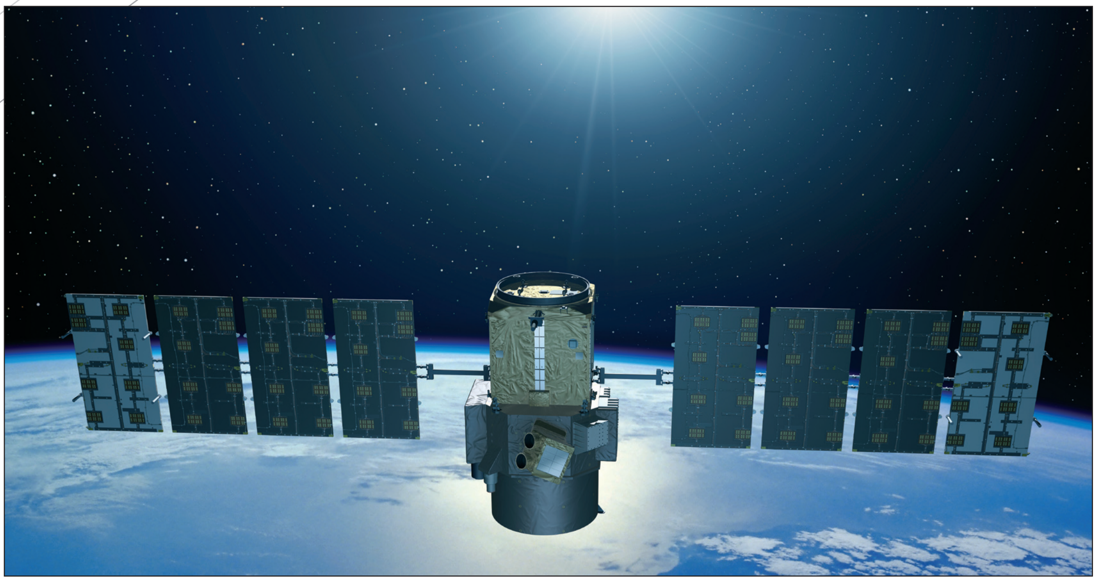
COSPAR 2010

Atmosphere

AUTHORS
D. Renaut
C. Deniel



[Fig. 1]

Better forecasting the weather with IASI

IASI is an essential instrument of the payload of the MetOp-type European meteorological satellites in polar orbit operated by Eumetsat. The first flight model was launched in October 2006. IASI, developed by CNES as part of a co-operation with Eumetsat, is a major scientific and technologic breakthrough since it provides atmospheric radiances in more than 8 000 infrared channels. These radiances, which enable to establish atmospheric humidity and temperature profiles with never-before-achieved vertical resolution and precision, are operationally assimilated in the weather forecast models of the world's main meteorological centres. Everywhere, the impact of IASI data on the quality of forecasts is significant. The potential of IASI data for weather forecasts is still far from being completely exploited and work on their assimilation is ongoing. As such, one of the objectives of the Concordiasi experimental campaign is to improve the assimilation of IASI data above iced surfaces of Antarctica.

IASI results in meteorology were presented during the second IASI international conference, along with those concerning the use of IASI for the follow-up of the climate and the atmospheric composition. This conference brought together more than 150 participants, coming from Europe and North America, between January 25 and January 29, 2010 in Annecy in France. In all fields, the quality of IASI measurements and the diversity of their scientific implications raised great enthusiasm.

