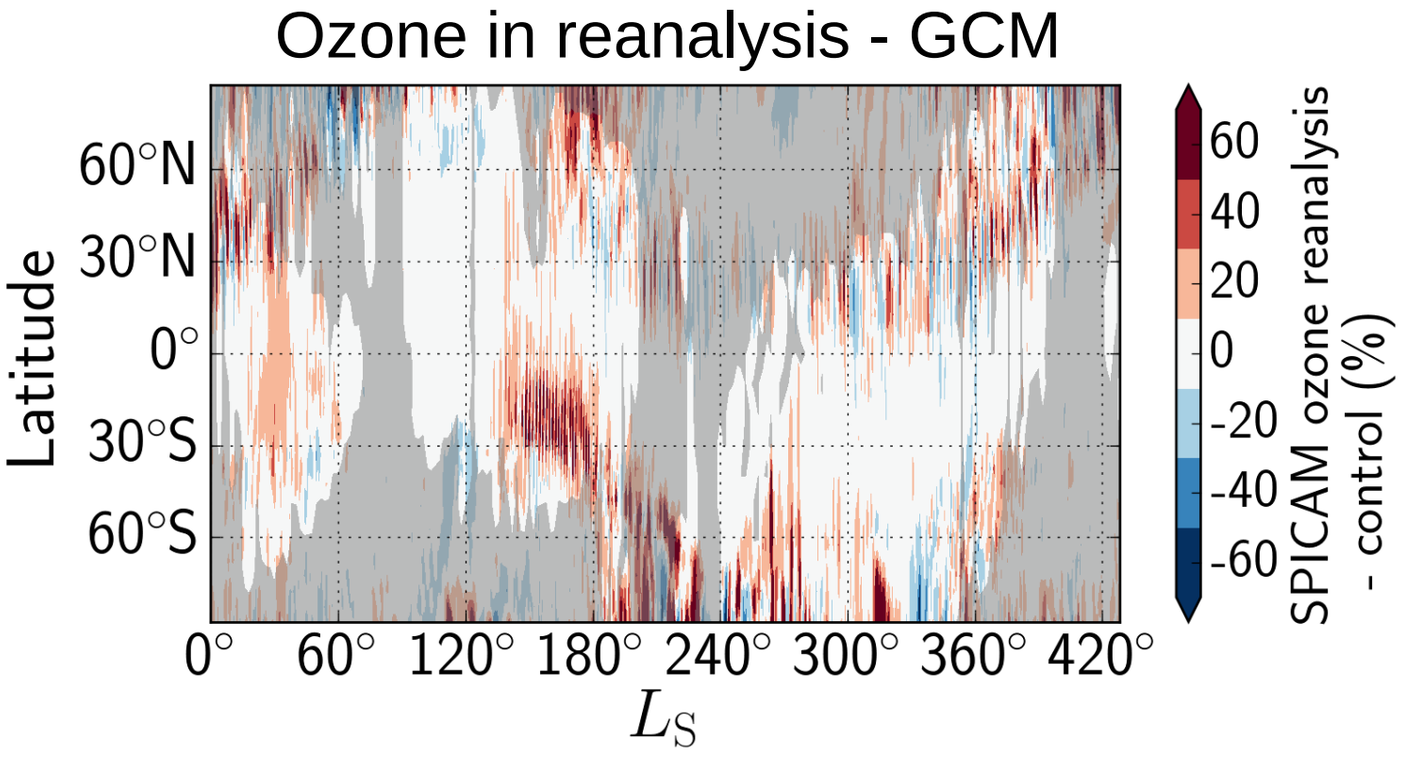


Data assimilation overview



SPICAM ozone reanalysis results





- Disagreement in total ozone between model prediction and reanalysis is observed between 45°S-10°S from L_S = 135-180° and at northern polar (60°N-90°N) latitudes during northern fall (L_S = 150-195°).
- Reanalysis allows us to investigate mechanisms which lead to total ozone disagreement

