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The problems of influenza peak forecasting in Russian cities by means of SEIR models

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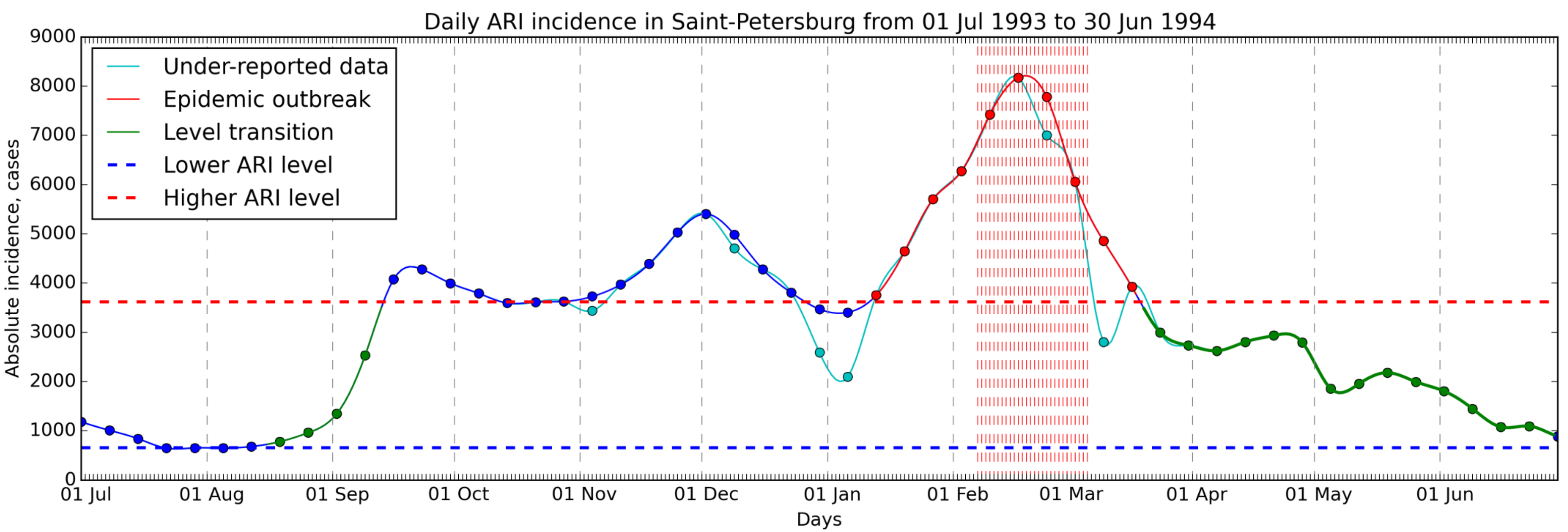
Reasons for influenza forecasting

- Store medications in advance
- Prepare means to prevent disease complications (heart diseases, strokes)
- Calculate the necessary number of hospital beds to treat the severe cases of influenza

Baroyan-Rvachev approach

- For a fixed epidemic season the influenza outbreak incidence curves are similar in different cities



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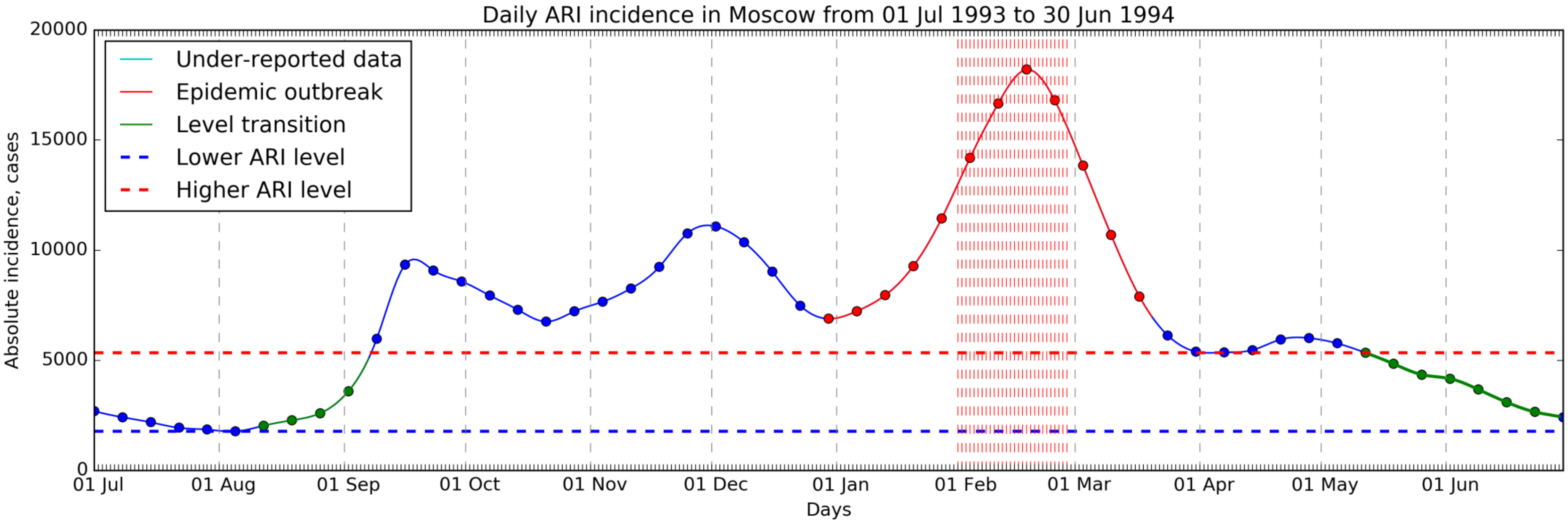

