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Spatio-Temporal Prediction of Freeway Congestion Patterns using Discrete Choice Methods

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In a Nutshell

- Predicting freeway traffic states based on predicting speeds or traffic volumes
- Congestion on freeways follows patterns:

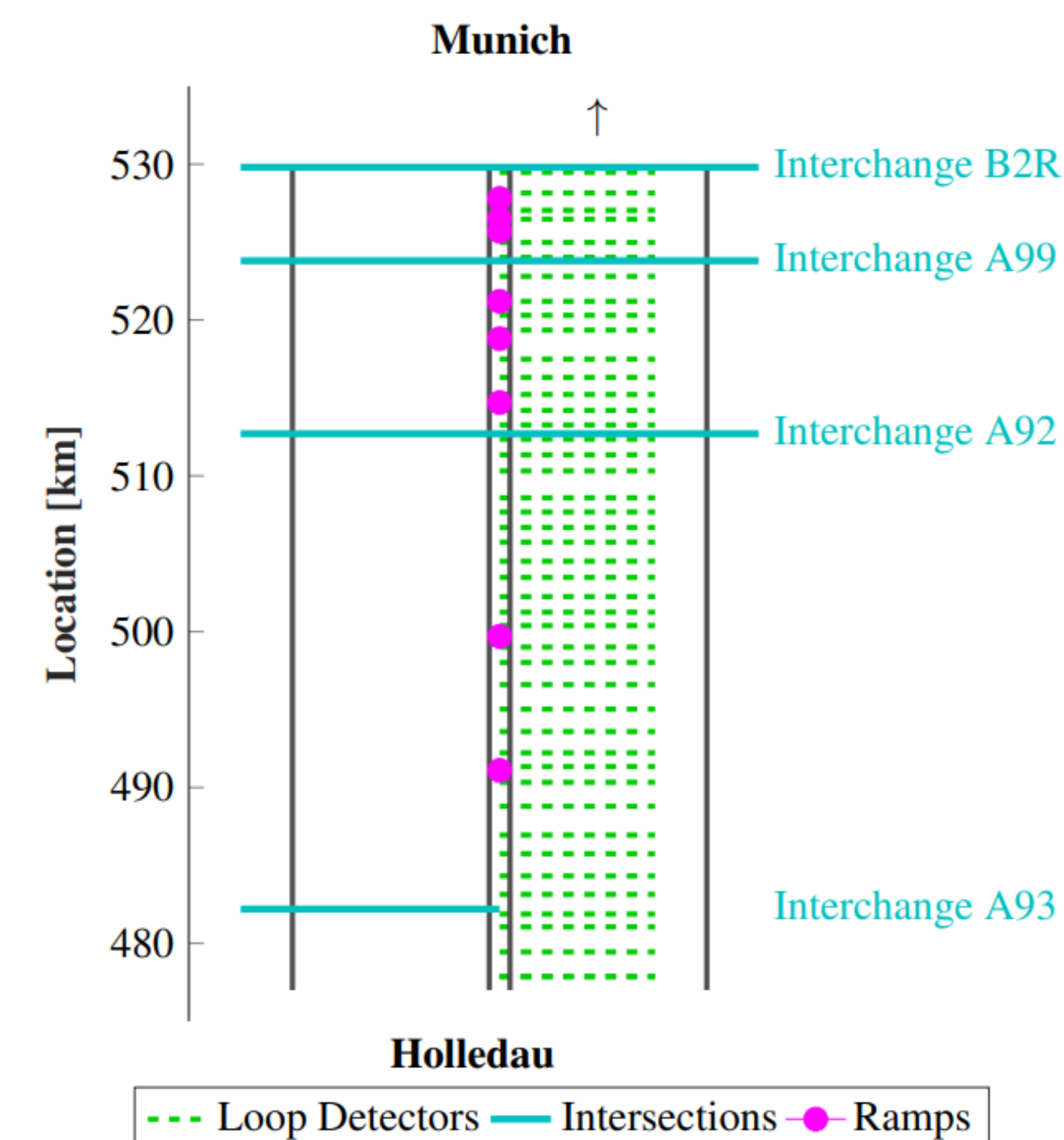
Congestion Patterns

- Jam Wave (short traffic breakdown)
- Stop and Go
- Wide Jam (broad congested area)
- Mega Jam (distinct congestion)

