

## Influence of external factors on inter-city influenza spread in Russia: a modeling approach

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Ministry of Healthcare of the Russian Federation  
**Research Institute of Influenza**  
WHO National Influenza Centre of Russia



Превышение эпидемического порога

■ - менее 20%

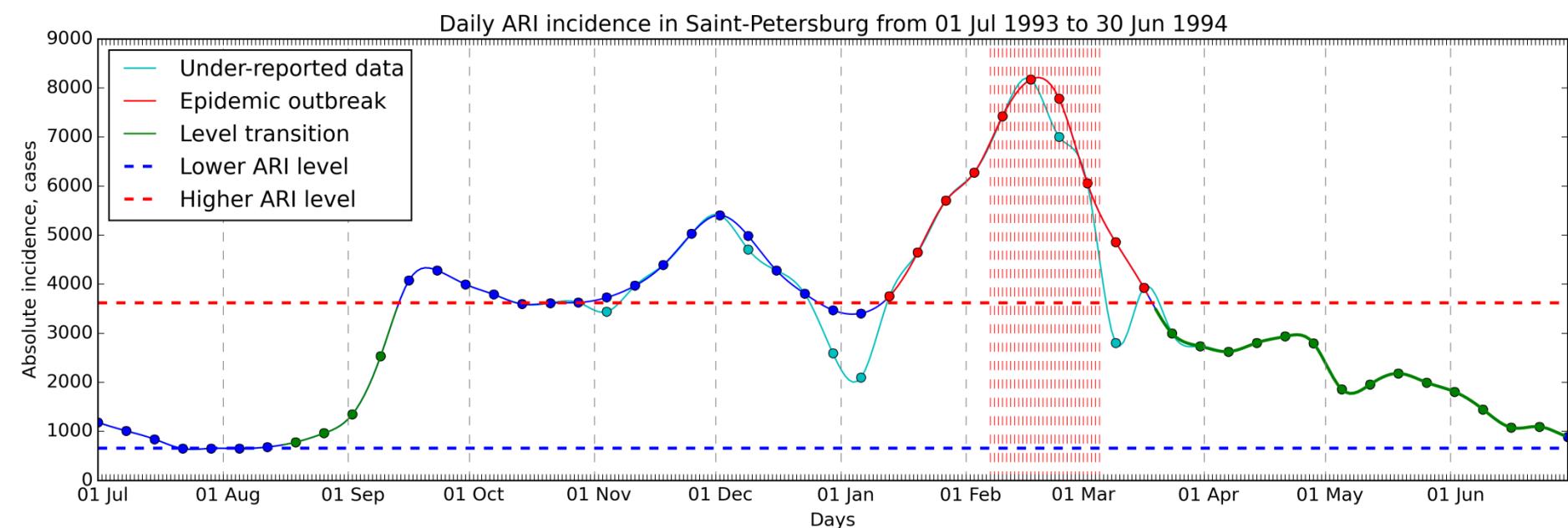
■ - 20 - 49%

■ - 50% и более



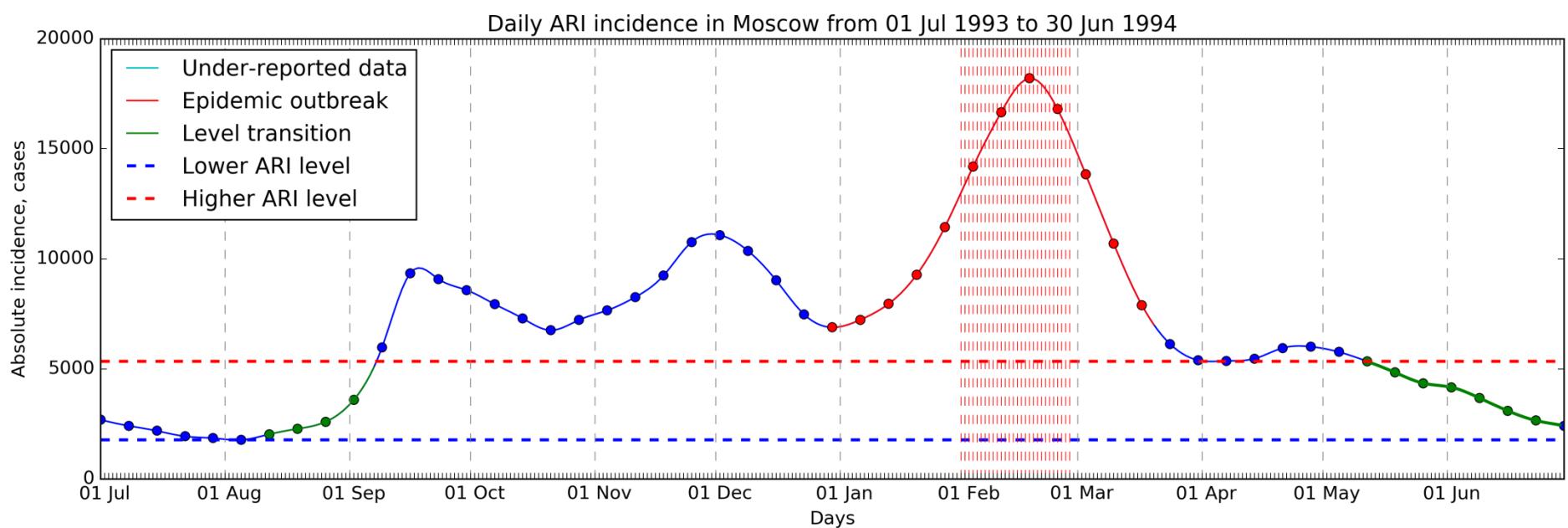
# Baroyan-Rvachev method

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



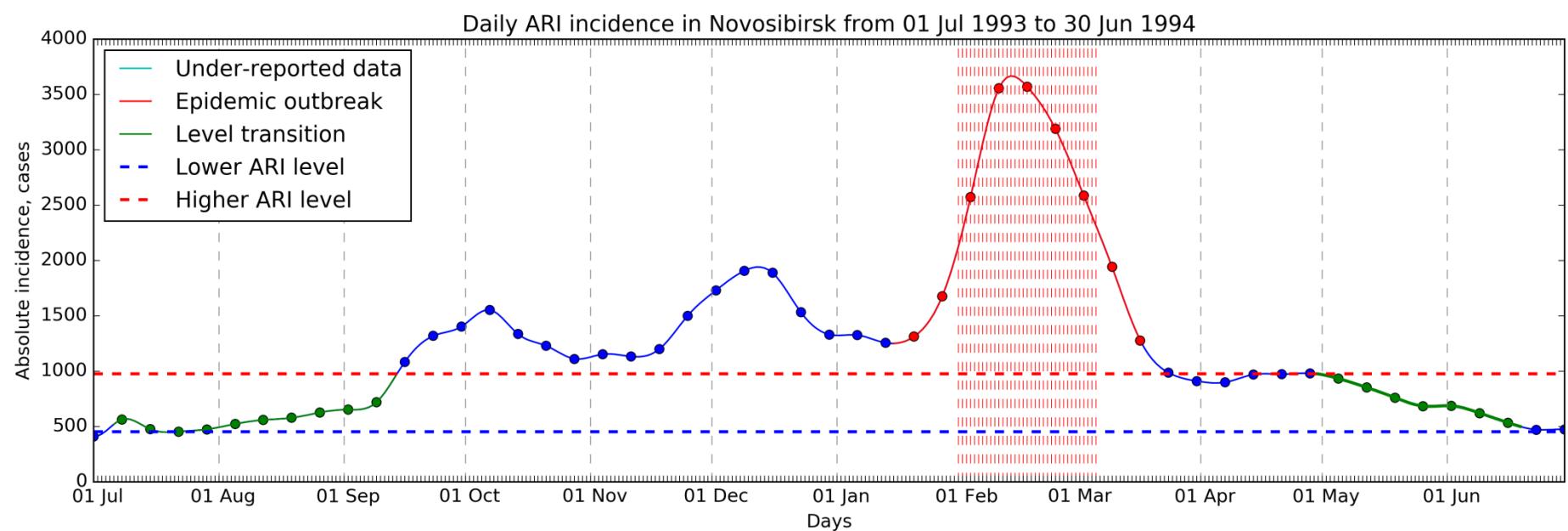
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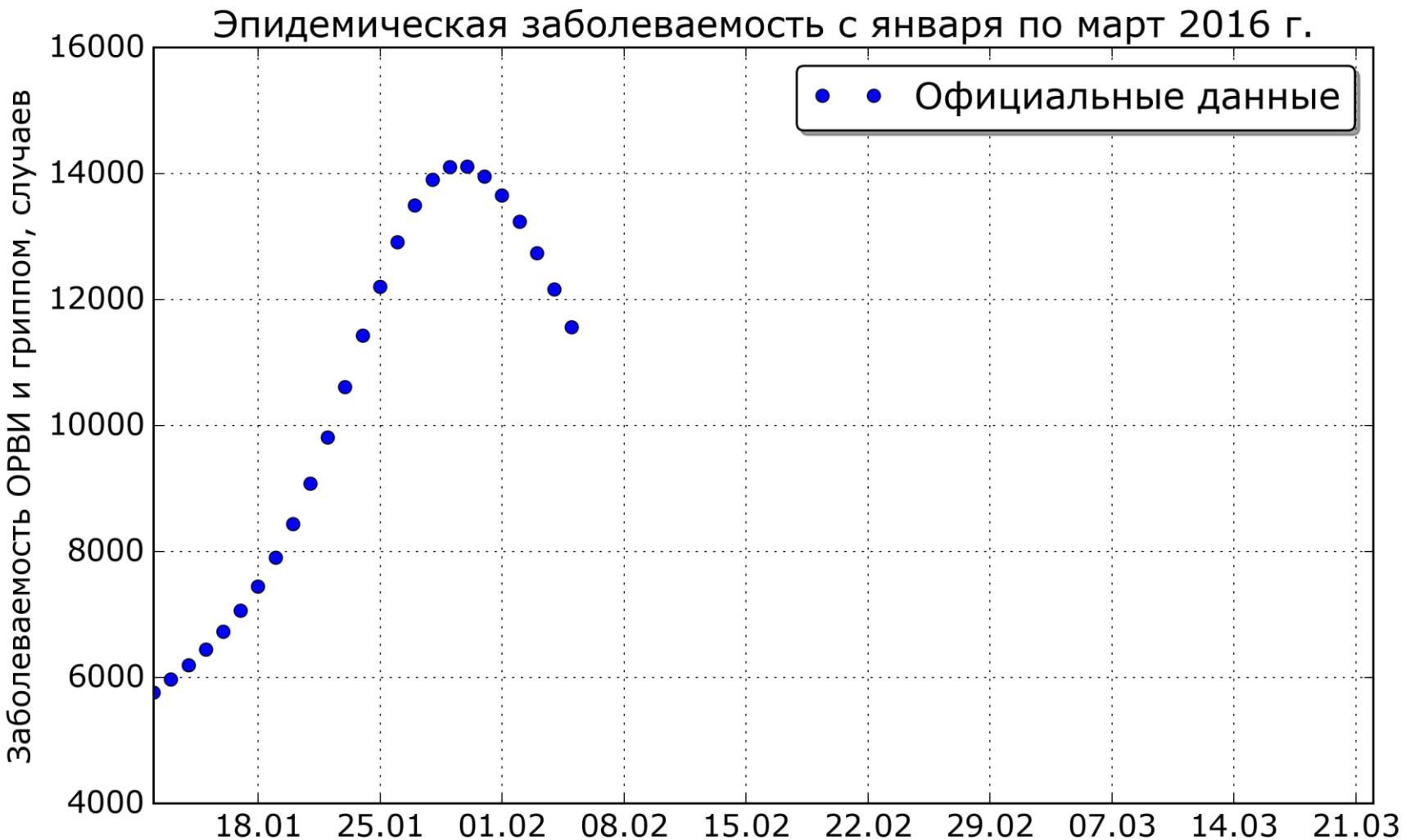


