# Predicting weather radar data using an ensemble of neural network models

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**WeADL 2024 Workshop**

**The workshop is organized by the Machine Learning research group (www.cs.ubbcluj.ro/ml) and the Romanian Meteorological Administration (https://www.meteoromania.ro/)**

Machine Learning Research Group

MLyRE

METEO ROMANIA

# Goal – Weather Nowcasting

- **Definition** (usually): weather forecast for the next 0 to 6 hours.
- The work presented here regards short time spans
  - less than 1 hour
- Data used: **radar data**
  - *inputs* are radar data
  - *outputs* are radar data (predictions on future radar data)

# Radar Data - from Romanian National Meteorological Administration (NMA)

- Data collected over central Romania
- Single polarization 458 S-band Weather Surveillance Radar - 98 Doppler (WSR-98D)
  - Full volume scan (all elevations, all products) every $\sim$ 5.5 minutes
- For our work we used the Reflectivity product on 6 elevations
  - expressed in decibels relative to the reflectivity factor Z (dBZ)

**Base Reflectivity product (R) suggests**

- location, intensity and type of precipitation
- storm structure and size
- distribution of water particles

# Dataset

- Data collected from 2020, 2021 and 2022
  - manually curated by meteorologists
- data set contains 264 days
  - 67,922 time steps
  - $\sim$ 257 timesteps per day
- area of 230 km radius around the radar site
- Data represented as **460x460** data grid
  - for each time step
  - for each elevation

# Data representation

- An instance is represented by the data grid containing all the data at a time moment – a 460x460 grid for every elevation

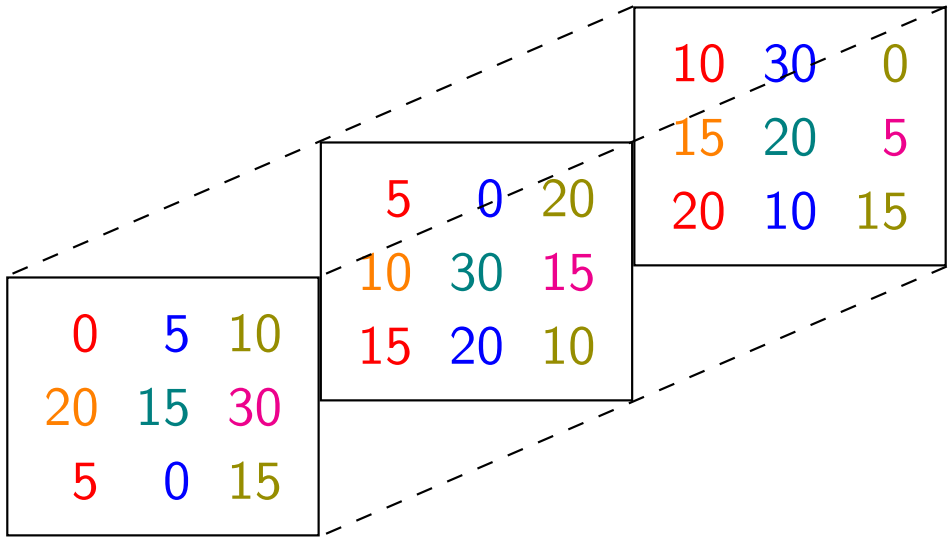



Figure: A sample data grid for a timestep.

