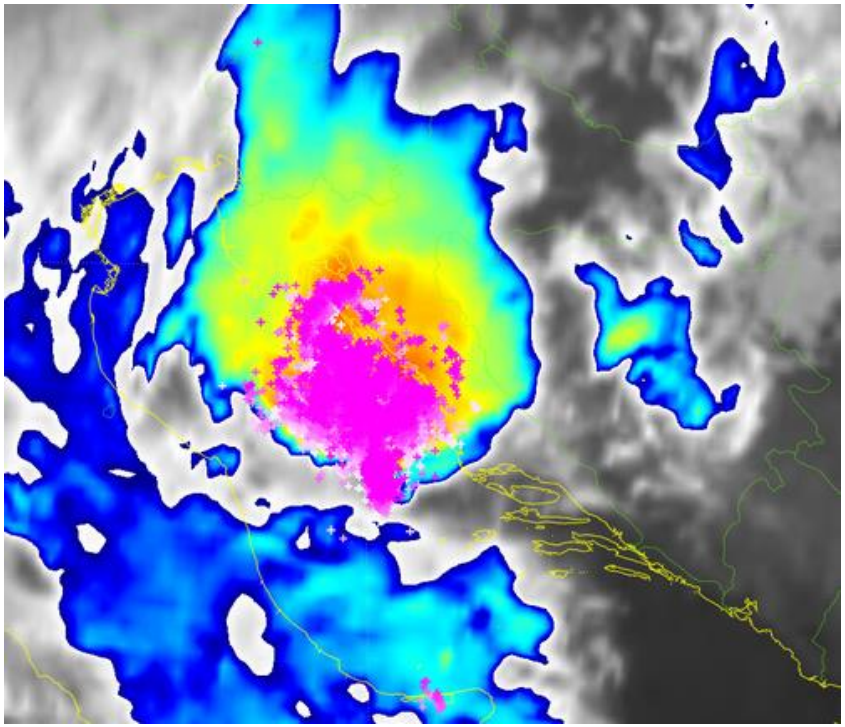
Forecasting and Nowcasting Deep Moist Convection



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Lecture overview

- Convection forecasting process in general
- Diagnosis (satellite products)
- Trend methods
- Ingredients for DMC
- The role of the synoptic scale
- Monitoring and nowcasting DMC

FORECAST = DIAGNOSIS + TREND

- DIAGNOSIS = What is happening (ANALYSIS) **and why**?

- Determine dominant mechanisms and the scale on which they operate

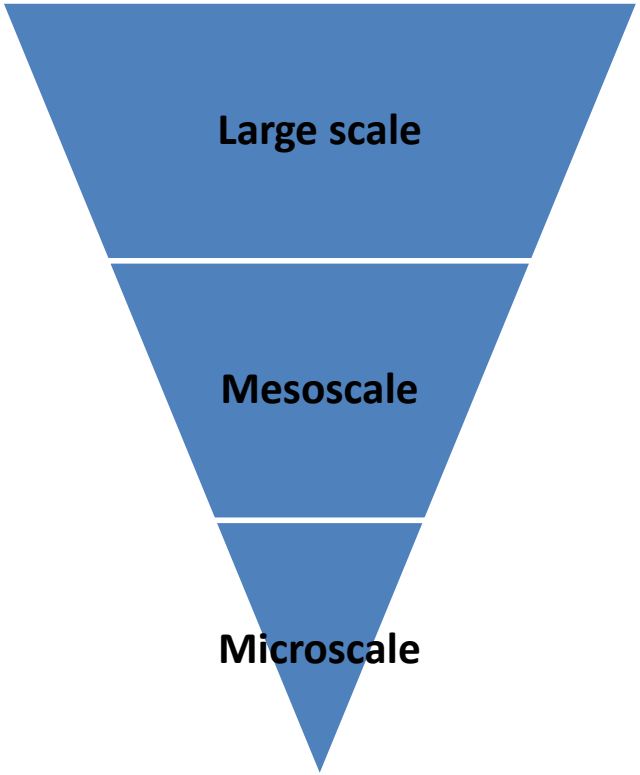
- **Where is the energy?**

How to do diagnosis?

- Quasigeostrophic forcing (**PVA**, **WA**, **Q**-vectors)

- Frontogenesis

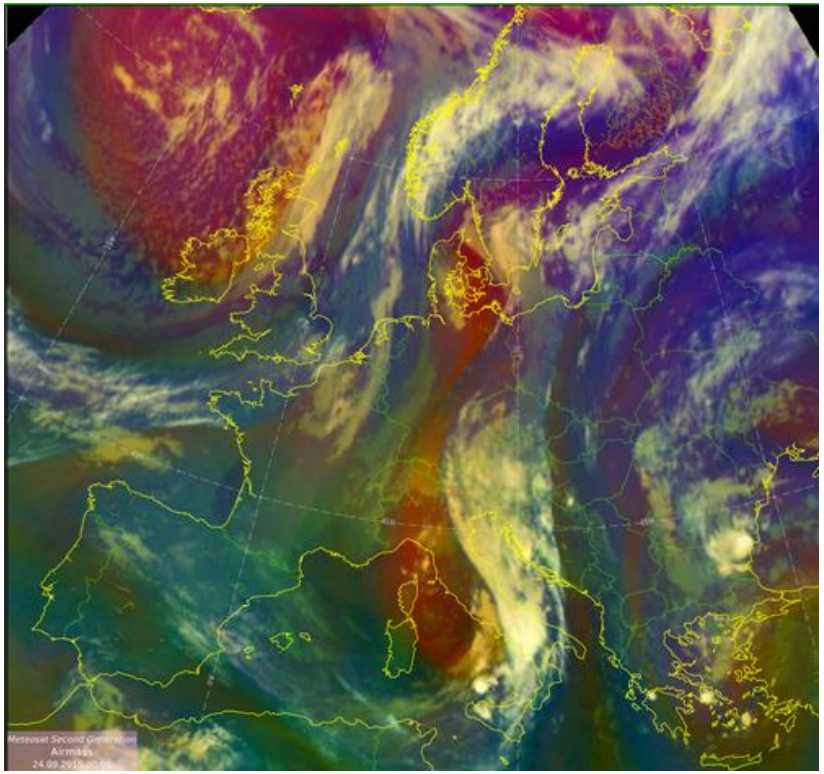
- Mesoscale processes (convergence, orography…)



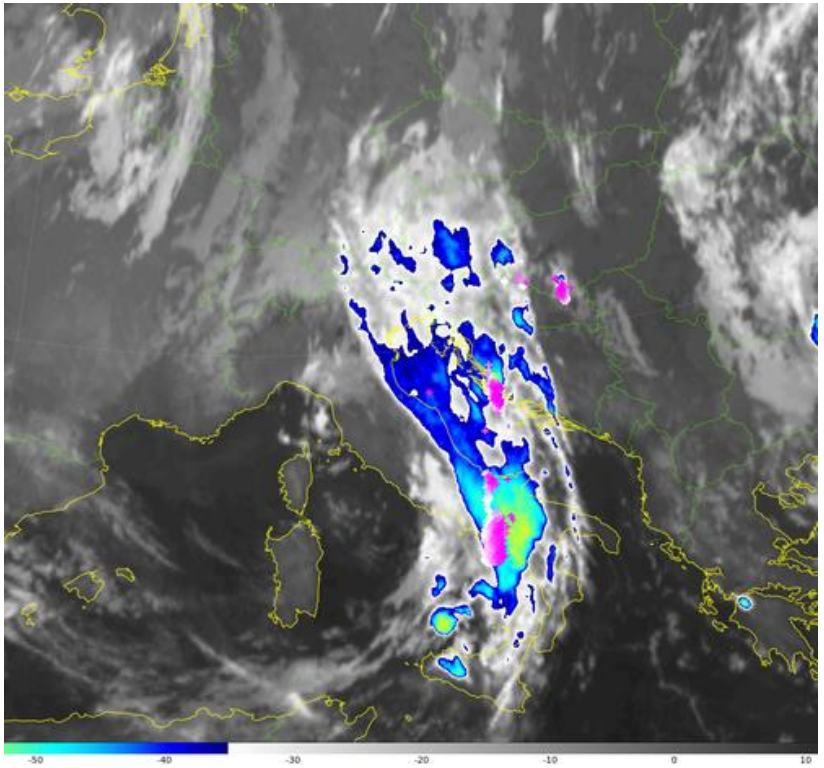
The forecast funnel, after Snellman 1982

The use of sat products in diagnosis

Airmass RGB

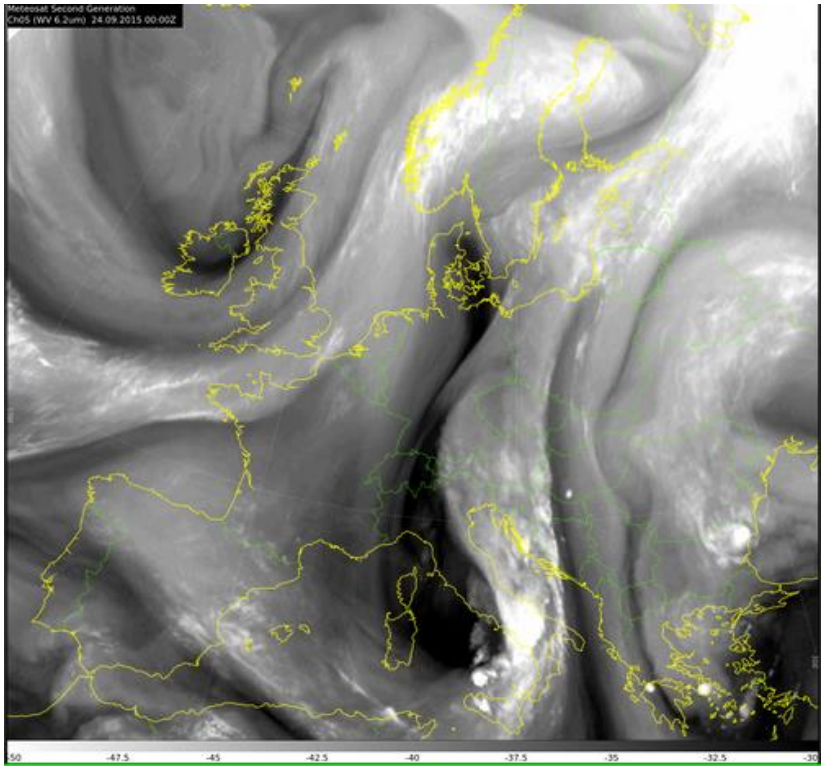


IR 10.8 + lightning detection

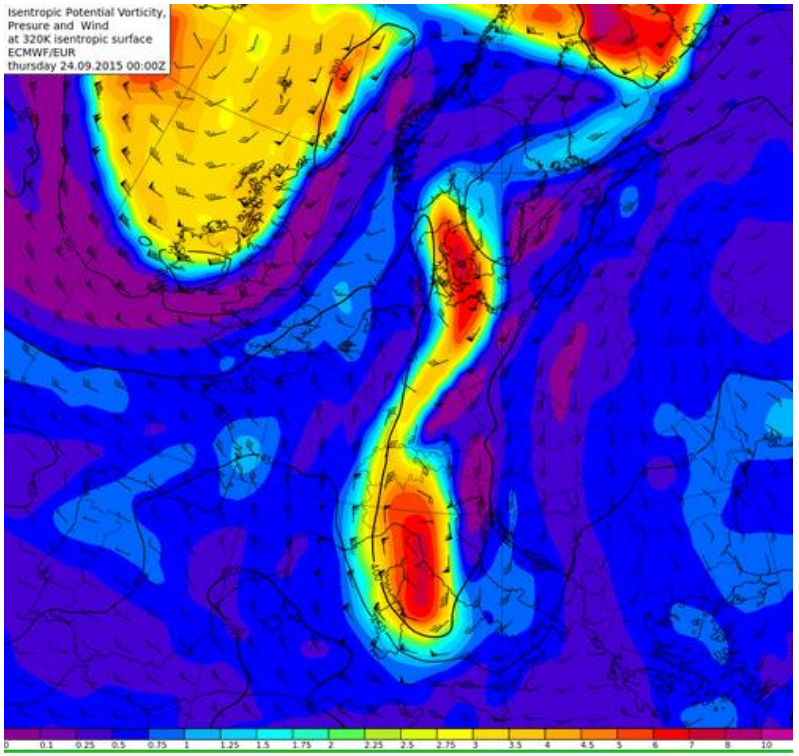


The use of sat products in diagnosis

WV 6.2 µm

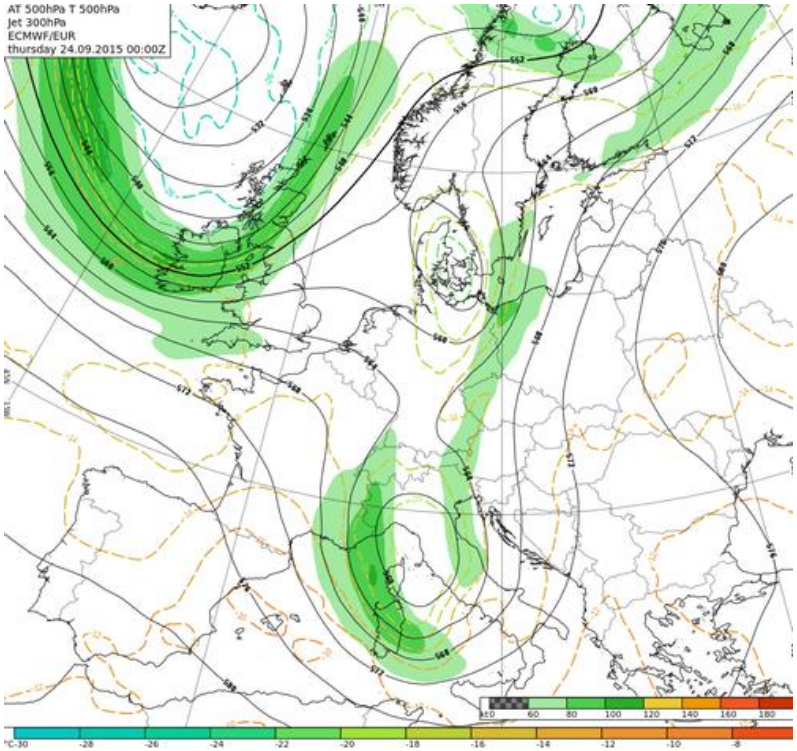


IPV 320K

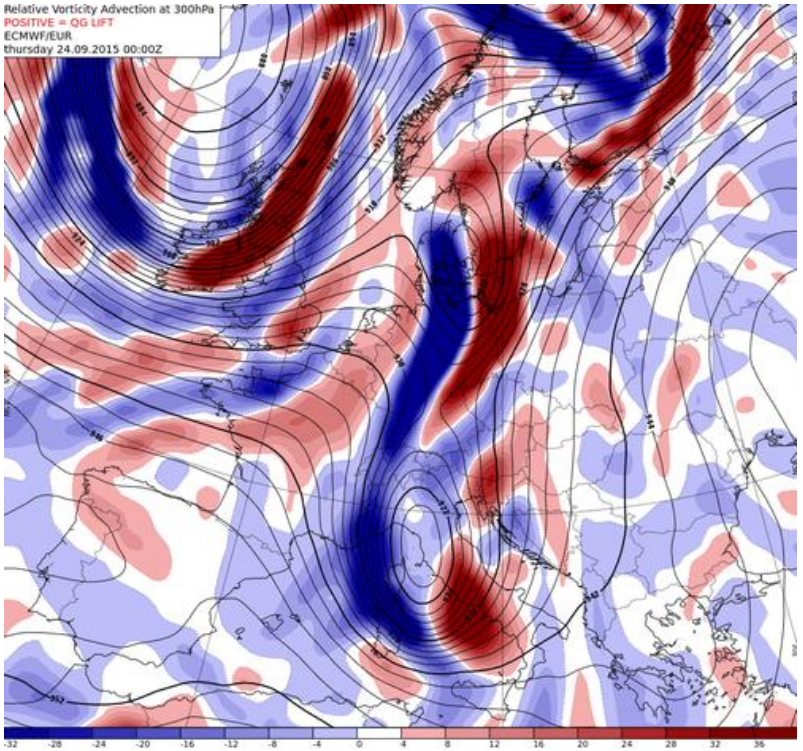


The use of sat products in diagnosis

AT 500 + jet 300hPa

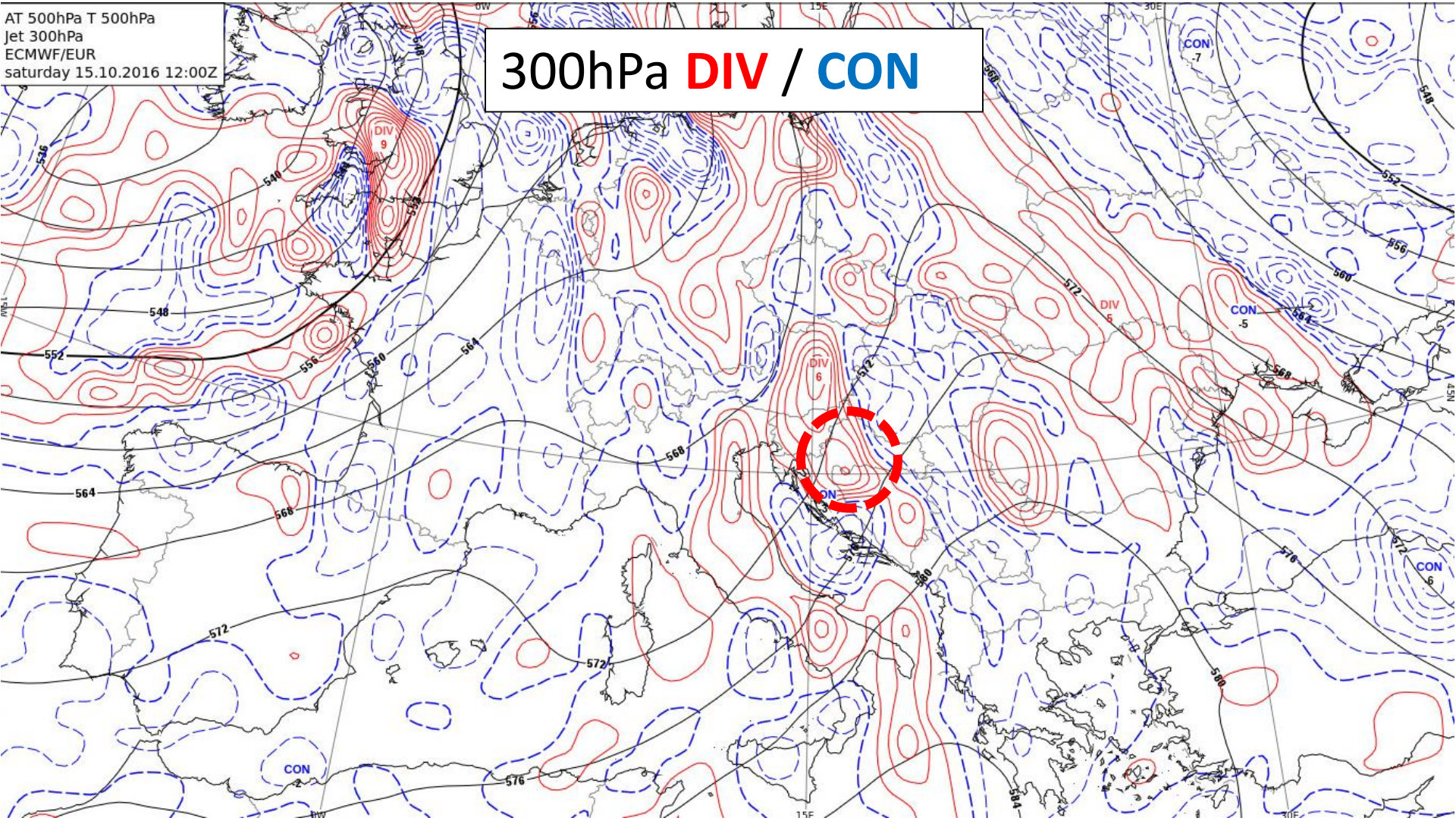


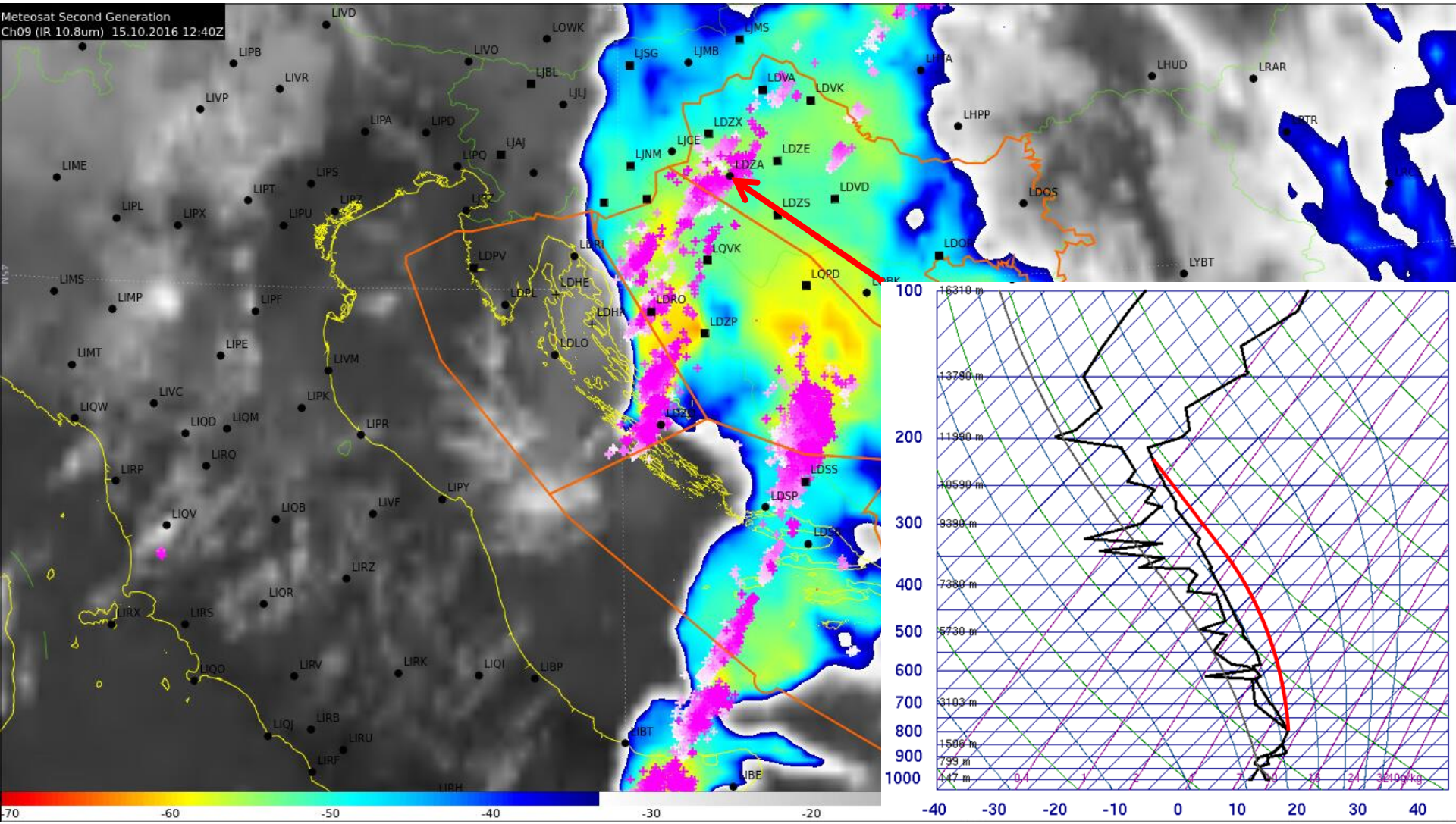
Relative vort. advection at 500hPa



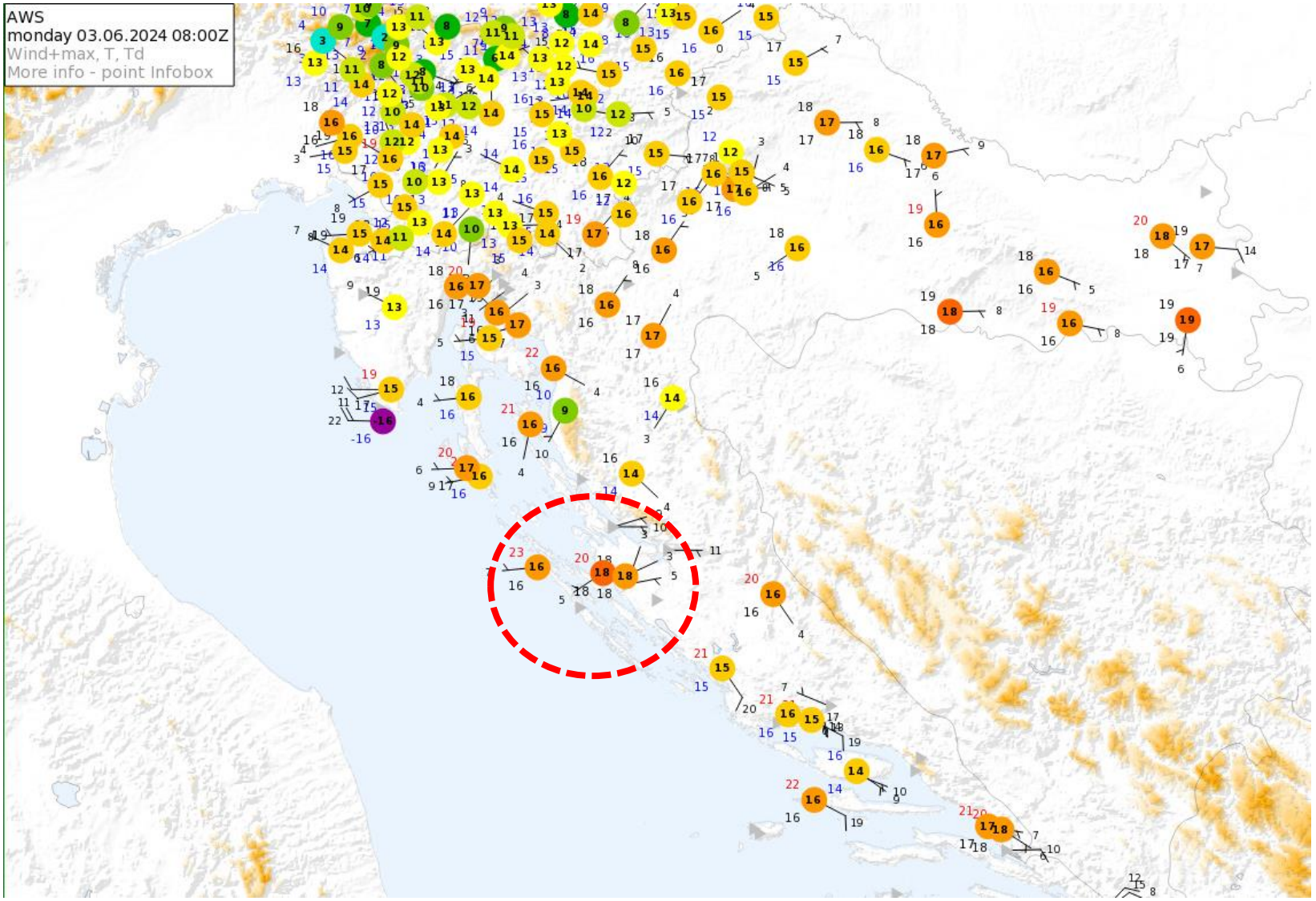
Positive vorticity advection (PVA) = LIFT *(most of the time)*

