Research and development: annual report

2008

METEO FRANCE
Toujours un temps d'avance

Table of contents

The main objectives of Meteo France Research Unit remain the following ones:
• making weather forecast more reliable and finer, in particular regarding early warning of high impact weather, and enriching weather forecast with an evaluation of its uncertainty and an assessment of the impacts to be expected;
• improving the performance of our Earth System model to reduce uncertainties on global and regional climate projections in order to deliver the knowledge which is necessary to mitigate climate change and to identify the best strategies for the adaptation of the territories.

Going through the articles of this annual report, the reader will see that this strategy relies on topics which are both scientific challenges and a response to the main expectations of our society and decision-makers in the field of weather forecast and climate change. Some illustrations are given, for example, by papers on the following topics: production of regional climate scenarios, assessment of the impacts of climate change on extreme discharges of Mediterranean rivers, development of the new mesoscale model AROME designed to improve the forecast of heavy precipitation, development of an ensemble of assimilations for the Numerical Weather Prediction system ARPEGE, ...

In order to achieve his objectives, Research Department has to conduct actions in many areas: improvement of observation systems, understanding and modelling the processes which interact in the atmosphere and at its interfaces. Any further progress is a challenge relying on top level scientific projects which are, in most cases, undertaken within a national or international cooperative framework. In this context, a key component of Météo-France research strategy comes from its association with CNRS, forming the joint laboratory GAME. This lab was acknowledged in 2008 as a laboratory of excellence by the assessment agency AERES.

Éric Brun

Head of Research at Météo-France

Modelling

2008 was the year during which AROME was put into operational mode. But it is not the only outstanding event of the latest 12 months in the area of numerical weather prediction. Thus, implementation of an ensemble assimilation system, operational use of IASI data, various actions conducted in the framework of Flysafe represent very important progress for Meteo-France.

Synoptic numerical weather prediction

Operational assimilation of IASI data

IASI was launched in October 2006, onboard the polar orbiting European satellite MetOp. This new instrument is a Michelson interferometer which was developed by CNES in collaboration with EUMETSAT. IASI sounds a wide spectrum in the infrared region and thus brings a huge amount of information: 8461 pieces of information (channels) per observation point.

Similarly to all satellite-based radiances, IASI data have to be bias corrected (e.g. from viewing geometry induced biases) before being assimilated. The variational bias correction is a method that continuously adapts to possible variations of the bias; it is used in operation since February 2008 and satisfactorily handles biases in IASI data. As IASI sounds the infrared, its measurement is affected by the presence of clouds inside the observed profile. Therefore, the other important pre-processing step is to detect clouds in order to reject cloud-affected channels and keep only "clear" channels for each observed profile.

Since July 2008, 50 IASI channels are operationally assimilated over open sea, both in ARPEGE and in ALADIN; they bring information about the atmospheric temperature. The subsequent impact on forecasts is largely positive up to 4-day range in extra-tropical regions, especially in the Southern Hemisphere.

As IASI data provide a huge amount of information, several steps will follow: e.g. to use more temperature and humidity channels, to use data over land and sea ice, to better characterize clouds and surface emissivity. ❶

Assimilation of the MSG Seviri data

Already used at high-resolution in the assimilation of the Aladin model, radiances observed by Meteosat Second Generation (MSG) are now assimilated into the global operational model Arpege as Clear Sky Radiances (CSR produced by Eumetsat), with a horizontal spacing of 250km similarly to what is done for other satellite data. The impact of these data is relatively small but always positive, especially over Europe, and contribute to strengthen the observation network in our areas of interest.

Beyond their traditional use, data from the MSG SEVIRI imager can be used to identify the coherent structures in the atmospheric flows which can then be compared to those simulated by the model. Some parameters of the cyclogenesis seem very sensitive to the position and intensity of these anomalies. Dry intrusions, which are the signatures of these phenomena, can be detected and tracked down in the water vapour images of geostationary satellites (see figure).
Since traditional assimilation systems are not able to integrate this kind of information, the use of pseudo-observations in order to shift horizontally potential vorticity anomalies linked to these dry intrusions has been implemented. Therefore, the statistical relationships between water vapour, brightness temperatures and potential vorticity profiles have been studied, and specially developed tools have been applied to several cases of cyclogeneses.

A preliminary study on the direct use of these information about the structures has also been started, in particular, with the assimilation of the vertical position of the tropopause. ❷

A new parameterisation of the land surface emissivity at microwave frequencies

Microwave observations from AMSU-A & AMSU-B (or MHS) instruments have been widely used in Numerical Weather Prediction (NWP) to improve the initial conditions for short-range forecasts. AMSU instruments are on board low orbiting satellites. Observations from AMSU-A give information about the temperature distribution in the atmosphere whereas AMSU-B/MHS observations are used to measure the humidity at different levels of the atmosphere. The use of these measurements in NWP has made substantial progress but additional efforts need to be devoted to assimilate many more observations in a wide range of atmospheric situations and with a variety of surface conditions. Indeed, many issues are still to be addressed, in particular, the assimilation of observations over land surfaces. So far priority has been given to the use of AMSU measurements over seas together with measurements for which the contribution of the surface is negligible.
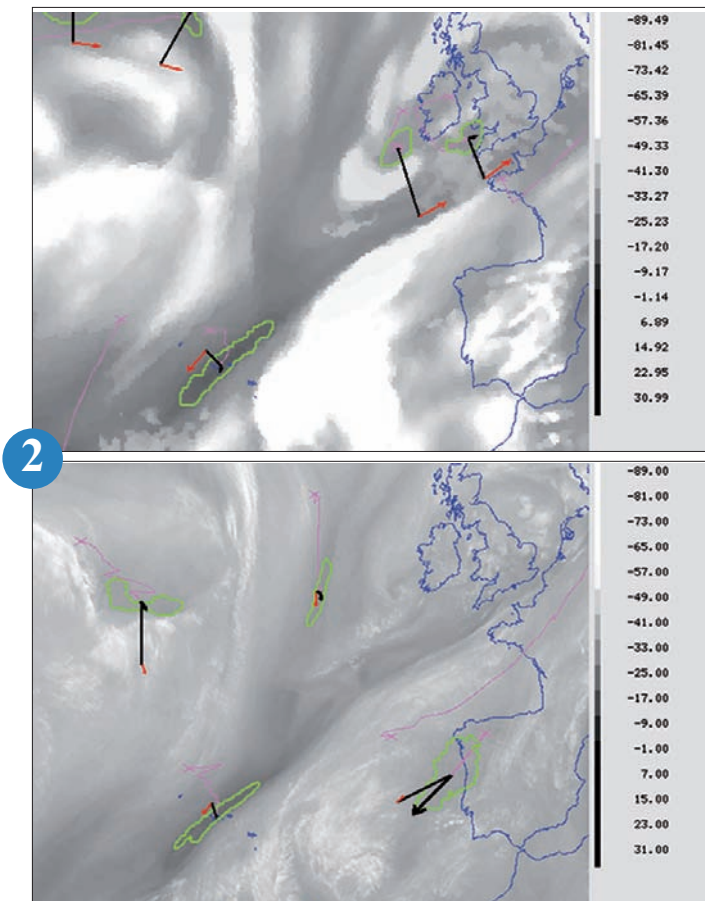
In July 2008, a new land surface emissivity parameterisation has been introduced in ARPEGE and ALADIN operational systems. The land emissivity parameterisation is based on a dynamic retrieval of the land surface emissivity at selected window frequencies (very sensitive to the surface) taking into account satellite observations and radiative transfer simulations of the atmosphere contribution to the radiometric signal. We have shown that the use of an improved description of the land surface emissivity allows the assimilation system to take advantage of the information content of AMSU temperature and humidity sounding channels over land. These results are very positive and suggest that it is now possible to explore new strategies to assimilate surface sensitive microwave observations such as humidity observations from AMSU-B/MHS which are still rejected from the assimilation system. Some feasibility studies have shown that the assimilation of low humidity observations over land is beneficial to the assimilation system as they better constrain the analysis of the humidity, especially in the Tropics. ❸
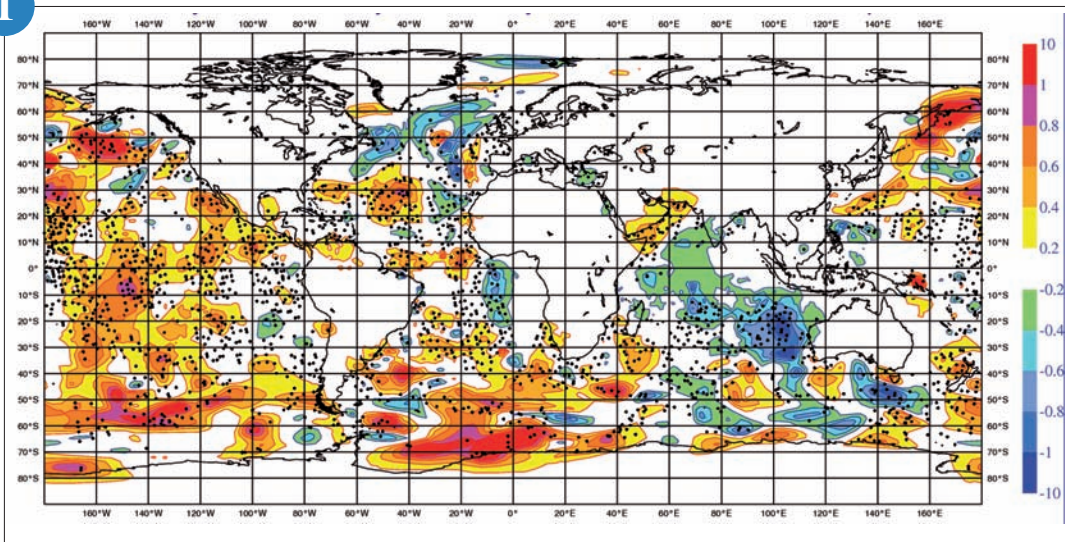
Impact on 500 hPa temperature analysis of assimilating 50 IASI channels over open sea (increments in shaded colours, unit is Kelvin). Crosses indicate IASI observations which are used in the analysis.

Example of water vapour image processing. Compared monitoring of the local maximum brightness temperature cells (green), with their estimated moving speed (black arrows) for images simulated by the model (top) and observed by the satellite (bottom).

Densité des observations assimilées (Nombre obs. par cellule de 2.5°x2.5°)

Densité des observations assimilées (Nombre obs. par cellule de 2.5°x2.5°)

Map of density of assimilated observations from AMSU-A channel 7 (sensitive to temperature at 8-10 km of altitude). The density values have been computed by counting the number of assimilated observations falling in a grid cell of 2° x 2° size and during August 2006. Results are for (a) the old operational system and (b) the new operational system.
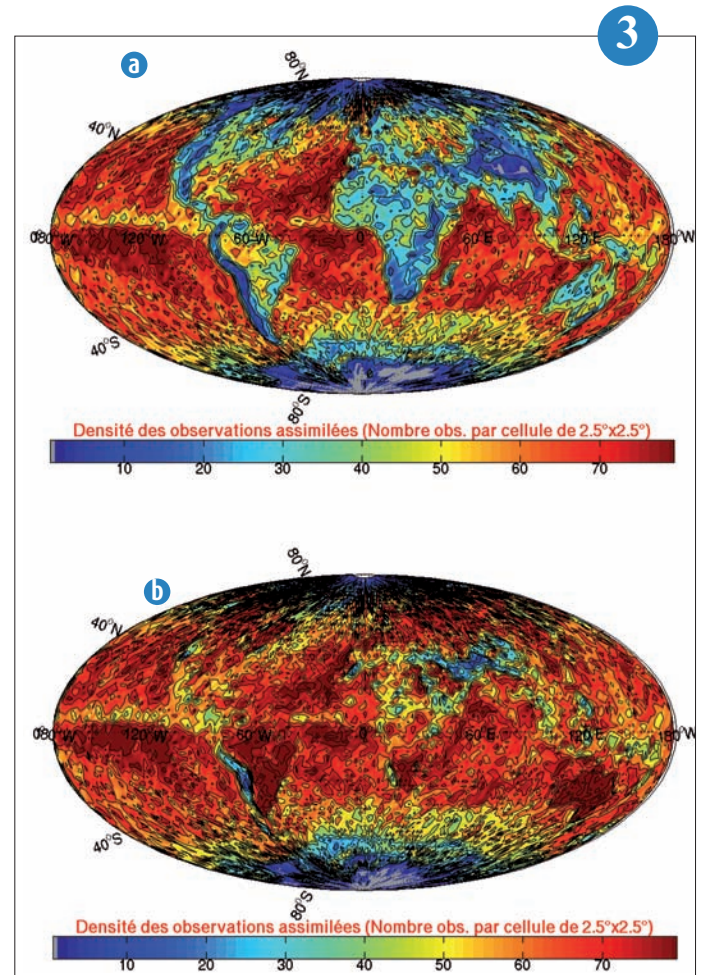
A 4D-Var convergence study of global model ARPEGE for an optimisation of operational implementation

The global forecast model ARPEGE is based on a 4D-Var assimilation system which minimises the distance (named J) between observations and a short range forecast of the model during a time window. Because of computational costs, this optimisation problem is solved by an iterative process with two minimisations computed at different and lower resolutions than those of the forecast model resolution. Recent and forthcoming increases of the horizontal and vertical resolutions in both assimilation and forecast parts of the model need a re-evaluation and a constant tuning of the assimilation parameters for an optimal configuration.

A 4D-Var convergence study shows that it is useless to do too many iterations during a minimisation and that it is better to perform more minimisations (see figure). It also shows the benefit of various components (variational quality, preconditioning ...). From these results and in order to save computational costs, a new configuration with one more minimisation and a tuning of the number of iterations is evaluated. It gives significant results and should be soon implemented. **4**

Evolution of the physical parameterisations of ARPEGE and ALADIN models

A major development of the ARPEGE and ALADIN models's physical parameterisations has been tested in an experimental suite during the second half of 2008 and became operational in February 2009. This development was a fruitful collaboration between all units of the CNRM which is characterised by a broad convergence between the parameterisations of hydrostatic models with those of AROME.

These changes include a passage to 6 spectral intervals in the short wave radiation scheme, the use of a new stratospheric ozone's climatology, the use of ECUME scheme to compute ocean's flux and a new approach for the parameterized subgrid vertical exchange treatment. This latter point involves a combination of a prognostic turbulent kinetic energy turbulence scheme, a parameterisation of the boundary layer top entrainment and a mass flux shallow convection scheme.

This new set of parameterisations allows more realistic temperature and humidity profiles in the boundary layer, consistent with those simulated by AROME. The prediction of low-level clouds is improved, this can be seen in figure (a) and (b). As it is shown in figure (c), an improvement of ALADIN's precipitation scores over France is also observed.

The next steps will be to increase the horizontal and vertical resolutions, to test the EDKF mass flux shallow convection scheme used in AROME since September 2008 and to evaluate an important evolution of the deep convection parameterisation, in the framework of the 3MT scheme developed in collaboration with ALADIN's partners. **5**

The collaboration within the Aladin and Hirlam consortia – recent activities on high resolution numerical weather prediction

Since the end of 2005, the international Aladin project has been deeply restructured, in order to reinforce its project management while maintaining a high level of scientific activity. In parallel, Météo-France with its Aladin partners are closely involved with the Hirlam consortium, in order to further strengthen the European and Mediterranean cooperation in numerical weather prediction. The goal is to pursue research and development on a common code software, and along a commonly defined strategy (kilometric scale forecasting, improvement of high resolution weather prediction for precipitations, fog, wind gusts etc ..., numerical efficiency, assimilation techniques and assimilation of high density observations). The Aladin/Hirlam group presently encompasses 25 countries. Strong links about software and research with ECMWF are also maintained, where Météo-France plays a key role through the IFS/Arpège collaboration.

One outcome of the past three years is the development and implementation of the Arome system within Aladin/Hirlam. To illustrate this point, the figure shows a case of summer convection over Sweden. The left panel shows 1h cumulated precipitation rates forecast by the Arome version run at the Swedish Meteorological Institute (SMHI). The right panel shows the values retrieved from radar observations. In this particular case, the model captures the precipitating areas inland, over Norway and Eastern Sweden, but also produces rainy patches over Western Sweden which were not observed at that time. **6**

Evolution of the distance J during the assimilation from the 3rd minimisation when 15 or 30 iterations are performed in each minimisation.
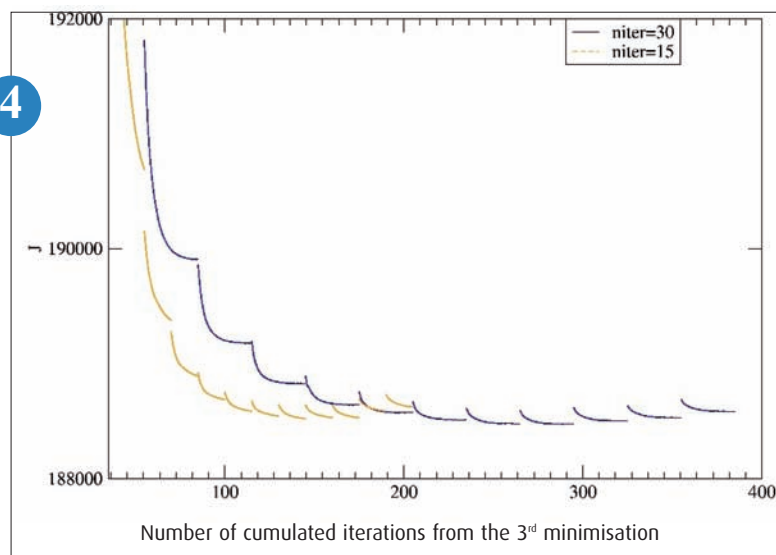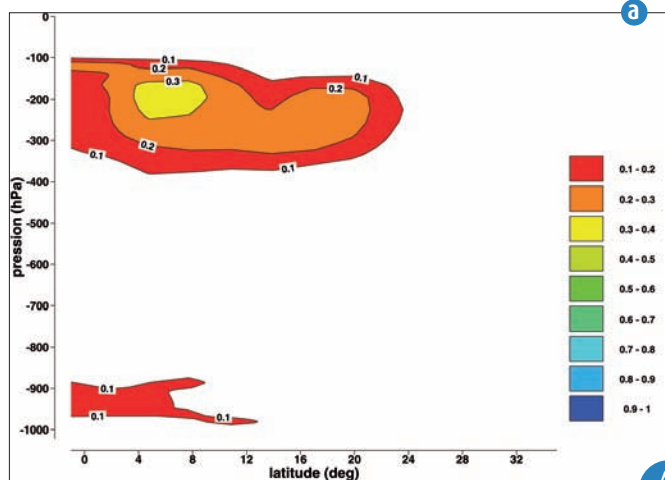
a : Cloud cover of the operational ARPEGE model for June 2007 along the GEWEX Pacific cross-section which starts from the Equator at 190° East to end by 35° north and 235° East close to the Californian coast. The ordinate represents the vertical graduated in pressure. Eastern Pacific stratocumulus are absent.

c : Heidke Skill Score of ALADIN's precipitation over France for September and October 2008. Perfect score is 1. On the abscissa the studied classes of precipitation (0.2, > 1, >3, >7, >15 mm/d) Experimental suite is in red, the operational one in black.

b : As figure (a) but with the new physical parameterisations. Eastern Pacific stratocumulus are now predicted.

Cumulated precipitations (mm/1h) of an Arome forecast (left) for August 12th 2008. Values retrieved from radar observations are on the right panel. By courtesy of Lisa Bengtsson (SMHI, Sweden)

Ensemble assimilation and forecast

Operational implementation of an ensemble assimilation

Data assimilation in systems such as Arpege, Aladin and Arome, are based on statistical characterization of forecast errors. In particular, one need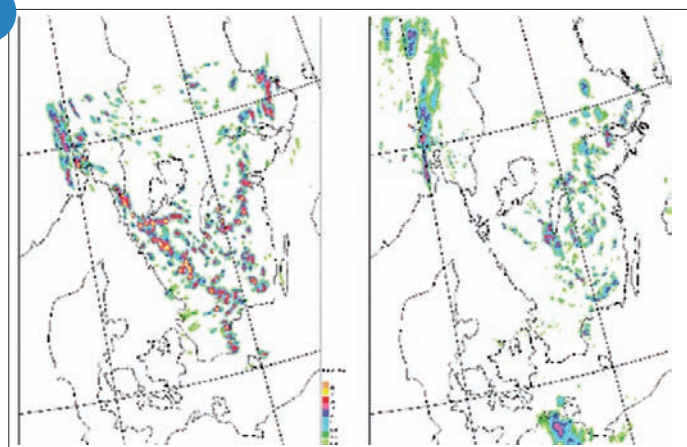s to specify expected amplitudes of these errors (which are described by variances). This is an important scientific challenge, knowing for instance that these errors depend on the weather situation.

In this context, an ensemble variational assimilation is now operationally run since the 1st of July 2008. This is the first implementation of this kind in the world, which is based on six perturbed variational assimilations. The spread of this ensemble allows space and time dynamics of forecast error variances to be estimated.

This is illustrated by the figure here, which shows a winter storm case over France, on the 8th of December 2006. Forecast error variances are relatively large there, in accordance with the strong uncertainty associated to this kind of intense weather system. This would suggest that greater weight should be given to observations in these critical regions.

It is planned to extend the use of this system to two aspects in particular. The ensemble assimilation will provide perturbed initial conditions to the ensemble prediction system. Moreover, spatial structures of forecast errors (described by correlations) will be estimated via the ensemble too. This will enable to take into account the weather situation in the way it spatially propagates the observed information. **7**

Towards upgrading the ARPEGE ensemble prediction system

PEARP, for Arpege ensemble prediction in French, is the global ensemble prediction system of Meteo-France. Originally developed within the Forecast Branch, it is an ensemble geared towards providing guidance for short-range probabilistic forecast.

During 2008, PEARP has undergone the following changes: a new version, numbered "1.5" has become operational early in the year; it included a new, fully global initialization, based on the previous day perturbations; the vertical resolution has been increased, being now similar to the one of the deterministic forecast ARPEGE without its mesosphere ; the forecast range has been extended to 108 h in order to cover the same period of time as the 00 UTC deterministic ARPEGE forecast ; finally, since November 2008, the evolution of a further ten members is computed every day beside the operational environment. The figure illustrates one point of interest of this ensemble forecast tool: to provide some help on early warnings, particularly warnings beyond the range covered by the AROME model on the risk of large cumulated precipitations.

Other experiments have also been made during 2008. The impact of several sets of physical parameterizations has been examined and compared to a simple random perturbation of the standard set of output: the probabilistic scores benefit more from the diversified set. The impact of coupling the ensemble forecast to the ensemble assimilation mentioned elsewhere in this document is also being assessed: this improves the scores too. All these changes will be gathered together to make up an important upgrade of PEARP in 2009, while the Forecast Branch is setting up a project in order to improve its usage. **8**

The Data Targeting System: a test of feasibility of operational adaptive observation

The concept of adaptive observation went into a new phase over Europe in 2008 : EUCOS implemented a system devoted to the tuning of the time frequency collection of in-situ data sent by commercial aircrafts and some radiosonde profiles from ships and surface stations.

This system called Data Targeting System, might be defined as a multi-stage rocket: at day D National Weather Prediction Services interested in this initiative (Meteo-France is one among the most interested), are supposed to work on one or two high impact weather elements that might affect Europe according to the lead-forecaster (who belongs to the UK Met. Office). Then, sensitivity computations are launched (see the figure for an example) in order to decide where to put the extra observations at day D+1 leading to a reduction of the forecast error at day D+3 or D+4. The whole decision-making process needs almost 6 hours. Meteo-France suggested cases to be targeted on a regular basis and for short periods, a senior forecaster has played the role of lead forecaster. **9**

Dependence of forecast errors on the weather situation, estimated with an ensemble assimilation.

(a) : mean sea level pressure, on the 8th of December 2006 (unit: hPa) ;

(b) : forecast error standard deviations of vorticity near 500 hPa, for the same date (unit: 10^{-5} s^{-1}).
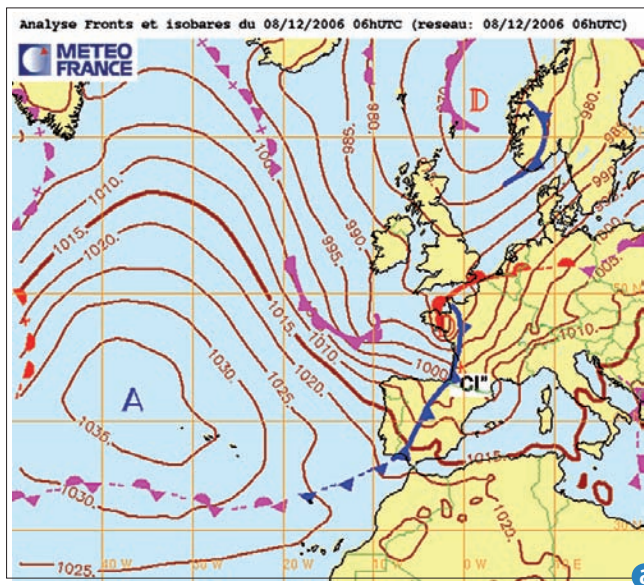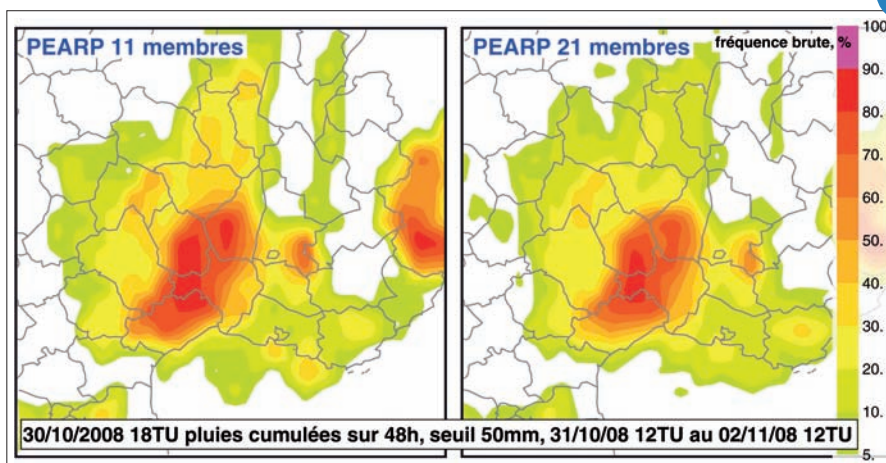
The risk of large 48 h accumulated rainfall is shown for the heavy rain case of 1 to 2 November 2008, taking the episode duration into accou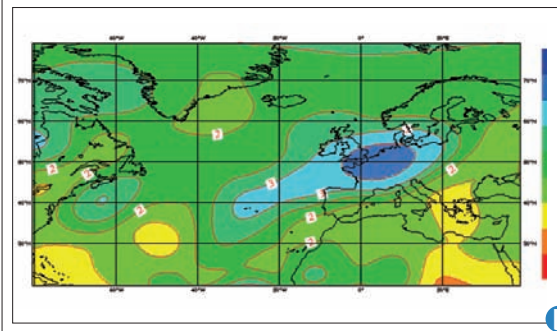nt. The large amount of rainfall is considered here within the framework of the model, without correction (also called calibration), hence the rather modest 50 mm threshold employed. Benefiting from the improvements described in the text, both ensemble size appeared to provide useful information : 11 members (left panel) and 21 members (right panel). The most exposed areas (with a raw frequency larger than 50 or 60 %) are more finely outlined by the 21 members ensemble.

Sensitivity maps available in real time on the 25th of November 2008 used to determine the optimal location of supplementary observations to be collected at 18 UTC (D+1) in order to reduce the forecast error within the area delineated by the blue square 30 h after the analysis which includes the extra observations. Here, the lead forecaster put the emphasis on the sensitive area provided by ECMWF since it is co-located with many targetable observations. CEPMMT sensitivity maps are based upon the linear version of the numerical weather prediction model and its adjoint as well UK Met. Office and Météo-France use their ensemble prediction system. ▼
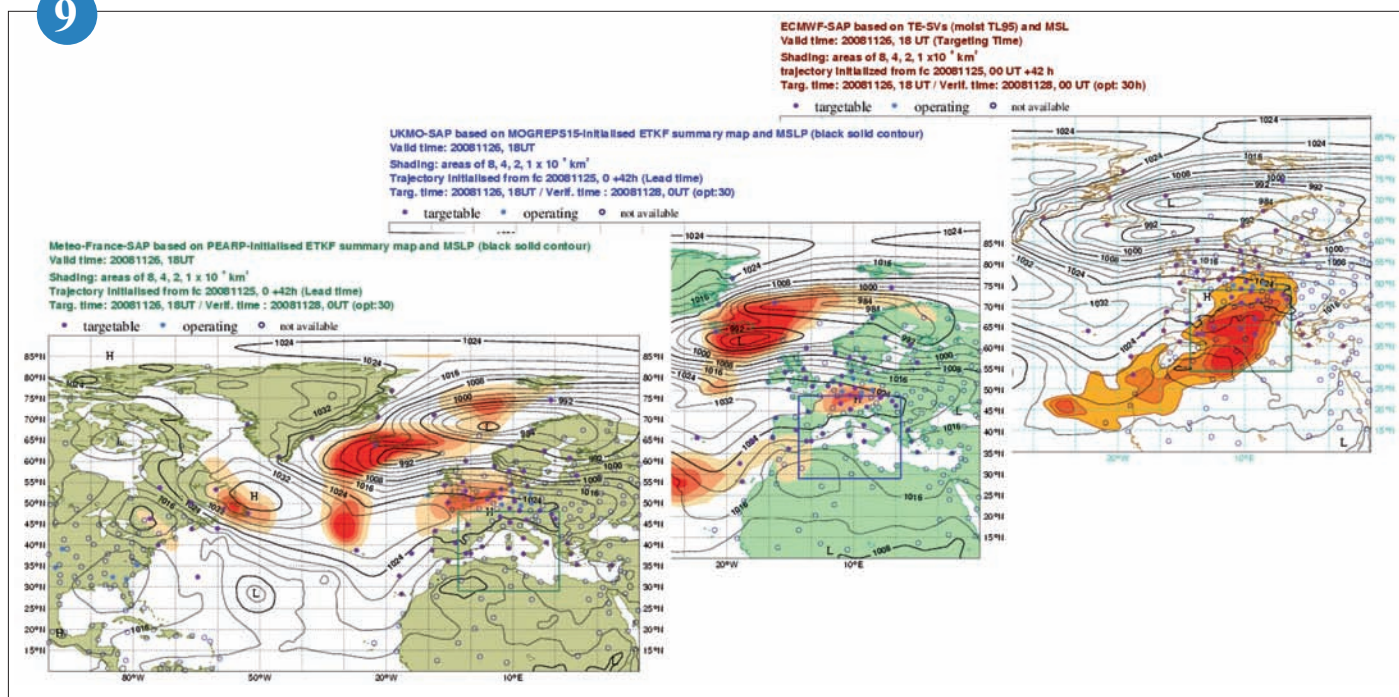
Mesoscale numerical weather prediction

AROME on operations

Since the 18th of December, the Arome model is routinely used by the Meteo-France forecasters once they have completed a training course.

The latest scientific developments activated inside the model at the beginning of the autumn 2008 consisted in :
• the activation of the EDKF scheme that was developed and tested during the previous years at CNRM by the GMME team for shallow convection
• the activation of the SLHD (Semi Lagrangian Horizontal Diffusion) numerical diffusion on the hydrometeor variables and developed in the framework of the ALADIN consortium, and which is used in some of the operational versions of our partners.

These latest modifications were installed in order to correct some of the defaults that were detected by the forecasters during their systematic evaluation of the Arome prototype, these subjective evaluations had started early in 2007. These defaults are an unrealistic wind circulation inside the boundary layer in some specific meteorological conditions and the occurrence of overestimation of intense precipitations.

As far as the technical aspects are concerned, the suite that was configured this year by the operational teams has got the same characteristics than the one managed by CNRM : in particular a geographical domain covering the French territory with a horizontal mesh size of 2.5 km, a 3-hours assimilation cycle using the same observations as its coupling model Aladin augmented by the observations of the wind of Doppler radars.
The training of all the forecasters of Météo-France started during the autumn 2008 and will carry on until the end of the first quarter of 2009. **10**

AROME bound for release 2

The AROME numerical weather prediction system went into operational production in December 2008. It improves short-term forecasts of most weather events thanks to its new model (non-hydrostatic with a 2.5 km horizontal mesh over mainland France, and renovated physics) and dedicated data assimilation (which uses radar-derived winds, Meteosat satellite radiances and data from automated French RADOME stations).

A new release of AROME is being developed and scheduled for operations in 2009. It will include a substantially improved vertical resolution, which will be doubled in low atmospheric layers for the benefit of fogs and low clouds prediction. Modelling of cloud and precipitation microphysics will be improved. Use of radar reflectivity data will improve humidity and precipitation initialisation, with a novel Bayesian data assimilation technique. Other data assimilation features will enable the use of high-frequency observations and improve the representation of surfaces. The emphasis is to improve short range (i.e. current-day) predictions.

In parallel, a very high resolution AROME prototype has been tested with a mesh of 1 km, even less; it has brought encouraging results over the Alps during skiing world championship in Val d'Isere. **11**

## Assimilation of radar data in the AROME model

After having shown a positive impact on the short term forecasts of precipitating systems, radial winds of 15 Doppler radars from the national network ARAMIS are included from now on in the 3DVar assimilation of the operational AROME model. Indeed, the four-month evaluation of the impact of these data in the system, along with daily monitoring of the quality of the observations, have provided satisfactory results, especially in case of a good sampling of the low-level dynamic linked to convective systems.

An important evolution is the assimilation of radar reflectivities, which is routinely evaluated since the end of 2008.

The algorithm consists in retrieving relative humidity profiles from the observed reflectivities, since the different hydrometeor types can not directly be used by the model. The profiles of the model in the vicinity of the observation are used in order to assess the necessary information about precipitating species to constraint the solution. These humidity profiles are then directly assimilated in the 3Dvar (see figure). An evaluation of two months of cycled assimilations have shown a positive impact on scores of precipitating forecasts.

In the short term, several additional radars (including coastal) may be used in the operational assimilation of Doppler winds, following the work performed in collaboration with DSO/CMR to better characterize clutters, such as sea clutters. This work has also led to a better characterization of the "no-rain" signal that is very useful to the algorithm to dry and to shift misplaced precipitating patterns. **12**
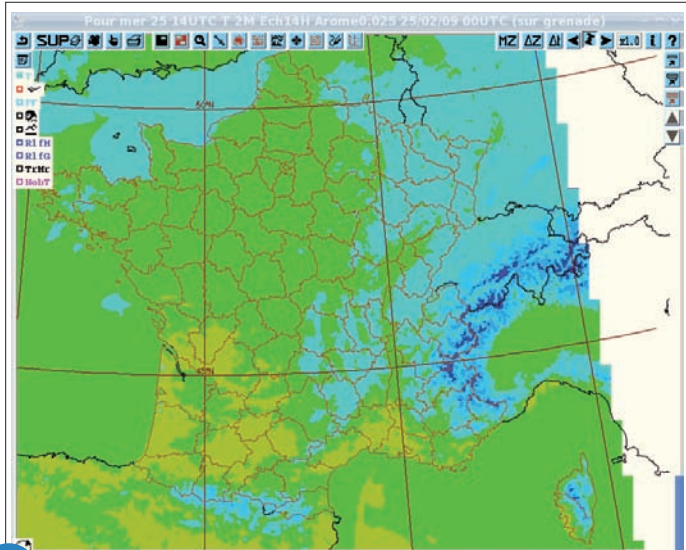
▲ 2 meters temperature forecast of the Arome model. 14 hours forecast starting the 25th of February 2009 at 00 UTC (visualisation on forecaster operational workstation)

▲ (a) low clouds and fog cover (in light grey) seen by the Meteosat satellite (visible channel), modelled by AROME with its end-2008 configuration (41 levels, panel b), and with its end-2009 planned configuration (60 levels, panel c). This case concerns the Garonne and Adour valleys on 27 January 2008.

▲ Squall line on the South-East of France October 2008, the 8th. Top panels : at 06 h UTC, composite reflectivity pattern (left), analysis increments of specific humidity at 850 hpa deduced from the AROME assimilation system with (middle) and without (right) radar reflectivities (yellow-orange contours denote positive increments, isocontours every 0,1 g/kg). Bottom panels : at 09 h UTC, composite reflectivity pattern (left), 3 h AROME forecast of the 900 hpa simulated reflectivity field from an analysis provided by the assimilation cycle with (middle) and without (right) reflectivities.

AROME ensemble simulations of Mediterranean heavy precipitation events

The southeastern region of France is prone to intense precipitation events during the autumn season. The aim of our study was to assess the convective predictability, that means to identify and to quantify the different uncertainty sources that impact Mediterranean heavy precipitation events based on the fine-scale atmospheric model AROME. A typical case of quasi-stationary mesoscale convective system with significant total precipitation (more than 450 mm in 24 hours over the Cévennes area) is presented here.

Due to strong non-linear physics at smaller-scale (water cycle processes, convection, turbulence,...), dedicated ensemble generation methods are developed and used to assess convective-scale predictability. The uncertainty on synoptic-scale initial conditions and lateral boundary conditions is provided by an appropriate selection (based on principal component analyses) of the members of the Meteo-France's short-range large-scale PEARP ensemble. A mesoscale data assimilation is also performed to have initial conditions and observations as close as possible.

