Tampere University

Challenges Caused by the Combination of Increasing Traffic Loads and Climate Change

Professor Pauli Kolisoja / Tampere University

Outline of the presentation

- Megatrends challenging our transport infrastructures
- Loading effects of heavy vehicles with regard to:
  - Tire configuration
  - Pumping of water from soft and wet subgrade soil into the road structure
  - Increasing number of axles in super heavy trucks
  - Potential effects of autonomous driving
- Open data environment for monitoring of traffic loading in Finnish Lapland – Aurora
- Some conclusions

Challenges faced by our traffic infrastructures

A number of on-going trends and developments are challenging the condition of our road and railway infrastructures. These include:

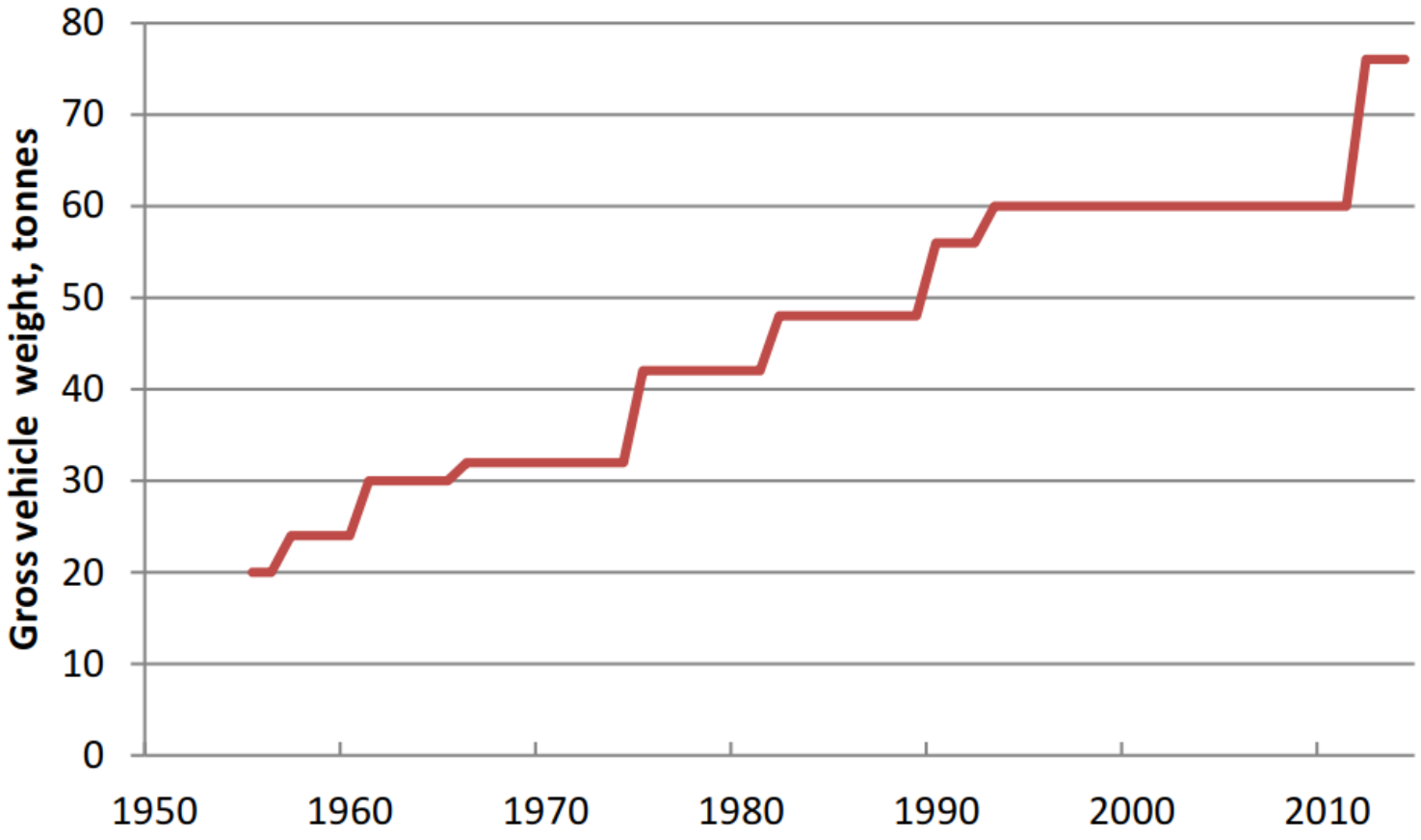
- Pressure on increasing the allowable truck weights and axle loads on rails so as to improve the efficiency of transports
  → reduction of environmental effects - concerning road transports especially the amount of CO_2 emissions
- Transition from dual wheels to single wheels
- Introduction of autonomous vehicles
- Climate change

At the same time:

- Continuous shortage of maintenance resources

Tampere University

Development of the maximum allowed vehicle weight on Finnish road network



Kaakkurivaara, T. (2018) https://dissertationesforestales.fi/article/9989

New legislation on super heavy trucks in Finland

- New legislation concerning allowable truck masses came into effect in Finland October 1st, 2013:
  - Maximum truck & trailer mass: 600 → 760 kN
  - Maximum double boogie mass: 190 → 210 kN
  - Maximum triple boogie mass: 240 → 270 kN
  - 65% of the trailer mass must be resting on dual tires
- With special permission truck weights even exceeding 1 MN can be allowed on specified transportation routes
- Allowable axle loads were not increased (except for existing trucks for a transition period of four years)
  → more axles in a single truck than before
  → higher load concentration under a group of axles

A 9 axle 76 ton heavy truck allowed to operate on the whole Finnish road network.

Tampere University

Some examples of newly introduced super heavy trucks in Finland

11 axles – 92 tons

Tampere University

Some examples of newly introduced super heavy trucks in Finland

13 axles – 104 tons

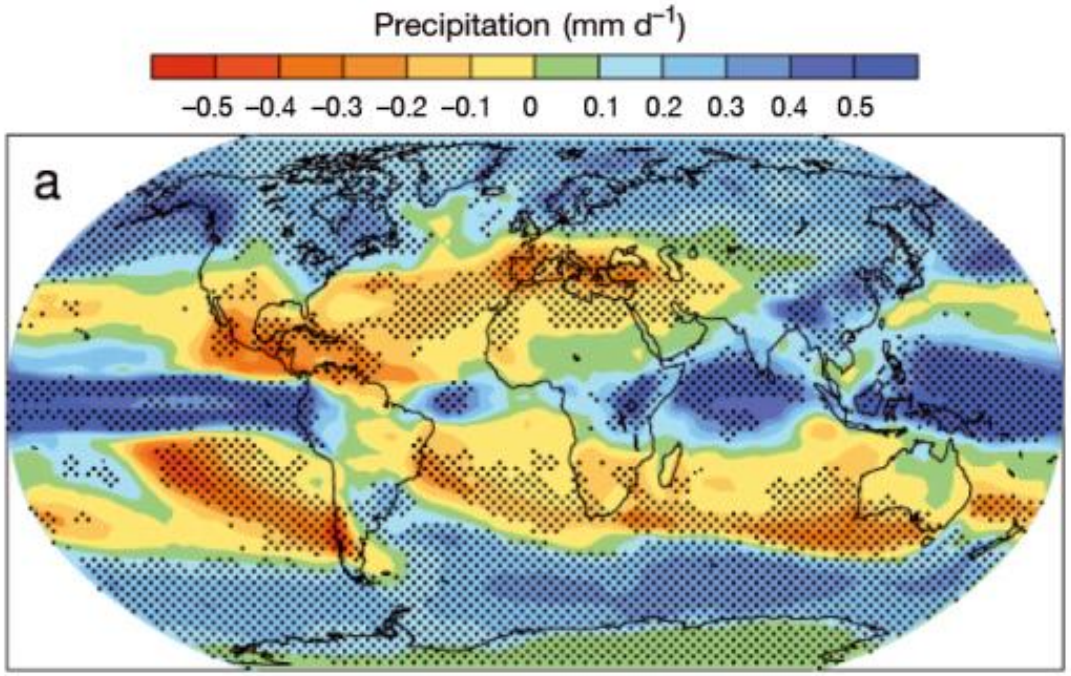
Introduction of autonomous vehicles can…

- Drastically increase the number of consecutive axles following each other if ‘platooning’ is applied
- Markedly decrease the amount of wheel path wander i.e. accumulate the loading effect in road cross section

Harmful effects of climate change on traffic infrastructures

Due to the on-going climate change we can expect:

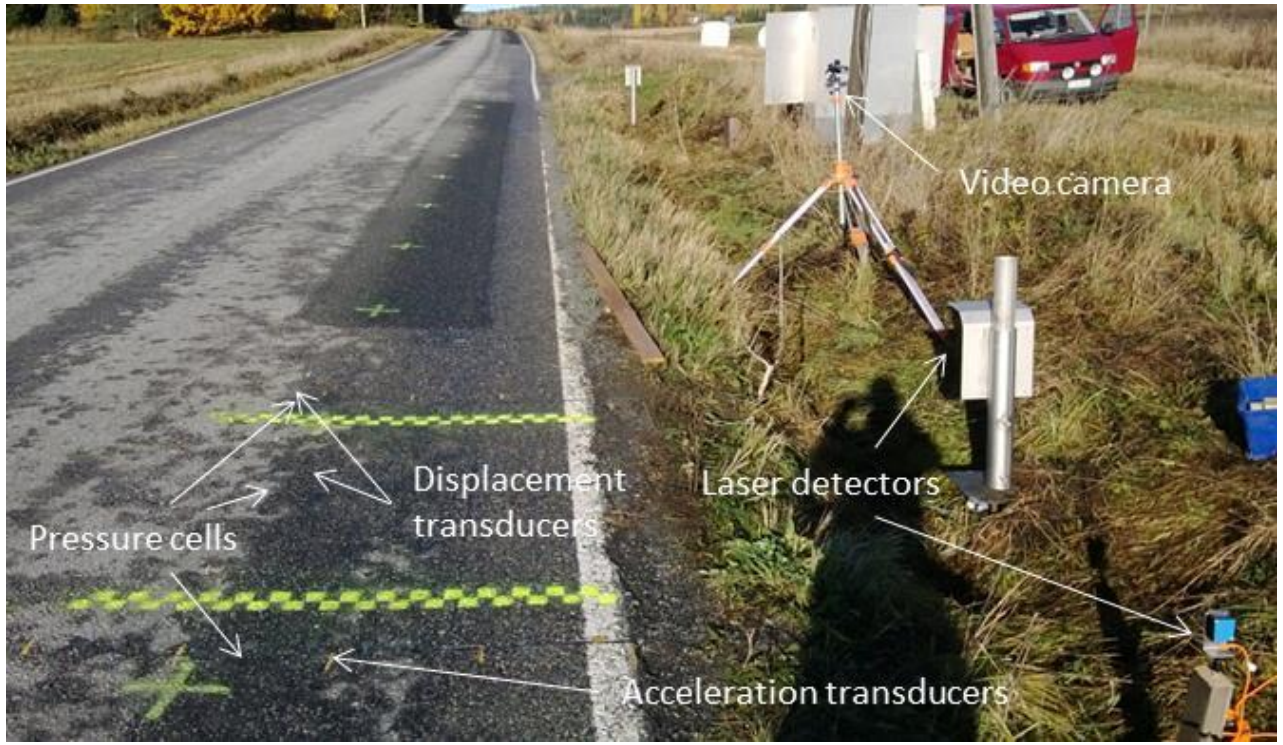
- Increasing amounts of rainfall on the Nordic areas
- Longer unfrozen season → more frequent autumn time weakening of road structures
- Shorter and more unstable freezing periods → in stead of one freeze-thaw cycle we can have a number of thaw weakening periods during a winter
- Faster thawing of permafrost



Trenberth KE (2011) Changes in precipitation with climate change. Climate Research 47, 123 – 138. doi:10.3354/cr00953

Test site for the loading effect of different tire types

- ADT of the road only about 400 vehicles per day – amount of heavy vehicles less than 10%
- Road structure consisted of:
  - 30 to 40 mm (about 1.5 in) of soft Asphalt Concrete
  - 450 mm (18 in) of unbound granular layers
  - Silty subgrade soil
- On both of the lanes there were about 20 mm (0.8 in) deep wide shaped ruts

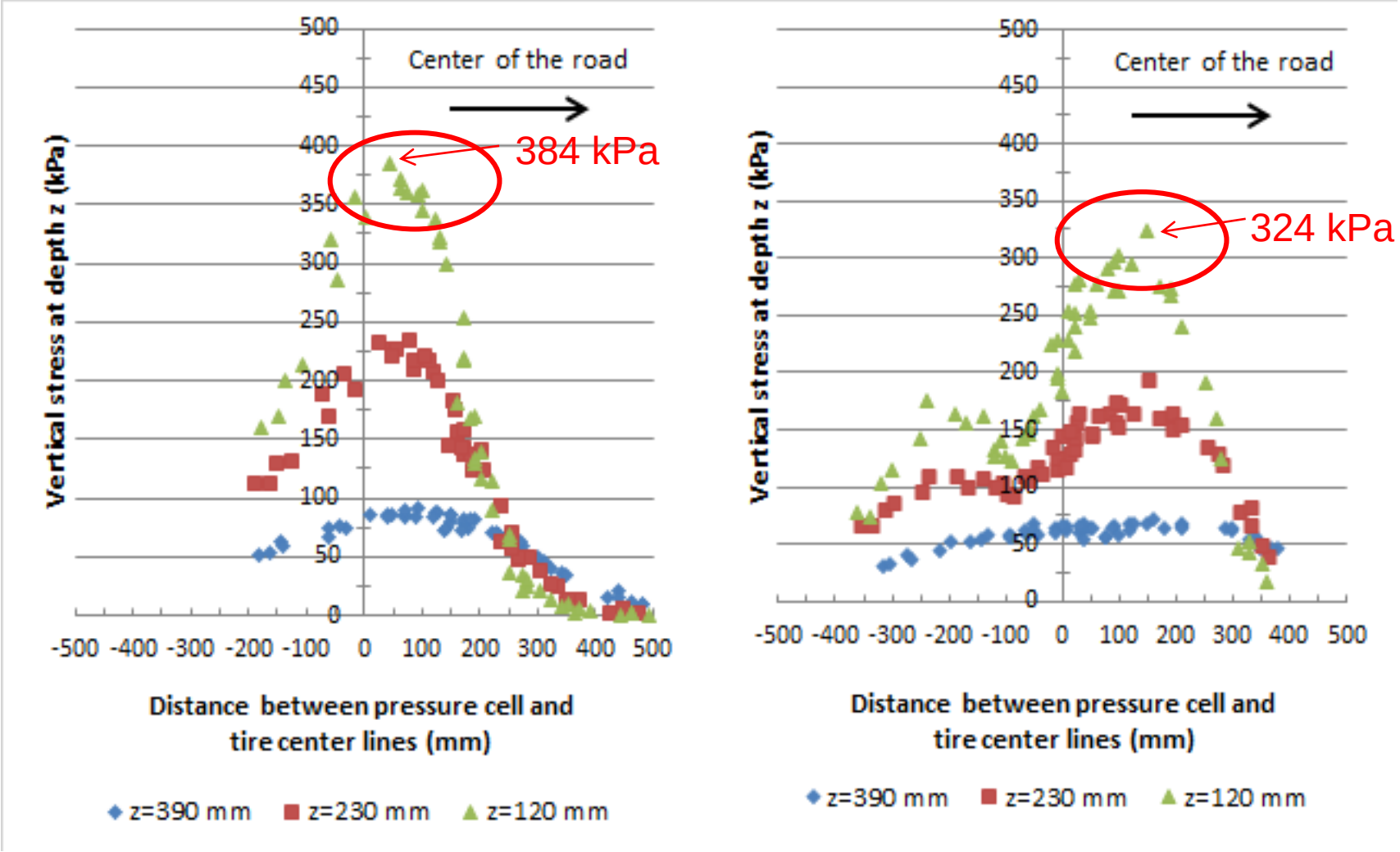


Loading vehicle, axle loads and tested tire types

Axle	Tire type
Front axle of the truck	385/55R22.5
First axle of the truck triple boogie	2 x 315/60R22.5
Trailer axles	2 x 275/70R22.5 385/65R22.5 425/65R22.5 455/45R22.5 495/45R22.5

Tampere University

Vertical stresses at three depths – single wheel (left) vs dual wheels (right)