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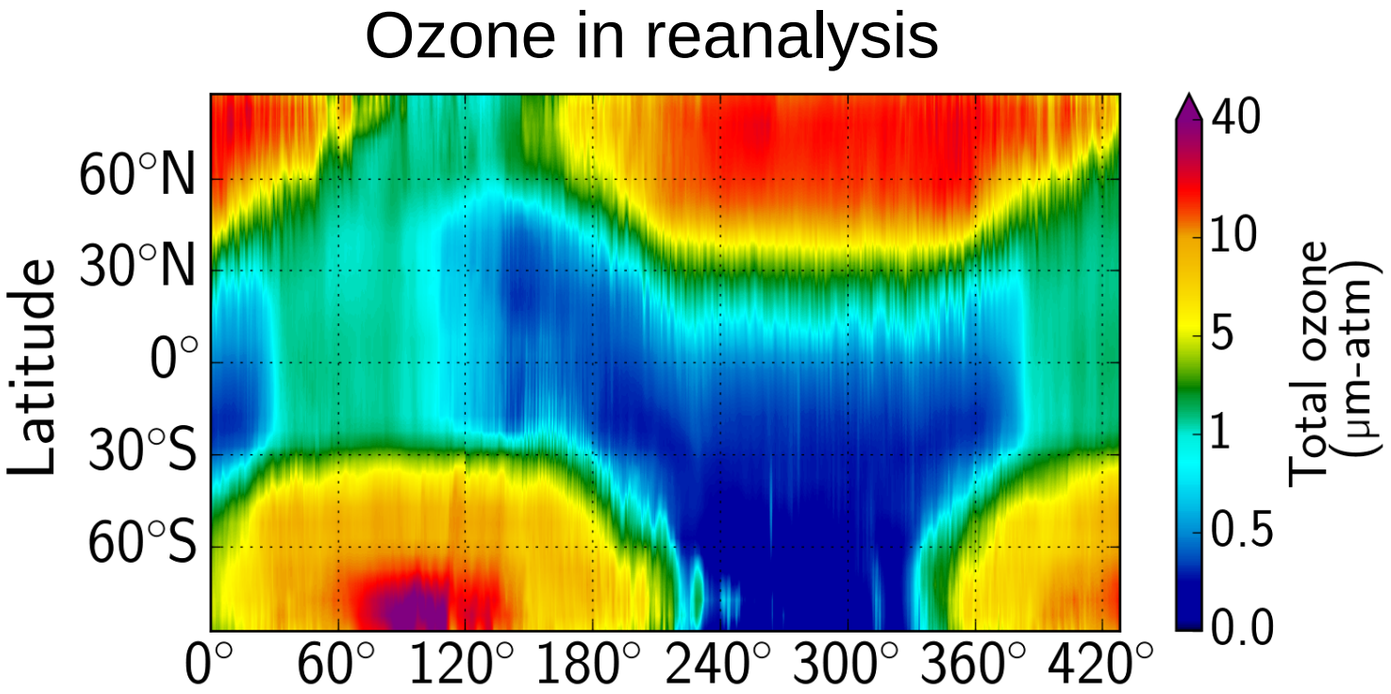

