# Mobility and Complexity

NPCS Conference 2018

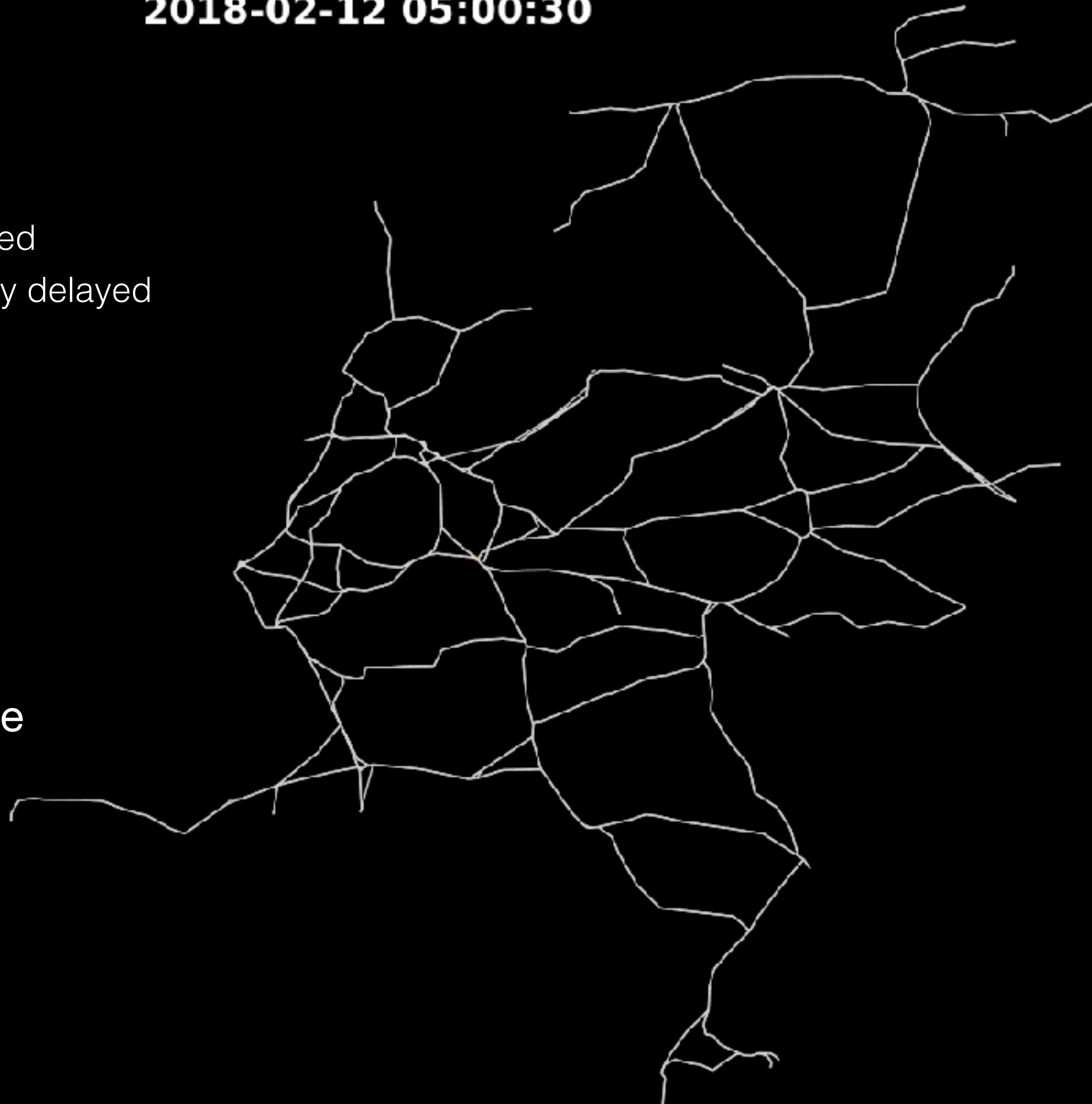
Mark Dekker

2018-02-12 05:00:30

| | |
|---|---|
| **Green** | A bit early |
| **Grey** | On time |
| **Orange** | A bit delayed |
| **Red** | Significantly delayed |

Observations:

- Advection
- Diffusion
- Direction/line
- Interference
- Emergence



# Aim

*To find early-warning indicators for large-scale disruptions*

*First step: delay propagation*

a. Quantify diffusion of perturbations ('advection')

b. Understand interacting perturbations and amplification effects

# Literature

Complex delay dynamics on railway networks: from universal laws to realistic modelling

Bernardo Monechi[1] Pietro Gravino[2] Riccardo Di Clemente[3] Vito D. P. Servedio[4]

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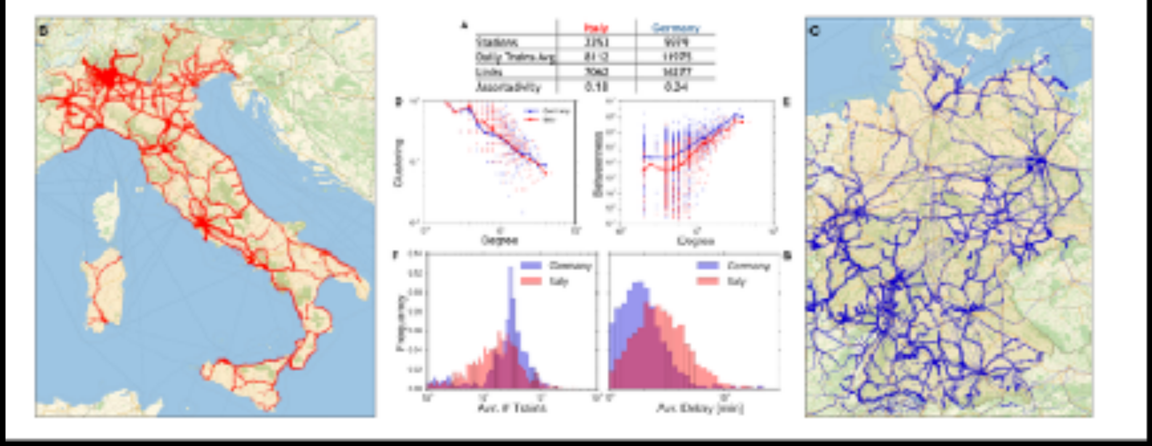
**Abstract**

Railways are a key infrastructure of any modern country where major disruptions and large delays compromising the correct mode of operation occur on a daily basis. Despite their importance, a general theoretical understanding of the underlying causes is still lacking so that a deeper comprehension of these critical situations will impact the effectiveness of traffic handling policies. Here, we report a detailed study of the Italian and German railway networks based on an extensive dataset retrieved during year 2015. We detect universal laws ruling the occurrence of delay at stations and find that both the Italian and German systems display a sort of delay contagion effect. We exploit these results to propose a simple modelling scheme of train dynamics on railway networks which is capable of reproducing the dynamical features of real systems.



