COSE:
COMPILATION OF ATMOSPHERIC OBSERVATIONS IN SUPPORT OF SATELLITE MEASUREMENTS OVER EUROPE.

Martine De Mazière

Belgian Institute for Space Aeronomy (BIRA-IASB), Ringlaan 3, B-1180 Brussel, Belgium
martine@oma.be

ABSTRACT

COSE represents a European effort to improve and widen the exploitation of Earth Observation (EO) data. It will provide the international EO users community with a validated, consistent and well-documented data set of mainly stratospheric constituent columns and/or profiles, by co-ordination of ground-based observations at existing stations throughout Western Europe. The network counts 15 European partners. The experimental datasets involved are derived from ground-based UV/VIS (UV-visible), FTIR (Fourier-Transform Infrared), microwave and lidar remote sensing data, FTIR surface measurements, and O_3 and aerosol in-situ sonde data. The covered species are: O_3, NO_2, ClO, important reservoirs and tracers, CO, CH_4, and aerosol. The data from past and ongoing time series are being archived in a dedicated database for easy immediate and future exploitation, e.g., satellite validation activities, data assimilation and scientific studies. Active participation of some representative EO customers assures that the delivered data sets satisfy the requirements of the EO user community, to be specified in a dedicated Customer Requirements Document.

COSE is supported through 1999 - 2000 by the EC Centre for Earth Observation (CEO) programme. This paper will focus the interaction within COSE between EO data providers and customers.

1. INTRODUCTION

Any investigation related to Earth Observation is in need of coherent sets of validated Earth Observation (EO) data, with a well-known precision, accuracy and clearly documented qualities. It is well recognised that the sources of such data are mainly to be found in the combination of satellite data, air-borne (aircraft, balloon) measurements and ground-based observations, once the various phases of validation have been performed successfully. The important role of ground-truth observation networks has been demonstrated in the recent past, e.g., for the TOMS and GOME validation.

Network operations started in the 50s with the world-wide Dobson network, for the monitoring of the ozone abundance, based on one single instrumental technique. The actual needs of the Earth Observation Community are ever expanding: the complexity of the Earth System requires ever more complex experiments covering a wide range of observed species on a global spatial and temporal scale. Also, steadily increasing numerical computation facilities have allowed the development of complex Earth atmosphere and climate models that deal with dynamic, chemical and radiative variables, on different temporal and spatial scales. Therefore, next to the ground networks based on one single technique, the value of ground observation networks which can provide a more complete and coherent experimental data set underlying such a more global view becomes evident. The NDSC has been defined on this rationale.

Thus far, the networks have devoted a lot of efforts in intercomparisons of instrumental techniques and data analyses, in order to improve the consistency among the various measurements, and to assess their ultimate precision and accuracy. By now, one has come to a point that techniques and corresponding data are well understood by the specialised experiment teams. The results of these past efforts should be brought to the attention of additional possibly non-specialised EO users, and the data sets that result from such a concerted network approach should be made accessible to them and be exploited to their benefit: this is the global objective of the COSE project.

In summary, the COSE global objectives are to co-ordinate ground-based observations at existing stations, mainly in Europe, and to provide the EO users community with a validated, consistent and well-documented data set of stratospheric compounds, columns and/or profiles, that builds on past time series, and that will be archived in a data base for immediate and future exploitation.

Active participation of some representative EO customers will assure that the delivered data sets will come up to their specific requirements.

COSE runs from October 1, 1998 until September 30, 2000.

2. METHODOLOGY

2.1 Representation of Customers

Some representative EO customers have been identified, for active participation to COSE. They are: (i) satellite experiment and validation teams, (ii) the THESEO scientific community, (iii) database customers, and (iv), data assimilation teams.

