Evaluation of IASI convective parameters –merging with Synop data

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Hungarian Meteorological Service

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This work was done in part of a EUMETSAT study, Contract number EUM/CO/18/4600002186/TA

WHERE ARE YOU FROM AND WHAT DO YOU DO?

Forecaster

Researcher

Trainer

Manager

Other

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Motivation

- MTG-S IRS will have sounding data from GEO orbit in 30 minute resolution – similar retrieval as IASI L2 – proxy for IRS
- IASI L2 EARS – data available within 30 minutes after sensing

↓

Good opportunity to start exploring the data and look into the potential usage

(Novelty – if we want to use the IRS from day1 we need to prepare and train ourselves and the forecasters)

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What indices was decided to be calculated from IASI? (Try to guess)

- Total Pecipitable Water (TPW),
- Layer precipitable water (BL, ML, HL),
- mean relative humidity in the lowest 0-3 km width layer (0-3km RH),
- K-index,
- Lifted Index,
- Best lifted index,
- Maximum Buoyancy,
- DTHETAE,
- SBCAPE,
- MLCAPE,
- MUCAPE,
- lowest 100 hPa lapse rate
- 400/700 hPa lapse rate,
- 600/925 hPa lapse rate,
- Td depression 2-8 km.

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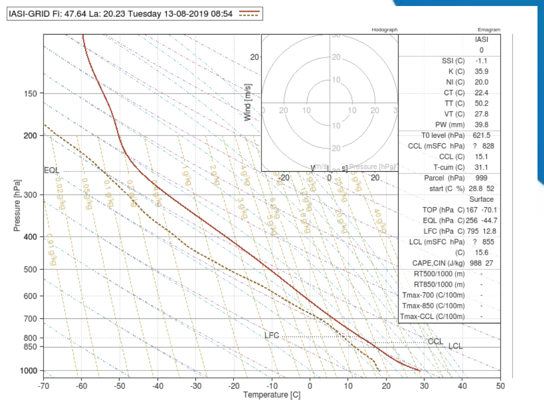

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- Total Pecipitable Water (TPW),
- mean relative humidity in the lowest 0-3 km width layer (0-3km RH),
- K-index,
- Best lifted index,
- Maximum Buoyancy,
- MLCAPE,
- 400/700 hPa lapse rate,
- 600/925 hPa lapse rate.

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Difficulties to evaluate the IASI profiles

- Most of the cases there are no reference data at the time of the Metop overpasses. (8-9 UTC)
- We can only rely what happened later on- whether the environment described by the IASI is supporting that or not.

- The indices calculated from the IASI data are done exactly the same way we calculate them from the model data.

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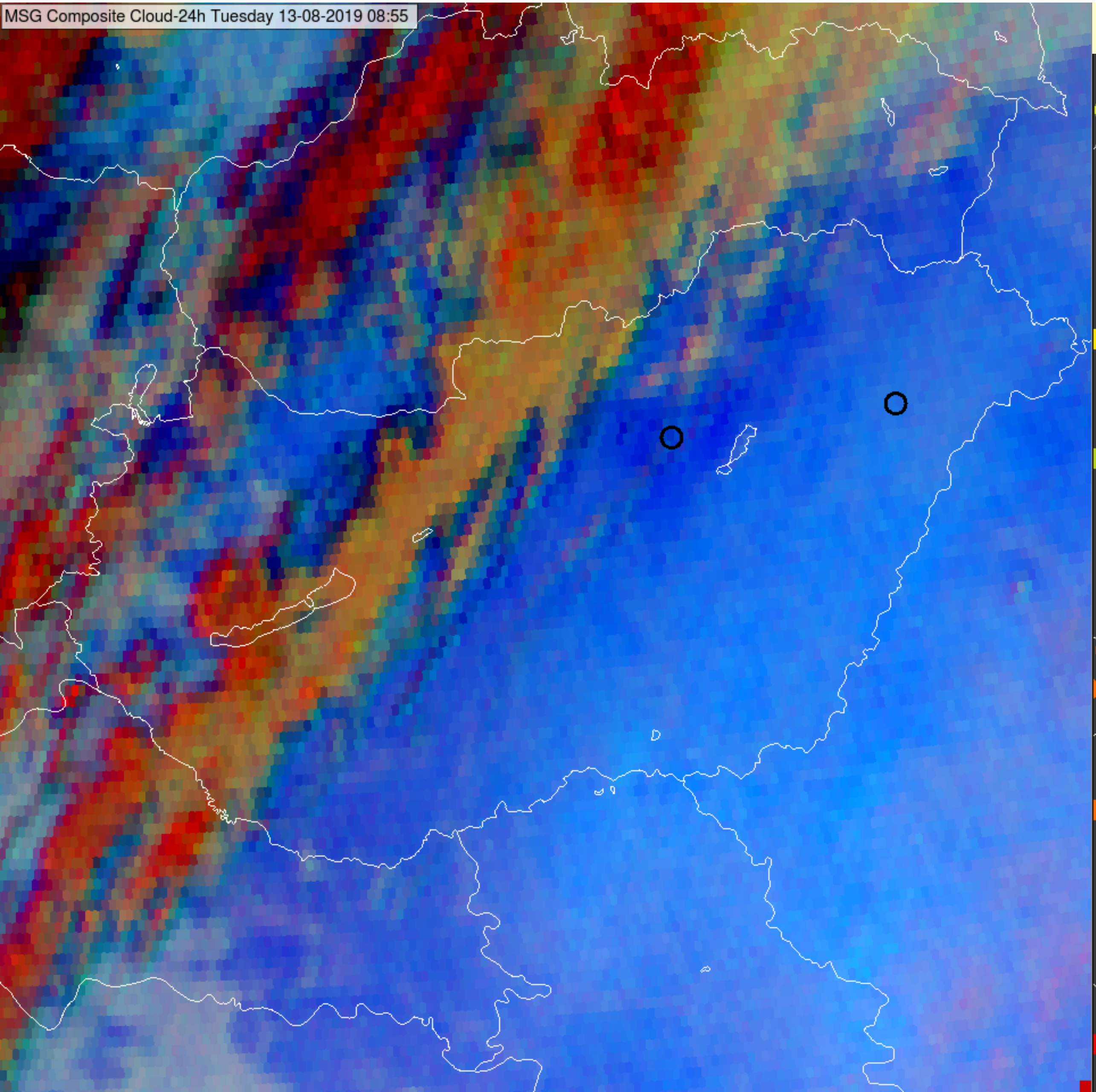
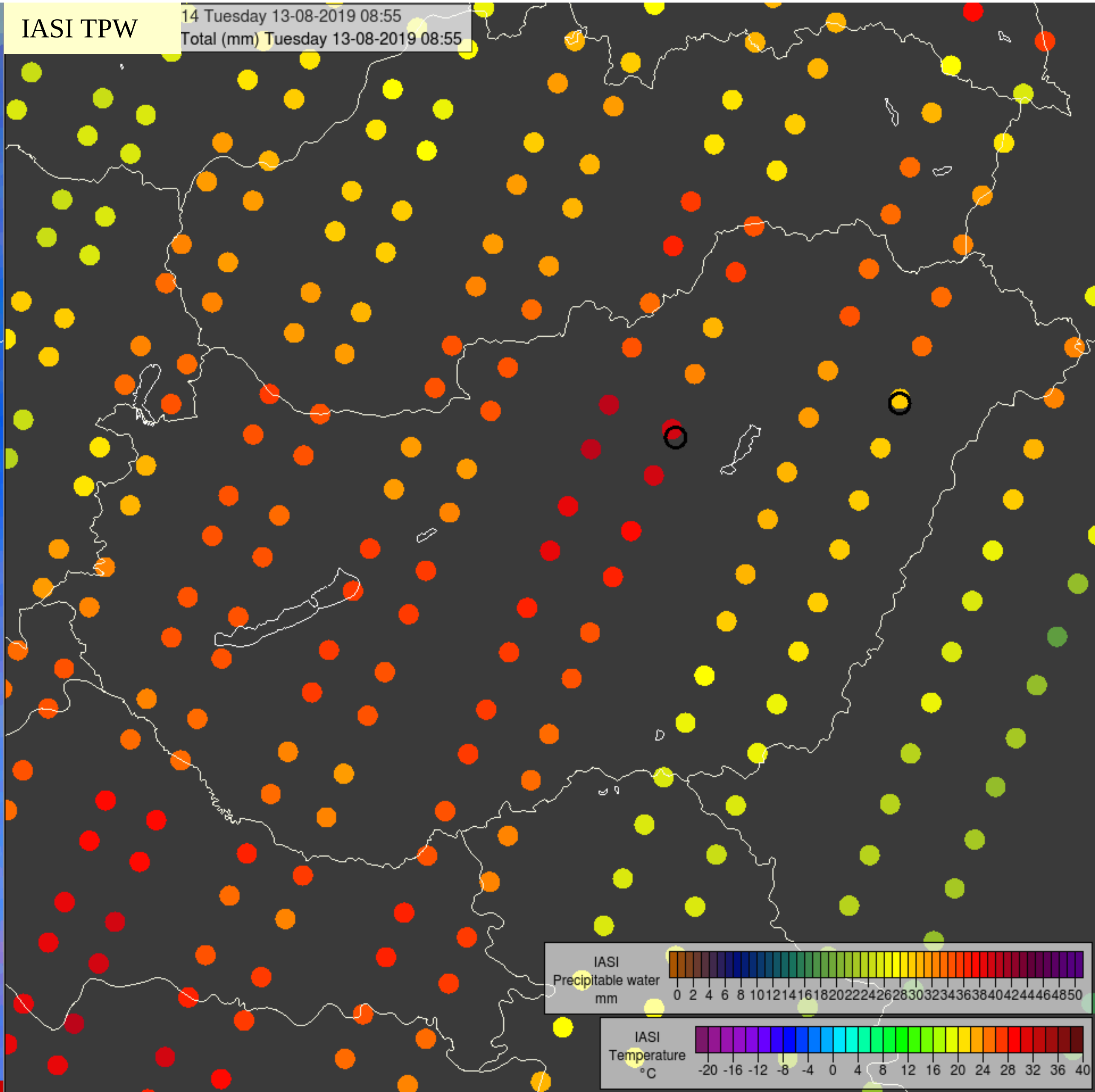
Some features we found when comparing IASI derived and ECMWF forecasted environmental parameters

IASI data reflects the moisture content - Moisture boundary - also seen seen in the 24h Microphysics RGB.





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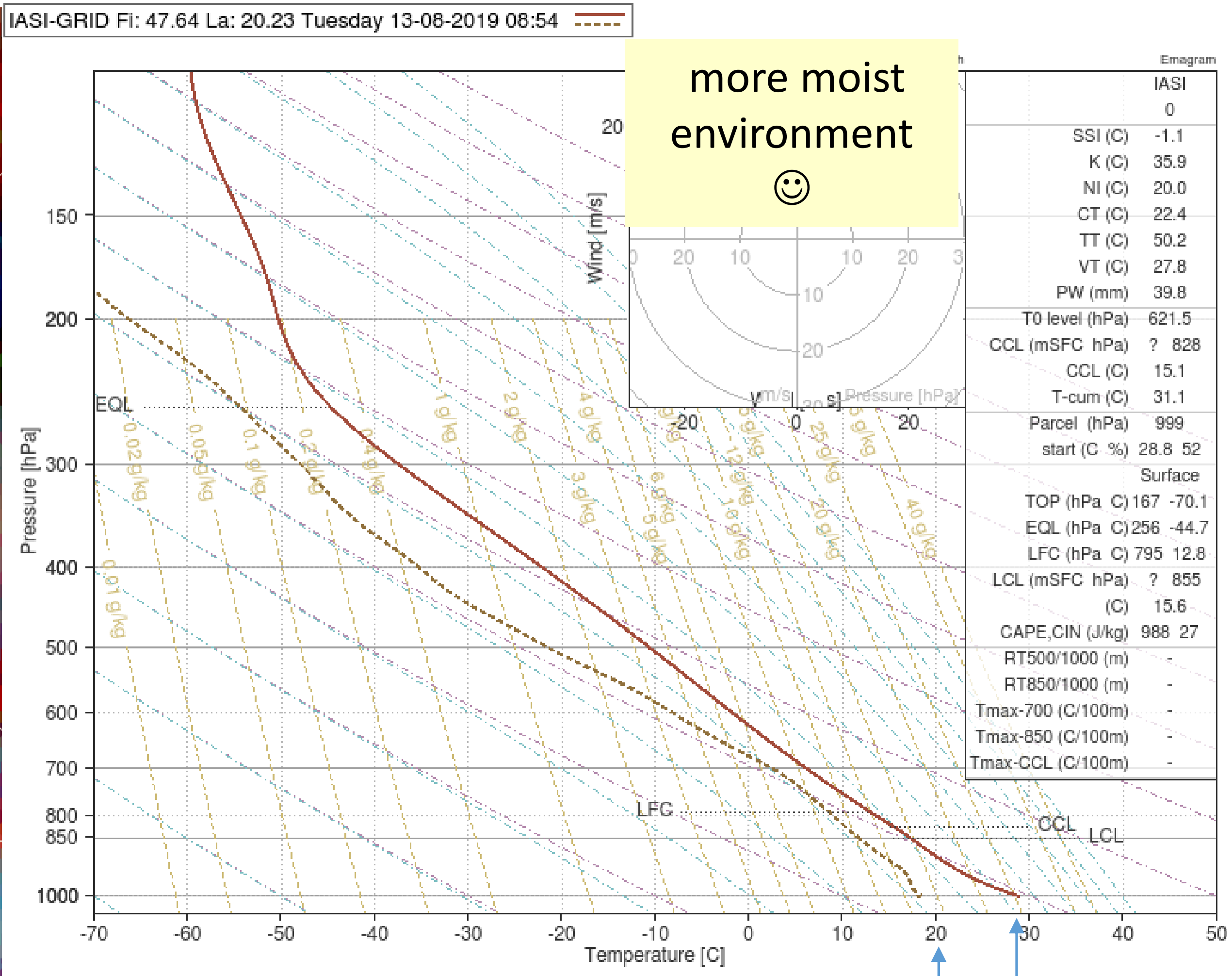
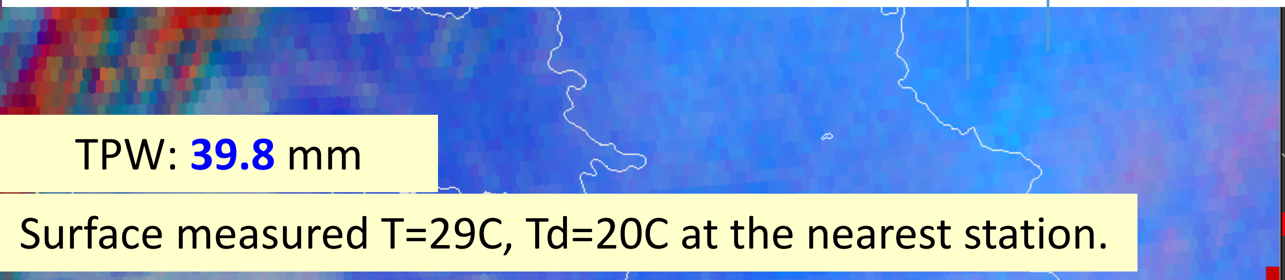
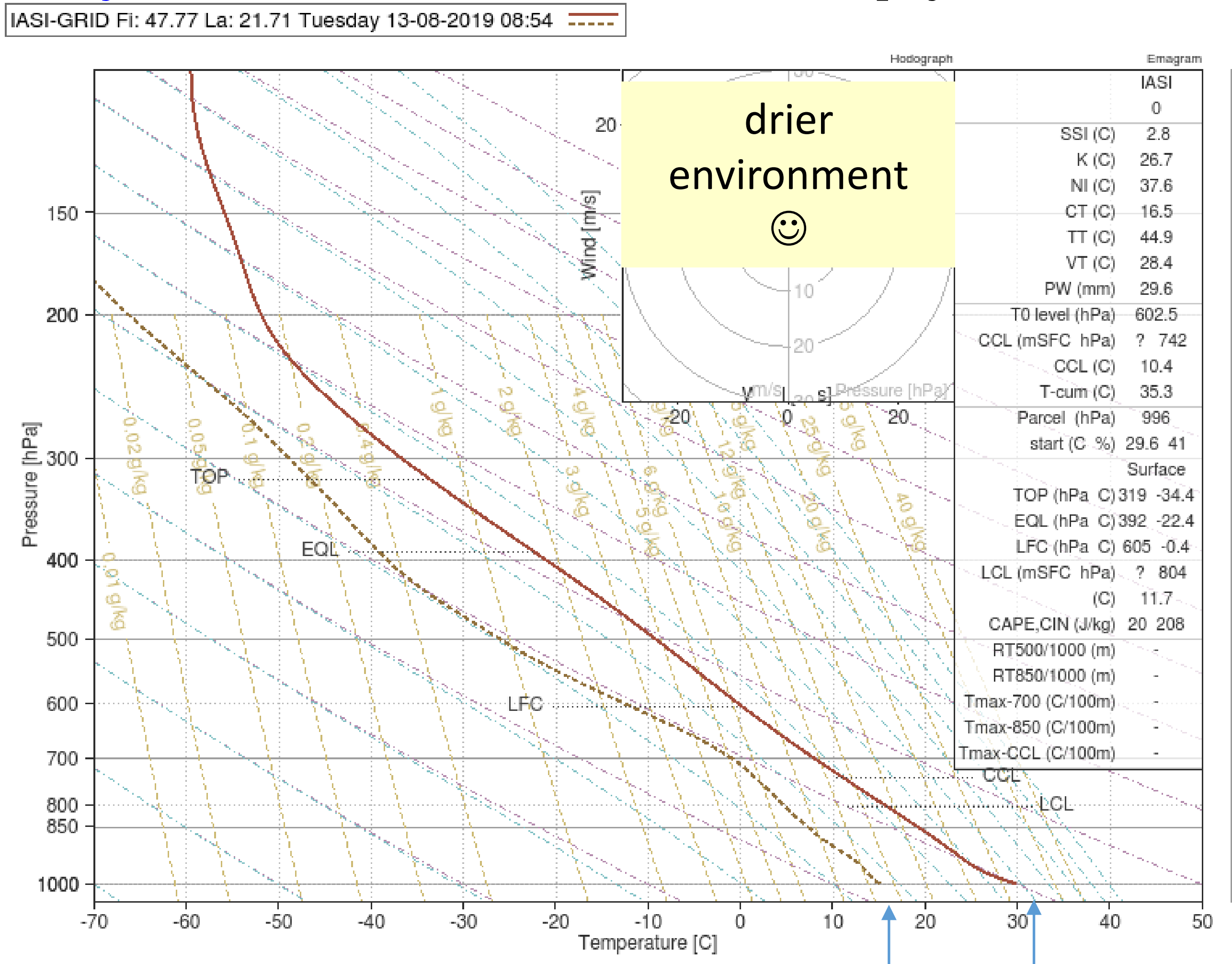


more moist environment ☺

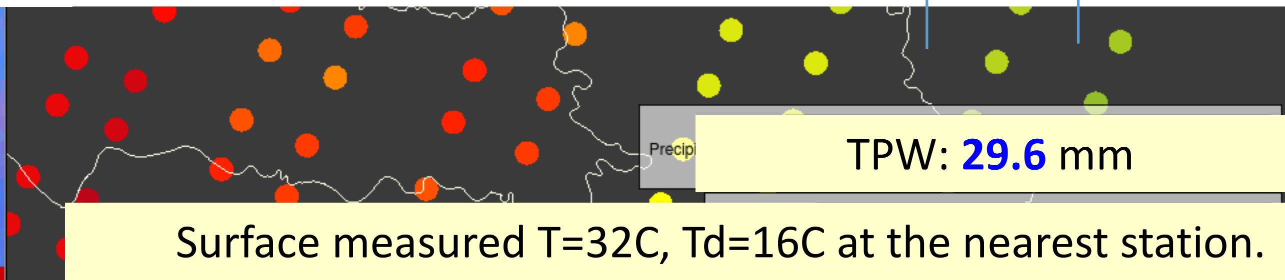


TPW: **39.8** mm

Surface measured T=29C, Td=20C at the nearest station.



drier environment ☺



TPW: **29.6** mm

Surface measured T=32C, Td=16C at the nearest station.

