IMPROVING VERTICAL GRIDDING BY USING MULTIPLE INTERVALS ON K-LOGICAL IN REFINEMENT FILES

Climatik, Mexico

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WindSim User Meeting 2015

HORIZONTAL REFINEMENT

Same location, up to 1 million cells
Refinements allows a better resolution in the interest area.

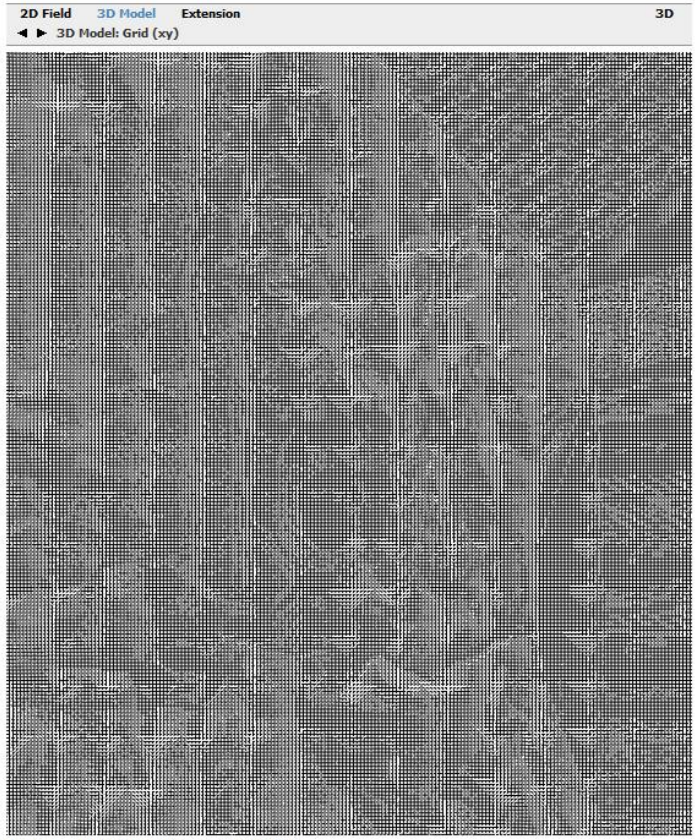


Fig 1. Digital terrain model - Grid (xy).

Body fitted co-ordinates (BFC) are used in grid generation. The above plot displays the resolution at ground level.

	x	y	z	total
Grid spacing (m)	75.0	75.0	Variable	-
Number of cells	194	222	20	861360

Table 1. Grid data.

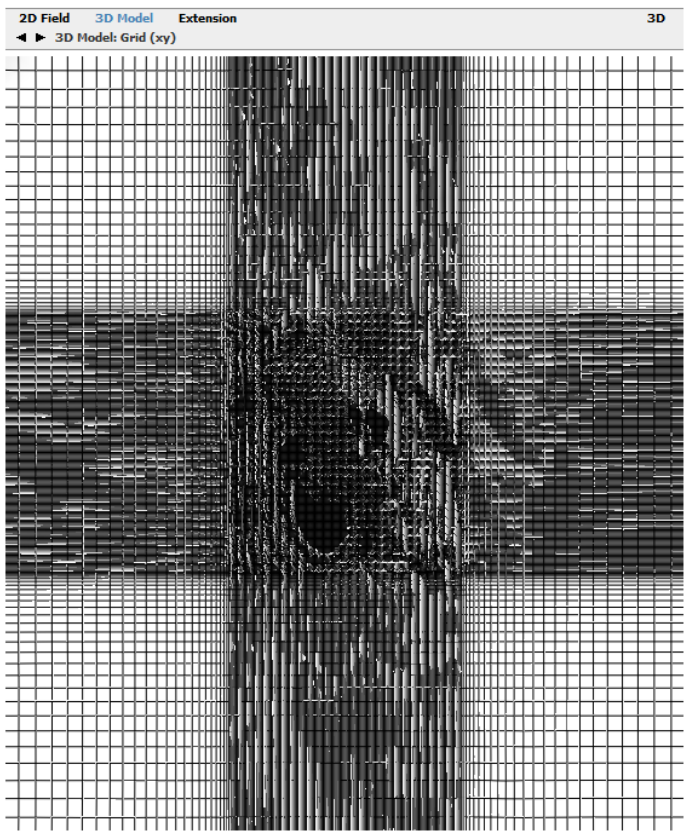


Fig 1. Digital terrain model - Grid (xy).

Body fitted co-ordinates (BFC) are used in grid generation. The above plot displays the resolution at ground level.

	x	y	z	total
Grid spacing, min - max (m)	29.8 - 375.2	29.8 - 414.6	Variable	-
Number of cells	211	236	20	995920

Table 1. Grid data.

VERTICAL REFINEMENT

Refined by default.
Similar in both refinement schemes.