Divergence in upper levels

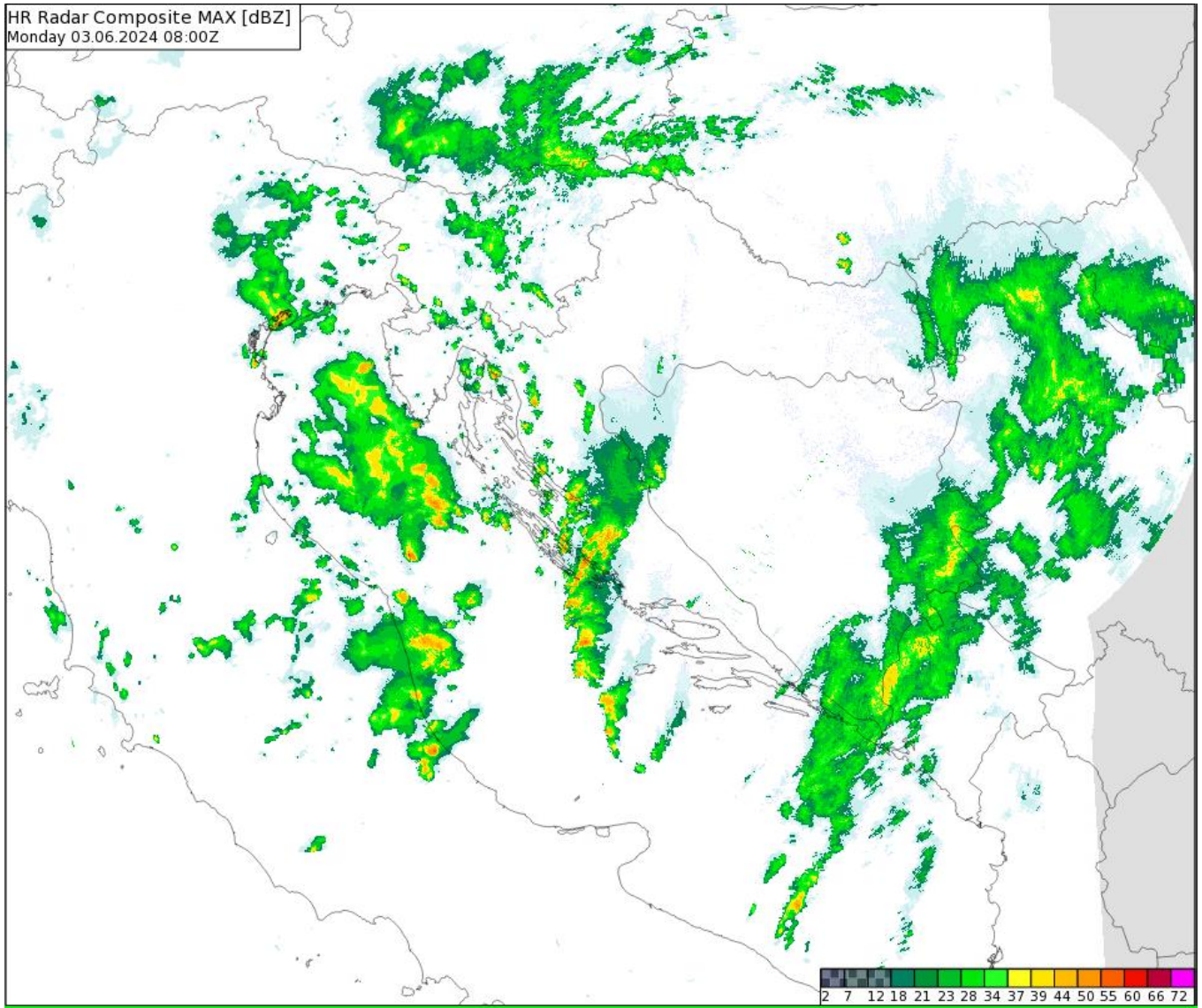


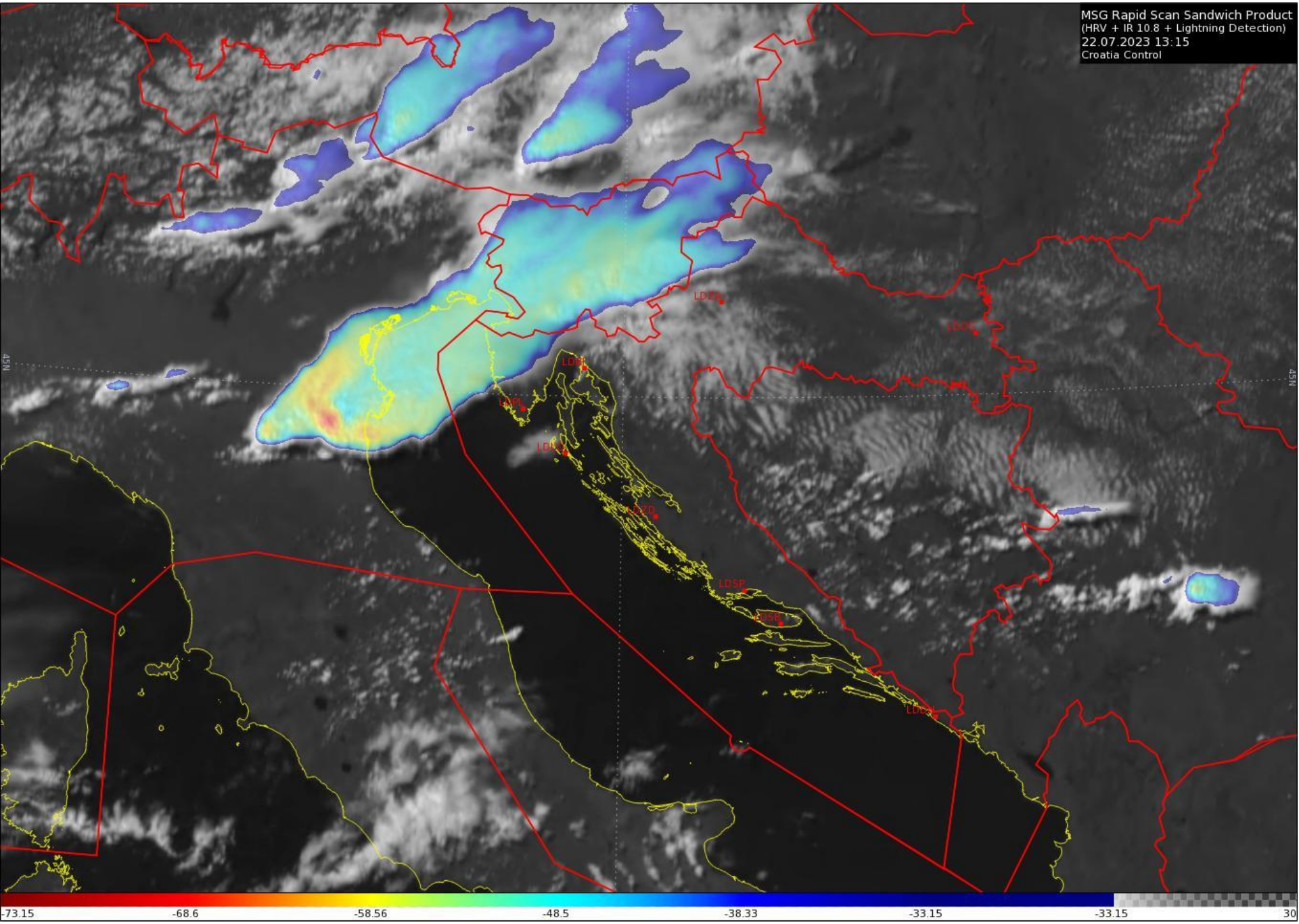

Meteosat Second Generation
Ch09 (IR 10.8um) 15.10.2016 12:40Z
LIVD
LOWK
LIPB
LIVO
LIVR
LJBL
LJLJ
LIVP
LIPA
LIPD
LJAJ
LIPQ
LIME
LIPS
LIPT
LIPZ
LIPL
LIPX
LIPU
LJMS
LJSG
LJMB
LDVA
LDVK
LDZX
LJCE
LJNM
LDZE
LDZA
LDVD
LDZS
LHTA
LHUD
LRAR
LHPP
LDOS
LYBT
LDPV
LDRI
LQVK
LQPD
LIMS
LIMP
LIPF
LDHE
LDPL
LDRO
LDHA
LDZP
LDLO
LIMT
LIPE
LIVM
LIVC
LIPK
LIQW
LIQD
LIQM
LIPR
LIRQ
LIRP
LDSS
LDSP
LIPY
LIQV
LIQB
LIVF
LIRZ
LIQR
LIRX
LIRS
LIQQ
LIRV
LIRK
LIQI
LIBP
LIBT
LIQJ
LIRB
LIRU
LIRF
LIBE
LIRH
-70
-60
-50
-40
-30
-20
100
200
300
400
500
600
700
800
900
1000
16310 m
13790 m
11990 m
10590 m
9390 m
7380 m
5730 m
3103 m
1508 m
799 m
147 m
-40
-30
-20
-10
0
10
20
30
40

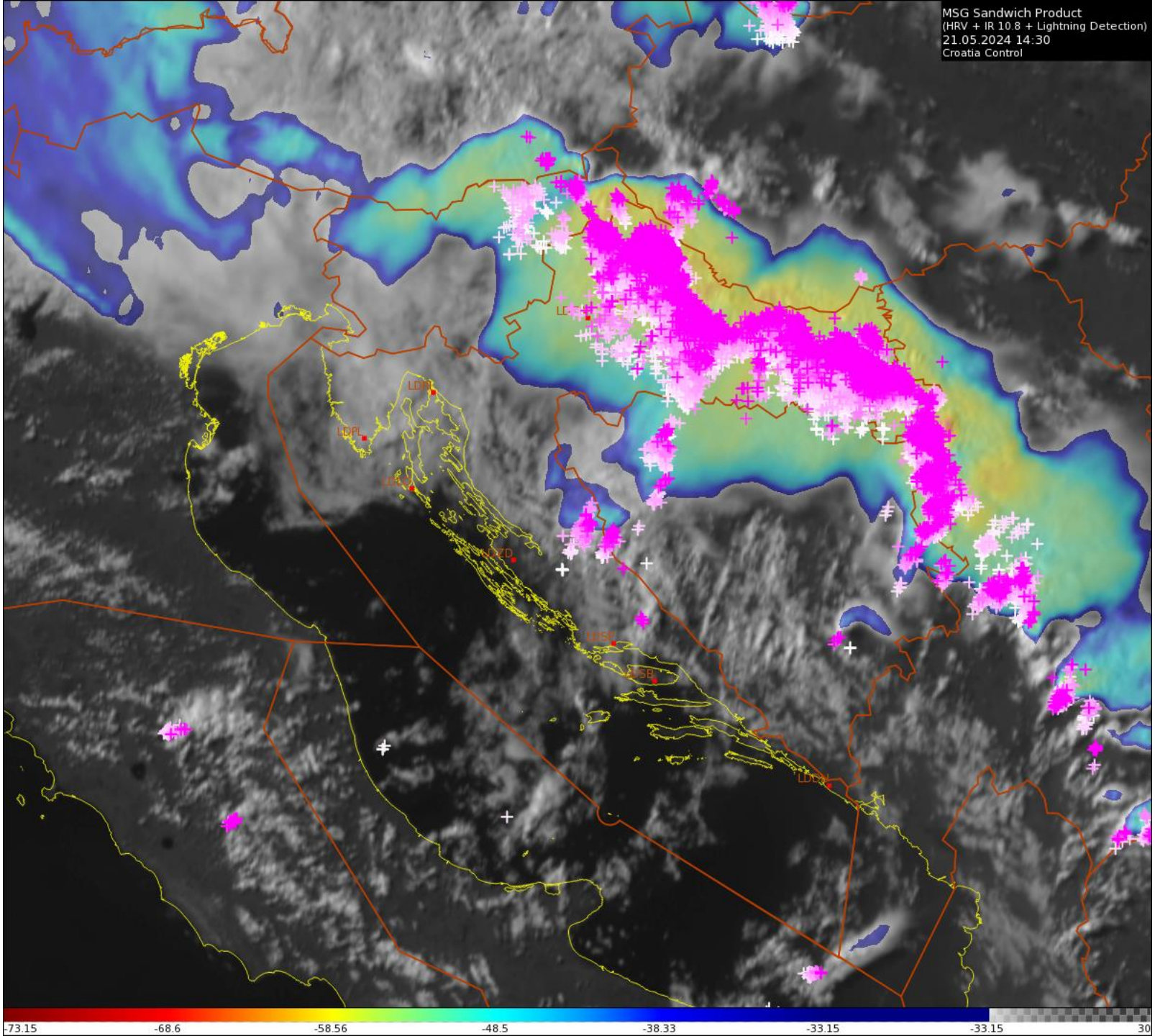
Mesoscale analysis / diagnosis



Radar products (ongoing DMC)




MSG Rapid Scan Sandwich Product
(HRV + IR 10.8 + Lightning Detection)
22.07.2023 13:15
Croatia Control
LDZA
LDDU
LDPL
LDZD
LDSP
LDSB
LDDC
45N
-73.15
-68.6
-58.56
-48.5
-38.33
-33.15
-33.15
30


MSG Sandwich Product
(HRV + IR 10.8 + Lightning Detection)
21.05.2024 14:30
Croatia Control
LDPL
LDZD
LDSB
-73.15
-68.6
-58.56
-48.5
-38.33
-33.15
-33.15
30

Analysis and diagnosis overview

- RGB Airmass (air masses and their boundaries)
- SAT VW 6.2um (diagnose with IPV 320K map)
- IR + lightning (convectively active areas)
- HRV (convergence lines – initiation, active areas)
- Radar (if there is DMC – convective mode diagnosis)
- SFC OBS (AWS, METAR, SYNOP – **watch T & Td**, **wind convergence, compare with NWP)**
- AT500hPa Jet 300-200hPa (geopotential, temp. advection, jet streams and jet streaks)
- Divergence at 300hPa (if needed check also 200hPa)
- Relative Vorticity Advection 500hPa (PVA = synoptic lift)
- Isentropic Potential Vorticity, Pressure and Wind at 320K (upper-level anomalies and lift in front of them = destabilisation)
- AT850 i T850 (temperature advection)
- Thermal front parameter - TFP (frontogenesis and fronts)
- Theta-e and MSLP (air masses, fronts, moist and warm areas) – compare with RGB airmass and other SAT images (is NWP on track with what is happening? Is it late or early?)

FORECAST = DIAGNOSIS + TREND

TREND = What will happen and why?

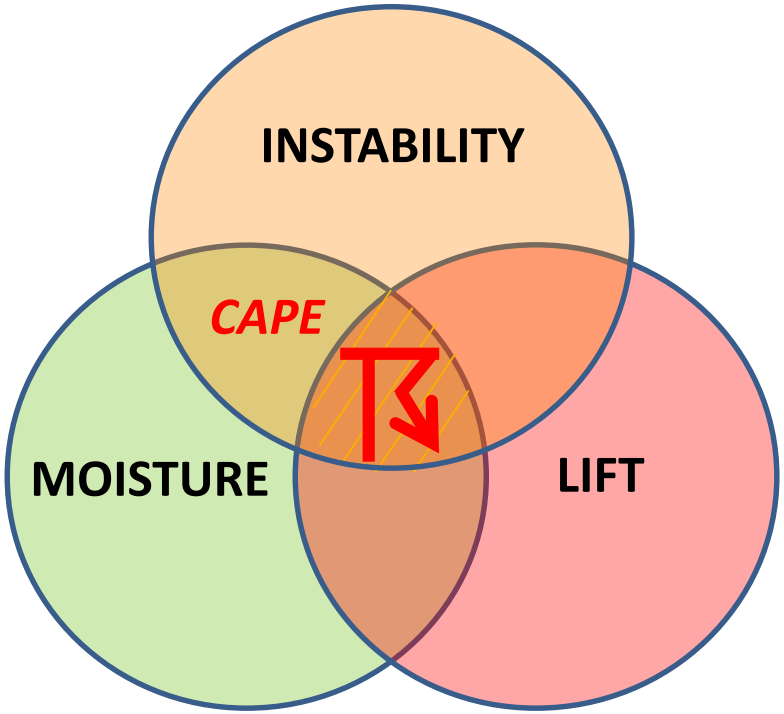
1. Extrapolation / persistence (flow continuity)
2. Climatology
3. Pattern recognition (**conceptual models**)
4. **Ingredient evaluation**
5. **NWP guidance**

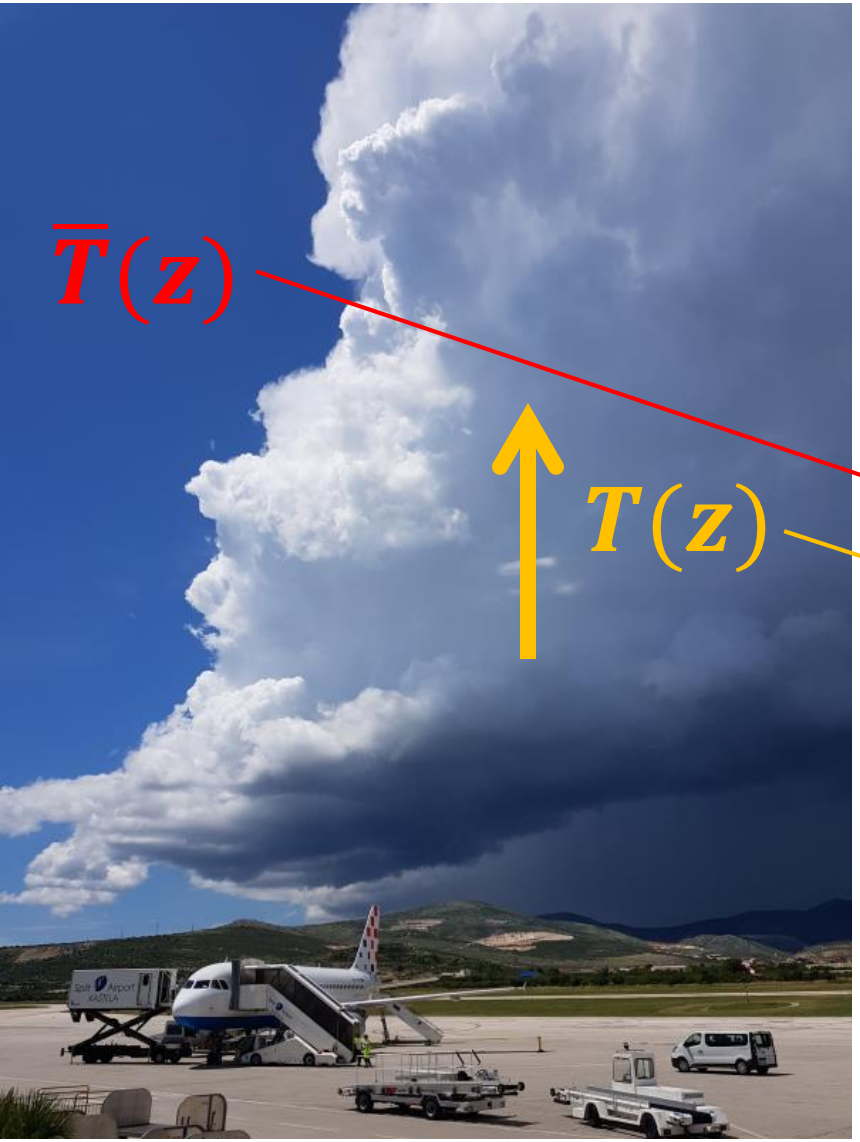
Adapted from Doswell 1986; Moller 2001

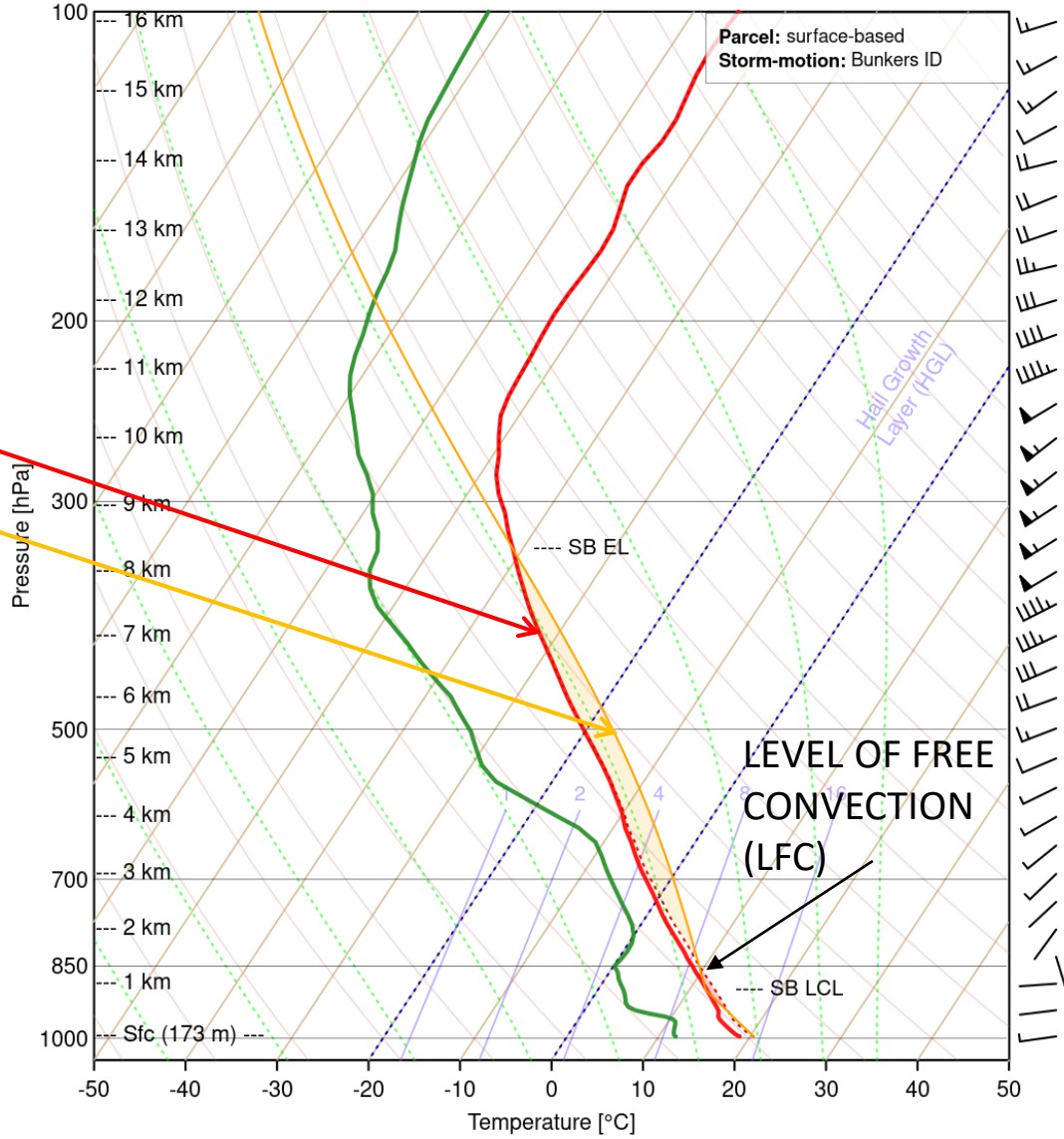
Ingredients for deep moist convection

1. **Instability** (steep lapse rates)
2. **Moisture** (lower troposphere)
3. **Lift** (process lifting air to LFC)

} **CAPE**




$\overline{T}(z)$
$T(z)$


Parcel: surface-based
Storm-motion: Bunkers ID
Pressure [hPa]
Temperature [°C]
100
200
300
500
700
850
1000
--- 16 km
--- 15 km
--- 14 km
--- 13 km
--- 12 km
--- 11 km
--- 10 km
--- 9 km
--- 8 km
--- 7 km
--- 6 km
--- 5 km
--- 4 km
--- 3 km
--- 2 km
--- 1 km
--- Sfc (173 m) ---
-50
-40
-30
-20
-10
0
10
20
30
40
50
---- SB EL
---- SB LCL
Hail Growth Layer (HGL)
LEVEL OF FREE CONVECTION (LFC)

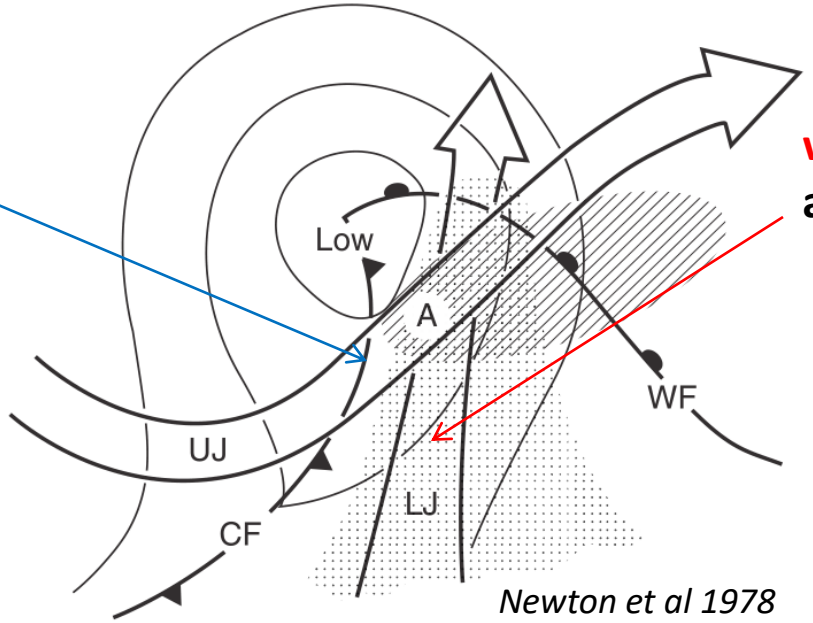
Synoptic scale and deep moist convection

- Synoptic-scale lift does not initiate storms directly
- ~ 1 cm/s => **42h** to reach 1500m LFC !
- **too slow** to lift air to **LFC** before it loses its buoyancy by mixing (heat and moisture loss)
- But...

Synoptic scale and deep moist convection

- Synoptic-scale circulations bring together necessary ingredients

Steep lapse rates advection, colder air in upper levels

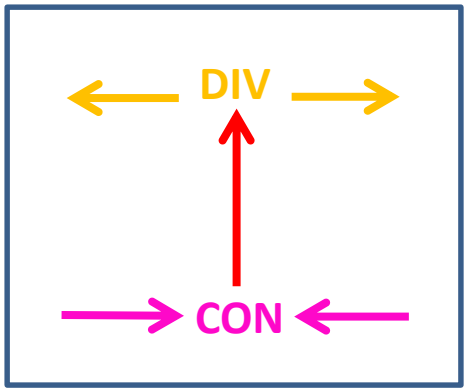


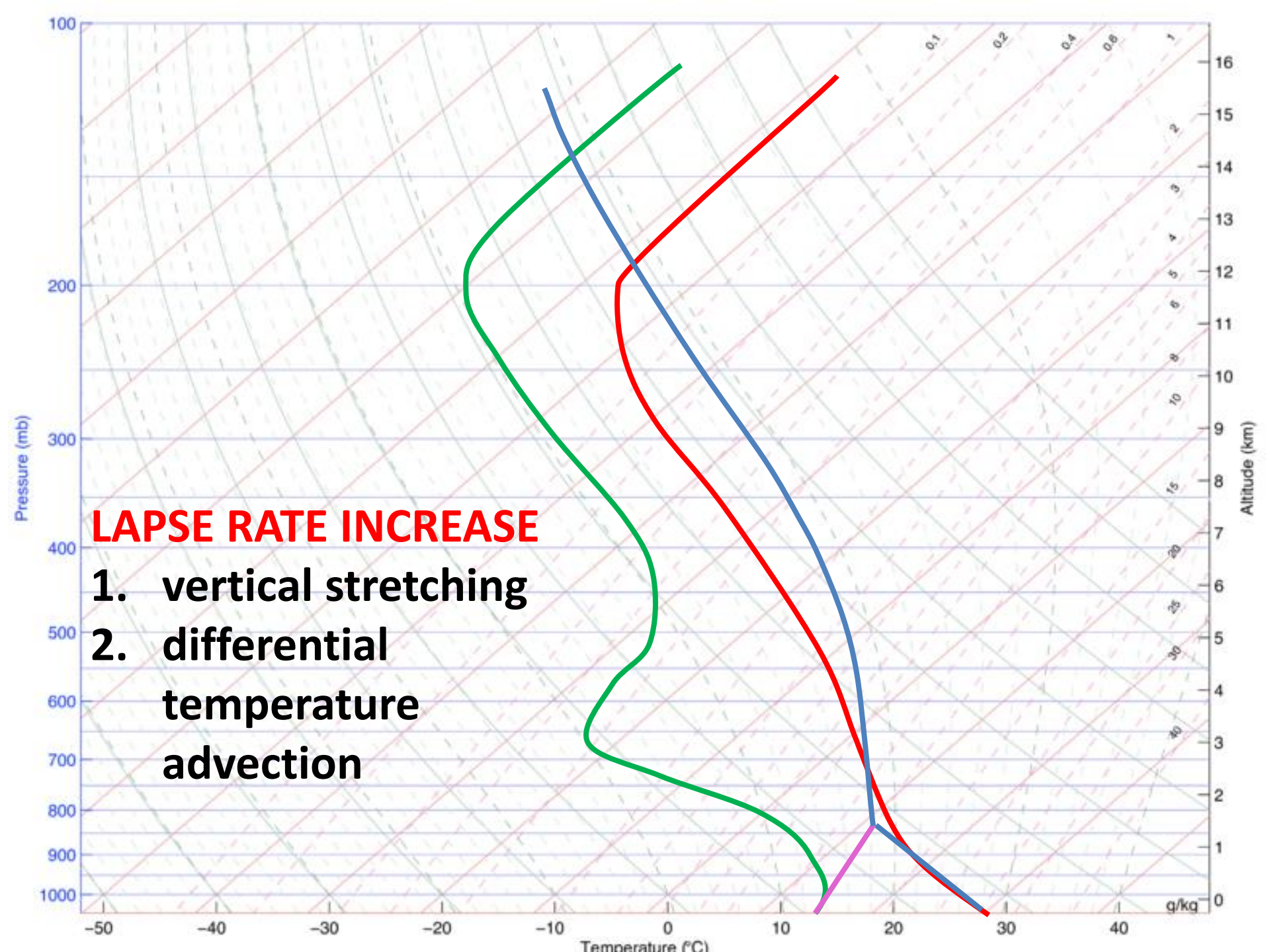
warm air and moisture advection in lower levels

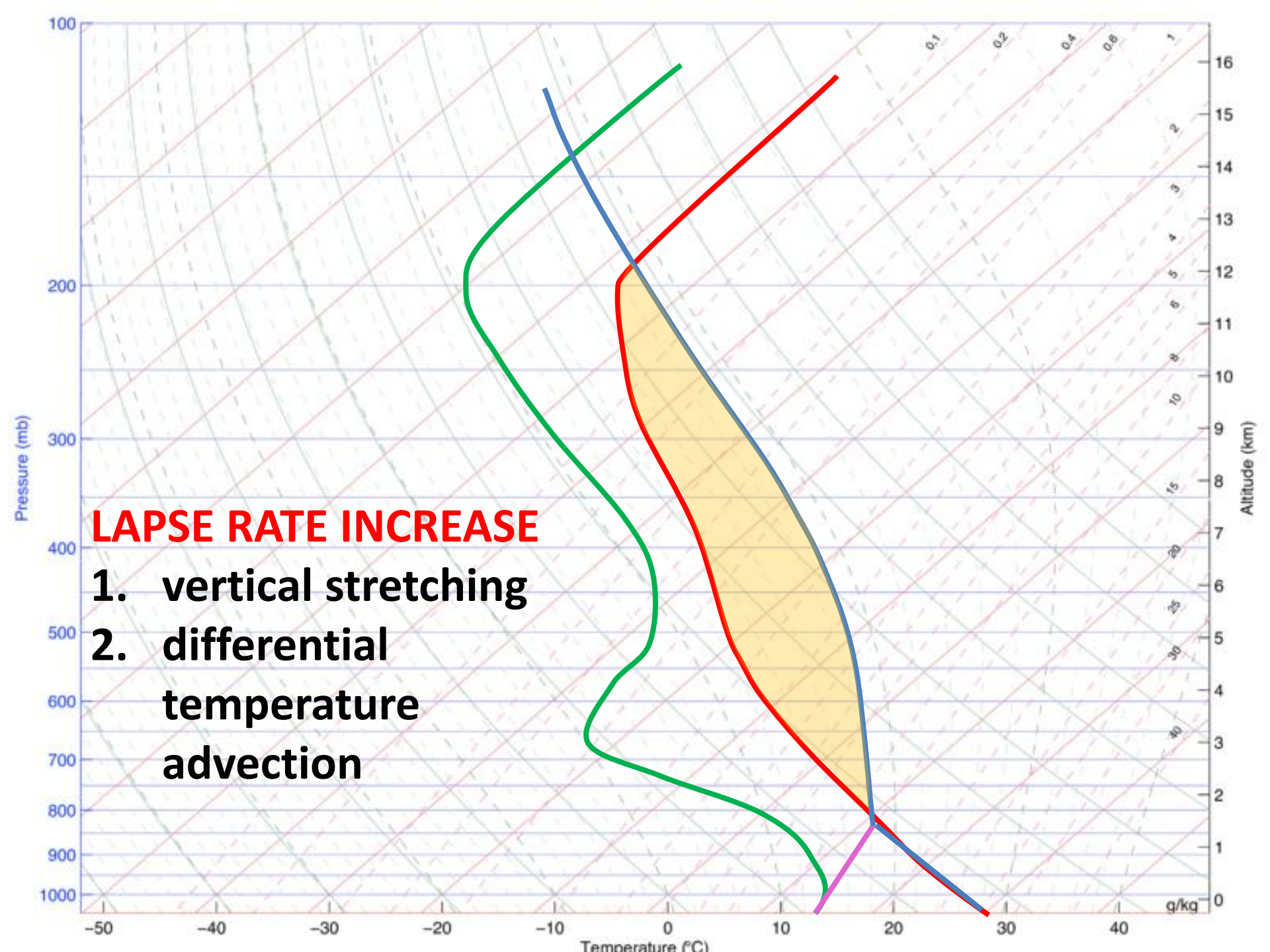
Newton et al 1978

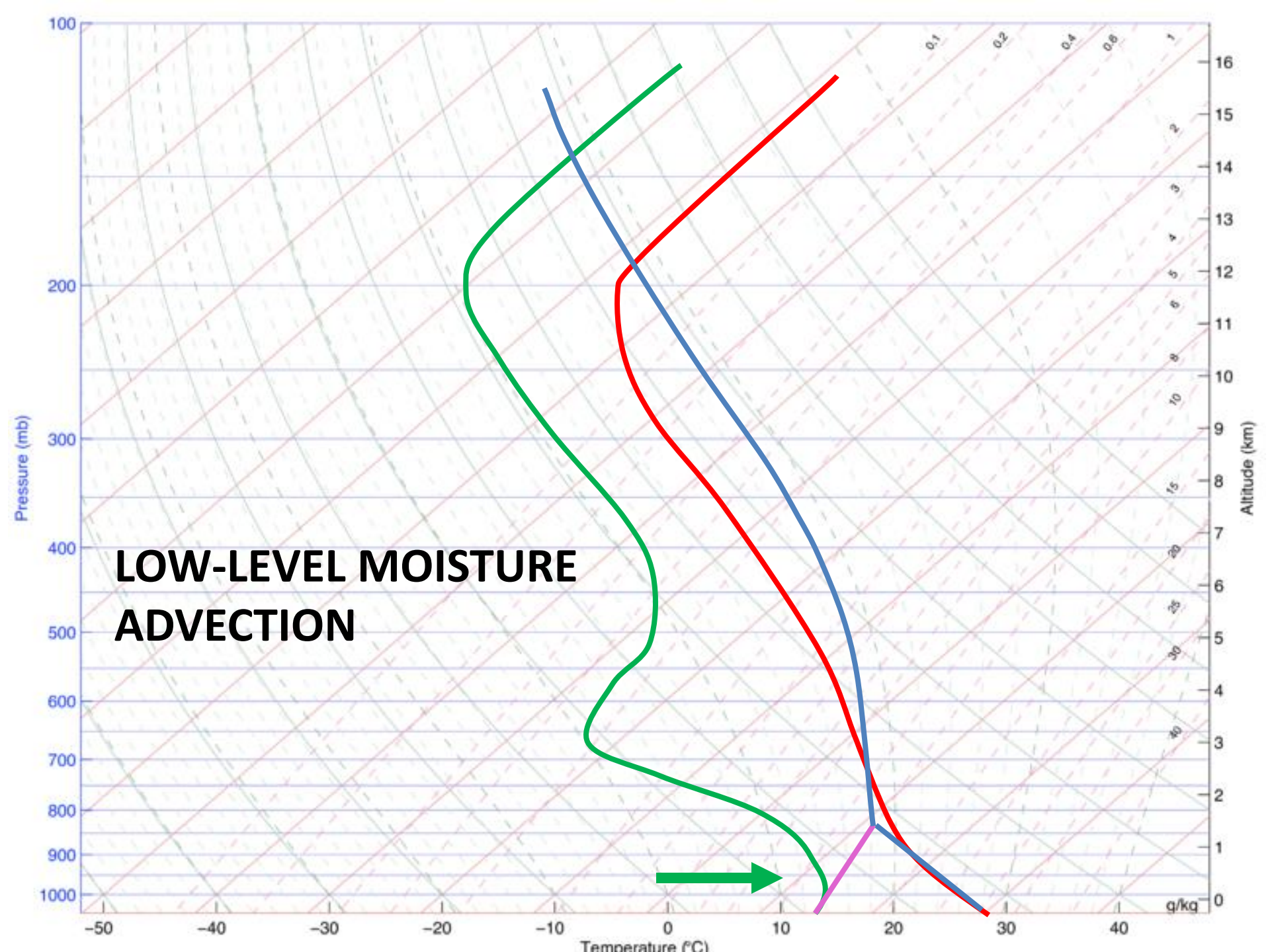
Synoptic scale and deep moist convection

