AUTHORS: D. Renaut and C. Deniel

Atmosphere

[Fig. 1]

[Fig. 2]

Better forecasting the weather with IASI

IASI is an essential instrument of the METOP-type 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 cooperation with Eumetsat (Fig. 1), is a major scientific and technological breakthrough since it provides atmospheric radiances in more than 8 000 infrared channels. These radiances 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. For example, IASI data brings a 3 hour gain at Météo-France. The potential of IASI data for weather forecasts is still far from being completely exploited and work on their assimilation is ongoing.

IASI is also successfully used by scientists for the follow-up of the atmospheric composition (see below) and the climate, giving access to many essential climate variables. At least, IASI has been recognized as the reference instrument for the intercalibration of infrared space sensors by the WMO's Global Space-based Intercalibration System. Building on this success, CNES is currently studying a new-generation instrument, called IASI-NG, intended to be the infrared sounder of the future European meteorological polar satellites after 2020.

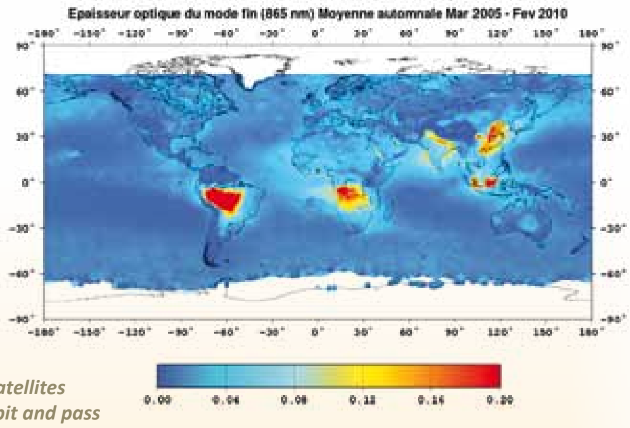
PARASOL and CALIPSO: better understanding the influence of clouds and aerosols on climate

The main objective of the space missions PARASOL (CNES) and CALIPSO (NASA-CNES) is to better understand the role of atmospheric aerosols and clouds in climate change. They were initially part of the A-Train, a constellation of five satellites dedicated to the study of atmospheric physics and climate (Fig. 2).

PARASOL, launched in December 2004, has been providing global measurements on aerosols and clouds for seven years thanks to its Polder-type instrument (Fig. 3). After having left the A-Train in December 2009, PARASOL is now flying on an orbit 10 km underneath in order to minimize risks in case of deficiency. However, PARASOL keeps fulfilling its cloud and aerosol observation mission, recently extended until the end of 2013. CALIPSO, launched in April 2006, is still inside the A-Train constellation where its mesurements of clouds and aerosol vertical profiles provides unique insights that are improving the understanding of the properties of clouds and aerosols thanks to its lidar in synergy with those of other A-train sensors. They are markedly improving the performance of models ranging from regional chemical transport to global climate models. At the end of 2011, nearly 500 scientific publications have appeared that use or reference CALIPSO data. Recognizing this scientific success and the good health of the CALIPSO platform and instruments, NASA and CNES decided last year to extend the CALIPSO mission until the end of 2013.

The thematic consortium Icare is managing the production and distribution of the scientific outputs of PARASOL and CALIPSO through its Data Center in Lille (CGTD Icare). In the case of CALIPSO, it acts as a mirror site of NASA. At the end of 2011, the CGTD was managing an archive of 850 terabytes of data, for the benefit of more than 900 registered users. Icare is a partnership between four French groups: CNES, CNRS, the University of Lille-1 and the Nord-Pas-de-Calais Region.

