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FORMEC

Analysing forwarder operation by consumer-grade GPS in mountainous conditions

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Aims

General objectives

Evaluate the use **consumer-grade GPS** in forwarder operation in terms of:

- forwarder patterns
- work cycle
- speed and work elements

Main limitations

- Low accuracy (5 to 15 m)

Main expectation

Possibility to integrate low accuracy GPS data to traditional time study for forest operation in complex environment

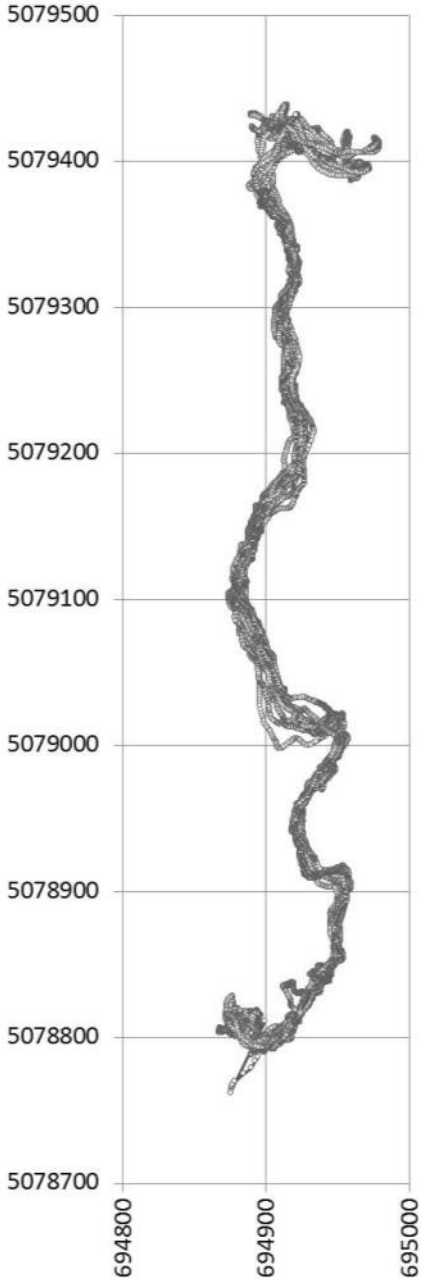
Materials and Methods

Consumer GPS base data

A consumer GPS gives the following base information:

- Longitudine
- Latitude
- Altitude
- Time (year, month, day; hour; minutes; seconds)

latitude	longitude	y_proj	x_proj	altitude	time
45.84070700	11.51012200	5079413.27932543	694919.80351329	1141.56	2013/11/07 7:17:16
45.84070100	11.51015500	5079412.69331199	694922.38699768	1139.28	2013/11/07 7:17:17
45.84069800	11.51016900	5079412.39420022	694923.48460977	1139.21	2013/11/07 7:17:18
45.84069600	11.51018300	5079412.20618937	694924.57872781	1138.53	2013/11/07 7:17:19
45.84069300	11.51019400	5079411.89975136	694925.44338374	1138.82	2013/11/07 7:17:20
45.84069200	11.51020600	5079411.81795715	694926.37870348	1138.49	2013/11/07 7:17:21
45.84069400	11.51021500	5079412.06213861	694927.07058423	1138.39	2013/11/07 7:17:22
45.84069500	11.51022400	5079412.19521941	694927.76595915	1138.59	2013/11/07 7:17:23
45.84069700	11.51022900	5079412.42963206	694928.14723132	1138.24	2013/11/07 7:17:24
45.84069900	11.51023500	5079412.66648699	694928.60615558	1138.48	2013/11/07 7:17:25
45.84070000	11.51024000	5079412.78979896	694928.99092193	1138.70	2013/11/07 7:17:26



Materials and Methods

Consumer GPS base data

From basic GPS data it is possible to calculate some useful parameters between each successive GPS points:

- Point to point 2D distance (*Dist*)

$$Dist = \sqrt{(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2}$$

- Velocity and acceleration (*Speed*)

$$Speed = \sqrt{(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2}/\Delta t$$

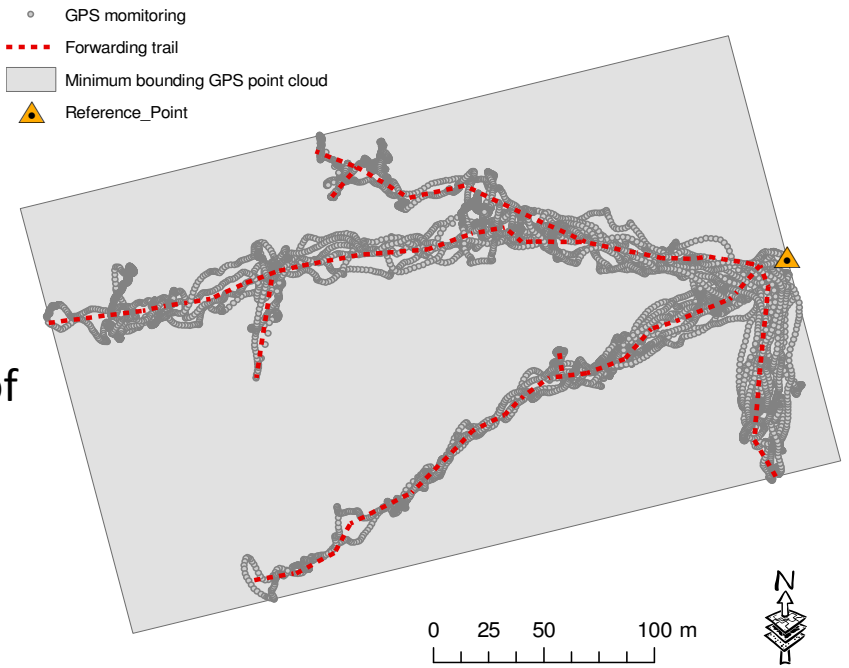
Positional precision of the GPS influence the correctness of the derived parameters