2D Field 3D Model Extension 3D
3D Model: Grid (z)

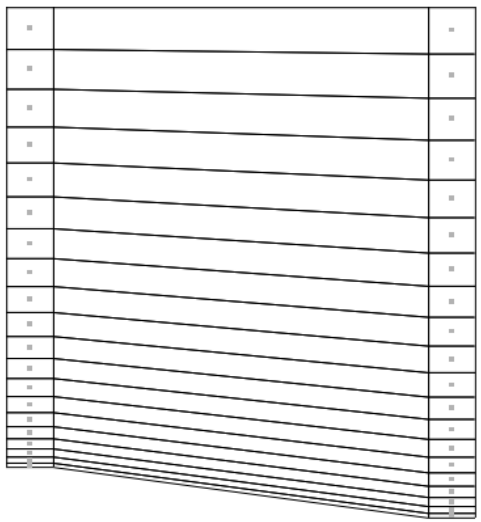


Fig 1. Digital terrain model - Grid (z).

The grid extends 800.0 (m) above the point in the terrain with the highest elevation. The grid is refined towards the ground. The left and right columns display a schematic view of the distribution at the position with maximum and minimum elevation respectively. The nodes, where results from the simulations are available, are situated in the cell centers indicated by dots.

.	1	2	3	4	5	6	7	8	9	10
z-dist. max (m)	3.6	12.6	25.1	41.0	60.3	83.1	109.3	138.9	172.1	208.6
z-dist. min (m)	4.0	14.0	27.8	45.5	66.9	92.2	121.3	154.3	191.0	231.6

Table 1. Distribution of the first 10 nodes in z-direction, relative to the ground, at the position with maximum and minimum elevation.

2D Field 3D Model Extension 3D
3D Model: Grid (z)

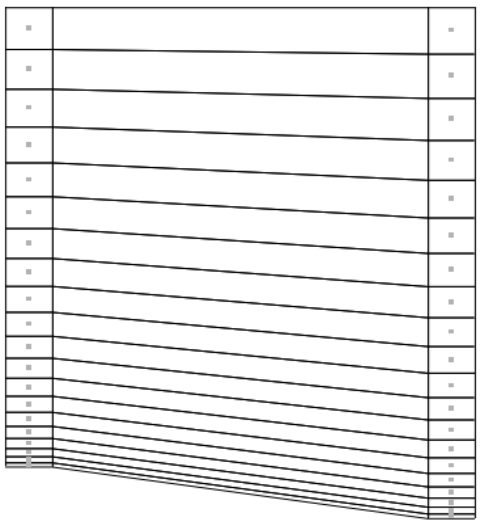


Fig 1. Digital terrain model - Grid (z).

The grid extends 798.2 (m) above the point in the terrain with the highest elevation. The grid is refined towards the ground. The left and right columns display a schematic view of the distribution at the position with maximum and minimum elevation respectively. The nodes, where results from the simulations are available, are situated in the cell centers indicated by dots.

.	1	2	3	4	5	6	7	8	9	10
z-dist. max (m)	3.6	12.6	25.1	41.0	60.3	83.1	109.3	138.9	172.1	208.6
z-dist. min (m)	4.0	14.1	27.9	45.6	67.1	92.4	121.6	154.6	191.4	232.1

Table 1. Distribution of the first 10 nodes in z-direction, relative to the ground, at the position with maximum and minimum elevation.

VERTICAL REFINEMENT

FOUR REQUIREMENTS TO BALANCE:

- At least 6 cells in the first 100 meters
  - To gain enough resolution close to the ground.
- Minimum Open Area / Maximum Open Area > 0.95
  - To avoid unphysical speedups due to channeling effects from upper boundary layer.
- Smooth cell size distribution
  - Too large differences might decrease accuracy and convergence.
  - Decreases on cell size with height might cause convergence troubles.
- First cell height
  - At least 2x the height of the maximum roughness element.
  - Width to height ratio should be at most 30:1

VERTICAL REFINEMENT

Easy to balance in even terrain

6 cells in the first 100 meters
Open Area Ratio
Smooth distribution
First cell size

2D Field 3D Model Extension 3D
◄ ► 3D Model: Open area

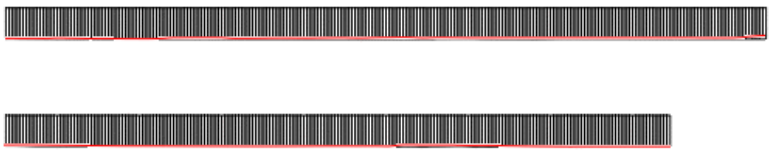


Fig 1. Digital terrain model - Open area.

The open area between the ground and upper boundary is calculated as the model is traversed in west-east and south-north direction. The maximum area is displayed as black rectangles while a red profile displays the ground level of the minimum area. The upper plot is for the traverse in west-east direction and the lower plot for the traverse in south-north direction. If the fraction between the minimum and maximum open area becomes too small, blocking effects might lead to unphysical speed-ups.

