Minutes

Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft

German Aerospace Center

Minutes-No.	Session	Org.	Date	Meeting-Loc.
AT2-01			Nov. 19-20, 2007	DLR, Oberpfaffenhofen

Subject

Satellite Water Vapour Retrieval Workshop

Begin: 11:00

End: 18:00

Session Chair	Telephone no..	Minutes Secretary	Telephone no.	Invitation and Agenda from
D. Loyola		D. Loyola		D. Loyola

Participants

de Haan Johan (KNMI)
Fischer Jürgen (Uni. Berlin)
Heygster Georg (Uni. Bremen)
Kalakoski Niilo (FMI)
Lang Ruediger (MPI-Chem/EUMETSAT)
Lesne Olivia (ACRI)
Loyola Diego (DLR)
Mieruch Sebastian (Uni. Bremen)
Noel Stefan (Uni. Bremen)
Piters Ankie (KNMI)
Schroedter-Homscheidt Marion (DLR)
Schulz Jörg (DWD)
Slijkhuis Sander (DLR)
Wagner Thomas (MPI Mainz)

Copy to

Borrell Peter (P&PMB)
Fanton Odile (ACRI)
Munroe Rose (EUMETSAT)
Zehner Claus (ESRIN)

Result

Action Item

Topics

1. Opening and Aim of the Workshop, Diego Loyola (DLR)

DLR welcomes the participants and provides general logistic information.

Satellite water vapour retrieval groups in Europe meet in the framework of this AT2 workshop to present their algorithms, to discuss the specific properties of the retrieved results, to perform an initial comparison between H_2O satellite products as well as to show initial validation results using ground-based measurements, and finally to discuss possible future collaboration activities.

2. Scientific Presentations

2.1 Retrieving total water vapour over polar regions from AMSU-B, C. Melsheimer & G. Heygster (Uni. Bremen)

The polar regions belong to the regions of which the least information is available about the current and predicted states of surface and atmosphere. We present advances in a method to determine the total (column) water vapour (TWV) of the polar atmosphere over open water, sea ice and land ice from space-bourne microwave radiometer data, in particular data from the sensor AMSU-B (Advanced Microwave Sounding Unit B) on the new generation polar orbiting satellites of NOAA, NOAA-15, NOAA-16, and NOAA-17; likewise, data from the sensor SSM/T2 (Special Sensor Microwave) on the DMSP (Defense Meteorological Satellite Program) satellites can be used.
The retrieval method uses the microwave radiances at five channels: two window channels (no strong absorption lines) at 89 and 150 GHz, and three channels close to the strong water vapour absorption line at 183.3 GHz. The basic idea is to use ratios of differences of radiances in three channels where the surface emissivity is similar but the water vapour absorption is different. The method is independent of daylight and most clouds. However, this method can only retrieve TWV values up to about 0.7 g/cm^2 (7 kg/m^2) over any surface (land, sea, sea ice); over sea ice, the upper limit of the retrieval can be extended to about 2 g/cm^2 (20 kg/m^2) by using knowledge on the frequency dependence of the surface emissivity of sea ice, but at a trade-off of reduced accuracy.
The method for TWV retrieval is suitable for the polar regions, where the TWV is generally low because of the low temperatures. Total coverage of the polar regions is achieved about twice daily with each of the satellites that carry AMSU-B (usually, two are operational at any one time) with a spatial resolution of about 50 km.
Note that our method which retrieves total water vapour works exactly

where operational humidity sounding with AMSU-B or SSM/T2 fails because of too low water vapour content (so that the ground is "seen" by the sensor) and it is mostly independent of the surface emissivity. Comparison with TWV derived from near infrared (NIR) radiances of SCIAMACHY by air-mass corrected differential absorption spectroscopy (AMC-DOAS) yielded good agreement and high correlation except in late summer when the microwave-based method has problems because of unknown sea-ice emissivity after surface melting. Microwave-based TWV data and NIR-based TWV data can complement each other very well..

