Overview over tropospheric NO_2 products available within ACCENT

Summarized by
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with inputs from T. Wagner, S. Beierle and H. Eskes.

This text provides a short summary of the discussions related to tropospheric NO2 satellite products during the ACCENT workshop in Bremen in January 2005. It also contains brief summaries of all available NO2 products and a list of references.

Topics addressed for tropospheric NO2 during the ACCENT / AT2 meeting

Scientific Applications

- emission estimates
- long term changes
- resolution effects
- determination of NO2 life time

Related Activities

- IPCC AQ Exp 2 R4 : (Frank Dentener / Henk Eskes)
    - intercomparison of GOME NO2 products for 2000
    - intercomparison models (xx) / GOME measurements
- data analysis intercomparison (Steffen Beirle)
- link to ITOP campaign / "Transport and Transformation" activity within ACCENT (PI: P. Monks)

Interaction with Modelling

- comparison SCIAMACHY over EUROPE with CHIMERE
- comparison GOME over EUROPE with CHIMERE
- comparison of SCIAMACHY and TOMCAT
- attempt to coordinate use of NO2 columns in models (N. Savage)
- attempt to derive emission estimates (inverse modelling)

Open Questions

- how representative are scarce measurements?
- how sensitive are the measurements to NO2 in the lower BL?
- what is the quantitative impact of clouds?
- (how) can emissions be determined from the column measurements?
- how can tropospheric NO2 columns be validated

Validation Opportunities

- comparison to ground-based measurements (Petritoli et al.)
- OMI validation campaign in Cabauw May 2005 (Brinksma et al.)
    - NO2 lidar + surface in-situ + MAX-DOAS measurements
- use of Swiss measurements for profile / column comparison (Schaub et al.)
    - surface in-situ in different altitudes + aircraft
- use of TROCCINOX measurements
    - aircraft + balloon + surface in-situ

What are the open questions / most important issues for tropospheric NO2 from GOME & SCIAMACHY (& OMI)?

- impact of clouds
- impact of aerosols
- validation
- differences introduced by a priori profile information used

University of Heidelberg GOME NO2 data set

data set	IUP Heidelberg GOME tropospheric NO2
instrument	GOME
coverage	01.01.1996 - 31.12.2002
data format	plain ASCII files of monthly averages (0.5° resolution)
data availability	on request
web site	http://satellite.iup.uni-heidelberg.de
contact person	Steffen Beirle: beirle@iup.uni-heidelberg.de
reference	Beirle, S., U. Platt, M. Wenig, and T. Wagner, Weekly cycle of NO_2 by GOME measurements: A signature of anthropogenic sources, *Atmos. Chem. Phys.*, *3*, 2225-2232, 2003 Beirle, S., 2004. Estimating source strengths and lifetime of Nitrogen Oxides from satellite data. *PhD Thesis, University of Heidelberg, 2004.*
short description	• fitting algorithm: DOAS • stratospheric correction: reference sector over pacific • cloud selection: optional • airmass factors: constant • *The philosophy of a constant AMF is not to introduce spatial structures by a-priori assumptions. The resulting VCDs are transparently defined and can easily be modified with appropriated AMFs afterwards for concrete studies.*

University of Heidelberg SCIAMACHY NO2 data set

data set	IUP Heidelberg GOME tropospheric NO2
instrument	SCIAMACHY
coverage	01.01.2003 - present
data format	plain ASCII files of monthly averages (0.5° resolution)
data availability	on request
web site	http://satellite.iup.uni-heidelberg.de
contact person	Steffen Beirle: beirle@iup.uni-heidelberg.de
reference	Beirle, S., U. Platt, M. Wenig, and T. Wagner, Weekly cycle of NO_2 by GOME measurements: A signature of anthropogenic sources, *Atmos. Chem. Phys.*, *3*, 2225-2232, 2003
short description	• fitting algorithm: DOAS • stratospheric correction: reference sector over pacific • cloud selection: optional • airmass factors: constant • *The philosophy of a constant AMF is not to introduce spatial structures by a-priori assumptions. The resulting VCDs are transparently defined and can easily be modified with appropriated AMFs afterwards for concrete studies.*

