Auroral Alert in Operation (ver 1.0)

A real-time judging of BIG aurora in all sky camera

M.Yamauchi *(Yama) and KAGO members*

Swedish Institute of Space Physics (IRF), Kiruna

www (www@irf.se) <aurora-alerts@irf.se> 2021-11-06 at 18:32

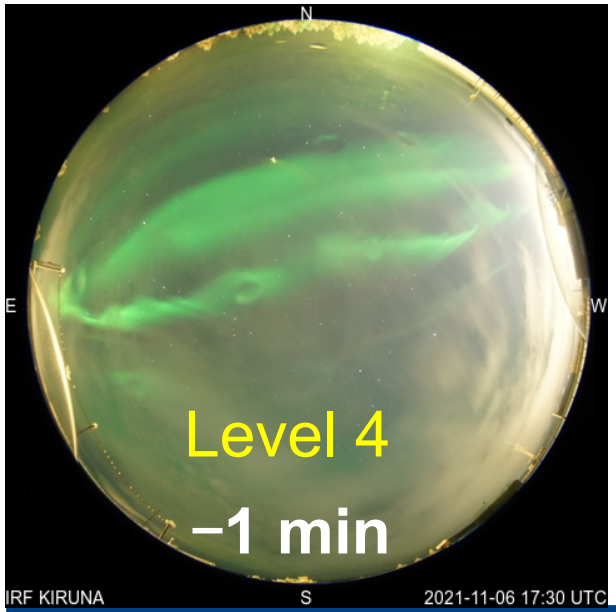
To: aurora-alerts@irf.se

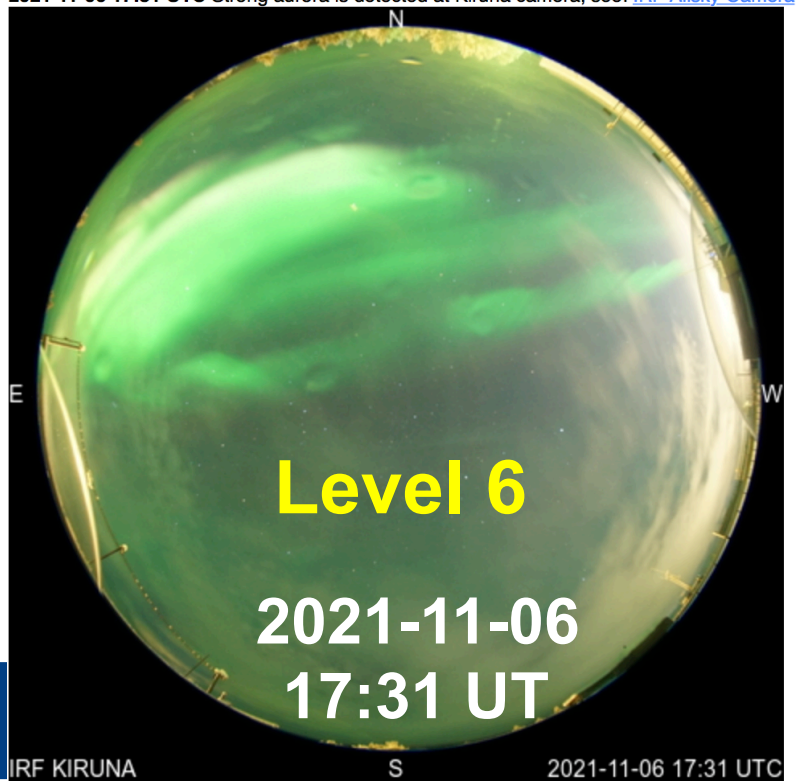
Reply-To: www@irf.se

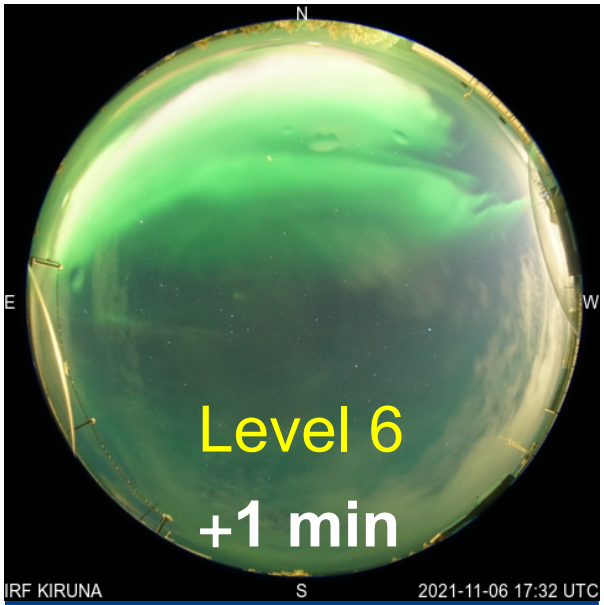
Alert e-mail

Strong aurora is detected at Kiruna camera

2021-11-06 17:31 UTC Strong aurora is detected at Kiruna camera, see: IRF Allsky-Camera







IRF

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Why Auroral Alert?

Visitors to Kiruna during September-March would like to see aurora.

Yes, can expect aurora every night. **But** it is easy to miss "BIG" aurora because

(1) Big one appears only 5-10 minutes after long "boring" weak aurora.

(2) The timing is unpredictable for this 5-10 minutes.

(3) It is too cold to wait outside.

(4) Even monitoring the nowcast (inside the room) make you bored, and easy to miss the important moment.

⇒ As the host and specialist of aurora, we dreamed an automatic alert system of "BIG" aurora, not the boring weak ones.

(Machine-leaning auroral classification? ⇒ No system has classified such "BIG event".)

Source Data = IRF all-sky camera (ASC)

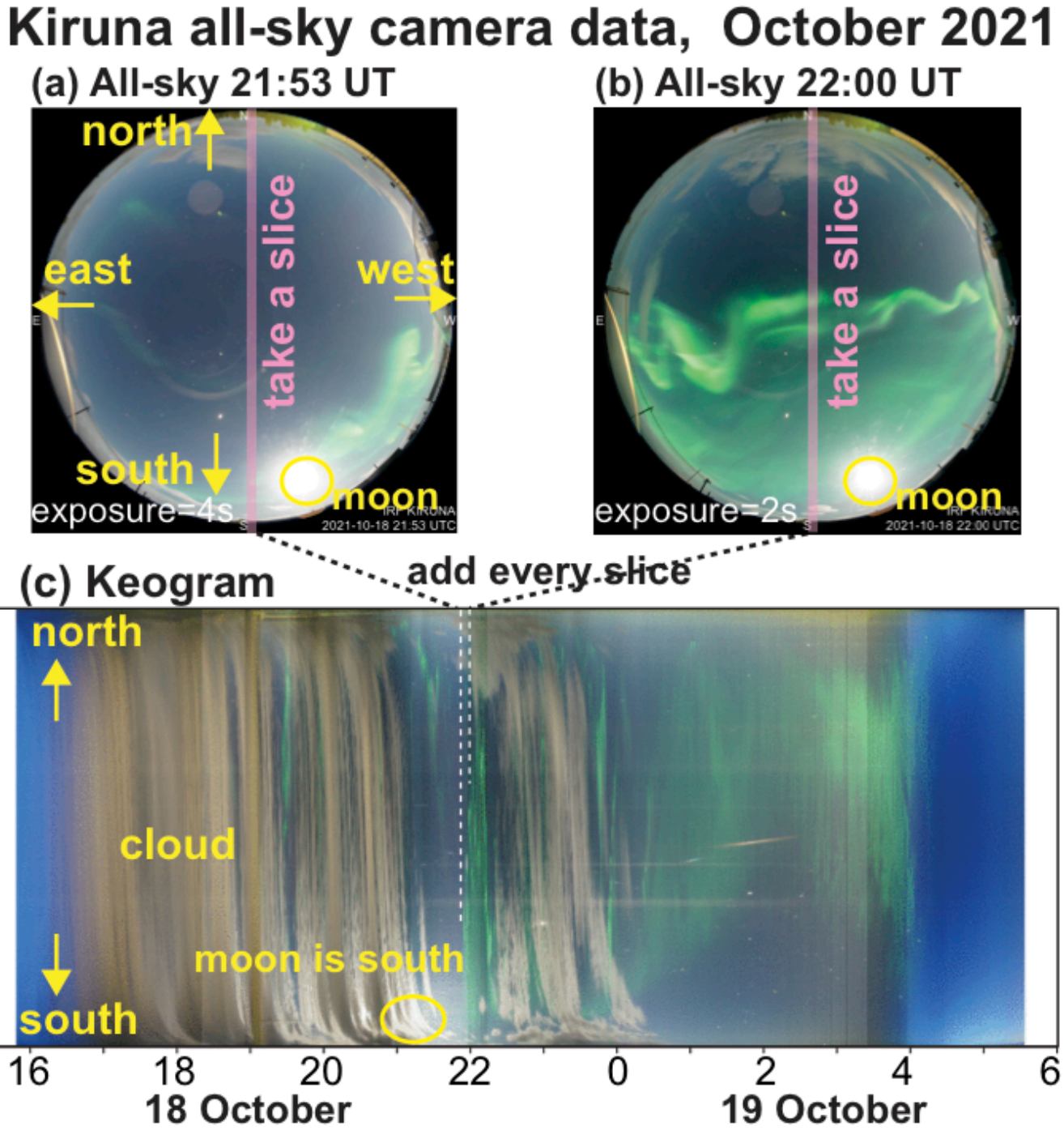
Sony α7s with a Nikon Nikkor 8 mm 1:2.8 objective lens

Inside a 30 cm heated dome at the roof of IRF optical laboratory.

Controlled by a Raspberry Pi 4 computer

Data is stored on a large disk-server and made available in real time at
https://www.irf.se/sv/observatorieverksamhet/firmamentkamera/

Data output from ASC + Keogram



Two-step calculation to define activity level

1. **Convert image (255x255x255 colors x 1 million pixels information) into simple set of numbers = ASC auroral index.**

Like calculating moment (n, v, p) from spectrogram (actually, its jpg image)

- solid calculation
- no AI

2. **Use this index to define the level of aurora.**

Define event/region from moment value only

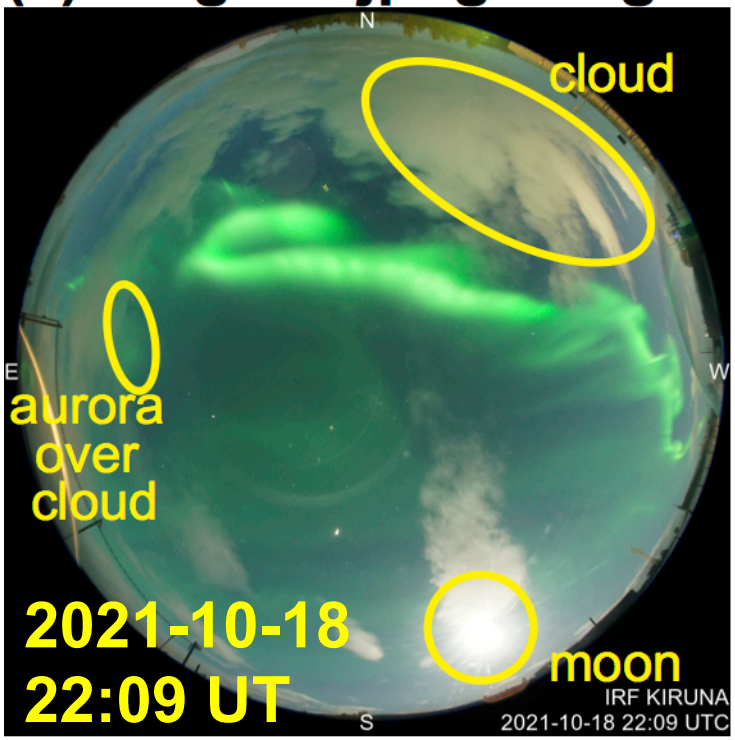
- solid criterion
- AI (neural network) is allowed