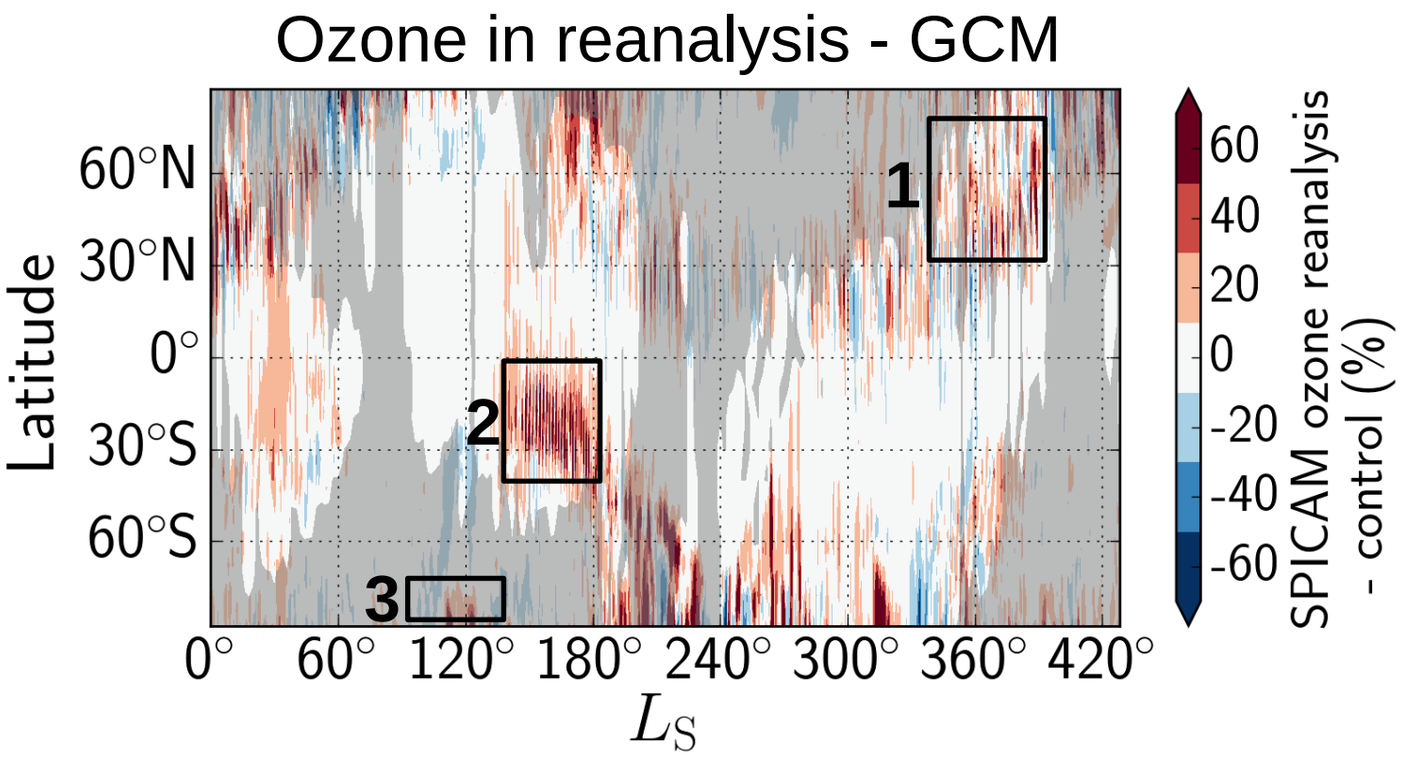

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