Materials and Methods

External reference point

As proposed by Gallo et al. (2013) GPS data will be analysed in relation to an external reference point (**Rp**):

- located on the edge of the minimum bounding rectangle of the GPS point cloud
- closeness to the first GPS point acquired



The use of the **Rp** allows to:

- elaborate the data without any reference data (coordinate x, y)
- reduce the influence of the low accuracy of the positional location

Materials and Methods

Field survey

Forwarder monitoring:
- Consumer grade GPS (Garmin 60csx)

Time study:
- UMTPlus (Laubrauss)

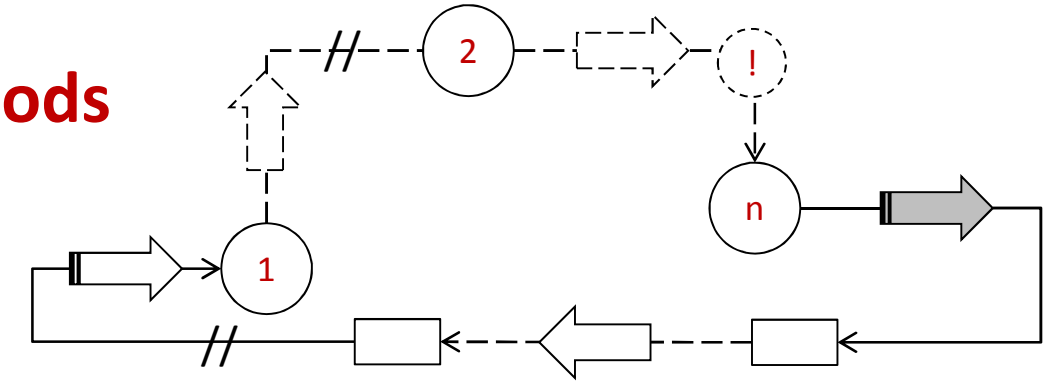
Trails survey:
- Antenna D-GPS Pro XH (Trimble)
- Laserfinder Trupulse 360B (Lasertech)

Other:
- 170° Videocamera (Drift)

Base software:
- Excel (Microsoft Office)
- ArcGIS 10.2 (ESRI)
- Roadeng (Softree)

Materials and Methods

Time study



Work elements	Description	Priority	Symbol
Driving unloaded	Starts when machine starts to move from landings and ends when the crane starts to move to the first pile of the cycles	1	⇨
Loading	Starts when the empty crane move to load the pile/log and ends when the crane back to the base position	2	1
Moving while loading	Starts when wheels start to turn to the next pile/log and ends when machine stop to load	2	⇢
Drive loaded	Starts when machine move from the last load and ends when it stops to unload	2	➡
Unloading	Starts when cran moves to unload the first log/logs and ends when the crane bak to the base position	1	▭
Moving while unloading	Starts when wheels start to turn to the next landing position and ends when machine stops to unload	2	⇨
Delay	Time not related to effective work time	4	//
Other	When wheel are stuck and crane are moving uch as when adjusts loads, loads are dropped and pick up again	3	1

