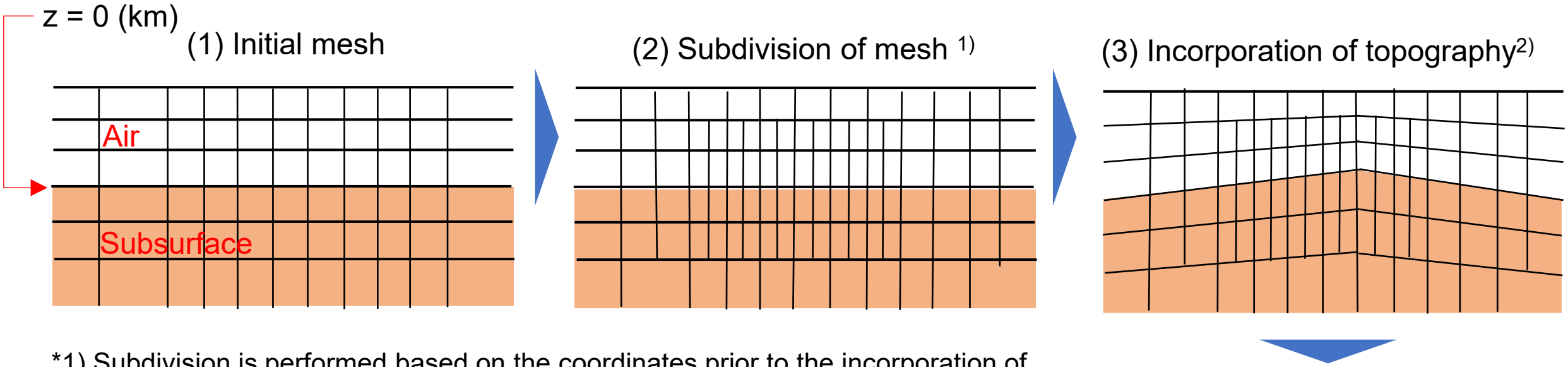
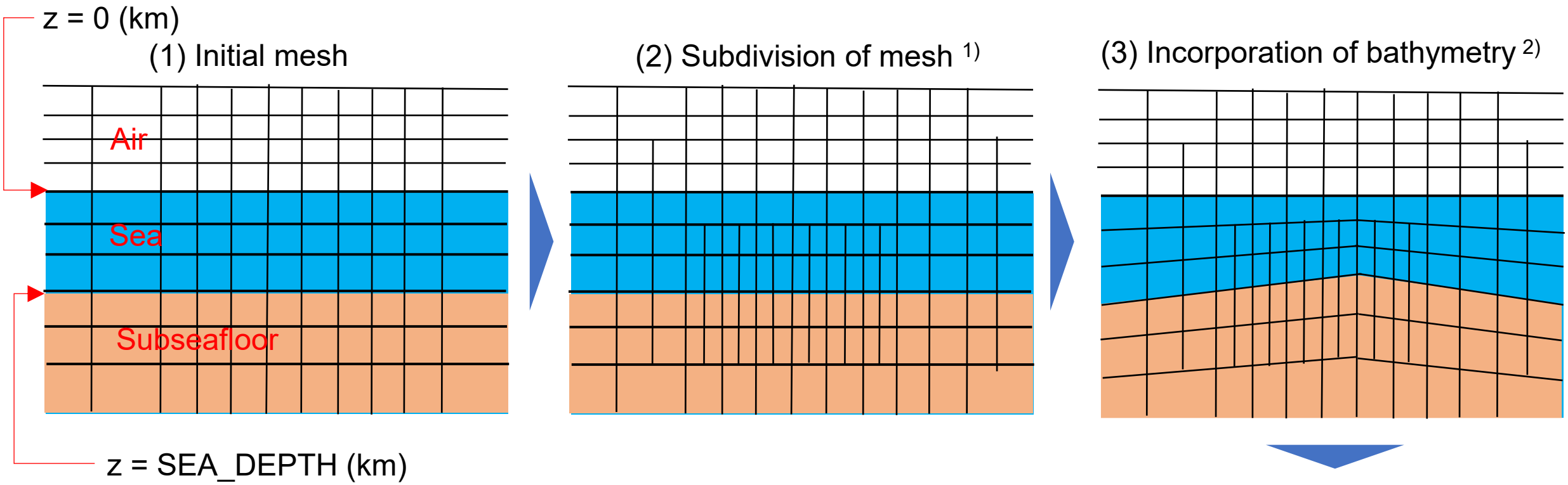
Algorithm of makeDHexaMesh (1) - Algorithm for land MT -



*1) Subdivision is performed based on the coordinates prior to the incorporation of topography. Therefore, you need to set the coordinates in the keyword 'CUBOIDS' of 'meshgen.inp' and the coordinates in 'obs_site.dat' based on the flat mesh. Therefore, z-coordinate values of 'obs_site.dat' should be usually equal to 0 (km).

*2) This step requires significant time because the coordinates of each node and each point of topography data are compared.

