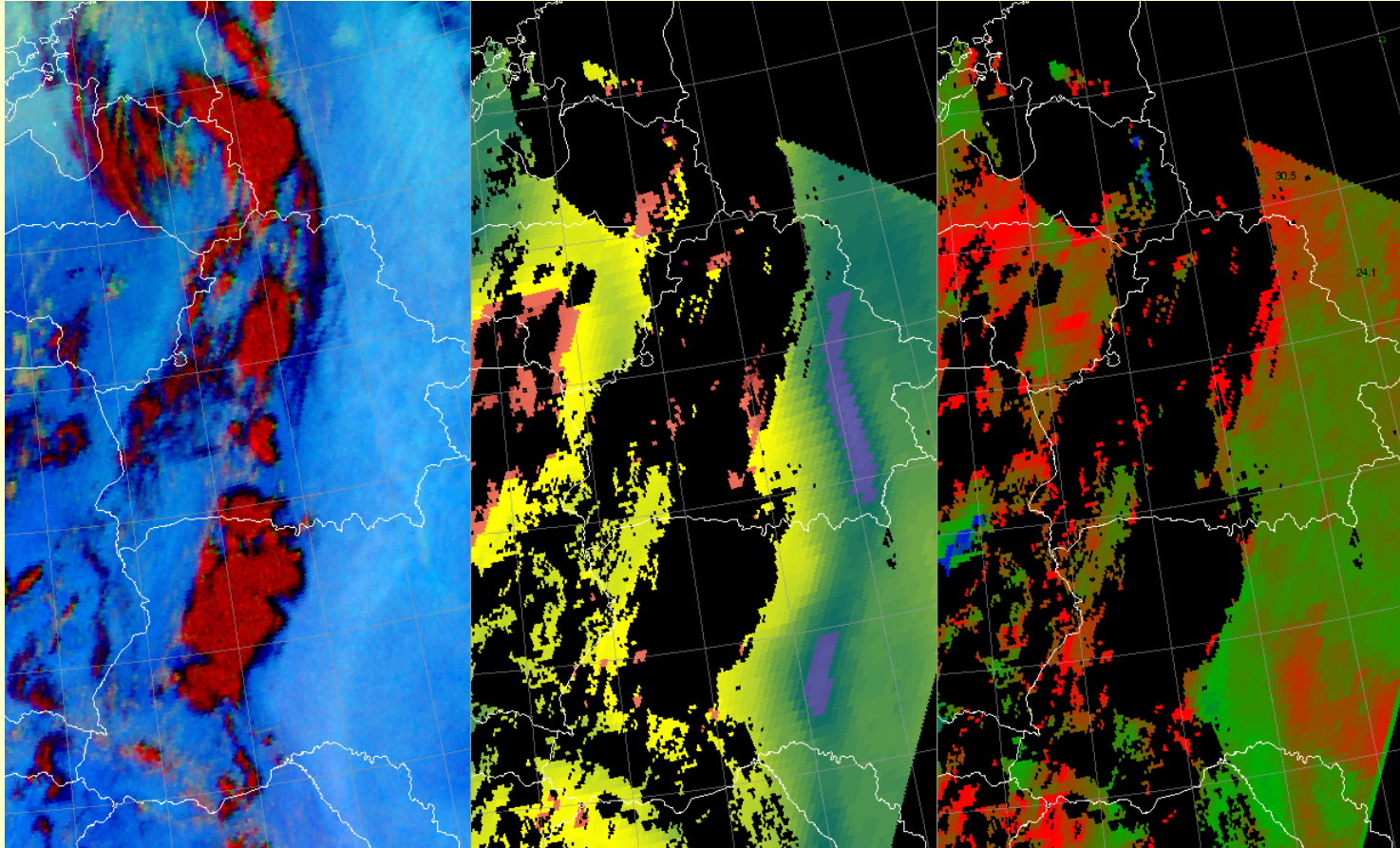


SATELLITE DERIVED INSTABILITY INDICES – SOME FURTHER INSIGHTS (PART I)

Case studies



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2014 Convection Working Group Workshop, Zagreb, Croatia, 07 April 2014

MPEF **Global Instability Indices** (GII) and **NWCSAF 'Clear Air'** products retrieve several instability indices from SEVIRI (and NWP) data (K-, KO-, Lifted and Showalter Indices, Maximum buoyancy).

Many users, forecasters ask why **ONLY** these instability indices are retrieved, and **WHY NOT the CAPE (Convective Available Potential Energy)** parameters, which are more complex, more developed instability parameters, **widely used at the forecasting duty**.

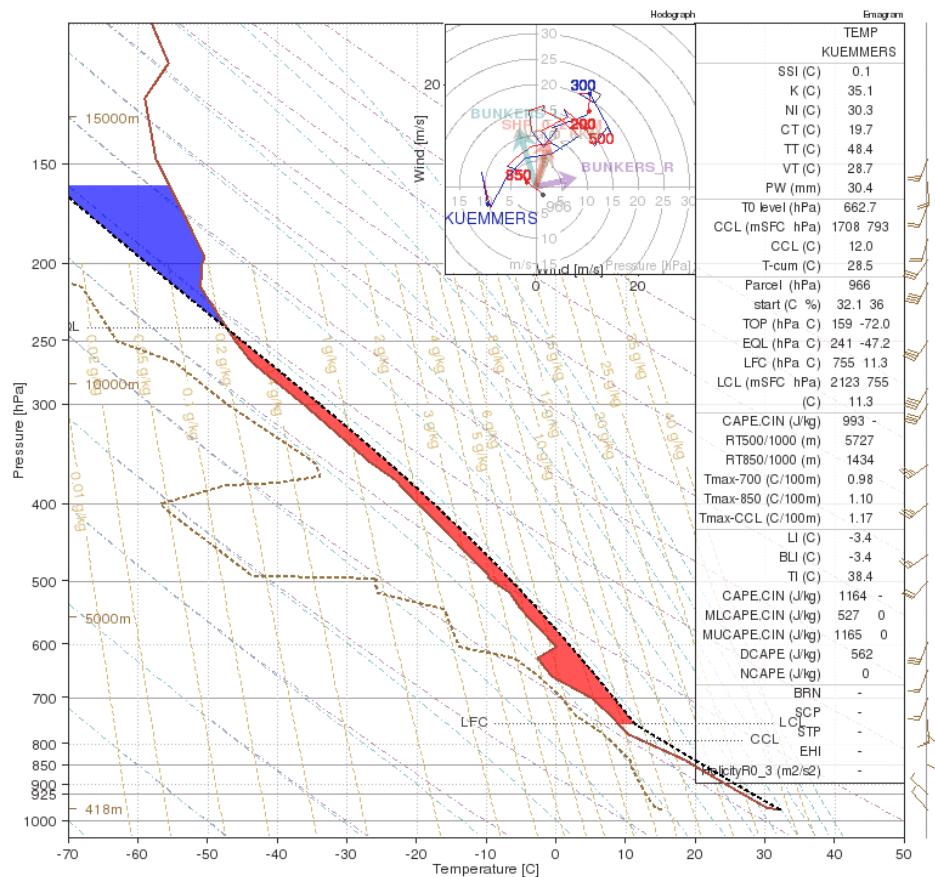


Aim of the study (sponsored by EUMETSAT)

- to retrieve different kinds of CAPE parameters from SEVIRI data,
- to evaluate qualitatively their performance in case studies,
- to perform sensitivity analyses (Zsófia will speak about)

Definition of CAPE - Convective Available Potential Energy [J/kg]

TEMP KUEMMERSRUCK 10771 Friday 16-07-2010 18:00



Maximum amount of potential energy which the air parcel has available for convection.

CAPE is calculated by integrating over pressure the virtual temperature difference of the adiabatically lifted air parcel and the environment.

$$CAPE = -R_d \int_{p_1}^{p_2} (T_{v,parcel} - T_{v,env}) d \ln p,$$

only if $T_{v,parcel} > T_{v,env}$

p_1 is the pressure level the air parcel is lifted from (or the pressure of the Level of the Free Convection)

p_2 is the pressure of the equilibrium level (EL, neutral buoyancy),

$T_{v,parcel}$ is the virtual temperature of the adiabatically lifted parcel,

$T_{v,env}$ is the virtual temperature of the environment,

R_d is the specific gas constant for dry air

If an air parcel is lifted adiabatically upward, it first moves dry-adiabatically from the starting pressure level to the Lifted Condensation Level (where it becomes saturated) and then moist-adiabatically.

On a thermodynamic diagram CAPE is represented by the area enclosed between the environmental temperature profile and the temperature of an adiabatically rising air parcel, over the layer(s) within which the air parcel temperature is warmer than the environmental temperature (**positive area**).

Definitions of different CAPE values 1

There are different kinds of CAPE indicators. Hungarian forecasters use the following kinds of CAPE values:

Surface Based CAPE (SBCAPE)) [J/kg]

The virtual air parcel is lifted from the surface.

Mixed Layer CAPE (MLCAPE)) [J/kg]

It takes into account the daytime mixing of the boundary layer.

The lowest 100 hPa layer just above the surface is mixed and the virtual air parcel is lifted from the top of this mixed layer with the ‘averaged’ temperature and humidity values. (Average T is calculated from the mean potential temperature, average humidity is the mean mixing rate.)

Most unstable CAPE (MUCAPE)) [J/kg]

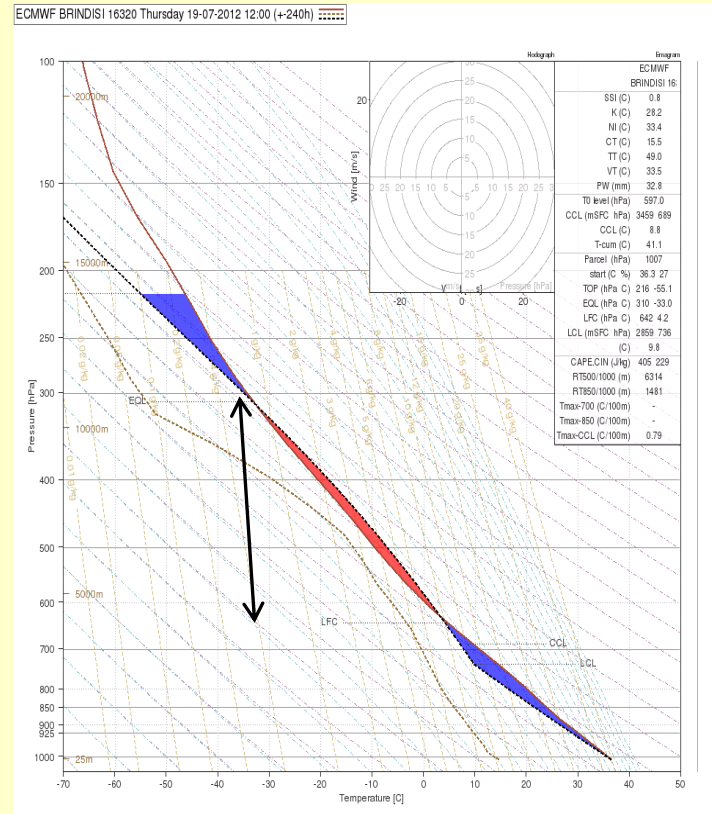
The CAPE value belonging to the most unstable level under 500 hPa is the MUCAPE.

MUCAPE helps to estimate the probability of elevated convection in case of a stable near surface layer (e.g. at night or behind a cold front)

Normalized CAPE (NCAPE) [J/kg/m]

SBCAPE is divided by the height range of the positive area.

NCAPE provides us information on the ‘fatness’ of the positive area. Lower NCAPE means higher probability of entrainment. In case of low NCAPE the entrainment may weaken considerably the updraft speed.



Definitions of different CAPE values 2

Downdraft CAPE (DCAPE)

DCAPE provides an estimation for the maximum energy of the downdraft, outflow wind, supposing that it was caused only by thermodynamic processes.

