Météo-France

Research Report 2011

METEO FRANCE
Toujours un temps d'avance

Research Report 2011

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The objective of research at Météo-France is to help the organization carry out its mission, defined as "monitoring the atmosphere, the upper ocean, and the snow mantel, anticipating their evolution, and distributing the corresponding information". The mission statement of Météo-France also mentions that "research activities shall contribute to improve the observation and understanding of the atmosphere, as well as its interaction with the environment, human activities and climate".

This Research Report for 2011 contains a wealth of examples of the various activities we conduct to meet the above requirements. Tools for numerical weather prediction are of course actively developed. New science results are derived from various field experiments. Developing new observation techniques or strategies is also a major axis of activity. A substantial part of our work is turned towards improving Meteo-France services to aviation. Research activities therefore span a wide spectrum, from upstream research to applications. They take place both in specialized laboratories, associated to the Centre National de la Recherche Scientifique (CNRS) and to universities, and in the operational departments of Météo-France.

The Centre National de Recherches Météorologiques (CNRM) plays a central role in the development of our research activities, with a triple mission: as a research unit, it conducts several research programmes of international quality and visibility. It also coordinates R&D activities in other departments of Météo-France. Finally it leads the partnership policy of Météo-France. Most of the contribution of Météo-France to AllEnvi, the alliance of research organizations on the environment, is delivered by CNRM.

In 2011, we have accomplished significant steps towards aligning research activities with the Observatoire Midi-Pyrénées (OMP), the main university research organization in Toulouse in the field of environment, which has about 1000 scientists and engineers. Météo-France has signed the agreement to support OMP and has become member of its Board. We have also decided to align the timing of our five-year contracts with CNRS and AERES (Agence d'Evaluation de la Recherche et de l'Enseignement Supérieur). An intermediate assessment of our research activities was requested from AERES and took place at the beginning of 2012. The assessment confirmed the high level and growing productivity of our labs. The next science prospective covering the period 2015-2019, will be prepared in close cooperation with OMP.

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In 2011, CNRM-GAME has also finalized its contribution to the IPCC 5th report. It started new developments for the numerical weather prediction systems, and conducted several field experiments. It contributed to defining the objectives of Météo-France for its new Contract with the government, covering the period 2012-2016, and the objectives of the French scientific community on atmosphere and oceans.

I wish you a good reading of this report!

Philippe Bougeault
Director, Centre National de Recherches Météorologiques

Weather forecasting models

Numerical weather prediction

The operational numerical weather prediction applications that are made available to Météo-France forecasters and clients undergo a consolidation phase. Thus, the set of four limited area 8km resolution Aladin systems deployed to cover four oversea regions has been extended to include an analysis of surface parameters. The assimilated observing system also is continuously extended. Some examples are shown in the following pages, an incomplete selection that does not enable to mention all the instruments the use of which is being prepared. In this spirit of consolidation, a well known drawback of the global model ARPEGE begins to be addressed: a change in the deep convection parameterization scheme, described in more details below, limits the tendency to develop small scale vortices within active lows. The convection resolving model AROME benefits from an upgrade of the network providing humidity measurements derived from the GPS, it benefits from an improvement of the low level cloud forecast and from a new hail risk diagnostic (figures a and b). Several significant new features should be ready next year, in the area, for example, of ensemble data assimilation and forecast. The current phase also enables to make progress on technical projects that are rarely highlighted but prepare the future. An ambitious refactoring of the common code with ECMWF and the Aladin and Hirlam consortia countries is clearly undertaken. The procurement of the next computing system, together with the implied availability of the new benchmark versions of the models is now running. A new common software infrastructure to run numerical experiments or operational applications is beginning to take shape, with a view to ease the transformation of one experiment to an operational setup.

The main map at the centre of the panel is the hail risk forecast from the AROME convection resolving model started 23/08/2011 00UTC between 05UTC and 09UTC (the yellow and red colours of the field correspond to two levels of hail intensity) and the surrounding pictures provide some verification: top left, a radar reflectivity composite image at 06UTC, bottom left, a NOAA16 AVHRR image a little later as the most active convective system reaches the northern border of France and some hail stones collected at Bavay (59) around 07UTC (from a photography published on the Keraunos association site, http://www.keraunos.org).

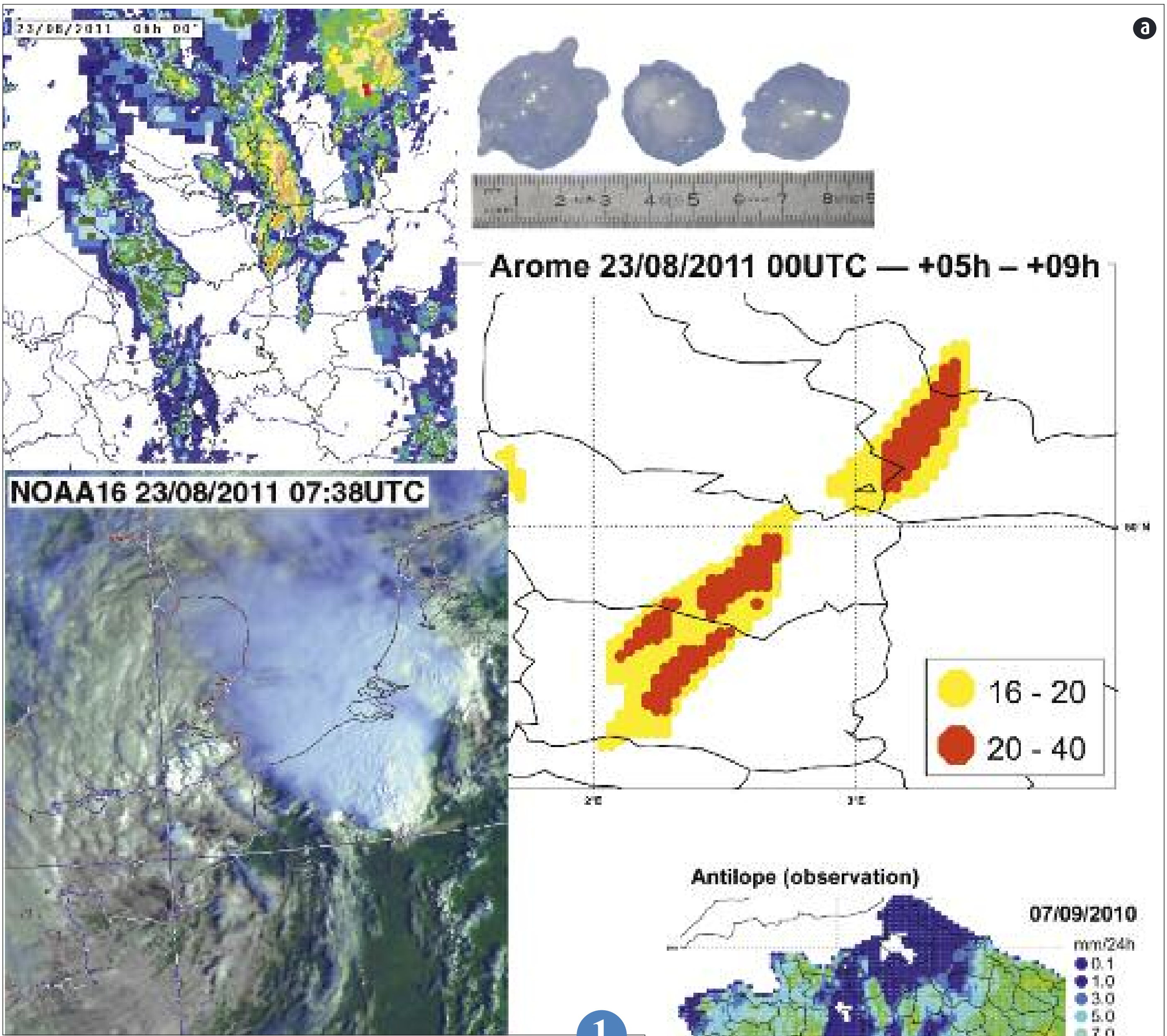
1

Modelling the spatio-temporal dynamics of forecast error correlations

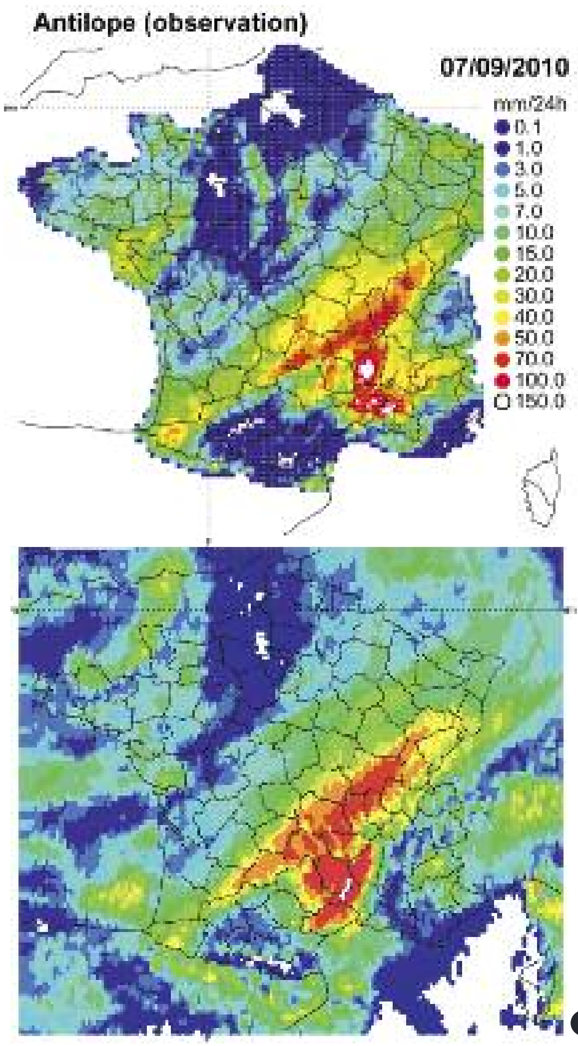
In data assimilation systems, maps of forecast error covariances are used to spatialize the difference between guess-field and observation. Modelling these covariances is based on an ensemble assimilation approach, currently made of six members, which simulates the evolution of analysis and forecast errors. The modelling technique also relies on tools which filter sampling noise associated to a small ensemble size. These tools have been developed for local error variances firstly, whereas spatial correlations currently remain homogeneous and static.
A wavelet model is experimented to extract robust information on the spatio-temporal dynamics of correlations. This is illustrated on the figure which corresponds to geographical variations of wind correlation length-scales, for a 4-day winter period. It can be seen that length-scales are relatively large over the Tropics, in connexion with large-scale tropical waves. During this period, length-scales are small in the eastern part of USA and near Europe, which is related to cyclogeneses with relatively strong wind gradients.
Impact studies indicate that using such a sliding time average of correlations over a few days has a positive impact over the forecast quality, compared to homogeneous and static correlations. These results also support the idea to increase the ensemble size, in order to describe more precisely the correlation dynamics from one day to the other, and within a given day too. This would also allow ensemble forecasts to be better initialized.

2

Horizontal length-scales (in km) of wind forecast error correlations near 500 hPa (iso-colours, in hPa), averaged over the period from 24 to 27 February 2010. The length-scale of a local correlation function is a measure of its spatial extension.

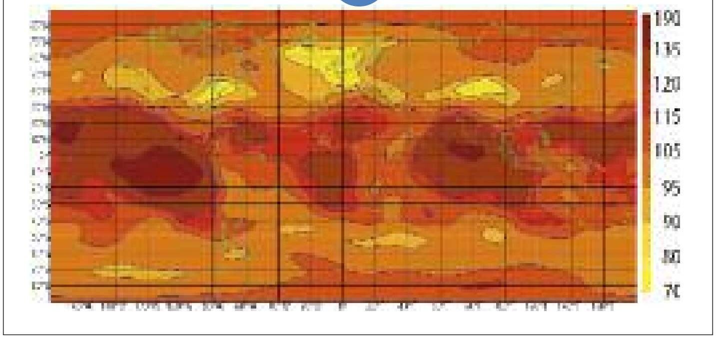


1



Reforecast of the red alert heavy precipitation situation of September 2010 in southern France performed with ARPEGE as part of the validation of the newly retuned deep convection parameterization scheme. Left panel is an observation derived 24h accumulated precipitation analysis for 07/09/2010. Right panel is the new forecast. The operational forecast already was informative: the purpose of the experiment shown is to check that, although the convection scheme has been made more active in frontal areas, it keeps the same behaviour as before in a more convective context. Indeed, the forecast of the maximum precipitation is slightly improved.

2



Modifications of the Arpege convection scheme

Deep convection plays an essential role in weather forecasting and in the Earth's climate. But it occurs at fine scales. So, a physical parameterization is used in global numerical weather prediction and climate models to represent the involved processes and their effects on the temporal evolution of model state variables.
In the Arpege model, this parameterization has weaknesses, including an underestimation of the vertical transfers of energy under specific conditions, leading to the occurrence of hyperactive subsystems of small spatial dimensions in active lows. Some changes were made in this scheme to increase its intensity depending on local characteristics of the flow, such as the large vertical velocity in the lower layers. The idea is to enhance the convective vertical mixing when a local unrealistic cyclonic circulation starts. This change limits significantly the formation of wrong small vortex, without affecting the general behaviour of the model and its scores. The Arpege's ability to simulate mid-latitude cyclogenesis is kept. This change also affects the tropical cyclones which are less deep.
A complete renewal of the convection parameterization is undertaken with the development of a new scheme including a prognostic treatment of several convective variables, memory of the convection evolution.

3

SEVIRI data assimilated over land surface

Infra-red satellite data from the SEVIRI radiometer onboard the geostationary satellite MSG, are assimilated in the AROME and ALADIN limited area models. Measurements are performed in 12 spectral channels with an unprecedented spatiotemporal resolution (1 image every 15 minutes with a 3km horizontal resolution). They provide useful information on the state of the atmosphere (temperature and humidity) at several levels. However, SEVIRI observations pertaining to low-levels are rejected over land partly because of the inappropriate description of the surface temperature in the model. This is improved by computing a new surface temperature from the SEVIRI data and with the help of a surface emissivity atlas. This new surface temperature estimate compares well with independent observations. Using this new temperature, surface sensitive SEVIRI observations have been assimilated in the ALADIN model for a 3 month period. The comparison with the forecast/analyses of the operational model (without SEVIRI data over land), reveals a significant drying over Spain supported by independent humidity measurements. These developments will soon be implemented in the operational AROME suite.

4

Improvements of surface processes representation in overseas ALADIN models

ALADIN forecast systems have been put in operation at the end of 2010 over three overseas domains (called ALADIN OM): French Polynesia, New Caledonia and the French West Indies and Guiana. These domains are an addition to the existing one that covers the southwest Indian Ocean whose primary goal is to help RSMC at the island of La Reunion in forecasting tropical cyclones. These models, with their own data assimilation system, generate more precise meteorological fields than those produced by global models.
The recent developments implemented in September 2011 mainly improve the representation of the surface processes. Firstly, the orography and the land-sea mask of the model are derived from more accurate and finer database (1 km resolution instead of 5 km). The use of the CANOPY prognostic scheme, which describes the atmospheric variables on several levels defined very close to the surface over continents, allows to better simulate the surface boundary layer, especially its diurnal cycle. Lastly, as from now, these surface variables are analysed using in-situ observations every 6 hours.
Further work will focus on the implementation of a more sophisticated version of the surface scheme itself (SURFEX) and on the simplification of output formats to render access easier to users.

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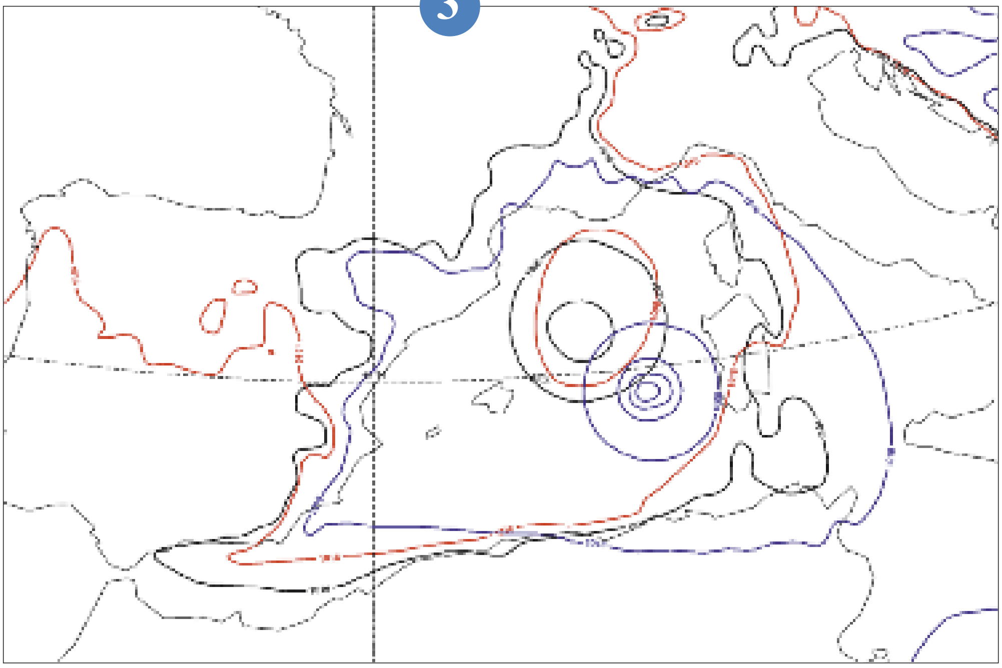
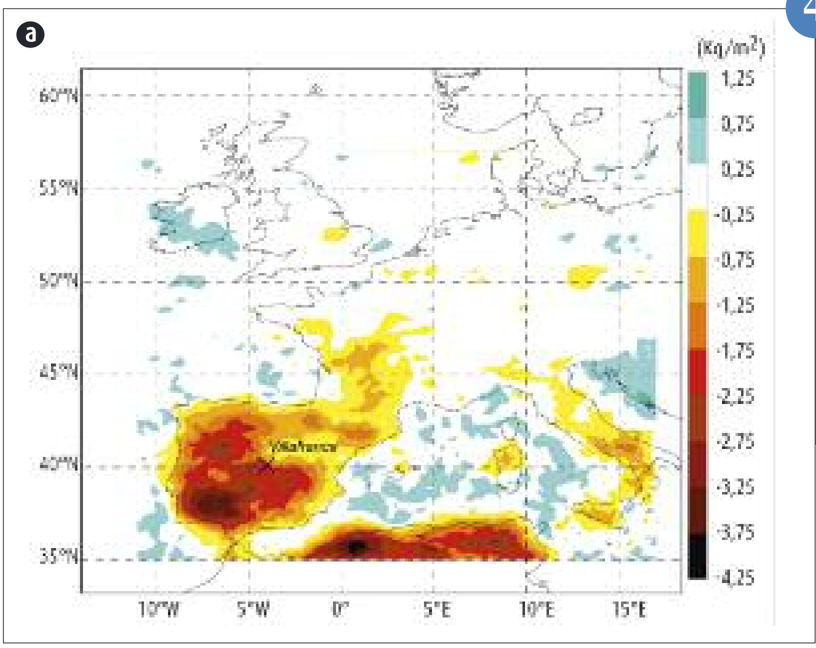
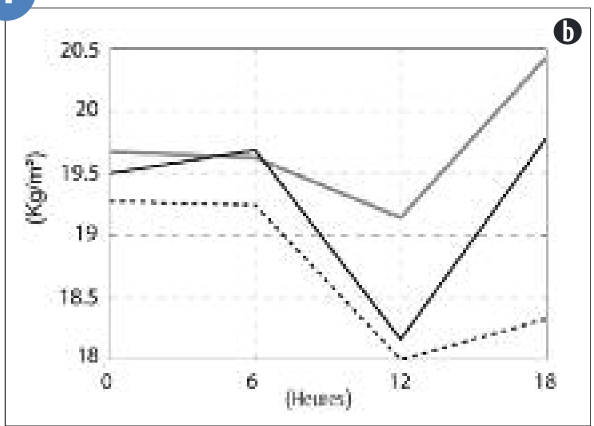


Mean Sea Level Pressure charts valid for 00 UTC of 08-11-2011: analysis (in red) and two 72h Arpege forecasts with (in black) and without (in blue) modifications in convection scheme.

4

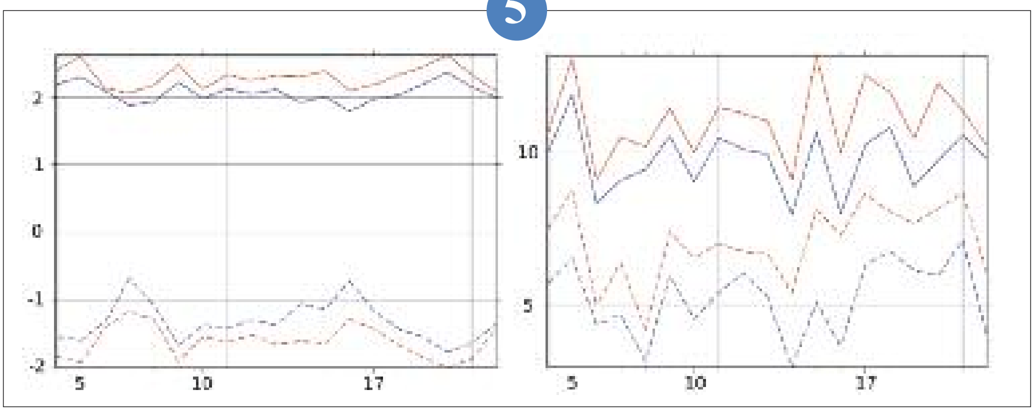
Average values of TCWV from GPS (Villafranca) (dotted black line), EXP (black thin line) and CTL (grey line) according to the assimilation cycle (0-6-12-18 UTC).TCWV values are averaged over 45 days (September 1 to October 15 of 2009).





Mean analysis difference in total column water content (TCWV) between EXP (with SEVIRI over land) and CTL (without SEVIRI over land) at 12UTC. TCWV maps are averaged over 45 days (1 September – 5 October 2009). Red (blue) colour means that EXP contributes to decrease (increase) moisture in the analysis as regard to the CTL.

5



Example of improvements over the French West Indies and Guiana area: nineteen 24h-forecasts, realised between the 3rd of July 2011 and the 21st of July (horizontal scale), are compared to observations for the following parameters: 2m temperature (top) and 2m humidity (bottom). Blue lines indicate the new version of the model, red ones the former one. Bold lines show the root mean square of the differences between the model and the observations, dash lines show the bias of these differences; units are Celsius degrees for temperature, percent for humidity (vertical scale).

1D simulations of cloudy boundary layers in the frame of the EUCLIPSE project

Simulating clouds in NWP or climate models is a fundamental challenge; cloud feedback remains the largest source of uncertainty in projections of future climate. The European EUCLIPSE project (2010-2014) is targeted at reducing this uncertainty.

Within this framework, simulations were carried out with the 1D version (SCM) of the global Météo-France ARPEGE model (either with the operational version or the climate one), and also with the operational meso-scale AROME model. Comparing the cloud processes simulated by high resolution models (LES) and those simulated by SCM is a way to identify and evaluate deficiencies in the representation of cloud processes in large-scale models. Some cases were studied after this methodology, so as to describe the transitions between shallow clouds (stratocumulus) and deeper clouds (cumulus type), as it is frequently observed over tropical oceans.

The results of the three models tested on the ASTEX case (1992) show an underestimation of the height of the top of the cloud and the rising of the bottom of the cloud, except for the AROME model, where the simulated cloud bottom is too high. In the climate version, this deficiency is linked to a too active convection that can clearly be improved by the introduction of a minimum value for the height of the simulated convective clouds. These 1D cases of stratocumulus/cumulus transitions contribute to an important test bed used to evaluate and calibrate sub-grid-scale processes in Météo-France models.

6

Estimating deformations of random processes, with application to data assimilation

A classical problem in computer vision consists in estimating the shape of a surface in a scene, by analyzing the distortion of its texture projected in an image. For instance, a photography renders the effect of perspective visible by shortening the texture elements that are further away from the photographer. Texture can be modelled either deterministically, by texture elements, or stochastically, which is of interest here. The underlying idea is that forecast errors in numerical weather prediction are deformed random processes, and they are deformed by the atmospheric flow in particular. It is possible to estimate this deformation by the algorithm developed in the computer vision community. This particular algorithm relies on continuous directional wavelets to measure the relative deformation gradient at different scales and orientations. By integrating a system of equations, it is possible to recover the original deformation. The methodology can be applied to the modelling of covariances of forecast errors, which is a topic of active research in data assimilation. In a first attempt, promising results have been obtained at convective scales: the obtained structure functions show flow-dependency consistent with the raw estimates. The algorithm has been found to be suitable for data assimilation in large dimensions. The extension to spherical geometry and further assessment are planned in the project MoMa founded by the RTRA-STAE.

7

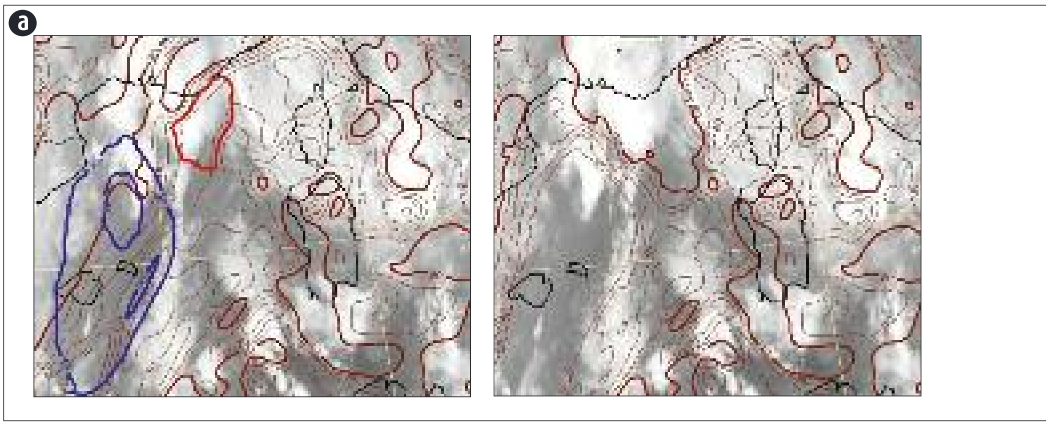
Potential of the methods of initial conditions corrections for the forecasts of remarkable meteorological phenomena

Initial conditions errors are an important source of forecast failure. A tool allowing to correct the initial state of the global model of Météo-France, ARPEGE, was developed at the Forecast Laboratory and applied to a sensitivity study to initial conditions of moisture on the situation of 14 to 15 June 2010 caracterized by very heavy rainfall on the region of Draguignan (Var).