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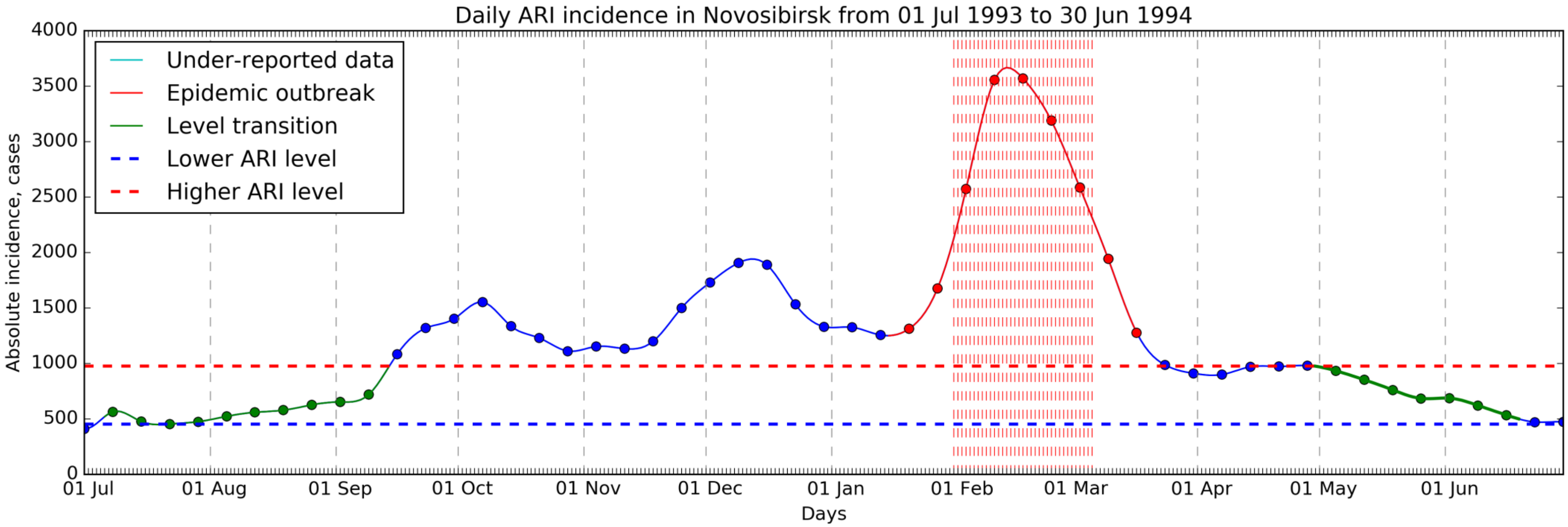
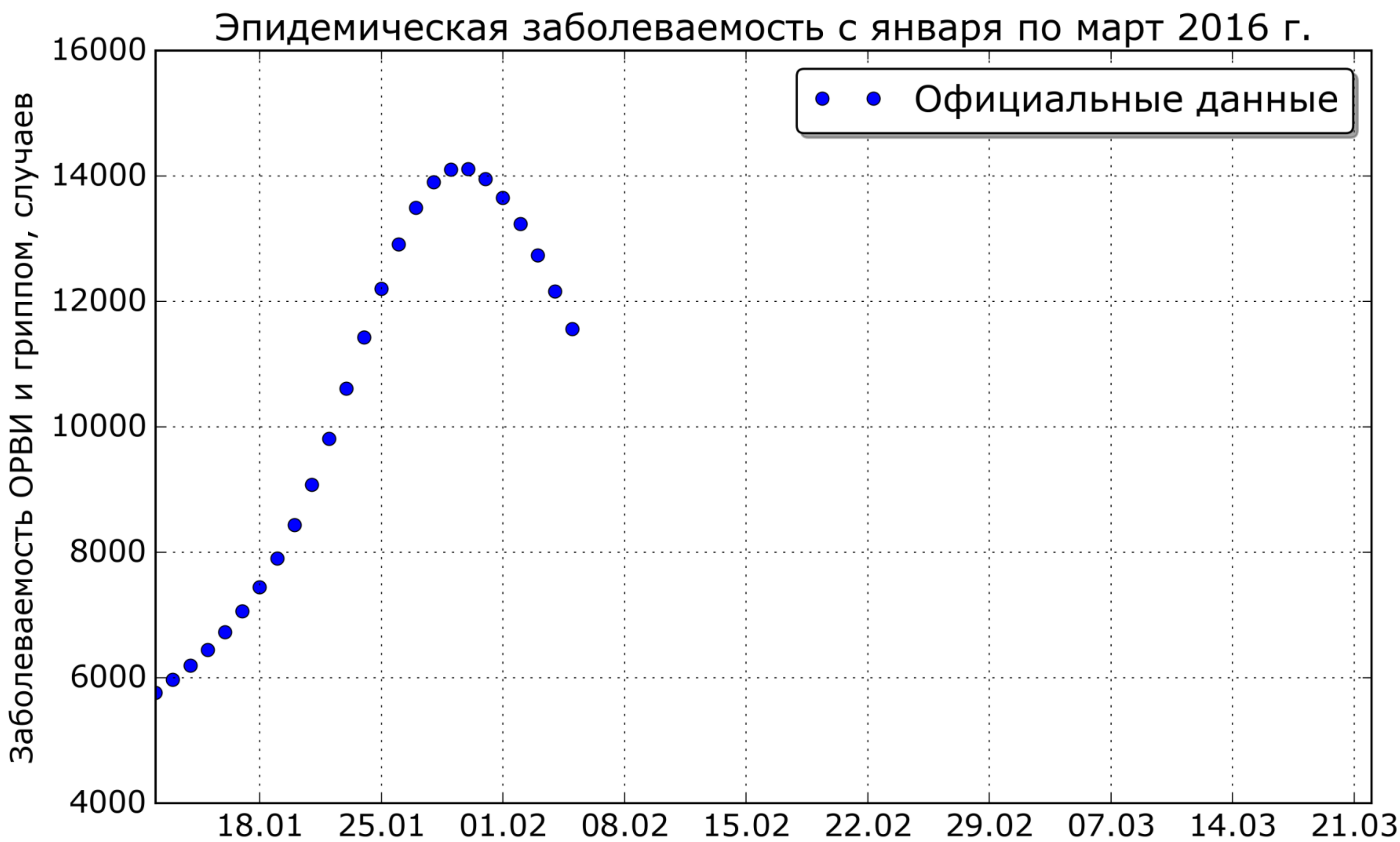
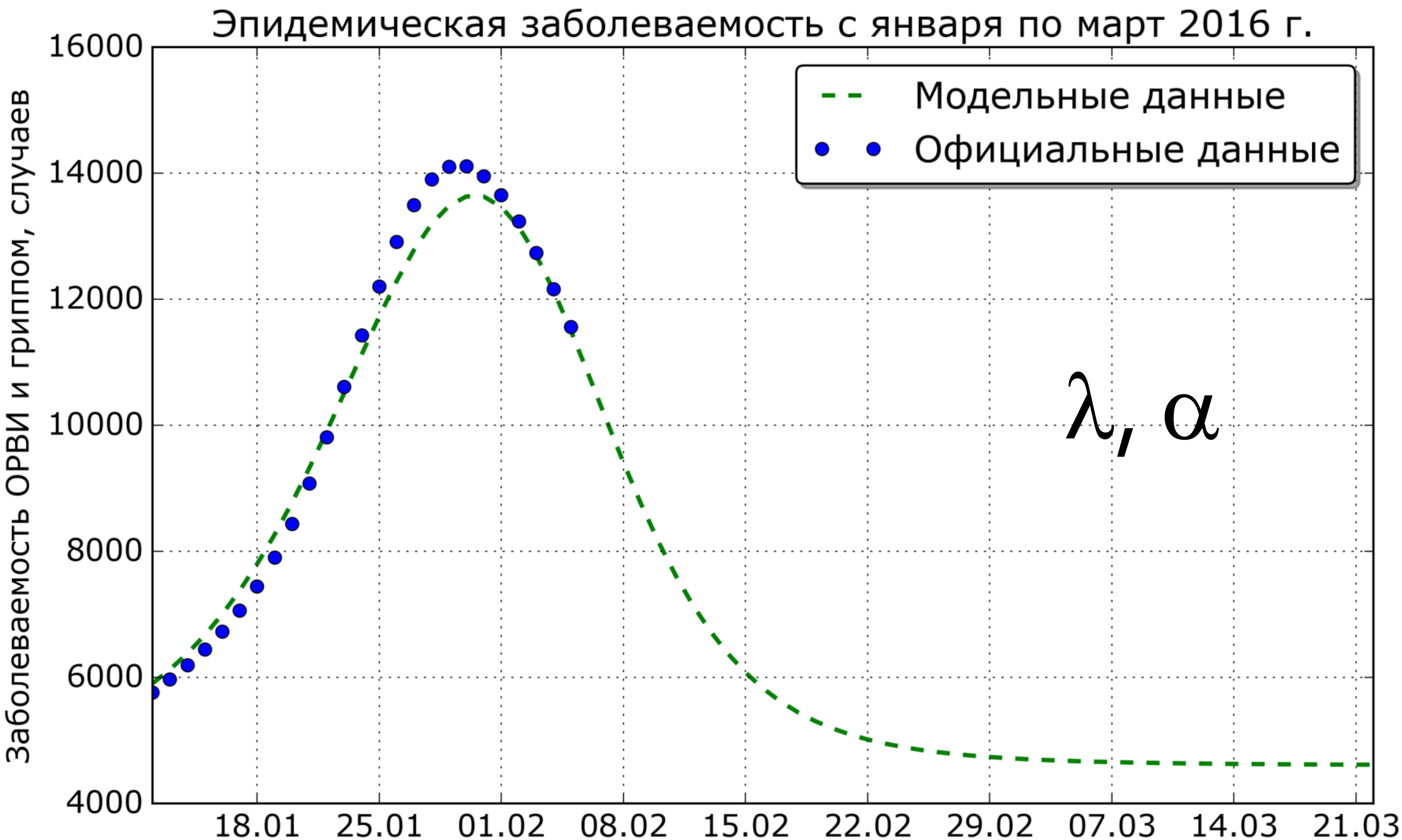


