CZECH HYDROMETEOROLOGICAL INSTITUTE

DEPARTMENT OF ATMOSPHERIC PHYSICS
CHARLES UNIVERSITY

CONVECTIVE STORM NOWCASTING

CAPABILITIES OF REMOTE SENSING IN CENTRAL EUROPE

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3rd European Nowcasting Conference

Madrid, Spain, 25 April 2019

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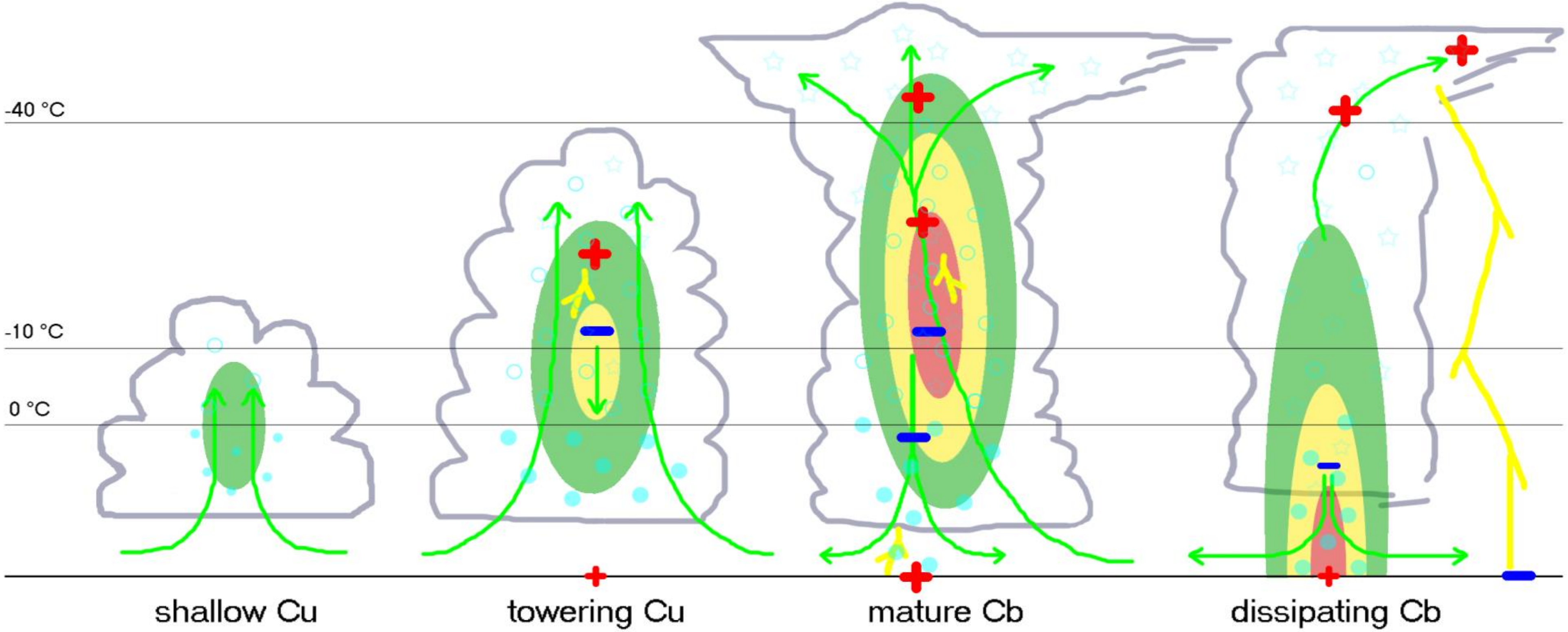
POSSIBLE UTILIZATION

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



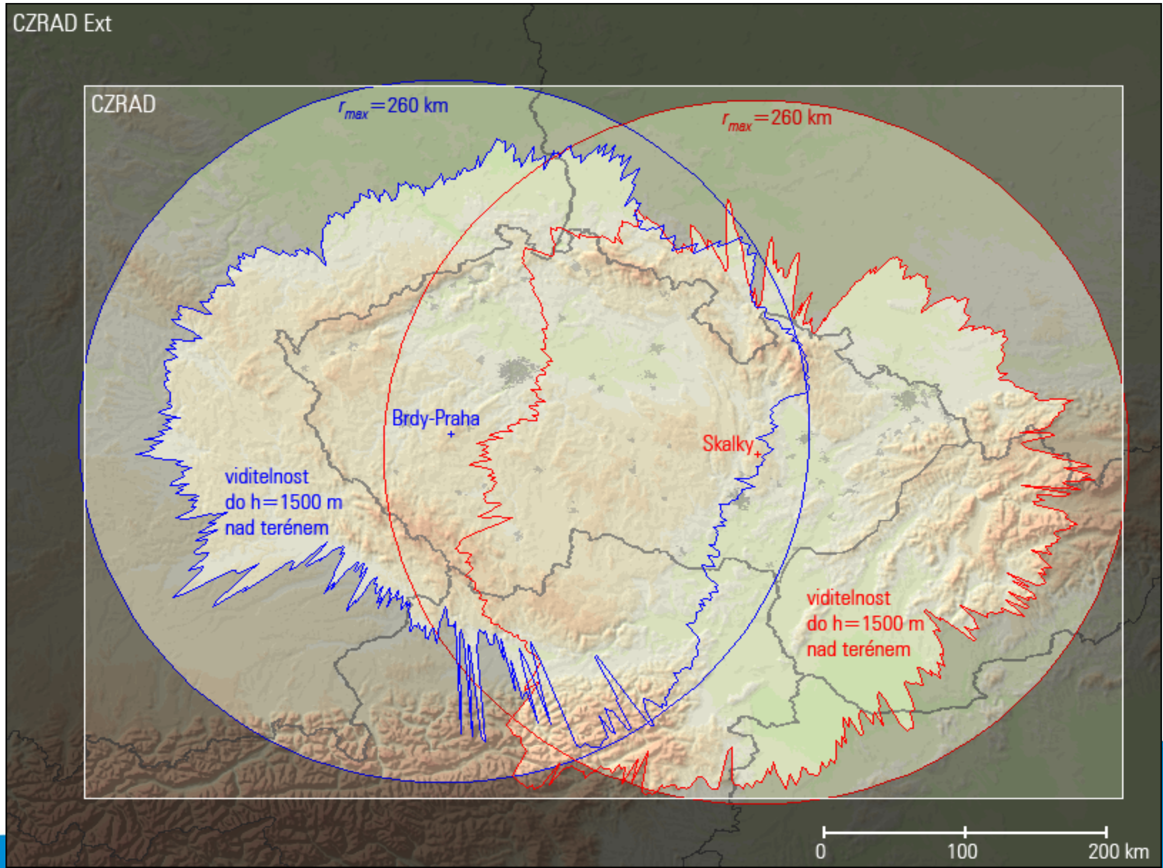
REMOTE SENSING

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, COTREC
    - CELDN strokes
    - PrecipView, WarnView

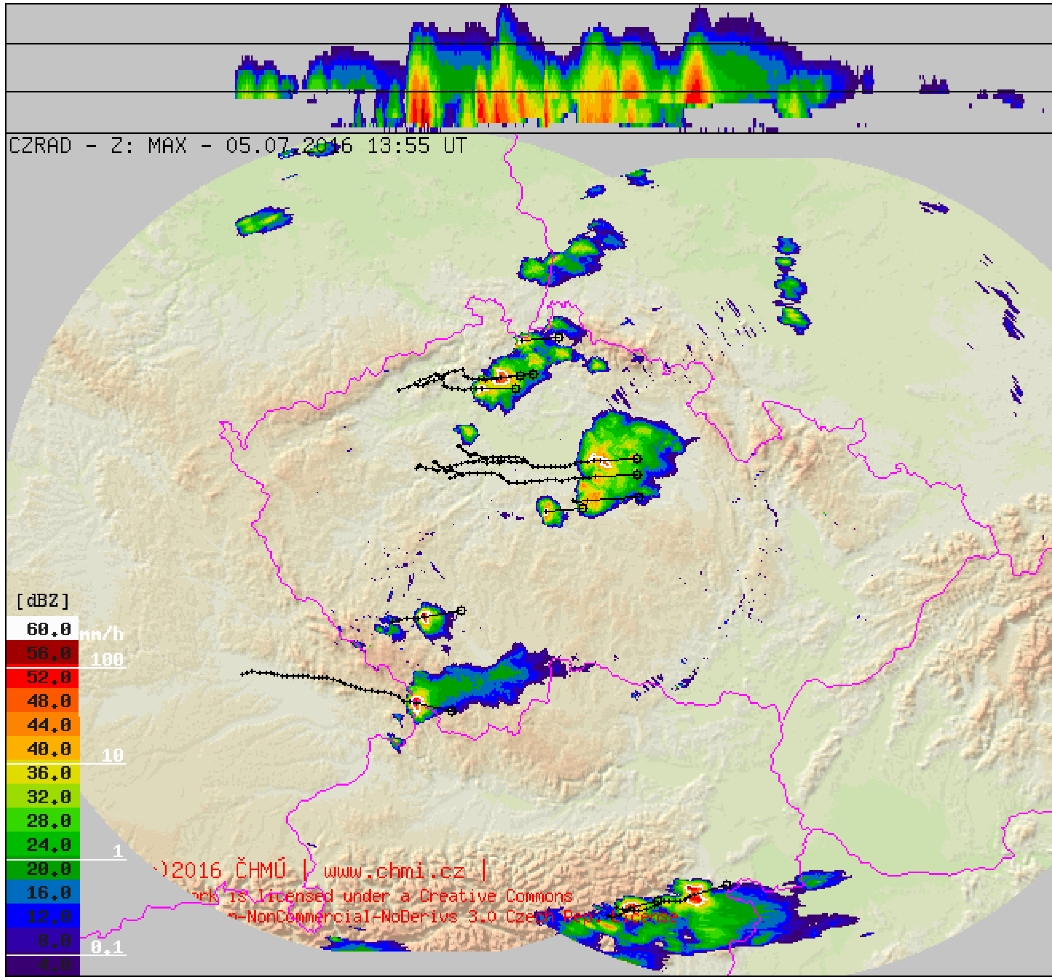


RADARS - CELLTRACK

- 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, POH, SHI, POSH, MESH



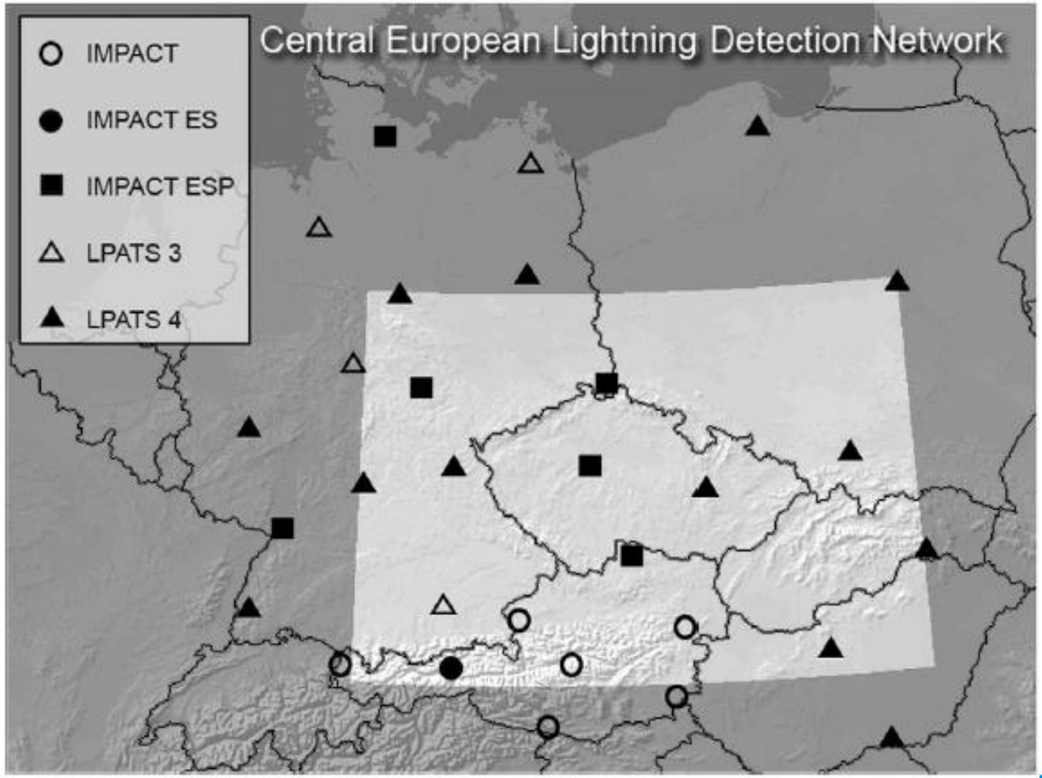
Operational output of CELLTRACK (JSMeteoView)

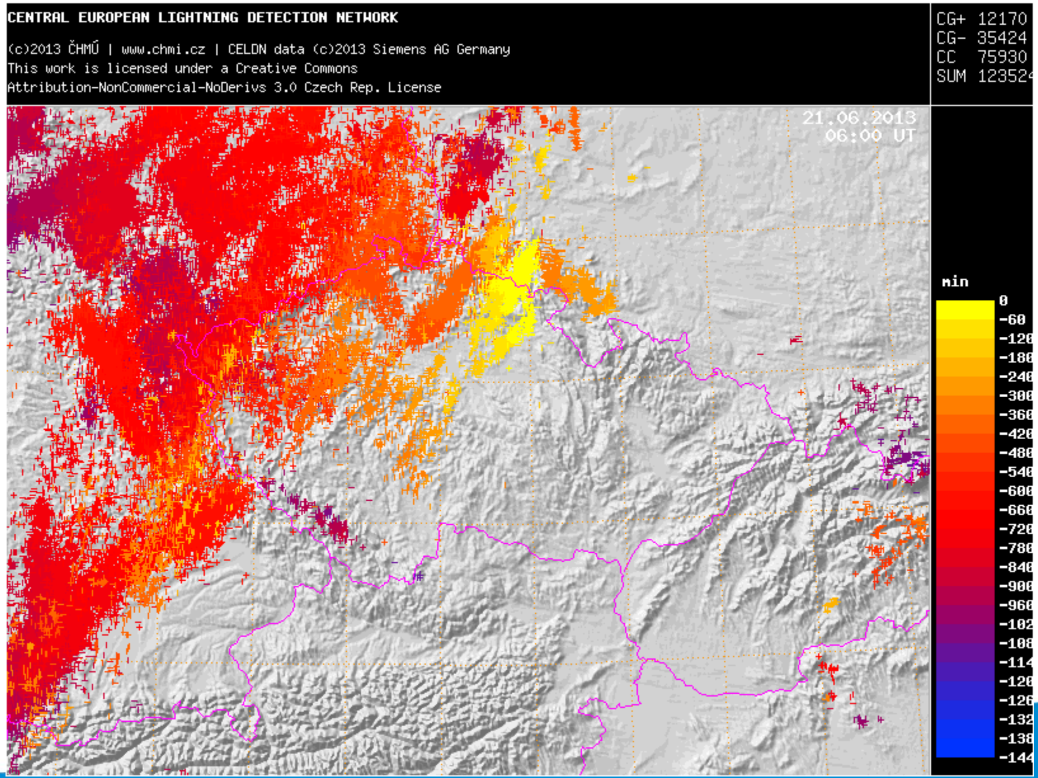
Kyznarová H., Novák P. (2009): CELLTRACK – Convective cell tracking algorithm and its use for deriving lifecycle characteristics, Atmospheric Research, vol. 93

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

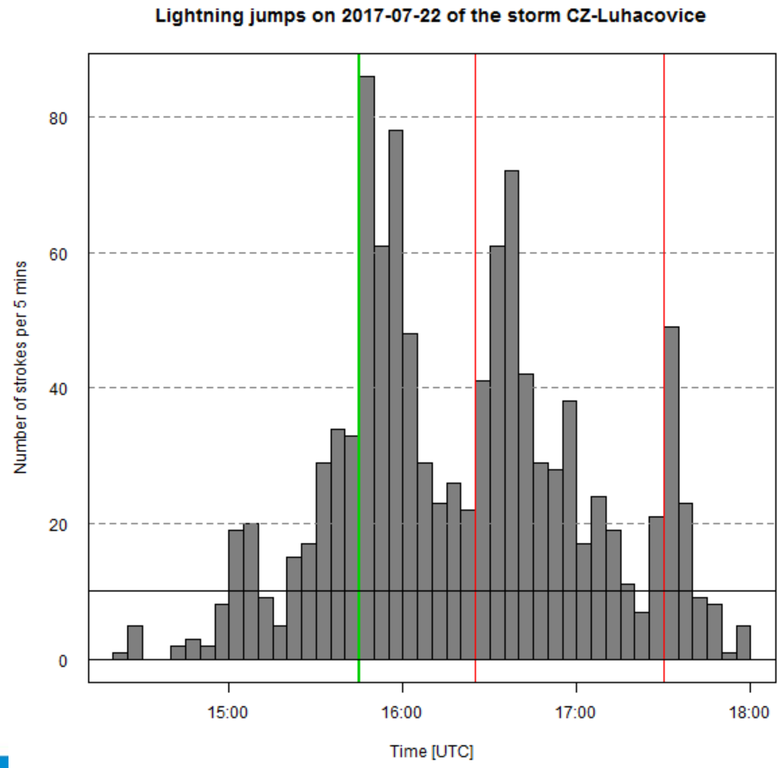
- microphysical properties, strength of updraft

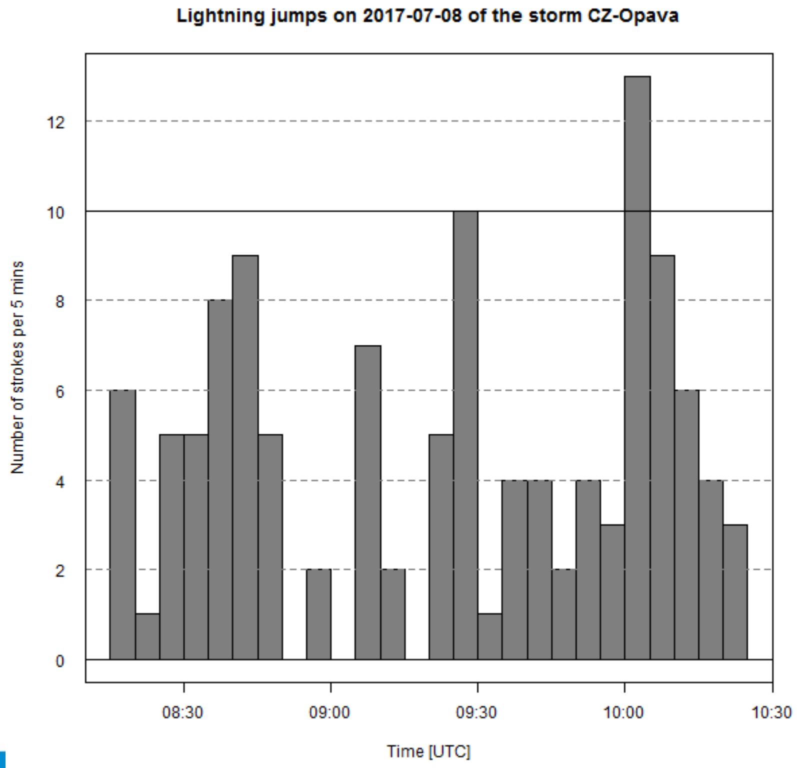
every stroke: type (CC, CG) and polarity, time [ms], location (LAT and LON), stroke peak current estimation [kA]

