FRANCE

Ozone and UV radiation research in France is managed by the CNRS – Institut National des Sciences de l'Univers (INSU) under a dedicated Programme National de Chimie de l'Atmosphère (PNCA). Long term monitoring activities relevant to NDSC are coordinated by the Institut Pierre Simon Laplace (IPSL). Space and balloon components are managed by the Centre National d'Etudes Spatiales (CNES). Additional contributions are provided by the Institut Paul Emile Victor (IPEV), Météo-France, the Ministère de l'Ecologie et du Développement Durable, the Ministère de la Recherche, the Institut National de Recherche Agronomique (INRA) and a number of Universities. Many of the above programmes are also supported by the European Commission under the 5th and 6th Environmental Programmes.

The research include the long term monitoring of the stratosphere and UV-B in the frame of NDSC at a variety of sites, the study of ozone depletion related mechanisms in polar areas, at mid-altitude and in the tropics using balloon, aircraft and space borne instruments, most of them being operated in cooperation with other European and international institutes.

OBSERVATIONAL ACTIVITIES

Ground-based

France is running two primary stations of the international Network for Detection of Stratospheric Change (NDSC) at the Observatoire de Haute Provence (OHP) and the Antarctic station of Dumont d'Urville (DDU), a complementary site at Reunion Island in the Indian Ocean and a number of instruments at other locations in cooperation with local institutes: a lidar at Alomar in Norway and the SAOZ UV-Vis spectrometers at Scoresbysund (Greenland), Sodankyla (Finland), Salekhard and Zhigansk (Federation of Russia), Bauru (Brazil), Tarawa (Republic of Kiribati) and Kerguelen Island.

The list of instruments at OHP includes a series of lidar for stratospheric temperature, aerosol, stratospheric and tropospheric ozone and water vapour, a SAOZ UV-Vis spectrometer, a BrO UV spectrometer of IASB-BIRA in Belgium, an automated Dobson from NOAA, weekly ozonesondes and a spectral UV-B monitor at the nearby Alpine station of Briancon. Additional Dobson measurements conducted previously at Bordeaux have been moved to Lanemezan.

In Antarctica, the instruments operating since 1988 are a PSC / aerosol lidar in cooperation with the Italian CNR, a SAOZ, a UV-B monitor and ozonesondes at Dumont d'Urville. The ozone lidar closed in 2001, has bee replaced in 2005. An additional SAOZ is in operation since 1995 at the sub-Antarctic Island of Kerguelen. The installation of a SAOZ and a microwave radiometer are anticipated at the inland French-Italian station of Concordia expected to run year round after 2006.

At the tropical site of Reunion Island, the instruments operating are a temperature / aerosol lidar, stratospheric and tropospheric ozone lidars, a SAOZ and weekly ozone sondes. A high altitude station is under construction at Maïdo at 2500 m asl for hosting all previous instruments after 2006 together with a microwave radiometer for ozone and water vapour and a FTIR operated by the Belgium IASB-BIRA.

France is also responsible for the temperature lidar measurements at the Norwegian-German lidar station of ALOMAR in Norway.

While part of the data (SAOZ ozone / NO_2 and ozonesondes) are made available in near real time to WMO and to the European data base at the Norwegian Institute for Air Research (NILU) for research programmes and satellite validation, they are made publicly available after reprocessing through the NDSC archive centre.