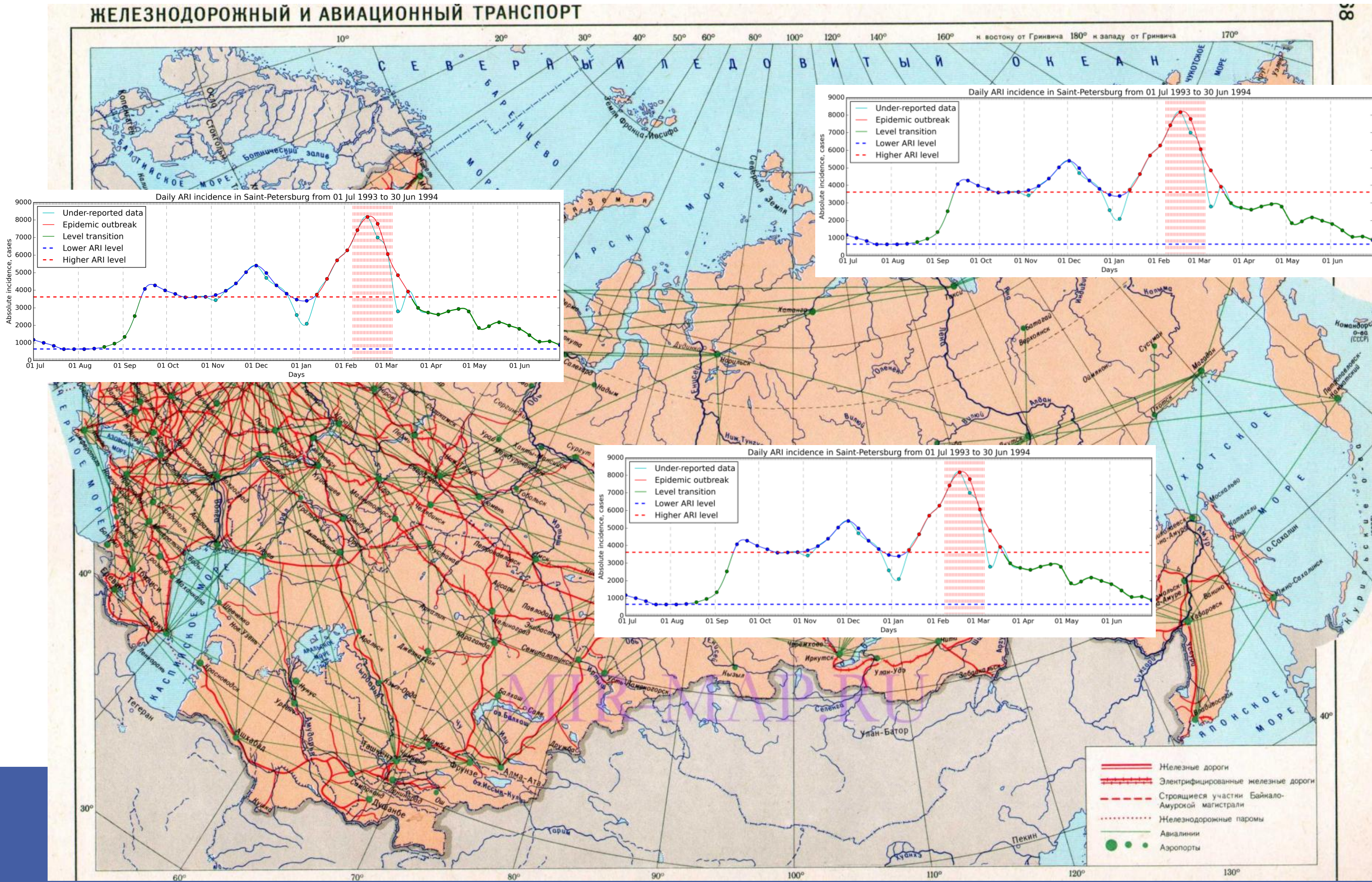
Taking the incidence of the first epidemic outbreak



Calibrating the outbreak model



Predicting the epidemic peaks with a local model



Why can't we make the forecasts now?

- Growing incoherence of the model in 80's (due to the reasons still not entirely clarified)

- Absence of daily incidence reporting
  Using interpolated weekly data

- Lack of transport data
  Applying alternative prediction methods

Local model types

- Continuous SEIR model

$$\frac{dS}{dt} = -\beta SI,$$
$$\frac{dE}{dt} = \beta SI - \gamma E,$$
$$\frac{dI}{dt} = \gamma E - \delta I,$$
$$\frac{dR}{dt} = \delta I,$$
$$S(t_0) = S_0 \geq 0, E(t_0) = E_0 \geq 0, I(t_0) = I_0 \geq 0,$$
$$S_0 + E_0 + I_0 = \alpha,$$
$$R(t_0) = 1 - \alpha.$$

