Research and development: annual report 2007

METEO FRANCE
Toujours un temps d'avance

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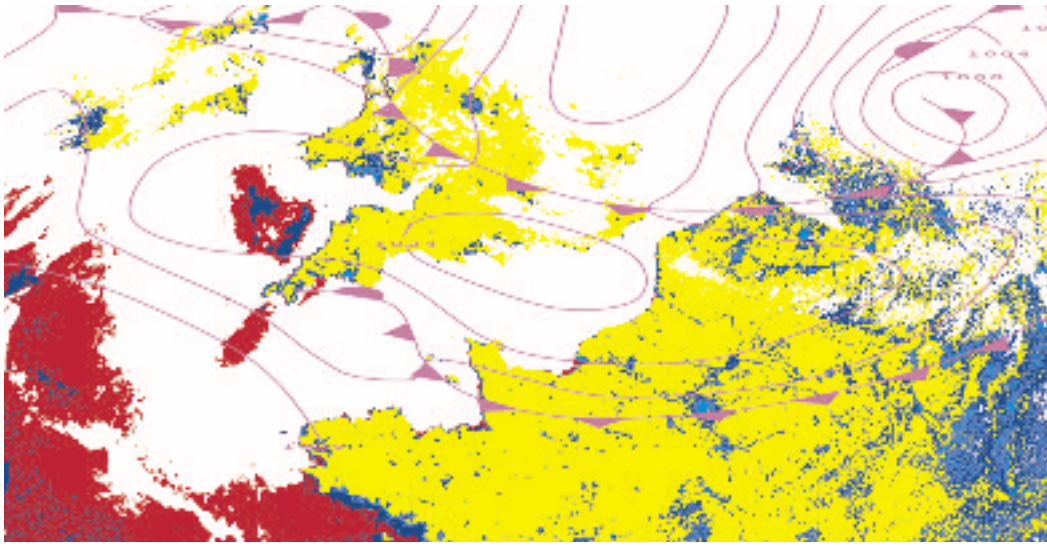
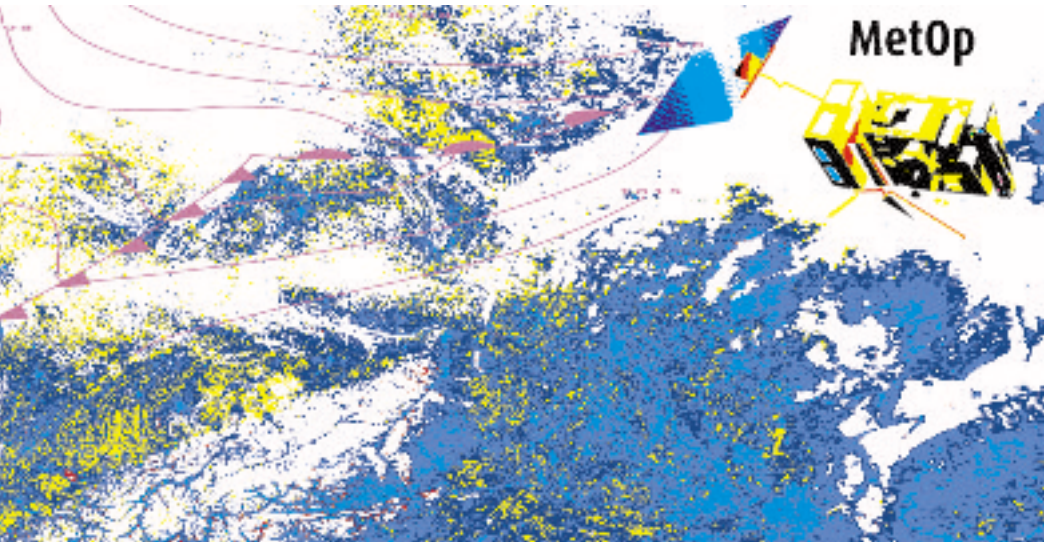


Several papers in the following annual report describe important aspects of the current research whose aim is to improve the Numerical Weather Prediction system ARPEGE. Four actions deserve particular attention :

- the improvement of the atmospheric model, including a significant increase in the horizontal and vertical resolutions were made possible by the new computer Nec SX 8R which is operational since the beginning of 2007. In addition to a spectacular improvement in the ARPEGE performances, this development can be considered as a first step towards the next increase in resolution which will make possible, as from 2009, a direct coupling between ARPEGE and the AROME high resolution model.
- the assimilation of new observations has been the subject of an intense activity, in particular for the observations produced by the MetOp satellite. Very promising results have been obtained with the assimilation of the IASI sounder. A specific effort is devoted to the assimilation of observations related to the water cycle. Recent progress have made the assimilation of the GPS radio possible-occultation data in an operational context, with a very positive impact over the Southern hemisphere.
- the ensemble forecast is a relatively new research domain at CNRM. The development of new methods for the perturbation of the initial conditions has been achieved in 2007. Presently, Météo-France operates a state of the art ensemble forecast which feeds up the TIGGE Grand Ensemble. TIGGE has been set up by the THORPEX program of WMO in order to initiate academic and applied research which focuses on the use of multi-model ensembles for probabilistic predictions.
- the development of an ensemble assimilation system proved itself to be a particularly promising method to evaluate background



errors depending on the current meteorological situation. Recent results show very good performances on relevant error statistics with only 6 members. This performance makes it possible to envisage the operational implementation of this technique in a very near future.

Improving the ARPEGE model does not only meet operational aims. Most developments, either on physics or on dynamics, are done in close cooperation with teams developing the limited area models ALADIN, Méso-NH and AROME as well as with teams developing climate models. At the same time, developments are also under way to include the same externalized scheme for continental and oceanic surfaces in all these different models.

Additionally, it must be emphasized that the ARPEGE model is also a powerful research tool which is a core component to investigate cyclogenis and fronts dynamics, as it is shown in this report.

Éric Brun

Head of Research at Météo-France

◄ Eric Brun, head of CNRM, during his opening lecture at the atmosphere modelling workshop, in January 2007.

Numerical Weather Prediction

2007 saw the first quasi real time experimentation of the AROME prototype which should be operational by the end of 2008. The research teams not only worked hard on AROME but they also implemented a new spatial resolution for ARPEGE and for ALADIN. Moreover, data assimilation systems have been improved, and specific forecast tools for aeronautic needs have been developed. In the meantime, cyclone forecasting made some significant progress.

Synoptic NWP

Assimilation of MetOp data

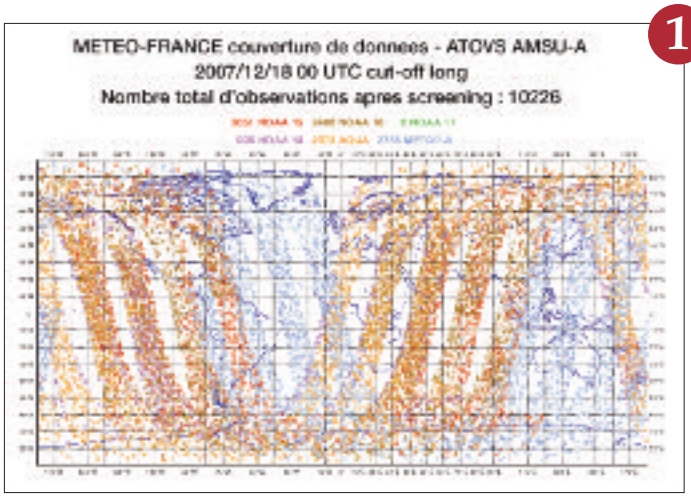
The Metop satellite, launched in October 2006 by EUMETSAT, is the first European contribution to the constellation of operational polar-orbiting satellites. The instruments onboard MetOp, innovating for some, in the continuity of existing instruments for others, provide data which have started to be assimilated in the numerical weather prediction models at Météo-France.
The ATOVS instruments (AMSU-A, MHS, HIRS) measure radiances which can be directly linked to atmospheric temperature and humidity. These data are now a useful addition to those originating from American satellites in the operational models (see Figure). The ASCAT scatterometer observes winds at the ocean surface in the continuity of the ERS scatterometer, but with a swath twice as broad. The most prominent instrument on MetOp is the Michelson Interferometer in the infrared spectrum, IASI, developed by CNES in collaboration with EUMETSAT. The amount of data collected by IASI is more than a hundred times greater than that provided by sounders from the previous generation such as HIRS, thus resulting in a finer description of the atmospheric vertical structure. The assimilation of ASCAT and IASI data is planned for 2008. Finally, the GRAS instrument will soon provide GPS radio-occultation measurements similar to those Météo-France recently started to assimilate.
Beyond the application to numerical weather prediction at short to medium range, the data collected by IASI will contribute to a better knowledge of the atmospheric composition in minor constituents of which radiative properties are of utmost importance for the climate. 1

Assimilation of GPS radio occultation data for Numerical Weather Prediction

Satellite observations of the Earth's atmosphere collected, thanks to the Global Positioning System (GPS), are now used beneficially at Meteo-France to improve numerical weather forecasts. The radio-navigation signals sent by the American GPS satellites located at a 20200 km altitude are refracted by the Earth's atmosphere. The atmospheric refraction measured by GPS receivers in lower orbit (between 400-1600 km altitude) enables then to characterize the temperature and water vapour distributions in the atmosphere.
In 2006, the USA/Taiwan FORMOSAT-3/COSMIC mission launched six such GPS radio occultation receivers. Numerical weather forecast experiments conducted at Meteo-France have shown that the bending angle data collected by these satellites, as well as similar data collected by the German satellites CHAMP and GRACE, helped improve numerical weather forecasts by reducing the errors in the estimated initial state of the atmosphere. The largest improvements were observed in the traditionally under-observed regions (Southern hemisphere) and those regions where the addition of high vertical resolution data is critical to help improve the atmospheric description in the model (tropopause region).
As a result of this study, Meteo-France's global numerical weather prediction model ARPEGE, as well as the limited-area model ALADIN over Europe and over La Reunion Island, have been operationally assimilating GPS radio occultation bending angle data since September 2007. 2

ARPEGE : seamless global to mesoscale forecasting system

The global data assimilation and forecasting system of Météo-France, Arpege, as well as the hydrostatic Aladin models which are coupled to it, change and improve continuously. The following paragraphs thus summarize the observation system extension and the new developments in data assimilation or in the parameterization schemes.
The overall framework within which all these changes are integrated also undergoes some evolutions. Foremost, a change of vertical resolution will be applied to all the Arpege and Aladin models: the atmosphere will be represented with 60 vertical layers instead of the 46 currently in operation. It has been chosen, in this instance, to focus the vertical refining around the altitudes 10-12 km in order to better represent the jet-streams. To better represent jet-streams, the vertical refining will be focussed around the 10-12 km altitudes. They influence many aspects of the weather evolution. Precision in the vertical computations is improved by activating a numerical scheme developed at ECMWF in Reading. Furthermore, the Arpege horizontal resolution is also increased. Everywhere around the globe, it tends to be less than 100 km, and even smaller than 50 km around La Réunion Island. In the Europe-North Atlantic broad area, Arpege has a finer resolution than ECMWF model, with an average resolution smaller than 20 km from Iceland to the Caspian Sea. Resolution reaches 15 km over France. The horizontal resolution changes continuously, therefore avoiding breaks that result from lateral coupling. This new resolution gives details of the internal structure of storms, as illustrated by the figure, with very realistic cloud systems.
These changes have been extensively tested during the last three months of 2007 and became operational early in 2008. 3



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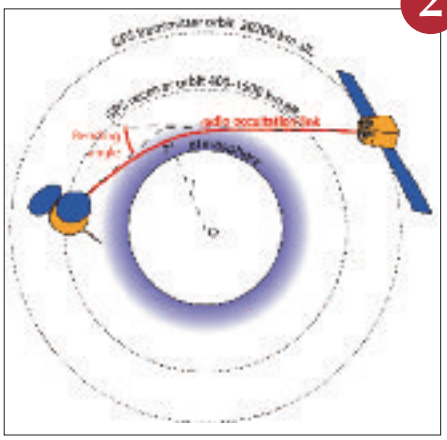
◄ Data coverage from AMSU-A sounders used in operations in the ARPEGE model assimilation, over a 6 hour assimilation period (MetOp is in blue).



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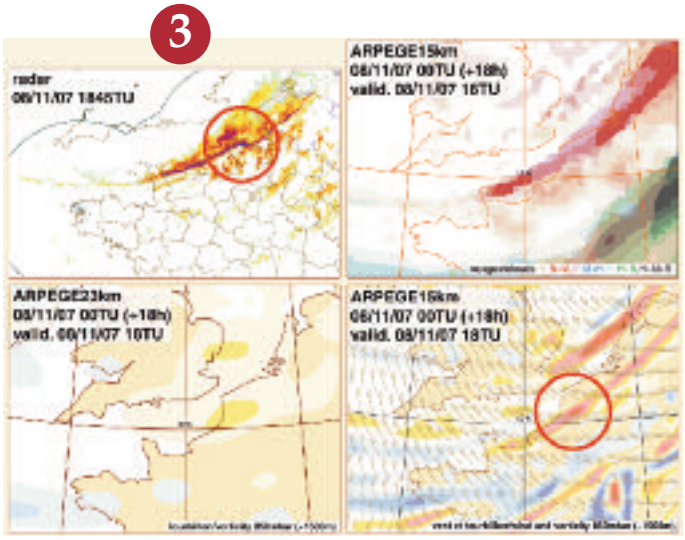
◄ Geometry of the GPS radio occultation technique: the atmosphere refracts the radio signal sent by a GPS transmitter; the refraction angle observed by a GPS receiver enables to characterize the atmospheric refractive index at the tangent point (T).



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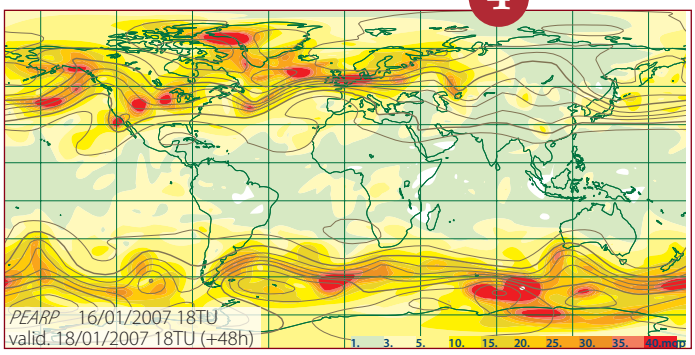
▲ The 08/11/2007 strong North Sea storm which amplified all day long. The related cold front, well marked, undergoing further internal fine scale perturbations that caused severe damages in the North of France (composite radar reflectivity composite, top left panel). The Arpege operational version (bottom left panel) does not represent such fine structures, but it did forecasts the storm. On the other hand, the new version of Arpege (right panels) further forecasts the front organization and it suggests the internal perturbation, both in its dynamical components (bottom) and in its cloud structure (top). Top right panel: 3 layer composite cloud cover, high level clouds (H), mid-level clouds (M) and low-level ones (B). Bottom: wind (barbs, kt) and relative vorticity (shading) at about altitude 1500 m. A maximum vorticity band is a good indicator of a frontal zone, while a spotty maximum outlines a vortex. Contour interval: warm colours 5 10^{-5} s^{-1} from light red, 2,5 10^{-5} s^{-1} below, cold colours, negative values.



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▲ Example of a 48 h uncertainty forecast by the upgraded global PEARP from the 16/01/2007 18 UTC, for the 18/01/2007 18 UTC. On that day, a strong storm hit the North Sea and nearby south-eastern countries. Contours are 500 mbar geopotential height (a pressure-like field, altitude about 5.6 km, contour interval 10 damgp) forecast by the ensemble mean. Shading shows the uncertainty as the standard deviation of the differences between ensemble members (interval: 5 mgp). Far from being uniform, uncertainty grows for specific areas shown in red and where it turns out that active bad weather systems are often located.

A first upgrade of the Arpege ensemble prediction system (PEARP)

PEARP, for Arpege ensemble forecasting in French, is Météo-France ensemble prediction system, initially developed by the Forecast Department. It is an ensemble targeted towards short range probabilistic predictions, that is for the following next 3 days.

On top of an unperturbed control forecast, PEARP consists in 10 more forecasts whose initial conditions are subtly non-randomly modified. The differences between the evolutions in time of the 11 forecasts provide a measure of the uncertainty and enable to outline the probability distributions of the predicted parameters. In the operational version, the perturbations that are used to prepare the various initial states are only computed within a domain restricted to North-Atlantic and Europe. CNRM initial action on PEARP has been to change these perturbations. Firstly, they are, from now on, computed over the whole globe. Secondly, part of the forecast uncertainty comes from the past, through the evolution of perturbations from previous runs during the period preceding the initial forecast time.

Finally, a small part of the uncertainty about the knowledge of the initial state is derived from the latest variationnal analysis and is used to adjust the amplitude of the final perturbations that are then added to that analysis. This is the first step of an evolution that aims to develop a state-of-the-art probabilistic forecast system, a step mostly directed towards improving Météo-France contribution to the WMO supported TIGGE project of collecting global ensemble forecast. This new version of PEARP became operational in february 2008. 4

Estimation of forecast errors with a small ensemble of forecasts and an optimized spatial filtering

Assimilation systems such as the Arpège, Aladin and Arome models enable to correct forecasts with observations. This is done by accounting for forecast error statistics. To estimate forecast errors, an appealing approach is to simulate the time evolution of errors by using an ensemble of perturbed assimilations. The idea is to add perturbations which simulate uncertainties at play, and to make them evolve through the analysis and forecast steps.

The ensemble size is a crucial factor to obtain an estimate which is both robust and not too costly. However, using optimized spatial filtering techniques allows the required ensemble size to be reduced in order to reach a given accuracy (or vice versa to increase the accuracy for a given ensemble size). The idea is to calculate a local spatial average of statistics, which allows the statistical sample size to be strongly increased. These notions are illustrated in the figure with four estimates of the error variance map of vorticity near 500 hPa. Panel (a) corresponds to a reference, which indicates that the errors are larger over the Atlantic and Pacific Oceans, and also in the Southern Hemisphere. Panel (b) is an estimate from an ensemble of 6 random realizations after an optimized spatial filtering. The resulting estimate is more accurate than the raw estimations from 6 or even 220 realisations (panels (c) and (d) respectively).

An operational implementation of these techniques is considered for 2008, in order to describe the dependence of errors on the ongoing weather situation. 5

Study of alternative formulation for IFS/ARPEGE/ ALADIN/AROME dynamic kernel

The non-hydrostatic (NH) dynamical kernel of our Numerical Weather Prediction tool is one of the key elements of the new AROME system, currently under tests for a future operational use (the other elements being the physics and the data assimilation). In parallel to this use at fine scales in small limited area domains, other types of applications are considered for the future. Work is underway with the ECMWF to see if the kernel is relevant to the global IFS model in NH mode. A cooperation with the HIRLAM group is also in progress for large limited-area domains.

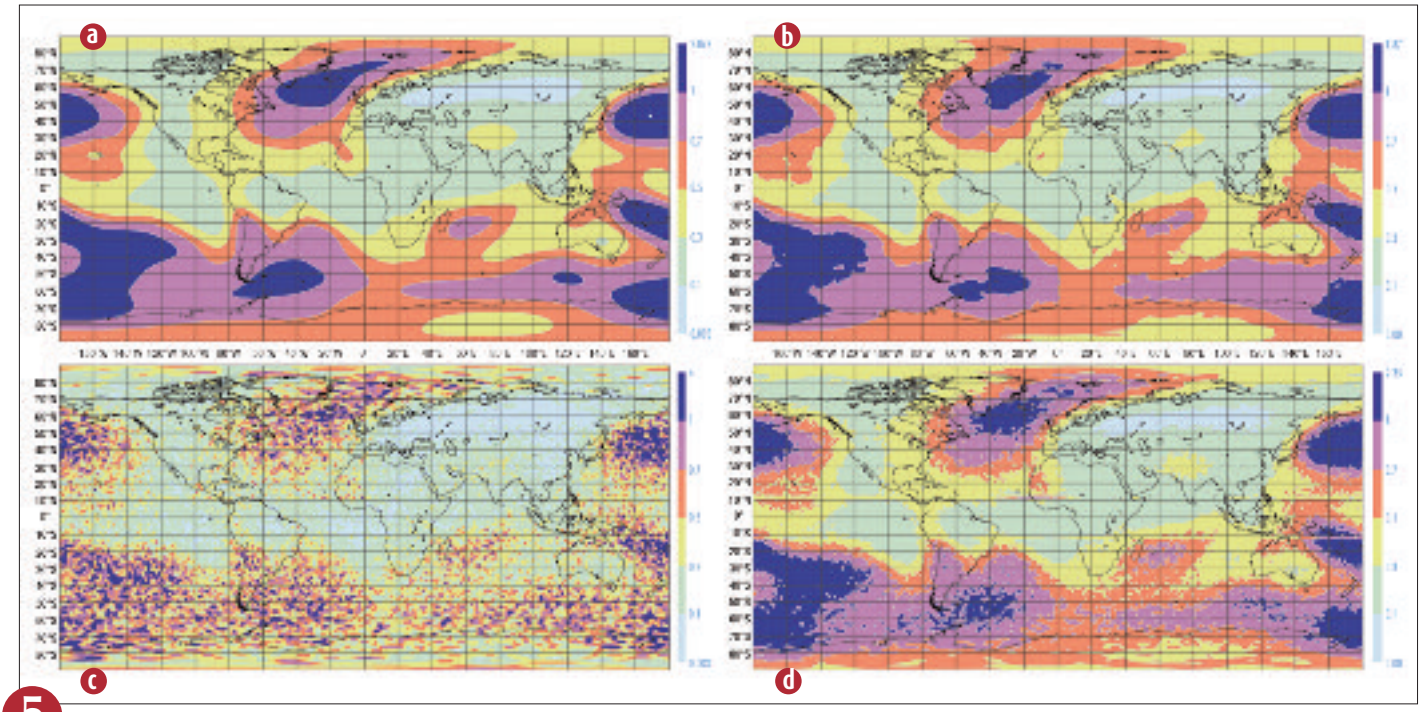
Such configurations depart significantly from the AROME one in many respects (geometry, inclusion of physics and algorithmic choices,...). Robust and accurate algorithms are required for a possible use of the NH dynamical kernel for this wide range of applications. For this, research mainly involved the increase of the robustness for large time-steps through a revision of the discretisation of some non-linear terms, and the improvement of the intrinsic accuracy through the implementation of a preliminary version with the discretisation of vertical finite elements. A longer-term work about the possible replacement of the prognostic NH variable set is undertaken with the aim of a more natural inclusion of finite elements. 6

10 m wind data assimilation inside ALADIN

10 m wind observations assimilation is a rather tricky/difficult task. As a matter of fact, wind near the ground depends a lot on small scale orography that can be quite different from large scale model orography. Besides, data are also influenced by small scale ground parameters such as vegetation type, height. At last, a wind measurement in mountainous areas can represent a phenomenum that has a time limitation is limited in time and is of little importance for large scales.

However, for limited area models whose surface characteristics are closer to reality, these observations can bring useful information to a data assimilation system. Because of the high temporal and spatial cover (cf figure a); we tried to test their impact inside the limited area model ALADIN. For that, first we selected stations, which presented, over the test period (4 month), a strong correlation with values forecasted by the ALADIN model.

The main impact of these observations is located inside the atmospheric boundary layer as shown in figure b, the vertical cross section shows that the impact is important below model level 35, that is to say at 1.5 km. The only relevant improvement of 10 m wind observations is the reduction of the ground pressure bias inside ALADIN, which is a known flaw of that model. That effect is possible thanks to the correlation of the model errors between surface pressure and wind. 7



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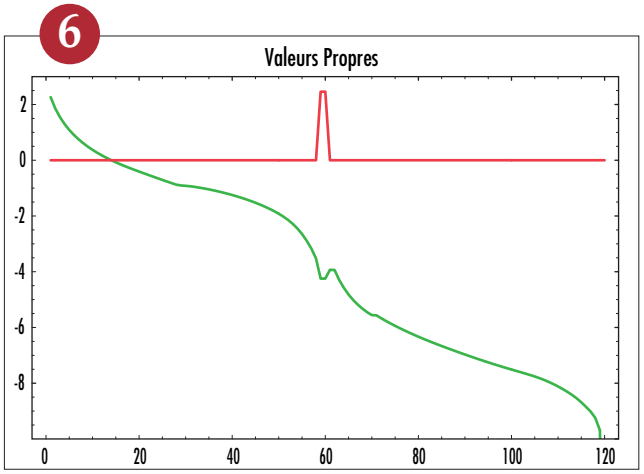
▲ Forecast error variances of vorticity (in 10^{-9} s^{-2}) near 500 hPa.
Panel (**a**): reference.
Panel (**b**): filtered estimate from 6 random realizations.
Panels (**c**) and (**d**): raw estimates from 6 or 220 realizations, respectively.
The filtered estimated is the closest one to the reference.



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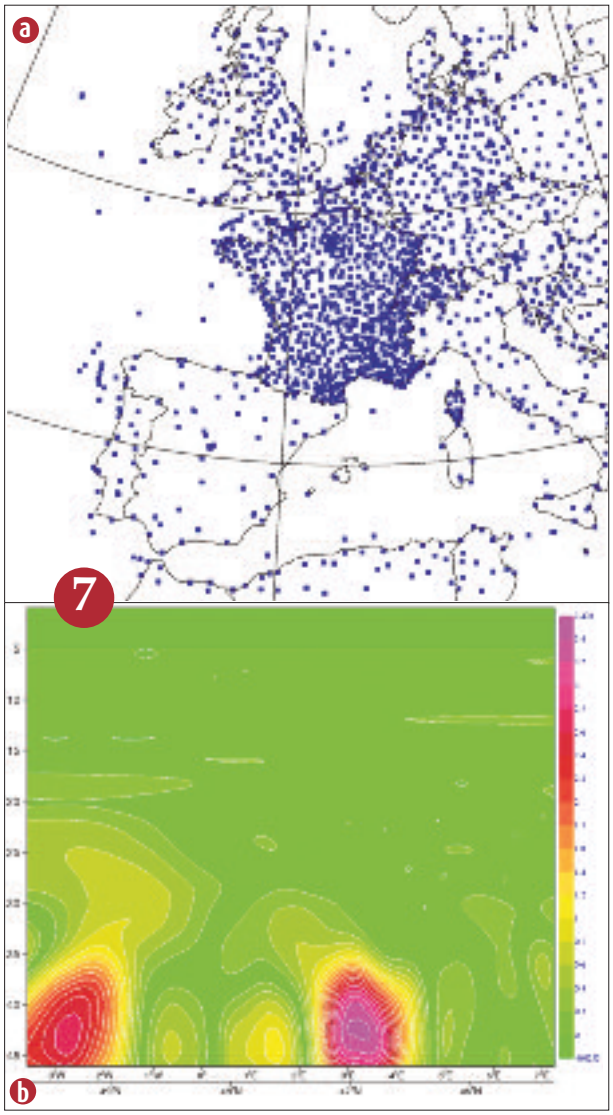
▲ An example of the NH dynamical kernel eigenfrequencies, analytically diagnosed for the case of a particular vertical finite-element discretisation with 60 irregularly-spaced levels.
Green: logarithm of the real part;
red: imaginary part (x10000). The appearance of a weak imaginary part indicates that the system would be unstable with this particular discretisation.
With this kind of analysis for the response of the system it is possible to anticipate its behaviour without heavy developments.



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▲ **a** : 10 m wind observations available for each analysis.
b : Vertical Cross section over France showing difference between two analysis at 12 h 00, one with 10 m wind observations, the other one without

Meso scale NWP

The AROME model uses its own assimilation

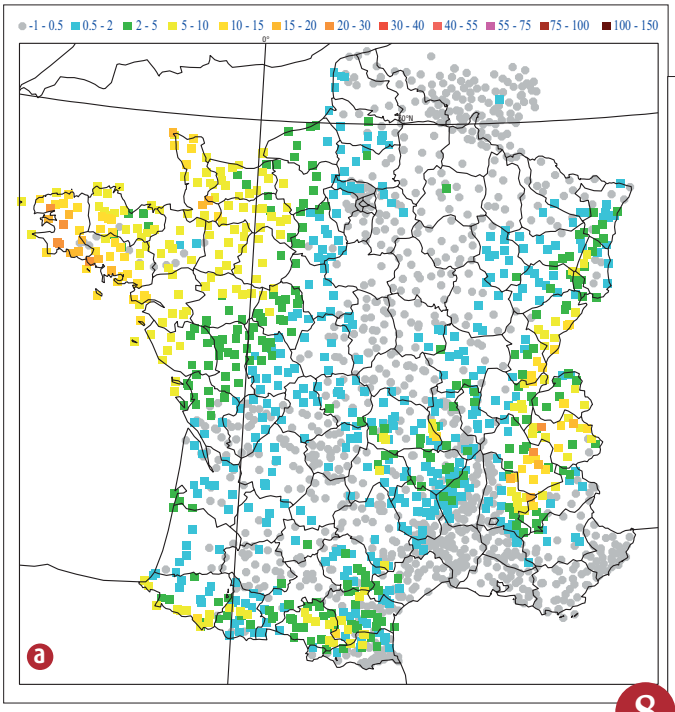
Since september 2007, the AROME model uses initial conditions provided by its own data assimilation system instead of those produced by the ALADIN-FRANCE operational suite.
This system is based on the ALADIN-FRANCE 3D-Var scheme that is operationally running at Météo-France at regional scale since June 2005. It uses high temporal and spatial frequency observations (RADAR measurements for example) to the best possible advantage, and a rapid forward intermittent assimilation cycle in order to compensate the lack of temporal dimension in the 3D-Var scheme. Observations every 3 hours (instead of 6 in ALADIN), are assimilated using the previous model forecast as a background to produce a new estimate for wind, temperature, humidity and surface pressure fields. The others fields are cycled from the background.
Observations that are assimilated in the system are currently those of the ALADIN-FRANCE operational suite. Works will be soon completed on the use of other types of observations such as wind measurements by Doppler radars.
This data assimilation system has been firstly tested on different precipitating cases. A daily assimilation cycle has been performed since September 2007. Forecast evaluation, using, for example, standard scores against observations, shows a general benefit of the use of the AROME analysis during the first 12 hour forecast ranges. After 12 hours, the influence of lateral conditions becomes more important than the initial conditions one. 8

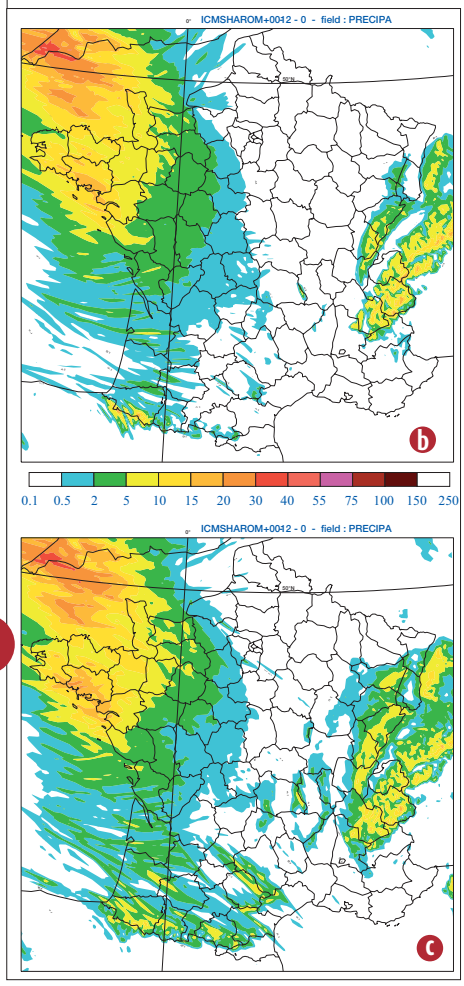
Use of radar data in AROME

Doppler radars observations allow to describe the tri-dimensional structure of precipitations and of air flow within a precipitating system with a high temporal and spatial resolutions. Consequently, these data will play a crucial role in the retrieval of AROME's analyses, which will be the starting point to forecast severe weather. For this purpose, studies are currently under progress in order to take into account radars from the French national network ARAMIS in the AROME assimilation system. As a first step, observation operators have been developed to simulate radial velocities and reflectivities using the model's variables.
The assimilation of Doppler winds in the AROME 3Dvar has been validated for several convective cases and is still being evaluated on a daily basis in a pre-operational configuration. It has been found that, when some favourable sampling conditions are present, short term forecasts of precipitations are improved thanks to a more realistic analysis of convergence structures in the boundary layer (figure).
The assimilation of reflectivities is more complex because microphysical variables are not considered as control variables in AROME, and because of the difficulty to linearize water cycle processes. A 1D statistical inversion method, which allows to retrieve relative humidity profiles from reflectivities, is firstly applied by using the model state in the vicinity of the observation as a probable source of information. These profiles are then directly assimilated in the 3Dvar. Encouraging results have been obtained so far and work is still in progress. 9

Validation of the Arome mesoscale model in test

The mesoscale Arome model is currently on its final phase. During the year 2007, the numerical suite saw several important evolutions for the production of fine scale forecasts. First, thanks to the computing resources of the supercomputer NEC, from early January 2007, it was possible to enlarge the size of the domain in order to cover the whole of Metropolitan France.
Then, during the year 2007, practical experimentations managed in the framework of the PARME (support to the implementation) project with forecasters coming from regional as well as central services allowed to detect some youthful defaults of the model. Some of them are already or on the way to be solved. For example, some dynamical tunings not well fitted to the horizontal scale of Arome have been revisited and some improvements of the physics have been evaluated such as a new scheme for the shallow convection. The objective validations such as comparisons of forecasts with respect to observations also allowed to detect several systematic bias. Some of them found a solution such as the implementation of a specific scheme for the canopy that has proved to improve the scores of the 2 metres temperature and of the 10 metres wind. Others, such as the overestimation of the heavy rainfall need to be re-examined. Finally, the implementation of the assimilation at the end of September 2007 ends a year full of changes for the Arome model.
To conclude at the close of 2007, one could say that the quality of the forecasts depends on the type of parameters and on the weather type. Objective comparisons with respect to observations are of the same level of accuracy as the ones in the Aladin model. The experimentations done by forecasters also showed some successes, in particular, the triggering of diurnal convection or as drawn in the figure below, in the cloudiness forecast. The next changes that will occur before switching to operations will contain, in particular, the assimilation of the Doppler wind data. 10





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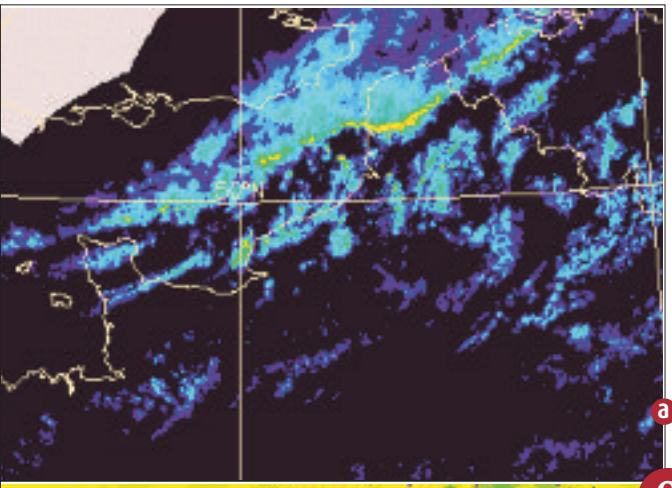
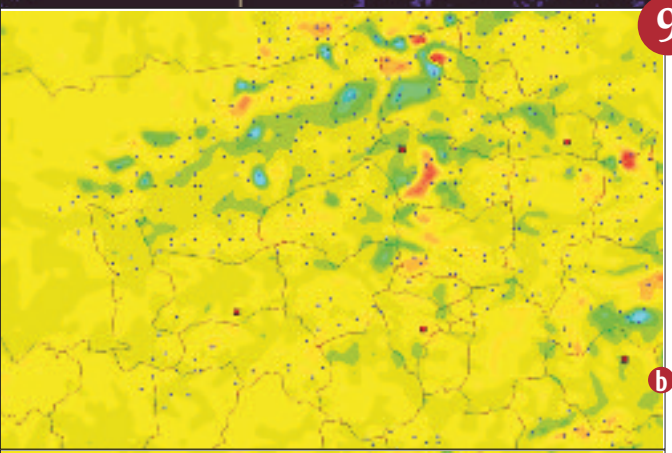
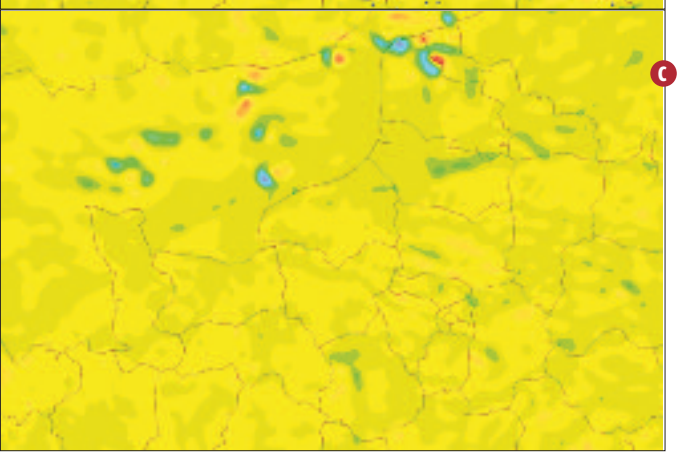
Cumulated rainfalls between 00 and 12 UTC December the 8th, 2007: raingauge measurements (**a**), simulated by an AROME forecast starting at 00 UTC and using initial conditions provided by the ALADIN analysis (**b**), and the AROME analysis (**c**).







