Investigating the Empirical Existence of Static User Equilibrium

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Traffic Modeling : User Equilibrium Frameworks

Equilibrium frameworks central in Transportation Research since Wardrop [Wardrop, 1952]

Diverse developments :

→ Dynamic Stochastic User Equilibrium [Han, 2003]

→ Restricted Stochastic User Equilibrium [Rasmussen et al., 2015] more realistic in alternatives

→ Boundedly User Equilibrium [Mahmassani and Chang, 1987]

→ Assignment techniques inspired from other fields such as Network Science [Puzis et al., 2013]

Validation and Practical Use

Static User Equilibrium lacks empirical validation in the literature

→ Some examples such as the behavioral study of user route choices ("Wardrop's first principle") in [Zhu and Levinson, 2010]

However still largely used

→ in theoretical literature, as for example [Leurent and Boujnah, 2014] : do refinements in the model such as adding parking cruising flows have a sense if the core is not validated ?

→ in real-world application, such as the MODUS model for Paris Metropolitan area : what are the implications of basing decision-making and traffic management on an unvalidated framework ?

Empirical Investigation of SUE Existence

Research Objective : *Investigate empirically the spatio-temporal stationarity of traffic flows, combining different complementary quantitative approaches*

$\rightarrow$ Construction of a real-time dataset for major links of Paris region on 6 month by data crawling

$\rightarrow$ Complementarity of approaches (Complex Systems general paradigm) : Spatio-temporal data visualization, Network analysis, Spatial analysis

Dataset Construction

Difficulty to find Open Data on Transportation Systems
[Bouteiller and Berjoan, 2013]
$\rightarrow$ Construction of an open historical travel time dataset for major links in the region of Paris, collecting in real time public traffic data from `www.sytadin.fr`

Data collection : Each two minutes, automated python script

- fetch raw webpage giving traffic information
- parse html code
- store in a `sqlite` database

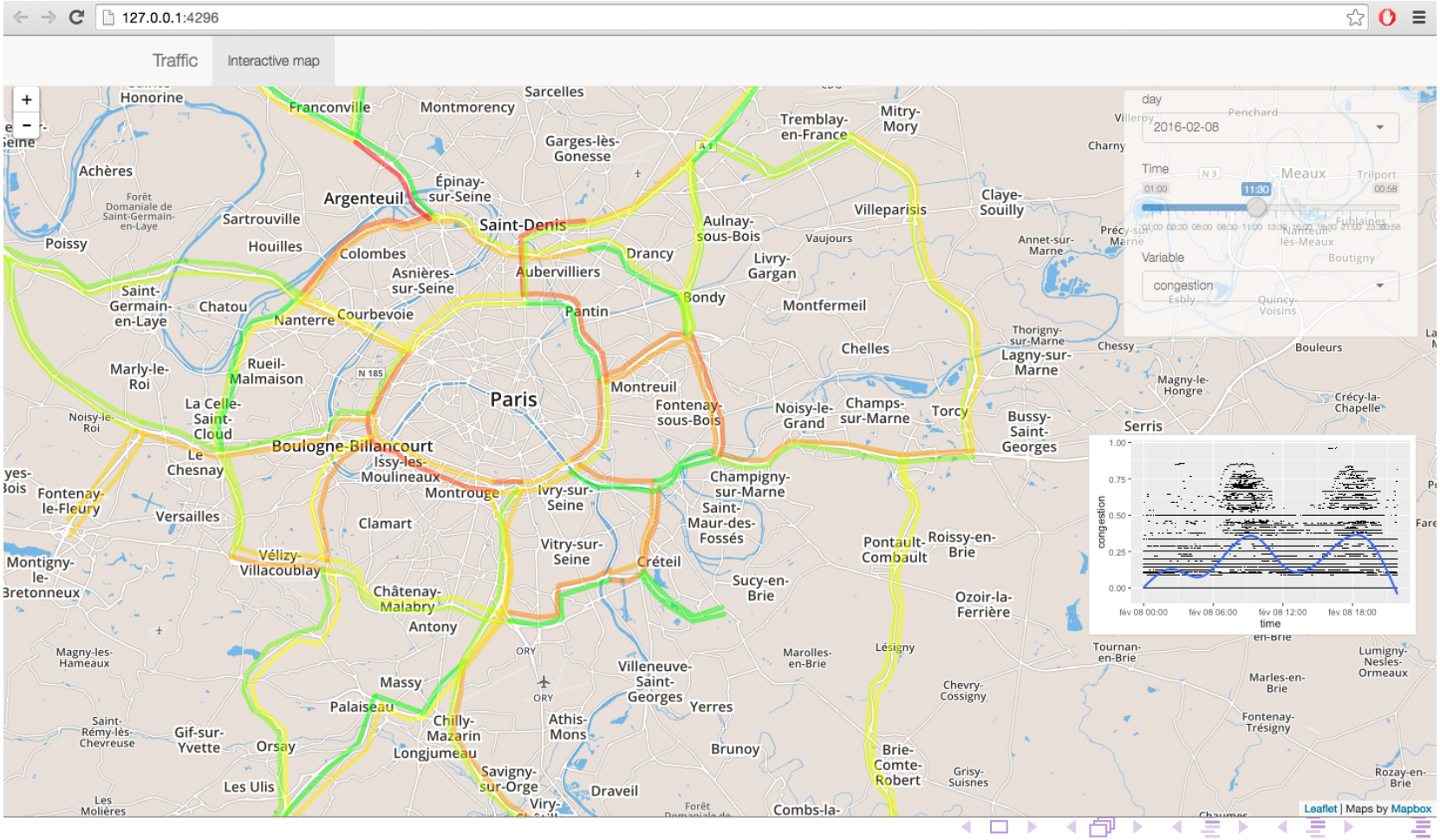
Openly available (CC Licence) at
`http://37.187.242.99/files/public/sytadin_latest.sqlite3`