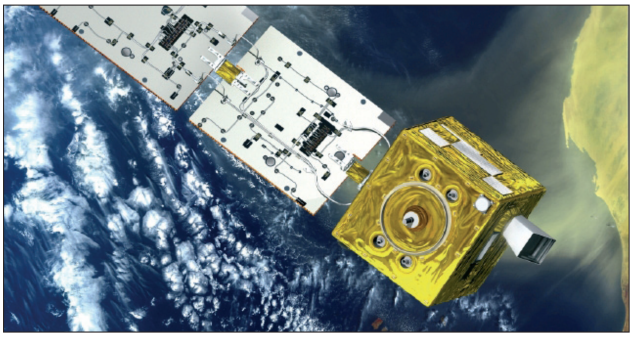
PARASOL and CALIPSO: better understanding the influence of clouds and aerosols on climate

The space missions PARASOL of CNES and CALIPSO of NASA and CNES are part of the A-Train, a constellation of five satellites dedicated to the study of atmospheric physics and the climate.

PARASOL, launched in December 2004, has been providing global measurements of excellent quality on aerosols and clouds for five years thanks to its Polder-type instrument. In December 2009, PARASOL left the A-Train for an orbit 4 km underneath in order to minimize risks in case of deficiency and thus ensure the security of the other satellites of the constellation. However, PARASOL will keep fulfilling its cloud and aerosol observation mission.

CALIPSO, launched in april 2006, provides global measurements of cloud and aerosol vertical profiles thanks to its lidar. In March 2009, NASA and CNES managed to realize a technical feat by replacing the main laser of CALIPSO with the backup laser. This change was necessary because a slow drop of pressure was observed in the container of the main laser. Since then, CALIPSO has been operating smoothly. Meanwhile, in 2009, NASA decided to extend the CALIPSO mission until the end of 2011, CNES having also given its approval.

The thematic pole Icare is managing the production and distribution of the scientific outputs of PARASOL and CALIPSO



[Fig. 2]

through its data processing and management center in Lille (CGTD). In the case of CALIPSO, it acts as a mirror site of NASA. In late 2009, the CGTD Icare was managing the distribution of four terabytes of data per month, for the benefit of 380 registered users. Icare is a partnership between four French groups: CNES, CNRS, the university of Lille and the Nord-Pas-de-Calais Region.

Megha-Tropiques and the water cycle

The French-Indian space mission Megha-Tropiques (CNES-ISRO) is dedicated to the study of the water cycle, the energy fluxes and the evolution of climate in the tropics. Placed on a low inclination orbit, the satellite will measure precipitations, water vapor and radiative fluxes in the tropical atmosphere with a good revisit rate. Launch is expected in India in the second half of 2010. It will carry four instruments: the microwave imager Madras (CNES-ISRO), the microwave sounder Saphir (CNES), the radiation balance measure instrument SCARAB (CNES) and a GPS radio-occultation receptor (ISRO).

On the technical level, various important steps were recently passed. In March 2009, CNES decided to contribute to the ground reception of data from the satellite through its stations of Kourou and Hartbeesthoek in order to enable the nearly instantaneous distribution of Megha-Tropiques data. In April 2009, CNES delivered in India the subsystem MARFEQ, the hyperfrequency part of Madras. The performances of MARFEQ were deemed excellent by ISRO. And in March 2010, CNES delivered the SCARAB instrument to ISRO. Once again, local tests were very good.

On the scientific level, an important international conference was held in Bangalore in March 2009. More than 100 scientists presented their plans and debated on the way to exploit future data of Megha-Tropiques to better understand water vapor variations, cloud liquid water variations, precipitations and radiation balance in the tropics. A call for proposals was launched in December 2009 by CNES and ISRO in order to establish an international team to validate and scientifically exploit the Megha-Tropiques measurements. At the same time, a partnership agreement between Megha-Tropiques and the international programme GPM (NASA-JAXA) is being finalized before signature.