- Synoptic-scale lift:
  - increases **instability** (lapse rates)
  - **moistens** the vertical profile
  - reduces stable layers (**CIN**)




LAPSE RATE INCREASE
1. vertical stretching
2. differential temperature advection
Pressure (mb)
Altitude (km)
Temperature (°C)
g/kg
100
200
300
400
500
600
700
800
900
1000
−50
−40
−30
−20
−10
0
10
20
30
40
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16


LAPSE RATE INCREASE
1. vertical stretching
2. differential temperature advection
Pressure (mb)
Altitude (km)
Temperature (°C)
g/kg


LOW-LEVEL MOISTURE ADVECTION
Pressure (mb)
Altitude (km)
Temperature (°C)
g/kg
100
200
300
400
500
600
700
800
900
1000
−50
−40
−30
−20
−10
0
10
20
30
40
0
1
2
3
4
5
6
7
8
9
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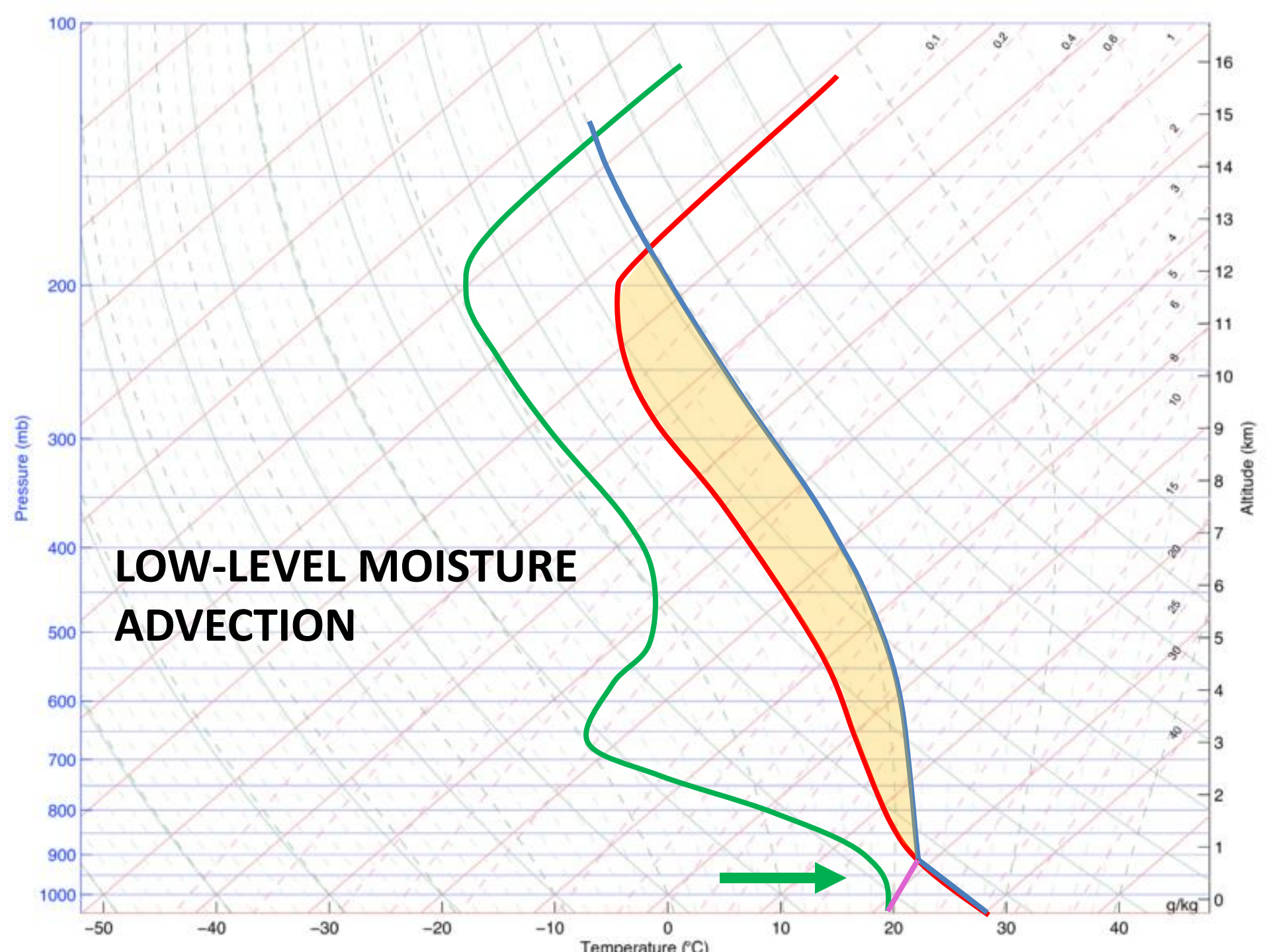
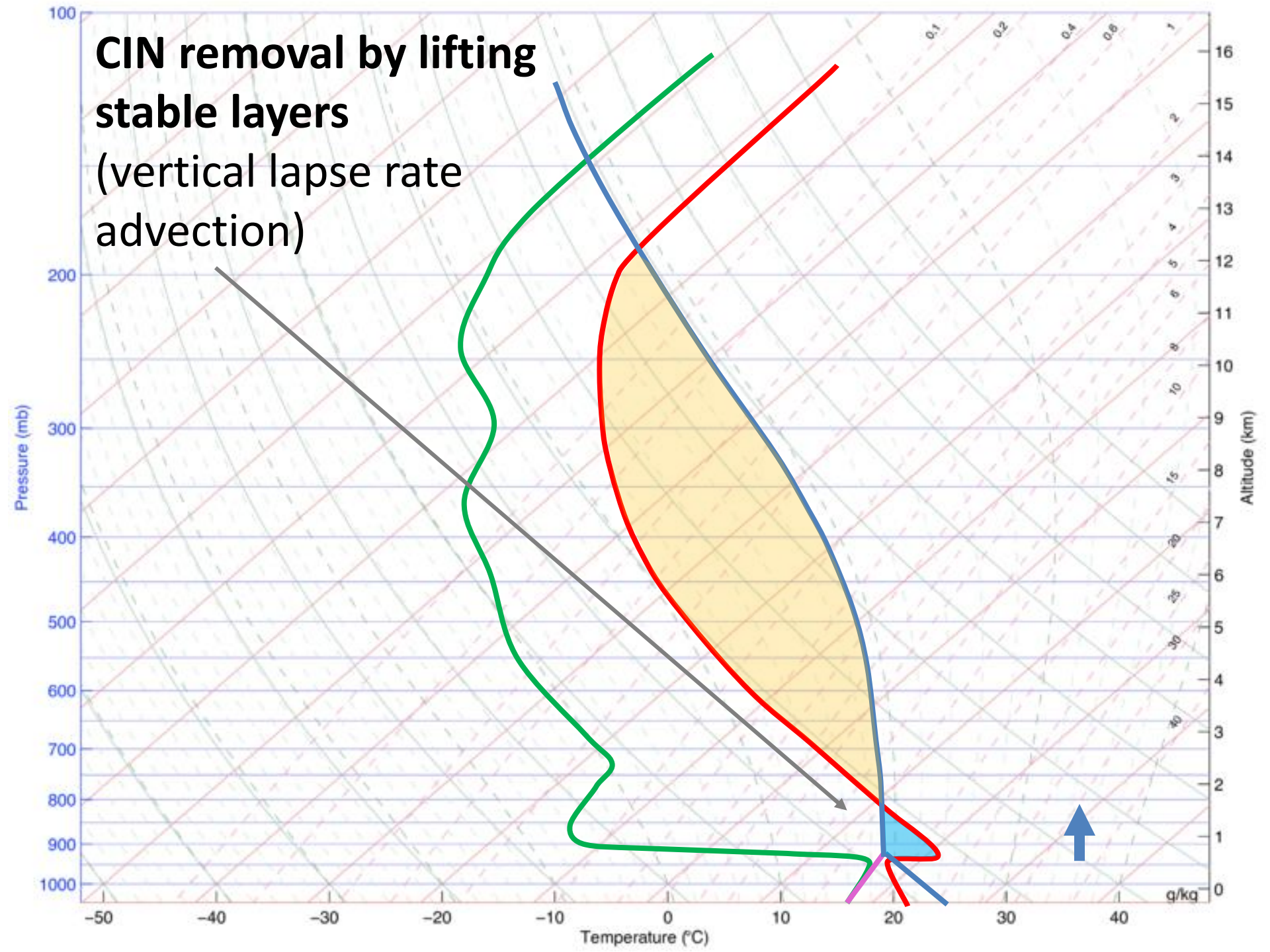
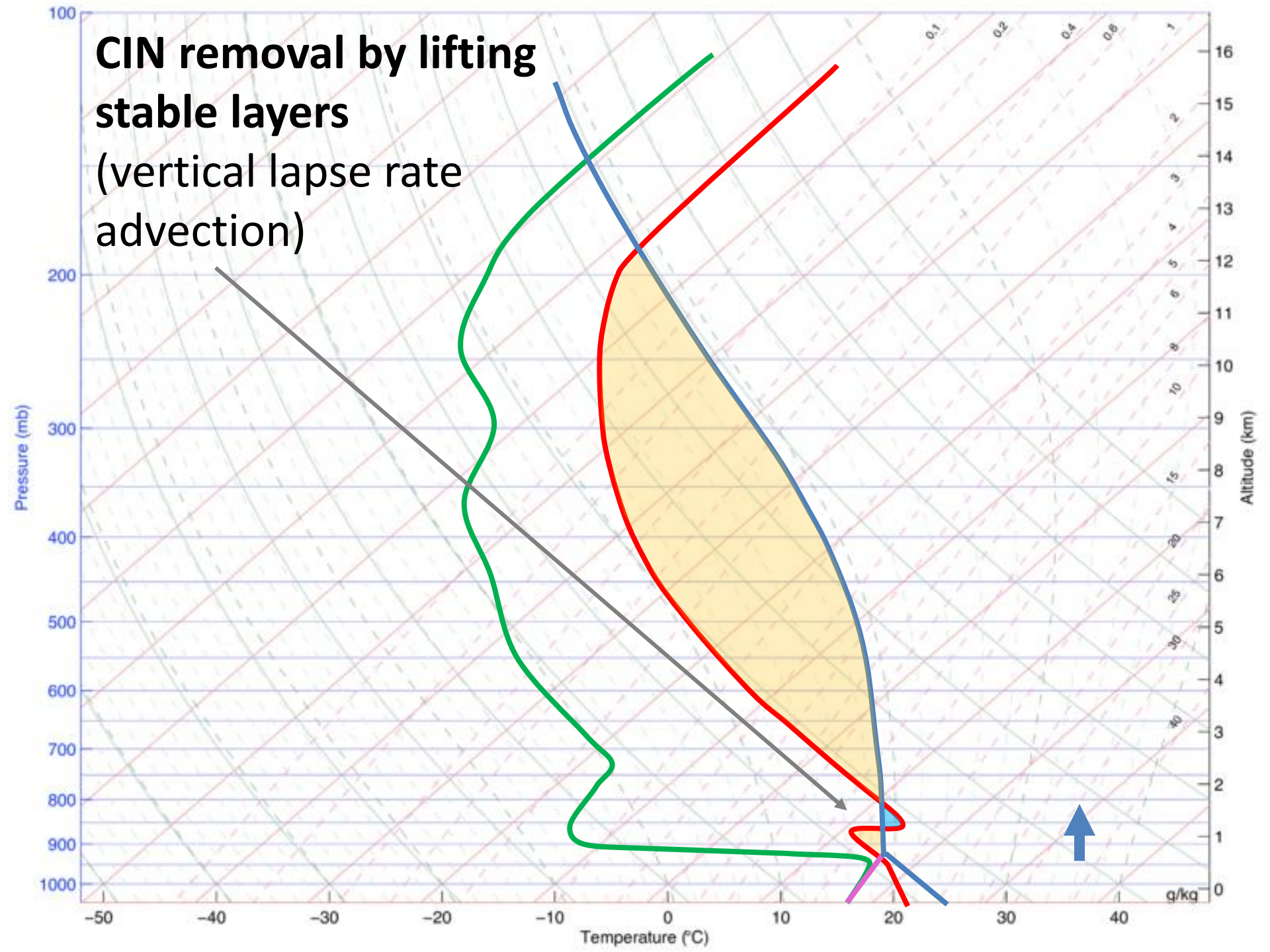
11
12
13
14
15
16


LOW-LEVEL MOISTURE ADVECTION
Pressure (mb)
Altitude (km)
Temperature (°C)
g/kg
100
200
300
400
500
600
700
800
900
1000
−50
−40
−30
−20
−10
0
10
20
30
40
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

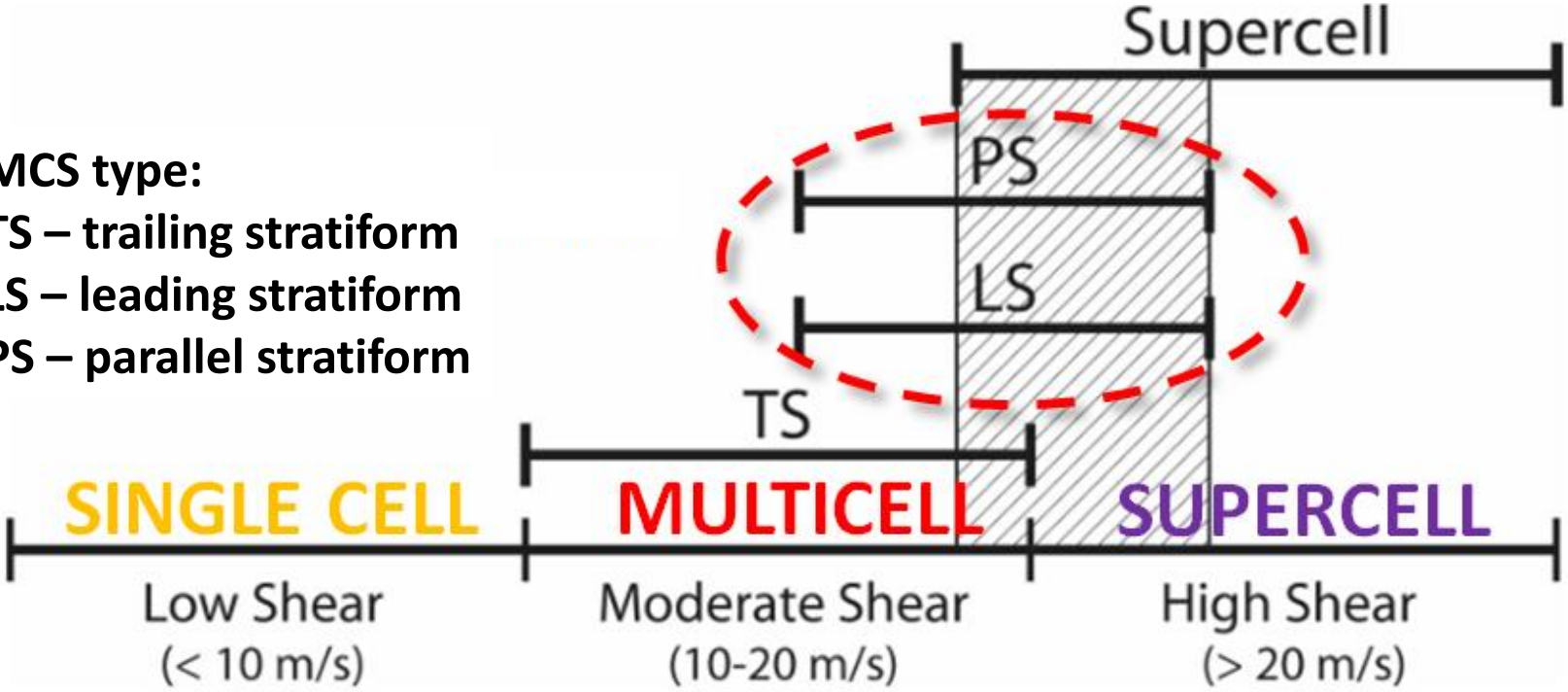

CIN removal by lifting stable layers
(vertical lapse rate advection)
Pressure (mb)
Altitude (km)
Temperature (°C)
g/kg


CIN removal by lifting stable layers
(vertical lapse rate advection)
Pressure (mb)
Altitude (km)
Temperature (°C)
g/kg

Deep layer shear (DLS)

DLS (bulk shear 0–6 km) statistics vs. storm type:

MCS type:
TS – trailing stratiform
LS – leading stratiform
PS – parallel stratiform

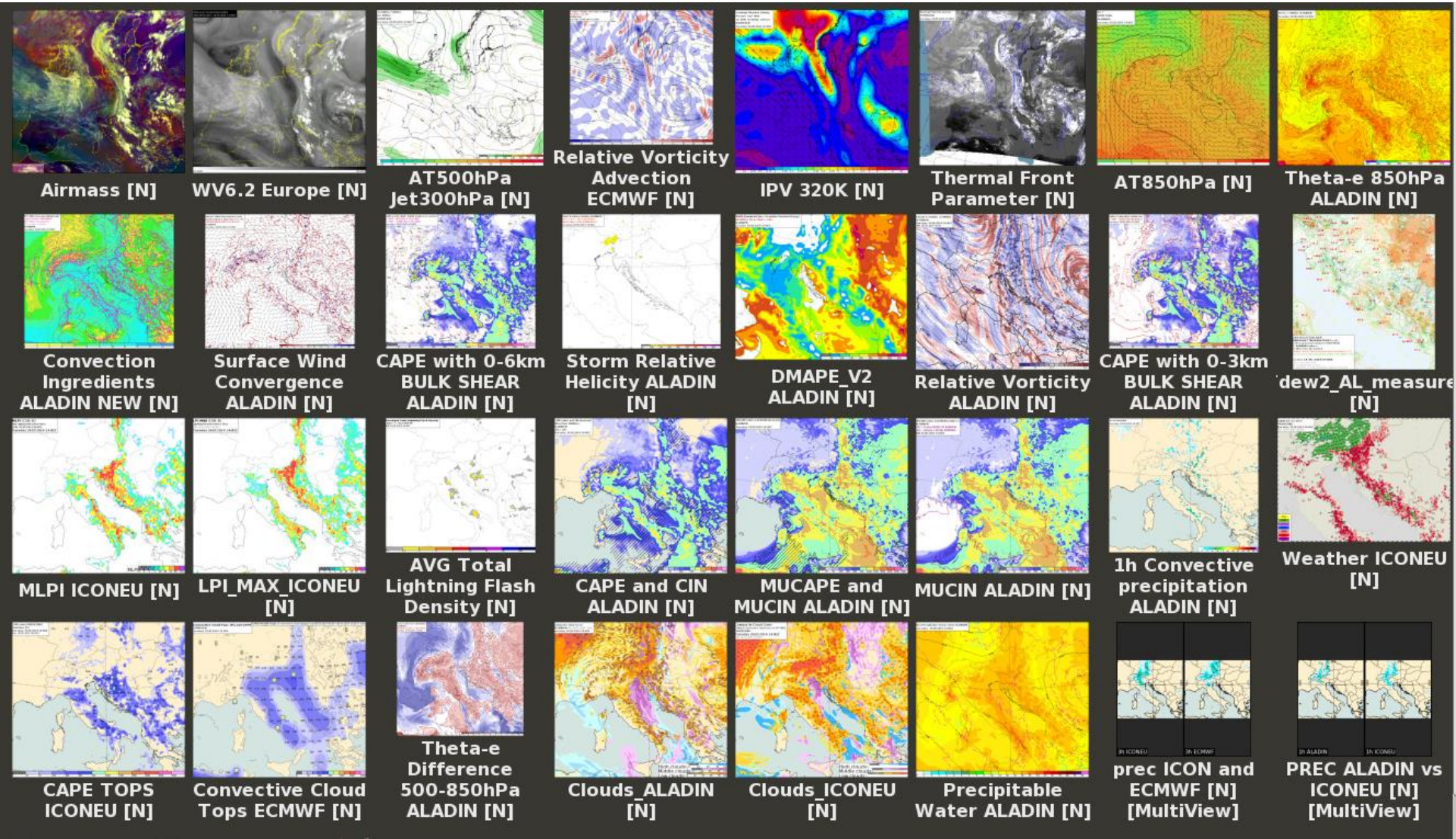


Adapted from French and Parker 2008

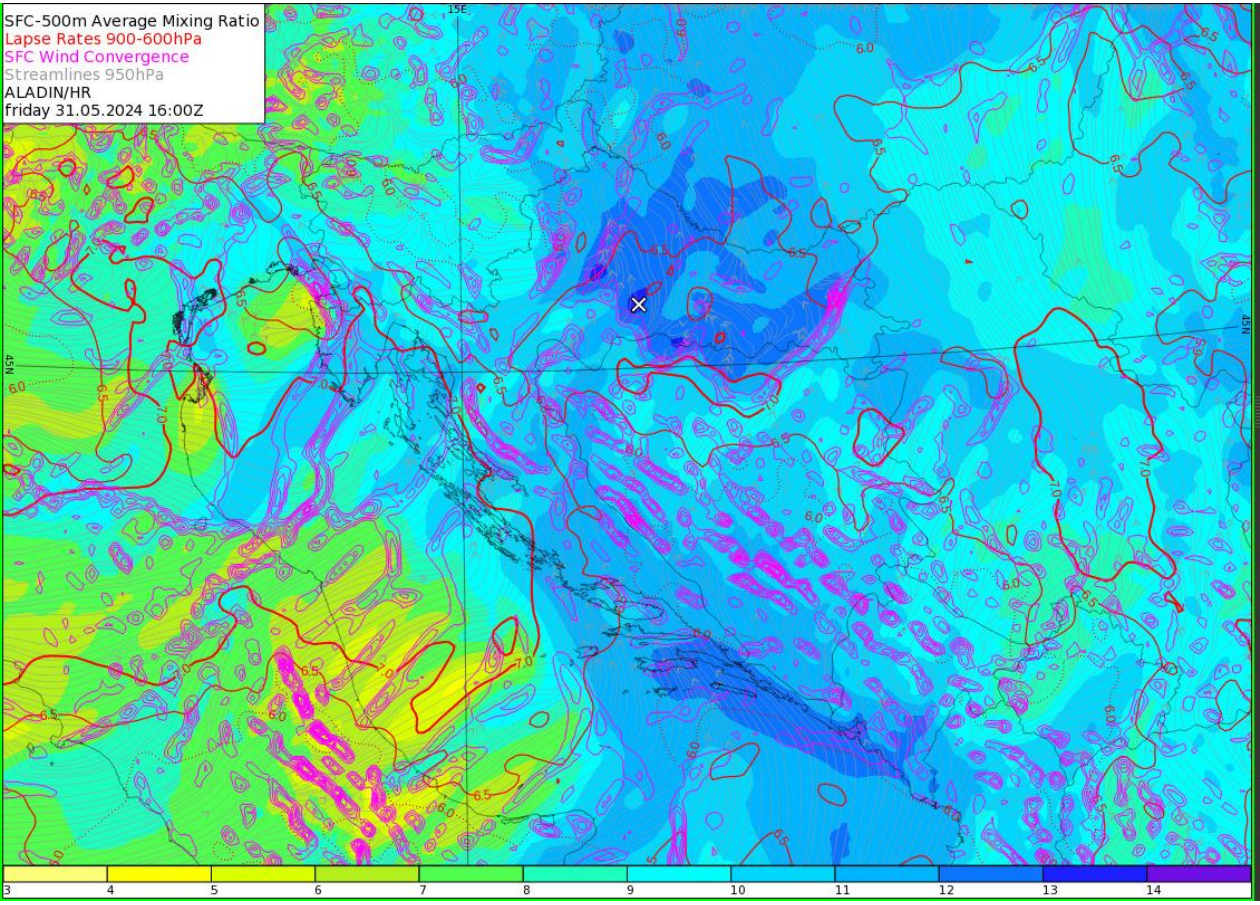
Forecasting process overview

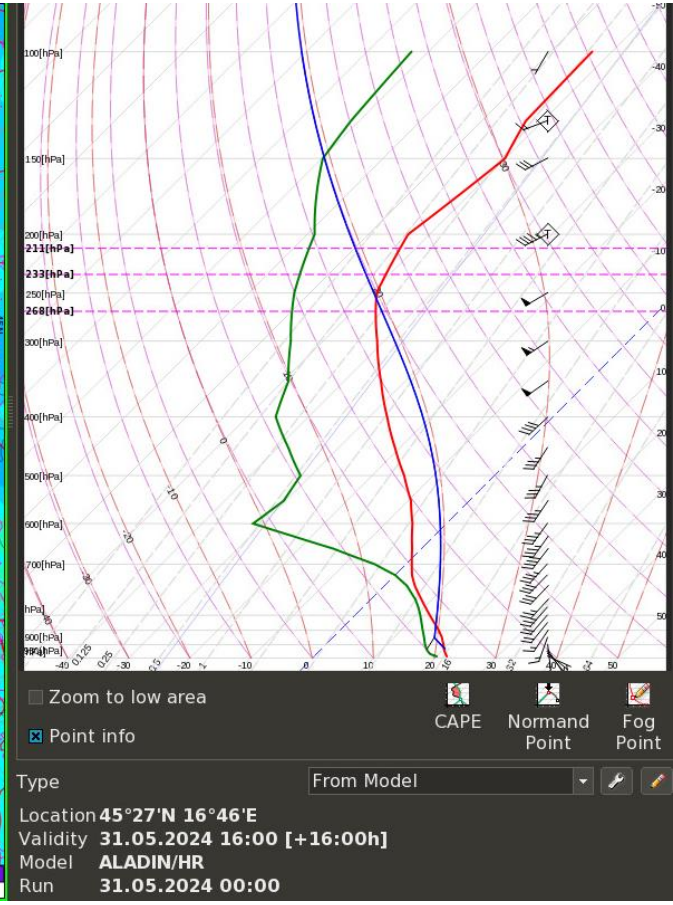
1. Analysis and diagnosis of beneficial synoptic factors (**increase of instability and advection of moisture**)
2. Distribution of basic ingredients (lapse rates and moisture, CAPE & CIN)
3. Possible areas of lift – **convergence zones**: orography, mesoscale circulations, frontogenesis
4. From overlap of above ingredients determine the most likely area of initiation and expected coverage (**isolated** vs **widespread**)!
5. Overlap with areas of **significant wind shear** + hodograph analysis
6. Which convective modes are possible (**ingredients** + forcing shape and type)?
7. With respect to expected convective mode, check **ingredients for associated hazardous phenomena** (e.g. hail, wind gusts, tornadoes).
8. Consider all other favorable and unfavorable factors

