Application of COSMO NWP to nowcasting system at IMGW-PIB

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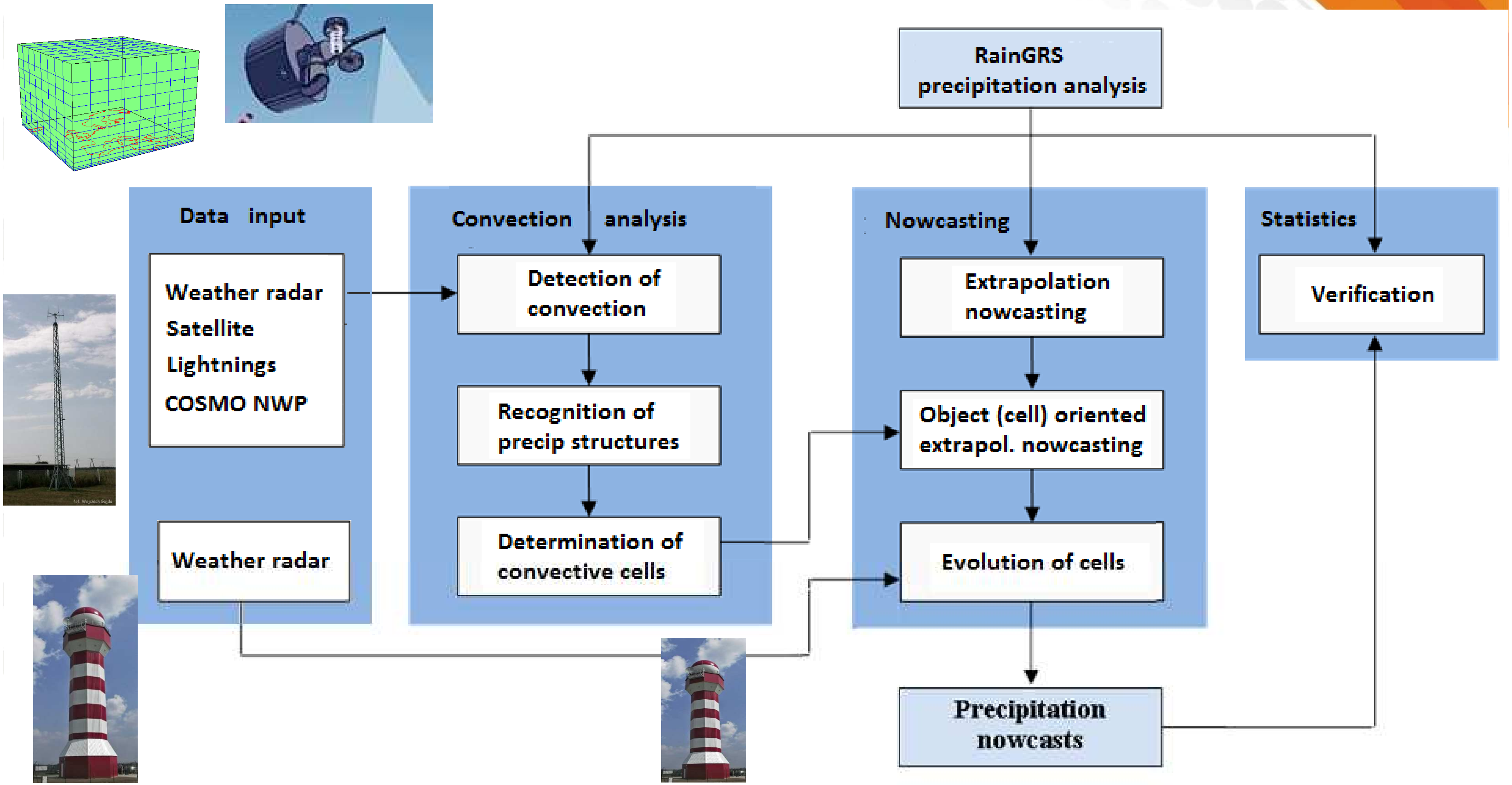
SRNWP/EWGLAM

SCENE (Storm Cell Evolution and Nowcasting

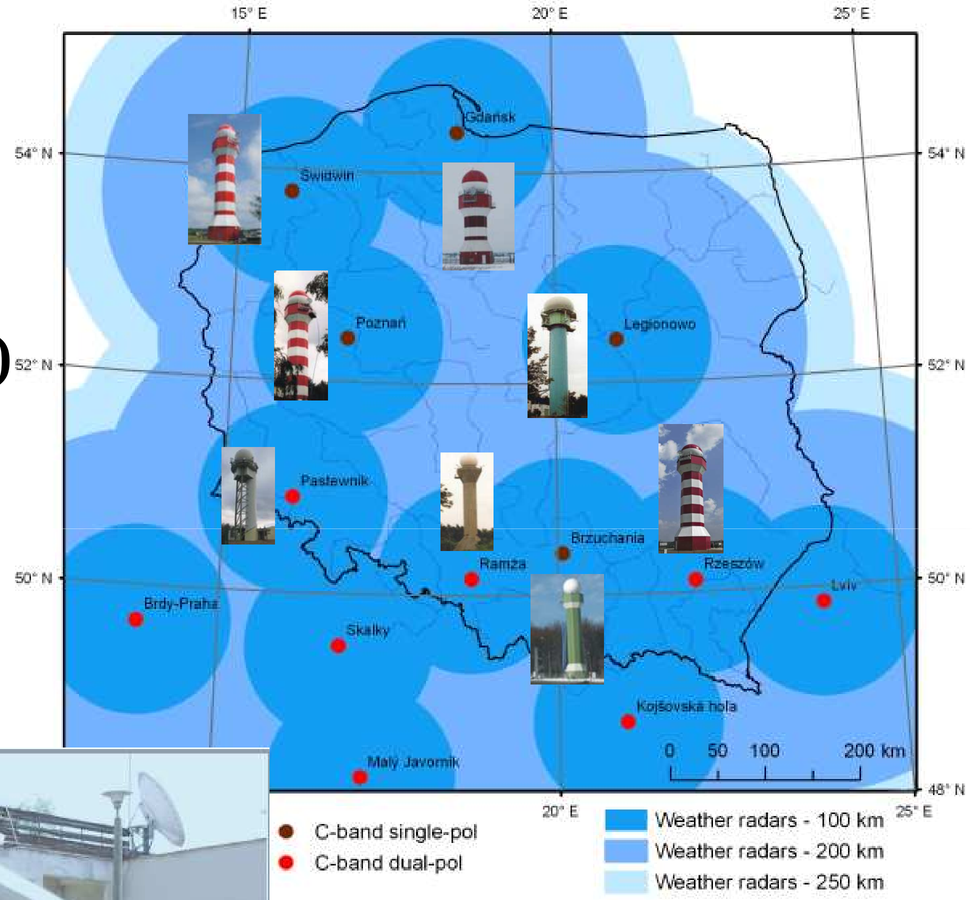
- Input data
- Convection analysis.
- Extrapolation
- Evoluton of the convective cell
- Verification

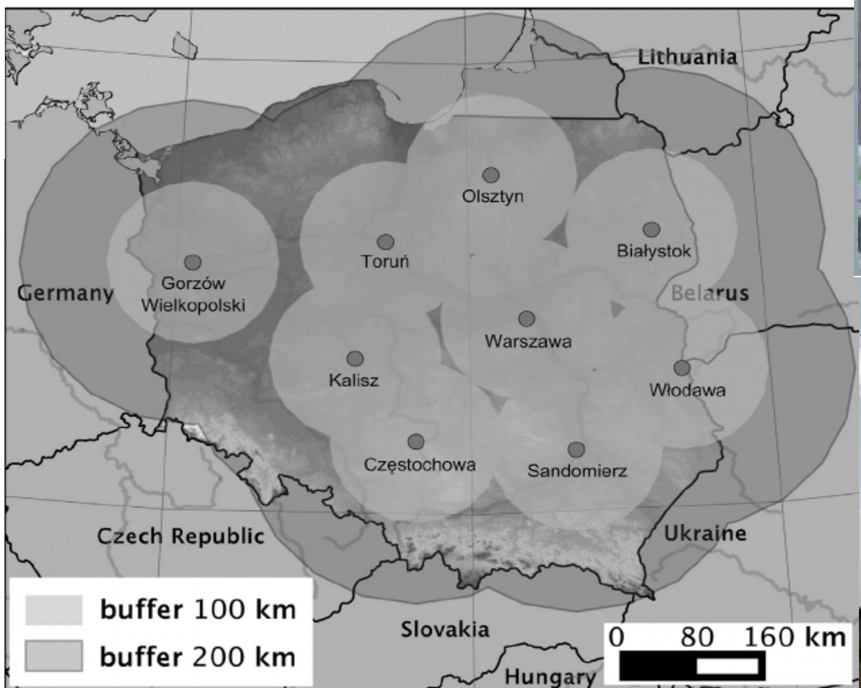
SCENE (Storm Cell Evolution and Nowcasting)

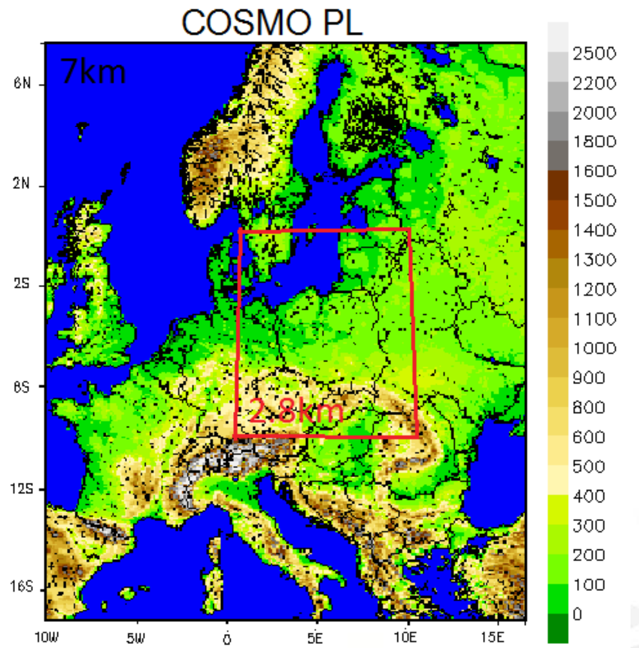


SCENE (Input data)

- ❑ **POLRAD+ radar network**
  (8 doppler C-band radars, inc. 3 dual-pol
  5 Radars from Czech, Slovakia, Ukraine)
- ❑ **METEOSAT data acquisition**
- ❑ **PERUN lightning detection**
  (9 stations Vaisala SAFIR 3000)
- ❑ **COSMO NWP (2.8km domain)**

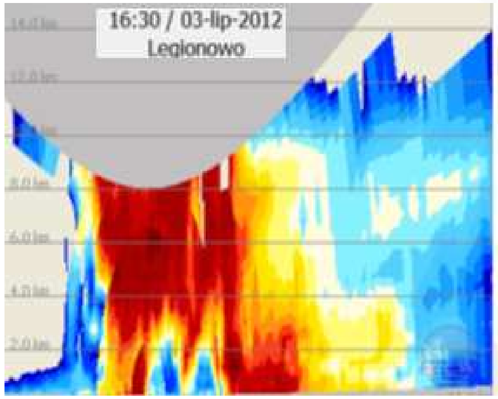


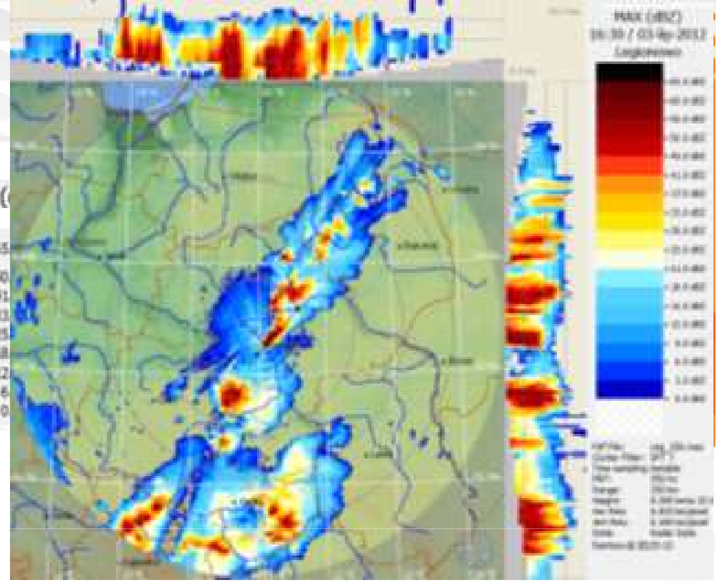




Radar network data (POLRAD+)

Composites 1 x 1 km spatial resolution, 900 x 800 km domain
10-min time resolution
PUWG 92 coordinates, HDF5
RADVOL-QC system



