City Traffic Forecasting Using GPS Data

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Joint work with

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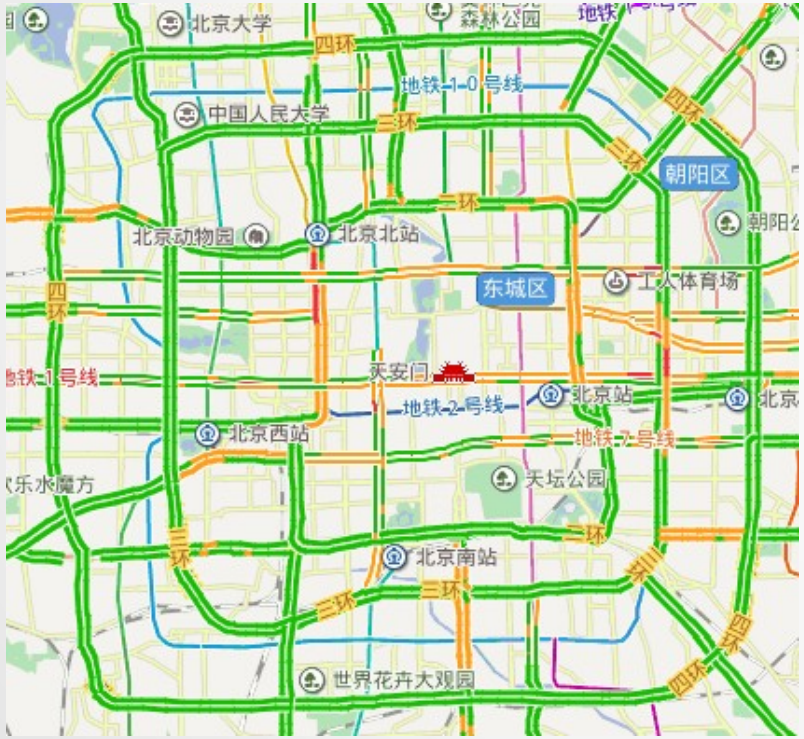
Haoshu Tian PrinceTechs

New Directions in Mathematical Approaches for Traffic Flow Management
Workshop II. Traffic Estimation
IPAM, UCLA, 2015.10.14

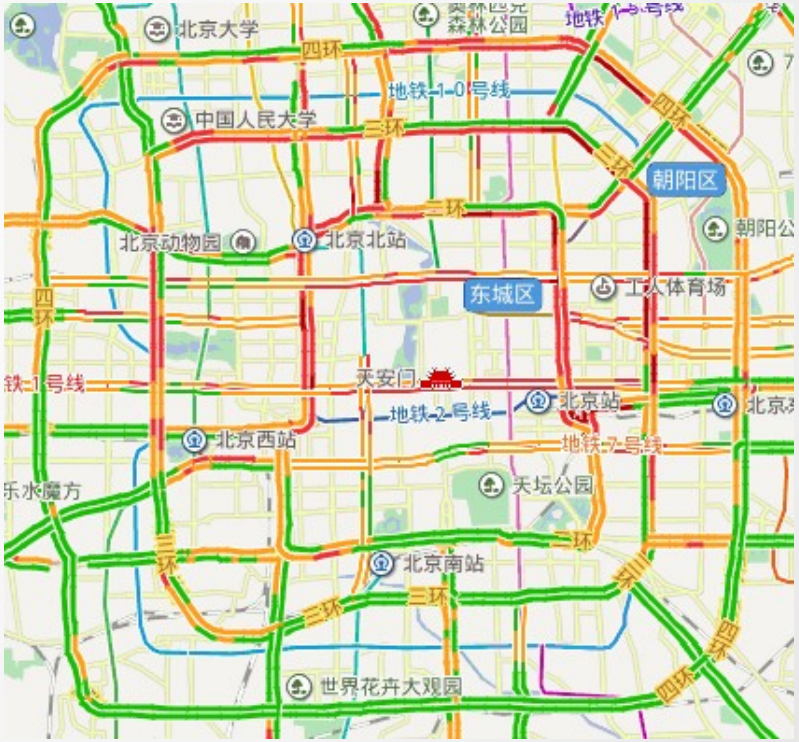

This is a “World Car-free Day”
650
FORLAND


This is NOT a parking lot
@法制晚报

The traffic problem in Beijing



12:00



18:00

source: Baidu Maps

The cost of traffic congestion

Cloth Food House Travel

Annual cost

$11.3 billion

Source: Peking University's National Development Research Institute

- **Money**
- **Fuel**
- **Happiness**
- **Lives**

Can mathematicians help?

Understanding traffic

Fluids
Particle system
Complex network
Big data

Taking actions

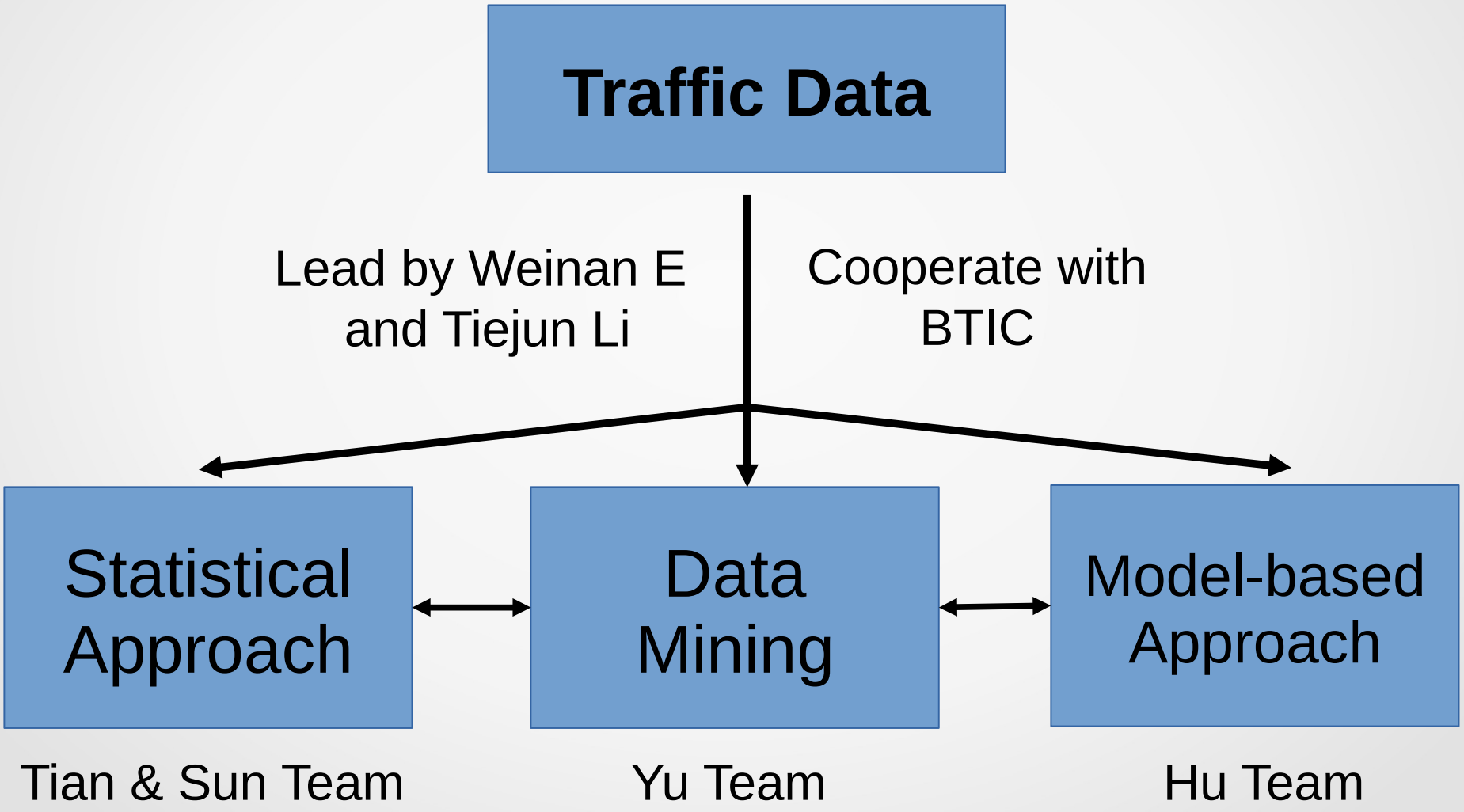
Route planning

Policy making

e.g. end-number license plate policy (1/5)

Source: Chinadaily

Big City, Big Data



Taxi GPS Data

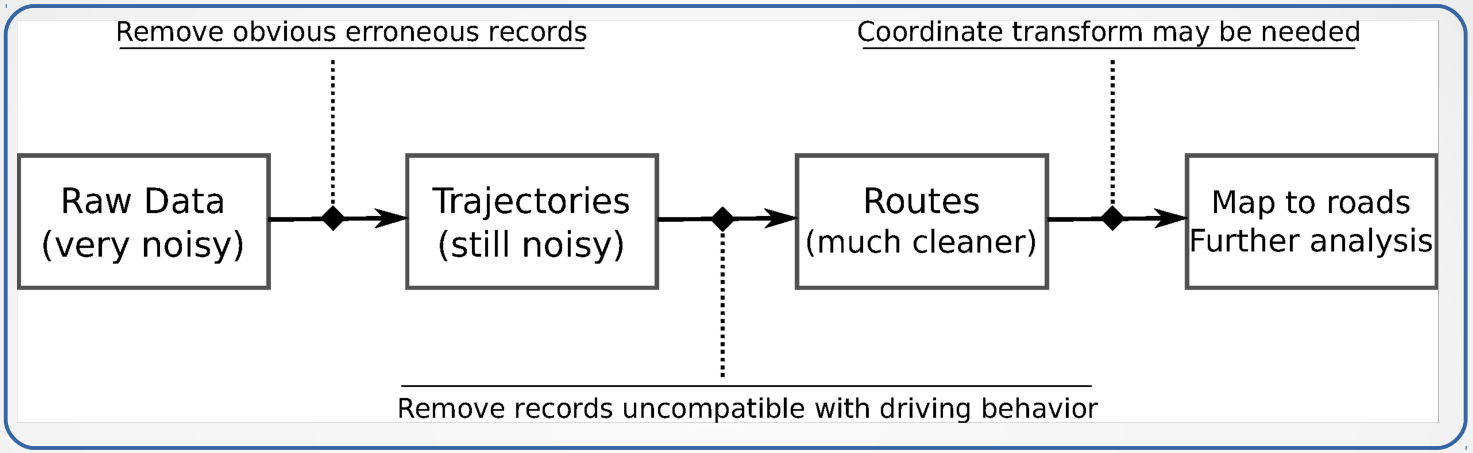
- From BTIC
- Near 70, 000 taxis
- Transmit signal once every minutes
- 4 months, 200G
- Real time in the future

2	ZHTC	657954585156	[redacted]	2013-03-03 23:09:17	116.411102	40.001732	0	1	1	170	CZ
3	ZHTC	657954505750		2013-03-03 23:09:17	116.353783	39.980301	0	1	1	86	CZ
4	ZHTC	657953575558		2013-03-03 23:09:17	116.420181	39.903393	0	0	1	86	CZ
5	ZHTC	658055505656		2013-03-03 23:09:17	116.483383	39.985168	2	1	1	184	CZ
6	ZHTC	657757535752		2013-03-03 23:09:17	116.427353	39.939289	41	0	1	90	CZ
7	ZHTC	657757545457		2013-03-03 23:24:11	116.587601	40.077305	0	1	0	116	CZ
8	ZHTC	657753575151		2013-03-03 23:09:17	116.304268	39.909069	63	1	1	0	CZ
9	ZHTC	658057515456		2013-03-03 23:09:17	116.087349	39.947639	0	0	1	0	CZ