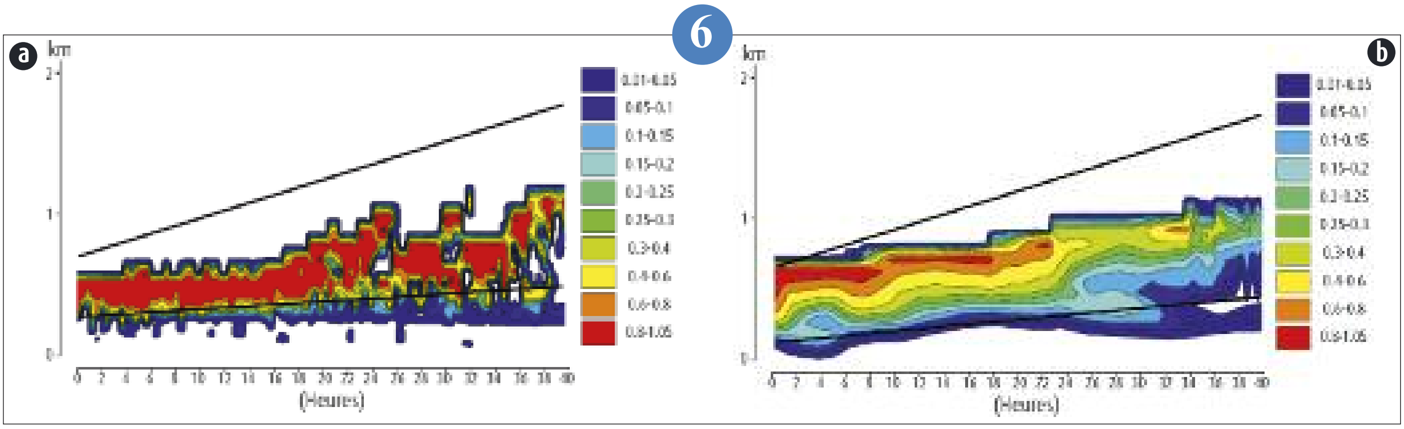
The comparison between the images of the Meteosat satellite in the water vapor channels and the moisture field in the mid-troposphere allows to criticize the initial conditions and to suggest corrections. The height of a surface with a given specific humidity is then modified in agreement with the satellite observations. The vertical consistence of the humidity correction is provided by a variational method.

A correction was applied in the direction to moisten the initial condition in the area of appearance of organized convection and to dry upstream (Figure a). Figure b shows a significant impact of the modification on the precipitation forecast. The initial phase of the system is also better captured by the model (not shown here) with strong accumulation at early ranges. This method of modification of the initial conditions allows to connect a consequence (in the weather forecast) to a cause (in the initial conditions) and opens up wide perspectives in the understanding of intense meteorological phenomena such as wind storms or organized convection.

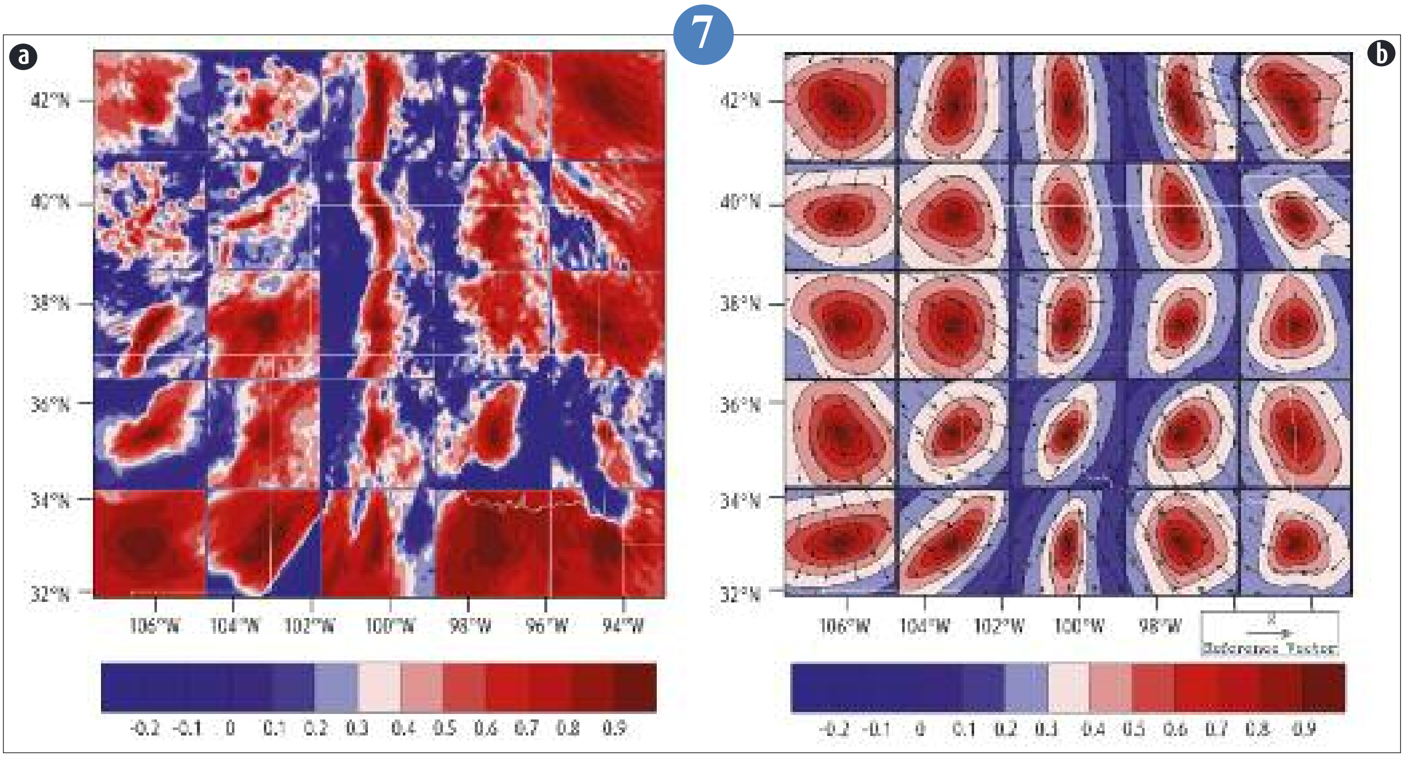
8



Left panel represents the relative humidity at 600 hPa for the ARPEGE analysis (brown contours every 10%. The bold contour stands for 90%) superimposed on the Meteosat image of water vapour in channel 7.3 m (at 0600 UTC 15 June 2010). The figure shows a region of relatively dry air in the observations (dark area), directed north-south, extending from Languedoc to North Africa and poorly represented in the initial conditions. We thus moisten the initial condition in the region of appearance of the organized convection (red contours every 35%) and we dry upstream (blue contours). On the right panel is represented the field of relative humidity at 600hPa, after modification, superimposed on the Meteosat image.

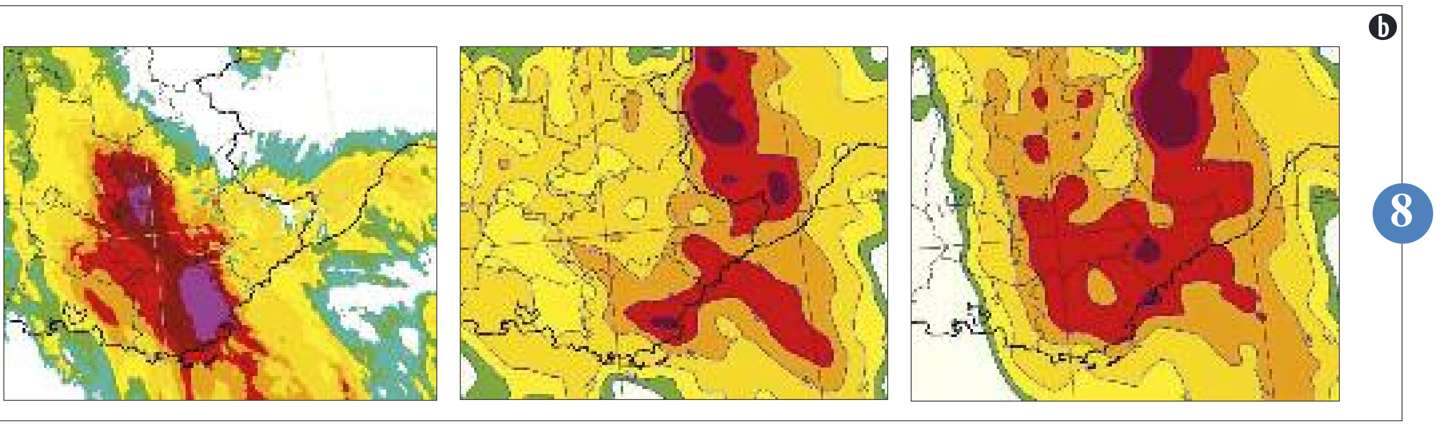


▲ Cloud cover vertical profiles during a 40 hour simulation. Black lines describe top and bottom of the simulated cloud in the high-resolution experiments (LES). Figure a: ARPEGE Climate. Figure b: ARPEGE NWP version.



▲ Structure functions in the assimilation at 5x5 locations of the prediction domain that are (a) raw estimates over a 30 member ensemble and (b) modelled by the deformation approach (spatial correlations of specific humidity at the surface in May 2007 for a convective situation over continental US). The deformation approach (b) allows to represent the stretching of structure functions at the centre of the domain that is likely to be due to the presence of a convergence line and also the large scale of the correlation near the borders probably due to coupling. The short scaled noise apparent in the raw estimate (a) is filtered with the modelling method (b).

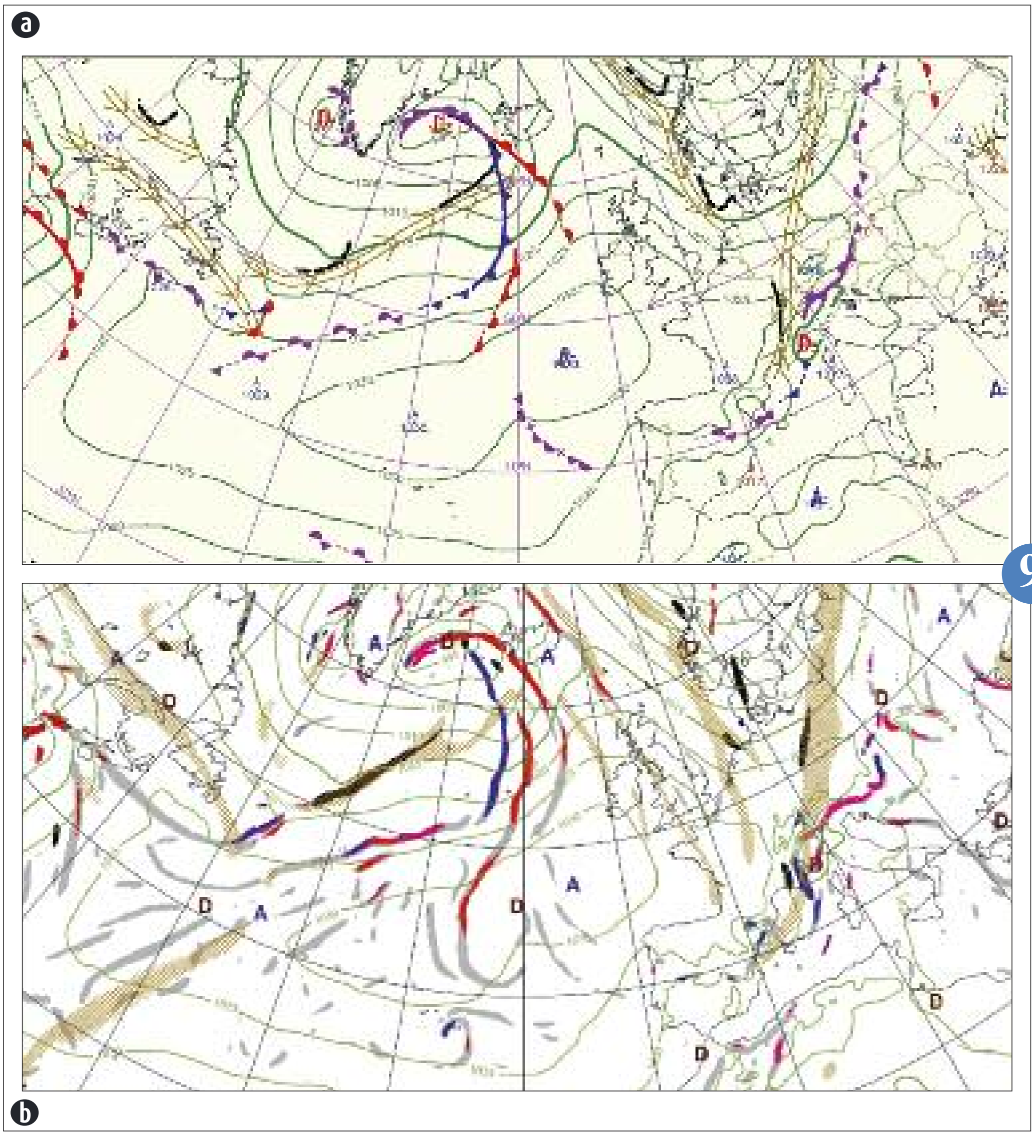
Precipitation observed (left) and forecasted between 0600UTC 15 June and 0600UTC 16 June. (Red = 70-100mm, Brown = 100-150mm and Pink> 150mm). In the middle, operational forecast run at 0600UTC 15 June and right, forecast obtained after modification of the humidity field. Note increased precipitation inside lands on the Var with the modified forecast as well as a decrease off shore in agreement with the observations. ▼



Objective fronts and the French ANASYG-PRESYG

The possibility to plot objectively a number of elements of the ANASYG and PRESYG charts has been addressed since several years at the Forecast LABOratory at Météo-France, Toulouse. The aim of the LABO is to assist the subjective work of forecasters by building a guess of these charts, obtained from numerical outputs of the French ARPEGE model. Forecasters would/could then validate or modify these elements.
The present version of the objective ANASYG and PRESYG tool allows the drawing of mean sea level pressure and the plotting of Jets, upper-air Potential Vorticity (PV) anomalies and (cold, hot, occluded and pseudo-) fronts.
The improvements made in 2010 and 2011 are: i) the use of parts of the algorithms of Tim Hewson who has implemented the objective plotting of fronts at the ECMWF, ii) the use of the moist entropy to compute the horizontal gradients of fronts (in place of the wet-bulb potential temperature).
A comparison of the resulting objective and subjective charts is presented on the Figures "a" and "b". The same objective charts will be daily computed and put on the LABO web page starting from the winter 2011-12. Additional developments are planned, concerning in particular the possibility for forecasters to manage the different objects of these "objective" ANASYG and PRESYG (Jets, anomalies, fronts).

9



◀ The "subjective fronts/PRESYG" corresponding to the figure a but handmade by the forecaster of the National Centre of Forecasting of Météo-France, at Toulouse.

◀ The "objective fronts/PRESYG" map valid for the 20th of October 2011 and the corresponding 24 hour forecast made with the French operational ARPEGE model. In comparison with the figure b, Jets (in shaded, brown) and upper-air anomalies (in solid, black) seem to be accurately represented. The warm (in red), cold (in blue) and occluded (in magenta) fronts correspond to horizontal limits clearly visible at the same time for high moist entropy gradients and high values of absolute vorticity. The pseudo-fronts (in grey) only correspond to the moist entropy gradient criterion and allow the connexion of sparse frontal limits.

Research and developments about AROME model

Increased use of ground-based GPS data in AROME-France

The European GPS stations network is deployed in a geodetic and meteorological context. The collected data are processed by several analysis centers that produce Zenithal Total Delays (ZTD) available in near real time. These ZTD are strongly correlated to the integrated water vapor content and can be used directly in variational assimilations. They were cautiously introduced in 2006 in the operational model ARPEGE and in 2008 in AROME with an ever growing but erratic network.
In recent years, the ground-based GPS network has continued to grow and the quality of data has reached a remarkable level. Thus, nearly a thousand stations are now available in the AROME-France domain. Several impact studies were conducted to assess the value of a substantial increase of their use. With five times more data assimilated, the results are positive in terms of classical scores, but they also show on improvement of local forecasts. This is especially true for the episode of exceptional precipitation over the Var (June 15, 2010), which was re-enacted in the context of an AROME-WMED model centered on the Mediterranean in preparation for the HYMEX campaign. The very short-term prediction of the beginning of the rainfall was significantly improved by increasing the number of ZTD (see illustration). Based on these results, the extensive use of GPS land was introduced in the operational AROME model in September 2011.

10

Increasing the frequency of the AROME analyses

The convective scale model AROME needs to take into account a large number of observations to be as close as possible from the real observed meteorological situation. Today this data assimilation process is performed every 3 hours, by increasing this frequency we should be able to benefit from all the high temporal frequency observations available such as radar data. However we are limited by a numerical and physical adjustment process at the beginning of the simulation ("spin-up") when carrying out assimilation cycles more frequently than every 3 hours, these imbalances accumulate at the expense of the forecast quality. Studies were performed on the choice of the first coupling file and on specifying the background error statistics coherently with the smallest scales resolved by the model. It allowed setting up a 1 hour cycled model by reducing the sources of spin-up (figure 1). In that case the number of radar observations and boundary layer observations are increased by a factor of 3. However for the time being the quality of the forecast is not globally better, some specific scores worsen compared to the 3 hour cycle. The use of the digital filtering method is currently under study as an attempt to completely remove the spin-up. Other approaches for improvement will be tested such as modifying the relative weight of specific types of observations.

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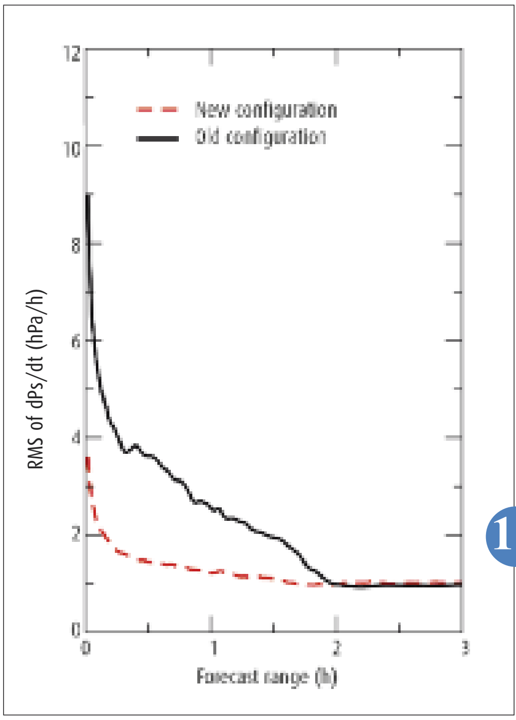
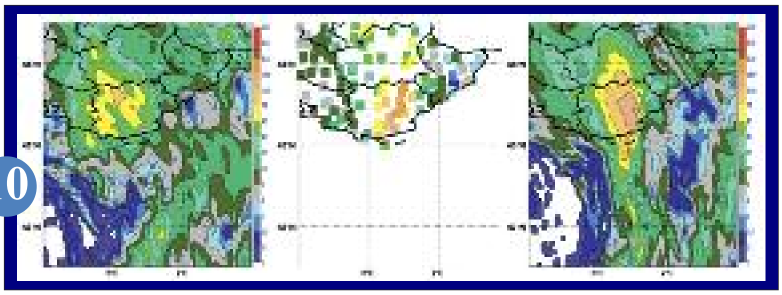


11

◀ Evolution for an AROME forecast of the standard deviation of surface pressure averaged over the whole domain.
The large non-physical values at the beginning, due to the initial "spin-up" and adjustment processes, are considerably reduced between the old (black curve) and the new (dashed red curve) system configuration. This decrease is a necessary condition to carry out more frequent observations.

10



◀ Very short-term forecast of rainfall in mm accumulated over 6 hours in the case study of Var (June 15, 2010 from 09UTC to 15UTC).
On the left: the forecast done with a small number of ground-based GPS.
On the right: the forecast with the extensive use of ground-based GPS.
In the center: the rain gauges observations.

Toward a probabilistic post-processing of AROME precipitation model outputs

High resolution models do simulate mesoscale structures with a high degree of realism. However large amplitude position errors are frequent. It is therefore crucial to be able to achieve an “up-scaling” of the model output as well as to estimate the uncertainty.
In the frame of a close collaboration with the team Fluminance at INRIA, a precipitation feature tracking algorithm which takes into account the local texture of the model outputs has been developed. Such a feature, or object, is defined by a precipitation histogram and an ensemble of 2D contours. The assumption of optical flow conservation together with a regularization constraint is used to exhibit a displacement field of the feature considered between two time steps. The prediction step consists of the displacement of each contour using this displacement field. Then a selection step is required: if the precipitation histogram associated to a contour matches the histogram that characterizes the structure, then the contour is allowed to remain within the ensemble. If not, the contour is removed. The mean contour represents the most likely object whereas the variance of the object positions represents the uncertainty (see the figure).
The probability density function of a station within the object is based on the histogram of the object and the distance to the contour. The assessment using a Brier score presents and improvement of the forecast using the object-oriented approach with respect to simply the use the direct model outputs

12

3D idealized simulations of convective super-cells with the AROME model

3D idealized simulations of super-cells are performed with the AROME model in order to assess its abilities for thunderstorms modelling at kilometric and sub kilometric scales.
A temperature perturbation is added in the low levels for triggering the convection in a homogeneous environment conditionally unstable with a strong vertical wind shear. A first simulation with a 1-km horizontal resolution reveals that the model is able to reproduce the evolution of a convective cell that splits into two systems: the left-moving one evolves into a multicellular system, the right-moving one into a super-cell with characteristic features: downdraft and updraft areas, hook echo, meso-cyclone … As in previous studies, the evolution of the convective systems depends on the vertical wind shear, a weak shear not generating a super-cell.
The impact of horizontal resolution (tested from 4 km to 500 m) shows that the finer the resolution is, the more intense the convective systems are, with more precipitation, strong vertical velocities, intense cold pools, more right-curved trajectories of the super-cell… A comparison with the Meso-NH model, the dynamical core of which is different, shows that both models generate quite similar convective systems, however, with finer structures, stronger vertical velocities and more curved trajectories of super-cell for Meso-NH.
The challenge now is to have some reference LES simulation (with horizontal meshes of about 100 m), in particular to determine the type of turbulence well adapted for a 500-m horizontal resolution.

13

The first steps of AROME for the prediction of tropical cyclones

Although Aladin-Réunion improved tropical cyclone forecasting, intensity forecasts remain uncertain, in particular for rapid intensification. Tropical cyclone intensification is due to external processes, such as interactions with the atmospheric and oceanic environment. But the evolution of the internal structure and the representation of convective processes play also an major role. A numerical model that is able to represent explicitly deep convection, like Arome, is expected to improve significantly intensity forecasts.
For the first time, some Arome simulations were conducted for a complete intensification stage (for 4 days) of a tropical cyclone (Ivan, 2008). The initial conditions were the analyses of the Aladin-Réunion model. With a resolution of 2,5km, the domain of integration of Arome was large enough to simulate the evolution of Ivan. The results demonstrated the ability of Arome to simulate the track and the intensity of Ivan. Moreover, the simulated structure of the storm was much more realistic than what the models at a lower resolution may show.
These simulations allowed also to assess the sensitivity of the forecasts to different numerical parameters, such as for instance the time step. The sensitivity of intensity forecasts to the time step showed indeed to be large. As a consequence, there remains some optimization work to do in order to improve the Arome forecasts of cyclone intensity and structure. In particular, it will be important to assess the benefit from coupling Arome with an ocean model and the opportunity to use a data-assimilation system.

14

Structure of tropical cyclone Ivan simulated by AROME at 82h forecast term. The field of wind speed at 10m and the streamlines in low-levels (upper panel) show an intense convergent cyclonic flow.
The vertical cross-section in isobaric levels (lower panel), indicated by the blue line, reveals an inclined eye-wall and extreme winds around 900hPa.
The wind speed unit is m/s.

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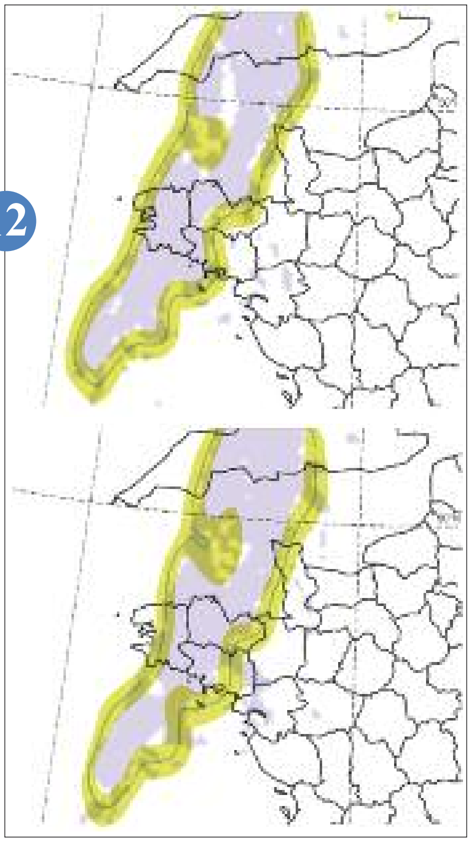
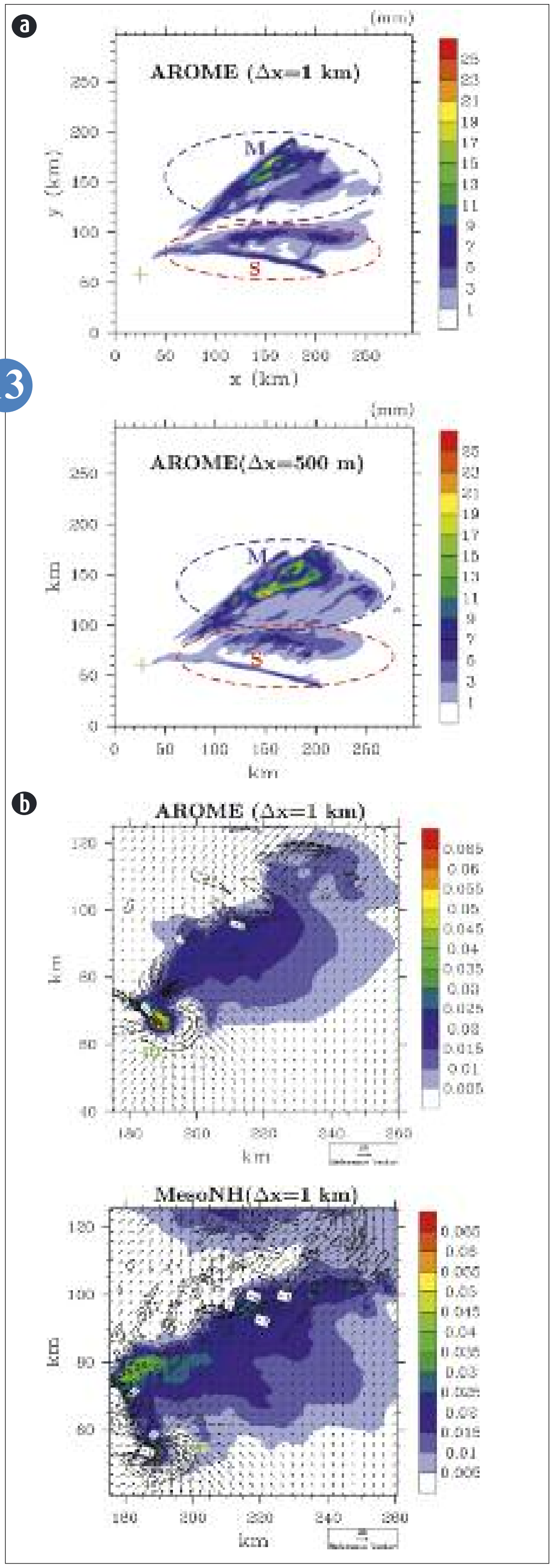


AROME Precipitations exceeding 1 mm/h (violet shading), mean contour (the dark green contour) and object position uncertainty (with green light shading) at time t (left panel) and at time t+1h (right panel).