[Fig. 3]



[Fig. 1] - Employees integrating IASI (Infrared Atmospheric Sounding Interferometer) detector. The IASI instrument features highly innovative technologies for polar orbit meteorological systems. This instrument will provide temperature and humidity of the atmosphere (stratosphere and troposphere levels) data with an high resolution and precision. ©THALES ALENIA SPACE

[Fig. 2] - The A-Train is a constellation of six Franco-American satellites flying in formation just minutes apart on a sun-synchronous orbit and pass over the equator at 13:30 local. This constellaton is intended to simultaneously implement all observational techniques currently available to provide the first 3D vision of the Earth's atmosphere. © CNES/ill./CARRIL Pierre, 2010

[Fig. 3] - Aerosol optical thickness inferred from the PARASOL data. The values shown are averages (at the wavelength 0.865 µm) over the months of September, October, November and available on five years, from 2005 to 2009. This map shows the Asian urban and industrial pollution (mainly in China and India) which is supplemented by shifting cultivation and deforestation in Central Africa, Indonesia and the Amazon. © LOA / ICARE /2010

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 exchanges and the evolution of climate in the tropics. Placed on a low inclination orbit, the satellite measures precipitations, water vapor and radiative fluxes in the tropical atmosphere with a good revisit rate. It carries four instruments: the microwave imager Madras (CNES-ISRO), the microwave sounder Saphir (CNES), the Earth radiation budget sensor Scarab (CNES) and a GPS radio-occultation receptor ROSA (ISRO).

On October 12, 2011, Indian rocket PSLV successfully launched the Megha-Tropiques satellite from Shiharikota (India). After separation of the satellite, ISRO confirmed that Megha-Tropiques has been placed very precisely into its intended circular orbit and in its final orbital configuration. Then the four instruments were energised. Since then, the Saphir and Scarab instruments have been functioning nominally. But at the end of 2011, an anomaly occurred on the Madras instrument, leading to the intermittent reception of erroneous data. ISRO and CNES teams are currently investigating to understand and correct this anomaly.

On the scientific level, the call for proposals launched in December 2009 by CNES and ISRO in order to establish an international Megha-Tropiques science team has been a success with 21 selected teams from all over the world. In parallel, a partnership agreement between Megha-Tropiques and the programme GPM (NASA-JAXA) has been signed on September 8, 2011 between CNES and NASA and should be signed very soon between ISRO and NASA.

Atmospheric composition, pollution, greenhouse gases

The data from IASI continue to offer a unique global vision of the atmospheric composition. Several French laboratories supported by CNES develop trace gas restitution algorithms from IASI spectrums.

Apart from meteorological products such as temperature and humidity, IASI offers measurements of key components such as tropospheric ozone or carbon monoxide to better understand and anticipate pollution phenomena at the intercontinental and regional scale. Thanks to its global and temporal coverage as well as its good horizontal resolution, IASI lets the atmospheric chemistry community imagine developments that are not only of use to science, but also of use for services looking for a better management of our environment (detection of fire-, industrial-, transport- and agriculture-caused pollution episodes). A second IASI instrument is planned to be launched on METOP B mid 2012. In 2011, CNES also led two definition phase studies dedicated to atmospheric greenhouse gas measurements. The first one, Microcarb is designed to measure atmospheric carbon dioxide (CO_2) from space in order to access regional fluxes. The CO_2 concentration will be retrieved from measurements of the absorption of reflected sunlight by CO_2 in the near infrared. A grating spectrometer instrumental concept with 3 spectral bands (0.76 µm, 1.6 µm and 2.0 µm) has been selected for the project (as the NASA OCO mission). The sensor will be a compact instrument as the satellite will be based on the CNES Micro-Satellite product line: Myriade Evolution.

The second one, MERLIN is dedicated to measure methane (CH_4) which is the second most important component of the global carbon cycle as it contributes significantly to the warming of the Earth's climate. Although its abundance is much less than that compared to carbon dioxide in today's atmosphere, it is a 25 times more effective greenhouse gas on a 100 year timescale. The MEthane Remote sensing LIdar missioN (MERLIN) is a joint French German cooperation decided in 2009. The lidar instrument, the first in space to measure greenhouse gas, is developed under German Space Administration (DLR) responsibility, is set up on the first model of the Myriade Evolution platform, which is developed under CNES responsibility. The project should end the phase A (feasibility demonstration) in mid 2012 and is planned to be launched in the 2016 time frame.