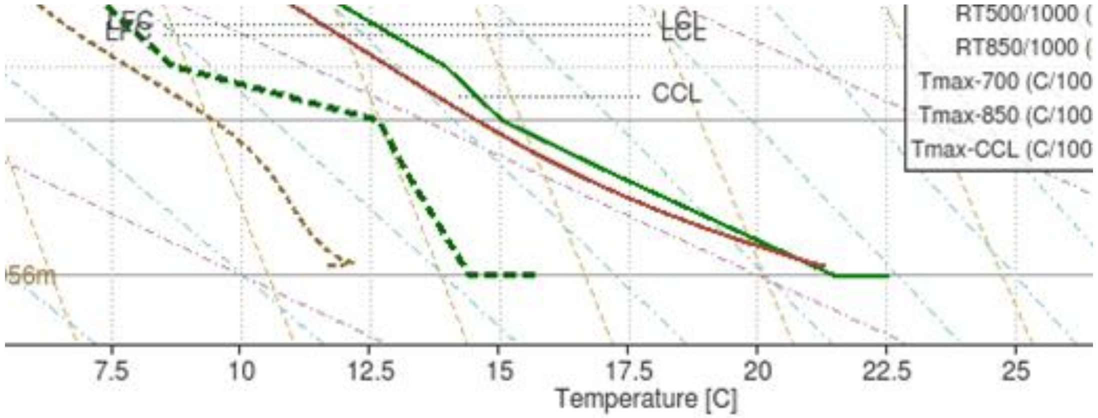
Some features we found when comparing IASI derived and ECMWF forecasted environmental parameters

‚Foot' in ECMWF –

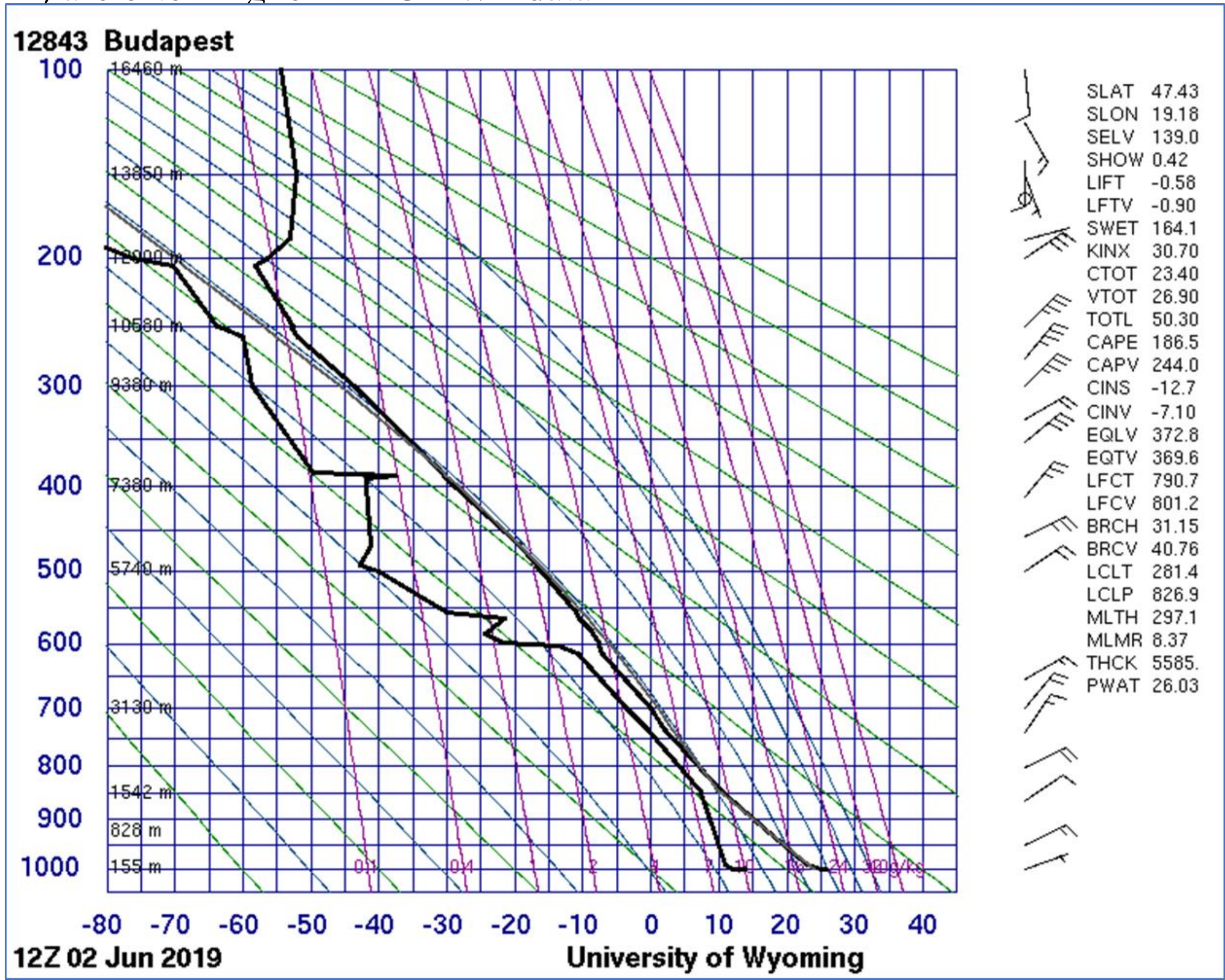
In such cases ECMWF 2m T and/or Td are much warmer than at the level just above it

- The same can be often seen in the radiosonde measurements.
- This ‚jump' is often missing from the IASI profiles.
- One reason why the ‚surface based' instability indices (like SBCAPE) are often higher in ECMWF data

Example of ‚foot' (02 June 2019) close to Budapest



08:43 UTC

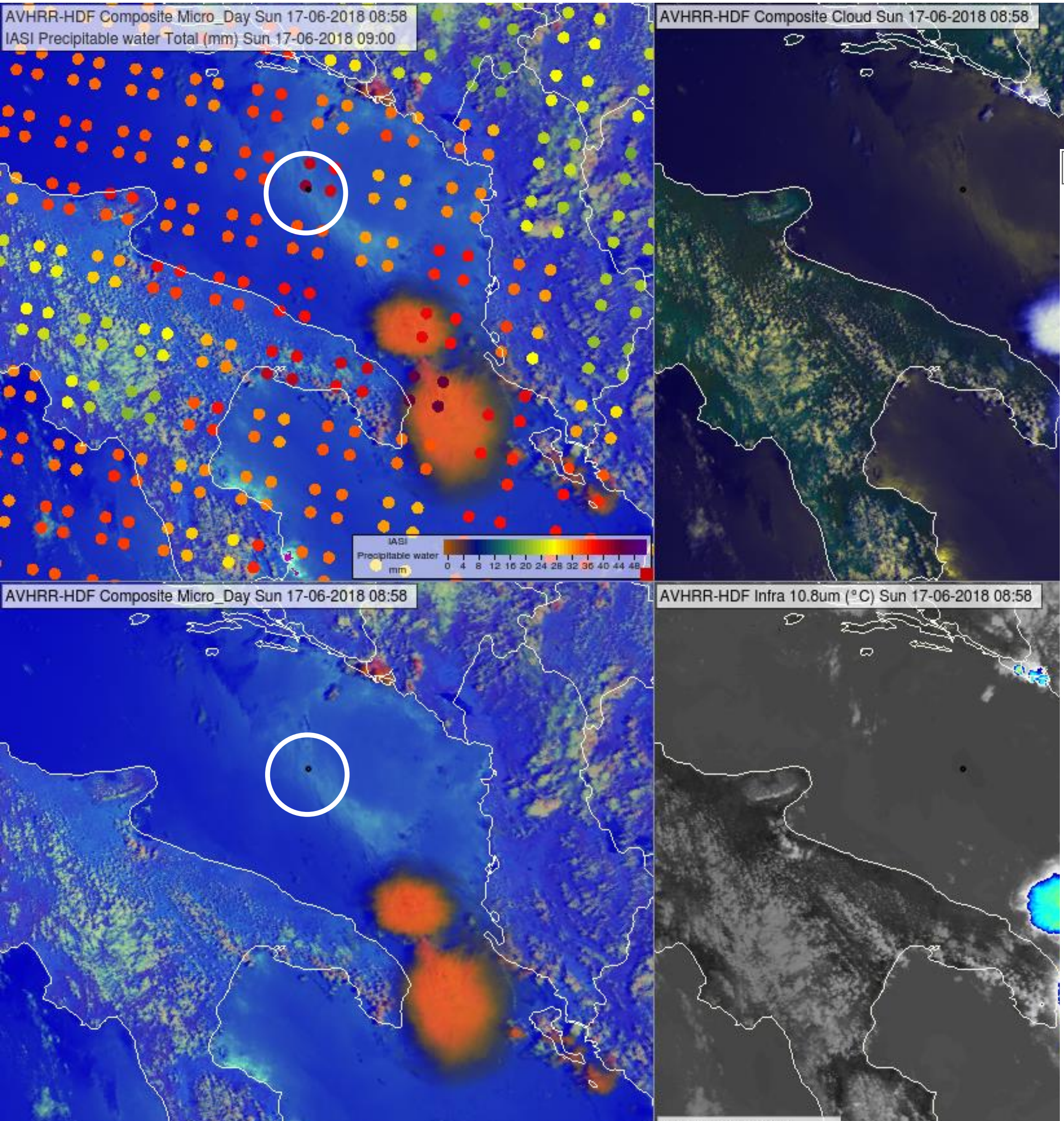


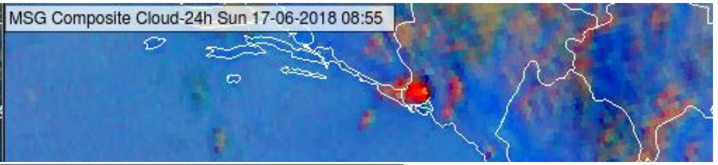
Some features we found when comparing IASI derived and ECMWF forecasted environmental parameters

It is important to check the vertically integrated error fields before using / trusting the IASI profiles.

The vertically averaged error of the IASI profiles are sometimes rather large (up to 5, 6 K). – These location could be masked.

Example of high uncertainty: Sunglint - Vertically averaged error of the IASI profile can be very high

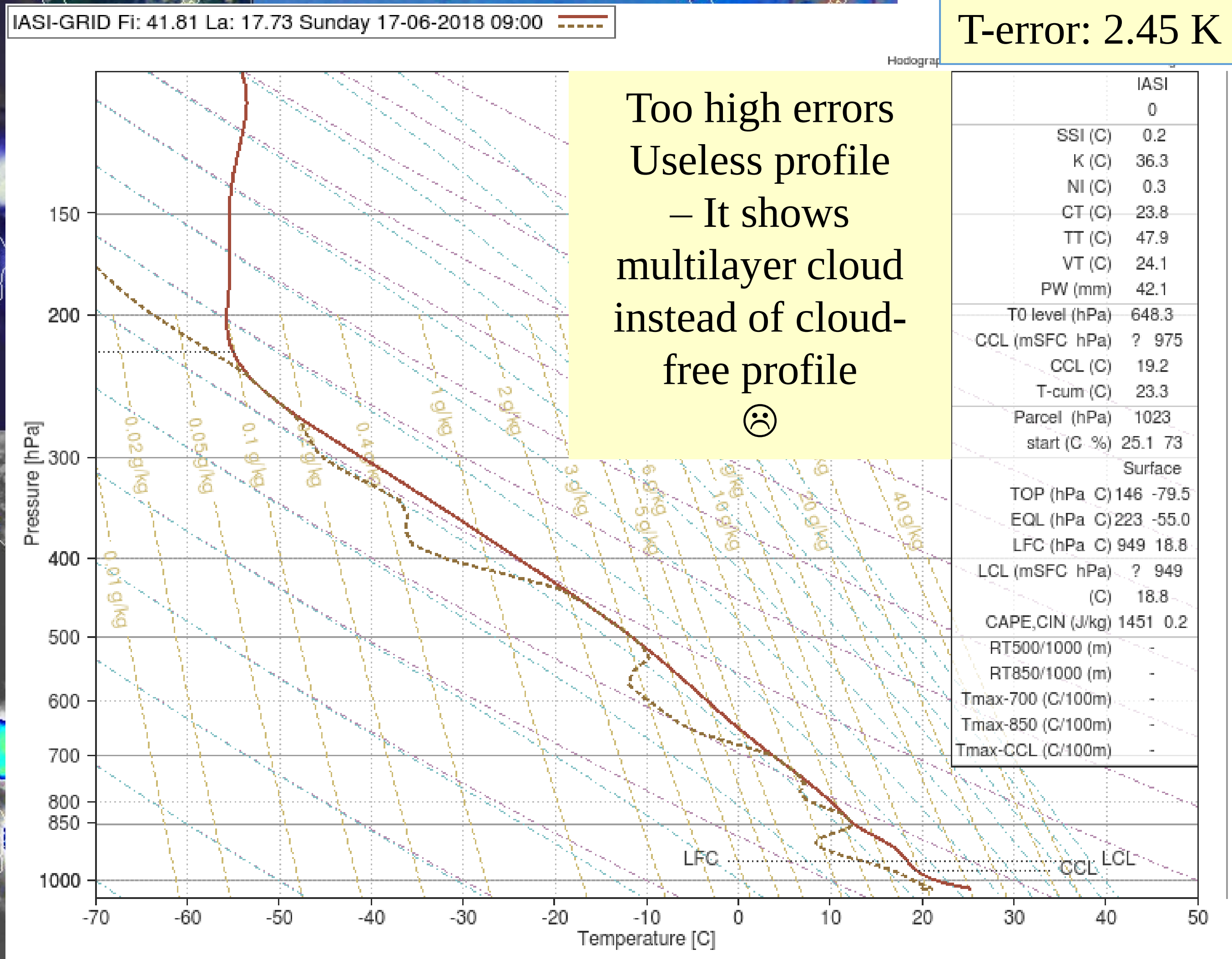




IASI: Cloud-free

Td-error: **5.27 K**

T-error: 2.45 K

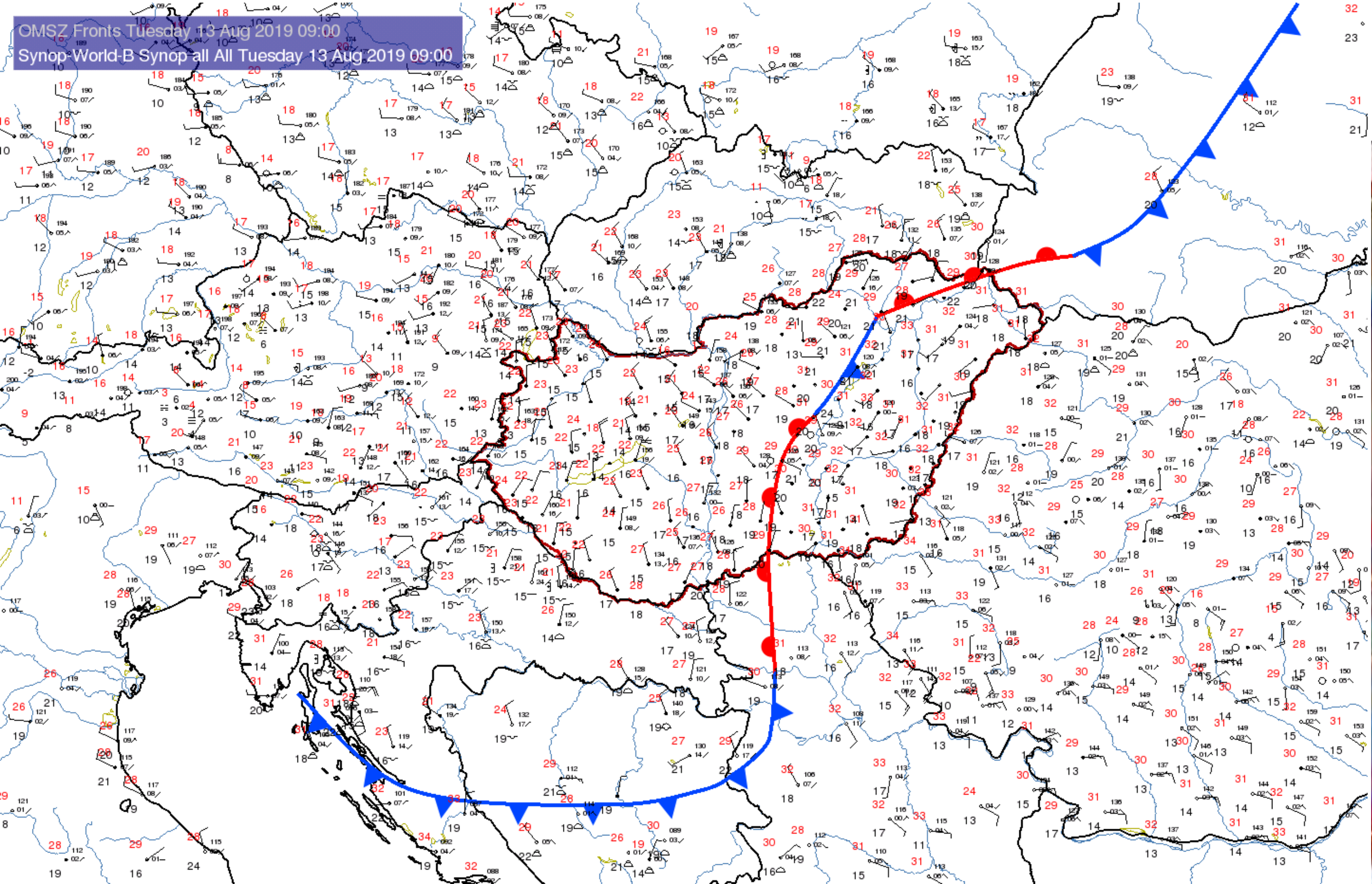


Too high errors
Useless profile
– It shows multilayer cloud instead of cloud-free profile
☹

Some features we found when comparing IASI derived and ECMWF forecasted environmental parameters

Front Behind the surface front one may see typical features in the ECMWF profiles, like cooling and much dryer airmass in low layer.
The IASI profile may not show these features.

