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7.4 Two techniques for constructing a uniform grid system covering the Earth's surface

In many geophysical studies there is a need to divide the entire earth's surface into areas of equal size and shape. An example, discussed in subsection 7.5 is the application of the Generalized BeamForming technique for global seismic monitoring. According to Rottman (1960), there are only five polyeders that can be used for a such division, and among these, the icosaeder has the largest number of subareas (20 equilateral triangles). For further refinement, approximations have to be made.

We have investigated the characteristics of two different techniques for quasi-uniform gridding of the surface of the globe. The first method uses a reference meridian and a reference latitude as a starting point, and deploys equidistant grid points along equidistant latitude circles, see Fig. 7.4.1. To obtain complete and non-overlapping coverage, special care has to be taken in the polar regions and near the longitude opposite to the reference meridian.

The other method is adopted from seismic prospecting (Vinje et al., 1992), where triangulation of the icosaeder has been used to construct regularly sampled wavefronts, see Fig. 7.4.2. Unlike the first method, complete and non-overlapping coverage are directly obtained.

Properties of the gridding techniques

To visually compare the two methods, we have in Fig. 7.4.1 plotted a complete global grid system produced by the first technique, hereafter called the rectangular method. In Fig. 7.4.2 we have plotted a similar grid produced by triangulation of the icosaeder, hereafter called the triangular method. The number of points in these plots are nearly identical, i.e., 645 versus 642. We see that for the rectangular method the shape of the area spanned by each grid point and its eight neigbours becomes heavily distorted in certain regions. This is especially the case in the polar regions and for longitudes far away from the reference meridian. For the triangular method, the shape of the area spanned by each grid point and its six neighbours remains much more uniform. It should, however, be noticed that the 12 points constituting the original icosaeder only have five neighbors.

To obtain complete coverage of the earth, we define a circular region around each grid point. For the triangular grid, we have found that circles with radii as shown in Fig. 7.4.4 completely cover the earth surface. We could as well have chosen types of geometries different from the circle, like the pentagon or the hexagon where the degree of overlap is smaller, but for use in our subsequent analysis, the simplicity of the circle is preferable. For the rectangular grid, we have in Fig. 7.4.3 plotted circles with the same radii as in Fig. 7.4.4, and we find that there are certain areas that have not been spanned by any of the circular regions, and hence, circles with larger radii are required. The triangular method therefore gives more effective coverage.

Another appealing property of the triangular technique is that each grid point has a well-defined pointer structure to its neighbours. For a given sub-region, this enables us to construct a refined grid system in a straightforward manner.

In contrast to the rectangular method, where an arbitrary number of grid points can be specified, the number of grid points obtained by the triangular method can only take on certain discrete values. These values are given in Table 7.4.1, together with the radii of the corresponding circular regions.

Number of divisions of the icosaeder	Number of points	Circle radius (degrees)
0	12	43.8
1	42	21.9
2	162	11.0
3	642	5.5
4	2562	2.7
5	10242	1.4
6	40962	0.7

Table 7.4.1.

In conclusion, there are strong arguments for preferring the triangular method to the rectangular method. The only argument in favour of the rectangular method is the possibility of constructing a grid of arbitrary density.

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References

Rottman, K.: Mathematische Formelsammlung (1960): Bibliographisches Institut Mannheim/Wien/Zurich

Vinje, V., E. Iversen, H. Gjøystdal and K. Åstebøl (1992): Traveltime and amplitude estimation using wavefront construction. Abstract of papers presented at the 54th Meeting and Technical Exhibition of the European Association of Exploration Geophysicists, Paris, France, 1-5 June 1992.

