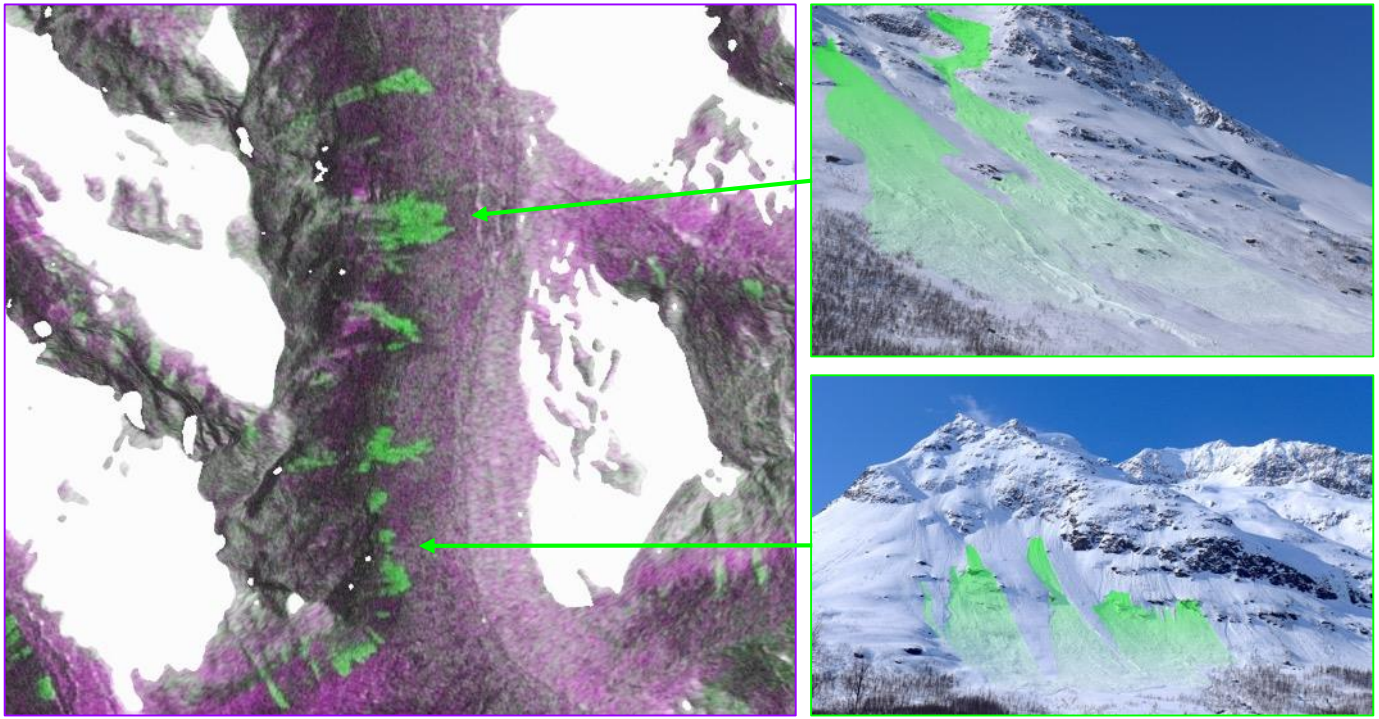
Snow avalanche detection in SAR images using CNNs