13

Accumulated precipitation over 180 minutes (mm) showing the surface trace of a convective cell that splits generating a left-moving multi-cell system (M) and a right-moving super-cell (S) for AROME simulations with horizontal resolution of 1 km (on left panel) and 500 m (on right panel). The green cross indicates the location of the initial warm bubble.



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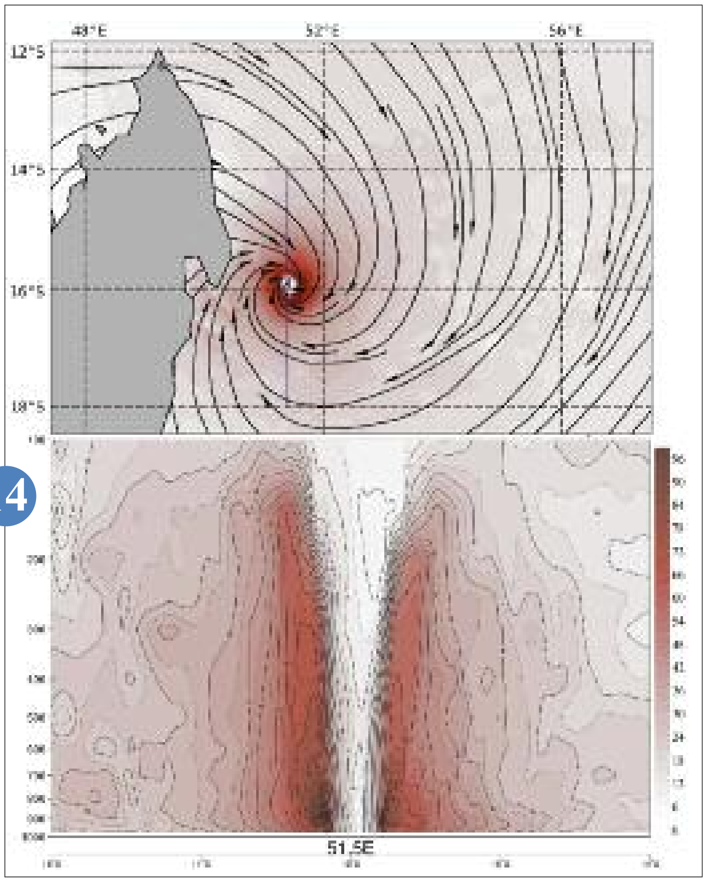


Zoom on the super-cell: sum of snow, rain and graupel integrated between 950 and 500 hPa in colour (kg/kg), 950 hPa wind vectors (m/s), 900 hPa vertical velocities in black line (m/s, downdrafts in dashed line and strong updraft in solid line associated with the meso-cyclone indicated by m) for simulations with AROME (on left panel) and Meso-NH (on right panel).

Ensemble prediction forecasting

PEARP: a global and mesoscale ensemble prediction system over France

Since June 2004, Météo-France runs a global ensemble prediction system at short range (i.e. 4.5 days). Initially composed of 11 members, several improvements have recently been introduced. Today, the ensemble is composed of 35 members. The initial conditions are produced by accounting for the errors of the past using the Météo-France global ensemble data assimilation system and the error growth to come using the singular vector technique. The model error is also taken into account by using 10 different physical packages. The high resolution of 15km over France enables to anticipate by several days the occurrence of some extreme mesoscale phenomena such as heavy rainfall or strong wind events. Several visualization products such as the quantiles, probabilities or low pressure tracks are available on the Météo-France intranet and allow a synthetic use of the ensemble prediction system. The figure shows an example of the ensemble quantiles for a heavy rainfall event which occurred at the beginning of November 2011 in South-East France. For this extreme weather event, a red hydrologic warning and an orange weather warning were issued.

15

Model error representation in ensemble forecasting at Météo-France

Ensemble forecasting is a method to construct empirical probability density functions using an ensemble of different forecasts. The ensemble forecasts must account for inherent forecast uncertainties arising from the initial condition determination and from the imperfections of physical mechanisms in the numerical weather model. The source of this latter error, named model error, is taken into account by varying several physical parameterisation options. However, the choice of these different parameterisation options is relatively empirical. Therefore, we envision to evolve towards a more objective model error representation based upon knowledge on model error statistics (e.g. magnitude). The estimation of the model error magnitude is a problem solved by assuming that the two forecast error sources (initial condition determination and model error) are statistically independent. In a first place, the figures show the model error accumulation as time evolves and the high spatial variability of the model error with maxima in mid-latitudes in both hemispheres. The mid-latitude band is a favourable region for cyclone development. Numerical weather models are highly parameterized to simulate cyclone development, thus generating model errors in the mid-latitude band.

An new approach to represent model errors in the ensemble forecasting system is envisioned. The approach consists of introducing systematic random perturbations associated with a magnitude that corresponds to that of the model error estimate.

16

Tropical cyclone track forecasts: definition of uncertainty cones using ensemble prediction

The prediction of tropical cyclones relies primarily on a good track forecast. Even though track forecasts have been greatly improving for the last years, their error remains sometimes large and such errors will ever exist due to the chaotic behavior of the equations of the atmosphere. End-users of cyclone forecasts need both the best possible forecast and a reliable measure of the forecast uncertainty.

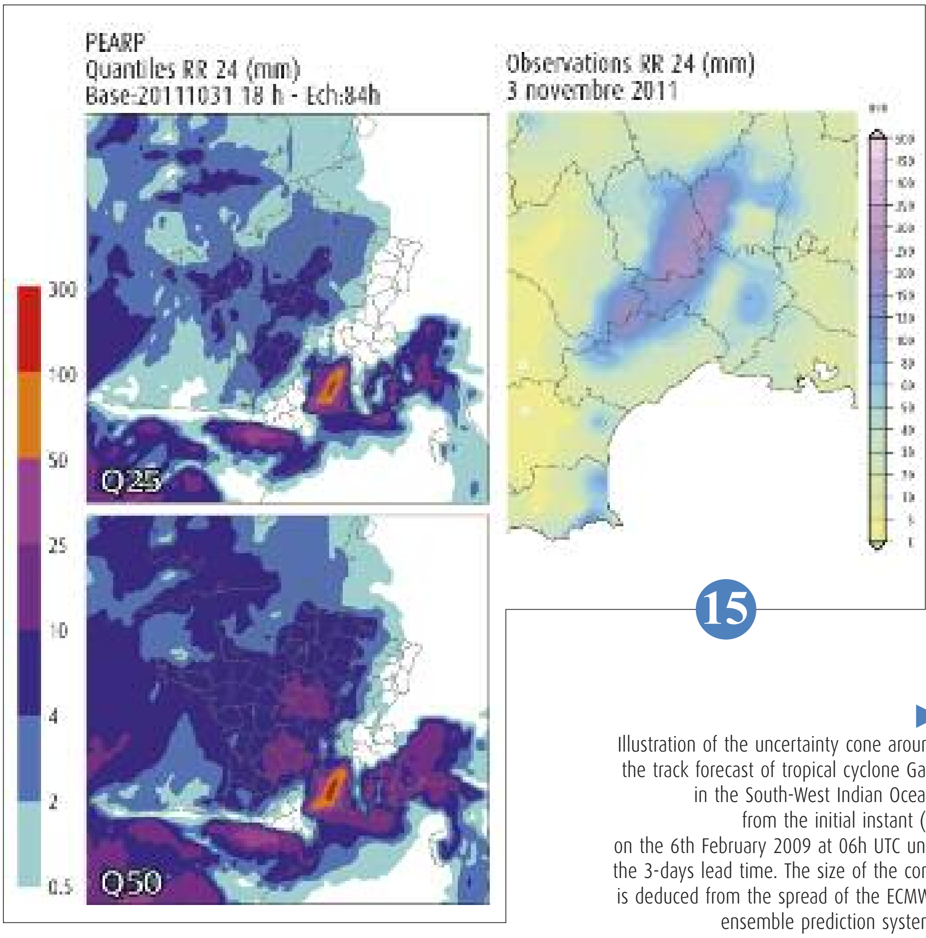
Thus, most of the international cyclone forecasting centres (such as for instance Miami and Tokyo) display an uncertainty circle around their official forecast track. The size of the cone is determined by a fixed threshold of the climatological error computed from the track forecasts of the last seasons. The Regional Specialized Meteorological Centre (RSMC) of Météo-France at La Réunion has developed a new method. The size of the cone is computed using an ensemble prediction system, expected that such a cone "of the day" could bring a more relevant information than a climatological cone.

This method has been successfully validated during two cyclone seasons using the ensemble forecasts of the European Centre for Medium-Range Weather Forecasts (ECMWF). It has been demonstrated that the size of such uncertainty cones corresponds well to the uncertainty of the forecasts until 3-days term. They bring some supplementary information with regard to a cone issued from the climatological errors.

This method has been used in operations at RSMC La Réunion since the cyclone season 2011-2012.

17

15



The first two 24h rainfall quartiles of the Météo-France global ensemble prediction system. Q25 means that 75% of the members forecast have accumulated precipitation reaching at least the values in the panel (Q50 for 50% of the members). On November 3 2011, most of the members forecasted more than 3 days before between 100 and 300 mm accumulated precipitation in South-East France. Accumulated precipitation was more than 250 mm on that day.

17

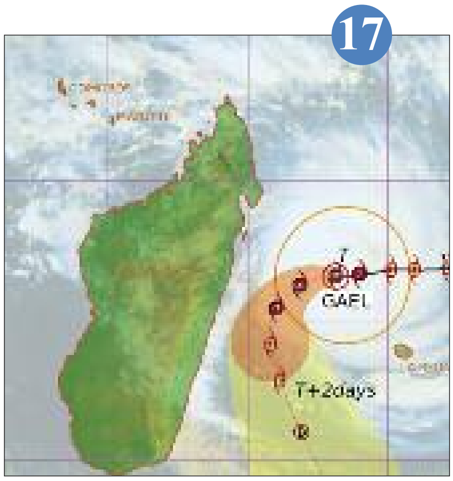
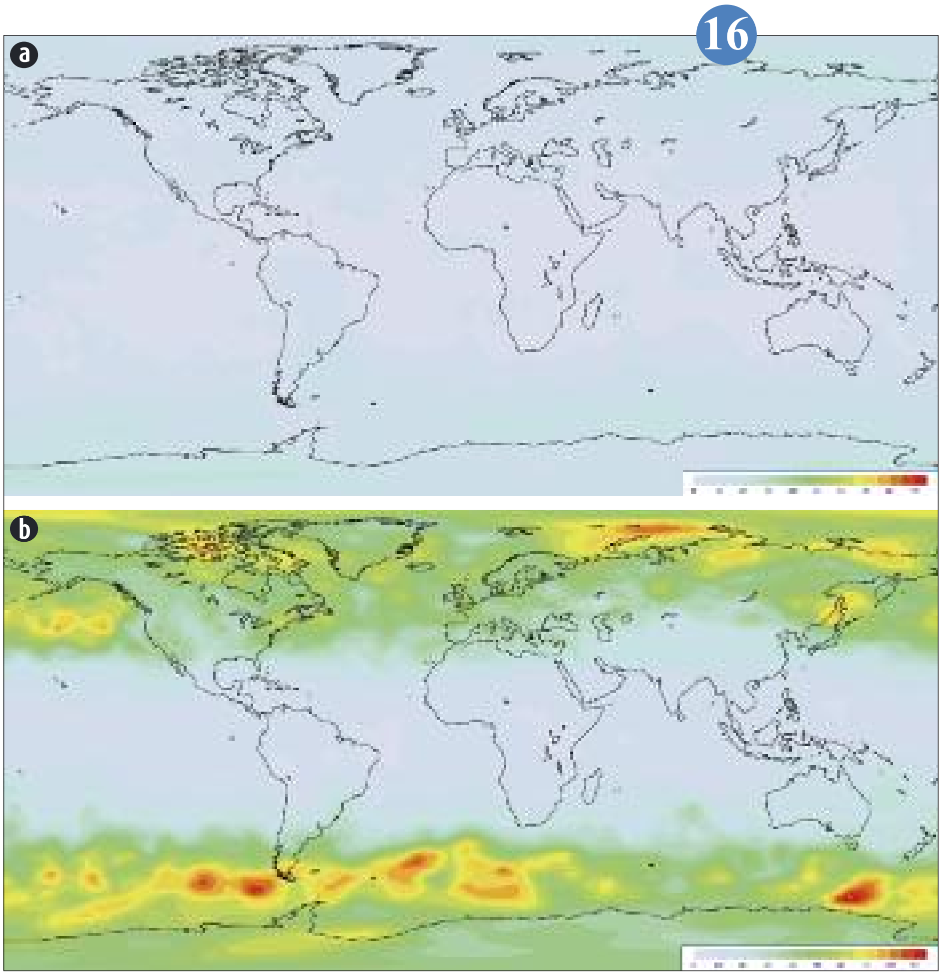


Illustration of the uncertainty cone around the track forecast of tropical cyclone Gael in the South-West Indian Ocean, from the initial instant (T) on the 6th February 2009 at 06h UTC until the 3-days lead time. The size of the cone is deduced from the spread of the ECMWF ensemble prediction system.

16



a: Standard deviation (i.e. magnitude) of accumulated model errors at 12-hour forecast range for the 500 hPa geopotential height.

b: Standard deviation (i.e. magnitude) of accumulated model errors at 102-hour forecast range for the 500 hPa geopotential height.

Research for aeronautics

Aviation is a major user of meteorology, although regulation and certification constraints restrained the use of the most innovative developments in MET observation and forecast, as attested by the current use of alphanumeric coded messages to exchange MET information.
With traffic and fuel cost increase and the necessity to reduce MET related incidents and the environmental impact, the aviation stakeholders have launched ambitious programs for the medium term (2020-30) restructuration of air traffic management: SESAR (Single European Sky ATM Research) in Europe and its mirror program NEXTGEN in the USA.
SESAR thus offers to the MET providers a unique opportunity to upgrade their services to aviation and design innovative solutions relying on emerging high bandwidth communication systems (System Wide Information Management, SWIM).
Aviation is mainly concerned with observation, for tactical decision when facing weather hazards, and short term forecast for traffic management. The 4 following articles illustrate these topics with the design of innovative observation systems for the detection of wake vortex and wind shear, the development of new nowcasting techniques for airport traffic management and the investigation of operational solutions to avoid the formation of contrails, hence reduce the environmental impact of aviation.

Wake vortex detection in the framework of SESAR

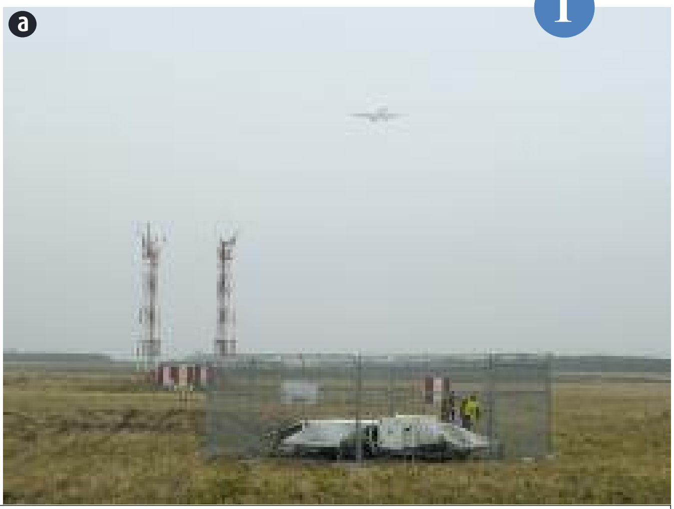
SESAR is the technological component of the Single European Sky ATM research project. It aims to upgrade the current aviation systems to optimize ATM and to reduce aviation emissions.
Météo-France contributes to the SESAR WP 12.2.2 Wake Vortex whose purpose is to experimentaly evaluate the value of wake turbulence observation and modelling tools for ATM in the approach area.
Between May and June 2011, the CNRM has deployed and operated two remote sensing observation systems at Roissy Charles de Gaulle airport during an field experiment called "XP0": a Doppler sodar, which provides vertical profiles of wind up to 350m elevation at the space-time resolution of 10 m and and 10' and a UHF wind profiler, which provides vertical profiles of winds within the layer 500m - 5000m altitude at space-time resolution of 350m and 15' (figure a).
A report on the performance of all meteorological instruments installed during XP0 including, in particular, inter-comparisons of wind measurement sensors (UHF wind profilers, sodar, wind lidar) has been provided to Thales (figure b). This first experiment will be used to provide recommendations about the type of sensors to be deployed in future experiments (XP1 and XP2) of the SESAR project.

1

1

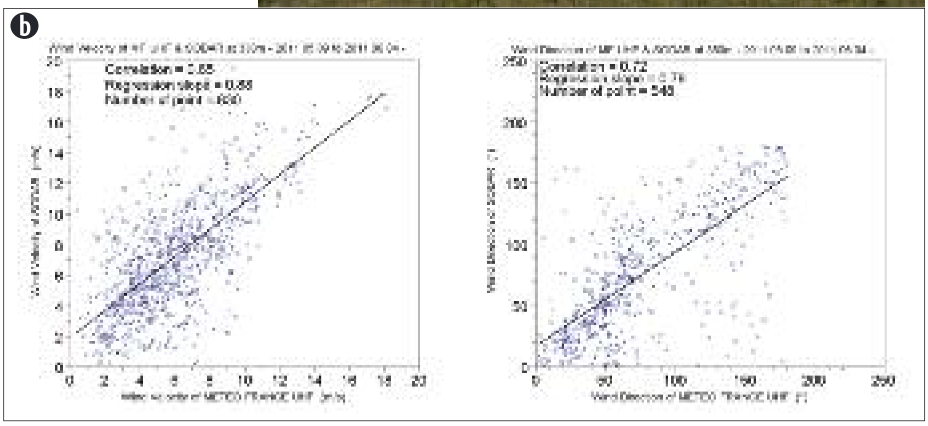
a

View of the UHF profiler in its electromagnetic enclosure and of the sodar at the end of CDG airport's runway 09L.



Scatterplots of wind speeds and directions measured by the UHF profiler and sodar at 350m above sea level.

b



Radial velocity PPI, measured by Nice radar at elevation 3°, 2011-06-05 at 1110 UTC. The radar is in the centre of the picture. Yellow colours indicate winds away from the radar and blue colours indicate winds toward the radar. Green arrows represent the wind direction. This example illustrates a case of wind reversal with the arrival of an Easterly component of the wind, close to the airport, in a previously Westerly flow. This situation caused air traffic disturbance.

Projects to study contrails

In a context of growth in air traffic, contrails emitted by aircraft at high altitudes are subject to increasing attention. Gases and particles emitted by engines contribute to increase greenhouse effect by altering both the global radiation balance and chemical balance of the atmosphere.
In this context SAFIRE has participated in setting up the TC2 and Hypatie projects. Both projects have been developed to meet the demands of CORAC (Council for Civil Aviation Research), which was established in July 2008 from commitments made at the "Grenelle de l'Environnement".
The TC2 project (contrails and climate) is to better characterize the conditions of formation and evolution of contrails. The SAFIRE Falcon 20 will perform measurements in chemistry and aerosol microphysics, by flying inside the condensation trails emitted by aircraft. This will validate the models that have been developed under the project.
The Hypatie Project focuses specifically on the development of hygrometers for low humidity, with the ultimate goal to install them on commercial aircraft. This would allow getting data on ice-supersaturated regions to parameterize the climate models, and provide pilots means to detect and avoid areas where contrails could appear. Hygrometers developed as part of Hypatie will be tested onboard the SAFIRE Falcon 20.

2

Toward a specification of a radar dedicated to the observation over airport platforms

In the context of improvement of the services provided by Meteo France to the Air Navigation Service Provider particularly in the area of detection and monitoring of wind shear events, a system combining an X-band Doppler polarimetric radar (rented to SELEX with its own software providing products and visualisation) and a Doppler lidar, was tested at the Nice airport for 6 months. On the radar side, the aim was to answer to the following questions::
Is it relevant to place the radar at the airport or should it be set up a few kilometres away from the airport?
Is it possible, in rainy situations, to obtain high quality wind measurements with an X-band radar?
What is the optimal scanning strategy for the radar in order to detect and monitor at best wind shear events?
A preliminary result based on the analysis of different situations is that the placement of the radar at the airport is satisfying and does not limit the capacity of observation at short distances (1 km), provided that a ground clutter filter and a second trip echo filter are applied. A positioning of the radar at the airport is interesting because it enables a direct observation in the take-off and landing plane of the aircrafts (slopes at about 3º).
Additionally, several tests allowed to converge towards an optimal scanning strategy, consisting in 10 elevations between 1 and 50º performed every 5 minutes, with the 3° elevation being repeated twice, as well as a RHI in the runway direction. Thanks to this scanning strategy, high quality radial velocity data can be obtained up to 60 km from the radar.

3

Evaluation of the hourly version of AROME dedicated to nowcasting

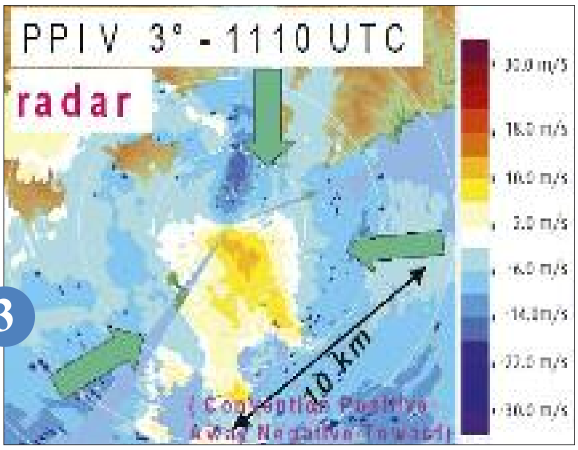
Up to recently some observed mesoscale phenomena were not analysed and foreseen by numerical weather models. This is no more the case and this improvement is due to progress in horizontal and vertical resolution of models and in radar data assimilation .
A « Nowcasting » version of AROME, named AROME-PI has been developped.
AROME-PI is a Limited Area Model. The boundary conditions and the initial conditions are provided by operational model AROME-France.
The forecasts of AROME-PI will be renewed every hour, with a 15 minutes cut-off following a compromise between the wish to use as rapidly as possible the results (30 minutes after forecast base time) and the necessity to assimilate a significant amount of new observations.
Horizontal resolution is 2.5 km and step between two forecasts is 15 minutes: the forecast are said "dense".
The evaluation of AROME-PI (against operational AROME-France) exhibits that AROME PI is better for the analysis up to a forecast range of two hours. The main improvements of AROME-PI concern the availability of refreshed dense forecasts put at disposal with very short delays and using recent observations.
The aeronautical domain will be highly concerned by AROME-PI. In 2015, AROME-PI will be available over FABEC domain. In the framework of SESAR program a real-time demonstration of an "airport" version of AROME-PI will provide forecast at a very high resolution.
AROME-PI will require the development of new systems relying on numerical modelling methods or nowcasting methods. For example a non-linear and continuous forecast of thunderstorms and rainfall using observations data and simulated data.

4

2

▲ Contrails.

3



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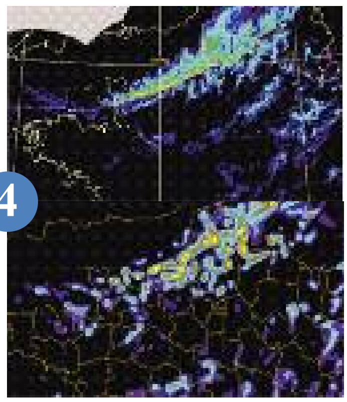


▲ Illustration of AROME ability. Squall line on French territory seen by French radar network (left side) and by AROME (right side). Reflectivities for the 19rd of May 2009. Assimilation of radar doppler data and forecast range to one hour.

Studies of meteorological process

Météo-France leads researches aiming at the advancement of knowledge on various meteorological phenomena with emphasis on high-impact weather events. Researches benefit from state-of-art numerical models and physical simulation, such as the MESO-NH model and the hydraulic ramp of CNRM, and also from dedicated field campaigns. These progresses enable more accurate representation of the processes within the Météo-France Numerical Weather Prediction and Climate models.
Major progresses have been achieved in 2011 in the understanding of mid-latitude and tropical clouds and precipitating systems, including their interaction with aerosols, as well in the knowledge of intra-seasonal variability of meteorological events (monsoon, synoptic systems). Some are illustrated afterward in this section.
Further highlights on our 2011 activities include major advances on the simulation of fog. A full life cycle has been successfully simulated with very high-resolution LES covering the whole period from the formation to dissipation of fog. This unique simulation necessitates horizontal resolution of about 2m during the fog formation, increasing to 10m during the dissipation phase. For the first time, it has been possible to evidence the heterogeneous structure of the fog layer with propagating waves at its top during the mature phase.
Regarding hydro-meteorological hazards, the meteorological situation associated with dramatic flash-flooding in June 2010 in the Var region (Southeastern France) has been further studied through high-resolution MESO-NH and AROME numerical simulations. Complex interactions between convection and cloud processes within the precipitating systems, steep orography of the region, upstream deep convection from the Var region to the North Africa disturbing the synoptic and orography-driven offshore low-level circulation and the upper-level synoptic dynamics are responsible for a low predictability of the event.

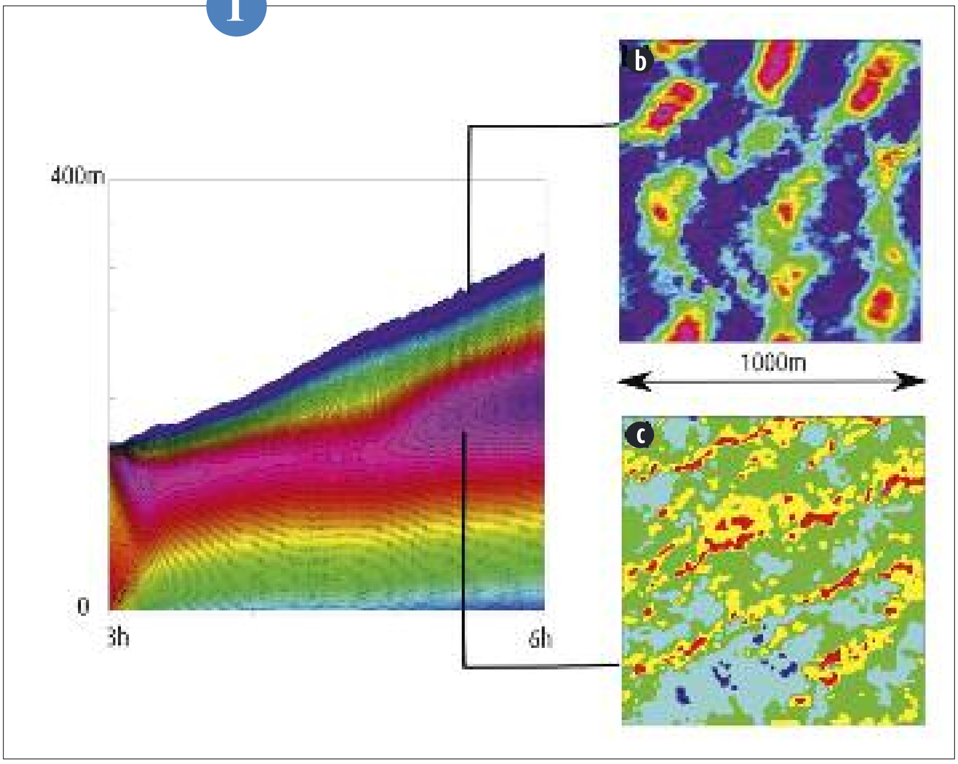
1

Study of the precursors of some weather regime transitions

The low-frequency variability of the atmospheric circulation can be characterized by fluctuations around a small number of quasi-stationary states of the atmosphere which are called weather regimes and which have a lifetime of about 8 to 10 days. There are four main weather regimes over the Europe-Atlantic sector which determines the European climate: the Scandinavian blocking, the Greenland anticyclone, the Atlantic ridge and the zonal weather regime. The purpose of this study is to determine the precursors of the weather regime transitions.
The most frequent transition over the 1958-2001 period is the transition from the zonal weather regime to the blocking. This transition presents a first precursor occurring about a week before the mature stage of the blocking and taking the shape of a low-frequency wave train. This wave train is illustrated on the figure by the succession of ridges and troughs (black contours) propagating from the Atlantic subtropics toward Scandinavia (before the peak of the blocking at lag 0) and then toward Asia (after lag 0). The presence of this wave train is also revealed by the arrows which show the direction of the wave energy propagation. The slowly varying anomalies of the long wave radiation, which indicate updraft (cold colours) and downdraft (hot colours) zones, suggest that the wave train is initiated in the subtropical Atlantic by downdraft anomalies at 30°N among others.
Rapidly varying waves, called baroclinic waves that are associated with surface depressions, are the second precursor. Such as oceanic beach waves, these waves break and when they do so, they tend to reinforce the emerging blocking.
One prospect of this work is to study the role of cyclogenesis during the evolution of the blocking in link with baroclinic wave breaking.