Monechi et al. (2017)

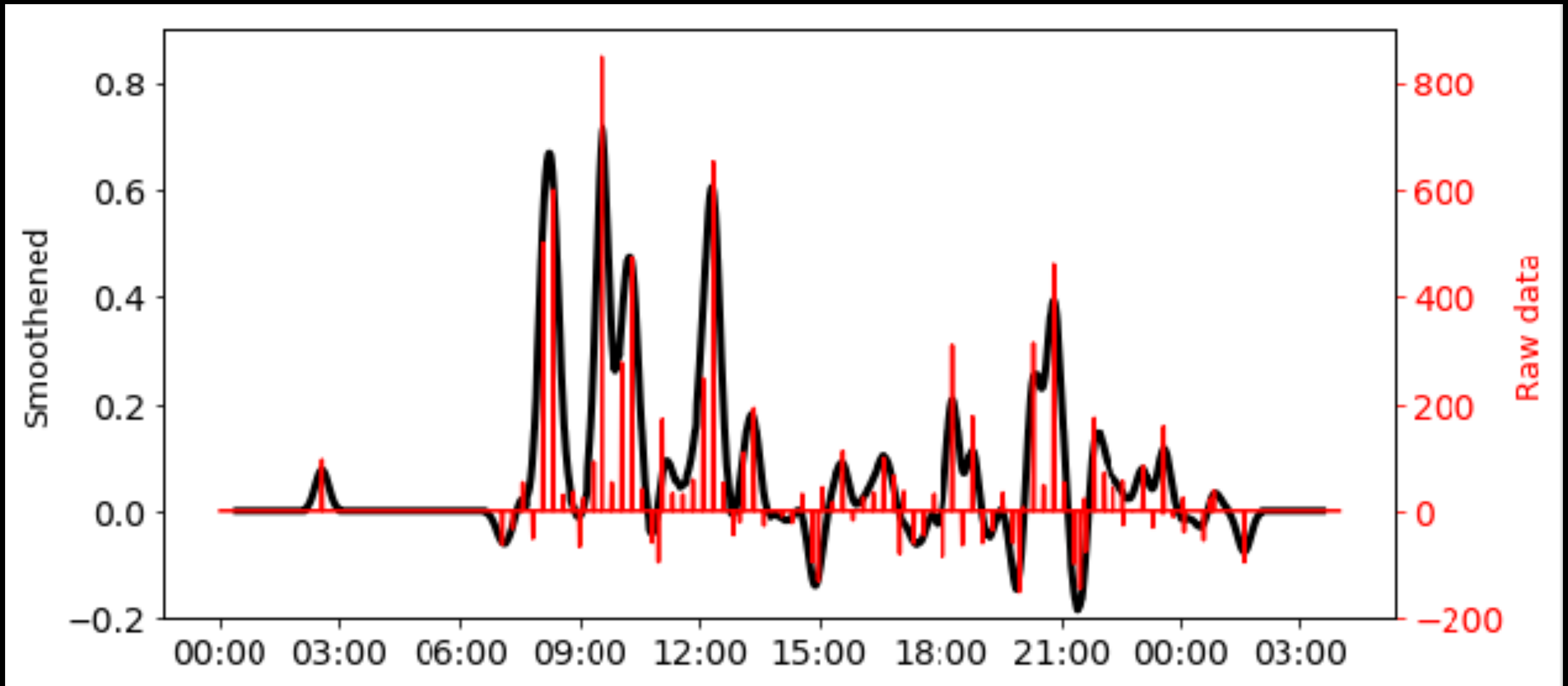
- ‘Gap’ in research
- Investigates dynamics
- Simple model

# Data

Logged train activity - register of the passing of trains and their characteristics

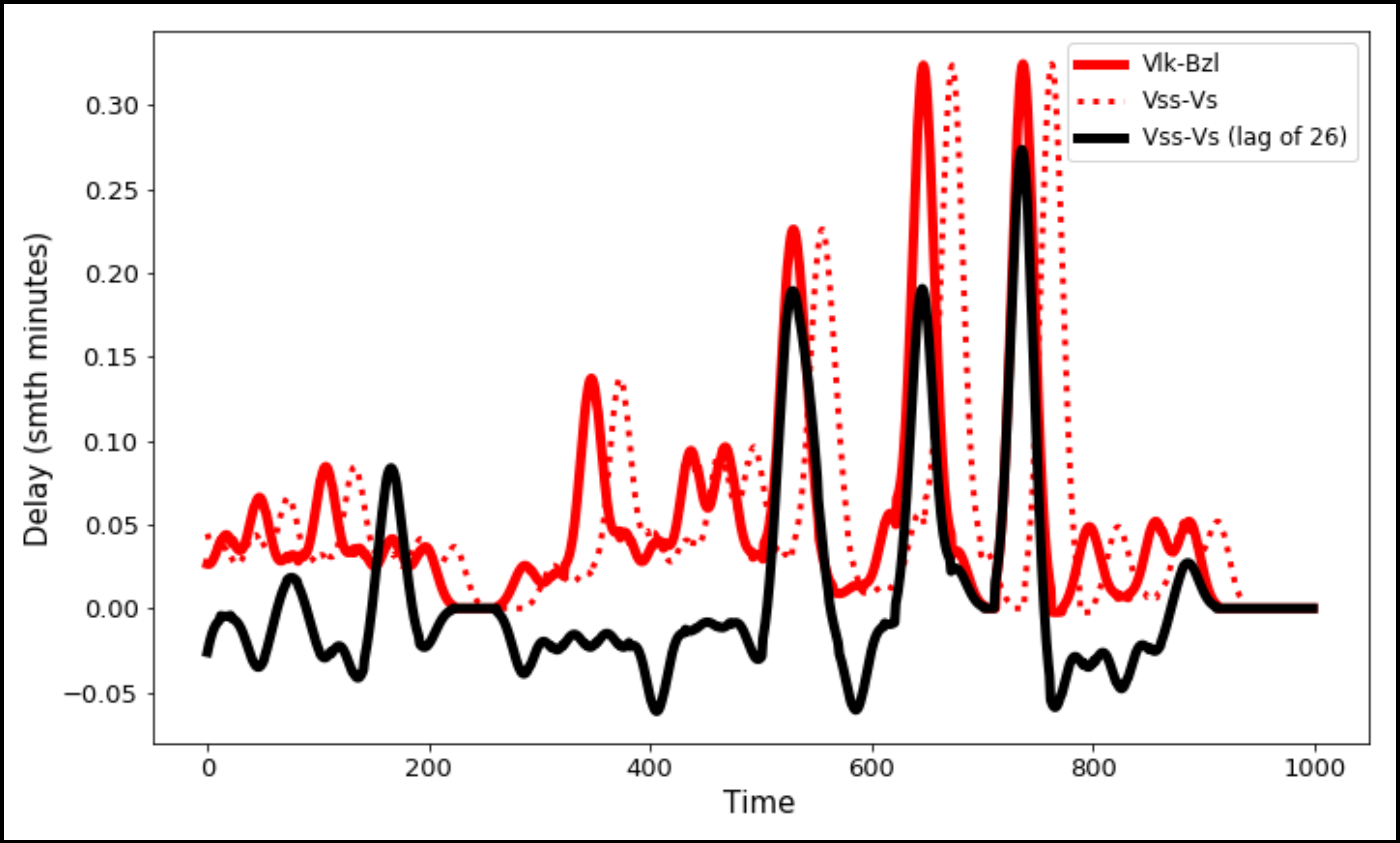
- Discrete -> continuous time series
  - Gaussian weighting function

- Future data: crew?