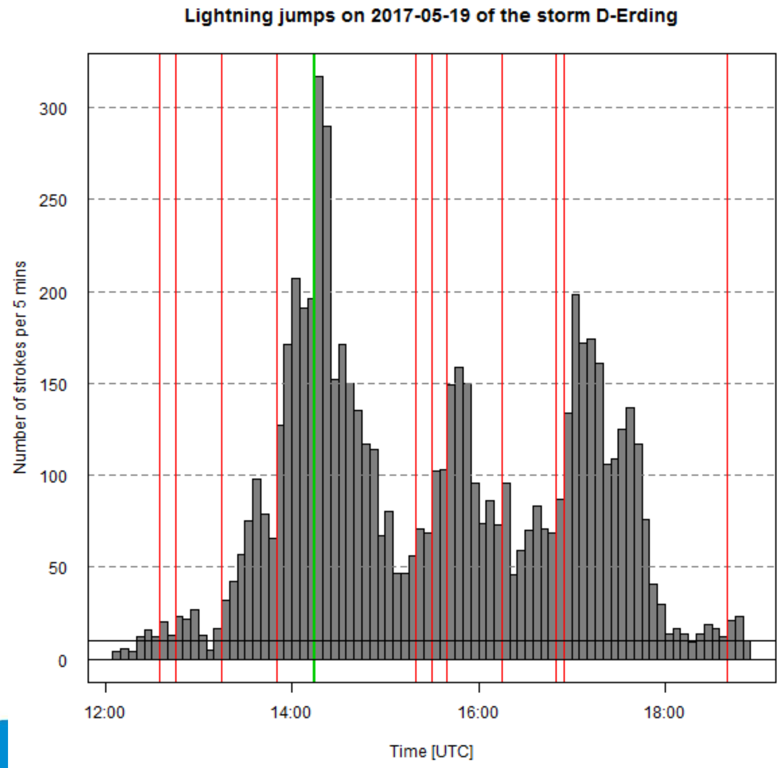
- detection efficiency: 85 % or higher for CG
- location accuracy: better than 500 m
- estimate of peak current: error ~ tens of %
- no stroke clustering into flashes

LIGHTNING JUMP

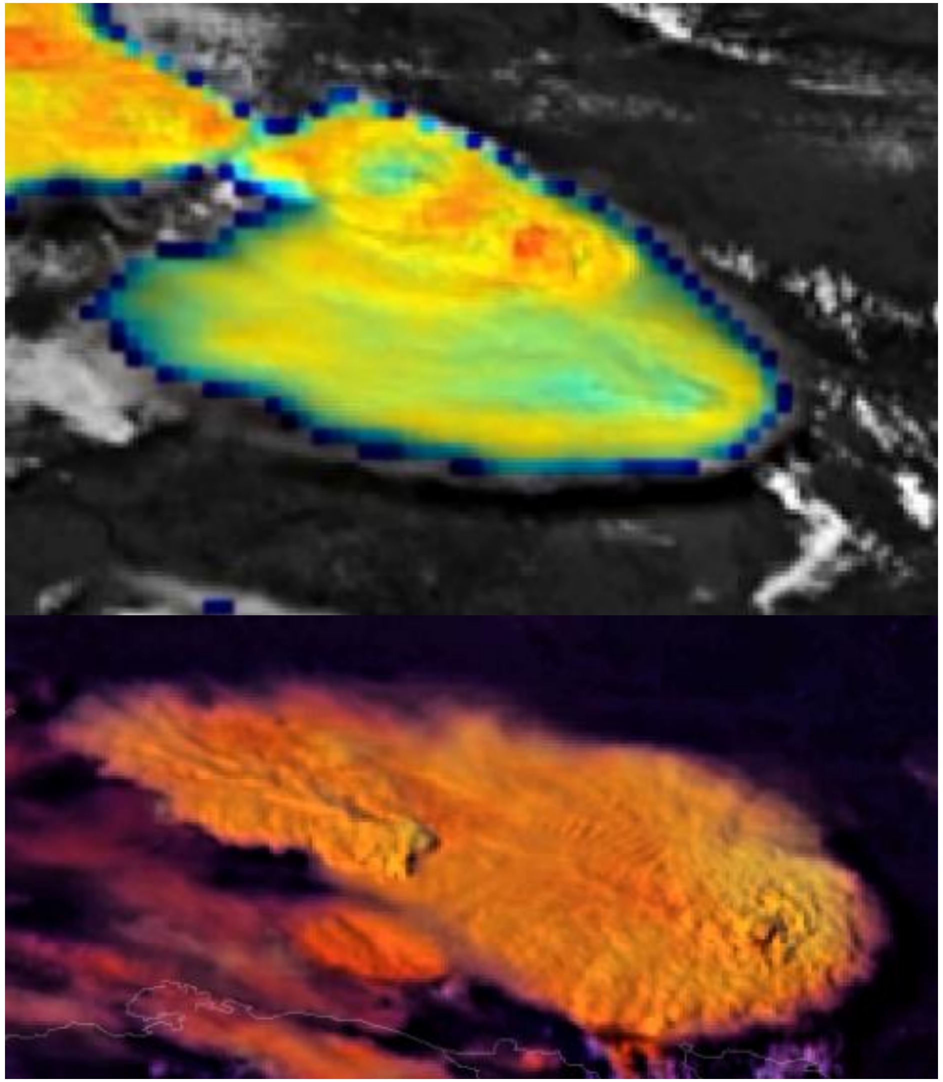
- lightning jump algorithm
  - threshold for activation: 10 strokes per 5 min (median for non-severe storms)
  - difference is higher than 2σ of previous 15 min (Schultz et al., 2009)
  - normalized difference between the amount of strokes = value of LJ



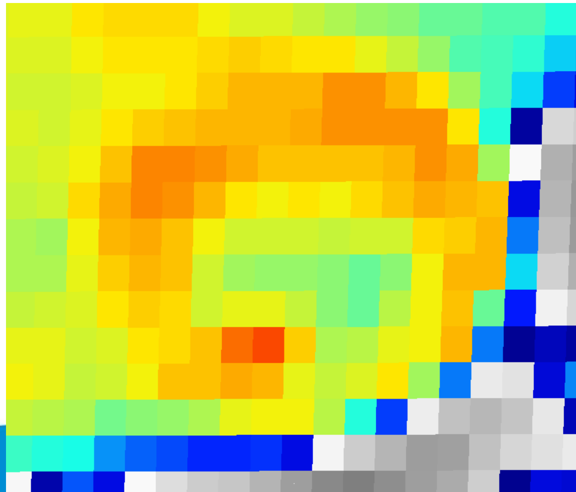




SATELLITES

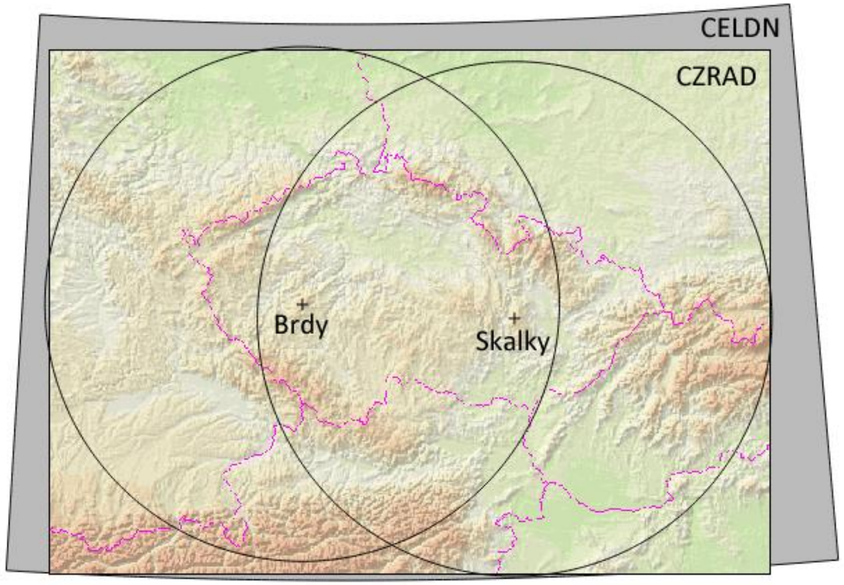


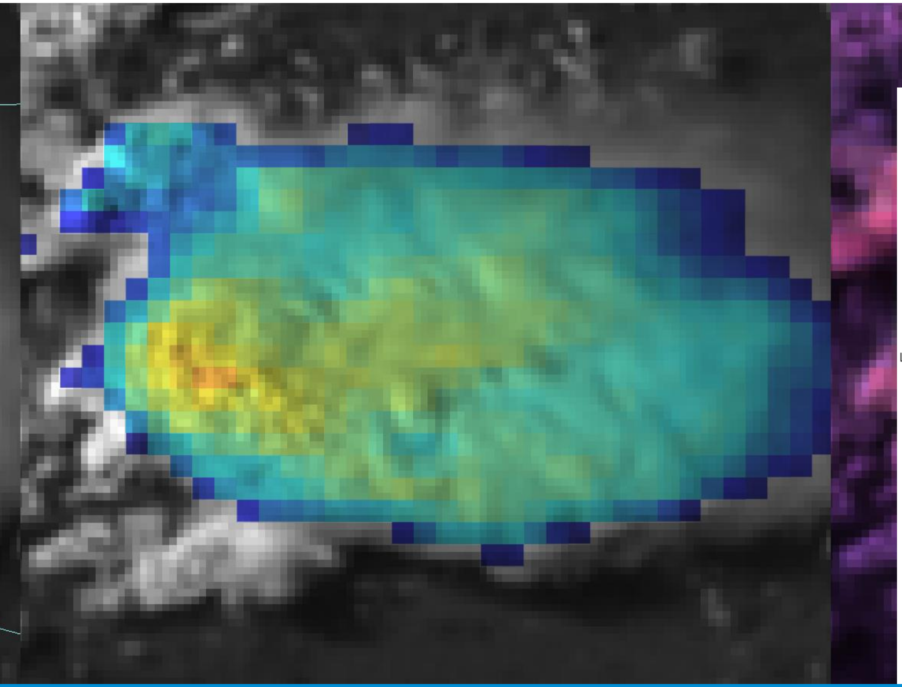
- microphysical properties and dynamics
- MSG/SEVIRI 5 min RSS or 15 min data
  - resolution 3×6 km (1×2 km in HRV)
  - individual channels:
    - » IR 10.8 and IR-BT, IR 3.9 and HRV
  - RGB products
    - » Storm, VIS-IR, Snow
  - sandwich products

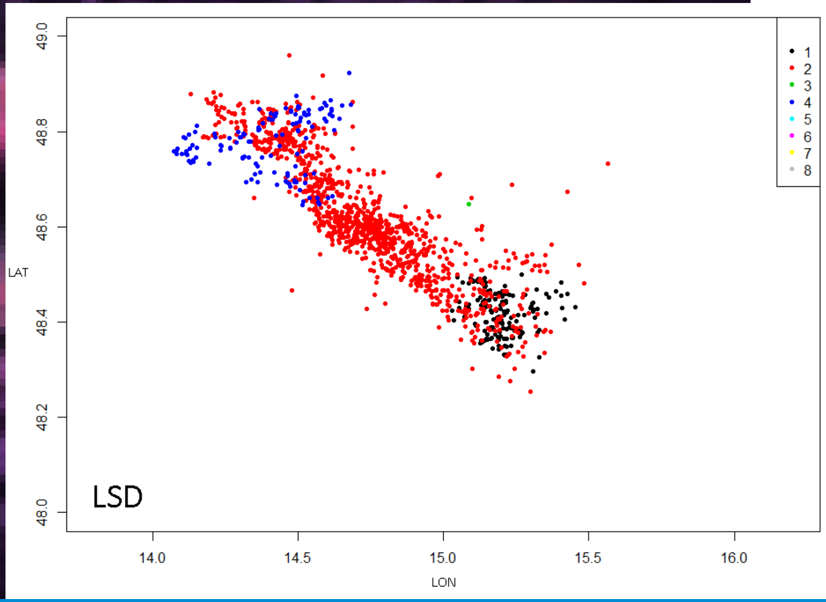


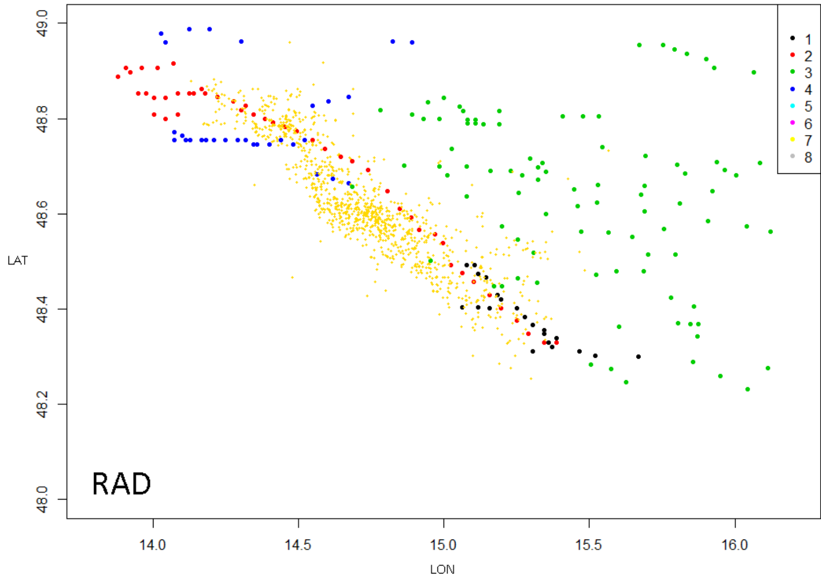
ISOLATED STORM SELECTION

- at least 5 strokes over the Czech republic
- CELLTRACK algorithm (30 dBZ threshold)
- remote sensing data available



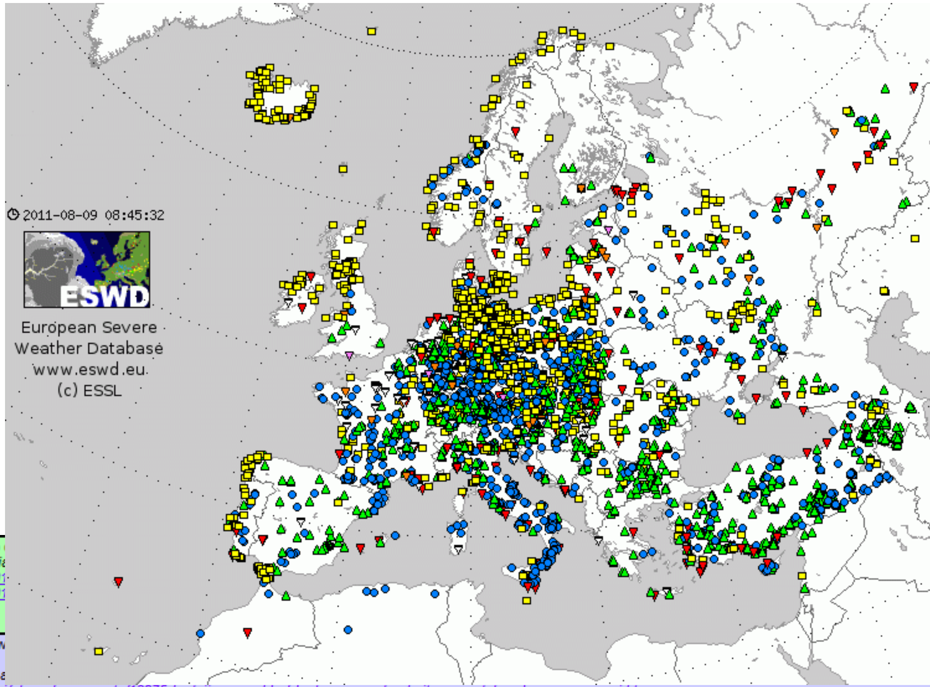


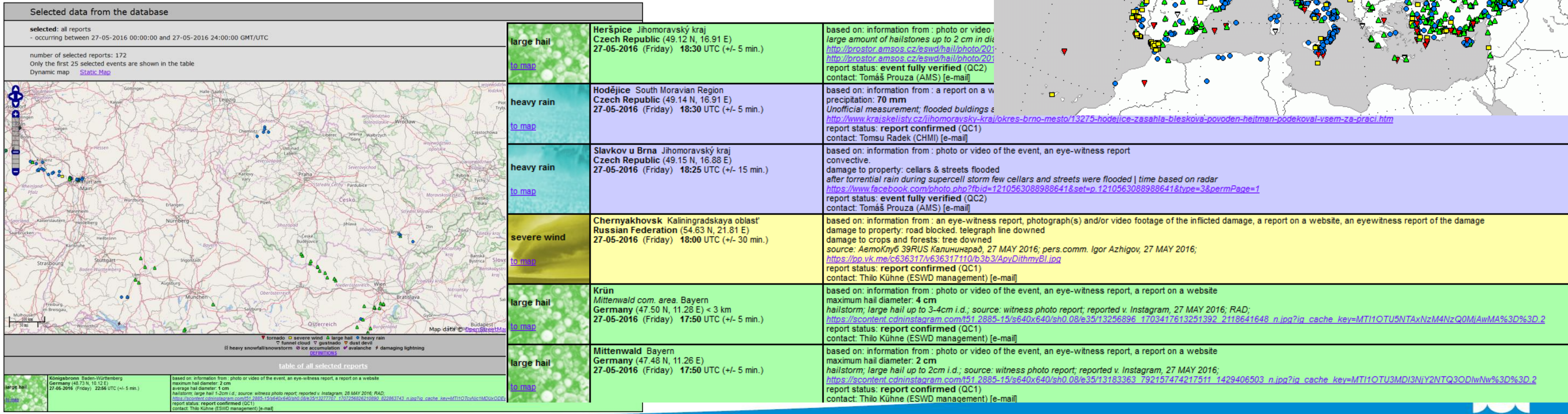




SEVERE WEATHER REPORTS

- 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

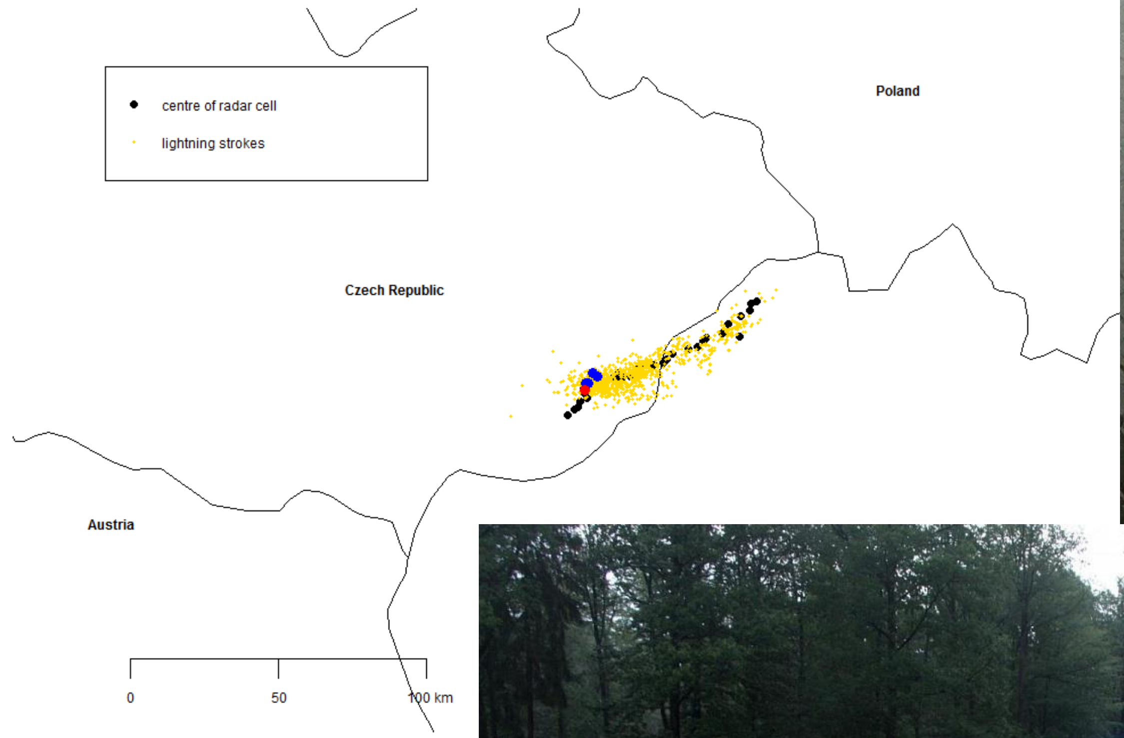
tornado, severe wind, large hail, heavy rain
funnel cloud, gustnado, dust devil
heavy snowfall/snowstorm, ice accumulation, avalanche, damaging lightning
DEFINITIONS

