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Article title

Vibrations induced by Tunnel Boring Machines in urban areas: dataset of synchronized in-situ measurements inside the shield and on the surface.

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Keywords

Ground borne vibrations, shallow tunnel, Tunnel Boring Machine, in situ measurement, dynamic characterization, vibration levels, data processing

Abstract

In order to evaluate the potential impact of the shallow tunnel excavation by a tunnel boring machine (TBM) in urban areas, the authors present original in-situ measurements of vibrations inside the TBM and simultaneously on the surface. Four experimental campaigns were carried out on French tunnelling or micro-tunnelling projects, whose geotechnical contexts vary from hard rock to clayey sands. Each campaign is divided into two steps: (i) before excavation, measurements on the surface under mechanic ambient noise, and (ii) during excavation, measurements on the surface and inside the TBM. The present dataset consists in collecting, for each campaign, the time histories of all the synchronised sensors. They could be use particularly to estimate the vibration levels at different locations, and to analyse the frequency domain of the different signals.

Specifications table

Subject	Civil and Structural Engineering
Specific subject area	In-situ measurements of vibrations emitted by a tunnel boring machine during excavation of tunnels.
Type of data	Table Figure
How the data were acquired	The experimental set-up is made of two kinds of geophones from Moho brand : 3D sensors (©Tromino) and 1D sensors (©Soilspy Rosina).
Data format	Raw

data collection 2021. Each campaign is divided in two steps: (i) acquisition under ambient mechanic noise (before excavation), then (ii) acquisition during excavation on the surface (at different locations) and inside the TBM. Signal processings are performed thanks to Python.

Data source location	Data collected from four french tunnelling projects in Paris, Lyon, Sorgues were analysed in ENTPE/LTDS, Lyon France.
Data accessibility	Figures are presented in this article and raw data are hosted in the following link : https://mycore.core-cloud.net/index.php/s/ybajakmrNwcRSqw
Related research article	A. Rallu, N. Berthoz, C. Charlemagne, D. Branque, "Vibrations induced by Tunnel Boring Machines in urban areas: in-situ measurements and methodology of analysis.", Rock Mech. Rock Eng, In Press

1. Value of the Data

- The dataset contains original measurements of vibrations generated by a TBM during excavation in several geotechnical contexts. The key point is synchronized acquisition between the TBM and the ground;
- Measurements on the surface provide the relevant level of vibrations which can be transmit to neighboured structures;
- Measurements inside the TBM allow to dynamically characterize the source of vibration;
- All the measurements during excavation can be used for matching parameters of numerical simulations;
- Ambient mechanic vibrations can be used to determine the stratigraphy of the ground and compute the mechanical properties of each layer;
- This dataset can be used by researchers, geotechnicists and engineers of underground works;
- Future data acquisition during tunnel excavation can be integrated in our dataset to better improve the understanding of physical phenomena.

2. Data Description

2.1 Structure of the data repository

The dataset <https://mycore.core-cloud.net/index.php/s/ybajakmrNwcRSqw> is organized by in-situ campaign performed in three french cities : Paris, Lyon and Sorgues. Following Figure 1, two sets of measurements had been performed on each campaign (except in Sorgues) : under mechanical ambient noise then during the excavation. For each set, the provided data come from 1D or 3D sensors. A data file is a UTF-8 text file (.dat), whose the structure is illustrated in Figure 2 : each column corresponds to a given sensor (orders of sensor names are given in Table 2) and each row to a time step dt , whose the value is given in Table 2. Two columns are delimited by a whitespace.

2.2 Time histories

The time histories of 1D and 3D sensors during the excavation phases of all the sites are presented in Figures 3-12 (correspondances are given in Table 2). These figures represent the plots of the data provided in the dataset without any preprocessing.

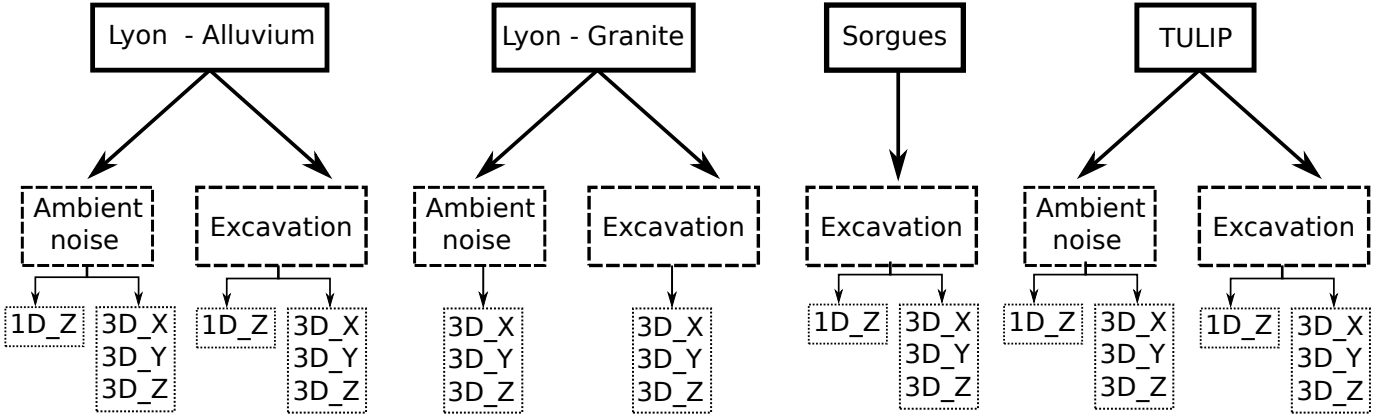


Figure 1: Organisation of the dataset.

Campaign	Lyon - Alluvium	Lyon - Granite	Sorgues	TULIP
	3D sensors			
Time step dt [s]	1/1024			1/512
Data unit	[mm/s]			
Ambient noise	{C1, C2, T70, T71, T75, T76}	{C1, C2, T71, T76}	-	{C1, C2, C3, C4, T20, T21, T40, T70, T71}
Excavation	{C1, C2, C3, C4, T70, T71, T75, T76} Figures 3-4	{C1, C2, C3, C4, T70, T71, T75, T76} Figures 6-7	{C1, C2, C3, C4} Figures 8	{C1, C2, C3, C4, T20, T21, T40, T70, T71, T75, T76} Figure 10-11
	1D sensors			
Time step dt [s]	1/1024		1/512	
Data unit	[mm/s]		[mm/s]	
Ambient noise	-	-	-	
Excavation	{R01, R02, R03, R04, R05, R06, R07, R08, R09, R10, R11, R12, R13, R14, R15, R16, R17, R18} Figure 5		{R01, R02, R03, R04, R05, R06, R07, R08, R09, R10, R11, R12, R13, R14, R15, R16, R17, R18} Figure 9	{R02, R03, R04, R05, R06, R07, R08, R10, R11, R12, R13, R14, R15, R16} Figure 12

Table 2: Orders of sensors in each data file.