Two-step calculation to define activity level

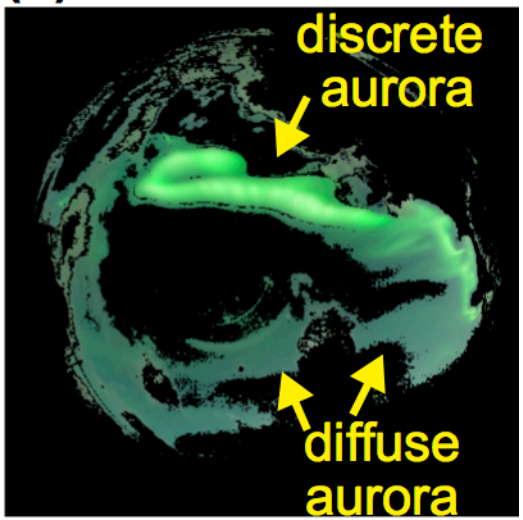
1. **First convert each image (1 million pixels) into a simple set of numbers.**

   1a. Classify each pixel into "strong", "green arc", "diffuse", cloud, artificial light, and moon. We use "expert system" on the color (RGB values) each pixel

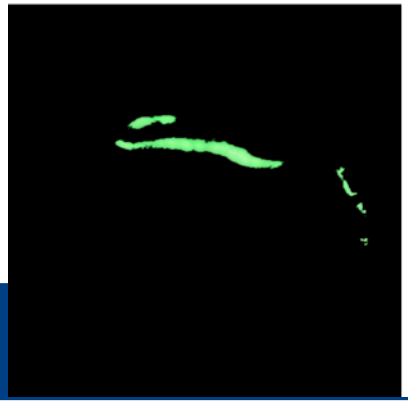
(a) Original jpeg image



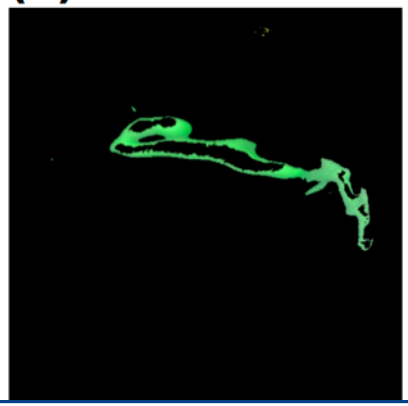
(b) Extracted aurora



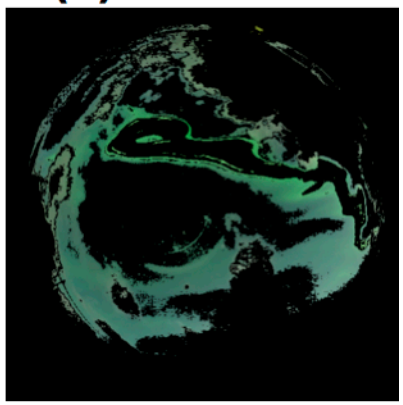
(c) “Strong”



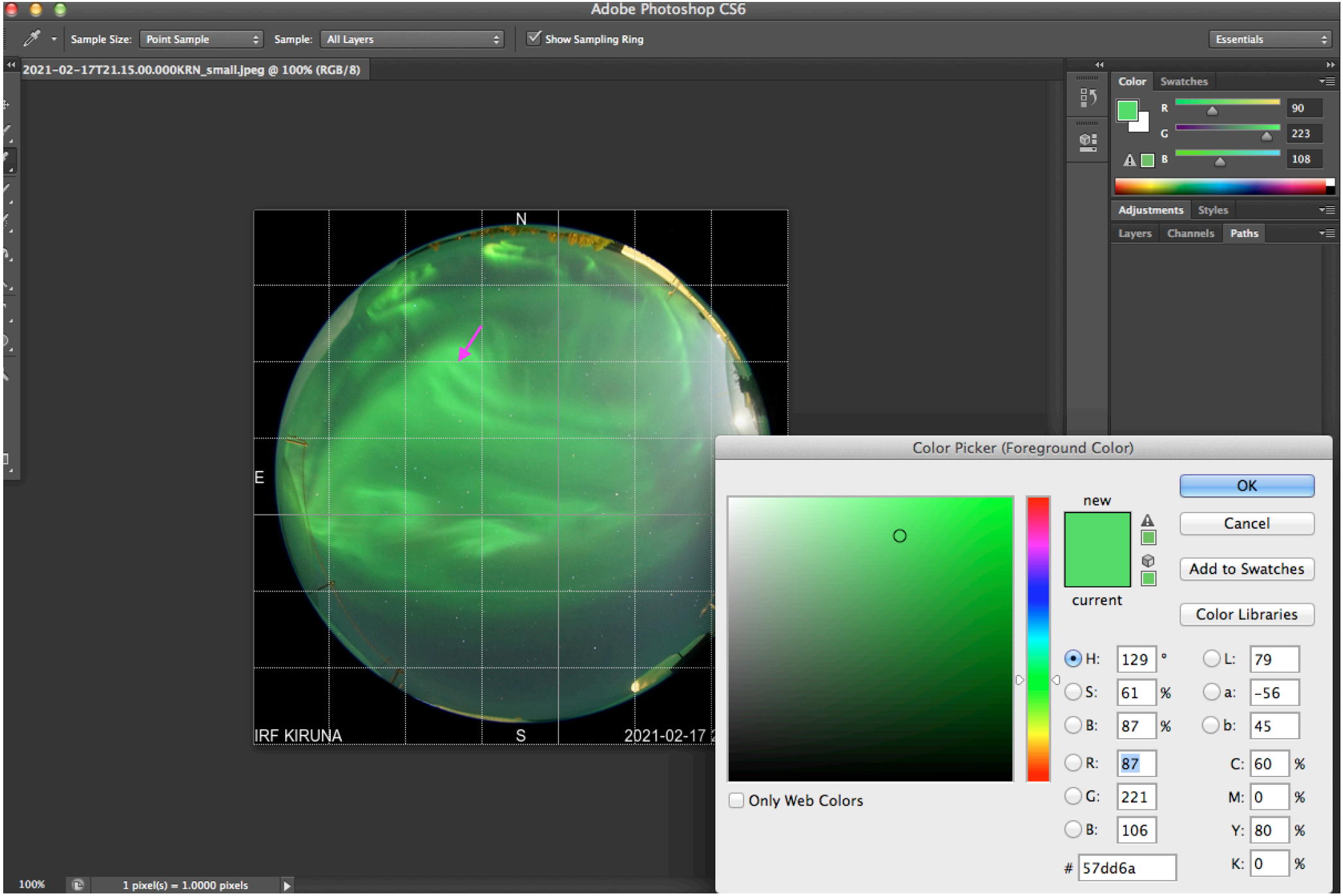
(d) “Green Arc”



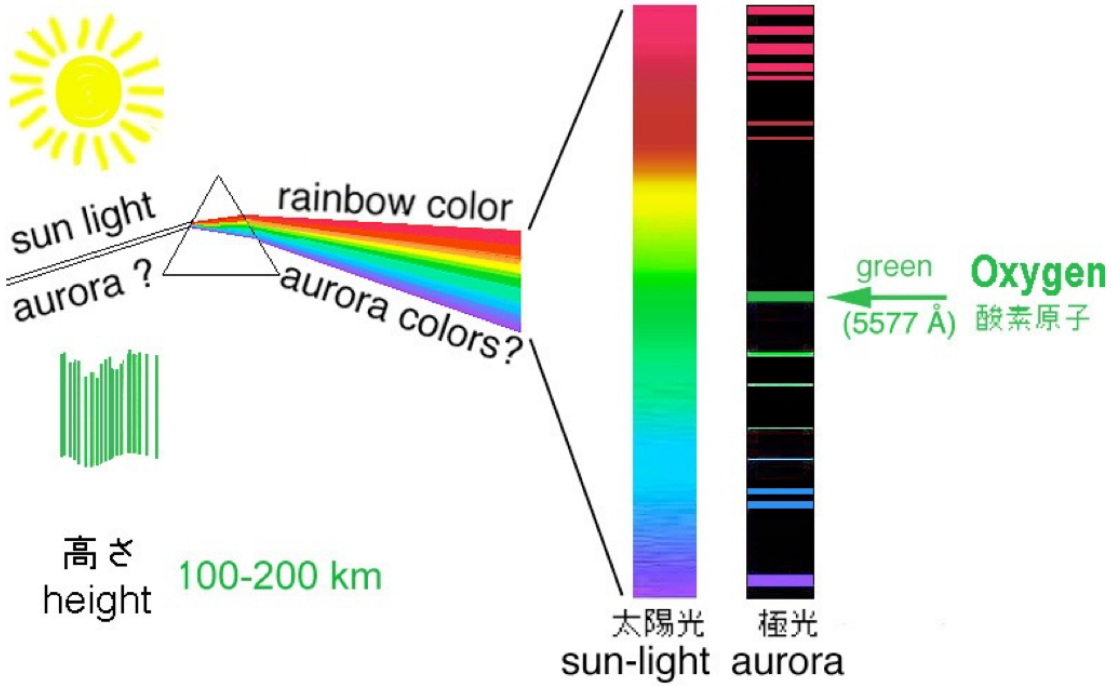
(e) “Diffuse”



