ANEJOS

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ANEJO A Archivos de RockGIS y mini-manual de usuario (versión diciembre 2021)

Archivos "parameters.txt":

Laja de Oliver:

```
## Path to input/output files
DEM_path = C:\\Users\\xcili\\Desktop\\Tesis\\Oliver\\DEM2X2CORTADO.txt
Sources_path = C:\\Users\\xcili\\Desktop\\Tesis\\Oliver\\sources.txt
Trajectories_path = C:\\Users\\xcili\\Desktop\\Tesis\\Output\\Vuelco\\Entero\\T_DG_5.csv
Stoppages_path = C:\\Users\\xcili\\Desktop\\Tesis\\Output\\Vuelco\\Entero\\S_DG_5.csv

## Cinematic parameters
TimeStep = 0.01 # Timestep for the parabolic flight [s]
StopVelocity = 0.1 # Stopping velocity criterion [m/s]
Kna = 19.5 # Multiplier of the power law relating the normal impact velocity with the normal restitution coefficient [-]
Knb = -1.03 # Exponent of the power law relating the normal impact velocity with the normal restitution coefficient [-]
Kta =150.0 # Parameter that controls the hyperbolic function for the tangential restitution coefficient [-]
KtRough = 0.15 # Controls roughnes variability when computing tangentian COR depending on volume [0-0.8]

RockDensity = 2500 # Rock density [kg/m³]
DragLayerHeigh = 2.5 # Height of the drag layer [m]
DragSpeedLimit = 50.0 # Maximum velocity at what drag force is applyed [m/s]
DragCoeficient = 5 # Acceletation in oposite direction of the velocity for stoppage [m/s2]

## Fragmentation parameters
r_variant = 0.0 # Scale variant power laws controlling parameter [0.0=scala invariant, >0 scale invariant]
na1 = 0.0031 # na1 and na2 control the power law relating the normal impact remaining energy andthe new area [-]
na2 = 0.7562
b1 = -1.6125 # b1 and b2 control fractal dimension when fragmenting depending on new area/total area ratio
b2 = 2.4875
q1 = -0.5125 # q1 and q2 control survival probability
q2 = 1.0
MinAreaRatio = 0.25 # Minim ratio between new area and total area to triger fragmentation [USUAL: 0.25. To disable fragmentation: 9999]
```

VminFrag = 0.00003 # Minimum fragment to consider when generating new fragments [m³]
Cone = 30.0 # Cone total oberture angle [º]
LimitAngle = 1.0 # Minimum accepted angle between cone output and terrain surface [º]

Stochastic control
InitialSeed = 15321 # Seed for stochasticity [int]
AspectVar = 4.0 # Random variation range on local Aspect at impact [º]
SlopeVar = 4.0 # Random variation range on local Slope at impact [º]

Program configuration
PrintMode = 0 # Prints in terminal details of the computation [1=True, 0=False]
StoreTrajectories = 1 # Stores full trajectories on selected file [1=True, 0=False]

Bloque de Esperon:

Path to input/output files
DEM_path = C:\\Users\\xcili\\Desktop\\Tesis\\Esperon\\Rockgis\\DEM2X2CORTADO.txt
Sources_path = C:\\Users\\xcili\\Desktop\\Tesis\\Esperon\\Rockgis\\sources.txt
Trajectories_path = C:\\Users\\xcili\\Desktop\\Tesis\\Esperon\\Output\\T.csv
Stoppages_path = C:\\Users\\xcili\\Desktop\\Tesis\\Esperon\\Output\\S.csv

Cinematic parameters
TimeStep = 0.01 # Timestep for the parabolic flight [s]
StopVelocity = 0.1 # Stopping velocity criterion [m/s]
Kna = 19.5 # Multiplier of the power law relating the normal impact velocity with the normal restitution coefficient [-]
Knb = -1.03 # Exponent of the power law relating the normal impact velocity with the normal restitution coefficient [-]
Kta =150.0 # Parameter that controls the hyperbolic function for the tangential restitution coefficient [-]
KtRough = 0.15 # Controls roughnes variability when computing tangentian COR depending on volume [0-0.8]

RockDensity = 2500 # Rock density [kg/m³]
DragLayerHeigh = 0 # Height of the drag layer [m]
DragSpeedLimit = 50.0 # Maximum velocity at what drag force is applyed [m/s]
DragCoeficient = 0 # Acceletation in oposite direction of the velocity for stoppage [m/s2]

