

Integration of multi-sensor nowcasting systems to improve the early detection of severe convective storms in the Alpine area

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Motivation

- In case of severe thunderstorms MeteoSwiss alerts authorities and population by means of flash-news warnings for small areas (250-300 km²), with very short lead-times (30-60 min).
- Anticipation of warnings of severe thunderstorms even of a few minutes can be crucial in regions with complex orography (Alps and pre-Alps) where flash-floods, intense hail and wind gust can cause severe damages.
- Therefore an improved early detection of intense convective cells would help the forecasters to anticipate the warnings of potentially severe thunderstorms → early warning.
- This could extend the lead-time of the flash-news severe thunderstorms warnings, moving from classical "warning on detection" towards "warning on early detection"



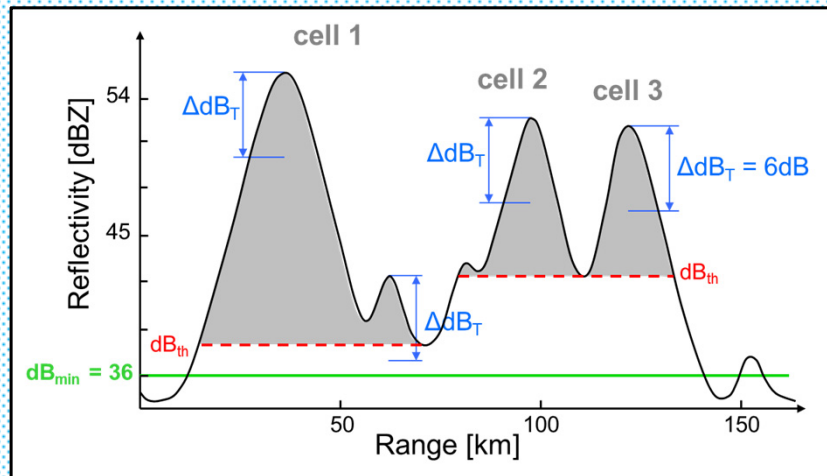
Objectives

- Current flash-warnings are mainly based on the real-time, multi-sensor nowcasting systems **TRT** (Thunderstorms Radar Tracking) and **COALITION** (Context and Scale Oriented Thunderstorm Satellite Predictors Development).
- TRT** includes a classical cell tracking and position extrapolation module.
- COALITION** estimates the future intensity of potentially severe thunderstorms.
- Objective:** Integrate the object-based, nowcasting systems **TRT** and **COALITION** to forecast the severity of developing convective cells and improve the early detection.
- Visualize the expected thunderstorm severity evolution in the Cell Severity Ranking module of **TRT**, used by the warning forecasters.

