

## 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 called Chimie Atmosphérique (CHAT). Long term monitoring activities relevant to the Network of Atmospheric Composition Changes (NDACC) 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 6<sup>th</sup> and 7<sup>th</sup> Environmental Work Programmes.

The research include the long term monitoring of the stratosphere and surface UV-B radiation in the frame of NDACC at a variety of sites, the study of ozone depletion 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 NDACC at the Observatoire de Haute Provence (OHP) and the Antarctic stations of Dumont d'Urville (DDU) and Dome Concordia, 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 spectro-photometer.

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 been replaced in 2008. An additional SAOZ is in operation since 1995 at the sub-Antarctic Island of Kerguelen. In addition a SAOZ and ozone soundings have been implemented at the inland French-Italian station of Concordia in 2007.

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 2010 together with a microwave radiometer for water vapour profile measurements and a FTIR operated by the Belgian IASB-BIRA.

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

Part of the data (SAOZ ozone / NO<sub>2</sub> 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 NDACC archive centre. The SAOZ data together with the lidar measurements at OHP and Dumont d'Urville are also part of the GEOMon European project, started in 2007 and which has for objective to harmonize ground-based European observations related to greenhouse gases, air quality, aerosols and stratospheric ozone.

## Summary of Ground-based observations

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

SAOZ Ozone and NO<sub>2</sub> at Scoresbysund (Greenland), Sodankyla (Finland), Salhekar (W. Siberia), Zhigansk (E. Siberia), OHP (France), Bauru (Brazil), Reunion Island (France), Kerguelen (France) and Dumont d'Urville (Antarctica)

Dobson at OHP

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

Stratospheric Ozone lidar at OHP, Dumont d'Urville (Antarctica) and La Reunion Island

Ozonesondes at OHP, Reunion Island, Dumont d'Urville and Concordia

Stratospheric temperature lidar at OHP, Reunion Island and Alomar (Norway)

Aerosol lidar at OHP, Reunion Island and Dumont d'Urville

Tropospheric ozone lidar at OHP and Reunion Island

### **UV measurements**

Broadband measurements at Dumont d'Urville (Antarctica)

Spectroradiometers at Villeneuve d'Asq and OHP (France)

### **Calibration activities**

NDACC 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 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 both other stratospheric chemistry instruments MIPAS and SCIAMACHY.
- A strong involvement in the validation of the measurements of GOME-ERS-2, ODIN, ENVISAT, OMI and Aura-MLS from ground based and dedicated balloon flights measurements in the Arctic, at Mid-latitude and in the tropics.
- The derivation of ozone total and partial columns from the IASI instrument on board METOP, the European meteorological polar platform launched in 2006. Several algorithms have been designed for the ozone products, which are currently validated.

In addition, Météo-France is contributing to the EUMETSAT's Ozone Monitoring Satellite Application Facilities hosted by the Finnish Meteorological Institute. This facility delivers ozone and minor constituents' products derived from the GOME-2 and HIRS instruments on board METOP. 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 aircrafts have been renewed for an ATR 42 and a Falcon 20, both have started 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 NO<sub>y</sub> (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 nitrogen and chlorine compounds; a star occultation UV-Visible spectrometer (AMON) for the night-time measurement of O<sub>3</sub>, NO<sub>2</sub>, NO<sub>3</sub> and OCIO; an aerosol particle counter (STAC) 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<sub>3</sub>, NO<sub>2</sub>, BrO and OCIO by solar occultation; the SALOMON moon occultation version; the SDLA diode laser for in-situ CH<sub>4</sub>, CO<sub>2</sub> and water vapour; and the Rumba meteorological payload for long duration balloons.

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

- an ESA-CNES ENVISAT validation campaigns of 5 large balloon flights in Teresina, Northern Brazil in June-July 2005;
- a VORCORE project of 20 long duration constant level balloons in September 2005 in Antarctica for studying the dynamics of the stratospheric polar vortex.
- Several campaigns organised in the frame of the SCOUT-O<sub>3</sub> European project (2005-2009): two campaigns in Australia (2005) and Niger (Africa, 2006) for the study of water vapour injection in the stratosphere and an equatorial long duration balloon experiment from the Seychelles Island (2008) for the study of clouds, ozone and water-vapour.

#### **Data interpretation, exchange and archival**

The data are analysed through many cross-exchanges with international scientists and particularly Europeans within cooperative projects. French institutes have also developed a full set of models ranging from Lagrangian, 3-D chemical transport (CTM), contour advection, meso-scale and chemistry climate models (CCM). The simulations of the ozone layer in the 21<sup>st</sup> century by the LMDz-Reprobus CCM have been involved in the last WMO ozone assessment published in 2007. While the experimental data as well as the results of simulation 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 2 shows the validation of ozone profiles retrieved from GOME satellite observations by ground-based lidar measurements performed within NDACC. The satellite ozone profiles were retrieved from neural network algorithms [Iapalo et al., 2007].

