CZECH HYDROMETEOROLOGICAL INSTITUTE

DEPARTMENT OF ATMOSPHERIC PHYSICS CHARLES UNIVERSITY

STORM SEVERITY ESTIMATION

NOWCASTING BY REMOTE SENSING IN CENTRAL EUROPE

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Convection Working Group Workshop

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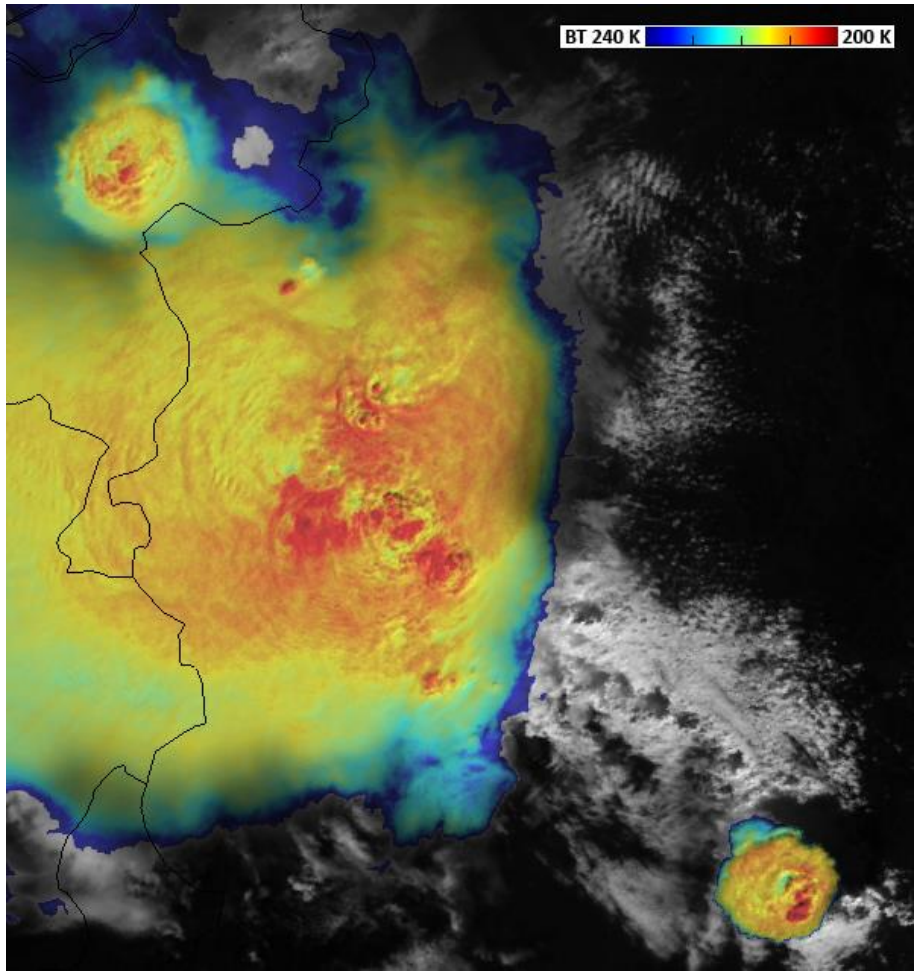
OUTLINE

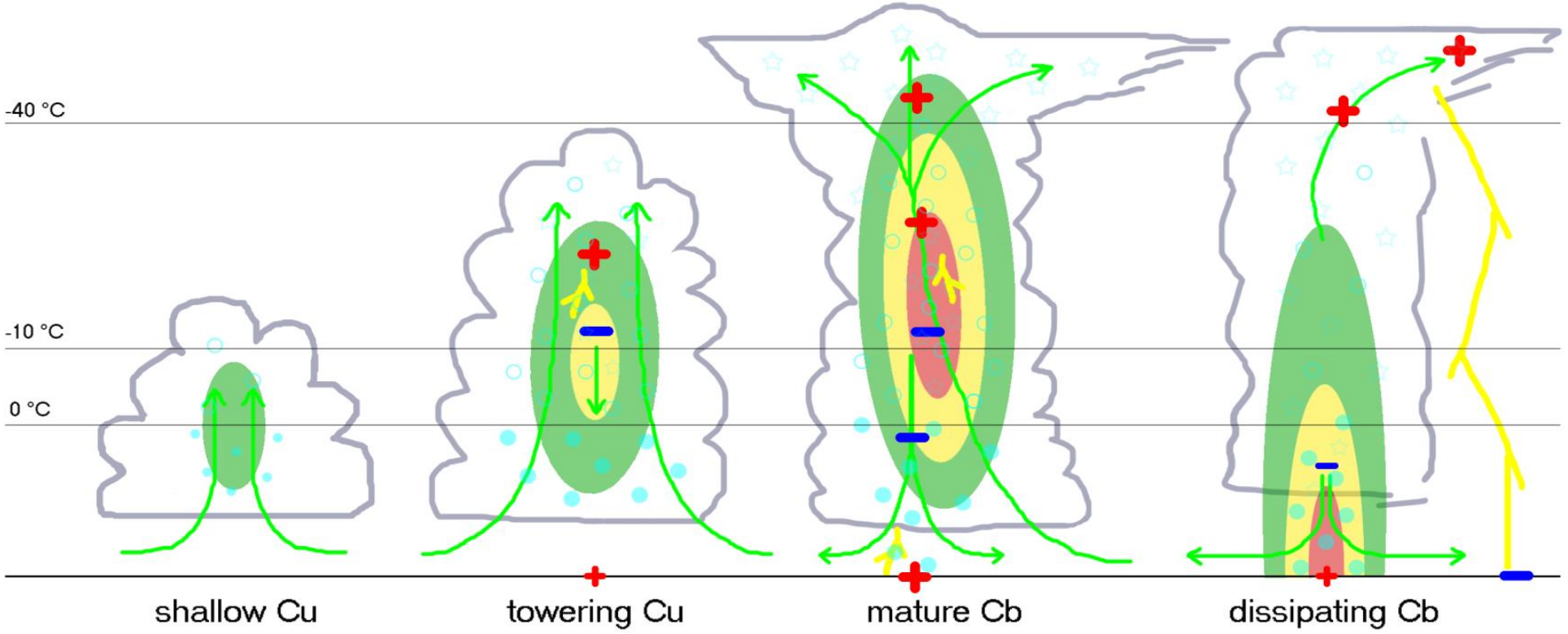


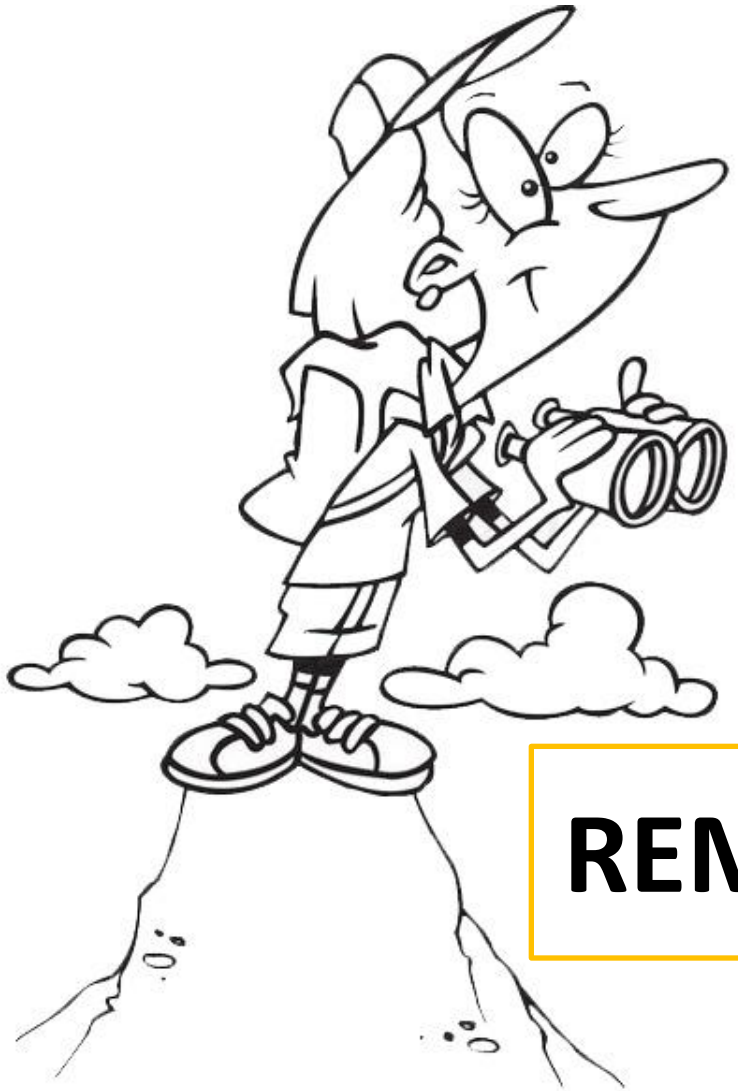
Suomi-NPP/VIIRS sandwich 2013-06-20 11:05 UTC

- motivation of this work
- data used in this study (source & software)
  - **lightning detection network** (CELDN & R)
  - **satellites** (EUMETSAT & McIDAS-V, Python)
  - **radars** (CHMI & CELLTRACK, R)
  - **ESWD** (ESSL & R)
- example: severe vs. non-severe storm
- storm database overview
- logistic regression models

POSSIBLE UTILIZATION

- electrification, dynamics and microphysics connected → changes visible in all remote sensing data → NOWCASTING



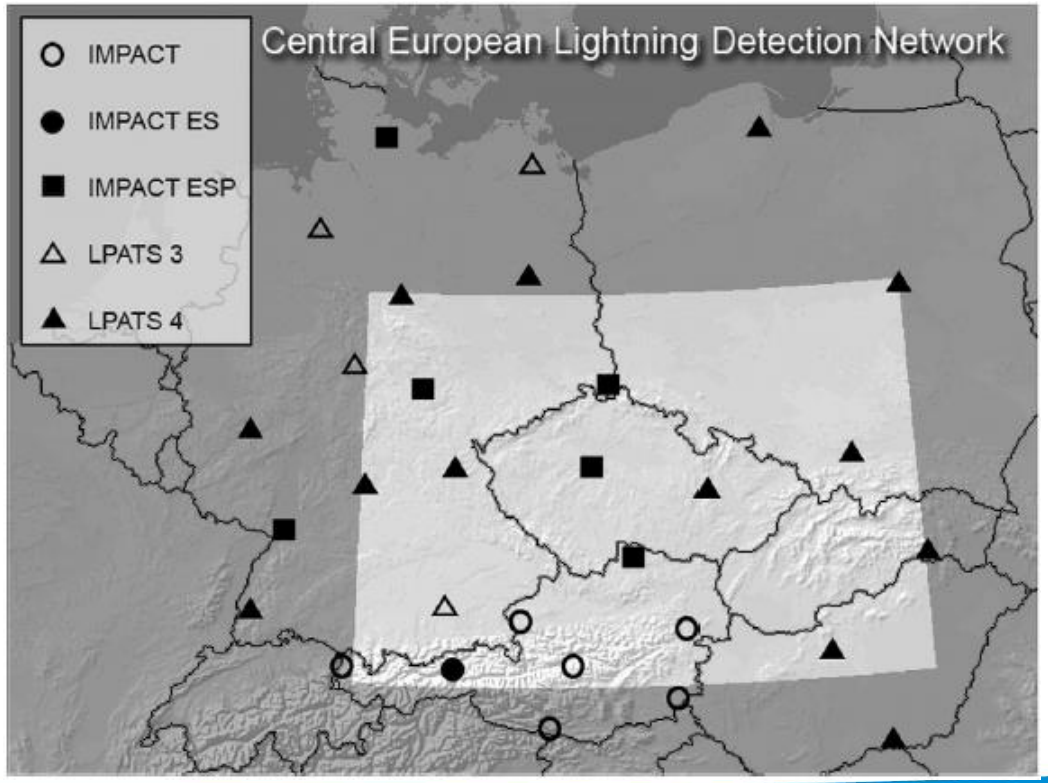


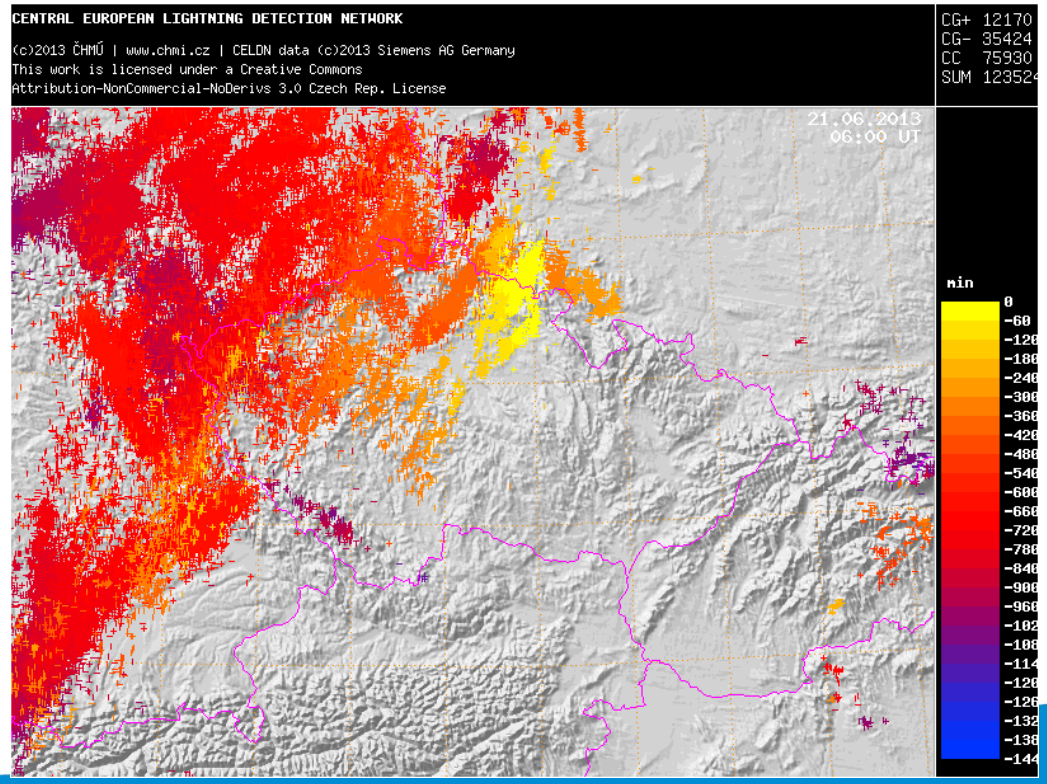
REMOTE SENSING

LIGHTNING DETECTION

CELDN (Central European Lightning Detection Network)

- part of EUCLID, operated by Siemens AG
- operatively used in CHMI until 30 Sep 2017





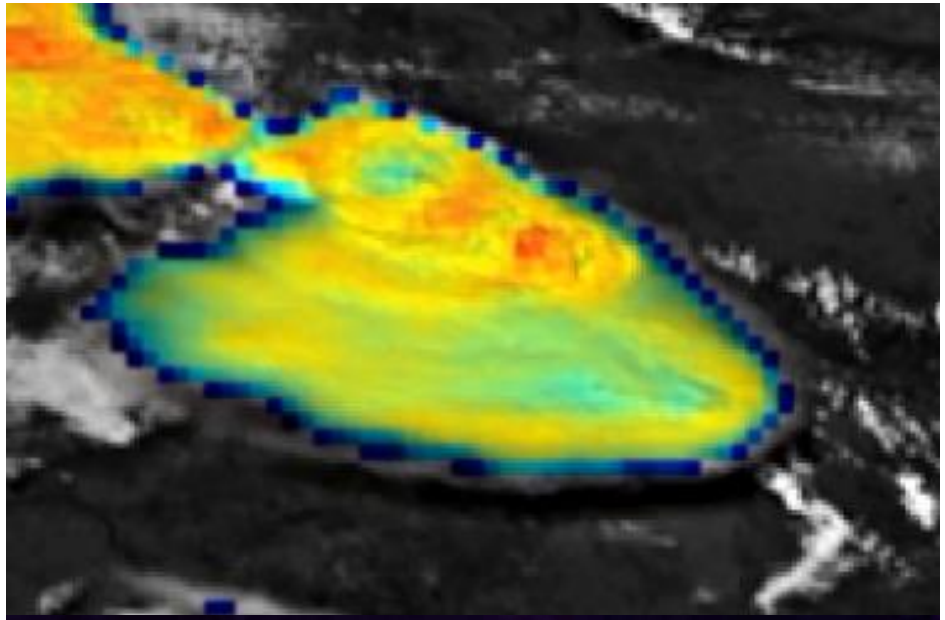
LIGHTNING DETECTION

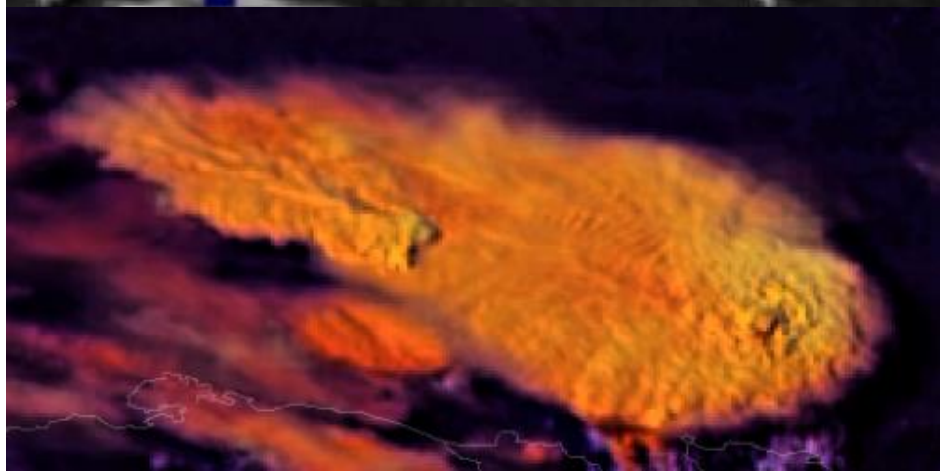
- microphysical properties, strength of updraft

every stroke: type (CC, CG) and polarity, time [ms], location (LAT and LON), stroke peak current estimation [kA]

- detection efficiency: 85 % or higher for CG
- location accuracy: better than 500 m
- estimate of peak current: error ~ tens of %
- no stroke clustering into flashes