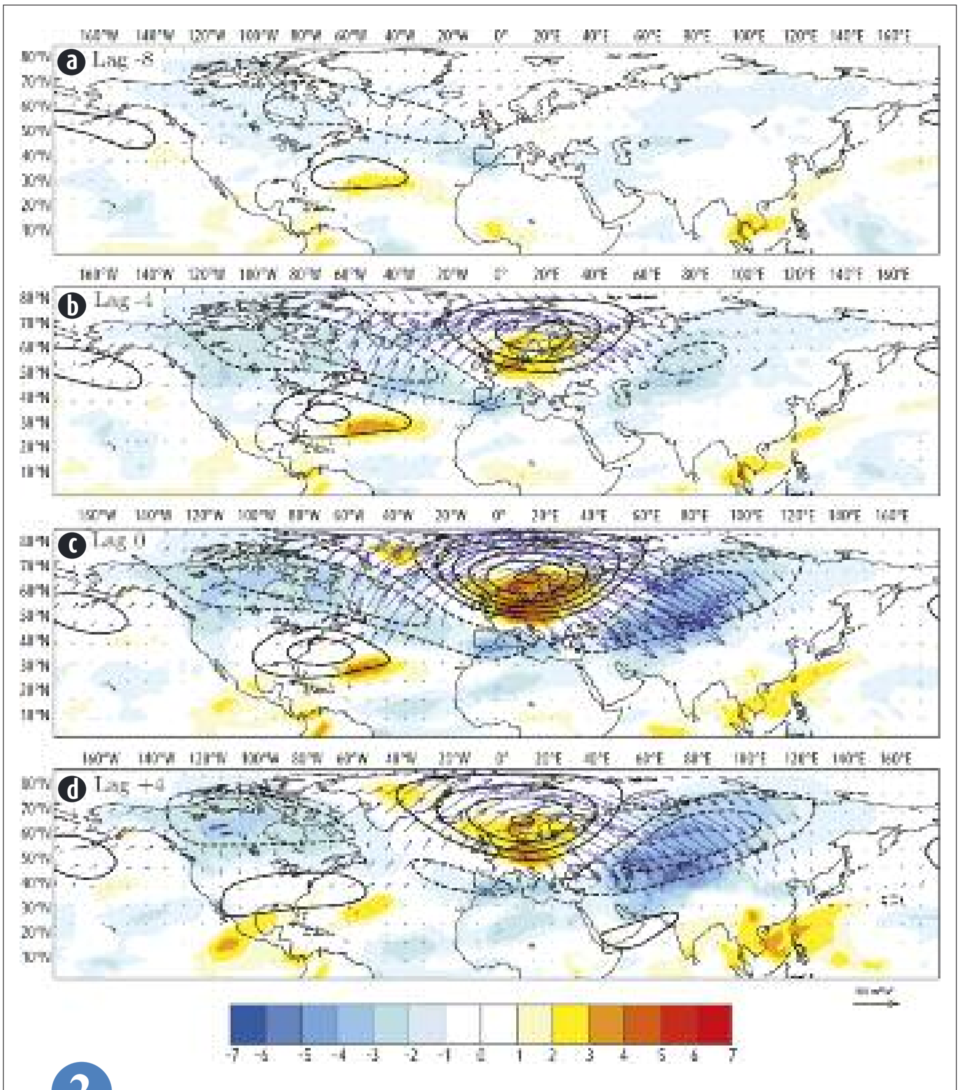
2

1



◀ LES of the mature phase of fog:
(a) time-series after 3 to 6 h of simulation of the mean vertical profile of liquid water content showing a maximum at about 2/3 of the total fog depth; the horizontal cross sections of the potential temperature show turbulent structures organized in bands stretched along the mean flow within the fog (c) and perpendicular to the mean flow at the top of the fog layer (b).

2



◀ Slowly varying atmospheric anomalies in connection with the Scandinavian blocking. These anomalies have been obtained by regressing different low-frequency atmospheric fields (periods greater than 10 days) on a blocking index during the period 1974-2001. The solid and dashed contours represent respectively positive and negative anomalies of the stream function (interval: 2.106 m2 s-1). The shadings correspond to anomalies of the outgoing long wave radiation (interval: 1 W m-2). The arrows represent the wave activity flux calculated from the stream function anomalies and are collinear to the group velocity.

Coupling between convection and dusts during the AMMA 2006 field campaign

The AROME model at a 5 km resolution coupled with a dust module has been developed for simulations over a large West African domain. Extensive comparisons with observations of the AMMA field campaign allowed the validation of this version. A case of intense dust storm observed in March 2006 allowed studying the dust lifting processes associated with this extra-tropical cold surge and with its channelling by the topography. The use of the Potential Vorticity suggested that dusts have a positive feedback on the dynamics of this storm.
This AROME version has been used to simulate the whole month of June 2006 corresponding to the "onset" of the monsoon and to a second maximum of dust activity after the spring maximum previously studied. AROME realistically simulated the mean dust plum at the June scale and its large variability. A set of simulations with and without the coupling with dusts allowed studying the processes involved in the dust lifting and the impact of dusts on the thermodynamics, dynamics and on convection at the month and diurnal scales. In June convection is a major source of dusts by intense gust fronts associated to cold pools fed by rain evaporation in dry air masses. The global impact of dusts is a weakening of the Saharian Heat Low that may delay the onset of the monsoon.
This study is furthered in the frame of the FENNEC project aimed at studying the Saharian Heat Low. Météo-France set up an operational forecast suite in June 2011 during the FENNEC field experiment including ALADIN (25 km) and AROME (5 km) models coupled with dusts. Those forecasts guided operations and flights of the French Falcon 20 and English Bae146 aircrafts. The ability of AROME to forecast dust events associated to convection has been appreciated.

3

Development of a parallelized electrical scheme to simulate multiple electrified clouds on large grids in Meso-NH

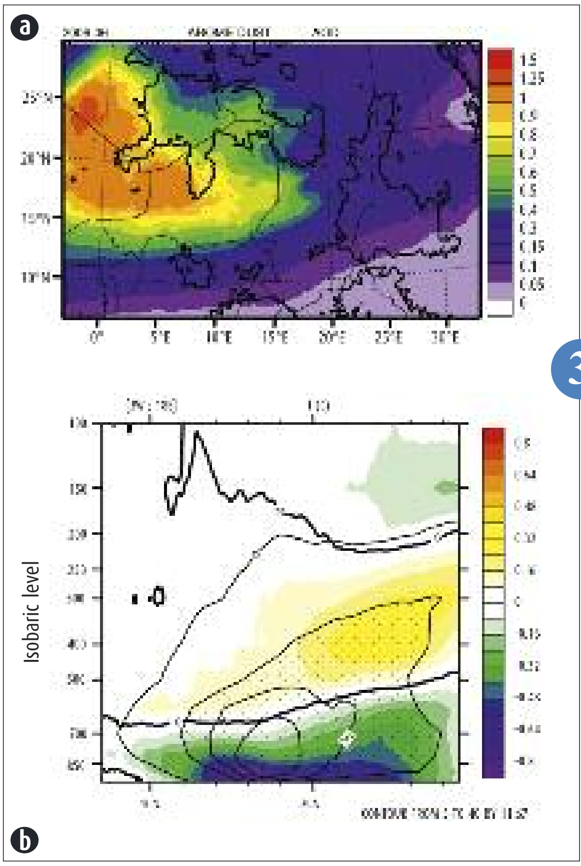
An explicit electrical scheme has been developed in the mesoscale model Meso-NH to simulate electrified storms on large grids with complex terrain, on parallel computers.
The scheme computes the electric charge attached to water and ice particles, and ions. Such particles receive electrical charges that are transferred between particles and transported by updrafts and downdrafts in the cloud. Thus, poles of charge are created at the cloud scale. The resulting electric field is deduced from the Gauss equation. A flash is triggered once the electric field exceeds a breakeven threshold (~100 kV m-1). The original feature concerns the lightning flash scheme. Flashes are composed of a vertical bidirectional leader flash and a secondary phase with branches obeying a fractal law (with horizontal extension on electrically charged zone).
The electrical scheme was tested for several storms on multiprocessor computers. For the 10 July 1996 STERAO1 storm, Meso-NH succeeded in reproducing the evolution from a multi-cellular to a super-cellular storm, and the trend and order of magnitude of the flash rate.
This opens a wide area of applications with the next objectives of running real meteorological cases on large domains during HyMeX, and studying the electrical activity associated with tropical cyclones intensification in the South-West Indian Ocean.

4

Mediterranean Heavy Precipitating Events – Origin and transport of moisture

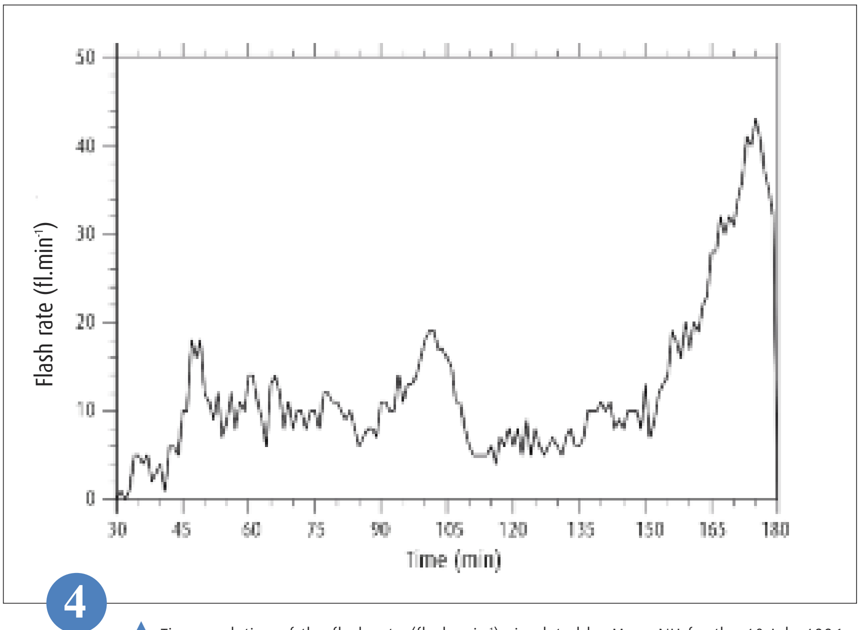
Mediterranean coastal regions are frequently affected by Heavy Precipitating Events (HPEs) often causing devastating flash floods. One of the main meteorological ingredients of these extreme events is the transport of moisture towards the coasts. In order to better understand and forecast HPEs, the features of the moisture supply were analysed for more than 10 events over South-eastern France and Corsica.
Based on multi-scale numerical simulations, both backward trajectories analyses and water budget calculations were performed. They showed that the moisture supplying the heavy precipitating systems is both provided by the evaporation of the Mediterranean Sea in the last two days before the HPE triggering, and transported over more than 3 to 4 days from remote sources – in the Atlantic ocean and in equatorial Africa. Remote moisture is confined in the low-levels when arriving above the Mediterranean Sea following either large-scale subsidences or down-slope flows. It is then led towards the French coast following two main transport branches along the Spanish coast and west to Sardinia. During this over-sea transport, the evaporation of the Mediterranean Sea contributes to moisten the air mass in the boundary layer. This contribution of the Sea is the main source of water supply when anticyclonic conditions prevail in the days before the HPE.
These results contribute to the preparation of the HyMeX field campaign dedicated to the hydrological cycle in the Mediterranean with a focus on HPEs.

5



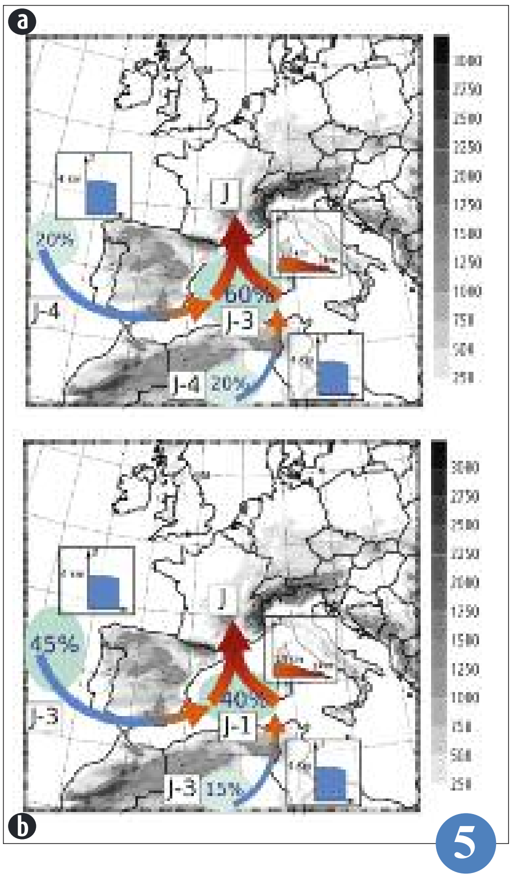
Optical thickness map of dusts averaged over the June 2006 as simulated by AROME.
The heavy isoline outlines areas with topography higher that 600 m.
The dust plum is very dense exhibiting optical thickness up to 1.5 m. It is located on southern to western flanks of the Hoggar Mountain. It is mainly fed by convective gusts due to intense evaporation of precipitation in dry air over bare soil at this time of the year before the arrival of monsoon rains. The dust plum is initiated to the East (~16°E) in the Bodélé region of surface wind acceleration south of the Tibesti Mountain.

Meridianal vertical cross-section averaged in the dust plum (3°W; 18°E) over the whole June 2006 month of the temperature difference between AROME simulations with and without the dusts coupling. The mean vertical structure of the dust plum by dusts is outlined by the isolines and dotted area of extinction by dust.
The absorption of solar radiation by dusts induces heating of the upper part of the dust plum (up to 0.3°C above 3-4 km) whereas its attenuation reduces the incoming solar flux at the surface resulting in a large cooling of low levels (up to −0.8°C at the surface). A major impact is a weakening of the Saharian Heat Low that may delay the monsoon onset.



Time evolution of the flash rate (flash min^{-1}) simulated by Meso-NH for the 10 July 1996 STERAO storm. Meso-NH reproduces well the observed transition from a multi-cell (~20 flash min^{-1}) to a super-cell with an increase and a peak (~50 flash min^{-1}) of the total flash rate during the last stage of the storm.

Conceptual schema synthesizing the spatial and temporal features of the water supply to the Heavy Precipitating Events over South-eastern France with both anticyclonic (a) and cyclonic (b) conditions in the days before the event.



Lake modelling

The lake model FLake, developed to represent the lakes in numerical weather prediction models, processes the exchange of moisture, energy and momentum between the surfaces of lakes and the atmosphere and resolves the diurnal cycle by changing its surface temperature. To improve understanding and parameterization of the model FLake in numerical models (Meso-NH, Arome) and climate models (Arpege-Climat), it was recently implemented in the externalized surface module SURFEX, platform interfaced with these models.
To date, most studies have been conducted with FLake forced by observations, to verify the correct model integrity and its ability to reproduce the characteristics of the diurnal cycle (figure a). The measurement campaign THAUMEX conducted during the summer of 2011 in the Thau lagoon in southern France, in collaboration with the University of Evora in Portugal and the IFREMER of Sète, has enhanced the knowledge of the model and its behaviour in shallow water. Initially, FLake was used forced by observations (figure b) to verify the correct specification of some characteristic parameters such as lake depth or the extinction coefficient of light in water. The model was then coupled with the atmosphere in numerical simulations made with Meso-NH, to document simultaneously the atmospheric boundary layer and the thermal profile in the water during sea breezes episodes.

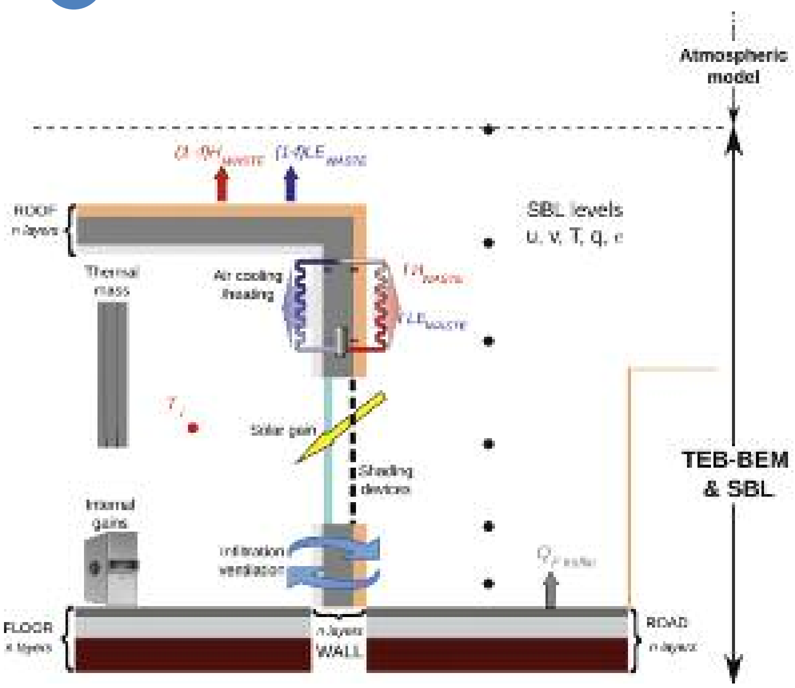
6

Energy boost in the TEB model!

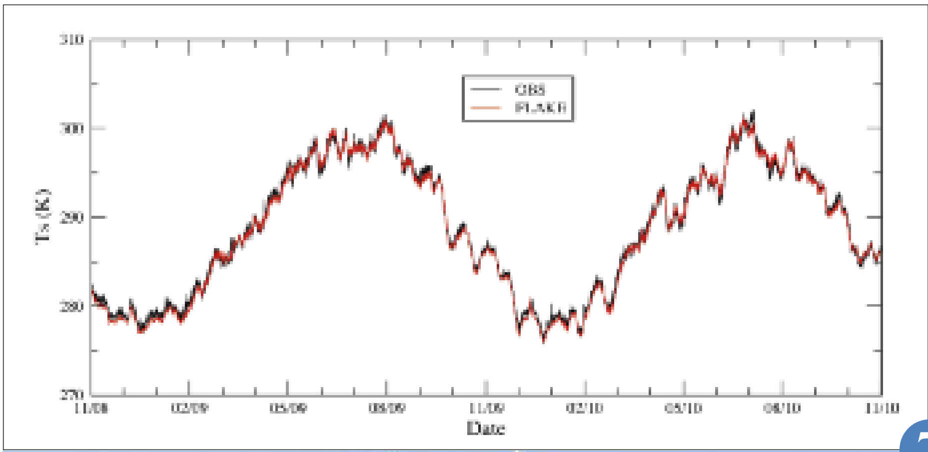
Several studies have demonstrated that the massive use of air conditioning systems impact urban temperatures. In general, building systems generate waste heat that affects the urban climate. Moreover, the adaptation scenarios of cities to climate change include new building designs.
To predict the urban climate, a building energy model (BEM) has been developed in the city-atmosphere exchanges model to reproduce the main processes within buildings. The geometric definition of the buildings remains simple with a single thermal zone and massive internal structures are represented as a single thermal mass to reproduce the thermal inertia (Figure a). The model takes into account solar heat gain through the windows, the ventilation and internal heat gains. It computes the need for heating or cooling and releases associated with the type of systems used (ideal or real system with wet or dry releases). Finally the model used to represent passive devices such as shading devices and natural “sur-ventilation”. BEM has gone satisfactorily through different evaluation steps including comparisons with the building energy model EneryPlus and with field data from the CAPITOUL campaign.

7

6



Sketch of the different processes represented in the TEB-BEM model.



Comparison of water surface temperature measured over Thau Lagoon and modeled by FLake model forced by in-situ observations, between November 2008 and November 2010.

7

View of the instrumented platform used during the THAUMEX field campaign.

Climate and climate change studies

The research activity on this theme was marked in 2011 by the end of the simulations of future climate performed in the context of the CMIP5 international project that serves as a basis of the AR5 (IPCC "Assessment Report" 5). Their results, like those of simulations of past climate, are made available to the international community through a node of the distributed database "Earth System Grid Federation" (ESGF) implemented at CNRM. Significant progresses have been achieved in the development of a prototype of a coupled climate-carbon model including ISBA-CC and PISCES biogeochemistry model of IPSL. In the area of climate regionalization, 2011 is the last year of the ANR project SCAMPEI with the opening of a database of climate change diagnostics. Furthermore, in preparation of HyMeX and MedCORDEX projects, a first configuration of a regional climate system model was established. On the topic of predictability studies, a new version of the seasonal forecasting model similar to that used for the CMIP5 simulations, has been tested. It will be used in operational mode in the next system of the European EUROSIP project. Studies on the predictability of midlatitude northern hemisphere have also shown the potentially important role of the stratosphere on the predictability. In the field of the global environment study, validation of the model ARPEGE-Climat with on-line chemistry (CNRM-CM) was concluded with a publication. This model will be used to revisit the results of the QUANTIFY project concerning the impact of aviation transport on the global environment and climate. In addition, we participate in the international intercomparison exercise of global chemical models ACCMIP ("Atmospheric Chemistry and Climate"), which also serve as the basis for the AR5 and the first results look promising.

1

Climate

Potential contribution of the tropics to summer climate predictability

The skill of operational dynamical seasonal prediction systems is particularly low during the boreal summer season, when the Southern Oscillation (ENSO) has a limited influence on the extra-tropical atmospheric circulation. Nevertheless, the IRCAAM project (http://www.cnrm.meteo.fr/ircaam/) funded by the French National Research Agency was aimed at highlighting the potential extra-tropical previsibility associated with an improved prediction of the monsoon climates, which like ENSO represent a major source of tropical diabatic heating that shows a significant variability at inter-annual timescales. The proposed methodology is the « grid point nudging » technique which allows us to relax a global atmospheric model (here the CNRM-GAME or IPSL atmospheric GCM) towards analyses within the whole tropics or a selected monsoon domain. Results emphasize for instance the influence of the tropical Atlantic as a forcing of the strong and persistent anticyclonic circulation observed over Europe during the hot summer 2003. More generally, they show to what extent an improved prediction of the tropical circulation is a necessary pathway for better seasonal predictions in the extra-tropics. Better predicting the summer monsoons is another issue, but seems feasible given the recent improvement of ENSO-monsoon teleconnections found in the CNRM-GAME coupled ocean-atmosphere model.

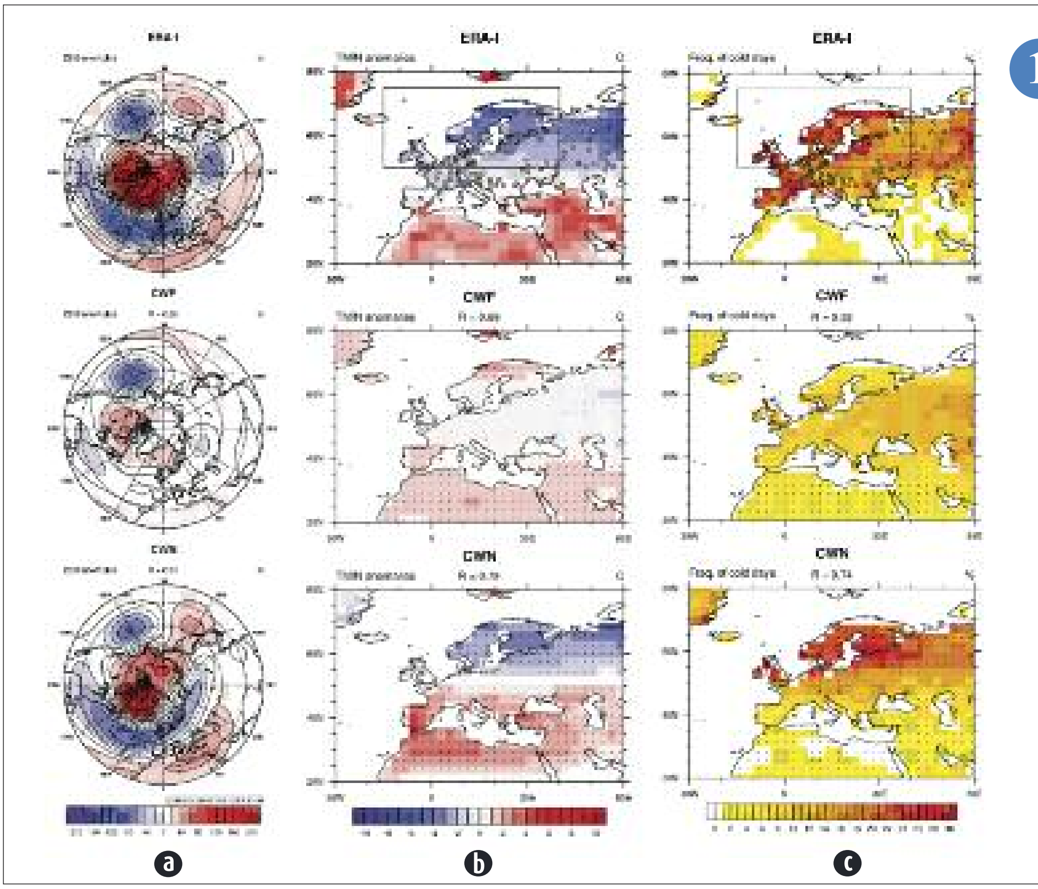
2

Ocean surface albedo: Integrating a new biophysical interaction

Ocean surface albedo plays a key role in the Earth's climate, because it controls at first order the heat stored within the global ocean. Satellite observations (e.g., SeaWiFS, MODIS) clearly show that the ocean surface albedo can vary greatly in time and space (~15-20%). However, the representation of the ocean surface albedo, in numerical ocean models (e.g., NEMOv3.2, which is currently used at CNRM-GAME) or coupled climate models (e.g. CNRM-CM5.1), is relatively crude. This representation generally assumes that the ocean surface albedo is fixed at its climatological value (~6.6%) or is a function of the solar zenith angle. Nonetheless, other representations have been suggested, which better represent the mechanisms contributing to surface albedo. These representations depend not only on numerous physical variables but also on biogeochemical variables such as the surface chlorophyll. The implementation of the biogeochemical model PISCES in CNRM-CM5.1 is an attempt to assess a new parametrization of the ocean surface albedo, which depends on surface wind, surface chlorophyll and solar zenith angle. Specifically, the contribution of both surface wind and surface chlorophyll induce large variations of ocean surface albedo, temporally and spatially (Figure 1). Especially during the summer, the ocean surface albedo of the Southern Ocean is substantially stronger than its climatological value. Such a change induces a cooling of the simulated sea surface temperature in the Southern Ocean of about 0.5°C.