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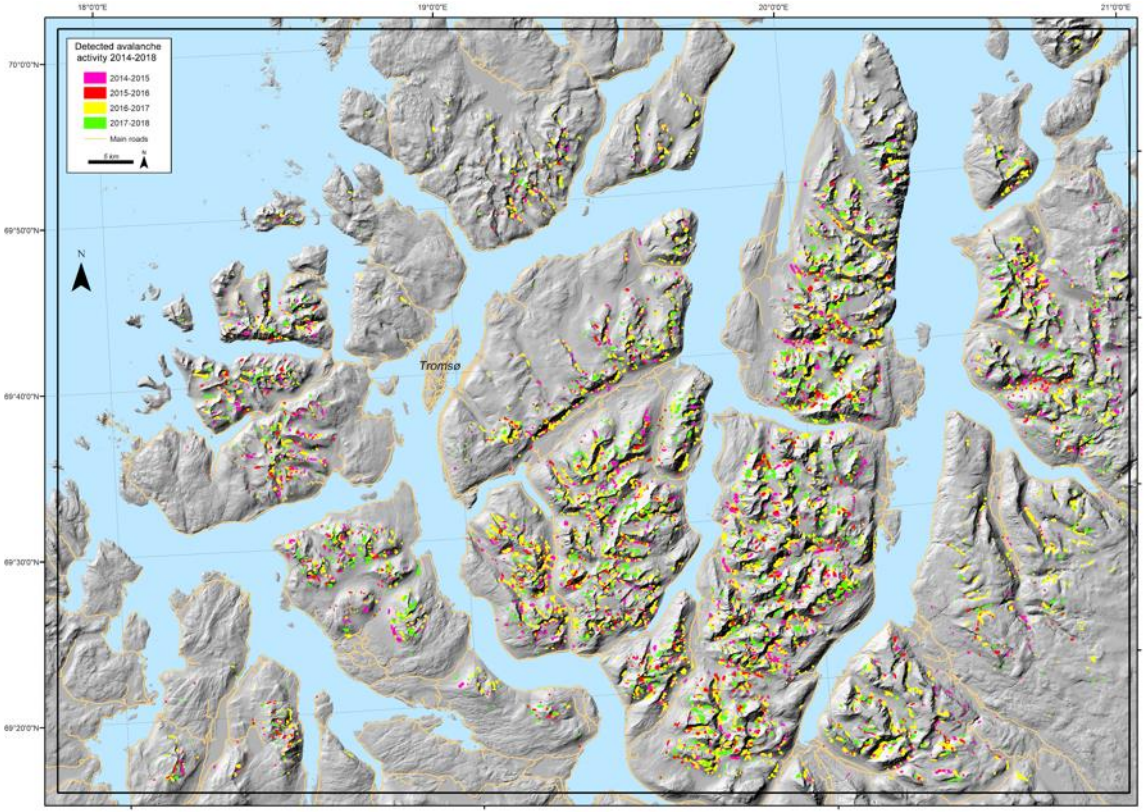
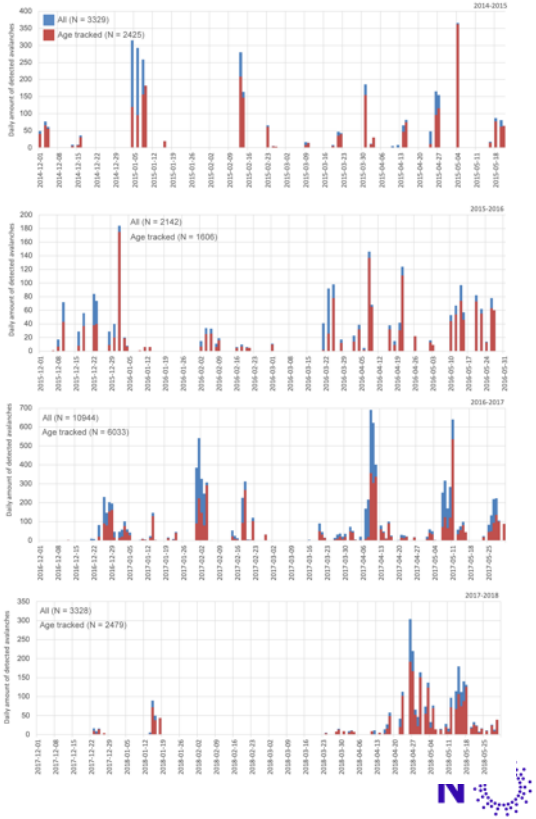
Filippo M. Bianchi