Atmospheric composition, pollution, greenhouse gases

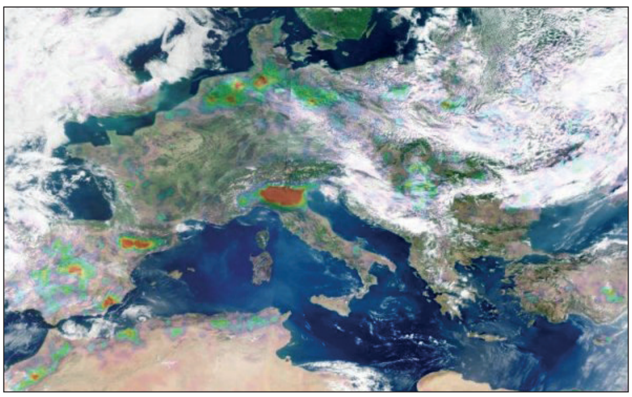
The data from IASI offer a new global vision of the troposphere, complementary to that of ground and *in situ* observations. However numerous questions remain, often raised by the new global and continuous vision that satellite observations offer. In particular, primary pollution sources remain uncertain, as well as their interregional and intercontinental transport. Quantifying the impact of a source region on the global composition of the troposphere and on the air quality in a neighboring region is a significant challenge to set up international coordinated actions. Various French laboratories supported by CNES have started preparing trace gas restitution algorithms from spectrums measured by IASI. The scientific exploitation of IASI data also requires the development of efficient tools, promoting in particular the real time mode that the gas inversion operational algorithms enable.

Apart from the needs for meteorological products such as temperature and humidity, IASI fulfills many other needs. We have access to the measurements of key components such as tropospheric ozone or carbon monoxide to better understand and anticipate pollution phenomena at the intercontinental and regional scale. Other chemical elements present at times or in very small quantities are also detected. For long lasting elements, carbon dioxide CO_2, N_2O, and CFCs; for average lasting elements (from a few weeks to a few years) such as water vapor and its isotopes, methane CH_4, ozone, carbon monoxide and nitric acid HNO_3; for short lasting ones such as ammonia NH_3, CH_3COOH, HCOOH, C_2H_4 in case of fires and SO_2 in case of volcanic eruptions.

Thanks to its global coverage, its revisit rate twice per day and most of all its good horizontal resolution (nadir ground pixel of 12 km^2), IASI lets the atmospheric chemistry community imagine developments that are not only of use for science (better understanding of chemical processes and interactions with the dynamics or surface events), but also of use for services looking for a better management of our environment (detection of fire-, industrial-, transport- and agriculture-caused pollution episodes). The following article on the detection of ammonia and its relation to intensive agriculture areas is an example of this.

With the other two IASI instruments ready to ensure the continuity of data for fifteen years, other chemical elements could very well be extracted by researchers from high resolution spectrums of IASI, thus providing us with great surprises in the years to come.

Building on this success, CNES has been studying new-generation concepts of IASI in preparation of post 2020.



[Fig. 3]

Fig. 1*: Impression of the minisatellite CALIPSO. It is a French-American mission whose objective is to understand the climate system and its evolution.*
Fig. 2*: Impression of the Myriad-type microsatellite PARASOL.*
Fig. 3*: Ammonia distribution above Europe measured by the IASI/MetOp instrument in 2008, on top of an image obtained by the MODIS instrument.*
From yellow to red, colors show ever-higher Ammonia concentrations. White structures are clouds.

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Atmosphere

The CALIPSO mission.

La mission Calipso.

AUTHORS
D. M. Winker [1]
J. Pelon [2]

[1] NASA Langley Research Center, Hampton, VA, USA.
[2] Université Pierre et Marie Curie, CNRS-Insu, IPSL, Latmos, Paris, France.

Abstract

Until very recently, information on the vertical structure and properties of clouds and aerosols was limited. It was one of the major objectives of the CALIPSO mission developed as a collaboration between NASA and CNES to bring this missing information. The platform has been flying since 2006 within the AQUA-Train constellation. It is the first mission to provide several years of such global observations. Some of the results obtained are presented here.