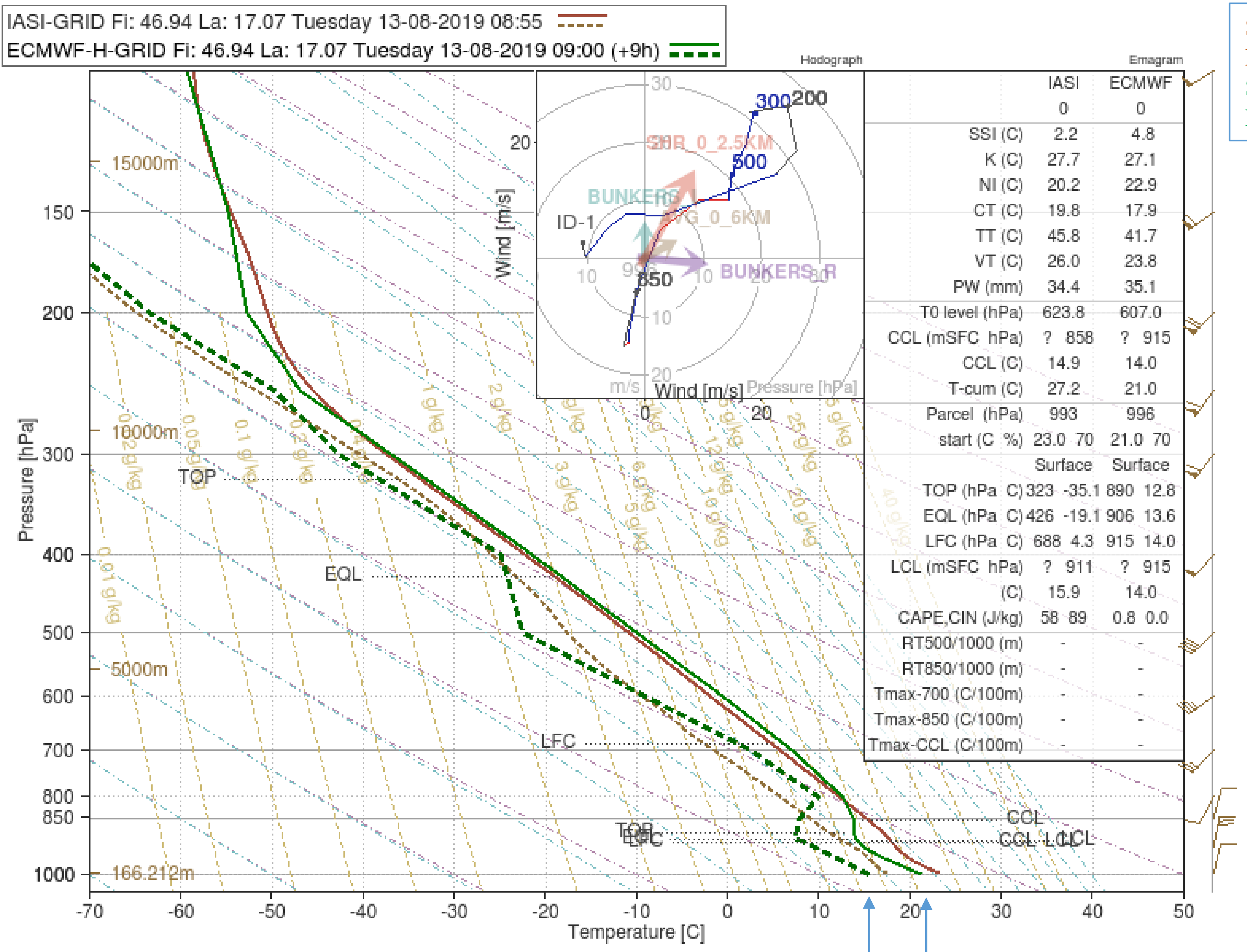
Example of **13 August 2019** – less strong front; colder, drier airmass in low layer in ECMWF data – not seen in IASI profiles



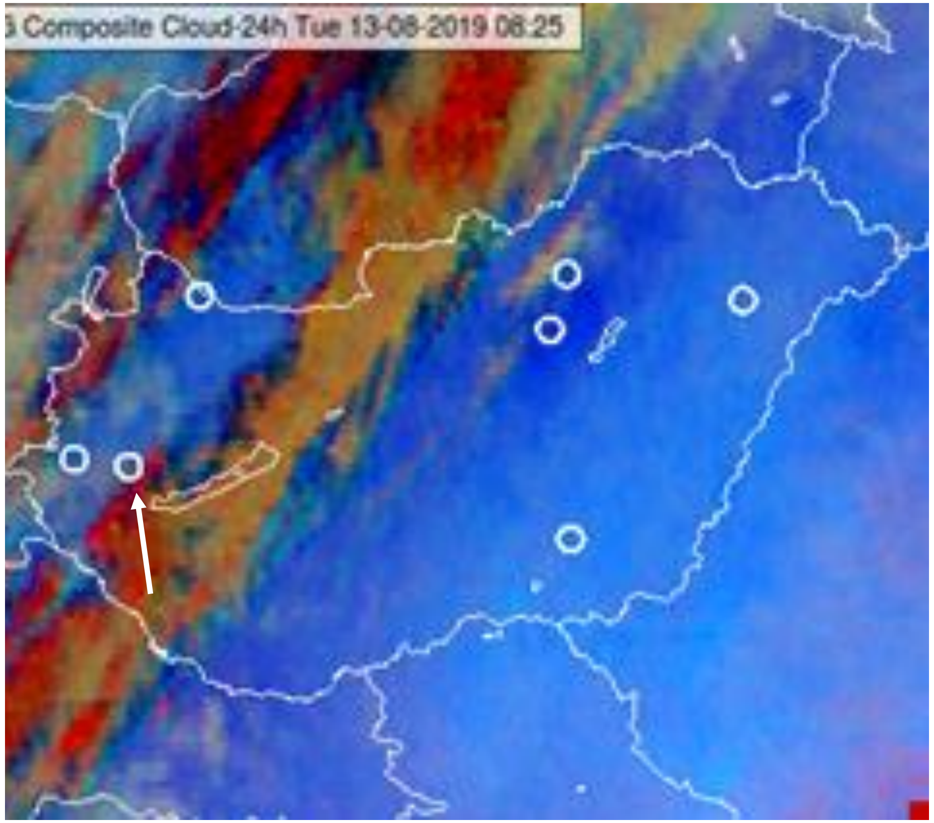
Some features we found when comparing IASI derived and ECMWF forecasted environmental parameters

Front (cont.)

Example of **13 August 2019** – less strong front; colder, drier airmass in low layer in ECMWF data – not seen in IASI profiles



Solid brown line: (IR+MW) T profile
Broken brown line: (IR+MW) Td profile
Solid green line: ECMWF T profile
Broken green line: ECMWF Td profile



Some features we found when comparing IASI derived and ECMWF forecasted environmental parameters

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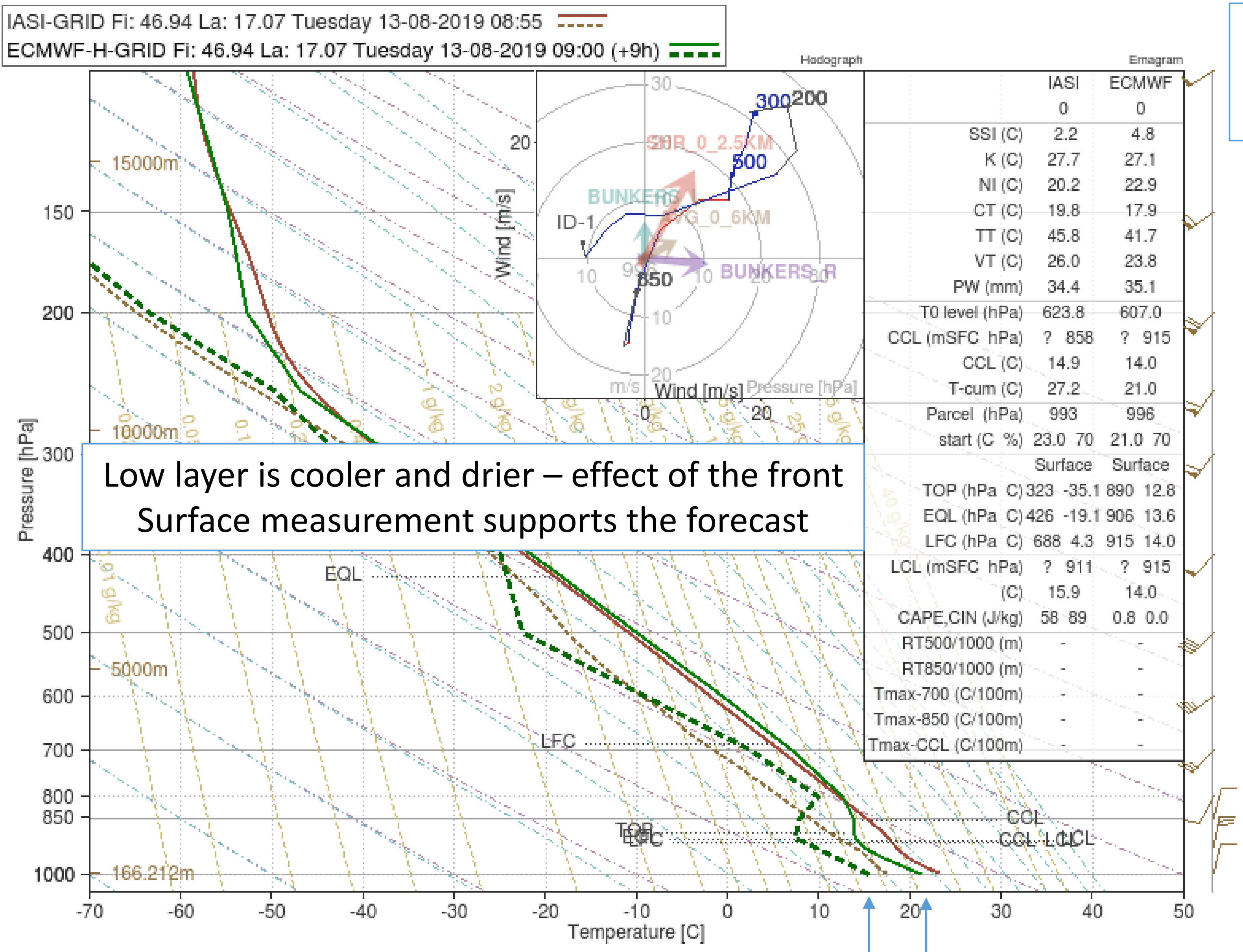
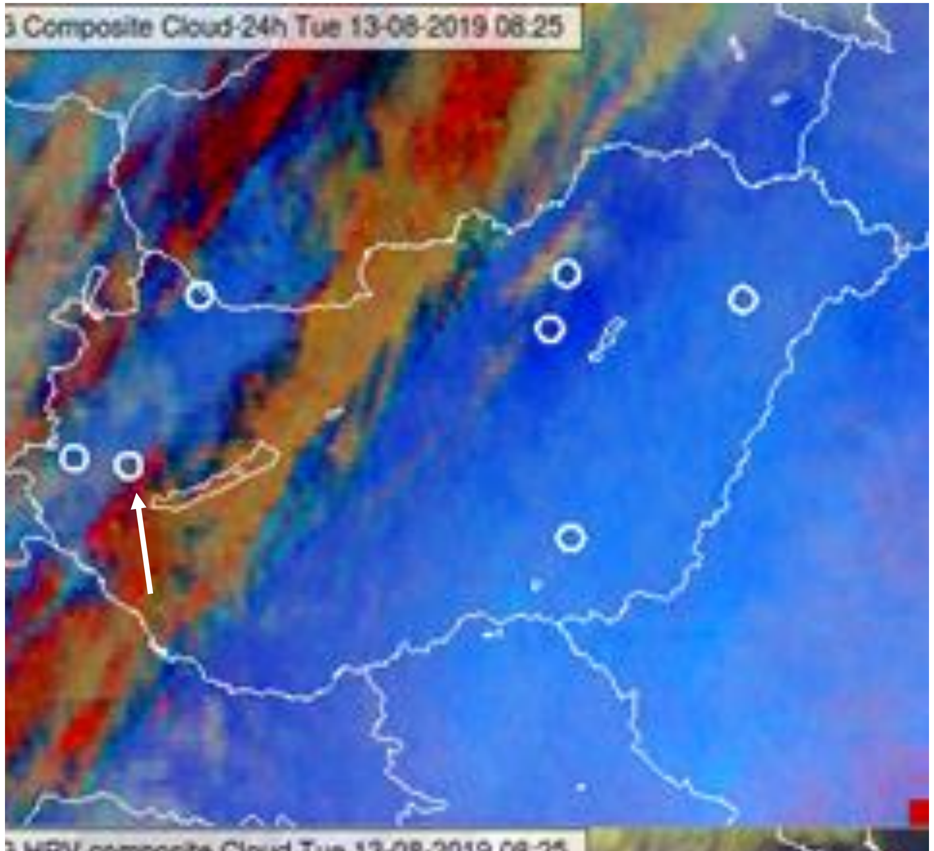


	IASI	ECMWF
	0	0
SSI (C)	2.2	4.8
K (C)	27.7	27.1
NI (C)	20.2	22.9
CT (C)	19.8	17.9
TT (C)	45.8	41.7
VT (C)	26.0	23.8
PW (mm)	34.4	35.1
T0 level (hPa)	623.8	607.0
CCL (mSFC hPa)	? 858	? 915
CCL (C)	14.9	14.0
T-cum (C)	27.2	21.0
Parcel (hPa)	993	996
start (C %)	23.0 70	21.0 70
	Surface	Surface
TOP (hPa C)	323 -35.1	890 12.8
EQL (hPa C)	426 -19.1	906 13.6
LFC (hPa C)	688 4.3	915 14.0
LCL (mSFC hPa)	? 911	? 915
(C)	15.9	14.0
CAPE,CIN (J/kg)	58 89	0.8 0.0
RT500/1000 (m)	-	-
RT850/1000 (m)	-	-
Tmax-700 (C/100m)	-	-
Tmax-850 (C/100m)	-	-
Tmax-CCL (C/100m)	-	-

Low layer is cooler and drier – effect of the front
Surface measurement supports the forecast

Solid brown line: (IR+MW) T profile
Broken brown line: (IR+MW) Td profile
Solid green line: ECMWF T profile
Broken green line: ECMWF Td profile



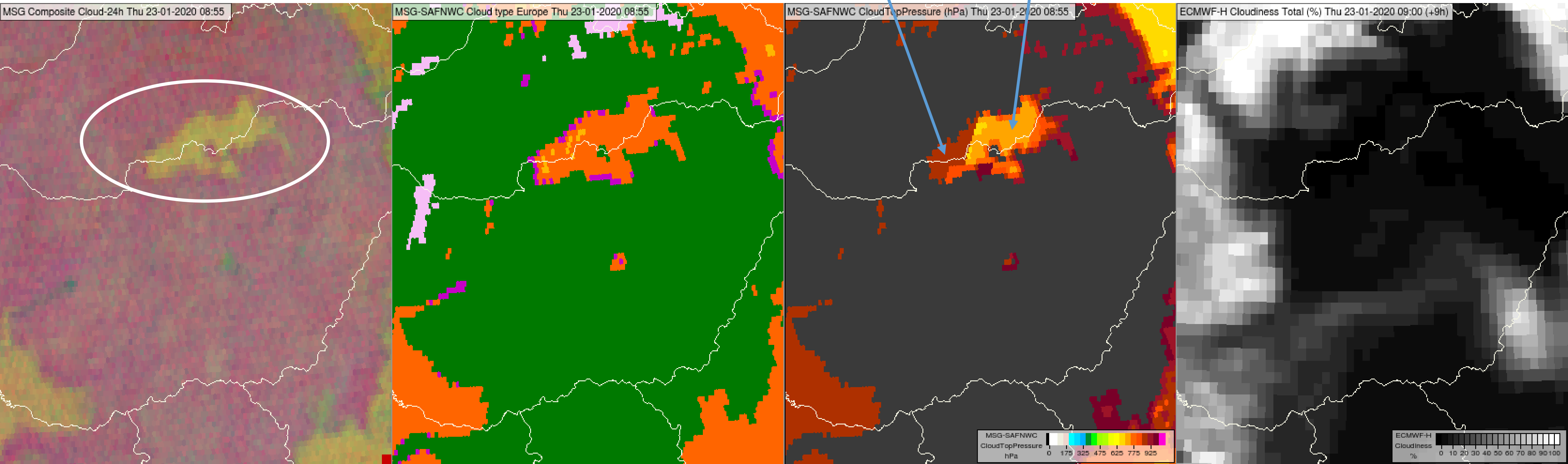
Some features we found when comparing IASI derived and ECMWF forecasted environmental parameters

IASI profile can reflect thermal inversion (non-convective case)

