IDENTIFICATION OF DEVELOPING SEVERE CONVECTIVE CELLS OVER THE ALPINE REGION BY MERGING SATELLITE, RADAR AND NWP DATA

EUMETSAT Fellowship at MeteoSwiss

L. Nisi, P. Ambrosetti, L. Clementi

36th Conference on Radar Meteorology, 20th September 2013
Severe thunderstorms in Switzerland

Domain of the Swiss Radar network:

Swiss Alps (view from 8800 ft)

View from Breckenridge (9600 ft)
**TRT (Thunderstorms Radar Tracking)**

Cell severity ranking:

- **WEAK (L1)**
- **MODERATE (L2)**
- **SEVERE (L3)**

Based on vertically integrated liquid water (VIL), 45 [dBZ] echo top and max echo [dBZ]

Legend:

- **Solid**: present position
- **Hatched**: 1 hour forecast
- **Blue vector**: cell velocity
- **White line**: past trajectory

*Hering et al., 2004*
Efficient warnings → all the elements of the chain have to be optimized, first of all the early detection of potential damaging severe thunderstorms.
**Goals**

- **What are we trying to improve?**
  - early detection of severe thunderstorm cells and nowcast their intensity evolution

- **What is the idea behind COALITION?**
  - merge selected data (radar, satellite, NWP, lightning, topography) using blending techniques packed into a heuristic model

- **What is the output?**
  - a frequent updating map (5 min) where the cells, for which the COALITION forecast shows a high probability to increase the intensity, are highlighted

- **Which are the users?**
  - weather forecasters (→warnings)
  - automatic ingest in NWC system TRT
Example: severe thunderstorms 06.08.2013

COALITION:

- Considerable cooling of the cloud top expected within the next 15 minutes (forecasted cooling > 5 °C). This doesn't mean the cell necessarily develop into a severe thunderstorm, but convection initiation is very likely to occur

- Cell’s intensity is likely to increase within the next 30 minutes (expected VIL between 15 and 22 kg/m2)

- Cell expected to develop to a severe storm within the next 30 minutes (forecasted VIL > 22 kg/m2)

TRT:

- Weak
- Moderate
- Severe
# Predictands and predictors

## Predictands (thunderstorm attributes)

- **Cloud Top Temperature and Height (CTTH)**
  - dCTT/dt and VIL are selected as identifiers of thunderstorm intensity
- **Vertically integrated liquid content (VIL)**

## Predictors (convective potentials)

<table>
<thead>
<tr>
<th>Predictors (convective potentials)</th>
<th>Description</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud Top Temperature (CTT)</td>
<td>cloud top cooling</td>
<td>e.g. Roberts and Rutledge, 2003, Zinner et al., 2008</td>
</tr>
<tr>
<td>Convection Initiation (CI)</td>
<td>cloud glaciation, cloud growth and cooling, updraft depth</td>
<td>Mecikalski et al., 2008</td>
</tr>
<tr>
<td>Conv. Av. Potential Energy (CAPE)</td>
<td>atmospheric stability</td>
<td>e.g. Doswell and Bosart, 2001</td>
</tr>
<tr>
<td>Directional Gradients (DGRAD)</td>
<td>orographic-induced invigoration</td>
<td>e.g. Pocakal et al., 2009, Saxen et al., 1999</td>
</tr>
<tr>
<td>Lightning Climatology</td>
<td>“historical information” to highlight preferred regions for thunderstorms</td>
<td>-</td>
</tr>
</tbody>
</table>
Methodology: an overview


• The COALITION methodology borrows the approach from the physics of general dynamic systems

• For analogy, the interaction of the storm attribute (predictand) with the surrounding environment (predictors), is modeled as a particle-field interacting system

• A pseudo-kinetic energy is estimated from the rate-of-change in time of attributes describing the objects (CTT or VIL, predictand)

• A pseudo-potential energy is estimated by including the evolution of the surrounding environment

• For each convective cell total energy conservation is assumed (Hamilton) over the time (i.e. no dissipation):

\[
E_{\text{tot}} = E_{\text{kin}} + E_{\text{pot}}
\]
Methodology: cell based pseudo kinetic energy

Example considering the VIL as predictand:

\[ f_k = \frac{1}{2} \cdot \left[ \frac{q_k(t_0)}{q_k(t_0)} \right]^2 \]
Methodology: energy conservation principle

\[ H(q, p, t) = \frac{p^2}{2m} - A \ast f(t)q^2 \]

\[ f \text{ (object based pseudo kin. En.)} \]

where \( \delta: g(\text{predictor}) \)

\[ \text{corr}(f_{\text{err}}, d\delta) \]