Local model types

- Discrete Baroyan-Rvachev model

$$\overline{y_t} = \sum_{\tau=0}^{T} y_{t-\tau} g_\tau,$$

$$y_{t+1} = \frac{\beta}{\rho} x_t \overline{y_t},$$

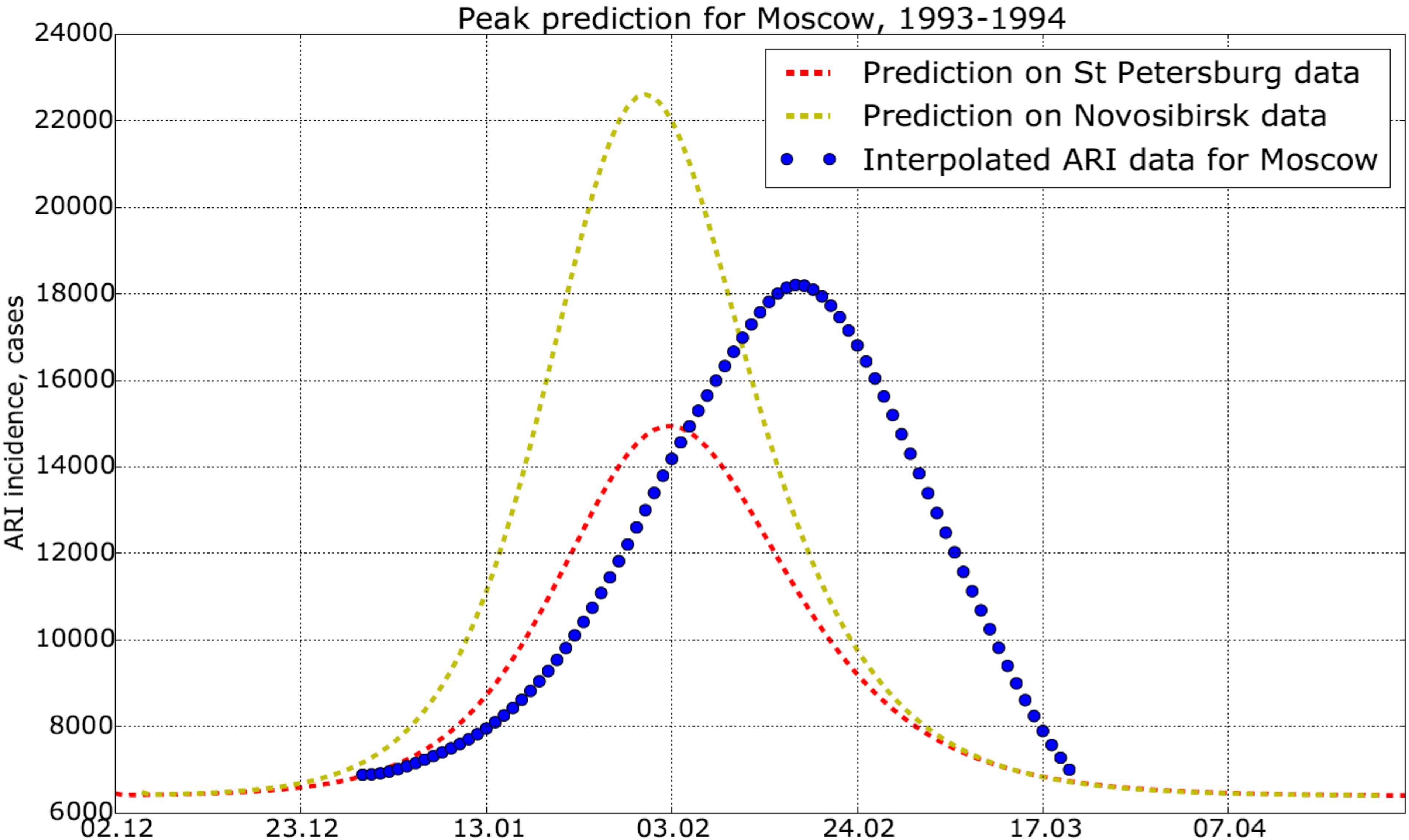
$$x_{t+1} = x_t - y_{t+1},$$

$$x_0 = \alpha\rho.$$

Simplified Baroyan-Rvachev forecasting

- Take the incidence data of the first Russian flu outbreak from its start to the peak
- Calibrate the local model on the outbreak data
- **Wait until the epidemics starts in other cities**
- Apply the calibrated local model to predict peaks

