CROATIA CONTROL

Fast Approximation for Diagnosing Convective Cloud Top Heights

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Jadran Jurković

Why is Cb top height important?

HAIL

SEVERE TURBULENCE

SEVERE ICING

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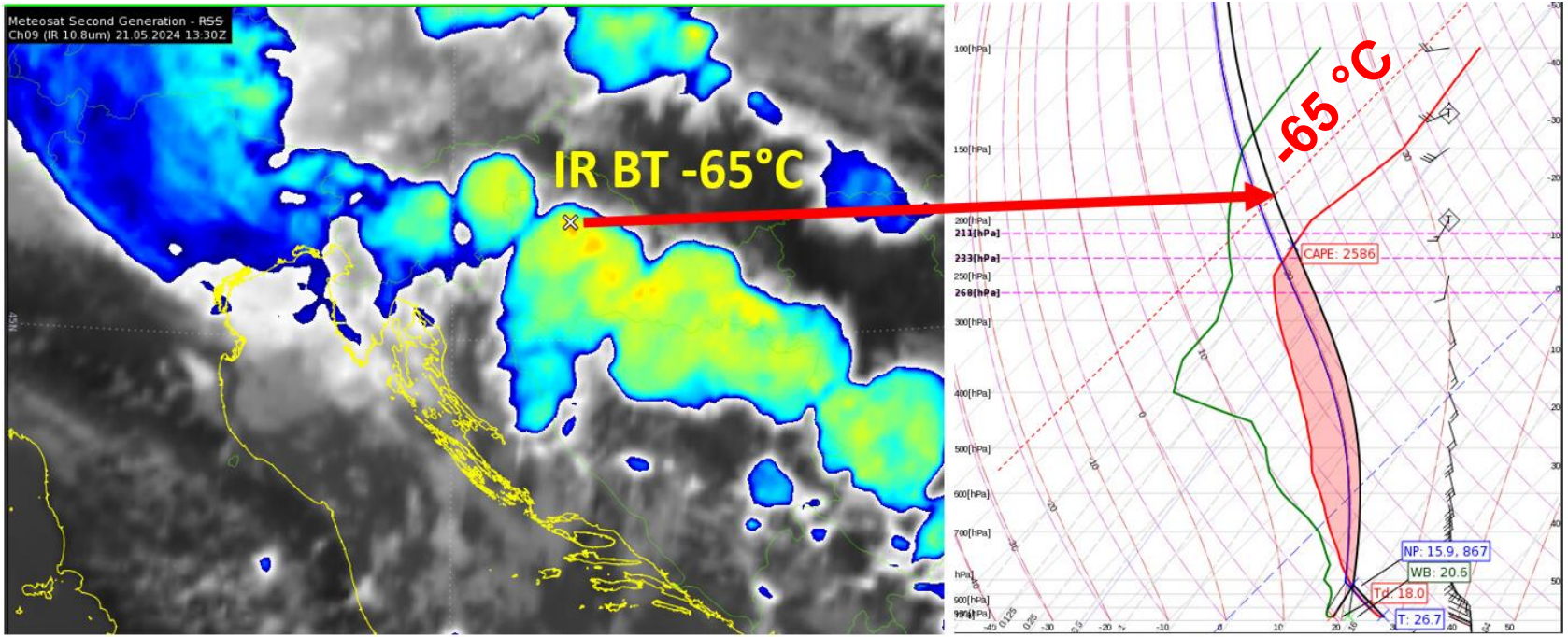
How to diagnose Cb top height?



Cb top pressure => standard atmosphere altitude in hectofeet = **Flight Level [FL]**

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Moist adiabat iterative calculation

$$e_s = e_o \exp\left[\frac{17.67(\quad 273.15\ \mathrm{K})}{T - 2\quad \mathrm{K}}\right] \qquad _s = \varepsilon e_s/(P - e_s).$$

$$b = [1 + (r/\varepsilon)]/[1 + (r/c)] \approx (\quad 0.24$$

or use the approximation $b \approx$

Bakhshaii and Stull 2013

$$\frac{\partial T}{\partial P} = \left(\frac{b}{P}\right) \frac{R_d T + L_v r_s}{C_{\mathrm{pd}} + \frac{L_v^2 r_s \varepsilon}{R}}$$

All this nee to be calculated for each small pr ure increment *ΔP* !

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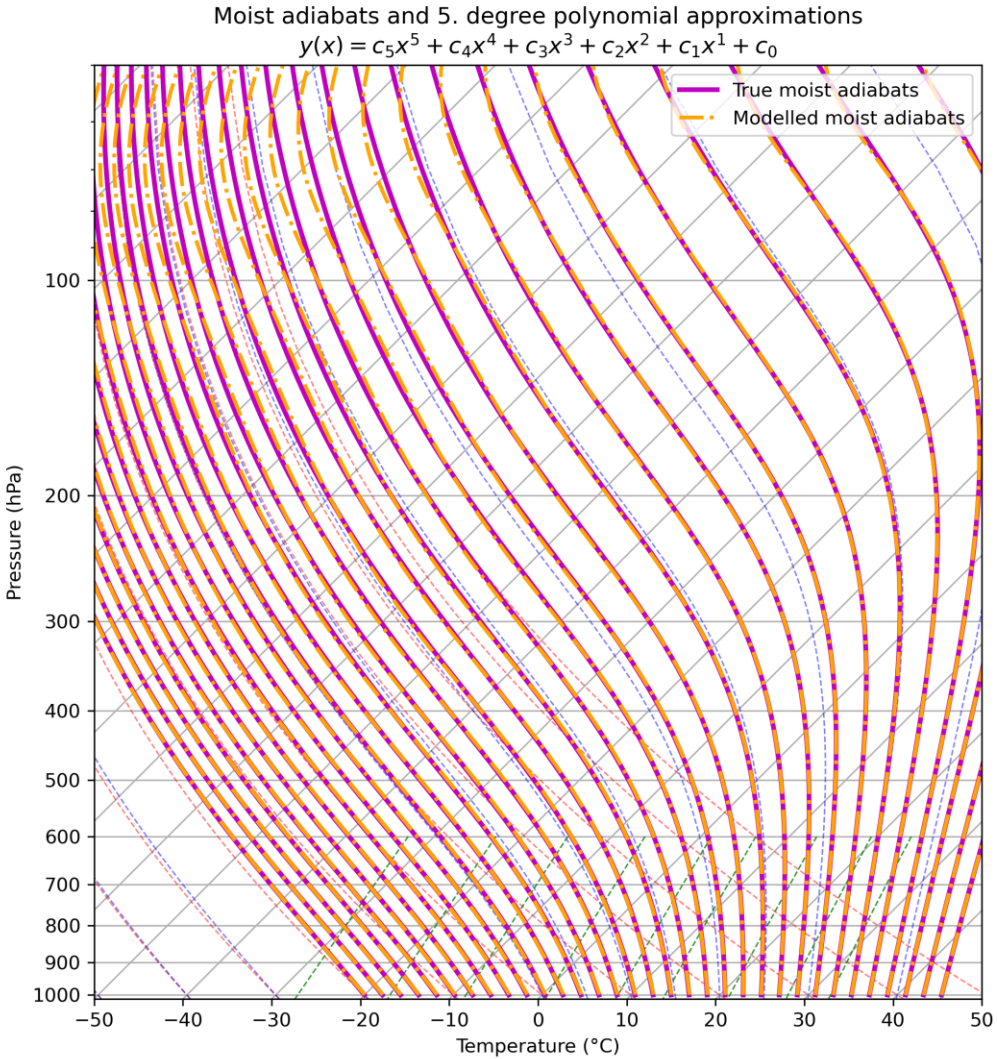

