Schweizerische Eidgenossenschaft
Confédération suisse
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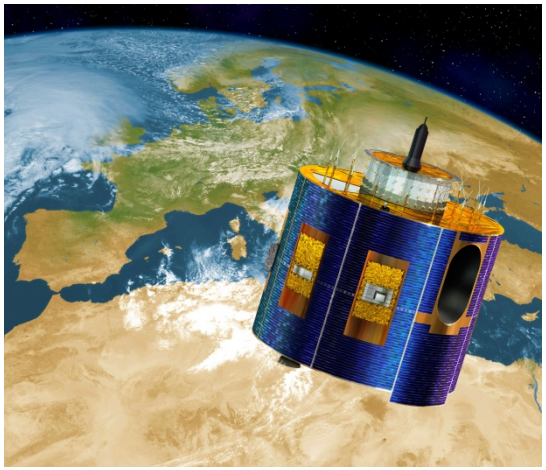
Swiss Confederation

Federal Department of Home Affairs FDHA
Federal Office of Meteorology and Climatology MeteoSwiss

Hail nowcast exploiting radar and satellite observations

Ulrich Hamann, Elena Leonarduzzi, Kristopher Bedka, Nikola Besic, Lorenzo Clementi, Jordi Figueras i Ventura, Marco Gabella, Alessandro M. Hering, Andreas Leuenberger, Luca Nisi, Marco Sassi, Urs Germann

Outline of the talk

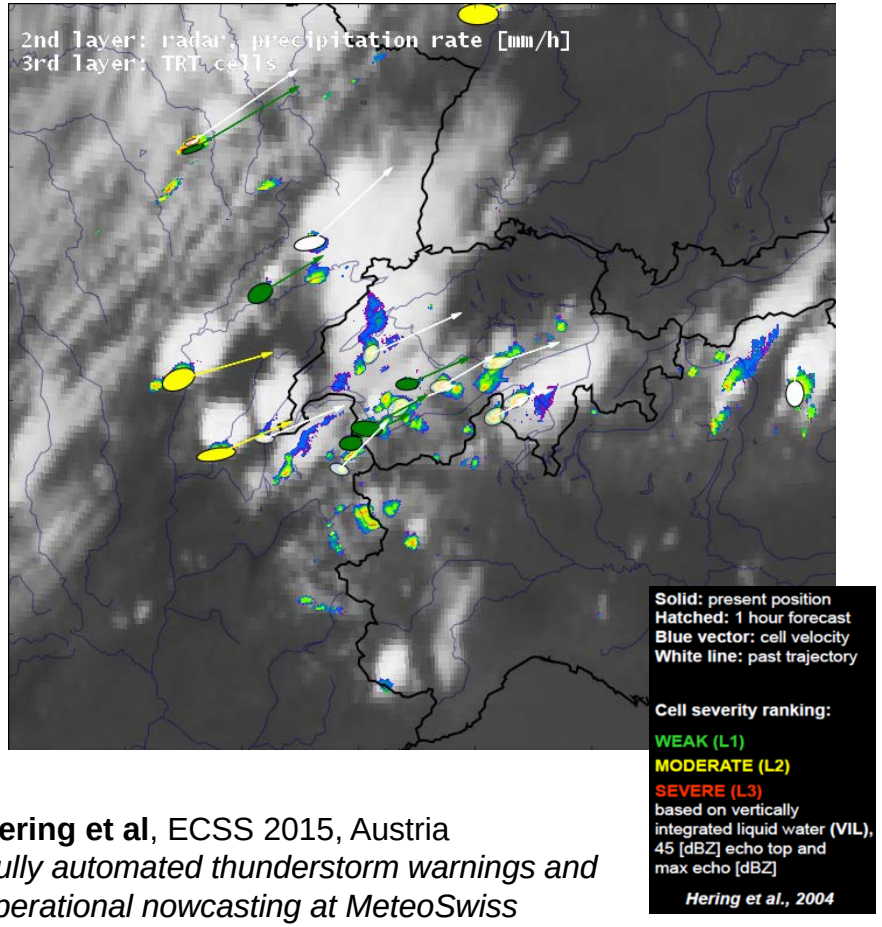


A hail event study with different sensors

- Thunderstorm Radar Tracking TRT (Hering, 2015)
- COALITION-2 algorithm based on MSG/SEVIRI (Hamann, 2016)
- Overshooting Top detection based on MSG/SEVIRI (Bedka, 2010, 2016)
- MeteoSwiss radar network
- Lightning observations (Meteorage)

Thunderstorm Radar Tracking TRT

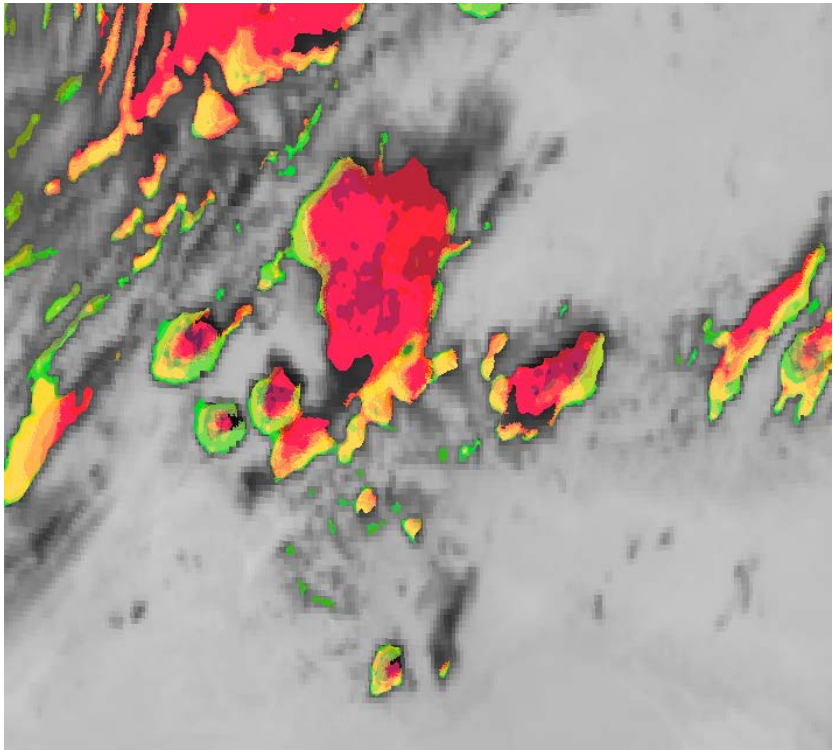
- Primarily based on Swiss radar network
- 5 dual-pole Doppler radars
- Temporal resolution 5min
- Spatial resolution 1 km
- automated detection, tracking of radar cells
- Severity ranking with VIL, Echo Top Altitude(45 dBZ), max. reflectivity, area (57 dBZ)
- Extrapolation of the position
- Tracking of various radar, satellite, lightning parameters



Hering et al, ECSS 2015, Austria
Fully automated thunderstorm warnings and operational nowcasting at MeteoSwiss

COALITION-2

- Primarily based on MeteoSat SEVIRI
- Based on 8 IR channels
- Temporal resolution 5min
- Spatial resolution 3x5 km
- automated detection, tracking of satellite cells
- Classification in early, developing and mature cells
- Extrapolation of the position



Hamann et al, 2016
Nowcasting of thunderstorms and severe convection in Switzerland
Eumetsat Conference 2016, Darmstadt, Germany

Thunderstorm detection from MSG

COALITION-2 uses brightness temperature, their spectral and temporal differences of SEVIRI channels (onboard of Meteosat Second Generation MSG)

Four categories of threshold tests detect
a) optical thick clouds
b) ice clouds
c) updraft
d) small ice crystals

Threshold test for «Convective Initiation»	Cathegory
WV6.2µm – IR10.8µm	cloud depth
WV6.2µm – IR7.3µm	cloud depth
IR10.8µm	cloud depth
IR7.3µm – IR13.4µm	cloud depth
WV6.2µm – IR9.7µm	cloud depth
IR8.7µm + IR12.0µm – 2xIR10.8µm	glaciation indicator
IR8.7µm – IR10.8µm	glaciation indicator
IR12.0µm – IR10.8µm	glaciation indicator
30min trend (WV6.2µm – IR7.3µm)	updraft strength
15min trend (IR10.8µm)	updraft strength
30min trend (IR10.8µm)	updraft strength
15min trend (WV6.2µm – IR7.3µm)	updraft strength
30min trend (IR9.7µm – IR13.4µm)	updraft strength
30min trend (WV6.2µm – IR10.8µm)	updraft strength
15min trend (WV6.2µm – IR12.0µm)	updraft strength

Inspired by Mecikalski et al, 2010, *Cloud-Top Properties of Growing Cumulus prior to Convective Initiation as Measured by Meteosat Second Generation. Part I: Infrared Fields*

