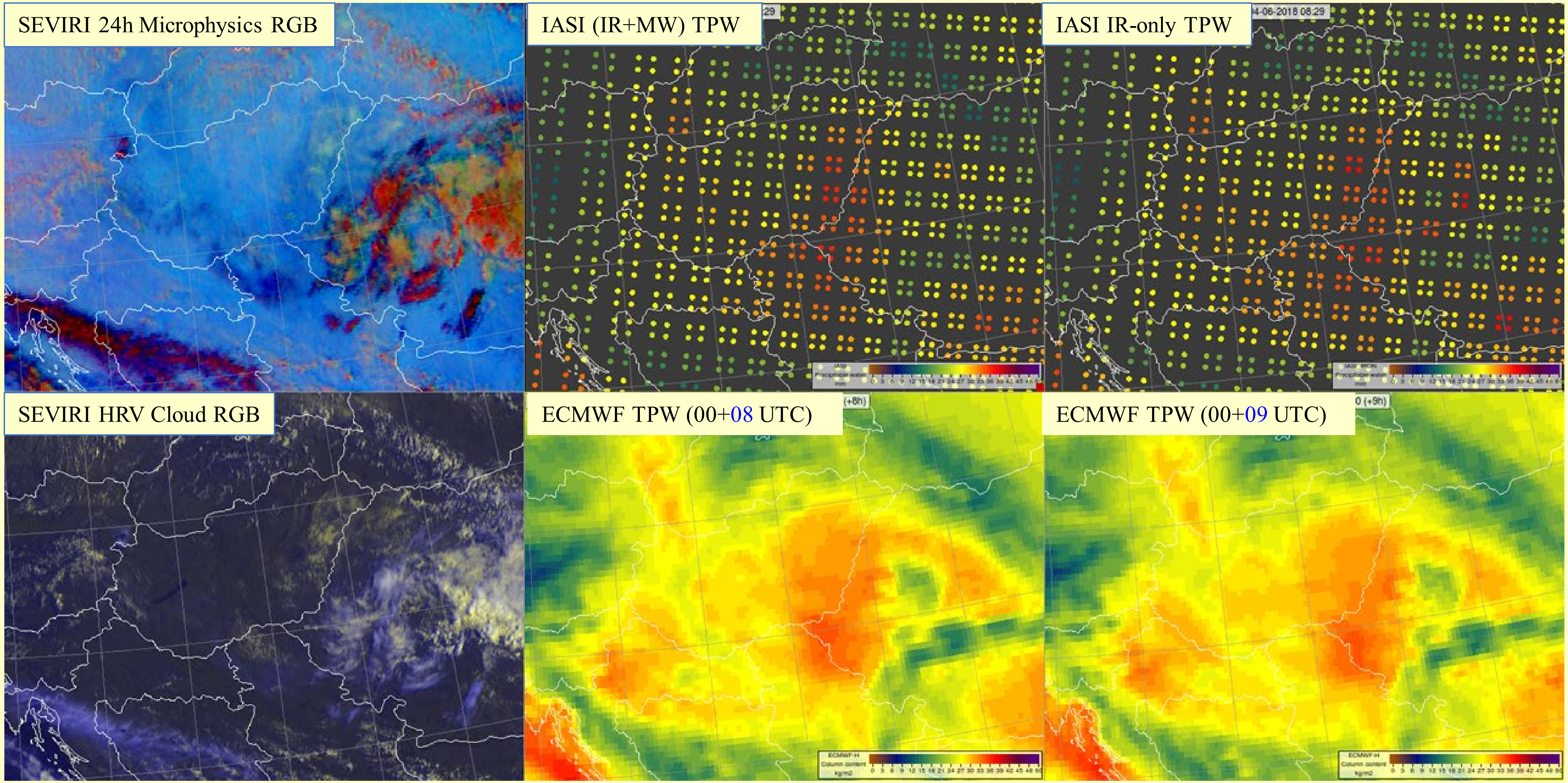
Detection and monitoring of instability from hyperspectral sounders, using IASI in view of MTG-IRS



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EUMETSAT study, Contract number EUM/CO/18/4600002186/TA, Final meeting, 25 February 2020, EUMETSAT

Outlines

- Introduction
- Global analyses of instability indices from the infrared-only IASI L2 products
- Case studies
  - How to gather interesting cases?
  - Comparison of IR-only and IR+MW data
  - Comparison IASI L2 and ECMWF data – typical features
  - Cases with added value and cases confirming the forecast
- Forecast and L2 differences dataset
- Merging IASI L2 product with surface measurements
- Suggestions
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Introduction – Aims - Tasks

Second EUMETSAT study on potential usefulness of IASI data for nowcasting purposes.

One of the aims of our **previous study:**

Potential usefulness of IASI L2 (IR+MW) data for nowcasting purposes

- 6 month **statistics** – on consistency of IASI L2 (IR+MW) derived and SEVIRI GII environmental parameters
- 7 **case studies** on potential usefulness of IASI derived environmental parameters, profiles for nowcasting

In the **present** study the focus is on the IASI L2 IR-only data – as proxy data for MTG/IRS

(including the usefulness of synergetic use of IASI data with ground measurements)

Statistics

- 6 month statistics – on consistency of IASI L2 (IR-only) derived and SEVIRI GII environmental parameters
- Comparison of the statistics between (IASI (IR+MW) and GII) and (IASI IR-only and GII)

Case studies - Gathering interesting cases (based on IASI (IR+MW) data)

Cases with considerable differences between IASI derived and ECMWF forecasted environmental parameters

- Analyse IR-only derived profiles, parameters
- Perform some detailed case studies
- Creating a database of typical IASI and ECMWF profile pairs

Merge the IASI profiles with surface measurement

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Global analyses of instability indices from the infrared-only IASI L2 products
6 month statistics

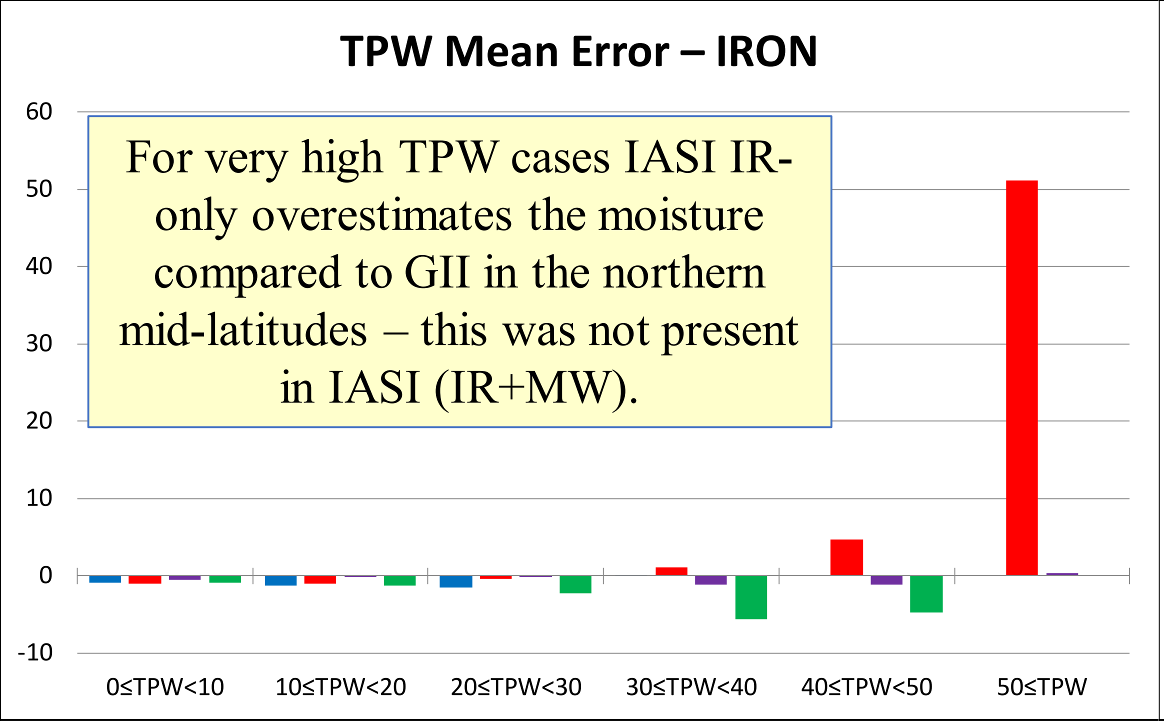
Comparison of
- **SEVIRI/GII** products with
- the same parameters retrieved from **IASI L2 product (processed in IR-only mode)**

in order to estimate their ***consistency***.

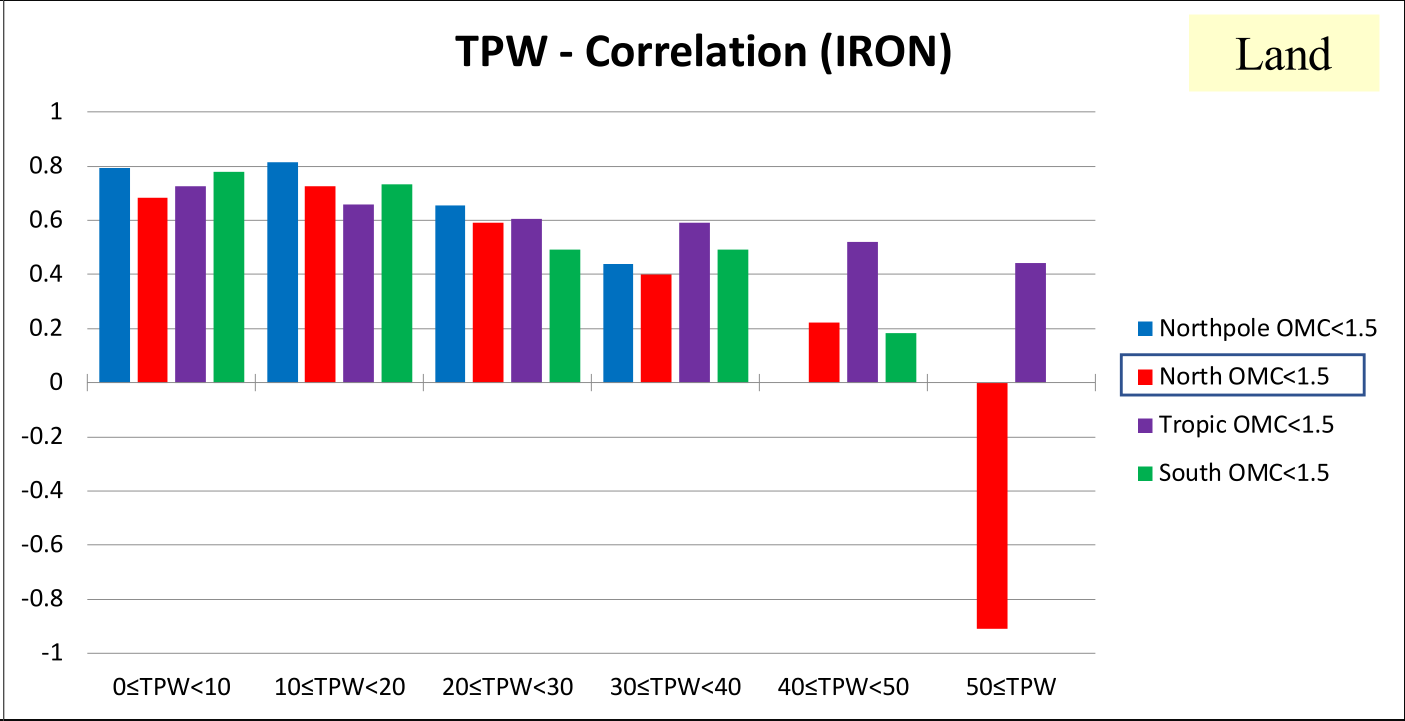
  - Mean error, RMSE, standard deviation and correlation were calculated for
    - six months period (April - October 2016),
    - different regions:
      - North Pole,
      - Mid-latitudes of the Norther hemisphere,
      - Tropics,
      - Mid-latitudes of the Southern hemisphere,
      - South Pole,
    - surface types (sea/land),
    - parameter intervals,
    - quality indicator intervals and
    - Metop-A and B.

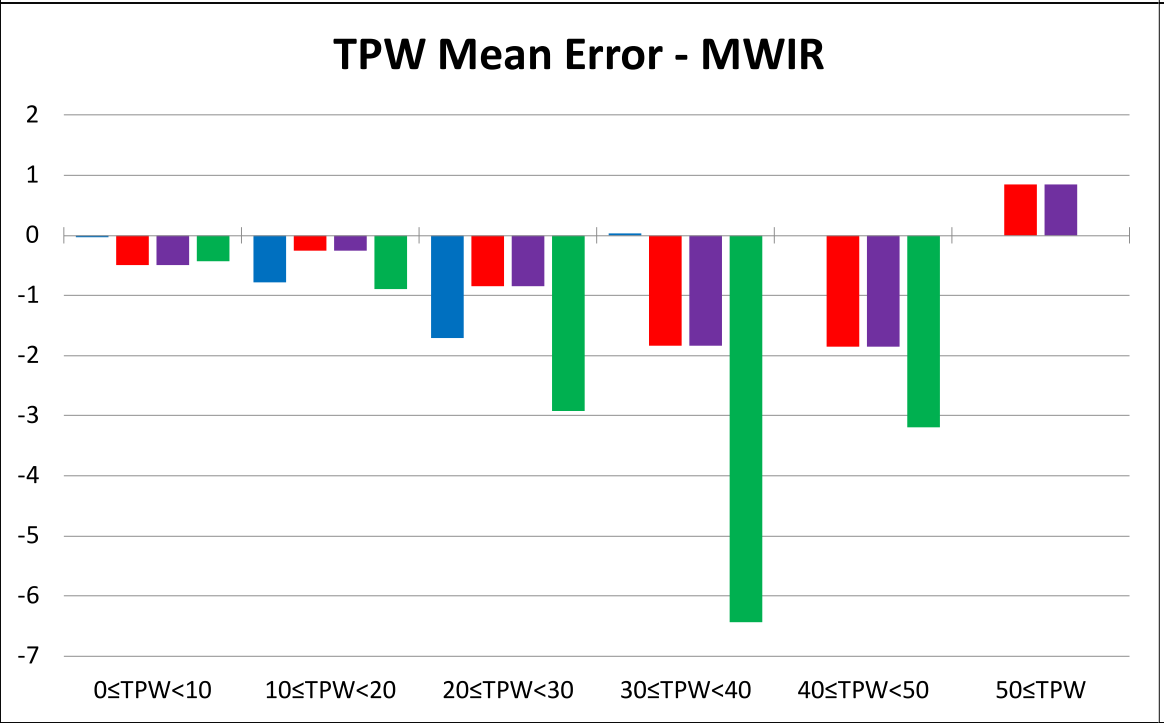
The results were compared with the results of the previous study when SEVIRI/GII were compared with the same parameters retrieved from **IASI L2 product (based on IR+MW measurements).**

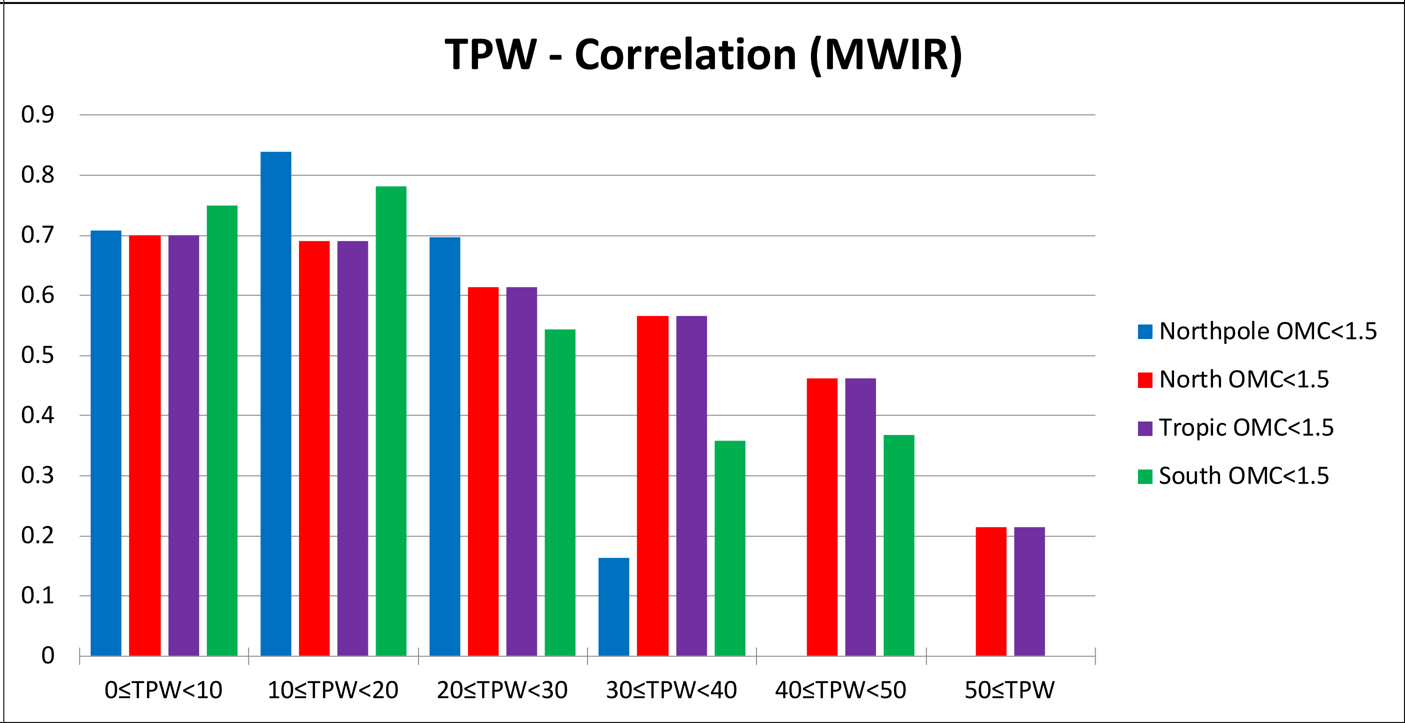
Land

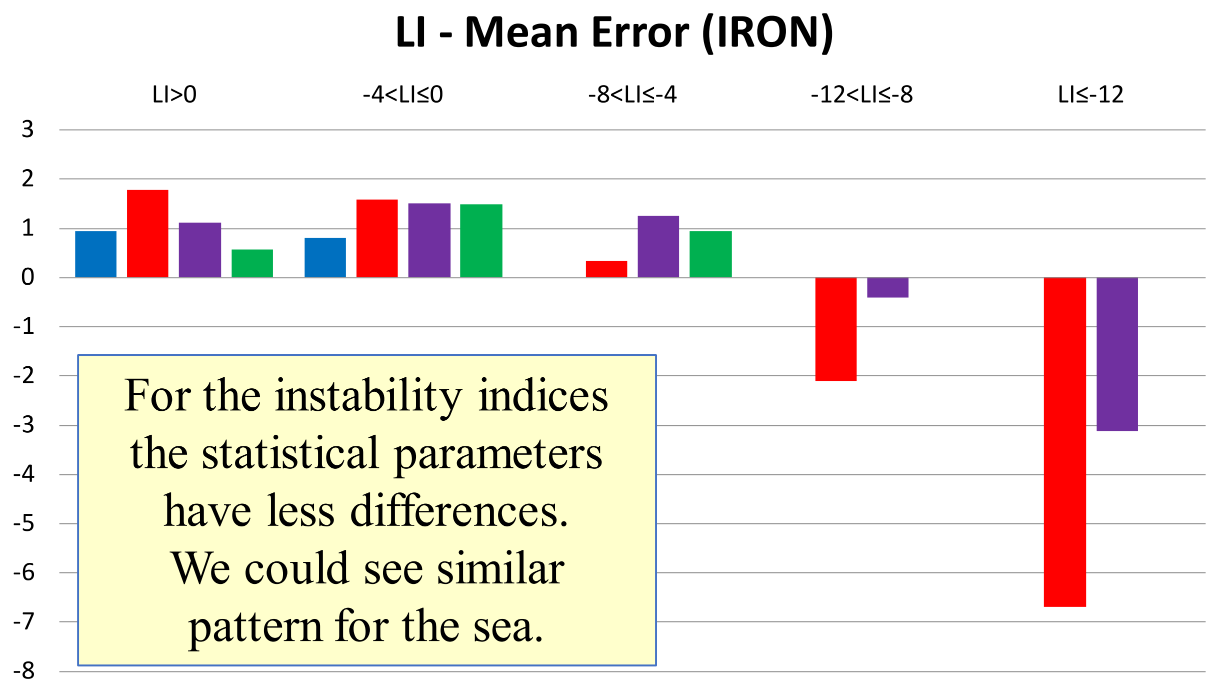


For very high TPW cases IASI IR-only overestimates the moisture compared to GII in the northern mid-latitudes – this was not present in IASI (IR+MW).

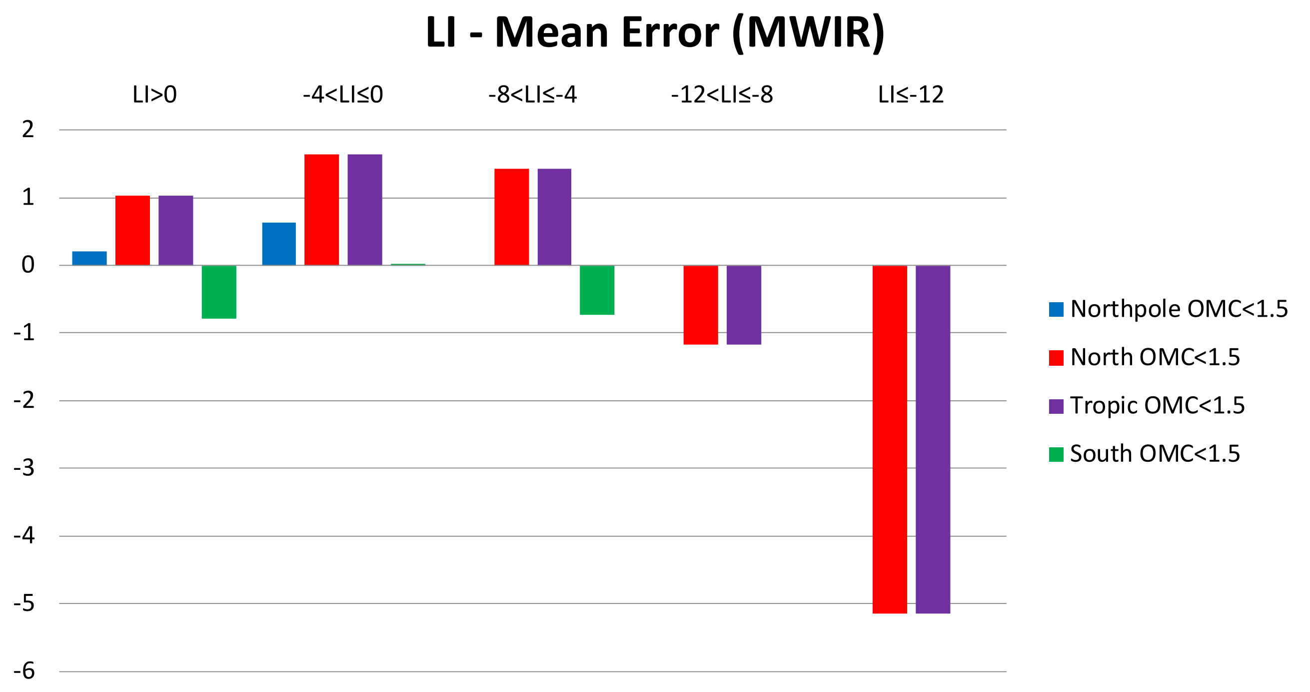


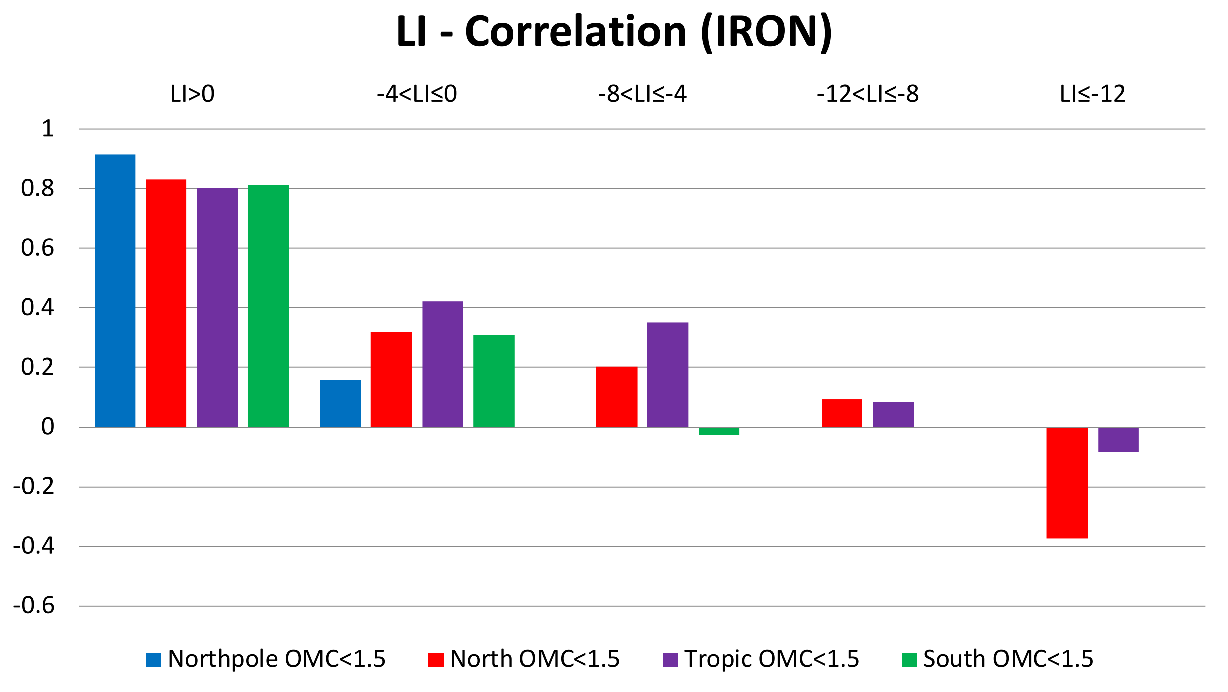


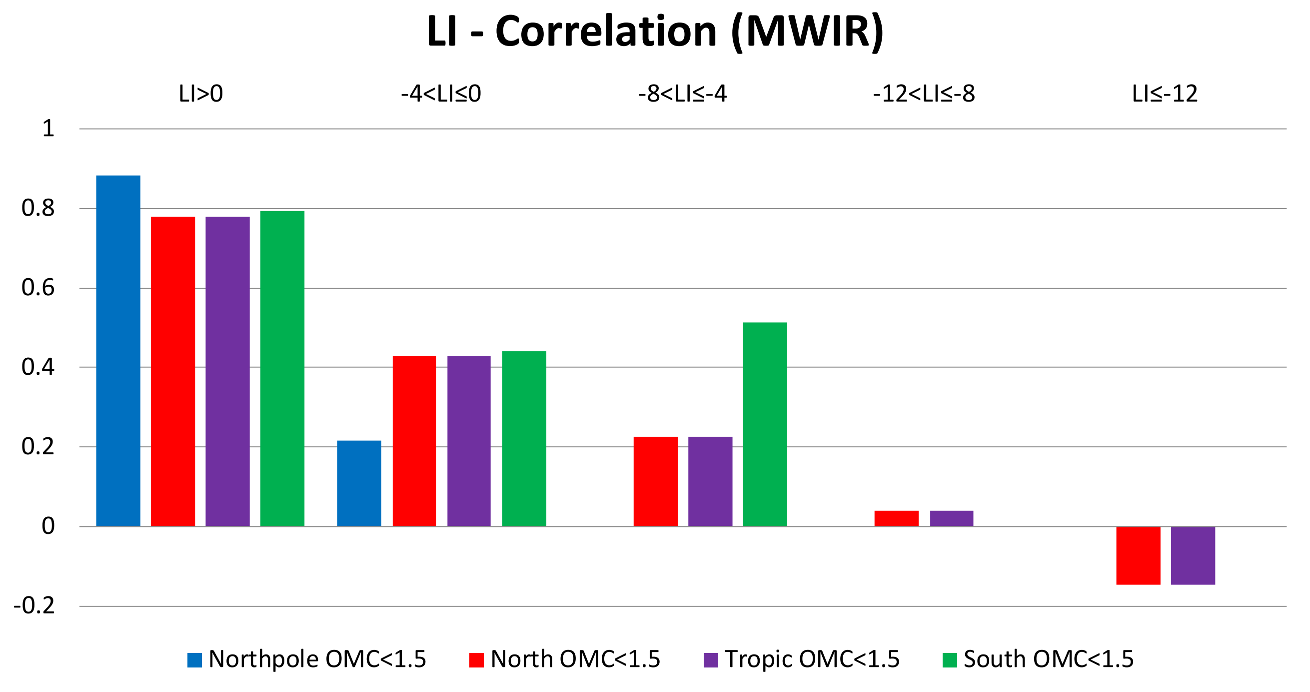




For the instability indices the statistical parameters have less differences. We could see similar pattern for the sea.







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Gathering of cases - based on IASI L2 (IR+MW) data

Preparation

- Regular reception of IASI L2 (IR+MW) data through EumetCast (since Mai 2018)
- Visualisation of IASI derived environmental parameters and profiles in the Hungarian visualisation system (HAWK)
  - Total Pecipitable Water (TPW), mean relative humidity in the lowest 0-3 km width layer (0-3km RH), K-index, Best lifted index, MLCAPE, 400/700 hPa lapse rate, 600/925 hPa lapse rate …
- Presentation for forecasters on IASI data

How to find interesting cases?

- Five severe weather forecasters checked daily the IASI derived environmental parameters during the 2019 convective season (from June to September). They compared the IASI information with NWP and evaluate them together taking into account which kinds of thunderstorms formed later on. They made notes whether the case was interesting from IASI point of view, (added value, same information, very poor, …)

  ↓
- Selected cases were analysed manually (two kinds of IASI L2 product, ECMWF + synop situation + satellite, radar, lightning data + …

- Some cases from the previous study were reanalysed

Remarks

Three „ingredients" of convection: **instability, moisture, lift**

From IASI L2 data we can derive parameters on instability and moisture, but as it does not contain wind profile we cannot get information on

- lift (to see e.g. a convergence line),
- **wind shear.** It would be very important, as it effects severity of the storm (life time).