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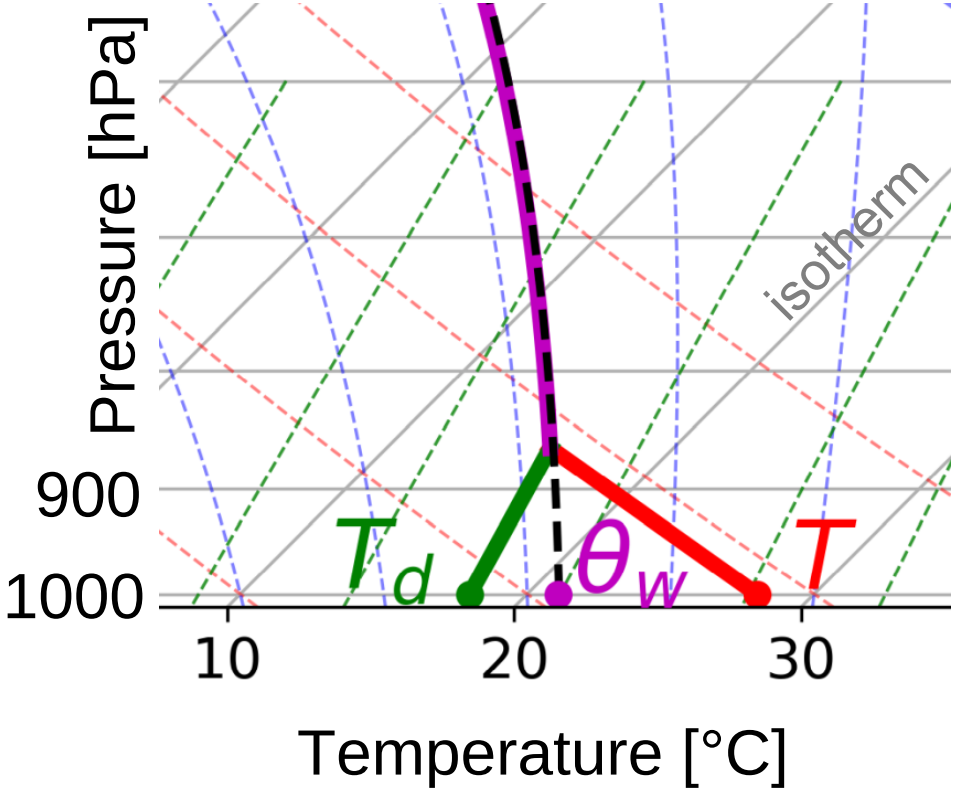
T and T_d represented as wet bulb potential temperature θ_w



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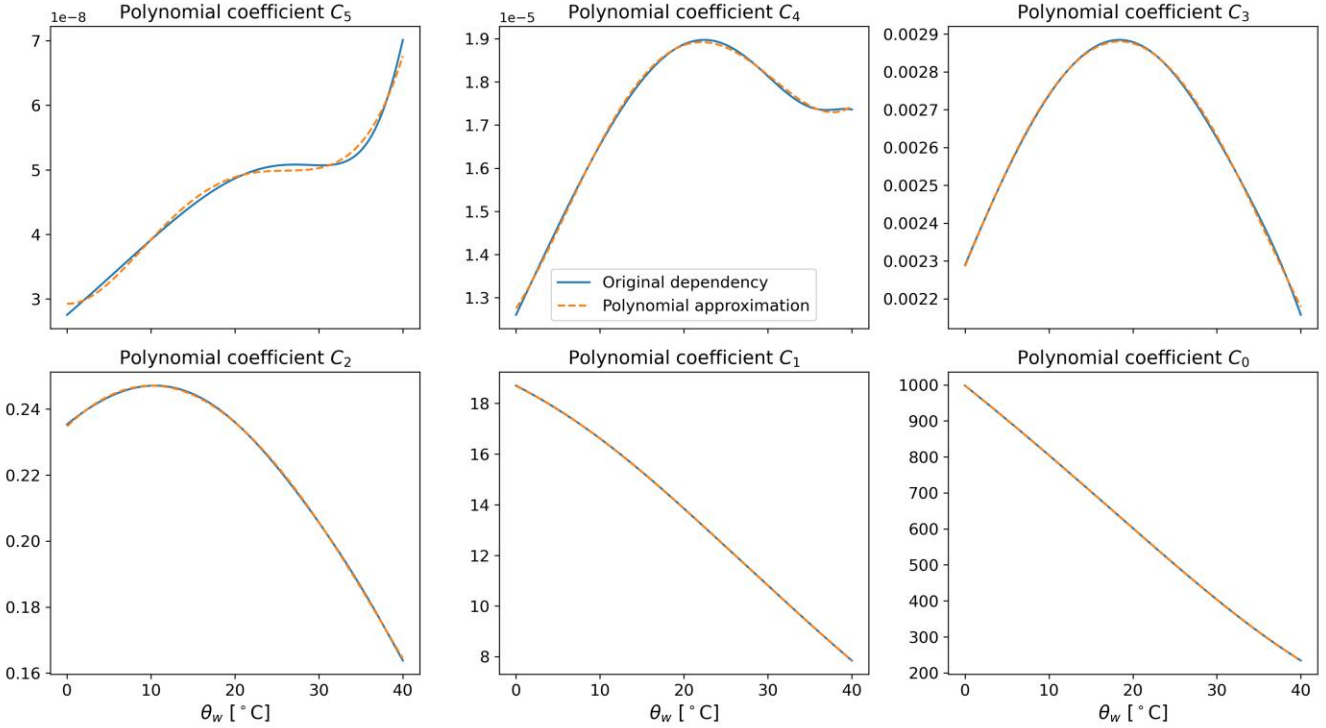
Moist adiabat fast approximation

- **Moist adiabat shape changes with wet bulb potential temperature ($\boldsymbol{\theta_w}$) !**
- Every polynomial coefficient (6 of them in total) can be modelled as a function of $\boldsymbol{\theta_w}$

$$p(t) = C_5(\theta_w)t^5 + C_4(\theta_w)t^4 + C_3(\theta_w)t^3 + C_2(\theta_w)t^2 + C_1(\theta_w)t + C_0(\theta_w)$$

Approximation Coefficients vs θ_w

$$p(t) = C_5(\theta_w)t^5 + C_4(\theta_w)t^4 + C_3(\theta_w)t^3 + C_2(\theta_w)t^2 + C_1(\theta_w)t + C_0(\theta_w)$$