SATELLITES





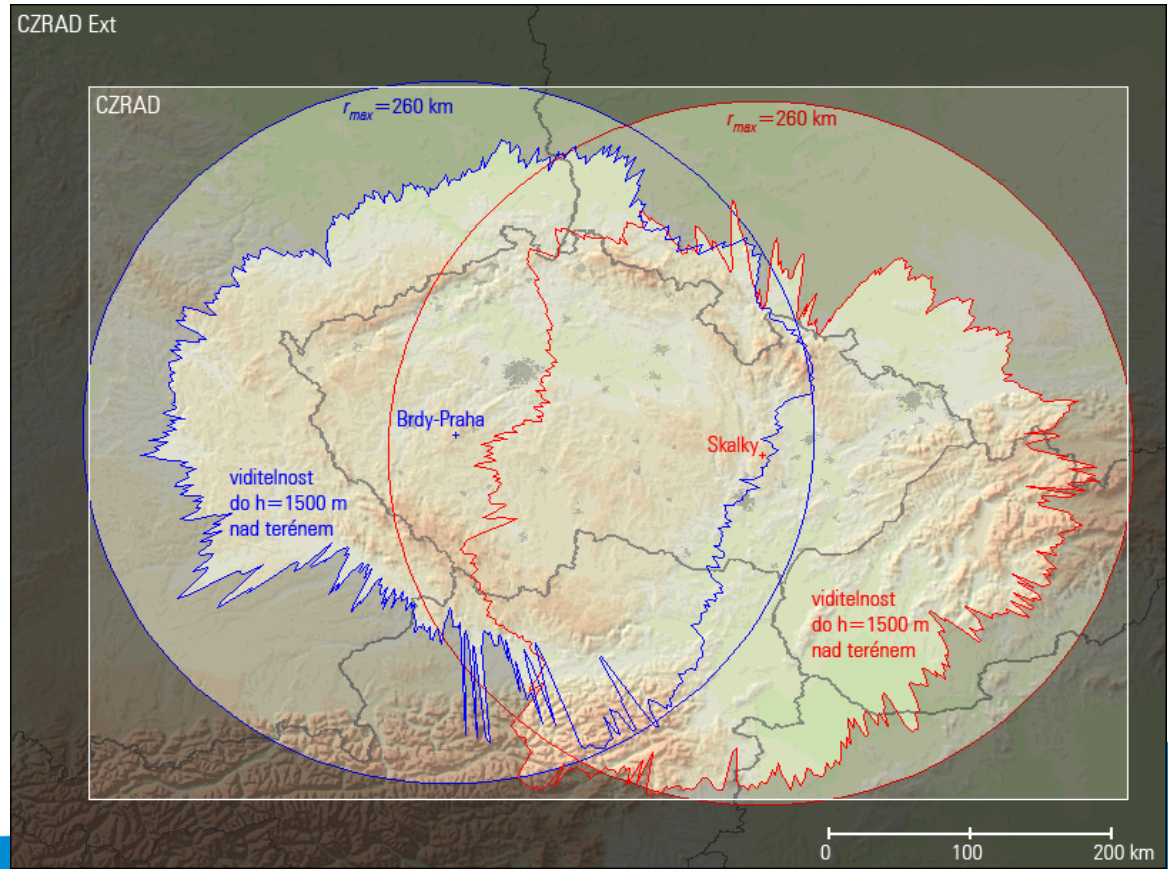
- microphysical properties and dynamics
- MSG/SEVIRI 5 min RSS or 15 min data
  - resolution 3×6 km (1×2 km in HRV)
  - individual channels:
    - » IR 10.8, IR 3.9 and HRV
  - RGB products
    - » Storm
  - sandwich products

RADARS

- microphysical properties and dynamics

Polarimetric Doppler radars (upgrade in 2015)

- C band (λ ~ 5 cm), 12 elevations
- resolution 1×1 km (whole domain)
- many useful applications:
  - CELLTRACK, COTRACK
  - CELDN strokes
  - PrecipView, WarnView

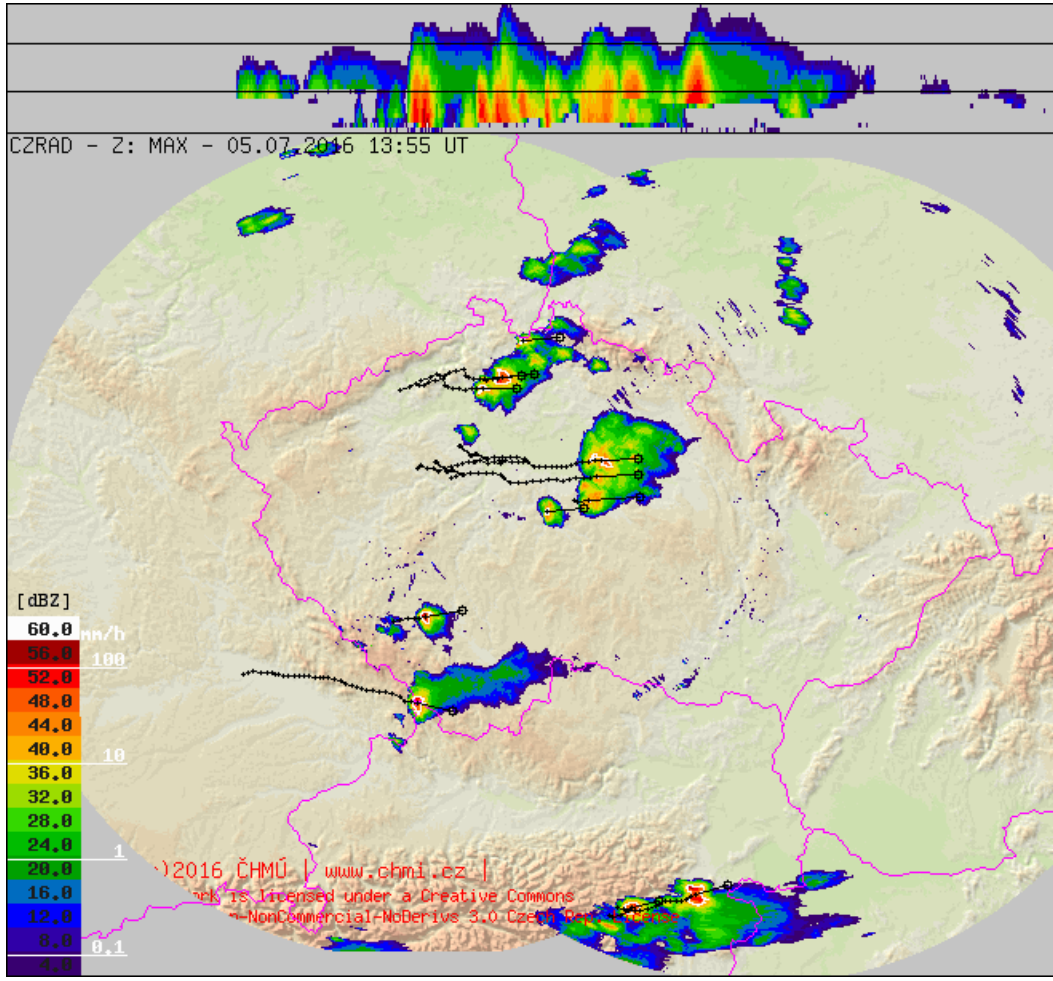


RADARS - CELLTRACK

- reflectivity cores tracking algorithm
- developed in CHMI (Hana Kyznarová)

<u>For the presented study:</u>

- no tracking, just identification of cores
- characteristics of cells:
  - threshold of 44 → 30 dBZ (isolated storms)
  - parameters:
    - AREA, VOL, VOL44, MAX_R, TOP
    - VIL, HP, SHI + POSH + MESH

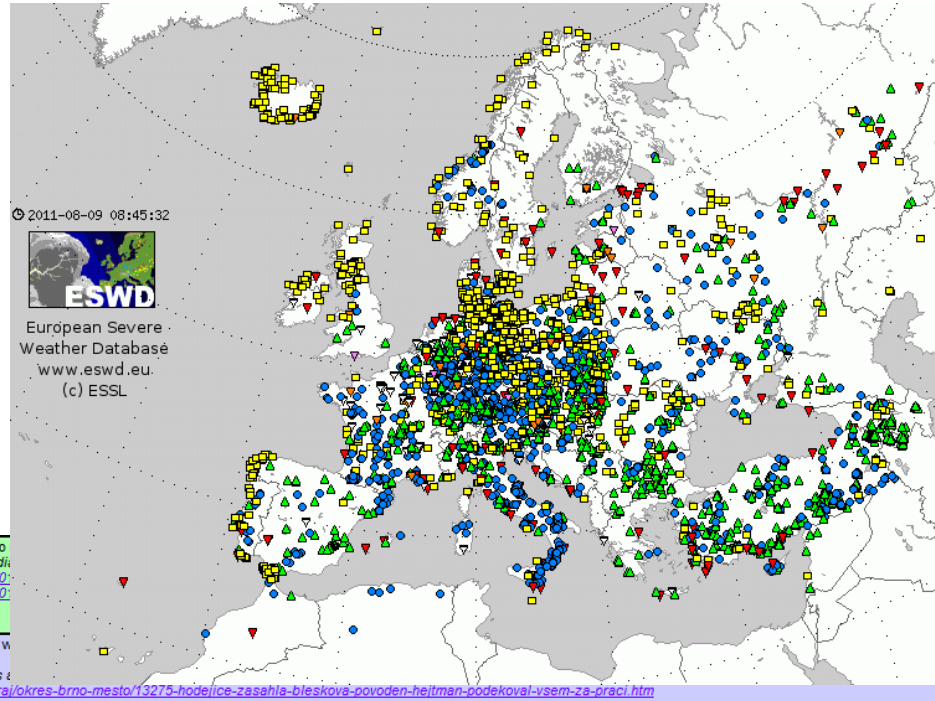


Operational output of CELLTRACK (JSMeteoView)

Kyznarová H., Novák P. (2009): CELLTRACK – Convective cell tracking algorithm and its use for deriving lifecycle characteristics, Atmospheric Research, vol. 93

SEVERE WEATHER REPORTS

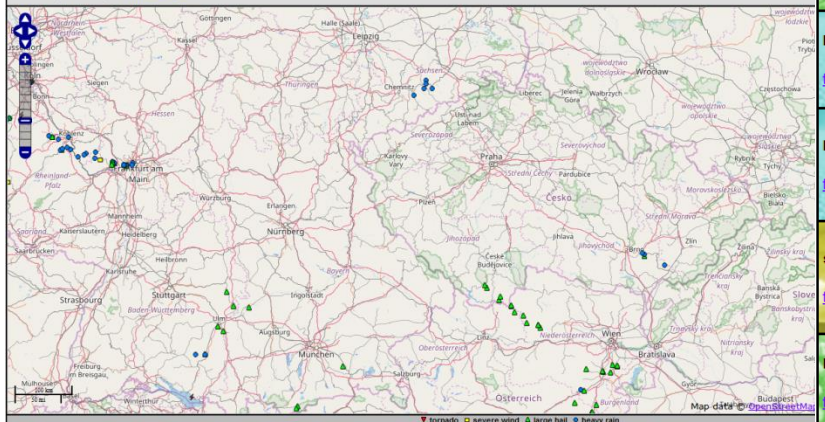
- reports from ESWD operated by ESSL
  - quality control: QC0+, QC1, QC2
  - time uncertainty up to 15 min
  - only “positive events”



Selected data from the database

selected: all reports
- occurring between 27-05-2016 00:00:00 and 27-05-2016 24:00:00 GMT/UTC

number of selected reports: 172
Only the first 25 selected events are shown in the table
Dynamic map Static Map

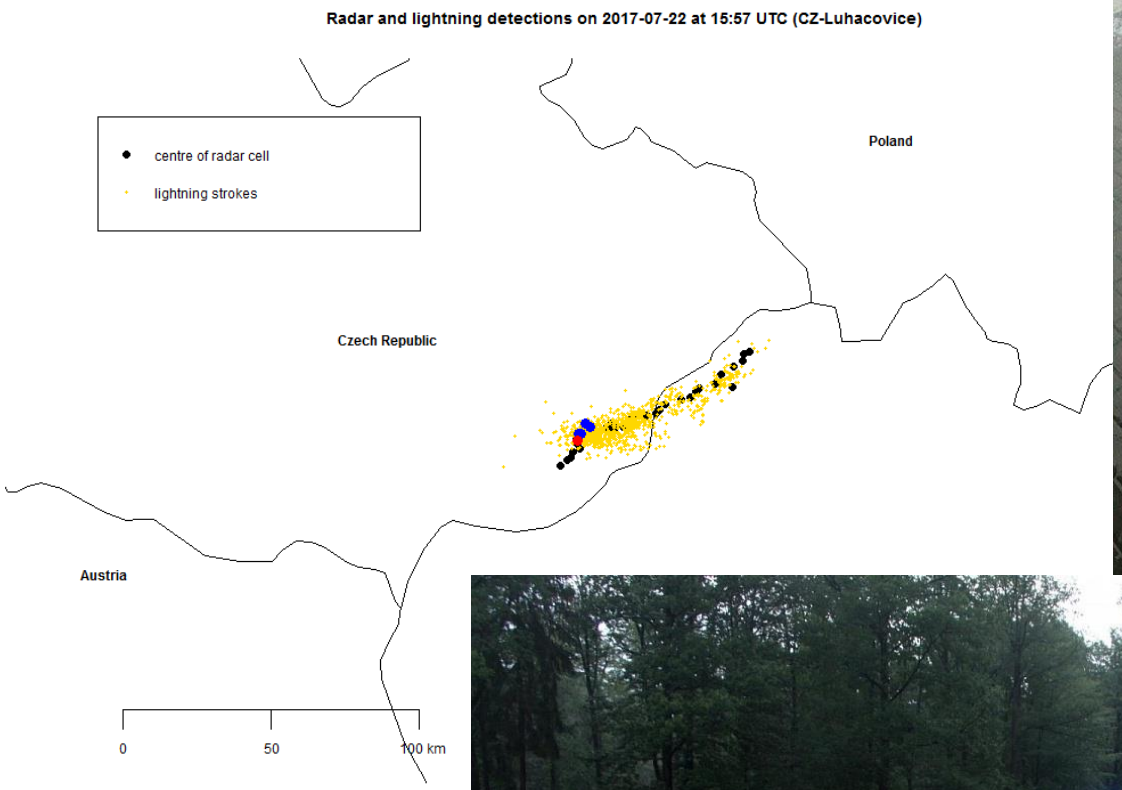


▼ tornado ▢ severe wind ▲ large hail ● heavy rain
▽ funnel cloud ▽ gustnado ▽ dust devil
⁞⁞ heavy snowfall/snowstorm ⊗ ice accumulation ✔ avalanche ⚡ damaging lightning
DEFINITIONS