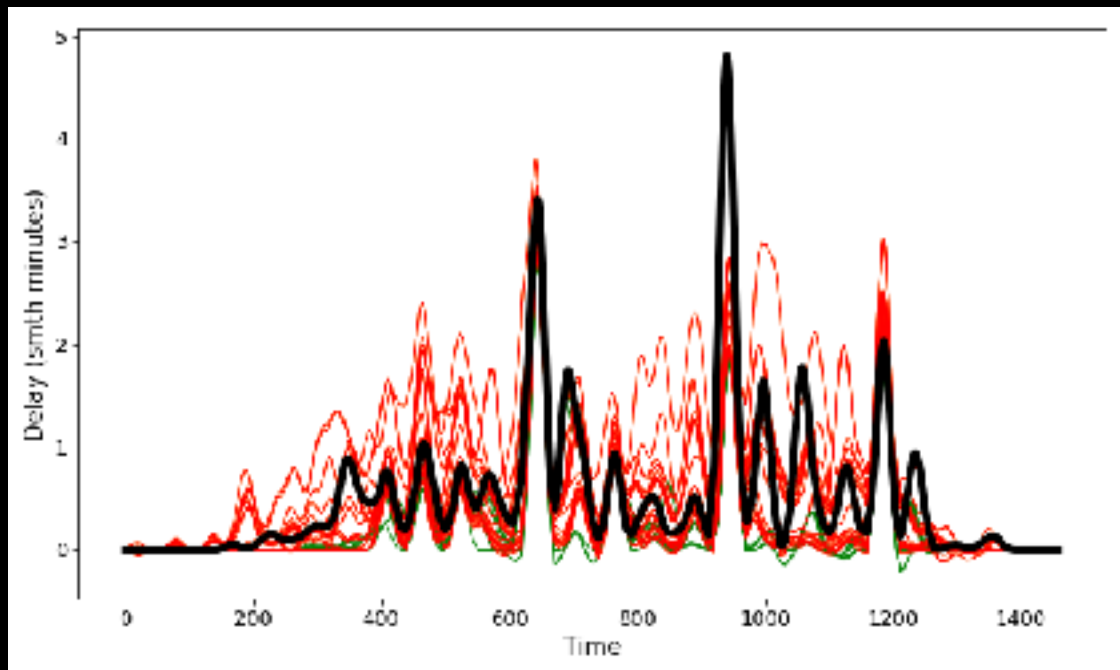


# First step

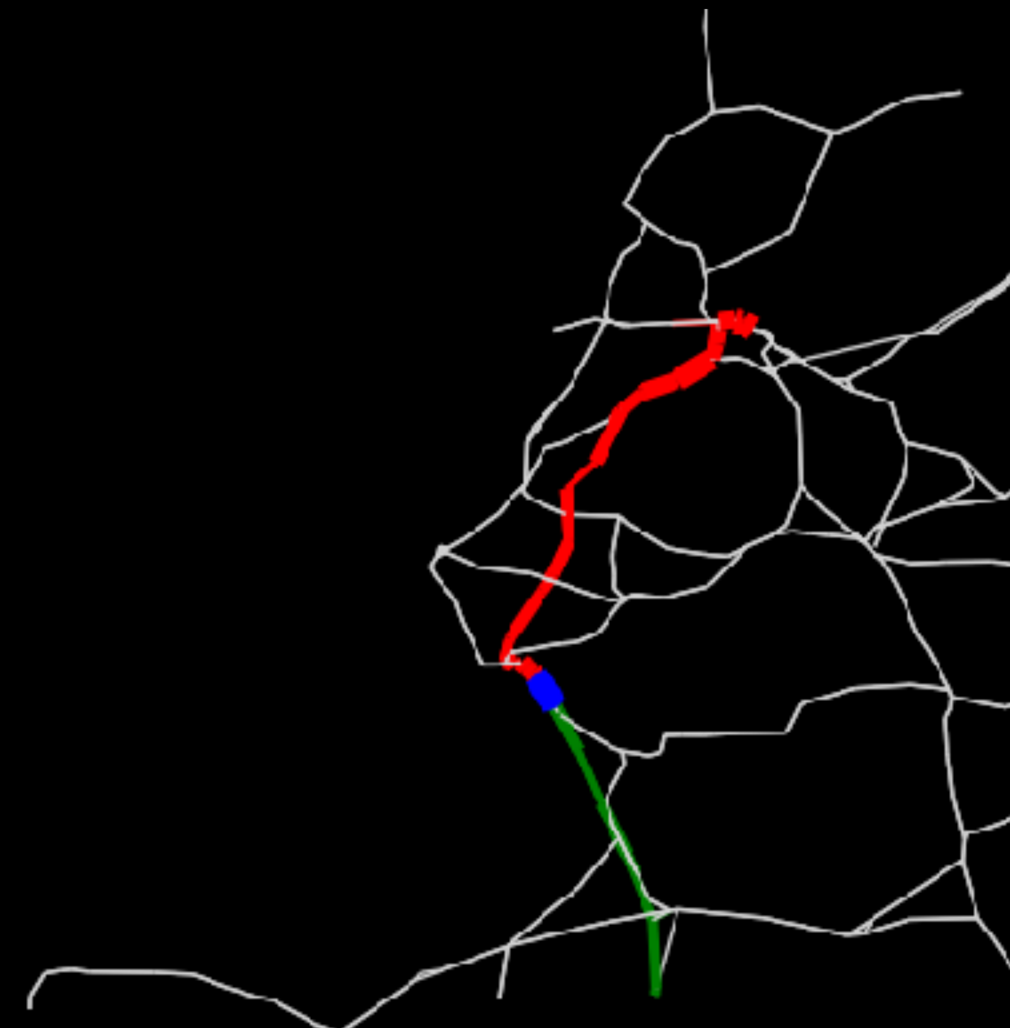
## Advection and Diffusion




Find true correlation by correcting for lag




**Top: Lag-corrected time series**
**Right: Correlated area**



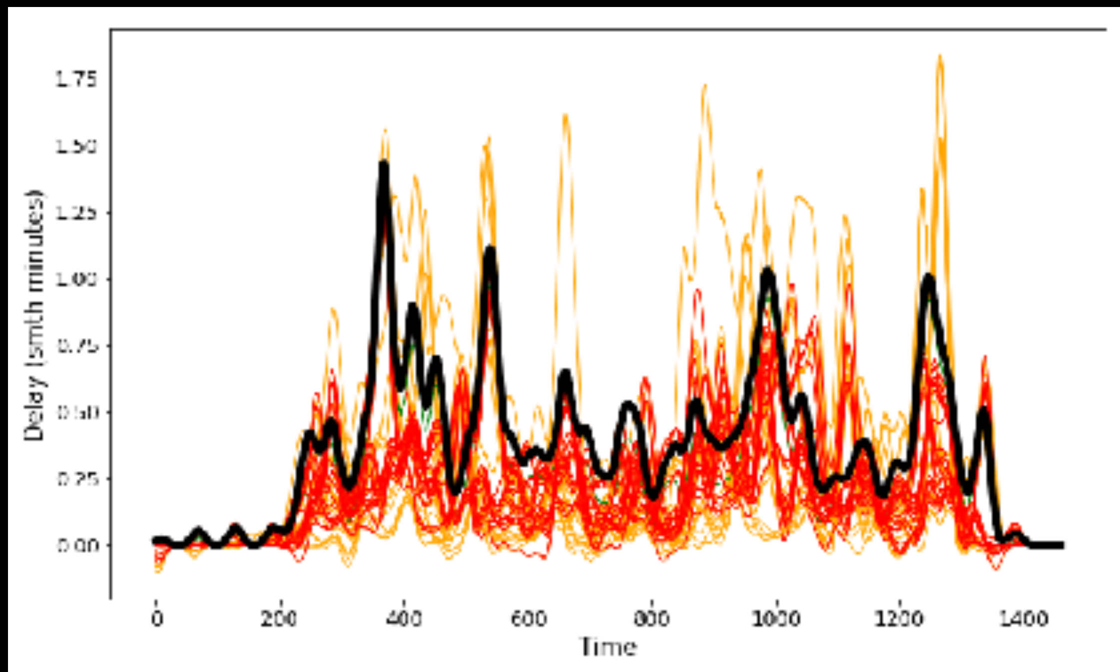
**Period** 6-14 February

**Time** All day

**From** RIb (Rotterdam Lombardijen)

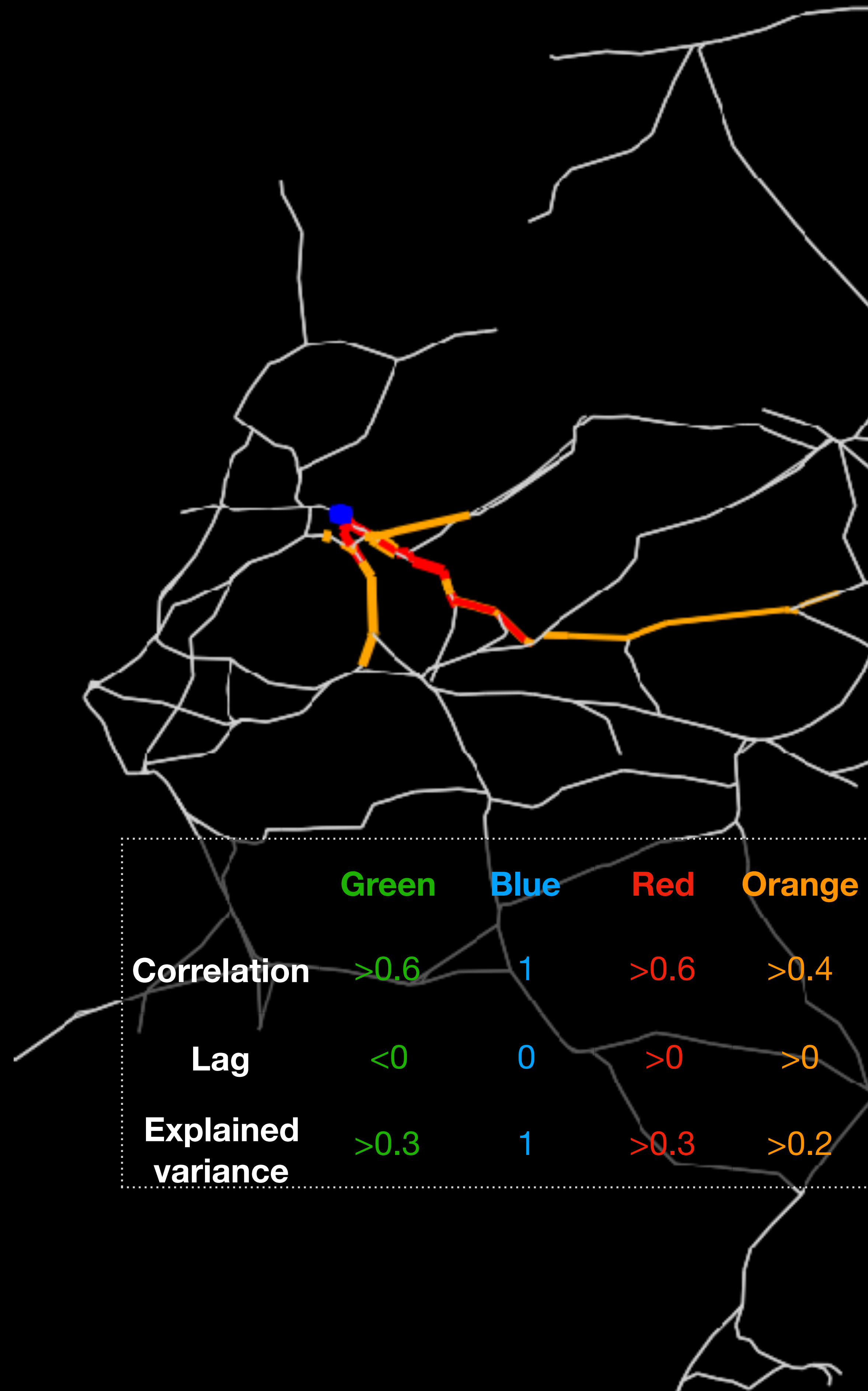
**To** Rtst (Rotterdam Stadion)

| | Green | Blue | Red | Orange |
|---|---|---|---|---|
| **Correlation** | >0.6 | 1 | >0.6 | >0.4 |
| **Lag** | <0 | 0 | >0 | >0 |
| **Explained variance** | >0.3 | 1 | >0.3 | >0.2 |




**Top: Lag-corrected time series**
**Right: Correlated area**

| | |
|---|---|
| **Period** | 6-14 February |
| **Time** | All day |
| **From** | Ods (Oosterdoksdoorvaart) |
| **To** | Dgrw (Dijksgracht Westzijde (Amsterdam)) |