2.2 SEVIRI, Marion Schroedter-Homscheidt (DLR)

The retrieval of total water vapor column (TWC) from observations in the Split Window over varying surface temperatures was extended for use in atmospheric correction and surface irradiance calculation schemes. Thermal infrared split window channels at 10.8 and 12.0 μm of the MSG-SEVIRI instrument are used. The temporal resolution allows exploitation of the daily land surface temperature variation. There is no further need for explicit auxiliary information on air and land surface temperatures, which is difficult to obtain on an operational basis. Updated coefficients for the split window parameterization are derived based on simulations of 'top-of-atmosphere' SEVIRI brightness temperatures for the globally representative Thermodynamic Initial Guess Retrieval set of radiosonde profiles. It turns out that the linear dependency on the transmission ratio in both split window channels as originally proposed by [Kleespies & McMillin ,1990] has to be extended towards a non-linear approach in order to make it applicable to the full range of global atmospheric conditions. Sensitivity studies reveal that the parameterization relies on the availability of input brightness temperatures with a variation larger than approximately 5 K during the daily cycle.

The new TWC algorithm was tested with MSG-SEVIRI data for European and African regions for the period March–August 2004 and compared with radiosonde data. The results show that the algorithm is capable of producing TWC values with a mean bias of -0.2 mm and an RMSE of 6.8 mm. A second comparison to European GPS measurements for the same period from March to August 2004 reveals a bias of -3.0 mm and an RMSE of 6.0 mm. Comparing MSG-TWC to daily cloud-free mean GPS values shows a lower bias of -2.56 mm and an increased RMSE of 6.6 mm. These findings support the usefulness of the new MSG-based algorithm for surface irradiance calculations and atmospheric correction purposes.

2.3 The CAMELOT project, Johan de Haan (KNMI)

The CAMELOT project is a follow up of CAPACITY and involves sensitivity studies as a preparation for Sentinel 4&5. In this presentation sensitivity studies for H2O retrieval were discussed. The retrieval algorithm is optimal estimation, which provides detailed information on the various error sources and how they contribute to the final error. A procedure was outlined to circumvent line-by-line calculations, based on interpolation and a post-processing step that accounts for the shape of the cross section of H2O as a function of altitude. Finally, some examples were given that show the large influence of aerosol on the retrieved water vapor column.

Result | Action Item

2.4 GOME/SCIAMACHY/GOME-2, Thomas Wagner (MPI Mainz)

The H2O algorithm of the satellite group Mainz-Heidelberg consists of two basic steps: in the first step a DOAS algorithm is applied to the satellite spectra in the spectral range 614 – 683.2nm. This wavelength range is slightly different from the early analysis [Wagner et al., 2003], but was chosen to allow a consistent retrieval for the different satellite instruments (GOME. SCIAMACHY, GOME-2). Besides the H2O cross section (from the HITRAN data base, for 290K), also the cross sections of O4 (Greenblatt et al.), O2 (HITRAN, 290K), a Ring spectrum (calculated from a direct solar spectrum), three vegetation reflectance spectra [Wagner et al., 2007a] and an inverse solar spectrum (to account for possible spectrograph straylight) are included in the DOAS retrieval. The second step of the H2O analysis includes the application of a 'measured' AMF to the retrieved H2O SCD. This measured AMF is derived from the results of the simultaneously analysed absorptions of O4 and O2, for which the atmospheric VCD is estimated from average temperature and pressure profiles. While in the early version of our algorithm [Wagner et al., 2003, 2005] the O4 absorption was used to determine the AMF, in the current version the O2 absorption is utilised [Wagner et al., 2006a,b, 2007b]. The O2 absorption was chosen, because it can be analysed with much smaller uncertainties compared to O4. The O2 absorption is also much less affected by variations of the etalon structure or the interference with the spectral reflectance of vegetation. The application of the measured AMF has several advantages: It can be used to correct the SZA-dependent H2O SCD into the corresponding VCD. In addition, it corrects (at least in first order) additional radiative transfer effects, especially due to aerosols, clouds and the surface albedo. It should, however, be noted that this correction contains systematic errors because of the different profile shapes of the concentrations of H2O and O2 (or O4); the largest errors are typically related to clouds. These errors become especially important for low cloud altitudes and large cloud fractions [Wagner et al., 2005, 2006a]. The effect of clouds (including also selection effects are discussed in detail in Wagner et al. [2005]. In the current version of our algorithm, observations with a strong cloud influence (O2 absorption < 0.8 of the maximum O2 absorption).
If the H2O data sets are applied to trend studies, also an upper threshold for the O2 absorption is applied.
In addition to the two basic steps of the retrieval, two further corrections are applied. First, the non-linearity of the derived SCDs of O2 ad H2O on the actual atmospheric SCDs is corrected using the relationships derived from the spectral simulation of this saturation effect: high resolution absorption spectra are calculated for an assumed atmospheric SCD. After convolution with the instrument function, these spectra are analysed using the same DOAS settings as in the analysis of the satellite spectra. The ratio of the SCDs assumed in the calculation of the absorption spectra and the retrieved SCD can then be used to correct the SCDs derived from the DOAS analysis of the satellite spectra [Wagner et al., 2003]. The second correction is applied to account for the altitude dependent sensitivity of the satellite instrument. Since the sensitivity decreases towards the surface, the sensitivity for the H2O VCD is systematically smaller than for the O2 SCD (or O4 SCD). From radiative transfer modelling, this difference in sensitivity is determined as a function of SZA, and the corresponding AMF-

