Investigating Conceptual Models (CMs) and meteorological tools to anticipate significant convective events developments at very short term

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Foreword

Our main motivation here is to investigate more tricky forecasts linked to convective situations during the summer season. Quite similar situations can give way to a large panoply of convective events with various degrees of severity at different scales. Sometimes these convective events simply do not develop at all.

Here we will mainly focus on the operational work of forecasters. They have to quickly make a realistic selection of data to estimate a risk of 'severe' and rapid development of convective events for the next few hours. To illustrate this work we will explore briefly the more relevant information for forecasters analyzing a potentially convective situation observed over Western Europe during summer 2013. We will introduce the most suitable Conceptual Models (CMs) at synoptic and sub-synoptic scales. Nowcasting tools selected by our forecasters will be also illustrated and discussed. Finally a short verification of our nowcasts will be made.We examine here the synoptic situation of 2nd August 2013. In many respects this selected situation has been very similar to previous ones like e.g. the situation of the 26th and 27th of July 2013 (not illustrated here). The synoptic scale analyses of both events were characterized by a 'Spanish plume' pattern. Several severe convective events had been observed the 26th and 27th of July over France and low countries and forecasters could suspect similar convective events one week later for the 2nd of August.

In the next figures we illustrate a 'Spanish plume' pattern in a pre-frontal situation over Western Europe with the ECMWF model analysis for the 2/8/2013 at 12h00 u.t.c.

Figure 1

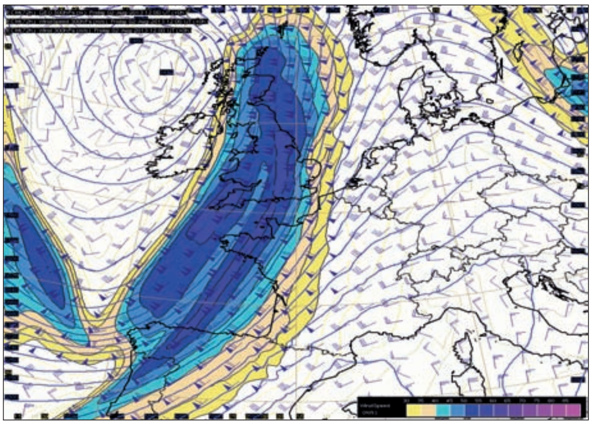
ECMWF upper air analysis – the 2/08/2013 at 12h00 UTC Z500 (—), W500 (wind flags), W300 (mean wind speed in reference to a coloured legend below).

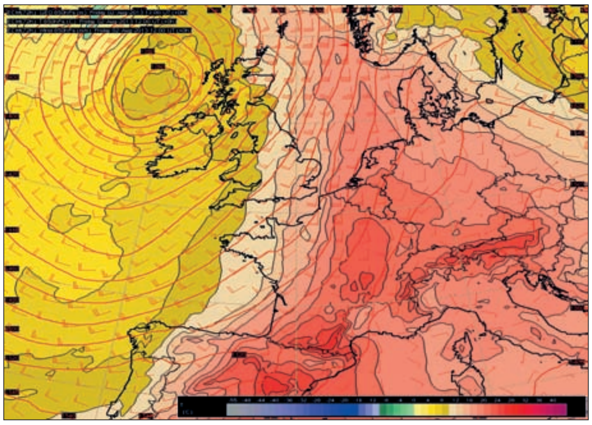
Figure 2

ECMWF analysis at 850 hPa – the 2/08/2013 at 12h00 UTC Z850 (—), W850 (wind flags), T850 (reference to a coloured legend below).

A strong south to southwesterly jet stream is flowing at mid and upper tropospheric levels (500 and 300 hPa) between a Low centred to the west of Great Britain and a High over Central Europe (Figure 1). In lower tropospheric levels (850 hPa) a warm air advection tongue and a ridge of (pseudo) wet bulb potential temperature are analyzed from Spain to the North Sea (Figure 2 and 3). We also retrieve a thermal trough characterized both by a high thickness pattern between 1000 and 850 hPa and a low pressure area over the North of France and the countries and the North Sea (Figure 4). Furthermore an ill-defined cold front pattern can be detected over the northwest of France and England (Figures 2 to 4).