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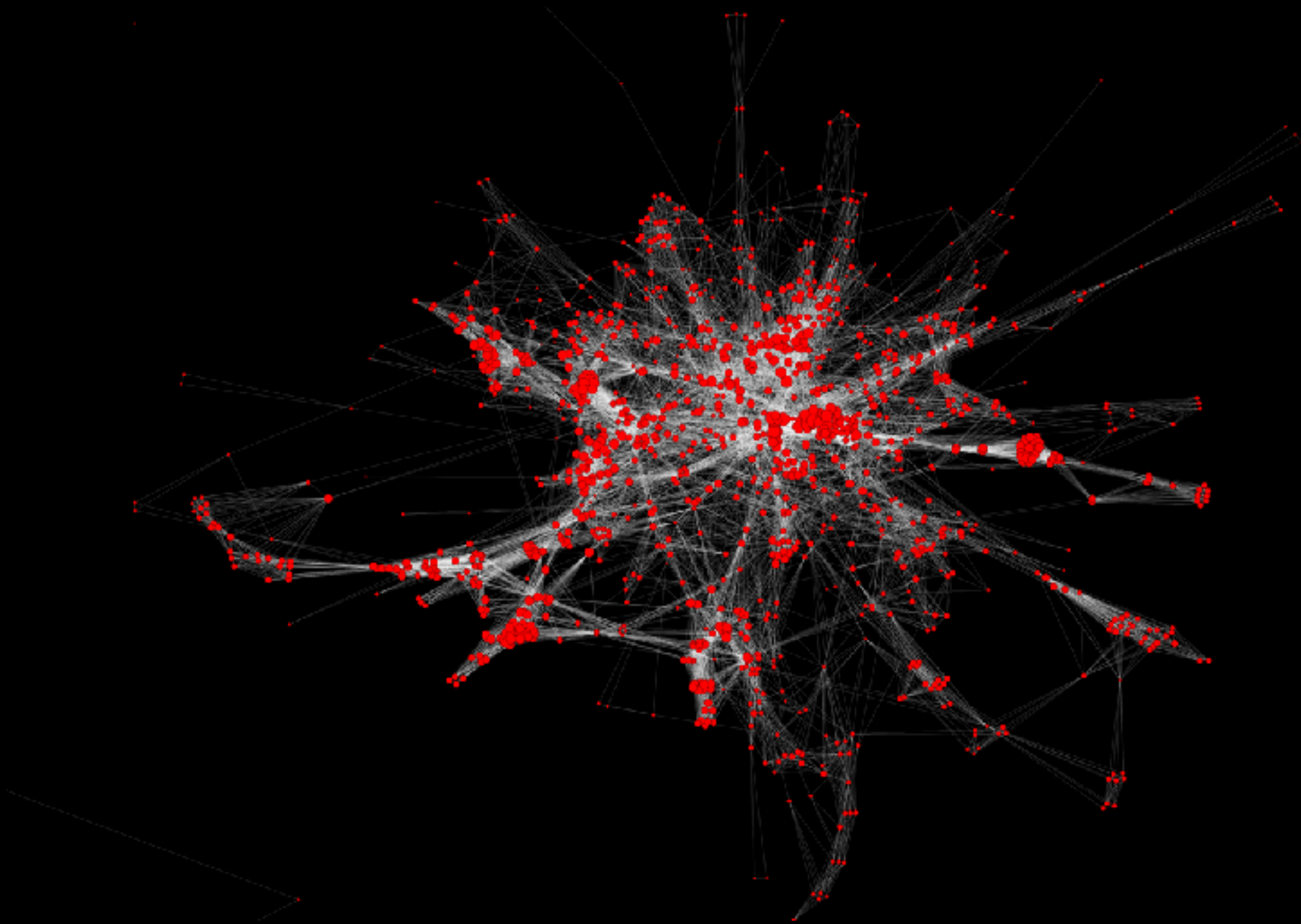

# Network of delay diffusion

Nodes:
- Represent segments of tracks in the Dutch Railway network

Links drawn under the conditions:
- Lag-corrected correlation: > 0.4
- Explained variance: >0.2
- All lags (i.e., between -90 to 90 min)

# Second step

## Interaction, Amplification and Emergence

# Idea

Van Sebille et al. (2012)

- Usage of transfer matrix
- Marine plastics -> delay

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ENVIRONMENTAL RESEARCH LETTERS
Environ. Res. Lett. 7 (2012) 044040 (6pp)
doi:10.1088/1748-9326/7/4/044040

**Origin, dynamics and evolution of ocean garbage patches from observed surface drifters**

Erik van Sebille[1,3], Matthew H England[1] and Gary Froyland[2]

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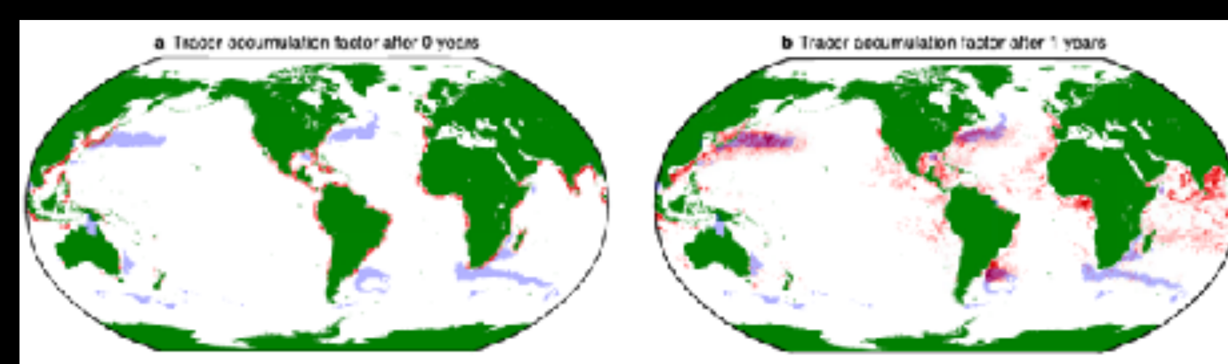
Received 20 September 2012
Accepted for publication 20 November 2012
Published 19 December 2012
Online at stacks.iop.org/ERL/7/044040

**Abstract**
Much of the debris in the near-surface ocean collects in so-called garbage patches where, due to convergence of the surface flow, the debris is trapped for decades to millennia. Until now, studies modelling the pathways of surface marine debris have not included release from coasts



# Transfer matrix

*To find a matrix J that maps the state of the system's dynamic variables in time.*

That is: to find a mapping *J* such that

$$S^{t+\Delta t} = J_{e(t)}(t, d) \cdot S^t$$

given discrete events set *e(t)*, time *t*, time step *Δt*, and accumulated delays *d*, and state vector *S* of the form:

$$S_i = \sum d_i$$

with segment index *i.* The state vector might also contain a bit of time series history.