ratios are applied to the H2O VCD retrieved from the satellite observations. It should be noted that in the current version of our algorithm this correction is only calculated for a pure Rayleigh atmosphere and standardised H2O profiles. In future versions of the algorithm, also the dependence on the surface albedo (especially over ice and snow) and the effects of clouds will be also taken into account. The dependence of the AMF-correction on the absolute value of the H2O VCD can be considered by applying an iterative approach.
In the current version of our algorithm, a systematically overestimation of the H2O VCD in regions over ice and snow is expected, because the AMF correction factor is calculated for a surface albedo of only 3%. This overestimation was indeed also be found in the comparison of our data set to other observations and model results.

Application to atmospheric investigations
We used our H2O data sets for the investigation of the Earth's hydrological cycle. There are two main advantages of the satellite data sets derived in the visible and near-IR spectral range: first, they are sensitive to the whole atmospheric H2O column, including also the surface-near layers. Second, these data sets cover the whole globe with similar sensitivity, making them especially well suited for global studies. Using the measured data sets alone, we investigated three specific aspects:
A) Performing global differences of normal years and ENSO years (1997/98) allows to study the variation of the atmospheric humidity during such events. In addition to tropical regions, large deviations were also found in mid and high latitudes [Wagner et al., 2005].
B) Our data set is well suited for trend analyses, because it is independent from additional information (like e.g. atmospheric temperature profiles, etc.)

From studying the linear trends (an their spatial variability) of the H2O VCD information on the dependence of the atmospheric humidity on surface temperature can be derived. Except over the continents in the northern hemisphere, a positive correlation between the atmospheric humidity and surface temperature was found [Wagner et al., 2006a].
C) We also investigated the correlation of monthly mean anomalies of the H2O VCD, cloud cover and surface temperatures. Similar relationships as for the trend studies were found. However, in contrast to trend studies, correlation analyses of monthly mean anomalies have a much larger amplitude and are hardly affected by instrumental degradation [Wagner et al., 2007b].
The comparison of our data set to model results started only recently and only preliminary conclusions can be drawn. In general, good agreement of the absolute values over low and mid latitudes is found. Also, the temporal evolution in model results and satellite observations show very similar behaviour. Substantial differences are found over polar regions where the satellite data are systematically too high and over regions with persistent cloud cover at low altitudes, where the satellite data are typically too low. These deviations are caused by the effects of high surface albedo and low clouds, and should be improved in future versions of our algorithm.

2.5 The Satellite Application Facility on Climate Monitoring (CMSAF), Jörg Schulz (DWD)

Result	Action Item

CMSAF is providing satellite-derived so called thematic climate data records that are geophysical variables in grid representation averaged over different spatiotemporal scales. Currently, within the CMSAF three different categories of data sets are considered (1) Data sets for operational monitoring are based on retrievals applied to nominal calibrated or intercalibrated radiance data. The retrieval schemes may change over time due to improvements in the retrieval technique. Application areas are process studies that, e.g., can lead to improvements of parameterisations in climate models. (2) A second category is formed by data sets suitable for the monitoring of seasonal to inter-annual variability and to analyse extreme event statistics. Those data sets are based on intercalibrated or at least homogenised radiance data and frozen retrieval schemes need to be applied for the whole temporal record. For most of the CMSAF geophysical variables this kind of data set will exist at the end of the current project phase in 2012. (3) A third category of data sets consists of time series that are suitable for decadal variability and climate trend monitoring, i.e., approximately 30 years and longer. Only very few satellite series provide data for such a long time but already flying satellite series will bring more and more instruments in reach for climate trend studies.
Among several products concerning clouds and the radiation balance of the Earth at the top of the atmosphere and surface the CMSAF also provides water vapour products derived from different sensors. Basically there are three different products provided:

1. Total column water vapour over ice free oceans derived from SSM/I measurements.
2. Temperature and moisture profiles, total column water vapour and integrated water vapour in five atmospheric layers derived from the ATOVS data that uses simultaneously HIRS, AMSU-A and AMSU-B/MHS data.
3. Total column water vapour and integrated water vapour for three layers derived from the geostationary SEVIRI instrument.