Eirik Malnes

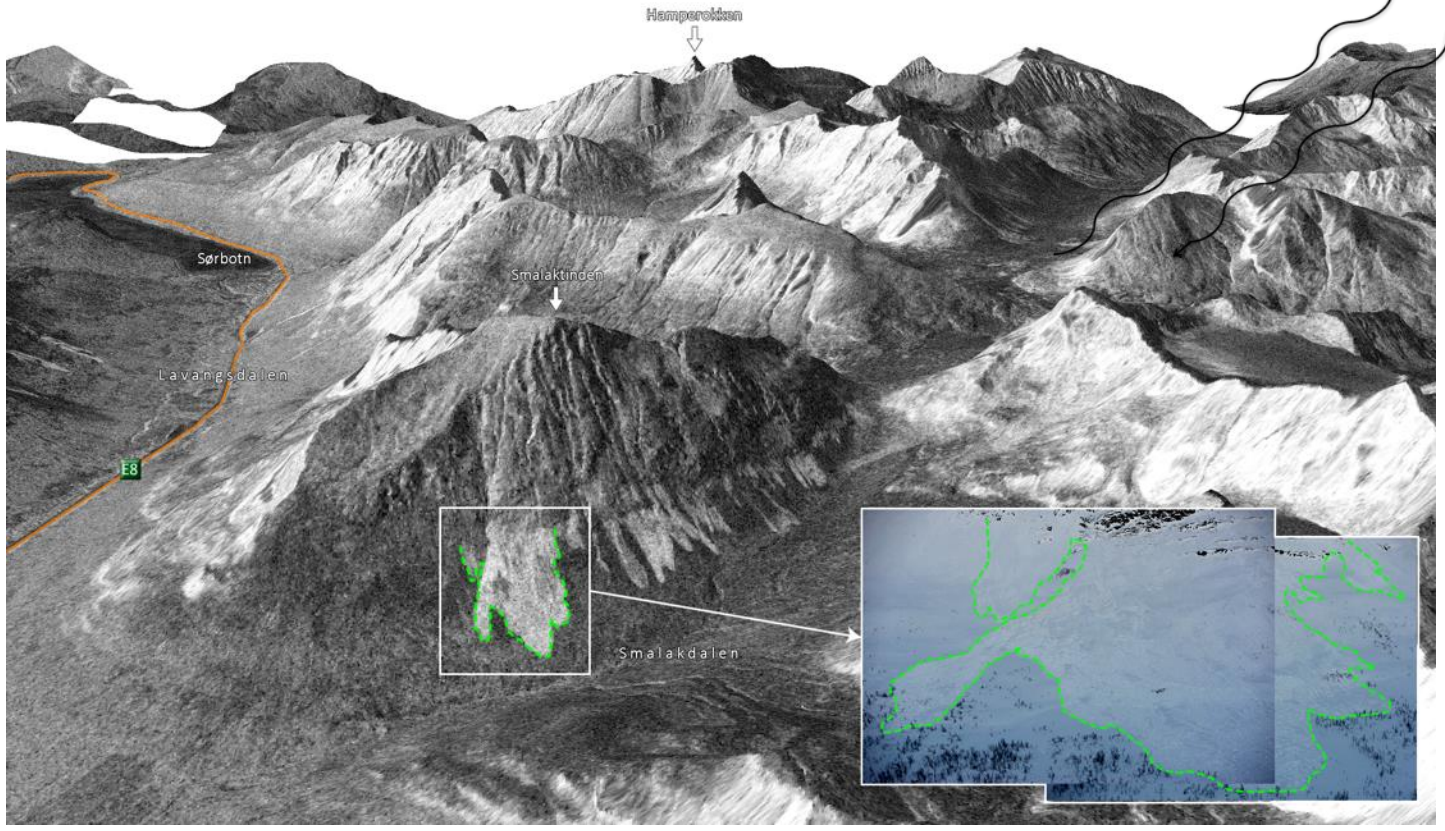
NORCE

Avalanche risk assessment critically depends on knowledge of spatio-temporal avalanche activity

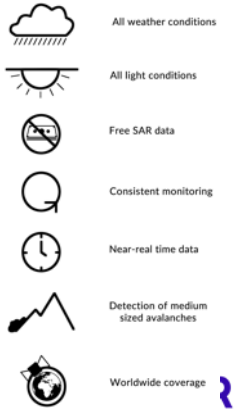




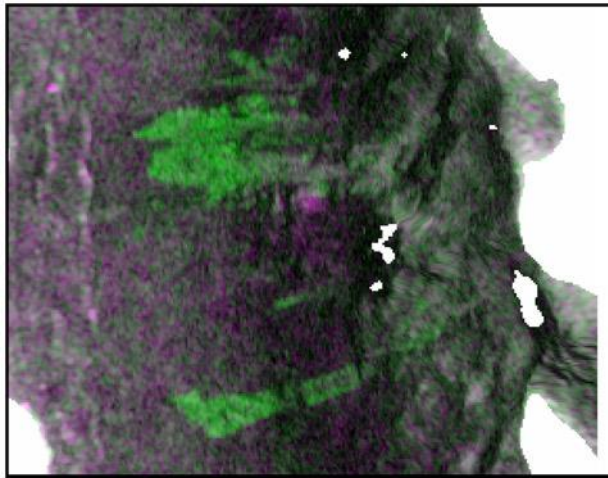
Avalanche debris reflects more energy to the satellite than undisturbed smooth snow



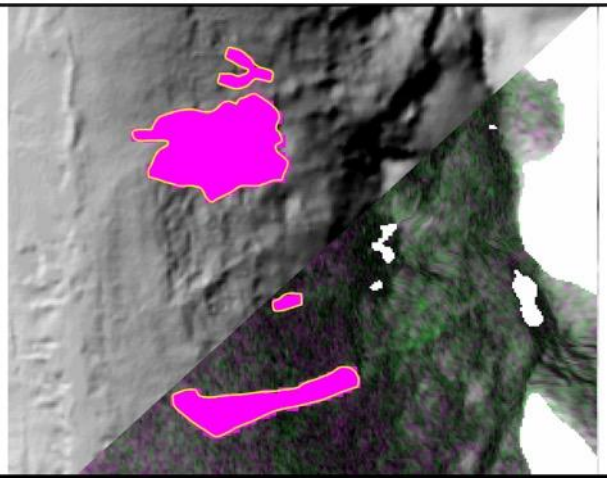
Sentinel-1
SAR satellites



We use temporal change detection, segmentation and filtering to automatically detect avalanches in S1 images