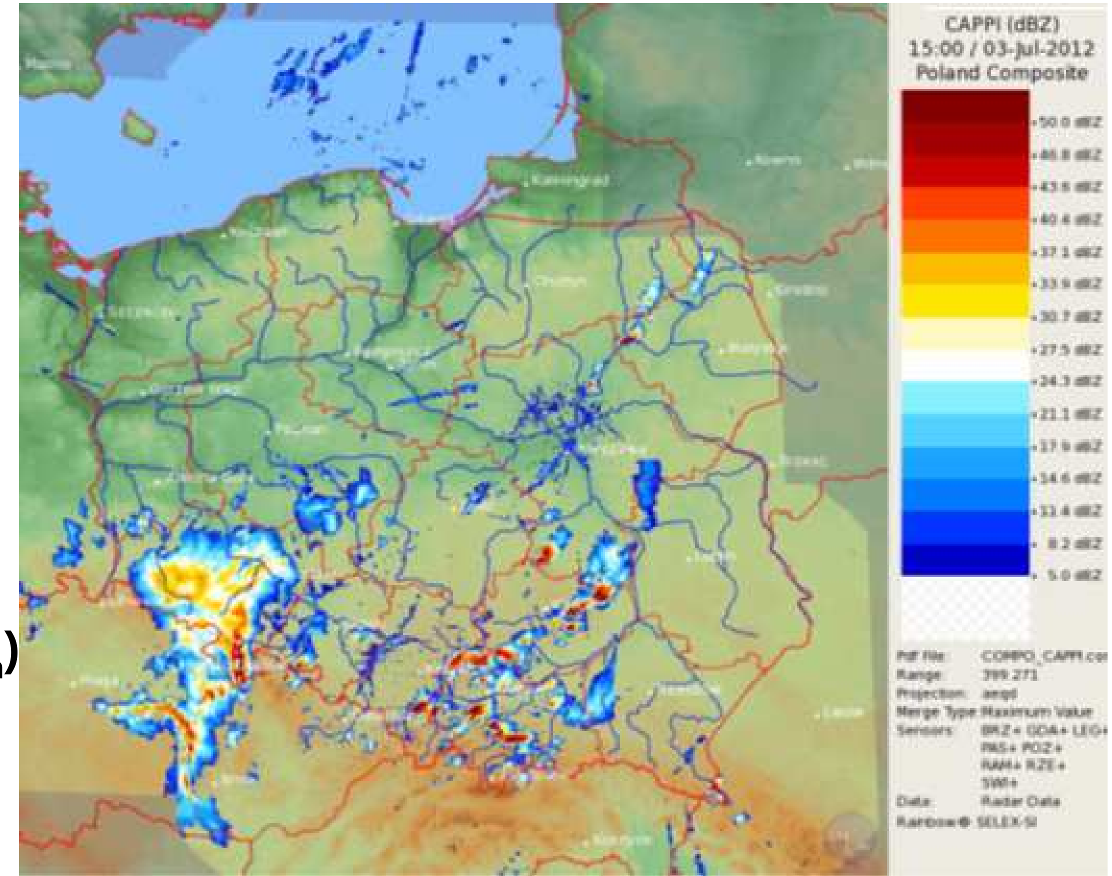


Employed products

- Maximum of reflectivity (Z_{max}),
- Vertically integrated liquid water (VIL)
- Radar echo top height: 4 dBZ treshold (*EHT*),
- …. and 20 dBZ (EHT20)

Additional available products

- Reflectivity horizontal crossection (*CAPPI*)
- Height of the maximum reflectivity (*EHM*)
- Horizontal wind (*HWIND*)
- Radial wind shear (*SHEAR*)
- Vertical wind shear (*VSHEAR*)
- Turbulence (*LTB*)



- **Mean backround refl. around 11 km (Z_{mean})**
- **Mean backgroud VIL around 11 km (VIL_{mean})**
- **Reflectivity perturb ($\Delta Z = Z_{max} / Z_{mean}$)**
- **VIL perturb ($\Delta VIL = VIL / VIL_{mean}$)**

RADVOL-QC - data **quality check and adjustment**

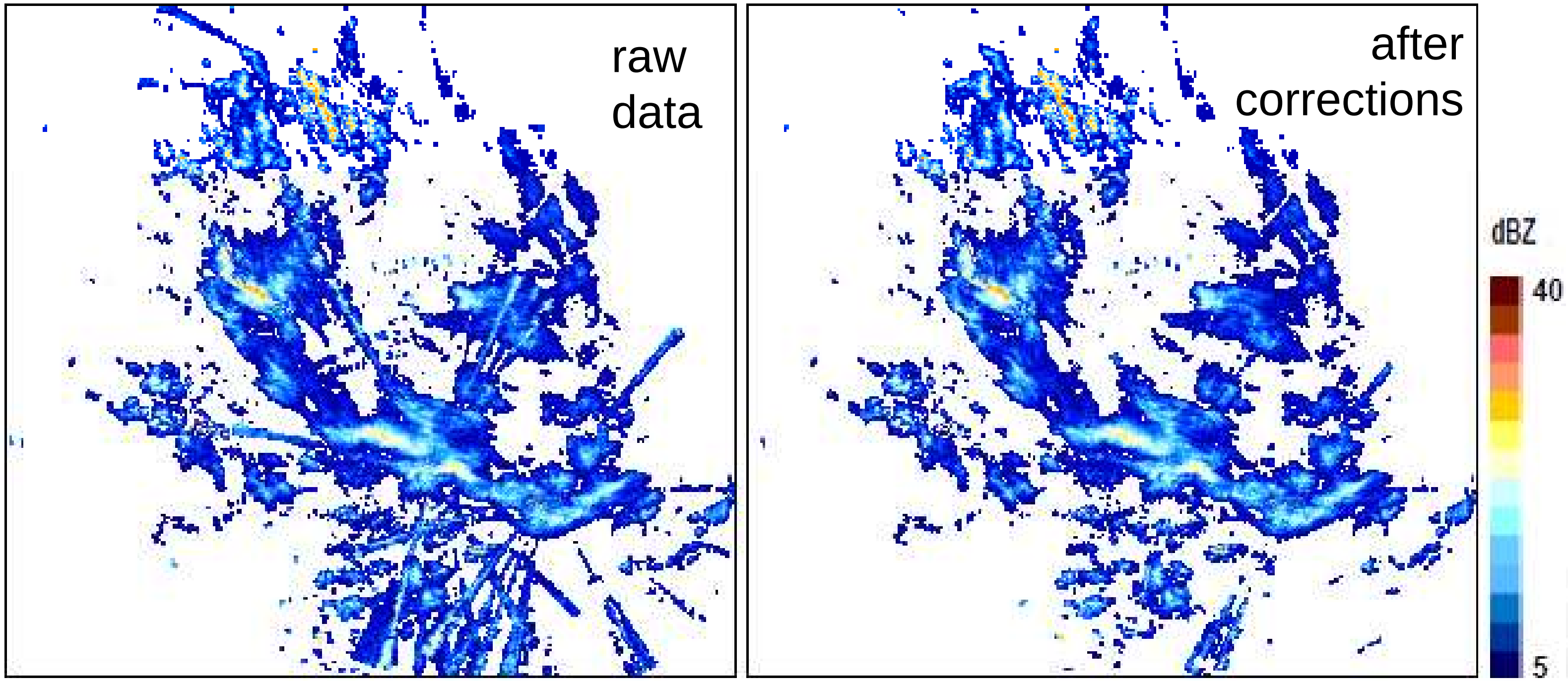
(Ośródka et al., 2014; Szturc et al., 2012)

radvol_qpe - data correction modules and quality indexing

- **DP. NMET: removing nonmeteorological features for dual-polarized radars,**
- **NMET: removal of biological characteristics and anomal propagation**
- **SPIKE: removing echoes from external antennas**
- **SPECK: noise removal,**
- **MHV: correction due to the height of the lowest radar beam on the ground surface**
- **BLOCK: correction of partial and total blockage of the radar beam,**
- **DP/ATT: beam attenuation correction in precipitation for single/dual-polarized radars.**

radvol_qpe_qi - provide 3D quality index -> 2D ground precipitation

- **BROAD: quality index due to errors related to the distance from the radar**.



Map of cumulative radar reflectivity (CMAX)

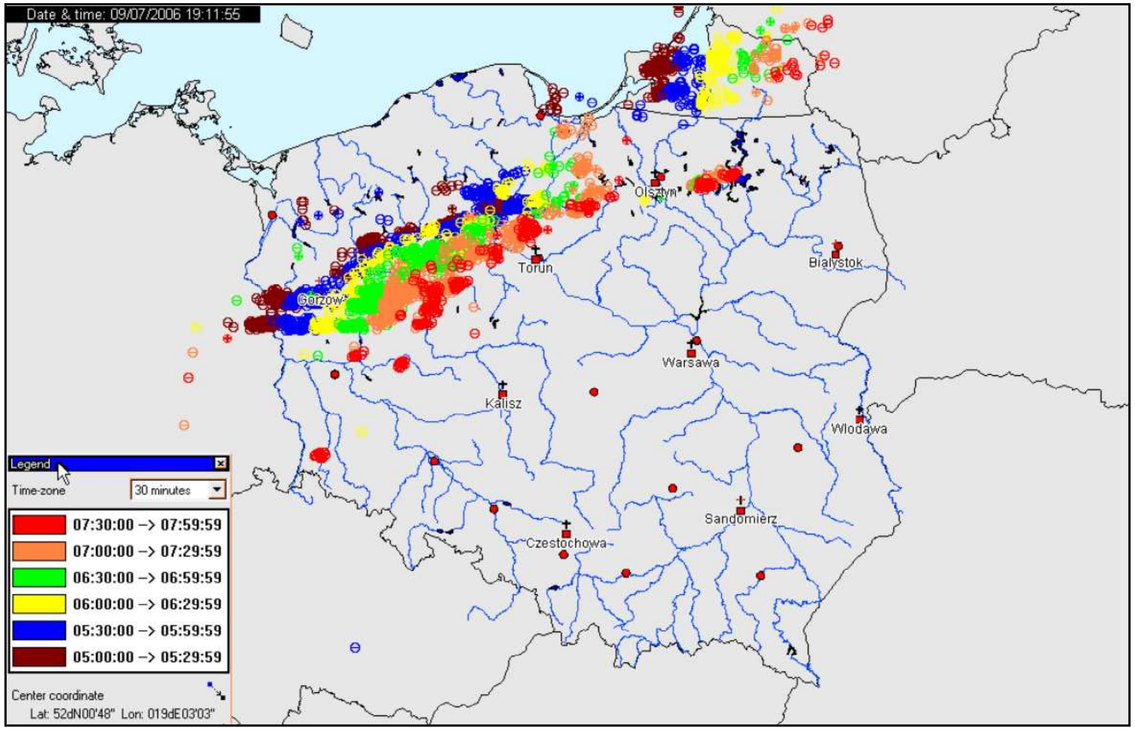
PERUN - lightning detection system

Vaisala
SAFIR 3000
9 detectors

SAFIR (Surveillance et d'Alerte Foundre par Interferometrie Radioelectriqe)

Location of the discharges

IC (intra-cloud)
CG (cloud-to-ground)



Employed products:

- **Inter-cloud lightnings (*IC*),**
- **Cloud to ground lightnings (*CG*)**

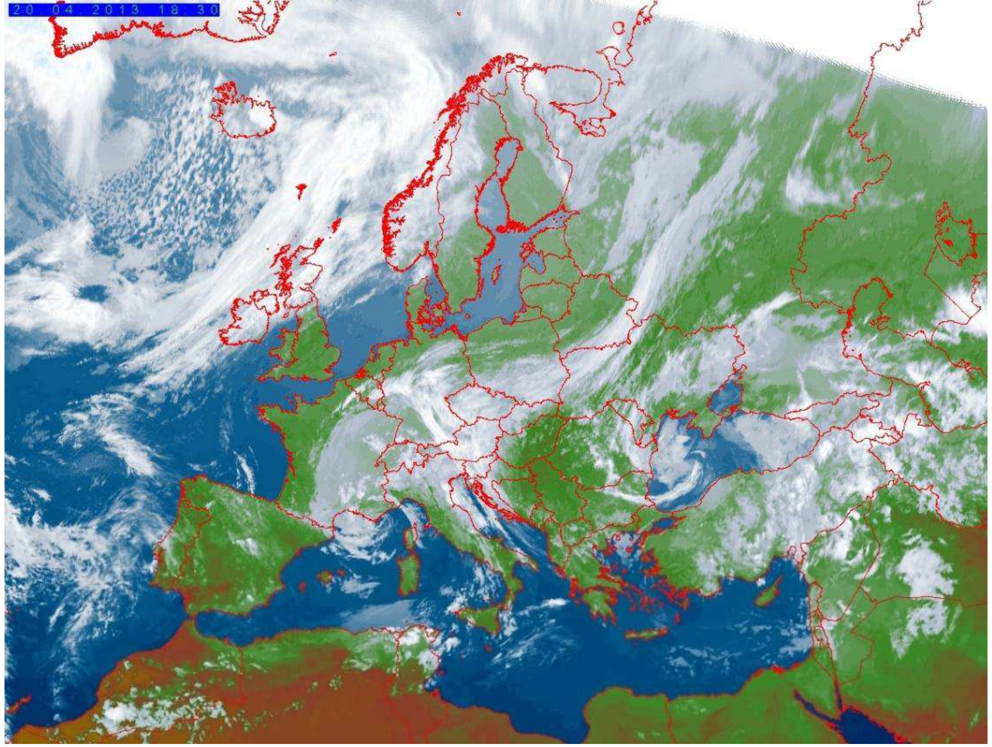
Other products:

Discharge density
number of discharges / [km^2] / [min], giving detailed information about the intensity of the storm

Storm cell tracking:
contours of the cells and their cores (areas with the highest intensity in the cell).

