Life cycle analysis of convective cells for Nowcasting purposes considering atmospheric environment conditions

Karlsruhe Institute of Technology

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Bundesministerium für Verkehr und digitale Infrastruktur

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Overview

The representation of the expected near-future life cycle of convective cells in state-of-the-art Nowcasting procedures has not reached a satisfying state yet. Whereas the future cell path can already be extrapolated quite accurately, cell intensity and extent tendencies are scarcely well incorporated (e.g., Wapler et al. 2017).

From a warning and precaution perspective, details about the cell evolution and its associated potential threats are desirable to know with a preferably long lead time. The goal of this project is to develop a sophisticated Nowcasting method for the probabilistic estimation of the life cycle of (already detected) cells, which takes the cell history as well as proper atmospheric parameters into account.

Life cycle information has been gained based on statistical analyses of historical convective cells tracked by the DWD Nowcasting algorithm KONRAD. High-resolution COSMO assimilation analyses from Numerical Weather Prediction (NWP) have been used to calculate several convective indices and other relevant meteorological quantities. A combined data set of cell life cycles and the prevailing atmospheric conditions has been created for the summer half-years 2011-2016.

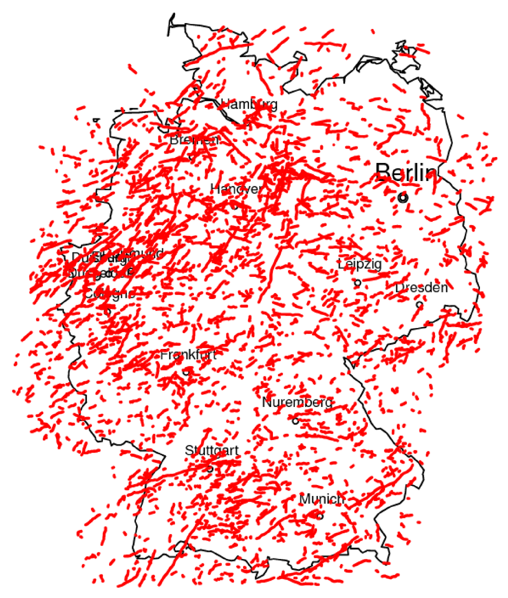
Recent analyses of the combined data set reveal, for example, that environment parameters known to be conducive for convection and the development of intense thunderstorms also promote longer lifetimes and larger cell extents on average.

Data and Methodology

Data basis (2011-2016)

- ✓ 6 summer half-years (April – September)
- ✓ 38577 KONRAD cell life cycles (5 min resolution)
- ✓ COSMO-EU assimilation analyses (1 h, 7 x 7 km², 41 vertical levels) used for calculation of more than 50 environment parameters:
  - Storm relative helicity, deep layer shear, …
  - Lifted indices, lapse rates, $\Delta\theta_e$, CAPE, …
  - Precipitable water, dewpoints, …
  - SWEAT, supercell composite parameter, …