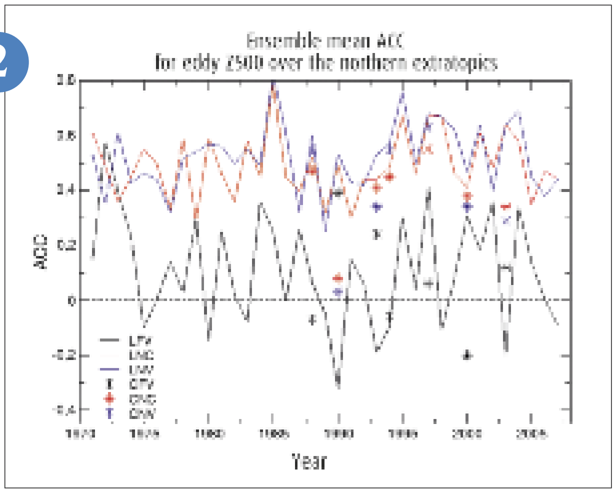
3

1



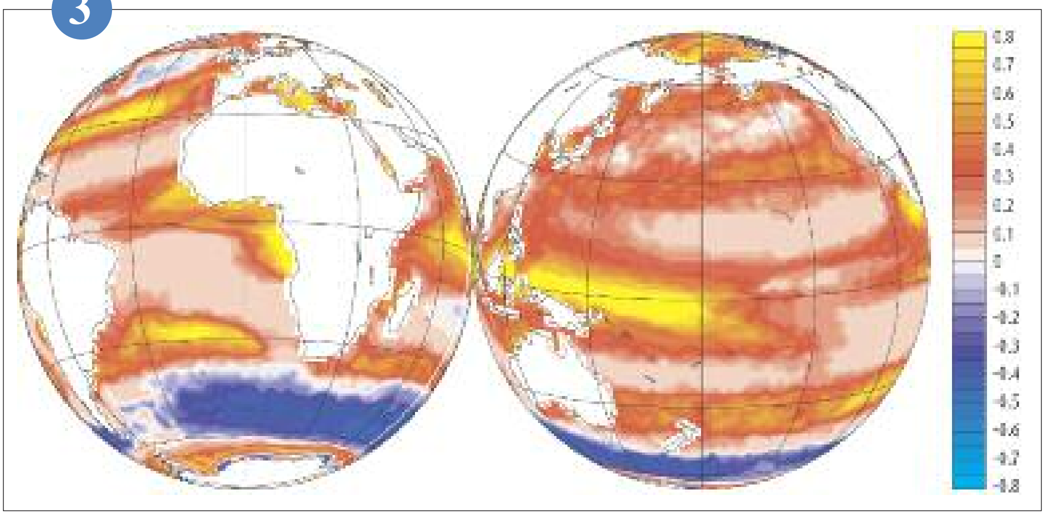
Comparison of 30-member ensembles of atmospheric simulations of October 2009-March 2010 performed with the ARPEGE-Climat model and driven by monthly-mean observed Sea Surface Temperatures (CWF and CWN), to ERA-Interim (ERA-I) reanalyses. CWN differ from CWF by the implementation of a stratospheric relaxation towards analyses north of 25°N. Are reproduced: daily Z500 (a) and Tmin (b) averaged anomalies and the number of cold days (c) over winter 2009/2010. The nudging of the stratosphere improves the comparison of this cold winter simulations to the observations, showing a potential improvement of seasonal predictability (see Ouzeau et al., GRL 2011, for futher details).

2



Anomaly of the annual mean ocean surface albedo with respect to its climatological value (~6.6%).

3



Pattern correlation coefficient for 500 hPa geopotentiel height in the northern extra-tropics and averaged from June to September à 500 hPa between observed and simulated anomalies. The ARPEGE-Climate model (stars) has been tested in selected case studies (30-member ensembles of seasonal integrations initialized on May 15th) while the LMDZ model (solid line, 10 members for each summer) was integrated over the whole 1971-2008 period. Control experiments (CFV and LFV in black) are driven only by observed sea surface temperature and show much lower scores than the tropically-nudged experiments driven either by observed (CNV and LNV in blue) or climatological (CNC and LNC in red) sea surface temperature.

Climate change impacts on drought and water soil in France: Results from CLIMSEC project

The CLIMSEC (2008-2011) project led by "Direction de la Climatologie" with the support of the Foundation MAIF, aimed to characterize the drought events in France over the period 1958-2008 and to establish a diagnosis on their future evolutions during the XXI century.
The study in present climate leaned on a retrospective modelling of the soil wetness over 50 years with the Safran-Isba-Modcou (SIM) hydro-meteorological suite. The various kinds of drought (meteorological, agricultural, hydrological) were characterized with standardized indices, allowing to build a high resolution climatology of drought events, recognized by the Norbert Gerbier Mumm price of the World Meteorological Organization in 2011.
The second part of the study was dedicated to the evaluation of the future characteristics of drought in a changing climate, by means of the preceding standardized indices and the regionalized climatic projections, available over France. The analysis highlighted the relative importance of the different uncertainties, linked to climatic models, socio-economical scenarios and regionalization methods.
Global results established:
In the middle of the XXI century, an important increase of the frequency and the intensity of extreme events in link with soil water deficit.
At the end of the century, with a probable reduction of precipitation in summer and autumn, an evolution towards very strong events, currently unknown (length, severity, magnitude, spatial extension).
Complete report on the website:
http://www.cnrm-game.fr/projet/climsec

4

Monitoring the 2011 drought using vegetation indicators

The spring of 2011 was exceptionally dry and warm in western Europe. Over France, it was one of the driest over the last 50 years. The drought was particularly marked in northern and western France. Leaf area index (LAI), soil wetness index (SWI), and photosynthesis (gross primary production or GPP) simulations performed by the ISBA-A-gs model show that this event had a marked impact on the vegetation development, leading first to unusually high LAI and GPP values, especially in April, then to low values from May (in western France) to June. In contrast, July 2011 tended to be wetter than normal, allowing the vegetation re-growth. At springtime, the vegetation drought indicators did not behave like the SWI anomaly. Indeed, in a first stage, the unusually high air temperatures and solar radiation tended to favour vegetation growth, while increasing evapotranspiration, and thus decreasing the SWI. Also, the higher LAI values tended to enhance the SWI decrease. The negative impact of the drought on the vegetation was only visible in a later stage, when the soil water content was too low to sustain plant growth. This intense early drought event, followed by higher than normal rainfalls is an excellent case-study to evaluate the capacity of the models to simulate the impact of drought on the vegetation, and the vegetation re-growth after a drought. Also, it shows that the interannual variability of vegetation variables impacts the SWI simulations, and that the ability to simulate both vegetation and soil moisture drought indicators could improve the monitoring of the impact of weather on the agricultural production.

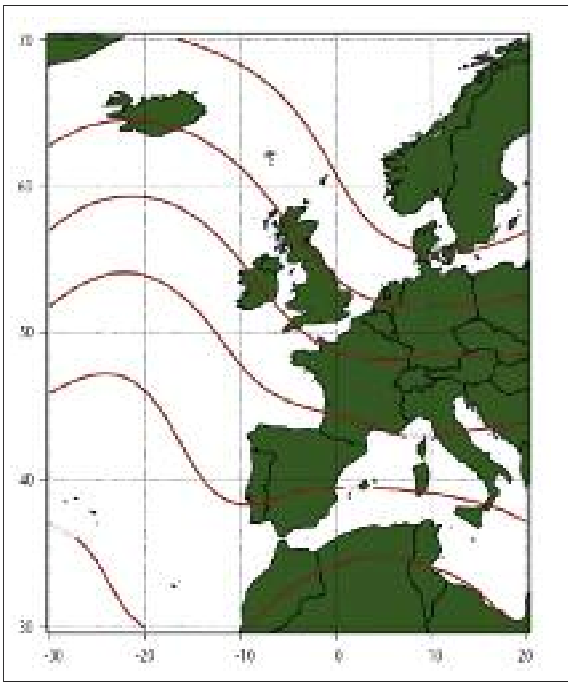
5

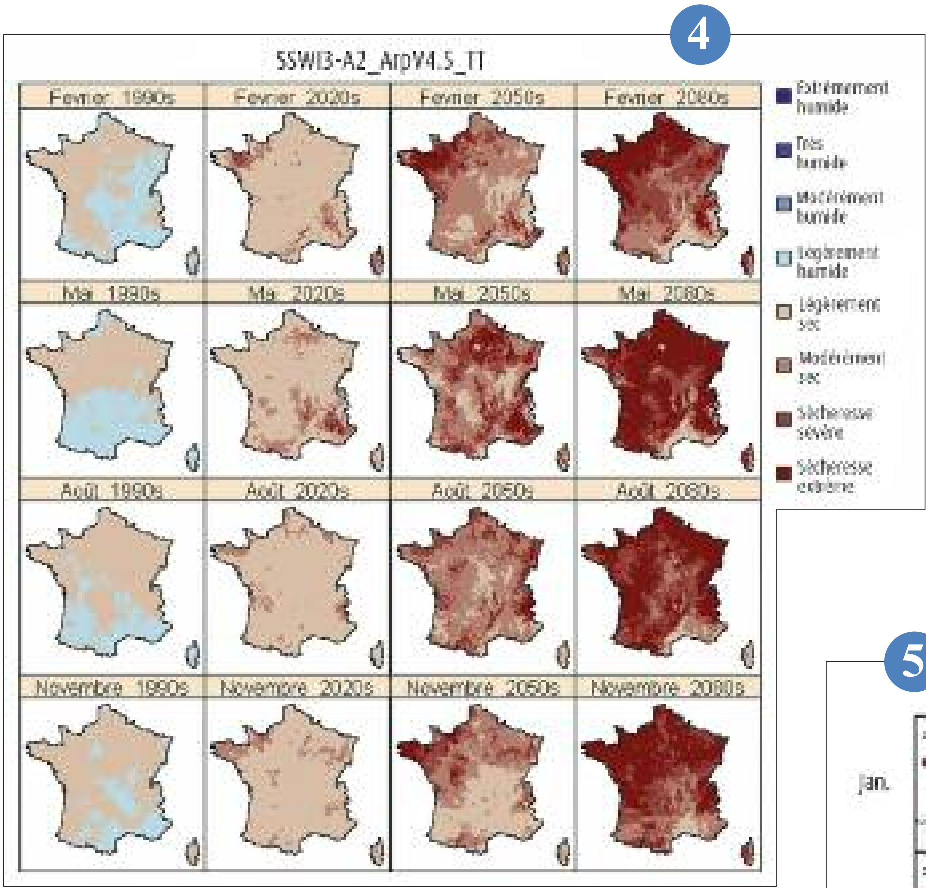
Provide new tools to realize an atlas by weather types

Some studies have established a link between weather regimes and local meteorological parameters such as the CYPRIM project and its part on weather regimes and intense precipitation in the Cévennes or the IMFREX project and its part on weather regimes and storms.
In pursuing this approach, a study on classification by weather types to obtain a wind climatology in France has been realized. This study explored various tools related to all stages of the classification: withdrawal of the annual cycle by Fast Fourier Transform of the geopotential at 700 hPa, determining the number of clusters by mixed classifications - k-means followed by hierarchical clustering-, automatic pruning of hierarchical clustering dendrograms, check the reproducibility of the classification using the test of 'concordance', development of 'mobile seasons' different from one year to another, examining the frequency of occurrence of clusters on four daily networks. The final classification identifies 5 clusters corresponding to winter periods and also 5 clusters corresponding to summer periods. Observed wind roses associated to the 5 winter clusters and to the 5 summer clusters were made for all dates of the clusters and also by network.

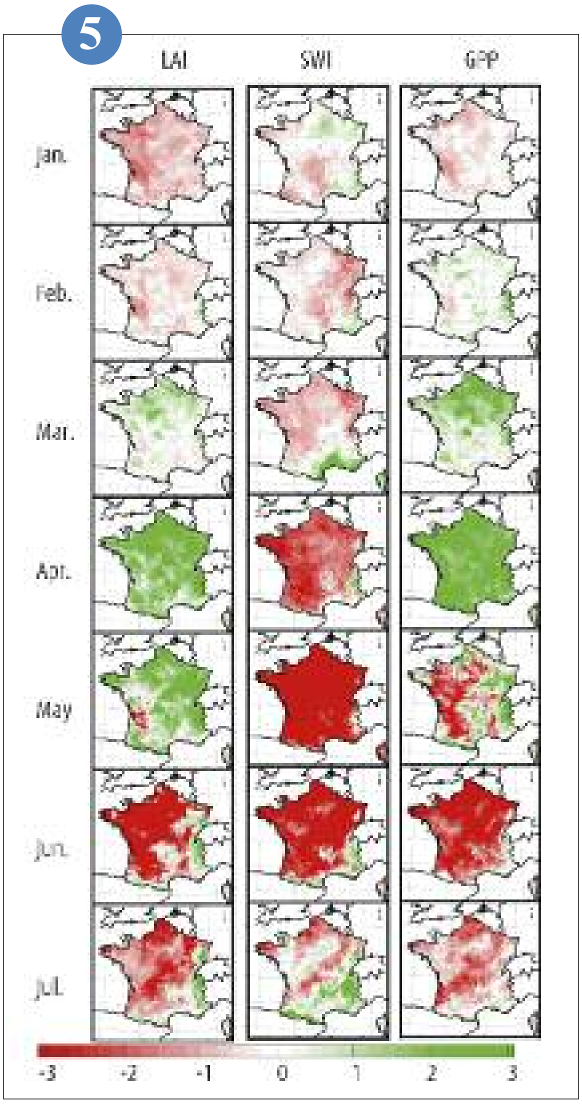
A user's guide for the classifications by weather types was created. This document is a technical guide detailing the different stages of a classification such as data preparation, classification methods with the corresponding R functions, statistical and meteorological validation, and the choice of representative dates of weather types, examples studies and a bibliography. These statistical tools will provide support for the realization of regional atlas by types of weather.

6





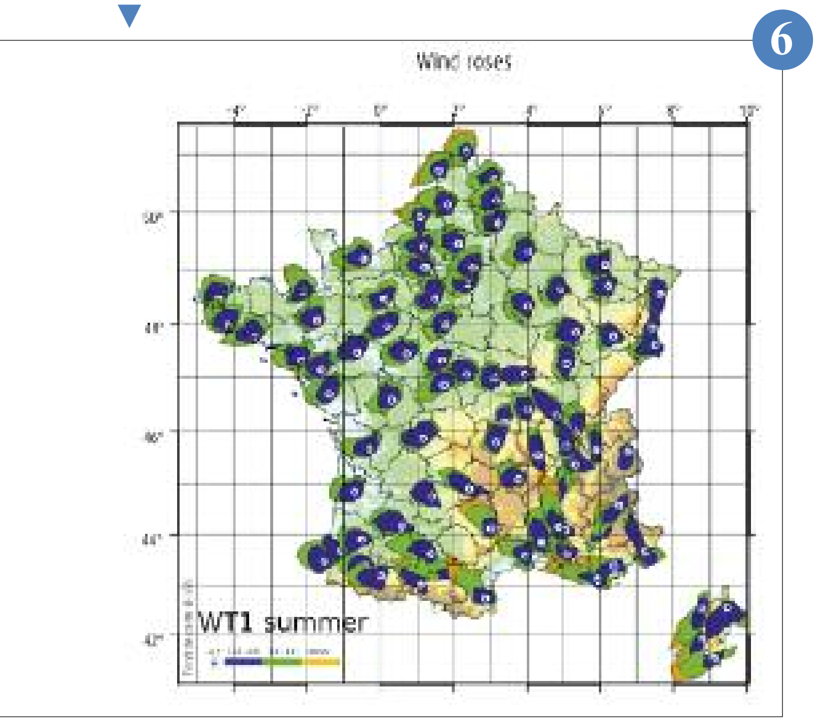
◀ Seasonal evolution over the XXI century of the average of the agricultural drought indices SSWI over 3 months, established from the climatic projections ARPEGE V4.6, scenario A2, regionalized by the method “type de temps”.



▲ Temporal evolution of three drought indicators, from January to July 2011: scaled anomalies of (from left to right) leaf area index (LAI), soil wetness index (SWI), and photosynthesis or gross primary production (GPP).

Composite of 700 hPa geopotential and associated wind roses corresponding to one of the five summer weather types.

▼



Climate change

Climate of the 21st century simulated by CNRM-CM5

In the context of the next IPCC report (2013), CNRM-GAME has completed more than 9000 years of new climate simulations in the framework of the CMIP5 international project. For this purpose, a new coupled global climate model, CNRM-CM5, has been designed in close collaboration with Cerfacs. It is based on the ocean-atmosphere coupling between NEMO v3.2 (IPSL) and ARPEGE-Climate v5.2 (Météo-France). Additionally, SURFEX v5, GELATO v5 and TRIP are included in CNRM-CM5 to simulate surface-atmosphere exchanges, sea-ice and river rooting. This new model has a horizontal resolution of 150km and is coupled through the OASIS software.
New greenhouse gases and aerosol concentration scenarios have been defined in the context of CMIP5. These new scenarios have been designed in order to reach a specified radiative forcing target at the end of the 21st century. Scenarios RCP2.6, RCP4.5 and RCP8.5 respectively correspond to a radiative forcing of $2.6W.m^{-2}$, $4.5W.m^{-2}$ and $8.5W.m^{-2}$ in 2100 compared to preindustrial conditions (1850). CNRM-CM5 simulates respectively a global mean surface temperature increase of 1.3K, 2.1K and 3.5K between 1970-1999 and 2070-2099. Under the most pessimistic scenario, CNRM-CM5 projects the annual mean near-surface air temperature to increase by more than 4K over continents, and by approximately 10K over the Arctic. As for previous IPCC simulations, whatever scenario is considered, the warming is larger over continents than over oceans and is a function of latitude. The decline of sea-ice and snow covered areas explain the more severe warming simulated over polar regions.

7

The future of snow in French mountains under anthropogenic climate change

Refining climate change scenarios over France is a goal for adaptation in the next decades as well as for a better knowledge of risks at the end of the century in the absence of mitigation.
In the French ANR/SCAMPEI project we have used an original approach to estimate snow cover at high resolution over France. The 3 French regional models have produced time slice simulation at the highest possible horizontal resolution (12 km for ALADIN). The outputs have undergone a statistical post-processing to behave in a similar way to SAFRAN re-analyses at one hour time step, over the 616 SYMPOSIUM areas, for various elevations (300 m vertical step).
We got 15 30-year meteorological series, 3 for the reference climate (1961-1990), 6 for possible climates of the mid-21st century, and 6 for possible climates at the end of the 21st century without mitigation. The hourly corrected variables have driven the ISBA-ES soil model at each location and elevation. We obtained thus a rather accurate description of the snow pack. Figure shows, for ALADIN, late 21st century and IPCC-A2 scenario the strong decrease of snow depth in winter in the mountain regions. More results and freely downloadable data are available at www.cnrm.meteo.fr/scampei/.

8

Trend analysis of annual discharge in large river basins provides evidence of permafrost thawing

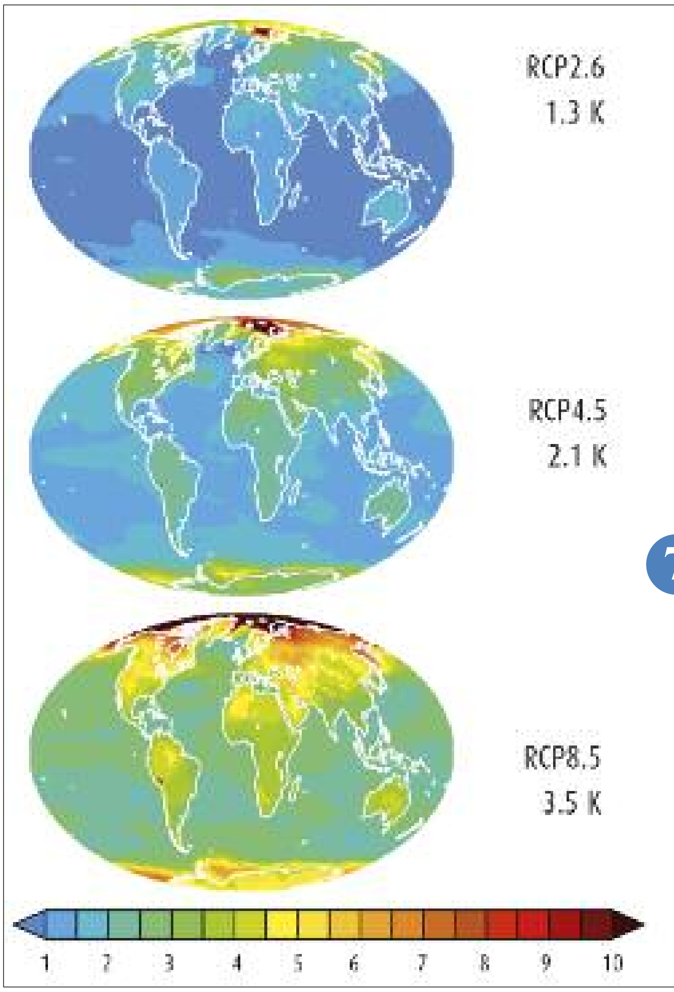
According to the 4th IPCC Assessment Report, the consequences of global warming on land surface hydrology remain unclear, including at continental scale. Understanding the multi-decadal variability of observed discharge in large river basins is therefore a challenge for reducing uncertainties in 21st century hydrological projections. As a contribution to the CYMENT project funded by the RTRA, the ISBA land surface model, feeding the TRIP river routing model, has been driven by atmospheric analyses corrected for their systematic biases in order to simulate the discharge of the largest worldwide river basins over the 1950-2006 period. Satellite observations (derived from the Gravity Recovery And Climate Experiment mission launched in 2002) have been used to evaluate the water storage variations simulated at the basin scale. Results indicate a realistic behaviour of the ISBA model, both at seasonal and inter-annual timescales, thereby increasing our confidence in the simulated water budget. River discharge variations at inter-annual and multi-decadal timescales are also well captured over most river basins, except at high-latitudes (basins with outlet located north of 60°N, cf. figure) where simulations and observations show opposite trends. This result highlights the need of accounting for permafrost (and its recent thawing) in the ISBA model like in most climate model that still neglect this component of the climate system whose thawing should also have a significant impact on carbon cycle.

9

Publishing climate projections with the Earth System Grid (ESG)

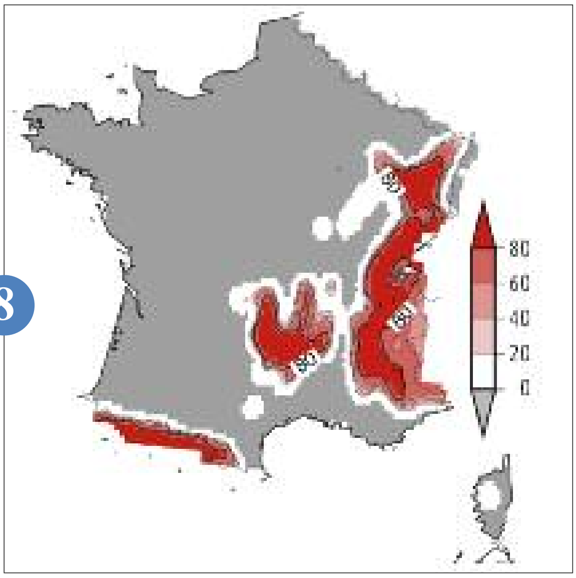
CNRM-GAME's contribution to the IPCC activities included this year providing the scientific community with the long-term simulation results of CNRM-CM5 Global Coupled Climate Model for the CMIP5 project.
This provision involved the use of the Earth System Grid (ESG). The ESG is a computer network, with « gateways » and « data nodes ». Gateways allow data discovery and data selection, while data nodes actually host and deliver the data. CNRM-GAME operates one such data node, which also hosts the results of CERFACS using CNRM-CM5 for CMIP5 decadal experiments. It was setup in the frame of a cooperation with the Institute Pierre-Simon Laplace. This data node is connected to the RENATER (French research information motorway) using a high speed link. The main ESG gateways are operated by the PCMDI (USA), le BADC (U.-K.) and DKRZ (Germany).
CNRM-GAME so publishes some 60 terabytes of data, among the 3 petabytes which should be eventually available for the whole of CMIP5. The effort put on setting up this system early, together with the use of a very tight schedule for simulations, allowed CNRM-CM5 climate projections to be widely known and early used by the scientific community. The expertise gained on the relevant technologies will be further used for publishing additional datasets of international interest.

10



7

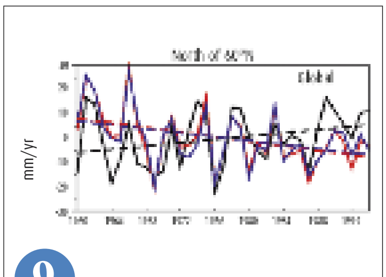
Change in annual mean near-surface air temperature (°C) between 1970-1999 and 2070-2099 simulated by CNRM-CM5 for three greenhouse gas emissions scenarios.



8

Relative decrease (%) in winter snow depth for a possible climate of the late 21st century (IPCC A2 scenario) with respect to a reference climate (1961-1990). Area with less than 1 cm on average in the reference climate are shaded.

Annual mean runoff anomalies, averaged over the largest worldwide river basins whose outlet is located north de 60°N and with available river discharge data, observed (in black) and simulated by ISBA (blue and red) using two different observed precipitation forcings. Inter-annual variability is well captured unlike the observed rising trend over the 1960-1994 period. This result can be interpreted as an evidence of the high-latitude permafrost thawing due to global warming which could be responsible for the observed increased runoff but is not considered in ISBA like in most land surface models used in global climate projections.



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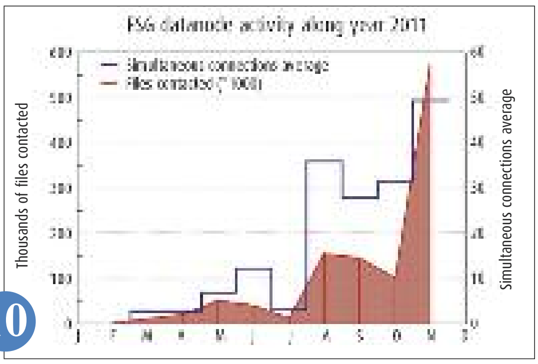


10

Earth System Grid data node at CNRM-GAME - activity along year 2011: the blue curve shows the average number of simultaneous connections on the data node for each month (scale on the right); the black shading shows the total number of files contacted from the whole month (scale on the left).