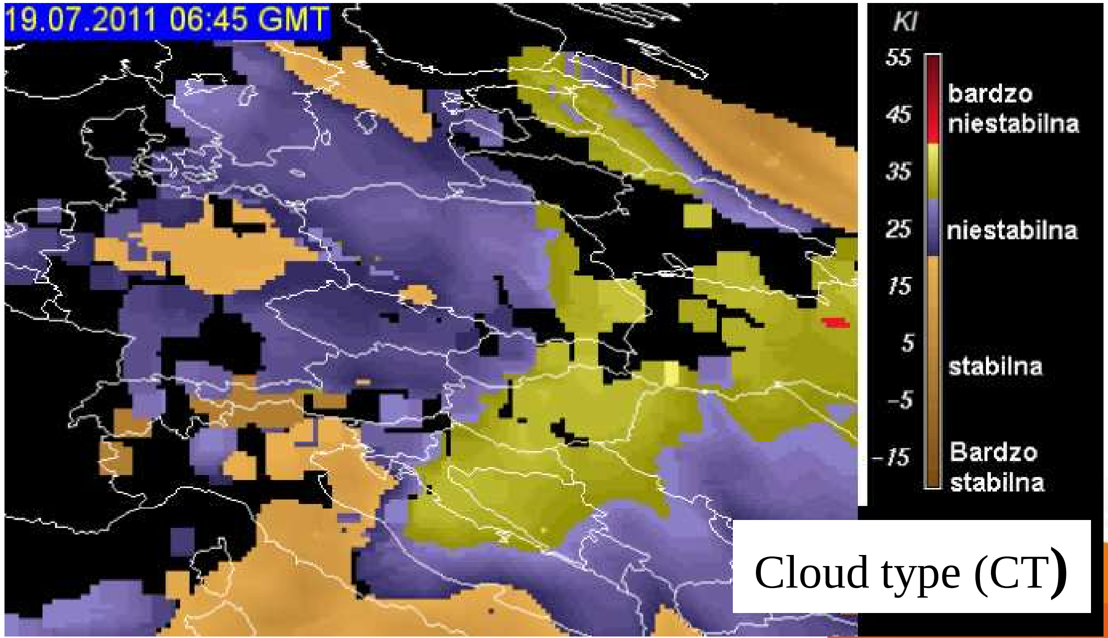
METEOSAT (second generation) - data acquisition and procesing center

- 5 x 6 km pixel -> downscaled into 1 x 1 km
- 5-min time resolution in rapid scan mode or 15-min in standard mode
- VIS and IR observations - processed by NWC-SAF (Satellite Application Facility) software

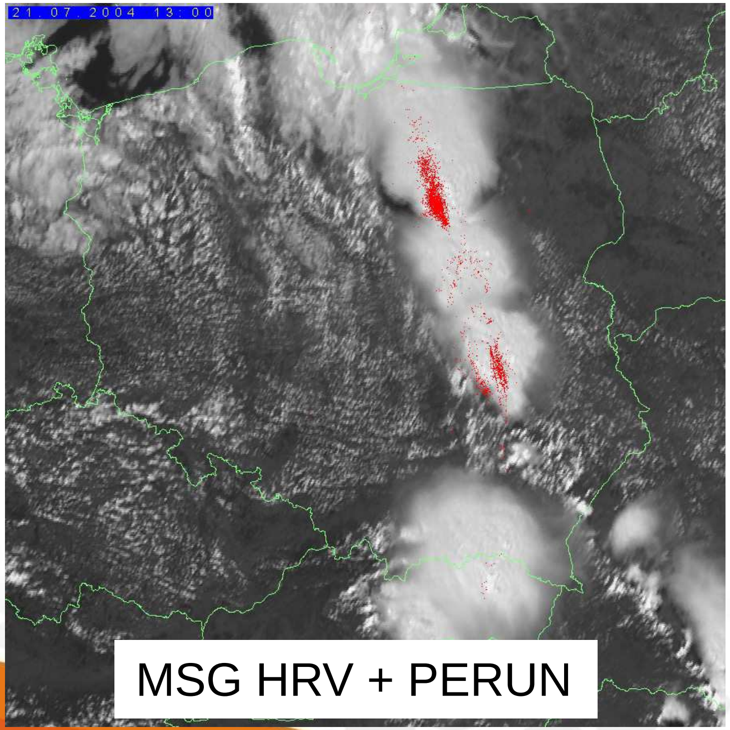


Employed products:

CRPh, CRR, CT, CT_PHASE, CTTH_EFFECT, CTTH_PRESS, CTTH_HEIGHT, CTTH_TEMPER, PC, PCPh



Cloud type (CT)



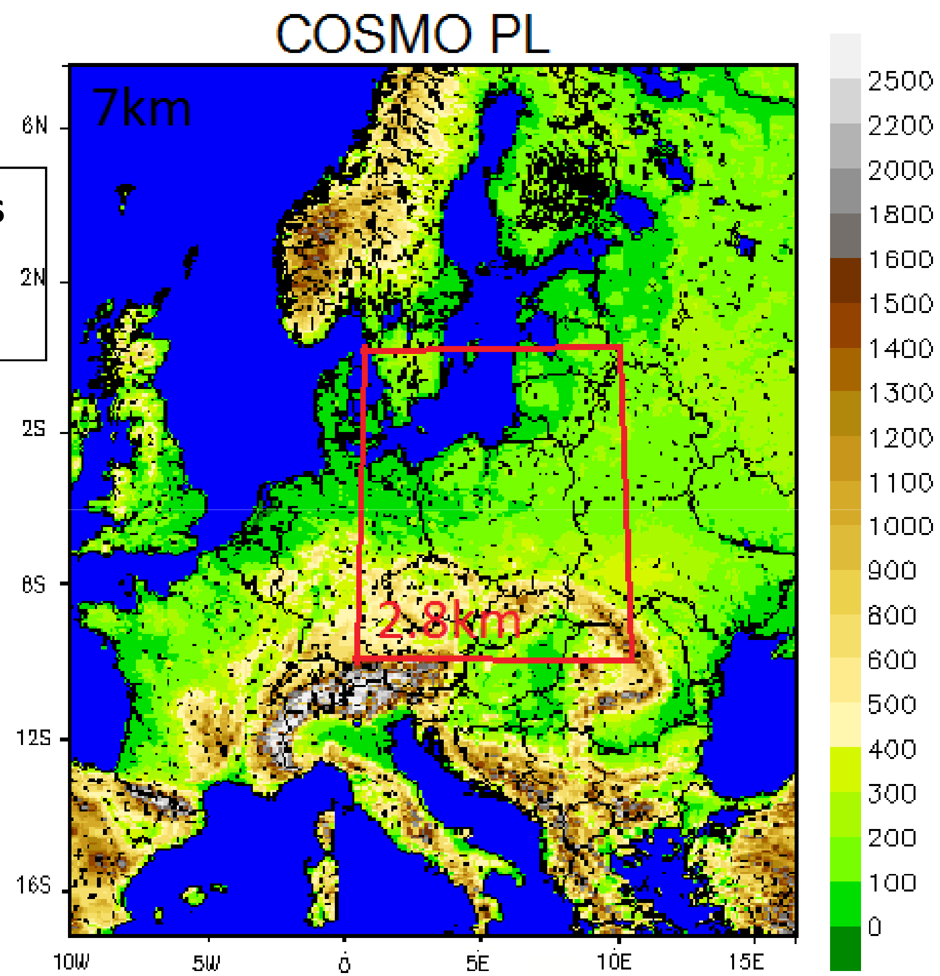
MSG HRV + PERUN

COSMO deterministic forecasts

Employed products:

- TWATER, TOT_PRECH,
- TOP_CON, TKE_CON,
- LCL_ML, LFC_ML,
- SWISS00, SWISS12, SLI, CLDEPTH,
- Convective Available Potential Energy (CAPE_CON, CAPE_ML, CAPE_MU, CAPE3KM)
Total Totals Index (TTI)
- Convective Inhibition (CIN_ML, CIN_MU),
- Showalter Index (SI),
- Supercell Detection Index 1/2 (SDI_1/ SDI_2)

- **2.8 km horizontal res**
- **10-min time step,**
- **start every 1 hour**

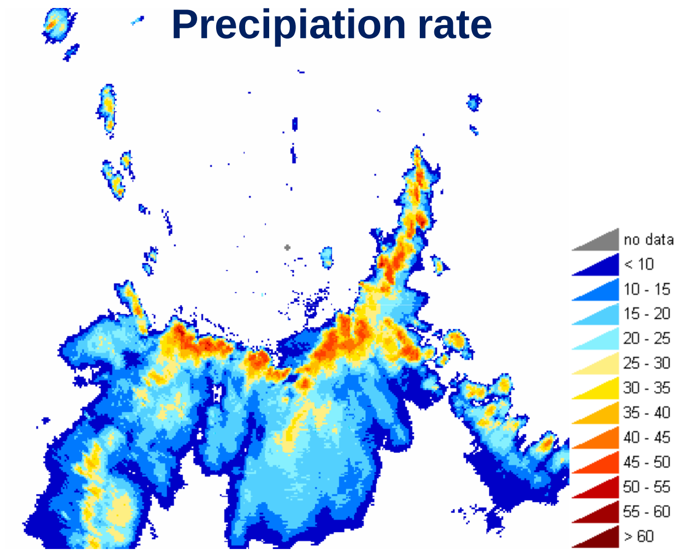


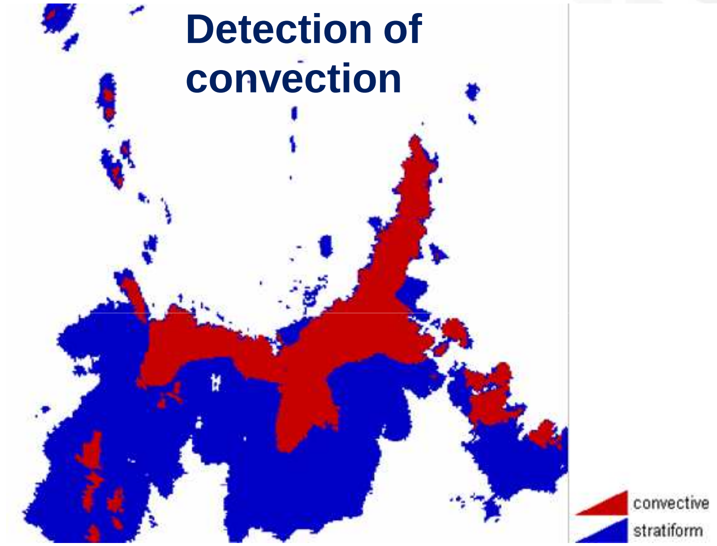
Additional available parameters:

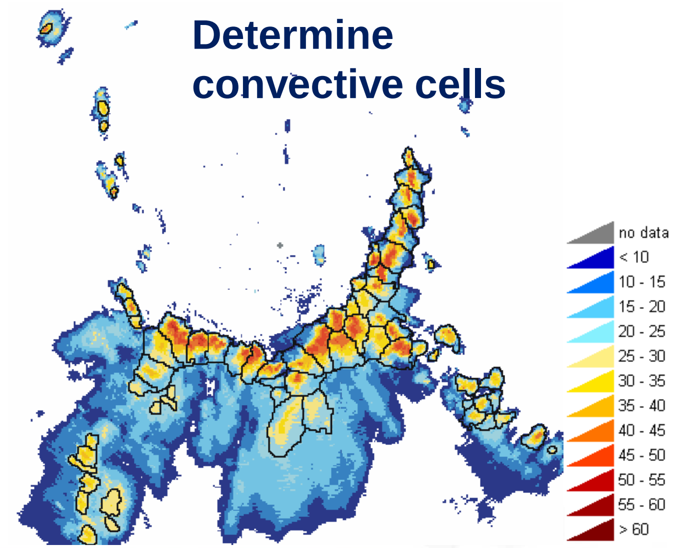
Density-weight Wind Shear 0-5 km (*DSH*),
Density-weight Wind Shear 0-2,5 km (*LSH*),
Lightning Rate (*LR*)
Storm Relative Helicity (*SRH*),
Storm Relative Helicity 0 – 3 km (*SRH3*),
Equivalent Potential Temperature (θ_e),
K Index (KI),
Lifted Index (LI),
Severe Weather Threat (SWT),