Filtered KONRAD cell life cycles



Example: 27 May – 26 June 2016

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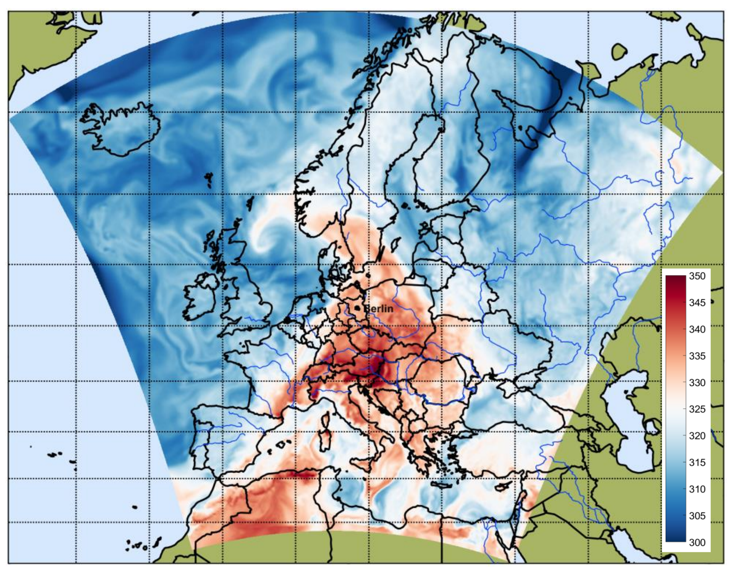
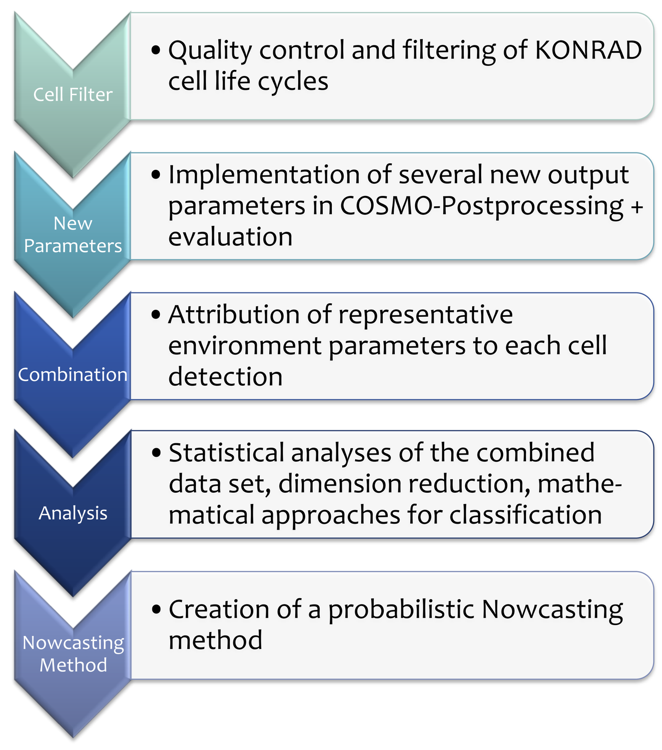
(New) COSMO-EU environment parameters



Example: θ_e @ 850 hPa (in K), 28 July 2013, 15 UTC



Results

Statistical analyses of the combined life cycle data set

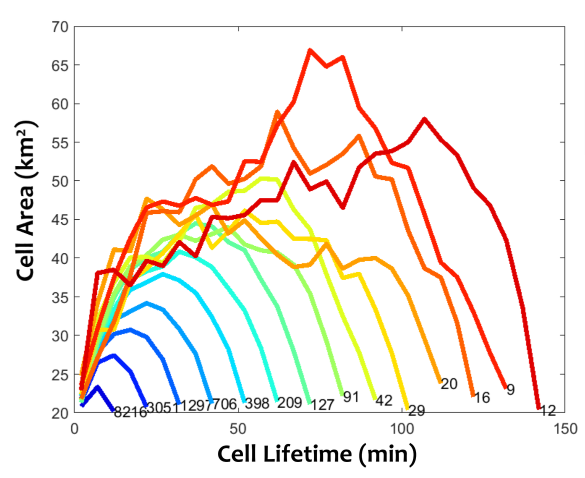


Figure 1: Time evolution of cell area of convective cells, averaged over all cells reaching a specific lifetime (colour-coded).

Mean cell area evolution has parabola shape.

The data set (38577 cells) represents best isolated convective cells with short detection lifetime (LT).

LT < 15 min:	60.8 %
15 min < LT < 30 min:	25.6 %
30 min < LT < 60 min:	10.7 %
LT > 60 min:	2.8 %

Cells occur in a variety of atmospheric conditions. Most of the cells occur at moderate 0-6 km deep layer shear (DLS) and slight latent instability. Air masses are mostly moderately warm and moist.

Cells occur in every week during the summer half-year, mainly from noon (10 UTC) until 8 pm. The last week of July (DOY ~ 208) is striking, as many cells have been observed in 2013, 2014 and 2016.

