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Deutscher Wetterdienst
Wetter und Klima aus einer Hand

SINFONY, the seamless combination of Nowcasting and NWP ensembles for storm-scale convective forecasting

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At Deutscher Wetterdienst (DWD), the pilot project SINFONY (Seamless INtegrated FOrecastiNg sYstem) has been set up in 2017 to develop a seamless ensemble prediction system for convective-scale forecasting with forecast ranges of up to 12 hours, which integrates nowcasting techniques with numerical model prediction (NWP) in a more or less seamless way. The focus is on severe summerly convective events with associated hazards such as heavy precipitation, hail and wind gusts.

Basis: Current operational setup at DWD

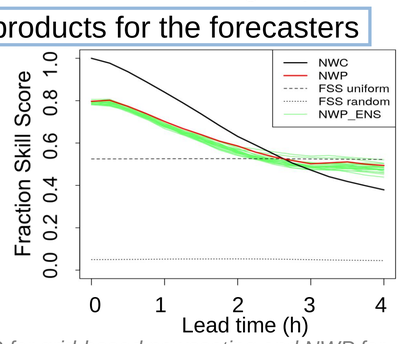
NWP ensemble system
- COSMO-D2-EPS (transition to ICON-LAM-EPS in preparation)
- Data assimilation: KENDA (LETKF)
- Radar observations used only for Latent Heat Nugding (LHN)
- Every 3 h; forecast range 27 h
- Available ~ 1:40 h after initialisation

Nowcasting
- Based on 2D composites (1 x 1 km) of radar reflectivity (17 radar stations)
- Grid-based: optical flow technique for motion vectors; linear extrapolation
- Object-based: cell detection & tracking with KONRAD, threshold: 46 dBZ
- Every 5min; forecast range up to 2 h

Mainly separated methods, only few common products for the forecasters

Comparative verification
- First 2 hours mainly covered by nowcasting
- NWP reaches quality of nowcasting after 2½ - 3 hours

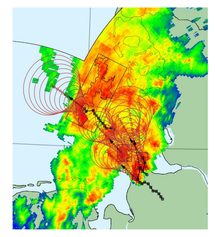
Goal
- Separate enhancements to both methods
- Combination and mutual information exchange



FSS for grid-based nowcasting and NWP for 25/05-08/06/2016; threshold: 25 dBZ, box: 33 km

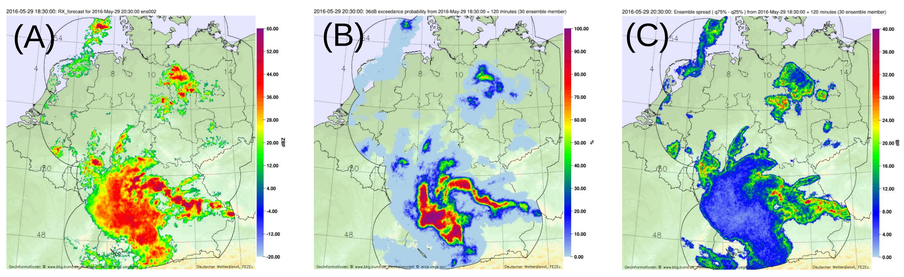
Nowcasting in SINFONY

KONRAD3D
- Deterministic detection, tracking and forecasting of convective cells (objects)
- 3D volumetric radar data (10 elevations + near-surface scan)
- Object tracking and uncertainty estimates using Kalman filter
- Developed within the software framework POLARA (Polarimetric Radar Algorithms)



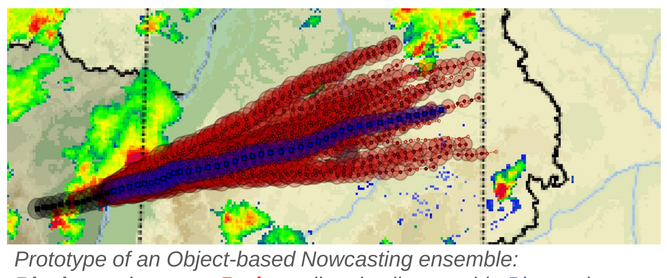
Cell tracks with uncertainty estimate using Kalman filter

