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Assimilation of Cloud-affected Radiances in Deep Convection
A Case Study

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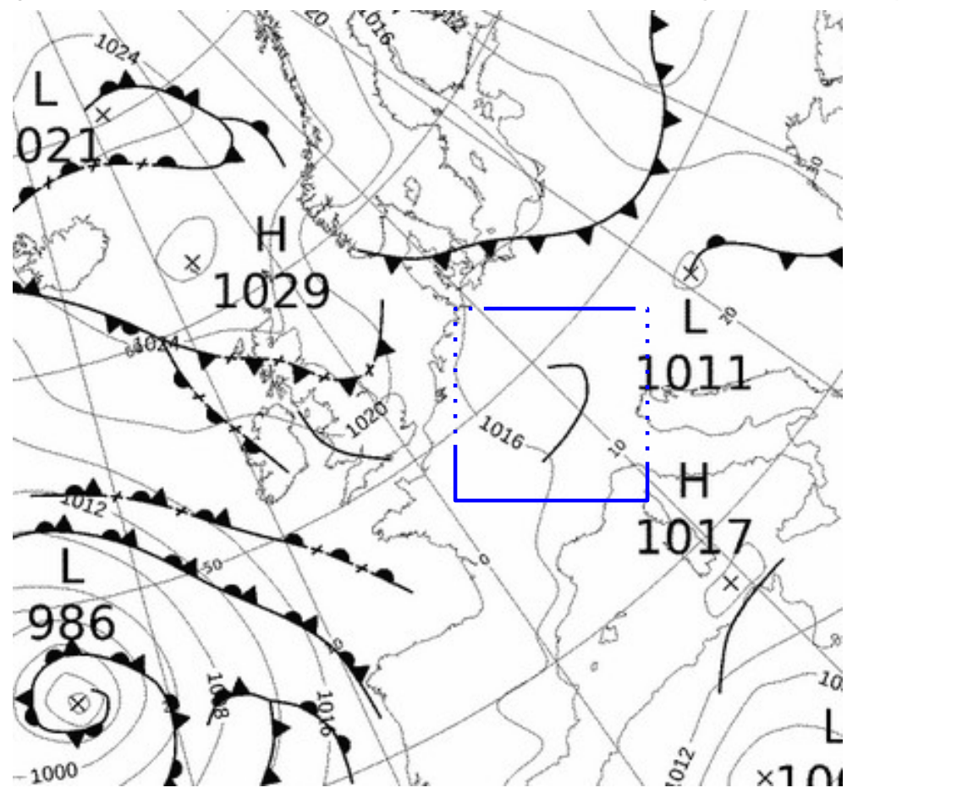
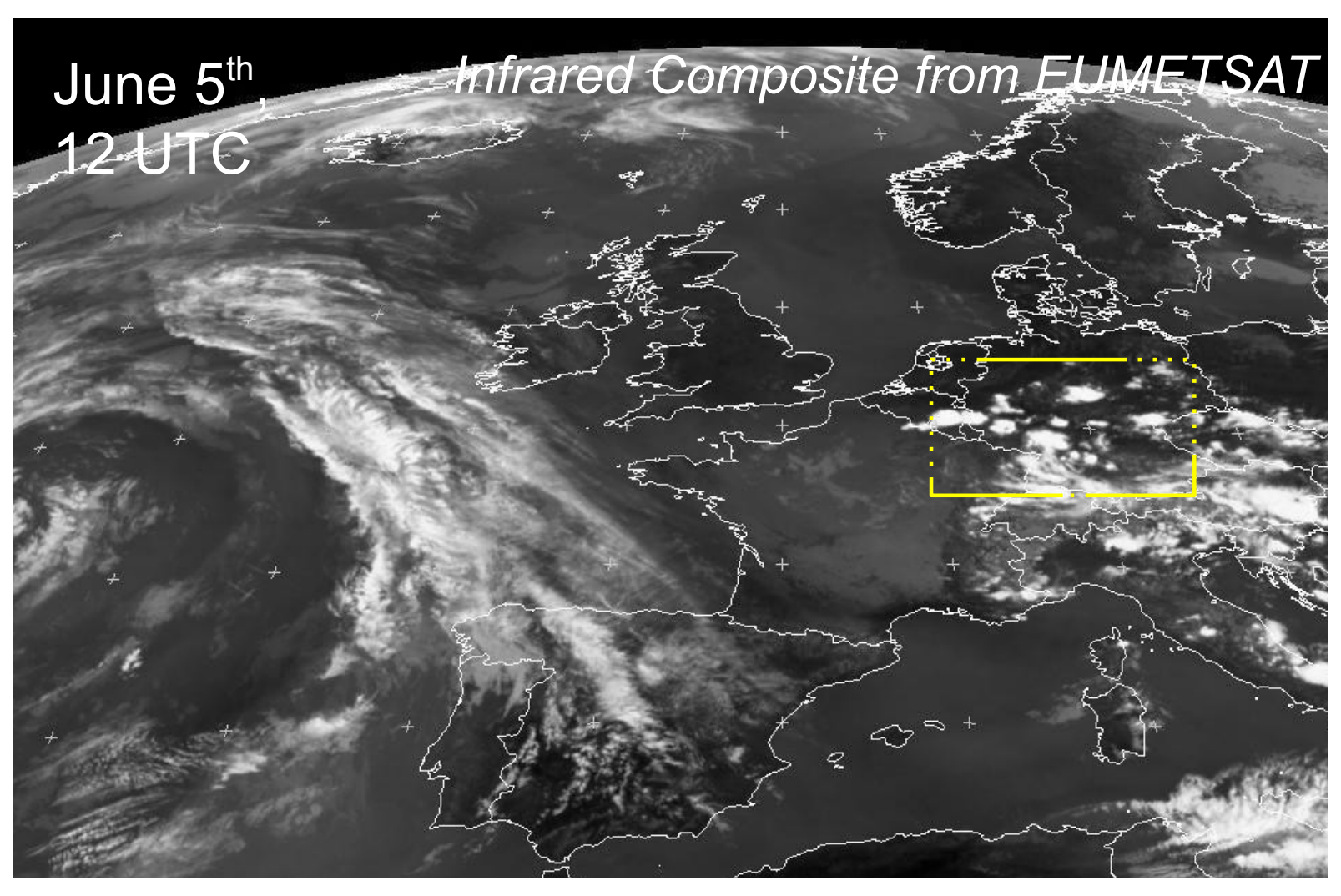
Moderate & Severe Convection during the Summer of 2016

