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Use of lightning data to improve observations for aeronautical activities

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I Introduction

Aeronautical activities are very sensitive to meteorological conditions and especially to convective conditions giving lightning but also wind gust, hail, heavy precipitations…

METAR messages are aerodrome special meteorological reports that describe meteorological parameters over the airport: wind, visibility, pressure, clouds, present weather…, with sometimes a trend forecast. The formal coding is described by FM 15-XIII from WMO. The observations are based on the past ten minutes before coding the message and are updated each hour or half hour. The message is sent via the Global Telecommunication System (GTS) of WMO to be available to all users in the world who coordinate the flights. In case of quick increase of worst conditions a SPECI is coded.

OBSMET is a local weather report delivered to local control and authorities to help them during take off or landing operations.

The convective information (present weather indicating thunderstorm, presence of cumulonimbus (CB) or tower cumulus (TCU)) on the airport or in its vicinity is coded in these messages when an observer detects them. Up to the early 2000 years, human observers were present but with air traffic increase, the number of airports has been growing while in the same time human resources for observation could not expand, in the best cases. It was thus decided with French Civil Aviation authorities to automate METAR observations.

The first automatic METAR was issued in 2001 and up to 2006, only pressure, visibility, temperature, wind… were coded but not the convective information.

Meteo France owned a lightning network and radar network and from 2002 to 2004, studies were conducted to test the capacity of detection of convective clouds. The tests turned out to be positive and in 2006, the first operational METAR AUTO with convective information was issued.

Aspoc is a French system to help air control to detect and follow convective conditions on the area of control. Updated every five minutes, by radar and lightning data, the controller can visualise lightning and convective cells detected in past thirty minutes and the scheduled trajectory for the next thirty minutes.

II Automatic METAR with convective information

Meteo France owned a lightning network tailored to detect Cloud to Ground (CG) strokes with an accuracy of less than 1 km at this time. The occurrence of lightning allows to code a present weather code indicating thunderstorm (TS) or thunderstorm in the vicinity (VCTS). But for cloud type, occurrence of lightning implies an occurrence of cumulonimbus (CB) but the reverse is not always true. It's why it was necessary to add another type of information: radar data.
High reflectivity on radar data may correspond to the presence of CB or TCU but it's also known that heavy precipitations with high level of reflectivity can also exist without CB. But we can also say that with CB or not CB, high levels of reflectivity are often bothersome or dangerous for an aircraft.
The METAR code doesn't precise the distance where CB are to be reported because a human observer reports CB when he detect it and it can be far away from the airport. In the study, different distances have been tested from the Aerodrome Reference Point (ARP).
The study was done using radar data from Trappes close to Paris, using data within a 100km range around.

Each half hour, the radar data of the last 5' and lightning impacts of the last 10' have been used. With these data, a program calculated the occurrence of CB/TCU and of TS or VCTS for the 7 airports in the area

covered by radar. A comparison was then done with official METAR based on human observation. The study took place during one year: 64338 METAR among which 1918 included convective information.
Several thresholds for reflectivity, and distances from the ARP were tested in order to choose those giving a comparability of observations between human and automatic algorithm.
The automatic detection gave some false detections due to false echoes in radar data (stationary objects, bright band, artefacts) but techniques have been improved to reduce them. Sometimes, a human observer can detect the convective clouds earlier because he can detect to a long range distance but also because Cb exists before lightning occurs for example. But on the reverse side, some cases where noticed where human observer didn't observe CB, for example in overcast conditions. As a conclusion, we can say that it is two different way to observe which are different. A human observer identify clouds and record thunder, the automatic process checks radar reflectivity and lightning that may occur in such conditions. But in the two cases, the users are advised to exercise caution with respect of a convective phenomenon.

From these studies, the following table was validated to code the convective information:

TABLE 1 METAR CODING

		LIGHTNING detected around the aerodrome				
RADAR: refelctivity (R) of 5 closely pixels		strokes within 8km	strokes from 8 to 16km	strokes from 16 to 30km	no strokes	no lightning data
	R≥41dBZ	TS CB	VCTS CB	CB	CB	missing CB
	33≤R<41dBZ	TS CB	VCTS CB	CB	TCU	missing TCU
	R<33dBZ	TS CB	VCTS CB	CB		missing
	no radar data	TS CB	VCTS CB	CB	missing cloud	missing . missing cloud

Remark: In automated METAR messages, the trend is not coded.

Operational timing:
The difficulty is to succeed to compute the METAR message at the right time (from 1 to 3 minutes after the official observed time) on local system after having collected ,processed and transmitted information from a central system.