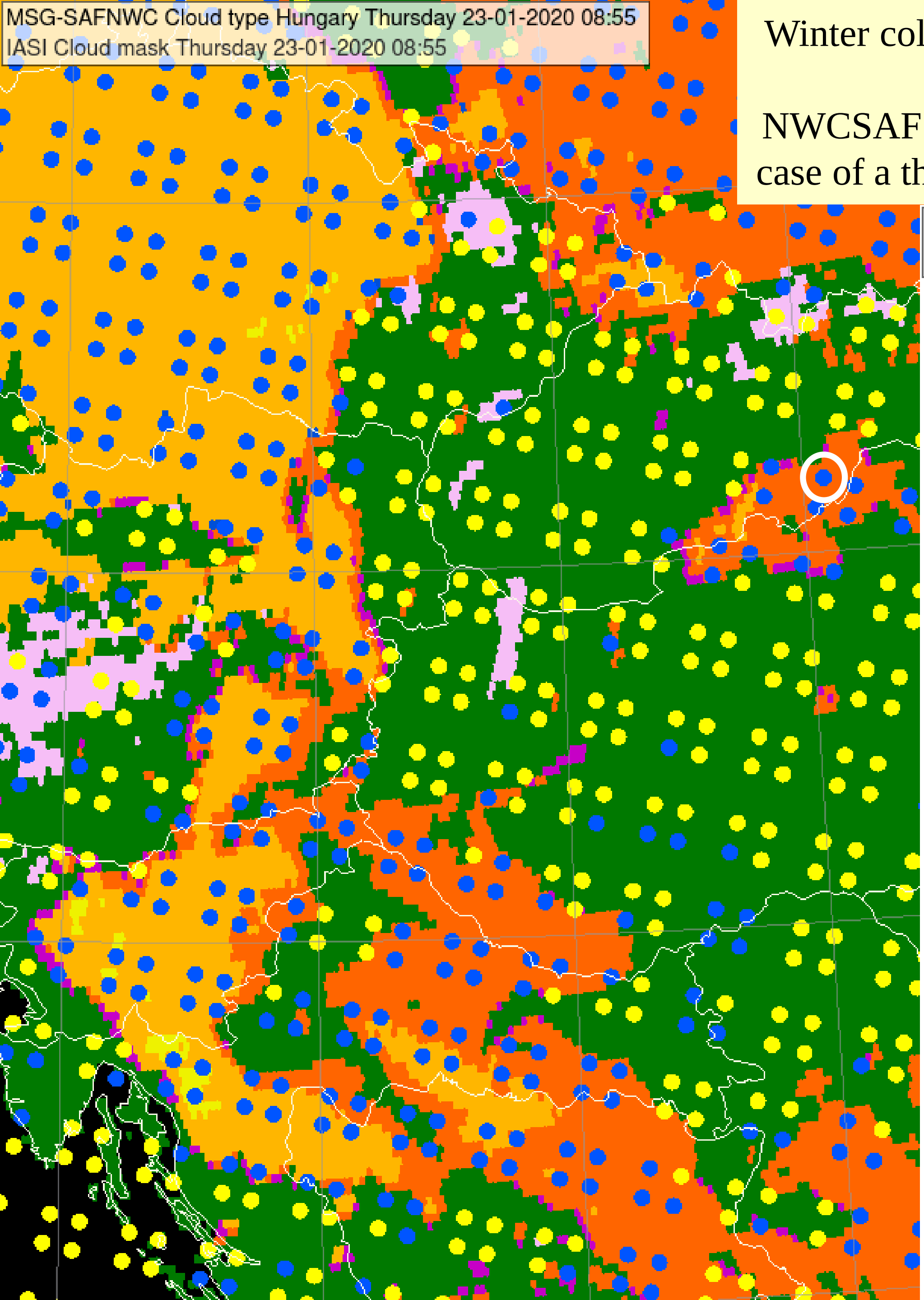
- 23 January 2020 - winter cold pool situation - fog/stratus in the encircled area
- According NWCSAF CT: very low cloud
- According NWCSAF CTTH: retrieved cloud top height ~ 3000 m in several pixels
- In ECMWF model this area is cloud-free

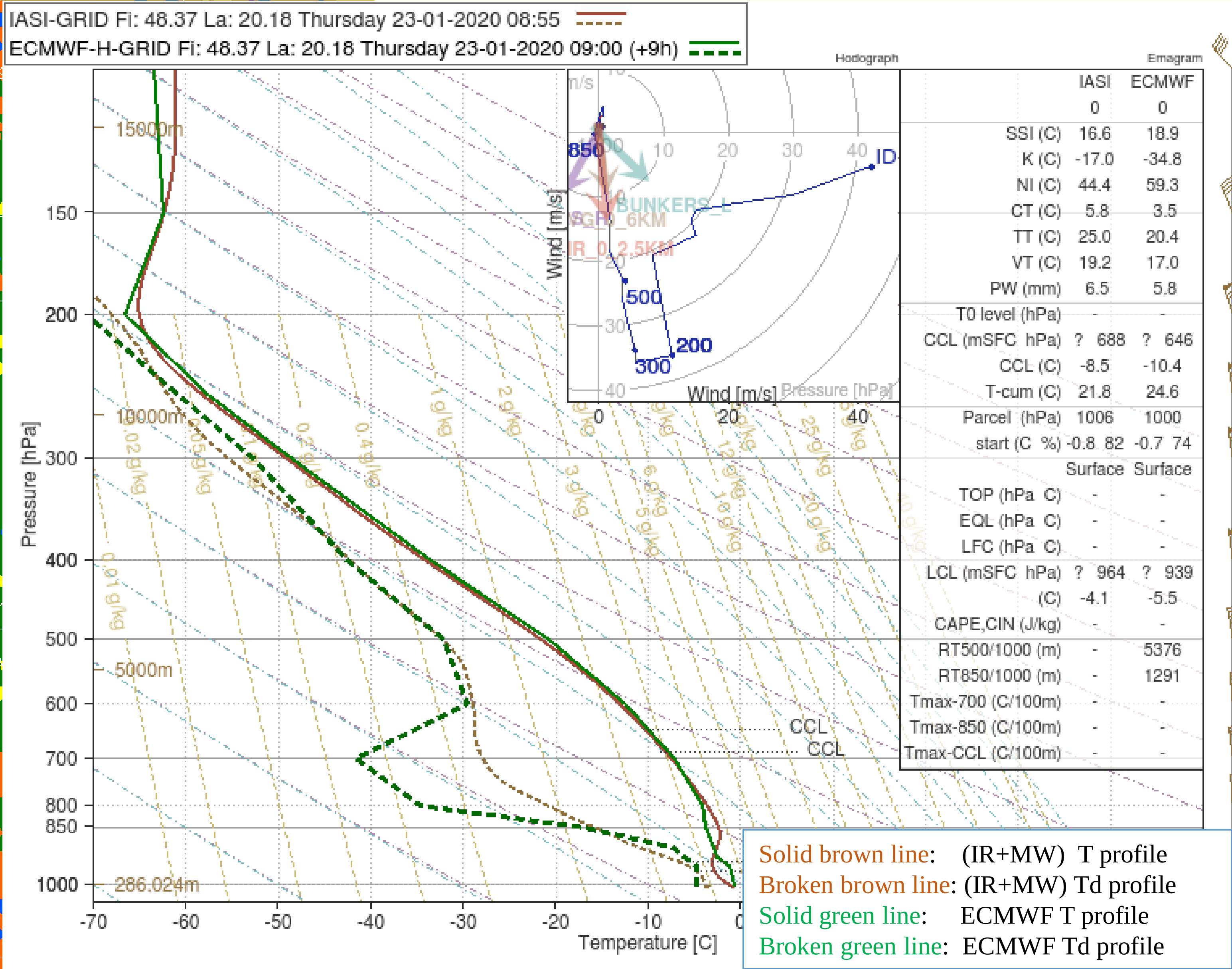
~850 hPa ~700 hPa

24h Microphysics RGB | NWCSAF Cloud Type | NWCSAF Cloud top Presssure | ECMWF Total cloudiness



Winter cold-pool situation, the area in the numerical forecast is cloud-free, while in reality there is fog/stratus present. IASI T profile shows characteristics of stratus.
NWCSAF uses NWP profile for the cloud top pressure/height retrieval. The method is different in case of a thermal inversion profile. With IASI profile the retrieved cloud top height might be lower.





Solid brown line: (IR+MW) T profile
Broken brown line: (IR+MW) Td profile
Solid green line: ECMWF T profile
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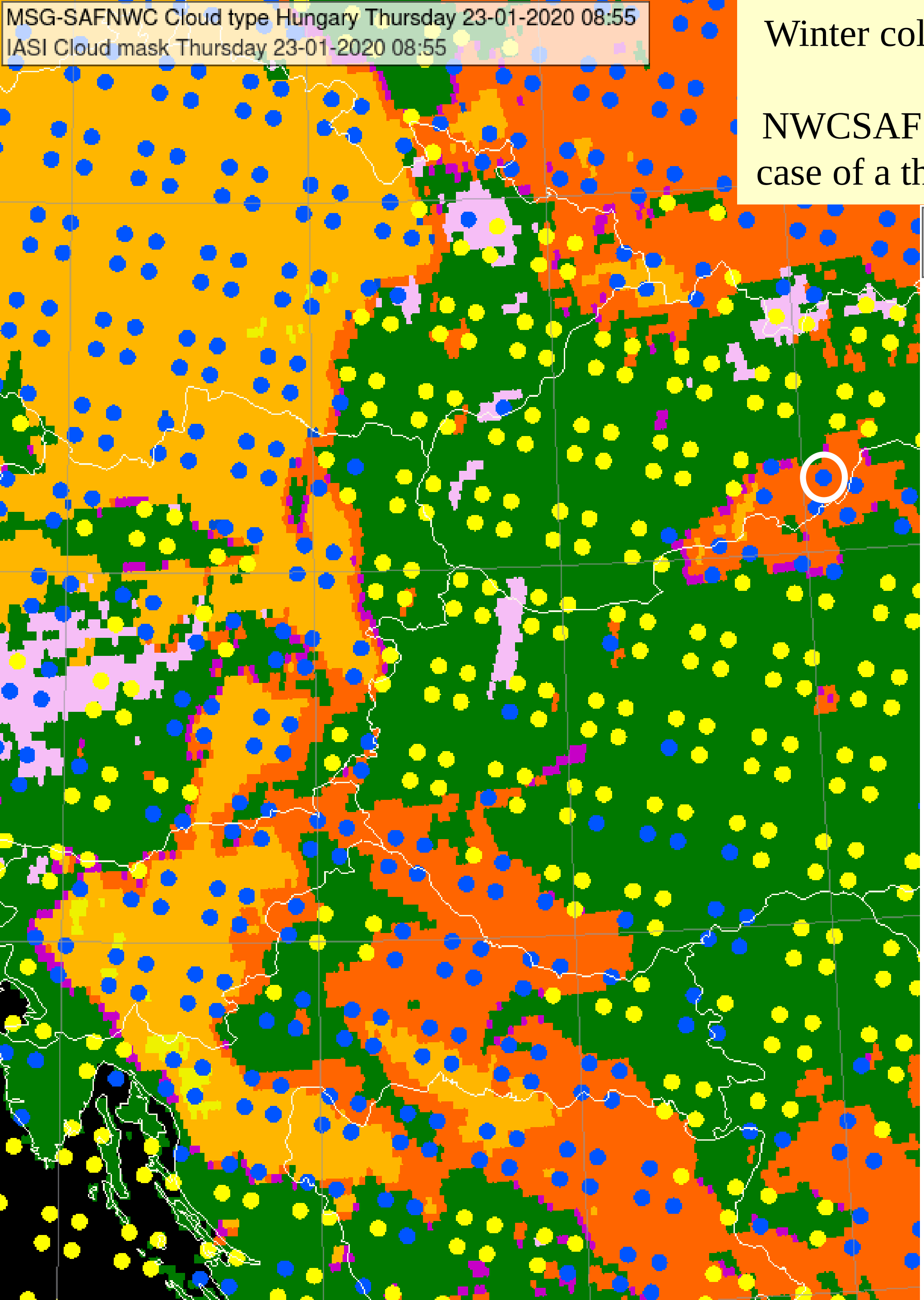
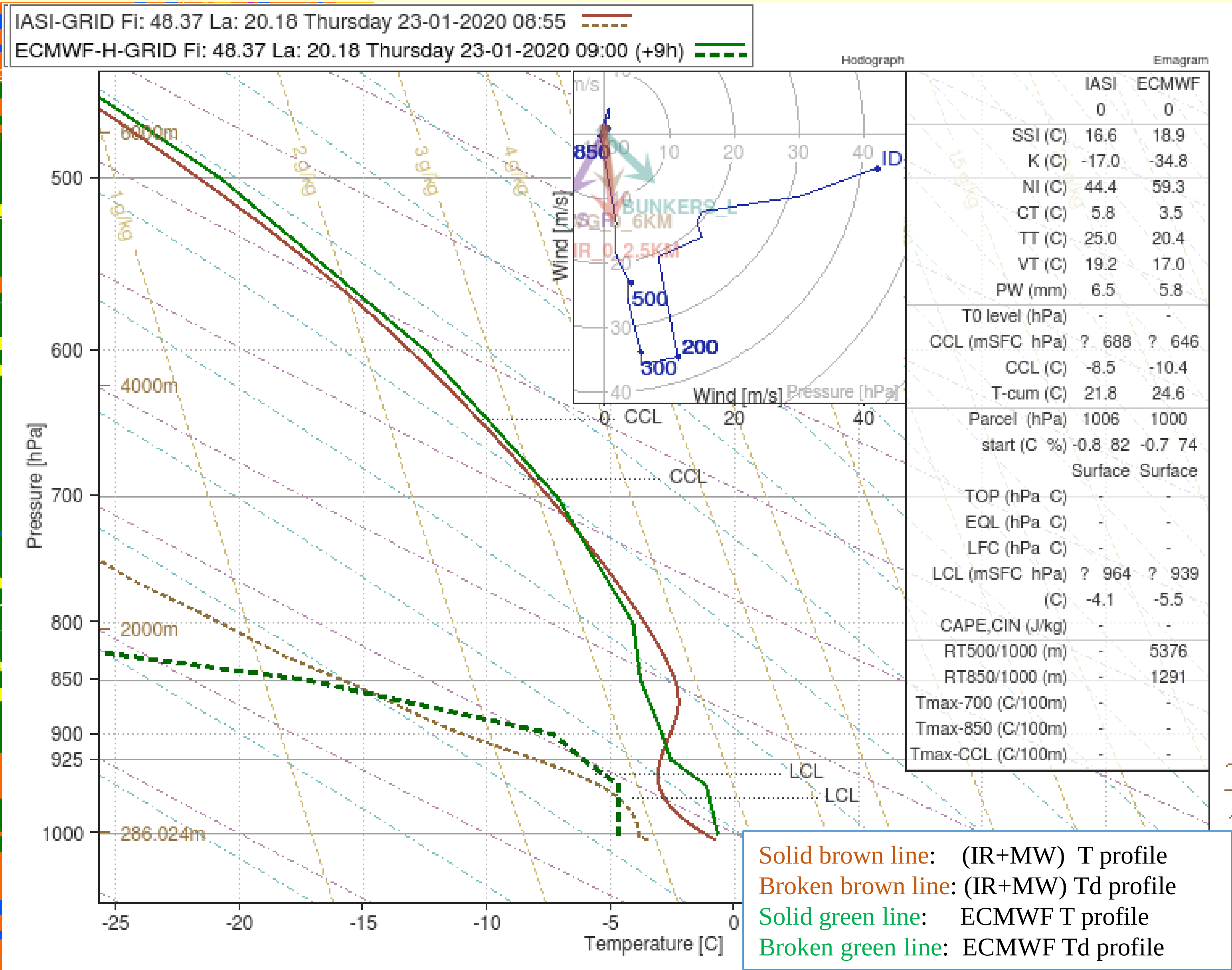




Some features we found when comparing IASI derived and ECMWF forecasted environmental parameters

IASI derived Mixed Layer CAPE (MLCAPE) is usually strongly underestimated compared to the ECMWF MLCAPE.

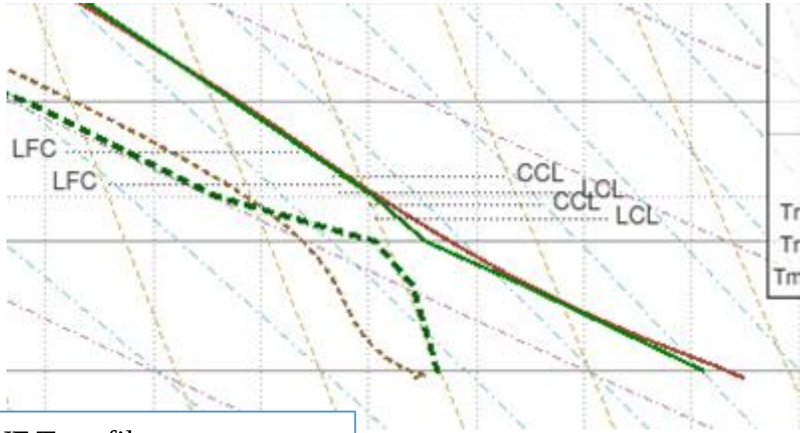
(Originally we chose MLCAPE, because we expected it to be more accurate than other kinds of CAPE values as it „starts” from an average values of a layer, instead of a single level value.)

Problem:
If a IASI derived parameter differs strongly and often from ECMWF then the forecasters may not trust it.

Why is it usually strongly underestimated?