- Patterns informative because they propagate in space-time in different ways
- Data set of congestion patterns on freeway in Germany
- Development of a mixed logit model to predict congestion patterns

Explanatory Variables

- Intersections or ramps
- Number of lanes
- Weekday and time
- Previous traffic conditions (up to 15 minutes)
- Mixed logit model to improve the prediction of congestion patterns
- Enhanced model by integrating speed information

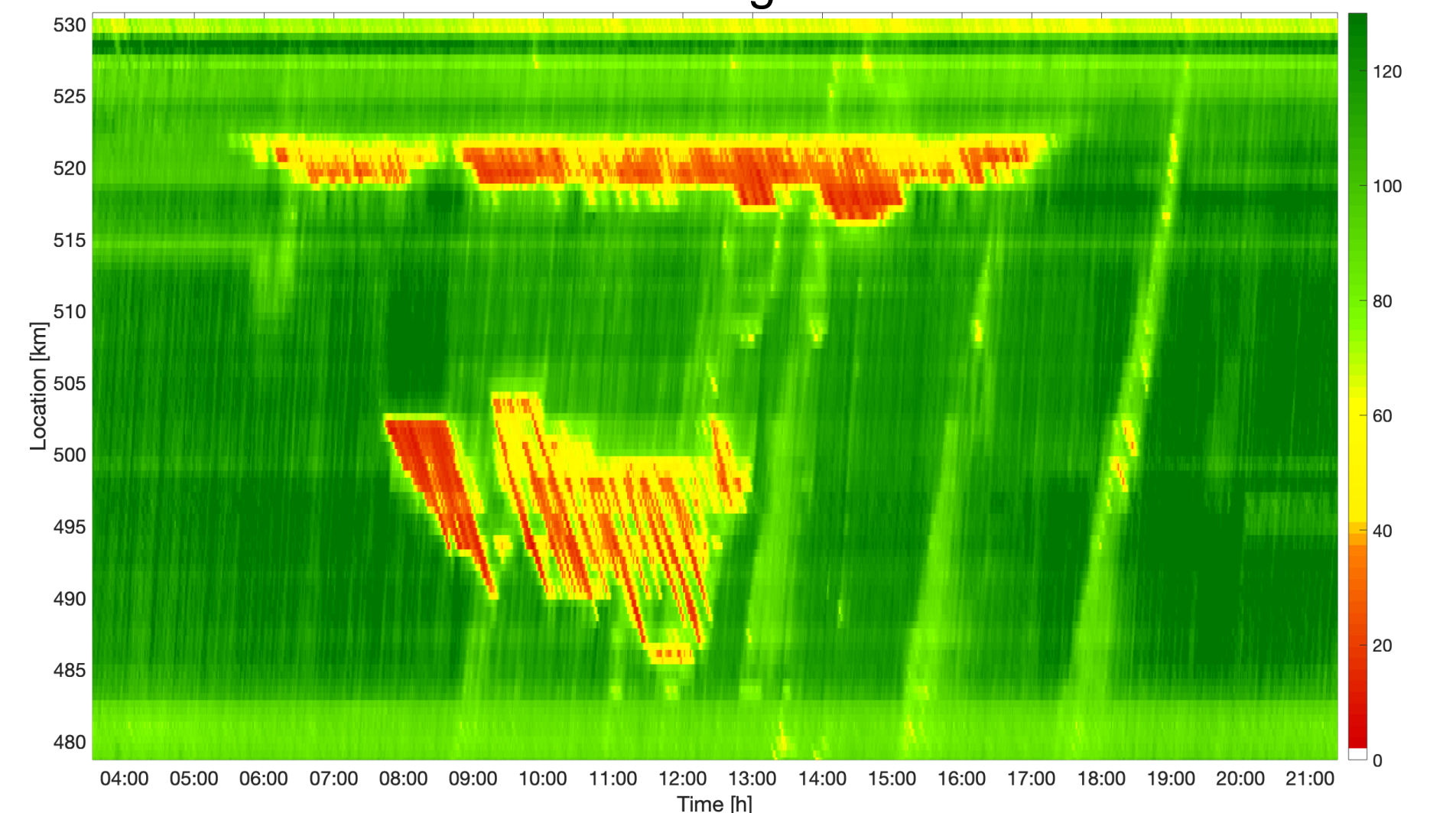


Sketch of considered road stretch

Data: Basis, Classification and Processing

Speed Data from 44 inductive loops from a German freeway stretch of 50 km within a period of five month in 2019

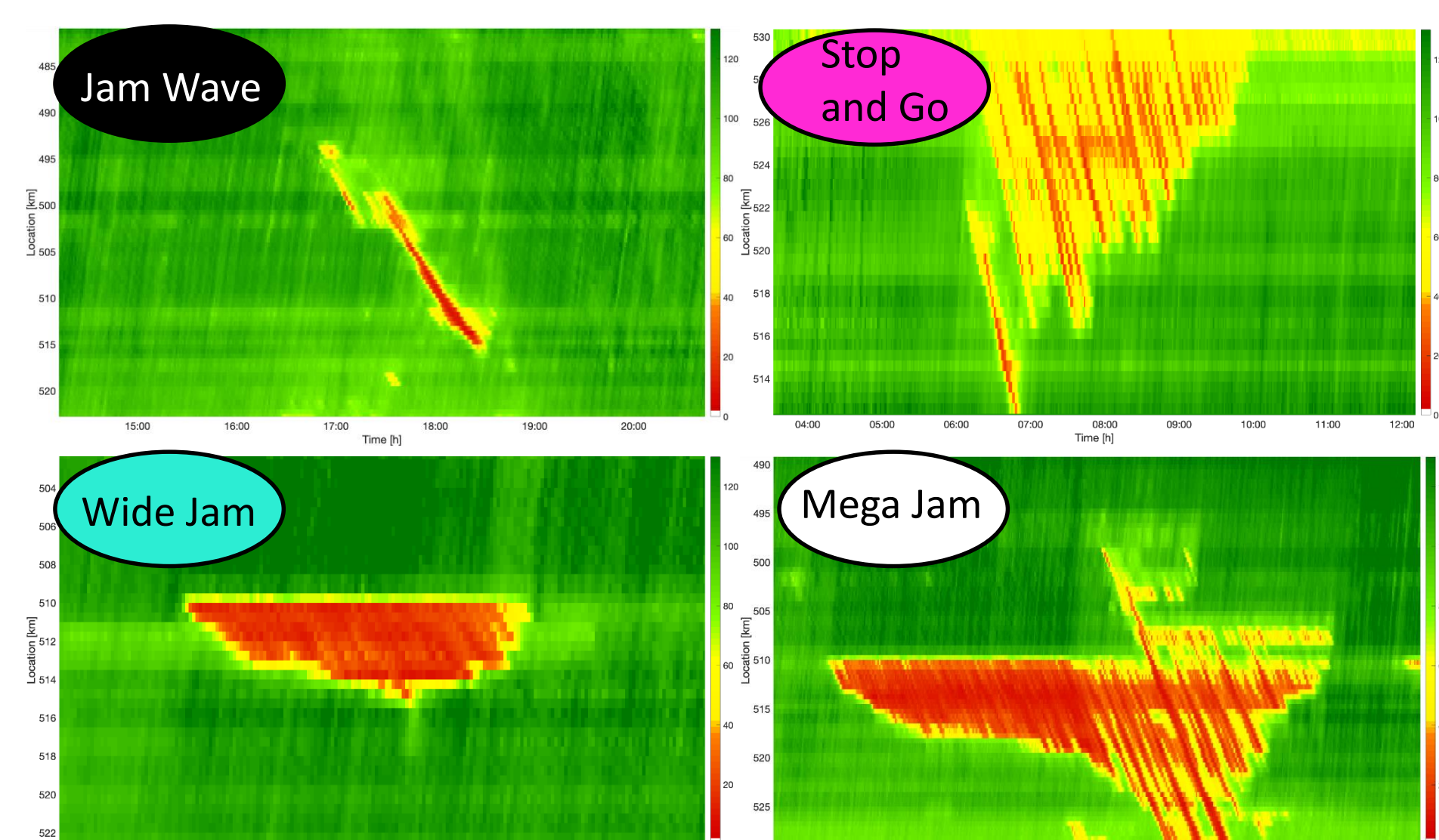
- Interpolation of the speed data using the *Adaptive Smoothing Method* by Treiber/Helbing, 2002: two traffic-characteristic directions: congestion and free-flow



