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Seamless prediction of multiple thunderstorm hazards with deep learning

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Objectives

EUMETSAT Fellowship:
Deep learning to predict thunderstorm hazards

- Direct warning for hazards rather than abstract measures of thunderstorm intensity
- Similar network architecture can predict many hazards

Predictions directly on a grid, avoiding storm object detection & tracking

Rain

Hail

Lightning

Wind

Recurrent-convolutional network

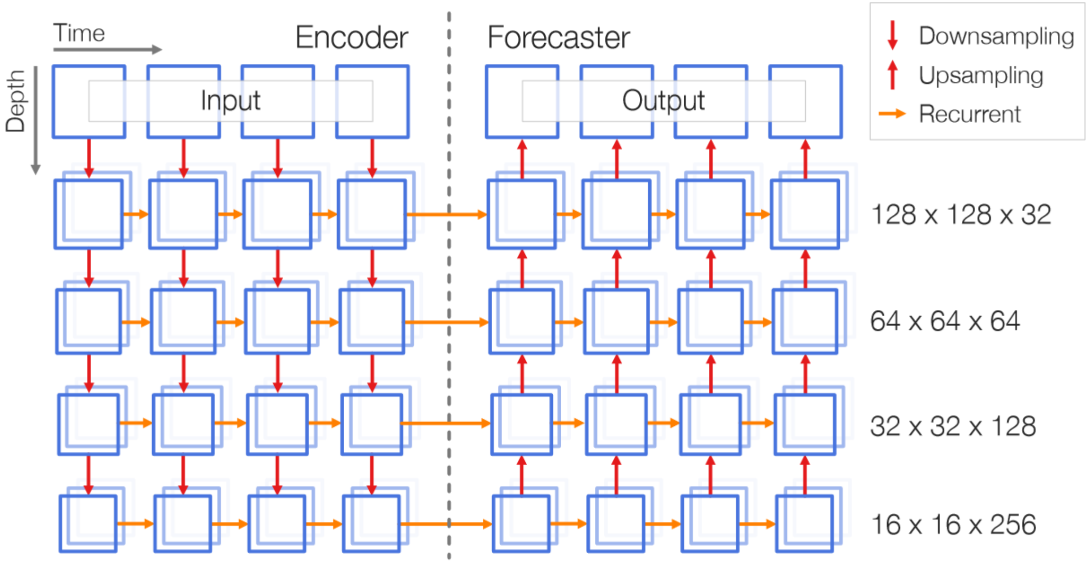
Encoder-forecaster model:

- Encoder produces an analysis of input data
- Forecaster turns the analysis into a forecast

Recurrent-convolutional architecture:

- Convolutional layers model spatial structure
- Recurrent layers model temporal evolution

General solution for modeling temporal evolution of 2D fields



Weather4Cast competition

- Organized by IARAI in cooperation with Nowcasting SAF
- Goal: Predicting time evolution of NWC SAF data products
- Two series: “Core” and “Transfer learning”
- 11 data regions in and around Europe
- Placed 1st in both series of the competition

