Nowcasting model of thunderstorms intensity and probability TSP

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The TSP (Thunderstorm Prediction) system enables the detection and forecasting of storms: probability and intensity, and tracking their movement within an assumed time horizon of 60 minutes. Additionally, the model generates a quality field related to the availability and quality of input data.

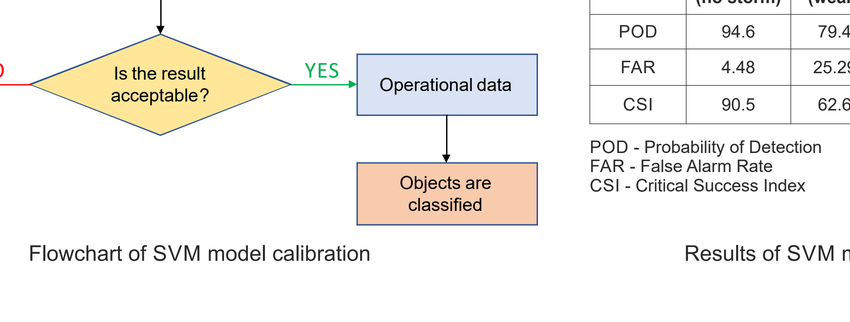
TSP input data

Data from the LIGHTNING application processing 1-minute reports from the PERUN system (lightning detection):
- IC (density of inter cloud lightning),
- CG (density of ground lightning),
- LJmax (maximum lightning jumps within 10 min),
- LJnum (number of lightning jumps within 10 minutes).

POLRAD radar data (including radars from neighbouring countries):
- VIL (vertical integrated amount of water in the air column),
- EHT (cloud top height, defined by 40 dBZ reflectivity, to determine the exceedance of the 0ºC isotherm from the COSMO model),
- CMAX (maximum radar reflectivity in the air column),
- CAPPI (radar reflectivity at an altitude of 4 km).

Meteosat satellite data processed by NWC-SAF software:
- CTTH (cloud top temperature and height),
- RDT-CW (rapidly developing thunderstorm – convection warning).

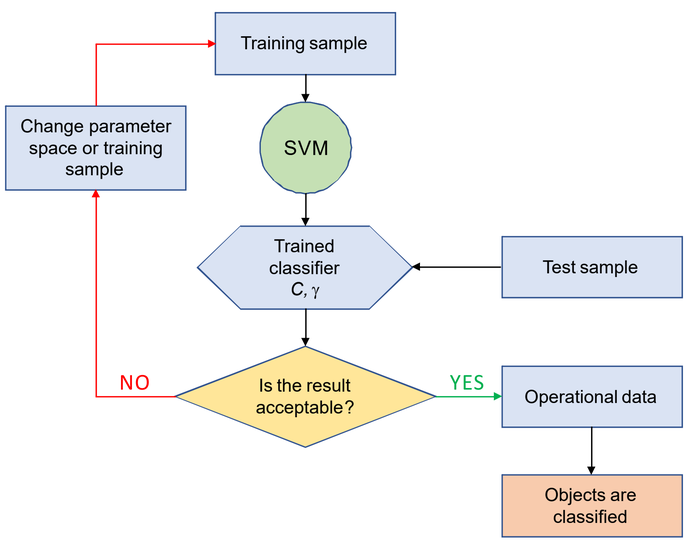
SCENE model data:
- WIND displacement vectors,
- QI (quality index).



Data sources for the TSP system: a) PERUN lightning detection system, b) POLRAD radar system + radars of neighboring countries, c) MSG3 and MSG4 satellites (seviri instument)

SVM (Support Vector Machine) Model for TSP

The role of the SVM model was to assess an intensity of storms based on the data listed above. The intensity was described using 3 classes. The calibration of the SVM model involved determining the parameters C and γ, where C corresponds to the width of the margin separating different intensity classes: a large value sets a small margin, while γ determines the topology of the plane (kernel function): the lower the value, the more complex the shape. The data for verification came from synoptic observations.