Forecasting process overview

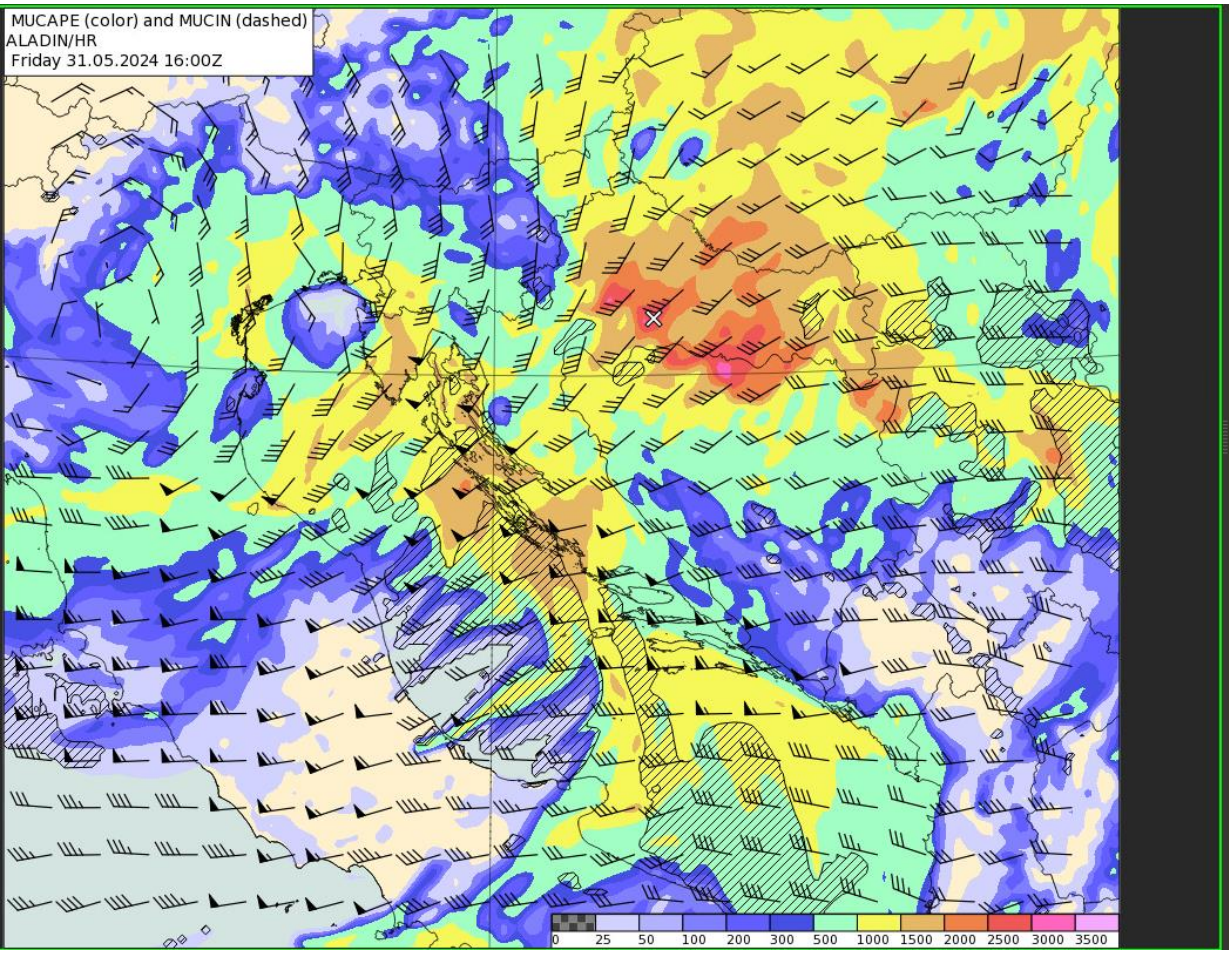


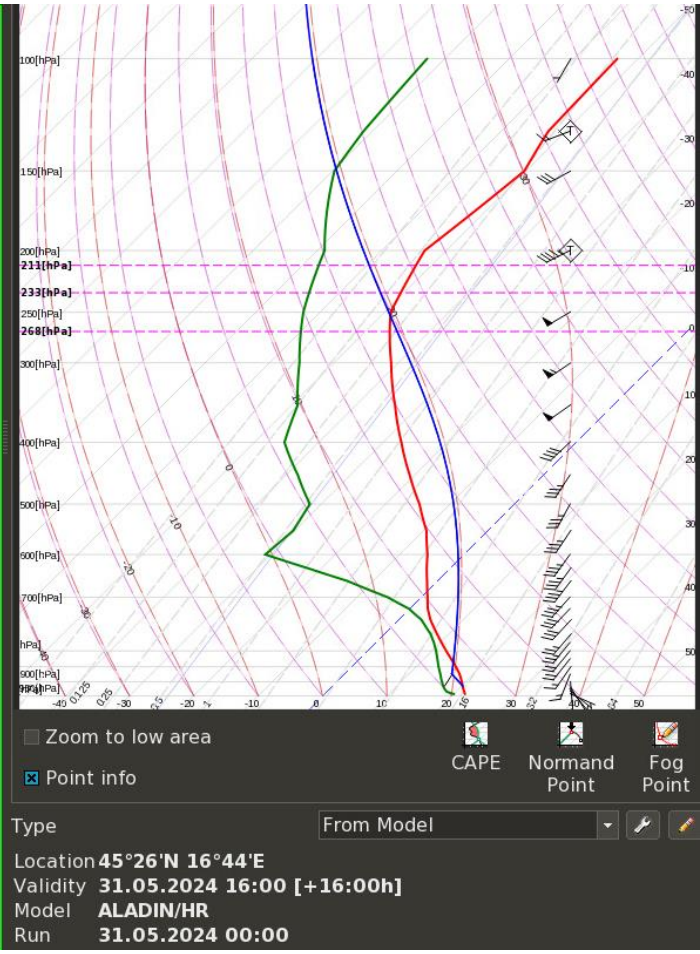
Ingredients map + roaming profile





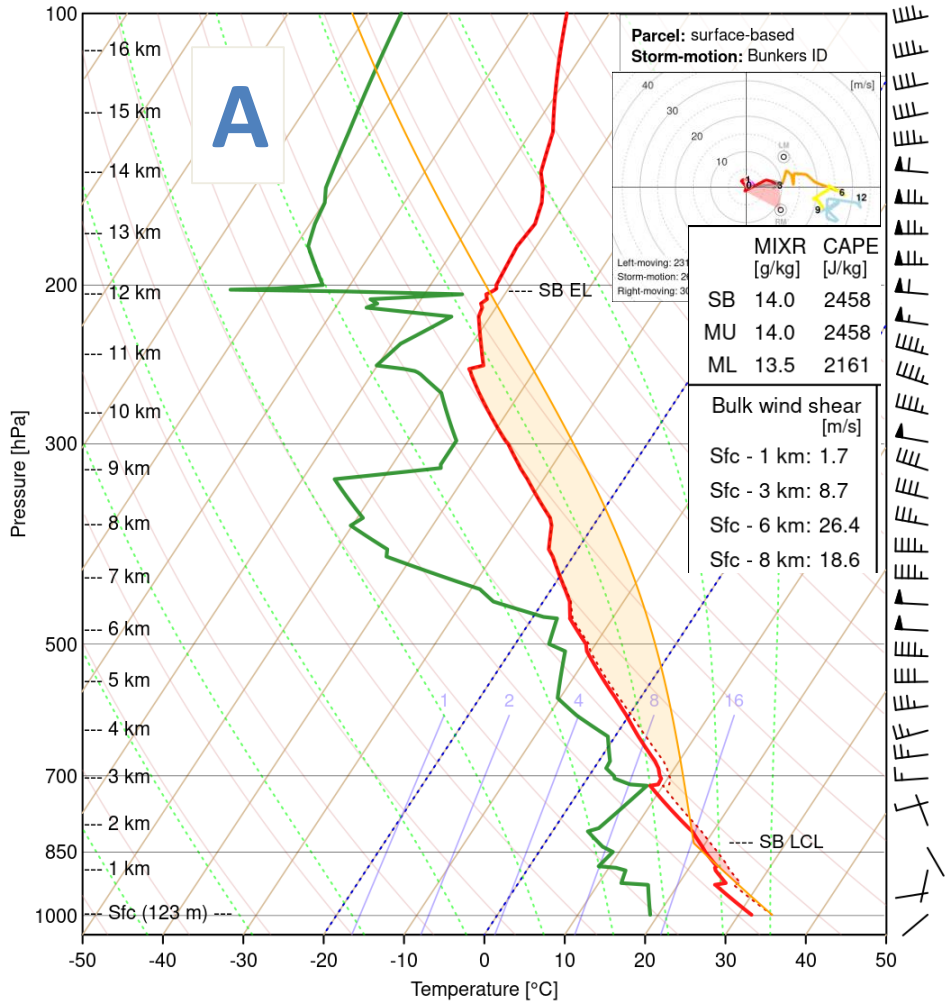
MUCAPE + DLS

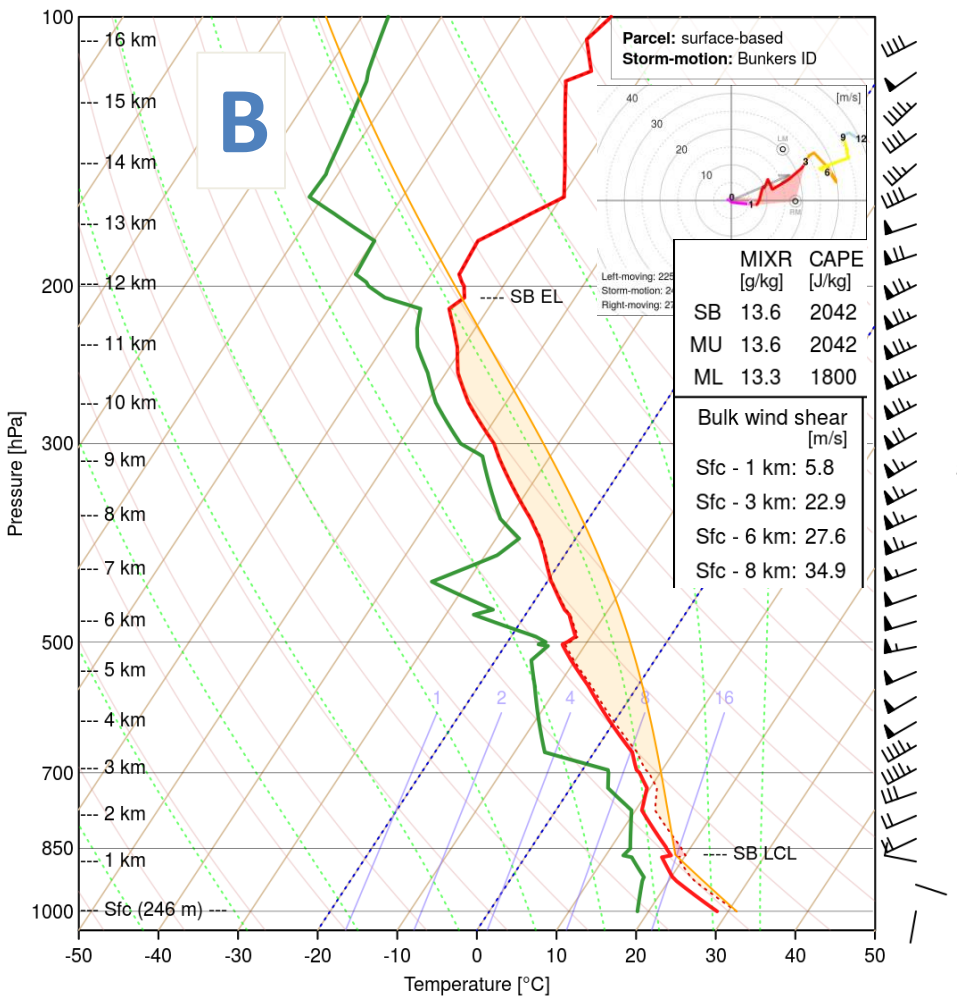

MUCAPE (color) and MUCIN (dashed)
ALADIN/HR
Friday 31.05.2024 16:00Z
0 25 50 100 200 300 500 1000 1500 2000 2500 3000 3500


Zoom to low area
Point info
CAPE
Normand Point
Fog Point
Type
From Model
Location 45°26'N 16°44'E
Validity 31.05.2024 16:00 [+16:00h]
Model ALADIN/HR
Run 31.05.2024 00:00

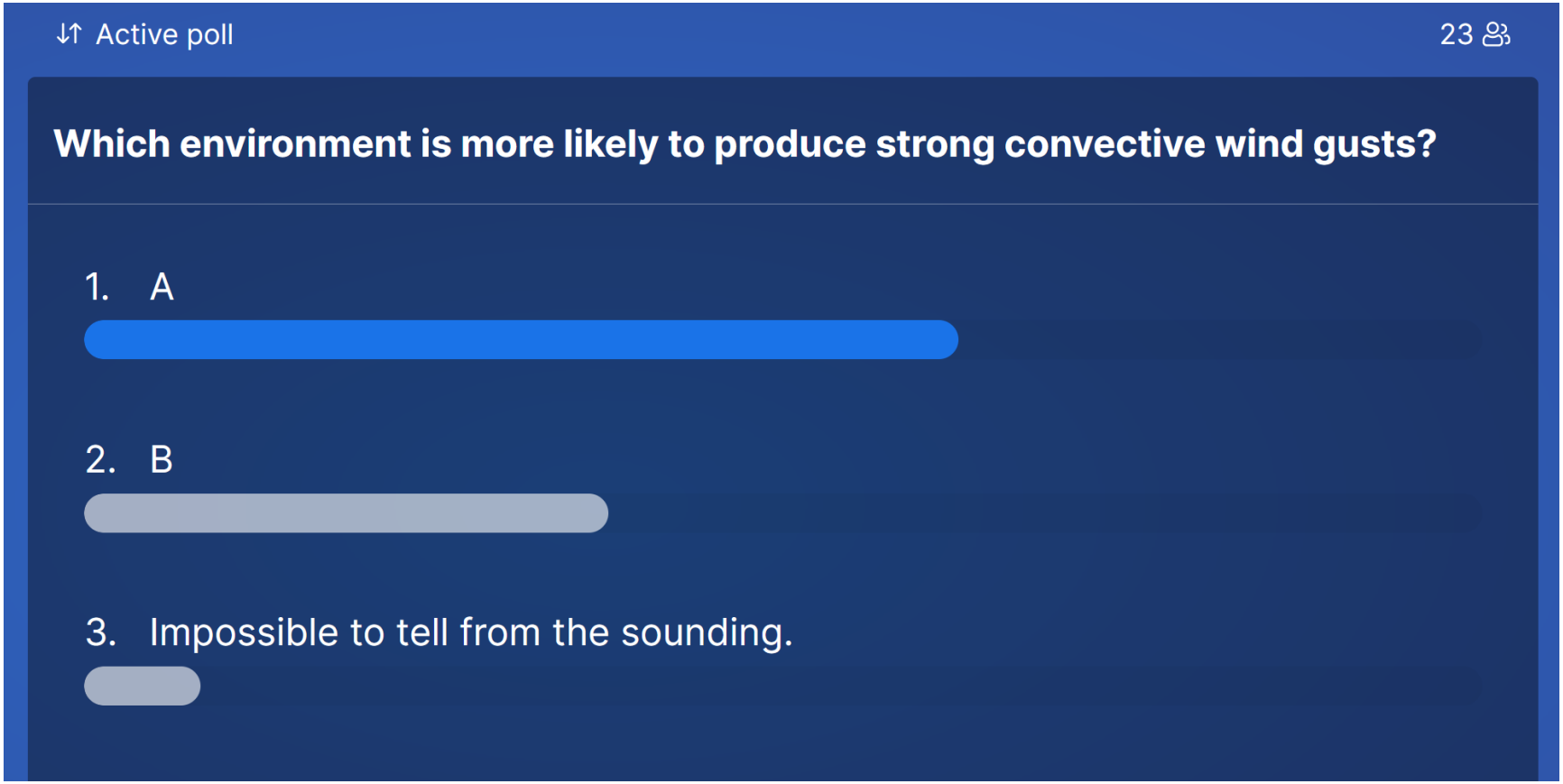
Which environment is more likely to produce strong wind gusts?

slido.com #3705 206

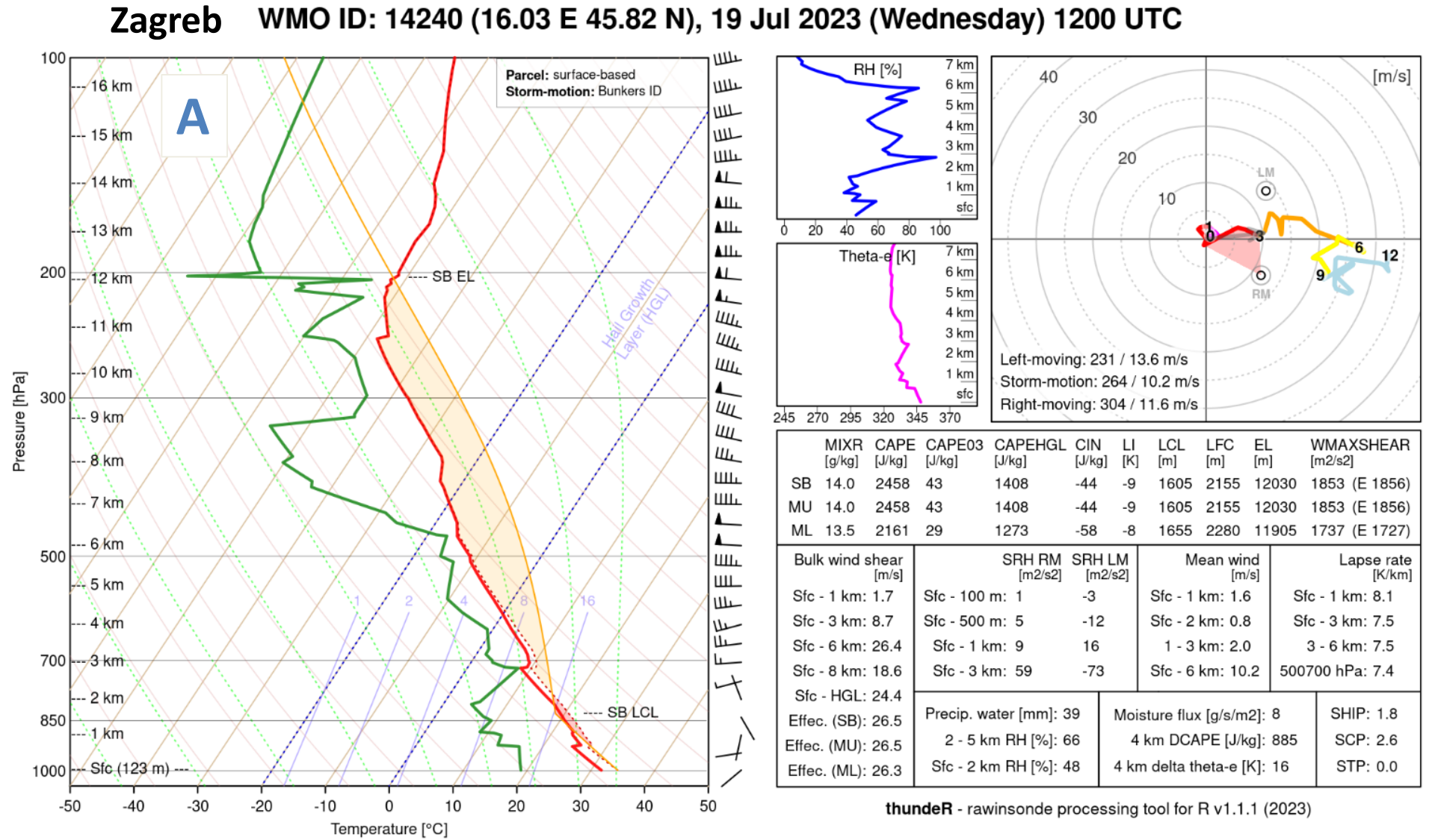




What happened…

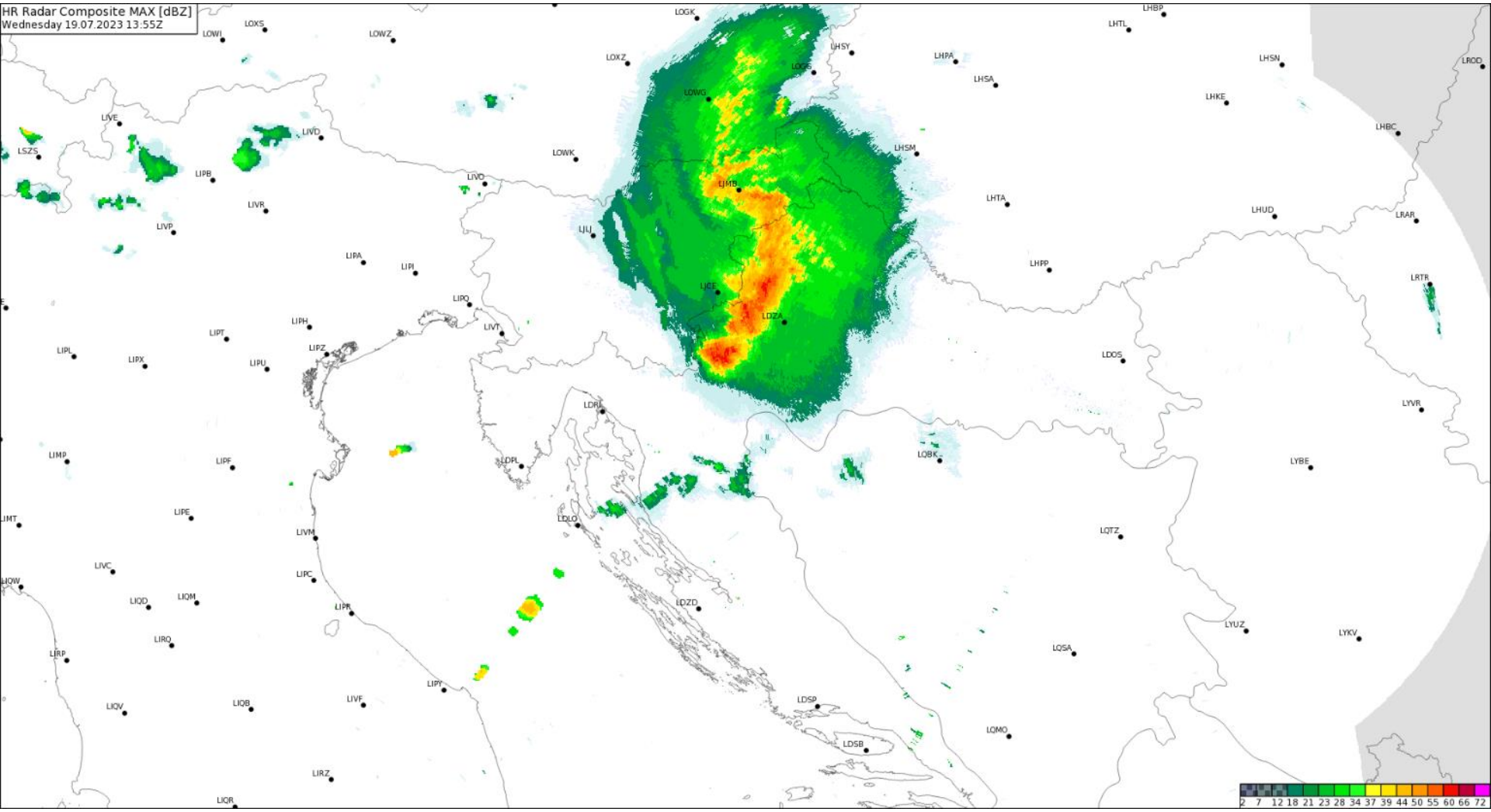


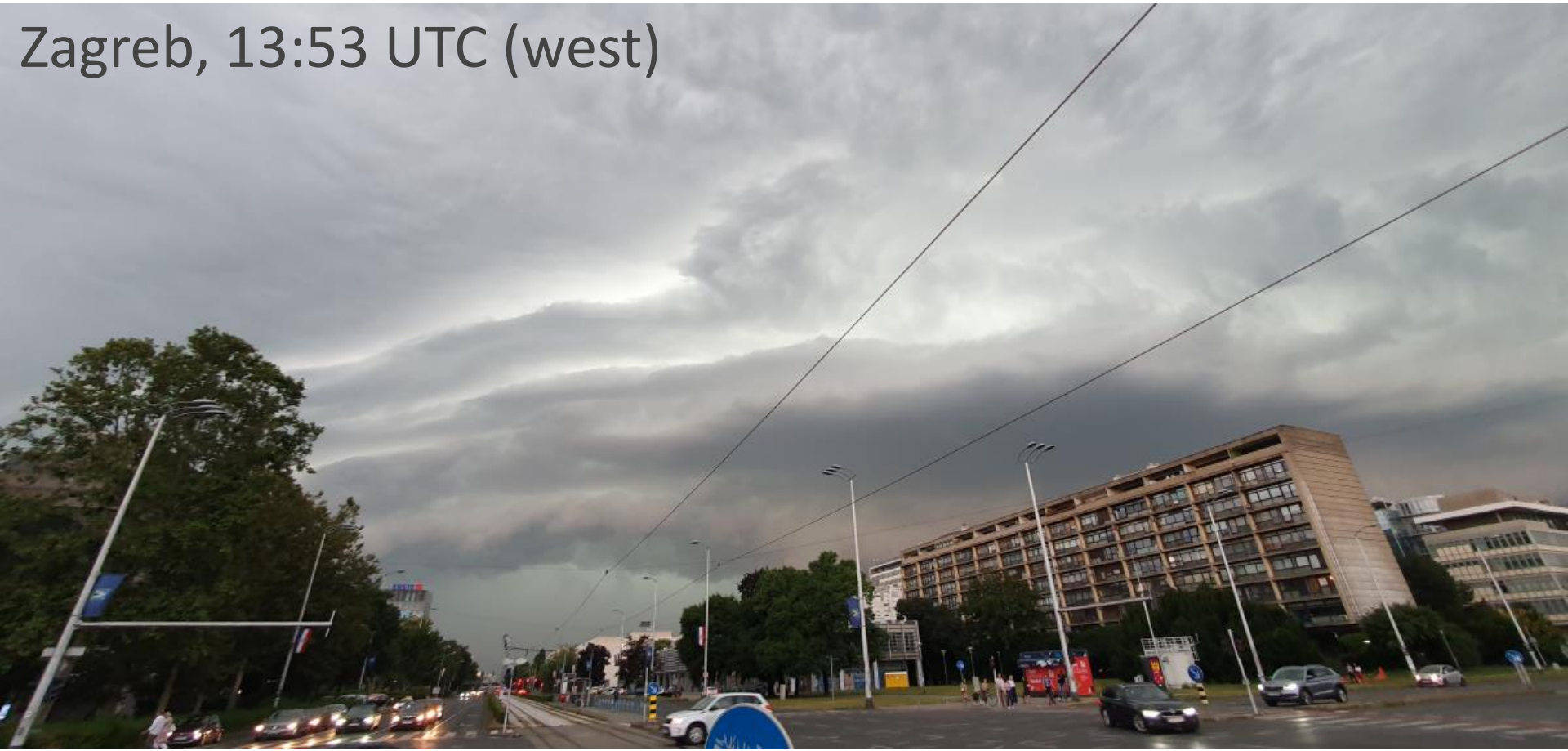
19.7.2023. MCS / BOW ECHO

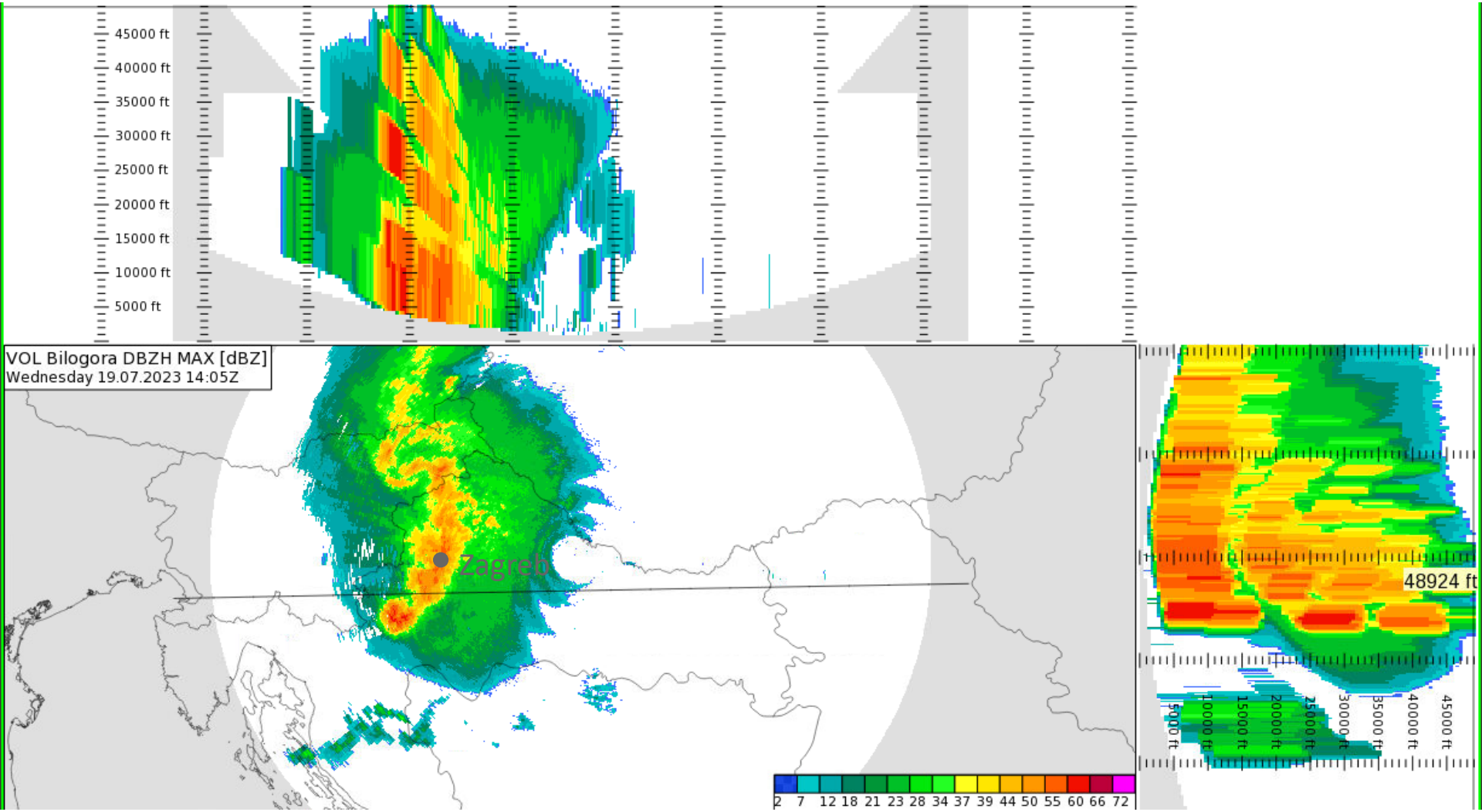


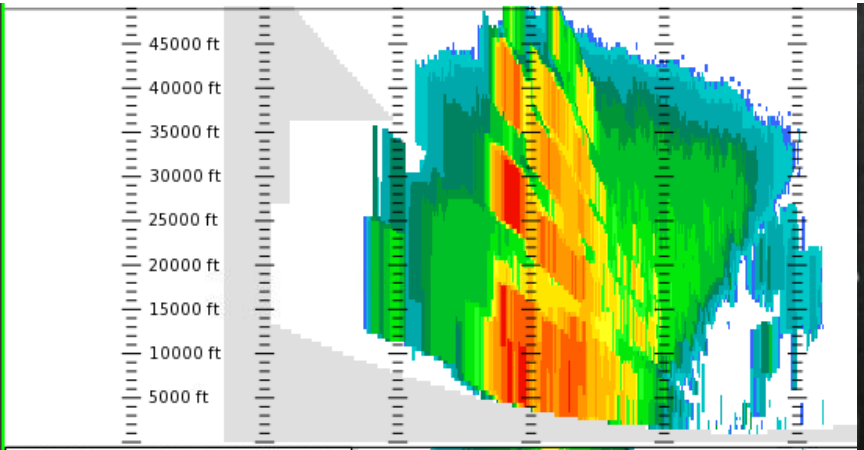
	MIXR [g/kg]	CAPE [J/kg]	CAPE03 [J/kg]	CAPEHGL [J/kg]	CIN [J/kg]	LI [K]	LCL [m]	LFC [m]	EL [m]	WMAXSHEAR [m2/s2]
SB	14.0	2458	43	1408	-44	-9	1605	2155	12030	1853 (E 1856)
MU	14.0	2458	43	1408	-44	-9	1605	2155	12030	1853 (E 1856)
ML	13.5	2161	29	1273	-58	-8	1655	2280	11905	1737 (E 1727)