Analysis of the synoptic weather situation





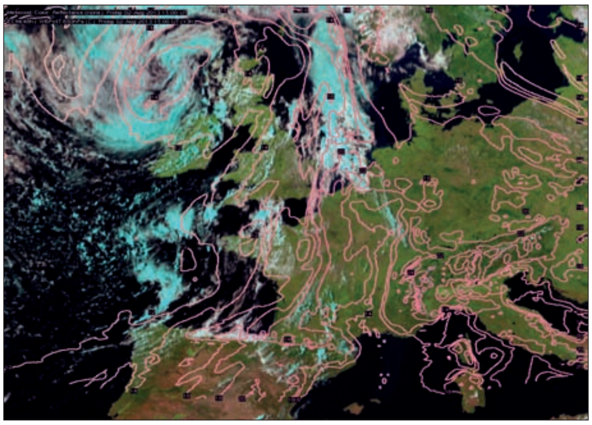


Figure 3: MSG satellite picture the 2/08/2013 at 15h00 UTC (composite of Visible channels)
ECMWF θw 850 field (continuous isolines in brown).

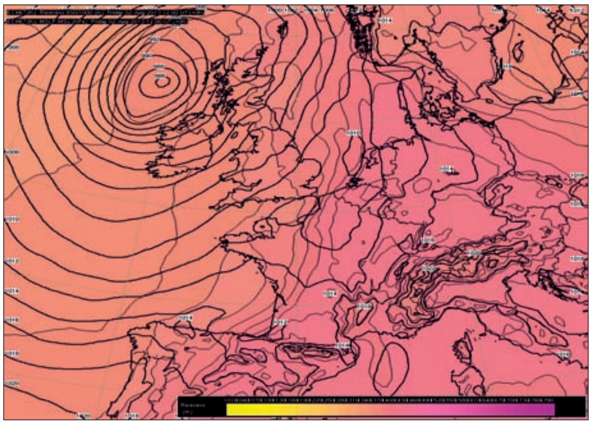


Figure 4: ECMWF analysis in the low troposphere – the 2/08/2013 at 12h00 UTC.
MSLP (—) and 1000 to 850 hPa thickness fields (continuous thin lines in reference to a coloured legend below).

Analysis of the sub-synoptic weather situation

Different types of observations and NWP data (from ECMWF model) had been used by forecasters over the north of France and the low countries for the 2nd August 2013. These data have been used around noon and up to the mid-afternoon to anticipate a potential development of severe convective events for the coming hours (a nowcast for the late afternoon).

A few convergence lines were identified using surface observations as well as cumuliform cloud patterns retrieved on satellite pictures and radar echoes (Figures 5 and 6). If we focus on the north of France and the low countries a main convergence line can be analyzed. The data show weak activity along the axis of a thermal ridge in the lower troposphere (Figures 3 and 5).

However more active convective patterns (probably MCS) can be observed over the North Sea and the Channel (Figures 5 and 6) but they are not likely to develop over Belgium.

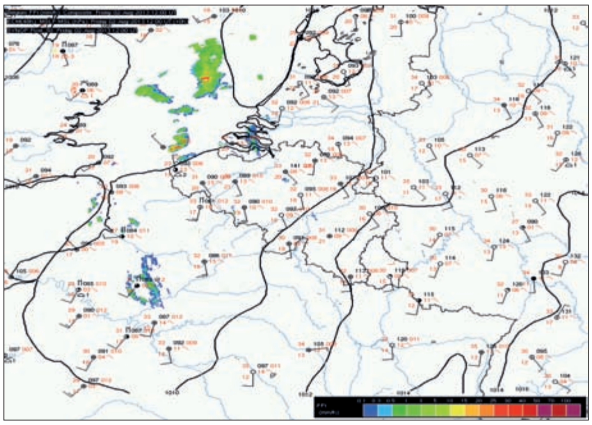


Figure 5: situation of the 2/08/2013 at 12h00 UTC
MSLP field from ECMWF (—) , synoptic observations (point symbols and values) , radar echoes (PPI (in mm/h)) in reference to the coloured legend below.

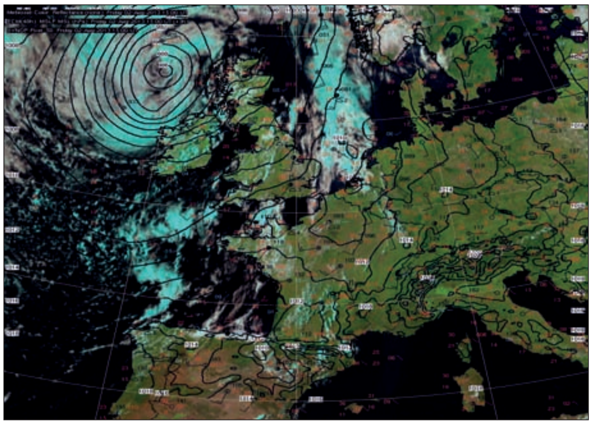


Figure 6: situation of the 2/08/2013 at 15h00 UTC
MSLP field from ECMWF (—) superposed on a satellite picture (composite of Visible channels) and synoptic observations (point symbols and values).