First, examine pixel by pixel & image by image

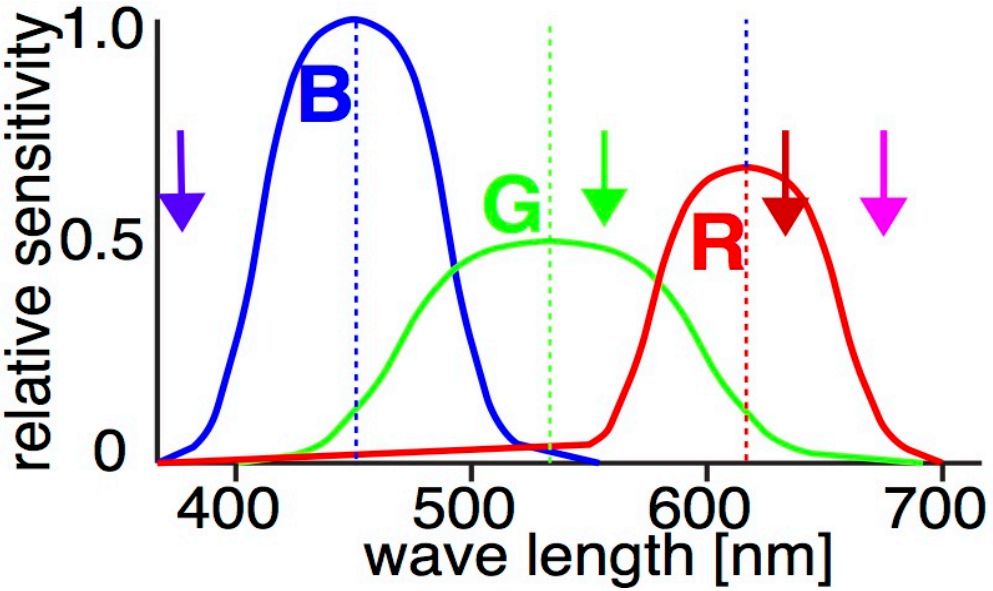


The reality of green color

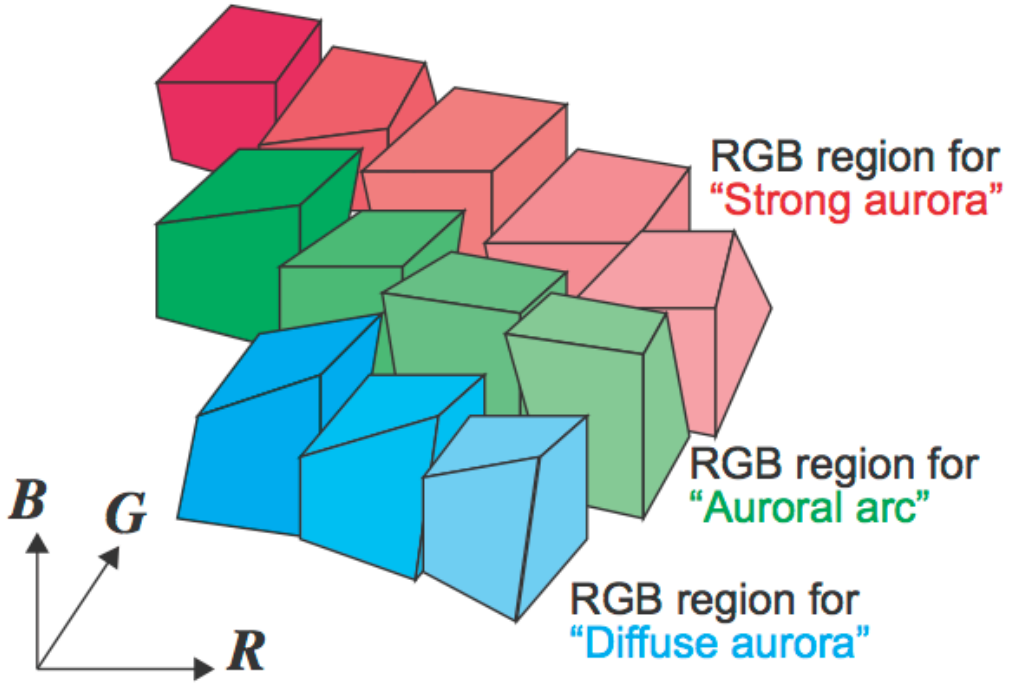


Almost all monitoring (nowcasting) camera uses RGB system, which (1) does not re-produce "real" 557.7 Å, and (2) mixes different green-color source, ending up large deviation from 557.7 Å

RGB color code cannot reproduce 557.7 Å



Followings are all "green aurora pixels"



Appendix-2: pixel data (eye-identified)

J269

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
245																						
246	saturate=safe (2021):																					
247	241	255	230	94.51	90.2	184.7		94°	26.1	100.00%		maskN_995			f1ffe6	94.5	100.0	90.2	284.7	pink	94	
248	239	255	229	93.73	89.8	183.5		97°	26.9	100.00%		maskN_995			efffe5	93.7	100.0	89.8	283.5	pink	97	
249	217	255	206	85.1	80.78	165.9		107°	29.7	100.00%		maskN_995			d9ffce	85.1	100.0	80.8	265.9	?	107	
250	213	255	174	83.53	68.24	151.8		91°	25.3	100.00%		maskN_995			d5ffae	83.5	100.0	68.2	251.8	pink	91	
251	212	255	201	83.14	78.82	162		108°	30.0	100.00%		maskN_995			d4ffc9	83.1	100.0	78.8	262.0	pink	108	
252	211	255	173	82.75	67.84	150.6		92°	25.6	100.00%		maskN_995			d3ffad	82.7	100.0	67.8	250.6	?	92	
253	209	255	197	81.96	77.25	159.2		107°	29.7	100.00%		maskN_995			d1fec5	82.0	100.0	77.3	259.2	pink	107	
254	204	255	194	80	76.08	156.1		110°	30.6	100.00%		maskN_995			ccffc2	80.0	100.0	76.1	256.1	pink	110	
255	200	255	190	78.43	74.51	152.9		111°	30.8	100.00%		maskN_995			c8ffbe	78.4	100.0	74.5	252.9	pink	111	
256	193	255	182	75.69	71.37	147.1		111°	30.8	100.00%		maskN_995			bafeb3	75.7	100.0	71.4	247.1	pink	111	
257	191	255	179	74.9	70.2	145.1		111°	30.8	100.00%		maskN_995			bfffb3	74.9	100.0	70.2	245.1	pink	111	
258	180	255	173	70.59	67.84	138.4		115°	31.9	100.00%		maskN_995			b4ffad	70.6	100.0	67.8	238.4	pink	115	
259	176	255	167	69.02	65.49	134.5		114°	31.7	100.00%		maskN_995			c3fda6	69.0	100.0	65.5	234.5	pink	114	
260	176	255	148	69.02	58.04	127.1		104°	28.9	100.00%		maskN_995			b0ff94	69.0	100.0	58.0	227.1	?	104	
261	170	255	167	66.67	65.49	132.2		118°	32.8	100.00%		maskN_995			aaffa7	66.7	100.0	65.5	232.2	?	118	
262	162	255	184	63.53	72.16	135.7		112°	31.1	100.00%		maskN_995			a2ff94	63.5	100.0	72.2	235.7	near pink	112	
263	234	254	217	92.13	85.43	177.6		92°	25.6	99.00%		maskN_995			eafed9	91.8	99.6	85.1	276.5	pink	92	
264	192	254	143	75.59	56.3	131.9		94°	26.1	99.00%		maskN_995			c0fe8f	75.3	99.6	56.1	231.0	?	94	
265	190	254	178	74.8	70.08	144.9		111°	30.8	99.00%		maskN_995			befeb2	74.5	99.6	69.8	243.9	pink	111	
266	186	254	179	73.23	70.47	143.7		114°	31.7	99.00%		maskN_995			bafeb3	72.9	99.6	70.2	242.7	pink	114	
267	179	254	163	70.47	64.17	134.6		109°	30.3	99.00%		maskN_995			b3fea3	70.2	99.6	63.9	233.7	?	109	
268	147	254	116	57.87	45.67	103.5		107°	29.7	99.00%		maskN_995			93fe74	57.6	99.6	45.5	202.7	pink	107	
269																						
270	208	253	194	82.21	76.68	158.9		106°	29.4	99.00%		maskN_97			d0fdc2	81.6	99.2	76.1	256.9	pink	106	
271	195	253	166	77.08	65.61	142.7		100°	27.8	99.00%		maskN_97			c3fda6	76.5	99.2	65.1	240.8	pink	100	
272	151	253	153	59.68	60.47	120.2		121°	33.6	99.00%		maskN_97			97fd99	59.2	99.2	60.0	218.4	ray	121	
273	**226**	254	**196**	**88.98**	**77.17**	**166.1**		**89°**	24.7	**99.00%**		maskN_97			**e2fec4**	**88.6**	**99.6**	**76.9**	**265.1**	**pink with town-light**	**89**	
274	**224**	252	**194**	**88.89**	**76.98**	**165.9**		**89°**	24.7	**99.00%**		maskN_97			**e0fcc2**	**87.8**	**98.8**	**76.1**	**262.7**	**pink with town-light**	**89**	
275	156	251	147	62.15	58.57	120.7		115°	31.9	98.00%		maskN_97			9cfb93	61.2	98.4	57.6	217.3	?	115	
276	155	251	118	61.75	47.01	108.8		103°	28.6	98.00%		maskN_97			9bfb76	60.8	98.4	46.3	205.5	pink	103	
277	152	251	134	60.56	53.39	113.9		111°	30.8	98.00%		maskN_97			98fb86	59.6	98.4	52.5	210.6	pink	111	
278	226	250	202	90.4	80.8	171.2		90°	25.0	98.00%		maskN_97			e2faca	88.6	98.0	79.2	265.9	pink	90	
279	222	250	199	88.8	79.6	168.4		93°	25.8	98.00%		maskN_97			defac7	87.1	98.0	78.0	263.1	pink	93	
280	185	250	166	74	66.4	140.4		106°	29.4	98.00%		maskN_97			b9faa6	72.5	98.0	65.1	235.7	pink	106	
281	163	250	143	65.2	57.2	122.4		109°	30.3	98.00%		maskN_97			a3fa8f	63.9	98.0	56.1	218.0	pink	109	
282	140	250	137	56	54.8	110.8		118°	32.8	98.00%		maskN_97			8cfa89	54.9	98.0	53.7	206.7	near pink	118	
283	131	250	130	52.4	52	104.4		119°	33.1	98.00%		maskN_97			84fa82	51.4	98.0	51.0	200.4	?	119	
284	223	249	201	89.56	80.72	170.3		92°	25.6	98.00%		maskN_97			dff9c9	87.5	97.6	78.8	263.9	pink	92	
285	179	249	150	71.89	60.24	132.1		102°	28.3	98.00%		maskN_97			b3f996	70.2	97.6	58.8	226.7	pink	102	

RGBcode_SONY.txt

Normal View | Ready | Sum=0

How criterion looks like (AND logic between columns)

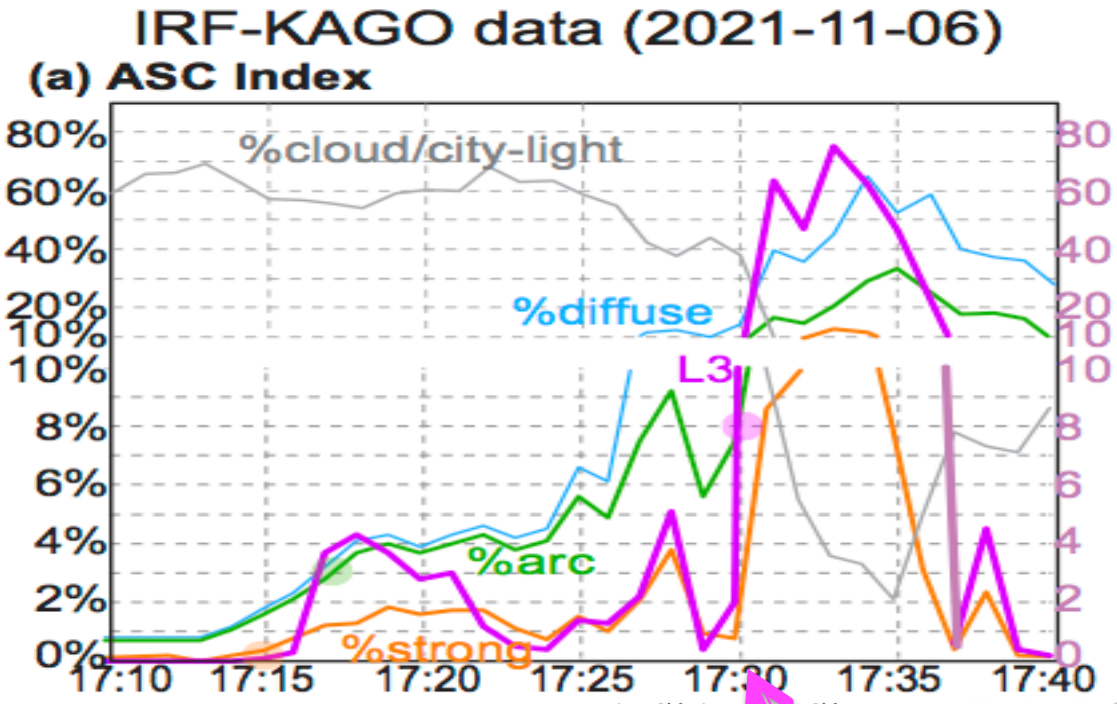
category	OR conditions	H	G	R/G	B/G	(R+B)/G
strong aurora	N_2-1a	0.25≤, <0.34	0.97≤	0.50≤, <0.92		<1.90
strong aurora	N_2-1b	0.25≤, <0.34	0.995≤	0.50≤, <0.95		<1.90
strong aurora	1	0.26≤, <0.36	0.95≤	<0.75		<1.90
strong aurora	2	0.30≤, <0.36	0.88≤	<0.70	<0.66	
strong aurora	3	0.30≤, <0.34	0.83≤	<0.62	<0.57	
strong aurora	4	0.32≤, <0.36	0.76≤	<0.43	<0.50	<0.89
strong aurora	5	0.30≤, <0.352	0.77≤, <0.83	<0.60	<0.64	≥0.96
strong aurora	6	0.26≤, <0.31	0.75≤, <0.95	<0.69	<0.54	
green arc	1	0.32≤, <0.36	0.69≤	<0.47	<0.51	
green arc	2	0.36≤, <0.41	0.69≤	<0.70	<0.80	
green arc	3a	0.28≤, <0.35	0.65≤, <0.80	<0.70		<1.21
green arc	3b	0.28≤, <0.35	0.65≤, <0.80	<0.70	<0.62	
green arc	4	0.24≤, <0.27	0.59≤, <0.70	<0.80	<0.55	
green arc	5	0.20≤, <0.24	0.59≤, <0.77	<0.92	<0.65	
green arc	6	0.30≤, <0.36	0.55≤, <0.68	<0.61	<0.61	
green arc	7	0.25≤, <0.35	0.50≤, <0.69	<0.75	<0.51	