Algorithm of makeDHexaMesh (2) - Algorithm for ocean bottom MT -

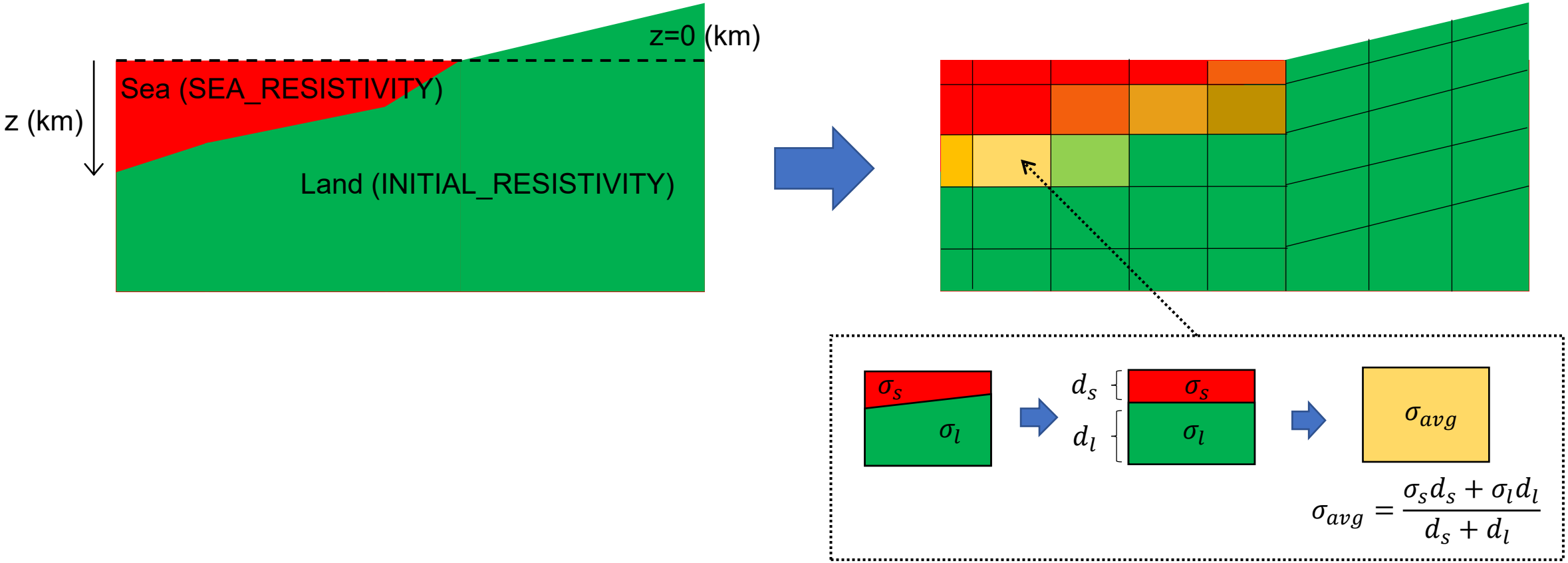


*1) Subdivision is performed based on the coordinates prior to the incorporation of bathymetry. Therefore, you need to set the coordinates in the keyword ‘CUBOIDS’ of ’meshgen.inp’ and the coordinates in ‘obs_site.dat’ based on the flat mesh. Therefore, z-coordinate values of ‘obs_site.dat’ should be SEA_DEPTH.

*2) This step requires significant time because the coordinates of each node and each point of bathymetry data are compared.

Algorithm of makeDHexaMesh (3)
- Averaging of sea conductivity and land conductivity -

If ‘SEA_DEPTH’ is NOT defined and there is sea area in topography data, the average conductivity of the sea and land sides is assigned to each element under the sea area.



Input-files of makeDHexaMesh

Input-files of makeDHexaMesh

File name	Contents
meshgen.inp	Controlling parameters
obs_site.dat	Desired edge lengths around observation sites
Arbitrary name	Topography/bathymetry (The name is defined in the keyword ‘TOPO’ of ‘meshgen.inp’)

How to run makeDHexaMesh

You need to execute the following command in the directory where input files exist.

makeDHexaMesh

Output-files of makeDHexaMesh

Output-files of makeDHexaMesh

File name	Contents
mesh.dat	Data of computational mesh (Input file of FEMTIC)
resistivity_block_iter0.dat	Information about parameter cells and the initial resistivity values (Input file of FEMTIC)
MeshData.vtk	Data of computational mesh (For the visualization by ParaView)
depth.vtk	Data of the surface mesh of the computational mesh (For the visualization by ParaView)

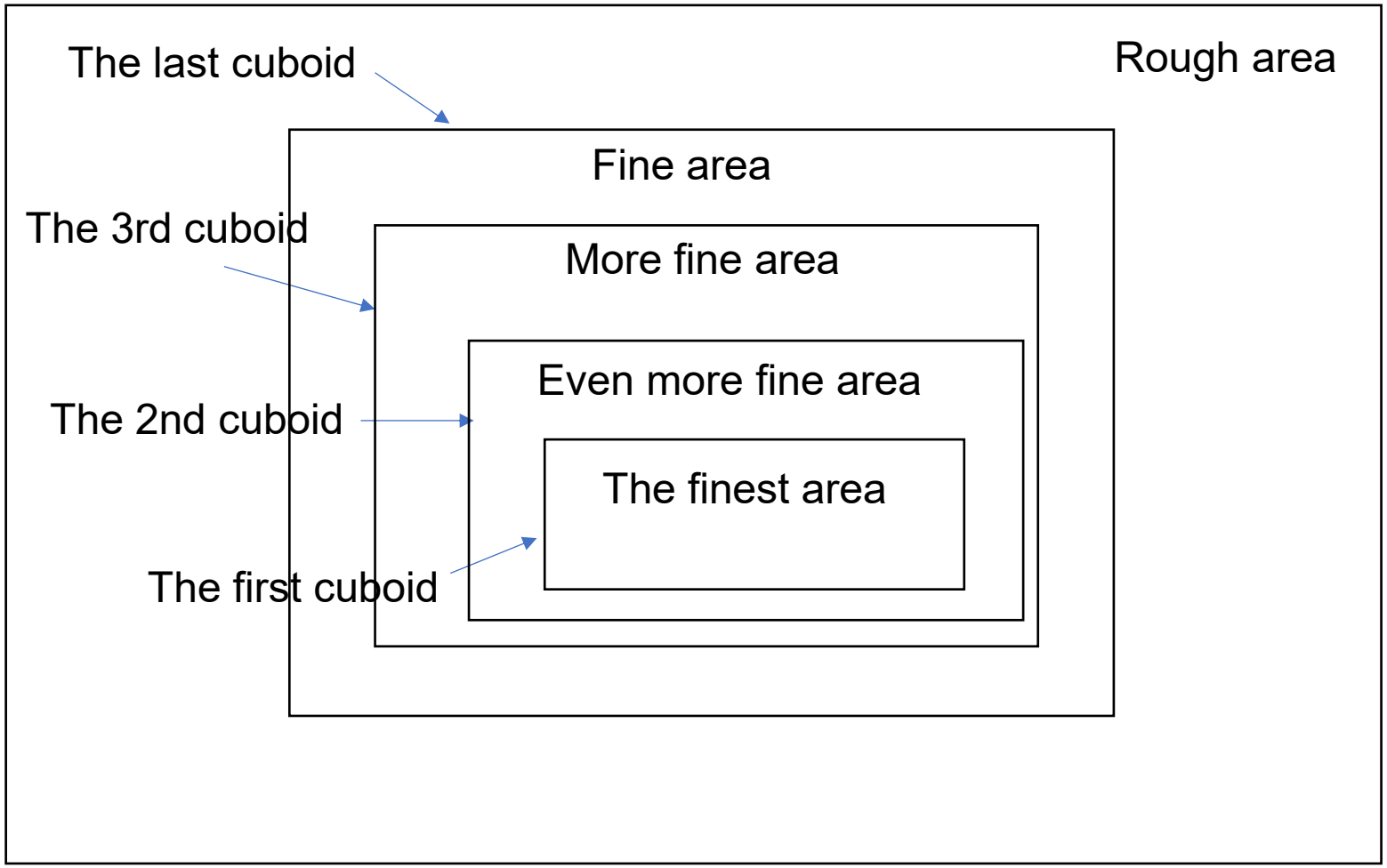
File format of ‘meshgen.inp‘ (1)