In the mid-afternoon radar observations superposed on to the cloud pattern associated to a main convergence line over the north of France and low countries showed isolated spots of precipitations (which may not have been reaching the surface). The mean sea level pressure field and the reported synoptic observations indicated that this convergence line was associated with a thermal trough over the low countries (Figure 7). However a loop of recent satellite and radar images did not show any significant convective development on this convergence line during the early afternoon.

The 'convective' fields (CAPE and CIN) issued from the ECMWF model for the 2/08/2013 at 12h00 UTC have been examined. Significant CAPE and CIN values were lying in the vicinity of the thermal trough over the low countries. The fields can be

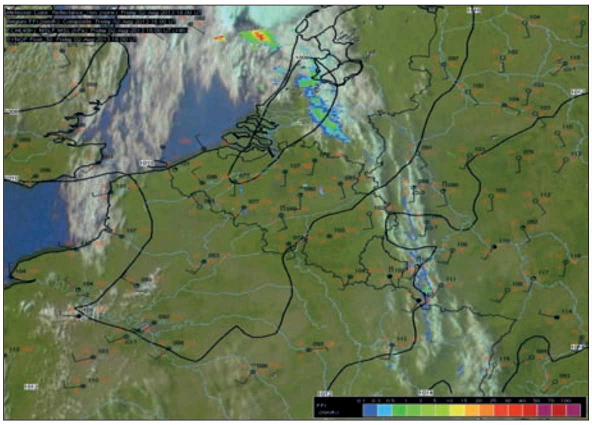


Figure 7: situation of the 2/08/2013 at 16h00 UTC
a radar image (a composition of three radars with radar echoes (PPI (in mm/h)) in reference to the coloured legend below) is superposed on a satellite image (composite of Visible channels) and on the MSLP field (—) with point synoptic observations.

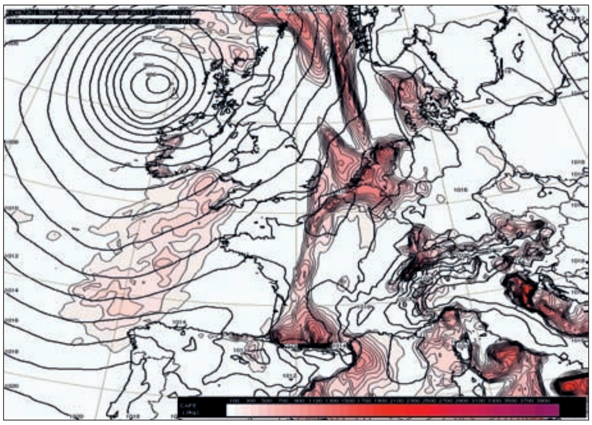


Figure 8: situation of the 2/08/2013 at 12h00 UTC
CAPE fields in J/kg (reddish coloured areas reported in the legend below) are superposed on the Mean Sea Level Pressure field (—) issued from the ECMWF model.

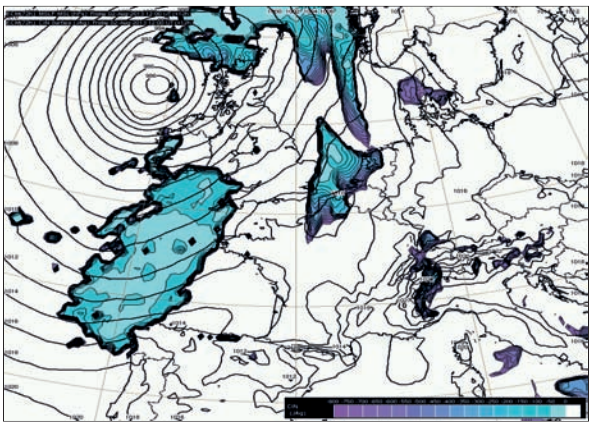


Figure 9: situation of the 2/08/2013 at 12h00 UTC
CIN fields in J/kg (bluish coloured areas reported in the legend below) are superposed on the Mean Sea Level Pressure field (—) issued from the ECMWF model.

exploited to predict potential convective developments over our areas (Figures 8 and 9).

In addition to CAPE and CIN fields the altitudes of typical levels for an air parcel uplifting to the Lifting Condensation Level (LCL) , the Level of Free Convection (LFC) and the EQuilibrium Level (EQL) have been considered. The Figure 10 shows the emagram of the pseudo radiosounding at Uccle (Belgium) for the 2/08/2013 at 12h00 UTC It has been chosen to be representative of the air mass in the thermal trough. It indicates a significant mid-level instability which is proportional to the red area on the emagram. In the lower layers (between ~900 and ~700 hPa) the air is more stable as traced by a (weak) cap proportional to the blue area on the emagram. Here it must be noticed that a conceptual model based on the convective parcel theory in the presence of a (weak) low level cap doesn't exclude convective initiation usually associated with forced vertical motions induced in the environment (reference to a ZAMG paper – August 2011 (1)).