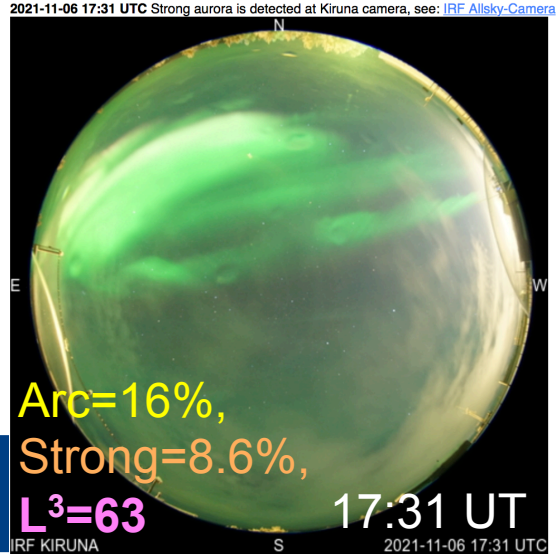
Two-step calculation to define activity level

1. **First convert each image (1 million pixels) into a simple set of numbers.**

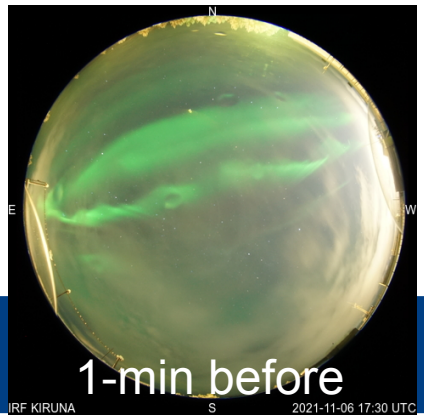
   1a. Classify each pixel into "strong", "green arc", "diffuse", cloud, artificial light, and moon. We use "expert system" on the color (RGB values) each pixel

   1b. Obtain coverage (%) of each category and average intensity of "strong" aurora in real-time (every minute).
   ⇒ This set of numbers is "All-Sky Camera auroral index"





2021-11-06



Real-time products

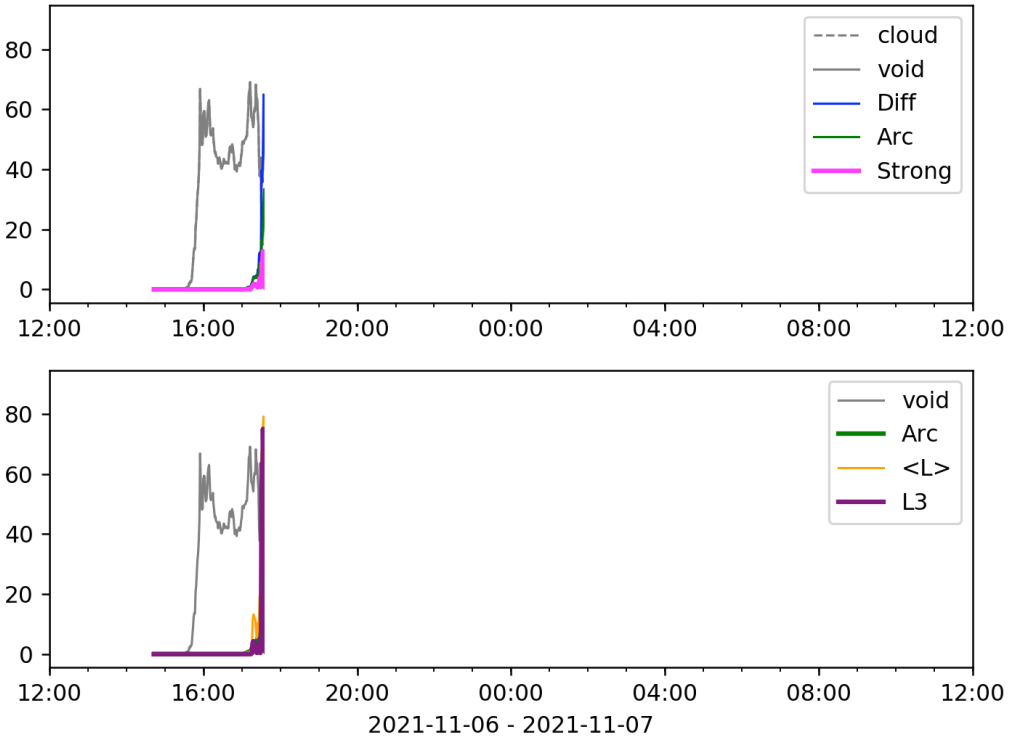
example: 2021-11-06

www.irf.se/alis/allsky/nowcast/latest.csv

DATE,	TIME,	DOY,	Diff,	Arc,	Strong,	void,	cloud,	<L>,	L^3
2021-11-06,	17:24:00,	310,	4.5,	4.1,	0.74,	63.5,	63.5,	5.4,	0.4
2021-11-06,	17:25:00,	310,	6.6,	5.6,	1.54,	58.5,	58.5,	10.4,	1.4
2021-11-06,	17:26:00,	310,	6.1,	4.9,	1.02,	54.9,	54.9,	7.7,	1.3
2021-11-06,	17:27:00,	310,	11.5,	7.5,	2.09,	42.2,	42.2,	12.2,	2.2
2021-11-06,	17:28:00,	310,	12.3,	9.2,	3.80,	37.7,	37.7,	19.2,	5.1
2021-11-06,	17:29:00,	310,	9.9,	5.6,	0.95,	44.0,	43.9,	5.7,	0.4
2021-11-06,	17:30:00,	310,	14.1,	7.5,	0.79,	38.0,	38.0,	10.6,	2.0
2021-11-06,	17:31:00,	310,	39.7,	16.5,	8.59,	10.0,	9.9,	66.8,	63.5
2021-11-06,	17:32:00,	310,	35.7,	14.8,	9.53,	5.5,	5.5,	57.8,	47.1

like moment file

www.irf.se/alis/allsky/nowcast/latest.png



last hour

www.irf.se/alis/allsky/nowcast/latest-hour.png

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Kiruna, Sweden

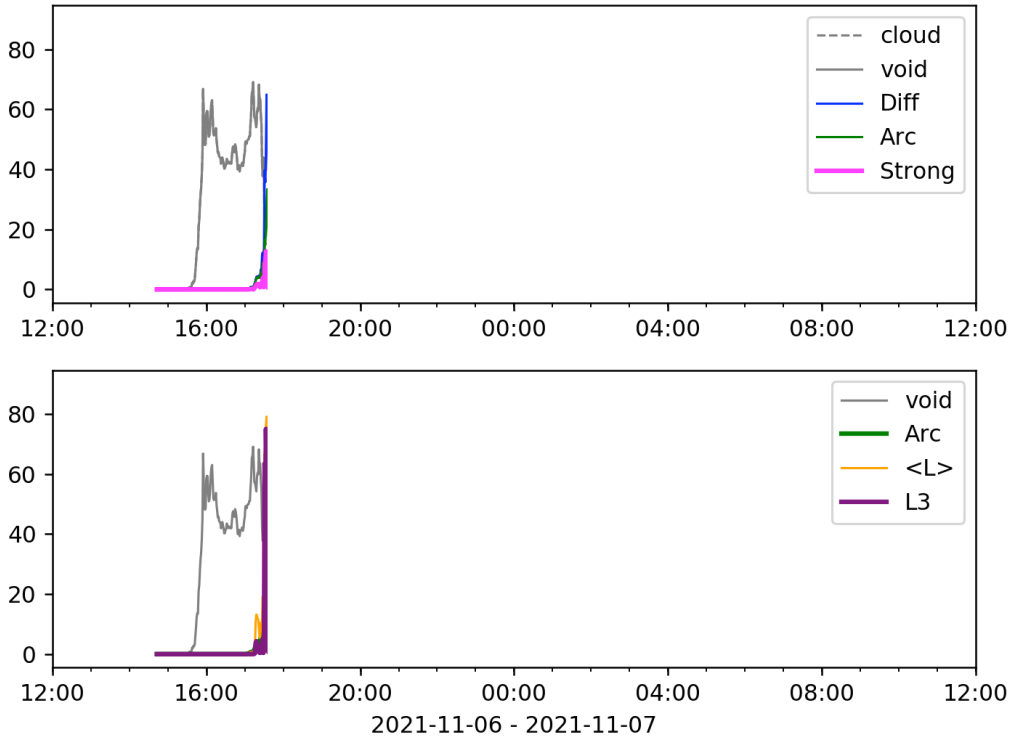
First break-up

Real-time products

www.irf.se/alis/allsky/nowcast/latest.csv

DATE,	TIME,	DOY,	**Diff,**	**Arc,**	**Strong,**	void,	cloud,	<L>,	**L^3**
2021-11-06,	17:24:00,	310,	4.5,	4.1,	0.74,	63.5,	63.5,	5.4,	0.4
2021-11-06,	17:25:00,	310,	6.6,	5.6,	1.54,	58.5,	58.5,	10.4,	1.4
2021-11-06,	17:26:00,	310,	6.1,	4.9,	1.02,	54.9,	54.9,	7.7,	1.3
2021-11-06,	17:27:00,	310,	11.5,	7.5,	2.09,	42.2,	42.2,	12.2,	2.2
2021-11-06,	17:28:00,	310,	12.3,	9.2,	3.80,	37.7,	37.7,	19.2,	5.1
2021-11-06,	17:29:00,	310,	9.9,	5.6,	0.95,	44.0,	43.9,	5.7,	0.4
2021-11-06,	17:30:00,	310,	14.1,	7.5,	0.79,	38.0,	38.0,	10.6,	2.0
2021-11-06,	17:31:00,	310,	39.7,	16.5,	8.59,	10.0,	9.9,	66.8,	63.5
2021-11-06,	17:32:00,	310,	35.7,	14.8,	9.53,	5.5,	5.5,	57.8,	47.1

www.irf.se/alis/allsky/nowcast/latest.png



Level-6:
arc ≥3%, str ≥0.2%
L^3 ≥8

Level-4a:
arc ≥2%, str ≥0.2%
L^3 ≥5

Level-4b:
arc ≥1%, str ≥0.1%
str·L^3 ≥1.5 (%)