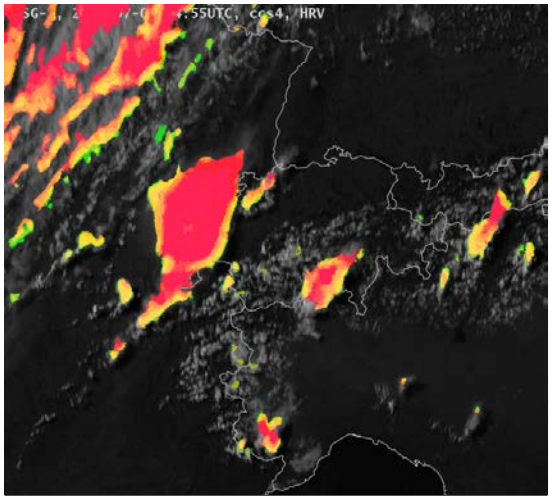
COALITION-2 RGB product

COALITION-2 uses the number of passed indicator tests as
a) optical thick clouds (red)
b) updraft (green)
c) ice clouds (blue)
to create a false colour composite (RGB)

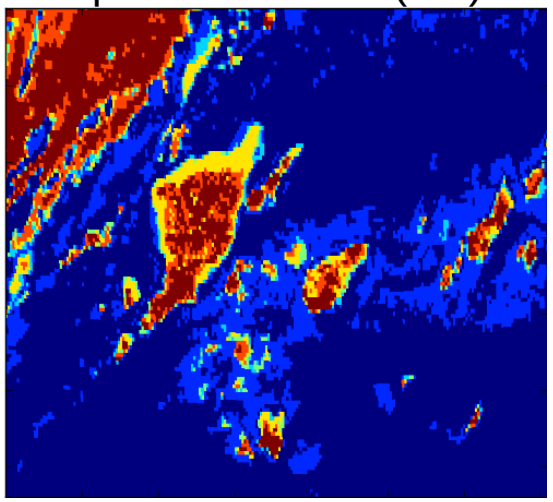
The colours have following meaning

- thick ice cloud
- strong updraft
- developing ice cloud

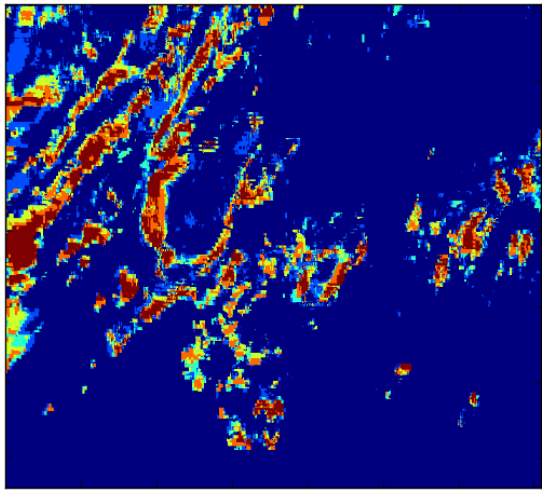
COALITION-2 RGB



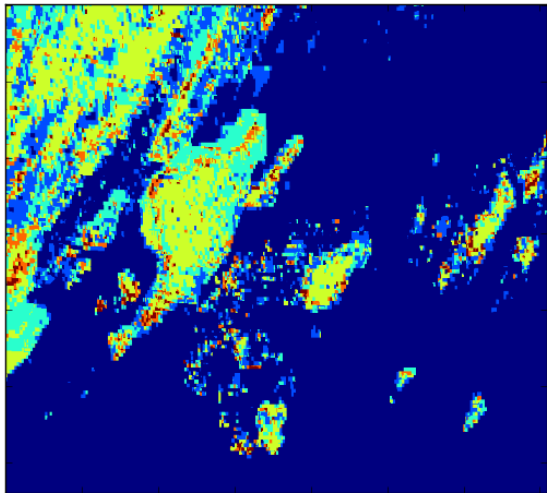
optical thickness (red)



updraft (green)



glaciation (blue)



Bedka and Khlopenkov (JAMC, 2016)
Visible and IR-Based Probabilistic Overshooting Cloud Top Detection

GOAL: Mimic the human OT identification process using IR & Visible imagery and NWP data within an automated computer algorithm

Satellite IR and Visible OT Indicators
Derived Via Image Pattern Recognition +
Atmospheric Reanalysis Data

↓

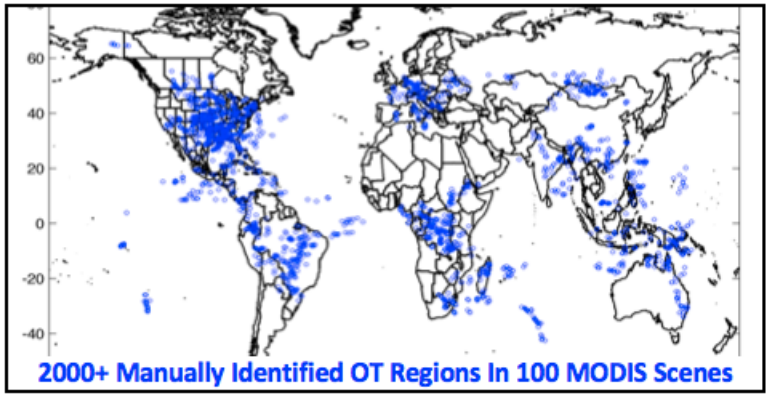
Large Global Training Database of Satellite
+ NWP Fields For Both OT and Non-OT Anvil Regions

↓

Statistical Model Used To Discriminate
Between The OT and Non-OT Anvil Populations

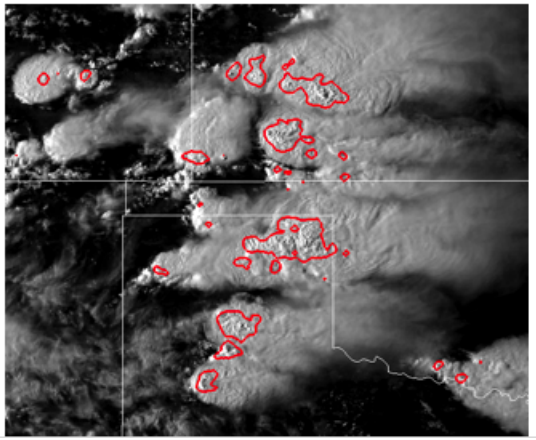
↓

Visible OT Texture Detection,
IR+NWP OT Probability,
and IR Anvil Detection Products

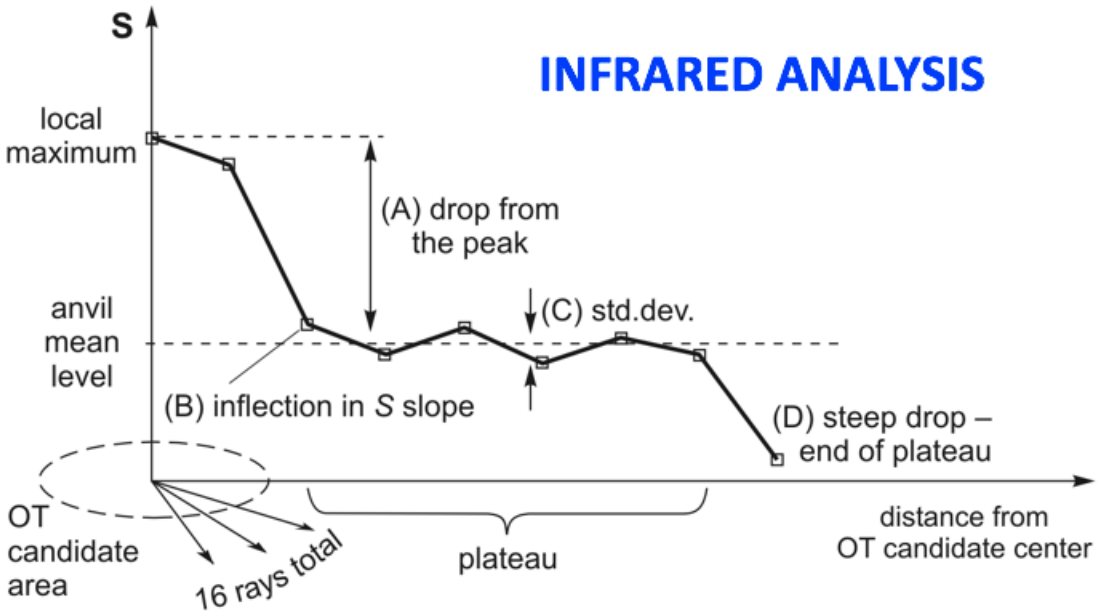


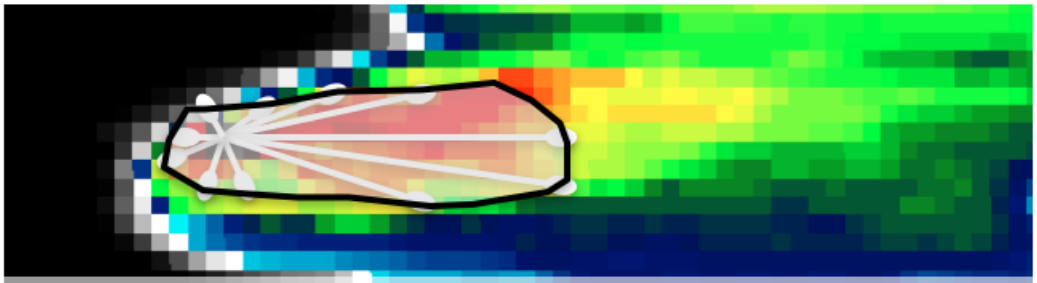
2000+ Manually Identified OT Regions In 100 MODIS Scenes