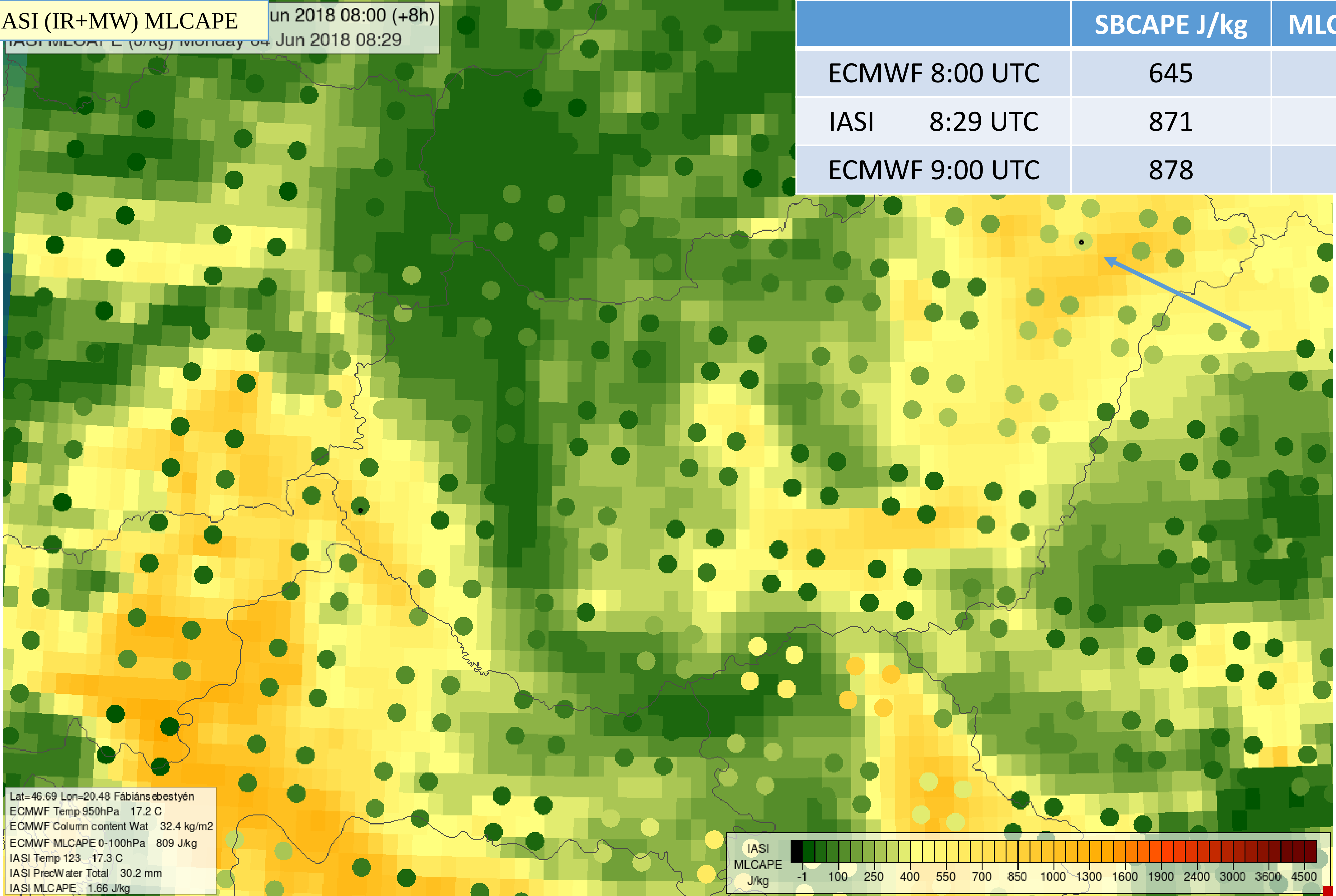
- The boundary layer modul of ECMWF creates a well mixed layer in the lowest 1 km.
  → **ECMWF Td profile has a typical shape in the low layer, which is often not present in the IASI profile.**
  →IASI Td often decrease faster in the boundary layer than ECMWF Td

  + IASI surface Td is often lower than forecasted.
  → The average Td over the lowest 100 hPa layer ***is often lower*** in the IASI data.
  + MLCAPE is extreme sensitive to starting Td value
  → MLCAPE is underestimated



Solid green line: ECMWF T profile
Broken green line: ECMWF Td profile
Solid brown line: IASI T profile
Broken brown line: IASI Td profile

ECMWF + IASI (IR+MW) MLCAPE



	SBCAPE J/kg	MLCAPE J/kg
ECMWF 8:00 UTC	645	661
IASI 8:29 UTC	871	**318**
ECMWF 9:00 UTC	878	717

ECMWF + IASI (IR+MW) MLCAPE

Profile - close to the surface
8:29 UTC IASI + 8/9 UTC ECMWF

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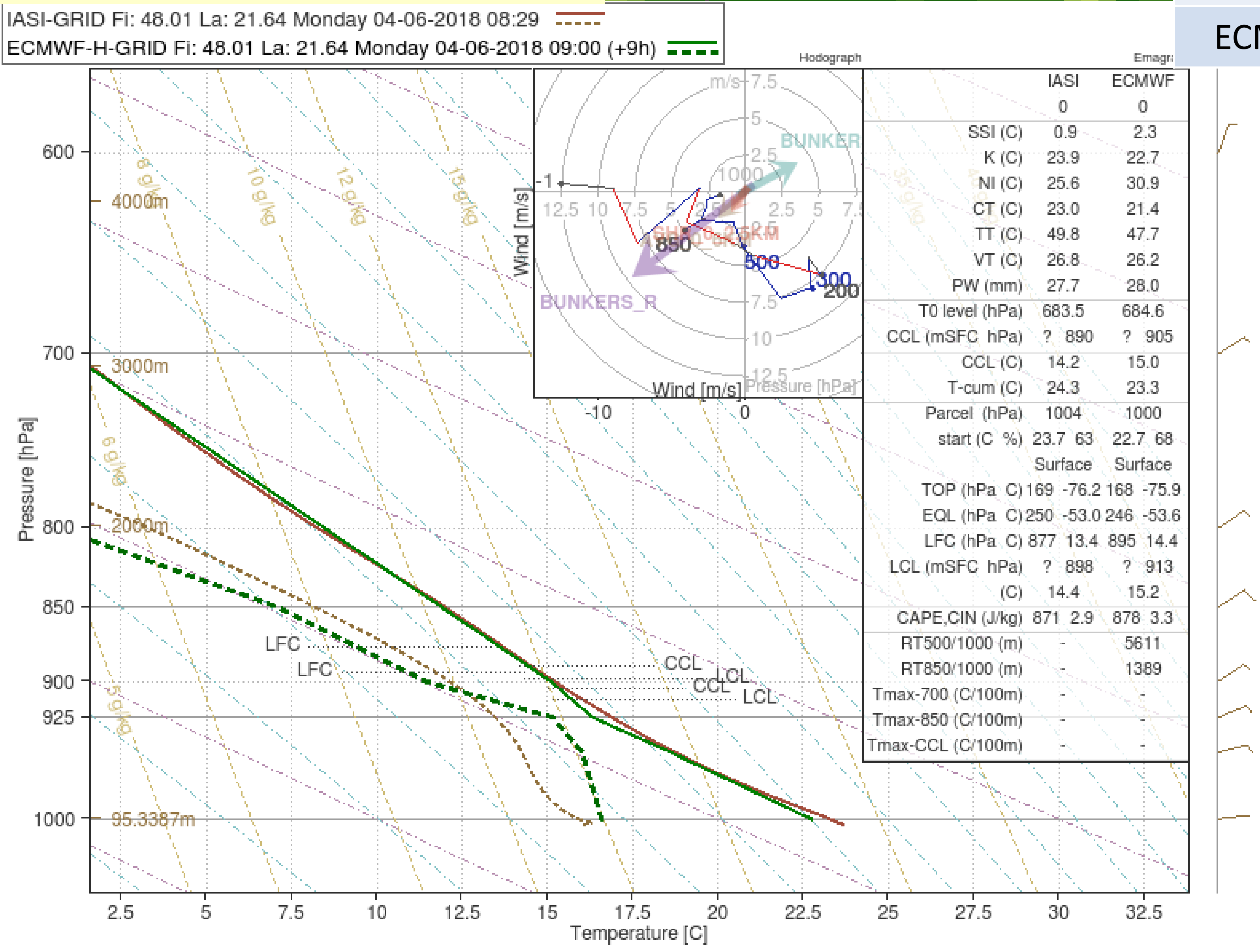

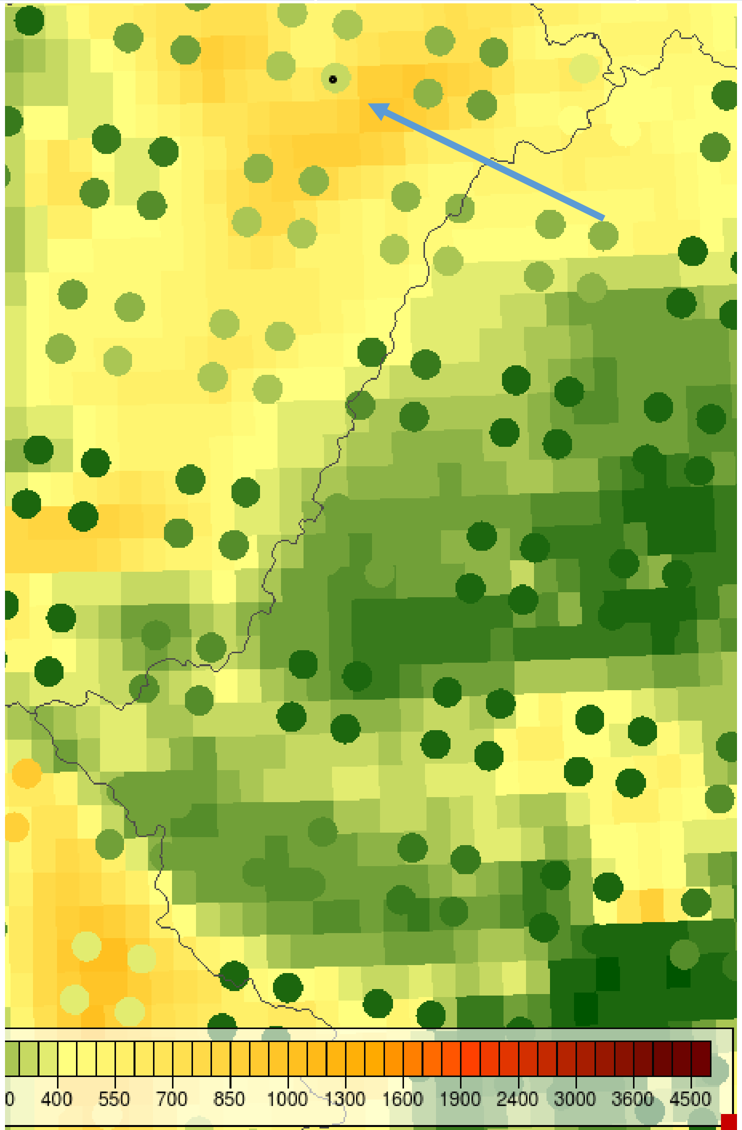

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Profile - close to the surface
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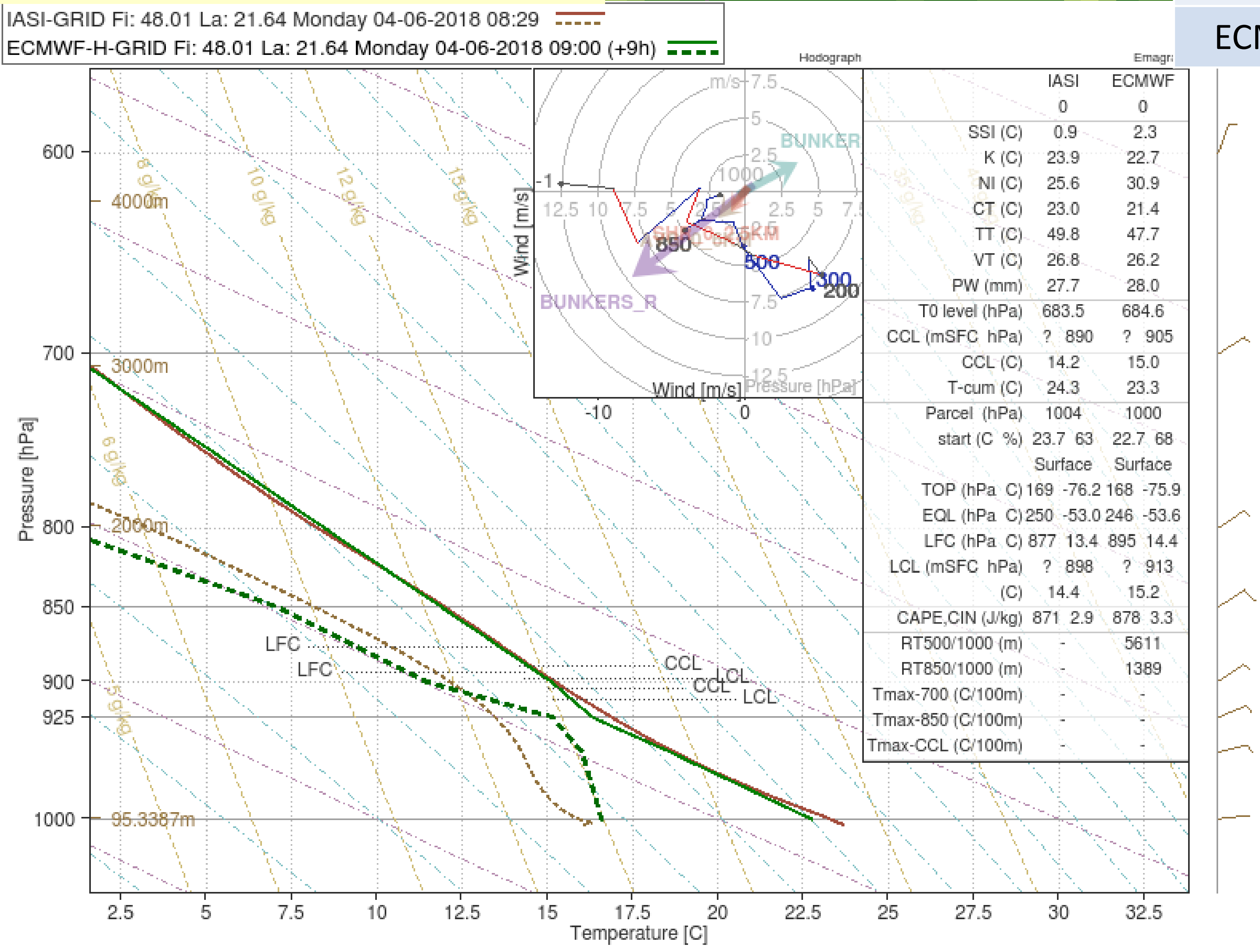
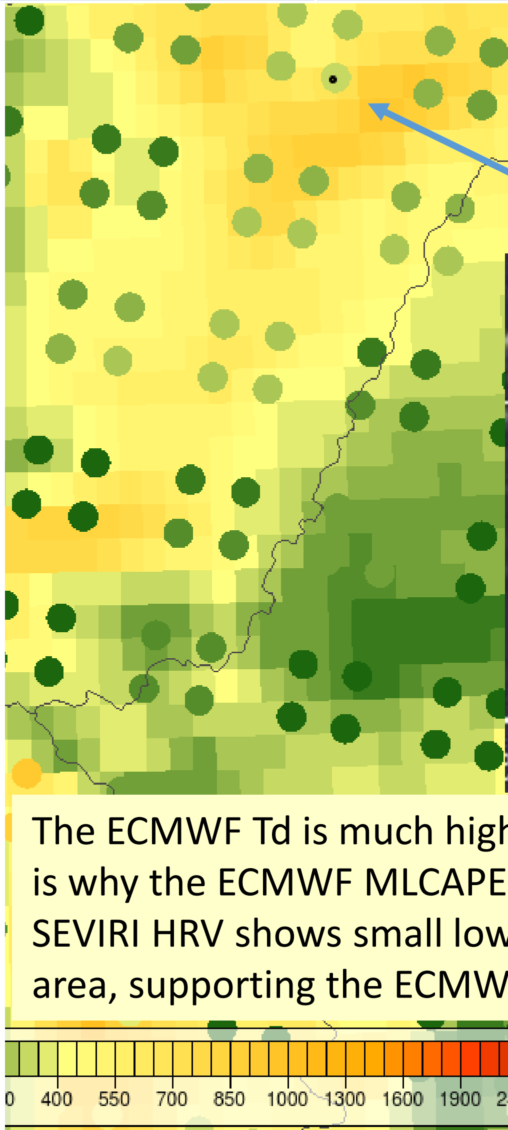
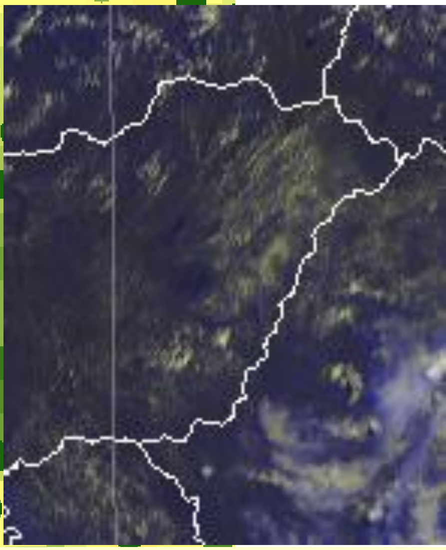


	IASI	ECMWF
	0	0
SSI (C)	0.9	2.3
K (C)	23.9	22.7
NI (C)	25.6	30.9
CT (C)	23.0	21.4
TT (C)	49.8	47.7
VT (C)	26.8	26.2
PW (mm)	27.7	28.0
T0 level (hPa)	683.5	684.6
CCL (mSFC hPa)	? 890	? 905
CCL (C)	14.2	15.0
T-cum (C)	24.3	23.3
Parcel (hPa)	1004	1000
start (C %)	23.7 63	22.7 68
	Surface	Surface
TOP (hPa C)	169 -76.2	168 -75.9
EQL (hPa C)	250 -53.0	246 -53.6
LFC (hPa C)	877 13.4	895 14.4
LCL (mSFC hPa)	? 898	? 913
(C)	14.4	15.2
CAPE,CIN (J/kg)	871 2.9	878 3.3
RT500/1000 (m)	-	5611
RT850/1000 (m)	-	1389
Tmax-700 (C/100m)	-	-
Tmax-850 (C/100m)	-	-
Tmax-CCL (C/100m)	-	-



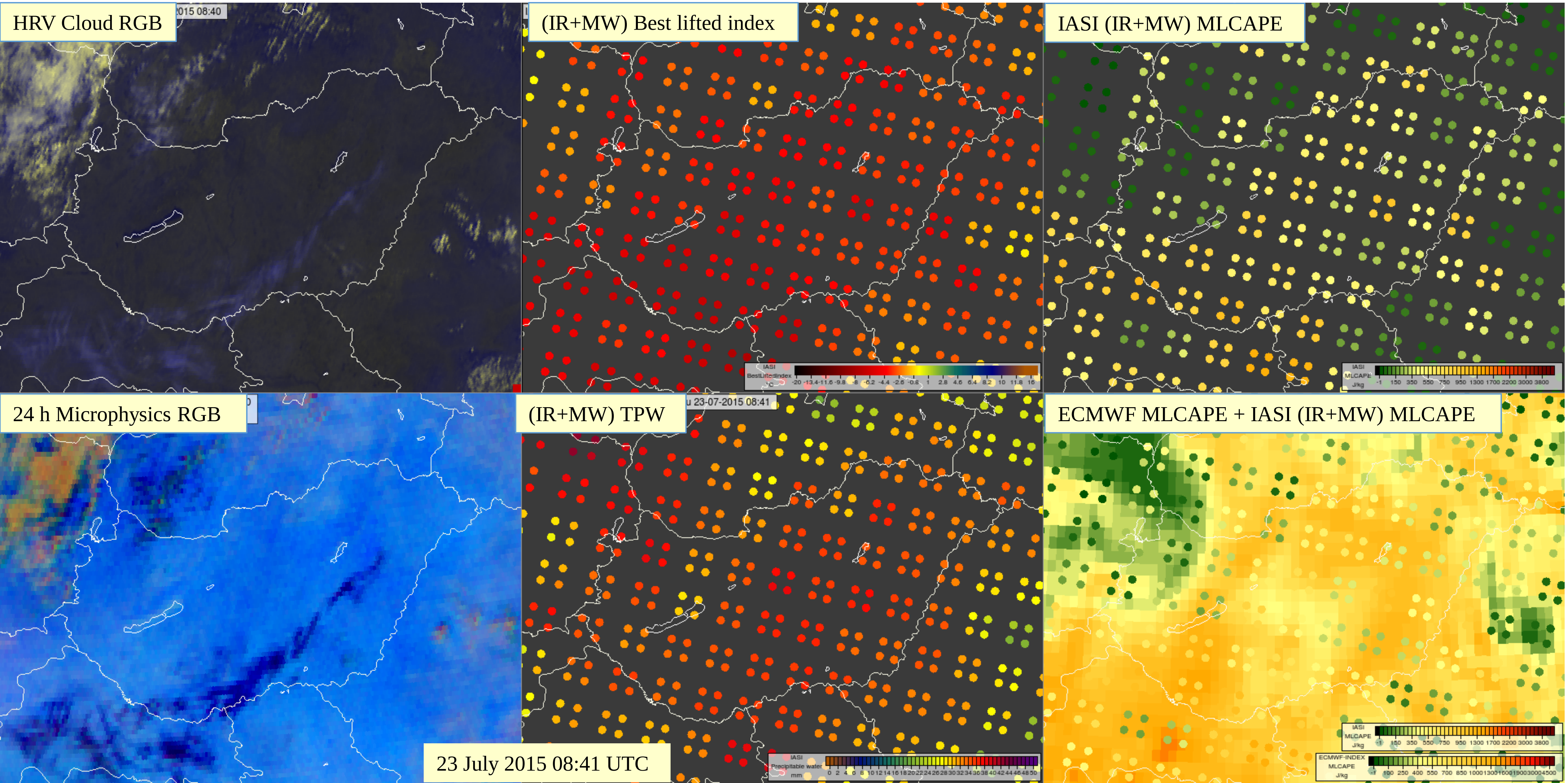


The ECMWF Td is much higher in **mixing layer**. That is why the ECMWF MLCAPE is significantly higher. SEVIRI HRV shows small low cumulus clouds in this area, supporting the ECMWF forecasted profile.