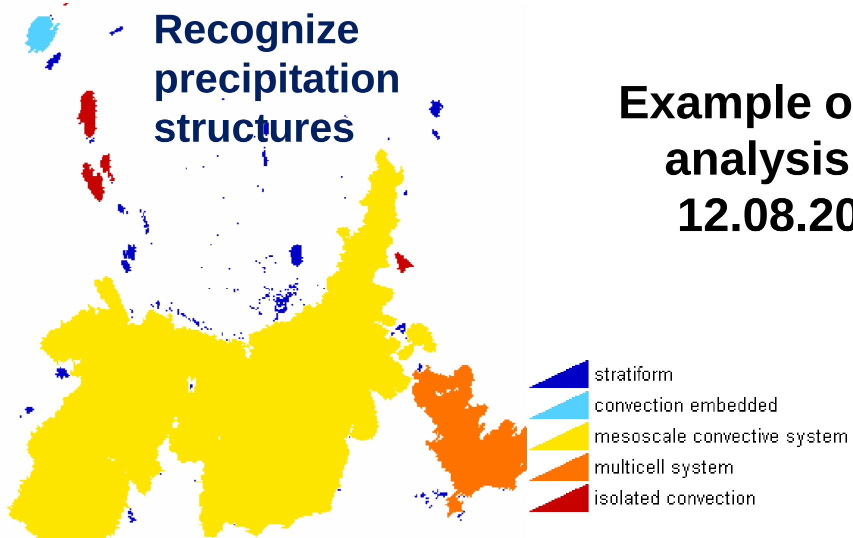
Horizontal Grid Spacing [km]	7	2.8
Domain Size [grid points]	415 x 445	380 x 405
Forecast Range [h]	78	12
Initial Time of Model Runs [UTC]	00 06 12 18	1h frequency
Model Version Run	5.01	
Model providing LBC data	ICON	COSMO PL 7
LBC update interval [h]	3h	1h
Data Assimilation Scheme	Nudging	

SCENE – convection analysis modules







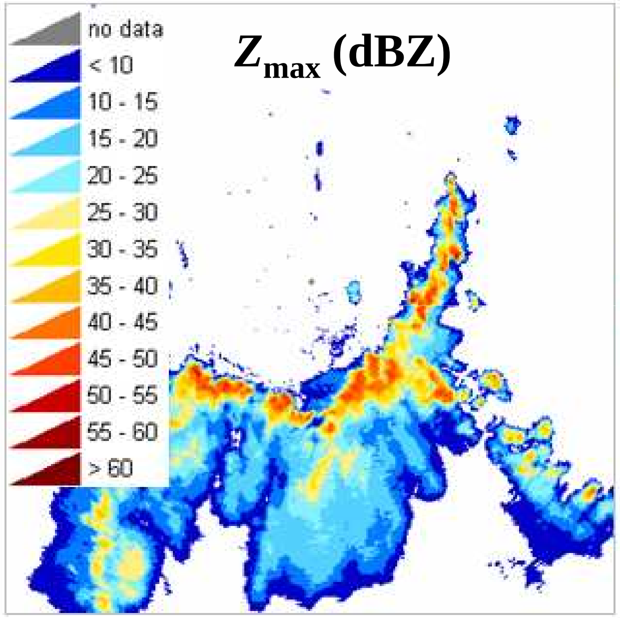


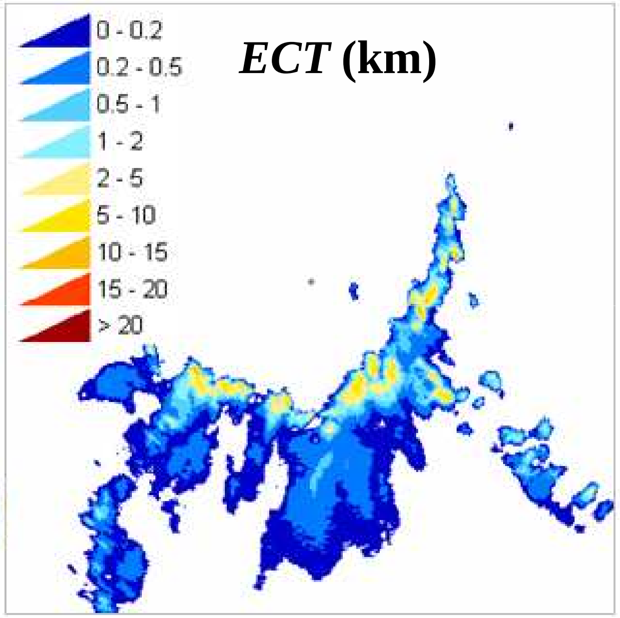
Example of convection analysis (Legionowo 12.08.2007, 14 UTC)

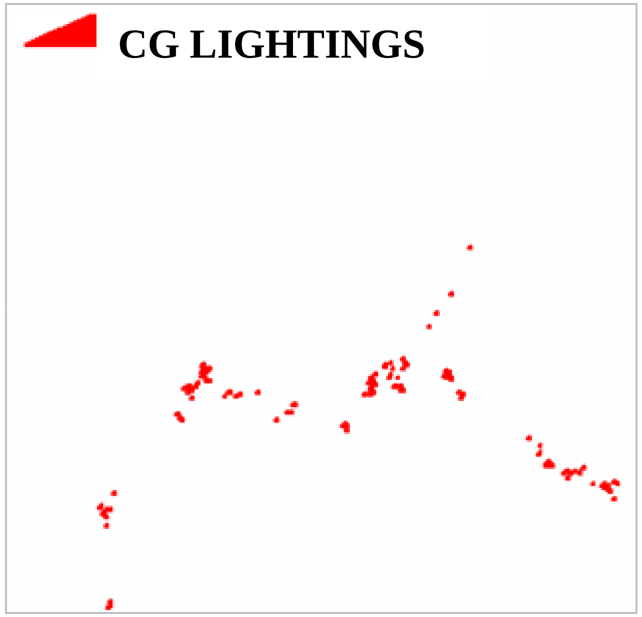
POGODYNKA.PL
SERWIS POGODOWY IMGW-PIB

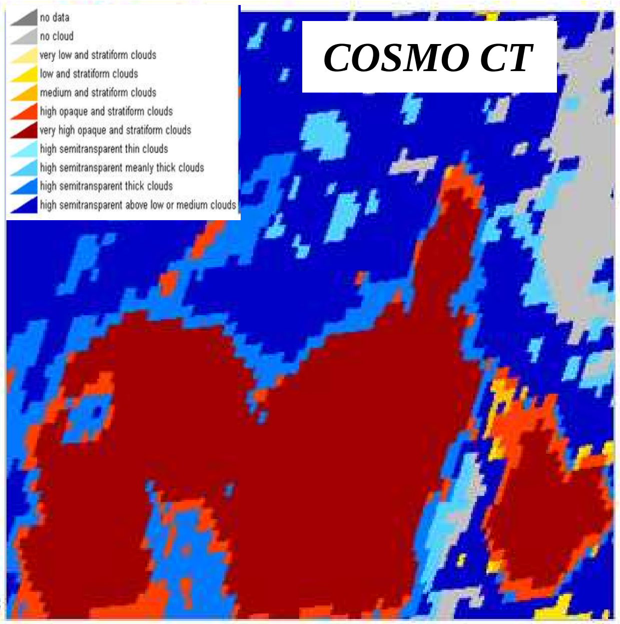
Detection of the convection

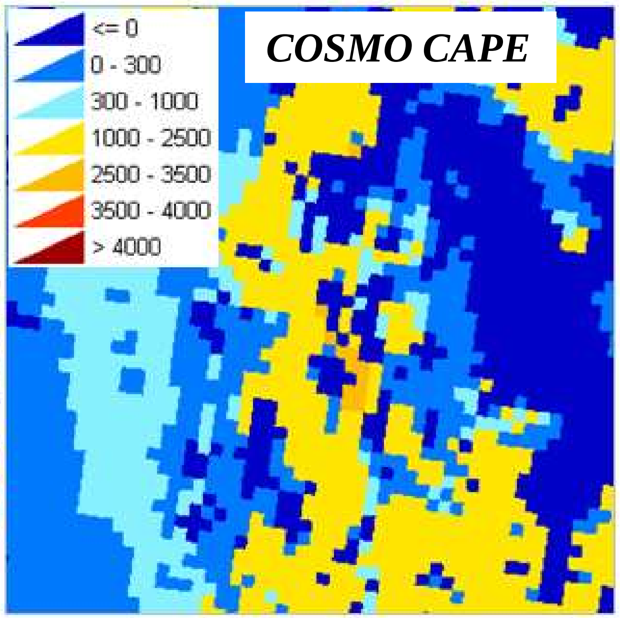
Range of radar in Legionowo, 12 sierpnia 2007 r., godz. 14 UTC











assign to a pixel
rain precipitation class:
stratiform or convective
due to parameter X

empirically selected
membership functions

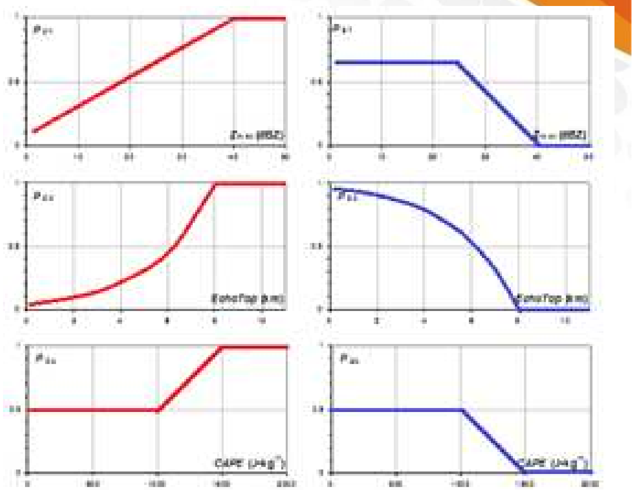
Detection of the convection

Empirical membership functions simple (1D) or comlex (2D):

P_S - for stratiform rainfall

P_C - for convective precipitation

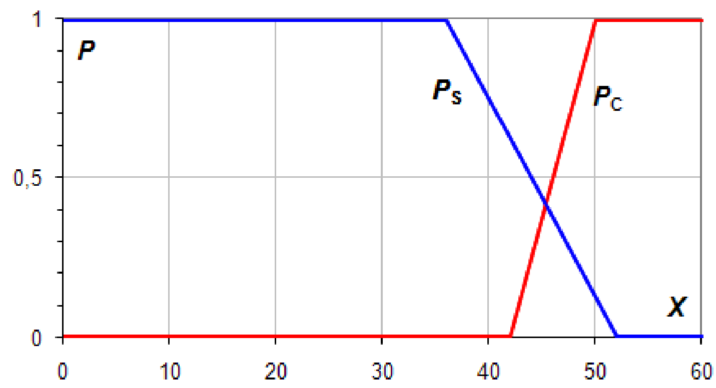
Parameter	Membership functions P_{xi}		Weights W_{xi}	
	Convective precip. (C)	Stratiform precip. (S)	C	S
Z_{mx}	$P_{C1}=\begin{cases}0.09\cdot\exp(0.049\cdot Z_{mx}) & Z_{mx}<49.1\,dBZ\\ 1 & Z_{mx}\ge 49.1\,dBZ\end{cases}$	$P_{S1}=\begin{cases}1-0.09\cdot\exp(0.049\cdot Z_{mx}) & Z_{mx}<49.1\,dBZ\\ 0 & Z_{mx}\ge 49.1\,dBZ\end{cases}$	0,20	0,20
ECT	$P_{C2}=\begin{cases}0.041\cdot\exp(0.4\cdot ECT) & ECT<8\text{ km}\\ 1 & ECT\ge 8\text{ km}\end{cases}$	$P_{S2}=\begin{cases}1-0.041\cdot\exp(0.4\cdot ECT) & ECT<8\text{ km}\\ 0 & ECT\ge 8\text{ km}\end{cases}$	0,10	0,10
$CAPE$	$P_{C6}=\begin{cases}0.5 & C_{APE}\le 1000\,\text{J}\cdot\text{kg}^{-1}\\ \dfrac{C_{APE}-500}{1000} & 1000<C_{APE}<1500\,\text{J}\cdot\text{kg}^{-1}\\ 1 & C_{APE}\ge 1500\,\text{J}\cdot\text{kg}^{-1}\end{cases}$	$P_{S6}=\begin{cases}0.5 & C_{APE}\le 1000\,\text{J}\cdot\text{kg}^{-1}\\ \dfrac{1500-C_{APE}}{1000} & 1000<C_{APE}<1500\,\text{J}\cdot\text{kg}^{-1}\\ 0 & C_{APE}\ge 1500\,\text{J}\cdot\text{kg}^{-1}\end{cases}$	0,05	0,05