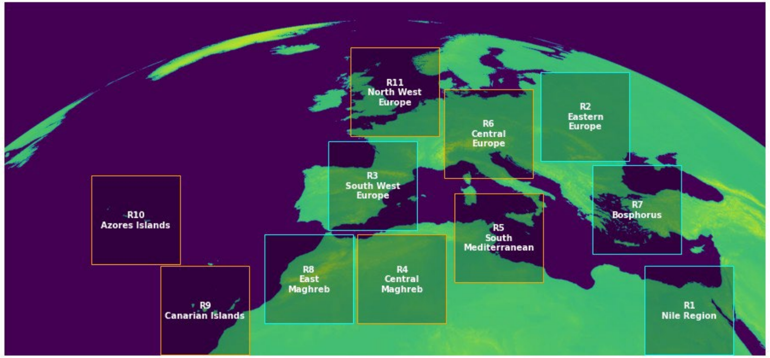


Image: IARAI

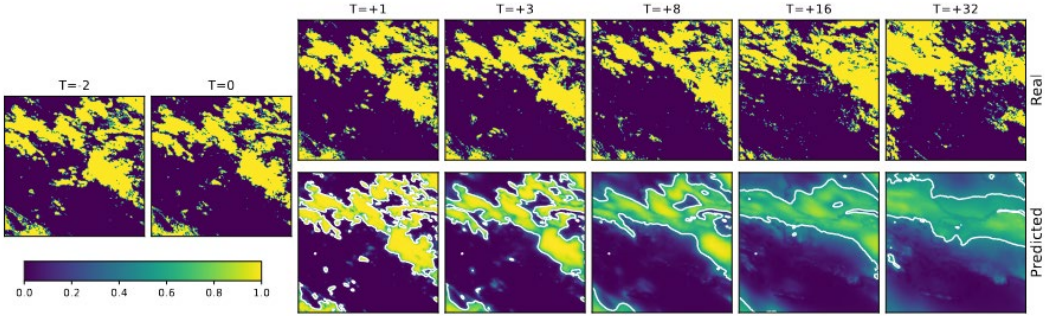
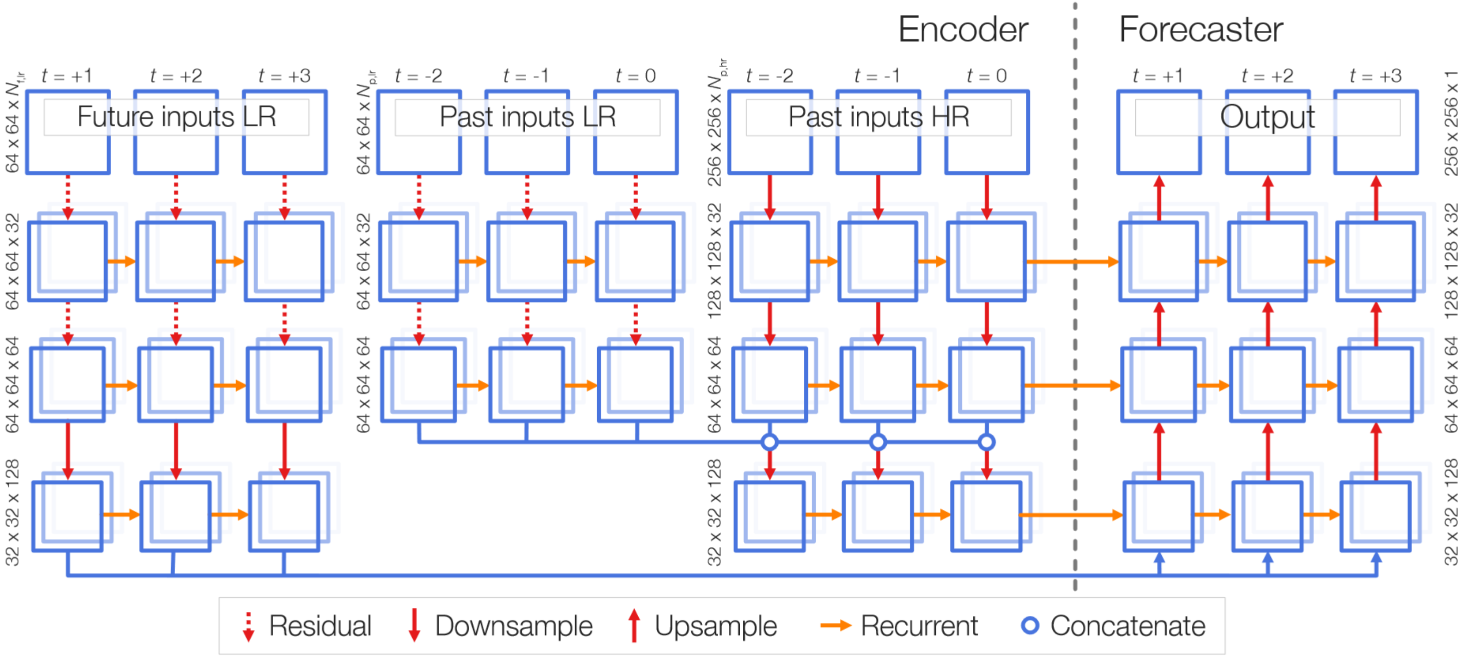


Fig. 4. As Fig. 1, but for *cma*. The white lines show the contour at 0.5, which is the decision threshold for a binary cloud mask.