Difficulty - no real ground truth:

Missing independent reference – very few soundings in time of the IASI data availability (e.g. at 09 UTC over Hungary)

We have only *surface measurements* and *12 UTC radiosonde measurement*

And we know what happened that day, which thunderstorms formed, developed – indirect info

Are IASI profiles, IASI derived parameters 'in contradiction' with the thunderstorms later developed?

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Experiences with IR-only data

No area is masked

We expected either no data for **area covered with thick clouds**, or profile data only above the cloud tops.

(Thick clouds are opaque in the IR spectral region – satellite do not „see" inside/below the thick cloud in IR region.)

The IR-only retrieval provide full profile output (down to the surface) for thick clouds as well.

(However, the vertically averaged error is usually high for these pixels.)

We suggest to mask the area covered by thick clouds or to provide profiles only above the cloud top.

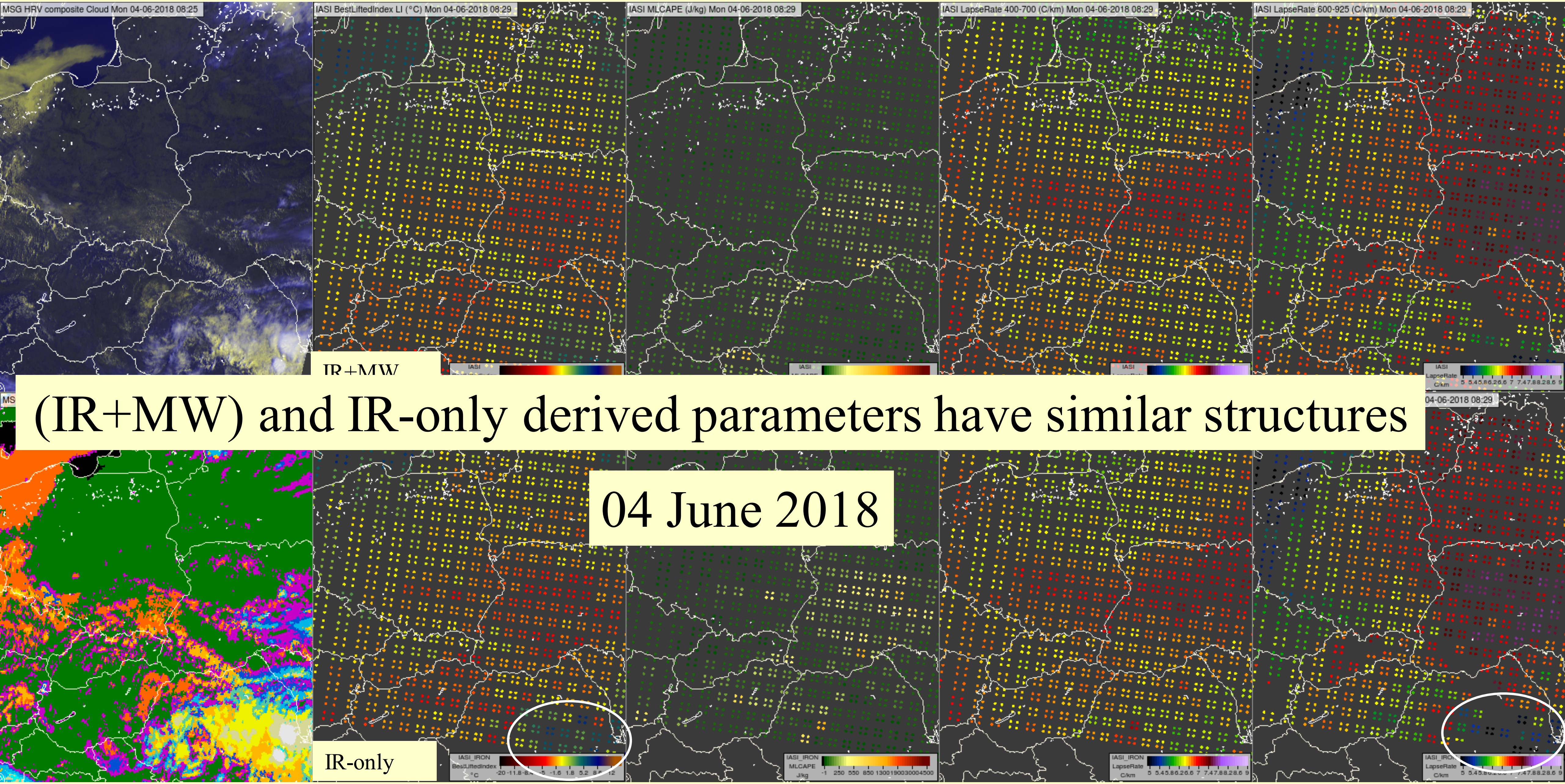
Comparison of IASI L2 (IR+MW) and IR-only data

There are some differences between (IR+MW) and IR-only data even on cloud-free areas, as we skipped/ignored the MW information

We compared **IR+MW and IR-only** data in different **NWCSAF Cloud Type** product classes

- On *cloud free* areas there are less differences, the structure is similar
- On areas covered by *thin cirrus* clouds the retrievals (profiles, parameters) are similar,
  the thinner the cirrus clouds, the more similar the profiles
- In case of *high opaque clouds* the difference is often considerable.
  Even the T profile is considerably different below the cloud, not only the Td profile
  The same can be seen in the vertically averaged error of the profiles. In case of opaque clouds it is much higher.

SEVIRI | Best Lifted index | MLCAPE | 400/700 hPa lapse rate | 600/925 hPa lapse rate



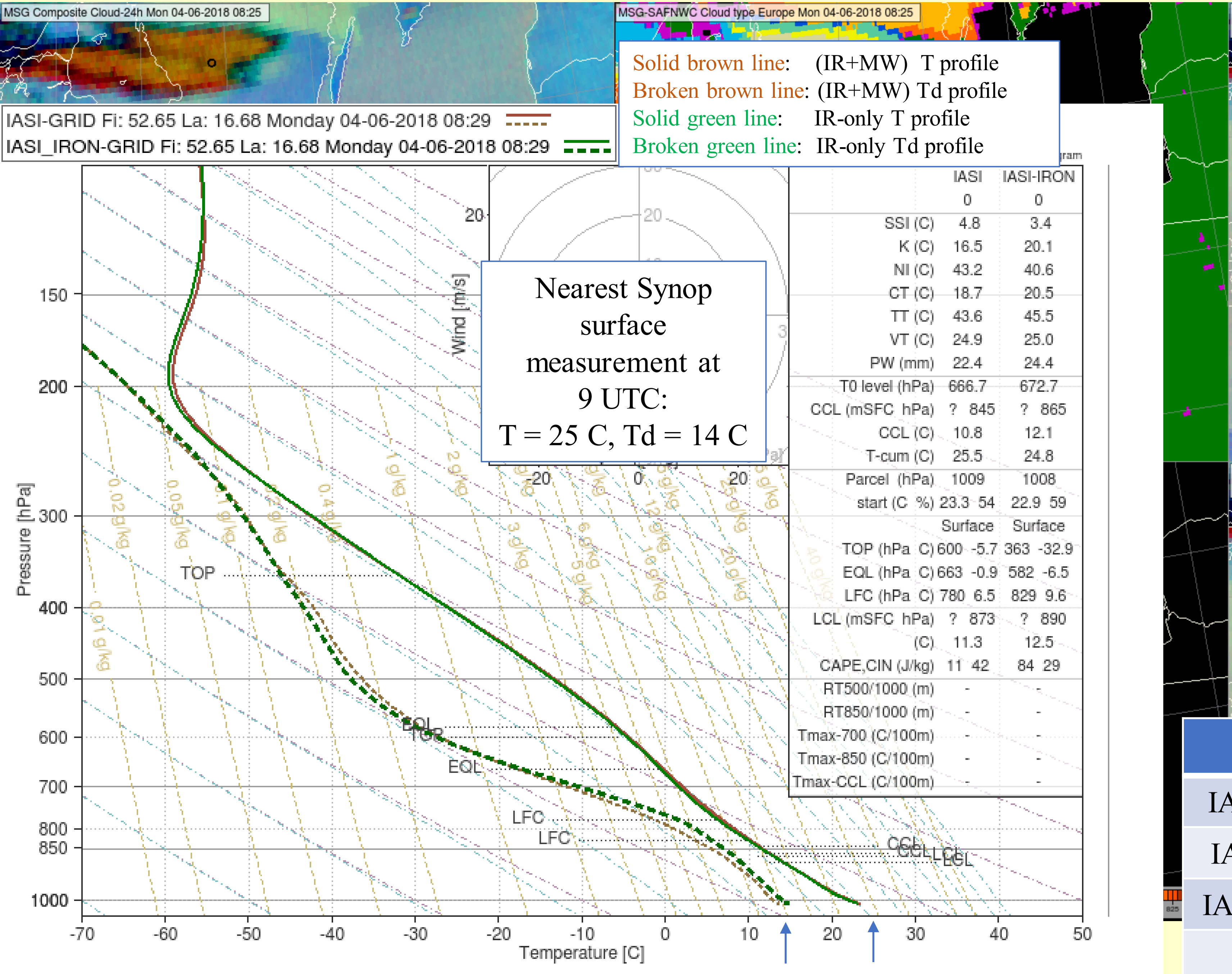
(IR+MW) and IR-only derived parameters have similar structures

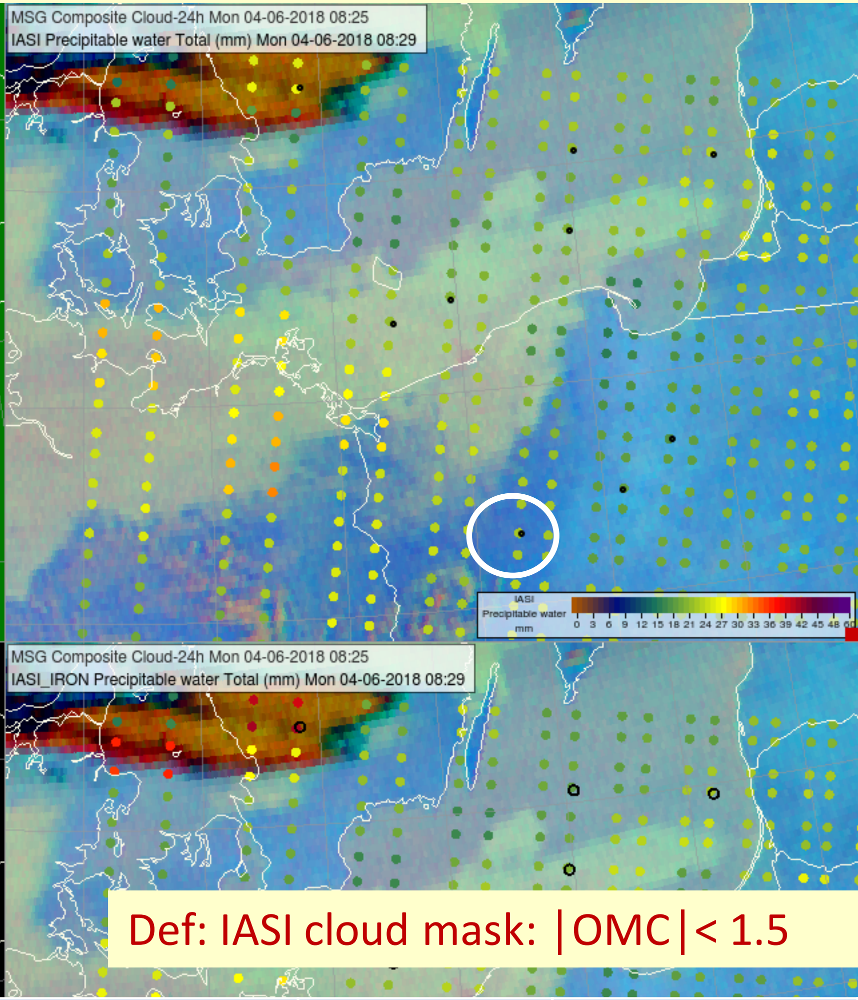
04 June 2018

(IR+MW) and IR-only derived parameters have similar structures, larger differences on areas covered by mid/high-level opaque clouds

Cloud-free land

24 h Microphysics RGB | NWCSAF Cloud Type | 24 h Microphysics RGB + IASI (IR+MW) TPW



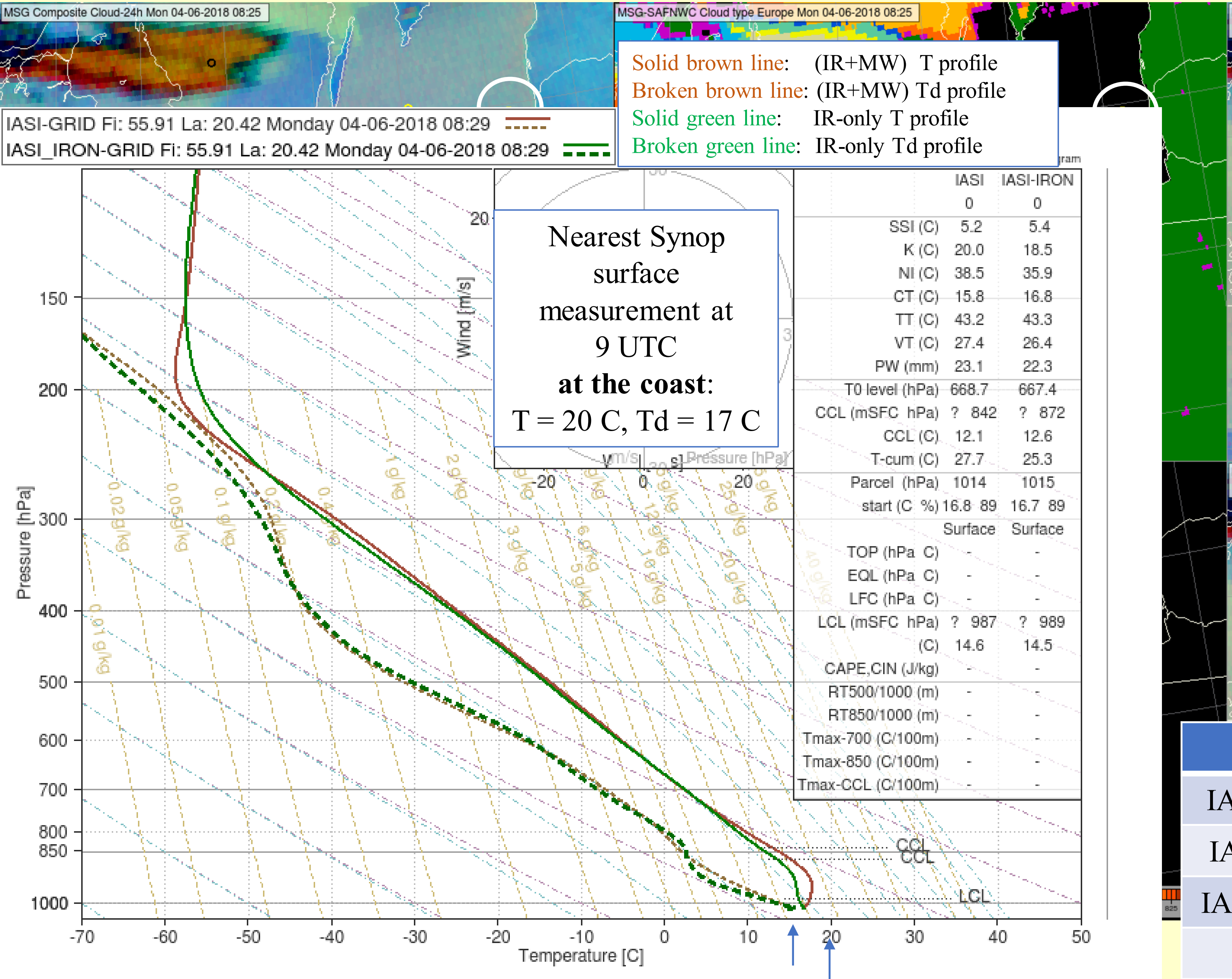


Def: IASI cloud mask: |OMC|< 1.5

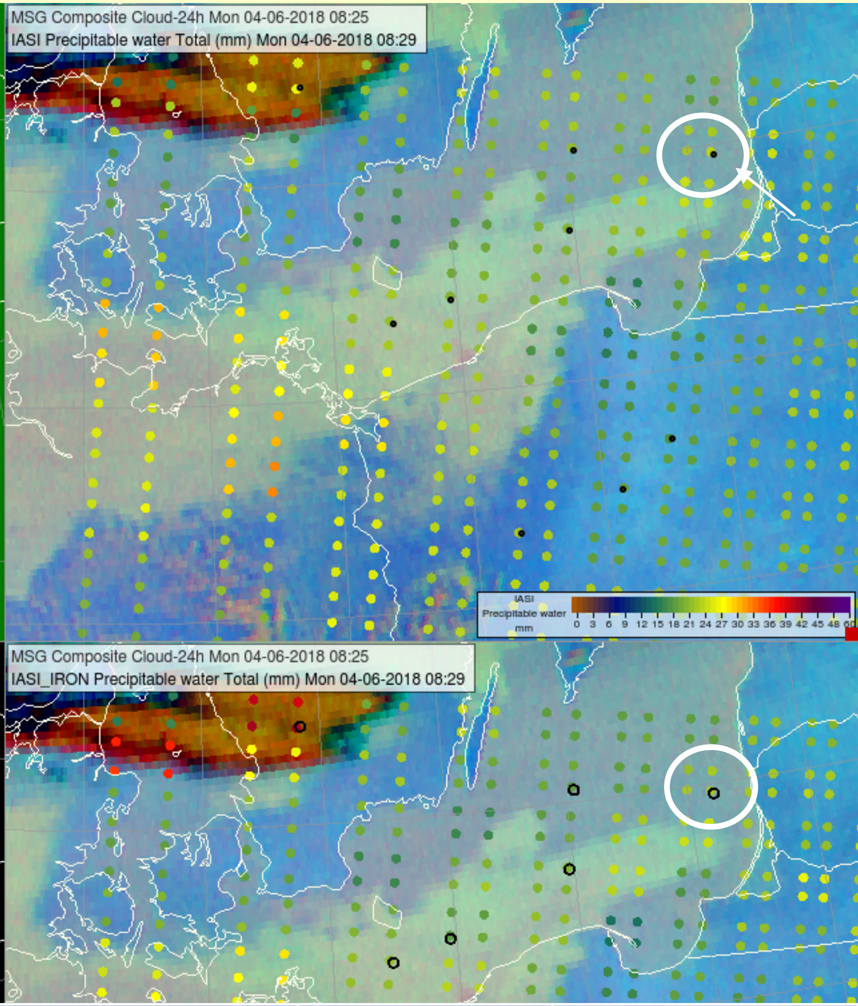
	(IR+MW)	IR-only
IASI cloud mask	Cloud-free	Cloud-free
IASI T error [C]	0.97	0.84
IASI Td error [C]	1.7	1.98
TPW [mm]	22.4	24.5

Cloud-free sea

24 h Microphysics RGB | NWCSAF Cloud Type | 24 h Microphysics RGB + IASI (IR+MW) TPW



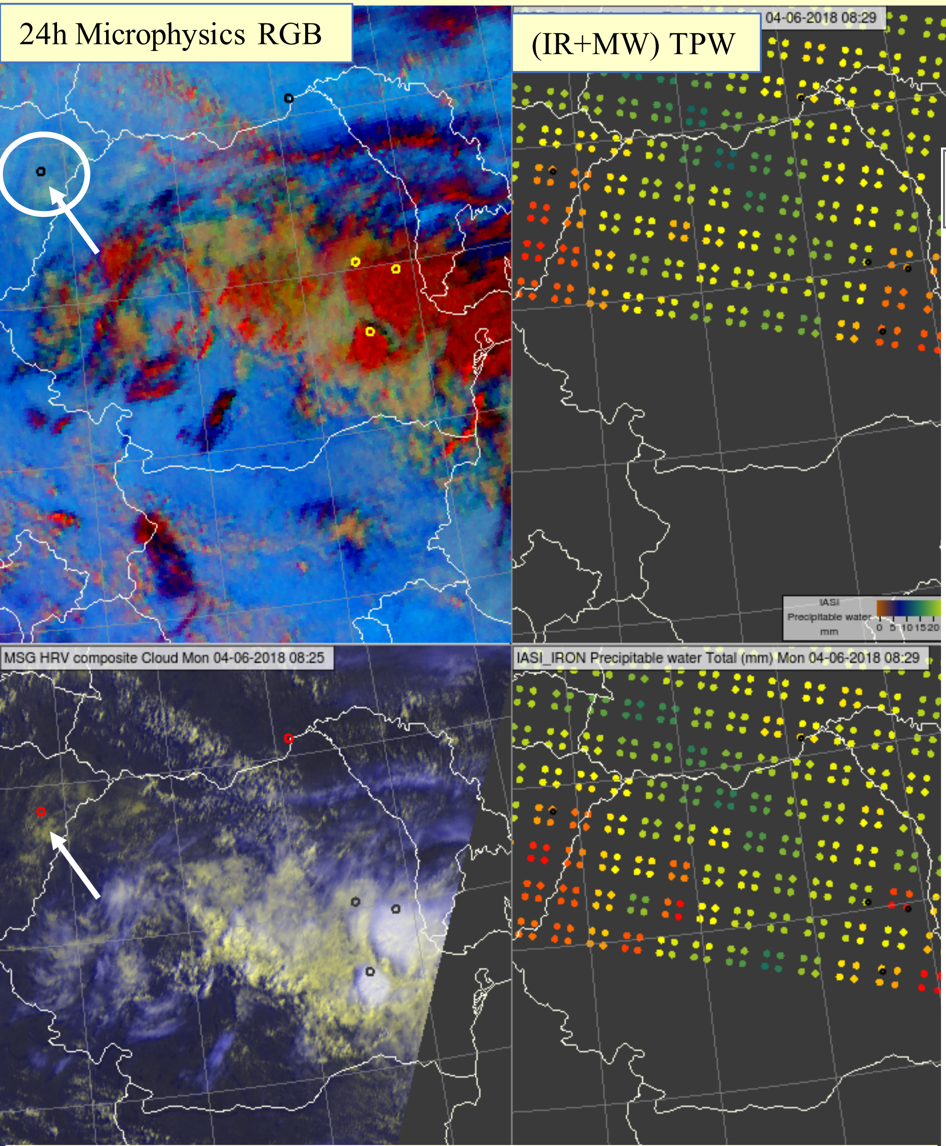
	IASI	IASI-IRON
	0	0
SSI (C)	5.2	5.4
K (C)	20.0	18.5
NI (C)	38.5	35.9
CT (C)	15.8	16.8
TT (C)	43.2	43.3
VT (C)	27.4	26.4
PW (mm)	23.1	22.3
T0 level (hPa)	668.7	667.4
CCL (mSFC hPa)	? 842	? 872
CCL (C)	12.1	12.6
T-cum (C)	27.7	25.3
Parcel (hPa)	1014	1015
start (C %)	16.8 89	16.7 89
	Surface	Surface
TOP (hPa C)	-	-
EQL (hPa C)	-	-
LFC (hPa C)	-	-
LCL (mSFC hPa)	? 987	? 989
(C)	14.6	14.5
CAPE,CIN (J/kg)	-	-
RT500/1000 (m)	-	-
RT850/1000 (m)	-	-
Tmax-700 (C/100m)	-	-
Tmax-850 (C/100m)	-	-
Tmax-CCL (C/100m)	-	-

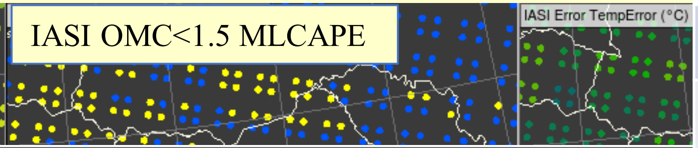


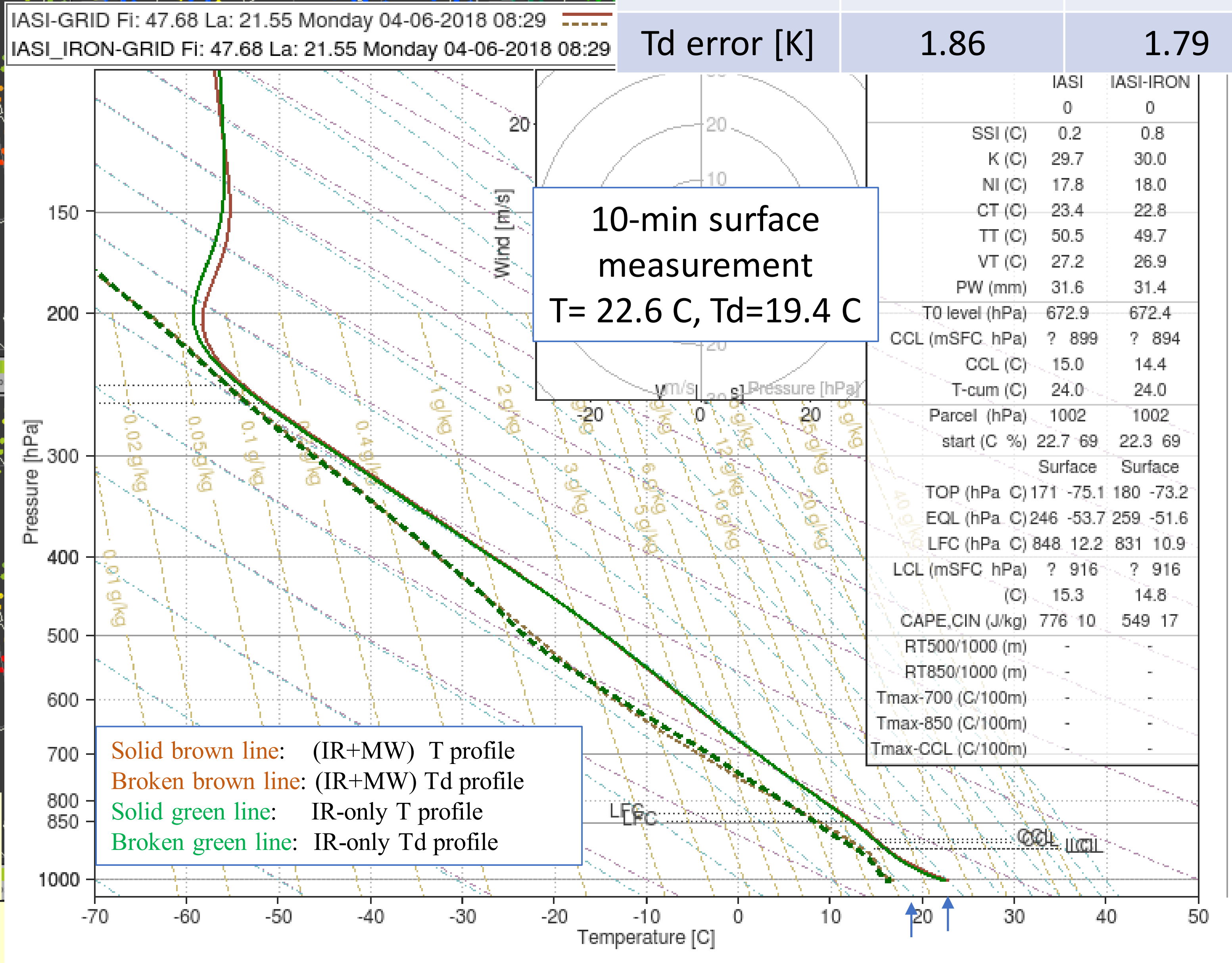
	(IR+MW)	IR-only
IASI cloud mask	Cloud-free	Cloud-free
IASI T error [C]	0.95	0.83
IASI Td error [C]	2.28	2.16
TPW [mm]	23.1	22.3

Area covered by some low-level small cumulus clouds.