DCAPE is proportional to the energy of a sinking saturated air parcel when it arrives to the surface. The starting level is the pressure level between 800 and 500 hPa with the lowest equivalent potential temperature (which is often the driest mid-level). It is supposed that the sinking air parcel remains saturated all along its path (until it reach the surface). DCAPE is represented by the area between the moist adiabatic and the environmental temperature curves.

$$DCAPE = \left| R_d \int_{p^1}^{p^{surface}} (T_{v,parcel} - T_{v,env}) d \ln p \right|$$

only if $T_{v,parcel} < T_{v,env}$

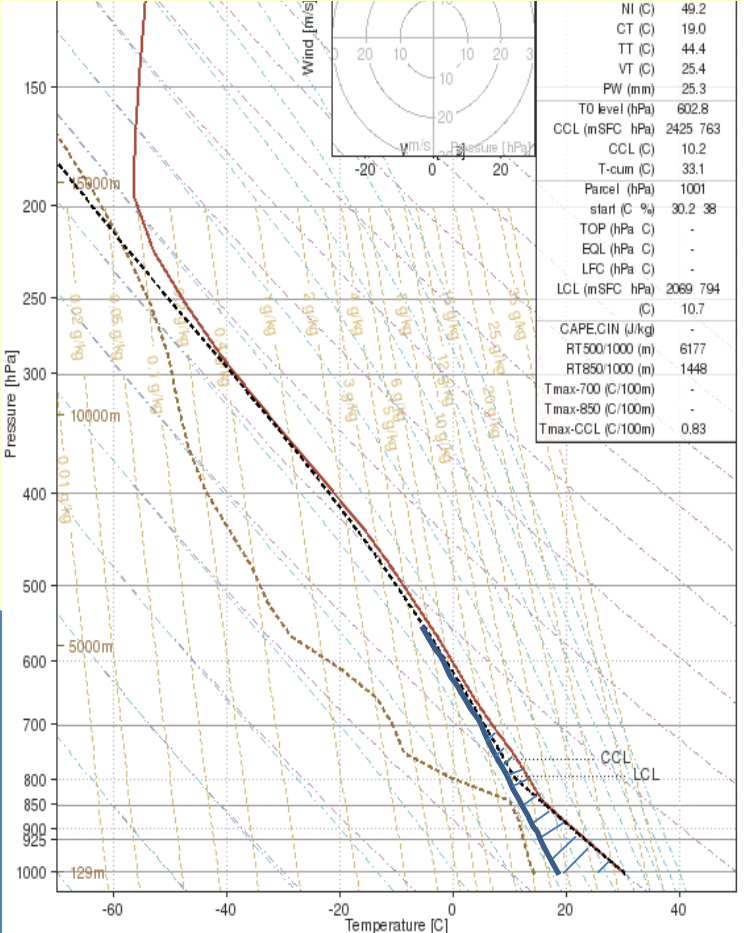
p_1 is the pressure level the air parcel sinks from

NOTE:

There are many other definitions of CAPE values, for example:

ECMWF' CAPE: Lifting the air parcel from all model levels in the lowest 350 hPa. Except for the lowest 30 hPa layer, which is mixed. The maximum value from the different ascents is retained.

'Wyoming' CAPE: The parcel is lifted from the lowest 500 m layer.



From a presentation of a Hungarian forecaster (Kornél Kolláth)

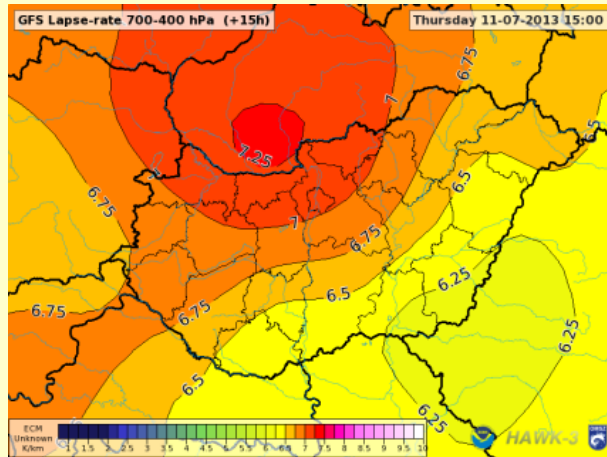
Ingredient Based Method (IBM)

NWP fields

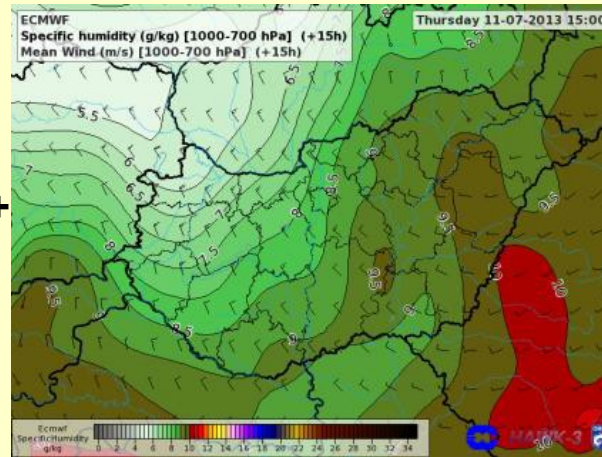
Lapse rate 700-400 hPa [$^{\circ}\text{C}/\text{km}$]

Mean specific humidity 1000-700 hPa

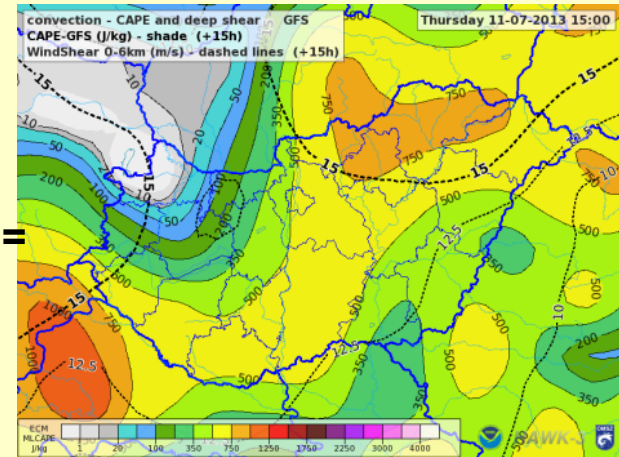
MLCAPE [J/kg]



+



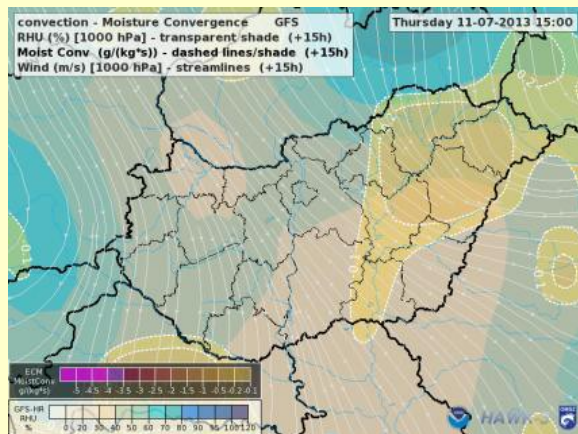
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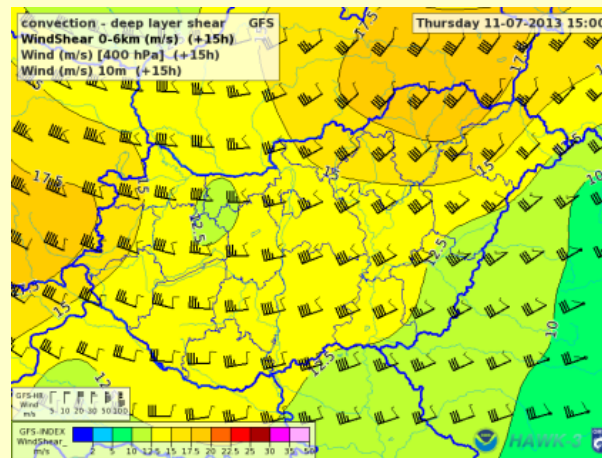
Moisture convergence, lifting

Wind shear (0-6 km)

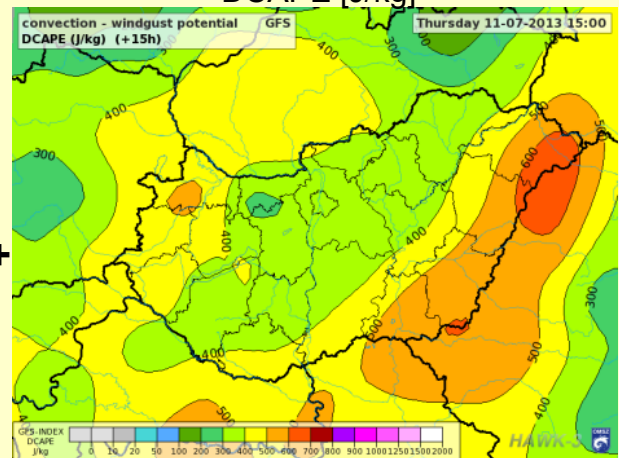
DCAPE [J/kg]



+



+



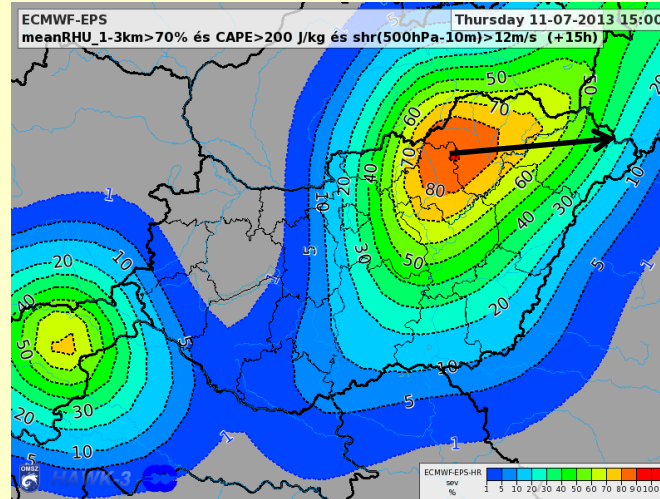
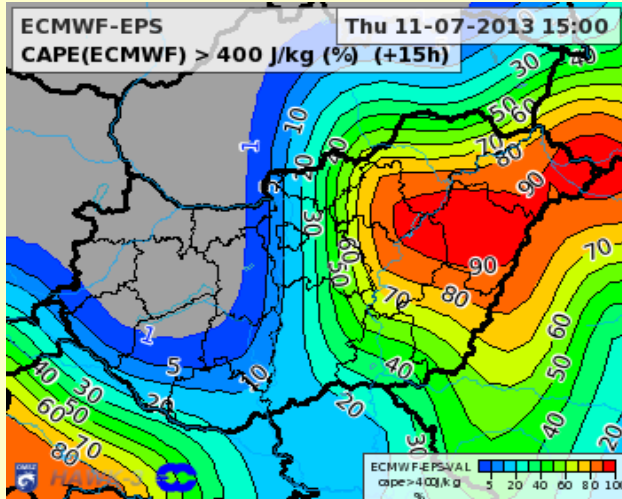
=

= Where is high potential for severe storm formation with potential for strong windgusts?

Probability fields from EPS forecasts

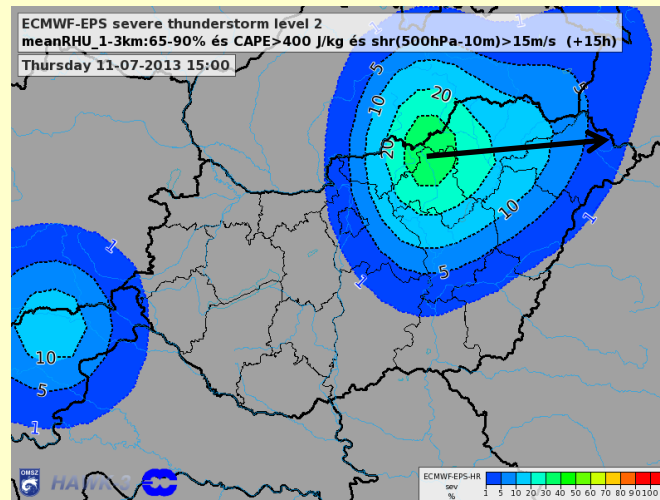
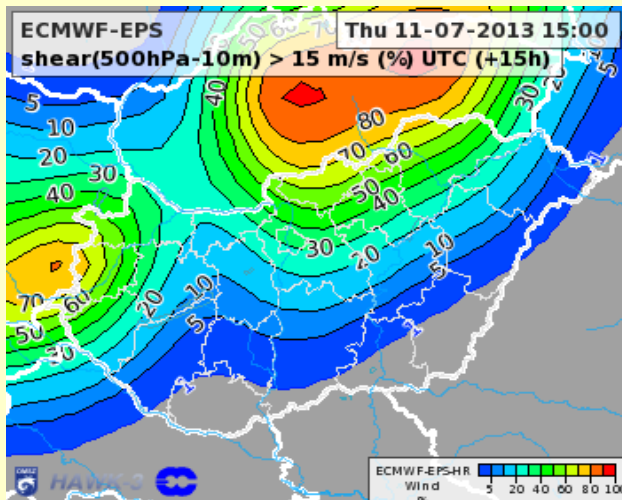
MLCAPE > 400 J/kg

mean RHU (1-3 km) > 70% &
MLCAPE > 200 J/kg &
shear (500 hPa – 10m) > 12 m/s

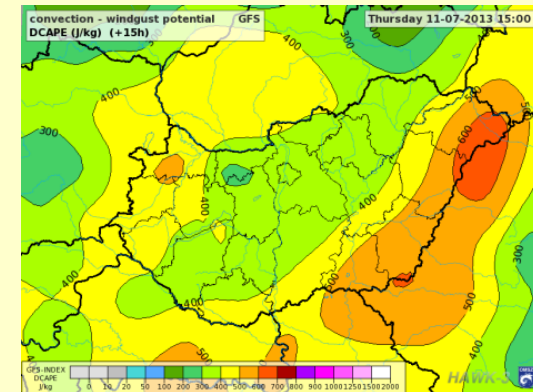


windshear (500 hPa-10m) > 15 m/sec

mean RHU (1-3 km) > 65-90% &
MLCAPE > 400 J/kg &
shear (500 hPa – 10m) > 15 m/s



DCAPE [J/kg]



How we retrieved CAPE parameters from SEVIRI data?