Keyword	Content	Data type	Option	Default	Example
DIVISION_NUMBERS	Division numbers in the x, y, and z direction of the initial mesh.	Three positive integers			DIVISION_NUMBERS 53 59 73
X_COORDINATES	X-coordinates (km) of the edges of the initial mesh	Real values (division number + 1)			
Y_COORDINATES	Y-coordinates (km) of the edges of the initial mesh	Real values (division number + 1)			
Z_COORDINATES	Z-coordinates (km) of the edges of the initial mesh [1)]	Real values (division number + 1)			
CUBOIDS	Information about the cuboids to control edge lengths	*Shown in the next slide*			*Shown in the next slide*
INITIAL_RESISTIVITY	Initial subsurface resistivity (Ωm)	Positive real value		100.0	INITIAL_RESISTIVITY 100.0

*1) Z-coordinate 0.0 (km) must exist.

Role of the keyword ‘CUBOIDS’

Cuboids are used to change the fineness of mesh hierarchically.



Keyword ‘CUBOIDS’

CUBOIDS

Coordinate values (x,y, and z in km) of the center of the cuboids

Rotation angle around the x-y plane (deg.) of the cuboids

Number of cuboids ($\mathrm{N_e}$)

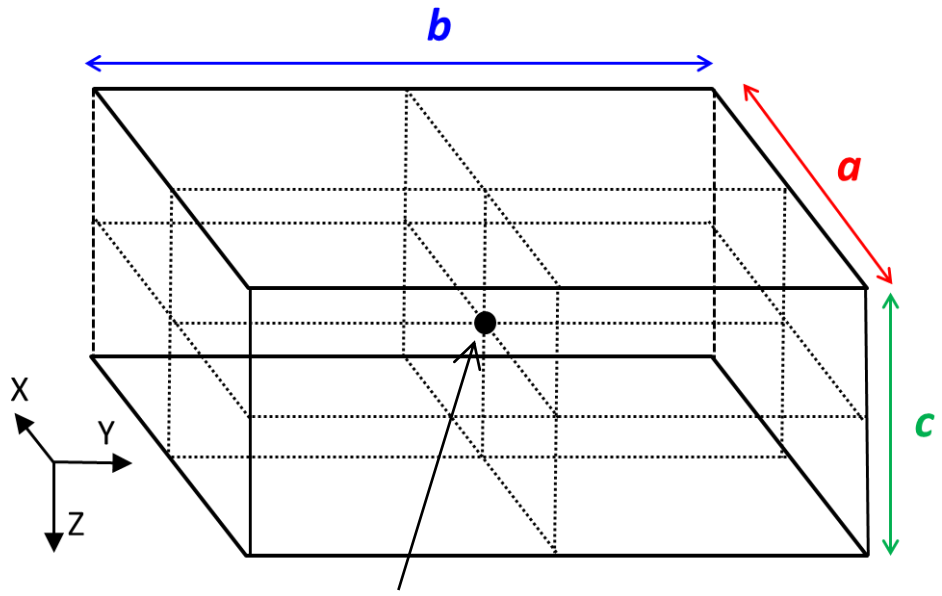
Information about the 1st cuboid

⋮

Information about the $\mathrm{N_e}$-th cuboid

[NOTE] Subsequent cuboids must cover the formers (must be larger than the formers)

a b c l_h



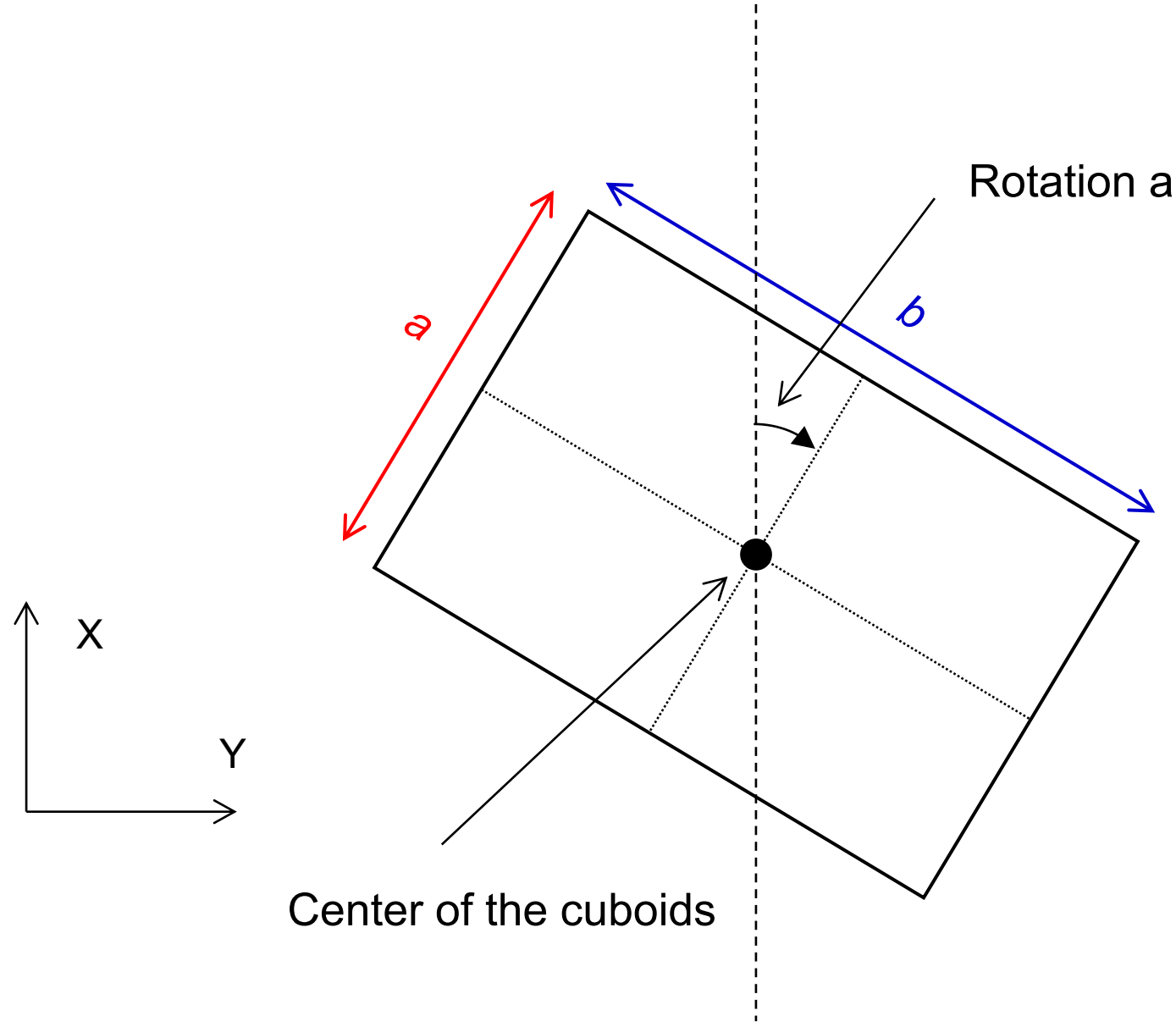
a: Length along x-axis (km)

b: Length along y-axis (km)

c: Length along z-axis (km)

l_h: The upper limit of the horizontal edge lengths within the cuboid (km)