# Data Representation 2

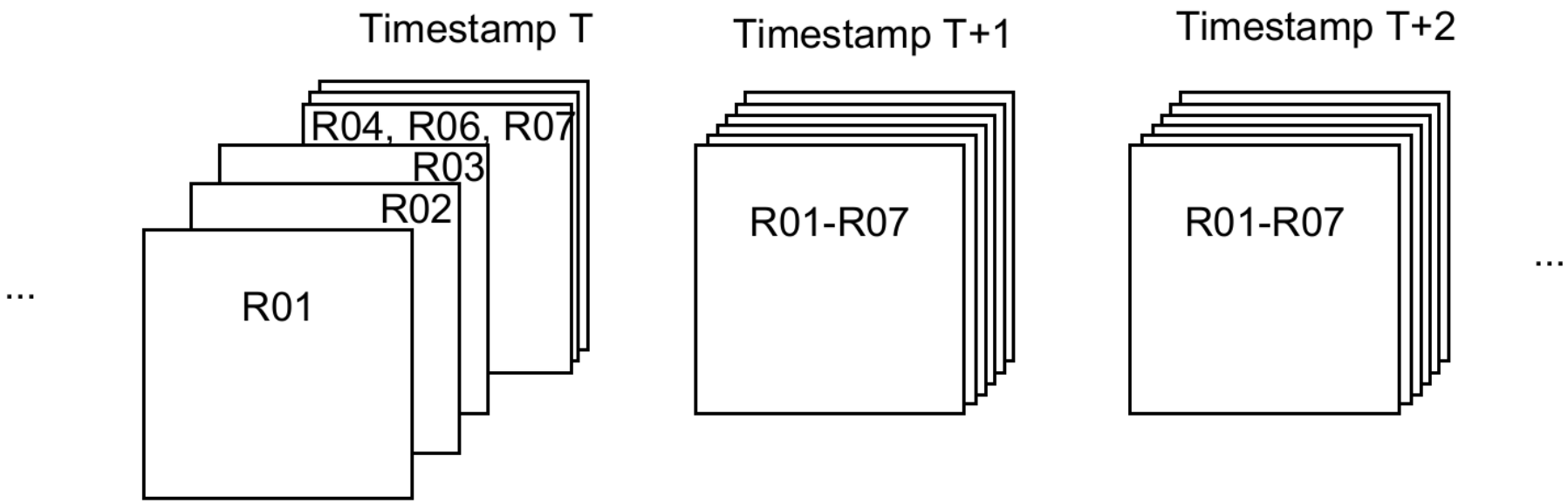



Figure: Data representation in time.

# *SepConv-ens* model – prediction goal

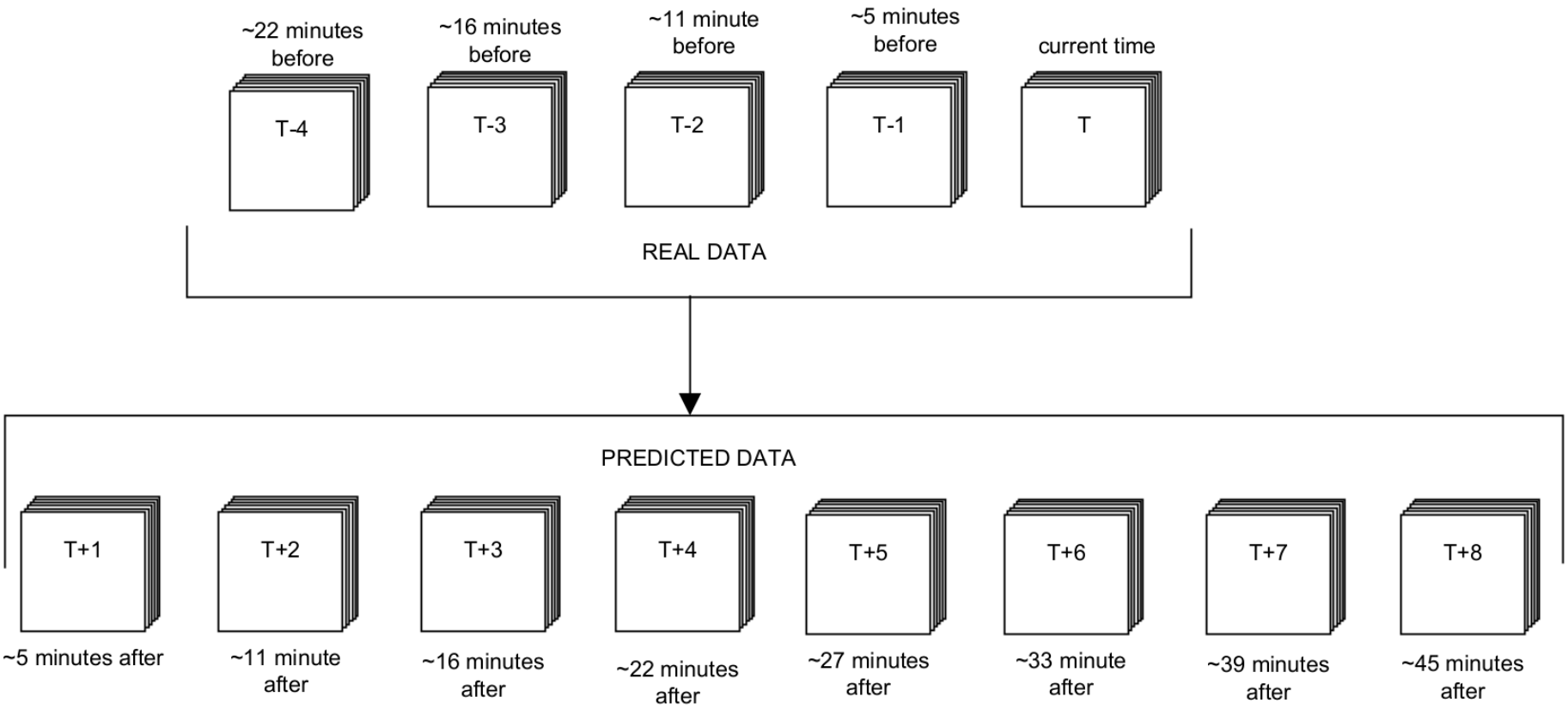



Figure: High-level overview of what the model does.