Time	C1	C2	C3	C4	T70	T71	T75	T76
dt	-0.00417851	0.00223849	0.2139398	0.13371237	-0.00764071	0.02235504	0.01417709	0.00250711
2dt	-0.00259665	0.0012834	0.34287673	0.17382608	-0.00325327	0.00623792	0.01068505	0.00226833
3dt	-0.00026862	0.00020893	0.22731103	0.1805117	0.00483513	-0.01089398	0.0111029	0.00286527
...	0.00232803	-0.00059693	0.25691877	0.1642752	0.01286385	-0.02557846	0.01098352	0.00322342
	0.0046859	-0.00131325	0.34096655	0.12034114	0.01602758	-0.03500996	0.00778994	0.00316373
	0.00662593	-0.00202956	0.22826612	0.11938605	0.01205799	-0.03891985	0.00140279	0.00235787
	0.0077004	-0.00289511	0.25023316	0.08977831	0.00280557	-0.04071064	-0.00781979	0.00149233
	0.00755117	-0.00399943	0.38299044	0.04393407	-0.00590961	-0.04369529	-0.018863	0.00074616
	0.00626777	-0.00531268	0.44029574	0.10792499	-0.00826748	-0.04900797	-0.02987636	0.00068647
	0.00399943	-0.00629761	0.5338944	0.12129622	-0.00188033	-0.05509666	-0.0372186	0.00131325
	0.00098493	-0.00665577	0.50333158	0.02005686	0.01083428	-0.05933487	-0.04005402	0.00289511
	-0.00214895	-0.00623792	0.43647539	-0.01146106	0.02298181	-0.05954379	-0.03972571	0.0046859
	-0.00492467	-0.00522314	0.46990348	-0.01241615	0.0282348	-0.05629052	-0.0393377	0.00629761
	-0.00713332	-0.00411882	0.29989775	-0.03629336	0.02333997	-0.05076892	-0.03981525	0.00707362
	-0.00865549	-0.00322342	0.1069699	0.03629336	0.01086413	-0.04282974	-0.04115834	0.00695424
	-0.00934196	-0.00286527	0.03151792	0.05061968	-0.00370097	-0.03139853	-0.04011371	0.00599915

Data in mm/s

Figure 2: Structure of a data file, example of first lines of Lyon-Alluvium 3D_z.dat : each column corresponds to a sensor, each line to a time step dt .

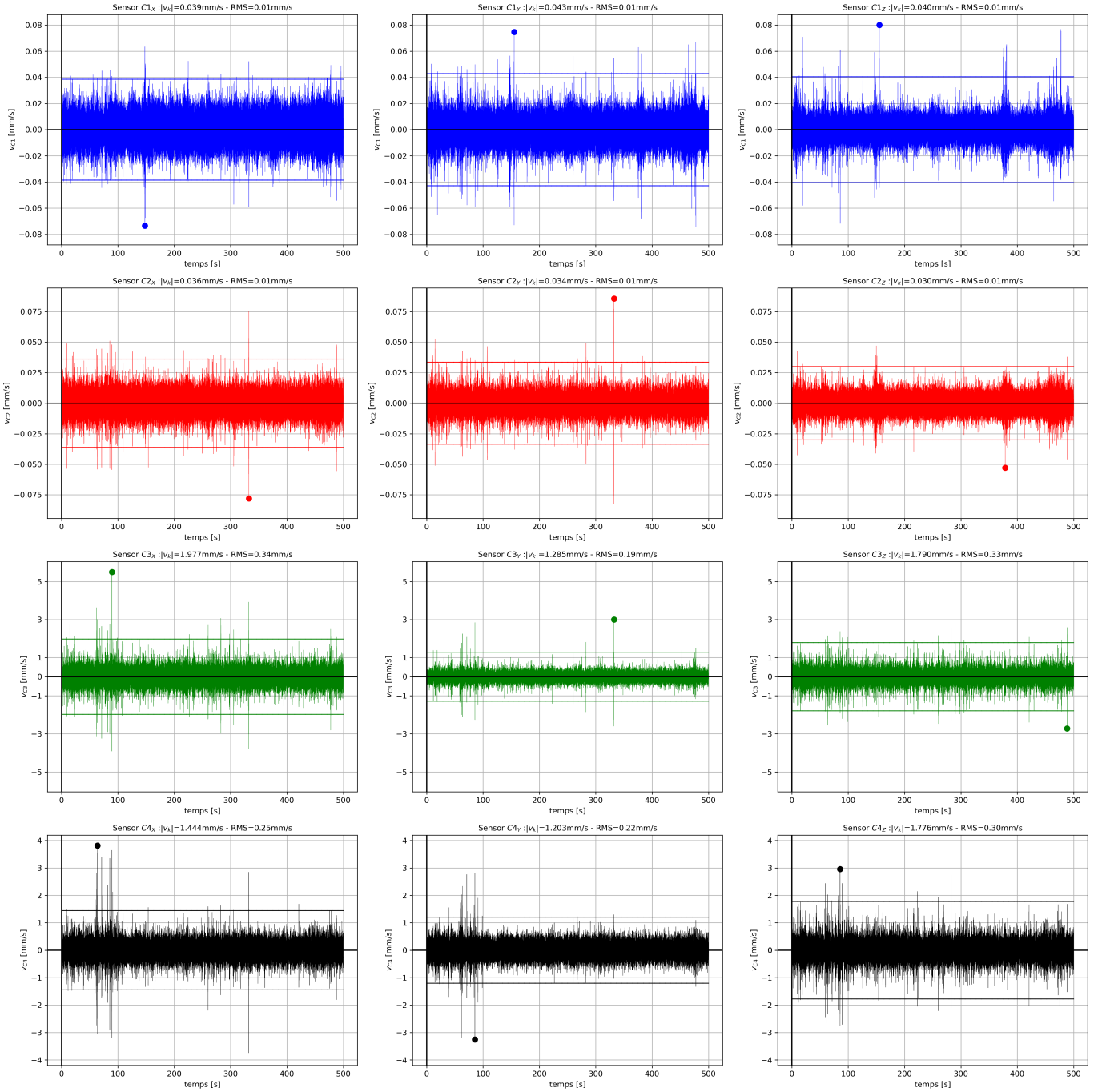


Figure 3: Lyon-Alluvium: time histories of 3D sensors (1/2).