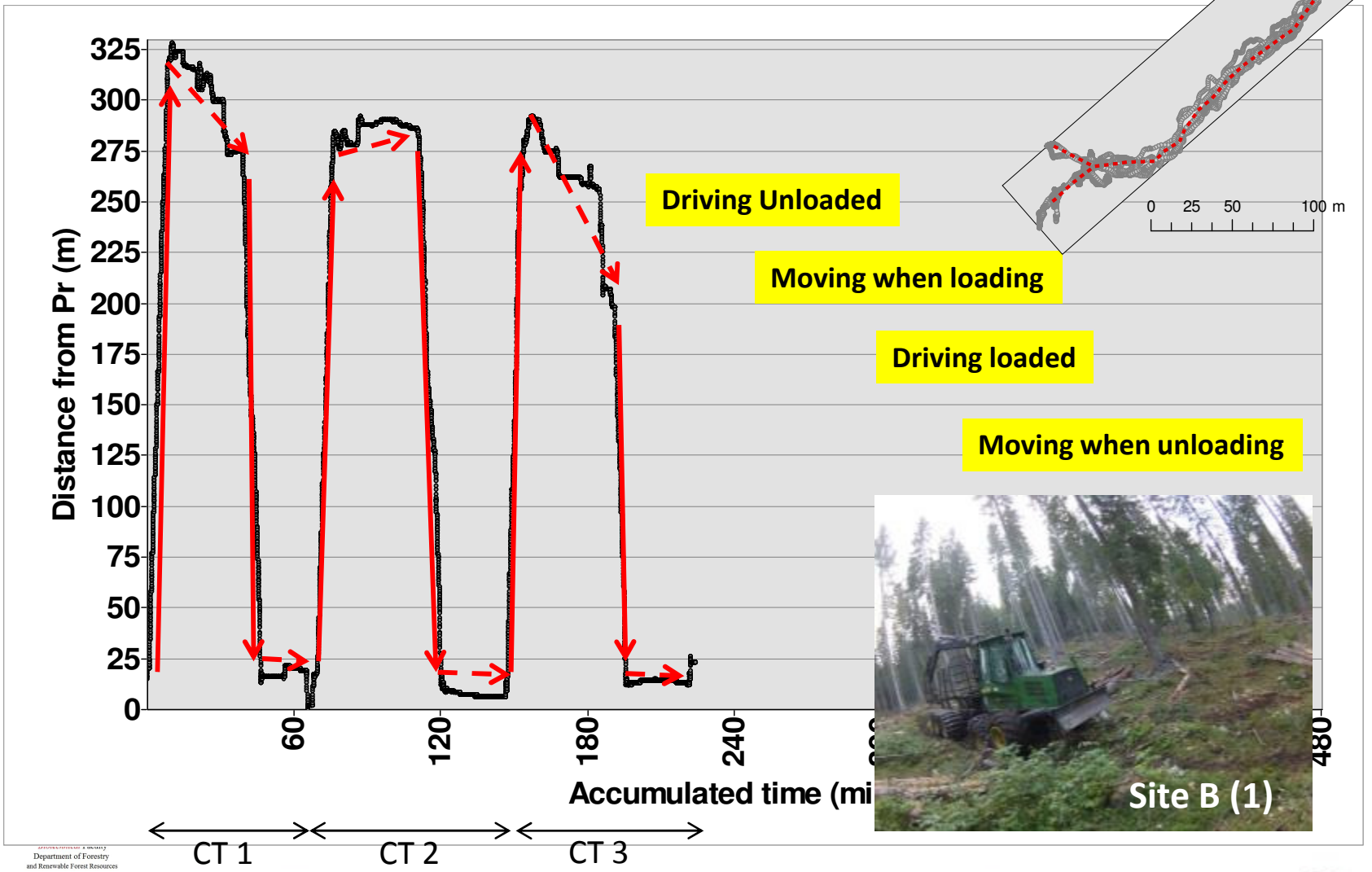
Materials and Methods

Test sites

	Site A	Site B (B1) (B2)	Site F	Site C	Site D	Site E
Location	Grigno ITA	Enego ITA	Asiago ITA	Kočevje SLO	Črnomelj SLO	Občice SLO
Model	JD 1110E	JD 1110D	JD 1110E	JD 1210E	JD 1410D	JD 1210E
Wheels (n°)	8	8	8	8	8	8
Cabin	Rotating	-	Rotating	Rotating	-	Rotating
Power (kW)	136	121	136	140	129	140
Sylvicultural management	SHW	TH/SHW	SHW	SHW	SHW	TH
Operator working experience (y)	7	0.3	7	3	1	0.8

Results

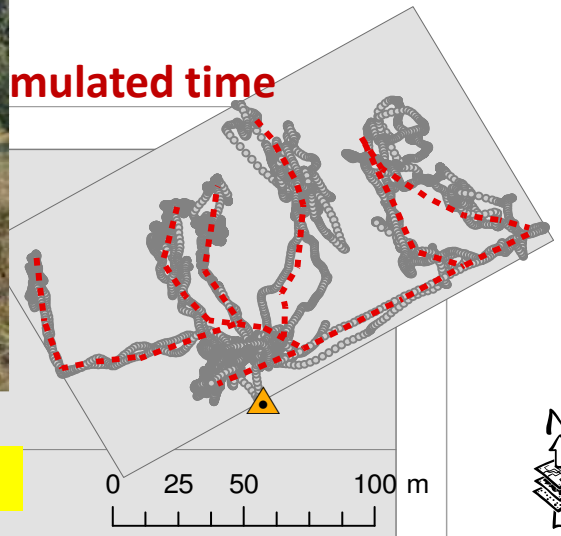
Distribution of the advanced direction in relation to the accumulated time



