Thunderstorm forecasting by a fuzzy logic combination of model data

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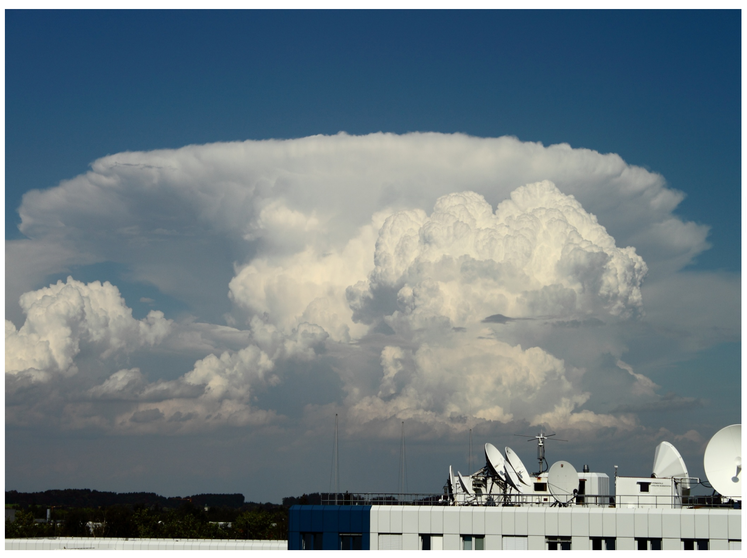
Phenomenology of thunderstorms

Storm cell lies directly above Munich airport about ca. 13:54 UTC at 19/08/2011
Photo: Martin Köhler



Hazards:

- heavy rain
- hail
- lightning strikes
- turbulence
- wind shear, downdrafts
- tornados

Effects, e.g. on air traffic:

- loss of safety (airport/runway, turbulence in flight)
- damage of the airplane by hail and lightning
- redirections
- cancellations
- delays (according to DFS **> 80 %** of summertime delays at Munich airport are induced by thunderstorms)

→ **Demand** for longer-range forecasts of thunderstorms

Thunderstorms are often short-lived local events → **Predictable?**

Thunderstorm prediction by usage of model data

Advantages: combination of many different data fields – long-range forecast (up to 21 h with the COSMO_DE model) – global models cover entire earth – data archive available

Disadvantages: coarse spatial & temporal resolution – parametrization of many physical processes – lack of observation data at convective scales

Thunderstorm forecast with the COSMO_DE forecast model of the DWD

Current approach: neighborhood method*

Used parameters of the COSMO_DE model:

- criterion for stability (KO – Index)
- total precipitation (last hour)
- maximum gusts on the 10 m level
- maximum ratio of freezing rain in the vertical column

Method:

- positive forecast of thunderstorms for each gridpoint in case of overriding certain thresholds of the four parameters
- definition of an isotropic, spatial-temporal environment around each gridpoint (diameter 56 km, temporal +/- 1 hour)
- division of the number of forecasted thunderstorms by the number of gridpoints in the defined environment → thunderstorm probability
- issue of the thunderstorm probability in percentage terms for each gridpoint of the COSMO_DE forecast model

* Theis et al. (2005)

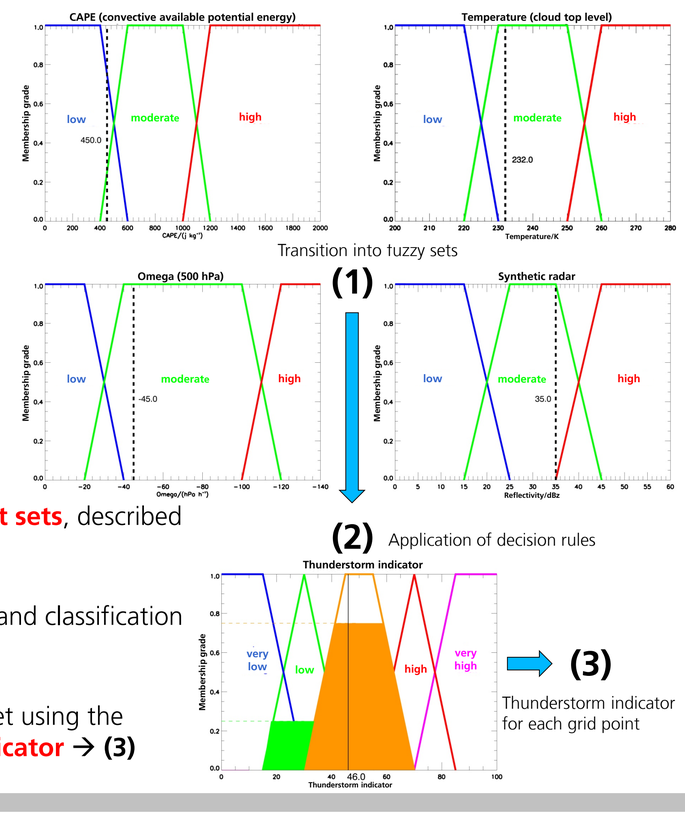
New approach: fuzzy logic

General notes on fuzzy logic:

- fuzzy logic deals with fuzzy or imprecise reasoning
- capability to translate human reasoning into mathematical decisions in a more appropriate way than binary logic
- fuzzy logic can handle the concept of partial truth

Introducing into the new fuzzy logic system:

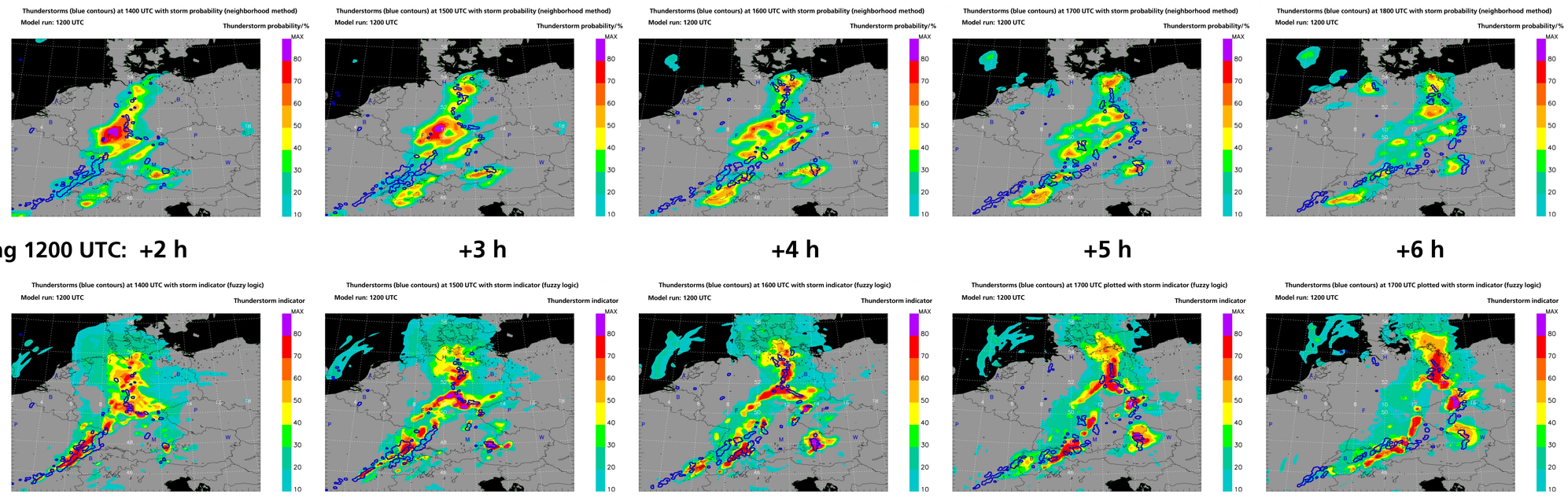
- combination of the model parameters **CAPE**, **uplift**, **synthetic radar** and **satellite data**
- **step 1:** transformation of "crisp" model parameters into **fuzzy input sets**, described by linguistic variables → **(1)**
- **step 2:** combination of fuzzy input sets with a set of **decision rules** and classification into a **fuzzy output set** → **(2)**
- **step 3:** calculation of a "crisp" output number of the fuzzy output set using the **"center of gravitiy method"** – final output is a **thunderstorm indicator** → **(3)**



Example case for a storm forecast: 22/06/2011 – model run 1200 UTC

Explanation to the figures: comparison of observed thunderstorms (blue contours) with corresponding thunderstorm forecasts of the COSMO_DE model (neighborhood method and fuzzy logic), shown as coloured surfaces.

- Neighborhood method:
- Forecast starting 1200 UTC: +2 h | +3 h | +4 h | +5 h | +6 h
- Fuzzy logic:



Conclusion: The example demonstrate that the new approach involving fuzzy logic seems to better agree with the observations. An ongoing evaluation for the whole summer period in 2012 will exhibit if this is true also in a statistical context.

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