table of all selected reports

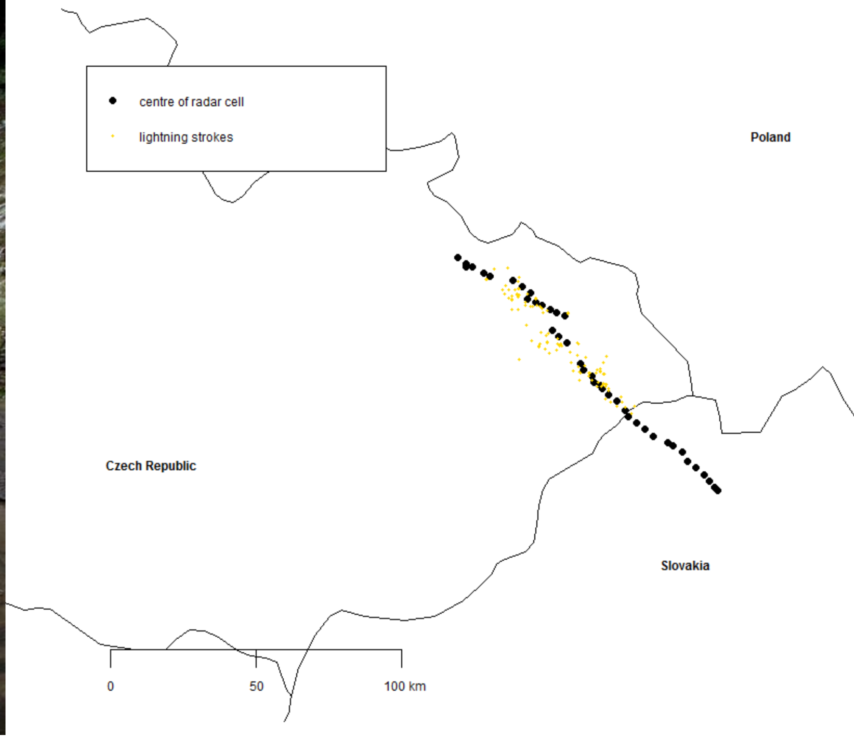
large hail to map	**Königsbronn** Baden-Württemberg **Germany** (48.73 N, 10.12 E) **27-05-2016** (Friday) **22:56** UTC (+/- 5 min.)	based on: information from : photo or video of the event, an eye-witness report, a report on a website maximum hail diameter: **2 cm** average hail diameter: **1 cm** *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/e35/13277707_1707256826210890_822863743_n.jpg?ig_cache_key=MTI1OTcyNjc1MDUxODEy 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 dia* http://prostor.amsos.cz/eswd/hail/photo/201 http://prostor.amsos.cz/eswd/hail/photo/201 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=MTI1OTU3MDI3NjY2NTQ3ODIwNw%3D%3D.2 report status: **report confirmed** (QC1) contact: Thilo Kühne (ESWD management) [e-mail]

SEVERE OR NON-SEVERE ?

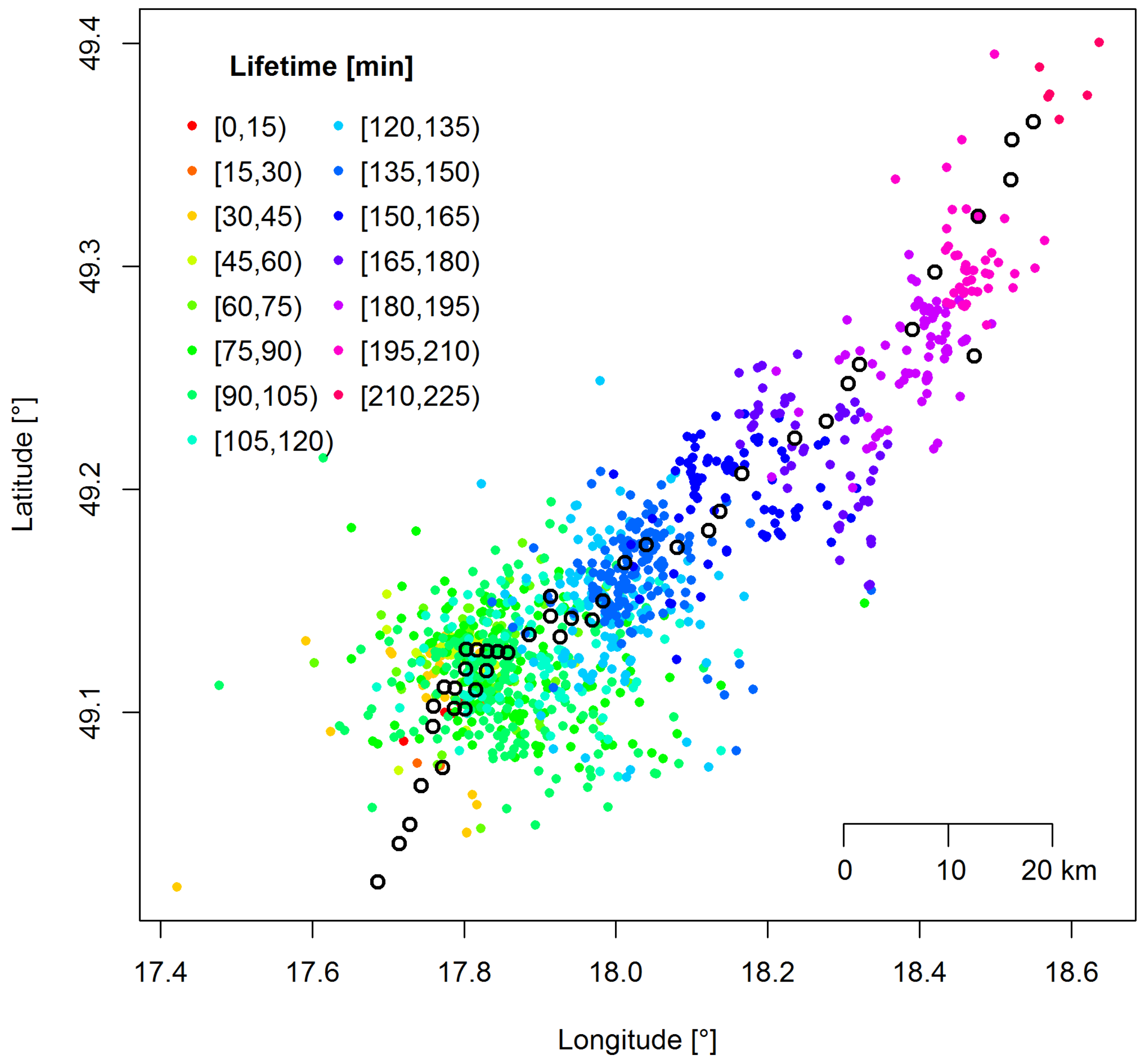
Radar and lightning detections on 2017-07-22 at 15:57 UTC (CZ-Luhacovice)



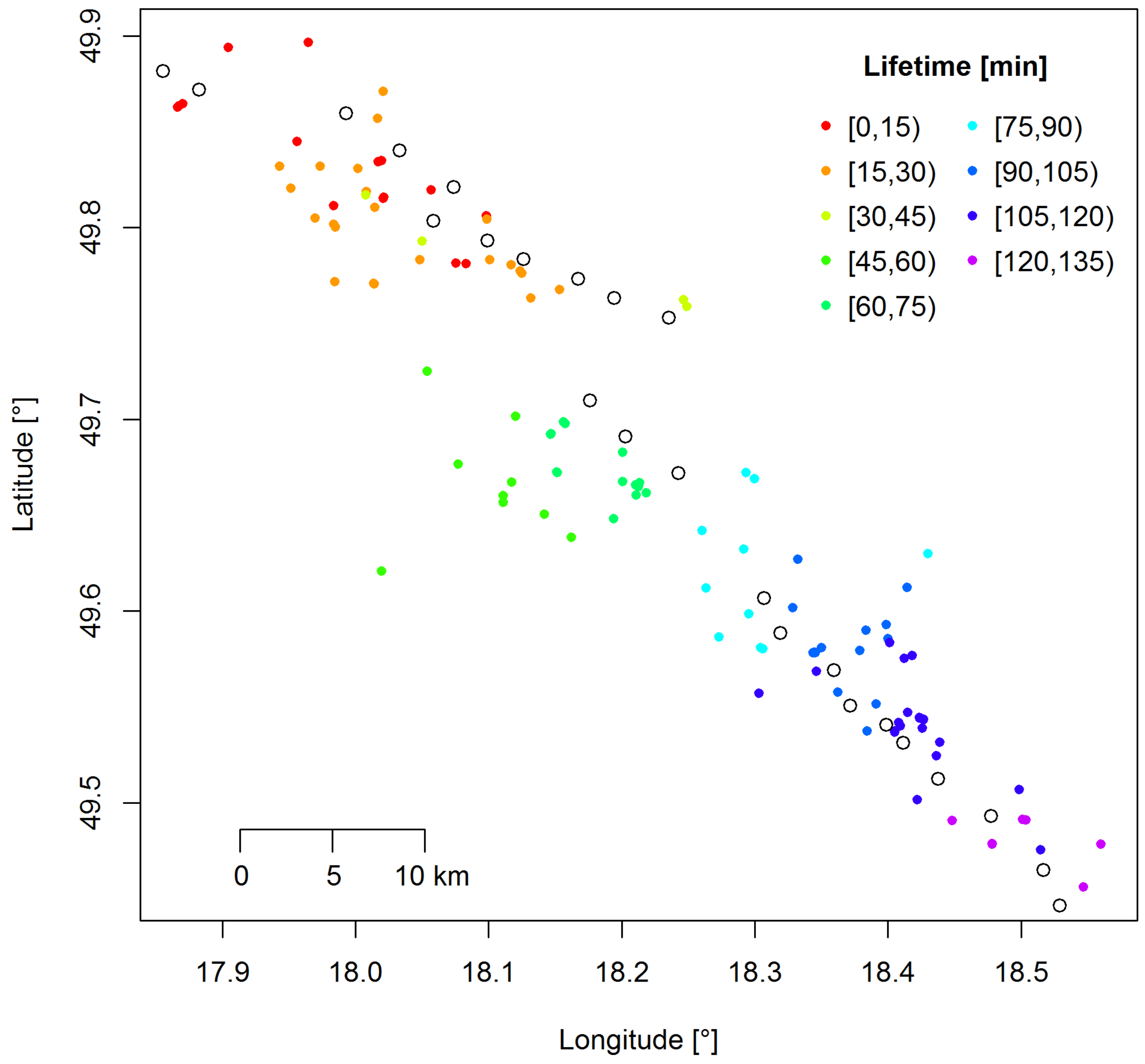
Radar and lightning detections on 2017-07-08 (CZ-Opava)