Sumof the weighted membership functions for individual classes (each grid pixel)

$$P_x=\sum_{i=1}^{n}P_{xi}\cdot W_{xi}$$

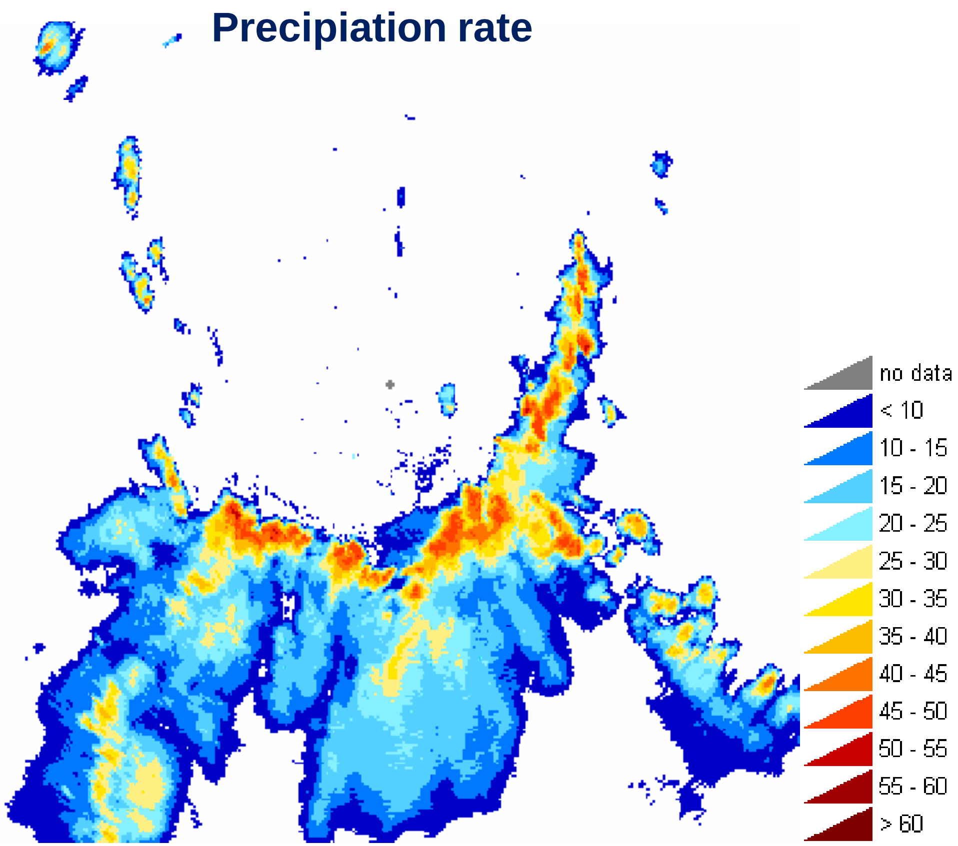
x – precipitation class (S or C);
i – *i*'th parameter;
n - number of parameters used;
P_{xi} - membership feature;
W_{xi} - weight

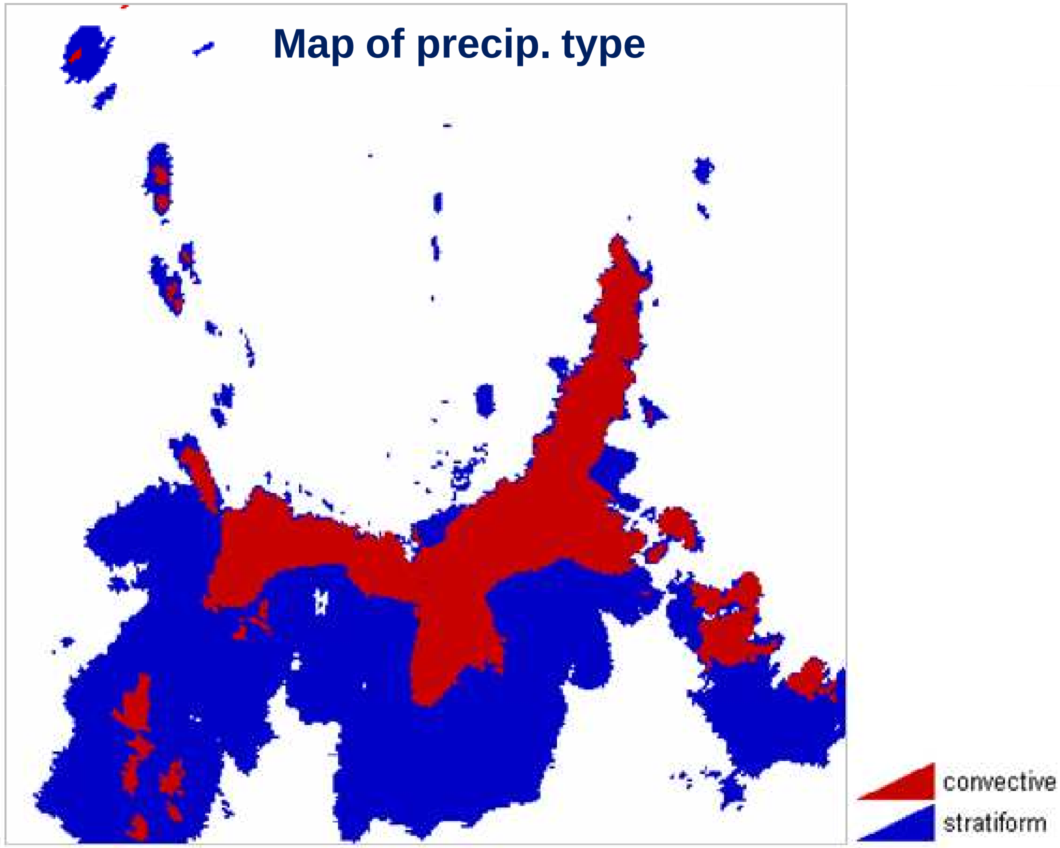


The higher value of the membership feature of the class indicates that in this pixel precipitation occurred from this class

Detection of the convection

Examples of recognized areas of convection for Legionowo radar coverage , 12 sept. 2007, 14 UTC





Recognition of the convective cells

Determination of convective cells centers

- ***search local reflectivity maxima in the Z_{max}***
- ***verify maxima by analysis of their relative positions***

pixel clustering convection.

- ***assignment of the pixel to the appropriate cells centre***
- ***minimalize function u (i, x) takes the smallest value:***

$$u(i,x) = \lambda \cdot grad(i,x) + (1-\lambda) \cdot dist(i,x)$$

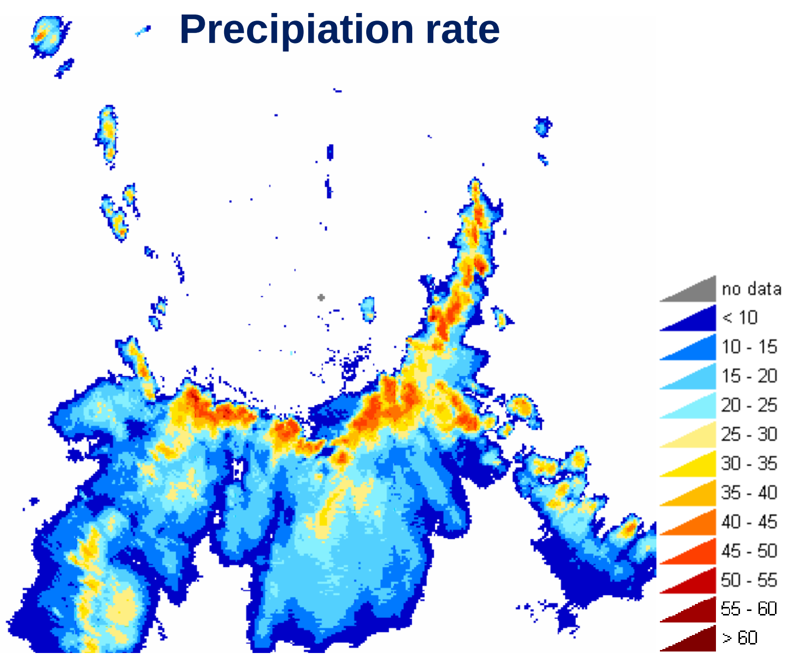
x **– piksel number,**
i **– cell numer**
grad **– reflectivity gradient beween pixel and cell center [dBZ]**
dist **– distance beween pixel and cell center**
λ – coefficient

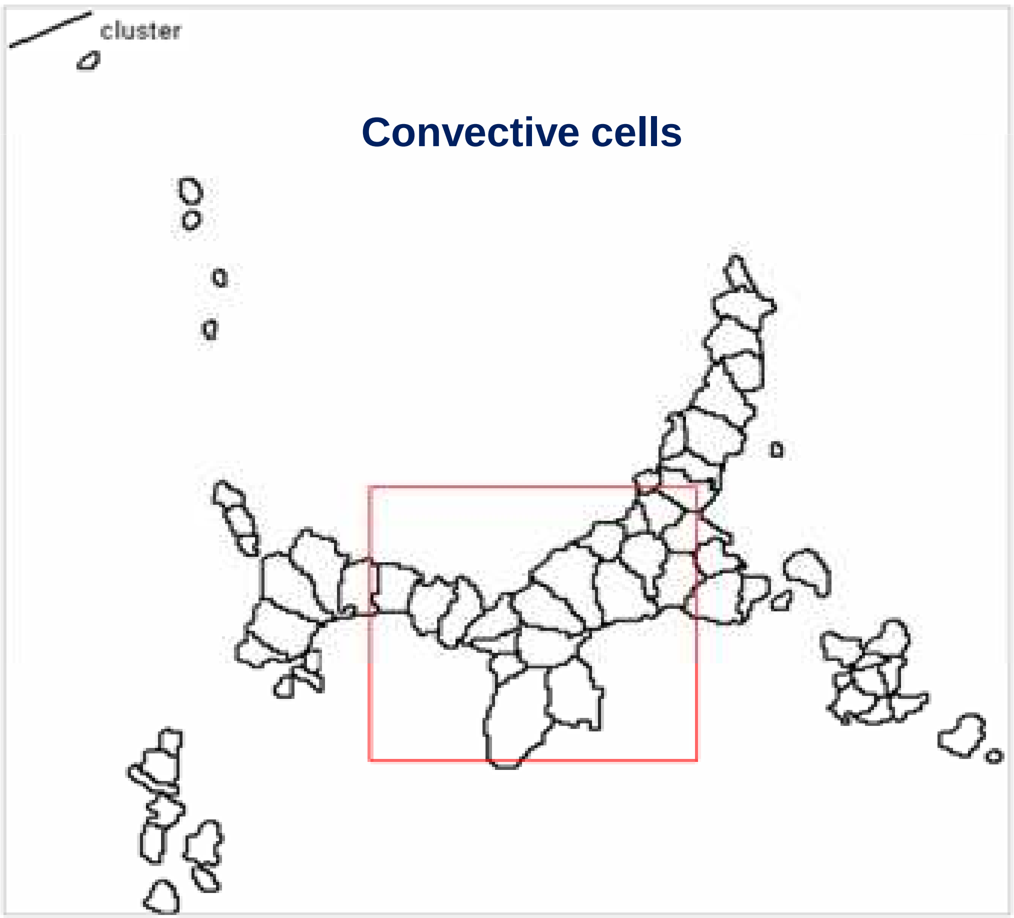
correction of cell clustering allocation

- ***delete individual pixels not assigned to any cell,***
- ***merge cells between which there is no significant reduction in reflectivity and they are located less than established distance threshold,***
- ***adding to cell its surrounding depending on the mean reflectivity inside this cell***
- ***smooth edges of cells***
- ***delete cells at the surface below the threshold.***

Recognition of the convective cells

convection cells for the Legionowo radar range on August 12, 2007 at 7:00 pm





Classification of the precipitation structures

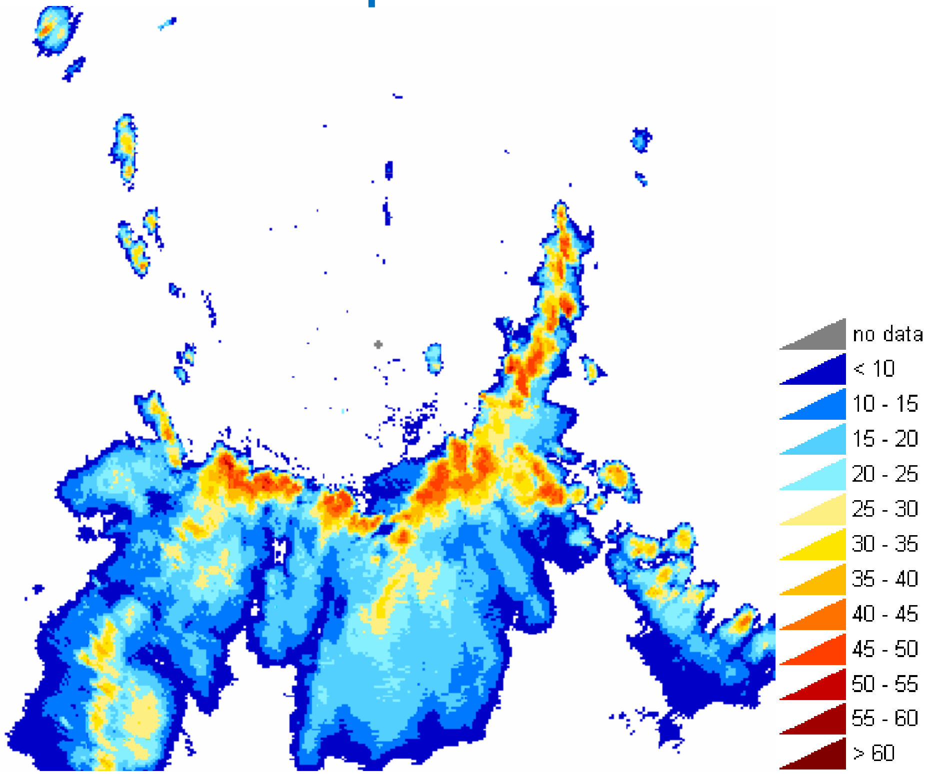
(Rigo and Llasata 2004)