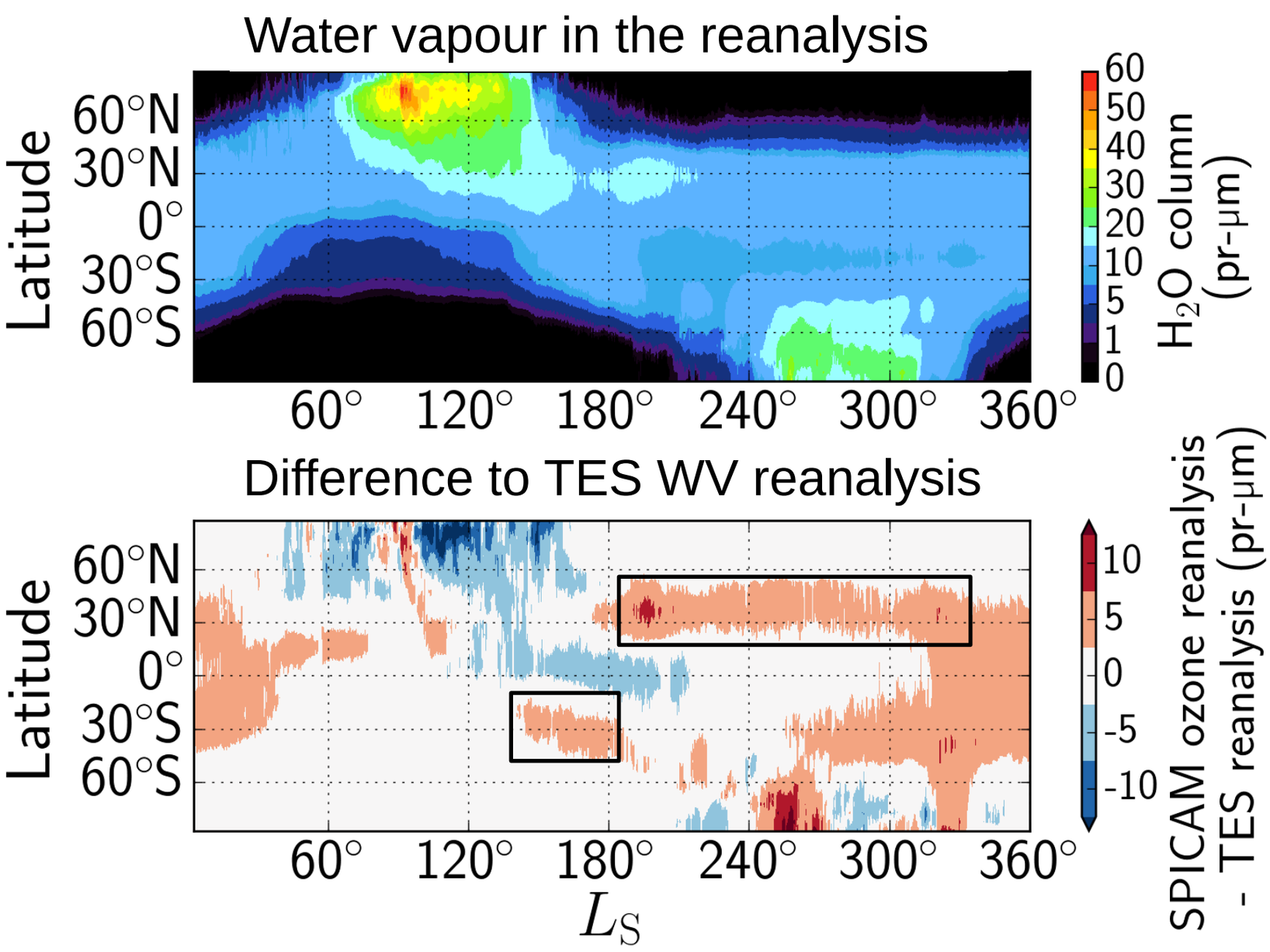
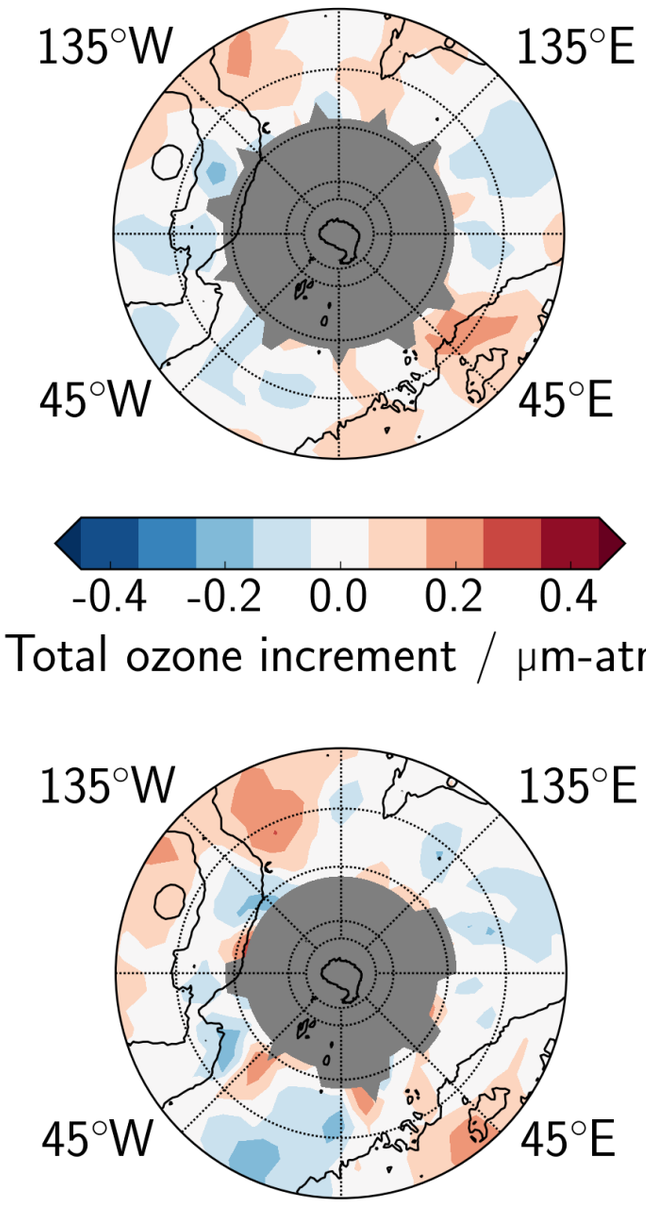
1 & 2: Interaction with water vapour