Automated Visible Texture Detection
Overlaid on GOES Visible Satellite Imagery



IR-Based Pattern Recognition Analyses





BT gradient along each ray is analyzed and the mean BT within the anvil is compared to cold spots to find prominent anvil penetrations

Normalize IR BT relative to regional mean BT within a 400x400 pixel window = "BT Score"

Pattern recognition used to ensure that 1) the region being analyzed is within deep convection and 2) the feature of interest has characteristics typical of OTs

Pattern recognition uses

- OT shape correlation
- BT Score prominence relative to surrounding anvil
- Anvil flatness, roundness, and edge sharpness

The net result is a cumulative rating obtained for each possible OT region. Pixels with a non-zero rating are considered final "OT Candidate" regions

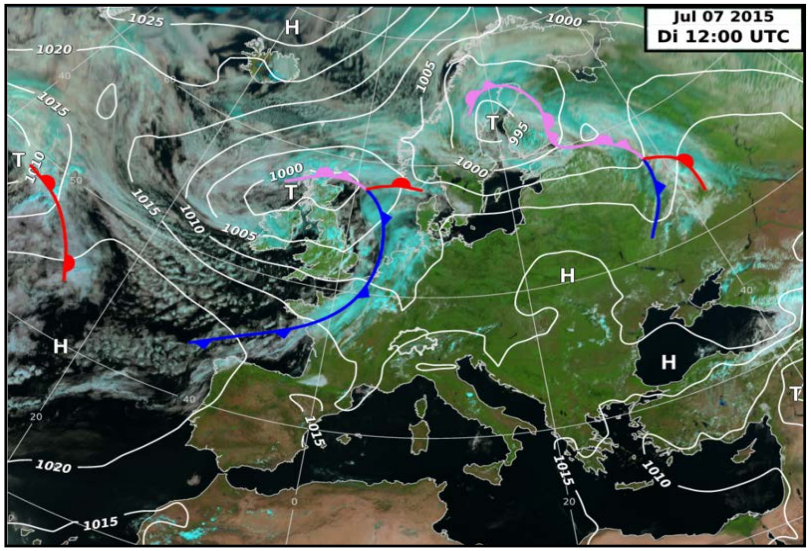
OT Candidates are then assigned an OT Probability based on BT comparison with anvil mean BT, NWP tropopause temp, and most unstable equilibrium level temp

OT Probability derived using logistic regression based on a large training database of human-identified OT and non-OT regions

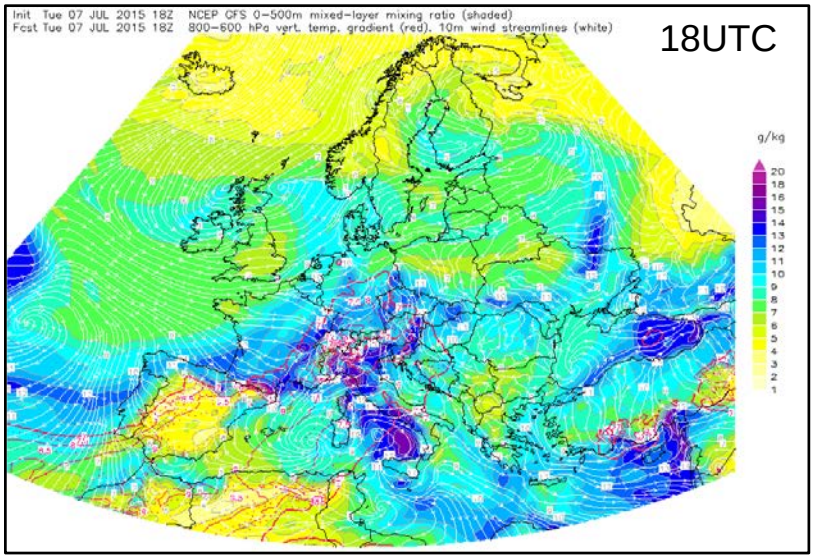
Badka and Khlopenkov, JAMC, 2016

Case Study 07 July 2015

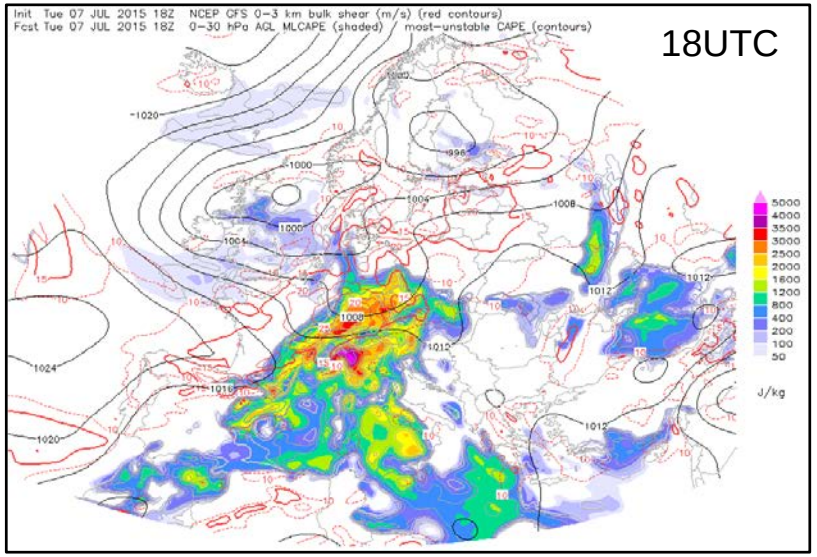
Frontal systems



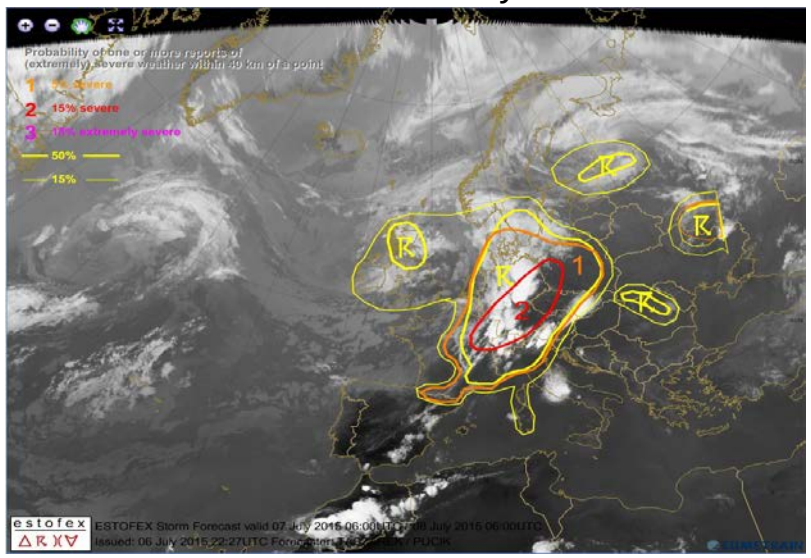
0-500m water mixing ratio



ML CAPE (color) and 0-3km wind shear



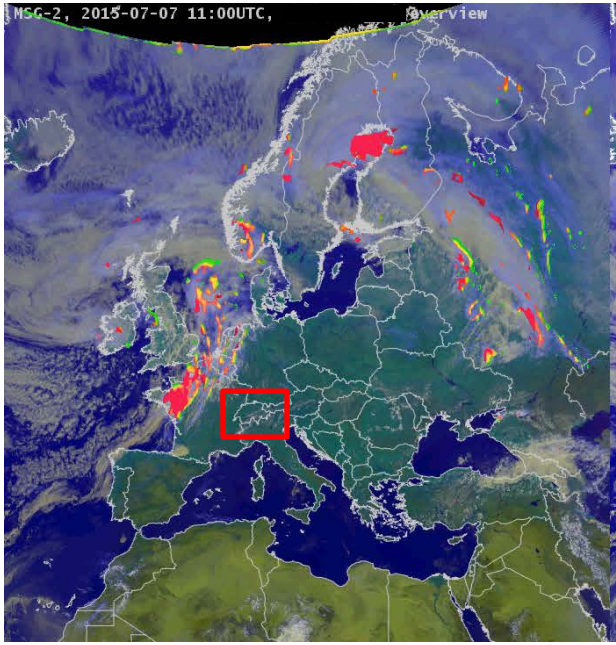
Estofex thunderstorm analysis + IR 18UTC