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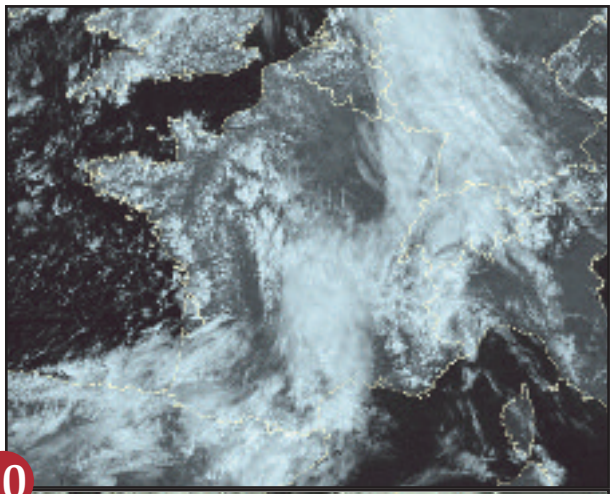
Rain-band associated to a cold front that has occurred in Northern France November the 8th, 2007, at 18 UTC:
(**a**) composite reflectivity pattern, divergence analyses at 950 hPa deduced from the AROME assimilation system (**b**) with and (**c**) without radial velocities (blue-green contours denote convergence; in (**b**): red squares show radars that have been taken into account, blue dots radial velocity profiles that have been considered in the analyses).



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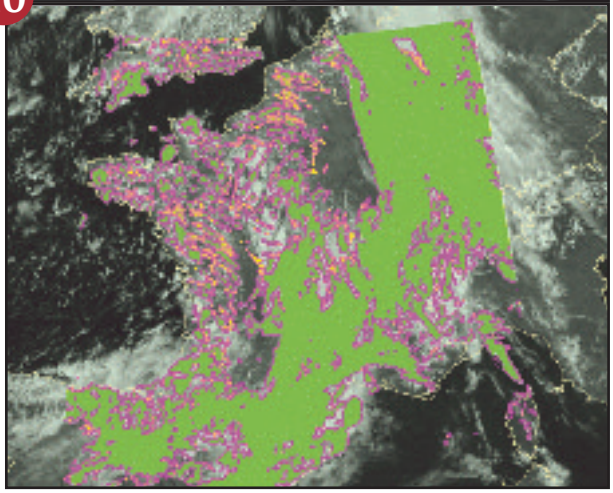
Satellite image in the visible channel for the 07th of August 2007 at 12 UTC.



Superimposed the 12 hours forecast of the Arome model in test based on the 07th of August 2007 at 00 UTC for the total cloudiness parameter.

Tests of a turbulent canopy scheme in AROME

A new Surface Boundary Layer (SBL) scheme developed by GMME has been evaluated in AROME. This scheme, named CANOPY, is integrated within the surface scheme. It consists in adding 6 vertical levels between the soil and the lowest model level (which is currently at 17.5 m in AROME). 2 metres and 10 metres diagnostics are computed using a turbulence scheme on these 6 added levels. Contrary to previous surface boundary layer diagnostics, CANOPY scheme affects all the results of the numerical simulation. Indeed, fluxes send by the surface to the atmosphere are changed.
The scheme has been evaluated during 2 months: January and July 2007, over South-Eastern France. The comparison with the 351 observation stations over the domain is improved as showed in figures (a) and (b) : 2 meters temperature bias and root mean square errors are reduced. AROME SBL scores have now a quality at least equivalent or better than the ALADIN ones. 11

Impact of the use of a new shallow convection scheme in AROME

The horizontal resolution of AROME (2.5 km) is not sufficient to explicitly resolve all types of clouds, and a subgrid representation of cumulus clouds and fractional stratocumulus is still needed. A new shallow convection scheme has been developed in AROME, called "EDKF" (Eddy-Diffusivity-Kain-Fritsch) to improve the mixing in the dry or wet convective boundary layers, associated to the subgrid thermals. This scheme is based on the mass-flux scheme of Soares et al (2004) improved by a formulation of the cloudy entrainment/detrainment of the original Meso-NH scheme (Bechtold et al., 2000). A non-local mixing is also applied to the wind, in addition to the mixing yet realized by the turbulent scheme via the eddy-diffusivity approach.
This new parameterization is currently tested with AROME daily runs and shows significant improvements on boundary layer clouds. A positive impact is also the removal of "herringbone" patterns on the low level wind which is frequently produced in convective boundary layers with weak winds (figure 12). This noisy dynamical structure was relative to an insufficient mixing in the simulated boundary layer, inducing typical "rolls", especially at kilometric resolutions, when eddies are partly resolved and partly parameterized. The new EDKF convection scheme contributes to the mixing relative to the thermals, modifying both the thermodynamical and dynamical profiles. 12

Local forecasting of low visibility conditions on airport

Accurate forecasts of the onset and burn-off of fog or low clouds matter a great deal for airports since the frequency of landings and taking-of is significantly reduced with low visibility conditions. COBEL-ISBA is a single column numerical model (developed jointly with Laboratoire d'aérologie and Université Paul Sabatier) which aims at forecasting fog and low clouds situations. It is in operational use at the Paris-Charles de Gaulle airport since 2002.
In 2007, research activities have mainly focused on the initial conditions of temperature and humidity of this model. These are given by an assimilation scheme which combines local observations and a guess, i.e. a forecast from the previous forecasting cycle. It has been shown that the vertical influence of observations on the initial profiles follows a strong diurnal cycle.
As a consequence, a new assimilation scheme, which takes more into account this variability, has been developed : an Ensemble Kalman Filter (EnKF). The correlation between humidity and temperature uncertainties in the guess has also been accounted for. This work also showed the impact of the initialization of fog and low clouds, and steps have been taken to improve it.
In 2008, work on the assimilation scheme will be pursued, using the numerous data from the field campaign "Paris-FOG", in which COBEL-IBSA took part by providing daily forecasts. The model is being installed on two other airports : Paris-Orly and Lyon-Saint Exupéry. Our goal is to make COBEL-ISBA available for operational use at the Lyon-Saint Exupéry airport by the winter of 2008-2009. 13

Targeted uplink of georeferenced weather information for commercial aircrafts

Selected and launched as part of the 6th Framework Programme of the European Commission, FLYSAFE aims at defining and testing new tools and systems which will contribute towards the safety of flights of all aircraft. This high-level objective is to provide crews with decision aids on the three "threats" which play a major role in accidents, amongst which adverse atmospheric conditions. Météo-France, the Met Office, the DWD (Deutsche Wetter Dienst), the DLR (Deutsche Zentrum für Luft and Raumfahrt) and University of Hannover have developed ground-based nowcasting systems (WIMSs: Weather Information Systems) focussed on weather phenomenons that have an impact on aviation: Cumulonimbus, In-flight icing, Clear Air Turbulence, Wake vortices. The WIMS products are georeferenced weather objects that describe hazardous areas with a polygon associated to several meta-informations such as the severity of the confidence index associated to the forecast. A Ground Weather Processor concentrates the WIMS products and answers aircrafts requests.
The GML-based exchange model that has been put in place and the associated web-features are compliant with the specifications of the Open Geospatial Consortium, which will contribute to the interoperability and ease the operational implementation.
This system will be evaluated in 2008 with two flight-test campaigns in which the SAFIRE ATR42 will be involved. 14

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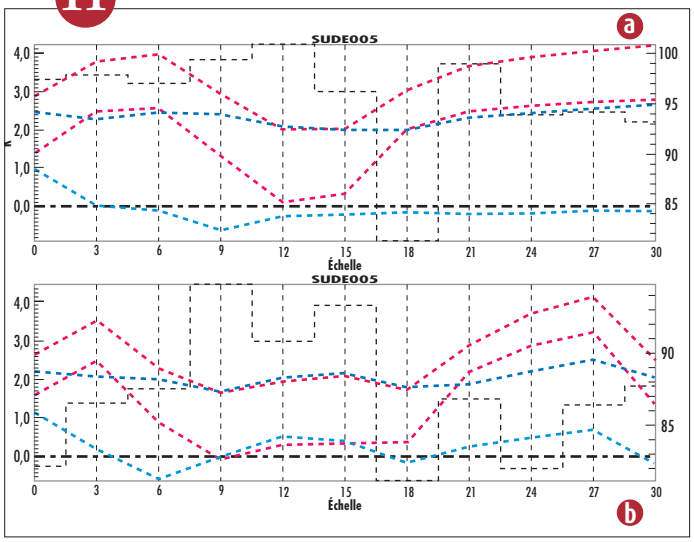

▲ T2m scores for January (**a**) and for July (**b**) 2007: AROME-Reference (pink), AROME-Canopy (blue), root mean square errors on the top, bias at the bottom.

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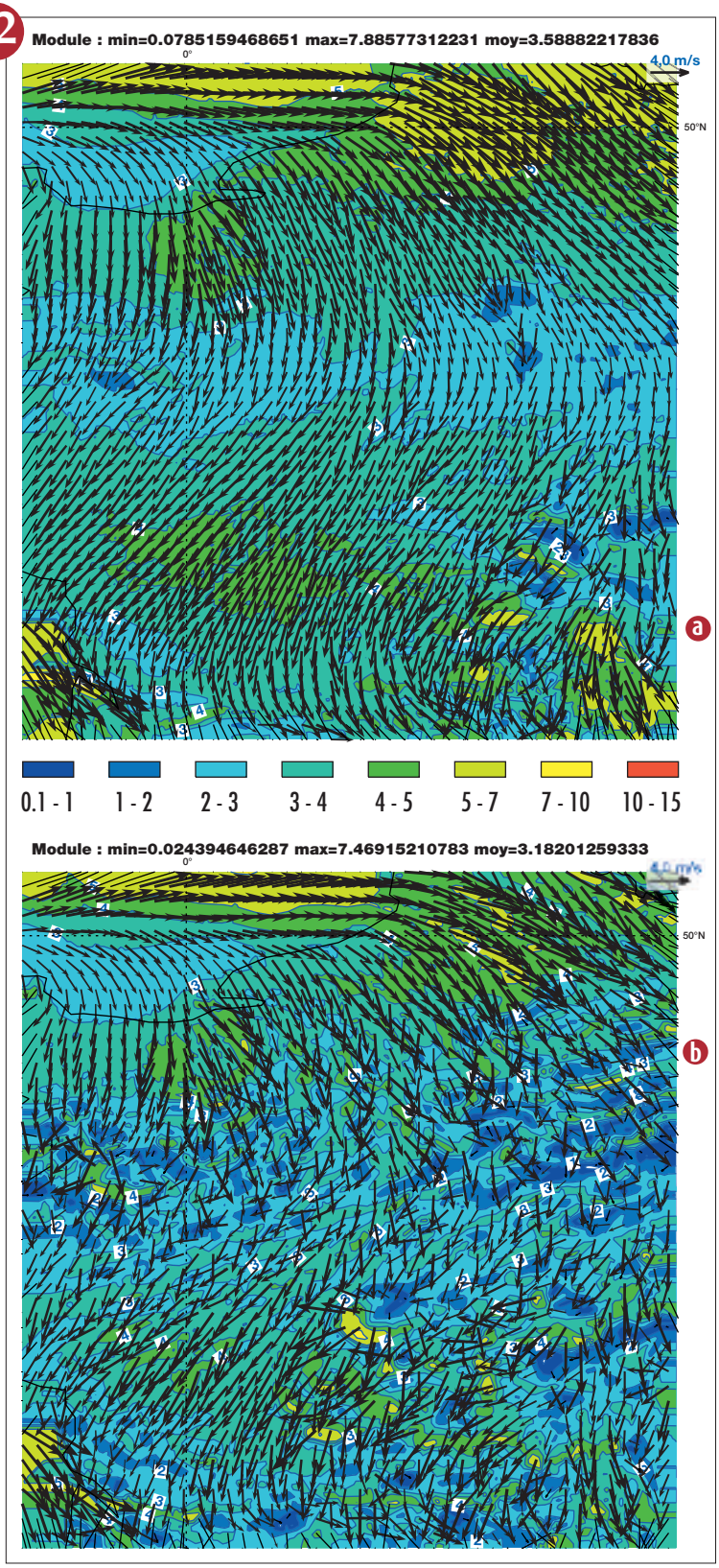
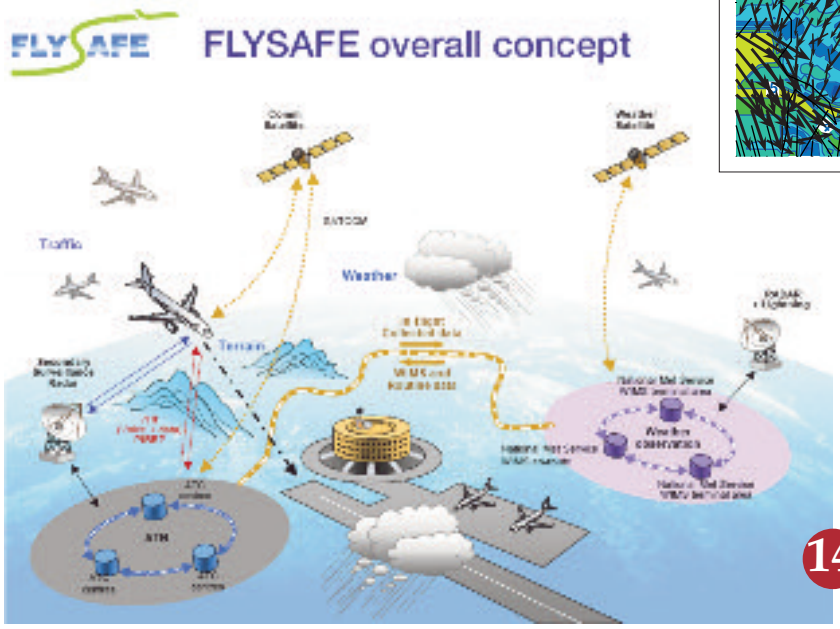


▲ Situation of the 30th of July 2007 at 14 h TU in the North-West of France forecasted with AROME. Module and vector of wind near the ground in the standard version of AROME (without EDKF) (**a**) and with EDKF (**b**).

13

▲ Fog can dramatically reduce airport traffic : persistent fog on the London-Heathrow airport, December 2006. Photo by Tim Ockenden, Associated Press.



◀ FLYSAFE overall concept

14

New generation observations and meso-scale model for aeronautical icing risk detection

The present work is conducted within the scope of FLYSAFE, a 4 year Integrated Project of the 6th framework of the European Commission started in February 2005. In order to increase aircraft safety, one of the main objectives of the FLYSAFE project is to improve weather information supplied to flight crew members. In the frame of FLYSAFE, Météo France is currently improving its nowcasting tool for the detection of in-flight icing areas called SIGMA.
Innovative SIGMA developments include the use of new generation observations such as volumetric radar images and high resolution Meteosat Second Generation satellite imagery, as well as the new Météo-France mesoscale non hydrostatic Numerocal Prediction Model AROME. SIGMA algorithm has been redesigned to be able to take advantage of these new observation input data elaborated by CMS (Centre de météorologie Spatial) and CMR (Centre de météorologie Radar).
Owing to these new observations, more emphasis is put on observations compared to NWP input data, and supercooled liquid water diagnostic is now enhanced.
In parallel to the improved observations, the new NWP model AROME produces humidity and temperature fields with a much better spatial resolution as well as new microphysics fields which are very useful for diagnostics and the forecast of super cooled liquid water areas.
Work on calibration and evaluation of the new SIGMA algorithm will carry on in 2008 with two flight tests campaigns to be held in February and August 2008 in the scope of FLYSAFE. 15

A thunderstorm nowcasting system for improving commercial flights safety

The aim of the European project Flysafe is to improve the New generation Integrated Surveillance System for commercial flights by 2015. The three risks addressed are meteorological factors, collision with the terrain and collision between aircrafts. Among the meteorological phenomena addressed, thunderstorms are handled through the development of a prototype "Weather Information Management System for Cbs", which is led in cooperation with the German DLR, the French ONERA, the British Met Office and the University of Hanover
Météo-France with DLR addresses two spatial scales: the so-called Terminal Manoeuvring Area (TMA) and the regional (i.e. European) scale. The goal is to identify, to describe and to forecast thunderstorms at a one hour range using an object representation, with a high refreshed rate. For the TMA scale, the data used is mainly the advanced Aramis radar network data: 3D scans and their 2D synthesis, and dual polarization data for hail detection; Doppler winds are used for detecting large wind shear. The forecast of maximum thunderstorm cell top is based on thermodynamic profile analysis. For the European scale, a radar mosaic is used, which includes data from neighbouring countries, while handling their time shift. Regarding the evaluation, diagnosed thunderstorm objects are checked against cloud-to-ground lightning data, and against thunderstorm objects diagnosed using satellite data. Forecast thunderstorms objects are diagnosed using a new approach which allows for uncertainty in time and in space.
During 2008, a further evaluation will imply on-board radar data collected during a flight test experiment. 16

Development for a rain occurrence warning product

In order to open a rain occurrence warning service, we have settled and assessed a rain nowcasting suite. The service is specific to each of the 38.000 French municipalities. It combines a warning message one hour before it rains, and gives more detailed information on the forecast rain time series. The forecast method is based on rain patterns movements analysis using a radar mosaic, followed by an extrapolation of the national rain depth radar estimate. Rain depth are translated in space without a change in magnitude. Using the rain depth estimate allows to benefit from its pixel-specific quality data, and the observation quality can hence be dynamically translated in service quality.
It was evaluated with 4 months of data, using the actual rain depth estimate as the reference. The criteria used were user-orientated, and their median values were computed among all the municipalities; the false alarm rate amounts to 37 %, which is acceptable; the non-detection rate is remarkably low (3 %) and the mean anticipation before rain starts is 25 minutes, which is below the objective. This nowcast is actually difficult because it addresses quite low levels of rain. As the quality is not homogeneous over the country, this leads to open the service for only a limited part of the territory.
Plans for 2008 include the use of an improved rain depth estimate, on deepening and enlarging the evaluation, and on improvement addressing the remaining shortcomings. 17

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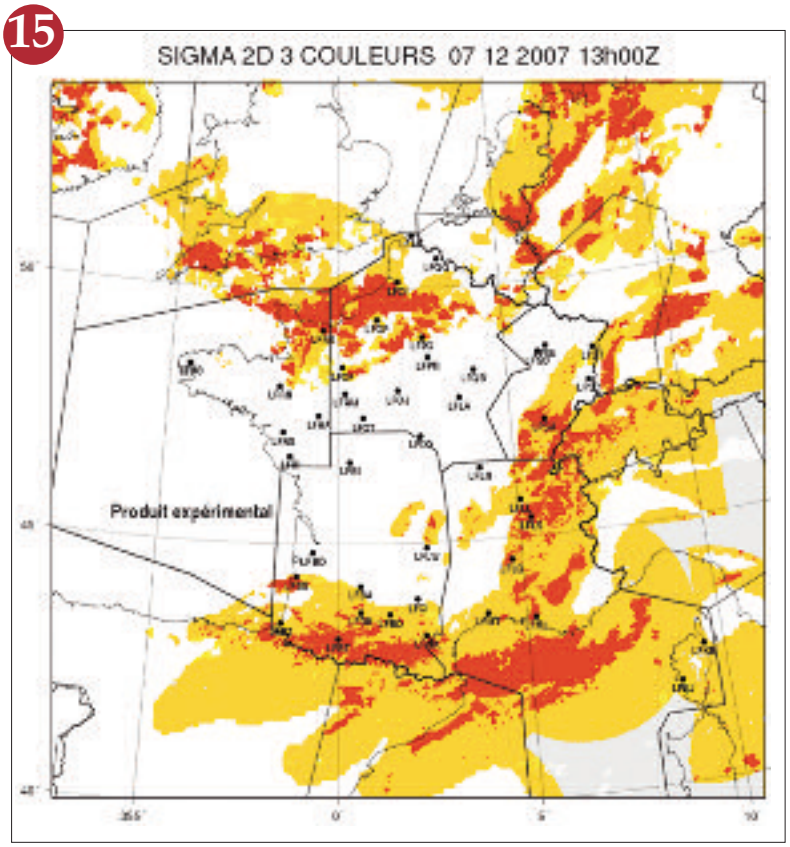

◀ SIGMA icing diagnostic for the 7th of December 2007 at 13 UTC, at 800 hPa, showing an area of moderate to severe icing conditions in red, an area of moderate icing conditions in orange and light icing risk in yellow.

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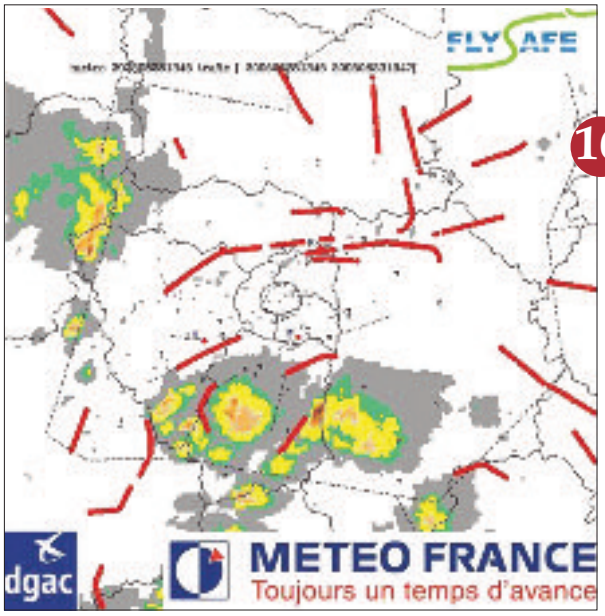

▲ Flysafe and thunderstorms : enabling pilot to safely avoid thunderstorms. On June 2005, 23rd, at 13 h 45, near Paris, aircrafts (tracks shown in red) have a difficult time moving around thunderstorms (shown as green, yellow and red pixels) before landing or even entering it, especially for those in the middle of the bottom half because they did not get an early enough accurate picture of the thunderstorms locations.

▼ Mean values of anticipation over rain start for the rain warning product. Color scheme : black < 30′ < blue < 25′ < green < 20′ < yellow < 15′ < red.

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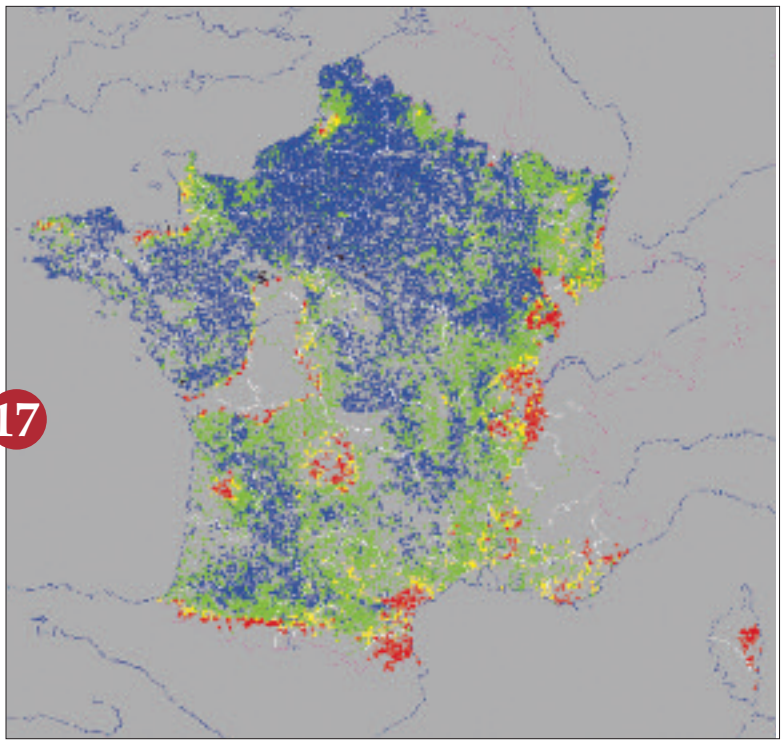


Cyclonic forecasting

A specific cyclone initialization

Météo-France Regional Centre based in La Réunion island watches over the south-west Indian ocean cyclones, an international duty entrusted by WMO. Numerical modelling has become an essential tool to forecast cyclones. The model initialization uses huge amount of data, mainly satellite measurements. However, data actually used in the cyclone body are very sparse (figure a) because of cloud, rain or strong wind contamination. Thus, the cyclone structure and intensity analysis is/are very difficult. Dvorak analysis, that forecasters perform by using satellite imagery, gives reliable estimates of the main cyclone characteristics. Forecasters use satellite imagery for (a) Dvorak analysis which gives main characteristics of a low atmospheric pressure system.

Based on some of these estimated parameters, analytical models can compute the corresponding three-dimensional cyclone structure. Pseudo-observations, deduced from the latter, are assimilated in the Aladin-Réunion model since December 2007. They considerably improve cyclone analyses and forecast positions (figure b). Great benefits are also visible on intensity forecasts. Forecasts about intensity also greatly benefit from them.

In the years to come, the use of satellite measurements in cloudy or rainy conditions will spread on. Another important progress for cyclone forecast is to improve the ocean description, since the ocean is the main energy source for the cyclone development. 18

The effect of La Reunion Island on the tropical cyclone Dina (2002)

The intense tropical cyclone Dina directly affected La Réunion Island on 22 January 2002, causing important material damages. This event is an interesting case study to investigate the interactions between the steep orography of La Reunion Island and a cyclone.

For this purpose, two simulations were conducted with Meso-NH model zooming on La Reunion at a 4 km horizontal resolution:

- the first named “Island” with La Reunion Island,
- the second named “Ocean” in which La Reunion Island has been replaced with ocean.

Both simulations give very similar tracks of cyclone Dina; “Island” shows a very slight northward deflection, which has been observed in reality but in a more pronounced way. The island seems to reduce natural oscillations existing in the eyewall: the cyclone intensity for “Island” is then weaker.

Big differences can be seen on the wind field with, for “Island”, weaker winds and a marked subsidence on the lee of the island. When the strongest winds reached the island, the stream goes over the island rather than around it. This excites an orographic wave, which is associated with the intrusion of stratospheric air, as shown by comparing figures 1a and 1b. This simulated wave, associated with maximum winds, is consistent with the observation of strong winds which have devastated forests in the Cilaos cirque, yet sheltered.

In addition to the understanding of these mechanisms, high-resolution simulations are very useful to estimate cyclonic winds and rainfalls over the whole island. Meso-NH has been able to simulate realistic characteristics of a mature tropical cyclone; in a future work, we will focus on an earliest cyclone life stage: the cyclogenesis. 19

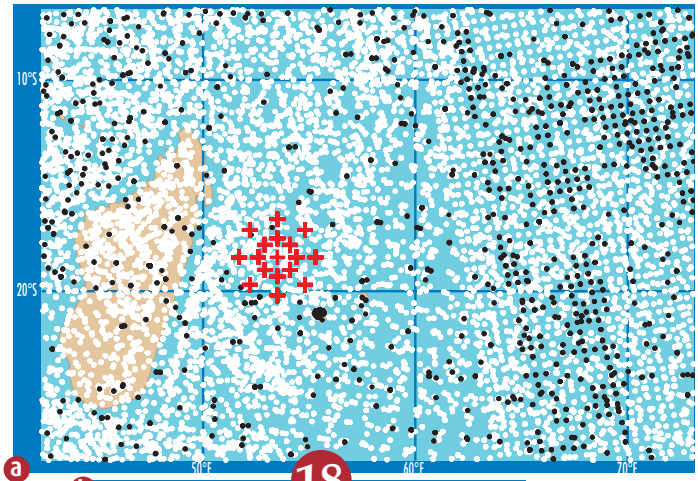
Upper ocean layer response to cyclonic conditions

In spite of significant improvements of hurricanes tracks prediction during the last years, their intensities are still affected by important uncertainties. The poor resolution and the lack of coupled ocean-atmosphere processes in current models are the main reason for this shortcoming.

Hurricanes extract most of their energy from the heat stored in the ocean upper-layers through the surface heat exchanges. The turbulent mixing induced by wind, waves and currents is also an important source of oceanic cooling which has a direct impact on hurricane intensity.

The upper ocean response to the hurricane Frances in 2004 has been studied using an ocean mixed-layer model in the Antilles region (figure a). The comparison of the simulated sea surface temperatures (SST) with the satellite SST data highlights a strong cooling on the right side of the hurricane track and gives a good validation of this model (figure b).

The consequences of such an upper ocean cooling on hurricanes life cycle will be shortly investigated with a coupled ocean-atmosphere model. 20



a - Ground projection of the 26th of February 2007 at 00 UTC observations : white dots symbolize available observations, black ones those actually used by the Aladin-Réunion analysis; red crosses locate pseudo-observations which correspond to the cyclone GAMEDE (three-dimensional wind vortex – at 100 and 200 km rings and at 10 m, 850, 700, 500 hPa levels – and the mean sea level pressure at the centre).

b - Mean direct cyclone position errors as a function of range of four models over the period 29th January 2007 at 0000 UTC - 15th March 2007 at 1200 UTC including Dora, Enok, Favio, Gamede, Indlala tropical systems. Samples are the same for every model and vary from 76 to 50 elements depending on the range. The comparison between "Aladin-Réunion 2008", which uses the new cyclone initialization, and "Aladin-Réunion 2007", which does not, illustrates the benefits of this technique.

a

b

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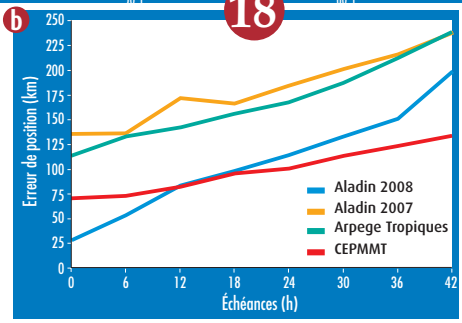
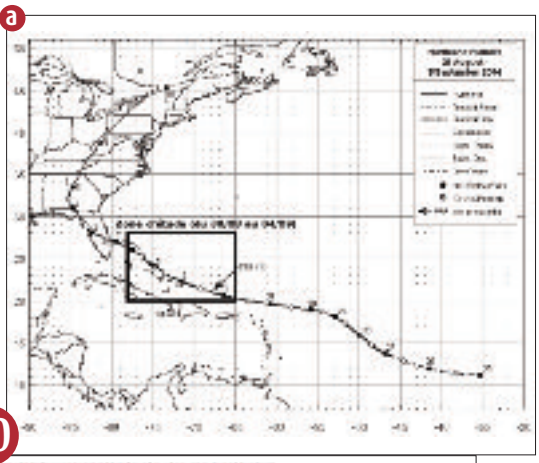


(**a**) Frances cyclone path from 30/08 to 04/09/2004, and comparison (**b**) of observed and forecasted sea surface temperature (SST).

a



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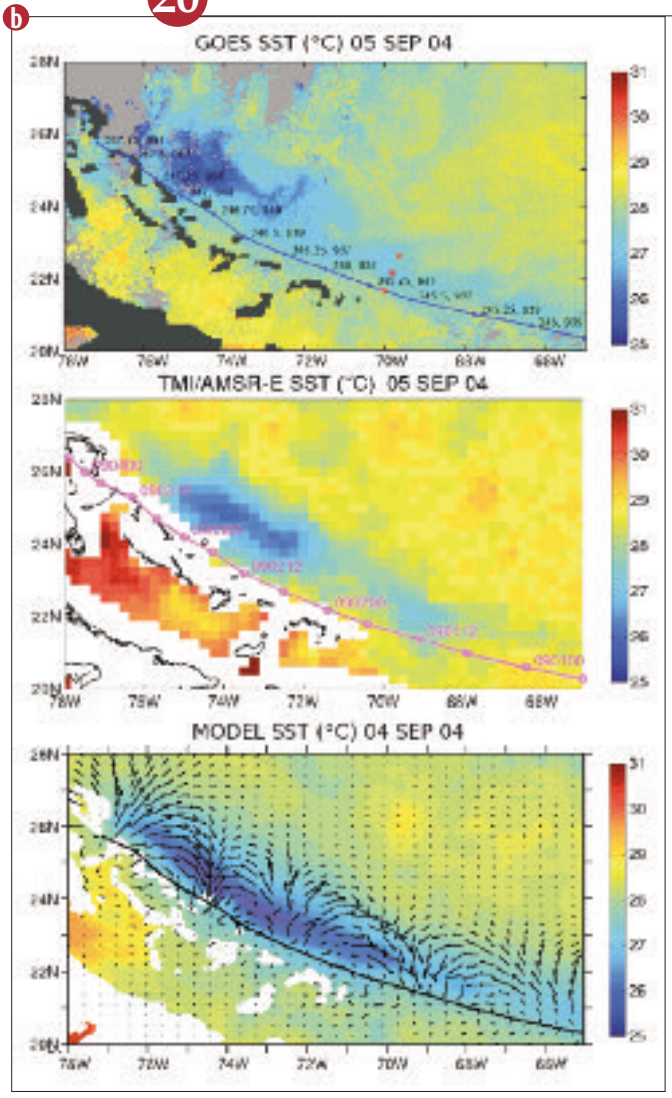
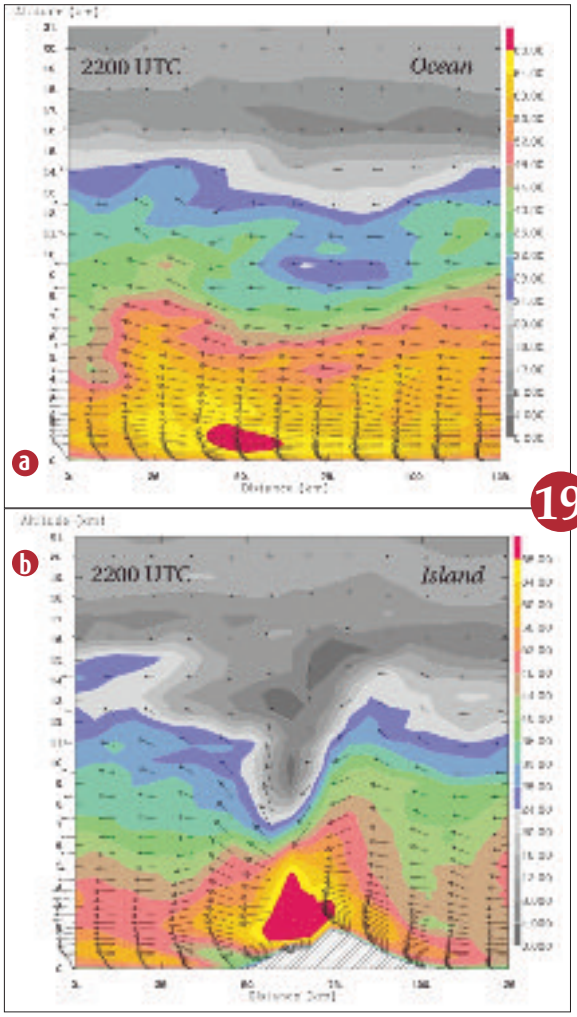




a

b

19

a - Vertical cross section of horizontal wind velocity (coloured isosurfaces in m/s) and wind vectors on 22/01/2002 at 2200 UTC at La Reunion Island location, for the experiment "Ocean" in which the island has been replaced by the ocean.

b - As in figure (**a**) but for the experiment "Island", that means with La Reunion Island orography.