Adapting network to multi-source data

Adapted network to nowcasting thunderstorm hazards probabilistically

Inputs of different resolutions in past and/or future timeframes



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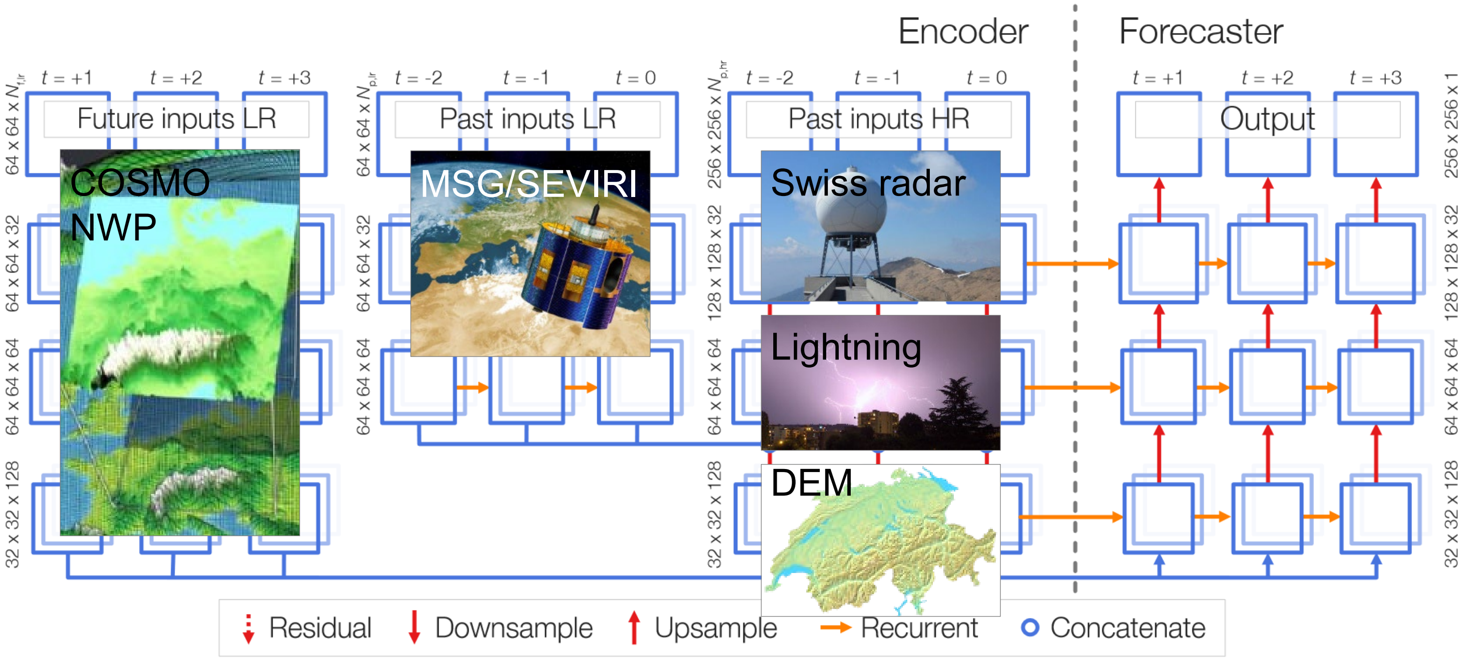
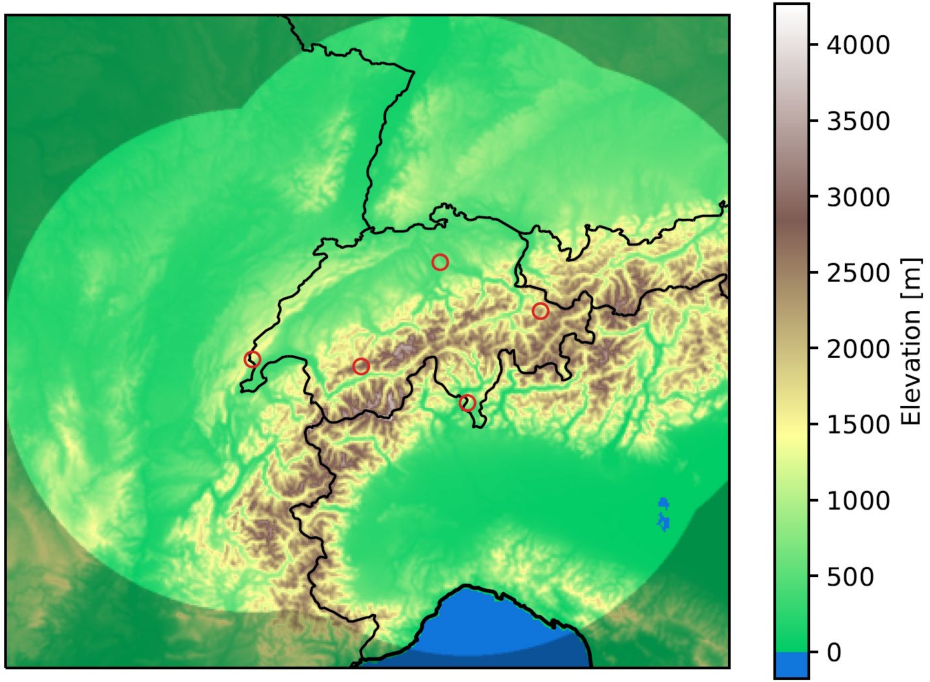
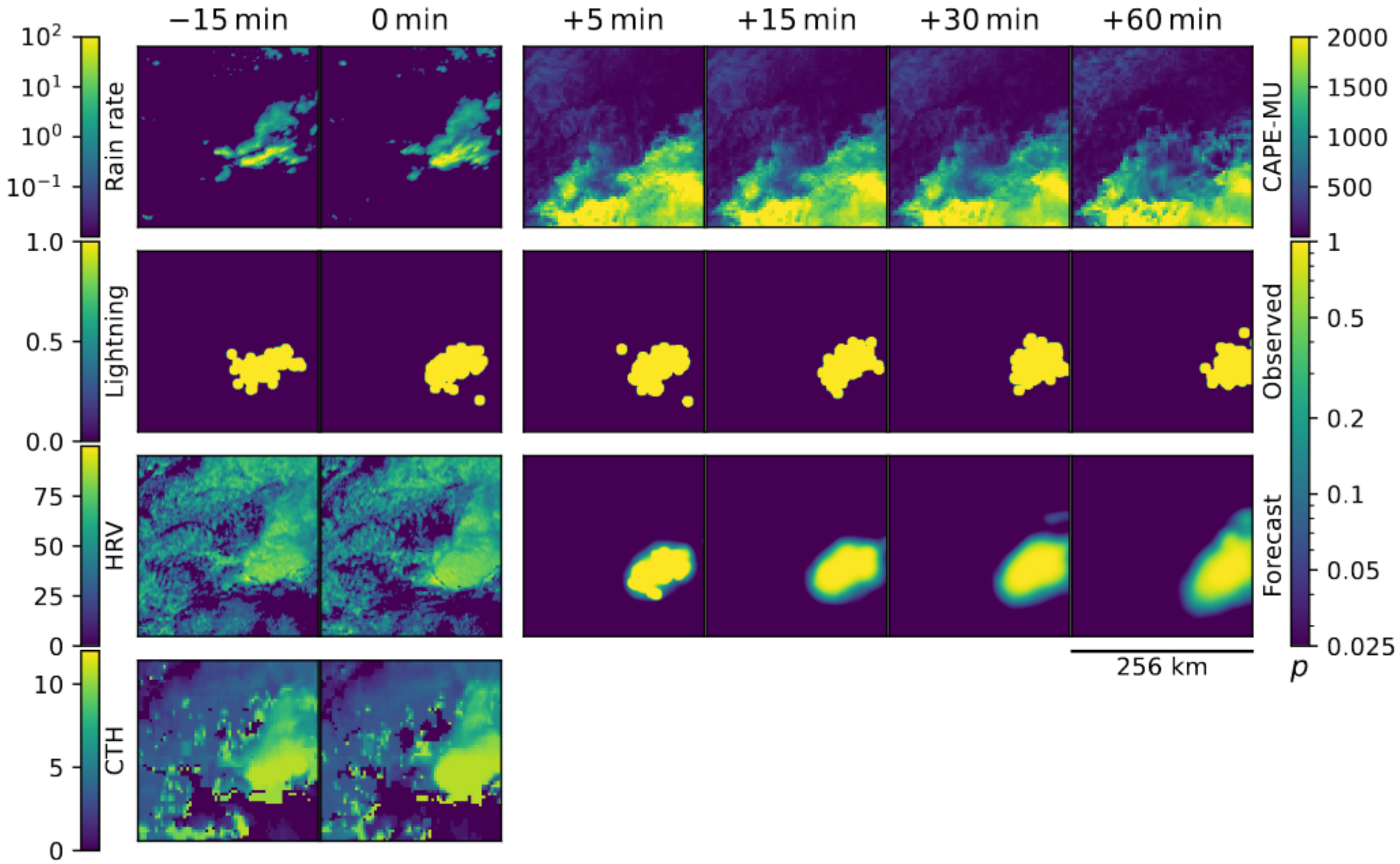