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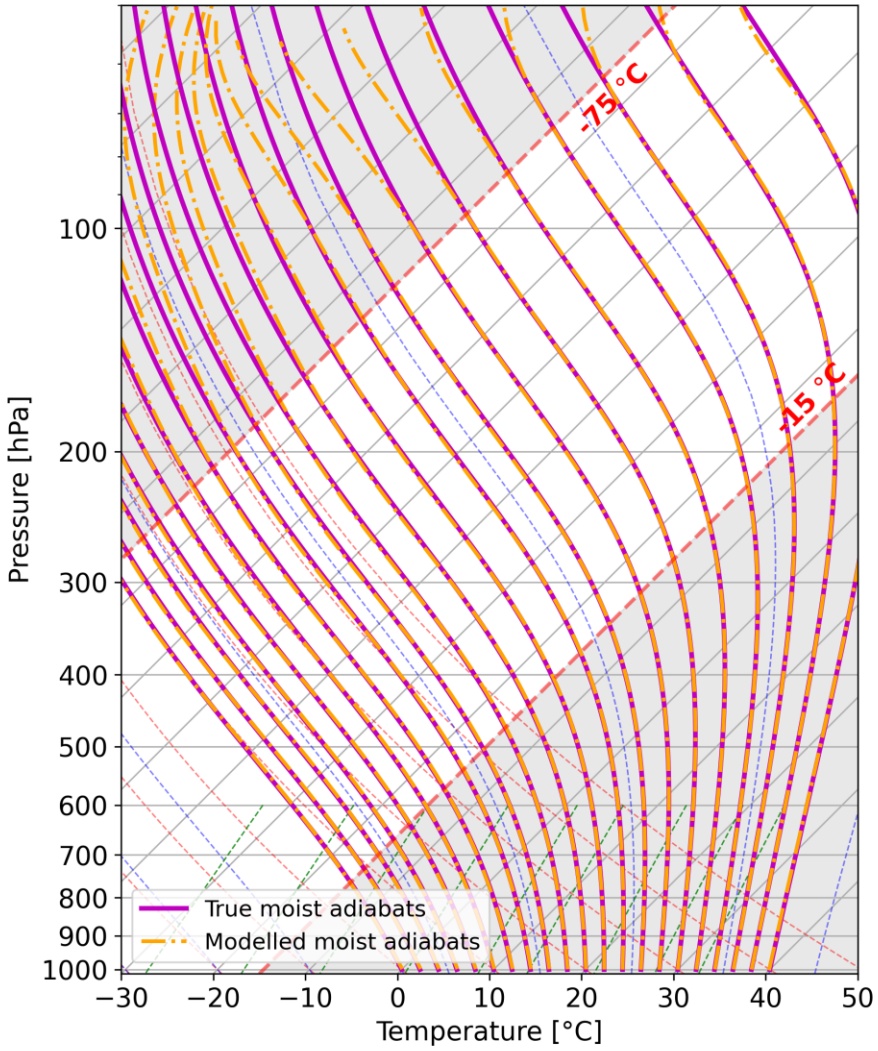
$$C_i(\theta_w) = \sum_{j=0}^{4} a_{ij}\theta_w^j$$

4th degree approximation

$$p(t, \theta_w) = \sum_{i=0}^{5} C_i(\theta_w)t^i$$



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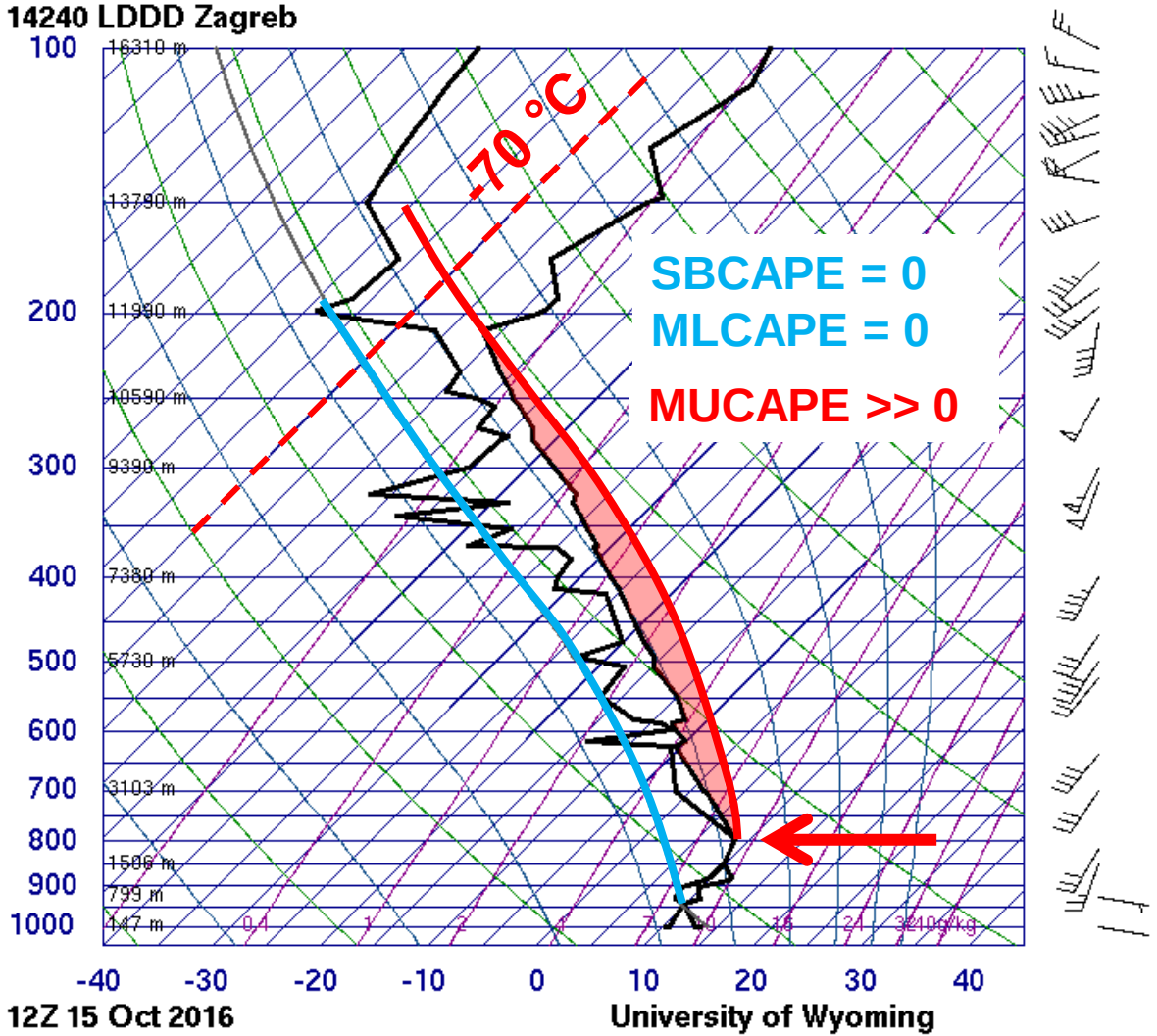
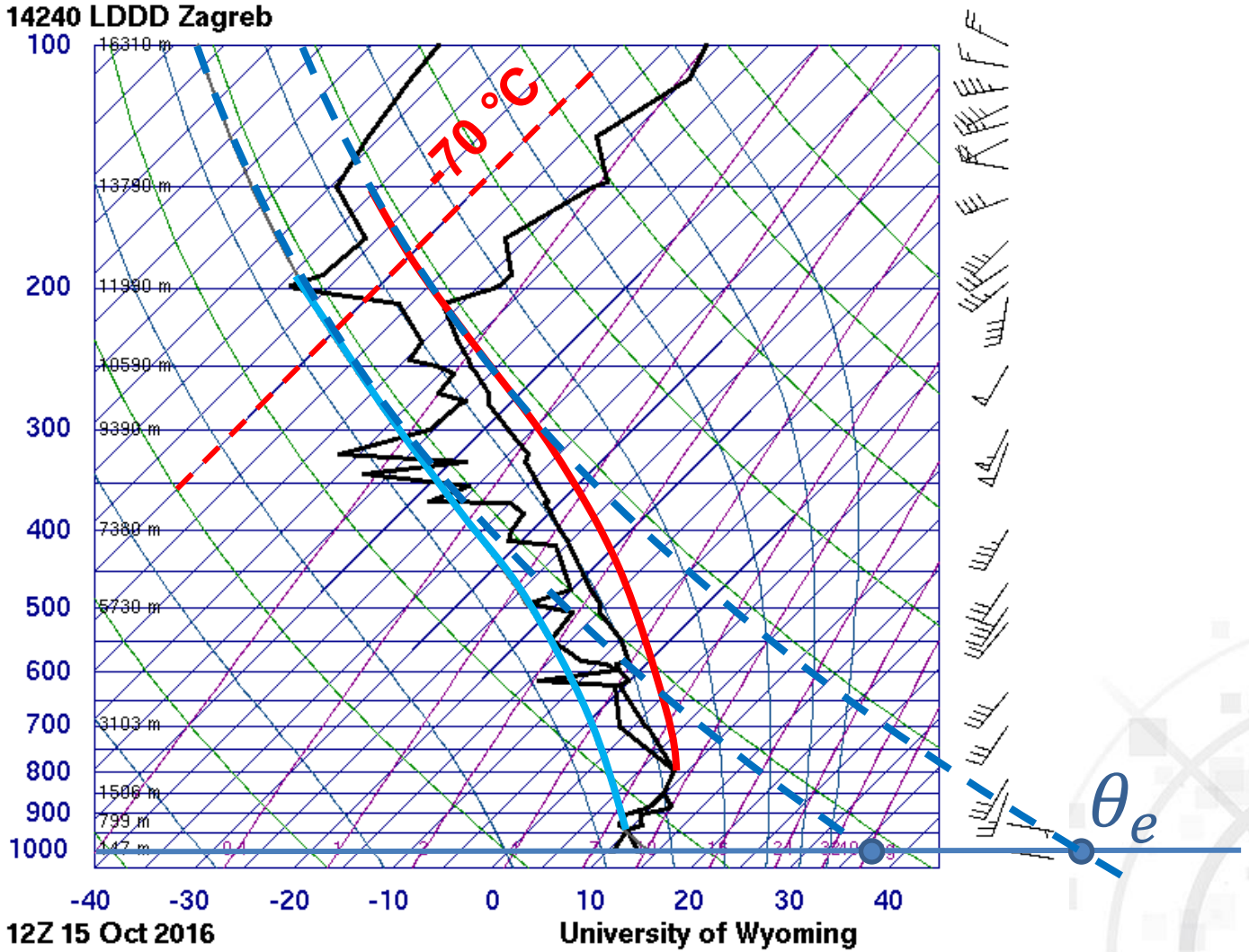
CCTH Calculation procedure