Fragmentation parameters
r_variant = 0.0 # Scale variant power laws controlling parameter [0.0=scala invariant, >0 scale invariant]

na1 = 0.0031 # na1 and na2 control the power law relating the normal impact remaining energy andthe new area [-]
na2 = 0.7562
b1 = -1.6125 # b1 and b2 control fractal dimension when fragmenting depending on new area/total area ratio
b2 = 2.4875
q1 = -0.5125 # q1 and q2 control survival probability
q2 = 1.0
MinAreaRatio = 0.25 # Minim ratio between new area and total area to triger fragmentation [USUAL: 0.25. To disable fragmentation: 9999]
VminFrag = 0.00003 # Minimum fragment to consider when generating new fragments [m³]
Cone = 30.0 # Cone total oberture angle [º]
LimitAngle = 1.0 # Minimum accepted angle between cone output and terrain surface [º]

Stochastic control
InitialSeed = 15321 # Seed for stochasticity [int]
AspectVar = 4.0 # Random variation range on local Aspect at impact [º]
SlopeVar = 4.0 # Random variation range on local Slope at impact [º]

Program configuration
PrintMode = 0 # Prints in terminal details of the computation [1=True, 0=False]
StoreTrajectories = 1 # Stores full trajectories on selected file [1=True, 0=False]

Archivos “sources.txt”:

Laja de Oliver
Caída sin fragmentación:

OLIVER
Rx = 399263.01
Ry = 4607671.34
Hz = 20.0
Vx = -1.0
Vy = 0.23
Vz = 0.0
NumBlocks = 10
15.2
%%

Caída con fragmentación

OLIVER
Rx = 399263.01
Ry = 4607671.34

Hz = 20.0
Vx = -1.0
Vy = 0.23
Vz = 0.0
NumBlocks = 10
7.5,4,1.5,1.5,0.7
%%

Bloque de Esperon:

Caída sin fragmentación inicial:
ESPERON
Rx = 399236.60
Ry = 4607658.89
Hz = 0.0
Vx = -1.0
Vy = 0.23
Vz = 0.0
NumBlocks = 10
40
%%

Caída con fragmentación inicial:
ESPERON
Rx = 399236.60
Ry = 4607658.89
Hz = 0.0
Vx = -1.0
Vy = 0.23
Vz = 0.0
NumBlocks = 10
20,10,5,2.5,2.5
%%

Archivo DEM.txt (muestra):

ncols	453
nrows	531
xllcorner	398564.000000000000
yllcorner	4607488.000000000000
cellsize	2.000000000000
NODATA_value	-9999

-9999	-9999	.	.	.	.	-9999	-9999
-9999	-9999					-9999	-9999
.		.			.		.
.			466,65	467,73			.
.			467,64	468,82			.
.		.			.		.

-9999	-9999					-9999	-9999
-9999	-9999	.	.	.	.	-9999	-9999

Mini manual del uso de RockGIS:

El uso de RockGIS consta de tres archivos:

- RockGIS.exe
- Parameters.txt
- Soures.txt

EL archivo parameters.txt contiene la información del escenario que se va a modelar, es decir:

- Control de la fragmentación

```
## Fragmentation parameters

r_variant = 0.0                # Scale variant power laws controlling parameter [0.0=scala invariant, >0 scale
invariant]
na1 = 0.0031                   # na1 and na2 control the power law relating the normal impact remaining energy
andthe new area [-]
na2 = 0.7562
b1 = -1.6125                   # b1 and b2 control fractal dimension when fragmenting depending on new area/total
area ratio
b2 = 2.4875
q1 = -0.5125                   # q1 and q2 control survival probability
q2 = 1.0
MinAreaRatio = 0.25            # Minim ratio between new area and total area to triger fragmentation [USUAL: 0.25.
To disable fragmentation: 9999]
VminFrag = 0.00003             # Minimum fragment to consider when generating new fragments [m³]
Cone = 30.0                    # Cone total oberture angle [º]
LimitAngle = 1.0               # Minimum accepted angle between cone output and terrain surface [º]
```

- Control estocástico

```
## Stochastic control

InitialSeed = 15321            # Seed for stochasticity [int]
AspectVar =  4.0               # Random variation range on local Aspect at impact [º]
SlopeVar = 4.0                 # Random variation range on local Slope at impact [º]
```

- Control de la vegetación

```
DragLayerHeigh = 2.5           # Height of the drag layer [m]
DragSpeedLimit = 50.0          # Maximum velocity at what drag force is applyed [m/s]
DragCoeficient = 5             # Acceletation in oposite direction of the velocity for stoppage [m/s2]
```

El control de la vegetación es de especial cuidado pues no se tiene registro a lo que va de este trabajo sobre un uso anterior.