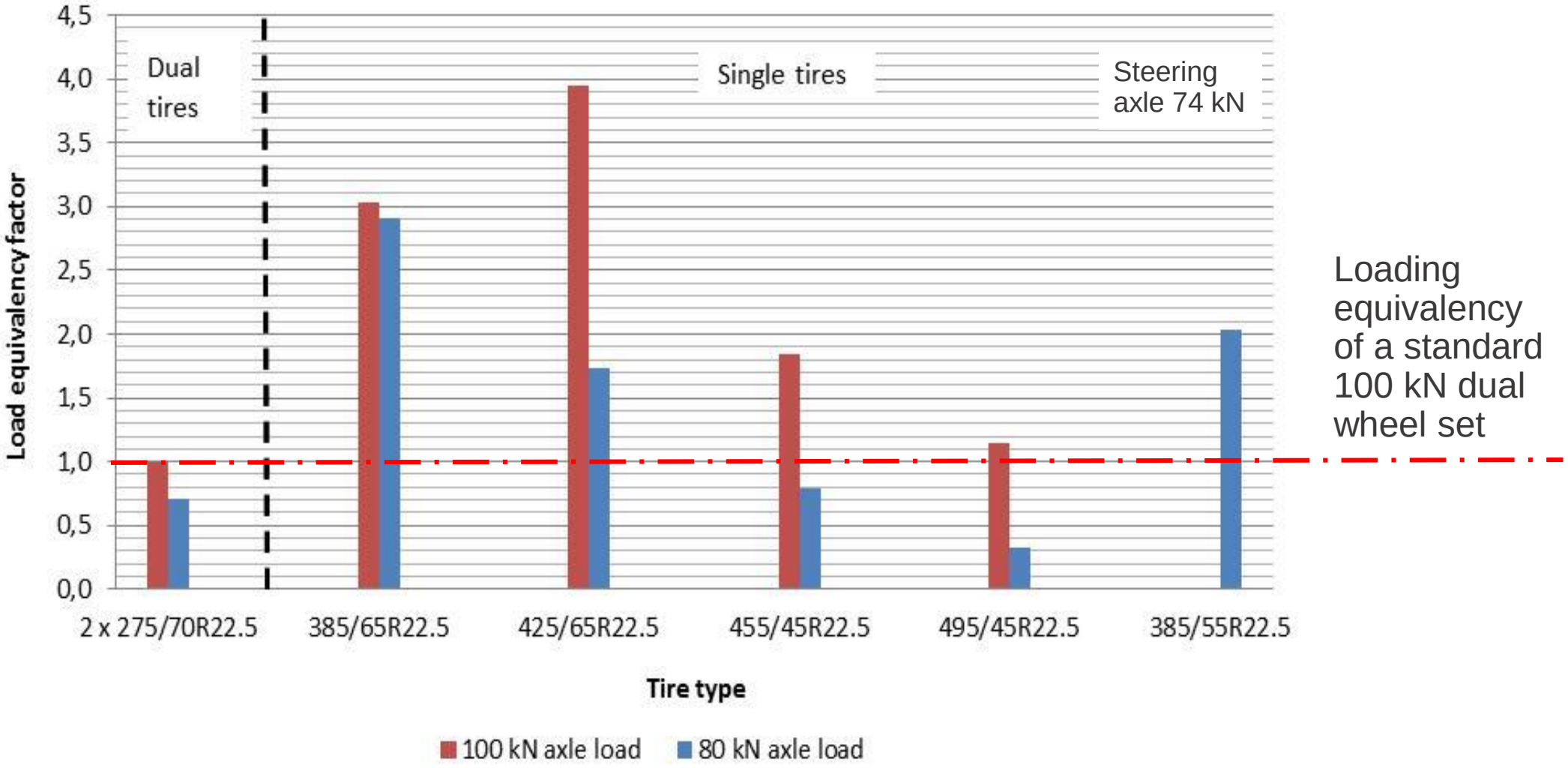
See more details at DOI: 10.3141/2474-20 and 10.3141/2474-21

Tampere University

Summary of the differences in the measured responses

Tire type		Difference in the vertical stress [%]			Difference in the road surface deflection [%]
		z=120 mm	z=230 mm	z=390 mm	
100 kN Axle load					
Dual wheel	275/70R22.5	0	0	0	0
Super single	385/65R22.5	20	20	18	13
	425/65R22.5	25	33	28	26
Wide base	455/45R22.5	11	15	16	13
	495/45R22.5	2	2	3	4
80 kN Axle load					
Dual wheel	275/70R22.5	-6	-13	-17	-22
Super single	385/65R22.5	19	20	6	15
	425/65R22.5	9	11	3	8
Wide base	455/45R22.5	-4	-9	-9	-7
	495/45R22.5	-17	-18	-17	-17
Truck wheels					
Super single (74 kN)	385/55R22.5	12	8	2	7
Dual wheel (76 kN)	315/60R22.5	-5	-12	-20	-12

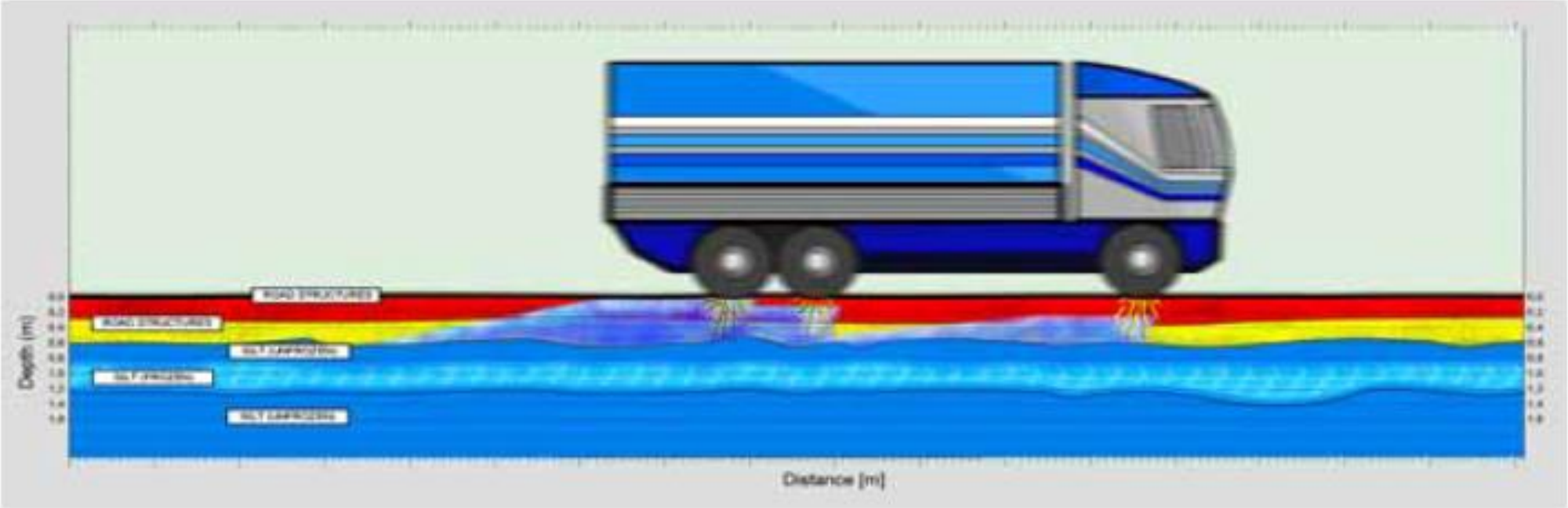
Effect of tire type and axle load on the loading equivalency factor



Loading equivalency of a standard 100 kN dual wheel set

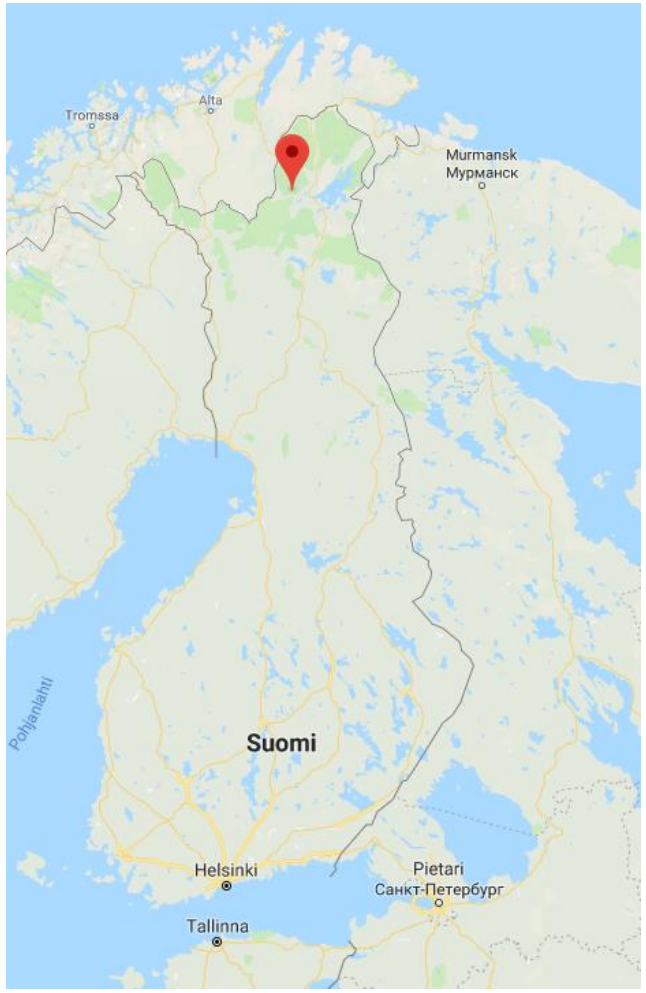
Principal mechanism of water pumping into the road structure