# *SepConv-ens* model – the 3 base models

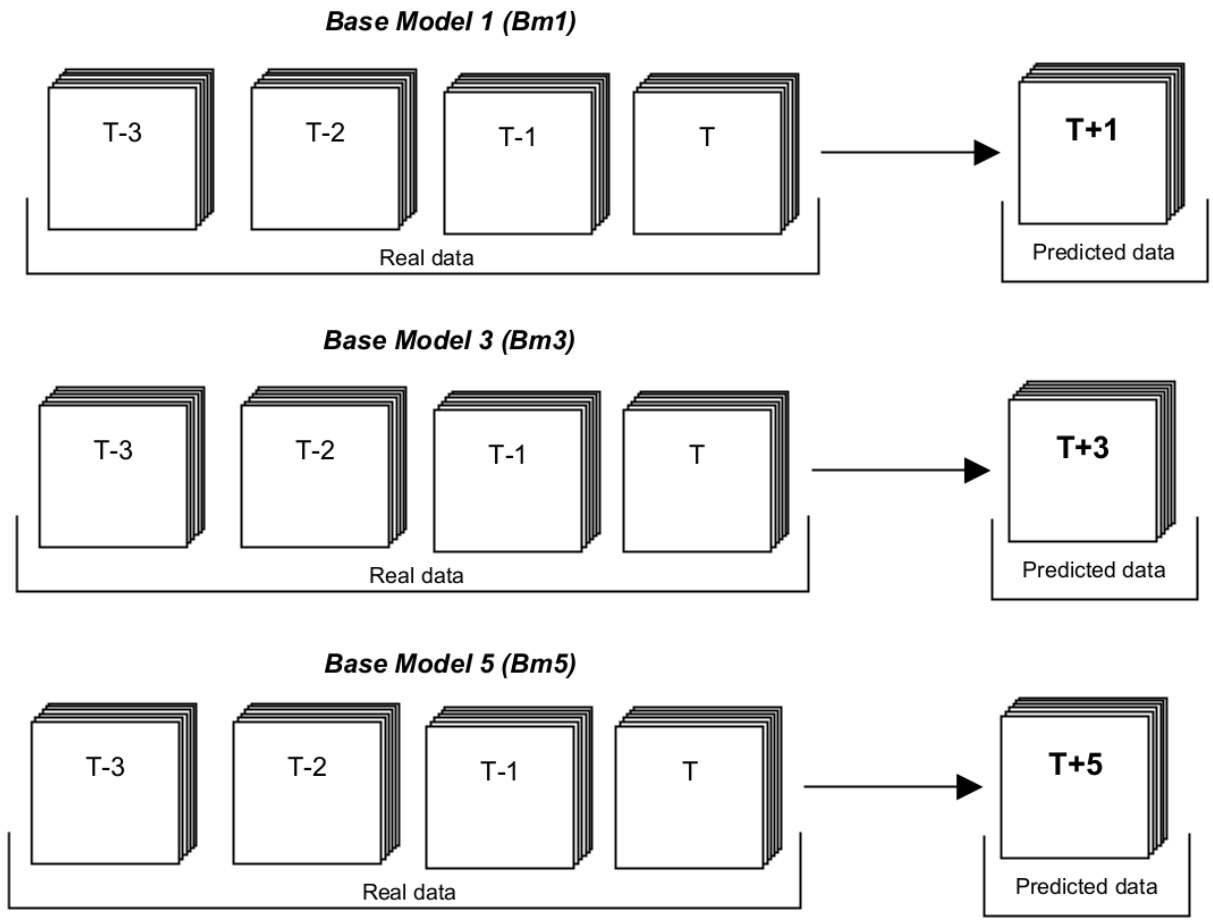



Figure: The base models that are part of *SepConv-ens*.

