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IMPROVED NOWCASTING OF HEAVY PRECIPITATION USING SATELLITE AND WEATHER RADAR DATA

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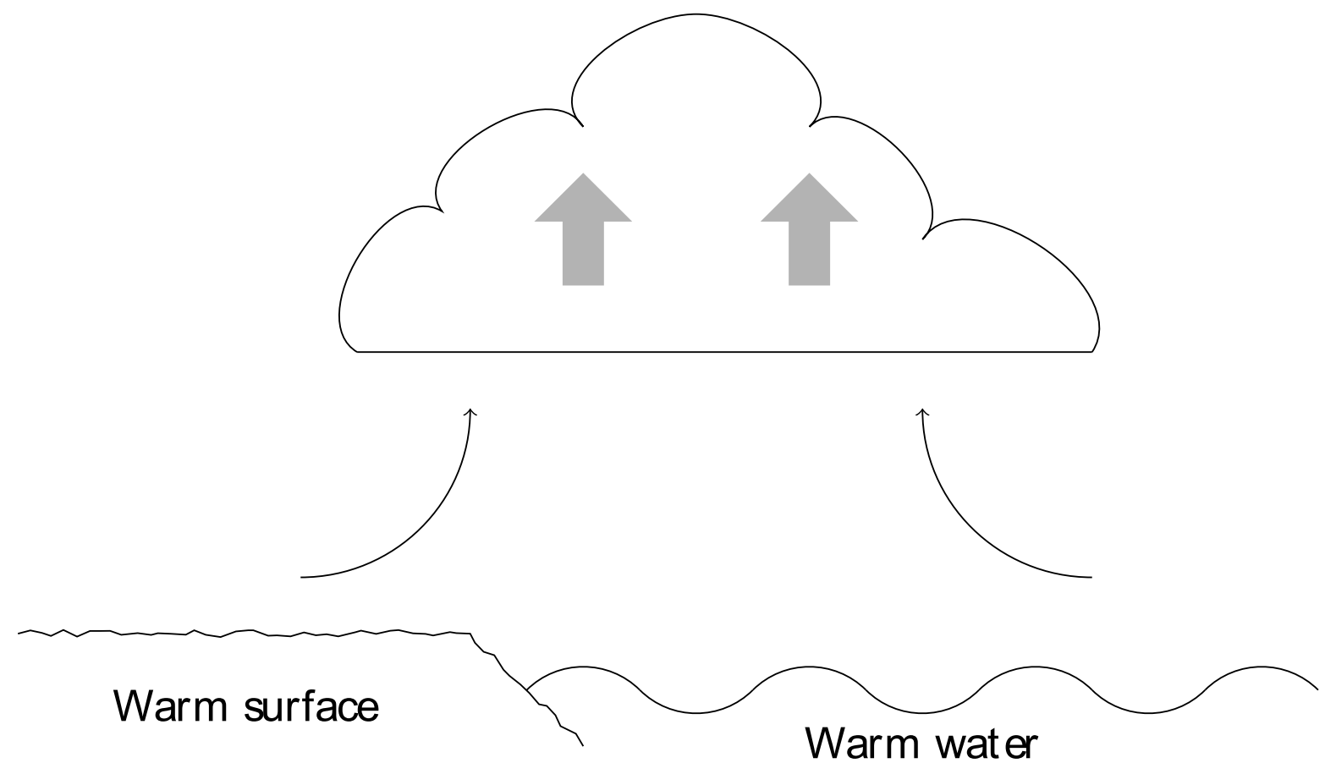
Nowcasting

Changes in the global climate over the last few years have increased the number of extreme precipitating events. Therefore the interest in predicting and understanding the cause of these events have increased as well.

Nowcasting is the short-term prediction of fx. weather, i.e. within a time span of 1-3 hours before occurrence. A good nowcast can aid fx. air traffic control and water flood management in making good decisions.