Some features we found when comparing IASI derived and ECMWF forecasted environmental parameters

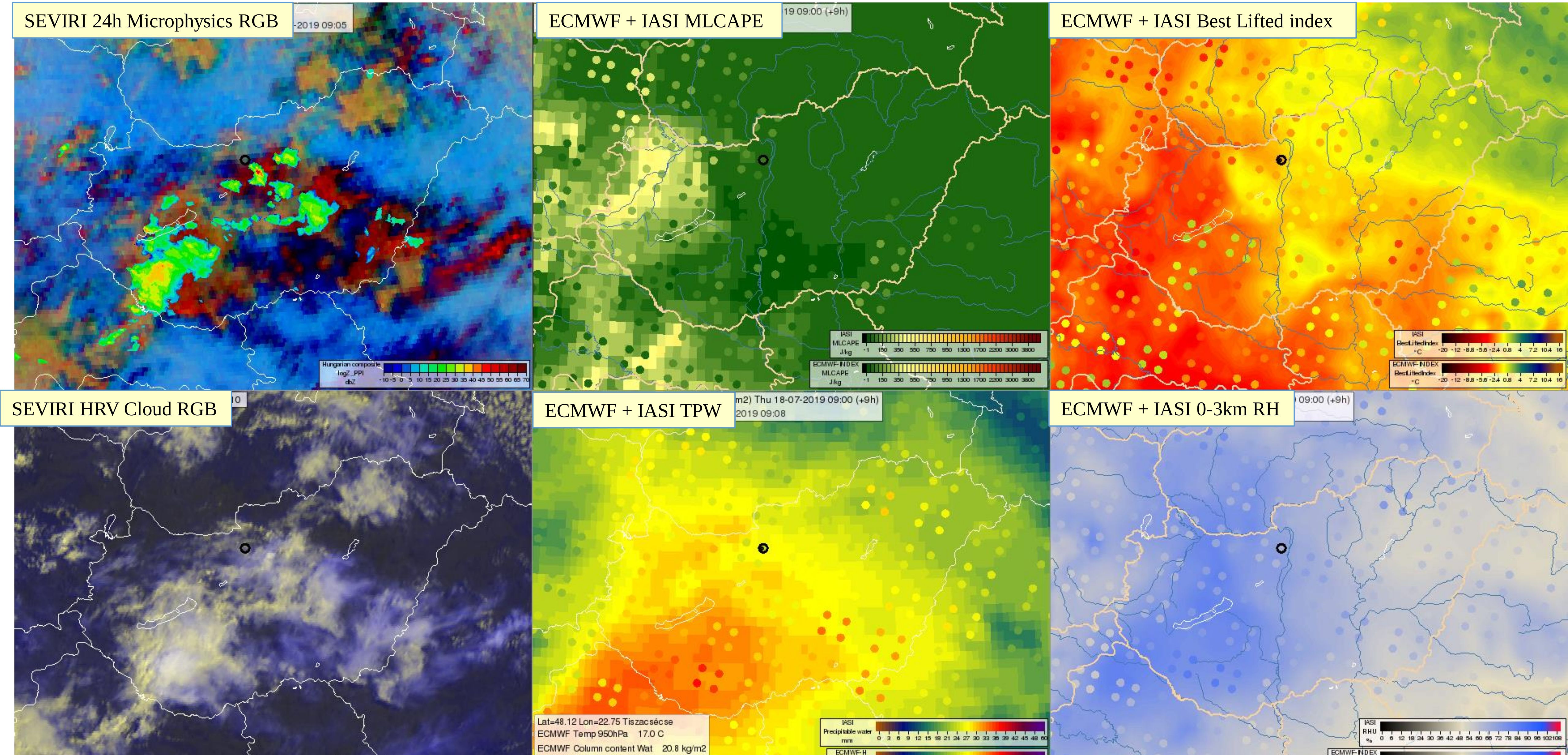
MLCAPE (cont.)

- Although IASI MLCAPE is usually strongly underestimated compared to the forecast - in extreme unstable situation it can reach relatively higher values. It delineates the most unstable areas. It is worth pay attention if IASI MLCAPE reach higher values in a bigger area.



Cases when IASI derived environmental parameters provided **added value** to the ECMWF forecast

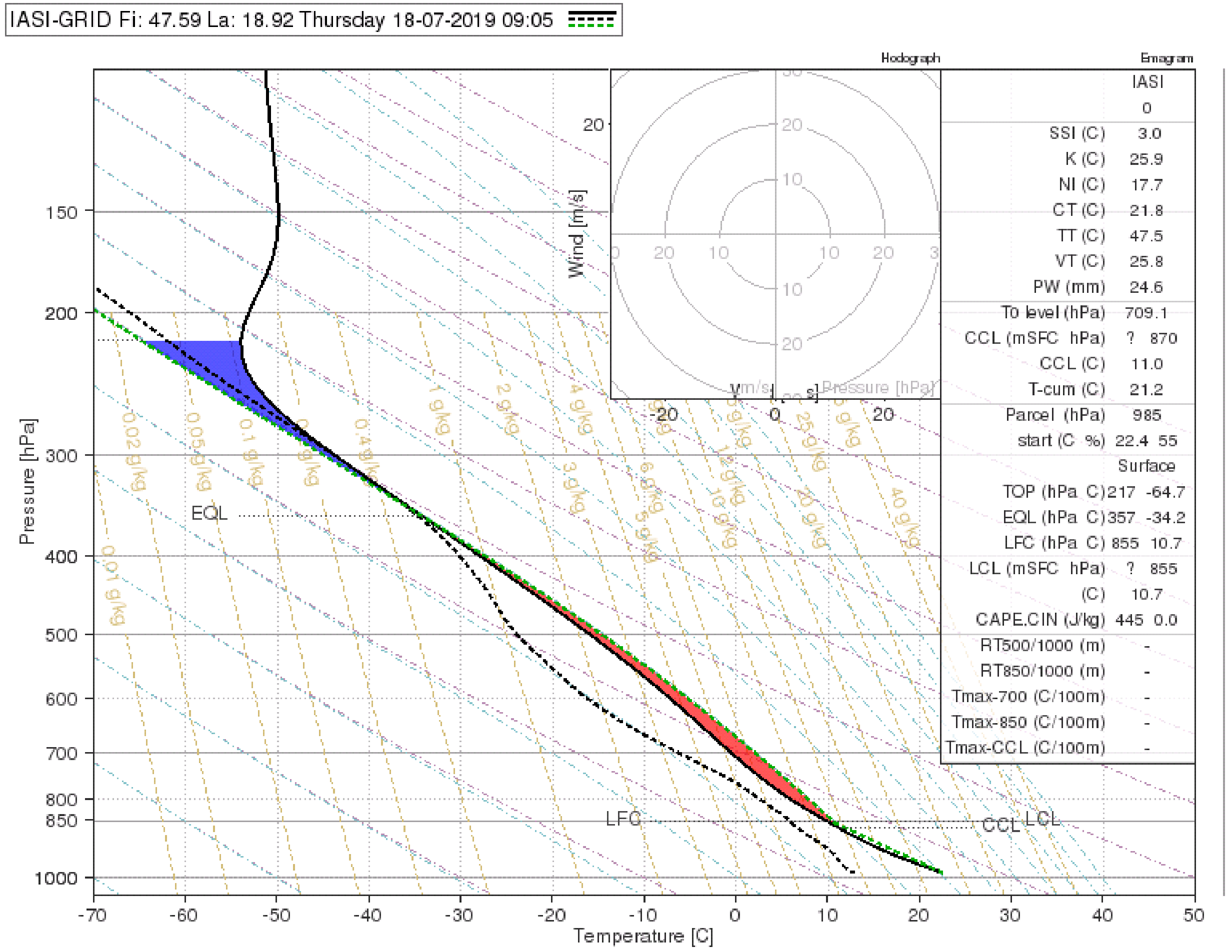
18 July 2019 (09:08 UTC) - Added value in some locations, The environment of an (already existing) developing thunderstorm is unstable according IASI data and much less unstable according ECMWF.



Environment of the developing storm near Budapest

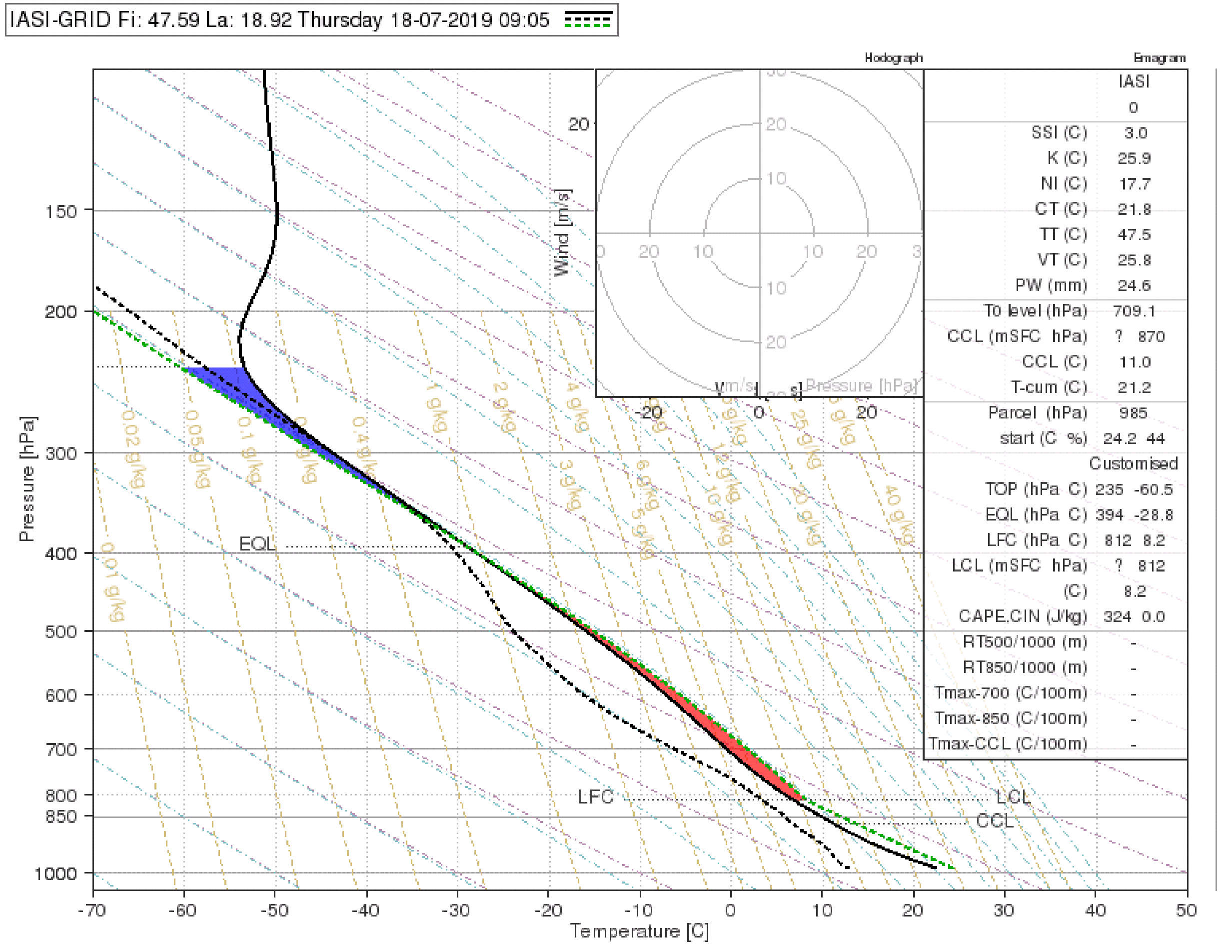
IASI T2: 22.4 °C
IASI Td: 12.8 °C

Steep lapse rate up to ~750 hPa without any inhibition.



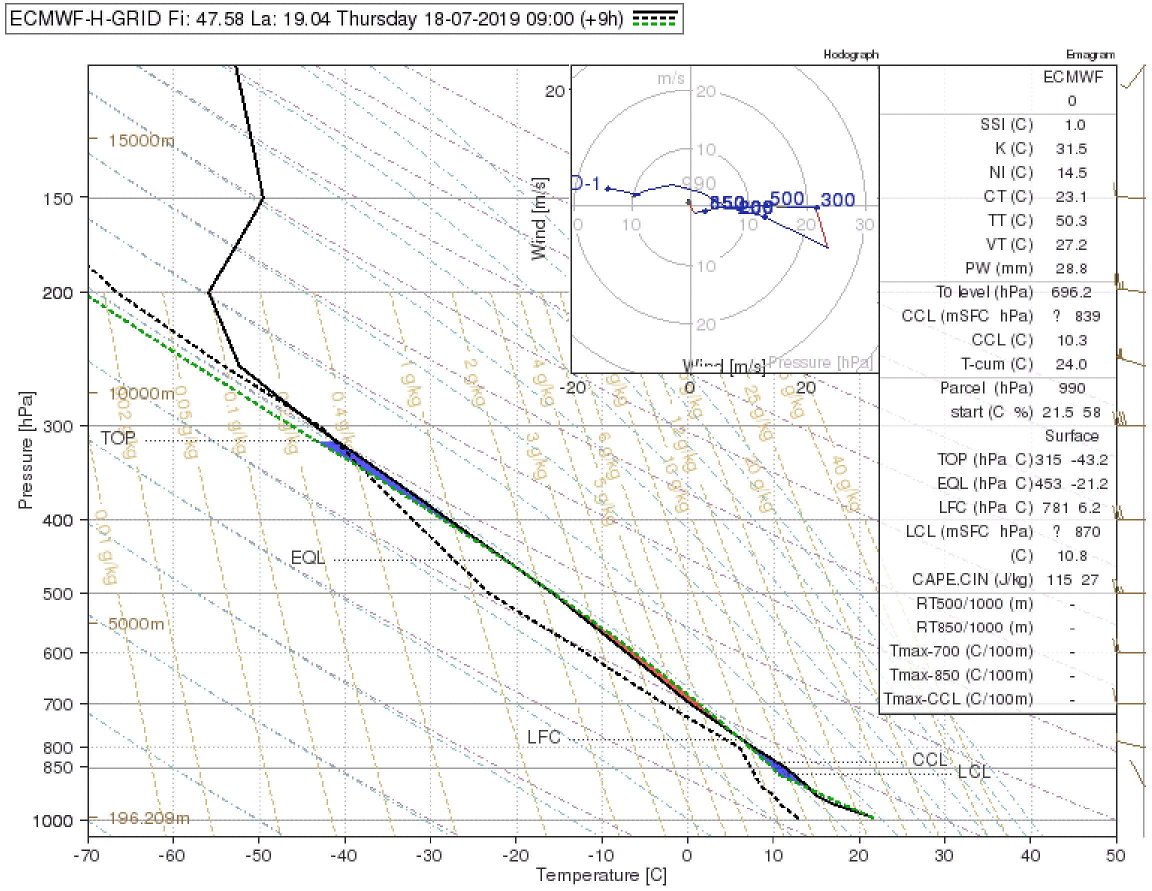
Synop T2: 24.2 °C
Synop Td: 11.1 °C

With SYNOP there is less instability but still unstable



ECMWF pseudo-sounding 09 UTC

There is considerable CIN, much less CAPE, lapse rate is smaller.
Based on this, the chance of thunderstorm is much smaller



Merging with surface observations

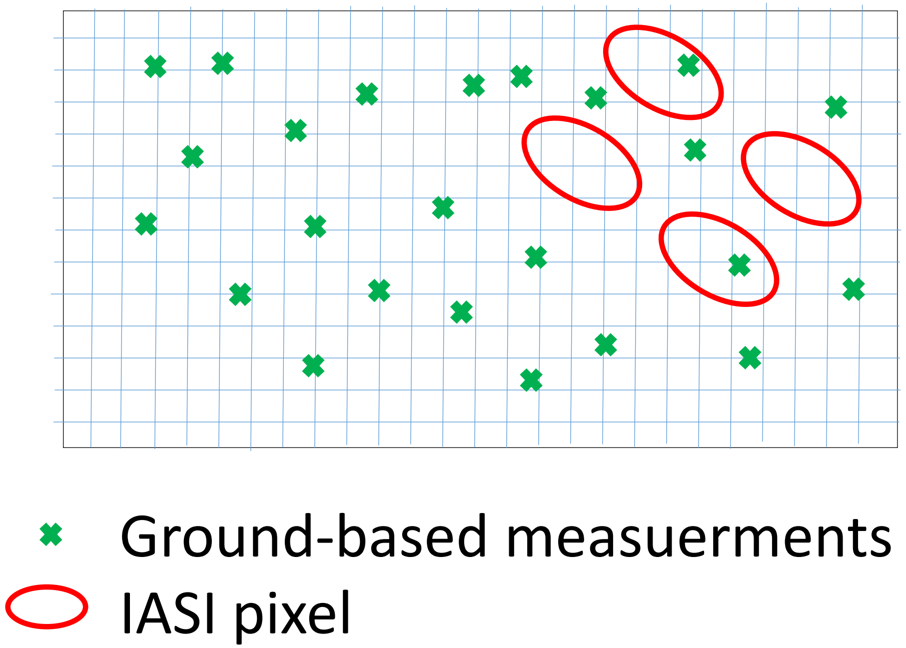
- Bloch et al. (2019) used Suomi NPP NUCAPS data and MADIS high resolution observation data
- Both dataset were transferred to 0.7^ox0.7^o grid
- To reflect to true surface parcel MADIS T and Td was substituted for the near-surface estimates from coincident NUCAPS vertical profiles of temperature and water vapor prior SBCAPE calculation

Bloch, C., R. O. Knuteson, A. Gambacorta, N. R. Nalli, J. Gartzke, and L. Zhou, 2019: Near-Real-Time Surface-Based CAPE from Merged Hyperspectral IR Satellite Sounder and Surface Meteorological Station Data. *J. Appl. Meteor. Climatol.*, **58**, 1613–1632, https://doi.org/10.1175/JAMC-D-18-0155.1.