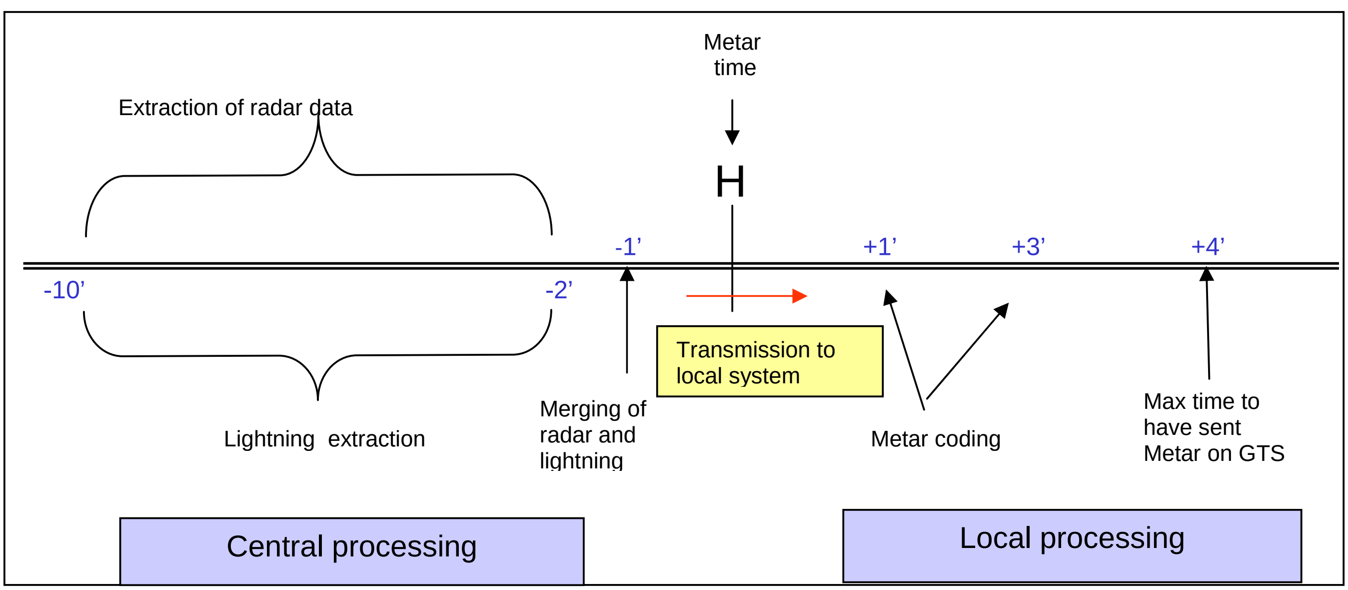


Figure 1: operational process

As illustrated on the figure 1, the process begins with the extraction of data to merge on the central system located in Toulouse. Occurrences of lightning are extracted from CATS lightning data base for each airports on 3 concentric rings of 8,16 and 30 km at H-1'. The process extracts lightning occurrences between H-10' and H-2' . For radar data, the last 5 minutes composite is used, and if not available , the previous one.
The 2 outputs are sent to a process that merges data to deliver a unique information to local systems.
The local computers add this information to other parameters received from local instruments such as a ceilometer used for calculation of cloud layers to code the METAR , using also table 1.

The local computers also produce the OBSMET for local air controllers, using convective information.

Automatic METAR process is running continuously on site without human observers, or part time to take over when no observer is on duty (for example during the night)
The deployment on local systems began in 2006. In 2007, around 60 sites were installed with such systems. The figure 2 gives the current state with around 90 operational sites.

Figure 2 map of installed or scheduled sites

Data control:
Since 2006, many quality controls have been performed. Globally, customer satisfaction is very high. We have noticed a very small number of false alarms, often due to false radar reflectivity. Some cases of non detection have also been detected by local controllers, especially in the coding of TCU when there is no lightning and radar reflectivity is just beyond the 30km limit.

Ongoing improvements:

OBSMET update:

The transmission links are now more efficient than in 2006. Central information was pushed to local systems every half hour for METAR production needs. This frequency will be increased to an update every 5 minutes in order to improve the OBSMET information for local controllers. A test period was done last winter and the new frequency is expected to be operational in the first half of 2010.