Grid-based Nowcasting ensemble
- STEPS approach: Scale-dependent precipitation extrapolation taking into account Lagrangian auto-correlation perturbed by correlated noise



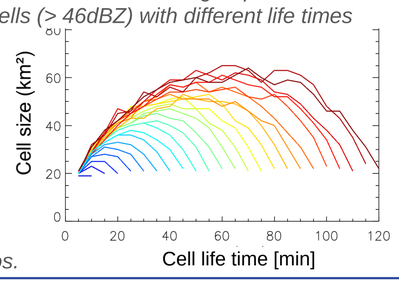
Forecasted reflectivity (2h forecast) in a nowcasting ensemble with 30 members generated using the STEPS approach:
***A)** One of the members*
***B)** 36 dBZ exceedance probability.*
***C)** Ensemble spread using inter-quartile range.*

Object-based Nowcasting ensemble
- Variation of algorithm parameters in cell detection, clustering of detected cells
- Stochastic ensemble generation for every cell cluster
- Cell evolution based on empirical life-cycle data and Ensemble Kalman Filter
- First prototype: ensemble of parabolas with different amplitudes and widths



Prototype of an Object-based Nowcasting ensemble:
***Black:** previous pos. **Red:** predicted cell ensemble Blue: subsequent pos.*

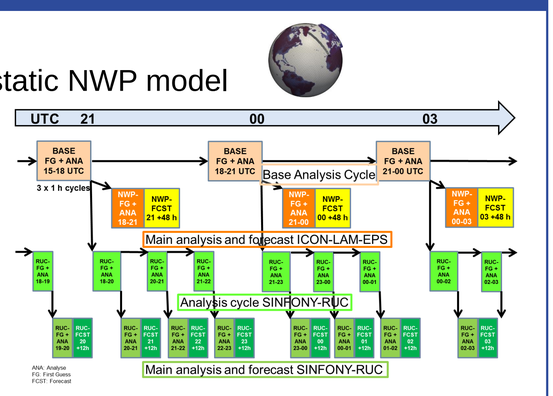
Cell size over time for groups of convective cells (> 46dBZ) with different life times



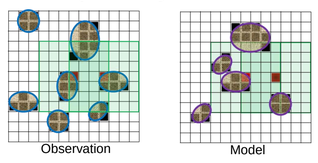
Numerical Weather Prediction in SINFONY

Based on new ICON model
- Newly developed ICOsahedral Nonhydrostatic NWP model
- Limited area mode ICON-LAM

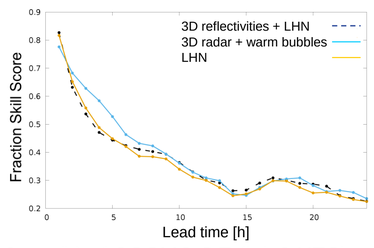
Rapid Update Cycle (RUC)
- 40 members
- Hourly update
- Forecast range up to +12 h
- Available ~ 0:40 h after initialisation



Data assimilation
- Assimilation of radar data
  - 3D reflectivities and radial winds
    - systematic studies ongoing; positive impact
  - Detected and tracked convective objects: texture assimilation (no object matching)

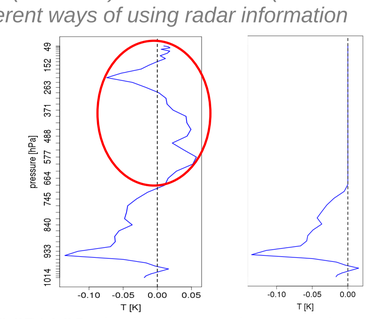


Sketch of the basic idea of texture assimilation



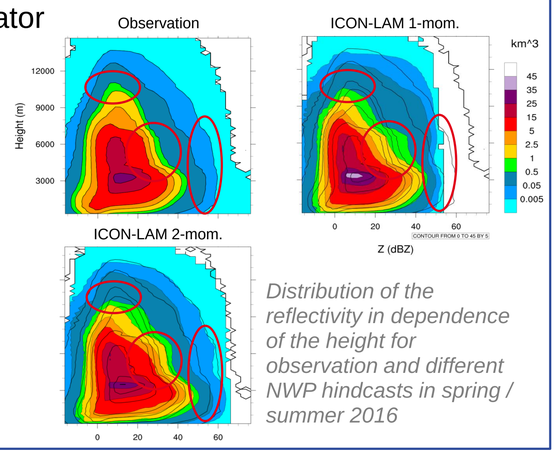
FSS (1.0 mm/h) of COSMO-DE (init 6 UTC) with different ways of using radar information