C_i	a_{i0}	a_{i1}	a_{i2}	a_{i3}	a_{i4}
C_0	9.981118e+02	-1.865352e+01	-7.228945e-02	-1.288899e-04	4.152094e-05
C_1	1.868462e+01	-1.584316e-01	-5.652978e-03	7.782649e-05	-1.697159e-07
C_2	2.347380e-01	2.461856e-03	-1.223192e-04	-1.929728e-07	1.532080e-08
C_3	2.285961e-03	5.360970e-05	-2.299950e-07	-6.829626e-08	9.717708e-10
C_4	1.275047e-05	2.984764e-07	1.986974e-08	-1.344314e-09	1.835750e-11
C_5	2.928147e-08	-7.653230e-11	1.876537e-10	-9.439792e-12	1.349002e-13

T, T_d [°C], p [hPa] => θ_e (Bolton's 1980 formulas), θ_e=> θ_w (Davies-Jones 2008 formula). Six C_i coefficients are calculated using values from the Table 1. and θ_w[°C] as follows:

$$C_i(\theta_w) = \sum_{j=0}^{4} a_{ij}\,\theta_w^j \quad \Rightarrow \quad p(t) = \sum_{i=0}^{5} C_i(\theta_w)\,t^i$$


14240 LDDD Zagreb
100
200
300
400
500
600
700
800
900
1000
16310 m
13790 m
11980 m
10590 m
9390 m
7380 m
5730 m
3103 m
1506 m
799 m
447 m
-70 °C
SBCAPE = 0
MLCAPE = 0
MUCAPE >> 0
-40
-30
-20
-10
0
10
20
30
40
12Z 15 Oct 2016
University of Wyoming