- A passing over axle load is inducing excess pore water pressure in soft water-saturated subgrade soil
- Water is pushed upwards into the road structure
- Successive axles are accumulating the phenomenon



Tampere University

Pumping effect test site in Inari in the autumn 2015



Tampere University

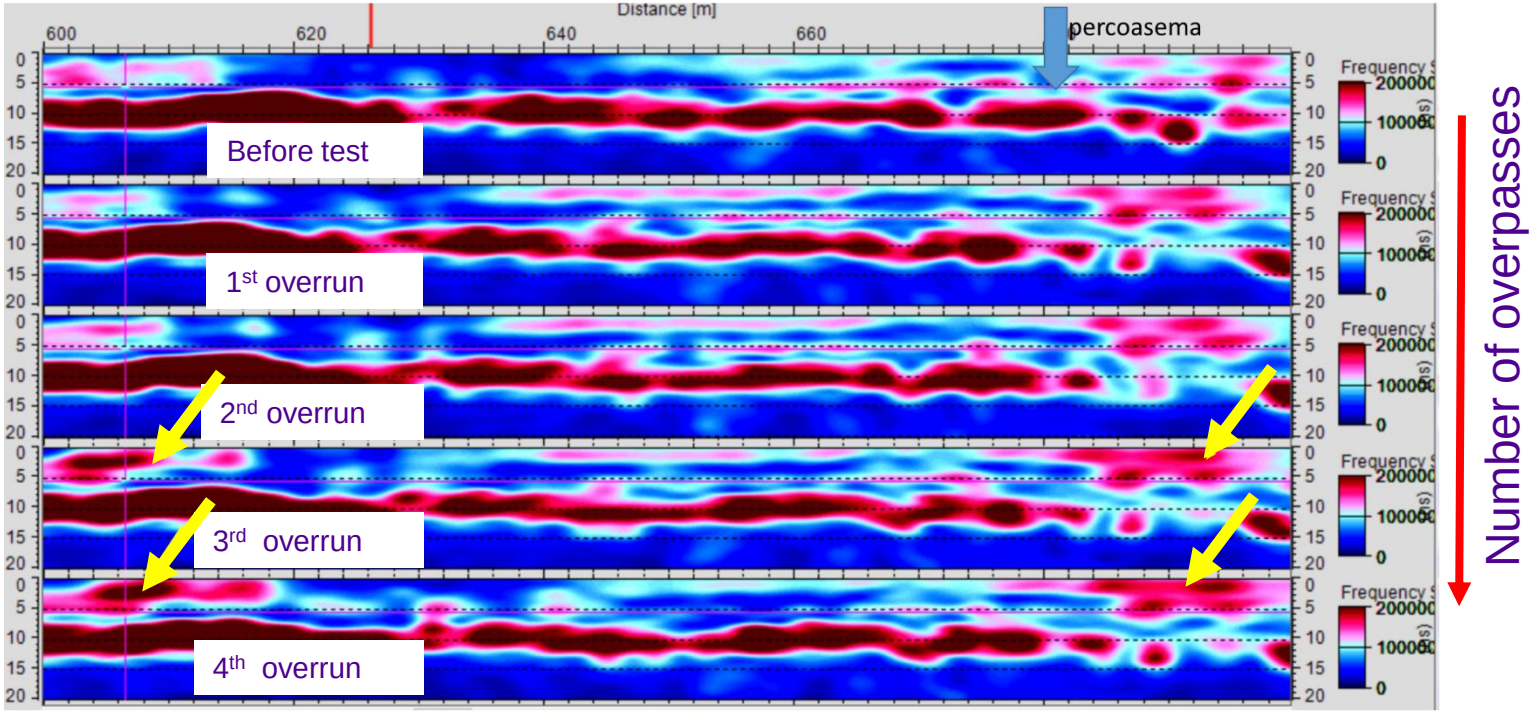
Road structure at the Inari pumping effect test site and monitoring technologies applied there

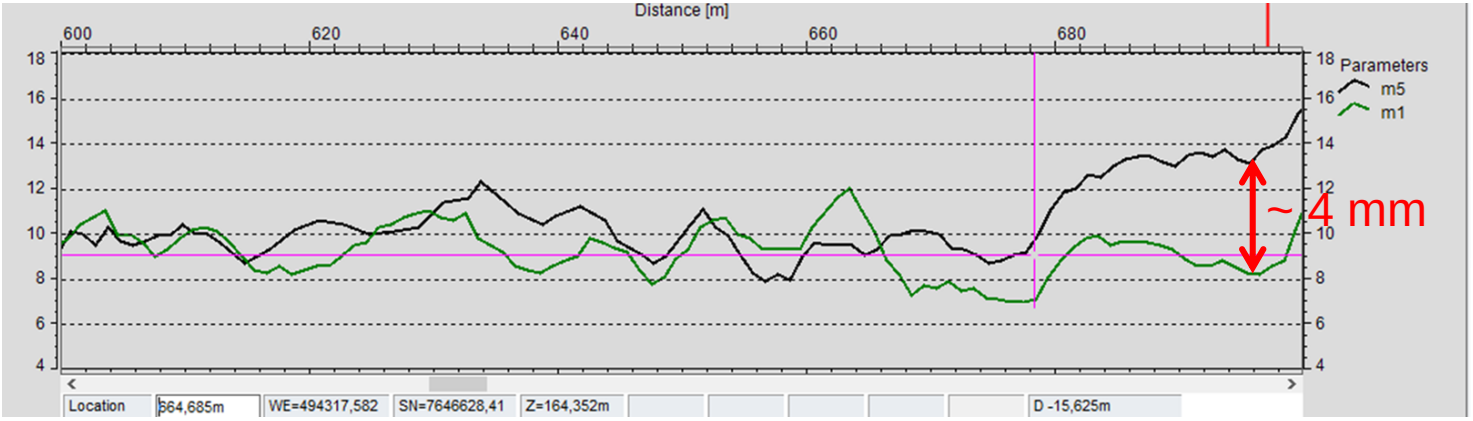
- The thickness of AC layer about 80 mm and the total thickness of road structure about 0.6 m
- Ground water level near to ground surface
- Rut development rate was monitored after each vehicle pass using laser scanning technology
- Moisture condition of road structure was monitored using Ground Penetrating Radar signal attenuation and a thermal camera

Road Doctor Survey Van RDSV® own by Roadscanners Ltd

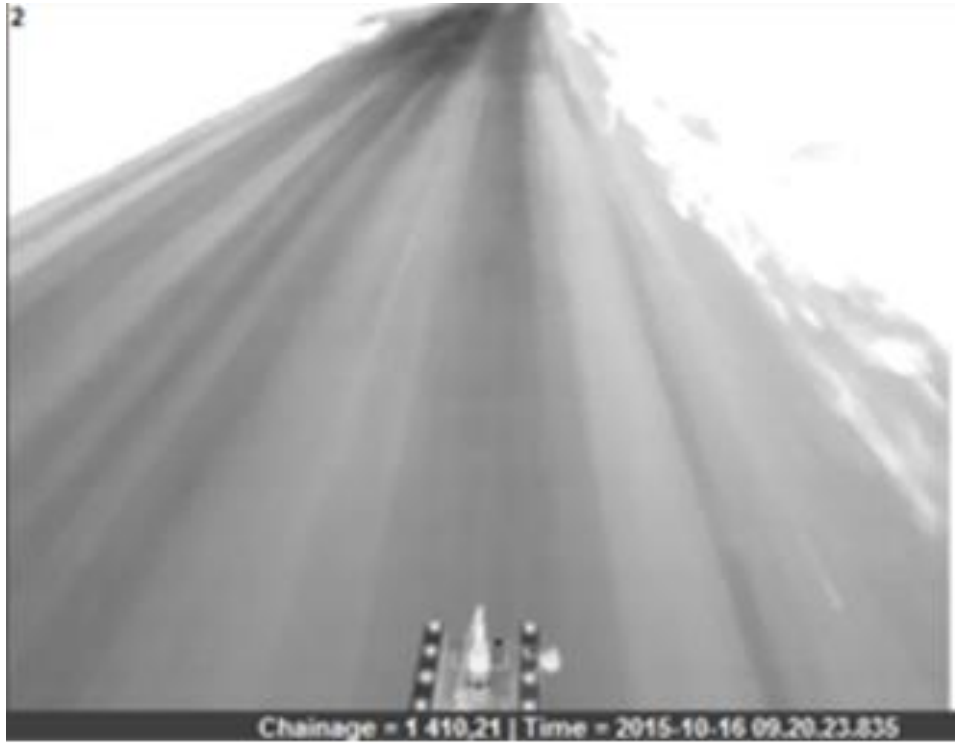
Pumping of water into the road structure and respective accumulated rut depth