Furthermore a moderate wind shear is indicated by a wind vector veering with altitude (wind flags are displayed on the left border of the Figure 10).

But the above-illustrated synoptic and sub-synoptic analyses aren't helpful enough to anticipate an initiation of (severe) convection in this case. Some ingredients seem to be missing for our nowcasts.

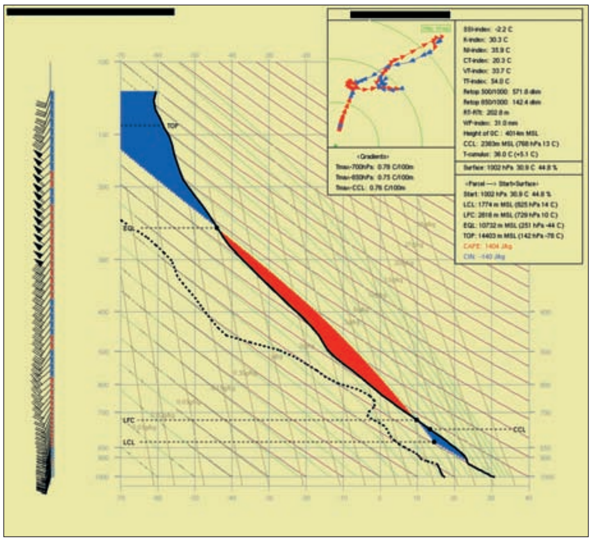


Figure 10: emagram of a pseudo radiosounding at Uccle – the 2/08/2013 at 12h00 UTC
T (—), Td (---) and Wind (flags) profiles are drawn in black. CAPE and CIN quantities in J/kg are represented respectively by the red and blue areas for an air parcel uplifted from the surface. Four crucial convective levels are pinpointed by white dots; LCL, CCL (Convective Condensation Level), LFC and EQL.

Forecasters who had been confronted in the previous week (26th and 27th of July 2013) with an intense development of Mesoscale Convective Systems (MCS) into a similar "Spanish plume" situation were looking for additional tools.

Exploitation of operational nowcasting tools

Here we briefly present two operational tools exploited by our forecasters for their analysis and nowcasts. We illustrate it for the situation of the 2nd of August 2013 with:
a 'checklist' tailored for (severe) convective events
the INCA-BE system (reference (2))

A/ a checklist tool

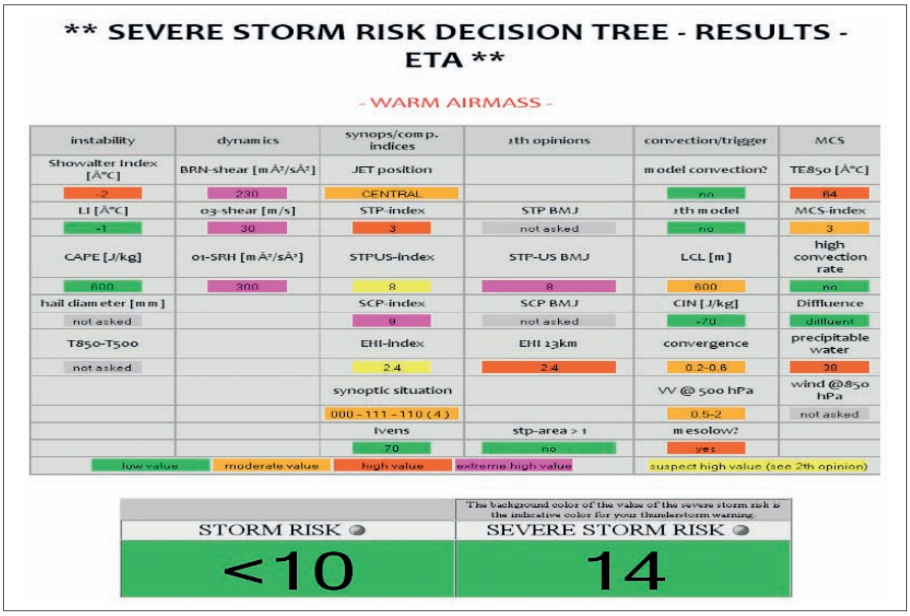
A 'checklist' based on meteorological parameters and typical weather patterns as retrieved in the Conceptual Models is operationally used. Forecasters exploit it when they think that (severe) convective storms over our areas could be predicted for the next few hours.