see also

www.irf.se/alis/allsky/nowcast/latest-hour.png

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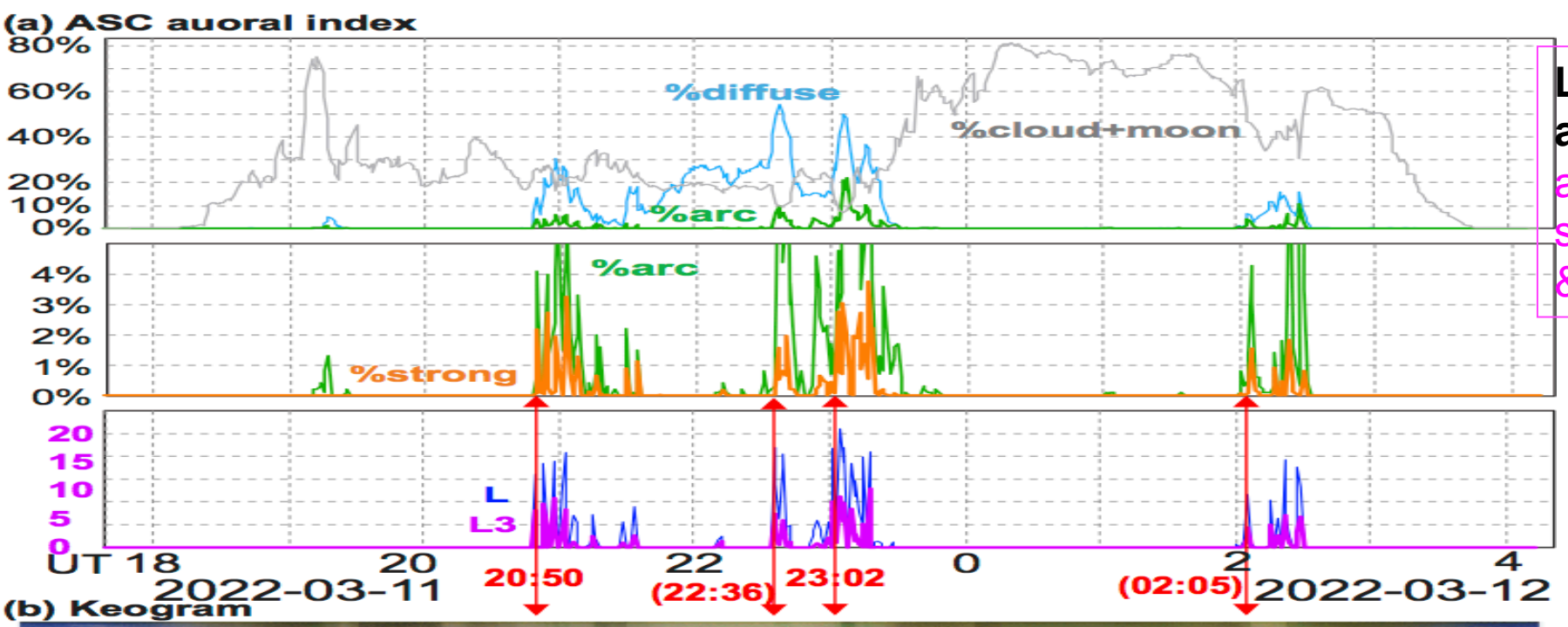
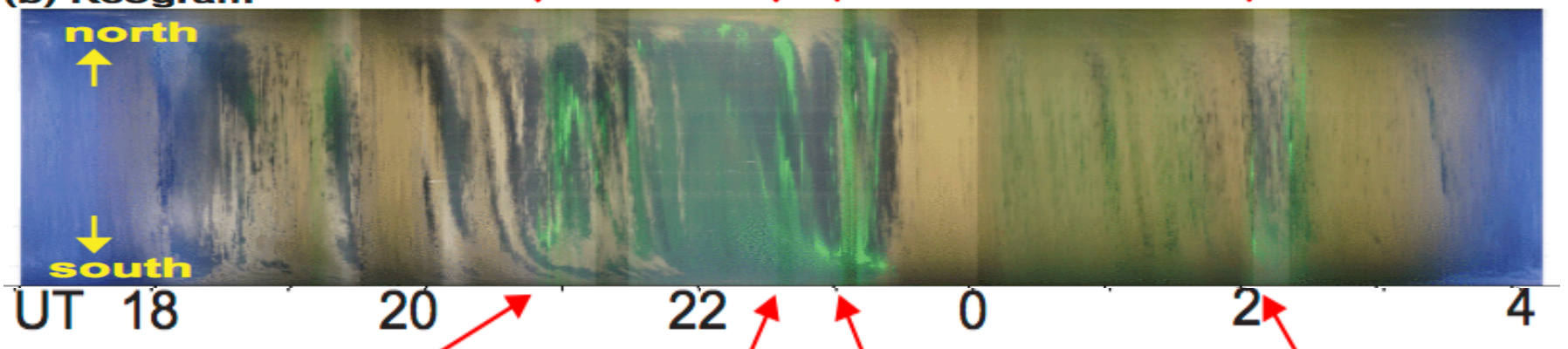
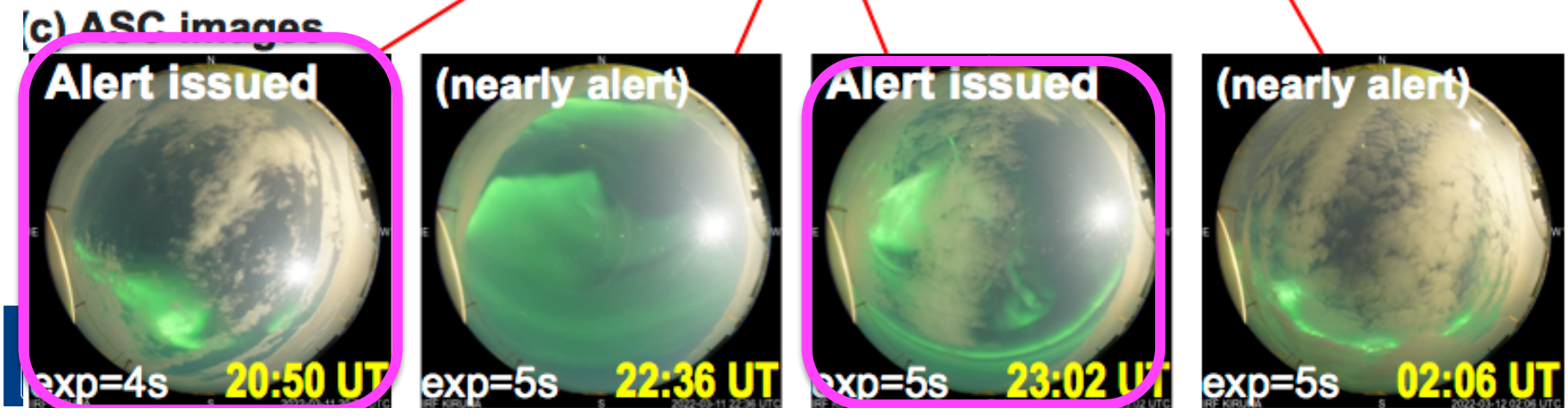


Level-6 = alert mail:
arc ≥3%,
str ≥0.2%,
& L3 ≥8





M. Yamauchi
Kiruna, Sweden

Two-step calculation to define activity level

1. **Convert image (255x255x255 colors x 1 million pixels information) into simple set of numbers = ASC auroral index.**

   1a. Classify each pixel into "diffuse", "green arc", "strong (=saturated or mixed with N_2^+ line)", cloud, artificial light, and moon. We use R, G, B, H (in version-0, we used H, S, L only)

   1b. Obtain % of pixel coverage of each category and also average intensity of "strong" aurora. ⇒ This set of numbers is "All-Sky Camera auroral index". ⇒ Real time production every minutes

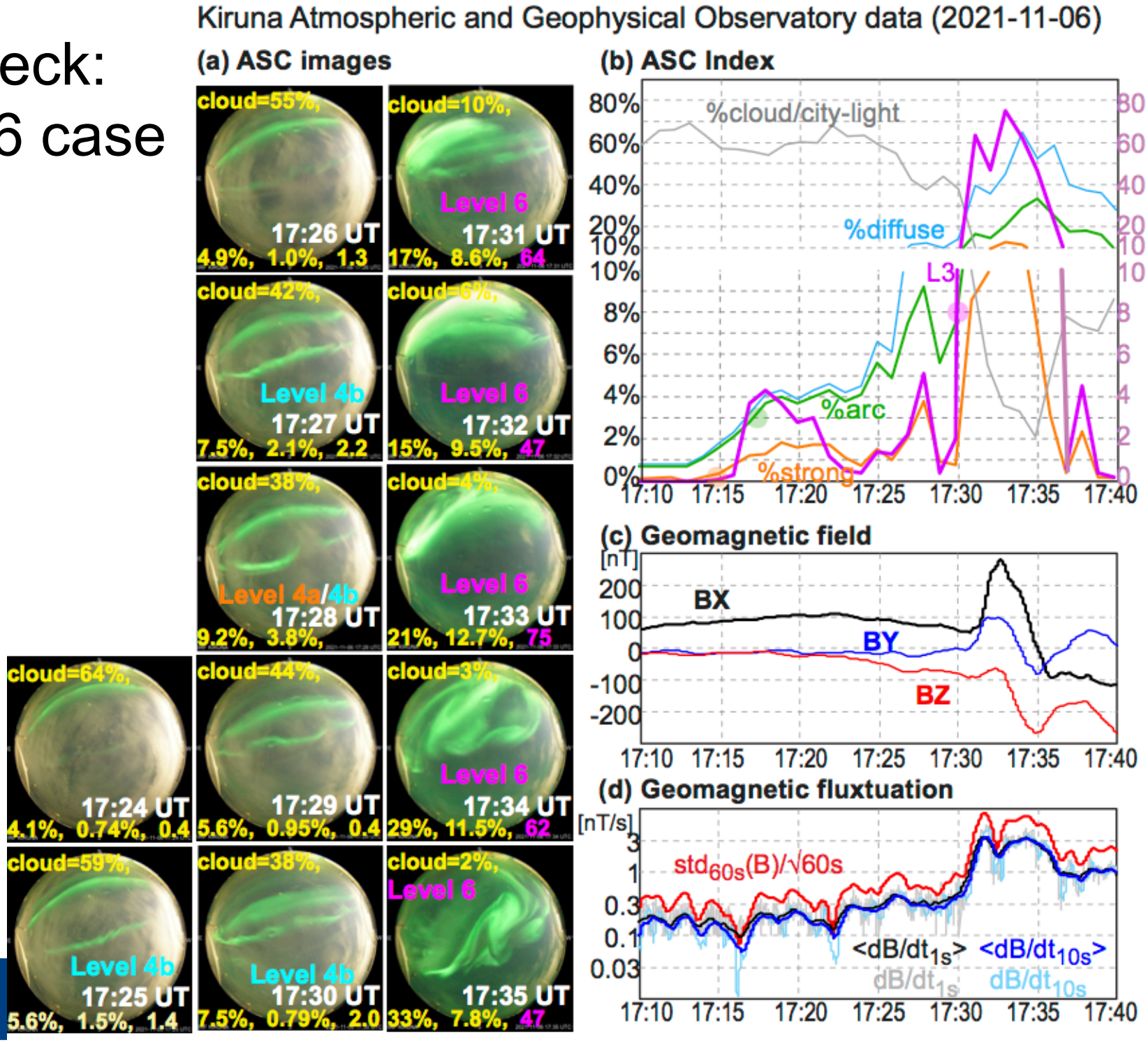
2. **Use this index to define the level of aurora.**