Flowchart of SVM model calibration

Training sample

Class	0 (no storm)	1 (weak)	2 (moderate)	3 (strong)
POD	94.6	83.9	88.5	99.9
FAR	11.31	9.43	2.35	0.04
CSI	84.4	77.1	86.6	99.9

Test sample

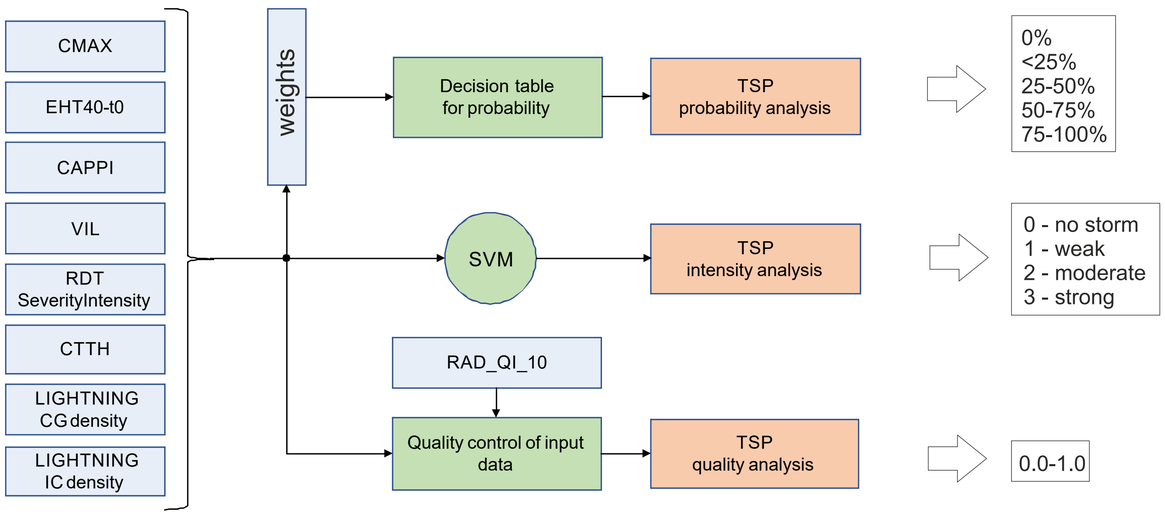
Class	0 (no storm)	1 (weak)	2 (moderate)	3 (strong)
POD	94.6	79.4	86.2	97.9
FAR	4.48	25.29	8.53	2.08
CSI	90.5	62.6	79.8	95.9

POD - Probability of Detection
FAR - False Alarm Rate
CSI - Critical Success Index

Results of SVM model training

Determining the intensity and probability of storm

Based on the trained and validated SVM model, a storm detection module was developed based on data from the LIGHTNING system, radar and satellite data. The system initially performs an analysis and determines the storm intensity class based on it. Based on the decision table, it determines the probability of a storm occurrence. Additionally, the quality field of such an analysis is also determined based on the availability of input data.



Flowchart of TSP system (storm detection)