Data summary : 10 month (since Feb. 2016), 2min time granularity, effective travel time for 101 links ($\simeq$ 10km spatial granularity)

Interactive Data Visualization

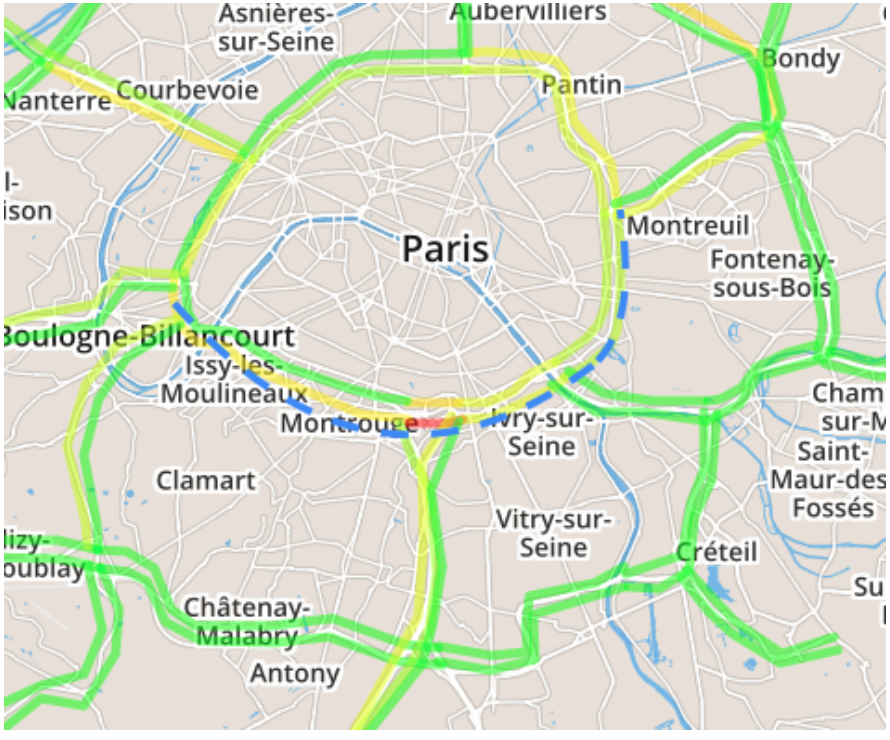
Interactive web-application for spatio-temporal exploration