Simplified Baroyan-Rvachev forecasting



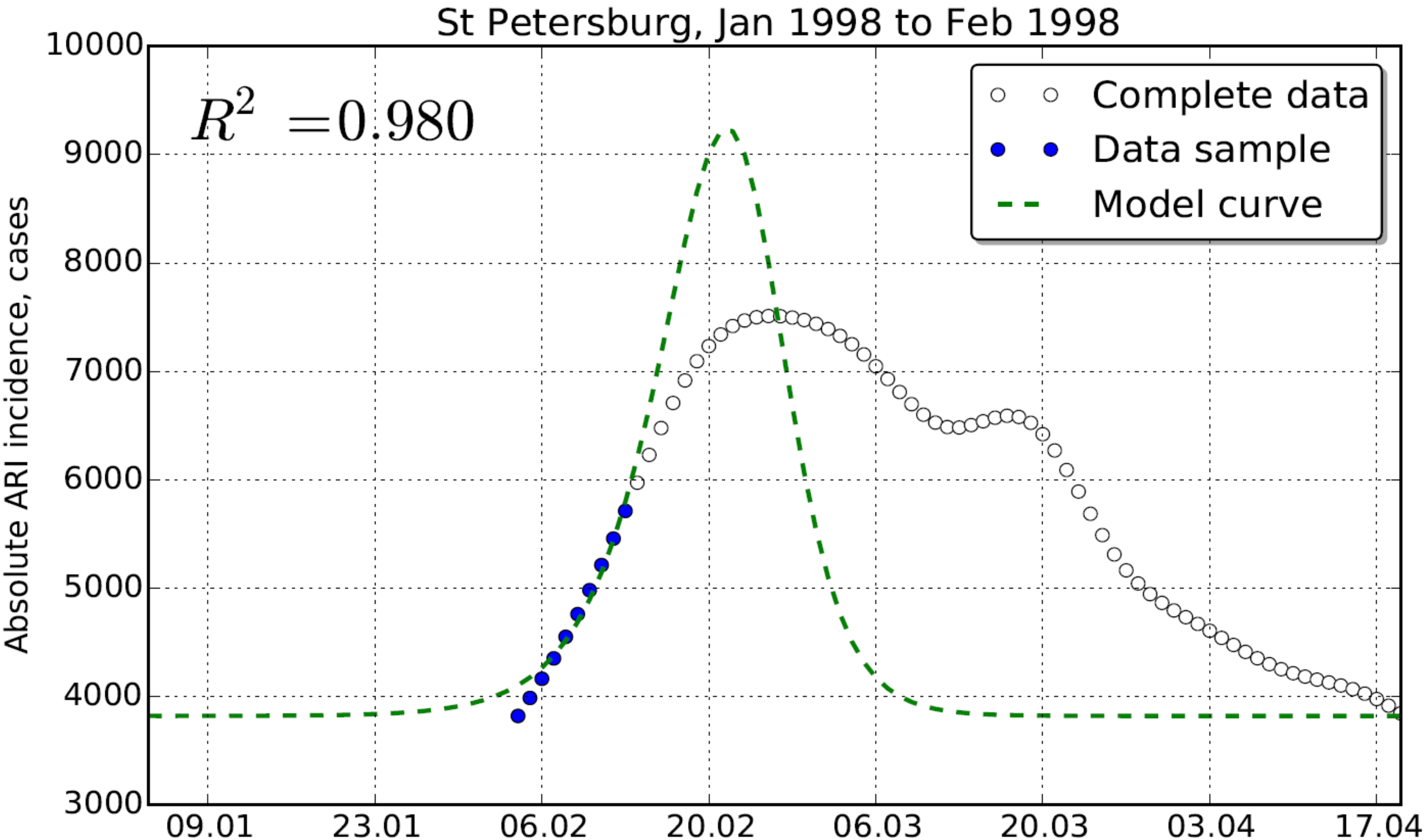
Forecasting via local model

- **Take the incomplete incidence data from the city under consideration**

- Calibrate the local model on the outbreak data

- Apply the calibrated local model to predict the peak

Forecasting via local model



Peak prediction quality criteria

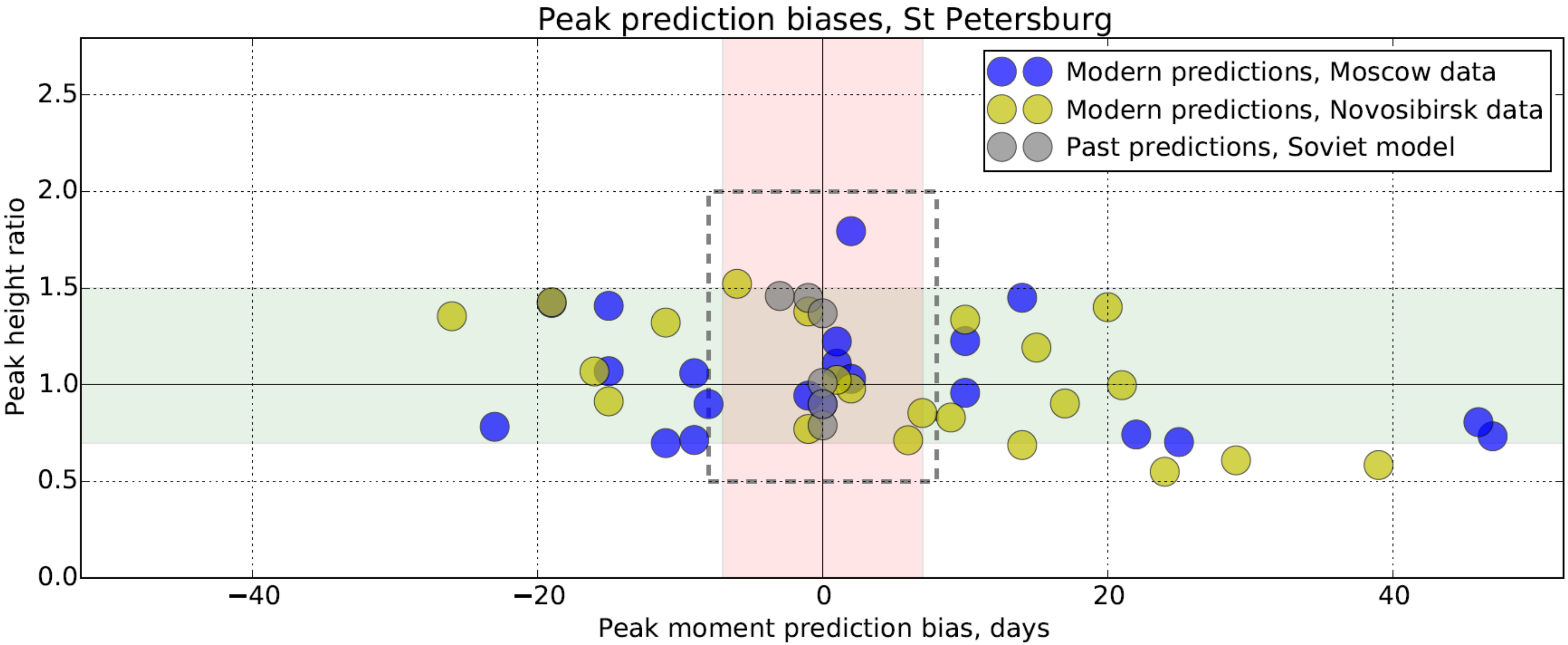
- **Measurements:**
  - *dt*, absolute error of peak day detection
  - *dh*, the relation between the heights of the modeled peak and actual epidemic peak

- **„Horizontal stripe“:** $dh \in (0.7; 1.5)$.

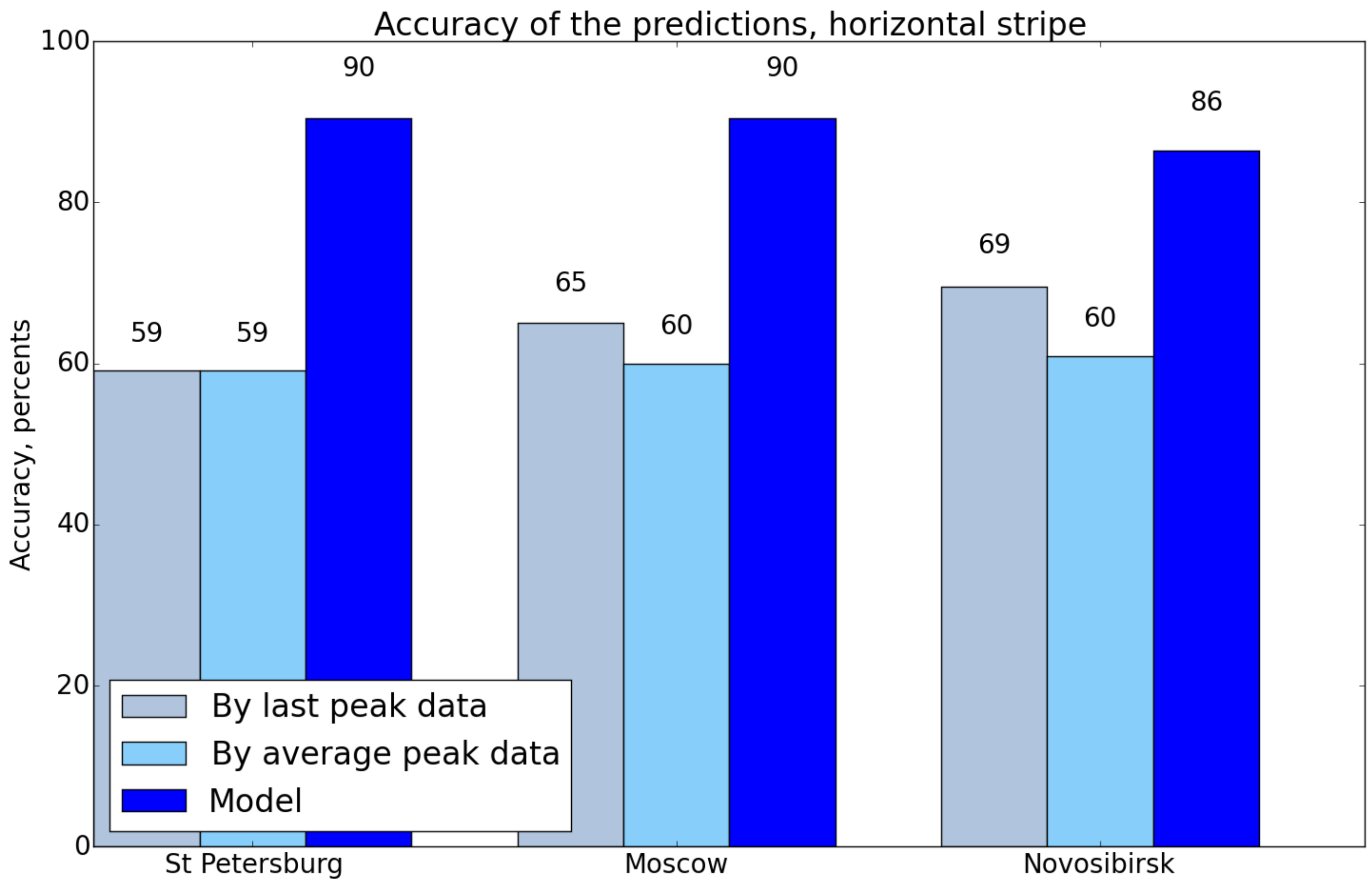
- **„Vertical stripe“:** $dt \in -7..7$.