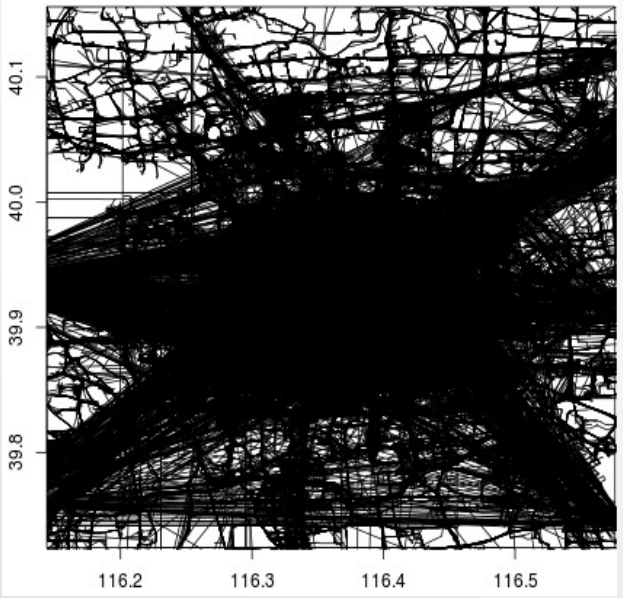
Sample data

Data Pre-processing

Trajectory-based denoising



Before



After

Traffic forecasting: overview

- **Pure Data**

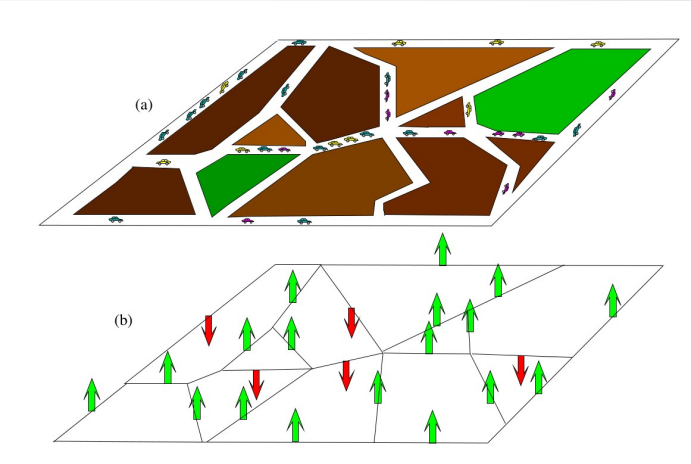
  Time-series

- **Road network + Data**

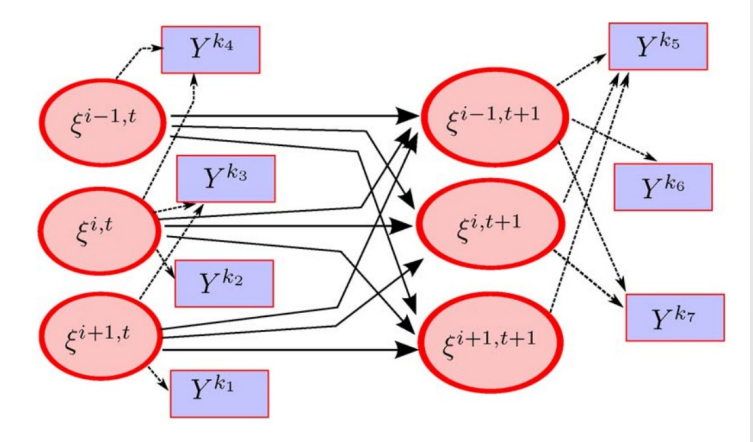
  Dynamic Bayesian network

- **Mechanism + Data**

  DYNASMART
  DynaMIT

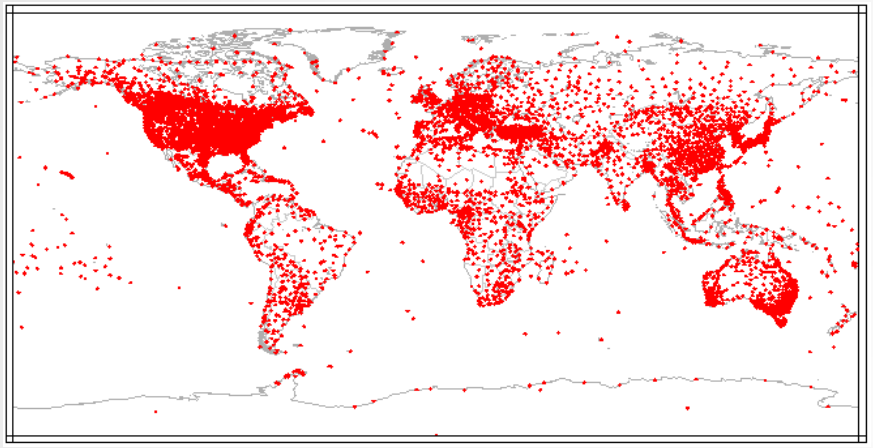


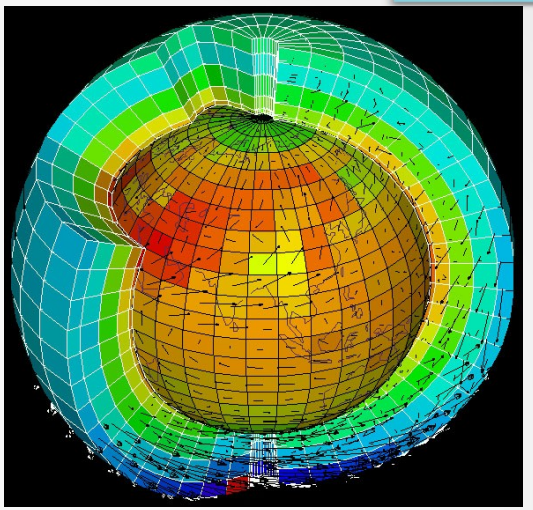
Furtlehner et.al, 2007



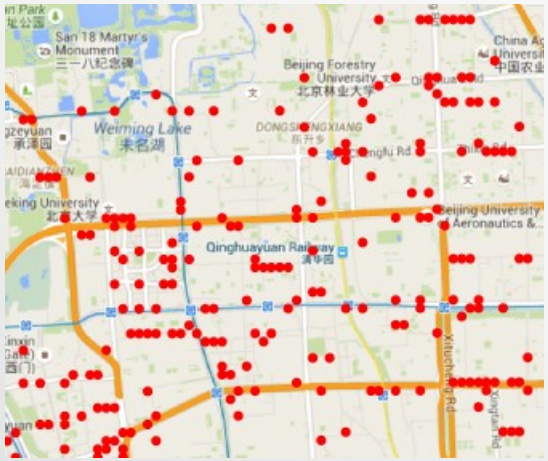
Hofleitner et.al, 2012

Numerical weather prediction

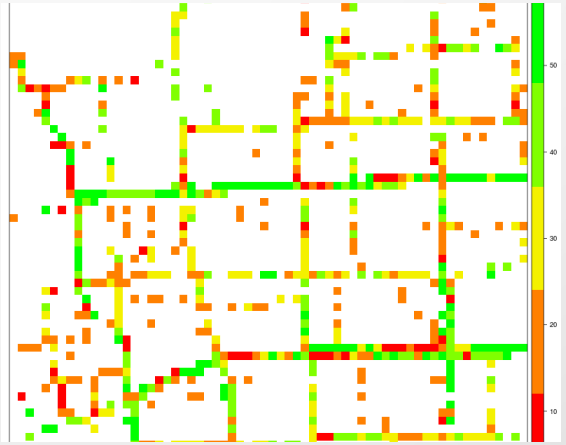




Data **Model**



Accidents
Weather
Social events

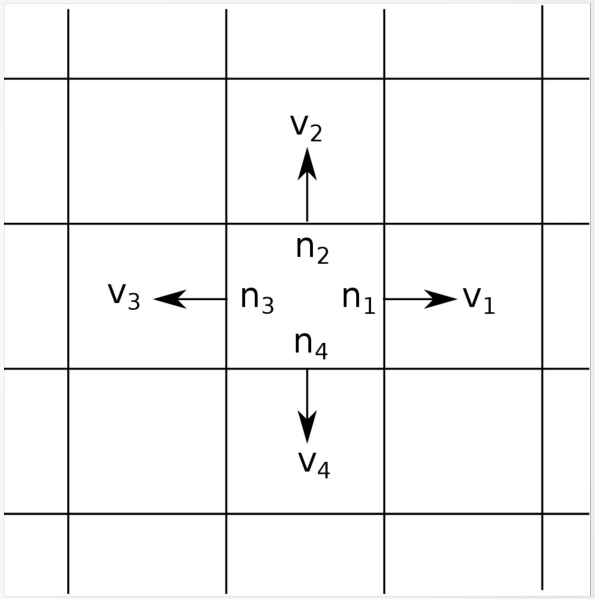


Modelling traffic

1. How many roads?
2. How many cars?
3. How do the cars move?

1. How many roads

- Partition Beijing into grids (100x100m)
- Count cars in each grid in every 10 mins
- Measure their average speed
- No car, no road
- More cars, more roads