How we get satellite retrieved T and RH profiles for the CAPE calculation?

The **NWCSAF 'Clear Air' algorithm** derives first the [temperature \(T\) and humidity profiles](#), which are [available as optional output](#). We used these satellite retrieved T and humidity profiles.

SAFNWC/MSGv2013 program package

Input: SEVIRI BT in 5 IR channels + ECMWF 3-hourly T and humidity forecasted profiles

The algorithm **interpolates the NWP profiles**
temporally (from 3-hourly to 15 minutes),
spatially (to each 3x3 pixel boxes) and
vertically (to the [43 RTTOV fix pressure levels](#))



ECMWF T and Q (volume mixing ratio) profiles – **background data**



Satellite retrieval



Precipitable Water and instability indices + [satellite retrieved T and Q profiles](#) (at 43 RTTOV fix pressure levels)



CAPE calculating program

The CAPE calculating program needs **T and RH values** at the **surface** (at 2m)! However, we had T and Q values only for the fix RTTOV pressure levels.

We had to interpolate/extrapolate T and Q to the surface pressure --- by using RTTOV in-build modules

2m T and Q data are twice interpolated vertically!

(once by the 'Clear Air' algorithm, once by the CAPE calculating program)

Problem:

As we will see - **SBCAPE is very sensitive to the uncertainty of the surface data.**

- **ECMWF forecast has its uncertainty.**

(summertime for 12 hour forecast RMSE of 2m T = ~ 2K, RMSE of 2m RH = ~8-12 % values

+

systematic errors, under estimation both for 2m T (~-0.5 K) and 2m RH (~0-(-5)%)

- The error of the ECMWF 2mT and 2mQ forecasts might be **further increased by the vertical interpolation.**

- **Satellite retrieving does not change the NWP 2m T and usually has very little effect to the 2m humidity**

Case studies – main features

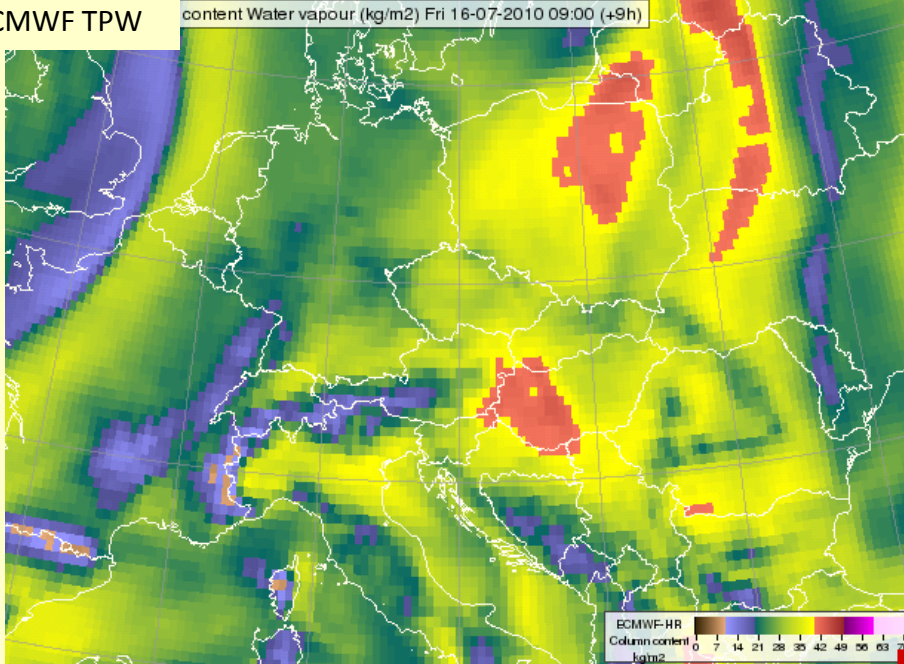
We calculated **SBCAPE**, **MLCAPE**, **MUCAPE**, **NCAPE**, **DCAPE** values from

- the T and Q profiles of the **background** ECMWF data
- the **satellite retrieved T and Q profiles**

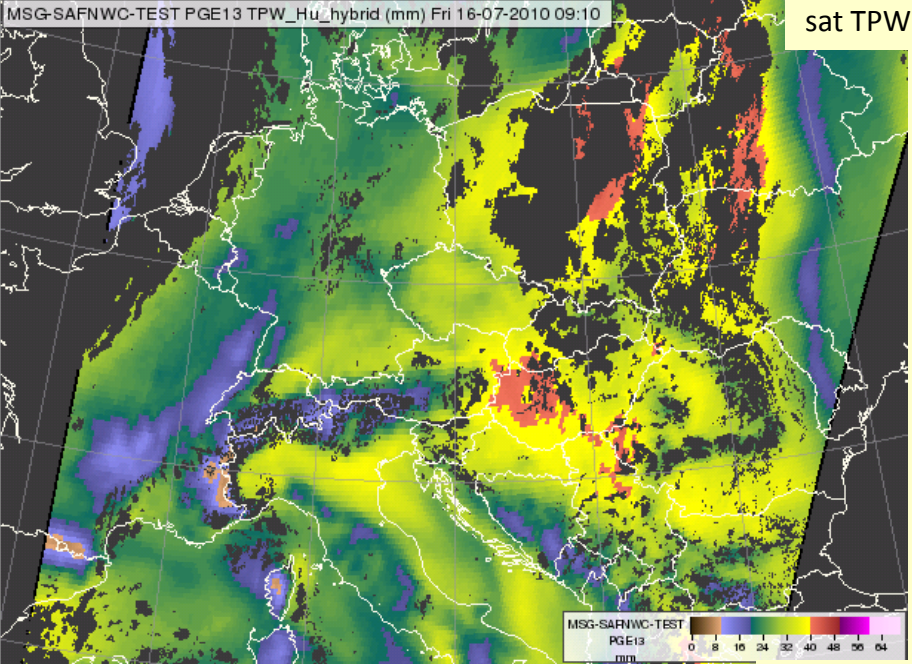
8 days were processed, 15-minute daytime data during 12- 8 hours each day

2005	July	29
2006	June	19
2007	July	16
2007	August	16
2010	May	25
2010	July	16
2010	August	13
2012	July	29

ECMWF TPW

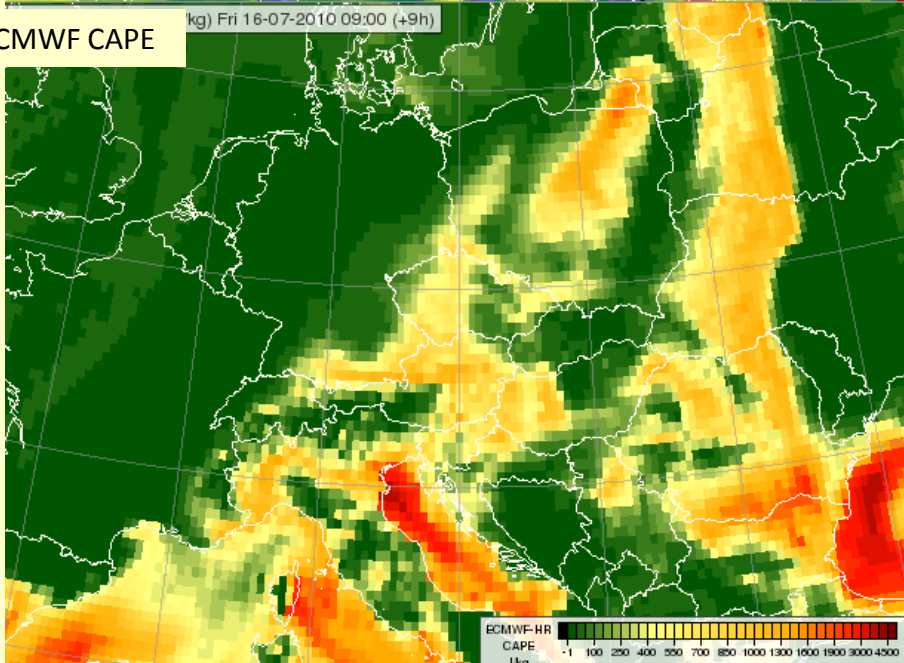


MSG-SAFNWC-TEST PGE13 TPW_Hu_hybrid (mm) Fri 16-07-2010 09:10

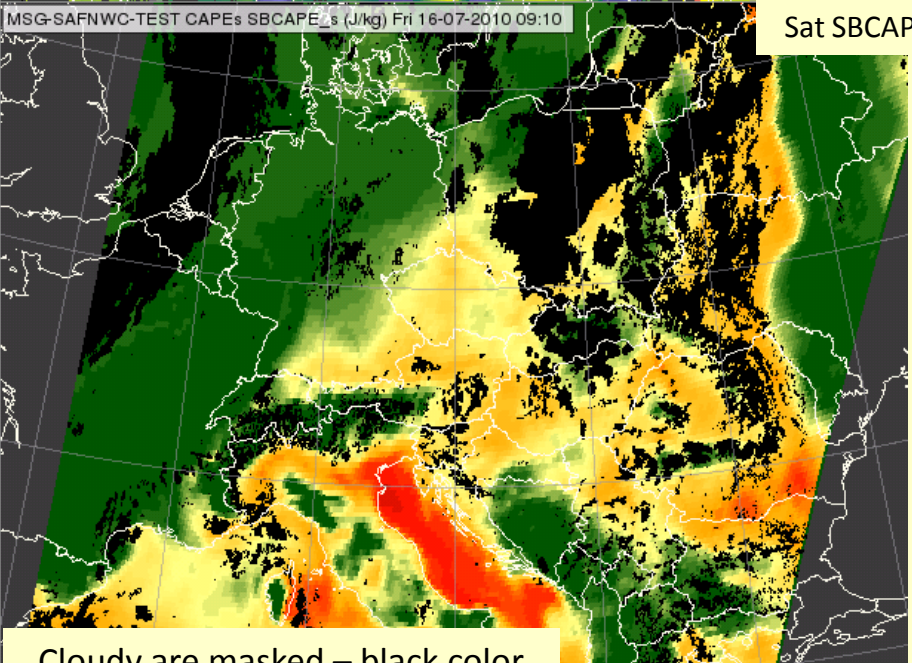


sat TPW

ECMWF CAPE



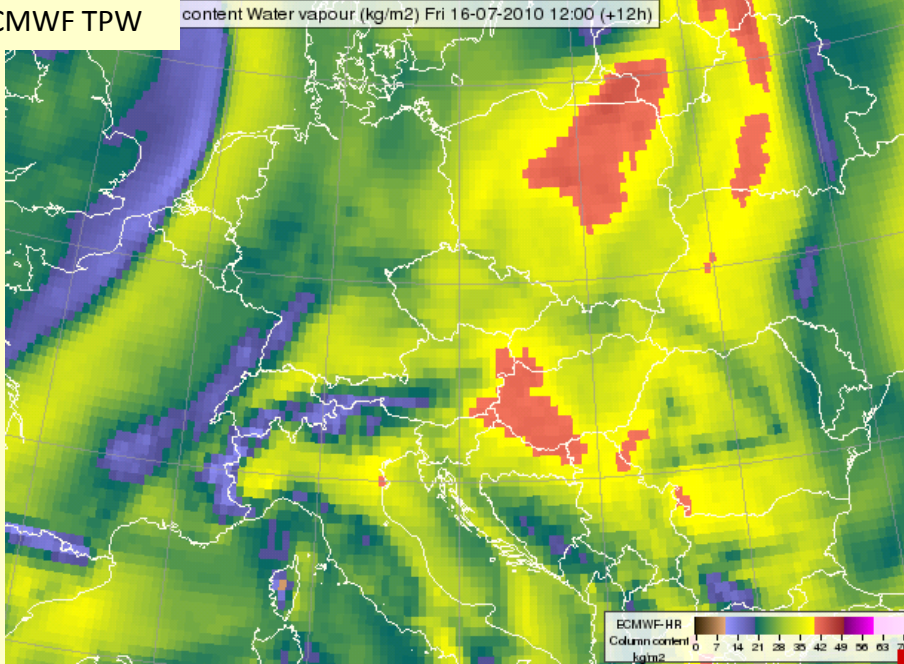
MSG-SAFNWC-TEST SBCAPE_s (J/kg) Fri 16-07-2010 09:10