Study area / data sources

- Switzerland + surroundings
- Highly variable terrain
- Some of the highest lightning intensities in Europe are found in the region

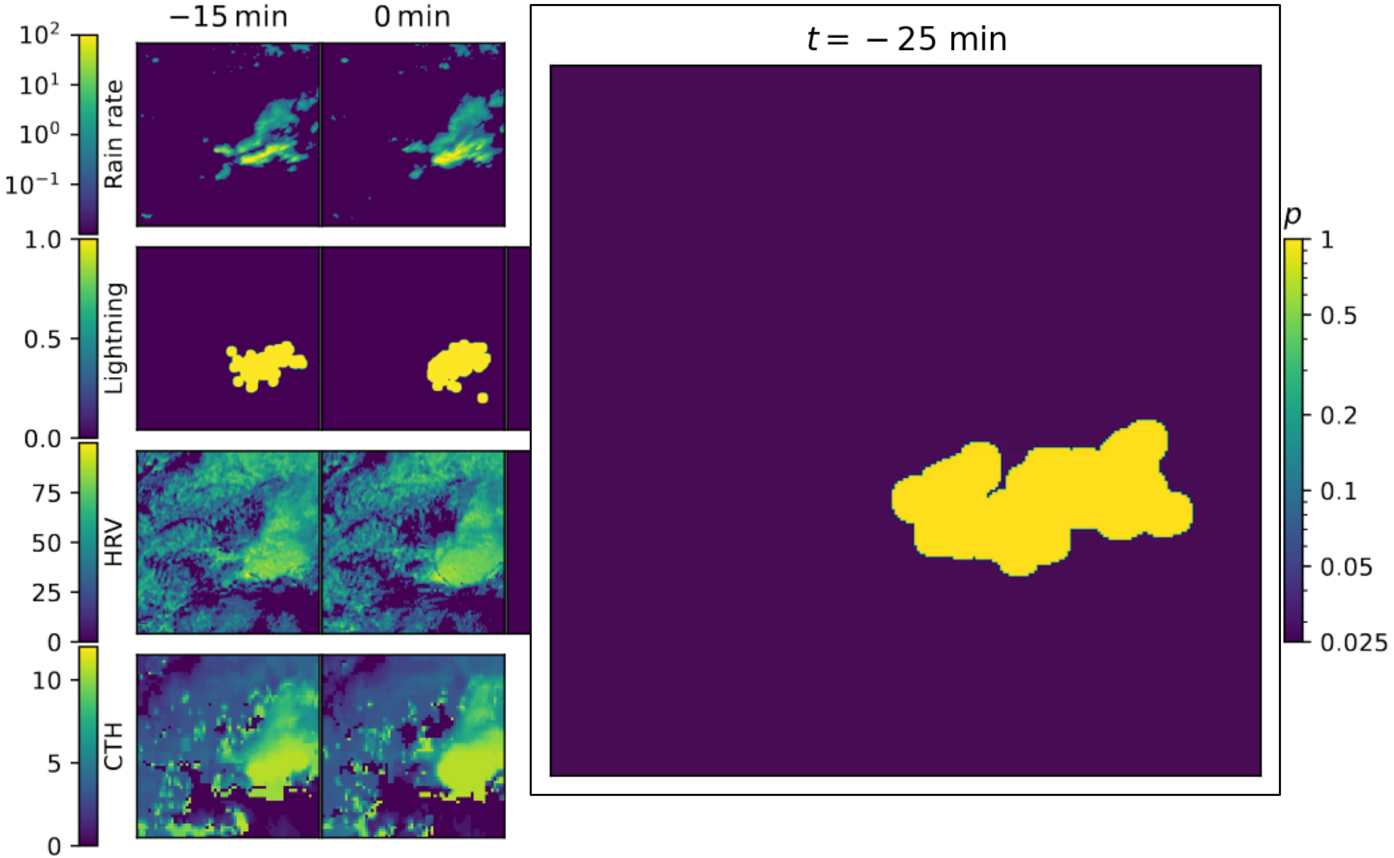


Lightning



−15 min
0 min
+5 min
+15 min
+30 min
+60 min
Rain rate
10^2
10^1
10^0
10^{-1}
Lightning
1.0
0.5
0.0
HRV
75
50
25
0
CTH
10
5
0
CAPE-MU
2000
1500
1000
500
1
Observed
Forecast
1
0.5
0.2
0.1
0.05
0.025
p
256 km