Time evolutions of domain-averaged simulated precipitation show the impact of the synoptic-scale conditions provided by PEARP members on the high-resolution precipitation forecasts. The spread of the forecasts characterizes the uncertainty on the quantitative precipitation forecast and this approach can fairly well capture the intensity of the observed precipitating system.

The uncertainty on mesoscale initial conditions and model errors will also be taken into account in future works. This study is currently in progress at CNRM and will be carried out within the framework of the MEDUP project, funded by the French national research agency (ANR- Vulnérabilité Climat et Milieux). **13**

Impact of GPS AROME data assimilation on COPS IOP9

Originally designed for navigation and positioning purposes, the signals transmitted by the GPS satellites to the GPS receivers have also proved to contain relevant meteorological information. In fact, the earth atmosphere induces a delay on the signal travel which is related to the refraction of the atmosphere and more specifically to the water vapour. Meteo-France is developing the assimilation of these delays in its Numerical Weather Prediction (NWP) systems in order to improve the humidity analyses. The data assimilation of GPS delays has been first developed within the global ARPEGE system and in the limited area ALADIN-France model, then during this past year in the new operational high-resolution NWP system AROME.

The impact of assimilating GPS delays has been studied more specifically for IOP9 (18-20 July 2007) of the COPS field campaign over the Black Forest and the Vosges region. A clear positive impact on the AROME precipitation forecast has been found when the GPS delays are assimilated. The impact is more important on IOP9b (19 July) as shown in the figure.

The high-resolution temporary GPS receivers network deployed during the COPS campaign over the Black Forest and the Vosges region provides a unique opportunity to evaluate the benefit of assimilating such high-spatial GPS data in addition to those from the operational European E-GVAP network. Results from the data assimilation experiments show that the forecast improvement obtained when GPS delays are assimilated, mainly come from assimilating the E-GVAP data. This constitutes an essential result from an operational point of view. Even though the spatial resolution of the E-GVAP network is well below the AROME resolution, the E-GVAP data provide relevant mesoscale information to improve the AROME analyses of low and mid-troposphere humidity. **14**

24-h accumulated rainfall from Meteo-France's raingauge network in **a)** and observed radar reflectivities from Nîmes radar, 21 Oct. 2008 at 15 UTC in **b)**.
Panel **c)** displays time-series from 21 until 22 Oct. of 3 h- accumulated rainfall averaged over the geographical area presented here. The different forecasts of the ensemble with AROME are represented by the curves and observations are the black squares.

▲ 12-h accumulated precipitation (mm) from 03 UTC to 15 UTC, 19 July 2007 (IOP9b of COPS) from the raingauge observations **(a)** and the AROME forecasts **(b,c)** starting from the analysis valid at 00 UTC, 19 July 2007. The AROME 00 UTC analysis is issued from a data assimilation cycle not using the GPS delays **(b)** or using the GPS delays **(c)**.

Nowcasting

Improvement of storm detection by satellite

Meteo-France develops under the SAF Nowcasting, a tool for the detection and tracking of storm from satellite imagery. This tool, known as RDT, is particularly useful in areas without ground network for detecting storm. It has been tested in West Africa and addresses various needs :
• research on the African monsoon ;
• meteorological support to African meteorological services via ACMAD ;
• meteorological support to the French armed forces.

The development effort conducted during the year 2008 focused on improving the discrimination of stormy phenomena. The complete overhaul of the discrimination algorithm has significantly reduced the number of false alarms while increasing the number of good detections. The temporal stability of detection was also considerably improved. Accordingly, the 2009 RDT version developed this year represents a leap in quality in the ability of Meteo-France to diagnose storm phenomena from satellite imagery. These improvements should enable the 2009 RDT to acquire the operational status from EUMETSAT.

This new version is already implemented by Meteo-France and will be available for SAF Nowcasting users from march 2009.

The diagnosis of stormy periods is now satisfactory. Nevertheless, the early detection of storm phenomena before the first occurrence of lightning has still to be improved. In 2009, research will mainly focus on this topic. **15**

New nowcast systems for aviation : validation using in-situ airborne measurements

Nowadays, pilots get weather information for their whole flight path only before take-off. They have limited access to updated forecasts during the flight. Since 2005, within the framework of Flysafe, a European project, a group of European national weather services, including Météo-France, is developing new weather information systems called Weather Information Management System (WIMS) enabling the uplink of up-to-date weather nowcasts during flight. These new weather information systems present dangerous areas as polygons with a severity level attribute. These dedicated nowcasts are produced using different observation networks. Three hazardous weather phenomena are studied: thunderstorms, in-flight icing and turbulence.

In 2008, two flight tests campaigns have been performed by research teams from Météo France and the Dutch National Aerospace Laboratory, from several European airports : Toulouse, Amsterdam, Paris area. The aim of these campaigns was to test these new weather information system prototypes for thunderstorms and in flight icing.

Engineers and scientists on board the two research aircrafts (Meteo-France's ATR 42 and NLR's Metro II) tested the uplink of weather information during flight and gathered atmospheric measurements that will be used for the validation of these new dedicated nowcasts.

The next steps will be the test of these new weather information management systems in a real cockpit environment in the NLR's flight simulator. The Flysafe programme will end in June 2009. **16**

Combining aircraft on-board radar data and thunderstorm nowcasts

The FLYSAFE EU 6th framework project aims at developing the New Generation Integrated Surveillance System, devoted to commercial aircraft flights security. It includes the handling of thunderstorm risk. A so-called Weather Information Management System for Cb (Wims-Cb) devoted to thunderstorm detection and one-hour range nowcasting has hence been developed. Its refresh rate is 5 minutes and it uses all ground-based observations : advanced radar data (3D scans, dual polarization data), a European radar composite, advanced satellite-based data (including cloud top height estimates and Rapid Scan data) and lightning detections.

This system has been tested during a flight tests campaign in august and september, with two aircrafts. The dutch NLR Swingo aircraft was equipped with Wims-Cb data acquisition and data fusion with on-board radar data, coming from an advanced radar provided by Rockwell Collins. The ATR 42 aircraft of the SAFIRE CNRM department was devoted to in-situ measurements and conventional onboard radar recording.

The Wims-Cb products added value (with respect to onboard radar data) lies in the comprehensive thunderstorm description they brought from various data sources, which covers the whole troposphere and wider areas, and in the forecast of the trajectories of thunderstorms. The comparison of both data, which is still ongoing, already clearly showed that Wims products provide a better anticipation of thunderstorms. **17**

Meteorological situation of August 2004, 17th :
comparison of the informations given
by RDT 2008 and RDT 2009.
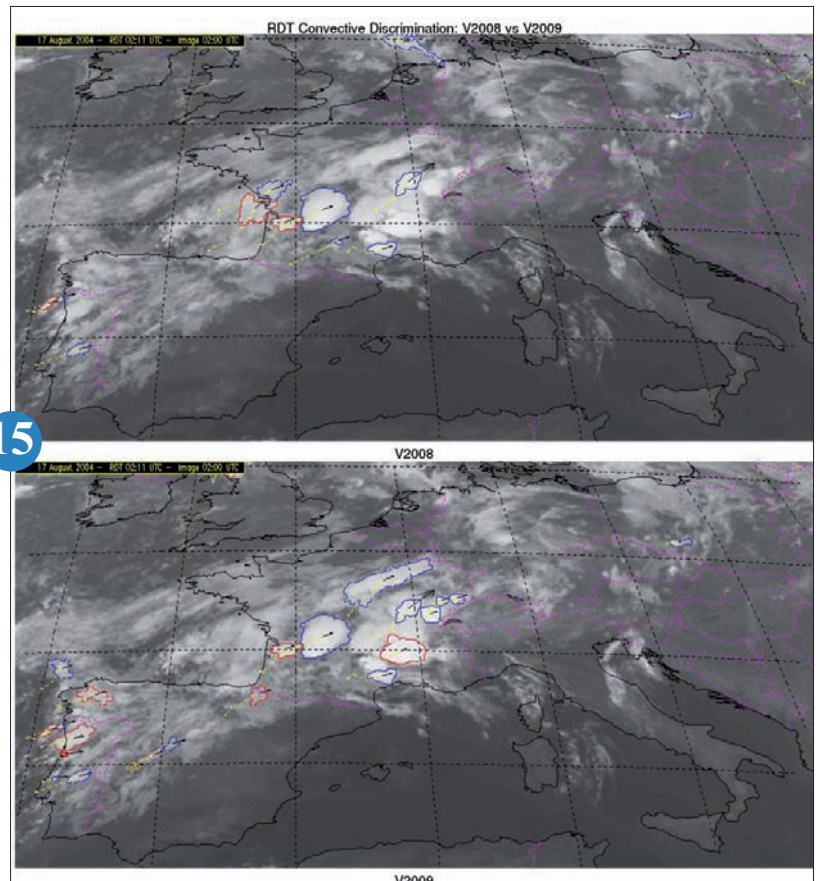
Ice accretion around the ice probe of the ATR 42 during
a test flight performed the 12th of August 2008

Thunderstorms and flights safety : the SAFIRE ATR42 onboard radar display
shows the measured reflectivity ahead of the aircraft (in green, yellow and
red) ; orange dashed contours show the corresponding Wims-Cb thunderstorm
depiction ; they show, at long ranges, thunderstorms which cannot be sensed
by the onboard radar due to its measurements limits. This case occurred
around Lyon on 19 august 2008, at 14 h 05.

The contribution of the Radar Meteorology Centre to the FLYSAFE European project

In the framework of the FLYSAFE European project, a special emphasis was put on elaborating new radar products tuned for aviation, based on new technologies such as three-dimensional exploration of the atmosphere, Doppler or polarimetry.

Three-dimensional wind, reflectivity and hydrometeors fields were delivered in real time over an area covering Paris and its main airports. They served as input to an icing forecasting expert system. Similarly, a specific multi-layer product (including the maximum reflectivity on the column, the altitude of the maximum reflectivity on the column, the vertically integrated liquid content, the altitude of the top of the convective cells, the probability of hail) was produced as an input to a thunderstorm forecasting expert system. Two flights campaigns, one in winter (February 2008), one in summer (August 2008), gave the opportunity to demonstrate the performances of such expert systems.

Meteo-France and its Radar Meteorology Centre gained experience in participating in the FLYSAFE project. This experience will benefit the new R&D projects planned in the frame of the SESAR (Single European Sky ATM Research Programme) program. **18**

Improvement of thunderstorm forecasting on the two-hour range

Thunderstorms are influenced by atmospheric processes that are difficult to observe and which require frequent observation updates. Typically, forecasters are left with a very limited time to examine a variety of observations for issuing a timely forecast of thunderstorms on the two-hour range. Hence, the forecasts rely substantially on automated prediction systems. Numerical weather prediction models are not the most appropriate tools to tackle this problem because by the time the model output is ready, the forecast is generally outdated. The extrapolation of observed thunderstorm motion - determined by radar or lightning detection network - is a more adequate approach, but only for forecast ranges varying from 30 min to 60 min; beyond the hour, it is also necessary to predict changes in the thunderstorm intensity.

A study was carried on in 2007 and 2008 to improve an automated prediction system (based on the extrapolation of radar fields) by seeking statistical relationships between changes in the thunderstorm intensity and atmospheric parameters known to influence its behaviour (see figure). These parameters include atmospheric moisture, instability necessary for vertical motions and lifting mechanisms to initiate the thunderstorms. The novelty of this system consisted in obtaining parameters from a high-resolution (about both time and space) atmospheric analysis system, called VarPack, that takes advantage from real-time data made available by the surface observing network .

After a preliminary tuning, it was found that the skill of the prediction system for regions of flat terrain is sensitive to large-scale atmospheric conditions: best skill (medium to high) is found for anti cyclonic conditions. Work is still underway in order to improve the statistical tuning, and to apply the statistical model to new cases before the system can be considered as operational. **19**

Thunderstorm risk monitoring service

The SIGnificant weather Object Oriented Nowcasting System (SIGOONS) is based on a scheme combining forecaster's expertise and observation data advanced automated processing; it is an object oriented system for detection and forecasting significant phenomena at a few hours'range. Downstream, SIGOONS feed nowcasting warnings automated generation. Up to now, SIGOONS manages thunderstorms only.

SIGOONS development follows two streams:
• To put on operations a "fully automated" SIGOONS able to produce useful thunderstorm risk warnings, in order to demonstrate the capability of warnings service for Météo-France's customers at the short nowcasting range. At this stage of automation, warnings are limited to a range of one hour.
• To ensure interaction feasibility and efficiency to match forecaster's expertise on thunderstorms forecasting, for improving warnings timeliness, intensity and location.

2008 was marked by the marketing of the thunderstorm warning service named "Thunderstorm risk monitoring service" and by experiments with three regional forecasting services in real-time to assess added expert value to warnings.

Beyond 2008, the goals are to operate thunderstorms expertise routinely using SIGOONS, to improve automation in thunderstorm description using new radar data (3D, doppler, polarization data) and mesoscale numerical weather prediction data (Arome, VarPack), to introduce a probabilistic description of warning location and intensity, and to manage the strong wind events. **20**

Extension of RDT product to overseas regions

LRDT is a product developed by Meteo-France based on data coming from geostationary satellite MSG. It detects and tracks cloud systems, and identifies those which are convective. This product is well adapted to regions without radar coverage or accurate electrical detection, and also to the early phase of thunderstorm development.

RDT has been first applied in tropical areas in 2006 in Africa in the framework of the AMMA campaign. It has been largely used for experimental flights planning and also for meteorological analysis. This production has been continuing from this period.

A new production has been undertaken in 2008 for the Antilles-Guyane region, covered by US GOES satellite. Despite a lower update rate over the area (30' instead of 15'), the tracking of thunderstorms remains relevant, and still brings an additional element for meteorological analysis. This product will soon be available to forecaster workstations.

On the other hand, the product itself has been improved with a new approach for thunderstorm identification.

The new version of RDT begins to be used in overseas departments, the closest to metropolitan France being provided first. This action will continue during the next few months, depending on the available geostationary satellites characteristics, with the Indian ocean first, then the Pacific regions. **21**

20070525 1600   6 RADARS
Abbeville Arcis Avesnes Bourges Falaise Trappes
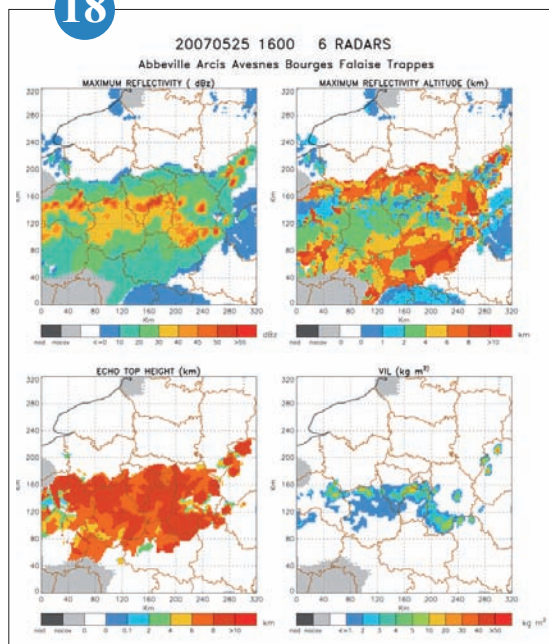
▲
Examples of 2D fields retrieved from 3D fields for aviation purposes. From top to bottom and from left to right: maximum reflectivity on the column, altitude of the maximum reflectivity on the column, altitude o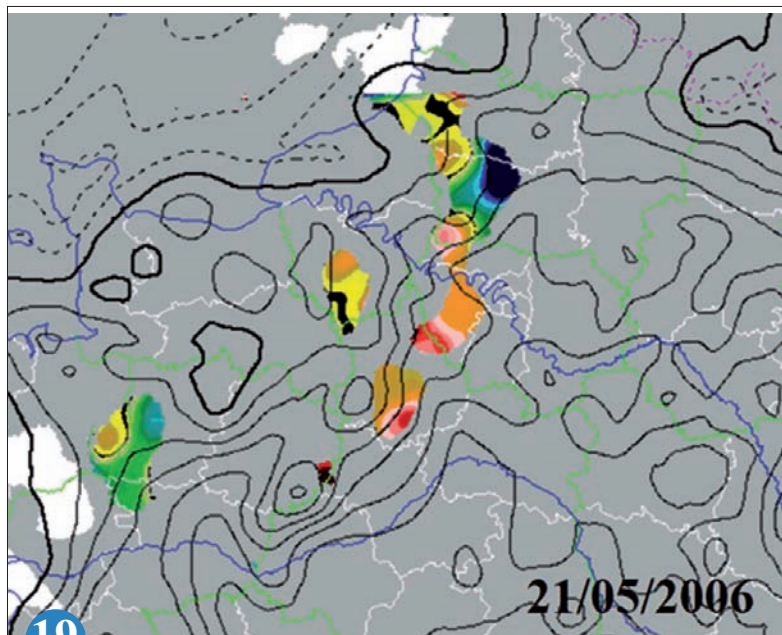f the echo top, vertically integrated liquid content (VIL). These parameters were produced each 5 minutes at an horizontal resolution of 1 km².

21/05/2006

▲
Change in the intensity of a thunderstorm over 45-min (coloured shading) and a measure of the atmospheric instability (black contours) for north-central France during the afternoon of 21/05/2006. Yellow, orange, pink and red colours indicate a storm intensification, while green and blue colours indicate a storm weakening. Dashed (Solid) lines indicate the level of instability below (above) a given threshold.

◄
Thunderstorm risk tracking service combine 24 hours range forecasts, 'Vigilance' informations, email or SMS nowcasting warnings and web and mobile phone graphical monitoring product. Example of the web graphical monitoring products on 17th September 2007 on Toulouse at the end of afternoon. The product includes loops, zoom, and warnings details display.
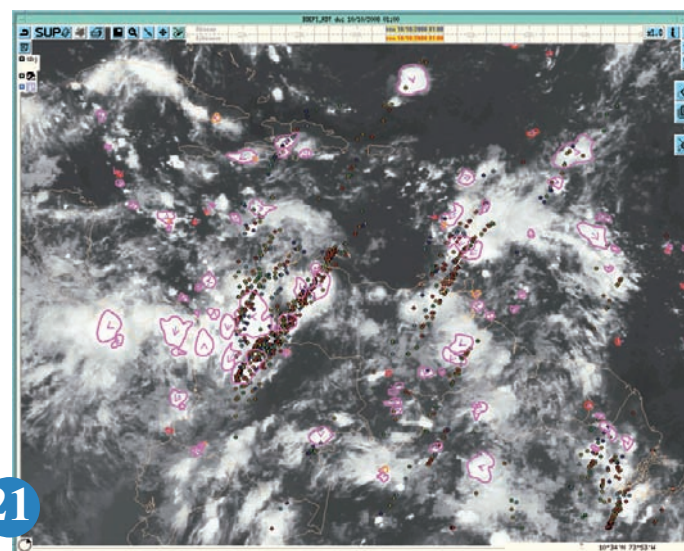
▶
Visualisation of Antilles – Guyane RDT on forecaster display. Overlay of GOES IR image, thunderstorm contours and lightning impacts of long range detection network from UK MetOffice.

Cyclonic forecasting

Observations for tropical cyclones forecasting: cloudy/rainy radiances and scatterometer winds

The description of tropical cyclones remains a major challenge in the initialization of forecast models. Several fields for improvement have been explored: processing of observations in cloudy/rainy areas and the introduction of new observations.

Radiance assimilation is currently limited to meteorological conditions with little or no clouds, because complex physical processes have to be taken into account to interpret the measurements in cloudy/rainy conditions. This is now performed at ECMWF and our aim was to test the potential of using these extra data, at a reduced cost. To this purpose, integrated water vapour content is estimated by multi linear regression of cloudy/rainy SSM/I radiances from ECMWF analysis. The 3D-Var assimilation in ALADIN Réunion of these pseudo-observations leads to an atmospheric humidity analysis more appropriate and better localized. Cyclone forecasting is improved in terms of intensity and structure. Humidity bias is reduced, even in clear sky, and the model better fits the wind measurements. This work is a preliminary step in the development of a pre-processing using moist physics in ARPEGE/ALADIN/AROME.

The ocean surface wind measured by scatterometry is retrieved but with an ambiguity about its direction which is solved by the model background. Taking into account the 4 most likely directions of the SeaWinds scatterometer (instead of 2) improves the quality of the measurement (mainly in dynamically active areas), in a similar way of the new data from ASCAT scatterometer, for which only two directions are considered. The combination of these two instruments together with the AMI scatterometer (similar to ASCAT) is the best observing system for the ocean surface winds (1.2 m.s^{-1} in terms of standard deviation vector), with an almost global coverage every 6 hours and therefore an improved monitoring of tropical cyclones. **22**

Better taking into account the ocean for the prediction of tropical cyclones

One of the key processes for the development and the life cycle of a tropical cyclone is its interactions with the ocean, which constitutes its principal energy tank. The modelling of fluxes between ocean and atmosphere is a critical ingredient to correctly take into account these heat exchanges. These fluxes depend on the sea surface temperature (SST) and on low-layer atmospheric variables.

Firstly, we tested a new SST analysis, that has a high spatial resolution and that incorporates various kinds of satellite observations ; this product, called ODYSSEA, has been developed in the framework of the MERSEA project.

Secondly, we assessed a new parametrisation of the fluxes, called ECUME, in the Aladin-Reunion model. Computed from several field campaigns, this parametrisation is more realistic than the previous one. Moreover, ECUME, which greatly modifies the representation of the fluxes for the strongest winds, has a significant impact on cyclones modelling. Since there are very few flux observations in cyclonic conditions, it is difficult to determine which is the best parametrisation. However, with a correct adjustment of the parametrisations of physical atmospheric processes, ECUME improves the forecasts of tropical cyclones over the South-West Indian Ocean basin.

The next step to improve the representation of interactions between ocean and atmosphere will be to couple oceanic and atmospheric models. **23**

Sensitivity of the oceanic response to the velocity of a tropical cyclone

At present, most numerical weather prediction models are purely atmospheric, and what they see of the ocean is only the sea surface temperature as a boundary condition that does not change with time. But, the upper layer of the ocean evolves strongly near a cyclone wich modifies, by retroaction, its structure and its intensity.

The velocity of the cyclone plays a major part on the ocean because, firstly, it defines the degree of interaction between the cyclone and the ocean (a slow cyclone has more time to interact with the ocean than a rapid one), and secondly, it generates different physical oceanic processes according to its value. Using a simplified upper ocean model, the effect on the ocean of the translation speed of a tropical cyclone was studied. One can see that the structure and the intensity of the oceanic currents near a cyclone strongly depends on its velocity. The cyclone that transmits the most energy to the ocean is the one with the wind field that changes over a timescale that equals the one of the oceanic currents (Uh=6 m/s). In that case, we talk of a resonant phenomenon between the cyclonic wind field and the oceanic current. This particular configuration leads to a more intense oceanic response and, as a consequence, a greater cooling down of the sea surface temperature.

Forthcoming work is about setting up ocean-atmosphere coupling for more realistic models, in order to assess its impact on some observed cyclones. **24**

Assimilation run on the 18th of february 2007 at 18 h UTC:
case of tropical cyclone Flavio
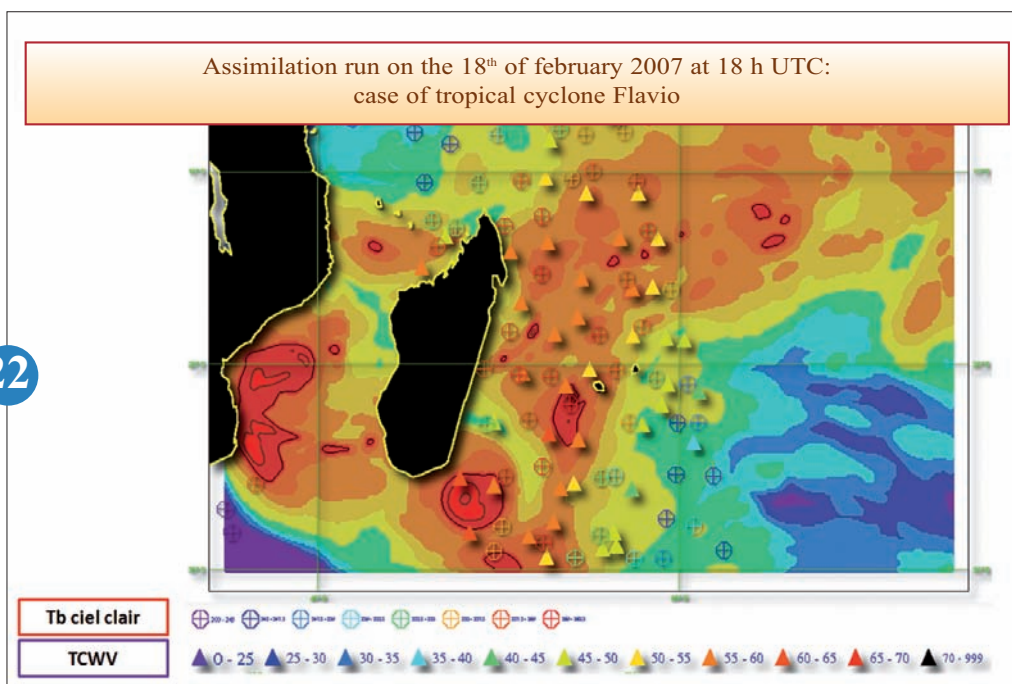
◄ Map of assimilated observations from the instrument SSM/I in the ALADIN Réunion domain: the brightness temperatures in clear sky are shown by a circle with a cross, and integrated water vapour content in cloudy/rainy areas by a triangle (in kg/m²). Assimilation run of the 18th of February 2007 at 18 h UTC: one can see the addition of new data to the assimilation.

Tb ciel clair

TCWV

24-hours mean latent heat flux simulated by Aladin-Reunion for the case of the cyclone Ivan (track in black) in the South-West Indian Ocean in 2008. The upper panel shows the fluxes for the present parametrisation, the lower panel shows the fluxes for ECUME. Some great differences may be noticed between the two fields, in particular close to the cyclone.
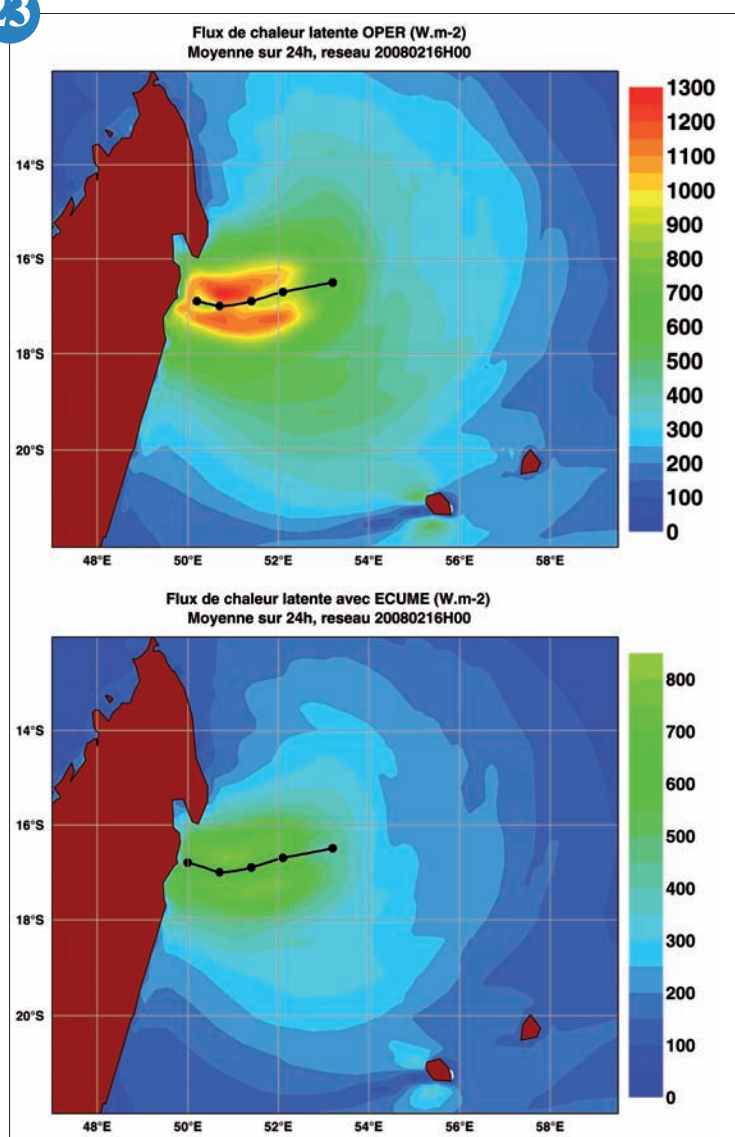
Impact on the ocean of a cyclone moving in a straight-line from the right to the left at different speeds (from top to bottom panels: 2 m/s, 6 m/s and 10 m/s): flux of kinetic energy transmitted to the ocean (colour shadings: legend on the right). A 6 m/s oceanic current is imposed. The cyclonic wind field (black contours, isolines 10 m/s) reaches 50 m/s in the eye-wall. The white isolines indicate the alignment between the cyclonic wind field and the oceanic current (solid lines for positive values, dashed lines for negative values).
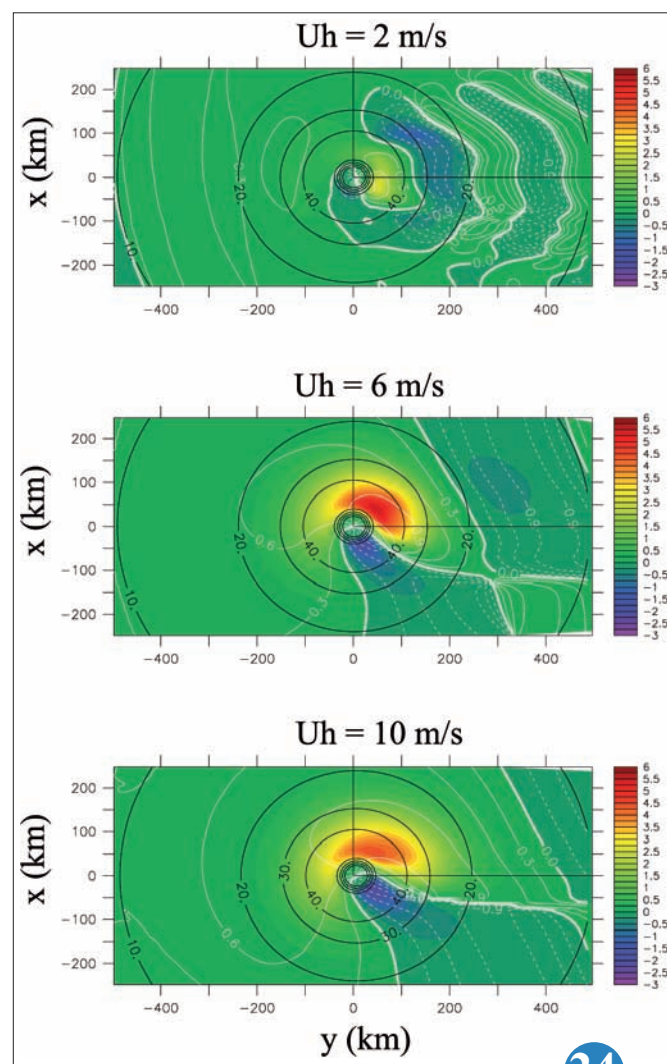
AMMA

In 2008, analysis of data collected during the AMMA campaign has been carried on. Our understanding of African monsoon was significantly improved, some examples of the main results obtained during this year are shown in the following articles.

Use of data collected during AMMA

Data assimilation experiments for AMMA, using radiosonde observations and satellite observations over land

Radiosondes are to date of prime importance for Numerical Weather Prediction. However, these observations are known to be biased and therefore need to be corrected. The additional data from the soundings recorded during the 2006 AMMA campaign have been assimilated into the Numerical Weather Prediction ARPEGE system, with and without a bias correction for relative humidity. Other assimilation experiments have used soundings which were received operationally at the time, or from a degraded pre-AMMA radiosonde network. The impact of different scenarii on the analysis and forecast over western Africa has been evaluated. For the full experiment using all data together with a bias correction, the humidity analysis and the daily and monthly averaged precipitation are improved. The impact of additional radiosonde observations is found to propagate downstream with a positive impact on forecast performance over Europe at the two and three-day forecast range (see figure).

Whereas radiosonde observations have then shown to be very relevant, an important additional source of information is provided by satellite microwave data. These data are more easily used over sea than over land and in-house developments have been necessary to advance the use of these data over the continents. Data assimilation experiments using for the first time ever AMSU-B humidity observations over land have emphasized strong drying and moistening features over Western Africa, which is consistent with results obtained with the enhanced radiosonde network. The drying or moistening of the atmosphere have been successfully evaluated using independent humidity measurements. As a consequence, the African Monsoon appears to be better organized with a stronger Inter-Tropical Convergence Zone.

Both series of data assimilation experiments have shown that additional data over the African continent, either in situ or satellite-based, if carefully processed, can help to improve the description and prediction of the monsoon. The positive impact can also propagate in time during the forecast and affect Europe after a few days. (1)
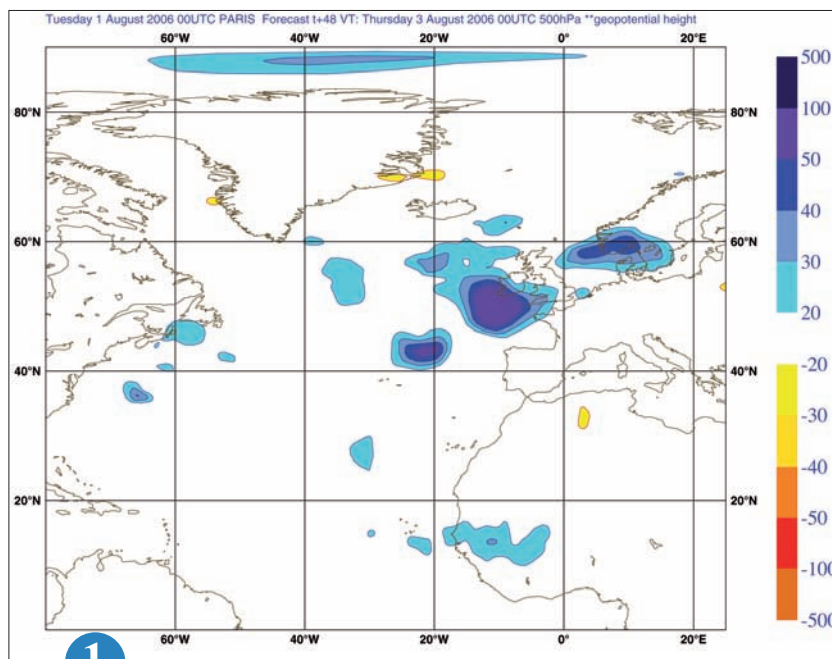
Case study of the 25-26/7/2006

As part of the AMMA campaign, the 25-26 July 2006 period corresponds to the active stage of the first intense monsoon burst over Sahel. This case study has been simulated with the cloud-resolving (CRM) nesting version of the Meso-NH model to understand the convection organization and its interaction with its environment from local scale to mesoscale. In particular, this period is also characterized by a high African Easterly Waves (AEW) activity. The radar observations (Doppler MIT radar & UHF radar) at Niamey allow to investigate the feedback of the convection on the AEW.
The precipitation and the meridional wind at 700 hPa can be considered as a marker of convection and a tracer of AEWs respectively (see the figure). The two successive mesoscale convective systems (MCS) are located ahead and in phase with the trough of an AEW followed by a local convection in the vicinity of

Niamey and no convection in the ridge of the AEW. The simulation succeeds to reproduce the propagative convection, the local and the suppress one, except the first MCS which is lacking in the initial fields.
The strong modulation of the convection by the AEWs is over-estimated by the simulation within the 5km-horizontal resolution model which resolves explicitly the deep convection. The deep parametrized convection within the 10km-horizontal resolution model strengthens this over-estimation and leads to very high precipitation (west of 2 W and east of 16 E).
As far as CRM are concerned, two key issues need to be treated to improve simulations in this region : (i) to capture the convection at the initial state by the assimilation and (ii) to better parameterize convection in order to study scales interactions. (2)

The ECOCLIMAP-II programme: a new land cover classification at 1 km over the Western Africa in the frame of the AMMA project.

The ECOCLIMAP programme includes a land cover classification and a database of surface parameters inferred from this classification based on look-up tables.

A new classification of the vegetation in functionally homogeneous ecosystems has been achieved over Western Africa for the AMMA project. The initial classifications at 1 km from Corine2000 (Global Land Cover 2000) and ECOCLIMAP-I were split in, following a supervised method of classification over 8 years (2000 to 2007) of data analysis from MODIS and SPOT/VEGETATION. Climatic factors, topography and agricultural modes are taken into account for decision criteria. The quality of the 37 classes product was verified from classifications at 20 m from SPOT. The classes ECOCLIMAP-II are then disaggregated into fractions of vegetation types from ISBA. This process of disaggregation relies on the identification of pure pixels of vegetation corresponding to the ISBA type at a 1 km resolution. The variable of disaggregation is the leaf area index because it is less contaminated by soil effect than the vegetation index. The leaf area index, the albedo and the fraction of vegetation are the more relevant biophysical variables of ECOCLIMAP. In this new release, they are derived from the combination of the 1 km MODIS and SPOT/VEGETATION products. We have found little inter-annual variability of the leaf area index for the classes of interest (tree savannah, grassland) and slightly more for tropical forests.

