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FRENCH UPPER AIR NETWORK DESIGN AND IMPLEMENTATION TECO 2008 – ST PETERSBURG

MAGALI STOLL, MÉTÉO-FRANCE
HEAD OF UPPER AIR OBSERVING SYSTEMS DEPARTMENT

DIRECTION OF OBSERVING SYSTEMS
42 AVENUE G.CORIOLIS – F 31057 TOULOUSE CEDEX - FRANCE
TEL : 00 33 5 67 69 87 60 – FAX : 00 33 5 67 69 87 69

ABSTRACT

From 2005 to 2007, Météo-France conducted a prospective study on the evolution of its upper air observing network, covering the French continental and overseas territories, for the next 10 years. This study took into account the context, the updated needs, the current and future capacity of the systems, as well as the staff and budget resources.

This study used a new approach to classify the needs of the meteorological applications. This allowed a clearer design for the future composite network on three scales : global, regional and national.

The main orientations for the evolution of the French Upper Air Network would be :

- Optimization of the radiosounding network to cover in priority the global and regional scales : the implementation will consist in the classification of the current stations at three levels, the adaptation of the schedules and altitudes depending on the needs to cover, the automation of some stations if it is necessary and feasible .

- Extension of the upper air network by the valorization and the improvement of existing networks for other kind of systems, to cover in priority the regional and the national scales : for example, the integrated water vapor retrieved from the GPS ground-based measurements, the wind profiles obtained from profilers and weather Doppler radars, the temperature and wind profiles acquired from onboard aircraft.

- Experimentation of recent and new systems to evaluate their operational ability to cover the national needs at meso and local scales : ground-based remote sensing systems e.g. profiler, lidar, sodar, radiometer, alone or collocated as well as onboard sensors T-AMDAR and WVSSII for new aircraft data.

- Preparation of the integration of environmental systems into the operational global observing systems : qualification of Ozone soundings collocated with PTUV (Pressure, Temperature, Humidity, Wind) soundings on French territories and preparation of the European operational infrastructure for physical and chemical airborne measurements (IAGOS)

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TEXT

1. STUDY ON FRENCH UPPER AIR NETWORK EVOLUTION

From 2005 to 2007, the Direction of observing systems has carried out a prospective study on the evolution of the upper air observing network for the needs of Météo-France.

The purposes of this study were

- to propose orientations for the evolution of the radiosoundings networks until 2008
- to propose one or more upper air networks for 2009 to 2012, taking into account the current networks, the needs, the potential offer, the context, the constraints and the means
- to propose various scenarios for short and medium terms evolutions

The domain covered by the study was the radiosoundings and other upper air measurements complementary to the satellite data. The main contexts taken into account were the European and International programs as Eumetnet, Eumetsat or WMO. Due to the fact that the technical context was also changing, e.g. the evolution of Loran C offer in Europe and a fatal accident due to hydrogen in a foreign country, Météo-France had to change Loran C by GPS technology and to secure some stations with helium gas. These changes resulted in an increased budget and there was an urgent necessity to find a way to limit the increasing cost of the radiosounding network.

The study was managed by the Direction of the observing systems and conducted by a working group coordinated by the upper air department in association with the networks department. All the other main departments in Météo-France contributed to the study : research, forecasting, climate, satellite, production. The study began in August 2005 and the final results obtained in 2007, with a first important step at the end of 2006 for the orientation of the radiosounding network evolution.

The first work packages produced by the study were a bibliography, an analysis of the current and future context, an update of the current and future needs in upper air data as well as the current and potential upper air data and offers in systems and networks, with an evaluation of their capacity to fulfill the needs. Attention has been given then to the identification of the human and financial resources needed by systems, especially for the radiosounding network.

At this stage of the study an important step was achieved by the classification of the needs into three embedded levels – global, regional and national. With this classification it was easier to work by families of systems (radiosoundings, remote sensing from the ground and aircraft measurements). For the mature systems it has been then possible to design the future networks and for the other ones to propose the actions necessary to progress towards operational networks.