Amma

After the intensive observations periods in 2006, data collected during the AMMA campaign were analyzed all along 2007. A first assessment by the scientific community was made during the Karlsruhe conference in autumn. The first results are very attractive ...

Use of data collected during the AMMA campaign

Observation of the Cold Tongue during the AMMA/EGEE experiments

Every year the Gulf of Guinea is the seat of an intense cooling along the Equator: this is the well-known Atlantic Cold Tongue (ACT). This signal is well developed in the eastern part of the Tropical Atlantic Basin where the thermocline is close to the surface. This cooling begins usually in May and the seasonal variations of the sea surface temperatures (SSTs) reach 5 to 7 °C on average. As soon as this cold anomaly is formed, its northern boundary is in contact with the warm waters of the northern part of the Gulf of Guinea: this generates important north to south SST gradients as well as a strong discontinuity of the sea surface fluxes.

One of the main objectives of the AMMA/EGEE program is to identify the mechanisms which set up the ACT and the coupling processes between the ACT and the African monsoon. The first results obtained from this program concern the strong SST differences observed between 2005 and 2006. These two years are very contrasted in term of ACT formation, since the 2005 ACT is the earliest for the past 25 years; conversely the 2006 ACT is one of the latest. Moreover, this time shift can be related to the delay of the African monsoon observed in 2006 compared to 2005.

The analysis indicates that the ACT cooling in 2005 was suddenly increased after a strong and early wind burst, associated with the trade winds from the southern hemisphere. This event induced an intense mixing of surface waters with colder waters from the upper thermocline south of the Equator. The central Atlantic also experienced strong winds as early as April 2005, which largely preconditioned the surface mixed layers over the whole basin. 1

The VHF wind profiler during AMMA campaign

Between April 2006 and November 2007, the VHF radar which operated on the Nangatchori site (Benin), in order to provide high-resolution observations of the West African Monsoon.

Every hour, this instrument measured the wind profile above its location from 1.6 to 10 km height with a 375 m vertical resolution, giving, in particular, a detailed analysis of the African Easterly Jet and of easterly waves around 4 km height. Together with low level phenomena observed by the UHF profiler, these events have a great influence on the precipitations occurring in the region and their consequences on agriculture, health and economical issues.

Besides, the observation of waves in a very large spectral range has given important informations on the energy budget and on the momentum transport, thus bringing complementary elements about the large-scale circulation and the structure of the atmosphere which characterize of the West-African Monsoon.

Finally, the radar reflectivity and the signal width on the spectrum allowed an estimation of the atmospheric turbulence. Extraction of the humidity component from these parameters has contributed to finely tune the estimation of the water vapour and to complete radiometric measurements.

The VHF profiler has given very satisfactory results during most of its stay in Benin. Hourly measurements have been systematically controlled and sent to the data base of AMMA Campaign. They include the three wind components, radar reflectivity and turbulent dissipation rate. The year 2008 will be dedicated to the scientific exploitation of the radar data combined with other remote-sensing instruments installed on the same site. 2

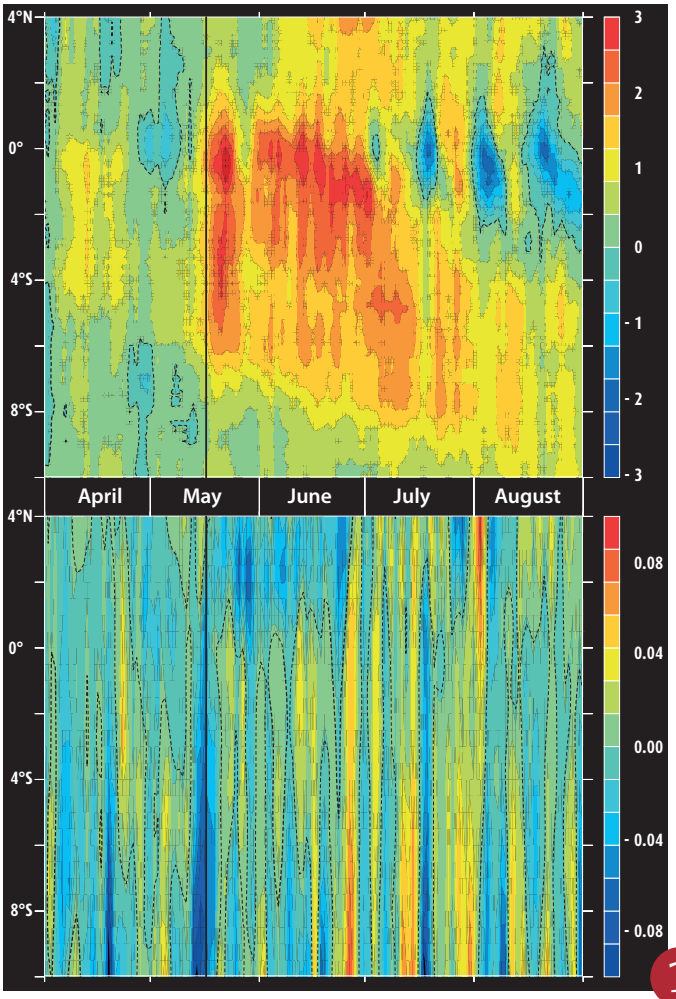
Humidity bias correction of radiosondes during the AMMA campaign

During AMMA SOP, the daily number of radiosoundings performed over Western Africa and transmitted on the Global Telecommunication System (GTS) was multiplied by 3, but some sondes showed systematic biases.

The first objective evaluation showed important dry humidity biases for stations having used Vaisala RS80 type radiosondes, which represents half of the stations of the AMMA domain. The station of Niamey (Niger) performed 8 soundings / day during the 2 periods of intensive observations of June, 2006 (IOP1, June 20-30, 2006 and IOP2, August 1-15, 2006). During these 2 IOPs Vaisala RS92 (good quality) were alternatively launched (00, 06, 12, 18 UTC) with Vaisala RS80 (03, 09, 15, 21 UTC).

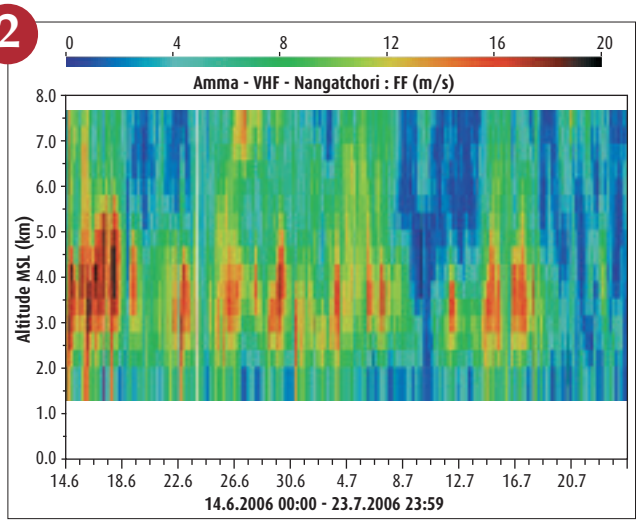
The impact of this staggered sampling is visible in the fig. 1 at Niamey: the dotted line exhibits a serrated shape, where the unrealistic very low values of CAPE correspond to the diagnosis computed from raw RS80 data. A statistically based correction method using the staggered sampling at Niamey is able to diagnose the differential humidity bias between the 2 types of Vaisala sondes. This bias is plotted in fig. 2, where one can see 2 maxima: one in the low troposphere (up to 15 %) and the other one in upper troposphere (above 20 %). The solid line in fig.1 corresponds to the CAPE temporal series with corrected RS80 data; this first correction produces a much more consistent series. This method was applied to different sites and validated with independent coincident GPS data.

After an extensive validation of the methodology, a correction of the whole AMMA database will be performed. 3

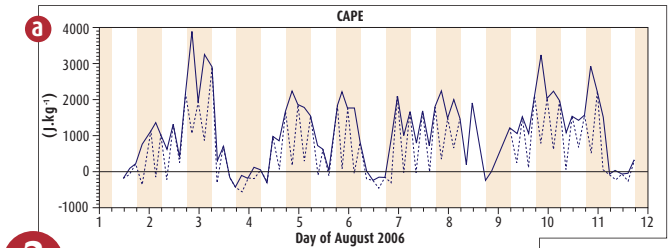


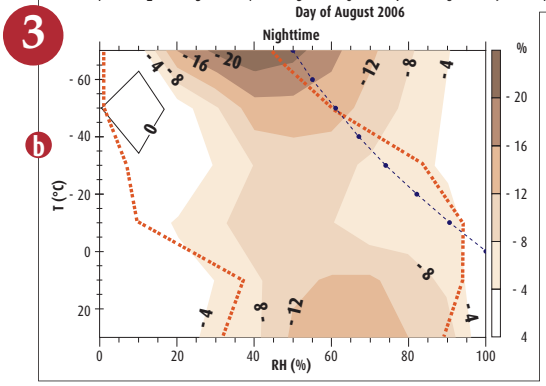
1

Hovmüller diagrams of the difference between 2006 and 2005 for the sea surface temperatures (top) and for the wind stress (bottom). Note that SST differences of nearly 3 °C appear soon after a strong wind burst coming from the southern hemisphere in May 2005.



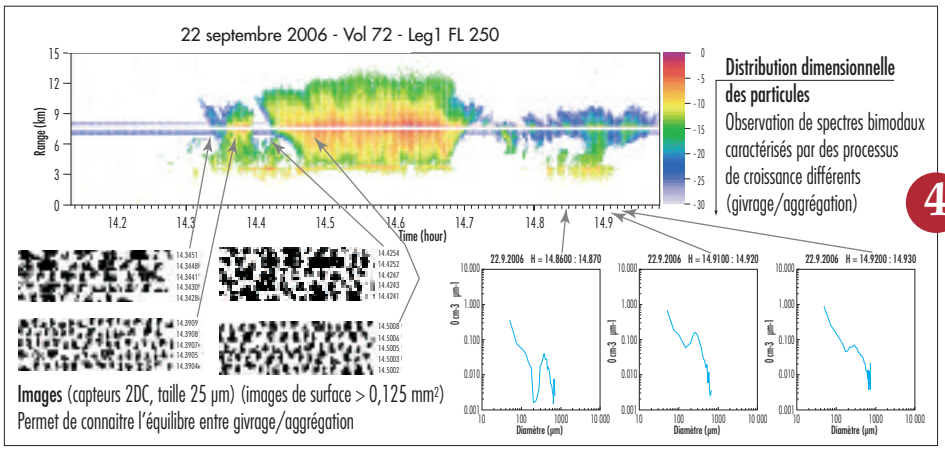
Evolution of the wind speed measured by the VHF profiler between 14/06 and 23/07/2006. Strong time variations occurring between 2.5 and 5 km height are clearly indicated.





a - Time evolution of the CAPE computed every 3 hours from radiosounding ascents at Niamey. The solid line is for corrected data, the dashed line for uncorrected data. Shaded background for night, white background for day.

b - Night humidity bias (in shading) of the Vaïsala RS80 sondes relative to RS92 sondes at Niamey. The axes are temperature and relative humidity as observed by RS80 sondes. Superposed dashed lines correspond to 1st and last percentiles (10 % and 100 % cumulative distribution function isolines respectively). Saturation line relative to ice has been superposed (thin line with dots).

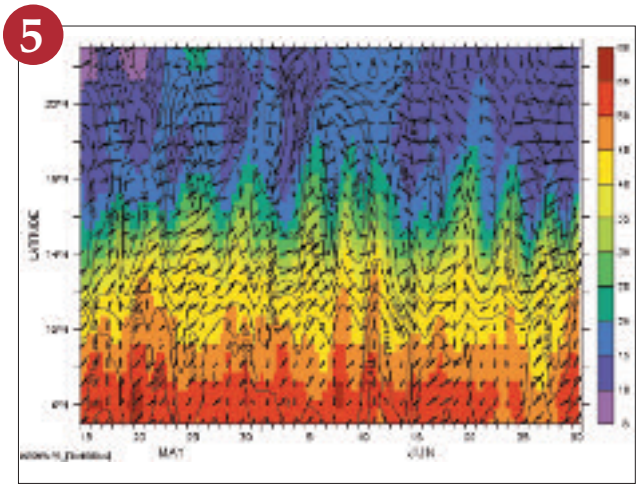


Vertical cross-section of radar reflectivity (colours) characterizing the ice content and the size of particles as observed by the zenith and nadir antenna of the RASTA radar onboard French Falcon 20 within a Cb anvil. The others curves correspond to microphysics in situ measurements.

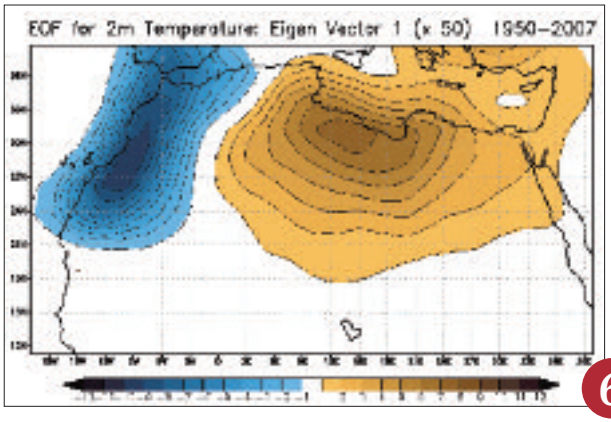
Observation of anvils during the AMMA SOP

The stratiform and cirriform parts formed at the rear of the convective parts of tropical mesoscale convective systems last from several hours up to several days. These widespread anvils have an important impact at large scale, and may modulate the monsoon components due to their radiative forcing.

The AMMA Specific Period of Observations (SOP) in 2006 allowed for the 1st time to document the internal properties of tropical anvils by combining remote sensing measurements (radars, lidars) from surface, aircrafts (microphysics, RALI) and from space (CloudSat, CALIPSO). The objective is, through the treatment of those measurements, to document the dynamical, microphysical and radiative properties of these anvils and cirrus clouds at different scales, and to evaluate their impact on the complex West African monsoon system.
The exploitation of these data have already allowed to document several anvils case studies and the calibration/evaluation of the RASTA radar. The comparison of Cloudsat data with RASTA radar revealed the occurrence of multiple scattering effects in spaceborne measurements. This result may have important implication to quantitatively exploit the Cloudsat measurements and to elaborate climatologies of cloud properties (Bouniol et al. 2007). 4



5 ◀ Time-latitude diagram of ECMWF analysis precipitable water (colours in kg.m^{-2}), mean sea-level pressure filtered to remove diurnal variability (black iso-contours in hPa) and 925 hPa daily wind (black arrows in m.s^{-1}) averaged over 0-10 E for 15 May to 30 June 2006.



6 ▲ Spatial structure of the first variability mode for daily 2 m temperature, calculated from NCEP reanalysis data (1950-2007).

First results from studies led within the AMMA campaign

Monsoon flux pulsation in West Africa: a fine-scale mode of intra-seasonal variability

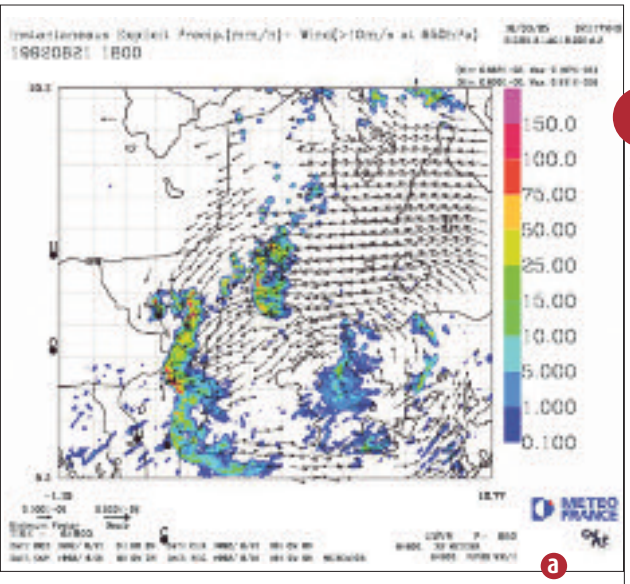
The establishment of the monsoon flux over West Africa has not been extensively explored and previous studies have focused on relatively large time-scales (› 10 days) and spatial (› 2°) scales. For the first time, we focus here on the variability at higher frequency.
When the West African monsoon sets in, iterative northward excursions of the monsoon flux are frequent. Quasi-periodic northward excursions of highly precipitable water are evident north of 14 N in ECMWF analysis (fig. 5). These penetrations last for about two days. They follow a maximum of intensity of the heat low (extension and minimum of pressure) and are concomitant with an intensification of the monsoon flux (fig. 5). Such pulsations are part of the intra-seasonal variability. They are better defined at the beginning and at the end of the monsoon than during the monsoon itself (when interaction with convection leads to different characteristics). These pulsations are stationary or westwardly propagative depending on their interaction with easterly waves. The following mechanism is proposed to explain such pulsations: the development of dry convection induces an increase of the heat low and of the relative vorticity and may explain such pulsations. This leads to an aspiration of the monsoon flux that brings moisture and which explains the increase in precipitable water. The monsoon flux also brings cooler air which tends to destroy the heat low.
Future works will analyse mesoscale simulations and observations in order to confirm the proposed mechanisms. Moreover, the factors that can modulate the characteristics of such pulsations will be explored. 5

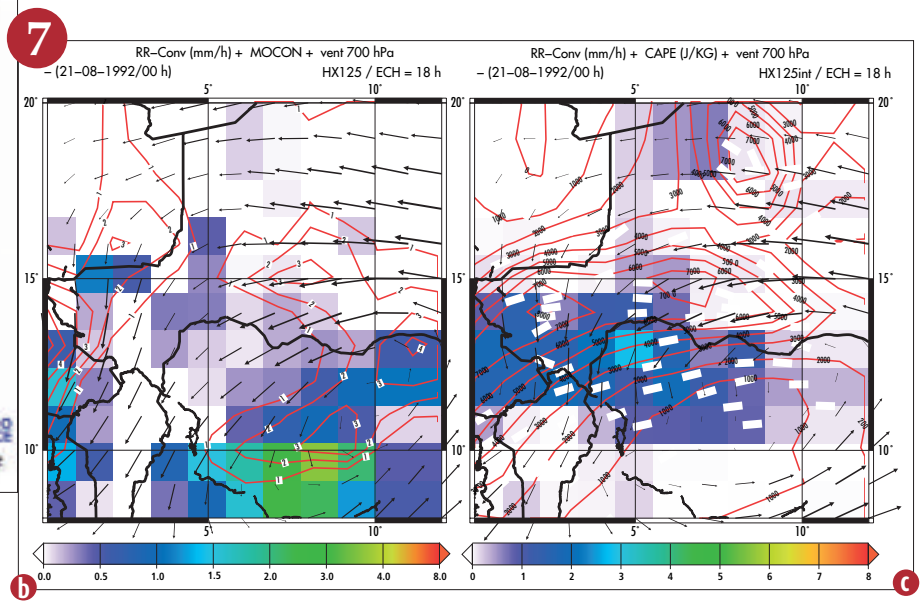
Variability of the African Heat Low and its link with mid-latitudes

In the frame of the AMMA project, a particular regard has been devoted to the Saharian thermal depression (Heat Low), especially during the 2006 summer measurement campaign. The climatic approach of the phenomenon allows to replace the 2006 season among the last 50 years seasonal observations.
By using an Empirical Orthogonal Function method on the daily datas from NCEP and ECMWF reanalyses, we identified a robust mode of variability of the 2 m temperature over North Africa. This mode presents a characteristic time of 20 to 30 days and an East-West dipolar spatial structure, opposing the coastal Morocco and Mauritania region with central Libya (see figure).
By isolating the successive maxima and minima during the 58 last years (1950-2007), we reconstructed the global daily atmospheric fields leading the extrema of this mode. These composite fields show a relation between the Heat Low and mid-latitude conditions. Indeed, the 4 summer weather regimes established by CERFACS, which are equally distributed in average, are fairly well discriminated when Heat Low phases are considered. The positive phase (colder western part) corresponds, in 75 % of the cases, to a blocking or NAO- regimes while the negative phase corresponds to NAO+ or Atlantic ridge in the same proportions.
Knowledge of the links between Heat Low and weather regimes may allow an increase of the prediction potential in this region, particularly if, in the same time, the role of the Heat Low in the monsoon behavior is assessed more deeply. 6

Validation of convective parametrization schemes on western Africa with the ALADIN-CLIMAT model

In large-scale models, mean effect of convective processes on a grid-mesh is computed in a simplified representation called convective parametrization. The behaviours of different convective parametrization schemes available in the global ARPEGE-CLIMAT model are studied, focussing on western Africa.
Then, comparisons are made between fine-mesh simulations in which convection is explicitely computed (non-hydrostatic Méso-NH simulation with a 5 km horizontal grid-mesh) and simulations run on the same horizontal area, with the same initial and lateral conditions, with the ALADIN-CLIMAT Limited Area Model (LAM), in which convective processes are parameterized. The case under study is that of a squall line observed on western Africa in August 1992 during the Hapex-Sahel experiment.
The results obtained in an ALADIN-CLIMAT simulation with a 125 km horizontal grid-mesh exhibit the different behaviours of the tested parametrization schemes and the improved precipitation pattern obtained with some of these schemes. Development of relevant diagnostics and tests on the horizontal grid-mesh used in the LAM are planned, before applying the methodology to cases observed during the AMMA field experiment (summer 2006).
These studies participate in improving current and under development parametrization schemes. 7

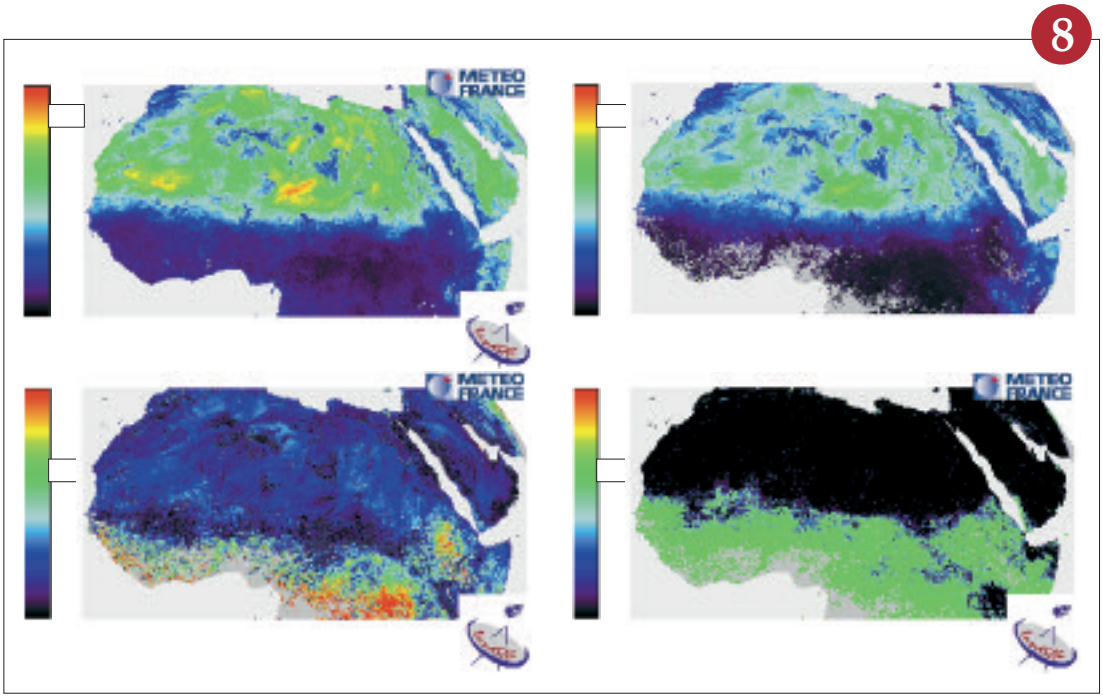




▲ **a**) Explicit precipitation field simulated with the 5 km horizontal grid-mesh model over western Africa (colours). Arrows: winds at 650 hPa. 21 August 1992, 18 UTC.

b) Convective precipitation field (colours) and winds at 700 hPa simulated with ALADIN-CLIMAT over the same domain. Standard version of the physical package (ARPEGE-CLIMAT V4). Convection triggering is determined by the parameter described by the red isolines.

c) Convective precipitation field (colours) and winds at 700 hPa simulated with ALADIN-CLIMAT over the same domain. Improved version of the physical package. Convection triggering is determined by the parameter described by the red isolines.



▲ Comparative maps of visible albedos for MSG (top left) and MODIS (top right) for the period from 12 to 26 July 2006 for the AMMA zone. The magnitude of relative errors (bottom left) is explained by the relative bad/good ? quality of MODIS product (bottom right).

The SAF programme on Land Surface Analysis: an operational production extended to Africa

The SAF (Satellite Application Facility) programme on Land Surface Analysis (LSA) produces operationally surface variables from the observations of MSG and EPS EUMETSAT satellites. LSA SAF is placed under the control of EUMETSAT who gave responsibility for piloting and for the production to the Institute of Meteorology of Portugal. The consortium encompasses 8 cooperative entities with 4 representing National Meteorological Services (Belgium, Finland, France, Portugal). The project will move into its operational phase in March 2007.

The project includes 5 types of products (operational, internal operational, candidate operational, demonstrative, experimental) generated at the nominal spatial resolution of MSG. Operational products only are available for public access over the MSG disk (www.landsaf.meteo.pt). They are the albedo, the surface temperature, the short-wave and long-wave radiation fluxes, and the snow cover.
CNRM is responsible for albedo and down-welling surface short-wave radiation flux. Their validation is achieved through a comparison with in situ measurements and equivalent satellite products. As for Europe, this latter was extended to spatial domains, the kriging network RADOME for radiation flux and MODIS imagery for albedo. An utilization of the albedo within SURFEX was initiated. An special effort was made for a validation over Africa, taking benefit from in situ data from the AMMA programme.
In 2008, it will consist to initiate the merging between MSG and EPS data, with, as a first goal, to extend the geographic coverage to high latitudes for all products, and to combine optimally the geostationary and polar observations for albedo over the MSG disk. 8

Meteorological process

One cannot understand and forecast meteorological process without an excellent knowledge of the atmospheric mechanisms.

All along 2007, works on cyclogenesis went on, some significant progress were made around carbon cycle modelling, ...

Cyclogenesis and previsibility studies

Critical regions of upper-tropospheric disturbances regeneration

Mid-latitude synoptic-scale anomalies appear in the upper troposphere and evolve along the jet streams. These upper-tropospheric anomalies are usually strongly stretched due to the action of the deformation field of the jet along which they evolve, leading to a loss of their energy. However, the same anomalies can be temporarily regenerated if they cross the jet. Jet crossing occurs preferentially in specific points along the jet axis, called critical points, as shown by the figure.
In each figure panel, the same green triangle appears. It is a remarkable point of the jet and more precisely it is a saddle point of a new key field called effective deformation which is represented by its positive values in light red shading. Two simulations using a barotropic model on the sphere are compared, one with all the terms (the nonlinear case) and the other with linear terms only (the linear case). In the nonlinear case, the perturbation is first strongly stretched on the southern side of the jet, then it crosses the jet around the critical point. At this moment, the perturbation is characterized by a contraction stage leading to an increase of kinetic energy. In the linear case, the perturbation remains on the southern side of the jet, it does not cross the jet and it keeps stretching which results in a strong loss of kinetic energy.
To conclude, the underlined mechanism depends on the combined effects of the effective deformation and nonlinearities and is not related to any linear instability. 1

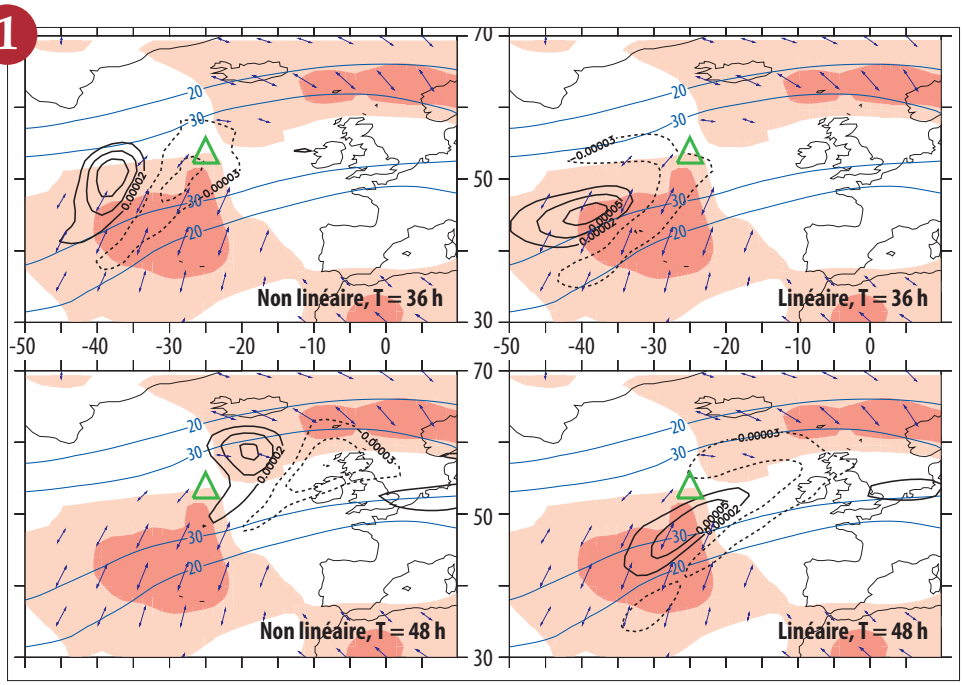
Towards an objective method to define humidity anomalies

Synoptic-scale depressions can be described with the potentiel vorticity field, that summarizes all the dry dynamical aspects, and a field that quantifies humidity. Whereas moisture is classically considered as modulating the growth of North-Atlantic depressions, the effect of water –more precisely its phase changes– on Mediterranean storms seems to be much more central. A description aiming at a better understanding of the evolution of these synoptic systems must therefore include information about moisture.
Newly defined methodologies at CNRM, namely wavelet decomposition for extracting tropopause folds, have been extended to humidity fields: specific or relative humidity or even other derived fields. Finding all the anomalies in a field requires two steps: firstly, the large-scale environment should be separated from all the anomalies, each of which has then to be isolated from the others. The first step has been refined in order to relax some assumptions made on the anomalies properties, that hold for upper-level potentiel vorticity but are not relevant for moisture fields. This leads to add a small portion of the large-scale of the total field to the small-scale in order to build the "anomalies" field.
In the near future, effort will be made to use this field to define individual anomalies. 2

The wavelet extraction improves the coherence of potential-vorticity structures

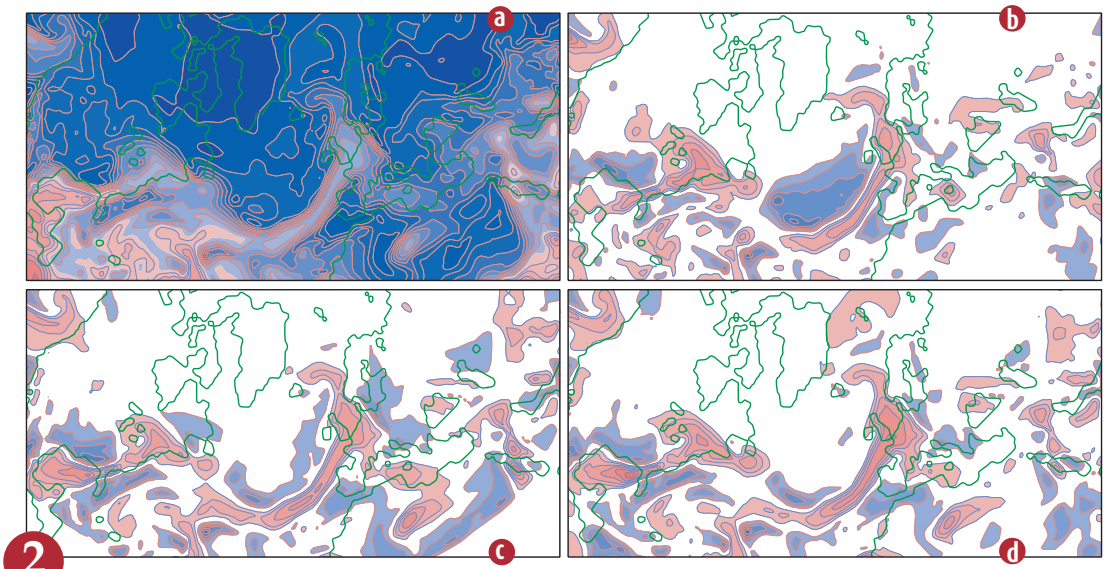
Mid-latitude storms often result from the interactions between a low-level vortex and an upper-level one. The inversion of potential vorticity provides a technique to attribute the meteorological fields (wind and temperature) to each vortex, and to study their interactions. The results depend on the technique used to extract these vortices. We show hereafter that the new objective method of extraction based on wavelet theory gives a structure that is more coherent in time than the more classical and subjective monopolar extraction.
If an anomaly is extracted at some initial time, its evolution may be predicted as the difference between the simulation with the initial anomaly and the simulation without it. The result is a predicted anomaly. At the same final moment of the forecast, another anomaly may be extracted from the predicted total field. If the anomaly interacts only with its environment, both anomalies must be similar. This criterium is a way to assess the performance of the extraction. From the figure, it is obvious that the wavelet anomalies, predicted and extracted, are quite similar, which is not true for the monopolar anomalies, which is much dispersed by the model simulation. This property makes the wavelet extraction preferable for the study of the interactions leading to storms and also for its numerical applications. 3

1



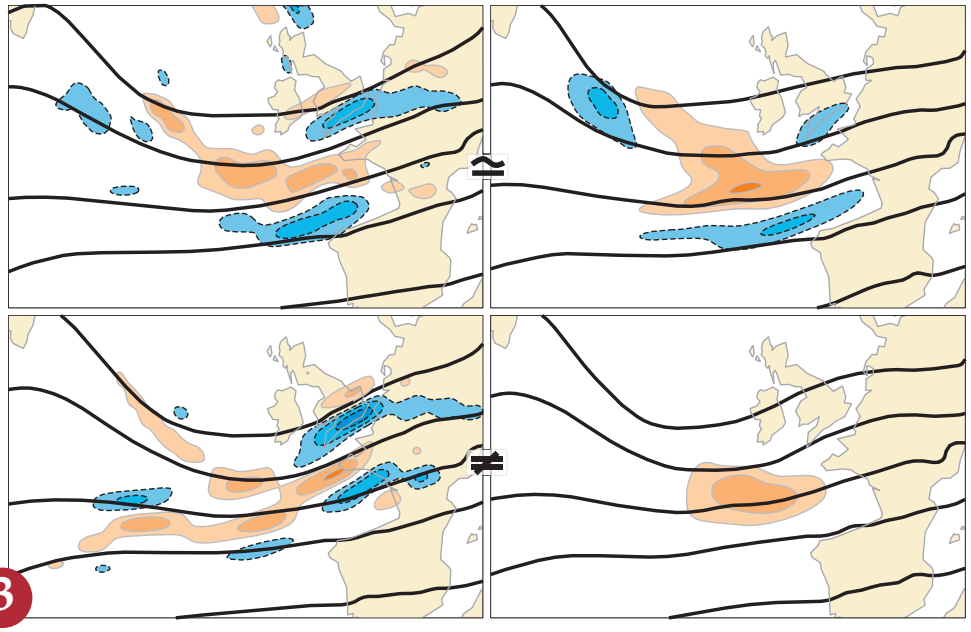
Nonlinear (left) and linear (right) evolution of a synoptic-scale perturbation moving along a jet with a critical point represented by a black triangle about 25° W, 54° N. Upper and lower panels correspond to 36 h and 48 h after the initial time. Blue contours are the jet wind speed isolines (interval: 10 m/s for values greater than 20 m/s). Light red shading, black arrows and heavy black isolines represent respectively regions of positive effective deformation (interval: 5 10^{-10} s^{-2}), the dilatation axes and the perturbation vorticity (interval: 2.5 10^{-4} s^{-1}, dashed and solid contours for negative and positive values).