The follow-on of this work is the implementation of test cases in SURFEX in order to assess the impact of the new ECOCLIMAP database. (3)

Tuesday 1 August 2006 00UTC PARIS Forecast t+48 VT: Thursday 3 August 2006 00UTC 500hPa **geopotential height

Differences in root-mean-square errors between the experiment using bias-corrected AMMA data and the experiment using data from a network as in 2005. The errors are computed for the geopotential at 500 hPa at the 48 h forecast range, over the period 1 August - 14 September 2006. Blue colours indicate that the AMMA data have contributed to improve the forecast.

(haut) Hovmöller diagram of the TRMM (3B42) 3-hour precipitation and of the ECMWF 6-hour analysis meridional wind at 700 hPa for the 23-28 July period (top);

(bas) Hovmöller diagram of the instantaneous precipitation and the 1-hour meridional wind at 700 hPa from Meso-NH for the 25-26 July period (bottom). For both figures, precipitation (colored areas) and meridional wind (contours at 2 m/s intervals ; solid and dashed lines represent southerly and northerly winds respectively) are averaged between 10°N and 15°N. The pink vertical line shows the longitude of Niamey. In the top figure, the horizontal dashed lines display the period simulated with Meso-NH (25-26 July). In the bottom figure, the black vertical dashed lines represent the lateral boundaries of Meso-NH domain 2.
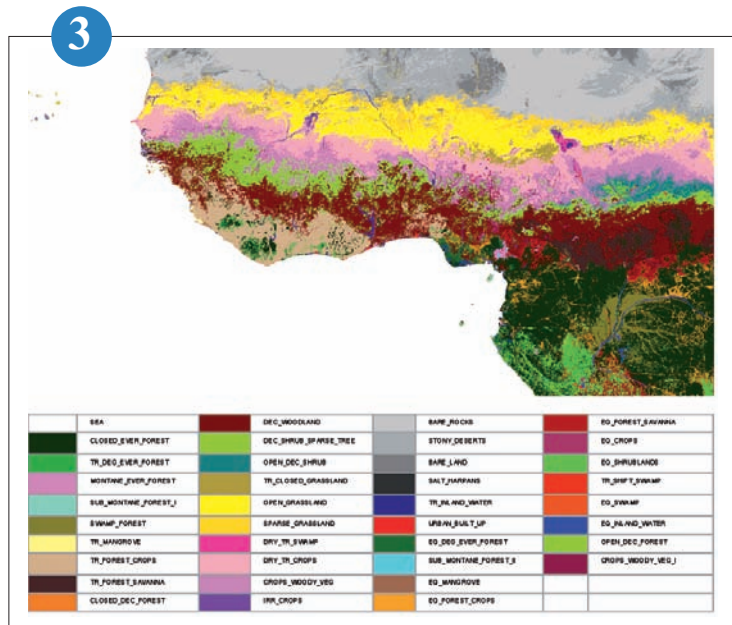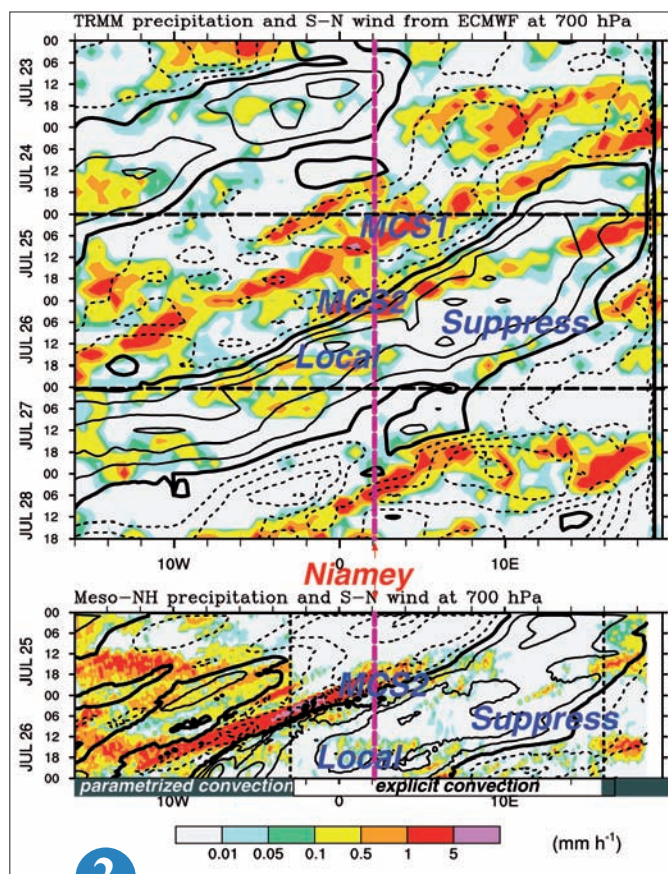
Land cover classification ECOCLIMAP-II over Western Africa with 37 classes.

Studies led in the frame of AMMA

A methodology to evaluate parametrization schemes over West Africa

The purpose of convection and turbulence parametrization schemes used in Global Circulation Models is to describe mean effect of these physical processes on a grid-mesh of the model. We evaluate the behaviour of the parametrization schemes in ARPEGE-CLIMAT V5 by comparing two types of numerical simulations over West Africa: referenced fine-mesh simulations in which convection is explicitly computed (non-hydrostatic Méso-NH simulation with a 5-km horizontal grid-mesh) and simulations carried out with the ALADIN-CLIMAT Limited Area Model (LAM), in which convective processes are parameterized. Both simulations cover the same horizontal area and have the same initial and lateral conditions.

The case under study is a squall line observed over Western Africa on the 21st of August 1992, during the Hapex-Sahel experiment. Various sensitivity tests were performed: physical parametrizations, horizontal (300, 125, 50 and 10 km) and vertical (31 and 46 levels) grid meshes. To compare the different schemes, the precipitation field simulated by

Méso-NH has been averaged on a Aladin grid-mesh. The 300 km horizontal grid mesh is not sufficient to simulate the convective system and its interaction with the easterly wave, whatever physical package is used. The results with a finer horizontal resolution highlight the interest of the scheme which uses CAPE as a closure criteria (control of the convective magnitude from the large scale), instead of moisture convergence in the other scheme: the simulated precipitation field (17 h, horizontal resolution: 50 km) is in better agreement with the observations and the reference Méso-NH field concerning its spatial pattern and its location with respect to the middle layer cyclonic circulation (700 hPa winds): consequently the large-scale dynamics is improved. These results are corroborated with the 125 and 10 km grid meshes. This methodology will be applied to cases observed during the 2006 AMMA field experiment over West Africa. 4
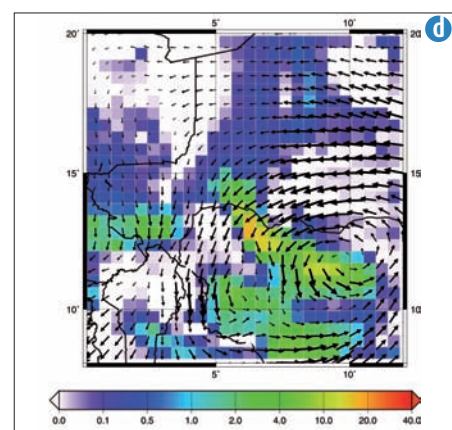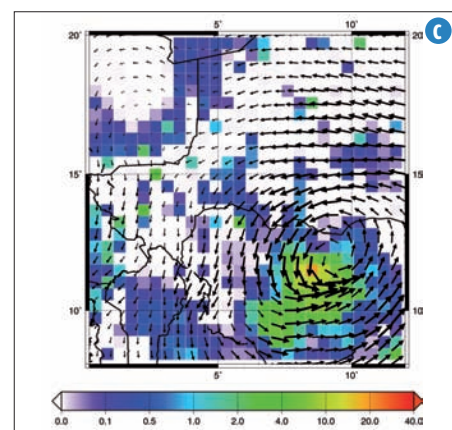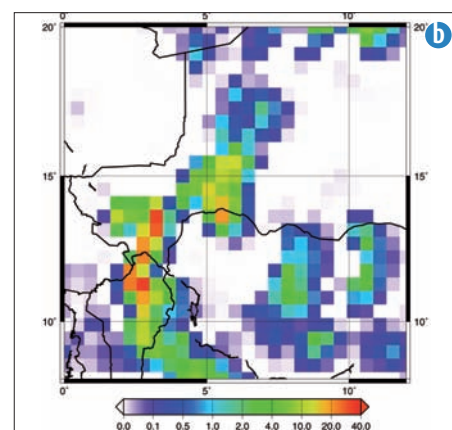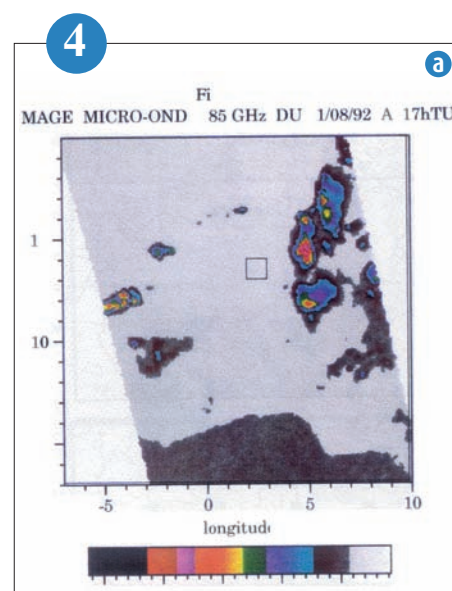
Effects of desert dusts on regional weather of West Africa with AROME meso-scale model

Aerosols are crucial agents of climate changes, although, in contrast to the radiative forcing attributed to greenhouse gases, the uncertainties of the impact of aerosols on the earth radiative balance are quite big [IPCC, 2007].

Africa is the world's largest source of dust. The variability of the African monsoon makes its forecast difficult and affects water resources, it is mainly related to the convection which has significant interactions with surface and aerosols. Global scale Numerical Weather Prediction model parameterizations are not sufficient to forecast this key phenomenon. A better understanding of these feedbacks is one of the AMMA field campaign aim.

Thanks to its high resolution and its numerical efficiency, the meso-scale AROME model coupled with the recently developed dust module, initially within the Meso-NH research model, allows the resolution of explicit

convection and also simulation of surface fluxes, of uprising, of atmospheric transport, washing out and sedimentation of dusts.

Indeed, the dust life cycle and the horizontal and vertical distribution are well represented (see picture A of horizontal Aerosol Optical Depth and B of vertical distribution of dust mass). We show how, through the absorption and scattering of long and short wave radiations, mineral dusts impact the thermodynamic vertical structure of the atmosphere thereby modifying local energy budgets and convection development (see picture B of potential temperature difference, C of zonal winds and D of rain amount).

We are now able to investigate more cases during the African monsoon and to understand further how dust interacts with convection and affects its predictability. 5

[Tp Dust] – [Tp no Dust]
10/03/2006 12UTC
Avg[5W17E] ; [K]

Dust mass [μg/m3]

hPa

AROME
AROME + dust

African Easterly Jet +1m/s

Monsoon flux +1m/s

8 m/s

MONSOON FLUX

Sandblasting +Saltation

SAHARAN AIR LAYER

transport

uprising

5N   6°N   8°N   10°N   12°N   14°N   16°N   18°N   20°N   22°N   24°N   26N   26..

Zonal Wind Avg [5N12N][5W17E]

RAIN
Accumulation
09→11/03/2006
Avg[5W17E]

mm

10

5

0

AROME
AROME + dust
TRMM

5N   7   8   9   10   11   12N

Latitude

a : Aerosol Optical Depth from AROME simulations coupled with the dust module and from AERONET observed values (squares) at 12 UTC on the 10/03/2006.

b : Dust mass (dots) and potential temperature difference between simulation with dust coupled to AROME and without dust (colour) cross section averaged [5W-17E] at 12 UTC on the 10/03/2006.

c : Zonal wind vertical profile mean [5N; 12N; 5W; 17E], at 12 UTC on the 10/03/2006.

d : Rain accumulation simulated by AROME coupled with dust, without dust and from TRMM satellite; from the 09 to 11/03/2006, averaged [5W-17E].

5

Microwave brightness temperature field at 17 h, as a proxy of observed precipitation (a), precipitation field (colours) and winds at 700 hPa, at 17 h, simulated with Méso-NH (b) and simulated with ALADIN-CLIMAT using the moisture convergence (c) and the CAPE (d) convection scheme.

Aerosol Optical Depth
10/03/2006 12UTC

m

0.1
0.2
0.4
0.6
0.8
1
1.2
1.4
1.8
2.2
2.6
3
3.4
3.8
4.2
5
6
7

Saharan Air Layer 8 m/s

Monsoon flux

Washed out

26N

12N

5N/5W   17E
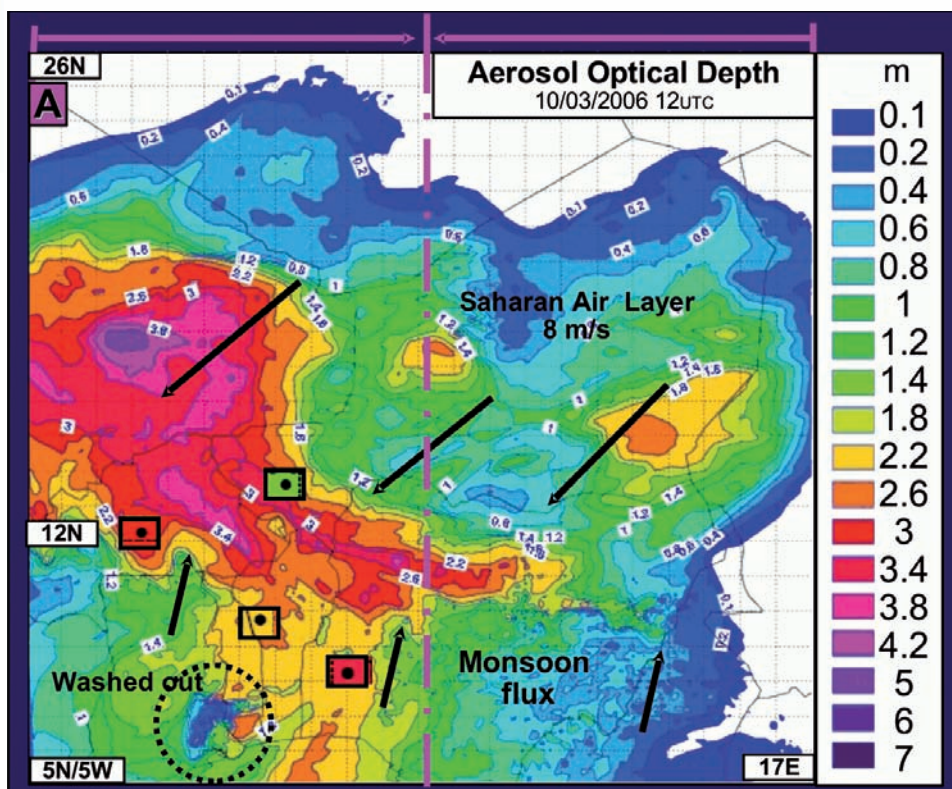
Seasonal cycle of the surface energy budget in the Sahel

Surface energy fluxes are major drivers of the low atmospheric levels and play a crucial role within the West African monsoon. The AMMA project provided measurements of these largely unknown fluxes.

The figure (a) shows that the net radiative flux, Rnet, which controls the sum of the surface heat and the moisture flux, displays a remarkable seasonal cycle in the semi-arid Sahel. It is about four time higher within the core of the monsoon, in august, than in winter. Such variations are among the largest observed over land. They are not only due to seasonal fluctuations of the insolation or of the surface albedo. Each of the four radiative components plays a distinct part in shaping the seasonal cycle of Rnet (fig. b). The incoming solar flux strongly decreases before the arrival of rainfall when the atmosphere is heavily aerosol-loaded, and then, it increases despite the enhancement of cloudinesss associated with the monsoon. The maximum of incoming longwave flux also takes place prior to rainfall, as the atmosphere is warmer and drier than in august. These non-intuitive fluctuations partly balance each other during the monsoon. Therefore, they do not participate to the summer increase of Rnet, which is actually explained by the fluctuations of the surface longwave emission and shortwave reflection (fig. c). This involves a decrease of the albedo associated with a vegetation growth, but also a significant cooling of the soil in response to rainfall.

These observations reveal a complex surface energy budget, where the water cycle plays a major role. This climatic specificity of semi-arid land regions constitutes for models a challenge to be taken up in the next few years. **6**

Intraseaonal variability of the West African Heat Low: linking mid-latitudes and the West African Monsoon

Within the scope of the AMMA project, a special interest has been dedicated to the West African Heat Low (WAHL), aiming at a better understanding of the role and the variability of this major actor of the monsoon, which partly drives the humidity transport to the Soudanian and Sahelian regions during the rainy season.

Thanks to a complex principal component analysis applied on the NCEP or ECMWF reanalysed temperature, a robust mode of the WAHL variability has been identified and studied. This 12-30-day timescale mode exhibits an East-West dipole, and opposes a phase where the low spreads to the East of the African continent to another one where it is located more at the West. A many folded approach led to track down its evolution and to pinpoint its origin and its impact on the monsoon. A Rossby wave-like pattern (figure a) modifies the mid-latitude dynamics all along the entire troposphere depth, in particular, altering temperature and humidity advections along the WAHL borders, and thereby its own dynamics. Downstream, convection is reinforced above the Sahel, East of Lake Chad. This anomaly propagates westward with a speed close to that of African Easterly waves. The signal is still significant in the middle of the Atlantic Ocean, suggesting a possible impact on the cyclonic activity (figure b).

This relationship between the WAHL and mid-latitudes should bring potential improvements for forecasting the West African monsoon. In this regard, a deeper investigation of the mechanisms driving this mode of variability, as well as the evaluation of its representation in global models are worthwhile. **7**

AMMA global chemistry and transport model evaluation exercise

In the framework of AMMA, several international groups contributed to an exercise of evaluation and inter-comparison of Chemistry and Transport Models. Several annual simulations were performed, all relying on the same pollutants emissions inventory. The results of the different chemical models were inter-compared and the simulations were evaluated with the data collected during the Special Observing Periods of 2006.

The MOCAGE model took part in this exercise, with a configuration that includes an African zoom at 0.5° horizontal resolution (a resolution today out of reach for global chemical models) and a comprehensive strato-tropospheric chemistry package. Several chemical components were considered in this study, in particular, the ozone (secondary pollutant) and carbon monoxide (primary pollutant), both of interest for assessing the impacts of biomass burning at planetary scale. At large scale, MOCAGE presents a good stability and annual cycles are generally nicely reproduced; the annual cycle of ozone at the ground-level station of Nangatchori (Benin) instrumented during AMMA is in particular remarkably well simulated. At regional scale, the results of the models were compared with in situ radio-sounding and research aircraft data. These observations highlighted a strong variability in time and in space of key chemical components, and the capability of MOCAGE to reproduce it is illustrated in the figure.

The study of chemical exchanges between Africa and the rest of the globe will be carried on at Meteo-France, in particular, taking into consideration detailed budgets including production (emissions, chemistry), destruction (chemistry, deposition) and transport (advection and convection-turbulence) terms. **8**

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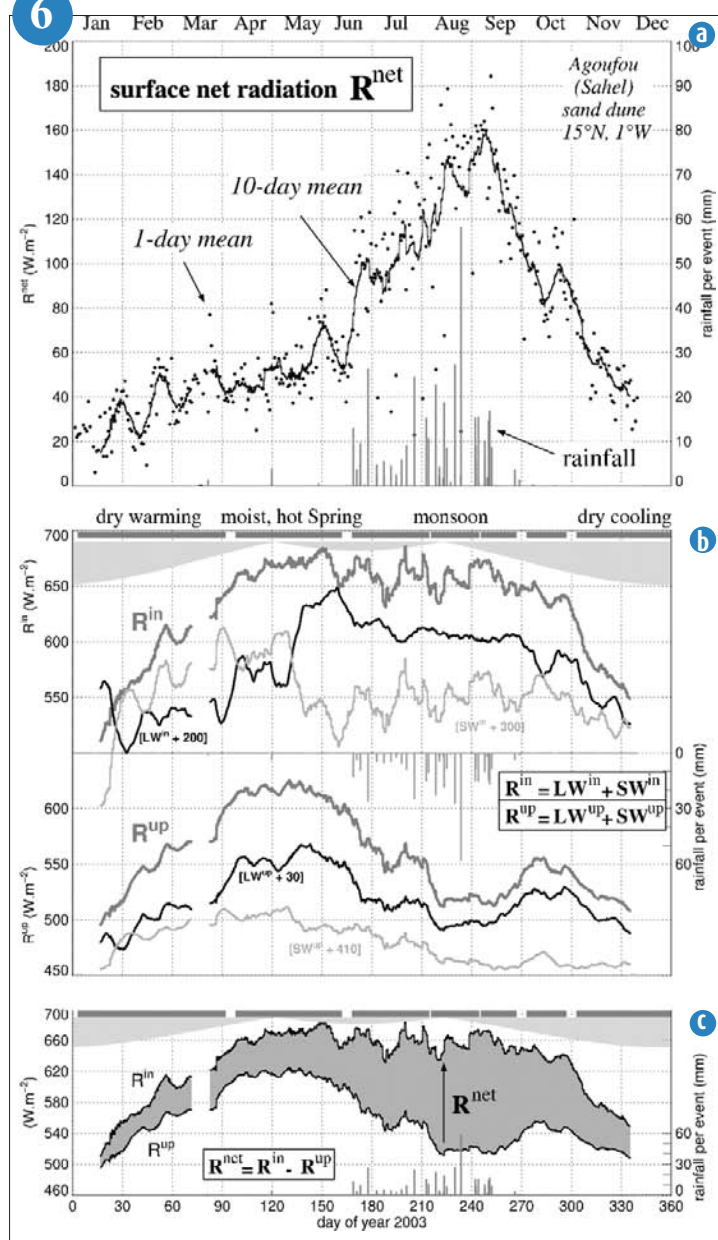
Time series over a whole year of measured surface radiative fluxes in Agoufou, Sahel : (a) net, (b) longwave and shortwave components and (c) sum of up welling and down welling fluxes.
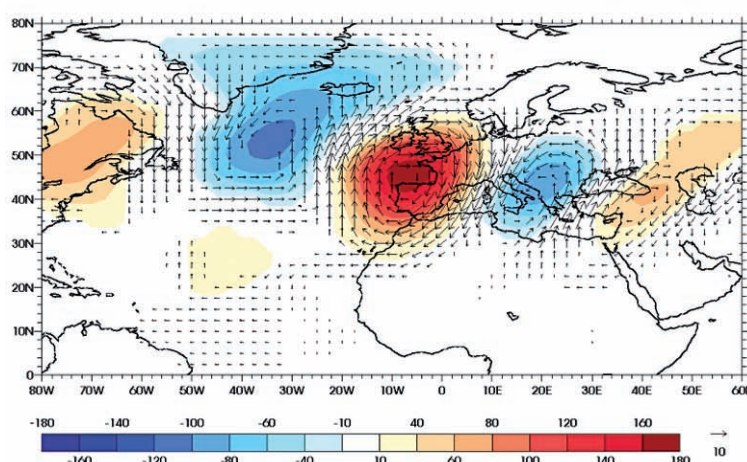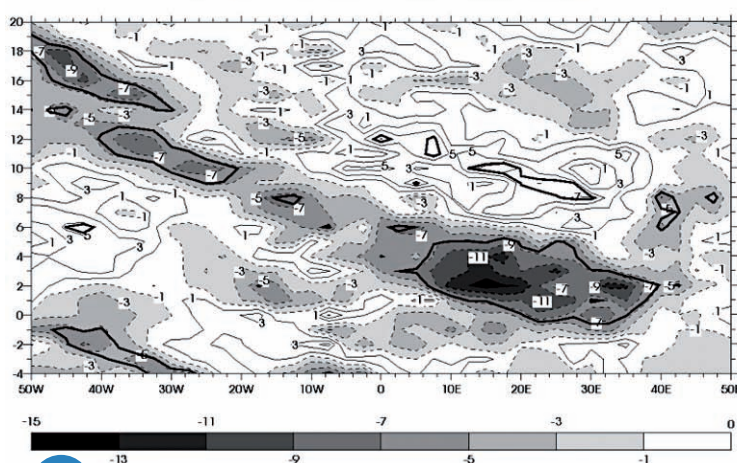
7

Composite analysis for the period 1979-2007 of the NCEP reanalysis. The mean field difference between a West phase and an East phase has been displayed. a) Composite of the geopotential height in m (shaded) and the wind (vectors) at 200 hPa, 2 days before the West phase. b) Composite of the Outgoing Longwave Radiation (weakest values correspond to deep convection over tropical regions) in W/m². The vertical axis is in days and zero corresponds to the date where the mode is in its West phase. The thick black outline is for the 95 % level significance of the anomaly (Student's test).

a : Aircraft Ozone observations collected during AMMA August 2006 Special Observing Period (adapted from Janicot et al, 2008)

b : Corresponding values simulated with MOCAGE.

8
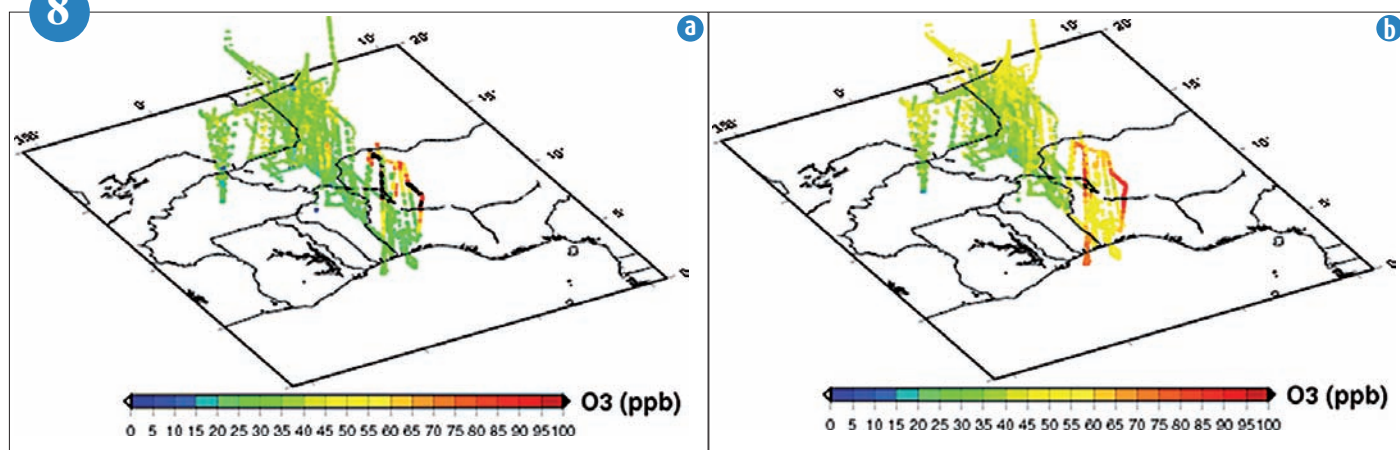
Meteorological process

Atmospheric process studies are compulsory to improve our understanding of meteorological and climatic phenomena. Some of the major 2008 results obtained in this area concern cyclogenesis, and lee waves breaking.

Cyclogenesis and previsibility

Modelling of structure functions based on a heterogeneous diffusion operator and estimated from an ensemble

Structure functions correspond to the background error covariance functions. They play a key role in the current data assimilation schemes used in operational centres. In particular, these functions contribute to spread the information from the observations. The spatio-temporal variability of these functions is highly flow dependent.

The structure functions can be estimated from an ensemble method, for example from an ensemble of perturbed assimilations. However, the huge memory size that would be required to store these functions is beyond the capacity of modern super-computer. One way to solve this problem consists in modelling these structure functions. It is for example possible to use a diffusion operator. It is well known that a Gaussian can solve the diffusion equation with an initial state centred on a point, on the real line. This kind of function can be used as a preliminary model of structure functions. However, the diffusion coefficient is not known ; more generally, the local diffusion tensor has to be estimated. This issue has been recently resolved by estimating the local diffusion tensor directly from an ensemble.

This method has been successfully tested in order to represent the horizontal component of the background error correlation functions in the framework of the MOCAGE-PALM chemical global assimilation system. This work has been done in collaboration with scientists from CER-FACS. The method was also tested to represent the transport uncertainty in CO_2 fluxes retrieval at mesoscale. The local diffusion tensor was estimated from a PEARP ensemble. [1]

Influence of Rossby wave-breaking on the North Atlantic Oscillation.

Jet streams in the upper troposphere usually reach their maximum on the western side of the oceanic basins where land-sea thermal contrasts are the strongest. Further East, synoptic eddies get larger amplitude and feedback onto the jet streams. This feedback is characterized by the breaking of Rossby waves in the upper troposphere and plays a crucial role in the low-frequency atmospheric variability such as the North Atlantic Oscillation (NAO). There are two kinds of wave breaking; cyclonic wave-breaking pushing the jet southward and closely linked with the negative phase of the NAO and anti-cyclonic wave-breaking shifting the jet poleward and favouring the positive phase.

Results of two simulations using a primitive-equations model without topography and humidity are shown on the figure, one of them reproducing the process involved during the negative phase of the NAO (the 2 figures at the top) and the other one during the positive phase (the 2 figures at the bottom). In the first case, the temperature gradient is maximum at 30 °N, it leads quite systematically to cyclonic wave-breaking, the jet is zonally oriented and is maintained at the same latitude as the forcing (30 °N) by the storm-track. In the second case, the temperature gradient is maximum at 45 °N, the breaking is essentially anticyclonic, the jet is southwest-northeast oriented, and is strongly displaced poleward where eddies are the strongest and where they most efficiently feedback.

In the future, this type of result should improve the understanding of the role played by sea surface temperature anomalies in the general atmospheric circulation. [3]

Adding the time evolution in order to extract coherent structures at synoptic scales

At synoptic scales, the dynamics of depressions can be described through a single field, the potential vorticity, that enables to retrieve all the dynamical fields : wind, geopotential and surface pressure.

Two levels are commonly considered as relevant in order to analyse a meteorological situation : one near the top of the atmospheric boundary layer and the tropopause. The methodology employed here consists in detecting and extracting from these two fields coherent structures or anomalies that can be described with a limited number of non-zero coefficients in a wavelet base which is adapted to the geographic position and to the shape of every detected element. All things being equal, especially the number and the selection of these coefficients, this adjustment is a real improvement, for example the aspect ratio and orientation of the structures are more realistic.

A tracking algorithm, such as those developed for the relative vorticity, is then operated in order to get some information about the life of these structures : where do they come from ? when did they appear ? Although this tracking only uses information linked with the amplitude and the position of the structures, and additionally the wind, a complete set of trajectories is obtained, some of the tropopause tracks are longer than ten thousand kilometres. [2]

1

Left panel: horizontal component of ozone forecast error correlation functions estimated from an ensemble over one month (during the Austral winter). Right panel: the correlation obtained from the model based on a diffusion operator whose local diffusion tensors were estimated from the same previous ensemble.

2
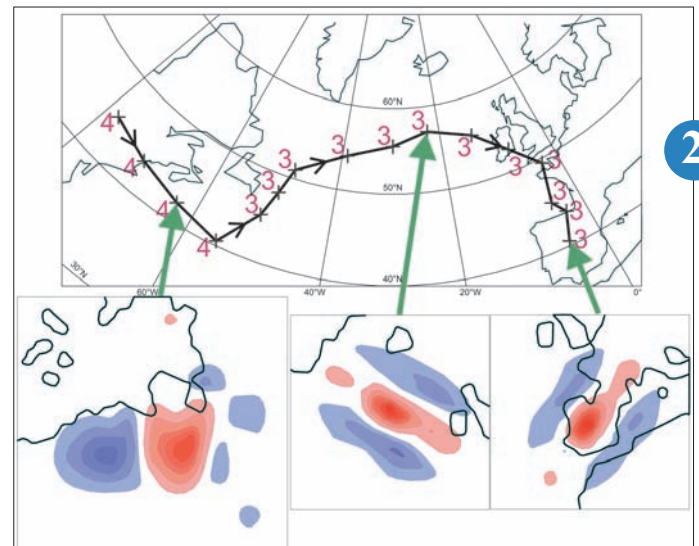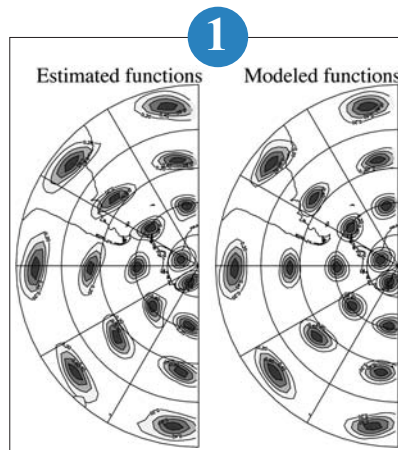
The upper panel shows the trajectory of a structure that has been tracked down between the 3 of January 1989, 06 UTC and the 7th of January 1989, 00 UTC on the 315 K potential vorticity field of the ERA-Interim reanalysis. The number next to the successive positions is the wavelet scale at which the structure has been extracted (the higher this number is, the wider the structure is). The three other panels illustrate the extracted structures at different instants (interval: 0.5 PVU, positive (resp. negative) values in red (resp. blue)).

3
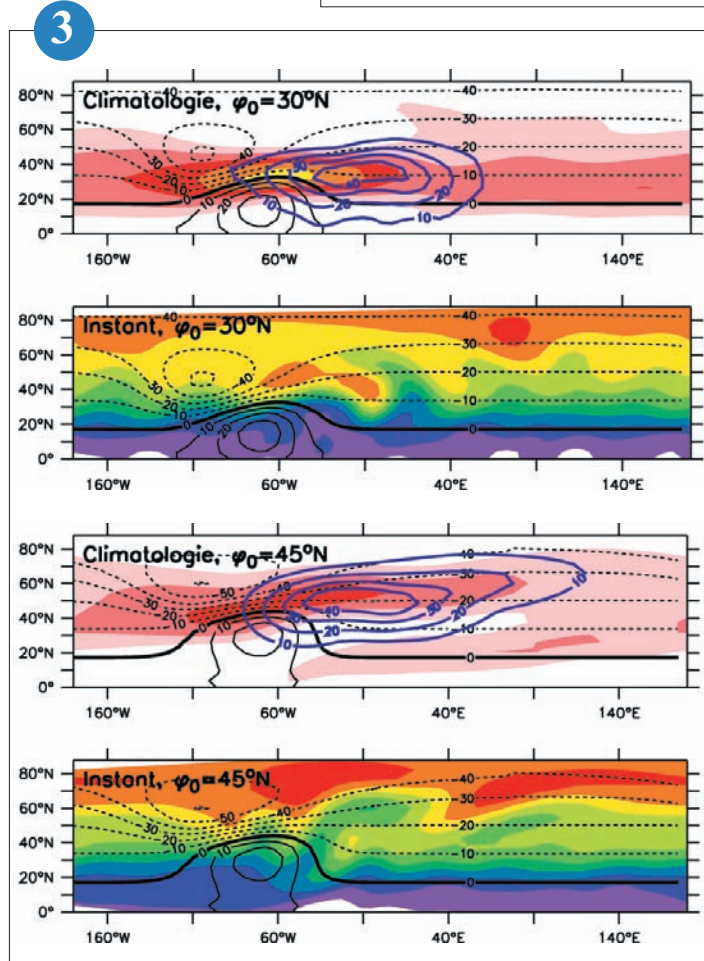
Comparison between two simulations using a dry and aquaplanet version of a primitive-equations model on the sphere in which the temperature is relaxed toward an analytically prescribed field. The latter is composed of a cold anomaly (dashed black contours) located northwest of a warm anomaly (solid black contours) to reproduce the land-sea thermal contrast in winter. The two simulations differ only from the latitude of the restoration-temperature gradient, 30 °N (top) and 45 °N (bottom). In the upper panels, blue contours and red shadings represent respectively the time average of the high-frequency kinetic energy (interval: 10 m²/s²) and of the zonal wind (interval: 10 m/s) at 200 hPa. In the lower panels, shaded areas show the absolute vorticity at 200 hPa at a given time; on the left, we recognize cyclonic wave-breaking, and on the right anticyclonic wave-breaking.

4
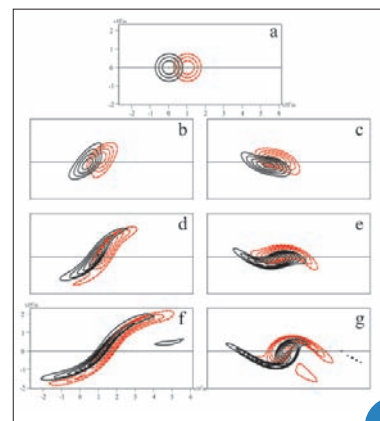
Evolution in a simple baroclinic two-layer model at t=0h, 12 h, 24 h and 36 h from top to bottom of vorticity anomalies (interval : 2 10⁻⁵ s⁻¹) at the upper (solid black) and lower (dashed red) level embedded in an environment characterized by a uniform vertical shear (2,4.10⁻⁵ s⁻¹) and a uniform horizontal shear (2,4. 10⁻⁵ s⁻¹ in the upper layer, 1,2.10⁻⁵ s⁻¹ in the lower layer). Left panels: anticyclonic shear; right panels: cyclonic shear.