BIRA/IASB KNMI GOME tropospheric NO2

data set	BIRA/IASB KNMI GOME tropospheric NO2 Software: WinDoas v.2.1; version 2 slant columns; TM4NO2A, version 1.1.1, August 2004
instrument	GOME
coverage	01.04.1996 - 30.06.2003
data format	HDF data files and images, daily and monthly averages, global and regional maps
data availability	from TEMIS and PROMOTE project website
web site	http://www.temis.nl/ http://www.gse-promote.org/
contact persons	Henk Eskes: eskes@knmi.nl Michel Van Roozendael: michelv@oma.be
reference	Boersma, K. F., H. J. Eskes, and E. J. Brinksma, Error Analysis for Tropospheric NO2 Retrieval from Space, J. Geophys. Res., 109 (D4), D04311, doi:10.1029/2003JD003962 (2004). Folkert Boersma, Satellite observations of tropospheric nitrogen dioxide: Retrieval, Interpretation and modelling, PhD thesis, May 2005. Van Roozendael, M., C. Fayt, J.-C. Lambert, I. Pundt, T. Wagner, A. Richter, and K. Chance, Development of a bromine oxide product from GOME, Proc. ESAMS'99-European Symposium on Atmospheric Measurements from Space, ESTEC, Noordwijk, The Netherlands, 18-22 January 1999, WPP-161, p. 543-547, 1999.
short description	• fitting algorithm: DOAS • stratospheric correction: assimilation of GOME NO2 slant columns with the TM4 chemistry-transport model, subtraction of analysed stratospheric column from total slant column. • cloud treatment: cloud correction based on FRESCO cloud fraction and cloud top height • airmass factors: tropospheric profile shape factors based on tropospheric TM4 NO2 field collocated in space and time

BIRA/IASB KNMI SCIAMACHY tropospheric NO2

data set	BIRA/IASB KNMI SCIAMACHY tropospheric NO2 Software: WinDoas v.2.1; TM4NO2A, version 1.1.1, August 2004
instrument	SCIAMACHY
coverage	01.01.2003 - present
data format	HDF data files and images, daily and monthly averages, global and regional maps
data availability	from TEMIS and PROMOTE project website
web site	http://www.temis.nl/ http://www.gse-promote.org/
contact persons	Henk Eskes: eskes@knmi.nl Michel Van Roozendael: michelv@oma.be
reference	Boersma, K. F., H. J. Eskes, and E. J. Brinksma, Error Analysis for Tropospheric NO2 Retrieval from Space, J. Geophys. Res., 109 (D4), D04311, doi:10.1029/2003JD003962 (2004). Folkert Boersma, Satellite observations of tropospheric nitrogen dioxide: Retrieval, Interpretation and modelling, PhD thesis, May 2005. Van Roozendael, M., C. Fayt, J.-C. Lambert, I. Pundt, T. Wagner, A. Richter, and K. Chance, Development of a bromine oxide product from GOME, Proc. ESAMS'99-European Symposium on Atmospheric Measurements from Space, ESTEC, Noordwijk, The Netherlands, 18-22 January 1999, WPP-161, p. 543-547, 1999.
short description	• fitting algorithm: DOAS • stratospheric correction: assimilation of GOME NO2 slant columns with the TM4 chemistry-transport model, subtraction of analysed stratospheric column from total slant column. • cloud treatment: cloud correction based on FRESCO cloud fraction and cloud top height • airmass factors: tropospheric profile shape factors based on tropospheric TM4 NO2 field collocated in space and time

KNMI OMI near-real time tropospheric NO2 product

data set	KNMI OMI near-real time tropospheric NO2 product Software: Operational OMI NO2 DOAS algorithm; TM4NO2A, version 1.1.1, August 2004
instrument	OMI
coverage	2005
data format	HDF data files and images, daily and monthly averages, global and regional maps
data availability	via website
web site	http://www.knmi.nl/omi
contact persons	Pepijn Veefkind: veefkind@knmi.nl Henk Eskes: eskes@knmi.nl
reference	OMI Algorithm Theoretical Baseline Documents, version August 2002; Boersma, K. F., H. J. Eskes, and E. J. Brinksma, Error Analysis for Tropospheric NO2 Retrieval from Space, J. Geophys. Res., 109 (D4), D04311, doi:10.1029/2003JD003962 (2004). Folkert Boersma, Satellite observations of tropospheric nitrogen dioxide: Retrieval, Interpretation and modelling, PhD thesis, May 2005.
short description	• fitting algorithm: DOAS • stratospheric correction: assimilation of GOME NO2 slant columns with the TM4 chemistry-transport model, subtraction of analysed stratospheric column from total slant column. • cloud treatment: cloud correction based on OMI operational cloud fraction and cloud top height product • airmass factors: tropospheric profile shape factors based on tropospheric TM4 NO2 field collocated in space and time

University of Bremen GOME NO2 data set

data set	IUP Bremen GOME tropospheric NO2 V2.0
instrument	GOME
coverage	01.01.1996 - 30.06.2003
data format	plain ASCII files of monthly averages, daily data on request
data availability	from website, password on request
web site	http://www.iup.physik.uni-bremen.de/doas
contact person	Andreas Richter; richter@iup.physik.uni-bremen.de
reference	Richter, A. and J. P. Burrows, Retrieval of Tropospheric NO2 from GOME measurements, *Adv. Space Res.*, 29, 16673-1683, 2002.
short description	• fitting algorithm: DOAS • stratospheric correction: daily SLIMCAT model columns scaled to GOME data over Pacific • cloud treatment: selection of pixels with FRESCO cloud fraction < 0.2 • airmass factors: monthly climatological airmass factors based on MOZART-2 model profiles from 1997