Jusqu'à très récemment, les informations sur les propriétés et la structure verticale des nuages et des aérosols étaient limitées. La mission Calipso développée dans le cadre d'une collaboration entre la NASA et le CNES a permis de combler ce manque. La plateforme vole depuis 2006 dans la constellation A-Train. C'est la première mission permettant de disposer de plusieurs années de telles observations globales. Quelques résultats sont présentés ici.

CALIPSO is a polar orbiting platform operating at 705 km of altitude. It carries the Cloud-Aerosol LIdar with Orthogonal Polarization (CALIOP), a nadir-viewing two-wavelength, polarization-sensitive lidar, along with two passive sensors: the Wide-Field Camera (WFC) and the Infrared Imaging Radiometer (IIR). Combining the coincident observations from the lidar and the passive sensors offers new possibilities for retrieving the properties of clouds and aerosols. Its place in the A-Train offers a variety of additional measurement synergies. Data and quick-looks are archived at the NASA LaRC Atmospheric Sciences Data Center (ASDC). A mirror data site, part of the French ICARE structure, is located in Lille and operated by CNES, CNRS, the University of Lille, and the Région Nord-Pas-de-Calais.

Validation of CALIPSO calibrated backscattered lidar data (level 1) has been performed by High Spectral Resolution Lidar (HSRL) airborne measurements from NASA and matches up to within 5% (average bias) have been obtained at 532 nm. Ground-based observations and other aircraft measurements have confirmed the very good quality of the data in terms of sensitivity and noise. A further refinement of the operational calibration procedures should be possible using either the surface return over ocean or aerosol analysis in the upper atmosphere. Tropospheric aerosol identification has been looked at using HSRL airborne data in the USA and ground-based Raman lidar measurements in Europe. HSRL data have allowed to derive satisfying comparisons of the retrieved lidar ratio with the *a priori* value operationally used for CALIPSO to retrieve extinction profiles. Work has also been undertaken on cirrus clouds and both remote sensing and *in situ* data have shown evidence of the impact of existing oriented crystals, which have been frequently observed in ice clouds on CALIOP signals. Their contribution has been reduced after tilting the platform to avoid lidar pointing at nadir.

CALIPSO observations are invaluable in testing the adequacy and biases of cloud properties that feed the existing climatologies. Additionally, lidar instrument simulators have recently been developed to aid in the comparison of CALIOP observations with output from global climate models opening new ways of investigation to modelers. Complementary cloud observations from CALIPSO lidar and CloudSat radar have been used to produce a merged CALIPSO-CloudSat cloud dataset providing the first 3D climatology of global cloud occurrence and have also been used to produce improved retrievals of ice cloud properties. One of the initial applications of the merged CALIPSO-CloudSat cloud product was the assessment of cloud overlap in a form which can be parameterized in global models.

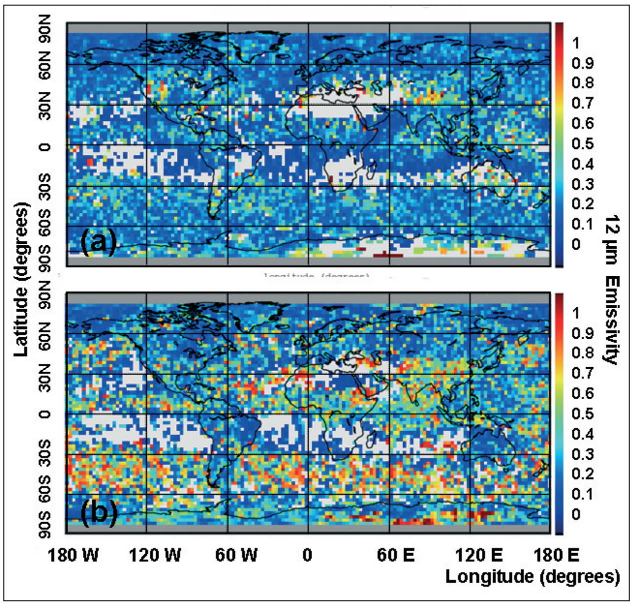
CALIOP provides new capabilities to identify boundary layer clouds and distinguish optically thin ones from aerosols. New investigations are undertaken in this very sensitive area, closely linked to climate change. Small variations in thin cirrus can have impacts on cloud radiative forcing that are comparable in magnitude to the radiative forcing due to human activity. Cloud emissivities can be retrieved from the IIR-CALIOP data for semitransparent high clouds occurring alone as well as above low-altitude opaque clouds, providing new insights of multilayered cloud structures (Fig. 1). The properties of ice crystals and the occurrence of supercooled water droplets can also be analyzed using CALIOP depolarization profiles. Such observations provide a new tool for evaluating climate model performance.