# Baroyan-Rvachev method

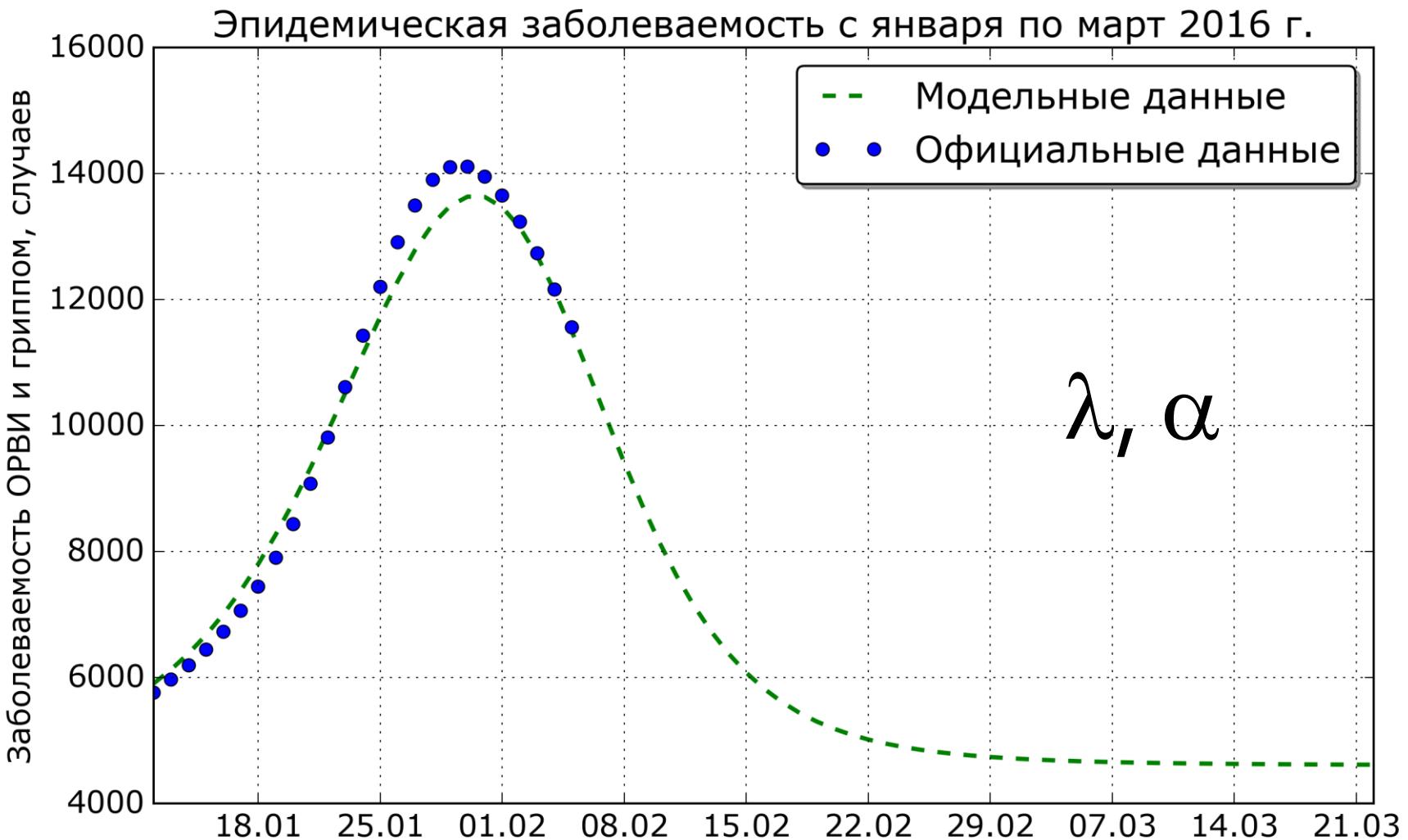
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