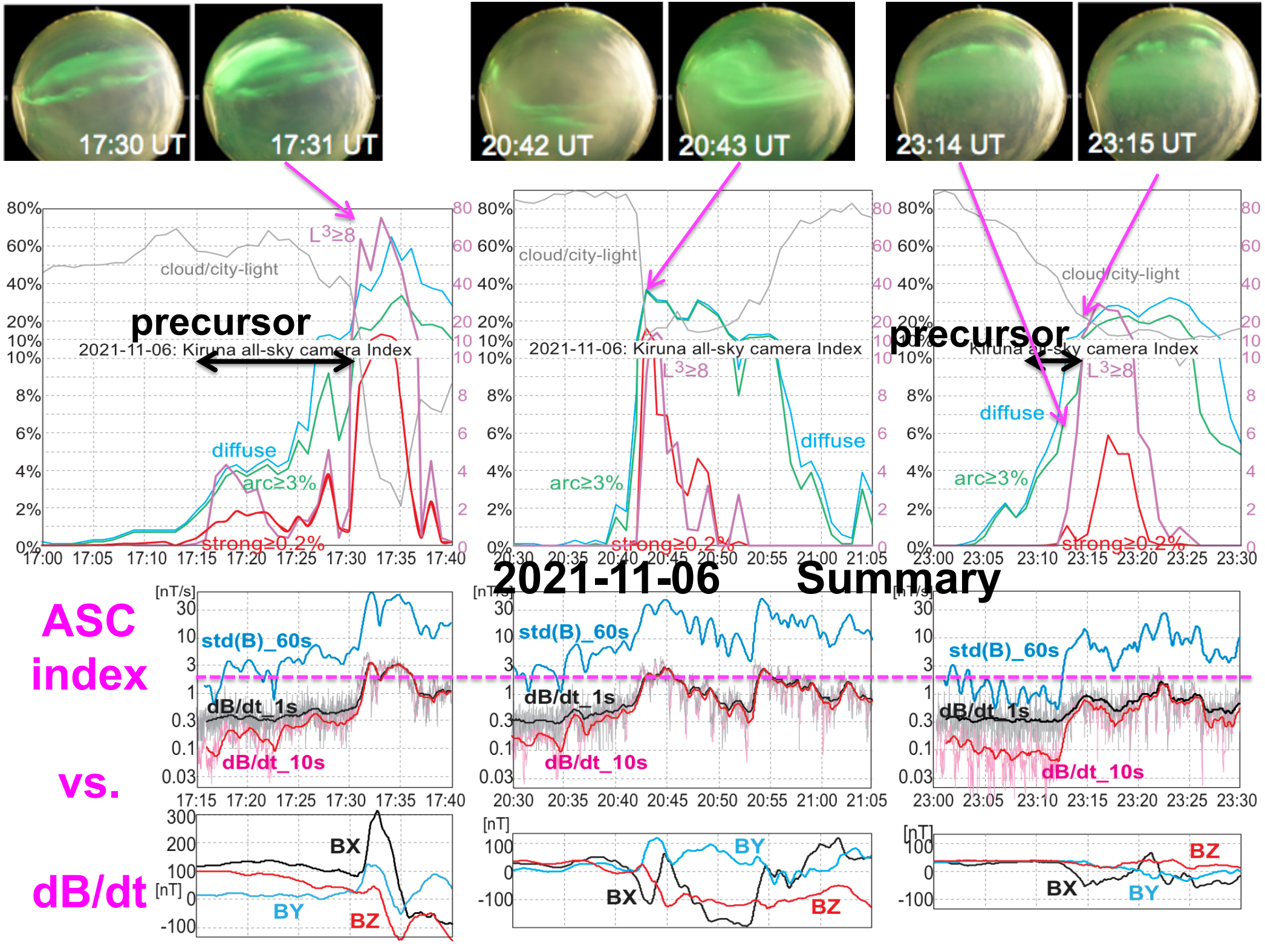
   2a. Level 6: clear breakup ⇒ Done

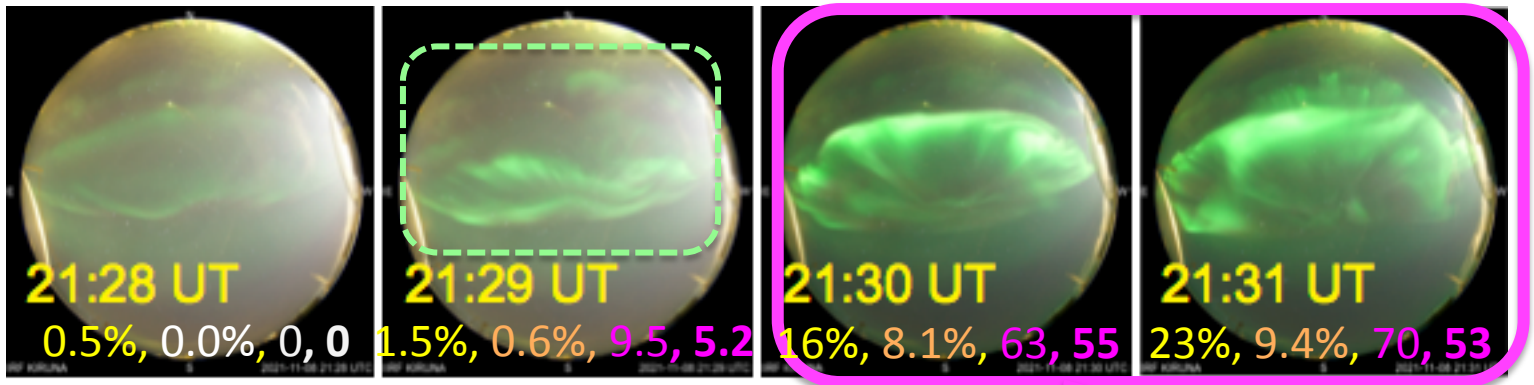
   2b. Level 5: breakup-like motion with less intensity ⇒ to be identified

   2c. Level 4: nearly breakup (possible precursor) ⇒ under tuning

Detail check: 2021-11-06 case

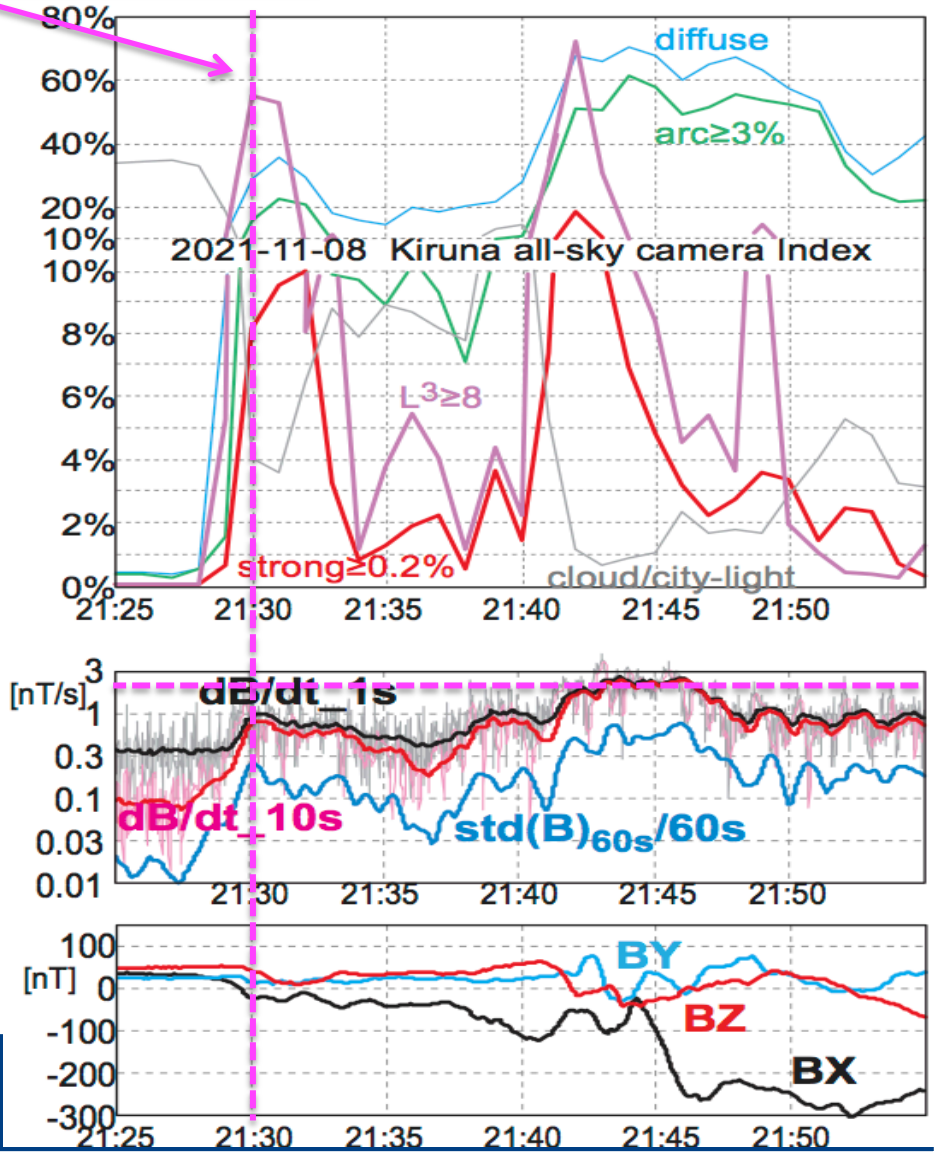



17:30 UT
17:31 UT
20:42 UT
20:43 UT
23:14 UT
23:15 UT
precursor
precursor
2021-11-06: Kiruna all-sky camera Index
cloud/city-light
L3≥8
diffuse
arc≥3%
strong≥0.2%
2021-11-06 Summary
ASC index
vs.
dB/dt
std(B)_60s
dB/dt_1s
dB/dt_10s
BX
BY
BZ
[nT/s]
[nT]



Works with cloud

2021-11-08



www (www@irf.se) <aurora-alerts@irf.se> Today at 01:04

To: aurora-alerts@irf.se

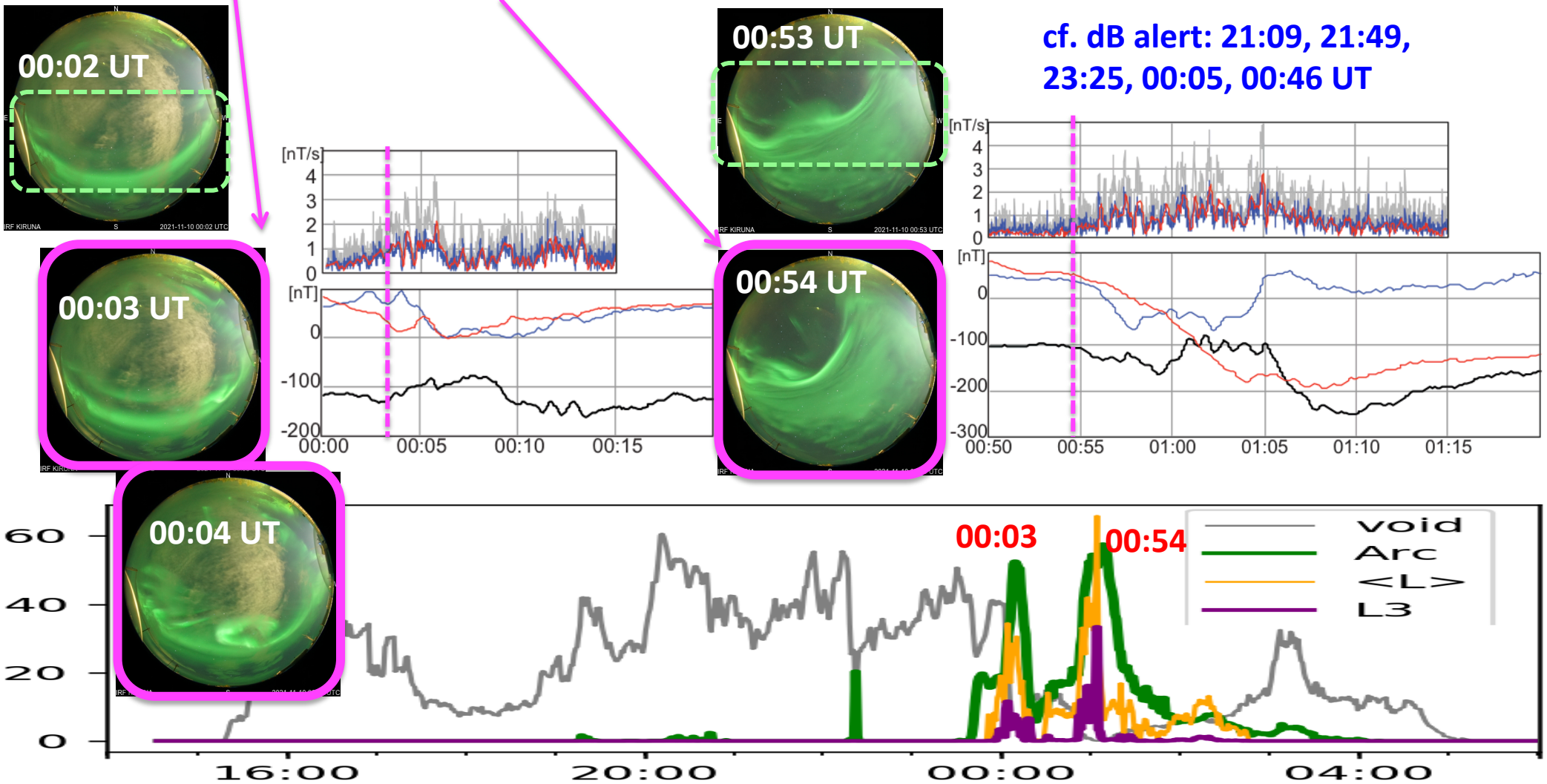
Reply-To: www@irf.se

Strong aurora is detected at Kiruna camera

post-midnight: after 01:30 LT, alert Omega band = success

2021-11-10 00:03 UTC Strong aurora is detected at Kiruna camera, see: IRF Allsky-Camera

2021-11-10 00:54 UTC Strong aurora is detected at Kiruna camera, see: IRF Allsky-Camera



Summary (version 1.0)

Pixel-to-pixel judging of color (R,G,B,H) to classify into "strong aurora", "green arc", "diffuse", "cloud", etc., using a simple criteria (expert system).