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Atmosphere

Laboratory contribution

The Concordiasi field campaign over Antarctica: first results from innovative atmospheric measurements

La campagne Concordiasi en Antarctique : premiers résultats de mesures atmosphériques innovantes

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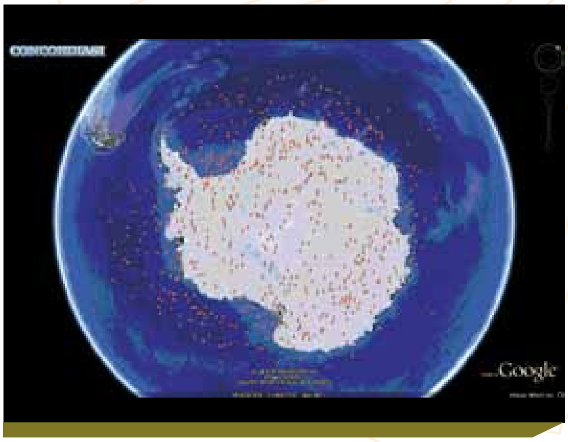
Abstract

Concordiasi is a multi-disciplinary effort studying the atmosphere and surface of Antarctica. In 2010, an innovative constellation of balloons provided a unique set of measurements. The balloons drifted for several months in the lowermost stratosphere around 18 km, circling over Antarctica in the winter vortex. In situ measurements included position, temperature, pressure, ozone, and particles, and profiles below the gondolas included temperature, pressure, humidity, and winds.

Résumé

Concordiasi est un effort multi-disciplinaire d'étude de l'atmosphère et de la surface en Antarctique. En 2010, une constellation innovante de ballons a fourni un jeu de mesures exceptionnel. Les ballons ont dérivé pendant plusieurs mois dans la basse stratosphère vers 18 km, tournoyant au-dessus de l'Antarctique dans le vortex polaire. Les mesures in situ comprennent température, pression, ozone, et particules, et les profils sous les nacelles incluent température, pression, humidité et vent.

[Fig. 1]



Concordiasi field campaign

In situ balloon-borne meteorological observations are useful to study the activity of mesoscale gravity waves above Antarctica and the surrounding oceans. Due to the quasi-Lagrangian behavior of long-duration balloons, the gravity-wave intrinsic frequencies and momentum fluxes can be directly inferred from these observations. First analyses indicate the enhanced signature of mountain waves above the Antarctic Peninsula, and significant activity above the ocean.

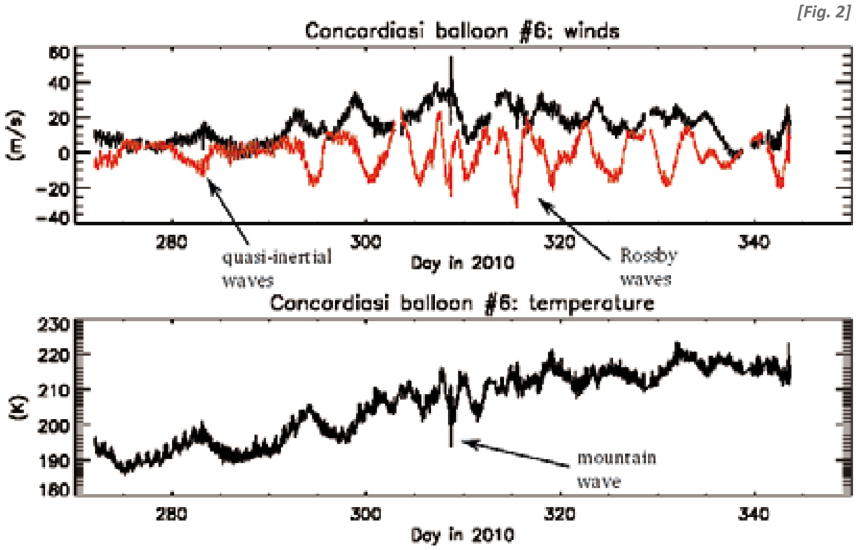
A proof-of-concept balloon-borne GPS radio occultation system was furthermore deployed on two of the Concordiasi campaign balloon flights to provide refractivity and derived temperature profiles for validation and improving satellite data assimilation.