Towards a better understanding of the sudden growth in cyclogenesis during the jet crossing

The dynamics of some frequently-observed sudden growths of East-Atlantic extratropical cyclones are still an open issue. Using highly idealized models, some dynamical aspects that need to be better understood are explored. This study aims at shedding some light on the interaction between high and low level cyclonic vortices embedded in different zonal jets that have both a vertical and a horizontal shear. In an anticyclonic shear which is observed on the south side of jets where a large number of future storms appear, the tropopause and surface anomalies are strongly and horizontally stretched but maintain their vertical tilt so that they can strongly extract energy from their environment through baroclinic processes. On the contrary, in a cyclonic shear, the rotation induced by the environmental jet contributes to the structures' rotation. This leads to the relative isotropy of both structures which wrap around one another. In this case, the initial westward vertical tilt of the perturbations which is the optimal configuration to extract energy from the environment is rapidly lost.

Furthermore, it has been shown that the meridional gradient of the environmental potential vorticity was a key factor controlling the poleward shift of cyclones, through similar processes as those in the dynamics of tropical cyclones and oceanic lenses. These mechanisms are two basic components of a synthetic explanation of extratropical cyclone growth when crossing the jet axis. 4

Mesoscale phenomena

Microphysical tests on convective systems including hail

The mixed microphysical scheme in Meso-NH and AROME includes the representation of graupel, with a possible extension to hail that is not used in the operational release of AROME.

The graupel is an efficient collector for condensed water as it sweeps an important air volume during its fall. When it collects other species, latent heat is released by the liquid accreted material and its surface temperature increases. As soon as its surface temperature reaches 0 °C, we can choose to represent explicitly the hail, corresponding to the apparition of a thin liquid film at the surface and to the wet growth mode of the graupel. A few simulated test cases, taking into account explicitly the hail, show a quite realistic representation of microphysical species in convective cells, but overestimate rainfall induced by the melting of hail.

An improvement is therefore necessary, consisting in a reconversion of hail to graupel when the amount of supercooled droplets in the environment is not sufficient. This evolution will imply a broad validation on tests cases before being introduced in the pre-operational version of AROME. **5**

Modelling the carbone fluxes with the Meso-NH Model in the frame of the CarboEurope Europeen Project

CarboEurope is a European project which started in 2004 and which ended at the end of 2008. This project was dedicated to carbon dioxide (CO_2), the main greenhouse gaz. The main objectives of CarboEurope were to better understand the atmospheric CO_2 behaviour as well as its terrestrial sources and sinks. In this context, several experimental campaigns (CERES) took place in may-june 2005 and in april and september 2007, in South West France, between the Landes forest and the city of Toulouse. The experimental set-up included measurements of surface energy and CO_2 fluxes, radiosoundings, drifting balloons, remote sensing instruments (radar, RASS-Sodar), as well as atmospheric CO_2 concentration measurements at ground sites and using instrumented research aircraft.

During these campaigns, one case was particularly interesting, while the aircraft flew in the Toulouse region. A numerical interpretation with the meteorological model Meso-NH was made at a 8 km resolution. Whereas the model could not reproduce the aircraft observations of the CO_2 concentration (fig. a), we pointed out errors in the map of the Leaf Area Index (LAI), for the year 2007, west of Toulouse. A high LAI related to a winter crop area led to a high assimilation rate of CO_2 by the vegetation, leading to an underestimation of the atmospheric concentration. As the LAI map from the MODIS sensor did not show this maximum (fig. c) LAI was more appropriately calibrated. The new comparisons between the observations and Meso-NH resulted in an improvement of the model (fig. b).

This study shows how the regional modeling of processes needs adequate and accurate surface conditions such as LAI. **6**

High frequency stochastic filtering of turbulent wind measurements

Research in the field of turbulence requires to measure the atmosphere with very fine temporal and spatial mesh. High frequency insitu measures are often perturbed by the dynamic of the sensors' platform or corrupted by data acquisition systems.

Stochastic filtering based on Monte-Carlo calculations gives an estimation of the signals by proposing a certain number of solutions (called particles) of observed states. These particles move with a mathematical model adapted to the tracked signal. The filter selects the most relevant particles and re samples the ill-adapted states.

We have developed new theoretical tools both for a probabilistic modelling of the mobile measures and for the nonlinear filtering of parameters occurring in turbulence. Lagrangian models proposed by the physicists of turbulence have been deeply modified in order to learn about parameters of large scales directly from the observations.

Experiments of filtering were made on fixed real measures for frequency up to 10 Hz. In figure (a), perturbed measures are represented by the light blue line, the red line represents the signal filtered by our method to be compare with the reference signal (black line) which is the true state. In figure (b), the same colour code shows power spectral density of the 3 signals. The spectral correction is very impressive. **7**
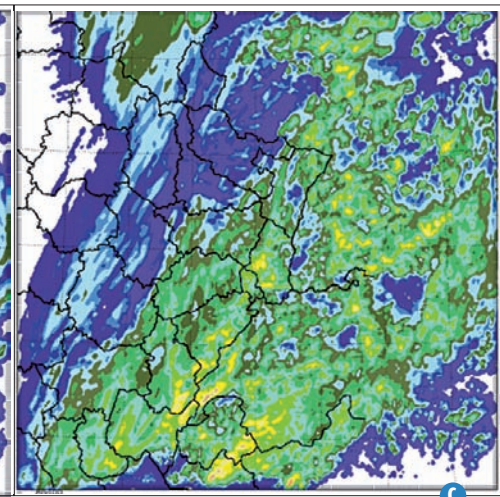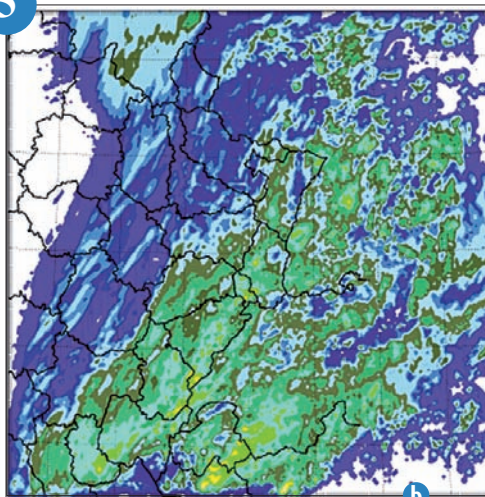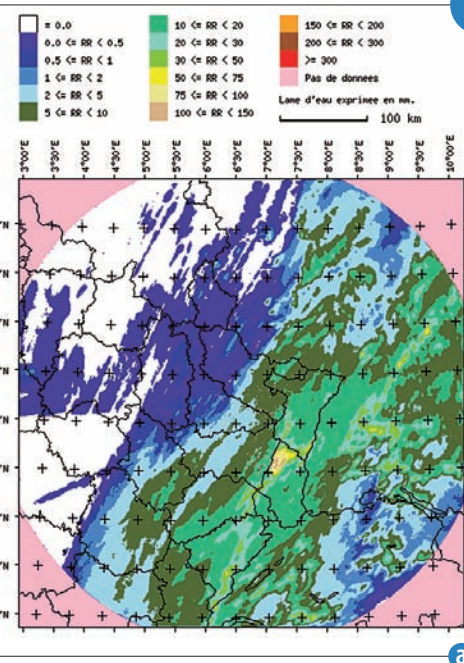
Case of convective cell with observed hail in Haut-Rhin the 20th of June, 2007:
(a) Observed 24 h cumulated rain (in mm).
(b) Simulated 24 h cumulated rain with Méso-NH without explicit representation of hail (current microphysical scheme in AROME).
(c) Simulated 24 h cumulated rain with explicit representation of hail but without reconversion of hail to graupel.
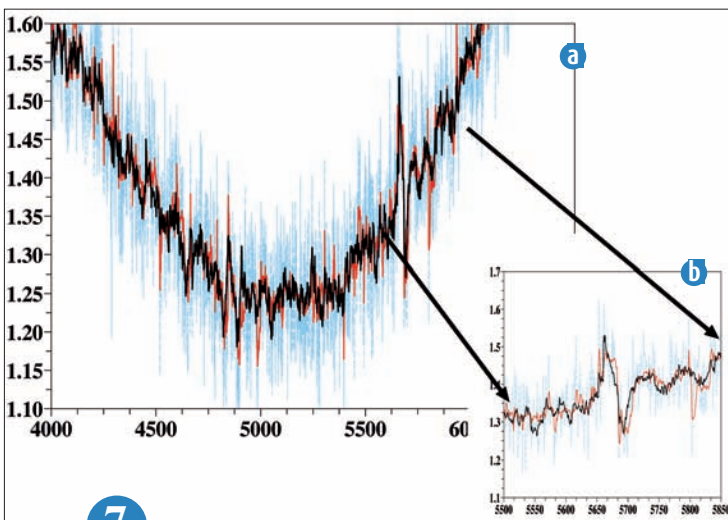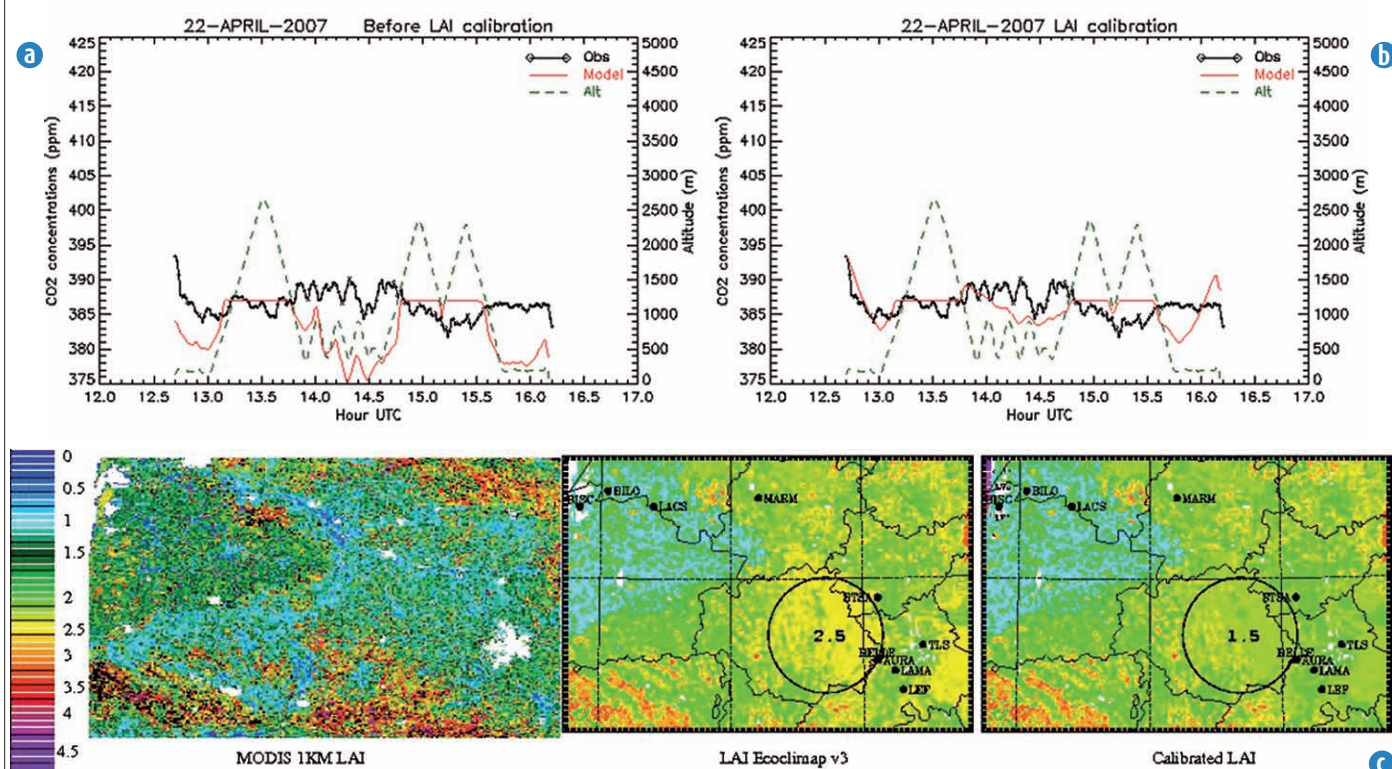
a et **b** : Temporal series of compared CO_2 concentrations from the aircraft observations (black) and the Meso-NH model (red), along the aircraft trajectory, on April, the 22nd. The green dashed line represents the altitude of flight. The model outputs are taken at the exact aircraft position and time. Figure (a) shows the comparison before the LAI calibration and figure (b) after the LAI calibration.

c : Maps of LAI: from the MODIS sensor observations (left), from the original database ECOCLIMAP (middle) and after the calibration. The black circle represents the area mainly concerned by this calibration.

a : 10 Hz real wind time series, light blue line is the perturbed wind with synthetic noise, black line is the reference signal to be retrieved, red line is the filtered wind using our methods. The detail shows the good estimation of an intermittency period.
b : Power spectral density for the 3 signals with, in light blue the corrupted signal, in black the reference and in red the filtered spectrum. We see that our filter is able to restore perfectly the energetic structure of the turbulent measures.

HyMeX : towards an experimental program on the Mediterranean hydrological cycle in 2010-2020

HyMeX, one of the programs of the French Mediterranean initiative coordinated by INSU, aims at improving the understanding and modelling of the Mediterranean hydrological cycle with emphases put on the predictability and evolution of intense events related to water cycle. In order to make progress on these issues, the HyMeX program consists in monitoring and modelling the Mediterranean coupled system (atmosphere-land-ocean), its variability (from the event scale, to the seasonal and interannual scales) and its characteristics over one decade (2010-2020) in the context of global changes. The first intensive observation periods with the deployment of research instrumented platforms are foreseen over the Gulf of Lions for 2011-2013.

Phase 1 (2006-2007) of the preparation of HyMeX was devoted to the drafting of a white book which organized the scientific questions along five main topics (see figure). The two first topics concern the analysis of the variability and the trend of the "slow branch" of the water cycle; the two followings deals with Mediterranean intense events and the last one is centered on the analysis of the vulnerability and adaptation capacity of the Mediterranean territory and population.

Phase 2 (2008-2009) of the preparation of HyMeX aims at elaborating the Science Plan and the Implementation Plan for the HyMeX program. Clearly, HyMeX has now taken an international shape, with, for instance, more than 250 registered members in the HyMeX Work-groups including 60 % of foreign researchers coming from more than 15 countries.

CNRM takes an active part in the preparation and coordination of this program which appears a necessary step to progress in the predictability of Mediterranean heavy rainfall events or to assess the impact of climate changes in the water cycle in the Mediterranean basin. **9**

◄
The five main HyMeX topics.

Experimental study of the lee waves breaking

Air plane crashes, accidents or forest blowdowns, mountains waves and their associated breakdown represent major natural hazards for human activities. This has led to many studies but, despite progress in computational fluid dynamic, the three-dimensional aspect of lee waves breakdown remains unclear.

The experimental study led at the large hydraulic tank of Meteo-France helped to lift the veil through a new PIV facility which allows to measure the three components of the velocity field in volume in a stratified turbulent flow. The development of this experimental facility has been a full-fledged study spanning over more than three years in an international collaboration with the University of Washington and the University of Southern California.

The results of the first measurement campaign reveal for the first time the details of the dynamics of the breakdown, with a very complex vorticity dynamic. The study has already helped to shed some light to the path that leads to turbulence in the advent and the destabilization of large vortex structures. New measurement campaigns should characterize the turbulence statistics in 3D.

These results will allow a better parameterization of numerical models for better forecasts. Beyond the progress made by this study of lee waves breaking, it is a milestone in metrology which gets access, for the first time all over the world, to the third dimension on a very large scale. **8**

8

Breaking wave region

Durran and Klemp 1983 / The COMET Program

Image a :
Lee waves breaking.

Image b :
Vortical structures in the wave breaking region. Vorticity surface and vorticity vectors.

Image c : Later, toroidal vortices.

Climate and climate changes studies

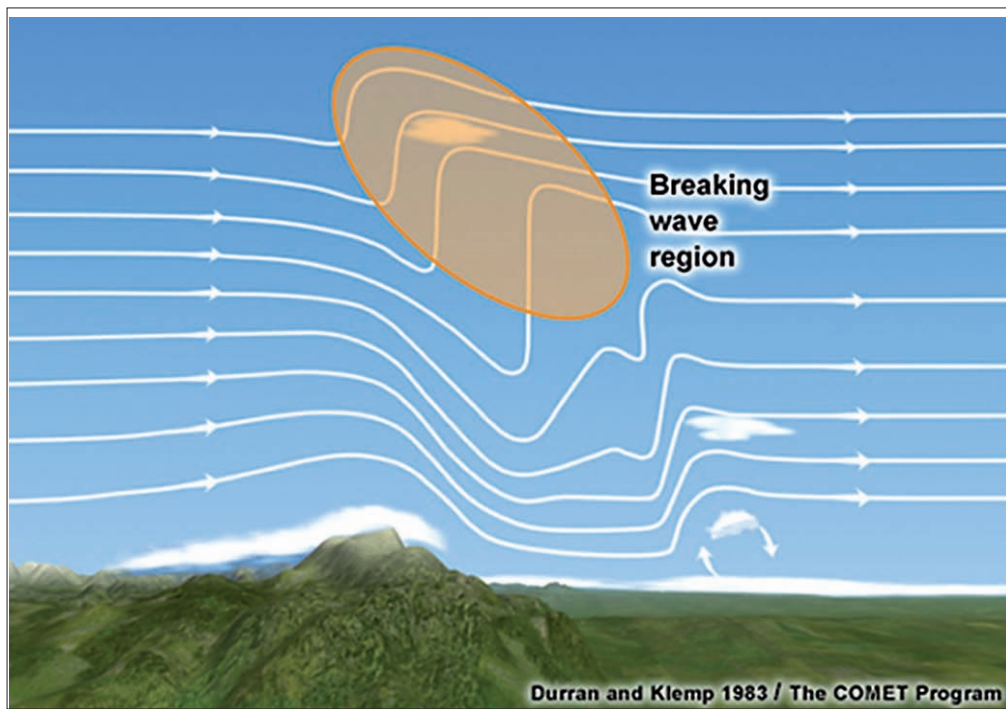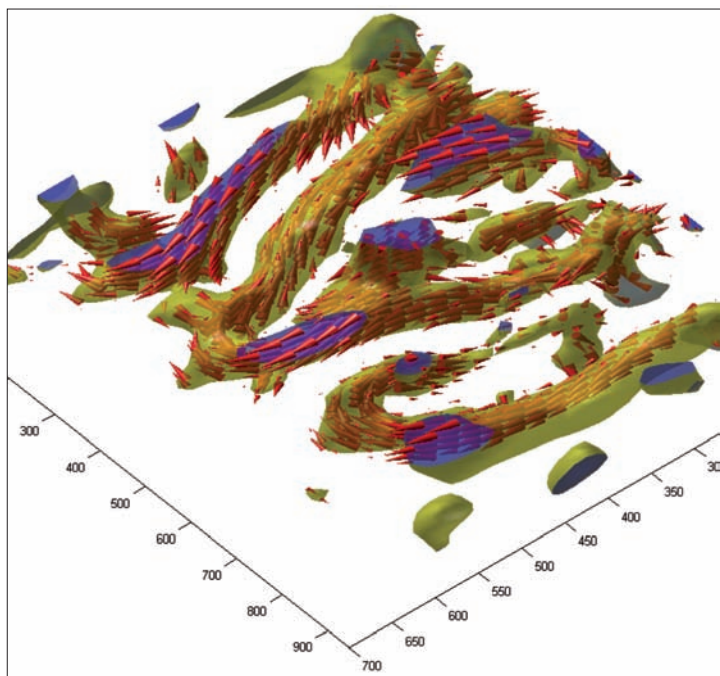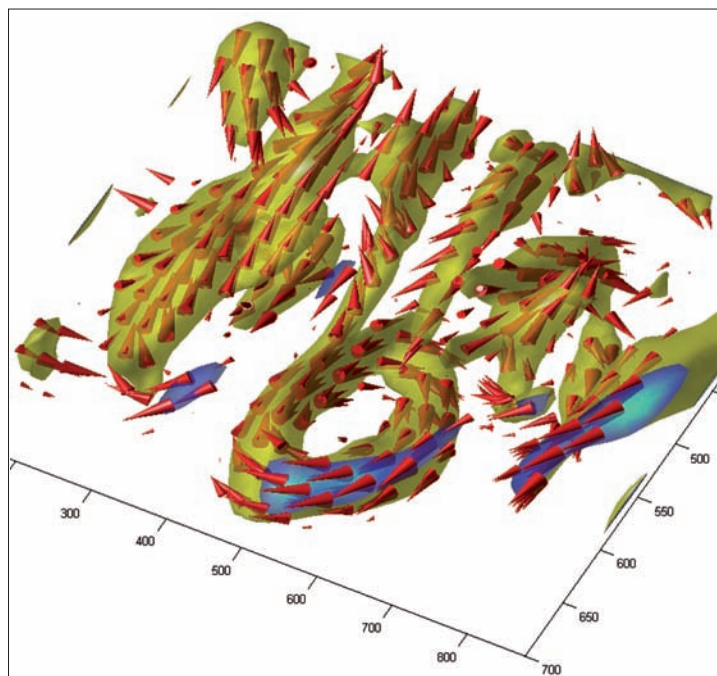In 2008, CNRM started the preparation of the climate simulations that will be taken in consideration for the next IPCC report, whose publication is planned for 2013. Besides, impact assessments associated with climate change have been strengthened, several research teams work now on that subject.

A new stream of centennial climate simulations with CNRM's coupled model

CNRM has completed a new set of climate simulations, in the framework of the FP6/ENSEMBLES European project. These simulations will be used in a wide range of applications, like climate regionalisation or climate impact assessments.

These simulations were run with the latest version of the global coupled system CNRM-CM3.3, an improvement of the system used for the previous IPCC simulations. A 1000-year control experiment, using fixed pre industrial concentrations of atmospheric gases and aerosols corresponding to the year 1860, was run in order to assess the natural equilibrium of the climate system. Starting from an initial state derived from this control simulation, a historical simulation using the observed evolution of greenhouse gases and aerosol concentrations has been carried out over the period 1860-2000. This simulation allowed to validate the simulated climate evolution with respect to observations. The state obtained at the beginning of year 2000 in this simulation has been used as a starting point for the production of three 21st century scenarii (A1B, A1B IMG and A1B 450). The new scenarios A1B IMG and A1B 450 were defined in the framework of the ENSEMBLES project. A1B IMG is actually an update of SRES-A1B, which was one of the baseline scenario of the latest IPCC report (2007). A1B 450 is consistent with the European Union's target – a stabilisation of the CO_2 concentration by 2050.

Our simulation suggests that if this target is reached, the global warming should be limited around 1.5 °C warmer compared to pre industrial climate. **1**

A simulation of the Last Glacial Maximum with CNRM-CM3.3 climate model

Until 2005, the ability of CNRM-CM to simulate the Earth's climate was only assessed through its capacity to simulate pre industrial climate and 20th century climate changes. However, the climate of the 20th century is not fundamentally different from the current climate. Hence, in this context, the ability of the same model to simulate a very different climate is not certain.

In collaboration with IPSL, it was decided to check whether CNRM-CM is able to simulate the climate of the last glacial maximum (LGM, 21 000 years before the present time), and to participate to PMIP (Paleoclimate Modelling Intercomparison Project). Proxy data (pollen, sediments...) allow to estimate that at that time, the continental global mean 2 m air temperature was cooler by 2 to 7 °C than currently, and that oceans were cooler by 1 to 4°. A 500-yr simulation with CNRM-CM yields values of respectively 2.8 and 2.5 °C, which is similar to what is obtained with other PMIP models.

It can be noticed that the simulated temperature change between current climate and LGM is nearly global, but is enhanced in the high latitudes of the northern hemisphere. This is mostly due to the presence of the Laurentide and Fennoscandian ice sheets. Their retreat has led to a amplification of the polar warming after the LGM, an amplification that is confirmed by reconstructed temperature data. **2**

Comparison of globally averaged surface air temperature in IPCC simulation performed with the CNRM-CM3.3 climate model: a control simulation with pre industrial concentrations, the 20th century (HT1) and the three scenarios (A1B IMG, A1B et A1B 450); ERA40 data (ECMWF) over 1958-2001 are plotted in grey.

1

◄ Difference in year mean 2 m temperature between the Last Glacial Maximum and pre industrial climate (°C), simulated by CNRM-CM3.3.

◄ Composites of snow depth (filled grid boxes, in cm) and snow cover (contours, in %) in spring for strong minus weak Indian monsoon years over the 1967-1995 period.
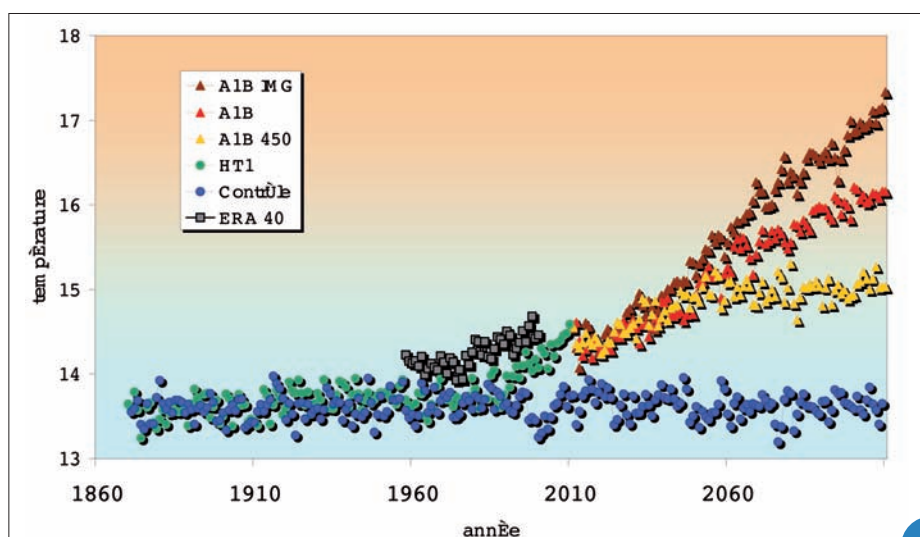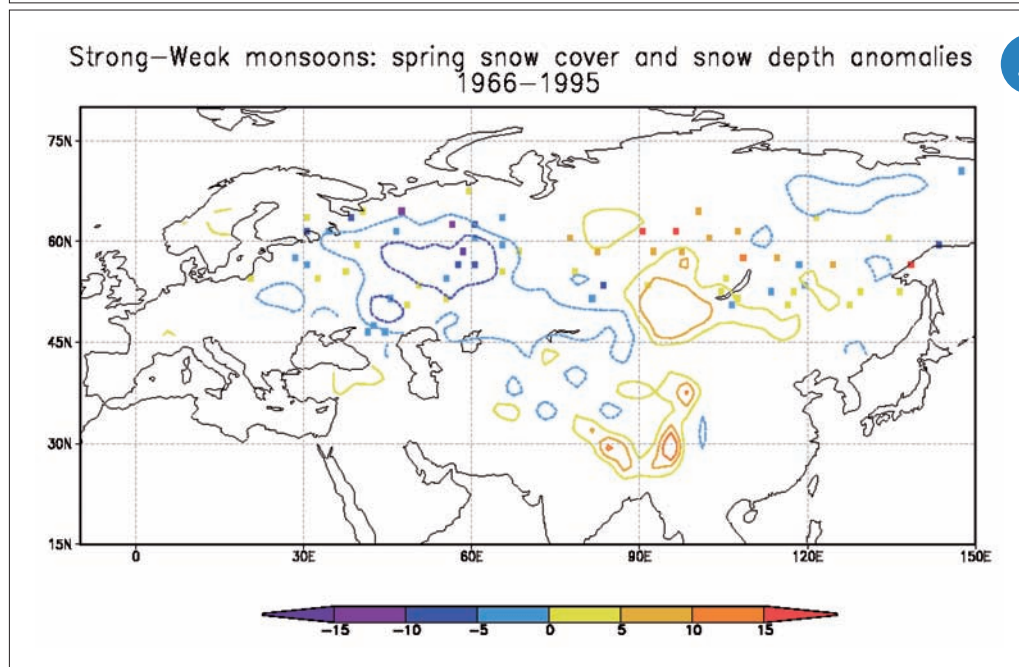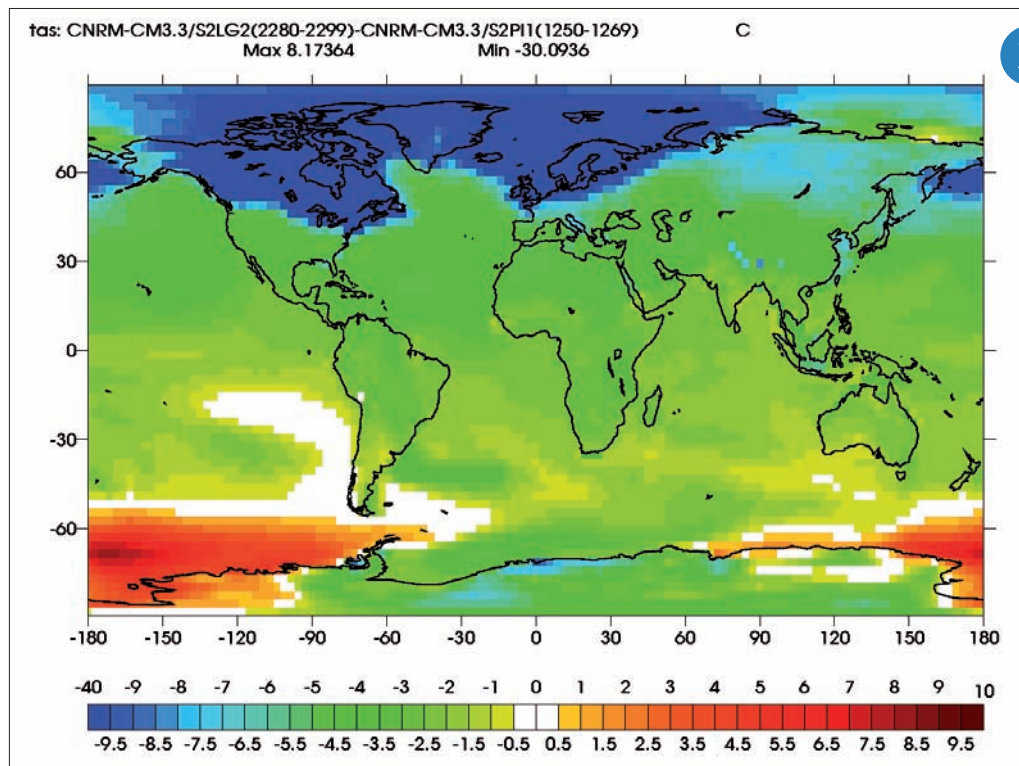
Snow cover and Indian monsoon:
a new episode of a debated relationship

Since the pioneering work of Blanford at the end of the 19th century, suggesting that Indian monsoon rainfall could be sensitive to former snow conditions over Eurasia, many studies have been devoted to a better evaluation and understanding of this possible teleconnection. This issue has been recently revisited at CNRM using a maximum covariance analysis.

This statistical tool has been applied to both observations (summer precipitation over India on one hand, satellite data of snow cover or in situ measurements of snow depth on the other hand) and to a subset of global coupled ocean-atmosphere simulations from the CMIP3 database. In line with former studies, the observations suggest a link between an east-west snow dipole over Eurasia and the Indian summer monsoon precipitation. However, our results indicate that this relationship is neither statistically significant nor stationary over the last forty years. Moreover, the strongest signal appears over eastern Eurasia and is not consistent with the Blanford

hypothesis whereby more snow should lead to a weaker monsoon. The 20th century CMIP3 simulations provide longer time series to look for robust snow-monsoon relationships. Some models do show an apparent influence of the Eurasian snow cover on the Indian summer monsoon precipitation, but the snow patterns are model-dependent and differ from those of the observations. Moreover, the apparent snow-monsoon relationship generally denotes a too strong ENSO (El Niño Southern Oscillation) influence on both winter snow cover and summer monsoon rainfall rather than a direct effect of the Eurasian snow cover on the Indian monsoon.

New sensitivity studies with the Arpège-Climat model are needed to assess the potential impact of snow anomalies on the monsoon, using climatological sea surface temperature to get rid of the oceanic variability. 3

Simulations of the long-term effects of the interaction between atmospheric chemistry and climate

The international research community on the interaction between atmospheric chemistry and climate prepares every four years, under the auspices of UNEP (United Nations Environment Programme) and WMO (World Meteorological Organization), a scientific assessment of ozone depletion. This assessment relies on results from coupled chemistry and climate modelling operations from the scientific community; these operations are coordinated by the SPARC Programme (Stratospheric Processes And their Role in Climate) in the framework of WCRP (World Climate Research Programme).

CNRM is one of the participants of the current exercise with its Chemistry Climate model (CNRM-ACM) that results from the coupling, via the ozone field, between the Chemistry Transport Model MOCAGE, with a stratospheric chemistry scheme, and the General Circulation Model ARPEGE-Climat.

The results from several coupled simulations will be inter-compared and analysed in 2009. Among these simulations, three will be used as reference: 20 years of simulation with the forcing conditions of the year 2000 to study the internal variability of the models; 40 years of simulation of the recent past period (1960-2000), taking into account the evolution of the solar radiation and the volcanic eruptions, where model outputs will be evaluated against observations, both in-situ and from satellites; and 140 years of simulation (1960-2100), with an intermediate scenario of the evolution of the greenhouse gases and of the ozone depleting substances (A1B scenario), in order to predict the evolution of the 21st century, in particular the ozone recovery. ④

Climate: from modelling to action

Meteo-France and the whole French climate community aim to provide an easy access to simulated climate data. The main idea is to implement a more complete service with observed series and also simulated data based on several assumptions of greenhouse gas emissions, several regional climate models and several downscaling methods (dynamical or statistical methods). This range of products will help to evaluate the different sources of uncertainty and will be used for impact studies. These actions have started in 2008, and will make easier the access to climate simulations and the proper use of scenario to end-users which are not necessarily familiar with climate modelling. They also contribute to relieve the research teams from data delivery tasks and part of the support.

In the framework of IPCC exercises, Meteo-France participates in numerous research projects on climate changes. This leads Meteo-France to be very frequently called for various climate change adaptation studies and to elaborate "Climate Plan" for many areas. Several different studies were conducted in 2008. For example, a study for the Poitou-Charente area was led, regional simulations contributed to the elaboration of thematic documents (impacts, adaptation solutions, sectors concerned, etc.). The figure illustrates the increase of heat wave risk (impact on agriculture, human health).

In order to be helpful to decision makers, Meteo-France will continue and strengthen its activities on climate impact assessments during the forthcoming years. ⑤

Regional climate scenarios adapted to impact studies

Meteo-France produced global scenarios as a contribution to the IPCC latest report. They have been downscaled by regional scenarios at a higher resolution (50 km) over France for 1950-2100. The model used is Arpege-climat with a variable mesh over the globe. Daily meteorological parameters were provided to a few impact studies.

Two main projects are mentioned here. In both cases, an original method has been developed to ensure the best fit with observed data for the 1971-2000 period. The first project is ANR-Climator. It deals with the impact on agronomy for 12 INRA stations over France : Avignon (see figure), Colmar, Mirecourt, St-Etienne, Bordeaux, Dijon, Mons, Toulouse, Clermont, Lusignan, Rennes and Versailles. The second is GICC-Rexhyss. It deals with the impact on hydrology for the Seine and the Somme river basins. The model output has been adapted to a 1660 point network (Safran analyses) over the region (northern part of the country).

Both projects will be achieved by the end of 2009. Our perspectives are to generalize to a larger number of impact studies the provision of corrected daily series for minimum and maximum temperature, precipitation and maximum wind over France (240 points). We will also increase the number of model simulations over 1950-2100 to better evaluate uncertainties. ⑥

Impact of climate change on extreme discharge in the Mediterranean region

Evolution of intense precipitations in the French Mediterranean area for the XXI century is a key question, when considering the high amount of damages caused by flash floods in this region. This point is one of the objectives of the French CYPRIM project. With the aim to estimate the precipitation at a very fine resolution, several downscaling methods were applied to a high resolution climate scenario. These data were used to feed the hydrometeorological model Safran-Isba-Modcou in order to calculate the evolution of water fluxes at the soil surface, in the soil and the

associated discharges. The expected warming, associated with the decrease in precipitation, leads a pronounced decrease in the soil wetness and a subsequent decrease in discharge throughout the century.

Regarding the rain and extreme flows, it appears that in some watersheds, the highest rates could be similar or even higher than those found today. This is consistent with the analysis of other climate scenarios leading to an increase in rainfall variability. However, the comparison of results obtained

with both downscaling methods give divergent results on the precise location of areas with high precipitation in the future (see figure).