Coverage (%) and weighted luminosity ⇒ All-sky camera "auroral index"
⇒ update every minute in ascii format www.irf.se/alis/allsky/nowcast/latest.csv
⇒ define the activity level from this index (Level 6 = alert e-mail).

Level-6 corresponds to all local "expanding enhancement", including traveling bulge, pre-midnight breakup & post-midnight omega band onset (cf. magnetic signature is not sufficient in many cases)

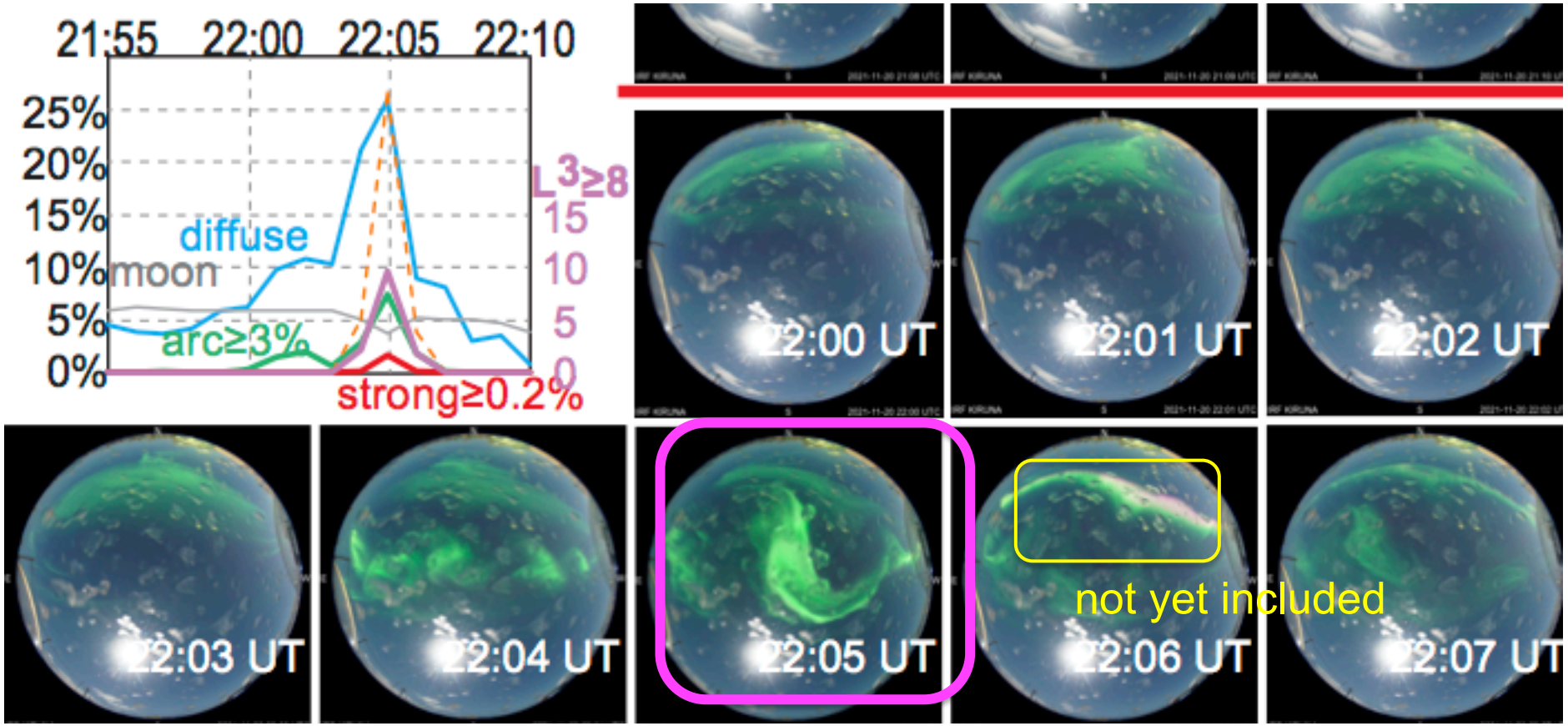
Beta-test in operation since November 2021

⇒ A 90% success rate so far (10% of false-negative and 10% of false positive)

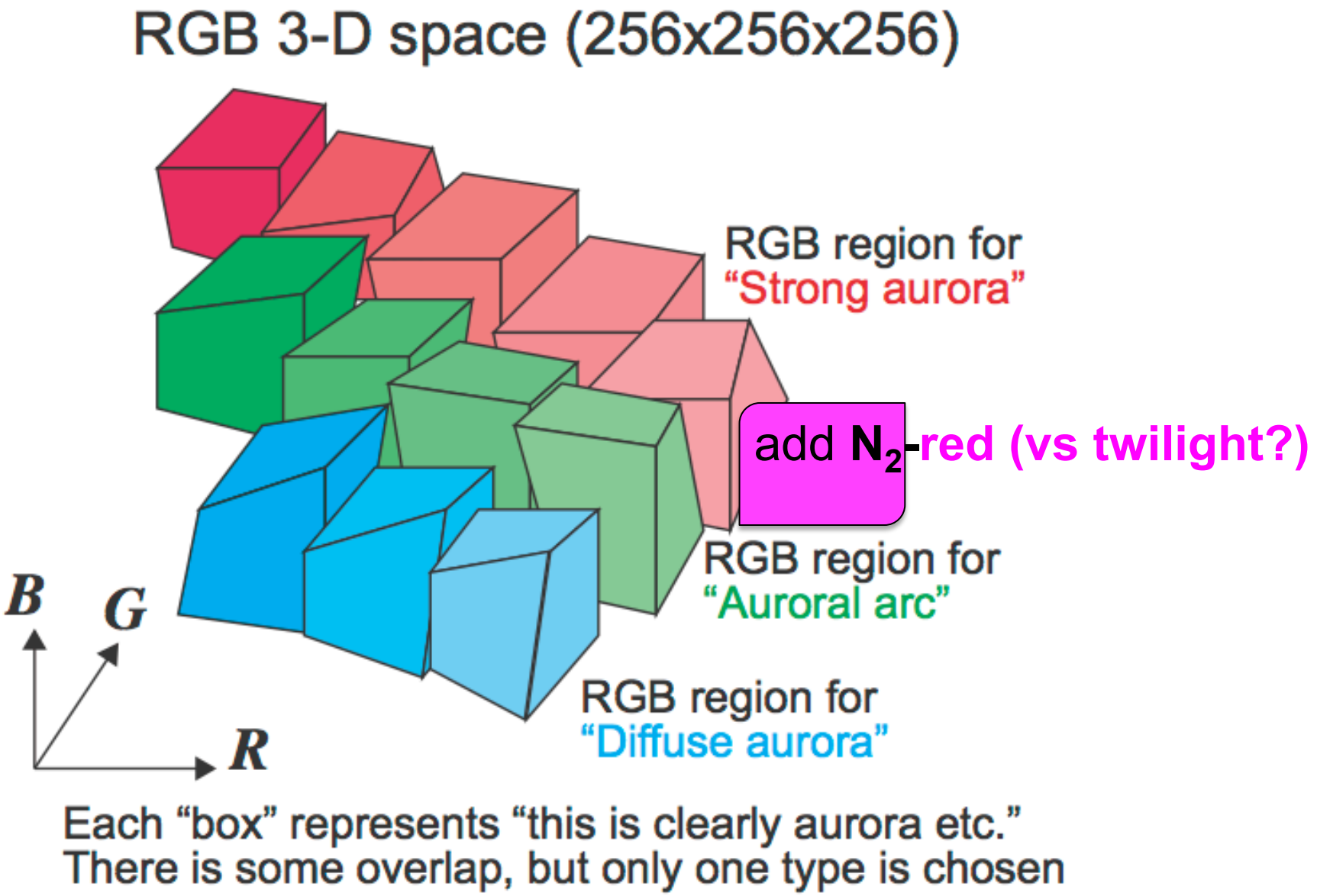
Thus, simple expert system (pixel-judge) works!

- Machine learning method to be combined in future
- Most important: camera with fixed exposure time is better

Future improvement: e.g., N_2-red



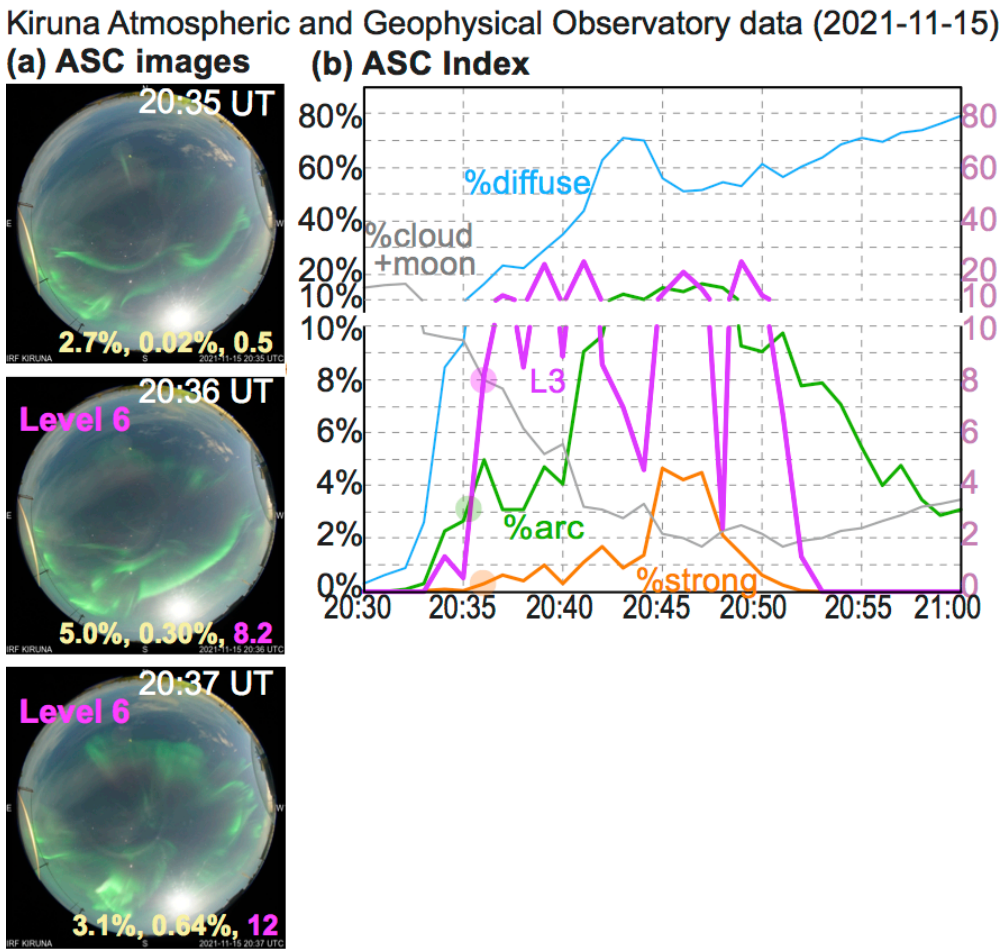
1. First, Classify each pixel (255x255x255 colors)