Summary of Ground-based observations

Column measurements of ozone and other gases /variables relevant to ozone loss

SAOZ Ozone and NO2 at Scoresbysund (Greenland), Sodankyla (Finland), Salhekard (W. Siberia-, Zhigansk (E. Siberia), OHP (France), Bauru (brazil), Reunion Island, Kerguelen and Dumont d'Urville (Antarctica)
Dobson at OHP and Lanemezan (France)

Profile measurements of ozone and other gases /variables relevant to ozone loss

Stratospheric Ozone lidar at OHP (France) and Dumont d'Urville (Antarctica)
Ozonesondes at OHP (France), Reunion Island and Dumont d'Urville
Stratospheric temperature lidar at at OHP (France), Reunion Island and Alomar (Norway)
Aerosol lidar at OHP (France), Reunion Island and Dumont d'Urville
Tropospheric ozone lidar at OHP (France) and Reunion Island

UV measurements

Broadband measurements at Dumont d'Urville (Antarctica)
Spectroradiometers at Villeneuve d'Asq and Briançon (France)

Calibration activities

NDSC intercomparison campaign of UV-Vis instruments in Norway, and ozone lidar intercomparison at OHP.

Satellites

Relevant to stratospheric ozone research, a variety of space activities have been carried out in France under the auspices of CNES:

- the scientific exploitation of the data of the Polar Ozone and Aerosol Monitoring (POAM) instruments of the Naval Research Laboratory in the United States placed on board the French CNES satellites (POAM II on SPOT III in 1994 and POAM III on SPOT IV in 1998), from which ozone destruction rates in the Arctic have been derived;
- the analysis of the measurements of the SMR instrument (ozone, water vapour and ClO) on board the Swedish-Finnish-Canada-French ODIN satellite placed in orbit in 2001 and still operating;
- the exploitation of the data of the French initiated GOMOS instrument on board the ESA ENVISAT satellite in orbit since March 2002, and more generally a participation to that of the two other stratospheric chemistry instruments MIPAS and SCIAMACHY; and,
- a strong involvement in the validation of the measurements of GOME-ERS-2, ODIN and ENVISAT from ground based and dedicated balloon flights measurements in the Arctic, at Mid-latitude and in the tropics

Finally, Météo-France is contributing to the preparation of EUMETSAT's Ozone Monitoring Satellite Application Facilities hosted by the Finnish Meteorological Institute. This facility will deliver ozone and minor constituents products derived from the GOME-2 and HIRS instruments on board METOP, the European meteorological polar platform to be launched in 2006. The derivation of ozone columns in the lower stratosphere from METEOSAT Second Generation and for METOP/HIRS is the specific contribution of Météo-France.

Aircraft

The two French research aircraft have been renewed for an ATR 42 and a Falcon 20, both anticipated starting operating in early 2006. France is also running since 1993 in cooperation with other European institutes and with support of the European Commission, the MOZAIC programme of in situ ozone, water vapour and NOy (since 2002) measurements on in-service commercial aircraft, from which tropospheric ozone climatology are derived at a number of airport worldwide.

Balloons

The French contribution to stratospheric balloon activities is twofold: CNES balloon operations in France, Sweden and Brazil for a number of European and international scientists, and development of scientific instruments designed for ozone related research at French laboratories.

The balloons used during the past several years include large open stratospheric balloons carrying heavy (500-600 kg) payloads for few hours (20 flights/year), small flexible and cheaper balloons which could be flown more frequently particularly in the Arctic in the winter for studying fast chemical changes (20 flights/year) and long duration balloons of two types: Infra-Red Montgolfier carrying 60 kg at 25 km flown for few weeks in the Arctic or in the tropics, and constant level super-pressure balloons carrying 20 kg at 19 km for few weeks.

Stratospheric chemistry instruments developed in France include: a FTIR (LPMA) for measuring profiles of long lived, reservoir and radical species; a tuneable diode laser system (SPIRALE) for the in-situ measurement of NOx and NOy species; a star occultation UV-Visible spectrometer (AMON) for the night-time measurement of O3, NO2, NO3 and OClO; and several light weight instruments flown more frequently on small balloons together with other European instruments at a variety of sites: the SAOZ UV-visible spectrometer for O_3, NO_2, BrO and OClO by solar occultation; the SALOMON moon occultation version; the SDLA diode laser for in-situ CH_4, CO_2 and water vapour; and the Rumba meteorological payload for long duration balloons.