- **„Square“:** $dt \in -8..8$, $dh \in (0.5; 2.0)$.

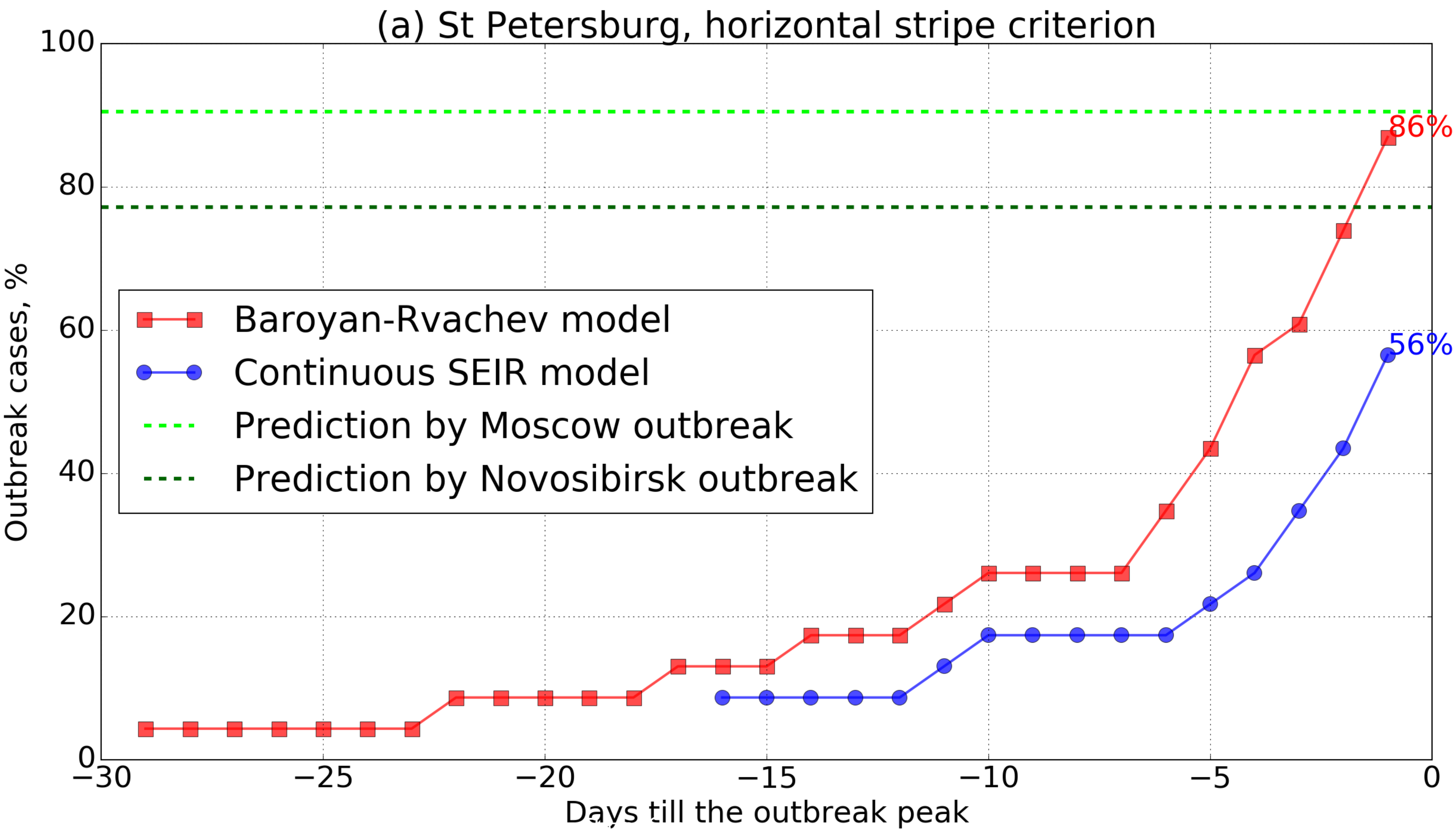
Simplified B-R prediction quality



Comparison with primitive forecasting



Local model prediction quality



Conclusions

- The **peak height** could be predicted with the same accuracy as in 70's

- The **peak date** prediction accuracy is unsatisfactory

Ways of accuracy improvement

- Bringing transport data into play
- Adding constraints to local model trajectories based on prior knowledge of the past outbreaks in the city
- Using of smoothed data and different fitting criteria to reduce the weight of the outliers
- Using special functions (deterministic or stochastic) to fit the incomplete outbreak half-wave*

* For instance, like in Viboud et al. (2016) A generalized-growth model to characterize the early ascending phase of infectious disease outbreaks

Thank you
for your attention!