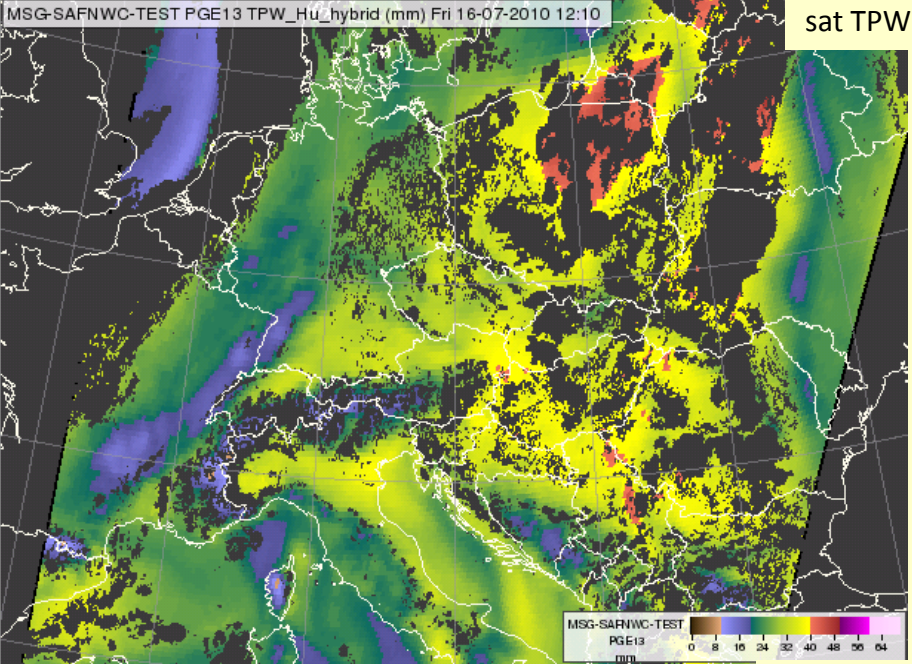
Sat SBCAPE

Cloudy are masked – black color

ECMWF TPW

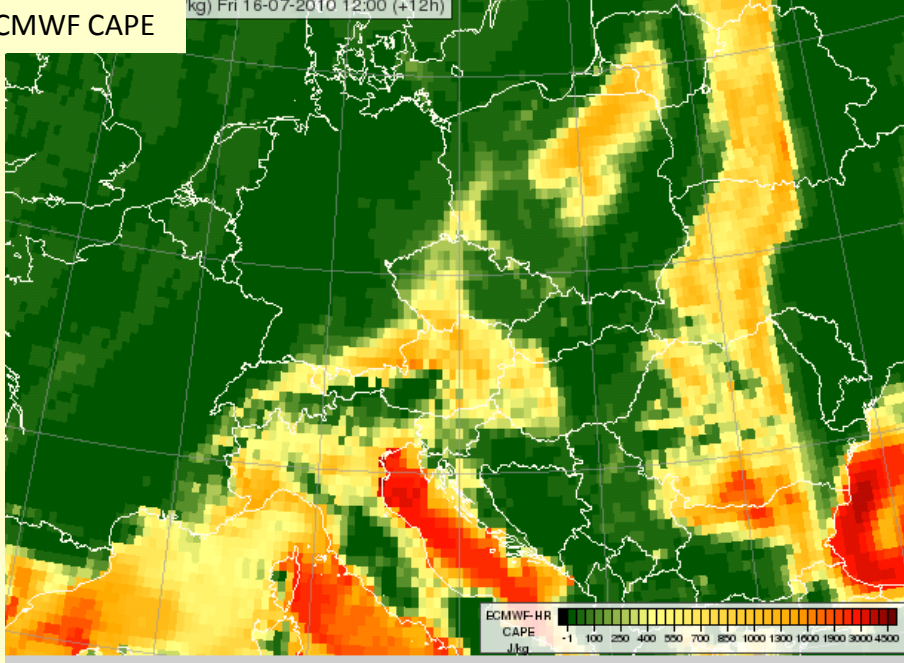


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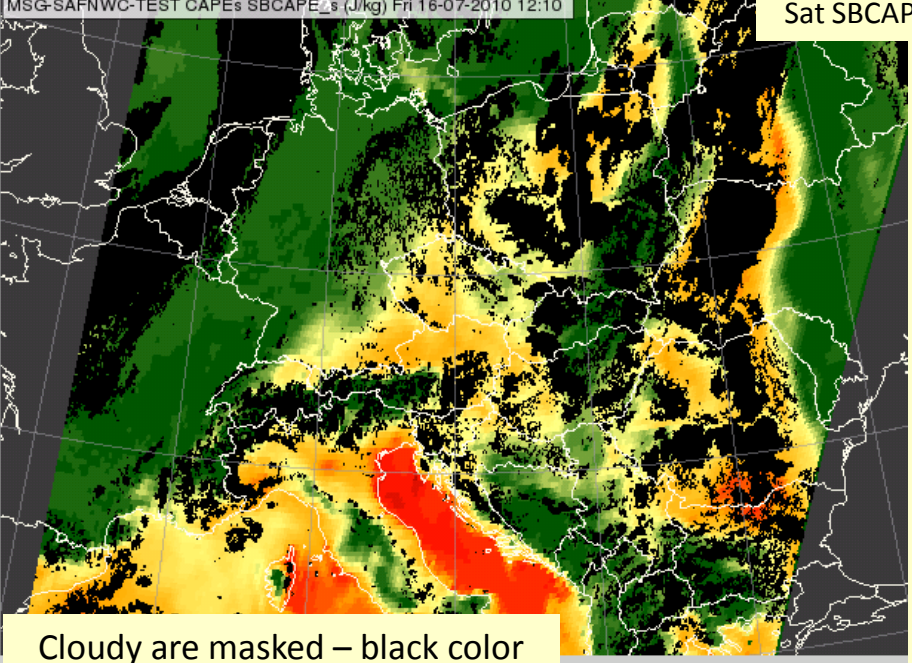


sat TPW

ECMWF CAPE

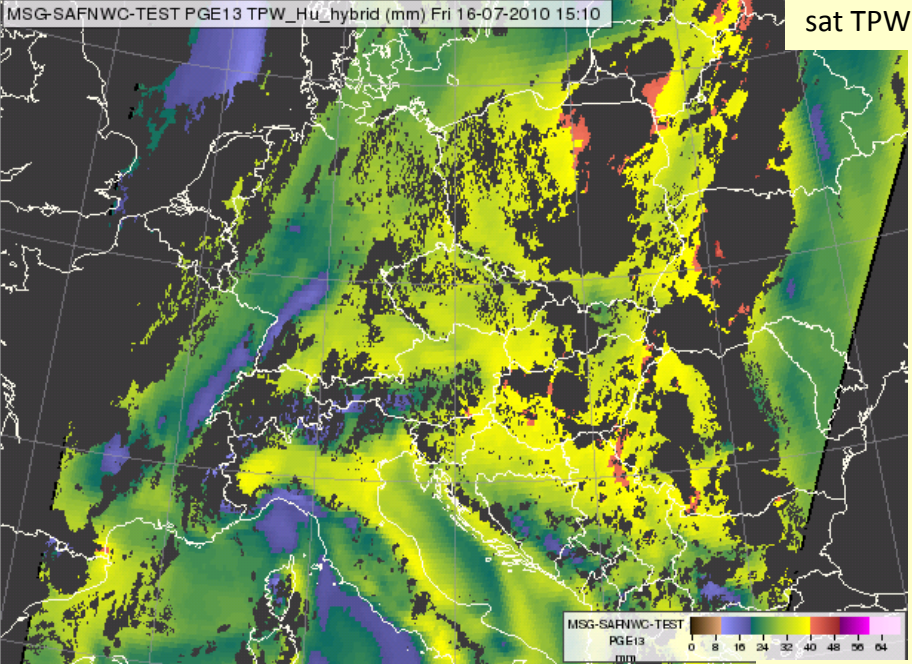
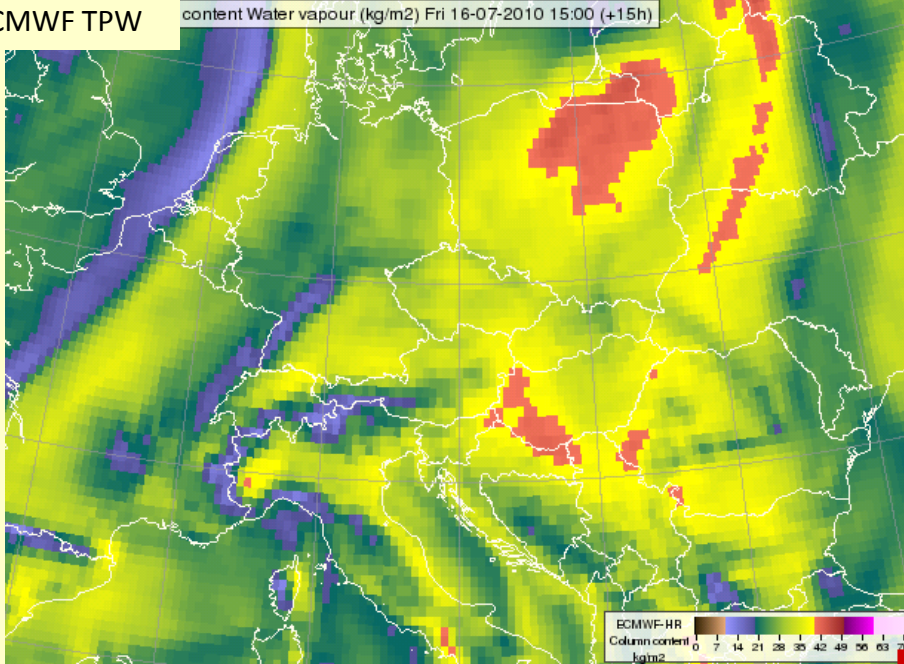


MSG-SAFNWC-TEST CAPEs SBCAPE_s (J/kg) Fri 16-07-2010 12:10



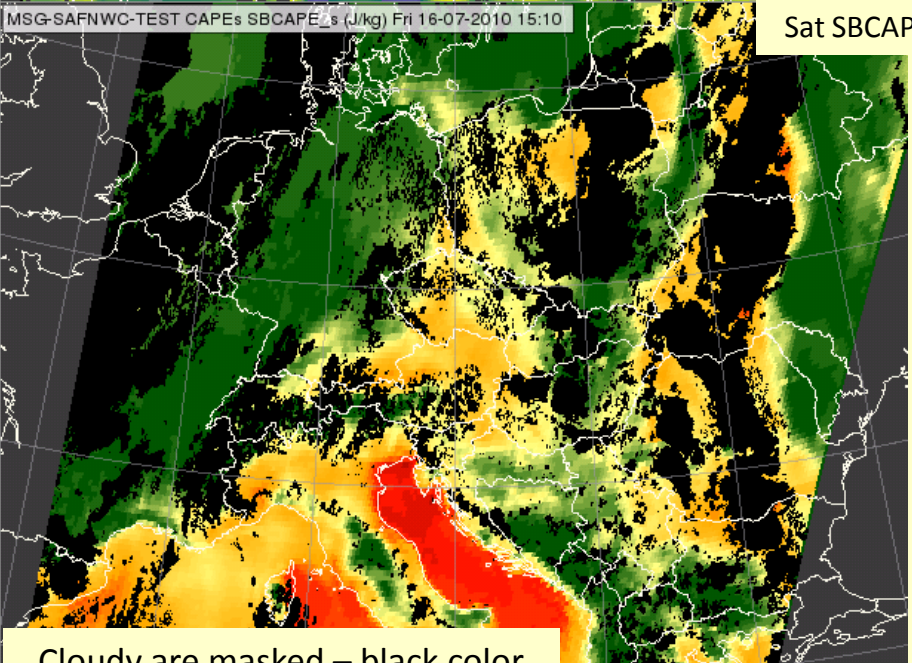
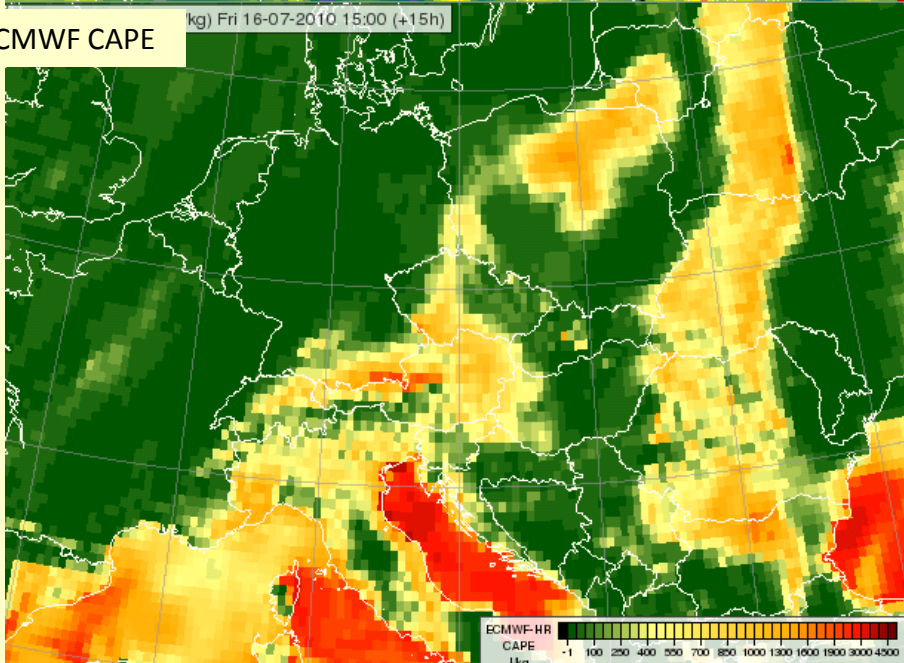
Sat SBCAPE