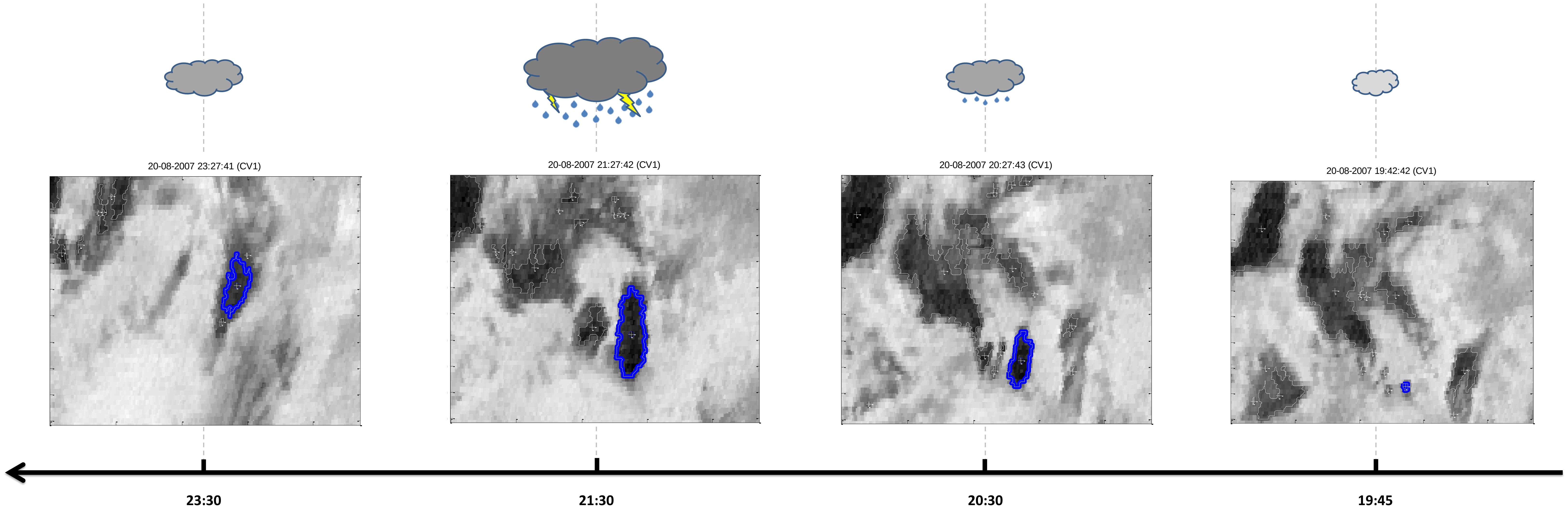
On August 20th, 2007, Gråsten in Jutland was hit by a shower, where 142mm of rain fell in 1.5 hours.