Including cloud to cloud stroke data:

Since 2009, the lightning network of Meteorage has been updated with LS7001 sensors from Vaisala (See figure 3 , map of Meteorage network). With these new sensors, some Cloud to Clouds (CC) strokes can be detected. We began to store CC strokes by the end of September 2009. A first study was made with October and November data which are not the most stormy months in France. The objective was to replay data for all the 93 airports concerned, for all the METAR of the 2 months with a half hour frequency.
On 272304 METAR tested, the calculation without CC strokes gave 881 METAR including lightning in the area of 30Km around the airport whereas 930 reported lightning when we included CC strokes. We also checked how many METAR were modified when including CC. Changes come because you can have CC without CG but also CC in a nearest area from the Aerodrome Reference Point. 62 METAR, 6% of stormy conditions,

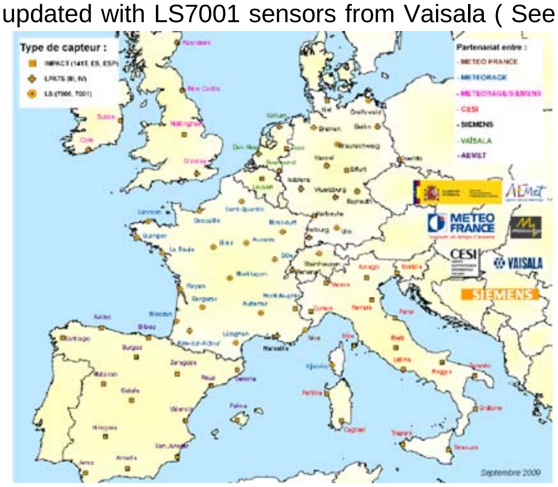


Figure 3 map of Meteorage network

are modified. Figure 4 shows the distribution between the three rings around the airports. If the most important changes concern the 16-30 Km area, the nearest is also impacted.

On the 62 modified METAR, we notice that for 51 (82%) , there were no CG detected in the 30 km area. On figure 5, we see that the far away area is more important , but some CC are also detected at less than 8 km from the airport, indicating CB and thunderstorm.

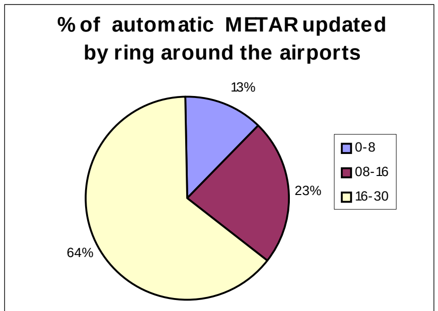


Figure 4

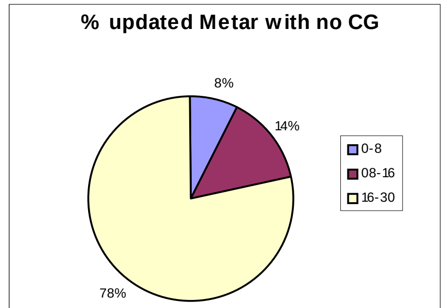
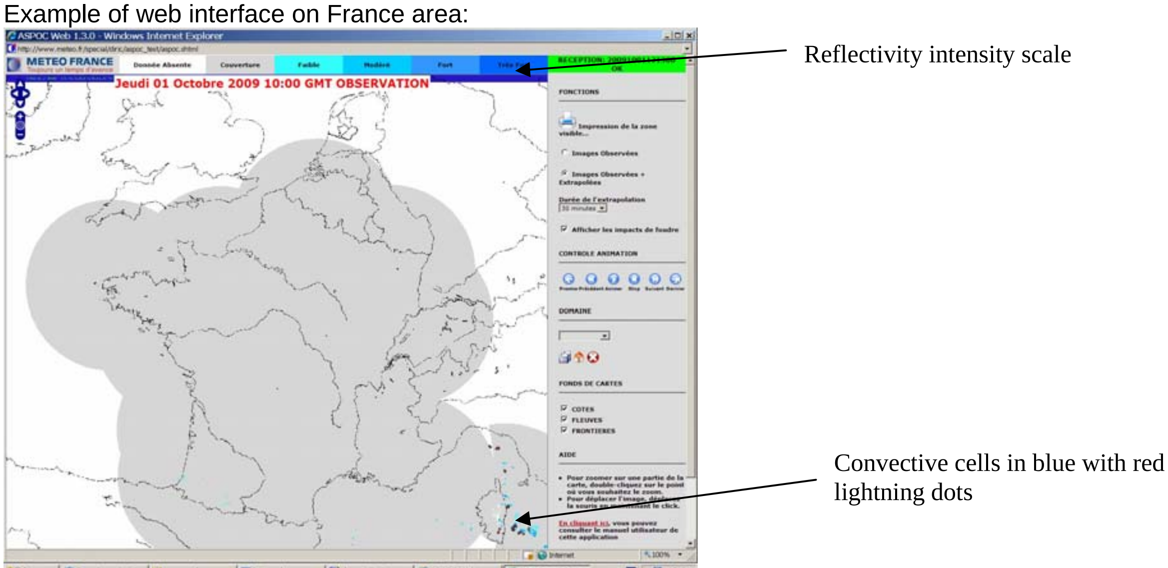