Bulk wind shear [m/s]	SRH RM [m2/s2]	SRH LM [m2/s2]	Mean wind [m/s]	Lapse rate [K/km]
Sfc - 1 km: 1.7	Sfc - 100 m: 1	-3	Sfc - 1 km: 1.6	Sfc - 1 km: 8.1
Sfc - 3 km: 8.7	Sfc - 500 m: 5	-12	Sfc - 2 km: 0.8	Sfc - 3 km: 7.5
Sfc - 6 km: 26.4	Sfc - 1 km: 9	16	1 - 3 km: 2.0	3 - 6 km: 7.5
Sfc - 8 km: 18.6	Sfc - 3 km: 59	-73	Sfc - 6 km: 10.2	500700 hPa: 7.4
Sfc - HGL: 24.4				
Effec. (SB): 26.5	Precip. water [mm]: 39		Moisture flux [g/s/m2]: 8	SHIP: 1.8
Effec. (MU): 26.5	2 - 5 km RH [%]: 66		4 km DCAPE [J/kg]: 885	SCP: 2.6
Effec. (ML): 26.3	Sfc - 2 km RH [%]: 48		4 km delta theta-e [K]: 16	STP: 0.0


HR Radar Composite MAX [dBZ]
Wednesday 19.07.2023 13:55Z
LOGK
LHBP
LHTL
LOXS
LOWI
LOWZ
LOXZ
LHSY
LHPA
LHSN
LROD
LOWG
LHSA
LHKE
LIVE
LIVD
LHBC
LSZS
LOWK
LHSM
LIPB
LIVO
LJMB
LIVR
LHTA
LHUD
LIVP
LJLJ
LRAR
LIPA
LIPI
LHPP
LRTR
LIPQ
LJCE
LDZA
LIPH
LIVT
LIPT
LIPL
LIPX
LIPZ
LIPU
LDOS
LDRI
LYVR
LIMP
LIPF
LDPL
LQBK
LYBE
LIPE
LDLO
LIVM
LQTZ
LIVC
LIPC
LIQW
LIQD
LIQM
LIPR
LDZD
LYUZ
LYKV
LIRQ
LQSA
LIRP
LIPY
LIQV
LIQB
LIVF
LDSP
LQMO
LDSB
LIRZ
LIQR
2 7 12 18 21 23 28 34 37 39 44 50 55 60 66 72


Zagreb, 13:53 UTC (west)


45000 ft
40000 ft
35000 ft
30000 ft
25000 ft
20000 ft
15000 ft
10000 ft
5000 ft
VOL Bilogora DBZH MAX [dBZ]
Wednesday 19.07.2023 14:05Z
Zagreb
48924 ft
2 7 12 18 21 23 28 34 37 39 44 50 55 60 66 72



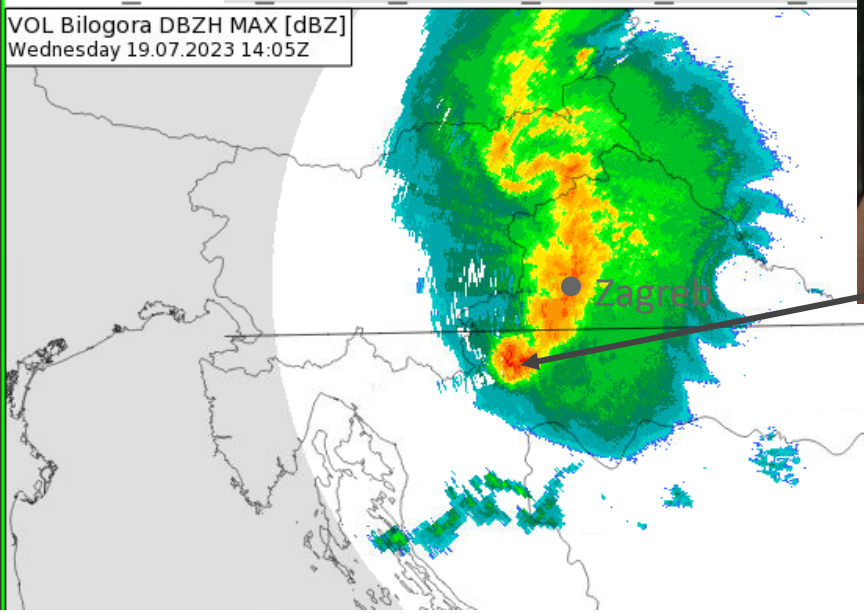
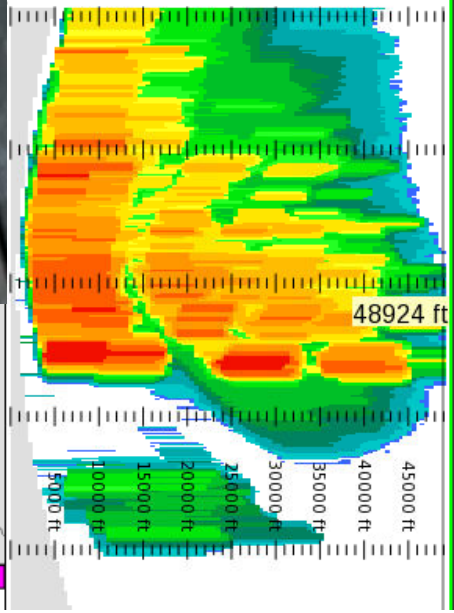
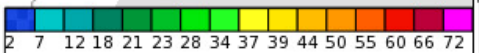


Photo by Jelena Fudurić Dolinar (published on Facebook)

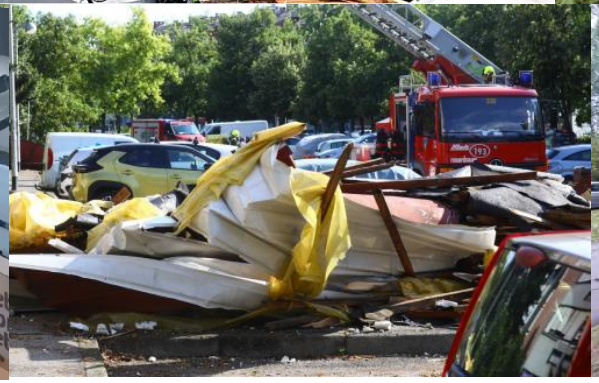
13 cm hail near Karlovac (Ribnik)

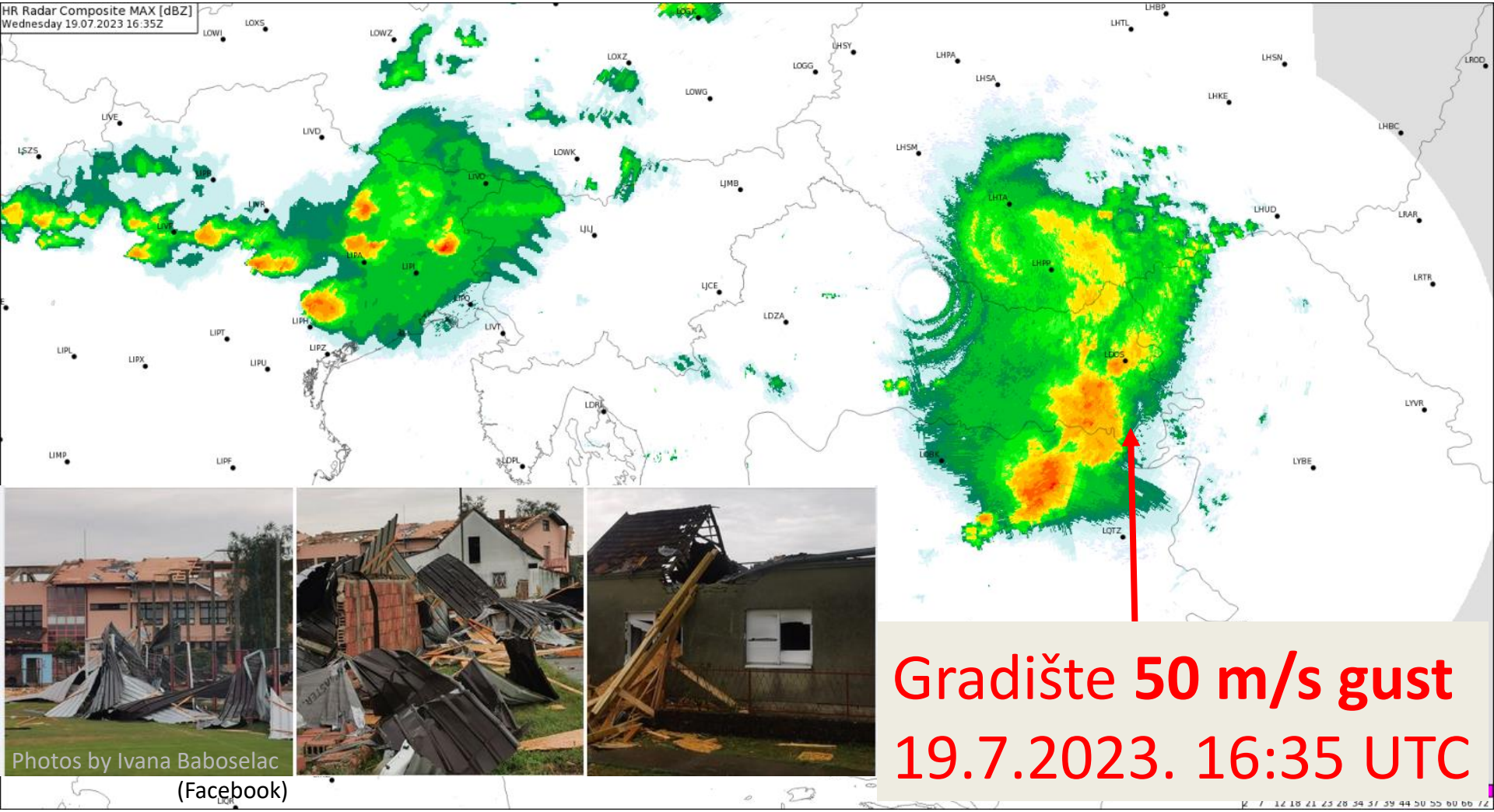




Zagreb aftermath

source: internet media

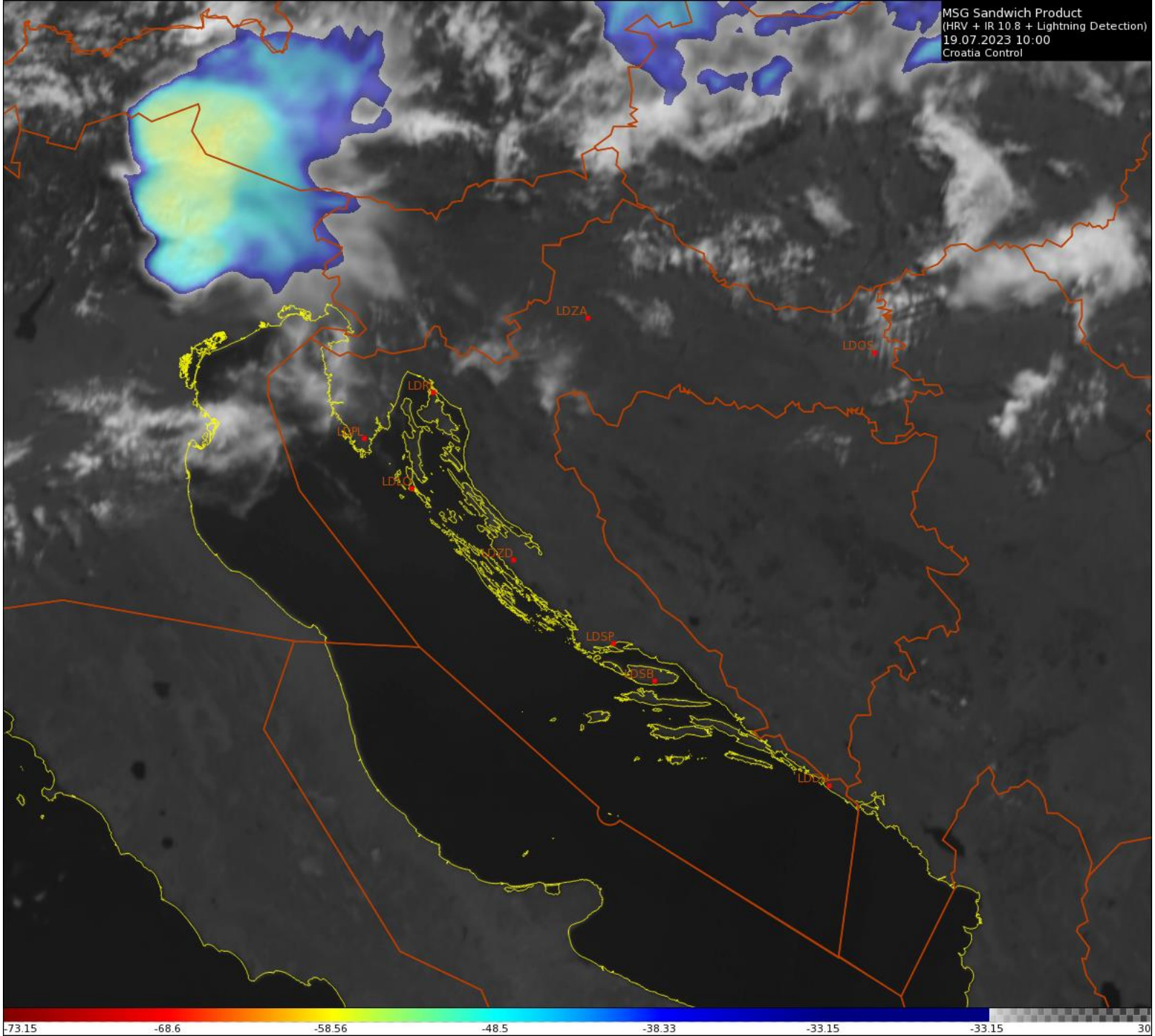


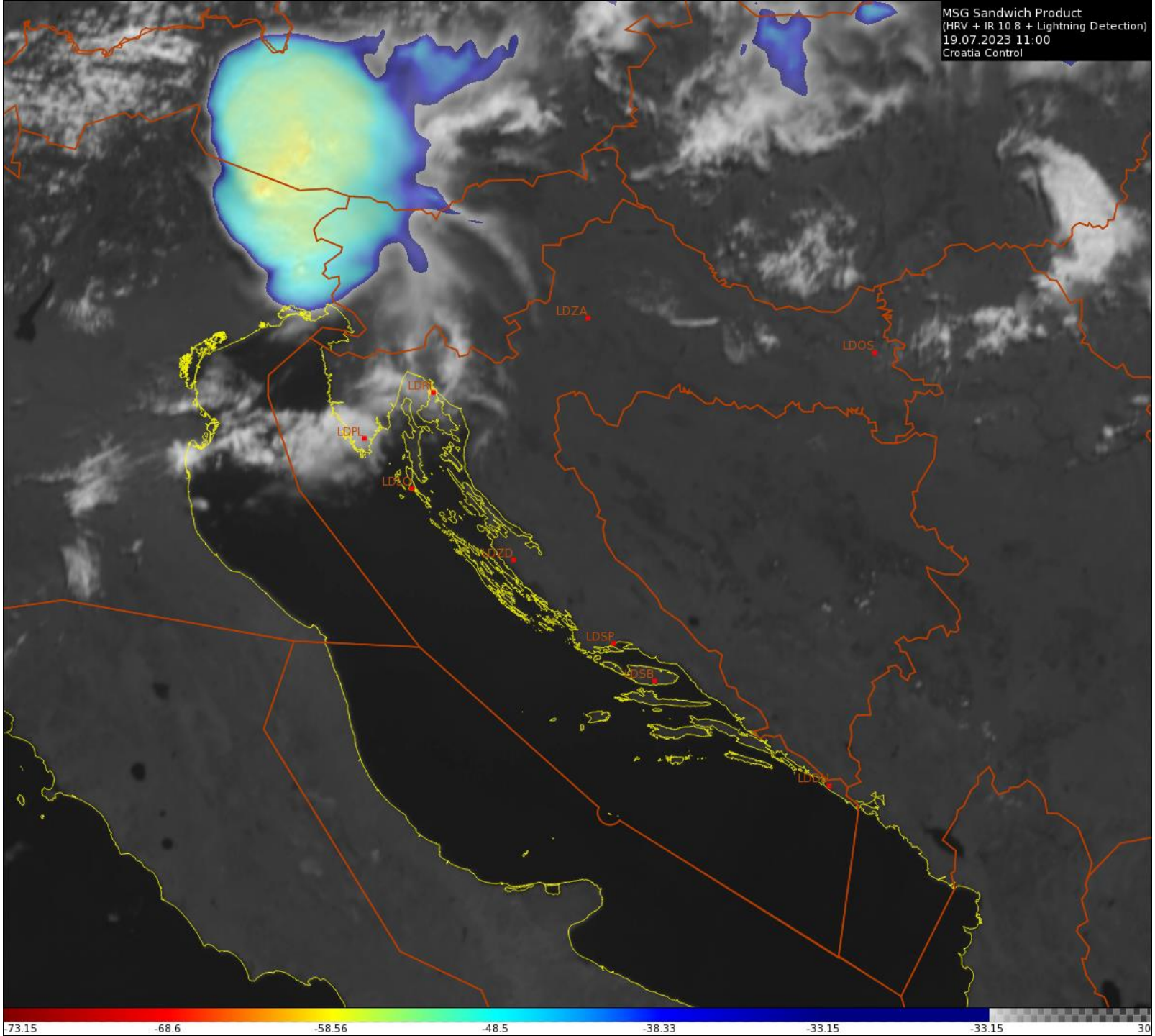

HR Radar Composite MAX [dBZ]
Wednesday 19.07.2023 16:35Z
Gradište **50 m/s gust**
19.7.2023. 16:35 UTC

Photos by Ivana Baboselac

(Facebook)


source: internet media


MSG Sandwich Product
(HRV + IR 10.8 + Lightning Detection)
19.07.2023 10:00
Croatia Control
LDZA
LDOS
LDRI
LDPL
LDZD
LDSP
LDSB
-73.15
-68.6
-58.56
-48.5
-38.33
-33.15
-33.15
30


MSG Sandwich Product
(HRV + IR 10.8 + Lightning Detection)
19.07.2023 11:00
Croatia Control
LDZA
LDOS
LDRI
LDPL
LDZD
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LDDU
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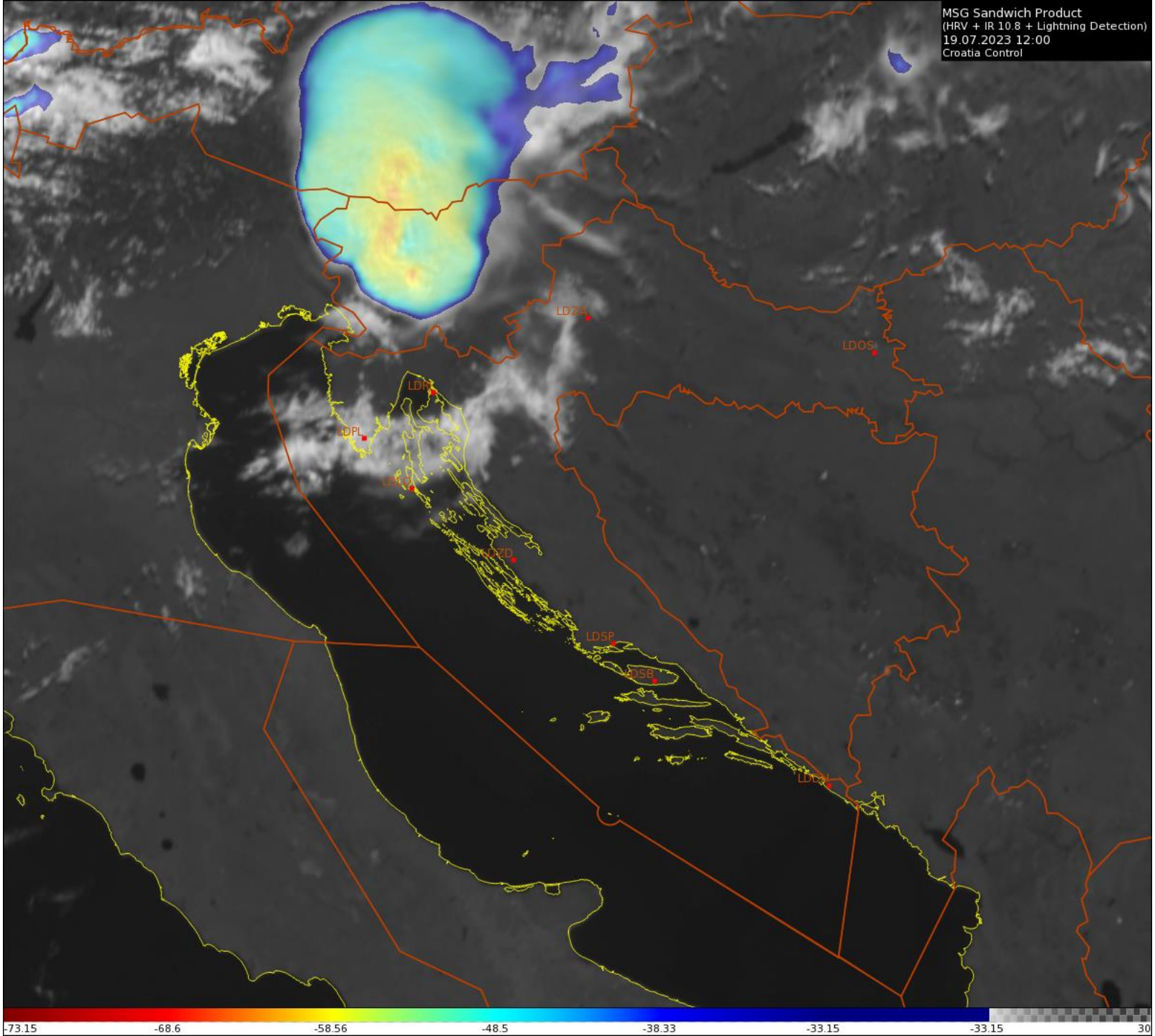
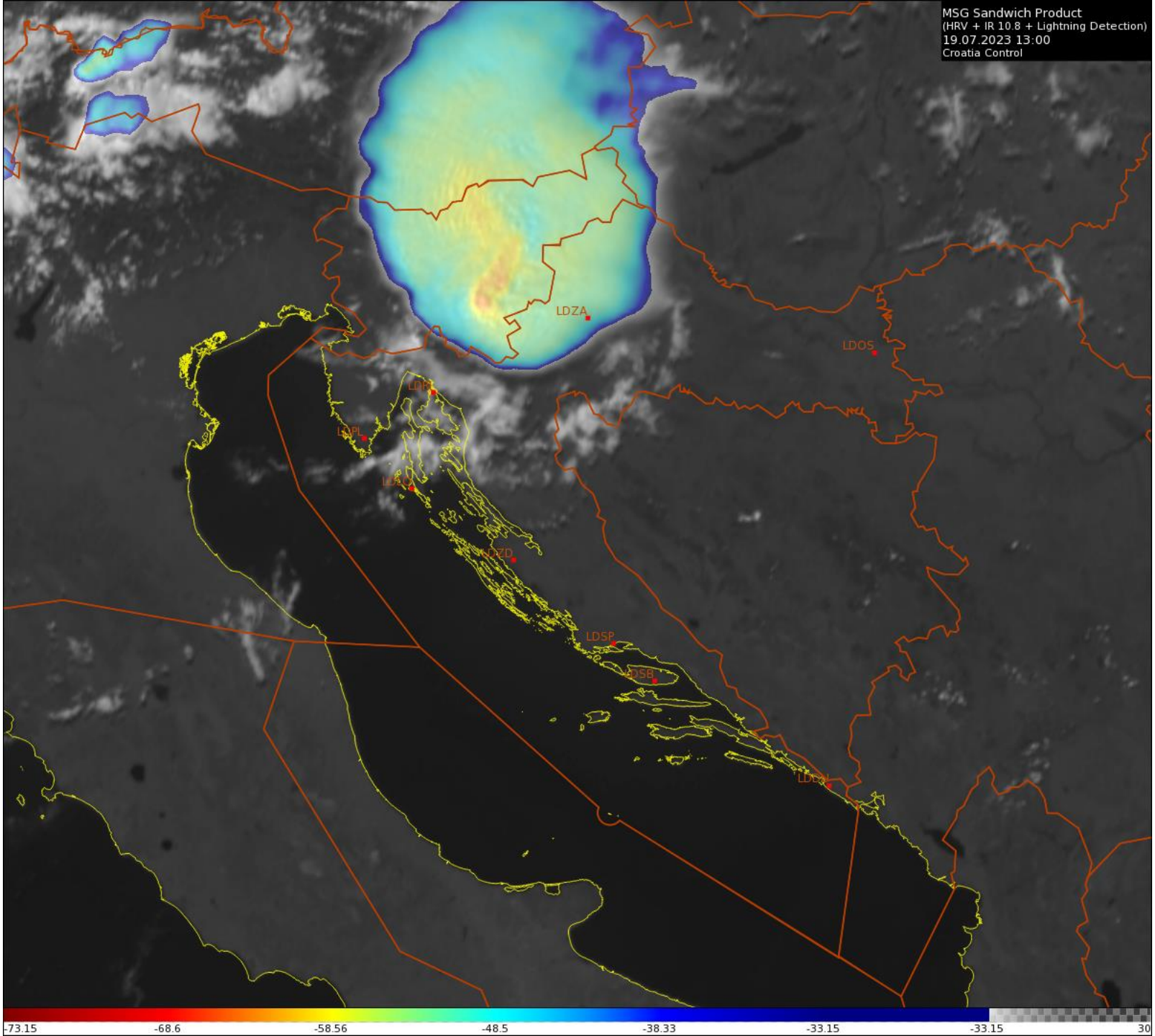
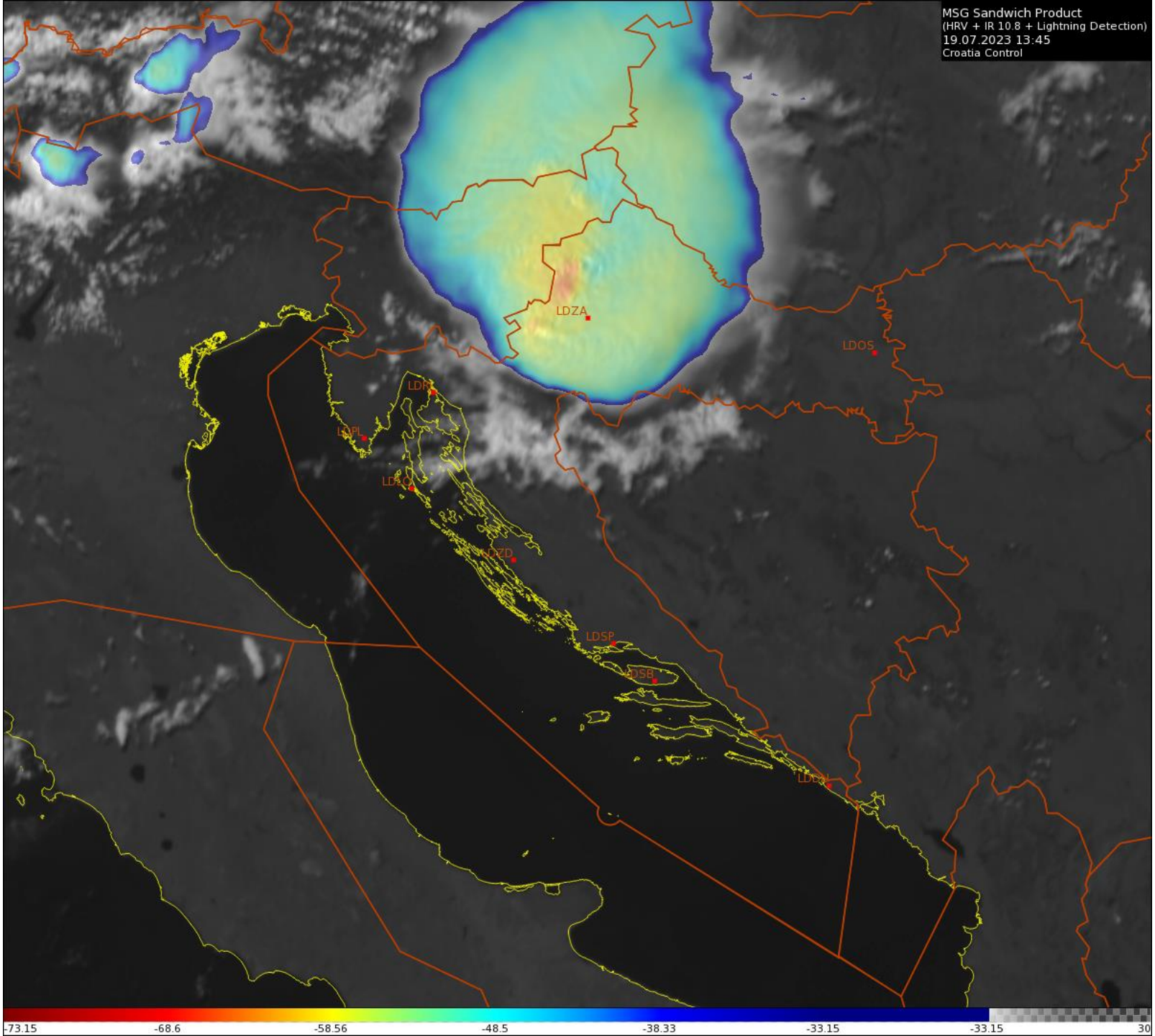
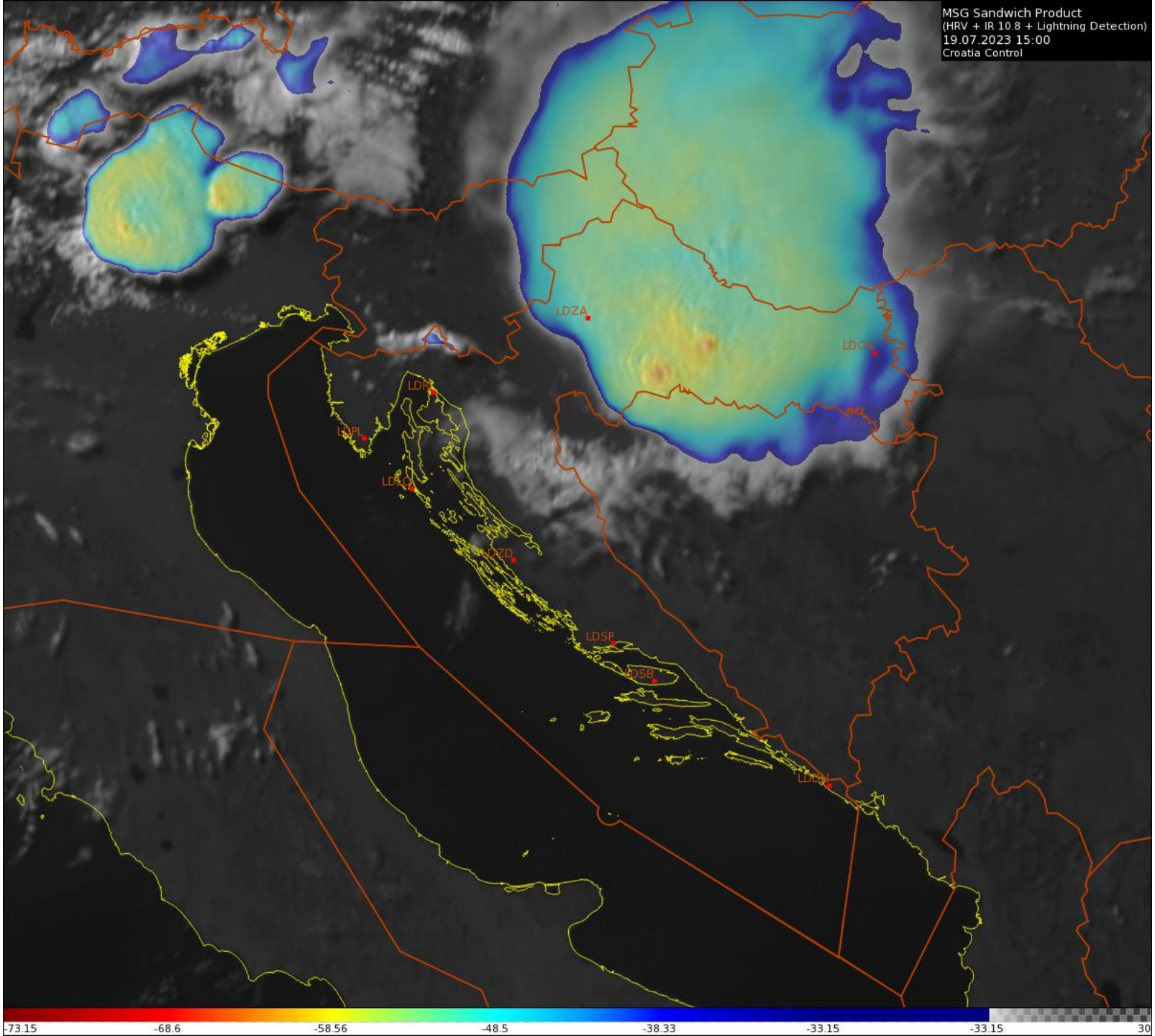
-48.5
-38.33
-33.15
-33.15
30