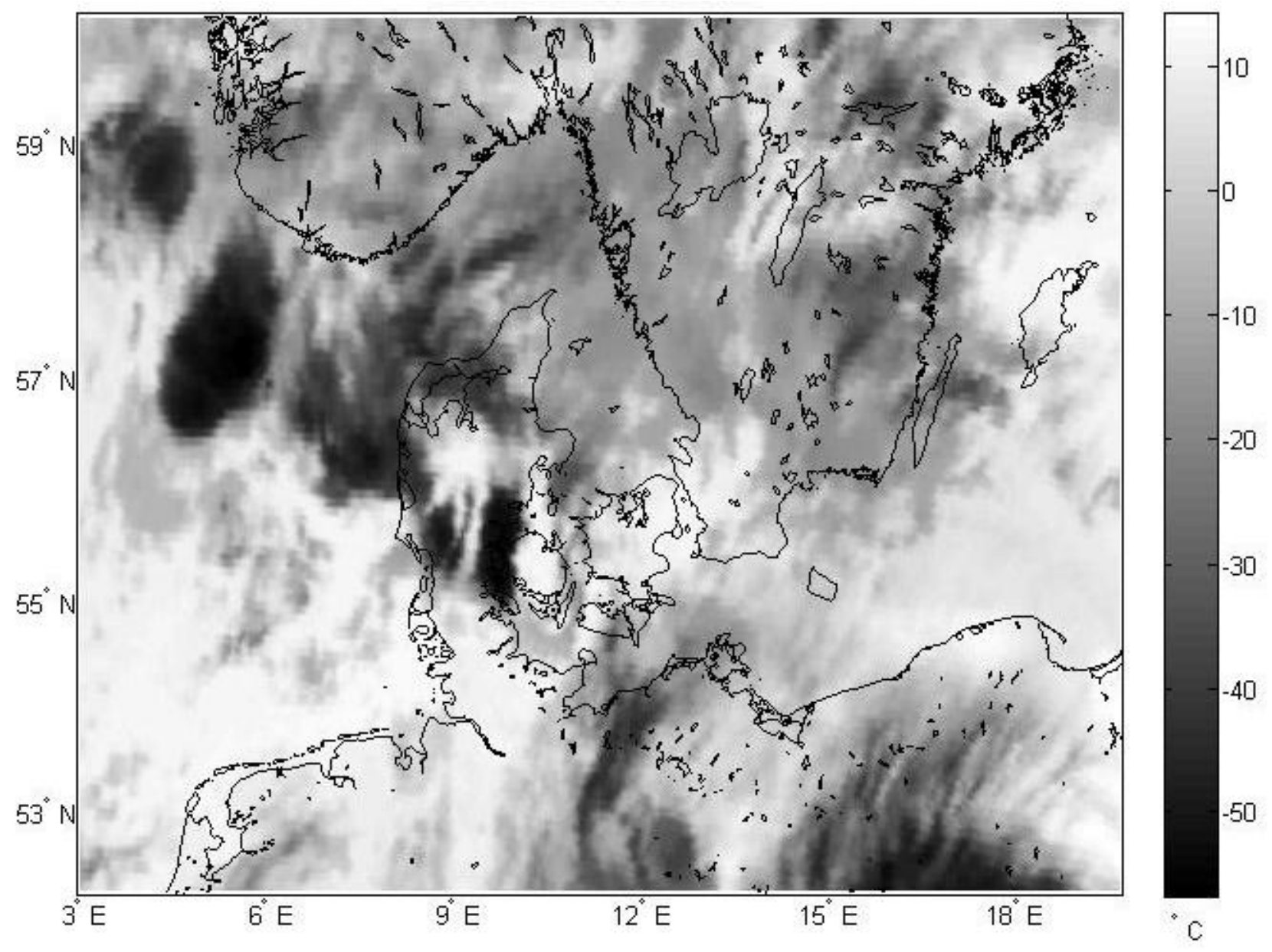
Heavy precipitation can occur in different meteorological scenarios, e.g. embedded cumulus nimbus, cold air thunder and heat thunder.

The heaviest showers are found during the summer, where the air temperature causes high atmospheric instability, whereby mature cumulus nimbus can develop rapidly.

The purpose of this project is to give a probabilistic nowcasting of isolated extreme precipitation in Denmark.



Radar And Satellite Data



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Satellite and radar data are provided by DMI for eleven cases of extreme precipitating events, from 2007 to 2010.

The satellite data are imagery from the Meteosat Second Generation satellite in a geostationary projection with a temporal resolution of 5-15 min.

The image values are brightness temperatures from 11 wavelengths (8 IR + 3 VIS).

Satellite and radar data are projected to a common grid for simultaneous analysis:

Grid size: 400 x 500 pixels
Pixel size: 2 x 2 km^2

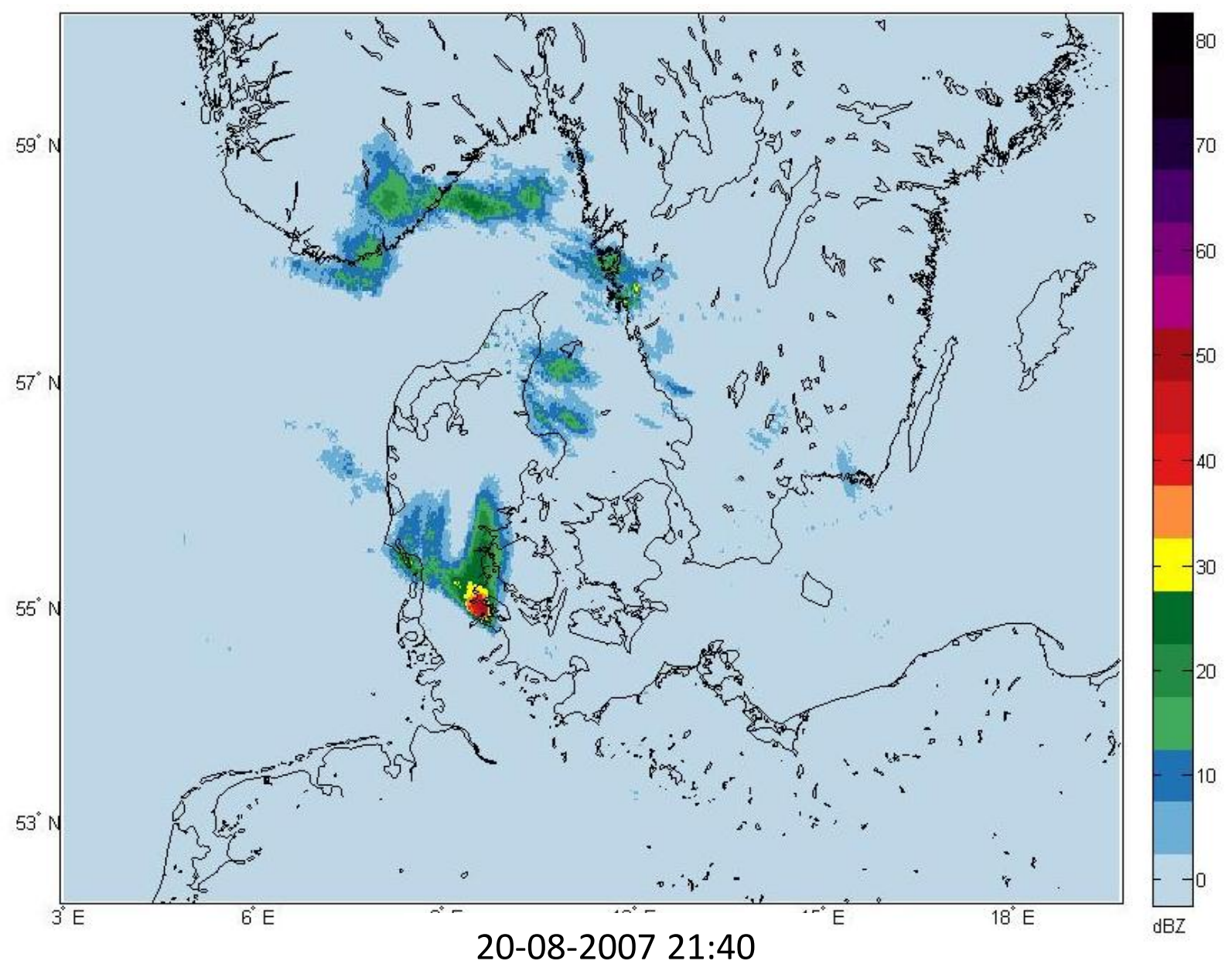
The radar data are reflectance values combined from five weather radars operated by DMI.. Extreme events are easily identified in radar data as they occur, but then it is too late.

Radar data have an original spatial resolution of 1 x 1 km^2 and a tempoeral resolution of 10 min.

Image values are converted to reflectances

$$\text{dBZ} = (\text{DN} \cdot 0.5) - 32$$

where values above 35dBZ are characterized as heavy rain. A missing value indicates no reflectance, i.e. no rain, or out of range.