El “drag coeficient” es una aceleración en la dirección opuesta a la del bloque. Cambios de tan solo 1 m/s pueden impactar significativamente en la propagación del bloque por lo que se recomienda calibrar el valor con un desprendimiento de propagación conocida y volumen conocido o estimado para obtener un coeficiente representativo de la zona.

Para realizar la calibración se recomienda tomar como parámetros la propagación longitudinal y transversal del bloque, así como la ubicación de su centro de masa.

- Rutas de input y output

```
## Path to input/output files

DEM_path = C:\\Users\\xcili\\Desktop\\Tesis\\Oliver\\DEM2X2CORTADO.txt
Sources_path = C:\\Users\\xcili\\Desktop\\Tesis\\Oliver\\sources.txt
Trajectories_path = C:\\Users\\xcili\\Desktop\\Tesis\\Output\\Vuelco\\Entero\\T_DG_5.csv
Stoppages_path = C:\\Users\\xcili\\Desktop\\Tesis\\Output\\Vuelco\\Entero\\S_DG_5.csv
```

- Control cinemático del bloque

```
## Cinematic parameters

TimeStep = 0.01                 # Timestep for the parabolic flight [s]
StopVelocity = 0.1              # Stopping velocity criterion [m/s]
Kna = 19.5                      # Multiplier of the power law relating the normal impact velocity with the normal
restitution coefficient [-]
Knb = -1.03                     # Exponent of the power law relating the normal impact velocity with the normal
restitution coefficient [-]
Kta =150.0                      # Parameter that controls the hyperbolic function for the tangential restitution
coefficient [-]
KtRough = 0.15                  # Controls roughnes variability when computing tangentian COR depending on volume
[0-0.8]
```

El usuario debe configurar dentro del archivo .txt cada uno de los parámetros que desee cambiar o dejar default.

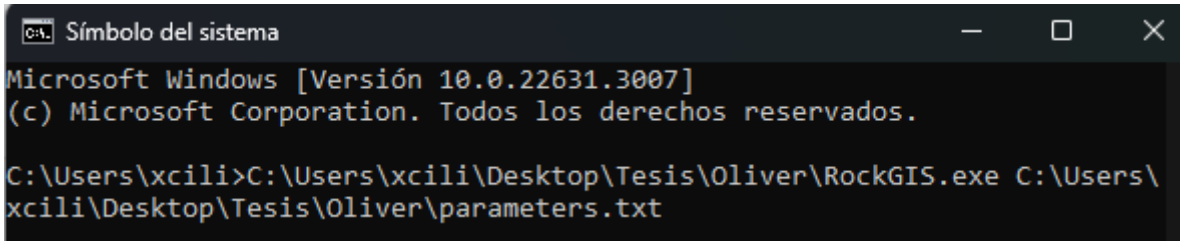
El archivo sources.txt contiene los parámetros propios del bloque, es decir, su ubicación, velocidad de salida, volumen y distribución del mismo.

```
## OLIVER
Rx = 399263.01
Ry = 4607671.34
Hz = 20.0
Vx = -1.0
Vy = 0.23
Vz = 0.0
NumBlocks = 10
7.5,4,1.5,1.5,0.7
%%
```

El usuario debe editar él .txt según la información disponible del bloque que quiere modelar.

Una vez el archivo parameters.txt y sources.txt se encuentran listos se debe abrir la consola de comando o “Símbolo del sistema”.

Dentro de la consola debe escribirse la ruta del ejecutable RockGIS.exe, seguido de un espacio y la ruta del archivo parameters.txt, una manera más fácil es arrastrar los archivos desde la carpeta en la que se ubican, siempre teniendo cuidado de dejar el espacio entre ambos archivos.



Una vez se tenga el comando listo se ejecuta haciendo “enter”. Los archivos de salida se escribirán en la ruta que se haya especificado en el archivo parameters.txt. El output consta de dos archivos .csv, uno contendrá la información de cada paso de tiempo de los bloques modelados y otro la información del lugar de detención d ellos bloques.

Estos archivos se pueden trabajar en sistemas de información geográfica, programas de nubes de puntos y similares.