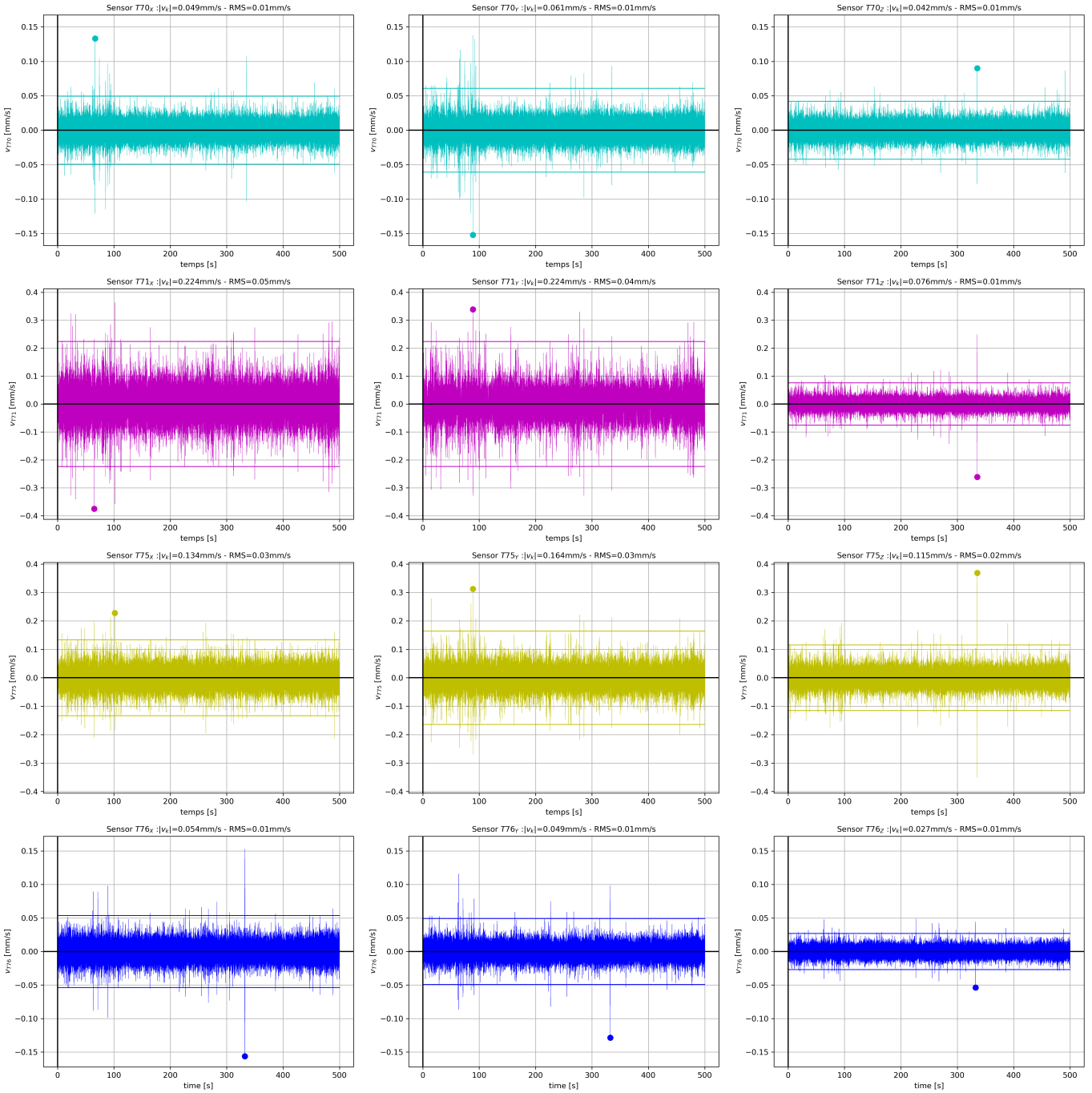


Figure 4: Lyon-Alluvium: time histories of 3D sensors (2/2).

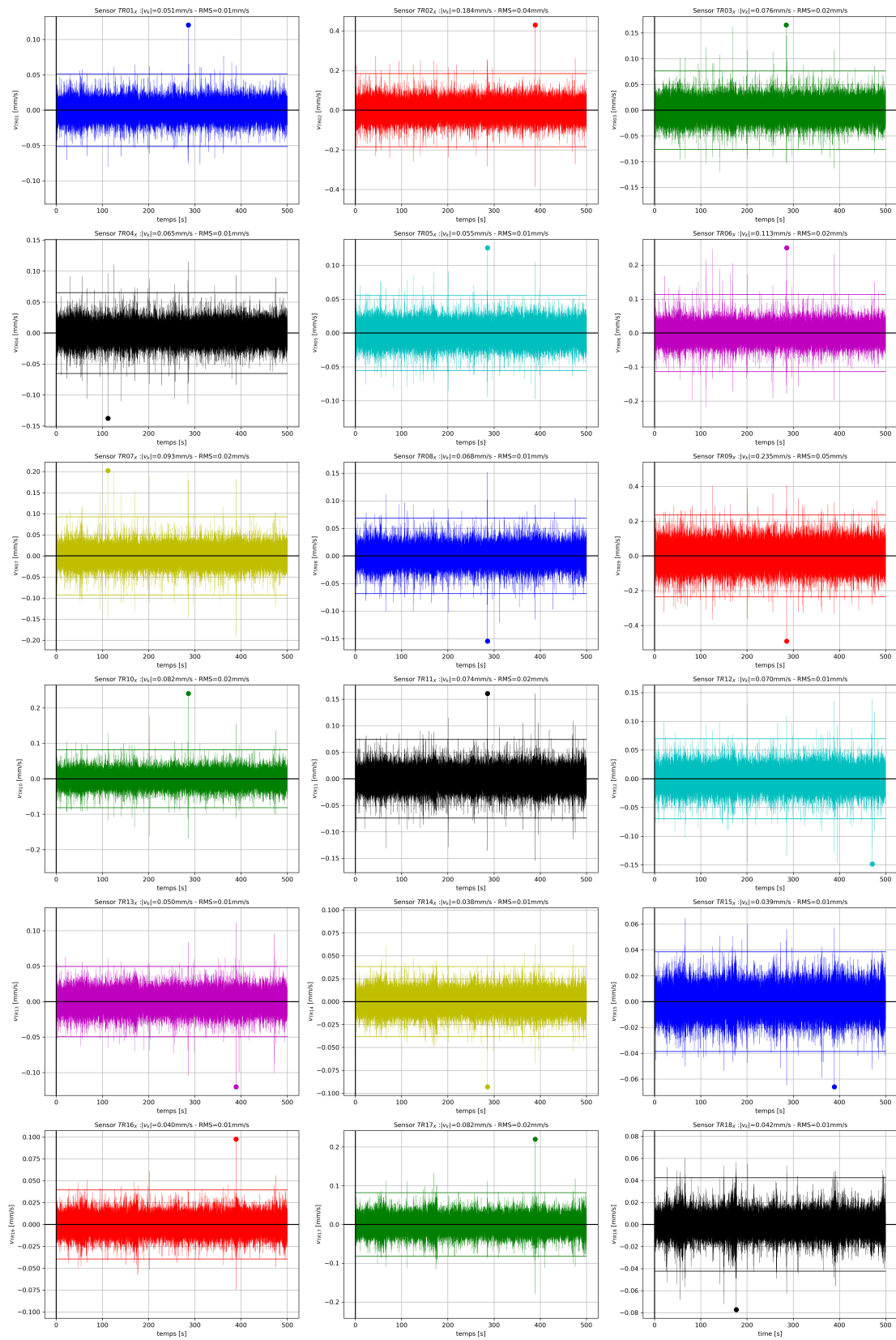


Figure 5: Lyon-Alluvium: time histories of 1D sensors.