Most recent balloon campaigns relevant to stratospheric dynamics and chemistry were:

- a European VINTERSOL campaign in the Arctic during the winter of 2002/2003 for the validation of ENVISAT, SAGE III and ILAS II as well as studying ozone depletion;
- an ESA-CNES ENVISAT validation campaign of long duration MIR balloon flights in Bauru (22°S) in Brazil in February 2003;
- a European HIBISCUS campaign of 18 short and long duration circumnavigation balloon flights at the tropics in Brazil in January-March 2004 for studying the impact of deep convection on the stratosphere;
- an ESA-CNES ENVISAT validation campaing of 5 large balloon flights in Teresina, Northern Brazil in June-July 2005;
- a VORCORE project of 20 long duration constant level balloon currently held (September 2005) in Antarctica for studying the dynamics of stratospheric vortex.

Planned in the 2006 is a balloon / aircraft campaign in West Africa in the frame of the new European FP6 SCOUT-O3 project for studying the Stratospheric Chemistry-Climate relationship.

Data interpretation, exchange and archival

Though the data are analysed through many cross-exchanges with international scientists and particularly Europeans within cooperative projects, France institutes have developed a full set of models ranging from Lagrangian, 3-D chemical transport (CTM), contour advection, meso-scale and assimilation models. While the experimental data as well the results of modelling relevant to European projects are archived into the NILU data base available through appropriate protocols, all

French space and field data relevant to the stratosphere are archived into a newly built national data base ETHER.

RESULTS FROM OBSERVATIONS AND ANALYSIS

A number of studies are being conducted based on the above observational data frequently in collaboration with foreign scientists and particularly European institutes within projects supported the European Commission. Among those studies, two are highlighted here as an illustration.

Figure 1 shows the results of the yearly evaluation of total ozone loss in the Arctic stratosphere since 1993 from the SAOZ ground based network illustrating the large inter-annual variability of the ozone destruction in relation with the meteorology of the vortex.

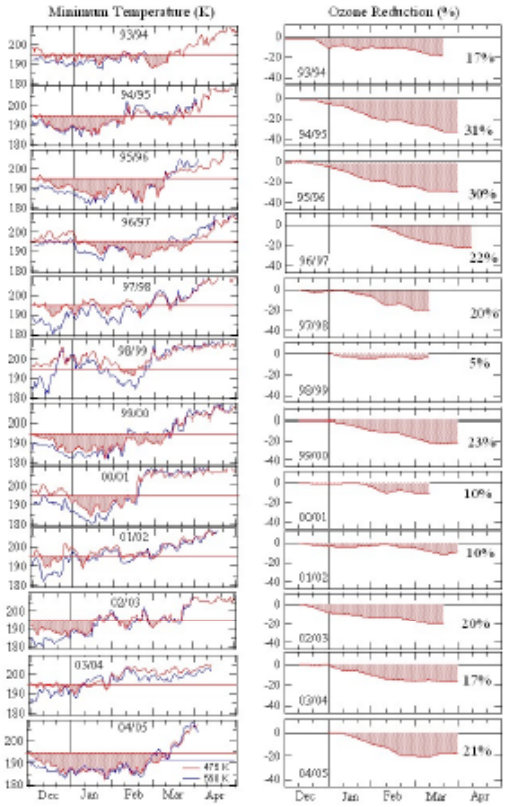

Figure 1: Estimation of amplitude of chemical stratospheric ozone reduction the Arctic during the winter season from the measurements of the SAOZ network. Left: minimum ECMWF temperature north of 60°N at 475 K and 550 K ; Right ozone chemical reduction after subtraction of the contribution of transport using a 3D CTM model. [Goutail et al., 2005].

Figure 2. shows a comparison of the 1985-2003 ozone concentration profiles trends above the Observatoire de Haute Provence evaluated from SAGE 2 and lidar observations. Although the exact figure depends a little on the period selected for the analysis, a consistent reduction of 4-7% / decade could be derived from both data sets in the upper stratosphere, and still of 1-3% at lower altitude.