14240 LDDD Zagreb
100
200
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16310 m
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11980 m
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9390 m
7380 m
5730 m
3103 m
1506 m
799 m
-70 °C
-40
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-20
-10
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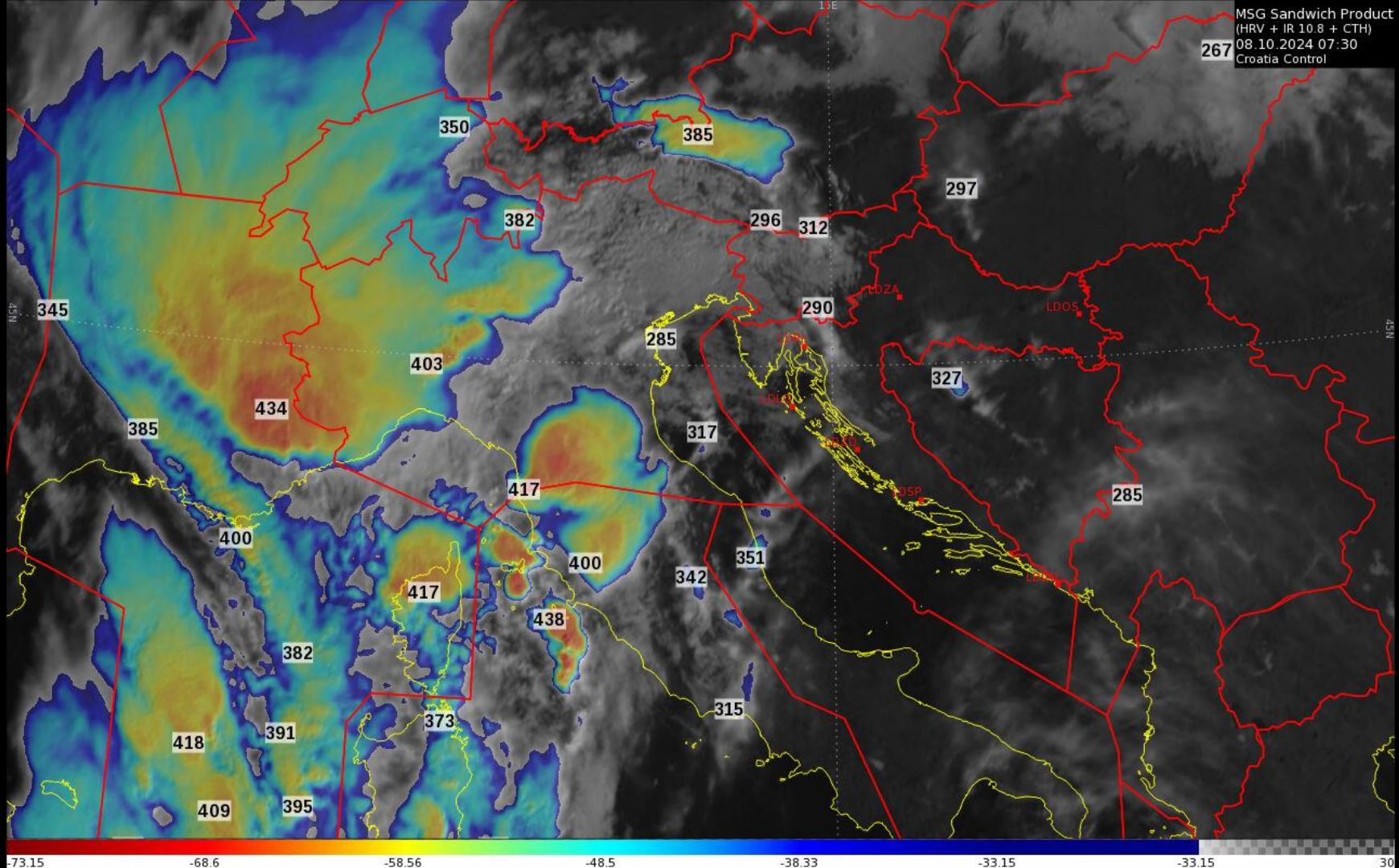
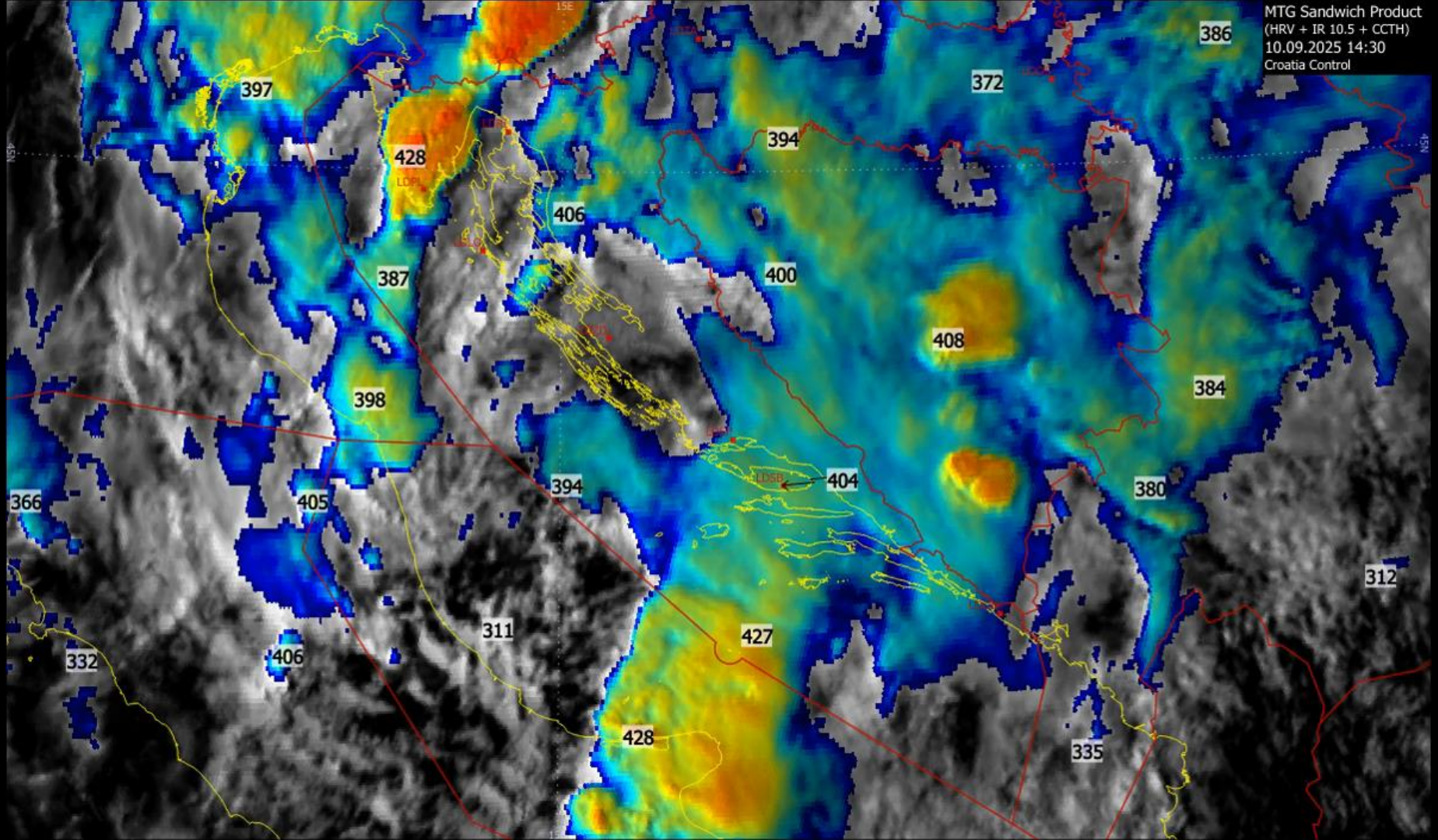
10
20
30
40
12Z 15 Oct 2016
University of Wyoming
θ_e


MSG Sandwich Product
(HRV + IR 10.8 + CTH)
08.10.2024 07:30
Croatia Control
15E
45N
LDZA
LDOS
LDSP
267
297
350
385
382
296
312
345
290
285
403
327
434
385
317
417
285
400
351
400
342
417
438
382
315
373
418
391
409
395
-73.15
-68.6
-58.56
-48.5
-38.33
-33.15
-33.15
30


MTG Sandwich Product
(HRV + IR 10.5 + CCTH)
10.09.2025 14:30
Croatia Control
386
372
397
428
394
406
387
400
408
398
384
394
404
366
405
380
312
311
427
332
406
428
335

Comparison with other cloud top height products

- **CCTH** (**C**onvective **C**loud **T**op **H**eight)

vs

- **NWC SAF CTTH** (**C**loud **T**op **T**emperature and **H**eight)
- Radar **ECHO TOPS** (Vaisala IRIS Focus product)
- **Radar volume data** (side views)