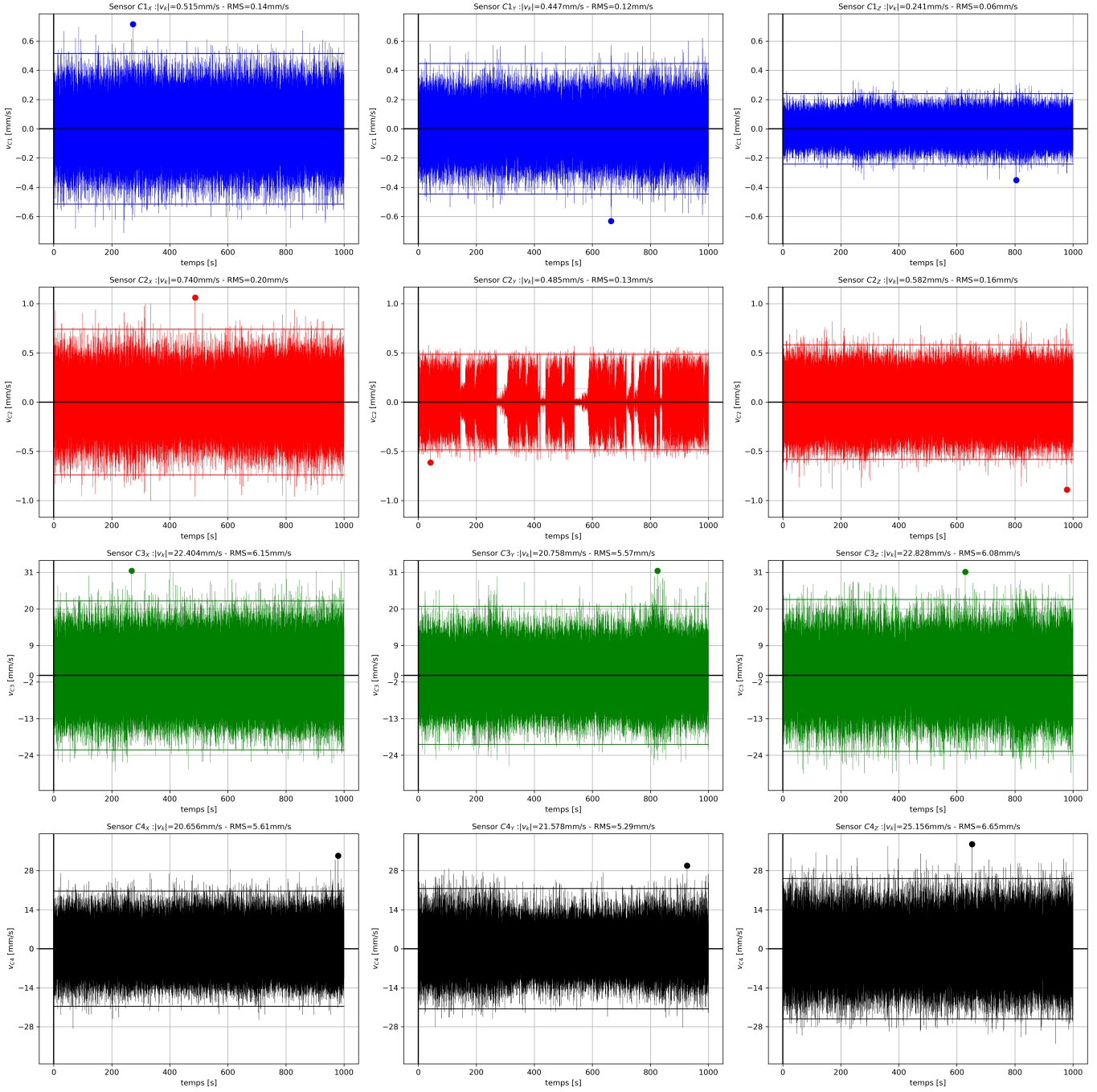


Figure 6: Lyon-Granite: time histories of 3D sensors (1/2).