2



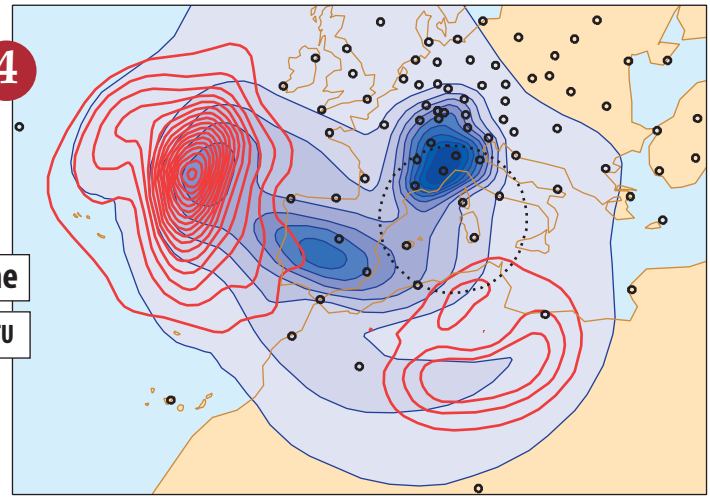
Several decompositions of the specific humidity field at 850 hPa, 01/12/2001, 00 UTC, contour interval : 1g/kg.
(**a**) total field (blue below 10g/kg, red above 10g/kg);
(**b**) 8-day high pass filtered field component (blue below -1g/kg, red above 1g/kg);
(**c**) small scale wavelets component of the field (same contouring as in b),
(**d**) the set of all anomalies extracted with the fully extended algorithm (same contouring as in b).

3



Coherence between the predicted anomalies (left) and the extracted anomalies at the same time (right) for the wavelet extraction (top) and for the monopolar extraction (bottom). The study focuses on the upper-level vortex associated with the 27 December 1999 storm. The initial extractions are made from the fields on the 27th at 06 UTC, and from those in the 6 h forecast so that the final extractions are made on the 27th at 12 UTC. The shown fields are: the relative vorticity of the anomaly at the 350 hPa level (interval 5 10^{-5} s^{-1}, positive in orange shading, negative in blue shading), and the geopotential of its environment at 350 hPa (interval 20 damgp, bold line). With the wavelet method, the anomaly are more coherent than the monopolar one.

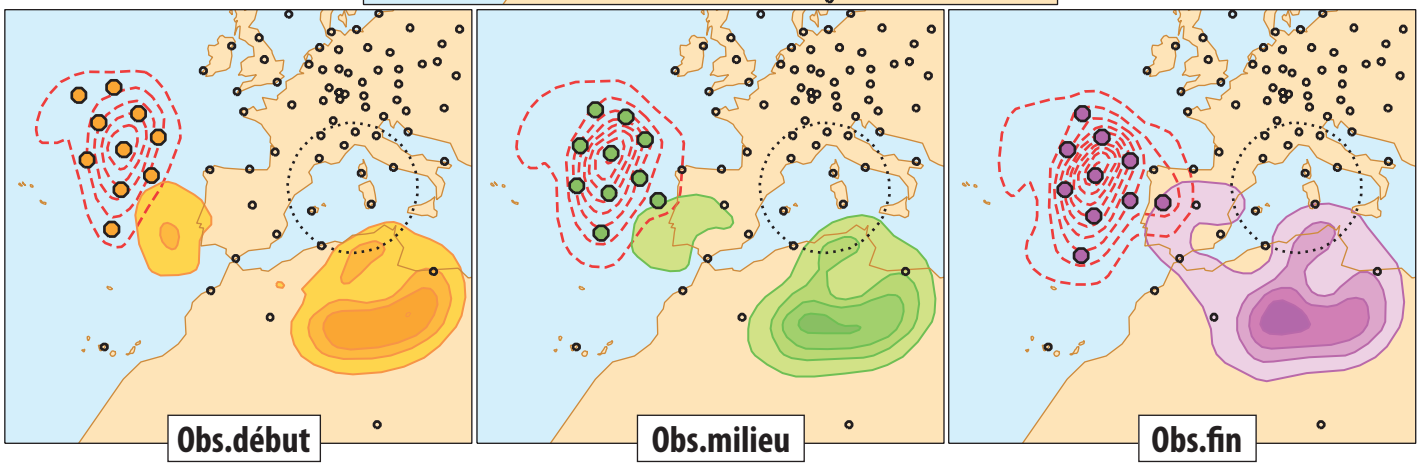
4



Routine

20 juin 2007 à 21 h TU

Top chart.
Blue shading: areas of need calculated for the case of 2007 June 21 at 00 h UTC, taking into account both the sensitivity of the forecast to its initial conditions and the uncertainty on the guess;
Red shading: same sensitivities plus that to the analysis of routine radiosoundings (RS). These areas are valid 15 hours before the event (forecast valid for June 21 at 12 UTC in the region shown with a dotted circle).

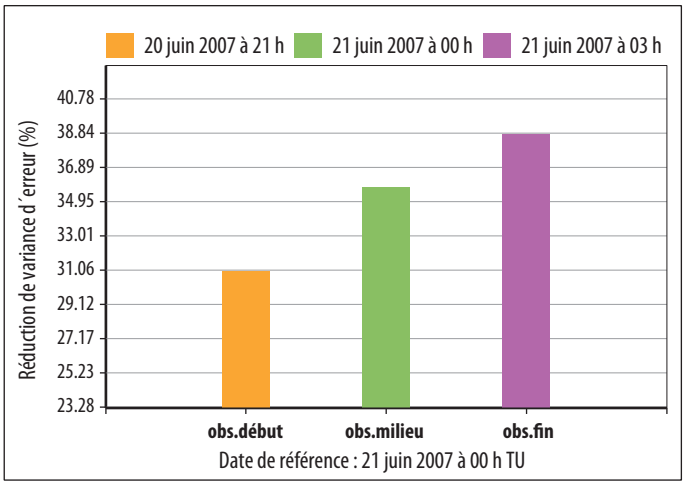


Obs.début
20 juin 2007 à 21 h TU

Obs.milieu
21 juin 2007 à 00 h TU

Obs.fin
21 juin 2007 à 03 h TU

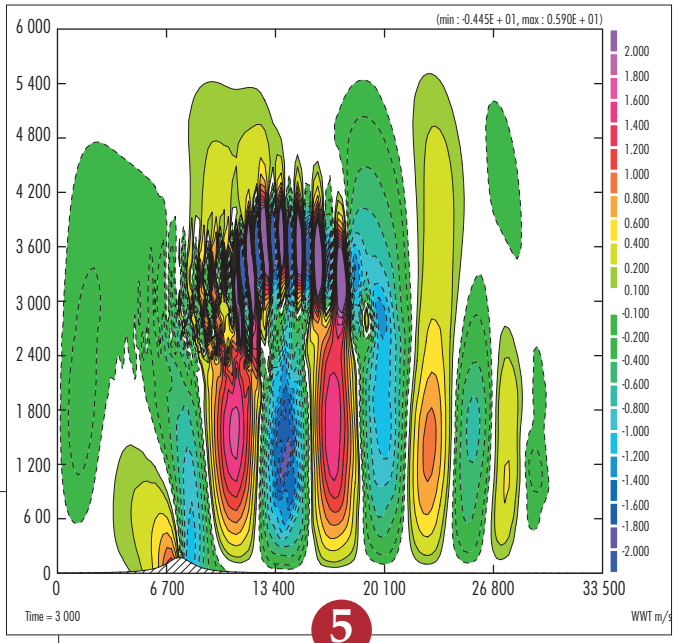
Histogram.
Prediction of the error variance reduction for the function with respect to which the sensitivity calculations were performed and due to the addition of the adapted RS (% of the reduction induced by the assimilated routine network against the first guess). These added RS were deployed with a variable delay within the assimilation time window, as shown in the legend of the histogram (middle and end, respectively).



Bottom charts.
Areas of residual need resulting from the assimilation of the extended network: routine RS plus additional RS drawn in the same colour (orange, green or purple) and with the same name (obs.start, obs.mid or obs.end) than on the histogram. The valid time is given on the figure. Dashed red contours depict the areas where uncertainty is reduced due to the extended network.

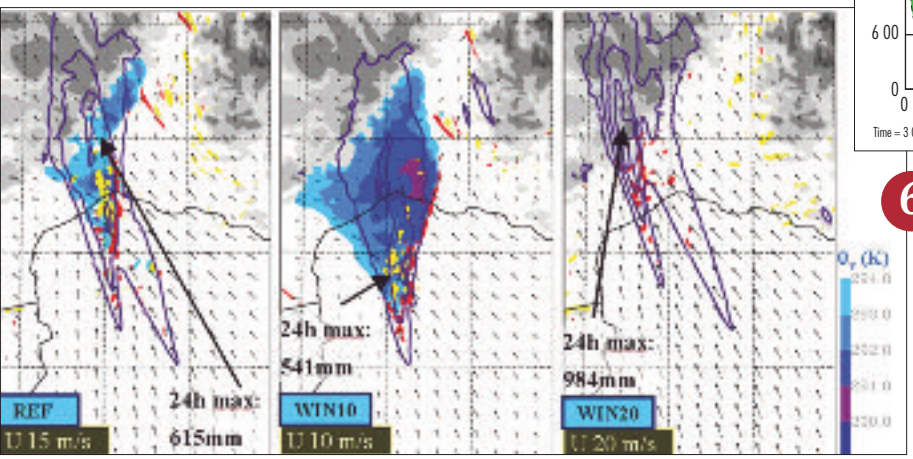
Prediction of the benefit of optimally located observations

Adaptive observation consists in the addition of observations in so-called sensitive areas computed to improve (locally) a numerical weather prediction. Linear techniques (using adjoint calculations) have been designed to investigate the sensitivity of forecasts to their initial conditions (ie. analysis, or the observations being assimilated to compute the former).
To design the most profitable deployment of additional observations, a quantitative tool is used in ARPEGE that compares the expected benefits from a variety of simulated additional observation networks (see histogram on the figure). The method (called KFS) computes an estimate of the uncertainty residing in the analysis (which is the initial conditions of the forecast of interest). Part of the code comes from ECMWF.
The national CYPRIM project focuses on large scale aspects of Mediterranean cases representative of heavy rainfall events. The first steps of the KFS computation deal with the routine observations only. These results may be used to design the extra deployments to be evaluated during the last steps of the KFS. The figure shows the expected benefit of three deployments (10 soundings each, all simulated, displayed on the histogram). It further shows the zones of needs where the addition of these observations is likely to be beneficial to the quality of the forecast. This shows a June 2007 case, using only TEMP (radiosoundings, RS) observations. The locations of the 3 deployments are similar, they differ primarily by the deployment time: either early (case shown), middle or late in the 4D-Var assimilation time window. The latest deployment promises the highest impact, which is consistent with the 4D-Var theory. 4



5

Vertical cross section of the vertical velocity (in $m.s^{-1}$) after 3000 s integration for orographic trapped waves induced by the hill in a west to east flow. On the left with the previous/former advection schemes, on the right with the new ones.



6

Sensitivity experiments to the low-level flow speed: Cold pool (virtual potential temperature in colour scale, K), 24 h accumulated precipitation (purples lines: 50, 250, 500 and 750 mm; the maximum is indicated), updrafts (red areas, > 1m/s) and downdrafts (yellow areas, < -0.5m/s) at 1000 m, wind vectors at 10 m (black arrows, m/s) after 48 h for the reference simulation (REF) and for the experiences of sensitivity to the wind speed of the low-level flow with a slower jet (WIN10) or a faster one (WIN20). The relief is represented in grey scale above 500 m.

Meso scale events

A new advection scheme for Meso-NH

Meso-NH, is a research model used to simulate real and academic mesoscale flows, with a scale resolution currently ranging from 50 km to 10 m, which, until now, used standard transport algorithms, associated to a "leap-frog" time stepping scheme. But the drawback was a strong time step limitation which prevented getting accurate results. Therefore, one major objective was to increase the time step of Meso-NH with a higher quality advection scheme.
A new Eulerian advection scheme has been successfully implemented for scalar variables, associated with a "forward in time" temporal scheme for the advection terms and a fourth order centred advection scheme for momentum. The impact is highly positive in terms of accuracy and stability (figure). But the increase of the time step should become more efficient once the "leap-frog" temporal scheme will have evolved to a new temporal scheme for the overall model. 5

Idealized modelling framework for quasi-stationary convective systems

South-eastern France is prone to heavy precipitation induced by quasi-stationary mesoscale convective systems. An idealized modelling framework has been set-up in order to study the sensitivity to low-level conditions on the location and the intensity of these systems.
Atmospheric simulations are performed with the MESO-NH research model at 2.5 km for an idealized moist unstable flow, and using real topography. Thus, an unstable low-level jet pointing towards the Cévennes is imposed.
The reference simulation succeeds in simulating a quasi-stationary convective system. Precipitations spread from the Sea to the Massif Central. The evaporation of part of the (falling) precipitation induces a cold pool under the system. The low-level jet impinges the leading edge of this cold pool, inducing upward motions that trigger new convective cells.
The characteristics of the low-level flow over the Sea (humidity, wind speed, instability) are varied. The figure shows the sensitivity to the wind speed: the slower the flow, the more upstream the system is located. Also, the drier the environment is or the more unstable the flow, the more upstream the system is located. Different lifting mechanisms compete to explain the specific location of the systems (orographic forcing, cold pool, low-level convergence due to relief).
In future work, we will continue to explore the predictability associated to these systems through this idealized framework by investigating more systematically the low-level conditions; the impact of the relief and the Mediterranean Sea will be assessed too. 6

The programme ECOCLIMAP-II: a new land cover classification over Europe

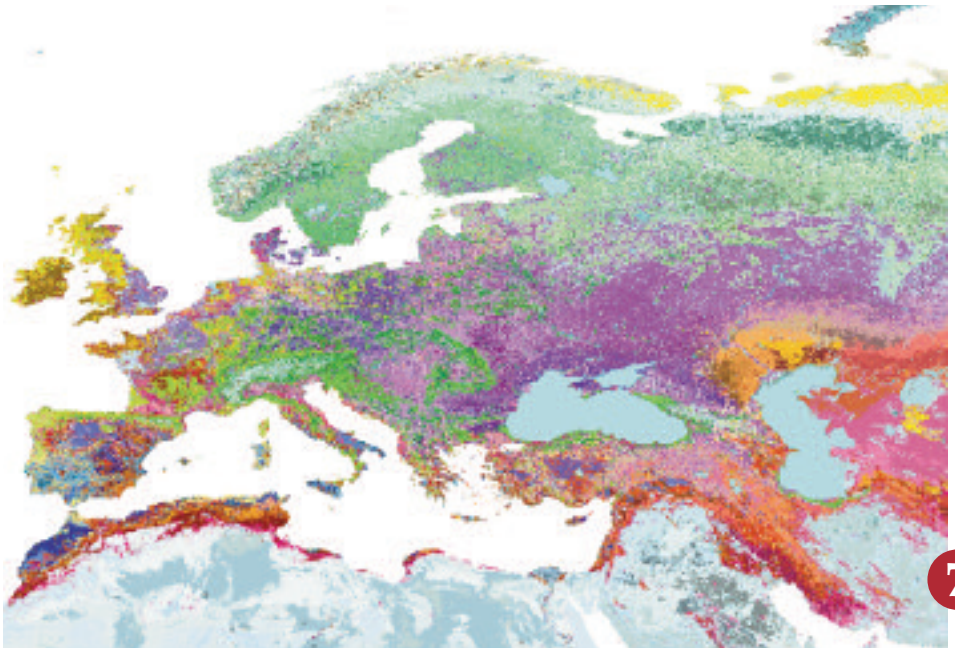
The ECOCLIMAP programme encompasses a land cover classification and a database of surface parameters inferred from the classification based on look-up tables.
A new classification of the vegetation in areas thematically and functionally homogeneous has been achieved over Europe. The initial classifications are Corine2000 at 100 m for most of the domain and GLC2000 at 1 km (Global Land Cover 2000, 1 year of SPOT/VEGETATION data) for the rest of the domain. They have been split, based on an automatic classification, considering 7 years (1999 to 2005) of data of the vegetation index SPOT/VEGETATION with a disregard this time to climate zoning. This has led to 273 classes. The criteria account for independent factors from vegetation cover like the climate or the agriculture modes implemented at the regional level. An independent validation considered the statistical data sets issued from agricultural practices in France.
The classes are disaggregated in one or several fractions of vegetation types from ISBA. This work relies in the new version on the search of pure pixels at 1 km of a vegetation type. The variable to disaggregate is the leaf area index, which is less contaminated by soil effect than the vegetation index. The leaf area index and albedo are the more relevant variables of ECOCLIMAP. In the new version, they are derived from the combination of the 1 km products MODIS and VEGETATION (European project CYCLOPES).
The follow-on of this work is the implementation of test cases in SURFEX in order to assess the impact of the new database ECOCLIMAP. 7

Spatial variation of atmospheric CO_2: the CarboEurope Regional Experiment Strategy CERES

A methodology to simulate the spatial variation of CO_2 within the Atmospheric boundary layer (ABL) based on observations has been developed during the CarboEurope Regional Experiment CERES. This year, a lot of effort has been devoted to the numerical interpretation of the data collected during the CERES 2005 field campaign.
Five atmospheric meso scale models, including an interactive simulation of CO_2 between the surface and the atmosphere, have been evaluated against a large variety of data (figure 8): flux of CO_2 close to the surface, ABL diurnal evolution in the Landes forest, spatial variation of CO_2 in the ABL as observed by the Piper Aztec instrumented aircraft. The 5 meso scale models showed a good ability to simulate CO_2 assimilation over a wheat field (a). However, a large scatter was found in the simulations of CO_2 observed by the aircraft within the ABL (c) as a result of large differences noted in the simulation of the ABL evolution (b).
Two new experiments have been conducted during April and September 2007 in order to sample different meteorological conditions and crop developments. 8

Continental carbon cycle modelling

A new option of the CNRM land surface model, ISBA (Interactions between Soil, Biosphere and Atmosphere) was developed in order to represent the terrestrial component of the carbon cycle. The new model, referred to as ISBA-CC (Carbon Cycle) simulates the main carbon fluxes exchanged between the continental surface and the atmosphere (photosynthesis, autotrophic respiration and heterotrophic respiration), as well as the stocks and the fluxes of carbon in the vegetation and in the soil.
The model was validated for 26 sites of the FLUXNET network located at middle and high latitudes of the Northern Hemisphere, which provide measurements of energy, water and carbon fluxes. The model reproduces well the main properties of the diurnal and annual cycles, as well as intra-seasonal and inter-annual variability. It also favourably compares with other terrestrial carbon models, among which the ORCHIDEE model of IPSL.
The ISBA-CC model will further be coupled with the general circulation model of CNRM, ARPEGE-Climat, along with the other components of the carbon cycle, to simulate the feedbacks between the carbon cycle and the climate. 9



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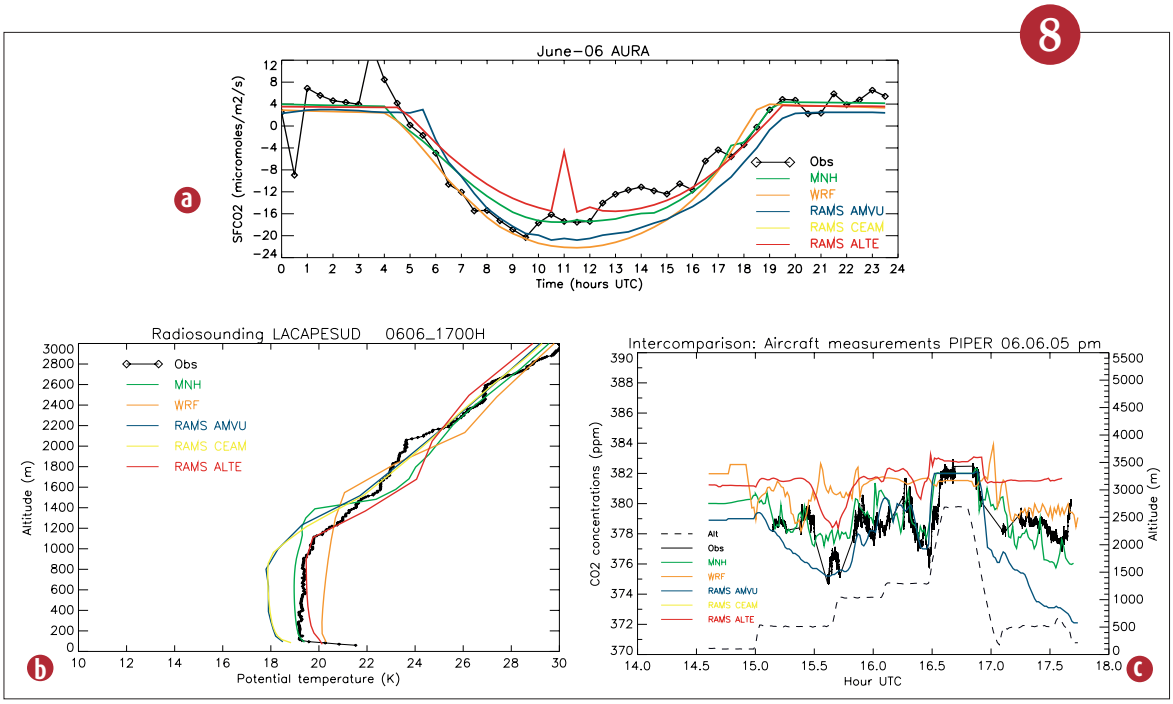
Land cover classification ECOCLIMAP-II over Europe with 273 classes.



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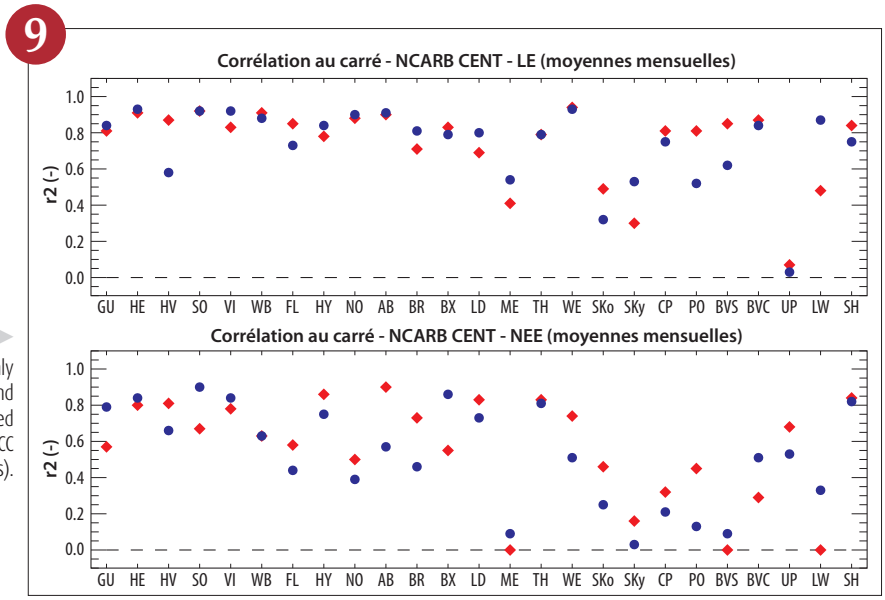
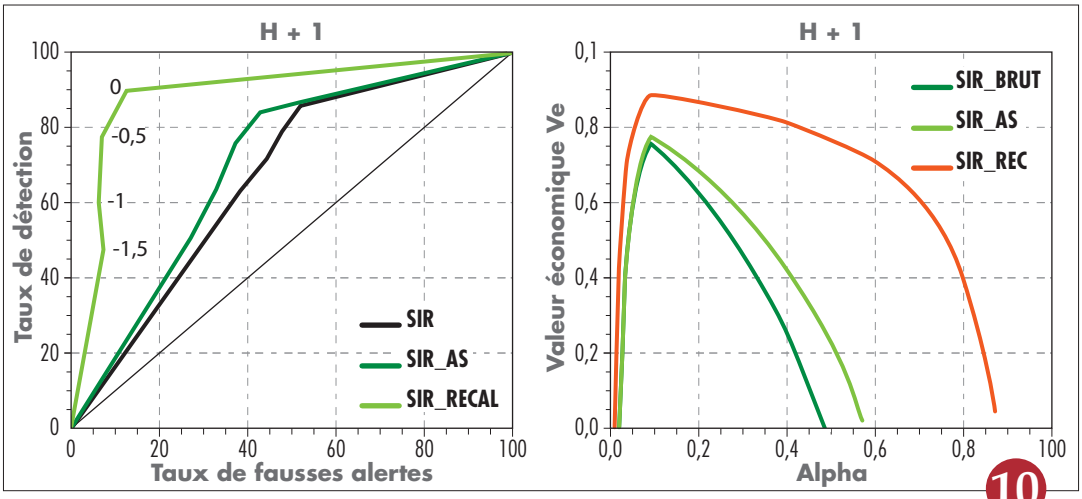
An inter comparison of 5 meso scale atmospheric models against observations collected in June, 6 during CERES 05: (**a**) comparison with observations of CO_2 over a wheat field, (**b**) with the vertical profile of potential temperature observed within the Landes forest (**c**) with the variation of CO_2 in the ABL monitored with/by the instrumented Piper Aztec aircraft.



9

Square correlations between the monthly means of the latent heat flux (LE, top) and of the net carbon flux (NEE, bottom) measured in 26 FLUXNET sites and simulated by ISBA-CC (blue circles) and by ORCHIDEE (red diamonds).



10

ROC diagrams (left) and cost/loss diagrams (right) for the first hourly forecast and for each models: brut model (SIR_BRUT), model with statistical adaptations (SIR_AS) and model with in situ measurements (SIR_RECAL). For SIR_RECAL and the 0 °C threshold, we obtain a hit rate equal to 90 %, a false alarms equal to 10 % and a great economic interest of the model for small cost/loss ratios.

Evaluation of a numerical model for the simulation of surface temperature installed for "Aeroports de Paris"

Thanks to a great collaboration between ADP LABO and the Studies Department of Météo-France in Paris, a numerical model for the simulation of surface temperature over two taxiways of PARIS-CDG airport was tested.
This model was used with predicted data (from the ARPEGE French meteorological model) in order to evaluate its behaviour in operational conditions. In particular, it was tested during the 2004-2005 and 2005-2006 winters on the taxiways of Paris-CDG airport thanks to the in situ measurements from ADP LABO. In order to evaluate the so-called SIR model in operational conditions of uses, the model was run in real time with predicted atmospheric data, and real time road temperature measurements during the 2006-2007 winter.
Two different ways of evaluation were investigated. The first one was done through simple statistics scores, such as Root Mean Square, bias,... for each hourly time step. With a negligible bias, a good RMS for the first 6 hourly forecasts (between 0.5 and 1.5 °C) despite a decrease of up to 2 °C for the 24 h forecast, the global results are satisfactory. The second way to evaluate the numerical model is to test its interest for frozen soil risk management. For each hour, contingency tables associated with hit rates and false alarms are produced which give an estimate of the economic value of the model as a function of cost/loss ratio. This one largely depends on the user needs.
By the way, the curves that were obtained give an idea of the interest of the model. The benefits seem important for the 6 first hours forecast, and decrease progressively when the forecast term increase. Nevertheless, it seems to be a good first step for using such a model as a help for frozen risk management. 10

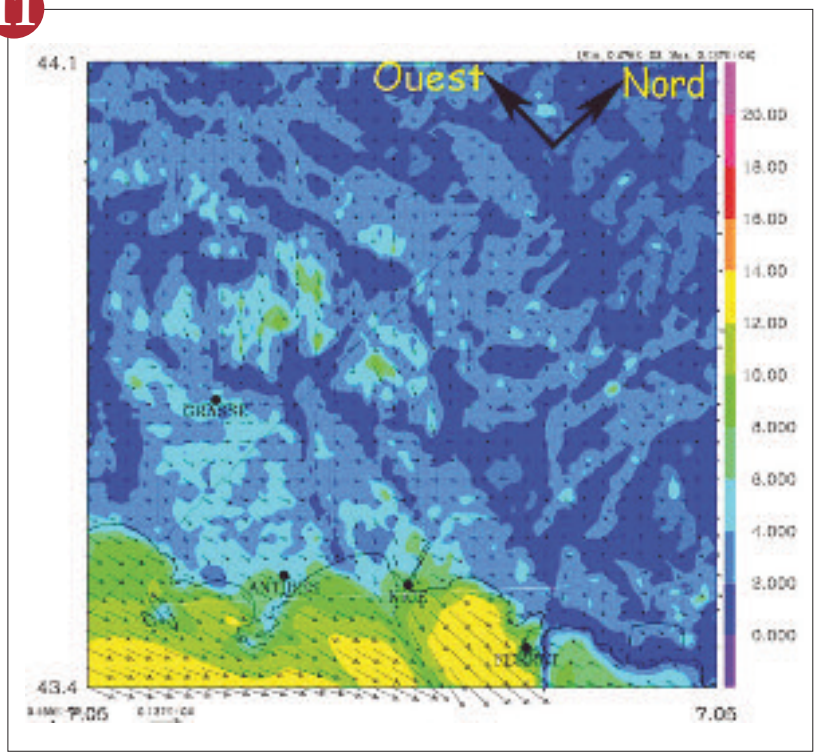
Mesoscale studies of wind shifts over the Nice region

For some meteorological situations, on the runway of Nice airport, sudden wind shifts are observed, turning abruptly from a western to an eastern sector, or conversely. This phenomenon strongly disrupts the air traffic control of Nice airport and leads to turbulences that can be dangerous for aircrafts.
A first study was conducted using the mesoscale research model MESONH, with a 500 meters mesh version, on a representative day of this phenomenon. By comparing the vertical structure of the predicted winds and the diverse available observations (low layers and plane soundings), we notice that MESONH succeeds in representing a phenomenon rather alike the one that occurred, but not at the right location (a gap of about 20 kilometers for the eastern wind zone) and with a wrong timing (4 hours in advance for Nice). We then used a prototype of the AROME model, which will become at the end of 2008 METEO-FRANCE operational mesoscale model (2,5 kilometers mesh). Nine globally similar meteorological situations over the Nice region were simulated, some leading to wind shifts on the airport platform and some not. In a majority of the treated cases, the opposition streams zones are realistic. The location of the wind shifts is not always precise, but we do think that the AROME model might drag the forecaster's attention to a possible occurrence of the phenomenon more efficiently than ALADIN, the current operational model.
At the end of 2008, the AROME model will benefit from a specific observations analysis. We expect further improvements of the forecast of the Nice wind shift phenomenon. 11

Three-dimensional measurements of stable stratified turbulence

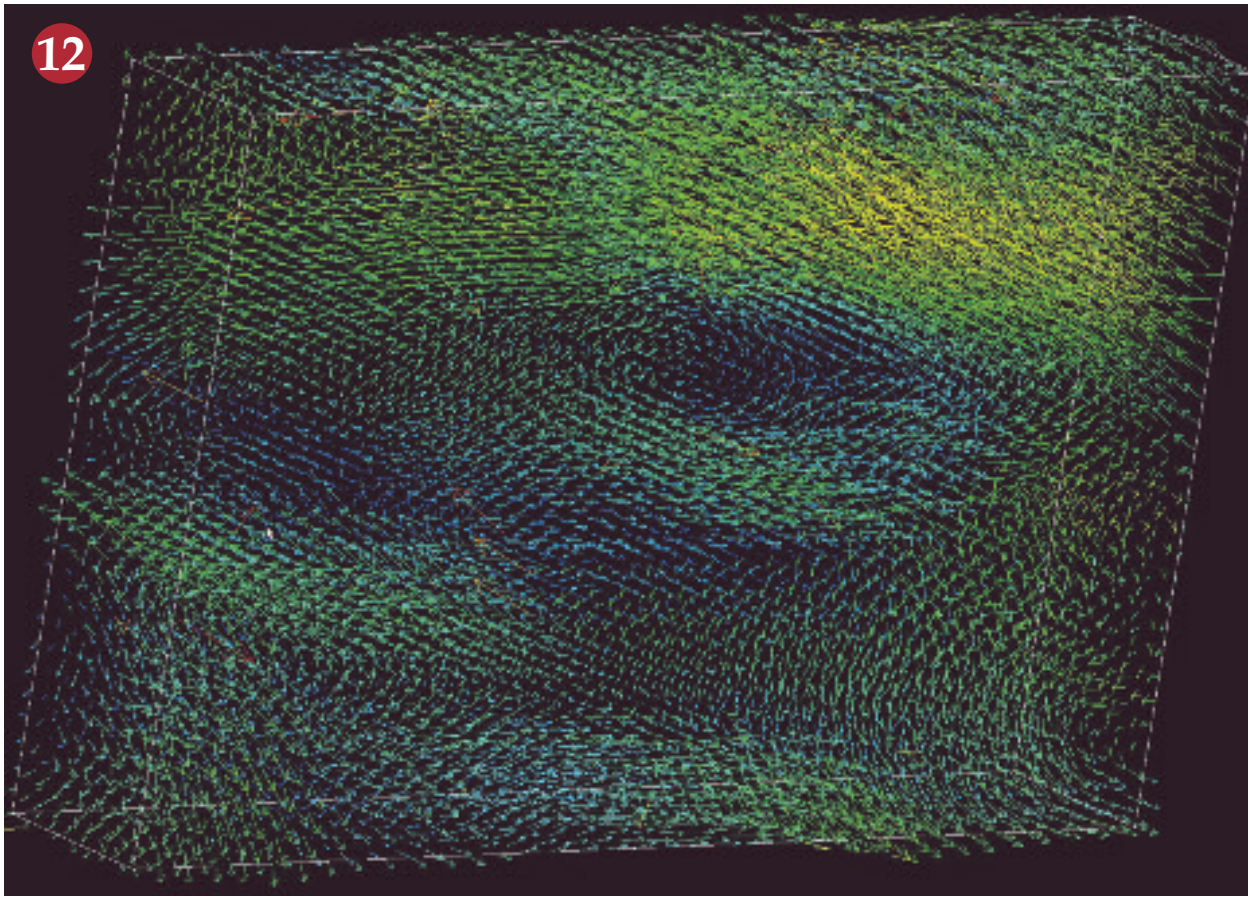
Atmospheric turbulence is often subject to negative buoyancy effects due to a stable atmospheric stratification. Although the effect is globally stabilizing, the resulting dynamics and structure are still only partially elucidated due to the complexity of the phenomena and to the difficult access to fully turbulent regimes by either direct numerical simulations or laboratory experiments.
In this situation in particular, the effects of viscosity become important quite rapidly. In the laboratory (wind-tunnels, hydraulic tanks or flumes) recently developed non-intrusive optical methods make possible the measurement of two-dimensional turbulent velocity fields. However, in the fully turbulent regimes of interest in stratified environments, these techniques have not been applied due to the strong variations in optical indices of refraction inherent to the density stratification which significantly distort the optical paths (a similar problem is also encountered for earth-based telescopes).
Another challenge is to be able to measure the three-dimensional velocity field to better describe and understand the three-dimensional and anisotropic dynamics. It also enables direct measurement of the Lagrangian dispersion, crucial for modelling dispersion of gaseous pollutants (for example aircraft wakes).
For this purpose, a rapid three-dimensional particle image velocimetry (PIV) technique was developed in collaboration with IMFT (Toulouse) and researchers in the USA, which eliminates the index of refraction problems and yields time-resolved three-dimensional and three-component velocity field measurements with a spatial resolution as good as the two-dimensional technique. One such example in a regime which is still highly three-dimensional and turbulent is shown in figure. 12

11



◀ MESONH predicted 10 meters wind on 12 march 2005 at 13.30 UTC (wind speed in m/s). The wind shift phenomenon is realistically simulated, but with a gap in space and time patterns.