- **Radar volume data taken as ground truth!**

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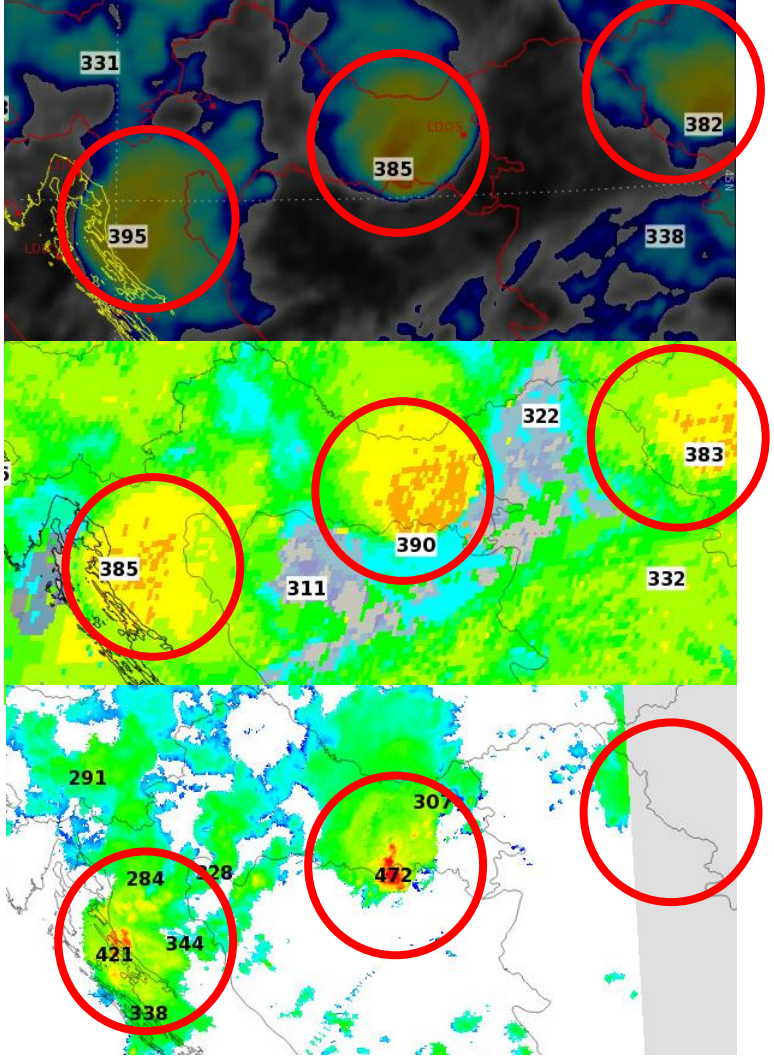
CCTH

NWC SAF CTTH

ECHO TOPS



5.5.2025.
18:30 UTC

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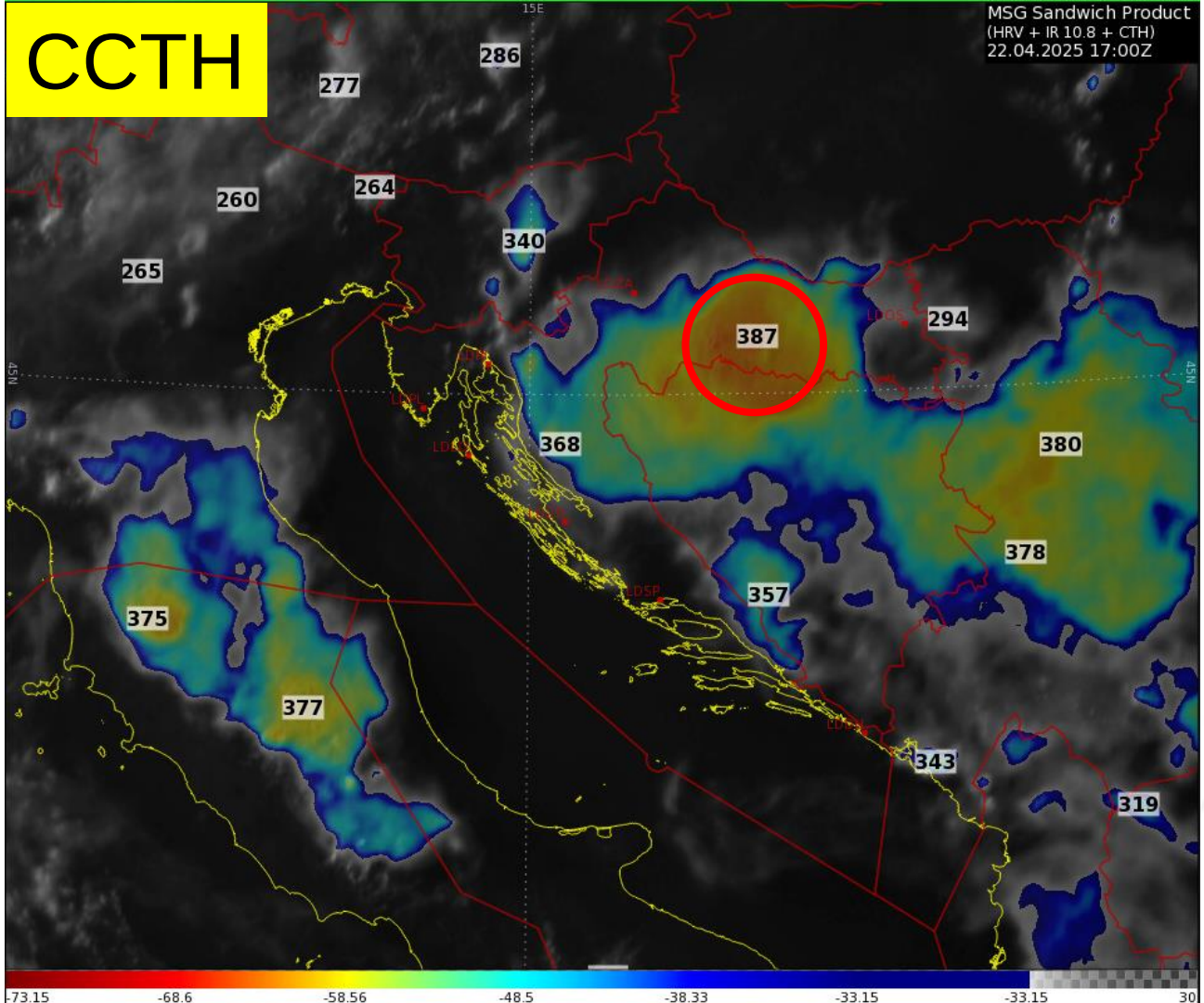
CCTH



