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Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Generation of an Object-based Nowcasting Ensemble

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As part of the SINFONY project, the generation of an object-based nowcasting ensemble ought to correctly assess the uncertainty of tracking, forecasting cell positions and cell evolution in a probabilistic manner.

Seamless INtegrated ForecastiNg sYstem

- Pilot project to integrate numerical weather prediction (NWP) and nowcasting techniques into a new ensemble-based forecasting system
- Focus on severe summertime convective events
- Forecast range up to 12 hours

Object Detection and Tracking at DWD

KONRAD3D (KONvektive Entwicklung in RADarprodukten)

- Deterministic object detection, tracking and forecasting system
- In-house development by Manuel Werner implemented in framework POLARA
- Has been evaluated by internal users in convective season 2019
- Uses 3D volumetric radar data (10 elevations and near surface scan)
- Adaptive thresholding for each individual 2D radar sweep
- 3D-cells obtained by grouping of 2D-cells according to overlap in 2D projection
- Object tracking and uncertainty estimates using Kalman filter for cell centroid

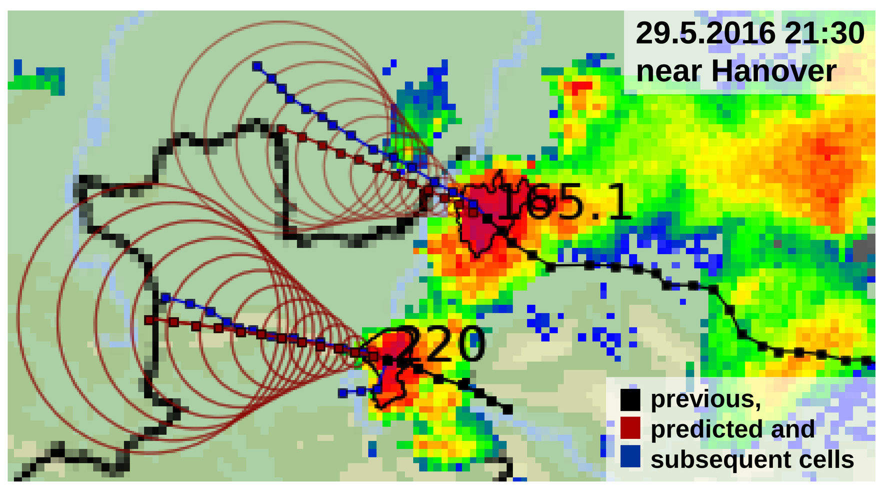

Fig 1: *KONRAD3D cells on 29 May 2016 at 21:30 near Hanover with uncertainty ellipses forecasted centroids.*

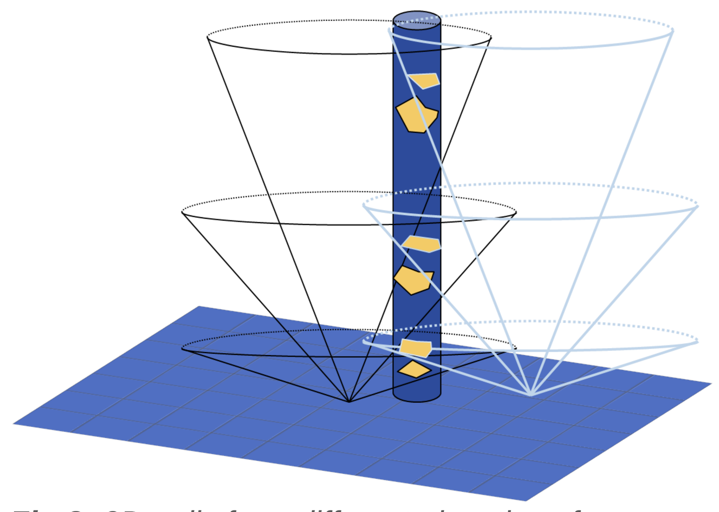

Fig 2: *2D-cells from different elevations from different radar sites grouped together to one 3D-cell.*

Object-based Nowcasting Ensemble

Advantages of Ensemble Approach

- Uncertainties from parameter variation can be captured by an ensemble of detection and tracking runs with different settings
- Non-linear cell evolution can be implemented in ensemble Kalman filter
- Ensemble Kalman filter is robust against non-linearities and thus deviations from Gaussian distributions (alternatively extended Kalman filter)
- Ensemble members as cell realizations easy to understand and reason about