University of Bremen SCIAMACHY NO2 data set

data set	IUP Bremen SCIAMACHY tropospheric NO2 V1.7
instrument	SCIAMACHY
coverage	01.08.2002 - present
data format	plain ASCII files of monthly averages, daily data on request
data availability	from website, password on request
web site	http://www.iup.physik.uni-bremen.de/doas
contact person	Andreas Richter; richter@iup.physik.uni-bremen.de
references	Richter, A. and J. P. Burrows, Retrieval of Tropospheric NO2 from GOME measurements, *Adv. Space Res.*, 29, 16673-1683, 2002. Richter, A., V. Eyring, J. P. Burrows, H. Bovensmann, A. Lauer, B. Sierk, and P. J. Crutzen, Satellite Measurements of NO2 from International Shipping Emissions, *Geophys. Res. Lett.*, **31**, L23110, doi:10.1029/2004GL020822, 2004
short description	• fitting algorithm: DOAS • stratospheric correction: reference sector over Pacific • cloud treatment: selection of pixels with intensity based cloud fraction < 0.2 • airmass factors: monthly climatological airmass factors based on MOZART-2 model profiles from 1997

List of publications using GOME and SCIAMACHY tropospheric NO2:

Beirle, S. , Platt, U., Wenig, M. and Wagner, T. , Weekly cycle of NO2 by GOME measurements: a signature of anthropogenic sources, *Atmospheric Chemistry and Physics*, Vol. 3, pp 2225-2232, 2003

Beirle, S. , Platt, U., Wenig, M. and Wagner, T. , Highly resolved global distribution of tropospheric NO_2 using GOME narrow swath mode data, *Atmos. Chem. Phys.*, **4**, 1913-1924, 2004

Beirle S., Platt U., Wenig M. and Wagner T., NO_X production by lightning estimated with GOME, *Adv. Space Res.*, accepted, 2003

Boersma, K.F., H.J. Eskes and E.J. Brinksma, Error Analysis for Tropospheric NO_2 Retrieval from Space, *J. Geophys. Res.* **109** D04311, doi:10.1029/2003JD003962, 2004

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Burrows, J.P., M. Weber, M. Buchwitz, V. Rozanov, A Ladstatter-Weissenmayer, A. Richter, R. De Beek, R. Hoogen, K. Bramstedt, K.W. Eichmann, M. Eisinger, and D. Perner, The Global Ozone Monitoring Experiment (GOME): Mission concept and first scientific results, *J. Atmos Sci.*, 56, 151-175, 1999.

Eckhardt S., Stohl1 A., Beirle S., Spichtinger N., James P., Forster C., Junker C., Wagner T., Platt U. and Jennings S.G., The North Atlantic Oscillation controls air pollution transport to the Arctic, *Atmos. Chem. Phys. Discuss.*, 3, 3223-3240, 2003.

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Hild, L., Richter, A., Rozanov, V., and J. P. Burrows, 2001, Air Mass Calculations for GOME Measurements of lightning-produced NO_2, *Adv. Space Res.*, **29(11)**, 1685-1690, 2002.

Konovalov, I. B., M. Beekmann, R. Vautard, J. P. Burrows, A. Richter, H. Nüß, N. Elansky , Comparison and evaluation of modelled and GOME measurement derived tropospheric NO_2 columns over Western and Eastern Europe, *Atmos. Chem. Phys*., **5**, 169-190, 2005

Kunhikrishnan, T., M. G. Lawrence, R. von Kuhlmann, A. Richter, A. Ladstätter-Weißenmayer, and J. P. Burrows, Semiannual NO2 plumes during the monsoon transition periods over the central Indian Ocean, *GRL*, **31**, L08110, doi:10.1029/2003GL019269, 2004

Kunhikrishnan, T., M. G. Lawrence, R. v. Kuhlmann, A. Richter, A. Ladstätter-Weißenmayer and J. P. Burrows, Analysis of tropospheric NOx over Asia using the model of atmospheric transport and chemistry (MATCH-MPIC) and GOME-satellite observations, *Atmos. Environ.*, 38, 581-596, 2004.

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Martin, R. V., D. J. Jacob, K. Chance, T. P. Kurosu, P. I. Palmer and M. J. Evans, Global inventory of nitrogen oxide emissions constrained by space-based observations of NO2 columns, *J. Geophys. Res.*, 108, 4537-4548, 2003.

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