	(IR+MW)	IR-only
TPW [mm]	31.6	31.5
T error [K]	0.75	1.26
Td error [K]	1.86	1.79







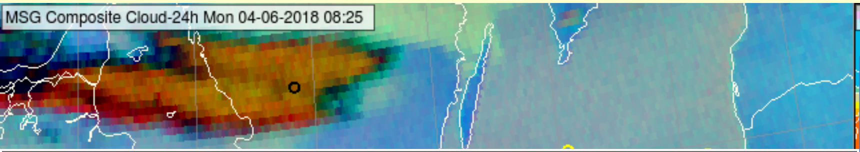
Not much difference between (IR+MW) and IR-only profiles

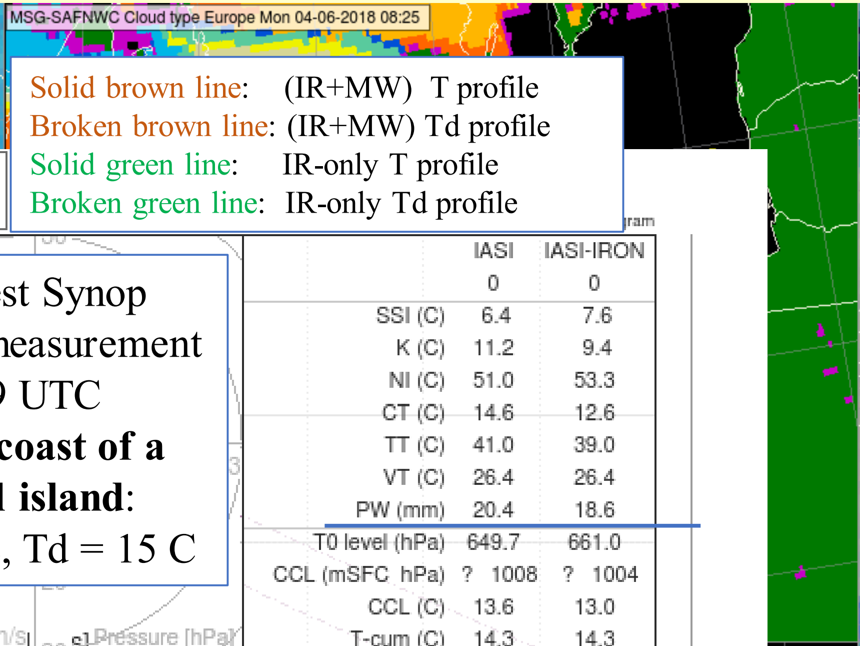
HRV Cloud RGB

(IR-only) TPW

Thick stratus/fog

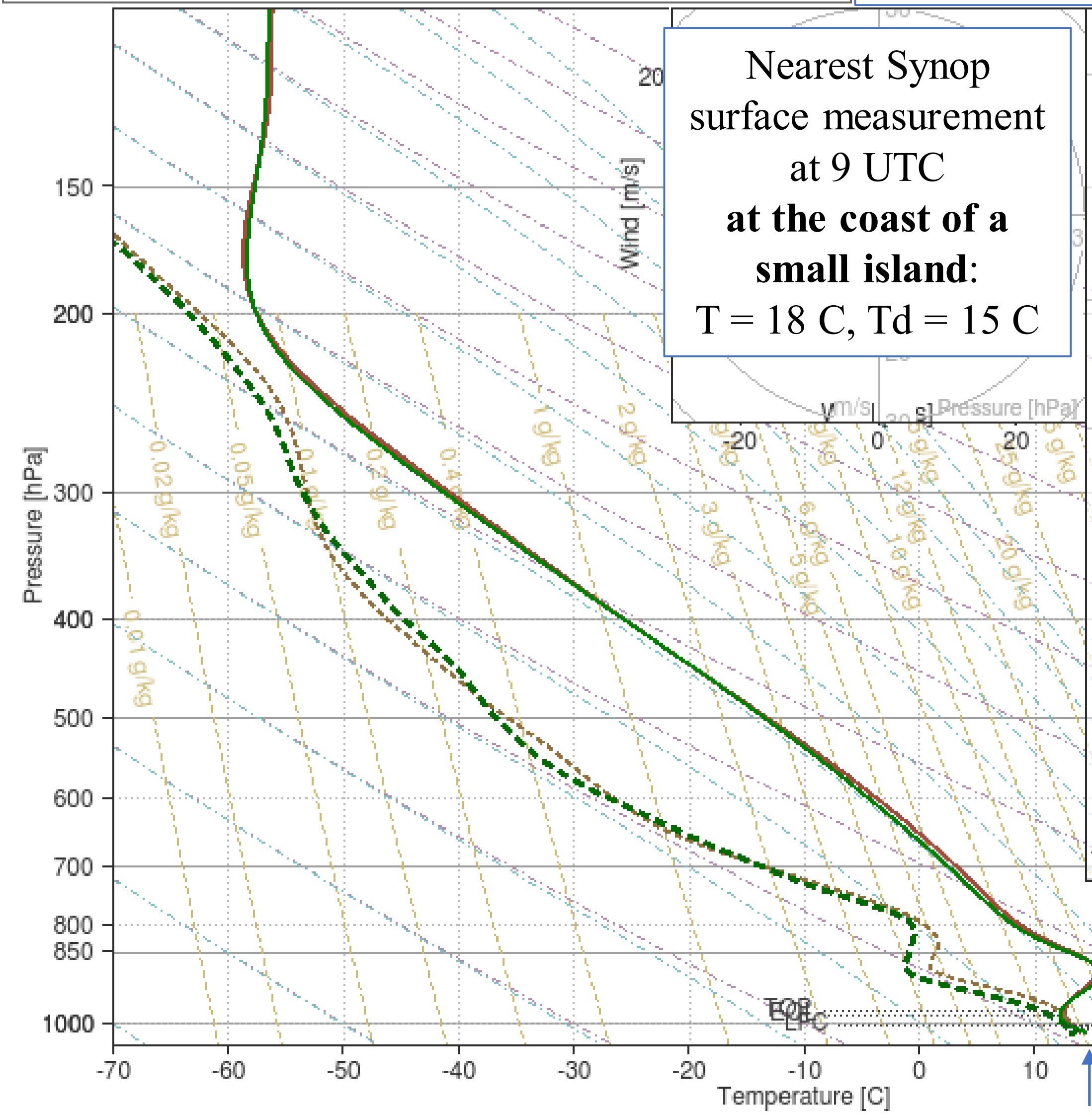
24 h Microphysics RGB | NWCSAF Cloud Type | 24 h Microphysics RGB + IASI (IR+MW) TPW





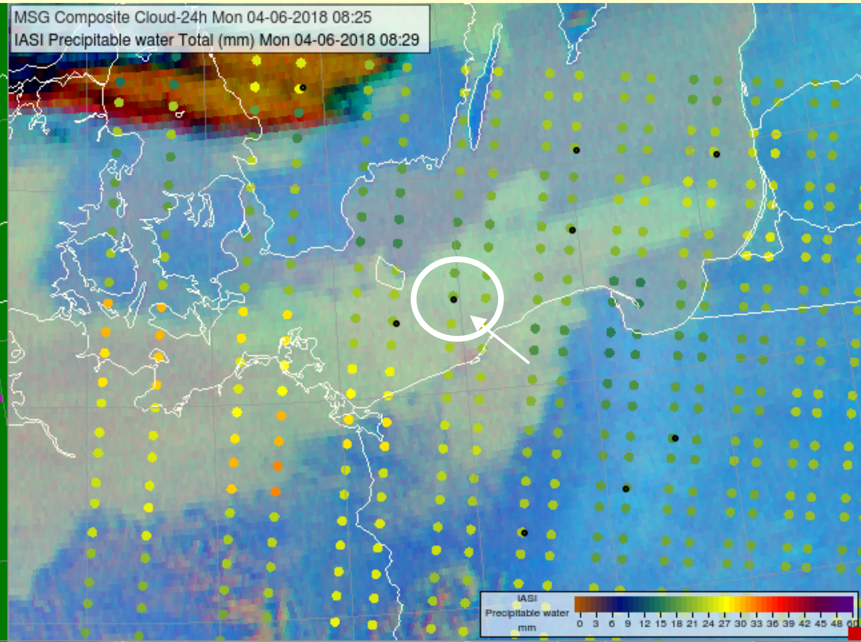
Solid brown line: (IR+MW) T profile
Broken brown line: (IR+MW) Td profile
Solid green line: IR-only T profile
Broken green line: IR-only Td profile

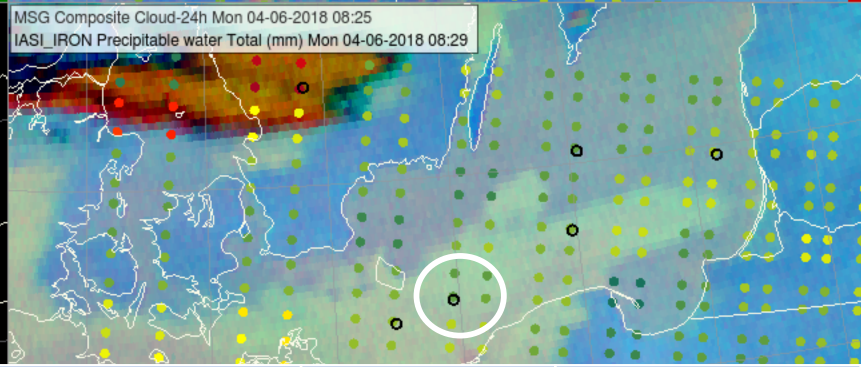
IASI-GRID Fi: 54.86 La: 15.90 Monday 04-06-2018 08:29
IASI_IRON-GRID Fi: 54.86 La: 15.90 Monday 04-06-2018 08:29



Nearest Synop surface measurement at 9 UTC **at the coast of a small island**:
T = 18 C, Td = 15 C

	IASI	IASI-IRON
	0	0
SSI (C)	6.4	7.6
K (C)	11.2	9.4
NI (C)	51.0	53.3
CT (C)	14.6	12.6
TT (C)	41.0	39.0
VT (C)	26.4	26.4
PW (mm)	20.4	18.6
T0 level (hPa)	649.7	661.0
CCL (mSFC hPa)	? 1008	? 1004
CCL (C)	13.6	13.0
T-cum (C)	14.3	14.3
Parcel (hPa)	1017	1020
start (C %)	13.9 99	14.3 94
	Surface	Surface
TOP (hPa C)	-	975 11.7
EQL (hPa C)	-	984 12.1
LFC (hPa C)	-	1003 13.0
LCL (mSFC hPa)	? 1014	? 1005
(C)	13.6	13.0
CAPE,CIN (J/kg)	-	0.5 0.7
RT500/1000 (m)	-	-
RT850/1000 (m)	-	-
Tmax-700 (C/100m)	-	-
Tmax-850 (C/100m)	-	-
Tmax-CCL (C/100m)	-	-



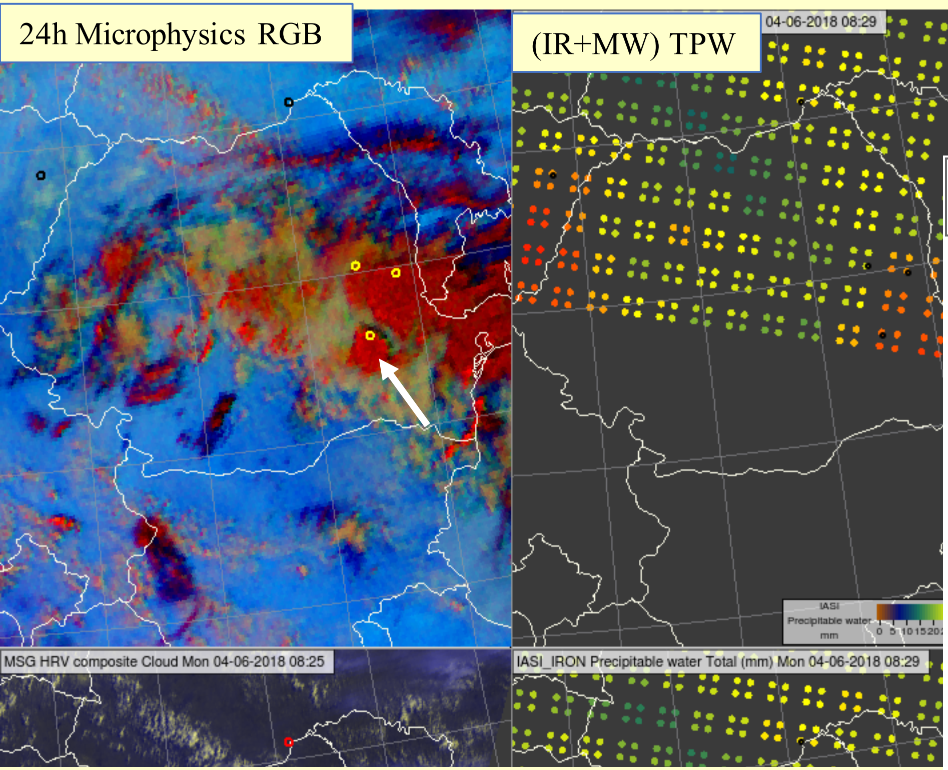


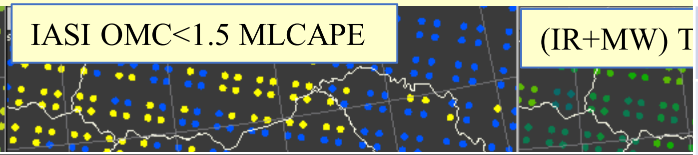
	(IR+MW)	IR-only
IASI cloud mask	Cloud-free	Cloud-free
IASI T error [C]	1.14	0.97
IASI Td error [C]	2.19	2.19
TPW [mm]	20.4	18.6

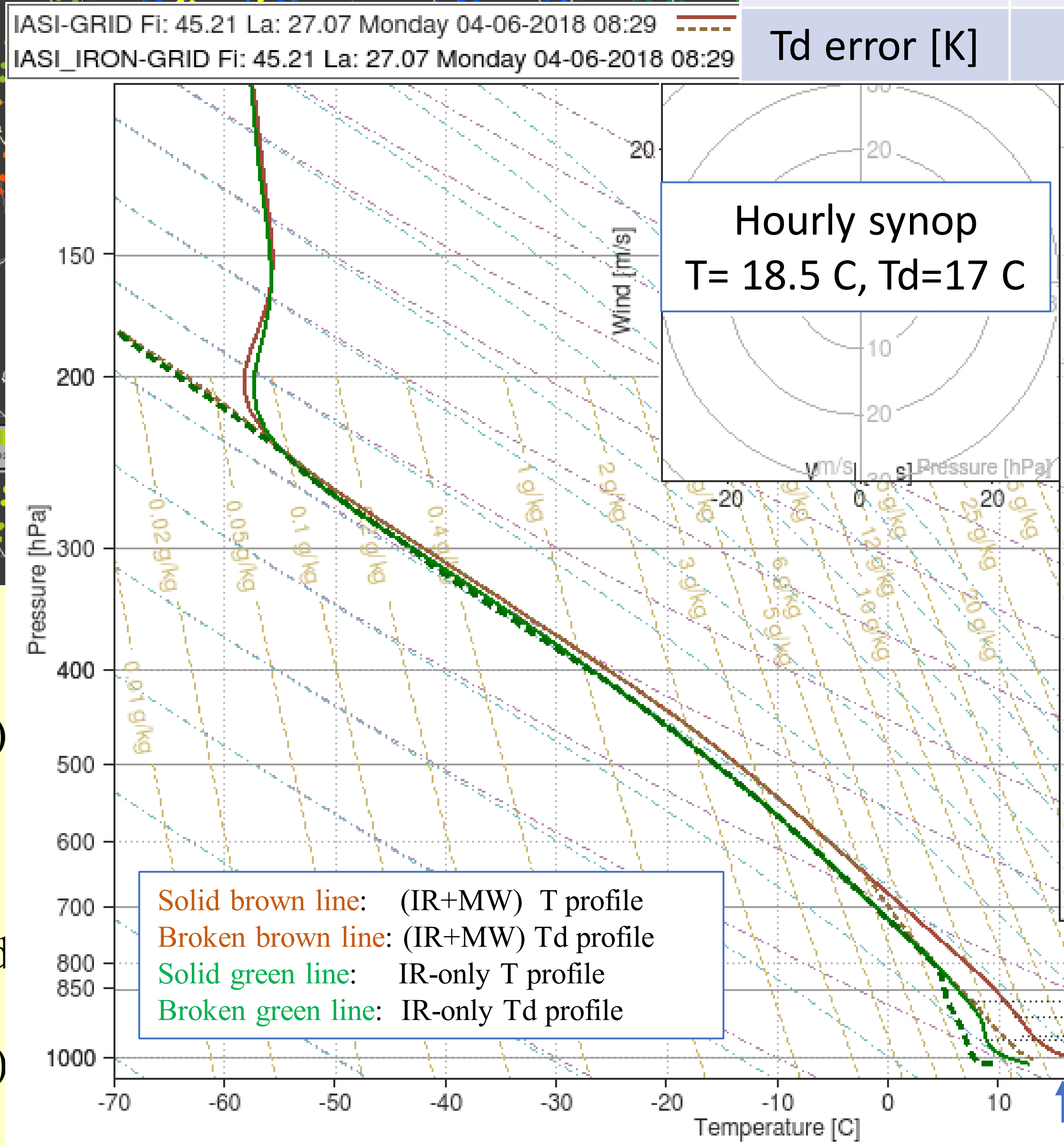
Area covered by **thick high-level opaque clouds.**

Uncertai

	(IR+MW)	IR-only
TPW [mm]	33.5	29.8
T error [K]	2.09	2.69
Td error [K]	4.42	4.29





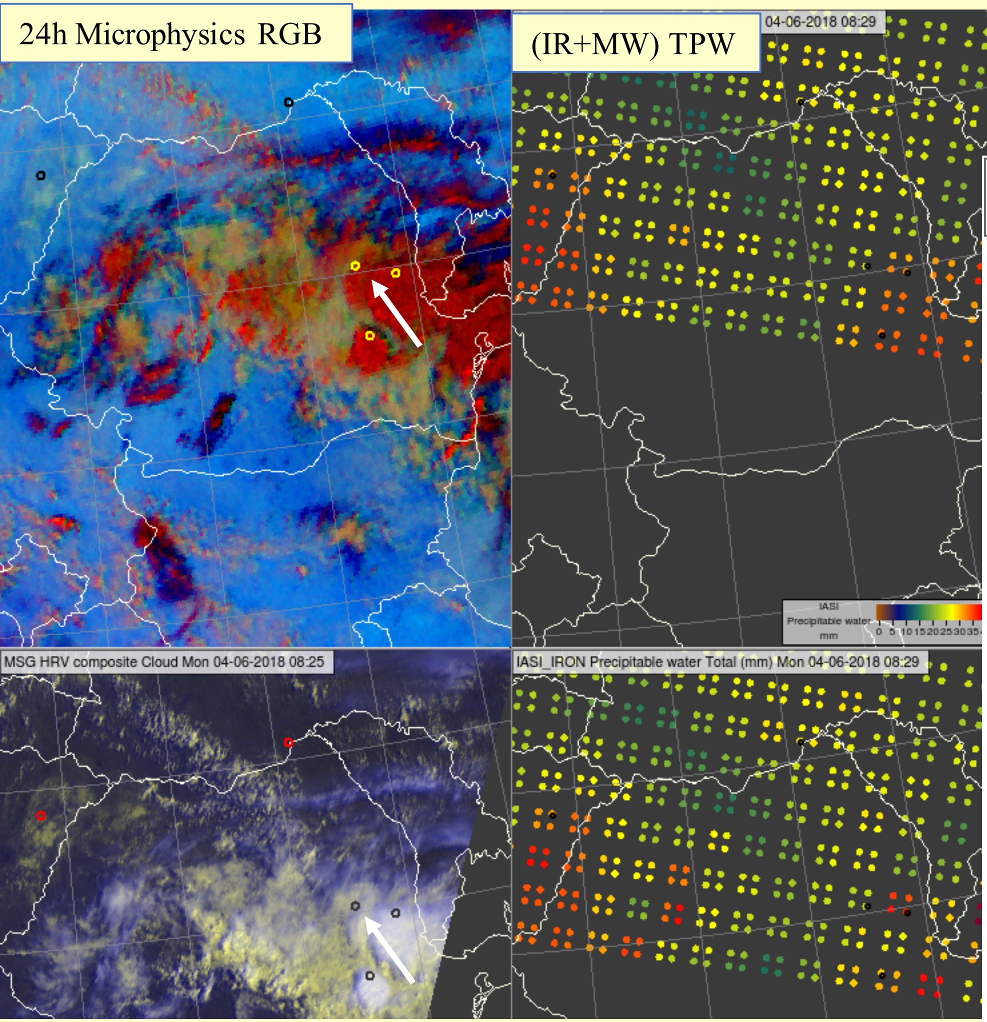


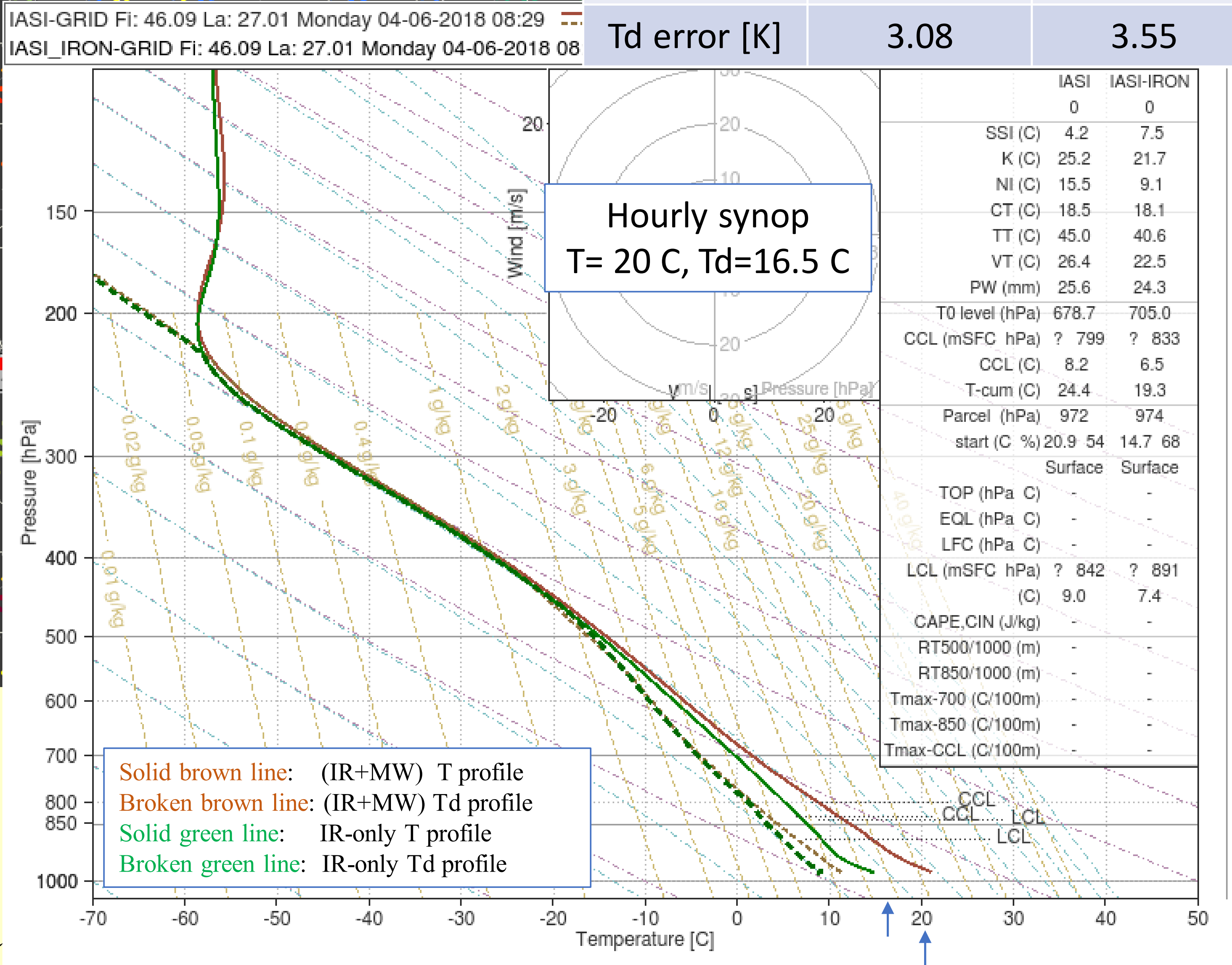
	IASI	IASI-IRON
	0	0
SSI (C)	4.9	6.4
K (C)	28.4	26.9
NI (C)	4.3	1.2
CT (C)	20.2	20.6
TT (C)	43.3	42.5
VT (C)	23.2	21.8
PW (mm)	33.4	29.7
T0 level (hPa)	678.1	720.6
CCL (mSFC hPa)	? 909	? 877
CCL (C)	11.5	7.1
T-cum (C)	19.5	18.9
Parcel (hPa)	1001	1012
start (C %)	16.5 80	12.6 80
	Surface	Surface
TOP (hPa C)	-	-
EQL (hPa C)	-	-
LFC (hPa C)	-	-
LCL (mSFC hPa)	? 951	? 962
(C)	12.2	8.5
CAPE,CIN (J/kg)	-	-
RT500/1000 (m)	-	-
RT850/1000 (m)	-	-
Tmax-700 (C/100m)	-	-
Tmax-850 (C/100m)	-	-
Tmax-CCL (C/100m)	-	-

- Different T profiles almost along the whole profile
- Saturation in a deep layer (above 800/650 hPa)
- Cloud base is at lower altitude in IR-only data
- The two profile pair differs from each other particularly in the low layer
- IR-only retrieval indicates lower surface T, and Td values
- Synop surface measurement support (IR+MW) data

Area covered by thick mid-level opaque clouds + cirrus Vertically

	(IR+MW)	IR-only
TPW [mm]	25.6	24.3
T error [K]	1.59	3.29
Td error [K]	3.08	3.55





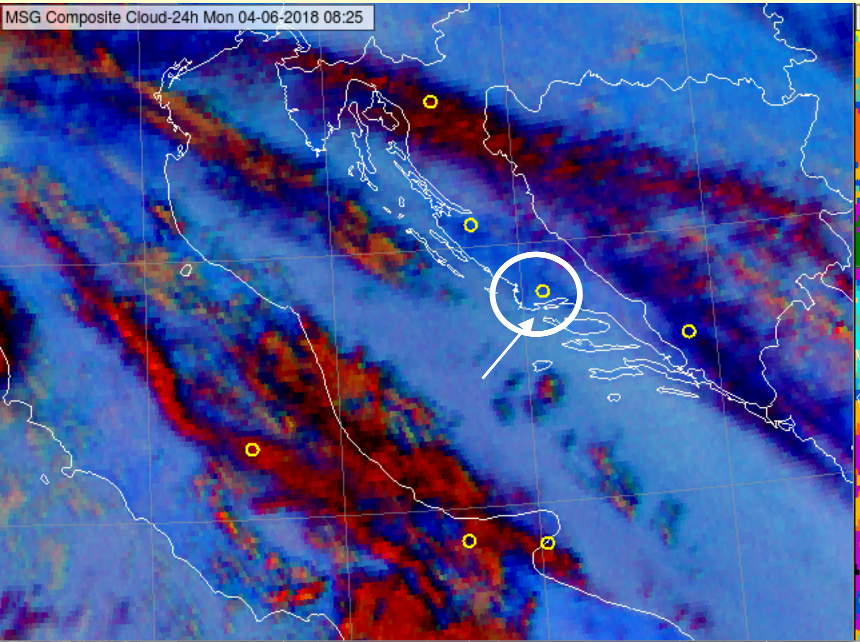
- Different T profiles between 1000 and 500 hPa
- Saturation in a deep layer (above 500 hPa), indicating thick cirrus, no mid-level cloud below it
- IR-only retrieval indicates lower surface T, and Td values
- Synop surface measurement support (IR+MW) data