This study will be extended in the future through the study of new scenarios and through works on improving descent of scale methods to complement these initial estimates. ⑦
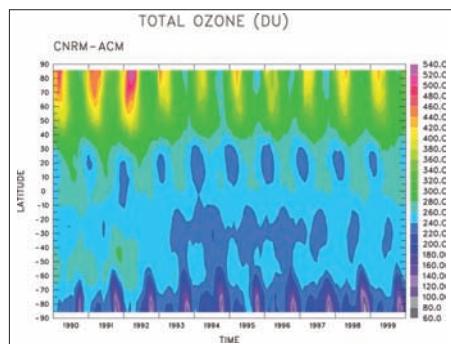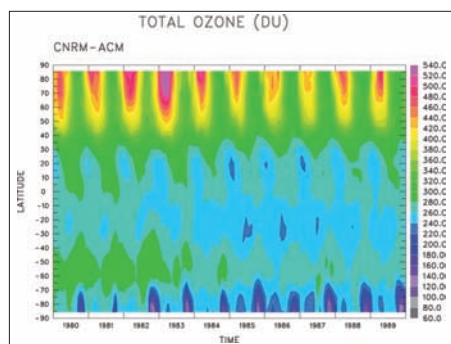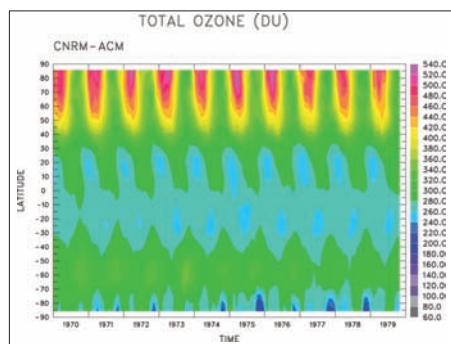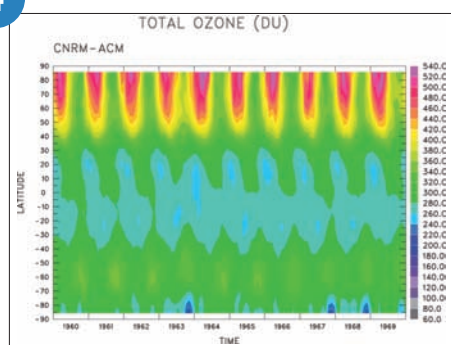
Evolution of the zonal mean of the ozone column (Dobson units) between 1960 and 2000, as simulated by CNRM-ACM. One can notice the setting up of the ozone hole in the decade 1980-1990.
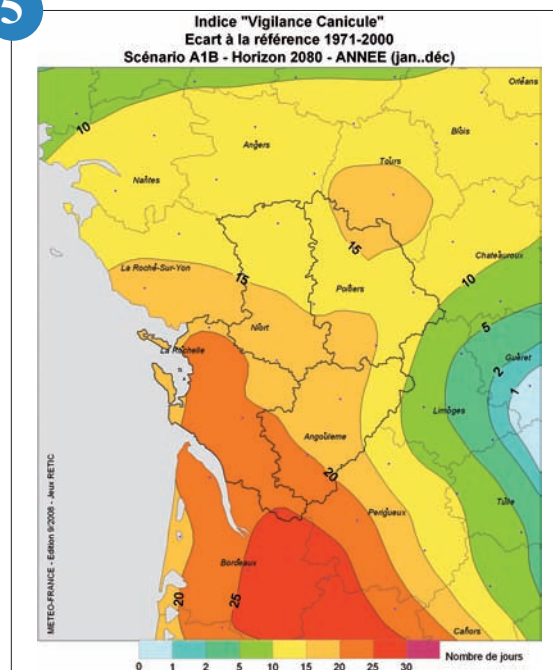
Heat wave index evolution in a Western region of France, index defined with French weather warning criteria. A2 emission scenario, regional climate model ARPEGE, difference between end of 21st century and end of 20th century (in number of days).
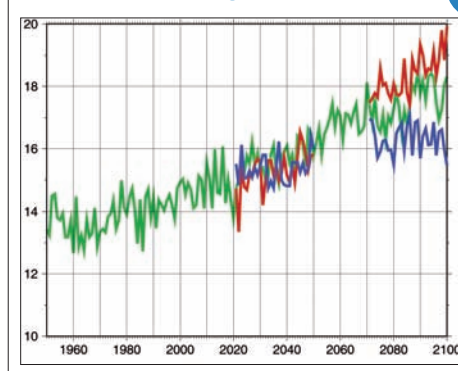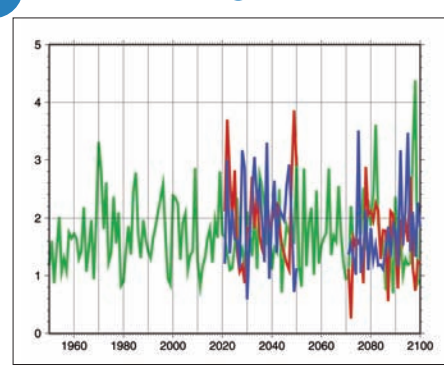
▲ Series of annual mean temperature (a, °C) and precipitation (b, mm/day) for Avignon Inra station according to IPCC-A1B (green), A2 (red) and B1 (blue) scenarios simulated by Arpege-climat regional model.
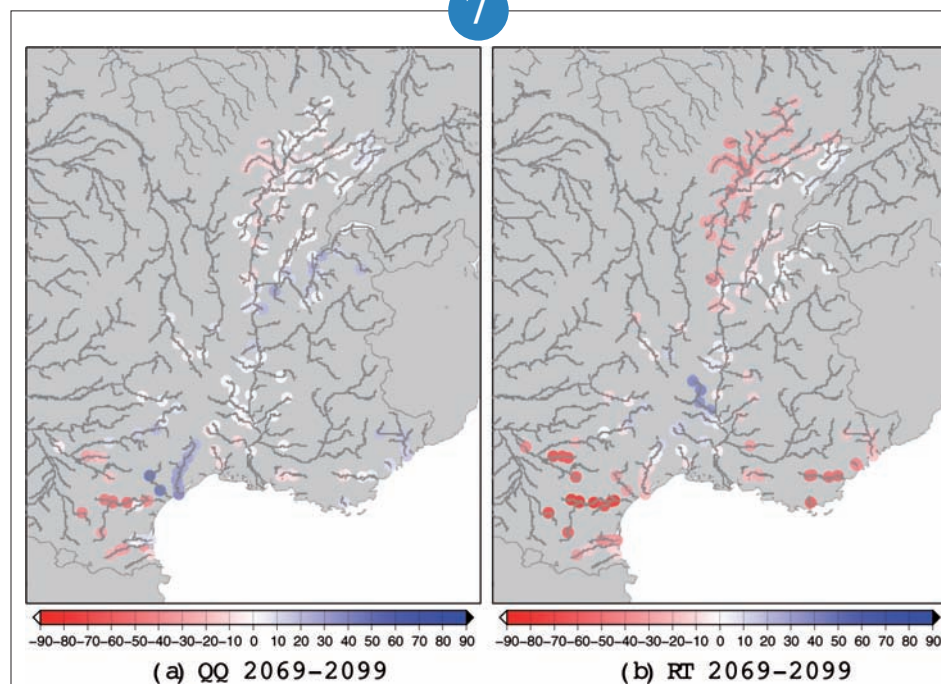
▶ Change (%) of the extreme flows (99 % percentile of the discharge : value exceeded 1 in 100) over the period September-December for the French Mediterranean region (variation between the periods 1969-1999 and 2069-2099). Left : downscaling method using a correction of the variables of the general circulation model (QQ). Right : downscaling method based on weather regimes.

International Polar Year

The 4th International Polar Year took place in 2008. Meteo-France was involved in this event, through several actions, like contributions to field campaigns, or original projects like Concordiasi …

Meteorological measurements on board ships in the Arctic Ocean

During the International Polar Year, the sailing ship TARA has been equipped with an automatic weather station (AWS) MINOS fitted with pressure and air temperature sensors, a GPS receiver and an Argos transmitter. After a drift of over 500 days in the ices of the Arctic Ocean (September 2006 – January 2008), the ship came back to port in February 2008. The MINOS AWS was controlled. In spite of several months spent in very severe weather conditions, the AWS was in perfect working state.

Then, the MINOS was shipped to Svalbard to be installed on board the VAGABOND during the summer 2008. The VAGABOND is an another sailing vessel, smaller than the TARA. This ship will contribute to study the ices before returning to France in 2010. **1**

POLARCAT: ATR42 participation at the atmospheric pollution study around the North pole

The POLARCAT airborne experiment (http://www.polarcat.no/) is part of the International Polar Year programme. Meteo-France's ATR, operated by the SAFIRE team (joint group of CNRS / Meteo-France / CNES), was involved in two campaigns : the first one in Northern Sweden (Kiruna, April 2008) and the second one in Greenland (Kangerlussuaq, July 2008).

During spring 2008, at the north of the polar circle, the first task of the ATR42 was to study the arctic smog. Therefore, the aircraft was equipped with in situ aerosols and trace gases sensors as well as a lidar and a radar for humidity measurements. Important pollution events were encountered, such as a strong Asian pollution that had crossed over the North pole.

On summer 2008, the second phase of Polarcat took place in Greenland with the objective of studying the summer forest fires dust transportation and deposit. For this purpose, the aircraft was equipped with another lidar for ozone measurements.

The operations of the aircraft with such a heavy set of instruments and in remote areas required one year of preparation. The programme took place in very good conditions and scientists now have a large set of data. On a global point of view, the ATR42 flew 120 hours in the framework of POLARCAT. **2**

Preparation for the Concordiasi campaign

The Concordiasi project takes place in Antarctica for two Austral spring seasons (2008 and 2010). One of the main goals is the validation and improvement of the assimilation of satellite data over polar areas, through measurements campaigns. In preparation for these campaigns, developments have been tested.

Many difficulties are associated with data assimilation over high latitudes, mainly due to the estimation of emissivity for cold areas and to the cloud detection, important for infrared measurements.

The method developed at CNRM for the estimation of the microwave emissivity from satellite observations has been applied for cold areas (land and sea ice). Thus, the assimilation of AMSU data has been performed over Antarctica. Currently, physical assumptions are being reconsidered for snow surfaces. These tests will help us to improve the emissivity calculation in the model.

Assimilation experiments have been run in order to increase the number of satellite observations assimilated for microwave (AMSU) and infrared (AIRS and IASI) over Antarctica and the sea ice surroundings. The increase of the number of observations for this area (see figure) has a positive impact on the analysis and the forecast in a model especially tuned for Antarctica. This release of the ARPEGE model has a finer resolution over the area and will be helpful for meteorological forecasts during the second phase of the campaign in 2010. During this austral spring, stratospheric balloons will be launched over Antarctica to document the stratosphere but also the troposphere by launching sondes on demand for a period of a few weeks. **3**

1

The ATR42, ready for departure at Kiruna, Sweden during the April 2008 flights. On the left, the heated hangar dedicated to the scientific aircraft: Arena Arctica.
▼

2

▲ Picture of the Vagabond
(Copyright Eric Brossier – Vagabond)

◄ TARA trajectory over the ices of Arctic ocean
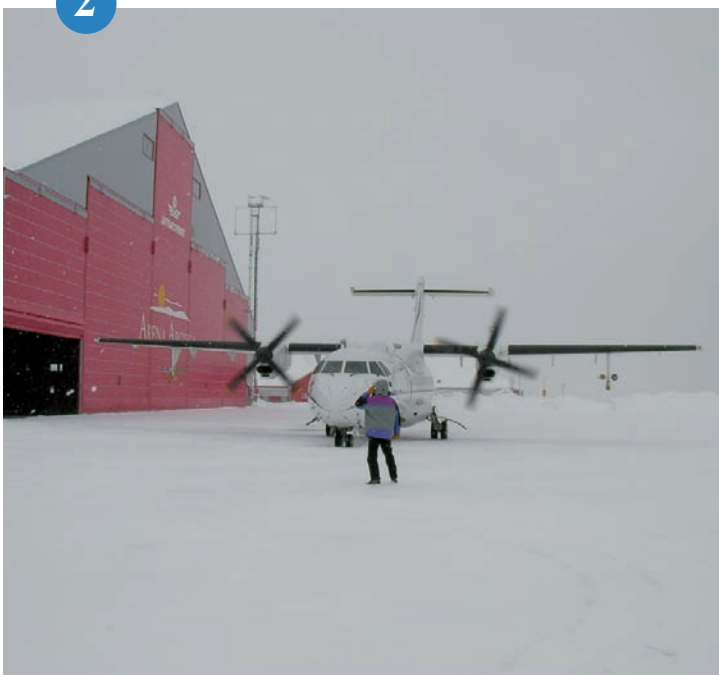
3
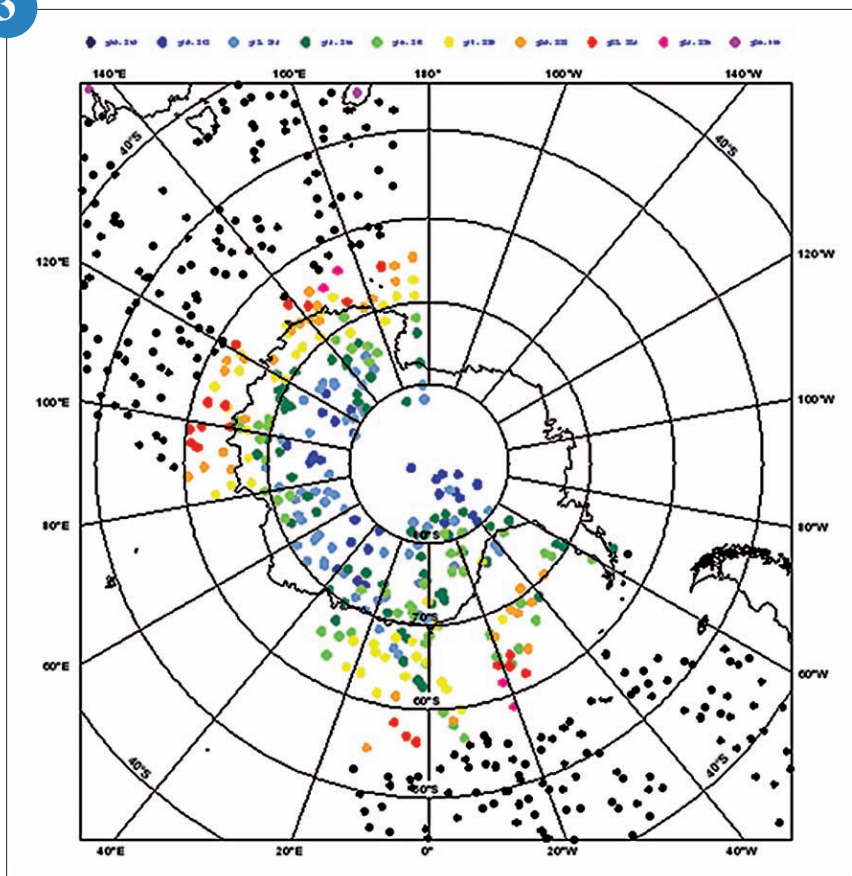
◄ IASI data coverage over Antarctica for channel 246. Black points show the observations assimilated in the operational model and the colour points are the additional observations (over sea ice and snow cover) assimilated in a tuned version of the model.

First phase of the Concordiasi campaign

A field campaign, called Concordiasi (http://www.cnrm.meteo.fr/concordiasi) took place in Antarctica in order to validate the satellite data assimilation at high latitudes. Our focus of interest is the hyperspectral IASI sensor on the European MetOp platform. The campaign is made up of two parts, each one during austral spring (2008 and 2010).

The first stage of the campaign took place from September to December 2008. During the campaign, the number of radiasoundings have doubled at two stations, Dumont d'Urville (DDU) on the coast and Concordia at DomeC (launch twice a day). The additional sondes, measuring the atmospheric profiles until 20 km and above, have been synchronised with the MetOp track over these stations. Moreover, a few sondes have been launched taking advantage of the co-location of infrared sensors AIRS, IASI and the Aqua-Train over these stations. This will help us to compare the data from radiosoundings (see figure), simulated data from different versions of the numerical forecast model and the data viewed by sensors. At the same time, sensors on the Aqua-Train will bring information on clouds.

Visual observations indicate that the cloud conditions are varied over Antarctica. Conditions are mostly cloudy over DDU and clear over DomeC. The infrared radiation measured by AIRS and IASI is strongly affected by clouds. The data obtained during the campaign will allow to study the satellite data assimilation for this area in different cloud cover conditions. **4**

The single-level drifting balloons: new observing platforms adapted to weather forecasting ?

Adaptive observation consists in the addition of observations in some deemed objectively computed sensitive areas and aims at improving (locally) a numerical weather prediction. Numerical techniques that predict the expected benefit on the forecast for some potential additional deployment have been developed for a decade.

Until recently, adaptive observation was done using additional platforms with a nearly full control of either space or time sampling (ground station), or both (deployment with aircrafts). With the ongoing projects CONCORDIASI and BAMED (Balloons in the Mediterranean, 2008-2010), drifting balloons are used as a new type of adaptive platforms.

During the CONCORDIASI campaign in the austral spring 2010, the stratospheric balloons will be entrapped for a few weeks, in the southern polar vortex, forming a small constellation of adaptive platforms. These balloons will drop sondes depending on the information on the predictability of the atmosphere provided by the numerical techniques. Only a prediction of the balloons' position should be needed in addition to classic targeting tools.

In BAMED, the problem is new and more complex. Small aerostats flying at low level (boundary layer) above the Mediterranean sea are considered. They will observe the atmospheric flow in the basin, upstream to heavy rain episodes such as the Cévennes events. This flow does not trap the balloons in the basin. The issue is then to determine the time and places of release of these balloons to guarantee that they hit their target (sensitive areas) and to maximize their contribution to the mesoscale data assimilation and prediction systems. This new kind of tool, combined with balloons from CNES, should be deployed during the HyMeX campaign. **5**

Temperature profile, during the campaign, at DomeC, the 09/20/08 at 0 h TU and at Dumont d'Urville, the 09/15/08 at 12 h TU. The black line is the radiosounding, the red line, the analysis from the operational model and the green line, the analysis from a version of the model especially tuned for Antarctica.
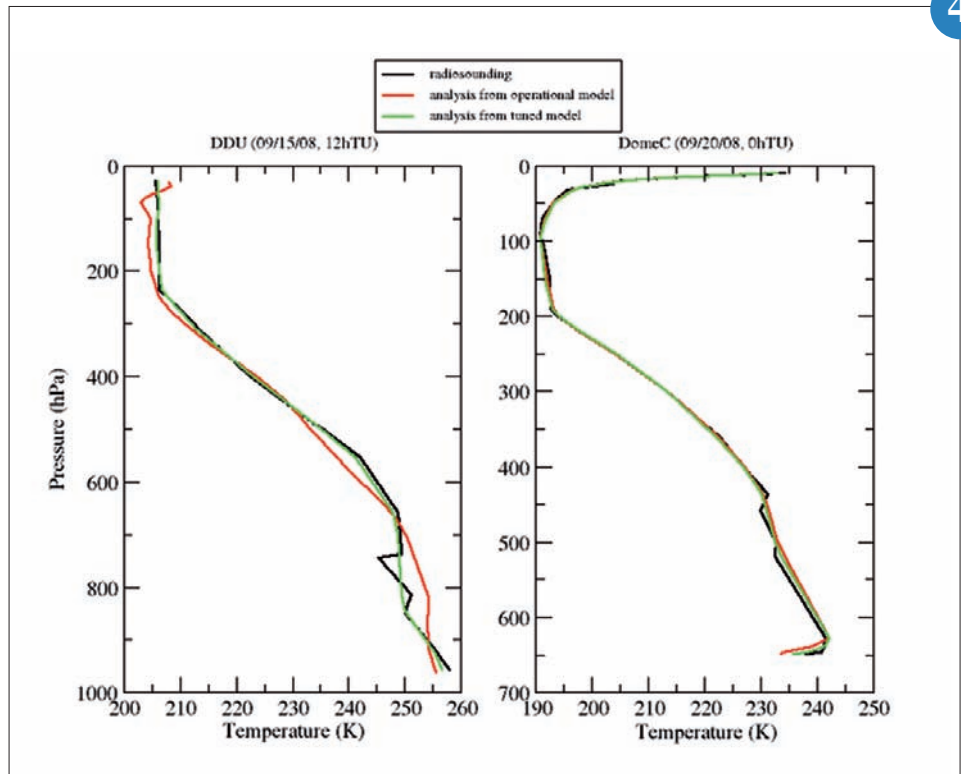
Simulation of a CONCORDIASI case.

The sensitive areas are shown in orange shadings. They are valid on the 2008/10/31 at 18 UT and are derived from singular vectors (optimized on 24 h). The trajectories of the stratospheric balloons are simulated with ARPEGE wind analyses at 50 hPa. These trajectories are plotted from the launch site (Mac Murdo, black dot) to the location at the valid time. The verification date is the 2008/11/01 at 18 UT and applies to the verification domain shown with a black circle (60°S). The light blue contour is the sea ice outer limit and circles the CONCORDIASI domain of interest. The blue shadings depict the Eady growth rate between 1000 and 300 hPa that has been computed on the period. This field mimics unconstrained dynamical sensitive areas and legitimates the position of the constrained (60°S) sensitive areas outside Antarctica vortex, at the limit of the iced regions. In this simulated case, two balloons could drop a sonde with an expected strong impact on the 24 h forecast : the green and the purple one.
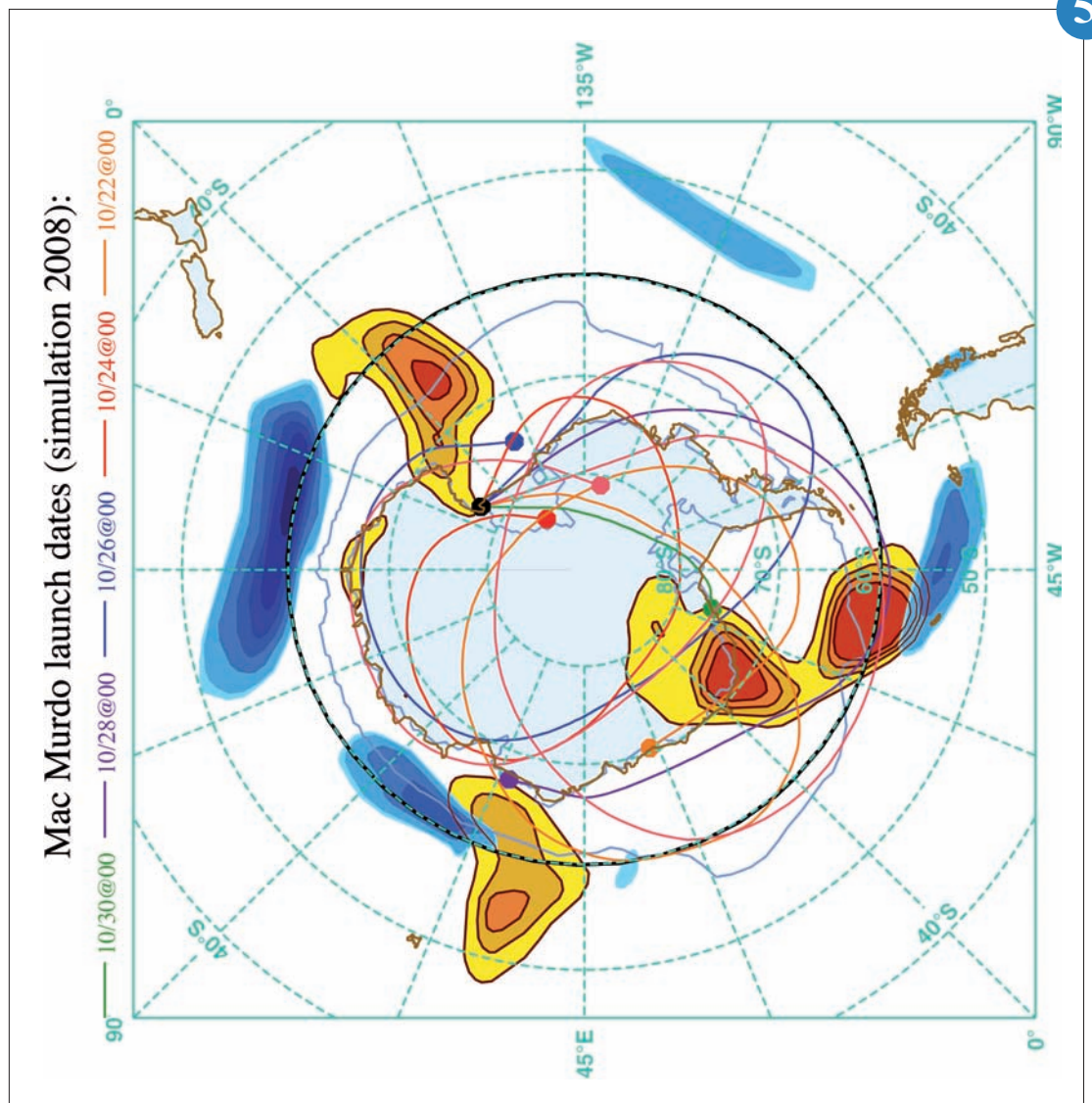
Atmosphere and environment studies

In 2008, numerous research activities have been led in the areas of hydrometeorology, oceanography, snow cover, as well as for low visibility or chemical modelling. Some of the major events of last year were the progress in discharge ensemble forecasts, air quality modelling control, knowledge on fog situations, ...

Hydrometeorology

Soil moisture monitoring: use of in-situ data to validate the ASCAT (EUMETSAT)

Surface soil moisture can be estimated by using microwave remote sensing data, and in-situ continuous measurements can be made with automatic probes.

In the South West of France, 12 ground weather stations of Meteo-France's RADOME network were upgraded in order to measure the soil moisture at several depths. The stations were chosen in order to sample a climatic gradient between the Mediterranean sea and the Atlantic ocean (the SMOSMANIA project). In-situ near-real-time observations are performed since the end of 2006 at a sampling rate of 12 minutes. The first soil moisture products of the ASCAT instrument on the METOP satellite (provided by EUMETSAT) were compared with in-situ observations of the surface soil moisture from April to September 2007. For most stations (10 out of 12), significant correlation levels between the satellite products and in-situ observations were found. The seasonal variability was suppressed by calculating normalised anomalies (see figure).

In 2008, the SMOSMANIA network was extended to the East, with 9 new stations located in the Mediterranean region. The 21 stations network will permit to validate the soil moisture products produced by the SMOS satellite (from the European Space Agency), whose launch is scheduled for 2009. **1**

Benefits of the use of the AROME/ISBA-TOPMODEL coupled system on Cevennes floods of 2008

During the autumn, the watersheds of the Cévennes region are often affected by heavy precipitation events that can trigger flash-floods. Forecasting those floods is not very easy because both the atmospheric forecasting and the hydrological response have to be taken into consideration.

In order to progress on the forecasting of these floods, the hydrological model TOPMODEL was coupled with ISBA which is the surface scheme of Méso-NH and AROME atmospheric models. ISBA deals with soil-atmosphere interaction especially water budget on soil columns while TOPMODEL performs soil water lateral transfers among the watersheds. Then sub-surface runoff and deep drainage are routed to a given outlet to estimate a discharge.

Since September 2008, the ISBA-TOPMODEL coupled system runs every day driven by the pre-operational AROME 00UTC forecast. Two major flood events occurred in the Cévennes during last autumn: 21/22 October and 1/2 November. In both cases, the hydrometeorological chain AROME/ISBA-TOPMODEL was able to simulate quite reasonably the discharges of the three main rivers (Gardon at Ners, Cèze at Bagnols et Ardèche at Vallon Pont D'arc) with well simulated flood dynamics and flood peak amplitude.

Although those results are encouraging, the discharge forecast strongly depends on the rainfall forecast. Indeed, quite small errors in location of intense rainfall can have large detrimental effects on the discharge forecast. Future work will be thus devoted to the design of an ensemble hydrometeorological forecasting system in order to take into account the uncertainties on the input rainfall forecast. **2**

A streamflow assimilation system on France for the SIM ensemble streamflow prediction suite

SAFRAN-ISBA-MODCOU (SIM) is an hydrometeorological suite simulating surface hydrological balances and the associated streamflows on a distributed way over France. This suite simulates around 900 streamflows of French rivers.

Two ensemble streamflow prediction suites based on SIM were built, the first one using the meteorological ensemble prediction from the ECMWF at a 10-day range, and the second one using the 60-hour PEARP prediction. Each member of the ensemble streamflow prediction comes from a SIM simulation forced by one of the members of the meteorological ensemble prediction. These two suites showed satisfactory statistical scores, despite of a low spread, the PEARP-based suite being better for small basins and for floods.

But in its current form, SIM is never calibrated with observed streamflows. That is why a daily assimilation of observed streamflows has been implemented into SIM. This assimilation uses the analysis operator BLUE (Best Linear Unbiased Estimation) and the CERFACS coupler, PALM, in order to adjust the soil moisture, which is the parameter used to correct the model or atmospheric forcing defaults.

The observed streamflow assimilation brings significant improvements on many stations, except for those where an aquifer layer is simulated into SIM (in this case, the streamflow is mainly related to the aquifer piezometric level, not to the soil moisture). A new validation of the 2 ensemble streamflow prediction systems will be performed using the new initial states coming from the assimilation system, in order to quantify its impact. **3**
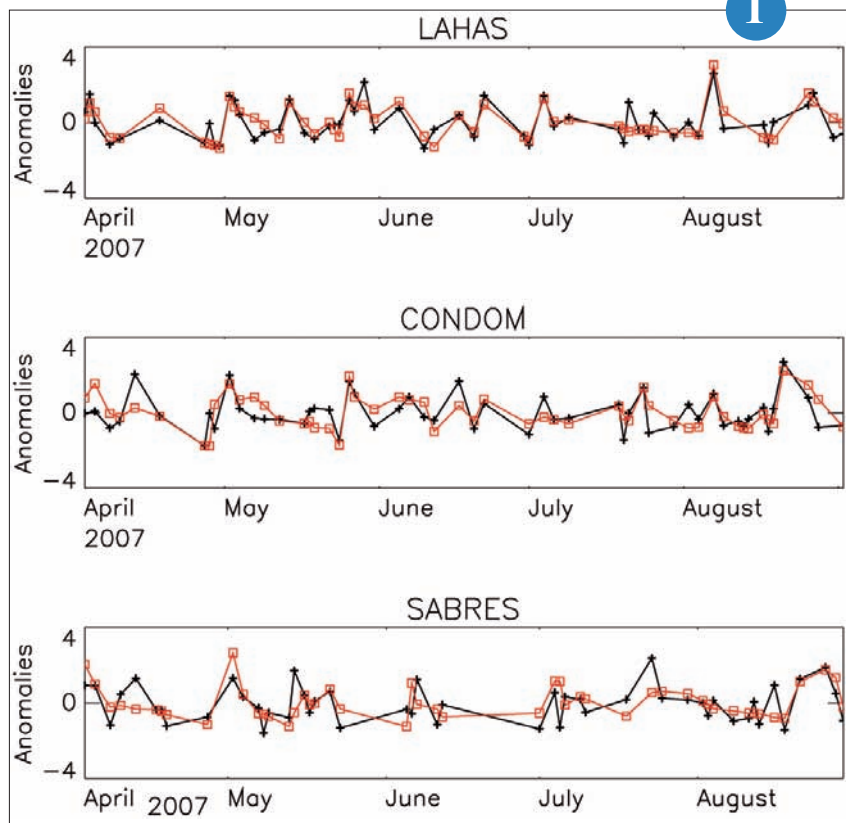
▲ Temporal evolution of surface soil moisture anomalies at three SMOSMANIA stations: ASCAT (in black) and in-situ observations at 5 cm (in red) for descending (a.m.) orbits between 1 April and 30 September 2007.
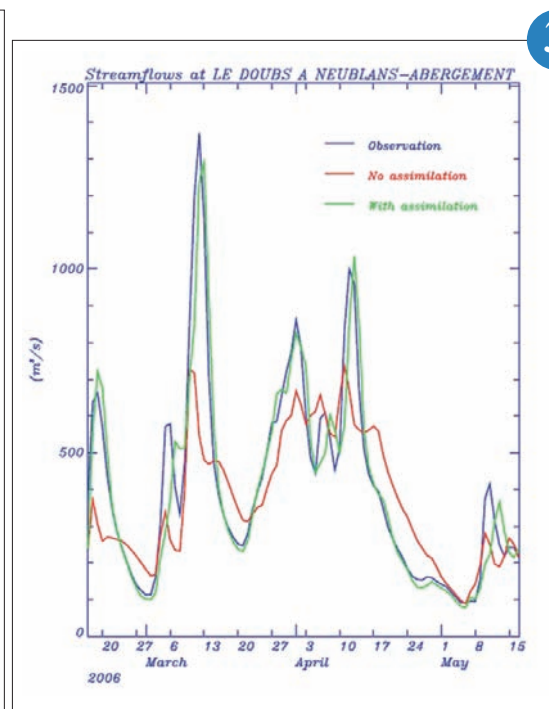
▲ Streamflow prediction of the SIM suite: observed streamflows (blue), reference SIM suite (red), SIM suite initialized with initial states coming from the streamflow assimilation (green)

Principle of the AROME/ISBA-TOPMODEL hydrometeorological chain and results for the 02/11/2008.
▼
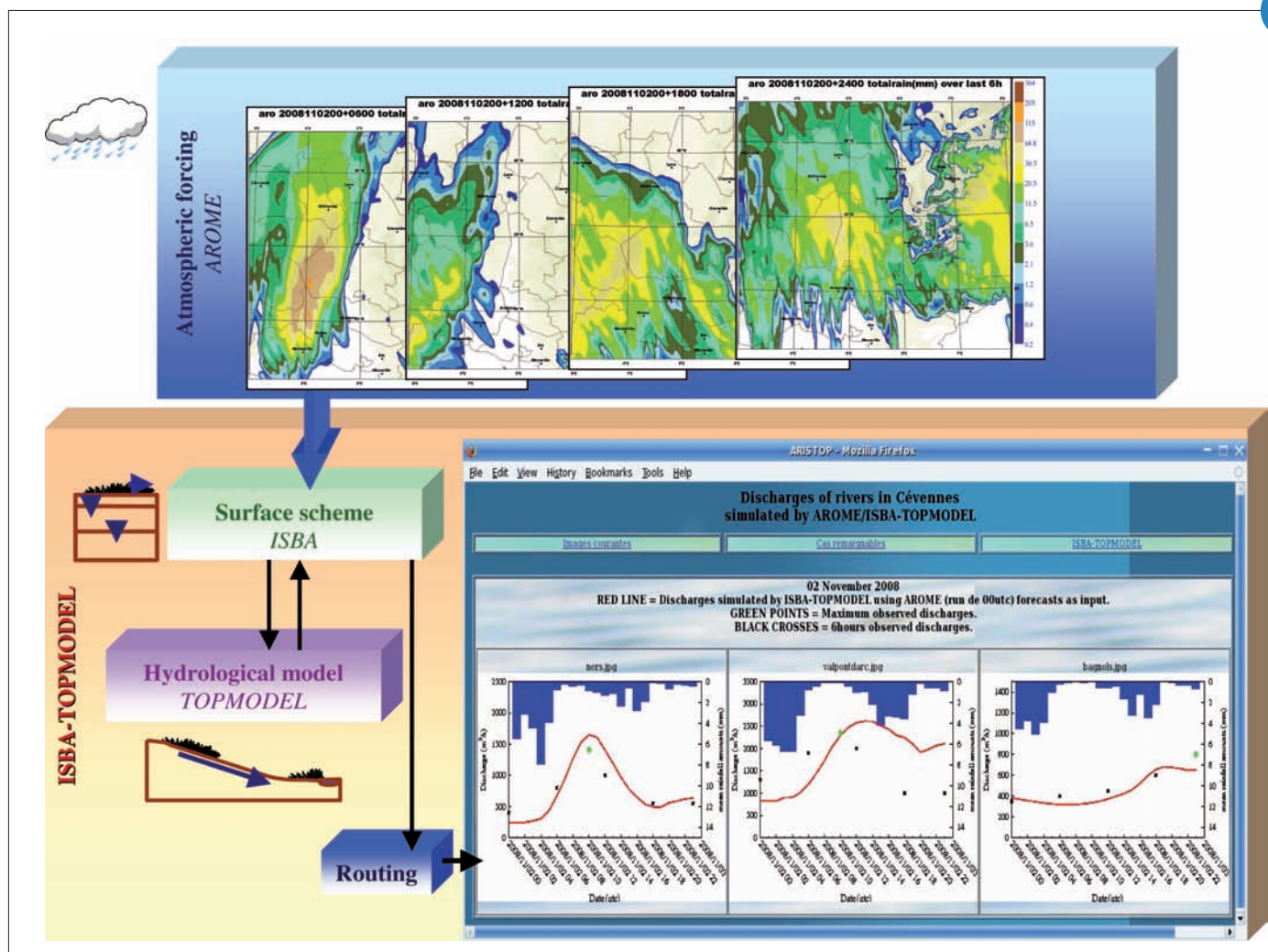
Hydrological seasonal forecast in France: feasibility and potentialities

Water management is a major issue for our society from the short term to the climatic change scales including the long range scale. To overcome the lack of information at seasonal scale, a study on the feasibility and potentialities of hydrological seasonal forecast in France was conducted at the Direction of Climatology, in collaboration with the CNRM/GMME.

A forecasting suite using the SIM modules (Safran-Isba-Modcou) and forecasts from the Demeter project for March-April-May (1971-2001 period) has been developed, thus demonstrating the feasibility of such forecasts. Then, the quality of downscaled atmospheric forcing from the scale of seasonal forecasts (2°5) to the one of Isba (8 km), of soil wetness index forecasts and of river flow forecasts for 4 river catchments (Seine, Garonne, Ariège, Durance) has been evaluated.