Current satellite-based aerosol retrievals are restricted to clear-sky conditions but the impact of radiatively absorbing aerosol located above cloud can be significant in regions characterized by strong sources of mineral dust, smoke from biomass burning, or pollution. The first estimations of aerosol optical depth above clouds as shown in Fig. 2 were obtained by CALIPSO.

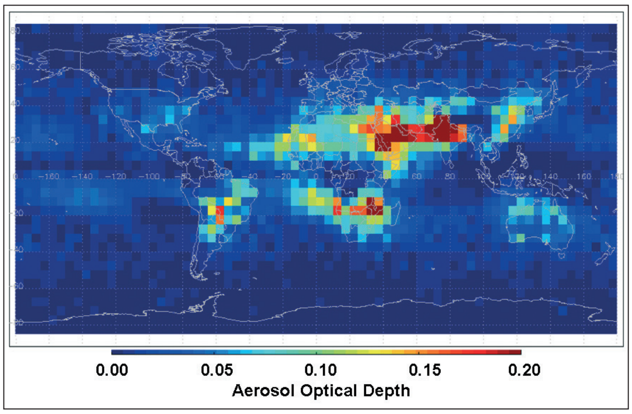
The CALIPSO mission represents a successful cooperative effort between NASA and CNES and has provided the first multi-year global dataset of lidar aerosol and cloud profiles. CALIOP active profiling in conjunction with A-Train and CALIPSO passive observations are opening new fields of investigation into the role of aerosols and clouds in the climate system, from direct comparison with model outputs and ongoing developments in data assimilation. Further missions should continue the record of aerosol and cloud profiles begun by CALIPSO, leading to a multi-decadal observational record needed to characterize climate trends.

We would like to acknowledge the support and successful cooperation of NASA and CNES in the development and operation of CALIPSO and the teams at NASA, CNES, Ball Aerospace, CNRS, SODERN, SSAI and Thales-Alenia-Space for the instrumental development, integration and tests, and teams at ASDC and ICARE data centers for processing and archiving data.

The results discussed here are presented in more detail in [1] and the reader is invited to refer to this publication and listed references from the teams involved for further information in the various topics summarized here.



[Fig. 1]



[Fig. 2]

Fig. 1*: Mean 12-µm emissivities of semitransparent upper-level clouds for August 2008 from combined IIR-CALIOP retrievals, day and night.*
a) Located above opaque low level clouds,
b) Single-layer cirrus clouds.

Fig. 2*: Mean Aerosol Optical Depth (AOD) above cloud from CALIOP observations for September-October-November 2007.*

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Atmosphere

First global maps of ammonia sources measured by the IASI remote sensor onboard the MetOp satellite.

Premières cartes de sources d'ammoniac mesurées par le sondeur Iasi à bord du satellite MetOp.

AUTHORS
C. Clerbaux [1]
P-F. Coheur [2]
L. Clarisse [2]

[1] UPMC Université Paris 06, Université Versailles St-Quentin, CNRS/Insu, Latmos-IPSL, Paris, France.
[2] Spectroscopie de l'atmosphère, Service de chimie quantique et photophysique, Université Libre de Bruxelles, Brussels, Belgium.