(i) The satellite experiment and validation teams have committed themselves towards their funding national organisations and international space agencies to deliver validated level-1 and level-2 products. Therefore they need easy access to certified, well-documented ground-truth data sets that are obtained in co-ordination with the satellite validation commissioning phases. The project will demonstrate the value of its deliverables for satellite validation, because it will be operational in part of the active validation phases of most customer satellites. Satellite customers involved are ODIN, SAGE-III, GOME, and MOPITT. Through the last one, important exchanges with NASA will happen. At the same time COSE will initiate the build up of the database required by the ENVISAT-1 user by mid-2000 nominally, an effort to be continued afterwards.

(ii) The THESEO community is much interested in observational data at sub-tropical to high latitudes in Europe

in 1998-1999 time frame, to complement the experiments that have been selected for contribution to the THESEO campaigns. The latter main objectives are: the investigation of northern mid-latitude ozone loss in the lower stratosphere, and the study of connections between the middle latitude lower stratosphere, the polar vortex and the sub-tropics, and the upper troposphere. Access to additional and well-qualified data will significantly complement the THESEO efforts and enhance their cost-effectiveness.

(iii) The Norwegian Institute for Air Research (NILU) has commitments towards ESA to collect qualified data on species like O_3 and NO_2, for the actual GOME/ERS-2 validation, and in addition HNO_3, N_2O, and OClO for the upcoming ENVISAT experiments validation. Ground-based data should match satellite overpasses and span the latitude range from the sub-tropics to the polar region, because of the polar orbits of ERS-2 and ENVISAT. Therefore its database called NADIR can get populated partly via COSE. The same database is used within THESEO.

(iv) Data assimilation is the concurrent use of information from observations and models to both extract the maximum of information from the observations and to improve the quantitative abilities of the model. Prior to the assimilation analysis is quality control, which includes pre-processing of the observational data; it strongly impacts the final assimilated data product. Therefore data assimilation teams foster a strong interaction with the experiment teams. It is one of the objectives of this project to establish this interaction and to provide the assimilation teams with the requested tools that are needed to develop a proper data assimilation.

The customers have engaged themselves to active participation: together with the data providers, they will establish the data needs, conventions as to formats and database structure, etc.

2.2 COSE activities

The methodology adopted here to meet the objectives consists of, (i), an experimental (observational) phase, for the data acquisition, (ii), a so-called consolidation phase in which the 'raw' experimental data are transformed into products and information directly supporting the customers applications, under the latter supervision and approval, and (iii), a demonstration phase. All three must run in parallel.

2.2.1 Experimental Phase

Table I gives an overview of the COSE network: data products, experimental techniques and partners involved. COSE covers southern to polar regions, mainly in Western Europe. All instrumental techniques involved are state-of-the-art and the major part of them have been validated in international measurement and algorithm validation campaigns. Only the capabilities of the EMCOR radiometer based on the latest superconducting diode technologies, for the measurement of ClO profiles at the Jungfraujoch, must still be proven.

2.2.2 Data consolidation Phase

In the data consolidation phase, the raw data will be converted into added-value data products. It comprises:

- the conversion of the delivered products representation to a requested one. For example, mixing ratio of constituents versus pressure, or concentration versus altitude. As to aerosols, a model is needed to convert measured backscatter ratios at a given wavelength to aerosol number densities or wavelength-dependent optical thickness, the quantities asked for by transport model studies or some satellite experiments like SAGE or GOME. The goal is to define a uniform representation or conversion between various sites.

- the construction of composite ozone profiles for sites where different techniques have quasi-simultaneous measurements, but with different vertical ranges and resolutions, and different error statistics, to provide a profile of the largest possible vertical range, or at least of the vertical range requested by the customer. The composite profile will be delivered together with the kernel function used for building it. This effort will allow comparisons of columns with integrated profiles where appropriate. Relevant sites are the alpine station, Sodankyla, and Ny-Alesund.