12



▲ Uvelocity field measured in a stratified turbulent flow

Climate and climate changes studies

The 4th IPCC report published in 2007 made medias and governments aware of the large scale climate changes already observed, or which should happen by the end of this century. Meteo-France scientists remained very active in this area, and worked mainly on regional climate forecast, extreme events, links between tropical and extra- tropical climate and much more...

Development of CNRM's coupled global climate model

The IPCC fourth assessment report (2007) was based on global climate simulations performed by about 20 research institutes. CNRM was able to participate to this project by using CNRM-CM global coupled model. This model consists of Arpège-Climat AGCM, OPA OGCM, Gelato sea ice model and Trip river routing model.
This complex coupled system is constantly improved and tested. In 2007, the 1860-2000 period was simulated with an updated version of CNRM-CM, in which ocean-atmosphere heat exchanges were better represented. More over, the effect of atmospheric sulphate particles on climate was considered in a more realistic way. In contrast with greenhouse gases, these particles tend to cause a cooling of the ocean and land surface, which can be particularly strong on the regional scale. Other simulations for the same period were run, in which land use changes were taken into account. More recently, the impact of volcanic eruptions was introduced in Arpège-Climat under the form of particles in the lower stratosphere, allowing to simulate the Pinatubo event (1991) more realistically.
This improved version of CNRM-CM was adapted to run on Météo-France's new supercomputer, and will allow to perform several IPCC-like climate simulations within ENSEMBLES European project by early 2008. Then, CNRM-CM will experience deep changes until 2009, in order to account for the most recent updates of its different components.
New couplings will be introduced with the carbon cycle, ice sheets and atmospheric chemistry, in order to obtain an even more realistic earth system model. This next generation model will serve as a tool to contribute to the next IPCC set of climate simulations. 1

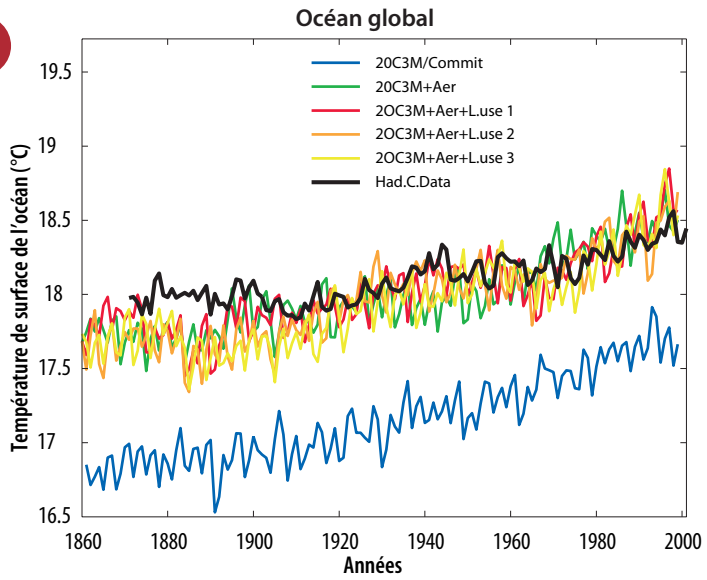
Tropical cyclogenesis indices in the IPCC AR4 simulations

Future evolution of tropical cyclonic activity is of major importance for the scientific community but its uncertainty is so high that the latest IPCC report could merely state the lack of consensus on this topic.
For some time now, methods have been developed in order to measure the probability of tropical cyclone formation in climate models. One of these models was finalized at CNRM from existing indices largely used by the scientific community. The refinement that we introduced in the calculation consisted in getting rid of the 26 °C sea surface temperature (SST) threshold which accuracy whose relevance for the actual climate will become questionable in the future.
We calculated our index for 15 out of the 19 A2 scenarios (among the most severe ones) performed in the frame of the IPCC. Models reproduce a realistic global distribution of the observed index despite some marked biases. When assessing the future climate, answers differ greatly from one model to another, so much so that no conclusion can be drawn regarding the sign of the tendency. This high spread among the models can also be found in the spatial structure of the SST anomaly calculated by the different simulations.
Several years will probably be needed before a reliable tendency can be deduced for the tropical cyclonic activity. Concerning our work for 2008, we will implement a new set of simulations with the ARPEGE/Climat model in which we will prescribe the SST anomalies from the different IPCC simulations; the underlying idea being to measure the part of these anomalies in the spread of the responses. 2

Tropical influence on extratropical variability

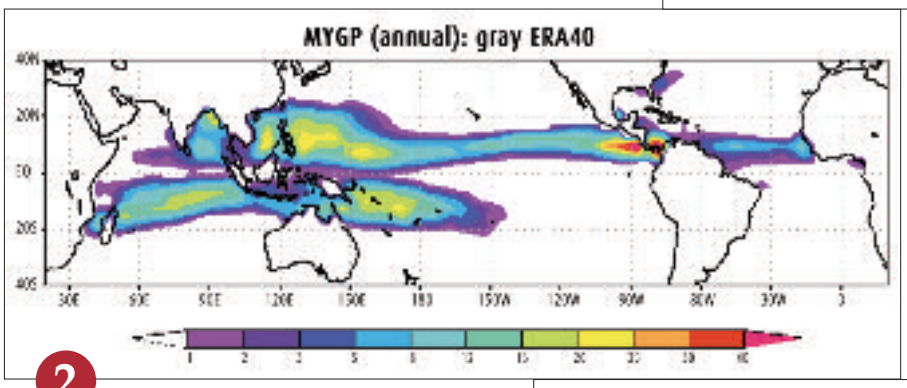
The IRCAAM project, funded by the French National Research Agency and coordinated by CNRM, mainly aims at understanding if and how the inter annual and/or intra seasonal modes of atmospheric tropical variability control the extra tropical climate, particularly over Europe and the Mediterranean basin. In addition to statistical analysis, the project is based on original numerical experiments in which the tropical dynamics of the global Arpège-Climat model is controlled through a 3D nudging towards the ERA40 reanalyses.
Though highly idealized, such experiments are not disconnected with the issue of long-range dynamical forecasting. The ultimate objective is to assess to what extent improved forecasts within the Tropics (where the persistence of sea surface temperature - SST - anomalies is maximum) could also increase skill scores in the mid-and-high latitudes. The first case studies achieved for the boreal summer season show encouraging results (see figure).
They show that inter annual anomalies in tropical circulation are likely to drive planetary waves that can propagate polewards and thus modify in a realistic way (i.e. in agreement with atmospheric analyses and observations) the extra tropical circulation simulated by the Arpège-Climat model. 3

1



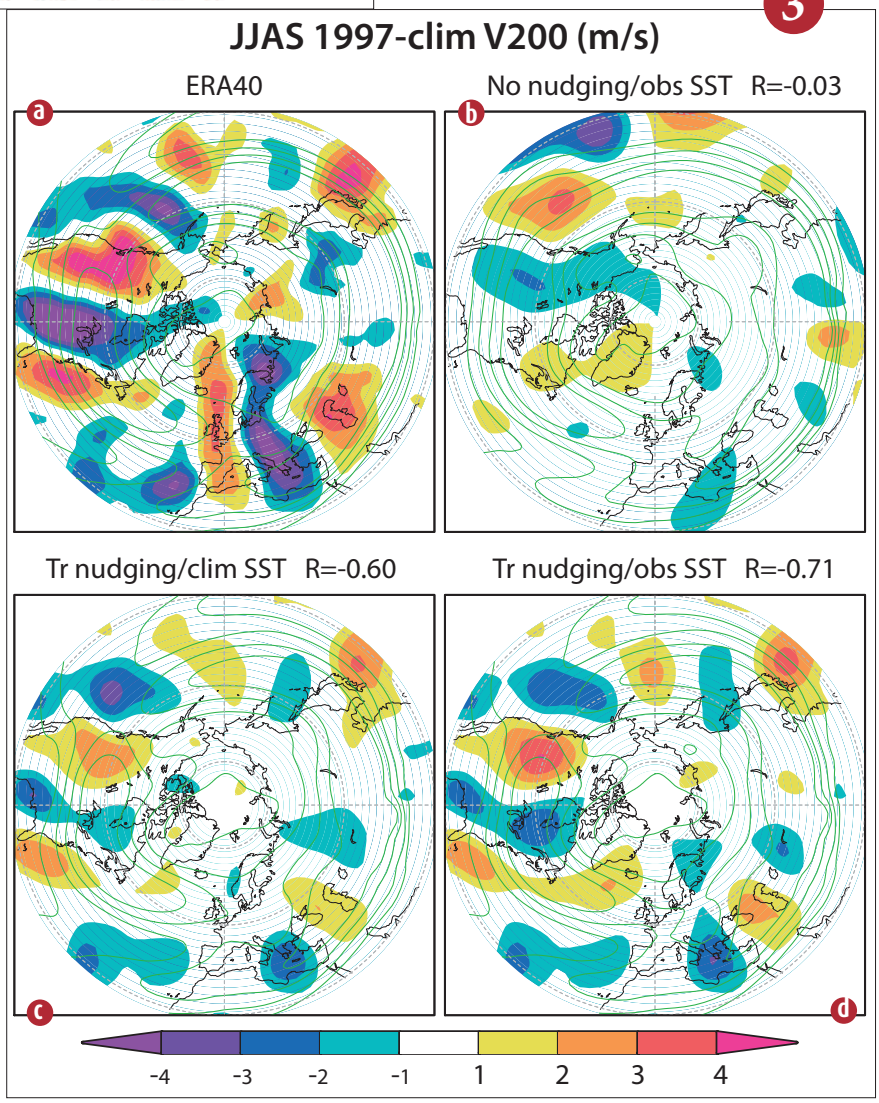
▶ Global mean ocean temperature. HadISST observations provided by UKMO/Hadley Centre (black curve). IPCC-AR4 simulation by CNRM-CM3.1 (blue). Simulation by CNRM-CM3.2 (green). Yellow, orange and red: same model, but with land use changes and different ocean initial conditions.

2

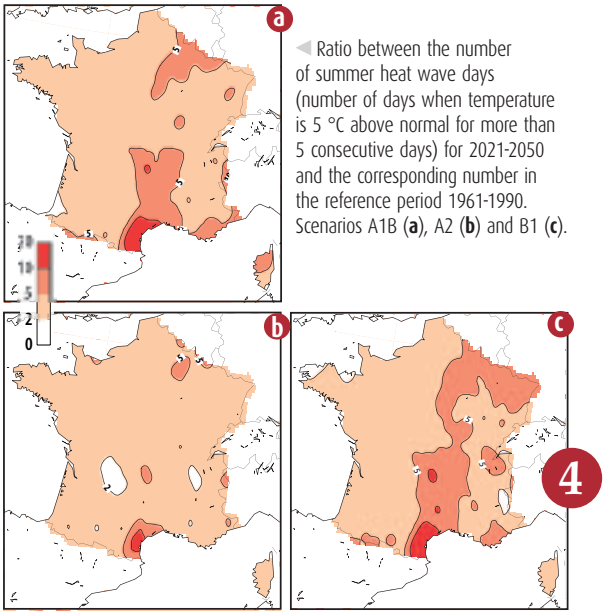


◀ Computation of tropical cyclone formation probability for the ERA40 reanalysis.

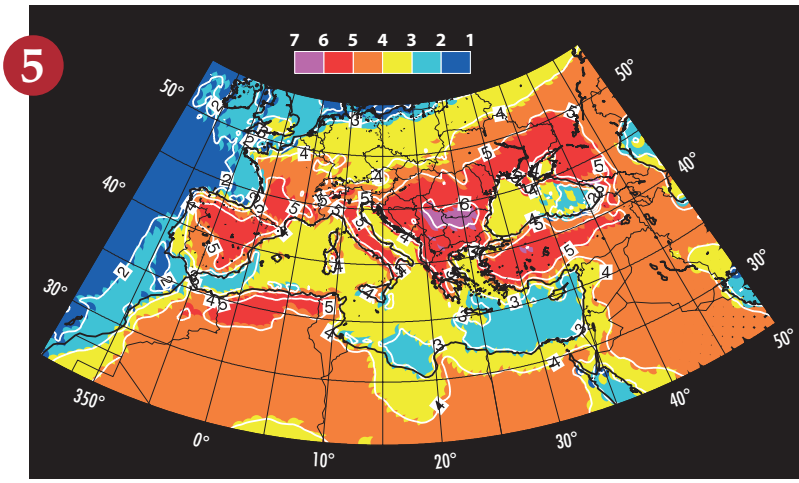
3



▶ Observed (**a**) and simulated (**b**,**c**,**d**) 200 hPa meridional wind anomalies averaged between June and September 1997. Three ensembles made of 30 simulations are compared:
b) control experiment without nudging and driven by observed SST,
c) experiment nudged within the Tropics and driven by climatological SST,
d) experiment nudged within the Tropics and driven by observed SST. R is the spatial correlation between observed and simulated anomalies north of 30° N. Green contours show the 1971-2000 climatology of the 200 hPa zonal wind (different for the experiments with and without nudging).



◀ Ratio between the number of summer heat wave days (number of days when temperature is 5 °C above normal for more than 5 consecutive days) for 2021-2050 and the corresponding number in the reference period 1961-1990. Scenarios A1B (**a**), A2 (**b**) and B1 (**c**).



▲ **a** : map of the warming en °C
b : drying in mm/d for the end of the 21st century (2070-2099 period versus 1961-1990) in summer (June-July-August)

Indices of extreme events over France in the latest regional scenarios 2021-2050

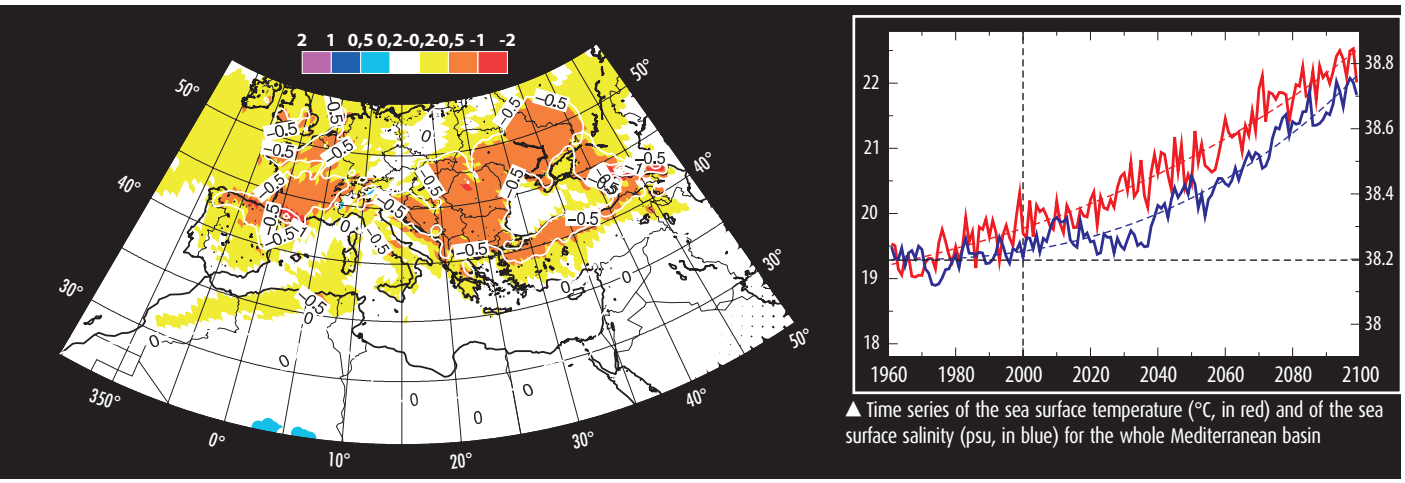
The IPCC 4th assessment report has required coupled ocean-atmosphere simulations that have enabled to produce a third generation of regional scenarios for France. After doubling carbon dioxide experiments (late 1990 s) and A2 and B2 scenarios of Gicc programme (early 2000 s), a new set of three scenarios A1B, A2 and B1 has been made recently available. For the first time, these simulations address the question of the climate for the first half of the 21st century.
For the forthcoming next decades, the main concern is not a moderate mean warming, but the evolution of the frequency of extreme phenomena. From the above mentioned three simulations at 50 km resolution over France, we have estimated the frequency of summer heat waves (figure 4), the intensity of heavy rainfall and the duration of dry spells for the period 2021-2050. Amidst the spread of model responses which result from the unpredictable inter-annual variability, three characteristic features arise, which were emphasized for the end of 21st century in Imfrex: increase in heat waves and droughts, paradoxical increase (since mean precipitation decreases) in intensity for the events above 20 mm/day.
Studies on these data will carry on, in order to update the results about strong winds and surface hydrology. 4

Climate change simulation of the Euro-Mediterranean area using a dedicated atmosphere-ocean regional climate model

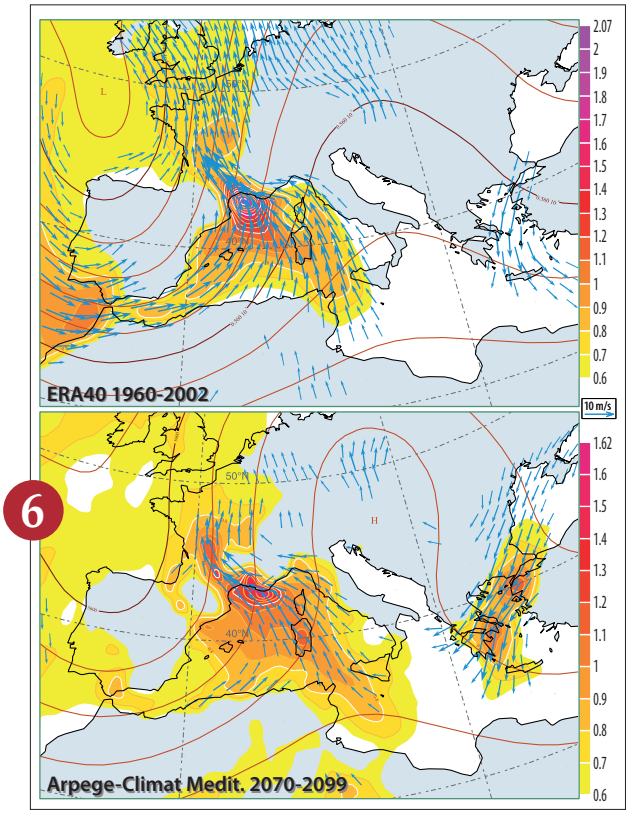
Following the last two IPCC reports (2001, 2007), the Mediterranean area has been pointed out as one of the main "hot spots" for a climate change during the 21st century. The various global climate models also agree very well about that area. This leads to robust results concerning the general warming and drying of the Mediterranean basin. These changes will be stronger in summer.
To obtain high-resolution information about the climate change in this area, the CNRM has been developing for some years a high-resolution regional version of the ARPEGE/OPA coupled model. This Atmosphere-Ocean Regional Climate Model (AORCM) is the first model which takes into account the air-sea coupling at high resolution for the Mediterranean area. The two coupled models are ARPEGE and OPA as for the CNRM-CM3 IPCC global models but their spatial resolution over the area of interest is enhanced to 50 km in the atmosphere and to 10 km in the sea. A 140-year simulation (1960-2099) has been carried out with the model following the A2 SRES hypothesis for the 21st century.
A high-resolution description of the warming and drying of the Mediterranean and southern Europe area is obtained thanks to the simulation (figure a). This model also allows to quantify the warming, saltening (figure b) and sea level rise of the Mediterranean Sea. The future of the Mediterranean regional coupled climate models will take place in the European CIRCE project with the inter-comparison of 6 different AORCMs. This will lead to a better assessment of the climate change uncertainty range for the Mediterranean basin.
These AORCMs are also seen as key numerical tools in the framework of the future HyMEx project. 5

Heavy precipitation Mediterranean events in a future climate, a preview...

The national CYPRIM project, started in 2005, provides a multidisciplinary framework aimed at heavy precipitation events (HPE) studies. One objective of CYPRIM is to assess the evolution of the related hazard linked with the climate change. The work summarized here is a better identification of the present climate and the development of an objective automatic detection of such events for future climate simulations. It has been achieved through a collaboration between 3 CNRM sections within 3 different groups.
The main task has involved combining rainfall data from the Météo-France network together with a reference data bank of weather fields (ERA40) obtained at ECMWF. A set of 1210 significant precipitation events has been collected and their large-scale environment have then been constructed using statistical automatic classification algorithms. This yields weather patterns related to the various zones of the average climatology of rainfall in the area. A close look at the statistical relationship reveals that only 2 weather patterns are linked to HPE. The meteorological ingredients that characterize HPE can then be highlighted. They lead to an algorithm that enables to detect favourable conditions that can lead to HPE from the dynamical information alone. The number of cases detected does not change much between now and the end of the century (A2 emission scenario). In the future climate composite of HPE, only the warm moist influx seems to take a more systematic preferred south westerly orientation (see figure).
High resolution simulations of present and future climate cases will allow detailed examination of possible evolutions of the local rainfall amounts or of the HPE structure. 6



▲ Time series of the sea surface temperature (°C, in red) and of the sea surface salinity (psu, in blue) for the whole Mediterranean basin



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▲ Heavy precipitation cases field composites, in the present climate from the ERA40 reanalysis (top panel) and in the future (A2) climate from the Arpege-Climat Mediterranean SAMM model (bottom). Fields are the geopotential height at 500 mbar (brown contours), the wind at 925 mbar stronger than 5 ms^{-1} (blue arrows), and the moisture flux magnitude at 925 mbar (shaded areas).

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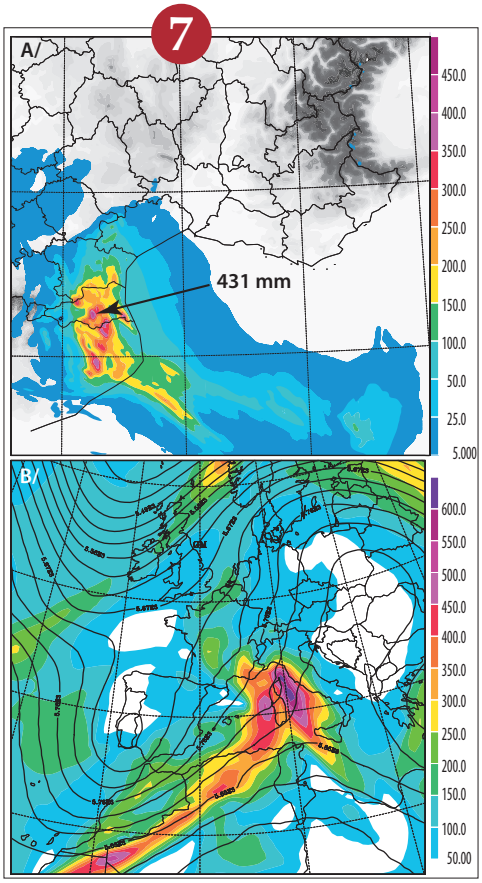


◀ 24 h accumulated surface rainfall simulated by MESO-NH (A/) and 500 hPa geopotential and moisture flux from the ARPEGE Climate/OPAMED system (B/) for a simulated HPE in the future climate.

Climate downscaling with Meso-NH for heavy precipitation events

The evolution of the frequency and intensity of heavy precipitation events is still an open question and cannot be simply assessed through a direct use of climate model outputs. To address this question, downscaling approaches are currently designed. As for instance, within the framework of the CYPRIM project, an hybrid downscaling (or statistico-dynamical downscaling) method is used to address whether frequency or intensity of Mediterranean Heavy Precipitation Events (HPEs) might change in a future climate.

This statistico-dynamical downscaling is based on a two-step method: i) firstly, some cases are selected from an ensemble of environments propitious to HPEs for the actual climate (1960-2000) and for the future one (2070-2099) as simulated by the climate scenarios and ii) secondly, the cases are simulated with a fine scale non-hydrostatic model which is particularly well suitable for the simulation of processes leading to the formation of heavy precipitation events. The statistical method that identifies propitious environment is based on a clustering of the 500 hPa geopotential field combined with criteria on the low-level moisture flow. It has been applied to the ARPEGE Climate/OPAMED outputs to identify twenty cases equally partitioned between the present and future climate. Then, these cases are simulated with the MESO-NH model at 2.5 km for the finest domain and using as initial and boundary conditions the ARPEGE Climate/OPAMED outputs.

For each of the 20 cases, MESO-NH produces heavy precipitating systems with 24 h accumulated precipitation above 100 mm and reaching in some cases more than 400 m. These results confirm that the statistical selection is relevant to identify propitious environment for heavy precipitation and that the dynamical downscaling is able to reproduce precipitating systems typical of Mediterranean heavy precipitation events.

Results about the evolution of heavy precipitation events and their environment are being finalized, given close attention to the evolution of key ingredients for the development of heavy precipitation events such as moisture flux, precipitable water, low-level jet and the available convective instability. 7

Atmosphere and environment studies

In 2007, several developments were carried out concerning hydrometeorology, oceanography, nivology, reduced visibility or modelisation of atmospheric chemistry... Some notable progress were made on discharge forecasts thanks to SIM improvements, on fog understanding, ... Moreover, air quality ensemble forecast and desert dusts forecasts were two major innovations of the last 12 months.

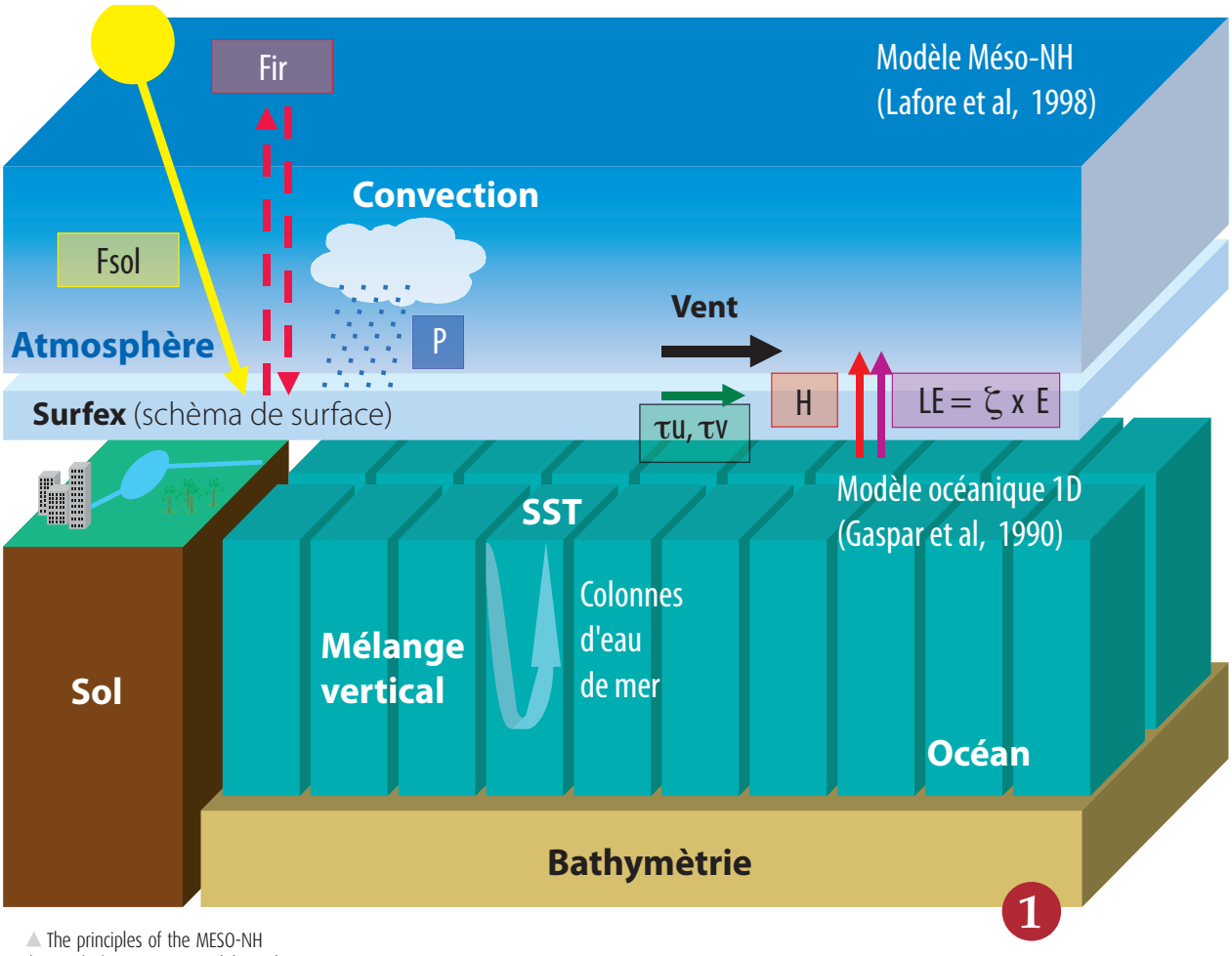
Hydro-meteorology

Sea-air coupled processes during heavy precipitating events

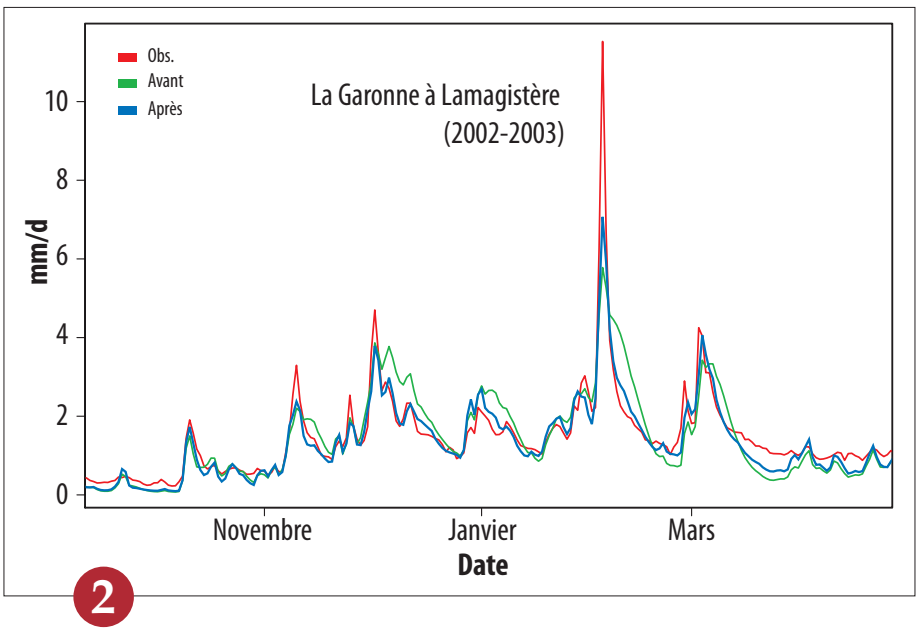
For the strongly precipitating events that frequently occur over the Mediterranean basin during the autumn, the Mediterranean Sea is an important source of heat and moisture. The sea can also sometimes contribute to amplify the flood due to the sea-level rise and the generation of a strong swell, generated by the strong winds that accompany the heavy rainfall.
To study the impact on the oceanic mixed layer of heavy precipitation and strong sea winds observed in these situations, as well as the feedbacks on the atmospheric events, a full 2-way ocean-atmosphere coupling has been designed between the atmospheric model MESO-NH, through its surface scheme SURFEX, and an oceanic 1D model (Gaspar et al.,1990). Applied to three heavy precipitation events (Aude 12-13 November 1999, Gard 8-9 September 2002 and Hérault 3 December 2003) at a 2.4 km horizontal resolution, the coupled system reproduces fine scale oceanic responses. A significant deepening and cooling of the oceanic mixed layer are thus found under the strong winds associated with the precipitating systems. An impact of the precipitation is also shown through a decrease of the salinity induced by fresh water inputs and the building-up of inner mixed layers relatively little salted. Compared with a simple one-way forcing, the 2-way interactive coupling tends to moderate the two boundary layers responses, without modifying the high-resolution and short range forecast of heavy precipitating events.
This study constitutes a first step in fine-scale air-sea coupled modelling and produces outcomes for a future campaign field on the hydrological cycle of the Mediterranean (HyMeX). 1

Improvement of the hydrological transfers in the surface model ISBA

A good representation of hydrological transfers is necessary for a good simulation of runoff and water transfers to the rivers. One option, amongst others, to improve the ISBA surface scheme consists in introducing a diminution of the saturated hydrological conductivity with depth. This parameter governs the speed of the water transfers in the soil, its diminution being linked to the compactation of the soil with depth.
After some very encouraging applications at the scale of the Rhône basin and at global scale, this modification has been tested in the application SAFRAN-ISBA-MODCOU at the French scale. After several one-dimensional tests, the calibration of corresponding parameters has been defined. Using the observed discharge observations at some 200 stations, the parameters were calibrated to reproduce as faithfully as possible the observed discharge.
The validation showed that the improvement was significant over most stations (increase of the Nash criterion). The impact on the root reservoir wetness is almost neutral, while the humidity of the sub-root reservoir is increased, allowing a better representation of floods and low flows. This new calibration improves the overall quality of the SAFRAN-ISBA-MODCOU runs. It will be used either in the framework of discharge forecast or on impact studies of climate change. 2



▲ The principles of the MESO-NH (SURFEX) / 1D oceanic model coupling: the variables exchanged at the air-sea interface are the radiation fluxes (Fsol and Fir), the turbulent fluxes (τ, H, LE) and the precipitation rate (P).



▶ Improvement of the discharge of the Garonne at Lamagistère (Haute-Garonne) during the winter 2002/2003.