Abstract

The first complete mapping of ammonia sources has been achieved using observation provided by the IASI instrument onboard the MetOp satellite. Several ammonia hotspots were found, primarily over agricultural regions in Asia, Europe, and North America. The satellite-derived estimates of ammonia concentrations exceeded those obtained from model simulations in the Northern Hemisphere, suggesting that current accounts underestimate emissions in this area.

Une première cartographie complète des sources d'ammoniac a été réalisée en utilisant les observations fournies par l'instrument Iasi à bord du satellite MetOp. Plusieurs sources importantes d'ammoniac ont été trouvées, notamment dans des régions agricoles en Asie, en Europe et en Amérique du Nord. Les concentrations dérivées à partir des mesures satellites dépassent celles simulées par les modèles dans l'hémisphère nord, ce qui suggère que les inventaires d'émissions actuels les sous-estiment.

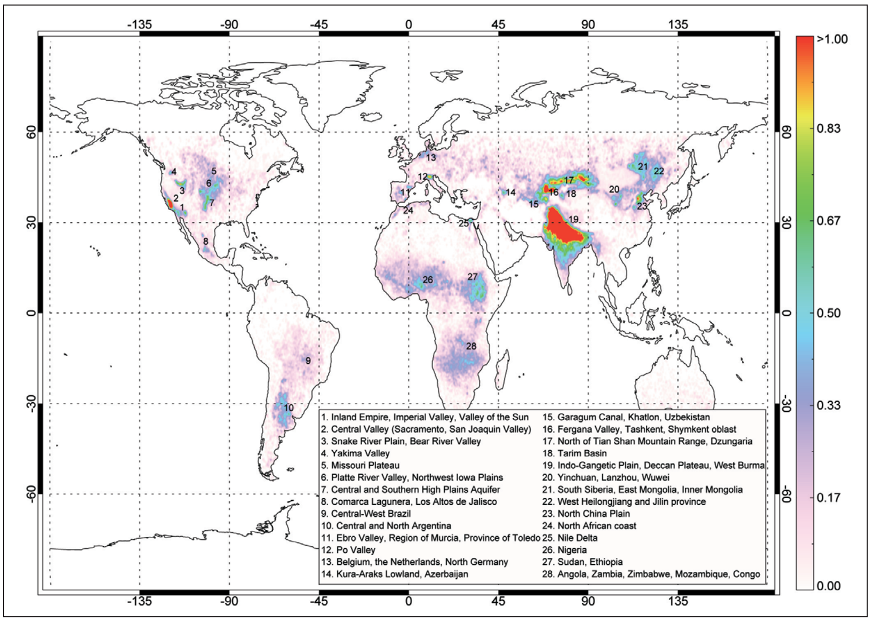
The IASI infrared remote sensor, launched onboard the MetOp satellite at the end of 2006, was designed with the double objective of providing data to be exploited by the meteorological community and for atmospheric composition monitoring. A series of key elements playing a major role in atmospheric chemistry are measured on a daily basis [1] [2], by taking advantage of the high spectral resolution and signal to noise. Although the IASI instrument onboard the meteorological MetOp satellite was not originally designed to detect ammonia in the atmosphere, a novel methodology developed by a Belgian-French team that helps to isolate the ammonia signature from the background noise of the instrument allowed to detect ammonia (NH_3) on local and global scales.

Ammonia significantly contributes to the formation of particles involved in the development of pollution episodes. It originates mainly from the intensive use of agricultural fertilizers and the development of farming practices. Ammonia is the most poorly understood of all pollutants regulated by EU air quality directives. The emission inventories are not precise and comprehensive, and systematic monitoring of this compound is difficult. Once emitted, ammonia stays a few hours in the atmo-sphere and generates a cascade of environmental problems. High concentrations of ammonia affect wild-life and air quality locally.