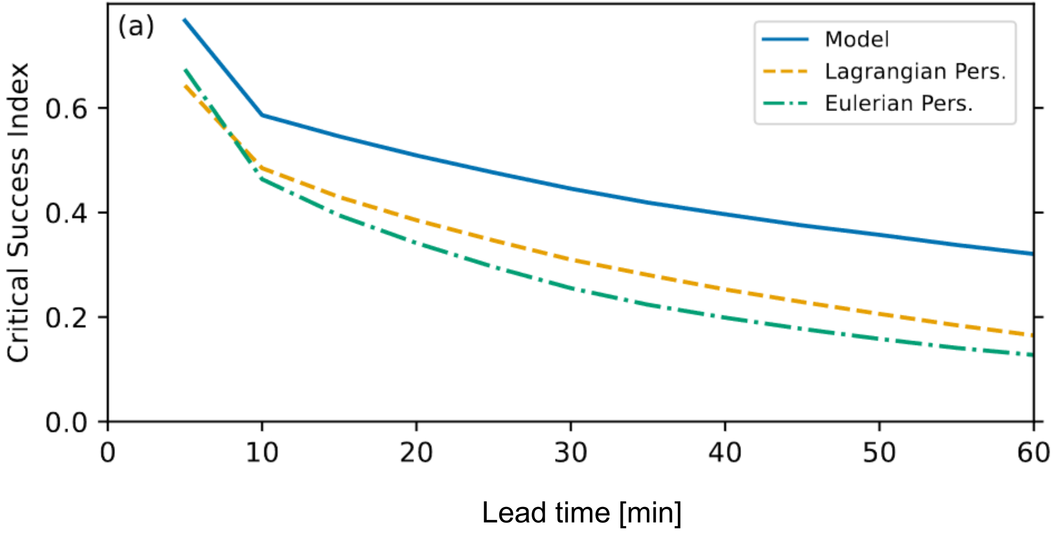
Lightning



−15 min
0 min
10^2
10^1
10^0
10^{-1}
Rain rate
1.0
0.5
0.0
Lightning
75
50
25
0
HRV
10
5
0
CTH
$t = -25$ min
p
1
0.5
0.2
0.1
0.05
0.025

Skill vs. lead time

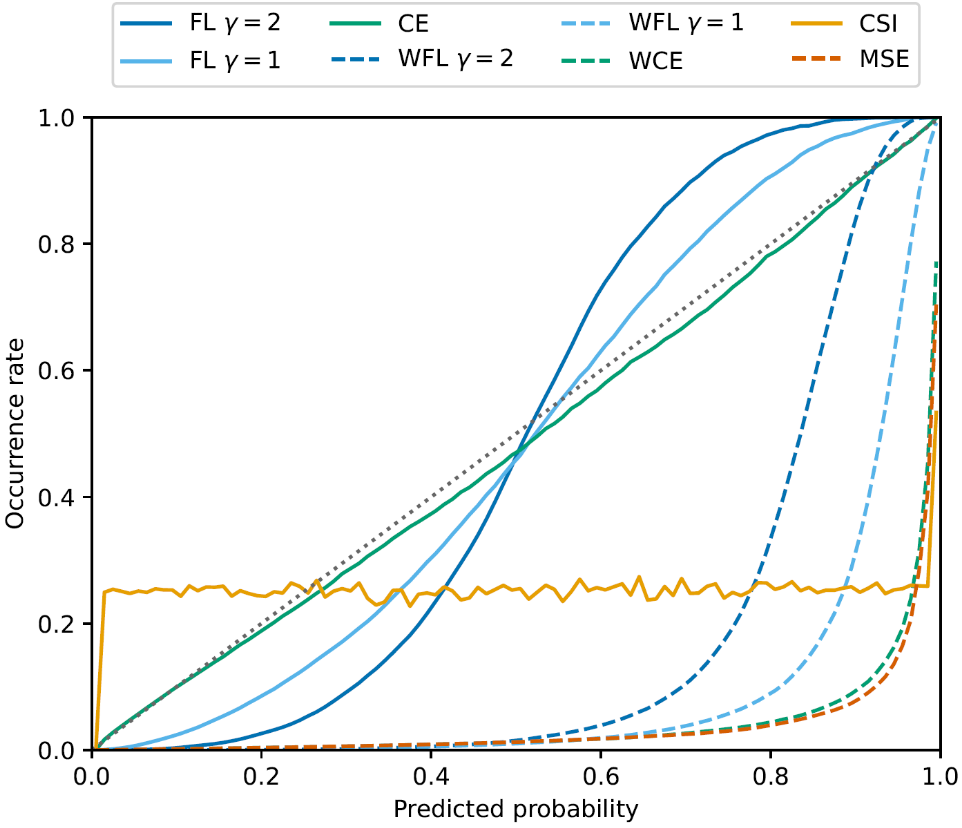
Comparison vs. Eulerian and Lagrangian persistence: Advantage over persistence, grows with time



Calibration

How does the predicted probability correspond to actual occurrence of lightning?