\( f_{\text{observed}} \)

\( f_{\text{extrapolated}} \)

\( f_i \)

\( f_{i-1} \)

\( f_{i-2} \)

\( t_{i-2} \)

\( t_{i-1} \)

\( t_i \)

\( E_{\text{kin}} \)

\( E_{\text{pot}} \)

Energy conservation principle
Methodology: 8 COALITION integration modules

Environment + Object ("thunderstorm") attribute

- Module 1: SAT + SAT → CTT
- Module 2: SAT + RAD → VIL
- Module 3: Lightning + RAD → VIL
- Module 4: SAT + RAD → VIL
- Module 5: NWP + RAD → VIL
- Module 6: Topography + SAT → CTT
- Module 7: Topography + RAD → VIL
- Module 8: SAT + NWP → CTT

+ other data for parallax correction, graphical visualization (…)

- Convection Initiation
- Cloud Top Temperature
- Lightning Climatology
- CAPE (conv. av. pot. en.)
- Directional Slope Gradients
- Directional Slope Gradients
- CAPE (conv. av. pot. en.)
- Cloud Top Temperature
- Vertical Integrated Liquid

Object based forecast (5-60 min) of:
- CTT
- VIL
Performance statistics

Population:
- total 80 thunderstorms (2012) analyzed:
  • 40 moderate or severe (→POD)
  • 40 weak or not detected by TRT (→FAR)

5 min leadtime:
POD: 0.92
FAR: 0.26
CSI: 0.70

20 min leadtime:
POD: 0.60
FAR: 0.44
CSI: 0.40

POD: Probability of Detection
FAR: False Alarm Ratio
CSI: Critical Success Index

<table>
<thead>
<tr>
<th>Lead-time</th>
<th>POD</th>
<th>FAR</th>
<th>CSI</th>
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<tbody>
<tr>
<td>5</td>
<td>0.925</td>
<td>0.260</td>
<td>0.698</td>
</tr>
<tr>
<td>10</td>
<td>0.800</td>
<td>0.385</td>
<td>0.533</td>
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<tr>
<td>15</td>
<td>0.725</td>
<td>0.420</td>
<td>0.475</td>
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<tr>
<td>20</td>
<td>0.600</td>
<td>0.442</td>
<td>0.406</td>
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<tr>
<td>25</td>
<td>0.375</td>
<td>0.487</td>
<td>0.276</td>
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<tr>
<td>30</td>
<td>0.225</td>
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<td>0.125</td>
<td>0.689</td>
<td>0.097</td>
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<tr>
<td>40</td>
<td>0.050</td>
<td>0.800</td>
<td>0.041</td>
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<tr>
<td>45</td>
<td>0.025</td>
<td>0.800</td>
<td>0.022</td>
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<td>50</td>
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<td>0.834</td>
<td>0.022</td>
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<tr>
<td>55</td>
<td>0.000</td>
<td>0.843</td>
<td>0.000</td>
</tr>
<tr>
<td>60</td>
<td>0.000</td>
<td>0.850</td>
<td>0.000</td>
</tr>
</tbody>
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POD = A / (A + C)
FAR = B / (A + B)
Conclusions and outlook

- COALITION is a Nowcasting system for the identification of developing severe thunderstorms
- Integrates data from MSG-RSS, radar, NWP, lightning and DHM
- Designed for the operational use, satisfies Nowcasting requests → operational at MeteoSwiss since May 2013
- Integration in a single Nowcasting system “TRT + COALITION”
  → POSTER NR. 348 (Hering et al.)
- Additional modules with other environmental parameters (low level moisture convergence, real time lightning, PV fields, ..)
- Tuning for later convection phase (decaying phase)
Acknowledgements

Thank you!

- I. Giunta (scientific support)
- R. Stuhlmann (EUMETSAT Fellowship program)
- MeteoSwiss Locarno-Monti staff, in particular:
  - M. Gaia (resources and administration)
  - A. Hering, S. Zanini and I. Sideris (scientific support)
  - M. Sassi (technical support)

- M. Koenig (scientific support)
- J. Mecikalski (Convection Initiation)
- EUMETSAT Central Application Facility (realtime and archived Meteosat data)
- SAF/Nowcasting Consortium (software and supports)