	Min (m^2)	Max (m^2)	Min/Max
Open area, west-east traverse	10917063	11159296	0.9783
Open area, south-north traverse	9724001	9904222	0.9818

Table 1. Open area data

20 cells in z-direction
Height above terrain: 600 m
Height distribution factor: 0.15

2D Field 3D Model Extension 3D
◄ ► 3D Model: Grid (z)

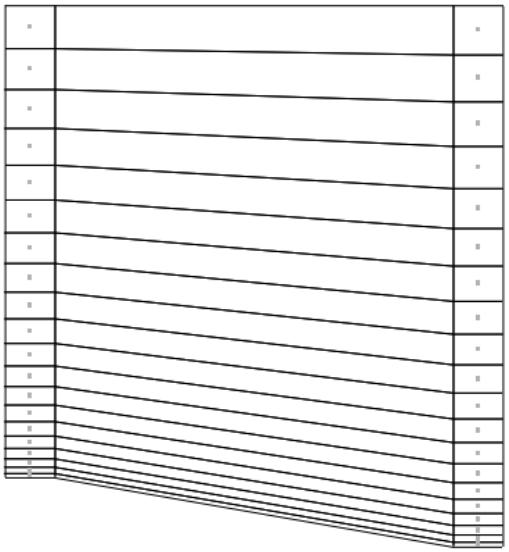


Fig 1. Digital terrain model - Grid (z).

The grid extends 600.0 (m) above the point in the terrain with the highest elevation. The grid is refined towards the ground. The left and right columns display a schematic view of the distribution at the position with maximum and minimum elevation respectively. The nodes, where results from the simulations are available, are situated in the cell centers indicated by dots.

.	1	2	3	4	5	6	7	8	9	10
z-dist. max (m)	3.9	12.9	24.2	37.9	53.9	72.2	92.9	115.9	141.2	168.9
z-dist. min (m)	4.5	14.8	27.8	43.5	61.8	82.8	106.5	132.9	162.0	193.7

Table 1. Distribution of the first 10 nodes in z-direction, relative to the ground, at the position with maximum and minimum elevation.

UNEVEN TERRAIN

Balance is harder to achieve

~~6 cells in the first 100 meters~~
~~Open Area Ratio~~
Smooth distribution
First cell size

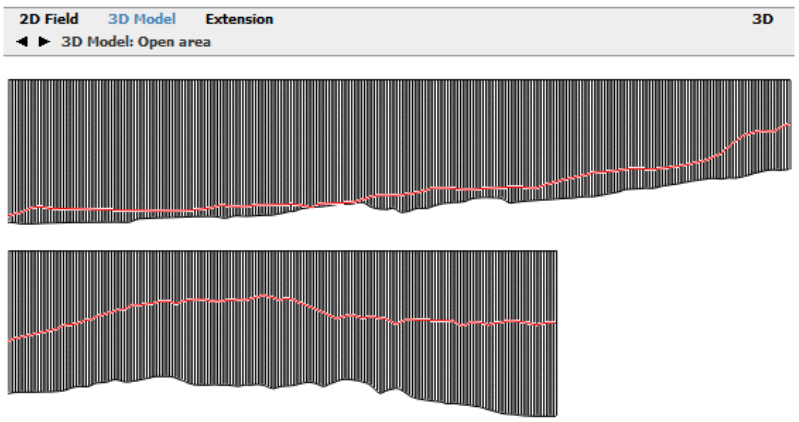


Fig 1. Digital terrain model - Open area.

The open area between the ground and upper boundary is calculated as the model is traversed in west-east and south-north direction. The maximum area is displayed as black rectangles while a red profile displays the ground level of the minimum area. The upper plot is for the traverse in west-east direction and the lower plot for the traverse in south-north direction. If the fraction between the minimum and maximum open area becomes too small, blocking effects might lead to unphysical speed-ups.

	Min (m^2)	Max (m^2)	Min/Max
Open area, west-east traverse	17954158	19107936	0.9396
Open area, south-north traverse	6862635	15147713	0.4530

