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8-years time evolution of stratospheric HNO₃ columns: investigation of the drivers of variability and of the link to O₃.

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Introduction

Nitric acid (HNO₃) is one of the main species involved in the stratospheric ozone cycles. Until recently, the distribution of HNO₃ in the stratosphere was available only from limb-sounding instruments, such as MUS, MIPAS or ACE-FTS. The IASI nadir looking thermal infrared instrument is now providing HNO₃ concentration distributions with unprecedented spatial and temporal sampling since 2007. Here, we briefly review the IASI observational capabilities for HNO₃ (in terms of vertical sensitivity and errors) and show the results of a validation exercise made through a comparison with ground-based FTIR measurements.

We also provide an analysis of the time evolution of HNO₃ concentrations from IASI measurements since the end of 2007, through global distributions as well as latitudinal time series of HNO₃ columns. The first results of a multivariate regression analysis are shown in order to highlight the various factors responsible for HNO₃ spatial and temporal variability. The capabilities of the IASI instrument also allows for a joint analysis between HNO₃ and O₃ evolutions throughout the years, also briefly described hereafter.

FORLI-HNO₃

- Fast Optimal Retrieval on Layers for IASI = near-real time processing chain, at ULB
- Retrieval range: 850-1200 cm⁻¹, Retrieval scheme: Optimal Estimation Method (Rodgers, 2000)
- Inversion on 41 layers, with a single a priori profile and covariance matrix
- Data kept if: DOFS > 1.0
- RMS of the spectral residual < 3 x 10⁻⁶ W m⁻² sr⁻¹ cm⁻¹
- Cloud coverage < 25%
- See Hurtmans et al. (2012) for detailed information

Spatial & temporal distributions

Multivariate regressions

- Good correlation between fit & observations (R=0.74-0.92) except for tropical latitudes (R=0.42)
- Annual cycles in stratospheric HNO₃ distributions
  - NH: build-up of columns during winter
  - SH: small build-up, then denitrification
- In equivalent latitudes: drop in stratospheric columns when polar stratospheric T’s (taken at 50 hPa) reach 195 K (PSCs formation threshold)
- Dominance of the annual cycle (B-D circ.) in the regression
- Large influence also of stratospheric T°

Validation

Choice of 6 stations, all part of the NDACC network

- Re-gridding and smoothing of the FTIR vertical profiles (bottom left figure) give good agreement with IASI profiles
- Comparison of FTIR and IASI time series (bottom right figure): Retrieved columns (35-35 km) of both datasets are within the error range of one another
- Differences between FTIR and IASI data (I-FTIR) vary between -30 and 30%
- Mean of differences (bias) = 4.0 %
- IASI slightly overestimates concentrations compared with FTIR
- Standard deviation = 9.7 %
- Bias > 0% differences not significant, compared to variability

HNO₃-O₃ time series

- systematic drop of HNO₃ columns when stratospheric T’s reach the PSCs formation threshold
- lowest columns when lowest T°
- at the lowest HNO₃, stratospheric column: start of decrease in O₃ stratospheric column (delay of few years)

Northern hemisphere:
- no such systematic pattern
- HNO₃ and O₃ depletion occur in the winters 2010-11 and 2015-16 (lower T° than usual)

References

Clerbaux et al., Monitoring of atmospheric composition using the thermal infrared IASI/MeaO3 sounder, Atmos. Chem. Phys., 9, 8041-8054, 2009
Wespès et al., Global distributions of nitric acid from IASI/MeaO3 measurements, Atmos. Chem. Phys., 3, 7949-7962, 2003

Conclusions & ongoing works

- The IASI instrument shows a good sensitivity to the HNO₃ vertical profile, with its maximum in the stratosphere
- The validation with the FTIR profiles suggests good performances of IASI overall, with a mean bias of 10.5%
- The seasonal variations observed are relevant and are in agreement with chemical and dynamical processes in the atmosphere, and more specifically the stratosphere
- Multivariate regressions allow fitting the HNO₃ time evolution; some unexplained residuals deserve more attention
- The co-located IASI measurements allow for a HNO₃/O₃ co-analysis
- Improvement of the regression model to reduce the residuals
- Implementation of a chemistry-climate model to apprehend climate variables and their effects on [HNO₃]
- Focus on the polar regions and their specific dynamics and chemistry

Contact

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