Efficient weather **forecasts** at the **convective time scale** are especially important for severe weather situations. A large number of flash floods, thunderstorms and **severe weather** events occurred over central Europe during the summer months of 2016 with CAPE values > 2500 J/kg. We aim to improve the prediction of such events in forecasts by assimilating cloud-affected radiances with COSMO-Kenda.

Synoptic Chart from June 5th, early morning



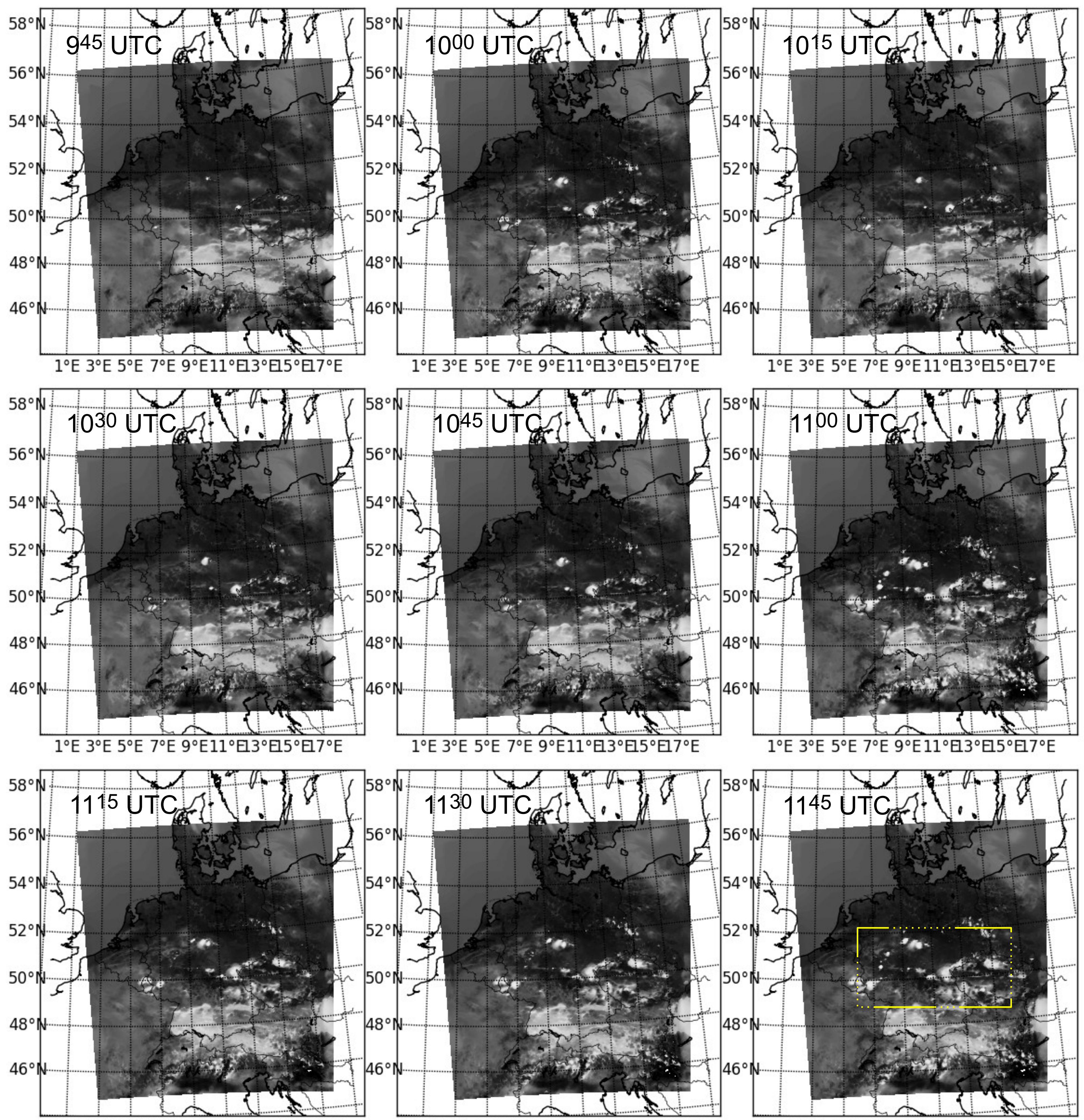
Locally unstable airmass over central Europe