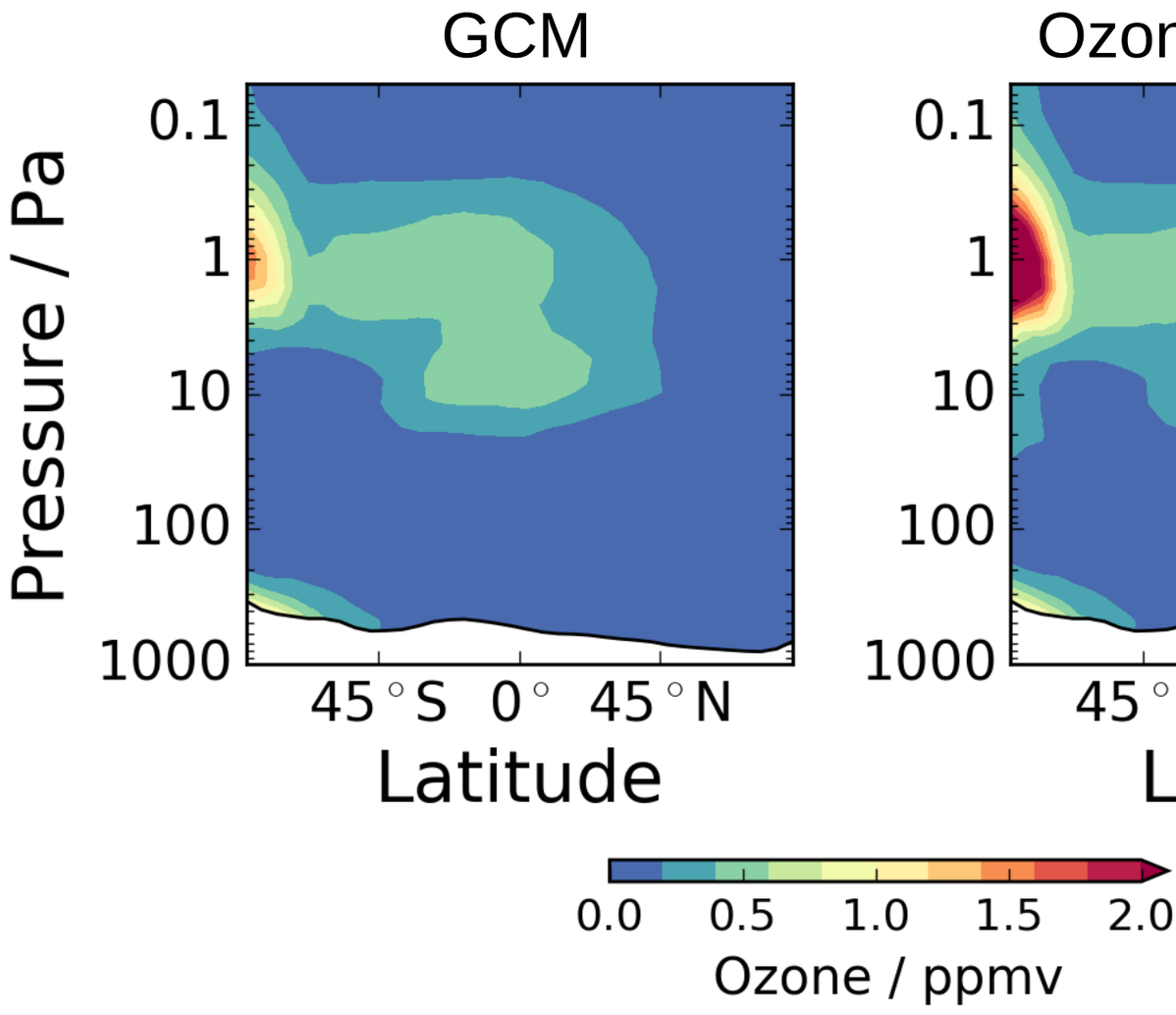
We can investigate links between water vapour and ozone