Temporal change detection



Filtering & segmentation

ID	DETECTION DATE	DETECTION TIME	REFERENCE DATE	COORDINATES EAST	COORDINATES NORTH	TOPOGRAPHIC PARAMETERS AREA	TOPOGRAPHIC PARAMETERS LENGTH	TOPOGRAPHIC PARAMETERS WIDTH	ELEVATION MIN	ELEVATION MEAN	ELEVATION MAX	ASPECT	SLOPE ANGLE
0	20161224	51153	20161212	664960	7713720	10800	180	100	318	363	407	74,5	28,4
1	20161224	51153	20161212	665220	7712880	7600	120	80	249	278	301	93,4	26,3
2	20161224	51153	20161212	665040	7712640	12800	160	100	319	349	387	103	25,4
3	20161224	51153	20161212	666440	7707100	12800	160	160	419	455	493	45,2	21,9
4	20161224	51153	20161212	666060	7706940	10000	120	160	676	715	747	44,2	23,2
5	20161226	161533	20161214	665660	7718920	13200	140	180	114	144	187	223,7	24,6
6	20161226	161533	20161214	666300	7715380	19600	260	140	138	183	232	257,5	21,7
7	20161226	161533	20161214	663840	7713940	14400	120	180	914	954	993	55,7	28,5
8	20161226	161533	20161214	664120	7713780	8000	120	80	859	882	914	53,3	27,7
9	20161226	161533	20161214	665120	7713060	44000	320	260	180	263	351	77,4	26,4
10	20161226	161533	20161214	665000	7713080	4800	80	80	382	404	415	82,3	28,3
11	20161226	161533	20161214	664900	7712220	24800	180	380	361	388	410	99,1	26,5
12	20161226	161533	20161214	664820	7711860	5200	100	80	399	416	437	75,5	25
13	20161226	161533	20161214	664620	7711800	14400	180	120	467	506	544	76,1	27,1
14	20161228	155854	20161216	664260	7712800	6400	100	80	909	934	947	42,4	27,2
15	20170103	52818	20161228	666840	7711000	7200	120	80	432	454	475	263,9	25,1
16	20170103	52818	20161228	666460	7706980	13600	160	180	446	476	520	30,7	18,3
17	20170103	155818	20161228	665260	7713180	32400	260	200	145	192	266	71,9	23,8
18	20170103	155818	20161228	665140	7712880	38800	260	240	220	269	345	91,7	26,4
19	20170103	155818	20161228	664960	7710920	12800	160	120	213	248	290	94,8	27,1
20	20170103	155818	20161228	664980	7710440	12000	160	100	211	239	276	81,9	24,1
21	20170104	51921	20161229	666660	7706660	6800	80	100	524	545	569	60,8	27,3
22	20170104	51921	20161229	668360	7705600	8800	140	80	146	174	201	280,9	26
23	20170107	161515	20170101	666980	7711140	13200	160	100	496	528	561	264	23,9
24	20170107	161532	20170107	666980	7711140	13200	160	100	496	528	561	264	23,9
25	20170111	51101	20170105	666120	7707580	39200	420	180	309	370	453	51,7	26,1
26	20170115	52818	20170109	668100	7702760	10800	120	120	19	21	25	171,4	3,4
27	20170116	51920	20170110	665680	7718960	12000	140	140	131	159	199	227,9	26
28	20170116	51920	20170110	664500	7715460	10400	100	140	348	365	381	78,6	21,1

Output as database

Detection hard limit is reached!

PODs: 82 % and 55.7 %

FARs: 26.4 % and 13.8 %

(compared to manual interpretation)

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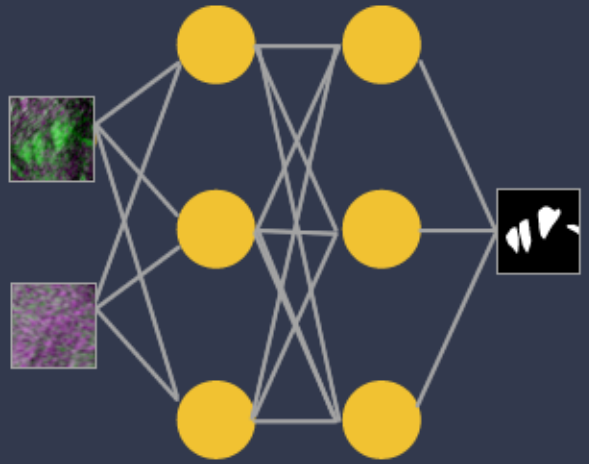
Putting some *magic sauce* over the Sentinel-1 images might increase our detection sensitivity



- Labeled dataset available
- Transfer learning increases size of dataset
- CNNs excel at image classification
- Auxiliary data as input layers are possible