Keyword ‘CUBOIDS’



Example

```
CUBOIDS
-40.0 -30.0 3.5
30.0
3
 30.0  30.0 20.0 1.0
 50.0  50.0 30.0 2.0
100.0 100.0 50.0 5.0
```

File format of ‘meshgen.inp‘ (2)

Keyword	Content	Data type	Option	Default	Example
AIR_RESISTIVITY	Resistivity of the air layer (Ωm)	Positive real value		1.0e+10	AIR_RESISTIVITY 1.0e+10
TOPO	Information about the topography/bathymetry data and the interpolation method of them [1)]	*Shown in the next slide*			*Shown in the next slide*
SEA_DEPTH	Sea-floor depth of the initial mesh (km) [2)]	Positive real value			SEA_DEPTH 3.50
SEA_RESISTIVITY	Resistivity of the sea (Ωm)	Positive real value		0.25	SEA_RESISTIVITY 0.30
THRE_SEA_DEPTH	Threshold of the sea-floor depth (km) [3)]	Positive real value		0.1	THRE_SEA_DEPTH 0.3
LEVEL_LIMIT_PARAM_CELL	Threshold about the partitioning of parameter cells [3)]	Positive real value		100	LEVEL_LIMIT_PARAM_CELL 1

*1) Details are described in the next slide. If this keyword is not defined, no topography/bathymetry is incorporated into the mesh.

*2) The initial sea depth should be equal to one of the z-coordinates written in ‘Z_COORDINATES’.

*3) Details are described in a later slide.

Keyword ‘TOPO’

TOPO

File name of topography/bathymetry data

Maximum number of the points used for interpolation (N)

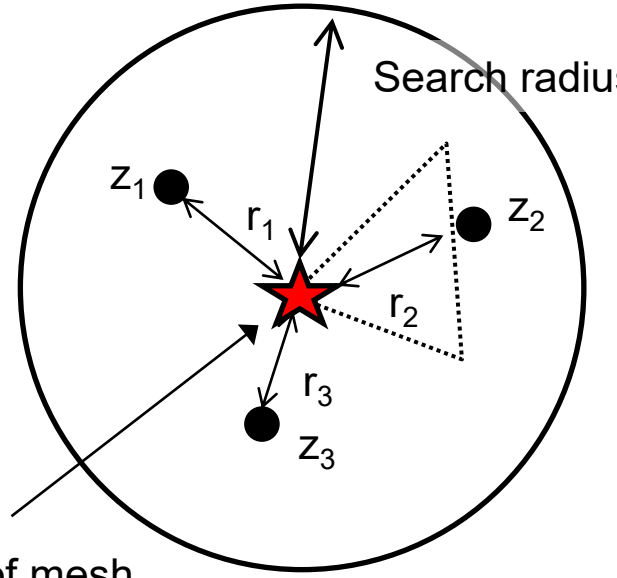
Search radius (km)

Small number to avoid zero divide (km) (ε)

Example

TOPO
topo.xyz
3
3.0
0.001

Inverse distance weighting method is used for interpolation of z-coordinates.