Atmosphere and environment studies

In 2011, numerous research activities were conducted in the areas of hydrometeorology, oceanography, snow cover and air quality modelling. Except the subjects developed in this chapter, we shall also retain the works on the simulation of flash-floods which includes now a perturbation of the fields of the determinist atmospheric model, the validation of the model of lake FLAKE based on the measures of the THAUMEX campaign over the pond of Thau and the development of a building energy model for a better representation of the city-atmosphere exchanges.

Hydro-meteorology

RHYTMME: First version of the radar processing chain is running

The RHYTMME project aims to provide local actors with appropriate tools to better manage natural disasters induced by precipitations (floods, avalanches, forest fires, ...). It focuses on mountainous areas because they are very exposed to natural hazards. The first experimental zone is located in the French Southern Alps.

A first step is to improve the radar coverage of this region. For that purpose, a radar was installed at the end of 2010 at the top of the Montagne Maurel (Alpes de Haute Provence). The data from another radar (Mont Vial, Alpes Maritimes), owned by CNRS and operated by NOVIMET, is also used. Both radars are X-band, polarimetric and Doppler. A processing chain was developed, including identification of non-meteorological echoes, correction for precipitation attenuation and production of reflectivity and quantitative precipitation estimation images for both radars. Mosaïcs are then constructed using both RHYTMME radars and the nearest radars of the METEO-FRANCE network.

This first version of the processing chain is running real-time since the end of June 2011. Its outputs are used by a platform service that is tested since the beginning of fall 2011. This system is a scientific innovation because of the adaptation of the processing chain to X-band. It is also an engineering innovation: radar products are generated by a central calculator and no more by all individual radar calculators. This can be considered as a prototype of the future radar processing chain at METEO-FRANCE.

A second version of this processing chain will be developed, including a better quantitative estimation of high rain rates and a hydrometeor classification (identification of rain, dry snow, wet snow, hail, ...). This new version should be running from the spring of 2012.

1

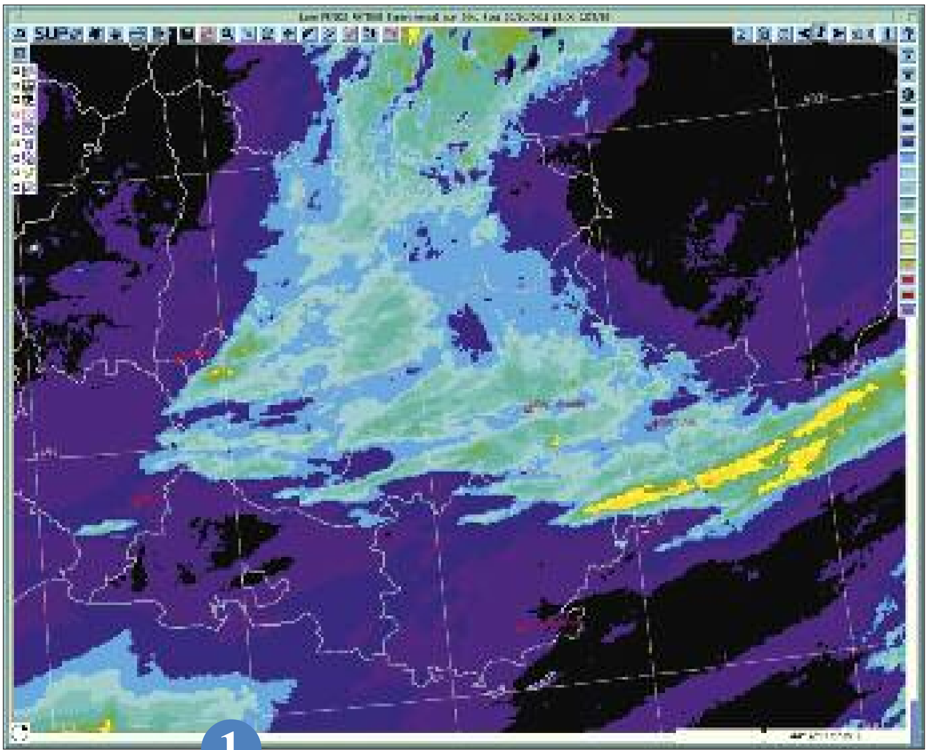
Participation of CNRM in RHYTMME

The Group of Instrumental and Experimental Meteorology (GMEI) of CNRM has been operating a set of sensors in the lower Var valley since in January 2011 to evaluate the reflectivity measurements of the first two X-band radars of the RHYTMME network as well as to test new ways to improve the quantitative precipitation estimates at the valley floor. The experimental setup (figure a), which consists in a surface meteorological station, a rain gauge, a disdrometer and a micro rain radar, is installed on the roof of Puget Théniers' police station, located approximately halfway between Maurel Mont and Mont Vial radars. Instruments are operated and monitored remotely from Toulouse via a 3G connection and will remain in place until June 2012 before being redeployed in the Cevennes for the HyMeX project.

The Numerical Weather Prediction and Assimilation Department (GMAP) is heavily involved in the RHYTMME project and is working on the use of radial wind data and reflectivity data collected from the X-band radar network in the AROME model. The assimilation of these two observations makes it indeed possible to shift badly located precipitation patterns through the joint analysis of the low-level dynamic and precipitation intensity. The first impact studies on specific cases show a good contribution of the first X-band radar of the network. Improved cumulated precipitations can be observed up to the six hours range (figure b).

2

Accumulation of RHYTMME quantitative precipitation estimation from October 19th 2011 at 13h00 UTC to October 20th at 13h00 UTC.



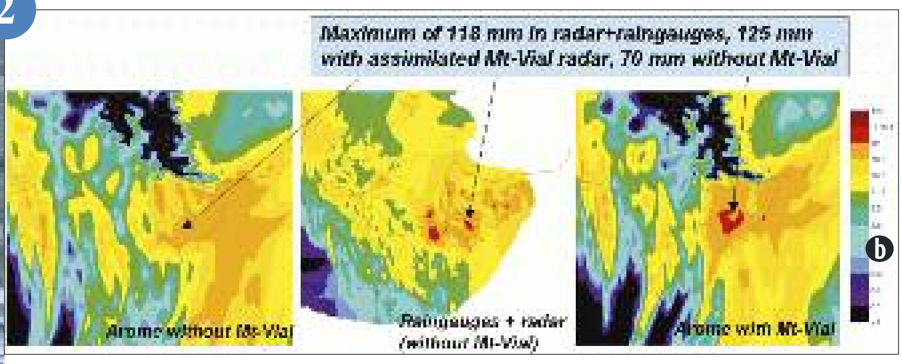
1

Experimental setup in Puget Théniers.

a

2

b



Cumulated ground rain rates between 14h TU and 19h TU on the 31th October 2010, in the middle, from a combination of rain gauges and rain rates from radar, and from an AROME forecast (between 2 and 7 hours range), left panel, without assimilation of Mt-Vial X-band radar, and on the right, with the assimilation of Mt-Vial X-band radar.

Oceanography (modelling and instrumentation)

In 2011, CMM has continued its role in the implementation of observation stations on the oceans, contributing to the international visibility of Météo-France. If many of the activities are carried out for operational purposes, the CMM plays an important role in the campaigns of the scientific community. A network of 100 drifters (SVP-B type) was maintained in the North Atlantic Ocean in the framework of ESURFMAR programme. Thirty drifters are deployed regularly in the Tropical Indian Ocean during the cyclonic period and in the Southern Indian Ocean to improve the coverage of this area. Five open ocean moored stations were maintained, two on the Eastern Atlantic Ocean in cooperation with the UK Met-Office, two in the Mediterranean Sea and one off the French West Indies.
In the framework of Hymex the CMM reinforced the scientific equipment of the two moored buoys in the Mediterranean Sea to study air-sea interface and the ocean mixed layer. The CMM also supports the preparation of campaigns at sea with the deployment and recovery of drifting buoys. The contribution to the validation of measurements provided by SMOS satellite is done by deploying drifters that measure sea surface salinity in Biscay Bay and off the Amazon.
In 2011, CMM also had an important role in the development of more accurate specific sea surface temperature sensors on SVP drifters to meet the needs of the scientific community.
The specific research action to better understand the waves impacts on fluxes between the ocean and the atmosphere continued in 2011. This requires the collection, the processing of in situ data and their interactions with the experimental parameterization of Numerical Weather Prediction models.

3

Contribution of a new regional wave model driven by ARPEGE model

A global third generation wave model (MFWAM), as a result of research and development activities in collaboration with SHOM, IFREMER and ECMWF is operational at Meteo-France. A new parameterization of the dissipation was implemented in December 2010. The overall scores were significantly improved and are among the best in the world, despite a spatial resolution (55 km) lower than for other systems.
In June 2011, a regional version of MFWAM driven by ARPEGE model winds has been implemented to take advantage of the maximum resolution of ARPEGE model which is about 10 km over Europe. This model aims to provide wave forecasts for French coastal areas, consistent with the ARPEGE wind forecasts for the production of regular bulletins and coastal innundation and high waves warnings. This model has been extensively tested and validated over several months. The reduction of systematic errors (bias) and random errors (dispersion index) with respect to the previous operational wave model VAG also driven ARPEGE winds with the same resolution, is highly significant (see figures a and b).
This model will also provide the boundary conditions for the future wave model MFWAM/AROME with 2.5 km resolution, which will be validated and possibly adjusted thanks to model experiments done in the framework of the HYMEX field campaign and with data of the future CNES Ka-band radar altimeter, better adapted to coastal areas, and that will be on board an Indian satellite with a launch expected before mid-2012.

4

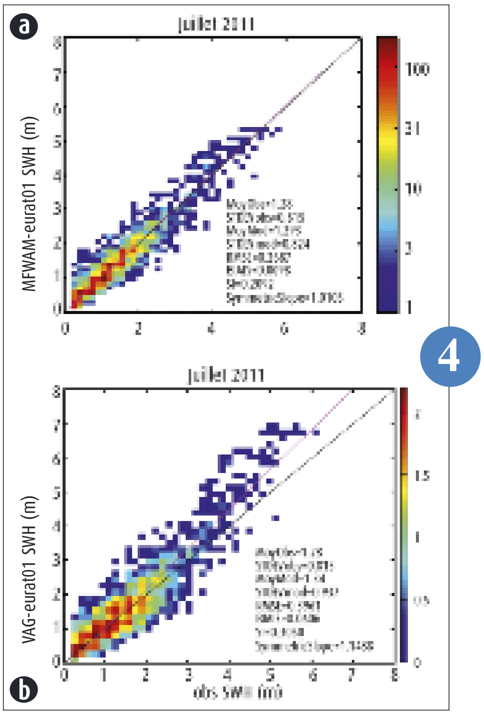
Internal solitary waves in the upper ocean

Propagating disturbances of gravitationally-stable density stratification, also called internal waves, are ubiquitous in the Earth atmosphere and oceans. Due to the temporal and spatial scales involved, data field measurements are difficult and explicit numerical modeling is only possible for very small domain. This is why laboratory work is such an important tool to investigate the complex phenomena associated with these waves.
These waves can occur at a density interface, such as the base of the oceanic mixed layer (pycnocline). Under certain conditions, these waves are called solitary waves and can propagate over hundreds of kilometers whereas both energy and form of the wave packet are conserved.
They are quite frequent in some areas, and can have a strong impact on sea structures (platform, plants, large ships, ...). Therefore prediction of such waves is crucial for these structures users. These waves influence also the oceanic mixed layer dynamics which is an effect difficult to parameterize because they are not generated locally.
Laboratory experiments are currently run on waves generated over a sea ridge at the pycnocline, either by direct interaction with the ridge as in the Sulu Sea or through an internal wave beam as in the Bay of Biscay. They are carried on by the CNRM-GAME geophysical fluid mechanics team, in collaboration with Laboratoire d'Aérologie and Institut de Mécanique des Fluides de Toulouse.
Expected benefits are a better knowledge of the conditions necessary for these large amplitude waves to exist and a better understanding of their role on the general oceanic circulation and on air-sea interactions.

5

SVP-B drifter at sea.

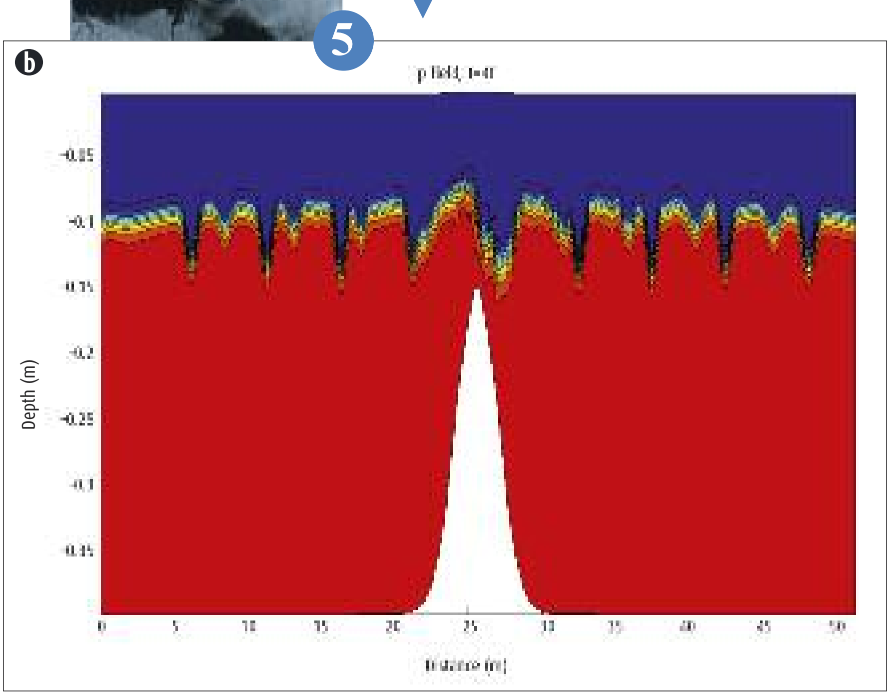
Scatter plot showing the density MFWAM data-buoy data.
The MFWAM model is driven ARPEGE MFWAM.
Buoys are located in the English Channel,
North Sea and the Mediterranean Sea.



Scatter plot showing the density VAG data-buoy data.
The MFWAM model is driven ARPEGE MFWAM.
Buoys are located in the English Channel,
North Sea and the Mediterranean Sea.

Primary generation of solitary waves on a Gaussian ridge
at a pycnocline from a direct numerical simulation
(ocean model Symphonie).

Sea surface deformation induced by solitary waves
propagating at the base of the mixed layer.
Image taken by a synthetic-aperture radar
in the Sulu Sea (©ESA 1998).



Continuous measurements at sea to investigate air-sea interactions

In the framework of HyMex and of the MOOSE SOERE observing system of the Mediterranean, the CNRM recently reinforced the scientific equipment of the Gulf of Lions and Côte d'Azur moored buoys. These buoys are providing for a decade now measurements of the atmospheric (air pressure and temperature, humidity, wind) and oceanographic parameters (sea surface temperature, waves). These observations are then used to constrain NWP models. The beginning of the HyMex Long Observing Period was a good opportunity to add several sensors to monitor continuously relevant parameters. Hourly records over long time periods are helpful to get insights into various timescales phenomena, from the development of a meso scale convective system within a few hours to seasonal variations or even long-term climate evolution. In addition to the standard atmospheric parameters, both buoys are now providing global and infrared radiative fluxes and surface salinity observations. Rain rate measurements are currently tested with two different rain gauges on the Côte d'Azur buoy. Twenty temperature sensors are monitoring the water temperature variations, from the sea surface down to 250-m deep. To improve the collocation of the Gulf of Lions buoy with the nearby deep mooring measuring underwater temperatures (Banyuls Observatory), the buoy was slightly moved during its last replacement. At this site, water temperatures are now recorded along a quasi continuous profile from the surface down to the 2000-m depth.

6

Improved accuracy of sea surface temperature measurements on drifting buoys

Drifting buoys are the main source of in situ sea surface temperature observations (SST) used to validate satellite measurements (see illustration). Meteorologists and oceanographers run an operational network of about 1300 buoys over the world ocean, under the Data Buoy Cooperation Panel (DBCP) framework. These buoys transmit their measurements in real-time with a resolution of 0.1 K. The accuracy of the temperature measurements is about 0.2 K.
In 2010, the GHRSST expressed the need for more refined data (0.05 K accuracy, 0.01 K resolution). Météo-France proposed that the buoys used in the context of E-SURFMAR are able to meet the requirements. A first generation of buoys called HRSST-1 was built and deployed. Data and position (GPS) are transmitted ashore through Iridium then onto the GTS in BUFR. The temperature sensors, more accurate than the previous ones, are however not calibrated after integration into the buoys. The values of calibration probes, provided by the manufacturer, are so used. The A/D converter is integrated in the buoy. In late October 2011, about 140 such buoys were deployed at sea, including 110 in the North Atlantic and 30 in the Indian Ocean.
Next step is to equip new buoys (HRSST-2) with digital temperature sensors removable for easy calibration before launch, and after possible recovery of the buoys. The A/D converter will be integrated to the temperature sensor. The first buoys of this type should be built in early 2012.

7

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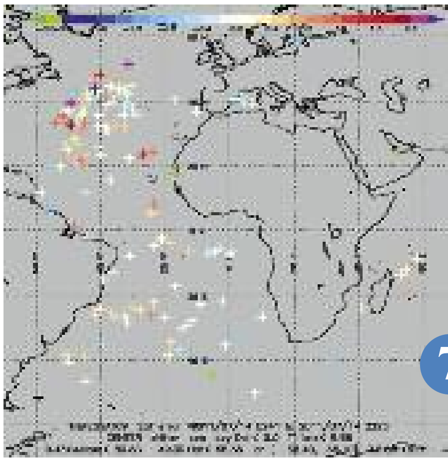
▲ The new Gulf of Lions moored buoy including radiative fluxes sensors and a rain gauge, during its replacement at the end of September 2011.

7



▲ Comparisons between buoy measurements and data from the SEVIRI sensor onboard the MSG satellite.

▶ Climatological monthly zonal total column ozone (DU) over two 10-yr periods, 1980-1989 (first row) and 1990--1999 (second row), for Bsv2.7 observations (left column), CNRM-ACM (middle column) and CNRM-CCM (right column) simulations.

Atmospheric chemistry and air quality

On the use of AROME fields to force MOCAGE air quality forecasts

During the summer 2011, MOCAGE operational forecasts were forced with ARPEGE to forecast air quality over France.
Simultaneously, some forecasts were run daily at CNRM using AROME operational outputs for the first day of forecast.
As a first step, AROME forecasts are used at the current resolution of MOCAGE, i.e. 0.1° over France. For the summer 2011, results are satisfactory, in the sense that the performances of MOCAGE forecasts are not perturbed by the change in the meteorological fields, which is a good prerequisite before reducing the horizontal resolution. The Table bellow illustrates the robustness of the forecasts of ozone maxima in different regions of France. The summer 2011 did not allow us to test the response of the new configuration in case of a heat-wave.
The goal now is to use AROME fields at the horizontal resolution of 0.025°, which should modify significantly MOCAGE performances. The main added value of high resolution relies partly on the use of the "Inventaire National Spatialisé" (1km/1h) which will be available soon.

8

Validation of the climate model CNRM-CCM that includes a detailed description of the stratospheric chemistry

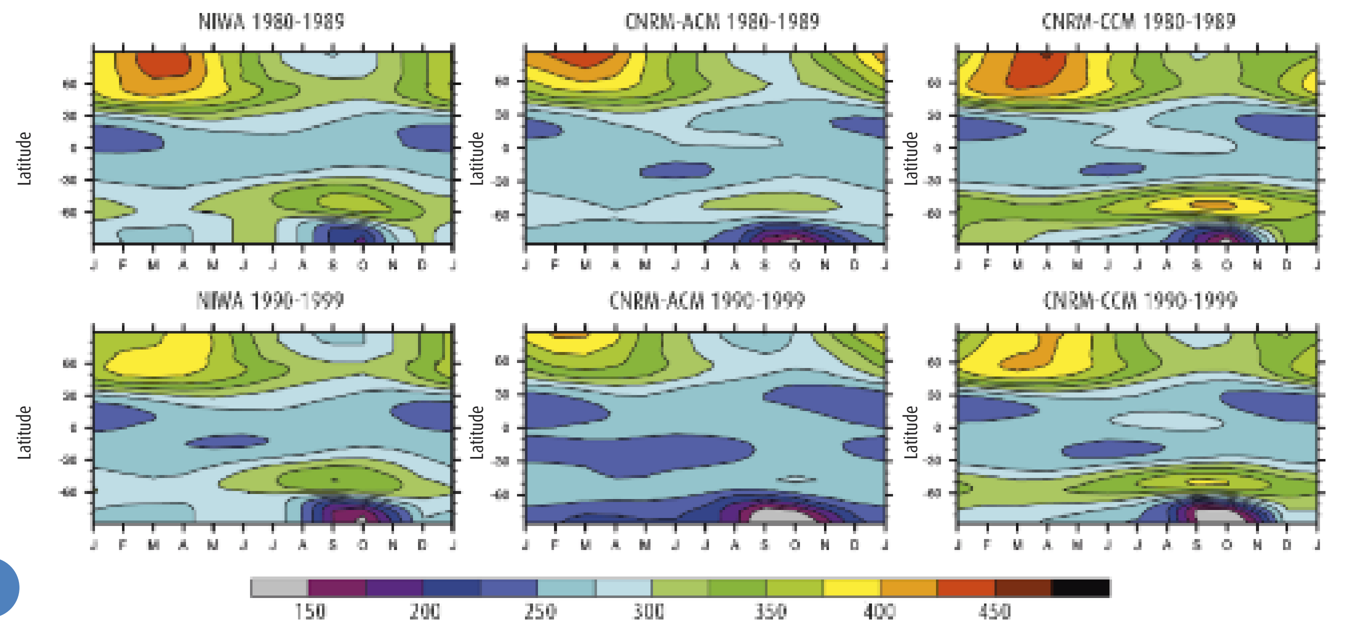
Three-dimensional atmospheric circulation models with a fully interactive representation of stratospheric ozone chemistry are known as stratosphere-resolving Chemistry-Climate Models (CCMs). They are key tools for the attribution and projection of stratospheric ozone changes arising from the combined effects of changes in the amounts of greenhouse gases and ozone-depleting substances. We present here results of a modelling activity that lead to the definition and implementation of a new version of the Météo-France CNRM CCM, « CNRM-CCM ». CNRM-CCM includes some fundamental changes from the previous version (CNRM-ACM) which was extensively evaluated in the context of the WCRP/SPARC/CCMVal-2 validation activity. The most notable changes concern the radiative code of the General Circulation Model (GCM), and the inclusion of the detailed stratospheric chemistry of our Chemistry-Transport model MOCAGE on-line within the GCM. CNRM-CCM generates satisfactory dynamical and chemical fields in the stratosphere (see Figure). Several shortcomings of CNRM-ACM simulations for CCMVal-2 have been eliminated. Remaining problems concern the upper stratosphere (5 to 1 hPa) where temperatures are too high, and where there are biases in the NO_2, N_2O_5 and O_3 mixing ratios. Despite these problems we show that this new CNRM CCM is a useful tool to study chemistry-climate applications, in particular in seasonal and decadal scales.

9

8

	ARPEGE	AROME
Ouest	0,73	0,72
Paris & Nord	0,70	0,71
Est	0,69	0,70
Sud-Ouest	0,67	0,64
Sud-Est	0,66	0,66

◀ Summer 2011: impact of the meteorological fields on MOCAGE air quality forecasts.
Median of the correlations between the ozone daily maxima forecasted and observed for the stations of classes 1 to 8, which is equivalent to discard the most polluted sites that are less representative (Joly & Peuch 2011).



9

Avalanches and snow-cover studies

In 2011, actions were developed in order to improve the modelling and forecasting of snowpack stability. In particular, several field campaigns were done concerning snowdrift (laser and nets) on Col du Lac Blanc site in order to validate simulations with the Meso-NH model. The studies on snow remote sensing have led to develop an electromagnetic propagation model for Ku and X bands into snow and to advances in determination of cryosphere characteristics such as emissivity and surface snow grain size. Studies on snow physics have continued in order to add new parameters in present snow models (like the snow surface specific area or the thermal conductivity for instance) and to improve the link between micro and macro scales (via experiments of metamorphism under strong thermal gradient in cold laboratory and the improvement of the micro-scale data analysis). Interactions between climate variability and cryosphere have been studied following three axes: comparison between a modelled snow climatology and MODIS data for Pyrenees mountain range, study of the snowpack evolution under climate change until the end of the century, water resources modelling for snow- and ice-covered catchments. The CEN has also had several support actions to operational avalanche forecasting activities, like the creation of a new avalanche bulletin, the installation of a new Nivôse station (Beaufortain, Savoy) or the organization of the 16th meeting of the European Avalanche Warning Services (EAWS) in Grenoble in September.

10

Natural avalanche activity and associated snow and weather conditions over the last 50 years in the French Alps

The ECANA project (Etude Climatologique de l'Activité avalancheuse Naturelle des 50 dernières années dans les Alpes françaises) is funded by the DGPR / MEDDTL and carried jointly by the Centre d'études de la neige (Météo-France/CNRM) and CEMAGREF / ETNA. Its main objectives:

– Develop a climatology of natural avalanche events of the past 50 years in the French Alps.
– Investigate the correlation between changes in average indicators of the avalanche activity (intensity and frequency of events) and the evolution of mean snow and weather indicators (temperature, precipitation, snowfall).

The first step was to build a database including:

– Avalanche activity index based on data from the Avalanche Permanent Survey (EPA) managed by the CEMAGREF.
– Index of avalanche activity (IAA) codified by the snow and meteorological network of Météo-France.
– A summary index of the avalanche risk analyzed by the model MEPRA.
– The results of the SAFRAN/Crocus chain for the snow and weather variables.
– A composite index (IC) based on EPA and MEPRA indices.

The first results on annual averages (figure) show:

– A good coherence and complementarity between the Cemagref and Météo-France databases.
– No significant trend of change in observed avalanche activity in the last 50 years.
– A MEPRA modeled avalanche risk very representative in winter situations but to improve in spring situation.

The study should be continued for smaller spatial and temporal scales then should advance to work on the relationship between climate change and avalanches.