MSG Sandwich Product
(HRV + IR 10.8 + Lightning Detection)
19.07.2023 12:00
Croatia Control
LDZA
LDOS
LDRI
LDPL
LDZD
LDSP
LDSB
LDDU
-73.15
-68.6
-58.56
-48.5
-38.33
-33.15
-33.15
30


MSG Sandwich Product
(HRV + IR 10.8 + Lightning Detection)
19.07.2023 13:00
Croatia Control
LDZA
LDOS
LDRI
LDPL
LDZD
LDSP
LDSB
LDDU
-73.15
-68.6
-58.56
-48.5
-38.33
-33.15
-33.15
30


MSG Sandwich Product
(HRV + IR 10.8 + Lightning Detection)
19.07.2023 13:45
Croatia Control
LDZA
LDOS
LDRI
LDPL
LDZD
LDSP
LDSB
LDDU
-73.15
-68.6
-58.56
-48.5
-38.33
-33.15
-33.15
30


MSG Sandwich Product
(HRV + IR 10.8 + Lightning Detection)
19.07.2023 15:00
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LDZA
LDOS
LDRI
LDPL
LDZD
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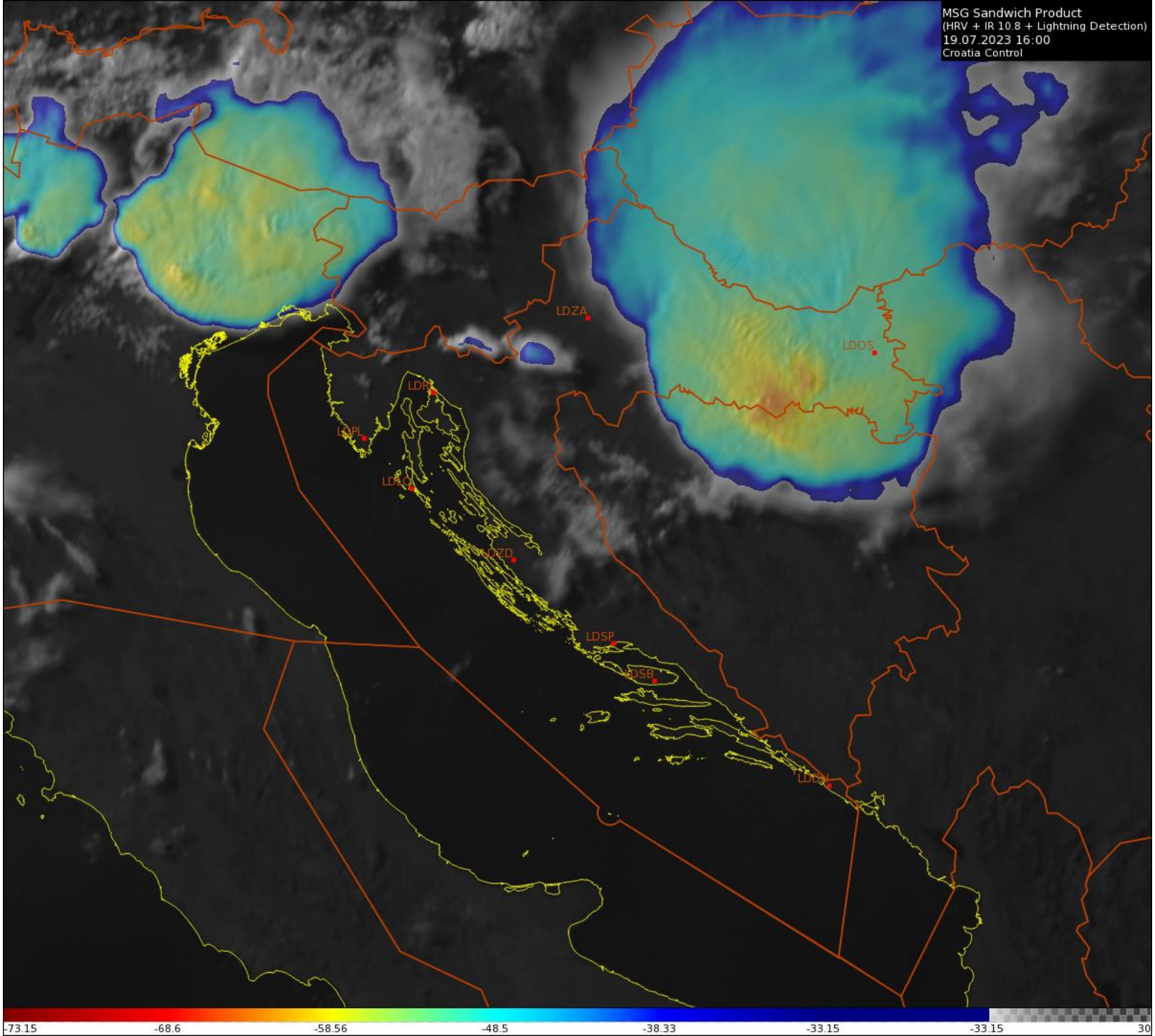
-58.56
-48.5
-38.33
-33.15
-33.15
30


MSG Sandwich Product
(HRV + IR 10.8 + Lightning Detection)
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Croatia Control
LDZA
LDOS
LDRI
LDPL
LDZD
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LDSB
-73.15
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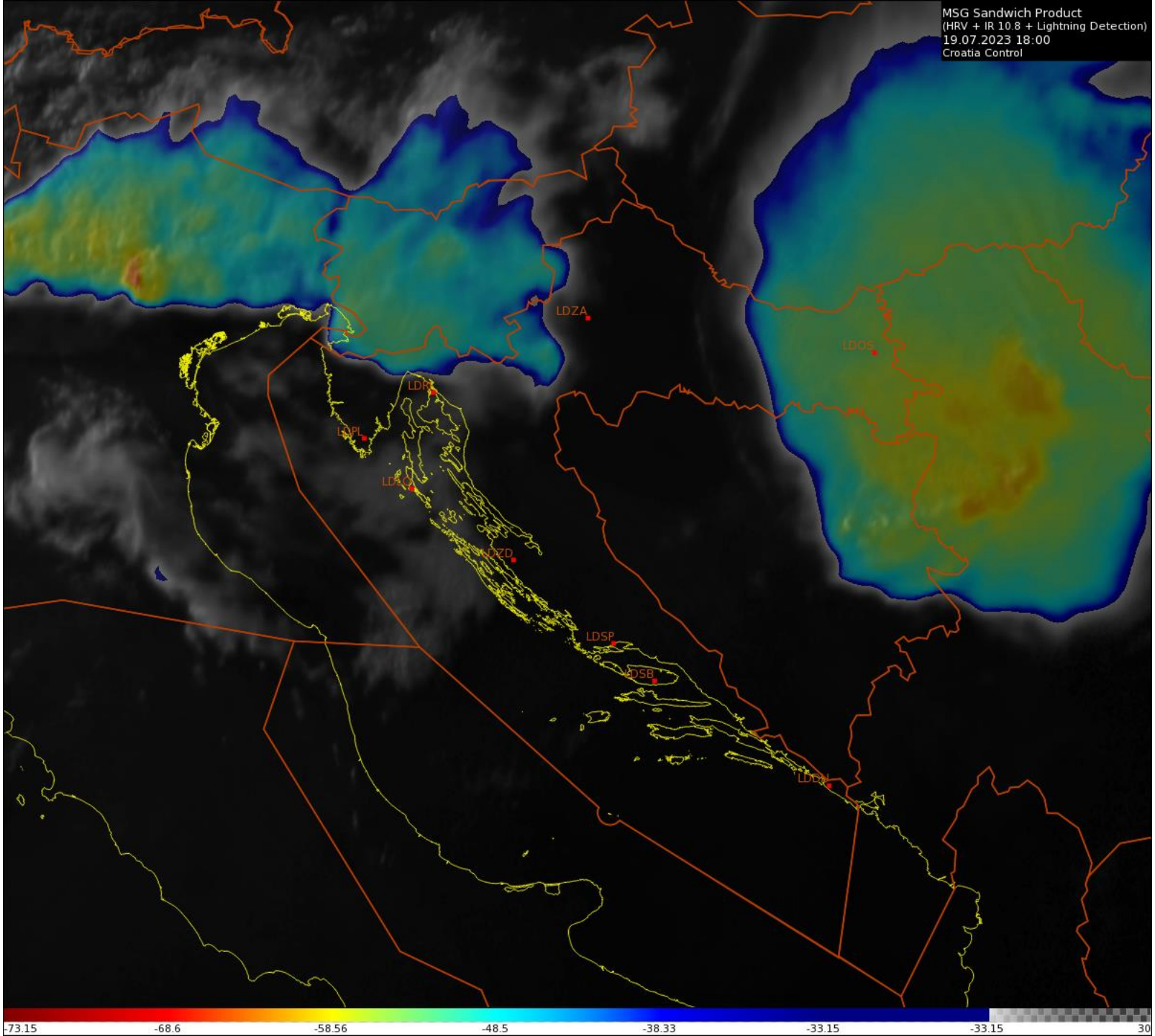
-58.56
-48.5
-38.33
-33.15
-33.15
30


MSG Sandwich Product
(HRV + IR 10.8 + Lightning Detection)
19.07.2023 18:00
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LDOS
LDRI
LDPL
LDZD
LDSP
LDSB
LDDU
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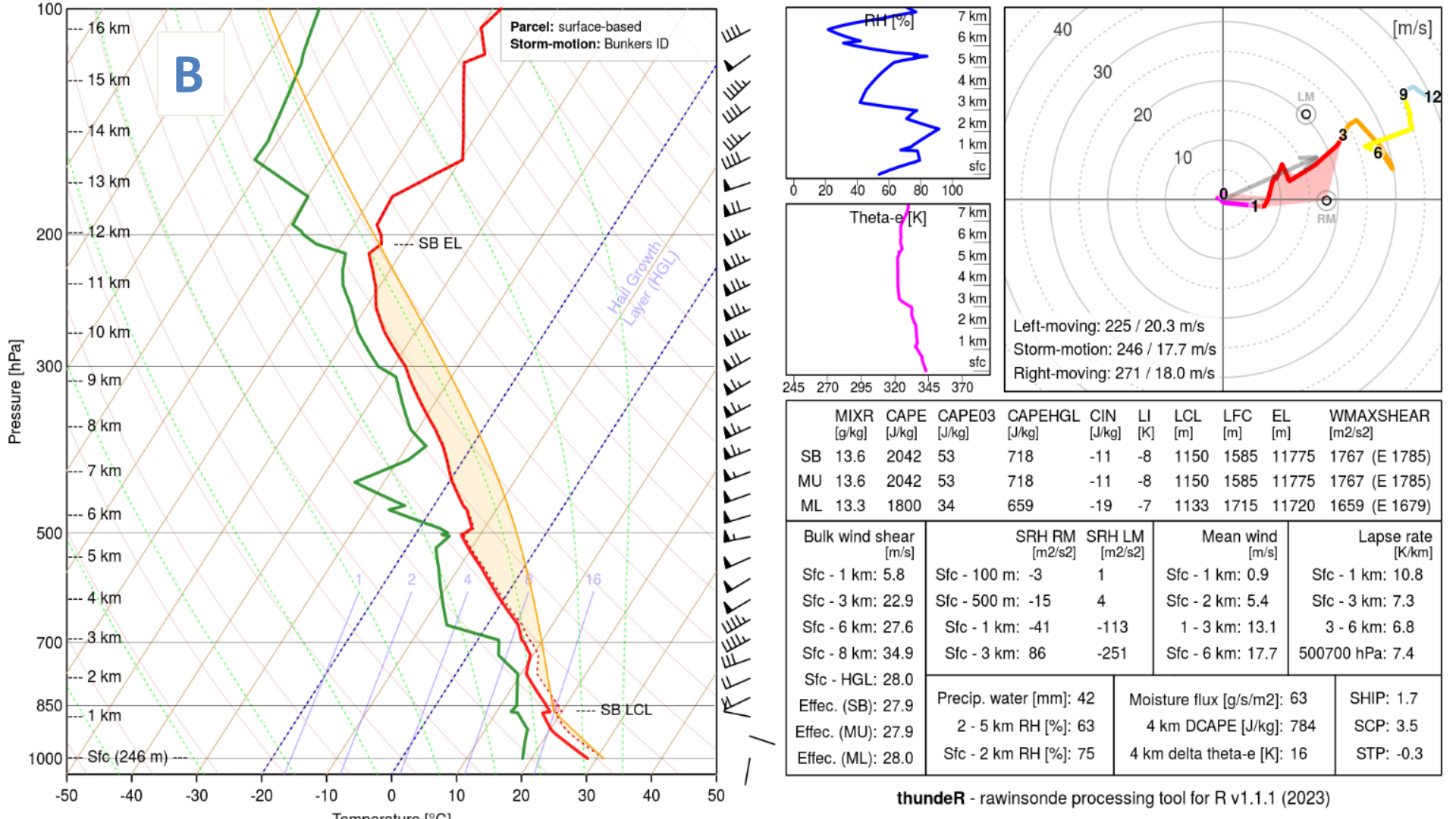
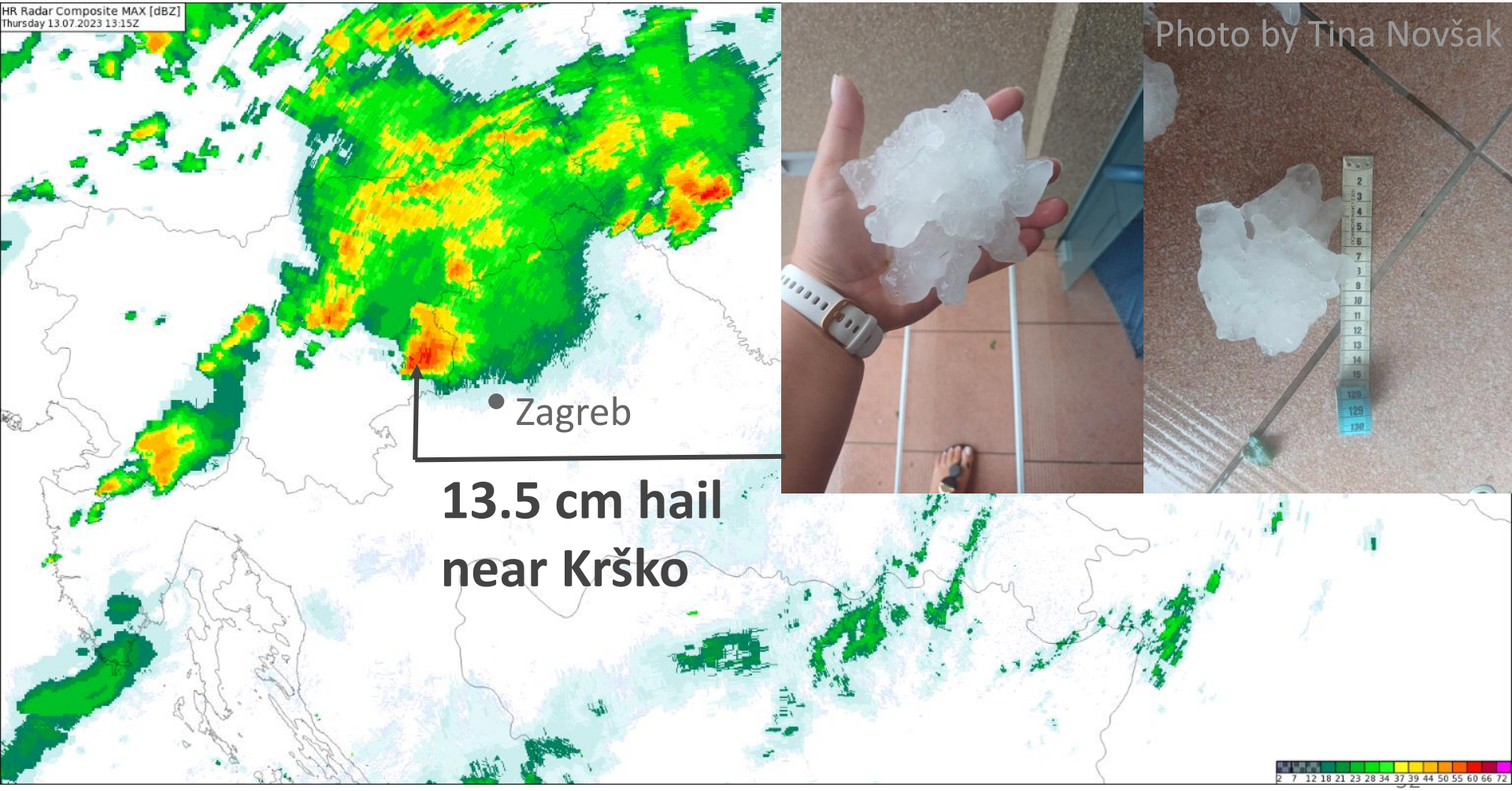
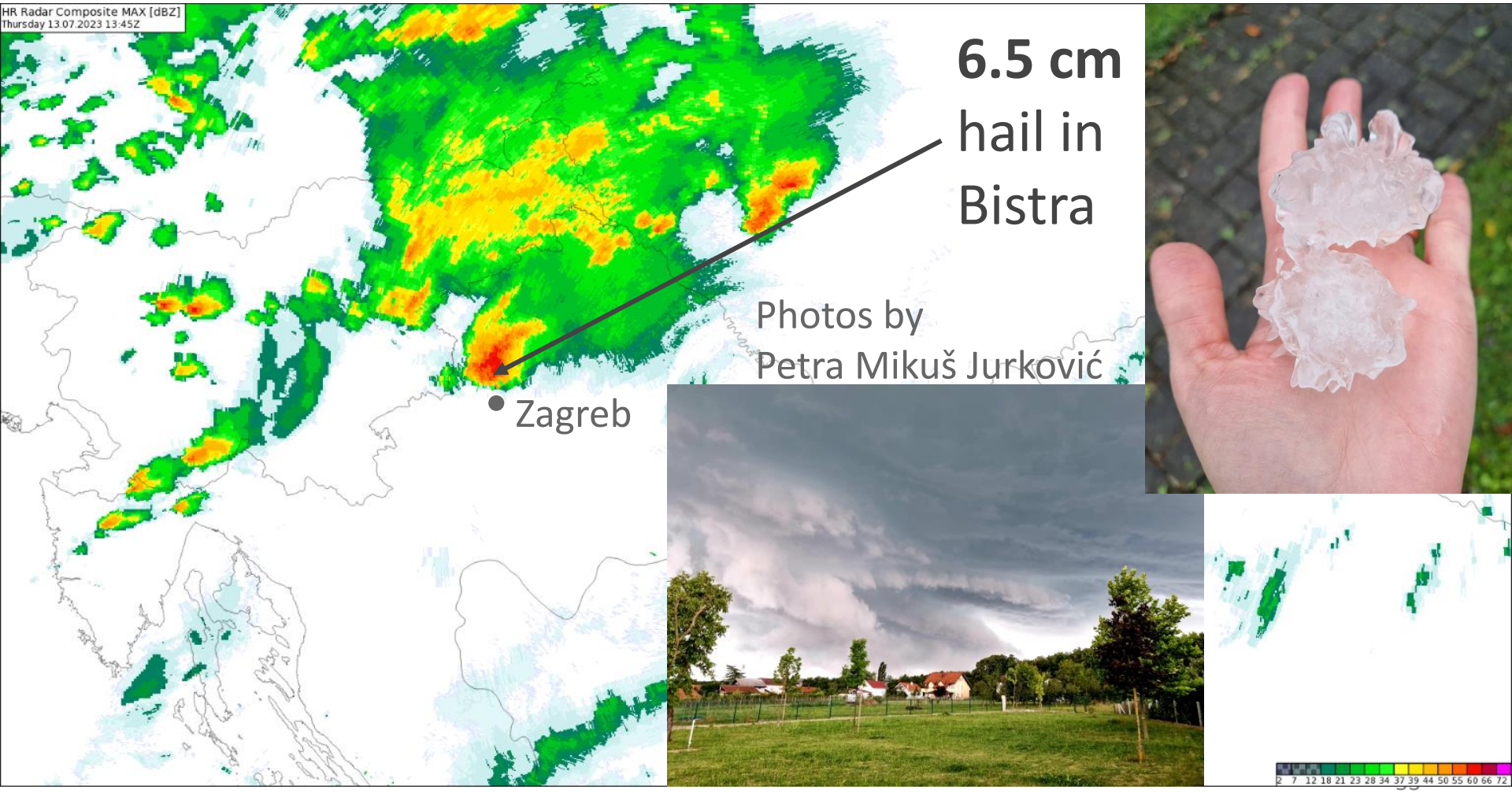
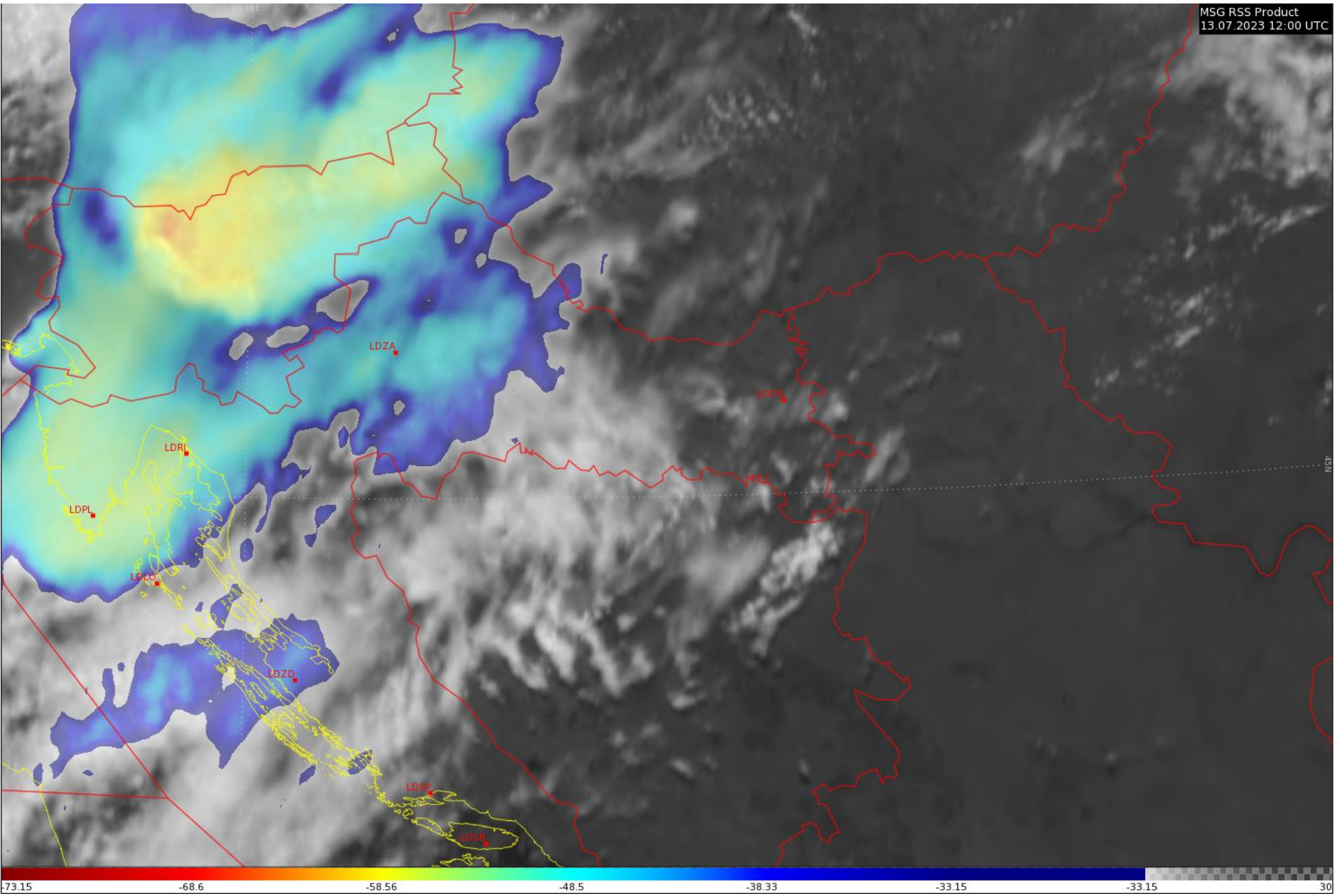
-58.56
-48.5
-38.33
-33.15
-33.15
30

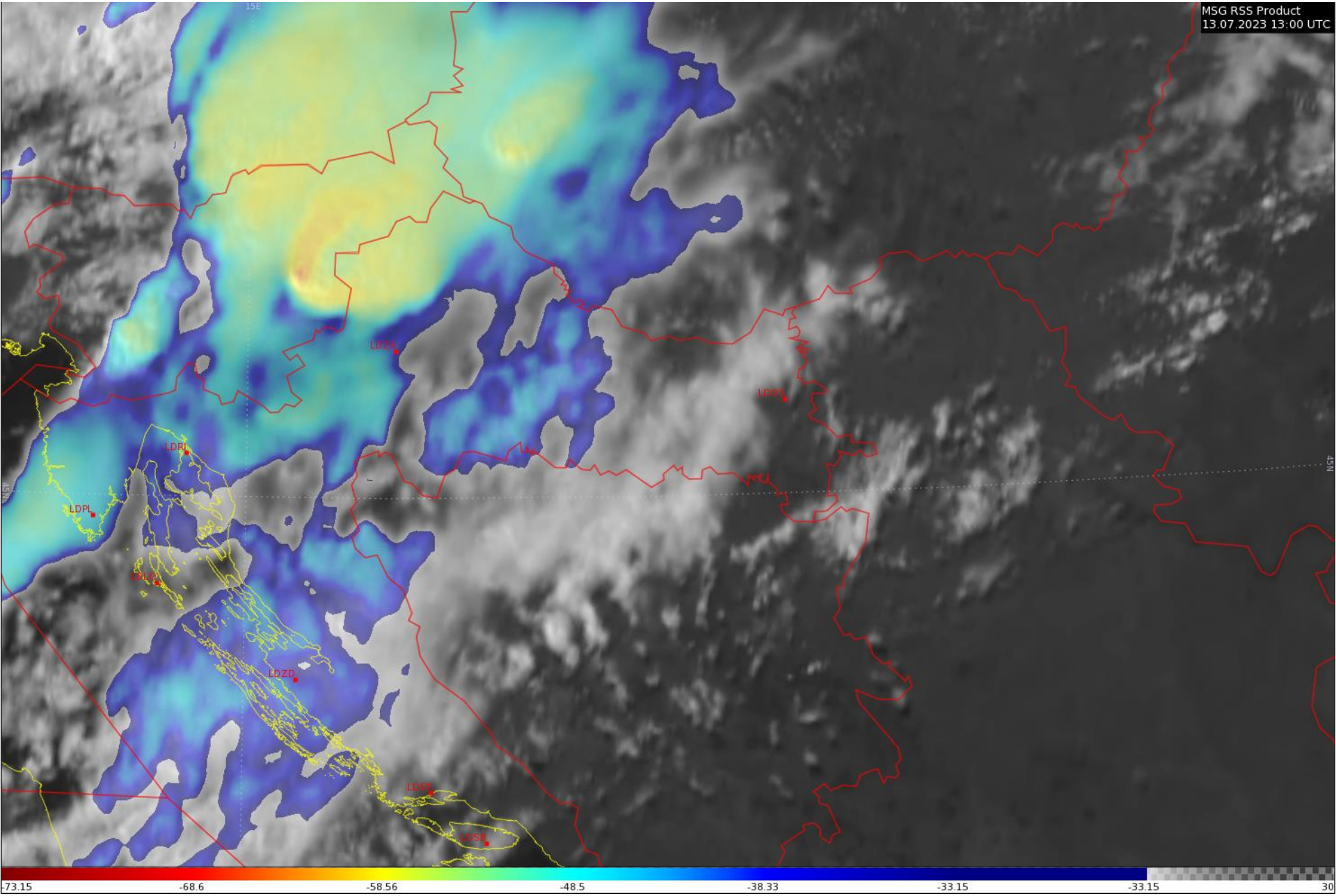
13.7.2023. Long-lasting supercell




HR Radar Composite MAX [dBZ]
Thursday 13.07.2023 13:15Z
Zagreb
13.5 cm hail
near Krško
Photo by Tina Novšak
2 7 12 18 21 23 28 34 37 39 44 50 55 60 66 72


HR Radar Composite MAX [dBZ]
Thursday 13.07.2023 13:45Z
6.5 cm
hail in
Bistra
Zagreb
Photos by
Petra Mikuš Jurković
2 7 12 18 21 23 28 34 37 39 44 50 55 60 66 72