The writing of a strategic document is underway with the objective to get a living document, which has to be updated every 4 or 5 years, and used as references for the upper air observations in Météo-France. A first set of evolutions have already been implemented for 2005 to 2008. The negotiation to integrate future evolutions into the next period 2009 to 2012 plan have also begun in Météo-France.

2. NEEDS IN UPPER AIR DATA

Météo-France is presently concerned by the global, the regional and the local scales due to the applications and the presence of France through the world. However all the needs in upper air data are not specific to Météo-France and much work has already been done by the international community e.g. WMO, Eumetsat and Eumetnet to collect the needs, analyze and give recommendations. The needs have just been updated and completed by asking to the different departments inside Météo-France their current use of upper air data related to their activities and their needs and capacity to use new or future observations. Actually all the services in charge of production are concerned by upper air data and have been consulted : research, climate, forecast, satellite center, end user production.

The main results of the review were that needs on upper air data have evolved recently in complement with permanent needs for usual applications (climate and forecast). New and emerging needs have been confirmed for the climate change detection, not only at the surface but also in the upper air, for the analysis and calibration of the new meso scale numerical model AROME, as well as for physical chemical applications.

The trends are to get more precise profiles on the vertical with information on the horizontal position, at a wide range of spatial and temporal resolutions depending on the applications, but with less constraints on the schedule due to 4D assimilation techniques. One of the main limitation is the capacity to the applications, the tools or the users to assimilate, to integrate and to visualize new upper air observations : that needs strong accompanying to use effectively these new observations and to change practices.

The needs could be analyzed following different views : the scales of the meteorological phenomena, the applications to cover, the parameters to measure, mainly under the form of collocated profiles, the mean and the maximum altitude to achieve, the horizontal density, the frequency and the time of delivery of the expected profiles. All the main issues could be thus synthesized into the following table :

	Global	Régional	National
Scale	> 1000 km	100 à 1000 km	< 100 km
Applications	Climate and changes Satellite calibration Global NWP control Global NWP assimilation	Regional NWP assimilation Regional NWP control Satellite control	Mesoscale NWP control Mesoscale NWP assimilation Short terme forecasting Nowcasting Systems calibration Users assistances
Profiles	P, T, U, V + (O3)	P, T, U, V	+ hydrometeores
Height	30 km	20 km	10 km
Density	500 to 1000 km	50 to 500 km	10 to 50 km
Frequency	12 h to 24 h	3 h to 12 h	5' to 3 h
Delivery	2 h to 1 month	1 to 2 h	15' to 1 h

3. OFFER IN UPPER AIR MEASUREMENTS

Four types of systems could cover the needs : the satellite sounders, the radiosondes, the aircraft onboard sensors and the ground based remote sensing systems. For each of them the level of operational implementation could be at a different stage of advancement and the effective offer in networks more or less developed in the different parts of the French territories. Moreover, the offer should not only concern the systems or networks owned by Météo-France but also French partners and international organizations.

The capacity of the systems and networks are quite different in term of parameter, precision, frequency, altitude, density and cost. It has been evaluated allowing a comparison between different systems. The main result is presented in the table below.

	Global	Régional	National	Cost / profile
P, T, U , V : RS	+++	++	+	- - -
V : profileur VHF	+	++	+	- -
V : profileur UHF		+	+++	-
T, U : radiometer		+	+++	-
V, T,(U) : lidar, sodar			++	- -
P, T, V (U, O3) : Aircraft	+	++	+++	+ (-)
V : radars (Doppler)		+	+++	+
U : GPS (ZTD)	+	++	+	+ +
T, U, (V) : satellite	++	++	+	To be evaluated

Even if the profiles retrieved from infrared sensors onboard satellites would give better vertical resolution than before they are still limited to temperature, humidity and above the clouds. Ground based remote sensing systems and airborne sensors should be better to complement the satellite data capacities. An other priority should be to get reference measurements for the calibration and the controls of satellite data.

The radiosounding presents a lot of advantages and could fulfill this requirement : in situ measurement, complete parameters observed at the same time and location, good precisions and resolutions, and possibility to achieve high altitudes. This measurement has no equivalent for at least 10 years and still remains the references. However it is a costly system in financial and human resources. Thus the use of radiosounding would be preferable for global and regional applications than for national ones.