Extension of the reanalysis of the hydrometeorological system SIM

The hydrometeorological system SIM (Safran-Isba-Modcou), used operationally at Météo-France since 2004, permits a continuous and real-time monitoring of soil water resources over France.
In order to detect anomalies concerning water resources availability and to allow a better qualification of a specific hydrological season, the reanalysis of the model is daily used as reference. In 2007, the reanalysis of the SIM model has been extended over the whole 1970-2006 period using ERA40 (1957-2001) atmospheric reanalysis of ECMWF and observations from the Météo-France climatologic network.
The extension of the temporal period covered by the reanalysis will be continued in 2008. This work will permit to obtain a climatology of the model covering the years 1958-2008 with an innovative dataset of 50 years of soil water resources at a 8 km spatial resolution all over France.
This reanalysis will be important for future studies, especially for assessing the impact of climatic changes on the hydrological resources. 3

Ensemble stream-flow predictions using the SAFRAN-ISBA-MODCOU chain

The hydrometeorological suite SAFRAN-ISBA-MODCOU (SIM) simulates the distributed surface hydrologic budget and the associated streamflows for the whole metropolitan France. SAFRAN is a meteorological analysis system, ISBA is a land surface model, MODCOU a hydrological model (developed by the Ecole nationale supérieure des Mines of Paris) which simulates the flows over 800 French rivers places.
The availability of this chain allowed new research on daily streamflow prediction, based on the ensemble prediction system of ECMWF. For that, precipitation forecasts are disaggregated at the scale of France (to take into account orography and forecast biases). The ISBA-MODCOU model runs for each member of the ensemble forecast. The performances of the ensemble streamflow forecast were tested over a period of more than one year.
Performances are satisfactory, despite a lack of spread at short time scale, especially for precipitation. The ensemble streamflow forecast will allow to improve the forecast term and the pre alert for the operational services. A test using the short term ensemble forecast from the ARPEGE model showed an improvement for short term forecasts, especially for small basins.
In the future, tests of the system will be continued. The emphasis will be put on the improvement of the model initial state, using an assimilation of the observed discharge. 4

Soil moisture monitoring: modelling versus satellite and in situ observations

Surface soil moisture can be estimated by using microwave remote sensing data. This quantity is simulated by land surface models. Automatic probes allow the continuous monitoring of soil moisture profiles, in situ. To compare soil moisture estimates given by various techniques improves the understanding and the modelling of biophysical processes.
The satellite mission SMOS (L band radiometer) will provide surface soil moisture estimates from space with a sampling time of 2-3 days and a spatial resolution of 20 to 60 km. A number of existing soil moisture products derived from satellite observations have the potential to be used in synergy with SMOS. The C band wind scatterometer data (ERS-Scat, ASCAT onboard METOP) or the C and X band passive microwave data (AMSR-E onboard Aqua), already provide surface soil moisture estimates, at a similar spatial resolution. ASCAT onboard METOP (an operational instrument) will enable EUMETSAT to issue global soil moisture products at a similar sampling frequency as SMOS. In situ soil moisture observations are available for south-western France : SMOS-MANIA (2007-2013) is a network of 12 RADOME weather stations equiped to measure soil moisture and temperature profiles (-5, -10, -20, -30 cm).
The comparison of in situ data with simulations (SIM) and the available remote sensing products (see figure) permits to cross-validate the satellite products with the model and to verify the representativeness of in situ data. 5

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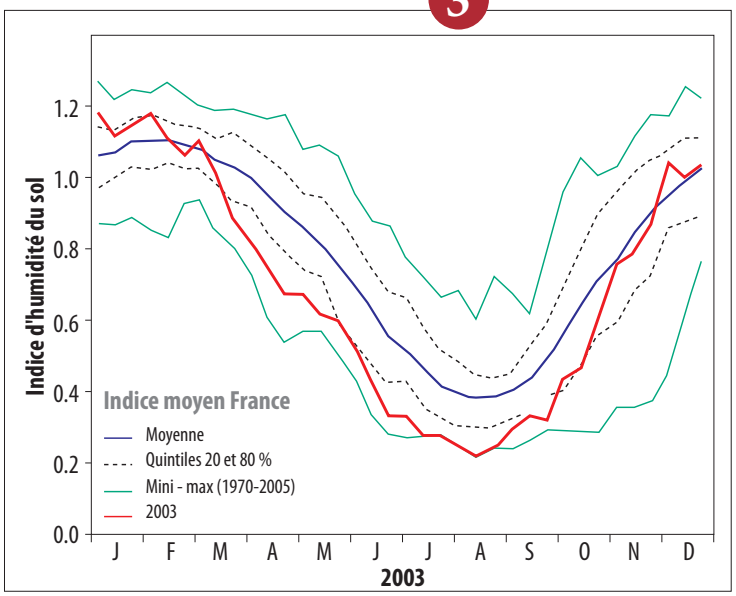

Mean soil water index (SWI) over France for the year 2003 and comparison with statistics on the 1970-2005 period

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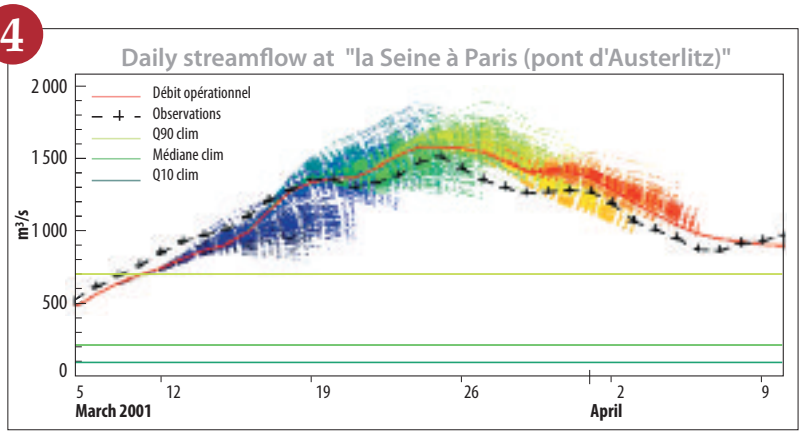

Ensemble streamflow prediction for the 2001 flood in Paris. Observations: black, simulation with SAFRAN analysis: red, ensemble prediction: dashed lines, green: climatological thresholds

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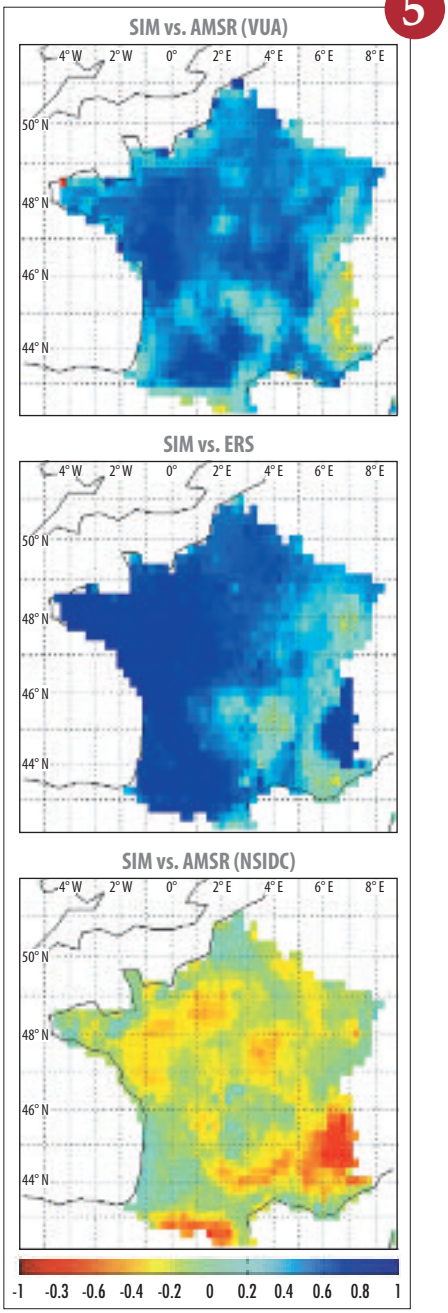

Correlation maps between the surface soil moisture simulated by SIM over France and 3 satellite products, for the 2003-2005 period.

From top to bottom: AMSR-E (Amsterdam University), ERS-Scat (Vienna University), AMSR-E (NASA, version 3-B03).

Oceanography (modelling and instrumentation)

Sea surface salinity measurement

The Centre de Meteorologie Marine (CMM) will take part in the validation and calibration of ESA SMOS satellite (Soil Moisture Ocean Salinity) which will be launched in 2009.
The GLOSCAL (Global Ocean Salinity Calibration and Validation) project aims to study the Sea Surface Salinity data (SMOS data, AQUARIUS data, in situ data) in collaboration with the national and international scientific community. The Sea Surface Salinity is important for a better understanding of the climate.
For this purpose, drifting buoys fitted with conductivity sensors were deployed off the Amazon river in the framework of PLUMAND and AMANDES campaigns, and in Biscay Bay for CAROLS experiment. The deployment of buoys off the Amazon river had two aims: a scientific one (to analyse the salinity variability in surface de-salted waters) and an instrumental one (validation in tropical oceans).
The aim is to have about thirty buoys to be ready to be deployed when SMOS will be launched. 6

E-Surfmar: European surface marine observation programme

Since 2003, the surface marine meteorological observation has been organized in Europe in the framework of Eucos, a composite observation programme of Eumetnet. Météo-France ensures the leadership of E-Surfmar, a programme which gathers observations from VOS (Volunteer Observing Ships) recruited by EMS as well as from drifting and moored buoys. The programme is steered by two advisory groups: one for ships and one for buoys. In 2007, its budget was about 820 k€.
Whereas the number of observations carried out by conventional ships are ever and ever decreasing, those collected by automated stations installed aboard European ships have doubled over the past 5 years. On average, observations have increased from 300 to 700 a day in the North Atlantic and in the Mediterranean Sea.
By the end of 2007, about 100 drifting buoys, funded by the programme, reported more than 2200 observations of air pressure and sea surface temperature per day, a level never reached before.
E-Surfmar is mainly concerned with the automation of the observation, the decrease of production cost, the improvement of its quality and the reduction of transmission delays. In 2007 the Iridium satellite system showed its potentialities compared to Argos in reporting drifting buoys data ashore. The decision to progressively extend this communication system to all the drifting buoys was therefore taken. 7

Participation in the International Polar Year (IPY)

Meteo France contributes to the International Polar Year (IPY 2007-2009) through the E-SURFMAR programme.
E-SURFMAR funded some buoys which were deployed in the framework of the International Arctic Buoy Program (IABP), a regional action group of the DBCP (Data Buoy Cooperation Panel). Two buoys were air deployed during the Summer 2006. Seven cheaper ones were put on the sea ice during the Summer 2007 by the German research vessel POLARSTERN. By December 2007, eight out the nine buoys were correctly working, transmitting their hourly data through either the Argos system satellite or the Iridium one.
The main objective is to take advantage of this campaign to contribute to the densification of the air pressure measurement network in this area and to quantify its impact through further studies.
In September 2006, the sailing-ship TARA V (ex-ANTARCTICA) which began a two-year drift in the sea ice of the Arctic Ocean since September 2006, was also equipped with an automatic weather station. 9

Use of Iridium for transmission of surface marine data

The tests realized in 2007 to use Iridium satellite system to transmit drifting buoys data were successful. The system is reliable, quick and cheap. By the end of 2007, about 20 SVP-B drifting buoys fitted with a SBD (Short Burst Data) transmitter were in operation in various ocean: Arctic Ocean, North Atlantic Ocean, Black Sea, South Atlantic Ocean, and Indian Ocean. Every hour, the data are received at CNRM/CMM in Brest, coded in FM18-BUOY messages and sent onto the GTS within less than 10 minutes.
Forty-five Iridium buoys, funded by the E-SURFMAR programme, have been purchased. Next year, they will be deployed at sea together with Argos buoys. Future orders for the E-SURFMAR network should be Iridium buoys only.
In 2007, CMM also developed a minimal ship borne Automatic Weather Station (AWS) to meet E-SURFMAR requirements i.e. measuring the atmospheric pressure at least. This AWS, so called Baros, is fitted with a barometer, a GPS and a SBD Iridium beacon. This prototype was put on board the French trawler Jericho. It has been working perfectly since the beginning of November 2007. Data have been sent in real time onto the GTS in FM13-SHIP messages. Four more stations devoted to E-ASAP ships not yet equipped with an AWS, are being produced. 8

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Salinity buoys: drifting buoys fitted with conductivity sensors

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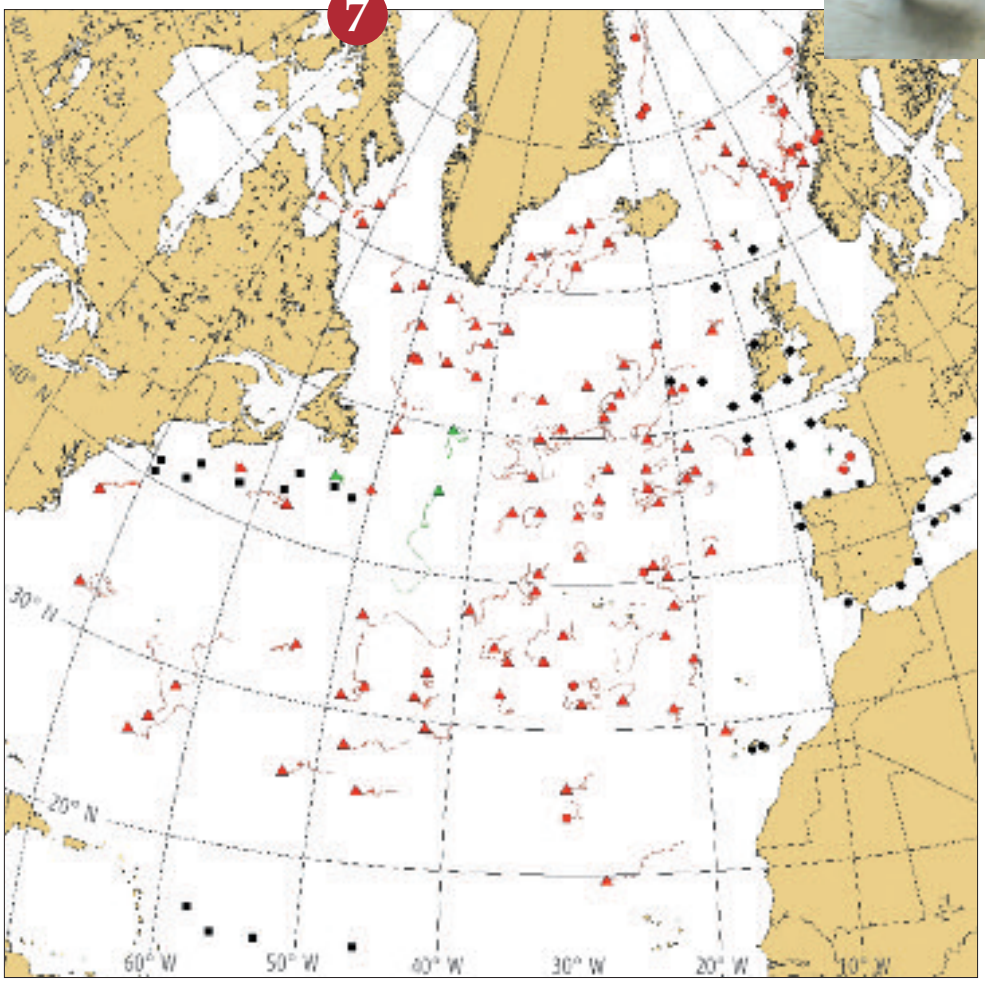

Drifting buoys (measuring atmospheric pressure) trajectories in the Eucos area in November 2007

Buoy on the sea ice
Buoys trajectories in November 2007 (in red E-SURFMAR buoys)

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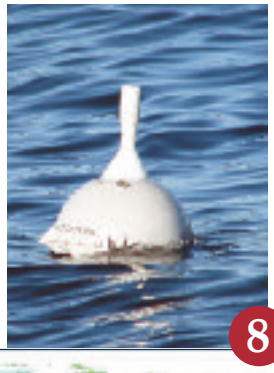

Iridium buoy at sea.

DBCP Iridium Pilot Project Map (Status 19 December 2007)

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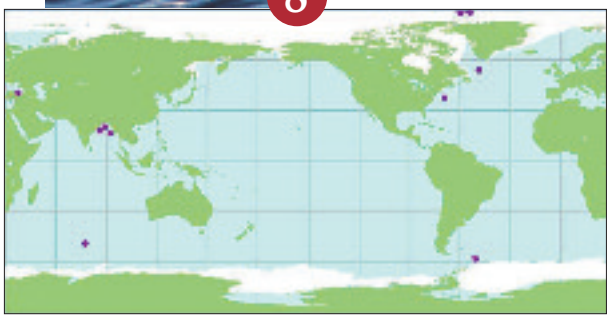


The moored buoys

The open ocean buoys Brittany (moored by 2 100 meters depth) and Gascogne (moored by 4 500 metres depth) are maintained in cooperation with the United Kingdom Met Office.
In addition, Météo-France is operating open ocean moored buoys in four other places: two off the French West Indies by 5 500 metres depth and two others in the Mediterranean Sea by 2 300 metres depth. The buoys weigh 3.7 tonnes, and measure 2.8 metres in diameter and 6 metres overall height. The hourly observations are transmitted in real time via the METEOSAT satellites. 10

10
Replacement of a buoy in Mediterranean Sea in February 2007.

From MERSEA to My Ocean : towards an integrated European system for operational oceanography

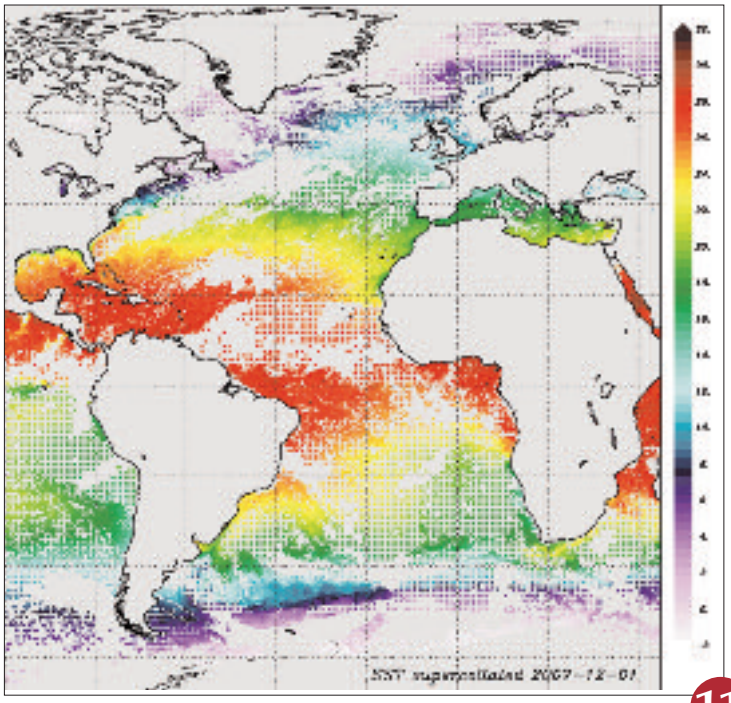
The aim of the European MERSEA Project (2004-2008), funded by the European Commission and coordinated by IFREMER, is to develop and to demonstrate, in pre-operational conditions, an integrated European system for operational oceanography, in response to the GMES requirements. This system is composed of analysis and forecast centres for the global ocean (under Mercator Ocean's responsibility) and for regional seas (Mediterranean Sea, North-Eastern Atlantic, North and Baltic Seas, Arctic Ocean), as well as satellite and in-situ data centres providing the necessary observations.
Météo-France contributes to MERSEA through research activities performed at CNRM about atmospheric forcing fields and the impact of high resolution global ocean analyses on seasonal prediction, demonstration activities performed in the Marine Forecast and Oceanography Division about the use of surface current forecasts for sea state and oil drift prediction, and development and production activities performed at CMS about sea surface temperature satellite observations.
In 2007, the CNRM has demonstrated and documented the positive impact of newly developed turbulent fluxes parameterisations on the global ocean circulation simulation. At CMS, the processing of new satellite multi-sensor sea surface temperature products, covering the Atlantic Ocean, has been implemented, and they are now made available to MERSEA users.
In 2008, the transition from MERSEA to My Ocean (2008-2011) will take place. This new project, funded by the European Commission, will transfer into operational exploitation the system developed in the framework of MERSEA. 11

ECUME: a new parameterisation for air-sea turbulent fluxes

In classical atmospheric circulation models, the estimation of air-sea turbulent fluxes (wind stress, sensible and latent heat fluxes) relies on the use of « bulk » formulations together with air-sea parameters and exchange coefficients for wind, temperature and humidity.
In 2007, a new parameterisation of the neutral exchange coefficients named ECUME (Exchange Coefficients from Unified Multicampaigns Estimates) was set up using the ALBATROS dataset (http://dataserv.cetp.ipsl.fr/FLUX/) which gathers all the measurements collected during several cruises over the past ten years, in close collaboration between CNRM and IPSL. This parameterisation is particularly consistent as it provides an analytical formulation for all the exchange coefficients (for wind, temperature and humidity) derived from turbulent fluxes estimates using simultaneous measurements together with homogeneous methods, while covering the widest range of wind and of atmospheric stratification conditions.
A first evaluation of this parameterisation was carried out in the MERSEA Integrated Project framework using the global ocean model OPA, developed at LOCEAN. This parameterisation is now being evaluated in atmospheric models ranging from the ARPEGE-Climat model to the meso-scale AROME and Meso-NH models. Two recent studies have indeed demonstrated the benefit of using this parameterisation in the Meso-NH model for the simulation of both the intense Mediterranean rainfall events and of hurricanes. 12

Laboratory experiments on Internal tide

Internal gravity waves in oceans, as well as in the atmosphere, interact with large-scale processes. In the ocean, the counterpart of the drag force for mountain waves is the amount of energy extracted from the barotropic tide due to the formation of the internal tide. This conversion rate is an essential information if the role of the internal tide in mixing the abyssal water masses is to be understood.
Rough estimates of this conversion rate are available, based on satellite data (Munk and Wunsch, 1998). These data also reveal that the energy conversion mostly occurs at topographic features, but many questions relative to internal tides generation, propagation and dissipation remain to be solved.
In this context, laboratory experiments on the generation of internal tidal over a seamount are performed. The tidal problem is mapped to an oscillating ridge in a static fluid. The Schlieren synthetic technique and the Particle Image Velocimetry technique provide measurements of the density and velocity fields induced by the waves.
The toolbox integrated into the numerical model Symphonie developed by the Laboratoire d'Aérologie in order to analyse internal tides energetic transfers must now be validated. These studies will improve our understanding of the thermohaline circulation, which works on a temporal scale of a thousand years. Therefore, they also contribute to climate research. 13



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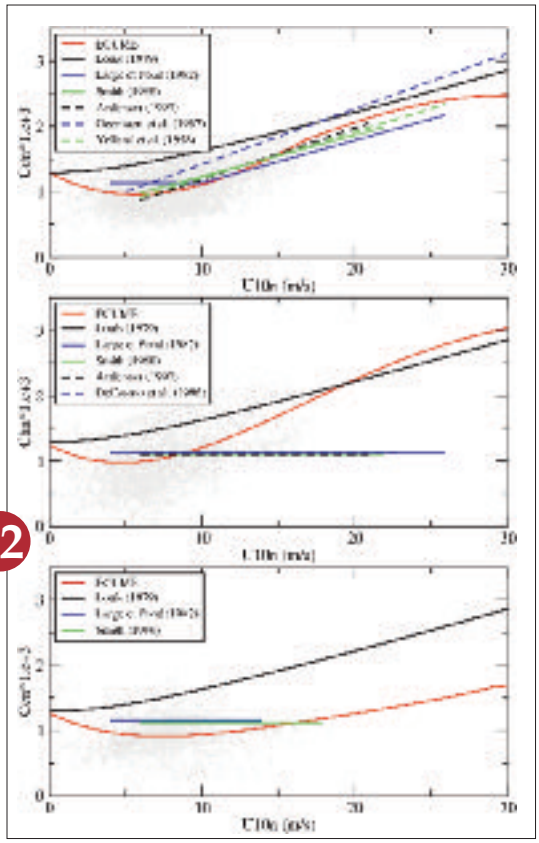
▲ Multi-sensor sea surface temperature field obtained on 1st December 2007, combining infra-red and microwave observations from geostationary and polar orbiting satellites.



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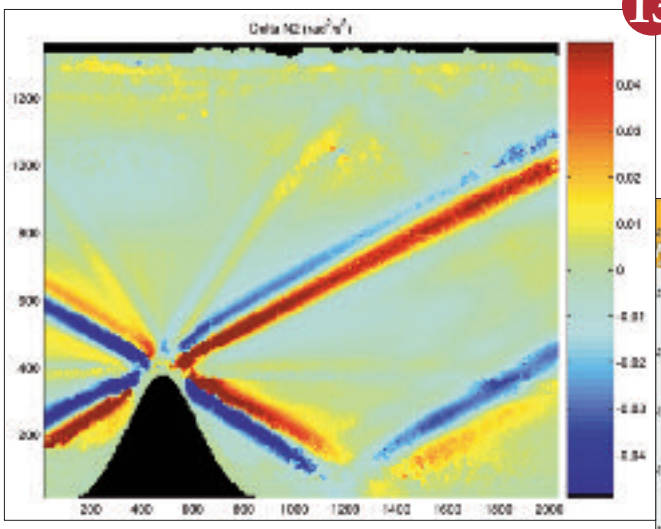
▲ Neutral exchange coefficients for the wind (Cdn), temperature (Chn), and humidity (Cen) issued from the ECUME parameterisation (red line), as a function of the wind gradient between the sea surface and 10 m height. Each dot represents a value provided by the ALBATROS dataset. Several (among the most commonly used) bulk parameterisations are also drawn.



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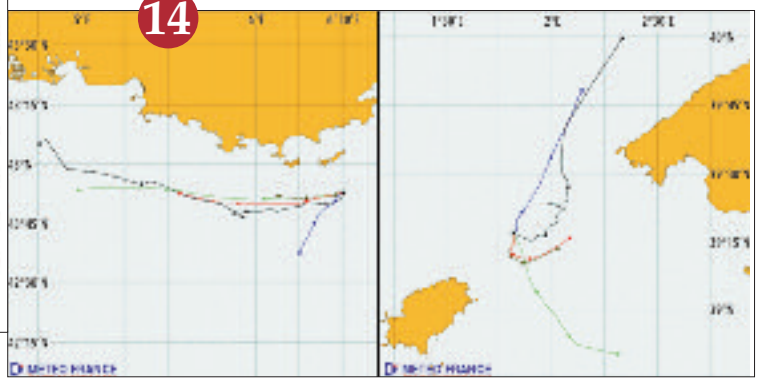
▲ Density field induced by internal tide beams



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▶ 72 hours drift observed with a buoy (black) and simulated by Mothy with only the wind forcing (brown) or when the currents of a monthly climatology are added (green), or the MFS analysis (red), or the Mercator-Ocean PSY2V2 analysis (blue).
On the left : drift started on the 13th October 2007 and we note a good agreement with the Mothy drift using the climatology whereas the oceanic systems reproduce badly the liguro-provencal current.
On the right : the drift start on the 16th November 2007 near the Balearics Isles and the Mercator currents are here the most accurate.

Observed and forecasted oil spill drift inter-comparison in the Mediterranean Sea

In the framework of its national and international duties, Météo-France operates the Mothy drift model. It is composed of a 2D ocean model (computation of currents due to wind and tides) and of a model simulating the behaviour in the ocean of oil spills (or object).
However, in some cases, the low frequency oceanic circulation can become the main instigator of the drift. One Météo-France of the participations to the European project MERSEA (Marine Environment and Security for the European Area) consisted precisely in the assessment of this contribution.
Thus, an experiment in the Mediterranean Sea has been organized during the autumn 2007 with French (Cedre, Ifremer), Norwegian (Met.No) and Cypriot (UCY) services in order to deploy buoys emulating a surface oil spill : 3 near Cyprus and 8 off Toulon in the South East of France. The experiment lasted for more than 3 weeks and allowed to collect precious data on oil spill drift in a sea where the drift forecast systems have not often been validated while its dynamic is very complex (variable currents associated with small tides). The Norwegian (OD3D), the Cypriot (MedSlik) and the French (Mothy) drift systems will be inter-compared and the different oceanic operational systems will be tested (Mercator (France), MFS (Italy) and CYCOFOS (Cyprus)).
Studies with these data started in November and will continue once the Mersea project is over, to improve the existing systems. 14

15

◀ Instrumentation for humidity and temperature measurements installed on Toulouse Météopole during the Toulouse-Fog campaign. This device allowed measurements at 0.5, 1, 2, 5 et 10 m height.

Atmospheric environment

Field experiments dedicated to fog: from Paris-Fog to Toulouse-Fog

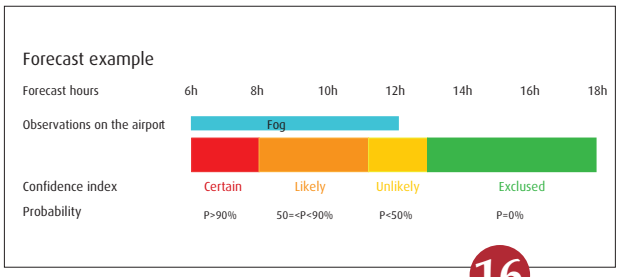
The short-term forecasting of fog is a difficult issue which has a large societal impact. For example, adverse visibility conditions are a problem for the security of air transportation or traffic.
CNRM-GAME has made significant efforts to improve the knowledge of the mechanisms involved in the life cycle of fog. Research is going on to improve fog forecasting by numerical models, and particularly, what influence have both surface heterogeneities and aerosol on fog.
The PArisFOG experiment has been performed during the 2006-2007 winter season to observe simultaneously all these processes. The project is based on an experimental setup that gathers instruments from different research laboratories (IPSL, CEREA and CNRM). Instruments have been deployed at SIRTA from November 2006 to April 2007. Data from the PArisFOG field experiment have been validated and are available on the web server http://parisfog.sirta.fr/ .
Unfortunately, technical problems made it impossible to collect enough observations of microphysical parameters during Paris-Fog. However, it is necessary to improve our knowledge on the microphysical properties of fog, in order to define, for example, new integrated system for road traffic. A new field experiment, called Toulouse-Fog, has been decided for the 2007-2008 winter season. Toulouse-Fog mainly focussed on microphysical parameters on fog layers.
These data will allow to investigate the dynamical, microphysical and radiative events which contribute to the formation and dissipation of fog. Improved physical parameterizations validated against data from Paris-Fog and Toulouse-Fog will also be defined and included in future numerical weather prediction models. 15

Fog ensemble prediction system

Over main international airports, air traffic is very dense. Consequently, low visibility conditions, occurring with fog and low clouds, strongly influence the airport management and safety. The economic issues related to the reduction of visibility over these airports are huge for the civilian and commercial aviation trades.
A Local Ensemble Prediction System (LEPS) has been designed for the prediction of low visibility events at Paris-Roissy Charles de Gaulle airport to optimise airport management and flight scheduling. The ensemble prediction system has been built around the numerical prediction model COBEL-ISBA. This local single column model, developed for the prediction of fog, is operational at Roissy airport since 2005. LEPS is an original system which provides confidence indexes for local fog forecasts. These probabilistic forecasts place the user at the centre of the decision making process. As a consequence, users can use the LEPS forecasts to minimise his operating losses related to fog occurrences.
In conclusion, LEPS is a reliable prediction system for forecasting low visibility events at Charles de Gaulle airport. Moreover, the system is portable and can be installed at any other airports. The system is an efficient tool and a valuable help for both management and safety for the civil aviation in the aeronautic area. 16

Risk maps of mist and fog: "CARIBOU"

Since the end of June 2007, risk maps of mist and fog are produced in an operational way at Météo-France. These maps show an estimation of the risk of occurrence of these phenomena, elaborated by merging satellite observations (MSG cloud type images, by SAF-NWC), surface analyses (DIAGPACK analyses) and radar data (radar quantitative precipitation estimation PANTHERE).
The cloud type images, produced by CMS from the geostationary satellite MSG data, supply a spatialized information about the presence of low clouds, in case of no cloudy layers at higher levels, obviously.
The DIAGPACK surface analyses, elaborated every hour by optimal interpolation using ALADIN fields as guess and all available ground observations, aim at fitting at best the latter ones and so supply fields closer to the observations.
The 2 m relative humidity and 10 m wind fields stemmed from these analyses, in association with the PANTHERE radar quantitative precipitation estimation, allow to discriminate, within the cloud type image, between "low clouds" being in contact or not with the ground. So, the risk of occurrence of mist and fog, that is visibility globally lower than 5000 m, is estimated all over the French metropolitan territory, with a 3 km spatial resolution and a one-hour time step.
Currently, the main limit of the product is a lack of quantification of the fall in visibility encountered within risk areas. A study is in progress in order to associate a class of visibility with the notion of risk. 17



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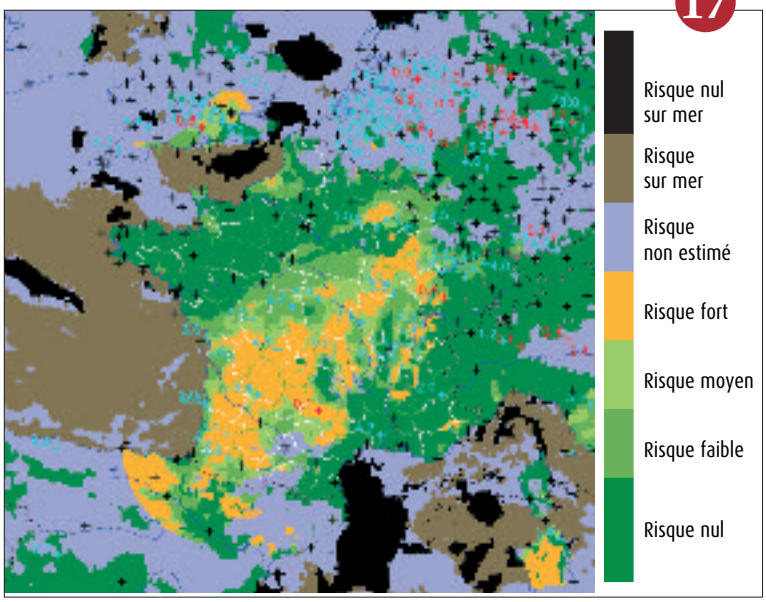
▲ Example of forecast provided by LEPS at Roissy Charles de Gaulle airport.



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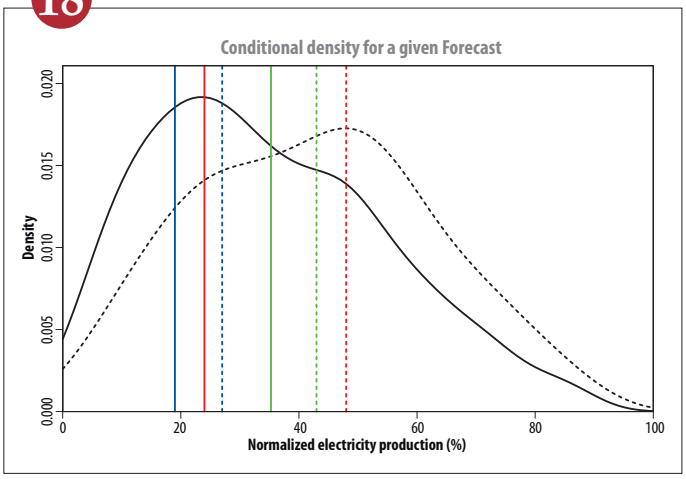
▲ "CARIBOU" product, February 1st, 2007 at 0000 UTC Plotted values are visibility observations (vv) expressed in km: vv < 1 km in red, vv < 5 km in cyan, et vv >= 5 km in black (crosses only).