Table 1. Open area data

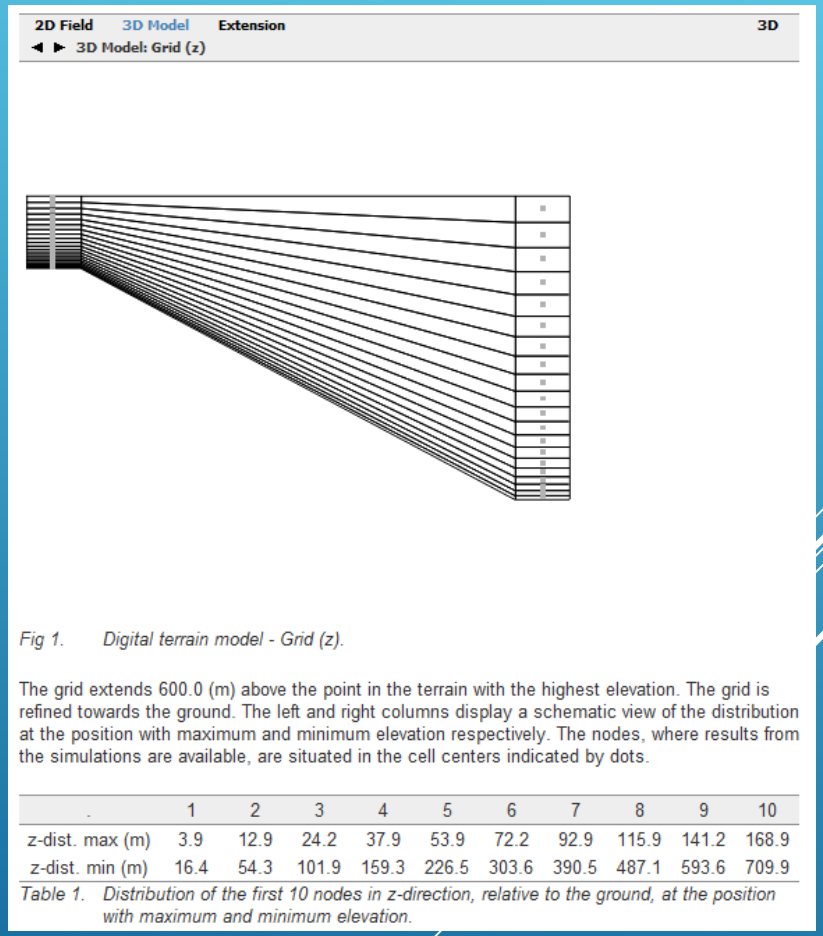


Fig 1. Digital terrain model - Grid (z).

The grid extends 600.0 (m) above the point in the terrain with the highest elevation. The grid is refined towards the ground. The left and right columns display a schematic view of the distribution at the position with maximum and minimum elevation respectively. The nodes, where results from the simulations are available, are situated in the cell centers indicated by dots.

.	1	2	3	4	5	6	7	8	9	10
z-dist. max (m)	3.9	12.9	24.2	37.9	53.9	72.2	92.9	115.9	141.2	168.9
z-dist. min (m)	16.4	54.3	101.9	159.3	226.5	303.6	390.5	487.1	593.6	709.9

Table 1. Distribution of the first 10 nodes in z-direction, relative to the ground, at the position with maximum and minimum elevation.

20 cells in z-direction
Height above terrain: 600 m
Height distribution factor: 0.15

UNEVEN TERRAIN

Default settings are not enough

~~6 cells in the first 100 meters~~
Open Area Ratio
Smooth distribution
First cell size

2D Field 3D Model Extension 3D
◄ ► 3D Model: Open area

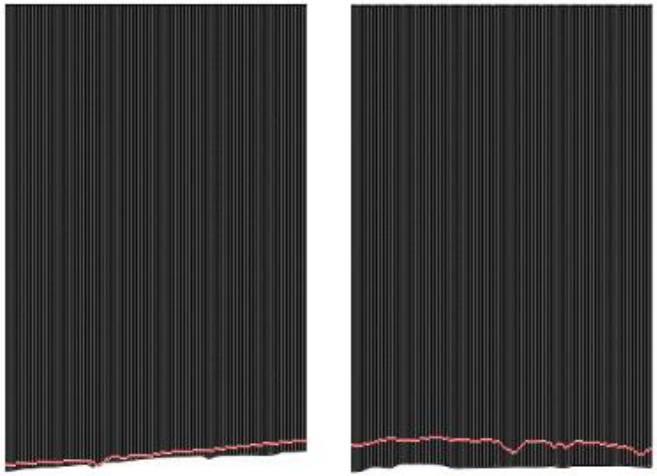


Fig 1. Digital terrain model - Open area.

The open area between the ground and upper boundary is calculated as the model is traversed in west-east and south-north direction. The maximum area is displayed as black rectangles while a red profile displays the ground level of the minimum area. The upper plot is for the traverse in west-east direction and the lower plot for the traverse in south-north direction. If the fraction between the minimum and maximum open area becomes too small, blocking effects might lead to unphysical speed-ups.

	Min (m^2)	Max (m^2)	Min/Max
Open area, west-east traverse	32721906	32932244	0.9936
Open area, south-north traverse	29583782	31175622	0.9489

Table 1. Open area data

20 cells in z-direction
Height above terrain: 6228 m
Height distribution factor: 0.1

2D Field 3D Model Extension 3D
◄ ► 3D Model: Grid (z)

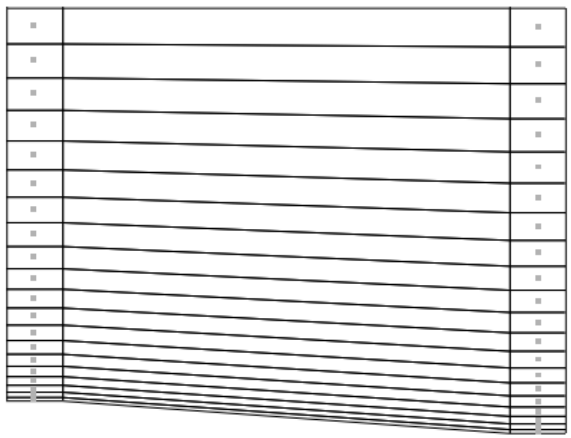


Fig 1. Digital terrain model - Grid (z).