2. How many cars

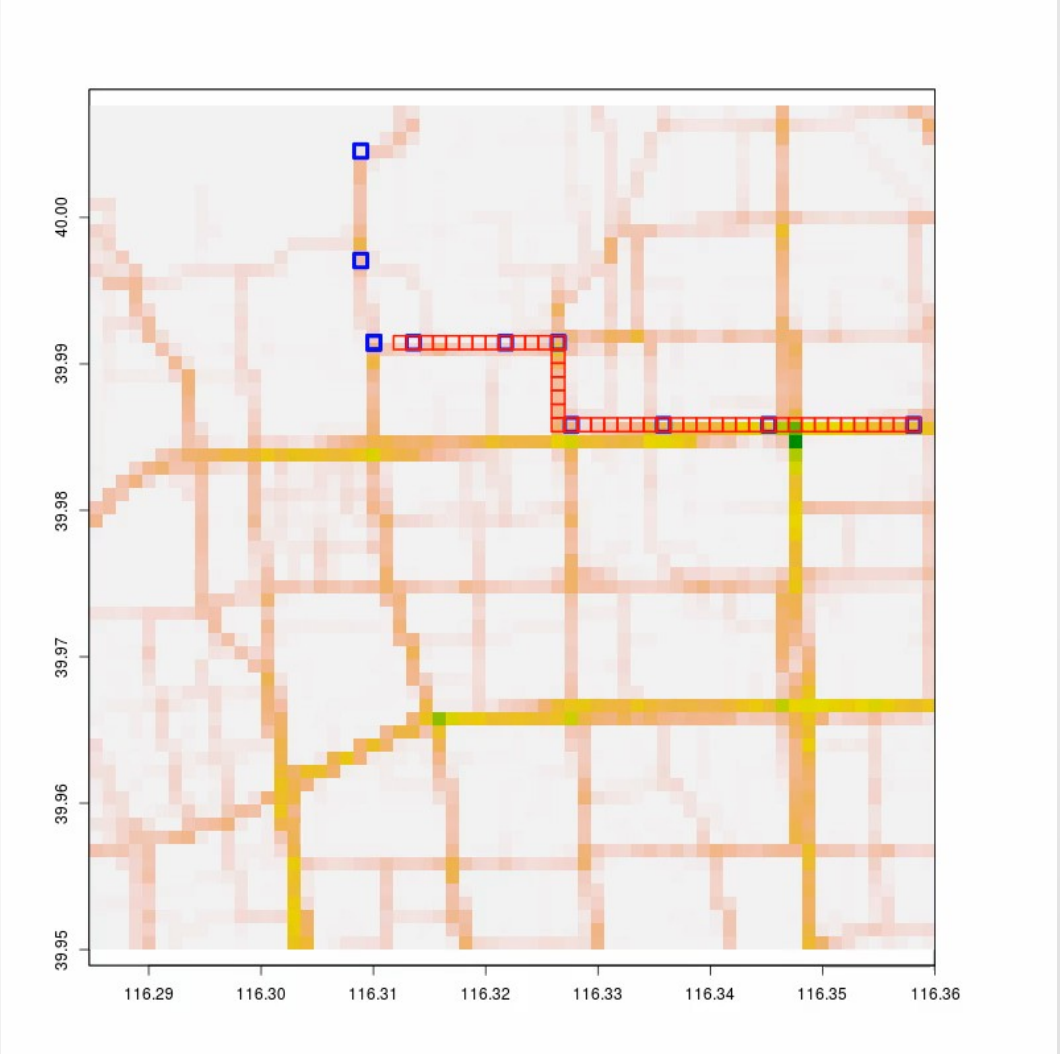
O/D Analysis

Current: historical path

Future: path sampling

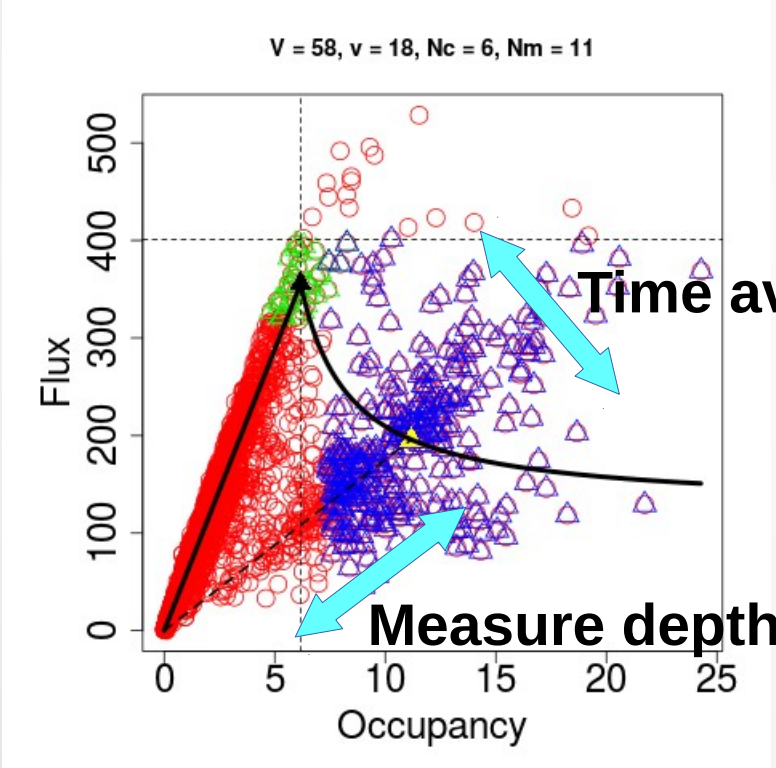
Taxi / Private car

More data is needed

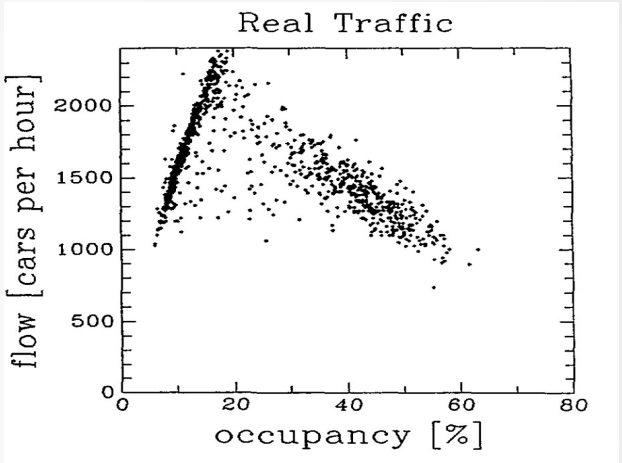


3. How do the car move

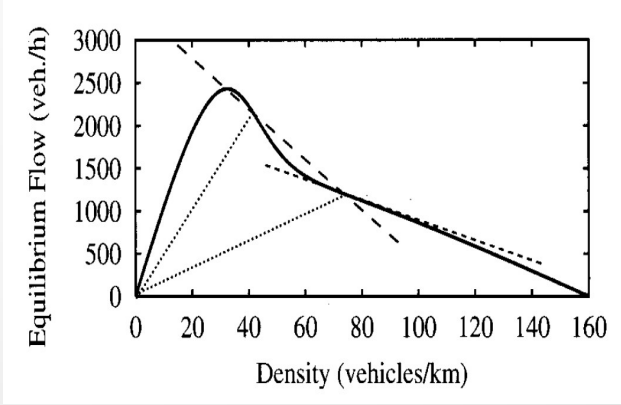
V(N) --- **constitutive law**



The fundamental diagram

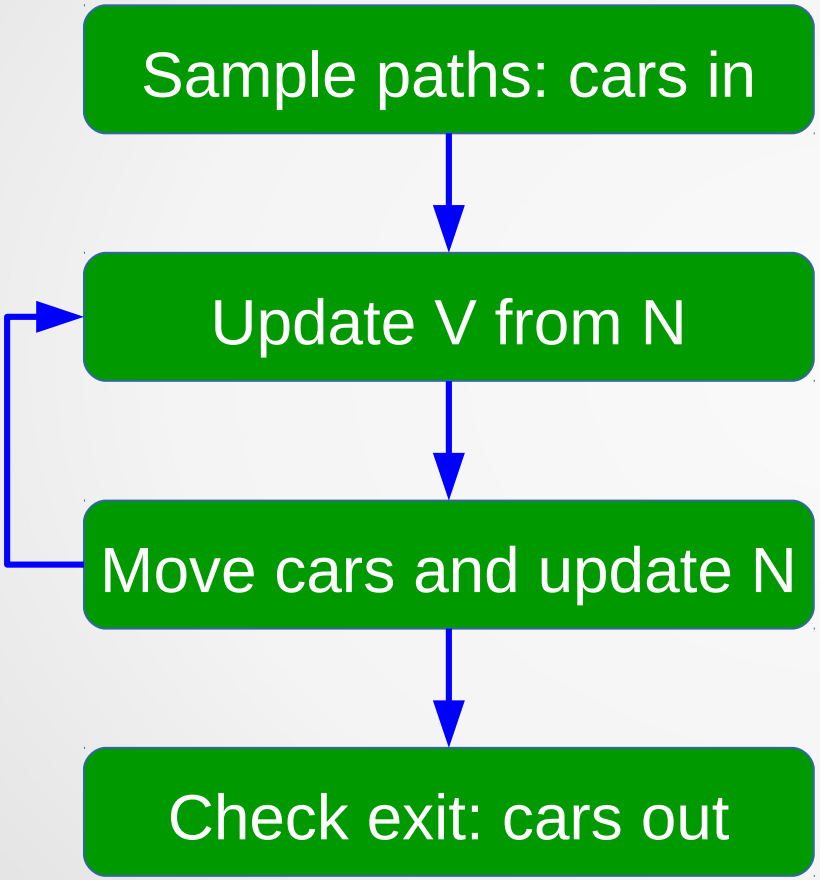


Nagel and Schreckenberg, 1992

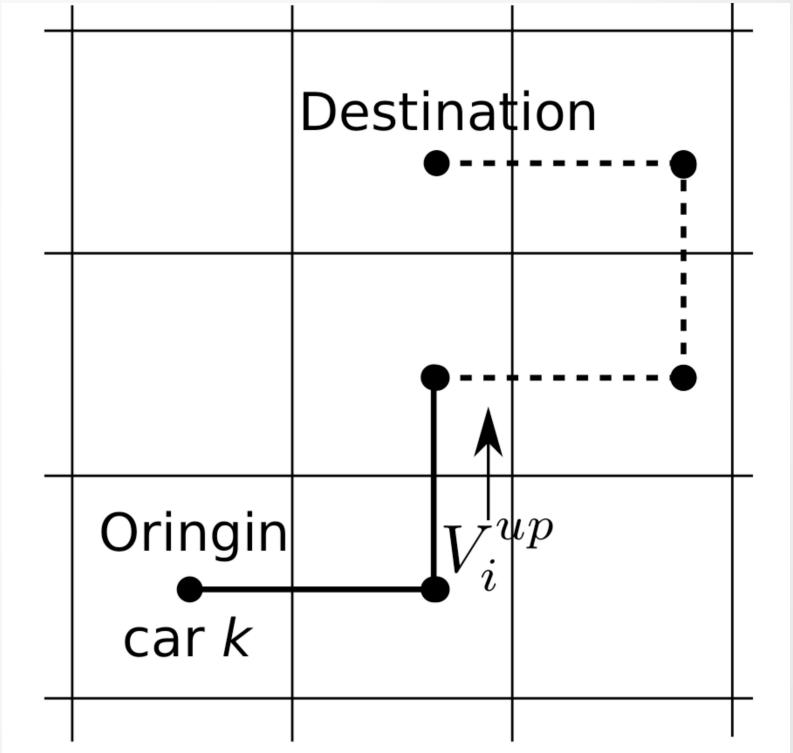


Helbing, 2001

Coarse-grained cellular automata model



mesh size: 256x256



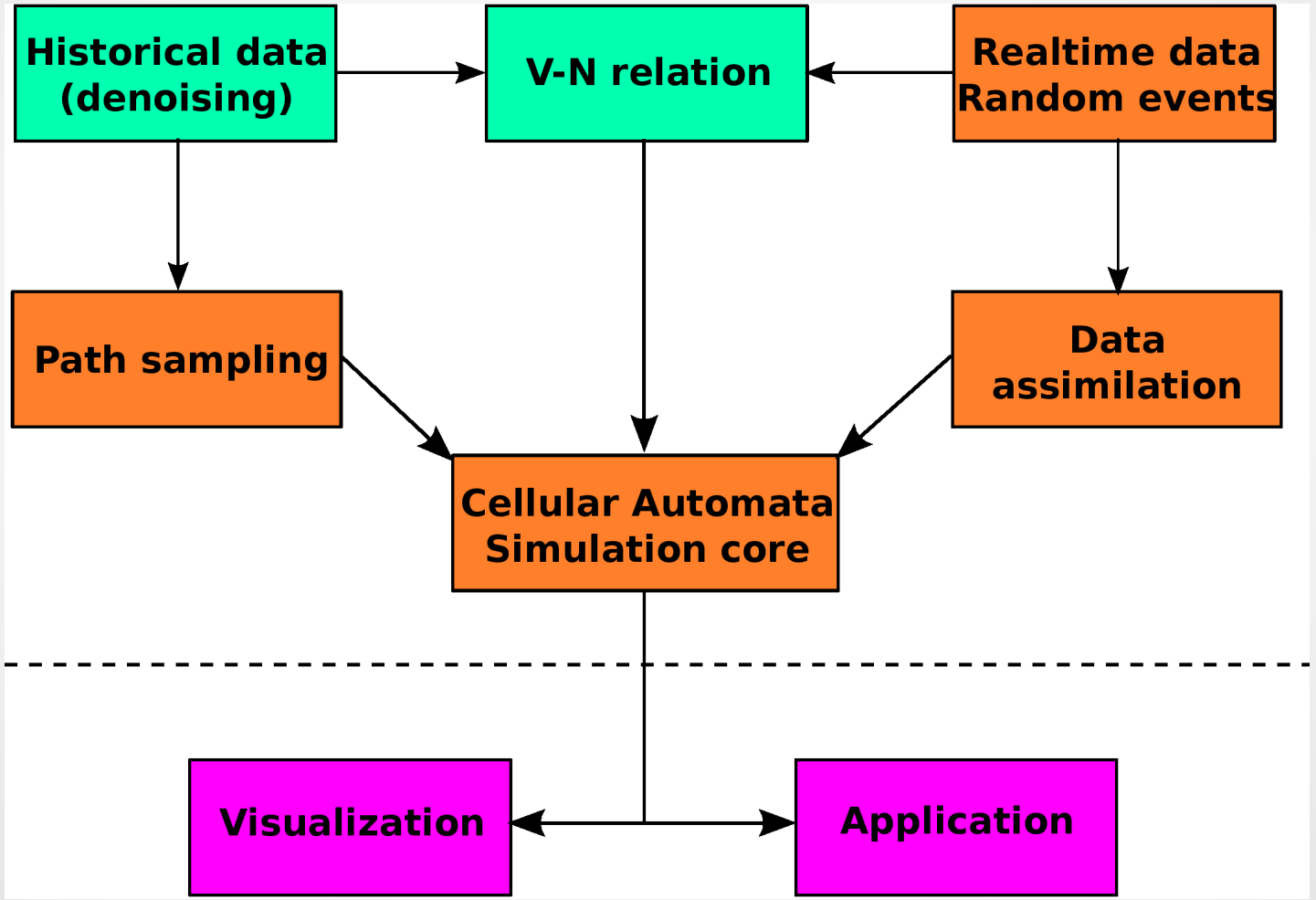
Features

- Powered by big data
- Model inside
- Requires no road information
- Similar work-flow with NWP