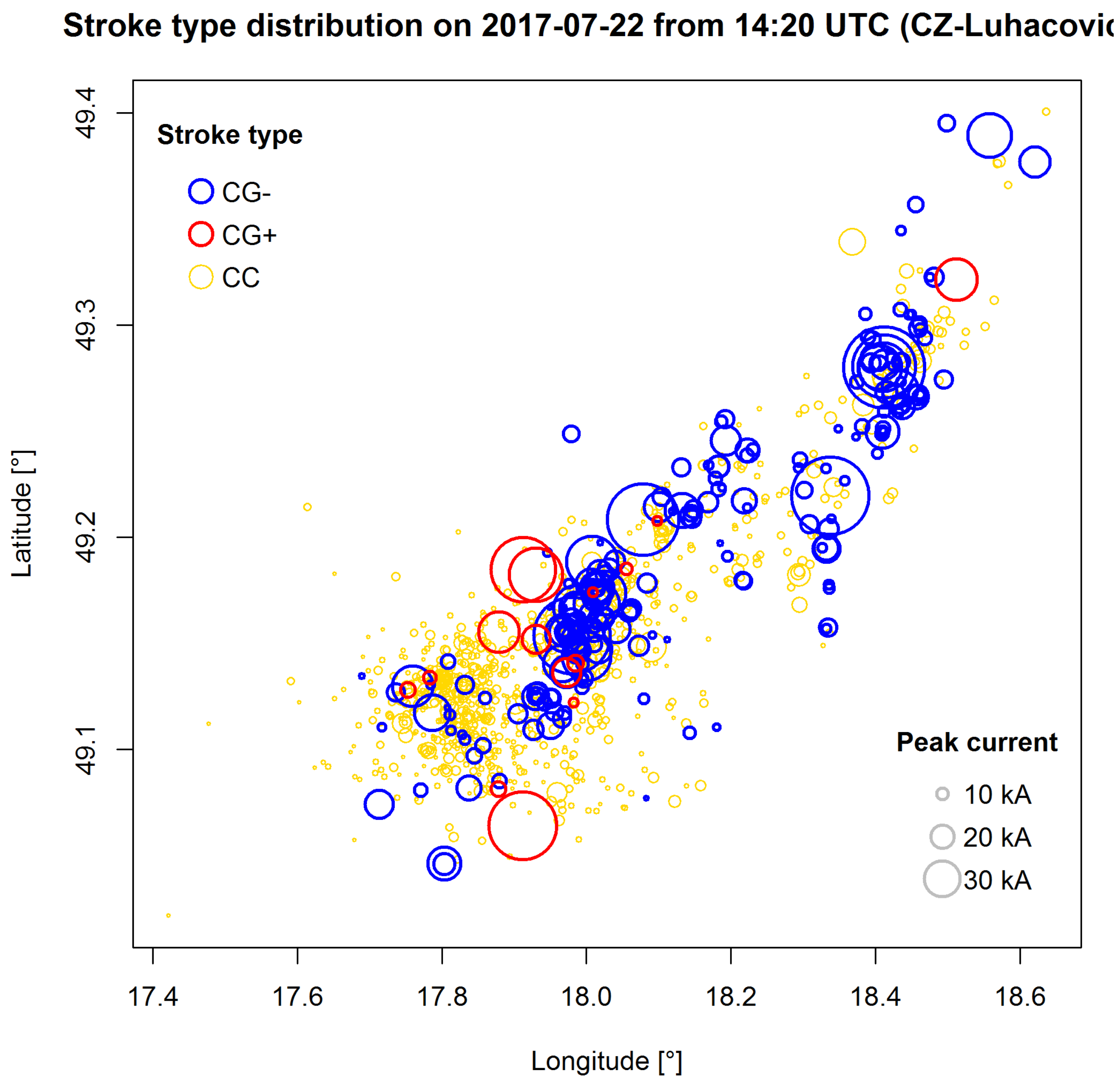


Time evolution of all strokes on 2017-07-22 from 14:20 UTC (CZ-Luhaco

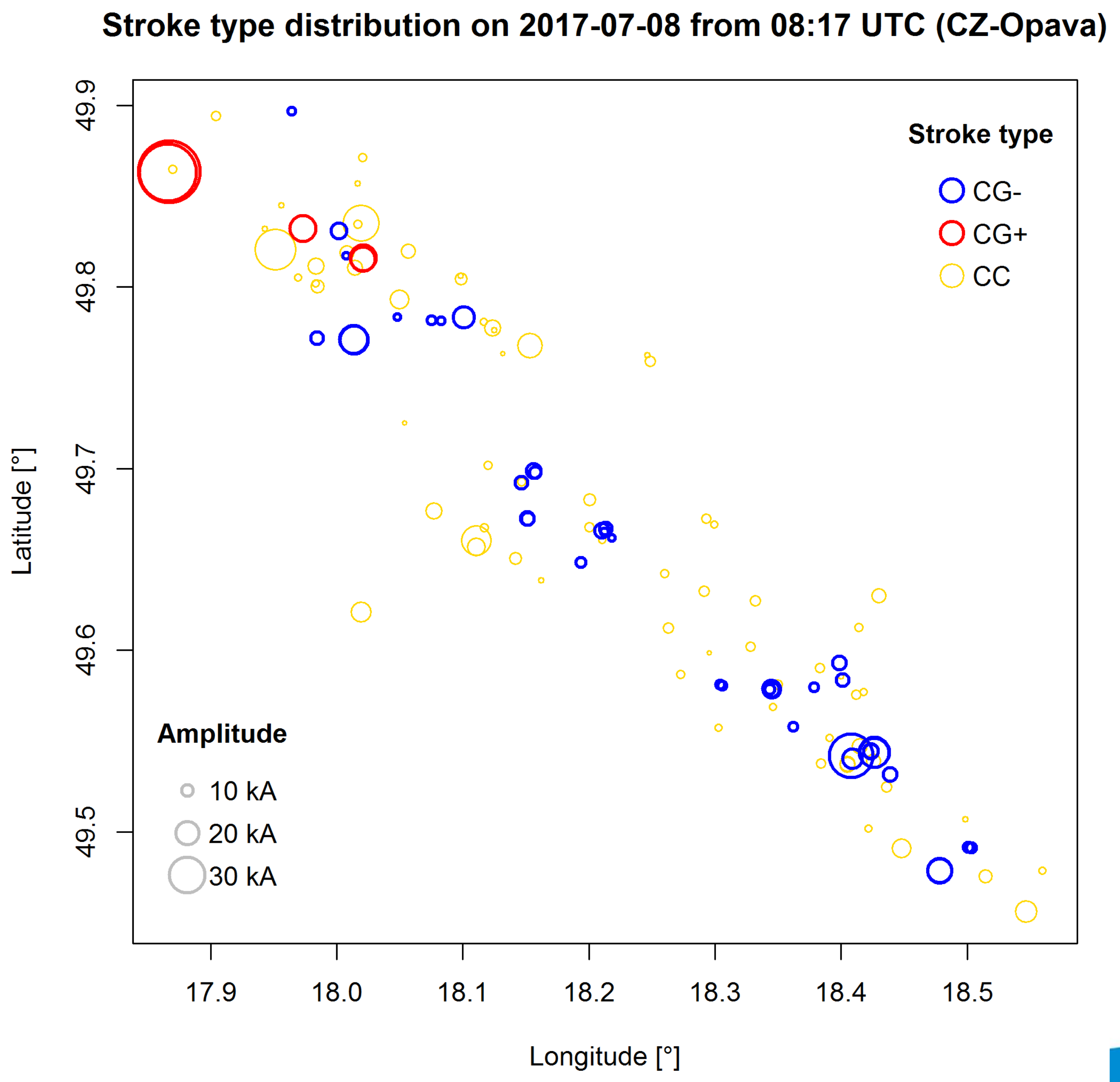


Time evolution of all strokes on 2017-07-08 from 08:17 UTC (CZ-Opav

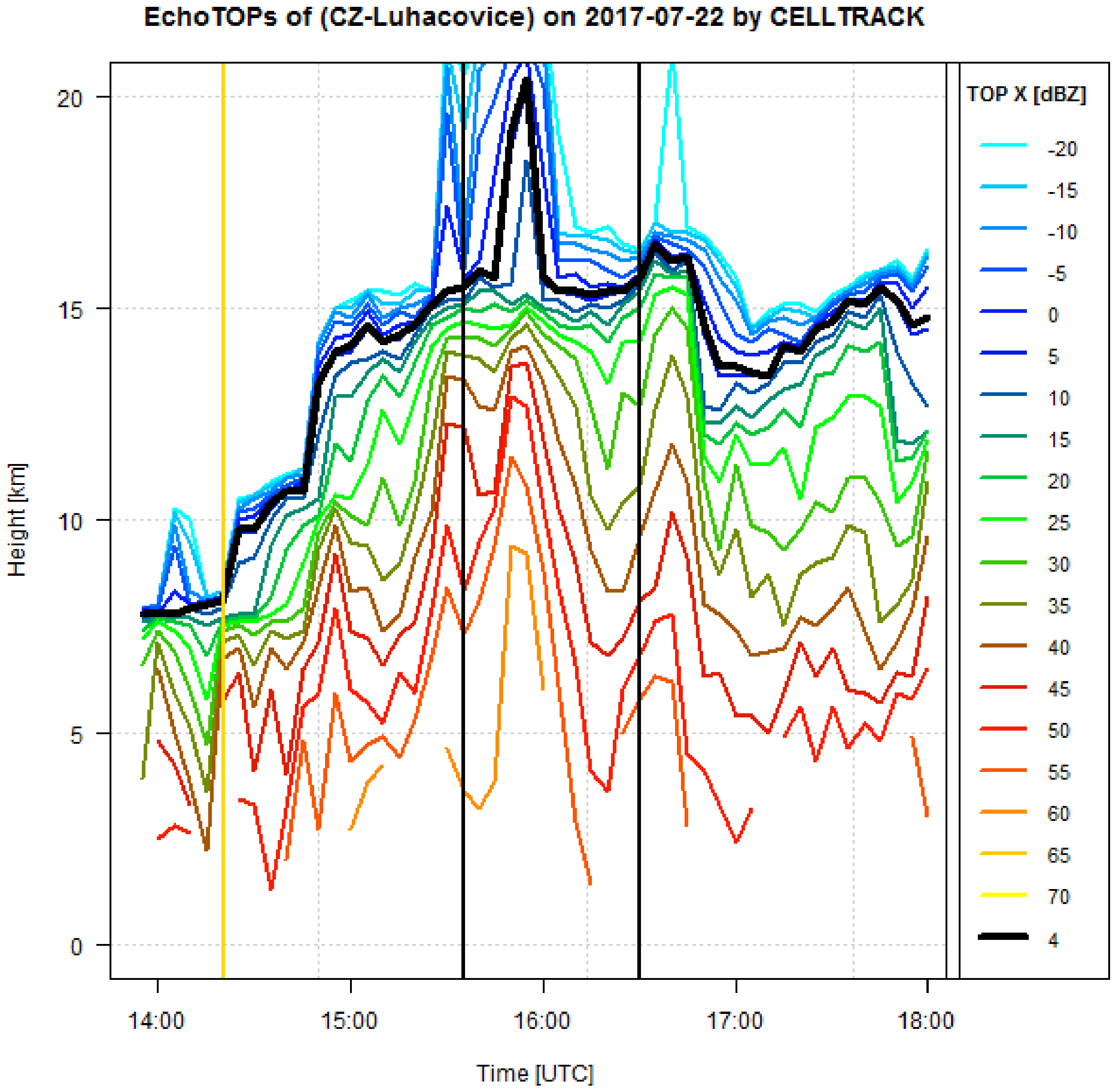


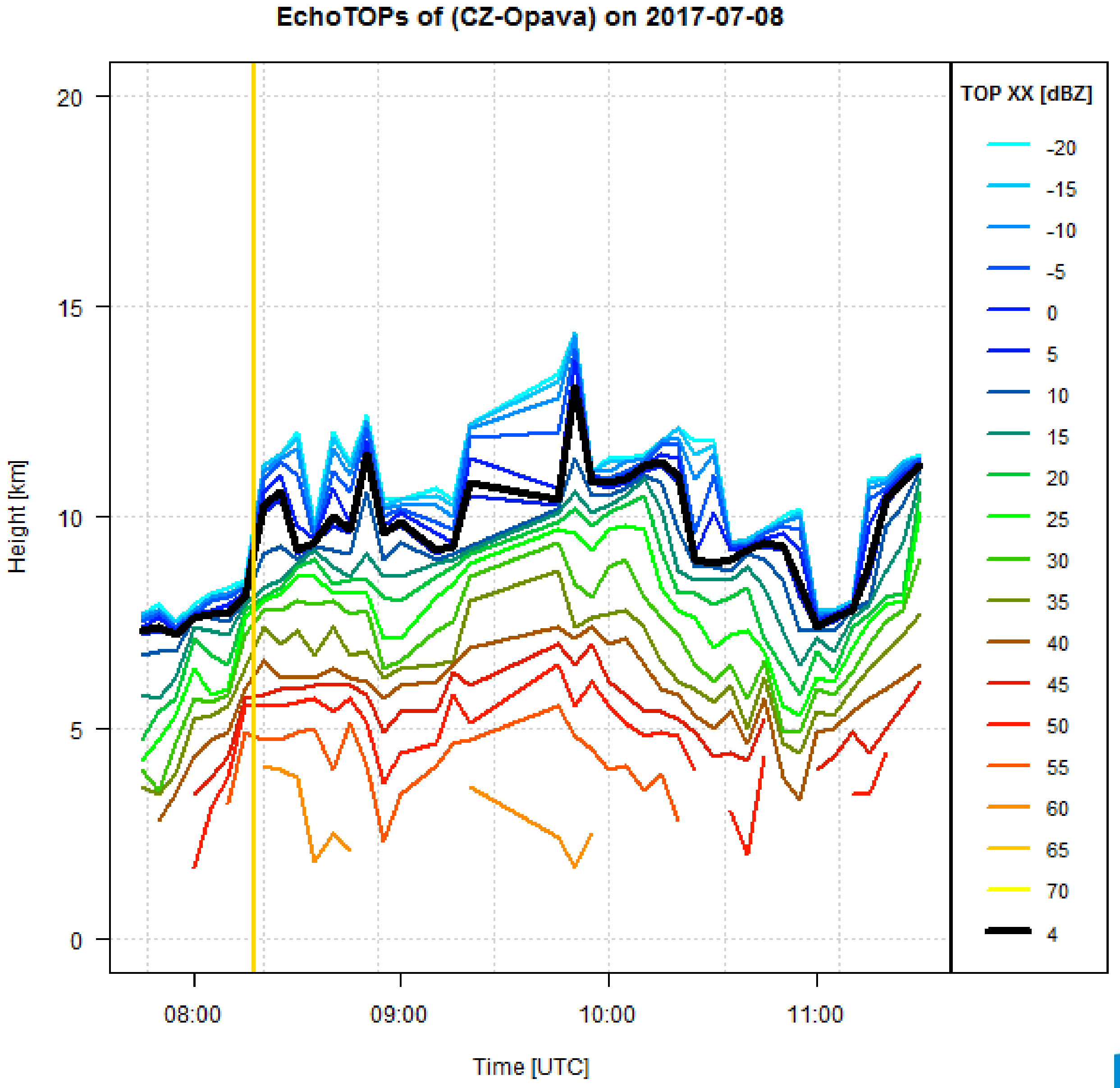


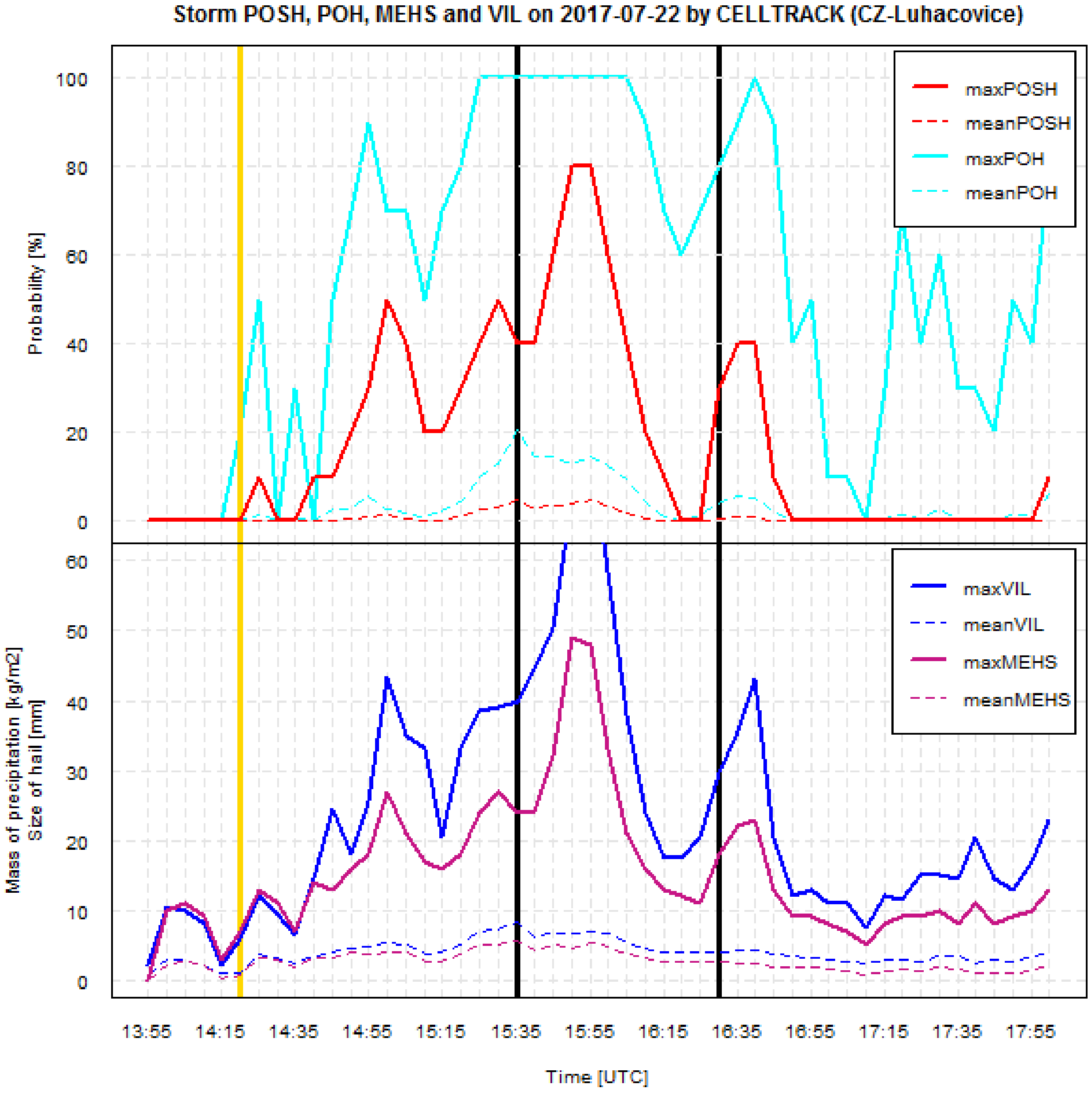
Stroke type distribution on 2017-07-22 from 14:20 UTC (CZ-Luhacovic
Stroke type
CG-
CG+
CC
Peak current
10 kA
20 kA
30 kA
Latitude [°]
49.4
49.3
49.2
49.1
17.4
17.6
17.8
18.0
18.2
18.4
18.6
Longitude [°]

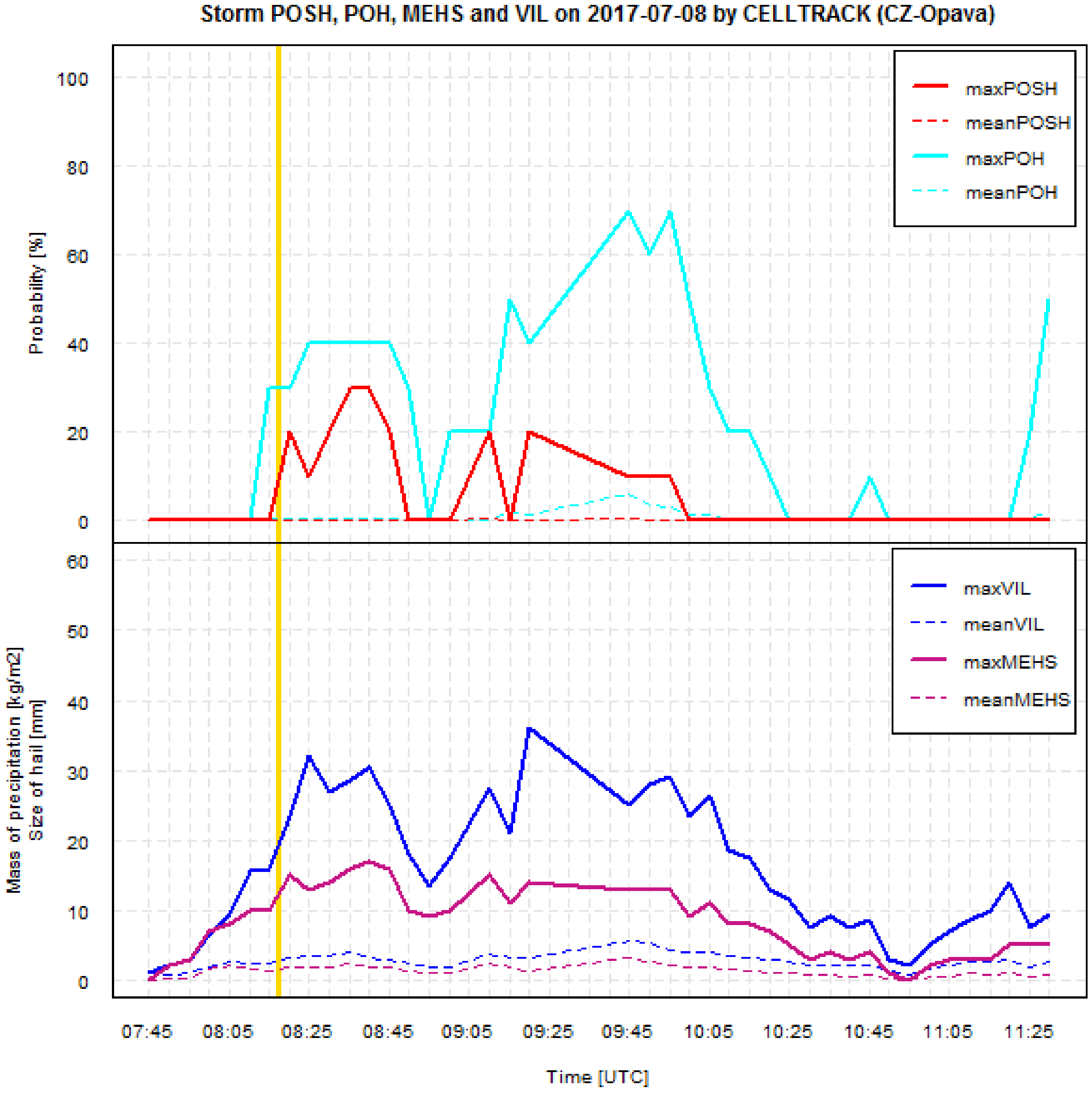


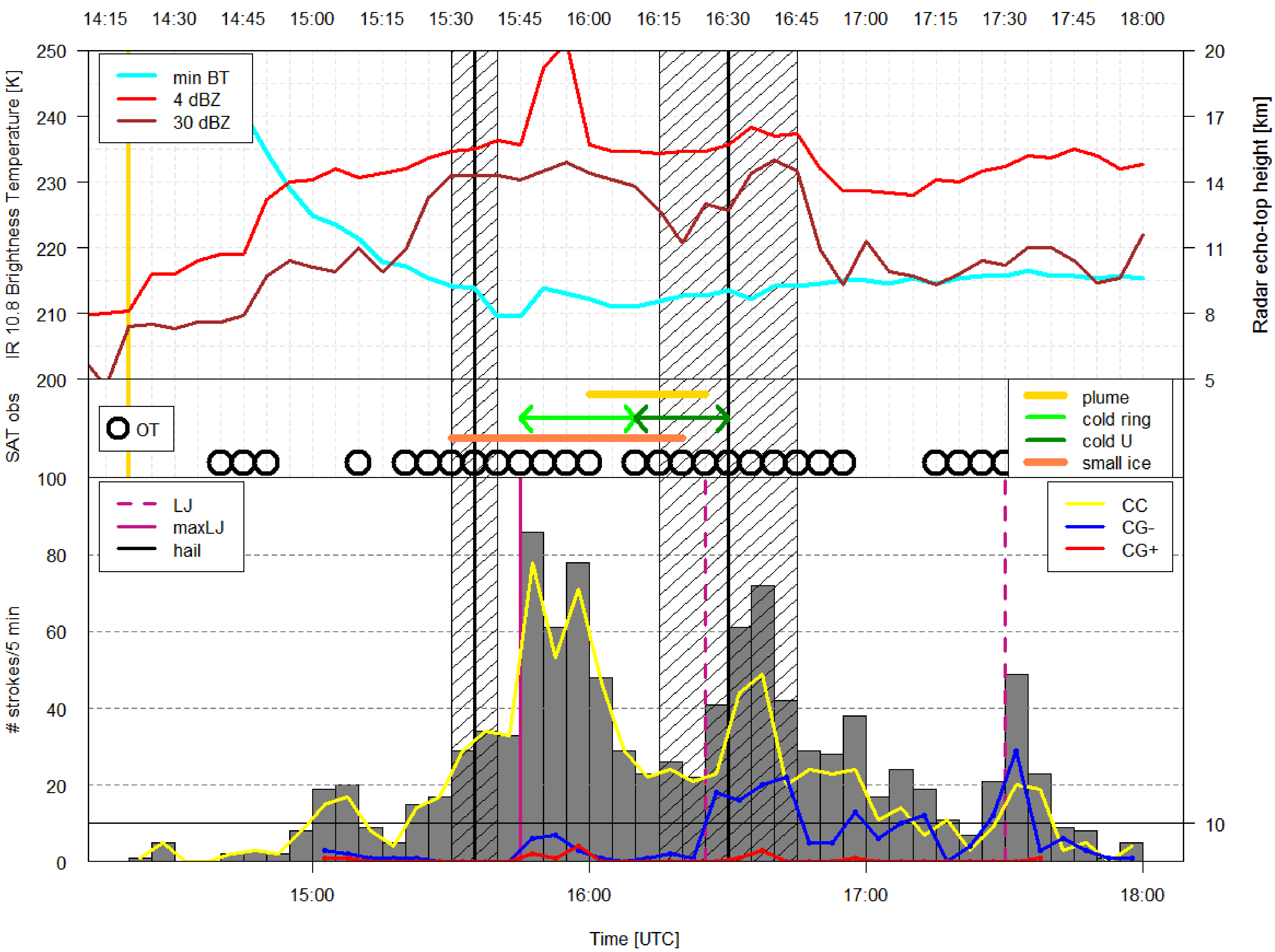
Stroke type distribution on 2017-07-08 from 08:17 UTC (CZ-Opava)
Stroke type
CG-
CG+
CC
Amplitude
10 kA
20 kA
30 kA
Latitude [°]
49.9
49.8
49.7
49.6
49.5
17.9
18.0
18.1
18.2
18.3
18.4
18.5
Longitude [°]