An other interesting system is the total water vapor retrieved by GPS technology. It offers a new way for obtaining non biased observations as it covers the whole atmospheric thickness.

4. OPTIMIZATION OF THE FRENCH RADIOSOUNDING NETWORK

The general orientation given by Météo-France to the radiosounding is to cover in priority the needs that could not be satisfied by the other systems and to consider the radiosounding network as the reference, the backbone or better, the load-bearing walls of the composite upper air networks and satellites soundings . The second orientation is to classify the network at three levels of scales : global, regional and national.

Thus the radiosoundings should be used first for the global scale i.e. in delayed time for the climate survey and climate change detection, the satellite calibration, the control of global models and the contribution to the reanalyses, and in real time as a contribution to the global model analysis. At the regional scale, the radiosoundings should be used in delayed time for the control of the regional models and as contribution to the regional reanalysis, and in real time to correct satellite biases and to contribute to the regional analyses. For the national scales the remaining radiosounding stations should be used in delayed time for the calibration of other upper air systems or meso scale models, and in real time as a guide for the forecasters.

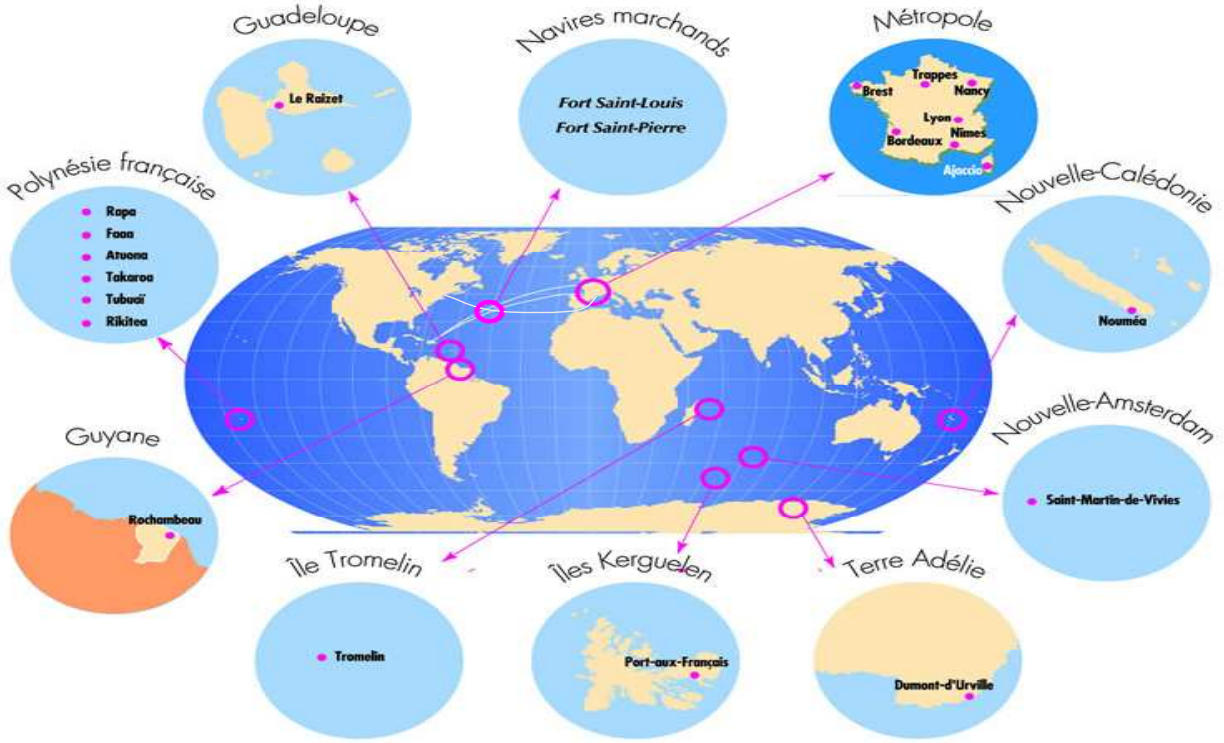
With this classification by scales the requirements should be different between the radiosounding stations in term of height and time schedule, and it should be possible to define three embedded radiosounding networks : global (more than every 1000 km, mean height 30000 m, at 00 and 12 UTC), regional (between 500 km and 1000 km, 20000 m, every 12 hours, more or less frequent depending on the season or the meteorological situation) and national (local, 10000 m, time schedule adapted to the national production).