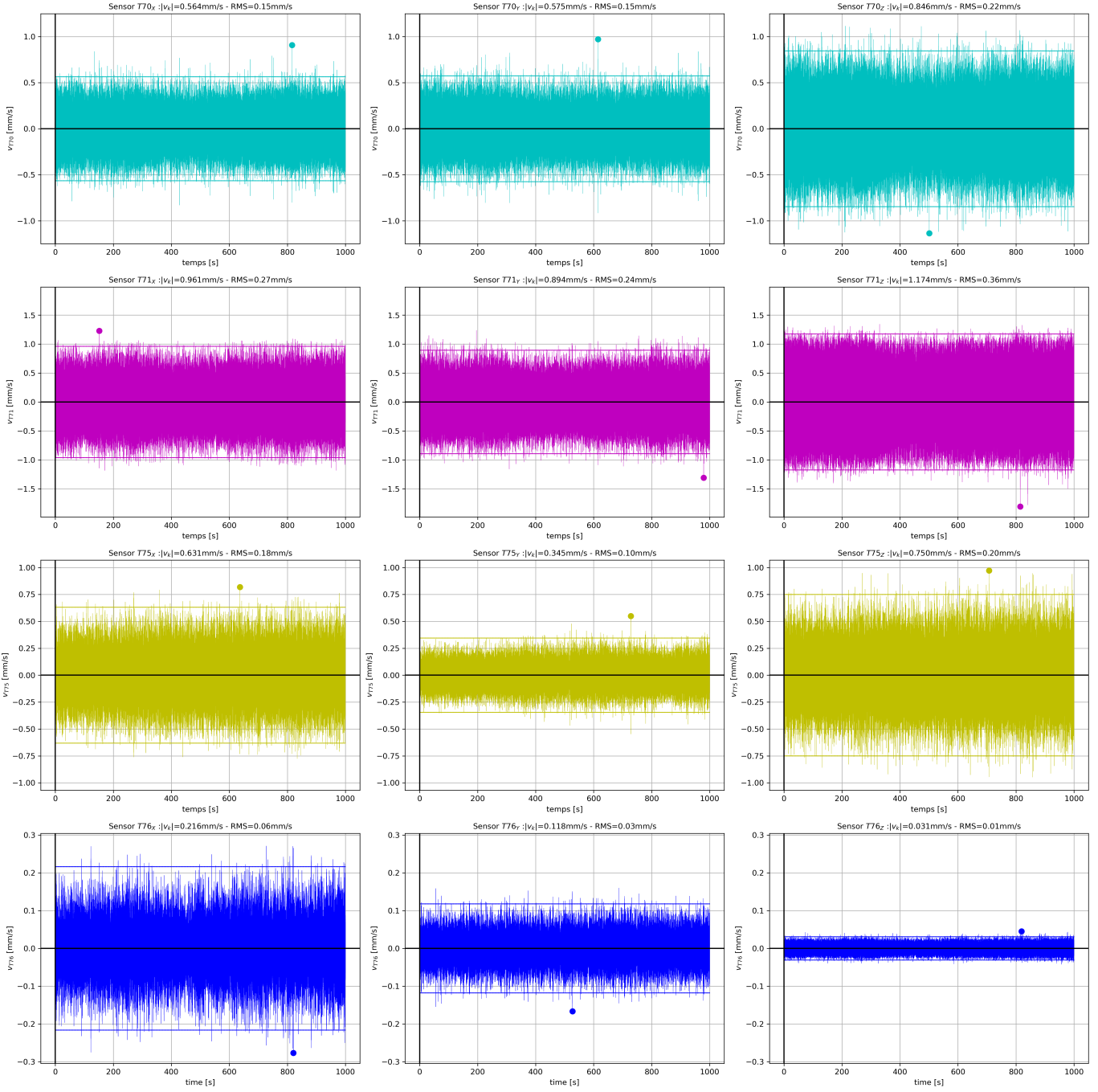


Figure 7: Lyon-Granite: time histories of 3D sensors (2/2).

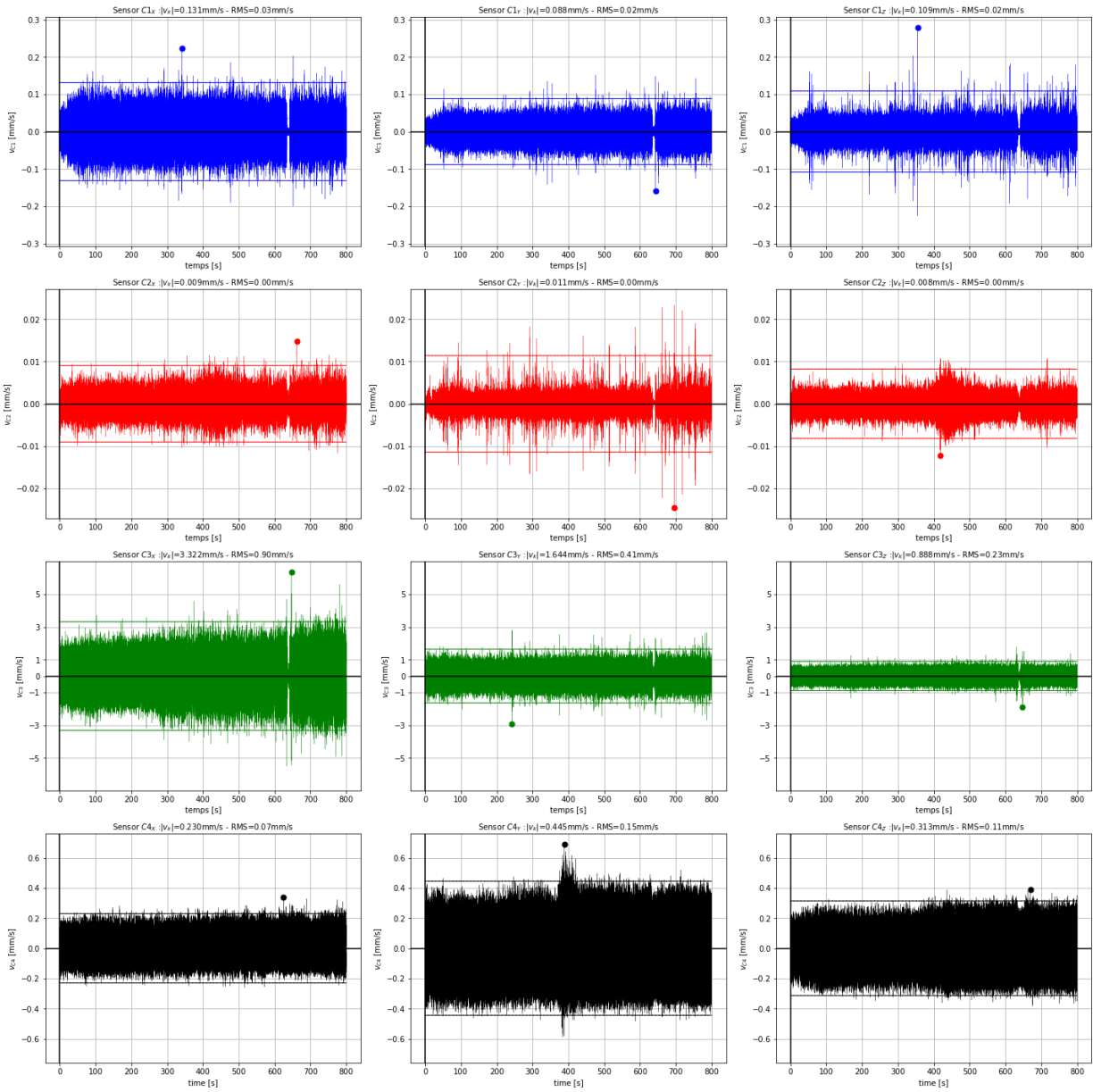


Figure 8: Sorgues: time histories of 3D sensors.