- It depends on the loss function!
- Usually easy to recalibrate

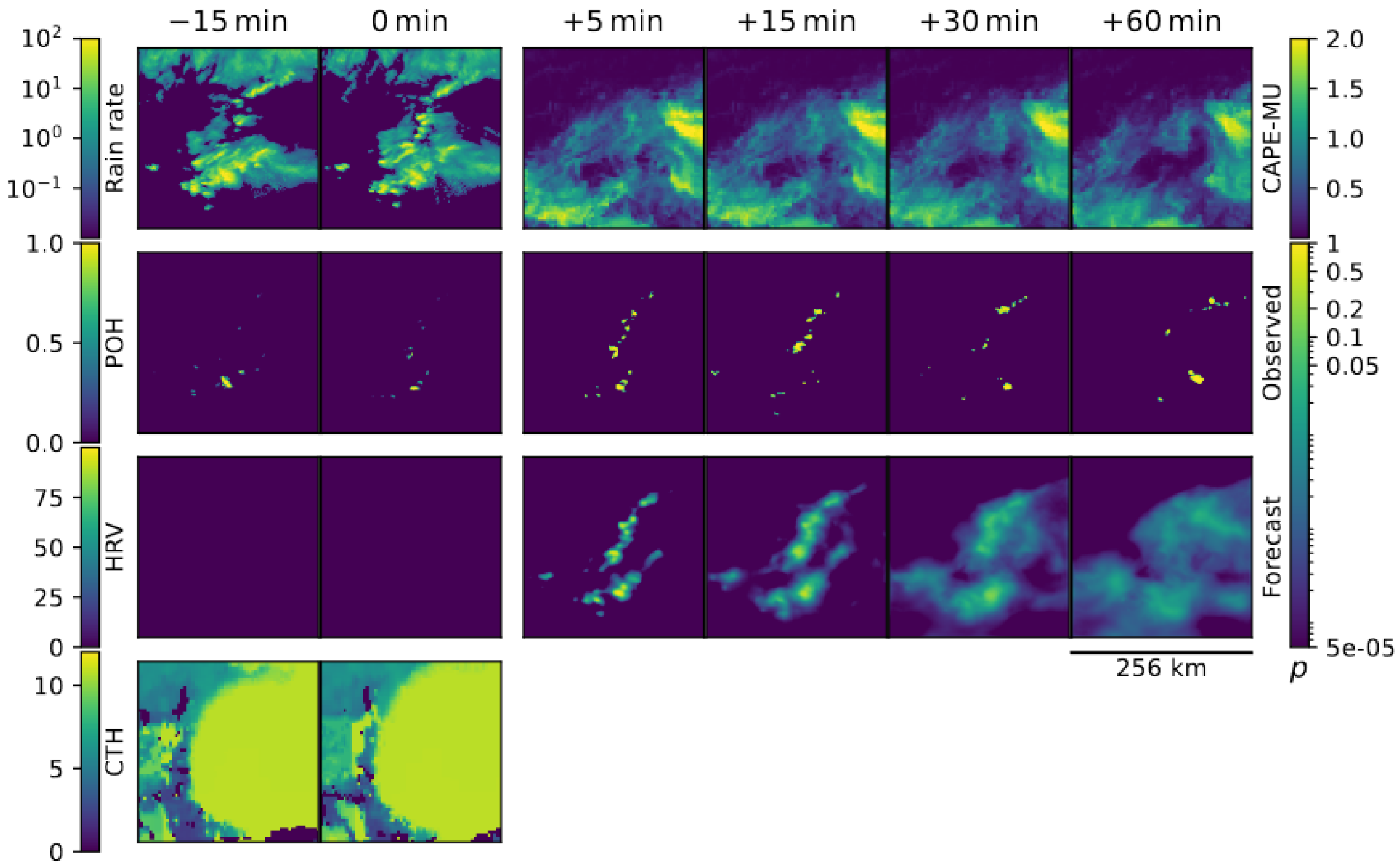


Hail

ML objective: probability of hail from Swiss radar network

Advance warning of hail initiation as short lead times

Prediction spreads out faster than lightning prediction