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▲ Cpdf of wind farm energy production (% of maximum power) given windspeed forecasts of ALADIN model (----) and ARPEGE ensemble forecasts (—), and corresponding forecasts: mode of the cpdf ARPEGE (|) and ALADIN (:), minimization of the economic loss function for ARPEGE (|) and ALADIN (:), computation of the conditional mean ARPEGE (|) and ALADIN (:). In our economic scheme, overestimating the production is more expensive than underestimation. Naturally then, forecasts based on economical loss functions tend to be underestimated.

Wind energy production forecasts by means of economical loss functions minimization

In classical Model Output Statistics techniques, a regression model between real observations and corresponding forecasts is used to improve numerical weather predictions. Those MOS techniques aim at minimizing the mean square error of predictions.
An alternative econometric approach is proposed. It is based on the simple statement that perfect predictions do not exist, and that positive errors may not have the same economical cost than negative ones. Instead of minimizing the error, we wish here to minimize the economical cost of this error. Moreover, when adding information provided by ensemble forecasts, the predictability state of the atmosphere is taken into account. Those techniques are tested in a context of wind farm energy production. Non-parametric kernel estimators are simple and powerful statistical tools that allow to estimate directly the full conditional probability distribution functions (cpdf) of energy production at a wind farm, given the wind speed forecasts of a meteorological model. The production forecast is the value that maximises the conditional expectation of a given economical utility function, provided the estimated cpdf.
We show that in terms of mean square error, classical MOS techniques behave better, but in terms of economical performance, the economical utility approach gives better results. 18

Atmospheric chemistry and air quality

Taking into account uncertainties in mesoscale dispersion modelling

Ponctual source atmospheric dispersion modelling is based on three main components: the meteorological parameters (wind, vertical stability...), the representation of the emission source, and the numerical representation and parameterization of transport and of the possible physical, chemical or radiological processes involved. Each of these components has its own uncertainties, and it is an objective to better take them into account when estimating the impact of an accidental pollution release.
Simulations were performed with the Perle system, used at Météo-France in operations for modelling the dispersion of pollutants at short distance, in order to illustrate the uncertainties connected with the meteorological forcings and with the representation of the emission source. In the first case, the ensemble weather prediction based on the Arpège model has been used as input to Perle; this prediction ensemble provides 11 meteorological scenarios obtained from slightly different initial conditions. The variability of the simulations of dispersion reveals a very high sensitivity of the results to weather conditions in certain types of weather. It was also shown that perturbations to the specification of the source term led to very different evolutions of the pollutant plume, and therefore to markedly different potential consequences. This is a concern, as these characteristics are generally not precisely known in the event of a real accident.
A prototype has been implemented on PC cluster and on the super-computer of Meteo-France. It already allows to appreciate, in post-accidental mode, the variability of dispersion scenarios provided by Perle using ensemble weather prediction or when making alternative assumptions on the characteristics of release source. 19

Operational forecasts of desert dusts

Desert dusts are atmospheric particles with sizes ranging between 1 and 10 micrometers, produced by wind erosion in arid and semi-arid areas. As everyone has already experienced, this aerosol can be transported over thousands of kilometres, before being deposited again. In addition to strong health and air quality impacts, desert dusts affect several sectors: operations of the armed forces, visibility, as well as, for instance, satellite imagery...
Forecasts of dust concentrations and deposition fluxes are thus much needed in order to anticipate major events and take well-adapted precautions. Research activities at Meteo-France in collaboration with LISA have allowed to set up an operational dust forecast service. Since November 2007, daily dust forecasts are provided for up to four days in advance. The 3D chemistry and transport model Mocage is used for this application and it takes into account dusts emissions from the two major worldwide sources: the Sahara desert and Saudi Arabia on the one hand, China on the other hand. Dusts are transported and deposited by winds and rain forecasted by Météo-France operational meteorological suites, Arpege and Aladin.
After a detailed validation activity and several months of testing in near-real time, the operational dust configuration of Mocage allows to provide a reliable and robust forecast service to users. In particular, all the French air quality regional networks get Météo-France dusts forecasts needed to interpret observed peaks of PM10, from the national air quality platform Prév'Air (http://www.prevair.org/) of the French Ministry of Environment. 20

Towards the use of "backtracking" tools for operational crisis management

During a crisis management, in particular of the nuclear kind , it is of prime interest to be able to determine the origin in space and in time of an atmospheric pollution, which has been detected at one or several locations of a measurements network. If the question "where is the air mass coming from?" can be answered rapidly with lagrangian trajectories, it is only in recent years that more sophisticated "backtracking" tools have emerged. These tools correspond to the integration backwards in time of 3D dispersion models, providing “retro-plumes”. The methods used share theoretical concepts with meteorological data assimilation; “backtracking” can be used for instance to determine the 3D "field of view" of a given site, at any given time in the past. The CTBTO, in charge of monitoring the treaty banning nuclear tests, has recently asked WMO to add to its missions the operational support in “backtracking”.
Météo-France’s CNP is one of WMO’s eight RSMCs worldwide. In 2007, CNP has been involved in an exercise in support to CTBTO. During one week, retro-plumes were calculated on alert and provided in near-real-time to the CTBTO in Vienna. The CTBTO was responsible for cross-checking the results from the different RSMCs, and for determining the likely characteristics of the fictitious source(s). Within Météo-France, calculations were made with the "reverse" configuration of the chemistry-transport model Mocage. The figure presents an example of validation of retro-plumes computed with Mocage by comparison with reference data from the CTBTO.
Such exercises of "backtracking" will be carried out regularly and, in the event of a real crisis, RSMCs could be asked for support for both plumes (direct) and retro-plumes (inverse) results. The "direct" and "inverse" configurations of Mocage will be available in permanent operational mode at the CNP in 2008. 21

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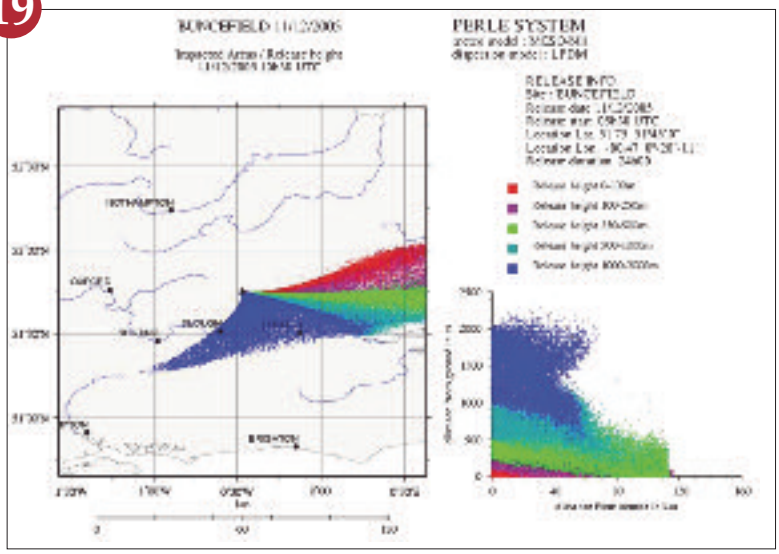

▶ Dispersion as a function of varying release heights. For the case of the fire of the Buncefield oil depot (England, December 2005), the dispersion on the horizontal (left) and on the vertical (right) is shown 5 hours after the start of the release in 5 colours corresponding to 5 different initial heights : between 0 and 100 (red), between 100 and 250 m (pink), between 250 and 500 m (green), between 500 and 1000 (blue) and between 1000 and 2000 m (dark blue).

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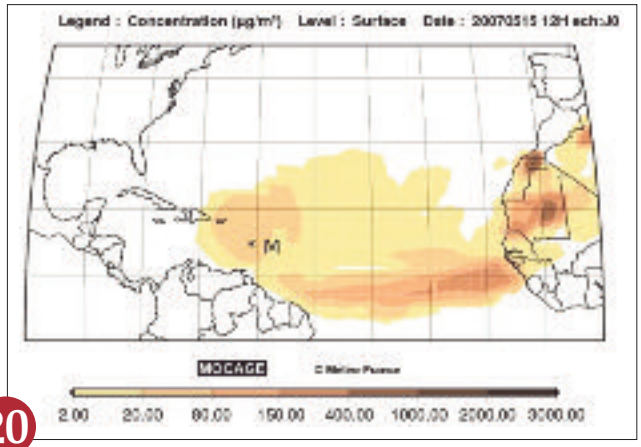

▲ An exceptional event of trans-Atlantic Saharan dust transport onto Martinique (M on the map) in mid-May 2007.

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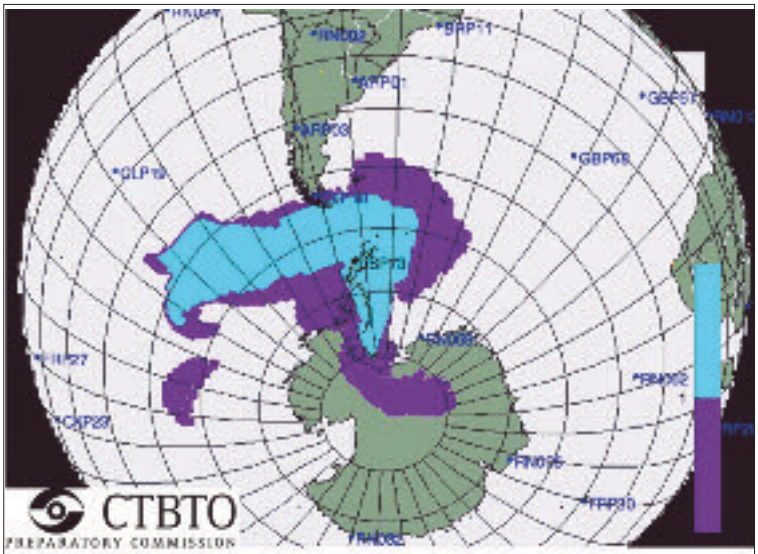

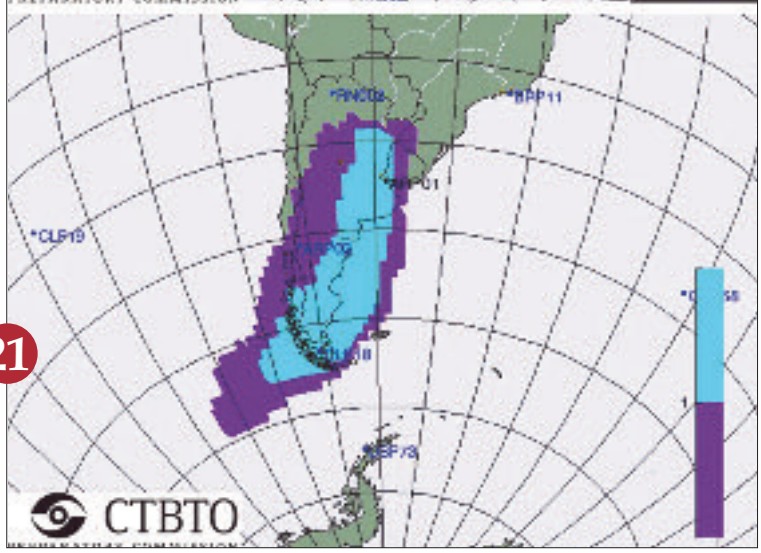

▶ Intersection (blue) and union (violet and blue) between retro-plumes computed by Mocage and by the CTBTO, for a situation in June 2007 at two sites located in Antarctica and Argentina.

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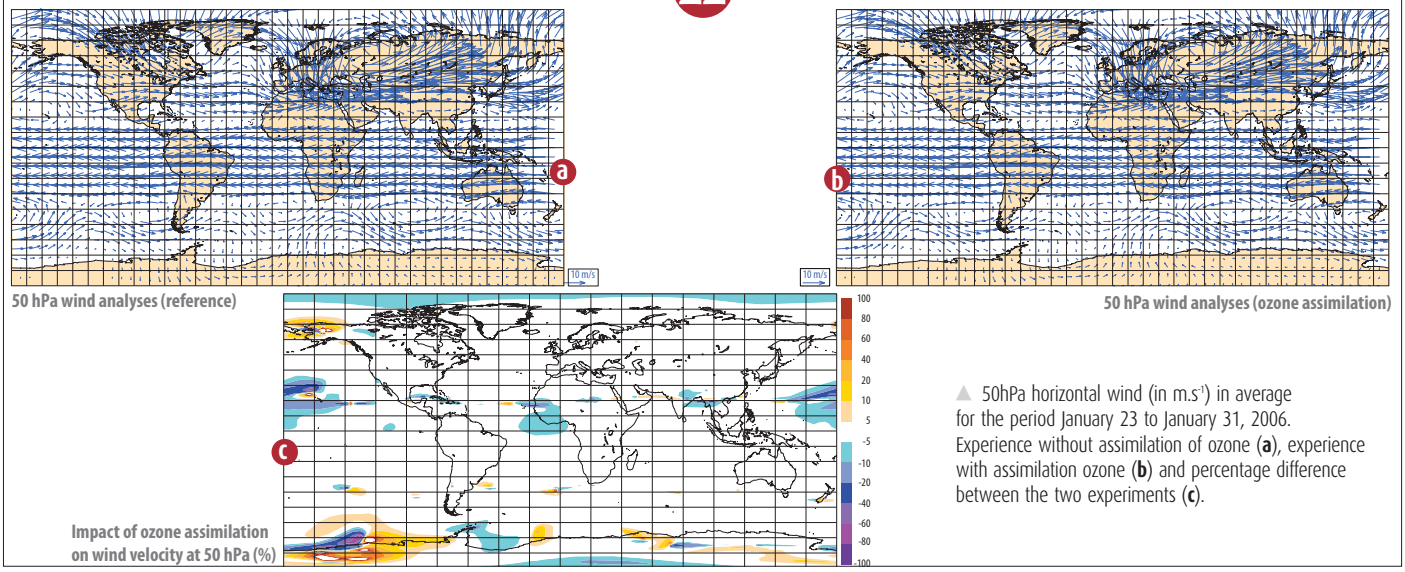


▲ 50hPa horizontal wind (in m.s^{-1}) in average for the period January 23 to January 31, 2006. Experience without assimilation of ozone (**a**), experience with assimilation ozone (**b**) and percentage difference between the two experiments (**c**).

Dynamical impact of ozone assimilation in ARPEGE

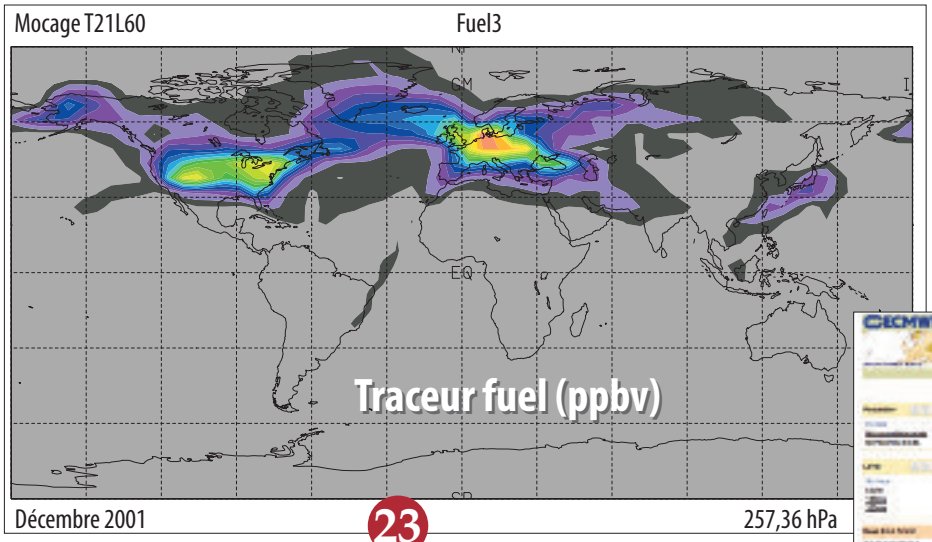
The assimilation of satellite measurements of chemical constituents allows to build reliable spatial and temporal distributions for key atmospheric gases, such as ozone. It is now expected to retrieve some information on atmospheric dynamics from the deformation of the structures of ozone in the lower stratosphere where its lifetime is sufficiently long. This information, additional to the one contained in operational meteorological observations, can potentially improve numerical weather forecasting, particularly in high altitude, in areas with poor meteorological coverage or for medium-range forecasts.
In order to characterize this impact, we have used two tools: the first one is a dedicated chemical assimilation suite, which is based on the chemistry-transport model Mocage of Météo-France and on the Palm software of CERFACS; the other one is an extension of the operational NWP suite ARPEGE, which assimilate simultaneously meteorological and ozone data. Specifically, the 4Dvar algorithm of ARPEGE was used to assimilate stratospheric ozone observations from the AURA/MLS sounder together with meteorological observations considered in current operations at Météo-France. In our experimental context, the variable "ozone" is treated as a passive tracer in ARPEGE while its first-guess, an independent 3D field analysis of ozone, is provided for each assimilation cycle by Mocage-Palm.
For the first time to our knowledge, the assimilation of actual ozone satellite measurements in the NWP suite ARPEGE has shown a non-neutral dynamical impact, although relatively small at this stage. The main impact is a slight improvement in the prediction of wind beyond 24 hours at 50 hPa (~ 20 km) in the tropical region. Further studies are on-going. 22

Simulating the impact from transport means on atmospheric chemistry and climate

Within the European research program QUANTIFY whose aim is to study the effects of terrestrial, sea and aircraft transport on the atmosphere and the climate, the ARPEGE-Climat model of CNRM has been adapted to take into account these features. A main difficulty is to link small-scale phenomena (e.g. contrails from aircraft for instance) to the global scale represented by ARPEGE-Climat. To bridge this gap, a “fuel” tracer is added to the model, with a lifespan varying from 50 minutes (typical for boats) to 2 hours, around 10 km of altitude (which corresponds to the dispersion of contrails generated by airplanes). Thus, ARPEGE-Climat considers the radiative effect of transport by altering cloudiness. The chemical impact is also taken into account by modifications of the simplified chemistry of the ozone layer that now can consider the effect of main pollutants that are nitrogen oxides, carbon monoxide and water vapour. Using this version of ARPEGE-Climat, simulations for the XXth and the XXIst centuries will be made during 2008 to assess the impact of transport for next decades.
In addition, ozone distributions simulated by ARPEGE-Climat will be compared to the MOCAGE model which has s a more sophisticated chemistry. This will be done for a 10 year snapshots, representative of today’s atmosphere and for the years 2025, 2050 and 2100. 23

Ensemble Air Quality Forecast for Europe

2007 was marked by the first demonstration of ensemble air quality forecasts over Europe, a decisive step towards providing an operational pan-European core service. These activities take place within the projects GEMS and PROMOTE (ESA), upon which the operational GMES Atmospheric Service will be built. Météo-France has a coordinating role together with its partners at Prév'Air at the European scale, and provides forecasts with the chemistry-transport model Mocage.
Validated systems for assimilating and forecasting air quality over Europe with relatively fine resolutions (less than 50 km) have now emerged, particularly in France with the platform Prév'Air. It is interesting to take advantage of the dispersion between models to develop better forecasts and to estimate their probabilities of occurrence. Since July 2007 and in the context of PROMOTE, three operational models (CHIMERE, EURAD and Mocage) are combined to offer the first demonstration of an ensemble Air Quality service to potential users. Within GEMS, an important harmonization work has been achieved on emissions, meteorological forcings and chemical boundary conditions; with about ten models involved, activities focus on the exploitation of uncertainties in the chemistry-transport model themselves, as well as on different possible methodologies for ensemble forecasting.
At the same time, an unprecedented effort of concentration in near-real-time of Air Quality observations in about fifteen European countries has been done, in collaboration with the local, regional and national measurement networks. These (non-validated) data are converted into the BUFR format and are used for forecasts’ verification and surface chemical data assimilation. 24



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◀ "Fuel" tracer distribution at level 250 hPa (corresponding to cruise altitude for subsonic aircraft). Apart from main airports, main atmospheric corridors can be seen, as the Northern Atlantic one, linking Europe to America.

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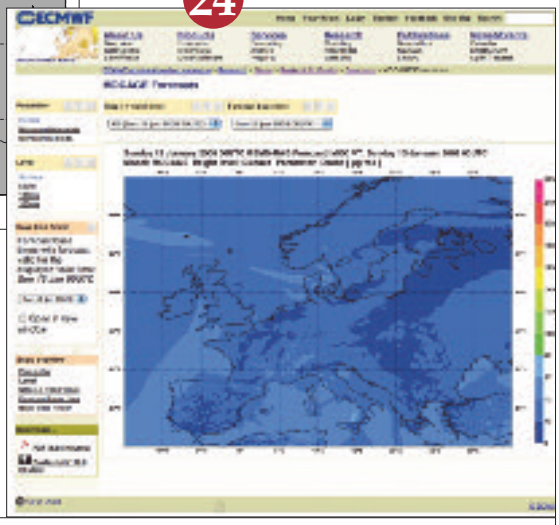

▶ On the website of ECMWF, forecasts from Mocage are presented together with several other individual forecasts from other state-of-the-art models. All contribute to the demonstration of a European air quality ensemble forecast service.

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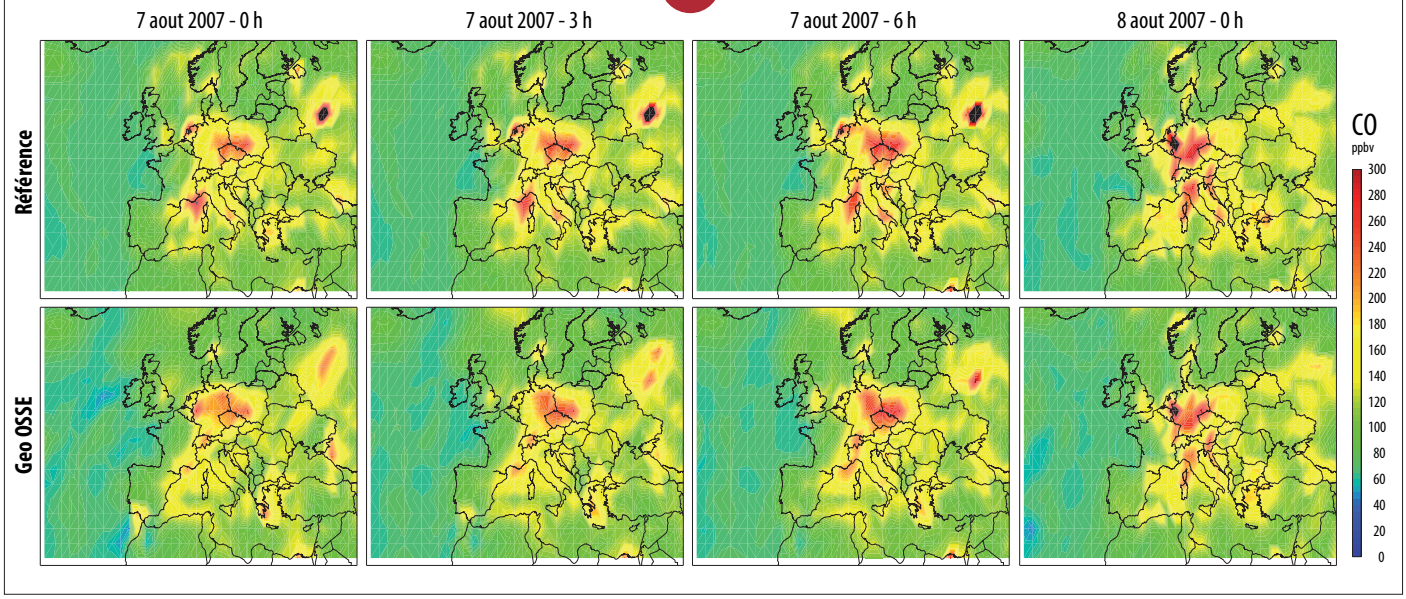


▼ A Simulated Observing System Experiment (OSSE) conducted with Mocage-Palm for CO over Europe. The assimilation of pseudo-observations built from a reference model run (top) can effectively constrain a simulation that starts with an erroneous initial state (low). In the case studied, it takes about 24 hours to correct the initial error.

Preliminary studies for air quality observation from the geostationary orbit

The observation of air quality from space is a challenge, especially in the context of GMES. In addition to ground-based observations, satellite measurements would provide a complementary spatio-temporal coverage, as well as some vertical information in the lower atmosphere. The French operational consortium Prév'Air for Air Quality favours a geostationary sounderwhich can provide the needed temporal resolutions, given the fast diurnal variations of target pollutants: ozone, NO_2, CO and aerosol optical depth.

The development of a remote-sensing instrument that would be suitable for a geostationary platform, and would allow sufficient precision and sensitivity raises many questions. In collaboration with LA, LISA and EADS/Astrium, CNRM contributes by conducting OSSEs (Simulated Observing System Experiment). The Mocage chemistry-transport model is used to simulate pseudo-observations that follow the potential characteristics (geometry, frequency, errors,...) of a geostationary instrument; then, we assimilate these "synthetic" observations in order to quantify their ability to constrain forecasts of air quality. Thus, OSSEs provide an objective basis to develop and optimize the instrument.

We illustrate here results from an OSSE for CO observation over Europe. From a reference simulation performed with Mocage, geostationary CO pseudo-observations are built. Starting from an erroneous initial state, we assimilate these in the model. Within 24 h, the CO assimilation run is progressively catching up with the reference which is an indication of the ability of the observing system to constrain the simulation and to compensate errors (here on the initial condition). This work is also performed in the context of many international collaborations. 25

Avalanches and snow cover studies

A new wind blows on the Nivôse network

Since the first station installed in 1981, the network of high mountain automatic Nivôse stations has been becoming one of the main tools for the operational avalanche forecasting. The French Snow Studies Centre (CEN) is responsible for the current deployment of the third generation of stations, which aims to improve quality and reliability of measurements.
This new station keeps a maximal mechanic compatibility with existing infrastructures, in order to reduce replacement costs. For the same reasons, the alimentation by batteries and solar panels and the satellite transmission (using the Météosat system) have been kept.
The station is now equipped with the new Campbell datalogger CR1000. All the sensors have been changed, using, for instance, a new Young anemometer (wind speed and direction) not too much perturbed by icing, the new Campbell snowdepth sensor SR50A, an optimised ventilated air temperature sensor,... Particular attention has been paid to reduce the station consumption, which was a major source of malfunctioning of the previous station generation.
Early 2006, 21 stations were initially deployed in the Alps, the Pyrenees and the Corsica massifs. During the summer 2007, 15 of them were replaced. Moreover, two new stations have been installed in southern Alps (Orcières in the Champsaur massif and Millefonts in the Mercantour massif), hence reaching a total number of 23 stations.
Next summer this rejuvenating operation of the whole network will be continued and completed, in order to monitor high mountain conditions for years to come. 26

The DOLMEN project : a successfully transfer from research to operational environment

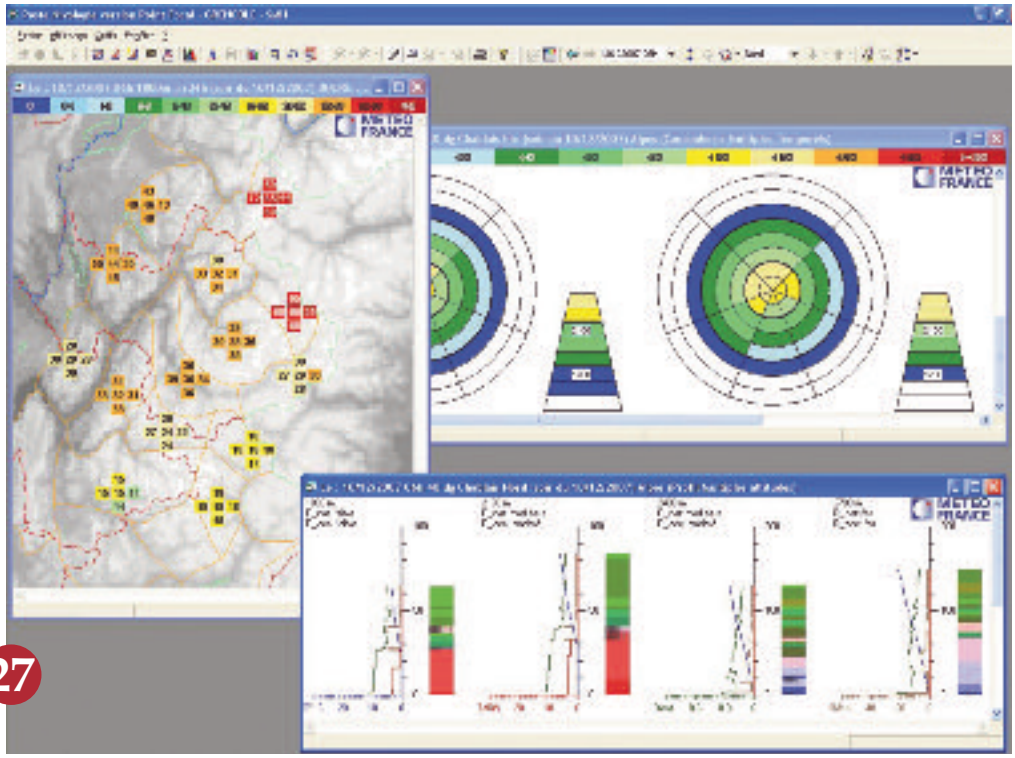
Begun in February 2004, the DOLMEN project aimed at improving the development of a second version of the operational applications used by avalanche forecasters in each departmental centre (CDM). The DOLMEN project whose aim was to improve the development of a second version of the operational applications used by avalanche forecasters in each CDM started in February 2004.
Its three major objectives were :
• The implementation of the SAFRAN chain (meteorological analysis) / the Crocus chain (snow model) / the Mepra chain (avalanche hazard assessment) in a 100 % operational environment (Toulouse computing centre and departmental servers). These chains, developed by CEN, have been operated in a semi-operational mode for several years but only a small part of the results was available for end users.
• The increasing of functionalities of the software named "Poste Nivologie" with an access to all the modelling results. Several comparison products between observation and model were developed especially to determine the relevance of modelling.
• The adaptation to the new codification system of snow-meteo data.
The deployment in December 2007 of the version V2.3 which fulfilled all these objectives, marked the end of the project. This transfer, which reflects a strong integration of the snow monitoring system in the technical architecture of Météo-France, has also been followed up by many training courses either for users of these new tools in CDM or for computing regional units in charge of monitoring these applications..
Subsequent developments will be performed within METEO-FRANCE standard framework. CEN obviously stays in charge of scientific models improvement, as well as the technical and functional responsibility of the tool DOLMEN. 27

3D modelling of water vapor diffusion in snow from microtomographic images: application to isothermal etamorphism

Snow, when placed in isothermal conditions and at negative temperatures, turns into a brittle material made of small rounded bodies which are typical of microstructures commonly obtained during the sintering of ceramics. This complete transformation is classically considered as limited by the water vapour diffusion that occurs in the pore space of the snow structure. In order to validate this hypothesis, the water vapour field from small snow samples was modelized from tri-dimensional images obtained by X-ray microtomography.
Thanks to already developed algorithms, the curvature field is first estimated at the air-ice interface. By using the Kelvin's equation, one can define the vapour pressure conditions near the interface. Then, the diffusion equation is numerically solved with an iterative method, which provides, after convergence, the water vapour field in the pore space (see Figure). The local vapour gradient, which is estimated close to the interface, yields the growth rate at each point of the interface (see figure).
From these results, the water vapour diffusion can be seen as a limiting mechanism for isothermal transformation. However they do not invalidate other mechanisms that could happen inside the snow, such as surface reaction phenomena or growth at grain boundaries.
This model, which can be used to simulate the evolution of small snow structures, is a first step for future more precise comparisons between different mechanisms. 28

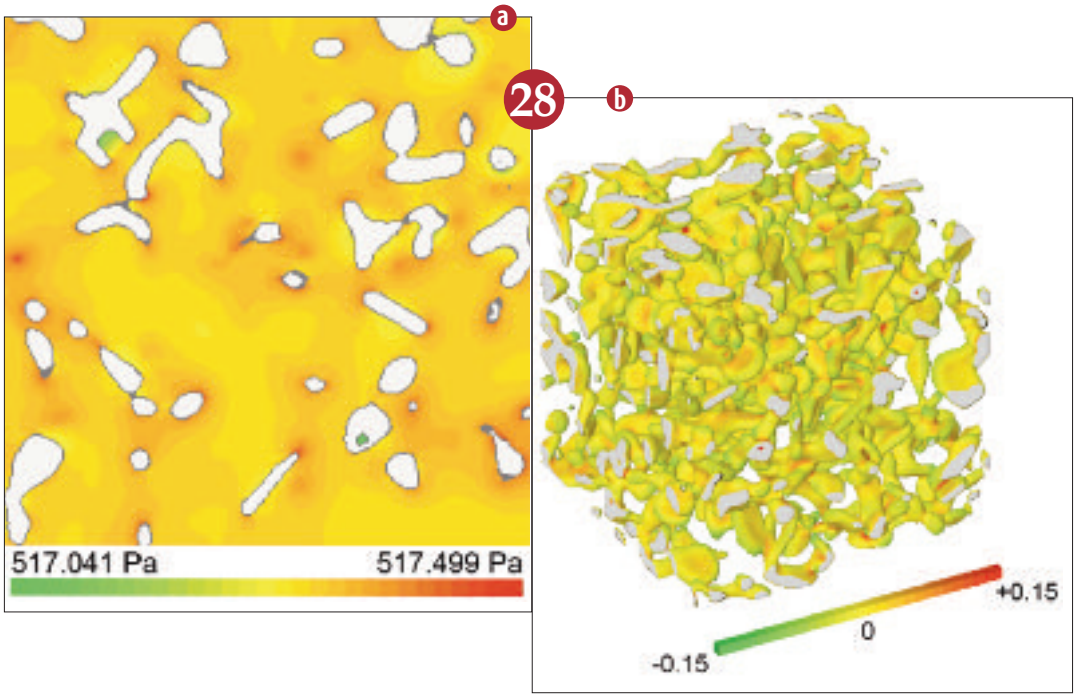
26

◄ the new Nivôse station of la Meije, at 3 100 m a. s. l. in the Oisans massif.



27

► "Poste Nivologie" software . Visualization of modelling results. Map of precipitations over French Alps massifs. Chablais : Simulated snow depth repartition and snow profiles.



28

◄ **a** - 2-D slice of the vapour pressure map computed from a snow image of a sample that has been metamorphosing during 12 days under isothermal conditions. Image edges are about 3 mm wide (300 voxels).

b - Map of the local growth rates computed from an image of natural snow assuming a vapor diffusion-limited mechanism in the snow matrix. Image edges are about 3 mm wide (300 voxels). Growth rates range from -0.15×10^{-10} m/s (green) to $+0.15 \times 10^{-10}$ m/s (red).

Instrumentation for Research

The instrumental teams were mainly concerned in 2007 by the COPS campaign, which took place in the Vosges and Germany. In the meantime, the first European Summer School dedicated to airborne measurements also took place and was so successful that it has been decided to renew the experiment in 2008. Meanwhile, the ADM-AEOLUS project went well ahead.