$$z = \frac{\sum_{i=1}^{N} w_i z_i}{\sum_{i=1}^{N} w_i}$$

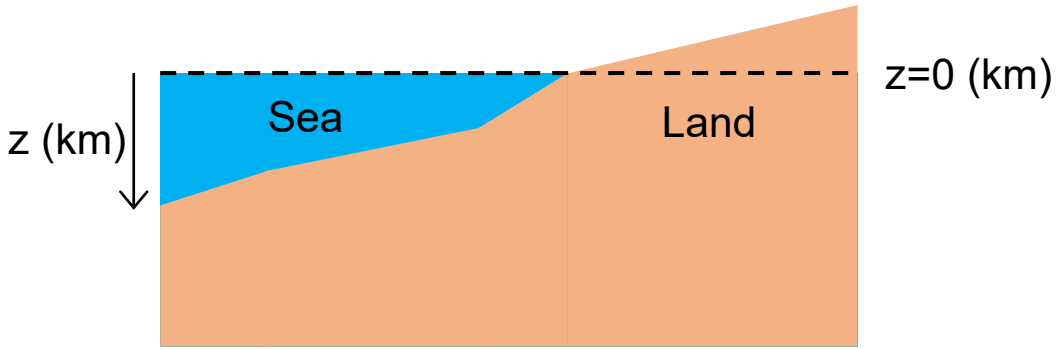
$$w_i = \frac{1}{(r_i + \varepsilon)}$$

Format of the files including topography/bathymetry data

X-coordinate (km)	*Y-coordinate (km)*	*Z-coordinate (km)*

⋮

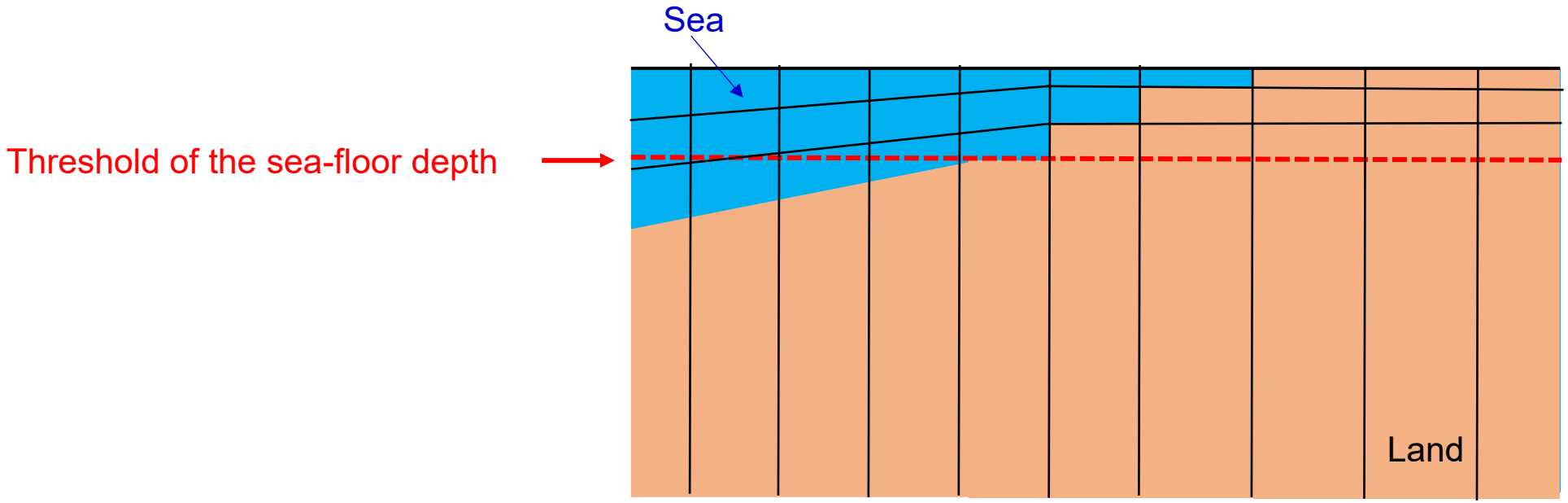
Z-coordinates are positive in the downward direction.



Example

```
-106.824031915  76.2046151595   2.100000e-003↓
-106.824276161  76.1651038245   6.000000e-003↓
-106.824459262  76.1354703228   8.500000e-003↓
-106.824642292  76.1058368206   7.400000e-003↓
-106.824886221  76.0663254836   9.000000e-003↓
-106.825069084  76.0366919804   9.300000e-003↓
-106.825251877  76.0070584767   8.600000e-003↓
-106.825495489  75.9675471378   8.600000e-003↓
-106.825678115  75.9379136331   9.400000e-003↓
-106.82586067   75.908280128    1.040000e-002↓
-106.826103966  75.8687687872   1.070000e-002↓
-106.826286354  75.839135281    9.300000e-003↓
-106.826468671  75.8095017744   1.110000e-002↓
-106.82671165   75.7699904316   1.390000e-002↓
```

Keyword ‘THRE_SEA_DEPTH’

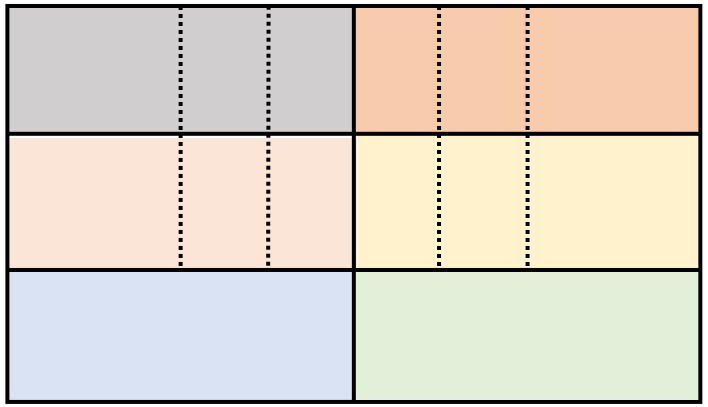


Above the threshold of the sea-floor depth, the bathymetry is represented by a stair-like mesh.

Keyword ‘LEVEL_LIMIT_PARAM_CELL’

By using this option, you can specify the level of partitioning of the parameter cell, based on the level of partitioning of the mesh.
If you set X as this option, the sub-elements generated at the X-th partitioning or later are forced to have the same resistivity.
*) In the figures below, different colors indicate different parameter cells.

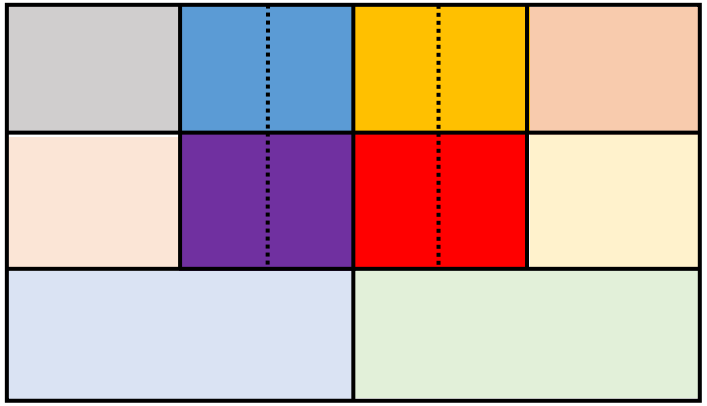
LEVEL_LIMIT_PARAM_CELL
0



Solid line indicates the edges of the initial mesh

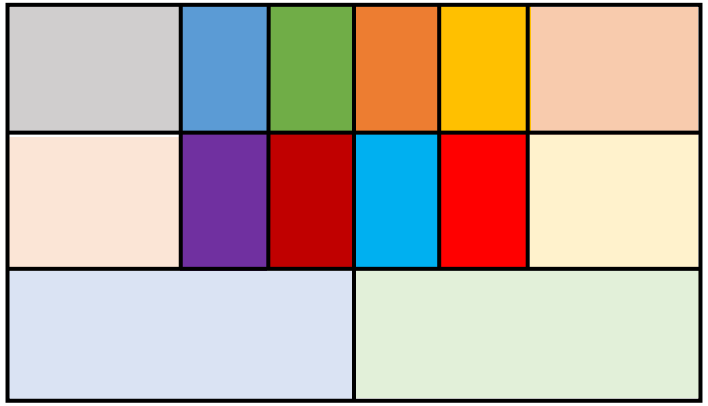
If the option is zero, all sub-elements in each element of initial mesh are forced to have the same resistivity.

LEVEL_LIMIT_PARAM_CELL
1



Solid line indicates the edges of the mesh after the 1st mesh partitioning

LEVEL_LIMIT_PARAM_CELL
2



Solid line indicates the edges of the mesh after the 2nd mesh partitioning

If the option is large enough (default), respective subsurface elements are allowed to have different resistivity values.