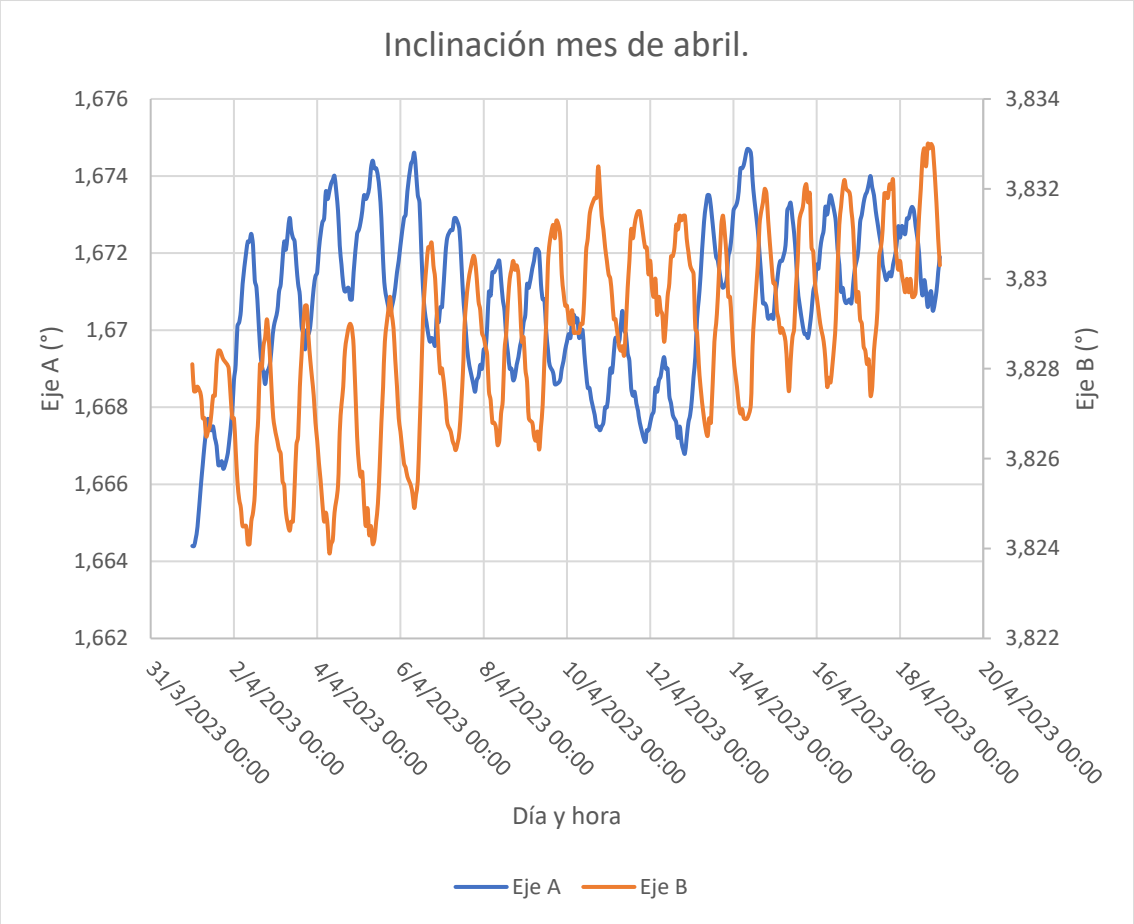
ANEJO B: Archivos de datos de clinometría del INC15 situado en la cabecera de laja Oliver

Muestra de datos obtenidos directamente del sensor:

Node ID	**20100**	
Gateway ID	21901	
Model,"LS-G6-INC15"		
Hw version		
Fw version		
Location Lat		
Location Lon		
Created time,"2023-02-11 17:00:38"		
Timezone,"Europe/Madrid"		
Date and time	Eje A (°)	Eje B (°)
1/4/2023 00:00	1,6644	3,8281
1/4/2023 01:00	1,6644	3,8275
1/4/2023 02:00	1,6646	3,8275
1/4/2023 03:00	1,6649	3,8276
1/4/2023 05:00	1,666	3,8274
1/4/2023 06:00	1,6665	3,8269
1/4/2023 07:00	1,667	3,8269
1/4/2023 08:00	1,6674	3,8265
1/4/2023 09:00	1,6677	3,8266
1/4/2023 10:00	1,6675	3,8267
1/4/2023 11:00	1,6674	3,827
1/4/2023 12:00	1,6675	3,8274