Duration of the Cycle time

Results

Distribution of the advanced direction in rel mulated time



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Duration of the Cycle time

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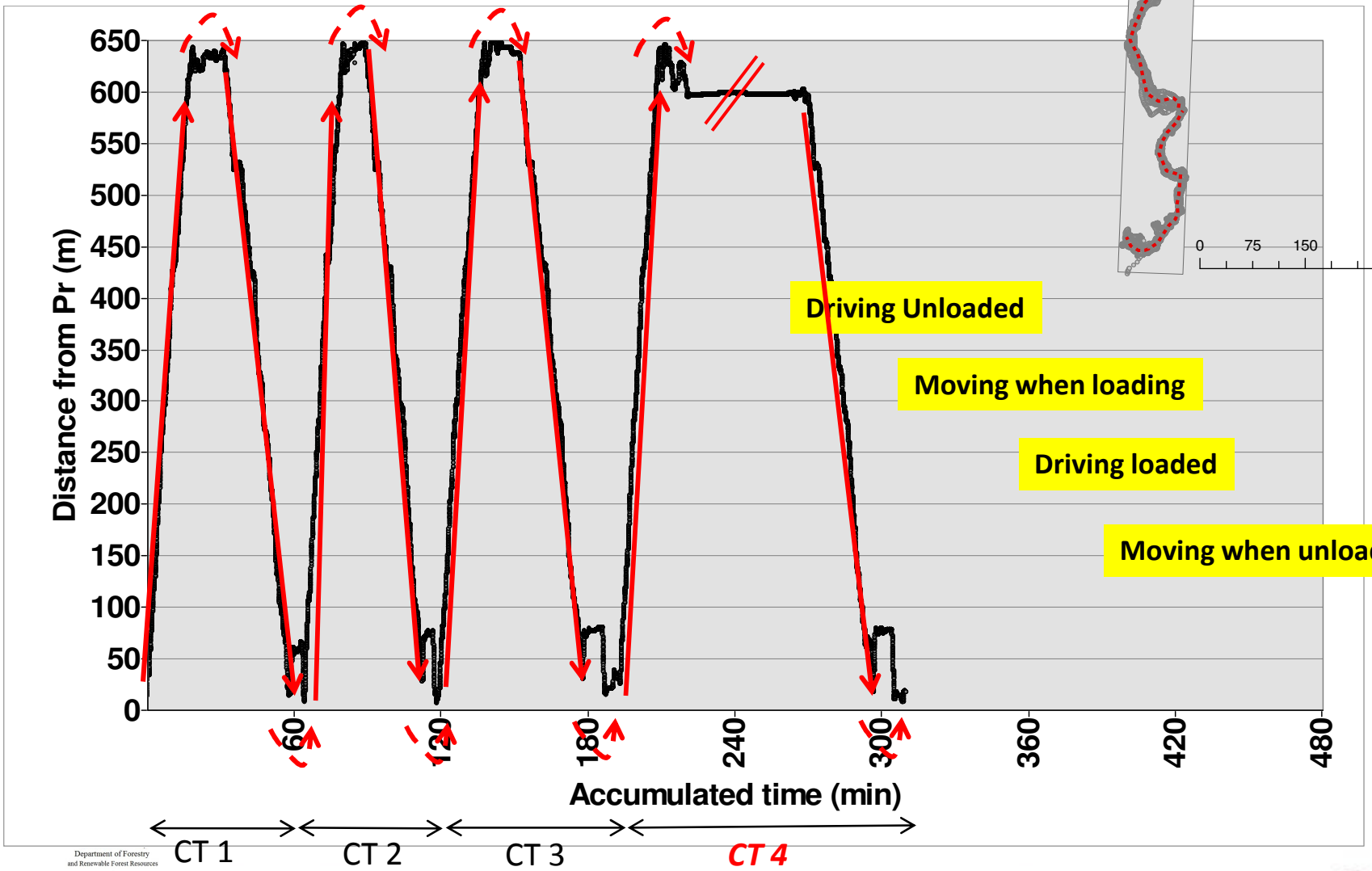
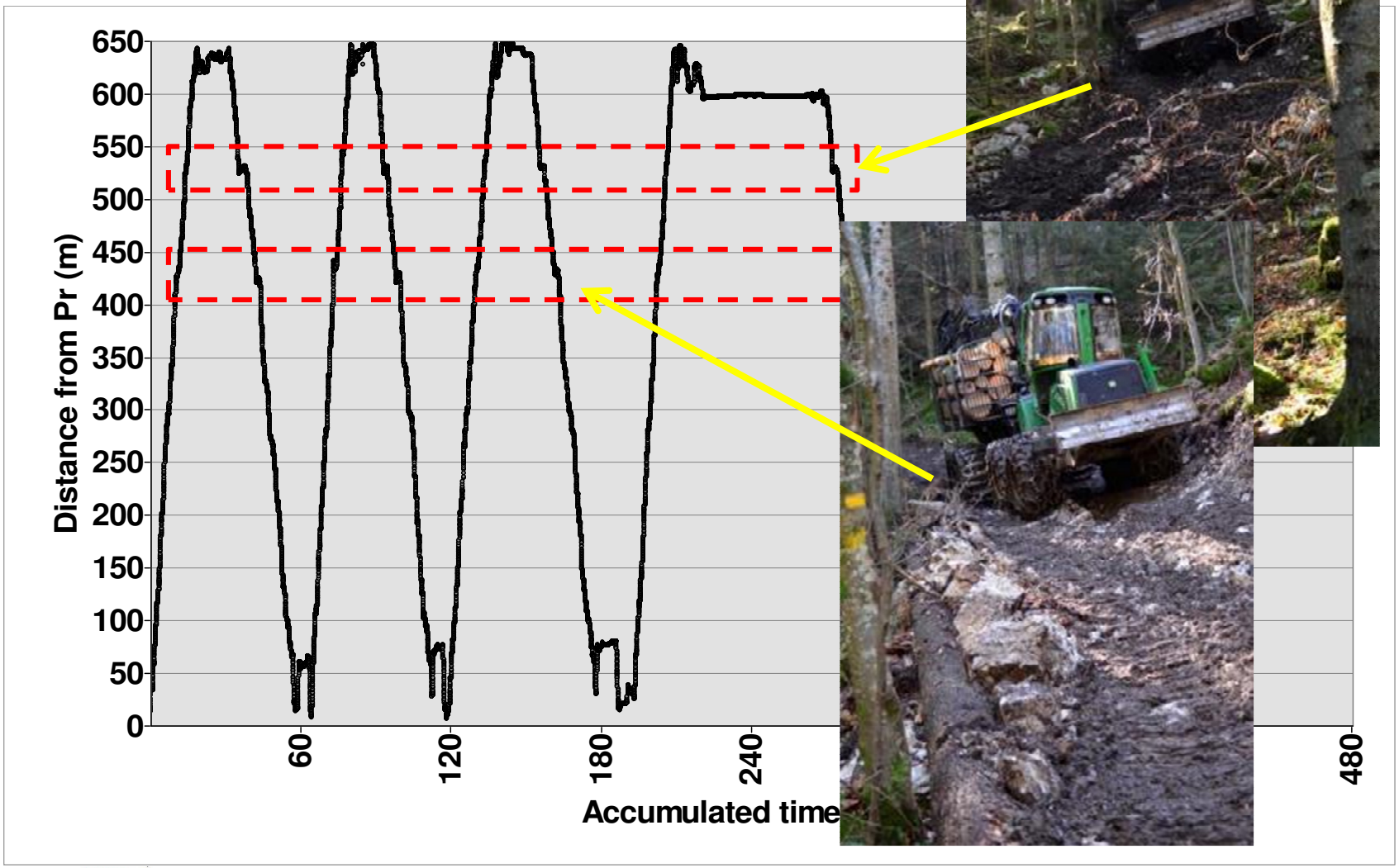
Results