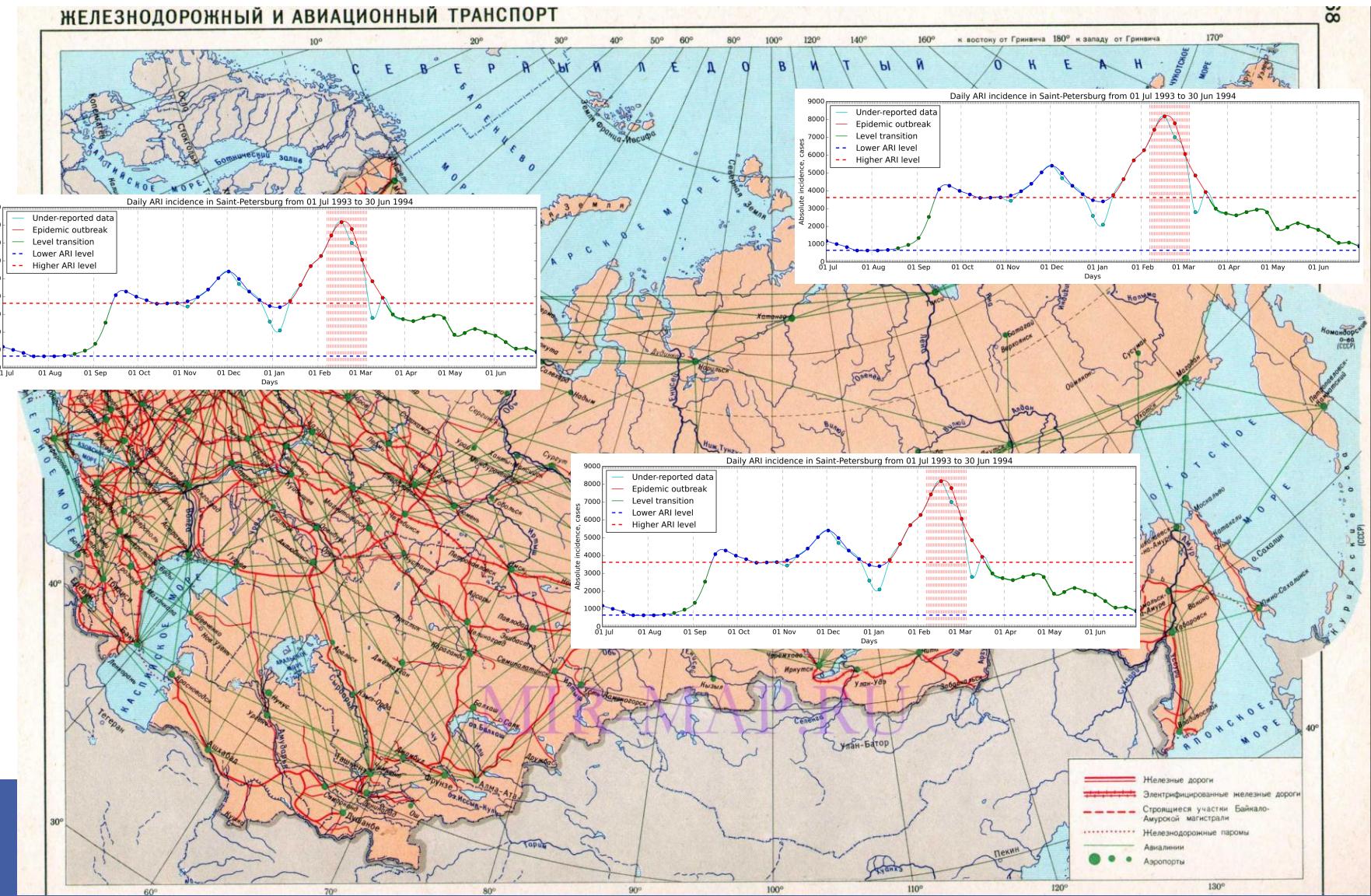
# Taking the incidence of the first epidemic outbreak