1/4/2023 13:00	1,6672	3,8274
1/4/2023 14:00	1,667	3,8281
1/4/2023 15:00	1,6665	3,8284
1/4/2023 16:00	1,6665	3,8284
1/4/2023 17:00	1,6666	3,8283
1/4/2023 18:00	1,6664	3,8282
1/4/2023 20:00	1,6667	3,8281
1/4/2023 21:00	1,667	3,828
1/4/2023 23:00	1,6679	3,8269
2/4/2023 00:00	1,6687	3,8269
2/4/2023 01:00	1,6691	3,8262
2/4/2023 02:00	1,6701	3,8255
2/4/2023 03:00	1,6702	3,8251
2/4/2023 04:00	1,6705	3,8249
2/4/2023 05:00	1,6712	3,8245
2/4/2023 07:00	1,672	3,8245
2/4/2023 08:00	1,6723	3,8241
2/4/2023 09:00	1,6723	3,8241
2/4/2023 10:00	1,6725	3,8246
2/4/2023 11:00	1,6722	3,8248
2/4/2023 12:00	1,6713	3,8252
2/4/2023 13:00	1,6711	3,8263
2/4/2023 14:00	1,6704	3,8269
2/4/2023 15:00	1,6696	3,8281
2/4/2023 16:00	1,6691	3,828
2/4/2023 17:00	1,6689	3,8285
2/4/2023 18:00	1,6686	3,8287

2/4/2023 19:00	1,6689	3,8291



Muestra de estadística realizada con los datos:

					(°)			
	Min A	**Min B**	**Max A**	**Max B**	**Rango A**	**Rango B**	**StdDevp of Eje A**	**StdDevp of Eje B**
11/02/23	1,670	3,817	1,671	3,818	0,001	0,001	0,000	0,000
12/02/23	1,670	3,816	1,673	3,819	0,003	0,003	0,001	0,001
13/02/23	1,667	3,817	1,672	3,820	0,004	0,003	0,001	0,001
14/02/23	1,667	3,818	1,670	3,820	0,003	0,003	0,001	0,001
15/02/23	1,665	3,819	1,668	3,822	0,003	0,003	0,001	0,001
16/02/23	1,666	3,818	1,669	3,821	0,004	0,003	0,001	0,001
17/02/23	1,664	3,819	1,667	3,823	0,004	0,004	0,001	0,001
18/02/23	1,663	3,820	1,666	3,823	0,003	0,003	0,001	0,001
19/02/23	1,664	3,820	1,666	3,823	0,002	0,003	0,001	0,001
20/02/23	1,663	3,820	1,665	3,822	0,002	0,002	0,001	0,001
21/02/23	1,664	3,819	1,666	3,822	0,003	0,003	0,001	0,001