Currently, the three data sets belong to different categories as defined above. The SSM/I data set belongs already to category 2 because it is based on intercalibrated SSM/I radiances and also uses the same retrieval for the whole time series ranging from 1987 – 2005. The ATOVS products belong to category (1) as although the same retrieval is used for all NOAA satellites a radiance intercalibration is still missing. Finally, the SEVIRI data set is still under development as the retrieval scheme is very sensitive to radiance bias errors and also to errors in the surface emissivity in the infrared window channels mostly pronounced at 8.7 µm.

2.6 MERIS, Jürgen Fischer (Uni. Berlin)

Summary missing.

2.7 GOME/SCIAMACHY/GOME-2, Stefan Noel (Uni. Bremen)

The Air Mass Corrected (AMC-)DOAS method uses the spectral region from 688 to 700 nm to derive water vapour total columns on the global scale. The method has already been successfully applied to measurements of GOME and SCIAMACHY (see e.g. Noël et al., 2005, and references

therein). A main feature of the AMC-DOAS method is that it does not rely on external calibration sources (like radio sondes); thus the GOME-type instruments can provide a completely new and independent water vapour data set. The AMC-DOAS retrieval method is fast and stable and thus well suited for operational data processing. The capability for operational processing has been already proven in NRT processing of SCIAMACHY data (running at IUP Bremen). The resulting AMC-DOAS H2O columns agree well with correlative data and each other. However, comparisons between different data sets typically show a considerably high scatter of about 0.5 g/cm^2 , which is mainly attributed to atmospheric variability. Thus, a validation of water vapour columns is in general very difficult.
Comparisons between AMC-DOAS water vapour columns derived from GOME and SCIAMACHY measurements have been performed to assess the possibility of generating a combined water vapour data set. These investigations showed that there is on global average essentially no offset between the water vapour results of both instruments, but also in this case there is a scatter of about 0.25 g/cm^2. This scatter results from local differences which need to be considered by applications using the combined GOME-SCIAMACHY water vapour data.
In October 2006 the MetOp satellite has been successfully launched, carrying on it the GOME-2 instrument, a successor of GOME. The main improvement of GOME-2 is the increased swath width of 1920 km (compared to 960 km for GOME and SCIAMACHY) while the spatial resolution of 40 km x 80 km is still almost as good as for SCIAMACHY (typically 30 km x 60 km) and much better than for GOME (40 km x 320 km).
The AMC-DOAS method could be easily adapted to GOME-2 such that now also GOME-2 data are regularly processed at IUP Bremen. The first GOME-2 water vapour results are very promising. There is a good agreement between GOME-2 and SCIAMACHY water vapour columns, although there is some indication for a small scan angle dependency in the GOME-2 data which is under further investigation.
Especially at high latitudes additional valuable information about the regional variability of water vapour can be obtained from GOME-2. For example, over the polar research station Ny Ålesund (Spitsbergen) GOME-2 can provide about 6 measurements per day at varying local times during daylight (of course, limited by the presence of clouds). From these measurements it is then possible to derive information on the diurnal cycle of water vapour (see Noël et al., 2007).
These promising first results for GOME-2 show that a combination of the AMC-DOAS water vapour products for the three GOME-type instruments is possible and that GOME, SCIAMACHY and GOME-2 have the potential to provide a new independent global water vapour climatology reaching up to 2020.