The main objectives followed by Météo-France to design its future radiosounding networks are to consider that the French global network (actually the GUAN) should be permanent with a French station by each WMO region where France is present, except if an other GUAN station is already operated. Then the regional network should be operated for at least 10 years and reviewed if other equivalent systems could be useful. Due to positive impact of radiosoundings operated on ships (ASAP) and the lack of ground based observations on the Atlantic ocean the current fleet of French ASAP (2) would be doubled (4) and integrated in the European program E-ASAP. Finally the national radiosounding network would be composed by non permanent stations to be replaced progressively by other systems already useful.

With these objectives in mind the current radiosounding stations have been classified at three levels to begin to design the future radiosounding network on the bases of the existing stations. As the current requirements for these stations do not correspond exactly to the new ones it has been necessary to identify the changes station by station, and to evaluate the impacts in term of budgets and human resources. This study pointed out that the total cost of the current and the future network would be quite the same but that the economy could be important in term of human resources.

To implement the new French radiosounding network it is also necessary to study the feasibility in term of technical evolution, organization and use. This implementation has already begun for some stations and should take about 10 years for the last ones. The possibility to adapt the frequency as well as the optimization of human resources should be easier by the way of automation. This issue is an other main evolution proposed for a part of the French radiosounding network.

Current French radiosounding network – 22 sites



Previous and designed targets for the French classified radiosounding stations

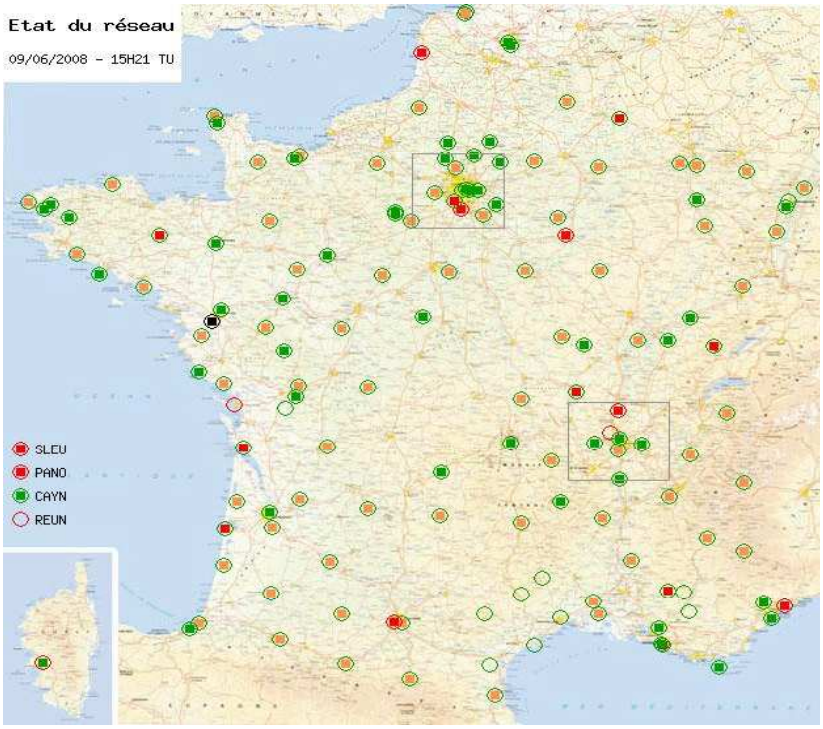
Station	WMO region	Previous number of RS per day	Designed number of RS per day	Previous targets (90%)	Designed Target (50%)
TRAPPES	VI	2	2	23 km	30 km
NOUMEA	V West	2	2	19 km	30 km
FAAA	V East	2	2	19 km	30 km
KERGUELEN	I	1	2	19 km	30 km
ROCHAMBEAU	III	2	2	19 km	30 km
TERRE-ADELIE	Antartic	1	2	19 km	30 km
Level Global		**10**	**12**		
BORDEAUX	VI	2	2	23 km	20 km
AJACCIO	VI	2	2	19 km	20 km
BREST	VI	2	2	19 km	20 km
NIMES	VI	2	2	19 km	20 km
ASFR1 (ASAP)	VI	2	2	19 km	20 km
ASFR2 (ASAP)	VI	2	2	19 km	20 km
ASFR3 (ASAP)	VI		2		20 km
ASFR4 (ASAP)	VI		2		20 km
LE RAIZET	IV	2	1,5	19 km	20 km
TROMELIN . REUNION	I	1	2	19 km	20 km
ATUONA	V East	1	2	19 km	20 km
RIKITEA	V East	1	2	19 km	20 km
Level Rgional		**17**	**23,5**		
LYON	VI	2	0	19 km	10 km
NANCY	VI	2	0	19 km	10 km
RAPA	V East	1	0	19 km	10 km
TAKAROA	V East	1	0	19 km	10 km
TUBUAI	V East	1	0	19 km	10 km
AMSTERDAM	I	1	0	19 km	10 km
Level National		**8**	**0**		