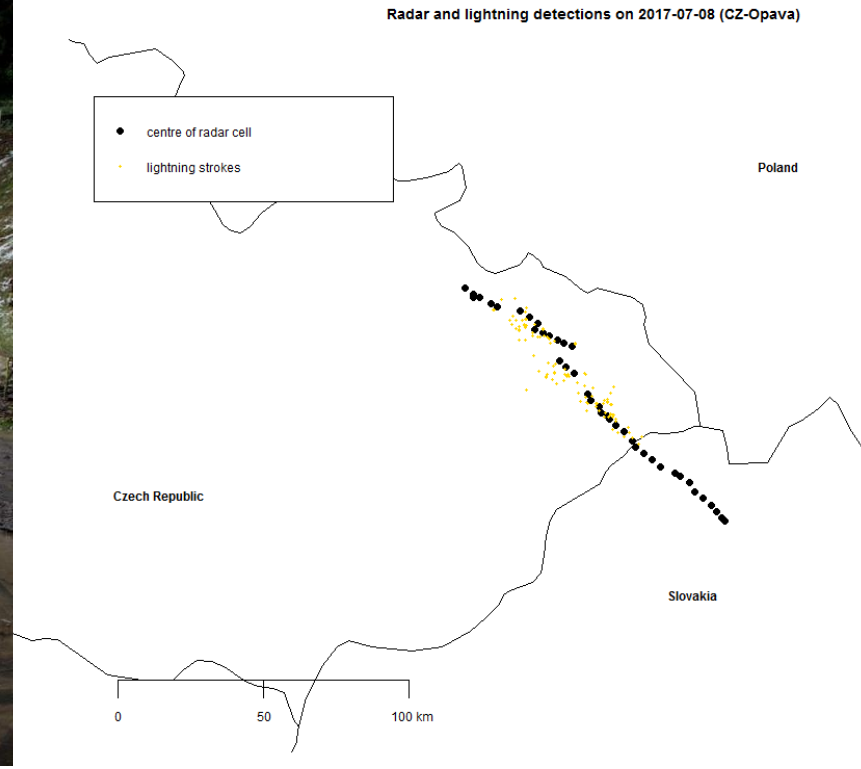
table of all selected reports

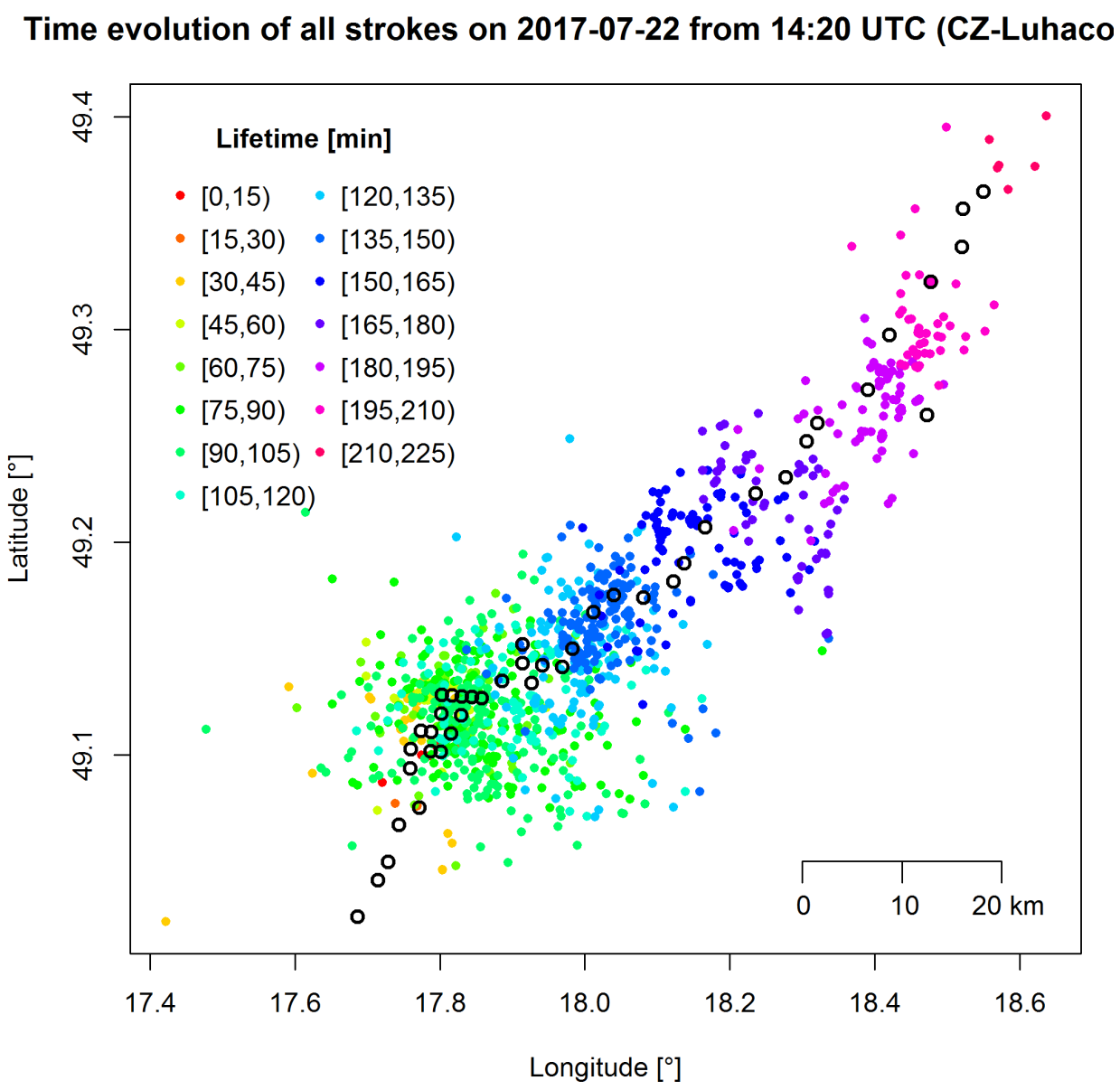
large hail to map	**Königsbronn** Baden-Württemberg **Germany** (48.73 N, 10.12 E) **27-05-2016** (Friday) **22:56** UTC (+/- 5 min.)	based on: information from : photo or video of the event, an eye-witness report, a report on a website maximum hail diameter: **2 cm** average hail diameter: **1 cm** *hailstorm; large hail 1-2cm i.d.; source: witness photo report; reported v. Instagram, 28 MAY 2016; RAD;* *https://scontent.cdninstagram.com/t51.2885-15/s640x640/sh0.08/e35/13277767_1707256826210899_922863743_n.jpg?ig_cache_key=MTI1OTcyNic1MDUxODEx* report status: **report confirmed** (QC1) contact: Thilo Kühne (ESWD management) [e-mail]
large hail to map	**Heršpice** Jihomoravský kraj **Czech Republic** (49.12 N, 16.91 E) **27-05-2016** (Friday) **18:30** UTC (+/- 5 min.)	based on: information from : photo or video *large amount of hailstones up to 2 cm in di* *http://prostor.amsos.cz/eswd/hail/photo/20* *http://prostor.amsos.cz/eswd/hail/photo/20* report status: **event fully verified** (QC2) contact: Tomáš Prouza (AMS) [e-mail]
heavy rain to map	**Hodějice** South Moravian Region **Czech Republic** (49.14 N, 16.91 E) **27-05-2016** (Friday) **18:30** UTC (+/- 5 min.)	based on: information from : a report on a w precipitation: **70 mm** *Unofficial measurement; flooded buildings a* *http://www.krajskelisty.cz/jihomoravsky-kraj/okres-brno-mesto/13275-hodejice-zasahla-bleskova-povoden-hejtman-podekoval-vsem-za-praci.htm* report status: **report confirmed** (QC1) contact: Tomsu Radek (CHMI) [e-mail]
heavy rain to map	**Slavkov u Brna** Jihomoravský kraj **Czech Republic** (49.15 N, 16.88 E) **27-05-2016** (Friday) **18:25** UTC (+/- 15 min.)	based on: information from : photo or video of the event, an eye-witness report convective. damage to property: cellars & streets flooded *after torrential rain during supercell storm few cellars and streets were flooded | time based on radar* *https://www.facebook.com/photo.php?fbid=1210563088988641&set=p.1210563088988641&type=3&permPage=1* report status: **event fully verified** (QC2) contact: Tomáš Prouza (AMS) [e-mail]
severe wind to map	**Chernyakhovsk** Kaliningradskaya oblast' **Russian Federation** (54.63 N, 21.81 E) **27-05-2016** (Friday) **18:00** UTC (+/- 30 min.)	based on: information from : an eye-witness report, photograph(s) and/or video footage of the inflicted damage, a report on a website, an eyewitness report of the damage damage to property: road blocked. telegraph line downed damage to crops and forests: tree downed *source: АвтоКлуб 39RUS Калининград, 27 MAY 2016; pers.comm. Igor Azhigov, 27 MAY 2016;* *https://pp.vk.me/c636317/v636317110/b3b3/ApyDithmyBI.jpg* report status: **report confirmed** (QC1) contact: Thilo Kühne (ESWD management) [e-mail]
large hail to map	**Krün** *Mittenwald com. area.* Bayern **Germany** (47.50 N, 11.28 E) < 3 km **27-05-2016** (Friday) **17:50** UTC (+/- 5 min.)	based on: information from : photo or video of the event, an eye-witness report, a report on a website maximum hail diameter: **4 cm** *hailstorm; large hail up to 3-4cm i.d.; source: witness photo report; reported v. Instagram, 27 MAY 2016; RAD;* *https://scontent.cdninstagram.com/t51.2885-15/s640x640/sh0.08/e35/13256896_1703417613251392_2118641648_n.jpg?ig_cache_key=MTI1OTU5NTAxNzM4NzQ0MjAwMA%3D%3D.2* report status: **report confirmed** (QC1) contact: Thilo Kühne (ESWD management) [e-mail]
large hail to map	**Mittenwald** Bayern **Germany** (47.48 N, 11.26 E) **27-05-2016** (Friday) **17:50** UTC (+/- 5 min.)	based on: information from : photo or video of the event, an eye-witness report, a report on a website maximum hail diameter: **2 cm** *hailstorm; large hail up to 2cm i.d.; source: witness photo report; reported v. Instagram, 27 MAY 2016;* *https://scontent.cdninstagram.com/t51.2885-15/s640x640/sh0.08/e35/13183363_792157474217511_1429406503_n.jpg?ig_cache_key=MTI1OTU3MDI3NiY2NTQ3ODIwNw%3D%3D.2* report status: **report confirmed** (QC1) contact: Thilo Kühne (ESWD management) [e-mail]

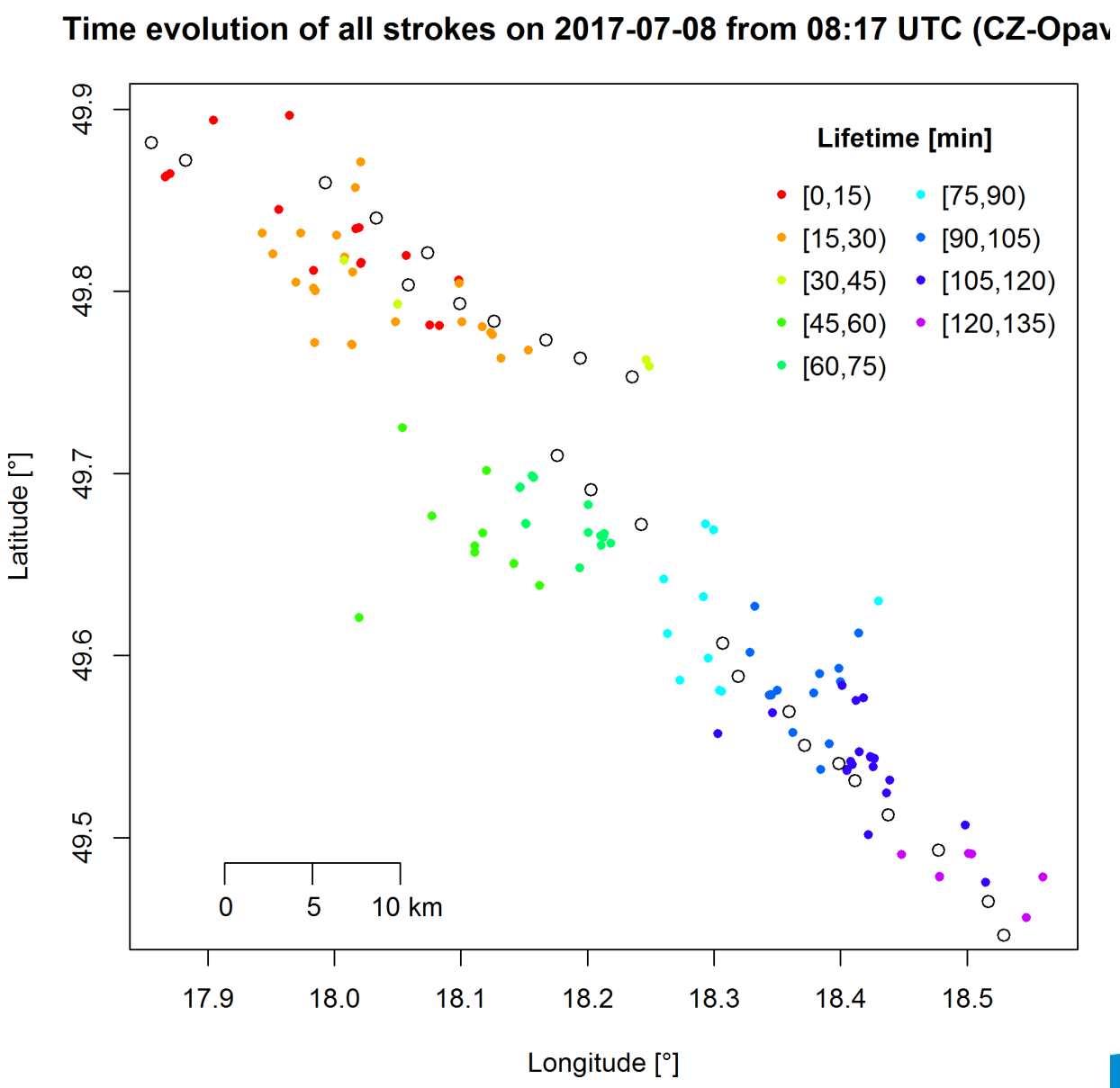
SEVERE OR NON-SEVERE ?


Radar and lightning detections on 2017-07-22 at 15:57 UTC (CZ-Luhacovice)
centre of radar cell
lightning strokes
Poland
Czech Republic
Austria
0
50
100 km

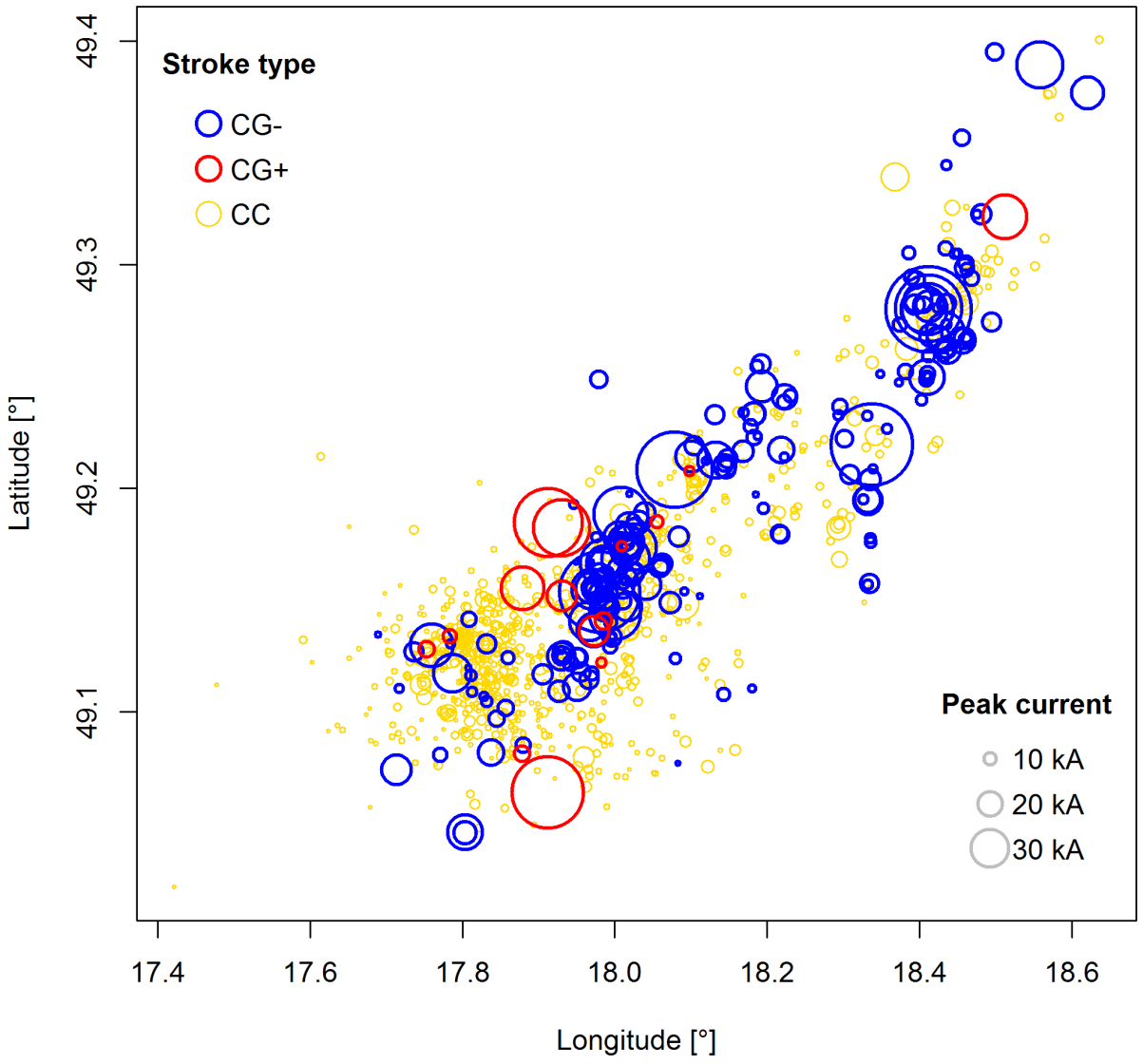

SLAVIČÍN


Radar and lightning detections on 2017-07-08 (CZ-Opava)
centre of radar cell
lightning strokes
Poland
Czech Republic
Slovakia
0
50
100 km

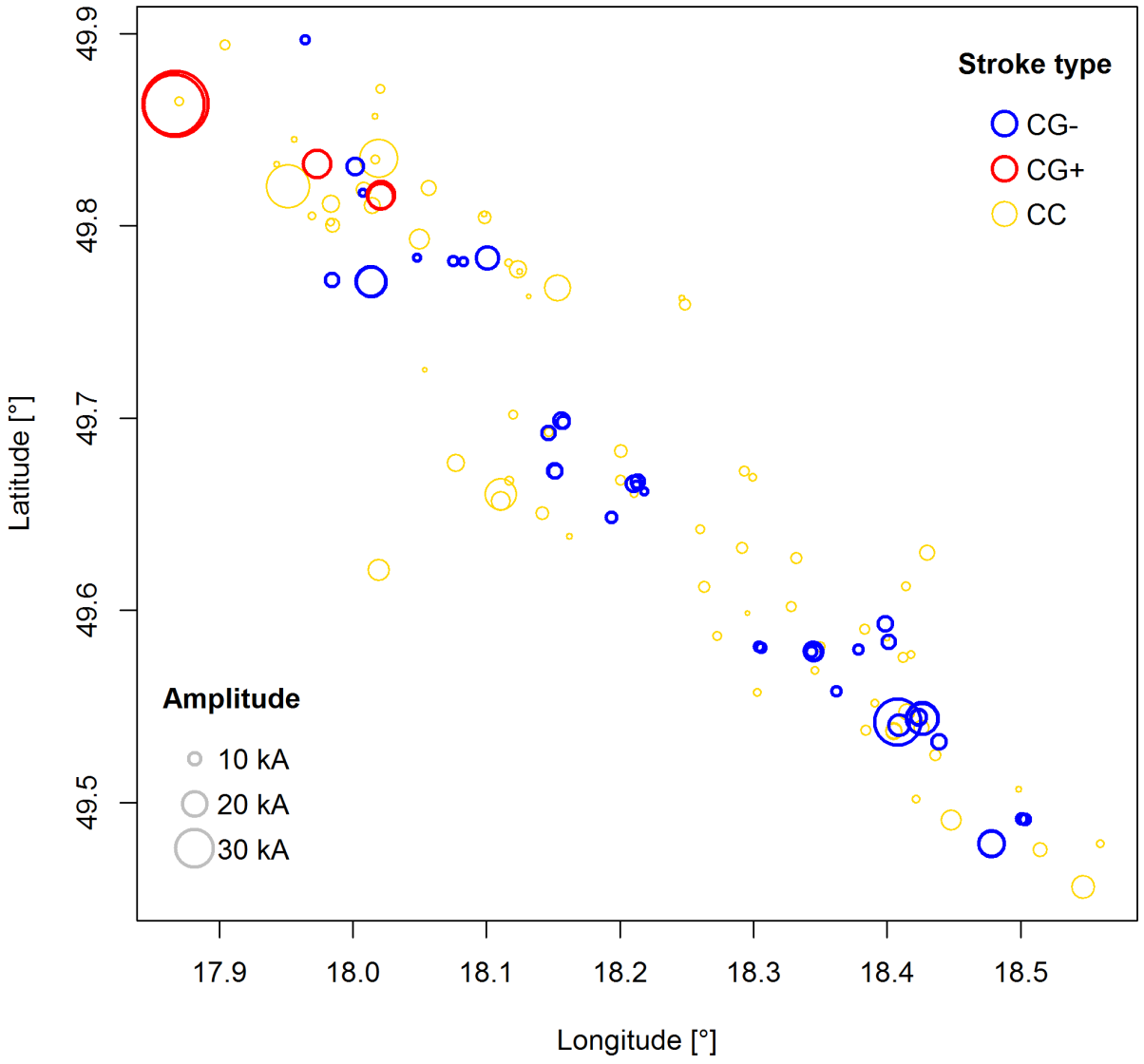

Time evolution of all strokes on 2017-07-22 from 14:20 UTC (CZ-Luhaco
Lifetime [min]
[0,15)
[15,30)
[30,45)
[45,60)
[60,75)
[75,90)
[90,105)
[105,120)
[120,135)
[135,150)
[150,165)
[165,180)
[180,195)
[195,210)
[210,225)
0
10
20 km
Latitude [°]
Longitude [°]
49.1
49.2
49.3
49.4
17.4
17.6
17.8
18.0
18.2
18.4
18.6