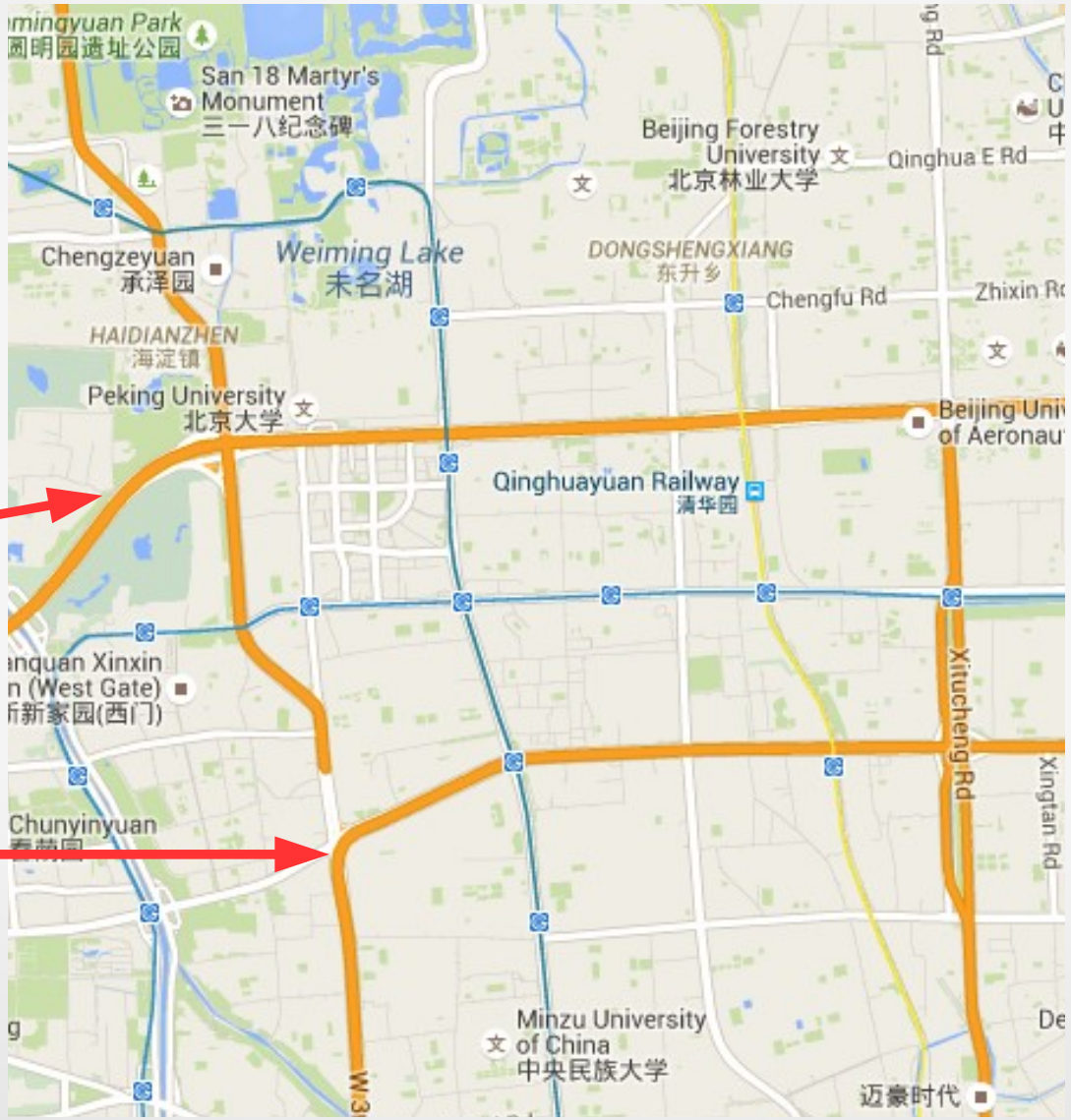
Difficulties

- Heavy computational load
- Choice of V-N relation
- The effect of private cars
- Incorporate real-time data

Work-flow


Historical data (denoising)
V-N relation
Realtime data Random events
Path sampling
Data assimilation
Cellular Automata Simulation core
Visualization
Application