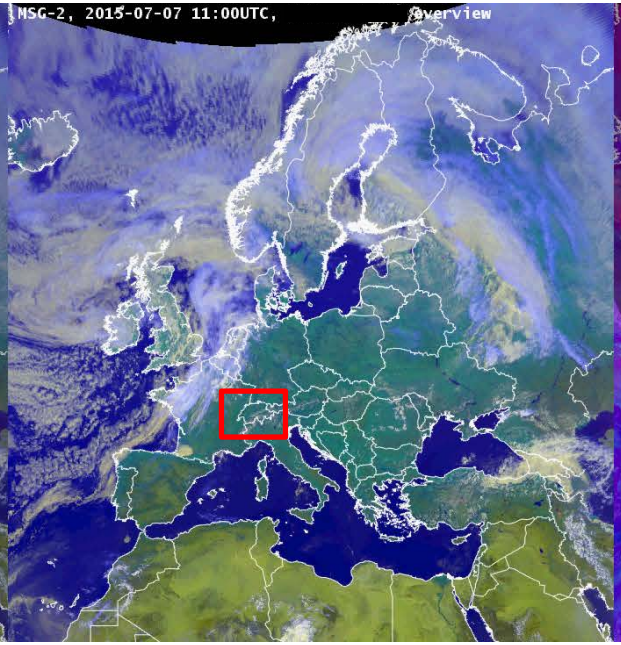
Synoptic situation

07.07.2015

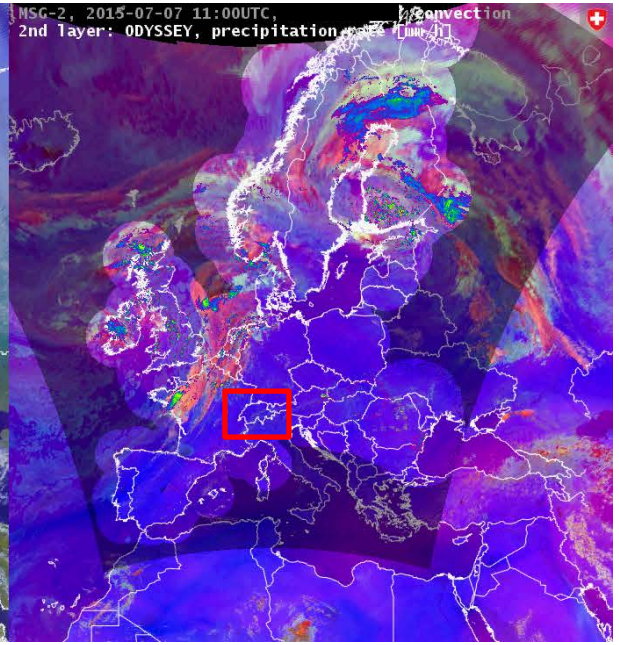
COALITION2



overview RGB



convection RGB
Odyssey Radar precipitation



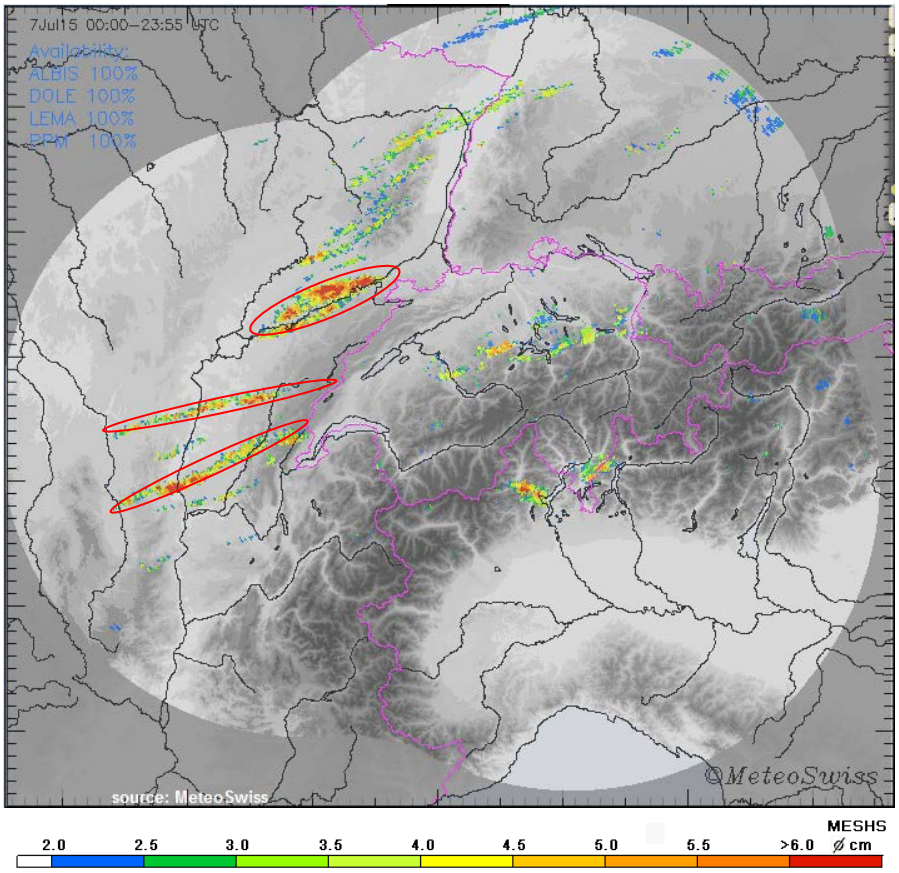
The three panels show a typical example of a convective situation (07.07.2015 11:00 – 18:30 UTC). The forecaster has access to information about convective activity for whole Europe.

Satellite data is available each 5min. Odyssey radar composite is available each 15min.

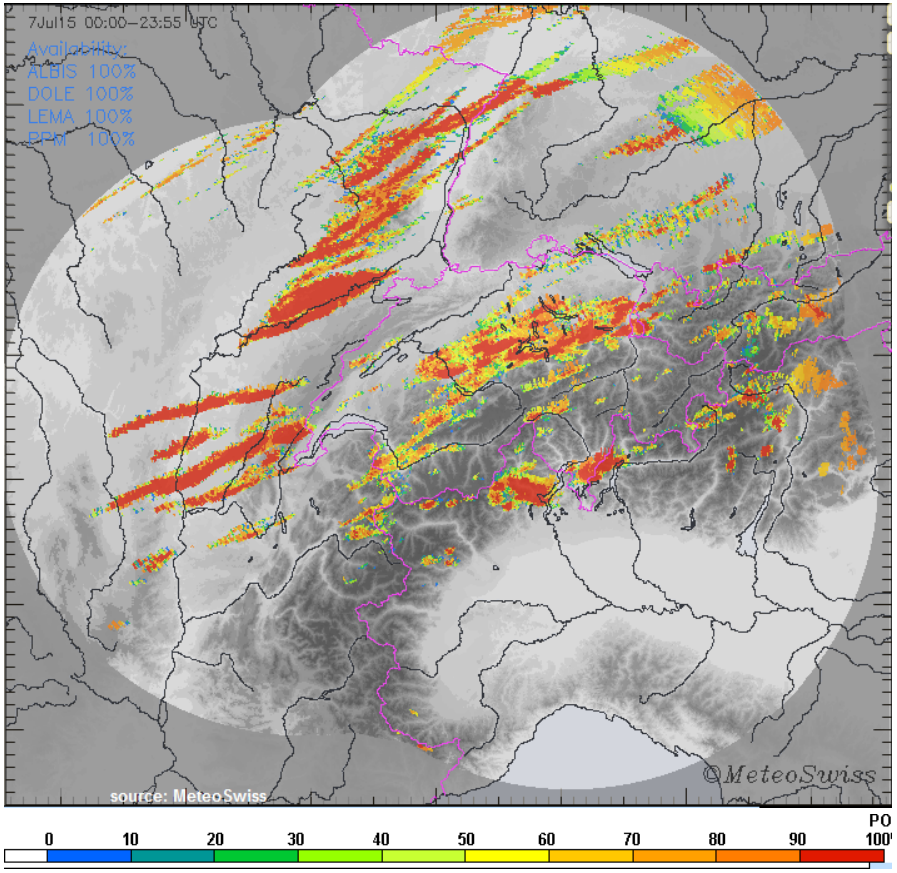
Hail in Switzerland

07.07.2015

Maximum Expected Severe Hail Size
(Treloar, 1998)

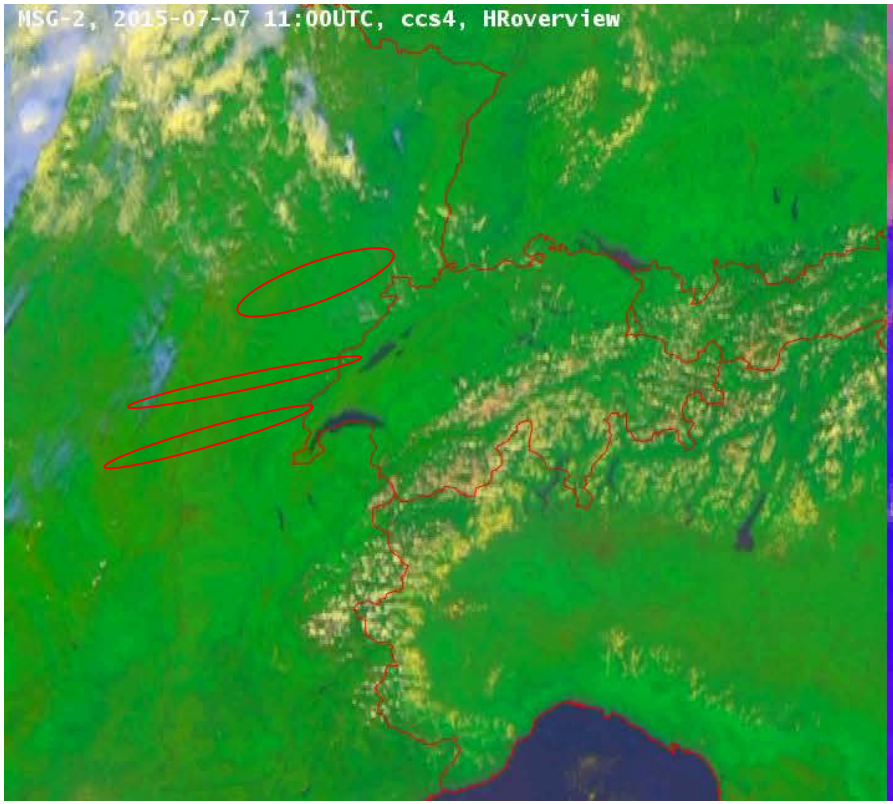


Probability Of Hail
(Waldvogel1979, Foote 2005)