ECMWF TPW



sat TPW

ECMWF CAPE

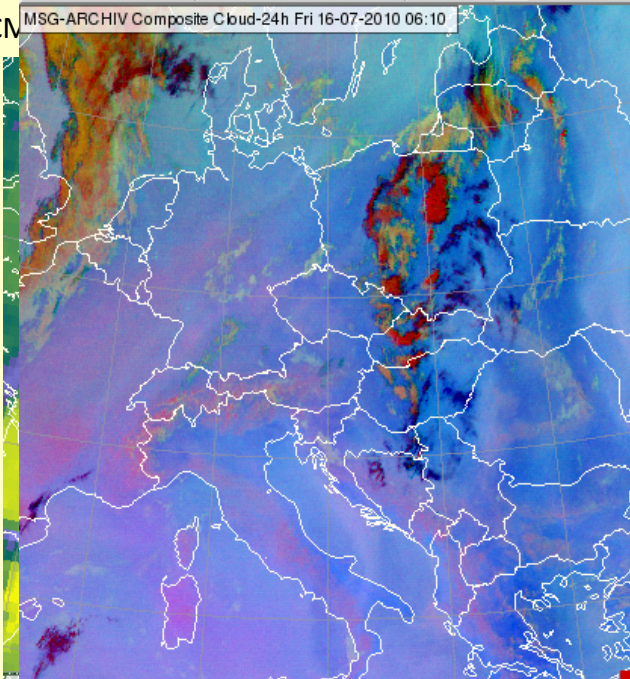


Sat SBCAPE

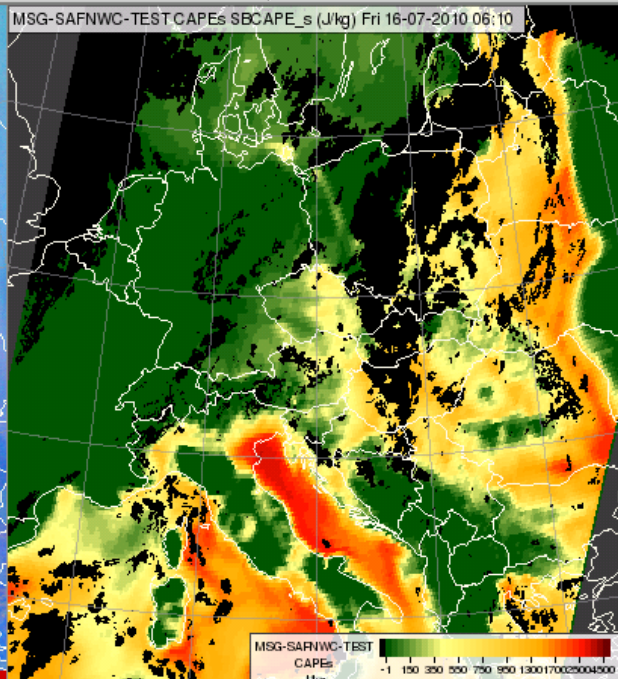
Cloudy are masked – black color

ECN

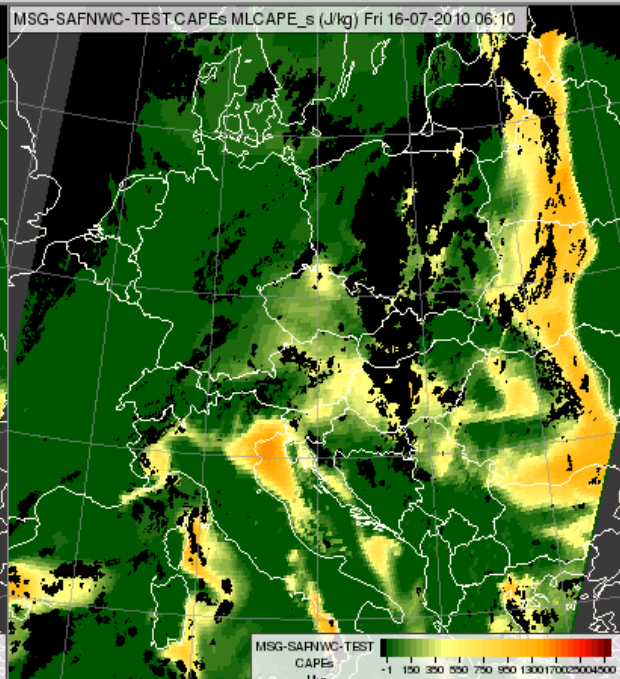
MSG-ARCHIV Composite Cloud-24h Fri 16-07-2010 06:10



MSG-SAFNWC-TEST CAPES SBCAPE_s (J/kg) Fri 16-07-2010 06:10

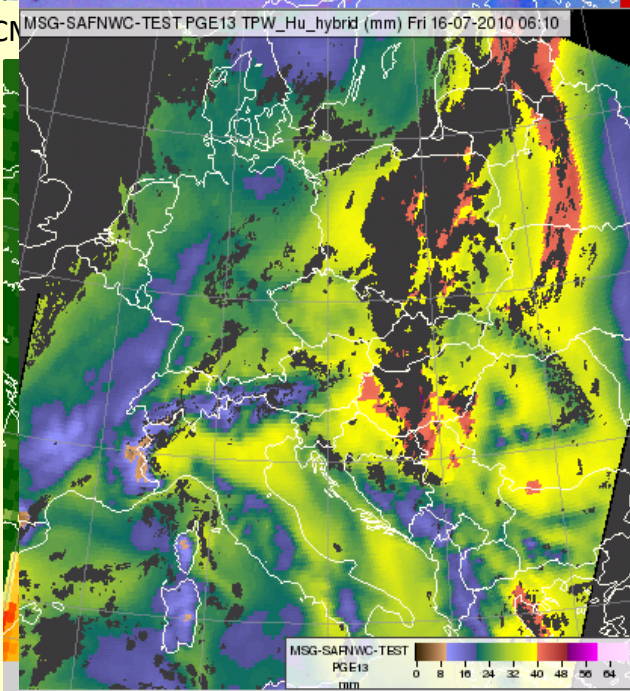


MSG-SAFNWC-TEST CAPES MLCAPE_s (J/kg) Fri 16-07-2010 06:10

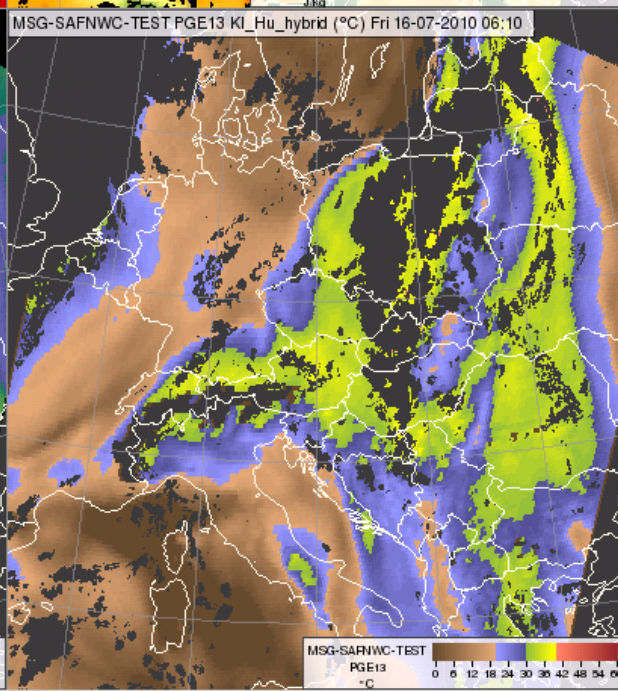


ECN

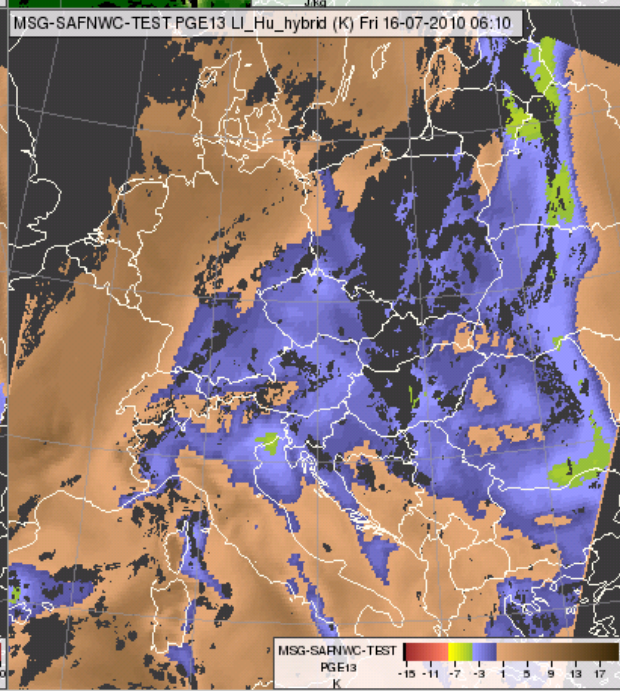
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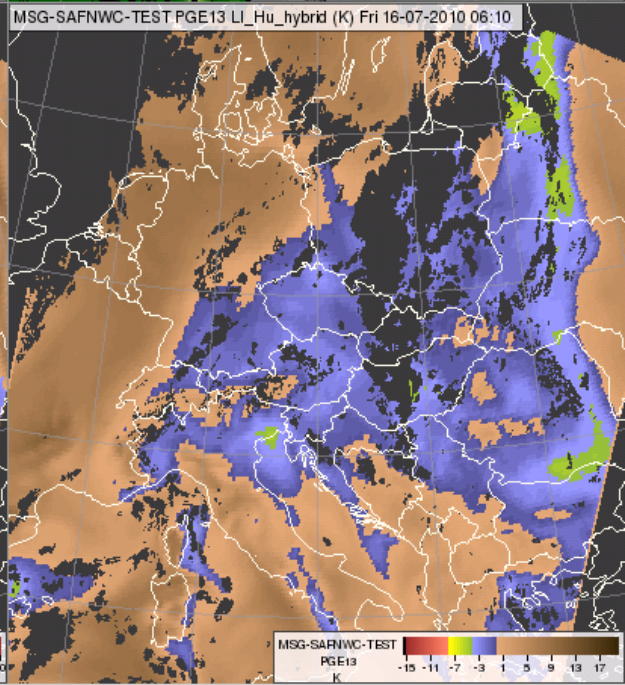
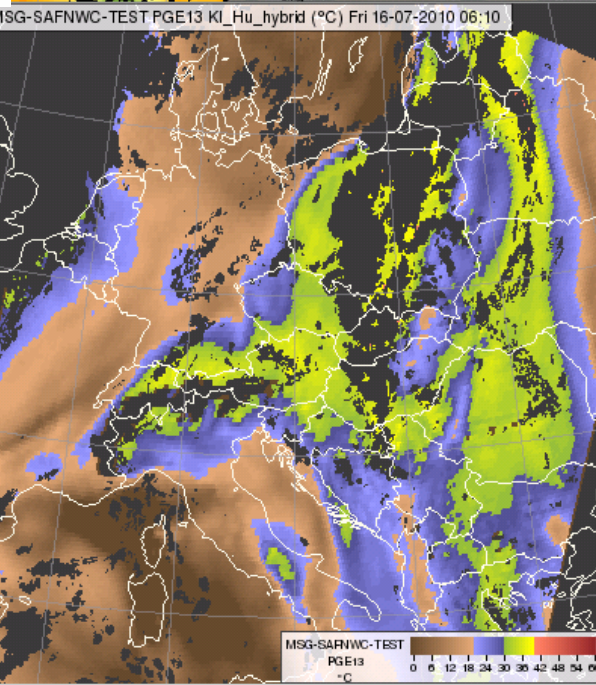
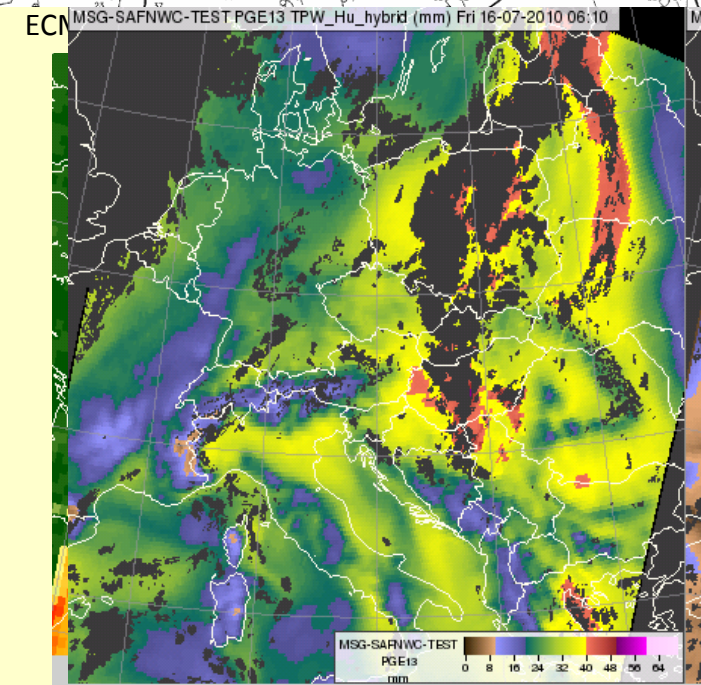
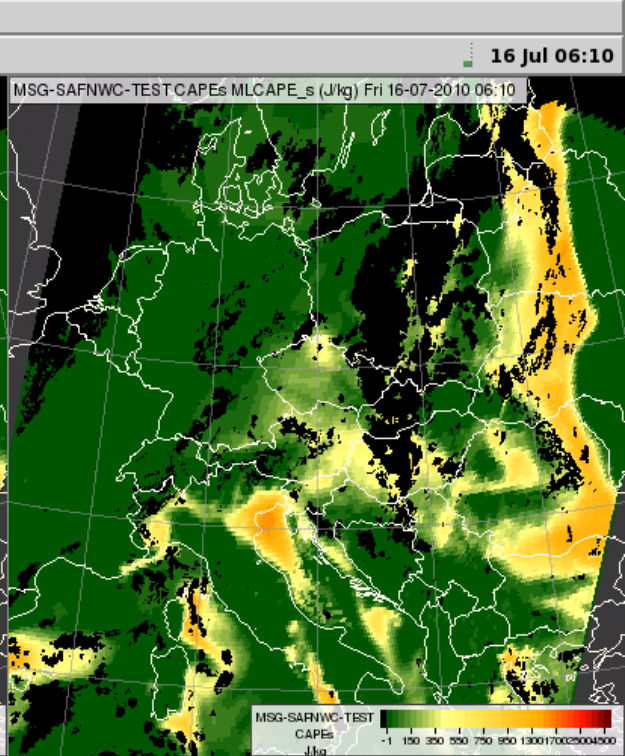
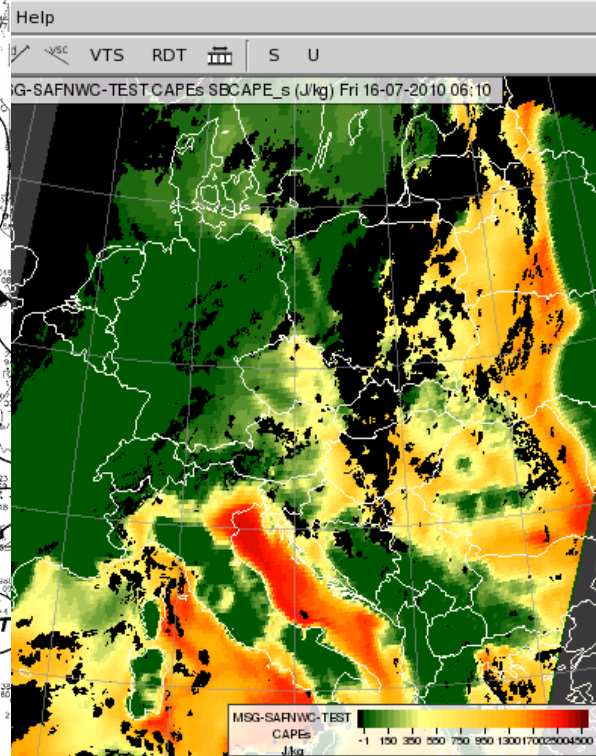
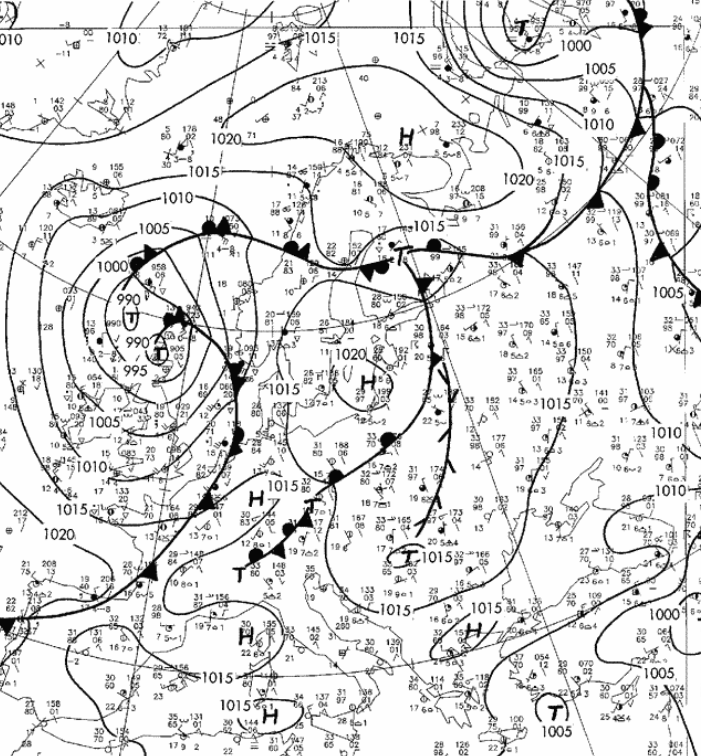