Results: 2D small

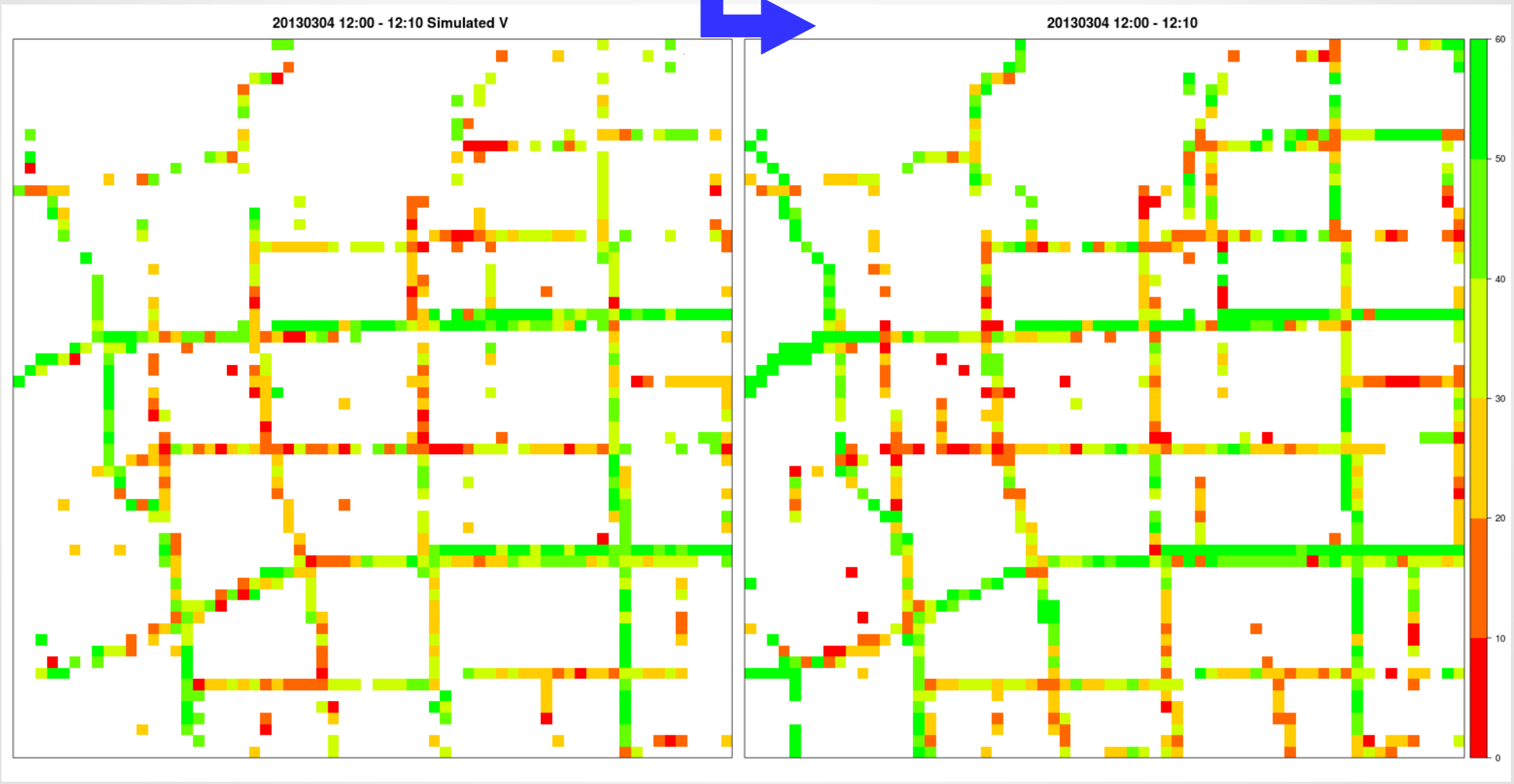


4th ring NW

3rd ring NW

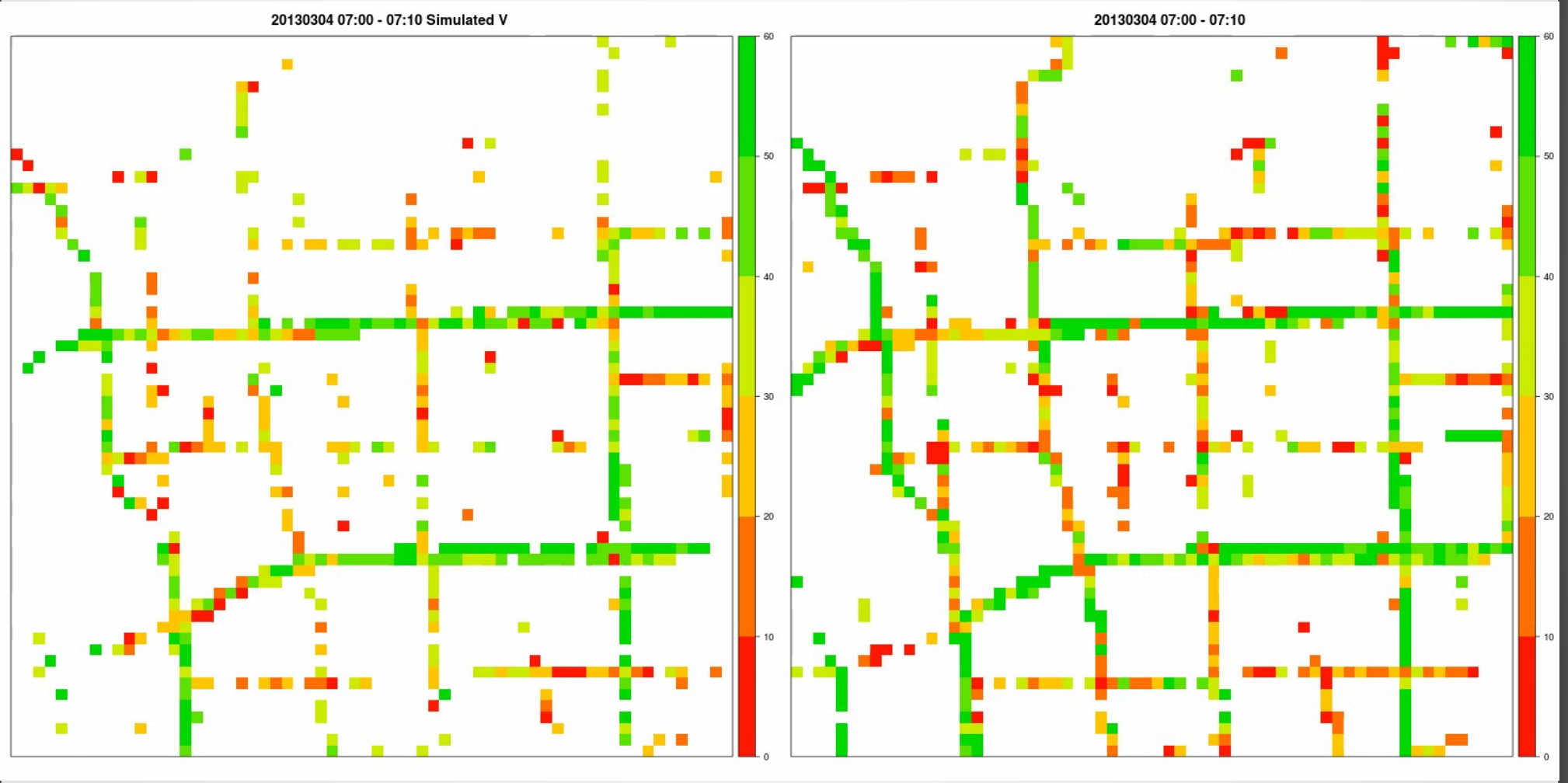
mesh size 64x64

Results: 2D small



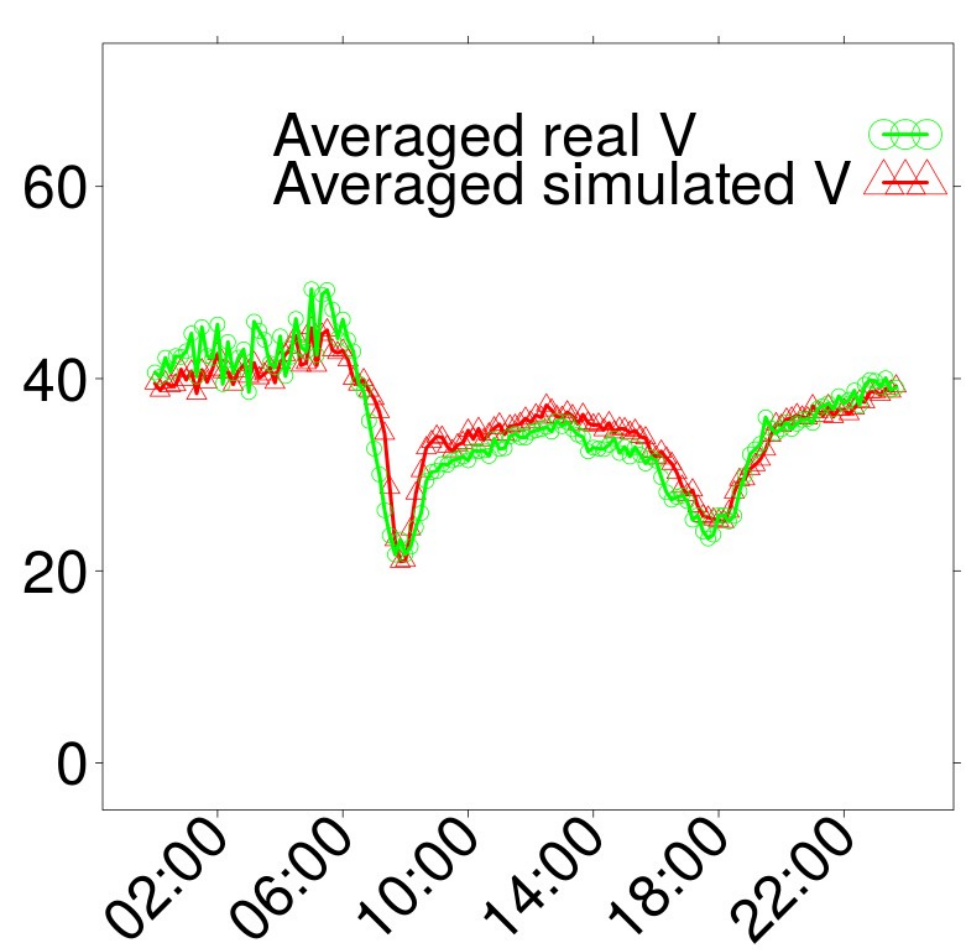
Simulation **Real data**

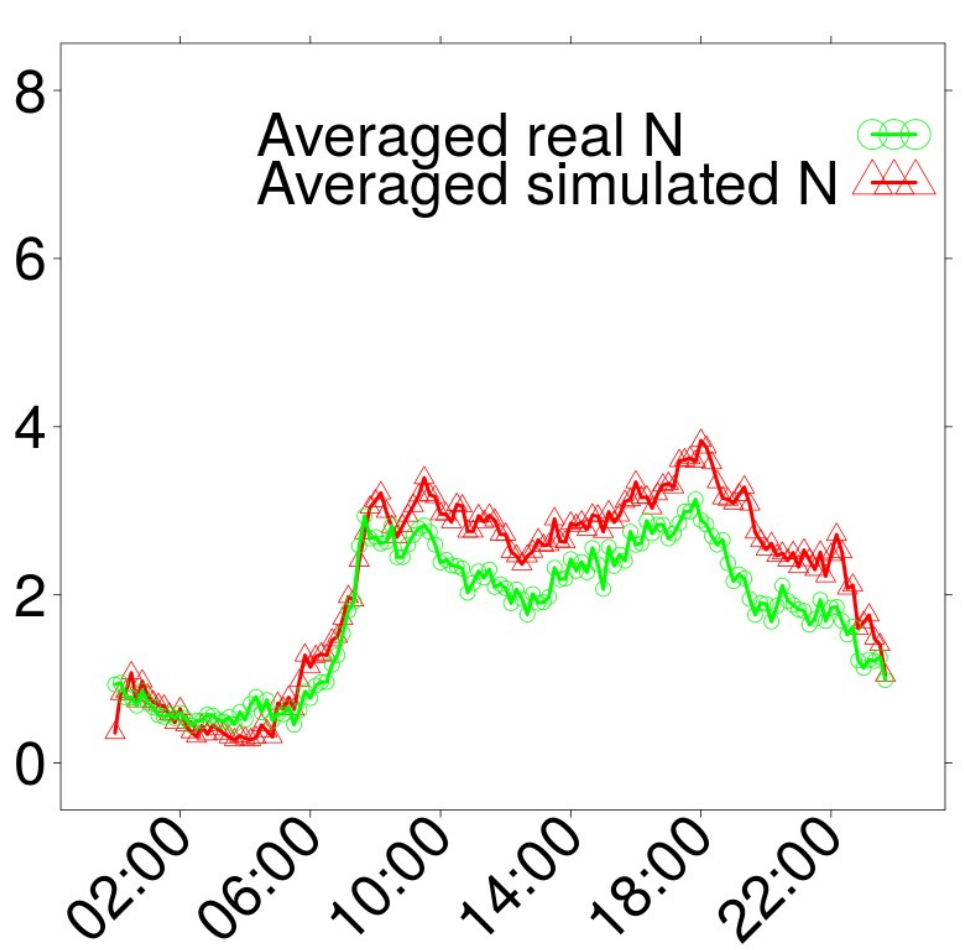
Results: 2D small



Simulation **Real data**

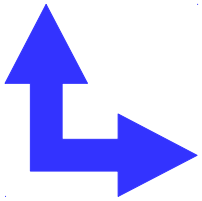
Results: 2D small

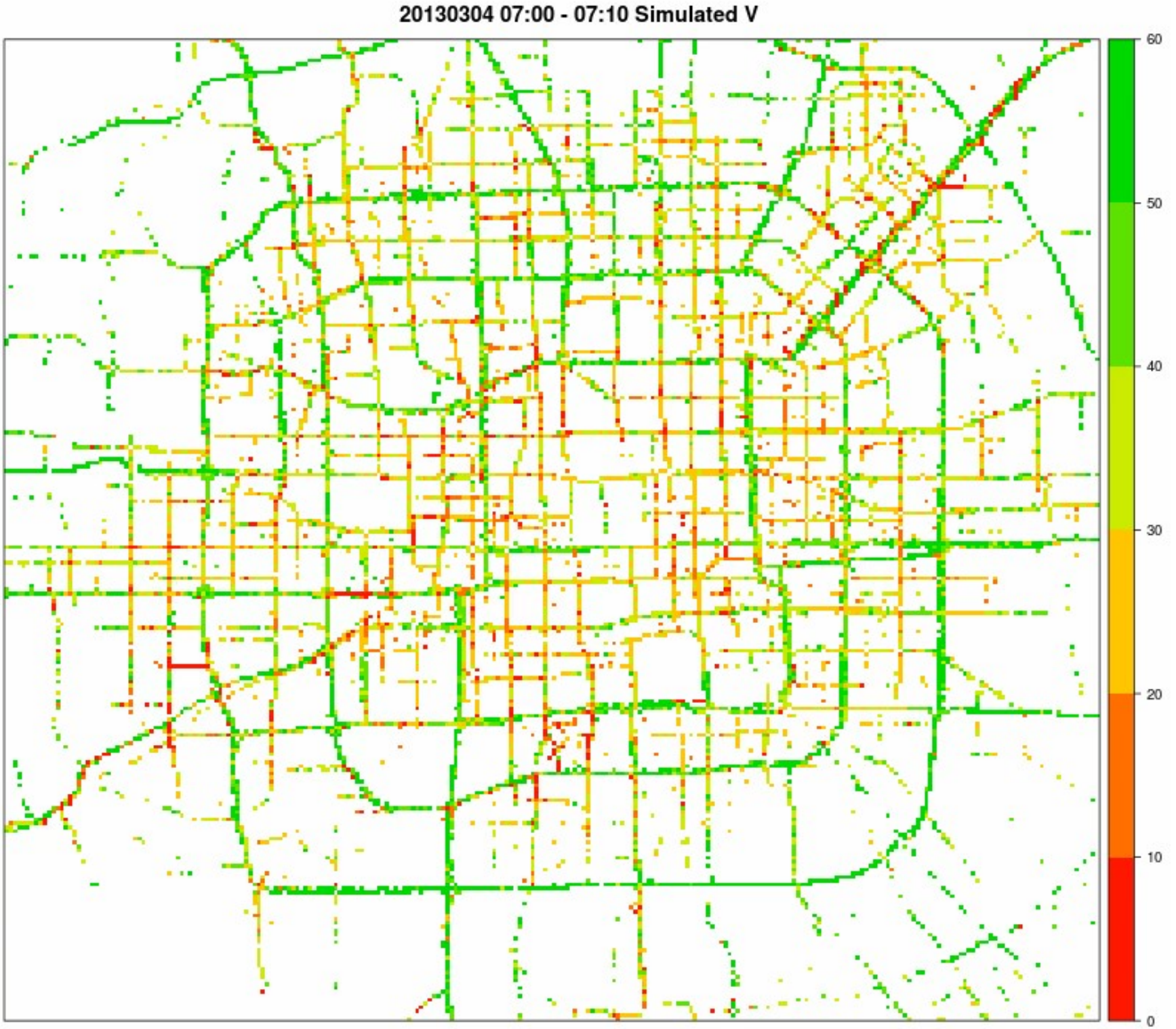




2D large

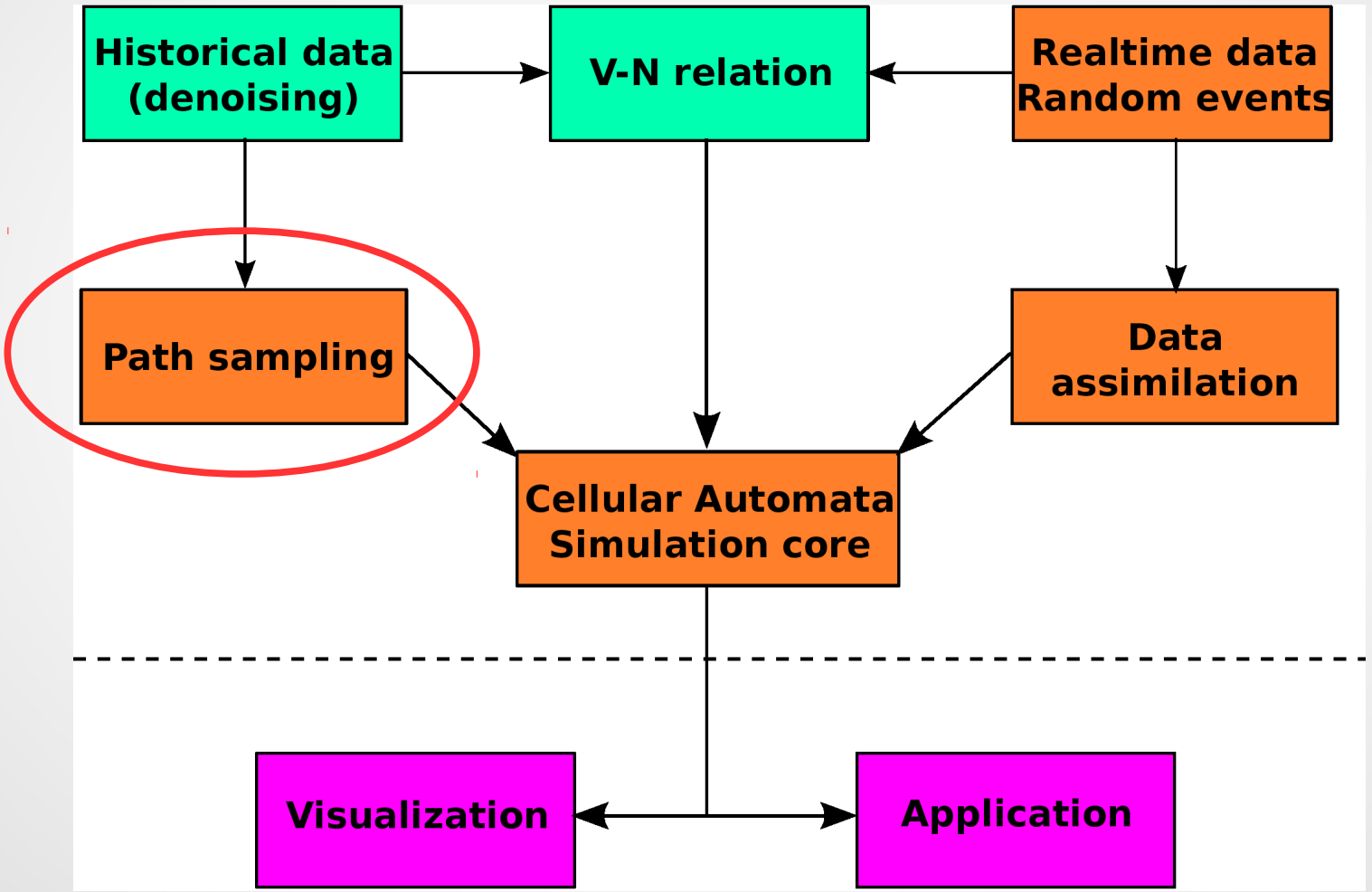
256x256





Sampling Taxi Origin-Destination Demands in Large Metropolitan Environment

O-D sampling


Historical data (denoising)
V-N relation
Realtime data Random events
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Visualization
Application