- the improvement of the NO_2 vertical column abundance, through a more accurate determination of the Air Mass Factor (AMF) that is required in the zenith-sky DOAS technique to convert the directly measured NO_2 slant column to the corresponding vertical column. Several studies have shown that the AMFs for ozone are dependent on the atmospheric model assumed in the radiative transfer model used for the AMF calculation, i.e., on the assumed temperature, pressure and ozone profiles. The ongoing GOME validation has demonstrated (i) the importance of exchanging information as to the model parameters used in each algorithm, and (ii) the mutual benefits of these exchanges for improving the algorithms and data interpretations. In this regard, much progress has been made for the O_3 AMF models, but there is still an urgent demand for analogous work concerning the NO_2 AMF. The latter climatology should be established for improving the satellite products based on the DOAS technique (GOME, and SCIAMACHY on ENVISAT-1, ODIN, ...). This is feasible with the existing observational data, especially from UARS, SAGE-II and balloon experiments. Therefore, a consistent set of AMFs for ozone and NO_2 will be defined and validated for all stations involved that operate UV/VIS spectrometers.

- the further exploration and validation of recently developed methods for the retrieval of vertical profiles from ground-based observations, in particular of NO_2 from UV/VIS DOAS observations. It's the purpose to enhance the effectiveness of the ground networks for the customers, by (i) adding requested deliverables (vertical profiles) that are actually unavailable from ground-based observations, and (ii) improving the delivered column accuracy. Indeed recent studies concerning these methods report, in addition to the profile information, an improvement in the accuracy of the vertical columns. A sensitivity study to analyse the quality of the retrieved profiles with respect to a number of critical factors (solar zenith angle, perturbed chemistry, quality of measurements, ...) will be performed. If feasible, some instruments will be selected for the retrieval of vertical profiles from new and possibly historic data sets, the

Table I *Latitudinal coverage of network, and distribution of measurements and techniques per site and per partner. The partner affiliations are (the responsible person between brackets): AWI for Alfred Wegener Institute (R. Neuber); BIRA for Belgian Institute for Space Aeronomy (M. De Mazière); CNRS-SA for Service d'Aéronomie - Centre National de Recherches Scientifiques (C. David); IFU-FhG for Fraunhofer Institut for Atmosphärische Umweltforschung (R. Sussmann); IVL for Swedisch Environmental Research Institute (B. Galle), NILU for Norwegian Institute for Air Research (G. Braathen); UBE for University of Bern (D. Maier), UBxI for Université de Bordeaux (J. de La Noë); ULG for the Université de Liège - Institut d'Astrophysique et de Géophysique (R. Zander); UNI BREMEN for the University of Bremen (U. Klein, A. Richter). 'Reservoirs and tracers' include $ClONO_2$, HNO_3, HCl, HF and N_2O. OClO is put between parentheses if its observation is possible only under special conditions or if it is not proven yet. MW = microwave, FTIR-hop= FTIR horizontal open path; DOAS= UV/VIS DOAS, incl. SAOZ. Additional contributing SAOZ instruments operated by CNRS-SA in the Northern mid-to high latitude hemisphere are located at Salekhard (66°N, 67°E), Zhigansk (67°N, 123°E), and Scoresbysund (70°N, -22°E). On user request or for obtaining a more global latitudinal coverage, sub-tropical SAOZ measurements by the same partner can also be included,: they are located at (1°N, 173°E), (21°S, 55°E) and (22°S, -49°E).*