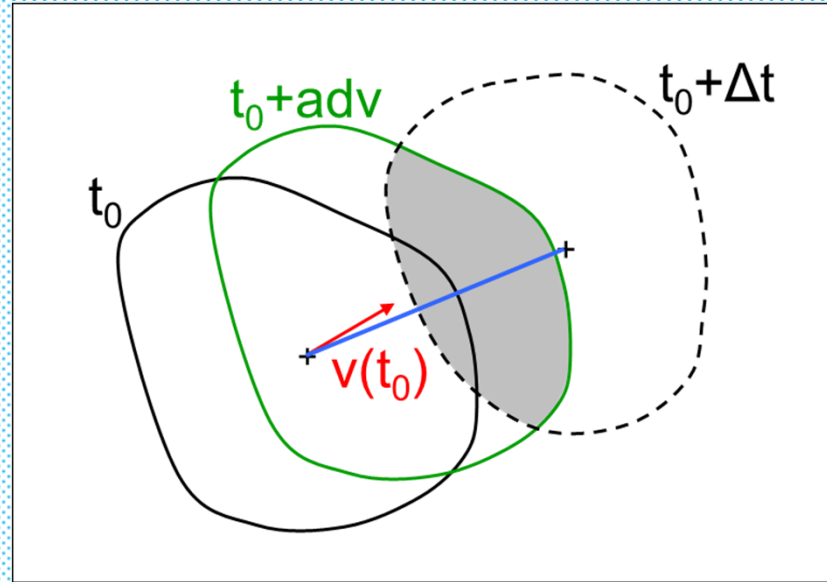
The TRT algorithm

TRT: real-time, object-oriented, multi-sensor system for thunderstorms nowcasting, based on volumetric multi-radar mosaic. TRT runs also a Cell Severity Ranking module and provides a trajectory extrapolation. Used operationally with a refresh time of 5 min, and 1 km resolution.

Detection: Dynamic reflectivity threshold scheme (individual thresholds: 36-48 dBZ)



Tracking: Geographical overlapping of advected cells



Input:

- 3D multi-radar mosaic (C-band, Doppler, dual-pol, 20 elevation scan, -0.2°/40°, every 5 min)
- Lightning: Cloud-to-Ground (CG) flashes
- NWP mesoscale model: COSMO-2 (high resolution: mesh-size 2.2 km, run every 3h,...)

Output: TRT-objects attributes (area, motion vector, trajectories, VIL, Hail, lightning, Cell Severity Ranking,...)

Cell Severity Ranking:

- Cell-based attributes (VIL, ET45 dBZ, max Zh, area>55dBZ) integrated with a weighting scheme.
- Storm cells classified into 4 categories, visualized by a color coded ellipse. Position forecast (use weighted displacement velocities) including uncertainty (ellipse size).

Severity	RANK	VIL [kg/m ²]	Median EchoTop 45 dBZ [km]	Max dBZ [dBZ]	Area 57dBZ [km ²]	Cell Area [km ²]
WEAK	RANK = [1.2-1.5]	<15	<4	>48	<15	>12
MODERATE	RANK = [1.5-2.5]	15-35	4-6	>51	15-24	>12
SEVERE	RANK = [2.5-4.0]	35-55	6-8	>54	25-34	>12
VERY SEVERE	RANK = [3.5-4.0]	<55	>8	>57	>35	>12

The COALITION algorithm

COALITION: real-time, object-oriented, multi-sensor system for the early identification of potentially severe thunderstorms, based on an innovative heuristic model. COALITION provides a warning map for severe convection development in the next 30 minutes. Used operationally with a refresh time of 5 min, and 1 km resolution.

Input: MSG rapid scan, radar, NWP, lightning climatology, orographic information

Output: For each convective cell ensemble forecast of CTT (Cloud Top Temp.) and VIL content provided for the next 5 to 60 minutes.

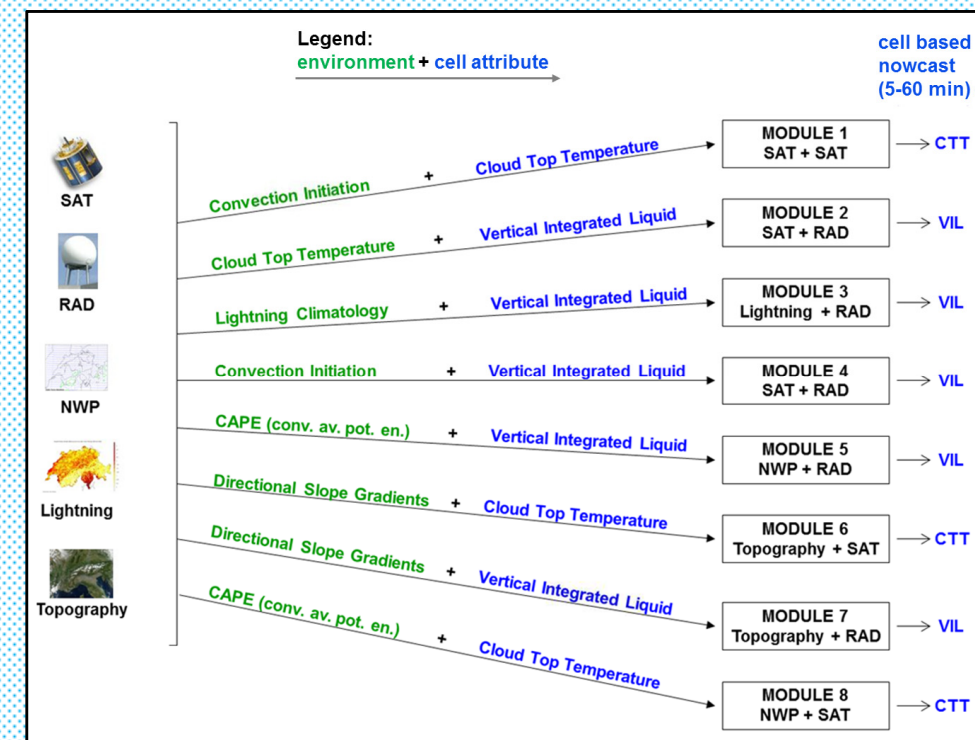
Methodology: borrows its approach from the physics of general dynamic systems (principle of energy conservation → Hamilton)