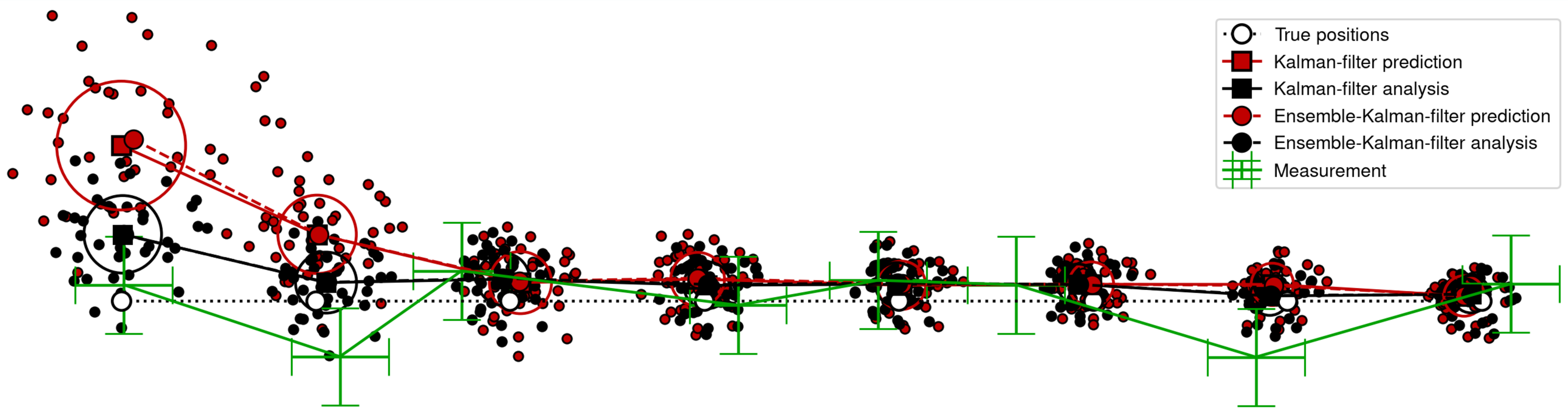

Fig. 3: *Example of tracking with ensemble Kalman filter vs. Kalman filter.*

Implementation Cell Life-Cycle

Parametric Model of Cell Evolution

- Approach from statistical life-cycle analysis by Kathrin Wapler: Cell area a versus cell age t as parabola opening down:
$$a(t) = -\frac{4a_{\max}}{\tau^2}\left(t-\frac{\tau}{2}\right)^2 + a_{\max}$$
with lifetime τ and maximum cell area $a_{\max}$.
- Initial guess of lifetime τ and maximum area $a_{\max}$ sampled from large variance Gaussian distribution
- Ensemble Kalman filter adapts parabola shape, i.e. lifetime τ and maximum area $a_{\max}$, to subsequent measurements of the cell area

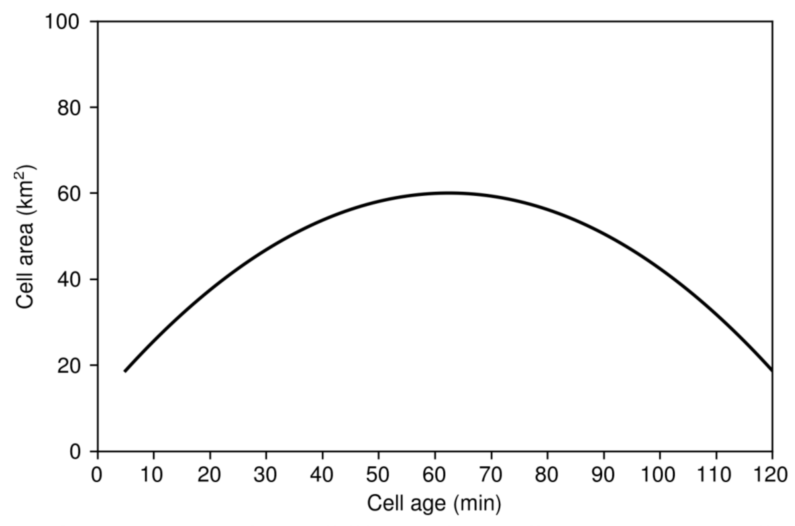

Fig. 4: *Ansatz for cell life-cycle: Cell area versus cell age as parabola opening down.*

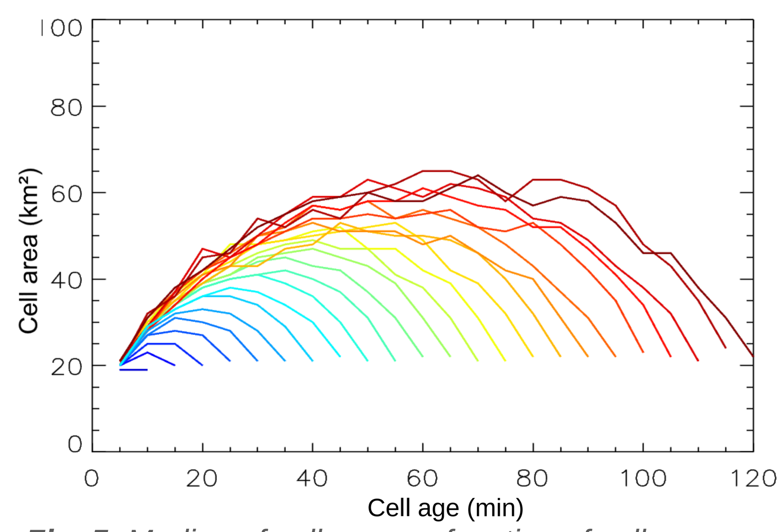

Fig. 5: *Median of cell area as function of cell age, sorted according to cell lifetime from multi-year statistics of convective events.*

Prototype Object-based Nowcasting Ensemble

Cell Detection

- Runs of KONRAD3D detections from variations of algorithm parameters (thresholds and Kalman-Filter noise) to capture the parameter uncertainty
- Clustering of detected KONRAD3D cells
- Cell cluster centroid and its variance from mean and variance of single KONRAD3D detections, respectively.