The grid extends 6228.0 (m) above the point in the terrain with the highest elevation. The grid is refined towards the ground. The left and right columns display a schematic view of the distribution at the position with maximum and minimum elevation respectively. The nodes, where results from the simulations are available, are situated in the cell centers indicated by dots.

.	1	2	3	4	5	6	7	8	9	10
z-dist. max (m)	28.3	98.3	195.2	318.9	469.3	646.6	850.8	1081.7	1339.5	1624.0
z-dist. min (m)	30.6	106.5	211.3	345.2	508.1	700.0	921.0	1171.0	1450.0	1758.1

Table 1. Distribution of the first 10 nodes in z-direction, relative to the ground, at the position with maximum and minimum elevation.

REFINEMENT FILE: SIMPLE_REFINEMENT.BWS

More flexibility and control

Intervals:
How the grid is going to be refined.

Junctions:
Where the grid is going to be refined.

Obstacles.

```
i-logical          :    line_i  points   distribution
                             1      23   13.0653
                             2     168    1.0000
                             3      23    0.0765

j-logical          :    line_j  points   distribution
                             1      24   13.3838
                             2     179    1.0000
                             3      24    0.0747

k-logical          :    line_k  points   distribution  z_upper
                             1      19    0.0100       6190.0

junctions          :         i       j       k  co-ord       x         y         z
                             1       1       1       3    677024.8   2090767.6         0.0
                             2       1       1       3    678585.8   2090767.6         0.0
                             3       1       1       3    680148.8   2090767.6         0.0
                             4       1       1       3    681709.8   2090767.6         0.0
                             1       2       1       3    677024.8   2092428.6         0.0
                             2       2       1       3    678585.8   2092428.6         0.0
                             3       2       1       3    680148.8   2092428.6         0.0
                             4       2       1       3    681709.8   2092428.6         0.0
                             1       3       1       3    677024.8   2094091.5         0.0
                             2       3       1       3    678585.8   2094091.5         0.0
                             3       3       1       3    680148.8   2094091.5         0.0
                             4       3       1       3    681709.8   2094091.5         0.0
                             1       4       1       3    677024.8   2095752.5         0.0
                             2       4       1       3    678585.8   2095752.5         0.0
                             3       4       1       3    680148.8   2095752.5         0.0
                             4       4       1       3    681709.8   2095752.5         0.0

junctions_obstacle :         i       j       k  co-ord       x         y         z

surfaces_obstacle  :       i_s     i_e     j_s     j_e     k_s     k_e    type

volumes_obstacle   :       i_s     i_e     j_s     j_e     k_s     k_e    kind    type      c1
```

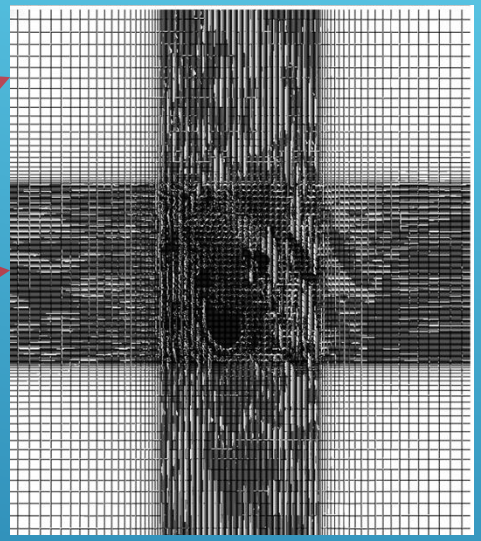
REFINEMENT FILE

Interval: How is the grid refined?

```
i-logical   X      :    line_i  points   distribution
                         1       23      13.0653
                         2      168       1.0000
                         3       23       0.0765

j-logical   Y      :    line_j  points   distribution
                         1       24      13.3838
                         2      179       1.0000
                         3       24       0.0747

k-logical   Z      :    line_k  points   distribution   z_upper
                         1       19       0.0100        6190.0
```



```
i-logical          :    line_i  points   distribution
                         1       23      13.0653
                         2      168       1.0000
                         3       23       0.0765
```

Interval number

Number of points

Distribution factor = First cell size / Last cell size

1/13.0653 = 0.0765

Only 1 interval in Z!