- Two main elements: objects and environments
- VIL and CTT selected as identifiers of thunderstorm intensity, used as predictands
- A number of predictors are selected among all available real time products and used as convective potentials
- 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)
- A pseudo-potential energy is estimated by including the characteristics of the surrounding environment

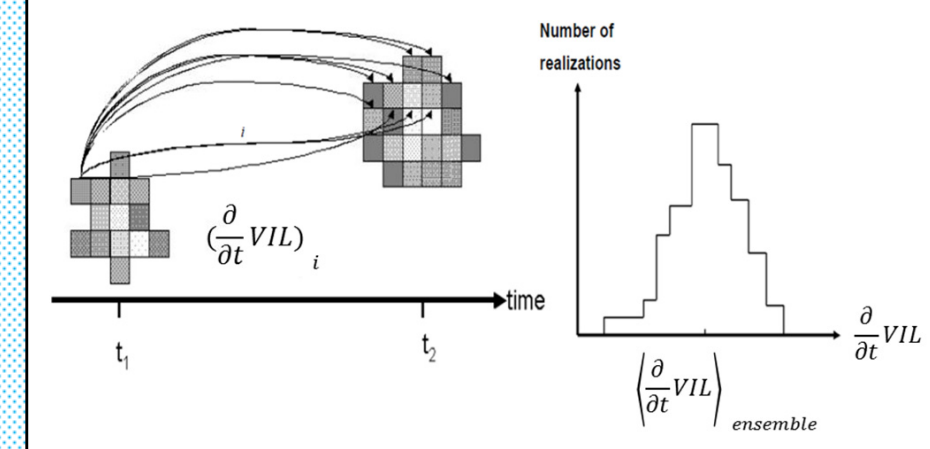
- Based on the intuitive expectation that losses and gains of the pseudo-kinetic energy are related and balanced by an exchange of energy with the surrounding environment, total energy conservation is assumed (dissipation is considered negligible)

- For each module a one-dimensional, time-dependent generalization of a harmonic oscillator is assumed: where q is the object attribute, p the momentum and $f(t)$ the correlation between the kinetic and the potential energy