Mean cell lifetime doubles for combined high mid-tropospheric instability and DLS. Interestingly, long-lasting cells do not appear more frequently for high lapse rates alone, but their frequency doubles for high compared to low DLS values.

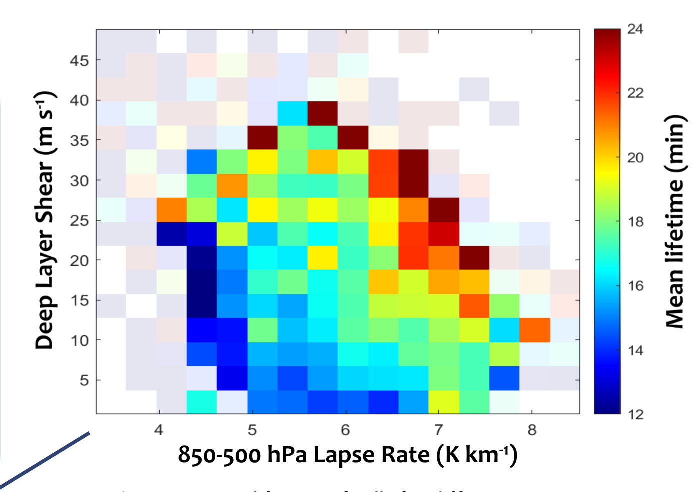


Figure 7: Mean lifetime of cells for different combinations of lapse rate and deep layer shear.

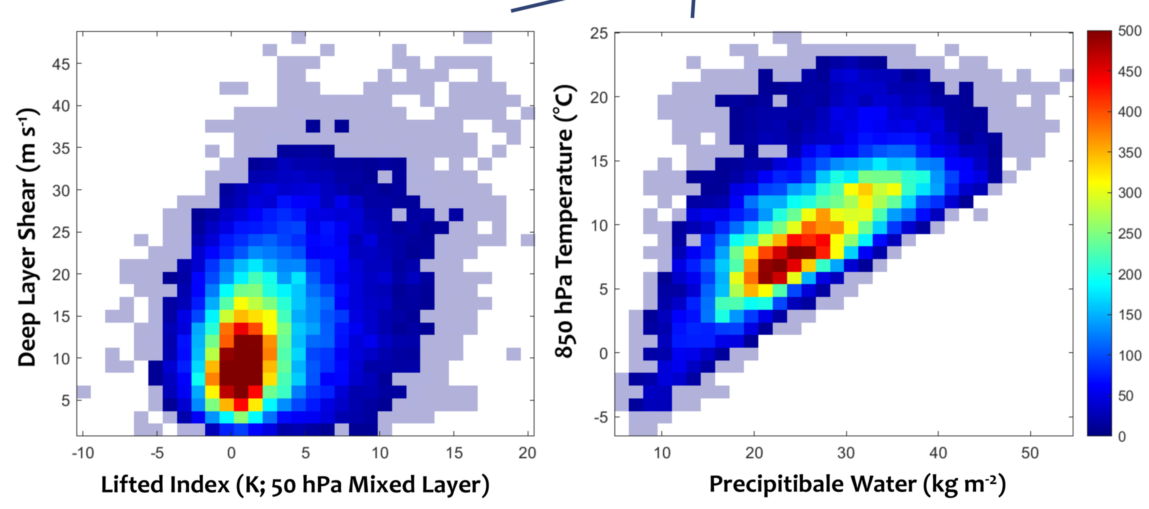


Figure 2+3: 2D frequency distribution of cells for different environment classifications.