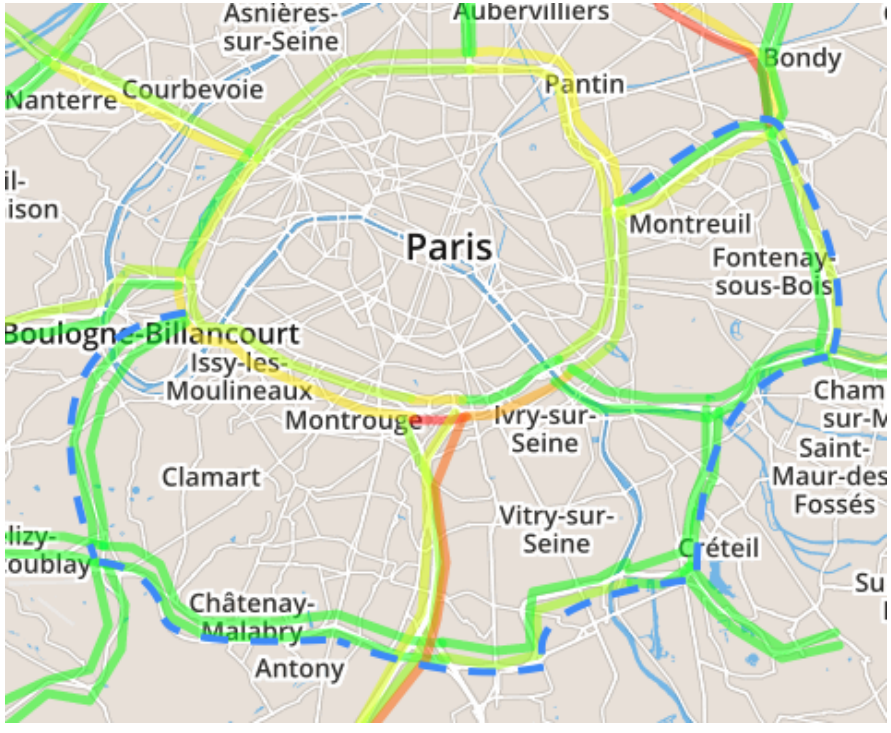
`http://shiny.parisgeo.cnrs.fr/transportation`



Spatio-temporal Variability : Example

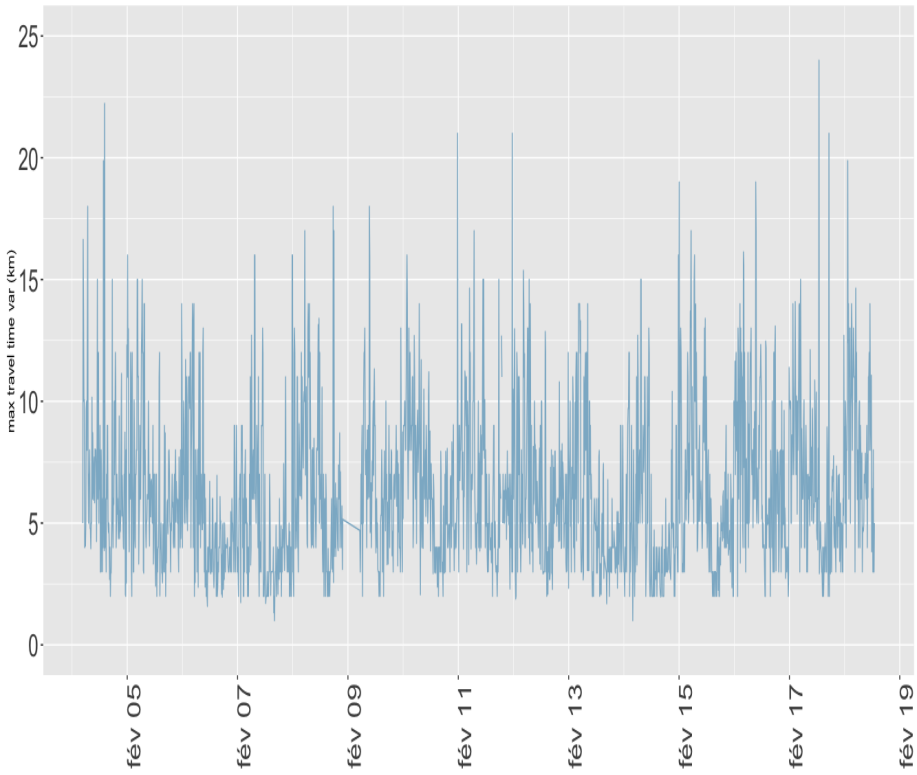
Very high spatial variability on 10min time interval, here on 11/02/2016 00:06-00:16