5. EXTENSION OF THE UPPER AIR NETWORKS

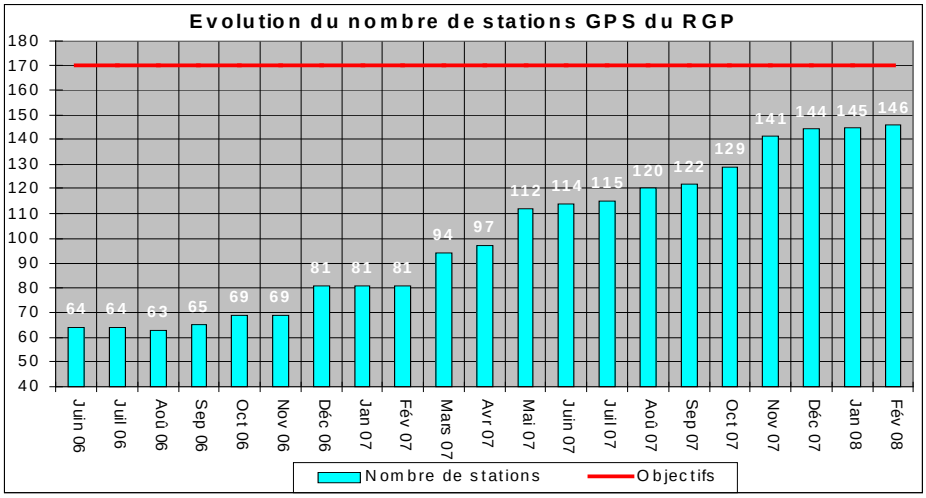
1. Improvements of GPS data and extension of the network

The total water vapor content can be retrieved form the signal between the GPS satellites and the ground based receptors used for the localization. A previous evaluation made by Météo-France pointed out the positive impact of these observations. A first version of a designed network composed by 170 stations has been defined with the French geographical partner IGN. The operational implementation would consist to enhance the availability and the quality of data for this network. In 2007 it has been integrated into the European E-GVAP program, and since February 2008 this network has been assimilated by the global numerical model Arpege in Météo-France. The next step should be to design a second network version with the objective to consolidate the processing and to satisfy the needs of the model Arome at meso scale, of now casting and of overseas territories.