- Assimilation of SEVIRI-VIS satellite data
  - Visible range (0.6 µm), to identify low clouds
  - Improvements in moisture fields, cloud cover, and convective precipitation
  - Present work: Vertical localization to avoid spurious analysis increments
- Assimilation of lightning flash density, using Lightning Potential Index as forward operator



SEVIRI-VIS single observation experiment without (left) and with vertical localization (right)

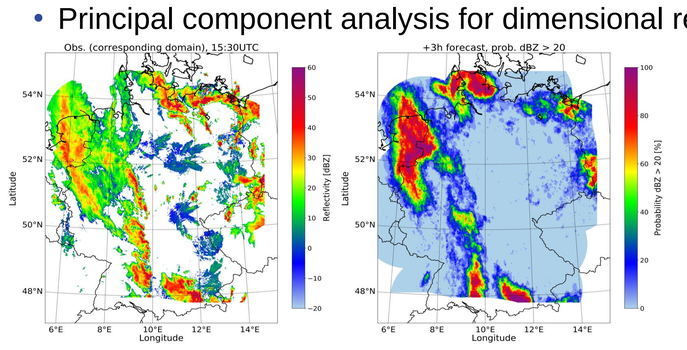
Model extensions
- Radar forward operator EMVORADO
- Warm bubbles to trigger convection (using radar information)
  - Positive impact for higher reflectivities
- Cloud physics: Two-moment scheme
  - Improved reflectivity-based scores in model forecasts for high reflectivities compared to one-moment scheme



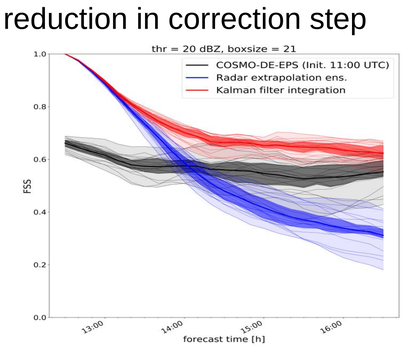
Distribution of the reflectivity in dependence of the height for observation and different NWP hindcasts in spring / summer 2016

Combine Nowcasting ensemble and NWP-EPS

Grid-based combination
- STEPS-approach combined with Ensemble Kalman filter **(Nerini et al., 2019)**
  - Nowcasting ensemble is iteratively corrected towards the NWP ensemble
  - STEPS-Nowcasting ensemble generation in prediction step
  - Principal component analysis for dimensional reduction in correction step



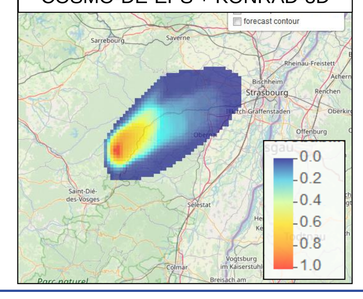
Radar observations of 25/06/2016, 15:30 UTC (left) and 3 h forecast (init 12:30 UTC) of the probability for exceeding 20 dBZ in the combined ensemble (right).



FSS over forecast time on 25/06/2016 (20 dBZ, box: 21 km) for COSMO-DE-EPS (init 11:00 UTC, black), and 12:30 UTC init of the Nowcasting ensemble (blue) and combination (red)

Object-based combination
- Detection of cells in both ensembles using identical methods (KONRAD3D)
- Spatial clustering of simulated cells (“DB scan”)
- Selection of simulated cells from the "most reasonnable" cluster (k-means) based on cell attributes (size, intensity, distance) for each observed cell
- Shifting of selected simulated cells to the location of the observed cells incl. forecast trajectory
- Probability products based on cell overlaps

27.05.2016 13:00 UTC (0 - 2 h)
Probability that observed cell will pass through a given location
COSMO-DE-EPS + KONRAD-3D



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