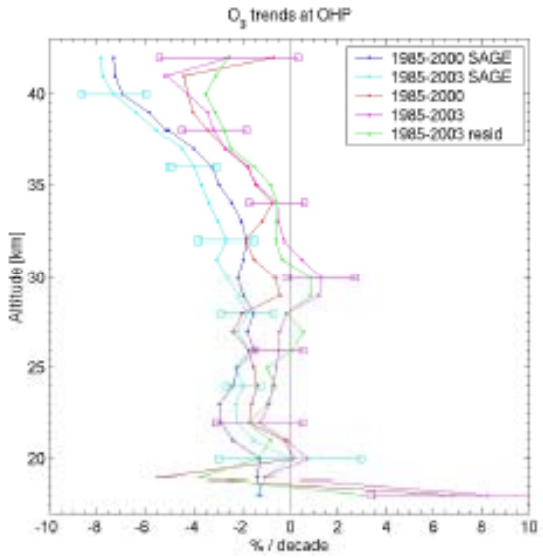

Figure 2: Stratospheric ozone reduction since 1985 above the OHP station in France derived from Lidar and SAGE II observations [Godin et al. 2005].

DISSEMINATION OF RESULTS

Data reporting

The SAOZ (ozone / NO_2) and ozonesondes data are made available in near real time to WMO, WOUDC and the ESA and EC data –bases at the Norwegian Institute for Air Research (NILU). All NDSC relevant data are deposited, after reprocessing, in the NDSC archive centre. In addition all French space and field data relevant to the stratosphere are archived into a national data base ETHER.

Relevant scientific papers

Brogniez, C., M. Houët, A.M. Siani, P. Weighd, M. Allart, J. Lenoble, T. Cabot, A. de La Casinière, E. Kyro, (2005) ozone column retrieval for solar UV measurements at ground level: Effect of clouds and results from six European sites, J. Geophys. Res. submitted

David, C.; Bekki, S.; Berdunov, N.; Marchand, M.; Snels, M. and Mégie, G.,2005, Classification and scales of Antarctic polar stratospheric clouds using wavelet decomposition, J. Atmos. Sol. Terr. Phys., 67(3), 293-300. doi: 10.1016/j.jastp.2004.07.043

Del Frate, F.; Iapaolo, M.; Casadio, S.; Godin-Beekmann, S., M. Petitdidier, 2005, Neural networks for the dimensionality reduction of GOME measurement vector in the estimation of ozone profiles,J. Quant. Spectrosc. Radiat. Transfer,92(3),275-291. doi:10.1016/j.jqsrt.2004.07.028

Denis, L.; Roscoe, H. K.; Chipperfield, M. P.; Van Roozendael, M. and Goutail, F., 2005, A new software suite for NO2 vertical profile retrieval from ground-based zenith-sky spectrometers, J. Quant. Spectrosc. Radiat. Transfer, 92(3), 321-333. doi: 10.1016/j.jqsrt.2004.07.030.

Goutail, F., J.-P. Pommereau, F. Lefèvre, M. Van Roozendaël, S. B. Andersen, B.-A. Kåstad Høiskar, V. Dorokhov, E. Kyrö, M. P. Chipperfield and W. Feng, 2005, Early unusual ozone loss during the Arctic winter 2002/2003 compared to other winters, Atmos. Chem. Phys., 5, 665-677.