Interpolated speed distribution

- Congestion classification method introduced by Kessler et al. (2020)

- Detection of congestion elements & assignment to one of the congestion patterns defined by Karl et al. (2019)
- Simulation of vehicles using virtual trajectories
- Determination of congestion type depending on speed profile of virtual trajectories
- Congestion defined below threshold per cell $v_{crit} = 40$ km/h



- For prediction, a list of congestion patterns and their properties is processed:

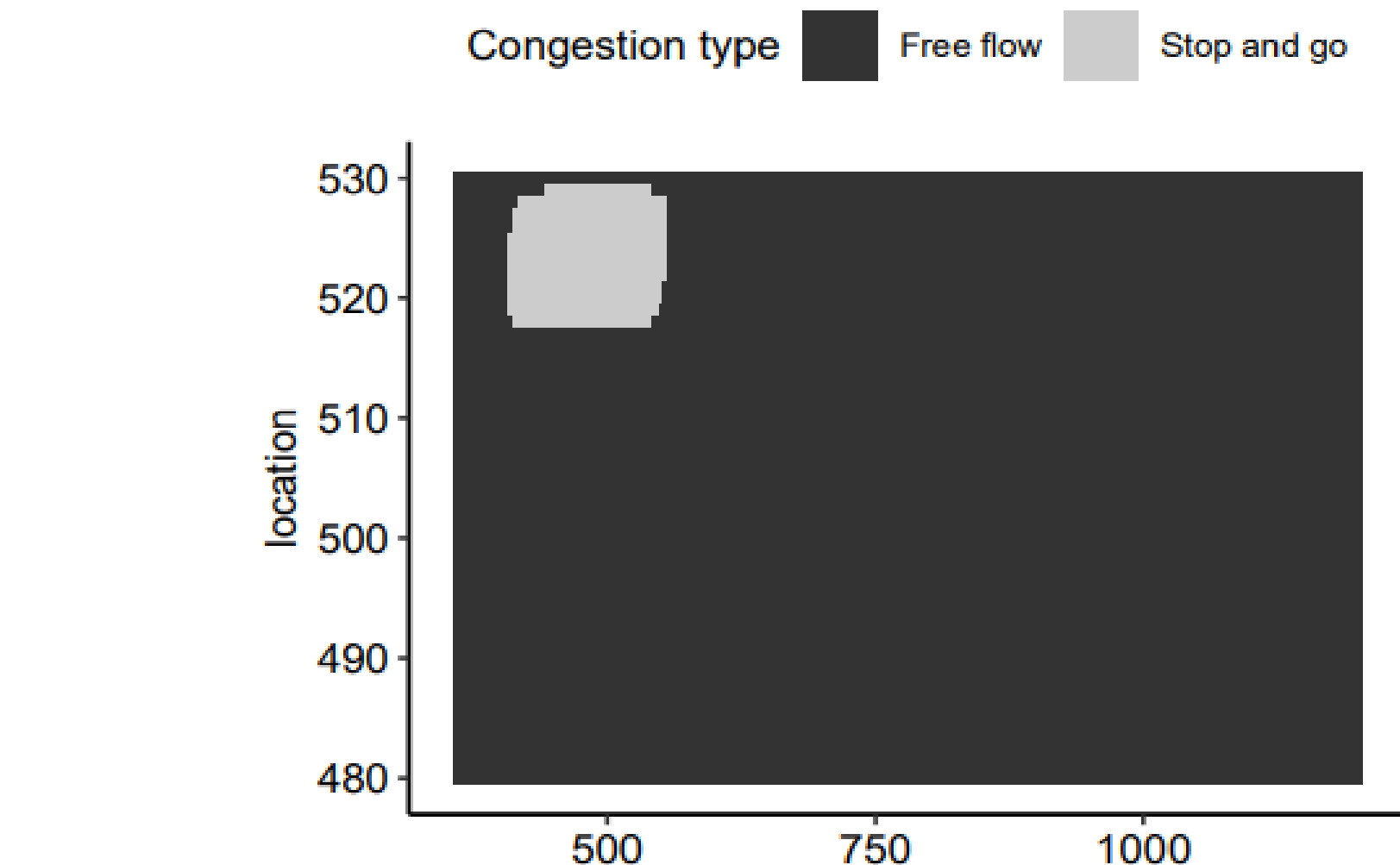
- Division of the stretch into space-time cells: 1 km and 5 min
- Storage of known local and temporary information to the cells in addition to the congestion pattern