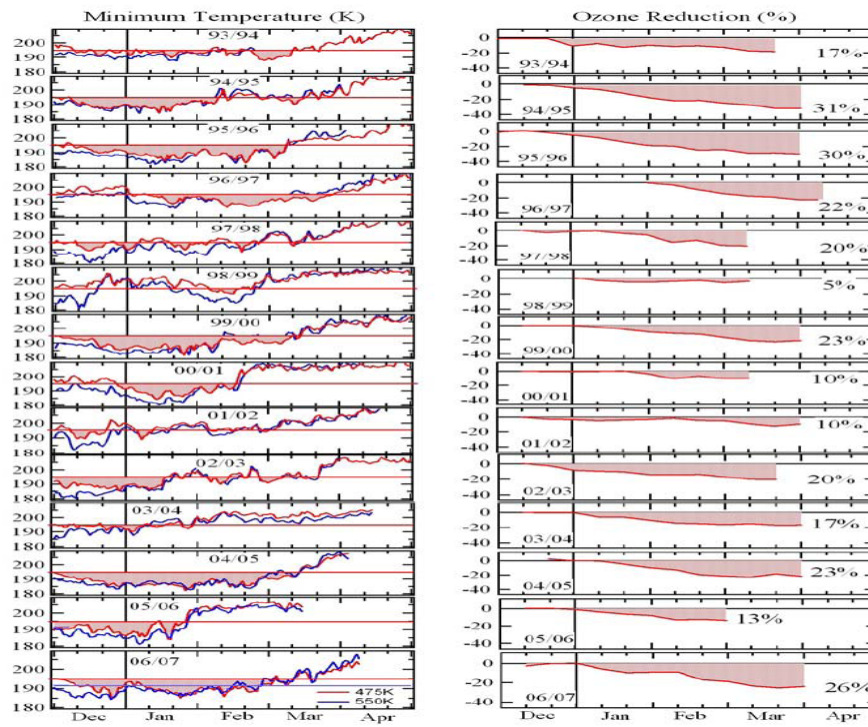


Figure 1: Estimation of amplitude of chemical stratospheric ozone reduction the Arctic during the winter season from the measurements of the SAOZ network. Left: minimum ECMWF temperature north of 60°N at 475 K and 550 K ; Right ozone chemical reduction after subtraction of the contribution of transport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

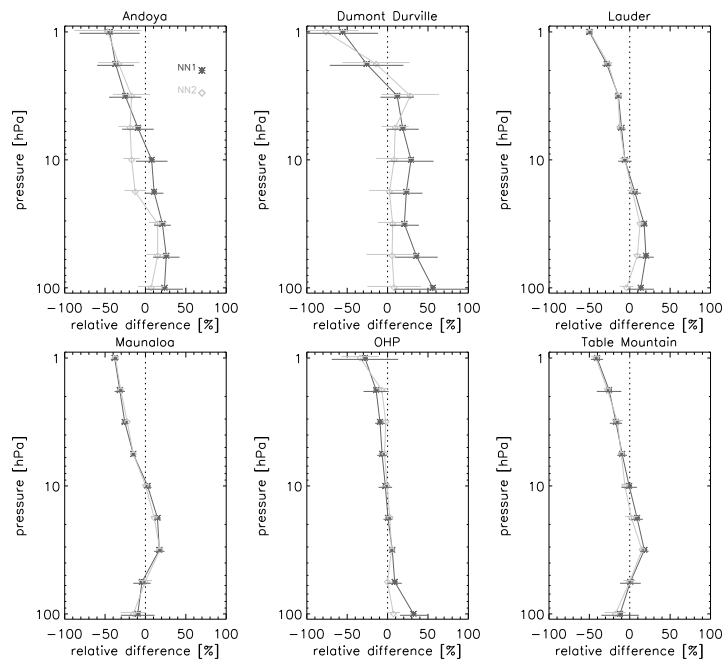


Figure 2 : Relative difference between ozone profile measurements from NDACC ground-based lidars and the GOME satellite instrument. The GOME ozone profiles were retrieved with two versions of neural networks (NN1 et NN2).

## DISSEMINATION OF RESULTS

### Data reporting

The SAOZ (ozone / NO<sub>2</sub>) and ozonesondes data are made available in near real time to WMO, WOUDC and the ESA and EC databases at the Norwegian Institute for Air Research (NILU). All NDACC relevant data are deposited, after reprocessing, in the NDACC archive centre. In addition

all French space and field data relevant to the stratosphere are archived into the ational data base ETHER.

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## FUTURE PLANS

NDACC ground-based observations will be continued at OHP, Reunion Island, Dumont d'Urville and Concordia as well as at the SAOZ stations. The coming NDACC relevant project is the implementation of the high altitude (2500 m asl) Mado station at Reunion Island planned to host most of the instruments presently installed at the campus of the University of La Reunion. 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 EU FP6 project (2004-2009) supported by the European Commission and coordinated by the University of Cambridge (UK). The harmonization of data and satellite observations validation are performed within the GEOMON FP6 project (2007-2011).

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