2.8 GOME Climatology, Rüdiger Lang (MPI-Chem/EUMETSAT)

An accurate knowledge of the 3-D water vapour (WV) field is still limited, because of the limited capabilities of sensors in the past to cover the whole Earth's surface and the lower part of the troposphere, as well as to measure over reasonably long time series. We show here WV total column retrieved from seven years of Global Ozone Monitoring Experiment (GOME) measurements collected from August 1995 until August 2002. Our aim is

Result | Action Item

two-fold: (1) to evaluate the accuracy and the limitations of the GOME WV total column and (2) to demonstrate its potential for climate studies. The column retrieval makes use of two innovative techniques operating in tandem, namely the University of Graz empirical air mass factor ratioing technique (IGAM) and the Spectral Structure Parameterization (SSP) retrieval method. The GOME instrument and its follow-up instruments (SCIAMACHY and GOME-2), using these algorithms, have the capability to cover nearly the whole globe in cloud-free situations and collect robust WV total column information over more than 3 decades. In this work we evaluate the results for the first 7 years against independent in situ measurements from the operational WMO radiosonde network, against high spatial resolution WV columns from MERIS (the Medium Resolution Imaging Spectrometer on EnviSat) and also compare with ERA40 model results. The GOME WV total column exhibits a bias of less than 2.5% with an uncertainty of around 5 mm for collocated measurements against radiosonde and MERIS measurements. Spatial patterns and trends in the global distribution of WV total column fields from GOME against re-analysis model results are well correlated with temperature in the tropics, and exhibit a lesser degree of correlation in the extra tropics. Cloud-free total columns from GOME can be systematically lower by up to 5 mm in the sub-tropics with respect to the all-sky case. In contrast, the impact of the diurnal cycle on the monthly mean values is found to be very small. We also showed that the impact of clouds on the climatologically mean values is strongest for the southern hemisphere especially in winter because of the large extend of low level clouds. The impact in the Tropics is visible even though not as strong because of an on average smaller cloud fraction. Cloud screening of model data using the satellite mask may lead to a dry bias of the model for the tropics and summer hemispheres as with respect to the unscreened model. However, screening model pixels for hemispheric winter using satellite data usually leads to a moist bias since, overall, pixels with low total WV column are removed. In total, cloud-screened model comparisons also lead to a global effect, which we tagged the "common-cloud-problem", for which cloud screening of model data using satellite masks usually moistens the screened model results on a global average. This is because grid points with dislocated model clouds, which are subsequently not screened, on average, correspond to pixels with higher humidity. Rigorous model validations using cloud screened satellite WV data can therefore only be carried out in case both, satellite detected cloudy pixels and all cloudy pixels in the model are removed from both datasets.

2.9 H2O profiles from SCIAMACHY limb, Ankie Piters (KNMI)

A retrieval method for H2O profiles from SCIAMACHY limb measurements was demonstrated. The retrieval method fits the differential structures in the ratio of radiances between two consecutive tangent heights, around 934 nm. The method is most sensitive between 10 and 30 km. Simulation studies showed that the combination with weaker absorption lines, e.g. ~823 nm, might enable the retrieval at lower altitudes. The influence of clouds and spatial straylight will need urther study.

2.10 Trends with GOME/SCIAMACH, Sebastian Mieruch (Uni. Bremen)

Result | Action Item

Global water vapour total column trends have been calculated from the combined GOME and SCIAMACHY data set for the time span from January 1996 to December 2006 (Mieruch et al., 2007). The water vapour products have been retrieved using the AMC-DOAS method, which was developed at the University of Bremen (Noël et al., 2004). The analysis of the overlapping data from GOME and SCIAMACHY from August 2002 to December 2003 reveals a negligible mean difference of -0.01 g/cm^2, but for single measurements differences up to ± 0.25 g/cm^2 are observed. Regarding these differences, the two data sets can be merged well together. Therefore the linear regression approach of Weatherhead et al. (1998) is quite suitable since it considers a mean level shift between the time series at their intersection. We have expanded the regression method to our requirements by introducing an amplitude change at the intersection of the two time series and using the Discrete Autocorrelation Function (Edelson and Krolik (1988)) to estimate the autocorrelation because of gaps in the data. The trend analysis places special emphasis on the calculation of the errors of the trends, which are influenced by the length of the time series, the noise, the autocorrelation of the noise and the level shift. From the knowledge of the trends and their errors, the significance of the trends has been estimated using standard statistics which reveal that a trend is significant on a 95 % confidence level if its absolute value is greater than two times its error.