# *SepConv-ens* model – base models architecture

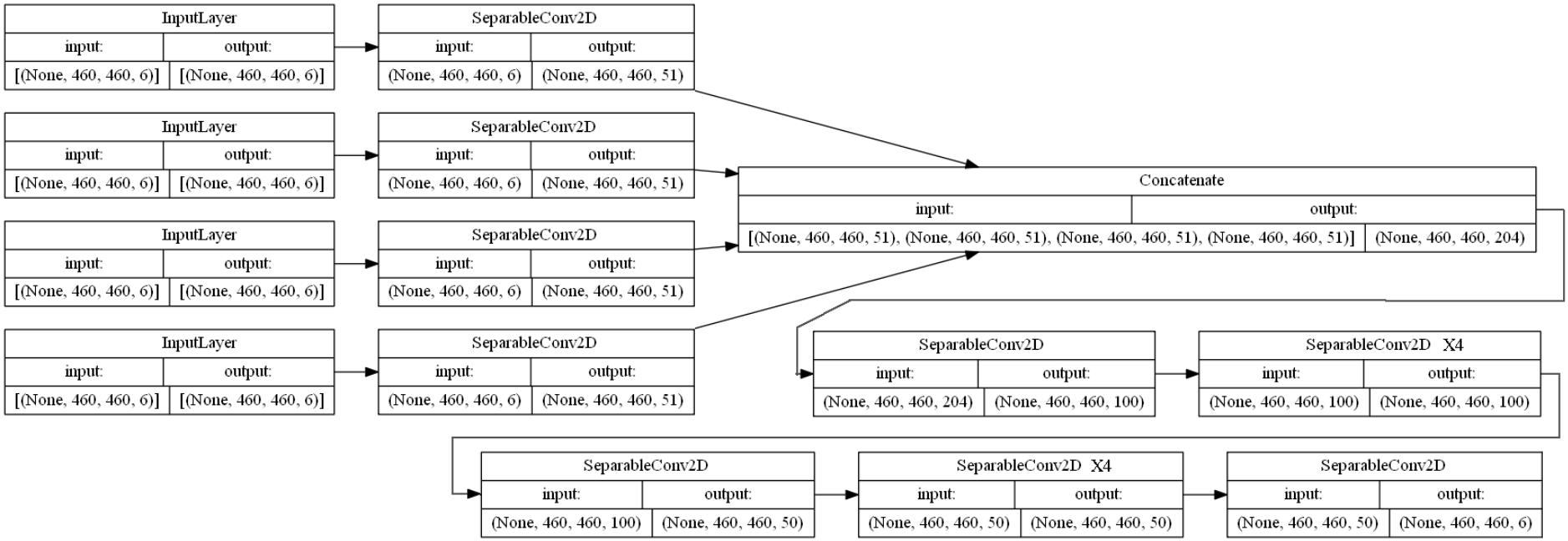



Figure: The neural network architecture of the base models.