22/02/23	1,664	3,819	1,666	3,823	0,002	0,004	0,001	0,001
23/02/23	1,666	3,820	1,667	3,821	0,001	0,002	0,000	0,001
24/02/23	1,666	3,819	1,671	3,822	0,005	0,003	0,001	0,001
25/02/23	1,668	3,818	1,671	3,823	0,003	0,004	0,001	0,001
26/02/23	1,668	3,819	1,672	3,822	0,003	0,003	0,001	0,001
27/02/23	1,670	3,818	1,673	3,821	0,003	0,003	0,001	0,001
28/02/23	1,671	3,818	1,674	3,822	0,003	0,003	0,001	0,001
01/03/23	1,673	3,816	1,676	3,819	0,003	0,003	0,001	0,001
02/03/23	1,672	3,817	1,675	3,822	0,003	0,005	0,001	0,002
03/03/23	1,671	3,818	1,675	3,822	0,004	0,004	0,001	0,001
04/03/23	1,670	3,818	1,674	3,822	0,004	0,003	0,001	0,001
05/03/23	1,668	3,820	1,672	3,824	0,004	0,004	0,001	0,001
06/03/23	1,667	3,821	1,670	3,824	0,003	0,003	0,001	0,001
07/03/23	1,665	3,820	1,669	3,826	0,005	0,005	0,002	0,002
08/03/23	1,662	3,823	1,665	3,825	0,003	0,003	0,001	0,001
09/03/23	1,661	3,822	1,663	3,824	0,002	0,002	0,001	0,000
10/03/23	1,661	3,822	1,664	3,824	0,003	0,002	0,001	0,001
11/03/23	1,660	3,823	1,662	3,824	0,002	0,002	0,001	0,000
12/03/23	1,660	3,823	1,662	3,825	0,002	0,002	0,001	0,001
13/03/23	1,659	3,824	1,661	3,826	0,002	0,002	0,001	0,001
14/03/23	1,660	3,823	1,664	3,825	0,005	0,002	0,001	0,001
15/03/23	1,664	3,822	1,668	3,825	0,004	0,003	0,001	0,001
16/03/23	1,665	3,822	1,669	3,826	0,004	0,004	0,001	0,001
17/03/23	1,665	3,822	1,669	3,827	0,004	0,005	0,001	0,001
18/03/23	1,664	3,823	1,669	3,828	0,005	0,005	0,002	0,002
19/03/23	1,663	3,825	1,667	3,828	0,003	0,003	0,001	0,001
20/03/23	1,664	3,824	1,667	3,828	0,003	0,004	0,001	0,001
21/03/23	1,663	3,824	1,667	3,829	0,004	0,005	0,001	0,002
22/03/23	1,662	3,825	1,666	3,828	0,004	0,003	0,001	0,001
23/03/23	1,662	3,826	1,664	3,828	0,002	0,002	0,001	0,001
24/03/23	1,662	3,826	1,664	3,829	0,002	0,003	0,001	0,001
25/03/23	1,662	3,826	1,665	3,829	0,003	0,002	0,001	0,001
26/03/23	1,663	3,827	1,664	3,828	0,002	0,001	0,001	0,000
27/03/23	1,664	3,825	1,668	3,828	0,004	0,003	0,001	0,001
28/03/23	1,667	3,825	1,669	3,828	0,002	0,003	0,001	0,001
29/03/23	1,664	3,825	1,669	3,829	0,004	0,004	0,002	0,001
30/03/23	1,664	3,826	1,666	3,829	0,003	0,003	0,001	0,001
31/03/23	1,664	3,828	1,665	3,829	0,001	0,002	0,000	0,001

ANEJO C: Características técnicas del INC15, WS, usado en Oliver

Es de la marca Worldsensing, modelo LS-G6-INC15. Se resume aquí datos del documento LS G6 wireless tiltmeter (LS-G6-INC15) User Guide.pdf (Worldsensing, 2023)

Wireless Tiltmeter
with an external antenna
(LS-G6-INC15)

Device Specifications

SENSOR	
Type:	MEMS inclinometer with internal offset compensation
Range:	+/-15°
Axes:	Two (Biaxial)
Accuracy within +/-5°	+/-0.003°
Accuracy Full range (+/-15°)	+/-0.010°
Resolution	0.001°
Repeatability	<0.0002°
Offset temperature dependency (*)	+/-0.002°/°C
Stability @ 6 hours	< 0.002°
Sensitivity	Specific and provided for each tiltmeter: see calibration report
Time required for reading	8.3 seconds
Mechanical bandwidth	18 Hz
Temperature sensor resolution	0.1 °C
Temperature sensor accuracy	+/-0.5 °C
A/D converter	24-bit-sigma-delta

MEMORY: CIRCULAR BUFFER STRUCTURE		
Memory records up to 200,000 readings, including time and 1 sensor		
MECHANICAL		
Device	LS-G6-INC15	LS-G6-INC15- I
Box dimension (WxLxH)	100x100x61 mm	100x100x61 mm
Overall dimensions	150x120x61 mm	103x100x61 mm
Operating temperature	-40°C to 80°C (-40°F to 175°F)	
Water ingress protection	IP67, IP68 (at 1 m for 1 week)	IP67, IP68 (at 2 m for 2 hours)
Weight (excluding batteries)	841 g	624 g
Antenna	External: 100 mm length (including connector)	Internal
Mounting options	Clearance holes for M4 hexagon socket head cap screws in bottom. Blind holes for M4 screws on the side.	
USB (configuration/EXT power)	Internal mini USB	
Box material	Aluminium alloy	Aluminium alloy
Lid material	Aluminium alloy	Polycarbonate
Batteries	Up to 2	
Vibration resistance	Random vibration test railroad profile according to level C.2 (on sleeper) of standard EN 50125-3:2003	
Impact resistance***	Can be dropped from 1 meter onto a concrete surface (20,000g)	

*** The wireless tiltmeter is impact resistant but should be treated carefully, like any precision instrument.