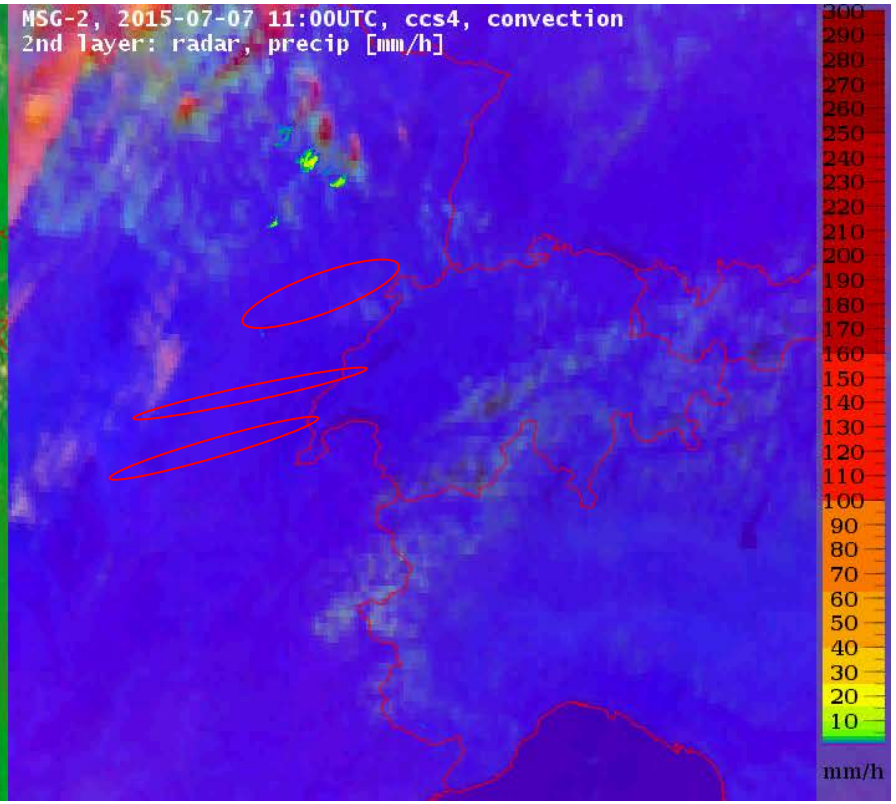


Local observation in Switzerland *07.07.2015*

High Resolution overview Satellite image



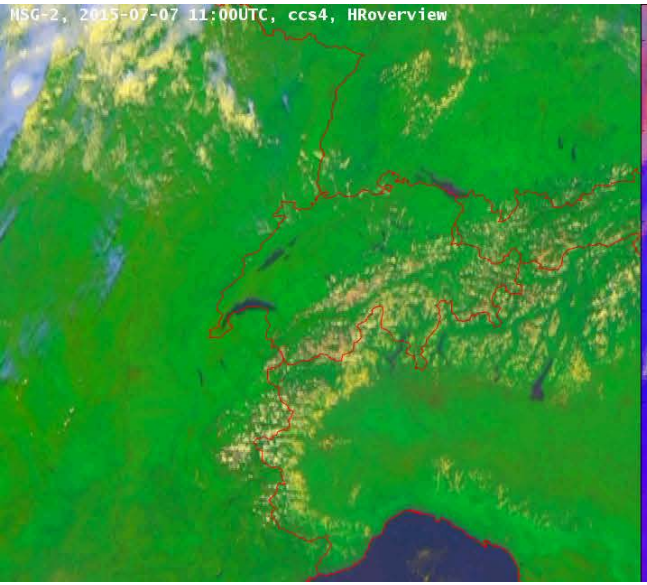
Instantaneous Radar Rain Rate



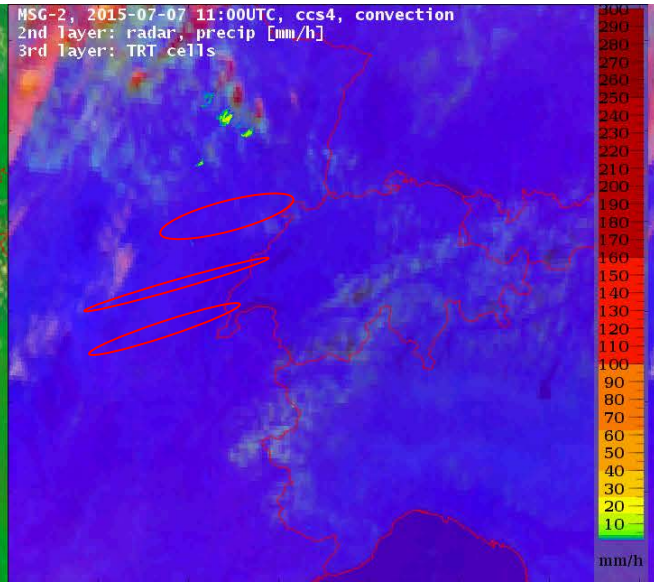
Local observation in Switzerland

07.07.2015

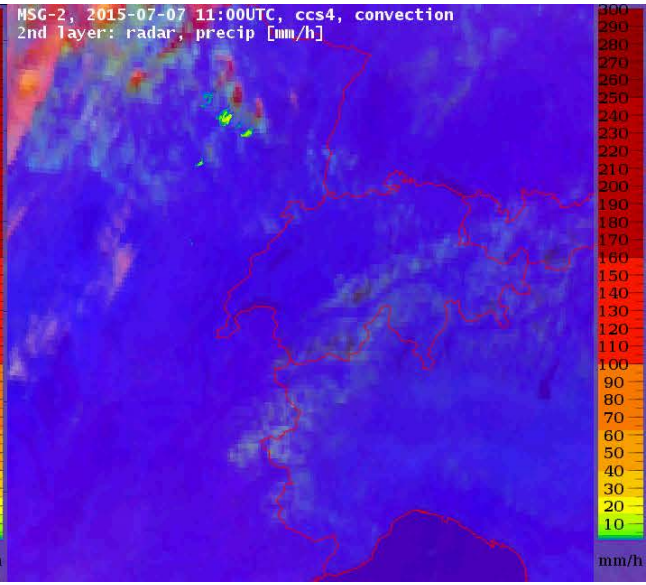
High Resolution overview Satellite image



Thunderstorm Radar Tracking (and Radar Rain Rate)