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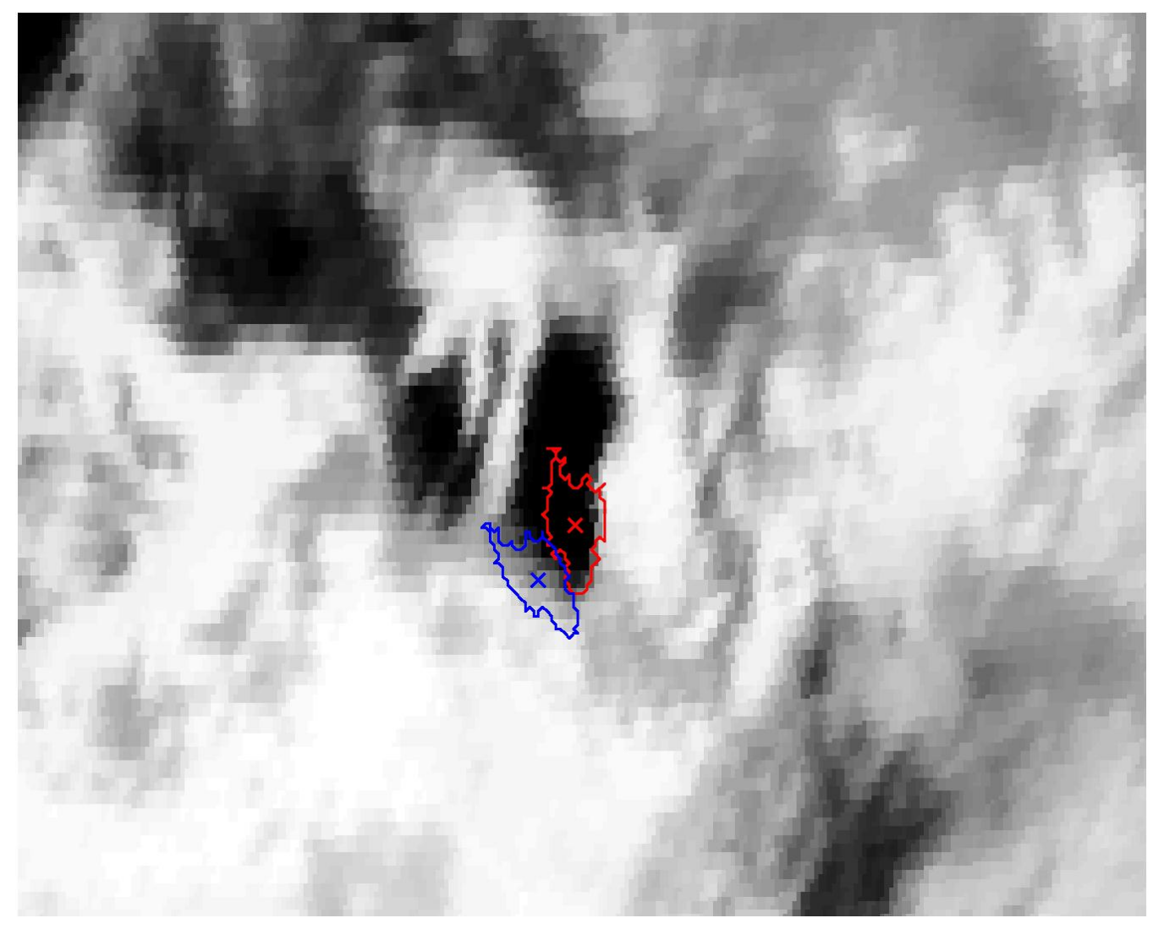
Cross Correlation Alignment