Distribution of the advanced direction in relation to the accumulat me



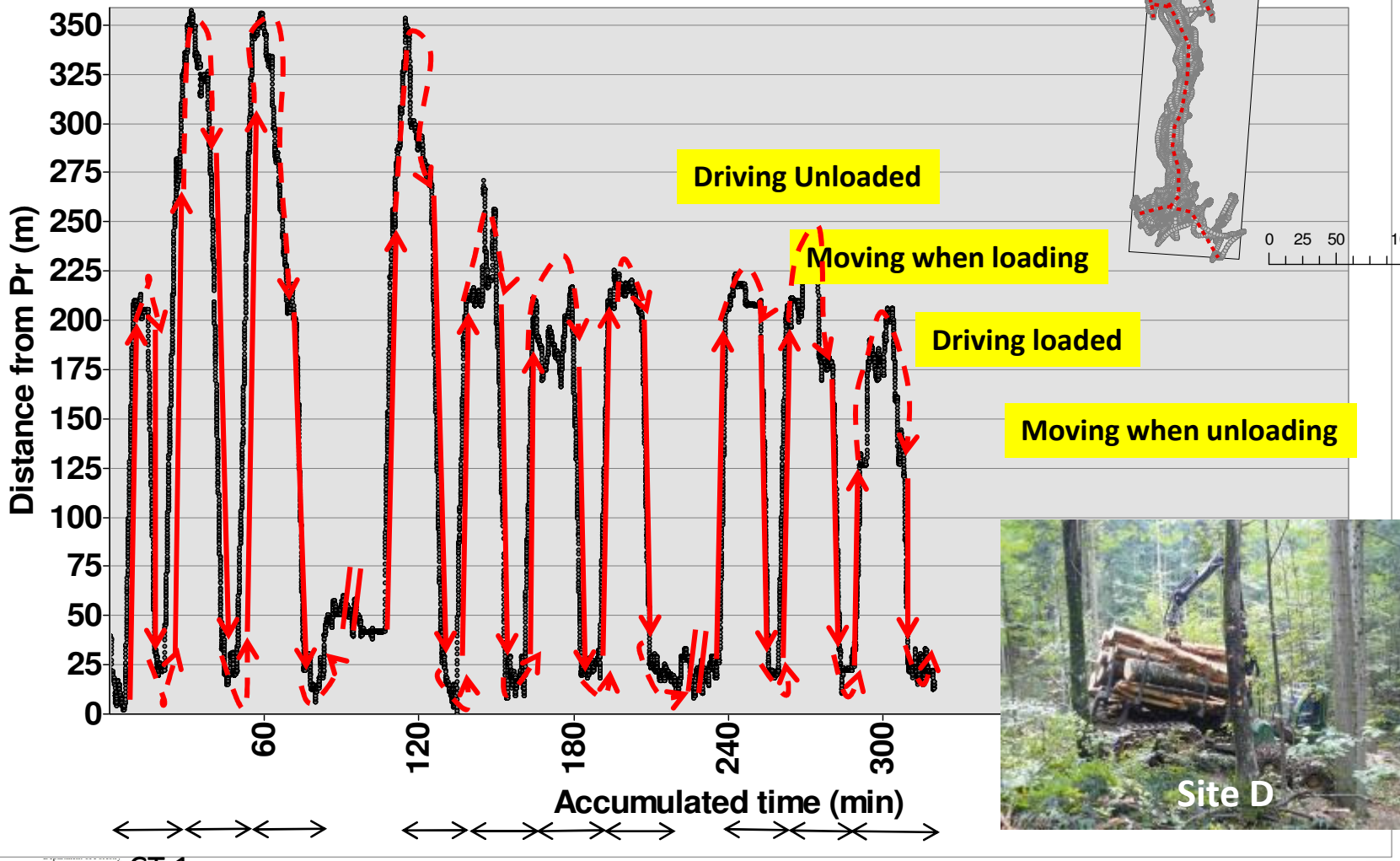
Results

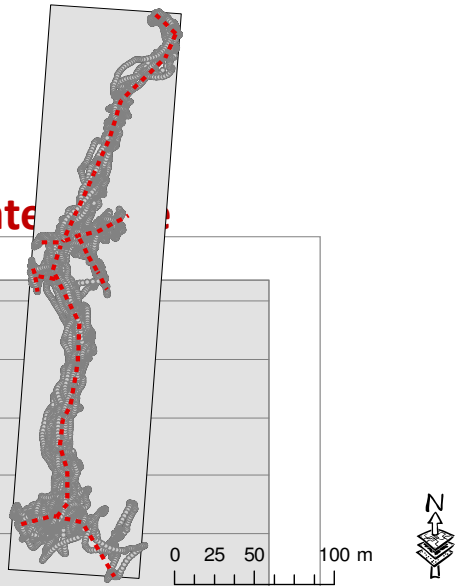
Distribution of the advanced direction in relation to the



Results

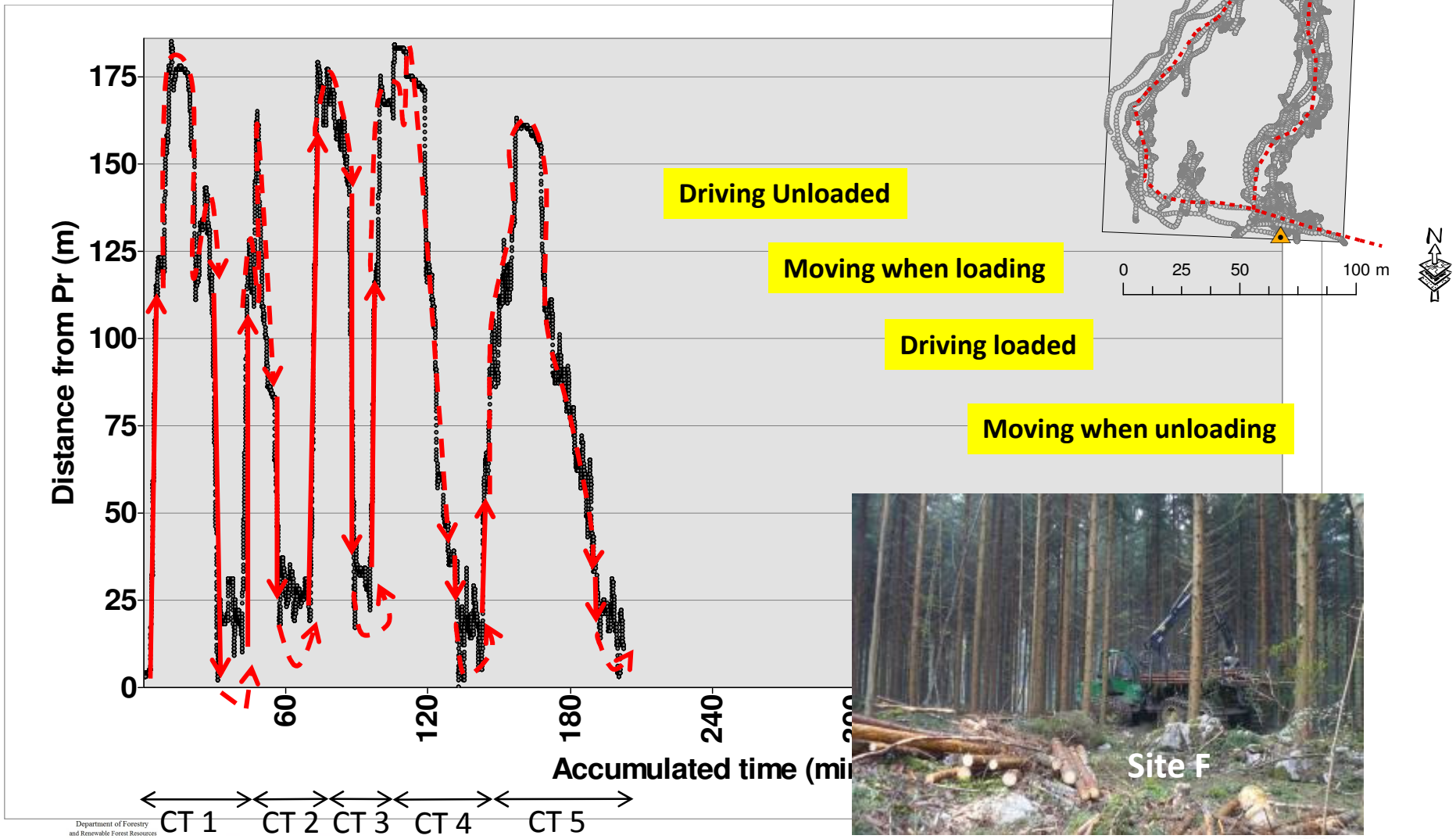
Distribution of the advanced direction in relation to the accumulate