Aircraft instrumentation

First EUFAR summer school

The 1st EUFAR summer school, SERAI, was organized by the Romanian National Meteorological Administration on July 2007 and was based at Iasi airport, Romania. It aimed at providing a theoretical background to boundary layer dynamics and associated physical processes. The aircraft operator (SAFIRE) also informed the students about issues specific to airborne measurements, such as safety rules, flight plan design and constraints and instrument calibration and operation.
Firstly, students attended lectures about airborne instruments and their performance during different flight patterns as well as information about flight restrictions and other airborne related problems provided by SAFIRE. Then, each student had the opportunity to design his/her own experiments and perform a research flight on the SAFIRE instrumented ATR-42. The main achievements of each group can be summarised as:
• before flight: preparing the flight scenario in accordance to the guidelines of lecturers and aircraft operators; presenting the objectives and methods to all students, followed by a discussion with pilots and lecturers,
• during flight: carrying out the necessary in-flight modifications of the scenario,
• after flight: preparing a report of the group activities including quick-look impressions of the acquired data; debriefing, including description of flight plans alteration, quick-look result presentation and difficulties encountered.
The collected data were processed and analysed with the support of experienced users of airborne facilities. Then, the students wrote a short scientific report and shared their experiments and results with the whole group and lecturers. During each step, students were helped by the lecturers and the SAFIRE crew. The whole flight preparation, execution and debriefing was interactive, thanks to direct contacts with pilots, aircraft operators, and scientific experts.
This summer school was both a good training experiments but also a great opportunity for knowledge exchange and scientific discussions. 1

SAFIRE participation to the COPS campaign

CNRS, Météo-France and CNES jointly operate 3 research aircrafts under the SAFIRE project (Service des Avions Français Instrumentés pour la Recherche en Environnement). Two SAFIRE aircrafts (an ATR42 and a Falcon 20) took part in July 2007 in the international research campaign COPS (Convective and Orographically–induced Precipitation Study) to study the convection above the Black-Forest and the Vosges.
The Falcon 20 flew during 55 hours and was equipped with a LEANDRE2 lidar (a powerful laser operating in visual wave-length, detecting atmospheric water vapour). The flights plans above the studied area were following a grid, at high altitude. The lidar, through a down-looking window, provided important information on the status of the atmosphere before the convection initiation. The Flacon also launched about 20 dropsondes (sensors under a parachute), which send in real time the information of pressure, temperature, humidity and wind of the crossed air.
The ATR42 flew 10 hours in the stratiform clouds which subsist after convective events. The flights were dedicated to inter-comparison of the measurements of super-cooled water droplets between ground radars and the aircraft.
In conclusion, the SAFIRE aircraft brought complementary data to the international community (german, english, dutch...) which will contribute to better understand this region's thunderstorms, and thus, improve the local weather forecasts. 2

Integration of the new CAROLS radiometer on the ATR 42 aircraft

SAFIRE is a joint unit of CNRS / Météo-France / CNES which operates 3 instrumented aircrafts, including Météo-France's instrumented ATR 42. This ATR can be equipped with existing but also with newly developed instruments, such as the CAROLS (Cooperative Airborne Radiometer for Ocean and Land Studies) radiometer. This radiometer will be used, in particular, during the preparatory campaign of the satellite SMOS (Soil Moisture and Ocean Salinity, of ESA).
This new L-band microwave radiometer (developed by CETP) has been installed for the first time on the ATR in September 2007. Two 1.5 meters high antennas have been fixed on the ATR fuselage. These very sensitive antennas had to be placed outside the fuselage in such a way as not to impede on the aircraft manoeuvrability. One antenna pointed at Nadir (to the ground) and the other one at 35°, giving a crossing of data. The radiometer can be coupled or not with the "Storm" weather radar. SAFIRE carried out the design of the radar integration inside the aircraft as well as the certification of the entire installation.
CAROLS estimates ocean salinity and soil moisture. In the coming years, the ATR will participate to many scientific campaigns with this new radiometer. Indeed, soil moisture content is an important factor in the meteorological phenomena initiation whose study is therefore fundamental. 3

1

◀ Students and lecturers together on Iasi airport (Romania), in July 2007, near the ATR42 aircraft from Meteo-France and operated by Safire.

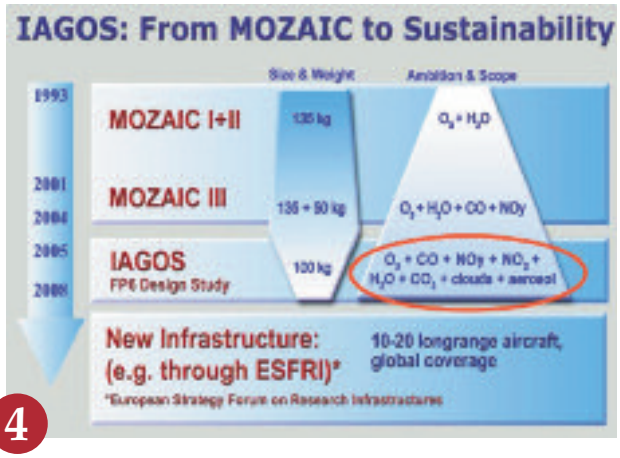
▶ The ATR42 and the Falcon 20 operated by SAFIRE on Baden Airpark airport, in July 2007, during the COPS campaign.

2

3

▲ CAROLS' installation in the ATR cabin (the antenna has a temperature regulation provided by the yellow cover)

▶ Agenda and plans for MOZAIC and IAGOS



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Infrastructure for routine observation of the atmospheric chemistry from civilian aircrafts

IAGOS aims to monitor large scale tropospheric chemistry using air-borne in situ observations from civilian Airbus aircrafts. It relies on the experience gained since 1994 from the MOZAIC research programme and prepares the transition into a sustainable infrastructure with enhanced measurement capabilities, global coverage, and real time transmission. IAGOS is part of IGACO (WMO Atmospheric Chemistry monitoring) for the detection of long term changes and it also meets the requirements of future regional scale Air Quality forecasting centres steered by the European initiative GMES (Global Monitoring for Environment and Security).
CNRM and DSO (management of operational observation) designed a real time data distribution system similar to the AMDAR one (Aircraft Meteorological Data Relay), which collects air-borne meteorological observations for weather forecasting. In 2007, it was decided to defined a new on-board equipment to act as an interface between the chemistry instruments (ozone, water vapour, nitrogen oxides, carbon monoxide and dioxide, droplets and aerosol) and the aircraft communication systems. This apparatus must be easily and cheaply fitted inside different kind of aircrafts and to be able to evolve with a future air analyzing instrumentation.
At the end of 2007, FP7 decided to support the preparatory phase of IAGOS that will start in September 2008 and will define the legal, economical and technical structure of the infrastructure. 4

On site instrumentation and teledetection

Retrieval of the three-dimensional wind field from the French operational weather radars in the frame of the FLYSAFE project

The French ARAMIS network is currently being upgraded with Doppler capacities. This upgrade will equip all radars with Doppler capacities in order to obtain radial velocity measurements at high-resolution (1 km²) in precipitating areas as far as 250 km away from the radars. The Doppler upgrade of the 24 operational radars should be completed by the end of 2008. At the end of 2007, the network was composed of 15 Doppler radarswhose data are about to be assimilated by the AROME model. Several tests have already demonstrated the positive impact of these measurements on the quality of forecasts.

Doppler velocities are in general difficult to interpret because radars only measure the projection of the wind vector along the beam axis. The values of radial velocities are therefore dependent on the wind field characteristics but also pon the relative position of the radar and on the precipitation system. With a network of Doppler radars with overlapping areas, the wind vector (u,v,w) can be retrieved. In that context, a real-time demonstrator has been implemented in northern France. In the frame of the FLYSAFE project, a mesoscale domain (size: 320 x 320 km², horizontal resolution: 2.5 km) has been defined encompassing the Orly and Charles-de-Gaulle airports. Doppler velocities from 6 radars (Trappes, Abbeville, Arcis, Falaise, Avesnes et Bourges) were concentrated, pre-processed and combined in real-time every 15 minutes.

Many different precipitation systems have been analysed (frontal and stratiform systems, squall lines, ...).

The results obtained in the frame of this work have demonstrated that very consistent information could be got about the mesoscale structure of the three-dimensional flow in precipitation areas. The reconstructed wind fields have been evaluated by comparison with wind profilers and by numerical simulations, where the reference wind field is perfectly known.

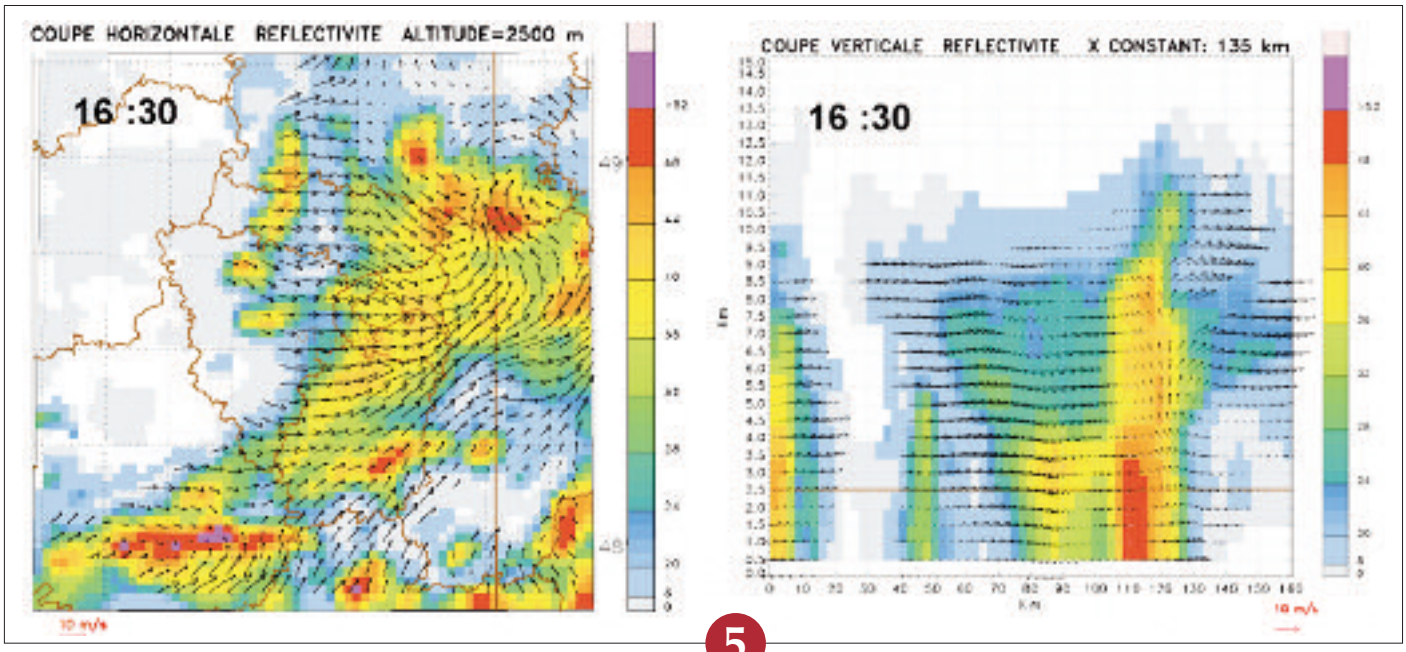
In that context, results from the real-time demonstrator have lead the Radar users' group of Météo-France to recommend the operational implementation of a national three-dimensional reflectivity and wind field mosaic (operational in 2009). 5

Meteorological measurements during the Cirene campaign

The CIRENE campaign, implemented by LOCEAN in the Indian Ocean by 55° E-80° E, 10° S-3° S, was launched to better understand the ocean-atmosphere coupling at intra-seasonal scale and to explain sea surface temperature variability mechanisms, and its influence on the atmospheric column.

This variability influences the monsoon, and can contribute to the formation of El Nino. Closely linked to the VASCO campaign that implemented Aeroclipper and pressurised balloons from the Seychelles Island, the CIRENE campaign took place aboard the French Research Vessel Le Suroît in January and February 2007. CNRM participated to this campaign together with CETP and DT/INSU for the implementation of turbulent heat and latent fluxes and precipitations measurements aboard IFREMER research vessels. This instrumentation was composed of turbulence, temperature, humidity, pressure, and radiatives fluxes measurements, usually duplicated to increase reliability. The set up was the same as the one on the French research vessel l'Atalante during the 2006 AMMA/EGEE campaign, but it has been necessary to set a special 11 metres mast to measure wind an radiative fluxes in good conditions, thus reducing the vessel structure influence.

In order to document atmospheric vertical structure, CNRM made between 2 and 8 radiosoundings; all transmitted in real time to the Global Transmission System. This dataset will contribute to a better understanding of atmospheric phenomena in this area. 6



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▲ Horizontal and vertical cross-sections at 2 500 m obtained by combining the data from Trappes, Arcis and Abbeville on the 23 June 2005 at 1630 UTC during a severe convective episode. The domain, centered on Trappes, has an extension of 160 x 160 km² and a resolution of 2.5 km. The reflectivity field is shown in colors. The arrow-less areas correspond to precipitation-free areas where no velocity data are available. Despite the rather large distance between radars, it can be seen that convective scale structures can be recovered.

6

◀ The French research vessel Le Suroît with it the 11 metre mast in Victoria harbour (Seychelles islands). On the bow, an Aeroclipper gondola ready for an instrumented mast inter comparison.

Instrumentation during the COPS campaign

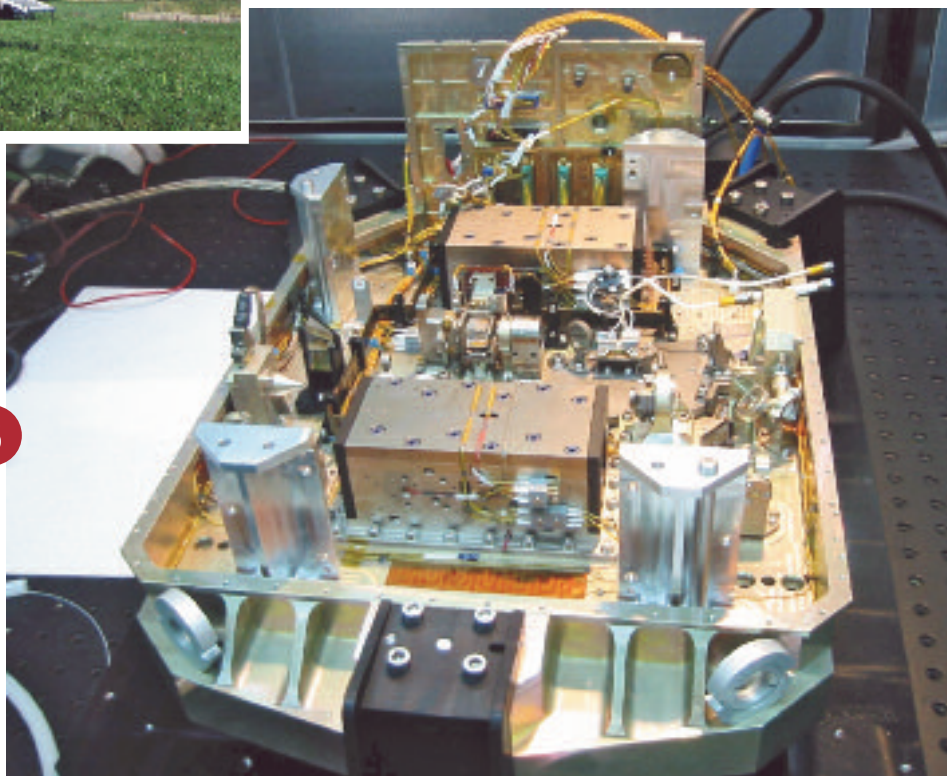
The German Research Foundation provides base funding for Quantitative Precipitation Forecast Researchs. One of the key action of this program was the Convective and Orographically induced Precipitation Study (COPS), an international field campaign. The field experiment was set in South-West Germany and South-East France (mainly Vosges and the Black Forest) from June to August 2007. Several French laboratories took part in this campaign like Laboratoire d'Aérologie, Institut Pierre-Simon Laplace, IGN, LAMP, SAFIRE, CNRM/GMEI... Among other things, Météo-France developed a super-site instrumentation in Meistratzheim (20 km South of Strasbourg) in July 2007.
This super-site was equipped with two surface flux stations recording ground temperature and moisture, a scintillometer for measures of the surface sensible heat flux over a 3 km long horizontal path. To describe the lower layers, a modified ceilometer, a doppler sodar and an UHF wind profiler will be used during the IOP campaign, when 110 radiosondes have been launched and incorporated into the data assimilation system of the forecast model.
Every days, quicklooks of all of the instruments were sent to the operation centre in Baden Baden, Germany, where a SYNERGIE station had been set. Forecasters of the inter-regional service of Météo-France (DIRNE from Strasbourg) also worked on forecasts for the researchers of the campaign and the pilots of aircrafts. This exchange between researchers and forecasters from different European countries happened to be a very fulfilling experience on both sides. 7

Preparation of the ADM-AEOLUS space mission

The wind lidar ADM-AEOLUS space mission of the European Space Agency is in its final stages of development before the launch now planned for mid-2009.
In 2007, CNRM has continued its work in 3 different activities related to the processors of level 1b (dated and geo-referenced winds uncorrected from pressure and temperature effects), 2a (optical products) and 2b (winds that weather forecasting systems can assimilate). The level 1b processor is now nearly completed. As far as level 2a is concerned, CNRM delivered two successive versions of the prototype processor. We also started a new activity on the in-flight radiometric calibration of the instrument required by the level 2a processor. Lastly, the development of the level 2b processor has progressed in collaboration with the European Centre for Medium-range Weather Forecast, and the Dutch weather service KNMI. Our contribution bore mainly on the development of a portable version of the processor dedicated to weather services that wish to assimilate ADM data themselves.
The A2D has passed several successful steps in 2007 thanks to the hard work of the DLR. Two ground-based campaigns were carried out, as well as a first airborne campaign. A second airborne campaign is planned for 2008.
An announcement of opportunity was published by ESA for the in-flight calibration / validation of the instrument. The AO was based on a requirement document to which we contributed through reviews. CNRM submitted an answer based on the work plan proposed and supported by CNES. The answer is made of 5 different proposals from 5 French research institutes. CNRM is responsible for their coordination. 8

7

▲ Radiosonde balloon in Meistratzheim



8

▶
Aeolus transmitter laser.
The two amplifier units
(the two rectangular blocks)
each contain eight laser diode stacks.

Communication and promotion

CNRM communicates and promotes its activities in the field of research. Two major events took place in 2007: the first one consisted in answering the numerous questions around climate changes, the other one was the creation of an access free archive to promote CNRM scientific publications.

Communication

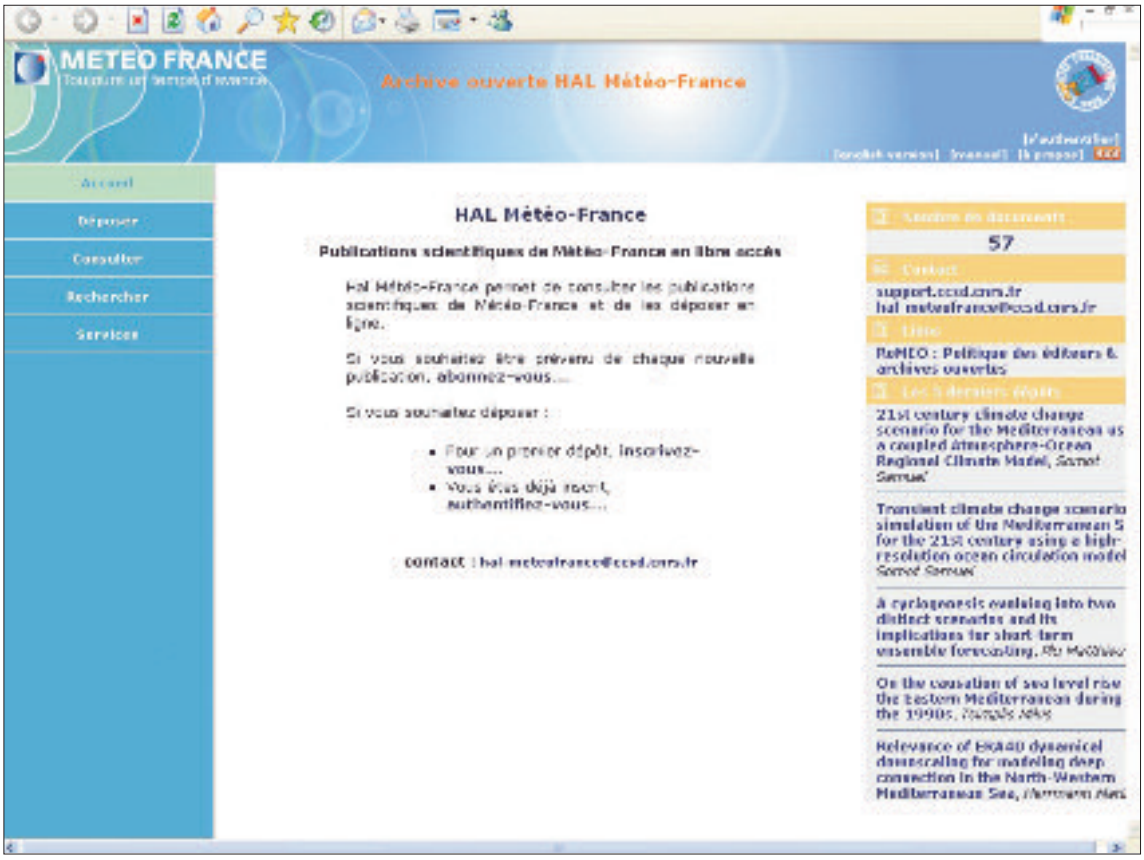
Strengthening the general awareness about climate change

The publication of the GIEC 4th report, followed by the Nobel prize awarded to climate experts, made the headlines in 2007. In this context, scientists from Météo-France were very much solicited.
Many popular scientific magazines (Science & Avenir, Pour la Science, La Recherche, Science & Vie, ...) released a special "climate change" issue in 2007. Papers written by CNRM or DCLIM scientists were systematically submitted and accepted by the editorial committee of these magazines. The non-specialized national press, whether newspapers, television or radio, followed suit and numerous interviews and reports were made. As an example, let us cite notably the interventions by S. Planton, by P. Delécluse or by E. Brun in several successful radio or television programs. (« Téléphone sonne » or « CO_2 mon amour » on France Inter, « C dans l'Air » on France 5, special program at 20 h 50 on France 3, television and radio interviews on TF1, France 2, RTL, Europe 1, France Info, ...).
CNRM researchers also took part in about 80 conferences on these themes, the debates being sometimes either very scientific or, sometimes, for the general public.
In term of internal communication, several events were organized on the site of the Météopole : presentation of first GIEC working group report at the CIC (250 persons), 5 CNRM seminaries on this topic (about 100 persons attending every session), talks following the projections of the film « An Inconvenient Truth ».
Efforts of internal training were also followed by the organization of 2 training sessions about "climate changes" in cooperation with ENM.
All these actions led to a better understanding of the work carried by Météo-France on climate, and to make our fellow citizens sensitive to planet warming. This step will go on in 2008, with notably for the first time, an external training course on the same topic. 1

The new open access archive HAL Météo-France

The open access archive HAL Météo-France has been implemented on the 3rd October 2007. This electronic repository of full-text Météo-France scientific publications gathers together articles published in peer-reviewed journals, PhD theses, "habilitations à diriger des recherches" and conference proceedings. It is a subset of HAL, an interdisciplinary online archive initiated by the Centre National de la Recherche Scientifique (CNRS). HAL Météo-France perpetuates the scientific production of Météo-France and increases its value. With this creation, Météo-France is joining the international movement for free access to scientific research results. As all other open archives, HAL Météo-France provides an easier access to the most recent scientific literature for researchers of the countries of the South.
The documents are deposited by their authors, in respect of the publishers copyright policies, with the support of Météo-France librarians. If full-text archiving is not authorized by the publisher of a journal, only the bibliographic metadata are accessible. A set of explanations and help resources are available on-line on the Météo-France Intranet. The implementation of HAL Météo-France is the first step to modernize the whole Météo-France scientific information system. 2

◄ Serge Planton, Head of Climate Resarch at Météo-France, with Joël Collado (Météo-France/Radio-France), during a lecture about climate changes during the jazz festival " Jazz in Marciac ", in August 7th 2007.



► Internet access to HAL Météo-France

Appendix

2007 scientific papers list

Papers whose at least one author is evaluated by CNRM and is not seconded appear in clear in the list below.

Papers published in rank " A " journals (Impact factor > 1)

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Glossary

Organisms

AASQA Associations Agréées de Surveillance de la Qualité de l'Air
CEDRE Centre de Documentation, de Recherche et d'Expérimentations sur les pollutions accidentelles des eaux
CEPMMT Centre Européen pour les Prévisions Météorologiques à Moyen Terme
CEREA Centre d'Enseignement et de Recherche en Environnement Atmosphérique
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
ESA European Space Agency (Agence Spatiale Européenne)
EUMETNET EUropean METeorological NETwork
EUMETSAT EUropean organisation for the exploitation of METeorological SATellites
HADLEY CENTER Centre Britannique de Recherche sur le Changement Climatique
IFREMER Institut Français de Recherche pour l'Exploitation de la MER
IGN Institut Géographique National
IMFT Institut de Mécanique des Fluides de Toulouse
INSU Institut National des Sciences de l'Univers
KNMI Koninklijk Nederlands Meteorologisch Instituut (Institutroyal météorologique des Pays-Bas)
MEDAD Ministère de l'Ecologie, du Développement et de l'Aménagement Durable
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
SPOT Satellite Pour l'Observation de la Terre
UKMO (MetOffice) United Kingdom Meterological Office

Laboratories or research/development teams

CEN Centre d'Etudes de la Neige
CETP Centre d'Étude des environnements Terrestre et Planétaire
CMM Centre de Météorologie Marine
CMS Centre Météorologie Spatiale
CNRM Centre National de Recherches Météorologiques
ENM/UFR Ecole Nationale de la Météorologie/Unité de Formation et de Recherche
GAME Groupe d'études de l'Atmosphère MétéorologiquE
IPSL Institut Pierre-Simon-Laplace
LA Laboratoire d'Aérologie
LaMP Laboratoire de Météorologie Physique
LCPC Laboratoire Central des Ponts et Chaussées
LISA Laboratoire Interuniversitaire des Systèmes Atmosphériques
LOCEAN Laboratoire d'Océanographie et du Climat : Expérimentations et Approches Numériques
NASA National Aeronautics and Space Administration
SAFIRE Service des Avions Français Instrumentés pour la Recherche en Environnement
SPEA Simulation Physique des Ecoulements Atmosphériques

National or european programms or projects

National programs or projects

ANR Agence Nationale de la Recherche
COPS Convective and Orographically-induced Precipitation Study
CYPRIM CYclogénèse et PRécipitations Intenses en région Méditerranéenne
IRCAAM Influence Réciproque des Climats d'Afrique de l'ouest, du sud de l'Asie et du bassin Méditerranéen
PERLE Programme d'Evaluation des Rejets Locaux d'Effluents

International programmes or projects

CERES CarboEurope Regional Experiment Strategy
CIRCE Climate change and impact research : mediterranean environment (FP6)
CIRENE Projet d'observation de l'océan indien tropical
ENSEMBLES Ensemble-based predictions of climate changes and their impacts (FP6)
EUCOS EUmetnet Composit Observing System
EUFAR EUropean Fleet for Airborne Research (FP6)
FLUXNET Programme international sur les mesures de flux de carbone dans les écosystèmes terrestres
FLYSAFE Système de vol intégré pour l'amélioration de la sécurité, la protection contre les imprévus, et les opérations tout temps
GEMS Global and regional Earth-system Monitoring using Satellite and in-situ data (initiative du CEPMMT)
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 (Système Global d'Observation de l'Environnement pour la Sécurité, programme de l'Union européenne)
HIRLAM HIgh Resolution Limited Area Model (modélisation)
HyMeX Hydrlogical cycle in the Mediterrannean EXperiment
IMFREX IMpact sur la Fréquence des EXtrêmes
IPCC Intergovernmental Panel on Climate Change (GIEC)
MERSEA Marine EnviRonment and Security for the European Area
MISSTERRE Modélisation Intégrée du SyStème TERRE (projet LEFE)
MOZAIC Measurement of OZone by Airbus In service airCraft
MyOCEAN Successeur du projet MERSEA, visant à sa consolidation, piloté par Mercator Ocean
PROMOTE PROtocal MOniToring for the GMES service Element for atmosphere project
QUANTIFY QUANTIFYing the climate impact of global and european transport systems (FP6)
SAF Satellite Application Facility
SAMM Sea Atmosphere Mediterranean Model (modéle couplé régional)
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 Approche Multidisciplinaire de la Mousson Africaine
COPS Convective and Orographically-induced Precipitation Study
Atmosphérique et de Transports d'Emissions
EGEE Volet océanographique de la campagne AMMA (golfe de Guinée)
PARIS-FOG Campagne de mesures pour l'étude du cycle de vie du brouillard (Palaiseau 2006)
SMOSMANIA Soil Moisture Observing System : Meteorological Automatic Network Integrated Application
VASCO Campagne intensive d'observations atmosphériques et des échanges océan-atmosphère

Others

ADM-AEOLUS Atmospheric Dynamics Mission (satellite d'observation de la dynamique de l'atmosphère terrestre, mis en œuvre par l'ESA)
ADP Aéroports De Paris
ALADIN Aire Limitée, Adaptation dynamique, Développement InterNational
ALADIN-Climat ALADIN-Climat
ALBATROS Autoflux Linked Base for TRansfer at Ocean Surface
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
AQUA Satellite du Earth observing system de la NASA
AQUARIUS Satellite de mesure de la salinité de la surface de la mer
AR-4 Annual Report 4 (4ème rapport annuel du GIEC)
ARAMIS Application RAdar à la Météorologie Infra-Synoptique
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
ARPEGE-SCM SAFRAN-CROCUS-MEPRA
ARGOS Advanced Research and Global Observation Satellite
ASAP Automated Shipboard Aerological Programme
ASCAT Advanced SCATterometer

ATE Analyse des Terres Émergées (SAF Eumetsat)
ATOVS Advanced Tiros Operational Vertical Sounder
ATR Avion de Transport Régional
AURA/MLS AURA (satellite)/Microwave Limb Sounder
BUFR Binary Universal Form for the Representation of meteorological data
CALIPSO Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observations
CAPE Convective Available Potential Energy
CARIBOU Cartographie des Analyses du RIsque de Brume et brOUillard
CAROLS Cooperative Airbone Radiometer for Ocean and Land Studies
CHAMP CHAllenging Minisatellite Payload
CHIMERE Modèle de prévision de la qualité de l'air du CNRS et de l'INERIS
CIC Centre International de Conférences
CLOUDSAT CLOUD SATellite (satellite d'observation de la NASA)
CMRS Centre Météorologique Régional Spécialisé
CNRM-CM3.1 CNRM - Climate Model Version 3.1
CNRM-CM3.2 CNRM - Climate Model Version 3.2
CNRM/GMEI Centre National de Recherches Météorologiques/Groupe de Météorologie Expérimentale Instrumentale
CNP Centre National de Prévision
COBEL Code de Brouillard à l'Echelle Locale
COSMIC Constellation Observing System for Meteorology, Ionosphere and Climate
CROCUS Modèle d'évolution du manteau neigeux
CYCOFOS Prévision pour la Méditerranée (plate-forme Chypre)
DCLIM Direction de la CLIMatologie
DGT Direction Générale Toulouse
DIAGPACK DIAGnostic PACKage
DIREN Direction InterRégionale Nord-Est
DIRIC Direction InterRégionale Ile-de-france Centre
DOLMEN Développement OpérationnelL des Moyens d'Expertise Nivologique
DT/DSO/CMR Direction Technique/Direction des Systèmes d'Observation/Centre de Météorologie Radar
ECOCLIMAP Base de données de paramètres de surface
ECUME Exchange Coefficients from Unified Multi-campaigns Estimates
EPI Evénements Précipitants Intenses
EPS Ensemble Prediction System
EQM Erreur Quadratique Moyenne
ERA40 Réanalyse (sur 40 ans) du CEPMMT
ERS European Remote Sensing satellite
ERS-SCAT ERS SCATterometer
EURAD EURopäisches Ausbreitungs- und Depositionsmodell
FM13-SHIP Message utilisé en météorologie marine
FM18-BUOY Message utilisé en météorologie marine
FORMOSAT Satellite operated by Taiwan's National Space Organization
GELATO Modèle d'évolution de la banquise développé au CNRM
GLC2000 Global Land Cover 2000
GMAP Groupe Météorologique d'Assimilation Prévision (CNRM)
GML Geography Markup Language
GNSS Global Navigation Satellite System
GPS Global Positionning System
GRACE GRAvity recovery and Climate Experiment
GRAS GNSS Reiver for Atmospheric Sounding
GT1 Groupe de Travail 1 (du GIEC)
GUR Groupe des Utilisateurs Radar
HADISST HADley centre global sea Ice and Sea Surface Temperature
HAL Hyper Article en Ligne
HIRS High resolution Infrared Radiation Sounder
IAGOS Integration of routine Aircraft measurements into a Global Observing System
IASI Interféromètre Atmosphérique de Sondage Infrarouge
IFS Integrated Forecasting System
IGACO Integrated Global Atmospheric Chemistry Observations
IOP Intensive Observation Period (IOP)
IPY International Polar Year
IRIDIUM Satellite en orbite polaire
ISBA Interaction between Soil, Biosphere and Atmosphere
ISBA-CC ISBA-Cycle du Carbone
KFS Méthode de réduction d'entropie KFS
LEANDRE2 Instrument Lidar aéroporté
LEF Langue d'Eau Froide
LES Large Eddy Simulation
L-EPS Prévision d'ensemble sur un domaine limité
LIDAR Light Induced Detection And Ranging
MedSlik Modèle de dispersion de polluants
MEPRA Modèle Expert de Prévision du Risque d'Avalanche
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
MFS Meteorological Forecasting System
MHS Microwave Humidity Sounder
MOCAGE MOdèle de Chimie Atmosphérique à Grande Echelle
MODCOU MODèle hydrologique COUplé surface-souterrain
MODIS MODerate resolution Imaging Spectroradiometer
MOTHY Modèle Océanique de Transport d'HYdrocarbures
MSG Meteosat Seconde Génération
NAO North Atlantic Oscillation
NH Non Hydrostatique
NIVOSE Station automatique de mesure en haute montagne
OD3D Modèle de météorologie marine
OPA Océan PArallélisé
OPAMED Océan Parallélisé/MEDiterranée
ORCHIDEE ORganizing Carbon and Hydrology In Dynamic EcosystEms
OSSE Observing System Simulation Experiments
OTICE Organisation du Traité d'Interdiction Complète des Essais nucléaires
PALM Projet d'Assimilation par Logiciel Multi-méthodes
PANTHERE Programme Aramis Nouvelles Technologies Hydrométéorologie Extension et REnouvellement
PCRD Programme Cadre de Recherche et Développement
PEARP Prévision d'Ensemble ARPège
Prév'Air Simulations déterministes de la qualité de l'air en France et en Europe
RADOME Réseau d'Acquisition de Données et d'Observations Météorologiques Étendu
RALI Système RAdar-LIdar
RASTA Radar Aéroporté et Sol de Télédétection Atmosphérique
ROC Relative Operating Characteristics
SAFRAN Système d'Analyse Fournissant des Renseignements Atmosphériques à la Neige
SAF-NWC Satellite Application Facility - NoWCasting
SBD Short Burst Data (bouées)
SIGMA Système d'Identification du Givrage en Météorologie Aéronautique
SIM Safran-Isba-Modcou
SIR Safran-prévision/Isba-Route
SMOS Soil Moisture and Ocean Salinity
SMT Système Mondial de Transmission
SOP Special Observation Period
SST Sea Surface Temperature
SURFEX SURFace EXternalisée
SVP-B Surface Velocity Program (océanographie)
SYMPHONIE Modèle 3D aux équations primitives développé par le Laboratoire d'Aérologie
TRIP Total Runoff Integrating Pathway
TSM Température de Surface de la Mer
UHF Ultra High Frequency
UTC Universal Time Coordonnated (TU)
VEGETATIONB Module du satellite SPOT
VHF Very High Frequency
WIMS-Cb Weather InforMation Systems on Cumulonimbus
3D-Var Assimilation variationnelle tridimensionnelle
4D-Var Assimilation variationnelle quadridimensionnelle

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