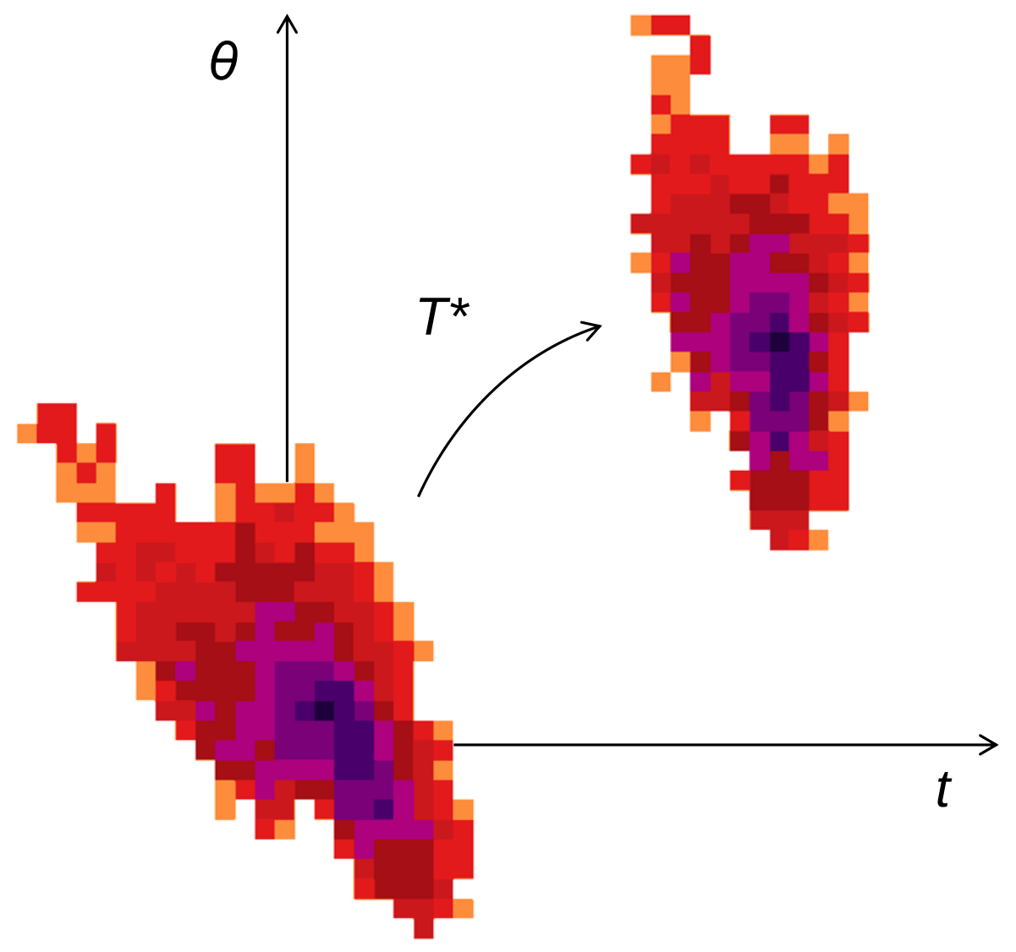
The satellite and radar data are not spatially aligned to each other. This is caused by different points of view, i.e. from above or from the ground, and difference in the spatial extent of a mature cumulus nimbus and the actual precipitation recorded by the radar. Furthermore, the time of maximum precipitation in the radar data does not necessarily coincide with the point in time of maximum cloud development in the satellite data.

A method for spatially and temporally aligning radar data with satellite data in terms of cross correlation has been developed. It finds the parameters

$$\theta = [\omega, s, t_x, t_y]^T$$

that minimize cross correlation *K* steps back in time.





Time and transformation of minimum cross correlation are found as

$$\theta_t^* = \underset{\theta}{\operatorname{argmin}} \left[\operatorname{Corr}\left\{\mathbf{X}, T(\mathbf{Y};\theta)\right\}\right]$$

$$t^* = \underset{t}{\operatorname{argmin}} \left[\operatorname{Corr}\left\{\mathbf{X}, T(\mathbf{Y};\theta_t^*)\right\}\right] \quad t \in [0, -K]$$

This method is invariant to translation, rotation and scaling and can be solved by a pattern search method, e.g. Simplex.

An important result of the aligment is a good basis for Canonical Correlation Analysis, which yields an appropriate subspace for segmentation of convective clouds in the satellite data.