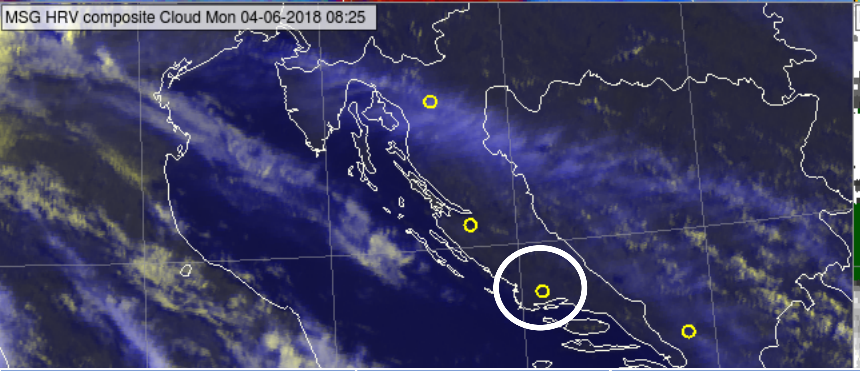
Very thin cirrus cloud

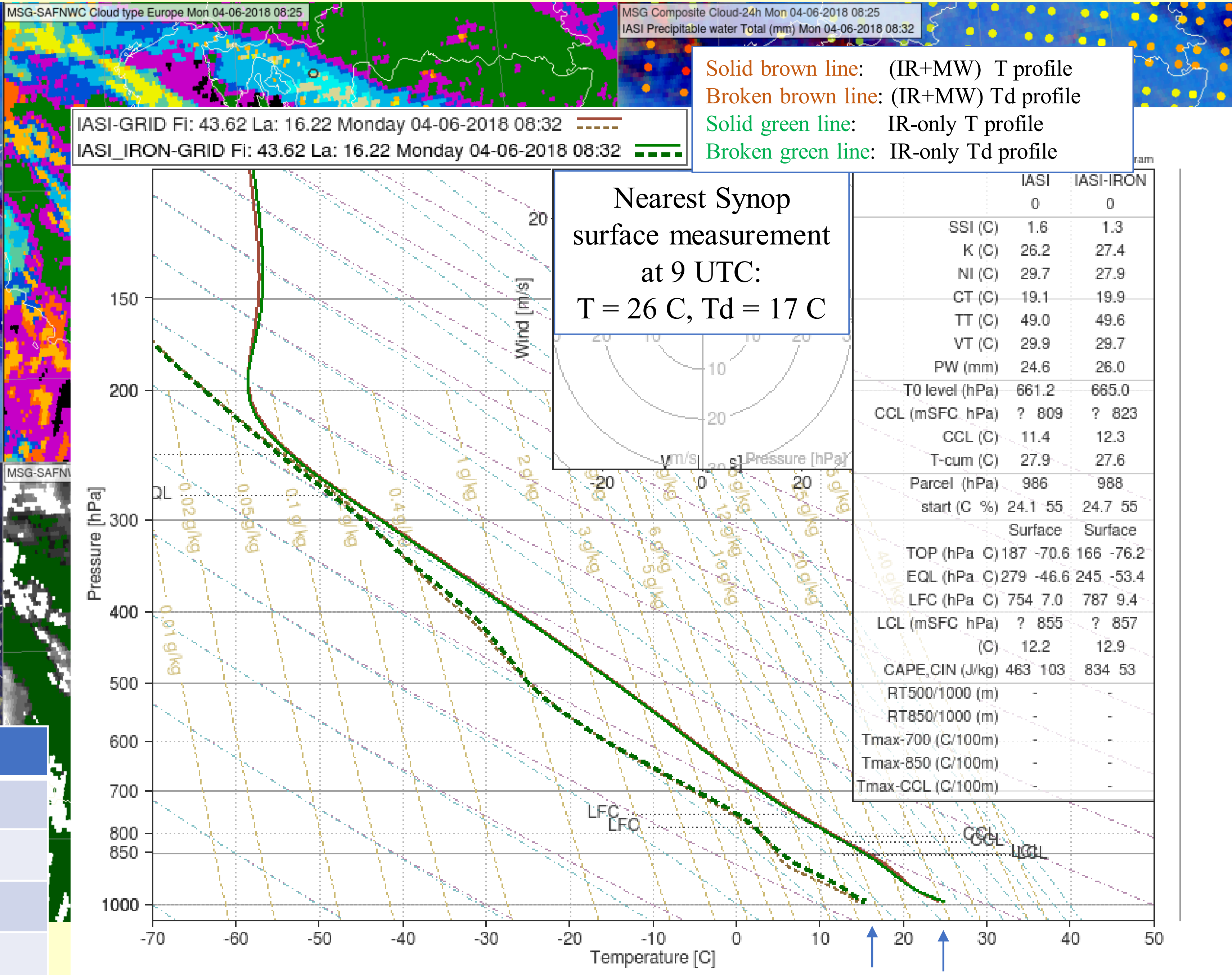
24 h Microphysics RGB

NWCSAF Cloud Type

24 h Microphysics RGB + IASI (IR+MW) TPW





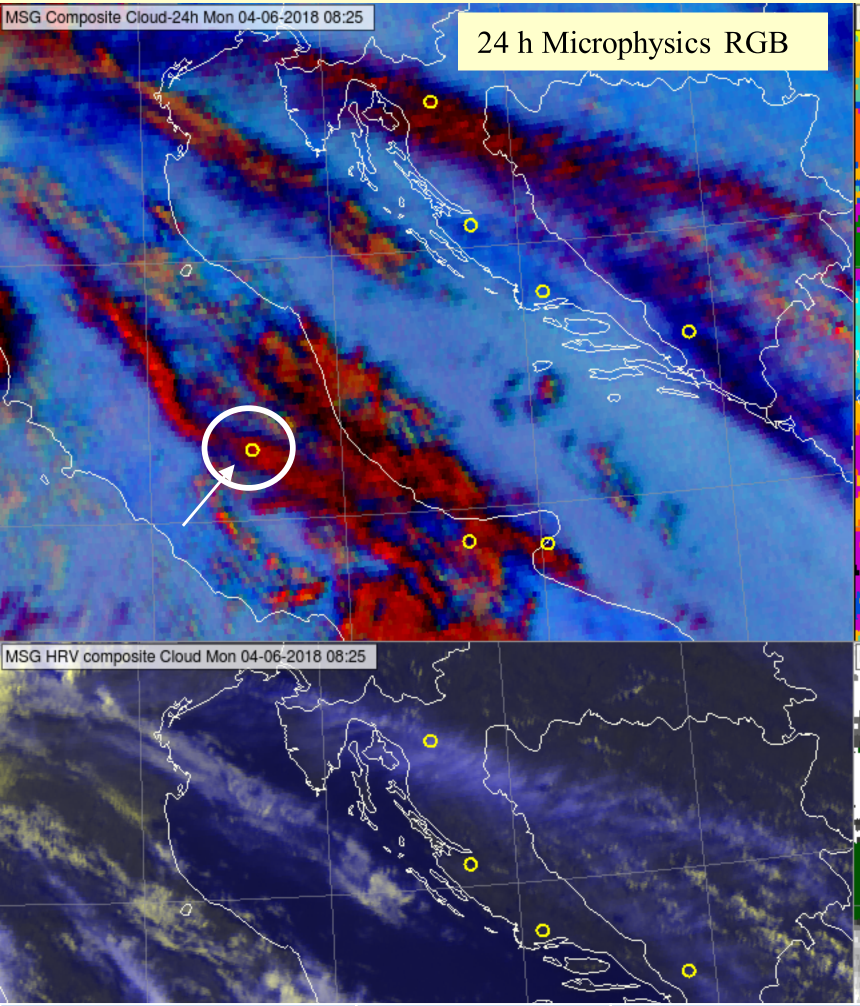


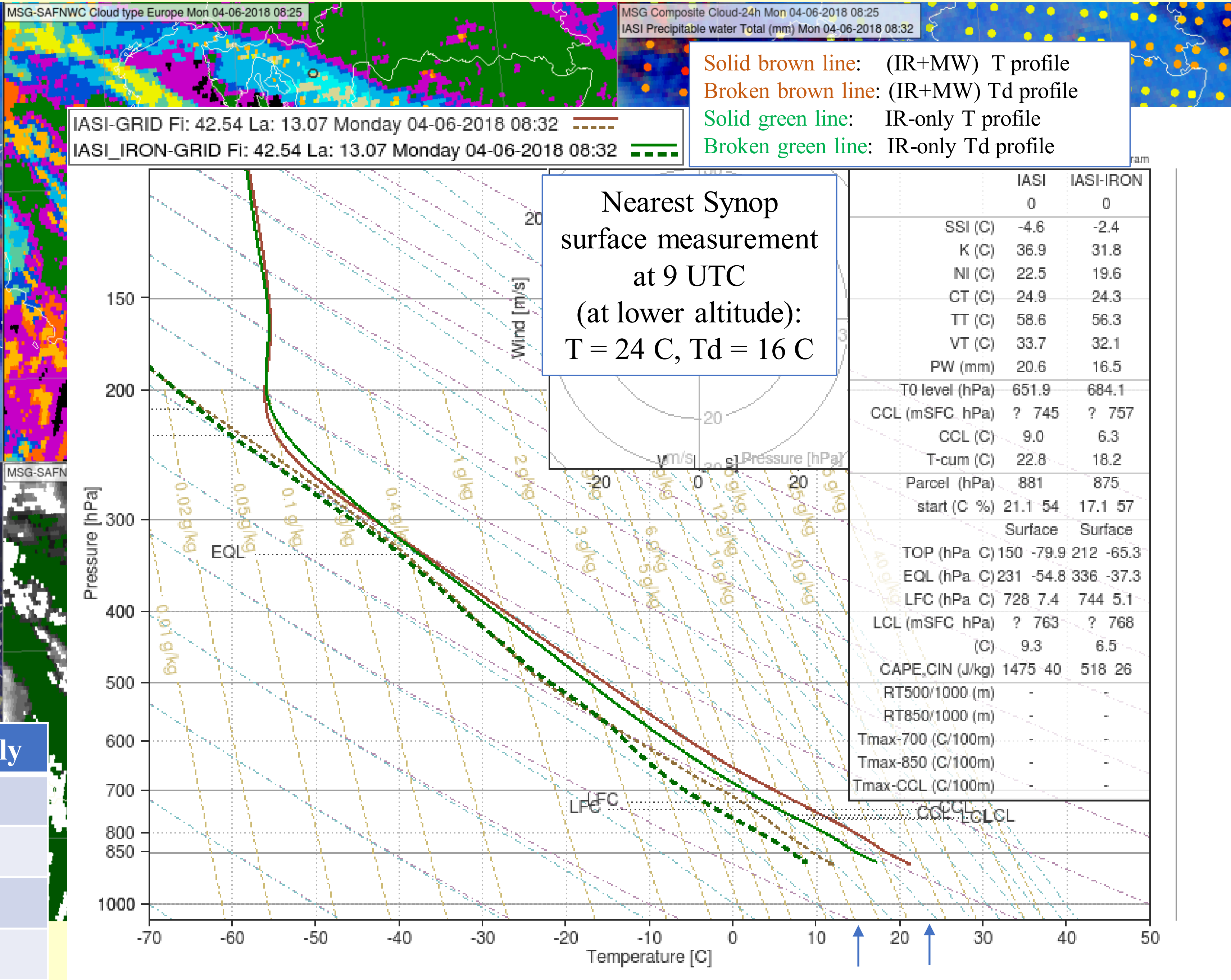
	(IR+MW)	IR-only
IASI cloud mask	cloudy	cloudy
IASI T error [C]	1.28	1.15
IASI Td error [C]	2.26	2.06
TPW [mm]	24.6	26.1

Thick cirrus (It is well seen in the HRV Cloud RGB)

NWCSAF Cloud Type

24h Microphysics RGB + IASI (IR+MW) TPW





	(Ir+MW)	IASI IR-only
IASI cloud mask	cloudy	cloudy
IASI T error [C]	1.61	3.88
IASI Td error [C]	2,46	4.77
TPW [mm]	20.6	16.5

Comparing IASI (IR+MW) and IR-only data - summary

The vertically averaged errors are usually higher for IR-only data than for (IR+MW) data. It can reach even 5-6 C.
It is important to take into account the vertically averaged errors.

On cloud-free areas, and areas covered by thin cirrus or small cumulus the structure of the retrieved parameters and the profiles are usually similar, the differences in general not high.

For opaque mid/high clouds the profiles may be not reliable, even the T profiles can be considerably different.

For areas covered by opaque mid/high level clouds the uncertainty of T profile may became large.
It often strongly differ both from the forecasted and from the (IR+MW) T profile.

Consider **masking** the areas covered by opaque clouds (based on uncertainty, OMC, cloud types)

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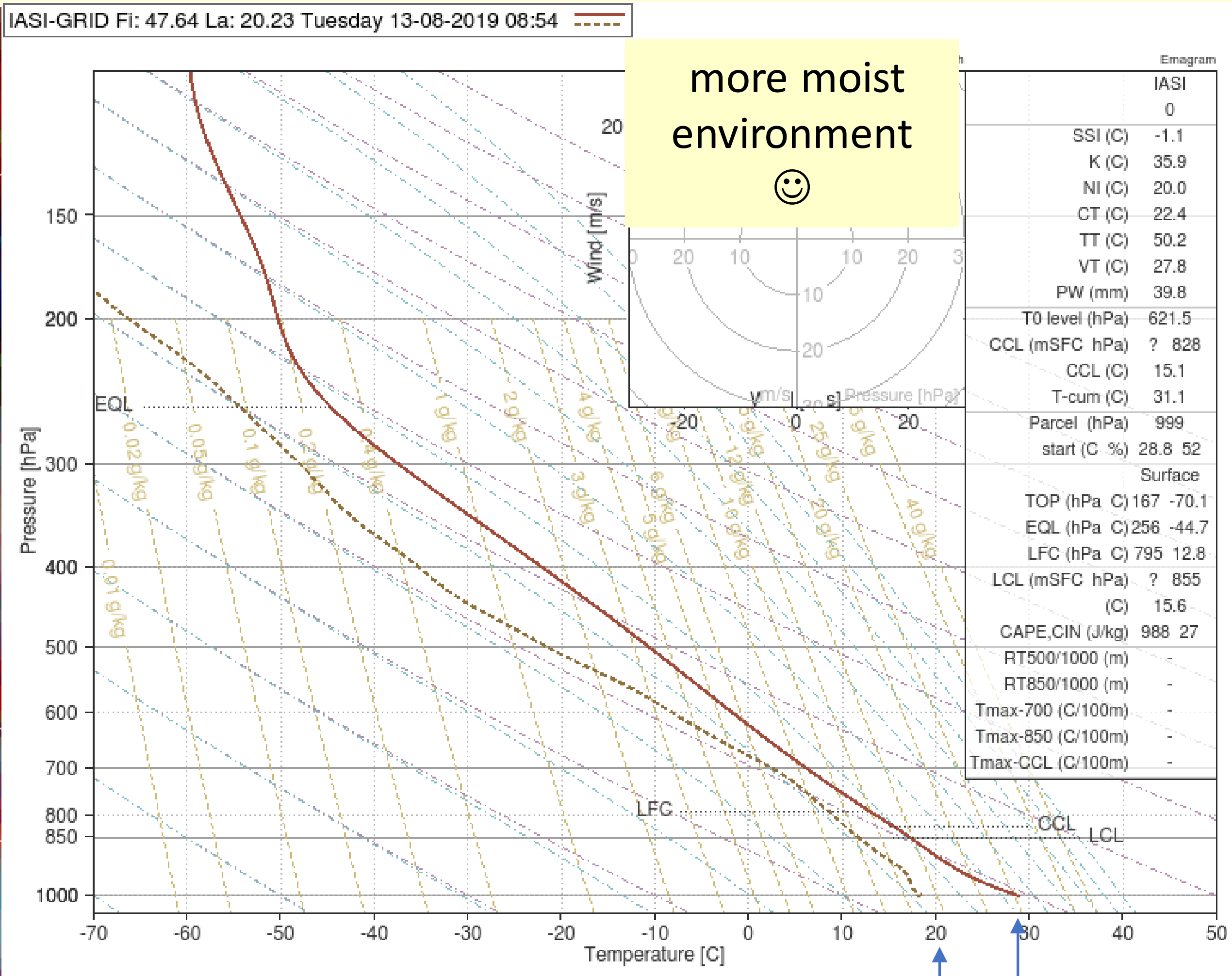
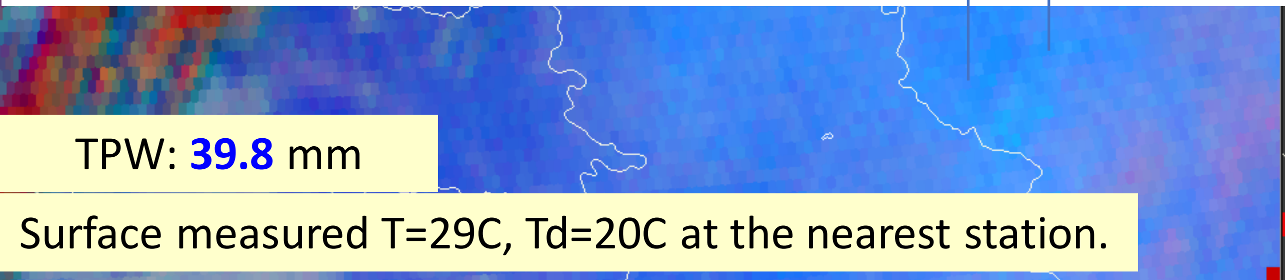
  - Comparison IASI L2 and ECMWF data – typical features
  - Cases with added value and cases confirming the forecast
- Forecast and L2 differences dataset
- Merging IASI L2 product with surface measurements
- Suggestions
- Summary

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.

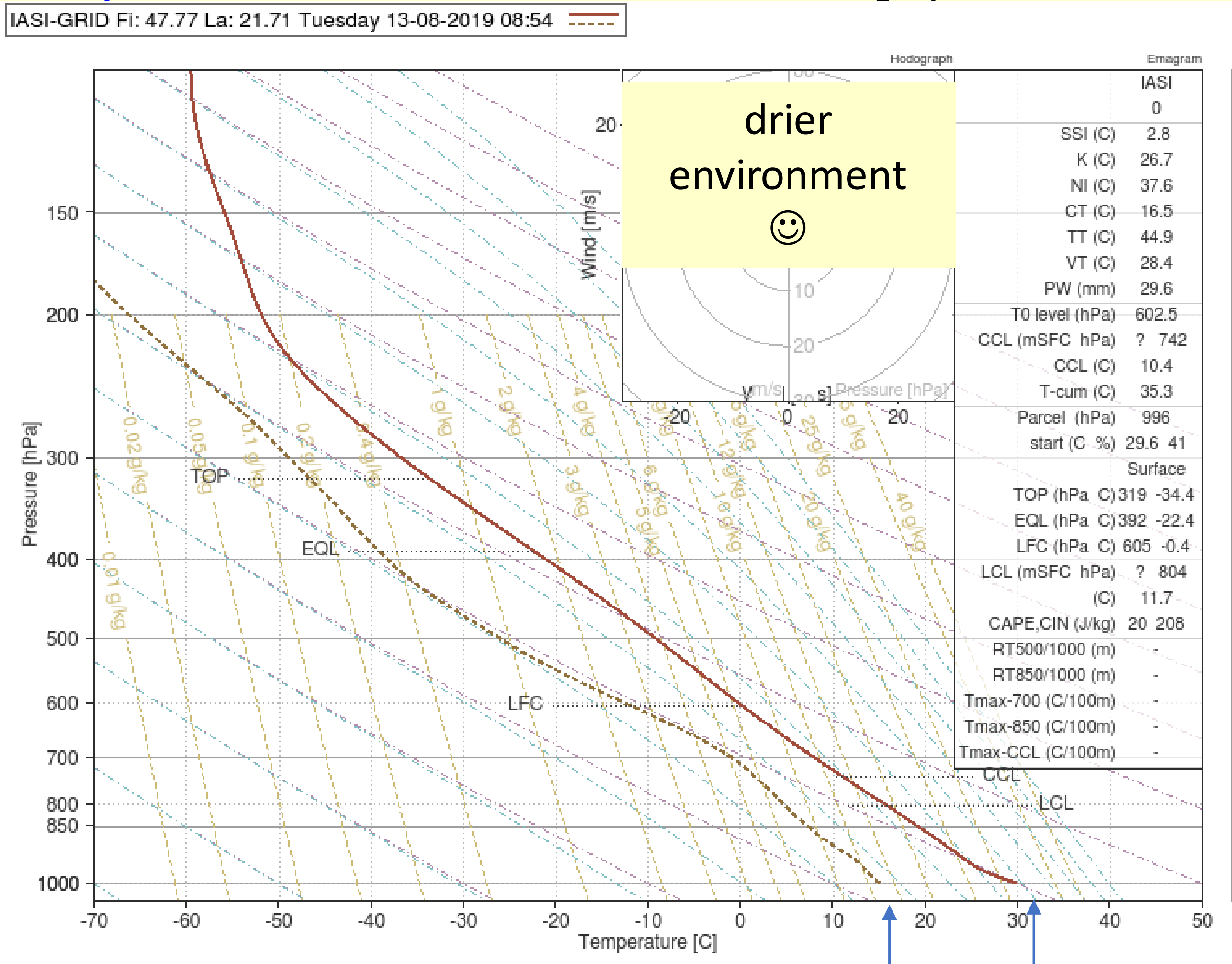


more moist environment ☺

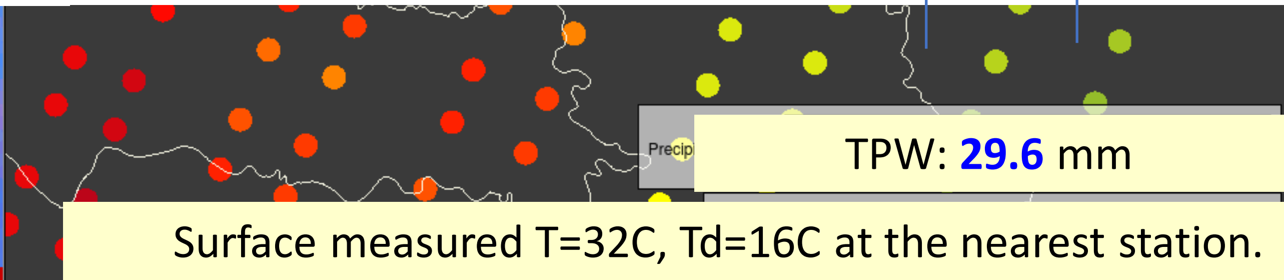


TPW: **39.8** mm

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

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.)

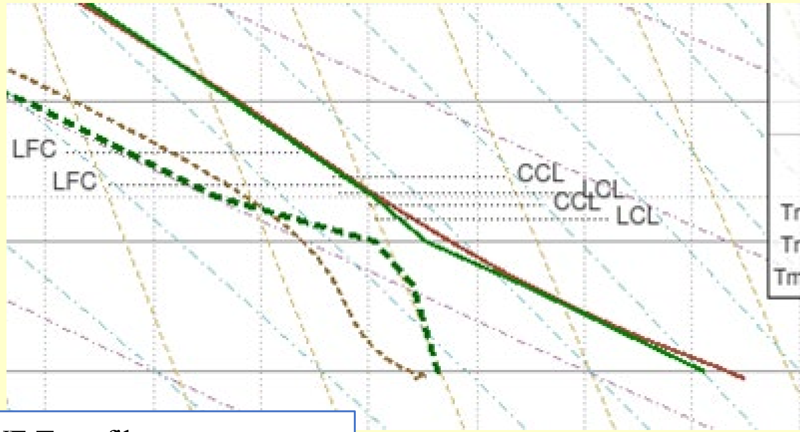
Problem:
If a IASI derived parameter differs strongly and often from ECMWF then the forecasters may not trust it.

Why is it usually strongly underestimated?

- In the ECMWF model there is a module to mix the boundary layer in convective situations.

→ **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

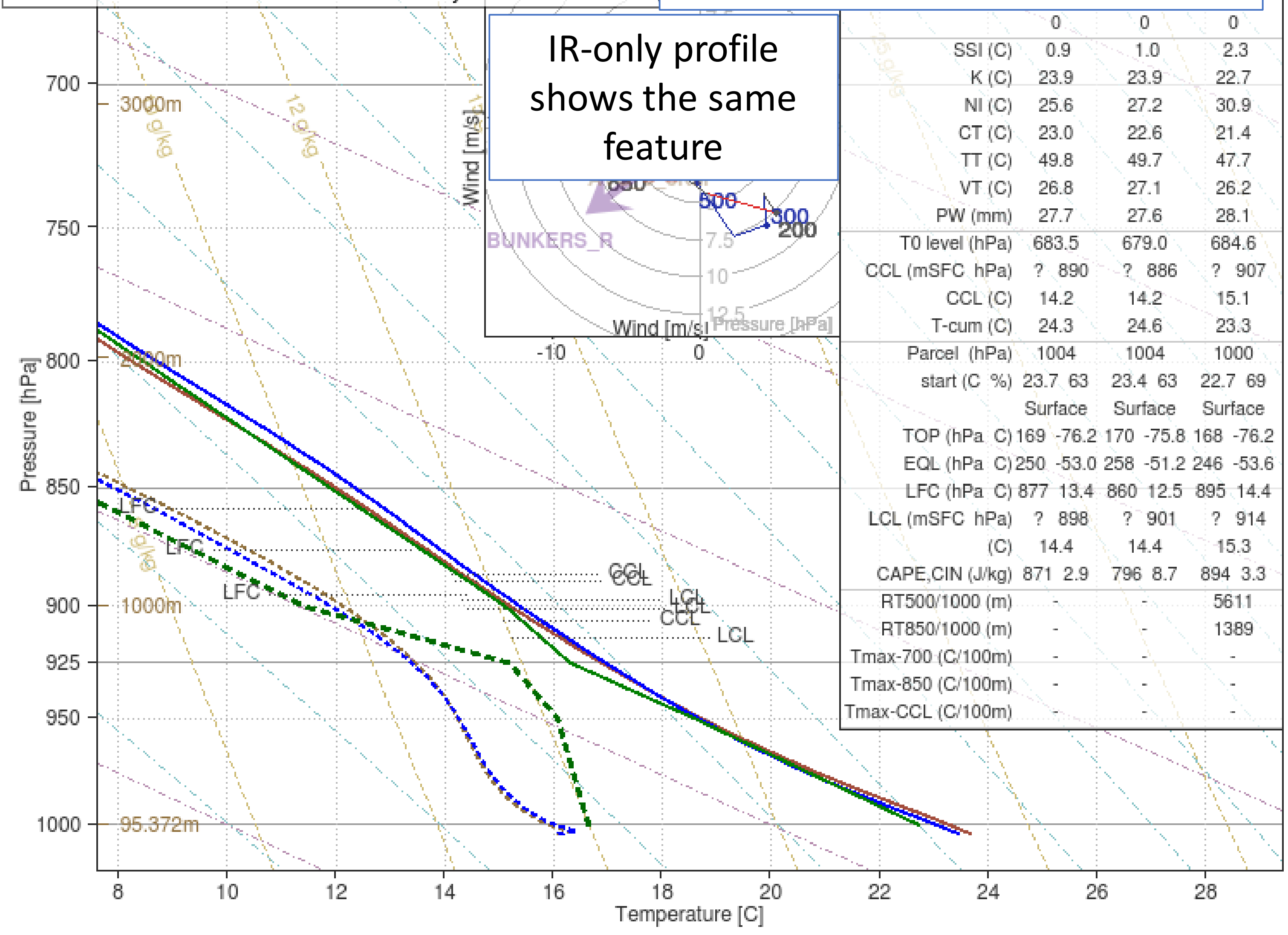
ECMWF + IASI (IR+MW) MLCAPE

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

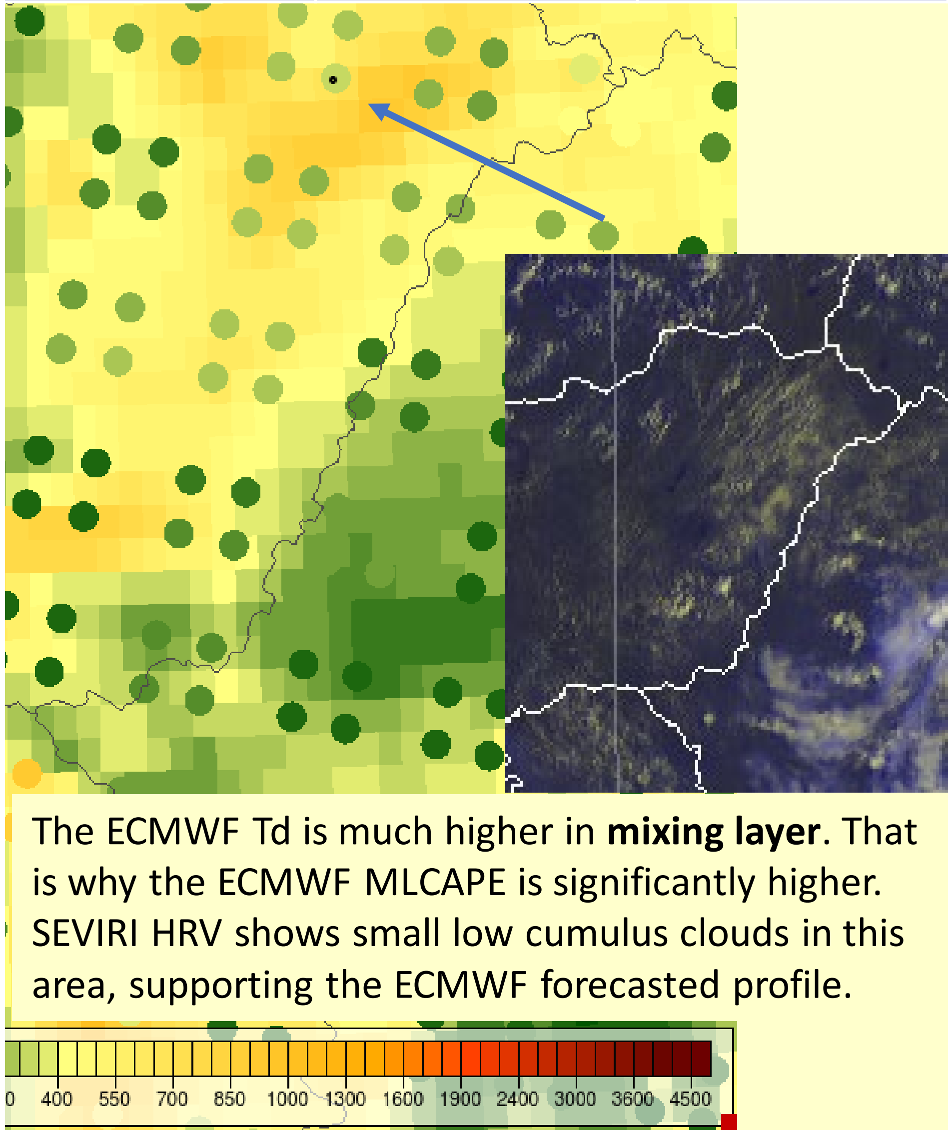
Profile - close to the surface
8:29 UTC IASI + 8/9 UTC ECMWF

Solid green line: ECMWF T profile
Broken green line: ECMWF Td profile
Solid brown line: IASI (IR+MW) T profile
Broken brown line: IASI (IR+MW) Td profile
Solid blue line: IASI (IR-only) T profil
Broken blue line: IASI (IR-only) Td profil

IR-only profile shows the same feature



	0	0	0
SSI (C)	0.9	1.0	2.3
K (C)	23.9	23.9	22.7
NI (C)	25.6	27.2	30.9
CT (C)	23.0	22.6	21.4
TT (C)	49.8	49.7	47.7
VT (C)	26.8	27.1	26.2
PW (mm)	27.7	27.6	28.1
T0 level (hPa)	683.5	679.0	684.6
CCL (mSFC hPa)	? 890	? 886	? 907
CCL (C)	14.2	14.2	15.1
T-cum (C)	24.3	24.6	23.3
Parcel (hPa)	1004	1004	1000
start (C %)	23.7 63	23.4 63	22.7 69
	Surface	Surface	Surface
TOP (hPa C)	169 -76.2	170 -75.8	168 -76.2
EQL (hPa C)	250 -53.0	258 -51.2	246 -53.6
LFC (hPa C)	877 13.4	860 12.5	895 14.4
LCL (mSFC hPa)	? 898	? 901	? 914
(C)	14.4	14.4	15.3
CAPE,CIN (J/kg)	871 2.9	796 8.7	894 3.3
RT500/1000 (m)	-	-	5611
RT850/1000 (m)	-	-	1389
Tmax-700 (C/100m)	-	-	-
Tmax-850 (C/100m)	-	-	-
Tmax-CCL (C/100m)	-	-	-

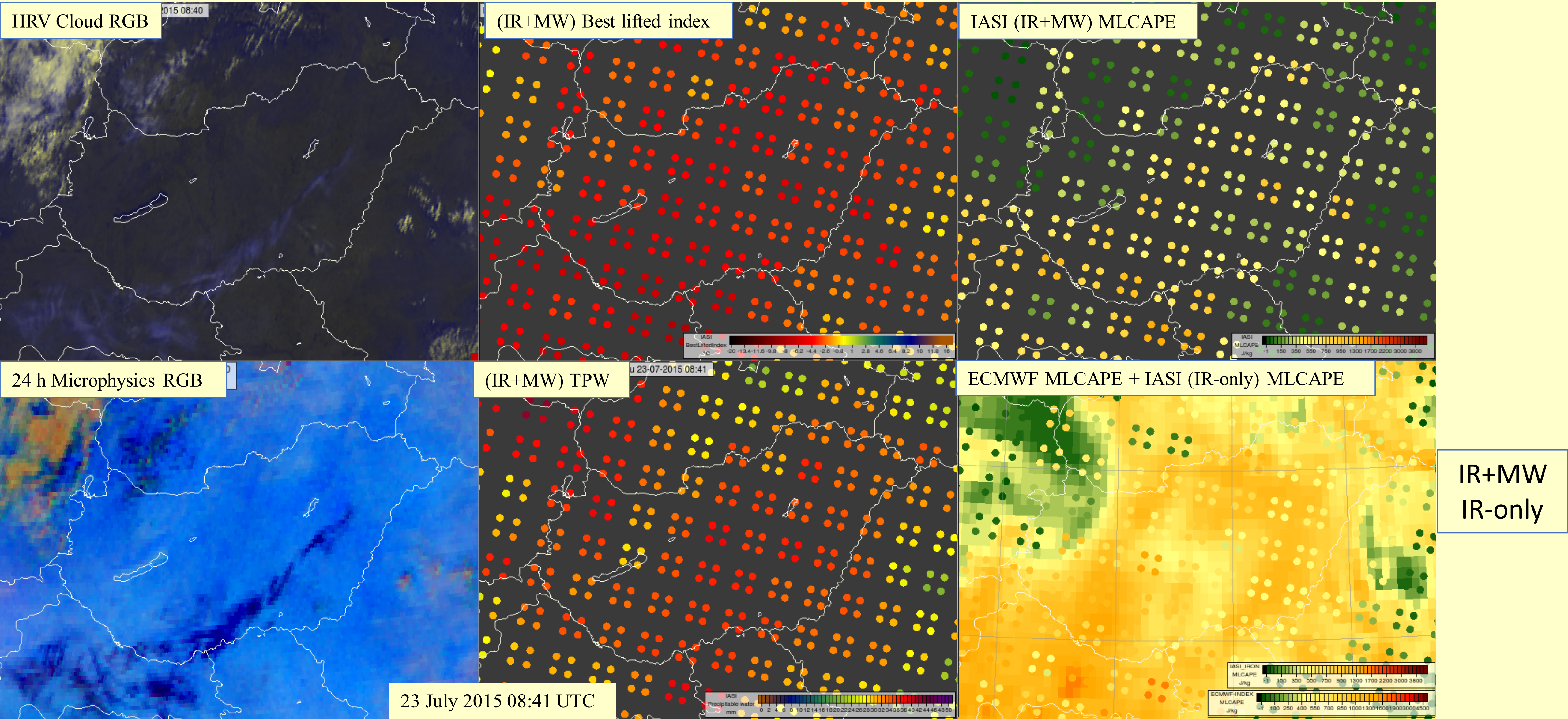


The ECMWF Td is much higher in **mixing layer**. That is why the ECMWF MLCAPE is significantly higher. SEVIRI HRV shows small low cumulus clouds in this area, supporting the ECMWF forecasted profile.