# *SepConv-ens* model – combining the models 1

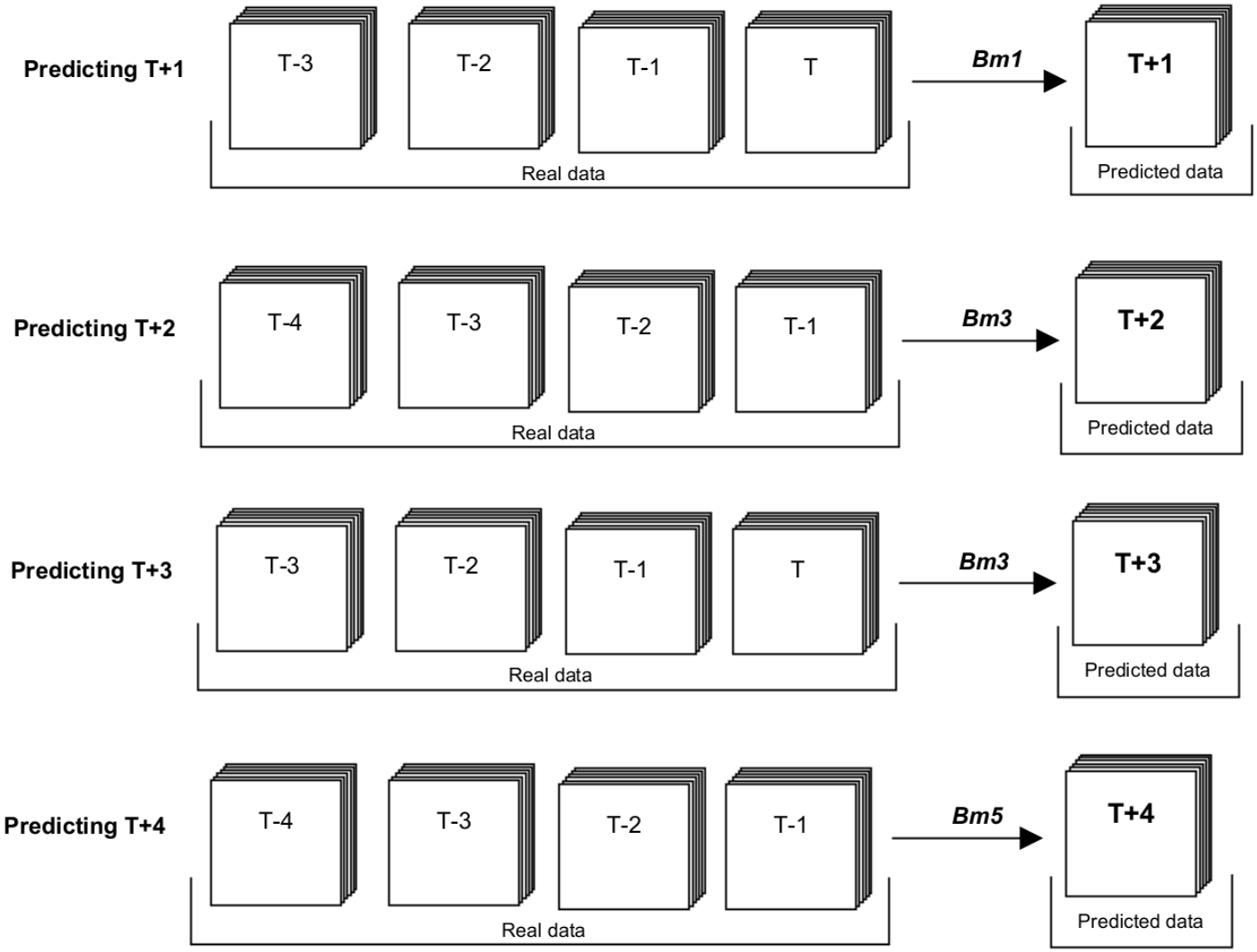



Figure: How predictions are made for T+1, T+2, T+3 and T+4.

# *SepConv-ens* model – combining the models 2

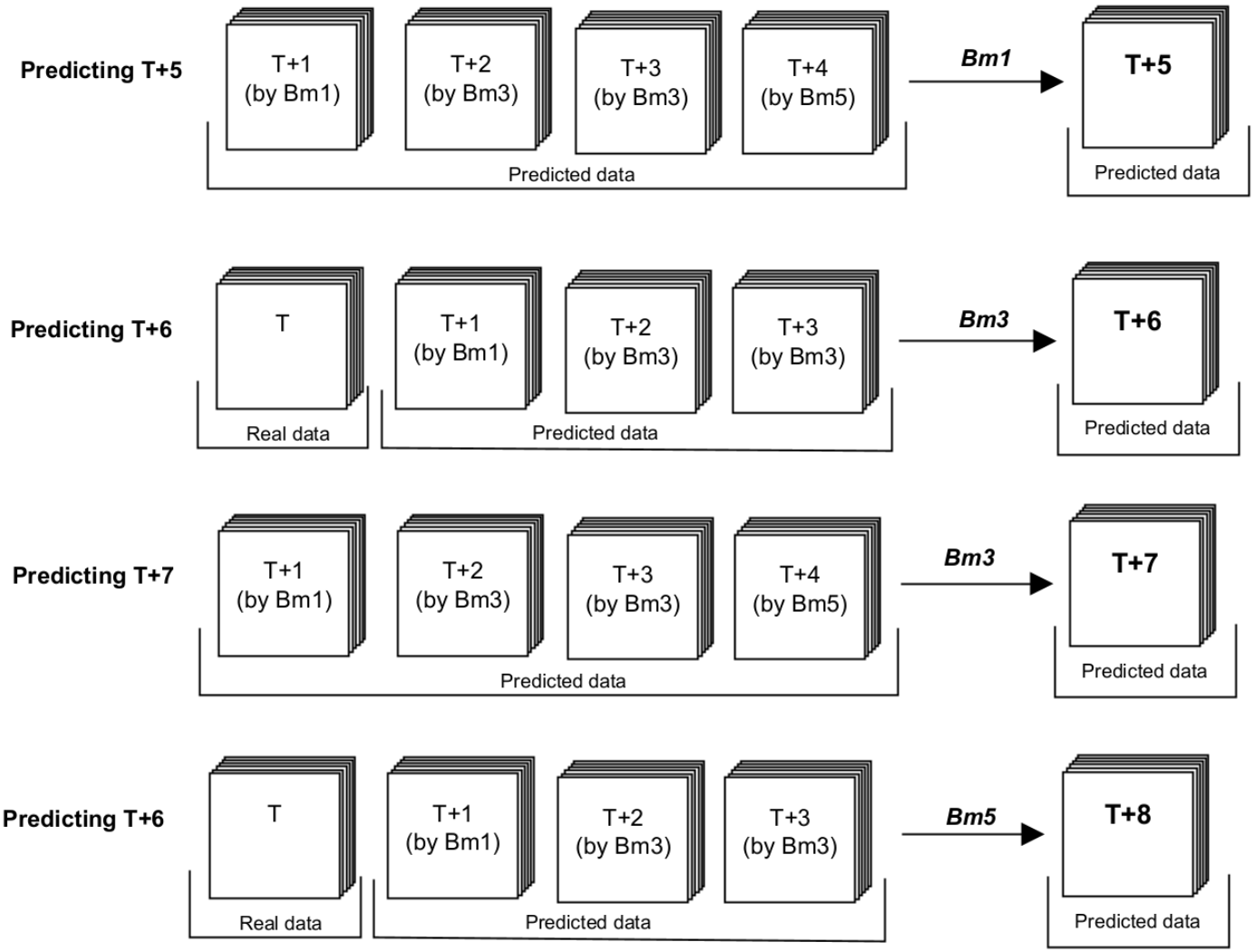



Figure: How predictions are made for T+5, T+6, T+7 and T+8.