Results

Distribution of the advanced direction in relation to the accumulate

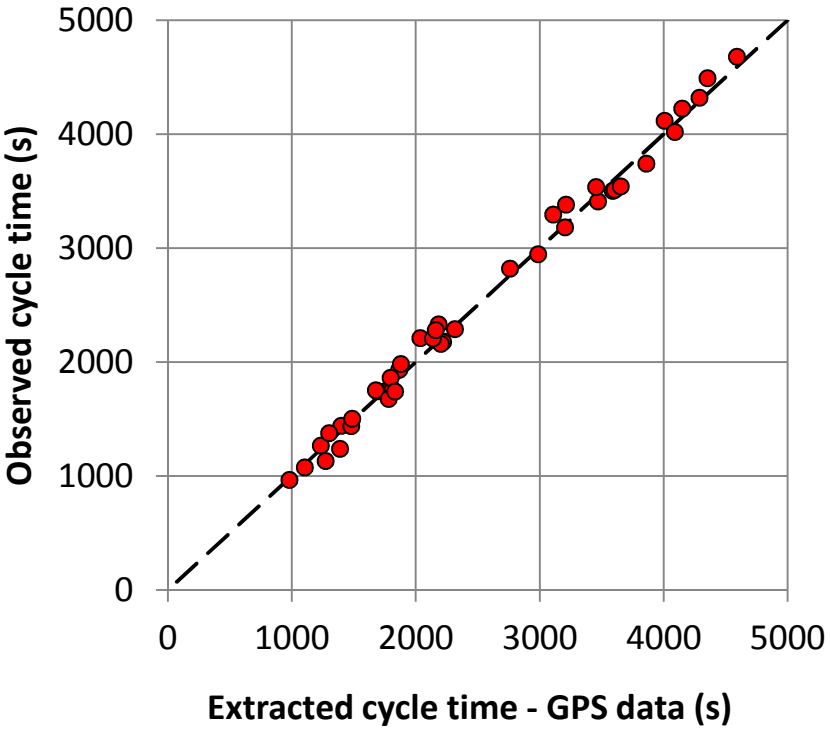


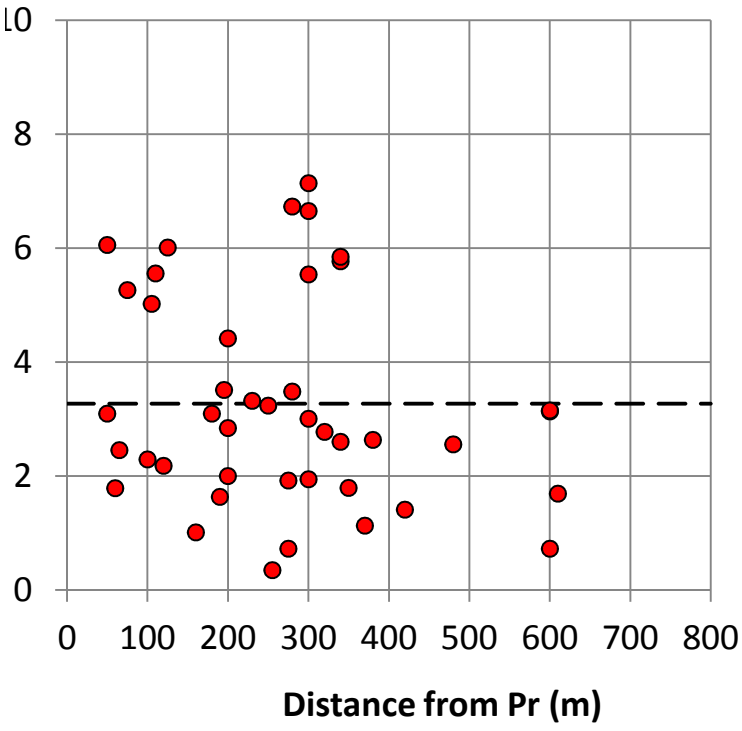
Duration of the Cycle time

Discussions

Comparison with Time study

Cycle time (including not productive time)