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 delineate the most unstable areas. It worth pay attention if IASI MLCAPE reach higher values in a bigger area.



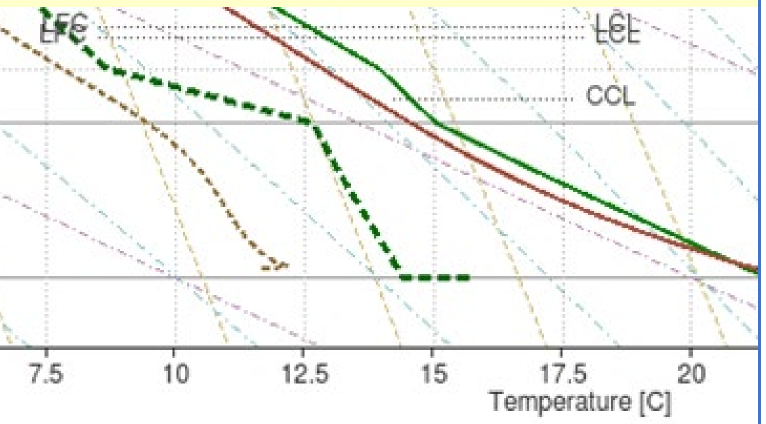
Some features we found when com

‚Foot' in ECMWF –

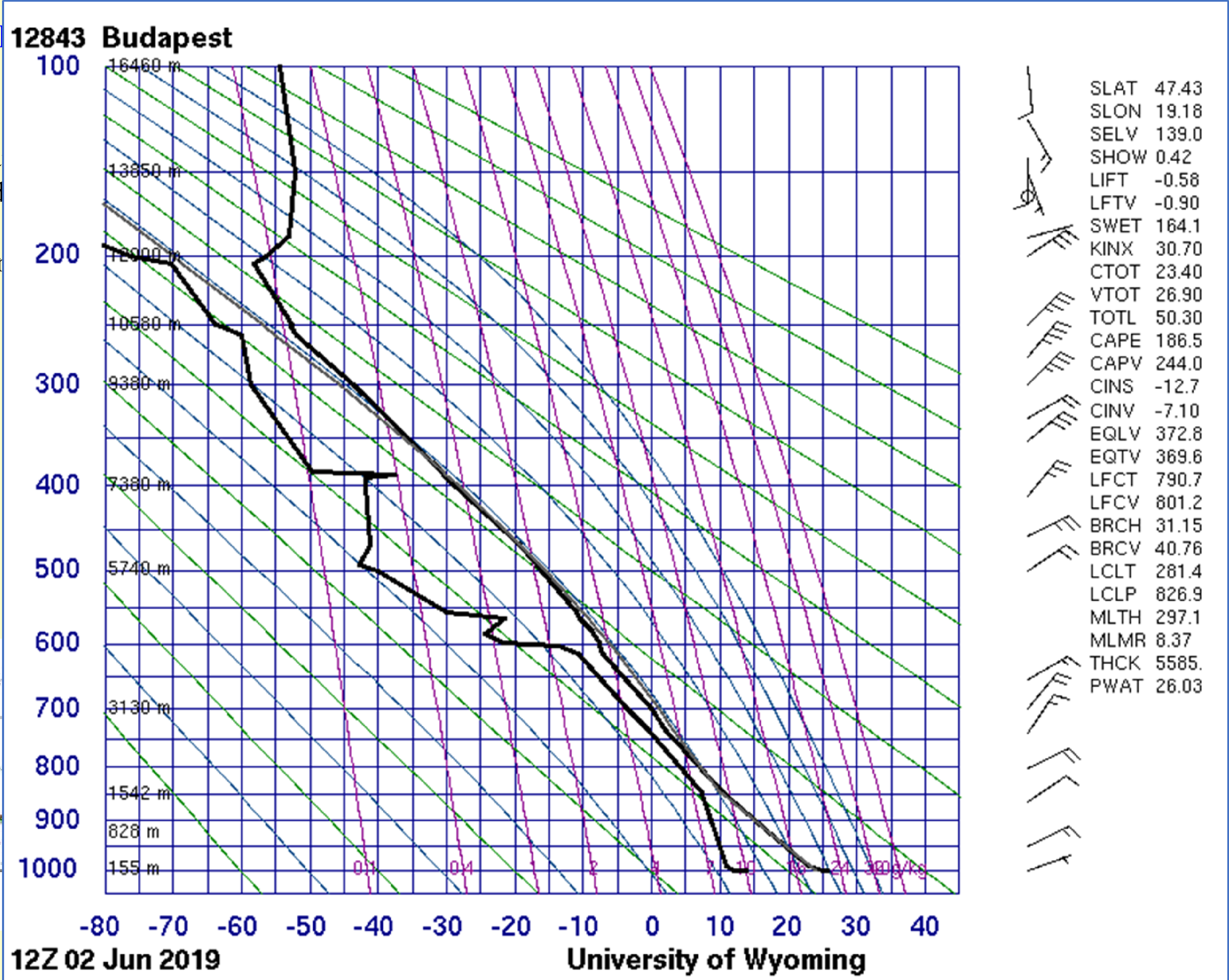
In such cases ECMWF 2m T and/or Td a

- The same can be often seen in the rad
- This ‚jump' is often missing from the
- One reason why the ‚surface based' ir

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



08:43 UTC

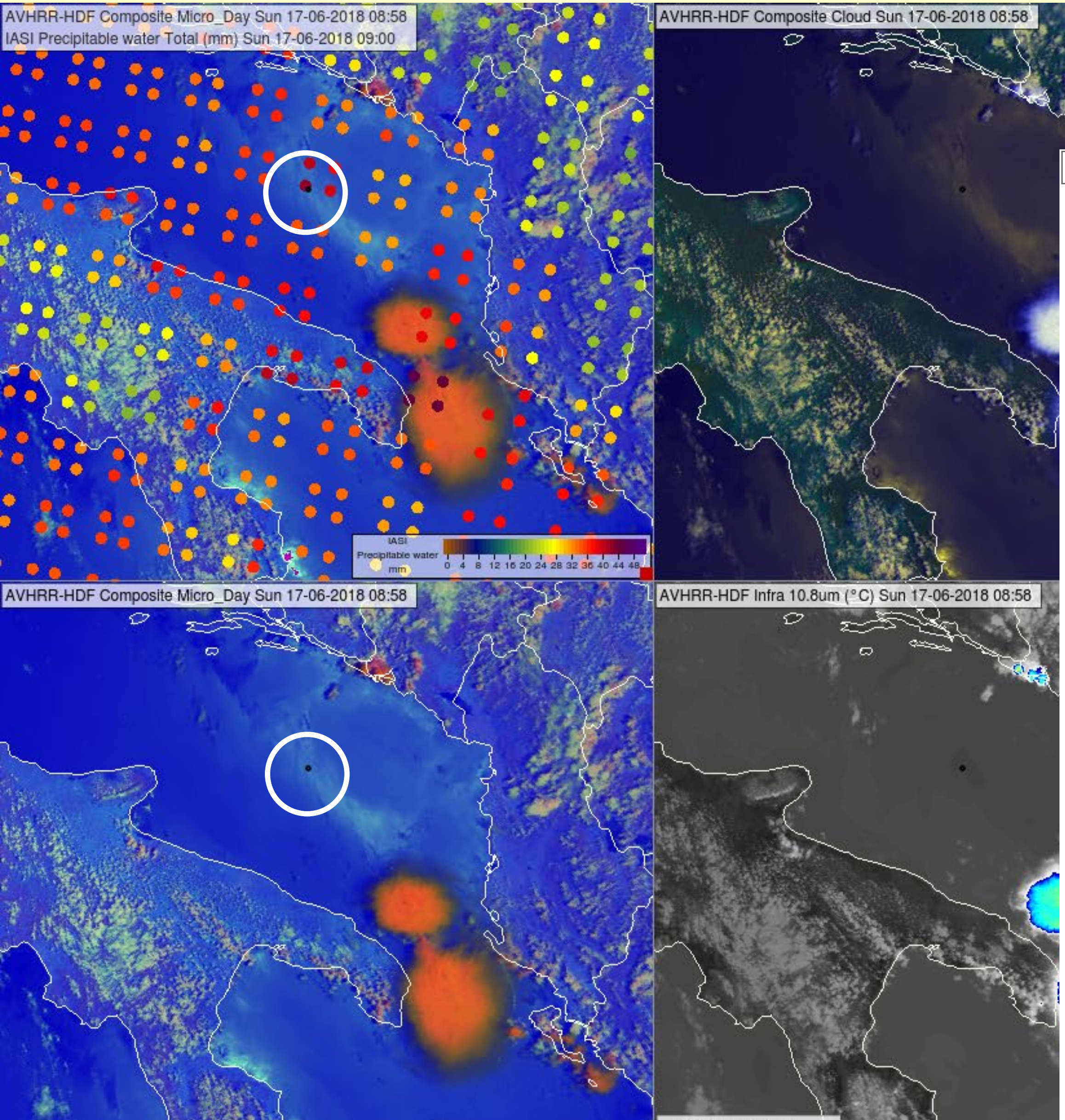


Some features we found when comparing IASI derived and ECMWF forecasted environmental parameters

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.

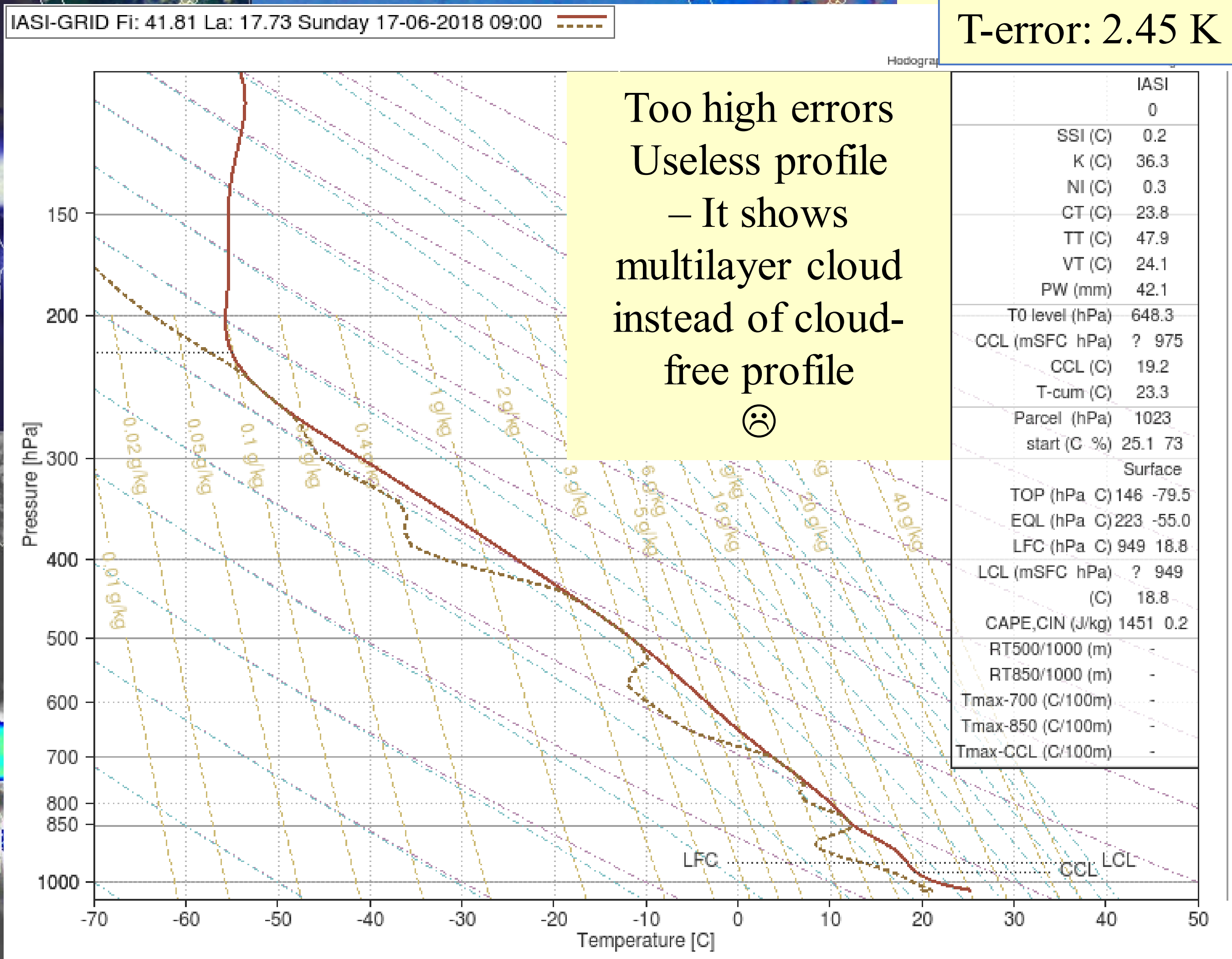
Example of high uncertainty: Sunglint - Vertically averaged error of the IASI profile can be very high



IASI: Cloud-free

Td-error: **5.27 K**

T-error: 2.45 K

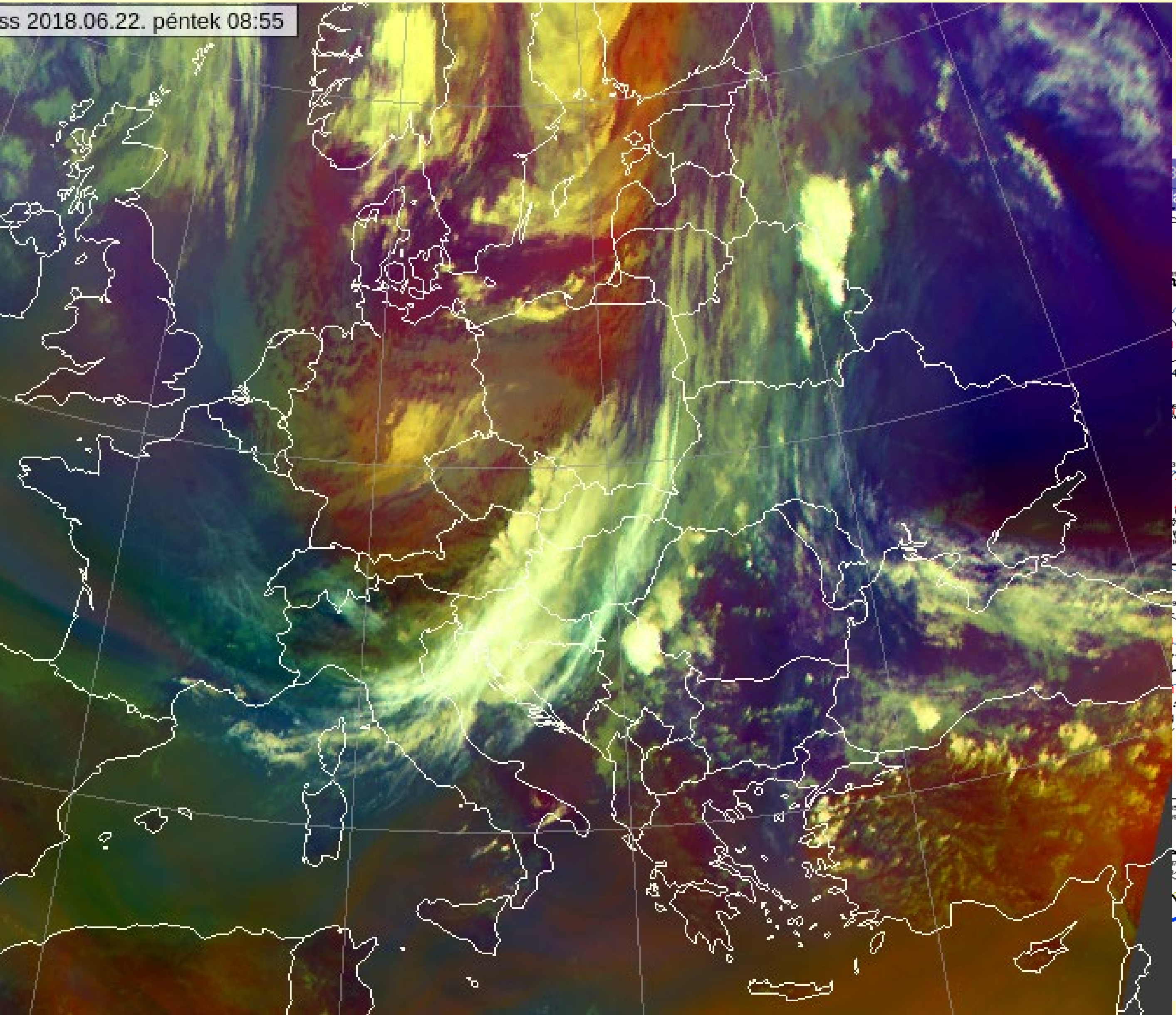


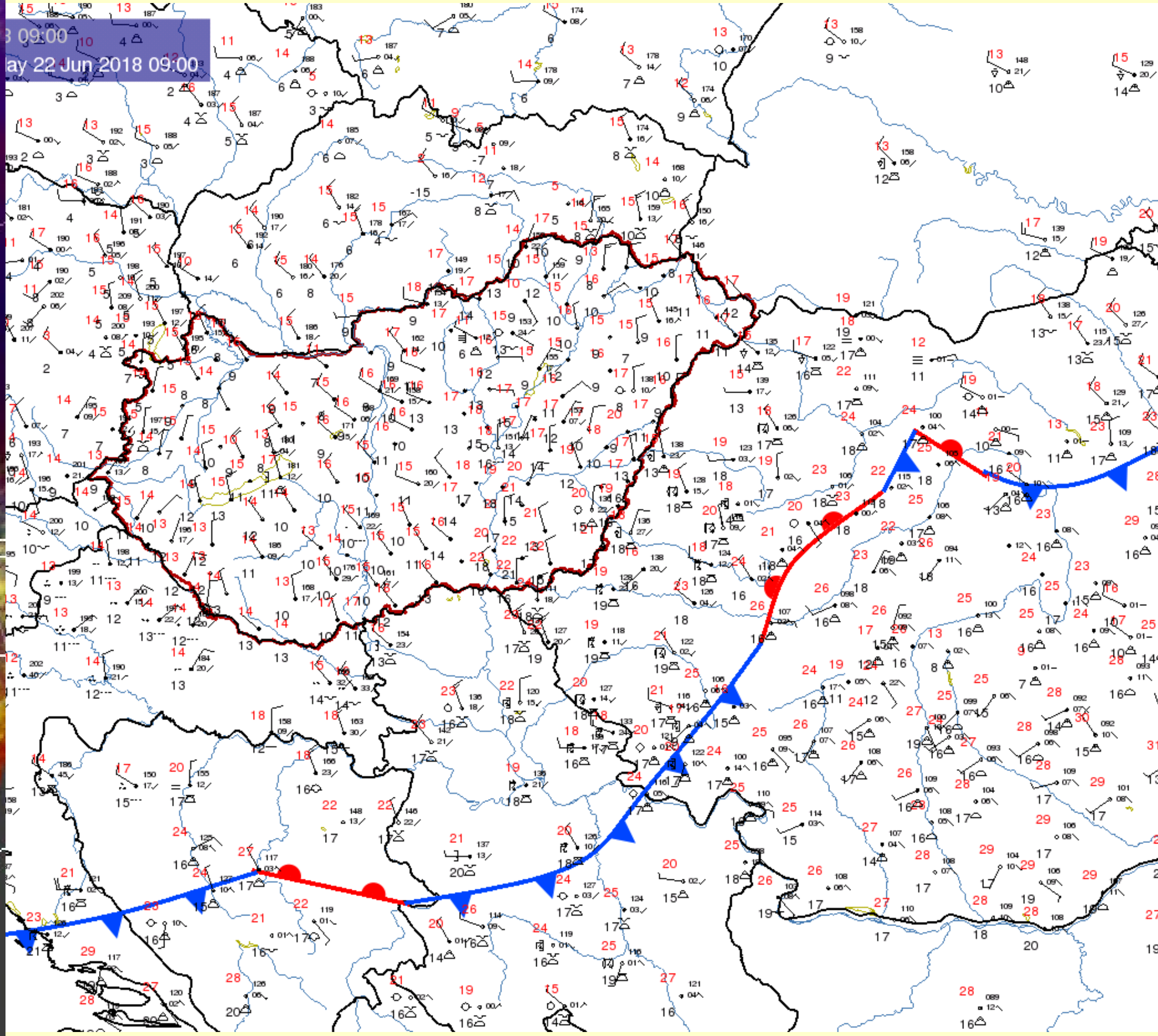
Too high errors
Useless profile
– It shows multilayer cloud instead of cloud-free profile
☹

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

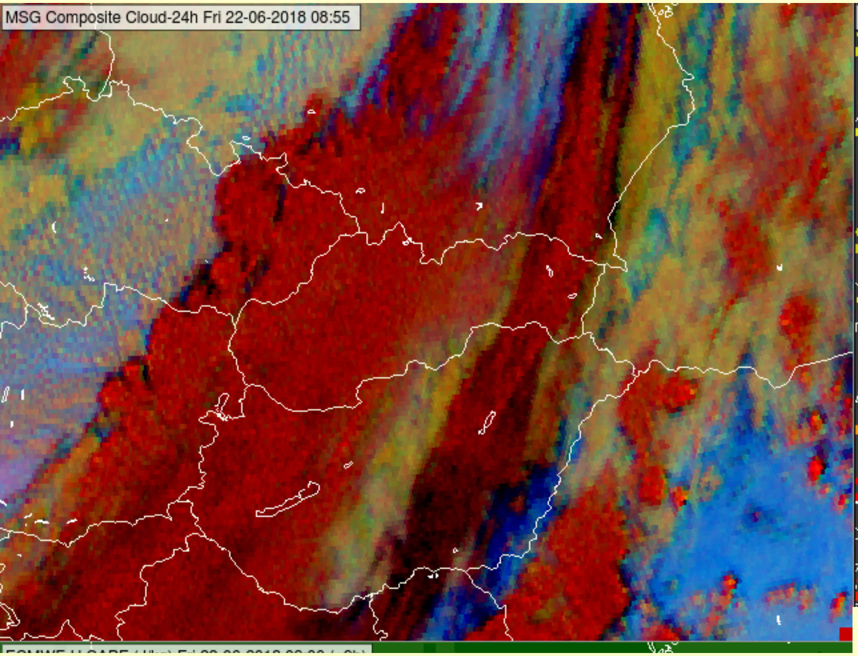
Front - Behind the surface front one may see typical features in the ECMWF profiles, like cooling and much dryer airmass in low layer. The IASI profile may not show these features.

Example of **22 June 2018** - strong front, very dry airmass in low/mid layer in ECMWF and radiosonde data – not seen in IASI profiles.

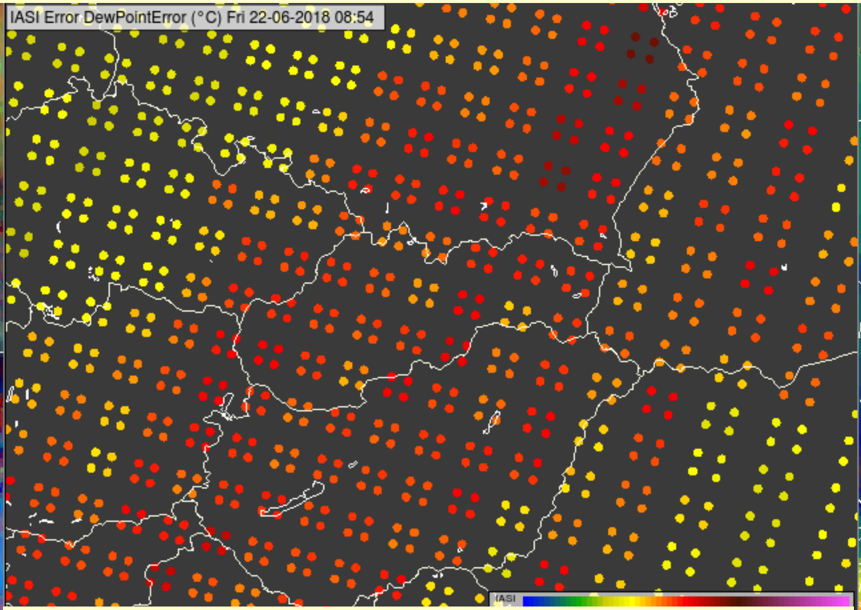




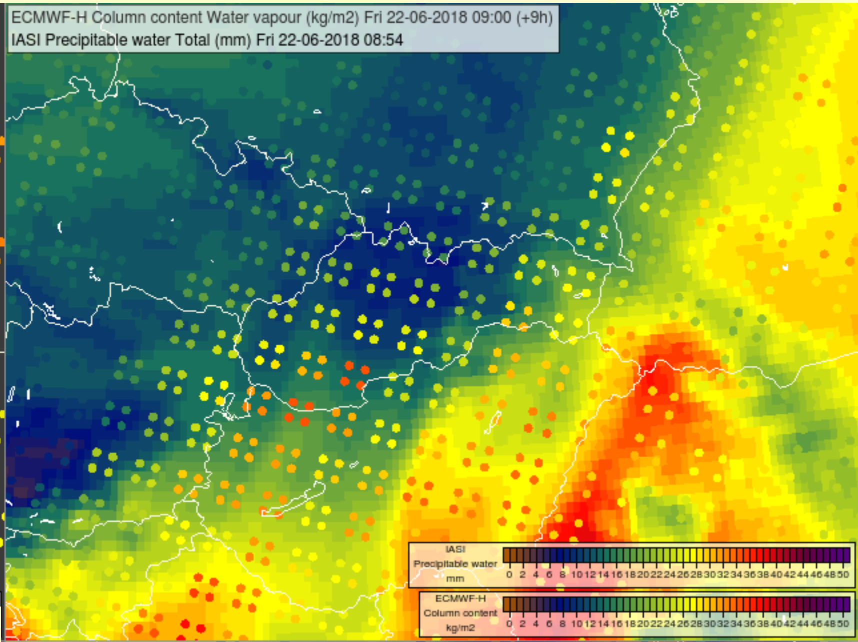
24h Microphysics RGB 8:55 UTC



IASI Td error 8:54 UTC

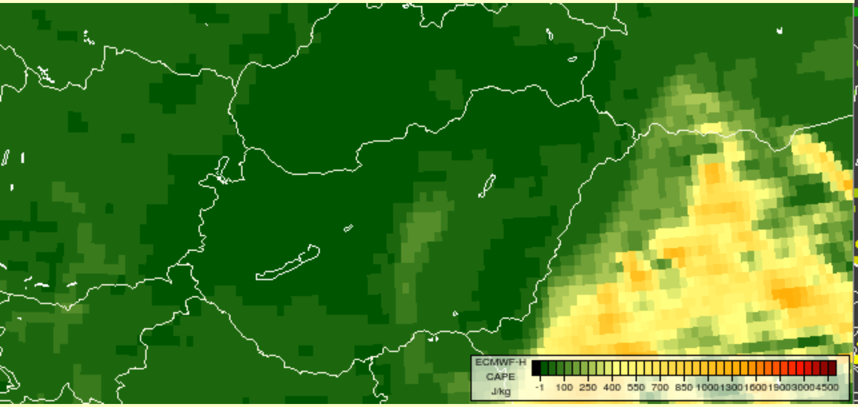


ECMWF + IASI TPW

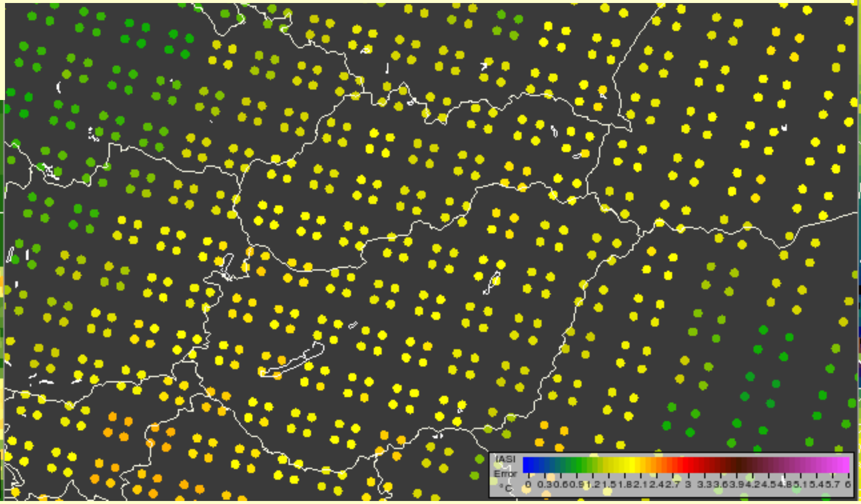


Significant differences between the ECMWF forecasted and IASI L2 derived TPW and the K-index, mainly in Slovakia, north Hungary and east Austria. **Which one is more realistic?**

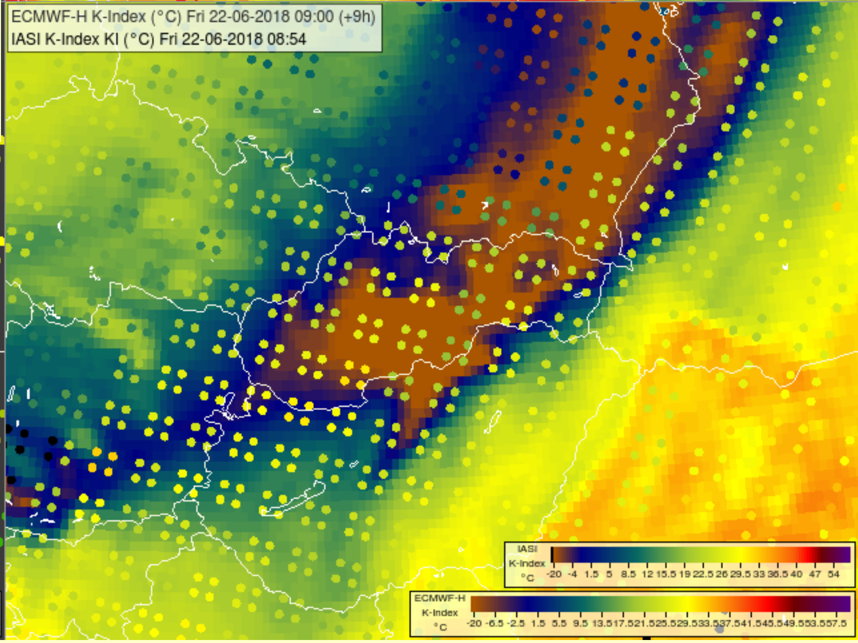
The IASI T and Td uncertainties are rather large along the thick frontal cloudiness (Td error > ~2.5 °C, IASI T error > ~1.5 °C).