645 grid points, rectangular

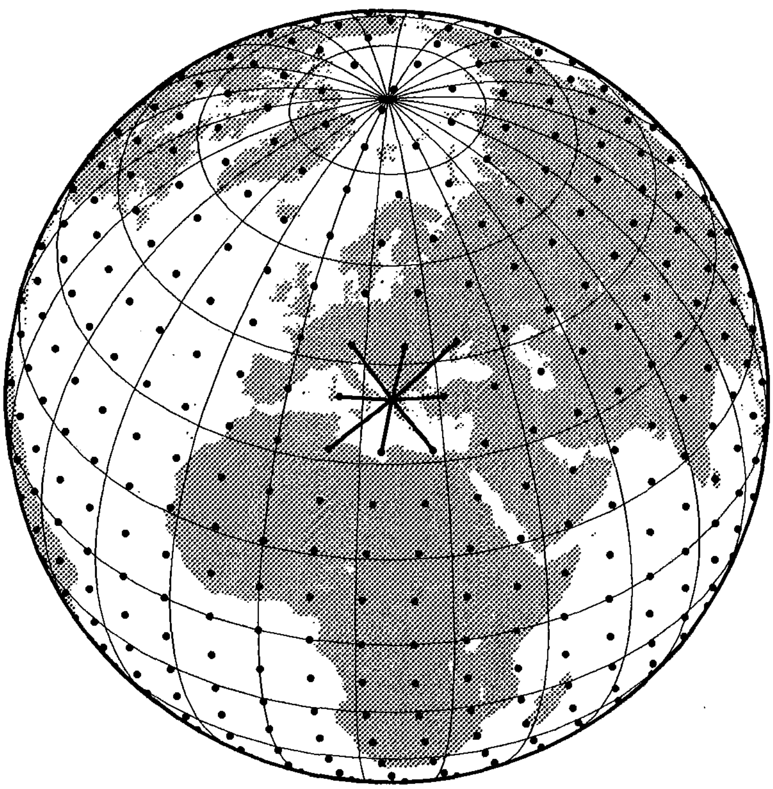

Fig. 7.4.1. Global grid constructed by the rectangular method. The latitude and longitude steps were chosen to be 7.95 deg. The connection lines between a grid point and its eight neighbours are also shown.

642 grid points, triangular

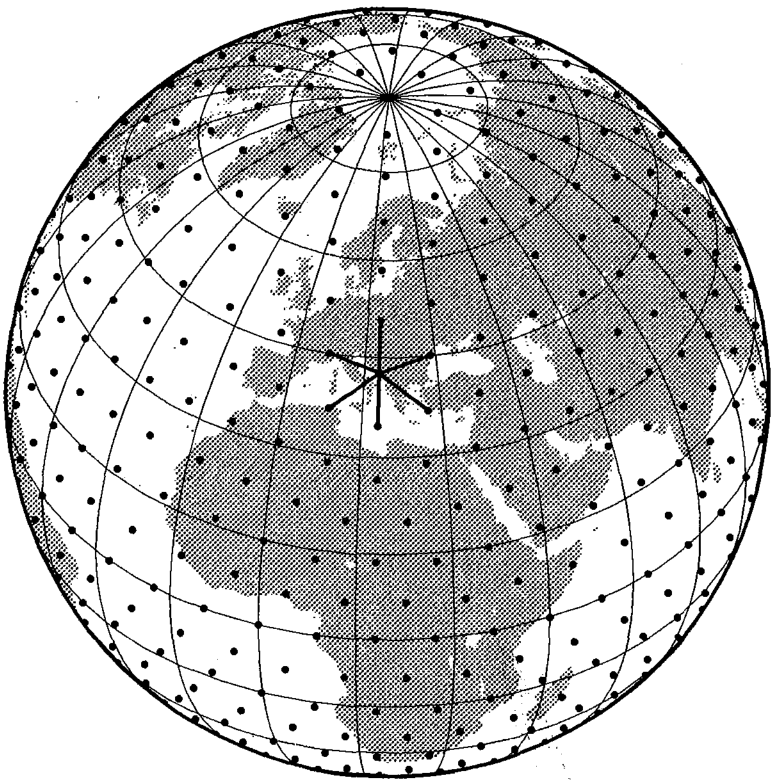

Fig. 7.4.2. Global grid constructed by the triangular method. The 642 points were obtained by a tree-fold triangulation of the original icosaeder. The connection lines between a grid point and its six neighbours are also shown.