# 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**



# The local model

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

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

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

$$x_0 = \alpha \rho.$$



# The global model

$$\overline{y_j}(t) = \sum_{\tau=0}^T y_j(t, \tau) g(\tau),$$

$$y_j(t+1, 0) = \frac{\beta_j}{\rho_j} x_j(t) \overline{y_j}(t),$$

$$y_j(t+1, \tau) = y_j(t, \tau-1) + \sum_{i=1}^n \sigma_{ij} \frac{y_i(t, \tau-1)}{\rho_i},$$

$$x_j(t+1) = x_j(t) - y_j(t+1, 0),$$

$$x_j(0) = \alpha_j \rho_j,$$

$$j = 1, 2, \dots, n;$$



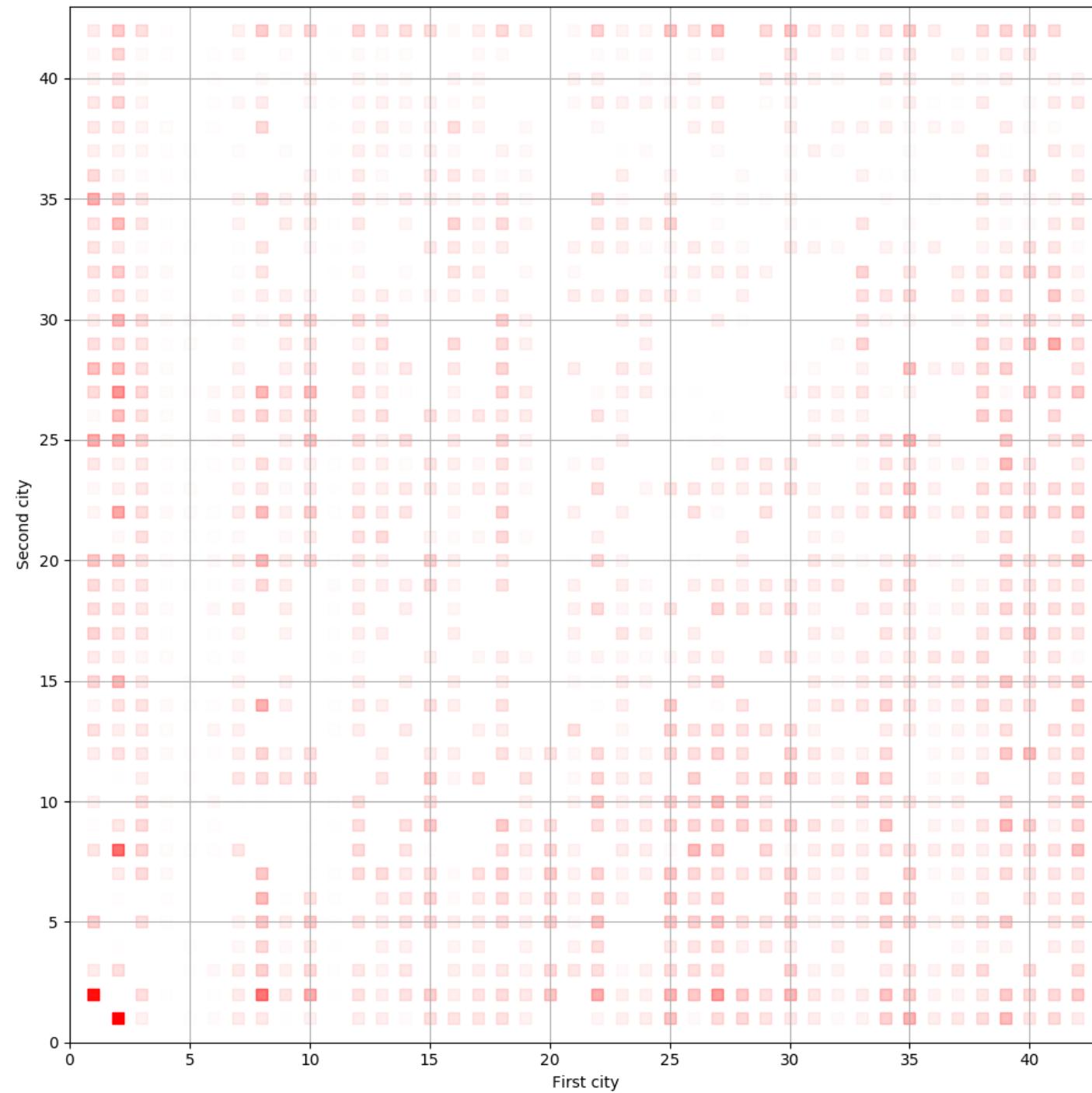
# Transport flow matrices

- No. 1: capacity of planes, daily schedule, October 20<sup>th</sup>, 2016
- No. 2: averaged capacity of planes, weekly schedule, February 27<sup>th</sup> to March 5<sup>th</sup>, 2017
- No. 3: gravitational model ( $\gamma$  assessed from open data)