ECMWF CAPE 9 UTC



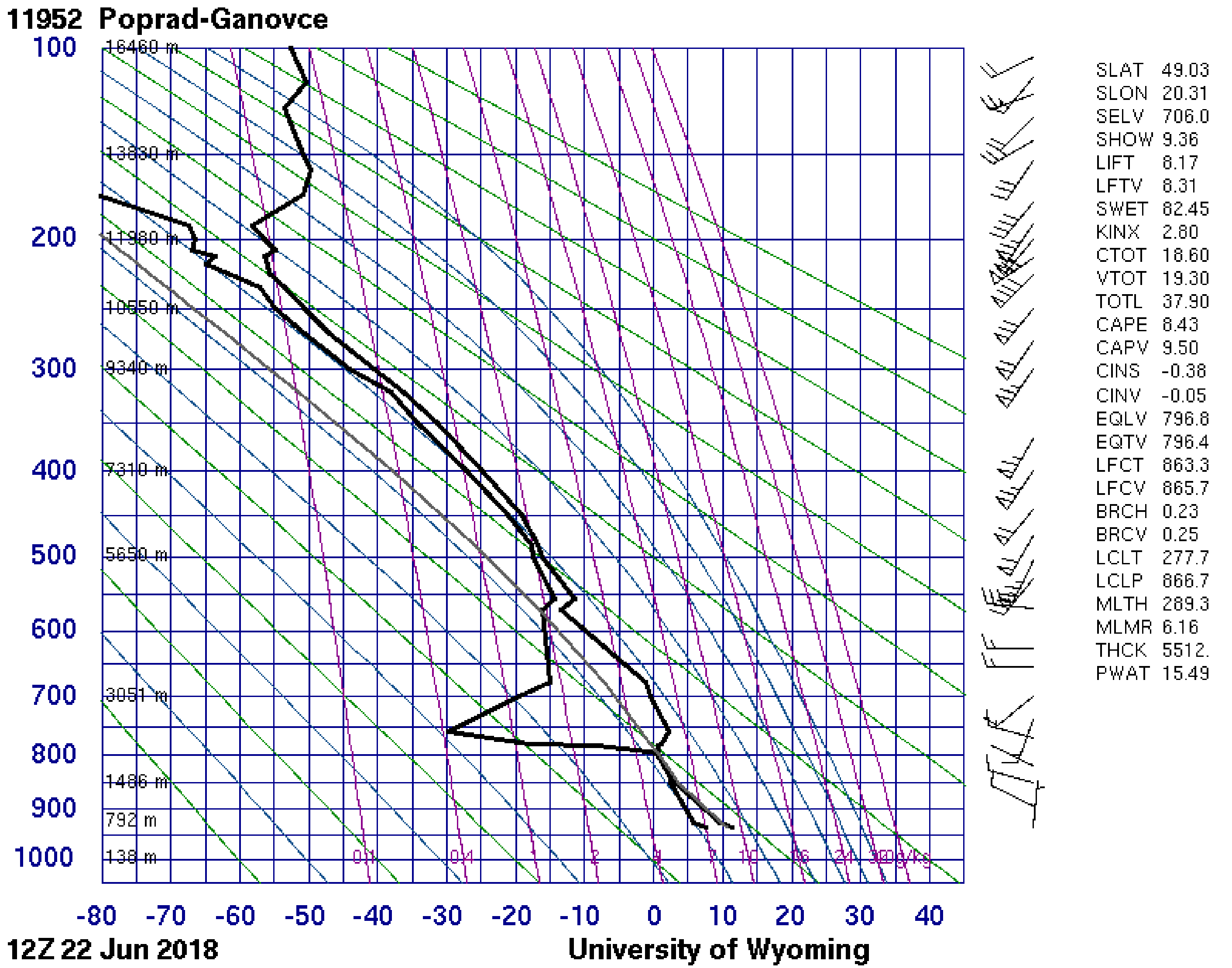
IASI T error 8:54 UTC



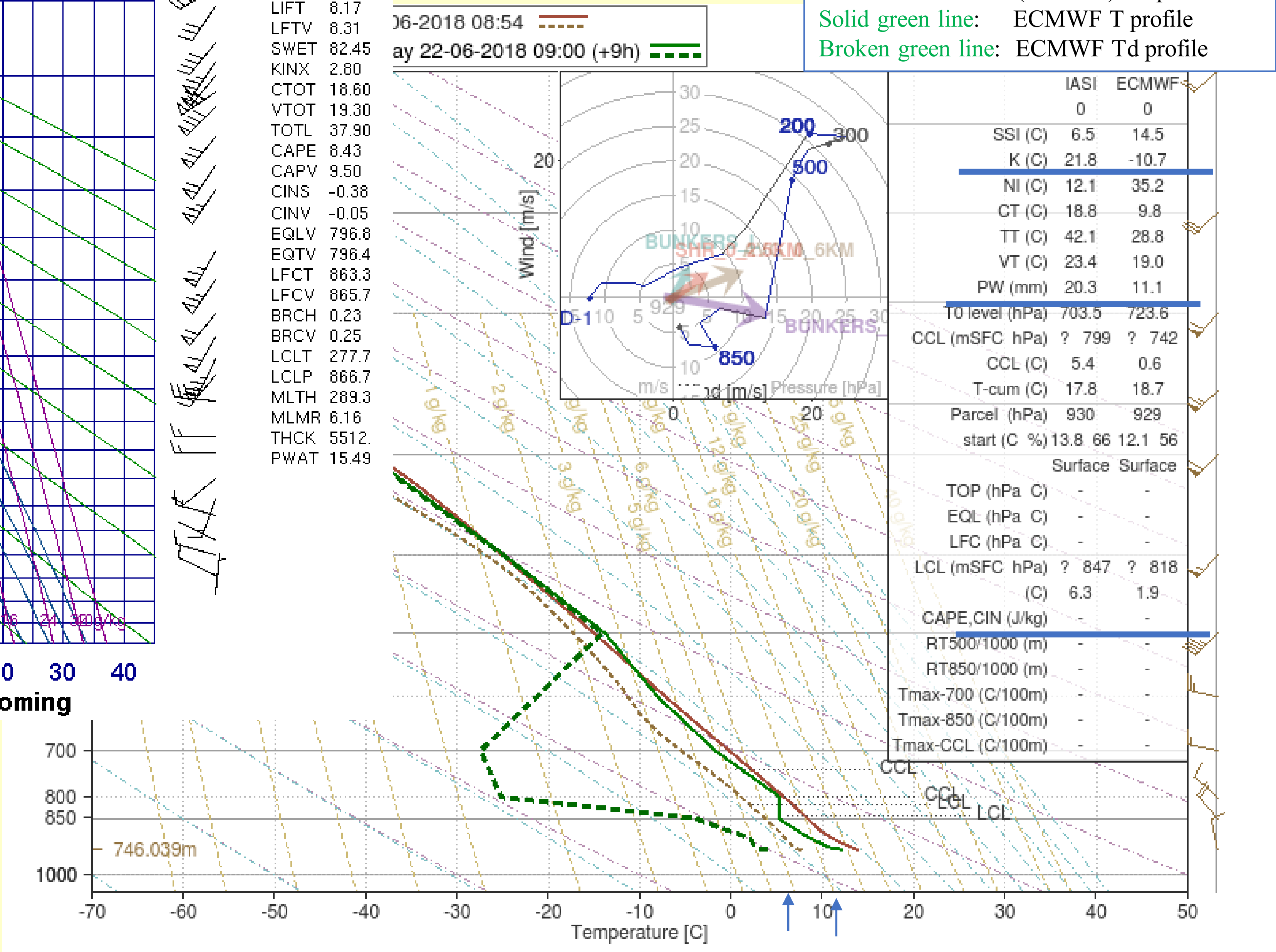
ECMWF + IASI K-index

ECMWF and IASI TPW fields.

istic?



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



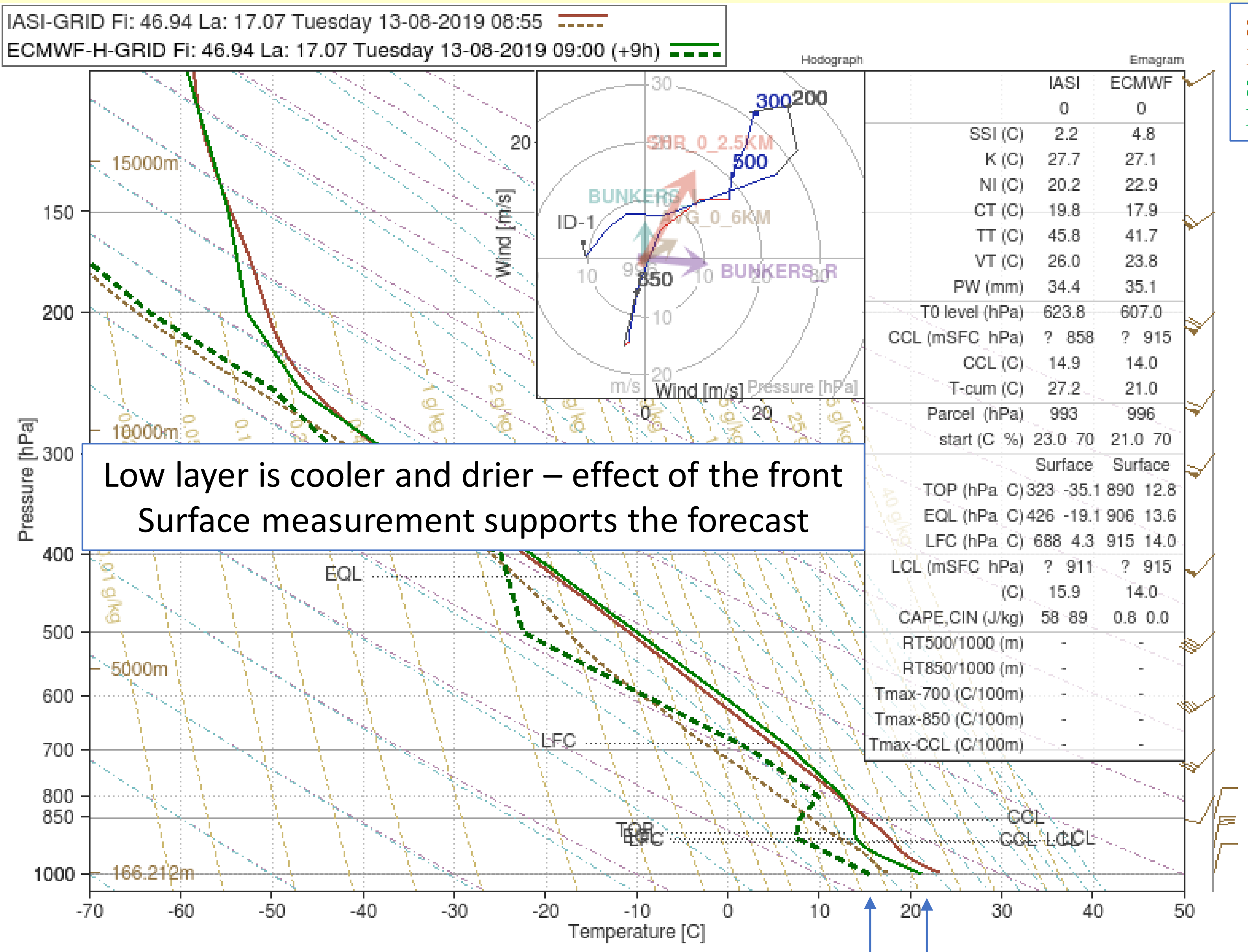
	IASI	ECMWF
	0	0
SSI (C)	6.5	14.5
K (C)	21.8	-10.7
NI (C)	12.1	35.2
CT (C)	18.8	9.8
TT (C)	42.1	28.8
VT (C)	23.4	19.0
PW (mm)	20.3	11.1
T0 level (hPa)	703.5	723.6
CCL (mSFC hPa)	? 799	? 742
CCL (C)	5.4	0.6
T-cum (C)	17.8	18.7
Parcel (hPa)	930	929
start (C %)	13.8 66	12.1 56
	Surface	Surface
TOP (hPa C)	-	-
EQL (hPa C)	-	-
LFC (hPa C)	-	-
LCL (mSFC hPa)	? 847	? 818
(C)	6.3	1.9
CAPE,CIN (J/kg)	-	-
RT500/1000 (m)	-	-
RT850/1000 (m)	-	-
Tmax-700 (C/100m)	-	-
Tmax-850 (C/100m)	-	-
Tmax-CCL (C/100m)	-	-

ECMWF profile shows a very dry layer at mid-levels, which is missing from the IASI profile.

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

Front (cont.)

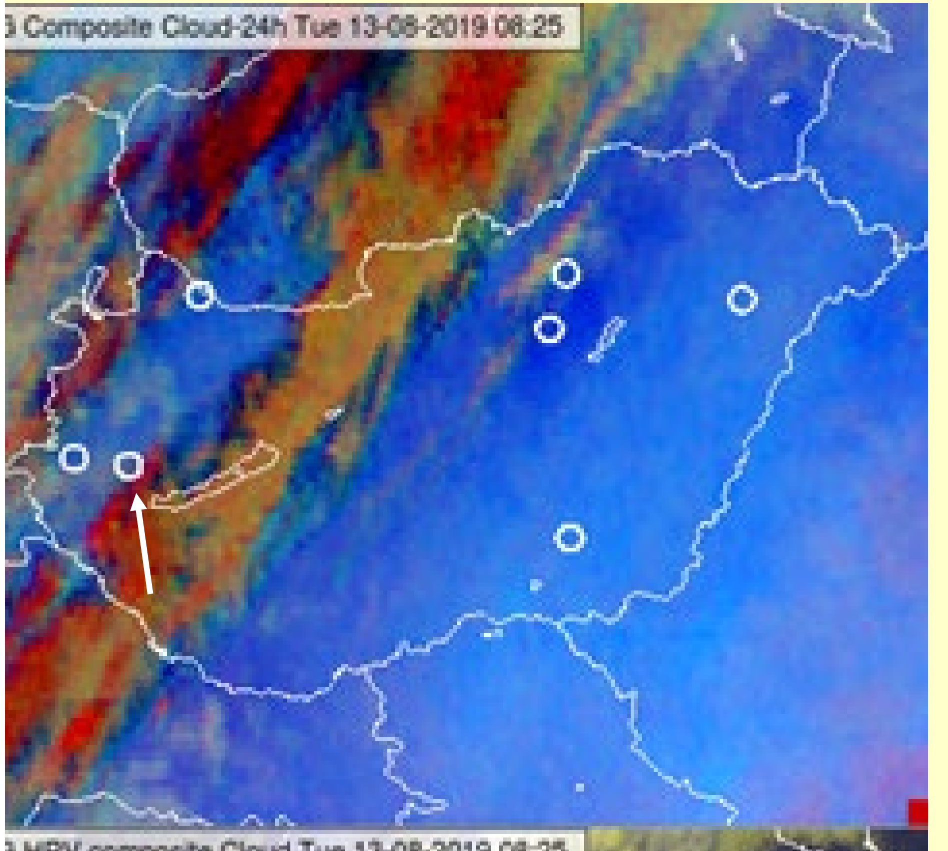
Example of **13 August 2019** – less strong front; colder, drier airmass in low layer in ECMWF data – not seen in IASI profiles



	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)

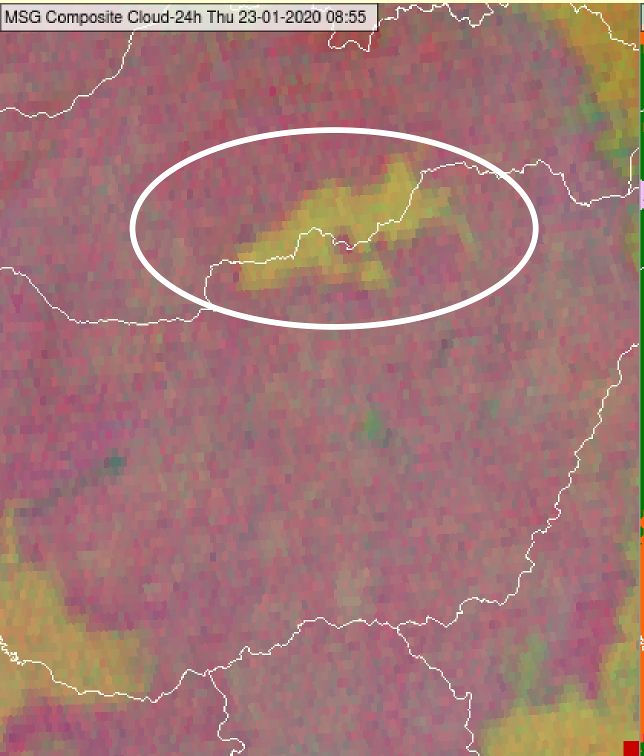
23 January 2020 - winter cold pool situation - fog/stratus in the encircled area

According NWCSAF CT: very low cloud

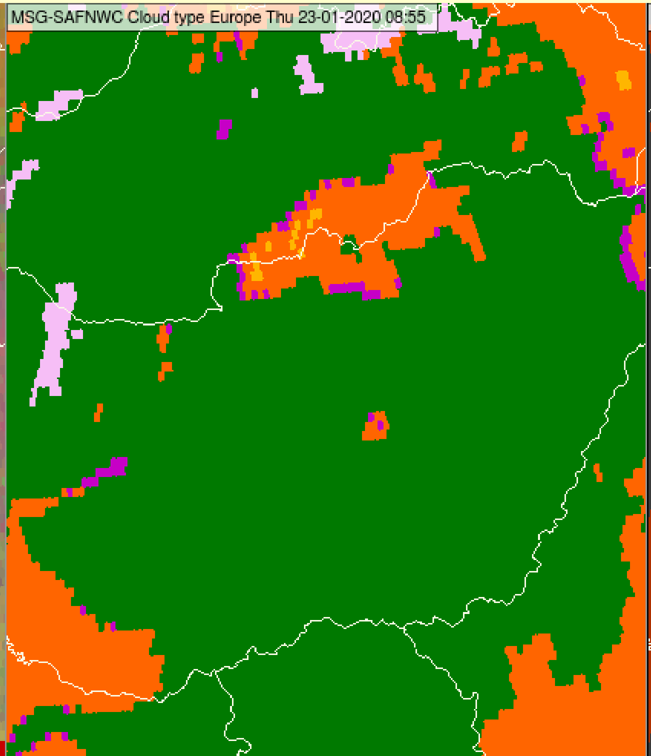
According NWCSAF CTTH: retrieved cloud top height ~ 3000 m in several pixels

In ECMWF model this area is cloud-free

24h Microphysics RGB



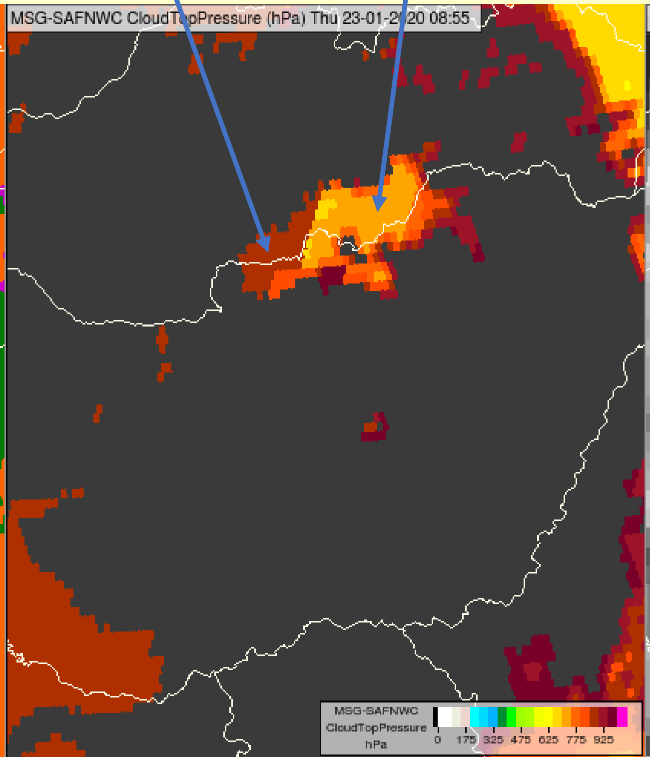
NWCSAF Cloud Type



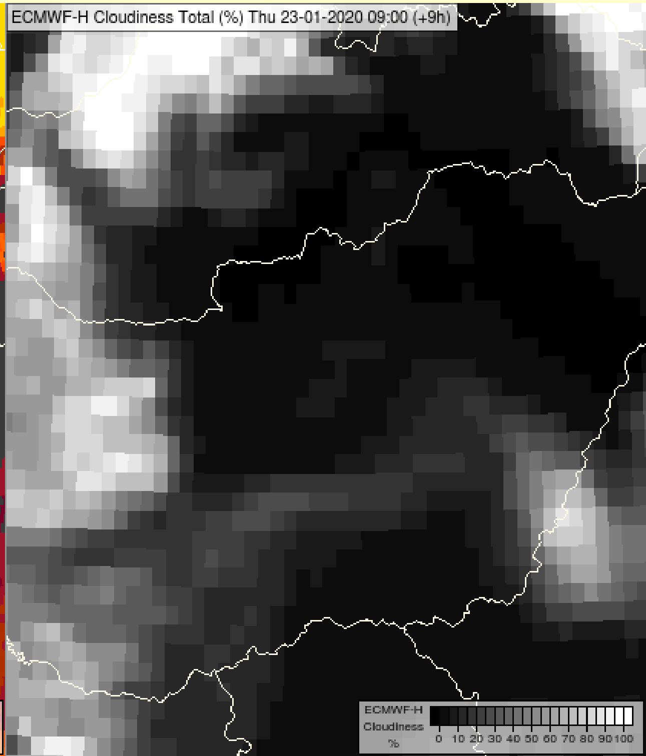
~850 hPa

~700 hPa

NWCSAF Cloud top Presssure

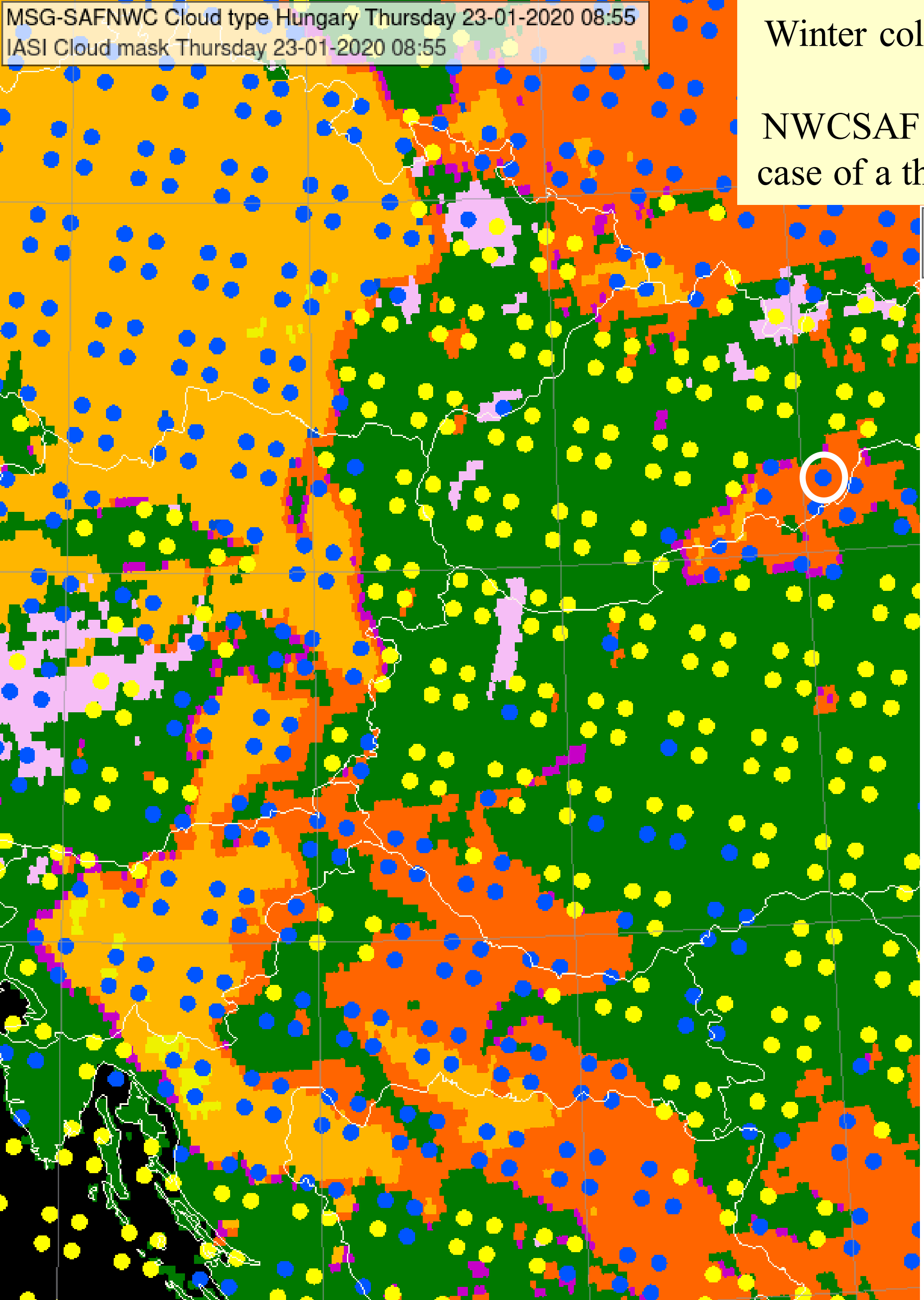


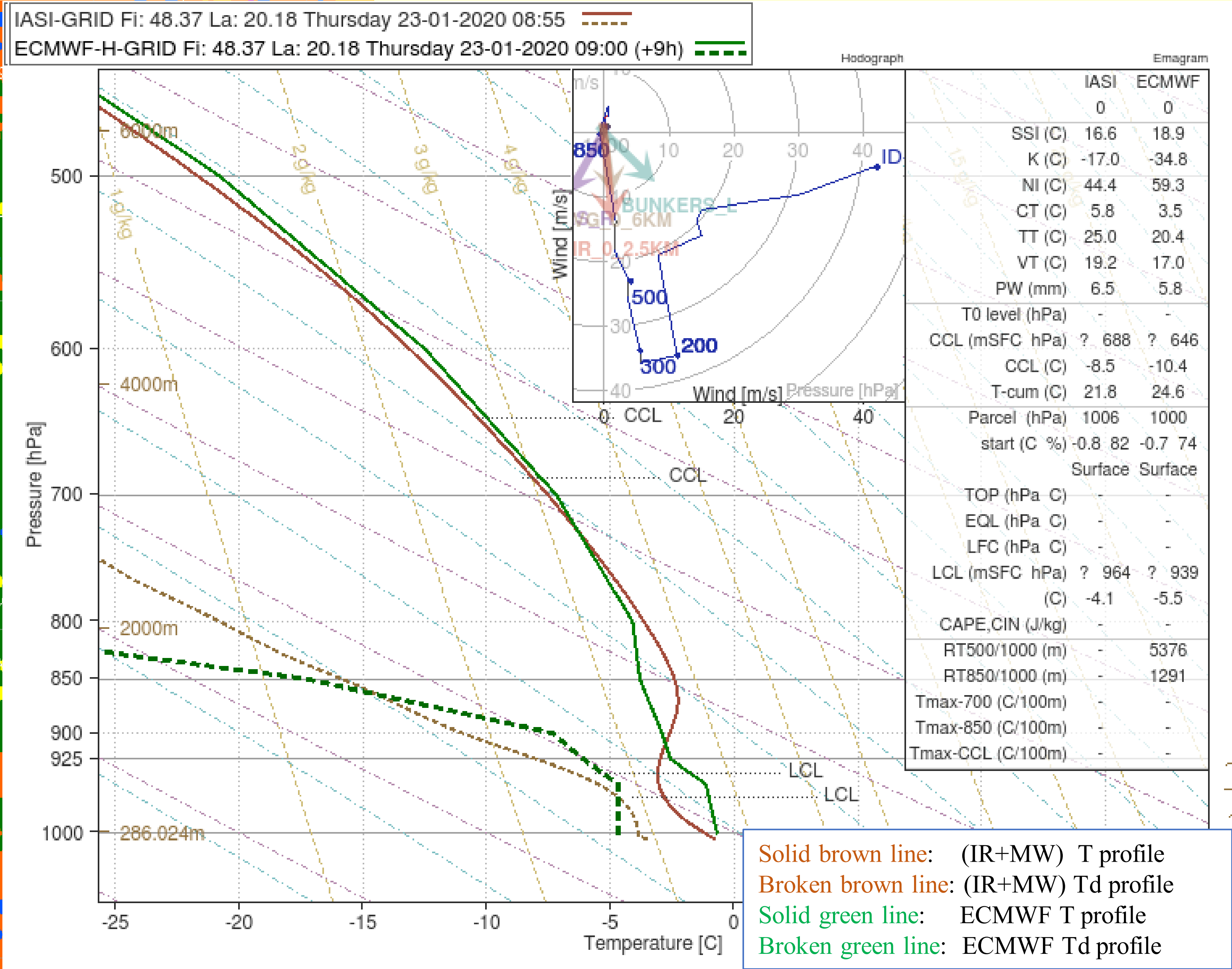
ECMWF Total cloudiness



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.