3: Effect on data sparse regions

How does assimilating ozone affect data sparse regions and other chemical species?



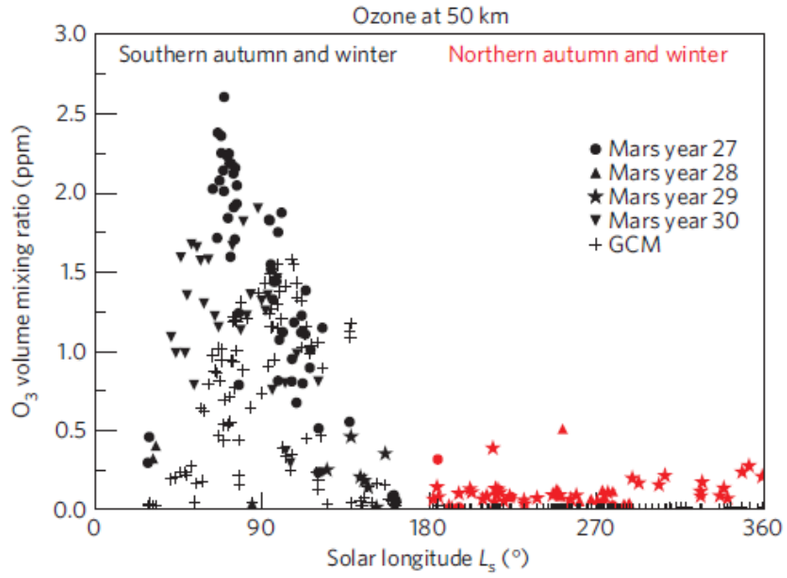


Figure 3 | Seasonal evolution of the polar ozone mixing ratio (ppmv) at 50 km for the two hemispheres. The figure shows, left versus right, the autumn and winter variation of the O_3 layer measured by SPICAM at 50 km for all martian years combined. Black symbols correspond to all locations sampled poleward of 60° S whereas the red symbols refer to latitudes poleward of 60° N. Co-located GCM results (plus symbols) are added to the plot to demonstrate the close correspondence between observations and predictions.