Moderate convection occurred at multiple scales around noon

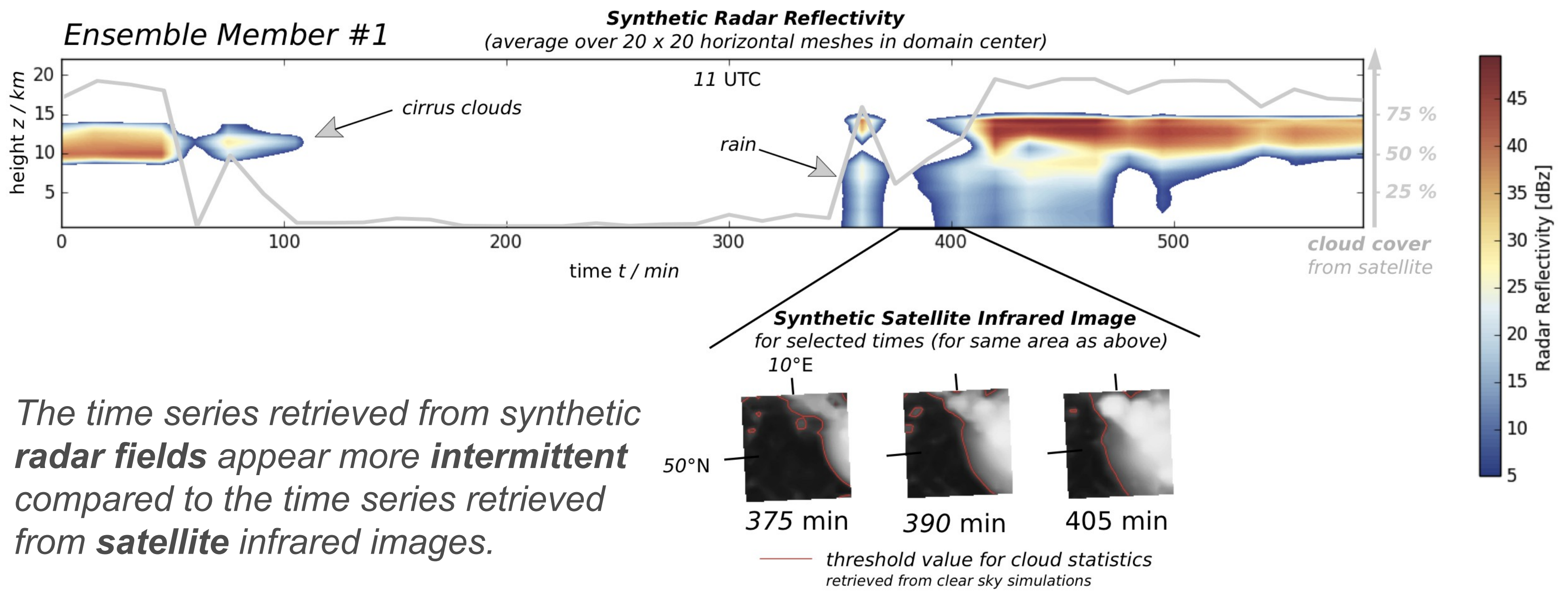
One day of the summer 2016 period is especially interesting in terms of assimilating convective clouds form the onset of convection to the evolution of severe thunderstorm clouds.

Synthetic Infrared Satellite Images with COSMO-Kenda



We simulate synthetic satellite infrared images for the morning hours of June 5th for each ensemble member (here, #1). Moderate convection begins to evolve after 9 UTC. The instantaneous satellite images reveal the multiscale structure of such cloud fields.