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

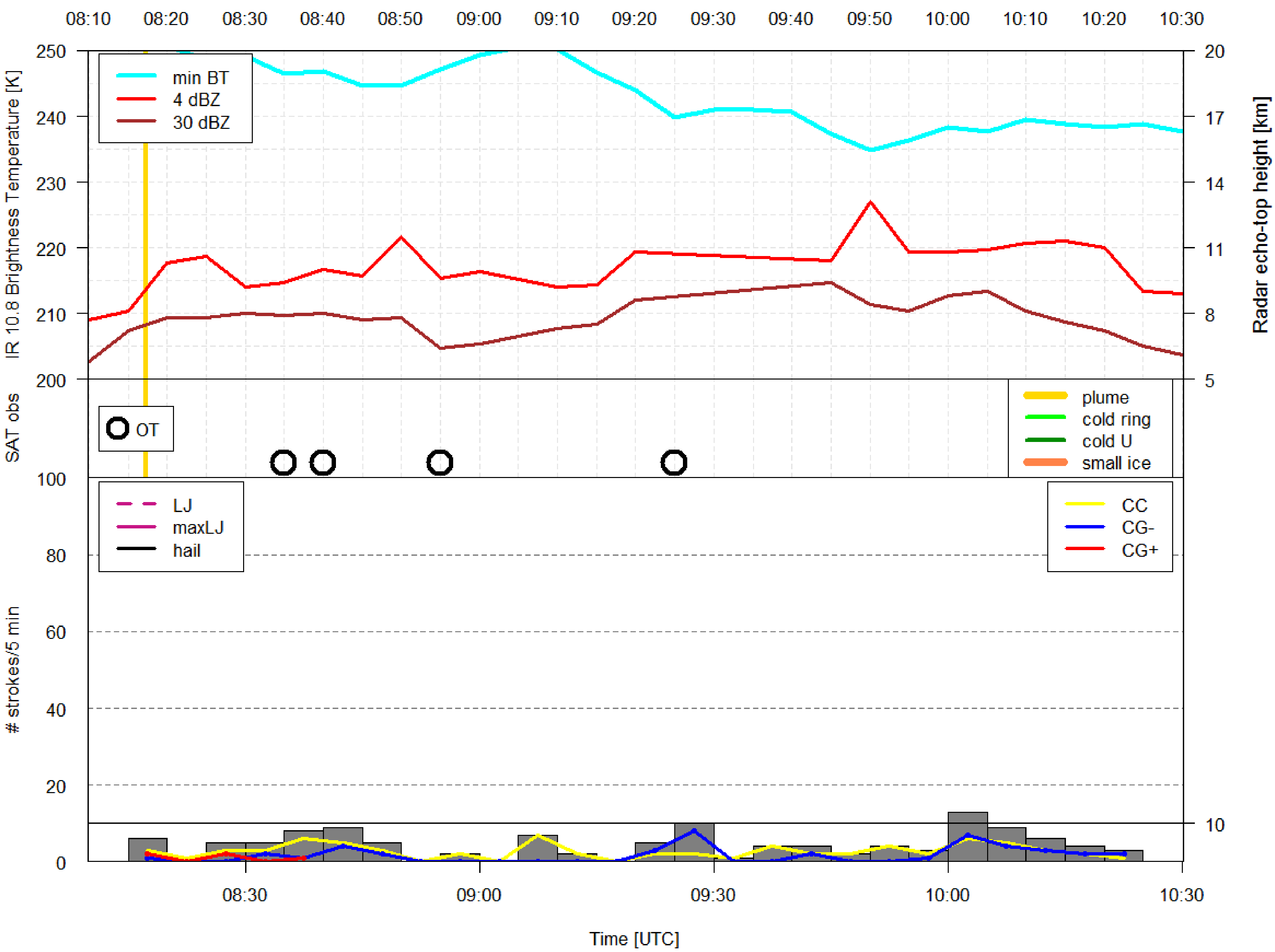

EchoTOPs of (CZ-Opava) on 2017-07-08
Height [km]
Time [UTC]
TOP XX [dBZ]
-20
-15
-10
-5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
4
08:00
09:00
10:00
11:00


Storm POSH, POH, MEHS and VIL on 2017-07-22 by CELLTRACK (CZ-Luhacovice)
maxPOSH
meanPOSH
maxPOH
meanPOH
maxVIL
meanVIL
maxMEHS
meanMEHS
Probability [%]
Mass of precipitation [kg/m2]
Size of hail [mm]
Time [UTC]


Storm POSH, POH, MEHS and VIL on 2017-07-08 by CELLTRACK (CZ-Opava)
maxPOSH
meanPOSH
maxPOH
meanPOH
maxVIL
meanVIL
maxMEHS
meanMEHS
Probability [%]
Mass of precipitation [kg/m2]
Size of hail [mm]
Time [UTC]

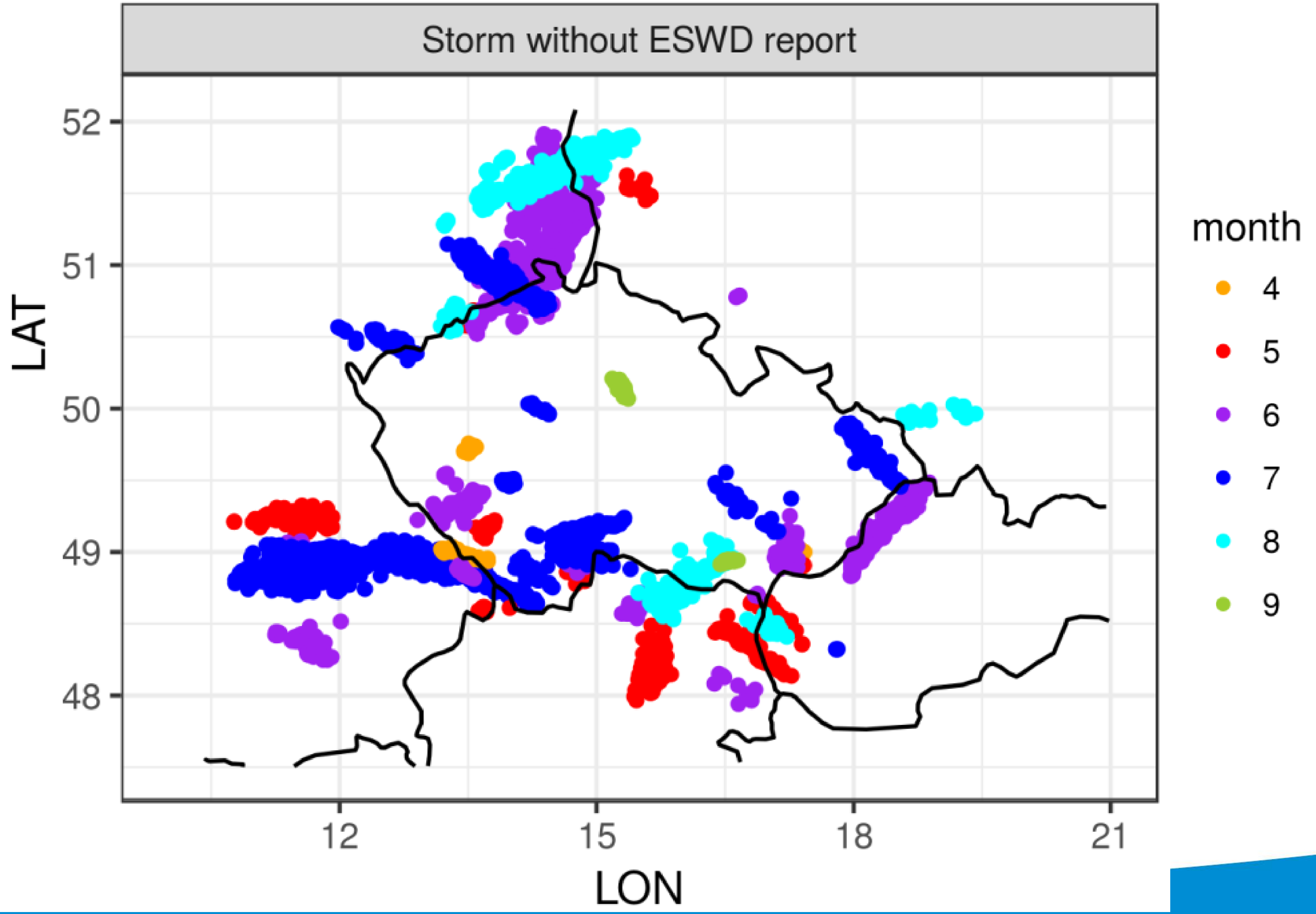


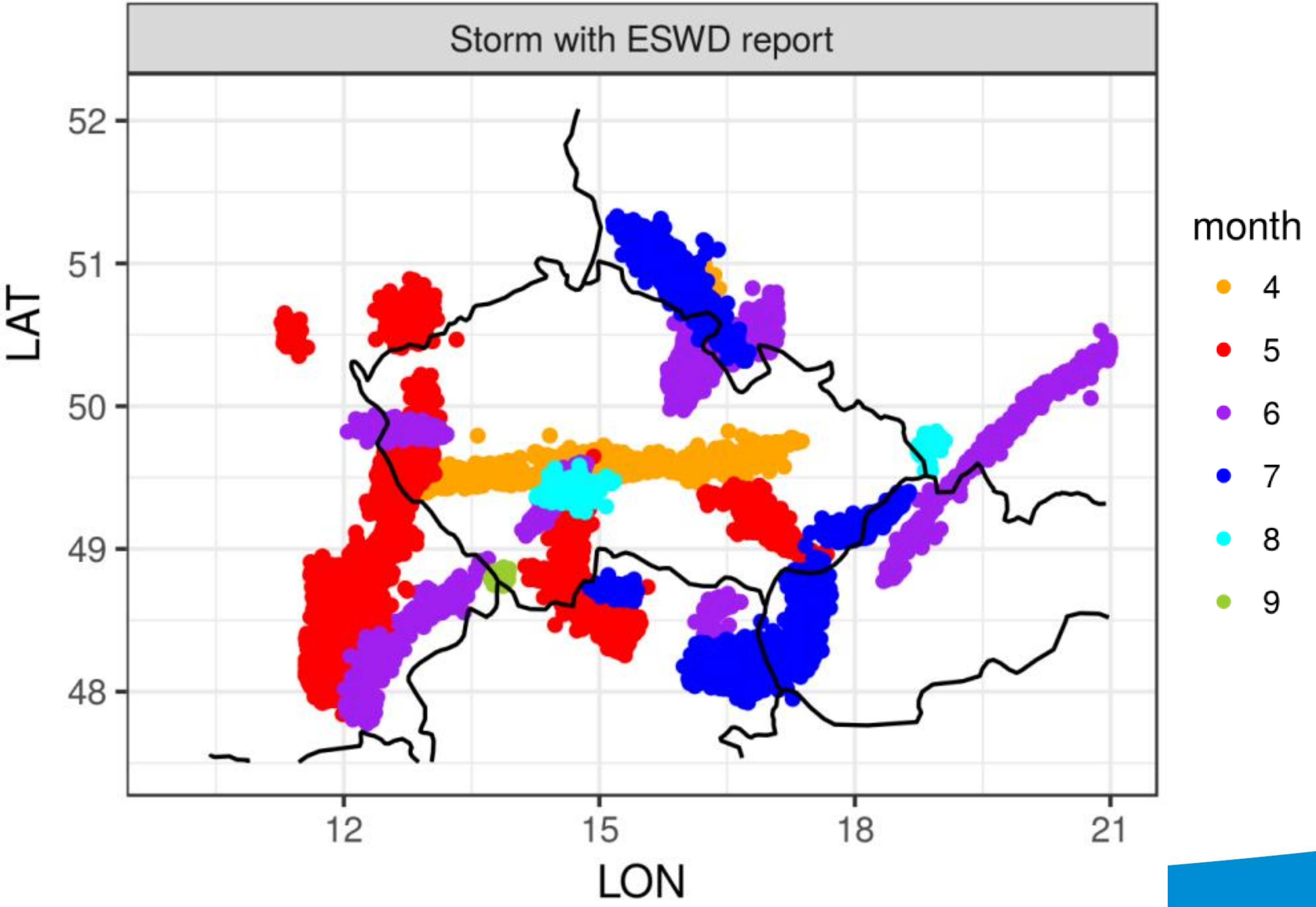
14:15
14:30
14:45
15:00
15:15
15:30
15:45
16:00
16:15
16:30
16:45
17:00
17:15
17:30
17:45
18:00
IR 10.8 Brightness Temperature [K]
Radar echo-top height [km]
250
240
230
220
210
200
20
17
14
11
8
5
min BT
4 dBZ
30 dBZ
SAT obs
OT
plume
cold ring
cold U
small ice
100
80
60
40
20
0
10
strokes/5 min
LJ
maxLJ
hail
CC
CG-
CG+
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
min BT
4 dBZ
30 dBZ
IR 10.8 Brightness Temperature [K]
Radar echo-top height [km]
SAT obs
OT
plume
cold ring
cold U
small ice
LJ
maxLJ
hail
CC
CG-
CG+
strokes/5 min
Time [UTC]

STORM DATABASE

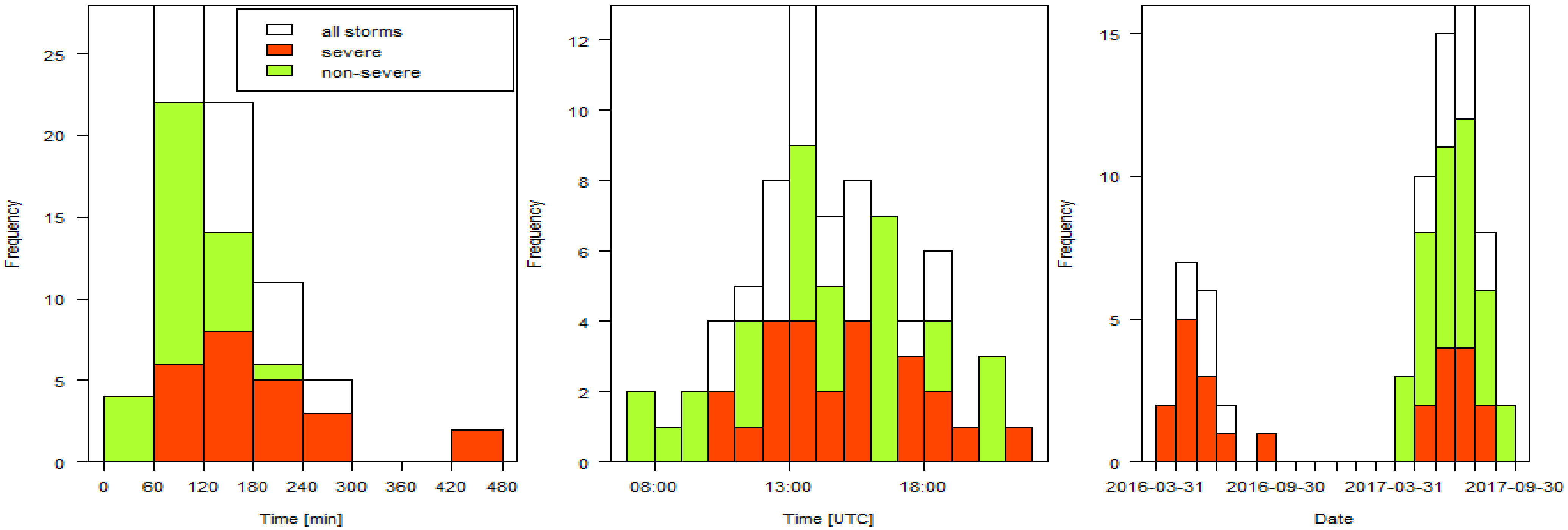

Storm without ESWD report
LAT
52
51
50
49
48
12
15
18
21
LON
month
4
5
6
7
8
9


Storm with ESWD report
LAT
LON
52
51
50
49
48
12
15
18
21
month
4
5
6
7
8
9

STORM DATABASE

72 storm cases from April to September 2016 and 2017

- 24 severe, 48 non-severe storms
- 19 supercells, 19 multicells, 34 single cells