Reproduced from Montmessin et al., 2013

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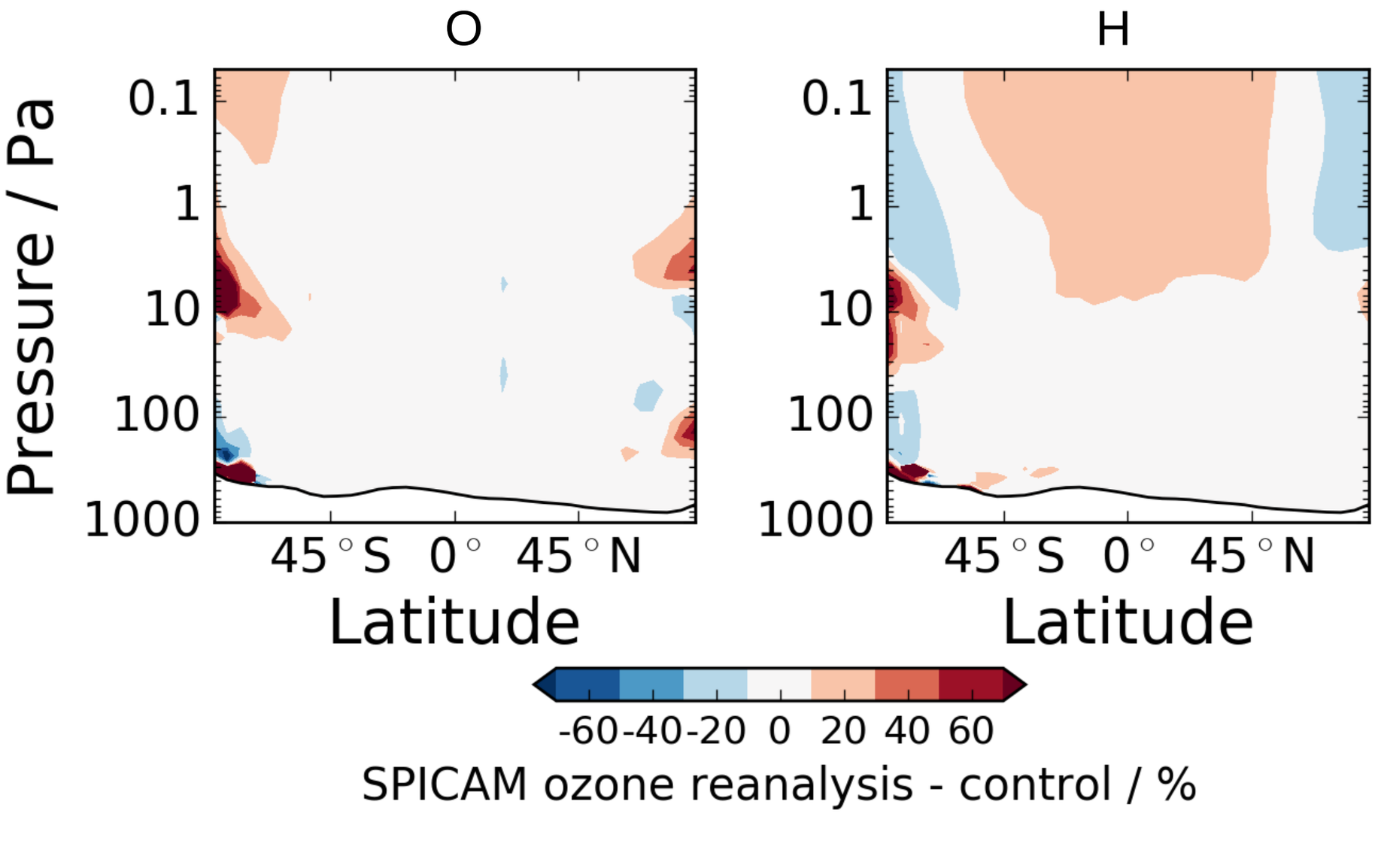

Conclusions

- Reanalyses of SPICAM/TES data show underestimation in total ozone after aphelion and northern winter can be attributed to modelling biases in water vapour transport, in particular over Arabia Terra and west of the Tharsis region for the latter

- Assimilation of SPICAM column ozone data provides southern polar ozone layer to match SPICAM stellar occultations as a result of alterations in chemical species

- A synthesis of model and observations via this assimilation method is a powerful tool to delve deeper into the ozone (and other trace gas) cycles on Mars

Holmes, J. A., S. R. Lewis, M. R. Patel, and F. Lefèvre (2017), A reanalysis of ozone on Mars from assimilation of SPICAM observations, Icarus, 302, 308–318, doi:10.1016/j.icarus.2017.11.026