File format of ‘meshgen.inp‘ (3)

Keyword	Content	Data type	Option	Default	Example
ANOMALIES	Information about the resistivity anomalies in the initial model	*Shown in the next slide*			*Shown in the next slide*
END	Indication of the end of controlling parameters				END

Keyword ‘ANOMALIES’

ANOMALIES

Number of anomalies (N_a)

Information about the 1st anomaly

⋮

Information about the N_a-th anomaly

x_{min} x_{max} y_{min} y_{max} z_{min} z_{max} ρ_{ano} $IFIX$

x_{min}: *The minimum x value of the anomaly (km)*

x_{max}: *The maximum x value of the anomaly (km)*

y_{min}: *The minimum y value of the anomaly (km)*

y_{max}: *The maximum y value of the anomaly (km)*

z_{min}: *The minimum z value of the anomaly (km)*

z_{max}: *The maximum z value of the anomaly (km)*

ρ_{ano}: *Electrical resistivity of the anomaly (Ωm)*

$IFIX$: *1 if the resistivity is fixed in the inversion / 0 if the resistivity is modifiable in the inversion.*

NOTE
Location determination of anomalies is performed based on the coordinates prior to the incorporation of topography/bathymetry.

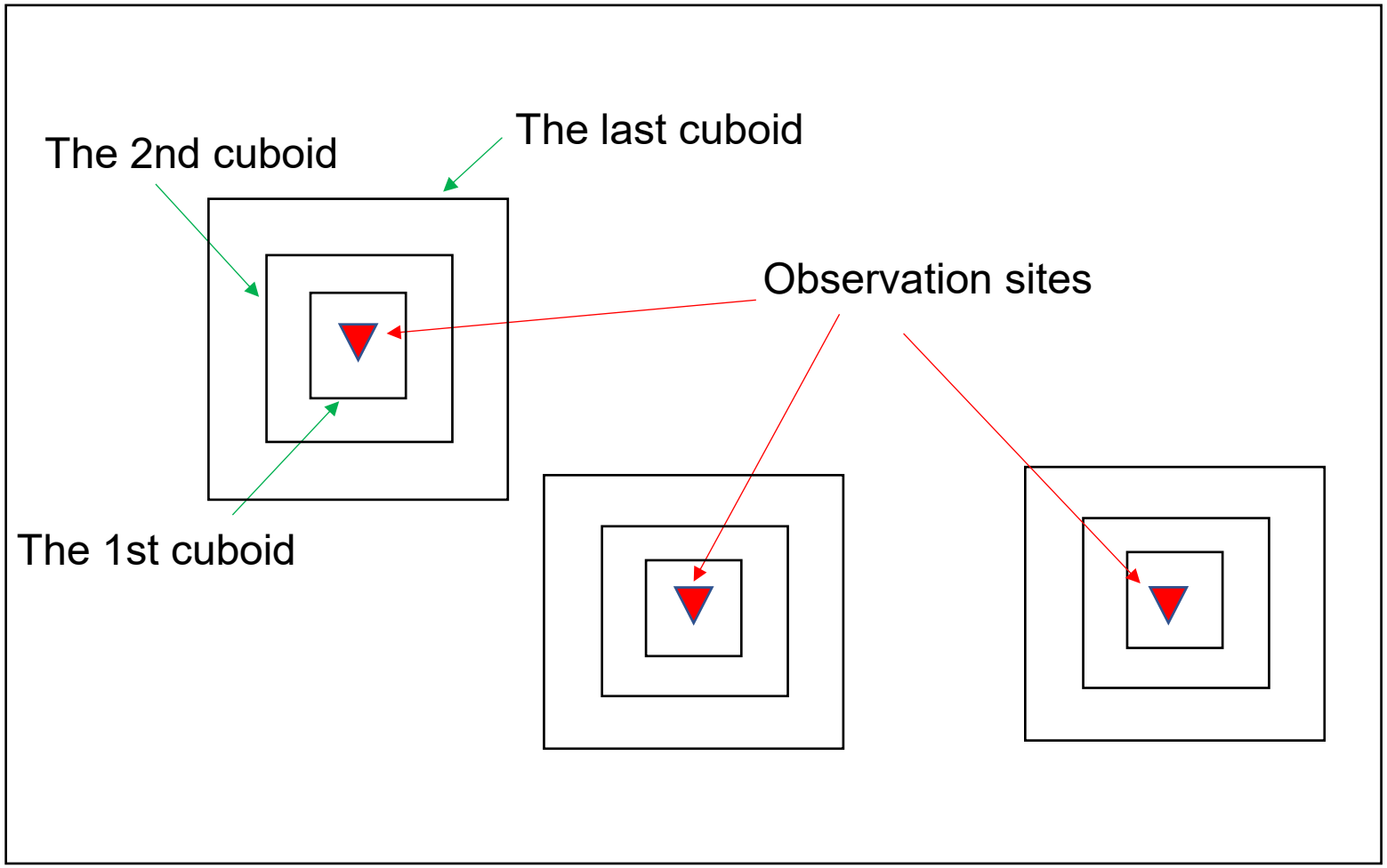
Example

```
ANOMALIES
2
 10.0   20.0   10.0   20.0  5.0  10.0  100.0  1
-20.0  -10.0  -20.0  -10.0  5.0  10.0  100.0  1
```