	IASI	ECMWF
	0	0
SSI (C)	16.6	18.9
K (C)	-17.0	-34.8
NI (C)	44.4	59.3
CT (C)	5.8	3.5
TT (C)	25.0	20.4
VT (C)	19.2	17.0
PW (mm)	6.5	5.8
T0 level (hPa)	-	-
CCL (mSFC hPa)	? 688	? 646
CCL (C)	-8.5	-10.4
T-cum (C)	21.8	24.6
Parcel (hPa)	1006	1000
start (C %)	-0.8 82	-0.7 74
	Surface	Surface
TOP (hPa C)	-	-
EQL (hPa C)	-	-
LFC (hPa C)	-	-
LCL (mSFC hPa)	? 964	? 939
(C)	-4.1	-5.5
CAPE,CIN (J/kg)	-	-
RT500/1000 (m)	-	5376
RT850/1000 (m)	-	1291
Tmax-700 (C/100m)	-	-
Tmax-850 (C/100m)	-	-
Tmax-CCL (C/100m)	-	-

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

Outlines

- Introduction
- Global analyses of instability indices from the infrared-only IASI L2 products
- Case studies
  - How to gather interesting cases?
  - Comparison of IR-only and IR+MW data
  - Comparison IASI L2 and ECMWF data – typical features
  - Cases with added value and cases confirming the forecast
- Forecast and L2 differences dataset
- Merging IASI L2 product with surface measurements
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- Summary

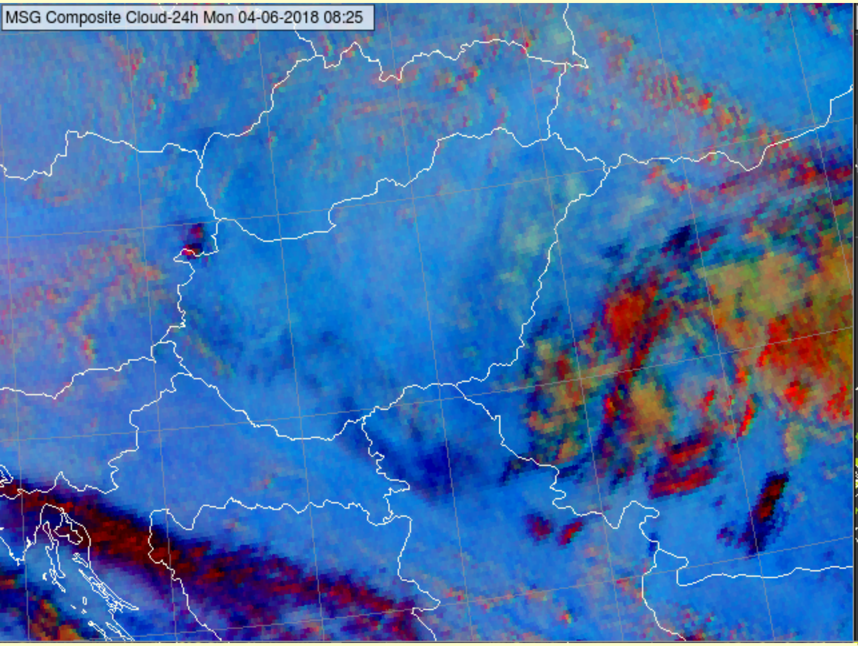
Cases when IASI derived environmental parameters provided **added value** to the ECMWF forecast

We found added value only in few per-cents of the cases

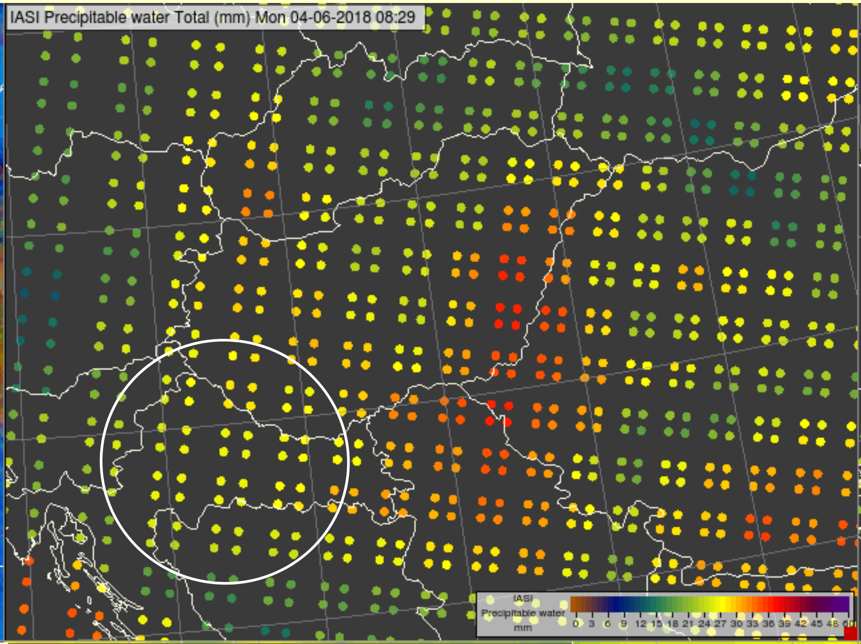
- ECMWF forecast is good
- We checked in a small country at the time of the Metop overpasses. For a bigger area with half hourly IRS data there might be more interesting cases.

04 June 2018 In the forecast there was a local TPW maximum over NW Croatia, this maximum was missing from IASI data.

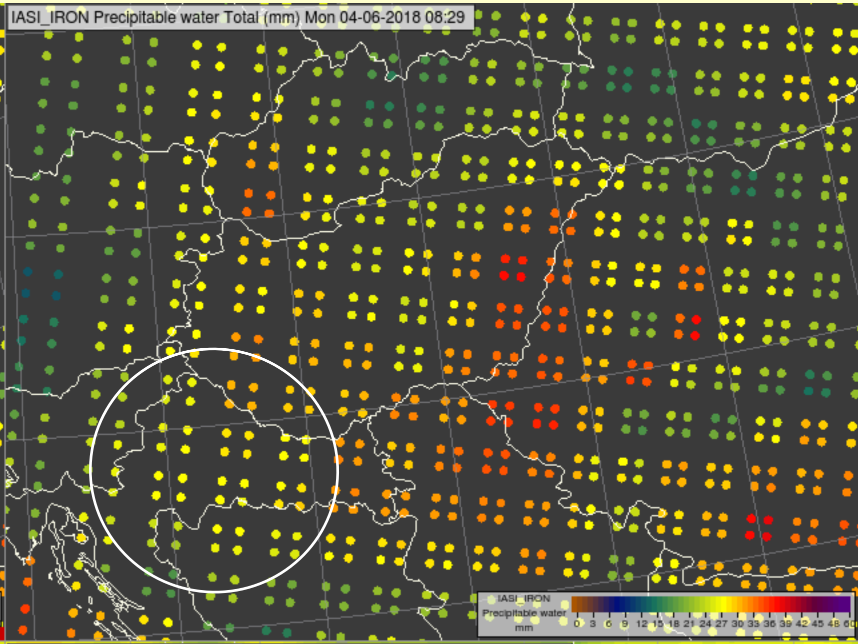
SEVIRI 24h Microphysics RGB



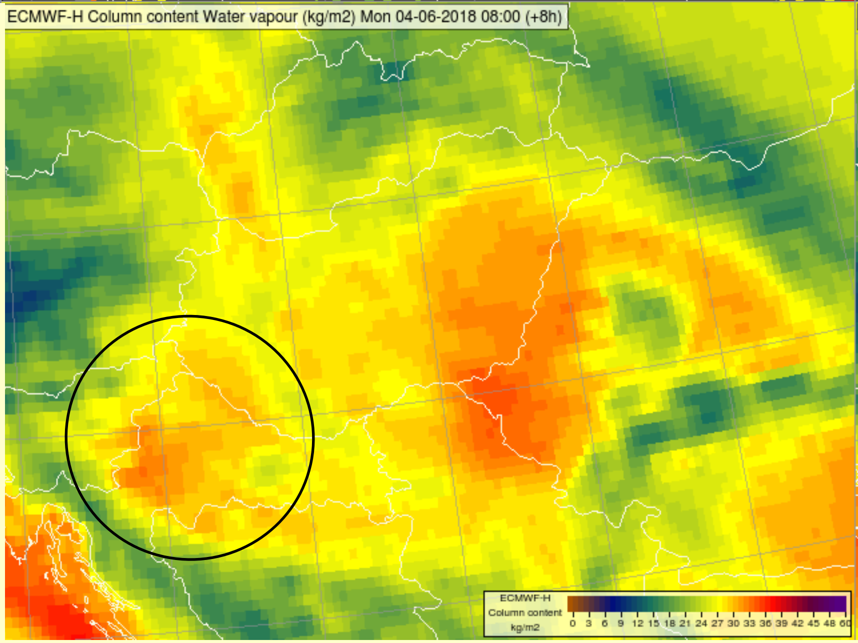
08:29 UTC IASI (IR+MW) TPW



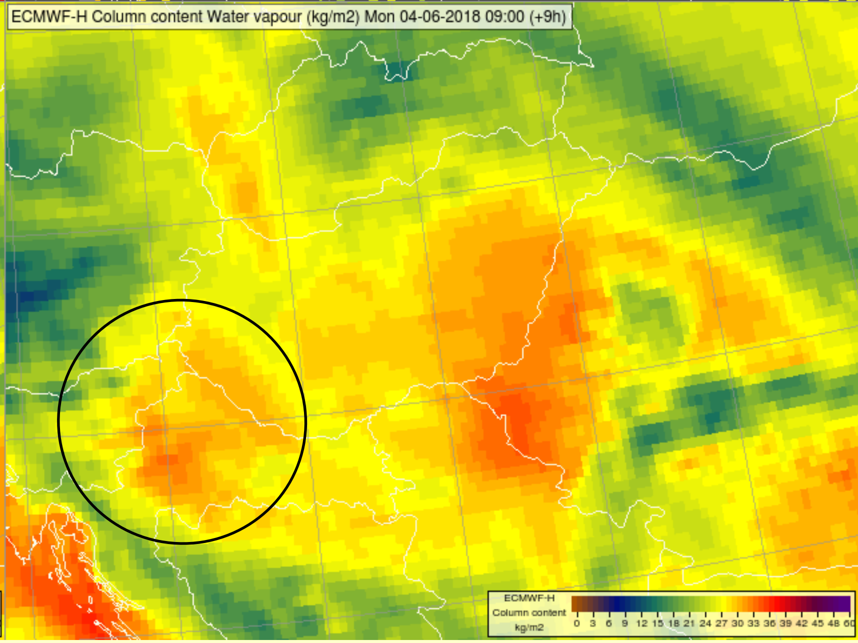
08:29 UTC IASI IR-only TPW



- ECMWF forecasted local TPW maximum for Croatia which was missing in IASI L2 (IR+MW) data
- Several thunderstorms formed, but not in NW Croatia. Thunderstorms formed elsewhere and propagated over this area started to dissolve here.
- Hungarian forecasters expected thunderstorms close to the Croatian border. However, almost no thunderstorms formed there.



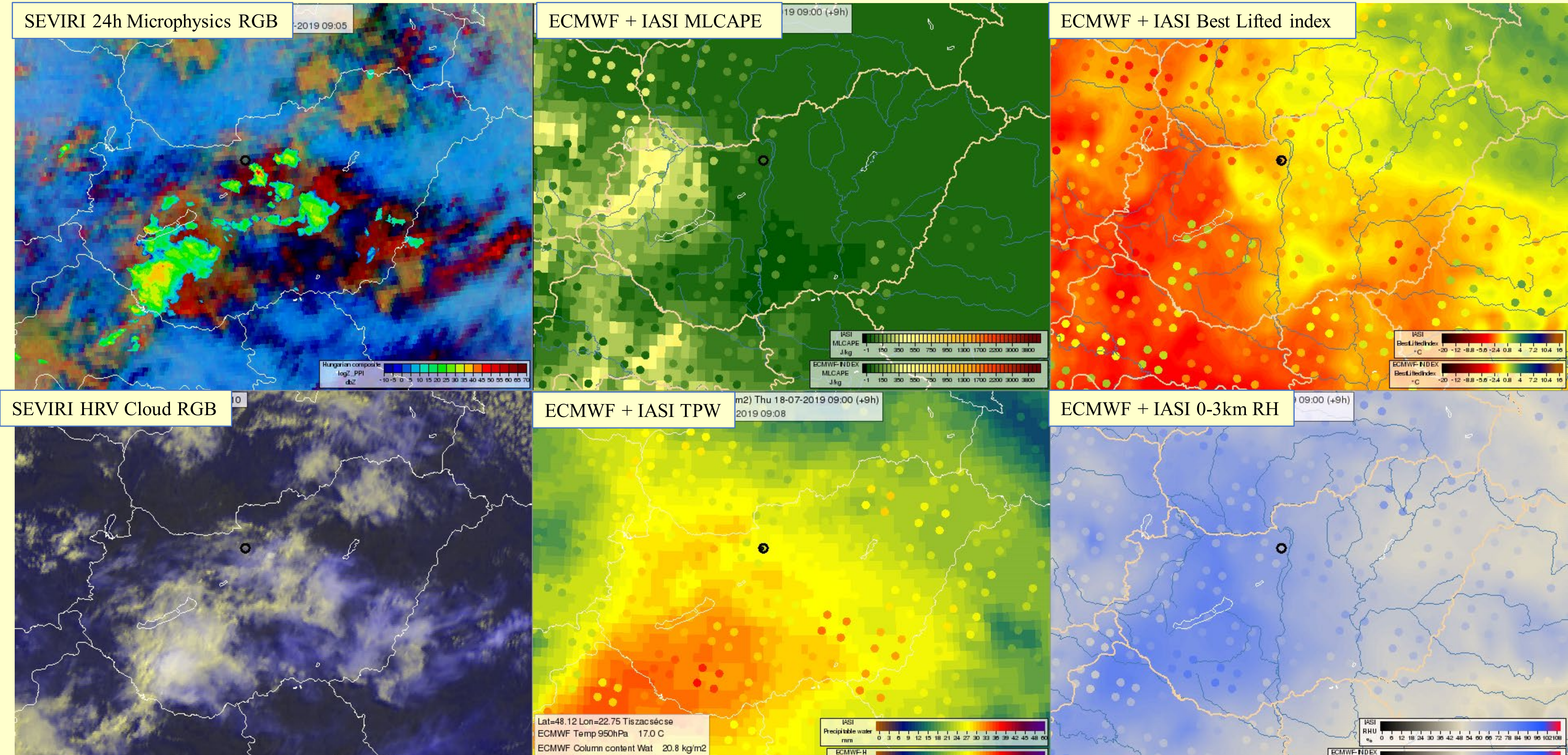
ECMWF TPW (00+08 UTC)



ECMWF TPW (00+09 UTC)

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.



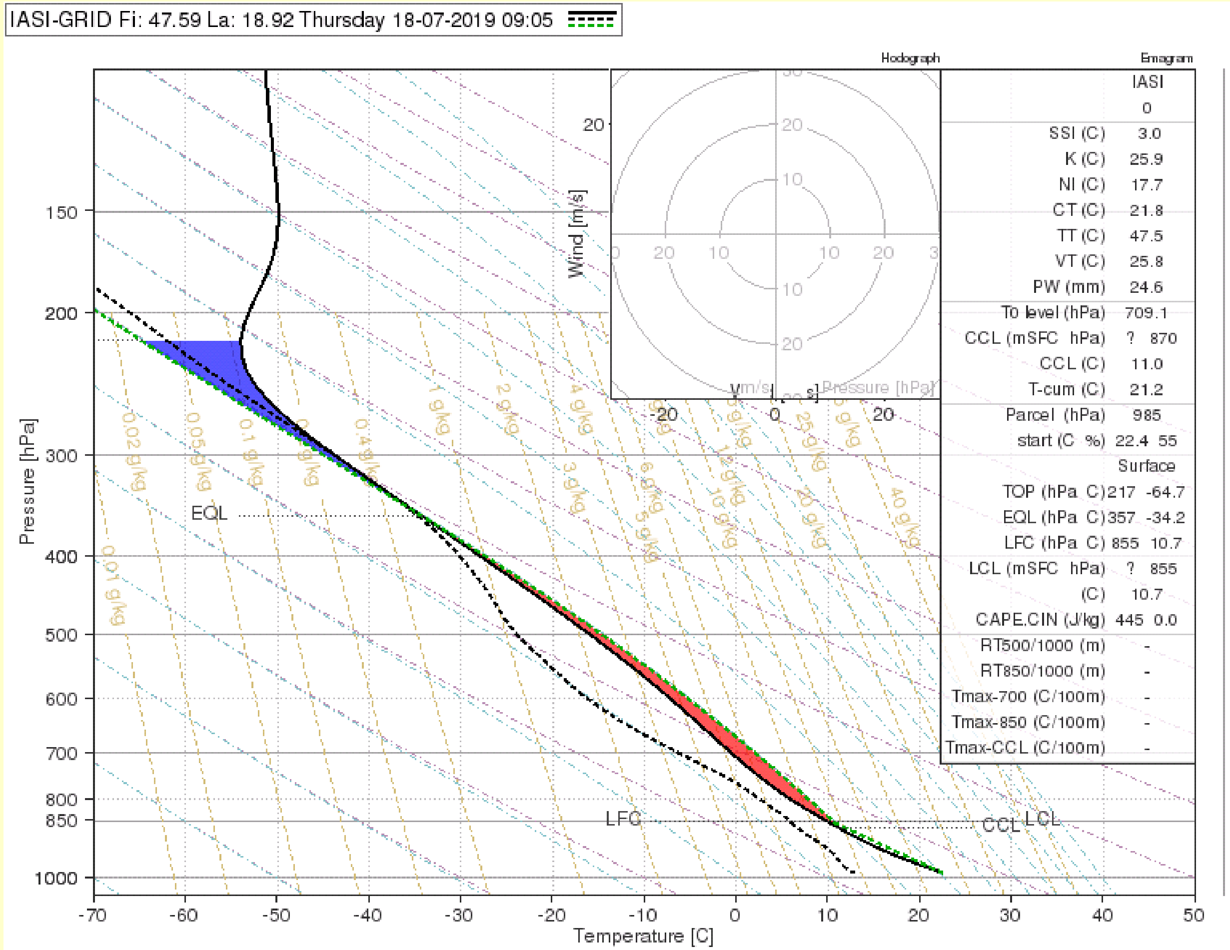
Environment of the developing storm near Budapest

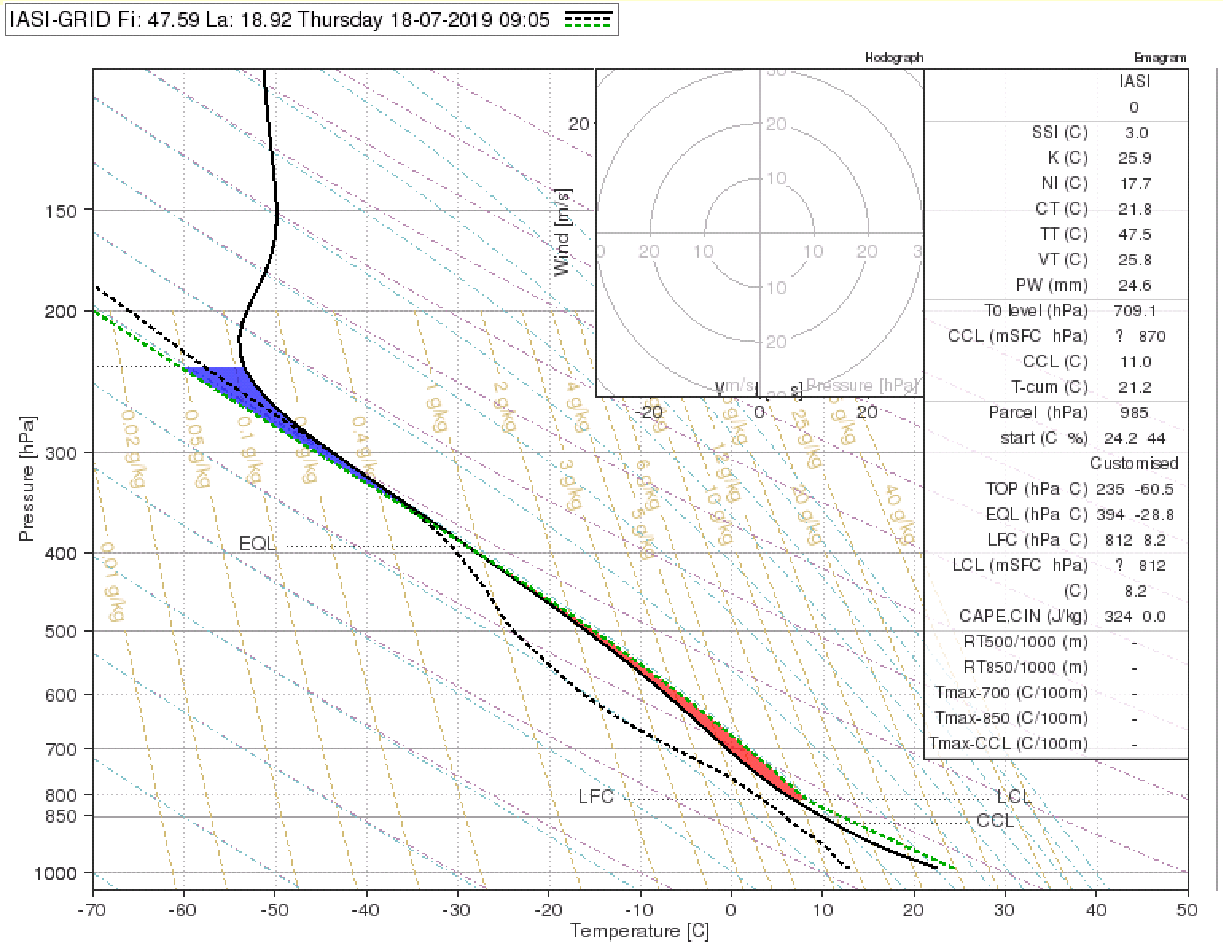
IASI T2: 22.4 °C
IASI Td: 12.8 °C

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

Synop T2: 24.2 °C
Synop Td: 11.1 °C

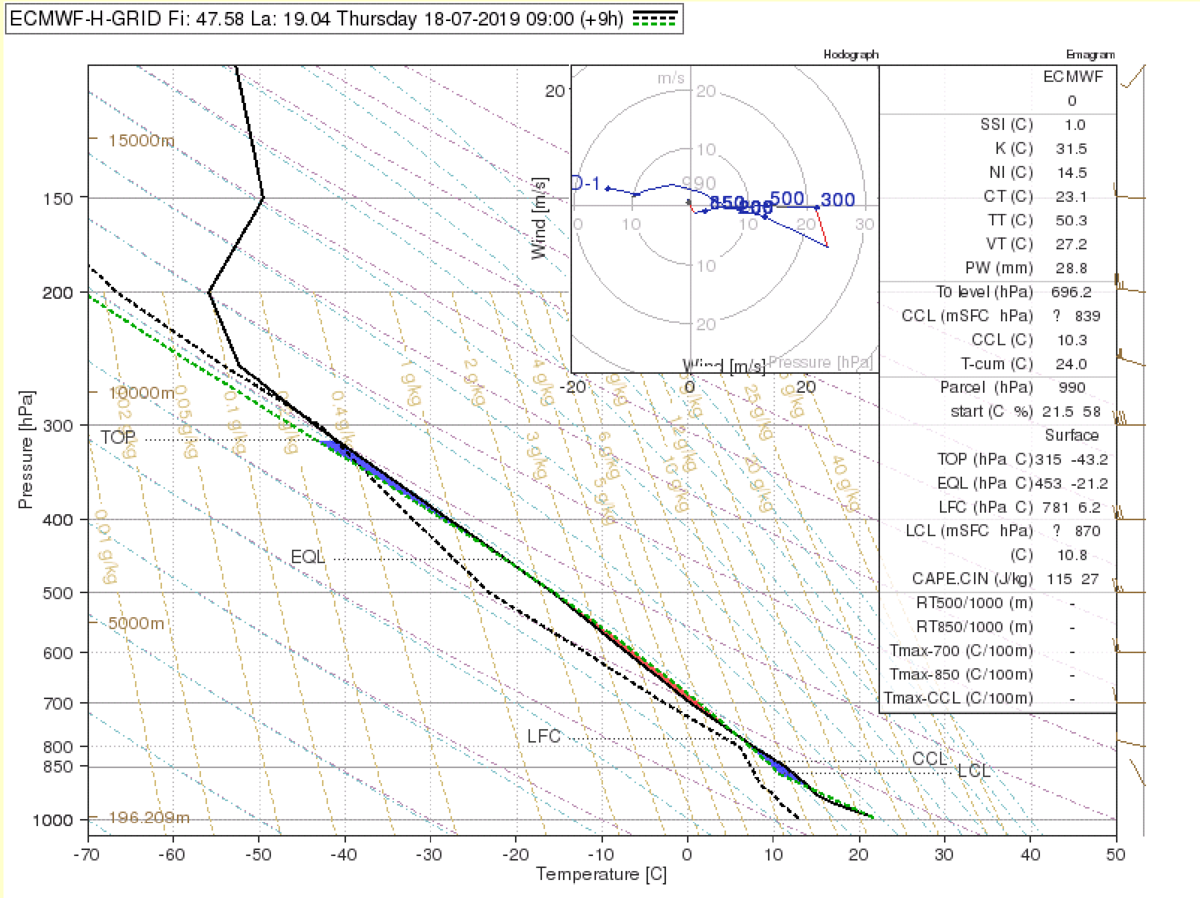
With SYNOP there is less instability but still unstable





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



Outlines

- Introduction
- Global analyses of instability indices from the infrared-only IASI L2 products
- Case studies
    - How to gather interesting cases?
    - Comparison of IR-only and IR+MW data
    - Comparison IASI L2 and ECMWF data – typical features
    - Cases with added value and cases confirming the forecast
- Forecast and L2 differences dataset
- Merging IASI L2 product with surface measurements
- Suggestions
- Summary

Forecast and L2 differences dataset

Collect convective cases where the ECMWF forecasted and the IASI L2 (MW+IR and IR-only) derived convective environment parameters **differ significantly.**

The cases will be classified according the **nature of the differences.**

The database will contain:

- A code indicating why the profile is included in the database
- geolocation
- date/time
- satellite angles
- quality indicators
- information on the cloudiness
- NWP analysed or forecasted temperature (T) and relative humidity (RH) profiles on isobaric levels
- IASI L2 (based on IR and MW data) p, T and specific humidity profiles
- IASI L2 (processed in IR-only mode) p, T and specific humidity profiles
- environmental parameters derived from the above profiles
- 2m T and relative humidity measurements

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Merging IASI L2 product with surface measurements

Why is it needed?

Satellite derived environmental parameters **may be not enough accurate for nowcasting purposes** as:

- Many environmental parameters depend strongly on the (near) surface T and Td values.
- These are the levels where the uncertainty of the satellite derived profiles is the biggest.