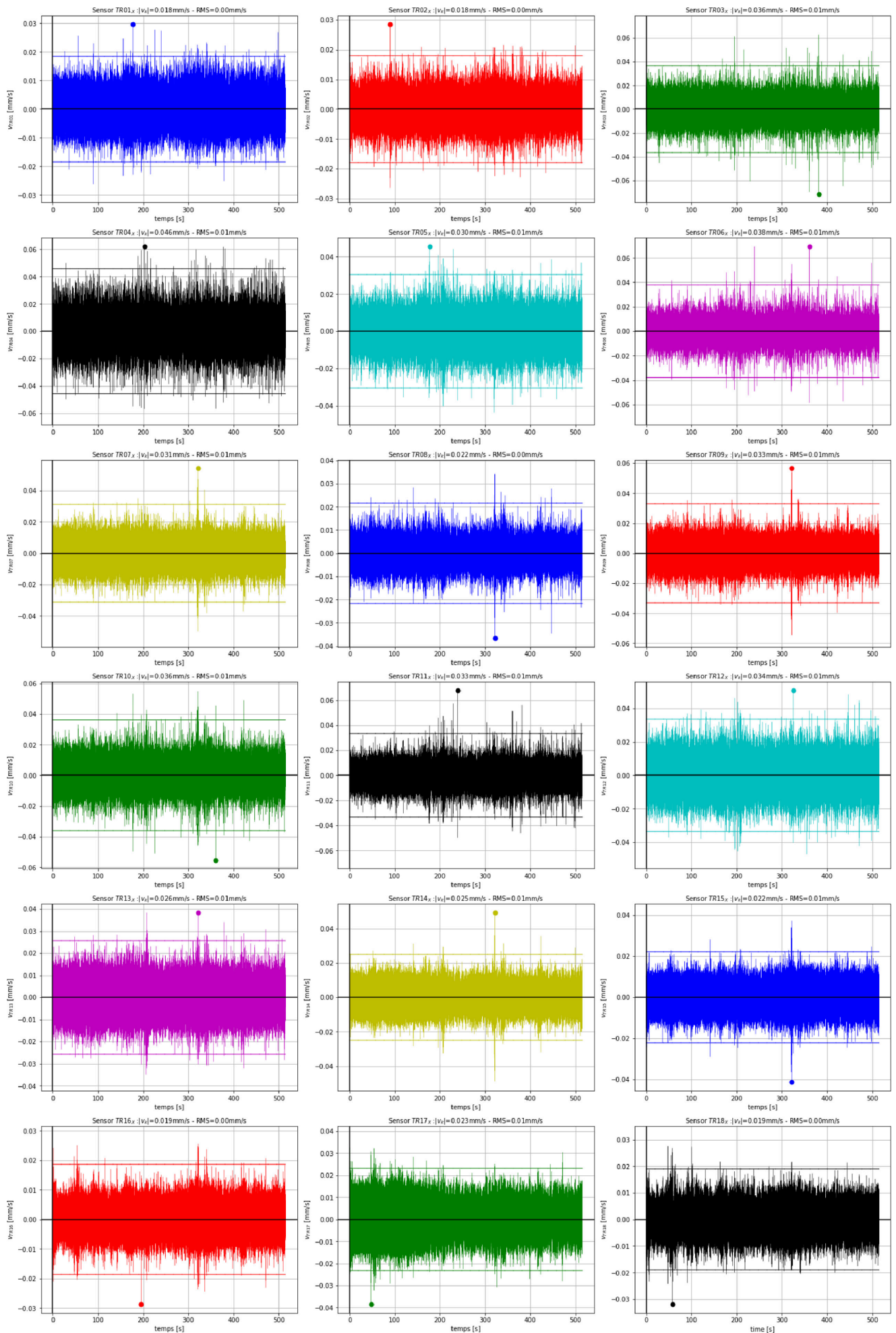


Figure 9: Sorgues: time₁ histories of 1D sensors.

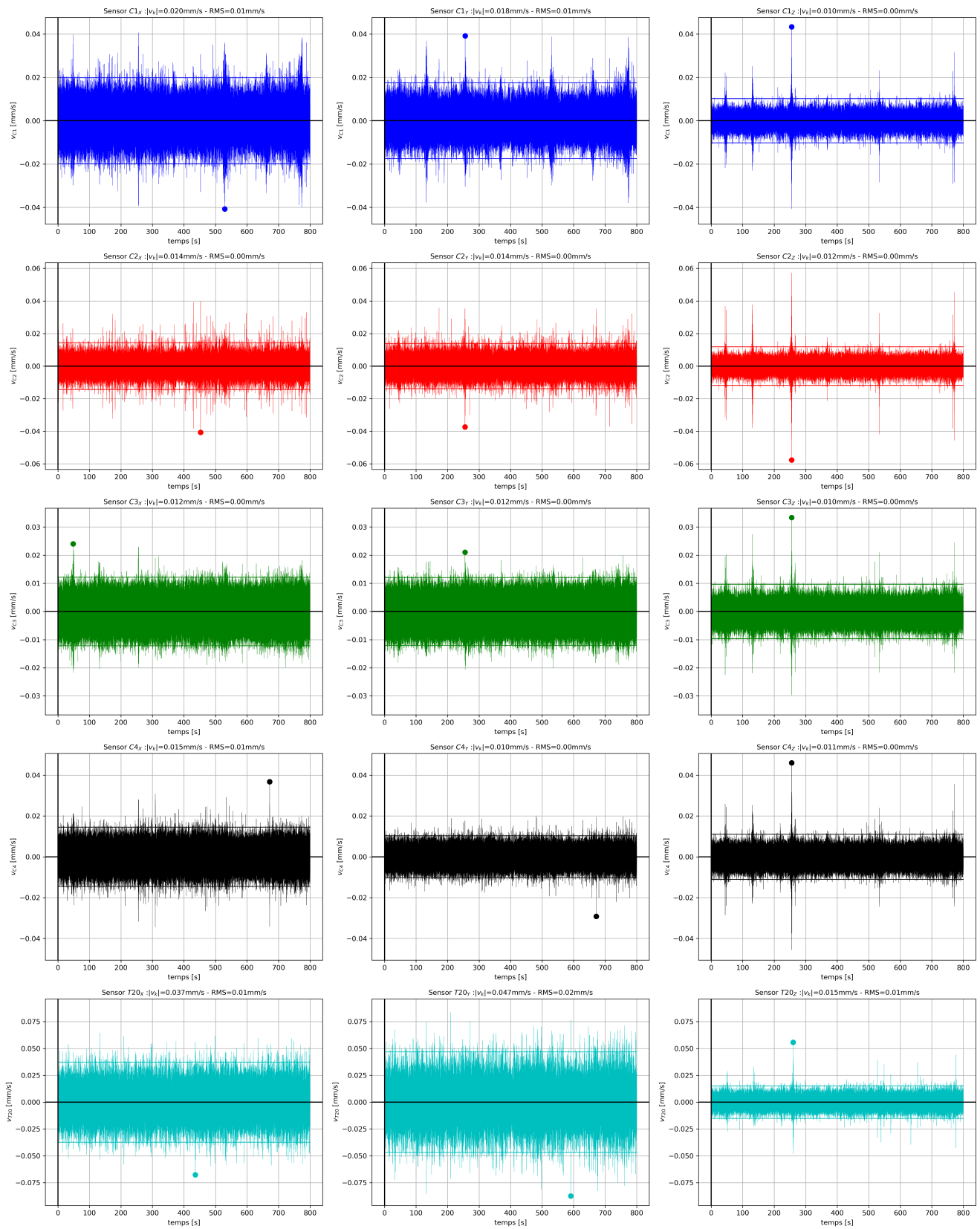


Figure 10: TULIP: time histories of 3D sensors(1/2).