Design of the French GPS network – V1



Implementation of the French GPS network for meteorological applications – V1



2. Intensification of AMDAR data and extension of programs to the overseas territories

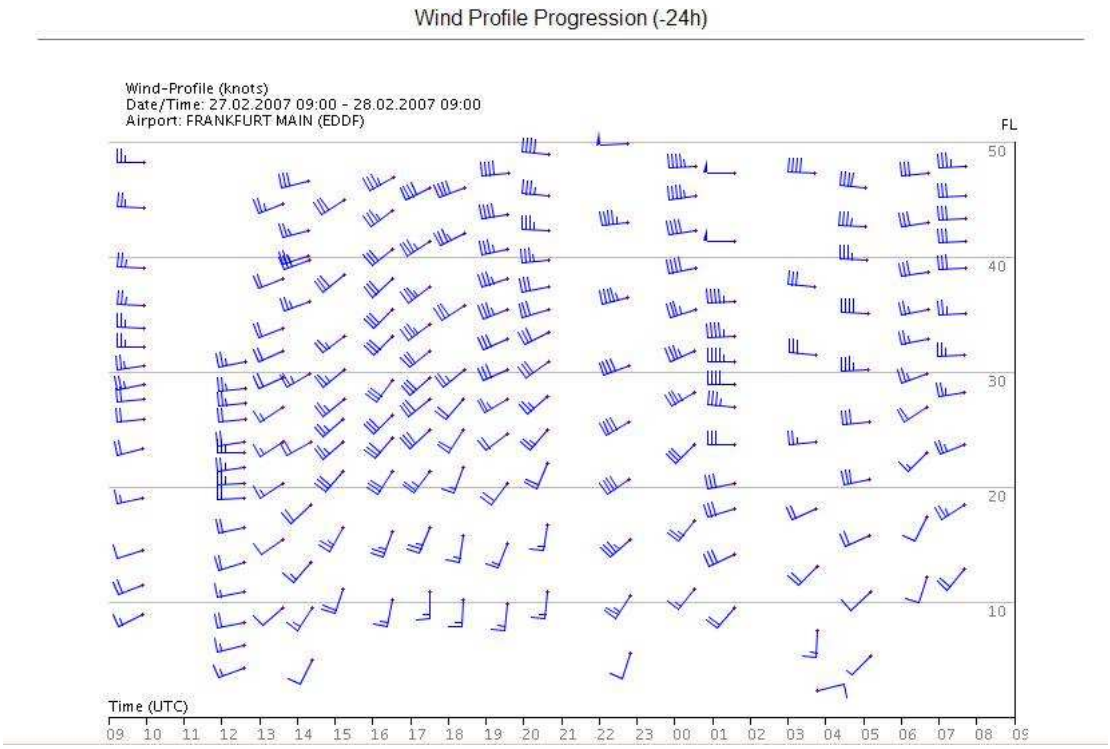
The major airline companies operate long haul flights aircraft enable to observe, with onboard sensors, meteorological parameters useful for the aviation : Pressure, Wind, Temperature, Turbulence, Icing. For more than 20 years the meteorological services as Météo-France have developed active cooperation with the companies to use these measurements for their applications, essentially the numerical assimilation and aviation forecasting. To get these data it is necessary to develop, install and update an onboard software enable to produce and send messages readable by the meteorological community : AMDAR. They represented in 2007 more than 250000 data per day.

Some years ago, to coordinate the relationships with the airline companies, the European meteorological services decided to fund a common program E-AMDAR under the umbrella of the Eumetnet Composite System EUCOS. The objectives of this program is to optimize the cover of AMDAR profiles on the major European airports and on the regions poor in upper air observations. The current design should cover in priority the needs for the regional numerical model and has been defined by one profile every 250 km and 3 hours.

To cover the other needs of Météo-France, at national scale and outside the EUCOS area of interest, the objectives has been defined to intensify the production of data on the French continental area and to develop similar programs on French overseas territories. The implementation would be conducted through the valorization of the infrastructure already implemented at the European level.

A first set of French airports has been chosen to get sub 3 hourly data. An example of such a production is given below for the major airport of Frankfurt in Germany. With these data the forecasters could get low cost observations in complement to the radiosoundings.