The reasons for the level shifts between GOME and SCIAMACHY water vapour columns are complex interactions between differences in the measurement times, instrumental differences and the natural variability of water vapour. SCIAMACHY onboard ENVISAT is crossing the equator at 10:00 local time, while GOME onboard ERS-2 crosses the equator at 10:30 local time and these 30 minutes time delay are sufficient to change atmospheric conditions slightly due to the high variability of water vapour (transport, dynamics, clouds, diurnal cycle). Thus the instruments measure slightly different atmospheric conditions. This is supported by the fact, that the size distribution of all fitted level shifts (for each grid point) is slightly narrower than Gaussian distributed around zero and shows no systematic signs. On the instrumental side, GOME has a resolution of typically 40 km x 320 km while SCIAMACHY's resolution is better with 30 km x 60 km. Therefore it is possible, that a GOME measurement (relatively large pixel) is rejected due to large cloud fraction, but SCIAMACHY (relatively small pixel) can resolve the cloud free or less cloudy parts inbetween the GOME measurement. Such situations are most probably connected with high humidity, hence SCIAMACHY is measuring more of these wet scenes than GOME yielding to slightly higher water vapour columns. This can be seen in the spatial distribution of the level shifts, where at the equator mostly positive level shifts are observed. It is important to note, that the level shift has an individual magnitude for every grid pixel (time series), because it depends on the atmospheric conditions and thus has to be estimated from time series in a least square sense.

The application of the trend model to the global water vapour data reveals significant positive and negative trends for the period from January 1996 to December 2006 distributed over the whole globe. As can be seen from Fig. 1 significant increase in the water vapour column is observed for example in Greenland, in East Europe, in Siberia and on several locations over the ocean. Significant water vapour decrease is found in the north west USA, in Amazonia, Central Africa, the Arabian Peninsular, on several locations over the ocean and over Antarctica.

2.11 Comparisons of CMSAF water vapour products to other satellite and in situ data, Jörg Schulz (DWD)

The data sets mentioned in the general contribution about the CMSAF have been compared to several in situ data sets and also cross comparisons among the CMSAF products have been performed.

Four different comparisons to other data sets were presented at the workshop:

1. SSM/I vs. the pre-release of the ECMWF interim reanalysis for 1989-2000: This comparison done with data in grid representation and for monthly time scale revealed very small differences showing mean absolute deviations between 1.18 to 1.74 mm and rms deviations from 1.5 – 2.3 mm at a dynamic range from 2-70 mm. Bias errors are small and most pronounced in tropical and very dry Arctic areas.
2. SSM/I and ATOVS data were compared for the year 2004: Here a slight underestimation of high water vapour contents in the Tropics from ATOVS but a slight overestimation for medium and low water vapour contents was found. The mean absolute deviation between both data sets is approximately 2.5 mm.
3. Comparisons of ATOVS with data from the radio occultation instrument CHAMP for 2004 and 2005 showed that both instruments agree best in the middle to upper troposphere between 700 and 300 hPa where systematic differences are in the order of 3% of the mean value.
4. Comparisons of ATOVS to globally distributed radiosonde data for the years 2004 and 2005 revealed a positive bias of ~1.5 mm for ATOVS which is fairly constant in time. During the investigated period the NOAA-18 satellite carrying the first MHS instrument was introduced into the processing. The temporal structure of bias and rms deviation remained unchanged, i.e., the missing intercalibration of sensors doesn't make this data set useless for climate analysis.

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2.12 MERIS water vapor validation using GPS, Olivia Lesne (ACRI)

The objective of the ESA project (Category 1 CAL/VAL project nr. 1429) is to validate the MERIS water vapour products through comparison with the GPS Integrated Water Vapour (IWV) in overflights over the ground based GPS network. The GPS system is a tool initially designed for positioning and navigation. As widely demonstrated, the GPS can also provide a reliable estimate of the Zenith Tropospheric Delay (ZTD) which can be used to derive the Integrated Water Vapour (IWV) content of the atmosphere. In the framework of the European project TOUGH, ACRI-ST processed in near real time (NRT) GPS data of more than 40 stations in Western Europe that we used for the comparisons.
We first examined our GPS ZTD estimates and resulting IWV through comparisons with independent equivalent data from radiosonde profiles and HIRLAM numerical weather prediction model over a two and half year