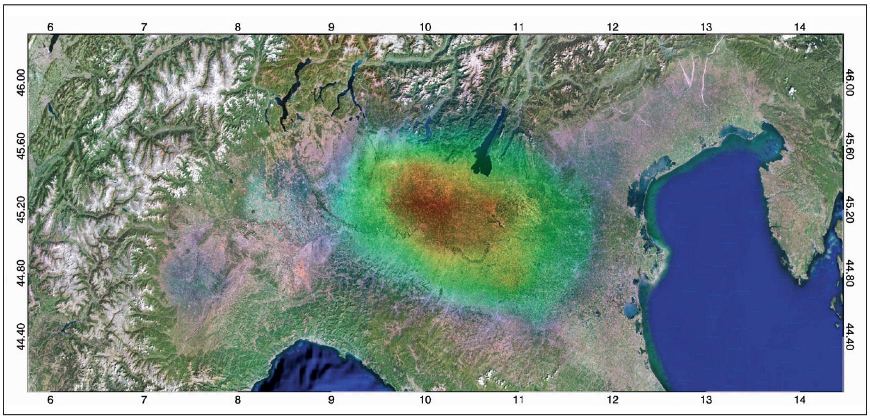
Even though daily observations are possible near the largest sources, because of low emission height and short lifetime, the NH_3 signature is often within the instrumental noise and only emerges over other regions when averaging over time. By filtering the data and by accumulating them during a year of continuous observation (more than one million measurements per day, with two observations per day anywhere on the globe) we were able to derive maps of concentration and compare them with recent atmospheric models [3] [4].

Monthly averages were calculated on a 0.25° by 0.25° grid from the daily values. The global average total columns for 2008 are shown in Fig. 1 with columns ranging from about 0.15 $mg.m^{-2}$ up to 3 $mg.m^{-2}$. A total of 28 hotspots with columns above 0.5 $mg.m^{-2}$ have been identified. In parts of the world, NH_3 emissions are linked to biomass burning. In 2008 there were large mid-latitude fires in South Siberia and Inner Mongolia from April to May and in the respective dry seasons of South America and East, West and Southern Africa. All the other hotspots indicated on the map are above the agricultural regions of North America, Europe and Asia. We observe the largest NH_3 columns in agricultural valleys. Surrounded by mountains, these areas exhibit stagnant weather allowing NH_3 concentrations to build up. Well known examples are the San Joaquin Valley in California, and the Pô Valley in Italy (Fig. 2), infamous for their poor air quality. Also in non-mountainous regions, we observe NH_3 columns well above background levels, for instance over the Nile delta and large parts of Western Europe (Belgium, the Netherlands and Germany).

This work has highlighted an under-estimation of ammonia sources provided by the current inventory for agricultural valleys of the Northern Hemisphere, particularly in America, Europe and Asia. The most significant differences are located in Central Asia with the identification of some sources that do not exist in current inventories. These first global maps of ammonia will help to establish more realistic emission inventories.



[Fig. 1]



[Fig. 2]

The work was performed by scientists from the *Université Libre de Bruxelles*, in collaboration with French CNRS and EU-Ispra JRC colleagues, and was reported in Nature Geoscience and Journal of Geophysical research.

Contact Belgium: Lieven Clarisse or Pierre François Coheur, ULB
[lclariss@ulb.ac.be, pfcoheur@ulb.ac.be]

Contact France: Cathy Clerbaux, LATMOS/CNRS
[cathy.clerbaux@latmos.ipsl.fr]

Fig. 1*: Yearly average total columns of NH_3 in 2008 retrieved from IASI measurements on a 0.25° by 0.25° grid. The yellow to red colors indicate areas with high concentrations of ammonia, and 28 hotspots are identified in the legend. Adapted from [3].*

Fig. 2*: Distribution of ammonia in 2008, measured by the IASI / MetOp satellite in the Pô Valley region (Italy). The yellow to red colors indicate areas with high concentrations of ammonia.*

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