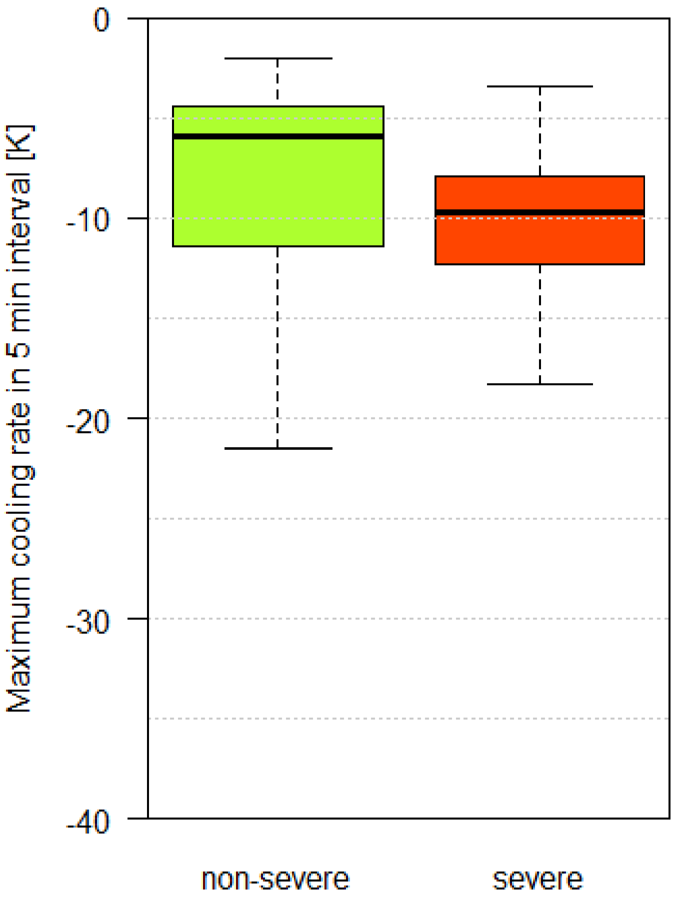


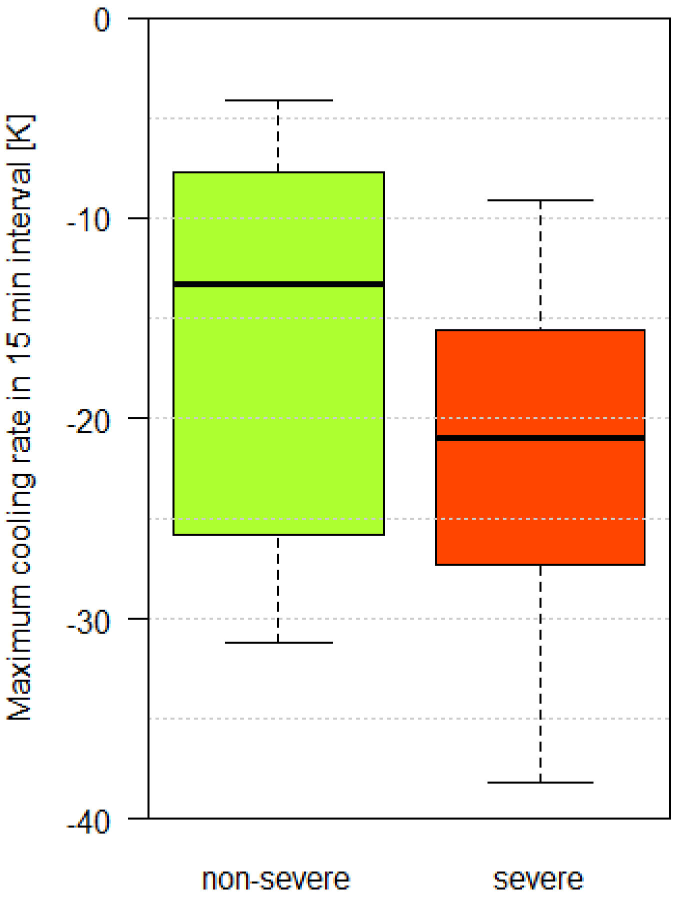
SATELLITES

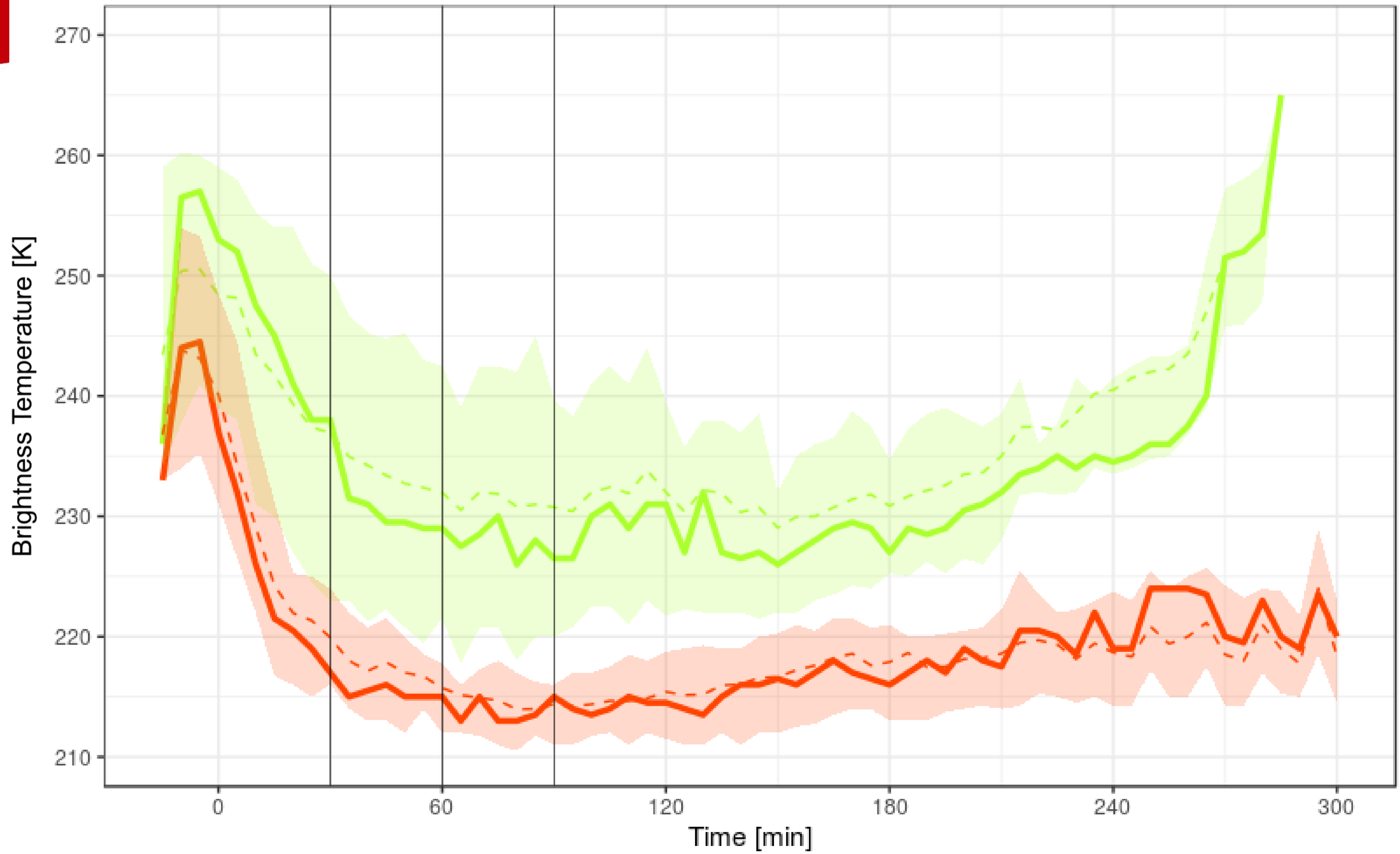
- minimum BT in IR 10.8
- cooling rate:

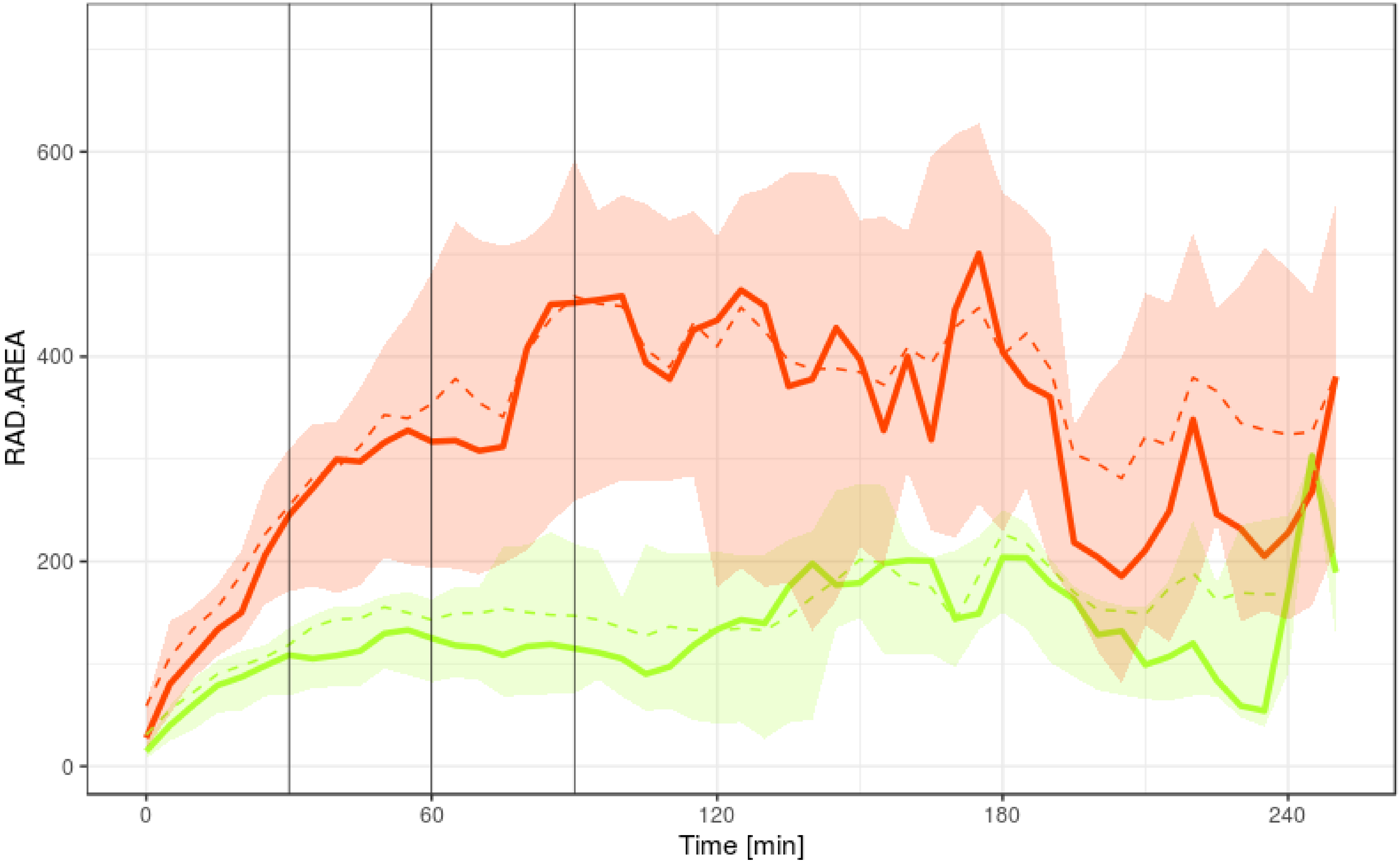
  in 5, 15 and 30 min
- cloud-top features:

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

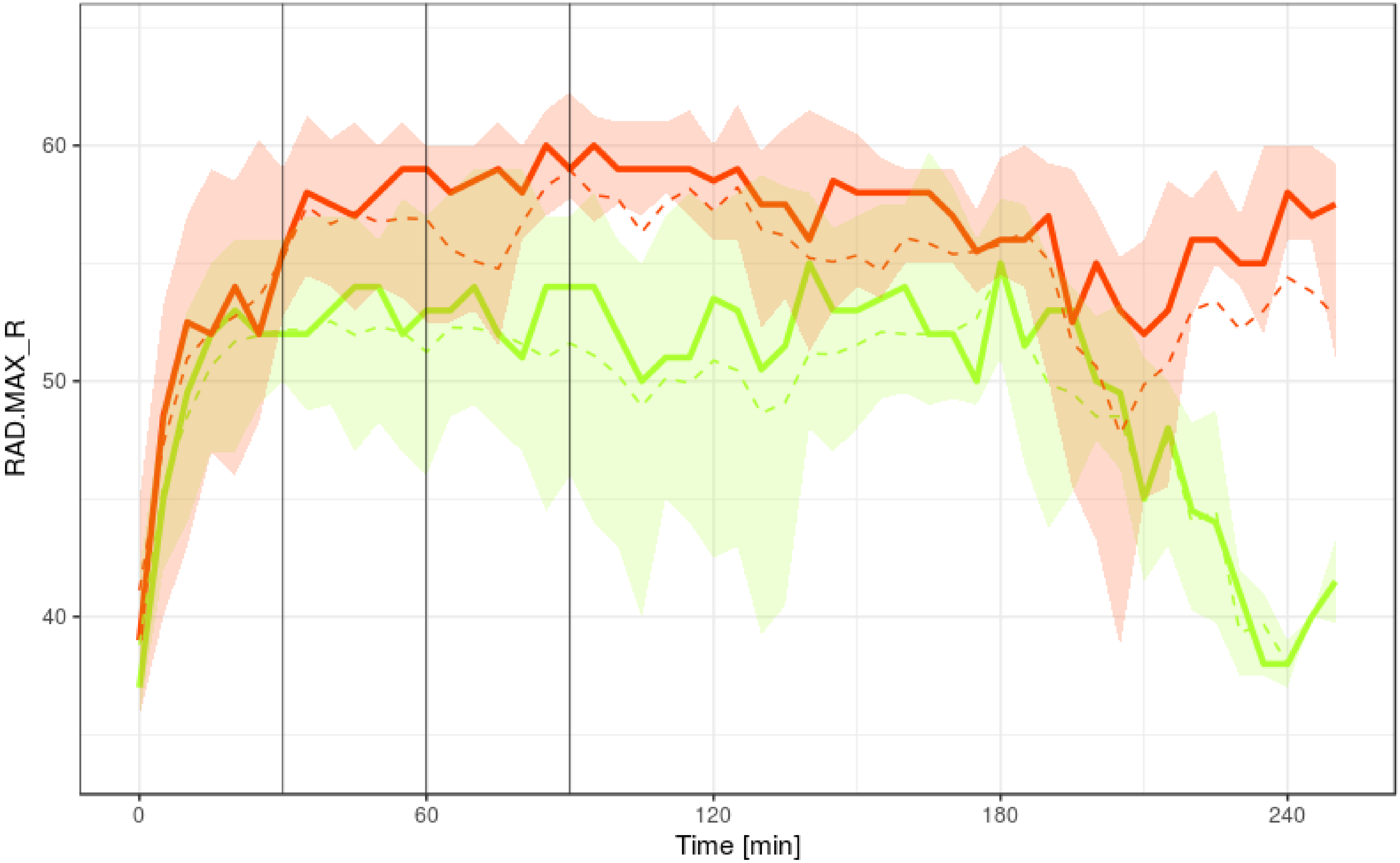


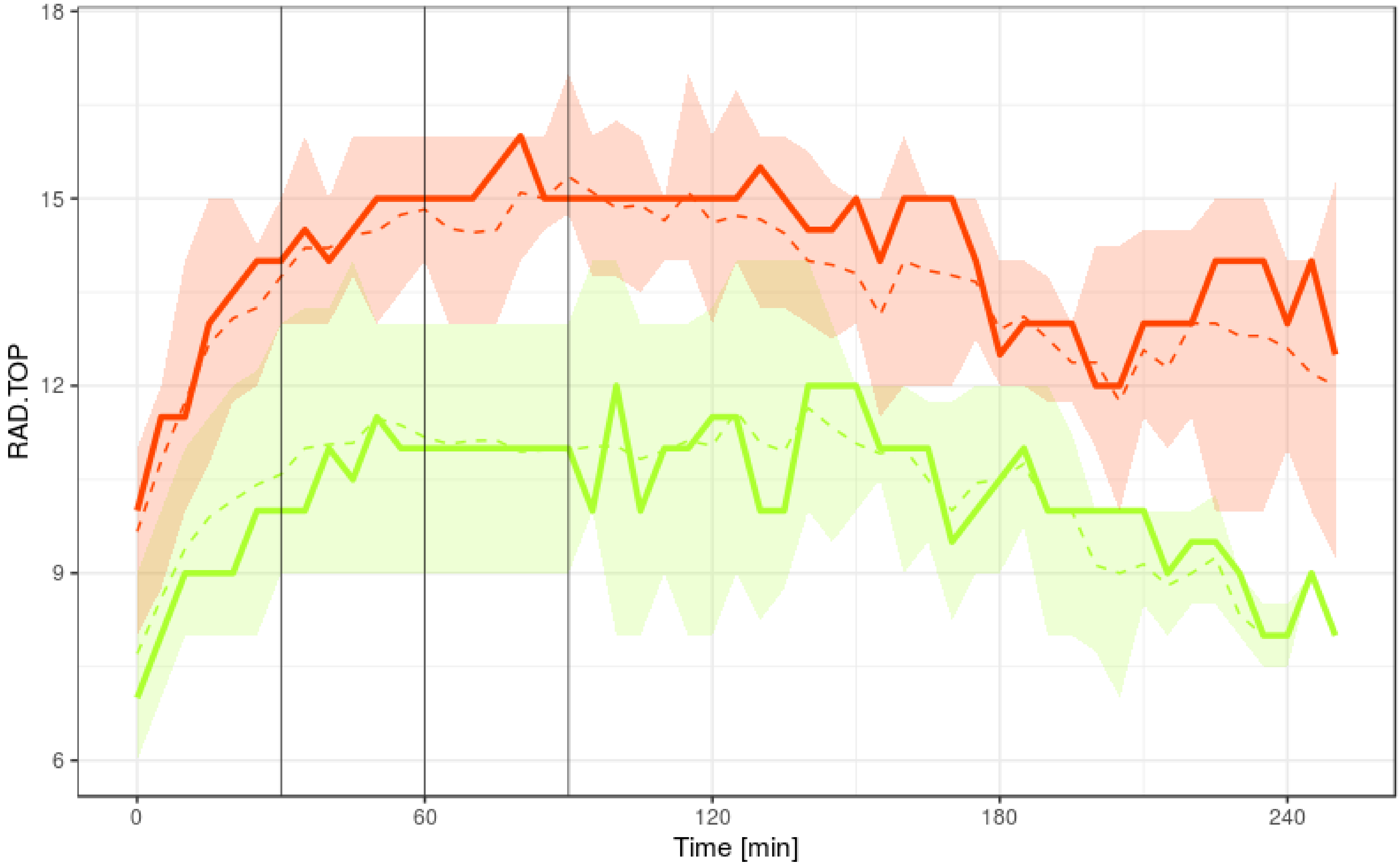



Brightness Temperature [K]
270
260
250
240
230
220
210
0
60
120
180
240
300
Time [min]