Figure 5

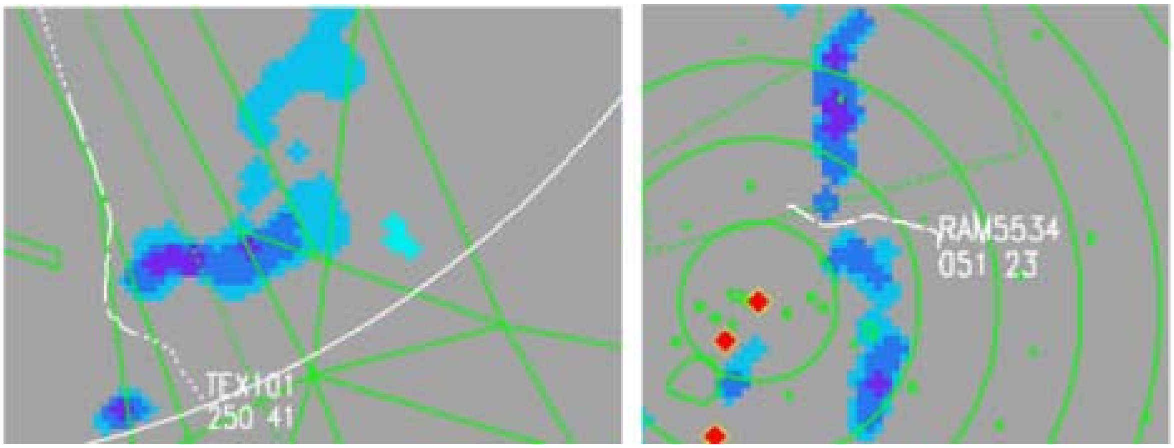
These results are very interesting and seem to confirm that CC can give an earlier warning of convective conditions in the area. The quality control indicates that on non detection cases, the problem was with radar reflectivity outside the area,, we can think that a response is to include CC.
At this state, we need to check with others meteorological data if the modified METAR correspond to a real improvement of detection or if we have some false detections giving false reporting in the METAR.
To do that, we run a daily comparison on the previous day data, giving the list of updated METAR to compare to real conditions with a forecaster workstation.
Since the study in autumn 2009, we acquired a TLP processor to replace the old LP2000. The first data delivered by the TLP in test phase, shows an increase of detected CC. So this study has to compare the operational data from LP2000 without CC with TLP data including CC, once TLP data is qualified.
This work is on progress.

III ASPOC System

As written in the introduction, Aspoc is a French system to help air control to detect and follow convective conditions on the area of control. Updated every five minutes, by radar and lightning data, the controller can visualise lightning and convective cells detected in past thirty minutes and the scheduled trajectory for the next thirty minutes. The graphic interface presents the data in a similar environment of others controller tools with control area limits.
The project has begun in 1997 with first operational deployments in 1999 on a dedicated visualization. The last improvement is the development of a web interface. At this state in France, 50 control centers and 10 air force bases are equipped, with an Aspoc interface, 11 less important approach centers have an Aspoc web service. The web service is also used as backup for other sites.
Example of web interface on France area:



The reflectivity R scale is:
Low convective cloud: R between 32 and 35 dBZ
Moderate convective cloud: R between 36 and 39 dBZ
High convective cloud: R between 40 and 47 dBZ
Very high convective cloud R ≥ 48dbZ. (In this case, the probability of hail is very high)
Users can launch an animation on the last 30 minutes of observations and can also display an extrapolation of the radar pictures for the next 30 minutes.
As an illustration of the usefulness of this application, figure 6 shows examples of modification of plane trajectory to avoid most dangerous cells . This example dates back to the 1998 study period.



(a) le 14/05/1998 à 17h15 UTC (b) le 02/06/1998 à 11h25 UTC

Figure 6 example of plane trajectory

On this picture, red dots represent lightning and radar cell are blue. Green lines represent the control area, and white dashes the real trajectory (1 minute by dash) of the plane. We can see that the pilot with help of controller using Aspoc has selected the less dangerous way.
For lightning, the next step will be to include Cloud to Cloud strokes as for automatic METAR to improve detection and provide earlier warnings.

IV Conclusion

Automatic METAR and more generally automation of observation is now more and more developed in order to respond to observation needs without increasing dedicated human resources
Lightning data are very useful to complete radar data and to help the processes to analyse and characterise the convective activity level.
Automatic METAR have now proved its reliability and is well accepted by aeronautical users. For the next years , we can hope a further improvement with cloud to cloud use, resulting in earlier detection of convective phenomena.
Aspoc was launched 10 years ago , the new web interface now authorizes new users and cloud to cloud may also improve this service in the future.
We now successfully deliver 2 products for aeronautical activities using lightning information and we expect that lightning data use for aeronautical activities will still increase in the next years.

References:

-Manual on codes, International codes, volume I.1, WMO n°306, section A alphanumeric codes, FM15-X (METAR) and FM-X (SPECI).
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