period (July 2003 to December 2005). Results show monthly biases better than 2 kg/m^2 between IWV derived from GPS and from radiosonde with standard deviations better than 1.5 kg/m^2 in winter and less than 3 kg/m^2 in summer. The GPS-HIRLAM IWV residuals are better than 1.5 kg/m^2. Standard deviations are less than 1.5 kg/m^2 in winter and less than 2.5 kg/m^2 in summer.
We then compared the resulting NRT GPS IWV with MERIS RR data from second re-processing. We proceeded to the systematic extraction of MERIS data over the selected GPS sites. The data has been retrieved within areas of 30x30 and 10x10 pixels around each calibration site, in order to provide a spatial average. To obtain the average value over these macro-pixels, some filtering has been performed using Product Confidence Data (PCD) flags and using MERIS surface pressure (value compared with z-corrected ECMWF pressure). Results show a good agreement between IWV estimates derived from GPS measurements and from MERIS instrument. When considering all data, the mean error is up to 0.5 g/cm^2 and with appropriate filtering, mean error falls below 0.2 g/cm^2 and RMSE around 0.35 g/cm^2. Results are slightly better when the average values are taken on areas of 10x10 pixels and could be improved using post-processed GPS data instead of NRT.
Results also show that cloud contaminated pixels must be identified and properly flagged in the MERIS products.
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2.13 Comparision with Global Radiosonde Network, Niilo Kalakoski (FMI)

Preliminary GOME-2 AMC-DOAS total water vapour column product version 0.4 was compared with radiosonde measurements from UK Meteorological Office global radiosonde dataset acquired via British Atmospheric Data Centre (BADC). At his stage comparison was only carried out for three Finnish stations: Jokioinen, Jyväskylä and Sodankylä. For Jokioinen and Sodankylä, radiosonde data was available from March to September 2007 and for Jyväskylä from May to August 2007. Comparison showed that for these three stations, GOME-2 total column underestimates radiosonde-based water vapour total column by 14%, with RMS error of 66%. Further comparisons will be performed using larger number of stations once the remaining data has been processed.

2.14 GOME and SCIA Intercomparison, Slijkhuis Sander (DLR)

Datasets used
Complete global datasets of H2O retrievals, using all available GOME data from 2003, were delivered by Thomas Wagner from MPI Mainz (previously at IUP Heidelberg) and Stefan Noel from IFE Bremen. The Mainz-Heidelberg data contain vertical column densities (VCD) of H2O and error on VCD, in units of $molecules/cm^2$. In the comparison these were converted to g/cm^2. The Mainz-Heidelberg algorithm has an option to perform cloud screening, but for the delivered dataset this was switched off. The Bremen data were calculated using the AMC-DOAS (airmass-corrected DOAS) algorithm. Apart from VCD H2O and error, in units of g/cm^2, it also provides an airmass correction factor, which may be used as quality indicator. Data with low airmass correction factors (below 0.8), usually indicating cloud contamination, were not included in the dataset.

Result

Action Item

SCIAMACHY AMC-DOAS data from 2003 and 2004 were also delivered. A qualitative comparison, based on quick-look images, was made with MERIS browse images from the ESA-ENVISAT webpage, and with SEVIRI images provided by Marion Schroedter-Holmscheidt from DLR-DFD.

Inter-comparison between GOME data products

At first glance, a worldmap of retrievals for 1 day shows a very high correlation of the retrieved H2O columns. Virtually every feature seen in the Mainz-Heidelberg data is also seen in the Bremen data (with the exception of cloudy scenes where Bremen has gaps). However, the VCD retrieved by the Mainz-Heidelberg algorithm is systematically larger.

A plot of VCD along the orbit confirms this impression: the VCDs of both algorithms follow exactly the same pattern, but with a systematic offset. For the central part of the orbit (SZA below 50-60o), the Mainz-Heidelberg VCD is larger by ~20%. For larger SZAs (solar zenith angle) this ratio increases until 2 to 3 in the polar regions, but the H2O column itself is very low there. The absolute differences are between ~0.15 and ~0.6 g/cm^2, and generally follow the VCD values (as expected for a constant ratio). A scatterplot of either the difference, or of the ratio, versus VCD suggests a somewhat different behaviour for very high solar zenith angle. Thomas Wagner suggested that this may be due to the treatment of snow/ice, which generally is present in this case. A significant dependence on GOME scan angle is not observed.

World plots of the VCD difference, and of the VCD ratio, confirm this behaviour for other orbits too. The behaviour is systematic, and (using visual inspection) independent of season as well.

The retrieval errors quoted on the products are completely different. The Bremen product quotes errors of ~0.2 g/ cm^2, fairly independent of VCD, whereas the Mainz-Heidelberg products has errors from ~0.4 g/ cm^2 to >1 g/ cm^2, correlating with VCD. Stefan Noel remarked that the Bremen errors denote precision, whereas the accuracy may be inferred from the value of the airmass correction factor (at present only qualitatively). The error from Mainz-Heidelberg is an accuracy error, including cloud errors, but seems rather high. It seems that either error estimate would need improvement, to be really useful for external data users.