Tracking In Projection Space

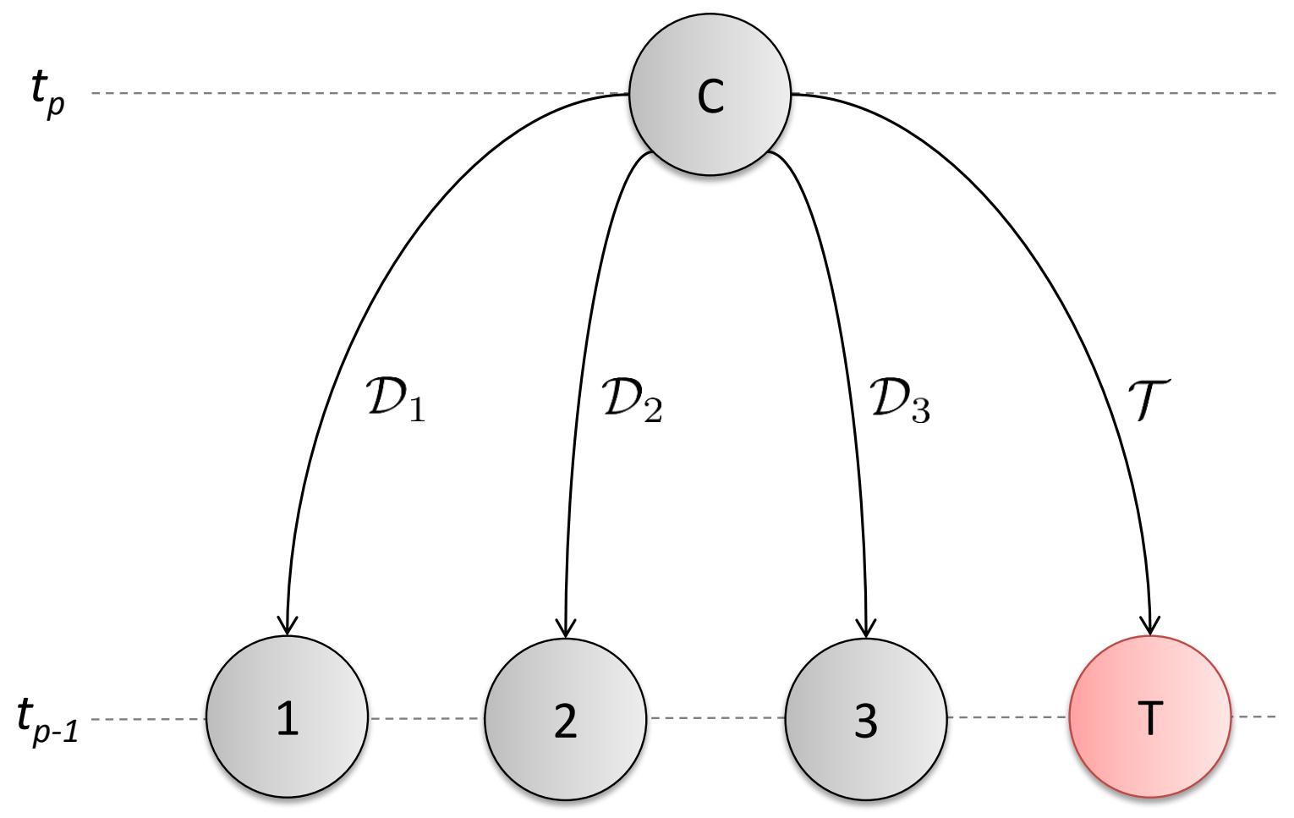
Tracking the convective cloud of interest between timesteps is done by choosing the minimum distance between two clouds. The distance function can be formulated in different ways, e.g. speed needed for the cloud to move from one point to another.