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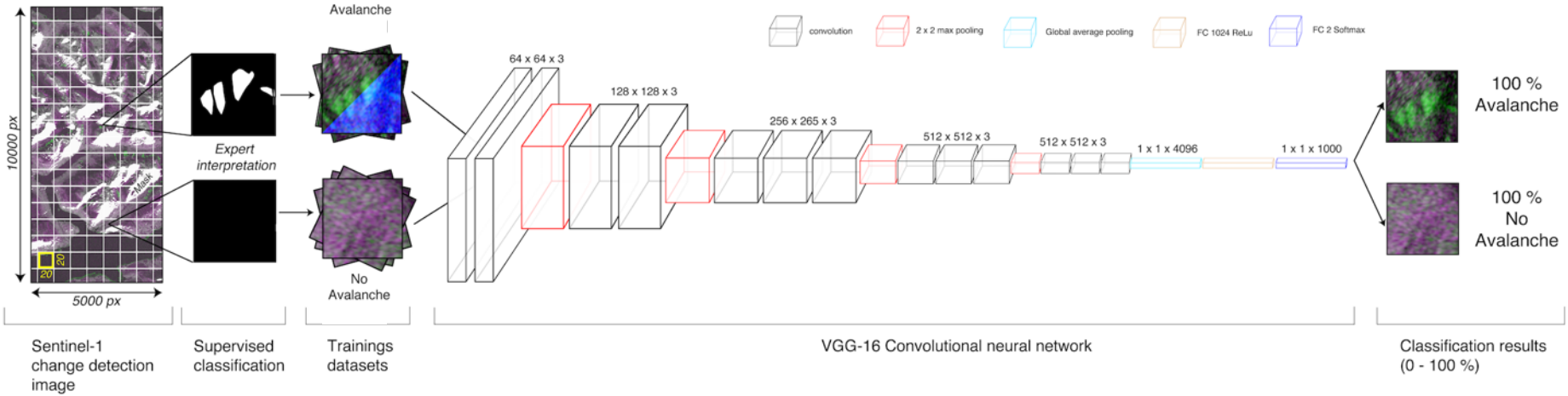
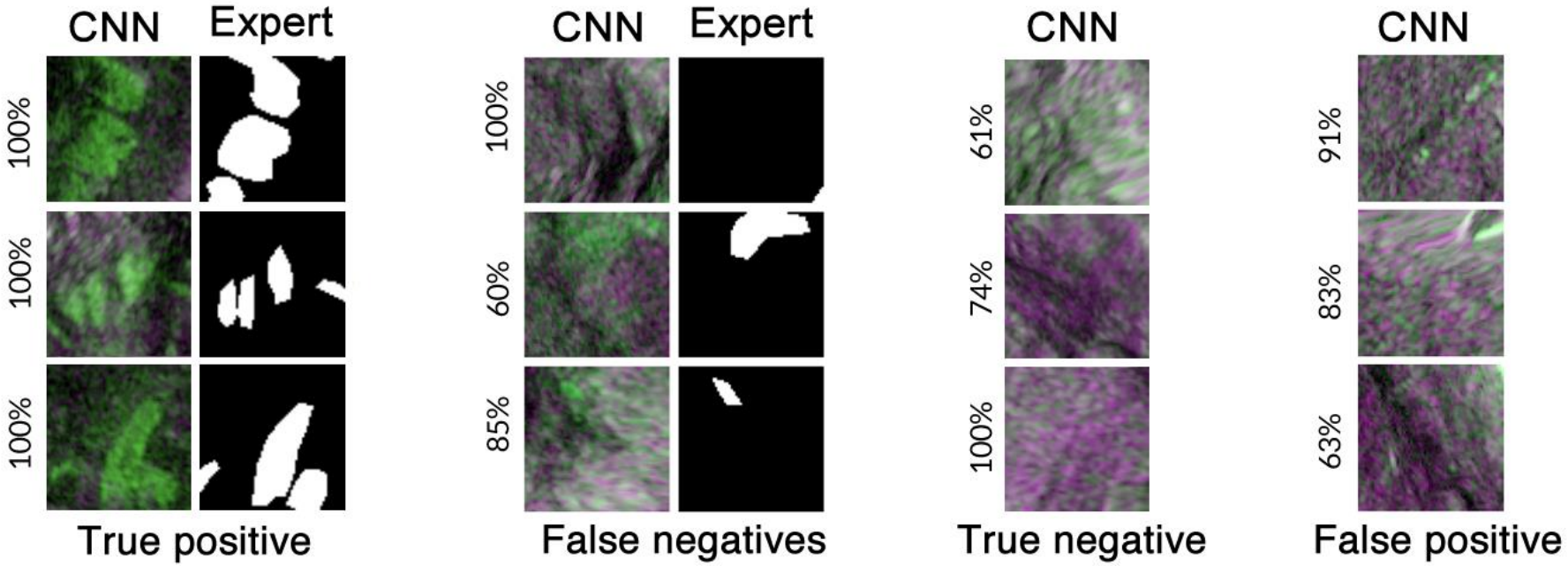
We trained two different CNNs on a labeled dataset of manually interpreted avalanches