The predictability of atmospheric forcing is not deteriorated by the downscaling process. The total precipitations are correctly estimated (including over the 4 river catchments) but one can notice an overestimation of rainfall compensated by an underestimation of snow. The forecasted soil wetness index shows a strong dry bias but with a fairly good predictability (ROC better than 0.7). The results for river flows are very contrasted, the relation between observed/forecasted river flow being stable and correct (0.5 up to 0.7) but with a dry bias particularly noticeable for the Seine and the Garonne contrary to the Ariège and the Durance (with reasonable bias).

In conclusion, these forecasts show an interesting predictability which is better than for atmospheric forcing. Therefore, the necessary developments will be carried out in order to routinely provide relevant products. 4

Potentiality of SIM system to characterise geotechnical draught

Meteo-France has been using outputs from a two-reservoir water balance model since 2000 in order to characterize geotechnical droughts over France within the "Natural Hazards" regulation framework. The small number of stations (a hundred all over the country) with required data and related normals implies to use a broad zoning which does not match anymore the requirements for small-scale administrative areas given the current progresses in spatialisation.

Both SIM operational output and reanalysis over the 1958-2008 period make it possible to consider using ISBA land surface scheme 8km gridded data and related normals.

In order to better understand climatic hazards and to approximate more closely to the hypotheses made by the two-reservoir model, Meteo-France developed a release of ISBA using a single uniform parameterisation of vegetation and soil properties over France. Droughts identified by the two-reservoir model and the uniform version of SIM built with around forty grids are very close, which is promising.

Furthermore, the 2005-2007 temporal evolution of SIM-based soil moisture matches closely with in-situ data from two observation sites set up within the ANR ARGIC project, proving the relevance of SIM modelling.

Meteo-France will finish implementing in 2009 the spatialised computation of geotechnical drought criteria derived from the Soil Wetness Index computed by the uniform version of SIM. 5

Towards an improvement of the assessment of the hydro-meteorological risks in the South-East of France

In 2008, a project whose aim was to develop a new tool to help the civil authority to assess hydrological risks in the South East of France was launched.

One of the major aspects of the project is the installation of a network of three X-band radars (3 cm wavelength) to improve the coverage of the existing network over the South East of France. Research and development is another important and ambitious aspect of this project. It is intended to test and to deploy a polarimetric, multi-radar suite of algorithms whose aim is to produce high-resolution 2D and 3D products such as rain rates, winds, types of hydrometeors (hail for instance) and humidity. One of the main objectives of the project is to take advantage of the redundancy of the information between the different radars, particularly to overcome the problem of attenuation by heavy precipitation.

Measurements in X band were simulated in 2008 during an intense precipitation event and compared to the non attenuated measurements from the Nîmes S band radar. The study showed that the signal could become completely extinct at ranges as close as 30 km from the radar. Such results help to understand the importance of taking advantage of the complementarity of the different means of observation. 6

Meteo-France's contribution to H-SAF project: hydrological assessment of satellite precipitation products

The main objective of the Eumetsat Satellite Application Facility on Support to Operational Hydrology and Water Management (H-SAF project), launched in 2005, is to provide satellite products which will make easier flood forecasting and water resources monitoring over Europe. These products (precipitation, snow parameters and soil moisture) have reached the pre-operational level and are bound to be used by several hydrometeorological models.

Meteo-France together with seven European national meteorological services (Poland, Belgium, Italy, Turkey, Slovakia, Germany, and Finland) performs independent evaluations of precipitation products. A first sensitivity test using the preliminaries satellite-derived products was made in 2008 at Meteo-France with the Safran-Isba-Modcou (SIM) hydrometeorological model applied over the Adour-Garonne basin.

This hydrological validation will be carried on in 2009 in order to assess the benefits of using such precipitation products within Meteo-France operational hydrometeorological applications. 7
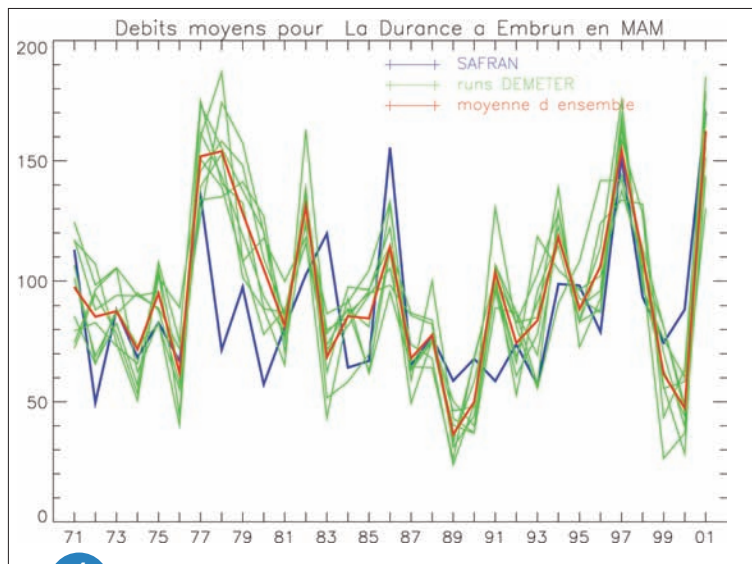
Comparison between observed (blue curve) et forecasted river flow (in m³/s) by the ensemble mean (red curve) for the Durance catchment at Embrun in March-April-May on the 1971-2001 period. Additionally to the correct representation of the interannual variability (stable correlation ~0.6) , one can also notice the good dispersion of individual members of the ensemble (green curves) which indicate a pretty well coverage of the range of value of the reference.

Comparison of the temporal evolution of soil moisture products from the uniform version of SIM with soil water contents measured at the Deffend instrumented site (near Poitiers) between December 2005 and July 2007 at depths of 0.5m and 1m.
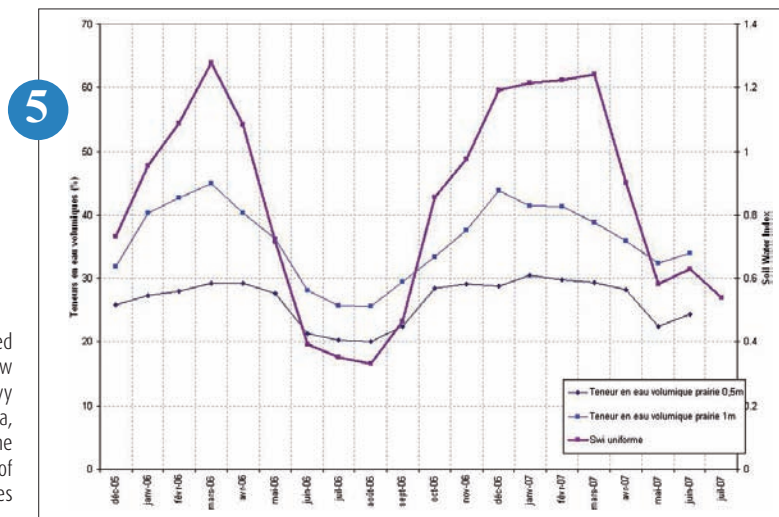
From left to right : rain accumulation from the Nîmes non-attenuated S-band radar over the rain event, same rain accumulation from raw simulated data from an X-band radar located in the chore of the heavy precipitation, same rain accumulation from corrected simulated data, apart from pixels where the signal is extinct (where the level of the signal is below the level of the noise). This shows the importance of the rain attenuation correction. Extinction can be important at ranges as close as 30 km from the radar.
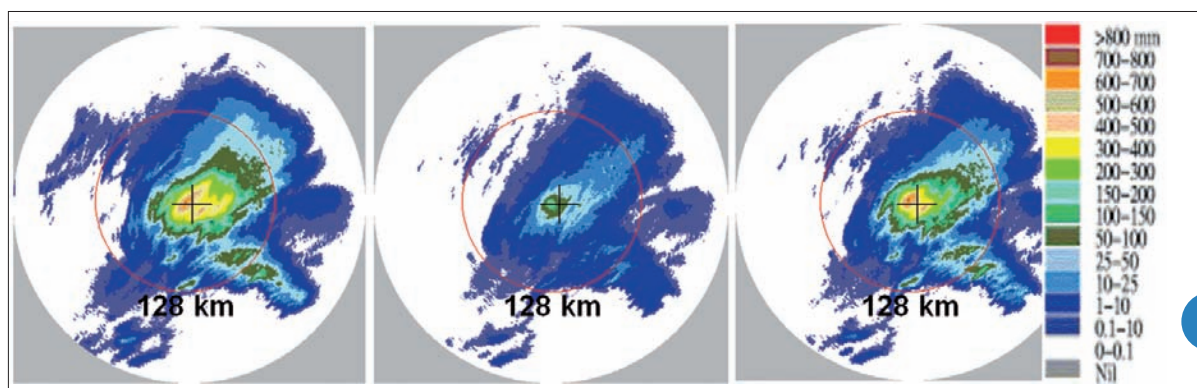
Comparison between observed daily discharges for the Garonne river at Portet-sur-Garonne and discharges simulated by SIM in reanalysis mode, in operational mode, and forced by preliminaries H-SAF products, 26-31 March 2008.
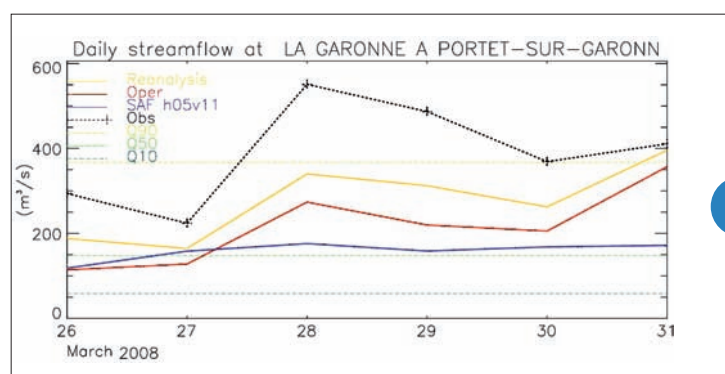
Oceanography (modelling and instrumentation)

E-Surfmar: European surface marine observation programme

Since 2003, the surface marine meteorological observation has been organized in Europe within Eucos, composite observation programme of Eumetnet. Meteo-France ensures the responsibility of E-Surfmar, program which is concerned by the Volunteer Observing Ships (VOS) recruited by the European meteorological services as well as the drifting and moored buoys.

Automation of the observation, decrease of its production cost, improvement of its quality and reducing of transmission delays are the main concerns of E-Surfmar. The Iridium satellite system showed its potentialities compared to Argos to report drifting buoys data. In 2008 the decision to progressively extend this communication system to all the drifting buoys was taken.

The number of observations collected by automated stations (AWS) installed aboard European ships increases. About 1000 observations are collected daily in average in the North Atlantic and in the Mediterranean sea. The installation of "simple" AWS, so called BAROS, equipped with a barometer and using Iridium system started in 2008 on E-ASAP ships.

At the end of 2008, more than 90 drifting buoys, half of them using Iridium, funded by the program, reported daily about 2500 observations of air pressure and sea surface temperature. **8**

Sea surface salinity

The Centre de Meteorologie Marine (CMM) contributes to the validation and the calibration of SMOS (Soil Moisture Ocean Salinity) satellite from ESA which will be launched in 2009, through the GLOSCAL (Global Ocean Salinity Calibration and Validation) project. This one aims to study the Sea Surface Salinity data (SMOS data, AQUARIUS data, in situ data) in relation with the national and international scientific community. The Sea Surface Salinity is thus important for a better understanding of climate.

The recovery, at sea, at the end of June 2008, of a drifting buoy which has been deployed in fall 2007, allowed to verify the stability of the sensor after a new calibration.

Drifting buoys fitted with conductivity sensors were deployed in the Amazon river in the framework of AMANDES campaigns, in the North Atlantic Ocean during OVIDE campaigns and in Biscay Bay for CAROLS experiment. Other new drifters have been equipped with a transmission through Iridium satellite system.

At the end of GLOSCAL, the aim is to have about thirty buoys deployed when SMOS will be launched. **9**

Global Sea Surface Temperature from METOP

METOP is the first EUMETSAT operational polar orbiting satellite. It carries, among other instruments, a classical multispectral imager radiometer: the AVHRR, enabling observations of the surface of the Earth in visible and InfraRed channels at a 1 km resolution. Meteo-France CMS is committed, within the Ocean and Sea Ice SAF of EUMETSAT, to produce full resolution Sea Surface Temperature (SST) fields over the globe within 3 hours after the time of measurement onboard the platform.

The METOP data processing raised first a problem of real time management of a large data flow. As far as algorithms are concerned, the issues related to SST retrieval at low or mid latitudes are not new, since CMS has been already processing geostationary data over the whole Atlantic. Data processing over the polar zones raised however new issues, that were addressed in collaboration with our colleagues from the norvegian meteorological office.

METOP has been declared operational in May 2007 and the routine production of SST fields in test mode started in July 2007. After an extensive validation phase that showed an accuracy of about 0.5 K, the SST product has been declared operational in September 2008. The METOP SST data are already a key contribution to the Met. Office fine scale SST analysis, which is operationally used by the ECMWF forecast model.

The study of the surface thermal features of the Arctic ocean will continue in 2009. Finally, CMS builds up, in a slightly delayed mode, a worldwide validation database for satellite IR radiometry derived SST which allows fundamental algorithmic developments. **10**

Sea temperature measurement

Drifting buoys fitted with a thermistor chain have been used for several years to contribute to the study of sea-air interactions.

The Marisonde buoys measure wind, atmospheric pressure and sea temperature at various levels. The ARGOS system is used for location and data transmission. New generation of Marisonde buoys is under construction. The bathythermic string is 300 meters long, includes 16 temperature sensors and 4 hydrostatic pressure sensors on two separate « bus ».

Work is also carried out to fit a thermistor string on SVP drifters. Two of these buoys, so called SVP-BTC have been deployed at sea in 2008. One was equipped with a line of 80 meters long with 16 temperature sensors. **11**

8

Drifting buoys trajectories – November 2008 ▶

BAROS AWS on board
the fishing vessel Jericho ▼

9

▲
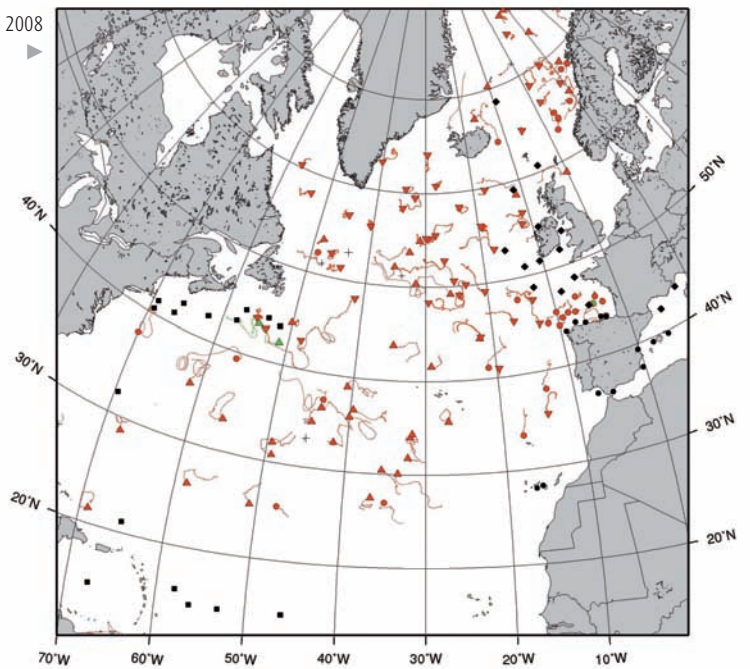
Deployment of a drifting buoy

Sea Surface Temperature field observed
by METOP between 18 00 UTC on the
30ᵗʰ and 06 00 UTC on the 31ˢᵗ
December 2008. The grid over the SST
field shows (except at high latitudes)
the 3 minute granules contributing to
this field. ▶

Metop SST 2008-12-31 0000

10

11
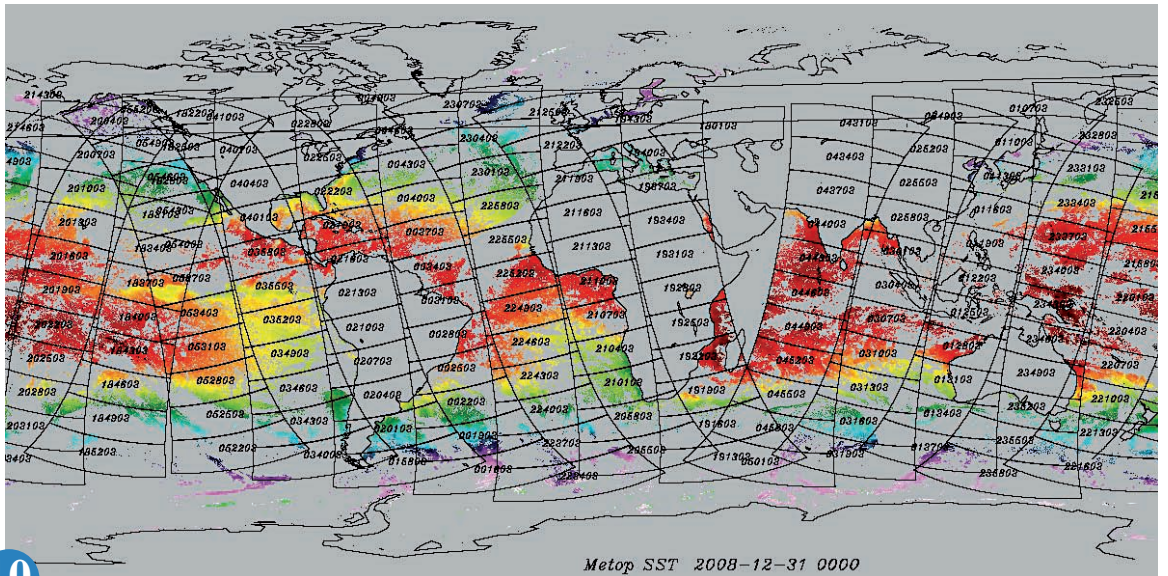
Sea temperatures in depth on SVP-BTC ▶

Marisonde buoy
▼
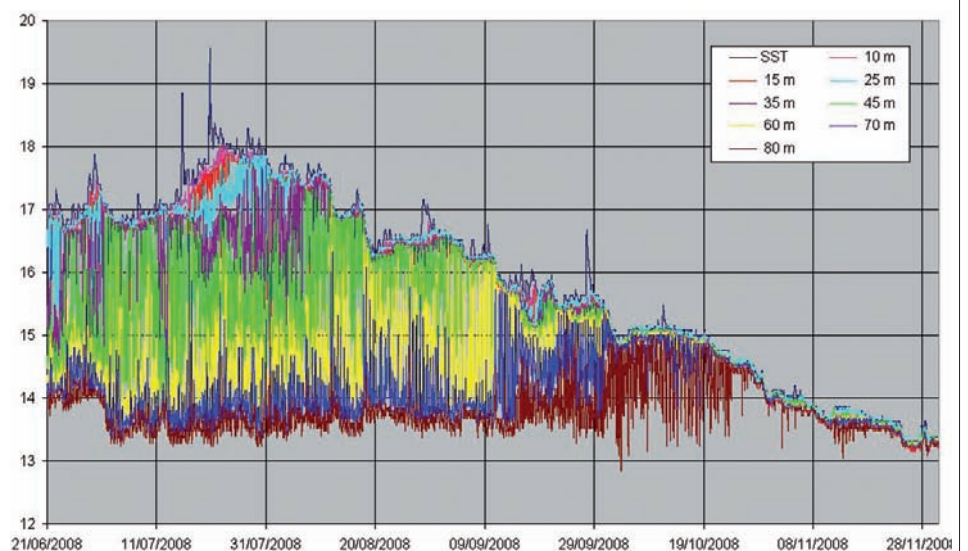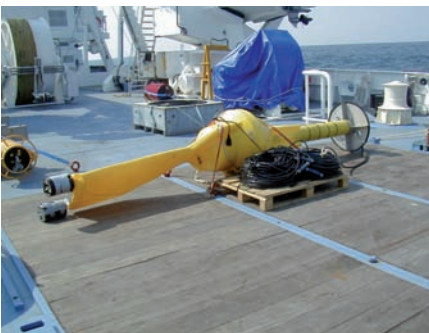
The moored buoys

The moored buoys watch the ocean and although they require important human and financial needs, they remain key elements of the weather watch system.

In addition to the two oceanic stations operated in Biscay Bay in co-operation with the Met Office, two buoys are anchored off the French West Indies (5500 meters depth) and two in the Mediterranean Sea (2700 meters depth). They are floating structures of 3,7 tons weight, 2,8 meters in diameter and 6 meters in height. These buoys transmit their data by METEOSAT.

The two buoys in the Atlantic Ocean (Brittany and Gascogne) have been replaced and a new mooring line was deployed for Gascogne. The Lion buoy in the Mediterranean Sea was checked twice for maintenance purposes. The Martinique buoy, off the French West Indies, was replaced and the aerial sensors of Guadeloupe were replaced. The Ushant huge navigation buoy was fully equipped with solar panels and moored again during the autumn.

The Atlantic moored buoys suffered from severe weather conditions with waves higher than 15 metres on December 2007, the 8th and on March 2008 the 10th. An English moored buoy recorded significant waves over 18 meters high during the storm of December 2007, which is believed to be the highest value ever recorded by a moored buoy. **12**

The PIRATA network

The Prediction and Research Moored Array in the Tropical Atlantic (PIRATA) has completed its pilot phase and has continued with 17 new surface moorings and one new subsurface ADCP mooring in 2008. Moorings preparation, data processing and evaluation are provided by the USA. Ship time for mooring maintenance is provided by Brazil, France and the USA. Cruises are staffed by American, French and Brazilian technicians. France effort is provided by IRD in collaboration with Meteo France, CNRS and IFREMER within the CORIOLIS framework.

PIRATA real-time data return for 2008 was about 80 %. PIRATA data return was unfortunately affected by vandalism (concentrated in the Gulf of Guinea) and by the cancellation of an April 2008 cruise aboard the NOAA Ship Ron Brown which should have checked moorings in the PIRATA North East Extension. Consequently, the deployment of these moorings had to be extended beyond their 12-month design lifetime.

A 2008 PIRATA cruise has been completed in March-May 2008 on Brazil's RV Antares. Another cruise took place in September 2008 on France's RV Antea. NOAA chartered RV Antea in October 2008 to replace the lost Ron Brown days.

PIRATA data contribute to research efforts, allowing to study the role of oceanic and atmospheric processes that affect regional climate variability on seasonal, inter annual and decadal time scales in the tropical Atlantic. **13**

Internal tides: from the lab to the ocean

Propagating disturbances of gravitationally-stable density stratification, also called internal waves, are ubiquitous in the Earth atmosphere and oceans. Due to the temporal and spatial scales involved, data field measurements are difficult and explicit numerical modelling is only possible for very small domain. This is why laboratory work is such an important tool to investigate the complex phenomena associated with these waves, and is particularly relevant to improve numerical models.

In the ocean, dissipation of internal tides is involved in the general circulation process. Related issues are addressed through laboratory experiments conducted by the CNRM physical simulation team, in a partnership with the Laboratoire d'Aérologie. Our goal is to estimate precisely the energy budget of internal tides generated on a seamount. One of the specificity of our work is to involve closely laboratory experiments, numerical simulation and field data. On one hand, laboratory experiments provide a valuable and detailed data set which would be impossible to be collected in the ocean. On the other hand, the numerical model Symphonie developed at Laboratoire d'Aérologie ensures the link between our laboratory work and the real ocean.

This study will improve our understanding of the thermohaline circulation. The results therefore contributes to climate research, but also more generally to the numerical modeling of atmospheric and oceanic internal waves. **14**

A new 3rd generation wave model at Meteo-France

Thanks to advances in numerical modelling and assimilation techniques associated with the use of data from many space sensors, the precision of analysis and forecasts of surface winds at global and regional scheme has been considerably improved over the last ten years. At the same time, numerous progress were made in the field of wave modelling and in the use of data from spacecraft sensors.

So far, these efforts have met satisfactorily the various civil and military requirements, even if the scores were not fully consistent with biases in the tropics for example, or for high values of significant wave height.

Important work has been made in recent years by the international scientific community to better understand and parametrize the mechanisms of wave dissipation with significant advances, thanks to efforts from SHOM and IFREMER. In the framework of the project called "Improving wave modelling" and partly founded by SHOM, this work should result in the operational implementation in early 2009 of a new 3rd generation wave model at Meteo-France (MFWAM). This new model will incorporate the new Jason-2, thus completing data in real time by the satellite radar altimeters Jason 1 and ENVISAT.

By the end of 2009, data from the ENVISAT synthetic aperture radar will also provide information about direction and period of the swell and will be used in the wave model MFWAM, thanks to work done at Meteo-France, with support from CNES and SHOM. **15**
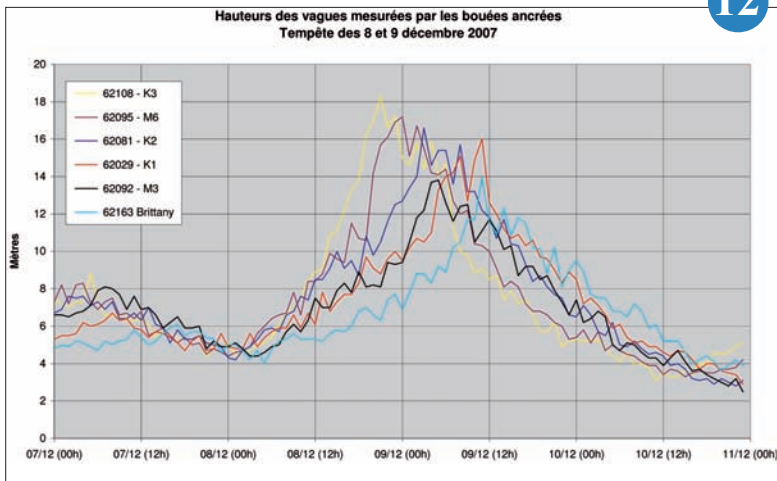
Waves height measured by moored buoys in December 2007
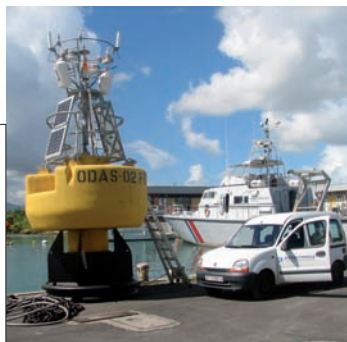
Preparation of a moored buoy in French West Indies

Mooring locations within PIRATA.
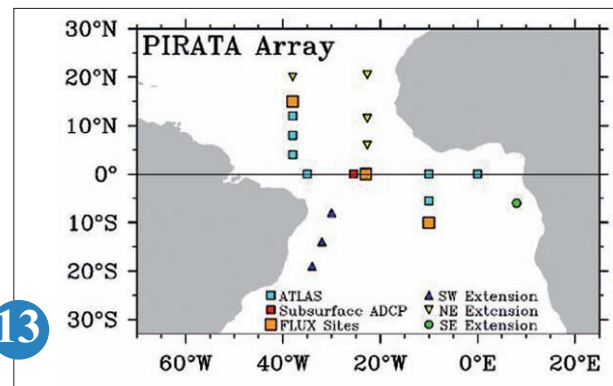
◄ Map showing the normalized mean square error for the significant wave height from the future model MFWAM over a period of one year, compared to data from Jason, Envisat and GFO altimeters.
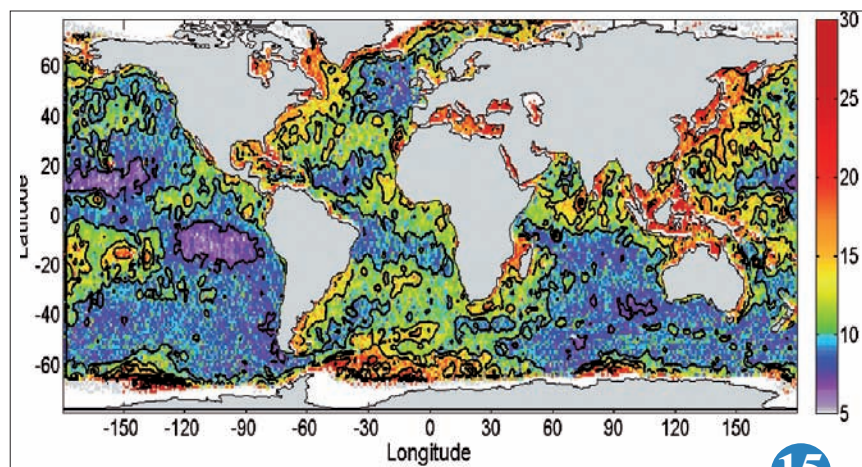
The tracks of the drifters released in the Western Mediterranean Sea, from October 10 to December 6, 2007.
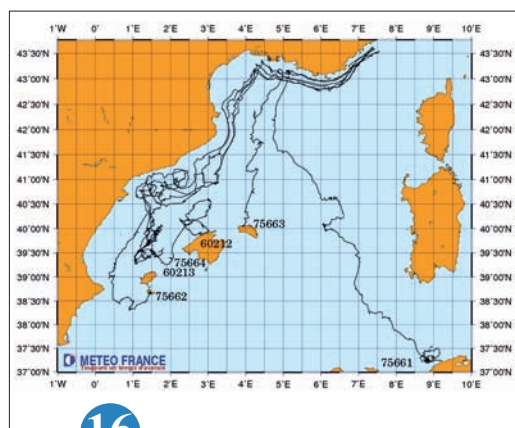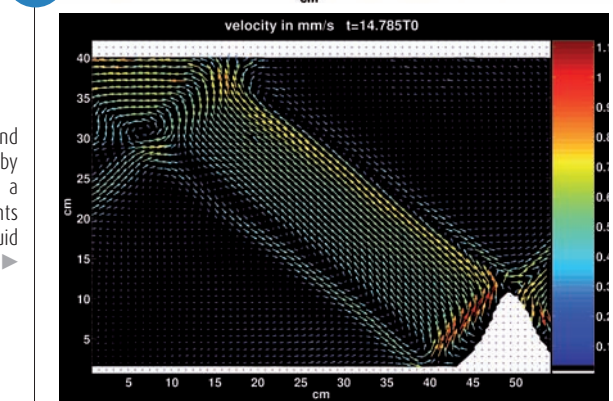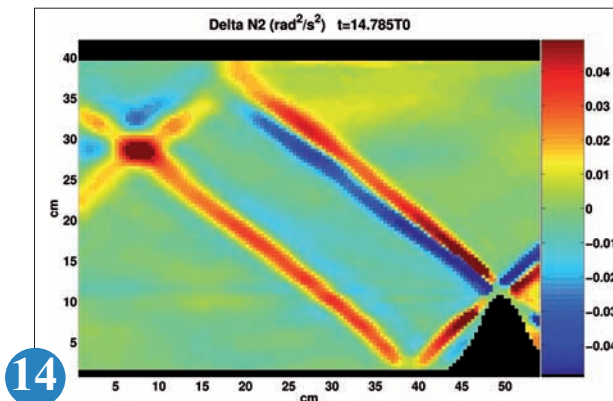
Density stratification (top) and velocity (bottom) induced by internal waves generated on a seamount in experiments conducted at the CNRM fluid mechanics laboratory. ▶

Integration of currents from operational oceanography in the Meteo-France drift model

As part of its national and international responsibilities, Meteo-France runs the drift prediction model MOTHY. It combines a simplified ocean model (calculation of the current in response to the wind) and a weathering model for oil (or object) in the marine environment. However, in areas poorly mixed, turbulent or subject to strong currents, as is the case in the Mediterranean sea, the simplicity of MOTHY does not allow it to remain efficient.

In collaboration with Mercator Ocean and Legos-CNRS, Meteo France seeks to provide an additional ocean forcing from operational oceanography systems. A preliminary study showed that a good description of ocean circulation, particularly the positioning of currents and meso-scale structures in Mercator systems, plays a decisive part on the results. It seems possible to use such a forcing in areas of strong currents in

steady state, with a fairly good level of confidence.

A PhD thesis has already started to extend this study in order to characterize the potential of operational oceanography to serve drift applications.

Atmospheric environment

Influence of aerosol on the life cycle of fog

Fog is a small scale meteorological phenomenon hard to forecast accurately. Fog is constituted of small droplets which develop inside the surface boundary layer where aerosols particles are numerous. Aerosols act as cloud condensation nuclei (CCN) on which water vapour can condensate depending on their size and chemical properties.

This study is based on the IOP13 (18-19/02/2007) of ParisFOG field experiment during which a dense fog event was observed. This fog event is associated to a polluted environment. The results from measurements allow to better understand the interactions between aerosol particles and fog droplets. These measurements are used to improve the physical parameterization of numerical weather prediction.

These data allowed us to estimate the sensitivity of aerosol activation to the cooling rate, to the concentration, and to the size and chemical properties of particles. A critical aerosol concentration (depending on the cooling rate, the aerosol size and chemical properties) has been clearly found. If the aerosol concentration exceeds this critical value, haze conditions (visibility between 1 km and 5 km) are more frequent. **17**

Evaluation exercises for the TEB model

In 2008, the TEB model (Town Energy Balance) dedicated to the surface energy balance computation in urban areas has been evaluated with the measurements of the CAPITOUL field project conducted in Toulouse between 2004 and 2005.

While the surface energy balance measurements have been used to demonstrate the importance of the anthropogenic heat release (mainly domestic heating) during winter in urban areas, they also have been used to evaluate the ability of TEB to reproduce this term during the autumn and winter periods. The domestic heating, which strongly depends on weather conditions, is parameterized in TEB and had never been evaluated before. The results are very satisfying for a first evaluation, since the model is able to reproduce the term by 5% during the autumn and 25 % during winter.

Then, an inter comparison model has been led for the infrared fluxes computation. Five models from ONERA, ECN, CESBIO, CERMA and CNRM have been compared, firstly, on two idealized urban canyons built from the CAPITOUL measurements and secondly, over the neighbourhood of the measurement site. TEB was competitive at both scales. For the computation of infrared fluxes, the difference between TEB and the most complete model from ONERA is lower than 5 %.

Works on heat releases associated with domestic heating will be undertaken by CNRM to improve computations. We will also take into account releases associated with air conditioning which have significant consequences during heat waves. **18**

Continuation of development in fog forecasting on airports

Prediction of fog banks or low-level clouds is very important for airport platforms, as low visibility conditions affect landing and take-off frequency. The COBEL-ISBA system (developed in cooperation with the "Laboratoire d'Aérologie") is a unidimensional numerical model for boundary layer. It provides 8 hours forecasts and is fully operational at Paris Charles De Gaulle since 2005 and at Lyon St-Exupéry since October 2008. The model is as well currently being under validation at Paris Orly.

Processing initial conditions is an essential part of fog prediction. This is why COBEL-ISBA takes into account data provided by a specific local observation system in its data assimilation system. The optimization of this system represents a fundamental area of research in order to improve the COBEL-ISBA performances. A new assimilation algorithm (Ensemble Kalman filter) has been set up. It improves significantly the quality of fog prediction, as much for fog installation (see figure) or dissipation.

Another issue is that the cost of dedicated local observation system installed in the three French main airports doesn't make possible to consider using this system in its current configuration on mid size airports. Preliminary tests have shown a satisfying behaviour for Kalman filter on a reduced set of local observations. **19**

Coupling Mothy and Perle for effluents dispersion study

In the event of a marine accident of a tanker, the gases possibly emitted from the ship or from the floating spill of product poured at sea can present risks for the rescue teams and the coastal populations. Within the framework of the GALERNE project funded by ANR, Météo-France studied the dispersion of the gas phase effluents in "remote" field, from a few and up to a hundred kilometres downwind from the disaster.

The models MOTHY (marine spill drift) and PERLE (atmospheric dispersion) were coupled to examine the dispersion of gas evaporating from drifting floating spills. The resulting system was used to assess the impact of a ficti-

tious accident causing the release of 2500 t of xylene in the Channel. Two releases were considered, a rapid one over 15 min and a longer one, over 24 h, under different meteorological and oceanographic conditions. Simulations indicate that the pollutant should not drift at sea over a distance of more than 10 km from the tanker before its evaporation from the marine environment and that the levels of concentration induced in the atmosphere should remain lower than the threshold of reversible effect estimated by INERIS.