MSG RSS Product
13.07.2023 12:00 UTC
LDZA
LDRI
LDPL
LDLO
LDZD
LDSB
45N
-73.15
-68.6
-58.56
-48.5
-38.33
-33.15
-33.15
30


MSG RSS Product
13.07.2023 13:00 UTC
15E
45N
LDZA
LDDK
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LDPL
LDLO
LDZD
LDSE
LDSB
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-38.33
-33.15
-33.15
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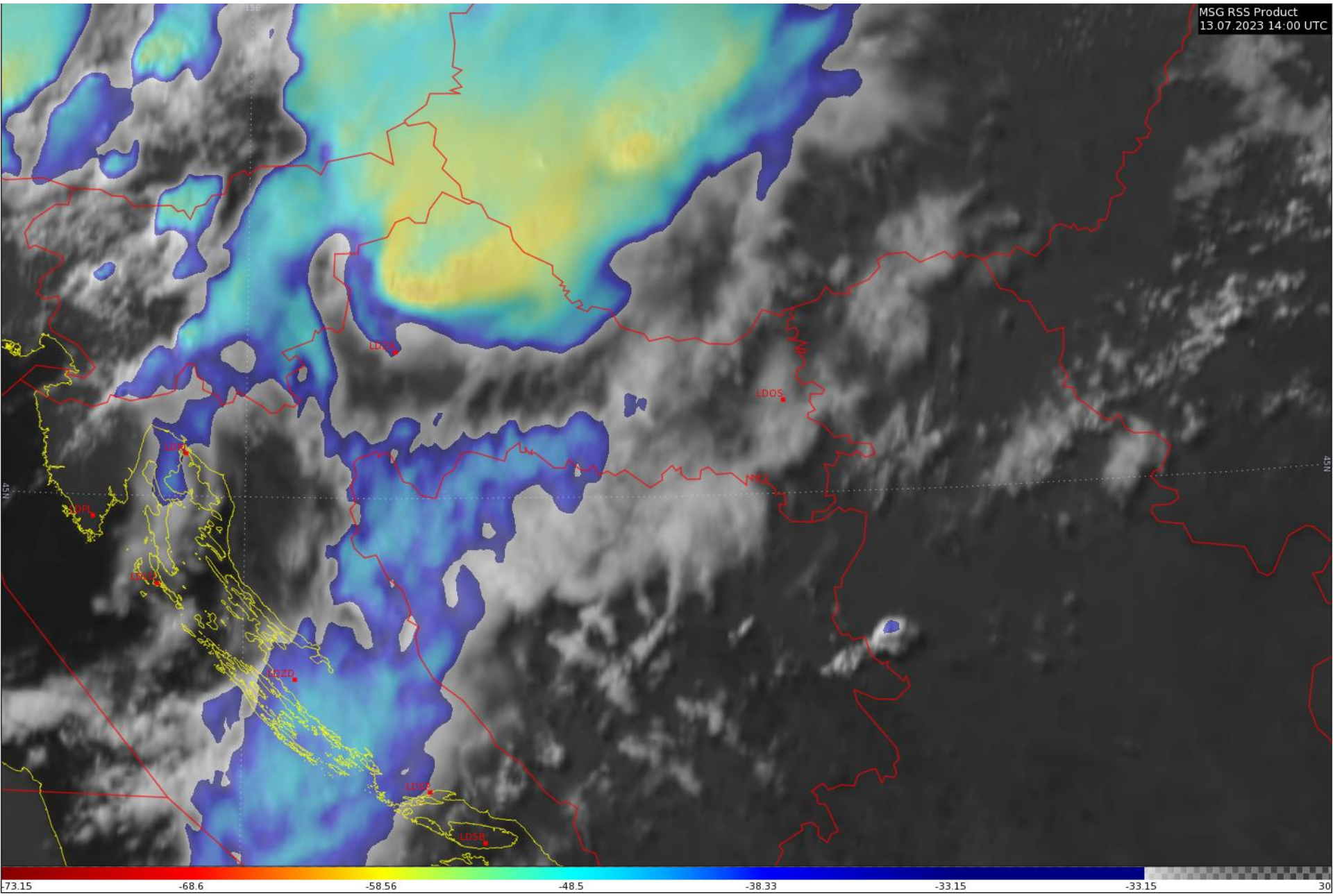
MSG RSS Product
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LDOS
LDPL
LDZD
LDSB
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45N
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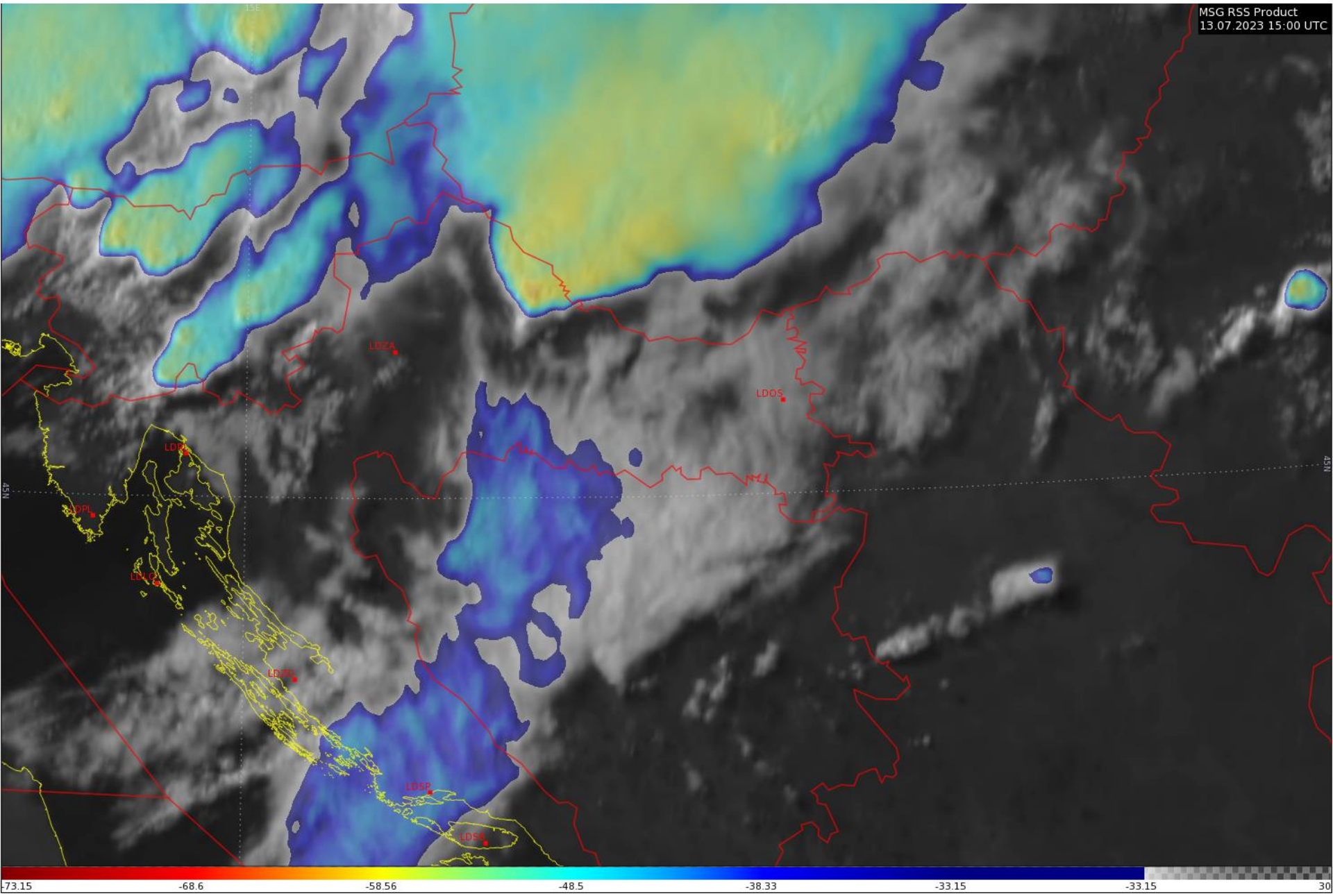
-68.6
-58.56
-48.5
-38.33
-33.15
-33.15
30


MSG RSS Product
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LDOS
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45N
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-58.56
-48.5
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-33.15
-33.15
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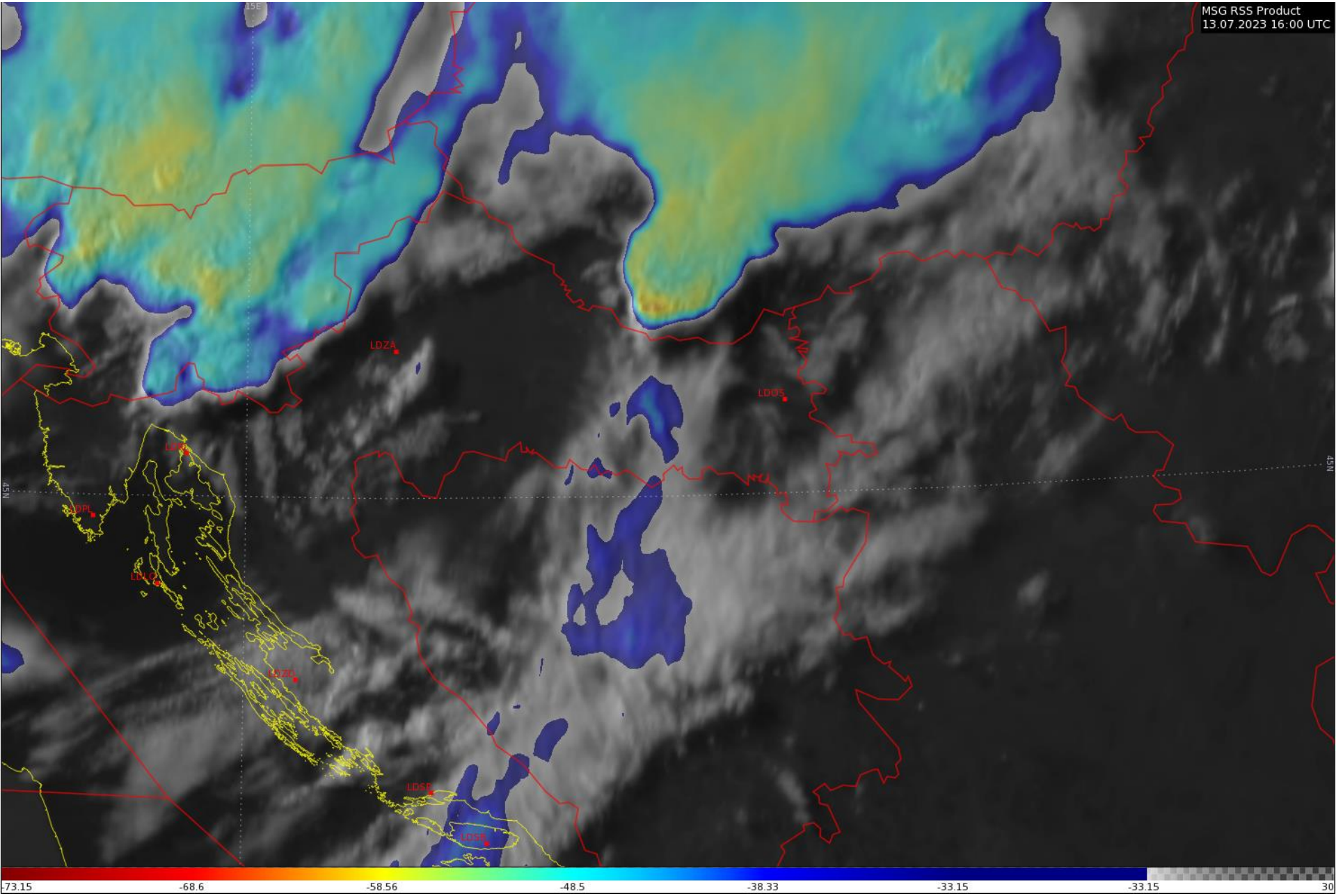
MSG RSS Product
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-38.33
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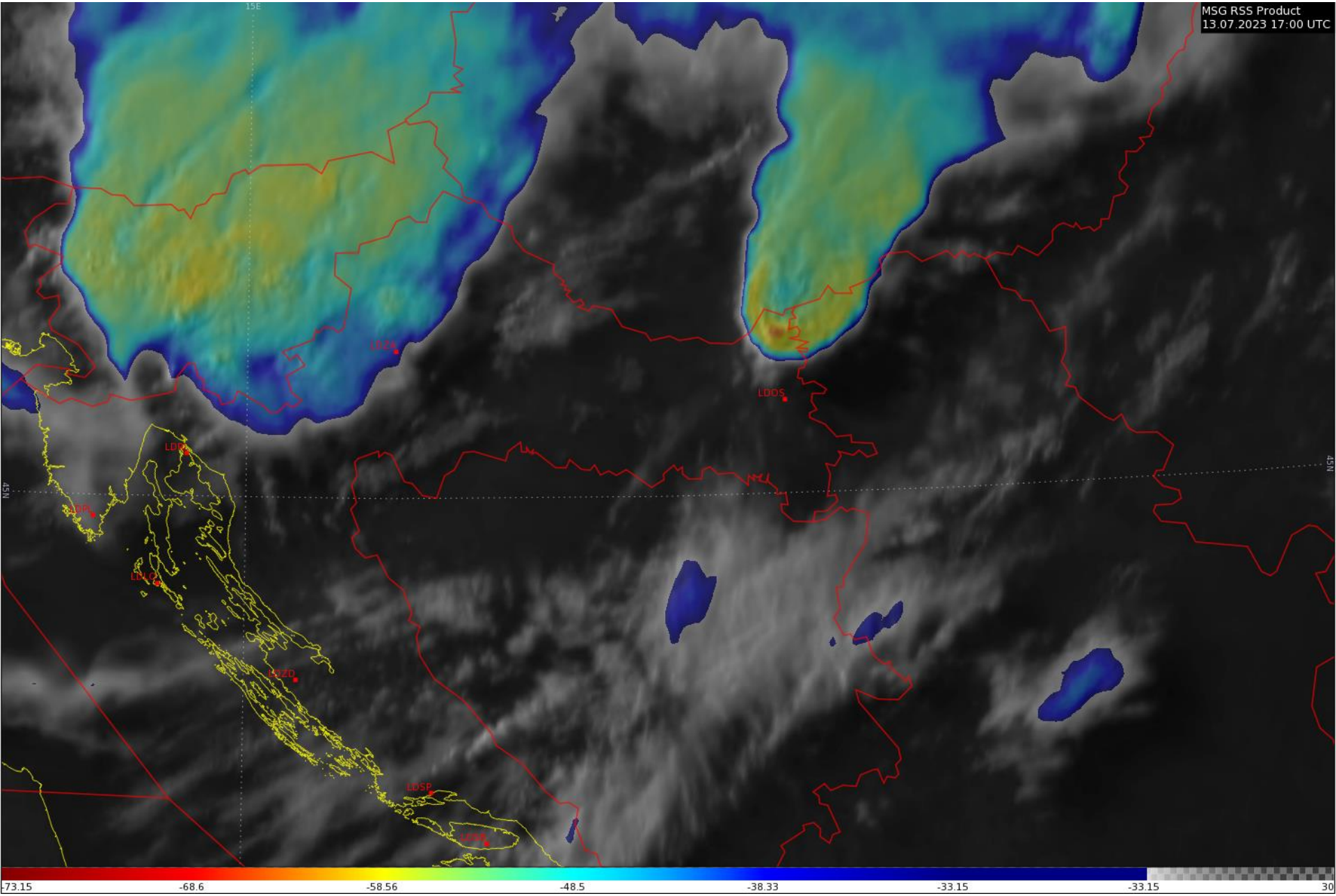
MSG RSS Product
13.07.2023 17:00 UTC
15E
45N
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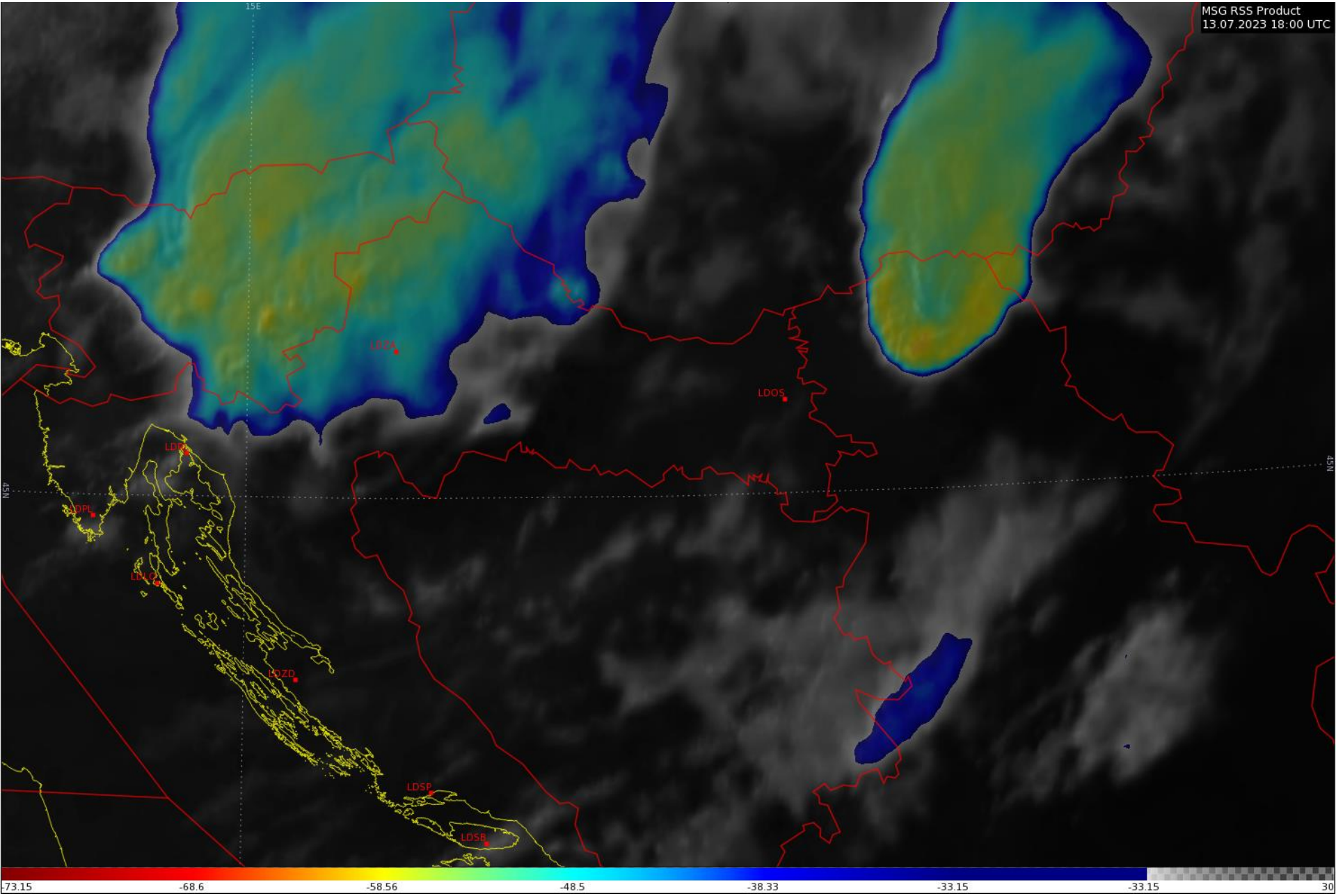
MSG RSS Product
13.07.2023 18:00 UTC
15E
45N
LDZA
LDOS
LDPL
LDLO
LDZD
LDSP
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-73.15
-68.6
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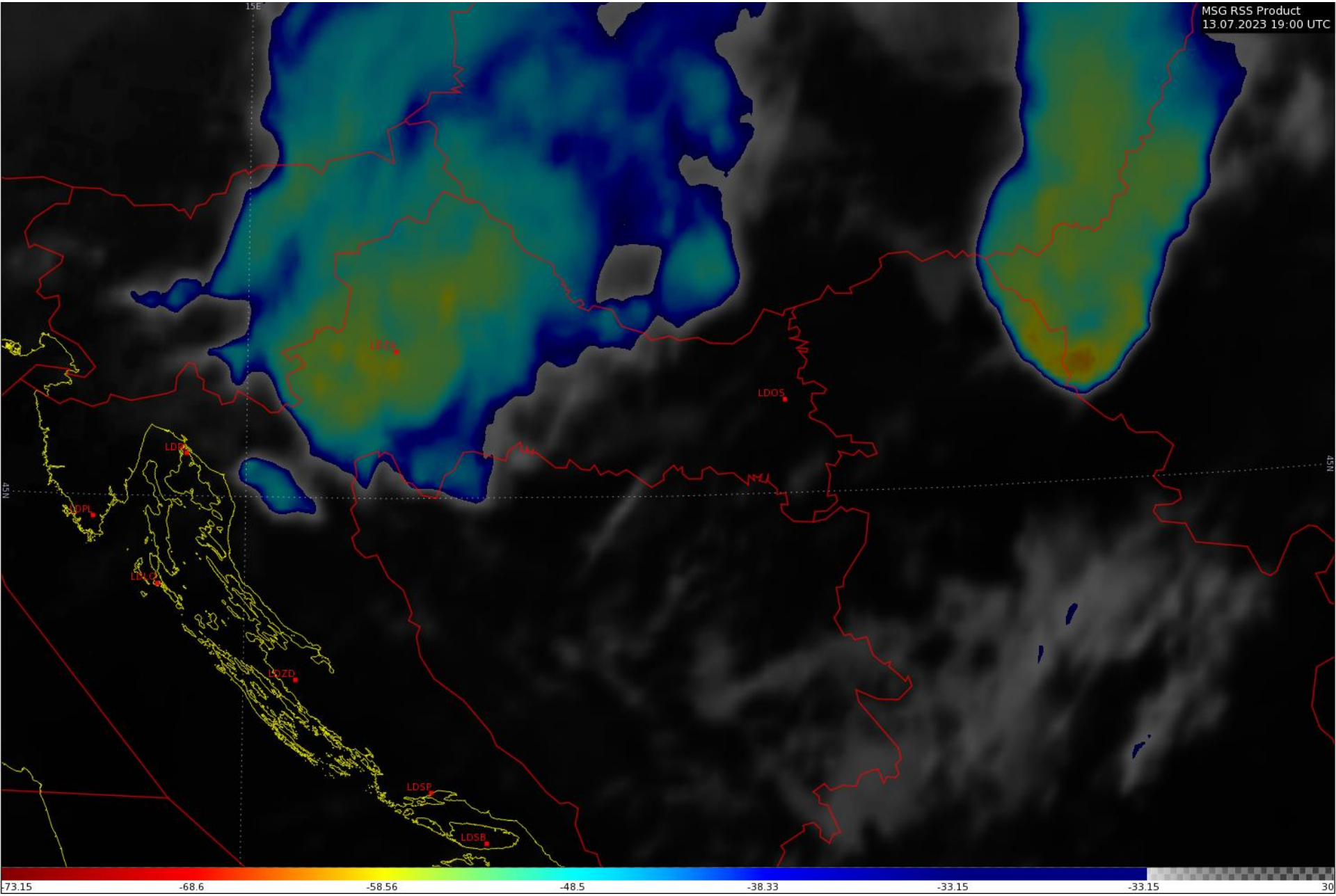
30


MSG RSS Product
13.07.2023 19:00 UTC
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LDPL
LDLO
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LDSB
-73.15
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-48.5
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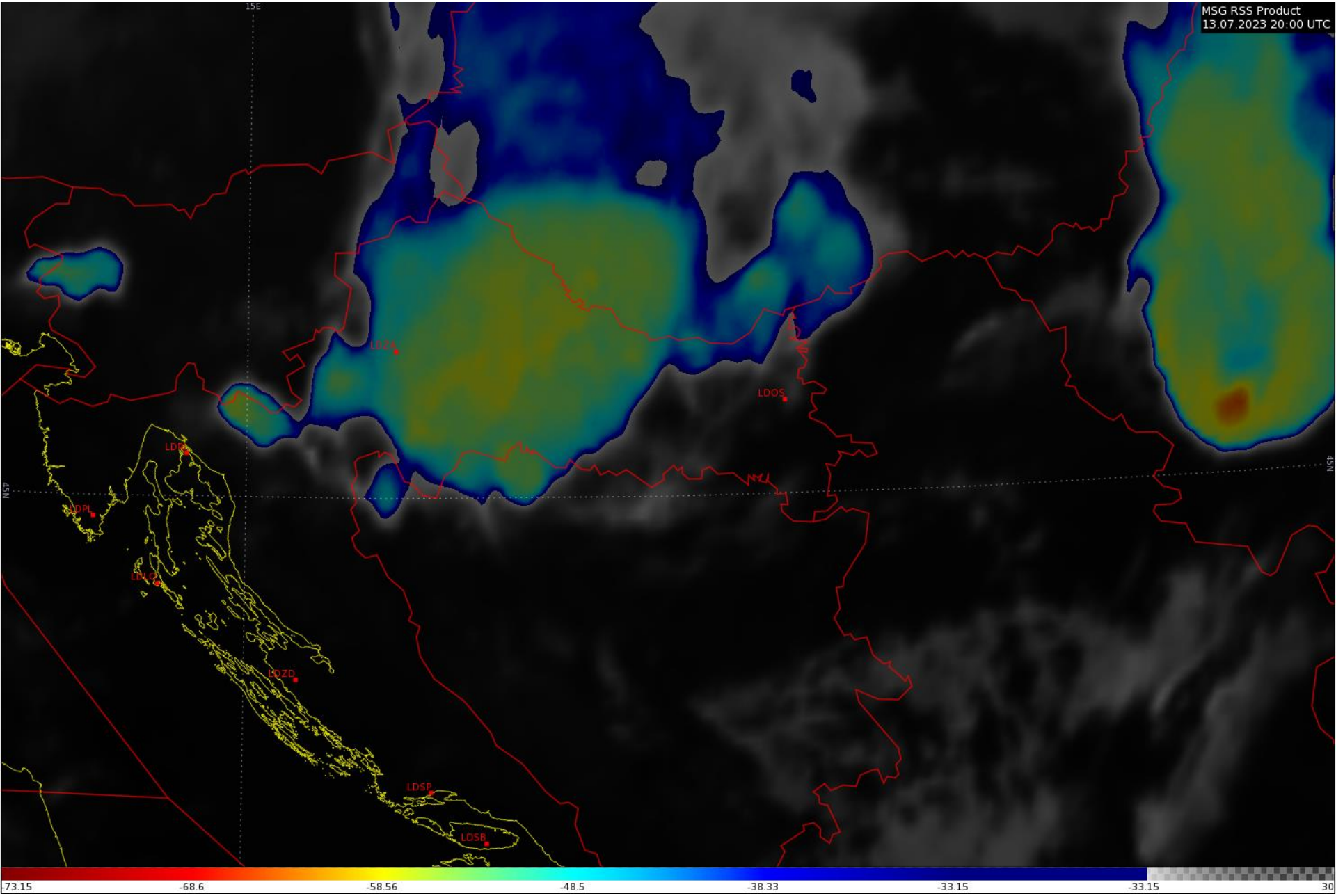
30


MSG RSS Product
13.07.2023 20:00 UTC
15E
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LDLO
LDZD
LDSP
LDSB
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-68.6
-58.56
-48.5
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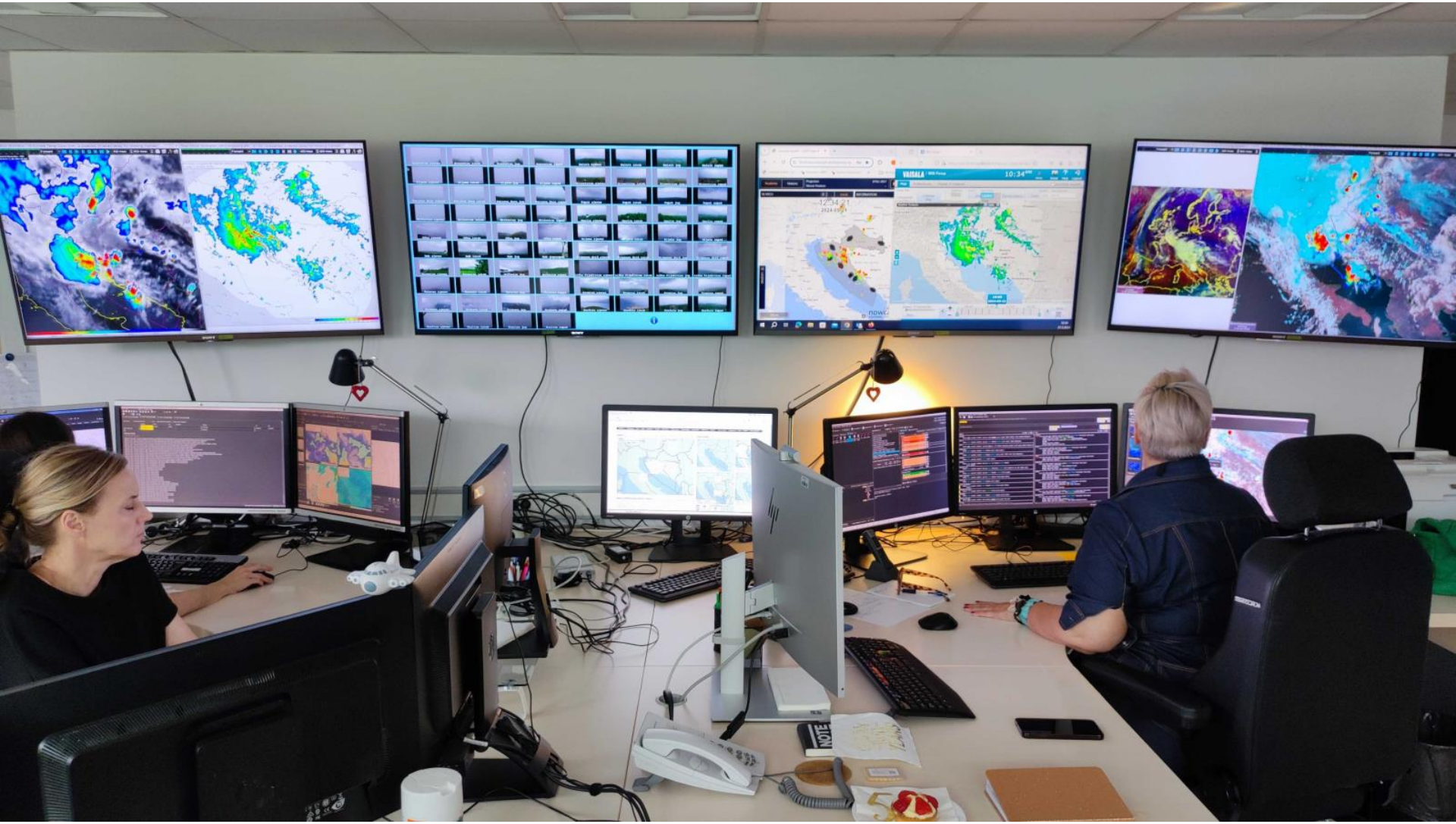
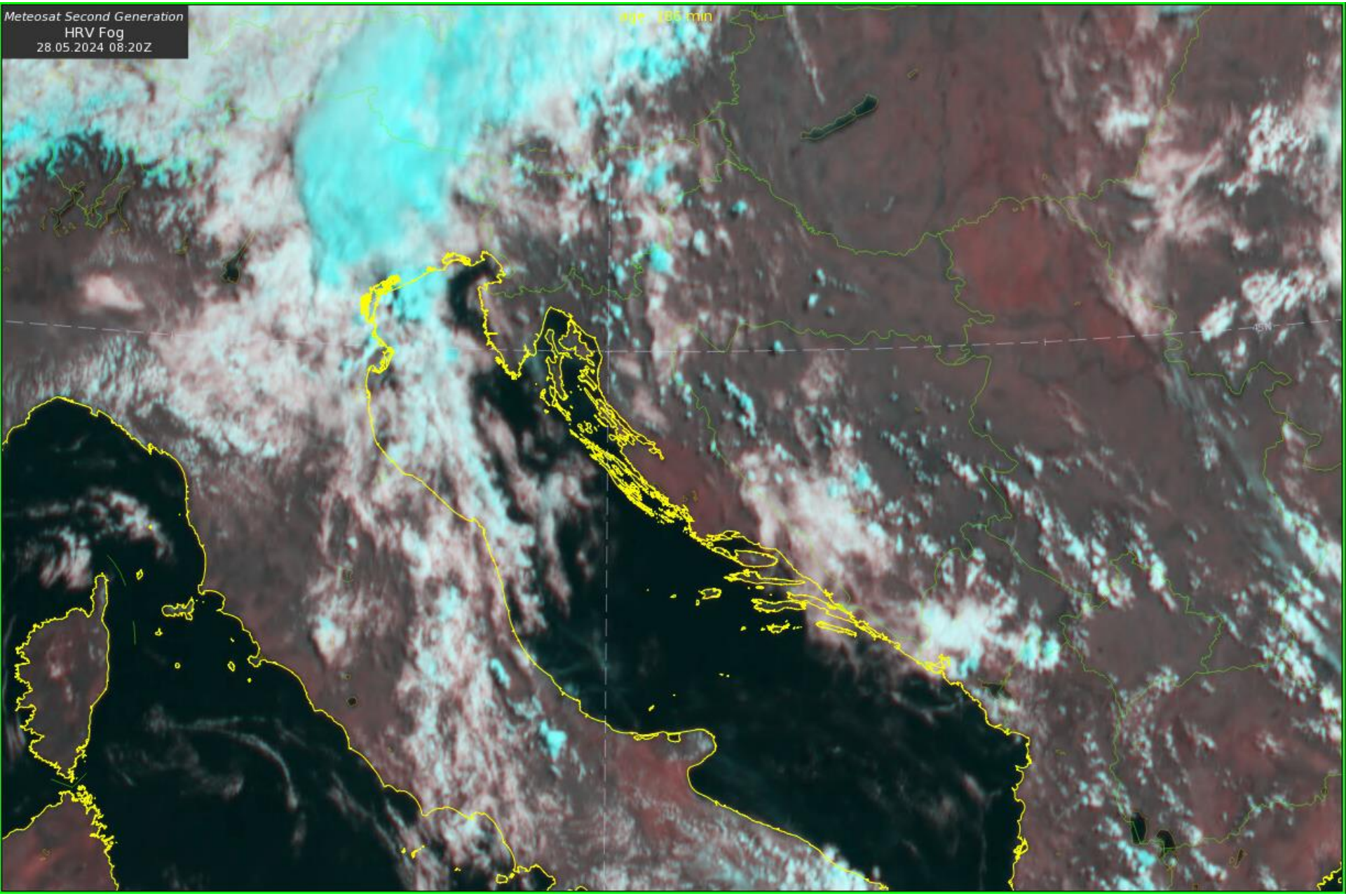
-33.15
-33.15
30