MSG-SAFNWC-TEST PGE13 KI_Hu_hybrid (°C) Fri 16-07-2010 06:10

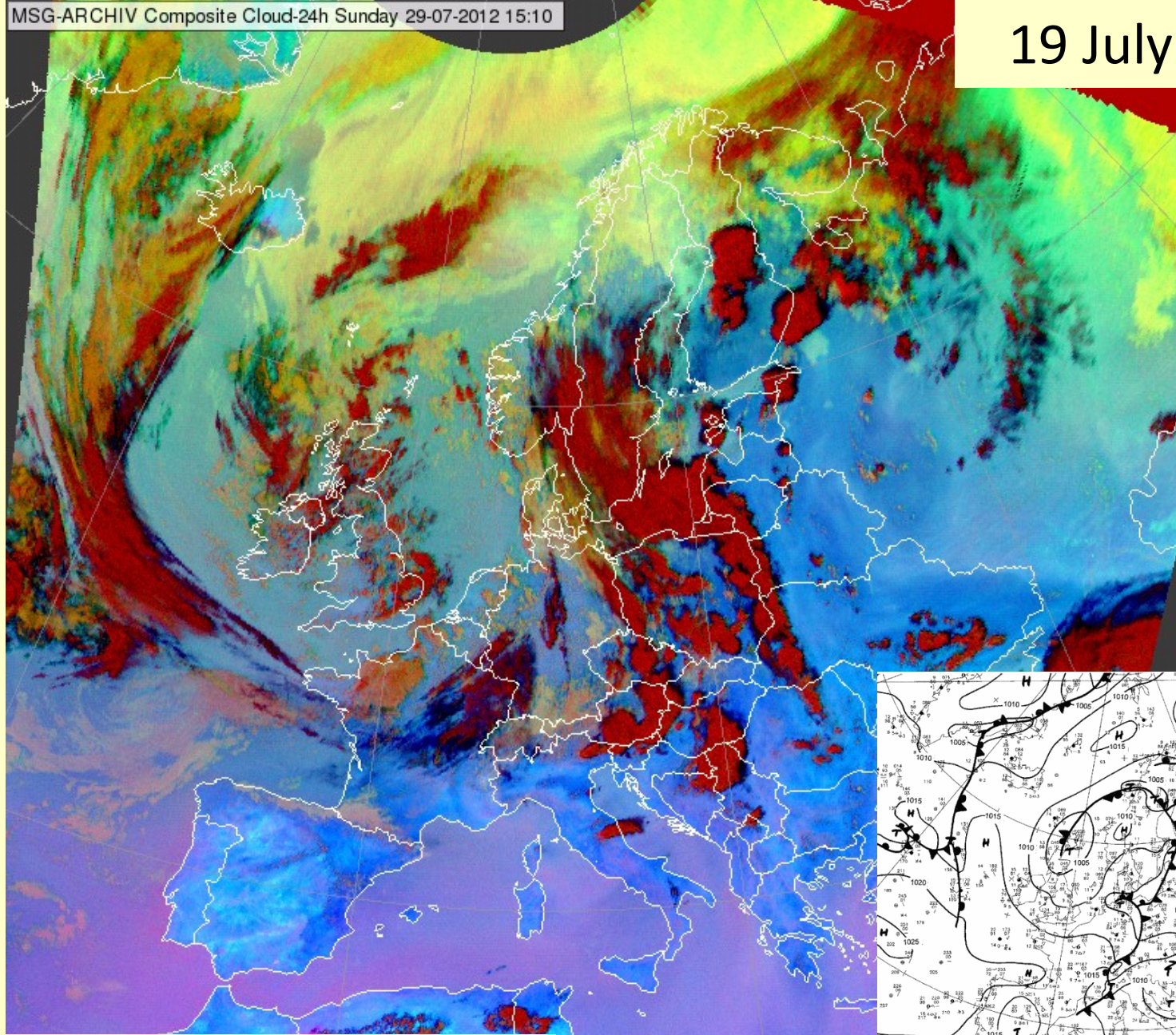


MSG-SAFNWC-TEST PGE13 LI_Hu_hybrid (K) Fri 16-07-2010 06:10

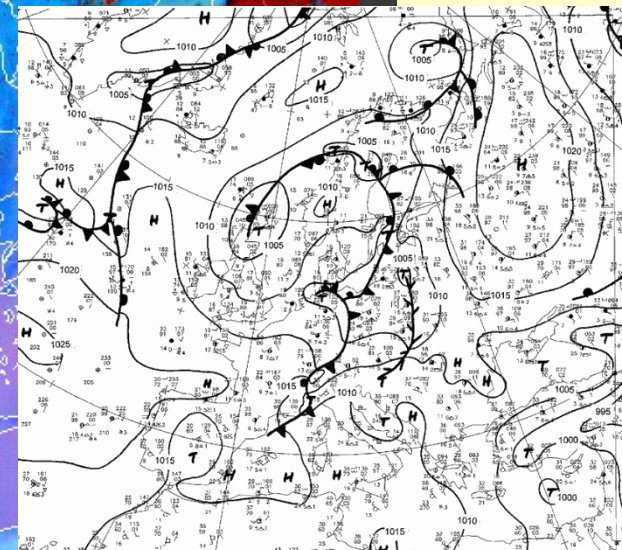




19 July 2012



Convergence line over Hungary

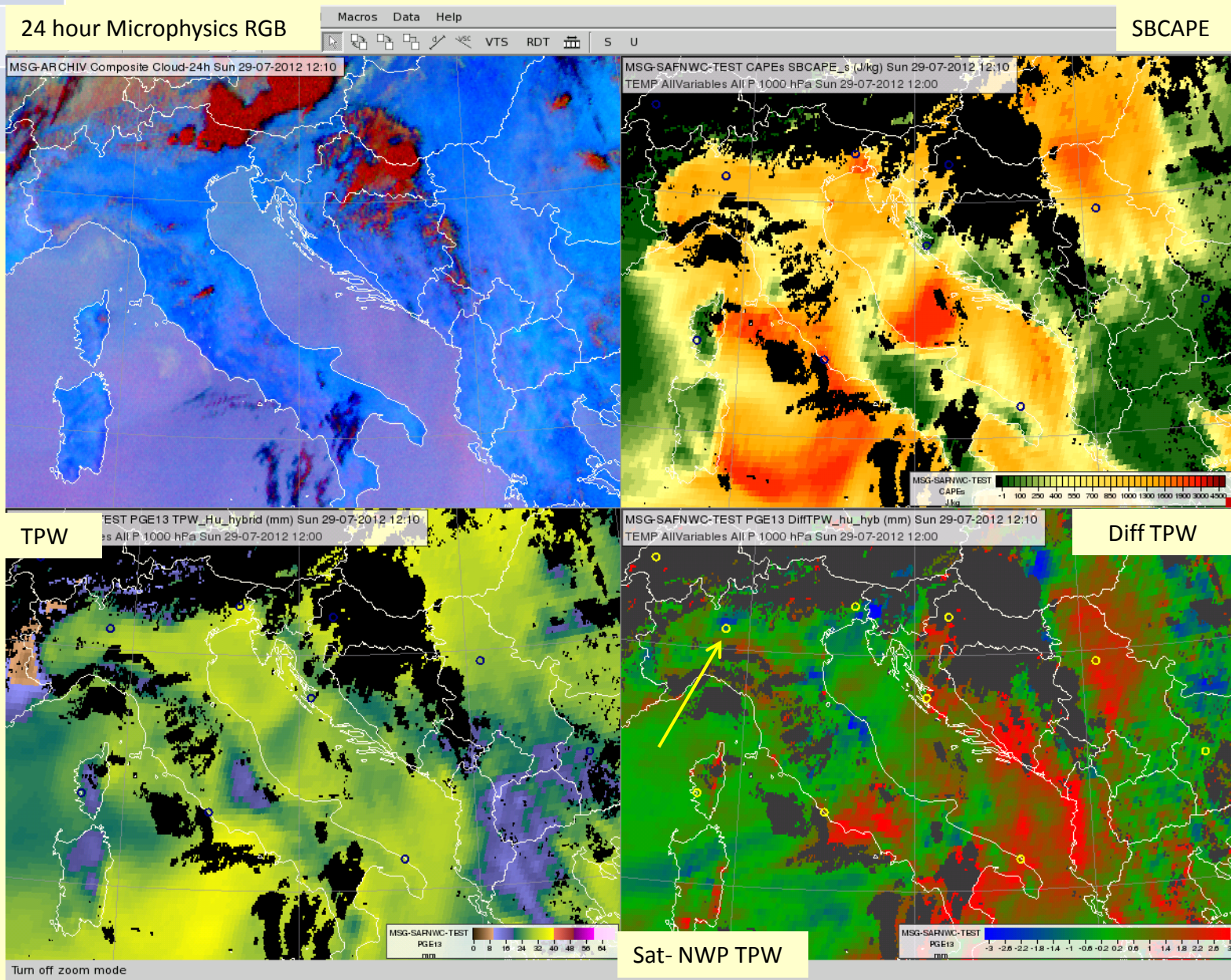


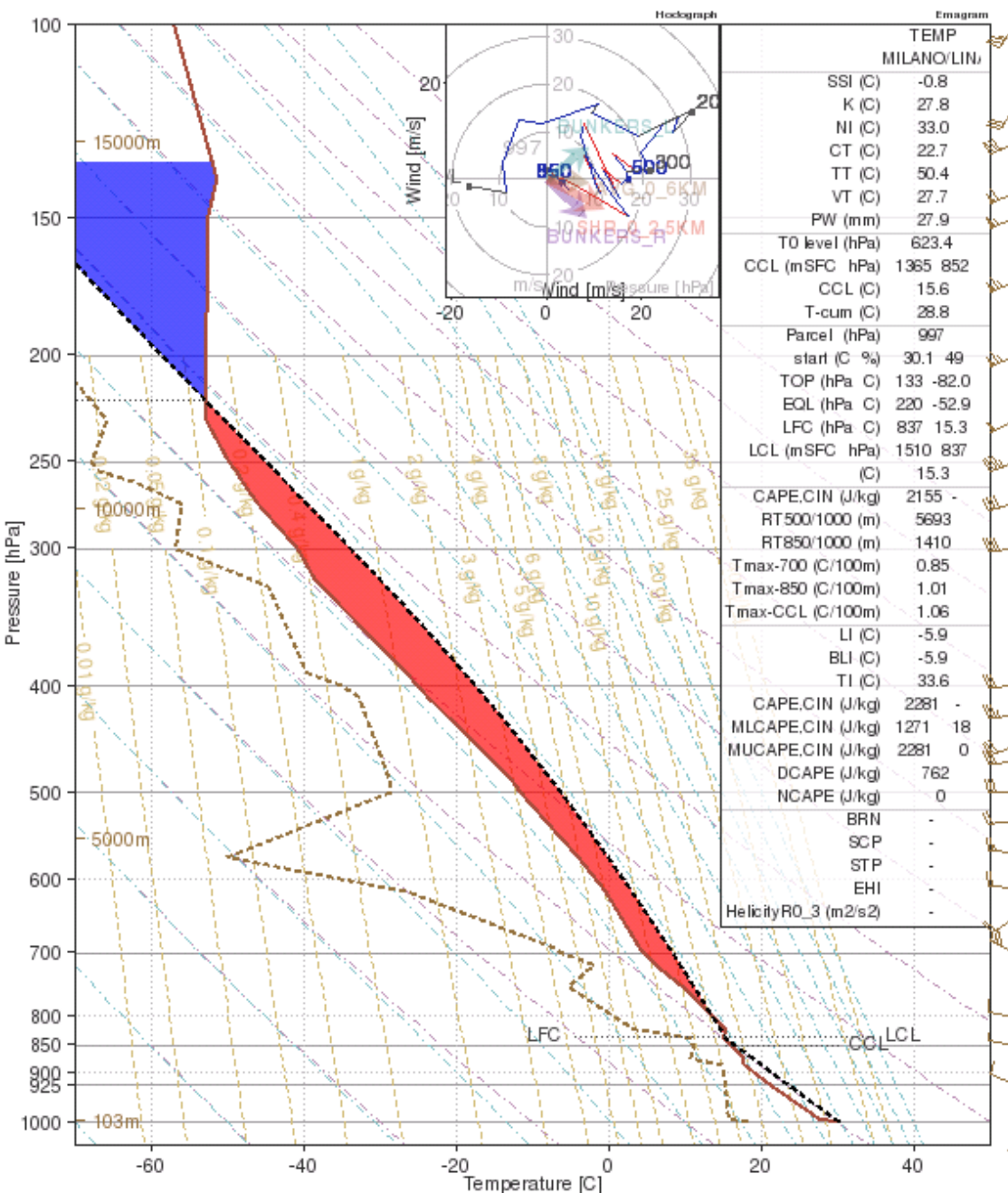
Surface chart 12 UTC

	Milano
radiosonde TPW	27.9
Sat TPW	28.8