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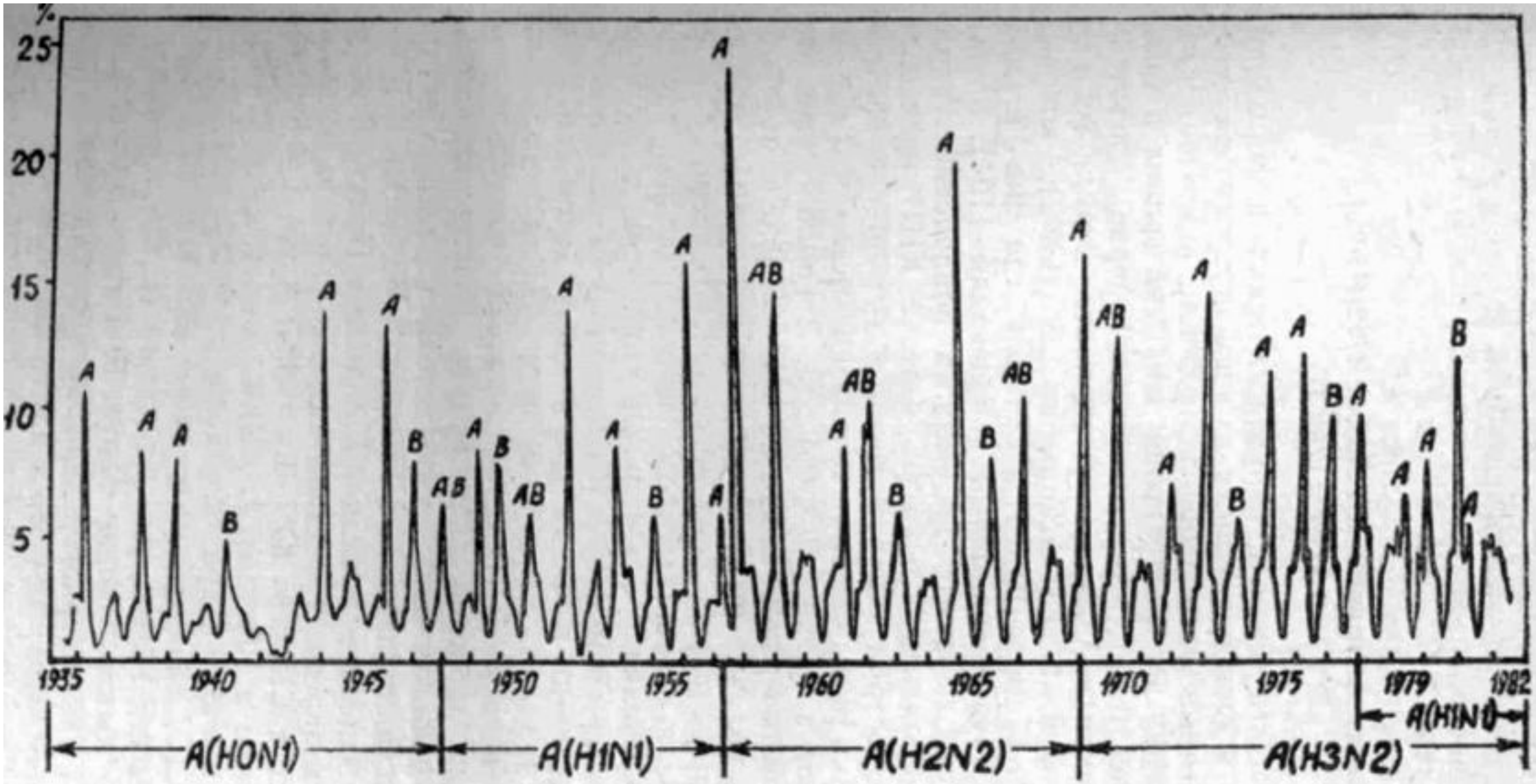
ARI and flu surveillance in Russia



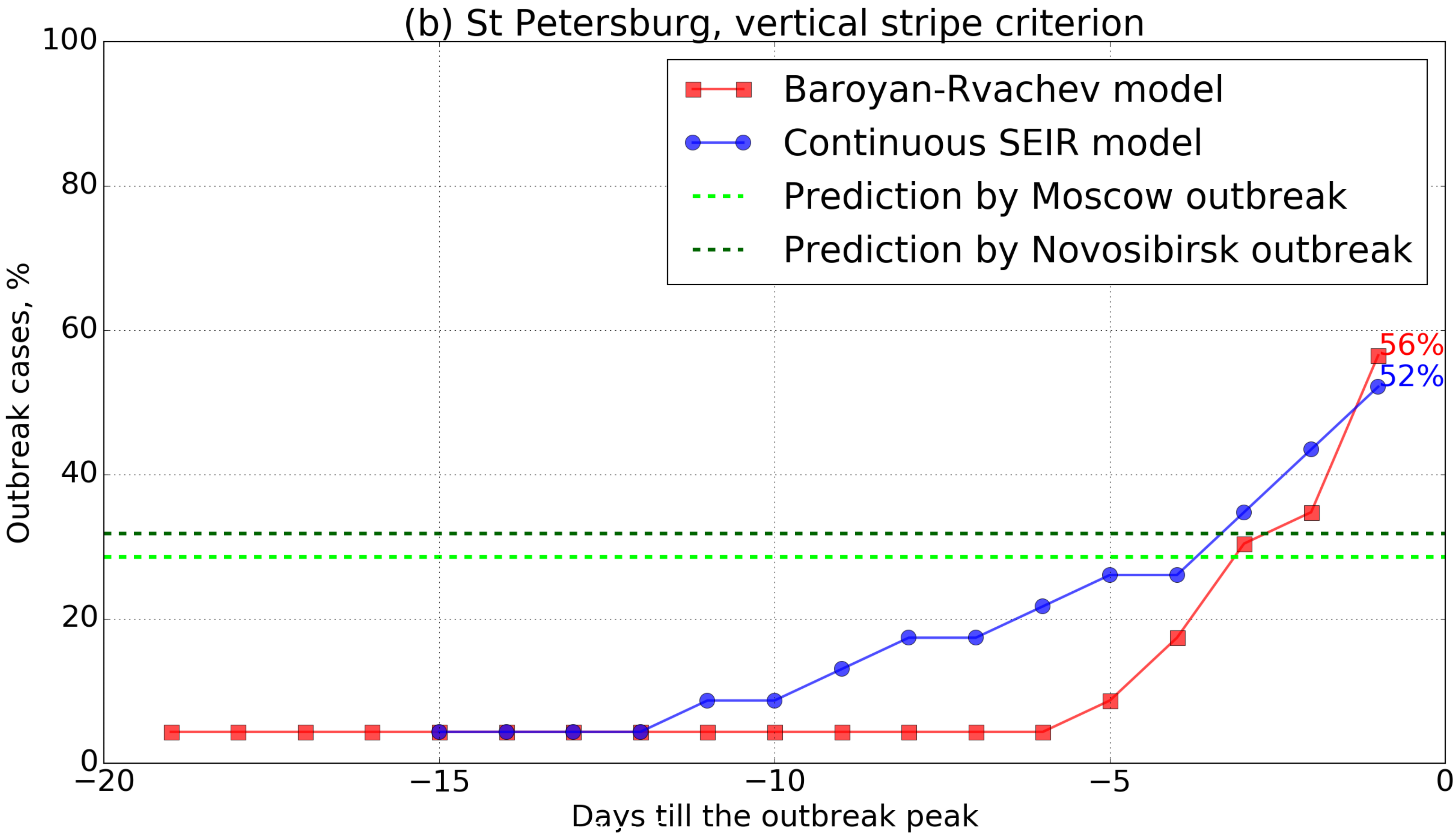
ARI and flu surveillance in the world

- Russia: weekly ARI reports on a number of cities (49 in total), daily epidemic ARI reports on Saint Petersburg (probably, also Moscow)