Example of intensification of profiles on a major airport



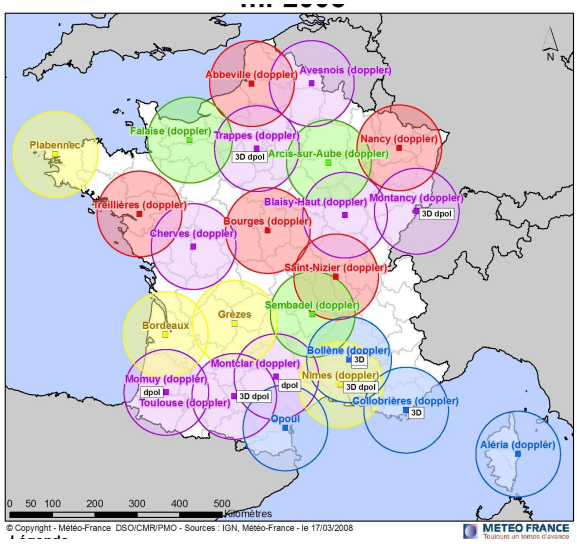
3. Consolidation of wind profilers and transformation of weather radars in Doppler radars

The active ground-based remote sensing systems operating in certain bandwidths can be used to retrieve the components of the winds, with the Doppler principle. To simplify, with VHF radar it is possible to retrieve wind profiles up to 20 km of height, with UHF radar it is possible to achieve 3 to 15 km range and with the weather radar in band C or S, 3D wind fields could be retrieved at least from raining areas and in a significant number of clear air cases. Thus the 3 kinds of profilers are complementary and give a potential of frequent observations for the winds. The technology is now robust and relevant progresses have been made to consider the capacity of these systems as operational.

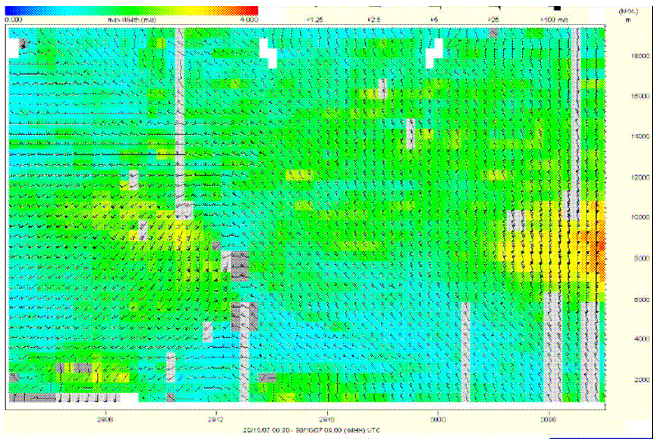
Actually the main difficulty remains the capacity for the numerical models to assimilate efficiently ctly frequent data and progresses have to be made on assimilation before to invest in a larger amount of profilers. The priority should be to consolidate the current wind profilers to product good quality measurements for the numerical models for regional and national applications. A first version of a designed wind profiler network would be composed by the data of 3 UHF and 3 VHF systems, owned by Météo-France or French laboratories. The other axis of the wind remote sensing network is the use of 16 Doppler weather radars to be able to produce vertical profiles and 3D winds and to qualify these new data for meso scale applications.

Current wind profilers in the EUCOS area (Winprof-II)

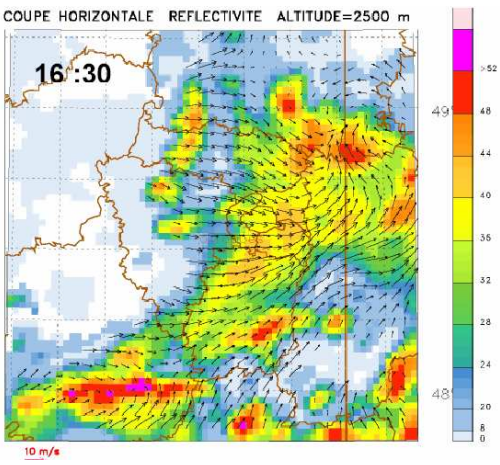
Potential French Doppler weather Radars



Vertical wind retrieved with a VHF profiler



Radial wind retrieved with weather Doppler radars



6. EXPERIMENTATION OF RECENT AND NEW SYSTEMS

1. Evaluation of the metrological quality of onboard aircraft sensors

The current operational AMDAR system can not be implemented on small aircraft operated by regional airline companies and are not able to give humidity measurements. This limitation does not allow to cover the needs at the national scale and slows the possibility to optimize the radiosounding network at national and regional scales. The solution could be the implementation of specific AMDAR sensors on small aircraft and to add humidity sensors and software on the aircraft already equipped with AMDAR system.