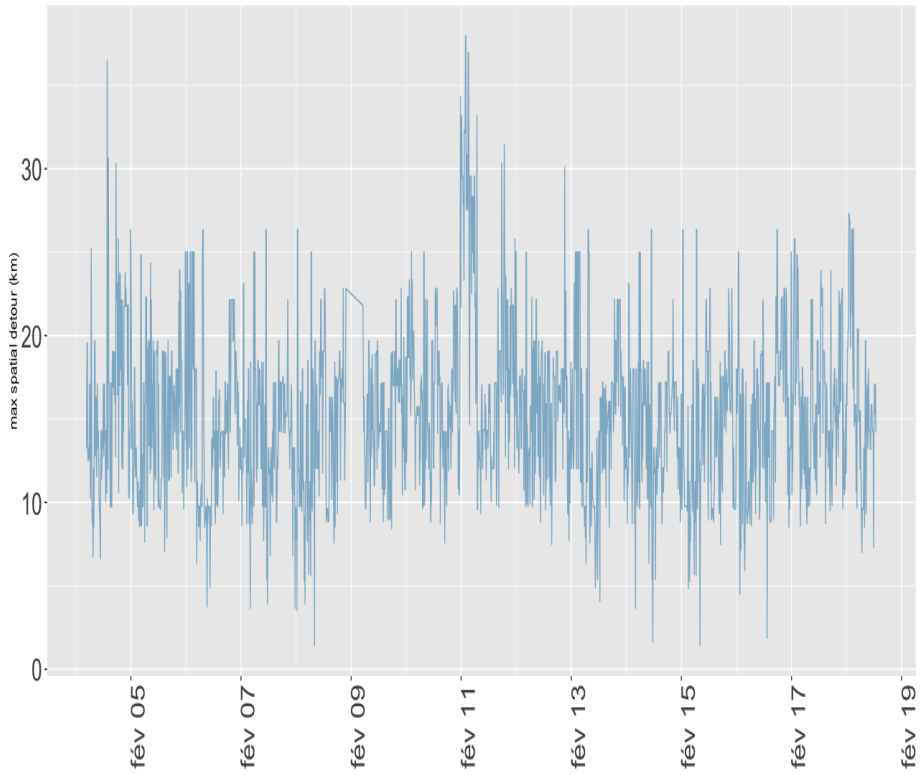




Spatio-temporal Variability

Maximal travel time and spatial variabilities on a two week sample





Stability of Network Measures

Network Betweenness Centrality

$$b_i = \frac{1}{N(N-1)} \cdot \sum_{o \neq d \in V} \mathbb{1}_{i \in p(o \to d)} \tag{1}$$