Simulations with PERLE were also carried out to assess the consequences of a direct release from the ship into the atmosphere of

3600 t of ammonia. Potentially serious health effects were identified. For example, in a weather situation inducing stagnation of the pollutant, the ERPG threshold of level 3 is exceeded during 3 h as far as 30 km from the ship; the ERPG-3 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects. **20**

▲ Experimental deployment of aerosol and droplets observations.
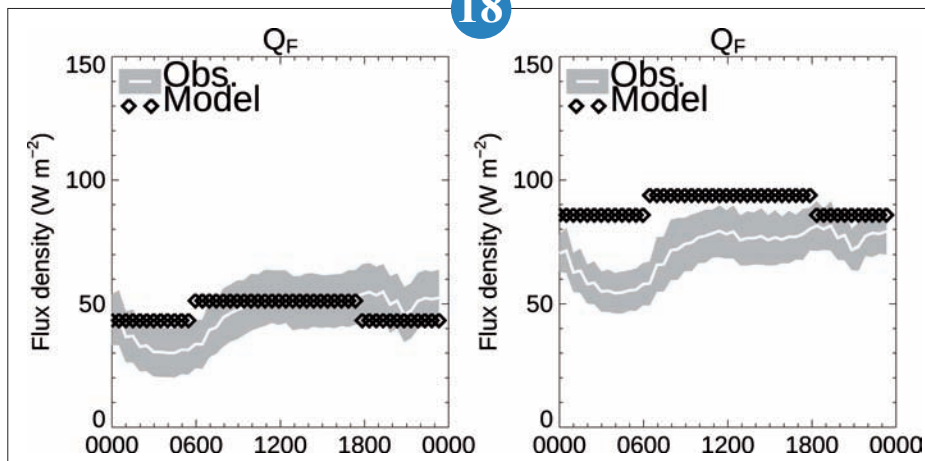
▲ Mean daily cycle of anthropogenic heat releases (QF) observed at the measurements site of the CAPITOUL campaign (white line and standard deviation in grey) and reproduced by the TEB model (black diamonds) during fall (left) and winter (right).
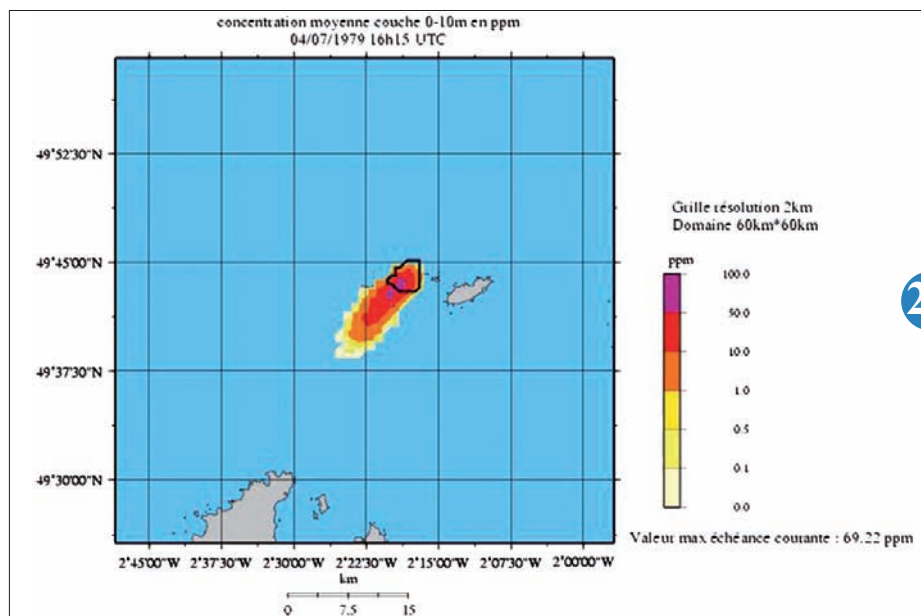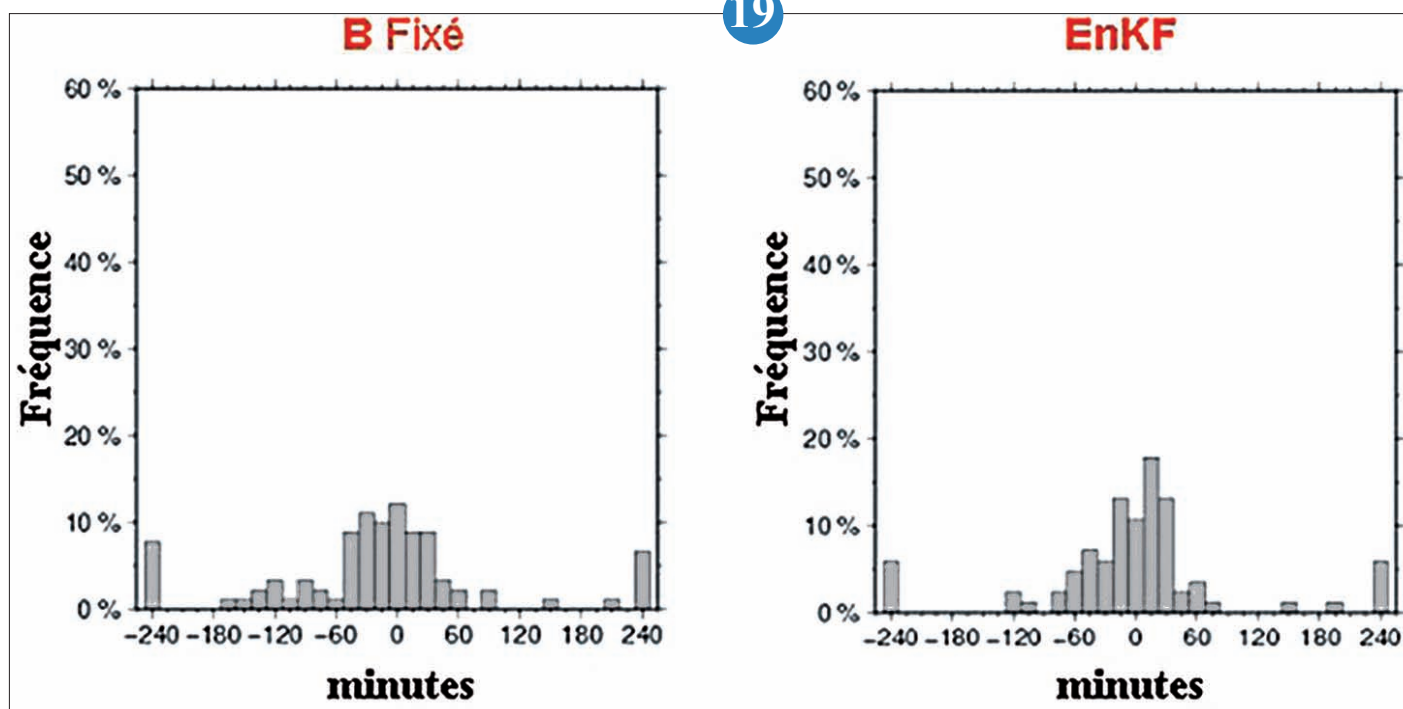
▲ Error (in minutes) on the forecast of the onset time of fog, over the 15 days of the FOG case; operational assimilation scheme on the left, modified on the right. A negative error indicates that the onset was forecast too early.

◄ MOTHY-PERLE coupled simulation on a fictitious release of 2500 t of xylene over 15 min. The black line delimits the edges of the spill of pollutant at the sea surface 1 h 15 after the beginning of the release ; colours indicate the levels of concentration of the gas phase pollutant in the atmosphere.

Atmospheric chemistry and air quality

Coupling between MOCAGE and IFS within the GEMS project

One of the main objectives of the GEMS FP6 project is to create a European operational system for the global monitoring and forecasting of atmospheric chemistry, including greenhouse gases, reactive gases and aerosols, that takes benefit from the assimilation of remote-sensing chemical observations.

The current ECMWF's meteorological NWP suite IFS is able to take in account for the transport of chemical tracers and to assimilate satellite observations of key species (CO, O3, NO2…). However, it does not contain the parameterizations that represent the other processes governing atmospheric composition (reactions, emission, deposition).

A first practical approach to extend IFS capabilities was to link it to existing dedicated CTMs. In the coupled system, IFS sends meteorological data to CTM while CTM provides tracers source and sink terms to IFS. The synchronization of the two parallel running models and the data exchanges are managed by the software OASIS4 from CERFACS.

The CTM MOCAGE has been coupled to IFS and the coupled system run for several test periods. Operational use of the system is however not at hand due to the computational burden involved and the lack of efficiency of MOCAGE on ECMWF's computer. Nevertheless, using a lighter CTM, the practicality of the approach has been demonstrated, as well as was highlighted the benefit of the assimilation of satellite chemical data.

The MACC FP7 project starting in June 2009 will further develop the results of GEMS, with the objective to lead to operational GMES atmospheric services (2012 and later on). Further refinements to the system will be tested, particularly by implementing the chemical modules of the CTMs (including those of MOCAGE) in the IFS, for possibly optimal consistency between tracers and dynamics and more efficient execution. **21**

Assimilation of IASI CO columns in MOCAGE-PALM

With a lifetime spanning from a few weeks to a few months, carbon monoxide (CO) is an excellent tracer of pollution at large scale. Biomass burning and human activities, both characterized by incomplete combustion processes, are the main sources of CO worldwide. Moreover, the chemical reaction of CO with OH yields ozone, which is one of the principal pollutants in the troposphere impacting human health.

Since 2000, the MOPITT instrument onboard the Terra satellite measures CO profiles and gives information on the vertical in the troposphere. Since the beginning of 2008, CO total column data from the IASI instrument onboard the MetOp platform have become available from EUMETSAT. The satellite covers the Earth twice a day. We studied the impact of these columns on the 3D distributions of CO, using assimilation techniques and the MOCAGE-PALM 3d-FGAT system. The vertical profiles obtained after assimilation of IASI CO columns are evaluated against MOPITT CO profiles, whose quality has already been assessed by comparison with independent in situ data.

The main conclusion of this study is that the assimilation of CO total columns from IASI shows its capability to constrain a global chemical transport model for reproducing the different structures associated with intercontinental transport of pollution. The assimilation, combining columns observations and model information, allows us to constrain the vertical structure of CO distributions. This is of prime interest because MetOP/IASI is operational, which guaranties real-time availability and a continuity of measurements over the next decade. Our work is now focused on quantifying the information brought in the lower tropospheric layers. **22**

GEMS: systematic evaluation of air quality forecasts over Europe

In 2008, the FP6 project GEMS reached pre-operational status for the forecast of Air Quality over Europe. Daily, the 72 h forecasts of 10 institutes are centralized and are provided to users on Internet (http://gems.ecmwf.int); they serve also as a basis to compute air quality ensemble forecast products, a world first to our knowledge.

Memoranda of Understanding have been signed between GEMS and about fifteen European countries, in order to be granted access in near-real time to hourly observations (not validated) for key pollutants: ozone, PM10, nitrogen oxides, sulfur dioxide and carbon monoxide. As illustrated, measurements for more than 1000 sites are obtained daily; this database is without equivalent to carry out analyzes and to evaluate air quality forecasts at the scale of Europe, similarly to what we have been doing for several years over France with our partners of Prév' Air.

The verification diagnostics of air quality forecasts are systematically computed by ECMWF, allowing end-users to evaluate on a daily basis the quality of the individual forecasts and of the ensemble products, as a function of time, of the different pollutants, or of the forecast valid dates. As an illustration for skill scores, we present here the root mean square error parameter for the forecast of surface ozone during the autumn of 2008; our model MOCAGE obtains among the best scores. Contrarily to results in weather forecasting, the quality of the forecasts little depends on the valid dates and much more on the hour in the day, reflecting the origin of main uncertainties affecting current air quality models (turbulence, emissions,…).

These forecasts and their systematic evaluation will be continued until the end of 2011 in the framework of the FP7 project MACC, which will succeed GEMS at the beginning of June 2009. **23**

CO (ppb)

Niveau/Level : surface   Date : 10/06/2004
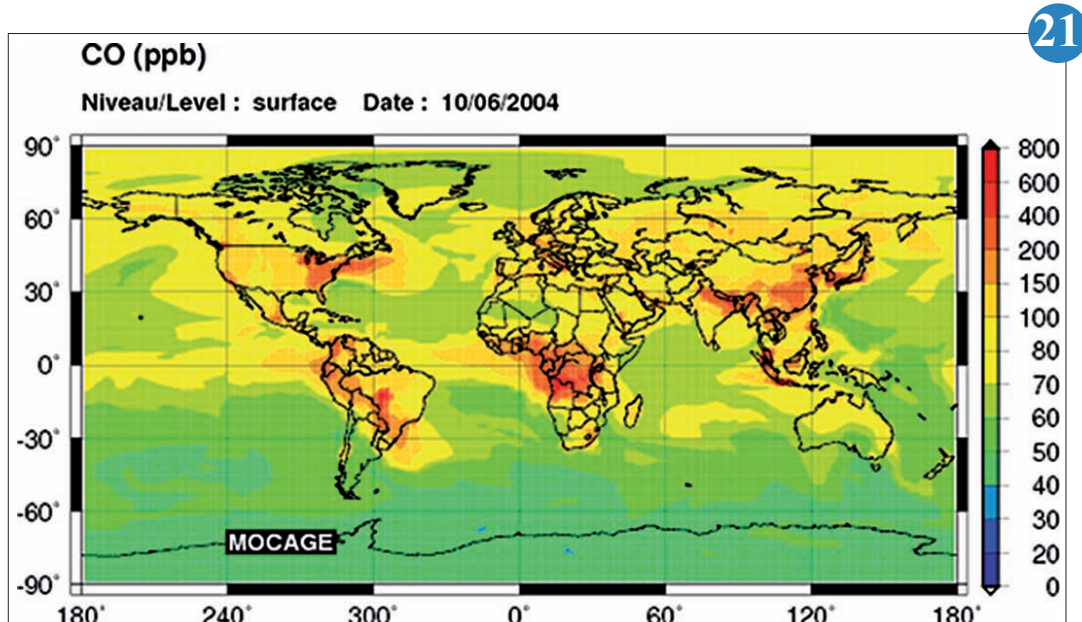
◀ Daily averaged surface CO concentration on the 10th of June 2004 obtained with the coupled IFS-MOCAGE system.

MOCAGE–PALM ASSIMILATION CO IASI, Avril 2008 – Valeurs de jour (x 1E18 molec./cm2)
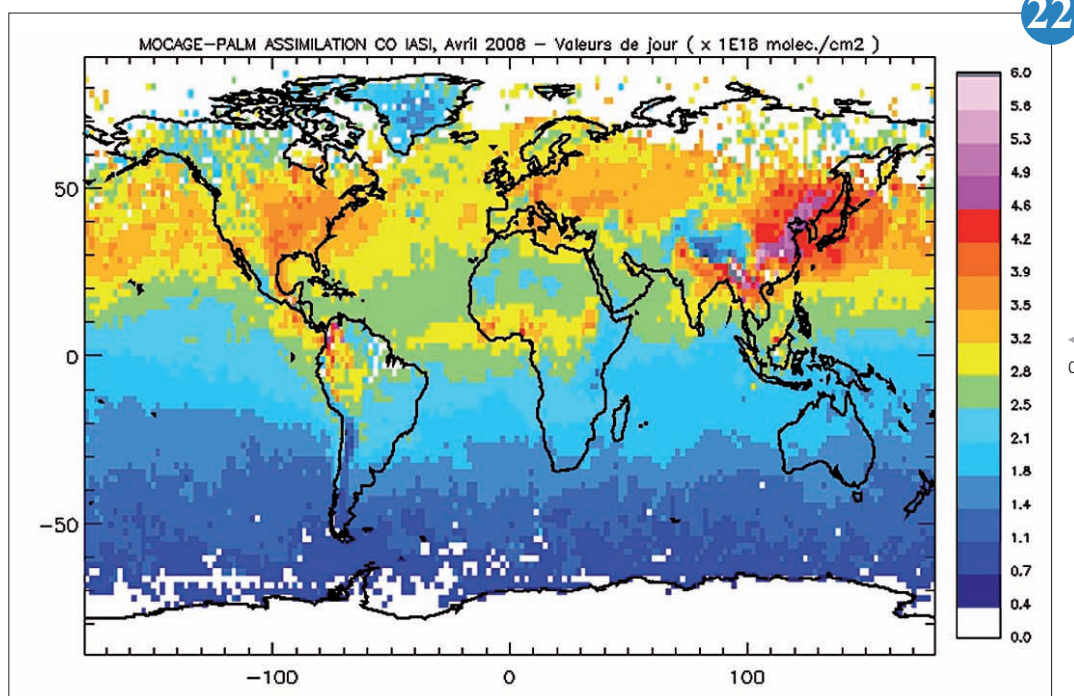
◀ Monthly average for April 2008 of IASI CO columns analysed in MOCAGE-PALM

Figure a : Observations of nitrogen dioxide at the surface for 25/12/2008 06 00 UTC (data not validated).

Figure b : Root mean square error of the European-scale surface ozone forecasts as a function of forecast valid dates, for the autumn of 2008 and all models involved in GEMS. Results for the model of Meteo-France, MOCAGE, are plotted in purple.

▼

GEMS-RAQ Observations VT: Thursday 25 December 2008 06UTC
Surface Nitrogen Dioxide [µg/m3]   N: 1019 mean: 17.7 max: 162.3

GEMS-RAQ Verification
Surface Ozone [µg/m3]
Root mean square error forecast
Europe
Date: 20080818 00UTC to 20081116 00UTC

CHIMERE
BOLCHEM
CAC
EMEP
MOCAGE
MOZART/IFS
MM5-CAMx
EURAD-IM
MATCH
ENSEMBLE MEDIAN
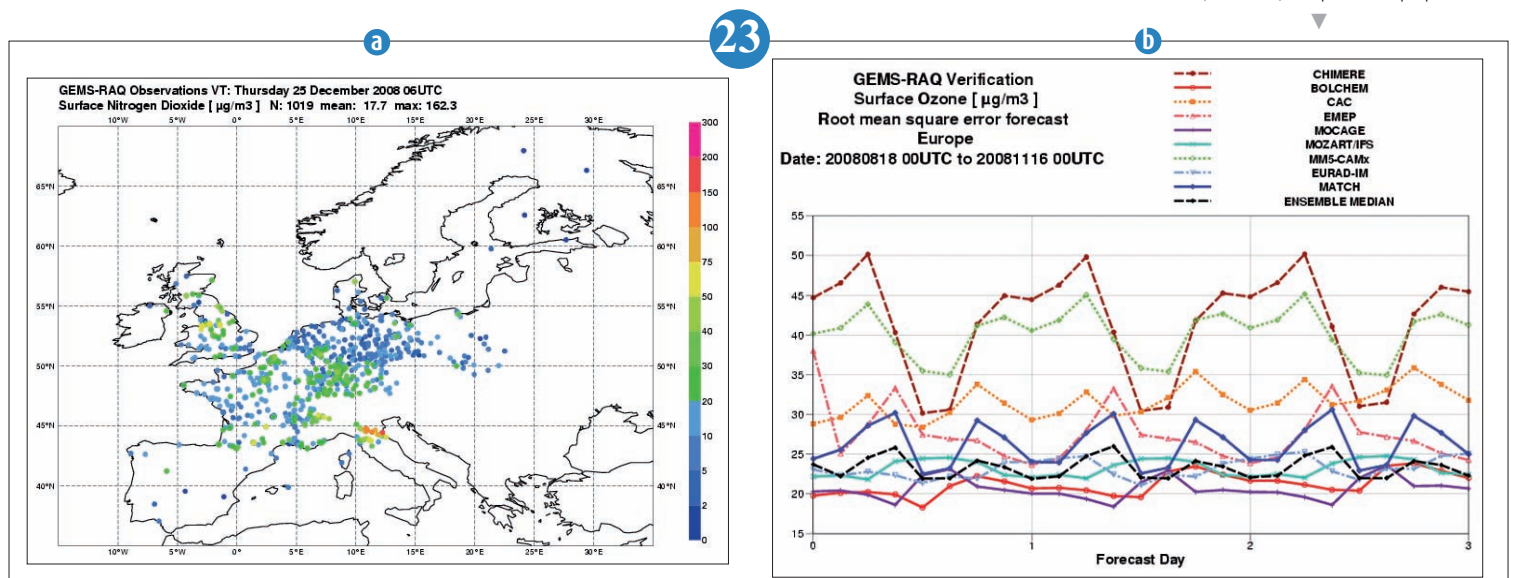
Snow cover and avalanches study

Discrete curvature for grain segmentation and application to tomographic snow images

Deposited snow on the ground consists in ice grains that have been welded by thermodynamical and mechanical constraints. Analyzing the snow microstructure and understanding its formation and its time evolution often requires to numerically separate ice grains. Conventional three-dimensional imaging methods do not provide any direct information on the boundaries between grains. To obtain an accurate segmentation, we developed a geometrical method that is based on the detection of concavities on the ice surface.

On a three-dimensional image, it is possible to compute, for each point of the surface, the Gaussian and mean curvatures, which, when combined, provide the sign of the smallest principal curvature (figure a). Then, the surface of the object can be split into two regions: a positive and a negative one. By using a Voronoi diagram, the regions are extended to the whole object. The volume elements of the negative region are then removed-to provide a set of disconnected objects.

These objects are then used as seeds for a second Voronoi diagram, giving the desired segmentation. This curvature-driven grain segmentation algorithm has been tested on granular-shaped snow images obtained by absorption tomography.

In order to validate the results, we used Diffraction Contrast Tomography (DCT), a technique recently developed to map individual grains in a material sample : as each snow grain has a particular crystalline orientation, this diffraction-based method is able to locate individual grains precisely. Results are presented in figures [b] and [c]. **24**

Developments and new analyses for the Seismic Detection of natural Avalanches (SDA)

Three stations for Seismic Detection of natural Avalanches (SDA), developed by the Centre d'Etudes de la Neige (CEN), have been used experimentally for several winters in Isère. Each station records seismic signals and identifies those which were generated by avalanches, thus providing objective information on the avalanche activity of the local mountainous area.

In 2008, new developments were made for the SDA system, involving notably installation and testing of a WiFi-ADSL transmission for the Ornon station and the implementation of an additional module for the analysis and identification signals.

The Wifi-ADSL transmission involves a WiFi-transmission between the SDA station isolated in altitude and a point of connection of the network in the valley, to retreive at CEN, almost in real-time, all the signals for analysis. This mode of transmission opens the way for more complex analyses and for more ergonomic presentations of data; but it can also facilitate some remotely operations of management and maintenances.

In order to better identify the signals associated with avalanches or to remove those who have other origins, we have developed new analyses that are based on the recognition of shapes in the Time-Frequency-Representation. These analyses turn on the automatic detection of narrow energy bands in filtered images, that are based on chanfrein distances and deducted from the time-frequency analyses. These narrow bands of energy can have very variable frequency and shapes, but they are characteristic of some non-avalanche signals. The application of this new module can reduce some false detections, generated, for example, by helicopters or civil engineering. **25**

Quebec snowpack simulation with the snow models CROCUS, SNOWPACK and SNTHERM

For high latitudes, the global warming is enhanced by the positive feedback due to the snow covered surface area changes. Hence, Sherbrooke University (Canada), the Laboratoire de Glaciologie et Géophysique de l'Environnement (LGGE, France) and the Centre d'Etudes de la Neige work together in order to improve the cryosphere observation using remote sensing from satellites.

Remote sensing in microwaves domain is a powerful tool for snowpack observation because the microwave emission is very sensitive to snowpack characteristics. This is why the researchers aim to couple a thermodynamic snowpack model with a microwave emission model in order to inverse the observed signal. This work began with the comparison of the results of three sophisticated snow models (Sntherm, Snowpack and Crocus) for the observation site of Sherbrooke University. The comparison (see figure) shows that the three models (fed with in-situ meteorological observation data) give results of a similar quality. For Crocus, it is ascertained that the prescribed soil/snow energy flux is not well adapted to the very cold snowpacks typical of Sherbrooke. A better simulation was performed by the coupled model Isba/Crocus, which explicitly simulates the snow-soil energy exchanges. The site snowpack was also simulated using Crocus fed with the NARR (North American Regional Reanalysis) data.

Good preliminary results show that the snowpack simulation could easily be extended to the whole northern Canada. In a second step, the research teams will work on the coupling of a snow model and a microwave model. **26**
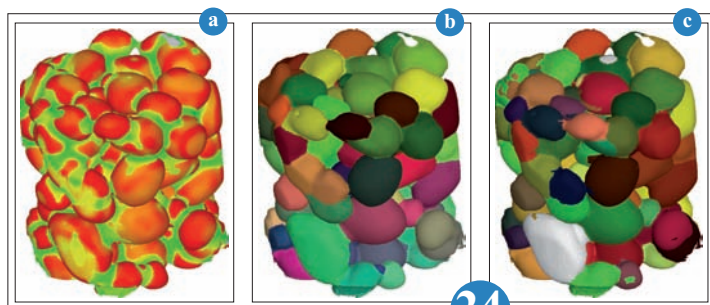
[a] Map of the smallest principal curvature for a snow sample obtained by X-ray absorption tomography: green colour corresponds to zones where the smallest curvature is negative (concavities are present, at least in some directions) while red corresponds to positive zones (no concavities).

[b] Segmentation of a snow sample obtained by X-ray absorption tomography: results after applying our curvature-driven grain segmentation algorithm (to each colour corresponds a single grain).

[c] Segmentation of the same sample, but obtained by Diffraction Contrast Tomography.
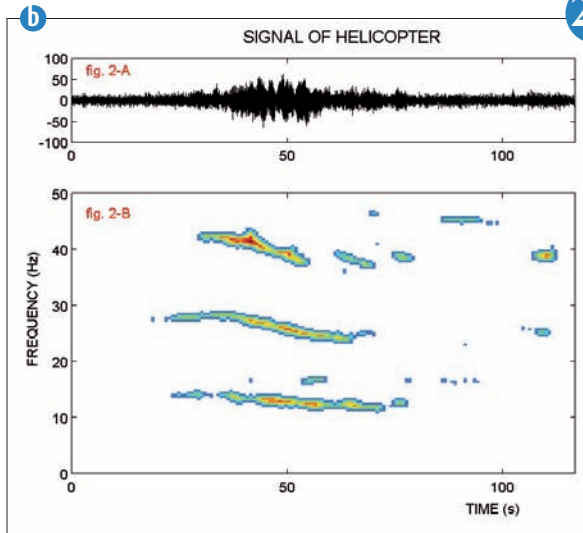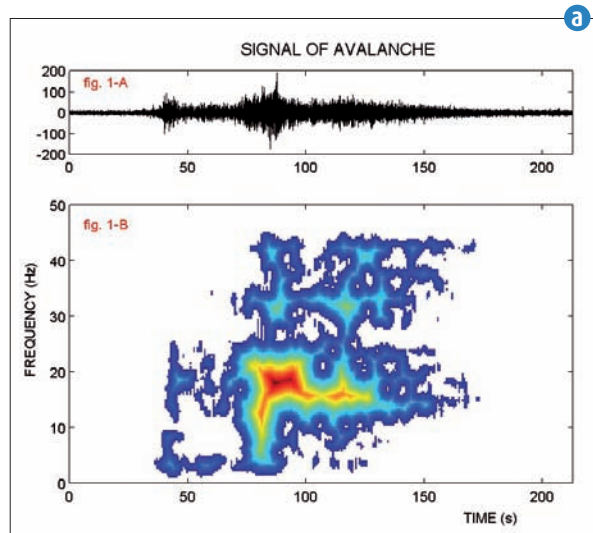
◄ Signal and chanfrein image for 2 seismic signals generated respectively by an avalanche (**fig.a**) and by a helicopter (**fig.b**).

Snow water equivalent observed (triangles) and simulated (curves) by different snow models for the winter 2004/05 for measures from the site of Sherbrooke University (Quebec). "ISBA-CROCUS" corresponds to the coupled model ISBA-CROCUS, "CROCUS NARR" to the Crocus model fed with the NARR data. ▼
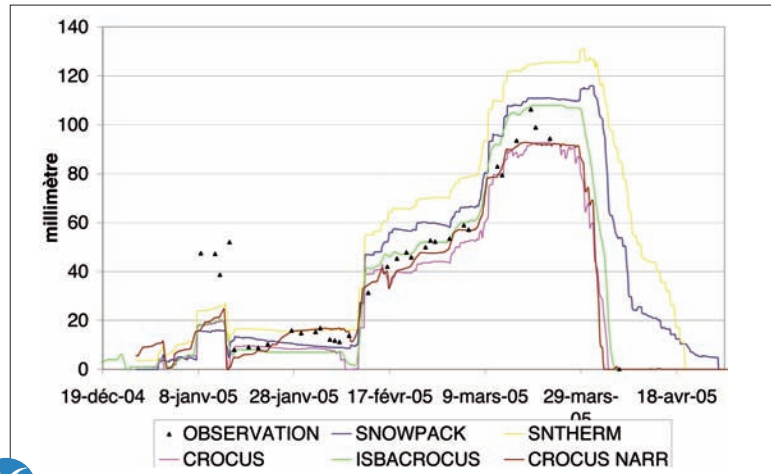
Figure a : The studied glacier is located on the North-West side of the Antizana. The first meteorological station is installed at 4 850 meters high, on the moraine, the second station is installed at 4 900 meters high, on the glacier ablation area.

Figure b : In close collaboration with Ecuadorian partners, a field trip was carried out in March and April 2008 in order to collect new data to refine our knowledge of the local environment.

Snowpack evolution study over high-altitude tropical area (Antizana, Ecuador), over glaciered and non-glaciered surface

In tropical Andes, glaciers are very important for water supply of big metropolis such as Quito and La Paz.

The French Investigation and Development Institute (IRD) recently increased its environment observation. Data collected, thanks to two meteorological stations installed on the Antizana volcano in Ecuador, were studied, applying Meteo-France snowpack numerical simulation tools (CROCUS, CROCUS-ISBA). They turned out to be useful to understand the processes involved in the snow evolution in tropical area (low seasonality).

Over the glacier, albedo is the key-parameter. Melting is faster when ice appears on the surface. A good representation of recent snow albedo evolution and a correct calibration of ice albedo are essential criteria to have good simulations.

Over the moraine, snow layers are thin and ephemeral. With the high solar radiation at these latitudes, and the low albedo of these surfaces, the ground stores a lot of heat. It is restored to the snowpack base, and then, by horizontal transfers, from the snowy surfaces to the not snowy surfaces. Thus, the result is a very fast melting .

This study completes current works over the Zongo volcano in Bolivia, where modelisation is spatialized over the whole catchment, in order to simulate the hydrological reaction of melting glaciers. 27

Instrumentation for Research

2008 was a very busy year for the SAFIRE team : besides Polarcat campaign within IPY, Flysafe and Carols were also two major operations. For in situ measurements, the first results for sodar validation in Roissy are to be emphasized.

Aircraft instrumentation

Participation of the ATR42 at the Flysafe campaigns

Meteo-France, member of the FLYSAFE program (http://www.eu-flysafe.org/Project.html) has been selected to perform part of the test flights. The ATR42 flew 80 hours in February and August 2008. The ATR is the property of Meteo-France and is jointly operated by CNRS, Meteo-France and CNES, under the name "SAFIRE" (French Group of Aircraft Equipped for Environmental Research).

The objective of the February campaign was to study icing events. The aircraft was equipped with an ice detector and a set of cloud microphysics instruments (droplets and ice crystals). Despite one of the most beautiful month of February for decades, the aircraft flew only 40 hours but gave precious information about icing conditions around Paris and the west of Europe.

The August 2008 campaign was dedicated to the study of thunderstorms. In addition to the core aircraft instrumentation, data from on-board weather radar were recorded (radar used by the pilots) in order to compare onboard information with real conditions encountered by the aircraft and ground information (weather radars or satellite images). For safety reasons, the aircraft flew very near, but never into thunderstorms.

All the recorded data are currently processed by the Flysafe partners and will be used to validate new tools (new radars and pilot's information interfaces) in order to increase air safety. ①

CAROLS campaign: airborne measurements of soil moisture and ocean salinity

The purpose of the CAROLS flights is to validate the namesake instrument, a passive radiometer, and the related algorithms, which measure the soil moisture as well as the ocean salinity. An equivalent radiometer (with synthetic aperture antenna) will equip the SMOS satellite which will be launched in 2009. Tests are currently underway with a view to validate future satellite measures. The first tests were made at the end of 2007 on Meteo-France ATR42 followed by a 15 days campaign in October 2008 by the same aircraft.

The following instruments were onboard half of the CAROLS flights: CAROLS radiometer and RASTA radar. The complementary measures of the radar give information about the sea surface: wind and waves height.

Two flights were made to test a new radiometer concept, called CAROLS-2. CAROLS-2 has the particularity to receive the signal very close to the radiometer. This installation prevents from using a thermo-regulated signal guide which is often at the origin of parasite noise. Meteo-France CEO, P-E Bisch, participated at one of these two flights in November 2008, following in real time, the scientific work onboard.

The test campaign has been very useful to improve and develop instruments. The SAFIRE and CETP (in charge of CAROLS instrument) teams are now ready for the next phase in 2010, when the first comparisons with satellite data will be made. ②

EUFAR makes the sky accessible to all researchers

EUFAR is the European network of operators of airborne facilities for research in environmental and Geo-sciences. EUFAR is supported by the European Commission with an allocation of 8 M€ over the next 4 years (2009-2012) to provide researchers with access to the best airborne facilities they need for their field projects, regardless of where the facility is operated in Europe. Building on 8 years of collaboration in airborne research and providing a central portal to European resources, EUFAR facilitates access to a large and diverse aircraft fleet and a range of state-of-the-art airborne instruments, fosters a culture of cooperation between aircraft operators and experts in airborne measurements for exchange of knowledge, standards and good practice, collects information on activities, scientific impact and user needs for an integrated approach to infrastructure developments and promotes tutoring of young scientists by experienced researchers.

With 33 partners, EUFAR combines nine networking activities, transnational access to 25 installations and three joint research activities.

National fragmentation of infrastructure operators has significantly hindered the use and development of airborne infrastructures for research in Europe. By subsidizing transnational access and providing training courses to young scientists, EUFAR progressively develops a broader community of experienced users.

EUFAR's biggest current challenge is the construction of a heavy-payload and long endurance aircraft for research in the troposphere (COPAL), that has recently been selected in the ESFRI roadmap for a Preparatory Phase. Since 2000, EUFAR is coordinated by Meteo-France (CNRM/GMEI). ③

1

◄ The ATR42 and its under-wing pylons, equipped with cloud microphysics instruments.

2

◄ The SAFIRE team installing the CAROLS rear antenna into the opening below the ATR42 fuselage. (On the picture : Michel Cluzeau, technician of the instrumentation team).

3

◄ The ATR42 operated by SAFIRE flying over the Pyrénées.

EUF**R**
**European Facility
For Airborne
Research**

CO**P**AL
European Community Airborne Laboratory

On site instrumentation - remote sensing

Introduction and exploitation of Doppler capabilities in the French radar network

At the end of 2008, nearly all radars of the French network are Doppler. The remaining three (Plabennec, Bordeaux and Grèzes) should be equipped at the beginning of 2009. Two articles were dedicated to an innovative technique (the so-called "staggered Triple Pulse Repetition Time" scheme) that was patented and implemented on all radars. With this technique, it is possible to collect at the same time reflectivity and radial velocity measurements up to a range of 250 km with no ambiguity.

In the framework of the FLYSAFE European project, a real-time demonstrator combining radial velocity measurements from 5 radars over the Paris area (Trappes, Arcis, Falaise, Abbeville, Bourges) was used to produce three-dimensional reflectivity and wind fields every 15 minutes at a horizontal resolution of 2.5 km. This innovation was granted in 2008 by the WMO Vilho Vaisala award. The method is currently being extended to the whole country and results should be available operationally in 2010. These reflectivity and wind fields are very useful for nowcasting (particularly for aviation) and for mesoscale numerical model verification (AROME for instance). Information from Doppler weather radars can directly be used to detect wind shear if not too far away from radars. For example, in August 2008, the Hautmont tornado occurred close enough to the radar of Avesnes and its signature could be observed on the radial velocity images (see figure).

Efforts should be continued to improve the quality of the high resolution Doppler measurements and to elaborate a robust algorithm to detect windshears in real time. **4**

The polarimetric upgrade of the operational French radar network

In 2008, the modernisation of the French network was carried on with the replacement of the old S-band Nîmes radar by a new S-band polarimetric radar, and with two C-band radars with dual-polarisation (Momuy and Montclar in the South-West of France).

This effort will be continued over the next two years with the replacement of the C-band radar in Abbeville by a new polarimetric one (still C-band) and three more existing C-band radars will be equipped with dual-polarisation (Cherves, Blaisy and Avesnes). At the same time, new polarimetric algorithms were finalised and tested using data from the Trappes radar in the framework of the FLYSAFE European project. These algorithms enable the monitoring of the quality of polarimetric data, the correction for attenuation by precipitation and the rejection of non meteorological echoes. They will be ready to be used in operations by the end of 2009. Studies were carried on in 2008 on the identification of the types of hydrometeors (particularly hail) and on the estimation of the rainfall rate from polarimetric data (tests with the ZZDR algorithm from Reading University and with ZPHI algorithm from the private company NOVIMET).

Over the 12 rainy events observed with the Trappes radar in 2005, the ZZDR and the ZPHI algorithms relying only on polarimetric radar data gave better results, compared to rain gauges, than the conventional rain accumulation product (which includes an hourly adjustment with rain gauges). **5**

UHF and VHF radars in the future ground-based automatic systems for upper-air measurements of basic parameters

During the last years, numerous studies were conducted in order to define a completely automated operational measurement of basic atmospheric parameters (wind, temperature, humidity, clouds). Among the investigated techniques, ground-based remote-sensing instruments such as wind profilers, lidars, hyperfrequency radars, radiometers and GPS stations appeared as the most promising tools.

For cloud measurements (water content, cloud base and top), an efficient combination has already been obtained between lidars, millimetric radars and satellites. The CLOUD-NET international project constitutes a good example of this synergy.

UHF and VHF profilers are able to detect the layers associated with stronger refractive index gradient from the maxima of radar echoes. These elements can be directly assimilated into numerical weather prediction models to improve the heights of inversion in the lower troposphere, or used as an additional element for fine-tuning radiometer measurements. Moreover, the humidity information included in the clear-air radar echoes can be used to extract humidity profiles, providing the temperature profile and a humidity reference point are known.