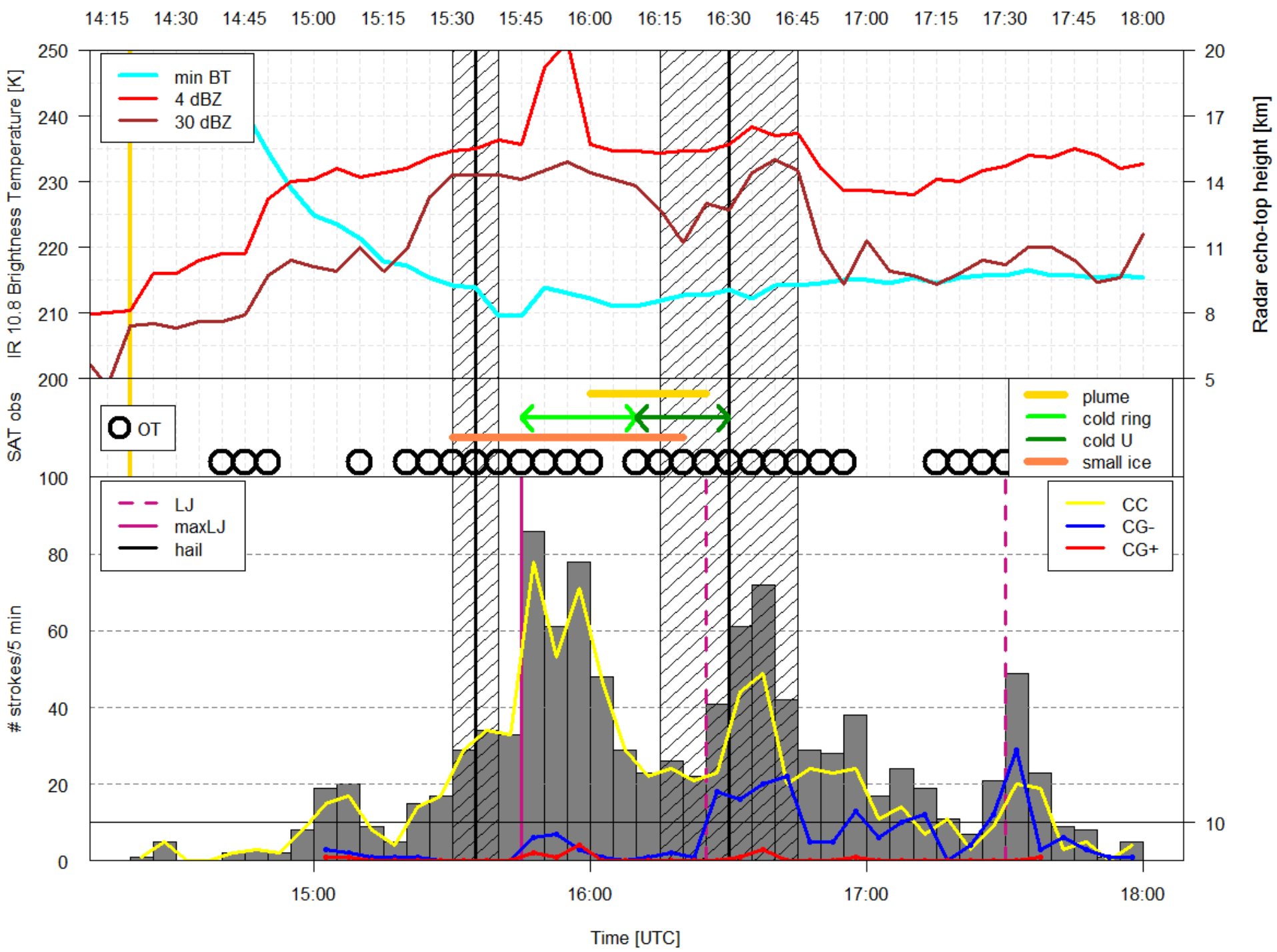

Time evolution of all strokes on 2017-07-08 from 08:17 UTC (CZ-Opav
Lifetime [min]
[0,15)
[15,30)
[30,45)
[45,60)
[60,75)
[75,90)
[90,105)
[105,120)
[120,135)
0
5
10 km
Latitude [°]
Longitude [°]
49.5
49.6
49.7
49.8
49.9
17.9
18.0
18.1
18.2
18.3
18.4
18.5

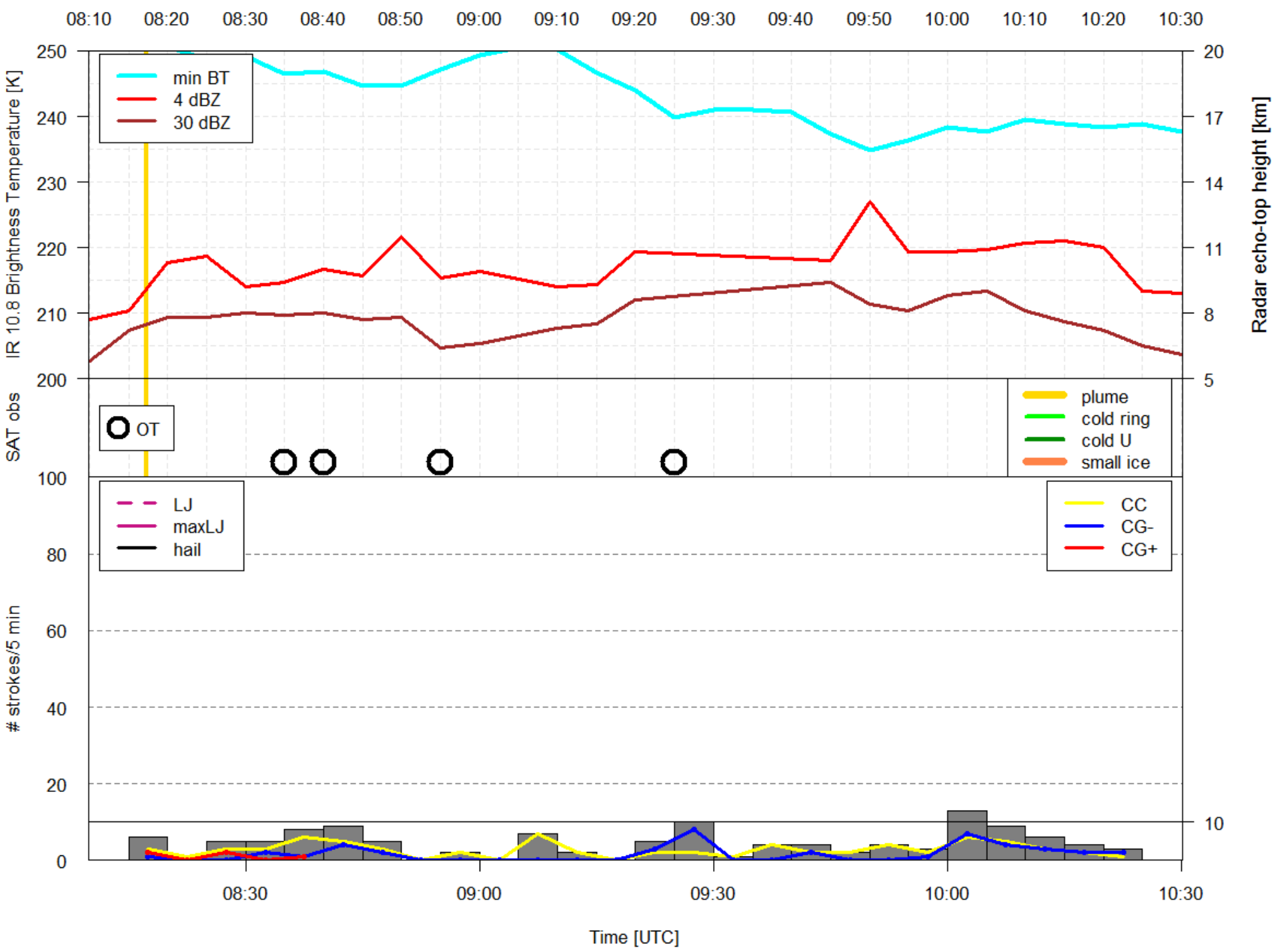
Stroke type distribution on 2017-07-22 from 14:20 UTC (CZ-Luhacovic

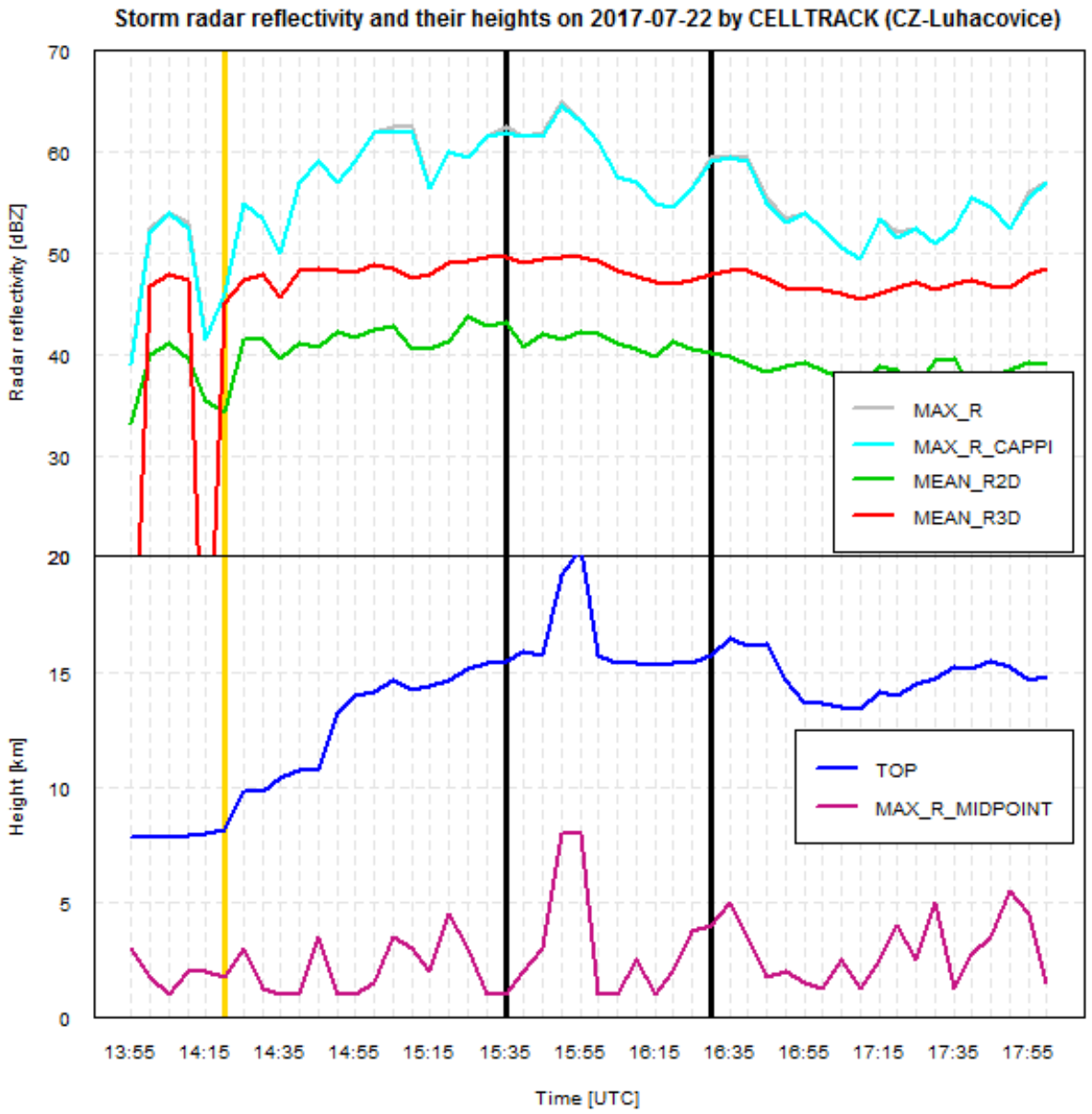


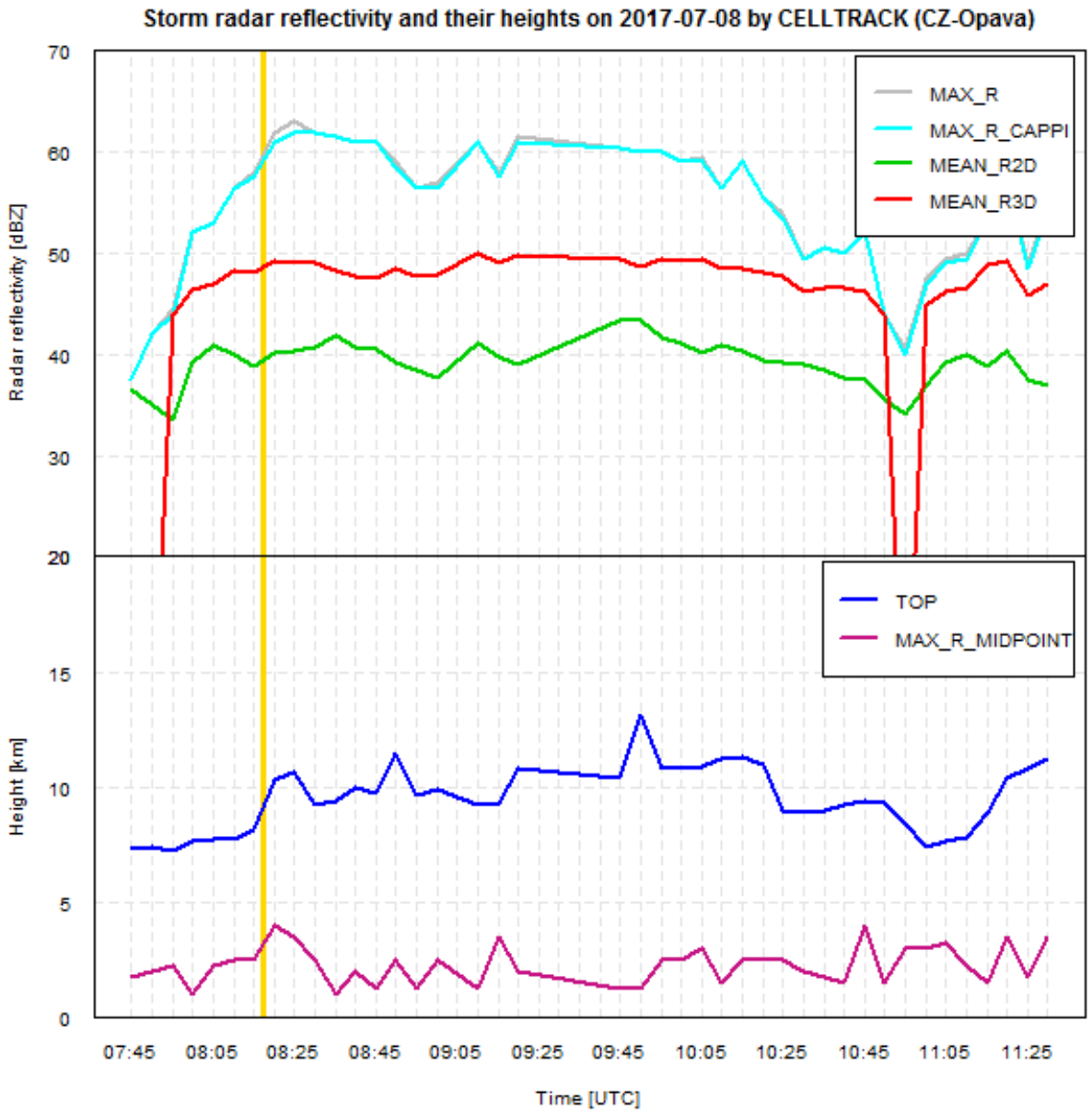
Stroke type distribution on 2017-07-08 from 08:17 UTC (CZ-Opava)