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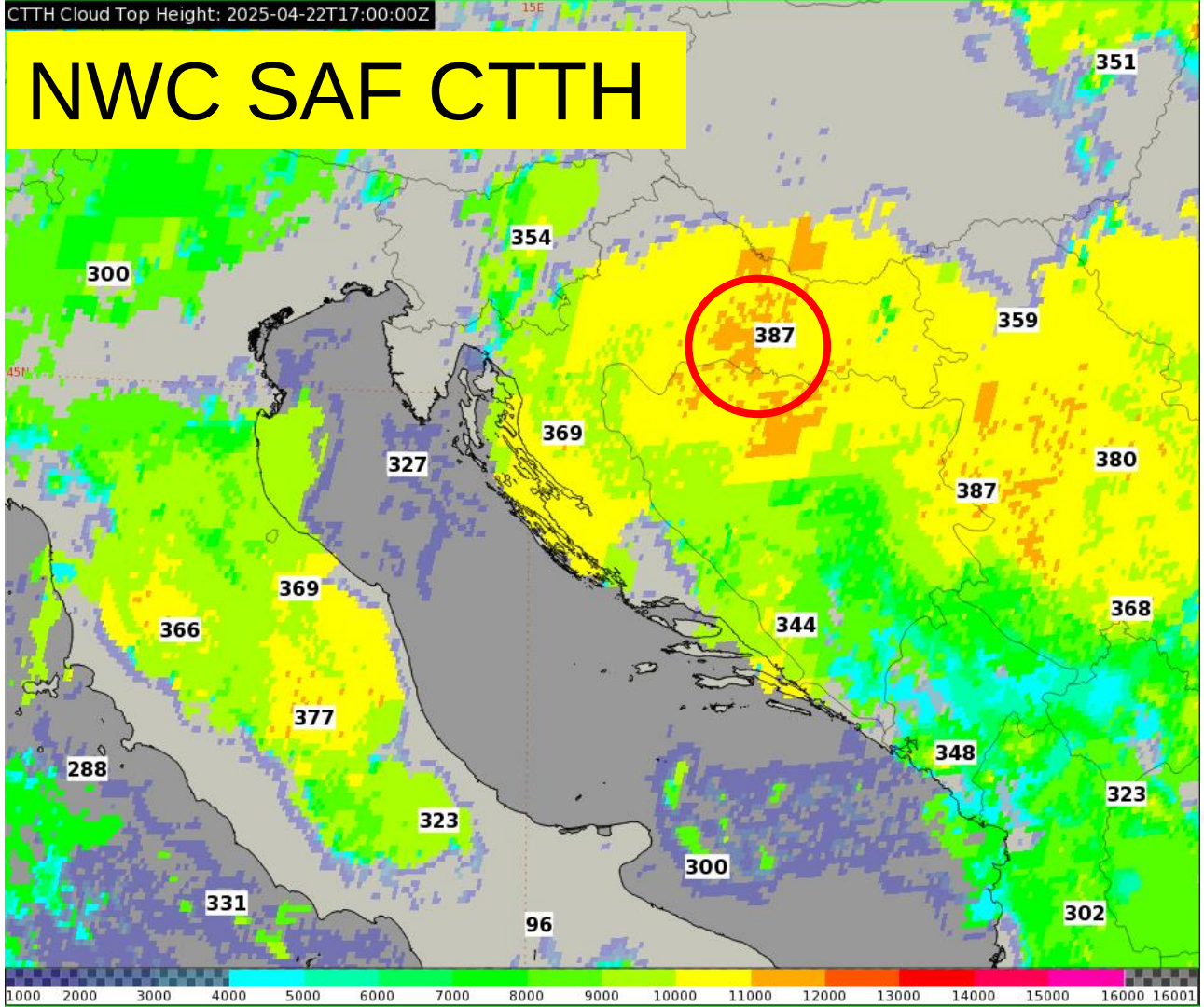
NWC SAF CTTH



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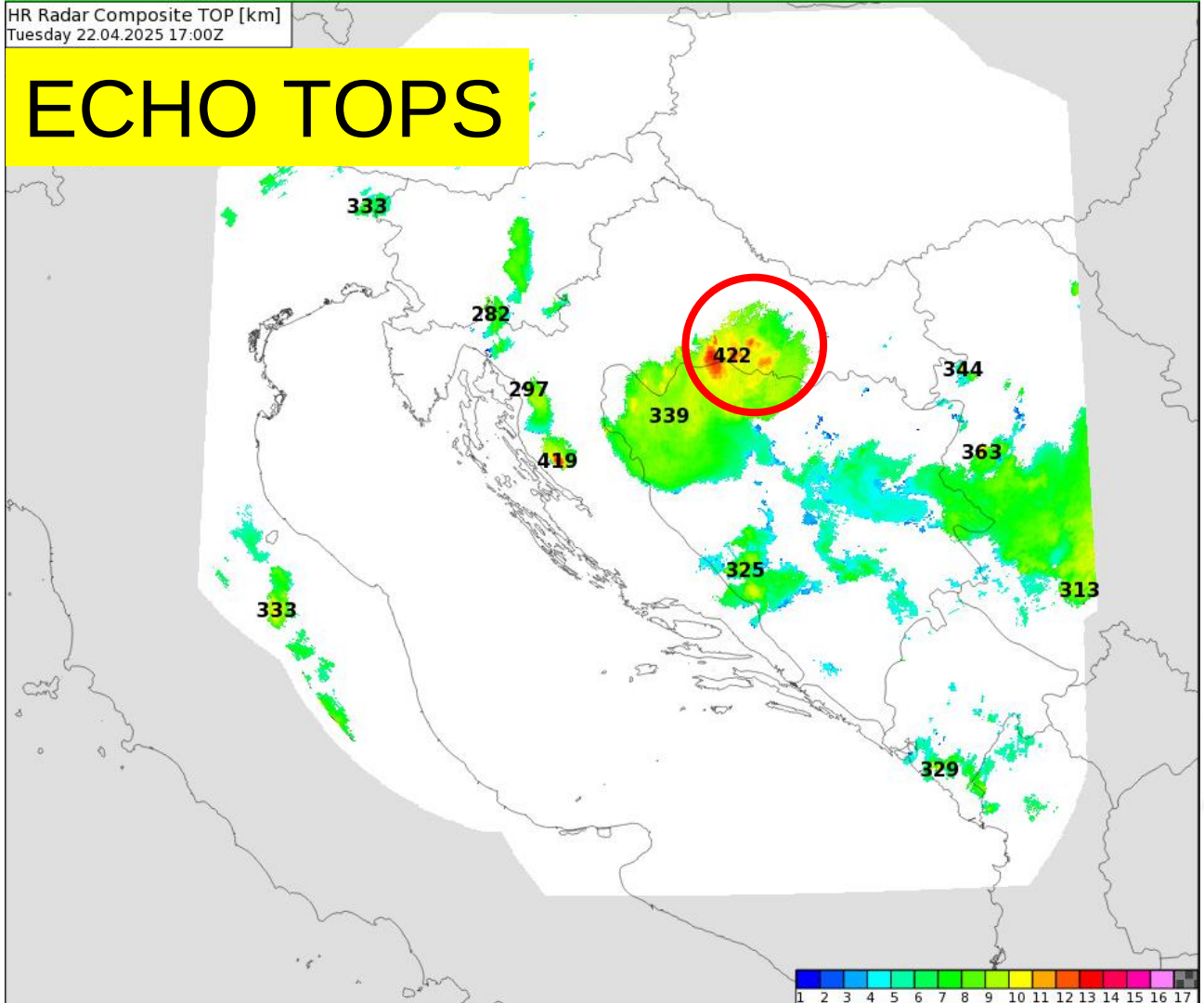