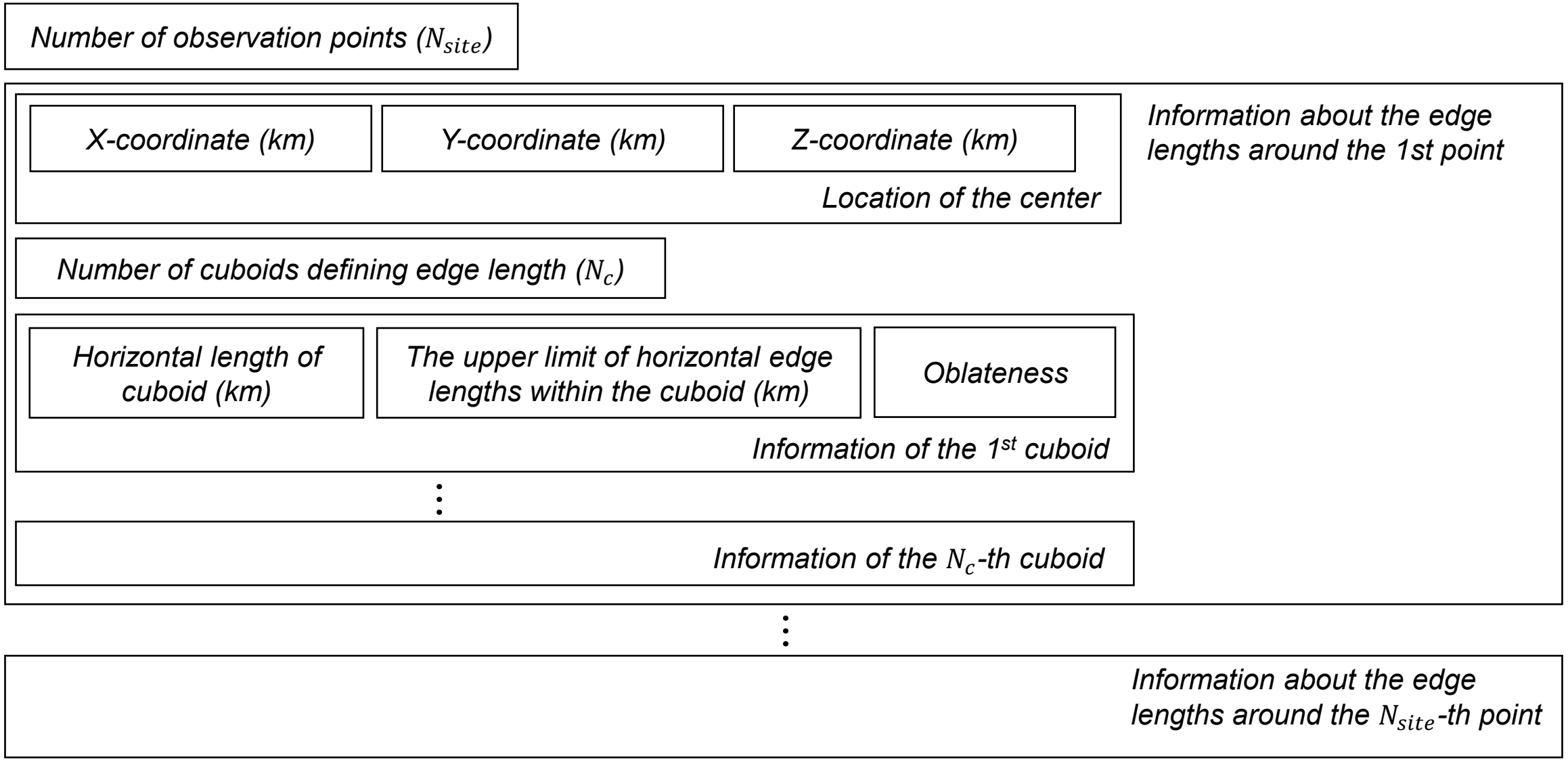
Role of ‘obs_site.dat’

The cuboids at the observing sites are used to make the area around observation sites even finer.

The 1st cuboid specified by keyword ‘CUBOIDS’

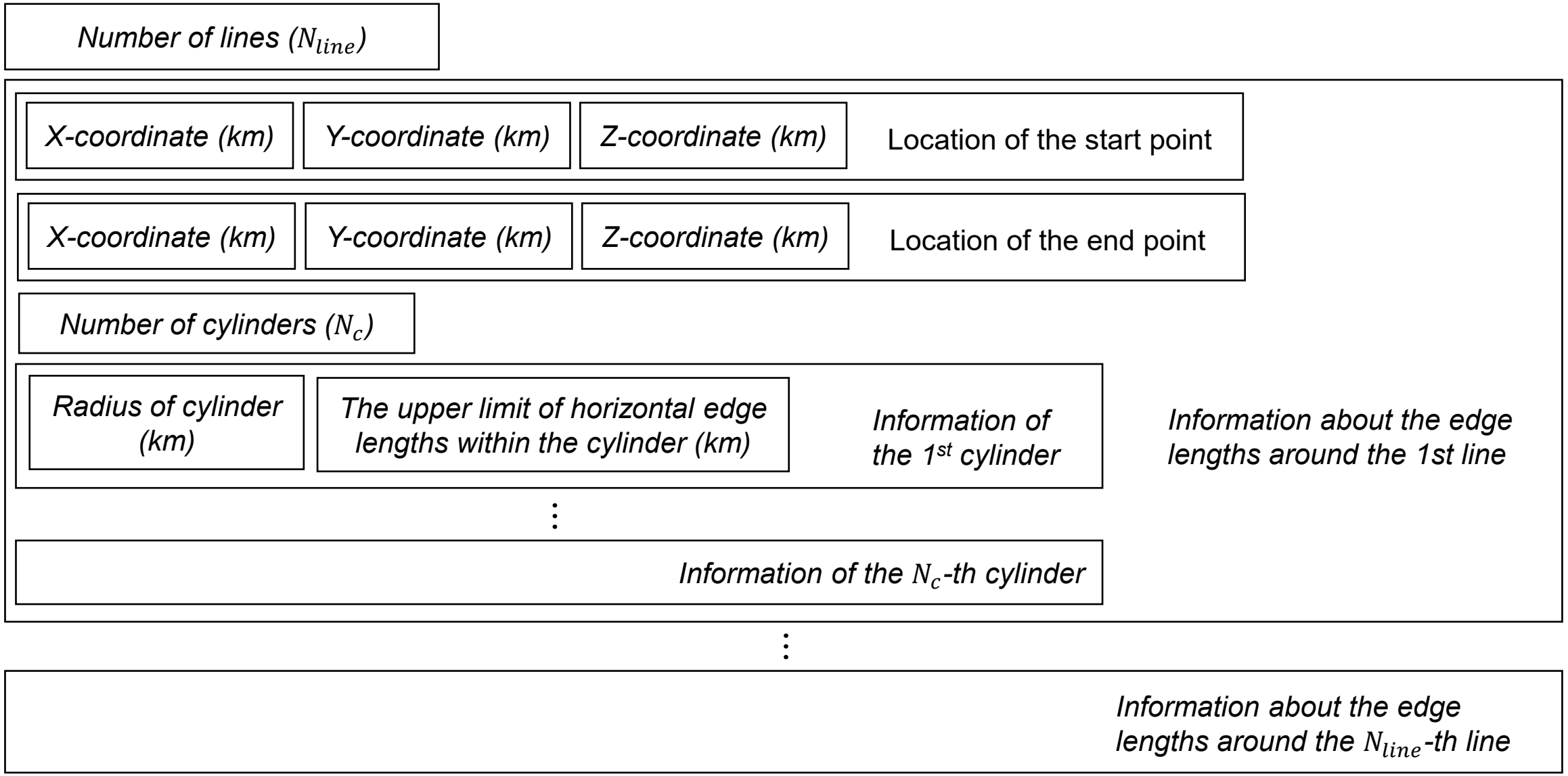


File format of 'obs_site.dat' (1/3)



*) Subsequent cuboids must cover the formers (must be larger than the formers)