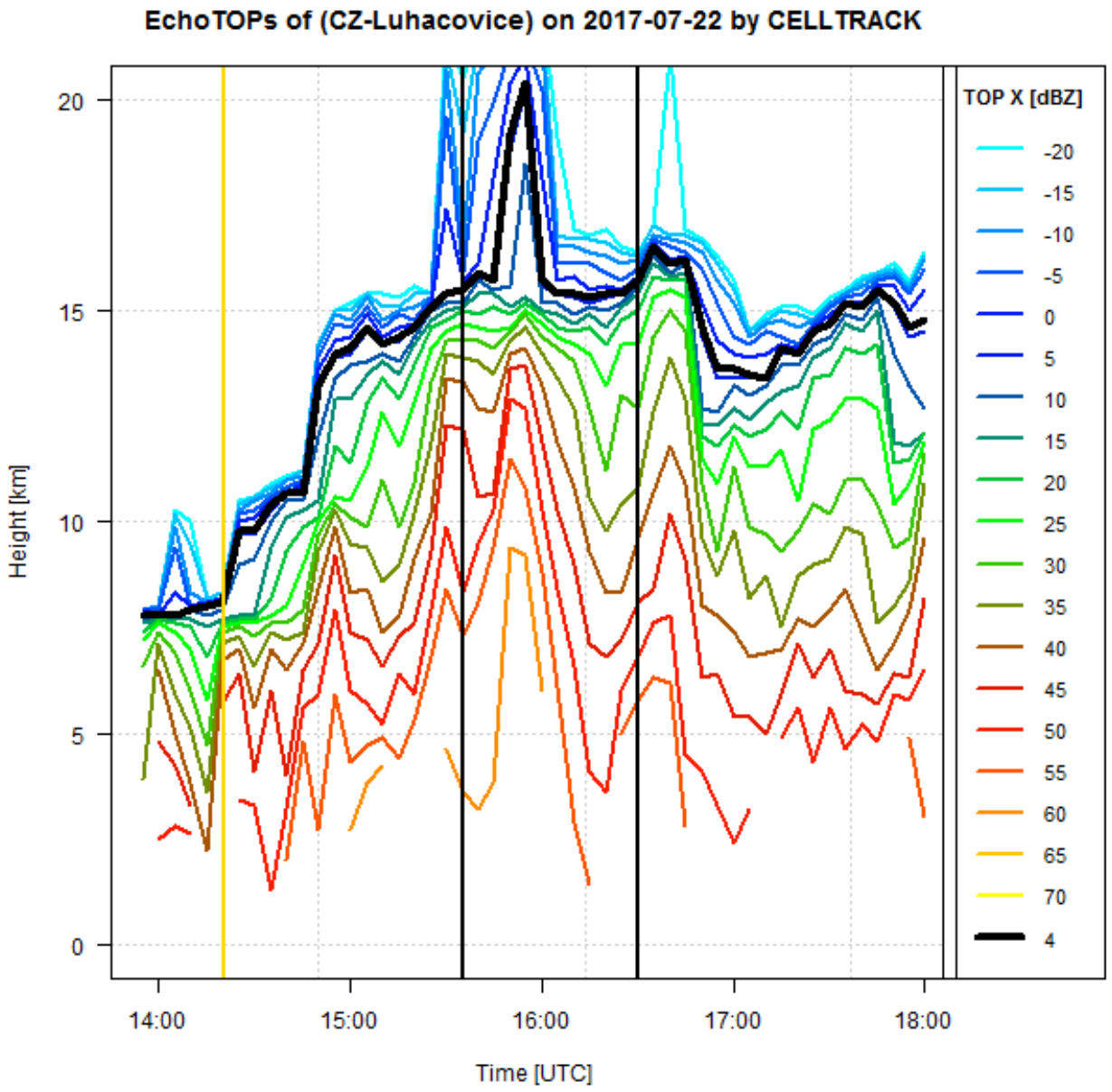


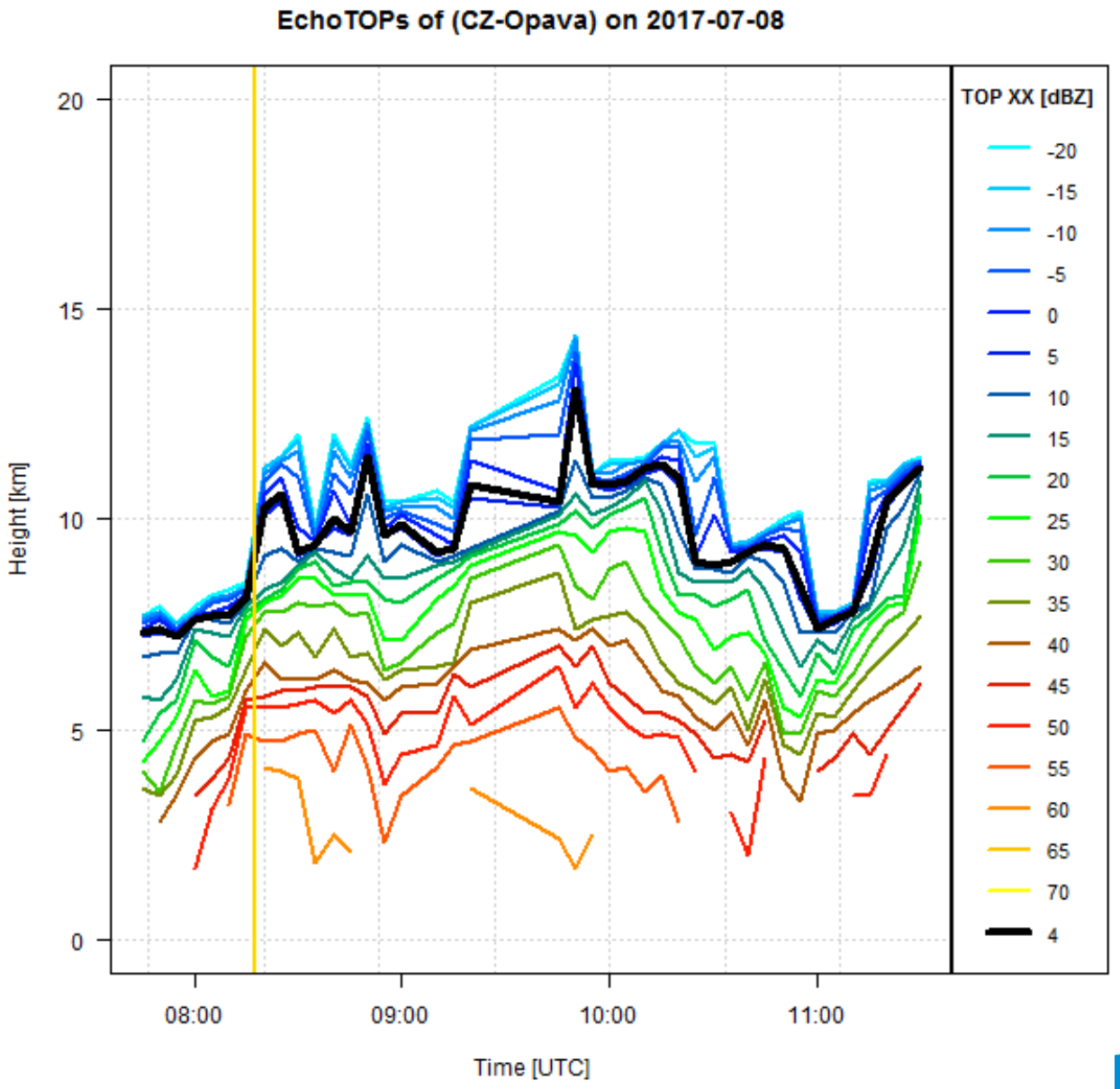

14:15
14:30
14:45
15:00
15:15
15:30
15:45
16:00
16:15
16:30
16:45
17:00
17:15
17:30
17:45
18:00
IR 10.8 Brightness Temperature [K]
Radar echo-top height [km]
min BT
4 dBZ
30 dBZ
SAT obs
OT
plume
cold ring
cold U
small ice
strokes/5 min
LJ
maxLJ
hail
CC
CG-
CG+
15:00
16:00
17:00
18:00
Time [UTC]

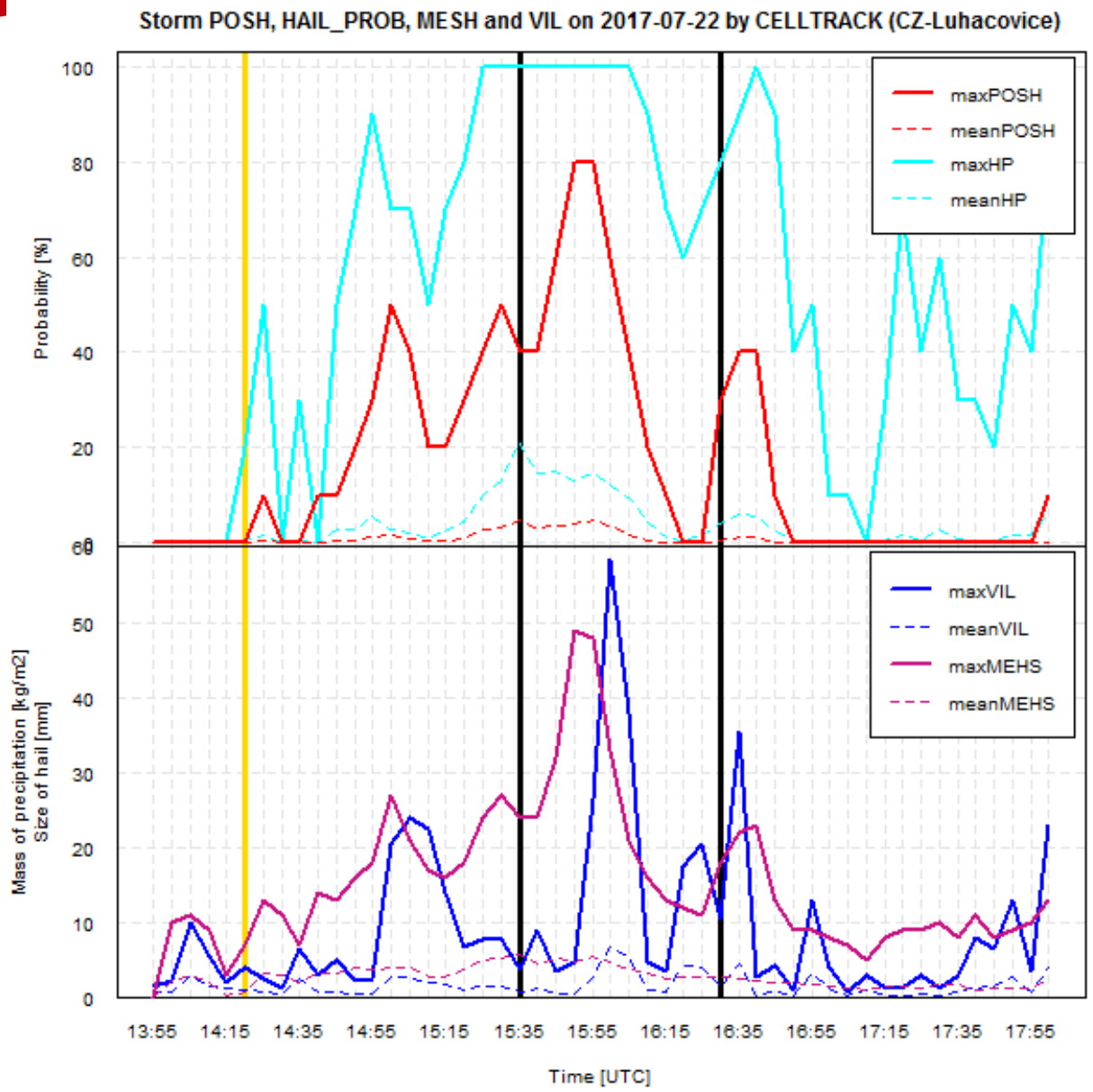

08:10
08:20
08:30
08:40
08:50
09:00
09:10
09:20
09:30
09:40
09:50
10:00
10:10
10:20
10:30
IR 10.8 Brightness Temperature [K]
Radar echo-top height [km]
min BT
4 dBZ
30 dBZ
SAT obs
OT
plume
cold ring
cold U
small ice
LJ
maxLJ
hail
CC
CG-
CG+
strokes/5 min
Time [UTC]

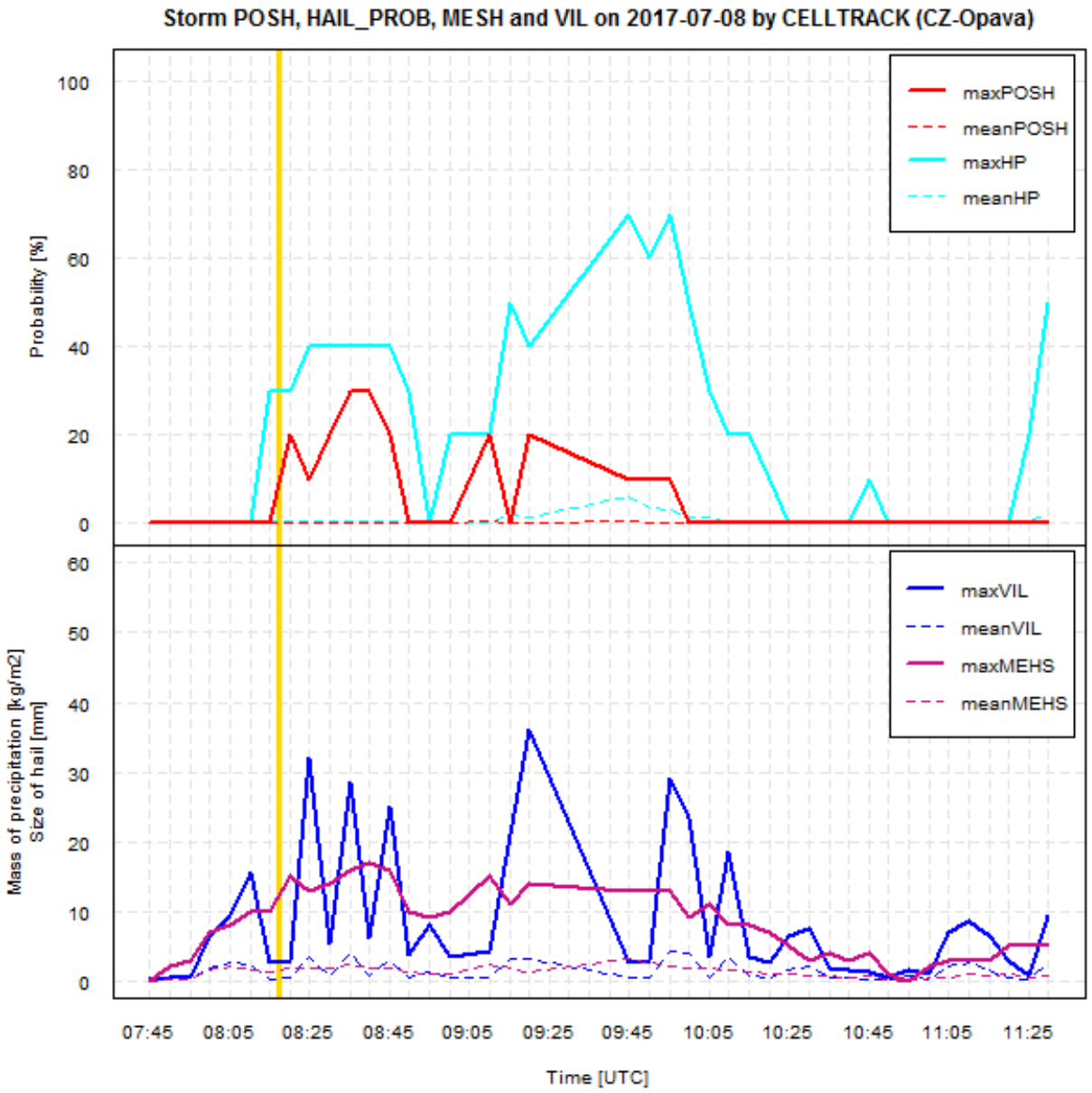

Storm radar reflectivity and their heights on 2017-07-22 by CELLTRACK (CZ-Luhacovice)
Radar reflectivity [dBZ]
Height [km]
Time [UTC]
MAX_R
MAX_R_CAPPI
MEAN_R2D
MEAN_R3D
TOP
MAX_R_MIDPOINT
13:55
14:15
14:35
14:55
15:15
15:35
15:55
16:15
16:35
16:55
17:15
17:35
17:55


Storm radar reflectivity and their heights on 2017-07-08 by CELLTRACK (CZ-Opava)
Radar reflectivity [dBZ]
Height [km]
Time [UTC]
MAX_R
MAX_R_CAPPI
MEAN_R2D
MEAN_R3D
TOP
MAX_R_MIDPOINT
07:45
08:05
08:25
08:45
09:05
09:25
09:45
10:05
10:25
10:45
11:05
11:25

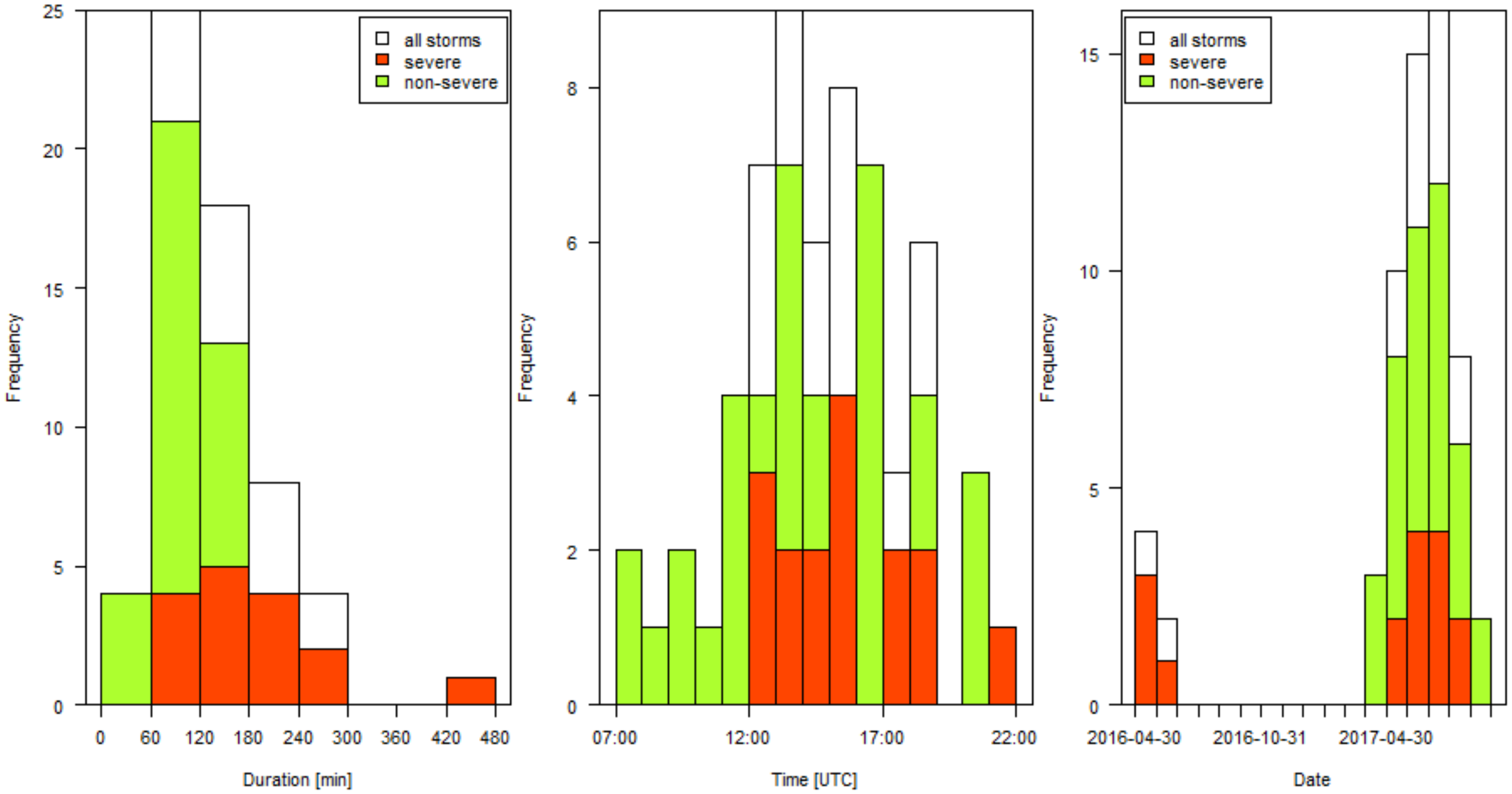

EchoTOPs of (CZ-Luhacovice) on 2017-07-22 by CELLTRACK
Height [km]
Time [UTC]
14:00
15:00
16:00
17:00
18:00
TOP X [dBZ]
-20
-15
-10
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
4