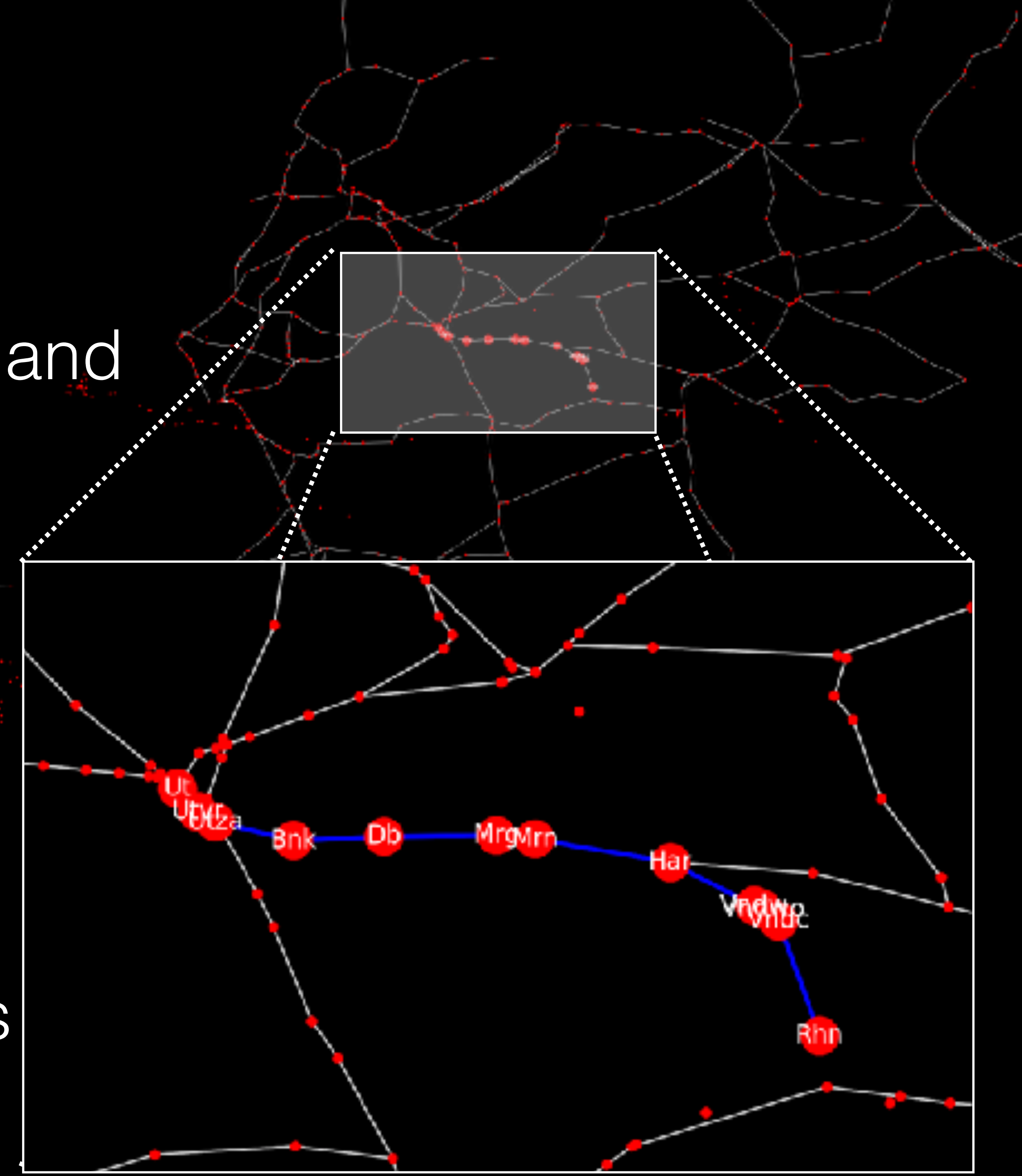
# Transfer matrix

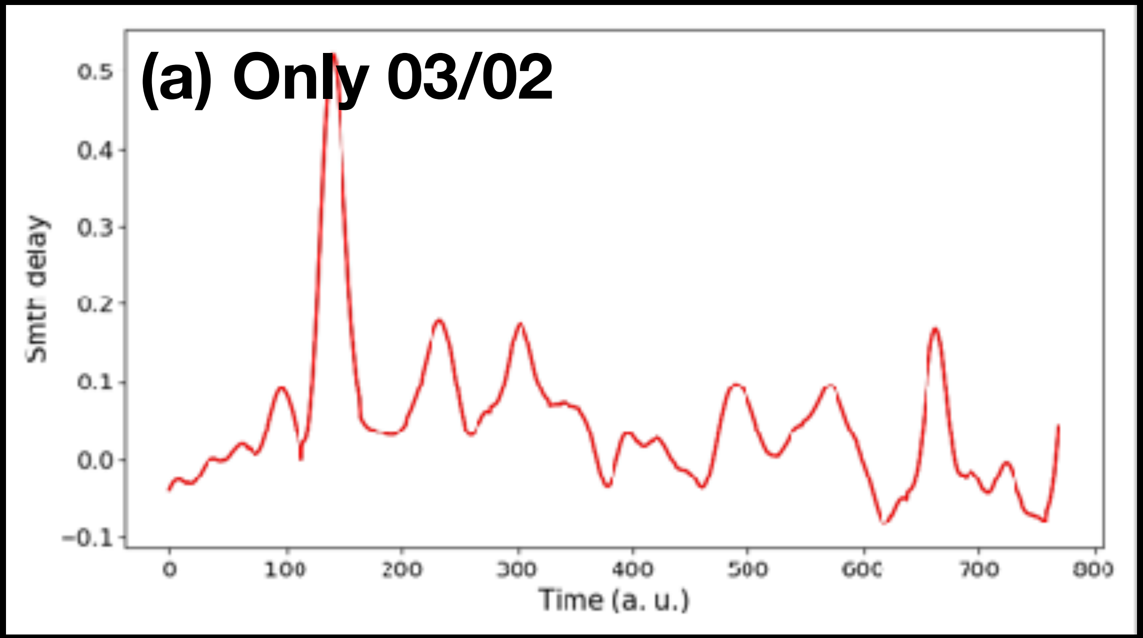
First approach

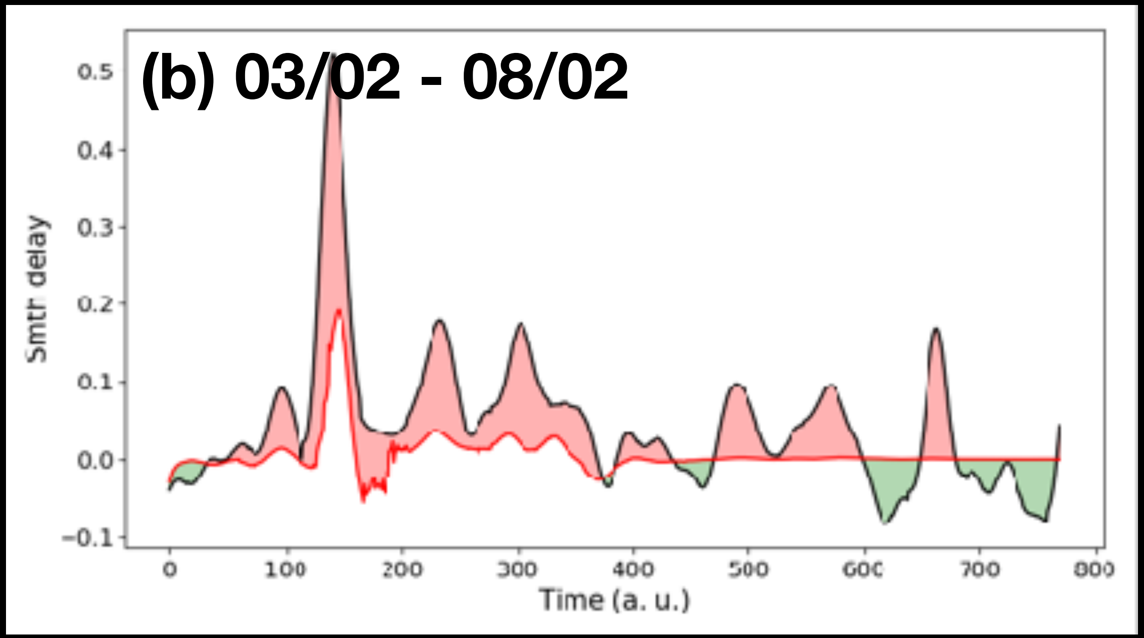
- Focus on the area between Rhenen and Utrecht CS
- Calculate the transfer matrix by:

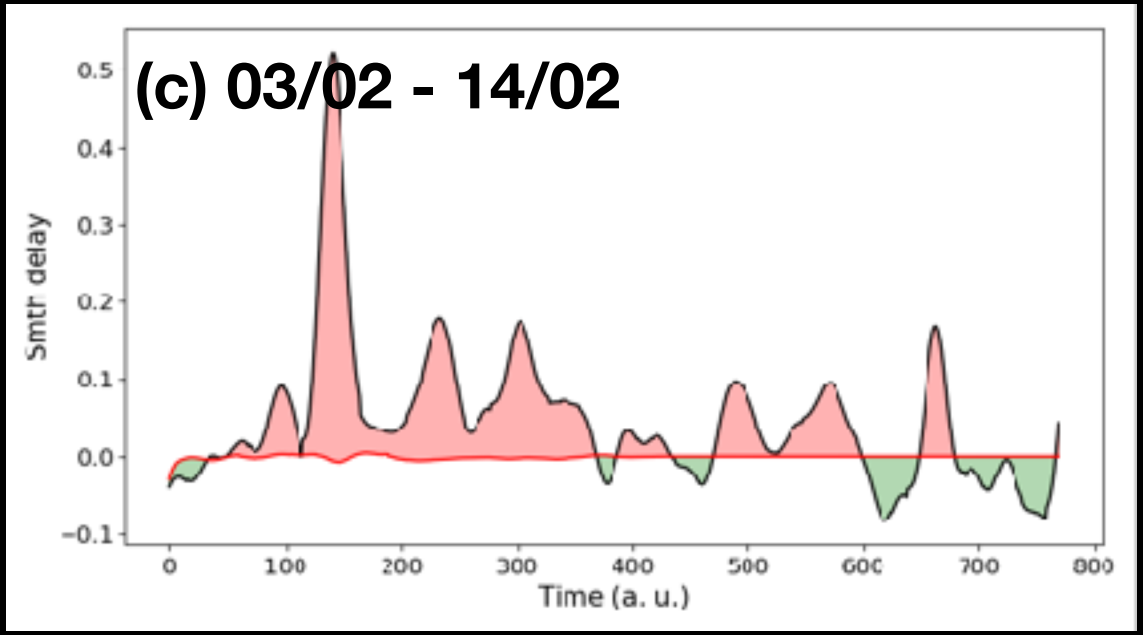
$$J = S_{t+\Delta t} \cdot S_t^{-1}$$

  - Pseudo inverse is used.
- Do this for every timestep: $J = J(t)$
- Average (per timestep) over all days covered






**Problems**:

- Flattening because of averaging, variation between days
- Primary versus secondary delays
- No differentiation yet among different types delays or events
- Parameter settings (window size)

# Example results

Mapping applied on February 3rd
Different mapping per timestep, averaged over days

# Outlook

## Diffusion and Advection

- Analyse diffusion network for high-impact spots (relate to buffer times)
- Model experiments
- Upscale in time

## Interaction, amplification and emergence

- Filtration of primary delays in transfer matrix calculation
- Upscale mapping in time/space
- Investigate sensitivity
- Investigate usability of principal components

… early warning signals?