DMC Monitoring and Nowcasting

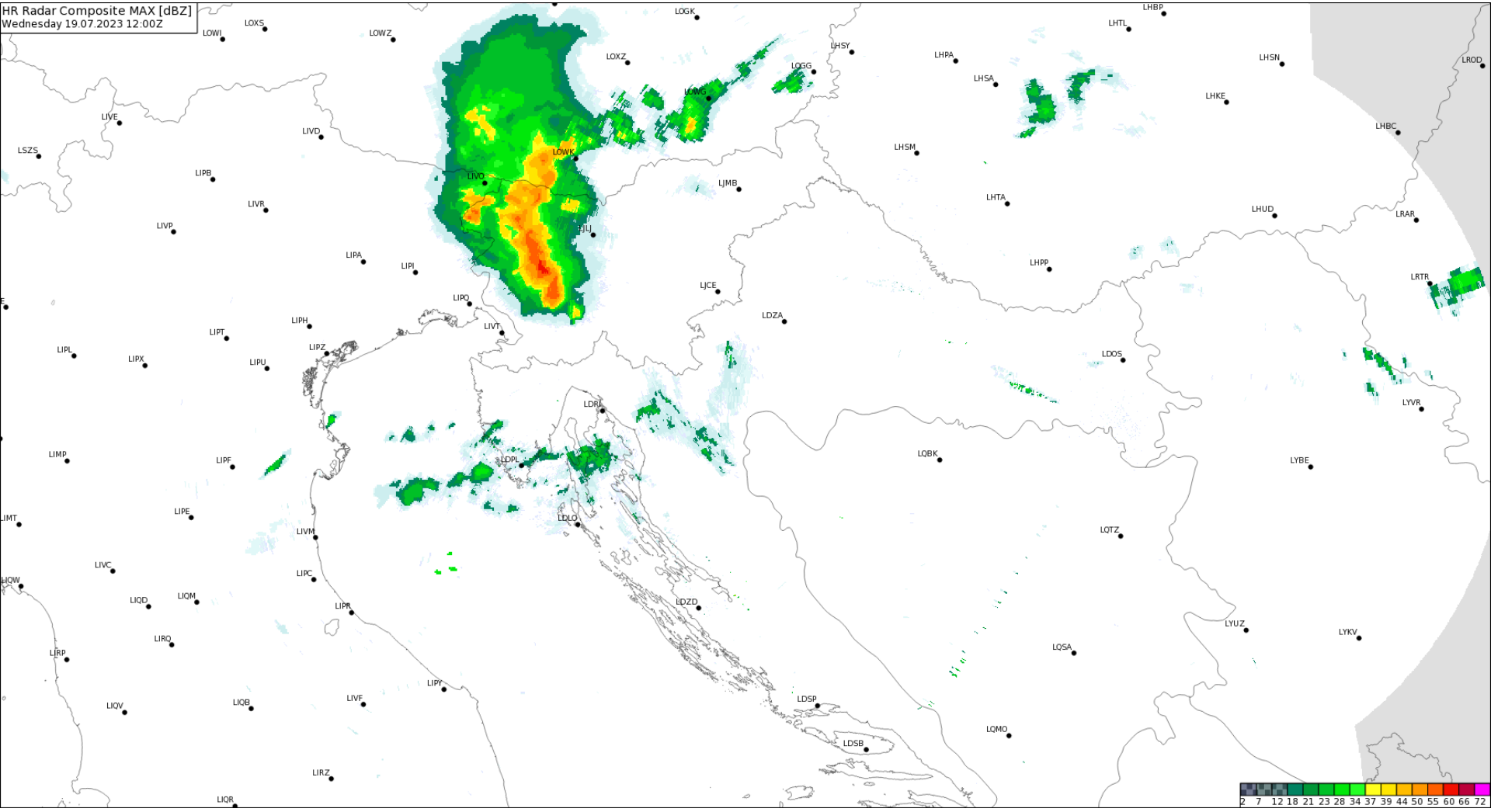



Meteosat Second Generation
HRV Fog
28.05.2024 08:20Z
age: 186 min

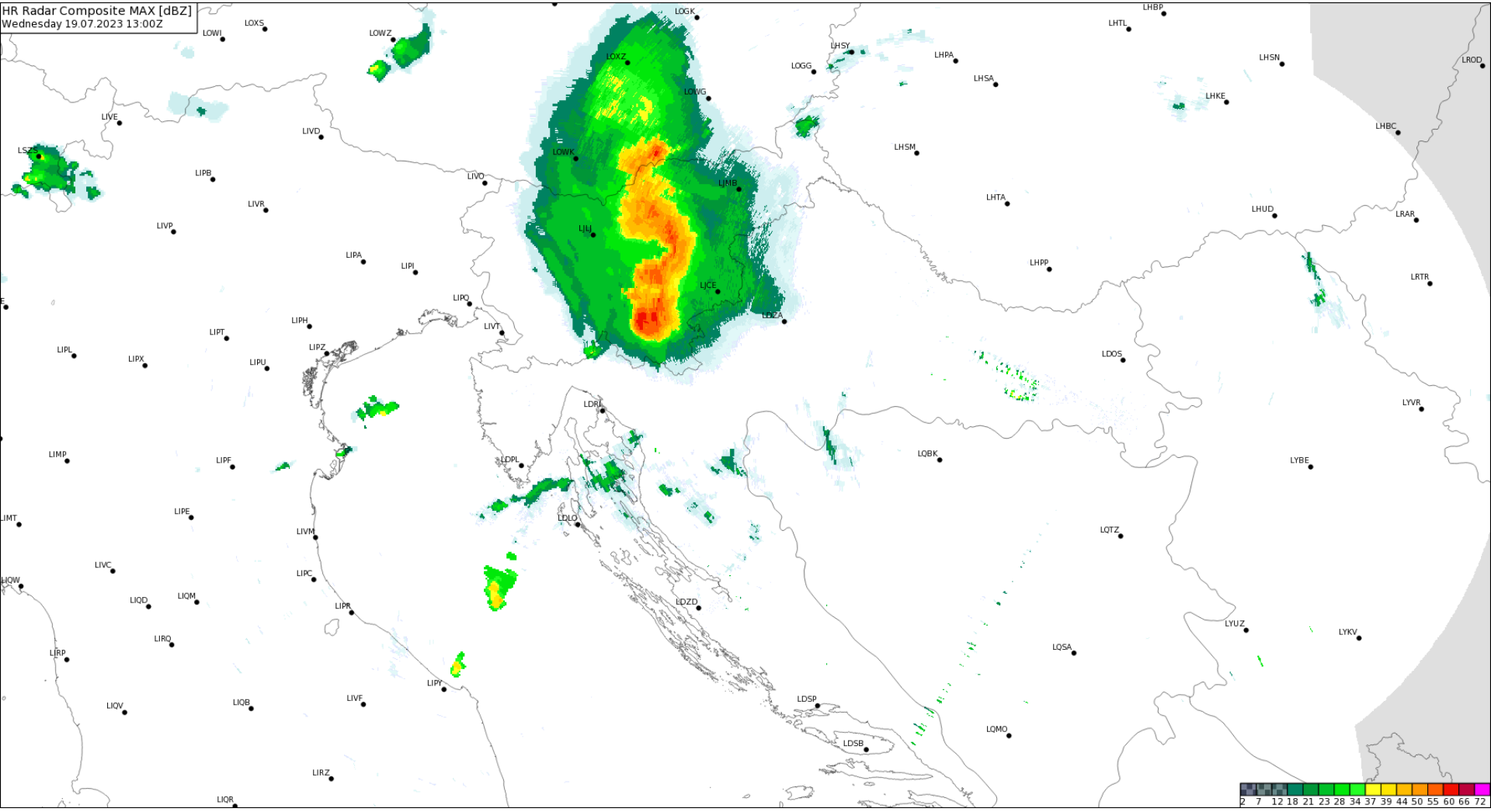
Nowcasting considerations

- multicells and supercells (RM) usually deviate right from the mean wind (0-6km) although they have different propagation mechanisms
- **It is important to observe spatial distribution of ingredients, as well as changes of those ingredients in time (NWP)!**
- e.g. storm moving to an area with less CAPE or SHEAR will likely become less organized or dissipate

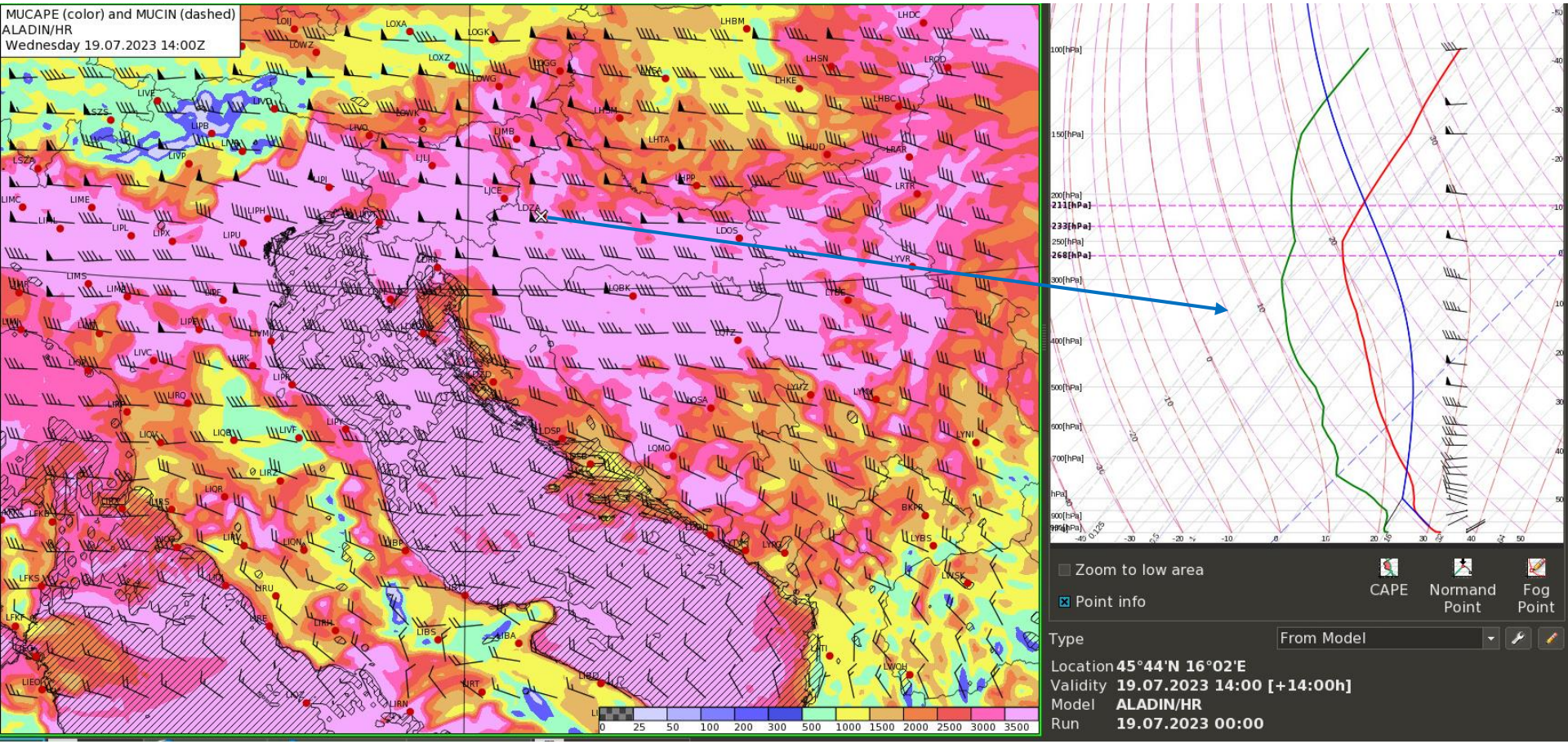
Radar composite 12Z 19.7.2023.



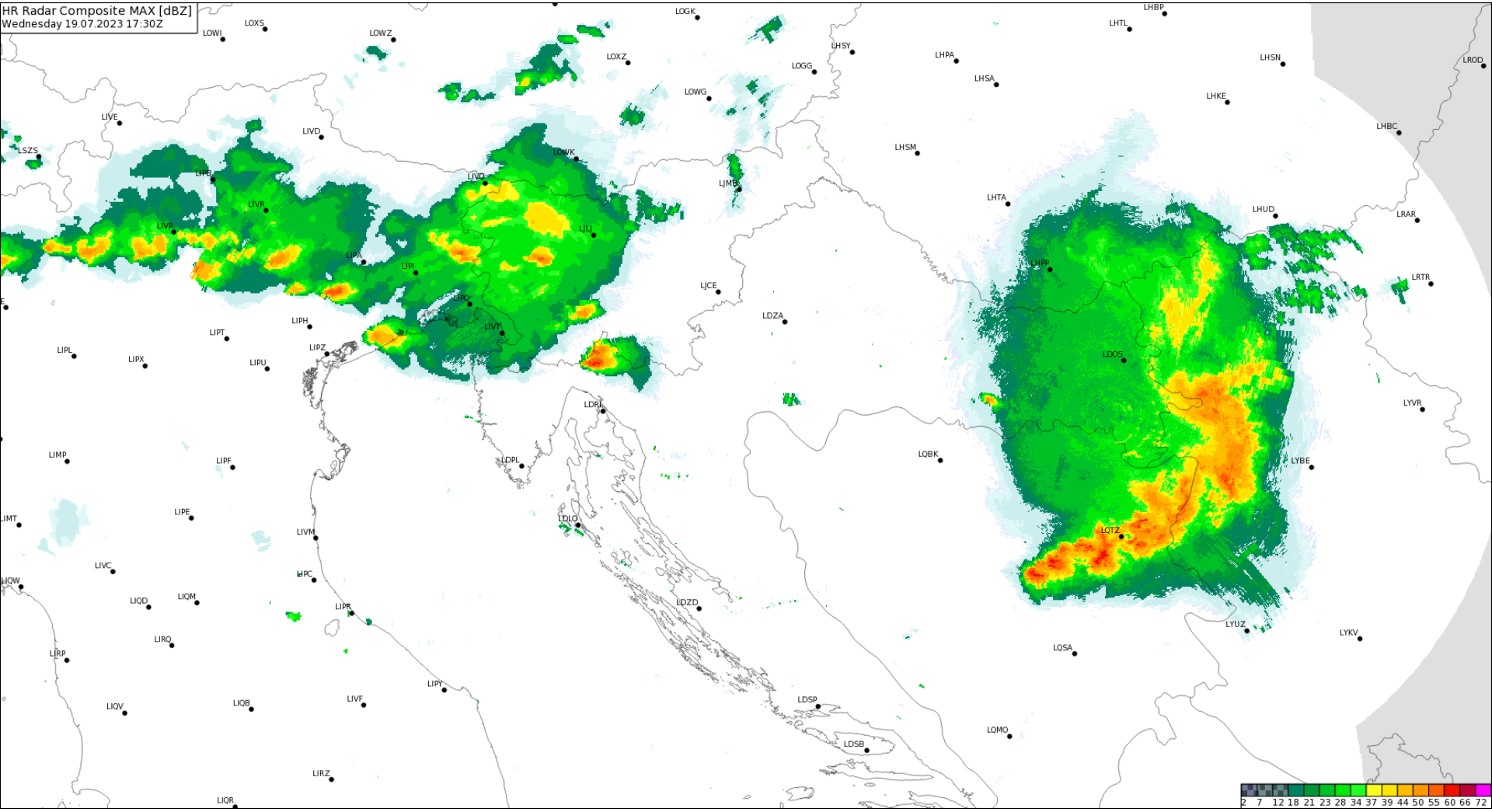
Radar composite 13Z 19.7.2023.



MUCAPE and DLS 14Z 19.7.2023.



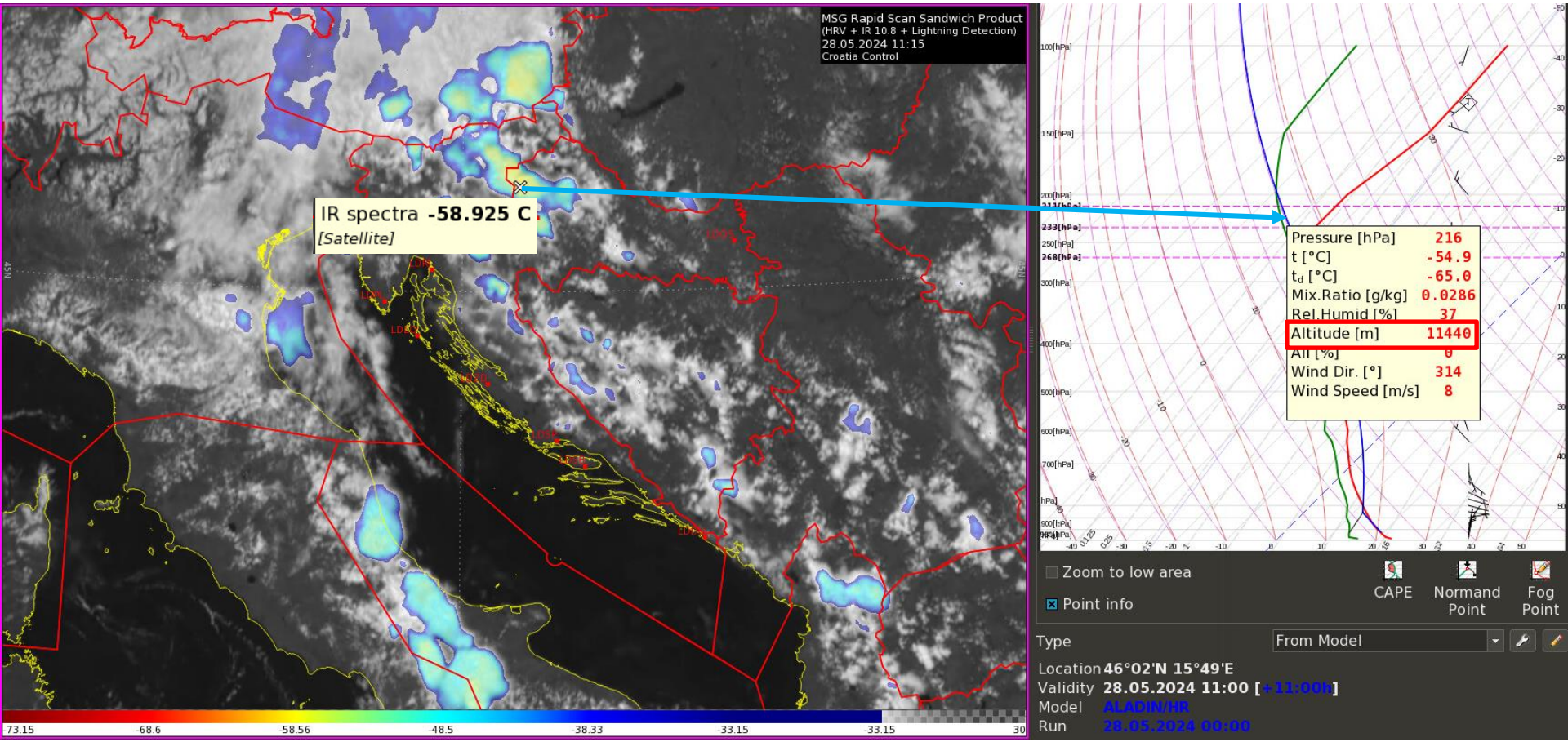
Radar composite 17:30Z 19.7.2023.

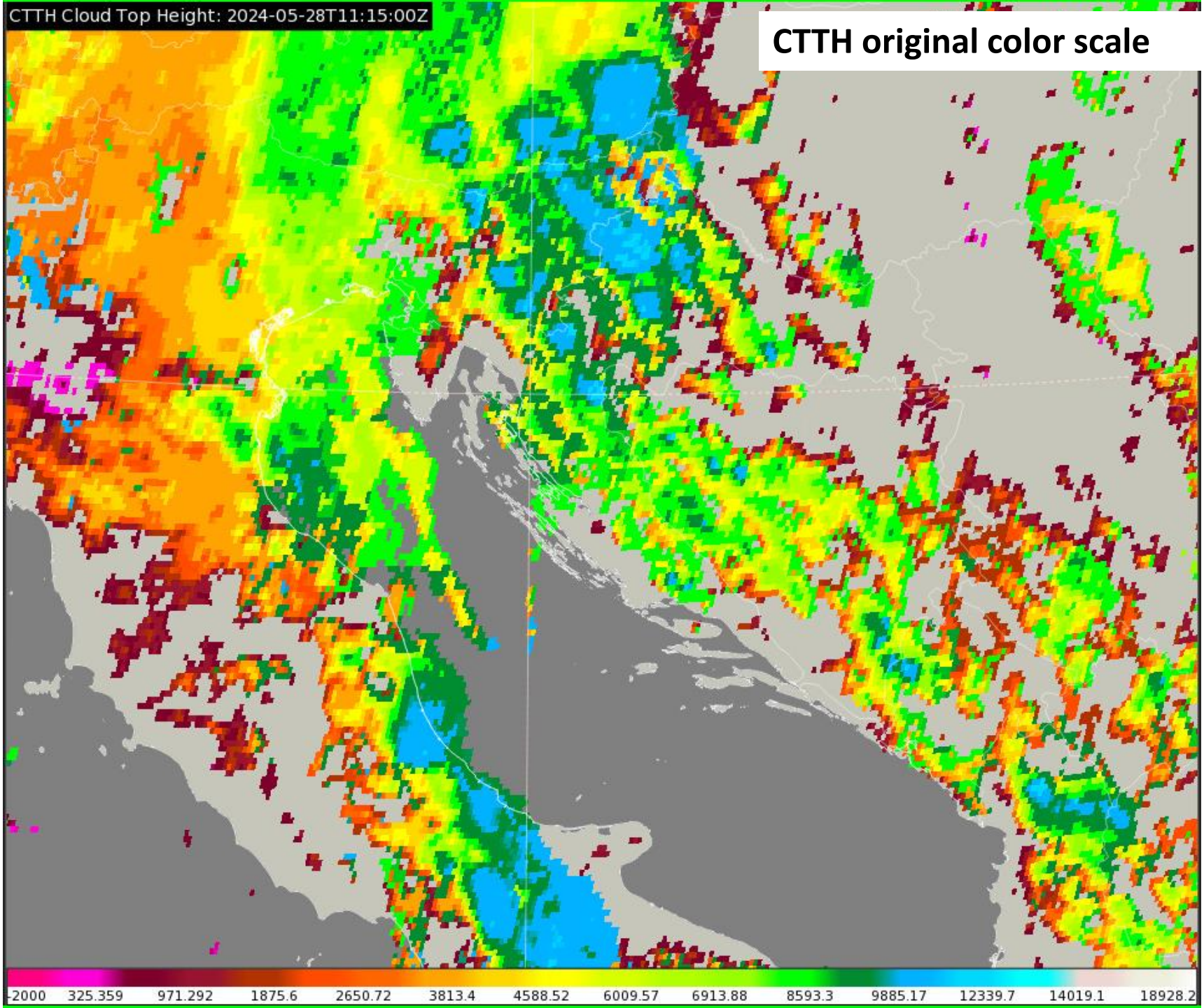


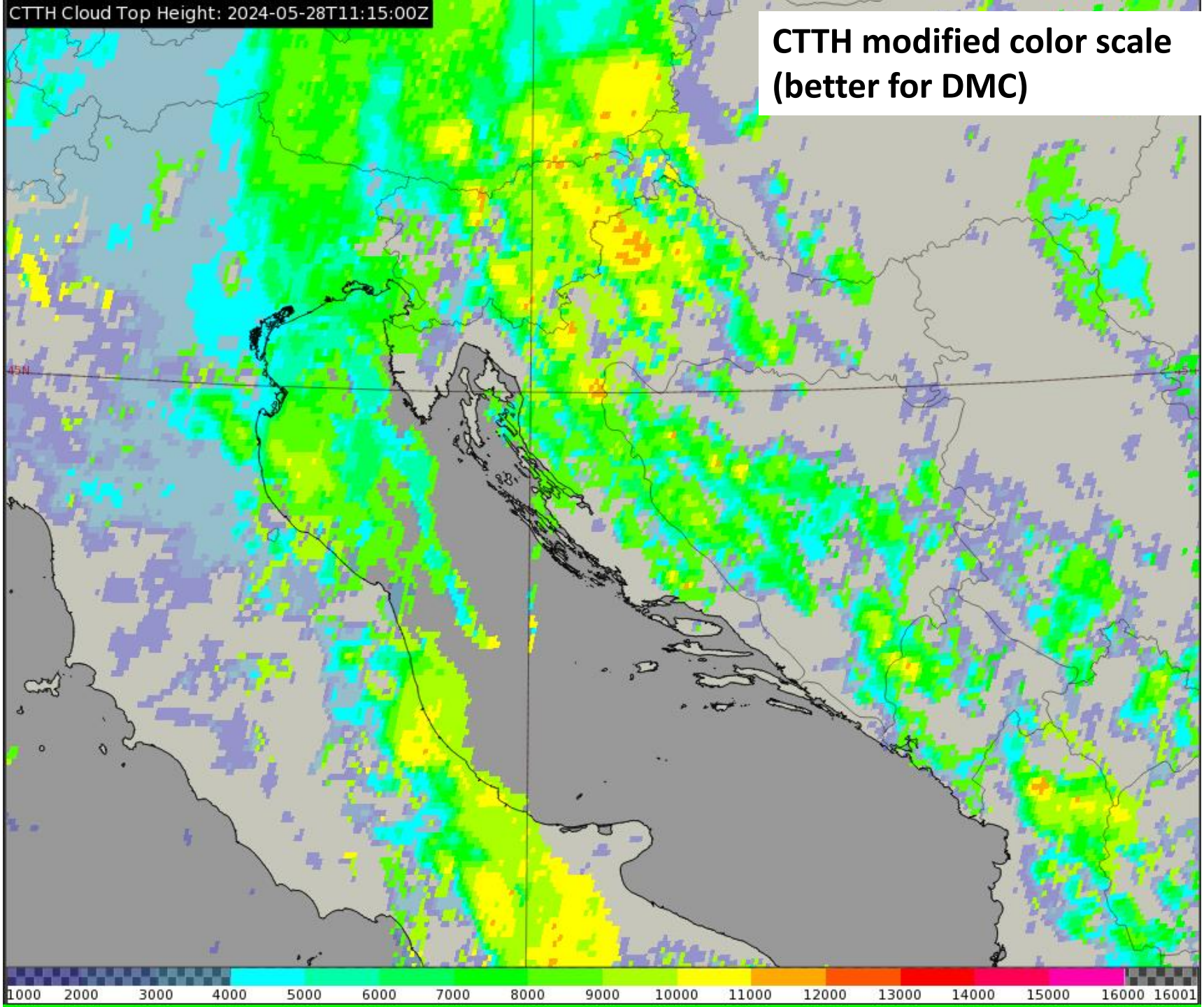
Diagnosing Cb top heights

- Manual method from IR BT + NWP profiles
- NWC SAF CTTH - Cloud Top Temperature and Height (pressure or altitude)
- Ground truth question always remains? How to verify Cb tops?

Manual IR BT + NWP method




CTTH Cloud Top Height: 2024-05-28T11:15:00Z
CTTH original color scale
-2000
325.359
971.292
1875.6
2650.72
3813.4
4588.52
6009.57
6913.88
8593.3
9885.17
12339.7
14019.1
18928.2


CTTH Cloud Top Height: 2024-05-28T11:15:00Z
CTTH modified color scale
(better for DMC)
45N
1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000 12000 13000 14000 15000 16000 16001

Summary

- **FORECAST = DIAGNOSIS + TREND**
- Satellite products are very useful for analysis and diagnosis
- **An accurate diagnosis is essential for a skillful forecast (and nowcast)!**
- Ingredients and NWP guidance for trend part
- For nowcasting, radars are the primary tool, while satellite products provide the bigger picture

References

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