# Training, testing and validation datasets

- Dataset split into: 10% testing, 10% validation, 80% training
- All 3 base models were trained with the same datasets
- The split was done on a day by day basis:
  - each day was split into 4 equal parts ($\sim$ 6 hours each)
  - each part was split into training/validation/testing
  - each datasets was made up by concatenating the smaller parts.

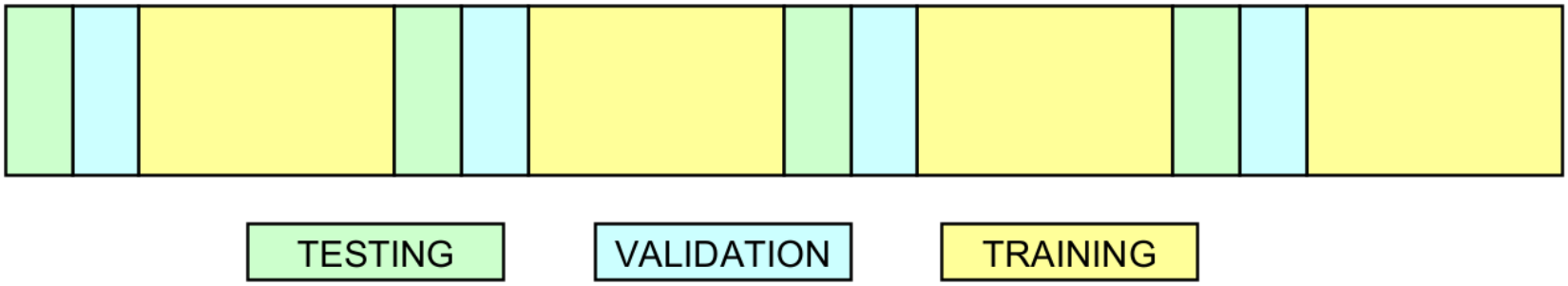



Figure: How data for 1 day is split into different datasets.

# Performance evaluation – metrics

- Regression metrics:
  - *Root mean squared error* (*RMSE*)
  - $R^2$ score: a statistical measure of how well the predicted values approximate the real observation
- Classification metrics:
  - *Probability of Detection POD* $= \frac{TP}{TP+FN}$
  - *False Alarm Ratio FAR* $= \frac{FP}{FP+TP}$
  - *Critical Success Index CSI* $= \frac{TP}{TP+FN+FP}$
  - *Heidke Skill Score* (*HSS*) *HSS* $= \frac{2\cdot(TP\cdot TN-FP\cdot FN)}{(TP+FN)\cdot(FN+TN)+(TP+FP)\cdot(FP+TN)}$
- Image processing metrics:
  - *VIF* (*Visual Information Fidelity*) – quantifies the visual quality of images
  - $F_{cbc}$ (*Index for the cell-by-cell comparison*) – the ratio of cells in the prediction that match with the corresponding cell in the real data

# Result

| Lead time | Regression metrics | | | | Classification metrics | | | | | Image processing metrics | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *RMSE* (↓) | | $R^2$ (↑) | | $\tau$ | *POD* (↑) | *FAR* (↓) | *CSI* (↑) | *HSS*(↑) | *VIF* (↑) | | $F_{cbc}$ (↑) | |
| | **All** | **Non-zero** | **All** | **Non-zero** | | | | | | **All** | **Non-zero** | **All** | **Non-zero** |
| **6 min** (1 step) | 0.963 | 7.000 | 0.446 | 0.324 | **10** | **0.604** | **0.066** | **0.580** | **0.729** | 0.103 | 0.120 | 0.971 | 0.114 |
| | | | | | **20** | 0.439 | 0.076 | 0.424 | 0.593 | | | | |
| | | | | | **40** | 0.249 | 0.386 | 0.215 | 0.354 | | | | |
| **18 min** (3 steps) | 1.927 | 10.31 | 0.094 | 0.396 | **10** | **0.503** | **0.109** | **0.474** | **0.637** | 0.014 | 0.013 | 0.955 | 0.049 |
| | | | | | **20** | 0.336 | 0.122 | 0.321 | 0.484 | | | | |
| | | | | | **40** | 0.082 | 0.572 | 0.074 | 0.137 | | | | |
| **30 min** (5 steps) | 1.838 | 10.17 | 0.094 | 0.496 | **10** | **0.434** | **0.129** | **0.537** | **0.480** | 0.012 | 0.011 | 0.955 | 0.046 |
| | | | | | **20** | 0.249 | 0.129 | 0.240 | 0.384 | | | | |
| | | | | | **40** | 0.040 | 0.528 | 0.038 | 0.074 | | | | |
| **48 min** (8 steps) | 1.532 | 9.722 | 0.190 | 0.539 | **10** | **0.249** | **0.234** | **0.232** | **0.369** | 0.016 | 0.014 | 0.963 | 0.047 |
| | | | | | **20** | 0.084 | 0.275 | 0.082 | 0.149 | | | | |
| | | | | | **40** | 0.006 | 0.875 | 0.006 | 0.011 | | | | |

Table: Experimental results for `SepConv-ens`.