Here the scores of the checklist flagged with green labels indicates a low probability of convective storms developments associated to the warm air advection (the 'Spanish plume' situation). Several meteorological parameters of the 'warm air mass' checklist are exceeding crucial values; see in Figure 11 the labelled orange, red and violet colours for a majority of parameters into each of the six columns). Nevertheless a few parameters are pinpointing a small convection triggering and a more diffluent flow pattern (see green labels for convection/trigger and MCS) which seems to be sufficient to get low probability scores (Figure 11).

In practice let us remember that scores were largely depending on the numerical model. The ETA model exploited in this checklist is not the best choice and the outputs of our Limited Area Model ALARO must be soon available to improve the checklist. It is not easy for forecasters to select the relevant region(s). They know by expertise that scores can differ significantly from one sub-region to another one even over a 'small' country like Belgium.

B/ the INCA-BE tool

The Integrated Nowcasting through Comprehensive Analysis system (INCA-BE) originally developed at ZAMG (Austria) has been adapted for a mesoscale domain around Belgium (see maps of Figures 12 to 17) and for a local observational data flow. The INCA-BE system implemented in Belgium combines different inputs like a high resolution Limited Area Model (ALARO-4km), a selection of observations (like synops, intensities of precipitations from the hydrological network and from radars, cloud types issued from a SAF nowcasting product, …). A maximum weight is put on the observations at the analysis stage while decreasing asymptotically to zero for a lead time of 12 hours (with the opposite for model data). Forecasters can easily visualize the most recent analysis and very short range forecasts computed at high resolution (1 km x 1km) in the mesoscale domain and at some flagged locations like for surface temperature, wind and precipitations (intensities and a few types).



** SEVERE STORM RISK DECISION TREE - RESULTS - ETA **

- WARM AIRMASS -

instability	dynamics	synops/comp. indices	2th opinions	convection/trigger	MCS
Showalter Index [Â°C]	BRN-shear [mÂ²/sÂ²]	JET position		model convection?	TE850 [Â°C]
-2	230	CENTRAL		no	64
LI [Â°C]	03-shear [m/s]	STP-index	STP BMJ	2th model	MCS-index
-1	30	3	not asked	no	3
CAPE [J/kg]	01-SRH [mÂ²/sÂ²]	STPUS-index	STP-US BMJ	LCL [m]	high convection rate
600	300	8	8	600	no
hail diameter [mm]		SCP-index	SCP BMJ	CIN [J/kg]	Diffluence
not asked		9	not asked	-70	diffluent
T850-T500		EHI-index	EHI 23km	convergence	precipitable water
not asked		2.4	2.4	0.2-0.6	38
		synoptic situation		VV @ 500 hPa	wind @850 hPa
		000 - 111 - 110 (4)		0.5-2	not asked
		Ivens	stp-area > 1	mesolow?	
		70	no	yes	
low value	moderate value	high value	extreme high value	suspect high value (see 2th opinion)	

	The background color of the value of the severe storm risk is the indicative color for your thunderstorm warning.
STORM RISK	SEVERE STORM RISK
<10	14

Figure 11: from a decision tree scores, are calculated over the western part of Belgium and during the afternoon of the 2nd August 2013; respectively a risk of 30% and 34% for convective storms and severe ones (with impacts).

Experimental analyses of cloudiness, visibility and a range of convective parameters like CAPE, CIN, indices of (static) instabilities (LIft and SHowhalter), crucial convective levels (like LCL and LFC), Moisture convergence (MOCON) and other triggering indices are also available.

Hereafter more relevant INCA-BE fields and diagrams for a selection of parameters have been illustrated exploiting the last model run (ALARO-4km run from 06h00 u.t.c.) and the more recent flow of observations for nowcasts starting the 2nd of August 2013 in the early afternoon (from 14h00 UTC)

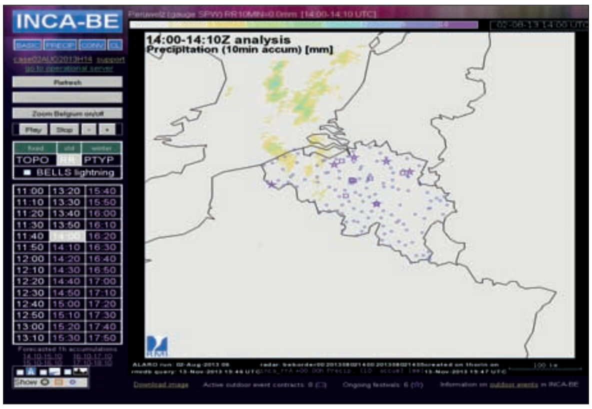


Figure 12.a: analysis field of precipitation intensities in mm/10 minutes – the 2/08/2013 at 14hoo UTC. (in reference to the coloured legend above).