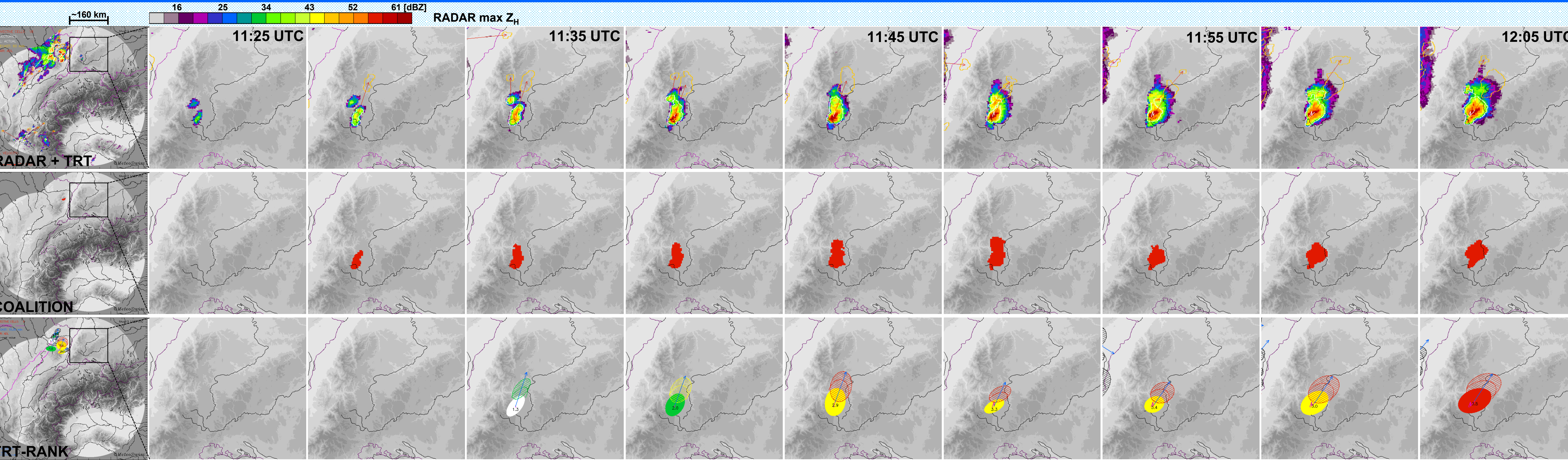
Eight implemented modules in COALITION and the corresponding thunderstorm attribute forecasts:



Rate-of-change of the predictors is used for estimating kinetic energy.



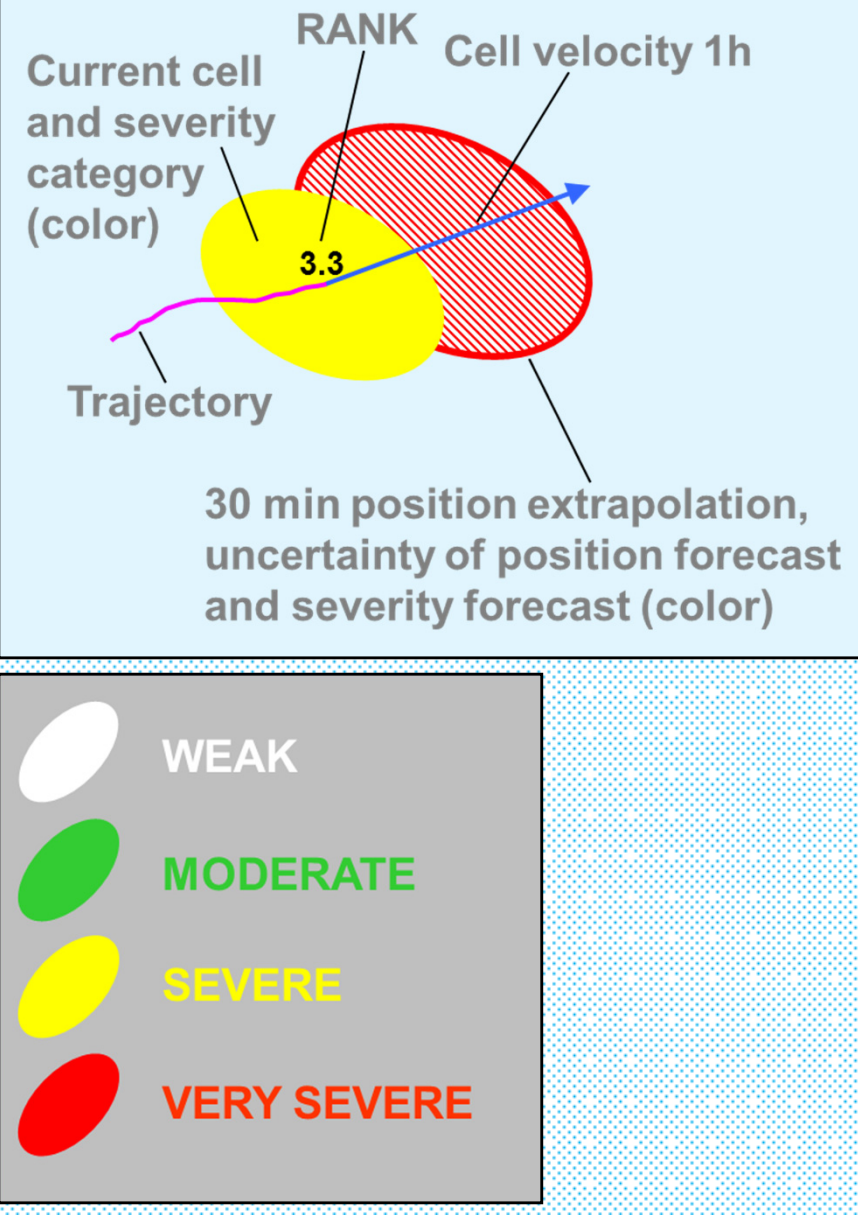
Results: Example of real time application (06.08.2013)