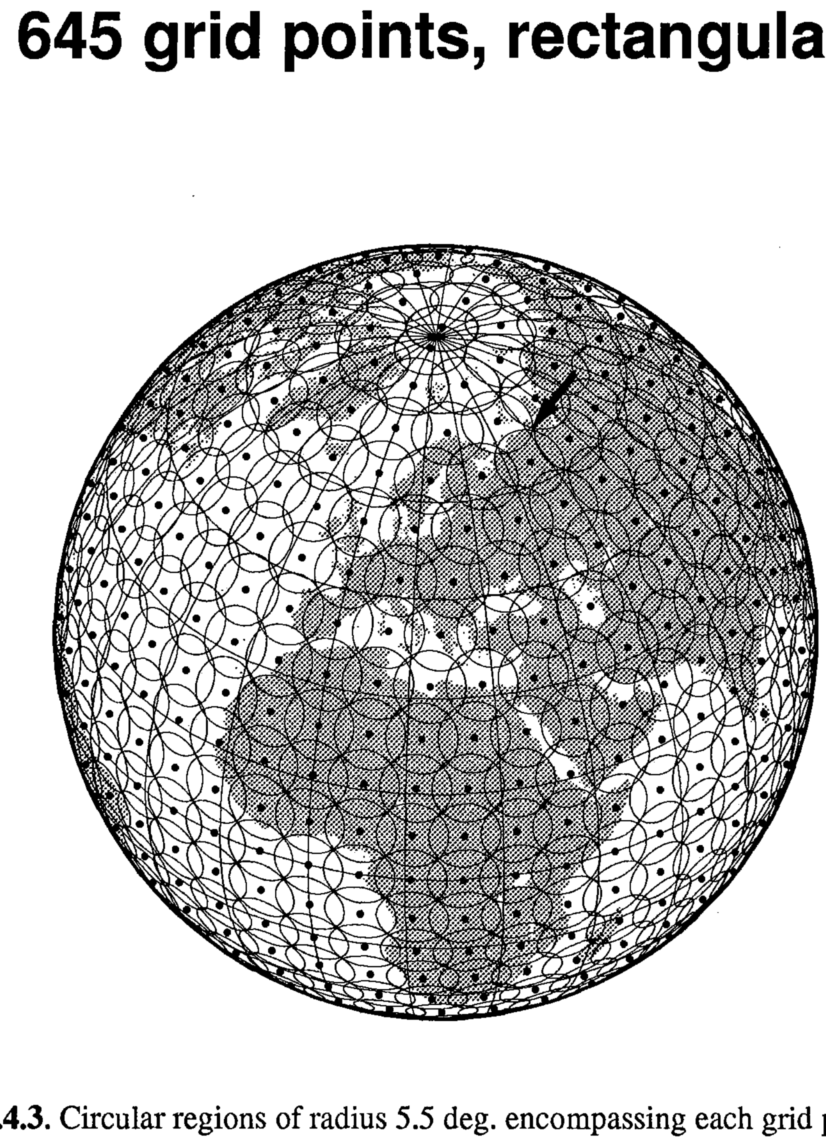

Fig. 7.4.3. Circular regions of radius 5.5 deg. encompassing each grid point constructed by the rectangular method. Note that for certain areas the coverage is not complete, e.g., around 70N, 60E (marked by an arrow).

642 grid points, triangular

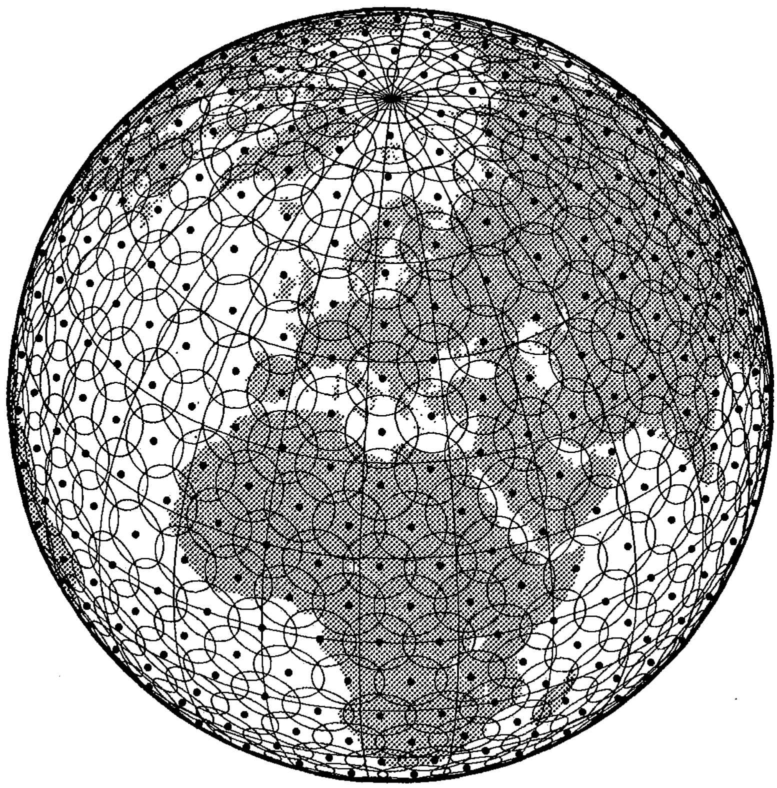

Fig. 7.4.4. Circular regions of radius 5.5 deg. encompassing each grid point constructed by the triangular method. Note that the coverage is complete.