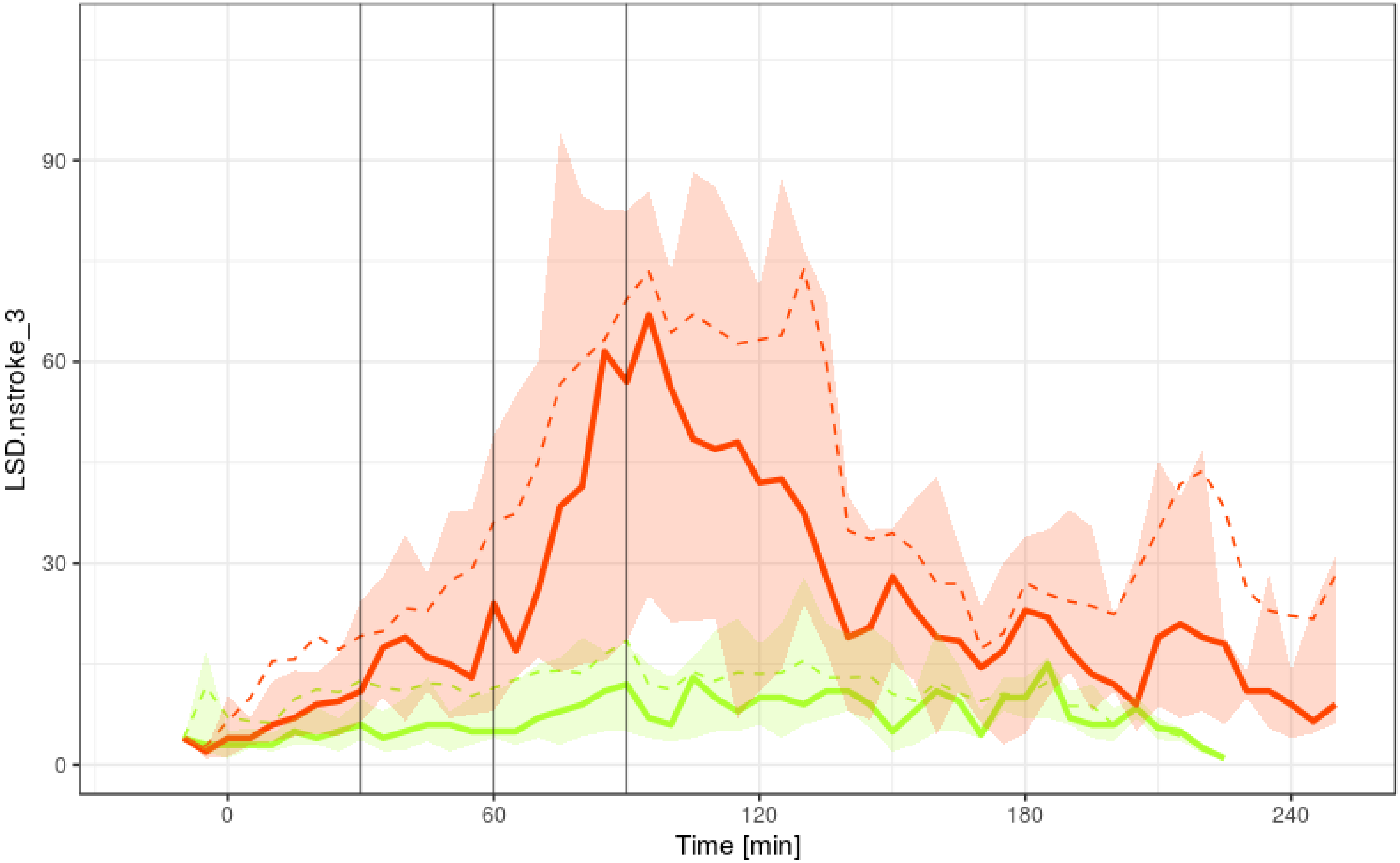


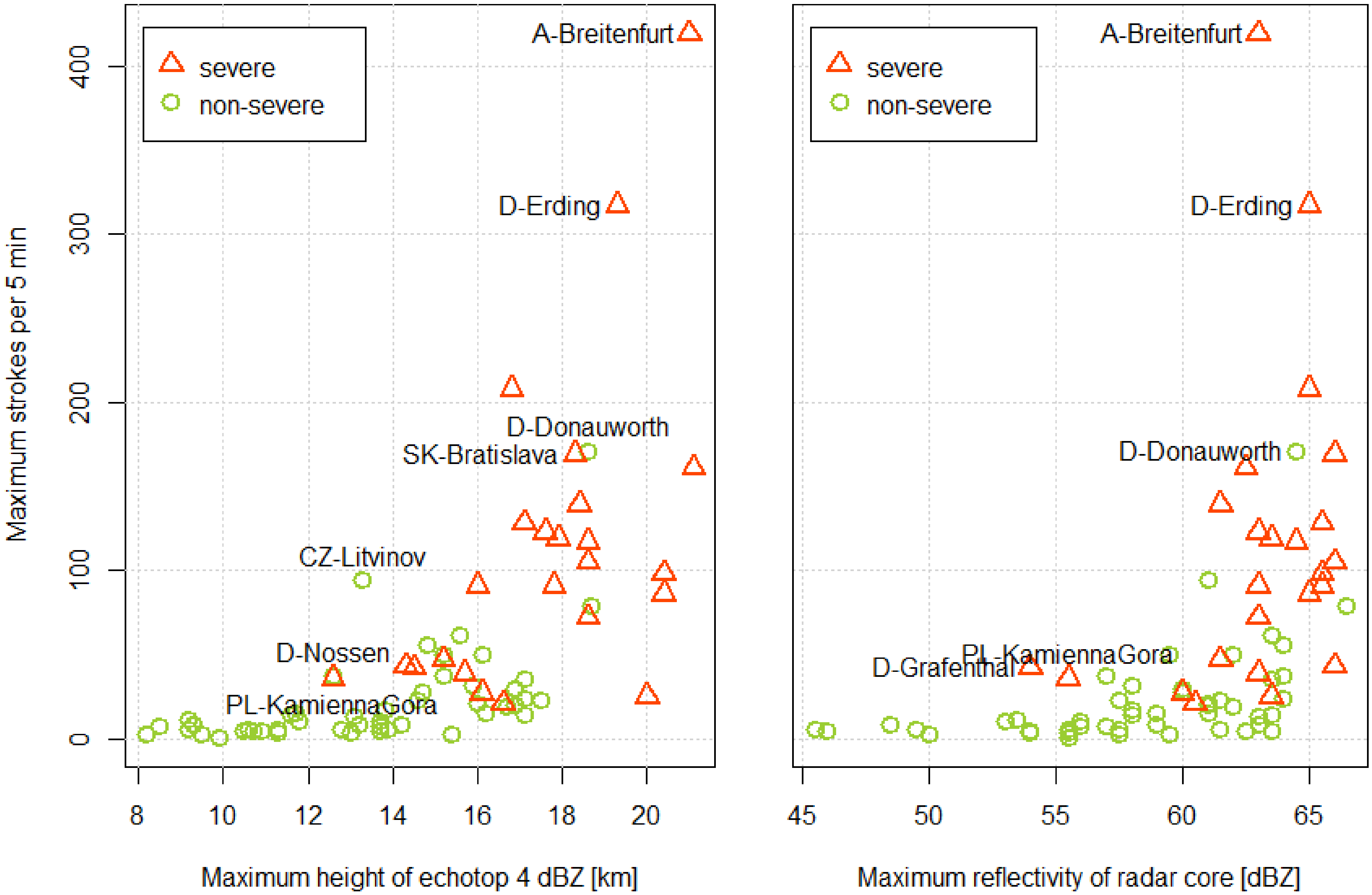
RAD.AREA
600
400
200
0
0
60
120
180
240
Time [min]


60
50
40
RAD.MAX_R
0
60
120
180
240
Time [min]

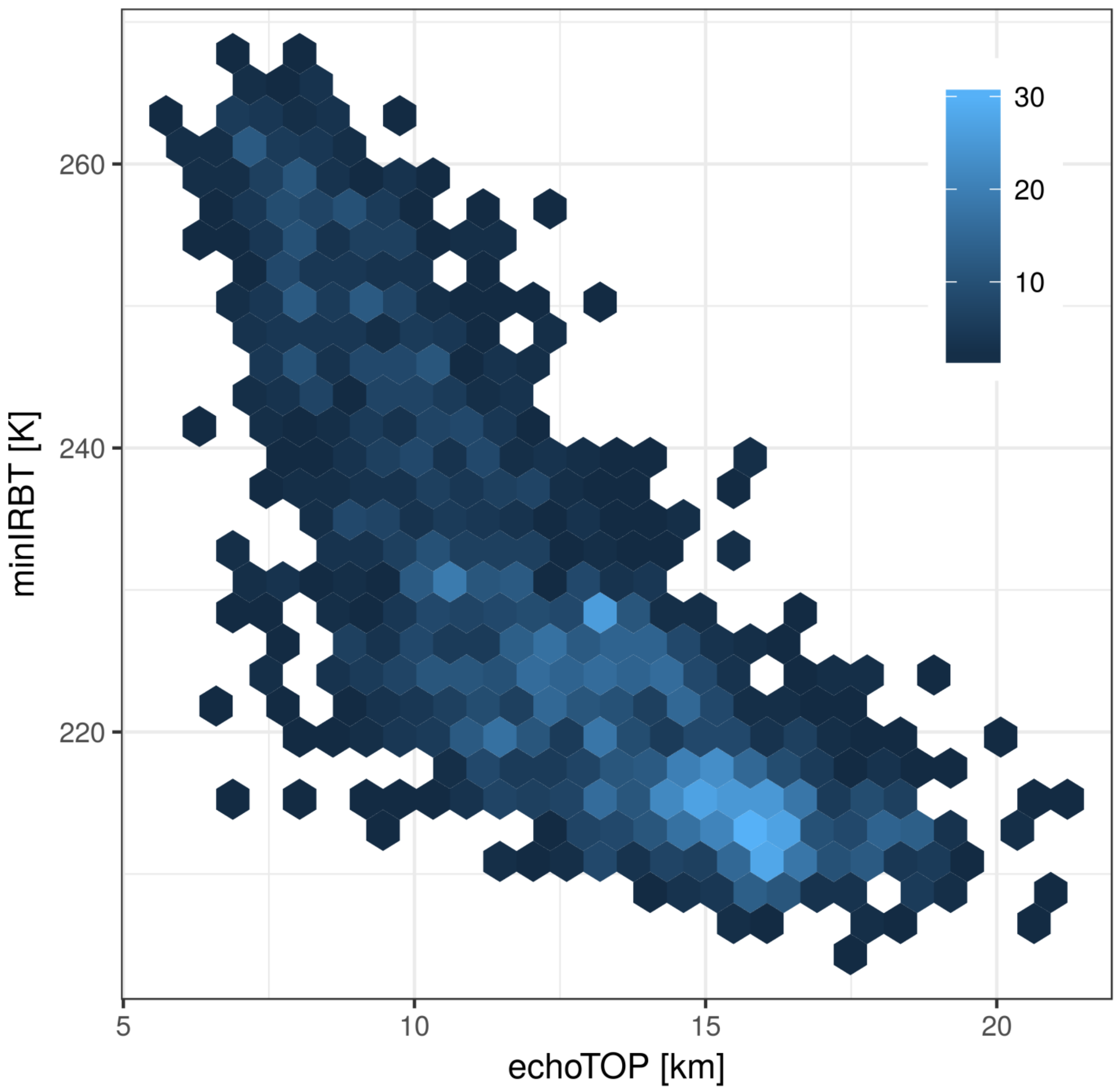


RAD.TOP
18
15
12
9
6
0
60
120
180
240
Time [min]

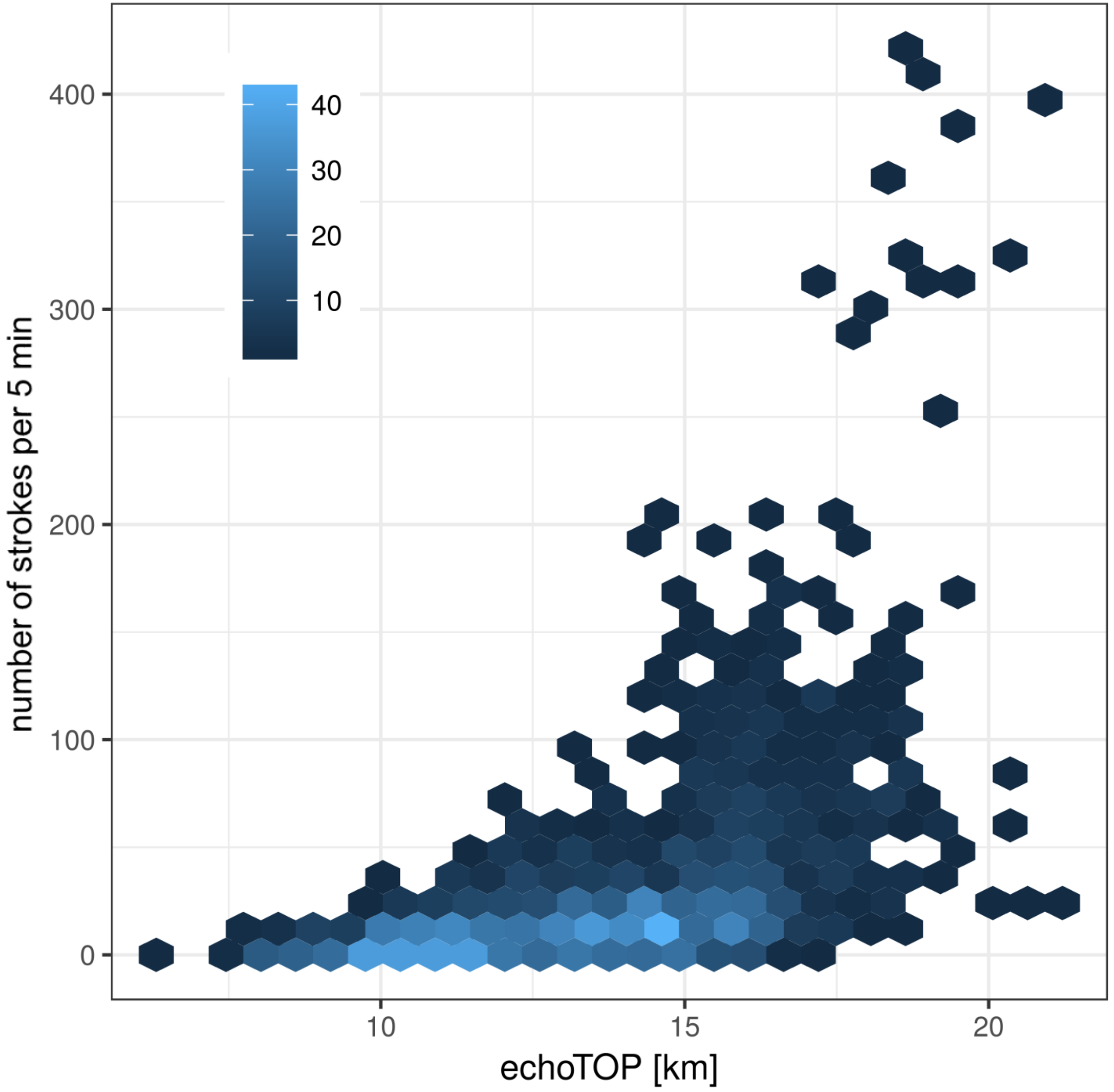

LSD.nstroke_3
90
60
30
0
0
60
120
180
240
Time [min]


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

n = 2536



minIRBT [K]
260
240
220
5
10
15
20
echoTOP [km]
30
20
10



number of strokes per 5 min
400
300
200
100
0
10
15
20
echoTOP [km]
40
30
20
10

REGRESSION MODELS

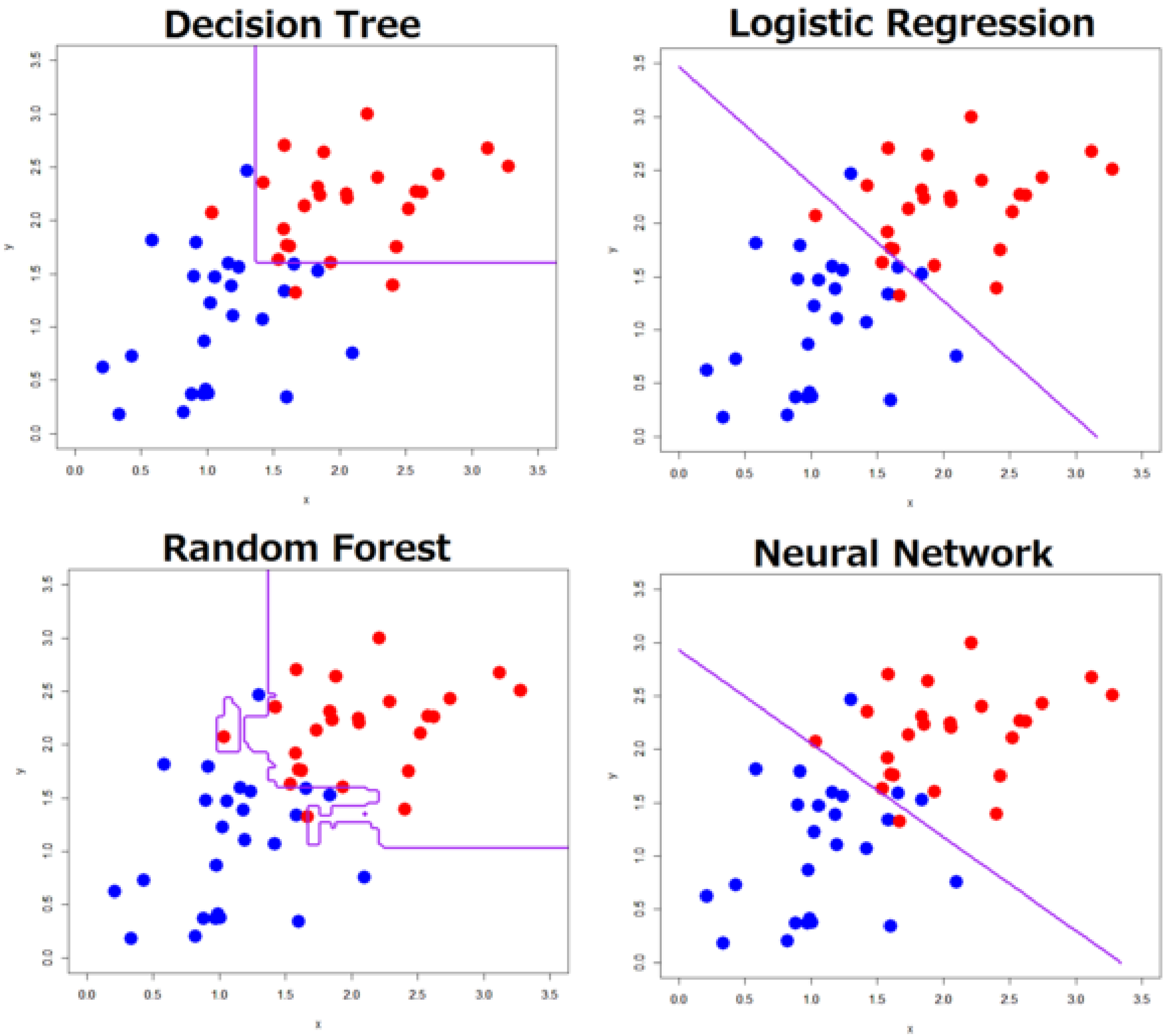
REGRESSION

- machine learning classifiers
- probability of the storm severity

When?

→ three time intervals

30, 60 and 90 minutes



LOGISTIC REGRESSION MODEL

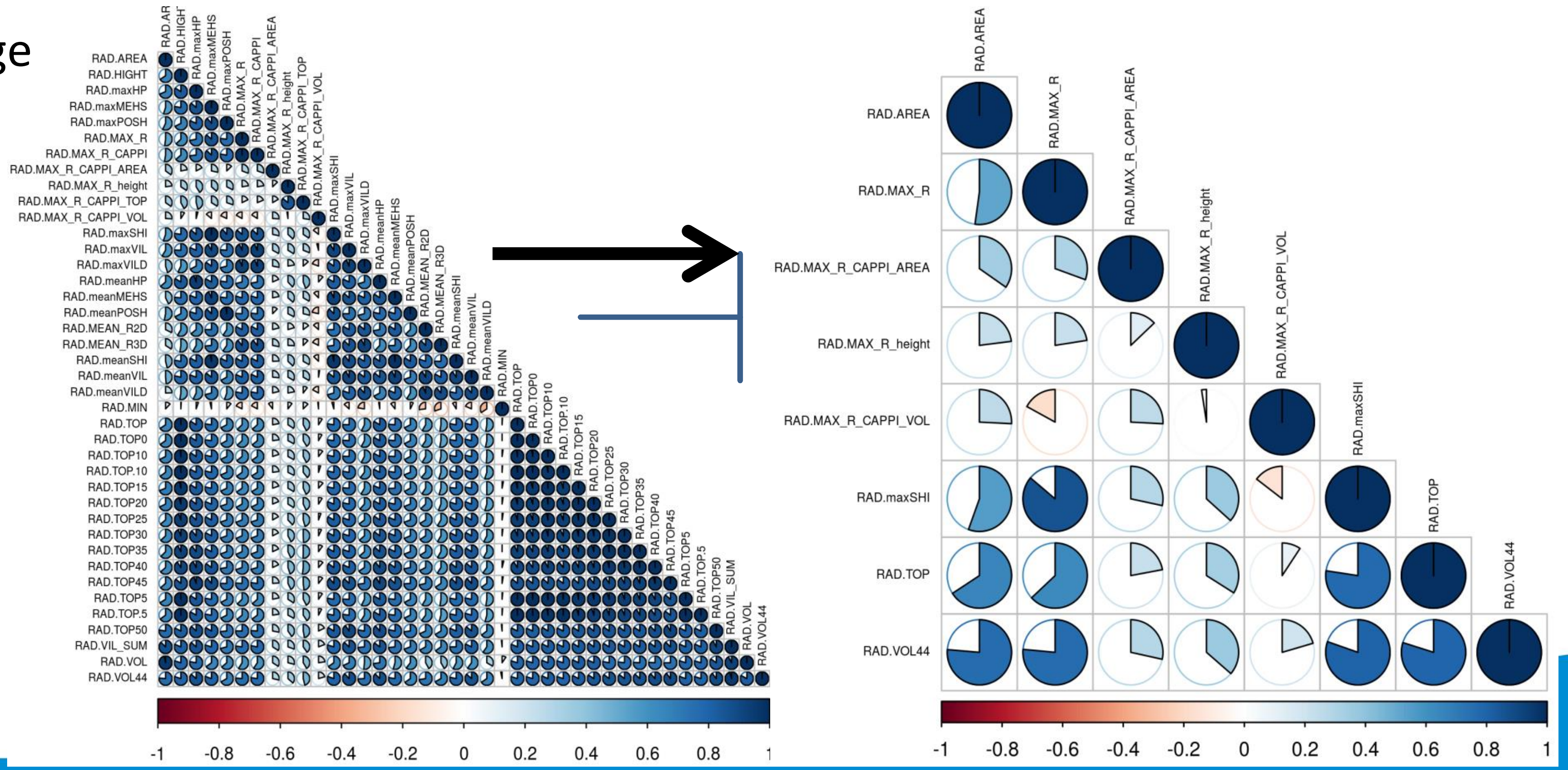
- explain relationships between one dependent dichotomous variable (0 or 1) and one or more independent variables →