Vandaele, A-C.; Fayt, C.; Hendrick, F.;Hermans, C.; Humbled, F.; Van Roozendael, M.; Gil, M.; Navarro, M.; Puentedura, O.; Yela, M.; Braathen, G.; Stebel, K.; Tørnkvist, K.; Johnston, P.; Kreher, K.; Goutail, F.; Mieville, A.; Pommereau, J-P.; Khaikine, S.; Richter, A.; Oetjen, H.; Wittrock, F.; Bugarski, S.; Frieß, U.; Pfeilsticker, K.; Sinreich, R.; Wagner, T.; Corlett, G.; Leigh, R., 2005, An intercomparison campaign of ground-based UV-visible measurements of NO2, BrO, and OClO slant columns: Methods of analysis and results for NO2, J. Geophys Research, 110, D8, D08305, DOI:10.1029/2004JD005423

Braathen, G. , Godin-Beekmann, S. , Keckhut, P. , McGee, T. , Gross, M. , Vialle, C. and Hauchecorne, A., 2004, Intercomparison of stratospheric ozone and temperature measurements at the Observatoire de Haute Provence during the OTOIC NDSC validation campaign from 118 July 1997, Atmos. Chem. and Phys. Disc., 4, 5303-5344.

Hendrick, F., B. Barret, M. Van Roozendael, H. Boesch, A. Butz, M. De Mazière, F. Goutail, C. Hermans, J.-C. Lambert, K. Pfeilsticker, and J.-P. Pommereau, 2004, Retrieval of nitrogen dioxide stratospheric profiles from ground-based zenith-sky UV-visible observations: validation of the technique through correlative comparisons, Atmos. Chem. Phys. Disc. , June 2004, 2867-2904.

Keckhut P., McDermid S., Swart D., McGee T., Godin-Beekmann S., Adriani A., Barnes J., Baray J-L., Bencherif H., Claude H., di Sarra A-G., Fiocco G., Hansen G., Hauchecorne A., Leblanc T., Lee C-H., Pal S., Mégie G., Nakane H., Neuber R., Steinbrecht W., Thayer J. 2004, Review of ozone and temperature lidar validations performed within the framework of the Network for the Detection of Stratospheric Change, J. Environ. Monit., 6 (9), 721-733, DOI: 10.1039/b404256e

Leblanc, T., McDermid, I. S. and Hauchecorne, A., 2004, A study of ozone variability and its connection with meridional transport in the northern Pacific lower stratosphere during summer 2002, J. Geophys. Res., 109 (D11), D11105, doi: 10.1029/2003JD004027.

Meijer, Y-J.; Swart, D-P-J.; Allaart, M.; Andersen, S-B.; Bodeker, G.; Boyd, I.; Braathen, G.; Calisesi, Y.; Claude, H.; Dorokhov, V.; von der Gathen, P.; Gil, M.; Godin-Beekmann, S.; Goutail, F.; Hansen, G.; Karpetchko,A.; Keckhut, P.; Kelder, H-M.; Koelemeijer, R.; Kois, B.; Koopman, R-M.; Kopp, G.; Lambert, J-C.; Leblanc, T.; McDermid, I-S.; Pal, S.; Schets, H.; Stubi, R.; Suortti, T.; Visconti, G. and Yela, M., 2004, Pole-to-pole validation of Envisat GOMOS ozone profiles using data from ground-based and balloon sonde measurements, J. Geophys. Res., 109(D23), D23305 , doi: 10.1029/2004JD004834

Randel, W., Udelhofen, P., Fleming, E., Geller, M., Gelman, M., Hamilton, K., Karoly, D., Ortland, D., Pawson, S., Swinbank, R., Wu, F., Baldwin, M., Chanin, M.L., Keckhut, P., Labitzke, K., Remsberg, E., Simmons, A. and Wu, D., 2004, The SPARC Intercomparison of Middle-Atmosphere Climatologies, J. Clim., 17(5), 986-1003.

Beig, G., Keckhut, P., Lowe, R.P., Roble, R.G., Mlynczak, M.G., Scheer, J., Fomichev, V.I., Offermann, D., French, W.J.R., Shepherd, M.G., Semenov, A.I., Remsberg, E.E., She, C.Y., Lübken, F.J., Bremer, J., Clemesha, B.R., Stegman, J., Sigernes, F. and Fadnavis, S., 2003, Review of mesospheric temperature trends, Rev. Geophys., 41(4), 1015, doi: 10.1029/2002RG000121.