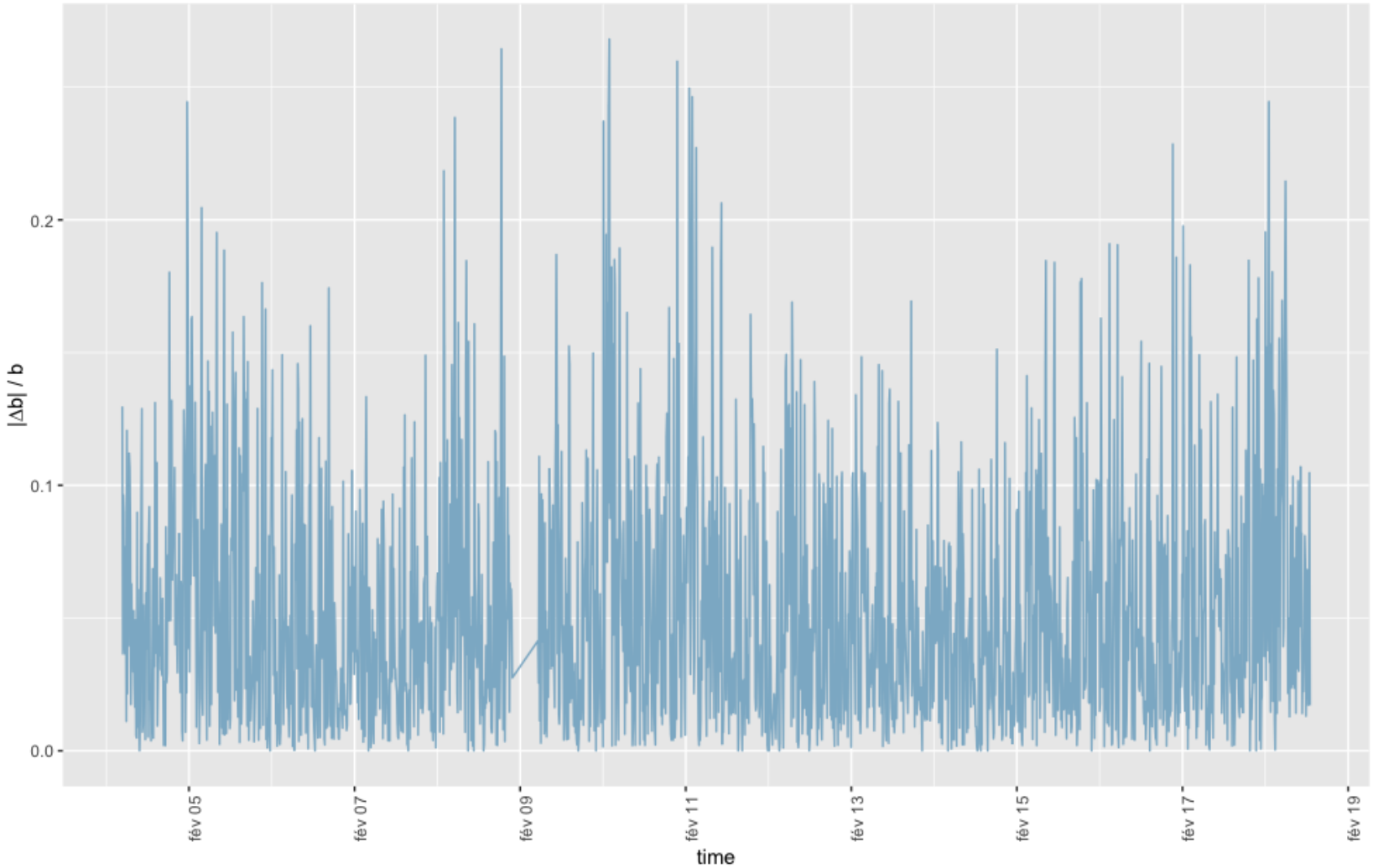
Temporal Maximal Betweenness Variability

$$\Delta b(t) = \frac{|\max_i(b_i(t+\Delta t)) - \max_i(b_i(t))|}{\max_i(b_i(t))} \tag{2}$$

$\rightarrow$ *Reveals either a proportion of rerouted travels (negative variation) or a minimal proportion of load increase for a single node (positive variation)*