EchoTOPs of (CZ-Opava) on 2017-07-08
Height [km]
Time [UTC]
08:00
09:00
10:00
11:00
TOP XX [dBZ]
-20
-15
-10
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
4


Storm POSH, HAIL_PROB, MESH and VIL on 2017-07-22 by CELLTRACK (CZ-Luhacovice)
Probability [%]
maxPOSH
meanPOSH
maxHP
meanHP
Mass of precipitation [kg/m2]
Size of hail [mm]
maxVIL
meanVIL
maxMEHS
meanMEHS
13:55
14:15
14:35
14:55
15:15
15:35
15:55
16:15
16:35
16:55
17:15
17:35
17:55
Time [UTC]

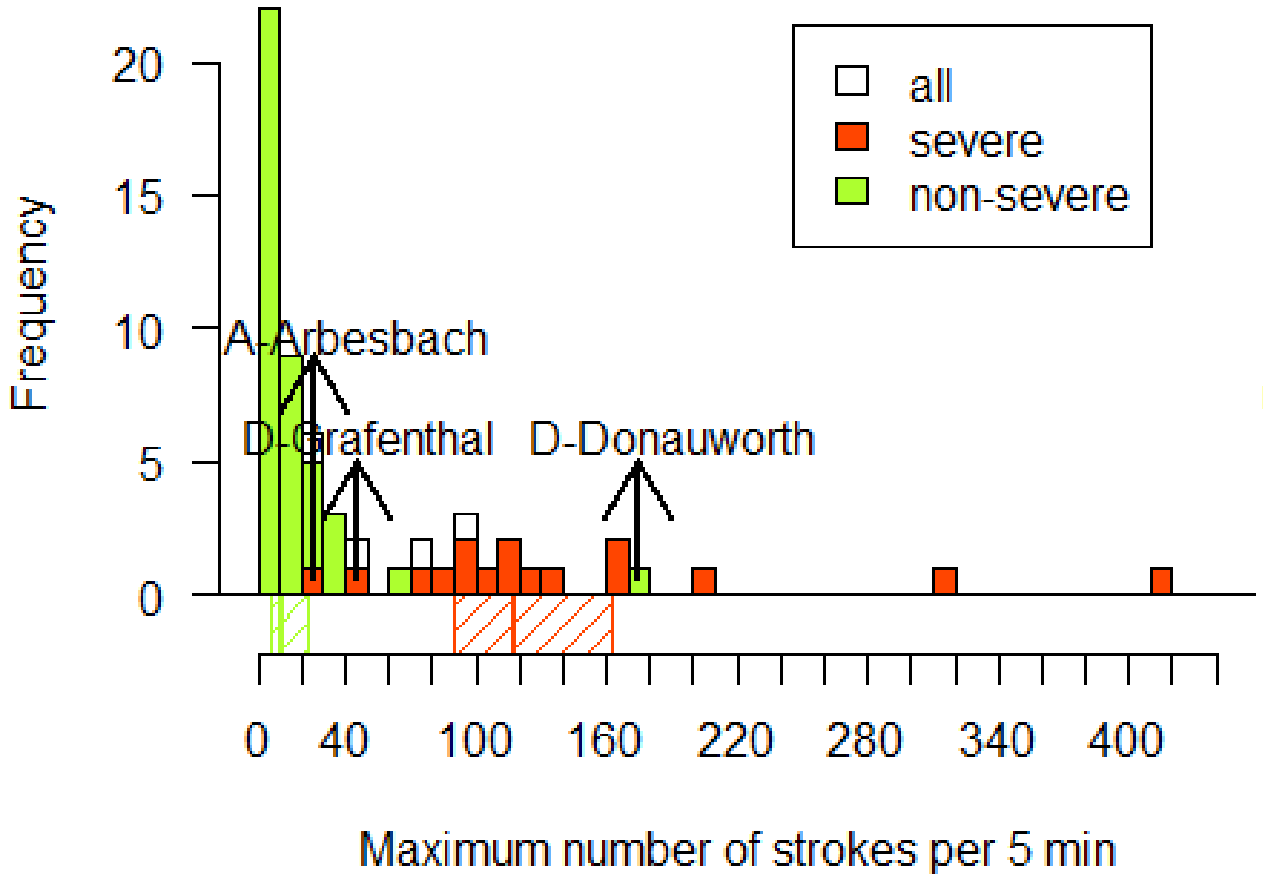

Storm POSH, HAIL_PROB, MESH and VIL on 2017-07-08 by CELLTRACK (CZ-Opava)
Probability [%]
maxPOSH
meanPOSH
maxHP
meanHP
Mass of precipitation [kg/m2]
Size of hail [mm]
maxVIL
meanVIL
maxMEHS
meanMEHS
07:45
08:05
08:25
08:45
09:05
09:25
09:45
10:05
10:25
10:45
11:05
11:25
Time [UTC]

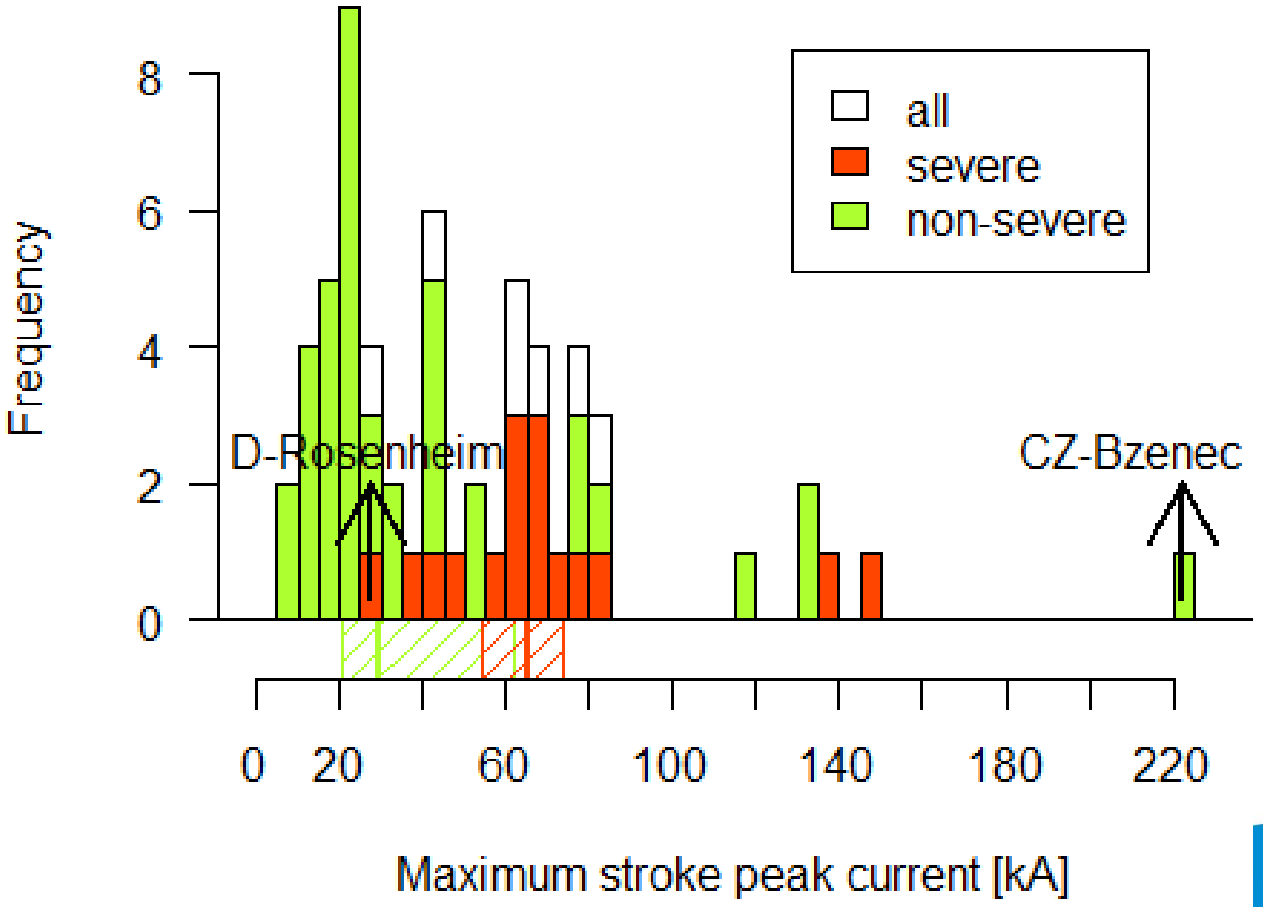
STORM DATABASE


all storms
severe
non-severe
Frequency
Duration [min]
0
60
120
180
240
300
360
420
480
0
5
10
15
20
25
Time [UTC]
07:00
12:00
17:00
22:00
0
2
4
6
8
Date
2016-04-30
2016-10-31
2017-04-30
0
5
10
15

LIGHTNING DETECTION

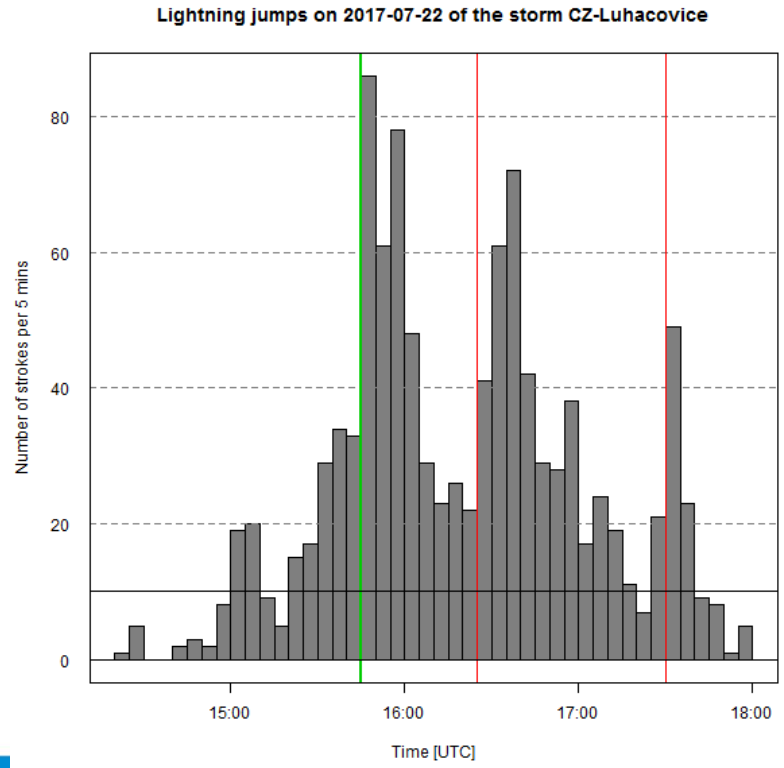
- absolute number of strokes, CC and CG rate, peak current

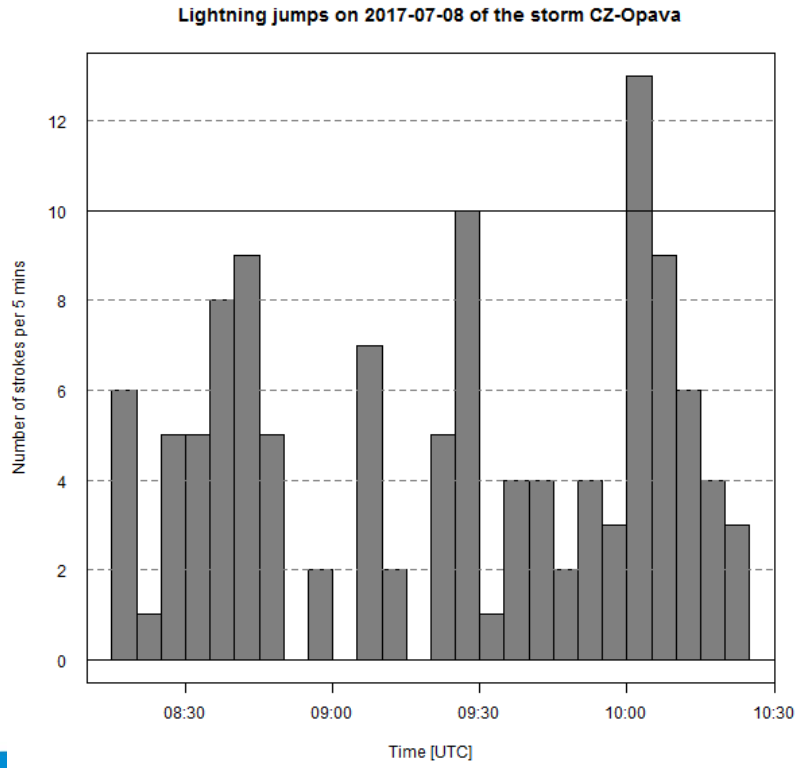


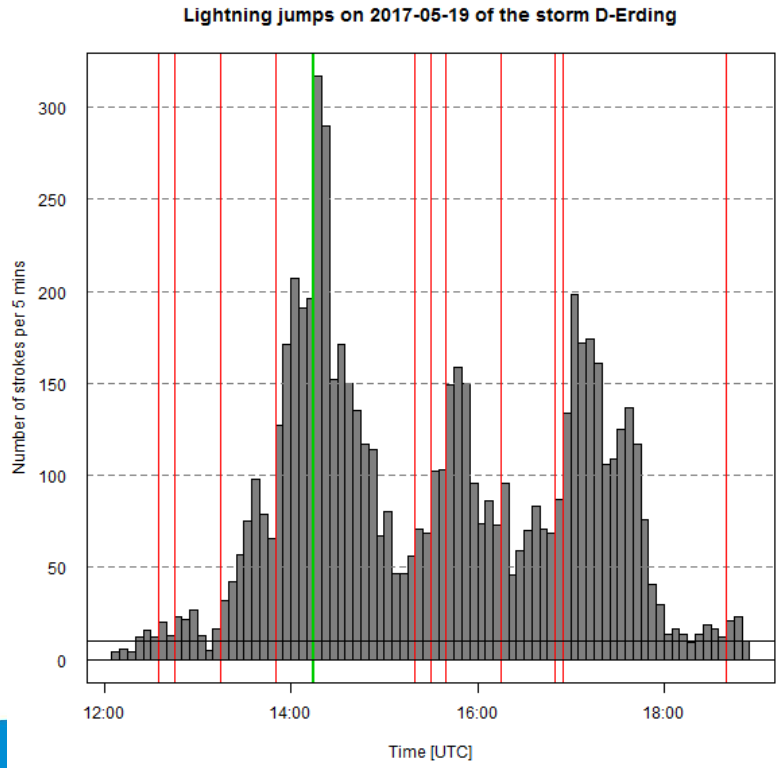


LIGHTNING JUMP

- lightning jump algorithm
  - threshold for activation: 10 strokes per 5 min (median for non-severe storms)
  - difference is higher than 2σ of previous 15 min (Schultz et al., 2009)
  - normalized difference between the amount of strokes = value of LJ



