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1 BACKGROUND

The composition of the atmosphere has undergone dramatic changes since pre-industrial times due to increased emissions related to human activity, e.g. industry, transport, heating, changed land use and biomass burning. These atmospheric changes are manifesting themselves through aspects like climate change (global warming of the Earth related to greenhouse gases such as CO_2 and CH_4), air pollution (e.g. smog, acid rain), and global ozone depletion.

Satellite Earth Observation instruments have been providing a good means to measure ozone changes on global scale during the last 20 years (e.g. NASA – TOMS instrument). Since the launch of GOME on-board the ESA satellite ERS-2 during 1995 Europe also has the possibility to monitor global ozone changes from space. This capability has been significantly enhanced by the 3 atmospheric sensors on the Envisat mission (launched successfully during March 2002) and will be further extended by the future GOME missions on the METOP satellites (operated by EUMETSAT - first satellite launch planned by the end of 2005).

Based on user recommendations (GOME User Consultation Meeting during Jan. 2002 at ESRIN) ESA issued during June 2002 an Invitation to Tender with the objective to develop a GOME total ozone column retrieval algorithm producing ozone data useful for ozone trend monitoring (ability to measure 1% change in total ozone concentrations globally over a period of 10 years) that can be included into the next planned ozone assessment report (to be issued by WMO during 2006).

3 institutes were awarded with a contract to perform this work in competition namely BIRA/IASB (Belgium Institute for Space Aeronomy), KNMI (Dutch Met. Office), and University of Bremen. The contracts started during autumn 2002 with a duration of about 1 year.

Mid November 2003 documents describing the theoretical background of the algorithms as well as geophysical validation results were provided to ESA external reviewers, who are giving advise to ESA on the selection of the most suitable algorithm for ozone trend monitoring. The external reviewers are W. Thomas (DLR), N. Harris (European Ozone Research Coordination Unit), R. Munro (EUMETSAT), PK. Bhartia, J. Gleason (NASA), and C. Zerefos (University Athens, WMO representative).

During December 02/03 a dedicated GOME algorithm review meeting (all 3 consortia presenting their results to the external reviewers) took place at ESRIN and this document summarises the findings/recommendations of the external reviewers to ESA.

2 RECOMMENDATIONS TO ESA

4 different new GOME total ozone retrieval algorithms were presented:

GDOAS (improved classical DOAS scheme), **GODFIT** (direct fitting approach), **TOGOMI** (improved classical DOAS scheme), and **WF-DOAS** (Weighting-Function DOAS)

1. Long Term Planning: The Review Panel clearly identifies the GODFIT algorithm as the most innovative approach, that will enable further future exploitation of GOME's wavelength coverage (below 325 nm and above 335 nm). The GODFIT algorithm provides the possibility for clear error calculation. Furthermore the system does not depend on any Look Up Tables (LUTs) as the radiative transfer calculations are performed on-line. The presented software system is flexible and can be easily used to retrieve other trace gases than ozone from GOME measurements and enables its application to other instruments (e.g. O_2 retrieval from MERIS measurements). In its current development stage GODFIT is clearly not ready for operational implementation, but shows already very promising results.

The review panel recommends continuing the development of the GODFIT algorithm with the same consortium.

2. Short Term Planning: The GDOAS, TOGOMI and WF-DOAS algorithms show very good and similar geophysical validation results (reaching the same total ozone accuracy level as ground-based measurements) as presented. All 3 algorithms are suitable for ozone trend monitoring and are ready for operational implementation based on their development maturity and processing performance. The review panel cannot easily judge which algorithm performs best.

The review panel recommends performing further geophysical validation by the end of Jan. 2004.

The extended validation shall highlight the impact of following issues on the algorithms used:

- How does the choice of temperature impact trend monitoring?
- How does the choice of the spectral wavelength range impact trend monitoring (window starting at 325 nm as compared to the window starting at 331 nm)?
- How does the ozone profile information impact the total ozone?
- How does the choice of a different ozone climatology (e.g. TOMS V7/V8) impact the total ozone column?
- Are there systematic differences between the 3 GOME ground-pixels (is there a scan angle dependence)?

- Ground-stations located in deserts should be included into the validation data set.
- Intercomparison to the new TOMS V8 (which will be provided by NASA by Dec. 10 via ftp server) data shall be performed (using all co-located GOME/TOMS measurements and not only TOMS data over ground-stations).
- How does different calibration (e.g. wavelength, polarization) impact the algorithm?
- How does aerosol in the stratosphere impact the algorithm?

Improvements as compared to the GOME Data Processor V3 (e.g. seasonal/solar zenith angle dependence) shall be presented in the same way for each algorithm and there shall be intercomparison of the different total ozone columns (especially for problem areas like large solar zenith angles).

The co-located (to ground-stations) GOME total ozone columns from all 3 consortia shall be made available to everybody via an ftp site.

Additional algorithm self-consistency checks should be considered if feasible:

- Intercomparison of overlapping data sets at high latitudes dated on the same day.
- Intercomparison of data having the same latitude within an orbit.
- Demonstration of long-term algorithm stability by looking at the ozone field over specific areas (e.g. zonal means at mid latitudes) over time (GOME total ozone algorithm tuning to ground-based measurements is not anymore appropriate as the same accuracy level has been achieved).

In case the extended validation will show again similar results for all 3 algorithms the review panel recommends the operational implementation of the most simple (fast and easy implementation) GOME total ozone algorithm (to ensure that a new GOME total ozone data set is available by the end of 2004 to be used as input for the 2006 ozone assessment report).

GDOAS has already been partially implemented at DLR (D-PAF hosting the GOME Data Processor) within a parallel activity, aimed at developing an improved total column ozone algorithm for GOME-2 on MetOp, and initiated by DLR through the Visiting Scientist programme of EUMETSAT's Ozone Monitoring SAF. W. Thomas reported this activity during the review meeting.

The review panel recommends coordination between ESA and EUMETSAT on issues related to GOME-1/ERS-2 and GOME-2/MetOp algorithm development.

It has to be noted that the review panel already sees the start of such coordination at this meeting.

The review panel recommends the usage of the GOMECAL algorithm for the generation of GOME Level 1 products and the usage of the FRESCO algorithm for the retrieval of cloud information (both developed and made available by KNMI).