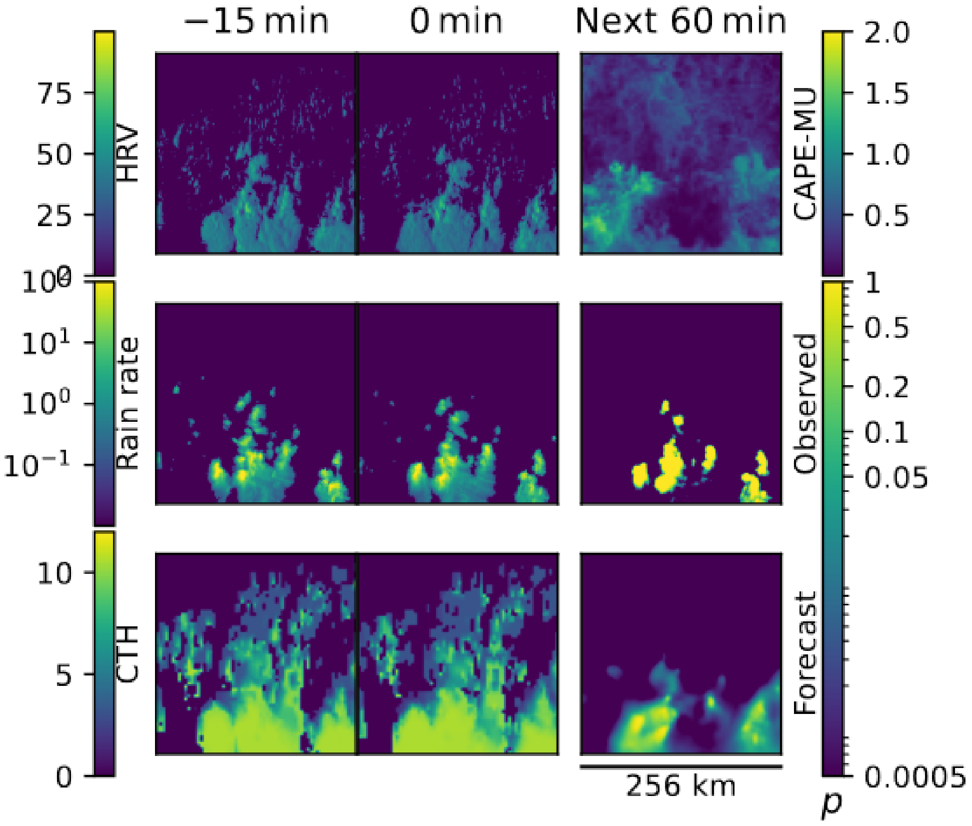


Heavy precipitation

“Ground truth”:
CombiPrecip radar+gauge precipitation estimate

Predicting the probability of heavy precipitation
(four classes, here > 10 mm/h)

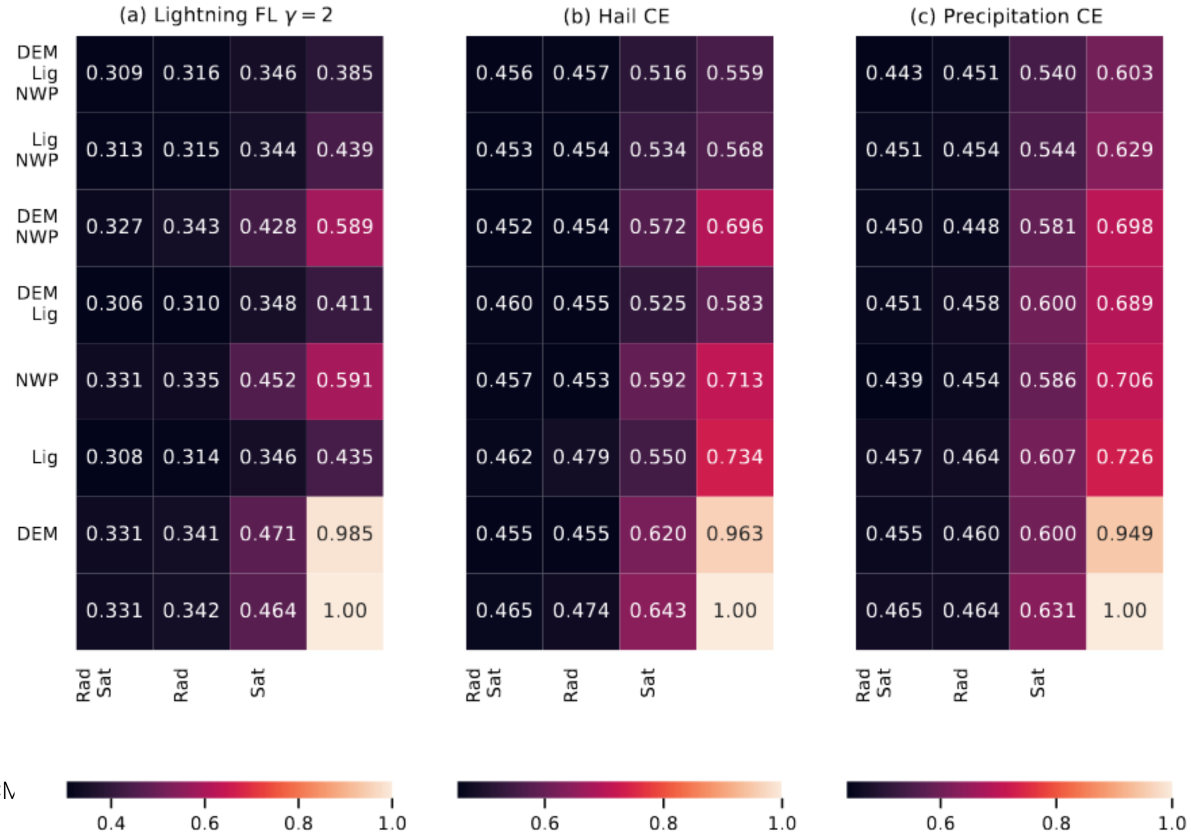
Predicting 1-h accumulation instead of 5-min timesteps