Background TPW	29.2

Comparison with radiosonde data

The satellite retrieval decreases the forecasted TPW. ☺



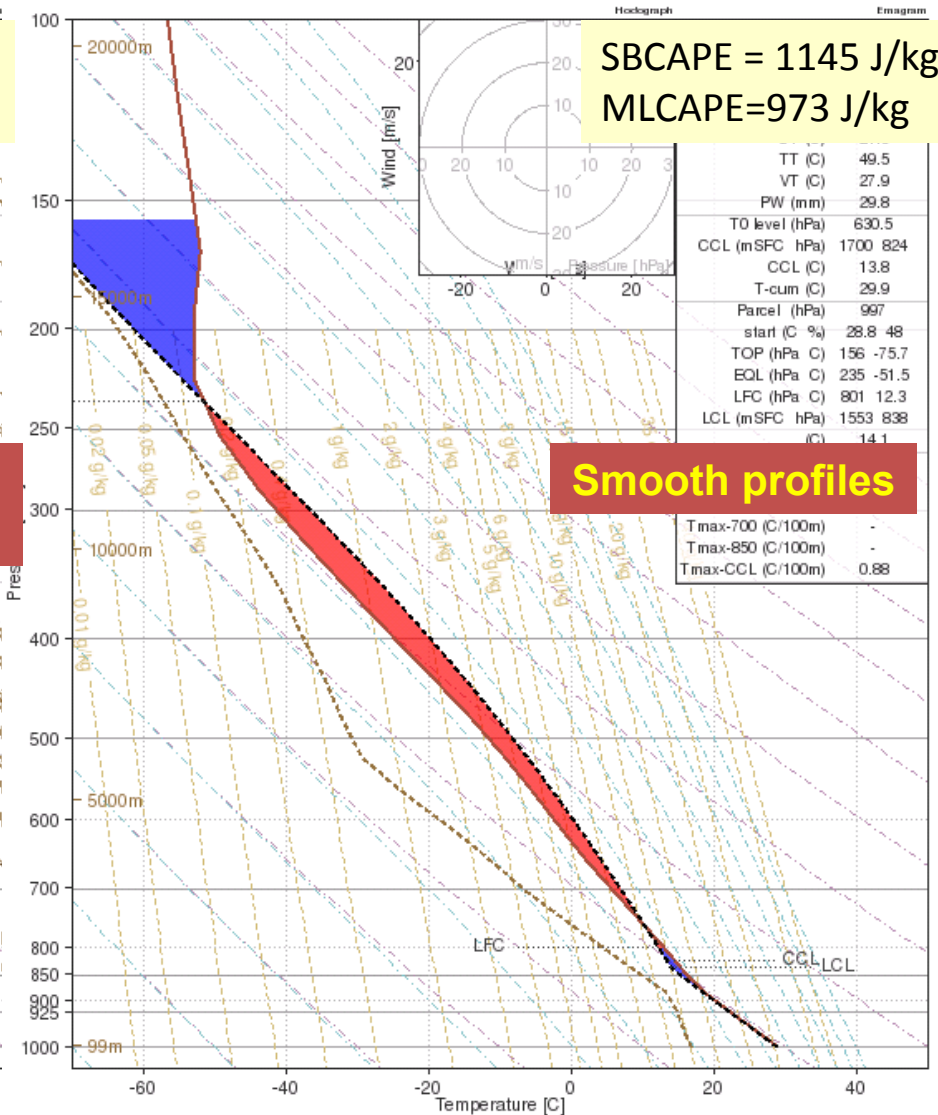
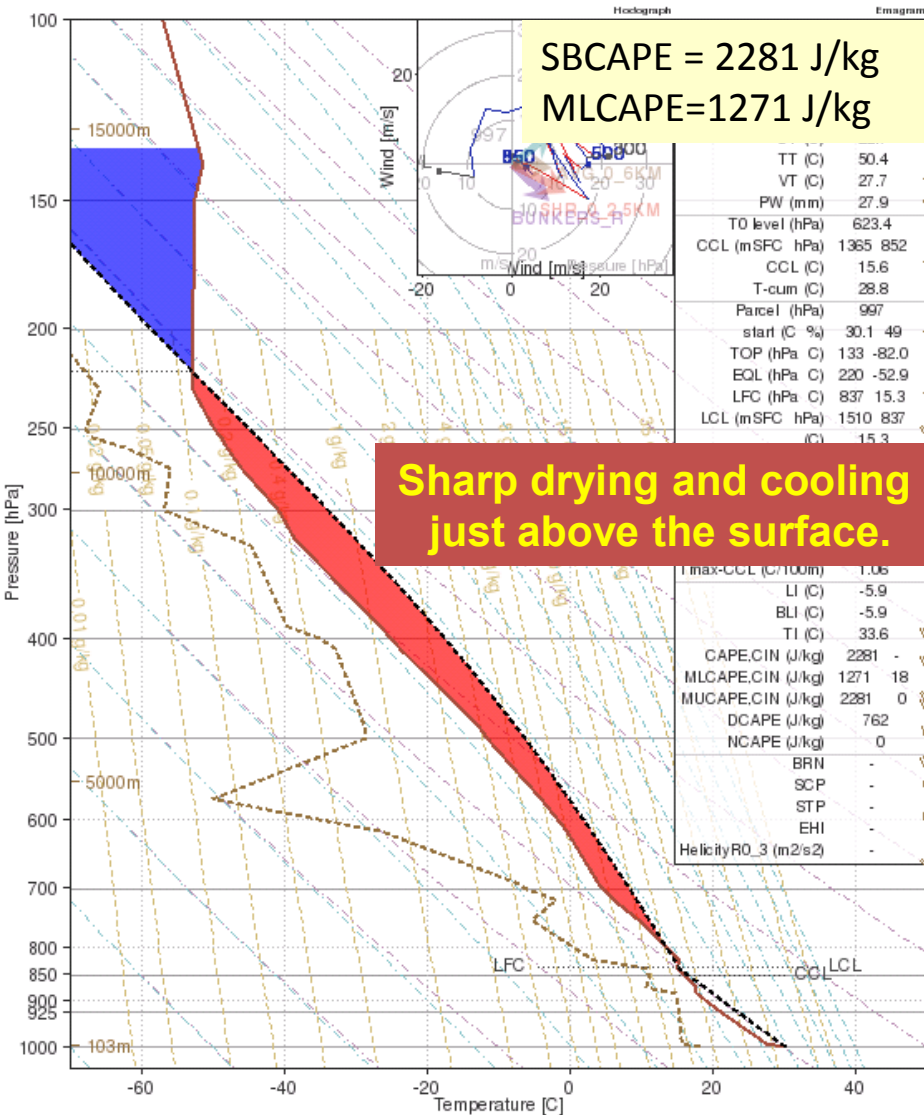


Milano radiosonde

Sat retrieval decreases the forecasted TPW. ☺ (The CAPEs increased.)

Wyoming CAPE is much lower than the radiosonde derived SBCAPE, because of the sharp drying and cooling just above the surface.