Ensemble Generation

- Stochastic ensemble generation for every cell cluster
- Application of ensemble transform Kalman filter
- Currently constant velocity model for cell-cluster centroid motion
- KONRAD3D cell cluster used as measurement

Outlook

- Implementation of prototype in C++-framework POLARA
- Consider other properties than cell size for life-cycle modeling
- Include data from numerical weather prediction
- Improve handling of cell splits and merges
- Tuning and verification

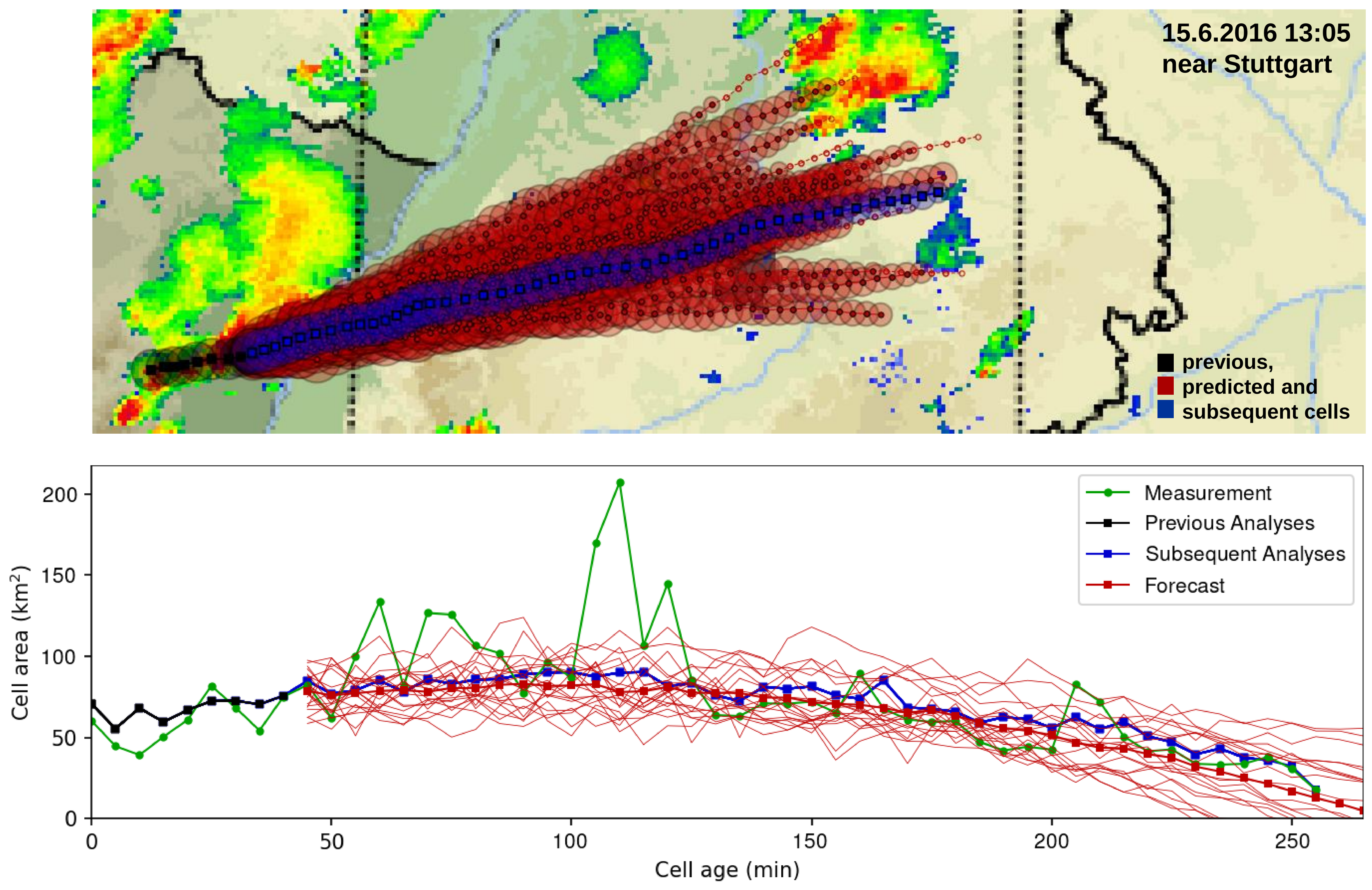

Fig. 6: (Top) Nowcasting ensemble of a convective cell on 15 June 2016 at 13:05 near Stuttgart. Ellipses represent the covered area and dots the cell centroid. Unfilled dots on dashed lines indicate the continued track of a dissipated cell. (Bottom) Nowcasting ensemble of the cell area versus cell age at the same reference time.

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