Hovmoeller Diagram of Synthetic Radar & Infrared Satellite Data

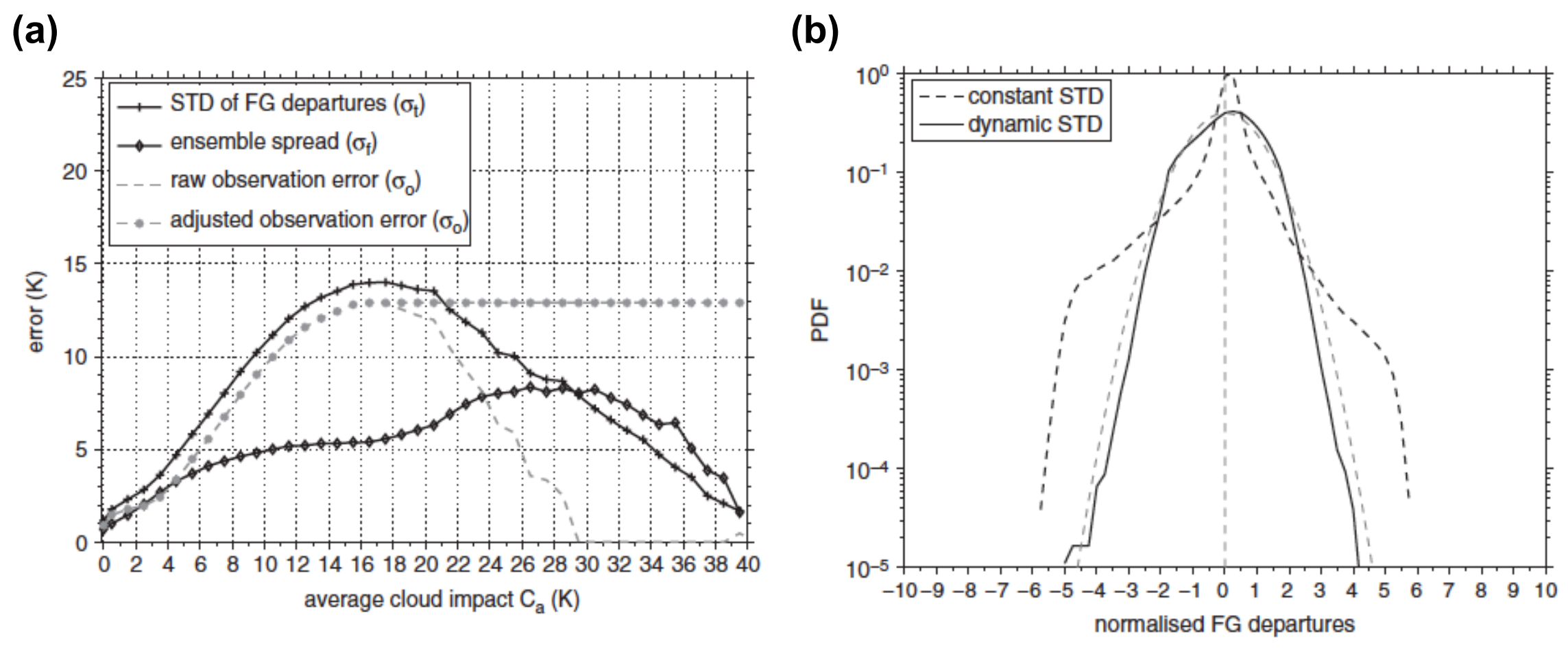


The time series retrieved from synthetic ***radar fields*** *appear more* ***intermittent*** *compared to the time series retrieved from* ***satellite*** *infrared images.*

We aim to combine both: radar & satellite data assimilation.

Dynamic Error Model

*Cloud-affected radiances induce large first guess (FG) departure errors σ_f (1), e.g., during typical convective flow scenarios. The presence of clouds can be a cause with variations of the brightness temperature by 10 K at the convective scale. A climatology (**a**) of the cloud impact C_a (2) forms part of a dynamic error model (Harnisch et al. 2016). With the error model for FG departures, the probability distribution can be transformed to a more Gaussian shape (**b**) for efficient data assimilation of cloud-affected radiances.*



Harnisch, F., M. Weissmann, and Á. Periáñez. *"Error model for the assimilation of cloud - affected infrared satellite observations in an ensemble data assimilation system."* Quarterly Journal of the Royal Meteorological Society 142 (2016): 1797-1808.

(1) $$\sigma_f^2=(k-1)^{-1}\sum_{i=1}^{k}\left(BT_x^i-\overline{BT_x}\right)^2,$$