Site	Lat (°N), Long (°E)	Instrumental technique	Product	Column/ Profile / Surface	Partner
Alpine Station	**40°-50° lat. band, Western Europe**				
ISSJ	46 °N, 8 °E	FTIR	reservoirs, tracers, O_3, NO_2, CO, CH_4	C	BIRA, ULG
		DOAS	O_3, NO_2, (OClO)	C	BIRA
		MW	ClO, O_3, HNO_3	P (C)	UBE, UBx1
OHP	44 °N, 6 °E	Lidar	O_3, aerosols (PSCs)	P	CNRS-SA
		Dobson	O_3	C	"
		DOAS	O_3, NO_2, (OClO)	C	"
Pl. Bure	44 °N, 6 °E	MW	O_3, ClO	P (C)	UBx1
Bordeaux	45 °N, -1 °E	MW	O_3	P	UBx1
		Dobson	O_3	C	"
Zugspitze	47 °N, 10 °E	Lidar	aerosol, PSCs	P	IFU-FhG
		FTIR	reservoirs, tracers, O_3, NO_2, CO, CH_4	C	"
		FTIR -hop	CO, CH_4	S	"
B	**50°-60° lat. band, Western Europe**				
Bremen	53 °N, 9 °E	DOAS	O_3, NO_2, (OClO)	C	UNI BREMEN
C	**60°-67° lat. band, Western Europe**				
Harestua	60 °N, 10 °E	FTIR	reservoirs, tracers, O_3, NO_2, ClO, CO, CH_4	C	IVL
		DOAS	O_3, NO_2, OClO	C	BIRA
		LIDAR	O_3, aerosol (PSCs)	P	IVL
Sodankyla	67 °N, 27 °E	O_3 sondes	O_3	P	AWI
		MW	O_3	P	"
		DOAS	O_3, NO_2, (OClO)	C	CNRS-SA
		LIDAR	Aerosol	P	AWI
		Backscatt. sonde	Aerosol	P	"
D	**high (polar) latitudes, Western Europe**				
Andoya	69 °N, 16 °E	DOAS	O_3, NO_2, (OClO)	C	NILU
		LIDAR	O_3	P	"
		O_3sondes	O_3	P	"
		LIDAR	aerosol (PSCs)	P	CNRS-SA
Thule	76 °N, -69 °E	O_3sondes	O_3	P	AWI
		DOAS	O_3, NO_2, (OClO)	C	"
Ny-Alesund	79 °N, 12 °E	FTIR	Reservoirs, tracers, ClO, O_3, NO_2, CO, CH_4	C	AWI
		Lidar	aerosol, PSCs, O_3	P	"
		O_3sondes	O_3	P	"
		DOAS	O_3, NO_2, OClO	C	UNI BREMEN
		DOAS	O_3, NO_2, (OClO)	C	NILU
		MW	O_3, ClO	P	UNI BREMEN

latter being requested by the data assimilation studies, databases, climatology studies (SPARC), etc.

- evaluation of the few recently developed techniques for the derivation of information about the vertical distribution of absorbers like HCl, HNO_3 and O_3 from FTIR ground-based measurements: the mutual agreement between the obtained results, their reliability, applicability to different species, etc., must be examined in order to select a most appropriate method to be used within the network to satisfy the customers requirements, if at least one of the techniques is found to be satisfactory. Actually, no ground-based profile data are available for the MIPAS products validation. Again, column data may be delivered with a higher accuracy.

- documenting the products. Apart from the experimental observation parameters (SZA (solar zenith angle), local and universal time, integration time, spatial and vertical resolution, ...), their quality, limits of confidence, known biases... will be joined to the data. Information regarding the data processing (algorithm parameters, auxiliary data used, ...) must be added also. In consensus among data providers and customers, COSE will set some guidelines to be respected by all data providers. General data documentation related to the instrumental technique and/or observation site will be made accessible on the WWW.

- collecting ancillary data (meteorological parameters,...) and possibly interesting auxiliary information (complementary observations at nearby stations, from satellites, meteorological synoptic data corresponding to the spatial resolution of the measurements, gradients in the fields of stratospheric compounds or parameters, like ozone or potential vorticity.....) that are useful for an optimum interpretation of the results. Discussions among the partners and the customers should lead to an agreement in this respect.

2.2.3 Demonstration Phase

The customer satisfaction will be measured through:

- delivery of data products to THESEO, as requested by them, for complementing their data. The THESEO efforts for analysis and interpretation of the combined data and associated results will demonstrate the value of this project's deliverables for THESEO and possibly additional scientific users in the future. The COSE database will be part of the THESEO database, with mutual access rights for both parties.