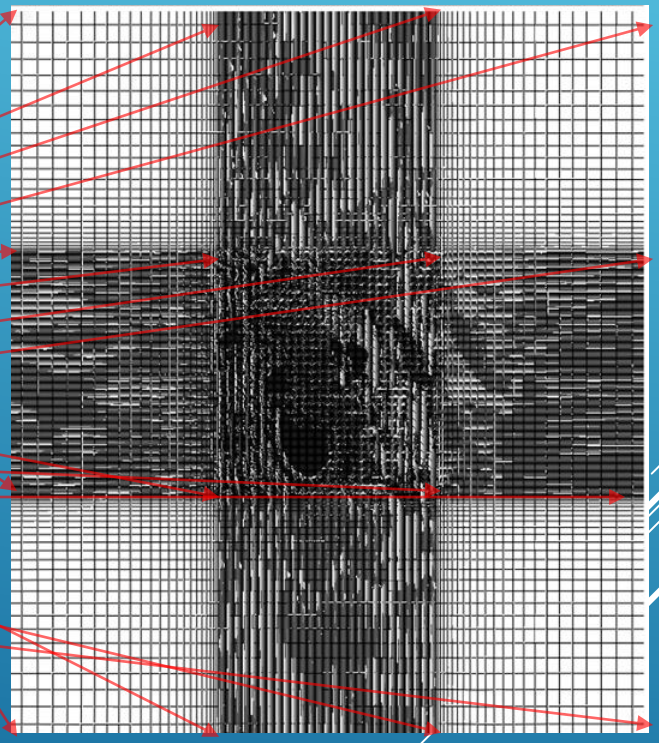
```
k-logical          :    line_k  points   distribution   z_upper
                         1       19       0.0100        6190.0
```

Upper limit of the interval

REFINEMENT FILE

Junctions: Where is the grid refined?

i	j	k	co-ord	x	y	z
1	1	1	3	770088.7	2144617.2	0.0
2	1	1	3	774948.7	2144617.2	0.0
3	1	1	3	779808.7	2144617.2	0.0
4	1	1	3	784668.7	2144617.2	0.0
1	2	1	3	770088.7	2150172.2	0.0
2	2	1	3	774948.7	2150172.2	0.0
3	2	1	3	779808.7	2150172.2	0.0
4	2	1	3	784668.7	2150172.2	0.0
1	3	1	3	770088.7	2155727.2	0.0
2	3	1	3	774948.7	2155727.2	0.0
3	3	1	3	779808.7	2155727.2	0.0
4	3	1	3	784668.7	2155727.2	0.0
1	4	1	3	770088.7	2161282.2	0.0
2	4	1	3	774948.7	2161282.2	0.0
3	4	1	3	779808.7	2161282.2	0.0
4	4	1	3	784668.7	2161282.2	0.0



All of them happen by defaul at Z=0

REFINEMENT FILE

Subdividing K-logical

k-logical :

line_k	points	distribution	z_upper
1	19	0.0100	6190.0

junctions :

i	j	k	co-ord	x	y	z
1	1	1	3	677024.8	2090767.6	0.0
2	1	1	3	678585.8	2090767.6	0.0
3	1	1	3	680148.8	2090767.6	0.0
4	1	1	3	681709.8	2090767.6	0.0
1	2	1	3	677024.8	2092428.6	0.0
2	2	1	3	678585.8	2092428.6	0.0
3	2	1	3	680148.8	2092428.6	0.0
4	2	1	3	681709.8	2092428.6	0.0
1	3	1	3	677024.8	2094091.5	0.0
2	3	1	3	678585.8	2094091.5	0.0
3	3	1	3	680148.8	2094091.5	0.0
4	3	1	3	681709.8	2094091.5	0.0
1	4	1	3	677024.8	2095752.5	0.0
2	4	1	3	678585.8	2095752.5	0.0
3	4	1	3	680148.8	2095752.5	0.0
4	4	1	3	681709.8	2095752.5	0.0

junctions_obstacle :

i	j	k	co-ord	x	y	z

k-logical :

line_k	points	distribution	z_upper
1	8	0.100	100.0
2	13	0.100	6190.0

Extra intervals

junctions :

i	j	k	co-ord	x	y	z
1	1	1	3	677024.8	2090767.6	0.0
2	1	1	3	678585.8	2090767.6	0.0
3	1	1	3	680148.8	2090767.6	0.0
4	1	1	3	681709.8	2090767.6	0.0
1	2	1	3	677024.8	2092428.6	0.0
2	2	1	3	678585.8	2092428.6	0.0
3	2	1	3	680148.8	2092428.6	0.0
4	2	1	3	681709.8	2092428.6	0.0
1	3	1	3	677024.8	2094091.5	0.0
2	3	1	3	678585.8	2094091.5	0.0
3	3	1	3	680148.8	2094091.5	0.0
4	3	1	3	681709.8	2094091.5	0.0
1	4	1	3	677024.8	2095752.5	0.0
2	4	1	3	678585.8	2095752.5	0.0
3	4	1	3	680148.8	2095752.5	0.0
4	4	1	3	681709.8	2095752.5	0.0
1	1	2	3	677024.8	2090767.6	100.0
2	1	2	3	678585.8	2090767.6	100.0
3	1	2	3	680148.8	2090767.6	100.0
4	1	2	3	681709.8	2090767.6	100.0
1	2	2	3	677024.8	2092428.6	100.0
2	2	2	3	678585.8	2092428.6	100.0
3	2	2	3	680148.8	2092428.6	100.0
4	2	2	3	681709.8	2092428.6	100.0
1	3	2	3	677024.8	2094091.5	100.0
2	3	2	3	678585.8	2094091.5	100.0
3	3	2	3	680148.8	2094091.5	100.0
4	3	2	3	681709.8	2094091.5	100.0
1	4	2	3	677024.8	2095752.5	100.0
2	4	2	3	678585.8	2095752.5	100.0
3	4	2	3	680148.8	2095752.5	100.0
4	4	2	3	681709.8	2095752.5	100.0