- Increasing amount of red color near to the top of road surface indicates increasing amount of water
- Very rapid rut development was observed on peat subgrade area were pumping took place
- The key issue in limiting this effect is to control rest periods in between heavy vehicles

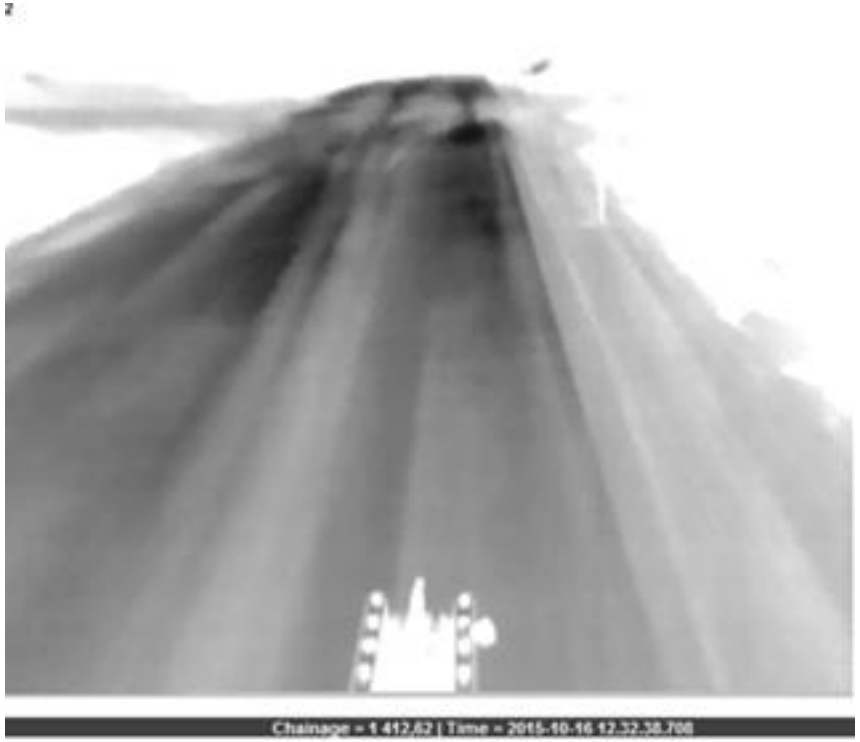




Thermal images of the road surface before and at the end of loading tests



Before the tests



After the tests

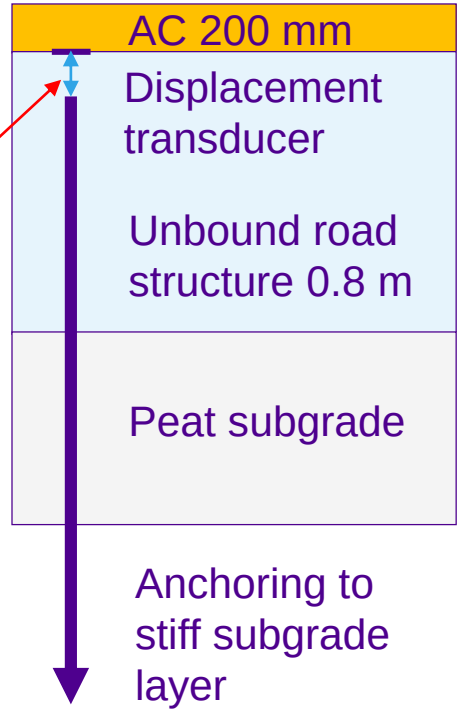
Increasing number of axles in super heavy trucks

- While trucks are getting heavier but the allowable axle loads are not increasing, there are more axles in a truck
- Platooning of autonomous trucks can lead to train type of loading on roads
- This effect was studied at four test sites representing different road classes and different subgrade conditions in Finland in 2016 – 2018:
  - Main road 77 in Karstula
  - Regional road 924 in Simo
  - Local road 16863 in Kyyjärvi
  - Gravel road 18824 in Ranua

Tampere University

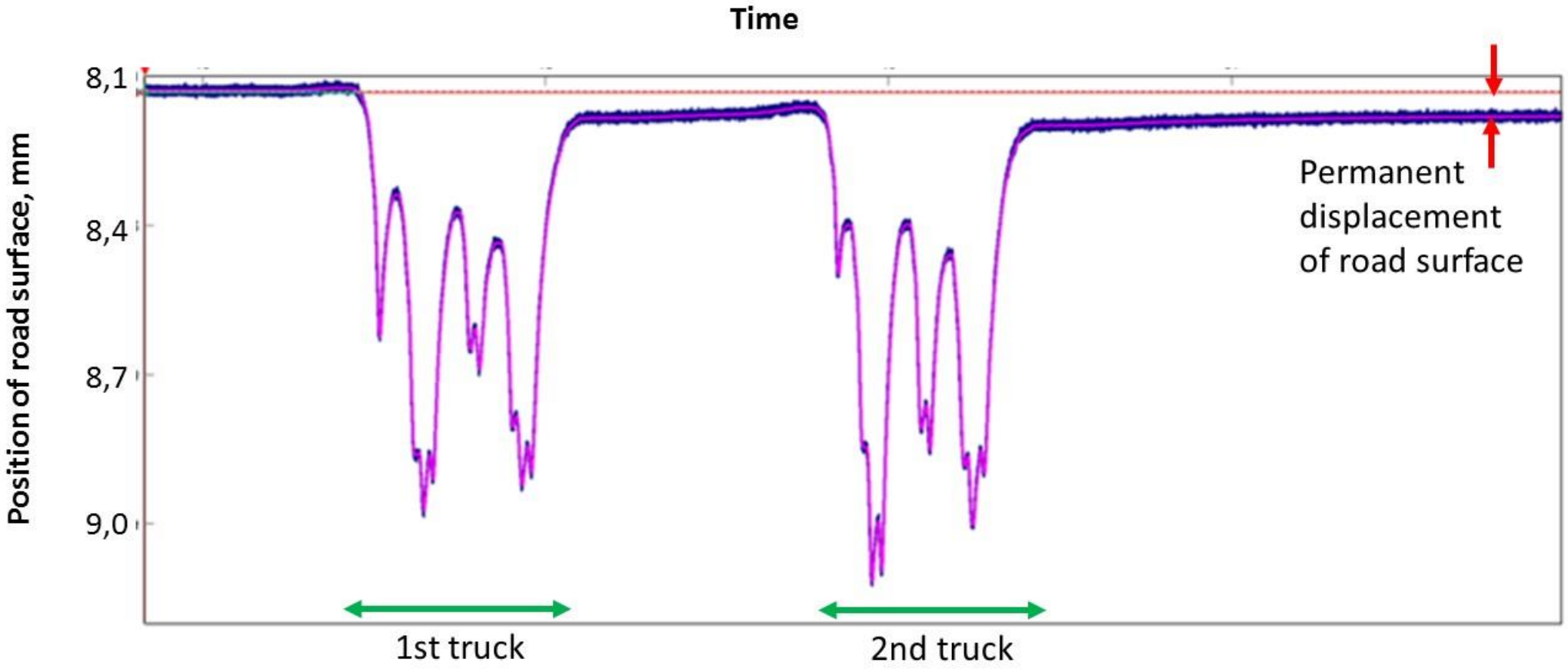
Road surface displacement measurements at the Karstula test site (Main road 77)

- 9-axle 76 ton (2016) and 7-axle 64 ton (2017) trucks were used in the tests
- Trucks were passing over the site either one at a time or in groups of two trucks following each other
- No traffic control on-site → there were a number of other passing by heavy vehicles using their own wheel paths