Methodology

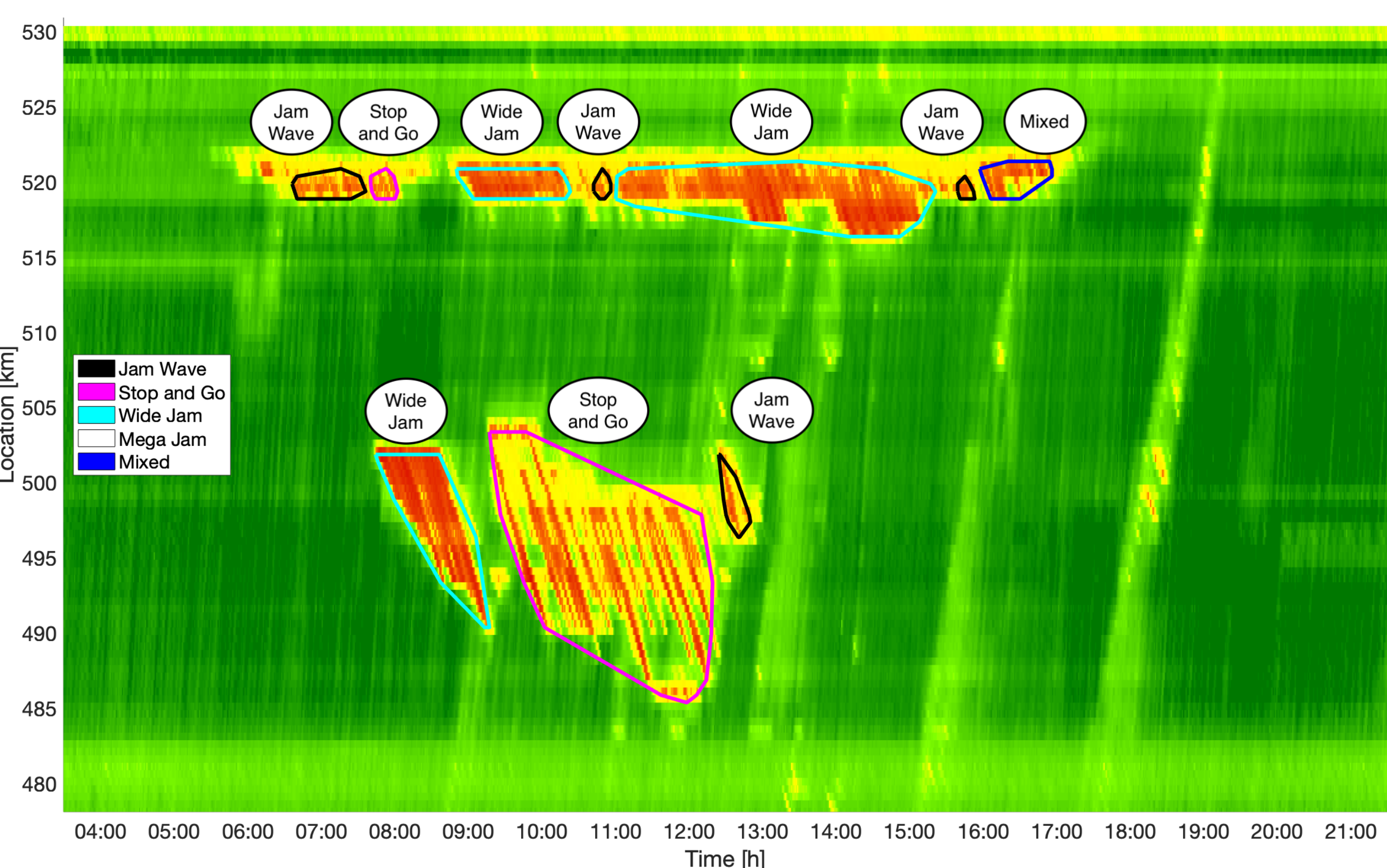
Mixed logit model: Prediction if specific congestion pattern occurs or if free flowing traffic for the next day