Extra junctions

TWO INTERVALS ON K-LOGIC

7-10 cells below hub height
Open Area Ratio
~~Smooth distribution~~
~~First cell size~~

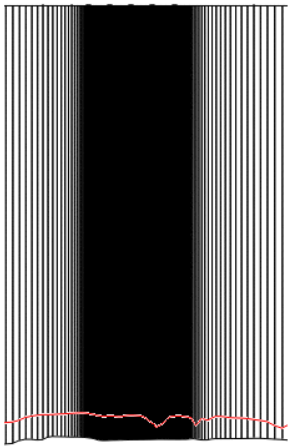


Fig 1. Digital terrain model - Open area.

The open area between the ground and upper boundary is calculated as the model is traversed in west-east and south-north direction. The maximum area is displayed as black rectangles while a red profile displays the ground level of the minimum area. The upper plot is for the traverse in west-east direction and the lower plot for the traverse in south-north direction. If the fraction between the minimum and maximum open area becomes too small, blocking effects might lead to unphysical speed-ups.

	Min (m^2)	Max (m^2)	Min/Max
Open area, west-east traverse	32350630	32560036	0.9936
Open area, south-north traverse	29498650	31015688	0.9511

Table 1. Open area data

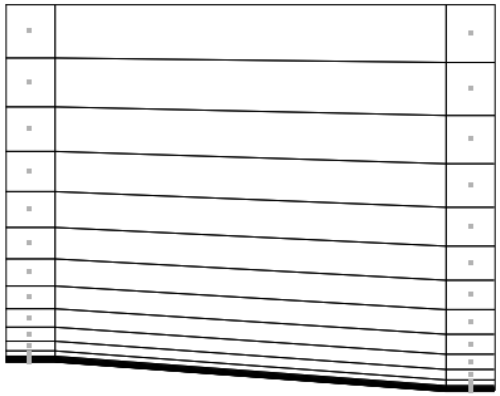


Fig 1. Digital terrain model - Grid (z).

The grid extends 6188.5 (m) above the point in the terrain with the highest elevation. The grid is refined towards the ground. The left and right columns display a schematic view of the distribution at the position with maximum and minimum elevation respectively. The nodes, where results from the simulations are available, are situated in the cell centers indicated by dots.

.	1	2	3	4	5	6	7	8	9	10
z-dist. max (m)	1.0	4.2	9.6	17.3	27.3	39.5	54.0	70.8	89.9	146.1
z-dist. min (m)	1.0	4.2	9.6	17.3	27.3	39.5	54.0	70.8	89.9	150.0

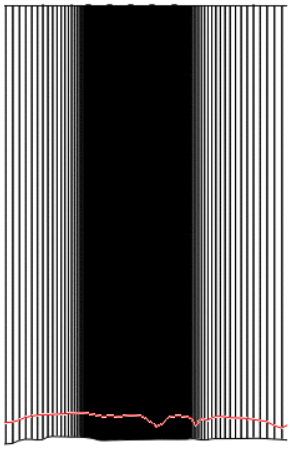
Table 1. Distribution of the first 10 nodes in z-direction, relative to the ground, at the position with maximum and minimum elevation.

```
k-logical          :    line_k  points   distribution  z_upper
                           1       8     0.100         100.0
                           2      11     0.100        6190.0
```

z-dist. min (m)	1	4.2	9.6	17.3	27.3	39.5	54	70.8	89.9	150
Cell Size	2	4.4	6.4	9	11	13.4	15.6	18	20.2	100

THREE INTERVALS ON K-LOGIC

7-10 cells below hub height
Open Area Ratio
~~Smooth distribution~~
~~First cell size~~



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Open area, west-east traverse	32350630	32560036	0.9936
Open area, south-north traverse	29498650	31015688	0.9511

Table 1. Open area data

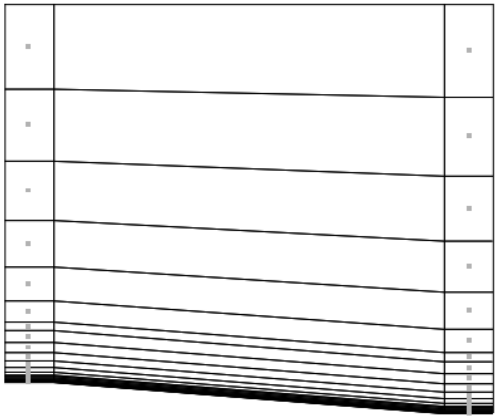

Fig 1. Digital terrain model - Grid (z).