Wind profilers can also determine the temperature profiles, not only with the RASS (Radio Acoustic Sounding System for virtual temperature), but also from the radar echo at levels where humidity is negligible (higher troposphere and above) and more generally from vertical wind variations. In these two cases, a temperature reference point is required in altitude.

The COST ES0702 European Action will help to coordinate the developments of these techniques in order to define cost effective operational applications for future meteorological needs. **6**

4
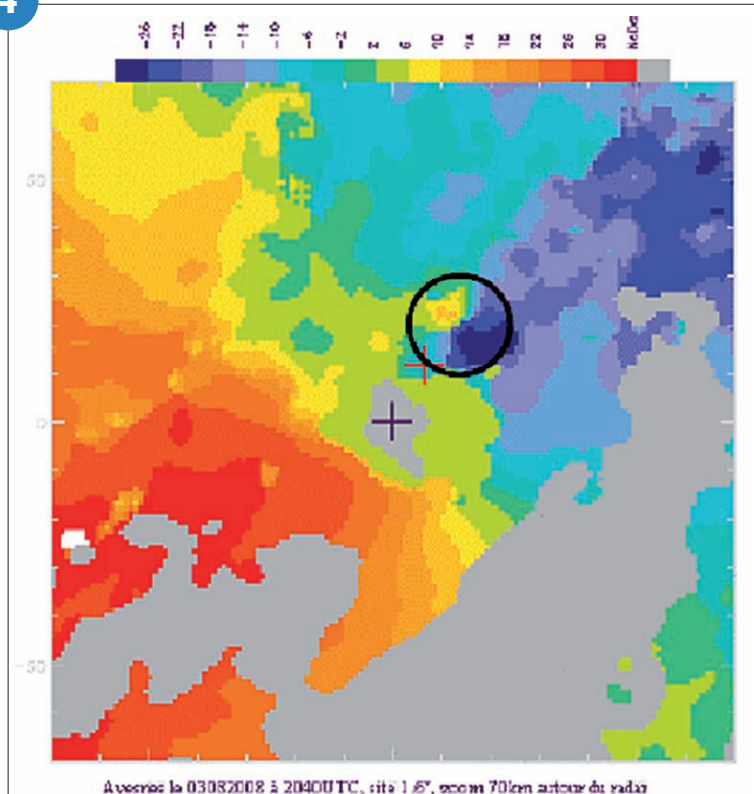
◄ Radial velocity image from the Avesnes radar at 20.40 UTC on the 3rd of August 2008 at an elevation of 1.6°. The image is 140 km by 140 km, its resolution is 1 km². The radial velocity has been filtered (median filter of 5 by 5 km²). The black cross corresponds to the radar, the red cross corresponds to the city of Hautmont. The velocity scale ranges from –30 m/s (dark blue, negative away from the radar) to +30 m/s (red, positive towards the radar). We can clearly see a positive/negative dipole that corresponds to the cyclonic rotation in the tornado.

Hourly comparison between rain gauges and the results of the polarimetric algorithms over 12 rainy events in 2005. Scales are logarithmic. The radar estimates are from left to right: the conventional QPE including an hourly adjustment with rain gauges, the ZZDR algorithm (based on radar data only) and the ZPHI algorithm (also based on radar data only). On the figure, we also represented the values of the correlation coefficient and of the normalised bias (-0.19 stands for an under-estimation of 19 %) for all rain rates and for rain rates over 1 mm/h. ▼

5

Conventional estimator Gauge-adjusted

ZZDR with attenuation correction

ZPHI® (attenuation + N0* adjustment)
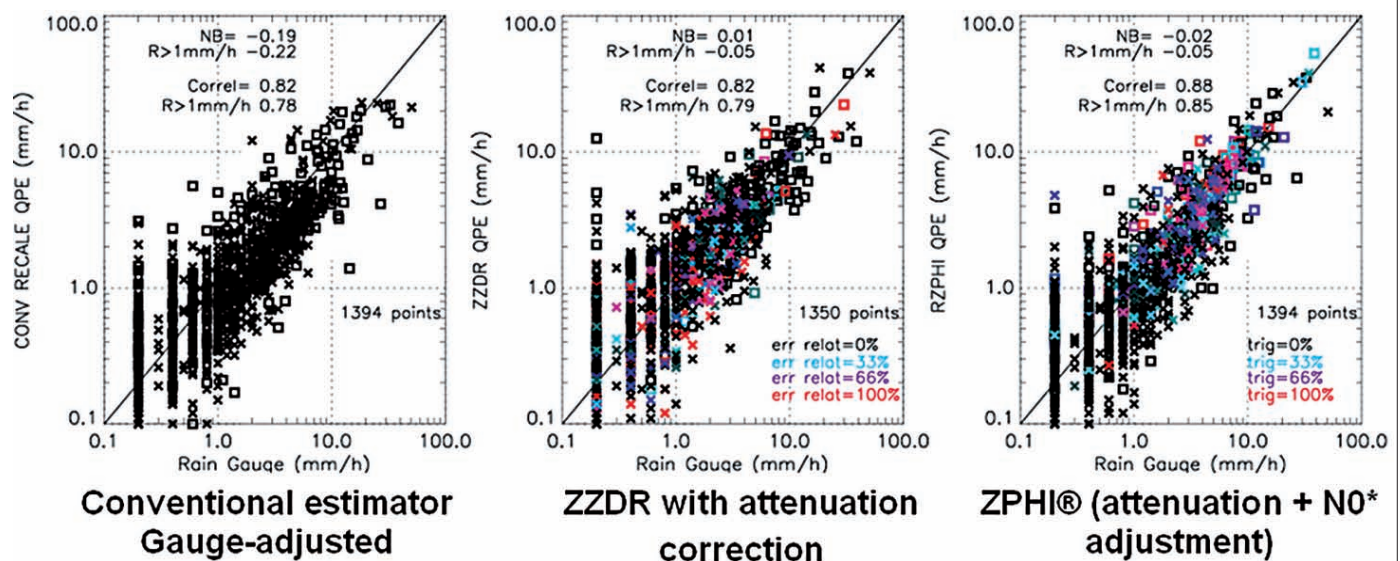
6
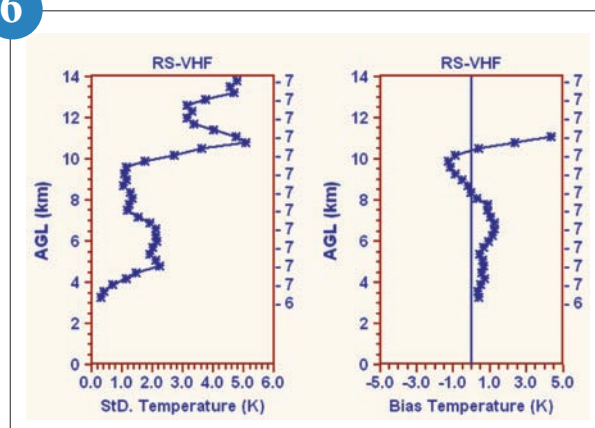
◄ Standard deviation (left) and bias (right) between temperature profiles provided respectively by radiosonde (RS) and VHF radar (VHF) using the vertical wind spectrum method at various range gates. The columns at the right of the figures indicate the number of comparisons used for the statistics.

Wind heterogeneousness characterization on the Thau lagoon

The IFREMER lab in Sète and CNRM set up a field campaign for wind measurement on the Thau lagoon with a view to better characterize wind events which are favourable to the development of toxics algae. These pollutions occur when winds are weak and harmful to the shellfish activities.

Until now, only wind data measured in the Sète semaphore were used. The instrumentation consisted of three automatic stations measuring wind, temperature and relative humidity. Among these stations, two were directly set on the water surface on structures specially designed to make water temperature measurements.

These stations have been working continuously since April and their data made it possible to spot two zones in the Thau lagoon. The dataset has already allowed to characterize the differences between two zones of the Thau lagoon. It is in the first one, called the Crique de l'Angle, that occurs most of the pollution, the second one is more central and opened.

The field campaign will continue in 2009 and the instrumentation and dataset will constitute a base for the evaluation of scintillometry technique for sensible heat fluxes measurement on liquid surfaces. (7)

Observation of fog at Roissy CDG airport

In the framework of Meteo-France Fog program, CNRM started a research action aimed at improving the observation of fog on airports. A first analysis of the potential of remote sensors led to the selection of the sodar technique (acoustic remote sensing) for its alleged capacity to detect the top of fog layers.

The action started by the acquisition of a sodar from the German company METEK. The sodar was ordered in February 2008 and delivered at Roissy Charles de Gaulle airport in June. Its capacity to operate in the noisy environment of the airport was checked in July. Since then, the sodar has been on operation at the airport, it is maintained by CNRM with the help of technicians from Meteo-France's local centre.

A sodar transmits acoustic waves and captures with microphones atmospheric echoes. The emitted wave is backscattered by the temperature heterogeneities of the atmosphere. Vertical wind profiles can be derived from the frequency Doppler shift of the received signals, while its intensity bears an information on the level of the thermal turbulence. The possibility to detect the top of a fog layer is based on this latter information.

In November 2008, a 4-month field campaign began with the aim to assess the real capacity of the sodar to detect fog top layers. The campaign mainly relies on fine time and space resolutions, temperature and humidity profiles acquired with a tethered balloon. A standard radio sounding balloon and a modified Vaisala RS92 sonde are used, the sounding site is located 7 km to the North of the airport. Profiles are hourly measured. The first results are promising, they suggest that the sodar does have a real capacity for fog top detection. However, as only a small number of fog cases were observed so far, more observations are needed before firm conclusions can be drawn. (8)

Carbon dioxide vertical profiles with tethered balloon in the ICOS framework

Within the framework of the European infrastructure ICOS intended to watch the greenhouse gas concentrations, CNRM was involved in October 2008 in a field experiment for the evaluation of instruments allowing to estimate the height of the atmospheric boundary layer.

This field experiment took place at the site of Trainou (Loiret) where a tower has been equipped, from a long time, by LSCE to measure CO_2 profiles on 5 levels, between ground and 200 meters high. A Vaïsala carbon dioxide sensor dedicated to vertical profiles with tethered balloons was thus evaluated in-situ. After a characterization of the performances of the sensor at the LSCE lab and the development of an instrumentation package with data transmission by radio link, this one was continuously operated under a tethered balloon from the 10th to the 14th of October. During this period, more than 200 vertical profiles of carbon dioxyde, temperature, humidity, wind velocity and direction between the ground and 200 m were realized, allowing on one hand to show the contribution of such a tool on the observation of the CO_2 accumulation in the atmospheric boundary layer and on the other hand to estimate the performances in situ in comparison with the concentrations measured on the 5 levels of the tower.

The first results show a good agreement between the balloons and the tower, and that the instrument is able to describe the evolution of the CO_2 in the low atmospheric layer, making easier this type of measures on any sites and with an important vertical resolution. (9)

MOBILEX experiment at Muret-Lherm airfield

Until now, stochastic filtering of high frequency turbulent wind measures had been tested only with fixed measures. Our objective is to complete these techniques by filtering mobile measures. To perform this filtering, we have to take into account the dynamic of the experiment platform.

For mobile measures, the filtering algorithm uses well-tried methods but for fixed measures, it is necessary to add a stage to follow the sensor during its evolution in the fluid. If the theoretical results are ready, the applications are being developed.

To validate all these works, measures of the turbulent parameters were made at the airport of Muret-Lherm by a specially equipped car. For the experimental campaign MOBILEX, a perch was conceived and instrumented by the CNRM. This horizontal measuring pole was fixed on the roof of a car that sped along the runway of the airport in between flights so as not to perturb the aeronautical users.

On the runway of Muret we recorded high-quality measures which will be considered as reference data set. The full treatment of the mobile measures in turbulence should be made during the year 2009. (10)

7

◄ Wind measurement station set on the Thau lagoon.

8

Reflectivity (dB) - Vertical beam

Time elapsed since 07 December 2008, 00:00 UTC (in hours)
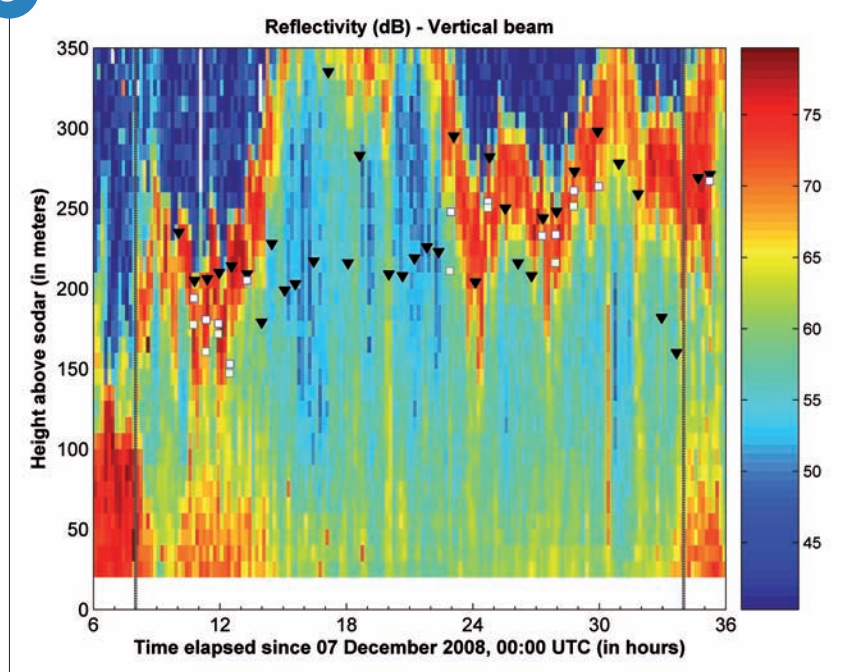
▲ Intensity (in dB units) of the sound echoes detected by the sodar as a function of time (x-axis) and height (meters above ground) during the fog episode of the 7th and 8th December 2008. The beginning and the end of the fog episode are indicated by grey dashed lines. A layer of enhanced intensity above 70dB can be seen in the altitude, first around 200 meters, then climbing above 300 meters, before stabilizing at the lower altitude of 250 meters. The black triangles indicate the maximum altitudes reached by the tethered balloon (one triangle per profile), while the white squares show the altitudes of the temperature inversions appearing in the profiles. They are nicely correlated with the bottom altitude of the layer of enhanced sodar echo intensity. All the profiles with no detected inversion have a maximum altitude below this layer.
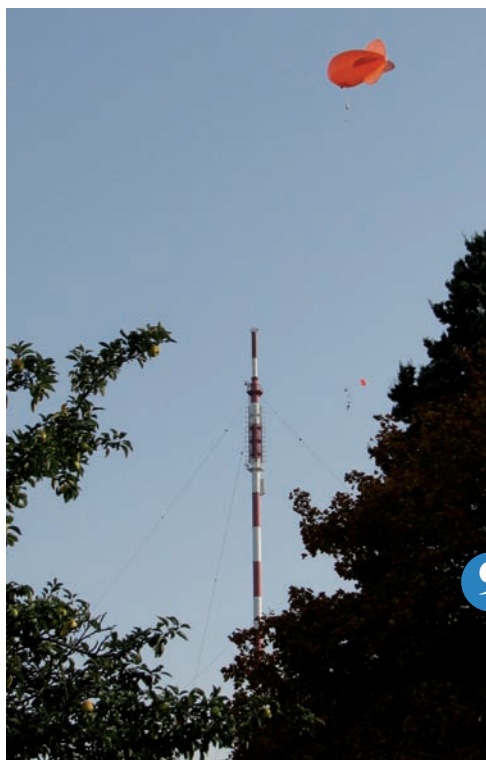
9

◄ Tethered balloon and instrumented tower during ICOS field campaign

figure a
The MOBILEX car waiting at Muret-Lherm airport runway before measuring the atmospheric turbulence.

figure b
The specially instrumented perch for turbulent measures.
▼

10

a

b
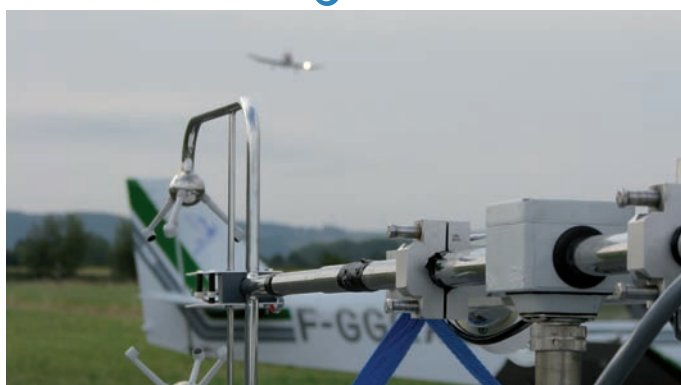
Communication

In 2008, Research Activities integrated Meteo-France's Quality Management System. In the communication area, the major event was our participation to the "European City of Sciences", on November in Paris.

Research activities now integrated inside Meteo-France Quality Management System

The process « Managing and Achieving Research Activities at Meteo-France » started in April 2008, after several months of preparation, conducted together by CNRM and Meteo-France's Quality Department. It was built on a global approach, since it is based on research program planning and research actions achievement monitoring.

The creation of this process was mainly reflected by the following points :
• annual research program preparation and control are now more accurate. They are still built from units' program sheets, but their elaboration has been clarified, both for research teams inside and outside CNRM.
• in order to reduce the risk of expertise loss in case of non permanent staff departure, interviews are now mandatory when an employee arrives (to precisely define his objectives) and when he leaves (to control that these objectives have been reached, and to transfer documentation).
• scientific publications monitoring has been strengthened, with creation of a distinction between major scientific journals and other magazines.

An activity sheet has been created for the research process, allowing a permanent control of indicators.

Internal and external audits of the Research Process took place in October and December 2008, they underlined the process 's maturity and CNRM head 's involvement was appreciated. The creation of this process has already been profitable: the 2009 research program preparation was more rigorous, it has been finalized sooner than usual. For non permanent staff, the utility of the new procedure for arrivals and departures has been understood.

The Research process will continue to progress in 2009, by taking in consideration different improvements proposals pointed by audit reports. ●1

Communication about the AMMA programme

The communication actions conducted for the AMMA programme allowed to diversify and increase the number of activities and the tools for internal as well as external communication.

Press relations have been developed with more than 50 media coverage between November 2007 and November 2008, all media taken together. Journalists have well-identified the AMMA programme as the African Monsoon reference. And since one year, the press covers more and more topics on climatic changes and their impacts on Africa. For internal communication, let us mention two major points: the AMMA community regularly receives informative mails as well as the newly revisited newsletter ; the websites have been updated, to obtain a larger audience and to make the information more accessible.

Scientific vulgarisation has been introduced in AMMA to reach a larger audience with, for the first time, an exhibition about the monsoon in Dakar, Senegal, which lasted a whole week and which was dedicated to climatic changes.

More than 2000 students visited it with a presentation from UCAD (University of Dakar) students. Later on, the exhibition went to other major cities of Senegal (Saint Louis, Zinguinchor, M'Bour...) as well as in 85 high schools in the suburb of Dakar. This exhibition was also presented in Toulouse, Place du Capitole, during the "science days 2008".

We will focus on two main aspects for 2009: the first one on scientific ground, when articles are published and the other one will be to make AMMA better understood by the inhabitants of West Africa. ●2

MP Devic explaining the AMMA exhibition, during the "science days 2008" in Toulouse, Place du Capitole.
▼
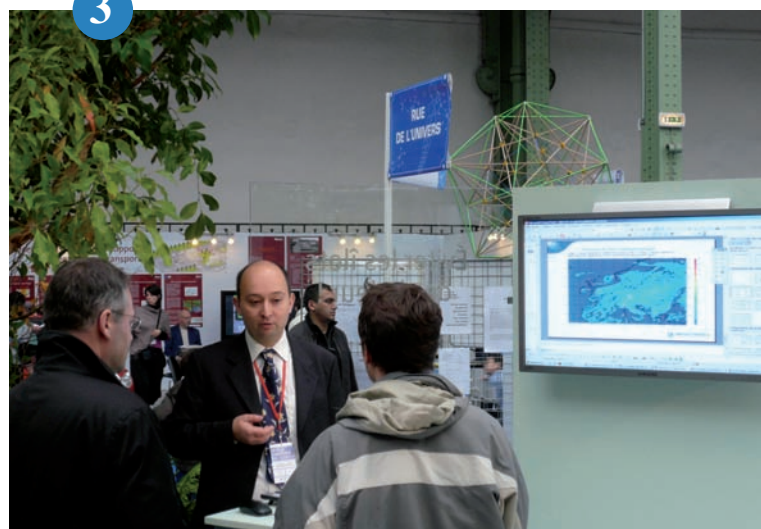
▲
Meteo-France quality certificate, including research activities, delivered in February 2009.

◄
Vincent-Henri Peuch (CNRM/GMGEC), answering to the visitors' questions, on "Air Quality" space in Meteo-France stand, on November 15th, in Grand Palais.

The "European City of Sciences": a direct and lively dialogue between Science and Society

To present its research activities to the general public and to increase young people awareness of scientific studies, Météo-France took part in the "The European City of Sciences", an exhibition organised, from 14 to 16 November 2008, in the Grand Palais, in Paris, by the Ministry of Higher Education and Research (Mesr), at the occasion of the French Presidency of the European Union.

With the themes: "Which climate tomorrow for the large European cities?", five topics were developed:
• Climate in the European cities for the last 150 years,

• Scenarios for the future climate evolution,
• Specific meteorological phenomena met in the cities,
• Weather forecast on an urban scale,
• Air quality forecast.

Through meetings, animations, innovative objects and play activities for the young people, our research methods and results were presented while focusing on their coherence with Agora 2000, the prospective process of the "Ministry for ecology, energy, sustainable development and regional development" (Meeddat) and the Grenelle of the environment, and with the Mesr's programs inclu-

ding those of the "National research agency" (ANR).

42.600 people visited the exhibition which was largely commented on the main national media. This demonstration was an excellent opportunity to explain the studies undertaken within Météo-France and to underline its major contribution in the fields of climate prediction, regionalisation, extreme meteorological events and modelling of the sustainable city. 3

Appendix

2008 scientific papers list

Papers published in rank « a » journals (impact factor > 1)

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GLOSSARY

ORGANISMS AND LABORATIES
Organisms

AASQA Associations Agréées de Surveillance de la Qualité de l'Air
ACMAD Centre Africain pour les Applications de la Météorologie au Développement
AERES Agence d'Evaluation de la Recherche et de l'Enseignement Supérieur
CERFACS Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique
CESBIO Centre d' Etudes Spatiales de la BIOsphère
CNES Centre National d'Etudes Spatiales
CNRS Centre National de la Recherche Scientifique
DLR Deutsche zentrum fur Luft und Raumfahrt
ECMWF European Centre for Medium-Range Weather Forecasts
ESA European Space Agency
EUMETNET EUropean METeorological NETwork
EUMETSAT EUropean organisation for the exploitation of METerological SATellites
HADLEY CENTER Centre Britannique de Recherche sur le Changement Climatique
IFREMER Institut Français de Recherche pour l'Exploitation de la MER
IMFT Institut de Mécanique des Fluides de Toulouse
INSU Institut National des Sciences de l'Univers
MEEDDAT Ministry for ecology, energy, sustainable development and regional development
MERCATOR Océan GIP visant à la mise en œuvre d'un système opérationnel de prévision océanographique global
NCEP National Centers for Environmental Prediction
OMM Organisation Météorologique Mondiale
ONERA Office National d'Etudes et de Recherches Aérospatiales
SHOM Service Hydrographique et Océanographique de la Marine
UCAD University Cheikh Antia Diop, Dakar, Senegal
UKMO (METOFFICE) United Kingdom Meterological Office
WMO World Meteorological Organisation

Laboratories or R&D Units

CEN Centre d'Etudes de la Neige
CERMA CEntre de Recherche Méthodologique d'Architecture
CETP Centre d'Étude des environnements Terrestre et Planétaire
CMM Centre de Météorologie Marine
CMR Centre de Météorologie Radar (DSO)
CMS Centre Météorologie Spatiale
CNRM Centre National de Recherches Météorologiques
DIRAG Direction Inter-Régionale Antilles-Guyane
DSO Direction des Systèmes d'Observation
ECN Ecole Centrale de Nantes
GAME Groupe d'études de l'Atmosphère MétéorologiquE
GMEI Groupe de Météorologie Expérimentale & Instrumentale
INERIS Institut National de l'Environnement industriel et des Risques
IPSL Institut Pierre-Simon Laplace
IRD Institut de Recherche pour le Développement
LA Laboratoire d'Aérologie
LaMP Laboratoire de Météorologie Physique
LCPC Laboratoire Central des Ponts et Chaussées
LEGOS Laboratoire d'Etudes en Géophysique et Océanographie Spatiale
LGGE Laboratoire de Glaciologie et de Géophysique de l'Environnement
LOCEAN Laboratoire d'Océanographie et du Climat : Expérimentations et Approches Numériques
LSCE Laboratoire des Sciences du Climat et de l'Environnement
MESR Ministère de l'Enseignement supérieur et de la Recherche
MIT Massachusetts Institute of Technology
NASA National Aeronautics and Space Administration
NOAA National Oceanic and Atmospheric Administration
SAFIRE Service des Avions Français Instrumentés pour la Recherche en Environnement
SMHI Swedish Meteorological and Hydrological Institute

NATIONAL OR INTERNATIONAL PROGRAMS OR PROJECTS
National programs or projects

ANR National research agency
COPS Convective and Orographically-induced Precipitation Study
CYPRIM CYclogénèse et PRécipitations Intenses en région Méditerranéenne

International programs or projects

CERES CarboEurope Regional Experiment Strategy
CONCORDIASI Validation de l'assimilation de IASI adaptée à l'Antarctique à l'aide de mesures in situ
COPAL COmmunity heavy-PAyload Long endurance instrumented aircraft for tropospheric research and geo-sciences
ENSEMBLES Ensemble-based predictions of climate changes and their impacts (FP6)
EUCOS EUmetnet Composit Observing System
EUFAR EUropean Fleet for Airborne Research (FP6)
FLYSAFE Système de vol intégré pour l'amélioration de la sécurité, la protection contre les imprévus, et les opérations tout temps
GALERNE GAz et Liquides Evaporants et Risques des Nuisances Environnementales et humaines
GLOSCAL Global Ocean Salinity Calibration and Validation
GEMS Global and regional Earth-system Monitoring using Satellite and in-situ data
GICC Gestion et Impacts du Changement Climatique (programme du ministère de l'écologie)
GIEC Groupe Inter-gouvernemental d'Experts sur le changement Climatique (IPCC)
GMES Global Monitoring for Environment and Security
HIRLAM HIgh Resolution Limited Area Model (modelling)
HyMeX Hydrlogical cycle in the Mediterrannean EXperiment
PREVIEW Projet Européen visant à améliorer la gestion des risques atmosphériques, géophysiques et anthropiques
PIRATA Prediction and Research Moored Array in the Tropical Atlantic
SAF Satellite Application Facility
THORPEX THe Observing Research and Predictability EXperiment (programme mondial du GARP sous l'égide de l'OMM)
TIGGE THORPEX International Grand Global Ensemble

CAMPAIGNS

AMMA African Monsoon Multidisciplinary Analyses
COPS Convective and Orographically-induced Precipitation Study Atmosphérique et de Transports d'Emissions
POLARCAT Polar Study using Aircraft, Remote Sensing, Surface Measurements and Models, of Climate, Chemistry, Aerosols, and Transport
SMOSMANIA Soil Moisture Observing System : Meteorological Automatic Network Integrated Application

OTHERS

ADCP Acoustic Doppler Current Profiler
AEW African Easterly Wave
AIRS Atmospheric Infrared Sounder
ALADIN Aire Limitée, Adaptation dynamique, Développement InterNational
AMDAR Aircraft Meteorological Data Acquisition and Relay
AMSR Advanced Microwave Scanning Radiometer
AMSR-E AMSR for Earth observing system
AMSU-A Advanced Microwave Sounding Unit – A
AMSU-B Advanced Microwave Sounding Unit – B
API Année Polaire Internationale
AQUA Satellite du Earth observing system de la NASA, doté du sondeur AIRS

Aqua-Train constellation de six satellites franco-américains qui volent en formation à quelques minutes d'intervalle sur une orbite héliosynchrone, comprenant entre autres le satellite Aqua

ARAMIS Application RAdar à la Météorologie Infra-Synoptique

ARGIC Analyse du Retrait-Gonflement et de ses Incidences sur les Constructions

AROME Application de la Recherche à l'Opérationnel à Méso-Echelle

ARPEGE Applications de la Recherche Petite Echelle Grande Echelle (modèle global de prévision numérique opérationnel de Météo-France)

ARPEGE-Climat Modèle de simulation climatique global du CNRM

ASCAT Advanced SCATterometer

AVHRR Advanced Very High Resolution Radiometer

BAMED Balloons in the Mediterranean, 2008-2010

BDPI Base de Données d'Expertise en Prévision Immédiate

CAPE Convective Available Potential Energy

CAROLS Cooperative Airbone Radiometer for Ocean and Land Studies

CCN Cloud Condensation Nucléi

CMIP Climate Model Intercomparaison Project

CNRM-CM CNRM-Climate Model

COBEL Code de Brouillard à l'Echelle Locale

CPER Contrat de Plan Etat Région

CROCUS Modèle d'évolution du manteau neigeux

CTM Chemistry and Transport Model

DCT Diffraction Contrast Tomography

DDU Dumont d'Urville (-66,6S;140E), meteorological station in Antartica

DomeC (-75,1S;123,4E), station de mesure sur le continent Antarctique

DTS Data Targeling System

E-GVAP The EUMETNET GPS Water Vapour Programme http://eqvap.dmi.dk/)

ECOCLIMAP Base de données de paramètres de surface

ECUME Exchange Coefficients from Unified Multi-campaigns Estimates

EDKF Eddy-Diffusivity-Kain-Fritsch

ENVISAT ENVIronmental SATellite

EPI Evénements Précipitants Intenses

ERA40 Réanalyse (sur 40 ans) du CEPMMT

ERPG Emergency Response Planning Guidelines

ESFRI European Strategy Forum on Research Infrastructures

FP6 6th Framework Program for Research and Development of the European Commission

FP7 7th Framework Program for Research and Development of the European Commission

GEWEX Global Energy and Water cycle Experiment

GFO Geosat Follow On

GLOSCAL Global Ocean Salinity Calibration and Validation

GPS Global Positionning System

Heat Low Dépression Thermique Saharienne

HIRS High resolution Infrared Radiation Sounder

IAGOS Integration of routine Aircraft measurements into a Global Observing System

IASI Interféromètre Atmosphérique de Sondage Infrarouge

ICOS Integrated Carbon Observation System

IFS Integrated Forecasting System

IPY International Polar Year

IRIDIUM Satellite en orbite polaire

ISBA Interaction between Soil, Biosphere and Atmosphere

LAI Leaf Area Index

LAM Local Area Model

LGM Last Glacial Maximum

LIDAR Light Induced Detection And Ranging

MACC Monitoring Atmospheric Composition and Climate

MERCATOR Projet d'océanographie opérationnelle de prévision des caractéristiques physiques de l'océan

MESO-NH Modèle numérique à MESO-échelle Non-Hydrostatique

METOP METeorological Operationnal Polar satellites

MFWAM Météo-France WAve Model

MHS Microwave Humidity Sounder

MOCAGE Global and regional chemistry and transport model of Météo-France

MODCOU MODèle hydrologique COUplé surface-souterrain

MOPITT Measurements Of Pollution Into The Troposphere

MOTHY Modèle Océanique de Transport d'HYdrocarbures

MSG Meteosat Seconde Génération

NAO North Atlantic Oscillation

NARR North American Regional Reanalysis

NWP Numerical Weather Prediction

OASIS Ocean Atmosphere Sea Ice Sol (coupleur ocean/atmosphere développé au Cerfacs)

OLR Outgoing Longwave Radiation

PACA Provence - Alpes - Côte d'Azur

PALM Projet d'Assimilation par Logiciel Multi-méthodes

PEARP Prévision d'Ensemble ARPège

PERLE Programme d'Evaluation des Rejets Locaux d'Effluents

PMIP Paleoclimate Modelling Intercomparison Project

PM10 Particulate Matter with a diameter lower than 10 micrometers

Prev' Air French National platform for air quality (http://www.prevair.org), operated by INERIS, ADEME, CNRS and Météo-France on behalf of the Ministry for Ecology

RASS Radio Acoustic Sounding System

RDT Rapid Development Thunderstorm

ROC Relative Operating Characteristics. Diagramme avec en abscisse le taux de fausses alertes et en ordonnée le taux de bonnes prévisions

SAFRAN Système d'Analyse Fournissant des Renseignements Atmosphériques à la Neige

SAF-NWC Satellite Application Facility – NoWCasting

SDA Seismic Detection of natural Avalanches

SESAR Single European Sky ATM Research Programme

SEVIRI Imageur SEVIRI

SIGOONS SIGnificant weather Object Oriented Nowcasting System

SIM Safran-Isba-Modcou

SLHD Semi-Lagrangian Horizontal Diffusion

SMOS Soil Moisture and Ocean Salinity

SOP Special Observation Period

SPARC Stratospheric Processes And their Role in Climate

SRES Special Report on Emissions Scenarios

SST Sea Surface Temperature

SURFEX SURFace EXternalisée

SVP-B Surface Velocity Program

TEB Town Energy Balance

TOPMODEL TOPography based hydrological MODEL

UHF Ultra High Frequency

UNED United Nations Environment Program

UTC Universal Time Coordonnated (TU)

VHF Very High Frequency

WAHL West African Heat Low

WIMS-Cb Weather InforMation Systems on Cumulonimbus

WCRP World Climate Research Programme

3D-Var Assimilation variationnelle tridimensionnelle

3d-FGAT Méthode d'assimilation variationnelle "3D First Guess at Appropriate Time"

4D-Var Assimilation variationnelle quadridimensionnelle

CNRM : Management structure

On : 31.12.2008

Head : **Éric Brun**

Deputy Head - Toulouse : **Joël Poitevin**
Scientific Deputy Head - Toulouse : **Jean Pailleux**
Deputy Head - Paris : **Pascale Delécluse**

SAFIRE : French Group of Aircraft Equipped for Environmental Research

METEOROLOGICAL AVIATION CENTRE   CAM - Toulouse
Centre head : **Marc Pontaud**

SNOW RESEARCH CENTRE   CEN - Grenoble
Centre head : **Pierre Etchevers**

MARINE METEOROLOGY CENTRE   CMM - Brest
Centre head : **Jean Rolland**

MODELLING FOR ASSIMILATION AND FORECASTING GROUP   GMAP - Toulouse
Group head : **François Bouttier**

EXPERIMENTAL AND INSTRUMENTAL METEOROLOGY GROUP   GMEI - Toulouse
Group head : **Jean-Louis Brenguier**

CLIMATE AND LARGE SCALE MODELLING GROUP   GMGEC - Toulouse
Group head : **Serge Planton**

MESO-SCALE MODELLING GROUP   GMME - Toulouse
Group head : **Joël Noilhan**

INTERNAL KNOWLEDGE TRANSFERS GROUP   RETIC - Toulouse
Group head : **Christine Dreveton**

GENERAL SERVICES   Paris & Toulouse
Head : **Joël Poitevin**

Nota :
The GAME is the Associated Reseach Unit between Météo-France and CNRS. Units on deep blue are fully included in GAME, units on light blue are partially included in GAME.

SAFIRE is a joint unit bewteen Météo-France, CNRS and CNES.

Research activities: major events in 2008

15-17/01
Research Centre evaluation by AERES.

27/01
PEARP release 1.5 becomes operationnal (increase of vertical levels number, additional global incertude information taken into account, ...).

4/02 – 1/03
Winter Flysafe campaign around Paris

6/02
Release T538/L60 of Arpege/Aladin models becomes operational (increase of vertical and horizontal resolution).

28/03 – 13/04
Polarcat campaign in Sweden (Kiruna).

1/04
Integration of Research Activities within Météo-France Quality Management System.

30/04 – 28/05
EUCARII campaign in the Netherlands.

2-6/06
GCSS (Gewex Cloud System Study) meeting at CIC/Toulouse.

10/06
Numerical Weather Prediction day at CIC.

29/06 – 17/07
Polarcat campaign in Greenland.

1/07
The new release « observation » of Arpege/Aladins models becomes operationnal (assimilation of IASI data, ensemble assimilation d'ensemble, emissivity of microwave frequencies).

4/08 – 4/09
Summer Flysafe campaign around Paris.

5/08
AERES classifies the CNRM/GAME in A+.

6-27/08
MOBILEX campaign at Muret-Lherm.

8/09
The Ushant huge navigation buoy is fully equipped with solar panels.

15/09
Beginning of Concordiasi phase 1.

22-24/09
Working Group on Climate Modelling meeting in Paris (preparation of simulations for IPPC 5th report).

24-25/09
Workshop « Convergence » on Physics for NWP models in Toulouse.

1/11
Beginning of Roissy campaign (sodar validation).

14-16/11
« European City of Sciences » exhibition at Grand Palais in Paris.

19/11
Conference « Regional climate change : from knowledge to actions » at CIC in Toulouse.

5/12
Météo-France integrates the Advanced Research Thematic Network / Aeronautic and Space Technology Sciences.

18/12
The AROME model becomes operational.

Research
and development:
annual report

2008

METEO FRANCE
Toujours un temps d'avance