Tampere University

An example of the measured road surface displacement as a function of time



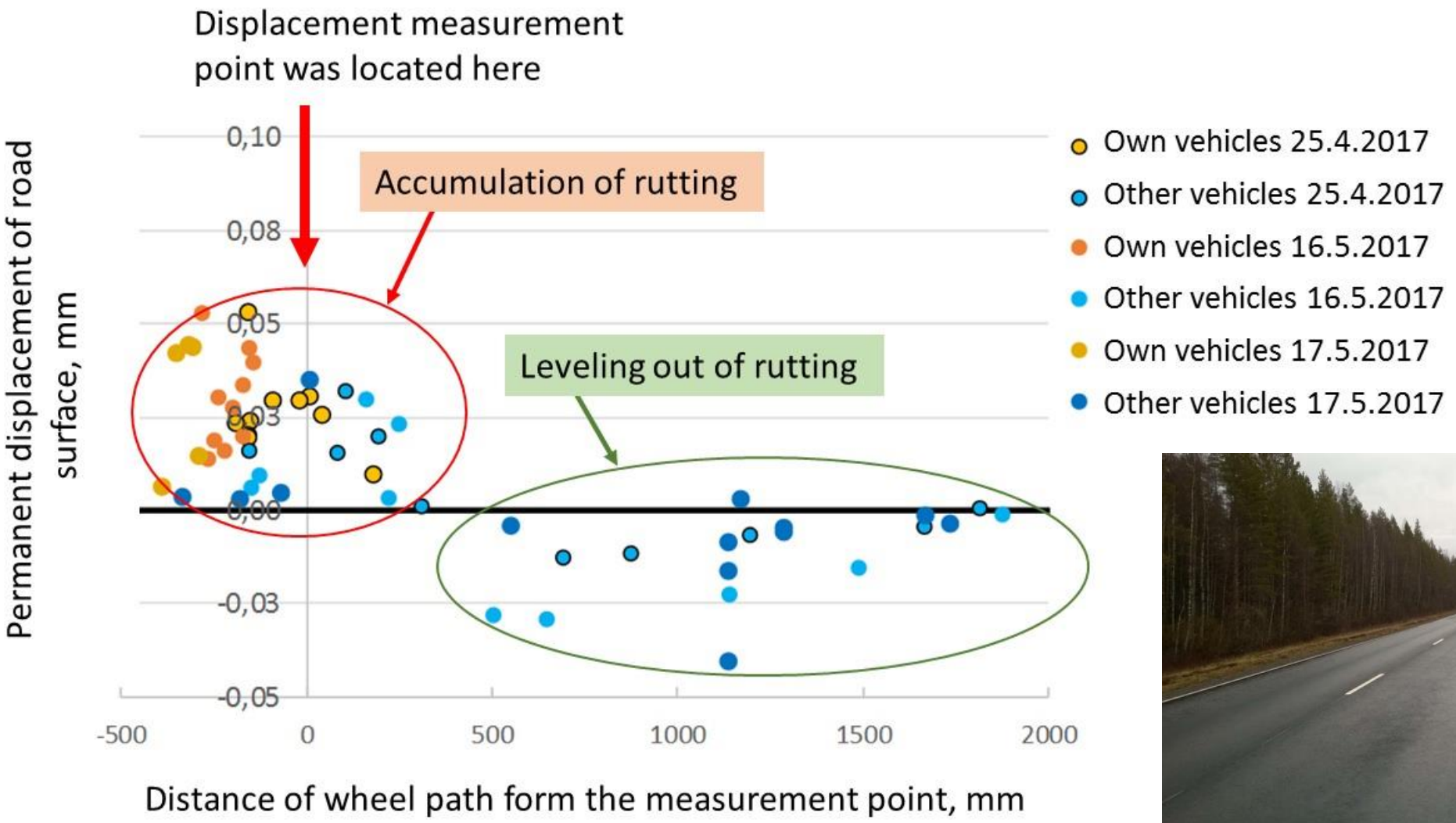
Tampere University

Effect of increasing number of axels on permanent deformation

- On good quality road structures – main road 77 in Karstula and local road 924 in Simo (on the right) - no measurable difference was observed in the accumulation rate of permanent deformations per transported mass at a certain time even if the number of consecutive axles was increasing
- On the contrary, on a gravel road and on a low volume road with thin asphalt concrete surfacing the permanent deformations were developing 50 to 100 % faster per transported mass when two trucks were driving close to each other

Tampere University

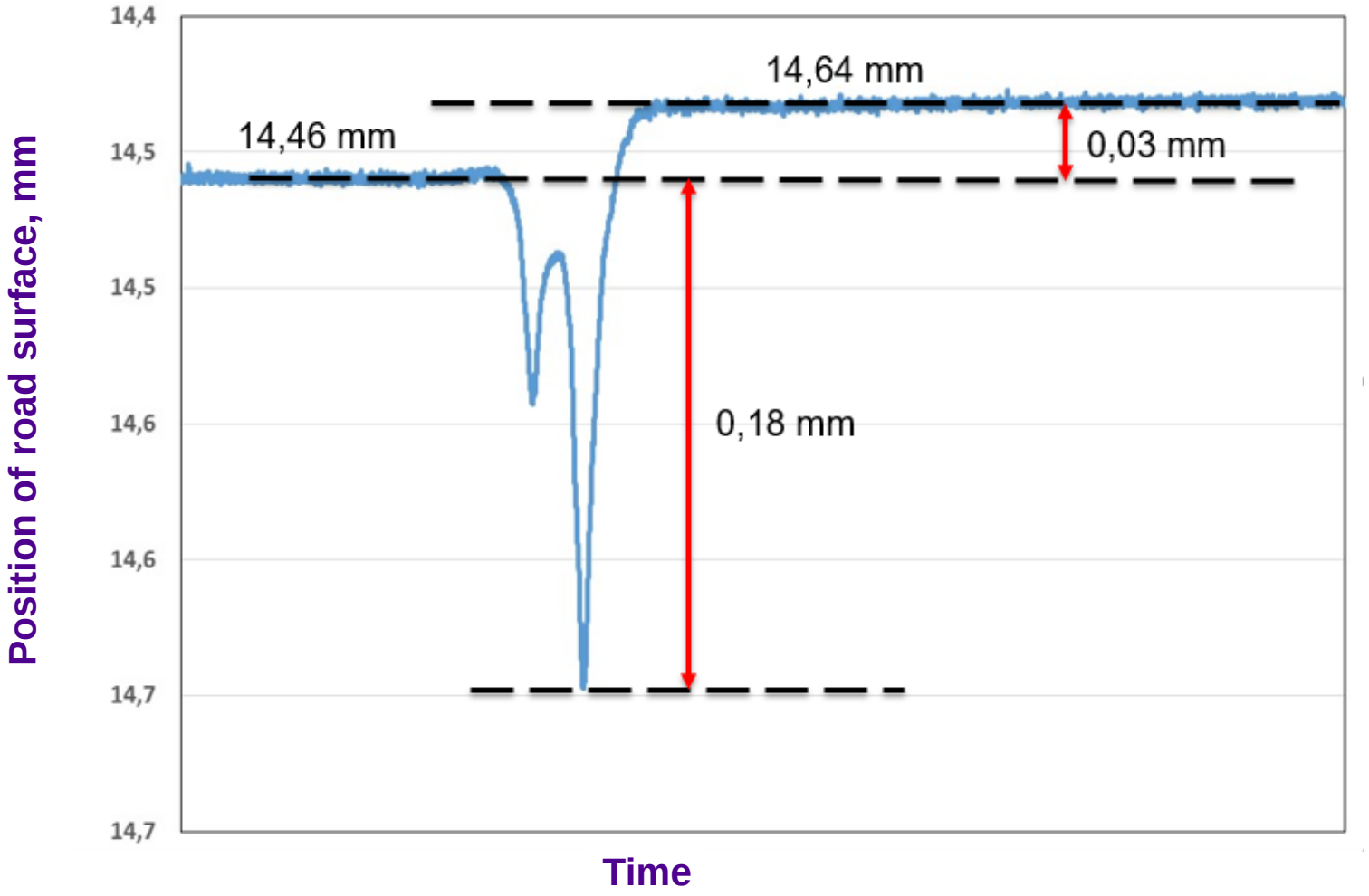
Permanent displacement of road surface in relation to the vehicle wheel path at the main road 77