Breakdown by types of structures

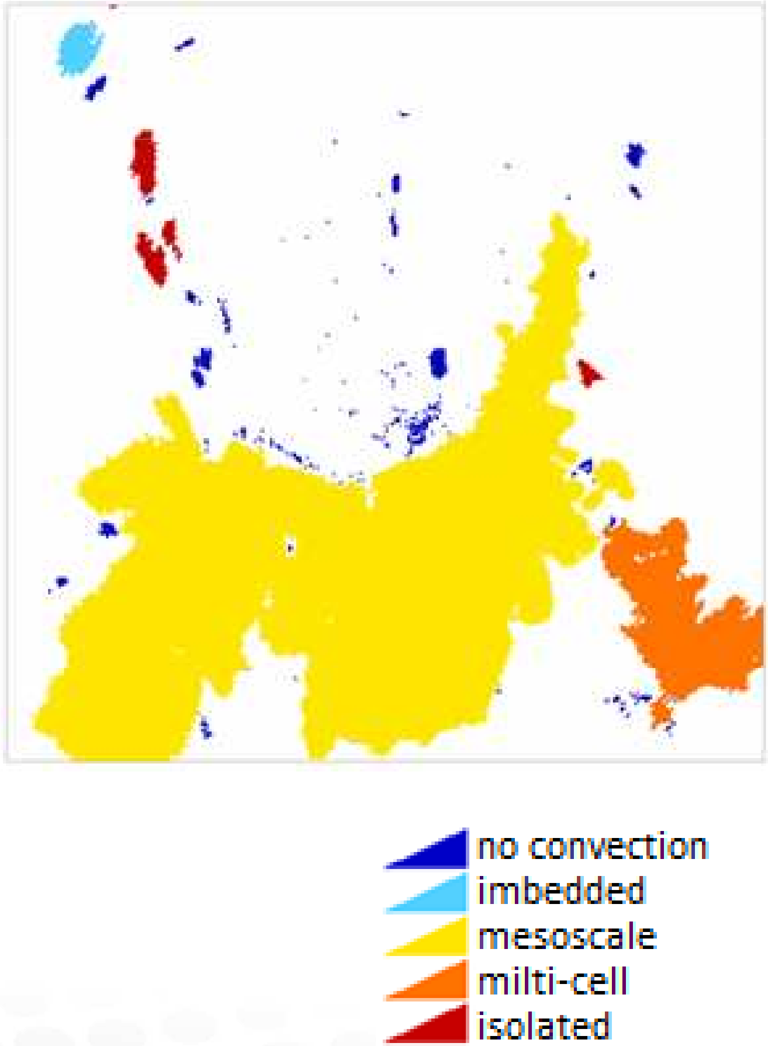
- **Mezoscale Convection Dystem (MCS)** – the rain recognized as an area of convection, in addition, has a spatial expansion and total area above the set thresholds.
- **Multi-cell System (MUL)** – structure similar to the mezoskale system, however, has a spatial expansion below the threshold.
- **Isolated convection (IND)** – occurs in small, isolated areas below the established threshold.
- **Embedded convection (EST-EMB)** – area of convection in the surroundings of precipitation occupies part of the surface of an object above the threshold established rain and below the threshold for objects of the MUL, or MCS.
- **Non convective precipitation** –surface convective precipitation is below a certain threshold.

Classification of the precipitation structures

Precipitation rate



Map of the structures of the rain



Extrapolation: control of movement vectors

- **Method for movement vector field estimation**
  - TREC (Tracking Radar Echoes by Correlation, Mecklenburg et al., 2005)
  - COTREC (Continuity TREC) avoids the divergence of reflectivity and fulfill the continuity equation
  - SCENE algorithms
    - bilinear interpolation
    - forward scheme, backward scheme
    - constant vector, semi-Lagrangian scheme

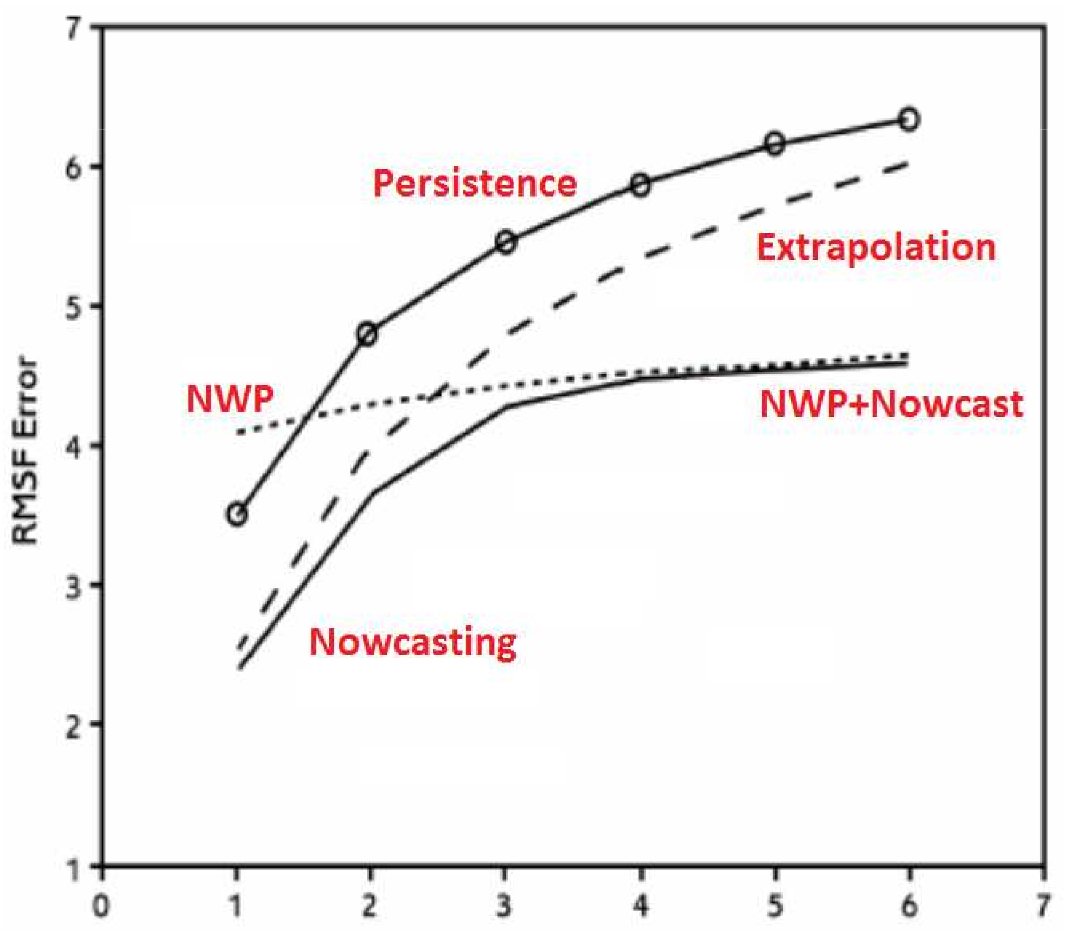
- **Criteria for determination of extrapolated movement vector**
  - correlation coefficient
  - area-related RMSE + correlation coefficient

- **Optimization of computational grid size**

Nowcast verification

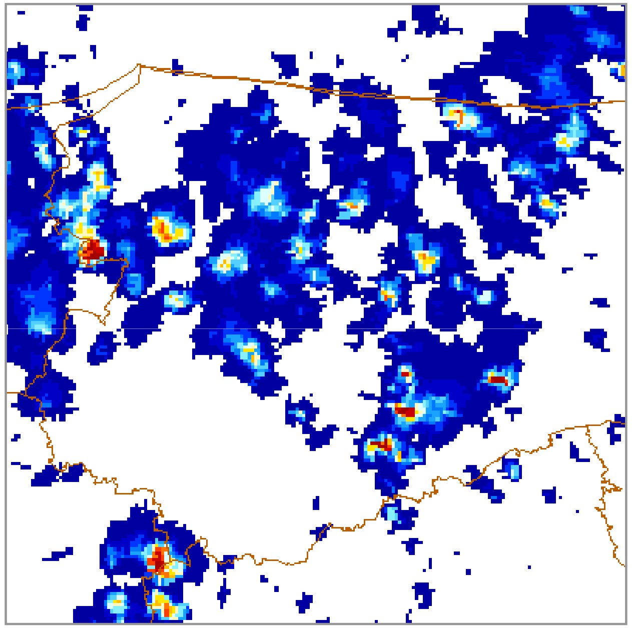
Quality criteria

- **Area-related RMSE (*A-RMSE*)** – the RMSE calculated for each pixel in 9 x 9 km grids around it, after sorting values in the descending order (Rezacova et al., 2007),
- **correlation coefficient**, *R*, and area-related R (AreaR)
- criteria calculated on the basis of **contingency table** (PC, POD, DPOD, FAR, CSI, SR, etc.).