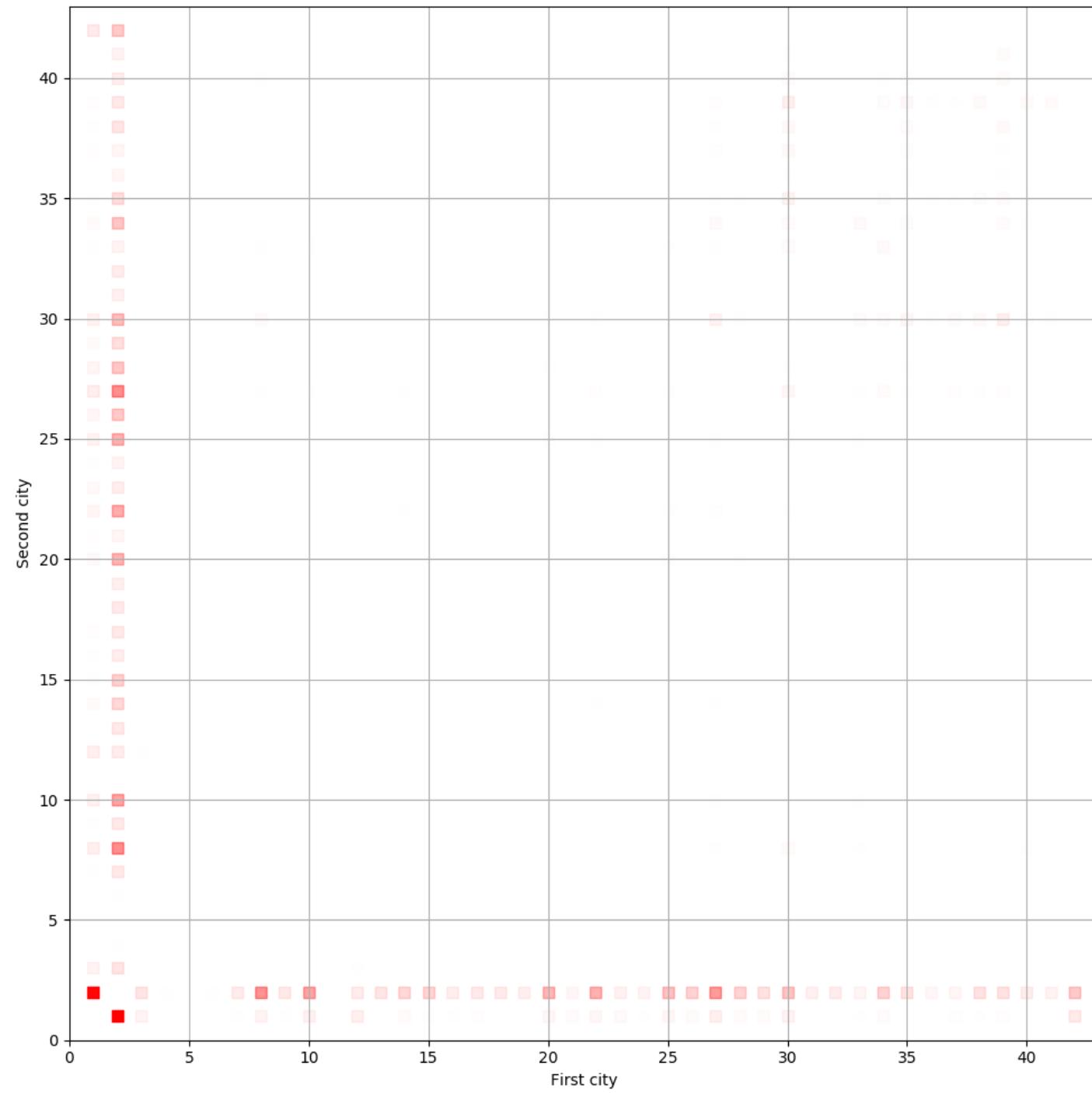
$$V_{ij} = \gamma \frac{\rho_i \rho_j}{d_{ij}^2}, \quad V_{ij} = \sigma_{ij} + \sigma_{ji}$$