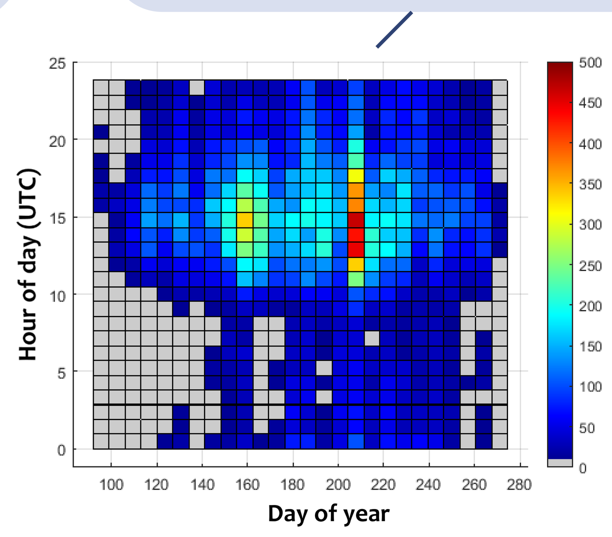


Figure 4: Temporal frequency distribution of cell life cycles.

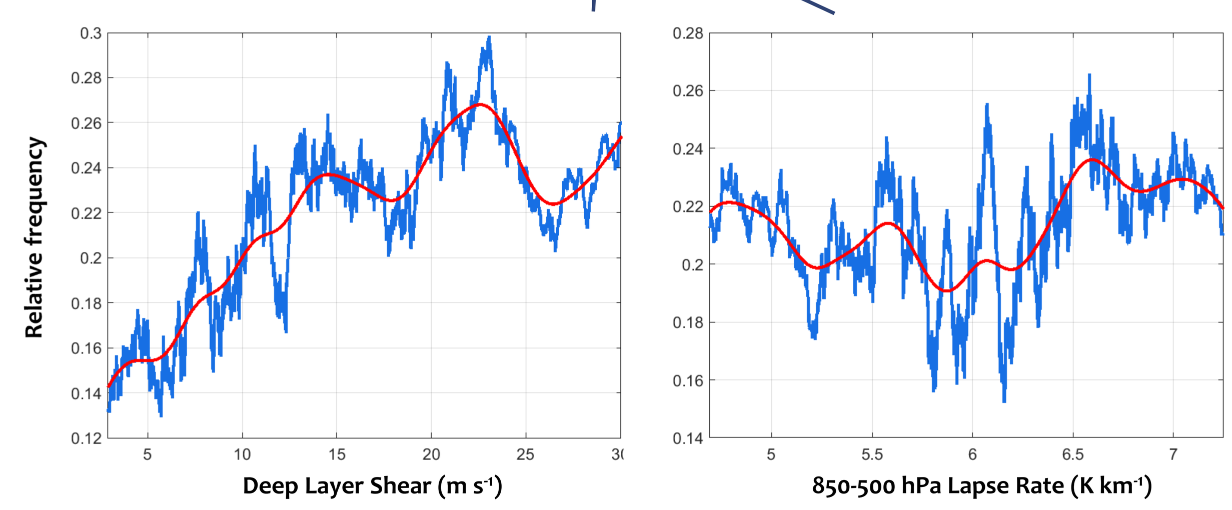


Figure 5+6: Relative frequency of long-lasting cells (LT > 60 min) compared to all cells lasting at least 30 min.

Summary

Main conclusions

- ✓ Investigation of cell life cycles gives simplified life-cycle parabola model, but variability is very high (small signal-to-noise ratio)
- ✓ Combination with atmospheric environment parameters may help to reduce uncertainty: several atmospheric parameters show indications to prove beneficial for the Nowcasting of cell life cycle properties (expected lifetime, extent evolution, …), e.g. deep layer shear, which discriminates well between long- and short-lasting cells.
- ✓ Mathematical methods more advanced than methods using linear combinations of atmospheric parameters might be productive.

Next steps

- ❖ Further intense statistical analyses of the combined data set
- ❖ Investigation of multivariate classification methods; development of statistically based dynamical, probabilistic life cycle models
- ❖ Testing the applicability of machine-learning methods such as neural networks
- ❖ Numerical test case studies for the Nowcasting of single cell life cycles using different methods and models
- ❖ Extension of the Nowcasting methods by further data sources

Literature

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