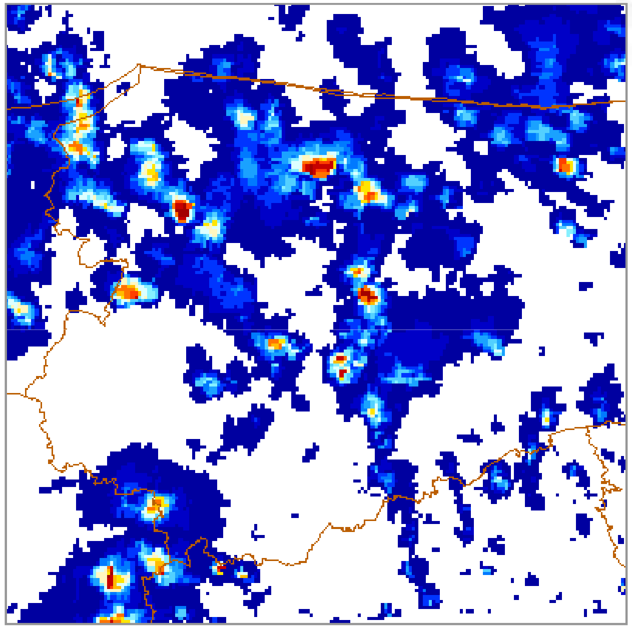


SCENE vs INCA-PL nowcasts, 30-min lead time

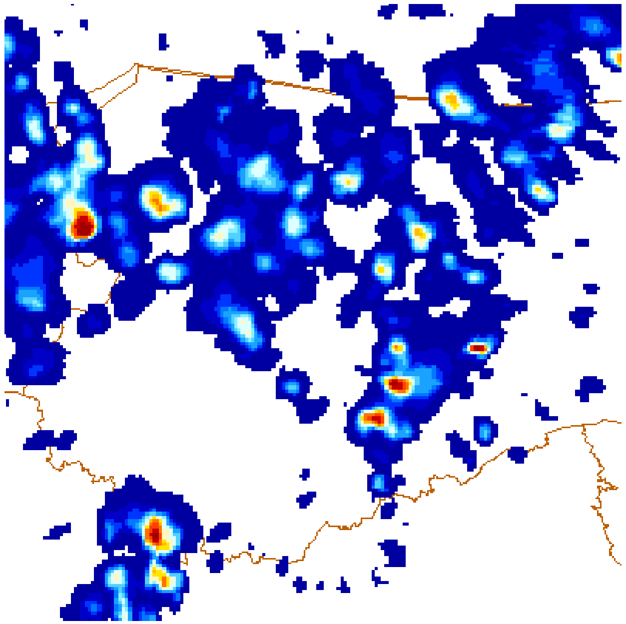
11:10 analysis



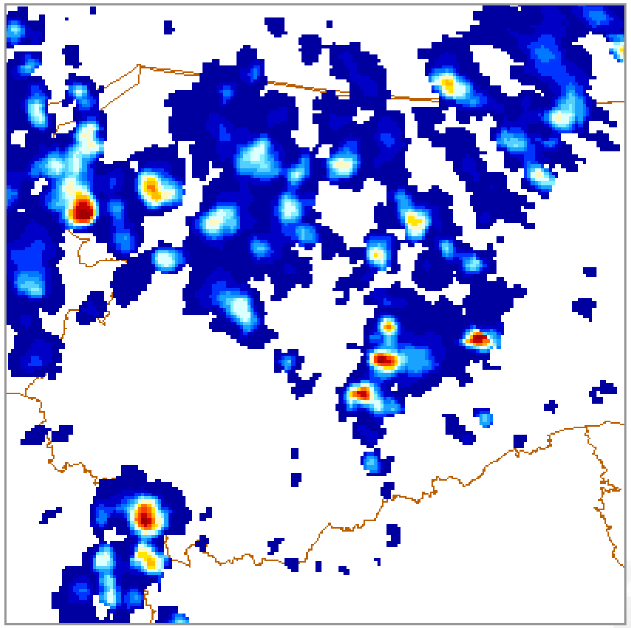
11:40 analysis



INCA11:40 nowcast

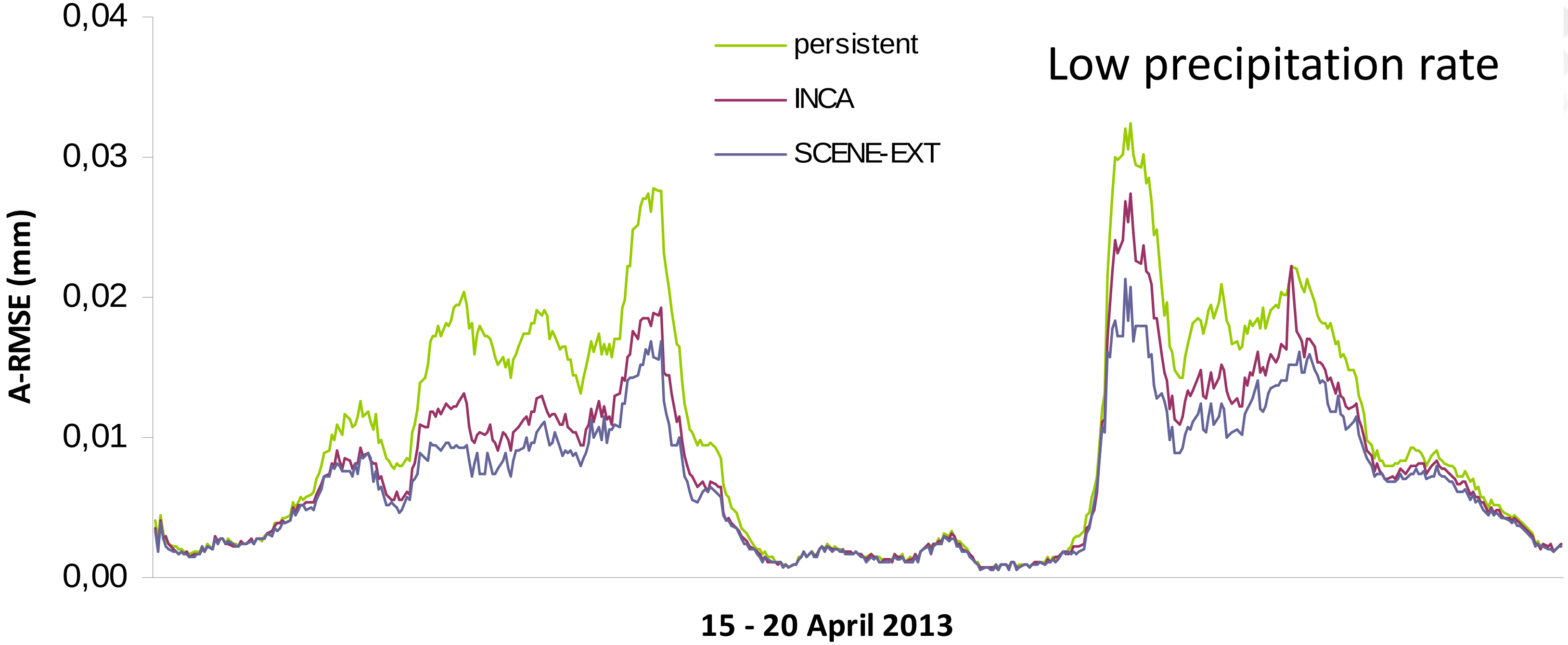


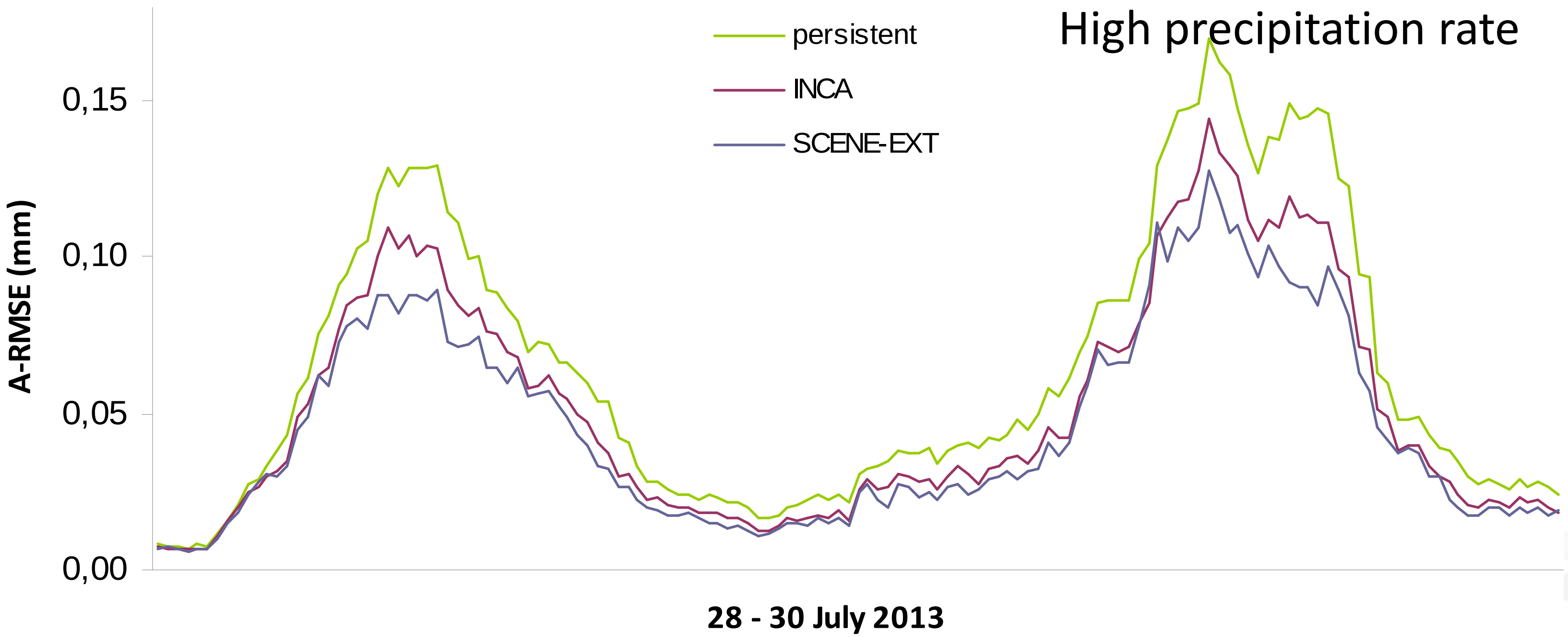
SCENE 11:40 nowcast



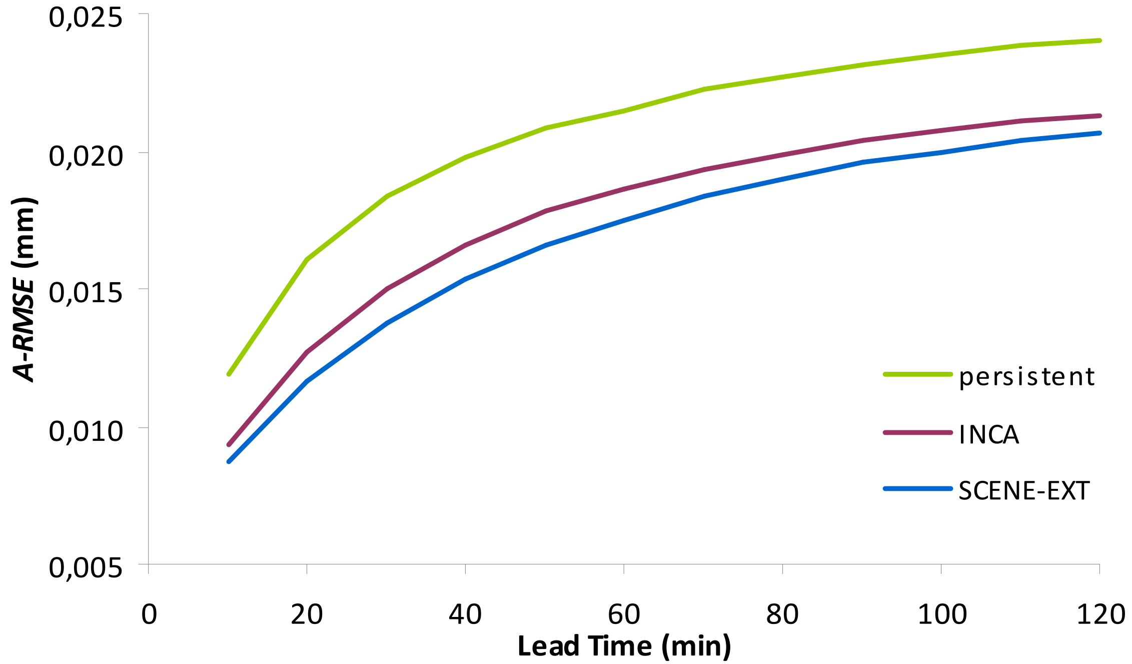
north excerpt of Poland domain, 22 May 2013

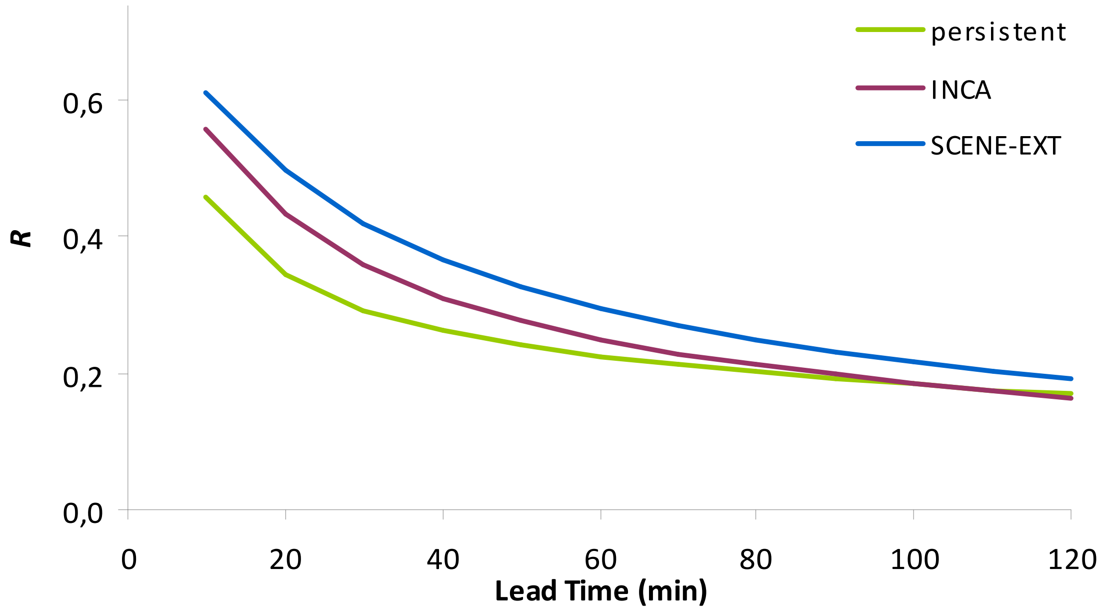
SCENE vs INCA-PL nowcasts
Area-related RMSE for 30-min lead time





SCENE vs INCA-PL nowcasts





Object-oriented extrapolation

Methods determined for convection area :

- individual vector for each convective pixel (using also COTREC),
- individual vector for the whole convective cell assigned to its centre,
- individual vector for the whole convective cell, determined by tracking of its centre.