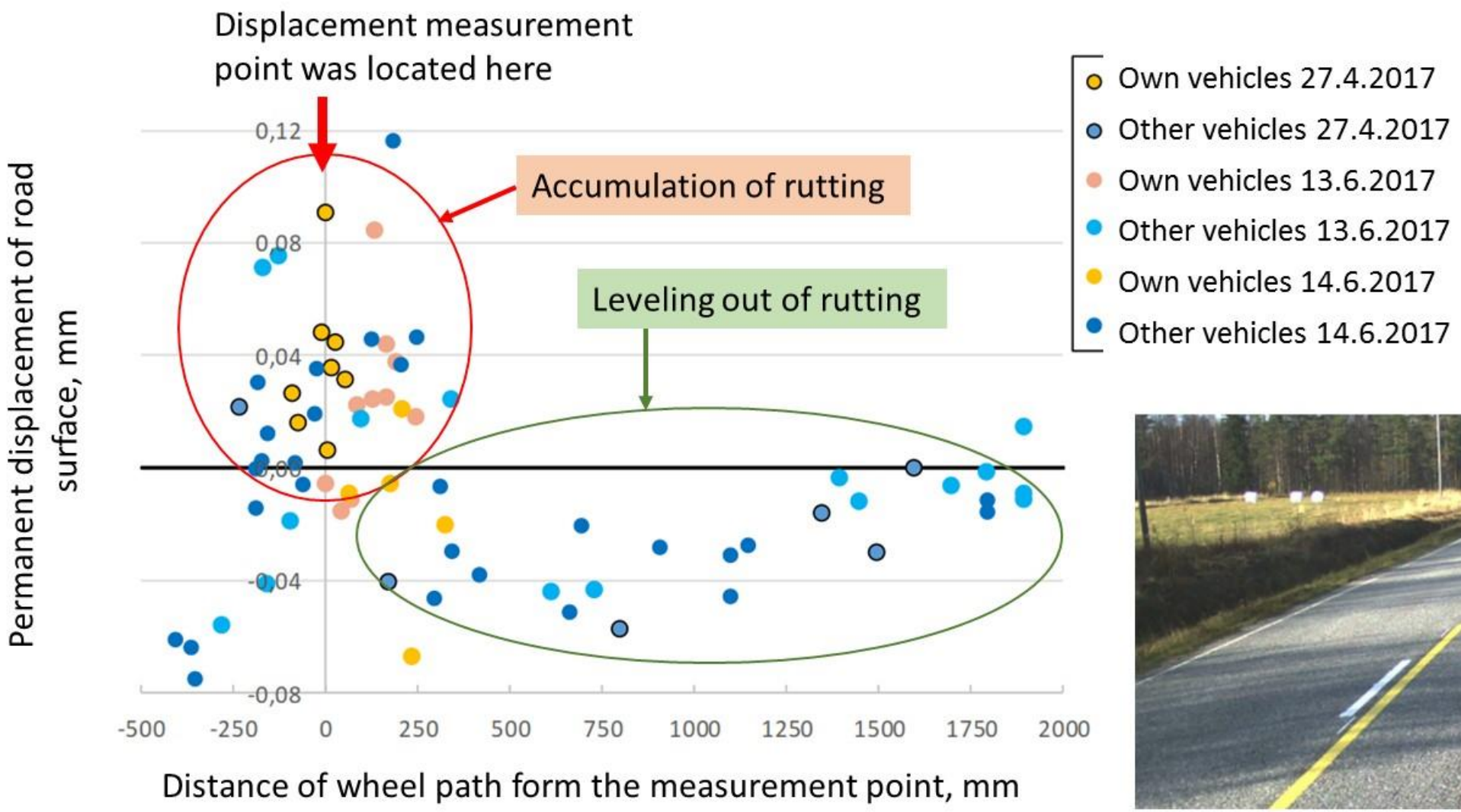
Plastic rebound of the road surface

Vertical displacement of road surface caused by a vehicle that passed next to the measurement point

→ Plastic rebound of 0.03 mm at the road surface level took place



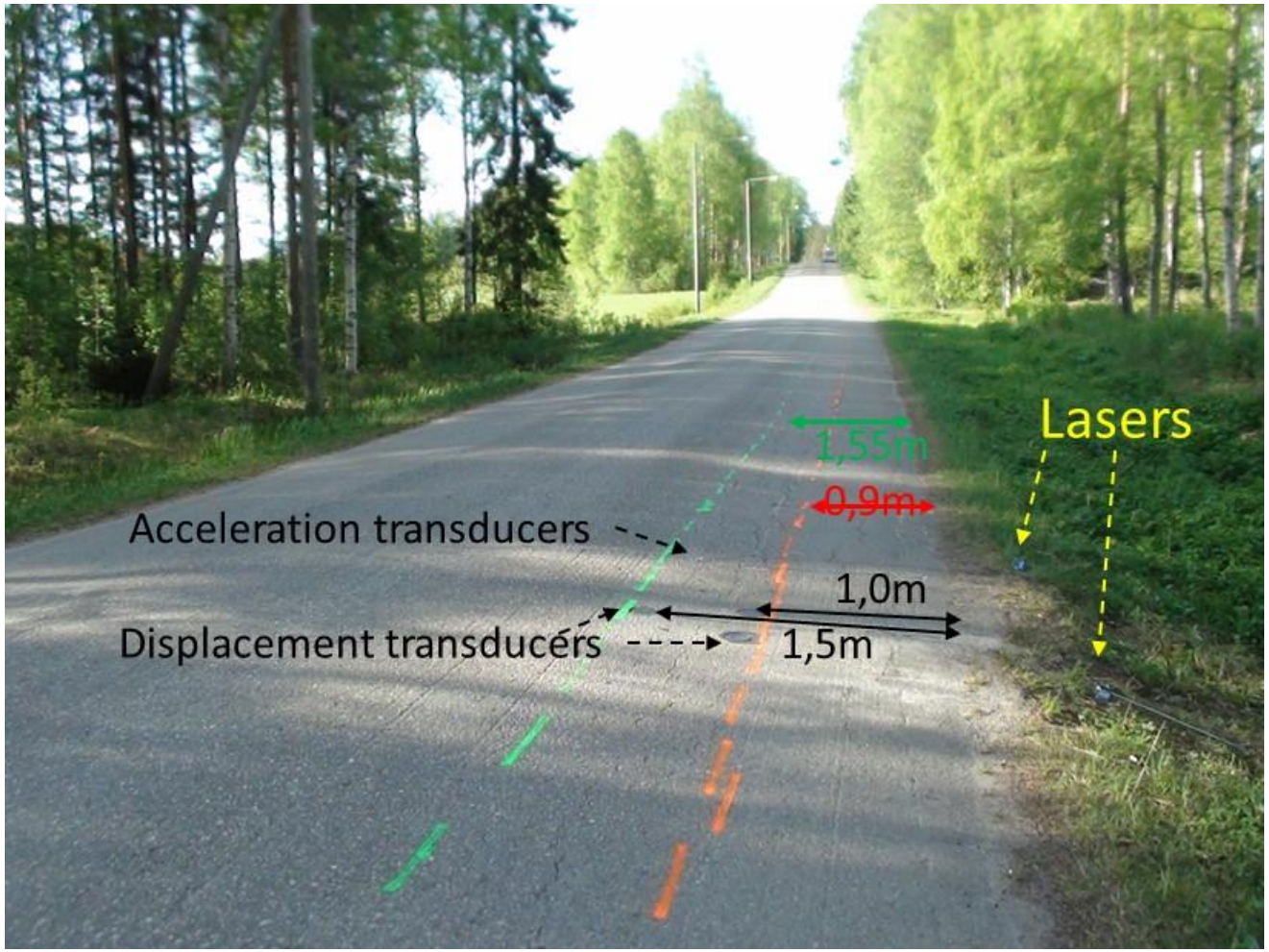
Permanent displacement of road surface in relation to the vehicle wheel path at the local road 924



Plastic rebound tests at the low volume road test site

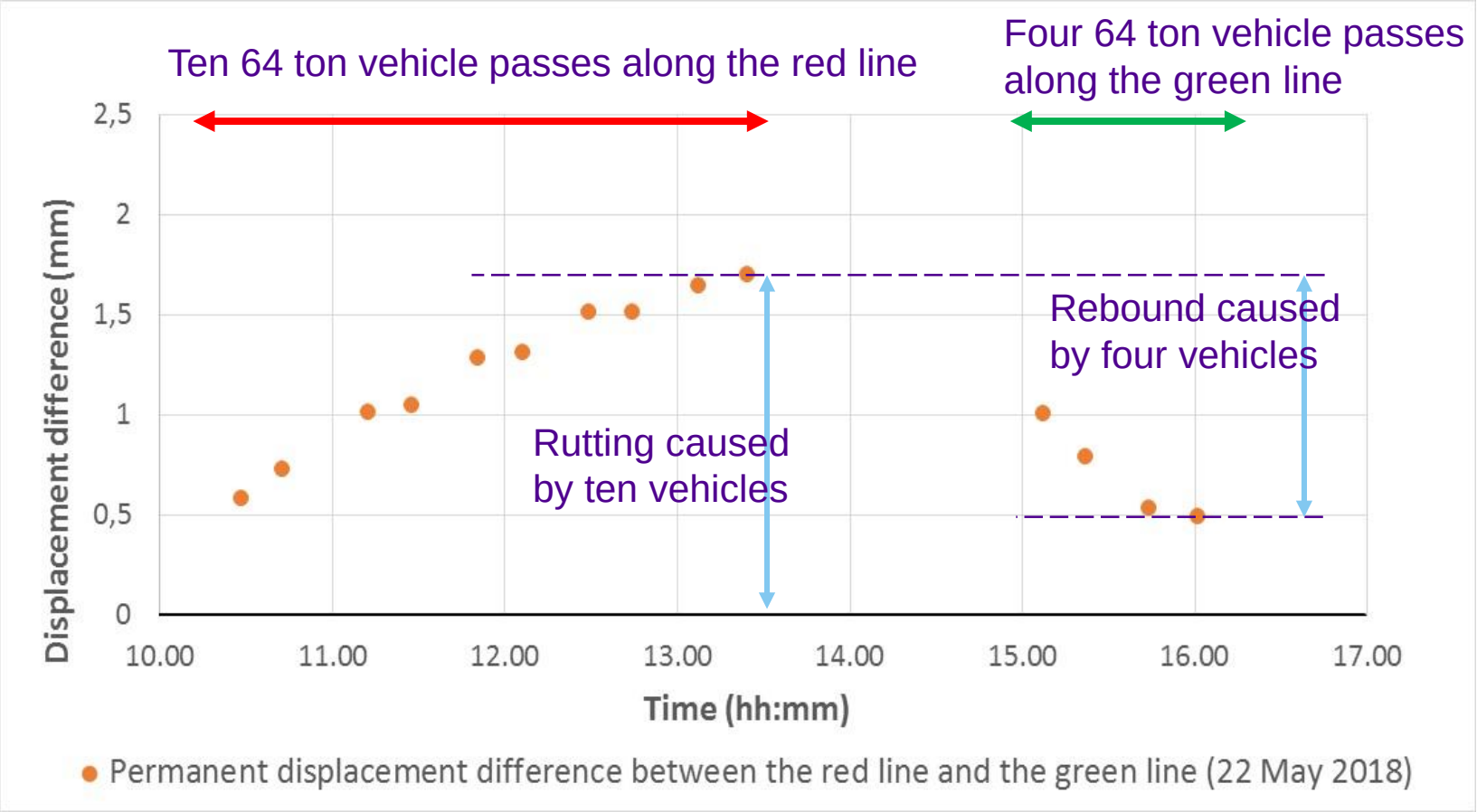
- Measurements were carried out on the low volume road site soon after the spring thaw in 2018
- Thickness of unbound layers was about 0.5 m + a thin soft AC layer on top
- Subgrade soil was peat