Cadet, B., Goldfarb, L., Faduilhe, D., Baldy, S., Giraud, V., Keckhut, P. and Réchou, A., 2003, A sub-tropical cirrus clouds climatology from Réunion Island (21°S, 55°E) lidar data set, Geophys. Res. Lett., 30(3), 1130, doi : 10.1029/2002GL016342.

Godin-Beekmann, S., Porteneuve, J. and Garnier, A., 2003, Systematic DIAL lidar monitoring of the stratospheric ozone vertical distribution at Observatoire de Haute Provence (43.92°N, 5.71°E), J. Environ. Monit., 5, 57-67.

Lumpe, J.D., Fromm, M., Hoppel, K., Bevilacqua, R.M., Randall, C.E., Browell, E.V., Grant, W.B., McGee, T., Burris, J., Twigg, L., Richard, E.C., Toon, G.C., Margitan, J.J., Sen, B., Pfeilsticker, K., Boesch, H., Fitzenberger, R., Goutail, F. and Pommereau, J.P., 2003, Comparison of POAM III ozone measurements with correlative aircraft and balloon data during SOLVE, J. Geophys. Res., 108(D5), 8316, doi: 10.1029/2001JD000472.

Marchand, M., Godin, S., Hauchecorne, A., Lefèvre, F., Bekki, S. and Chipperfield, M., 2003, Influence of polar ozone loss on northern midlatitude regions estimated by a high-resolution chemistry transport model during winter 1999-2000, J. Geophys. Res., 108(D5), 8326, doi: 10.1029/2001JD00906.

Marchand, M., Bekki, S., Denis, L., Pommereau, J.P. and Khattatov, B.V., 2003, Test of the night-time polar stratospheric NO2 decay using wintertime SAOZ measurements and chemical data assimilation, Geophys. Res. Lett., 30(18), 1920, doi: 10.1029/2003GL017582.

Portafaix, T., Morel, B., Bencherif, H., Baldy, S., Godin-Beekmann, S. and Hauchecorne, A., 2003, Fine-scale study of a thick stratospheric ozone lamina at the edge of the southern subtropical barrier, J. Geophys. Res., 108(D6), 4196, doi: 10.1029/2002JD002741.

Randriambelo, T., Baray, J.L., Baldy, S., Thompson, A.M., Oltmans, S. and Keckhut, P., 2003, Investigation of the short-time variability of tropical tropospheric ozone, Ann. Geophys., 21, 2095-2106.

Wu, D.L., Read, W.G., Shippony, Z., Leblanc, T., Duck, T.J., Ortland, D.A., Sica, R.J., Argall, P.S., Oberheide, J., Hauchecorne, A., Keckhut, P., She, C.Y. and Krueger, D.A., 2003, Mesospheric temperature from UARS MLS: retrieval and validation, J. Atmos. Sol. Terr. Phys., 65, 245-267.

FUTURE PLANS

NDSC ground-based observations will be continued at OHP, Reunion Island, Dumont d'Urville as well as at the SAOZ stations. The two new coming NDSC relevant projects are: (i) the beginning of the construction of the high altitude (2500 m asl) Maido station at Reunion Island planned to host a FTIR of the Belgium IASB, and a microwave radiometer of the Laboratoire d'Aerologie in Toulouse; (ii) the opening of the Concordia station inland Antarctica for its first wintering in 2005, where the installation of a SAOZ spectrometer is planned in 2006, followed later by an ozone/ water-vapour microwave radiometer.

The analysis, interpretation and modelling of most of French stratospheric ozone relevant ground-based, satellite, aircraft and balloon observational projects are part of the SCOUT-O3 FP6 project (2004-2009) supported by the European Commission and coordinated by the University of Cambridge (UK).

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