- Three models for prediction:

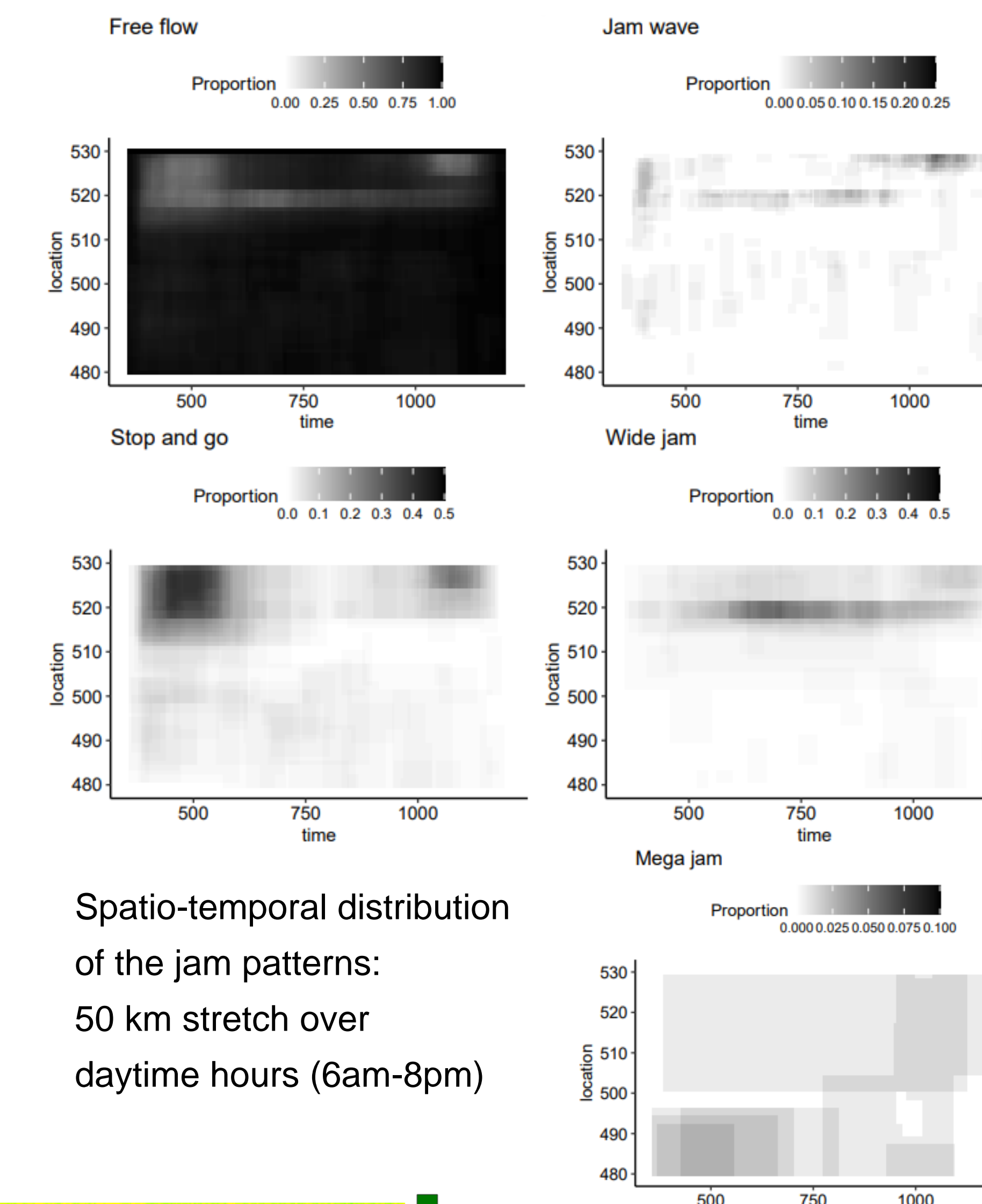
- Base Model: prediction by the average occurrence
- Model I: additionally infrastructure effects
- Model II: additionally infrastructure effects and information on the existence of previous congestion patterns
- Cells are separated into free flow, Jam (Jam Wave, Wide Jam and Mega Jam) and Stop and go
- High performance computing package *mixl* in R is used for estimation



Most likely weekday congestion pattern (Basis Model)



Classified congestion clusters in interpolated speed distribution



Spatio-temporal distribution of the jam patterns: 50 km stretch over daytime hours (6am-8pm)

Sample characteristics

Characteristics	Value
Days	143
Weekdays	104
Weekend days	39
Jams	783
Cells	2.265.120
Free flow cells	2.148.724 (95,0%)
Jam Wave cells	6.855 (0,3%)
Stop and go cells	63.431 (2,8%)
Wide Jam cells	31.316 (1,4%)
Mega Jam cells	12.335 (0,5%)
Mixed Jam cells	2.459

Results

Classification table of observed versus predicted congestion patterns.

Predicted congestion pattern	Observed congestion pattern			Classification Rate
	Freeflow	Stop&Go	Jam	
Base model				0.886
Free flow	0.978	0.018	0.004	
Stop and Go	0.657	0.335	0.007	
Jam	0.899	0.050	0.050	
Model I				0.877
Free flow	1	0	0	
Stop and Go	1	0	0	
Jam	1	0	0	
Model II				0.907
Free flow	0.990	0.007	0.003	
Stop and Go	0.480	0.351	0.168	
Jam	0.518	0.211	0.270	

Discussion and Conclusion

- Approach applicable and promising to improve the prediction of traffic patterns
- Model II shows substantial improvements compared to the base model
- The free flow pattern dominant outcome, which can result in over-fitting issues
- Sequential or nested logit will be tested with current speed information
- Advantage: parameters are explainable

References

- Karl B., Kessler L., Bogenberger K., Automated Classification of Different Congestion Types, IEEE ITSC 2019.
- Kessler L., Karl B., Bogenberger K., Congestion Hot Spot Identification using Automated Pattern Recognition, IEEE ITSC 2020.

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