The in situ observations of temperature, ozone, and particle size from the Concordiasi balloons provided new observations, along near Lagrangian trajectories, of the evolution of ozone and particle size as the sun returned to the Antarctic stratosphere. The instruments were designed to take advantage of this unique opportunity to observe, along air parcel paths, changes in ozone due to photochemical destruction, and changes in particle size due to temperature changes. The ozone measurements were made on six balloons, four of which were launched in early September. The Concordiasi payloads provided unique observations of ozone from which near-instantaneous ozone loss rates can be determined. Initial calculations suggest that ozone is being lost at rates up to 10 ppb per sunlit hour, which is slightly larger than published values.

The needs of Concordiasi spurred technological advances of the NCAR driftsonde system, which provided unprecedented high-quality, high vertical resolution upper air observations from float level to the surface.

[Fig. 1]
Location of the dropsondes deployed over Antarctica and the surrounding sea-ice during the Concordiasi field experiment (September-December 2010).

[Fig. 2]



[Fig. 2]
Upper panel: Timeseries of zonal (black) and meridional (orange) velocities measured in-situ (at ~ 18 km) during Concordiasi flight # 6 showing various kinds of waves with different amplitudes and characteristic timescales.

Lower panel: Corresponding timeseries of temperature.

Overall, the 13 driftsonde gondolas returned 644 high quality profiles. Consistent cold biases are found in all satellite data except in the upper troposphere in Microwave Integrated Retrieval System (MIRS) and in the lower troposphere in the Infrared Atmospheric Sounding Interferometer (IASI). The cold bias is larger relative to dropsondes than radiosondes as a result of a larger cold bias over the Antarctic continent than the coast and ocean. All radiosonde stations but a couple are located along the coast. The satellite data can reproduce observed temperature profiles reasonably well in spite of the biases.

Concordiasi meteorological observations, both at the gondola level and from the dropsondes were used in real-time at Numerical Weather Prediction Centres. The comparison between short-range forecasts and the data was investigated for centres in the US, France, Canada, ECMWF, Japan, Germany and the United-Kingdom. Results show that models suffer from deficiencies in representing near-surface temperature over the Antarctic high terrain. The very strong thermal inversion observed in the data is a challenge in numerical modeling. Dropsondes were shown to have a positive impact on the forecast performance, with an impact of the same order of magnitude as the one brought by radiosondes. Observations, both temperature and wind data have more impact when they are closer to the pole, with temperature information contributing most at low levels while wind information dominates at high levels (< 400 hPa).

On a per-observation basis, however, both wind and temperature have larger impact closer to the surface (lower troposphere). This corresponds to areas where there are very few other competing observations, mainly because of the difficulty of using satellite radiance information close to the surface, especially over high terrain.

The development of a Lagrangian approach to assimilating the driftsonde positions into the GEOS-5 assimilation system at NASA's Global Modeling and Assimilation office has been developed. Lagrangian assimilation utilizes position observations by producing a forecast of the balloon positions through a forward model of the balloon trajectory. At the surface, particular attention has been paid to the observation and the modeling of the interaction between snow and the atmosphere, which controls surface and near-surface temperatures and strongly influences the radiances as measured by the IASI satellite-borne sensor. The Dome-C Concordia station has been the focal point of this activity, thanks to its exceptional instrumentation, including observations of atmospheric profiles with a 45 m tower, turbulence, radiation, and snow-profile, among others. Both NWP operational and research models have been evaluated. This research has led to an improvement of snow representation over Antarctica in the IFS model at ECMWF. Coupled snow-atmosphere simulations performed at Météo-France with the Crocus/AROME models have been shown to realistically reproduce the snow internal and surface temperatures and boundary layer characteristics.