O-D data

a

Raw data

Pre-process

Routes

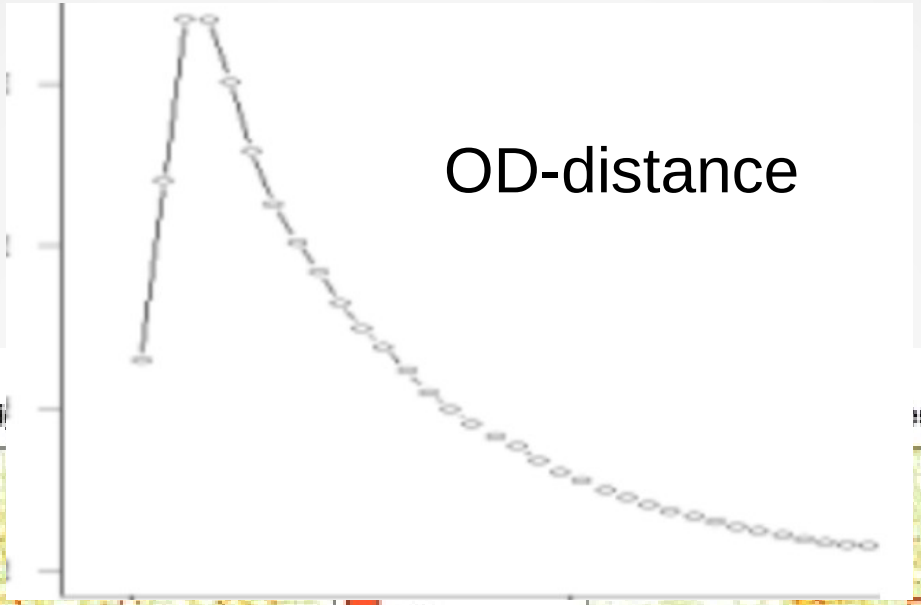
46	2013-03-05 11:56:58	116.40073	39.90125	0
47	2013-03-05 12:00:16	116.40066	39.90478	0
48	2013-03-05 12:02:28	116.40066	39.90482	1
49	2013-03-05 12:04:19	116.40062	39.91098	1
50	2013-03-05 12:05:46	116.40282	39.91281	1
51	2013-03-05 12:06:46	116.40441	39.91402	1
52	2013-03-05 12:08:30	116.40879	39.91419	1
53	2013-03-05 12:13:37	116.41022	39.91418	1
54	2013-03-05 12:14:20	116.41113	39.91414	1
55	2013-03-05 12:14:58	116.4115	39.91389	0
56	2013-03-05 12:15:15	116.41149	39.91384	0
57	2013-03-05 12:15:16	116.41149	39.91383	0
58	2013-03-05 12:16:13	116.41172	39.91365	0

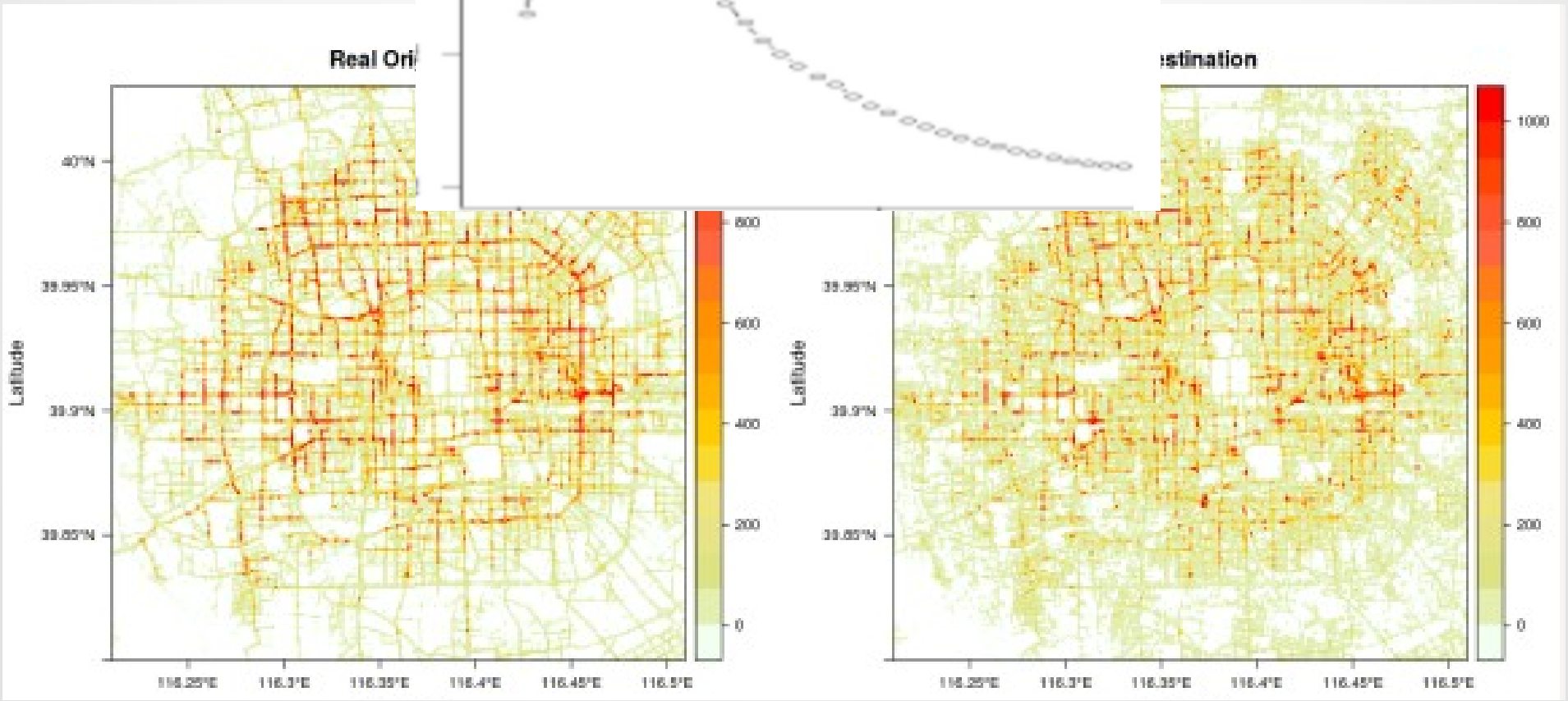
Origin

Destination

b

O-D statistical





O-D sampling

For some time period 8:00-9:00, given

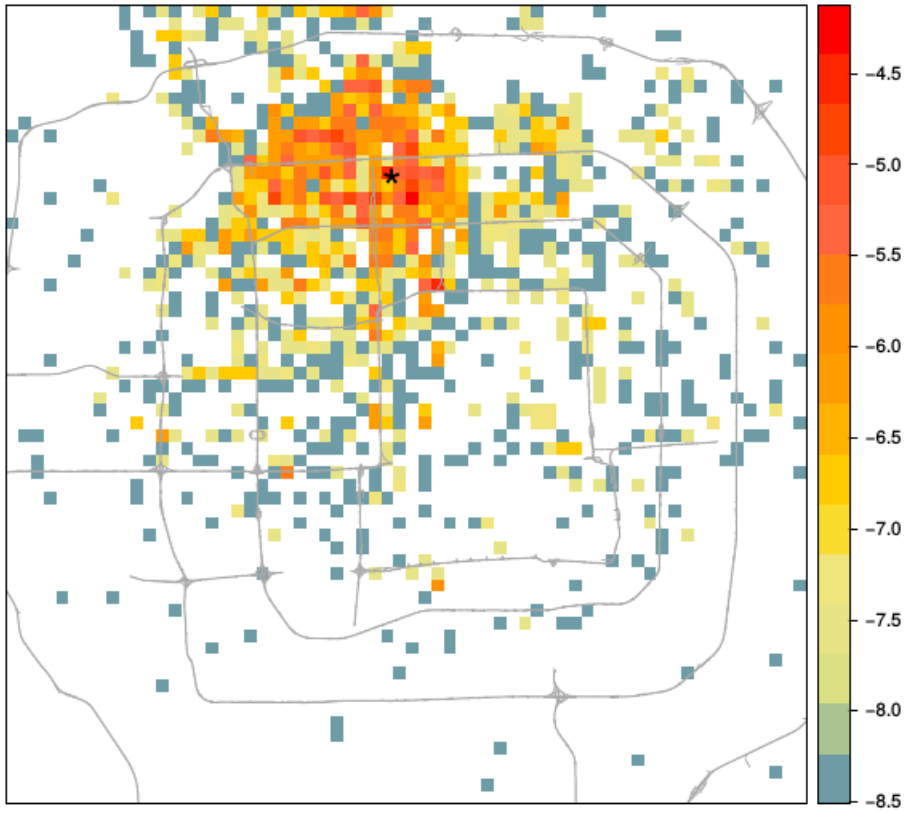
- N: the total number of OD;
- $P_O(\mathbf{x})$: the probability density of origins;
- $P_D(\mathbf{y})$: the probability density of destinations;
- $P_{dist}(r)$: the probability density of OD-distance.

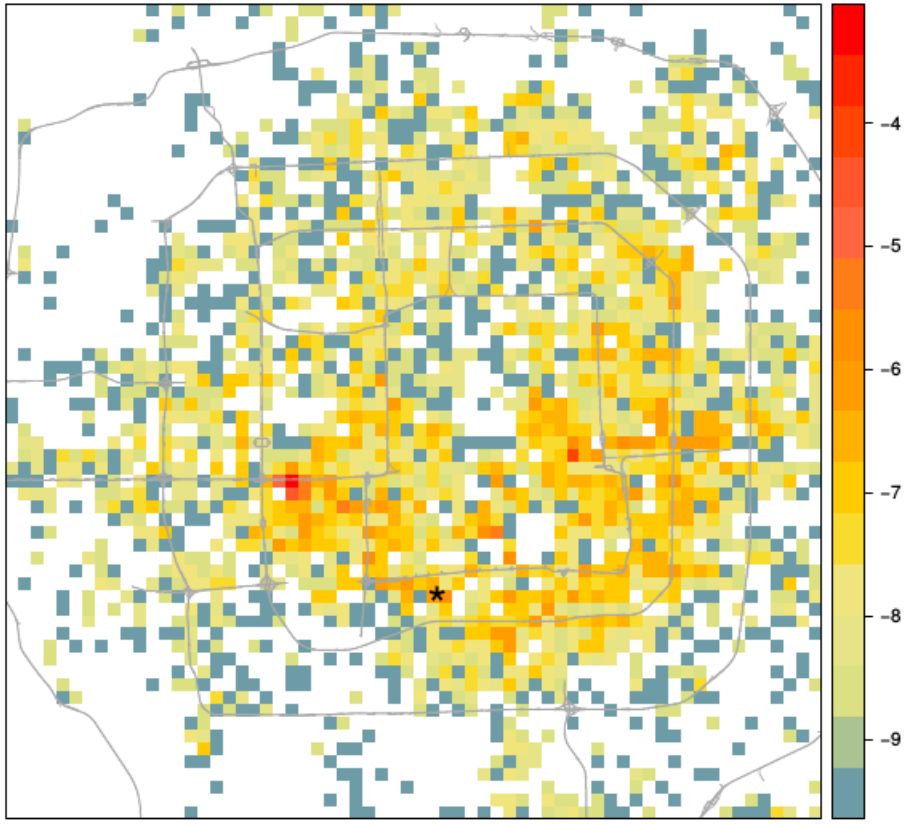
Generate OD samples that fit the above quantities.