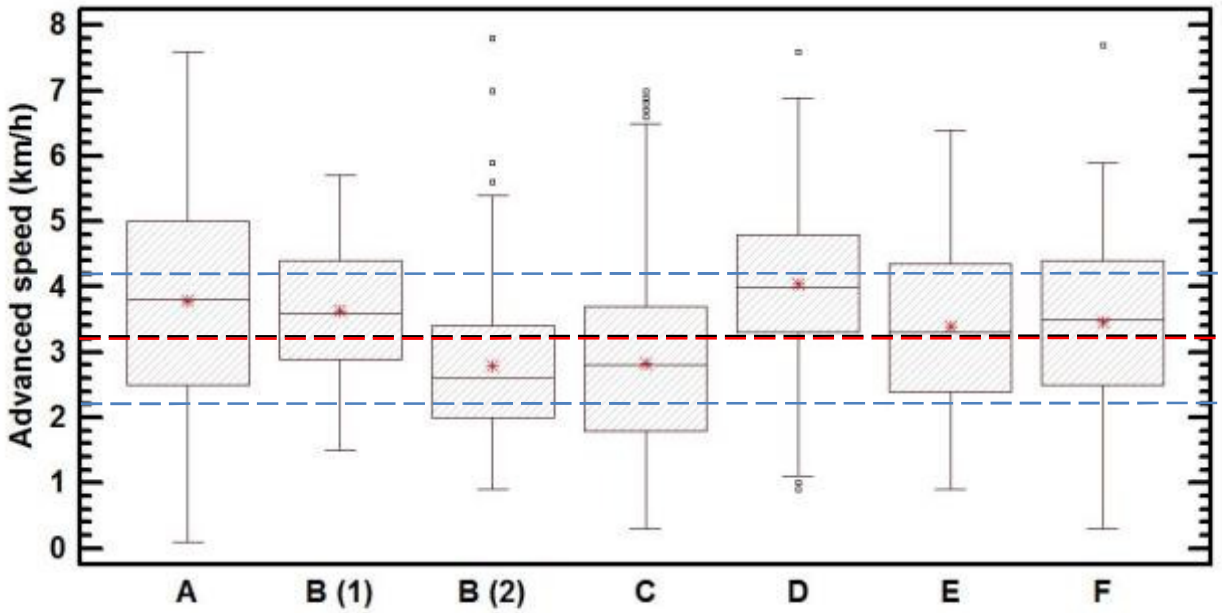


RMSE = 92 s (1.53 minutes)

Ab. Error mean = 3.27% (1.26 minutes)

Results

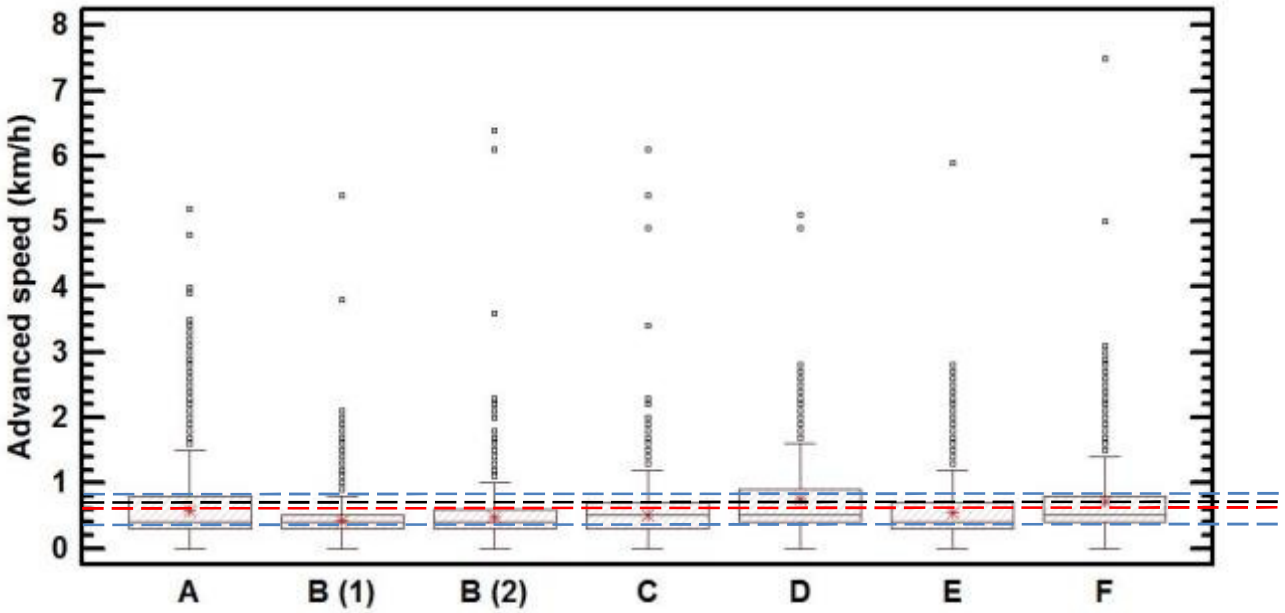
Advanced speed – Driving unloaded



Q1 (4.20 km/h)
Mean (3.24 km/h)
Median (3.20 km/h)
Q3 (3.20 km/h)

Results

Advanced speed – Moving when loading



Q1 (0.80 km/h)