11

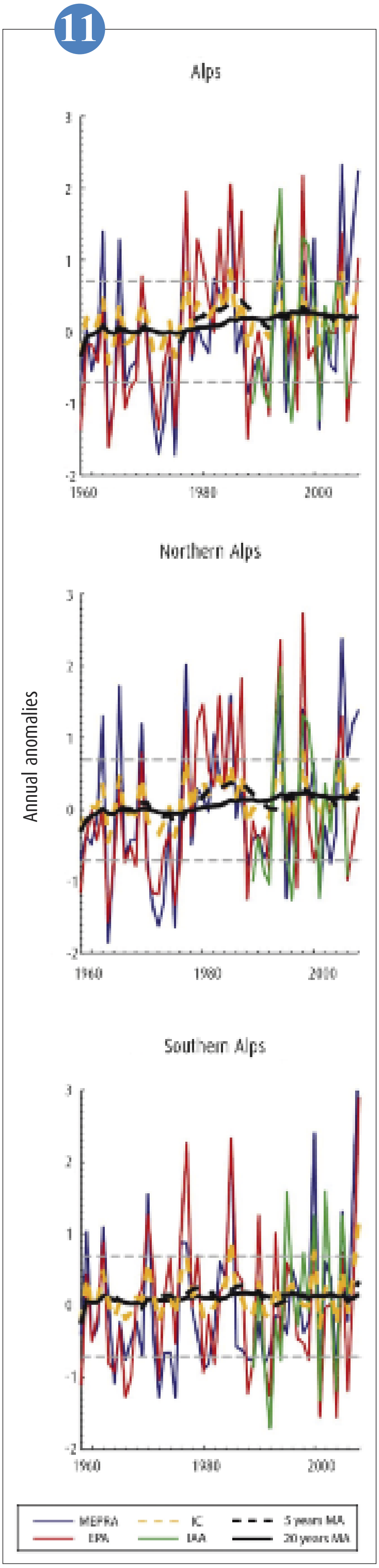
18 years of snow and meteorological data at col de Porte, for use in snowpack schemes development and evaluation

The experimental research station located at col de Porte (1325 m altitude, near Grenoble, France) has been devoted since 1960 to the study of the snowpack. It includes all the necessary dedicated instrumentation, among which in-house developments, to continuously monitor the meteorological conditions (air temperature, relative humidity, wind speed, incoming solar and thermal radiation, liquid and solid precipitation) and snowpack-relevant properties (depth, albedo, snow water equivalent). In addition, weekly manual profiles provide complementary information on the snowpack vertical structure (snow type, temperature, density, liquid water content). This unique dataset has been used in the past to develop and evaluate the snow component of land surface models, such as the snowpack model « Crocus » developed at CNRM-GAME/CEN. In 2011, all the data gathered since 1993 were put together and described within a unified framework so that they can be even more widely used by the snow-hydrology research community. Data will also be transferred to the climate department within Météo-France for inclusion in ad-hoc databases, and freely distributed to the research community. Ongoing developments of the snowpack scheme Crocus are strongly dependent upon such high-quality datasets. Several collaborative projects currently take place at this site, including research on the surface energy budget of the snowpack, or on impurities within the snowpack.

12

Snowdrift monitoring at the site of Col du Lac Blanc (2800 a. s. l., French Alps).

Overview of the experimental research site at col de Porte, and close-up on some of the instruments used, such as : precipitation sensors (1,2), anemometers (3), lysimeters (used to measure basal runoff) (4), snow depth gauges and instruments measuring the vertical profile of height and temperature of snow layers (5), air temperature and relative humidity sensors (6), radiation sensors (7 and 8), snow water equivalent through cosmic rays counting (10), webcam (11) and automatic weather station « Nivose » (12). Weekly snow pit observations are carried out in a dedicated area (14). Measurements of snow water equivalent are carried out in collaboration with EDF – Direction Technique Générale.
Pictures: D. Poncet, B. Lesaffre (CNRM-GAME/CEN).



Annual anomalies of EPA, MEPRA and IC avalanche activity index (last 50 years) and IAA avalanche activity index (last 20 years).

Numerical and experimental investigation of the thermal conductivity of snow

The thermal conductivity of snow strongly influences the vertical heat flux through the snowpack. It is thus an important variable to account for to quantify and simulate temperature vertical gradients which in turn drive morphological transformations of the snow with time (metamorphism).
To study the impact of the three-dimensional structure of snow (microstructure) on its thermal conductivity, numerical computations were carried out using 3D images obtained by X-ray tomography. figure a shows some of the 30 images used for this study, and illustrates the large range of shapes that snow crystals can feature throughout their transformations. Computations were done in collaboration with the laboratory 3S-R and allowed to estimate the three components of the thermal conductivity of snow. It was found that, in contrast to prevailing consensus, the thermal conductivity of snow is strongly correlated to snow density, and that the needle-probe method used for field measurements leads to underestimated values (figure b). In addition, numerical computations have revealed a strong anisotropy of the thermal conductivity, i.e. a direction more favorable for heat transfer than others. It was also found that conduction in interstitial air, although 100 times less efficient than in ice, plays a significant role in the overall thermal conductivity.
These results, which are important to improve the representation of thermal processes in snowpack models, will be included in the snow numerical scheme Crocus.

13

Comparison of MODIS-Terra satellite snow data with those of SAFRAN-Crocus snow model

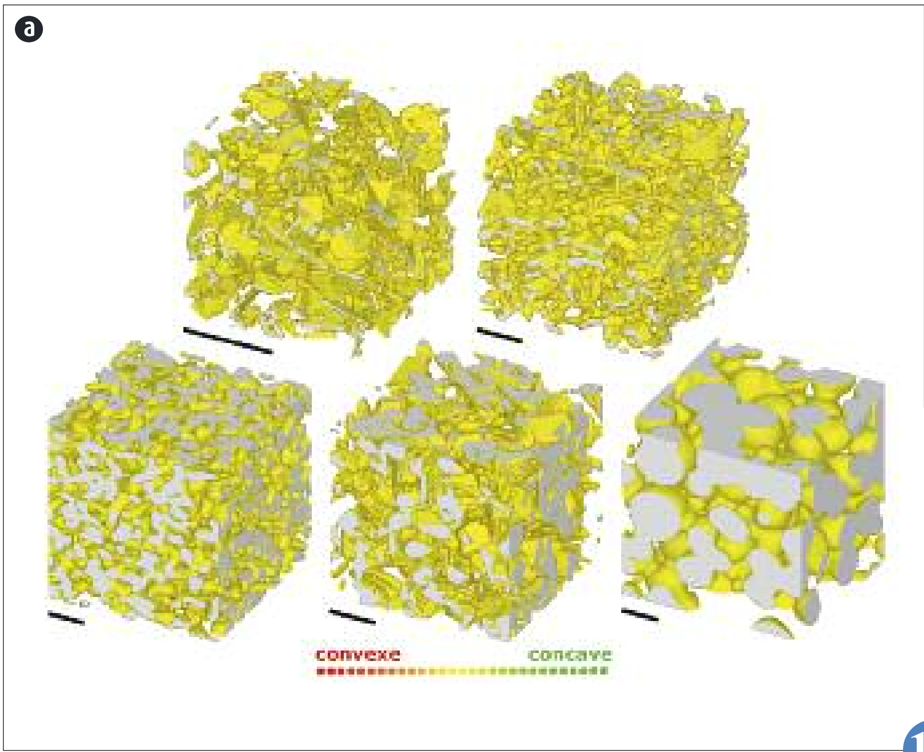
The objective of the European project Fluxpyr (2009-2012) is the study of water, carbon and energy fluxes of the Pyreneans soils. All these fluxes being strongly modified by the presence of snow, a good knowledge of the snow cover is necessary for their evaluation. Considering the wide variety of involved slopes and the small number of measurement points of the snow cover, it is a major asset to have modelled snow data at different altitudes, aspects and slope angles in the Pyrenees. But it is also necessary that these snow data, which are provided by SAFRAN-Crocus snow model, are in accordance with reality. To know that, a comparison with a limited number of observed snow data has already been done. The opportunity to make a comparison in the whole Pyrenees, using snow data from MODIS-Terra satellite, arose with the Fluxpyr project. This comparison covered the 2000-2010 period (that of the existence of data), and for the only available parameter, namely the presence/absence of snow.
The results of this comparison show that the two types of data well correspond on the whole. The more precisely analysed results indicate that the differences are more important in the (fluctuating) areas where the snow line is. On the other hand, the eastern massifs have more differences. In contrast, forest areas do not present more differences than the other areas.
With the credit of such a validation on the entire relief, the modelled snow data in the Pyrenees on the one hand allow to meet the inquiries of snow climatology, on the other hand constitute a reference database in the study of the present and future climates.

14

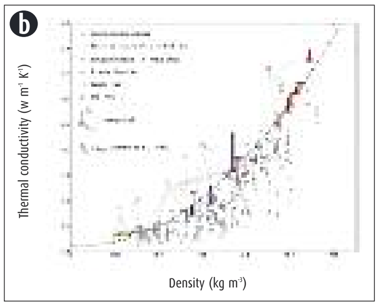
Measurement campaign on the transport of snow by the wind on the Col du Lac Blanc

In the mountains, snow transport by wind causes a redistribution of the snowpack and changes the quality of snow on the ground. This is an aggravating factor for avalanche danger, both for natural avalanches or departures caused by the practitioners of the mountain. To study this phenomenon, a measurement site was installed on the site of the Col du Lac Blanc (2700m above sea level) near the ski resort of Alpe d'Huez (Isère).
This site, which involved over 20 years CEN and Cemagref, hosted in February and March 2011 a measurement campaign designed to better describe the snow transport by the wind. The instrumentation of the site has been enhanced by manual and automatic measurements of particle flux at different levels. Remote sensing terrestrial laser has documented the spatial variations of snow depth with an accuracy of around 10 centimeters over the pass area. Three episodes of transport have been documented. This campaign is part of a project of the National LEFE/IDAO, involving the CNRM-GAME, Cemagref, LEGI and LGGE. The laser measurements were performed by the University of Natural Resources and Life Sciences in Vienna. All these data will be used to improve and validate the simulations of this phenomenon in the fine-scale atmospheric models oriented research, such as Meso-NH and the operational models used for avalanche hasard forecasting.

15



◀
3D visualization of five typical snow samples used for this study (from left to right and from top to bottom: precipitation particles, decomposing and fragmented precipitation particles, rounded grains, depth hoar, melt forms). The scale is indicated by the black segment (1 mm long).
Fresh snow is generally made of precipitation particles (top left) and reaches the melt forms (right bottom) after transformations involving one or several intermediate stages.
3D images were obtained in collaboration with the European Synchrotron Radiation Facility (ESRF) or the 3S-R laboratory.



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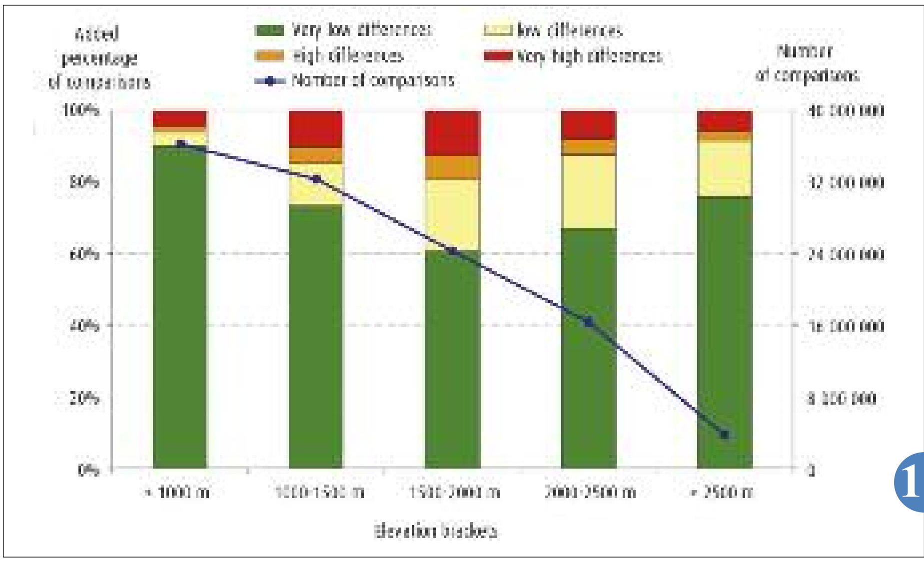
▲
Overview of the results in terms of the computed thermal conductivity of snow vs. snow density. Colors and symbols refer to the relevant snow type. T-shape symbols indicate the orientation and magnitude of the anisotropy of the thermal conductivity of snow, which is maximized in facetted crystals and depth hoar. Gray symbols represent a compilation of experimental data, which quasi-systematically fall below the results of the numerical computations.



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▲
Distribution, as a function of elevation, of the differences between SAFRAN-Crocus modelled snow cover and that seen by the MODIS-Terra satellite (November-May periods from 2000 to 2010).

15

▶
The site of the Col du Lac Blanc (2700m above sea level, Isère). In the center of the picture: the measurements fields with different masts for the measurement meteorological parameters, snow particles fluxes, snow depth and a cabin housing the datalogger. In the foreground: the terrestrial laser measuring the height of snow cover in the area.

Instrumentation and experimental research

R&D activities at Météo-France in the observation domain have a double goal of improving the operational observation network and exploring the atmospheric physics for a better understanding and a better representation in numerical models.
As far as operational observation is concerned, a main event in 2011 has been the operational deployment of the first version of the polarimetric processor of operational radars. A first milestone has thus been reached of a programme started in 2004 that was aiming at giving Météo-France a state-of-the-art radar network.
In the space domain, a long-awaited event has been the successful launch of the French-Indian Megha-Tropiques mission dedicated to the observation of clouds. The launch was followed by an intense activity of calibration / validation to which the research aircrafts of SAFIRE have contributed.
Since it was put into orbit in 2006 aboard METOP-A, the IR interferometer IASI has been the object of intense work at Météo-France. In addition to activities aimed at widening the domain of application of the instrument, 2011 has seen the first scientific results of the CONCORDIASI campaign carried out in the Antarctic region in 2010 under the responsibility of CNRM.
Experimental activities were driven by two campaigns. The first one was organized as part of the PREVIBOS research programme aimed at studying the lifecycle of fog. It was carried out during the winter of 2010-2011 on the SIRTA. It will be followed by two additional winter campaigns. The second campaign called BLASST took place at Lannemezan, France, on the instrumented site of the Observatoire de Midi-Pyrénées, under the responsibility of the Laboratoire d'Aérologie. It was a good opportunity for CNRM to test new instrumental developments: a system of double radio-sounding that improves the repetition rate of soundings, and a gondola for altitude turbulence measurements with a tethered balloon.
Intense experimental activities are planned for 2012 with campaigns organized within the research programmes HYMEX and CHARMEX of the Chantier Méditerrannée. A lot of work was conducted this year for their preparation.

In situ Instrumentation – remote sensing

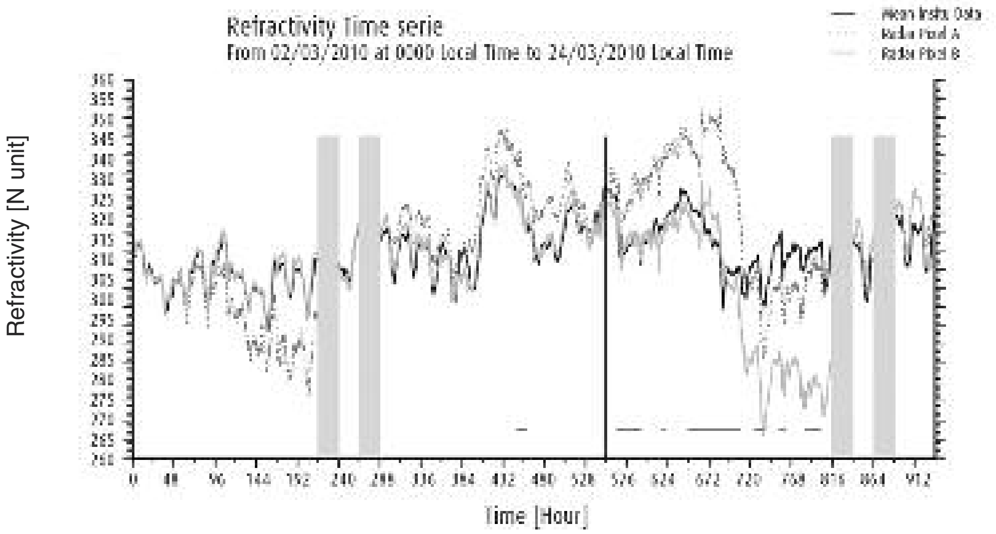
Evaluation of meteorological interest of measuring refractivity by precipitation radar

The idea is to exploit the returns of precipitation radar from fixed-target, to extract information on the atmosphere between the radar and the target, by exploiting changes in the refractive index of the environment that result in measurable changes of phase of the radar signal received from the fixed target. The challenge is to obtain spatialized measurements of the moisture in the low level atmosphere that would be useful to improve weather forecasting through their assimilation by the numerical model.
At the DSO, efforts have focused on:
– the verification of the feasibility of the measure with the operational radar network ARAMIS, which uses non-coherent radars characterized by a varying transmitted-frequency. A new theoretical formulation of the radar signal has been proposed to take into account these deviations in frequency, and to determine correction factors. This advance has been validated by a comparison work between measures of the Falaise operational radar and in-situ measurements (figure a).
– by using high-definition outputs MESO-NH for the convective event of October 20, 2008 in the South-East France region, we have shown (figure b) that a significant anomaly of refractivity is located at the front of the convection. This shows the potential of the method. This work has also helped to understand the dependence of the measurement problem of ambiguity with the radar wavelength, the time between successives measurements, the integration-time and the integration with distance.
The goal now is to move towards operational implementation of the measurement: adaptation of the method to shorter wavelengths (5 cm, 3 cm) for which the problems of ambiguity are the most difficult; setting up in real-time; validation across the network by comparison with in situ measurements.

1

Temporal variation, over a period of 40 days, of the refractivity measured by the Falaise radar, and by in-situ sensors. Until the arrival of the rain, marked by the thin black horizontal lines, the radar measurements are in good agreement with the in-situ measurements for the "pixel B" (solid gray), which comes from a communication antenna while the problems are visible on the second day for the "pixel A" (dashed gray), which comes from an obliquely oriented cliff.. Extracted from Errors caused by long-term drifts of magnetron frequencies for refractivity measurement with a radar. Theoretical formulation and initial validation. Chiraz Boudjabil, Lucas Besson and Jacques Parent du Chatelet, submitted to JAOT.

a



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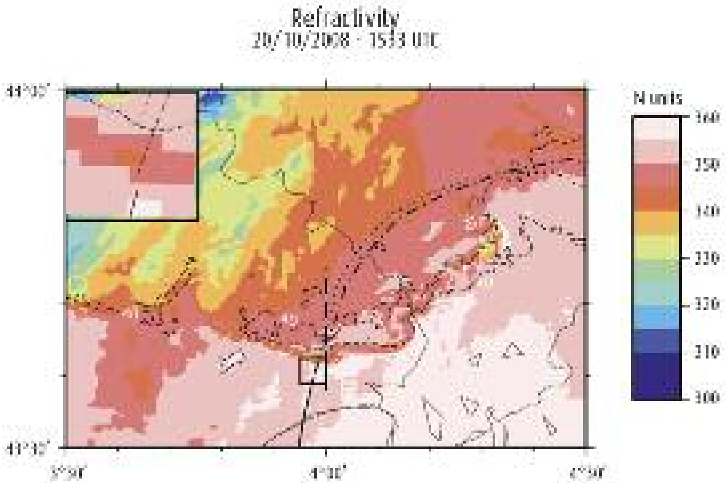


b

Horizontal cross-section (October 20, 2008, 3:33 p.m. UTC) simulated by Meso-NH at the altitude of 15m refractivity, superimposed on the reflectivity (40 dBZ iso contours in dashed line). There is a marked minimum of the refractivity at the front of the convection. This minimum also corresponds (images not shown here) to the maximum of the convective energy CAPE, to temperature and humidity decreases, and to a confluence of horizontal winds. Extracted from Links between weather phenomena and characteristics of refractivity measured by precipitation radar. Lucas Besson, Chiraz Boudjabi, Olivier Caumont and Jacques Parent du Chatelet 2011. Boundary Layer Meteorology, DOI 10.1007/s10546-011-9656-7.

Operational introduction and perspectives of polarimetry

Polarimetry has become over the years the new standard for operational meteorological radars. By emitting two waves, one polarized horizontally and the other polarized vertically, polarimetric radars have the capability to distinguish meteorological echoes to non-meteorological echoes and to correct for the attenuation induced by precipitation. This one is done using a phase parameter measured directly by the radar, immune to partial beam blocking and calibration biases, and almost linearly related to attenuation.
The first version of the polarimetric chain, including attenuation correction, non meteorological echoes removal and monitoring of polarimetric variables, was deployed on the 21st of September 2011 on the radars of Trappes, Abbeville and Montclar after a significant amount of work that started in 2004 with the installation of the first French polarimetric radar in Trappes and that was concluded in 2009-2010 with a one year experiment with a parallel production of all operational products (with and without using the polarimetric processing chain) on the 10 polarimetric radars of the ARAMIS network. Comparison with gauges has shown that attenuation correction allows the QPE**'s algorithm to reduce the under estimation of heavy rain (> 10 mm per hour) by a factor two and the over estimation of weak rain (< 1 mm per hour) also by a factor 2. The polarimetric processing chain will be gradually generalized to all the polarimetric radars of the network until the beginning of 2012. A second version is already under development. It will include hydrometeor classification and a better estimation of precipitation rate in heavy rain.

2

Microphysics of ice clouds to simulate the cloudy radiances in the IASI spot

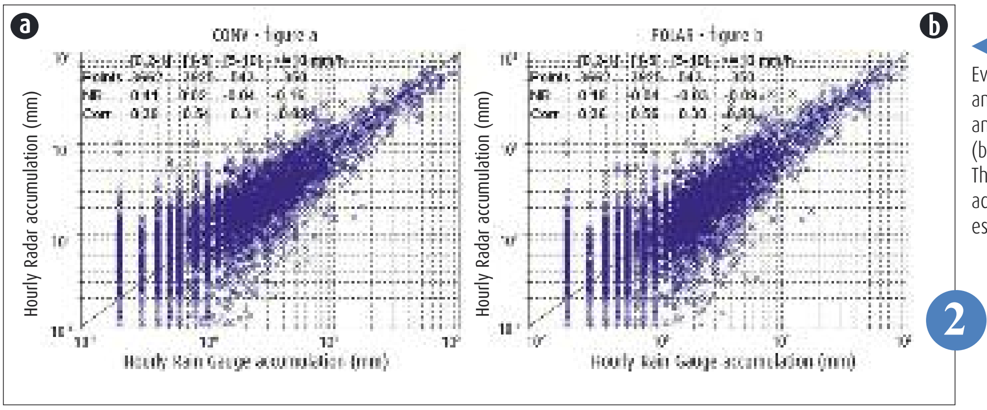
The main operational meteorological centres began to assimilate cloud-affected IASI and AIRS sounder data. But it remains mainly limited to the marine situations of opaque, homogeneous cloud in liquid phase which are described with a good accuracy by 'classic' cloudy radiative transfer models. The assimilation of the situations covered by clouds in ice phase or by semi-transparent clouds require to know how to calculate the radiative effect inferred by the microphysics of the cloud. This work was set up to estimate the current quality of the IASI cloudy spectra computed in these conditions and to give some selection criteria within the framework of an assimilation of these data. For this study we used the two radiative transfer models RTTOVv10 (SAFNWP) and HISCRTM (University of Texas) to describe the ice clouds and compare with the observations of the Lindenberg and Concordiasi field experiments. The figure a is an example of cloudy radiances simulated with RTTOVv10 using the forecast profiles of liquid and ice water contents from ECMWF and compared to the IASI observation. The strong slope of the observed spectrum between 800 and 1000cm-1 was well captured by the model what is not the case if we do not take into account the microphysics of the cloud. The figure b shows the statistics between observed and RTTOVv10 calculated spectra for ice clouds during Concordiasi. The use of the microphysics (blue curves) has strongly decrease the departures compared to classic cloudy model calculations (red curves) with cloud top height and effective emissivity in input. However, there is still important and long-term work before being able to use with confidence the microphysics modelisation in a cloudy assimilation.

3

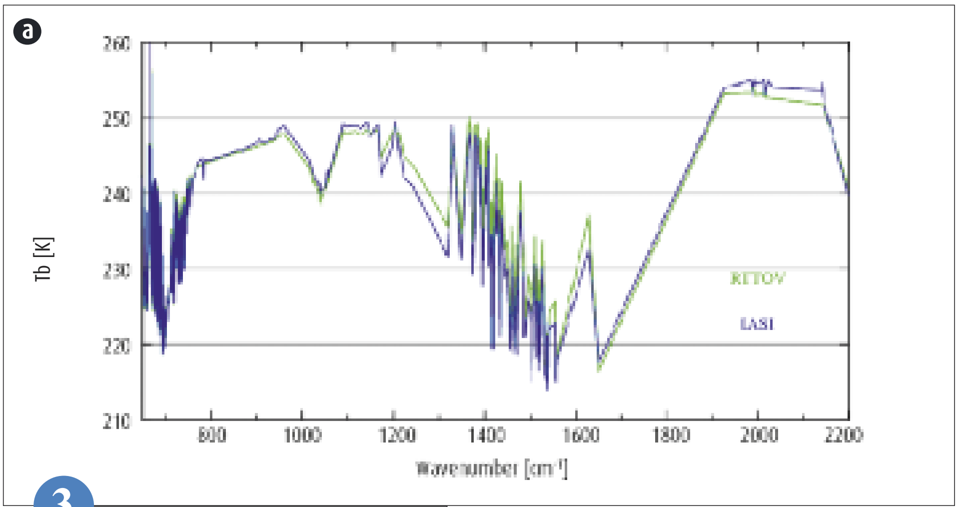
In situ measurements of fog microphysics

The PreViBOSS project, a collaboration with CNRM-GAME, IPSL and the company Hygeos, aims at increasing our capability to diagnose the spatial and temporal variability of the visibility at the surface, and to better forecast the visibility evolution during the fog life cycle, from surface and satellite observations.
In this framework the GMEI/MNPCA team of CNRM-GAME deployed its ground base measurement platform of aerosol and fog microphysics for the first field campaign that was carried out during the winter 2010/11 at the SIRTA experimental site.
Strength of this instrumental set up is the in situ measurement of cloud particles at ambient humidity. The Palas-Welas that measures the size distribution from 0.4 to about 10 µm in diameter has been completed by a Fog-Monitor from DMT that measures the droplet size distribution over [2-50 µm], and by a PVM from Gerber Scientific Inc. that provides the liquid water content and the particle surface area (proportional to the extinction) over the same size range. These data are presently analyzed to document the fog microphysics and to relate these characteristics to the aerosol properties (total number, size distribution and hygroscopicity of particles).
This platform will complete the SIRTA observatory (active and passive remote sensing, instrumented masts) for the two next field campaigns during winter 2011/12 and 2012/13. A major objective is to document several events in various conditions to provide a suitable dataset characterizing the dynamical, microphysical and radiative processes involved in the fog life cycle.

4



Evaluation of the conventional QPE and the polarimetric QPE (cf. figure "a" and figure "b") based on 11 episodes (between summer and winter 2010). The x-axis corresponds to the hourly rain gauge accumulations and the y-axis to the hourly radar estimations.



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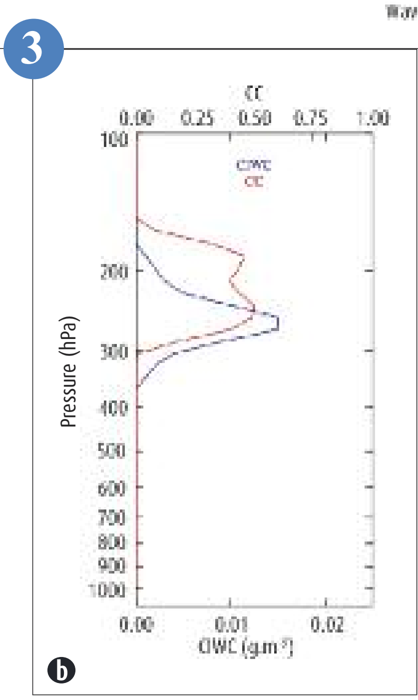


S

Instrumental set up dedicated to fog particles.