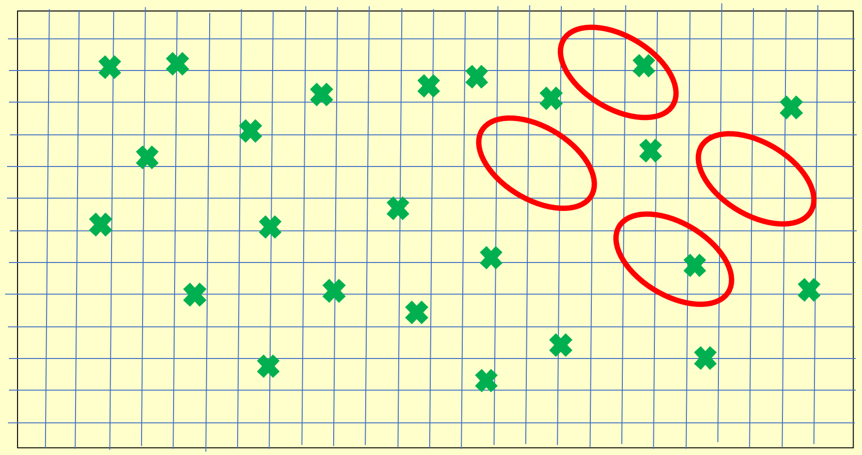
One option to overcome these problems:

- **combine the satellite derived profiles with surface T and Td measurements**

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:



Ground-based measuerments
IASI pixel

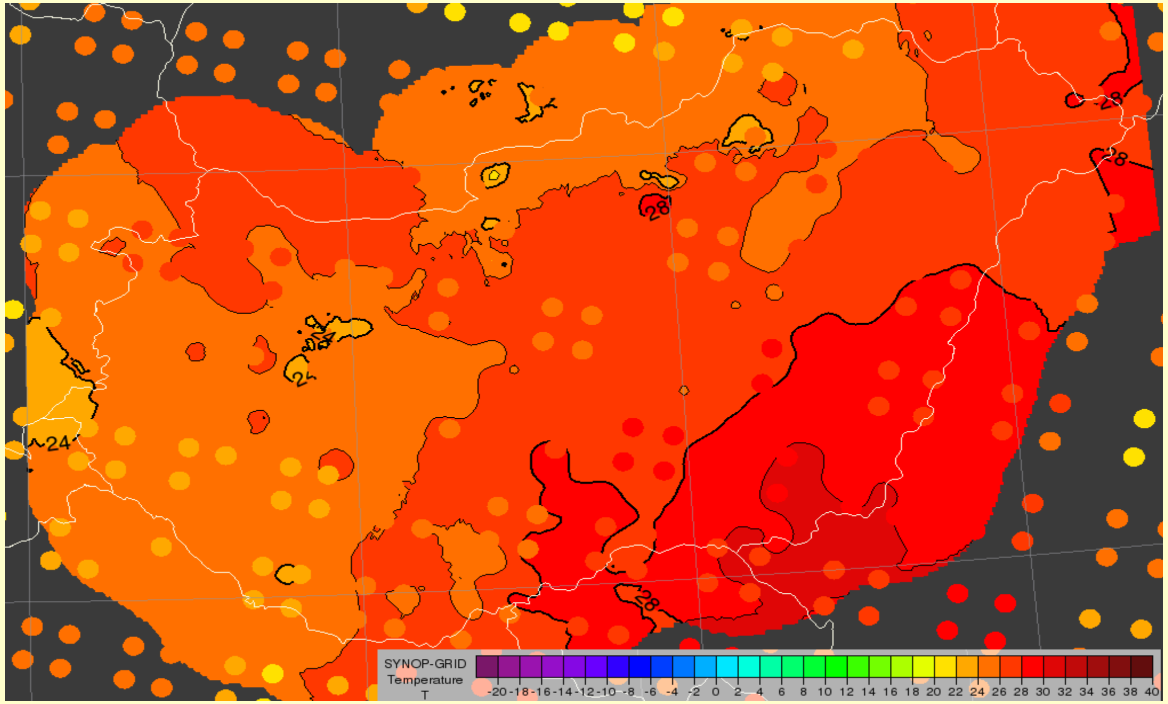
1. Interpolate the ground-based measurement to a grid (0.02°) using inverse distance weighting (IDW) taking into account topography. – For each grid the stations within 50 km were used. (HAWK-3)
2. Within the IASI ellipses: calculate average T, Td of the grid points.
3. Use this new T, Td as the surface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

Merge with surface measurements

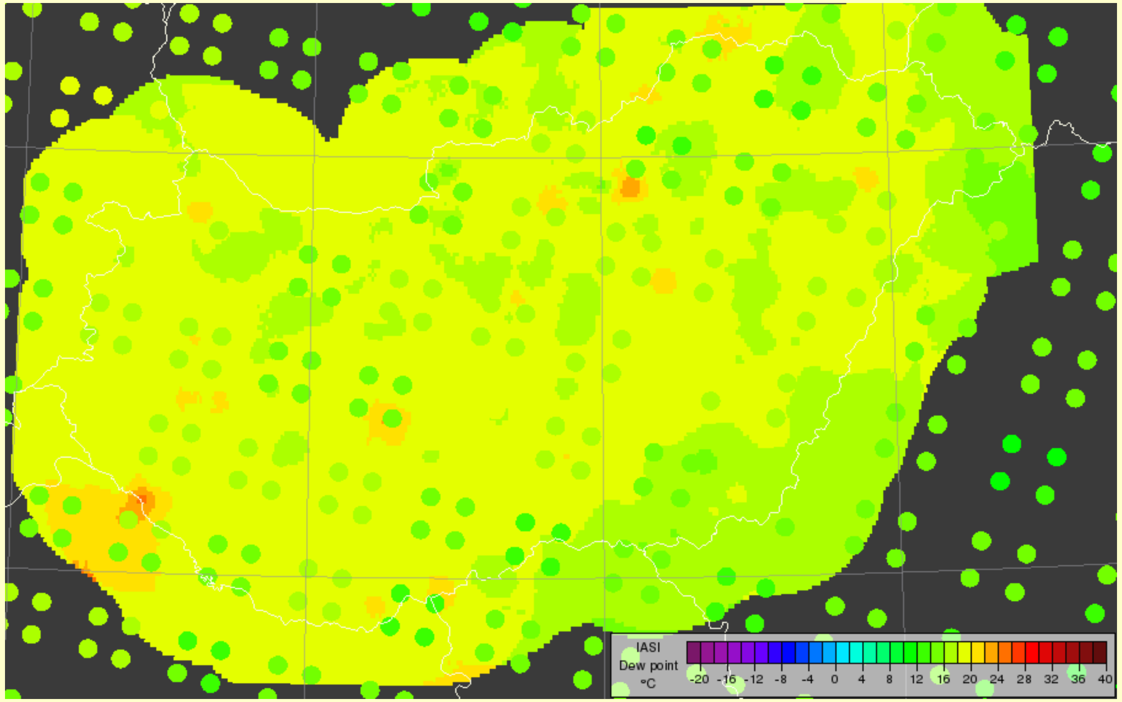
The IASI profiles have larger uncertainties at low levels, they are often **drier (and colder)** than indicated by the model profiles or surface measurements. Would merging with synop help?

24 August 2019

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



Interpolated surface measured 2m T + IASI 2m T



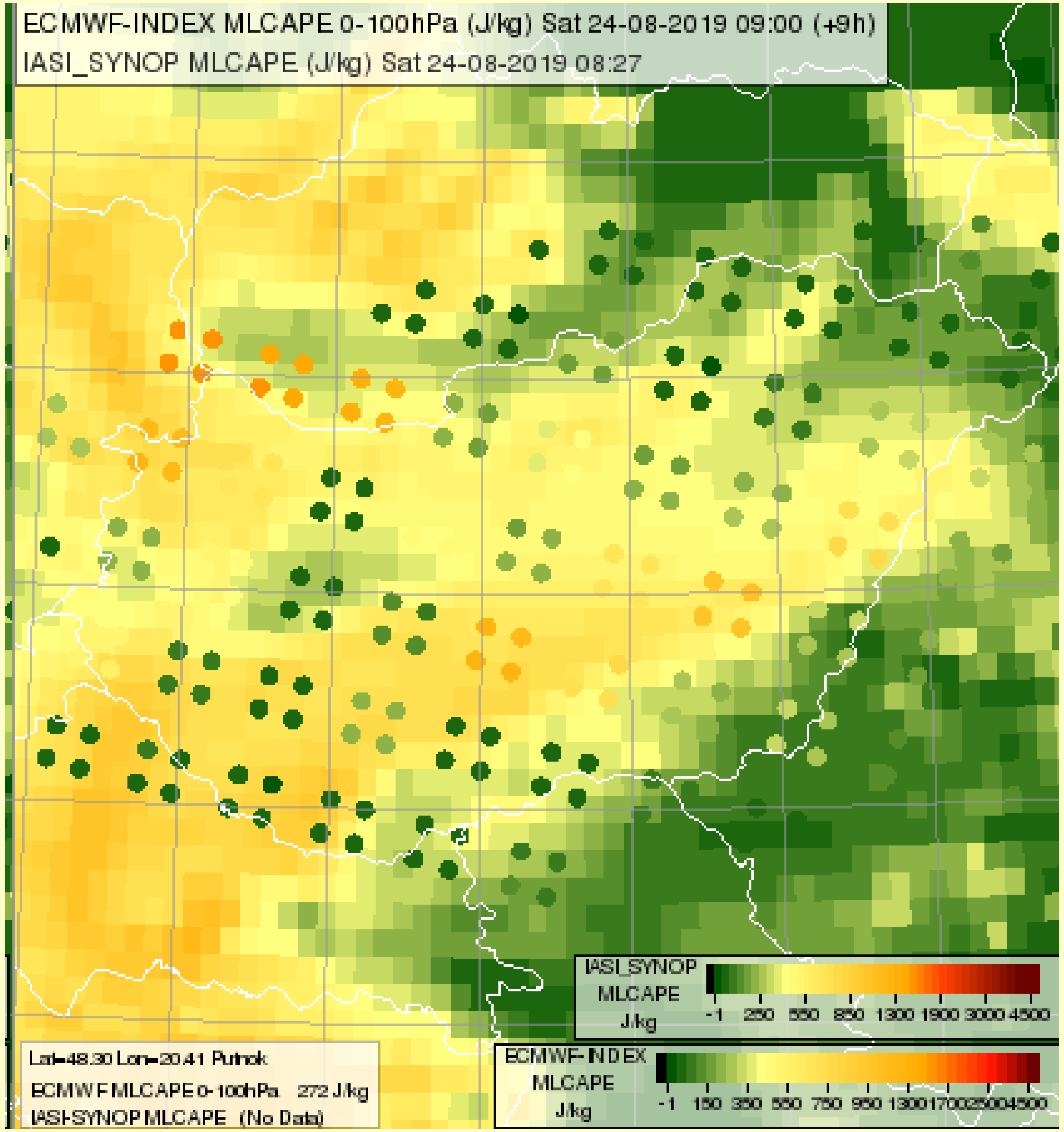
Interpolated surface measured 2m Td + IASI 2m Td

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

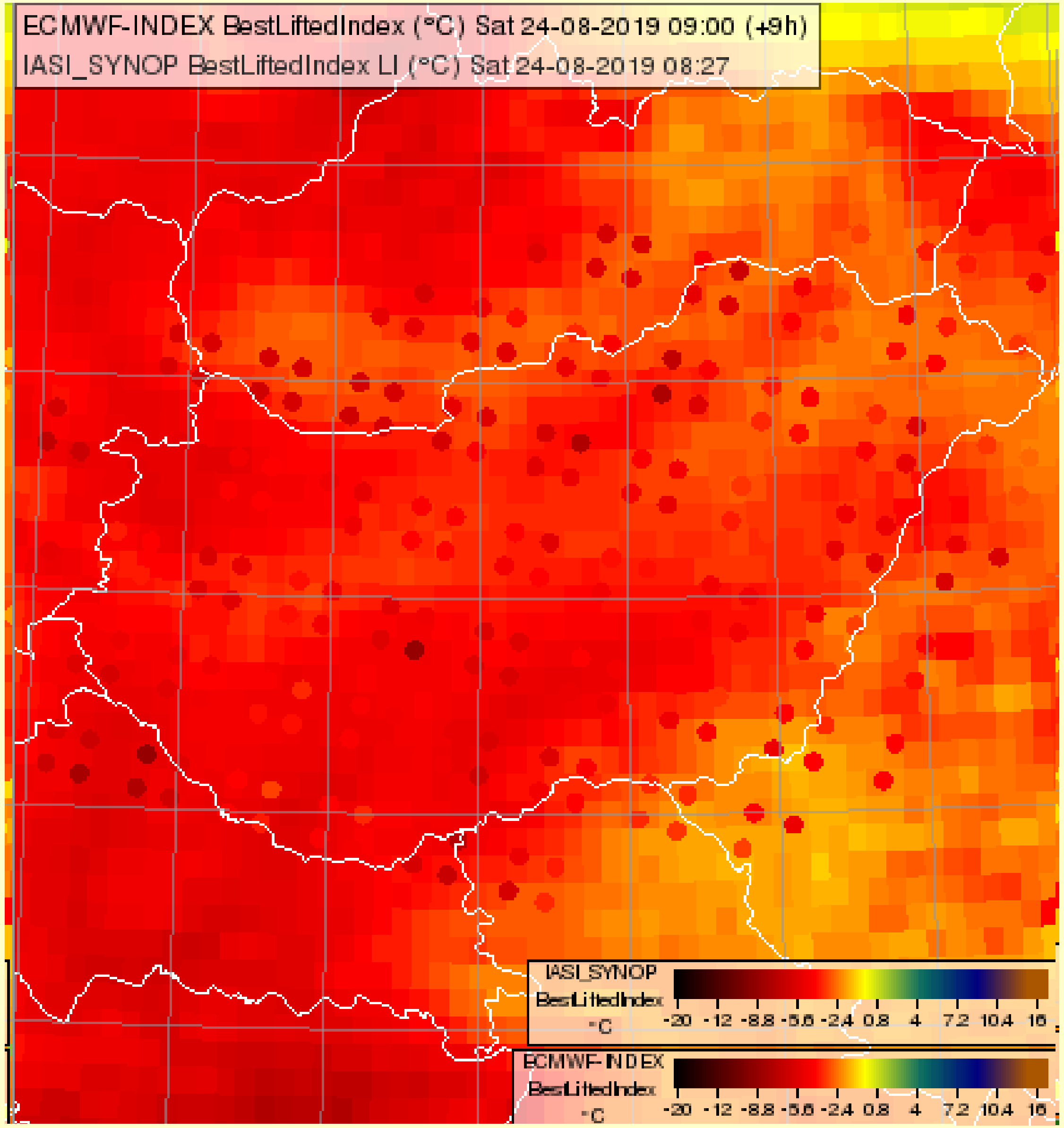
Differences between the surface measurements and retrieved IASI 2m Td are up to 3 °C.

Merge with surface measurements

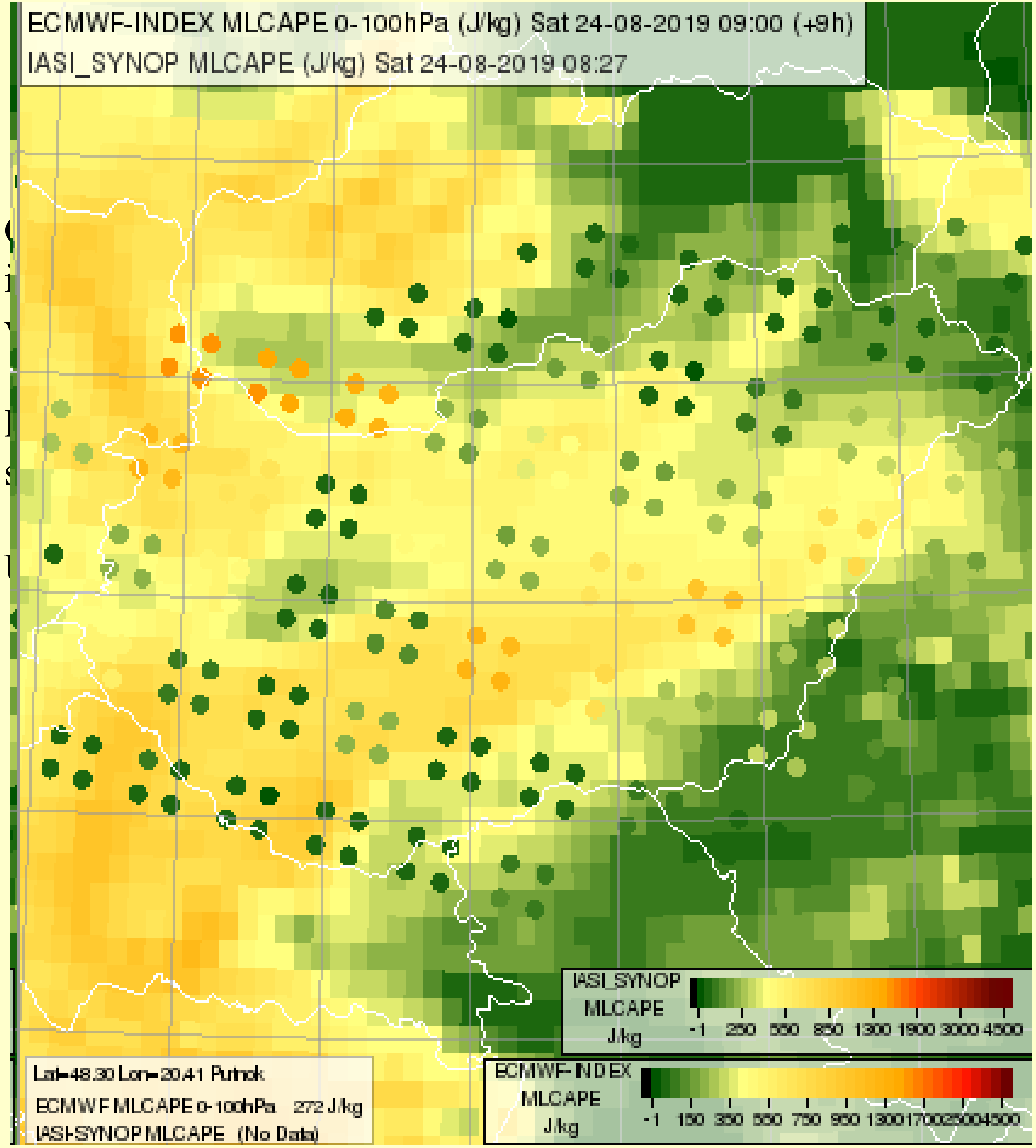
24 August 2019 (IASI data from 08:27UTC, forecast valid for 09UTC



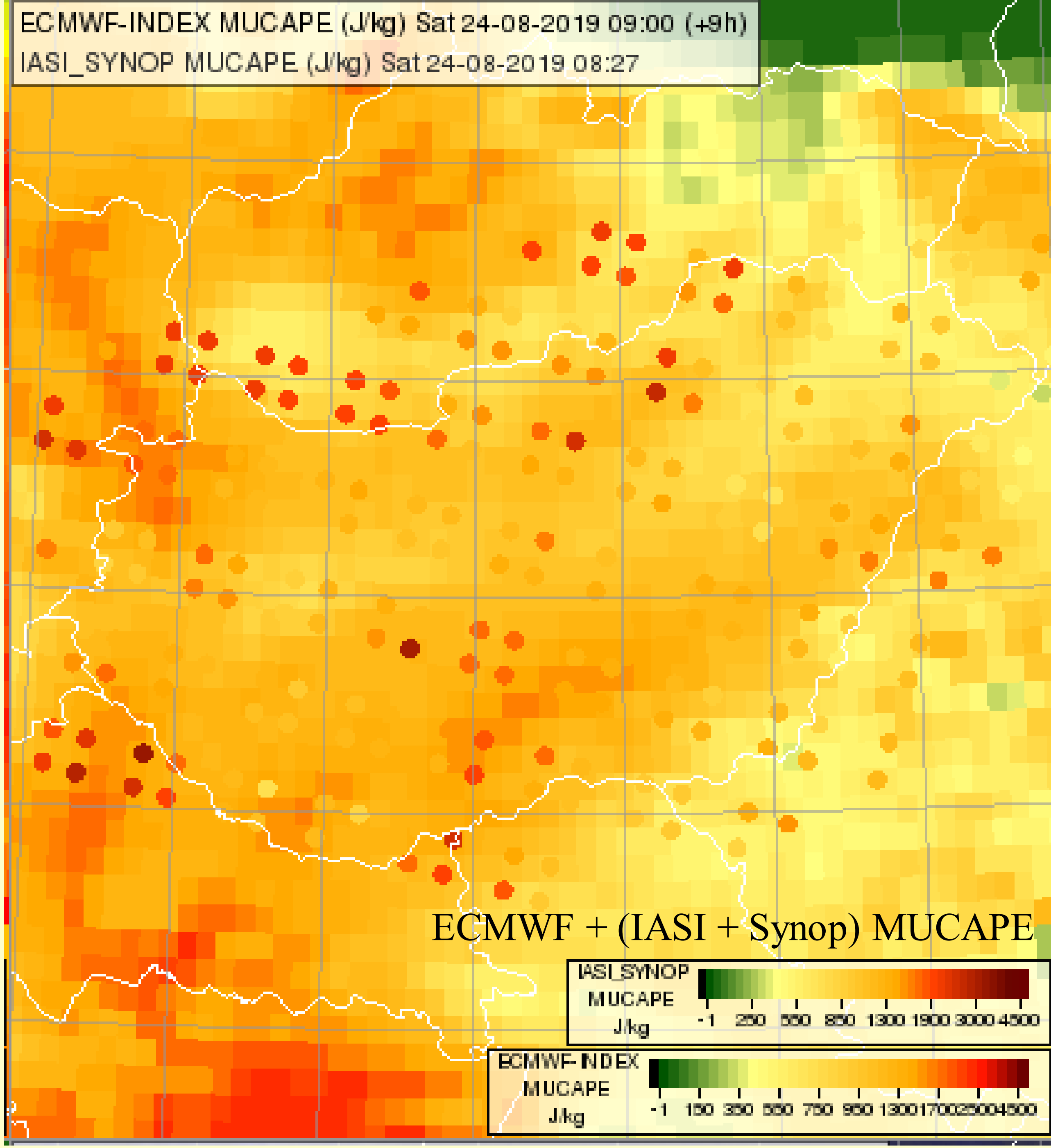
ECMWF + (IASI + synop) MLCAPE



ECMWF + (IASI + synop) Best Lifted index



ECMWF + (IASI + synop) MLCAPE



ECMWF + (IASI + Synop) MUCAPE

Why is ‚good’ if the merged IASI data become more often closer to the forecast?

In most of the cases the forecast is rather good. If a IASI parameter very often differs strongly from the forecast – the forecaster will not trust it.

IASI derived parameter may differ from forecast because

- the forecast is not enough accurate or
- the IASI retrieval is not enough accurate.

We are interested in cases when the forecast is not enough accurate.

↓

We have to improve the quality of the IASI retrieval. Merging IASI profiles with surface measurements improves the quality of the IASI retrieval.

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Summary

IASI retrieval reflect the impact the **actual cloudiness**, while the forecasted cloudiness may differ from the real one (which impact the forecasted profile shape).

Merging IASI profiles with surface measurements make possible to retrieve more accurate surface based instability indices, like SBCAPE, MUCAPE, Best lifted index.

With IRS data one will able to see the temporal tendencies of humidity content and instability.

IASI profiles can show thermal inversion.

IASI L2 (IR+MW) and IR-only retrievals may differ even in cloud-free situation. However, their structures are similar .

The IR-only retrieval uncertainties are much higher in case of thick mid/high level clouds. In this case even the T profiles may differ considerably inside the opaque cloud.

Wind shear information is very important for monitoring convective environment. IRS data will include 3D wind information. Will it be enough accurate to derive wind shear?

More investigations, tests are needed, for example on the usefulness of the merged data.

Suggestions

- We found only **few cases** when IASI data had **„added value”** to the ECMWF forecast.
  → It is practical to use a **pre-sorting program** to find the potentially interesting cases with considerable differences between IASI derived and forecasted environmental parameter fields.

- Draw attention to the importance to take into account the **vertically averaged errors.**

- One has to take into account the main characteristics, benefits, limitations of IASI data.
  Some limitations:
  - IASI profiles are smoothed profiles.
  - higher uncertainty close to the surface.
  - IASI profile may not show the frontal characteristics.
  - IASI data often underestimate MLCAPE in convective situations (compared to the forecasted values), because it reflects less the humidity distribution within the mixed layer.
  - It might be not reasonable to calculate those parameters for which good vertical resolution and accurate values are needed. For example to calculate a reliable CIN (convective inhibition) value information needed only from the lowest layer but accurate T, Td values with good vertical resolution.

- It is worth to use IASI retrieval together with numerical forecasts and radiosonde measurements, as supplementary data.

Suggestions (cont.)

In case of **visual applications:**

- Consider to **cut Td to T in case it is higher.**

- It might be useful to **visualize the uncertainty of the profiles**. (It would be even better if we had vertical distribution of the error not only the vertically averaged value.)

- We suggest to **mask the non-reliable pixels**.
  - In case of IR+MW data:
    - Pixels with large vertically averaged error
  - In case of IR-only data:
    - Pixels with large vertically averaged error
    - Large absolute value of OMC
    - Pixels covered by mid- or high-level opaque clouds, (taking into account the Cloud Type classes)

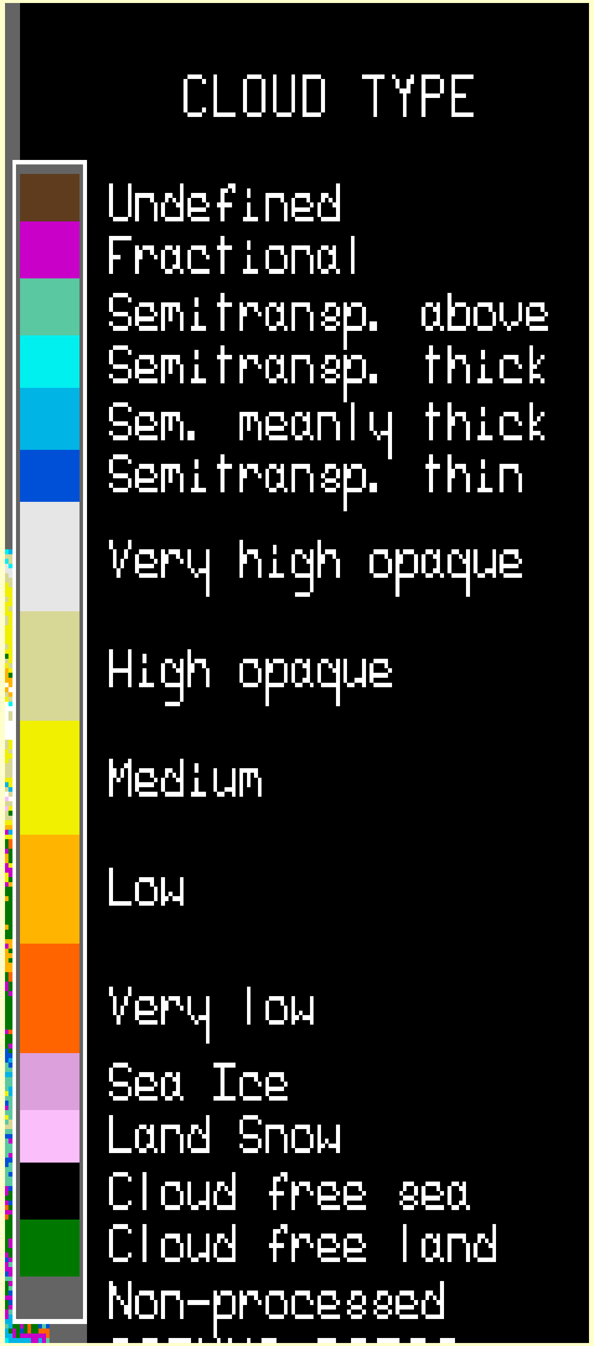
Remark:

- For an **automatic application** it might be not so important to **mask** the less reliable IASI pixels, in case quality flags (error values), Cloud Type and Cloud Top Pressure products are available and a description/recommendation how to take them into account.
- In case of **visual application masking** is more important (forecasters have limited time, and they had to process visually a lot of different kinds of information).

Thank you for the attention!

Spare slides

Colour scale of the NWCSAF Cloud Type product



Lifted Index

$LI = T^{obs} - T^{\text{lifted from surface}}$ at 500 hPa

where:

T^{obs}	is the observed temperature

K Index

$KI = (T^{obs}(850) - T^{obs}(500)) + TD^{obs}(850) - (T^{obs}(700) - TD^{obs}(700))$

where:

$T^{obs}(x)$	is the observed temperature at x hPa height
$TD^{obs}(x)$	is the observed dew point temperature at x hPa height.

KO Index

$KO = 0.5 * (\Theta_e^{obs}(500) + \Theta_e^{obs}(700) - \Theta_e^{obs}(850) - \Theta_e^{obs}(1000))$

where:

$\Theta_e^{obs}(x)$	is the observed equivalent potential temperature at x hPa height.

Maximum Buoyancy

$MB = \Theta_e^{obs}$(maximum between surface and 850) – Θ_e^{obs}(minimum between 700 and 300)

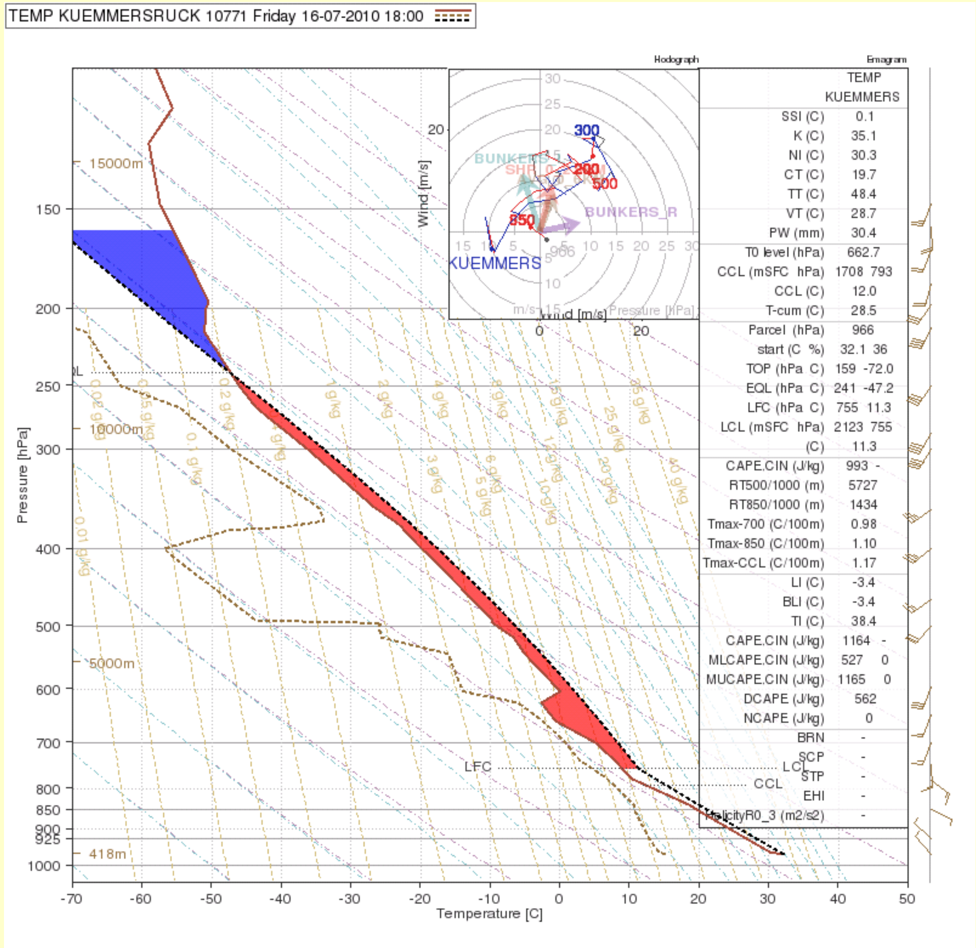
where:

Θ_e^{obs}	is the observed equivalent potential temperature

Precipitable Water

$$W = \frac{1}{g}\int_{surface}^{0} q(p)dp$$

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



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.

$$CAPE = -R_d \int_{p1}^{p2} (T_{v,parcel} - T_{v,env})\, d \ln p,$$

$$\text{if } T_{v,parcel} > T_{v,env}$$

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. The forecasters use them together.
The 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)

- LCL lifted condensation level
- LFC level os free convection
- CCL convective condensation level

LCL Lifted Condensation Level (where it becomes saturated)

EL equilibrium level (EL, neutral buoyancy),

Convective Inhibition (CIN): Convective inhibition is a numerical measure that indicates the amount of energy that prevents an air parcel from rising from the surface to the level of free convection.

About the „pre-sorting” program

running operationally since 2018

It calculates the number of the IASI pixels with considerable difference between some ECMWF and satellite derived parameters:

- **on moist and unstable areas,**
- **on moist and unstable cloud-free areas.**

Such a program would be very useful for forecaster to draw their attention when to focus on IASI derived profiles. (Forecasters have limited time.)