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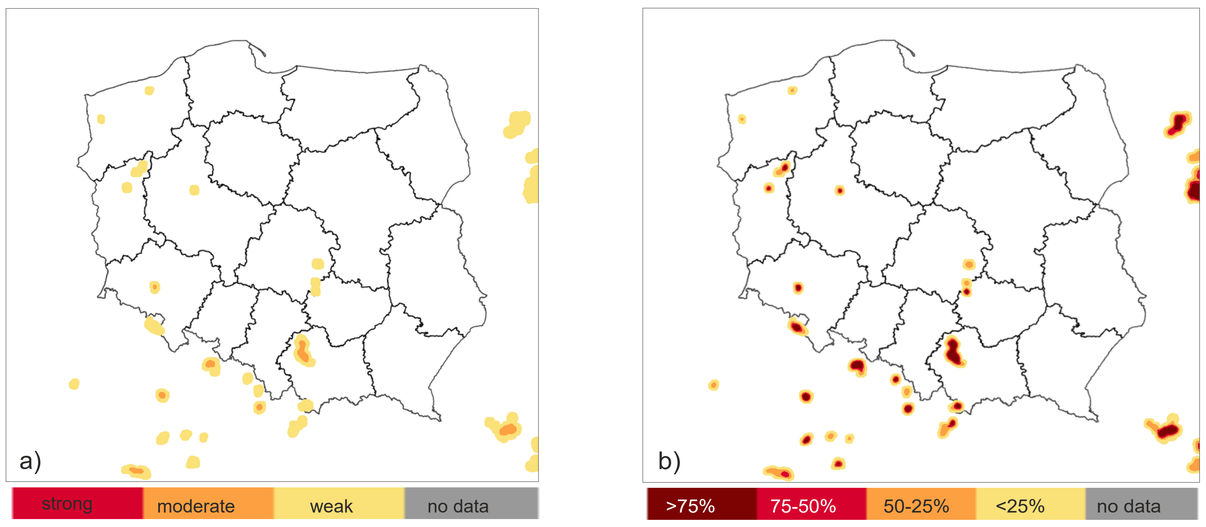
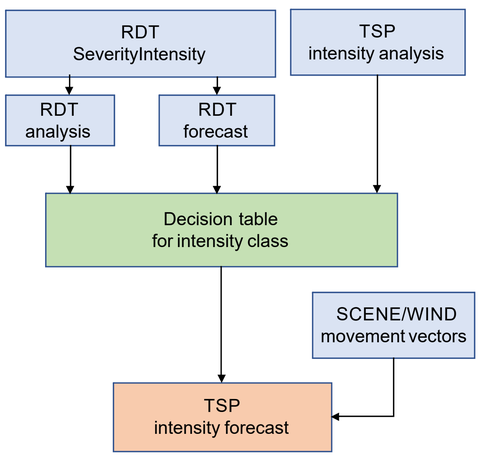
Example of storm intensity and probability analysis



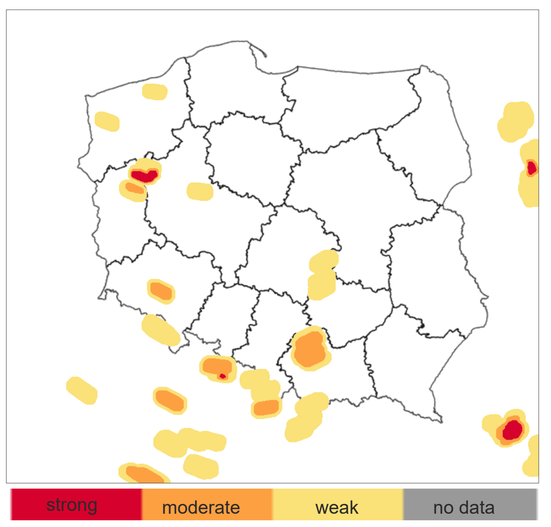
Example of the TSP model analysis for 2024-07-24 09:30 UTC:
a) storm intensity field, b) storm probability field

Storm intensity and probability forecast

The forecast model of the storm intensity is based on the TSP model analysis and on satellite RDT-CW data processed with the NWC-SAF software. The latter provides data in the analysis and forecast mode up to 60 min (step 15 min). Based on the RDT and TSP data, a decision table was developed to determine the forecast intensity. By including the advection vectors of the SCENE model, the movement of storm cells is determined.