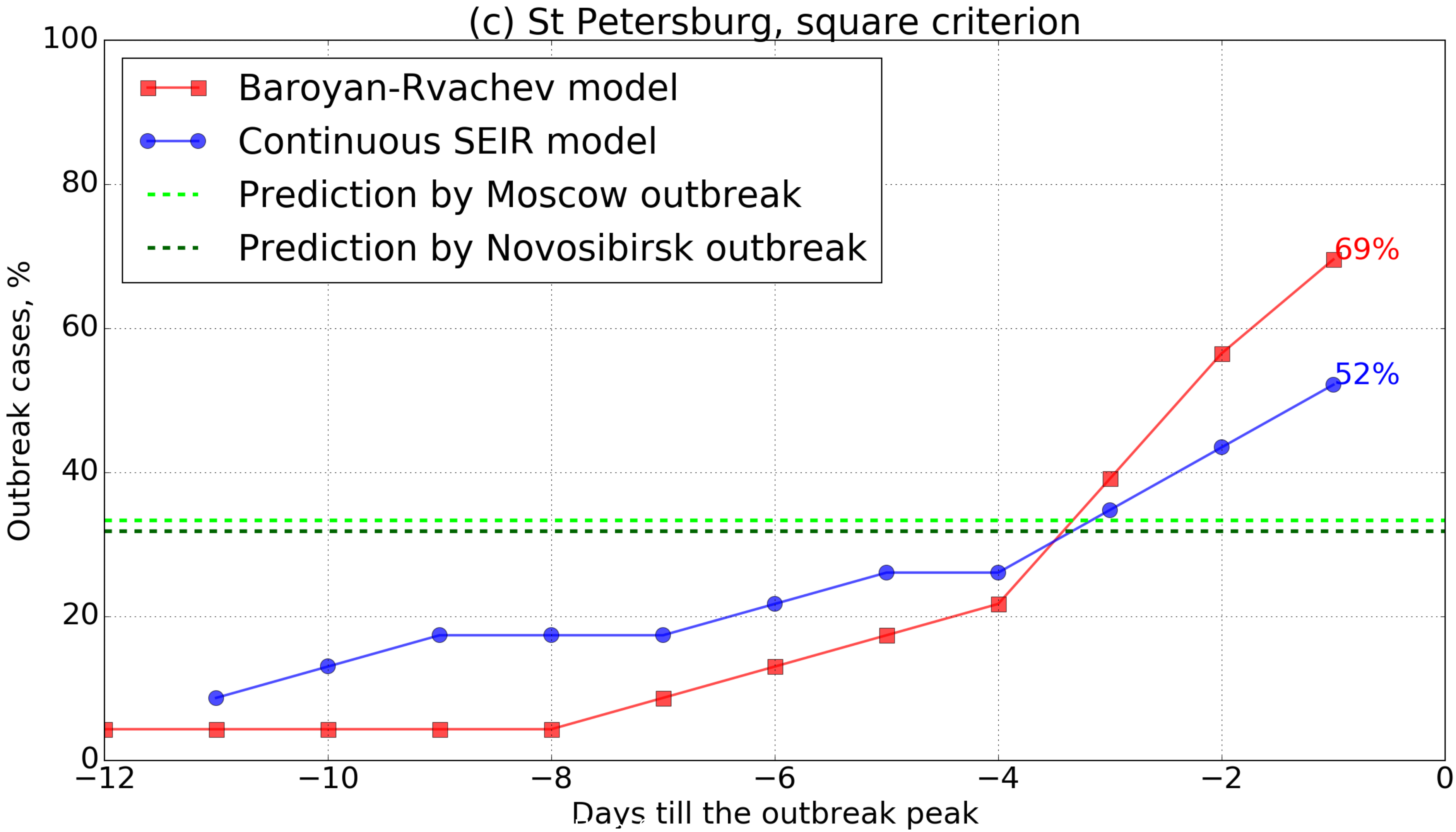
- Europe: severe acute respiratory diseases only («influenza-like illness»), incidence is reported on weekly basis

- The USA: not reportable, only pneumonia and influenza mortality

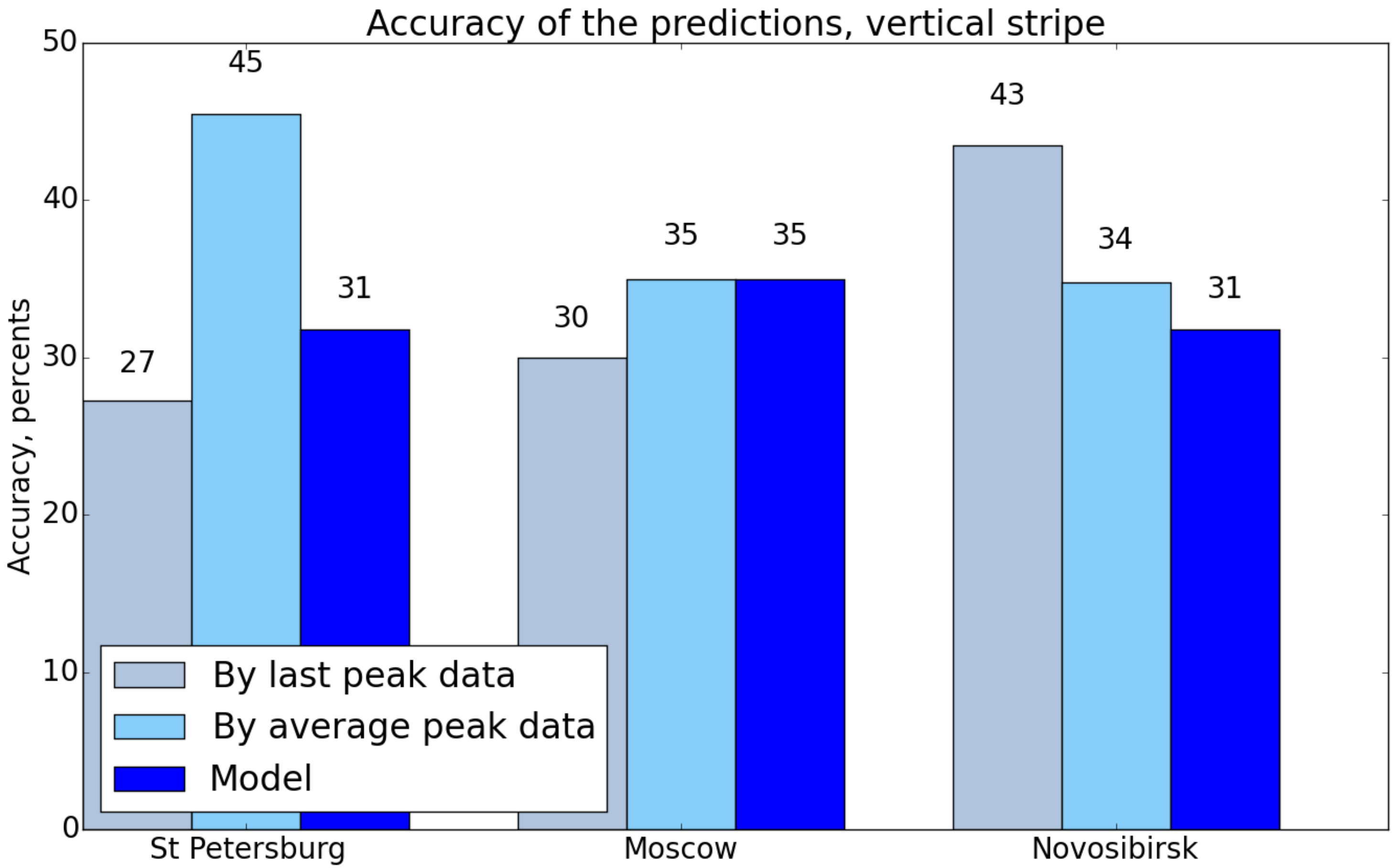
Local model prediction quality



Local model prediction quality



Comparison with primitive forecasting



Comparison with primitive forecasting