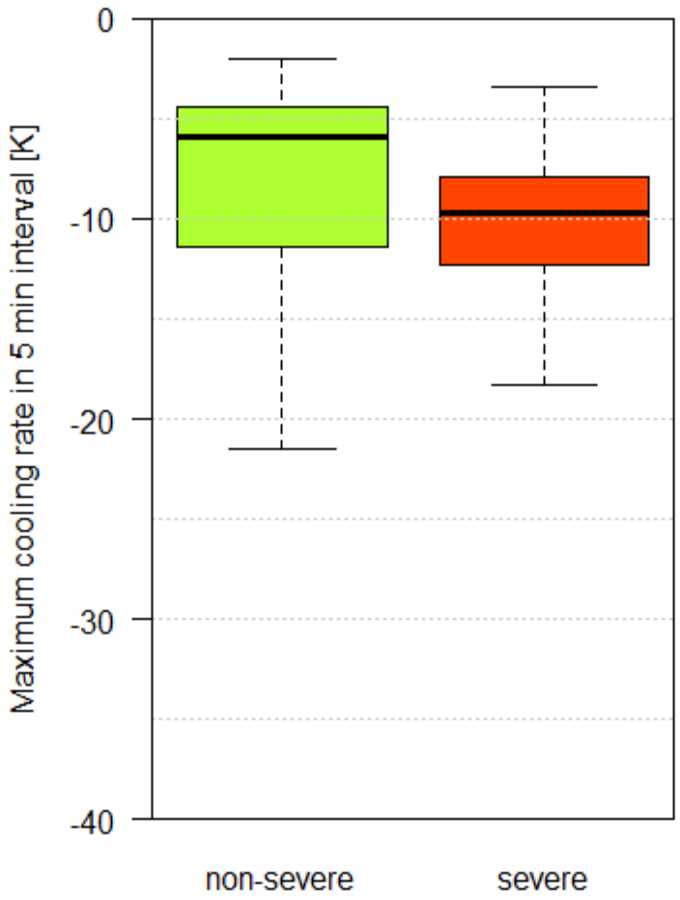


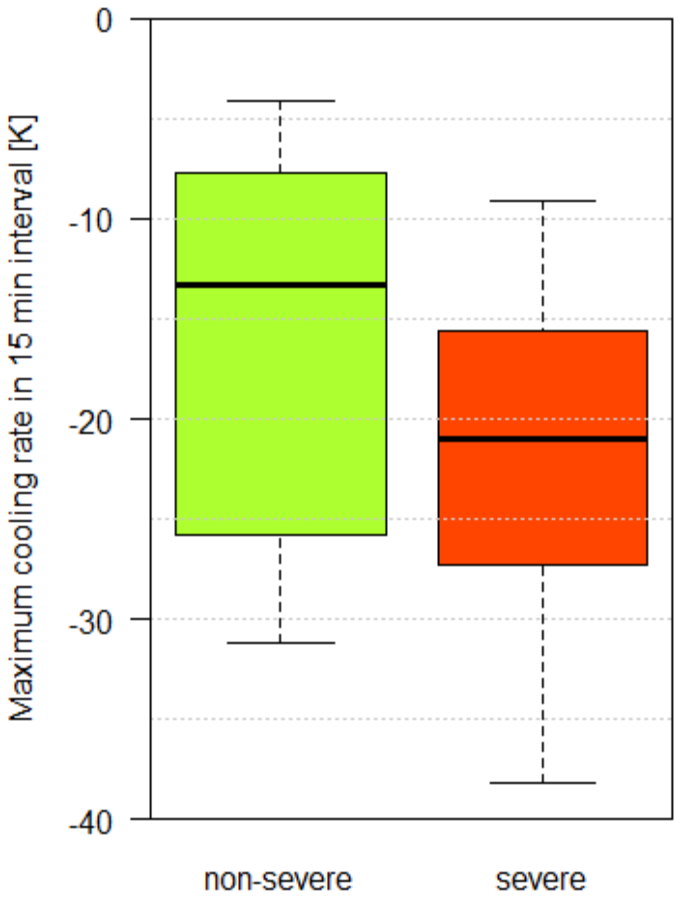


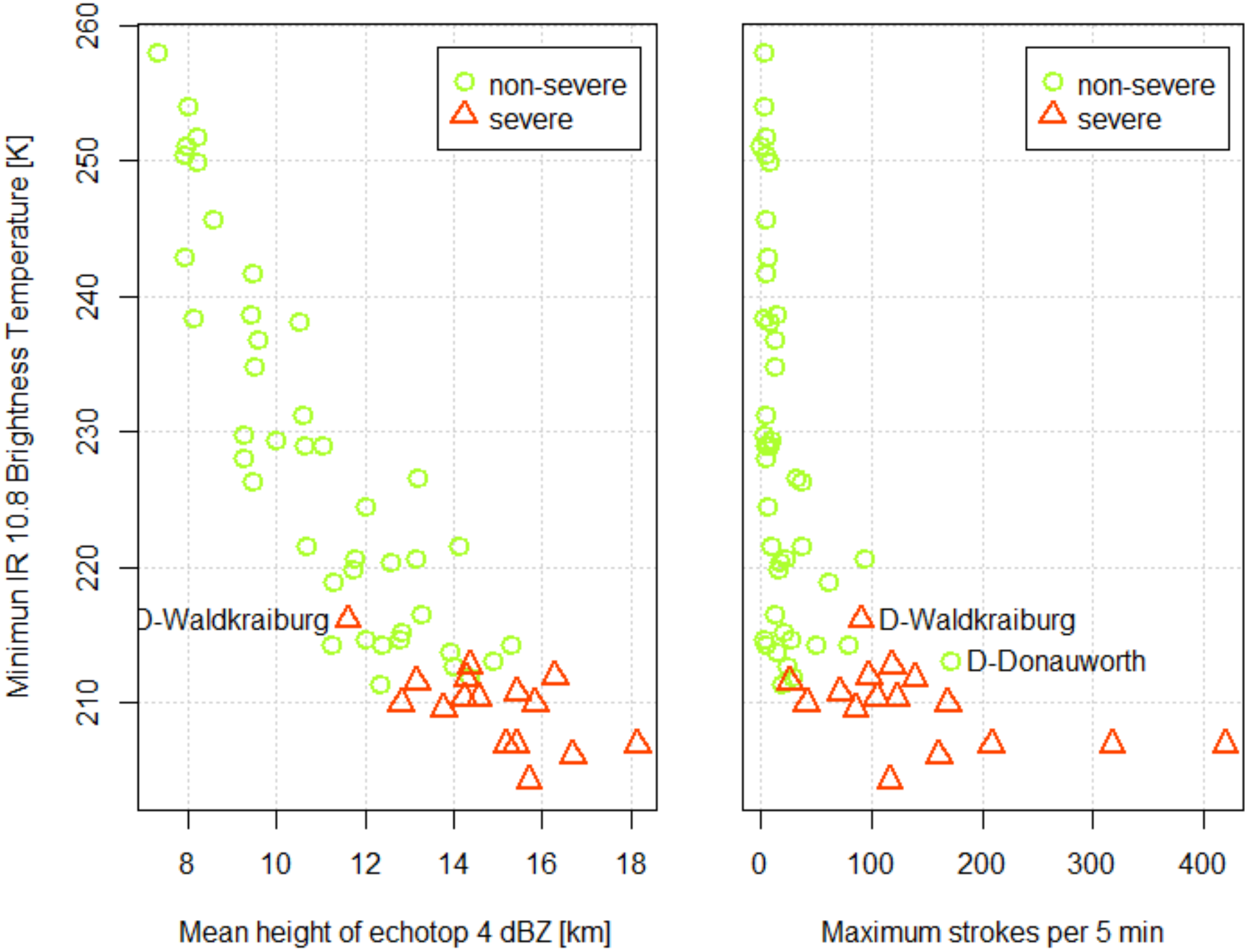
SATELLITES

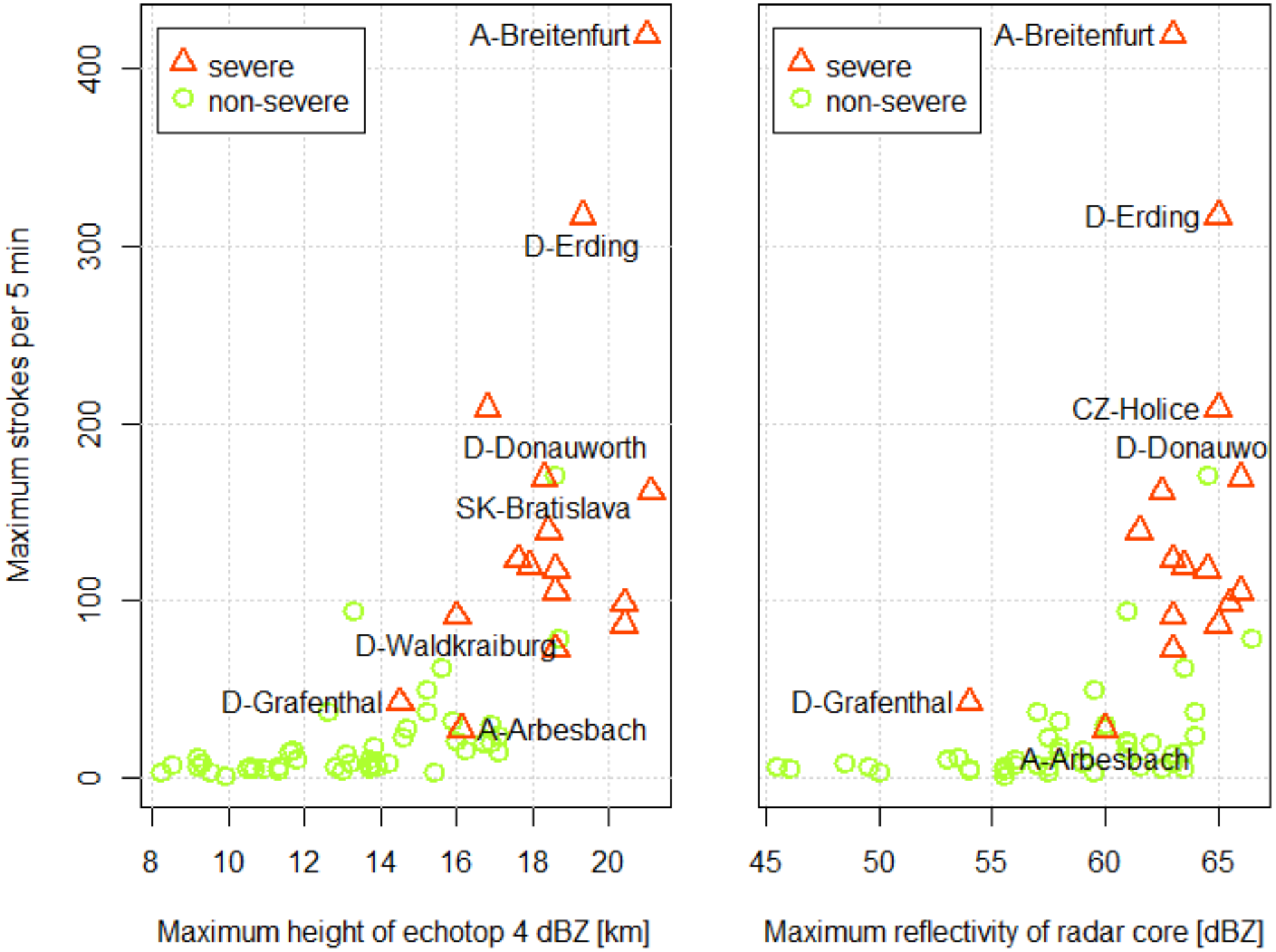
- minimum BT in IR 10.8
- cooling rate in 5, 15 and 30 min
- cloud-top observed features:

  OTs, cold-U or cold ring shapes, plume, small ice particles






Minimun IR 10.8 Brightness Temperature [K]
260
250
240
230
220
210
non-severe
severe
D-Waldkraiburg
8
10
12
14
16
18
Mean height of echotop 4 dBZ [km]
non-severe
severe
D-Waldkraiburg
D-Donauworth
0
100
200
300
400
Maximum strokes per 5 min


severe
non-severe
A-Breitenfurt
D-Erding
D-Donauworth
SK-Bratislava
D-Waldkraiburg
D-Grafenthal
A-Arbesbach
Maximum strokes per 5 min
0
100
200
300
400
8
10
12
14
16
18
20
Maximum height of echotop 4 dBZ [km]
severe
non-severe
A-Breitenfurt
D-Erding
CZ-Holice
D-Donauwo
D-Grafenthal
A-Arbesbach
45
50
55
60
65
Maximum reflectivity of radar core [dBZ]

LOGISTIC REGRESSION MODEL

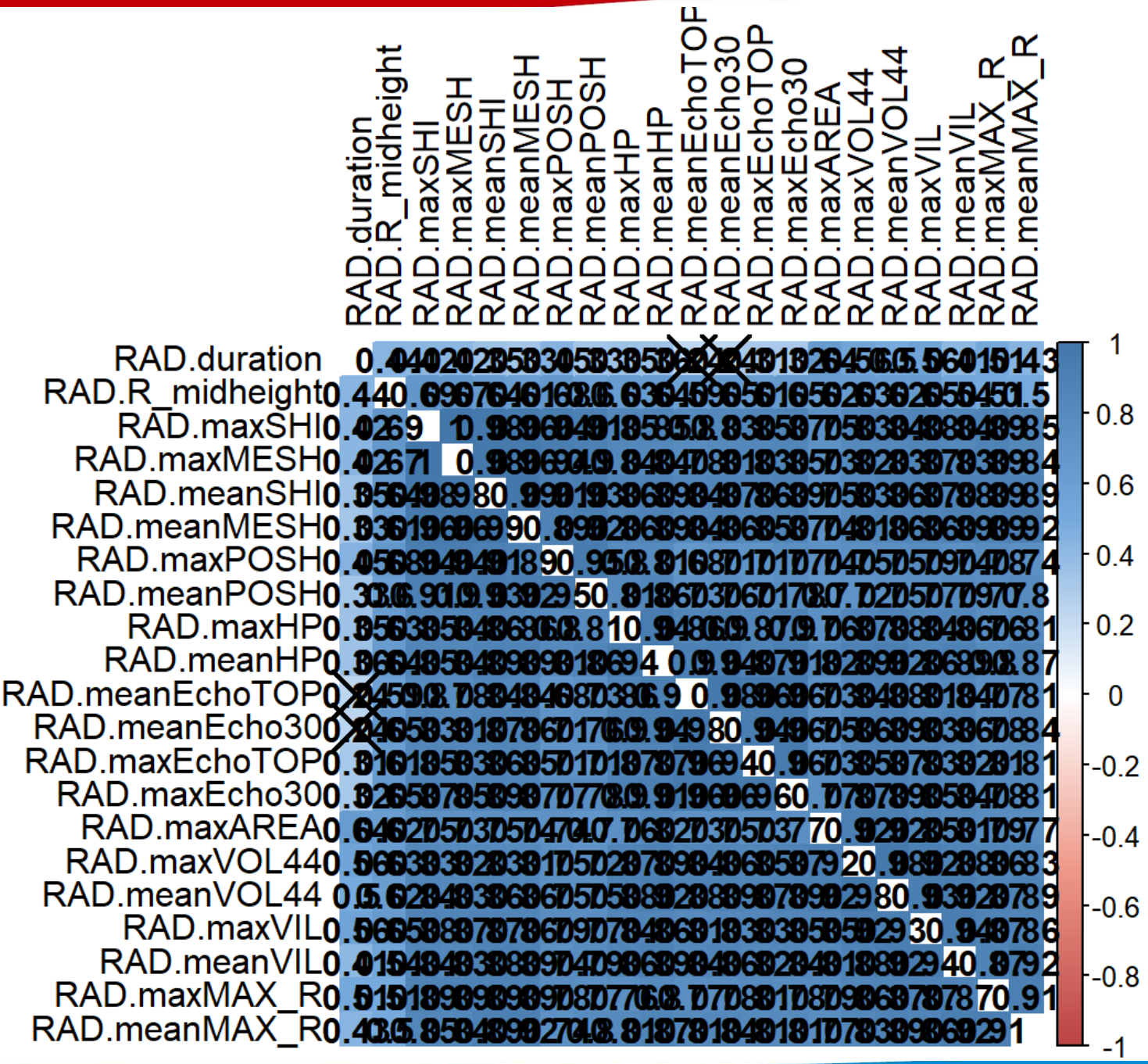
- explain relationships between one dependent dichotomous variable (0 or 1) and one or more independent variables →

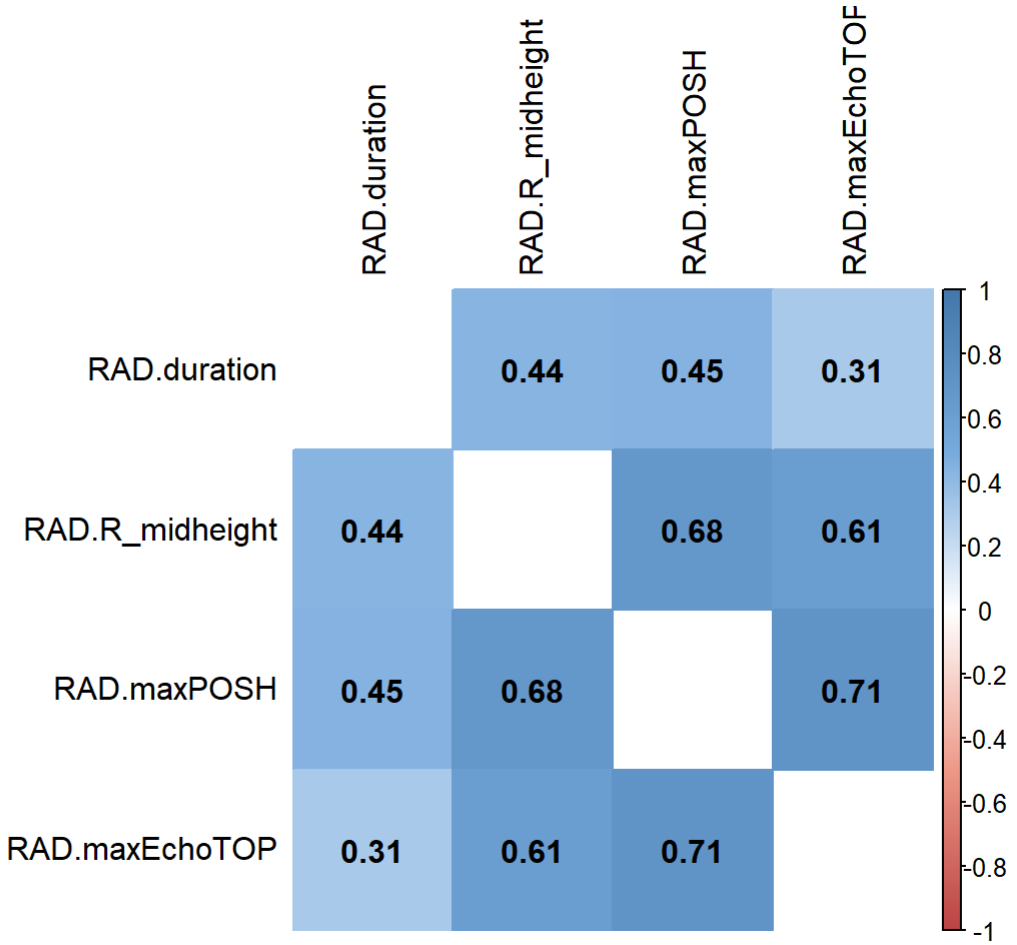
  odds of the storm being severe based on predictors from remote sensing measurements

- probability of the storm being severe
- conditions:
  - no high correlations among the predictors !!!
  - about 1 predictor per 10 cases to make model converge