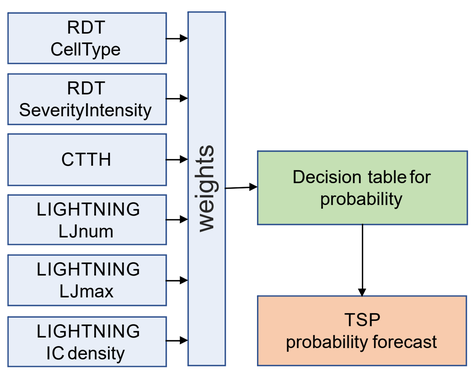


Flowchart of model for storm intensity forecast

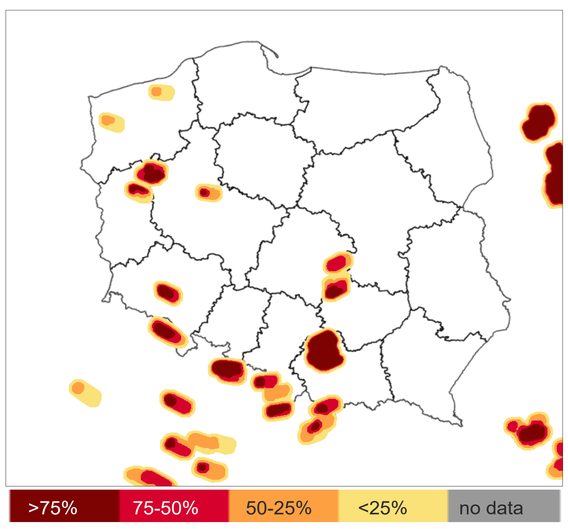


Example of the TSP model storm intensity forecast for 2024-07-24 09:30 UTC

The storm probability model is based on LIGHTNING system data and satellite data processed with NWC-SAF software (RDT-CW and CTTH). Empirically developed weighting factors combined with this data determine a weighted average, which then enters the decision table determining the probability of storms.

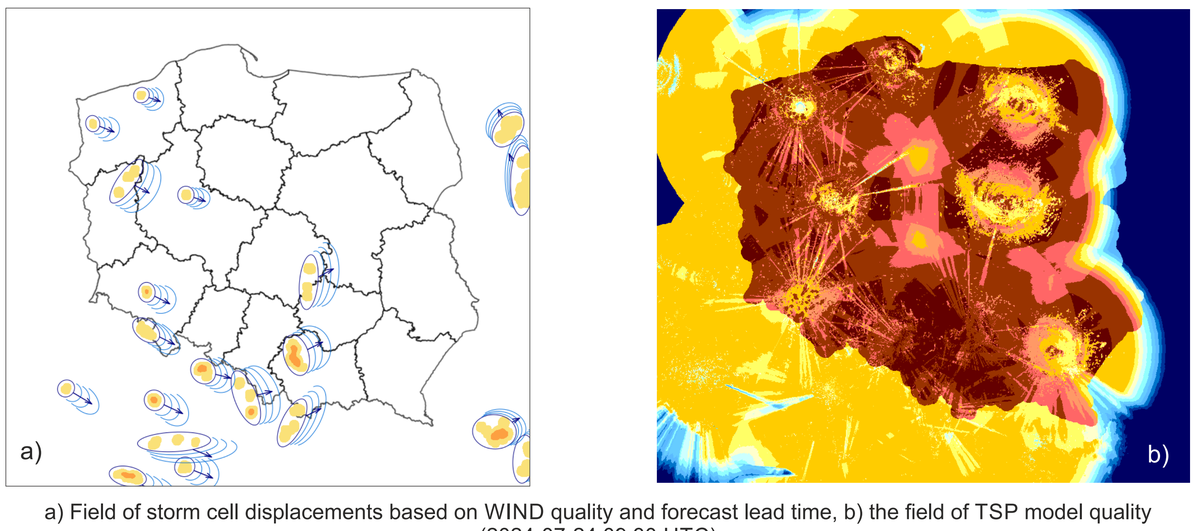


Flowchart of model for storm probability forecast



Example of the TSP model storm probability forecast for 2024-07-24 09:30 UTC

Additional visualization of storm intensity and the movement has been introduced. The ellipse encloses the set of clustered storm cells obtained from the TSP model and the arrow shows the direction of advection from the SCENE model. The half-ellipses show the movement of the cluster in 20-minute steps. The size of the half-ellipse results from the WIND quality field of the SCENE model (the worse, the larger the half-ellipse), and from the lead time (the longer, the higher uncertainty, so size of half-ellipse increases).



a) Field of storm cell displacements based on WIND quality and forecast lead time, b) the field of TSP model quality (2024-07-24 09:30 UTC)