How to combine satellite derived profiles (representing **larger areas)** with **pointwise** surface measurements? The lowest level of the IASI profiles was modified.

Merging IASI profiles with surface measurements

- In some dates and locations we performed it interactively using the in-built tools of the HAWK visualisation system
- For the automatic merging, we did the following:



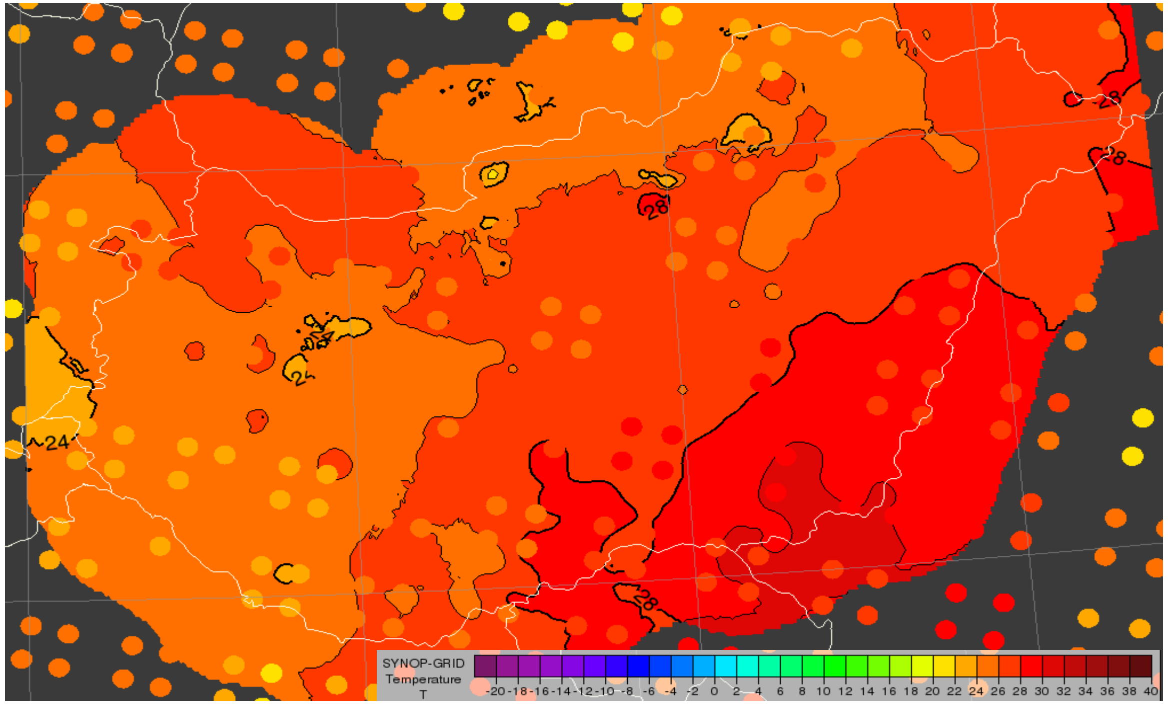
1. Interpolate the ground-based measurement to a grid (0.02°) using inverse distance weighting (IDW) taking into account topography. – For each grid the stations within 50 km were used. (HAWK-3)
2. Within the IASI ellipses: calculate average T, Td of the grid points.
3. Use this new T, Td as the surface value in the IASI profile.

Merge with surface measurements

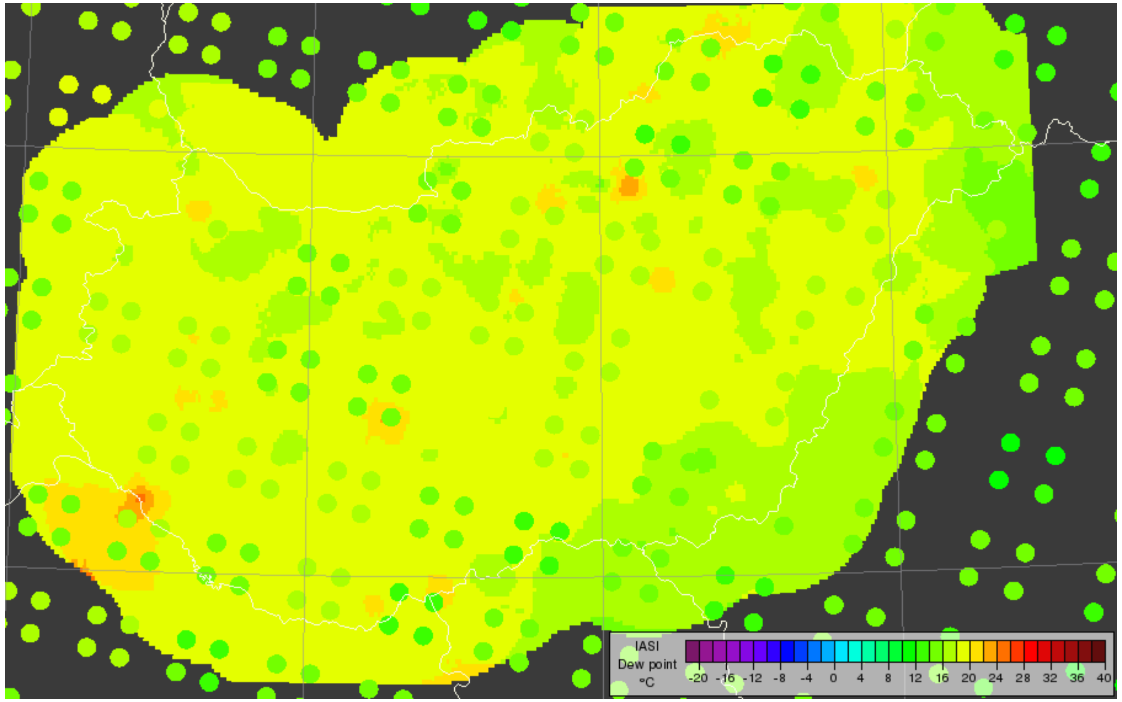
The IASI profiles have larger uncertainties at low levels, they are often **drier (and colder**) than indicated by the model profiles or surface measurements. Would merging with synop help?

24 August 2019

IASI data from 08:27 UTC, surface measurement from 08:30 UTC



Interpolated surface measured 2m T + IASI 2m T



Interpolated surface measured 2m Td + IASI 2m Td

Interpolation is based on 10-minute surface measurements performed by the Hungarian automatic station network.

Differences between the surface measurements and retrieved IASI 2m Td are up to 3 °C.

Which parameters are effected by the merging? (Try to guess)

- Total Pecipitable Water (TPW),
- mean relative humidity in the lowest 0-3 km width layer (0-3km RH),
- K-index,
- Best lifted index,
- Maximum Buoyancy,
- MLCAPE,
- 400/700 hPa lapse rate,
- 600/925 hPa lapse rate.

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Which parameters are effected by the merging?

- The K-index and the 400/700 and 600/925 hPa lapse rates and are not affected by the merging.
- TPW and 0-3km mean RH are only slightly affected, as the merging modifies only the surface temperature and humidity.
- The MLCAPE parameter is affected by merging as it is slightly sensitive to the surface temperature and dew point values. (It is extreme sensitive to the mean Td of the lowest 100 hPa layer.)
- The Best Lifted index is either the most sensitive to the surface temperature and dew point values, or not effected by them at all. (The Best lifted index is calculated by lifting the virtual air parcel from several levels inside the lowest 100 hPa layer and the most unstable value is taken. If the most unstable value belongs to a lifting from an elevated level, then BLI is not affected by the surface temperature and humidity.)

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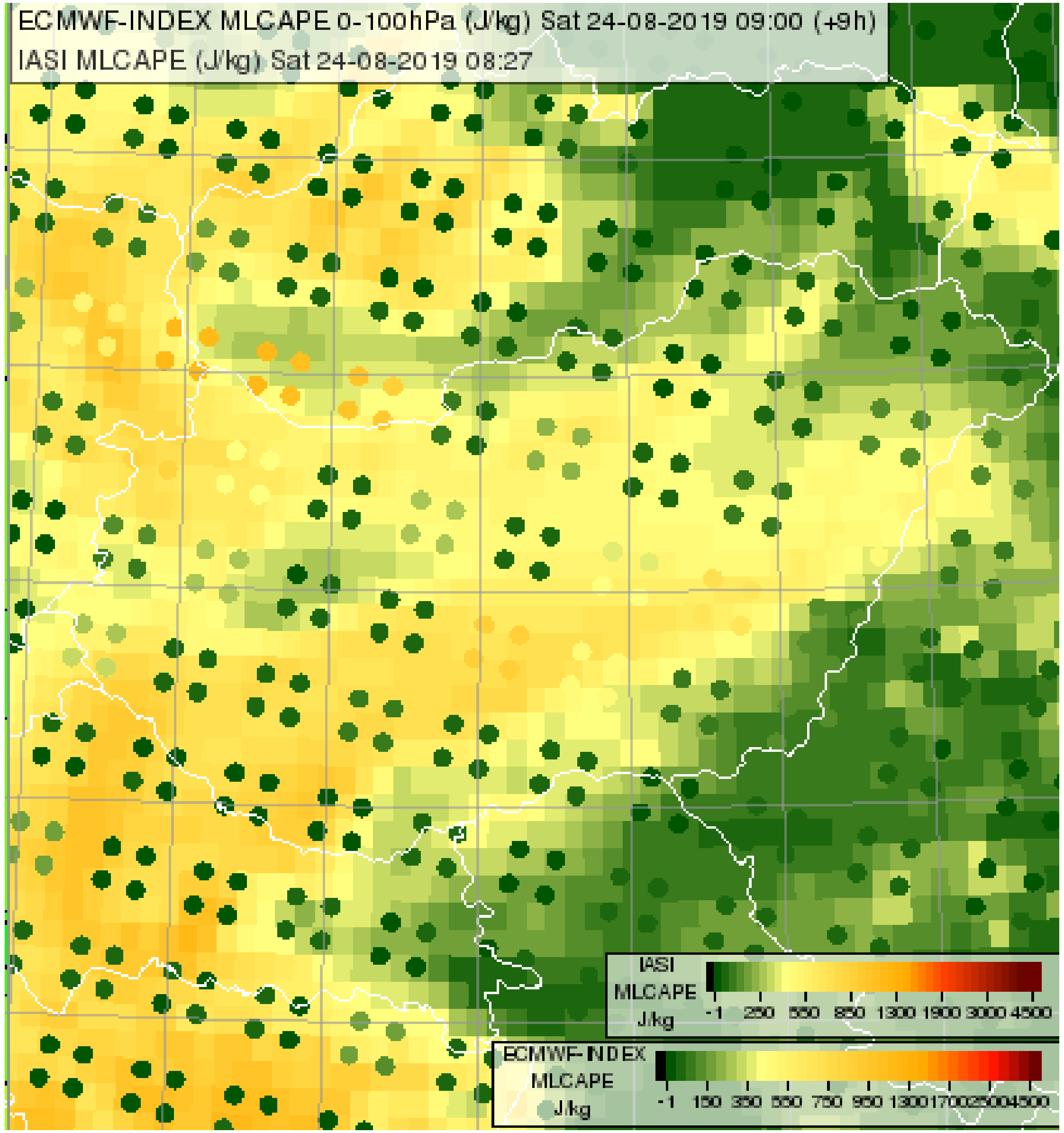
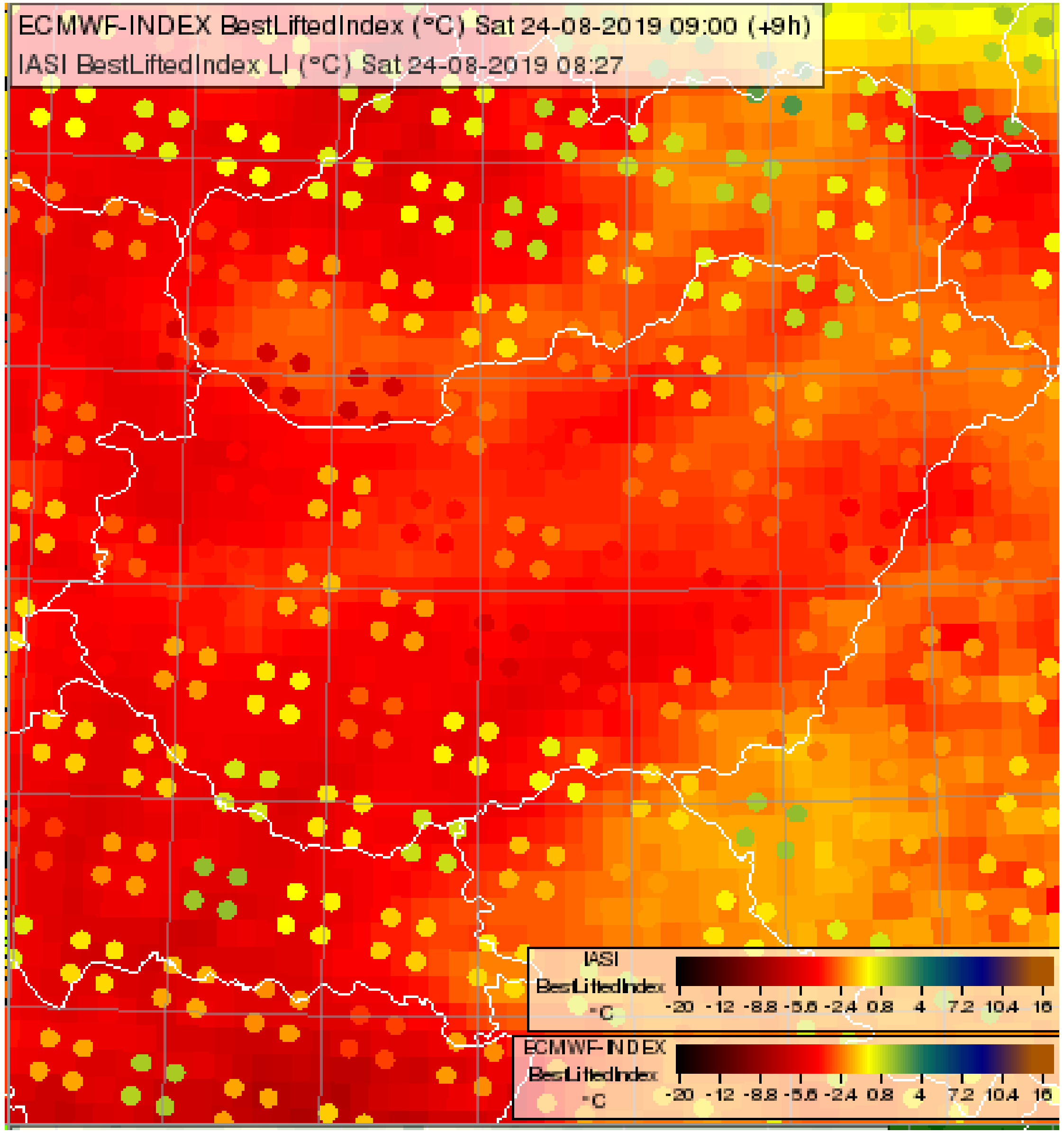
Merge with surface measurements