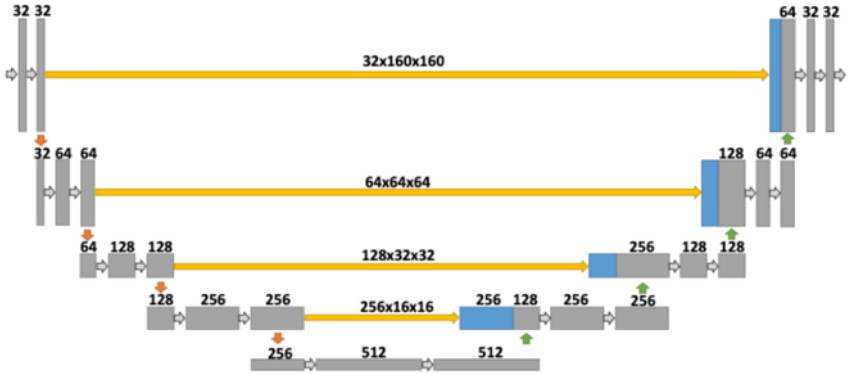
Kummervold et al., 2018

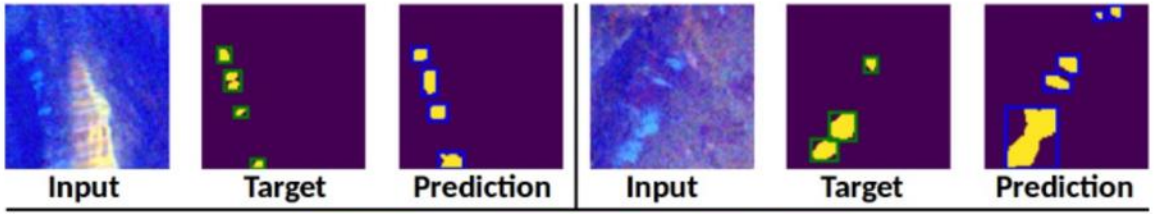
Using CNNs, sensitivities consistently over 90 % were achieved



Kummervold et al., 2018

Further increase of sensitivity was achieved using U-net architecture as segmentation network