The grid extends 6188.5 (m) above the point in the terrain with the highest elevation. The grid is refined towards the ground. The left and right columns display a schematic view of the distribution at the position with maximum and minimum elevation respectively. The nodes, where results from the simulations are available, are situated in the cell centers indicated by dots.

.	1	2	3	4	5	6	7	8	9	10
z-dist. max (m)	1.1	4.9	11.5	21.1	33.6	49.0	67.4	88.6	109.7	143.8
z-dist. min (m)	1.1	4.9	11.5	21.1	33.6	49.0	67.4	88.6	109.7	143.8

Table 1. Distribution of the first 10 nodes in z-direction, relative to the ground, at the position with maximum and minimum elevation.

```
k-logical          :    line_k  points   distribution   z_upper
                           1       7      0.100          100.0
                           2       6      0.100          850.0
                           3       6      0.100         6190.0
```

These are our parameters

z-dist. min (m)	1.1	4.9	11.5	21.1	33.6	49	67.4	88.6	109.7	143.8
Cell Size	2.2	5.4	7.8	11.4	13.6	17.2	19.6	22.8	19.4	48.8

THREE INTERVALS ON K-LOGIC

7-10 cells below hub height
Open Area Ratio
~~Smooth distribution~~
First cell size

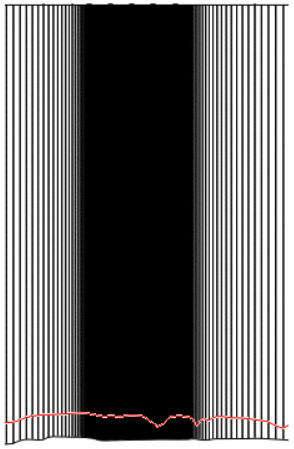

Fig 1. Digital terrain model - Open area.

The open area between the ground and upper boundary is calculated as the model is traversed in west-east and south-north direction. The maximum area is displayed as black rectangles while a red profile displays the ground level of the minimum area. The upper plot is for the traverse in west-east direction and the lower plot for the traverse in south-north direction. If the fraction between the minimum and maximum open area becomes too small, blocking effects might lead to unphysical speed-ups.

	Min (m^2)	Max (m^2)	Min/Max
Open area, west-east traverse	32350630	32560036	0.9936
Open area, south-north traverse	29498650	31015688	0.9511

Table 1. Open area data

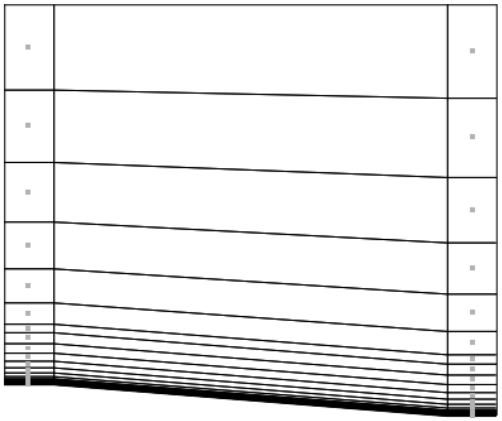

Fig 1. Digital terrain model - Grid (z).

The grid extends 6188.5 (m) above the point in the terrain with the highest elevation. The grid is refined towards the ground. The left and right columns display a schematic view of the distribution at the position with maximum and minimum elevation respectively. The nodes, where results from the simulations are available, are situated in the cell centers indicated by dots.

.	1	2	3	4	5	6	7	8	9	10
z-dist. max (m)	4.2	13.1	23.2	34.5	47.0	60.7	75.6	91.7	117.9	165.5
z-dist. min (m)	4.2	13.1	23.2	34.5	47.0	60.7	75.6	91.7	117.9	165.5

Table 1. Distribution of the first 10 nodes in z-direction, relative to the ground, at the position with maximum and minimum elevation.

```
k-logical          :    line_k  points   distribution  z_upper
                          1       7       0.500         100.0
                          2       6       0.200         850.0
                          3       6       0.100        6190.0
```

z-dist. min (m)	4.2	13.1	23.2	34.5	47	60.7	75.6	91.7	117.9	165.5
Cell Size	8.4	9.4	10.8	11.8	13.2	14.2	15.6	16.6	35.8	59.4

INTERVALS IN K-LOGICAL

USEFUL RULES OF THUMB:

- Increasing the distribution factor enlargens the first cell on each interval.
- Increasing z-upper enlargens all cells in an interval.
- We can add as many intervals as needed.

THANK YOU