Stability of Network Measures

Temporal maximal betweenness variability on a two weeks period



Spatial Heterogeneity

Spatial Autocorrelation as an index of spatial variability, for link i

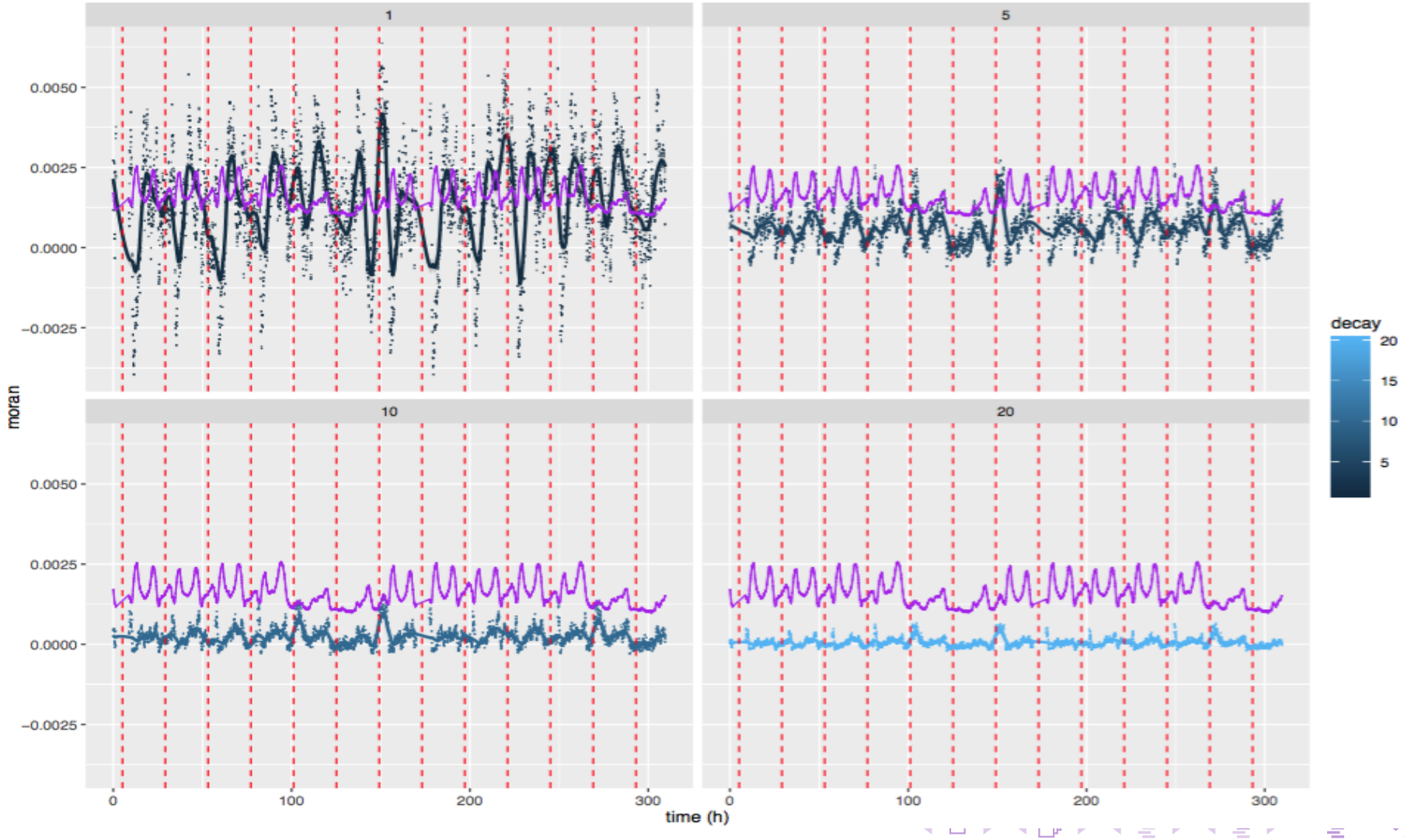
$$\rho_i = \frac{1}{K} \cdot \sum_{i \neq j} w_{ij} \cdot (c_i - \bar{c})(c_j - \bar{c}) \tag{3}$$

with spatial weights $w_{ij} = \exp\left(\frac{-d_{ij}}{d_0}\right)$

$\rightarrow$ *Indirect measure of the spatial stationarity of flows : a decreasing correlation implies a chaotic system*

Spatial Heterogeneity

Spatial autocorrelation on a two weeks period for different decays



Theoretical and Practical Implications

Theoretical Implications

→ Need for more systematic comparison of framework validity ([Kryvobokov et al., 2013] compares two LUTI models e.g.)

→ Can still be used e.g. for integration within more complex models

Practical Implications

→ Difficulty of transferring academic results to real-world engineering, that can be tied to habits, myths, political interests, etc. [Commenges, 2013] ; [Offner, 1993]

Possible Developments

Further assessment of chaotic nature of traffic flows

Conclusion

All code available at
`https://github.com/JusteRaimbault/TransportationEquilibrium`
Paper preprint available at `http://arxiv.org/abs/1608.05266`

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