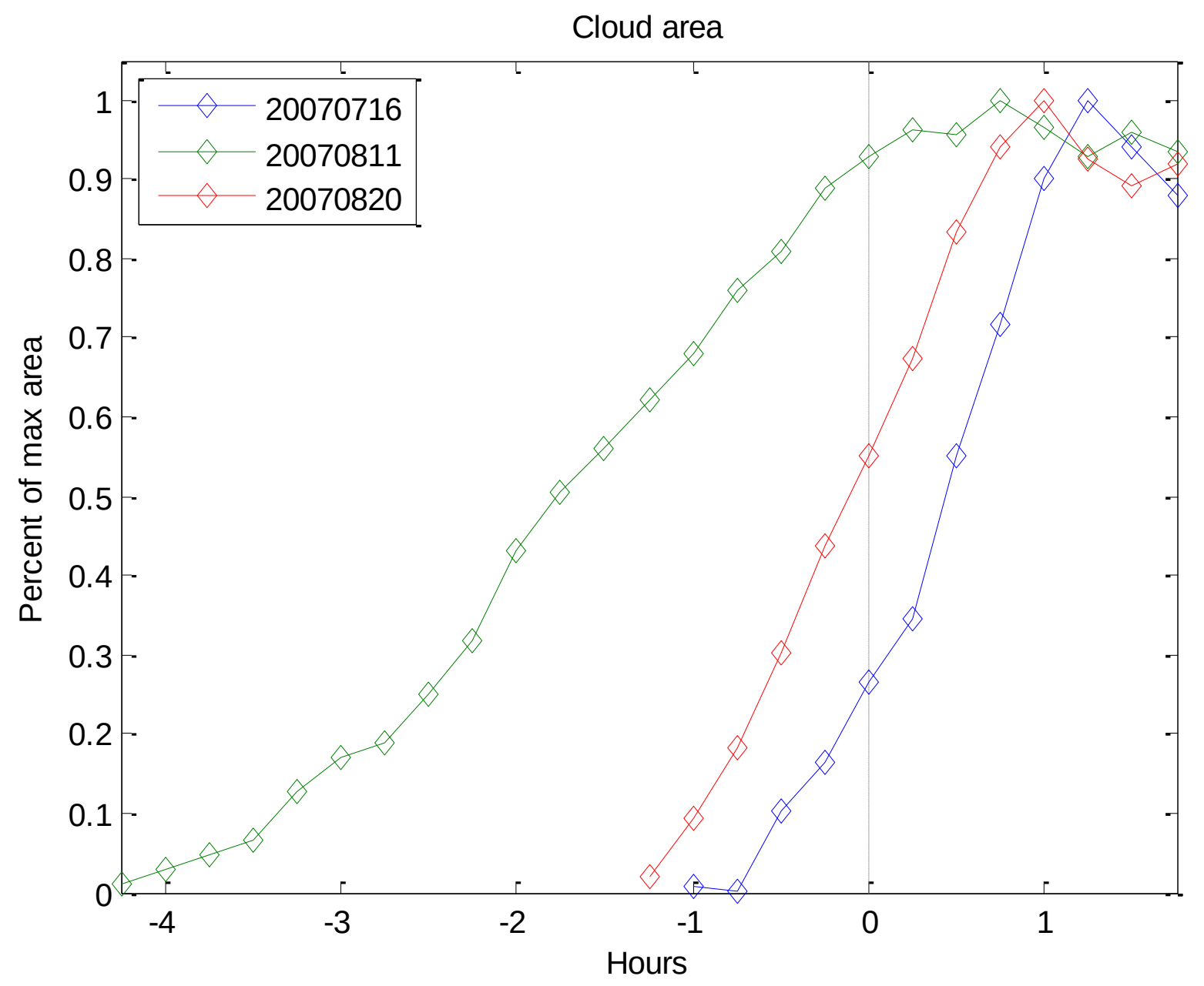
$$i^\star = \underset{i}{\operatorname{argmin}}\{\mathcal{D}_i\} \quad i \in [1, N_{p-1}]$$

A cloud can also terminate, i.e. if the minimum possible distance is larger than a chosen termination value, the tracking is stopped.

$$\text{stop?} = \mathcal{D}_{i^\star} > \mathcal{T}$$

For a speed distance function, a termination criterium could be an allowable speed of 100 km/hr.





When clouds are tracked properly, features can be collected easily. Features can include :

- Spectral signature
- Neighbourhood
- Area, speed, shape
- …

Future work

- This work is part of a master's thesis. The remainder of the thesis will concern probabilistic prediction of convective cloud severity and movement.
- Methods will include the use of dictionaries of discriminative image patches to recognize patterns of developing cumulonimbi.

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