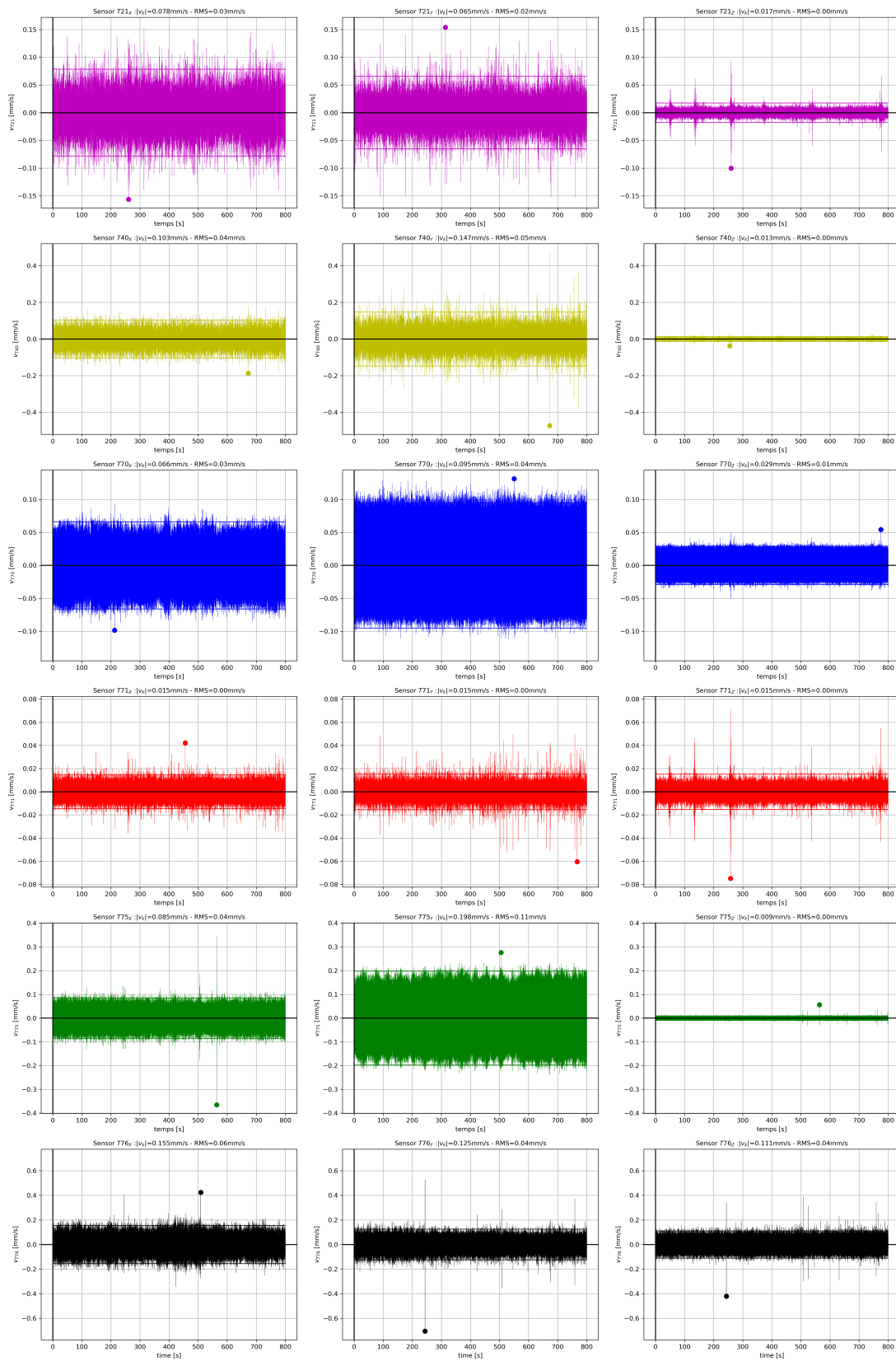


Figure 11: TULIP: time histories of 3D sensors(2/2).

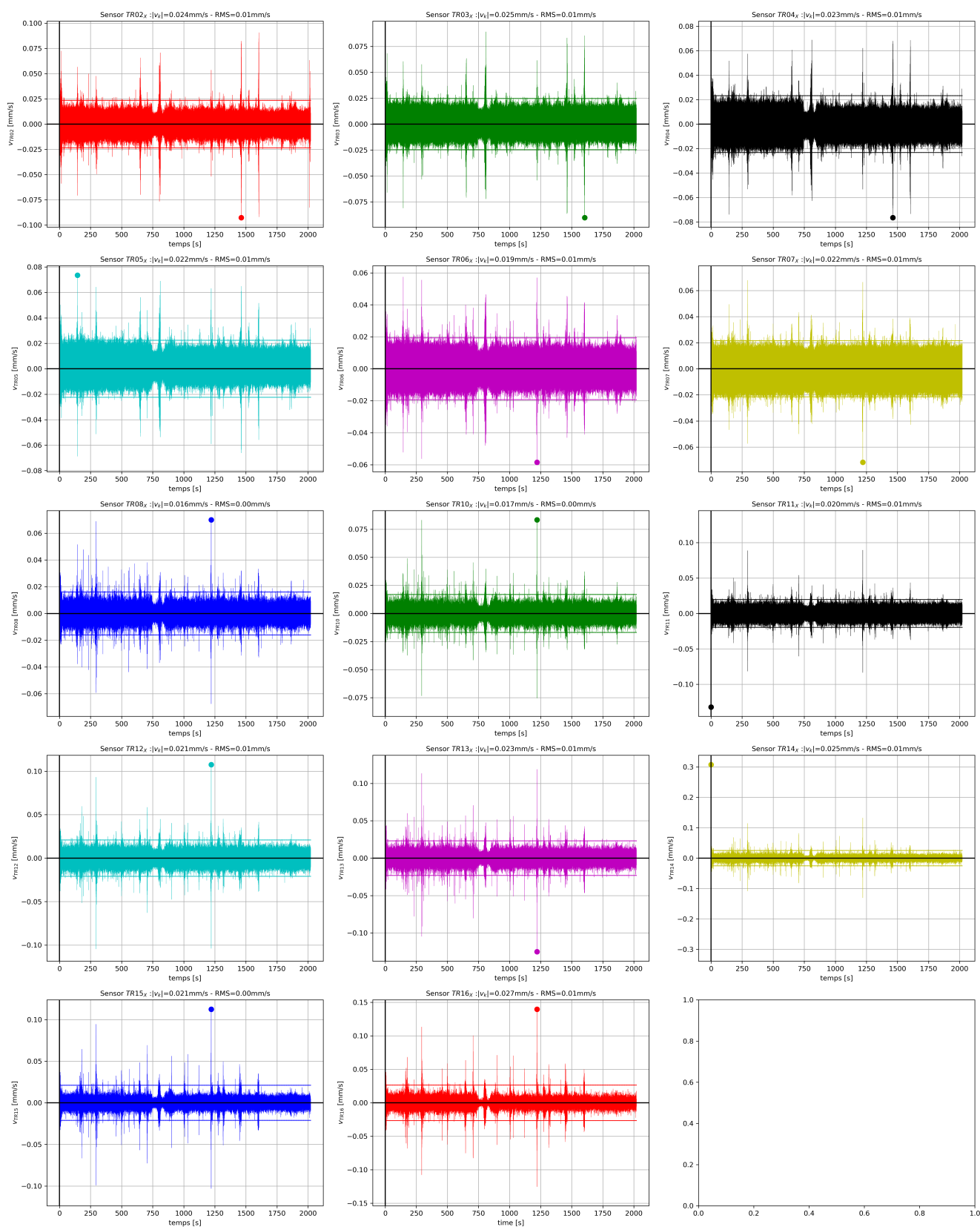


Figure 12: TULIP: time histories of 1D sensors.