Figure 12.b: diagram of precipitation intensities (mm/10 minutes) for Uccle;
no precipitation have been observed at the station during the last three hours (from 11hoo to 14hoo UTC) and no precipitation is forecast for the next four hours (see the purple line from 14hoo to 18hoo UTC).

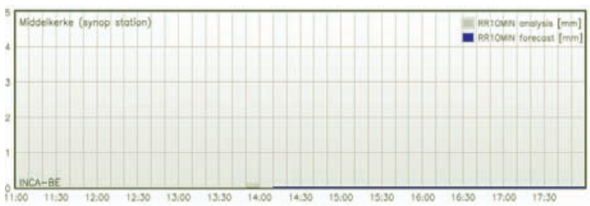


Figure 12.c: same diagram like Figure 11.b but for Middelkerke (northwest of Belgium). A (very) weak spot of precipitation has been observed at this station just before 14hoo UTC and no precipitation is forecast for the next four hours (see the purple line).

In the Figures 12 the analysis of the INCA-BE system made in the early afternoon show only very localized precipitation spots associated to the conver-

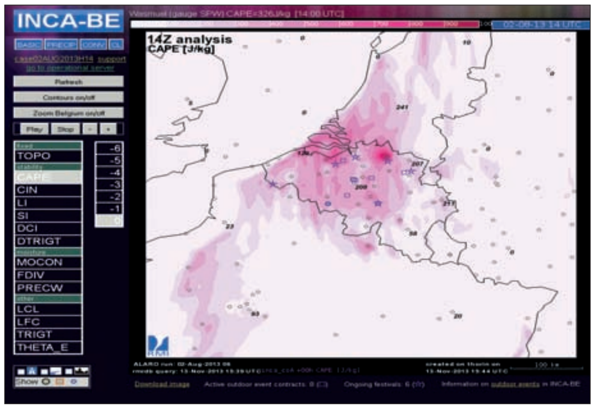


Figure 13.a: analysis field of CAPE (in J/kg)– the 2/08/2013 at 14hoo UTC.

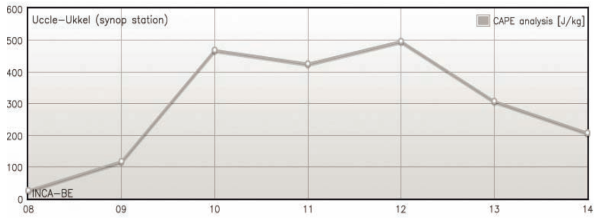


Figure 13.b: diagram of recent CAPE analysis at Uccle - the 2/08/2013 between 8hoo and 14hoo UTC.

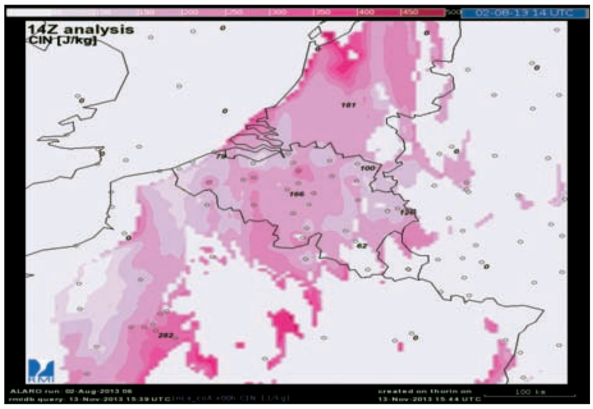


Figure 14.a: analysis field of CIN (in J/kg) – the 2/08/2013 at 14hoo UTC.

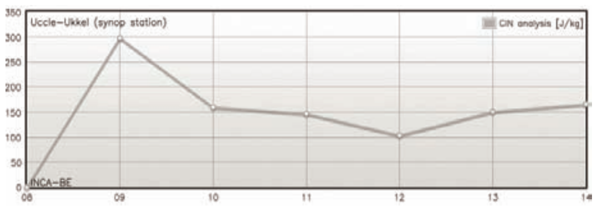


Figure 14.b: diagram of recent CIN analysis at Uccle - the 2/08/2013 between 8hoo and 14hoo UTC.