# Results 2

| Experiment | Model | Regression metrics | | | | Classification metrics | | | | Image processing metrics | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *RMSE* (↓) | | $R^2$ (↑) | | *POD* (↑) | *FAR* (↓) | *CSI* (↑) | *HSS*(↑) | *VIF* (↑) | | $F_{cbc}$ (↑) | |
| | | **All** | **Non-zero** | **All** | **Non-zero** | | | | | **All** | **Non-zero** | **All** | **Non-zero** |
| **E1** - prediction at $t+3$ | **M1** | 1.927 | 10.31 | 0.094 | 0.396 | 0.071 | 0.839 | 0.052 | 0.097 | 0.014 | 0.013 | 0.955 | 0.049 |
| | `SepConv-ens` | **1.149** | **7.874** | **0.353** | **0.674** | **0.245** | **0.293** | **0.222** | **0.363** | **0.054** | **0.058** | **0.968** | **0.086** |
| **E2** - prediction at $t+5$ | **M2** | 1.838 | 10.17 | 0.094 | 0.496 | 0.033 | 0.815 | 0.029 | 0.055 | 0.012 | 0.011 | 0.955 | 0.046 |
| | `SepConv-ens` | **1.455** | **9.221** | **0.219** | **0.591** | **0.055** | **0.385** | **0.053** | **0.101** | **0.021** | **0.018** | **0.964** | **0.054** |
| **E3** - prediction at $t+8$ | **M3** | 1.854 | 10.248 | 0.090 | 0.516 | 0.004 | 0.618 | 0.004 | 0.007 | 0.011 | 0.010 | 0.952 | **0.057** |
| | `SepConv-ens` | **1.532** | **9.722** | **0.190** | **0.539** | **0.033** | **0.540** | **0.032** | **0.062** | **0.016** | **0.014** | **0.963** | 0.047 |

Table: Comparisons with other combinations.