Instantaneous Radar Rain Rate



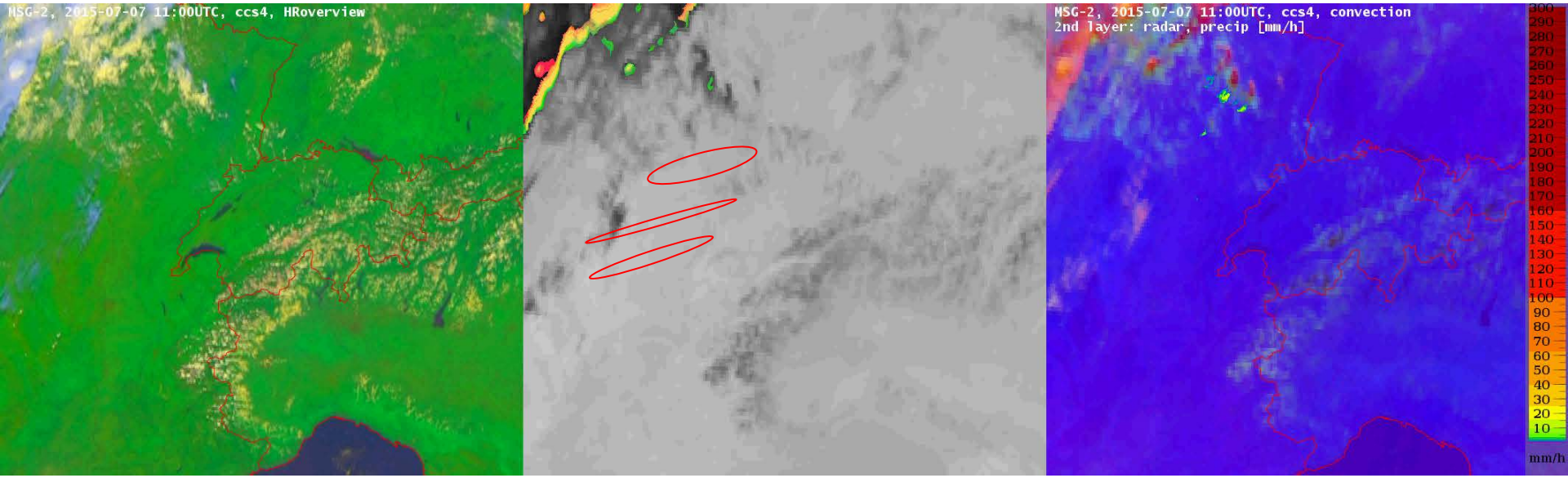
Local observation in Switzerland

07.07.2015

High Resolution overview Satellite image

COALITION-2

Instantaneous Radar Rain Rate



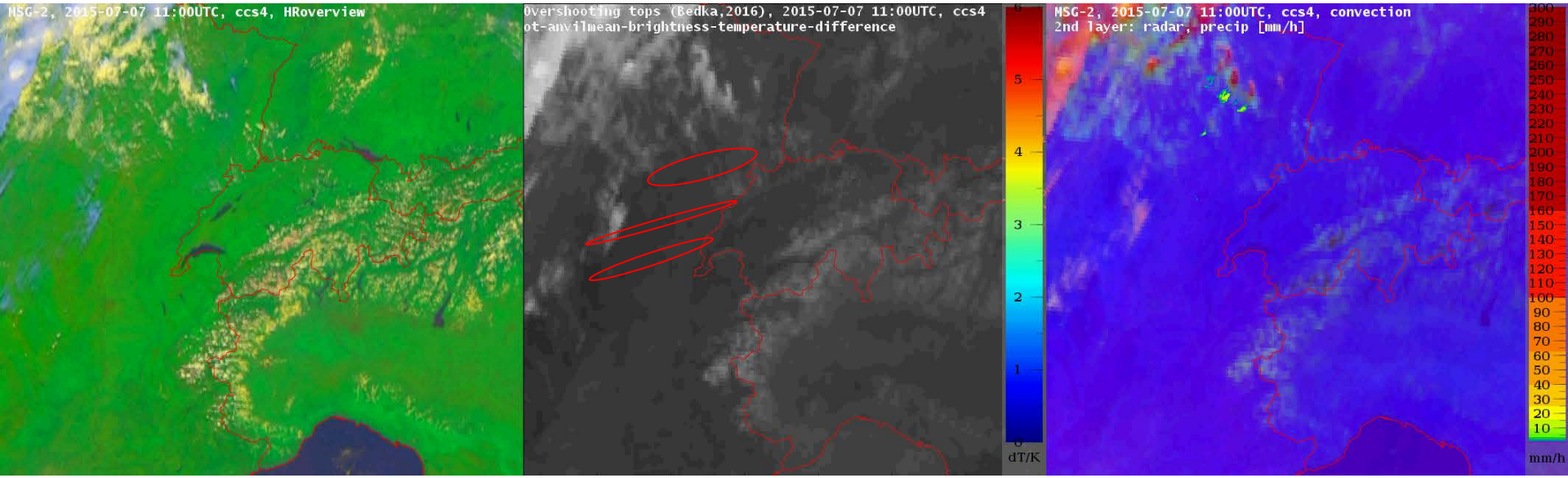
Local observation in Switzerland

07.07.2015

High Resolution overview MSG/SEVIRI

Overshooting Top detection Bedka based on MSG/SEVIRI

Instantaneous Radar Rain Rate



Anvils

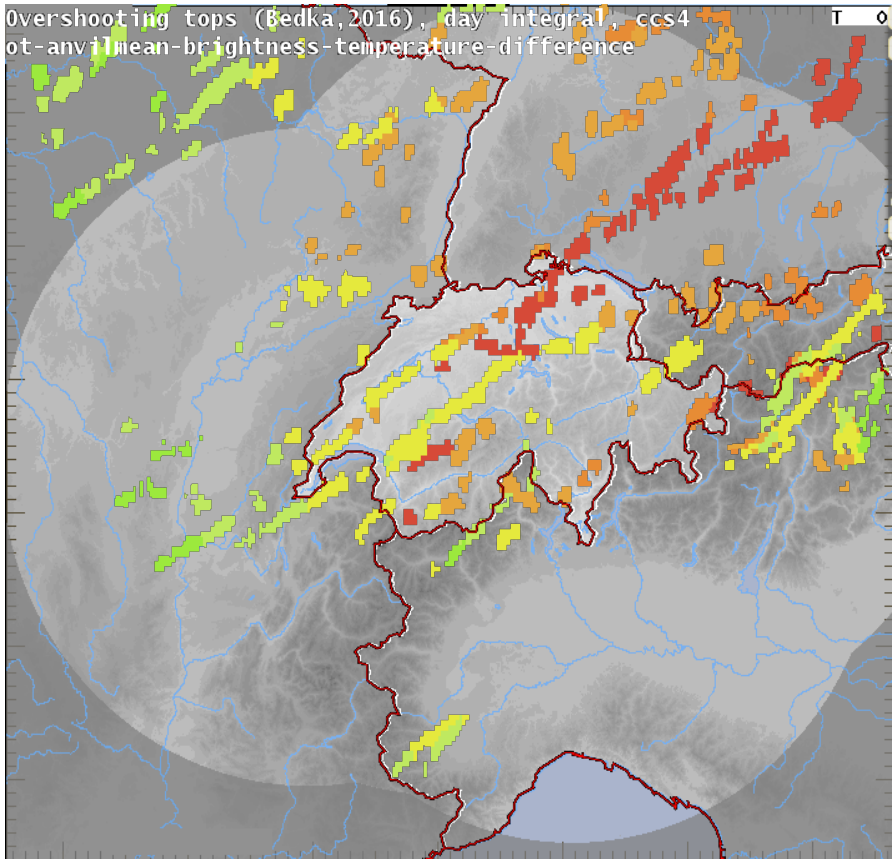
Overshooting Tops

dT(OT)>5K, p(OT)>0.7

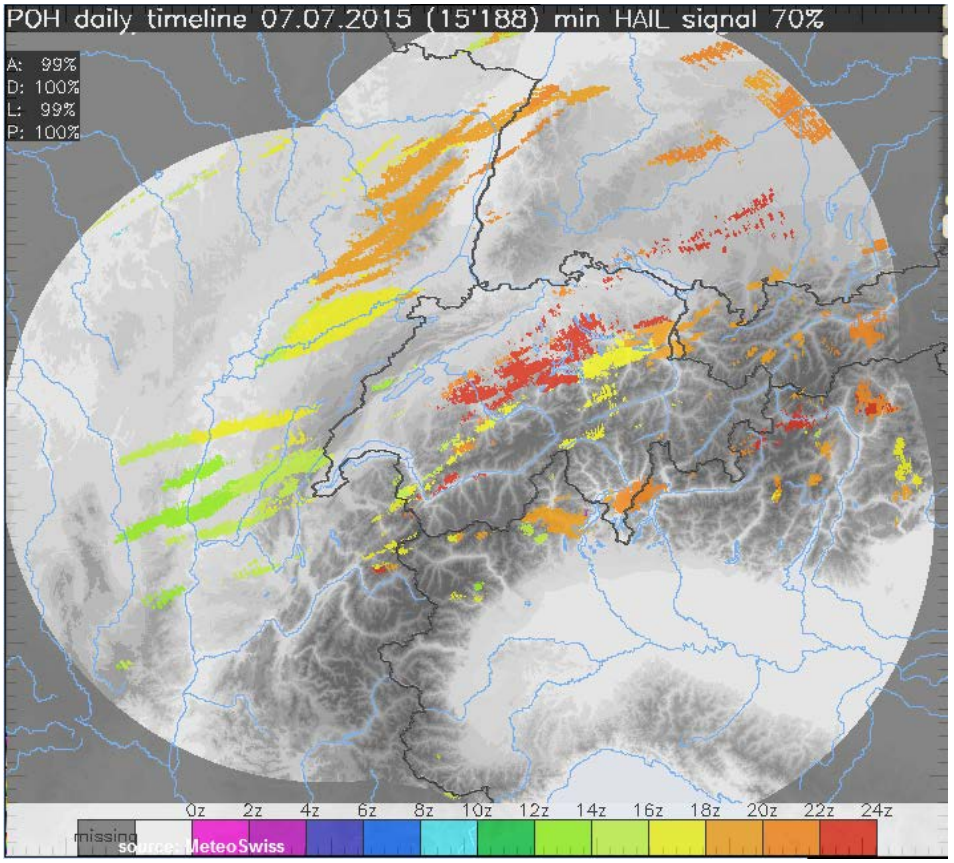