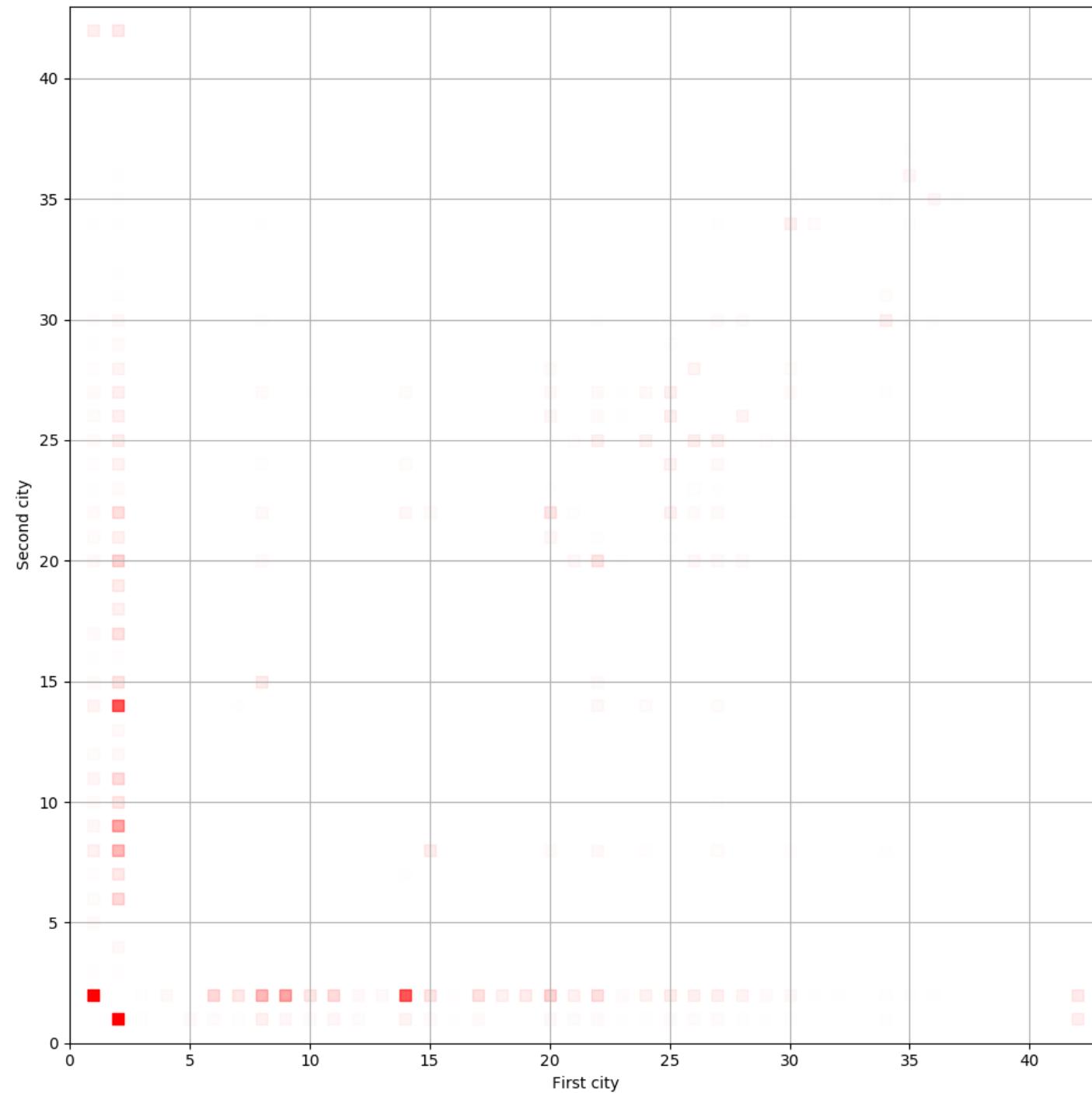


**Matrix 1**  
Max flow =  
**7953**



**Matrix 2**  
**Max flow =**  
**9399**





**Matrix 3**

Max flow =

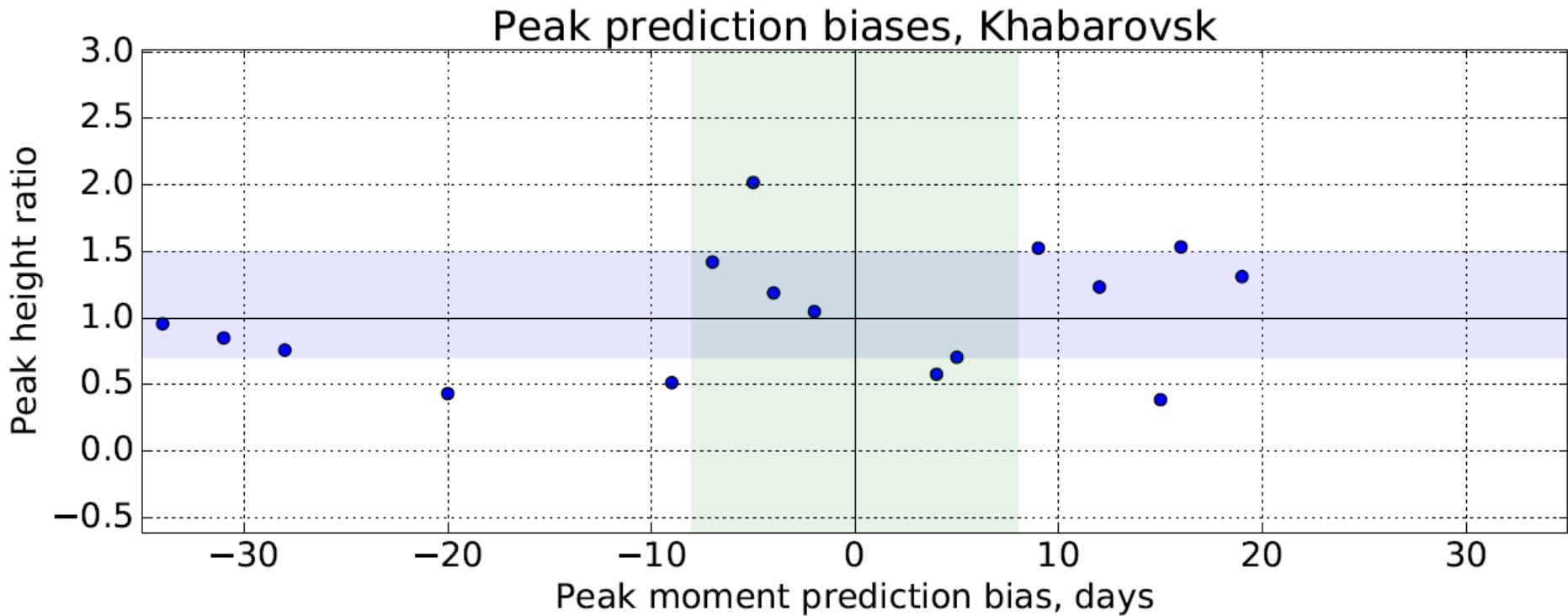
54662

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



# An example for Khabarovsk



# Accuracy by matrix selection

Overall compliance of peak predictions to accuracy criteria for different transport matrices and different cities chosen for calibration, 2012-2013 epidemic season

Transport matrix generation	Vertical stripe	Horizontal stripe	Square
Daily schedule	14.71 2.94 11.76	5.88 50.0 44.12	2.94 2.94 11.76
Weekly schedule	14.71 2.94 11.76	5.88 47.06 44.12	2.94 2.94 11.76
Gravitational model	0.0 2.94 11.76	41.18 47.06 44.12	0.0 2.94 11.76



# Accuracy by year

Overall compliance of peak predictions to accuracy criteria, transport matrix No. 2 (averaged weekly schedule). The highest accuracy is marked with bold.

Year	Vertical stripe	Horizontal stripe	Square
2000	3.85 0.0 <b>3.85</b>	7.69 11.54 <b>30.77</b>	3.85 3.85 <b>3.85</b>
2001	<b>23.08</b> 11.54 3.85	15.38 0.0 <b>73.08</b>	<b>7.69</b> 7.69 3.85
2002	<b>72.73</b> 6.06 9.09	<b>54.55</b> 54.55 54.55	<b>60.61</b> 3.03 12.12