# Visualization

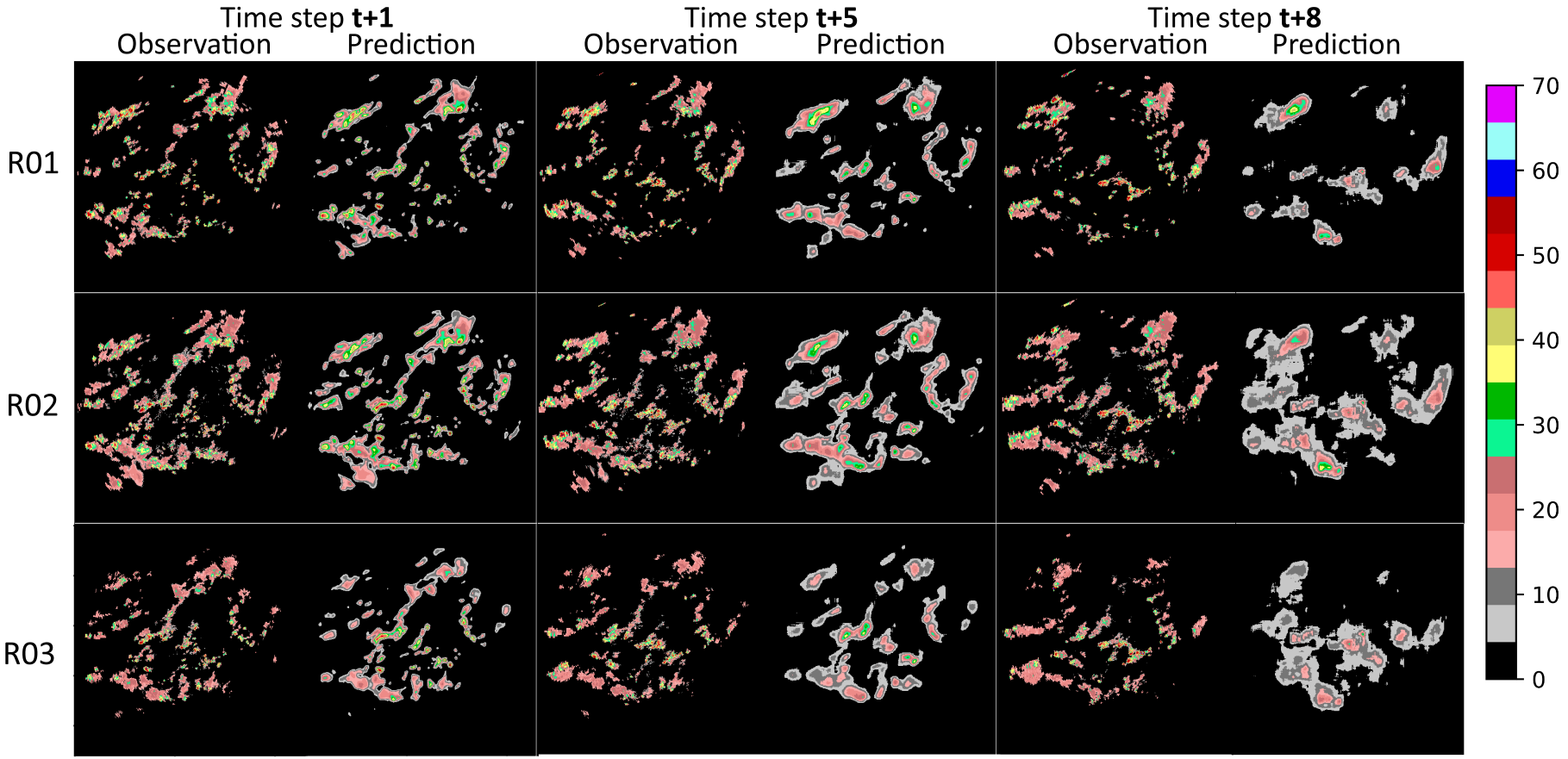
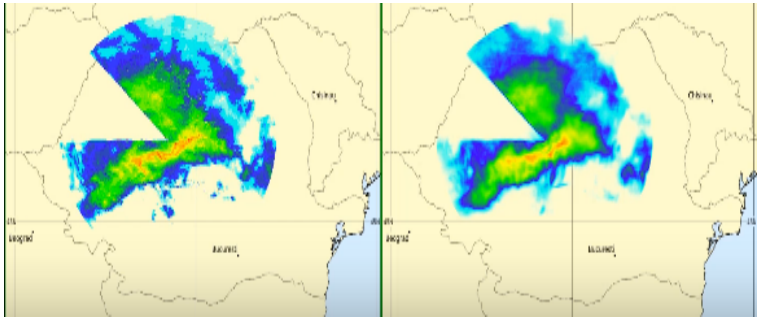
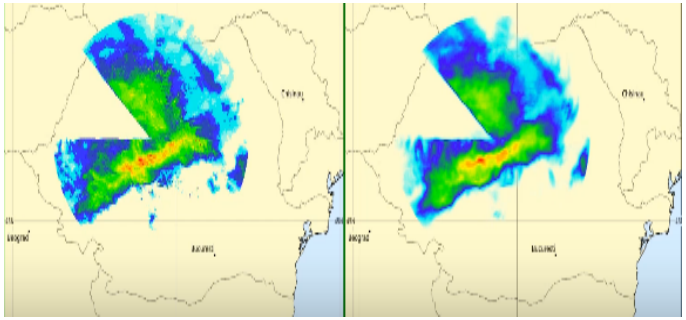



Figure: A visualisation of the `SepConv-ens` predictions for a sample time step.

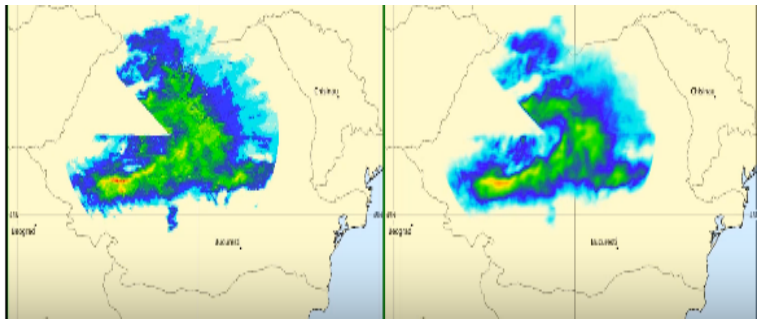
# Visualization 2



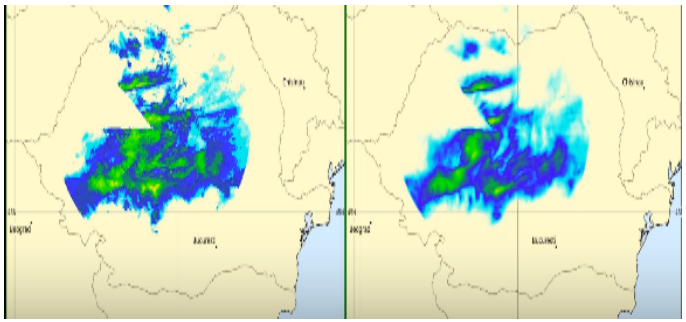
(a)



(b)



(c)



(d)

Figure: The images depict a comparison of the actual composite reflectivity, derived from data captured by the Bobohalma weather radar (shown in the left panel), and the predicted composite reflectivity generated by `SepConv-ens` model (the right panel).

Thank you!
Questions?