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Atmosphere

Laboratory contribution

Enhanced retrieval of aerosol properties from PARASOL

Parasol et sa nouvelle génération d'algorithmes d'inversion

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Abstract

By measuring the spectral, angular and polarization properties of the radiance at the top of the atmosphere, POLDER/PARASOL observations form the most comprehensive data set currently available from space and provide an opportunity for use of statistical optimization principles in satellite data inversion. The statistical optimization principles concept improves retrieval accuracy relying on pronounced positive data redundancy (excess of the measurements number over number of unknowns) that is not common in satellites observations.

Résumé

Grâce à ses mesures spectrales polarisées directionnelles, la mission POLDER/PARASOL fournit le jeu de données spatiales le plus complet. Cela nous permet d'envisager de lui appliquer des méthodes d'inversion de type estimation optimale où le nombre de mesures est supérieur au nombre d'inconnues, ce qui est actuellement unique dans le domaine de la télédétection des propriétés des aérosols depuis l'espace.

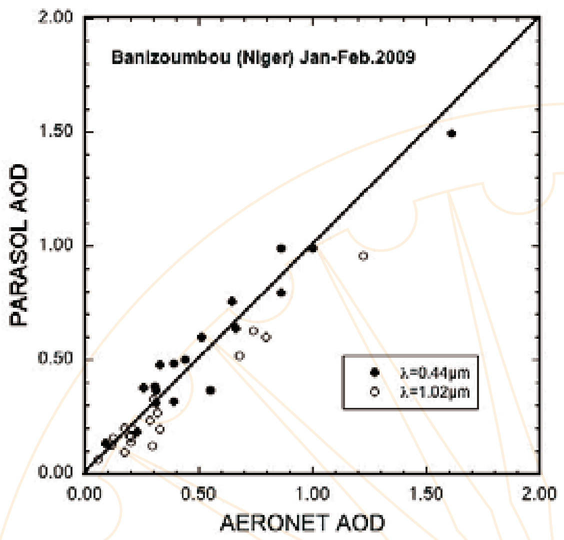
The POLDER (Polarization and Directionality of the Earth Reflectance) instrument on board of the PARASOL (Polarization and Anisotropy of Reflectances for Atmospheric Sciences coupled with Observations from a Lidar) micro-satellite registers spectral polarimetric characteristics of the reflected atmospheric radiation in up to 16 viewing directions over each observed pixel. The completeness of such observations is notably higher than for most currently operating passive satellite aerosol sensors and as illustrated in [1] from synthetic data, the PARASOL-like measurements associated with new sophisticated inversion algorithm are the most accurate means for retrieving the aerosol properties. The approach is expected to provide more detailed information (compared to the current operational PARASOL algorithm) about aerosol properties over land including information about aerosol sizes, shape, absorption and composition (refractive index).

The methodology is fully described in [2]. It unifies the principles addressing such important aspects of inversion optimization as accounting for errors in the data used, inverting multi-source data with different levels of accuracy, accounting for a priori and ancillary information, estimating retrieval errors, clarifying potential of employing different mathematical inverse operations (e.g. comparing iterative versus matrix inversion), accelerating iterative convergence, etc. The described concept uses the principles of statistical estimation and suggests a generalized multi-term Least Square type formulation that complementarily unites advantages of a variety of practical inversion approaches, such as Phillips-Tikhonov-Twomey constrained inversion, Kalman filter, Newton-Gauss and Levenberg-Marquardt iterations, etc.