Comparison to other instruments

This comparison was only made qualitatively, by visual inspection of world plots. As starting point we took the AMC-DOAS retrievals of SCIAMACHY.

Comparison of SCIAMACHY to GOME showed a very high correlation between the two, which indicates that the algorithm is not sensitive to ground pixel size. Comparisons of SCIAMACHY to MERIS browse products also showed a high correlation, both in terms of features and also of total column (although the visually detectable difference is probably not smaller than ~0.5 g/cm^2). There may be some differences at the highest values, but as these are generally associated to clouds that may simply be due to different cloud screening. Comparison to SEVIRI data were hampered by the fact that either data set showed large gaps (SCIAMACHY because of limb measurement time) without much overlap. Therefore MERIS was used as proxy. The matching between MERIS and SEVIRI was clearly worse than between MERIS and SCIAMACHY. However, the SEVIRI data are based on measurements spanning several hours (whereas SCIAMACHY and MERIS measure simultaneously), and also the algorithm used was not optimized for scientific quality but for the needs of the solar industry.

Conclusions

- ~The Mainz-Heidelberg data and the Bremen data show a very high correlation in H2O column, but have a systematic difference of ~20%
- ~The error estimates of both algorithms are completely different, neither is quite satisfactory
- Qualitatively, there is good matching between H2O features retrieved from GOME/SCIAMACHY and from MERIS.

3. Discussion Points, Conclusions and Recommendations, summary by S.Slijkhuis (DLR)

The final discussion quickly focused on validation aspects:

- All instruments mentioned during the workshop provide data which may be useful for validation. SSM/I provides high accuracy but only over ocean. MERIS provides good data over land. AMSU may be very useful in polar regions, only for low H2O column. GPS retrievals have high potential for accurate measurements, but the accuracy depends on the processing algorithm used by each station; the near-real time algorithms may have (slight) biases.
- Inter-comparisons are sensitive to cloud selection effects. A bias between various instruments may just be caused by differences in cloud screening. But validation on clear pixels only is also not optimal, since this systematically selects on lower H2O values.
- J. Fischer remarked that a protocol would be needed for inter-comparisons, where at least record would be kept of processing versions and data selection criteria used.

Specifically for the H2O retrievals from GOME:

- During the workshop it appeared that inter-comparisons of various instruments always displayed a scatter of at least 0.25-0.3 g/ cm^2, which might be just a limit induced by natural variability. In this light, the two GOME algorithms (Bremen and Mainz-Heidelberg) are already within each other's error bars. Rather than preferring one algorithm over the other, by comparison to data from other instruments, it would be useful to understand what causes the differences.
- Possible causes of the differences for the two GOME datasets might be use of different cross-sections, or use of different ground albedos or snow/ice artifacts. To be checked by the algorithm developers.
- A cloud screening or cloud quality flag would be needed for an operational GOME-H2O product.
- A ghost H2O column under clouds could be derived for GOME. However, this was not seen as preferable. There are already many H2O datasets around which use model input, unfortunately mostly in a virtually untraceable manner. A model-independent data set from GOME would be of more value than one which uses model input to achieve "better" global averages.

On trend analysis:

- One needs to be extremely cautious with trends derived from a dataset which span less than 10-15 years.
- It is questionable if global or hemispheric trends are useful, because there are so many biases and selection effects (clouds being one of those). For regional trends these effects are often easier to identify. However, there is always a question in how far derived H2O trends are caused by cloud trends which creep into the cloud selection.

- There are pros and cons for excluding known anomalies (e.g. El Niño) from trend analysis. No clear recommendation came out of the discussion.

4. Contribution to the current aims of AT2 and ACCENT, summary by D. Loyola (DLR)

The satellite water vapour retrieval workshop contributed to the following aims of AT2:

- The continuation of the co-ordination and optimisation of the efforts of European scientists in the retrieval of the data products for tropospheric research from the measurements by instrumentation aboard orbiting satellite platforms.
- Encouragement of validation and intercomparison excercises to verify and improve the quality of satellite data.

In the same way, this workshop contributed to the overall goals of ACCENT, specially:

- ... to develop and maintain durable means of communication and collaboration within the European scientific community.