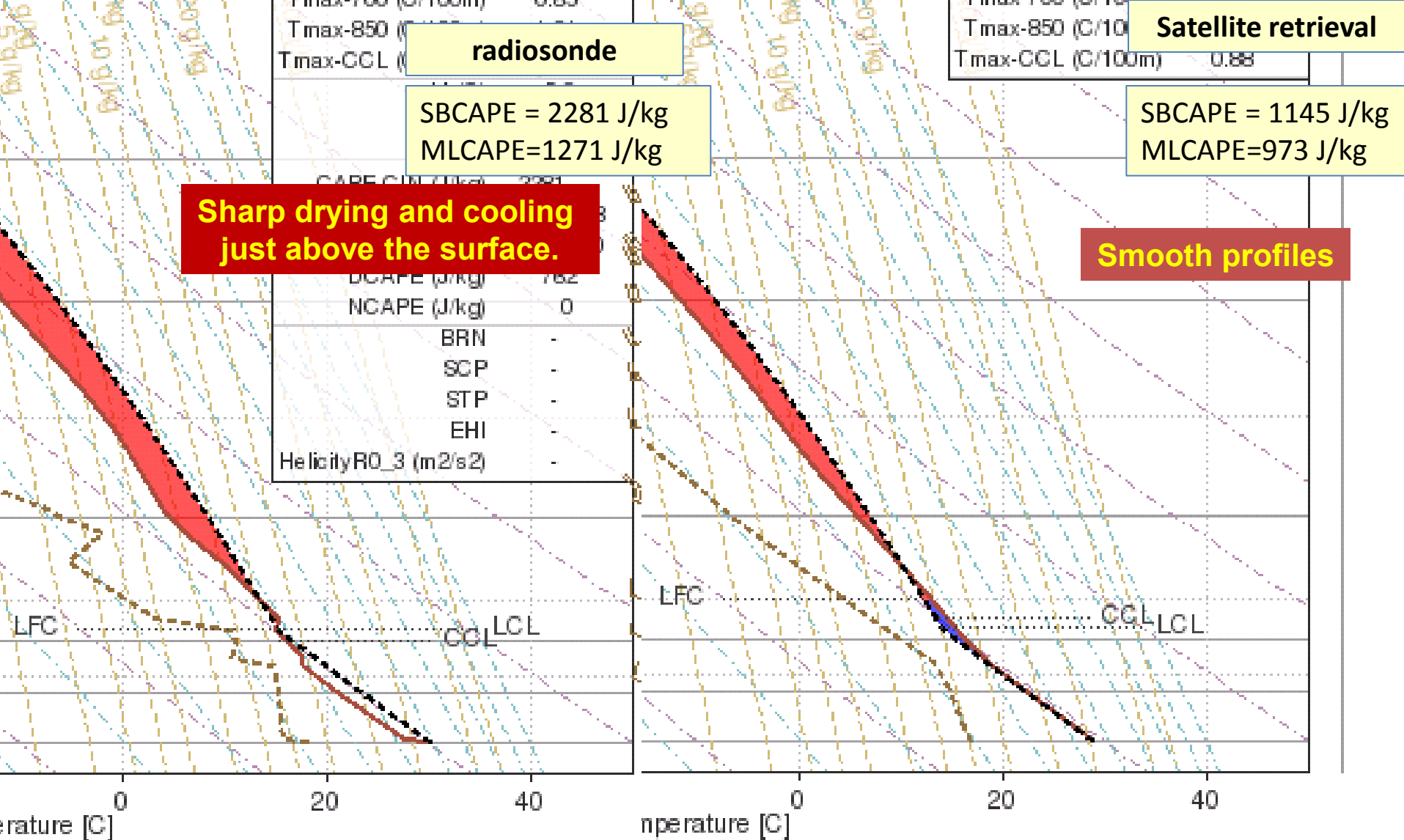
	Radiosonde	Satellite retrieval	Derived from background data
TPW	27.9	28.8	29.2
Wyoming CAPE	1078		
SBCAPE	2281	1145	992
MLCAPE	1271	973	868
MUCAPE	2281	1145	992
DCAPE	762	540	517
NCAPE		0.112	0.1



MLCAPE is better than SBCAPE.

CAPE is very sensitive to the initial state of the lifted virtual air parcel.
It is easier to estimate/retrieve an average value of a layer than the actual value of a level.

surface is drier and colder
The moist adiabat curve is lower



MLCAPE is better than SBCAPE.

CAPE is very sensitive to the initial state of the lifted virtual air parcel.
It is easier to estimate/retrieve an average value of a layer than the actual value of a level.

surface is drier and colder
The moist adiabat curve is lower

Conclusions of the case studies

The satellite retrieved CAPE fields are in good correspondence with the NWP fields and the synoptic situation.

The radiosonde derived SBCAPE values **often strongly differ** from the

- satellite retrieved SBCAPE values or from the

- SBCAPE values derived from the background ECMWF data.

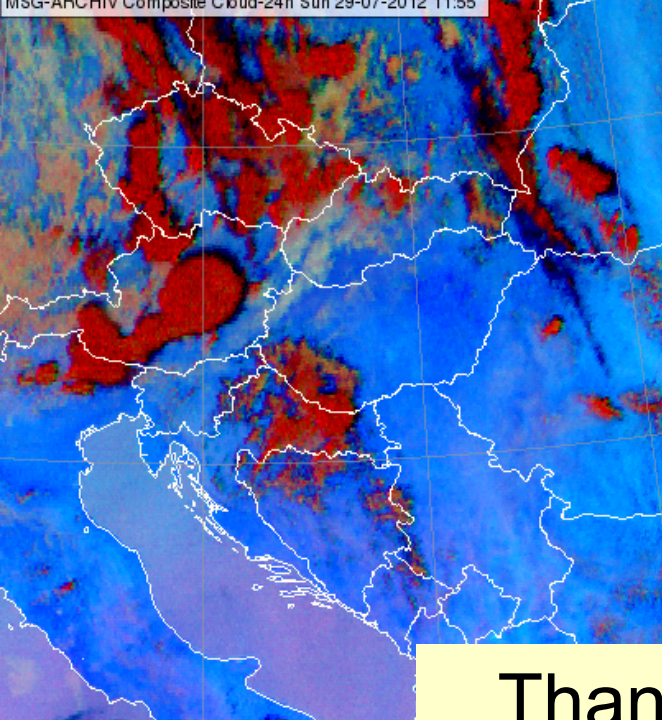
For MLCAPE and DCAPE the differences were smaller, but still high.

Why are the differences so high?

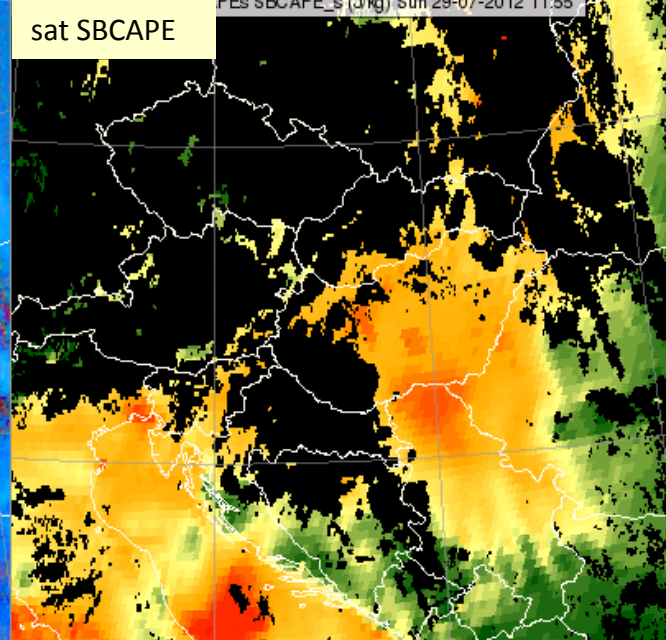
- The radiosonde measurement is lasting around one hour and the radiosonde may float far away. However, we compared the radiosonde derived CAPE values with the CAPE values derived from the profiles of a 3x3 pixel area of one slot.
- The NWP profiles are typically smoother than the radiosonde measured ones, first of all the humidity profiles. The correction made by the satellite retrieval algorithm is also smooth. **The details of the actual shape of the profiles may affect (sometimes strongly) the CAPE values.**
- SBCAPE showed the largest differences from the radiosonde derived ones.
 - The NWP forecast uncertainties are quit high at 2m height.
 - We work only with cloud-free areas. The temperature and humidity uncertainty above a sunlit summer surface is even higher.
 - Vertical interpolations might increase further the uncertainty.
- Satellite measurements provide information on the mid- and high-level humidity and some of the low-level humidity as well, but very limited information on the 2m T and humidity. So satellite retrieval cannot improve the profile at 2m.

A **sensitivity analyses** of the CAPE values may help to understand the reasons of these big differences.

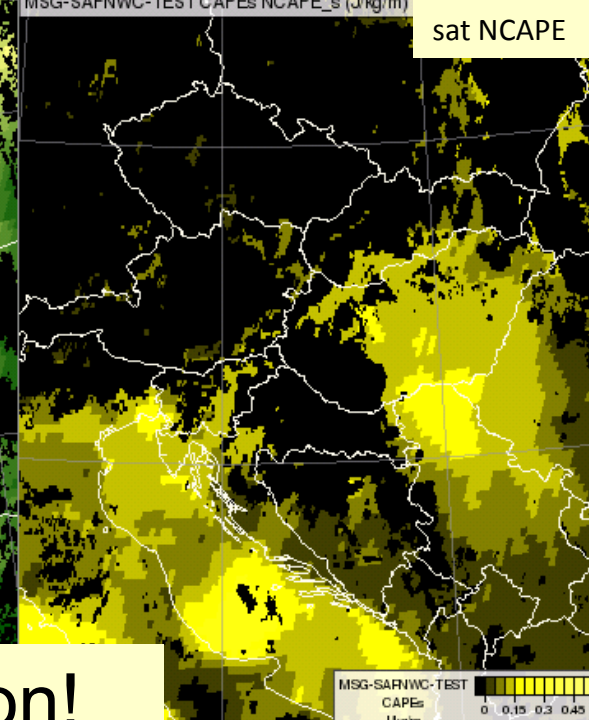
MSG-ARCHIV Composite Cloud-24h Sun 29-07-2012 11:55



sat SBCAPE



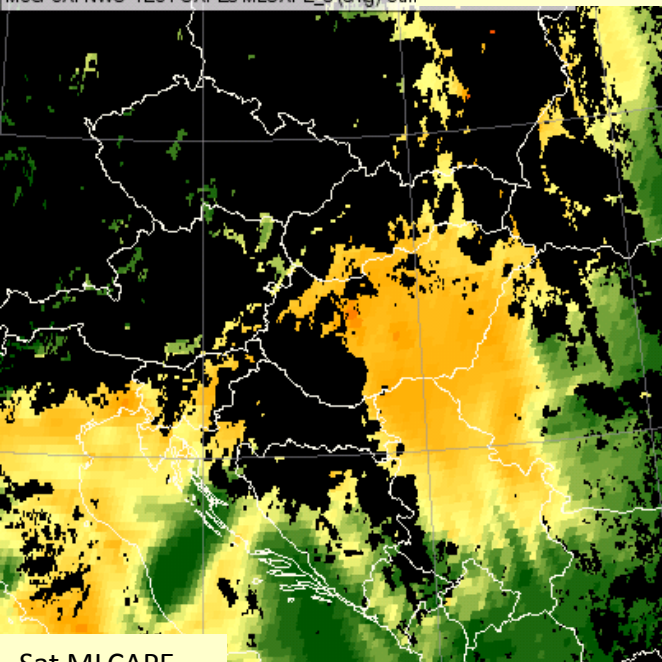
FES SBCAPE_s (J/kg) Sun 29-07-2012 11:55



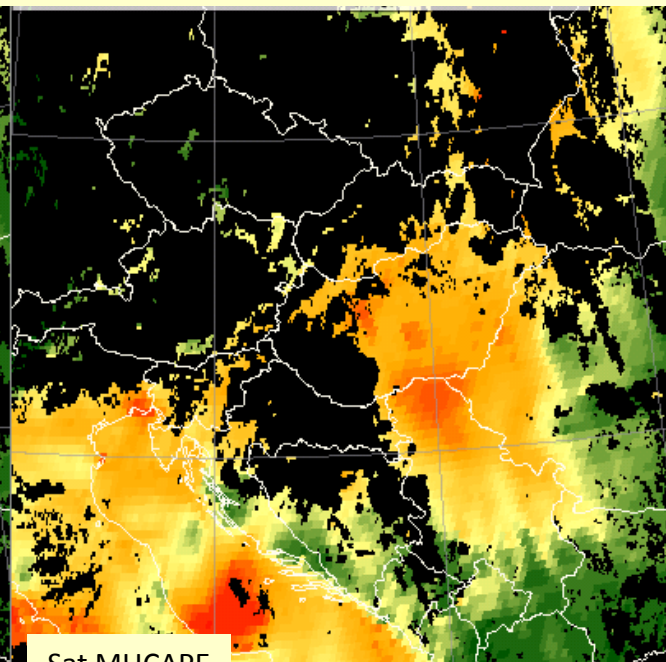
MSG-SARNWC-TEST CAPES NCAPE_s (J/kg/m)

Thank you for the attention!

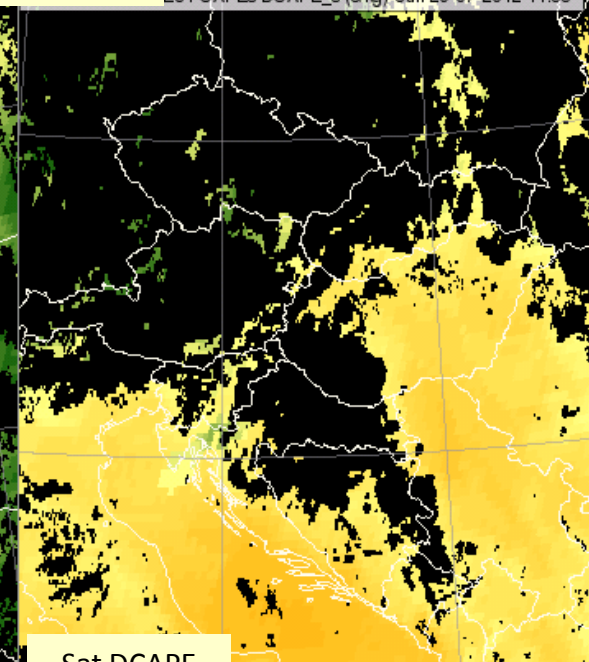
MSG-SARNWC-TEST CAPES MLCAPE_s (J/kg) Sun



MSG-SARNWC-TEST



MSG-SARNWC-TEST



MSG-SARNWC-TEST

EST CAPES DCAPE_s (J/kg) Sun 29-07-2012 11:55