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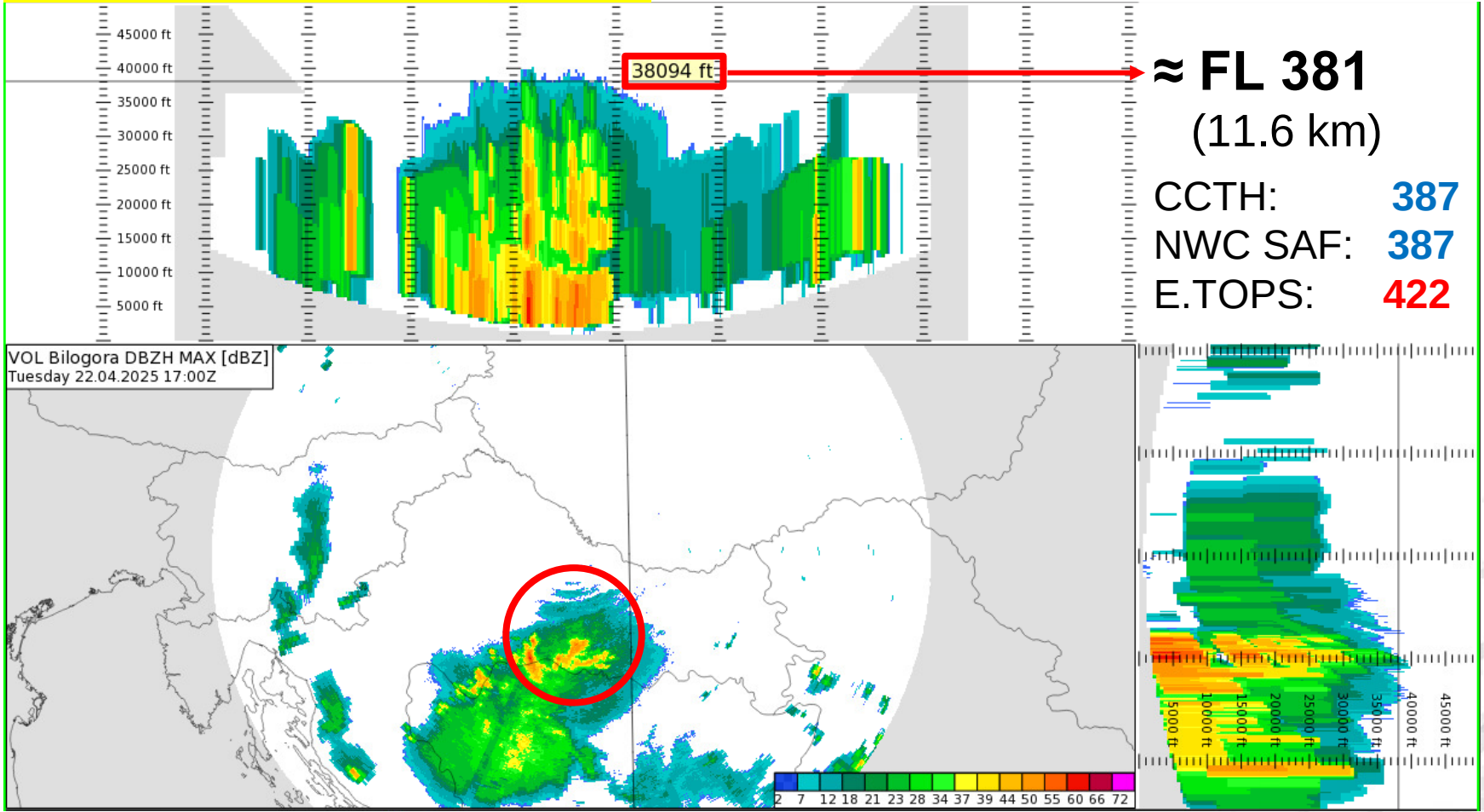
3D RADAR DATA

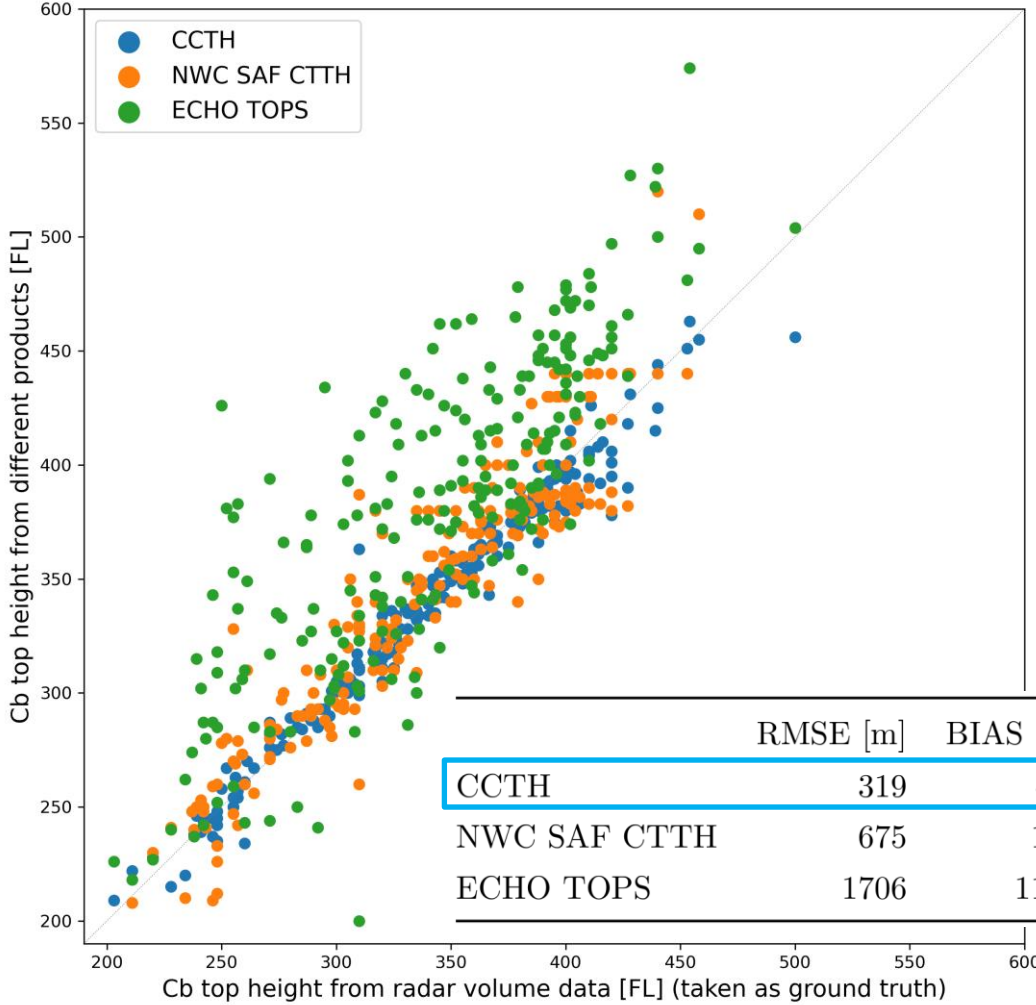


Number of cases: 223

16 km

11 km

6 km



	RMSE [m]	BIAS [m]	MAX ABS ERR [m]	r^2
CCTH	319	-67	1615	0.97
NWC SAF CTTH	675	187	2438	0.87
ECHO TOPS	1706	1195	5364	0.66

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Summary

- **Novel and very efficient moist adiabat non-iterative approximation** for estimating convective CTH
  => **CCTH product**
- Implemented in operational visualization software (Visual Weather)
- **Ongoing validation shows very good results!**

- https://github.com/vsoljan/cloud-top-height

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