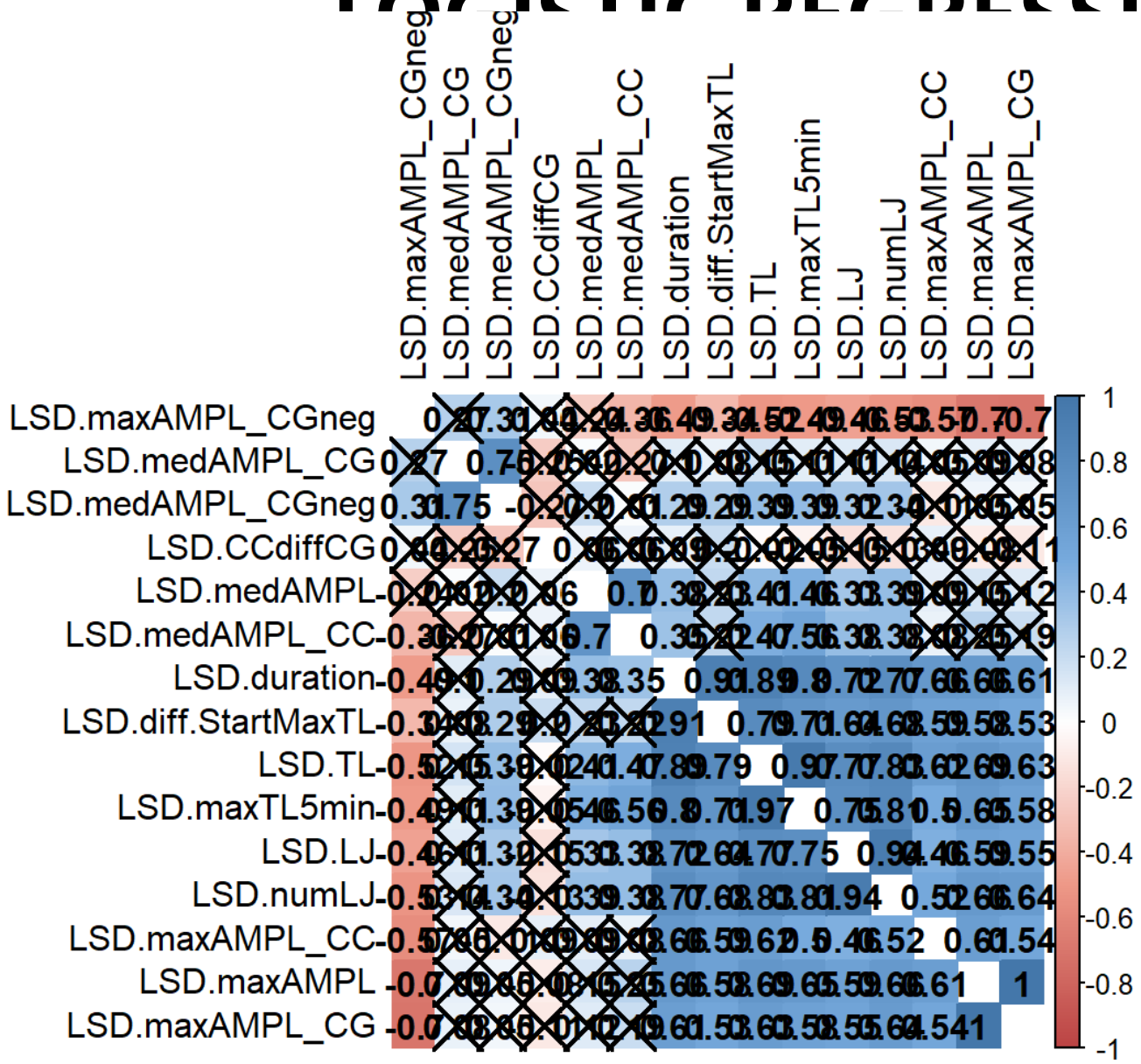
$$P = \frac{e^{a+bX}}{1+e^{a+bX}}$$

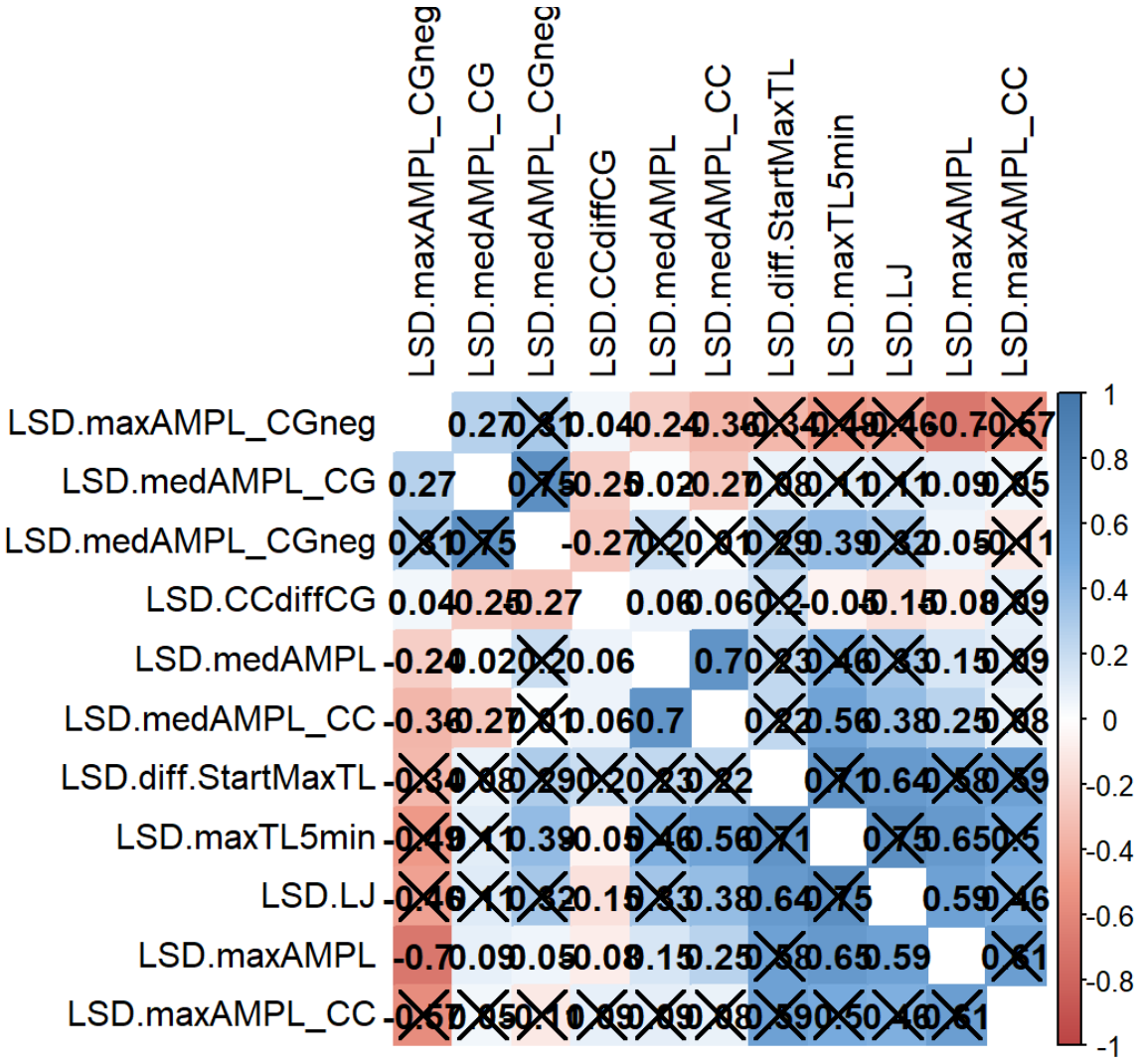
MODEL - RAD


RAD.duration
RAD.R_midheight
RAD.maxSHI
RAD.maxMESH
RAD.meanSHI
RAD.meanMESH
RAD.maxPOSH
RAD.meanPOSH
RAD.maxHP
RAD.meanHP
RAD.meanEchoTOP
RAD.meanEcho30
RAD.maxEchoTOP
RAD.maxEcho30
RAD.maxAREA
RAD.maxVOL44
RAD.meanVOL44
RAD.maxVIL
RAD.meanVIL
RAD.maxMAX_R
RAD.meanMAX_R
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

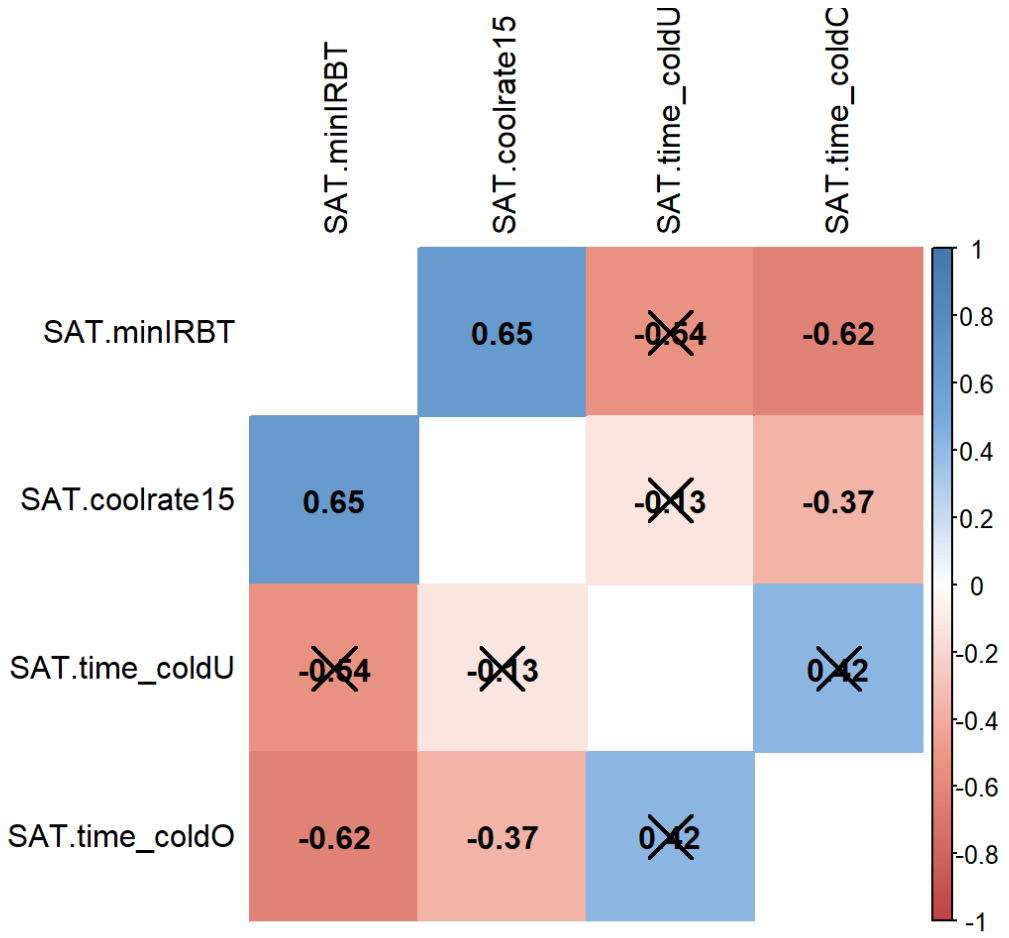

RAD.duration
RAD.R_midheight
RAD.maxPOSH
RAD.maxEchoTOP
0.44
0.45
0.31
0.44
0.68
0.61
0.45
0.68
0.71
0.31
0.61
0.71
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

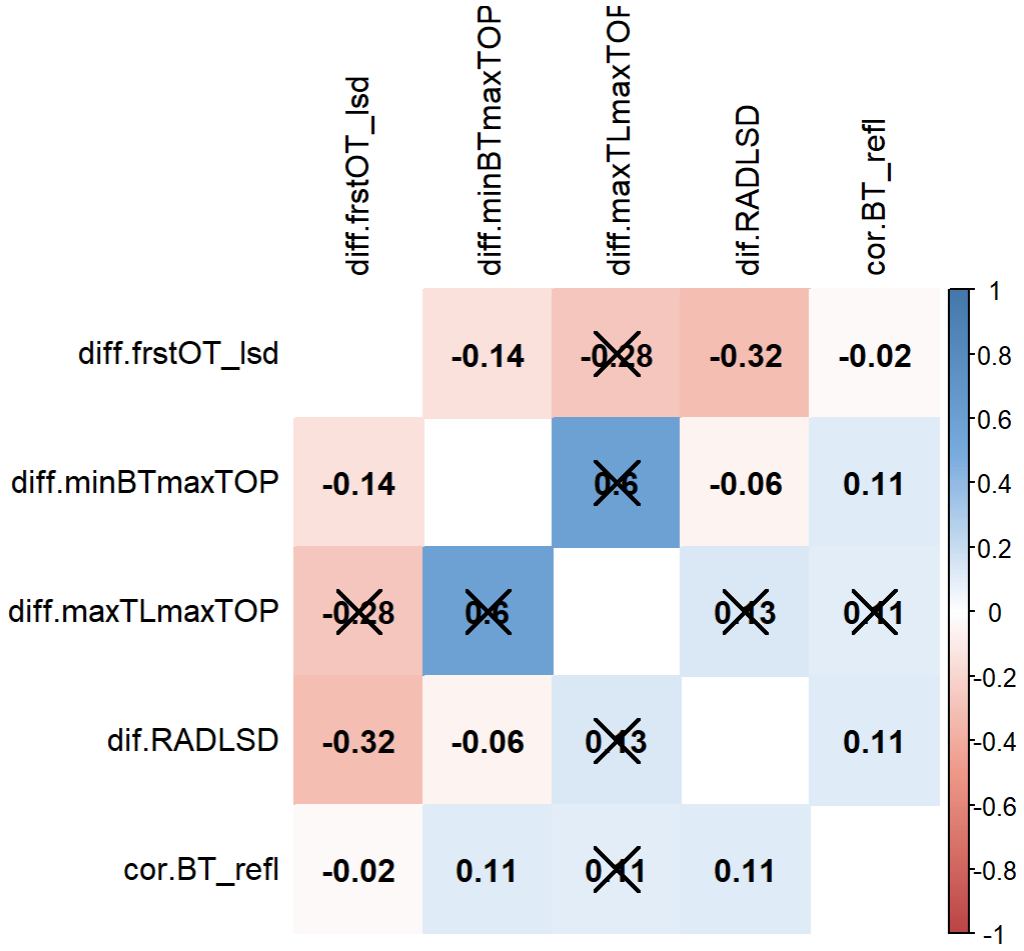
LOGISTIC REGRESSION MODEL - LSD





LOGISTIC REGRESSION MODEL – SAT & DIFF



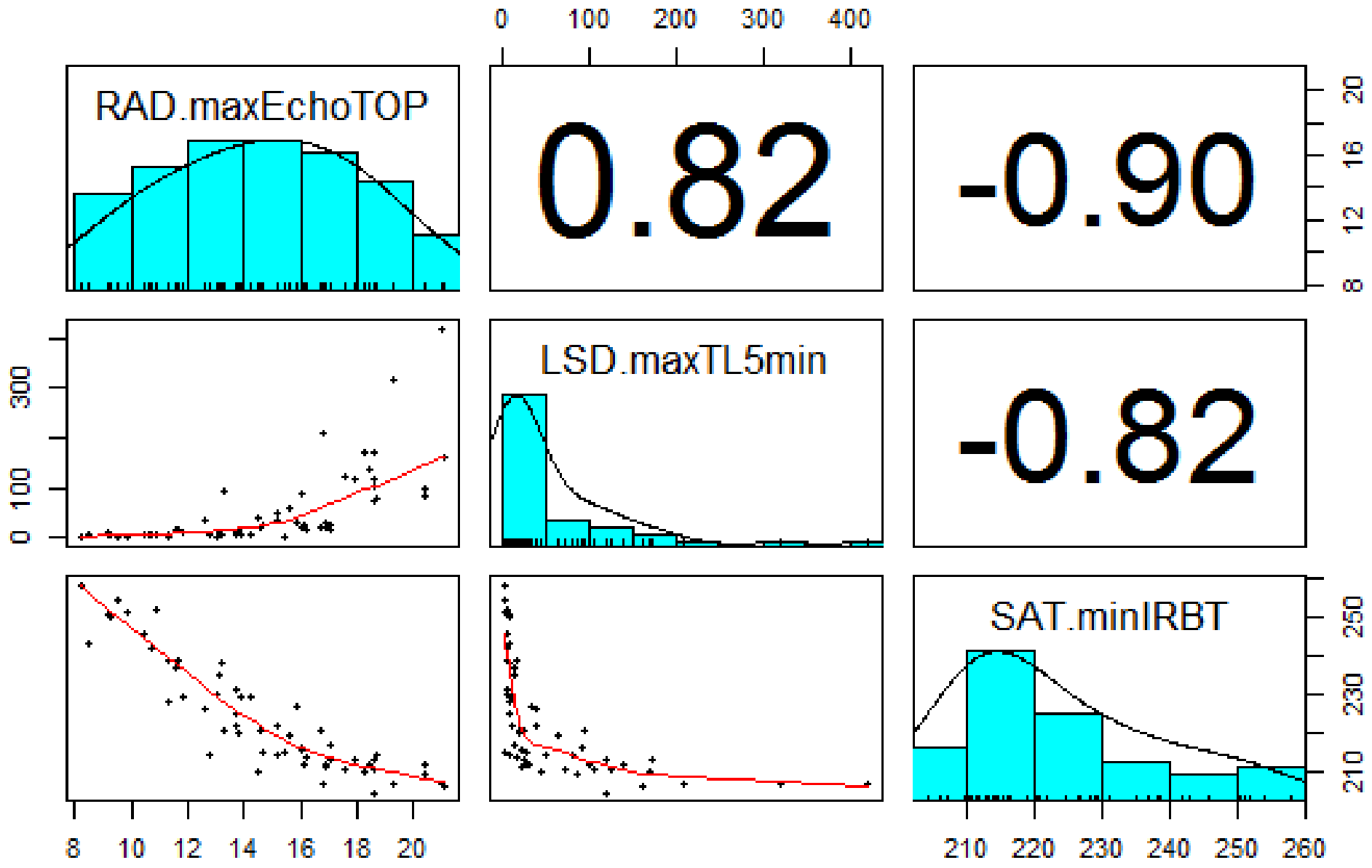


LOGISTIC REGRESSION MODEL

- all tests non-parametric, two-sided, 5% level of significance
- variables with $p < 0.25$ from univariate analyses → backward stepwise variable elimination → odds ratio
- accuracy of the model for a given set of data

parameter	odds ratio	p-value	accuracy*	AIC*
RAD.maxEchoTOP	3.98	0.002	92.98 %	28.1
LSD.maxTL5min	1.06	0.007	94.74 %	19.9
LSD.LJ	2.04	0.112		
SAT.minIRBT	2.33	0.008	90.91 %	24.2

* Leave-One-Out Cross Validation and Akaike Information Criterion


RAD.maxEchoTOP
0.82
-0.90
LSD.maxTL5min
-0.82
SAT.minIRBT
0
100
200
300
400
20
16
12
8
300
100
0
250
230
210
8
10
12
14
16
18
20
210
220
230
240
250
260

ELASTIC NET

- a penalized regression technique
  - number of features (k=81/69) exceeds the number of observations (n=57)
  - presence of highly correlated predictors
- two penalty terms (α, λ) providing:
  - selection of important predictors
  - shrink the predictor's coefficients to reduce the model over-fitting
- *cv.glmnet* in R tests the performance of each λ by using the cross validation
  - small size of dataset → Leave-One-Out Cross Validation method

ELASTIC NET

parameter	odds ratio
RAD.maxEcho30	1.116
RAD.maxVOL44	1.000
RAD.maxAREA	1.001
RAD.R_midheight	1.086
RAD.maxSHI	1.003
LSD.maxTL5min	1.003
LSD.LJ	1.157

- accuracy: 92.73 %
- 7 of 39 parameters
- majority are RAD variables
- omit SAT variables

model	α	accuracy
LASSO	1	91
Ridge	0	91
Elastic net	0.85	93

SUMMARY

- most of studied remote sensing parameters are dependent on the storm severity → useful information for nowcasting
- lightning jump algorithm was proposed
  - beneficial parameter for the estimation of the storm severity
- logistic regression models were employed
  - small data sample (up to 60 cases) → Leave-One-Out Cross Validation
  - high level of accuracy (over 90 %)
- lightning stroke amount seems to be the best predictor
  - maximum number of all strokes in 5 min interval and relative changes (LJ)

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Marian Rybář (MATSTAT)

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