- → Fairly large permanent deformations were developing



Measured permanent displacements

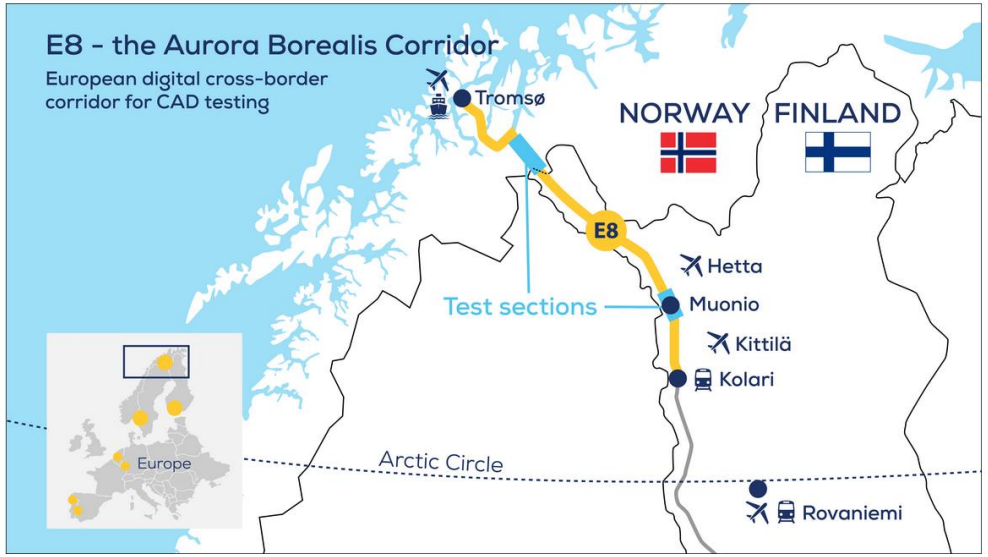
- The biggest change in rut depth is observed in connection with the first heavy vehicle overpass along a certain wheel path
- As the number of vehicles on the same wheel path is increasing, rut depth keeps on growing but the rate is getting slower



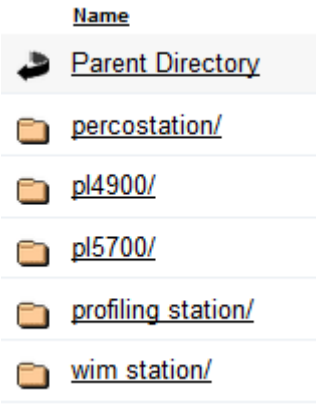
Tampere University

Aurora – ITS testing ecosystem in arctic conditions

- Structural instrumentation (two sites)
  - Road surface deflection
  - Strains in asphalt concrete
  - Stresses and strains in unbound layers
  - Moisture content/dielectric value
  - Electrical conductivity
  - Temperature
  - Recovery times
- Weigh in Motion bridge (one site)
- Laser scanner
  - Vehicle type
  - Wheel paths
- Thermal camera

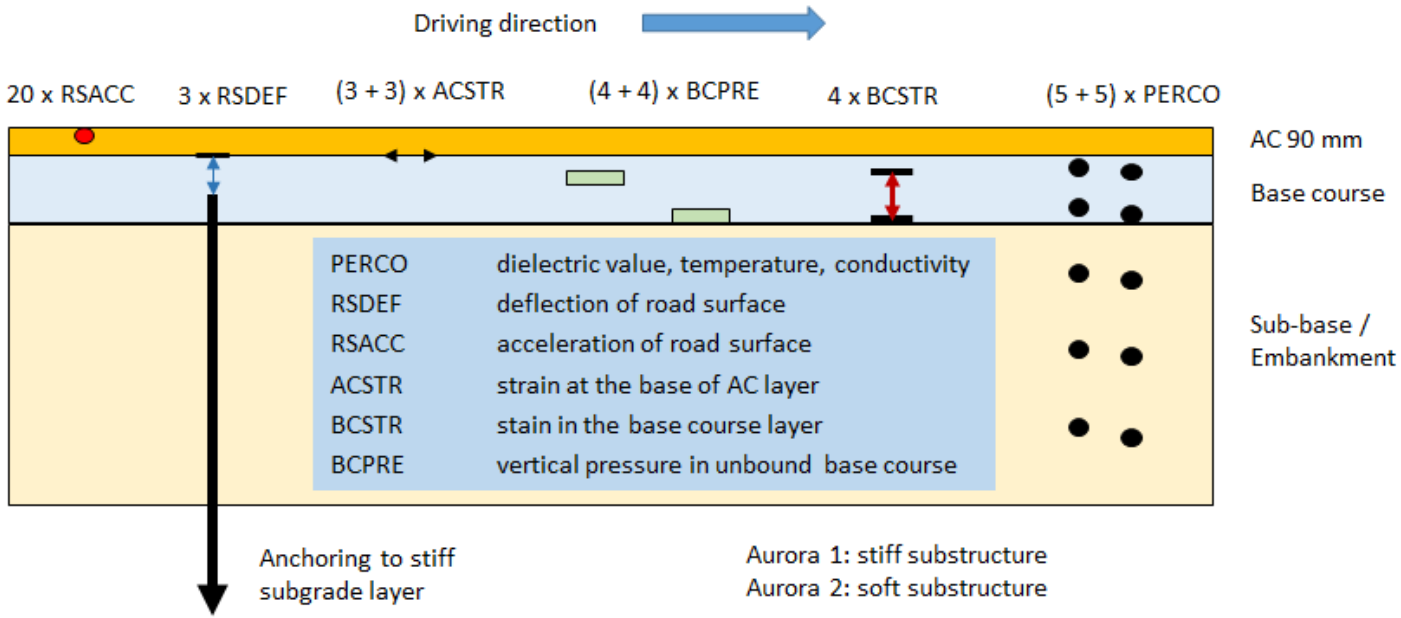


All the results are made available as open data via the FTIA website at: https://aineistot.vayla.fi/aurora/



Tampere University

Structural instrumentation at Aurora 1 and 2 sites



Some more details and some early results will be available in two papers to be published later this year:

- Kolisoja et al. (2019) Open structural monitoring data from two extensively instrumented road sections – case Aurora, Proceedings of the XVII ECSMGE, Reykjavik, Iceland
- Kolisoja et al. (2019) Integrated monitoring of seasonal variations and structural responses to enable intelligent asset management of road infrastructures, Proceeding of the 3rd ICITG, Guimaraes, Portugal

Conclusions

- A number of on-going trends and developments are really challenging the condition of our road and railway infrastrutures
- In road transports dual wheels and/or new generation wide-base single tires should be preferred
- On soft and wet subgrades pumping induced rutting of the road can be a serious problem when the trucks are getting heavier and especially if they start platooning
- Another big potential danger is autonomous driving of heavy trucks if all of them are following exactly the same wheel path

Questions, comments?