Bianchi et al., 2018

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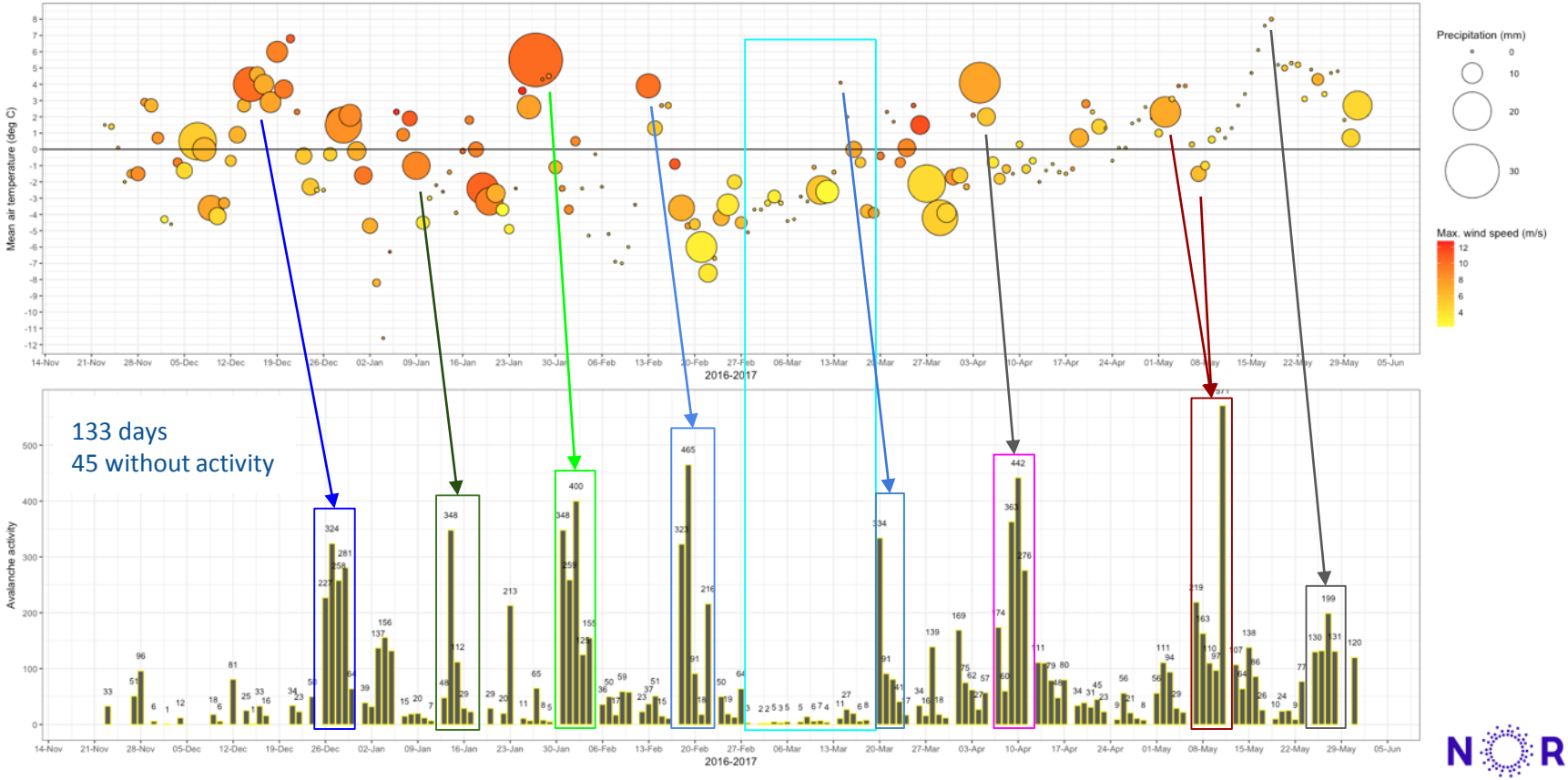
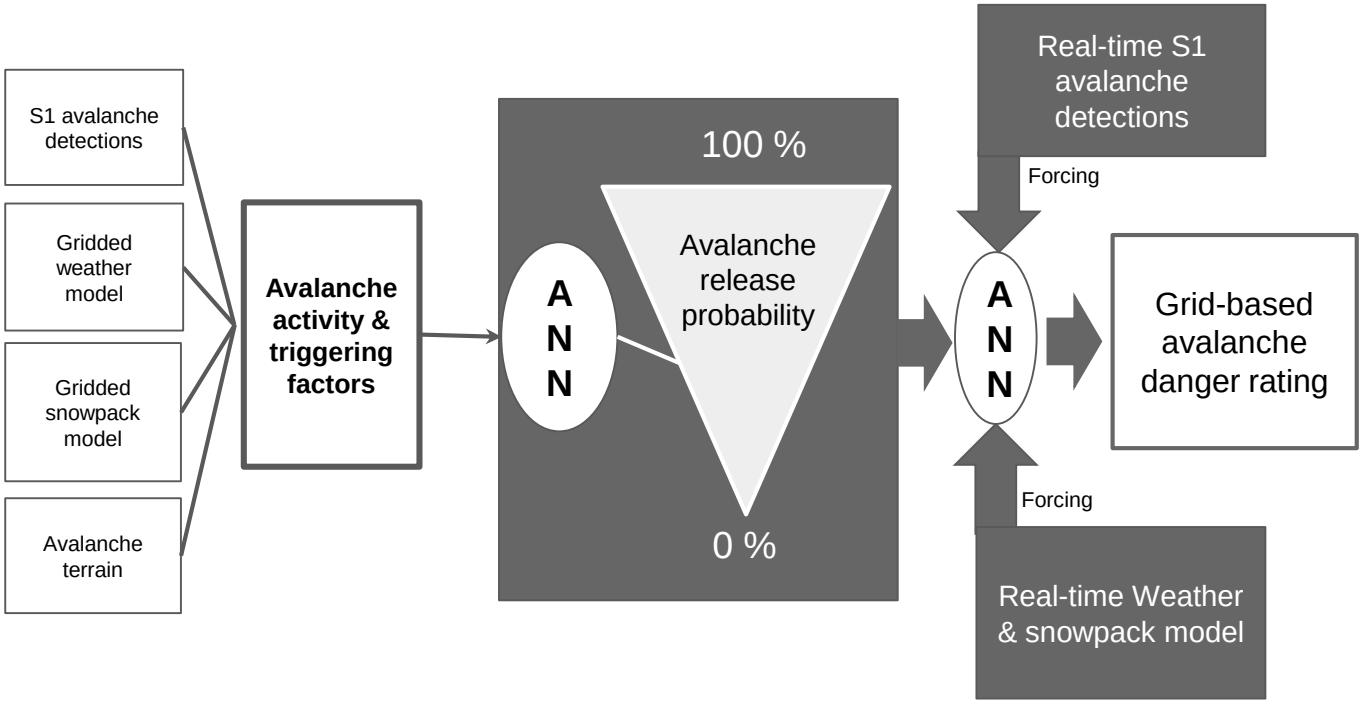
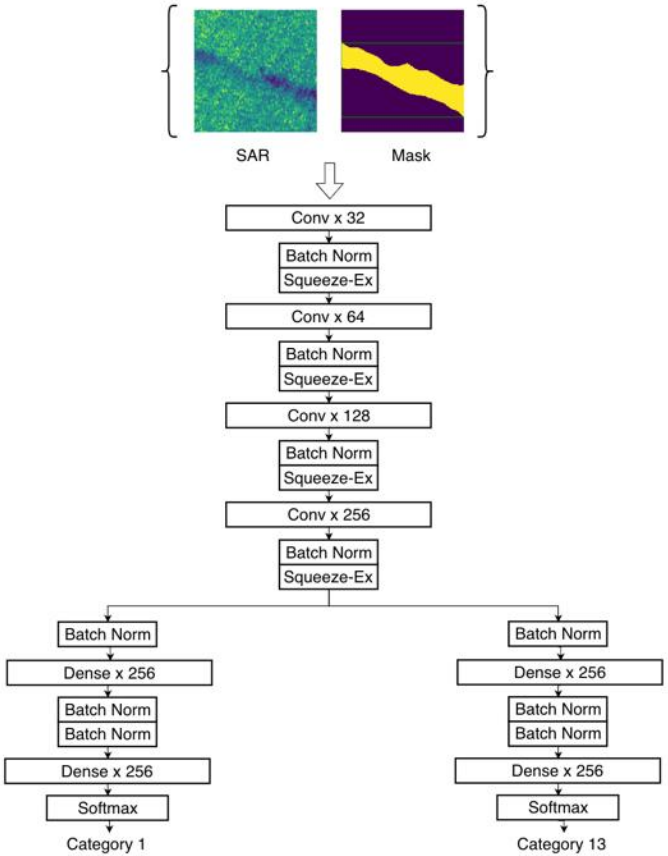
Complete avalanche records allow for exploring the causal relationship of activity with triggering factors



ML and our complete avalanche activity dataset will be used for automatic avalanche forecasting