2003	0.0 <b>33.33</b> 33.33	<b>45.45</b> 27.27 24.24	3.03 27.27 <b>33.33</b>
2004	3.33 10.0 <b>43.33</b>	<b>43.33</b> 23.33 36.67	3.33 6.67 <b>26.67</b>
2005	7.41 <b>14.81</b> 3.7	44.44 18.52 <b>48.15</b>	7.41 <b>7.41</b> 3.7
2006	<b>21.43</b> <b>21.43</b> 3.57	3.57 <b>39.29</b> 28.57	7.14 <b>17.86</b> 3.57
2007	3.23 <b>38.71</b> 3.23	<b>38.71</b> 32.26 35.48	6.45 <b>22.58</b> 3.23
2008	23.53 <b>41.18</b> 14.71	41.18 35.29 20.59	11.76 <b>23.53</b> 2.94
2009	<b>5.41</b> 2.7 2.7	<b>45.95</b> 13.51 27.03	<b>5.41</b> 2.7 2.7
2010	<b>10.81</b> 2.7 2.7	2.7 <b>5.41</b> 0.0	<b>2.7</b> 0.0 0.0
2011	<b>45.45</b> 18.18 9.09	36.36 <b>54.55</b> 0.0	<b>36.36</b> 18.18 9.09
2012	<b>14.71</b> 2.94 11.76	5.88 <b>47.06</b> 44.12	2.94 2.94 11.76
2013	35.29 <b>35.29</b> 17.65	41.18 <b>52.94</b> 23.53	29.41 <b>29.41</b> 17.65
2014	3.23 <b>3.23</b> 3.23	35.48 <b>51.61</b> 3.23	3.23 <b>3.23</b> 3.23
2015	<b>18.42</b> 10.53 5.26	34.21 31.58 <b>55.26</b>	7.89 <b>10.53</b> 5.26



# Results

- Prediction of time: 3.23..72.73% (26,6% avg)
- Prediction of peak height: 5.41..73.08% (45,5% avg)
- For USSR: 96.5% avg for time, 76,6% for peak height



Thank you  
for your attention!

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