Daily distribution of severe weather

07.07.2015

Overshooting Top detection Bedka
dT(OT)>5K & p(OT)>0.7



Radar POH>0.0



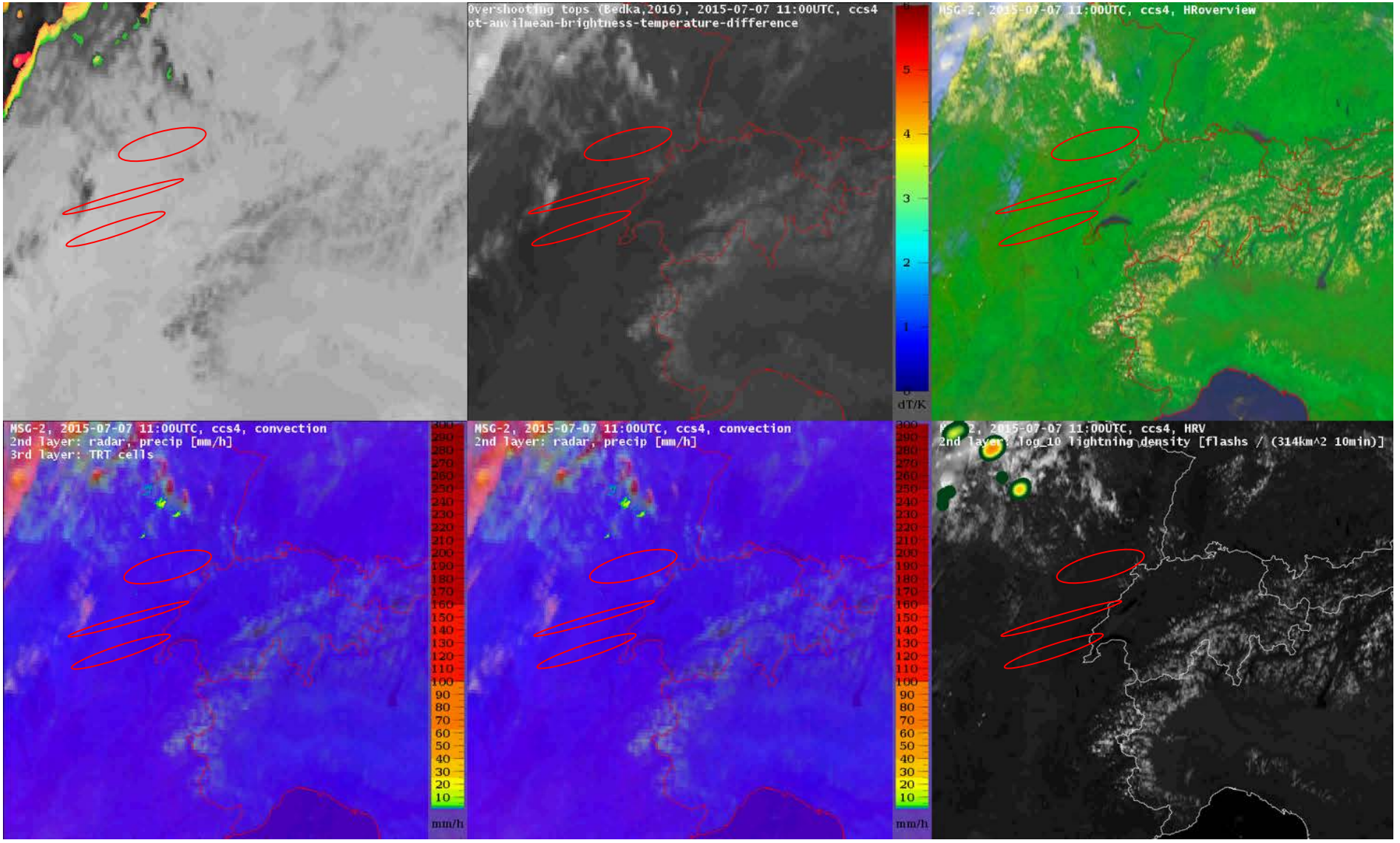
Local observation in Switzerland

07.07.2015

COALITION-2
Satellite algorithm

Overshooting Top detection Bedka
dT(OT)>5K & p(OT)>0.7

High Resolution Overview
Satellite image



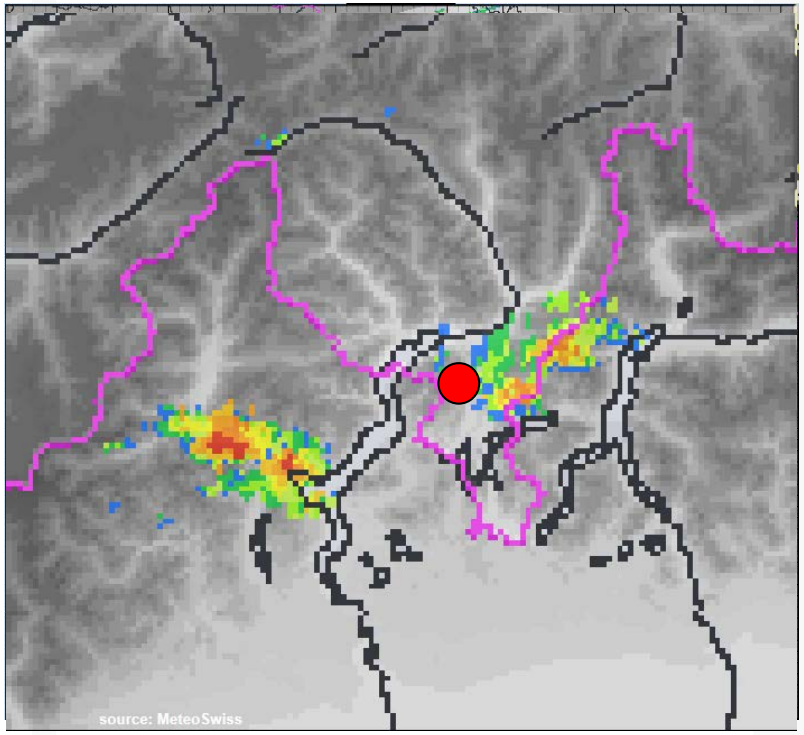
Thunderstrom Radar Tracking

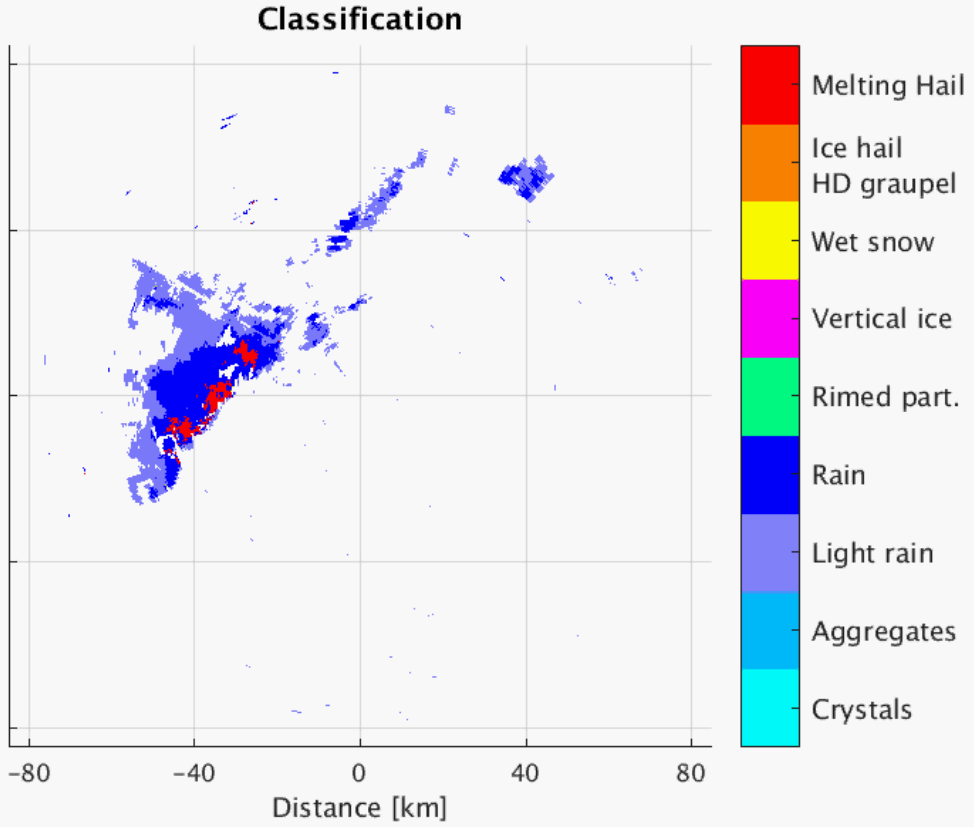
Instantaneous Radar Rain Rate

Lightning Density / (10min 314km^2)