24 August 2019 (IASI data from 08:27UTC, forecast valid for 09UTC



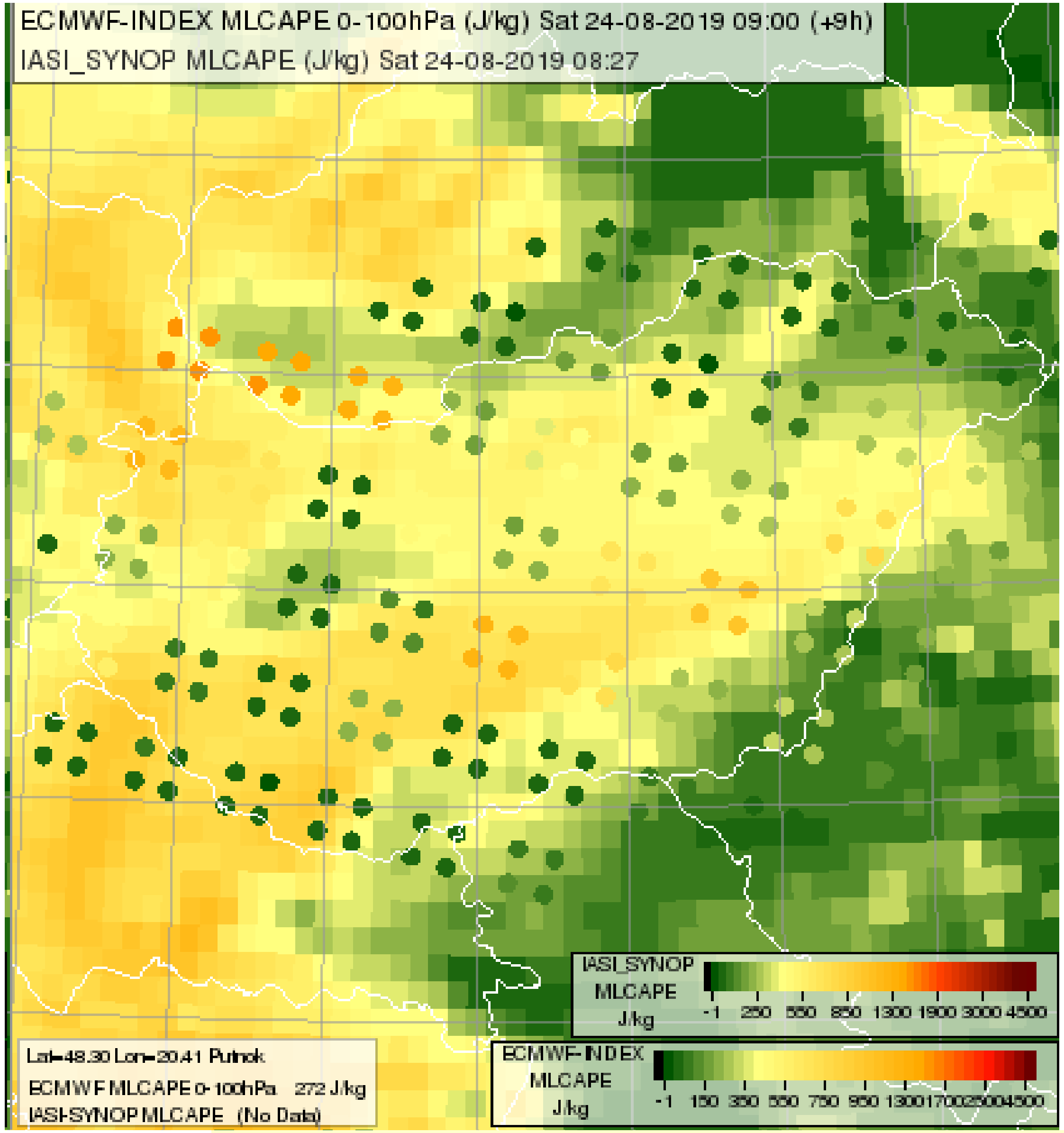
ECMWF+IASI MLCAPE



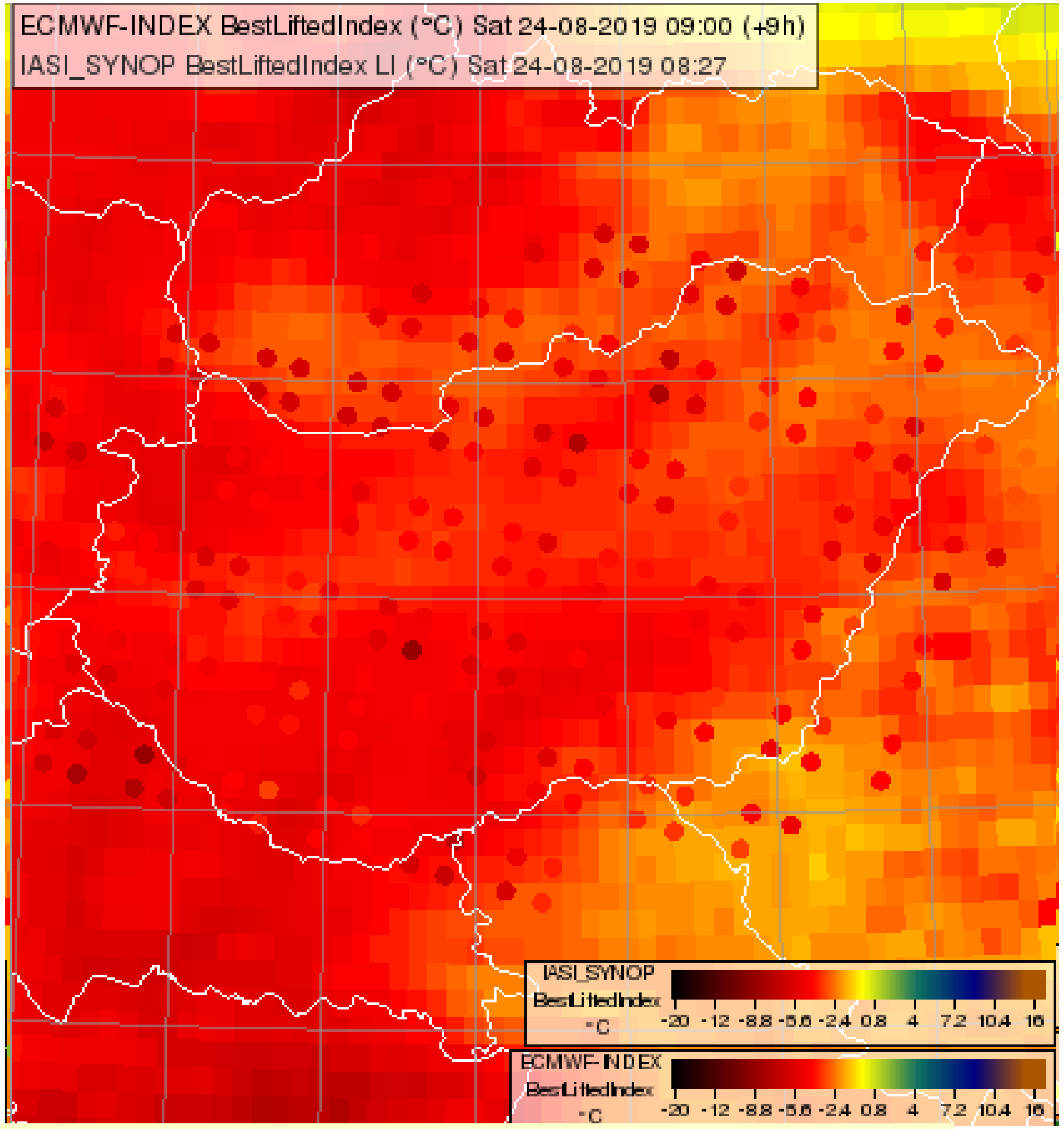
ECMWF+IASI Best Lifted index

Merge with surface measurements

24 August 2019 (IASI data from 08:27UTC, forecast valid for 09UTC)



ECMWF + (IASI + synop) MLCAPE



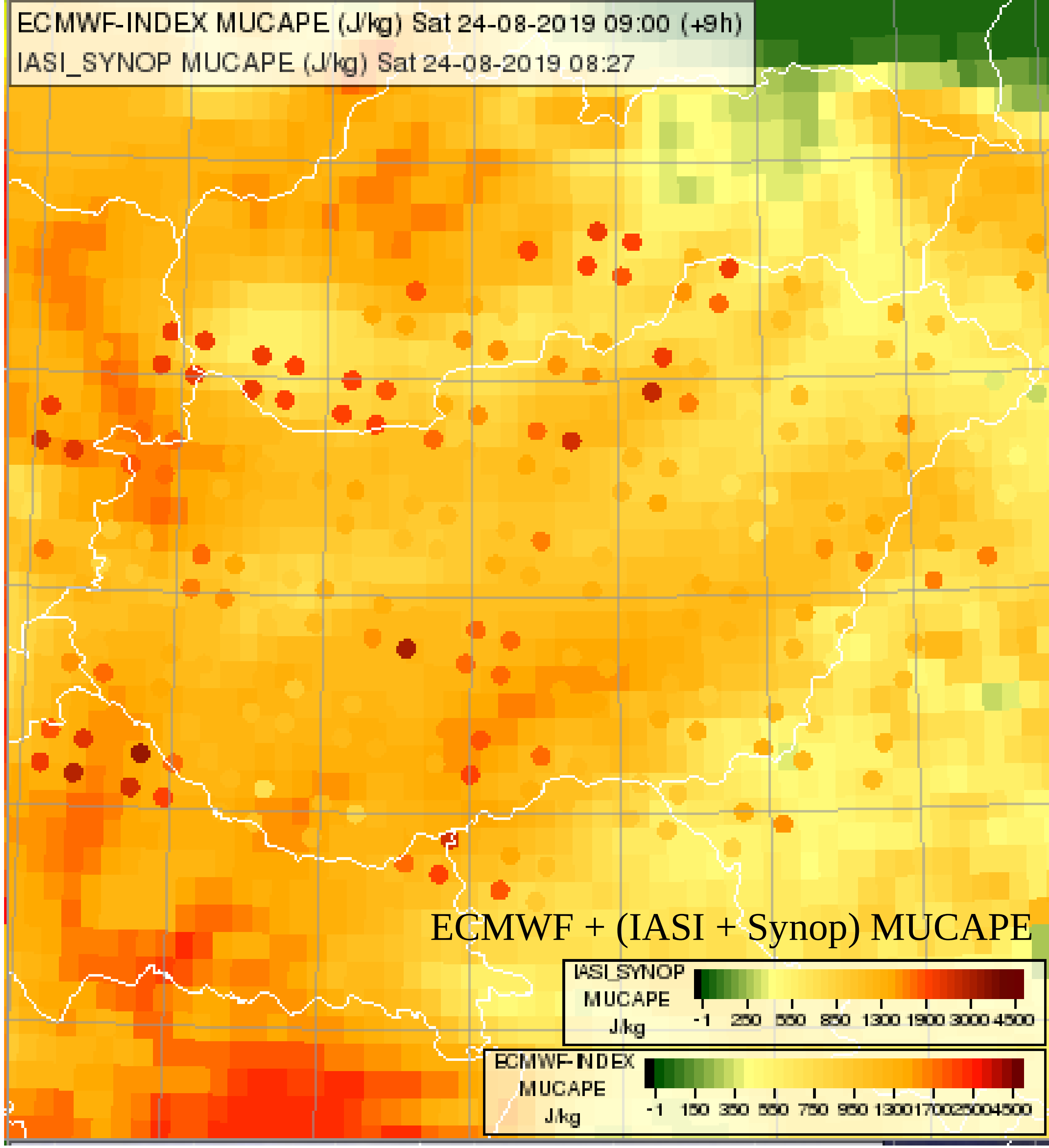
ECMWF + (IASI + synop) Best Lifted index

Merge with surface measurements

Combining the IASI profiles with synop measurements can improve indices which are more dependent on the 2m values.

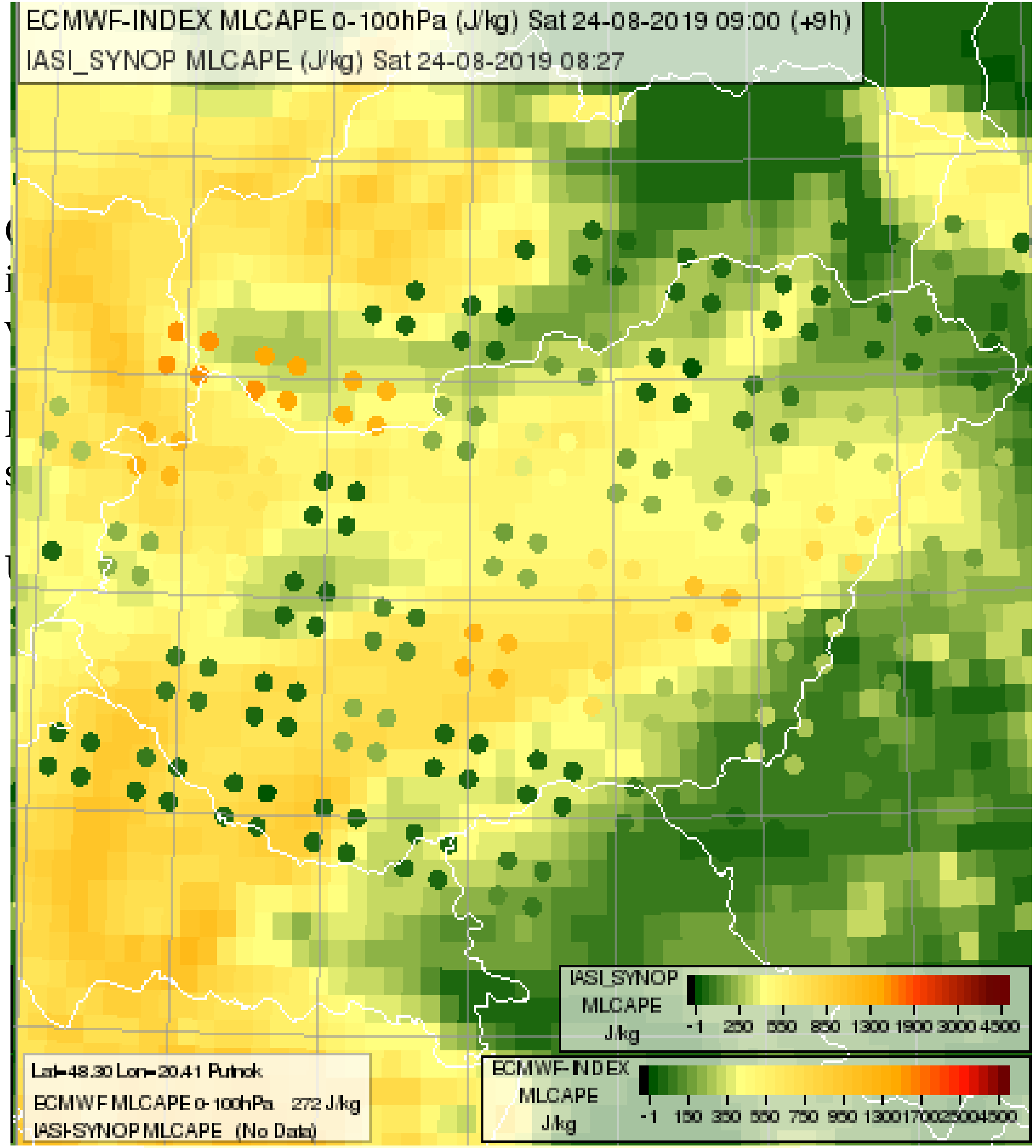
MLCAPE is dependent in the lowest 100 hPa layer which is still often dryer than the models.

Using MUCAPE might be a better choice.

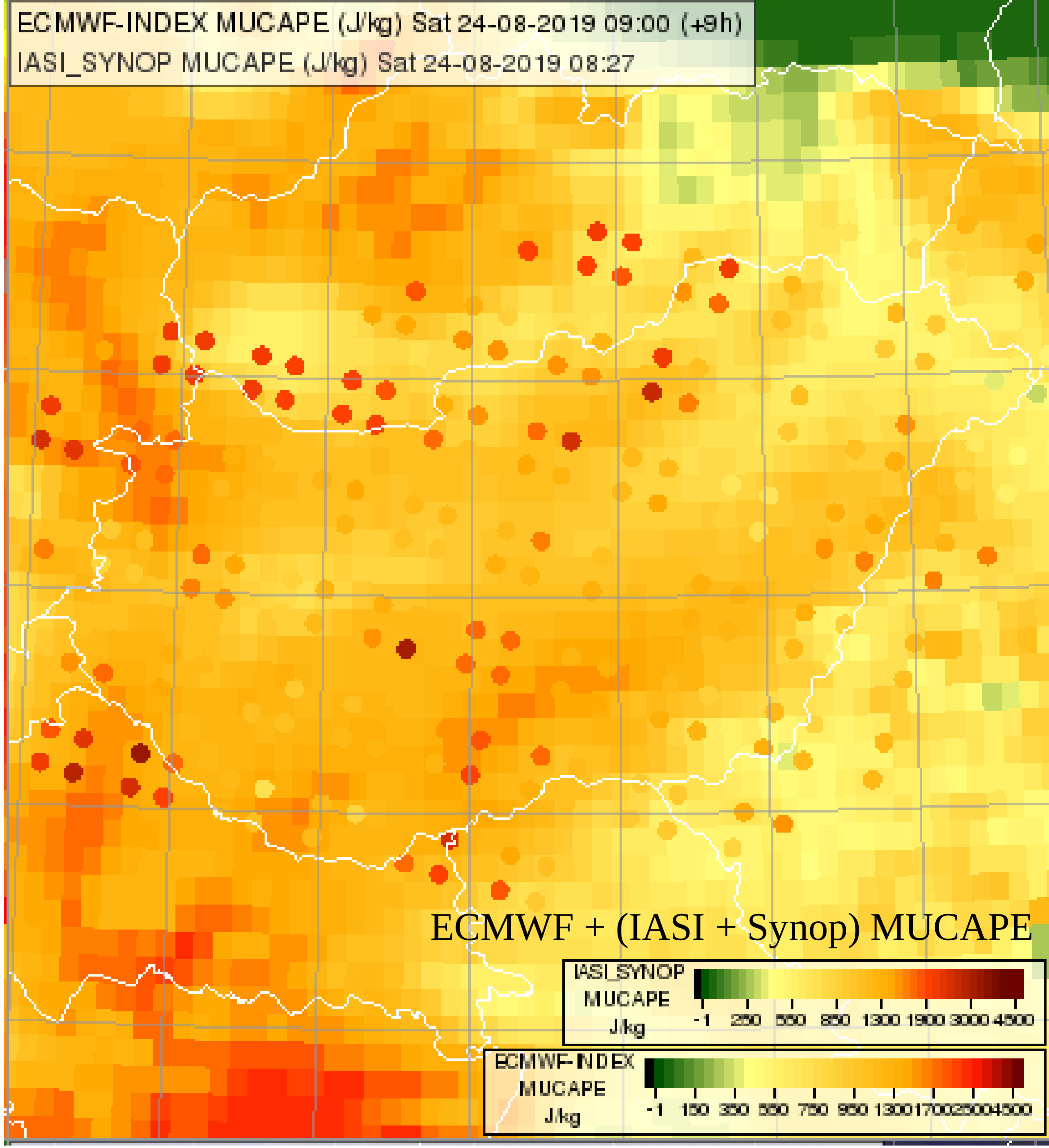


ECMWF + (IASI + Synop) MUCAPE

24 August 2019
IASI data from 08:27UTC,
forecast valid for 9 UTC
surface measurement from 9 UTC



ECMWF + (IASI + synop) MLCAPE



ECMWF + (IASI + Synop) MUCAPE

Experiences with the merged product and feedback from the forecasters

- Forecasters routinely monitored the merged product and the IASI L2 EARS product – diary about the performance
- One feedback: include the CIN calculation (it was only visible if they have looked at the profile)
- View of the forecasters:
  - „Usually the stable environment is well captured in the IASI data"
  - „The merged IASI data better describes the instability (then the EARS L2) but very often overestimates it– mostly using only for confirmation of the forecast"
  - „Sometimes the merged IASI indices seem to be better while other times the original IASI – never both – difficult to rely on one or the other
  - „Very often the existing convective inhibition in the EARS IASI L2 disappears from the merged product (when it is present in reality)

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Further plans

- Further evaluate the summer cases - making case studies
- Look into whether the performance can depend on different synoptic situations and if yes how
- Try to find a solution for the ‚overestimated’ instability and disapperaing CIN in the merged product

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Thank you!

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