3.1 Experimental set-up

All the sensors are geophones designed by Moho : 3D sensors refer to ©TROMINO devices (denoted C1, C2, C3, C4, T20, T21, T40, T70, T71, T75 and T76), and 1D sensors to ©Soilspy ROSINA devices (noted R01 to R18).

The 3D sensors are made of three orthogonal acquisition sensors for which the high-resolution (on the magnitude of $10^{-7}mm/s$) is designed to measure ambient noise : the three directions of the direct reference frame (X, Y, Z) refer respectively to tunnel axis, its the transverse direction and the vertical direction. Before each acquisition, all the ©TROMINO are synchronized by GPS then moved to their location. This is particularly true for the sensors inside de TBM, where no GPS signal can be received. Finally, due to the low vibration levels and the heavy weight of the sensors preventing them from coming off, these sensors are not sealed but only placed on the support (cement slab, ground or pile).

The ©Soilspy ROSINA device consists in several 1D vertical geophones (resolution about $4 \times 10^{-8}mm/s$.) physically linked to a computer used as an acquisition centre.

All the data acquired are exported in their rawest form (without additional filtering for example) to ascii files thanks to the software ©GRILLA, provided by Moho. Then the synchronization between 3D sensors and the restriction of the time histories had been performed in python.

3.2 Locations of the sensors

The four measurement sites are full presented in [1]. The locations of 1D and 3D sensors are given in [1] on the Figures 1,2,4,5. The distances d between each sensor and the centre of the cutting wheels are listed in Tables 3,4,5,6. These are derived ($d = \sqrt{x^2 + y^2 + z^2}$) from x, y, z representing respectively the longitudinal, transverse and elevation distance from to the tunnel axis from the cutting wheel axis. Note that all sensors are oriented in the direction and sense of of the tunnel (sensor parallel to the tunnel axis).

3D sensor	C1					C2					C3			C4				
$x[m]$	0.0					20.0					0.0			Close to the excavated material processing plant				
$y[m]$	0.0																	
$z[m]$	11.1					0.0					0.0							
$d[m]$	11.1					20.0					0.0							
1D sensor	R01	R02	R03	R04	R05	R06	R07	R08	R09	R10	R11	R12	R13	R14	R15	R16	R17	R18
$x[m]$	17.5	12.5	7.5	4.5	0.0	-5.0	-10.0	-15.0	-10.0	-5.0	0.0							
$y[m]$	0.0										5.0	10.0	15.0	20.0	25.0	30.0	35.0	
$z[m]$	9.8					11.1												
$d[m]$	20.1	15.9	12.3	12.4	11.1	12.2	14.9	18.7	14.9	12.2	11.1	12.2	14.9	18.7	22.9	27.4	32.0	36.7

Table 3: Locations of sensors to the cutter head of the Sorgues measurements.

3D sensor	C1	C2	C3	C4	T70	T71	T75	T76										
$x[m]$	-57.0	-42.0	-2.0	-2.0	-22.0	7.0	22.0	46.0										
$y[m]$	-7.0	-6.0	1.5	-1.5	-5.0	-4.0	-2.0	3.0										
$z[m]$	26.0		1.5		26.0													
$d[m]$	63.0	49.8	2.9	2.9	34.4	27.2	34.1	52.9										
1D sensor	R01	R02	R03	R04	R05	R06	R07	R08	R09	R10	R11	R12	R13	R14	R15	R16	R17	R18
$x[m]$	-20.0	-21.0	-22.0	-17.0	-12.0	-7.0	-2.0	3.0	8.0	13.0	18.0	23.0	28.0	33.0	38.0	43.0	46.0	50.0
$y[m]$	-22.0	-17.0	-12.0	-11.0	-10.0	-8.0	-7.0	-6.0	-5.0	-3.0	-2.0	-1.0	1.0	2.0	3.0	4.0	3.0	3.0
$z[m]$	26.0																	
$d[m]$	39.5	37.5	36.1	32.9	30.2	28.1	27.0	26.8	27.6	29.3	31.8	34.9	38.4	42.2	46.4	50.4	52.9	56.0

Table 4: Locations of sensors to the cutter head of the Lyon-alluvium measurements.

3D sensor	C1	C2	C3	C4	T70	T71	T75	T76
$x[m]$	-40.0	-20.0	-2.0	-2.0	0.0	30.0	55.0	85.0
$y[m]$	0.0							
$z[m]$	20.0	24.0	1.5	1.5	25.0	30.0	30.0	30.0
$d[m]$	45.0	31.0	2.0	2.0	25.0	44.0	63.0	90.0

Table 5: Locations of sensors to the cutter head of the Lyon-granite measurements.

3D sensor	C1	C2	C3	C4	T20	T21	T40	T70	T71	T75	T76			
$x[m]$	0.0	0.0	9.9	9.9	-9.9	26.2	-9.9	5.0	10.8	-17.0	-3.0			
$y[m]$	-7.0	-8.6	9.9	8.2	-1.5	0.0	33.5	8.2	0.0	0.0	-4.0			
$z[m]$	22.5									-4.5	2.0			
$d[m]$	23.6	24.1	26.5	25.9	24.6	34.5	41.6	24.5	25.0	17.6	5.4			
1D sensor	R02	R03	R04	R05	R06	R07	R08	R10	R11	R12	R13	R14	R15	R16
$x[m]$	-9.9							-5.5	1.0	6.0	10.8	16.2	21.3	26.2
$y[m]$	33.5	30.5	25.2	19.6	15.0	9.4	4.7	0.0						
$z[m]$	22.5													
$d[m]$	41.6	39.2	35.2	31.4	28.8	26.3	25.0	23.2	22.5	23.3	25.0	27.7	31.0	34.5

Table 6: Locations of sensors to the cutter head of the TULIP measurements.

Following Figure 1, each measurement campaign (except for Sorgues) is split in two set of acquisitions (i) a measurement phase carried out before excavation, under ambient mechanical noise: in particular road and pedestrian traffic, and rotating machines (in particular the generator of the TULIP project presented in [1]§2.4), (ii) a measurement phase during the excavation phase, with synchronous acquisitions between the sensors on the surface and in the TBM. The latter are positioned as close as possible to the cutting wheel, mainly in the TBM's manlocks.

Ethics Statement

The present work did not involve the use of human subjects, animal experiments, or data collected from social media platforms.

CRedit author statement

Antoine RALLU: Conceptualization, Methodology, Software, Formal analysis, Investigation, Data curation, Writing - Original Draft **Nicolas BERTHOZ**: Conceptualization, Methodology, Formal analysis, Investigation, Writing - Review & Editing

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] A. Rallu, N. Berthoz, S. Charlemagne, and D. Branque, "Vibrations induced by Tunnel Boring Machines in urban areas: in-situ measurements and methodology of analysis.", *Rock Mech. Rock Eng.*, in Press