Conditional probability

$$p_D(\mathbf{y}) = \int_{\mathbf{x}} p_O(\mathbf{x}) p(\mathbf{y}|\mathbf{x}) d\mathbf{x}$$

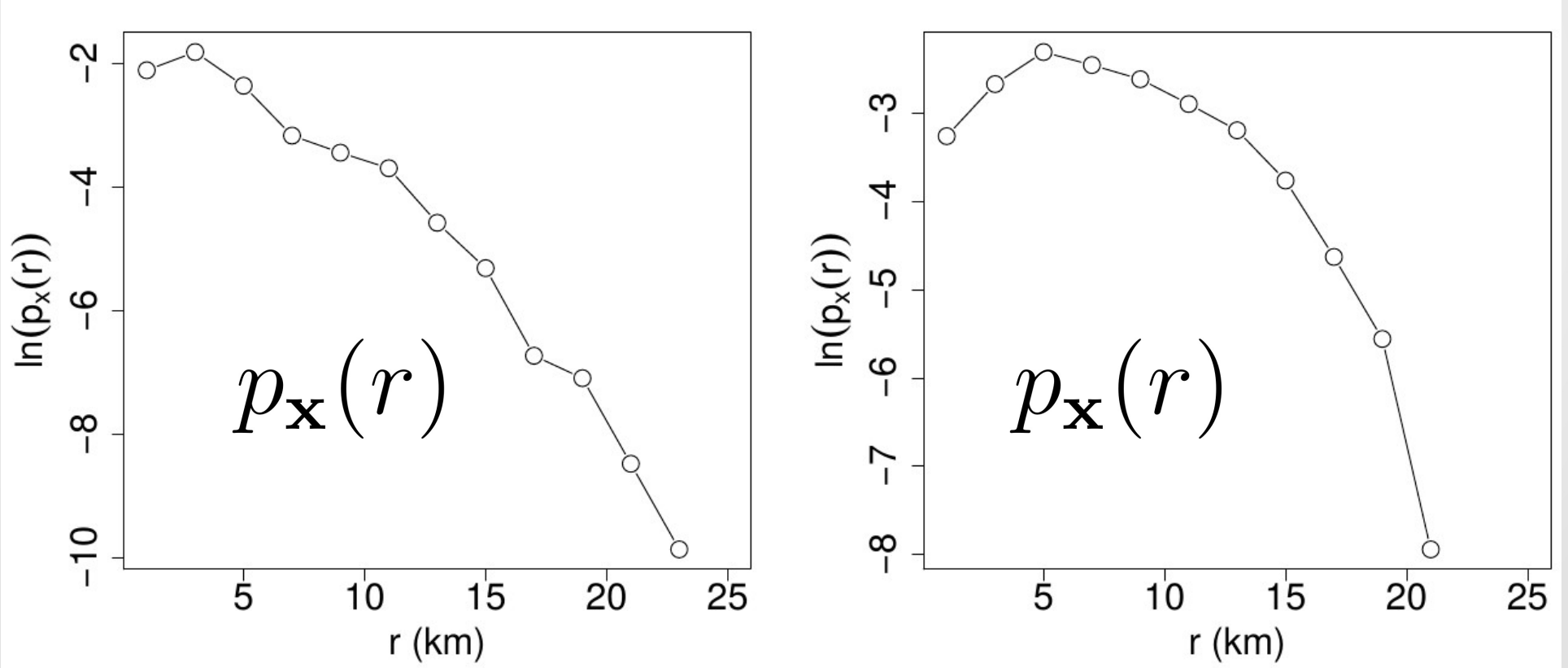
OD matrix: 256^4





O-D modeling

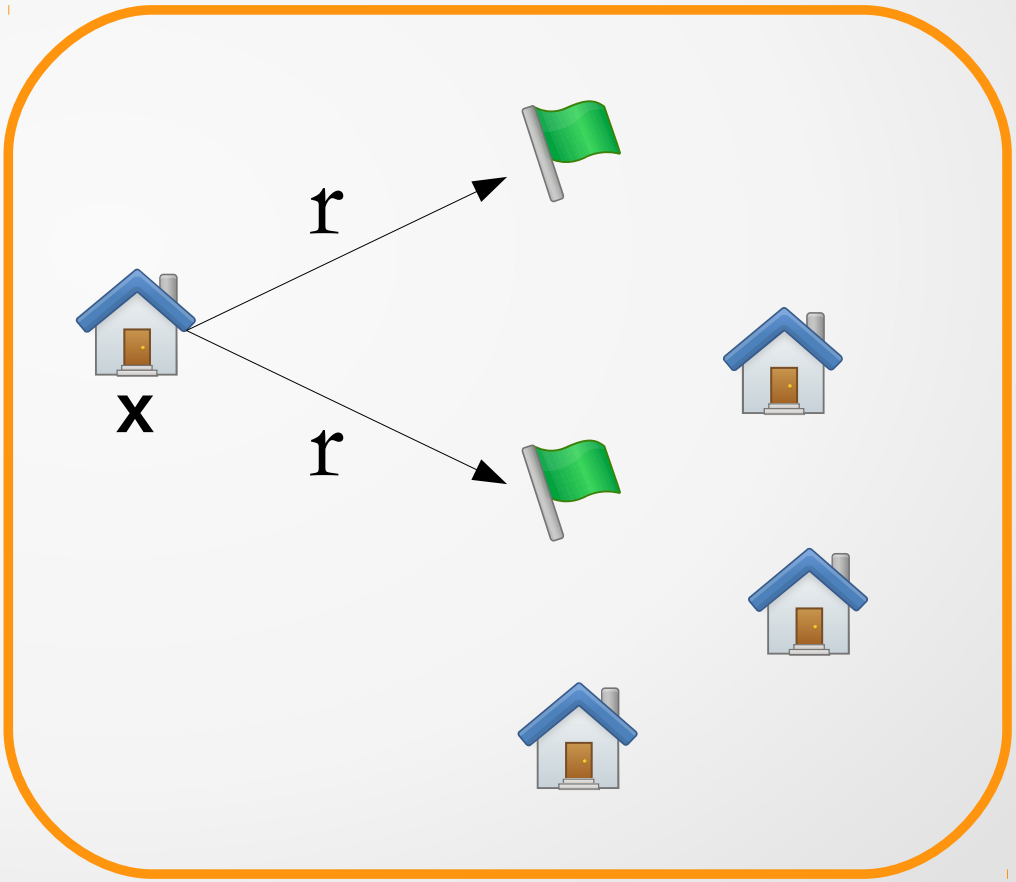
$$p(\mathbf{y}|\mathbf{x}) = p(r|\mathbf{x})p(\mathbf{y}|r,\mathbf{x})$$



Attractivity

$$p(\mathbf{y}|r,\mathbf{x}) = A^r_{\mathbf{x}} q(\mathbf{y})$$

$$q(\mathbf{y}) = p_D(\mathbf{y})$$

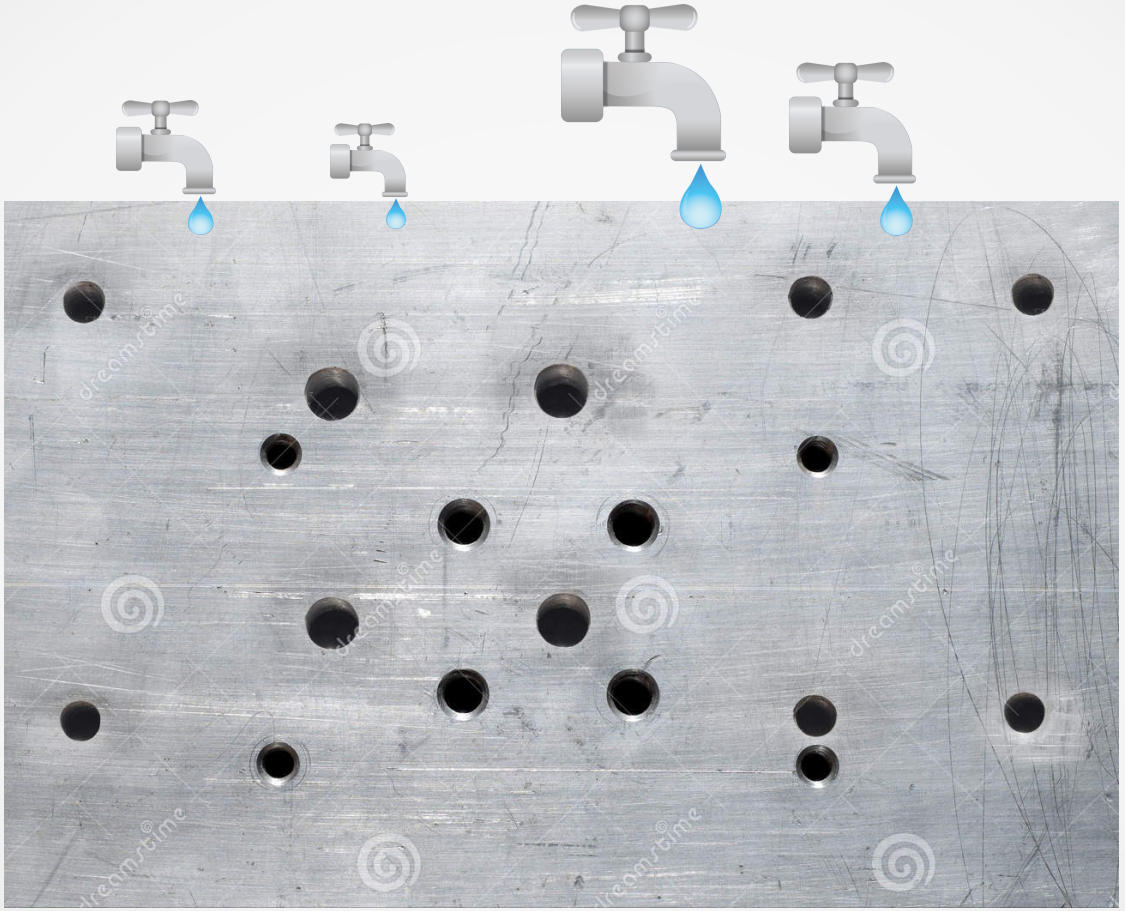


Radiation-absorbtion

$p_O(\mathbf{x})$

$q(\mathbf{y})$

$p_D(\mathbf{y})$



Consistency relation

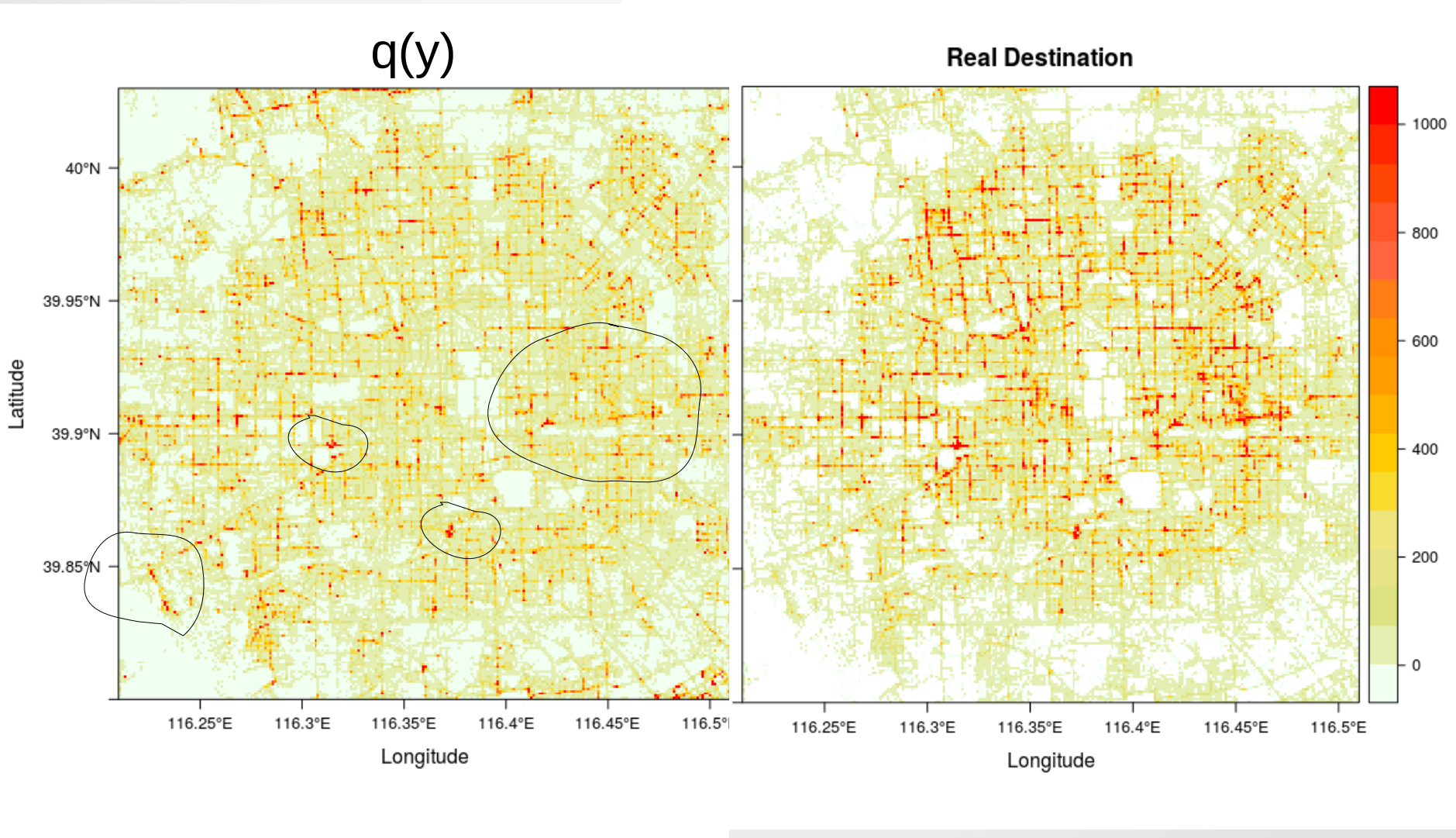
$$p_D(\mathbf{y}) = \int_{\mathbf{x}} p_O(\mathbf{x}) p_{\mathbf{x}}(r) \frac{q(\mathbf{y})}{\int_{\mathbf{y}' \in \Omega^r_{\mathbf{x}}} q(\mathbf{y}') d\mathbf{y}'} d\mathbf{x}$$