COALITION forecast

- 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-RANKING:



TRT-COALITION system integration

- The system integration is done by ingesting the gridded COALITION warning map for severe convection development in the next 30 minutes into the TRT Cell Severity Ranking module.
- If the cell identified by TRT includes some red COALITION pixel (severe convection development), the severity forecast ellipse is increased by one intensity level (color). In case of orange pixel (convection intensification) the 30 min severity forecast ellipse maintains the color of the current ellipse. If the COALITION pixels are yellow (cloud top cooling) the forecast ellipse is black because no reliable severity forecast is possible for these cells (bottom left figure in the sequence).

Results

- At 11:25 UTC two small convective cells (highlighted with a square) were detected by the radar (top figures), showing low intensities (max 30/36 dBZ). They were not yet identified by the TRT Cell Tracking module, the Cell Ranking module (bottom figures), and no COALITION forecast was possible (central sequence). Therefore no information about the future intensity development of the cells is available.
- At 11:30 UTC the radar indicates an increasing intensity for the southernmost cell, identified also by the TRT Cell Tracking. The cell was not intense enough to be identified and visualized by the TRT Ranking module. The COALITION forecast indicated that a probable further intensification of this cell up to severe convection was expected within the next 30 minutes.
- The image sequence (top and bottom figures) from 11:35-12:00 shows in fact an intensification of the thunderstorm, up to a vertical max greater than 61 dBZ, classified from "weak" to "severe" by the TRT Ranking module (Rank 1.3 → 3.4).
- The cell intensification was forecasted correctly by COALITION since 11:30. This is a significant anticipation of the identification of potentially dangerous convective cells. This information can be used by the forecasters to anticipate the flash-news warnings of potentially severe thunderstorms.

Conclusions and Outlook

- The TRT Cell Severity Ranking is a well-established product to help forecasters during the flash-news warnings. The newly developed system COALITION provides a very useful cell-based warning map for severe convection development in the next 30 minutes.
- Preliminary results show encouraging performance of the integrated nowcasting systems TRT and COALITION. The integration allows a direct visualization of the future cell severity evolution in a well-known environment.
- Outlook:** COALITION is able to provide an ensemble forecast of the VIL evolution for the next 30 min. This could be ingested into the TRT Cell Severity Ranking module to compute directly the numerical Rank value of convective cells also for the next 30min. Cells that are weak at present but with a forecasted increased intensity and increased cell ranking can be visualized. This would help forecasters to improve the early detection and to anticipate the warnings of severe thunderstorms → "early warning"

References

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