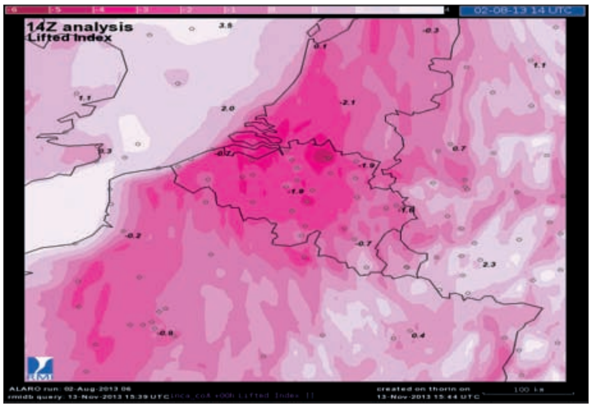
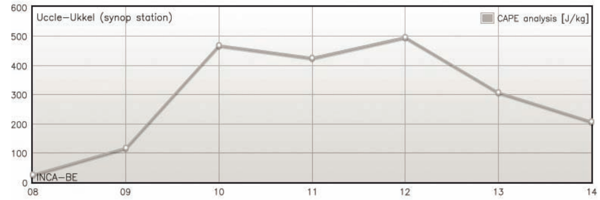


Figure 15.a: analysis field of LI (in degrees) – the 2/08/2013 at 14h00 UTC.

Figure 15.b: diagram of recent LI analysis at Uccle - the 2/08/2013 between 8h00 and 14h00 UTC2/08/2013 between 8h00 and 14h00 UTC.



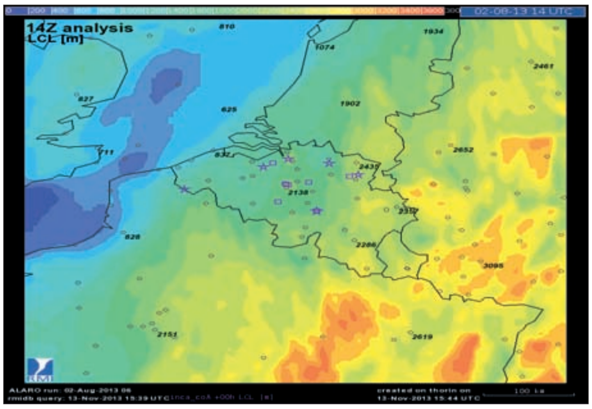
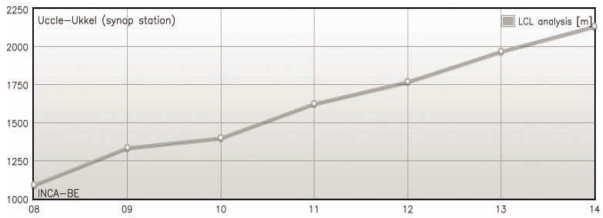


Figure 16.a: analysis field of LCL (altitude in m) – the 2/08/2013 at 14h00 UTC.

Figure 16.b: diagram of recent LCL analysis at Uccle - the 2/08/2013 between 8h00 and 14h00 UTC.



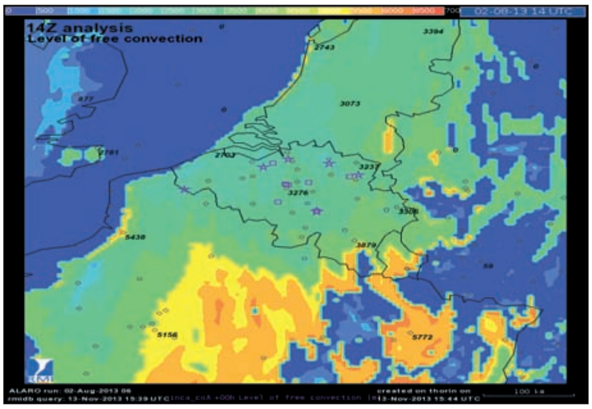
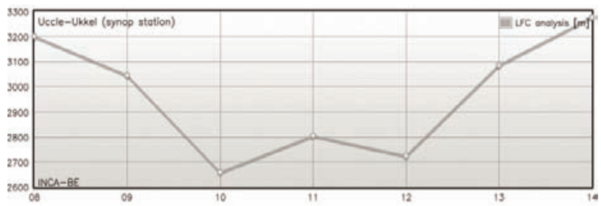


Figure 17.a: analysis field of LFC (altitude in m) – the 2/08/2013 at 14h00 UTC.

Figure 17.b: diagram of recent LFC analysis at Uccle - the 2/08/2013 between 8h00 and 14h00 UTC.



gence line crossing the low countries, mostly over the northwest of Belgium. The very short range forecasts of INCA-BE (up to four hours) respectively illustrated for the central part of Belgium (Uccle) and the northwest area close to the North sea (Middelkerke) don't indicate any precipitation up to the early evening.