  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

VARIABLE SELECTION

- **multicollinearity**
  - detected based on Variance Inflation Factor (VIF)
  - pre-selection of predictors based on:
    - scientific knowledge
    - VIF < 4



VARIABLE SELECTION

- **sign OK**
  - remove predictors, if its multivariable (MVA) sign is different from univariable (UVA) sign
  - repeat, until all selected predictors have a correct sign

	UVA	MVA
RAD.AREA	0.0134	0.0138
RAD.MAX_R	0.0991	-0.0464
RAD.MAX_R_CAPPI_AREA	0.3579	-0.1183
RAD.MAX_R_height	0.0004	0.0002
RAD.MAX_R_CAPPI_VOL	0.0677	0.0199
RAD.maxSHI	0.0088	-0.0029
RAD.TOP	0.0004	0.0004
RAD.VOL44	0.0043	-0.0030

VARIABLE SELECTION

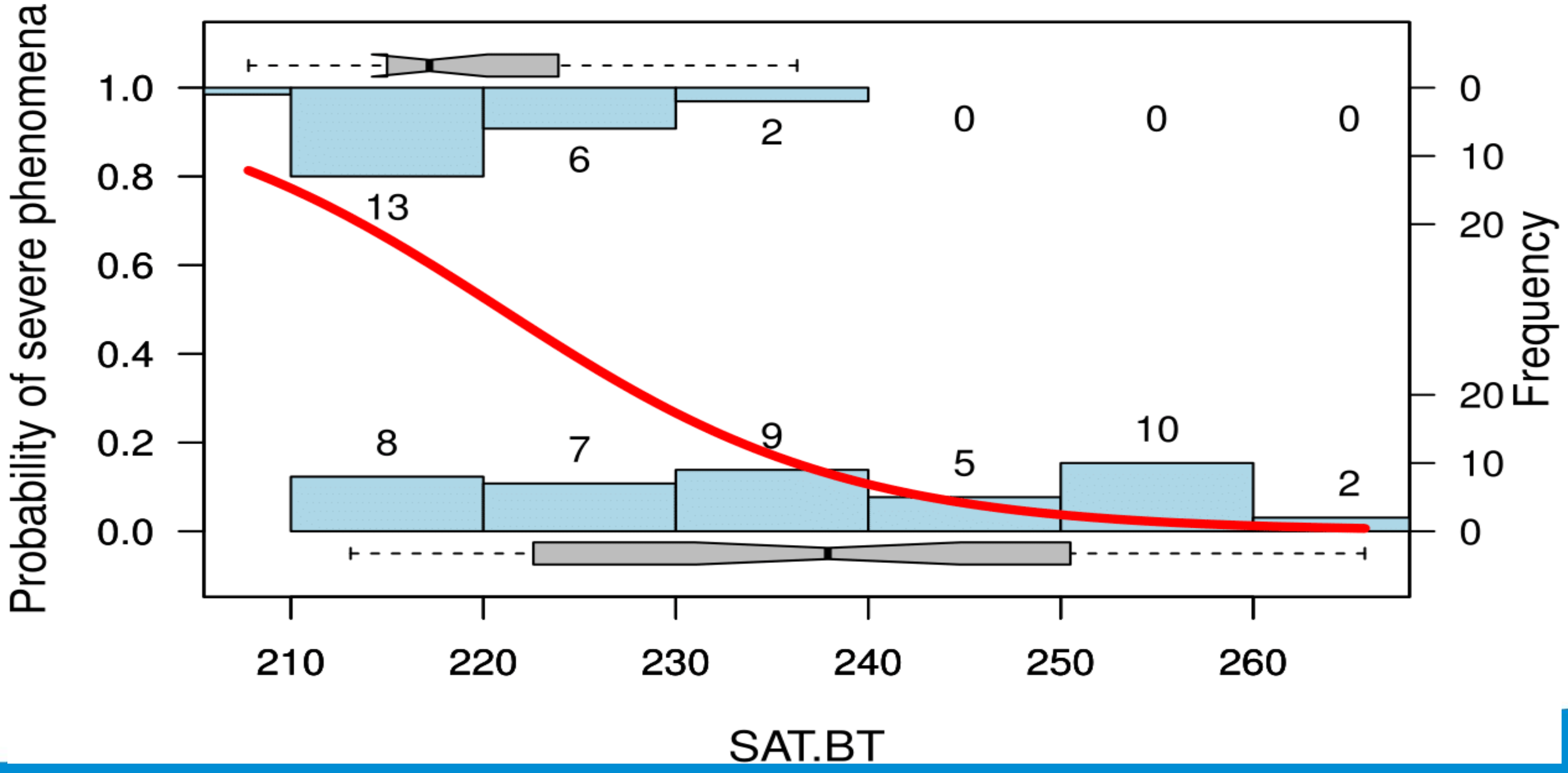
- **stepwise backward method**
  - remove the most insignificant predictors (p-value > 0.157) and reestimate
  - repeat until all predictors are significant

```
## Coefficients:
##                     Estimate Std. Error z value Pr(>|z|)
## (Intercept)       -5.3353710  1.5954852  -3.344 0.000826 ***
## RAD.AREA           0.0090681  0.0038440   2.359 0.018324 *
## RAD.MAX_R_height   0.0001049  0.0002060   0.509 0.610690
## RAD.MAX_R_CAPPI_VOL 0.0321039  0.0498861   0.644 0.519871
## RAD.TOP            0.0001863  0.0001286   1.449 0.147423
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' '
```

```
## Coefficients:
##               Estimate Std. Error z value Pr(>|z|)
## (Intercept) -4.9580578  1.5187031  -3.265   0.0011 **
## RAD.AREA     0.0096687  0.0039140   2.470   0.0135 *
## RAD.TOP      0.0001957  0.0001260   1.553   0.1203
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

LOGISTIC REGRESSION MODEL

- individual model for:
  - remote sensing methods (RAD, LSD and SAT)
  - the first 30, 60 and 90 minutes of the storm lifecycle



RESULTS OF MODELS

	Dependent variable:		
	sev.phenomena		
	RAD30	RAD60	RAD90
	(1)	(2)	(3)
RAD.AREA	1.010	1.007	1.007
	$p = 0.014^{**}$	$p = 0.001^{***}$	$p = 0.0005^{***}$
RAD.TOP	1.000		
	$p = 0.121$		
RAD.maxHP		1.037	
		$p = 0.010^{***}$	
RAD.MAX_R_height			1.001
			$p = 0.007^{***}$
Observations	72	72	72
Log Likelihood	−33.145	−29.612	−28.251
Akaike Inf. Crit.	72.291	65.225	62.501
Note:			$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

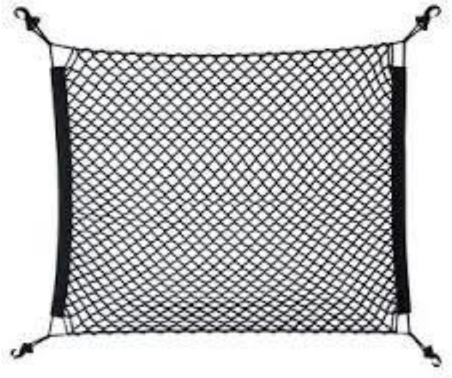
RESULTS OF MODELS

	Dependent variable:		
	sev.phenomena		
	LSD30	LSD60	LSD90
	(1)	(2)	(3)
LSD.sum_curr_3		1.004	
		$p = 0.090^{*}$	
LSD.LJ	2.105	1.463	
	$p = 0.007^{***}$	$p = 0.019^{**}$	
LSD.nstroke_3			1.035
			$p = 0.001^{***}$
LSD.sum_curr_0_neg			0.996
			$p = 0.043^{**}$
Observations	72	72	72
Log Likelihood	−38.568	−36.036	−30.952
Akaike Inf. Crit.	81.136	78.073	67.905
Note:			$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

RESULTS OF MODELS

	Dependent variable:		
	sev.phenomena		
	SAT30	SAT60	SAT90
	(1)	(2)	(3)
SAT.BT	0.894	0.820	0.773
	p = 0.0005^{***}	p = 0.002^{***}	p = 0.002^{***}
Observations	63	63	63
Log Likelihood	−29.744	−27.657	−25.068
Akaike Inf. Crit.	63.487	59.314	54.136
Note:			*p<0.1; **p<0.05; ***p<0.01

ELASTIC NET



- a penalized regression technique
    - number of features (k=81/69) exceeds the number of observations (n=63)
    - presence of highly correlated predictors
- two penalty terms (α, λ) in the maximum likelihood formula:
    - objective selection of relevant predictors
    - shrink regression 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 (LOOCV)

RESULTS OF MODELS

Table 1: Elastic model coefficients for 30 min

Predictors	Coefficient	Odd_ratio
(Intercept)		
RAD.AREA		
LSD.sum_curr_0_pos		
LSD.LJ		
SAT.BT		

Table 2: Elastic model coefficients for 60 min

Predictors	Coefficient	Odd_ratio
(Intercept)		
RAD.AREA		
LSD.LJ		
SAT.BT		

Table 3: Elastic model coefficients for 90 min

Predictors	Coefficient	Odd_ratio
(Intercept)	5.537	253.937
RAD.AREA	0.002	1.002
RAD.MAX_R_height	0	1
LSD.nstroke_3	0.001	1.001
LSD.sum_curr_0_neg	-0.001	0.999
SAT.BT	-0.035	0.966

EVALUATION OF MODELS

- Recall, Precision and F1 Score by LOOCV

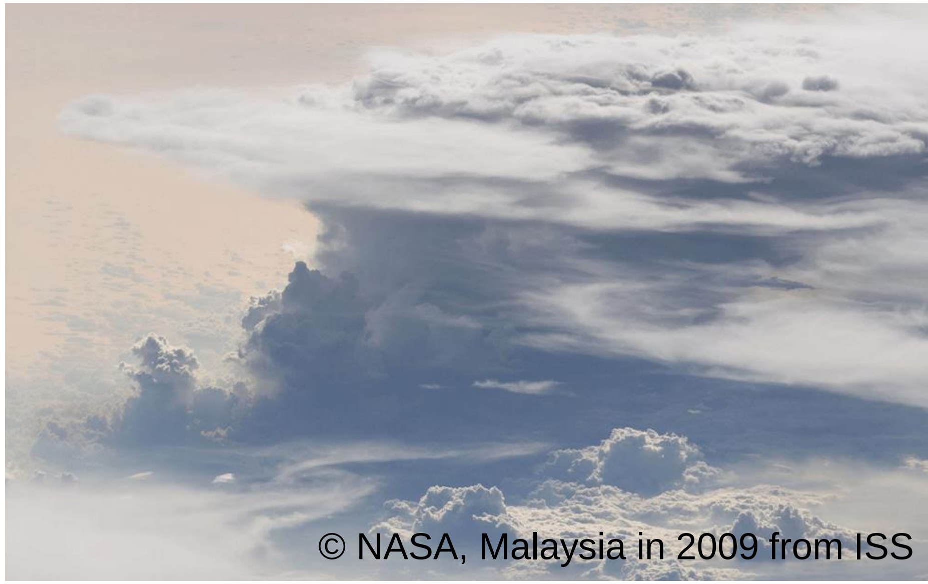
https://towardsdatascience.com/accuracy-precision-recall-or-f1-331fb37c5cb9

	Recall [%]	Precision [%]	F1 Score
LRM-RAD	64	78	0.70
LRM-LSD	36	89	0.52
LRM-SAT	68	62	0.65
ENet	75	94	0.83

Performance of the models for the first 30 minutes of the storm lifecycle

SUMMARY

- most of studied remote sensing parameters are dependent on the storm severity → useful information for nowcasting
- regression models were employed
  - high precision of the models (over 70 %)
  - similar predictors for logistic regressions and elastic nets
- predictors of the storm severity:
  - SAT.BT, RAD.AREA, LSD.LJ
- future steps:
  - improve the LJ algorithm, find relations for new data sources
  - adaptations for the operation in CHMI
  - probability of the storm severity, thresholds



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Marian Rybář (MATSTAT)

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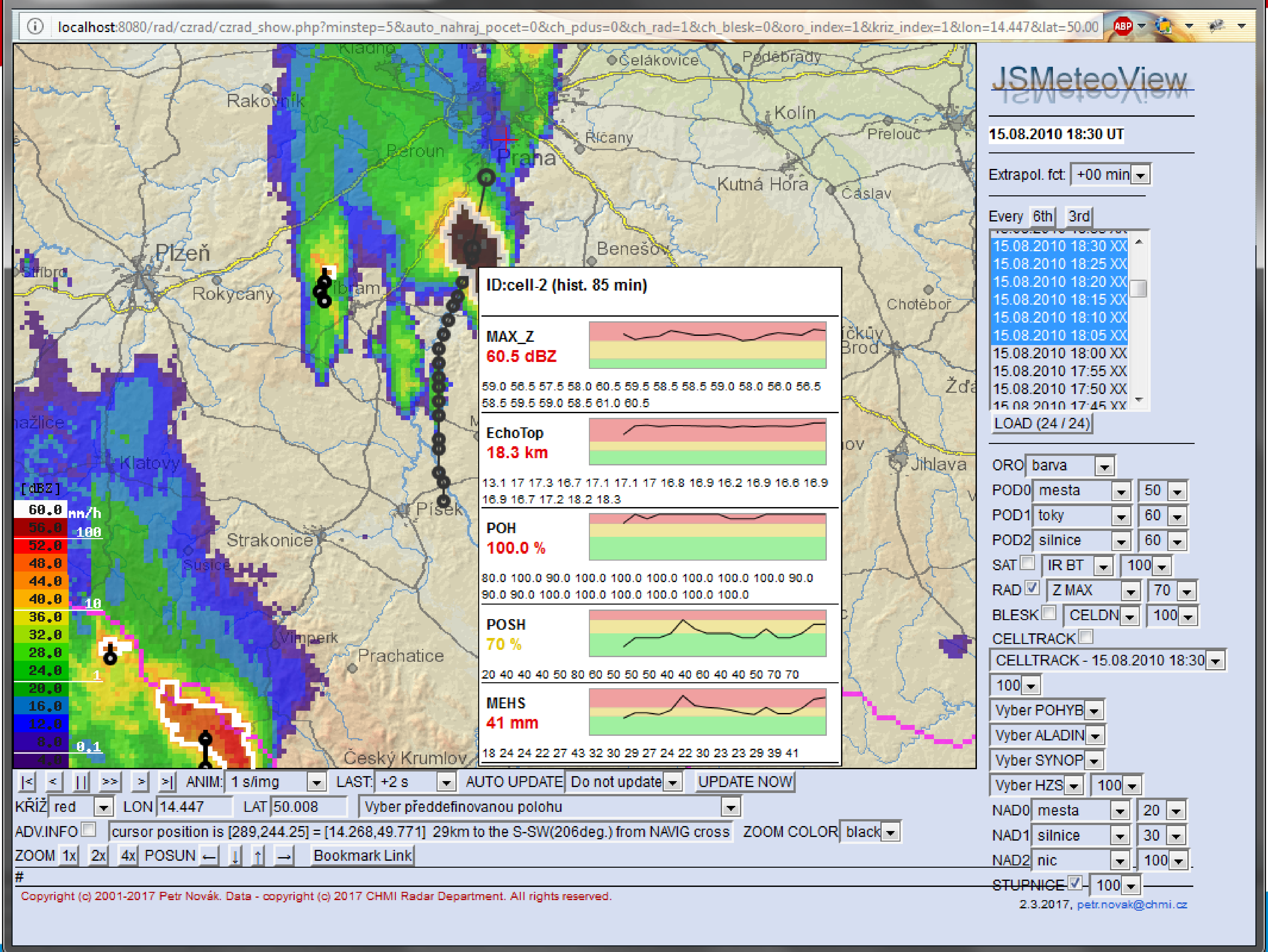

localhost:8080/rad/czrad/czrad_show.php?minstep=5&auto_nahraj_pocet=0&ch_pdus=0&ch_rad=1&ch_blesk=0&oro_index=1&kriz_index=1&lon=14.447&lat=50.00
JSMeteoView
15.08.2010 18:30 UT
Extrapol. fct: +00 min
Every 6th 3rd
15.08.2010 18:30 XX
15.08.2010 18:25 XX
15.08.2010 18:20 XX
15.08.2010 18:15 XX
15.08.2010 18:10 XX
15.08.2010 18:05 XX
15.08.2010 18:00 XX
15.08.2010 17:55 XX
15.08.2010 17:50 XX
LOAD (24 / 24)
ORO barva
POD0 mesta 50
POD1 toky 60
POD2 silnice 60
SAT IR BT 100
RAD Z MAX 70
BLESK CELDN 100
CELLTRACK
CELLTRACK - 15.08.2010 18:30
100
Vyber POHYB
Vyber ALADIN
Vyber SYNOP
Vyber HZS 100
NAD0 mesta 20
NAD1 silnice 30
NAD2 nic 100
STUPNICE 100
2.3.2017, petr.novak@chmi.cz
ID:cell-2 (hist. 85 min)
MAX_Z
60.5 dBZ
59.0 56.5 57.5 58.0 60.5 59.5 58.5 58.5 59.0 58.0 56.0 56.5
58.5 59.5 59.0 58.5 61.0 60.5
EchoTop
18.3 km
13.1 17 17.3 16.7 17.1 17.1 17 16.8 16.9 16.2 16.9 16.6 16.9
16.9 16.7 17.2 18.2 18.3
POH
100.0 %
80.0 100.0 90.0 100.0 100.0 100.0 100.0 100.0 100.0 90.0
90.0 90.0 100.0 100.0 100.0 100.0 100.0 100.0
POSH
70 %
20 40 40 40 50 80 60 50 50 50 40 40 60 40 40 50 70 70
MEHS
41 mm
18 24 24 22 27 43 32 30 29 27 24 22 30 23 23 29 39 41
[dBZ]
60.0 mm/h
56.0 100
52.0
48.0
44.0
40.0 10
36.0
32.0
28.0
24.0 1
20.0
16.0
12.0
8.0 0.1
4.0
Kladno
Čelákovice
Poděbrady
Rakovník
Kolín
Říčany
Přelouč
Beroun
Praha
Kutná Hora
Čáslav
Plzeň
Benešov
Stříbro
Rokycany
Příbram
Chotěboř
Brod
Žďá
Domažlice
Klatovy
Jihlava
Písek
Strakonice
Sušice
Vimperk
Prachatice
Český Krumlov
|< < || >> > >| ANIM: 1 s/img LAST: +2 s AUTO UPDATE Do not update UPDATE NOW
KŘÍŽ red LON 14.447 LAT 50.008 Vyber předdefinovanou polohu
ADV.INFO cursor position is [289,244.25] = [14.268,49.771] 29km to the S-SW(206deg.) from NAVIG cross ZOOM COLOR black
ZOOM 1x 2x 4x POSUN ← ↓ ↑ → Bookmark Link
#
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