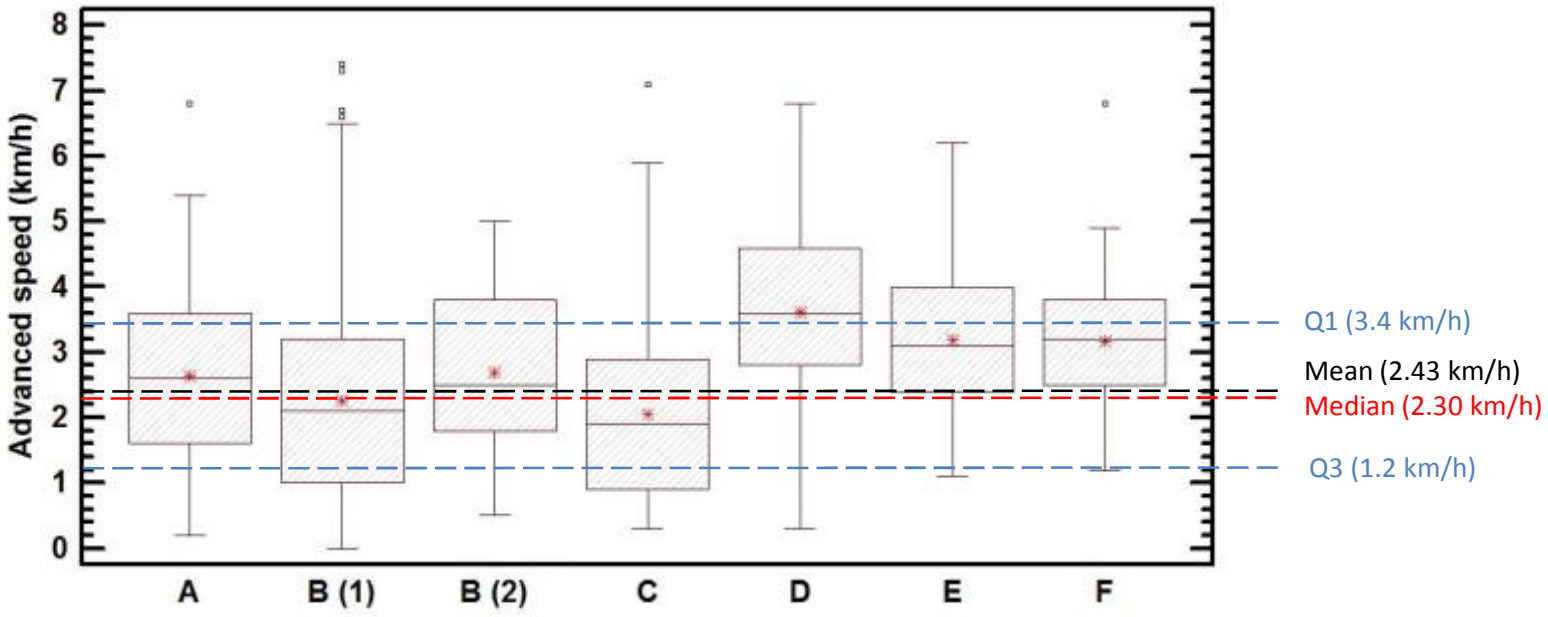
Mean (0.74 km/h)

Median (0.50 km/h)

Q3 (0.30 km/h)

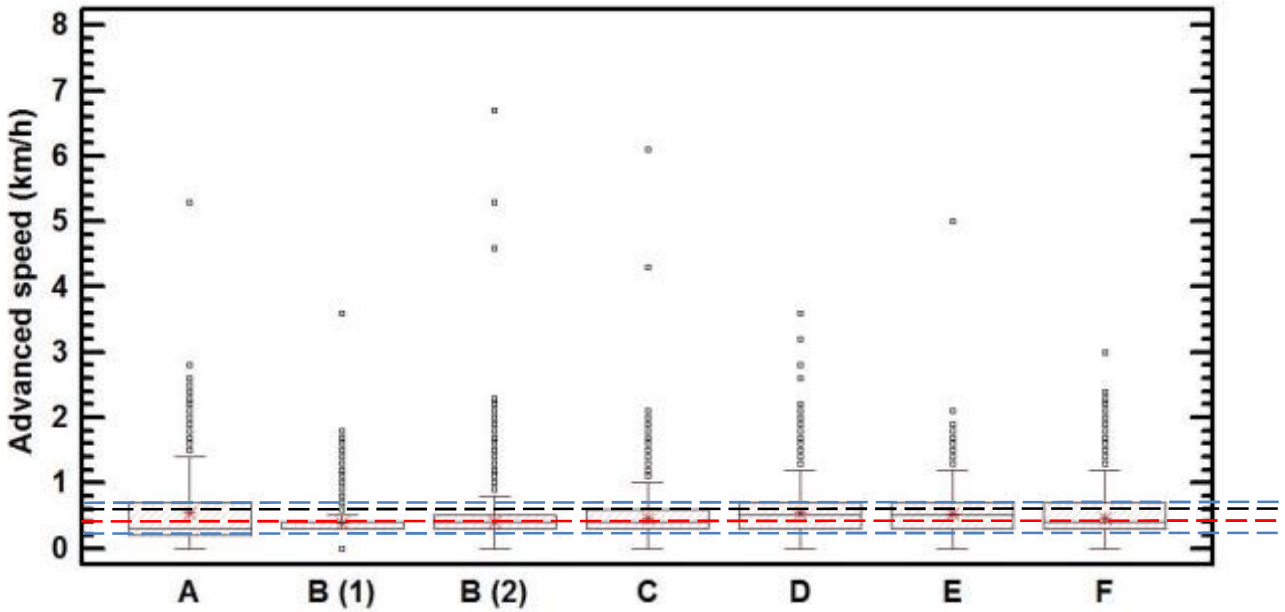
Results

Advanced speed – Driving loaded



Results

Advanced speed – Moving when unloading



Q1 (0.70 km/h)
Mean (0.62 km/h)
Median (0.40 km/h)
Q3 (0.3 km/h)

Conclusions

Accuracy of the results and determination of the parametrs

- By using an external reference point, patterns and work cycles can be identified by the analysis of the GPS data

- Single speed values are strongly influenced by the GPS data accuracy *(a better accuracy with consumer grade receiver equipped with GLONASS and GPS is expected)*

Integrating GPS monitoring to time study

- The integration of the GPS for monitoring patterns and work cycles can support the work time study by adding useful spatial and time information to the researcher

- Consumer GPS shows the flexibility because of the easy installation and the setting (few seconds before the beginning of the operation)

- Automatic elaboration for cycle time identification (from driving unloaded to loading) is possibible by Excel® and also by GIS software

THANK YOU FOR YOUR ATTENTION