Data source importance

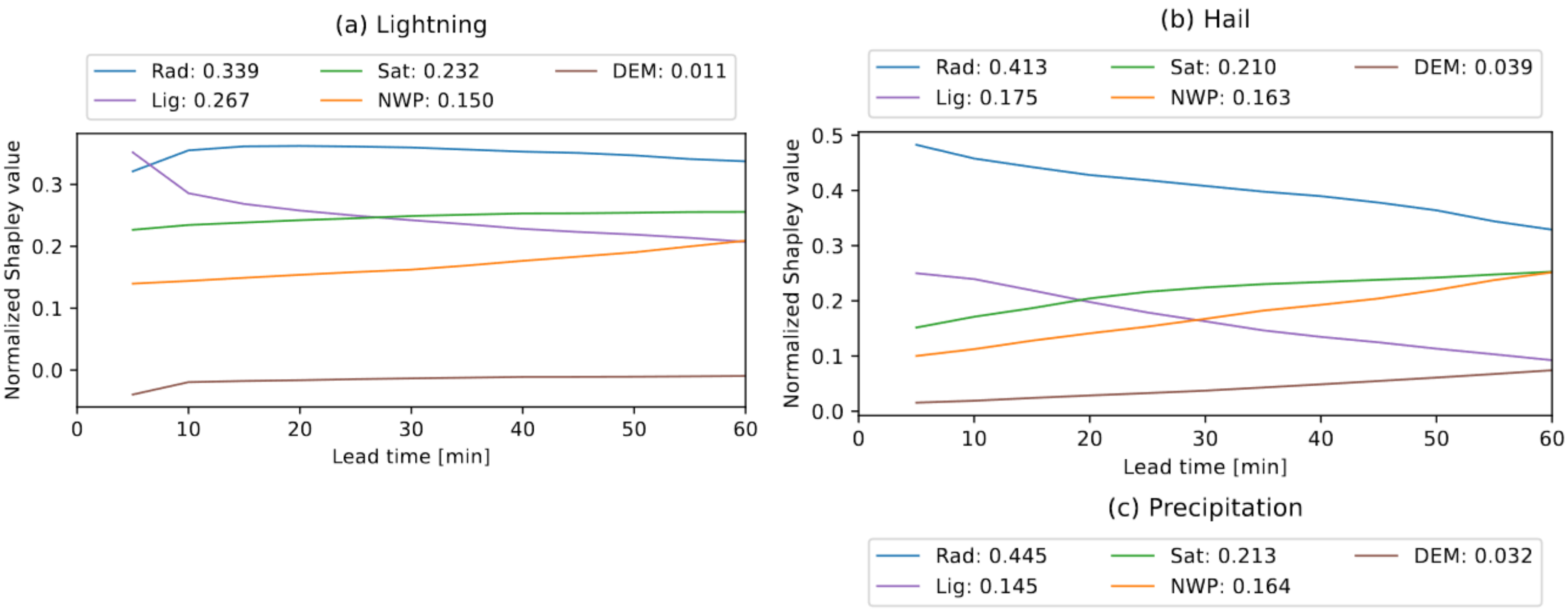
Trained the model with all different combinations of data sources

- **Radar**: dominant source
- **Satellite**: useful everywhere, available globally
- **Lightning**: good for predicting lightning
- **NWP**: Would be better at longer lead times?
- **DEM**: marginal benefits



Data source importance

Shapley values quantify data source importance as a function of lead time



Outlook

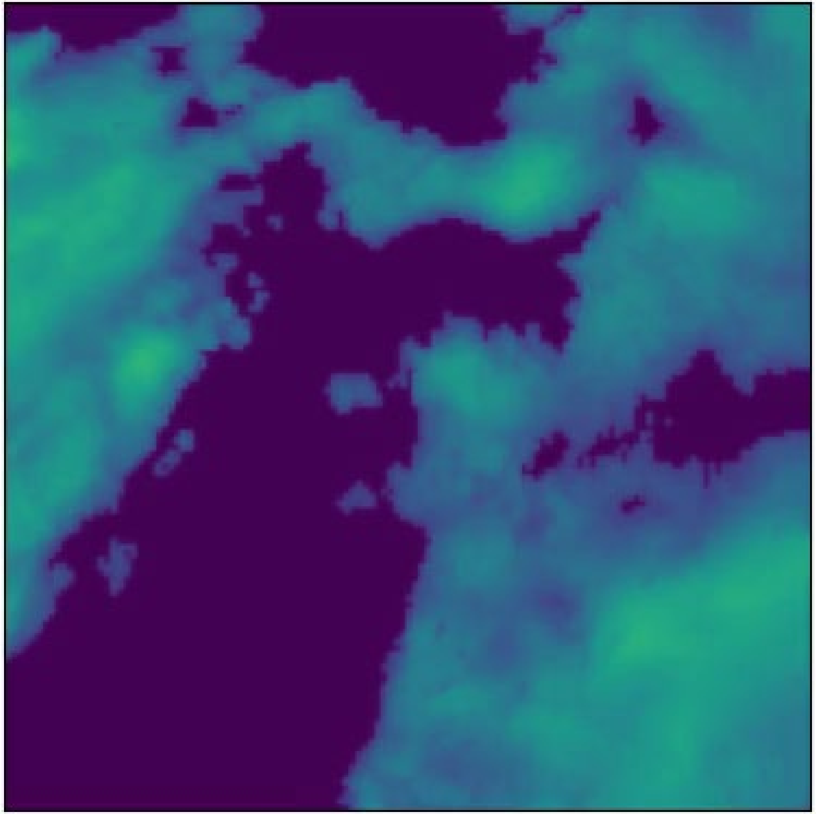
Wind warnings

- But what to use for ground truth?

Including new data sources

- MTG (FCI + LI)
- Polarimetric radar

Generative nowcasting →



Summary

- Recurrent-convolutional network to predict multiple thunderstorm hazards
  - Demonstrated for lightning, hail, heavy precipitation
  - Can be adapted to other prediction tasks
- Can predict motion, growth and decay of thunderstorms
- Will work on running model real-time at MeteoSwiss
- Paper submitted, preprint available (https://arxiv.org/abs/2203.10114)