A selection of convective analysis parameters has been made in the mesoscale domain (a) and the station of Uccle (b) for the Figures 13 to 17. These analysis issued from our INCA-BE system illustrates the investigation of forecasters. This latter was built on the (very) recent evolution of a few crucial convective parameters like CAPE – CIN - LI and a few specific levels (LCL and LFC). In this convective analysis it appears that the situation is potentially unstable in the early afternoon mostly at mid-levels and on the northern part of Belgium

A short verification of our nowcasts

A quick look at the Figure 18 shows that in the late afternoon and early evening of the 2nd of August the weather was fine and mainly dry over the low countries and the neighbouring areas over the north of France. In the thermal trough over Belgium observations don't indicate well-organized convective

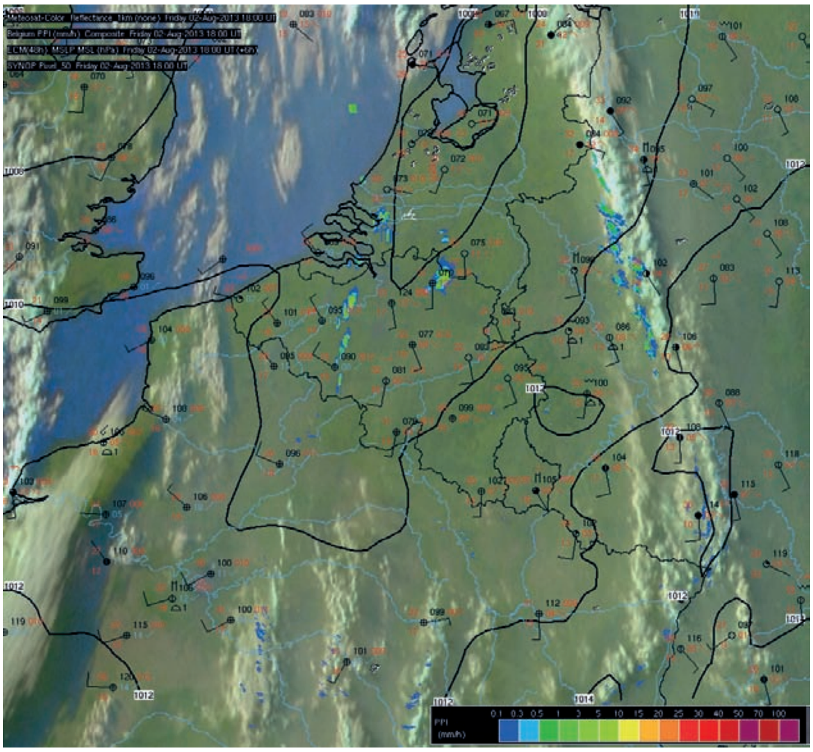


Figure 18: situation of the 2/08/2013 at 18h00 UTC a radar image (a composition of three radars with isolated radar echoes (PPI (in mm/h)) in reference to the coloured legend below) is superposed on a satellite image (composite of Visible channels) and on the MSLP field (—) with point synoptic observations.

systems. Here we neglect a few isolated spots of precipitations displayed on the radar image and which are difficult to verify against other observations.

Concluding remarks

Forecasters dealing with pre-convective situations use parameters and meteorological patterns selected in the Conceptual Models at synoptic and sub-synoptic scales to make their nowcasts. We have illustrated the fact that in these situations some ingredients are still missing to exploit completely a Conceptual Models approach. To help forecasters more and more Nowcasting tools are developed to facilitate a high resolution analysis and nowcast. Additional data from observations (teledetection,...) and more realistic Limited Area Models are needed to improve these tools. Our INCA-BE system must certainly be developed and tested to tackle the tricky problem of the initiation of (severe) convective events at sub-synoptic scales and very short range (more information on the INCA-BE system can be found in the reference (2). For this situation helpful and consistent information has been given by the operational nowcasting tools.

We hope that an exchange of expertise between research and operational European services in meteorology will be intensified to stimulate a better investigation of pre-convective situations. For forecasters making decisions it should lead to a better discrimination of potentially severe convective situations during the pre-convective stage, as the impact of their nowcasts including warnings on society is significant.

Last but not least I would like to thank the radar team at RMIB (Uccle) and in particular Dr. Laurent Delobbe and Dr. Maarten Reyniers for their friendly co-operation aiming at implementing the radar products and the INCA-BE system.

References:

(1) Detection of convective Initiation by Objective analysis Methods and its Use for Precipitation Nowcasting, Georg Pistotnik, Stefan Schneider and Christoph Wittmann – 6th European Conference on Severe Storms (ECSS 2011), 3 – 7 October 2011, Palma de Mallorca, Spain

(2) Reyniers M., Delobbe L., 2012, The nowcasting system INCA-BE in Belgium and its performance in different synoptic situations, the 7th European Conference on Radar in Meteorology and Hydrology (ERAD2012), Toulouse, France