Similar CNN architectures are also used for oil spill detection in SAR images

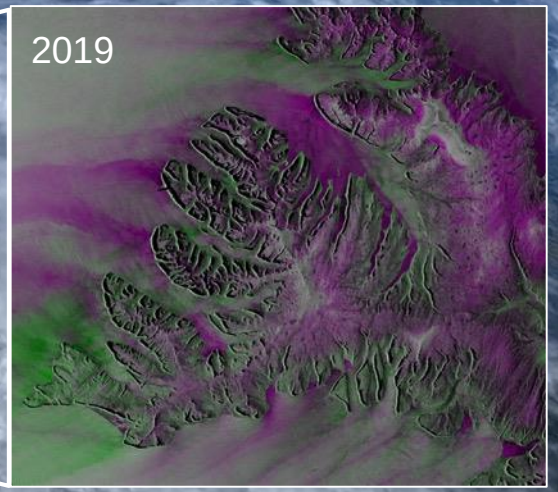


Category	Accuracy
Category	70.0 %
Patch shape	82.5 %
Linear shape	77.5 %
Angular shape	94.5 %
Weathered attribute	72.1 %
Tail attribute	79.2 %
Droplets attribute	99.2 %
Winding attribute	95.5 %
Feathered attribute	97.5 %
Outline	93.8 %
Texture	55.4 %
Contrast	61.3 %
Edge	63.8 %

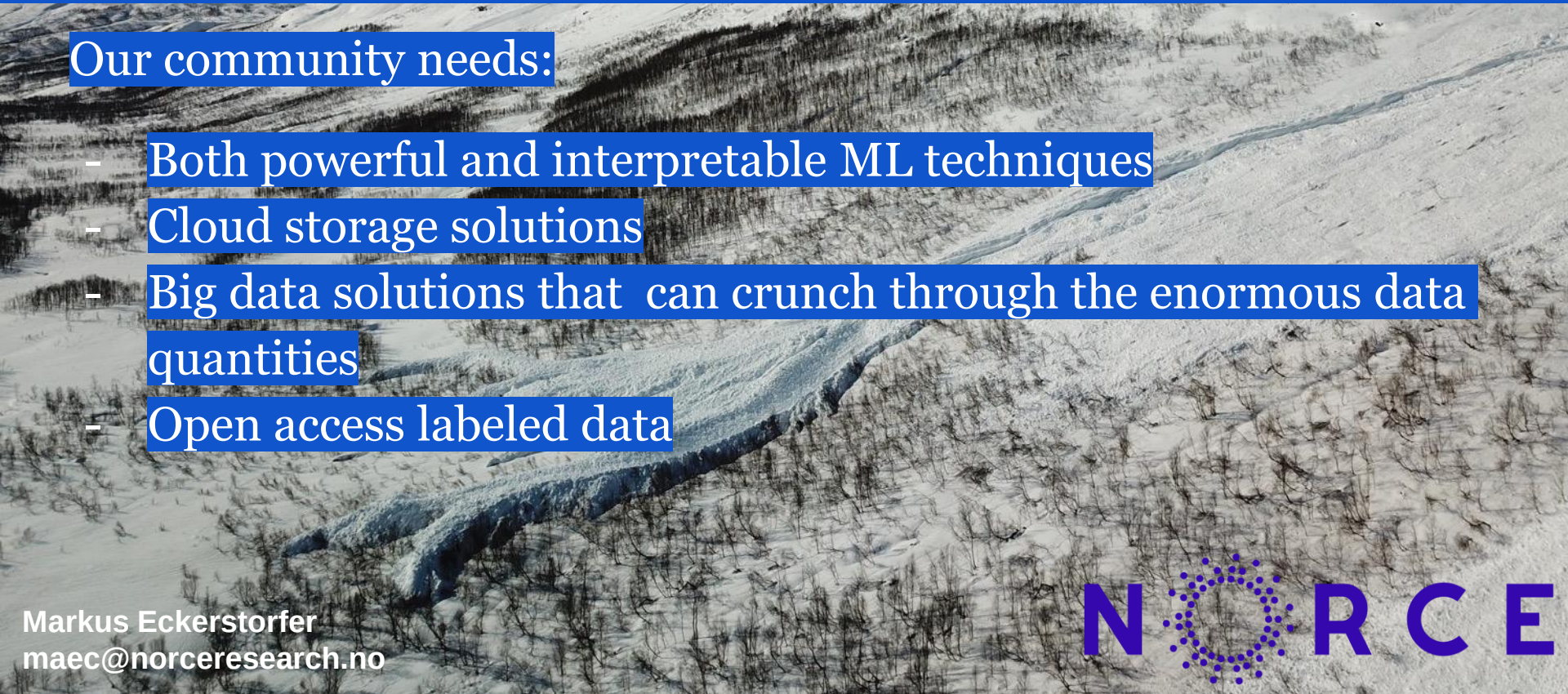
Bianchi, 2019

EU's Copernicus environmental monitoring programme produces roughly 15 TB of free data daily

6 of 30 satellites launched



Remote sensing produces big data and is in need of various ML techniques for analysis



Our community needs:

- Both powerful and interpretable ML techniques
- Cloud storage solutions
- Big data solutions that can crunch through the enormous data quantities
- Open access labeled data

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