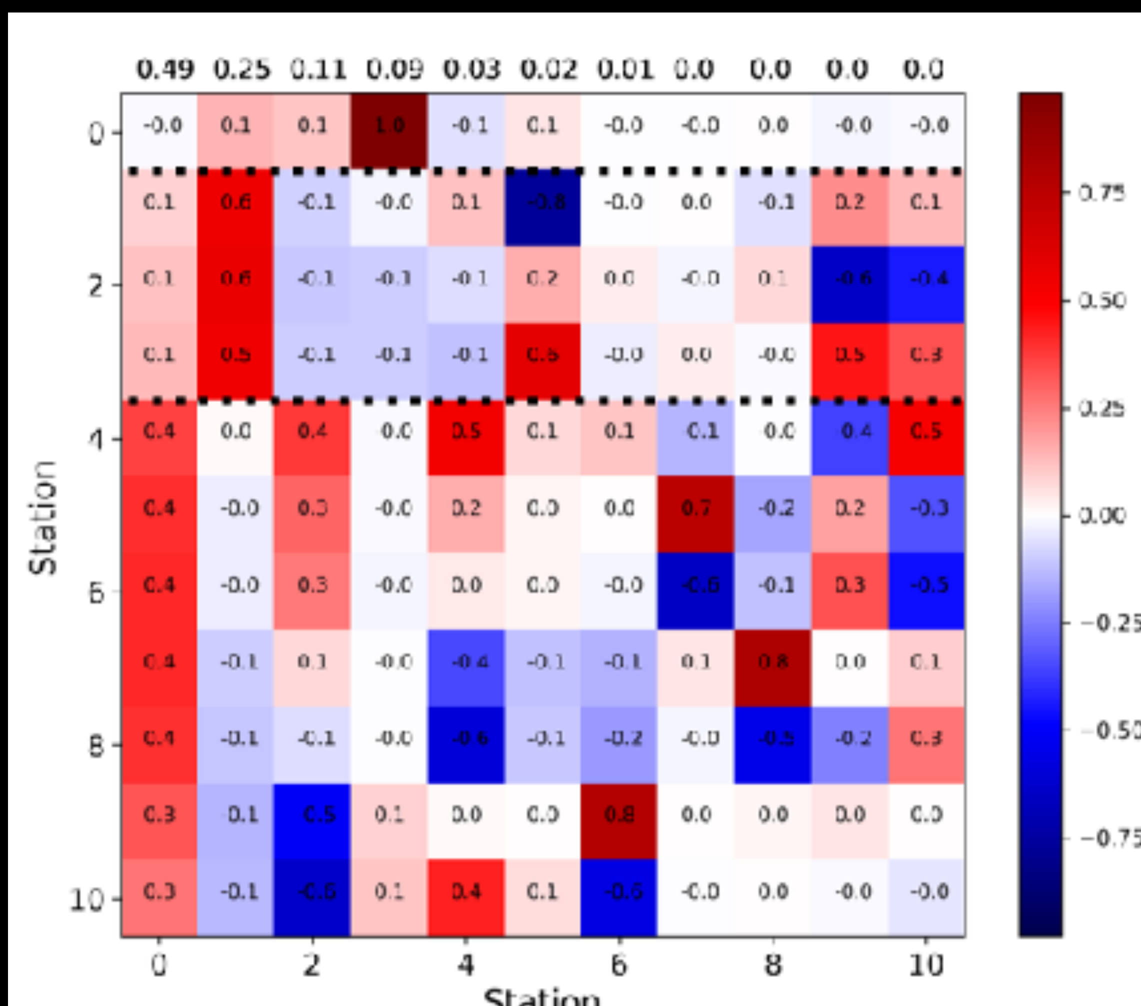
Thank you for you attention

# Appendix

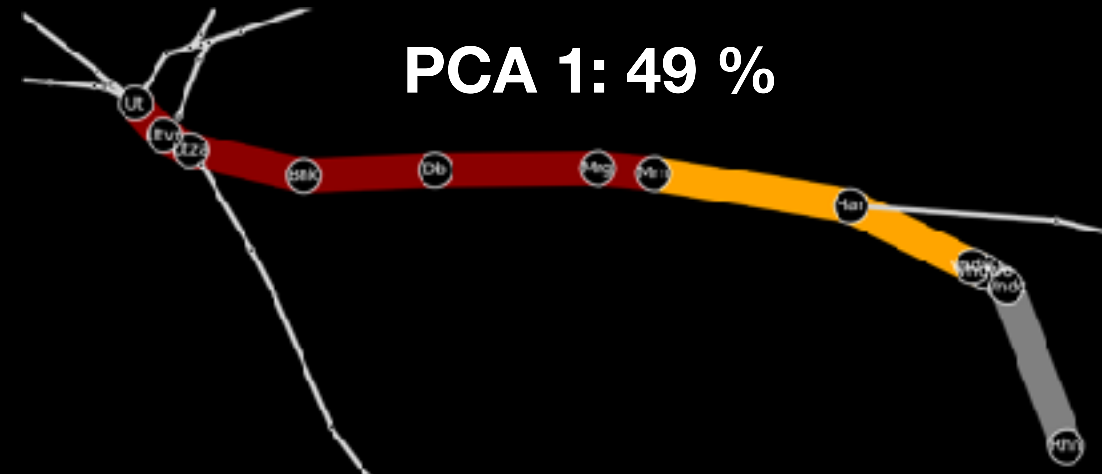
## Principal Component Analysis

# Principal Component Analysis

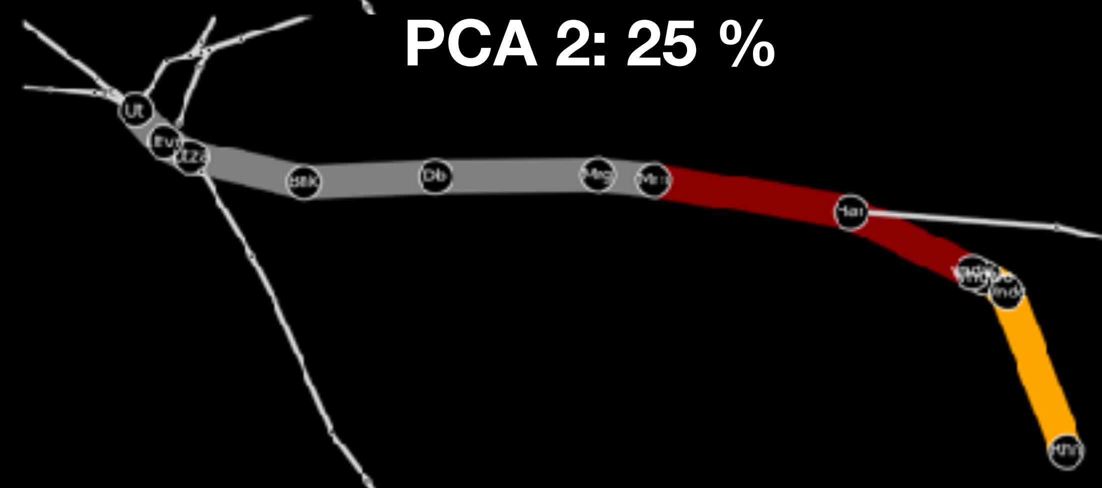
(3-14 Feb)



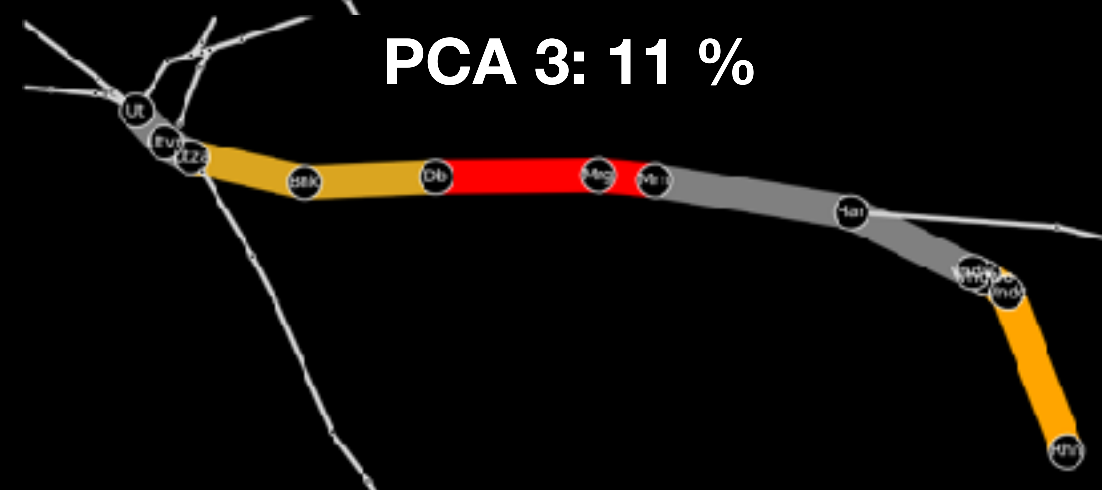

PCA 1: 49 %



PCA 2: 25 %



PCA 3: 11 %



PCA 4: 9 %