Measurements campaigns

Concordiasi : first results

In the context of the Concordiasi project, an unprecedented field campaign took place over Antarctica in the autumn 2010. Nineteen super-pressure balloons from CNES were launched from the american McMurdo base. These balloons drifted at 17km height for a few weeks, carrying NCAR dropsondes, particle counters, meteorological and ozone sensors and GPS receivers. 640 dropsondes were released, covering a wide range of meteorological conditions over Antarctica and the surrounding seas (figure a). Thanks to these data, deployed in areas usually unreachable by in situ observations, a thorough documentation of model performance and quality of IASI retrievals from EUMETSAT has started. An example is provided in figure b. Results show that models (here, the ECMWF model) and IASI retrievals have difficulties reproducing the large temperature inversion at the surface. Data impact studies show an improvement of forecast performance when using the dropsonde data, with a particularly large impact of observations near the pole and at lower altitudes. Another activity has started on the documentation of chemical-transport model performance with the ozone observations obtained during the field campaign. Data are available to the scientific community through a website: http://www.cnrm.meteo.fr/concordiasi/

5

Meteorological measurements aboard Marfret Niolon ship in the framework of HYMEX

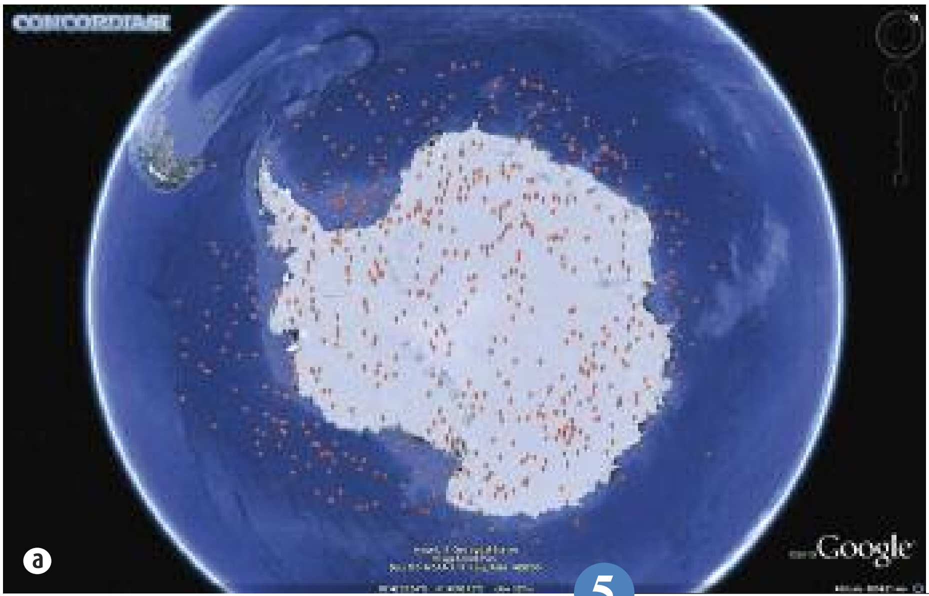
As part of the HYMEX project and in collaboration with IFREMER, CNRM contributed to the ship's Marfret Niolon equipment on the Alger Marseille line with the system SEOS (Sea Observation Embedded System). This systeme allows measurements of wind, air temperature and humidity, precipitation, downward radiative fluxes and skin temperature of the sea surface.Aboard a ship, the quality of the measurement depends mainly of the position chosen for the sensors. These locations are often constrained by the architecture of the current stations and electrical wiring.
SEOS system, designed by CNRM, addresses these limitations with a decentralized architecture whose elements are linked by radio, a choice of low power sensors and independent power supply with battery and solar cells, allowing the installation of sensor to the best location without constraints. Moreover, given the intermittent assignment of ships on interesting lines, this architecture will allow a easier transfer of the system from a ship to another. The measurements performed on the ship, combined with measures of salinity and water temperature implemented by IFREMER, will feed the Hymex database in air-sea energy exchange estimations on the long-term.

6

HyMeX – Preparation of the fall 2012 field campaign

The HyMeX programme – Hydrological cycle in the Mediterranean Experiment – is preparing its first special observation period to be held from September 5, to November 6, 2012 over the North-Western Mediterranean target area.
The fall 2012 field campaign is dedicated to the observation and modelling of heavy precipitation events and flash-flooding affecting Mediterranean coastal regions. The objectives of the campaign are to monitor the upstream conditions, air-sea interaction, and deep convection initiation and life cycle associated with intense events. The campaign should provide a thorough documentation of the thermodynamic, microphysical and electrical properties of the precipitating systems, as well as of the ocean and atmosphere boundary layer characteristics upstream convection.
For the HyMeX campaign, the mid- (2011-2013) and long-term (2010-2020) observation networks already contributing to the programme will be complemented with airborne measurements (French F-20 and ATR-42, German Do-128 aircraft), enhanced radio soundings, CNES boundary layer pressurized balloons, ship-borne measurements of air-sea fluxes and thermal oceanic content, deployment of gliders and drifting buoys. These measurements will be performed synergistically with in-situ observations over 8 hydro meteorological and atmospheric sites regularly affected by Mediterranean precipitation – Valencia, Catalonia, Balearic Islands, Cévennes-Vivarais, Corsica, Liguria-Tuscany, Central Italy, North-Eastern Italy– the equipment of which will also be enhanced with the specific deployment of research radars, wind profilers, and lidars for instance. The operations will be coordinated from Montpellier airport, where the French aircraft will be based, in relation with secondary centres in Majorca, Corsica, and Italy.
http://www.hymex.org/

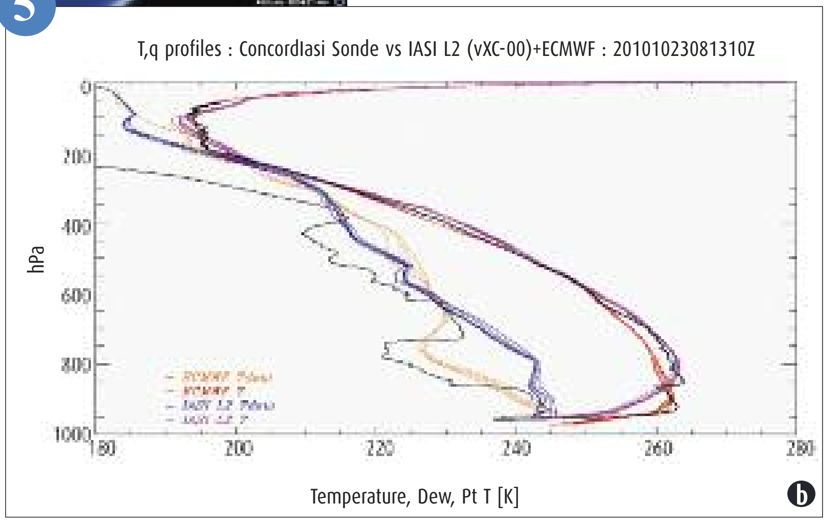
7



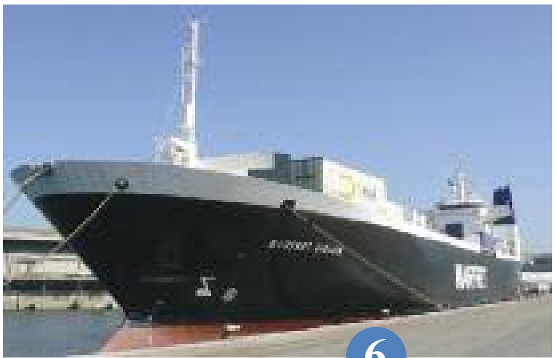
Location of the 640 « dropsondes » released in the context of the Concordiasi project, from September to December 2010, providing meteorological profiles from 17km height down to the surface.

5

Temperature (T) and dewpoint temeprature (Tdew) for a Concordiasi dropsonde (in black), for a few surrounding ECMWF profiles (in red and orange), and for EUMETSAT IASI retrieval profiles (in pink and blue).



The Marfret Niolon ship at Marseille harbor.



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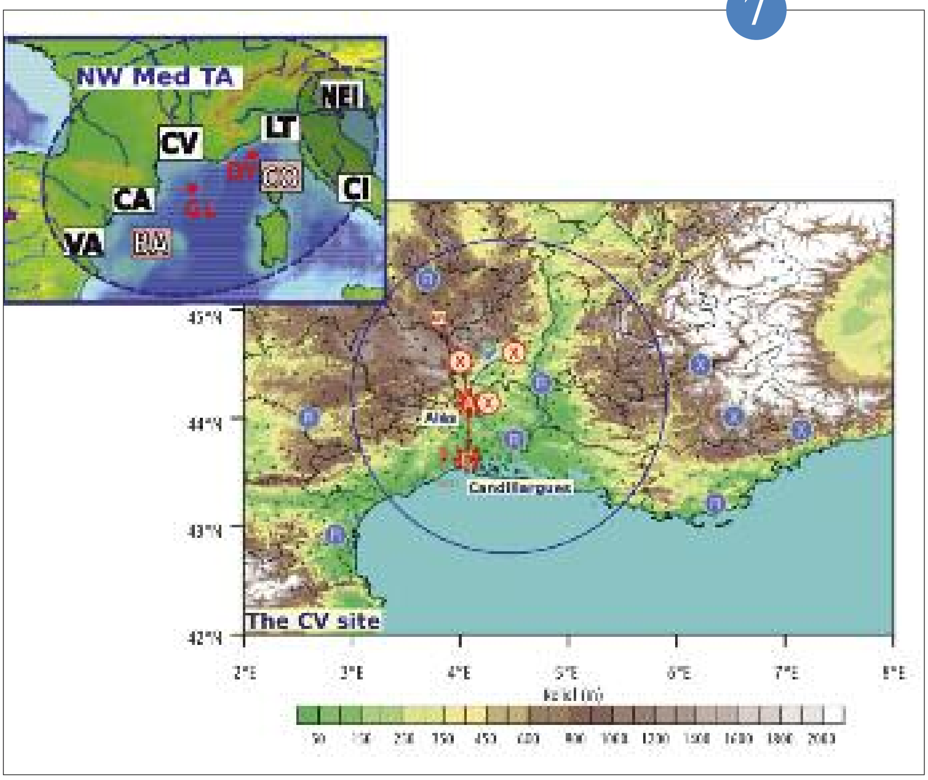

Top: hydrometeorological (white), atmospheric (pink), and ocean (red) sites of the HyMeX 2012 campaign over the North-Western Mediterranean area.
Bottom: the hydrometeorological Cévennes-Vivarais site. During the campaign, the Candillargues (C) and Alès (A) supersites will gather a series of research instruments (lidars, a wind profiler, a cloud radar, radiometers, a radiosounding station, ...). Both sites are the Southern part of a North/South transect equipped with radars and lightning detection sensors.
Several research radars (X in red circles) and a high performance lightning mapping array (the range of which is represented by the blue circle) will be deployed over the instrumented watersheds of Gard and Ardèche. The raingauges (black crosses) and radars (R or X in blue circles) of the Météo-France operational networks are also plotted, as well as the HyMeX operation center (HOC) in Montpellier (orange flag).

CNRM contribution to the BLLAST project experimental phase

The BLLAST project (Boundary Layer Transition Late Afternoon-Sunset), initiated by the Laboratoire d'Aérologie, aims to better understand, document and simulate the transition between the convective boundary layer and the stable boundary layer in the afternoon, until now little studied. This phase is difficult to observe because the turbulence becomes weak and intermittent.

The experimental phase of this project took place in June and July 2011 around the instrumented tower of the Centre de Recherches Atmosphériques in Lannemezan (Hautes Pyrenees). During five weeks, an important set of instrumental ground and air devices (research aircraft, UAVs) deployed by fifteen international teams, with an important contribution of CNRM. Besides the participation of the SAFIRE Piper Aztec, most moving means of meteorological measurements were made CNRM: aerosol lidar, radar wind profiler, ceilometrer, radiosonding and tethered balloon for the documentation of the atmospheric boundary layer on the vertical, measurement stations of turbulent flow by the eddy correlation method and scintillometer to document the heterogeneity of energy exchange between the surface and atmosphere.

This field campaign was an opportunity to successfully test two new measurement systems designed at CNRM: a sounding means under free balloon with recovery of the probe for frequent soundings at a lower cost to the height of the boundary layer and an instrument of measurement of turbulence with a tethered balloon. This latter instrument will also contribute to the validation of lidar methods for estimating the vertical turbulence profile.

8

The Megha-tropiques campaign in Maldives: tropical clouds microphysics

The Megha-tropiques scientific field campaign aims at validating the algorithms used with the eponymous satellite. This Indian-French (ISRO-CNES) satellite launched on October, 12th 2011, overflies the tropical regions and is meant to study the tropical rain systems over both land and ocean in terms of water and energy budgets. During the airborne campaign, the focus was on the characterization of ice particles in the clouds. The microphysics of ice is not only very important to understand the dynamics and the life cycle of the clouds, but it also plays a very important role in the algorithms designed to retrieve rain from the MADRAS microwave radiometers on board the platform.

In order to better understand these clouds microphysics properties the SAFIRE Falcon20 was equipped with the RASTA (W-band Doppler) radar developed by the LATMOS (Paris) and numerous in-situ sensors mounted under the wings (joint operation with the LaMP from Clermont-Ferrand). The measurements performed over Gan (south of Maldives) during a month have provided useful information, completed with the remote measurements from American ground based radars (Smart-R and Spol-Ka) deployed for the DYNAMO experiment.

These measured ice characteristics will then be used to build parameterizations incorporated in turns in the retrieval algorithms. This better description of the ice properties should improve our ability to retrieve the rain from satellite data, improving the rain products quality.

FENNEC

The FENNEC project tends to a better understanding of the Saharan climate. Its principal topics are physic-chemical processes of meso-scale in the central Sahara area (North of Mali, Mauritania, and south of Algeria). The goal of this project is to characterize the dynamic, the thermodynamic and the aerosol composition above desert, in the Saharan boundary layer and in the free troposphere, and to evaluate their representation in the global and regional models. A second aim is to study the mechanisms of dusts uprising near the sources, in function of the surface and meteorological conditions to improve forecasts of dusts storm in the central Saharan area.

This experimental campaign has been held from Canaries isle of Fuerteventura, the closest one from Morocco. It has begun on May 5th and ended on June 24th.

Two aircraft have been involved in the campaign, the BAE146 from FAAM and the Falcon 20 from SAFIRE.

The F20 airborne instrumentation was constituted with the cloud radar RASTA, radiometers (visible and IR), a high definition camera towards nadir to dusts uprisings and a "dropsonde" launching system.

More than 60 flight hours have been flown during this campaign and 136 "dropsondes" were launched. The goals have been reached. The data are being processed at CNRM/GMEI and at the LATMOS from where the radar RASTA is derived.

9

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Measuring station of the energy balance of a corn surface.

The Falcon 20 just before takeoff at Fuerteventura airport.
(Photo Hubert Bellec, Météo-France).

9

Appendix

2011 Scientific papers list

Papers published in peer-reviewed journals (impact factor > 1)

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Glossary

Organisms and Laboratories

Organisms

ADEME Agence de l'Environnement et de la Maîtrise de l'Energie
AIEA Agence Internationale de l'Energie Atomique
ANR Agence Nationale de la Recherche
BEC Bureau d'Etudes et de Consultance
CDM Centre Départemental de la Météorologie
CDMA Cellule de développement Météo-Air
CEH Centre for Ecology and Hydrology
CEMAGREF CEntre national du Machinisme Agricole, du Génie Rural, des Eaux et Forêts (Institut national de Recherche en Sciences et Technologies pour l'Environnement et l'Agriculture)
CEN Centre d'Etudes de la Neige
CEPMMT Centre Européen pour les Prévisions Météorologiques à Moyen Terme
CERFACS Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique
CMM Centre de Météorologie Marine
CMRS Centre Météorologique Régional Spécialisé
CMS Centre de Météorologie Spatiale
CNES Centre National d'Études Spatiales
CNP Centre National de Prévision
DGPR Direction Générale de la Prévention des Risques
EEA Agence Environnementale Européenne
ESA European Space Agency
ETNA Division Ecoulements Torrentiels, Neige et Avalanches du CEMAGREF
EUFAR EUropean Facility for Airborne Research
EUMETNET EUropean METeorological NETwork
EUMETSAT European Organisation for the Exploitation of Meteorological Satellites
ICARE International Conference on Airborne Research for the Environment
IFREMER Institut Francais de Recherche pour l'Exploitation de la MER
INERIS Institut National de l'Environnement et des RISques
INRIA Institut National de Recherche en Informatique et en Automatique
INSU Institut National des Sciences de l'Univers
IPEV Institut Paul Emile Victor
IRD Institut de Recherche pour le Développement
IRSTEA Institut national de Recherche en Sciences et Technologies pour l'Environnement et l'Agriculture (anciennement CEMAGREF)
JMA Japan Meteorological Agency
MEDDTL Ministère de l'Ecologie, du Développement Durable, des Transports et du Logement
MetOffice United Kingdom Meteorological Office
MPI Max Planck Institut
NASA National Aeronautics and Space Administration
NCAR National Center for Atmospheric Research
NEC Nippon Electric Company
NOAA National Ocean and Atmosphere Administration
OACI Organisation de l'Aviation Civile Internationale
OMM Organisation Météorologique Mondiale
RTRA-STAE Réseau Thématique de Recherche Avancée Sciences et Technologies pour l'Aéronautique et l'Espace
SHOM Service Hydrographique et Océanographique de la Marine
UKMO United Kingdom Meteorological Office
VAAC Volcanic Ash Advisory Centre

Laboratories or R&D units

3SR Laboratoire Sols – Solides – Structures – Rhéologie, UJF Grenoble/CNRS/ Grenoble INP
CESBIO Centre d'Etudes Spatiales de la BIOsphère
CNRM Centre National de Recherches Météorologiques
CNRM-GAME Groupe d'études de l'Atmosphère MEtéorologique
CNRS Centre National de Recherches Scientifiques
DSO Direction des Systèmes d'Observation (Météo-France)
GAM Groupe d'Etude de l'Atmosphère Météorologique
IPSL Institut Pierre Simon Laplace
LAMP Laboratoire de Météorologie Physique
LATMOS Laboratoire ATmosphères, Milieux, Observations Spatiales
LCP Laboratoire Chimie et Procédés
LEGI Laboratoire des écoulements physiques et industriels
LGGE Laboratoire de Glaciologie et de Géophysique de l'Environnement
LMD Laboratoire de Météorologie Dynamique
LOCEAN Laboratoire d'Océanographie et du Climat : Expérimentations et Approches Numériques
LSCE Laboratoire des Sciences du Climat et de l'Environnement
SAFIRE French group of Aircraft Equipped for Environmental Research - Unit of the CNRS, Meteo-France and the CNES which operates the 3 French research aircraft

National or international programs or projects

BAMED BAlloons in the MEDiterranean
CHFP Climate Historical Forecasting Project
CIDEX Calibration and Icing Detection EXperiment
CMIP Coupled Model Intercomparaison Project
CYPRIM projet Cyclogénèse et précipitations intenses dans la zone méditerranéenne
ESURFMAR Eumetnet SURFace MARine programme
GHRSST International Group for High Resolution SST
GLOSCAL GLobal Ocean Surface salinity CALibration and validation
HyMeX Hydrological cYcle in the Mediterranean EXperiment
LEFE programme national « Les Enveloppes Fluides et l'Environnement »
MEPRA Modèle Expert de Prévision du Risque d'Avalanche (modélisation)
MERCATOR-OCEAN Programme coopératif d'océanographie opérationnelle
METOP METeorological Operational Polar satellites
PNRA Programma Nazionale di Recerche in Antartide
QUANTIFY Programme QUANTIFYing the climate impact of global and European transport systems
RHYTMME Risques HYdro-météorologiques en Territoires de Montagnes et MEditerranéens
SCAMPEI Scénarios Climatiques Adaptés aux Montagnes : Phénomènes extrêmes, Enneigement et Incertitudes - projet de l'ANR coordonné par le CNRM
SMOS Soil Moisture and Ocean Salinity
THORPEX THe Observing system Research and Predictability EXperiment
USAP United States Antarctic Program
WCRP World Climate Research Programme

Campaigns

AMMA Analyse Multidisciplinaire de la Mousson Africaine
CORDEX COordinated Regional climate Downscaling EXperiment
MEGAPOLI Megacities : Emissions, urban, regional and Global Atmospheric POLlution and climate effects, and Integrated tools for assessment and mitigation
SMOSREX Surface MOnitoring of the Soil Reservoir EXperiment

Other acronyms

AIRS Atmospheric Infrared Sounder
ALADIN Aire Limitée Adaptation Dynamique et développement InterNational
AMSR Advanced Microwave Scanning Radiometer
AMSU Advanced Microwave Sounding Unit
ANASYG ANAlyse Synoptique Graphique
ANTILOPE ANalyse par spaTIaLisation hOraire des PrEcipitations
ARAMIS Application Radar A la Météorologie Infra-Synoptique
ARGO Array for Real time Geostrophic Oceanography
AROME Application de la Recherche à l'Opérationnel à Méso-Échelle
AROME-COMB AROME - COMBinaison AROME-PERTOBS AROME (OBServations PERTurbées aléatoirement)
ARPEGE Action de Recherche Petite Échelle Grande Échelle
AS Adaptations Statistiques
ASAR Advanced Synthetic Arperture Radar
ASCAT Advanced SCATterometer
ASTEX Atlantic Stratocumulus Transition EXperiment
AVHRR Advanced Very High Resolution Radiometer
BAS British Antarctic Survey
BPCL Ballon Pressurisé de Couche Limite
CALIPSO Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CAPE Convective Available Potential Energy
CAROLS Combined Airborne Radio-instruments for Ocean and Land Studies

CFOSAT Chinese-French SATellite
CISMF Centre Inter-armées de Soutien Météorologique aux Forces
CLAS Couches Limites Atmosphériques Stables
CMC Cellule Météorologique de Crise
CNRM-CM5 Version 5 du Modèle de Climat du CNRM
COPAL COmmunity heavy-PAyload Long endurance instrumented aircraft for tropospheric research in environmental and geo-sciences
CROCUS Modèle de simulation numérique du manteau neigeux développé par Météo-France
DMT Dropplet Measurement Technologies
DP Direction de la Production
DPrévi Direction de la Prévision
DSI Direction des Systèmes d'Information (Météo-France)
DSNA Direction des Services de la Navigation Aérienne
ECMWF European Centre for Medium-range Weather Forecasts
ECOCLIMAP Base de données de paramètres de surface
EGEE Etude du golfe de GuinEE
ENVISAT ENVIronmental SATellite
ERA Re-Analysis
EUCLIPSE European Union Cloud Intercomparison, Process Study & Evaluation (Project LES : Large - Eddy Simulation)
FAB Fonctionnal Aerospace Block
FABEC Functional Airspace Block Europe Central
FAR Fausse AleRte
GELATO Global Experimental Leads and ice for ATmosphere and Ocean
GIEC Groupe Intergouvernemental d'experts sur l'Evolution du Climat
GMAP Groupe de Modélisation et d'Assimilation pour la Prévision
GMEI Experimental and Instrumental Meteorology Group
GMES Global Monitoring for Environment and Security
GPP Gross Primary Production
GPS Global Positionning System
HIRLAM HIgh Resolution Limited Area Model
HISCRTM HIgh Spectral resolution Cloudy-sky Radiative Transfer Model
HSS Measurement of improvement of the forecast
IAGOS In-service Aircraft for Global Observing System
IASI Infrared Atmospheric Sounding Interferometer
IFS Integrated Forecasting System
ISBA - ES Numerical model developped at CNRM to represent soil-vegetation evolution, with a refined snow pack tretament
ISFC Indice de Segmentation de la Composante de Fourier
ISIS Algorithme de suivi automatique des systèmes identifiés à partir de l'imagerie infra-rouge de Météosat
LAI Leaf Area Index
Land-SAF LAND Satellite Application Facilities
LCCS Land Cover Classification System
LES Large Eddy Simulation model
LISA LIdar SAtellite
MEDUP MEDiterranean intense events : Uncertainties and Propagation on environment
Megha-Tropiques Satellite fanco-indien dédié à l'étude du cycle de l'eau et des échanges d'énergie dans la zone tropicale
MERSEA Marine EnviRonment and Security for the European Area
MESO-NH Modèle à MESO-échelle Non Hydrostatisque
MFWAM Météo-France WAve Model
MHS Microwave Humidity Sounder
MNPCA Microphysique des Nuages et de Physico-Chimie de l'Atmosphère
MOCAGE MOdélisation de la Chimie Atmosphérique de Grande Echelle (modélisation)
MODCOU MODèle hydrologique COUplé surface-souterrain.
MODIS MODerate-resolution Imaging Spectro-radiometer (instrument)
MoMa Méthodes Mathématiques pour le couplage modèles et données dans les systèmes non-linéaires stochastiques à grand nombre de degrés de liberté
MRR Micro Rain Radars
NAO North Atlantic Oscillation
NEMO Nucleus for European Modelling of Ocean
NSF Norges StandardiseringsForbund
OPIC Objets pour la Prévision Immédiate de la Convection
OSTIA Operational Sea surface Temperature sea Ice Analysis
OTICE Organisation du Traité d'Interdiction Complète des Essais nucléaires
PALM Projet d'Assimilation par Logiciel Multi-méthodes
PEARP Prévision d'Ensemble ARPège
PI Prévision Immédiate
PN Prévision Numérique
PNT Prévision Numérique du Temps
POD PrObabilité de Détection
POI Période d'Observation Intensive
PRESYG PREvision Synoptique Graphique
Prev'Air Plateforme nationale de la qualité de l'air
PREVIBOSS PREvisibilité à courte échéance de la variabilité de la VIsibilité dans le cycle de vie du Brouillard, à partir de données d'Observation Sol et Satellite.
Prévi-Prob Projet sur les prévisions probabilistes
PSI Pollutant Standard Index
PVM Particulate Volume Monitor
RADOME Réseau d'Acquisition de Données d'Observations Météorologiques Etendu
RHI Range Height Indicator (coupe verticale)
ROC Relative Operating Characteristic curve
SAFNWP Satellite Application Facility for Numerical Weather Prediction
SAFRAN Set of reconstructed data from observations over France for 1958 to present at high horizontal, vertical and temporal resolution
SCM Single-Column Model
SESAR Single European Sky ATM Research
SEVIRI Spinning Enhanced Visible and Infra-Red Imager
SFRI Système Français de Recherche et d'Innovation
SIM SAFRAN ISBA MODCOU
SIRTA Site Instrumental de Recherche par Télédétection Atmosphérique
SMOSMANIA Soil Moisture Observing System – Meteorological Automatic Network Integrated Application
SMT Système Mondial de Télécommunications
SOERE/GLACIOCLIM Système d'Observation et d'Expérimentation sur le long terme pour la Recherche en Environnement : "Les GLACIers, un Observatoire du CLIMat".
SOP Special Observing Period
SSMIS Special Sensor Microwave Imager/Sounder
SURFEX SURFace EXternalisée
SVP Surface Velocity Program
SWI Soil Wetness Index
SWIM Surface Wave Investigation and Monitoring
SYMPOSIUM Split of French territory into climate heterogeneous areas, the size of which is to 10 to 30 km
TEB Town Energy Budget
TRIP Total Runoff Integrating Pathways
TSM Températures de Surface de la Mer
UHF Ultra-Haute Fréquence
UNIBAS Modèle de précipitations
VARPACK Current tool for diagnostic analysis in Meteo-France
VHF Very High Frequency

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