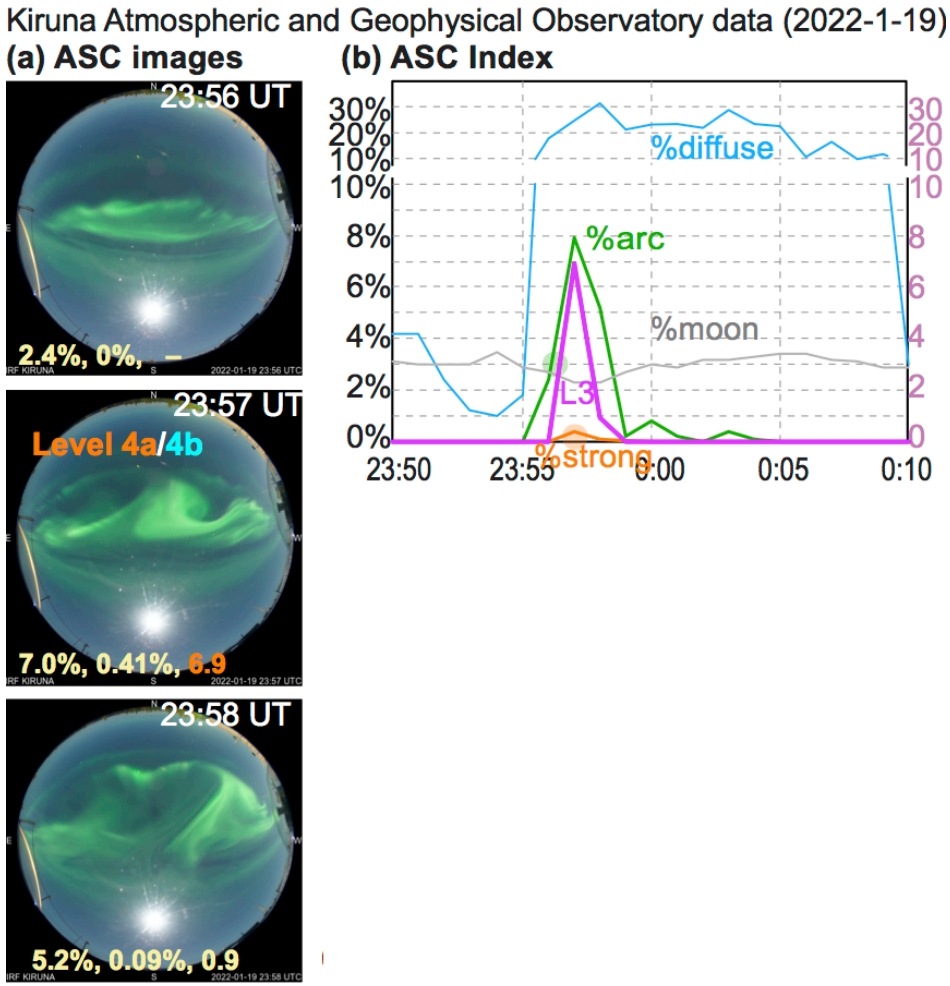
Each "box" represents "this is clearly aurora etc."
There is some overlap, but only one type is chosen

Future improvement: e.g., moon cases

success



fail

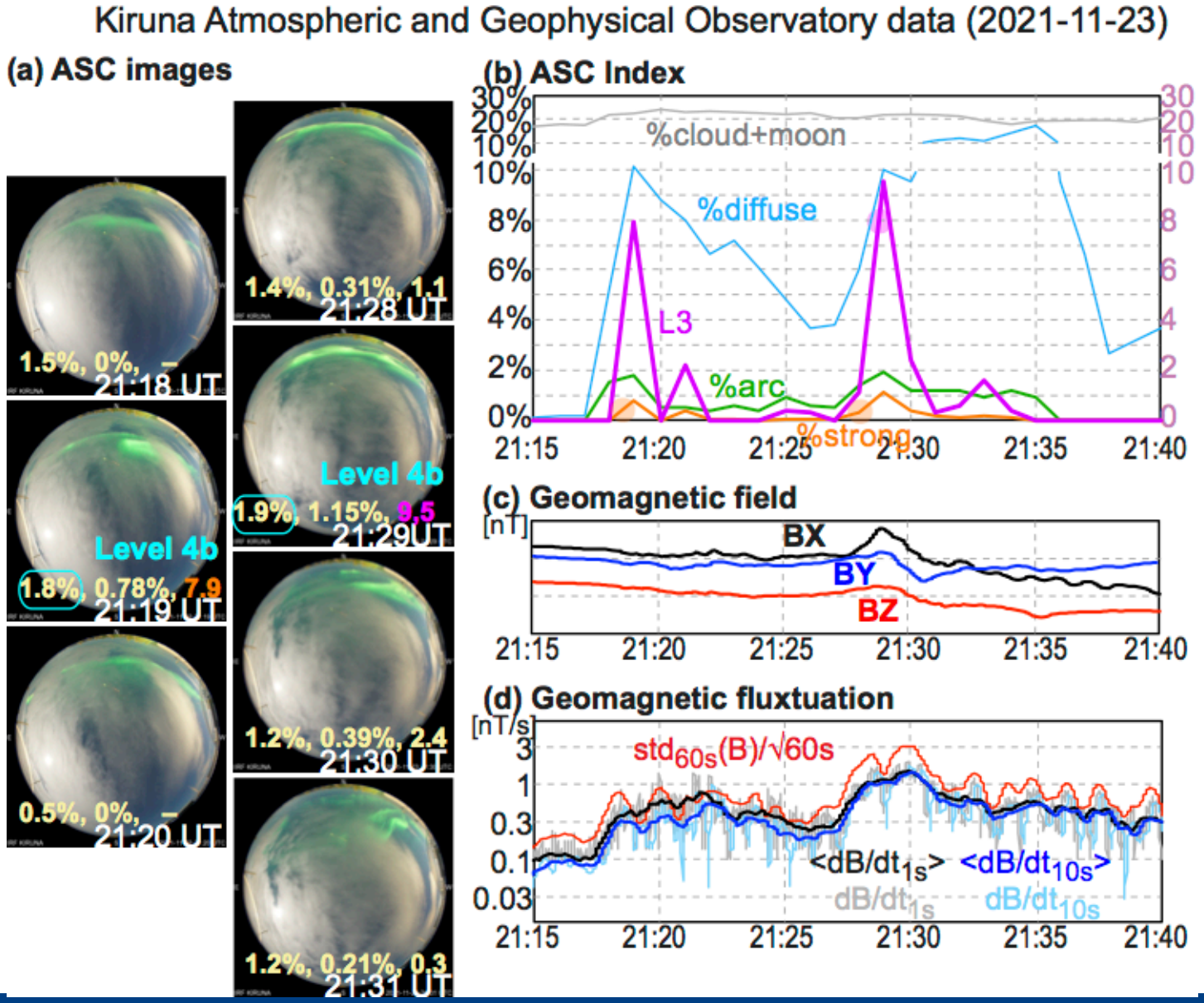


Color changes with moon/twilight

⇒ need further non-linear treatment when the moon is detected

northern edge

fail



toward v. 2 and v.3

As additional parameter to define the level, UT information and previous 5-min activity should be included ⇒ version 1.2

We plan to add "weak-breakup" and "strong N_2 line") in the definition of aurora because there are some rooms to add them in the R-G-B space. ⇒ version 1.3

Level-4a and Level-4b are good candidate for last minute precursor, but need more tuning ⇒ We plan to use NN to find out good set that predicts Level-6. ⇒ version 2

As external index, magnetic activity can be used to define the level. Baseline is ΔBx and dB/dt_10sec. ⇒ version 2 (i.e., additional "index")

The moon filter can be tuned (currently 14 times the moon radius are masked), i.e., reducing R,G,B values when moon is identified . ⇒ version 3

Entire FOV should be divided into two-three regions (north, middle, south) and obtaining the index values for each regions when computer power improves. ⇒ version 3

some useful links (nowcast/Kiruna)

Magnetometer + keogram combined

https://www2.irf.se/mag/

All-sky camera (image + past movie + keogram)

https://www.irf.se/alis/allsky/krn/dark.html

ASC auroral index (past 1 hour)

https://www.irf.se/alis/allsky/nowcast/latest-hour.png

Weather forcast

https://www.smhi.se/q/Kiruna/605155#ort=605155,Kiruna,Kiruna,Sverige,67.85/20.216667

Appendix-3: file format

Level-6:
arc ≥3%, str ≥0.2%
L^3 ≥8

Level-4a:
arc ≥2%, str ≥0.2%
L^3 ≥5

Level-4b:
arc ≥1%, str ≥0.1%
str·L^3 ≥1.5 (%)

ASC auroral index is a good start in defining auroral activity level.

Ascii form text file is good format to store real-time data

```
Format                  similar to IAGA-2002
Source of Data          Swedish Institute of Space Physics
Station Name            Kiruna
IAGA CODE               KIR
Geodetic Lat.           67.83
Geodetic Long.          20.42
Elevation               400
Pixels (for average)    140000 (2500)
Reported                occupancy of auroral pixels and intensity
  Occupancy (% pixels)  Diff(diffuse), Arc, Strong, void, cloud
  Intensity (average)   <L>, <L*L*L> (for strongest pixels only)
Sensor                  ASC, Sony alpha7s, Nikon Nikkor 8 mm 1:2.8
Digital Sampling        1 minute
Integration time        1 sec
Data Type               Provisional
DATE,      TIME,    DOY, Diff,  Arc,Strong, void,cloud,   <L>,   L^3
2021-11-15,14:16:00,319,  0.0,  0.0,  0.00,  0.0,  0.0,   0.0,   0.0
2021-11-15,14:17:00,319,  0.0,  0.0,  0.00,  0.0,  0.0,   0.0,   0.0
...
2021-11-15,20:33:00,319,  2.6,  0.3,  0.01,  9.8,  0.9,   0.0,   0.0
2021-11-15,20:34:00,319,  8.5,  2.3,  0.10,  9.6,  0.8,   4.1,   1.3
2021-11-15,20:35:00,319,  9.4,  2.7,  0.02,  9.5,  0.7,   1.6,   0.5
2021-11-15,20:36:00,319, 16.6,  5.0,  0.30,  8.0,  0.6,  14.1,   8.2
2021-11-15,20:37:00,319, 23.4,  3.1,  0.64,  7.7,  0.5,  17.2,  12.1
2021-11-15,20:38:00,319, 22.4,  3.1,  0.43,  6.2,  0.6,  13.6,   8.5
2021-11-15,20:39:00,319, 29.2,  4.7,  0.99,  5.2,  0.9,  29.1,  23.6
2021-11-15,20:40:00,319, 34.8,  4.1,  0.31,  5.6,  1.4,  12.7,   8.9
2021-11-15,20:41:00,319, 43.6,  9.1,  1.13,  3.2,  0.6,  37.8,  24.6
2021-11-15,20:42:00,319, 62.6,  9.7,  1.71,  3.1,  0.8,  24.1,   8.6
2021-11-15,20:43:00,319, 70.8, 12.6,  0.87,  2.8,  0.8,  23.1,   7.0
2021-11-15,20:44:00,319, 70.1, 10.6,  1.39,  3.3,  0.8,  16.8,   4.6
2021-11-15,20:45:00,319, 55.7, 15.2,  4.66,  2.2,  0.3,  35.9,  12.5
```