Cell evolution model

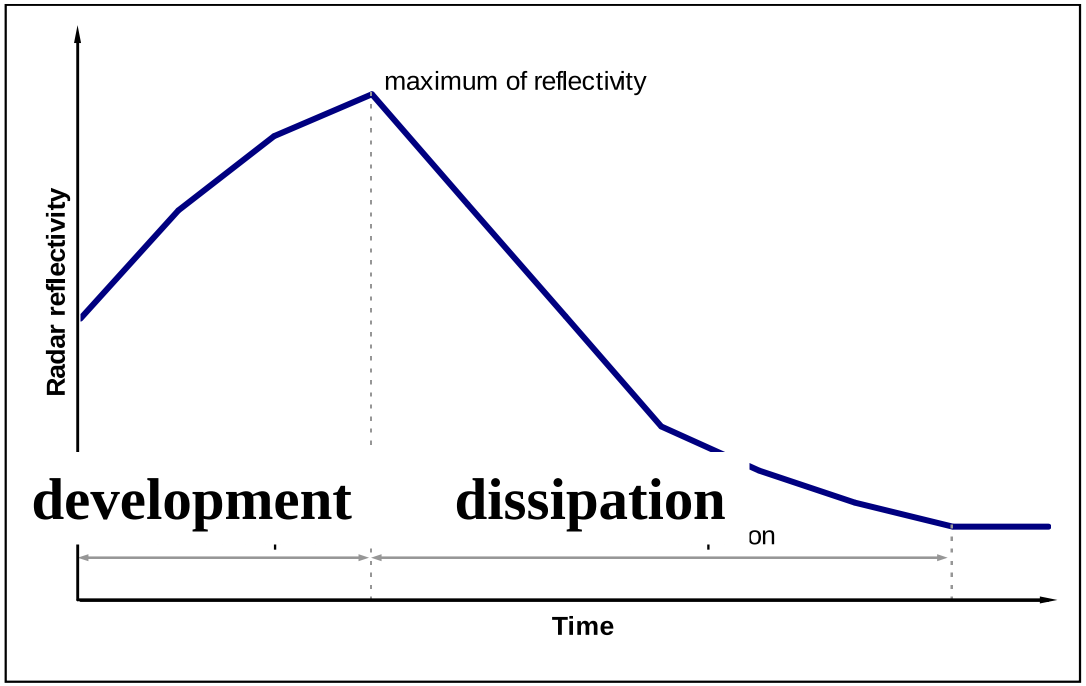
Parameters relevant to classify stages of life cell convection:

- **Maximum refleectivity (Z_{max}),**
- **Integrated amount of water in the vertical column above the cell (*VIL*),**
- **The height of the radar echo tops with the threshold of 4 dBZ (*EHT*).**

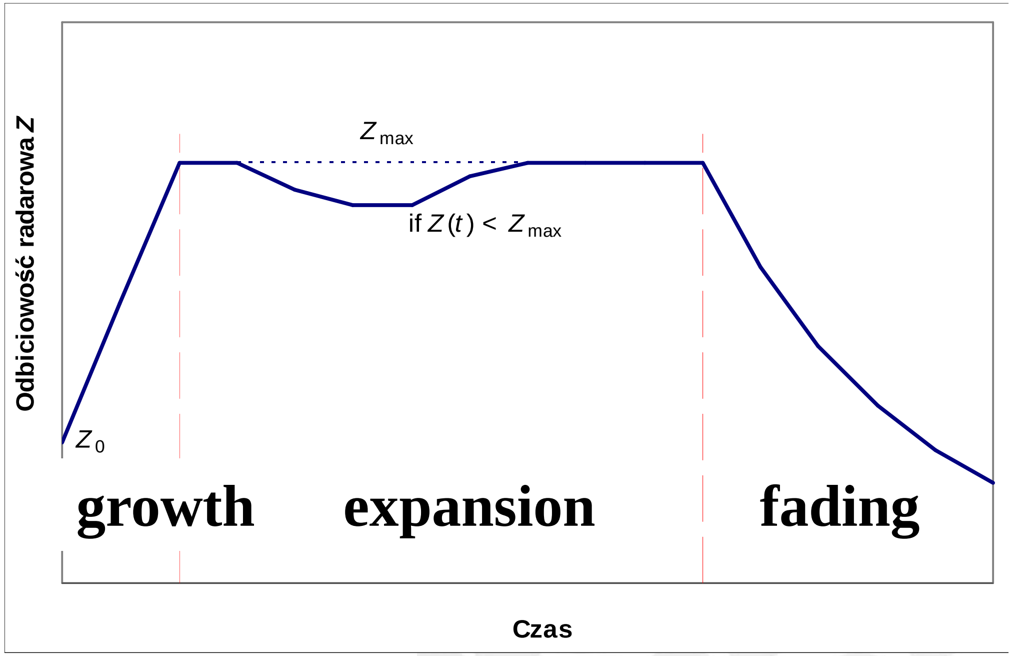
The evolution sub-models of the precipitation field:

- **convection cells located in the structures IND and EST-EMB**
- **convection cells located in the structures MUL and MCS**
- **initialization of the convection cells in systems IND**

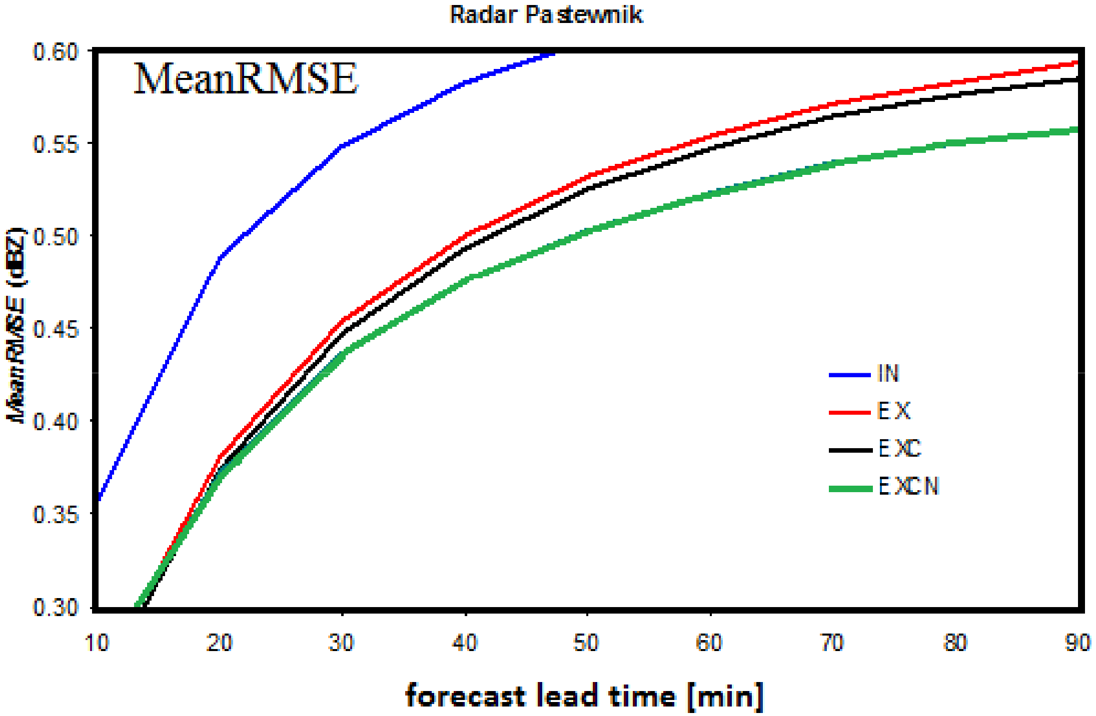
IND and EST-EMB

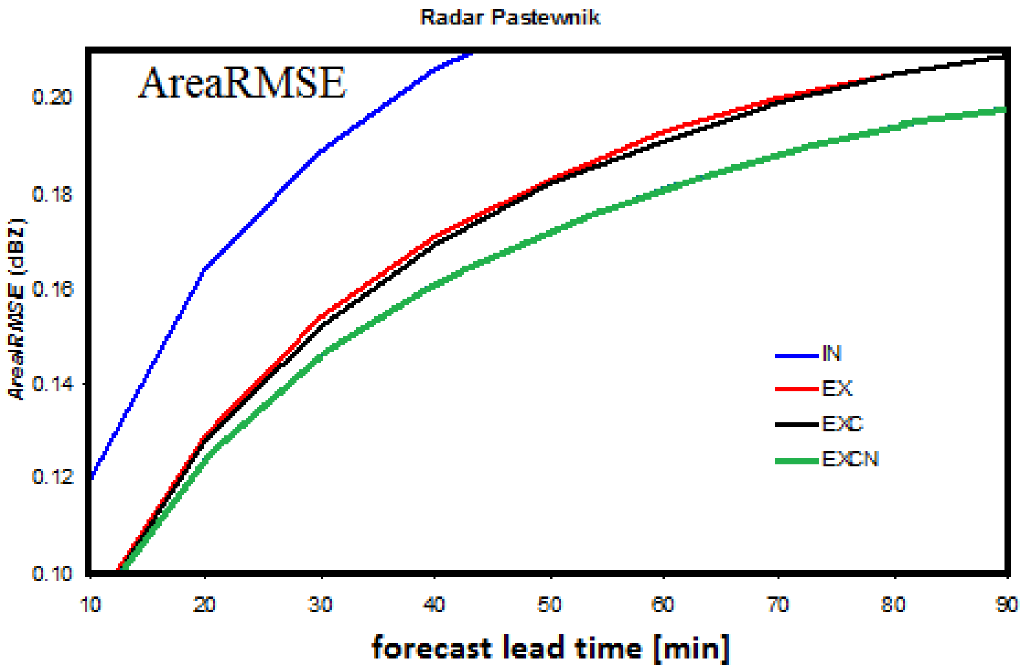


MUL and MCS



Cell evolution model





- ❑ EX - extrapolation
- ❑ EXC - object extrapolation
- ❑ EXCV – object extrapolation with cell evolution

Radar Pastewnik, Sept. 2007

Ongoing activities and future plans

- comparison of the spatial distribution of the parameters of the COSMO and satellite data with radar data

- detection of convection cells based on COSMO (COSMO does not show the whole storm front as one object),

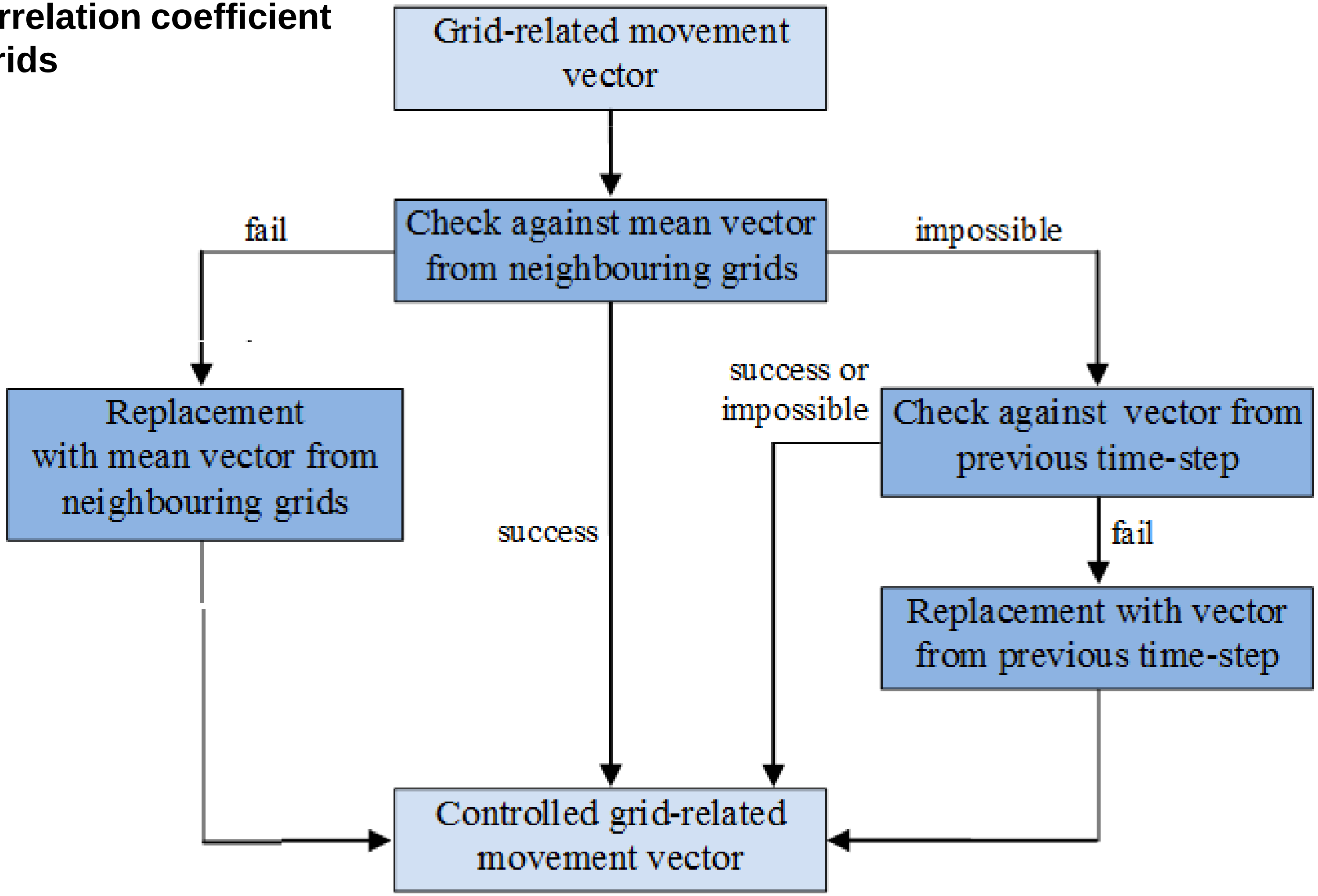
- select best parameters to describe properties of the cell objects (needs to include knowledge of the physics of storms/precipitation)

BACKUP SLIDES

Extrapolation: control of movement vectors

Important parameters:

- minimum number of grids for which the calculated displacement vectors
- maximum amount of time since the last calculation of displacement
- minimum occupancy in domain
- minimum correlation coefficient
- size of the grids



Result:
value of the displacement vectors for particular grids;
map of the extrapolated radar image.