Algorithm:

1. Generate **x**;
2. Generate r for this **x**;
3. Generate **y** for this **x** and r;

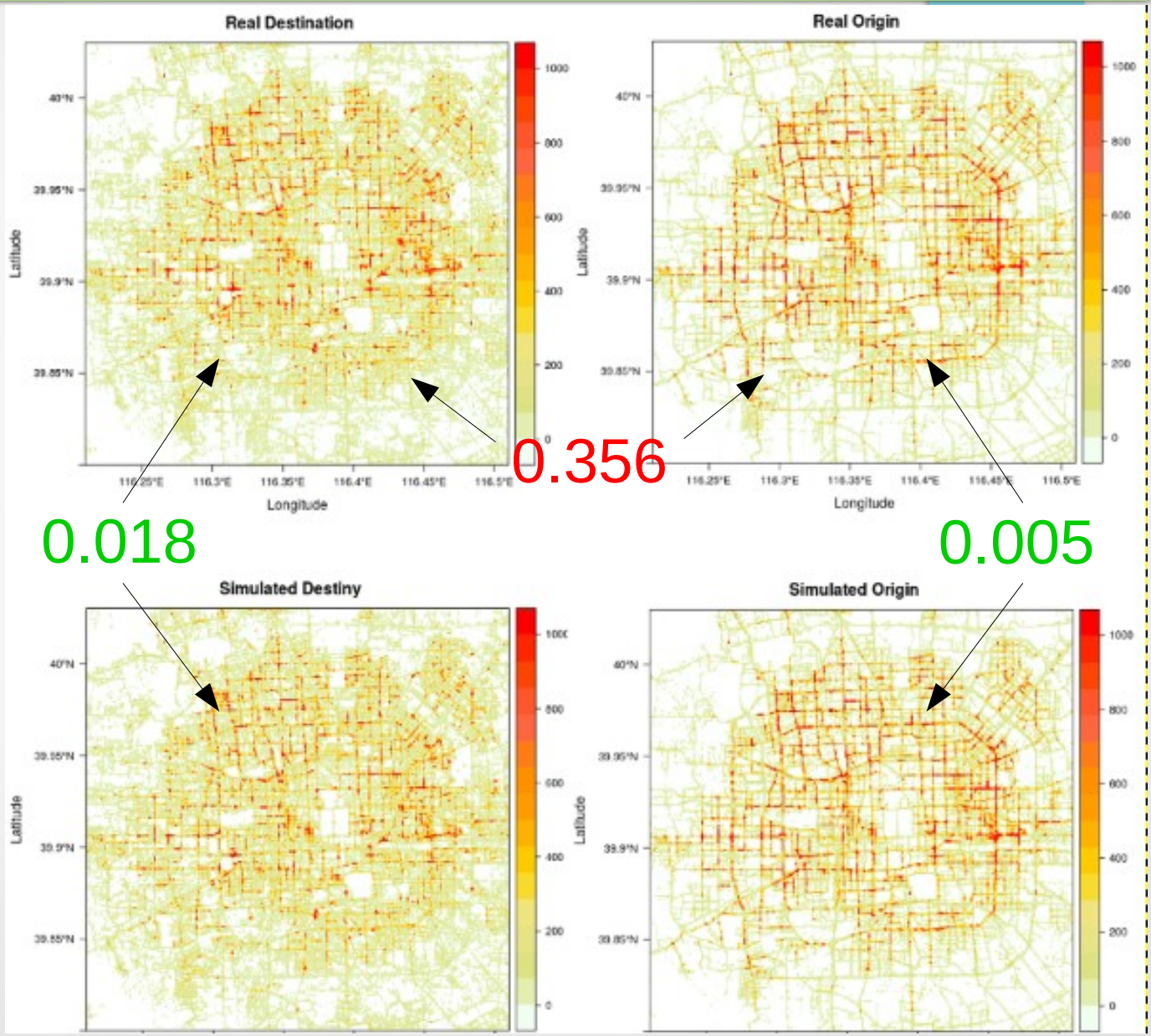
Approximation: $$q(\mathbf{y}) \sim \frac{p_D(\mathbf{y})}{\int_{\mathbf{x}} p_O(\mathbf{x}) p_{\mathbf{x}}(r) \frac{1}{r} d\mathbf{x}}$$

Attractivity

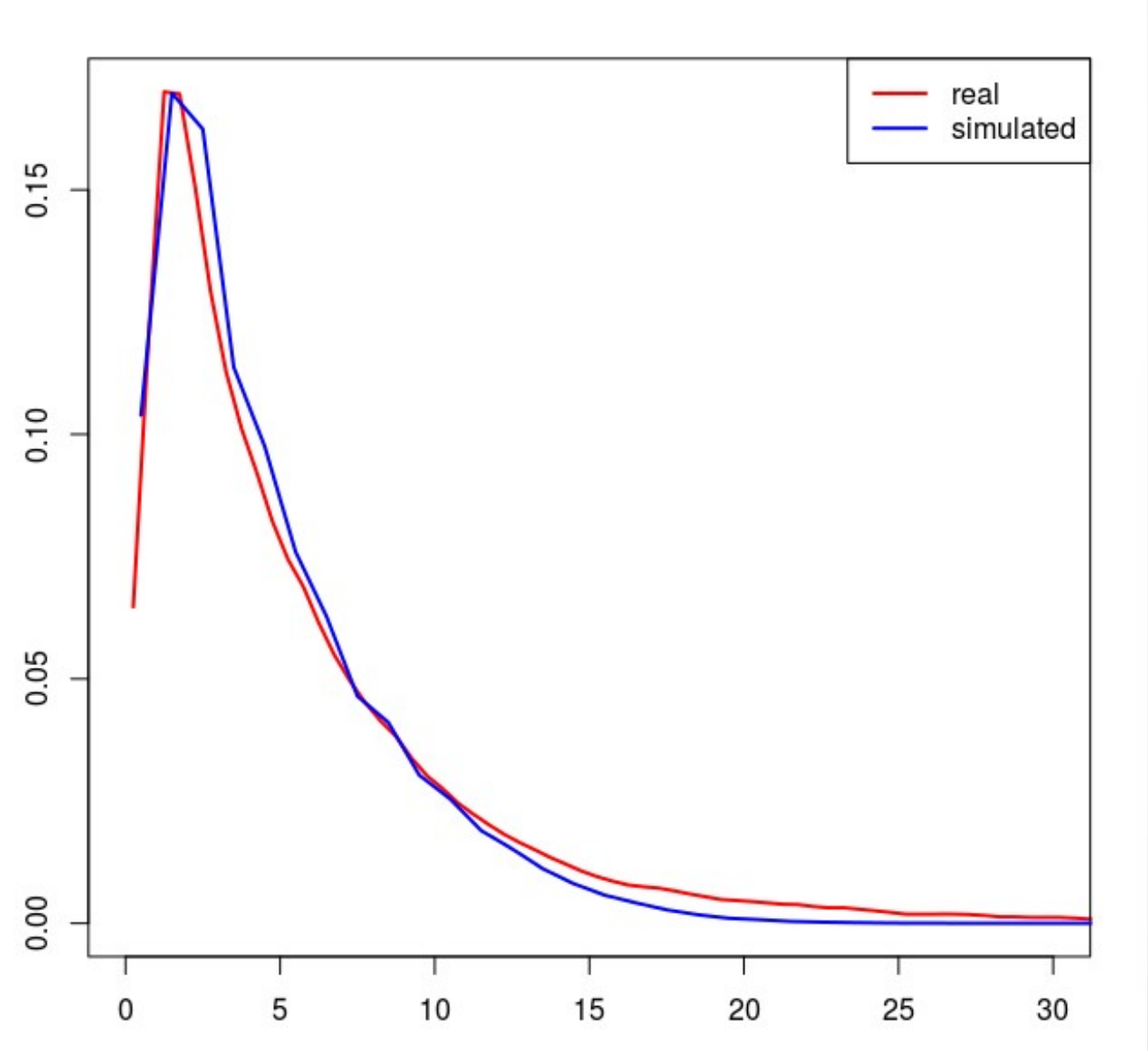


Numerical results

KL distance



Numerical results



Total OD-distance distribution

Summary

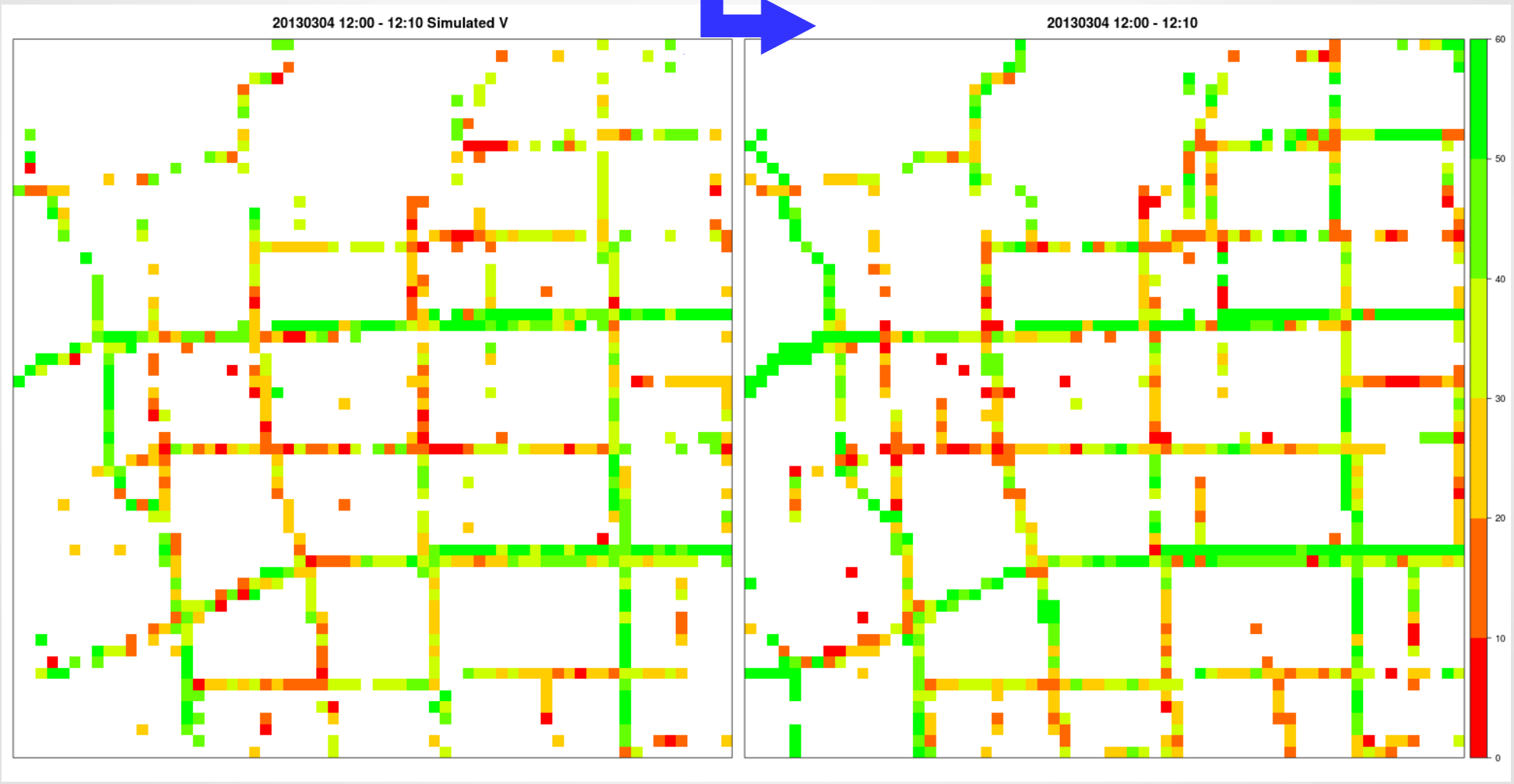
- A model-based OD sampling approach.
- Accounts for spatial heterogeneous.

Acknowledgements

- Peking University: Weinan E (Princeton), Tiejun Li, Xiaowei Wang, Xiaolu Guo, Huizhuo Yuan
- BTIC: Hao Liu
- CAS: Haijun Yu
- PrinceTechs: Haoshu Tian
- BIU: Yong Zhang

Thank You!

Results: 2D small



Simulation **Real data**

Road space rationing


HTTP://DARKKENJIE.DEVIANTART.COM/