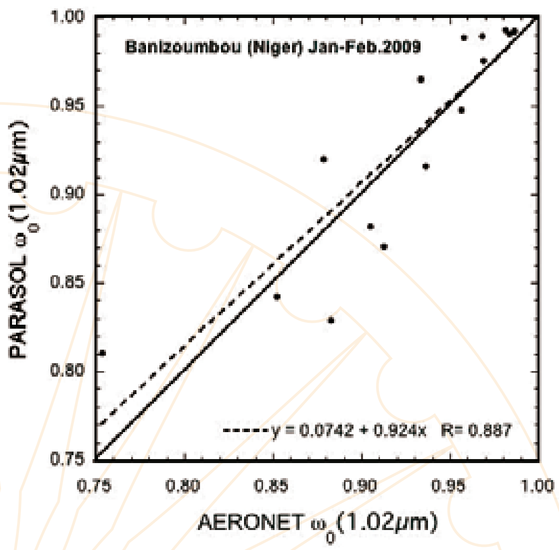
This methodology has resulted from the multi-year efforts on developing inversion algorithms for retrieving comprehensive aerosol properties from AERONET ground-based observations. The algorithm applied to satellite observations includes, additionally, constraints on the retrieved surface properties, e.g. a priori constraints on the spectral variability of the parameters describing surface reflection. It simultaneously retrieves the surface reflectance together with aerosol properties. Specifically, in processing observation over land, the algorithm is set to retrieve both the optical properties of aerosol and underlying surface.

For retrieving more accurately the aerosol properties, a new inversion option is considered in the algorithm: a simultaneous inversion of a large group of pixels within one or several images.

[Fig. 1]



[Fig. 2]



[Fig. 1]
Scatter plot of the AOD retrieved at 0.440 and 1.020 µm from POLDER/PARASOL in January-February 2009 over Banizoumbou/Niger with the corresponding values provided by AERONET.

[Fig. 2]
As in Fig.1, except for the single scattering albedo ω_0 at 1.020 µm.

Such, a multi-pixel retrieval regime takes the advantage from known limitations on spatial and temporal variability in both aerosol and surfaces properties. The multi-pixel constraints are rigorously integrated in statistically optimized retrieval in frame of multi-term Least Square formalism. Specifically, the pixel-to-pixel or day-to-day variations of the retrieved parameters are enforced to be smooth by additional appropriately set a priori constraints. This new concept is expected to provide retrieval of higher consistency for aerosol retrievals from satellites by enriching the retrieval over each single by co-incident aerosol information from neighboring pixels, as well, from the information about surface reflectance (over land) obtained in preceding and consequent observation over the same pixels. For aerosol contribution, the spatial variability is restricted to moderate for all aerosol parameters with the exception of aerosol loading driven by aerosol total concentration. For surface reflectance between pixels, all parameters of surface reflectance are assumed constant during ~7 days with no constraints at spatial variability of the corresponding parameters.

The retrieval capability is illustrated in Fig. 1. It shows a preliminary comparison of AODs retrieved at 440 and 1020 nm from PARASOL with coincident AERONET measurements over Banizoumbou, Niger, in January-February 2009. The values of aerosol single scattering albedo also agreed reasonably well with AERONET data for observations with high aerosol loading (Fig. 2). The differences between the values of $\omega_0(0.44)$ obtained from PARASOL and from AERONET did not exceed 0.03-0.05 for the cases when $\tau(0.44) \geq$ ~0.5.

Overall analysis showed very encouraging performance of the developed algorithm over bright land surfaces, i.e., in conditions that are considered traditionally the most difficult for retrieval of aerosol from satellites. This result is particularly encouraging because the algorithm is designed to provide a rather extensive set of the retrieved parameters providing detailed characterization of the properties of aerosol and the underlying surface.
Both the results of numerical sensitivity tests and the obtained results of actual PARASOL data inversion suggest that processing the PARASOL data with developed algorithm can provide global products of total aerosol optical thickness and additional radiative parameters such as the single scattering albedo consistent as required for computing the aerosol radiative forcing.

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