Uncertainty Analysis of Thunderstorm Nowcasts for Utilization in Aircraft Routing

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Outline

• Thunderstorms, motivation and nowcast data used
• Methodology and results of the uncertainty analysis
• Application in weather avoidance routing
Thunderstorms

- Small scale phenomena
  - cell diameter: 5 - 50 km
  - life time: 20 - 60 min

- After generation: further life cycle and movement is in principal predictable

- Prediction of onset?
  - generation mechanisms need to be forecasted:
    - deterministic components: orography, surface convergence lines
    - stochastic components: gravity waves, temperature inhomogeneities

Motivation

approaching an event in time and space

decreasing inherent uncertainty

increasing uncertainty

remaining nowcast uncertainty

nowcast systems

lead time
Rad-TRAM nowcast system
Radar Tracking and Monitoring

• Based on radar composit with timely resolution of 5 minutes
• object-based (> 37 dBZ)
• Pyramidal image matcher
  ➢ displacement
  ➢ life cycle: growth and decay of cells

Further information:
Tafferner, A., C. Forster, 2012: Weather Nowcasting and Short Term Forecasting, in Atmospheric Physics, U. Schumann (ed.), Springer Verlag

Source: http://www.pa.op.dlr.de/MUCSOMMER/2012/
Rad-TRAM nowcasts

timely resolution: 5 minutes
horizontal resolution: 2 km

no further detection of this cell
Nowcast uncertainty determination

METHODOLOGY & RESULTS
Methodology

\[ \Delta \text{dist}_{\text{left}} \]

\[ \Delta \text{dist}_{\text{right}} \]

\[ \Delta \text{dist}_{\text{forward}} \]

\[ \Delta \text{dist}_{\text{backward}} \]

Frequency distributions

\[ \Delta = \text{obs} - \text{nowcast} \]
Results 20120715

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Increase of uncertainty with lead time

60 min  LEFT  lead time  RIGHT

17.14 km ← $P_{90,\text{abs},60\text{min}}$ → 18.24 km

35 min

1.98 km ← $P_{90,\text{abs},60\text{min}}$ → 3.79 km

observation is always larger than nowcast in direction right
Increase of uncertainty with lead time

- 60 min: LEFT 17.14 km, RIGHT 18.24 km
- 35 min: LEFT 1.98 km, RIGHT 3.79 km
- 5 min: LEFT 1.98 km, RIGHT 3.79 km
80% intervals in all directions

FORWARD, 35 min

nowcast time: 35 min

RIGHT, 35 min

LEFT, 35 min

BACKWARD, 35 min

10th and 90th percentile

mean uncertainty

100 km
80 % intervals in all directions

moving direction  5 min

forward

left

right

backward

nowcast time: 10 min

nowcast time: 20 min

nowcast time: 25 min

nowcast time: 30 min

nowcast time: 35 min

nowcast time: 40 min

nowcast time: 45 min

nowcast time: 50 min

nowcast time: 55 min

nowcast time: 60 min

50 km
Differing results for different days/situations

July 15th, 2012

nowcast time: 35 min

July 15th & 10th, 2012

nowcast time: 35 min

No characteristic distribution on right extent!
Separate uncertainty analysis – propagation error

No systematic misplacement!

Gravity center displacement (rel. to obs)

- 5 min
- 35 min
- 60 min

Separate uncertainty analysis – propagation error
Separate uncertainty analysis – extension error

Relative small uncertainties

\( P_{90,\text{rel, right, 60min}} = 5.87 \text{ km} \)

Extension difference in direction RIGHT

- 5 min
- 35 min
- 60 min
Correlated distances in separate analysis

Regular growth or shrinkage on both sides

Equivalent correlation between FORWARD and BACKWARD deviations
Integrated uncertainty development

Regressions:

\[ u_{90, \text{left}}(t) = -0.0023 \cdot t^2 + 0.4275 \cdot t - 0.0921 \]
\[ u_{90, \text{right}}(t) = -0.0021 \cdot t^2 + 0.3908 \cdot t + 2.1487 \]
\[ u_{95, \text{left}}(t) = -0.0029 \cdot t^2 + 0.4784 \cdot t + 2.4620 \]
\[ u_{95, \text{right}}(t) = -0.0039 \cdot t^2 + 0.5162 \cdot t + 4.0876. \]
Integrated uncertainty development

Uncertainty development in absolute mode

Larger 90th percentiles for directions

BACKWARD and RIGHT

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Nowcast uncertainty determination

APPLICATION IN WEATHER AVOIDANCE ROUTING
Add uncertainty margin around a nowcast

Uncertainty development in absolute mode

- 35 minutes nowcast of a point cell
- 90th percentile uncertainty margin

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Add uncertainty margin around a nowcast

Uncertainty development in absolute mode

- BACKWARD
- LEFT
- FORWARD
- RIGHT

~ 1.3°

12 km

525 km at 480kt

Additional heading change to that forced by the nowcasted cells extent.
Conclusion I

• Spatial uncertainty determination method of nowcast cells considering extent and displacement
  – Isotropic behavior for both components
  – BUT: integrated uncertainty shows characteristic features

Separate view

Integral view
Conclusion II

- Spatial uncertainty determination method of nowcast cells considering extent and displacement
  - Isotropic behavior for both components
  - BUT: integrated uncertainty shows characteristic features

- Quantified rate of increasing uncertainty with lead time
Conclusion

• Spatial uncertainty determination method of nowcast cells considering extent and displacement
  – Isotropic behavior for both components
  – BUT: integrated uncertainty shows characteristic features

• Quantified rate of increasing uncertainty with lead time

• Uncertainty is even higher due to
  – new, not yet nowcasted cells
  – Other not yet considered statistics
    • dissipating cells
    • merged/splitted cells

• Further analyses on different thunderstorm situations
THANK YOU

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