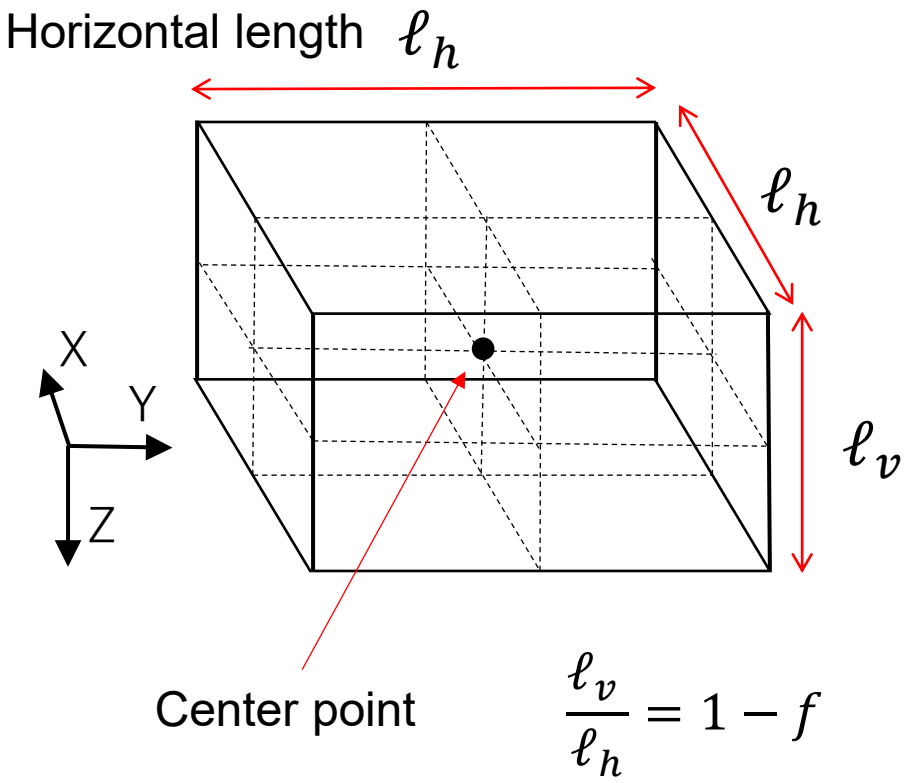
File format of ‘obs_site.dat’ (2/3)



*) Subsequent cylinders must cover the formers (must be larger than the formers)

File format of ‘obs_site.dat’ (3/3)

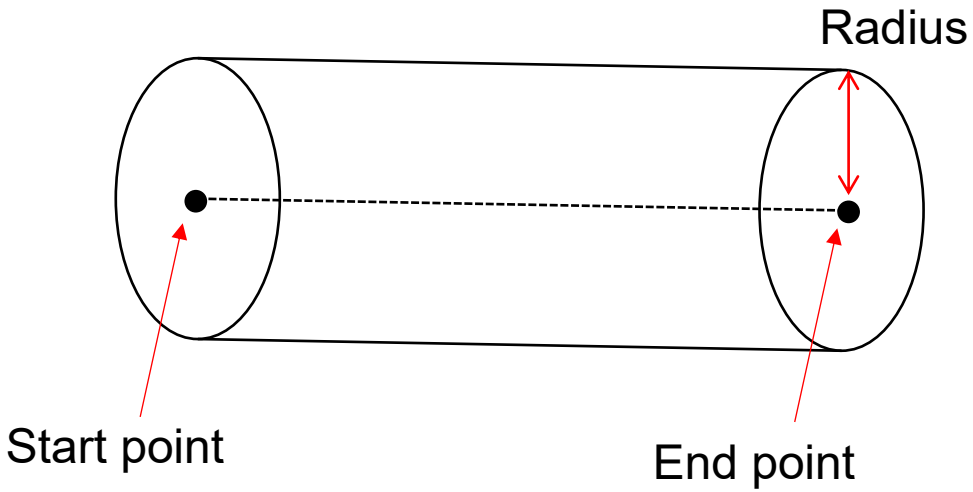
Cuboid for an observation points



$$\frac{\ell_v}{\ell_h} = 1 - f$$

f : *Oblateness*

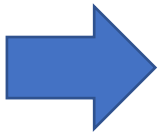
Cylinder for a line



How to make a mesh without topography

meshgen.inp

```
INITIAL_RESISTIVITY
100.0
AIR_RESISTIVITY
1.0e+10
CENTER
-40.0 -30.0 3.5
ROTATION
0.0
CUBOIDS
3
 30.0  30.0 20.0 1.0 1.0
 50.0  50.0 30.0 2.0 2.0
100.0 100.0 50.0 5.0 5.0
LEVEL_LIMIT_PARAM_CELL
0
TOPO
ETOPO1_Ice_g_int_prjected_mod.xyz
3
3.0
0.001
END
```



meshgen.inp

```
INITIAL_RESISTIVITY
100.0
AIR_RESISTIVITY
1.0e+10
CENTER
-40.0 -30.0 3.5
ROTATION
0.0
CUBOIDS
3
 30.0  30.0 20.0 1.0 1.0
 50.0  50.0 30.0 2.0 2.0
100.0 100.0 50.0 5.0 5.0
LEVEL_LIMIT_PARAM_CELL
0
END
```

If ‘TOPO’ keyword is not included, topography/bathymetry is not incorporated into the mesh.

How to make a conforming hexahedral mesh

meshgen.inp

```
5664.511
SEA_DEPTH
3.61
SEA_RESISTIVITY
0.30
THRE_SEA_DEPTH
0.1
INITIAL_RESISTIVITY
500.0
AIR_RESISTIVITY
1.0e+10
CUBOIDS
-40.0 -30.0 3.61
0.0
1
100.0 100.0 10.0 2.0
ANOMALIES
```

obs_site.dat

```
0
0
```

If ‘CUBOIDS’ keyword is not included in ‘meshgen.inp’ and set both numbers of points and lines as zeros in ‘obs_site.dat’, we can make a conforming hexahedral (subdivision is not performed)

Recommended setting for the initial trial

meshgen.inp

```
DIVISION_NUMBERS
…
X_COORDINATES
…
Y_COORDINATES
…
Z_COORDINATES
…
INITIAL_RESISTIVITY
100.0
AIR_RESISTIVITY
1.0e+10
END
```

obs_site.dat

```
0
0
```

Cautions

When both land topography and bathymetry are incorporated into mesh, some elements that originally belong to the sea are changed to the land elements in the program.

However, the algorithm of the above procedure is NOT robust.

Please check the surface mesh by using 'depth.vtk before you perform inversion.