Future work

Usage of hydrometeor classifications and polarimetric radar observations

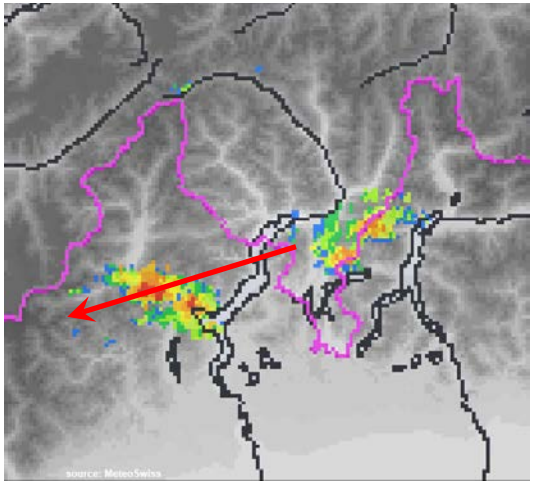


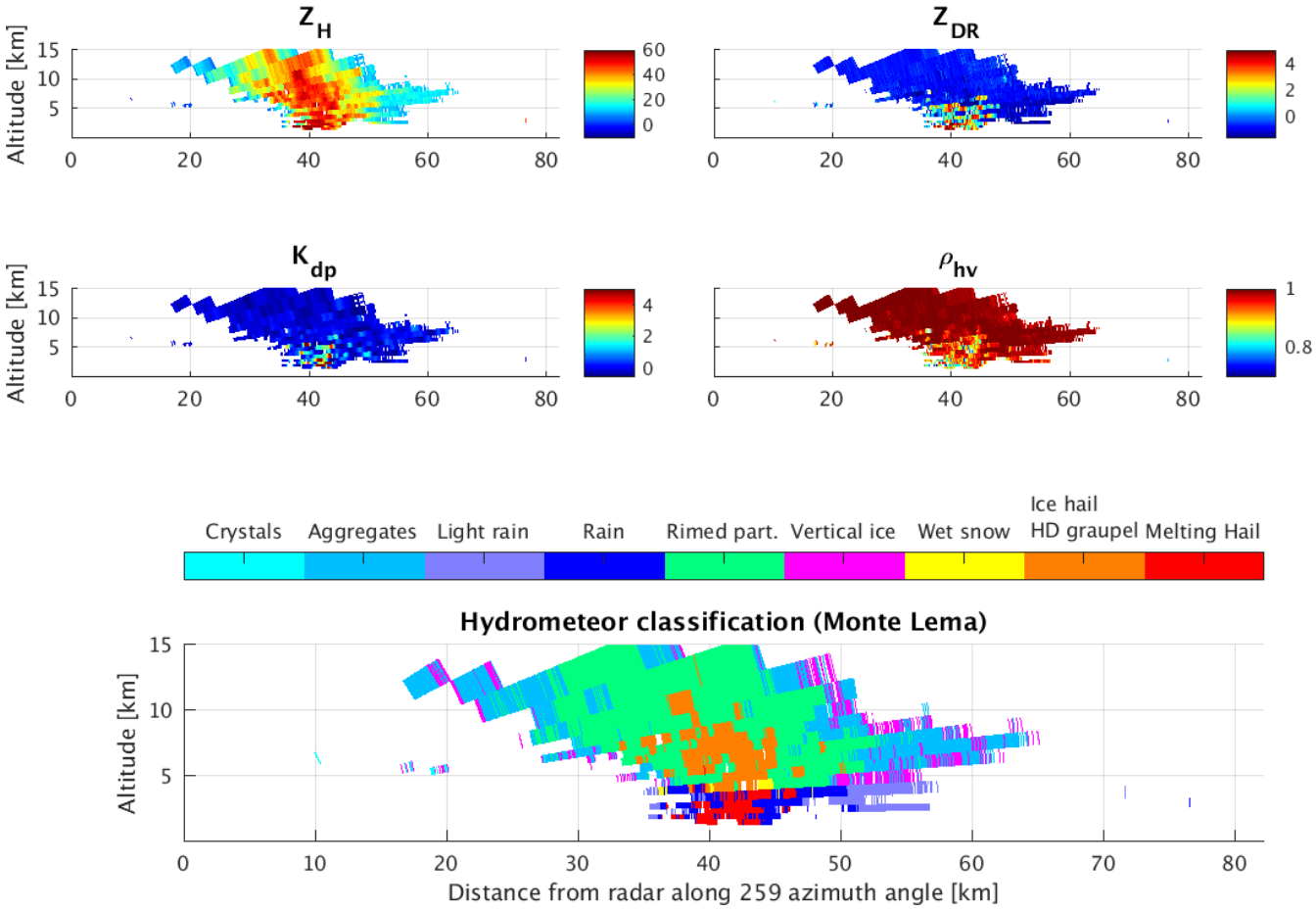


Besic, Nikola, et al. "Hydrometeor classification through statistical clustering of polarimetric radar measurements: a semi-supervised approach." *Atmospheric Measurement Techniques* 9.9 (2016): 4425-4445.

Future outlook

Usage of hydrometeor classifications and polarimetric radar observations



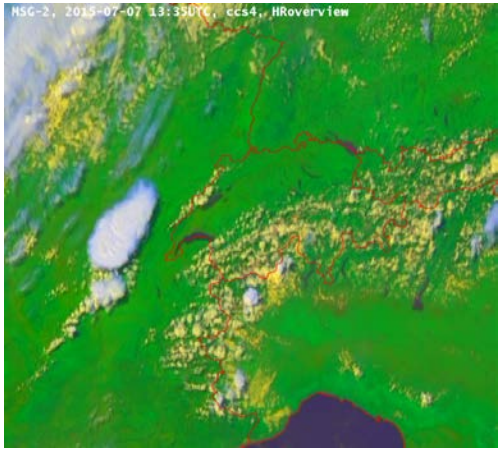


Summary

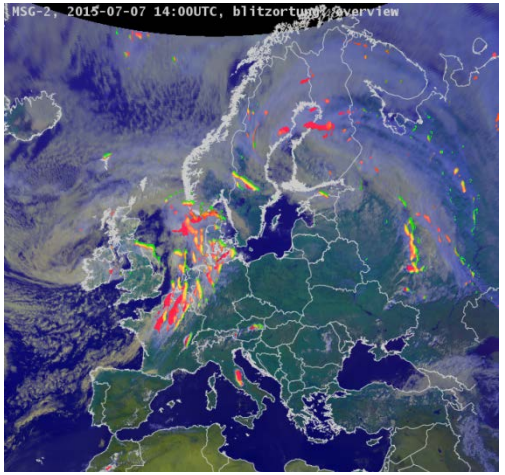
- Three algorithms were investigated
  Thunderstorm Radar Tracking (Hering, 2015)
  COALITION-2 (Hamann, 2016)
  Overshooting Top (Bedka, 2010, 2016)
- TRT based on radar is most direct measurement of hail
- COALITION-2 detects convection very early, for mature stage the detection of the anivl is not precise enough to locate hail
- Overshooting Tops captures severe weather very well and indicates a hail production accurately

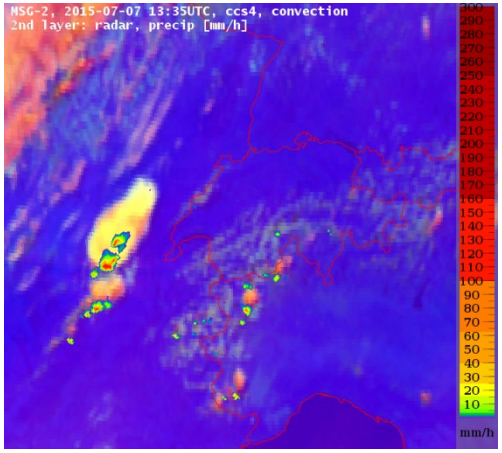
Future work

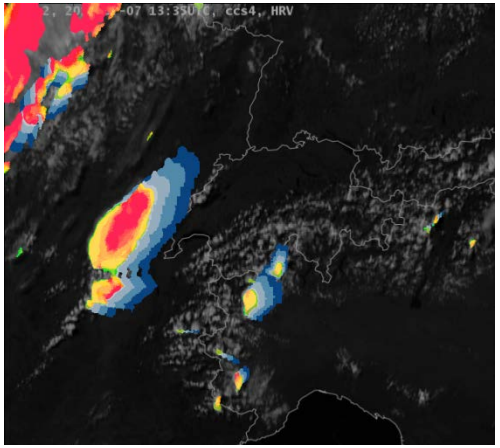
- Usage of polarimetric radar observation and hydrometeor classification
- Development of a radar-satellite algorithm combining the strengths of all three algorithms for Switzerland

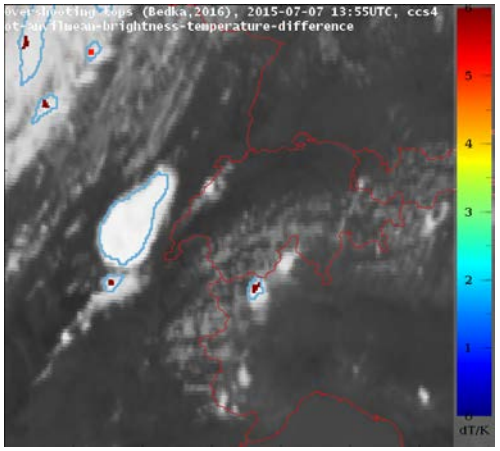


Thank You
Mahalo
Kiitos
Tack
Toda
Grazie
Obrigado
Thanks
Takk
Merci
Gracias









Flowchart COALITION-2