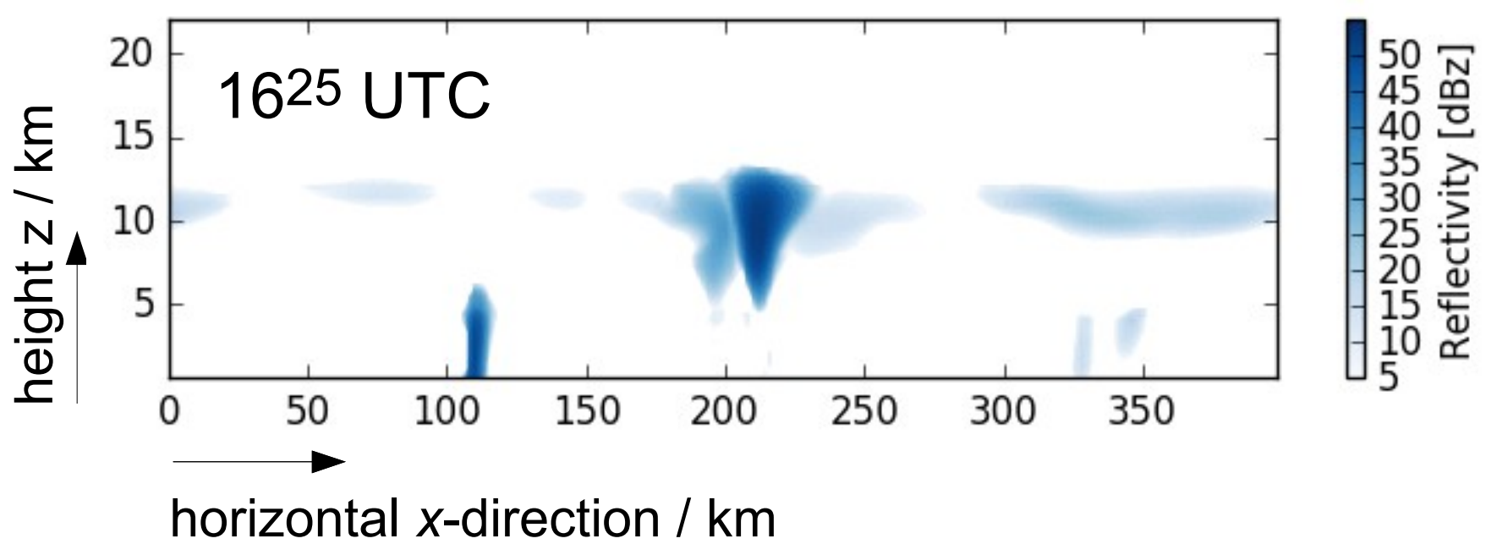
where k indicates the ensemble size, BT_x is a model equivalent brightness temperature and the overbar symbolizes the ensemble mean

(2) $$C_a=(C_x+C_y)/2,$$
$$C_x=max\left(0,BT_0-BT_x\right),$$
$$C_y=max\left(0,BT_0-\left(BT_y-BC\right)\right),$$

where BT_0 is a limiting brightness temperature, BT_y is the measured value and BC is a bias correction.