- development of a COSE dedicated Web site, and a COSE database, with its catalogue distributed on the WWW. The COSE database will be an integral part of NADIR at NILU, which was already designated to archive the validation data for ENVISAT-1. The exploitation of the database by the customers will be evaluated.

- effective contributions to satellite validations for NO_2 (total columns)/GOME, and NO_2 (profiles)/ODIN. Any progress regarding the zenith-sky AMF calculations for NO_2 will significantly improve the value of the validation for the GOME and ODIN teams and will help these customers to improve their processing algorithms and resulting data. If vertical profiles of NO_2 can be delivered, the GOME team will even be more satisfied, because of the associated increased accuracy of the total columns. At the same time, the validation of the NO_2 profiles measured by ODIN can be initiated. Validation of satellite NO_2 profiles with ground-based data, with the advantage of extended spatial and temporal coverage, has never been possible before.

- effective contributions to the validation of O_3, aerosol and ClO profiles measured by ODIN. Access to network-type ClO ground-based profile data is a 'primeur'.

- effective contributions to the validation of CO and CH_4 total columns obtained by MOPITT.

The satellite validation efforts will demonstrate the adequacy of the project's deliverables for actual and upcoming satellite validation requests. ENVISAT-1 is considered to be an important future customer.

2.3 Interactions between customers and data providers

The methodology includes the development of a Customers Requirement document (CRdoc) and a Data Consolidation document (DCdoc), in which the data needs and specifications, per data product, are specified precisely by each of the parties involved. The development of these documents is an interactive and iterative learning process, in which customers and data providers are actively involved. In a first iteration, the following items have been selected for specification, for each data product (per site, per instrument): timing of observation (local time, am/pm...), frequency of observation, observation conditions (winter, clear sky,...), data accuracy or bias, data precision, vertical range of profile or column extent, horizontal extent of the sampled airmass, natural coordinates of the delivered product, and product delivery time. An annex will allow to specify some data processing parameters or auxiliary data, like for example, the use of standard retrieval algorithms, the use of NCEP pressure and temperature profiles, the spectral microwindow for retrieval, etc. The preliminary results of this exercise indicate a need to establish a sound consensus regarding the specifications one announces to the customers. For example, how do we define and calculate precision and accuracy? What is the best way to describe the sampled airmass? Should the integration time of the measurement be mentioned? etc. But the draft version of the DCdoc also shows that interesting information may pop us, like, e.g., the difference in precision of the UV/VIS DOAS NO_2 column measurements between a site like Bremen and one like Ny-Alesund, due to the difference in local tropospheric pollution.

3. SUMMARY

The activities within COSE are primarily intended to assess and implement the complementarity between observations performed from a network of ground-based European monitoring stations and from satellites. While the latter provide global information about the Earth's environment over periods commensurate with their lifetimes (typically 3-5 years, during which operation degradation and calibration drifts may occur), the former has the advantage of long-time, multi-decadal operation with regular stability and external consistency and quality tests.

COSE will, therefore, greatly contribute to the synergistic use of data from satellite and ground-based origin for long-term atmospheric studies allowing to assess current environmental issues, in particular the ozone depletion in the northern hemisphere. It will be valuable to the THESEO community and to international research programmes such as WCRP/SPARC, NDSC, ... The archived data will be beneficial to any current and future atmospheric studies over Europe.

COSE should be a step forward towards the validation and scientific exploitation of ENVISAT-1. Its efforts should be extended and expanded throughout the ENVISAT's lifetime, and be portable to a large extent to follow-on missions like METOP (Meteorological Operational satellite series). Additional products and additional sites may be included, for example, BrO among the products list and Southern-European and Mediterranean sites among the network stations. Additional customers might be attracted.

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