In the framework of the European E-AMDAR program Météo-France has proposed to evaluate the measurements obtained by two potential operational sensors (T-AMDAR for tropospheric AMDAR and WVSSII for humidity AMDAR) by comparison with research sensors onboard the French research aircraft during campaigns. These steps are essential after the tests conducted on these sensors in laboratory and before their operational implementation onboard the aircraft of the airline companies.

In parallel of these evaluation Météo-France could facilitate the relationships between the AMDAR community and the Airbus departments located in Toulouse France, with the objective to implement new sensors onboard the aircraft fleet. It has been demonstrated recently that the impact of contrails could be negative for the climate and the implementation of humidity sensors has becoming an issue for the aeronautical activities. A collaboration between both communities should be the best way to progress.

2. Evaluation of wind profiler lidar and sodar for aeronautical purposes

The capacity to detect local phenomena e.g. fog and wind shear is still limited and is becoming a big challenge for aeronautical purposes as the traffic is increasing. Ground-based remote sensing systems operating in the low level should be a good solution. A first experiment has been conducted with an UHF wind profiler implemented on the airport of Nice with the objective to detect wind shear and to inform the pilot before landing. This experiment pointed out that the geographical situation in Nice was too complex for a single profiler, measuring wind above it, to detect and anticipate this kind of phenomena.

A strategy of observations has been defined for this situation by using meso scale numerical model to progress on the assimilation of the data of such systems and identify the best location to implement them depending on the attempt : detection or anticipation. To go further on Nice it is planned to evaluate the capacity of Lidars to detect wind shear and use the current wind profiler to progress on the assimilation by the model Arome.

For the fog an experimentation is under way on the airport of Paris Roissy CDG to evaluate the capacity of sodars to detect the upper level of the fog layer. This information completed with a 1D model and sensors mounted on a mast already implemented should be a good strategy to give a chance of detection of fog and anticipation on its evolution.

3. Integration of collocated remote sensing systems to retrieve complete profiles

Measurements of wind, temperature and humidity on the vertical could be retrieved separately by different systems. An efficient method has been developed by the research center in Météo-France to combine systems and retrieve one complete profile. Evaluation of this original method would be conducted for the campaigns where the systems are deployed and the transfer of these method would be prepared for an operational use.

7. PREPARATION OF THE INTEGRATION OF ENVIRONMENTAL UPPER AIR OBSERVATIONS

1. Integration of Ozone radiosoundings into the operational network

In France and on French overseas territories the responsibilities of Ozone radiosoundings depend on institutes and laboratories in charge of climate study and research. However the launchings could be made by the operators of Météo-France in charge of the regular radiosoundings. These operators have to be trained to do it correctly. As the soundings of ozone should be simultaneous with the operational ones, it is necessary to control the capacity of both systems to operate without interferences. Technical cooperation should be strengthened between both communities to integrate the ozone measurement into the operational network standards.

2. Preparation of operational structure for physico chimical airborne measurements

Mozaic was a European research project conducted by laboratories, airline companies and aircraft manufacturers to develop and implement new onboard sensors enable to produce environmental measurements, essentially O3, H2O, CO, NOy. From 1994 to 2007 this project became a real success with a production of 5000 vertical profiles per year.

The new project IAGOS (Integration of routine Aircraft measurements into a Global Observing System) follows Mozaic with the objectives to measure other chemical species, to extend the fleet and to deliver data in real time. The goal is to prepare the infrastructure to collect these data for the climate and forecasting applications. The first phase of the project, IAGOS DS for the design, is planed to end in 2009. The second phase, IAGOS ERI, for the European Research Infrastructure would end in 2012.

Météo-France was an actor of the Mozaic project and is involved in the two phases of the IAGOS project to design the real time system which would produce and send data through the GTS and to prepare the real time infrastructure in a similar way as the AMDAR system do in connection with E-AMDAR and WMO.

Design of physical chemical profiles that could be delivered in real time