Idealized Case Study with COSMO-KENDA Sofia

Synthetic Radar Field (Vertical Slice)



Evolving storms from **13 UTC** to **21 UTC** with a 5 min resolution appear on the Radar reflectivity field at y=0.

The storms **intensify** as low clouds after the **onset** of convection.

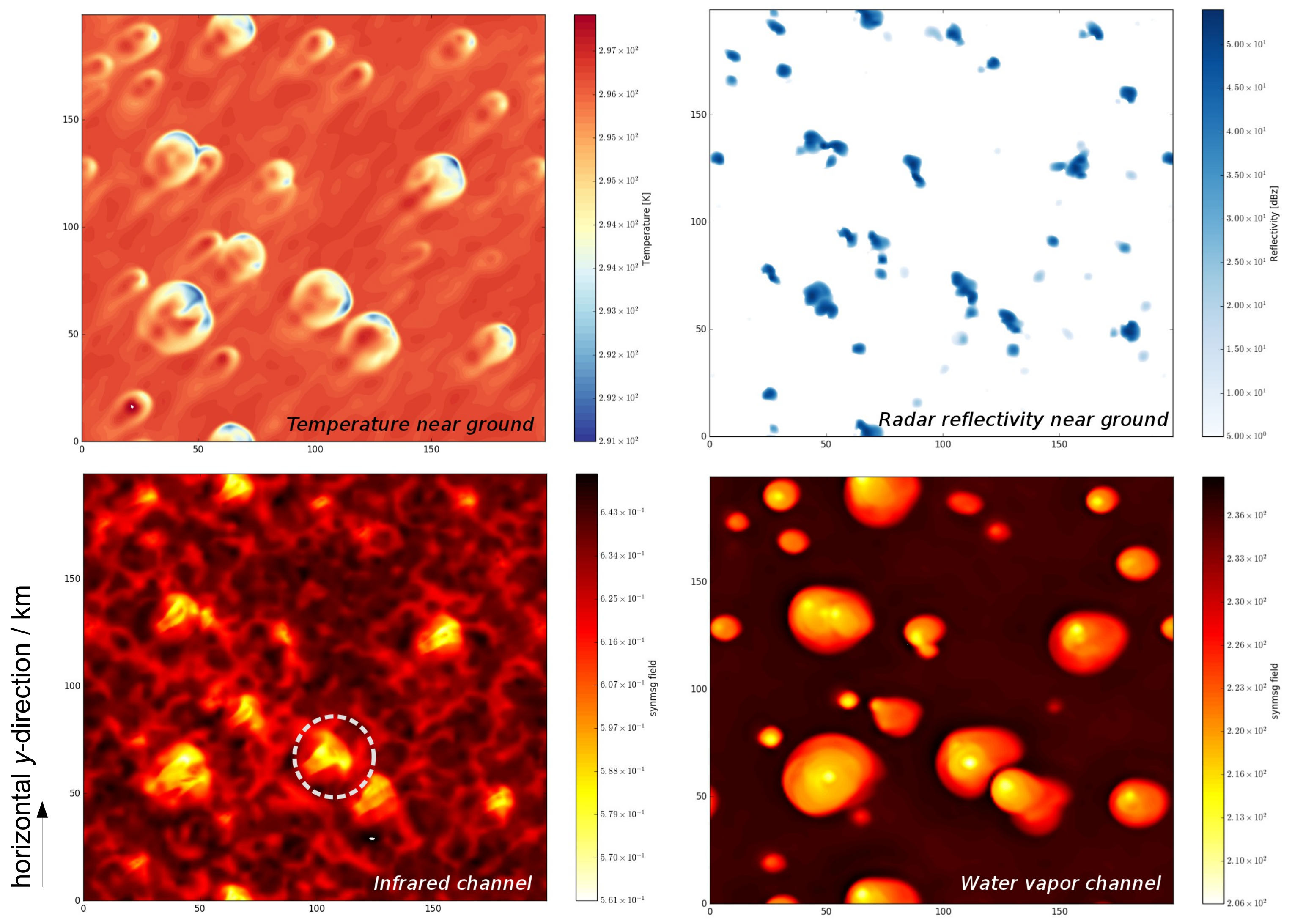
At later times, the **storm forms a cirrus anvil aloft**.

Data Assimilation Configuration

Initial *U(z), V(z), θ(z), ...* profile from Radiosonde (**Payerne**, Switzerland at 12 UTC, July 20th 2007)
Cyclic boundary conditions
Integration over ***15*** **h** – full output every *5* min
(n, m, l) = (200, 200, 50)
The increments *dx* and *dy* are ≈ **2 km**. The model levels *dz* vary from ***100*** **m** at the surface to **800 m** at domain top. Overall, *(Lx, Ly, Lz) corresponds to (394* km, *394* km, *22* km*)*
Timestep *dt* = *6* s, can be increased to *12* s, *24* s
Follows previous study by **Lange & Craig (2014)**
Typical runtime is *12* h for *15* h with ***40*** **Ensemble members** for the COSMO simulation and ≈ *4* h for the LETKF
… similar idealized configuration as for talk given by Kevin Bachmann (2017)

Horizontal Structure of Flow Fields

(Horizontal Slices of Temperature, Radar, Infrared- & Water Vapor Satellite fields)



Areas can be identified in the synthetic satellite infrared image (dashed white circle) correlating with cold pools near the ground. The synthetic water vapor satellite image appears more laminar.

Objectives & Goals

Why do we choose Radiation Fields for assimilation?

- **Relative early coherent** and strong signal, e.g., compared to radar observations
- \> **6000 measurements** every hour in case study
- The satellite measures radiation at **suitable spatial (≈ km)** and **temporal (15 min) resolution**.

What can we gain by assimilating the Infrared Satellite Images

- for **short term forecasting** (≈ *2-12* h) ?
- in order to characterize the **uncertainty** of the whole ensemble ?
- We aim to identify the **limits** of predictability of the convective systems in the idealized case.

What is the most efficient way to assimilate Cloud Measurements?

- **Direct assimilation** of the measured brightness temperatures
- **Cloud structure**, e.g., average cloud cover $<C(x,y)>_{Area}$, cloud displacement & amplitude score $DAS(x_0,y_0)$, fractal dimension D_H
- **Temporal derivative** of brightness temperature, e.g., ∂_t BT(x_0, y_0)

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